Laboratory and field text in invertebrate zoology

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INVERTEBRATE ZOOLOGY

S. F. LIGHT

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in
INVERTEBRATE ZOOLOGY

By
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PREFACE

This volume represents accumulations from fifteen years of teaching the natural history of the invertebrates of the central California coast. The course is given at Berkeley in the spring semester every other year and at the seashore in the summer sessions of the intervening years. The students have been of two very different types, in the spring semester largely those preparing to teach biology in the high schools and in the summer (Intersession) largely those meeting the requirements for the doctorate in zoology. They have responded to essentially the same materials somewhat differently presented. The main objective of the course is firsthand knowledge of the invertebrate animals as going concerns in relation to their physical environment and to other animals and plants. This involves a knowledge of the ecological distribution, the interrelations, and the behavior of the animals concerned, which can be obtained only by field studies.

In order to study animals in the field it is necessary to be able to identify them, to recognize them and to know them by name. A considerable part of the time of the course, therefore, is devoted to the study in the laboratory of animals of the various groups with a view to learning the characteristics important in the identification of the species of these groups. This is followed in most cases by practice in the identification of common species by means of keys. No attempt is made to study taxonomy as such, valuable as this would be, nor even necessarily those features most fundamental in the classification of the different groups. Our end is the prosaic one of learning names for the local assemblage as rapidly and simply as possible.

This end, unpretentious as it is, is by no means easily attained. The invertebrate animals of the Pacific Coast are very imperfectly known. For some there is no monographic account. For example, there is no monographic source for the identification of local sea anemones nor any sufficiently complete or recent to allow for the identification of local amphipods.

Furthermore, such monographs as do exist have a way of getting out of date. Thus Richardson's monograph on the isopods (1905) is incomplete and badly in need of revision and even so excellent a monograph as Schmitt's (1921), The Marine Decapod Crustacea of California, which we use to very great advantage contains a number of names that have been changed since its publication.

Finally, modern monographs with keys would not be enough for our purpose. Limited time would still require that these be brought within the range of the student by simplification and limitation of terminology and by limitation of consideration to those species of the various groups significant in our local assemblages. Otherwise it would be impossible for the student to get that familiarity with the fauna as a whole which is one of the greatest values to be obtained in such a study. Coe's (1940) admirable key to the nemerteans, for example, while entirely up to date requires a knowledge of internal characters not available to the student in the brief time which can be devoted to these animals. His key must be replaced, therefore, for our purposes by one based on such superficial characters as color and color pattern, and limited to the species commonly encountered.

The Illustrated Key to West North American Pelecypoda by Keen and Frizzell is a splendid example of what can be done to facilitate identification, but this still leaves us at the genus and in many instances it is just the difference between species of the same genus which is important in an ecological study.

The present work, incomplete as it is and continually in process of revision as it is, is the only one known to me which attempts to bring together in more or less completely illustrated keys and lists the information necessary for even a tentative identification of the common invertebrates of this area. The work has been enriched by special studies made by students in the class and by graduate students specializing in the invertebrates. Many of the keys were thus originated. Such contributions are too numerous to mention and have been so extensively revised by teacher and students as to be no longer attributable to a single person. To all of those who have contributed in large or small part I wish to express my appreciation of their unselfish devotion.

Two names, however, must be mentioned by reason of the great extent and value of the contributions made, those of Dr. Olga Hartman and Dr. Avery Grant Test. Each has contributed in turn, as student in the course, as teaching assistant, and as specialist in one of the groups involved. Each has contributed materially to this volume, although no one key can be attributed wholly to either of them in its present form. Each has contributed most effectively, however, by clarifying the classification of a group important in our fauna, in each case a group in chaotic condition previous to their studies. Dr. Hartman has devoted herself to that enormous, everywhere present, and extremely difficult group, the polychaete annelids; and Dr. Grant to a smaller group, the limpets of the genus *Acmaea*, but a group of great importance in any study of the invertebrate animals of the California coast.

Under the conditions existing with regard to our knowledge of Pacific Coast invertebrates changes of name are bound to be the order of the day and a volume such as this is constantly undergoing revision as new works appear or new information is obtained. For its errors, which are numerous, probably beyond even the author's imagination, he accepts full responsibility, consoling himself by the hope that the knowledge of these errors, inevitably forced on the students' attention, may stimulate some of them to undertake corrective investigations such as those mentioned above.

The sequence of events in a field course will naturally depend not so much upon the logic of the material as upon the exigencies of tide, season, etc. In earlier editions the subject matter was arranged on the (zoologically speaking) illogical basis of chronological sequence. Thus the groups most significant in the intertidal fauna were considered first in preparation for field trips at the first low tide. These groups were Decapoda, Pelecypoda, Gastropoda, Polychaeta, Amphineura, and Isopoda, in that order, clearly not a taxonomic sequence. Furthermore the exercises dealing with the faunas of limited areas or special ecological situations as well as those concerned with the field trips themselves were interspersed with the exercises dealing with the various groups studied.

The sample schedules for spring and summer, given in Appendix A, show the usual order of events in the course, or rather the lack of it, as determined by time and tide.

This arrangement had decided practical values offset, admittedly, by various pedagogic disadvantages. In this edition, for the first time, the groups of animals are considered in taxonomic sequence each followed in most cases by a key and a list of the common species. The series of directions for field trips accompanied in some cases by keys to local faunas and local faunal lists and other material concerned with these phases of the course make up the later portions of the book.

More groups of animals are considered than are usually studied by any one class. Thus, for example, the sponges, the flatworms, the Kamptozoa, the Bryozoa, the barnacles, the Pycnogonida, the balanoglossids, and the ascidians are seldom given special laboratory consideration. This is especially the case in the undergraduate course. The discussions of these groups are used for reference, however, both in the undergraduate course and in the course as given to graduate students at the shore.

Numerous sources were drawn upon for illustrations. All have been redrawn except those from Animals of the Seashore, by Muriel L. Guberlet, and are acknowledged in the legend by the name of the author. I wish to acknowledge here permission to use illustrations as follows:

From The McGraw-Hill Book Company permission to use redrawings of several figures on the sponges from The Invertebrates: Protozoa through Ctenophora, by Libbie H. Hyman.

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Redrawings of figures from various scientific publications are acknowledged where used by the name of the author.

Especially to be noted are the labeled figures of decapod crustacea from the Marine Decapod Crustacea of California, by Waldo L. Schmitt, University of California Publications in Zoology, Vol. 23, used by permission of the University of California Press, and several figures from Littoral Fauna of Great Britain, by N. B. Eales, Cambridge University Press.

I also wish to acknowledge assistance rendered in the preparation of some of the materials in this book by personnel of the Work Projects Administration, A. P. No. 165-03-6296 and O. P. No. 165-1-08-73, Unit C-1.

S.F.L.

Berkeley, California
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INTRODUCTION

No picture of organisms which ignores their physical and organic environment can be even approximately complete. Studies of dead animals or their parts or even of living animals in the laboratory, valuable and indispensable as they are, give but partial pictures. In the studies here contemplated we seek a firsthand knowledge of living invertebrate animals in their natural setting, their behavior and interrelations, their distribution within the habitat, the influence of physical conditions on this distribution and the correlation between their structures and their behavior patterns on the one hand and the places they occupy in the environment on the other.

Field trips are naturally of prime importance in such studies. The more time spent in actual study of animals in the field the better. Under most circumstances these periods must each be confined to a part of a day. Experience has amply proved, however, that continuous studies over a period of days increases the values received out of all proportion to the time spent. Appendix A gives specific information with regard to field trips and the schedules of such trips during the spring and summer courses at Berkeley.

Such a field study might be thought to require previous courses designed to give the student a knowledge of the animals which make up the faunas to be studied. Certainly the animals must be recognized and known by name if their behavior and ecologic distribution is to be studied. In practice it is usually necessary and perhaps more advantageous to combine this type of study with the field study.

This portion of the work involves the laboratory. It falls naturally into four phases (1) the study of those external characters of the various animal types which are used for their classification and identification, (2) preliminary practice in the use of keys for the identification of some member of each group, (3) a study of demonstration sets previous to field trips to give a preliminary knowledge of the important animals to be expected in the particular fauna, and (4) the identification of animals collected on the field trips.

THE IDENTIFICATION OF INVERTEBRATE ANIMALS

A necessary preliminary to the study of any animal is the determination of its scientific name or authentic common name. This is necessary if only to make possible the satisfactory designation of the animal in conversation or in class exercises. A correct determination is especially important, of course, if the animal is to be made the subject of a scientific investigation, since in no other way can the facts be made available to others.

Few students of zoology realize the difficulties involved in identifying with certainty most species of animals, particularly the species of many of the numerous groups known collectively as invertebrates. A relatively few species are readily recognized because of distinctive color, pattern, or structure. Such an animal, for example, is the striped shore crab, *Pachygrapsus crassipes,* which is abundant in rocky crevices above low-tide mark along the Pacific Coast. In many other cases, however, identification can only be approximated by the beginner, and in still others even the specialist will find difficulty in making identification. These difficulties are aggravated on the Pacific Coast by the fact that the study of many groups of invertebrates has been greatly neglected. During the period when systematic work was the vogue in zoology, there were very few zoologists on this coast. With the change in emphasis in zoology these have largely abandoned this field and few others have entered it. For a few groups such as the Amphipoda, and the littoral copepods, the fauna of the Pacific Coast is largely unknown. In other groups a considerable amount of work has been done, but much remains to be done.

Some groups, such as the decapod Crustacea, the marine Mollusca and the echinoderms, are fairly well known to systematists. Even here there remains much need for complete and careful systematic revision and monographing. But when all this has been done there will be necessary still another step if this information is to be available to students of zoology or biology not specialists in the particular groups, and also to the intelligent laymen. This is the production of manuals of faunas, containing brief diagnostic descriptions and keys to the species, illustrated, if possible, and accompanied by careful definitions of terms.

Familiar works of this type are the floras of various regions and in the various mammals for the identification of birds. A Manual of the Common Invertebrate Animals, by H. S. Pratt (Blakiston), is an attempt at such a manual for the identification of the invertebrate animals of the United States. Because of the imperfect knowledge of the local fauna, the first edition was of very little value for identification of the invertebrates of the Pacific Coast. The new edition (Blakiston) is better, but still reflects the difficulties arising from the scope of such an attempt and the lack of available information with regard to the invertebrates of the Pacific Coast.

Freshwater Biology, by Ward and Whipple, represents a more satisfactory attempt in this direction for the animals of the United States which inhabit fresh water. Since many of these tend to be widely distributed, the Pacific Coast species are better covered. In addition, this work includes valuable discussions of the biology of the different groups, as well as directions for their collection and study. Here again, however, there is great need for revisions of the various groups and a new edition is to be hoped for. Every student or teacher of zoology should own this book when the new edition is available.

Seashore Animals of the Pacific Coast, by Johnson and Snook, represents the only attempt at a comprehensive treatment of our local marine invertebrates. It is a valuable contribution and it also should be in the library of every student or teacher of zoology or biology located on the Pacific Coast. Its excellent illustrations make possible the definite identification of certain common forms, but the absence of keys or any comprehensive treatment of the various groups makes it impossible to use it as a manual. Indeed, the lack of completeness of our knowledge makes it impossible to produce such a general manual at the present time, and if the knowledge were available it could not be compressed within the limits of a single volume.

Between Pacific Tides, by Ricketts and Calvin, published by the Stanford University Press, will be of great value to students of the invertebrates of the Pacific Coast and its reading is required of all students in this course. While it will not serve as a manual for the identification of animals it will give a valuable picture of faunas characteristic of the major environments of the seashore in this area, and its excellent illustrations in conjunction with references to classification lists will make possible the identification of many common animals.

Fortunately we have a slowly increasing number of well-illustrated, authentic monographs on separate groups of California invertebrates. Such are: Schmitt, The Marine Decapod Crustacea of California (1921, University of California Publications); Coe, Revision of the Nemertean Fauna of the Pacific Coasts of North, Central, and Northern South America (1940, University of Southern California Press); Fraser, Hydroids of the Pacific Coast (1937, The University of Toronto Press), and others. Some of these are in need of revision and others are too technical to be available to the student involved in such a study as this.

As mentioned in the preface, the Illustrated Key to West American Pelecypod Genera, by Keen and Frizzell (1939, Stanford University Press), is an excellent example of what can and should be done in this field. Students are encouraged to obtain and use this valuable work. Unfortunately it stands practically alone and even it leaves the species undetermined.

It will be seen, therefore, that if the invertebrate fauna of a given area of the Pacific Coast is to be used for field studies, it becomes necessary, as a temporary measure, at least, to develop keys to aid in the identification of the species concerned. Such is the purpose of the keys here given, which are tentative, in many cases requiring to be corrected and amplified as our knowledge increases. It will be noted that in numerous instances the determinations are only to genus, and in some cases even only to the family. This may be because there is only one species concerned in the area, and the burden of scientific names to be learned may be thus reduced, or because either the knowledge is lacking to carry the identifications further, or the identifications are too difficult for any except the specialist.

It cannot be too strongly emphasized that keys are short-cuts and often very misleading; that their function is merely to clear the way to an approximation, and that identifications made by them, if to be of scientific value, must be reinforced by comparisons with descriptions and illustrations in monographs, if such exist, or by comparisons with authentic named specimens, or by submission to a specialist.

The first two methods are available in a course such as the one for which these keys are designed. Comparison with named specimens should be considered as a last resort, however, since such named collections are rarely available and the gaining of experience in the use of keys and works of reference is one of the important opportunities offered by the course.

A list of the publications and manuscripts most available for verification or identifications of species of Pacific Coast invertebrates will be found at the end of this volume.

THE USE OF SCIENTIFIC NAMES

A scientific name consists of the name of the genus (capitalized) followed by the name of the species (rarely capitalized by zoologists and then because it is derived from a proper noun) followed by the name of the original describer. The name of the author is properly placed in parentheses if the generic name used is not that used at the time of the original description, thus *Hemigrapsus nudus* (Dana). This usage is under discussion at present and it has not been followed for all groups discussed in this text. For the sake of convenience, the name of the describer may be omitted in our use of scientific names but should always appear on properly labeled specimens.

The genus name may be used alone, the specific name never, unless it has already been used with the generic name on the same page. Both generic and specific names should be underlined. This indicates italics to the printer and is of value in picking out the scientific names in manuscript.

Great pains should be taken to spell scientific names correctly. The correlation between careless, unscientific work, and careless use of scientific names is very high.

THE USE OF COMMON OR VERNACULAR NAMES

Common or vernacular names are convenient but have many disadvantages. The rule of priority fixes the correct scientific name, which is universal. Common names are local since there are no rules to determine which of many such names is the correct name, and the same name may be applied to very different species or types in different regions, or by different persons in the same region. Vernacular names of American birds and certain other groups of vertebrates are relatively uniform owing to the united action of the workers in these fields, but no such authentic common names exist for invertebrates.

It is necessary to make a sharp distinction between these two types of names and to use the vernacular name only after having connected it with the scientific name. Thus *Hemigrapsus nudus* will be known to or identifiable by all zoologists, but the purple shore crab would have no meaning or a different meaning in areas in which *H. nudus* is not found or even in certain parts of the range of that particular species.

LABORATORY STUDIES

In this section materials are presented for the study, classification, and identification of the invertebrate animals generally encountered in the progress of the course. This material is arranged under the headings of the various phyla of invertebrates considered. In general, the consideration of each group includes (1) a laboratory exercise acquainting the student with the general characters of the animals and explaining terms used in the identification keys, (2) a key or keys for the identification of specimens, and (3) a list of genera and species which have been encountered in the localities visited in the course, giving for each the full scientific name if it has been definitely determined.

A careful study of the external anatomy of many types in each group as well as of the internal anatomy would be an ideal preparation for the use of keys in the identification of animals. Time does not permit such an approach within the limits of this course. Some knowledge of those characters, chiefly external, which are of taxonomic significance and are commonly used in keys and descriptions is, however, an absolutely necessary prerequisite to any successful attempt at identification such as will be necessary in the faunal surveys and ecological studies to be initiated later in the course.

The rapid studies of various groups outlined below are designed to furnish this knowledge of characters of taxonomic importance in so far as the very brief time available makes possible and must be entered upon with this purpose in mind. They must by no means be considered as an attempt at any complete study of the external anatomy. A copy of some text dealing with the group concerned will be a valuable adjunct to such studies. Some such texts are (1) Invertebrata, by Borradaile and Potts; (2) A Text Book of Zoology, Parker and Haswell, Vol. 1; (3) College Zoology, by Hegner.

Each such study should be followed by the use of keys and the consultation of specific descriptions in the publications listed at the end.

THE TAXONOMY OF THE INVERTEBRATES

The invertebrates include a large number of diverse types of animals including all but one of the phyla of the animal kingdom and even some of the branches of that one phylum (Chordata). The classification of this assemblage is therefore of cardinal importance in the study of the invertebrates. It is, however, also a matter of considerable controversy. The student must be prepared to find that different writers use different systems of classification. These differences are chiefly of two sorts: first, the using of different names for the same group, and second, the placing of the same group in different systematic categories, as, for example, the designation of a group as a class by one writer, but as an order by another. Discrepancies of the second sort are so abundant that in some cases it is advisable not to have a fixed concept of the taxonomic rank of a certain group, but rather to remember only that it is a part of a certain superior group and can be divided into a number of subordinate groups. Thus it is not so important that one decides whether the Crustaceae is a subphylum or a class as it is that one knows that it is a major division of the Arthropoda and that it includes the Malacostraca, Copepoda, etc. Appendix B gives a synopsis of the classification used in this course. This agrees most closely with that used by Borradaile and Potts, Invertebrata, and in most features with that of Hyman, Invertebrates.

DIRECTIONS FOR THE STUDY OF THE VARIOUS GROUPS OF INVERTEBRATES

PHYLUM PORIFERA (THE SPONGES)

References: de Laubenfels, 1932; Hyman, 1940

Terminology and Instructions for Study.—The sponges are structurally primitive animals, very ancient as a group and only distantly related to the animals of other groups. They are multicellular but have attained relatively little histological differentiation either as regards cell types or their integration in layer and organs. Organs can hardly be said to exist, and whole tissues characteristic of higher animals are lacking, such as nervous and muscular tissues. Specialized gland cells also are few or lacking. Indeed the body consists (fig. 2,A) of a rather loose mesenchyme, which produces the skeletal elements, covered by external and internal layers of cells so loosely organized as to be called epithelium only by courtesy.

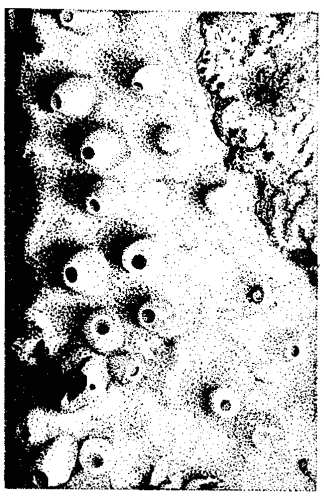


Fig. 1.—Surface of portion of encrusting sponge showing oscula (after Guberlet).

The sponges are in contrast to all higher animals also in that they lack a true mouth, the body being pierced by numerous minute incurrent pores connecting with canals and cavities through which water flows to reach the outside by larger openings (figs. 1, 2) known as oscula (singular osculum). These features, as well as the characteristic digestive cells, the choanocytes, are well seen in a schematic diagram of the simplest type of sponge (fig. 2,A) such as is exemplified by *Leucosolenia* in this region. In the complicated sponges which constitute the vast majority of those encountered at the seashore and all those of fresh water, the choanocytes occur in small, scattered, spherical chambers (fig. 2,D).

Sponges are attached, non-locomotor, nearly always colonial, and typically irregular in form, conforming to the surfaces on which they grow (fig. 1). In all save the simplest sponges the colony is so closely integrated that it is difficult or impossible to designate the individuals constituting it or at least to determine the limits of the individuals (fig. 1).

Except for a very few parasitic species all sponges are plankton feeders, the minute organisms and organic particles in the water currents being seized and taken in by the individual choanocytes. The skeletal system of calcareous or silicious spicules serves as a protection against predators and the unpleasant odor characteristic of a

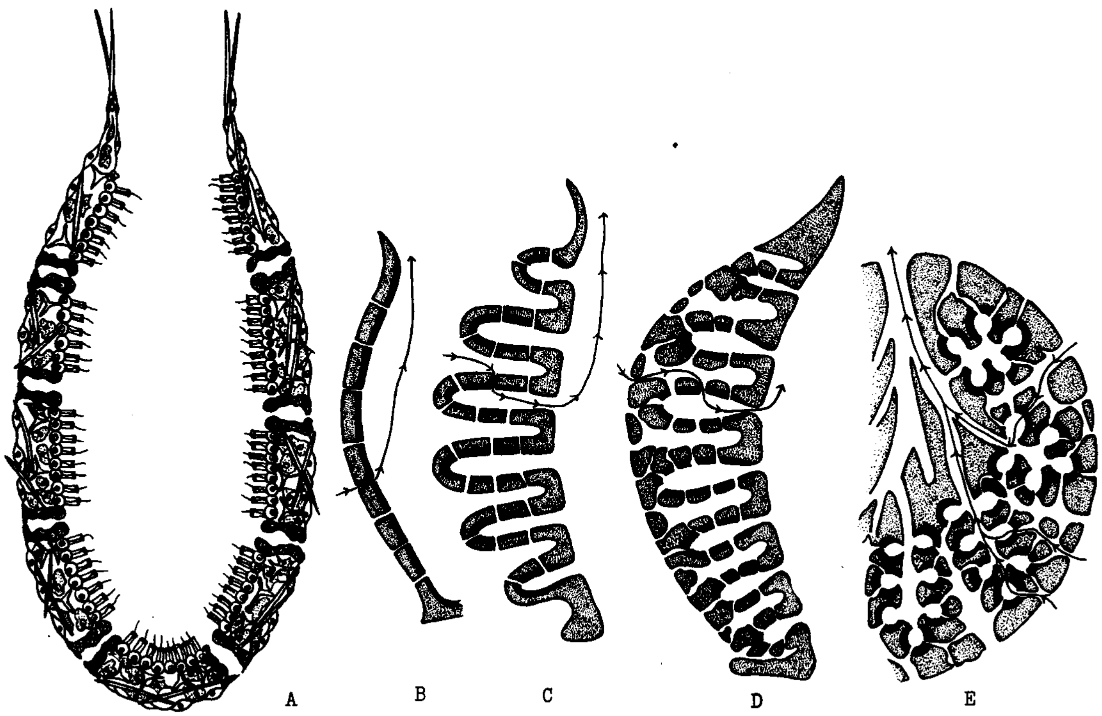


Fig. 2.—Diagrams of types of sponge structure (after Hyman, 1940). A. Diagrammatic vertical section of simplest type of sponge (ascanoid type seen in Leucosolenia), showing cellular elements. B-D, sections of one wall; B, ascanoid; C, primitive syconoid; D, developed syconoid such as is seen in Grantia; E, leuconoid, that of all local encrusting sponges. Choanocyte layer shown in heavy black. Arrows indicate course of water.

number of sponges would seem to indicate the presence of distasteful chemical secretions. They lack, however, devices to protect against intertidal exposure and hence they are confined to protected situations at, near, or below low-tide level. There they compete with other plankton feeders such as the Bryozoa and tunicates as also with the micropredators such as the hydroids and corals.

Until recently the identification of California marine sponges has not been possible. De Laubenfels' treatise (1932) makes this possible, but it requires study of spicule types and other internal characters and is not usually feasible for the average student. A key to the more common littoral species of central California, based on de Laubenfels' descriptions, is given below.

See demonstration specimens of the calcareous sponges, *Leucosolenia* (asconoid type, fig. 2,A,B) and *Grantia* (syconoid type, fig. 2, C,D) and understand the arrangements of parts characteristic of such sponges.

Study pieces of a local encrusting sponge. Note its consistency. Is it hard and stony, soft and fragile, or leathery and spongy? What is the nature of the surface? Note the shape, size, and distribution of the oscula and the pores. The oscula are the larger, excurrent openings (figs. 1, 2,A); the pores or ostia are the very small incurrent openings. Remove a small but characteristic portion, mount on a slide in a drop of water. Tease apart sufficiently to make a clear mount.

Examine under the microscope to make out the types of spicules. Spicules with a single point are termed monactinal (fig. 3,A,C,I), those with two, diactinal (fig. 3,H,J). Monaxon spicules are straight rods, needles, clubs, etc. Triaxons have three projecting points; if all are approximately equal they are triradiate or triaenes (fig. 3, E). Tetraxons may be quadriradiates or consist of three short rays radiating from a long axis. Hexactinal spicules have six (or five) rays radiating from a common center.

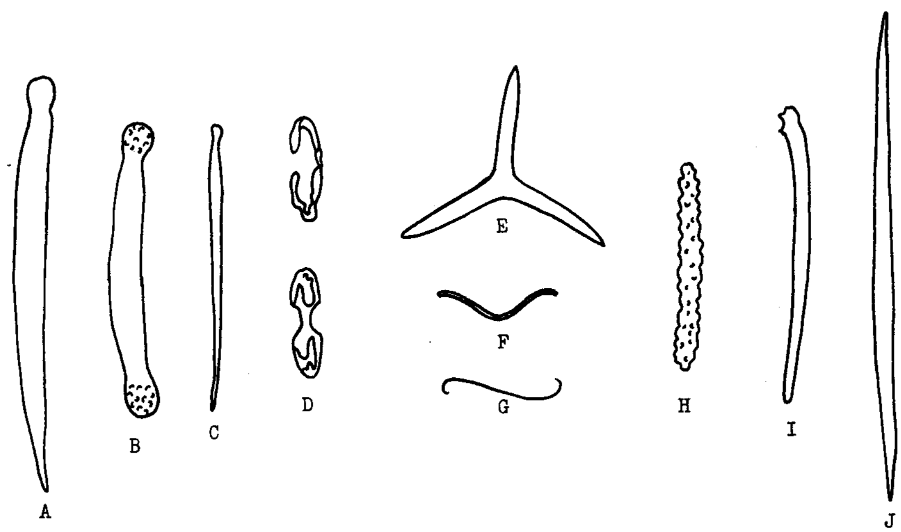


Fig. 3.—Types of sponge spicules (after de Laubenfels, 1932). A, C, subtylostyles; B, spiny-headed tylote; D, chelas; E, triaene; F, toxa; G, sigma; H, acanthostyle; I, spiny subtylostyle; J, oxea.

Siliceous spicules, found in all save the simple sponges, include, usually, two very different types, larger megascleres which make up the true skeleton, and the smaller microscleres in the softer tissues (cf. fig. 3,A,B with D,F, and G). The megasclera may be poly-, di-, or monactinal, called respectively triaenes (fig. 3,E), tylostyles, subtylostyles (fig. 3,A,B,I). Oxeas (fig. 3,J) are straight or somewhat curved, more or less fusiform and gradually pointed at the ends. Subtylostyles or monactinals have one of the ends rounded (fig. 3,A). These principal spicules may be sparsely spiny as in *Lissodendoryx* (fig. 4) or extensively spined acanthostyles (fig. 3,H). Tylotes are diactinals with both heads rounded as in *Plocamia* (fig. 3,B).

Microscleres may be sigmas (S- or C-shaped, fig. 3,G) as in *Lissodendoryx* (fig. 4); chelas (dumbbell-shaped, figs. 3,D and 4); toxas (broad V-shaped, fig. 3,F).

Using the characters so far determined for your specimen, attempt to run it down, using the key below. Verify your identification by the description in de Laubenfels and by comparing with the labeled mount of that species.

A KEY TO THE PORIFERA OF MOSS BEACH

(Page references are to de Laubenfels, 1932)

Through the kindness of Dr. de Laubenfels it has been possible to construct a key, based on field and histological characters, which should enable the recognition of at least fourteen of our common species. It would be preferable to use color and gross external characters only; unfortunately, this is not possible. For at least five of the red species, spicules must be examined to verify identification. This is done readily by teasing apart a bit of the matrix, mounting in water on a slide and observing under low or medium magnification.

1. Spicules calcareous (this may be determined by noting reaction to dilute acid; $CaCO_3$ releases CO_2) (CALCAREA). 2
1. Spicules siliceous (DEMOSPONGIAE) 4

2. Colonies of branching, anastomosing white tubes . . . . *Leucosolenia eleanor* (p. 8)
2. Unbranched; cup-like 3

3. Cups slender, vasiform; superficially smooth . . . . *Rhabdodermella nuttingi* (p. 16)
3. Like an inverted pear (distorted when crowded); surface spiny . . . . *Leuconia heathi* (p. 12)

4. Strongly radiating in cross section (TETRAXONIDA) . . . . *Stelletta clarella* (p. 29)
4. Not radiating in cross section (MONAXONIDA) 5

5. Red in life 6
5. Not red in life 8

6. With subtylostyles (fig. 3,A) and chelas (fig. 3,D) only. Color in life light brownish-red; stiff, brittle; usually small thin patches encrusting rocks . . . . *Esperiopsis originalis* (p. 70)
6. With subtylostyles (fig. 3,A) and toxas (fig. 3,F) only. Scarlet in life; pores minute, abundant . *Ophlitaspongia pennata* (p. 103)
6. Spicules of more than two kinds 7

7. Chief spicules spiny-headed tylotes (fig. 3,B). Scarlet in life; consistency firm, woody; emitting great quantities of slime when injured . . . . *Plocamia karykina* (p. 101)
7. Chief spicules acanthostyles (fig. 3,H). Brilliant vermillion in life; usually encrusting; brittle, gritty; oscules rare . . . . *Isociona lithophoenix* (p. 99)

8. Brilliant yellow in life, smooth, rubbery . . . . *Ficulina*
8. Not brilliant yellow, nor rubbery 9

9. Usually with small craters projecting above matrix 10
9. Without craters 11

10. Lavender in life; extensively encrusting surfaces at low-tide levels; height and size of craters variable; principal spicules usually forming definite triangular patterns; oxeas only (fig. 3,J) . . . . *Haliclona permollis* (p. 120)
10. Color in life not lavender . . . . *Haliclona* spp.

11. Principal spicules tylotes and styles (fig. 4). (With a strong sulphurous odor) . . . . *Lissodendoryx noxiosa* (p. 76)

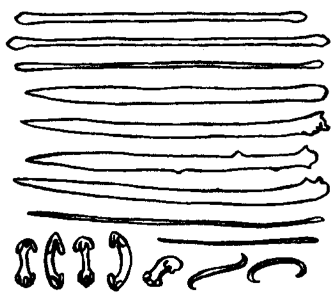


Fig. 4.—The spicules of Lissodendoryx noxiosa. From above downward: tylotes, styles of three types (smooth, sparsely spiny, and very slender), arcuate chelas (left), and contort sigmas (after de Laubenfels).

11. Principal spicules oxeas (fig. 3,J). Orange to green in life; usually massive; resembling crumb of bread when broken; spiculation very irregular; "the bread sponge" . . . . *Halichondria panicea* (p. 56)
11. Principal spicules subtylostyles (fig. 3,A,C). Closely and densely surrounding objects so as to appear massive; usually giving off burnt-umber color in alcohol; tough; solid; fine-grained . . . . *Prosuberites sisyrnus* (p. 54)

LIST OF SPONGES IN KEY

Phylum PORIFERA

Class CALCAREA

M[1] *Leuconia*
B M *Leucosolenia eleanor* Urban
D *M *Rhabdodermella nuttingi* Urban

[1]In this and other lists of species throughout this section, the following symbols are used (placed before the names of species): D, found at Dillon Beach, Marin County or vicinity; TB, found in upper end of Tomales Bay near Dillon Beach (since the Tomales Bay region is relatively new territory many more species will be found than are indicated in our list as occurring there); M, found at Moss Beach, San Mateo County, or other ocean beaches of the vicinity; B, found in San Francisco Bay; F, found in fresh water; T, terrestrial. For further information concerning the location of species in the San Francisco Bay Region, consult the check lists for the various localities.

The symbol * indicates that the species is relatively abundant at the location indicated. It must be understood that these marks of abundance cannot always be relied upon, owing to faulty or incomplete information, or to changes in the relative abundance of species from year to year or from locality to locality.

Class DEMOSPONGIAE

M	*Esperiopsis originalis* de Laubenfels
D *M	*Ficulina*
D *B *M	*Halichondria panicea* Pallas
D B *M	*Haliclona permollis* Bowerbank
TB B M	*Haliclona* spp.
D M	*Isociona lithophoenix* de Laubenfels
D *M	*Lissodendoryx noxiosa* de Laubenfels
D M	*Ophlitaspongia pennata* Lambe
D *M	*Plocamia karykina* de Laubenfels
*M	*Prosuberites sisyrnus* de Laubenfels
D *M	*Stelletta clarella* de Laubenfels

PHYLUM COELENTERATA

References: Hyman, Invertebrates, I
Fraser, Hydroids of the Pacific Coast
Mayer, Medusae of the World

The coelenterates resemble the sponges in that they are an ancient group, relatively simple in structural organization, wholly aquatic in habit, with their greatest development in the oceans, where they are to be found from shore line to abyssal depths. At the seashore they are confined, with few exceptions, to low tide level or below, as are the sponges, Bryozoa and tunicates, because, like these groups, they are not adapted to withstand intertidal exposure. In contrast to these groups, which are all plankton feeders, all coelenterates are predators, although many of them are stationary. Their continued success seems to be explained by two devices for food getting and defense, tentacles and nematocysts, combined with effective means of distribution, by ciliated larvae (blastulae or gastrulae known as planulae) and, in addition, in many groups (Scyphozoa, Hydrozoa), a free-swimming sexual medusa stage.

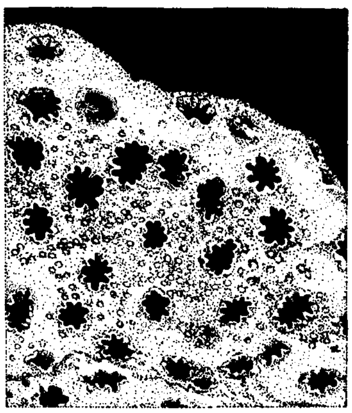


Fig. 5.—Part of a colony of *Allopora porphyra* Fisher, a purple encrusting hydrocoral. x2. (After Fisher, 1938.)

Representatives of three major types of coelenterates occur regularly in the littoral fauna of California: (1) hydroids of several species and their medusae (figs. 7-9) and a species of hydrocoral (fig. 5), (2) a coral, and (3) several species of sea anemones. In addition a scyphomedusan jellyfish, *Aurellia*, is occasionally washed in and its asexual generation (scyphistoma) occurs at several points along the coast. Another scyphomedusan occasionally encountered is *Pelagia*. *Velella* (fig. 6), a purple siphonophore (Class Hydrozoa), occasionally washes up on the beaches in great numbers.

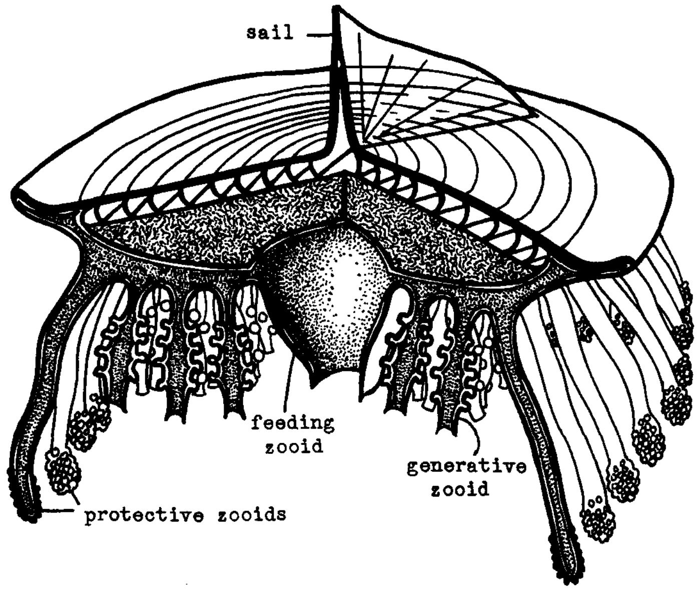


Fig. 6.—Diagrammatic representation of part of colony of Velella, a purple siphonophore. (After Buchsbaum, 1938.)

As we have but one species of coral, *Balanophyllia elegans,* easily recognized by its orange to red color, and of course by its calcareous skeleton (see demonstration specimens), no attempt will be made to study the diagnostic characters of that group. In the case of the anemones also, the characters used by us for their identification are simple (see key on page 19). The hydroids, however, require more detailed treatment.

Study or review *Obelia.* Make certain of your ability to use the rather numerous technical terms, defined below, which occur in the keys and descriptions of specimens of the animals of this group, and which unfortunately are used with different meanings by different authors. Observe them on the mounts of *Obelia, Gonothyraea, Syncoryne,* and the demonstrations of various other types.

Certain terms are widely used with regard to the parts of the hydroid colony. Unfortunately, however, they by no means always have the same meaning nor are they always consistently applied. We shall use these terms in the sense in which they are used by C. McLean Fraser in Hydroids of the Pacific Coast. In Pratt, for example, you will find a different usage and again in other works. It will be necessary to know these different usages. Figure 7 illustrates them as used in the key.

The hydroid colony consists essentially of a continuous cellular tubular portion, the coenosarc (fig. 7). The coenosarc consists of a layer of ectoderm (or epidermis), separated by a thin layer of non-cellular mesoglea, from an inner layer of endoderm (gastrodermis) surrounding the continuous central cavity, the coelenteron or gastrovascular cavity. Surrounding the coenosarc more or less completely is a thin, chitinous, non-cellular layer, the perisarc (or periderm) secreted by the epidermis.

The colony arises by budding of new individuals from an original zooid which developed from a zygote. It consists, therefore, of a number of individuals known in general as zooids. Actually no definite

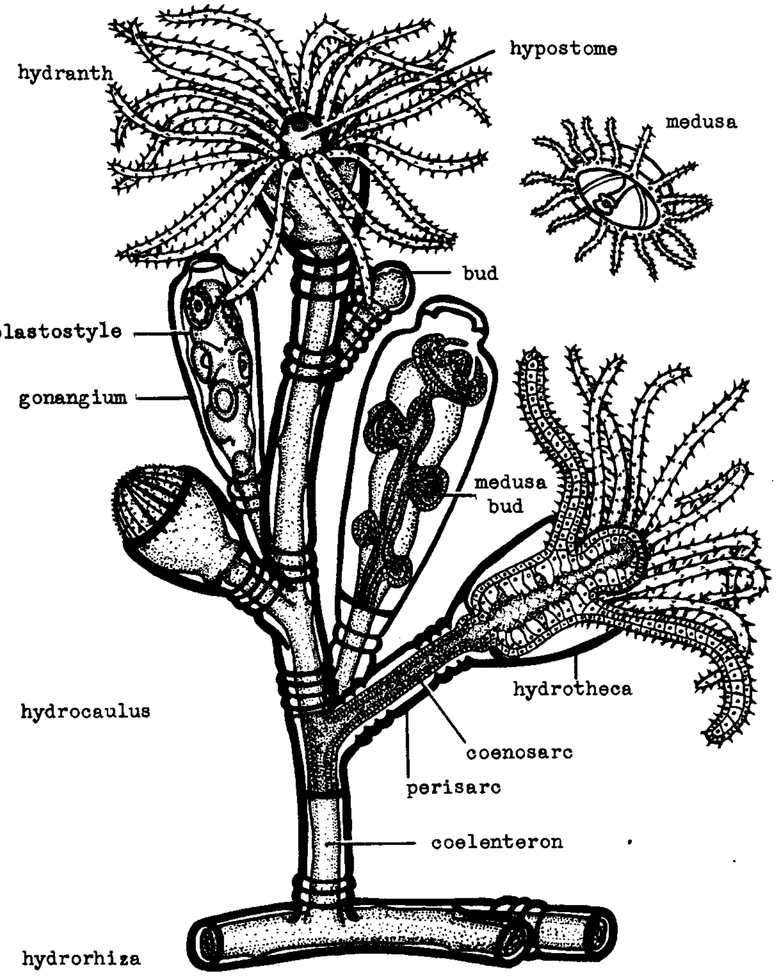


Fig. 7.—Diagrammatic representation of part of a colony and a medusa of a thecate hydroid (Obelia), with complete metagenetic cycle. One of the blastostyles and one hydranth are shown longitudinally sectioned. (After Buchsbaum, 1938.)

limits can be set to the individuals and much of the colony is made up of connecting and rooting branches.

There is always a certain amount of polymorphism and the zooids may be of several different types, named on the basis of the function for which they are specialized, nutritive, generative, defensive, or sensory zooids. The term hydranth is used to designate the terminal portion of a nutritive (vegetative) zooid but does not include any associated perisarcal structures such as the hydrotheca. The hydranth therefore is entirely coenosarcal, consisting of the body, hypostome, and tentacles. The term trophosome is used to include all the non-generative zooids, typically nutritive zooids, of the colony together with any perisarcal structures associated with them.

The term gonosome is used to include all the specialized generative zooids of the colony, with the perisarcal structures associated with them, and is thus in contrast to the term trophosome which refers to the rest of the colony. In thecate hydroids (fig. 7) the gonosome would include those asexual generative zooids, the blastostyles, which are specialized to produce the sexual zooids by budding, together with the coverings of the blastostyles, known as gonangia (Fraser) or gonothecae, and the sexual zooids to which the blastostyles give rise by budding (fig. 7). Fraser uses the term gonosome in this sense, while Pratt restricts it to the medusoid stage (sexual generative zooids). The sexual zooids are termed gonophores by some (I prefer this usage) or referred to in general as the medusoid stage in contrast to the hydroid stage. By others the term gonophore is confined to certain reduced sexual zooids which remain sessile. More commonly (e.g., Fraser) the term is used synonymously with blastostyle including often the budding sexual zooids and protective coverings. Others would term this a gonangium, a term which Fraser uses as synonymous with gonotheca. Such an element of a colony (blastostyle with buds and protective covering, if any) is often spoken of as a "fruiting body."

The sexual zooids, spoken of in general as the medusoid generation in contrast to the hydroid generation, produce gametes from which by fertilization arise the zygotes which develop into the initial zooids from which new colonies arise by budding. All the zooids of a given colony are derived from a single zygote, and hence the sexual zooids of a colony are all of the same sex and we speak of the colony as being male or female (somewhat incorrectly of course).

Typical or highly developed sexual zooids are free-swimming medusae. All intermediate conditions are found between medusae with a long free life on the one hand and sessile, completely reduced, sexual zooids which have lost all remnants of medusa structure on the other. The latter have the appearance of being gonads of the asexual generative zooids (blastostyles) on which they arise. These extremely reduced sexual zooids are spoken of as sporosacs, or, as noted above, as gonophores. We shall see them in *Clava* among athecate hydroids (fig. 8,A) and in thecate hydroids in *Campanularia*. Intermediate types, sessile but still showing vestiges of medusa structure, are termed medusoids. Such are seen in *Gonothyraea* (fig. 8,C) in contrast to the fully developed medusae of *Obelia* or the sporosacs of *Campanularia* or *Clava*. In *Gonothyraea* the ripe sexual zooids (medusoids) are extruded from the gonothecal aperture by continued growth of the blastostyle.

The term gonophore is used therefore, with the most diverse meanings and we must be certain to know with which of these meanings it is used in each case. I prefer to use it for any sexual individual, whether a free medusa, a sessile medusoid on a sporosac (thus used by Hyman). Pratt defines it as any sessile reproductive individual (whether medusoid or sporosac, thus not including medusae under it; but in his keys he seems to use it in the broad sense since on p. 116 we find, "The gonophores are medusae"). We shall use it here as does Fraser for any asexual generative zooid together with the sexual individuals budding from it and its protective coverings, that is, for what I would term a gonangium, consisting of a blastostyle bearing budding sexual zooids and enclosed in a gonangium (gonotheca), the whole also spoken of as a fruiting body.

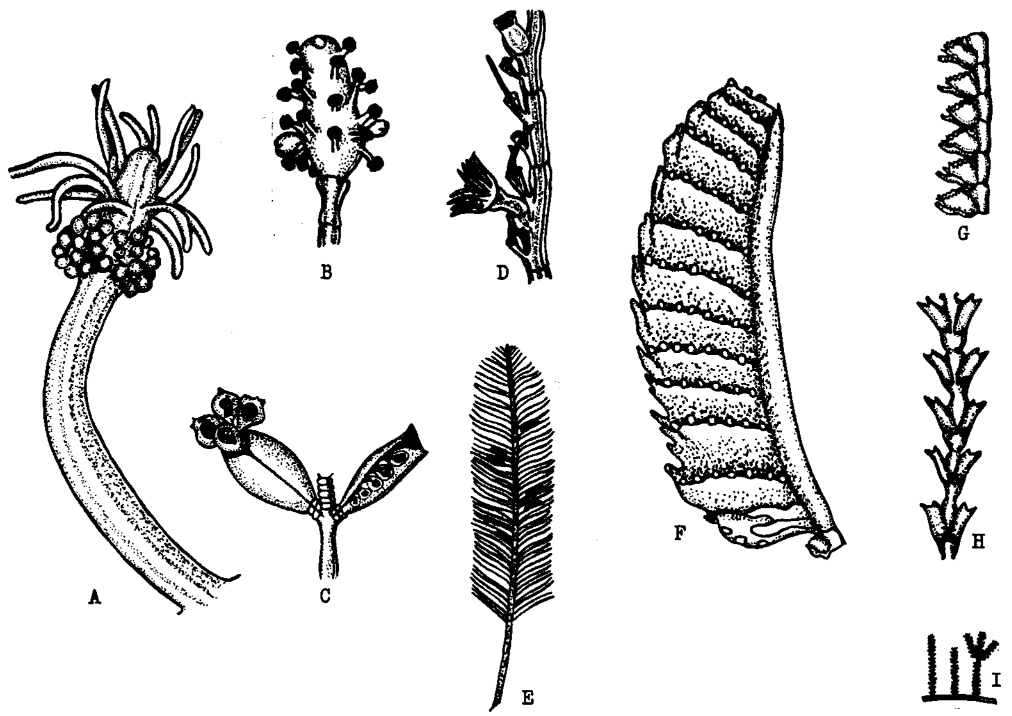


Fig. 8.—Hydroid types (after Fraser, 1937, except D). A, single hydranth of Clava leptostyla showing filiform tentacles, developing sporosacs, and absence of perisarc. B, hydranth of Syncoryne mirabilis showing scattered capitate tentacles and young medusa buds. C, Gonothyraea clarkii. Two gonophores (gonangia): left, mature with protruding medusoids; right, immature. D, Plumularia. Portion of a branch (hydrocladium) enlarged to show hydranths and nematophores (after Allman). E-G, Aglaophenia struthionides. E, colony, 3/4 natural size; note six scattered corbulae. F, a corbula much enlarged. G, portion of a hydrocladium, enlarged. H, Sertularia furcata. I, same, 3/4 natural size.

In certain genera of thecate hydroids the fruiting body is made even more complex by complicated protective structures derived from other elements of the colony. Such is the corbula in *Aglaophenia* (fig. 8,F). These would be included in the gonosome but would be in addition to the gonophores as defined by Fraser.

This necessity of using terms whose meanings differ with the author, while annoying for the moment, affords very excellent intellectual experience.

The tentacles of the hydranth may form a single whorl as in *Obelia* (fig. 7), or two whorls as in *Tubularia*, or may be scattered over the hypostome, the elevation which bears the mouth, as in *Syncoryne* (fig. 8,B). They may be filiform (slender) as in *Clava* and *Obelia* or capitate (knobbed) as in *Syncoryne*. In one large group of thecate hydroids, the plumularian hydroids (Family Plumulariidae), there are present in addition to the typical hydranths numerous small individuals which function entirely for offense and are known as <u>nematophores</u> (fig. 8,D). The small branches which bear the hydranths and nematophores are known as <u>hydrocladia</u>.

The hydrotheca may be stalked (*Obelia*, fig. 7) or sessile (*Sertularia*, fig. 8,H; *Abietinaria*, fig. 9; *Plumularia*, fig. 8,D; *Aglaophenia*, fig. 8,F). They may be uniserial (Plumulariidae, fig. 8,D,F) or biserial (Sertulariidae, figs. 8,H, 9). When biserial they may be opposite (*Sertularia*, fig. 8,H) or alternate (*Abietinaria*, fig. 9; *Sertularella*).

Study mounts of various types of hydroids and, using the key below, identify several of them. See also keys in Fraser.

Be able to recognize the following genera commonly encountered in the local fauna; *Syncoryne, Clava, Eudendrium, Tubularia, Obelia, Gonothyraea, Campanularia, Plumularia, Aglaophenia, Sertularia, Polyorchis* (medusa only), *Abietinaria*, and *Sertularella*. Be able to make sketches of each, bringing out diagnostic characters.

KEY TO THE HYDROZOA

1. Fresh-water; solitary, or in small imperfect colonies 2
1. Marine; colonial 3

2. With tentacles; without distinct sexual stage but the polyps bearing gonads which probably represent vestiges of such a stage . . . . *Hydra*
   (For species see Hyman, <u>Amer. Micros. Soc. Trans</u>., 48, 49, 50)
2. Without tentacles; with well-developed medusae . . . . *Craspedacusta sowerby* (= *Microhydra ryderi*)

3. Colony floating; in our common form blue in color. Order SIPHONOPHORA. . . . . *Velella*
3. Hydroids; with attached, flexible colony 4
3. Hydrocorals; colony calcareous, encrusting; vividly purple, with scattered circular craters. . *Allopora poryphora* (Fisher) (fig. 5)

4. Medusae relatively large, up to an inch in diameter; hydroid stage undetermined . . . . *Polyorchis*
4. Medusae very small or not formed as such; known by the hydroid stage 5

5. Hydranths athecate. Suborder GYMNOBLASTEA OR ANTHOMEDUSAE. 6
5. Hydranths thecate. Suborder CALYPTOBLASTEA OR LEPTOMEDUSAE. . . .14

6. Hydranth with a single basal whorl of filiform tentacles 7
6. Hydranth with tentacles scattered 12
6. Hydranth with two whorls of filiform tentacles; hydranths the largest of any of our hydroids; medusae borne on long blastostyles just above the basal whorl of tentacles . . . . *Tubularia*

7. Stalks of hydranths without perisarc, unbranched, rising from a spiny calcareous crust . . . . *Hydractinia*
7. Stalks of hydranths with a perisarc (except *Clava*), usually branched, not rising from a calcareous crust 8

8. Hydranth with trumpet-shaped hypostome; perisarc stiff, brown, closely and sharply annulated . . . . *Eudendrium*
8. Hydranth with a conical hypostome; perisarc usually not sharply annulated, or if so only on the smaller branches 9

9. Colony very small, stems not at all or very slightly branched . . . . *Perigonimus*
9. Colony larger (up to several centimeters in length); stems branched 10

10. Hydranths relatively large, orange-colored, conspicuous . . *Garveia*
10. Hydranths smaller, not orange-colored 11

11. Hydranths very small; colony finely branched; annulations of perisarc almost entirely lacking . . . . *Bougainvillia*
11. Hydranths larger, colony with few branches; annulations distinct at base of hydranths . . . . *Bimeria*

12. Tentacles capitate (enlarged at tip); colony small, very slightly branched; medusae arising among tentacles (fig. 8,B) . . . . *Syncoryne*
12. Tentacles filiform (tapering at tip); sexual zooids borne below tentacles 13

13. Hydranths, large, unbranched, arising from a filiform hydrorhiza; sexual zooids are sporosacs and colored, pink in male, purple in female; no perisarc (fig. 8,A) . . . . *Clava*

13. Hydranths small, colony very slightly branched; with free medusae; perisarc present . . . . *Turritopsis*

14. Hydrothecae stalked 15
14. Hydrothecae sessile (fig. 8,D-I). 18

15. Hydrothecae tubular; colony extremely small . . . . *Calycella*
15. Hydrothecae bell-shaped; colony larger 16

16. Sexual zooids sporosacs; blastostyle not projecting . .*Campanularia*
16. Sexual zooids medusiform but sessile; blastostyle and mature medusoids projecting from gonotheca (fig. 8,C) . . . *Gonothyraea*

17. Medusae globular with 4 tentacles at time of liberation; colony not much branched . . . . *Clytia*
17. Medusae flatter with 16 or more tentacles; colony usually more branched . . . . *Obelia*

18. Hydrothecae on one side of branches; nematophores present (fig. 8,D-G) 19
18. Hydrothecae in two rows on opposite sides of branches; no nematophores (figs. 8,H, 9) 20

19. Colony slender and flexible, colorless; hydrothecae at considerable intervals, margins of hydrothecae not toothed or sculptured (fig. 8,D) . . . .*Plumularia*
19. Colony large, stiff, brown or greenish-brown; branches of colony resemble feathers (fig. 8,E); hydrothecae close-set with toothed and sculptured margins (fig. 8,F); "the ostrich plume" . . . . *Aglaophenia*

20. Hydrothecae exactly opposite each other; operculum of two pieces; colony small, delicate, without branches (fig. 8,H,I) . . . . *Sertularia*
20. Hydrothecae alternate or subalternate 21
21. Hydrotheca with smooth margin; operculum of one piece; colony larger, plume-like, with numerous side branches in one plane (fig. 9) . . . . *Abietinaria*

Fig. 9.—Abietinaria filicula Ellis and Solander. Enlarged (from Guberlet).

21. Hydrotheca with toothed margin; operculum of 3-4 pieces; colony small, without side branches . . . . *Sertularella*

LIST OF SPECIES OF HYDROIDS MOST LIKELY TO BE FOUND INTERTIDALLY IN THE SAN FRANCISCO REGION

(There are many other species which have been taken from shallow water in this region, so that definite identification can be made only by careful reference to Fraser, 1937. None of the species has been marked abundant, because of insufficient information.)

Athecates (Gymnoblastea or Anthomedusae)

B	*Bimeria franciscana* Torrey
B	*Bougainvillia mertensi* Agassiz
B	*Clava leptostyla* Agassiz
TB D B M	*Eudendrium californicum* Torrey
D B M	*Garveia annulata* Nutting
TB M	*Hydractinia milleri* Torrey
B	*Perigonimus repens* Wright
D B M	*Syncoryne mirabilis* Agassiz
B M	*Tubularia crocea* Agassiz
M	*Tubularia marina* Torrey
B	*Turritopsis nutricula* McCrady

Thecates (Calyptoblastea or Leptomedusae)

D B M	*Abietinaria anguina* Trask
D B M	*Abietinaria greenei* Murray

D B M *Aglaopenia struthionides* Murray
D B M *Calycella syringa* Linnaeus
D M *Campanularia fusiformis* Clark
B *Campanularia gelatinosa* Pallas
D B M *Campanularia urceolata* Clark
D M *Campanularia volubilis* Linnaeus
B *Clytia edwardsi* Nutting
B M *Gonothyraea clarki* Marktanner-Turneretscher
B *Obelia commissuralis* McCrady
TB B M *Obelia dichotoma* Linnaeus
B *Obelia longissima* Pallas
B *Obelia plicata* Hincks
M *Plumularia goodei* Nutting
B M *Plumularia lagenifera* Allman
D B M *Plumularia setacea* Ellis
D B M *Sertularella turgida* Trask
D B M *Sertularia furcata* Trask

OTHER HYDROZOA (See key)

Order Calyptoblastea
Polyorchis penicillata Eschscholtz, common Pacific Coast medusa

Order Hydroida
F *Hydra*

Order Hydrocorallina
M D *Allopora porphyra* Fisher

Order Siphonophora
Velella lata Chamisso and Eysenhardt (often washed on shore)

Class SCYPHOZOA

Aurellia aurita Linnaeus
Pelagia

Class ANTHOZOA

KEY TO THE SEA ANEMONES

(Modified from MS keys by A. S. Harrison and N. E. Kemp. Nomenclature adapted to that of Carlgren, as reported on p. 263 of Ricketts and Calvin. This group is very much in need of study in the Pacific Area.)

1. Base attached to rock, wood, or other firm substrate 2
1. Base unattached—true burrowing anemones . . . . . Group *Athenaria*
(Genera and species unidentified)

2. Margin of tentacle-bearing disc deeply frilled or lobed when extended; tentacles short and very numerous; tentacle-free area around mouth very small . . . . *Metridium dianthus*

2. Margin of disc circular and not frilled when extended; tentacles fewer, leaving a larger area free around mouth 3

3. Column thickly covered with papillae (sticky tubercles capable of holding bits of shells and other debris to the column . . 4
3. Column smooth or, if with papillae, these arranged in a few vertical rows and very small 8

4. With relatively small papillae, probably suckers, extending over the upper two-thirds of the column in longitudinal rows; living completely covered in sand (but attached to rock) . . . . unidentified "sand anemone"
4. With papillae practically covering the entire column 5

5. Column embedded in mud: found along bay shore where mud and rocks occur together . . . . . "The Mud Anemone" (unidentified)
5. Column never embedded in mud 6

6. Column dark red, often with brown patches; tentacles blunt, sometimes with the middle half of the tentacle rose-tinted . . . . *Tealia (= Urticina) crassicornis*
6. Column green to yellowish-white 7

7. Papillae irregular, branching, not conspicuously in longitudinal rows; tentacles uniform in color, not tipped with pink; solitary; large . . . . . *Anthopleura (= Cribrina* or *Bunodactis) xanthogrammica*
7. Papillae round, arranged in longitudinal rows; tentacles usually tipped with pink; color of column very variable; usually in close-set aggregations . . . . *Bunodactis (= Cribrina) elegantissima*

8. Lateral buds or young anemones attached in a circlet around the column near the base . . . . *Epiactis prolifera*
8. No lateral buds or young anemones attached to the column . . . 9

9. Found on underside of ledges on rocky ocean coast; column dark red; tentacles white and capitate . . . . *Corynactis* sp.
9. Found mostly in bay waters 10

10. Tentacles opposite each end of mouth-slit differently marked from others by having a yellow base in contrast to the dark reddish-brown base of the other tentacles; main portion of the tentacles yellowish or banded with alternate yellowish and brown bands; faint radiating lines from the mouth all yellow; found on pilings at Fruitvale Bridge . . . ."Yellow-striped Anemone" (unidentified)
10. Tentacles opposite ends of mouth-slit not differently colored from others 11

11. Column dark olive green, often with vertical orange stripes; small (extended column may reach 14 mm.); found all along East Bay shore . . "The Orange-striped Anemone," *Diadumene (= Sagartia luciae)*
11. Same as *D. luciae* (may be a variety) except that every specimen has longitudinal double rows of white lines on the column; found on pilings at Fruitvale Bridge . . . . "Double-striped Anemone" (unidentified)

11. Column never dark olive green 12

12. Column bright orange-red; inner base of each tentacle with white spot; oral opening surrounded by flaky white ring with white lines radiating out to tentacles; on ocean coast . . . . *Sagartia (?) stimpsonii*

12. Column and tentacles salmon to flesh color; column long and slender when extended; surface of column with vertical lines; on wood at Lake Merritt and Fruitvale Bridge . . . . *Sagartia leucolena*

CHECK LIST OF ANTHOZOA

Alcyonaria

Unidentified, rare

Sea Anemones

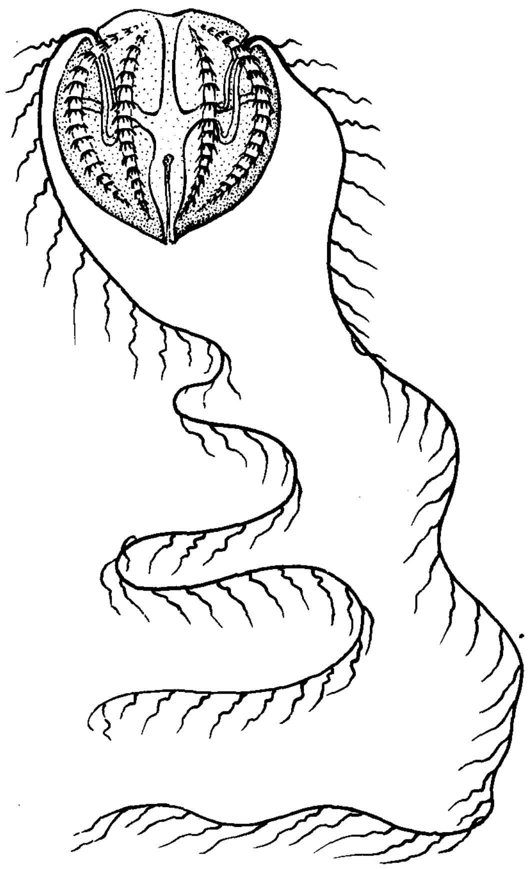
TB D *M *Anthopleura xanthogrammica* Brandt
(= *Cribrina* or *Bunodactis xanthogrammica*)
D *M *Bunodactis elegantissima* Brandt
(= *Cribrina elegantissima*)
M *Corynactis*
*B *Diadumene luciae* Verrill
(= *Sagartia luciae*)
D *M *Epiactis prolifera* Verrill
*B *Metridium dianthus* Ellis
M *Sagartia* (?) *stimpsonii* Fewkes
B *Sagartia leucolena* Verrill
M *Urticina (Tealia) crassicornis* Ehrenberg
*B "Mud Anemone" unidentified
B "Yellow-striped Anemone" unidentified
B "Double-striped Anemone" unidentified
*M "Sand Anemone" unidentified
M Unidentified burrowing anemones

Corals

D *M *Balanophyllia elegans* Verrill

PHYLUM CTENOPHORA

The subspherical transparent jelly-like animals of this small pelagic phylum which occasionally wash up on our shores (see figure in text), belonging usually to the species *Pleurobrachia bachei*, are variously known as cat's-eyes (by fishermen), sea gooseberries, or sea walnuts. They are micropredators, capturing their prey by means of the lasso cells of the long paired tentacles.



A ctenophore

PHYLUM PLATYHELMINTHES

The phylum Platyhelminthes is the lowest of the truly bilaterally symmetrical phyla (the Bilateria). Two of the three classes, the Trematoda and the Cestoda, are parasitic and are not studied in this course. The third class, the Turbellaria, is composed of slow-moving but free-living forms, all of which are predators.

The class Turbellaria contains four groups: (1) the Acoela, minute marine forms without an intestine, not ordinarily encountered in the local fauna; (2) the rhabdocoeles (Rhabdocoela), small, typically narrow forms in which the intestine is a single straight tube; (3) the triclads (Tricladida), in which the intestine has three main trunks, one forward from the pharynx and two backward (in marine species, mouth in hinder part of body, intestine little branched); (4) the polyclads (Polycladida), a large group of marine species of considerable size with thin, leaf-like body and with numerous branches of the intestine.

The Turbellaria of the Pacific Coast are very poorly known. The only important paper is that of Heath and McGregor (1912), New Polyclads from Monterey Bay, California. Previous to that time but three species of polyclads had been reported from the 7000 miles between Panama and Asia. They report 18 species, all new, belonging to 9 genera, three of them new.

The common species in Central California seems to be *Leptoplana acticola* (Ricketts and Calvin, p. 26) but the larger *Planocera* (Ricketts and Calvin, p. 16) also occurs. Any who desire to carry further their studies of the species of this very difficult group should consult Lang, <u>Die Polycladien des Golfes von Neapel</u>, and various works referred to in Pratt.

The well-known triclad flatworms of the genus *Planaria* (properly *Dugesia*, according to Hyman) are frequently found in fresh water in this region (especially in Golden Gate Park). Terrestrial flatworms of two genera (*Bipalium kewense* Moseley and *Geoplana mexicana* Hyman), also of the Tricladida, are found on the Berkeley campus where they may most easily be found feeding on earthworms killed during the spring rains.

Ricketts and Calvin mention three genera of rhabdocoeles, p. 265. Of these, *Syndesmis* is very abundant in the intestine of the sea urchins. The other two have not been identified from the areas here considered.

PHYLUM NEMERTEA (NEMERTINEA)

References: Coe, W. R., 1940, <u>Revision of the Nemertean Fauna of the Pacific Coast</u>
Coe, W. R., 1905, <u>Nemerteans of the West and Northwest Coasts of America</u>
Coe, W. R., 1904, <u>Nemertinea</u>, <u>Harriman Alaska Expedition</u>

Nemertean worms are readily recognizable by their relatively elongated and narrow, highly contractile, more or less flattened, unsegmented bodies as also, of course, by their long, slender, eversible <u>proboscis</u>. This <u>proboscis</u> may be caused to evert by adding alcohol, a few drops at a time, to a small amount of sea water containing the worms or by putting them into fresh water. Like the polyclads they are predators with a wide range of prey.

They are handled with difficulty because of their extreme contractility and the slimy mucus which they secrete in large quantities, and should, therefore, be kept separated from other animals. For scientific purposes they should be preserved in formalin.

Using the key below, identify your specimen. Check your identification with Coe's description. Identify as many species as time permits.

KEY TO THE MORE COMMON NEMERTEANS

(For other species see plates of Coe: 1940, 1901, 1904, 1905. Figure numbers refer to Coe, 1940.)

1. Entire body or dorsal surface solid color, no lines or rings . . 2
1. With longitudinal lines or transverse rings of color contrasting with ground color 8

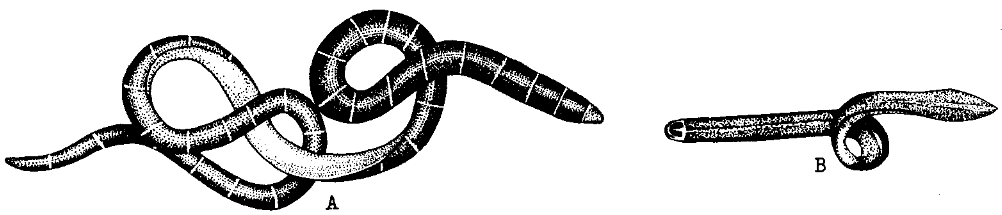
2. Of same shade above and below 3
2. Dark above, light below 5

3. Minute, very slender; whitish, somewhat transparent; living in delicate parchment tubes under stones or among algae . . . . *Tubulanus pellucidus* (= *Carinella pellucida*)
3. Large free-living species with distinctive colorations (red, dark red, or brown) 4

4. Bright red; very soft-bodied; living in or on rocks . . . . *Tubulanus polymorphus* (= *Carinella rubra*)
4. Dark red to brown; firm bodied; living in mud or sand . . . . *Cerebratulus californiensis* (Coe, 7)

5. Color of head not noticeably different from rest of body . . . 7
5. Head darker (*Lineus*) or lighter (*Amphiporus*) 6

6. Broad fleshy species; head light, with two large, conspicuous, dark brown to black spots; oval to triangular in shape (see figure in text); dorsal body color deep brownish-orange . . . . *Amphiporus bimaculatus*



Two Common Nemerteans (after Coe). A, Micrura verrilli Coe. Its distinctive white caudal cirrus or tail has been lost as is often the case. B, Amphiporus bimaculatus Coe.

6. Very slender species; head darker than rest of body; body light olive green to brown; a line of 2-8 ocelli on either side of anterolateral region of head; often with fine circular and longitudinal lines (see elsewhere in key) . . . . *Lineus vegetus* (Coe, 13)

7. Very slender; uniform green above, whitish below . . . . *Emplectonema gracile*
7. Stouter; uniform brown, orange brown, or purple brown on dorsal surface and sides . . . . *Paranemertes peregrina*

8. Very slender 9
8. Stouter and larger 10

9. Extremely slender, as much as one hundred times as long as wide; a single row of 2-8 ocelli on each anterolateral margin of head; usually with fine circular and longitudinal lines (see elsewhere in key for those without) . . *Lineus vegetus* (Coe, 13)
9. Slender but less so than above; dorsal surface with two narrow longitudinal dark lines on light background; two large ocelli on each side . . . . *Nemertopsis gracilis*

10. General body color deep brown; five or six very slender, often broken, longitudinal white lines; numerous narrow white rings spaced at fairly regular intervals . . . . *Tubulanus sexlineatus* (= *Carinella sexlineata*)

10. General body color ivory white, with a series of rectangular dorsal areas of deep purple or wine color, separated by narrow white bands (see figure in text); posterior end with narrow colorless "tail," caudal cirrus (not shown in figure)
. . . . *Micrura verrilli*

LIST OF COMMON NEMERTEA

D B *M *Amphiporus bimaculatus* Coe
TB D M *Tubulanus polymorphus* Renier (= *Carinella rubra* Griffin)
D *M *Tubulanus sexlineatus* Griffin (= *Carinella sexlineatus* Griffin)
M *Tubulanus pellucidus* Coe (= *Carinella pellucida* Coe)
TB D M *Cerebratulus californiensis* Coe
*B *M *Euplectonema gracile* Johnston
*M *Micrura verrilli* Coe
M *Nemertopsis gracilis* Coe

PHYLUM ROTIFERA

These minute animals chiefly plankton feeders are almost always present in freshwater cultures. Isolate a rotifer on a slide and anesthetize it for study or find one immobilized on a mount from a rich culture. Study it under low and high power, making out the various structures referring to figure 10. Figure 11 shows another type of rotifer (*Brachionus*) very commonly encountered. Attempt to identify your specimen, using the key below.

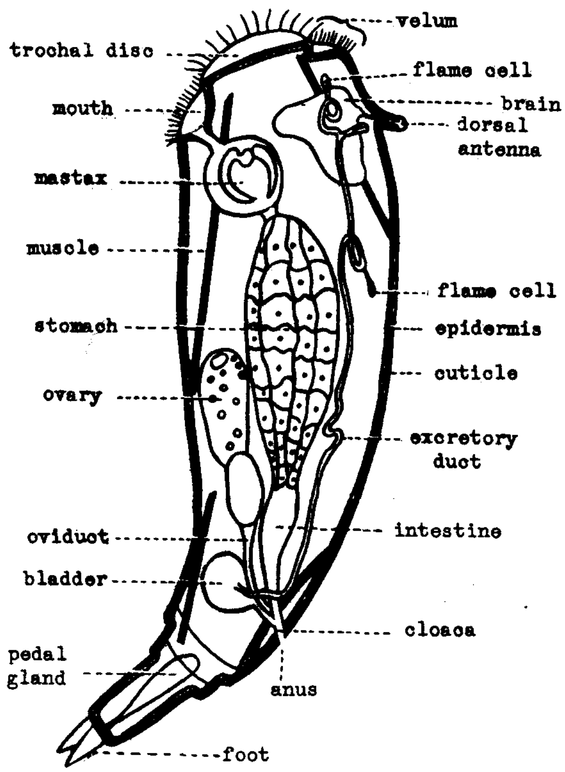


Fig. 10.—Diagrammatic hemisection of a typical rotifer (after Shipley and MacBride).

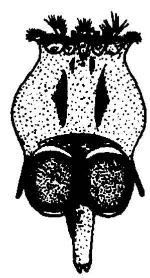


Fig. 11.—Brachionus vitrea with two resting or winter eggs (after Whitney).

Make yourself familiar with the chapter on rotifers in Ward and Whipple and with the monograph of Hudson and Gosse (2 vols., 1889).

A KEY TO THE ROTIFERA OF LONE TREE POND

By A. B. Burch

1. Colonial . . . . *Megalotrocha alboflavicans*
1. Solitary 2

2. Lorica pronounced 3
2. Lorica poorly developed or absent 12

3. Lorica laterally compressed 4
3. Lorica dorsoventrally flattened 5
3. Lorica more or less radially symmetrical, toothed anteriorly with or without one long spine posteriorly; no foot . . . . *Anuraea cochlearis*

4. Lorica with three dorsal furrows, toothed before and behind; foot with two toes . . . . *Salpina spinnigera*
4. Lorica with hooked head-shield, not toothed . . . . *Colurus*

5. Lorica with distinct longitudinal furrows 6
5. Lorica without distinct longitudinal furrows 8

6. Lorica with one median dorsal furrow, teeth absent, one eye . . . . *Diplois*
6. Lorica with one median dorsal furrow, teeth absent, eye absent . . . . *Diplax*

8. Lorica toothed anteriorly and posteriorly 9
8. Not so toothed 11

9. Lorica very convex dorsally . . . . *Brachionus bakeri*
9. Lorica very flat 10

10. With foot and two toes . . . . *Noteus quadricornus*
10. Without foot . . . . *Anuraea aculeata*

11. Lorica toothed anteriorly, with a median notch posteriorly; foot short, two medium-sized toes, each with an oblique bristle at the base . . . . *Euchlanis macrura*
11. Lorica toothed anteriorly, no notch posteriorly; foot long, with one toe . . . . *Brachionus punctatus*

12. Foot absent; body round . . . . *Trochosphaera*
12. Foot present 13

13. Body highly contractile, telescopic 14
13. Not so 15

14. With three fine toes on very long, contractile foot, two spurs midway of length of foot . . . . *Rotifer neptunius*
14. With two toes . . . . *Philodina roseola*

15. Body more or less triangular in general outline; two antero-lateral projecting styles . . . . *Synchaeta stylata*
15. Not so 16

16. Body very flat, quite round with a projecting corona; with a small cylindrical foot, no toes; vase-shaped. . *Pterodina patina*
16. Body not flat, but slightly flattened dorsally when swimming; somewhat elongate; divided into a head and body region; foot short, with two toes . . . . *Triphylus lacustris*

LIST OF ROTIFERA (ALL FRESHWATER)

(Some may, however, be found in Lake Merritt when that water has little salt.)

Names as in key and in Ward and Whipple:	Names as in Harring, H. K.,. 1913. "Synopsis of the Rotatoria," <u>Bull. U.S. Nat. Mus.</u>, 81
Anuraea aculeata	*Keratella quadrata* Müller
Anuraea cochlearis Gosse	*Keratella cochlearis*
Colurus	*Colurella*
Brachionus bakeri	*B. capsuliflorus* Pallas
Brachionus punctatus Hempel	*B. budapestinensis* Daday
Diplax	*Mytilina* sp.
Diplois	*Diplois*
Euchlanis macrura Ehrenberg	*Euchlanis macrura* Ehrenberg
Megalotrocha alboflavicans Ehrenberg	*Sinantherina socialis* Linnaeus
Noteus quadricornis Ehrenberg	*Platyias quadricornis*
Philodina roseola Ehrenberg	*Philodina roseola* Ehrenberg
Pterodina patina Hermann	*Testudinella patina*
Rotifer neptunius Ehrenberg	*Mytilina mucronato spinigera*
Salpina spinigera Ehrenberg	*Synchaeta stylata* Wierzejski
Synchaeta stylata Wierzejski	*Synchaeta stylata* Wierzejski
Triphylus lacrustris Ehrenberg	*Enteroplea lacustris* Ehrenberg

THE GASTROTRICHA

These microscopic creatures, often grouped with the rotifers but structurally very distinct (fig. 12), are commonly encountered in ponds and in freshwater cultures and should be recognized.

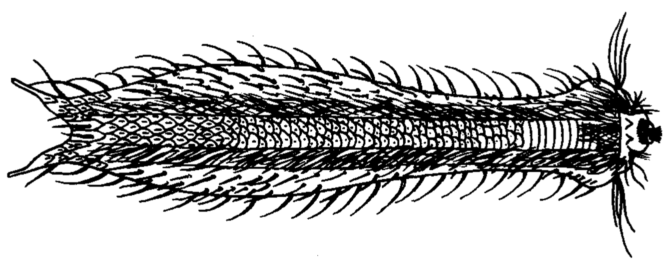


Fig. 12.—A gastrotrich, <u>Chaetonotus maximum</u> Ehrenberg (from Wessenberg-Lund after Zelinka).

PHYLUM ANNELIDA

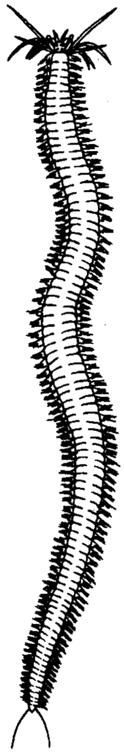
The annelids or segmented worms can be divided into the following classes: (1) *Archiannelida*, a small, poorly known group with distinct segmentation in our representatives, parapodia often poorly developed, often lacking setae and with the two ends of the body often developed for rapid locomotion through sand. When more completely known they may be found to represent modified forms of widely separated, already known families. (2) *Polychaeta* (fig. 13,A), which have many setae (hence the name) and parapodia; they are almost entirely marine and are very numerous. (3) *Oligochaeta* (fig. 13,B,C), with a few setae and no parapodia; they are predominantly freshwater or terrestrial. These last two classes are often combined to form the single class *Chaetopoda*, but there is evidence that the two are not so closely related to each other as each is to other groups in the phylum. (4) *Hirudinea* or leeches (fig. 13,D), with no setae or parapodia and with important internal anatomical differences from the other classes; they are mostly inhabitants of fresh water. (5) *Echiuroidea*, consisting of a few marine species, of which *Urechis caupo* (fig. 13,F) is our local representative (burrowing in mud). They have a few annelid characters, but are unsegmented externally. (6) The *Sipunculoidea* (fig. 13,E), of very doubtful affinities with the annelids. Like the echiurids, they are unsegmented and they are likewise marine. The last two classes are probably more properly considered as separate phyla.

Class POLYCHAETA

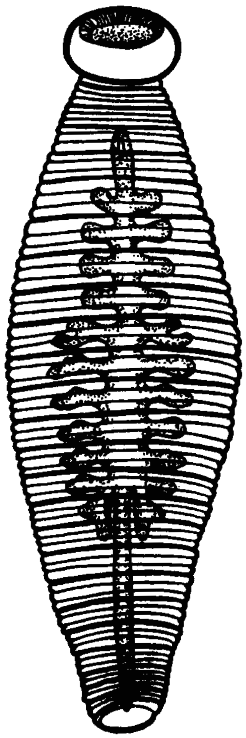
The names and characters of the major divisions of the polychaetes are very much in dispute. One useful but perhaps not scientifically justifiable division is into the Sedentaria or sedentary polychaetes, chiefly tube dwellers, and the Errantia or free-living families. More useful is the designation of family types (fig. 17), such as nereid, polynoid, serpulid, syllid, sabellid, cirratulid, spionid, etc.

On your specimen (*Nereis*) make out the paired locomotor parapodia (sing. parapodium) each (fig. 14) composed of an upper lobe, the notopodium, and a lower, neuropodium. Remove and mount a parapodium to make out the structures noted below. Each lobe typically contains a bundle of slender chitinous rods or spines, the setae (sing. seta) which project from the parapodium, and buried in it a larger dark spine known as the aciculum (pl. acicula) which functions as a fulcrum for moving the parapodia and the setae. The shape, size, number, and position of the setae are of importance in classification. Arising from the base of the notopodium above and the neuropodium below there are often present slender flexible outgrowths (fig. 14), the dorsal cirrus (pl. cirri) and ventral cirrus respectively. The notopodium consists of a dorsal lobe and a middle lobe between which the setae and aciculum project (fig. 14); the neuropodium consists of a neuro-acicular lobe provided with setae and an aciculum, and a ventral lobe.

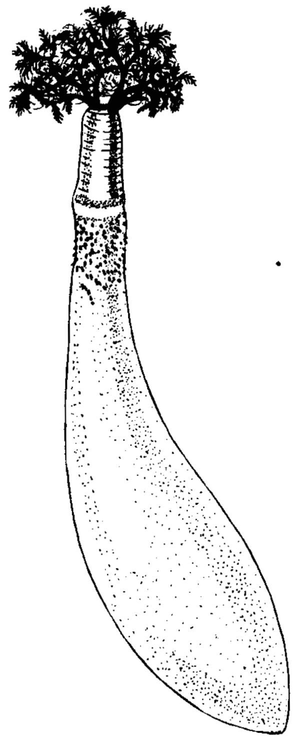
The setae are of widely varying form and furnish very precise characters for the determination of species. The use of such characters has been avoided where possible in the key but has been found necessary in some cases. The common types and their names should be



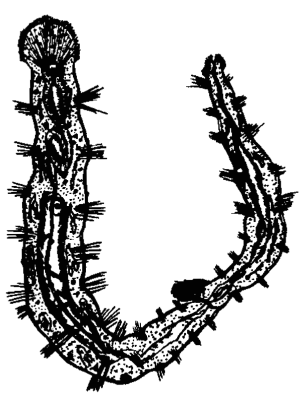
A. Nereis
(Polychaeta)



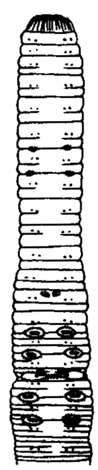
D. A leech (Hirudinea)



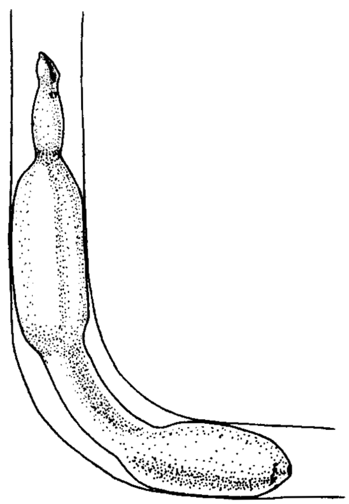
E. Sipunculoidea



B. Aeolosoma, a fresh-
water oligochaete



C. An earthworm
(Oligochaeta)



F. Urechis (Echiuroidea)

Fig. 13.—Types of Annelida. (C, after Altman; D, after Buchsbaum; E, after Fisher; F, after Ricketts and Calvin after MacGinitie.)

recognized. Plate I (after Fauvel, 1922) gives some idea of the wide variety of types. First we may distinguish simple setae (Plate I, nos. 1-19) from composite or jointed setae (nos. 21-28). Long slender simple setae are spoken of as capillary setae (no. 6). The tips of setae whether simple or composite may be entire or bifid (no. 8) or trifid. If bent like a cycle they are termed falcate.

Some simple setae have bent, usually bifid ends. These are spoken of as hooks or crotchets (Plate I, nos. 29-32). These are usually relatively stout setae and graduate into broadened types known as uncini (nos. 33-42), which are especially characteristic of the Sedentaria.

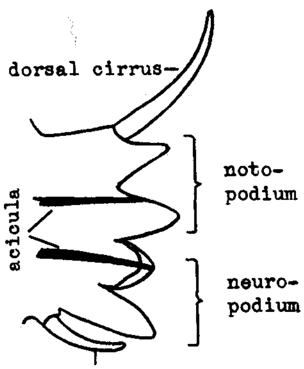


Fig. 14.—A parapodium of a nereid polychaete.

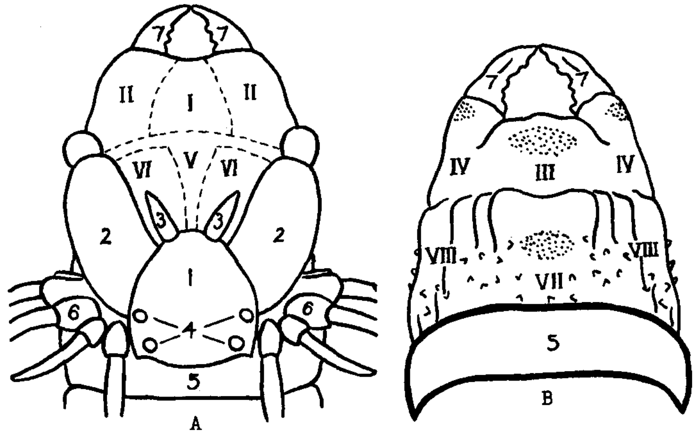
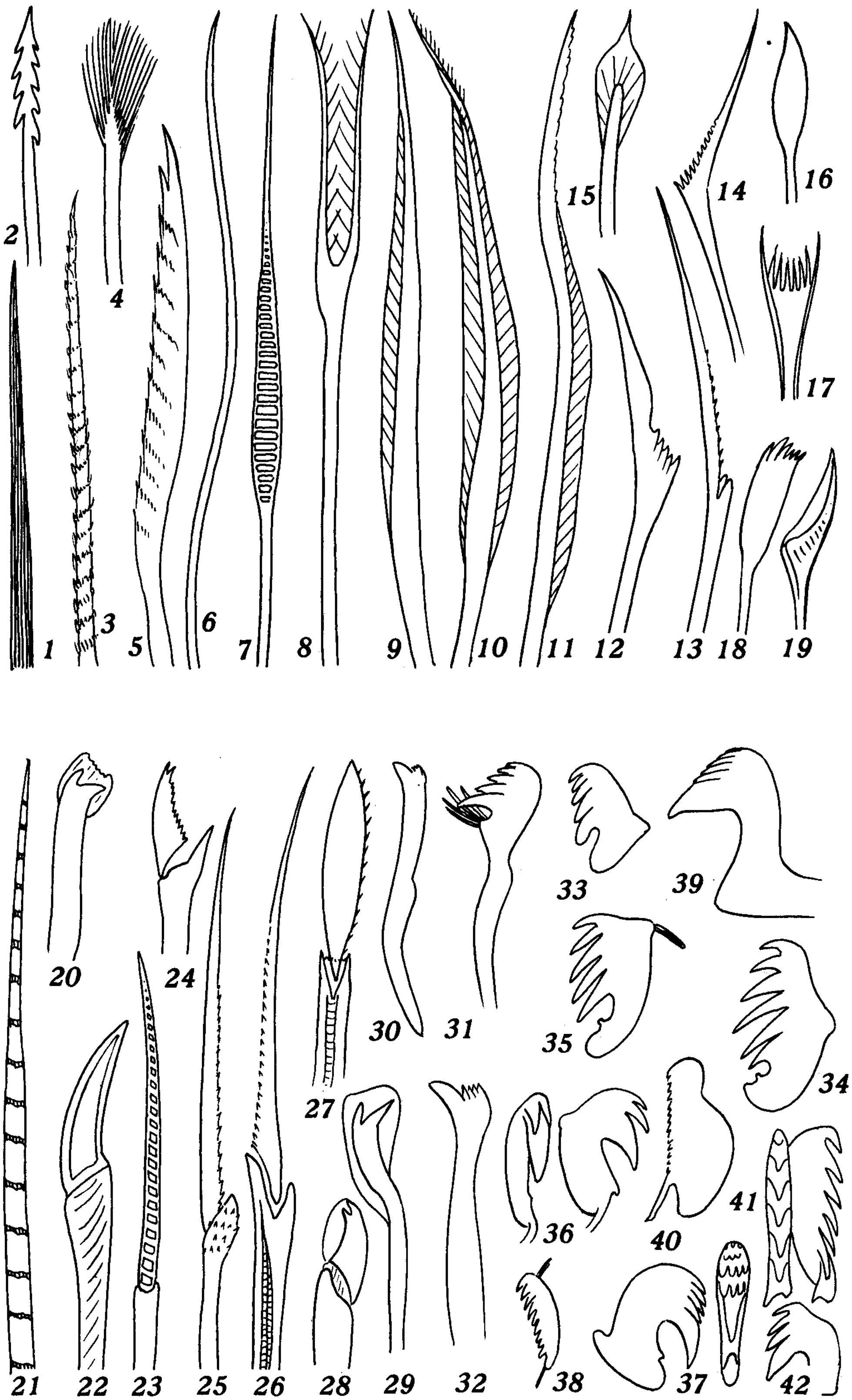


Fig. 15.—Head of Nereis with everted proboscis: A, dorsal view; B, ventral view. (1) prostomium; (2) palpi; (3) prostomial tentacles; (4) eyes; (5) peristomium; (6) peristomial or tentacular cirri; (7) jaws. I-VIII, areas of proboscis; V-VIII, on oral ring; I-IV, on maxillary ring.

Composite setae may be articulated as in the long bristles of the Flabelligeridae (Plate I, no. 20), but are characteristically two-jointed, composed of a shaft and a blade (nos. 22-28). This blade in turn may have various shapes and may itself be a crotchet (no. 28). The blade rests in a notch in the end of the shaft. If the two sides of the notch are equal, it is spoken of as homogomph (no. 27); if somewhat unequal, as hemigomph; and if distinctly so, as heterogomph (no. 26). Finally setae, either simple or compound, may be embedded distally within a clear matrix and these are spoken of as "hooded." Thus we may have simple hooded crotchets (no. 29) or composite crotchets (no. 28).

Identify the following structures of the head; a pre-oral prostomium (fig. 15,A), provided at its anterior border with a pair of antennae, and at the sides with paired, fleshy, biarticulated palpi. Two pairs of eyes, more or less in rectangular arrangement are to be found on the dorsal side of the prostomium, the more posterior pair sometimes concealed by the peristomial ring. The peristomium is the first complete

PLATE I



Types of polychaete setae (after Fauvel) ring or segment. It may, however, represent two coalesced segments as in *Nereis*. There are four pairs of slender, tentacular cirri (peristomial cirri) on short stalks at the antero-lateral margin of the peristomium. Note that the first parapodia are found on segment two (considering the peristomium as one), and that the first two pairs of parapodia are uniramous, that is, each contains a single aciculum and setal fascicle, and that all succeeding parapodia are biramous.

Make a ventral longitudinal incision starting from the mouth and extend the cut posteriorly through about twenty segments. Pin back the flaps and identify the parts of the proboscis. The following parts (fig. 15) are to be found. (In the retracted proboscis the position of oral and maxillary rings is in reverse order): (1) an oral ring which is just external to the mouth (internal when proboscis is everted) and bounded by the mouth on one end and the maxillary ring on the other, divisible into six areas, numbered from V to VIII; and (2) beyond this a second ring, the maxillary ring, bounded on one end by the oral ring, provided with stout, horny jaws at its other end and divisible into six areas numbered from I to IV. Area V lies on the median dorsal line of the oral ring and in *Nereis* is usually without the dark chitinous denticles termed paragnaths; areas VI are paired, lying on either side of V, and normally are provided with a circular mount of tiny paragnaths. Area VII lies on the mid-ventral line of the oral ring and areas VIII are paired patches at the sides of VII. In *Nereis* areas VII and VIII usually have a continuous band of chitinous paragnaths. The areas of the maxillary ring occupy positions similar to those of the oral ring. Area I lies in line with V, II with VI, III with VII, and IV with VIII. Even numbered areas are always paired, odd numbered areas lie in the median dorsal and ventral lines.

Identify your specimen to the group, using the key on page 34.

Study living individuals of the serpulid *Mercierella* under the dissecting microscope. Remove from tubes and identify: (1) a feathery tentacular crown (fig. 16), consisting of modified peristomial cirri and often called branchiae, one branch of which is specially modified to form the operculum (fig. 16). The prostomium is greatly reduced and made out with difficulty. The mouth marks the ventral side, and lies on the side opposite the operculum. Arising from the posterior border of the peristomium is a broad, thin membranous collar, open dorsally, and richly supplied with blood vessels and nerves. Its function is thought to be respiratory. The collar is continued posteriorly as the thoracic membrane along the posterior border of the thorax thus sharply setting off the thorax from a posterior region of the body, called the abdomen.

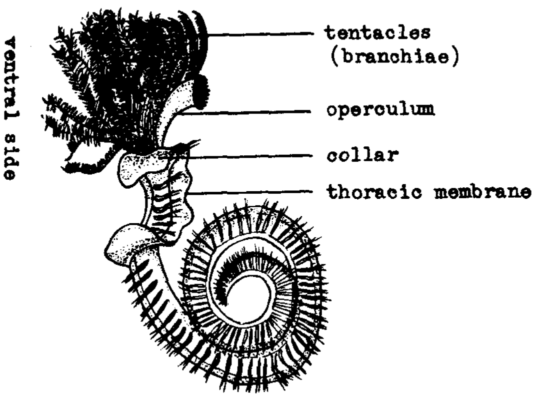


Fig. 16.—Mercierella enigmatica Fauvel, the Lake Merritt tubeworm, removed from its tube; somewhat enlarged.

See and be able to recognize at this time the types given on the list below.

Important Polychaete Types (Families)

Nereid (figs. 13,A, 15)
Lumbrinerid (fig. 17,A and Plate V, no. 1)
Glycerid (fig. 17,F)
Phyllodocid (fig. 17,E and Plate VII, no. 1)
Polynoid (fig. 17,B)
Syllid (17,D and Plate VII, nos. 2, 3)
Sabellid (fig. 17,C and Plate I, no. 3)
Serpulid (figs. 16, 17,I)
Spionid (fig. 17,J and Plate IX, no. 2)
Cirratulid (fig. 17,H and Plate IV, no. 1)
Terebellid (fig. 17,G and Plate III, no. 3)

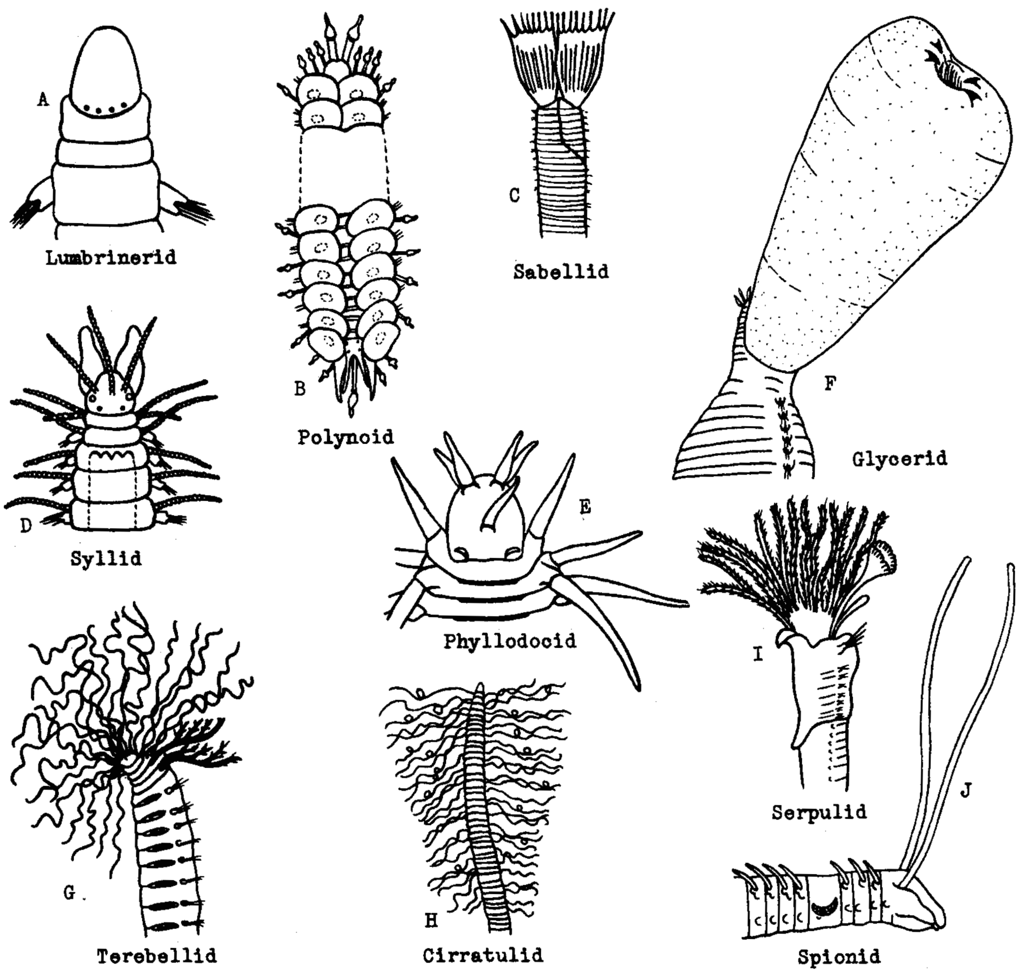


Fig. 17.—Types of polychaetes: A, Arabella, a lumbrinerid; B, Halosydna, a polynoid; C, Myxicola, a sabellid; D, Syllis, a syllid; E, Eulalia, a phyllodocid; F, Glycera, a glycerid; G, Terebella, a terebellid; H, Cirratulus, a cirratulid; I, Serpula, a serpulid; J, Boccardia, a spionid.

KEY TO THE POLYCHAETA

1. Dorsal surface more or less completely covered by overlapping scales (elytra) (fig. 17,B; Plate II, no. 2), paleae (modified flattened setae, fig. 188), or overlain by a thick felty layer (Plate II, no. 1) (APHRODITIDAE, POLYNOIDAE, POLYODONTIDAE, SIGALIONIDAE, CHRYSOPETALIDAE) 2
1. Dorsal surface not covered with elytra, paleae, or felt 14

2. Dorsal surface more or less concealed by a felty layer that covers the elytra. APHRODITIDAE . . . *Aphrodita* (Plate II, no. 1)
2. Dorsal surface more or less concealed by elytra (fig. 17,B; Plate I, no. 2) 4
2. Dorsal surface more or less concealed by paleae (fig. 18,B) CHRYSOPETALIDAE 3

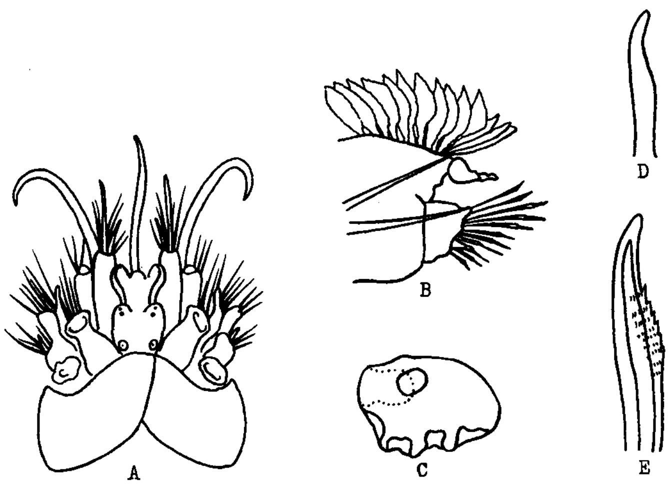
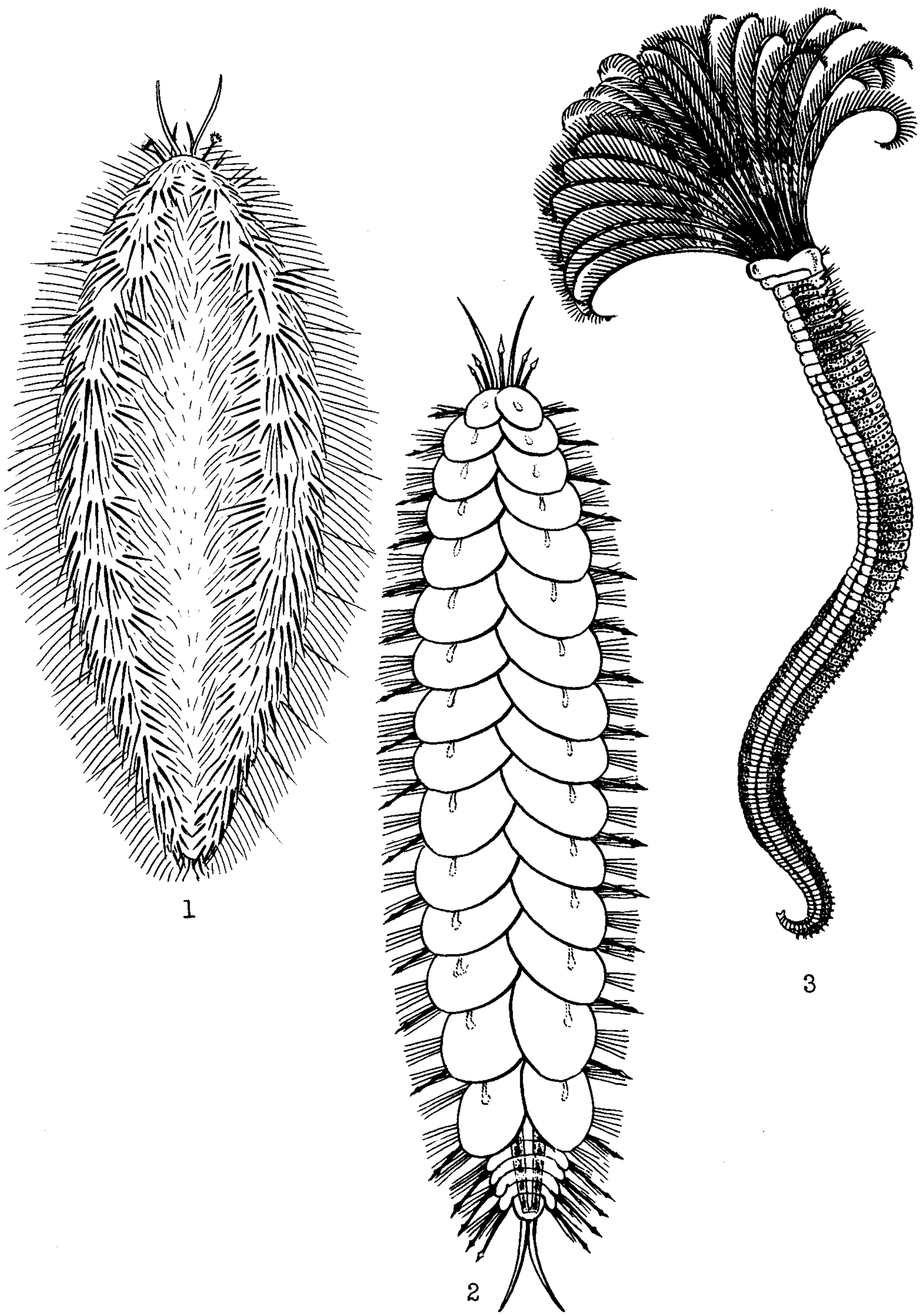


Fig. 18.—A, head of <u>Sthenelais fusca</u>; B, parapodium of a chrysopetalid; C, elytrum of <u>Arctonoë fragilis</u>; D, neuropodial seta of same; E, neuropodial seta of <u>Halosydna brevisetosa</u>.

3. Paleae of one kind; color in life, pale rust to yellowish . . . . *Chrysopetalum*
3. Paleae of two kinds; color in life, glistening white or greenish . . . . *Paleonotus*

4. Elytra and dorsal cirri alternate regularly from fifth segment to posterior end of body. POLYODONTIDAE. Neuropodia with composite setae; prostomium without median antenna; body short, subrectangular, to 12 mm. long . . . . *Peisidice*
4. Elytra and dorsal cirri alternate in anterior segments, but in the posterior segments elytra are present on all segments and entirely replace the cirri. SIGALIONIDAE. Median prostomial antenna (fig. 18,A) with broad base and lateral wings; elongate; dusky brown; among roots of eel grass . . *Sthenelais fusca*
4. Elytra and dorsal cirri alternate regularly to about the 23d segment, thereafter there are two elytra followed by a dorsal cirrus. POLYNOIDAE (Plate II, no. 2.) 5

PLATE II



Polychaete types (after McIntosh): 1, Aphrodita aculeata (Linn.) (Aphroditidae); 2, Harmothoe imbricata (Linn.) (Polynoidae); 3, Megalomma vesiculatum (Montagu) (Sabellidae).

5. With 12 pairs of elytra . . . . *Lepidonotus caelorus*
5. With 15 pairs of elytra 10
5. With 18 pairs of elytra . . . . *Halosydna* 6
5. With more than 18 pairs of elytra 7

6. Elytra more or less firmly attached; neuropodial setae entire at end (fig. 18,E); common in mussel beds, or commensal with *Thelepus* . . . . *Halosydna brevisetosa*
6. Elytra easily shed; neuropodial setae bifid at end; free-living, under stones . . . . *Halosydna johnsoni*

7. Elytra more or less completely covering the dorsum in the anterior region; dorsal cirri and antennae club or pear-shaped; neuropodial setae strongly falcate (sickle-shaped, fig. 18,D), the sides smooth . . . . *Arctonoë* 8
7. Elytra reduced in size throughout, those in the posterior half not noticeably smaller than those in the anterior half; dorsal cirri and antennae cirriform; neuropodial setae serrated 9

8. Elytra strongly frilled at external margins (fig. 18,C); in ambulacral grooves of *Pisaster* . . . . *Arctonoë fragilis*
8. Elytral margin smooth externally; a broad, transverse dark band across anterior segments; in branchial grooves of mollusks . . . . *A. vittata*
8. Elytra slightly undulate at margins; commensal with holothurians . . . . *A. pulchra*

9. Elytra in pairs throughout length of body; notopodia without setae; commensal often with tube-building worms . *Lepidasthenia*
9. Some elytra in posterior region not paired; some anterior notopodia have setae; commensal . . . . *Lepidametria*

10. Notopodial and neuropodial setae each of one kind 12
10. Notopodial and neuropodial setae each of two kinds, a stout and a slender form . . . . *Hesperonoë* 11

11. Elytral surface smooth or with very few minute, low papillae; commensal with *Urechis* . . . . *Hesperonoë adventor*
11. Elytra with numerous scattered low papillae; commensal with *Callianassa* . . . . *H. complanata*

12. Neuropodial setae entire at distal end 13
12. Some neuropodial setae with tips bifid . . . . *Harmothoë* (Plate II, no. 2)

13. Neuropodial setae long, slender, the distal ends hairlike. . . . . *Antinoë*
13. Neuropodial setae with distal ends thicker, not hairlike. . *Eunoë*

14. Anterior end completely concealed by feathery tentacles. SABELLIDAE (fig. 17,C; Plate II, no. 3), SERPULIDAE (fig. 16). 15
14. Anterior end completely concealed by chitinous spines forming an operculum. SABELLARIIDAE (fig. 19,A), PECTINARIIDAE . . . 31
14. Anterior end with long, strong, spinous setae, not forming an operculum, but projecting forward and concealing the prostomium (fig. 18,B and Plate III, no. 1). FLABELLIGERIDAE . . . 33

[See opposite page.]

14. Anterior end more or less completely covered by many long, filamentous outgrowths concentrated on anterior region (fig. 17,G); body usually with two distinct regions. AMPHARETIDAE, (Plate III, no. 2) TEREBELLIDAE (fig. 17,G; Plate III, no.3) . 34
14. Anterior end more or less completely covered by many long, filamentous outgrowths as in category above, but also with similar outgrowths continued along sides of body (fig. 17,H) (except *Dodecaceria*); body not divided into two distinct regions. CIRRATULIDAE (Plate IV, no. 1) 40
14. Anterior end otherwise; prostomium generally not concealed . . 44

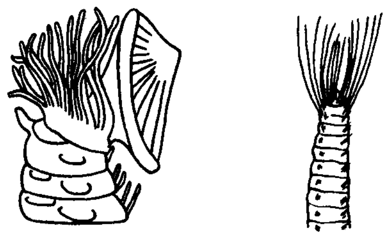


Fig. 19.—A, Phragmatopoma, Family Sabellariidae; B, a flabelligerid.

15. Thoracic membrane well developed (figs. 16, 17,I); operculum usually present; in calcareous tubes. SERPULIDAE 16
15. Thoracic membrane little developed or absent; no operculum; in sandy chitinized tubes. SABELLIDAE (fig. 17,C and Plate II, no. 3). 22

Serpulidae (see 14 and 15)*

16. Minute; in small neatly coiled tubes. . . . . *Spirorbis*
16. Small to larger; tubes straight or twisted, but not coiled . . 17

17. Without operculum; tentacles few; forming small fragile tube masses; red in life . . . . *Salmacina*
17. With operculum; tentacles few to numerous 18

18. Operculum bladder-like with smooth stalk; tubes usually solitary, fragile, sometimes longitudinally ribbed . . *Vermiliopsis*
18. Operculum funnel-shaped 19

19. Stalk of operculum smooth; tubes solitary, fairly large, cylindrical to somewhat twisted . . . . *Serpula*
19. Stalk of operculum with lateral wings; tubes strongly ridged longitudinally . . . . *Spirabranchus*
19. Operculum with spines but without lateral wings on stalk . . . 20

20. Spines of operculum produced from a single terminal plaque (fig. 16); estuarine (Lake Merritt) . . . *Mercierella enigmatica*
20. Spines produced in a two-storied structure; marine 21

21. Distal series of spines with lateral projections . . . *Hydroides*
21. Distal series of spines with smooth sides . . . . *Eupomatus*

*Figures thus given refer to the categories in the key through which the particular family has been arrived at and permit of a quick review of the characters stressed.

Sabellidae (see 14 and 15)

22. Without a thoracic collar; tentacles without eye-spots; large, to 10 inches long or more; white or pale yellow in life; in sand or muddy sand. . . . . *Myxicola* (fig. 17,C)
22. With a thoracic collar (fig. 20,A,B,C) (rarely absent); with (fig. 20,E) or without tentacular eye-spots 23

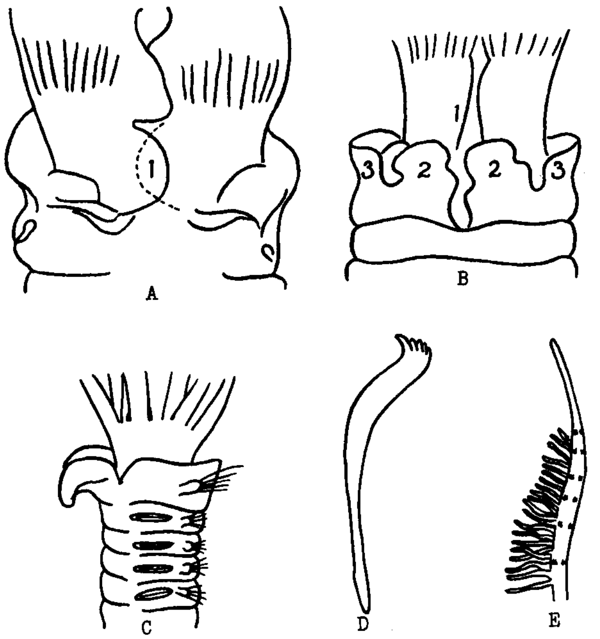


Fig. 20.—Sabellidae: A, Pseudopotamilla occellata. (1) Tentacular membrane with a dorsal lobe or flap. B, P. intermedia. (1) Dorsal edge of tentacular membrane straight; (2) collar with two dorsal lobes; and (3) two lateral lobes. C, Sabella. D, long-stemmed uncinus from thoracic neuropodium of Fabricia. E, tentacular radiole of Sabella crassicornis showing paired eye-spots.

23. Tentacular filaments divided several times . . . . *Schizobranchia*
23. Tentacular filaments not divided 24

24. Composite eyes at distal end of some radioles . . . . . *Megalomma*
24. Without composite eyes in such position 25

25. With tentacular eye-spots 27
25. Without tentacular eye-spots 26

26. Tentacular filaments united for most of their length by a palmate membrane (fig. 17,C); thoracic collar conspicuous forming a smooth, entire membrane, open in mid-line; thoracic crotchets with a long stem (fig. 20,D) . . . .*Chone*
26. Tentacular filaments not united by membrane or at most for a relatively small part of their length; thoracic collar not strongly developed; thoracic uncini with short stem . . . . *Sabella media*

27. Tentacular eye-spots disposed in pairs (fig. 20,E); tentacular bases not arranged in a spiral . . . . . . *Sabella crassicornis*
27. Tentacular eye-spots not in pairs; tentacular bases in a spiral (*Eudistylia*) or not (*Pseudopotamilla*) 28

28. Base of tentacular membrane conspicuously spiraled (*Eudistylia*) 29
28. Base of tentacular membrane not spiraled (*Pseudopotamilla*) . . 30

29. Dorsal edge of tentacular membrane deeply cleft, the two lobes thus formed overlapping; tentacles deep maroon except for a pale band distally; in rocky crevices especially on reefs. . . . . *Eudistylia polymorpha*
29. Dorsal edge of tentacular membrane with rectangular flaps; tentacular crown crossed with numerous bands of maroon and pale color; ventral lobes of collar produced; in sand or mud flats . . . . *E. vancouveri*

30. Dorsal tentacular membrane with notched flaps, dorsal collar lobes short; tentacular eye-spots conspicuous . . . . *Pseudopotamilla occelata* (fig. 20,A)
30. Dorsal tentacular membrane a narrow rectangular flap; dorsal collar lobes long . . . . *P. intermedia* (fig. 20,B)

31. Thorax with two pairs of pectinate (comblike) branchiae; caudal appendage (tail) annulated and with setae; operculum formed of a single series of a few large spines; constructs solitary, conical tubes (fig. 35,A), open at both ends. PECTINARIIDAE (see 14) . . . . *Cistenides*
31. Thorax without pectinate branchiae; with many filiform branchiae in longitudinal rows above the oral aperture; caudal appendage smooth, slender; operculum formed of three whorls of numerous closely-spaced spines; constructs masses of tubes more or less firmly cemented together. SABELLARIIDAE (fig. 19,A) (see 14) 32

32. Opercular spines form a neat, black cone (fig. 19,A) . . . . *Phragmatopoma*
32. Opercular spines form an open pattern, amber-colored. . *Sabellaria*

Flabelligeridae (see 14)

33. With only simple setae; inhabits U-shaped burrows in shales . . . . *Stylarioides* (Plate III, no. 1)
33. With some composite (jointed) setae; inhabits gelatinous or chitinized tubes, or among the spines of *Strongylocentrotus*. . . . . *Flabelligera*

34. Tentacles retractile into mouth, leaving branchiae exposed and extending over the anterior end; prostomium often clearly visible. AMPHARETIDAE (Plate III, no. 2) (see 14) . . . . *Schistocomus*
34. Tentacles not retractile into the mouth; prostomium and branchiae usually not visible except by lifting tentacles away; branchiae dorsal. TEREBELLIDAE (fig. 17,G and Plate III, no. 3) (see 14) 35

35. Without branchiae; dorsal peristomial lip large, broad. *Polycirrus*
35. With branchiae on the dorsal side, posterior to the tentacles . 36

36. Branchial filaments simple, cirriform; thoracic setigerous segments more than 20; color in life, salmon with bright red branchiae; in coarsely constructed tubes on under sides of stones; often with *Halosydna brevisetosa* . *Thelepus* (fig. 21)
36. Branchial filaments branched; thoracic setigerous segments 17 or more 37

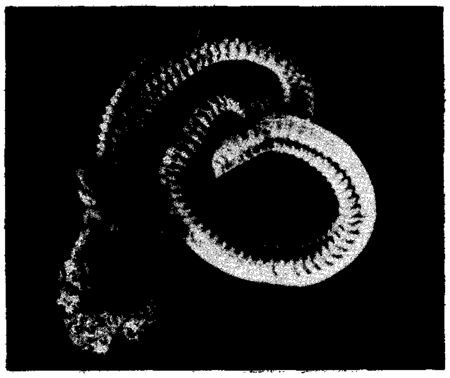


Fig. 21.—Thelepus (after Guberlet)

37. First few segments have broad, lateral flaps; branchiae elongate, dendritic, greenish; constructs tubes in rock crevices, the distal end of the tube with an open, reticulated, sponge-like mass through which the tentacles are extended. . . . . *Pista*
37. Not so. 38

38. With about 25 thoracic setigerous segments; branchiae three pairs, much-branched, the first pair the largest . . . . *Terebella* (fig. 17,G)
38. With 17 thoracic setigerous segments 39

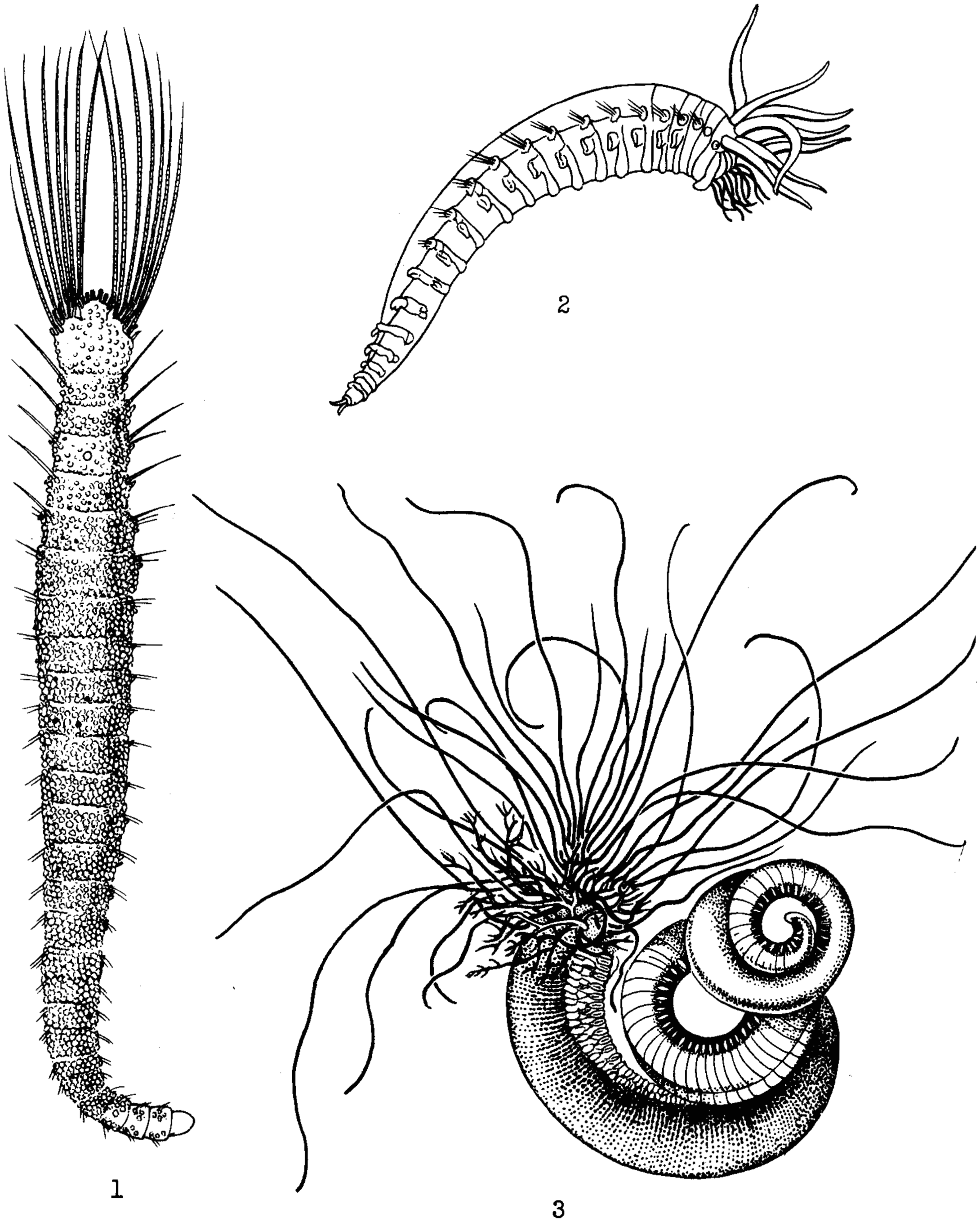
39. Chocolate-brown in life; tentacles white, crowded; branchiae red; constructs soft mud tubes. . *Amphitrite* (Plate III, no. 3)
39. Greenish; tentacles light tan; branchiae deep reddish-brown; in sandy tubes . . . . *Eupolymnia*

Cirratulidae (Plate IV, no. 1); (See 14)

40. Body with few pairs of long, tentacular cirri; constructing calcareous rock masses; dark to black in life . . . *Dodecaceria*
40. Body with more numerous tentacular cirri (fig. 17,H), not constructing calcareous masses; reddish- to greenish-brown in life 41

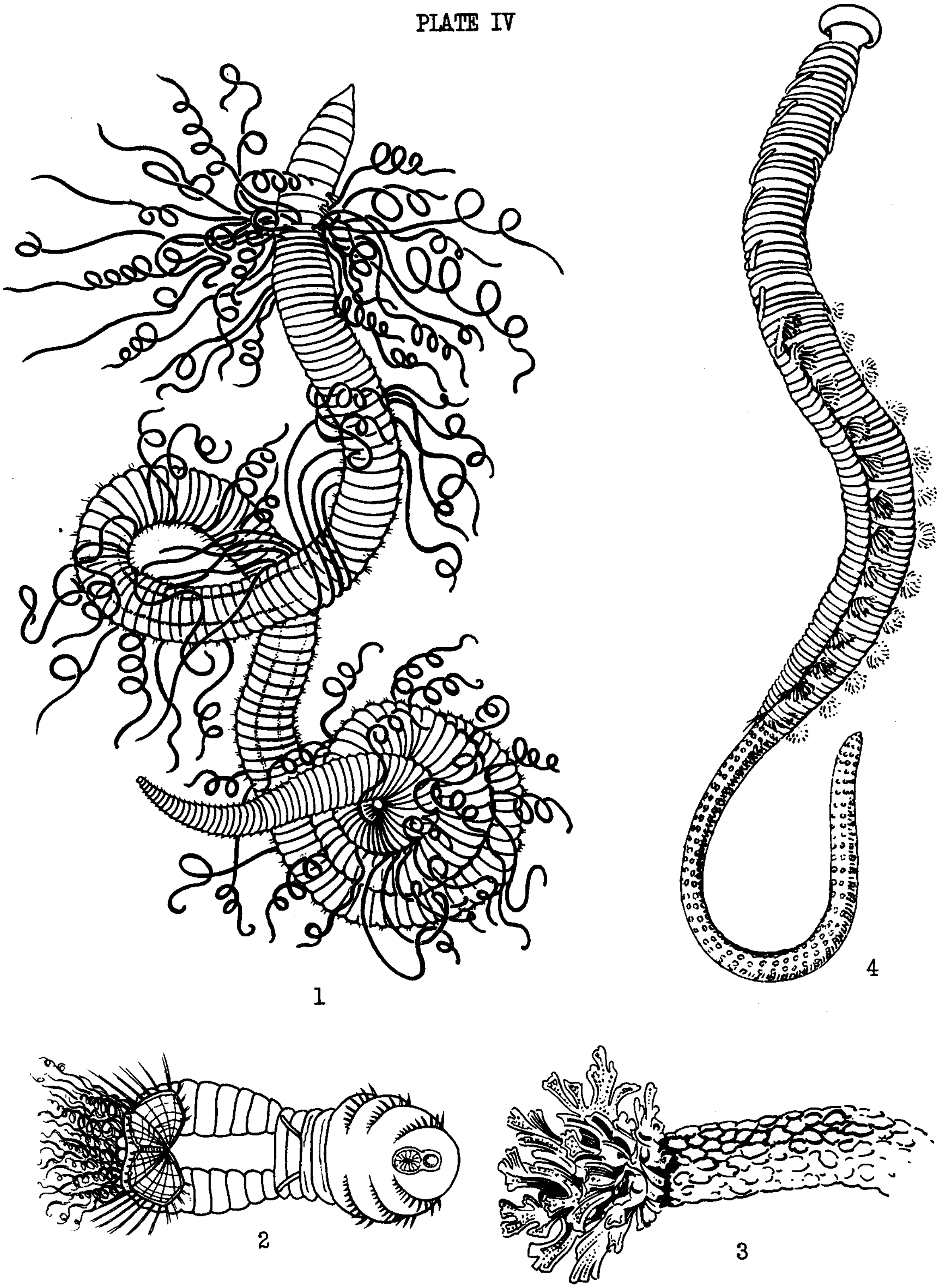
41. Anterior end with a pair of stouter, grooved palpi (fig. 22,B) in addition to the tentacles . . . . *Tharyx* (*T. parvus* on San Francisco Bay mud flats; a different undescribed species at Moss Beach)
41. Anterior end without palpal structures (fig. 22,A). 42

PLATE III



Polychaete types (after McIntosh): 1, Stylarioides flabellata (Sars) (Flabelligeridae); 2, Amage auricula Malmgren (Ampharetidae); 3, Amphitrite gracilis (Grube) (Terebellidae).

PLATE IV



Polychaete types (after McIntosh): 1, *Cirriformia tentaculata* (Montagu) (Cirratulidae); 2, *Sternaspis scutata* Rietsch (Sternaspididae); 3, *Owenia fusiformis* Delle Chiaje (in tube) (Oweniidae); 4, *Arenicola marina* (L.) (Arenicolidae).

42. Tentacles extending as far anteriorly as setae (fig. 17,H), prostomium with eye-spots on either side . . *Cirratulus cirratus*
42. Tentacles first present on the third to fifth setigerous segment . . . . *Cirriformia* (fig. 22,A) 43

43. Posterior segments with few, stout, thick, dark spines (fig. 23,B); inhabits burrows or crevices in rocks . . . *Cirriformia luxuriosa*
43. Posterior segments with more numerous, finer, pale spines (fig. 23,A); inhabits sand among rocks . . . . *C. spirabrancha*

Fig. 22.—Cirratulidae: A, anterior end of Cirriformia; B, anterior end of Tharyx.

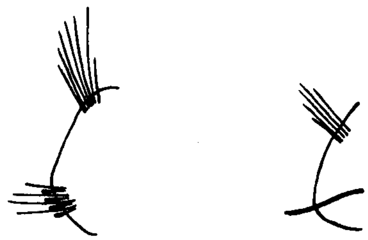


Fig. 23.—Setae of posterior segments of Cirriformia: A, C. spirabrancha; B, C. luxuriosa.

44. Prostomium without tentacles, although occasionally with a lobed, flaring membrane (STERNASPIDAE, OPHELIIDAE, ORBINIIDAE, CAPITELLIDAE, MALDANIDAE, ARENICOLIDAE, OWENIIDAE, LUMBRINERIDAE) 45
44. Prostomium with minute tentacles, which are usually inconspicuous unless rendered conspicuous because of reduced size of head (fig. 17,F); prostomium usually reduced in size, or, if large, partly concealed by the first few segments of body; no palpi. NEPHTYIDAE, GLYCERIDAE, GONIADIDAE, AMPHINOMIDAE, EUPHROSINIDAE 62
44. Prostomium with tentacles more or less conspicuous, these accompanied by a pair of thick, fleshy palpi (except in Phyllodocidae). SYLLIDAE (fig. 17,D), NEREIDAE (fig. 15,A), EUNICIDAE, ONUPHIDAE, STAURONEREIDAE, PHYLLODOCIDAE 73
44. Prostomium with a pair of long, prehensile, tentacular palpi, sometimes accompanied by a pair of minute anterior antennae. SPIONIDAE (Plate IX, no. 2), MAGELONIDAE, CHAETOPTERIDAE . . 108
44. Prostomium with three tentacles; palpi slender, biarticulate (Plate V, no. 4) . . . . HESIONIDAE
    Short; with long filamentous dorsal cirri (Plate V, no. 4); purple to brown in life; in ambulacral grooves of asteroids or under rocks . . . . . . *Podarke pugettensis*

45. Posterior end of body provided with conspicuous sternal shield (Plate IV, no. 2) bordered with stiff bristles; anal branchiae present; body short, distended. STERNASPIDAE (see 14 and 44) . . . . *Sternaspis* (Plate IV, no. 2)
45. Posterior end without such anal plates 46

46. Anterior end forms a flat plaque; (fig. 24,A) posterior end terminates in a plaque provided with cirri; segments very long, the segmental grooves node-like. MAIDANIDAE (see 14 and 44) . . . . *Clymenella* (fig. 24,A)
46. Anterior end with flat, lobed membrane (fig. 24,C). OWENIIDAE (= AMMOCHARIDAE)
. . . . *Owenia* (figs. 24,B,C and Plate IV, no. 3)
46. Anterior and posterior ends pointed or rounded; segments usually not elongated 47

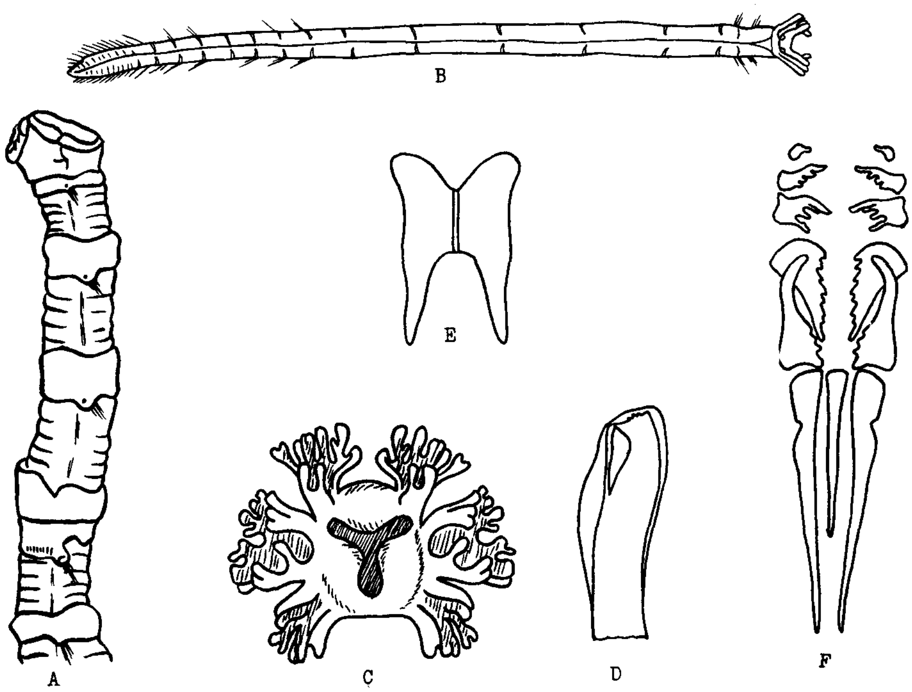
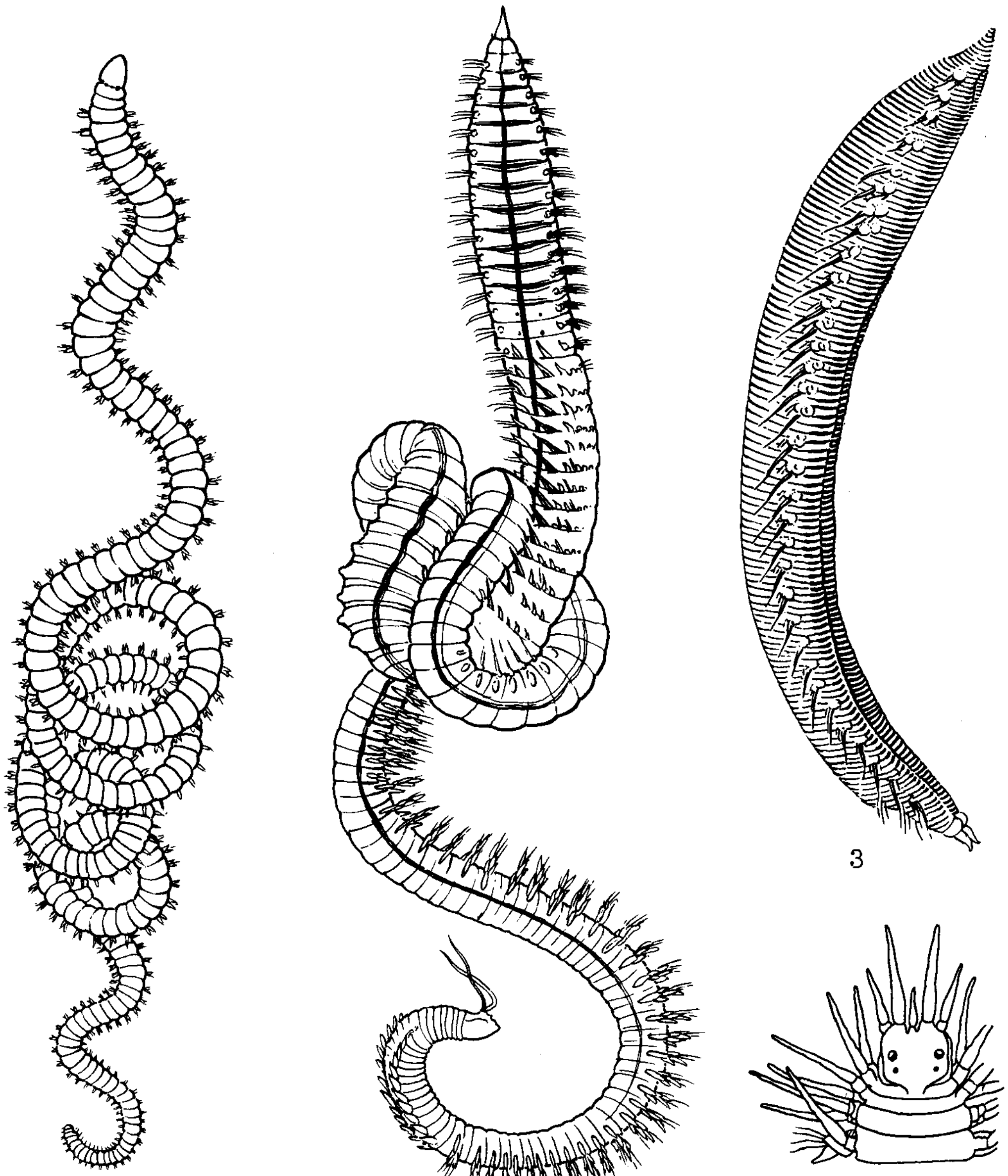


Fig. 24.—A, Clymenella. B, Owenia. C, head expansion of Owenia. D, hooded crotchet of Lumbrineris. E, mandible of Arabella. F, maxillary apparatus of Arabella.

47. Proboscis without chitinous jaw pieces; form variable 52
47. Proboscis provided with dark chitinous jaw pieces (figs. 24,E,F); smooth, elongate, cylindrical, resembling an earthworm; parapodia weakly developed or, at most, simple lobes; dorsal and ventral cirri often tiny
. . . . . LUMBRINERIDAE (Plate V, no. 1)(see 14, 44, 45, and 46)

48. Parapodia with some hooded crotchets (fig. 24,D); prostomium without eye-spots . . . . *Lumbrineris* 49
48. Parapodia without hooded crotchets; prostomium with or without eye-spots 51

PLATE V



1

2

3

4

Polychaete types (after McIntosh): 1, Arabella iricolor Mont. (Lumbrineridae); 2, Scoloplos armiger (O. F. Müller) (Orbiniidae); 3, Ophelia limacina (H. Rathke) (Opheliidae); 4, Podarke pallida Claperède (Hesionidae).

49. Parapodial lobes elongate, erect in posterior parapodia . . . . *Lumbrineris erecta*
49. Parapodial lobes short throughout 50

50. Anterior parapodia with some composite hooded crotchets in addition to pointed setae; prostomial lobe spatulate . . . . *L. japonica*
50. Anterior parapodia without composite setae; prostomial lobe bluntly conical . . . . *L. zonata*

51. Parapodia with a stout acicular seta projecting from the lobe. . . . . *Drilonereis*
51. Parapodia without stout projecting acicular setae . . . . *Arabella* (fig. 17,A and Plate V, no. 1)

52. Body consisting of 3 regions, an anterior and a posterior without branchiae, and a median region with conspicuous branchiae; parapodia with uncini (hooks) sometimes of great size (up to 50 cm.). ARENICOLIDAE (see 14, 44, 45, 47) . . . . *Arenicola* (Plate IV, no. 4)
52. Body consisting of 2 regions which are not always easily distinguishable from each other (Plate IX, no. 3) 54
52. Body uniform; dorsum sometimes more or less completely concealed by interlacing, cirriform branchiae (fig. 25), no uncini in parapodia. ORBINIIDAE (= ARICIIDAE) (see 14, 44, 45, 46, 47) (Plate V, no. 2) 53

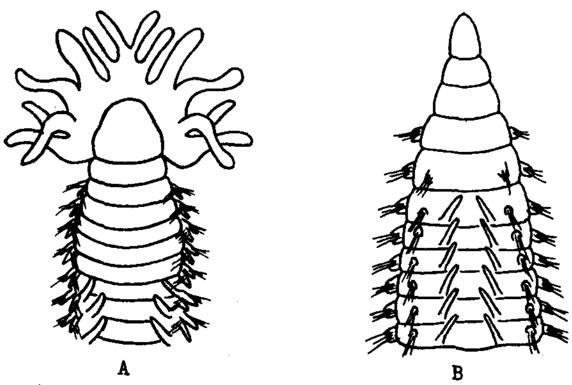


Fig. 25.—Orbiniidae: A, Nainereis; B, Scoloplos.

53. Prostomium terminating in a broad, spatulate lobe (fig. 25,A) . . . . *Nainereis*
53. Prostomium terminating in a pointed cone (fig. 25,B) . . . . *Scoloplos* (Plate V, no. 2)

54. No uncini; branchiae not restricted to posterior region; body often broad . . . . OPHELIIDAE (fig. 26 and Plate V, no. 3) 57
54. Parapodia with tori bearing uncini; body slender; branchiae, if present, only on a posterior portion. CAPITELLIDAE (see 14, 44, 45, 46, 47, 52) (Plate IX, no. 3) 55

55. Larger; with divided branchiae in posterior region . *Dasybranchus*
55. Smaller; without divided branchiae 56

56. Thorax consists of 9 setigerous segments, the first 7 with capillary setae, the last two with uncini; constructs tubes in mud flats . . . . *Capitella* (Plate IX, no. 3)
56. Thorax consists of 17 or 18 segments . . . . *Eunotomastus*

Opheliidae (see 14, 44, 45, 46, 47, 52, 54)

57. Without lateral branchiae; with dark eye-spots at sides between the parapodia; resembling a nematode. . . . *Polyophthalmus*
57. With lateral branchiae; lateral eye-spots present or absent . . 58

58. Ventral side with a well-marked groove (fig. 26) 59
58. Ventral side without a longitudinal groove; resembling a maggot. . . . . *Travisia*

59. Ventral groove posteriorly only; color in life, bronze to purple 60
59. Ventral groove throughout length; color in life, otherwise . . 61

60. Branchiae simple . . . . . *Ophelia* (fig. 26 and Plate V, no. 3)
60. Branchiae branched . . . . *Pectinophelia*

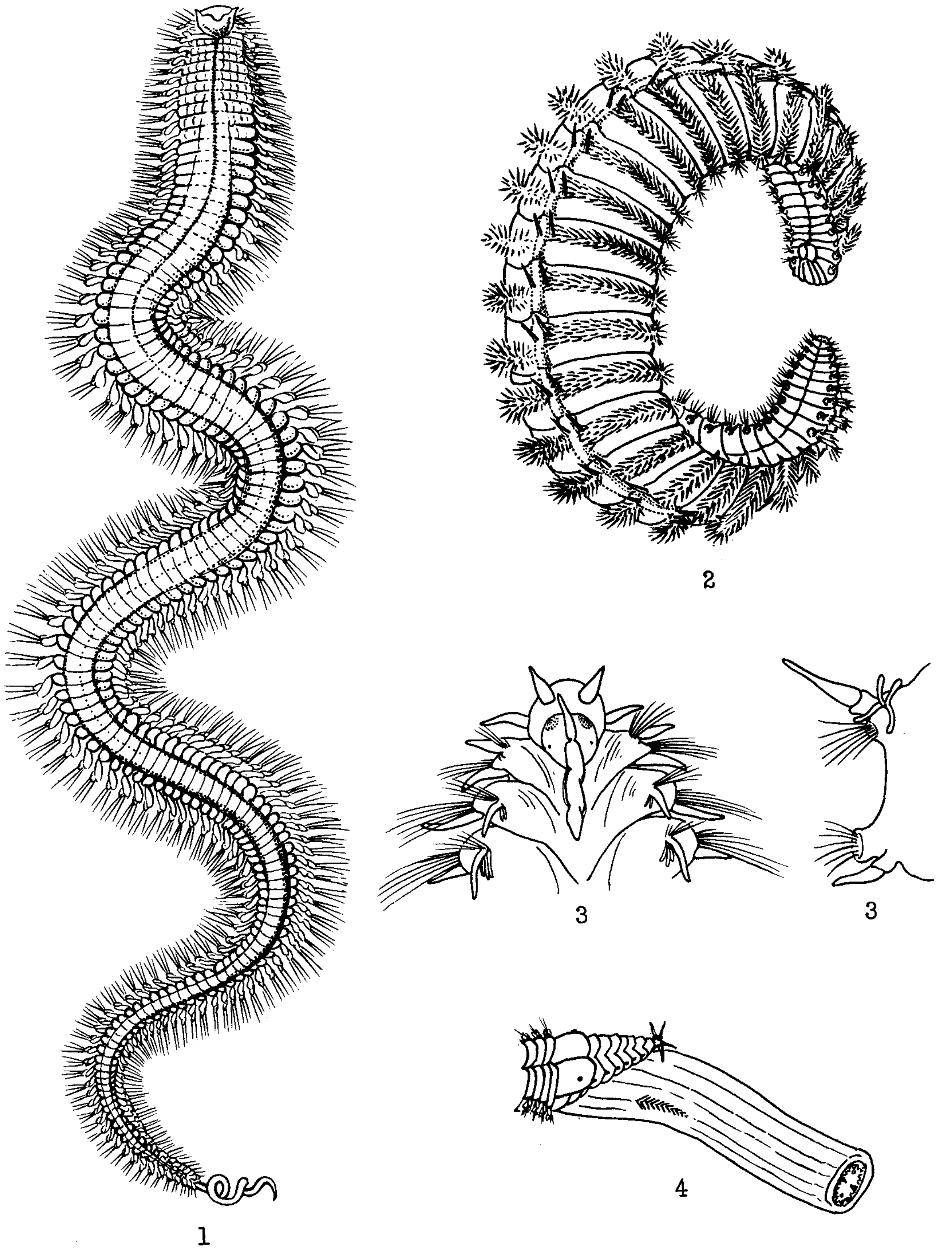
Fig. 26.—Ophelia.

61. With lateral eye-spots between some successive parapodia . . . . *Armandia*
61. Without lateral eye-spots; ventral funnel greatly elongate . . . . *Ammotrypane*

62. Prostomium quadrate (fig. 27,A) or subcircular 63
62. Prostomium pointed (fig. 17,F), provided with four tiny tentacles in a cross at tip; proboscis large, stout, terminating distally in dark chitinous jaw pieces (fig. 17,F) . . . 66

63. With branchia-like structures in the form of a recurved cirrus between the two rami of the parapodium (fig. 27,B); prostomium trapezoidal (fig. 27,A), the anterior part with two pairs of small antennae; proboscis eversible, large. NEPHTYIDAE (see (Plate VI, no. 1) 64
63. With branchia-like structures in tufts above notopodia (Plate VI, nos. 2 and 3); parapodial lobes not visible in dorsal view, because of thick, tufted, setal fascicles; a peculiar dorsal appendage (caruncle) extending back from the prostomium 65

PLATE VI



Polychaete types (after McIntosh): 1, Nephtys caeca O. Fabricius (Nephtyidae); 2, Euphrosine foliosa Aud. and Ed. (Euphrosinidae); 3, Pareurythoe californica (Johnson) (Amphinomidae); 4, Goniada maculata OErsted (Goniadidae).

64. Setae stiff; prostomium with extensive pigmented pattern (fig. 27,C); recurved cirri usually present from fourth segment posteriorly . . . . *Nephtys caecoides*

64. Setae soft, flowing; prostomium with limited pigmented pattern; recurved cirri present from third segment back . . . . *N. californiensis*

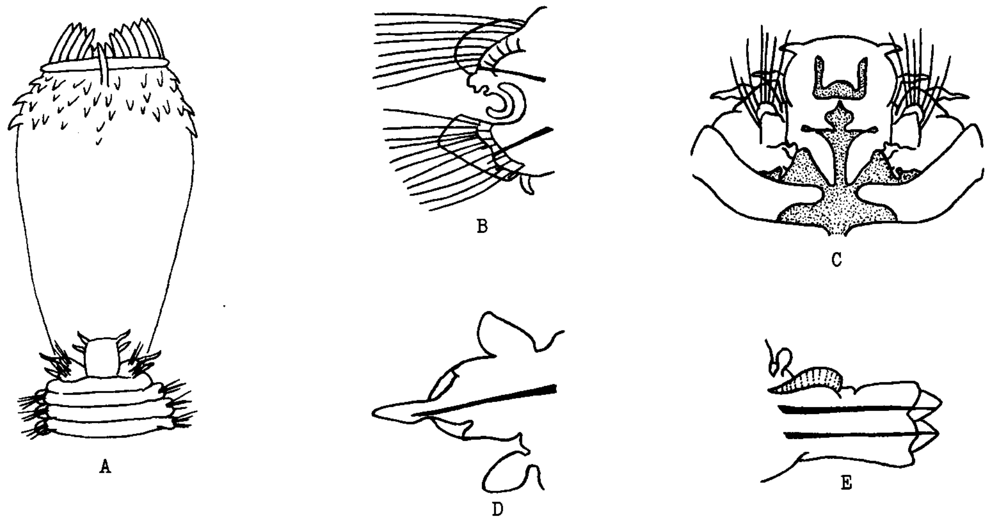


Fig. 27.—A, Nephtys with everted proboscis; B, left parapodium of Nephtys showing recurved cirrus; C, Nephtys caecoides; D, left parapodium of Hemipodus; E, right parapodium of Glycera robusta.

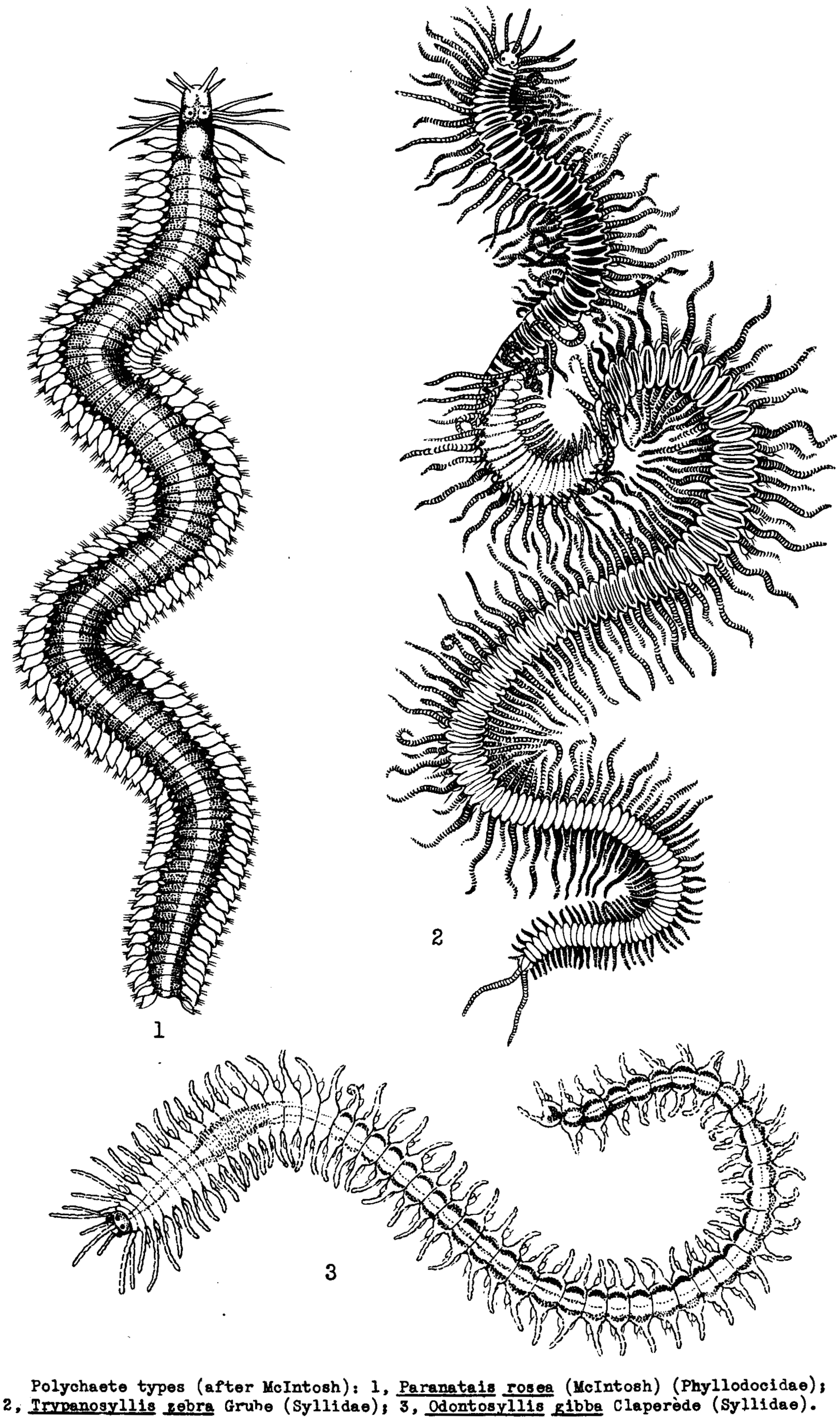
65. Setal tufts form transverse series, segmentally arranged (Plate VI, no. 2), broad, almost reaching across dorsum; branchiae not conspicuous; EUPHROSINIDAE (see 14, 44, 63). Bright red to orange in life; crawling over surfaces or in crevices . . . . *Euphrosine*

65. Setal tufts limited to sides of body, not forming transverse series (Plate VI, no. 3); branchial tufts conspicuous, usually arborescent. AMPHINOMIDAE. Pale red or yellowish in life; on under sides of stones or in crevices . . . *Pareurythoë*

66. Parapodia uniramous in anterior part, biramous and larger in posterior part of body; distal end of proboscis with numerous chitinous jaw pieces. GONIADIDAE (Plate VI, no. 4) . . . 72

66. Parapodia similar throughout, either all uniramous or all biramous. GLYCERIDAE (see 14, 44, 62) 67

PLATE VII



Polychaete types (after McIntosh): 1, Paranatais rosea (McIntosh) (Phyllodocidae); 2, Trypanosyllis zebra Grube (Syllidae); 3, Odontosyllis gibba Claperède (Syllidae).

67. Parapodia uniramous with a single aciculum (fig. 27,D); setae composite . . . . *Hemipodus*
67. Parapodia biramous, with two acicula (fig. 27,E); setae both simple and composite. . . . . *Glycera* 68

68. Parapodial lobes broadest subdistally; segmental retractile branchiae emerge from the posterior faces of the parapodia. . . . . *Glycera americana*
68. Without retractile branchiae; parapodial lobes otherwise . . . 69

69. Parapodia with two presetal and two postsetal lobes 70
69. Parapodia with two presetal and one postsetal lobe . *G. capitata*

70. Parapodial rami long, with a blister-like branchiae on the dorsal surface (fig. 27,E) . . . . *G. robusta*
70. Parapodia without such branchiae 71

71. The two posterior lobes of parapodium unequal, the dorsal the longer . . . . *G. alba*
71. The two posterior lobes of about the same length . . *G. tesselata*

Goniadidae (see 14, 44, 62, 66)

72. Parapodia change abruptly from uniramous in anterior region to biramous in posterior region; proboscis with chevron at base (consists of 10 or more V-shaped pieces (Plate VI, no. 4) *Goniada*
72. Parapodia change gradually; proboscis without chevron at base . . . . *Glycinde*

73. With fleshy, usually biarticulated palpi (figs. 15,A; 17,D) . . 78
73. Palpi relatively slender, tentacle-like (fig. 28,A); one pair of annulated prostomial tentacles 100
73. Without palpi; parapodia uniramous; dorsal cirri often large, foliaceous, glandular; sometimes resembling the elytra of a polynoid; proboscis without chitinous jaws. PHYLLODOCIDAE (Plate VII, no. 1) (see 14, 44) 74

(Many of the genera are represented by several species; for keys to these reference must be made to Hartman's papers)

74. With two pairs of peristomial cirri (fig. 28,C) . . . . . . *Eteone*
74. With four pairs of cirri at the anterior end (on several segments) (fig. 28,B) 75

75. Segments 1 and 2 at least partially fused; color in life reddish-yellow or rust-colored . . . . *Genetyllis castanea*
75. Segments 1 and 2 free from one another (fig. 17,E), although sometimes reduced 76

76. The first three segments form complete rings; prostomium with a median antenna . . . . *Eulalia* (fig. 17,E)
76. The first three segments dorsally reduced; prostomium with median antenna; proboscis smooth . . . . *Eumida*
76. The first three segments dorsally reduced; prostomium without median antenna but often with a nuchal papilla (fig. 28,B), proboscis papillated 77

77. Proximal part of proboscis diffusely papillated; yellow or rust-colored in life . . . . *Phyllodoce*
77. Proximal part of proboscis with longitudinal rows of papillae; bluish or purple in life . . . . *Anaitides*

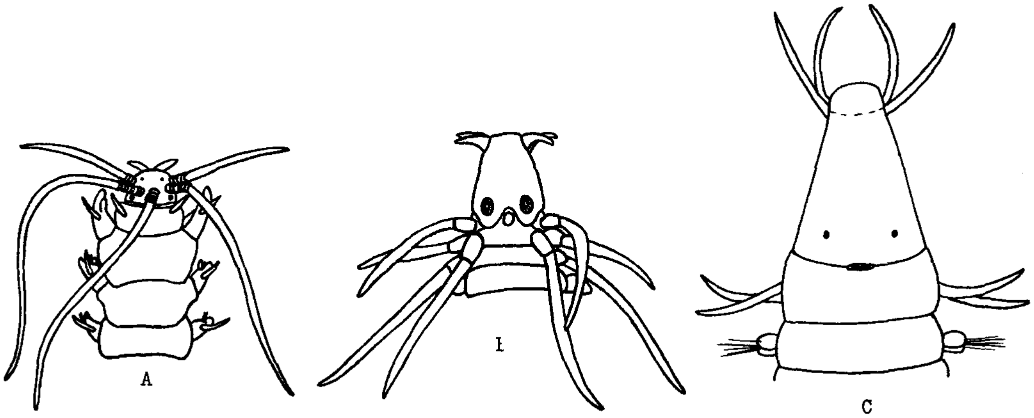


Fig. 28.—A, Nothria, Family Onuphidae; B, Anaitides williamsi Hartman, Family Phyllodocidae; C, Eteone dilatae Hartman, Family Phyllodocidae.

78. With an unpaired median prostomial antenna, with or without paired peristomial tentacles; parapodia uniramous; dorsal cirri often moniliform (fig. 17,D). SYLLIDAE (Plate VII, nos. 2 and 3) 92
78. With only paired prostomial tentacles and peristomial cirri (fig. 15); parapodia biramous; never with moniliform (beaded) cirri. NEREIDAE (see 14, 44, 73) 79

79. Peristomium forms a conspicuous ventral flap that projects forward under the prostomium; commensal with pagurids . . . . *Cheilonereis* (Plate VIII, no. 1)
79. Peristomium does not form such a flap 80

80. Posterior notopodia have simple stout, uncinate setae (fig. 29,A); peristomial cirri elongate, extend posteriorly to about segment 8; tube-building, gregarious. . . . . *Platynereis (= Uncinereis) agassizi* (Plate VIII, no. 2)
80. Posterior notopodia without simple, stout, uncinate setae . . . 81

Fig. 29.—Nereidae: A, simple seta; B, homogomph falcigerous (composite) seta; C, heterogomph composite seta; D, posterior parapodium of Neanthes brandti Malmgren; E, Neanthes succinea Frey and Leuckart.

PLATE VIII

California Nereidae: 1, Cheilonereis cyclurus; 2, Platynereis agassizi; 3, Eunereis longipes; 4, Eunereis longipes; 5, Ceratonereis tunicatae; 6, Nereis vexillosa; 7, Nereis latescens; 8, Nereis procera; 9, Nereis zonata; 10, Nereis mediator; 11, Nereis pelagica; 12, Perineis monterea; 13,14, Neanthes lighti.

81. Paragnaths absent from one or the other of the proboscideal rings (fig. 15) 82
81. Paragnaths present on both rings 83

82. Paragnaths present only on oral ring . . . . *Eunereis* (Plate VIII, nos. 3, 4)
82. Paragnaths present only on maxillary ring . . . . *Ceratonereis* (Plate VIII, no. 5)

83. Posterior notopodia with a few homogomph falcigerous setae (fig. 29,B) . . . . *Nereis* 84
83. Posterior notopodia without homogomph falcigerous setae 90

84. Posterior parapodial dorsal lobes greatly elongate, strap-like . . . . *Nereis vexillosa* (Plate VIII, no. 6)
84. Posterior parapodial lobes not greatly elongate 85

85. Dorsum with a broken transverse pattern; small, usually less than 30 mm. long . . . . *N. latescans* (Plate VIII, no. 7)
85. Dorsum without broken transverse pattern; usually larger . . . 86

86. Dorsal edge of posterior notopodial lobes convex; area VI of proboscis with four large cones . . . . *N. callaona*
86. Notopodial lobe otherwise 87

87. All paragnaths minute though dark . *N. procera* (Plate VIII, no. 8)
87. Paragnaths not minute, some larger than others 88

88, Area VI of proboscis (fig. 15) with four or five large cones disposed more or less in a diamond 89
88. Area VI of proboscis with an oval mass of 6 or 7 small cones . . . . *N. zonata* (Plate VIII, no. 9)

89. Cones more numerous and larger; posterior parapodia with dorsal and ventral sides of dorsal lobes approximately parallel . . . . *N. mediator* (Plate VIII, no. 10)
89. Area VII (fig. 15) without mass of smaller cones; posterior dorsal lobe with dorsal edge shorter than ventral edge . . . . *N. pelagica* (Plate VIII, no. 11)

90. Area VI with transverse paragnaths . . . . *Perinereis* (Plate VIII, no. 12)
90. Area VI with only conical paragnaths . . . . *Neanthes* 91

91. Marine; posterior parapodial lobes broad, foliaceous (fig. 29,D) . . . . *N. brandti*
91. In brackish water:
   a) Posterior parapodial lobes elongate (fig. 29,E); Lake Merritt and upper San Francisco Bay . . . . . . *N. succinea*
   b) Posterior parapodial lobes short (Plate VIII, no. 13); in coastal streams and lagoons . . . . *N. lighti*

Syllidae (see 14, 44, 73, 78)

92. Without ventral cirri . . . . *Autolytus*
92. With ventral cirri 93

93. Palpi fused throughout their entire length (fig. 30,C); minute, a few millimeters long; parapodial cirri inconspicuous or absent . . . . *Exogone*
93. Palpi free from one another through most of their length; larger 94

94. Prostomium partially concealed by a nuchal hood (fig. 30,B) . . 95
94. Prostomium without a nuchal hood 96

95. Pharynx unarmed; dorsum purple; in algal clumps . . . . *Hesperalia*
95. Pharynx armed with a semicircle of papillae (fig. 30,A); dorsal surface pale, with black transverse stripes; in sponges, and Bryozoa . . . . *Odontosyllis* (Plate VII, no. 3)

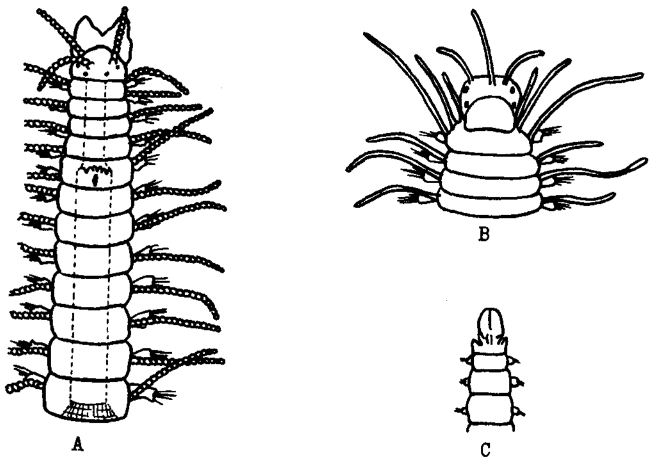


Fig. 30.—Syllidae: A, Odontosyllis; B, Pionosyllis; C, Exogone.

96. Proboscis with a large tooth and a semicircle of hard papillae (trepan) . . . . *Trypanosyllis* (Plate VII, no. 2)
96. Proboscis with a large tooth but no trepan 97

97. Antennae and dorsal cirri smooth (fig. 30,B) . . . . *Pionosyllis*
97. Antennae and dorsal cirri articulated 98

98. Parapodia with only simple setae . . . . *Haplosyllis*
98. Parapodia in median region contain both simple and composite setae . . . . *Syllis* (fig. 17,D)
98. Parapodia with only composite setae 99

Fig. 31.—Two types of composite setae of Ehlersia.

99. Composite setae all alike . . . . *Typosyllis*
99. Composite setae of two kinds, some with a short, some with a long appendage (fig. 31) . . . . *Ehlersia*
(Many other genera and species)

100. With one to five prostomial tentacles (fig. 32,A) which are simple, cirriform or annulated, but without distinct basal parts. EUNICIDAE 103

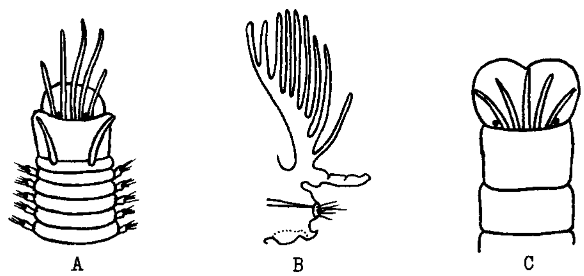


Fig. 32.—Eunicidae (after Hartman): A, anterior end of Eunice; B, right parapodium of Eunice longicirrata Webster; C, anterior end of Marphysa.

100. With one pair of long palpi and a pair of prostomial tentacles that are simple cirriform or annulated (fig. 33,A). STAURONEREIDAE 107

100. With seven prostomial tentacles including 5 larger which have distinctly annulated bases, and 2 small, simple, at anterior margin of prostomium (fig. 28,A). ONUPHIDAE (see 14, 44, 73) 101

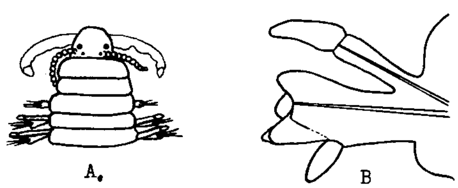


Fig. 33.—Stauronereidae: A, anterior end of Stauronereis moniloceros Moore; B, right median parapodium of Stauronereis articulatus Hartman.

101. Without tentacular cirri on first segment dorsally; subintertidal . . . . *Hyalinoecia*

101. With tentacular cirri on first segment dorsally (fig. 28,A) . 102

102. Branchial filaments spiraled on the main stalk . . . . *Diopatra*

102. Branchial filaments pinnately arranged on the main stalk *Onuphis*

102. Branchial filaments simple, cirriform . . . . *Nothria* (fig. 28,A)

Eunicidae (= Leodicidae) (see 14, 44, 73, 100)

103. Second segment without dorsal tentacular cirri 105

103. Second segment with dorsal tentacular cirri (fig. 32,A) . . . . *Eunice* 104

104. Heavy acicular setae tridentate at free end; branchiae with 30 or more pinnae . . . . *Eunice hawaiensis*

104. Heavy acicular setae bidentate at end, branchiae with about 10 pinnae; acicula yellow . . . . *E. biannulata*

105. Branchial filaments not present before about the 100th segment . . . . *Palola*
105. Branchial filaments present from about the 10th segment; acicula black . . *Marphysa* (fig. 32,C, and Plate IX, no. 1) 106

106. Branchiae simple, cirriform throughout . *Marphysa stylobranchiata*
106. Branchiae with four to seven filaments where best developed . . . . *M. californica*

Stauronereidae (see 14, 44, 73, 100)

107. Larger, brilliantly banded with coral and cream; prostomial antennae thick, blunt (fig. 33,A) . . . *Stauronereis moniloceras*
107. Small (length 17 mm. or less), pale or colorless; prostomial antennae long, slender, articulated . . . . . *Stauronereis* spp.
108. Body clearly divisible into two or more clearly defined regions (fig. 35,B) 116
108. Body not divisible into regions, although sometimes a single anterior segment is specially modified. SPIONIDAE (see 14, 44) 109

109. Sixth segment (fifth setigerous) modified (fig. 17,J) provided with special hooks 110
109. Sixth segment not modified 113

110. Branchiae present anterior to modified segment (fig. 17,J); prostomium with sooty pigmentation; inhabiting narrow crevices and soft shales . . . . *Boccardia* 111
110. Branchia first present posterior to modified segment . . . . *Polydora* (Plate IX, no. 2) 112

111. Branchiae on posterior fifth of body; 20-40 mm. long . . . . *Boccardia proboscidea (= B. natrix)*
111. No branchiae on posterior fifth of body; 8-20 mm. long . . . . *B. truncata*

112. Posterior segments without large stout hooks; constructs soft tubes; estuarine . . . . *Polydora ligni*
112. Posterior segments with large stout hooks, burrowing in corralines, shells, etc. . . . . *P. armata*

113. Anterior end with two pairs of large tentacular structures (fig. 34,A); other branchial structures absent; estuarine . . . . *Streblospio*
113. Anterior end without such structures; branchiae present more posteriorly 114

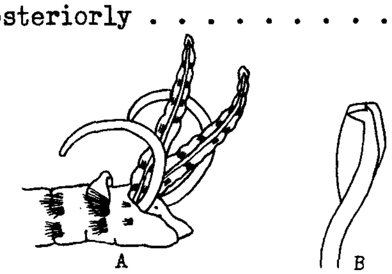
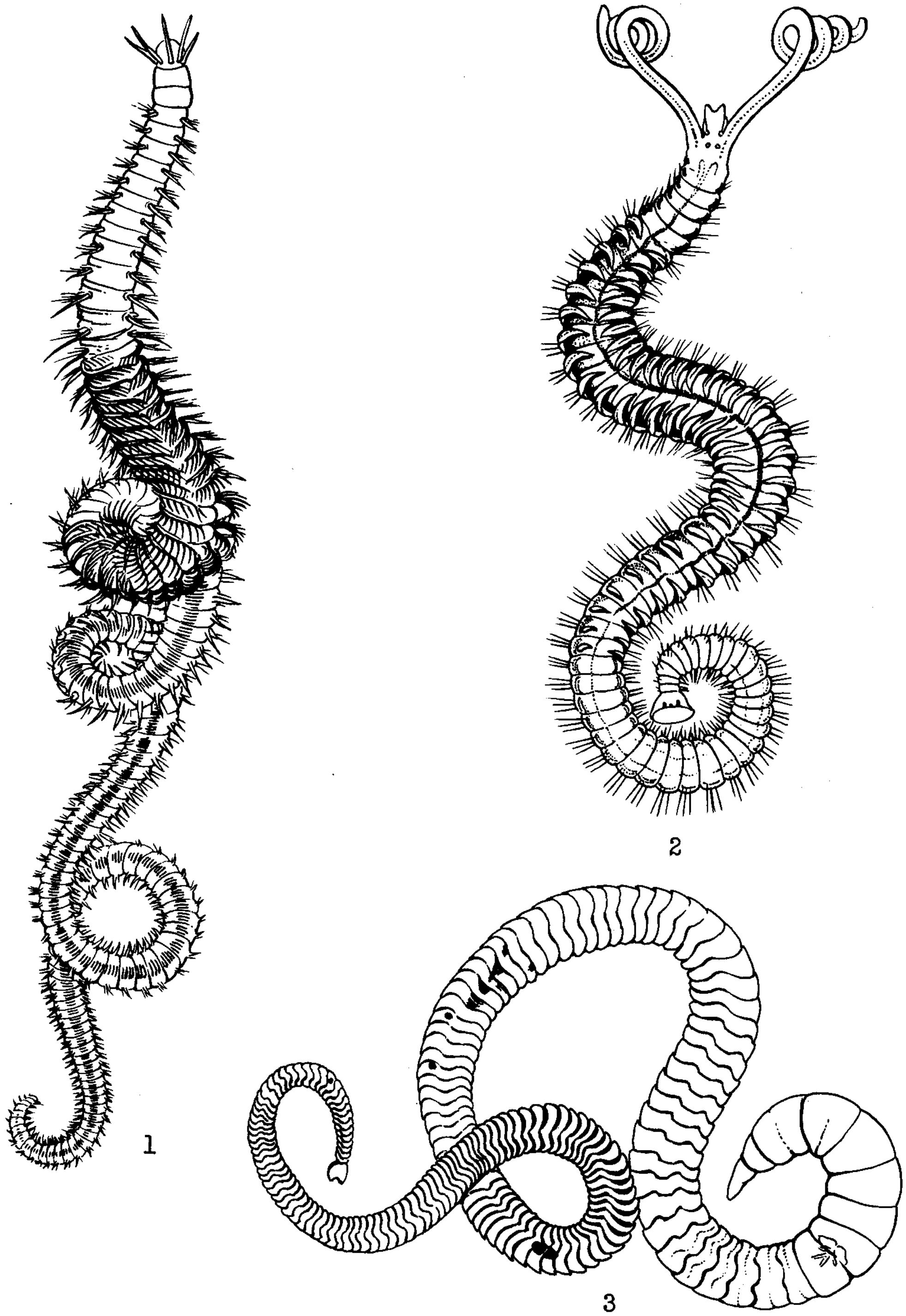


Fig. 34.—A, Streblospio lutincola Hartman; B, hooded hook of Nerine.

114. Branchiae present from fifth segment back . . . . *Spio*
114. Branchiae present from second segment back 115

PLATE IX



Polychaete types (after McIntosh): 1, Marphysa Belli (Aud. and Edw.) (Eunicidae); 2, Polydora ciliata (Johnson) (Spionidae); 3, Capitella capitata (O. Fabricius) (Capitellidae).

115. Hooded hooks (fig. 34,B) in notopodia and neuropodia . . *Nerine*
115. Hooded hooks in neuropodia only . . . . *Laonice*

Magelonidae (see 14, 44, 108)

116. Prostomial palpi greatly elongated, heavily papillated; body consists of an anterior region of about eight segments, separated from a longer posterior region by a ninth segment which is quite different. MAGELONIDAE . . . . *Magelona*
116. Palpi not greatly elongated, without such papillations; body consists of two or more regions, each markedly different from the others (fig. 35,B). CHAETOPTERIDAE (see 14, 44, 108). . 117

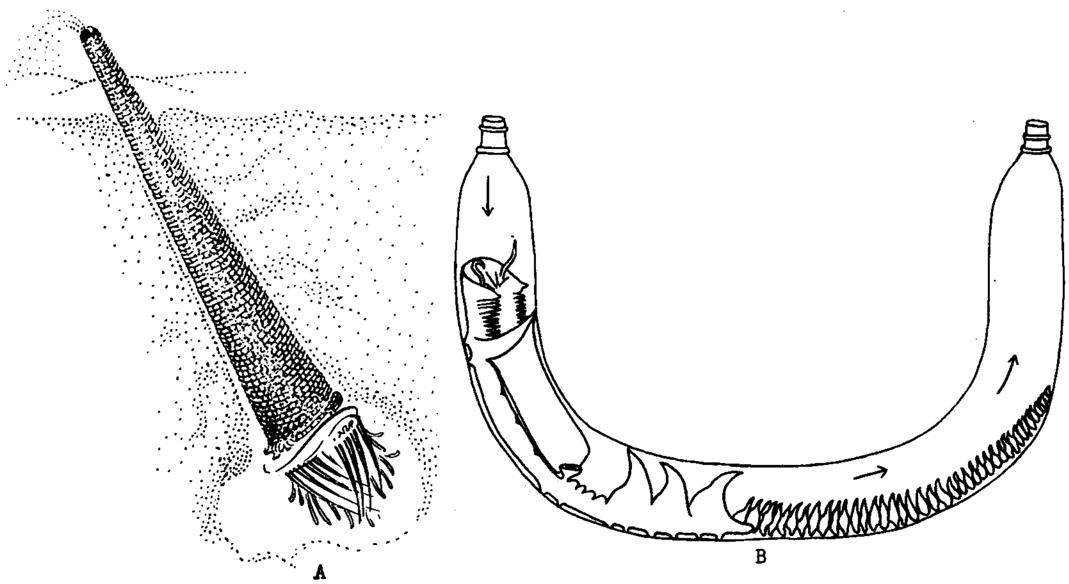


Fig. 35.—A, Lagis Kareni, family Pectinariidae, excavating in sand (after MacIntosh); B, Chaetopterus variopedatus Rénier et Claparède in tube (after MacGinitie).

117. Inhabiting large, coarse, chitinous, U-shaped tubes, both ends of which are exposed; on sandy beaches . . . . *Chaetopterus* (fig. 35,B)
117. Inhabiting large, coarse, somewhat curved, but not U-shaped tubes; in eel-grass beds . . . . *Mesochaetopterus*
117. Inhabiting smaller, annulated, more or less translucent tubes; usually in clusters . . . . *Phyllochaetopterus*

A LIST OF COMMONLY ENCOUNTERED POLYCHAETA
(Alphabetically arranged by families)

Ampharetidae

D M *Schistocomus hiltoni* Chamberlin

Amphinomidae

D M *Pareurythoë californica* (Johnson)

Aphroditidae

M *Aphrodita* spp. (typically subintertidal, occasionally washed in)

Arenicolidae

TB B M *Arenicola pusilla* Quatrefages
TB *Arenicola marina* (Linnaeus)

Capitellidae

TB *B M *Capitella capitata* (Fabricius)
TB M *Dasybranchus giganteus* Moore
M *Eunotomastus* sp.
TB *Notomastus angulatus* Chamberlin
TB B M *Notomastus tenuis* Moore

Chaetopteridae

TB M *Chaetopterus variopedatus* Renier
TB M *Mesochaetopterus taylori* Potts
D M *Phyllochaetopterus prolifica* Potts

Chrysopetalidae

D M *Chrysopetalum occidentale* Johnson
D M *Paleonotus chrysolepis* Schmarda

Cirratulidae

D TB B M *Cirratulus cirratus* Müller
D B *M *Cirriformia luxuriosa* (Moore)
D TB B *M *Cirriformia spirabrancha* (Moore)
D *M *Dodecaceria pacifica* (Fewkes)
*B *Tharyx parvus* Berkeley
M *Cauleriella pacifica* (Berkeley)

Eunicidae

D *Eunice antennata* (Savigny)
D M *Eunice biannulata* Moore
D M *Eunice hawaiensis* Treadwell
D *Eunice longicirrata* Webster
M *Marphysa californica* Moore
*M *Marphysa stylobranchiata* Moore
D M *Eunice (Palola) pallida* Hartman
D M *Nematonereis unicornis* Schmarda

Euphrosinidae

D M *Euphrosine* spp. (Typically below the intertidal; occasionally washed in)

Flabelligeridae

D M *Flabelligera affinis* (Sars)

Flabelligeridae (Continued)

D *M *Stylarioides eruca* (Claparède)
D *Stylarioides plumosa* (O. F. Müller)

Glyceridae

TB B *M *Glycera americana* (Leidy)
TB *Glycera convoluta* Keferstein
M *Glycera nana* Johnson
TB B *M *Glycera robusta* Ehlers
TB M *Glycera tesselata* Grube
TB D B M *Hemipodia borealis* Johnson

Goniadidae

D M *Goniada brunnea* Treadwell
D M *Glycinde armigera* Moore

Hesionidae

D M *Podarke pugettensis* Johnson

Lumbrineridae

TB B *M *Arabella iricolor* (Montagu)
TB M *Arabella semimaculata* Moore
TB M *Drilonereis falcata* Moore
TB *Drilonereis nuda* Moore
TB D M *Lumbrineris zonata* Johnson
M *Lumbrineris erecta* Moore
TB D M *Lumbrineris japonica* Marenzeller

Magelonidae

TB M *Magelona longicornis* Johnson

Maldanidae

TB M *Clymenella rubrocincta* Johnson

Nephtyidae

TB *B M *Nephtys caecoides* Hartman
TB B M *Nephtys californiensis* Hartman

Nereidae

D M *Ceratonereis paucidentata* (Moore)
D *Ceratonereis tunicatae* Hartman
TB M *Cheilonereis cyclurus* (Harrington)
TB M *Eunereis longipes* Hartman
TB D M *Neanthes brandti* Malmgren
D *Neanthes lighti* Hartman
TB B *Neanthes succinea* (Frey & Leuckart)
D *M *Nereis callaona* Grube
D B M *Nereis latescens* Chamberlin
D M *Nereis mediator* Chamberlin
TB D M *Nereis pelagica* Linnaeus
D M *Nereis procera* Ehlers
TB *B *M *Nereis vexillosa* Grube
D M *Nereis zonata* Malmgren
D M *Perinereis monterea* (Chamberlin)
TB D B *M *Platynereis agassizi* (Ehlers)

Onuphidae

TB M *Dioptatra ornata* Moore

Onuphidae (Continued)

TB *Diopatra splendidissima* Kinberg
M *Hyalinoecia* (subintertidal; rarely washed in)
TB *Nothria elegans* (Johnson)
D *M *Nothria geophiliformis* Moore
D M *Onuphis eremita* (Audouin and Malne-Edwards)

Opheliidae

D TB M *Ammotrypane aulogaster* Rathke
D *Armandia bioculata* Hartman
M *Armandia brevis* Moore
D M *Ophelia limacina* (Rathke)
D *Pectinophelia dillonensis* Hartman
D *Pectinophelia williamsi* Hartman
D M *Polyophthalmus pictus* (Dujardin)
D *Thoracophelia mucronata* (Treadwell)
D M *Travisia pupa* Moore

Orbiniidae (= Ariciidae)

TB D B M *Nainereis laevigata* Grube
TB D M *Scoloplos ameceps* Chamberlin

Oweniidae (= Ammocharidae)

D M *Owenia fusiformis* della Chiaje

Pectinariidae

TB M *Cistenides brevicoma* Johnson

Phyllodocidae

D M *Anaitides mediapapillata* Moore
D *Anaitides mucosa* (OErsted)
TB *Anaitides williamsi* Hartman
TB M *Eteone dilatae* Hartman
B TB *Eteone lighti* Hartman
B TB *Eteone longa* Fabricius
TB M *Eteone pacifica* Hartman
D *Eulalia aviculiseta* Hartman
D M *Eulalia viridis* (Linnaeus)
TB D M *Eumida sanguinea* (OErsted)
D M *Genetyllis castanea* (Marenzeller)
D *Hypoeulalia bilineata* (Johnston)
D M *Phyllodoce ferruginea* Moore

Polynoidae

D M *Arctonoë fragilis* (Baird)
D M *Arctonoë pulchra* (Johnson)
D M *Arctonoë vittata* (Grube)
D M *Eunoë senta* (Moore)
TB D *B *M *Halosydna brevisetosa* Kinberg
M *Halosydna johnsoni* (Darboux)
M *Harmothoë hirsuta* Johnson
TB B M *Harmothoë imbricata* (Linnaeus)
TB M *Hesperonoë adventor* (Skogsberg)
TB B *Hesperonoë complanata* (Johnson)
M *Lepidametria gigas* (Johnson)
TB B M *Lepidonotus caelorus* Moore

Polyodontidae

D M *Peisidice aspera* Johnson

Sabellariidae

D M *Phragmatopoma californica* (Fewkes)
D B M *Sabellaria cementarium* Moore

Sabellidae

TB M *Chone infundibuliformis* Krøyer
D *M *Eudistylia polymorpha* (Johnson)
TB M *Eudistylia vancouveri* (Kinberg)
D M *Fabricia sabella* Ehrenberg
D M *Megalomma roulei* (Gravier)
TB M *Myxicola infundibulum* (Montagu)
D M *Pseudopotamilla intermedia* Moore
D M *Pseudopotamilla occelata* Moore
D *M *Sabella crassicornis* Sars
Sabella media (Bush)
D M *Schizobranchia insignis* Bush

Serpulidae

D M *Eupomatus gracilis* Bush
D M *Hydroides uncinatus* (Philippi)
*B *Mercierella enigmatica* Fauvel
D *M *Salmacina dysteri* (Huxley)
D B *M *Serpula vermicularis* Linn.
D M *Spirabranchus spinosus* Moore
D B *M *Spirorbis spirillum* Linn., and other species.
M *Vermiliopsis* sp.

Sigalionidae

D M *Sthenelais fusca* Johnson

Spionidae

D B *M *Boccardia proboscidea* Hartman
TB M *Laonice cirrata* Sars
TB B *Polydora ligni* Webster
D M *Polydora armata* Langerhans
M *Pygospio californica* Hartman
M *Rhynchospio arenincola* Hartman
M *Spio filicornis* Muller
B *Streblospio benedicti* Webster

Stauronereidae

D M *Stauronereis articulatus* Hartman
D M *Stauronereis moniloceras* Moore
D M *Stauronereis minor* Hartman

Sternaspididae

D M *Sternaspis scutata* (Ranzani) (subintertidal; rarely washed in)

Syllidae

D B M *Autolytus varius* Treadwell
TB M *Ehlersia cornuta* Rathke
D B *M *Exogone* spp.
D TB M *Haplosyllis spongicola* (Grube)

Syllidae (Continued)

D M	*Hesperalia californiensis* Chamberlin
D M	*Odontosyllis phosphorea* Moore
D M	*Pionosyllis gigantea* Moore
D B *M	*Syllis alternata* Moore
D M	*Syllis elongata* (Johnson)
TB B *M	*Trypanosyllis adamanteus* Treadwell
TB	*Trypanosyllis gemmipara* Johnson
D M	*Typosyllis armillaris* (Müller)
D	*Typosyllis hyalina* (Grube)

Terebellidae

D M	*Amphitrite robusta* Johnson
TB M	*Eupolymnia heterobranchia* (Johnson)
D M	*Pista elongata* Moore
D *M	*Polycirrus californica* Moore
D M	*Terebella californica* Moore
D TB *M	*Thelepus setosus* (Quatrefages)

Class OLIGOCHAETA

The oligochaetes which are likely to be found in this course are (1) the earthworms (fig. 13,C) and (2) the usually much smaller freshwater worms (fig. 13,B). A key for the earthworms is given below. See also Altman, 1936, Oligochaeta of Washington. For identification of freshwater oligochaetes refer to Altman (1936).

KEY TO THE TERRESTRIAL OLIGOCHAETES (EARTHWORMS) FOUND IN BERKELEY

By Marjorie E. Olney

1. Clitellum beginning (anterior edge) anterior to somite 15 . . . . MEGASCOLICIDAE 7
1. Clitellum beginning posterior to somite 20 . . . . . LUMBRICIDAE 2

2. Prostomium completely divides peristomium, extending back to boundary with second somite 3
2. Peristomium continuous behind prostomium 4

3. Clitellum from somites 27-32 . . . . *Lumbricus rubellus*
3. Clitellum from somites 32-37 . . . . *Lumbricus terrestris*

4. Spermaducal pores (fig. 13,C) on somite 13 . . . . *Eiseniella tetraedus typica*
4. Spermaducal pores on somite 15 5

5. Clitellum begins on or anterior to somite 26 . . *Eisenia foetidus*
5. Clitellum begins on or posterior to somite 27 6

6. Clitellum somites 29-37 . . . . *Allolobophora chloroticus*
6. Clitellum somites 27-34 . . . . *Allolobophora caliginosus*

7. Clitellum encircling body . . . . *Diplocardia singularis*
7. Clitellum saddle-shaped, not extending to ventral side . . . . *Diplocardia communis*

Class HIRUDINEA

From Lone Tree Pond and other fresh water: *Glossiphonia stagnalis* a predaceous leech. Blood-sucking leeches are less common.

Class ECHIUROIDEA

See bibliographic list for references to *Urechis caupo* Fisher and MacGinitie (fig. 17,F) found in tidal mud flats. This is the only species of this group occurring in this region.

Class SIPUNCULOIDEA

Study externally a sipunculid (fig. 13,E). Note the absence of any segmentation or true setae. The anterior portion is called the introvert, as it can be retracted into the rest of the body. Preserved specimens usually have the introvert retracted. At the anterior end of a specimen with extended introvert note the mouth surrounded by tentacles. The anus is not posterior, but is situated on the dorsal side of the body near the base of the introvert. This is one of the reasons for doubting the relationship of the sipunculids to the annelids.

Sipunculids are abundant at Moss Beach and vicinity, mostly living in holes and crevices in the soft sandstone rock and occur in great numbers in mussel beds on Tomales Point. One undetermined species is found at Point Richmond in San Francisco Bay. The following identifications and distinguishing characters are due to Dr. H. E. Brown.

KEY TO THE SIPUNCULIDS OF MOSS BEACH

1. Body nearly cylindrical; conspicuous irregular black spots on the introvert or on entire body; tentacles very short, unbranched, extending only three-quarters of the distance around the mouth . . . . *Physcosoma agassizi*
1. Body pyriform, enlarged posteriorly; no black spots on body; tentacles larger, fewer, branched, surrounding mouth 2

2. Dark-brown hooks on the anterior part of the introvert; tentacle groups four, alike, each with a single base and with many branches . . . . *Dendrostoma petraeum* (fig. 13,F)
2. No hooks on introvert; tentacles of two sets, an inner (nearer mouth) of longer tentacles, an outer of shorter tentacles . . . . *Phascolosoma procerum* (?)

LIST OF SIPUNCULOIDEA

B? M D *Physcosoma agassizi* (Keferstein)
M *Dendrostoma petraeum* Fisher
M *Phascolosoma procerum* (?) Moebius

PHYLUM ARTHROPODA

We shall consider four of the classes of Arthropoda: (1) the Crustacea, (2) the Myriapoda, (3) the Insecta, and (4) the Arachnida. Of these the first three are much more closely related to each other than they are to the Arachnida, which differ in the possession of very different head appendages. The Crustacea have two pairs of antennae, the Myriapoda and Insecta one, while the Arachnida have no antennae, nor have they mandibles as do the others or appendages corresponding to the two pairs of maxillae found in the other three subphyla.

SUBPHYLUM CRUSTACEA

The Subphylum Crustacea is distinguished in a general way from the other arthropods on the basis of habitat in that the crustaceans are almost entirely aquatic, while the other arthropods are predominantly terrestrial. One obvious morphological distinction of the crustaceans is their possession of two pairs of antennae, other arthropods having one pair or none. Two major divisions of the Crustacea were formerly recognized, the Malacostraca and the Entomostraca. The latter, although it may still be used as a convenient term, is generally considered to be without taxonomic validity, since it comprises at least four groups, each of equal rank with the Malacostraca. Following is a key to the divisions of the Crustacea considered in this course.

KEY TO THE MAJOR GROUPS OF CRUSTACEA

1. Firmly attached, either to a solid substrate (Plate X, no. 3) or rarely as a parasite which is partly internal (no. 2). Class CIRRIPEDIA 2
1. Free living, or, if parasitic, generally external 3

2. Non-parasitic; protected by a calcareous shell of several valves . . . . Barnacles (Plate X, nos. 1, 3)
2. Parasites of an extremely simplified morphologic nature; usually found on decapods (*Peltogaster* on hermit crabs; *Sacculina* on true crabs, Plate X, no. 2). . . . . Order Rhizocephala

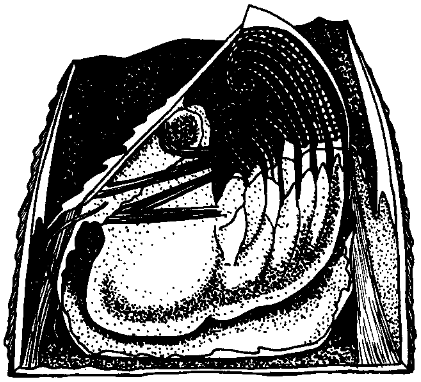
3. Body appendages leaf-like (Plate X, no. 4) and numerous (except in Cladocera) . . . . Class BRANCHIOPODA 4
3. Body appendages not leaf-like, generally differentiated into two or more types, relatively few in number 7

4. Without a carapace (brine shrimp) . Order Anostraca (Plate X, no. 4)
4. With a carapace 5

5. Carapace broad, shield-like . .Order Notostraca (Plate X, nos. 5, 6)
5. Carapace conspicuously folded; body laterally compressed 6

6. Carapace two-valved, hinged dorsally, enveloping the entire body and head; appendages very numerous . . . . Order Conchostraca (Plate X, nos. 7, 7,A)
6. Carapace apparently two-valved, actually not hinged; head uncovered by carapace; appendages few . . Order Cladocera (Plate X, no. 8)

PLATE X



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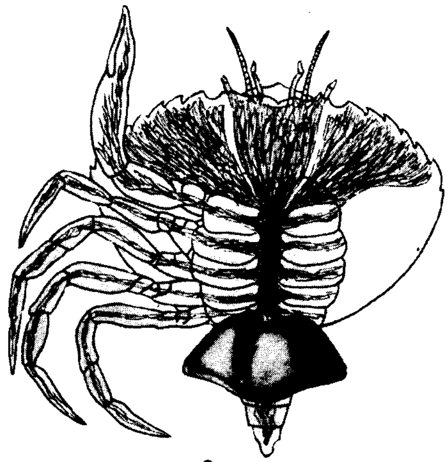

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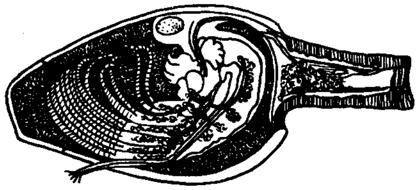

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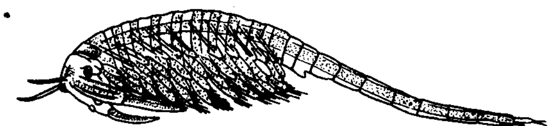

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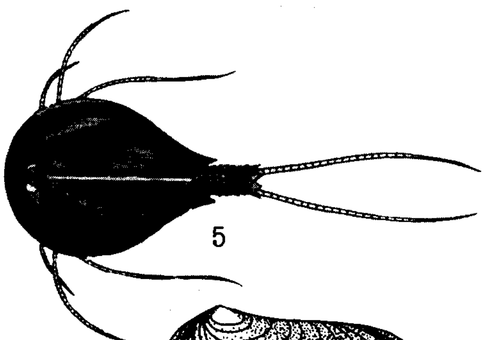

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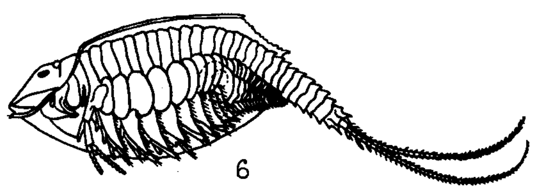

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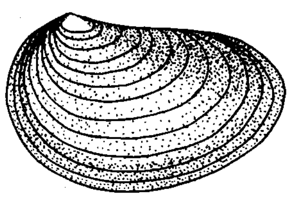

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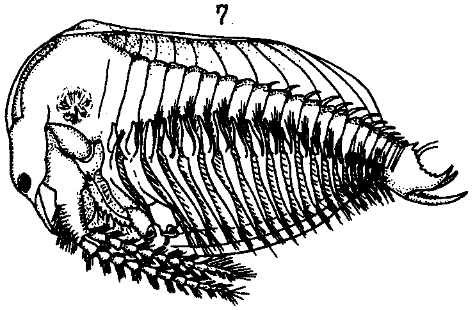

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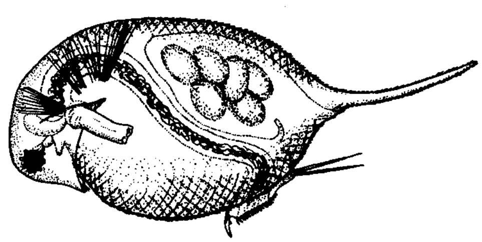

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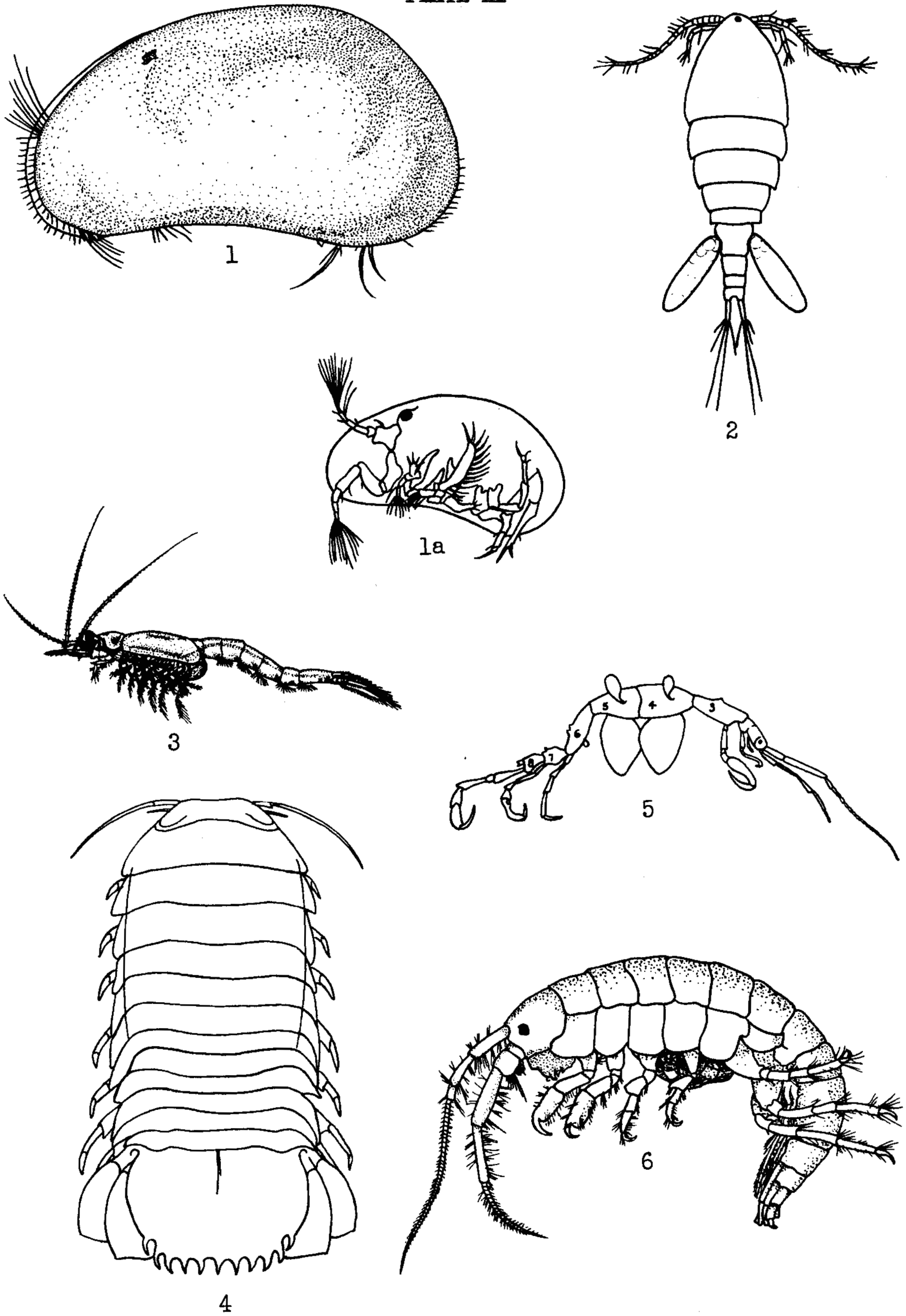
Types of Crustacea. Cirripedia: 1, Acorn barnacle (half of shell removed) (after Darwin); 2, Sacculina (Rhizocephalia) on a crab (after Delage); 3, Acorn barnacle (half of shell removed) (after Claus); 4, Artemia (Anostraca) (after Bronn). Branchiopoda: 5, Apus (Notostraca) (dorsal view; after Bronn); 6, Apus (appendages from the side) (after Lankester); 7, Estheria (Conchostraca) (after Lankester); 7a, Estheria (one valve removed) (after Lankester); 8, Daphnia (Cladocera) (after Sars).

PLATE XI



Types of Crustacea: 1, *Ostracoda* (after Sars); 1a, *Cypris* (Ostracoda) with left valve removed (after Sars); 2, *Cyclops* (Copepoda) (after *Hartog*); 3, *Mysis* (Mysidacea) (after Gerstacker); 4, *Isopoda* (after Lankester); 5, *Caprella* (*Amphipoda*) (after Eales); 6, *Ampithoe humeralis* (Amphipoda)

7. With a bivalve carapace enveloping body and head, externally resembling the Conchostraca, but differing in smaller size (not more than 2 or 3 mm. in length) and in small number of appendages . . . . Class OSTRACODA (Plate XI, nos. 1, 1a)
7. Carapace absent, or present but covering at most the thoracic region 8

8. Flattened fish parasites with compound eyes, suctorial mouth and limbless abdomen; often placed with next class . . . . Genus Argulus, Class BRANCHIURA (fig. 47)
8. With a median simple eye; consisting of very small swimming forms and of parasites which may be somewhat larger; abdominal region without appendages . . . Class COPEPODA (Plate XI, no. 2) 9
8. With paired compound eyes; swimming or crawling forms generally much larger than in Copepoda; abdomen in swimmers almost always with swimming appendages . . . . Class MALACOSTRACA 11

9. Body not abruptly narrowed behind; first antennae (antennules) short, rarely of more than 8 or 9 segments (both prehensile in male); largely bottom living . . . . Order Harpacticoida (fig. 43,D,E)
9. Body abruptly narrowed behind; antennules long (fig. 43,A and B), usually with numerous segments 10

10. Antennules very long, usually with more than 20 segments; antennae (second) biramous; a single, ventrally located egg sac . . . . Order Calanoida (fig. 43,B,C)
10. Antennules moderately long, with 8-20 segments; two laterally or dorso-laterally located egg sacs . . . . Order Cyclopoida (Plate XI, no. 2; and fig. 43,A)

11. Carapace, if present, does not fuse with more than 4 thoracic segments; oöstegites present (plates on ventral side of body of female which form a brood pouch for the hatching of the eggs and the carrying of the young, figs. 52, 53) . . . . .Subclass Peracarida 12
11. Carapace fusing with all the thoracic segments (fig. 78); no oöstegites . . . . .Subclass Eucarida (including Order Decapoda)

12. Eyes stalked; thoracic limbs biramous . . . . Order Mysidacea (Plate XI, no. 3)
12. Eyes not stalked; thoracic limbs uniramous 13

13. Body usually depressed (flattened dorso-ventrally); abdominal appendages generally all alike, leaf-like, functioning mainly for respiration . . . . Order Isopoda (Plate XI, no. 4)
13. Body usually compressed laterally; abdominal appendages usually of two sorts, the three anterior leaf-life, used for swimming and respiration, the three posterior bent backward, used as a leaping organ. The aberrant caprellids (Plate XI, no. 5) do not fit this description, but are distinguished by the reduction of the abdomen to a small stump. . . . . Order Amphipoda (Plate XI, no. 6)

Class BRANCHIOPODA

Of the four orders of the Branchiopoda listed above, only one, the Cladocera, will be frequently encountered during the course. The others, chiefly to be found in seasonal ponds, may be briefly discussed as follows. The Anostraca are represented by the brine shrimp, *Artemia salina* (Plate XI, no. 4), found in this region in the highly concentrated sea water of pools for the commercial production of salt by evaporation. The brine shrimp is much used as food for small fish in aquaria. Other genera, commonly known as fairy shrimps (fig. 36), occur in enormous

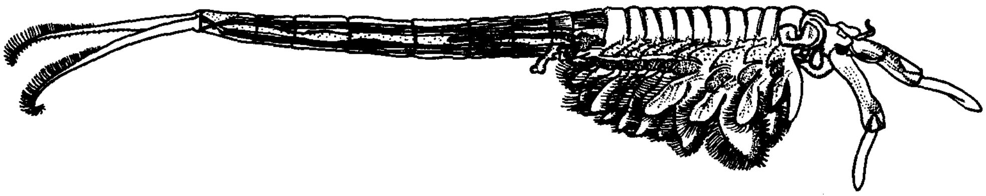


Fig. 36.—Male of Branchinecta gigas Lynch (after Lynch).

numbers at times in seasonal freshwater ponds. Living specimens of *Artemia* will be seen in the laboratory. The Notostraca are represented by *Lepidurus*, and *Apus* (Plate X, nos. 5, 6) also occurring in seasonal freshwater ponds and will probably not be encountered in the coastal area. A member of the Conchostraca, *Estheria* (nos. 7, 7a), is also widely found in seasonal freshwater ponds and is often mistaken for a small bivalved mollusk which its external appearance strongly suggests.

Order Cladocera

On a specimen anaesthetized with nicotine and on mounted stained specimens make out (see fig. 37) head, carapace (not truly bivalved), compound eye, and the large antennae (second antennae). The head ends in a depressed rostrum near which are the vestigial first antennae or antennules. Above the origin of the antennae is a ridge known as the fornix (see *Pleuroxus*, fig. 39). A notch or transverse groove, the cervical sinus (fig. 37), marks the dorsal junction of head and body in some species. A black spot, closely associated with the brain in some species, usually below and behind the compound eye, is the single eye or ocellus.

The head may be in line with the body or depressed. The posterior end of the shell or carapace may bear a spine as in *Daphnia* (Plate X, no. 8). The spine may lie at the postero-dorsal angle or at the postero-ventral (= infero-posteal) angle, when the posterior end of shell is truncated. The postero-ventral angle may be acute, rounded, smooth, or toothed. The nature of the shell surface is often of diagnostic importance. The number of setae on the various joints of the two branches of the antennae beginning at the proximal end is made into a formula of systematic value. The formula for *Daphnia* is $\frac{0\text{-}0\text{-}1\text{-}3}{1\text{-}1\text{-}3}$. Make it out for your specimen.

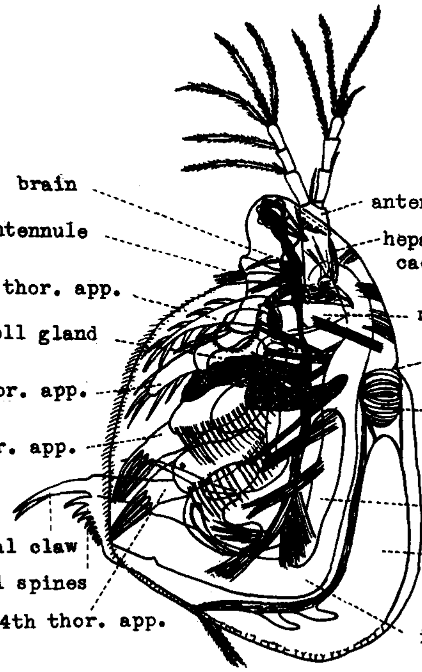


Fig. 37.—Simocephalus sima (after Shipley and MacBride).

Identify a specimen by means of the key in Ward and Whipple. If this is not immediately available use the key below but identify at least one species using Ward and Whipple.

A KEY TO THE COMMON GENERA OF FRESHWATER CLADOCERA

1. Antennules (fig. 37) of female very small (save in *Moina,* where large, freely movable, and inserted near or behind middle of ventral surface of head, fig. 38) . . . . Daphniidae 2
1. Antennules of female long, immovable, inserted near anterior end of ventral surface of head and recurved forming a beak (fig. 39,A). Bosminidae . . . . *Bosmina* (fig. 39,A)
1. Antennules of female long, freely movable, inserted at anterior surface of head (fig. 39,D) . . . . .Family Macrothricidae
1. Antennules of female inserted on ventral surface of head, partly covered by fornices which form a beak with the rostrum extending downward in front of antennules (fig. 39,B). Chydoridae 1a
   1a. Rostrum long and slender, often upcurved at tip; posterior margin short, often toothed . *Pleuroxus* (fig. 39,B)

2. Cervical sinus present (fig. 37) 3
2. Cervical sinus absent . . . . *Daphnia* (Plate X, no. 8)

3. Antennules very small, hardly movable if at all; head small, depressed, with a rostrum 4
3. Antennules large, freely movable; head large, extended, thick in front; without a rostrum; valves small, not covering body; long ciliated spines from dorsal side of postabdomen . . . . *Moina* (fig. 38)

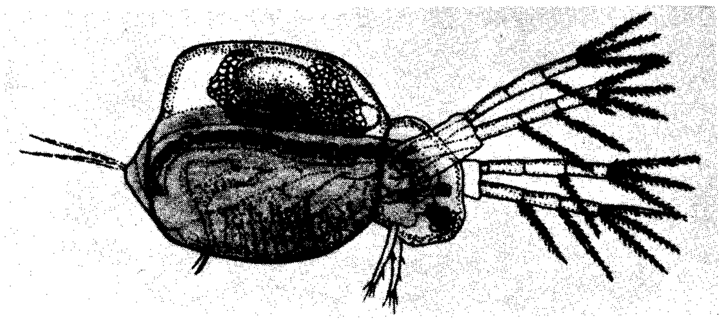
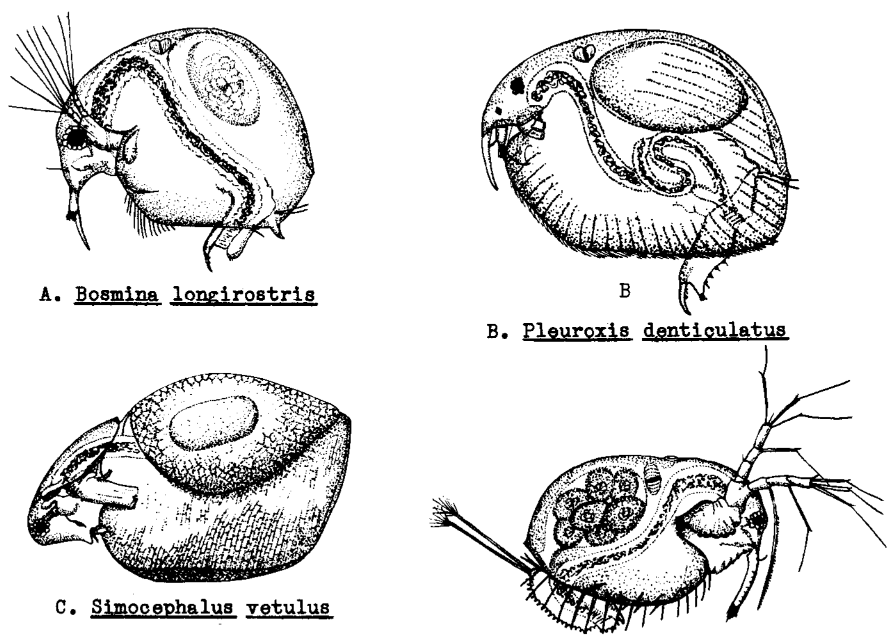


Fig. 38.—Moina (after Baird).

4. Head moderately depressed; valves more or less quadrate 5
4. Head greatly depressed; eye almost directly below bases of antennae; valves oval or round . . . . *Ceriodaphnia*



A. Bosmina longirostris

B

B. Pleuroxis denticulatus

C. Simocephalus vetulus

D. Macrothrix rosea

Fig. 39.—Types of Cladocera (after Birge).

5. Large; valves subquadrate with rounded angles; body large and heavy; yellow to yellow-brown . . . *Simocephalus* (figs. 37, 39,C)
5. Smaller; valves almost rectangular, posteroventral angle of each produced into a spine; color variable . . . . *Scapholeberis*

LIST OF COMMON GENERA OF BRANCHIOPODA
(All except *Artemia* in fresh water)

Anostraca

Artemia salina (in highly concentrated salt water)
Branchinecta

Notostraca

Apus
Lepidurus

Conchostraca

Estheria

Cladocera

Bosmina
Ceriodaphnia
Daphnia
Macrothrix
Moina
Pleuroxus
Scapholeberis
Simocephalus

Class OSTRACODA

Examine whole mounts and living specimens. Note the truly bivalved shell (Plate XI, no. 1), which entirely encloses the head and body, and the absence of segmentation or of leaf-like appendages (fig. 40 and Plate XI, no. 1a). These characters differentiate the ostracods from other entomostraca.

Remove one valve to identify such structures as time allows. Refer to figure 40 of *Asterope*.

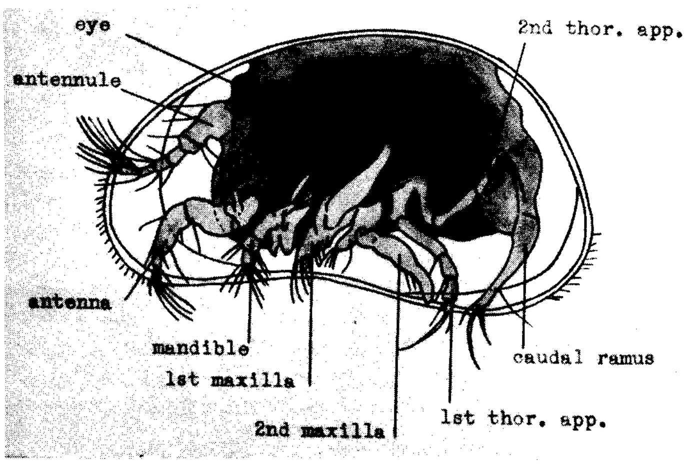


Fig. 40.—An ostracod (Asterope) with left valve removed (after Sars).

Be able to recognize ostracods when encountered. We shall not attempt to identify them to genus or species.

Class COPEPODA

Laboratory Exercise.—Anaesthetize your specimen with a drop of dilute nicotine solution. Note the enlarged anterior portion of the body in front of the movable articulation, known as the metasome, and the smaller posterior urosome (fig. 41). These terms are safer than thorax and abdomen, about the limits of which opinions differ. The last or anal segment bears a pair of caudal or furcal rami (or furcae). See the large uniramous first antennae (antennules) and the smaller, often biramous, second antennae. How many pairs of thoracic legs (swimming legs) do you find (refer to fig. 41)? These legs, particularly the last (fig. 44), are often of very great systematic importance.

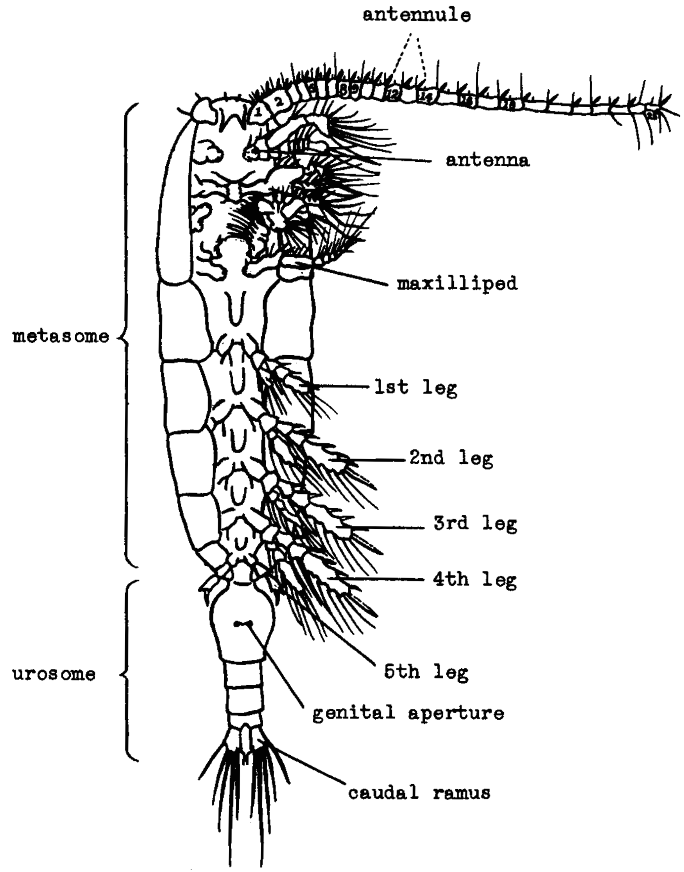


Fig. 41.—Diagrammatic figure of female calanoid copepod (after Giesbrecht and Schmeil).

Study stained mounts of appendages of a large freshwater species (genus *Diaptomus*). Using both low and high power of the compound microscope see the antennules of male and female. Note the special features of the right (clasping) antennule of the male, especially the process on the antepenultimate segment (fig. 44,D,E) and the heavy spines on segments 10, 11, and 13. On a swimming leg make out basipodite and two distal branches, the exopodite and endopodite. How many segments in each of these?

Study the fifth legs of the female (fig. 44,B) noting that they are greatly modified but symmetrical. Note the great asymmetry of the male fifth leg (fig. 44,A). The position of the spine on the outer side of the second segment of the right exopodite is important in classification as also the nature of the medial apical process of the terminal segment of the left exopodite (fig. 44,A).

Figure 42 illustrates the functions in copulation of the peculiarly modified right antennule of the male, the male fifth legs, and the usually asymmetrical urosome of the male.

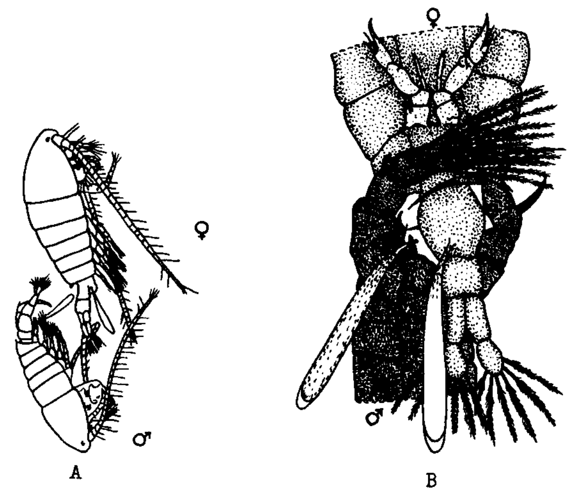


Fig. 42.—Copulation in Diaptomus (after Wesenberg-Lund): A, function of clasping antennule of male; B, function of urosome and fifth legs of male.

See examples and learn the general distinguishing characters of the three subclasses, the Calanoida (figs. 41, 43,B,C), Cyclopoida (fig. 43,A), and Harpacticoida (fig. 43,D,E). The calanoids are usually larger (figures in 43 entirely out of scale), the antennules very long (with 25 segments), the urosome sharply distinct from the metasome, which is considerably longer and broader than the urosome (furcal rami included in measurement, but not setae); the cyclopoids (fig. 43,A) are smaller, the antennules shorter, usually with less than 17 segments, the urosome and metasome distinct and of about the same length; the harpacticoids (fig. 43,D,E) are very small, the antennules very short with few segments and the urosome is not conspicuously different from the metasome.

A key to the orders of Copepoda is included in the key on p. 69, but is repeated below, together with the identification of some local genera and species.

A KEY TO THE MOST COMMON COPEPODA OF THE SAN FRANCISCO BAY REGION

1. Body not abruptly narrow behind; urosome nearly as wide as metasome (fig. 43,D,E); first antennae short, rarely of more than 8 or 9 segments (both prehensile in male); largely bottom-living. . . . . Harpacticoida 2

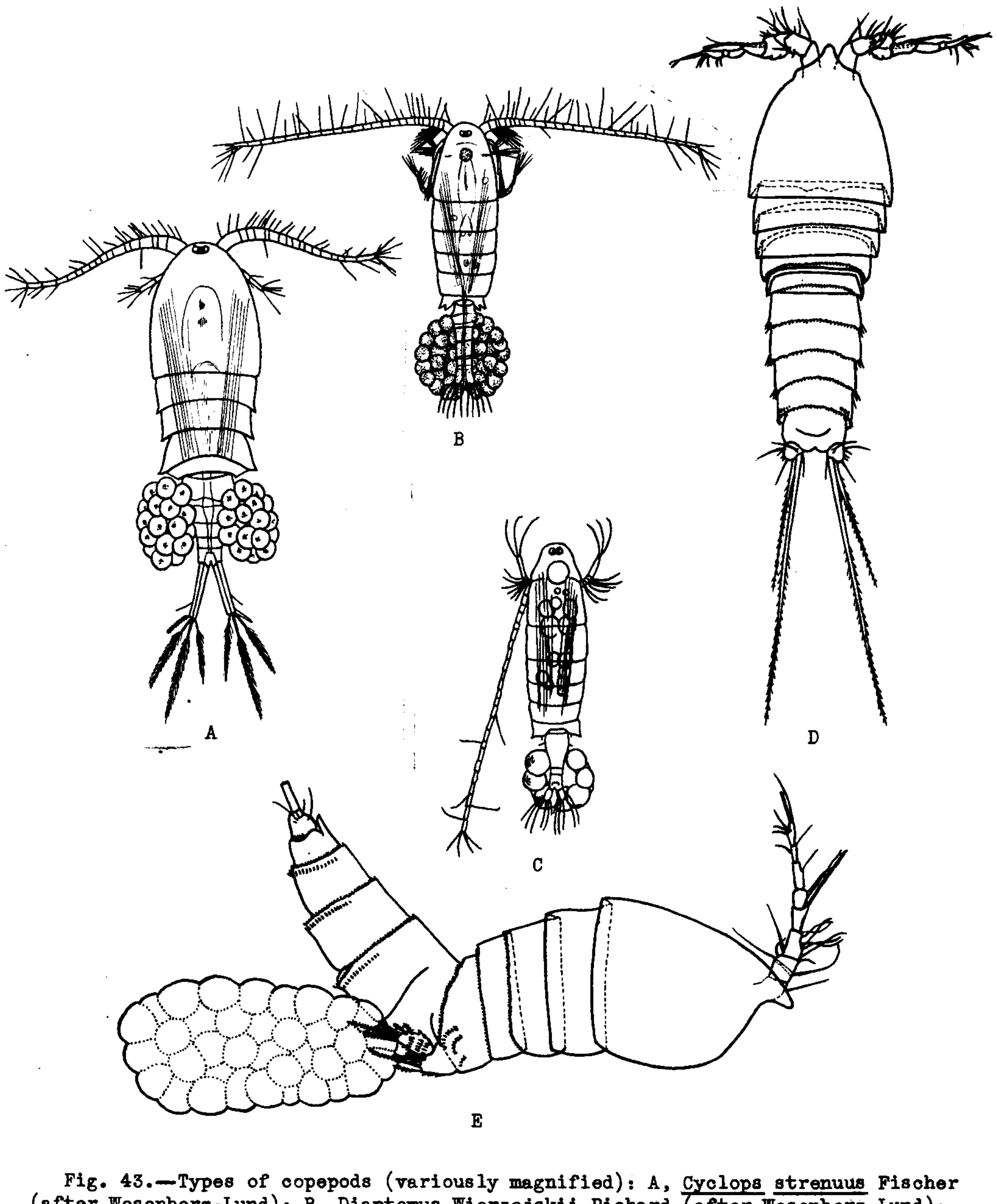


Fig. 43.—Types of copepods (variously magnified): A, Cyclops strenuus Fischer (after Wesenberg-Lund); B, Diaptomus Wierzejskii Richard (after Wesenberg-Lund); C, Diaptomus gracilis Sars (after Gurney); D, E, Atthyella illinoisensis Forbes (after Coker).

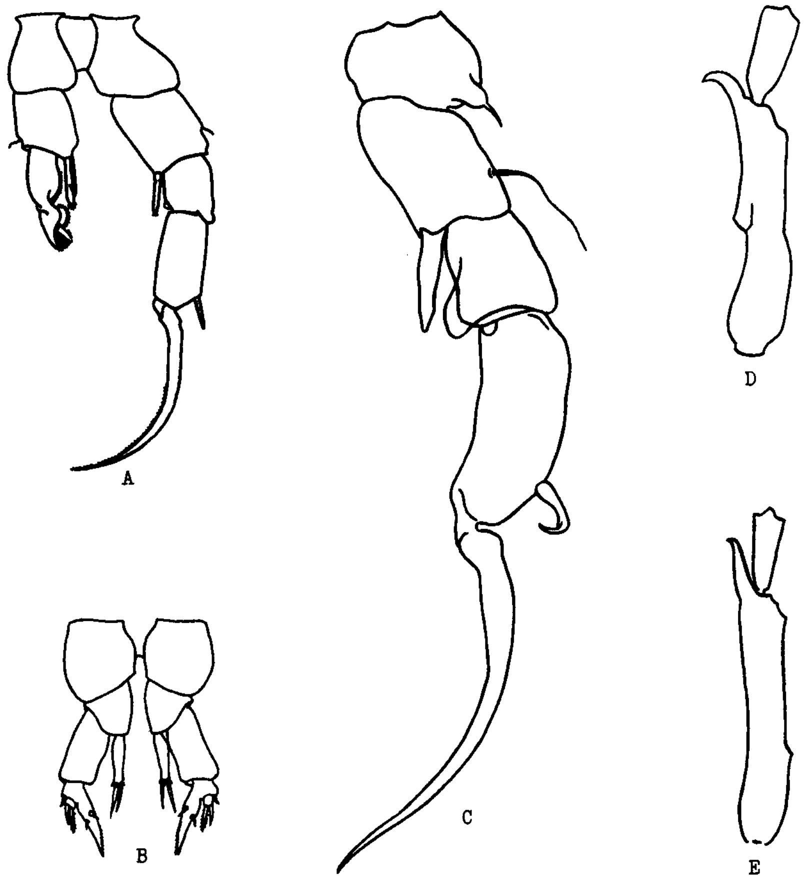


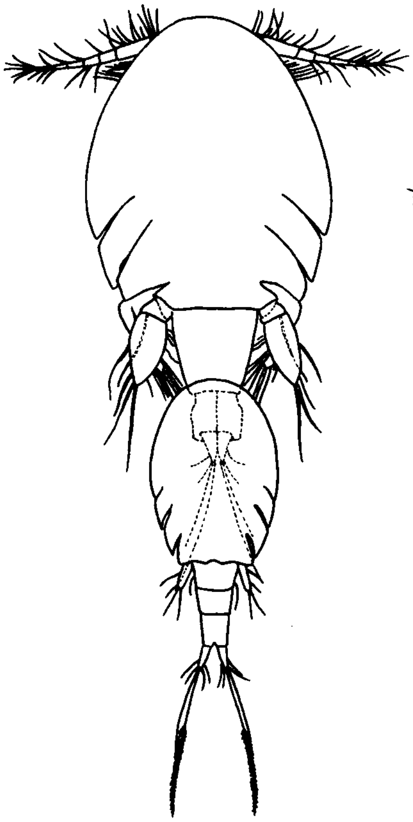
Fig. 44.—Fifth legs and right antennules of local species of Diaptomus, variously magnified: A, fifth legs of male of Diaptomus caducus Light; B, fifth legs of female of same species; C, right fifth leg of male of Diaptomus siciloides Lilljeborg, much enlarged; D, antepenultimate segment of right antennule of male of Diaptomus novamexicanus Herrick; E, same of D. siciloides.

1. Body abruptly narrowed behind, urosome narrow; antennules long (fig. 43,A-C), usually with numerous segments; chiefly free-swimming 3

2. Fresh water . . . . *Canthocamptus (Atthyella)* (fig. 43,D,E)
2. Marine; orange red; present in high tide pools . . . . *Tigriopus californicus*

3. Antennules very long, usually with more than 20 segments (figs. 41, 43,B,C); a single, ventrally located egg sac. . . . . Order Calanoida 5
3. Antennules moderately long, with from 8-20 segments, usually from 10-16; two laterally or dorsolaterally located egg sacs (fig. 43,A) . . . . Order Cyclopoida 4

4. Freshwater; free-living; with relatively narrow body. . . . . *Cyclops* and related genera.
4. Marine, on surface of *Callianassa*; red; female broad (figs. 45, 46); male much smaller (fig. 45) . . . . . . *Clausidium* (figs. 45, 46)



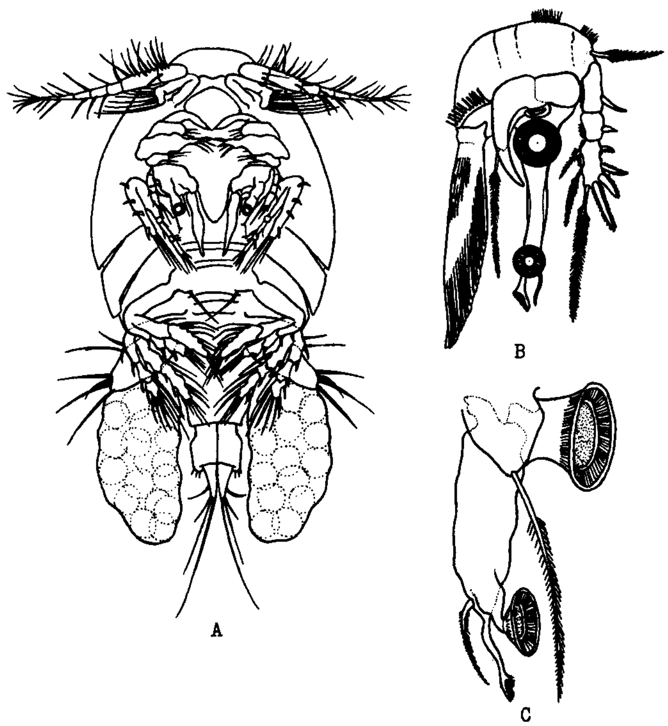


Fig. 45.—Clausidium vancouverense Haddon, dorsal view of clasping pair.

Fig. 46.—Clausidium vancouverense Haddon: A, female in ventral view; B, first thoracic leg, magnified to show modifications; C, a portion of this more highly magnified to show nature of suckers.

5. Urosome of female 4-segmented (fig. 41); metasome showing five distinct somites behind head; left fifth leg of male enlarged; marine . . . . *Calanus*
   Commonest pelagic species . . . . *C. finmarchicus*
5. Urosome of female 3-segmented; metasome showing 3 or 4 distinct somites behind head; exopod of right fifth leg of male tipped with long, curved claw (fig. 44,A,C); fresh water . . *Diaptomus* 6

6. Spine of right fifth leg of male nearly straight, located near distal end of second segment of exopodite (fig. 44,A); medial process of left exopodite of male fifth leg a slender curving, flat spine (fig. 44,A); third segment of exopod of female fifth leg distinct (fig. 44,B) 7

6. Spine of right fifth leg of male curved, much nearer middle of segment (fig. 44,C); medial apical process of left exopod digitiform; third segment of exopod of female fifth leg vestigial, represented only by seta and spine 9

7. Antennules with setae more numerous than usual, two each on segments 13-19, and four on segment 2 . . *D. caducus* (fig. 44,A)
7. Antennules with but one seta on segments 13-19 and three on segment 2 8

8. Larger; process on antepenultimate segment of right male antennule much longer than penultimate segment, slender distally; right fifth leg of male with a prominent rugose swelling on median margin of second basal segment . . . . *D. eiseni*
8. Smaller; process on antepenultimate segment of right male antennule rarely as long as penultimate segment, thicker distally; no such swelling on right fifth foot of male . . *D. franciscanus*

9. Antepenultimate segment of right male antennule without hyaline lamella but with a short process abruptly outcurved near tip (fig. 44,E); fifth leg of male with prominent hyaline lamella on distomedial margin of basal segment of right exopod (fig. 44,C); this segment nearly twice as long as wide . *D. siciloides*
9. Antepenultimate segment of right male antennule with both hyaline lamella and a process; process with gentle distal curvature (fig. 44,D); basal segment of right exopodite of male fifth leg wider than long, without hyaline lamella. . . . . *D. novamexicanus*

LIST OF COMMON LOCAL COPEPODA

Order Harpacticoida

F *Atthyella*
M *Tigriopus californicus* (Baker) (= *T. triangulus* Campbell)
Many other unidentified genera and species, freshwater and marine. For marine species see Monk, Trans. American Micros. Soc., 1941, p. 75.

Order Calanoida

M *Calanus finmarchicus* Gunner
M *Calanus* spp.
Other marine species
F *Diaptomus caducus* Light
F *Diaptomus eiseni* Lilljeborg
F *Diaptomus franciscanus* Lilljeborg
F *Diaptomus novamexicanus* Herrick (= *D. washingtonensis*)
F *Diaptomus siciloides* Lilljeborg

Order Cyclopoida

M *Clausidium vancouverense* Haddon
F *Cyclops* spp.
Many other freshwater genera and species

Class BRANCHIURA or ARGULOIDEA

These animals (fig. 47) are ectoparasites of fish, freshwater and marine. Two species are commonly encountered in this region, *Argulus japonicus* Thiele (fig. 47) common on goldfish, and the much larger *A. pugettensis* Dana common on the various types of marine perch.

The family Argulidae has been recently reviewed by Meehean (1940, Proc. U.S. National Museum). The group is variously considered to represent an order or subclass of the Copepoda or a separate class.

See the demonstration specimens and be able to recognize the two common local species.

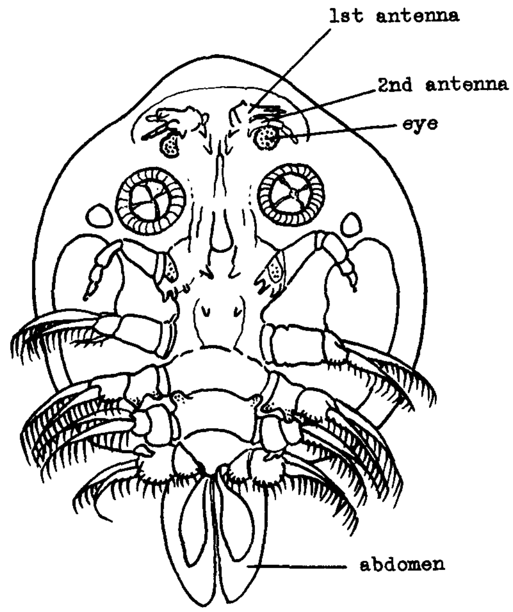


Fig. 47.—Argulus, the fish louse, Class Branchiura (after Meehean).

Class CIRRIPEDIA

Order Thoracica, Barnacles

(Refer to Cirripedia of Puget Sound, by Dora Henry, 1940.)

On a goose barnacle (*Lepas*, fig. 48,A) make out the five plates making up the armor, a pair of large scuta (sing. scutum) at the stalk end, a pair of smaller terga (sing. tergum) at the free end, and a single narrow median carina at the hinge side. The homologues of these five plates are present in the sessile barnacles as well as several other plates. In *Mitella*, the leaf barnacle, many accessory platelets are found, some of which may be homologous with the extra plates in the sessile barnacles.

On the sessile or acorn barnacle, *Balanus glandula* (figs. 48,B,C,

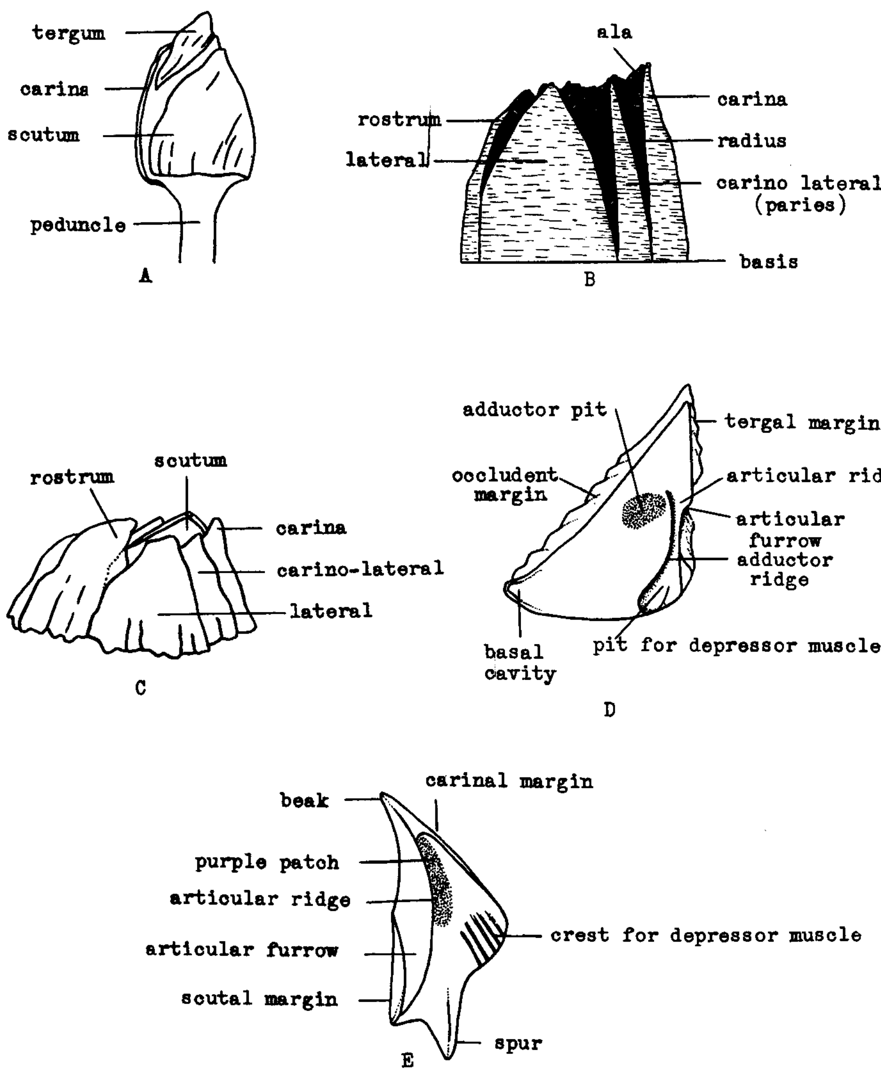


Fig. 48.—Types of barnacles and terms used in their description (C-E after Henry): A, Lepas, a goose barnacle; B, Balanus glandula pugettensis Henry; C, Balanus glandula; D, scutum of Balanus nubilus, inner view; E, tergum of same inner view.

Plate X, no. 1), make out three calcareous regions: (1) the basis by which it is attached, (2) the parapet or wall, and (3) the movable portion, the valves, shutting the aperture at the free end of the wall.

The wall of a sessile barnacle consists primitively of 8 plates, each known as a compartment. The one farthest from the head (dorsal or posterodorsal) is the carina (figs. 48,B,C), homologous with that in *Lepas*; that at the opposite end is the rostrum. Those on either side of the carina are the carino-laterals, and the pair next the rostrum the rostro-laterals, while the middle compartments are known as laterals. Various combinations and eliminations of these primitive 8 plates have occurred in different genera. In the genus *Balanus* (fig. 49,B) the rostro-laterals are fused with the rostrum. In *Chthamalus* (fig. 49,A) the carino-laterals are lacking and in *Tetraclita* there are only four plates, the rostro-laterals being fused with the rostrum and the carino-laterals absent. The exposed median triangle of each compartment (fig. 48,B) is known as a paries (pl. parietes.) The edges of a compartment which overlap another compartment are known as radii

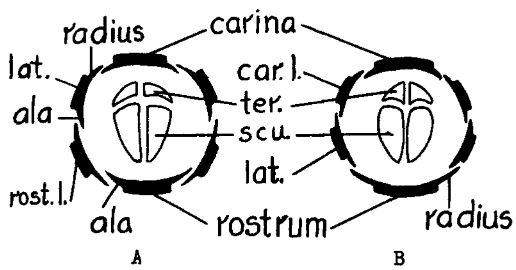


Fig. 49.—Schematic cross sections to show arrangement of plates in Chthamalus (A) and Balanus (B).

(sing. radius) if the lines of growth are different from the paries, otherwise they receive no special designation. The edges of a compartment which are overlapped are known as alae (sing. ala). The rostrum and carina are symmetrical, typically each with two alae. The lateral compartments are symmetrical each with a radius on the posterior (carinal) side and an ala on its anterior (rostral) side. In *Chthamalus* the rostrum is normal with two alae (fig. 49,A). In *Balanus* (fig. 49,B) and *Tetraclita*, however, it seemingly has two radii, but these are really the radii of the rostro-laterals which are joined with it. The carina has two alae in all cases since, while the carino-laterals are lacking in some genera (*Chthamalus* and *Tetraclita*), they are never fused with the carina as are the rostro-laterals with the rostrum (*Balanus* and *Tetraclita*). The movable upper portion consists of two pairs of plates, two longer anterior scuta (figs. 48,D and 49), and two shorter posterior terga. Numerous characters important in the classification are found on the inner bases of these plates (see fig. 48,D,E).

Identify your specimen using the key below. At some future time attempt to identify other species by means of Henry's key (1940) or using Pilsbry, U.S. Nat. Mus. Bull. 93. Our local barnacles are not well known and species may be found which are not in the key.

KEY TO THE BARNACLES

1. Stalked (goose barnacles) 2
1. Sessile (acorn barnacles) 4

2. With many plates and thickly scaly peduncle; attached to rocks . . . . *Mitella polymerus*
2. With but five plates and smooth, slender peduncle; attached to seaweed or floating wood (fig. 48,A) 3

3. Plates thin and papery; carina ending below in flat disc . . . . *Lepas fascicularis*
3. Plates thicker; carina forked below . . . . *Lepas hilli*

4. Very small, less than 1/4 inch long, without vertical ridges; front and hind plates (rostrum and carina) overlapped on both sides by lateral plates (fig. 49,A) . . . . . . *Chthamalus fissus*
4. Larger; with vertical ridges; anterior plate (rostrum) overlapping lateral plates (fig. 49,B) 5

5. Wall red, finely ridged, consisting of but 4 compartments, the divisions between which are hardly discernible externally. *Tetraclita squamosa rubescens*

5. Wall grayish or white, variously ridged, consisting of 6 compartments, the margins of which may not be discernible externally 6

6. Outside of wall with numerous fine ridges (see figure below); suture between scuta strongly sinuate . . . . . .*Balanus cariosus*
6. Outside of wall without or with few ridges, these relatively heavy; suture between scuta feebly or minutely sinuate . . . 7

7. Small to medium size, usually about 1/2 inch in diameter or smaller 8
7. Usually much larger; at low tide mark . . . *Balanus nubilis* (fig. 48,D,E)

8. Commonly with distinct ridges on wall; common high intertidal species . . . . *Balanus glandula*
8. Wall smooth; rare lower intertidal species . . . *Balanus crenatus* (See Henry, 1940, and the special report of C. D. Michener for more technical differences between species of *Balanus*)

LIST OF CIRRIPEDIA

Order Rhizocephala

Unidentified parasitic forms (*Sacculina*, *Peltogaster* or other Rhizocephala) on crabs, especially on hermit crabs.

Order Thoracica

Balanus cariosus Pallas
Balanus crenatus Brugiere
Balanus glandula Darwin
Balanus nubilis Darwin
Chthamalus fissus Darwin
Lepas hilli Leach
Lepas fascicularis Ellis and Solander
Mitella polymerus Sowerby
Tetraclita squamosa rubescens Darwin

The Thatched Barnacle, Balanus cariosus Pallas (from Guberlet)

Class MALACOSTRACA

Three subclasses of the Malacostraca, the Leptostraca, the Hoplocarida, and the Syncarida, will not be encountered. The other two, Peracarida and Eucarida, include many important elements of the faunas studied.

Subclass Peracarida

Two orders, Mysidacea (Plate XI, no. 3) and Cumacea (fig. 50), include minute forms not important in such studies, although representatives of each may be encountered. A third order of many authors, the Tanaioidea (fig. 51), is included in this syllabus with the Order Isopoda as the Suborder Chelifera.

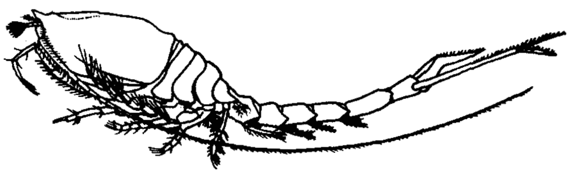


Fig. 50.—Diastylis, a cumacean (after Sars).

Order Isopoda

You will be given specimens of the five free-living suborders, Chelifera, Flabellifera, Valvifera, Oniscoidea, and Asellota. Distinguish them by means of the key below adapted from M. A. Miller (1940) and Richardson (1905).

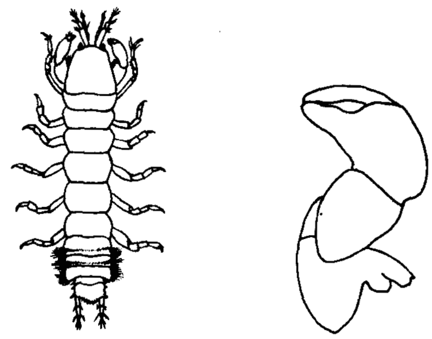


Fig. 51.—Tanais, Suborder Chelifera (= Order Tanaioidea) (after Richardson): A, dorsal view; B, chela enlarged.

1. First pair of legs chelate (fig. 51); uropods terminal . . . . *Chelifera (Tanaioidea)*
1. First pair of legs without chelae; uropods terminal or lateral . 2

2. Uropods lateral (fig. 58) or ventral (fig. 54) 3
2. Uropods terminal (figs. 52, 53, 61) 4

3. Uropods lateral, visible dorsally, with flattened branches forming with telson a caudal fan (fig. 58) . . . . *Flabellifera (Cymothoidea)*
3. Uropods ventral, not visible dorsally, modified to form larger opercular plates hinged laterally and covering the pleopods (fig. 54) . . . . *Valvifera (Idotheoidea)*

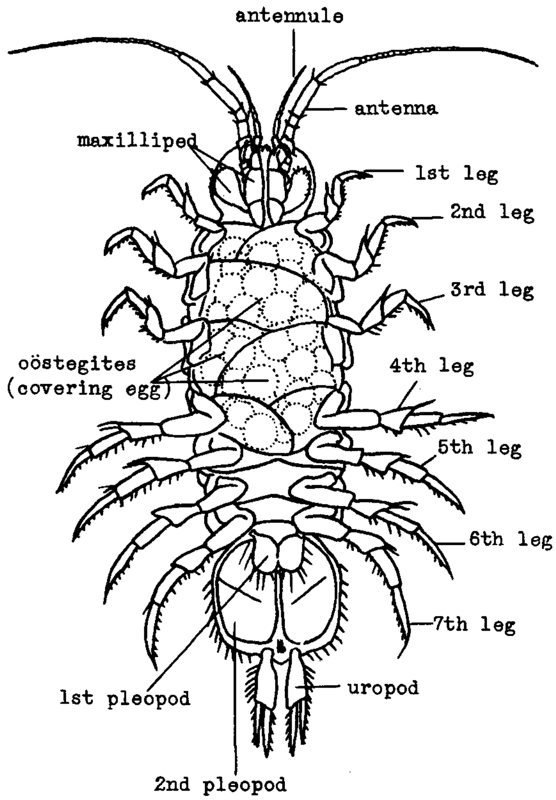


Fig. 52.—Asellus communis Say, Suborder Asellota (after Van Name).

4. Aquatic forms; pleopods branchial; abdominal appendages usually covered by larger opercular plates formed by an anterior pair of pleopods; abdominal segments fused . . . . *Asellota (Aselloidea)* (fig. 52)
4. Terrestrial forms; pleopods uncovered, adapted for air breathing; sometimes provided with tracheal trees; abdomen with 6 well-defined segments (the last fused with telson) . . . . *Oniscoidea* (fig. 53)

In your specimens note the characters of the order, the depressed bodies, the long thorax with seven pairs of legs (peraeopods or periopods), in addition to the one pair of maxillipeds (figs. 52, 53), and the short abdomen. The last abdominal segment is united with the telson and other reductions in visible numbers of abdominal segments will be encountered (e.g., fig. 54). See the flat leaf-like pleopods functioning for respiration and for swimming (figs. 53, 54).

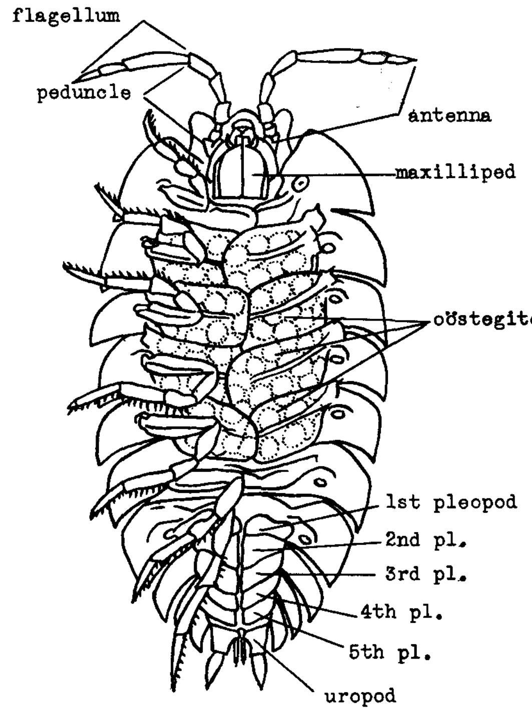


Fig. 53.—Porcellio scaber Latreille, Suborder Oniscoidea (after Van Name).

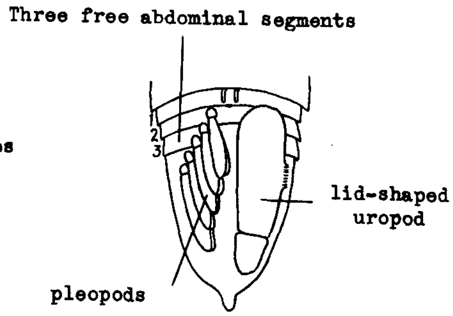


Fig. 54.—Idotea baltica Pallas, Valvifera: ventral view of abdomen with lid-like uropod removed on one side (after Eales).

On a female make out the oöstegites (figs. 52, 53), or marsupial plates, arising from the inner bases of the thoracic appendages. These form the marsupium in which the eggs develop.

Study the mounts of the head appendages of *Sphaeroma*. Make out antennules, antennae, mandibles, maxillules or first maxillae, maxillae or second maxillae. The maxillipeds are the first thoracic appendages.

Make yourself familiar with the following valuable works of reference listed in the terminal bibliography: Richardson (1905), Monograph of Isopods of North America (naturally far from complete); Miller, M.A. (1938), Comparative Ecological Studies on the Terrestrial Isopods of the San Francisco Bay region (includes a key to species); Van Name (1936), Monograph of Land and Freshwater Isopods.

A KEY TO THE COMMON LOCAL ISOPODS

1. Legs of first pair cheliform (fig. 51), uropods terminal; pleopods, when distinctly developed, exclusively natatory. Chelifera (often considered a separate order, Tanaioidea). 2
1. First pair of legs not cheliform 4

Suborder Chelifera

2. Two pairs of pleopods; abdomen of 3 segments; uropods of 2 articles . . . . *Pancolus californiensis*
2. Three pairs of pleopods; abdomen of 5-6 segments; uropods of 3-7 articles 3

3. Abdomen of 6 segments . . . . *Anatanais*
3. Abdomen of 5 segments . . . . *Tanais* (fig. 51)

4. Uropods lateral (fig. 58) or ventral (fig. 54) 5
4. Uropods terminal (figs. 52, 53, 61) 20

5. Uropods forming with terminal segment of abdomen a caudal fan (fig. 58); most pleopods natatory (Cymothoidea or Flabellifera 10
5. Uropods valve-like, inflexed, arching over pleopods (fig. 54) which are largely branchial (Idotheoidea or Valvifera) 6

Suborder Valvifera

6. Palps of maxillipeds with five articles (fig. 55,A); epimera of thoracic segments free (figs. 56,A-C) . . . . . *Pentidotea* 7
6. Palps with four articles (fig. 55,B), epimera of all save first thoracic segment free . . . . *Idothea*

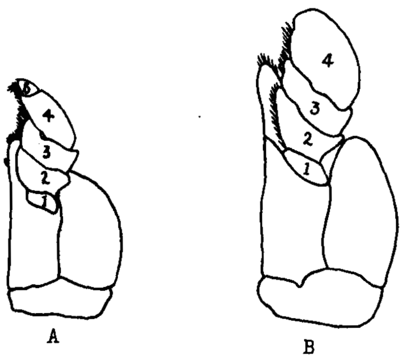
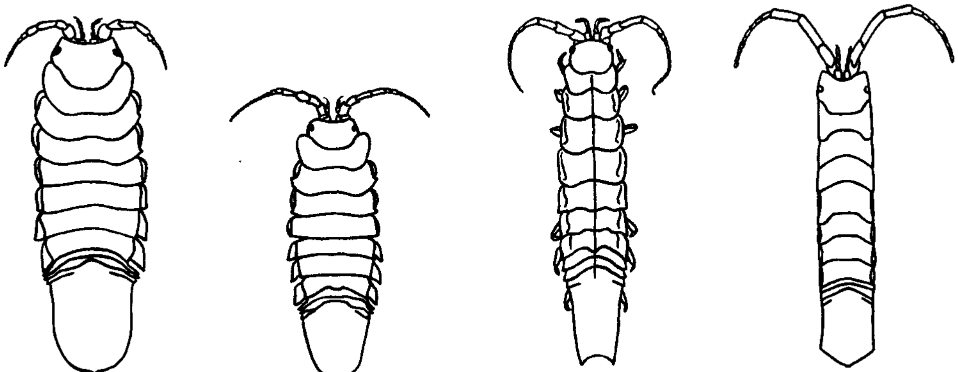


Fig. 55.—A, mandibular palp of Pentidotea wosnesenskii showing five articles; B, same of Idothea rectilinia showing four articles.

7. Posterior margin of telson concave, often deeply so, postero-lateral angles greatly extended (fig. 56,C) . *Pentidotea resecata*
7. Posterior margin of telson convex, postero-lateral angles not extended 8

8. Telson broadly rounded at posterior end, with a very small median tooth; commonly dark green or brown; found among seaweed . . . . *Pentidotea wosnesenskii* (figs. 56,A,B)

8. Telson more nearly rectangular, postero-lateral angles fairly distinct, a distinct median tooth at posterior end 9



A B C D

Fig. 56.—Idotheoidea (after Richardson): A, B, Pentidotea wosnesenskii Brandt; C, P. resecata Stimpson; D, Idothea rectilinia Lockington.

9. Sides of thorax approximately straight; thorax not half again as wide as telson; long diameter of eye about twice short diameter . . . . *Pentidotea whitei*

9. Sides of thorax convex; thorax twice as wide as telson; long diameter of eyes five times short diameter . *Pentidotea stenops*

Suborder Flabellifera

10. First pair of legs subchelate, larger and stouter than the others; mouth parts sucking; uropods lateral and superior . . . . *Anthuridae* (fig. 57)

10. First pair of legs resembling others; uropods not superior; mouth parts normal 11

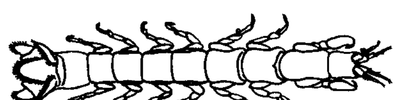


Fig. 57.—Cyathura carinata Krøyer, Anthuridae (after Richardson).

11. Abdomen, including telson, of 6 short segments (often only 5 visible) (figs. 58,C,D) 12

11. Abdominal segments reduced in number and imperfectly separated, usually 2 visible segments (fig. 58,A); uropod with one immovable branch . . . . *Sphaeromidae* 14

12. Two pairs of antennae unequal in length (fig. 58,C); uropods well developed, forming a fan with the telson and last abdominal segment (fig. 58,C); speckled or dark gray in color . . . . *Cirolana* 13
12. Two pairs of antennae equal or subequal; uropods small, outer branch rudimentary; body white, eyes black; boring in wood . . . . *Limnoria*

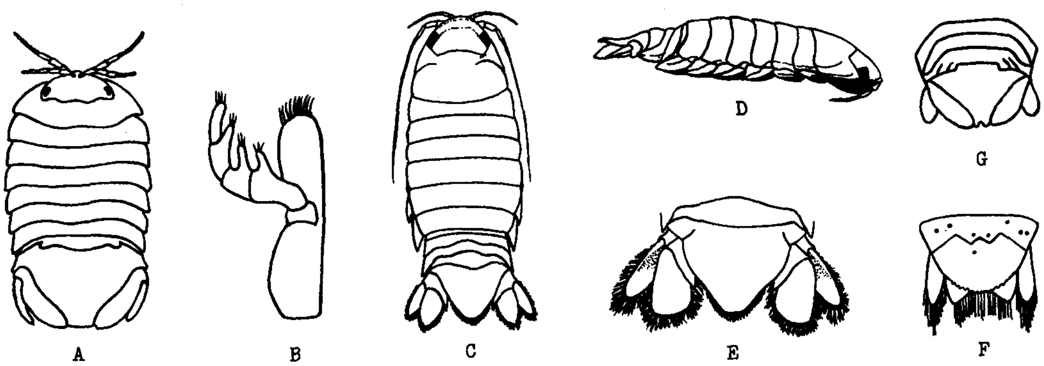


Fig. 58.—Sphaeromidae (after Richardson): A, Exosphaeroma thermophilum Richardson; B, maxillary palp of Exosphaeroma showing lobes; C-E, Cirolana harfordi Lockington; F, Cirolana linguiformis Richardson; G, Dynamenella.

13. Fifth abdominal segment with lateral parts covered by fourth segment; anterior margin of telson approximately straight (fig. 58,C,E) . . . . *Cirolana harfordi*
13. Lateral angles of fifth segment free; anterior margin of telson with three angular projections (fig. 58,F) . . . . *Cirolana linguifrons*

14. Posterior margin of telson entire (fig. 58,A) 16
14. Telson with a median emargination (fig. 58,G) 15

15. Surface of abdomen smooth; flagellum of second antenna with 10 articles . . . . *Dynamenella*
15. Surface of abdomen with tubercles; flagellum of second antenna with less than 6 articles . . . . *Dynamene*

16. Second to fourth articles of palp of maxilliped not produced into lobes; surface densely granular, dark brown; in mud flats, and in colonies of *Mercierella* at Lake Merritt . . . . *Sphaeroma pentodon*
16. Second to fourth articles of palp produced into lobes (fig. 58,B) . . . . *Exosphaeroma* 17

17. Body broadest posteriorly, thorax ridged with three longitudinal rows of small tubercles; branches of uropods expanded . . . . *Exosphaeroma amplicauda*
17. Body otherwise 18

18. Extremity of telson produced in a rhomboid process; surface of body punctate; color whitish yellow . . . *Exosphaeroma rhomburum*
18. Extremity of telson not produced in rhomboid process 19

19. Surface of abdomen with tubercles; all thoracic segments but first marked with four conspicuous brown spots and with two spots on first abdominal segment . . . . *Exosphaeroma octoncum*
19. Surface of abdomen without tubercles; body ovate, twice as long as wide; head three times as wide as long . . . . *Exosphaeroma oregonensis*

20. Littoral; abdominal segments fused (figs. 59, 60) (Suborder Asellota) 21
20. Supralittoral or terrestrial; abdomen consisting of 6 well-defined segments (Suborder Oniscoidea) 24

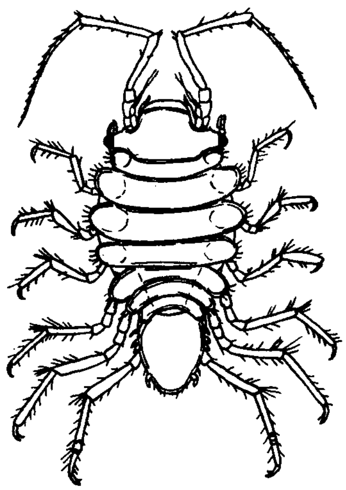


Fig. 59.—Munna krøyeri Goodsir (after Richardson).

Suborder Asellota

21. Mite-like in appearance; last three thoracic segments short, constricted . . . . *Munna* (fig. 59)
21. Not mite-like; last three thoracic segments not constricted . . 22

22. Second pair of antennae long, with multiarticulate flagellum . 23
22. Second antennae short; flagellum reduced (figs. 60,B,C) . . . . *Jaeropsis*

23. Uropods tiny; first pair of antennae very tiny (fig. 60,A); second pair without a scale . . . . *Jaera*
23. Uropods and first antennae well developed (fig. 60,D,E); second antennae with a scale . . . . *Janiropsis*

Suborder Oniscoidea

24. Living just above water on the shore of ocean or bay 25
24. Truly terrestrial or near fresh water 28

25. Slow-moving; under rocks or debris; not actually entering water; antennae and uropods short 26
25. Rapidly moving; living more in the open and entering water at times; antennae and uropods long 27

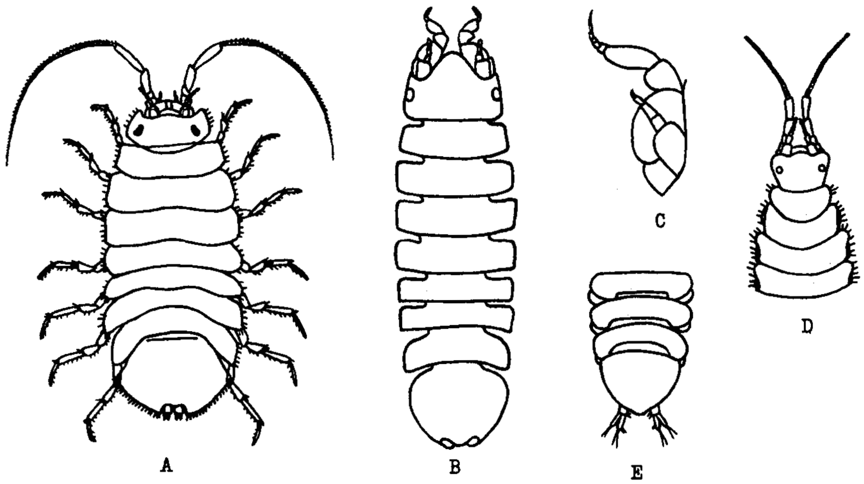


Fig. 60.—Jaeridae (after Richardson); A, Jaera marina Fabricius; B, Jaeropsis lobata Richardson; C, antennule (small) and antenna of same; D, E, Janiropsis californica Richardson.

26. Larger; found only just above high-tide line under debris; with characteristic large white spots . . *Alloniscus perconvexus*
26. Small; found in other moist locations; with uniform color or at least not conspicuously mottled 29

27. Basal segment of uropods at least twice as long as wide (fig. 61,B) . . . . *Ligia occidentalis*
27. Basal segment of uropods about as wide as long (fig. 61,A) . . . . *Ligia pallasii*

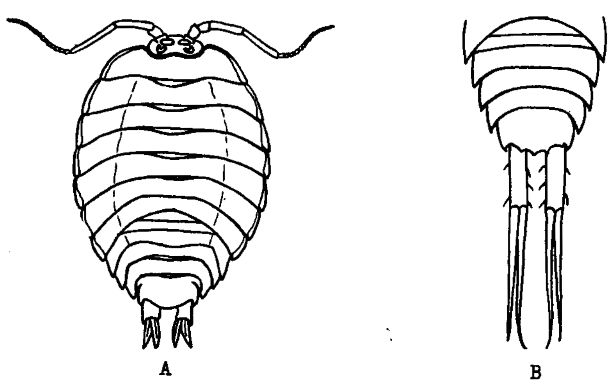


Fig. 61.—Ligia (= Ligida) (after Richardson): A, Ligia (Ligia) pallasii Brandt; B, Ligia (Megaligia) occidentalis Dana.

28. In or near streams, generally under stones; flagellum of second antenna multi-articulate; dorsal surface dark gray, glossy . . . . *Ligidium gracile*
28. Not confined to streams; flagellum of second antenna with three joints or less (fig. 53) 29

29. Abdomen abruptly narrower than thorax; brown or reddish; surface slightly granulated; usually under decaying vegetation . . . . *Porcellionides pruinosus*
29. Abdomen not abruptly narrower than thorax 30

30. Body very convex, capable of being rolled into a ball; uropods not extending beyond tip of abdomen. "The Pill Bug" . . . . *Armadillidium vulgare*
30. Body more or less depressed, not capable of rolling into a ball; uropods extending beyond tip of abdomen. "The Sow Bugs" 31

31. Body roughly granulate or tuberculate . *Porcellio scaber* (fig. 53)
31. Body smooth or minutely granulate 32

32. Body very smooth and shiny; posterolateral margin of first four thoracic somites straight; terminal process of abdomen (telson) pointed at tip, with a deep longitudinal dorsal groove . . . . *Porcellio formosus*
32. Body smooth or slightly granular; posterolateral margins of first four thoracic somites produced posteriorly; telson rounded at tip and with but a faint dorsal groove . . . . *Porcellio laevis*

LIST OF ISOPODS

Suborder <u>Chelifera</u> (or regarded by some authorities as a separate order, <u>Tanaioidea</u>)

M *Pancolus californiensis* Richardson
M *Anatanais*
M *Tanais*

Suborder <u>Valvifera</u> (Idotheoidea)

*D M *Idothea rectilinea* Lockington
D D *Pentidotea resecata* Stimpson
D *M *Pentidotea stenops* Benedict
D M *Pentidotea whitei* Stimpson
*D *M *Pentidotea wosnesenskii* Brandt

Suborder <u>Flabellifera</u> (Cymothoidea)

M *Anthuridae*
B *D *M *Cirolana harfordi* Lockington
M *Cirolana linguifrons* Richardson
M *Dynamene dilatata* Richardson
M *Dynamenella glabra* Richardson
M *Exosphaeroma amplicauda* Stimpson
M *Exosphaeroma octoncum* Richardson
B *M *Exosphaeroma oregonensis* Dana
M *Exosphaeroma rhomburum* Richardson
*B *Limnoria lignorum* Rathke
D M *Livoneca* (clinging to gills of fish; not in key)
*B *Sphaeroma pentodon* Richardson

Suborder <u>Asellota</u>

M *Jaera*
M *Jaeropsis lobata* Richardson
*M *Janiropsis californica* Richardson
M *Munna*

Suborder <u>Oniscoidea</u>

(NOTE:—*Ligia* and *Alloniscus* are almost as truly terrestrial as the others of this suborder, but live very near the sea, just above the high tide marks, often descending into the intertidal when the tide is out.)

TB M *Alloniscus perconvexus* Dana
*T *Armadillidium vulgare* Latreille
*B D *M *Ligia occidentalis* Dana
*M *Ligia pallasii* Brandt
T *Ligidium gracile* Dana
*T *Porcellio formosus* Stuxberg
*T *Porcellio laevis* Latreille
*T *Porcellio scaber* Latreille
T *Porcellionides (Metoponorthus) pruinosus* Brandt

Order <u>Amphipoda</u>

The Amphipoda are divided into three suborders: Gammaridea (Plate XI, no. 6), Hyperiidea (fig. 62), and Caprellidea (Plate XI, no. 5); the first two with seven free thoracic segments, the third with six. The Caprellidea are further distinguished by a very narrow body and a rudimentary abdomen. The Hyperiidea which are commonly parasitic and will not be seen by us are further characterized by a very large head (fig. 62) and large eyes. The Gammaridea are represented by the familiar "sand flea" of the seashore and a large number of species living on seaweed, under rocks, etc. We shall confine our study to the Gammaridea, but the student should be able to recognize caprellids.

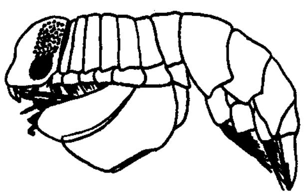


Fig. 62.—<u>Platycelus</u>, Suborder Hyperiidea, Order Amphipoda.

Using the dissecting microscope or low powers of the compound microscope study fixed specimens of *Gammarus* and whole mounts of *Gammarus* and *Hyallela*. Make out (fig. 63) <u>antennules</u> and <u>antennae</u>, known also as first and second antennae. The elongate basal joints constitute the <u>peduncle</u>, the small distal joints the <u>flagellum</u>. Note that there is a small secondary flagellum on the antennule of some genera (fig. 71).

The mouth-parts will be studied later using mounts of the separated appendages of *Allorchestes*. On the whole mounts see the subchelate first and second legs (2d and 3d thoracic appendages) known as <u>first</u> and <u>second gnathopods</u>, the five simple <u>walking legs</u> known as <u>periopods</u>, the three biramous <u>pleopods</u> with slender, multiarticulate <u>rami</u>, and the three pairs of biramous leg-like <u>uropods</u> ("springing feet").

The first two legs, called the first and second <u>gnathopods</u> (fig. 63), commonly terminate in expanded hands, and in one or both or neither the terminal segment (seventh segment or dactylus) closes on

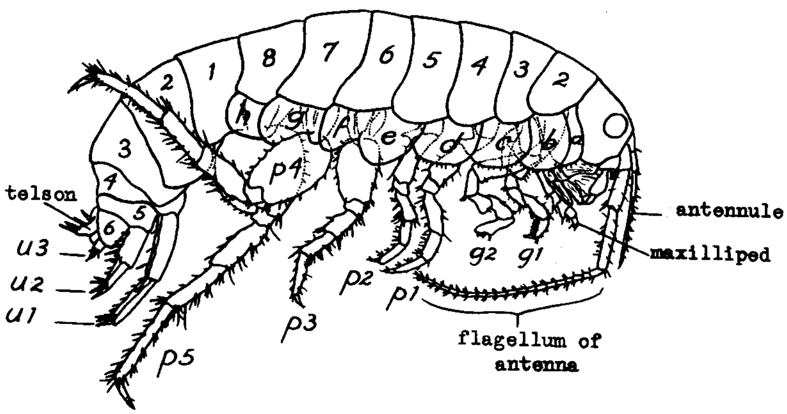


Fig. 63.—Talitrus sylvaticus Haswell, a gammarid amphipod labeled to show characteristic structures: Pleopods 1-3, the appendages of the first three abdominal segments are omitted (after Shoemaker). Segments of thorax and abdomen are numbered; G1, G2 = first and second gnathopods; p1-p5 = the walking legs or periopods; U1-U3 = the three posterior abdominal appendages termed uropods; a-h = the side plates or coxal plates of the thoracic appendages.

the expanded palm (propodus or sixth segment) as a clasping finger. Such appendages are termed subchelate (fig. 64,B). The finger may form with the sixth joint a forceps-like pinching claw, in which case the appendage is chelate (fig. 64,A). Finally the finger may not close, but remain stationary like a claw, as in the other legs, when the gnathopod is said to be simple.

Note the flat extensions of the chitinous bases of the thoracic appendages which are known as side plates or coxal plates (fig. 63).

Study mounts of the mouth-parts of *Allorchestes*. The most posterior appendages are the maxillipeds (fig. 64,C) united by their two basal segments. Each extends distally as a palp and bears internally two endites or lobes known respectively as the outer and inner plate. More anteriorly are two very small appendages, the paired second and first maxillae (figs. 64,E,F). In *Allorchestes* (in contrast to the condition in *Gammarus*, fig. 64,E,F) the second maxilla is largest and bears a tiny palp, while the first is small and without a palp. The mandibles are heavily chitinized structures lacking a palp in *Allorchestes* (fig. 64,D) but having one in *Gammarus* (fig. 64,G). In front of and behind the mandible are the fleshy upper and lower lips (fig. 64,H).

Sex dimorphism is frequently marked and it is often necessary to recognize the sex in order to identify. This may often be done on the basis of the size of the gnathopods which are usually larger in the male. In sexually mature females the egg mass on the ventral surface of the abdomen enclosed in the marsupial plates (= oöstegites) is a distinguishing character.

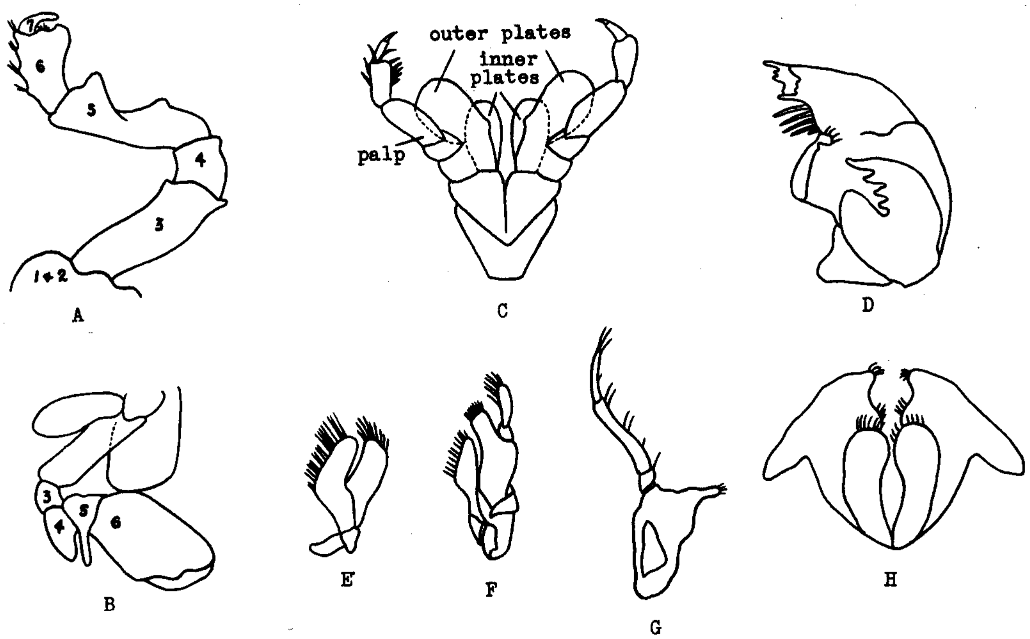


Fig. 64.—Mouth parts of various amphipods: A, first gnathopod of Allorchestes with segments numbered, showing chelate condition; B, second gnathopod of same, subchelate; C, maxilliped of Gammarus; D, mandible of Allorchestes (lacking palp); E-G, second maxilla, 1st maxilla, and mandible of Gammarus (mandible with palp); H, lower lip of Ampithoë, showing notched front lobes.

Using the key, identify the specimen given you and such others as time allows. This will require a certain amount of dissection. Do this with needles under the higher powers of the dissecting binocular. Mount dissected parts under coverslips and study by means of the compound microscope.

KEY TO THE AMPHIPODS (Suborder Gammaridea)

1. Side plates 2-4 united, forming a large lateral shield . *Metopa* sp.
1. Side plates 2-4 not united (fig. 63) 2

2. Uropod 3 (most posterior) vestigial, seemingly absent; species living in sponge . . . . *Podocerus spongicolus* (fig. 65)
2. Uropod 3 of at least moderate size, functional 3

3. Rostrum conspicuous, at least 1/3 as long as first joint of antennule 4
3. Rostrum inconspicuous, less than 1/3 as long as first joint of antennule 9

4. Antennule with long accessory flagellum (fig. 66,A); legs with many bristles, adapted for burrowing . . . . *Pontharpinia obtusidens* (fig. 66)
4. Antennule without accessory flagellum; legs not adapted for burrowing 5

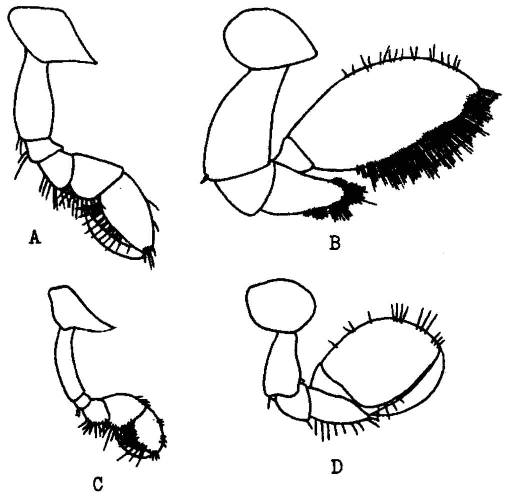


Fig. 65.—Podocerus spongicolus Alderman (after Alderman): A-B, first and second gnathopods of male; C-D, same of female.

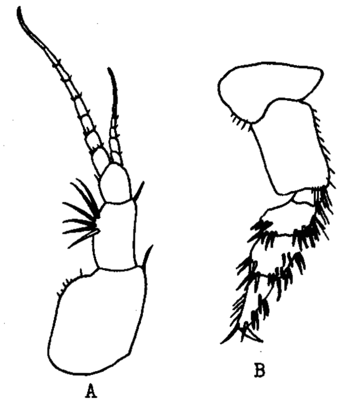


Fig. 66.—Pontharpina obtusidens Alderman (after Alderman): A, antennule; B, third periopod.

5. Integument indurated, bearing processes; mouth-parts prolonged, as if for piercing . . . . Acanthonotozomatidae (fig. 67)
5. Integument and mouth-parts not especially indurated 6

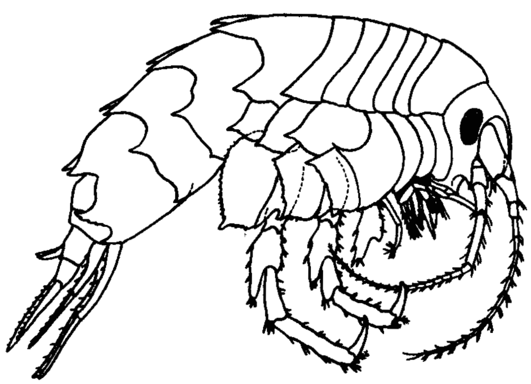


Fig. 67.—Panoplea, family Acanthonotozomatidae (after Shoemaker).

6. Antenna longer than antennule; telson cleft to base; abdominal segments 5 and 6 fused . . . . . . *Nototropis tridens* (fig. 68)
6. Antennule longer than antenna; telson undivided; abdominal segments 5 and 6 not fused 7

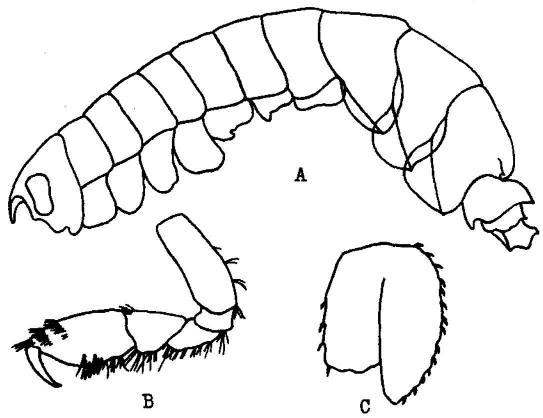


Fig. 68.—Nototropis tridens Alderman (after Alderman): A, side view; B, first gnathopod; C, second joint of fifth periopod.

7. Body not laterally compressed but somewhat depressed . . . . *Pleustes depressus* (fig. 69)
7. Body laterally compressed 8

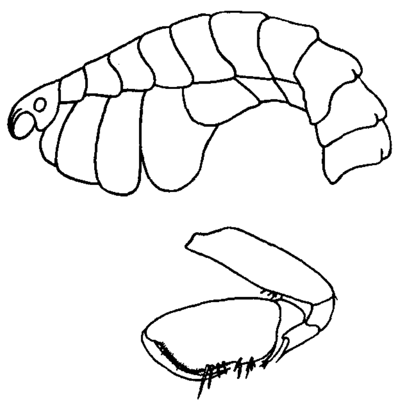


Fig. 69.—Pleustes depressus Alderman (after Alderman): A, side view; B, second gnathopod.

8. Flagellum of antennule 11-jointed, less than twice as long as peduncle . . . . *Neopleustes brevicornis*
8. Flagellum of antennule more than 11-jointed, more than twice as long as peduncle . . . . *Neopleustes pugettensis*

9. Body somewhat depressed (flattened dorsoventrally); usually living in tubes or in ascidian colonies, etc. 10
9. Body laterally compressed; not usually living in tubes 12

10. Flagellum of antenna with many joints . . . . . . *Ericthonius* sp.
10. Flagellum of antenna with 3 or fewer joints (fig. 70) 11

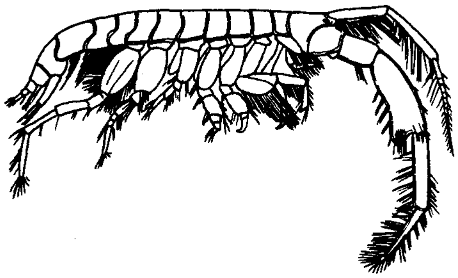


Fig. 70.—Corophium curvispinum G. O. Sars (after Sars).

11. Flagellum of antenna with 3 joints . . . . . . *Corophium bonellii*
11. Flagellum of antenna absent, last joint of peduncle claw-like . . . . *Corophium insidiosum*

12. Uropod 3 uniramous 13
12. Uropod 3 biramous, although one branch is sometimes very small 23

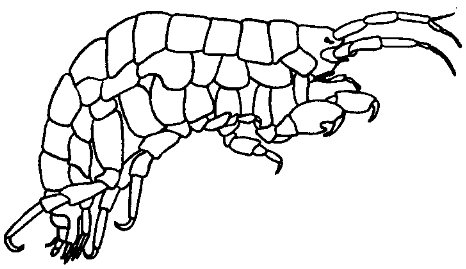


Fig. 71.—Microprotopus.

13. Antennule with accessory flagellum; side plate 5 as deep as 4 . . . . *Microprotopus* (fig. 71)
13. Antennule without accessory flagellum; side plate 5 much shallower than 4 14

14. Antennule much shorter than peduncle of antenna 15
14. Antennule longer than peduncle of antenna 17

15. Gnathopod 1 subchelate in male; often on sand, but not burrowing in it . . . . *Orchestia traskiana* (fig. 72,E)
15. Gnathopod 1 simple in male; burrowing in sand 16

16. Antenna longer than body . . . . *Orchestoidea californiana*
16. Antenna not more than half the length of body . . . . *Orchestoidea corniculata* (Perhaps intergrading varieties)

17. Inhabiting freshwater; size small; antennule, antenna about same length, flagellum of each with only 12 or fewer joints . . . . *Hyalella knickerbockeri*
17. Marine; size larger, antennule and antenna generally with more joints 18

18. Antennule short, little more than half the length of antenna 19
18. Antennule longer, generally much more than half length of antenna 21

19. Color black and gray with sometimes transverse white stripes; size fairly large; found in San Francisco Bay . . . . *Hyale pugettensis*
19. Color pink or pale; size small 20

20. Color pink; found with red algae on ocean coast . . . *Hyale rubra*
20. Color pale whitish; San Francisco Bay shore . *Allorchestes angusta*

21. Antenna with dense tufts of bristles, bristles being at least as long as width of flagellum; bay shore . . *Allorchestes plumulosus*
21. Antennal bristles much fewer and shorter 22

22. Joints 4 and 6 of male gnathopod 2 in contact (fig. 72,B) . . . . *Hyale* sp. (fig. 72,A,B)
22. Joints 5 of male gnathopod 2 produced between joints 4 and 6 (fig. 64,B) . . . . *Allorchestes* sp.

(Character 22 is decisive in distinguishing between the genera *Hyale* and *Allorchestes* but it is often difficult to observe and consequently has not been used above where other distinctions are possible.)

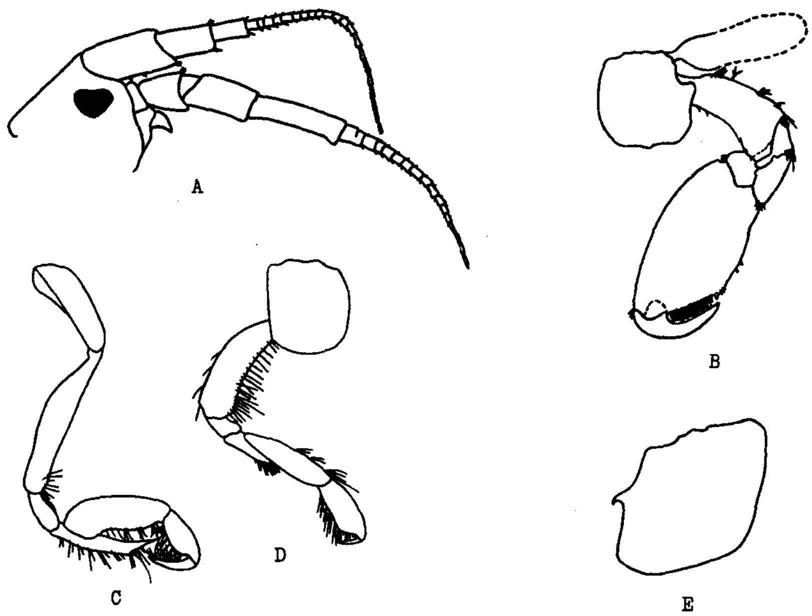


Fig. 72.—A,B, Hyale sp.; C,D, Aoroides californica Alderman; E, Orchestia traskiana Stimpson, side plate 4.

23. Gnathopod 1 much longer than 2, very long in male . . . . *Aoroides californica* (figs. 72,C,D)

(*Aoroides columbiae* reported common on rocky coast [see Ricketts and Calvin])
23. Gnathopod 1 not larger than 2 24

24. Uropod 3 with prominent upward-turning hooks at the end of the outer ramus 25
24. Uropod 3 without such hooks 30

25. Antennule shorter than antenna; one hook to each uropod 26
25. Antennule usually longer than antenna; two hooks to each uropod 27

26. Hind margin of joint 6 of male gnathopod 2 produced into strong tooth; female gnathopod 2 much larger than 1 . *Jassa* sp.
26. Male gnathopod 2 without posterior teeth; female gnathopod 2 little larger than 1 . . . . *Ischyrocerus* sp.

27. Palm of male gnathopod 2 transverse; flagellum of antennule with 35 or more joints 28
27. Palm of male gnathopod 2 oblique; flagellum of antennule usually with less than 35 joints 29

28. Joint of 5 of male gnathopod 2 small; flagellum of antennule with about 50 joints . . . . *Ampithoë valida*
28. Joint of 5 of male gnathopod 2 longer than joint 6; flagellum with about 35 joints . . . *Ampithoë humeralis* (Plate XI, no. 6)

29. Flagellum of antennule twice as long as peduncle; a prominent tooth defines palm of male gnathopod 2 . . *Ampithoë vaillantii*
29. Flagellum of antennule usually less than twice as long as peduncle; a very small tooth defines palm . . *Ampithoë rubricata*
29. Flagellum of antennule little longer than peduncle; a large blunt tooth defines palm . . . . *Ampithoë simulans*

30. Antennule longer than antenna and possessing an accessory flagellum 31
30. Antennule not longer than antenna; accessory flagellum absent except in *Eurystheus* 35

31. Rami of uropod 3 very unequal, outer ramus much longer, or at least, much larger 32
31. Rami of uropod 3 about equal 34

32. Outer ramus of uropod 3 several times as long as the inner ramus; eye round or irregular, but usually not bean-shaped . . . . *Melita californica* (fig. 73)
(And other species of *Melita*. *M. palmata* reported abundant by Ricketts and Calvin.)
32. Outer ramus of uropod 3 not more than 3 times as long as inner ramus in our species, but the inner ramus is very much more slender; eye bean-shaped 33

33. Inner ramus of uropod 3 at least 2/3 length of outer ramus . . . . *Gammarus pribilofensis*
33. Inner ramus of uropod 3 less than 1/2 length of outer ramus . . . . *Gammarus confervicolus*

34. Accessory flagellum of antennule 2-jointed; regular flagellum longer than peduncle . . . . *Elasmopus* (fig. 74)
34. Accessory flagellum 7-10 jointed; flagellum shorter than peduncle . . . . *Maera inaequipes*

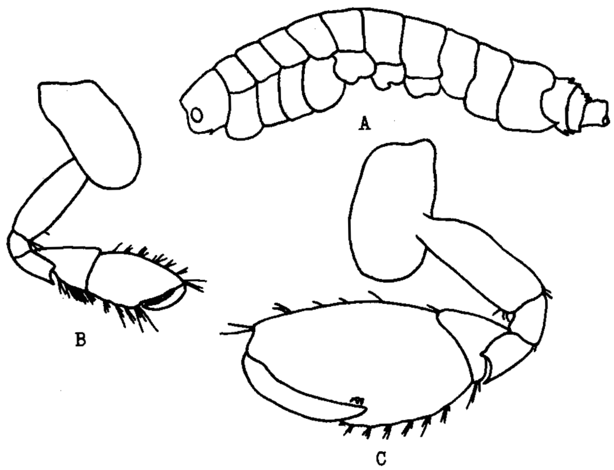


Fig. 73.—Melita californica Alderman (after Alderman): A, side view; B, first gnathopod; C, second gnathopod.

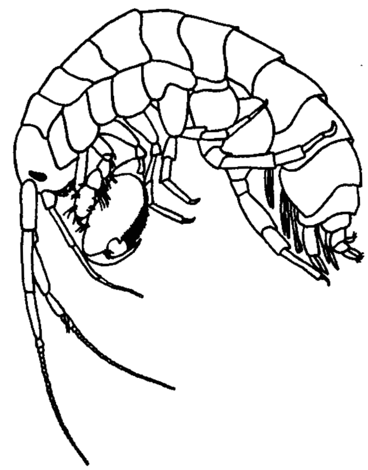


Fig. 74.—Elasmopus.

35. Legs 1-5 all with fingers pointing backward; abdominal segments 5 and 6 coalesced . . . . *Polycheria antarctica*
35. Some of legs 1-5 with fingers not pointing backward; abdominal segments 5 and 6 not coalesced 36

36. Side plate 4 concave posteriorly; gnathopods rather small . . . 37
36. Side plate 4 convex or straight posteriorly; gnathopod 2 usually powerful, at least in male 39

37. Telson entire, pointed (fig. 75,A) . . *Kinonema* sp. (fig. 75,A,B)
37. Telson cleft or emarginate 38

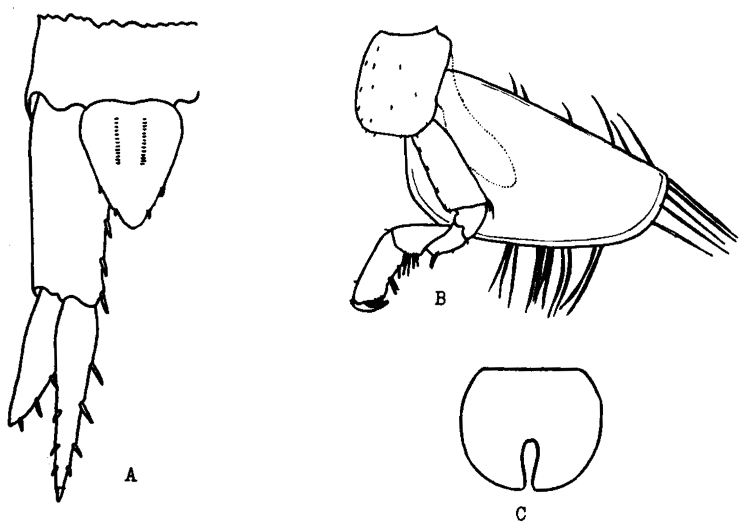


Fig. 75.—A, Kinonema, telson and uropod; B, second gnathopod of same with side plate and oöstegite; C, emarginate telson of Pontogenia.

38. Telson deeply cleft (fig. 75,C); side plate 4 deeply excavate behind . . . . *Pontogenia inermis*
38. Telson emarginate, notch only 1/5 length of telson (fig. 76,A); side plate 4 with shallow excavation . *Oligochinus* sp. (fig. 76)

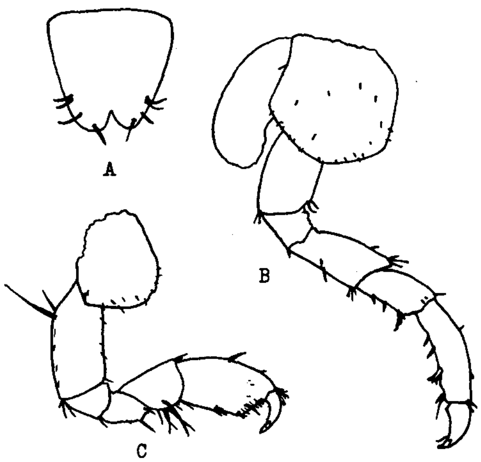


Fig. 76.—Oligochinus: A, telson; B, second periopod with side plate; C, first gnathopod.

39. Rami of uropod 3 about equal . . . . *Eurystheus tenuicornis*
39. Inner ramus of uropod 3 much smaller than outer 40

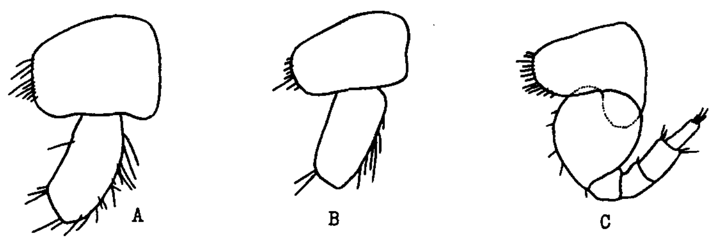


Fig. 77.—Photis conchicola Alderman: A, side plate 3 and second segment of first periopod; B, side plate 4; C, side plate 5 and third periopod.

40. Male has side plates 1 and 2 much shallower than others; female has side plate 4 broader than front lobe of 5 . . . . *Photis conchicola* (fig. 77)
40. Male has side plates 1 and 2 not much shallower than others; female has side plate 4 narrower than front lobe of 5 . . . . *Photis reinhardi*

LIST OF AMPHIPODS

Suborder Gammaridea

- M Acanthonotozomatidae
- B *Allorchestes angustus* Dana
- *B *Allorchestes plumulosus* Stimpson
- M *Allorchestes* sp.
- M *Ampithoë humeralis* Stimpson

Suborder Gammaridea *(Continued)*

M *Ampithoë rubricata* Montagu
M *Ampithoë simulans* Alderman
M *Ampithoë vaillantii* Lucas
B *M *Ampithoë valida* Smith
M *Aoroides californica* Alderman
M *Aoroides columbiae* Walker
*B *Corophium bonellii* Milne-Edwards
B *Corophium insidiosum* Crawford
F M *Corophium* spp.
M *Elasmopus brasiliensis* Dana
M *Elasmopus rapax* Costa
*M *Ericthonius* sp.
M *Eurystheus tenuicornis* Holmes
*B *Gammarus confervicolus* Stimpson
B *Gammarus pribilofensis* Pearse
*M *Hyale* sp.
*M *Hyale rubra* Thompson
*B *Hyale pugettensis* Dana
*F *Hyalella knickerbockeri* Bate
M *Ischyrocerus* sp.
M *Jassa* sp.
*M *Kinonemc*
M *Maera inaequipes* Costa
*M *Melita californica* Alderman
M *Melita palmata* Montagu
*B *Melita* sp.
B M *Metopa* sp.
*M *Microprotopus*
M *Neopleustes brevicornis* Sars
B *Neopleustes pugettensis* Dana
M *Nototropis tridens* Alderman
*M *Oligochinus*
*B *M *Orchestia traskiana* Stimpson
M *Orchestoidea californiana* Brandt
*M *Orchestoidea corniculata* Stout
M *Photis reinhardi* Krøyer
M *Pleustes depressus* Alderman
M *Podocerus spongicolus* Alderman
M *Polycheria antarctica* Stebbing
M *Polycheria osborni* Calman
M *Pontharpinia obtusidens* Alderman
M *Pontogenia inermis* Kroyer

Suborder Caprellidea

*B *Caprella aequilibra* Say
*M *Caprella kennerlyi* Stimpson
M *Caprella acutifrons* Latreille
*M *Caprella scaura* Templeton

Subclass Eucarida

This subclass includes two orders, a small group of small pelagic shrimps, Order Euphausiacea, and the larger Order Decapoda including the true shrimps, crabs, and other higher crustacea. We shall confine our consideration to the Decapoda and to three suborders under it: the shrimps, Suborder Caridea; the crabs, Suborder Brachyura; and the hermit crabs and relatives, Suborder Anomura.

Order Decapoda

The caridoid fascies or macrurous type, best exemplified by a shrimp or prawn (fig. 78) best represents the basic plan of structure of the decapods. It should be familiar from earlier studies of the crayfish or lobster. Review it if not. This type of body structure is termed macrurous in contrast to the brachyurous type of the true crab and the anomurous type of the hermit crabs.

Make yourself familiar with the brachyuran type of structure by identifying on a crab all the appendages and all other structures and regions labeled in figures 80-82.

Key out your specimen, using Schmitt, also the key below.

The typical anomurous body plan is that of the hermit crabs in which the abdomen is reduced asymmetrically and many of its appendages are vestigial or lacking. Among the species which other characters show to belong to the Suborder Anomura, however, are some which are very crablike in appearance (fig. 94) and which may be termed brachyurous anomurans, and others again (figs. 95 and 96) which have large symmetrical abdomens and may be termed macrurous anomurans.

Using the keys in Schmitt's Decapod Crustacea of California, identify further (1) a shrimp, (2) a hermit crab, and (3) a brachyurous anomuran.

Be ready for a fifteen-minute test on terminology at the end of the laboratory period.

KEY TO THE DECAPODA

1. Abdomen used for swimming, with well-developed tail-fan, and pleopods; abdomen in our species with sharp bend; shrimps (fig. 78) 2
1. Abdomen generally not used for swimming, with tail-fan and pleopods more or less reduced, except the Callianassidae (37) which can be distinguished from the true shrimps by their large unbent abdomen and their burrowing habits 9

2. Rostrum very short, dorsally flattened; eyes free; hands subchelate (fig. 83) 3
2. Rostrum very small or wanting; eyes covered by carapace; hands chelate, one or both powerfully developed 4
2. Rostrum distinct, usually well developed and spinose (fig. 87); eyes free; hands weakly chelate 5

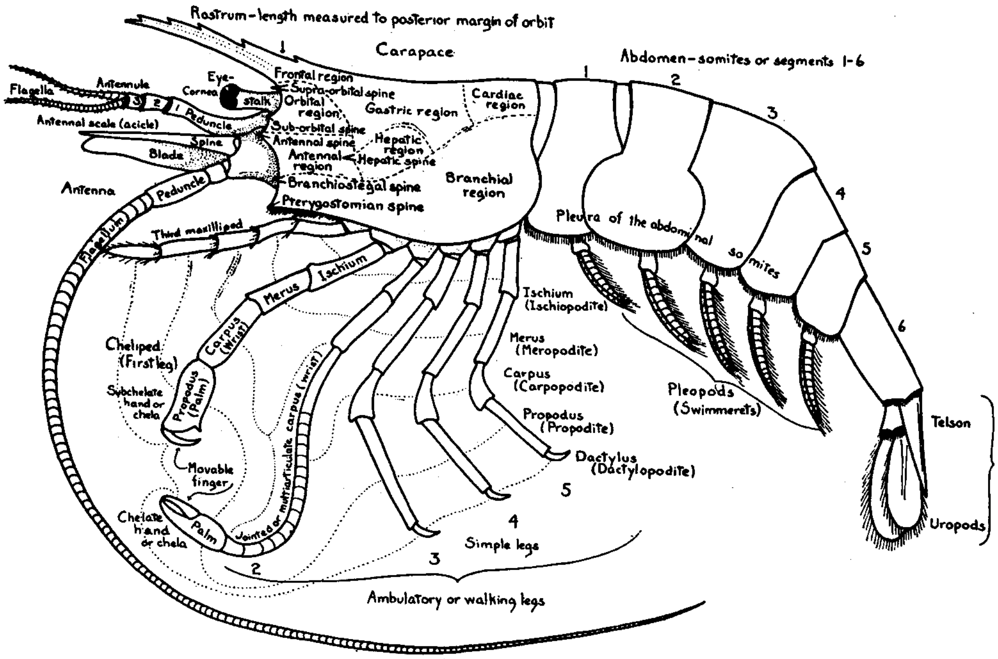


Fig. 78.—A macruran (shrimp-like) decapod (from Schmitt).

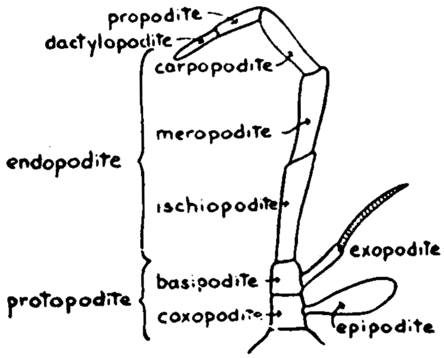


Fig. 79.—Typical third maxilliped of a macruran decapod (from Schmitt).

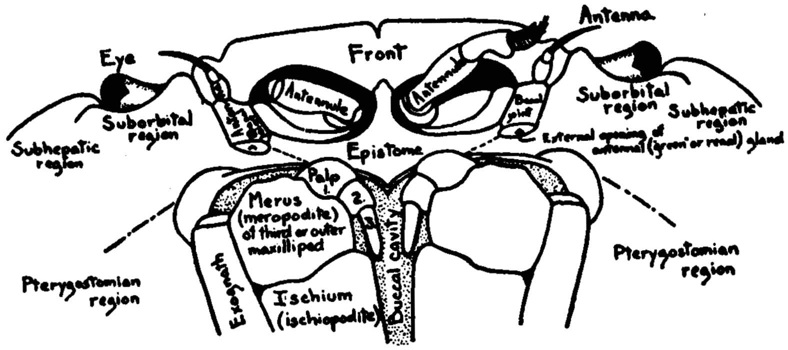
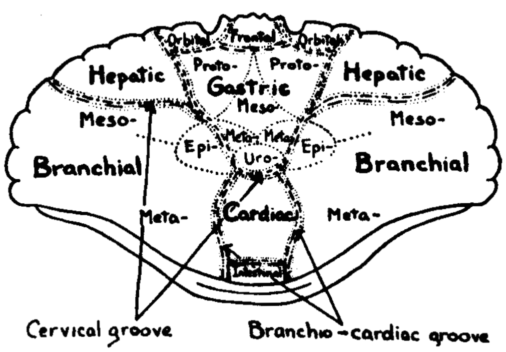


Fig. 80.—Ventral view of anterior part of body of a brachyuran decapod (from Schmitt).

Fig. 81.—Dorsal view of brachyuran carapace showing regions used in descriptions.



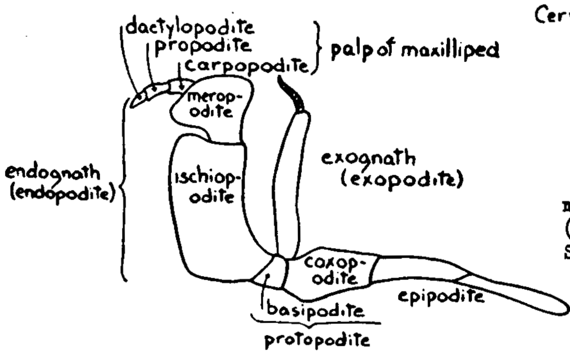


Fig. 82.—Typical third maxilliped of a brachyuran (crablike) decapod (from Schmitt).

3. Sixth segment of abdomen with a large, circular dark spot on either side; antennal scale nearly three times as long as wide (fig. 83,A) . . . . *Crago nigrimaculata*
3. No such spot; body more or less covered with minute dark spots; tail entirely black; scale hardly twice as long as wide (fig. 83,B) . . . . *Crago nigricauda*

Fig. 83.—Crago; A, hand and scale of C. nigrimaculata Lockington; B, hand and scale of C. nigricauda Stimpson.

4. One chela greatly enlarged, complex with dactyl above (fig. 84). "The Pistol Shrimp" . . . . *Crangon*
4. Chelae about equal, simple; dactyl below . . . . *Betaeus*

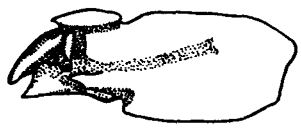


Fig. 84.—Chela of Crangon dentipes Guerin (after Schmitt).

5. Large; both legs of first pair simple; second pair of legs very unequal, both with multiarticulate carpi (30 segments) . . . . *Pandalus danae*
5. Smaller; both legs of first pair chelate (chelae very small); second pair equal or nearly so, carpus with seven segments . . . . *Spirontocaris* (figs. 85-87) 6

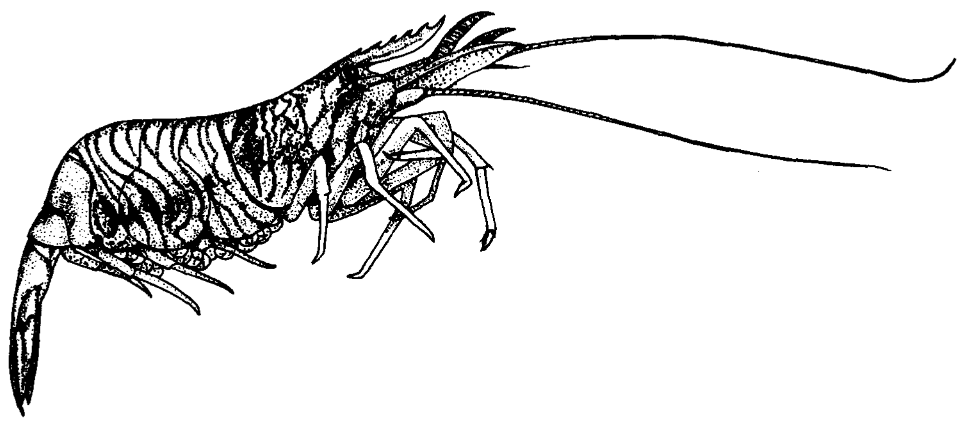


Fig. 85.—Spirontocaris paludicola Holmes. (After Ricketts and Calvin.)

6. Rostrum elongate (figs. 85, 87,A), reaching beyond middle of antennal scale. 8
6. Rostrum short (figs. 86, 87,B), not reaching middle of antennal scale 7

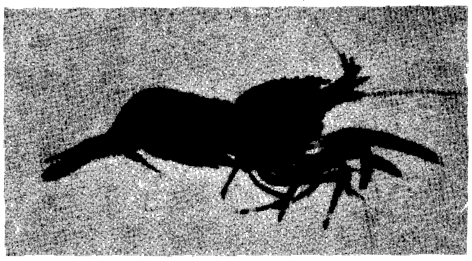


Fig. 86.—Spirontocaris brevirostris Dana (from Guberlet).

7. Rostrum not reaching as far as cornea of eye . . . . *Spirontocaris taylori*
7. Rostrum reaching cornea or beyond . . . . . *Spirontocaris palpator*

8. Rostrum reaching beyond middle of antennal scale but not into distal quarter; greenish, semitransparent, with oblique reddish bands on carapace and crimson bars on legs; common in tidepools . . . . *Spirontocaris picta* (fig. 87,C)
8. Rostrum longer, reaching to or beyond end of antennal scale; uniform green; common in eelgrass and on mud flats . . . . *Spirontocaris paludicola* (figs. 85, 87,D)

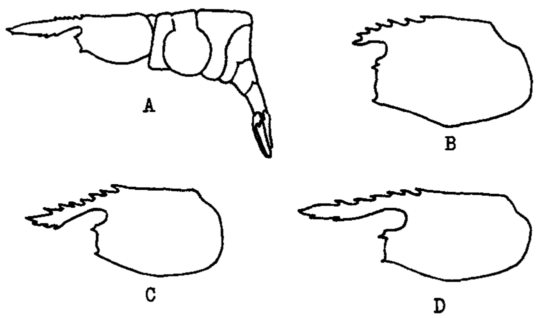


Fig. 87.—Rostra of common species of Spirontocaris (after Schmitt): A, S. carinata Holmes; B, S. brevirostris Dana; C, S. picta Stimpson; D, S. paludicola Holmes.

9. Antennae situated internal to eye, with short flagellum (figs. 80, 90); abdomen always small, folded under thorax, with uropods lacking; last pair of legs generally about the same as others . . . . *Brachyura* 10
9. Antennae situated external to the eye, with long flagellum (fig. 88); abdomen variable, often asymmetrical (fig. 98) or much reduced, but generally with uropods present (exceptions under 29); last pair of legs usually much different from others, often smaller . . . . *Anomura* 27

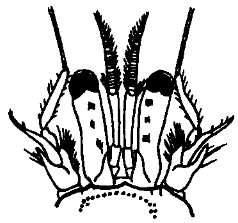


Fig. 88.—Head of Pagurus californiensis (after Schmitt).

10. Carapace generally elongated, drawn out anteriorly between the eyes as a rostrum (figs. 89, 91). Spider Crabs 11
10. Carapace square or transversely oval, with very short rostrum if any 15

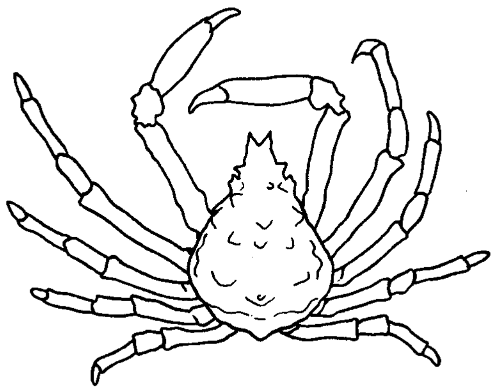


Fig. 89.—Loxorhynchus crispatus Stimpson (after Rathbun).

11. Carapace roughly triangular in shape, broadest behind; very hairy, with much foreign matter attached to hairs; rare above the low tide mark. The Masked Crab . . . . *Loxorhynchus crispatus* (fig. 89)
11. Carapace not triangular; generally not as hairy as above; found also intertidally 12
12. Carapace about as broad as long (fig. 90) . . . . *Mimulus foliatus* (fig. 90)
12. Carapace longer than broad 13

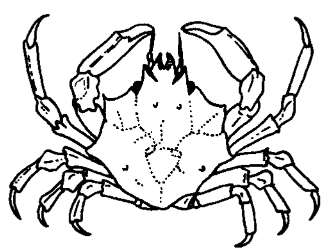
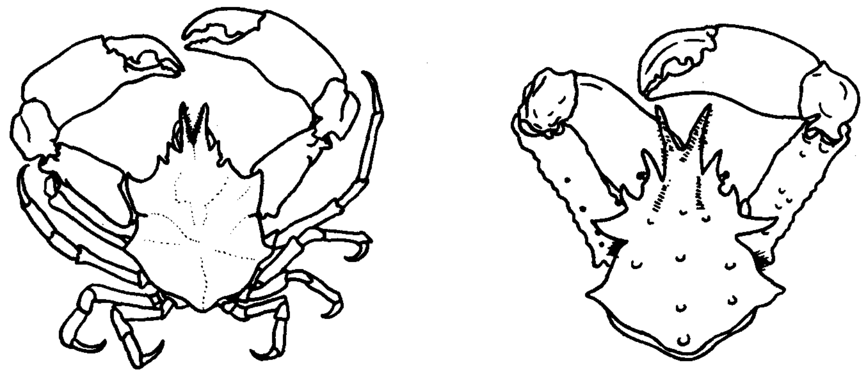


Fig. 90.—Mimulus foliatus Stimpson (after Schmitt).

13. Surface of carapace smooth; distance between eyes less than 1/3 the width of carapace. The Kelp Crab . . . . *Pugettia (= Epialtus) producta*
13. Surface of carapace tuberculated or spiny; distance between eyes about 1/2 greatest width of carapace (fig. 91) 14



A B

Fig. 91.—Pugettia (after Schmitt): A, P. gracilis Dana; B, P. richii Dana.

14. Smaller; carapace not expanded posteriorly; anterolateral tooth broad, anteriorly directed (fig. 91,A) . . . . *Pugettia gracilis*
14. Larger; carapace distinctly broader posteriorly; anterolateral tooth narrow, laterally directed (fig. 91,B) . . . . *Pugettia richii*

15. Commensals with mollusks, annelids, etc.; eyes reduced, carapace often poorly calcified. Pinnotherid Crabs 16
15. Free-living; eyes and carapace normal 18

16. Carapace much wider than long . . . . *Pinnixa*
16. Carapace not much wider than long 17

17. Carapace with two longitudinal grooves leading back from orbit . . . . *Fabia*
17. Carapace without such grooves . . . . *Pinnotheres*

18. Body square, sides nearly parallel, anterior edge nearly transverse; palp of external maxilliped does not articulate near the inner angle of the merus (segment basal to palp) . . 25
18. Body usually round or transversely oval, with sides not parallel and anterior edge of carapace rounded; palp of external (third) maxilliped articulates at or near inner angle of merus 19

19. Carapace much broader than long, with front (between eyes) narrow, cut into five teeth (fig. 81) 20
19. Carapace not much broader than long; front wide, without teeth 23

20. Front produced, with five nearly equal teeth; fingers with dark color. The Red Crab . . . . *Cancer productus*
20. Front not produced, with five unequal teeth 21

21. Hairy; with red spots on ventral surface; antennae as long as width of front. The Rock Crab . . . . *Cancer antennarius*
21. Not very hairy; not spotted below; antennae very short 22

22. Very large, widest at tenth tooth lateral to eye, which is the largest tooth. The Edible Crab . . . . *Cancer magister*
22. Small, widest at ninth tooth; teeth alternately longer and shorter . . . . *Cancer jordani*

23. Fingers of same color as rest of chela (introduced from the Atlantic; now in San Francisco Bay and Lake Merritt) . . . . *Rhithropanopeus harrisii*
23. Fingers much darker than rest of chela; found on ocean coast . 24

24. Hand of cheliped with a tooth on inner side of upper margin . . . . *Lophopanopeus heathi*
24. Hand without tooth . . . . *Lophopanopeus bellus* (fig. 92)

Fig. 92.—Lophopanopeus bellus Stimpson (from Guberlet).

25. Surface of carapace with numerous transverse lines. The Lined Shore Crab. . . . . *Pachygrapsus crassipes*
25. Carapace without transverse lines 26

26. Color generally dark red or purple; spots on chelae; no hair on legs. The Purple Shore Crab . . . . *Hemigrapsus nudus*
26. Color generally greenish; no spots on chelae; legs hairy. The Mud Crab. . . . . *Hemigrapsus oregonensis*

27. Abdomen short, crablike, reflexed under thorax 28
27. Abdomen elongate, not reflexed (fig. 95) 36

28. First pair of legs chelate; carapace crablike (fig. 94) 29
28. First pair of legs simple, carapace subcylindrical with wings which cover legs; second to fourth legs with last joint curved and flattened. The Sand Crab . . . . . . *Emerita analoga*

29. Fifth legs very small, folded under carapace, seemingly absent; uropods lacking 30
29. Fifth legs reduced but held over the back; uropods present . . 32

30. Carapace wider than long, covering legs; abdomen small, flattened . . . . *Cryptolithodes sitchensis*
30. Carapace as long as, or longer than, broad; abdomen thick and fleshy 31

31. Legs and carapace hairy; carapace as long as broad . *Hapalogaster*
31. Legs and carapace rough; carapace longer than broad . . . . *Oedignathus inermis*

32. Body and chelae thick; chelae unequal, tuberculate; legs hairy 33
32. Body and chelae thin (fig. 94); chelae equal and smooth; legs nude 34

33. Chelipeds granulated and tuberculate above; telson of 5 large plates (fig. 93,A) . . . . *Pachycheles rudis*
33. Chelipeds not tuberculate, granules hidden by short, thick pubescence which fills gap between fingers and extends almost to end of fingers; telson with 5 large and 2 very small plates (fig. 93,B) . . . . *Pachycheles pubescens*

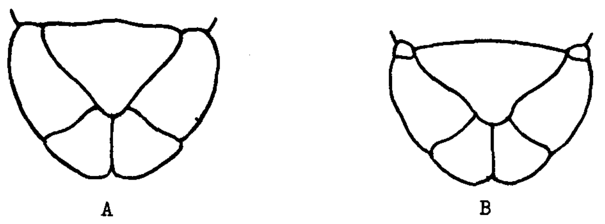


Fig. 93.—Pachycheles: A, telson of P. rudis; B, telson of P. pubescens (after Schmitt).

34. Carpus of chelipeds about once and a half as long as wide; sides converging toward distal end; palp of third maxilliped orange . . . . *Petrolisthes cinctipes*
34. Carpus longer, sides parallel; outer edge of palp of third maxilliped blue 35

35. Carpus rough; cheliped a solid color on upper surface; proximal inner base of finger of cheliped blue . . . . *Petrolisthes eriomerus* (fig. 94)

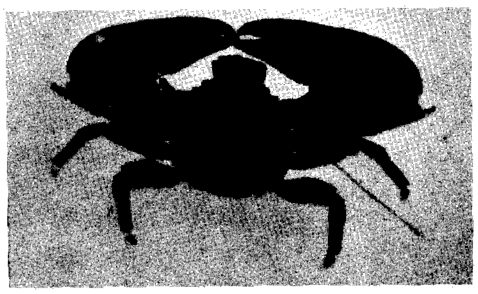


Fig. 94.—Petrolisthes eriomerus Stimpson (from Guberlet).

35. Carpus relatively smooth; a median row of blue dots on hand of cheliped; proximal inner base of finger of cheliped orange . . . . *Petrolisthes manimaculis*

36. Abdomen symmetrical (fig. 95), extended; burrowing in mud flats 37

36. Abdomen asymmetrical, soft and twisted (fig. 98), protected by a snail shell. The Hermit Crabs 38

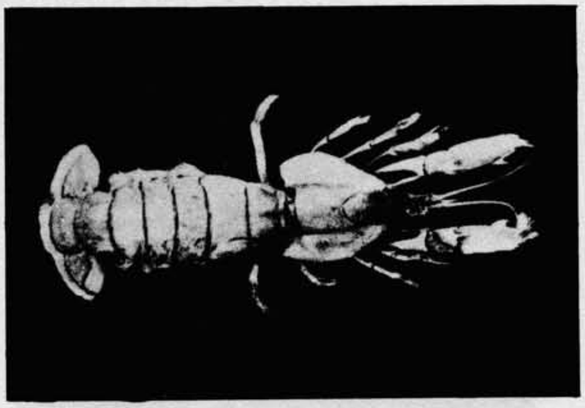


Fig. 95.—Upogebia (from Guberlet).

37. First pair of legs subequal (fig. 95), subchelate, others simple. The Mud Shrimp . . . . *Upogebia pugettensis*

37. First pair of legs very unequal (fig. 96), chelate; second pair small, chelate; fifth pair subchelate. The Ghost Shrimp . . . . *Callianassa californiensis*

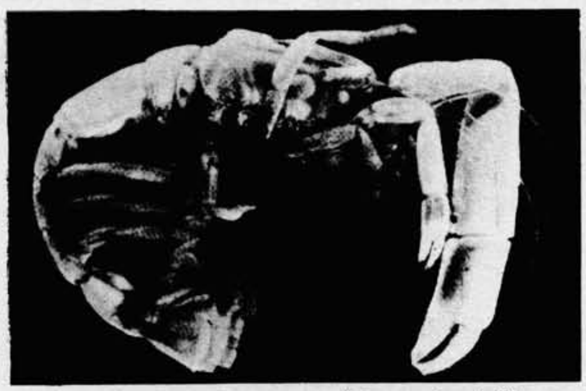


Fig. 96.—Callianassa (from Guberlet).

38. Dactyls of walking legs with longitudinal stripes (in life the stripes are red, the ground color of the dactyl deep blue; in preserved specimens the stripes are dark on a light orange background) 39

38. Dactyls of walking legs without longitudinal stripes; color not blue in life 40

39. Antennae red in life; distal end of propodi of walking legs with blue band; distal margin of telson with three subequal indentations, the lateral ones with minute, closely packed teeth . . . . *Pagurus samuelis*
39. Antennae greenish brown in life, with yellow markings on some segments; distal end of propodi with white band; distal margin of telson with five indentations, the extreme lateral ones small and without minute teeth; median indentation U-shaped . . . . *Pagurus hirsutiusculus* (fig. 97)

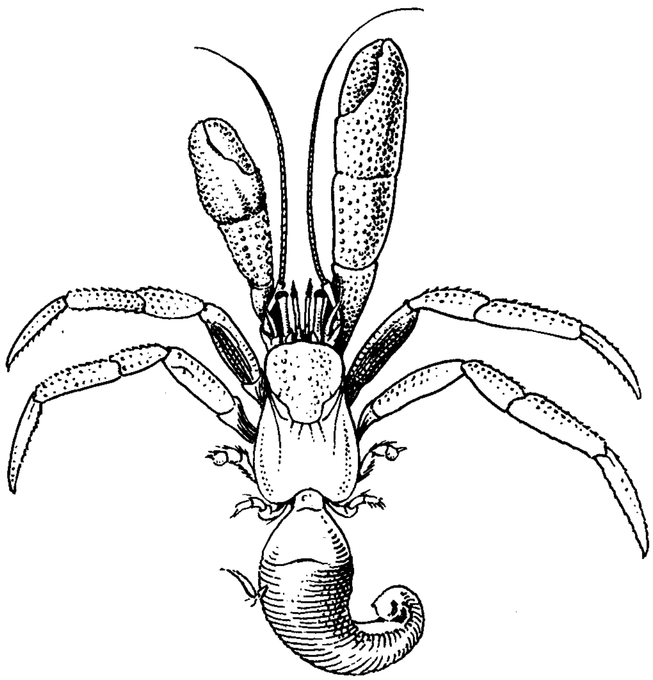
Fig. 97.—Pagurus hirsutiusculus Dana (from Guberlet).

40. Dactyls of walking legs of same color throughout; anterior margin of carapace obscured by heavy growth of long hairs; median (rostral) projection short, blunt or broadly rounded (fig. 98,A) . . . . *Pagurus granosimanus*
40. Distal third of dactyls white; anterior margin of carapace not obscured by hairs, its rostral projection prominent and acute (fig. 98,B) . . . . *Pagurus hemphilli*

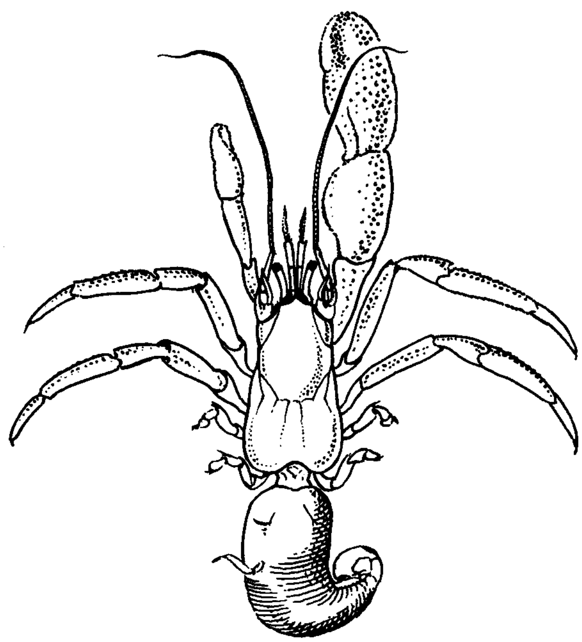
LIST OF DECAPODA

Caridea

M *Betaeus harfordi* (Kingsley)
B M *Crago nigricauda* (Stimpson)
Crago nigromaculata (Lockington)
M *Crangon dentipes* (Guerin)
M *Crangon californiensis* (Holmes)
Pandalus danae Stimpson
Spirontocaris brevirostris Dana
M *Spirontocaris palpator* (Owen)
B D M *Spirontocaris paludicola* (Holmes)
B *M *Spirontocaris picta* (Stimpson)
B M *Spirontocaris taylori* (Stimpson)



A



B

Fig. 98.—A, *Pagurus granosimanus* Stimpson; B, *Pagurus hemphilli* Benedict

Anomura

*B TB M _Callianassa californiensis_ Dana
D M _Cryptolithodes sitchensis_ Brandt
D *M _Emerita analoga_ (Stimpson)
M _Hapalogaster cavicauda_ Stimpson
M _Oedignathus inermis_ (Stimpson)
M _Pachycheles pubescens_ Holmes
*D *M _Pachycheles rudis_ Stimpson
*B TB D M _Pagurus hirsutiusculus_ (Dana)
*M _Pagurus granosimanus_ (Stimpson)
*M _Pagurus hemphilli_ (Benedict)
*M _Pagurus samuelis_ (Stimpson)
D *M _Petrolisthes cinctipes_ (Randall)
D *M _Petrolisthes eriomeris_ Stimpson
*M _Petrolisthes manimaculatus_ Glassell
TB M _Upogebia pugettensis_ (Dana)

Brachyura

*B D M _Cancer antennarius_ Stimpson
M _Cancer jordani_ Rathbun
B TB D M _Cancer productus_ Randall
*B M _Cancer magister_ Dana
TB M _Fabia subquadrata_ (Dana)
B D *M _Hemigrapsus nudus_ (Dana)
*B TB M _Hemigrapsus oregonensis_ (Dana)
D M _Lophopanopeus bellus_ (Stimpson)
*M _Lophopnaopeus heathii_ Rathbun
M _Loxorhynchus crispatus_ Stimpson
D M _Mimulus foliatus_ Stimpson
TB M _Pinnixa faba_ (Dana) and other spp.
M _Pinnotheres concharum_ (Rathbun)
D M _Pugettia gracilis_ Dana
*M _Pugettia richii_ Dana
TB D *M _Pugettia (Epialtus) producta_ (Randall)
*L _Rhithropanopeus harrisii_ (Gould)

THE TERRESTRIAL ARTHROPODS

Most of the arthropods except the Crustacea are adapted to terrestrial life, although some of them have returned to aquatic habits.

It is customary to group these under three subphyla (or classes) the Myriapoda, the Insecta, and the Arachnida, although the first group, the Myriapoda, is almost certainly polyphyletic. In addition the groups Pycnogonida and Tardigrada, while placed by some in the Arachnida, are better considered as of doubtful taxonomic relationships.

This enormous assemblage of animals can have but brief and fragmentary consideration here since our emphasis in these studies is largely on the aquatic habitats. Our excursions into the terrestrial domain are usually confined to one field trip to a near-by canyon where varied environmental types including stream bed, stream banks (riparian), tangled thickets, open forested hillsides, and grassy hill-top furnish a rich and varied fauna largely of mollusks and arthropods.

The student should recognize all of the types of terrestrial arthropods encountered and place them in the food cycles of the communities studied. No attempt will be made to identify them further except that the insects should be placed at least to the order.

Groups commonly encountered are the garden centipedes (Class Symphyla), the true centipedes (Class Chilopoda), and the millipedes (Class Diplopoda) (all of the subphylum Myriapoda), the insects (Subphylum Insecta), and of the Subphylum Arachnida, the Scorpions (Class Scorpionida), and the spiders (Class Araneida), the mites and ticks (Class Acarina), the harvestment (Class Phalangida), and occasionally the book scorpions (Class Pseudoscorpionida).

The food habits of the terrestrial arthropods are extremely varied. Certain groups, however, have relatively uniform habits. Thus the Symphyla and Diplopoda are plant feeders, while the Chilopoda and practically all Arachnida are predators.

The Insecta run the gamut as to food habits. Many are predatory carnivors, others are parasites, while a vast number are plant feeders and serve as key industry animals in important food chains. Such, for example, are the aphids.

SUBPHYLUM MYRIAPODA

Class SYMPHYLA, The Garden Centipedes

See mounts of *Scutigerella*. These are progoneate as are the Diplopoda but differ from them in many important features. They possess many structural indications of relationship to the primitive stock from which the insects have arisen. Note that there are only 12 leg-bearing somites. See the peculiar coxal sacs at the bases of the legs below. There is but one pair of tracheae opening at the bases of the antennae.

These tiny white wormlike creatures will be found in loam and among decaying leaves. They feed on vegetation and cause damage of considerable importance to some crops.

Class DIPLOPODA, The Millipedes

Note the rounded body of many segments (except in Polydesmidae). The first few segments bear a single pair of appendages each, others bear two and each is really two fused segments. The appendages of the seventh free segment of the male are modified for copulation, the reproductive ducts opening near the anterior end.

The types commonly encountered are the relatively large dark-brown cylindrical millipedes of the genus *Tylobolus* and the flattened species of the family Polydesmidae. See special paper by Ellsworth for more definite identification.

Class CHILOPODA, The Centipedes

Note the depressed body of many segments, varying in size, each bearing a pair of appendages. Appendages of first postcephalic segment modified as poison jaws (maxillipeds). Those of last pair are tactile. Reproductive apertures (not easily made out) open on last true segment.

Most commonly encountered is a stout, flattened, reddish species, *Otocryptops sexspinosus* Say, an inhabitant of decaying wood, characterized by having 23 leg-bearing segments, and two prominent spines on the first segment of the anal legs. For other species see special paper by Gressitt.

SUBPHYLUM INSECTA

Time does not permit any adequate study of this enormous group, many of whose species are among the most important in terrestrial communities. An elementary knowledge is assumed. The student should know at least the orders and where possible abundant species should be identified. For those who wish to attempt identification by means of keys, Lutz's Handbook of American Insects is the most available, although its examples are largely Eastern species. For specific Western species, Essig, Insects of Western North America, is recommended, although the absence of keys, inevitable in such a work, makes identification more difficult.

For aquatic insects reference may be had to A Guide to the Study of Fresh-Water Biology, by Needham and Needham (Comstock Co., 1930) and to various other works listed under that heading in the bibliography.

SUBPHYLUM ARACHNIDA

Class SCORPIONIDA

See the segmented body made up of (1) the prosoma, covered by a carapace and bearing the six pairs of appendages characteristic of arachnida, the chelicerae, pedipalpi and four pairs of legs; (2) the mesosoma, consisting of seven broad somites, the first of which bears the reproductive organs covered by the genital operculum (seen between bases of last two pairs of legs), the second the pectines, and the next four stigmata opening into book-lungs; (3) the metasoma, consisting of five segments, and the telson modified as a caudal sting. Mesosoma and metasoma together constitute the opisthosoma.

Class ARANEIDA, The Spiders

The body consists of cephalothorax and unsegmented abdomen. See the eight simple eyes. Identify the eight pairs of appendages. The chelicerae are poison jaws. See the modified terminal segment of the male pedipalp serving to transfer sperm. Locate the openings to the book-lungs and (just posterior) the genital aperture. Near the tip of the abdomen below see the three pairs of spinnerets.

For a general treatment see Comstock, The Spider Book. For a key to the local genera see special paper by Maehler.

Class ACARINA, Mites and Ticks

See the fused body without segmentation or subdivision. Make out the appendages characteristic of the arachnids.

Mites are the only arachnids occurring also in marine and fresh-water habitats.

Class PHALANGIDA, The Harvestmen or Daddy Longlegs

These are spider-like, but differ from the spiders in their segmented abdomen, chelate chelicerae, and number of eyes (2). One species is frequently seen under pieces of wood or under leaves in the Berkeley Hills. Because of lack of information concerning our local species, no list is given here.

The PYCNOGONIDA

The pycnogonids are a group of arthropods usually placed in the Arachnida, but of decidedly doubtful relationship to that group. Several species are common in the intertidal zone of ocean and bay. For the morphology of this class see Borradaile and Potts, Parker and Haswell, or another advanced text.

A KEY TO THE PYCNOGONIDS OF THE PACIFIC COAST OF NORTH AMERICA (ESPECIALLY OF CENTRAL CALIFORNIA*)

By Joel W. Hedgpeth

This key is based on obvious characters without reference to their value in indicating systematic relationships and is intended as an aid to identification of pycnogonids in the field. The distribution of many species is imperfectly known.

The characters used in this key should be visible under the medium power of a dissecting microscope, although for many of the smaller species it is difficult to make out details because of the debris adhering to the surface of the animal. This is particularly true of the spiny forms, and in some cases it will be necessary to brush the animal off with a camel's hair brush, perhaps even to pick at it with a dissecting needle. Specimens are best killed for study purposes by placing them in fresh water for a few minutes, which causes them to die in an extended condition. They are strongly thigmotropic, and should be kept separately to prevent them from becoming inextricably tangled.

For terms used in the key see figure 99.

1. Proboscis one jointed (figs. 99, 100) 2
1. Proboscis two jointed; minute species with angular first coxal joints; chelifores and palpi present, chelifores chelate; 3-6 mm. long. Laguna Beach, Santa Cruz Island . . . . *Eurydyce spinosa* Hilton

*For a complete key, including the species described in Hilton's preliminary papers, see Hedgpeth, J. W., "A Key to the Pycnogonids of the Pacific Coast of North America," Trans. San Diego Soc. Nat. Hist., March, 1941.

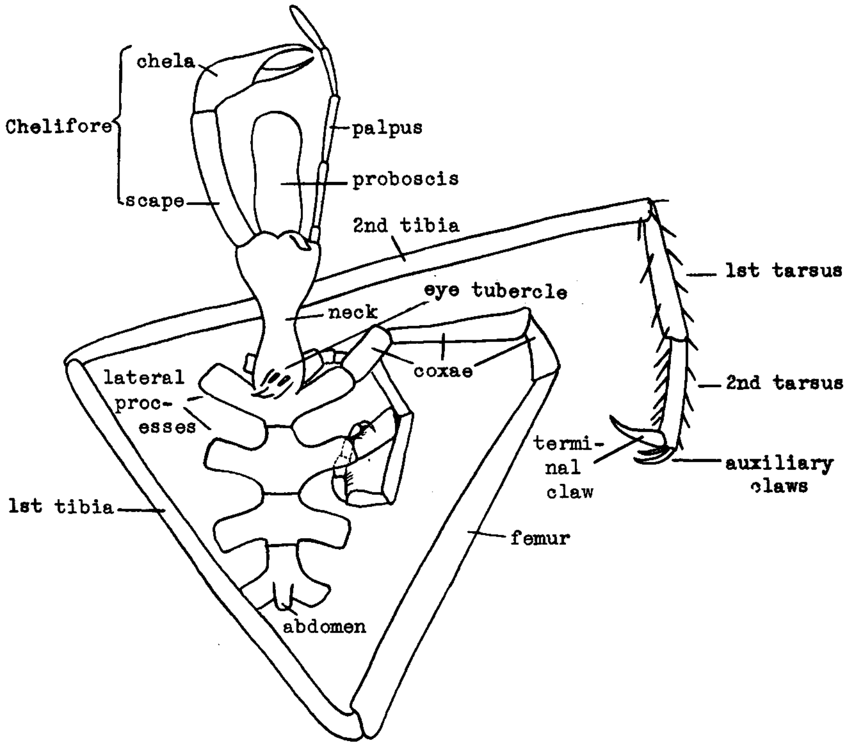


Fig. 99.—Nymphon sp. Labeled to illustrate characters used in the key.

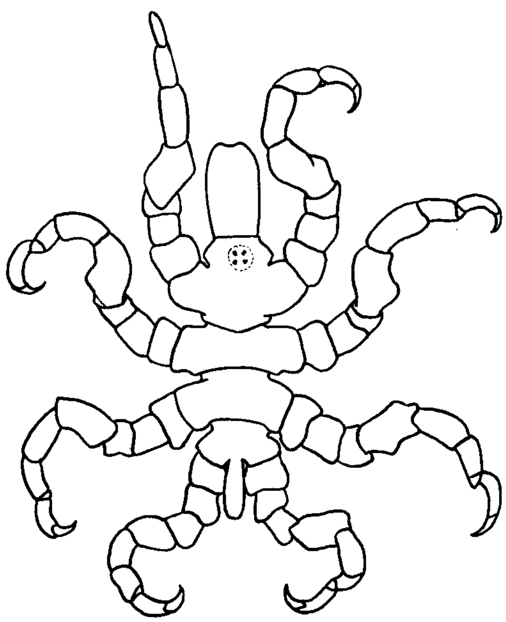


Fig. 100.—Pycnogonum stearnsi Ives.

2. Chelifores or palpi (fig. 99), or both, present 3
2. Chelifores and palpi lacking (fig. 100); stout-legged, knobby forms, oval in outline . . . . *Pycnogonum*
   a. Body granular; dorsal tubercles inconspicuous or absent. Littoral species, often on *Cribrina* or *Metridium*, and *Abietinaria*. Body of female 6 mm. long, male smaller. Alaska to San Diego . . . . . *P. stearnsi* Ives (fig. 100)
   b. Body reticulated; prominent dorsal trunk tubercles which are higher than eye tubercle; male 6-7 mm. long, female smaller. Subtidal, wharf pilings and anemones. Monterey Bay, Tomales Point . . . . *P. rickettsi* Schmitt

3. Chelifores or palpi present, the other lacking 18
3. Both chelifores and palpi present 4

4. Chelifores rudimentary or achelate in adult 6
4. Chelifores chelate in adult 5

5. Scape of chelifore shorter than proboscis; small; body compact; male 5 mm. long, female 11.8 mm. long. Central California coast . . . . *Ammothea chelata* Hilton
5. Scape longer than proboscis . . . . *Nymphon*
   a. Fingers of chelae short, thick; legs stout, with scattered spines; neck short; 50 mm. long. Puget Sound-Bering Sea, circumpolar . . . . *N. grassipes* (O. Fabr)
   b. Fingers of chelae slender; legs slender; neck long; 80 mm. long. Puget Sound, Departure Bay, B.C., offshore Southern California . . . . *N. pixellae* Scott

6. Body compact, disciform; segmentation indistinct (fig. 102); legs short, stout 7
6. Body more or less elongate (fig. 101); lateral processes separated; legs long and slender
   a. Proboscis cylindrical; chelifores one-jointed stumps; body 18-20 mm. long. On *Abietinaria*, Marin County to Laguna Beach . *Lecythorhynchus marginatus* Cole (fig. 101)
   b. Proboscis elliptical; chelifores three-jointed; legs without large tarsal claws; 8-9 mm. long. San Pedro Point, (Los Angeles) to Laguna Beach . *Ammothella bi-unguiculata*

7. Proboscis broad, clavate or bulbous, long as body, sometimes directed ventrally and apparently shorter from above 10
7. Proboscis tapered to a point or considerably shorter than body; small compact circular forms . . . . *Tanystylum*

8. Proboscis tapered to a point 9
8. Proboscis rounded; body very compact; 7 mm. long. Pacific Grove . . . . *T. occidentalis* (Cole)

9. Light-brown knobby form with white articulations; 4-6 mm. long. Usually on *Abietinaria*, Marin County to Southern California . . . . *T. californicum** Hilton (fig. 102)

*This is the common central California coast species which has been confused with T. intermedium. It is a little larger, with stouter legs, than T. intermedium. See Hedgpeth (1940) for more detailed distribution, under T. intermedium.

9. Delicate pale form with sharp spinelike protuberances on lateral processes; female more rounded. On *Obelia* San Diego to Carmel . . . . *T. intermedium* Cole

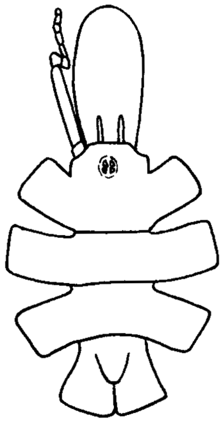


Fig. 101.—Lecythorhynchus marginatus Cole.

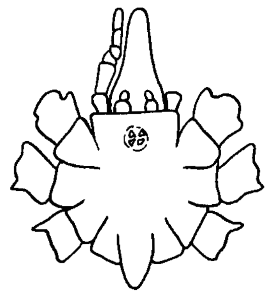


Fig. 102.—Tanystylum californicum Hilton.

10. Neither body nor legs conspicuously spiny 13
10. Body or legs spiny (fig. 103) or with conspicuous spiny tubercles 11

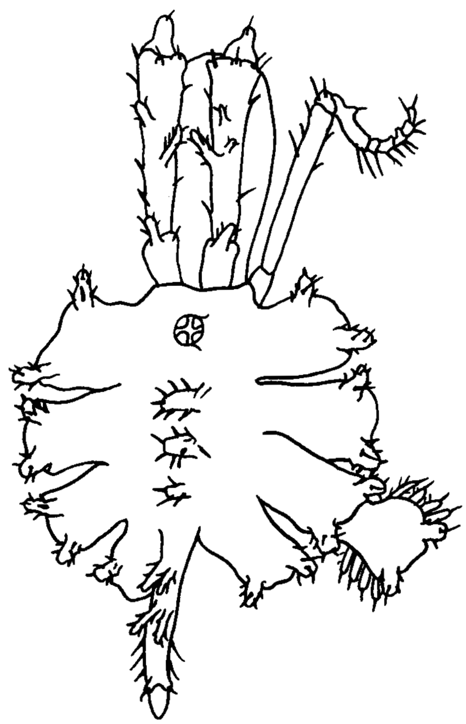


Fig. 103.—Nymphopsis spinosus Hall.

11. Without tall spiny tubercles on body 12
11. Three tall spiny tubercles on body; two rows of spiny tubercles on tibial joints; coxae smooth; 10 mm. long. Sub-

tidal, Laguna Beach to Tomales Point
. . . . *Nymphopsis spinosissimus* (Hall) (fig. 103)

12. Chelifores and abdomen knobby; legs spiny; body compact; chelifores two-jointed; 16.mm. long. Bering Sea, Monterey Bay
. . . . *Ammothea latifrons* Cole
12. Chelifores and abdomen not knobby; lateral processes separated; spines or slender tubercles on trunk; chelifores three-jointed; 10 mm. long. San Diego to Marin County
. . . . *Ammothella spinifera* Cole

13. Chelifores less than half as long as the proboscis 15
13. Chelifores at least half as long as proboscis 14

14. Tubercles on dorsal posterior margins of first two or three trunk segments; proboscis broad as body; chelifores three-jointed; 6-9 mm. long. In holdfasts and on sheltered rocks, Marin County to Laguna Beach
. . . . *Ammothella tuberculata* Cole (fig. 104,A)
14. Without such tubercles; proboscis narrower than body; chelifores two-jointed; 18-20 mm. long. Hydroids, Puget Sound
. . . . *Ammothea discoidea* Exline

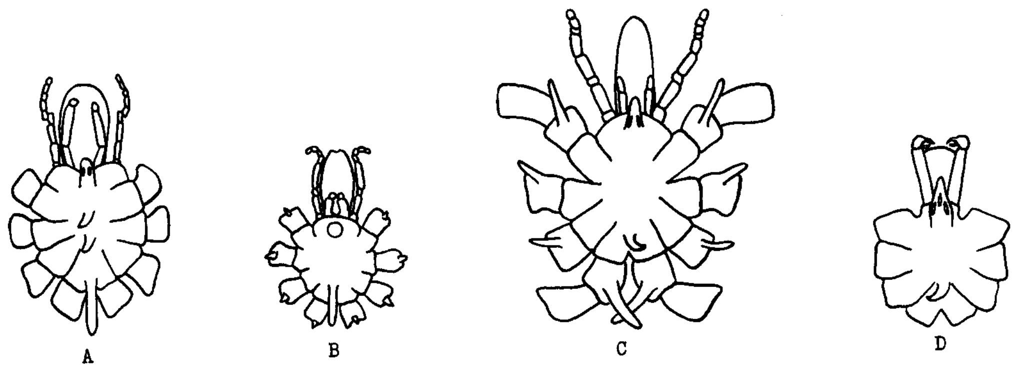


Fig. 104.—A, Ammothella tuberculata Cole; B, Ammothea nudiuscula Hall; C, Ammothea gracilipes Cole; D. Halosoma viridintestinalis Cole

15. Proboscis elliptical or tapered at tip (figs. 104,B,C) 16
15. Proboscis blunt or truncate; 30 mm. long. Pribiloff Island
. . . . *Ammothea pribilofensis* Cole

16. Protuberance on dorsum of first coxal joint half as long as first coxal joint 17
16. Protuberance less than half as long as first coxal joint; proboscis broadly elliptical; 7 mm. long. San Francisco Bay . . . . *Ammothea nudiuscula* Hall (fig. 104,B)

17. Protuberance half as long as coxal joint; body 13 mm. long. Alaska. . . . . *Ammothea alaskensis* Cole
17. Protuberance three-fourths as long as coxal joint; proboscis narrowly elliptical; 8 mm. long. San Francisco, Marin County, Vancouver, B.C. . . . . . *A. gracilipes* Cole (fig. 104,C)

18. Chelifores present, chelate (fig. 105), usually overreaching proboscis; palpi lacking 19
18. Chelifores lacking; palpi present; elongate; distinctly segmented; proboscis large, dilated; eye tubercle tall; 50 mm. long. Offshore water, Southern California . . . . *Colossendeis californica* Hedgpeth

19. Chelae and proboscis not extended forward on a neck; chelae small 20
19. Chelae strong, heavy, flanking the rather blunt proboscis at the end of a well-developed neck . . . . *Callipallene*
    a. Body rather compact; segmentation of last two trunk segments indistinct; 9-10 mm. long. Littoral, Laguna Beach . . . . *C. californiensis* Hall
    b. Body extended; lateral processes separated; body distinctly segmented. Offshore waters, Southern California . . . . *C. pacifica* Hedgpeth

20. First trunk segment not conspicuously overhanging proboscis (fig. 105) 21

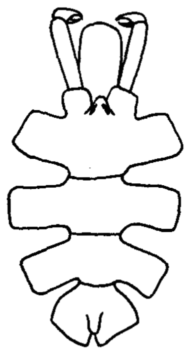


Fig. 105.—Phoxicilidium femoratum Rathke.

20. First trunk segment overhanging forward so that proboscis appears ventral in origin . . . . *Anoplodactylus*
    a. Lateral processes separate at base; eyes present; 8-9 mm. long. Littoral, Monterey to San Diego, also offshore waters . . . . *A. erectus* Cole
    b. Lateral processes contiguous at base; eyes lacking; 15-16 mm. long. Littoral, Laguna Beach . . . . *A. californiensis* Hall

21. Body extended, lateral processes separated; 8-10 mm. long. Alaska to Laguna Beach; circumpolar . . . . *Phoxichilidium femoratum* (Rathke) (fig. 105)
21. Body compact; small delicate form with vivid green intestine; 7.5 mm. long. Marin County to Laguna Beach . . . . *Halosoma viridintestinalis* Cole (fig. 104,D)

PHYLUM MOLLUSCA

This great phylum includes many of the important animals of the littoral marine and the freshwater and terrestrial faunas to be studied. In the intertidal zone it ranks with the arthropods as a dominant structural type.

Five classes, each with a very distinctive structure, constitute the phylum:

1. Class Amphineura, the chitons
2. Class Gastropoda, the snails, whelks, limpets, slugs, nudibranchs, etc.
3. Class Scaphopoda, the tooth shells
4. Class Pelecypoda, the clams, mussels, oysters, pectens, etc.
5. Class Cephalopoda, the squids, octopi, and nautili.

We shall confine our attention to the animals of three of these classes, the chitons, the gastropods, and the pelecypods. The tooth shells are not found in our region. Of the cephalopods, the squid are pelagic and only one species of octopus, *Paroctopus appolyon* (= *Polypus hongkongensis*) is encountered along the central and northern California coast and that only occasionally. For an interesting account of its behavior and breeding habits see Ricketts and Calvin (p. 96-99).

The evolution of the various molluscan types has concerned chiefly three plastic regions, the head, the foot, and the mantle (figs. 114, 115). The mantle is the body wall over the visceral region. This grows out as a mantle fold (figs. 113,B and 114) enclosing a mantle cavity or mantle chamber within which lie the gills, the anal opening and the openings of reproductive and excretory ducts.

The mantle secretes the shell and that typical molluscan structure varies with the shape, size, position, and habit of growth of the mantle. The mantle cavity, primitively posterior, has taken on various positions in the various molluscan types.

The characteristic feeding organ of the mollusk, known as the radula, is a band of chitinous teeth (fig. 106) produced in the ventral cavity of the pharynx from which it is extended by muscular action and used to scrape away the food. It may be seen in use by watching freshwater snails feeding on the walls of an aquarium. The radula, which is found in all classes of Mollusca except the Pelecypoda, is most commonly used in feeding on large leafy plants or large algae (thus in some chitons and many Gastropoda) or for scraping off encrusting layers of minute unicellular organisms (many chitons, the limpets, some snails). In the Cephalopoda and some snails it has been adapted to predatory habits.

The Pelecypoda are plankton feeders sifting the tiny organisms from the water currents caused to flow through the large mantle chambers by the action of cilia on the large, complicated gills. The radula, having no function in such a habit of life, has been lost in the Pelecypoda along with the sense organs of the head, and, indeed, the head itself since, covered by the mantle folds and the shell, it has no direct contact with the environment.

Class AMPHINEURA

The Aplacophora, shell-less forms, often considered to belong to the Class Amphineura, are largely deep sea in distribution and will not be encountered by us. The chitons, Order Polyplacophora, are important and interesting members of the intertidal faunas and we should be familiar with all the known species. Unknown species should be preserved for study by the specialist. They may be killed in extended form by allowing them first to flatten out on glass slides to which they may be tightly tied before fixation.

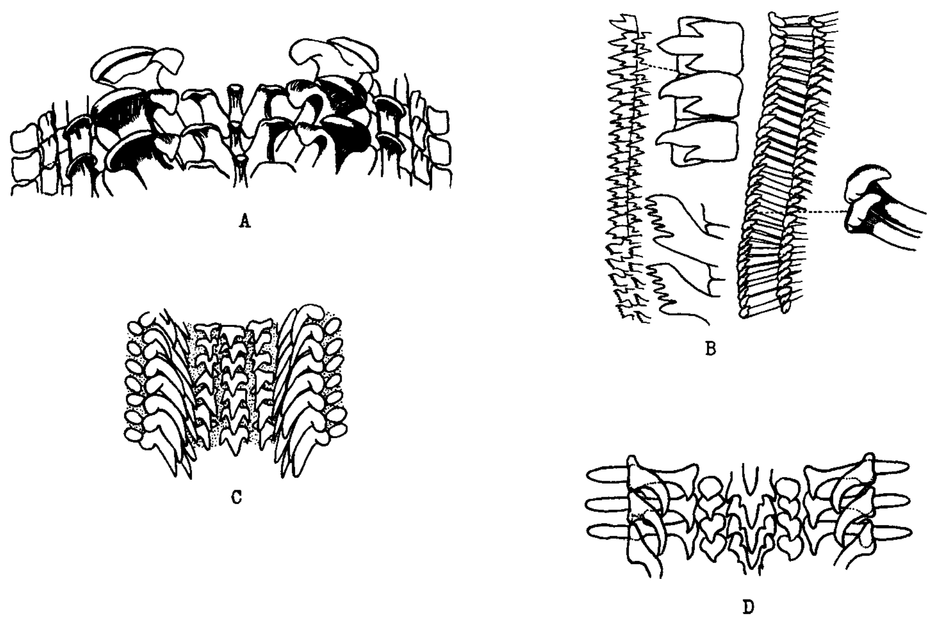


Fig. 106.—Small portions of the radulae of various Mollusca (from various sources).

The characters used in the identification of chitons have chiefly to do with the 8-valved shell (figs. 107-111) the width and ornamentation of the muscular integumental area between the shell and the margin, known as the girdle (fig. 107), and with the proportions of the body.

Each valve consists typically of two layers, a basal and more extensive articulomentum which extends under the other plates anteriorly and is more or less covered by the girdle laterally, and the upper tegmentum, covering only the exposed portion of the valve. In *Crypotochiton* the valves are entirely covered by the girdle and the tegmentum is lacking. The valves overlap posteriorly and the portion of a valve underlying the one in front is often also designated the articulomentum and that portion covered by the girdle, the insertion plate.

Examine the girdle. Note its width in proportion to the width of the exposed portions of the valves (cf. figs. 110 and 111). Note also its ornamentation (fig. 107). Is it smooth, rough and leathery, covered with granules, or with scales, or with fine hairs, or spines, or long stiff hairs?

Note the proportion of width to length. Is it half as wide as long, etc.?

Dissect out the valves of your specimen. Place one of them under the microscope to see the tiny pits which form patterns on the surface of the tegmentum. In these pits lie characteristic sense organs known as esthetes. Examine the posterior margin of the last valve. The slit or notch in it is known as a sinus.

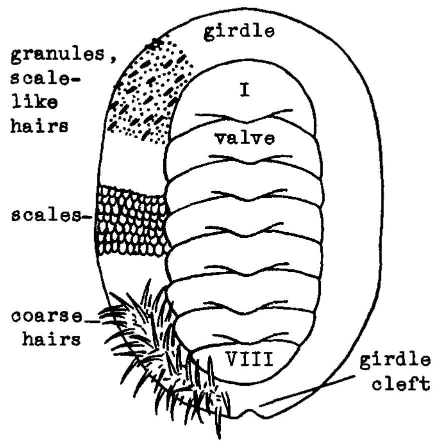


Fig. 107.—Diagrammatic figure of a chiton illustrating some of the various types of girdle ornamentation.

Using the key below identify your specimen. When Pratt is available identify another species to the family. See the figures in Tryon and Pillsbry, A Manual of Conchology.

KEY TO THE CHITONS

1. Girdle completely covering valves, thick, red, gritty; large (6-8 inches) . . . . . "The Giant Chiton," *Cryptochiton stelleri*
1. Girdle two to three times as wide as exposed portion of valves; girdle smooth and black . "The Black Chiton," *Katharina tunicata*
1. Exposed portion of valves at least as wide as girdle 2

2. Valves marked with conspicuous zigzag lines of color . . . . . . "The Lined Chiton," *Lepidochitona (Tonicella) lineata*
2. No such lines 3

3. Girdle (Observe under the lens!) covered with hairs (figs. 107, 108) 4
3. Girdle covered with scales like a coat of mail (figs. 107, 109) . . . . *Ischnochiton* 7
3. Girdle with minute granules (fig. 107), minute scales or minute papillae 10

4. Hairs coarse and stiff 5
4. Hairs lighter, flexible 6

5. Oval in shape; girdle coarsely mossy, narrowed at ends; valves often corroded, with dorsal ridge, ornamented with nodules in lines . . . . "The Mossy Chiton," *Mopalia muscosa*
5. Nearly circular; girdle much elongated in front, with scattering hairs; valves short and broad, without nodules . . . . "The Veiled Chiton," *Placiphorella velata*

6. Girdle conspicuously cleft posteriorly (fig. 107); valves sculptured in concentric lines (often covered with red deposit); hairs slender, very pale, easily lost . . . "The Hairy Chiton," *Mopalia ciliata*
6. Girdle not conspicuously cleft; valves smooth, gray, green, or blue, with brown lines slanting from apex of valves; hairs thick at base, slender and incurved distally, each rising in a light spot . . . . *Mopalia lignosa* (fig. 108)

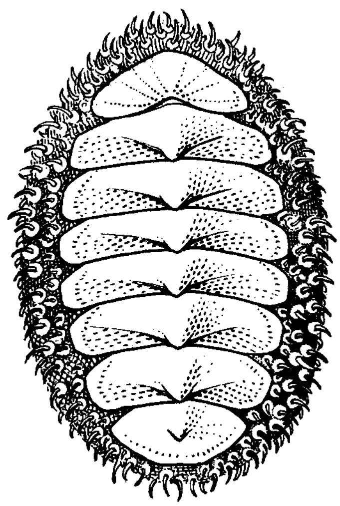
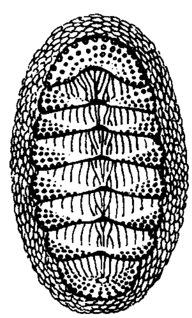
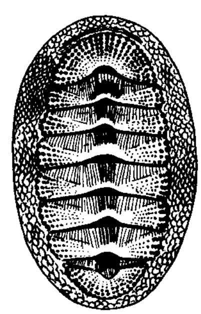


Fig. 108.—Mopalia lignosa

7. Central areas of body valves set with raised riblets; lateral areas of body valves, usually all of head valve, and posterior region of tail valve set with radiating rows of nodules 8
7. No nodules visible to the naked eye 9



A



B

Fig. 109.—Ischnochiton: A, I. mertensii (Middendorf); B, I. cooperi Carpenter. x 1 1/2.

8. Red to dull brown; nodules and ribs of valves and scales of girdle conspicuous . . . . . "The Red Chiton," *Ischnochiton mertensii* (fig. 109,A)
8. Gray; nodules, ribs, and scales less conspicuous . . . . *Ischnochiton cooperi* (fig. 109,B)
(These are probably varieties of the same species.)

9. Body elongated, considerably more than twice as long as wide; valves obscurely sculptured; light gray in color . . . . "The Gray Chiton," *Ischnochiton magdalenensis*
9. Body about twice as long as wide; valves apparently smooth; with an intricate pattern of white spots on a mottled blue-green background . . . . *Ischnochiton regularis*

10. Girdle with scale-like hairs (figs. 107, 110); girdle broad; valves nearly as long as wide . . . . *Nuttallina californica* (fig. 110)
10. Girdle narrow, ornamented otherwise; valves short and broad (fig. 111) 11

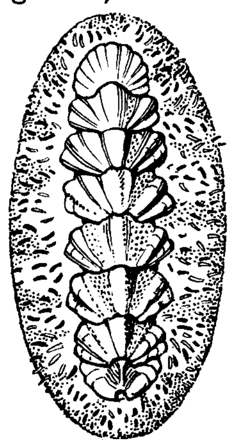


Fig. 110.—Nuttallina californica (Reeve).

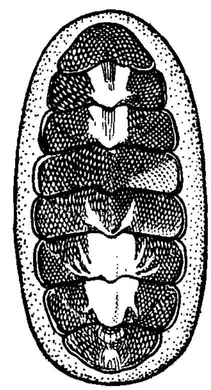


Fig. 111—Lepidochitona raymondi Pilsbry. x 2.

11. Broad oval, low; dull olive green; girdle covered with close-set granules; valves covered with fine granulations and larger (.04 mm.) wart-like granules on lateral areas . . . . *Lepidochitona hartwegii*
11. Narrower; darker, some almost black; usually small in size (1/4 to 1/2 inch); girdle leathery, minutely papillose; valves covered with very fine granulations and slightly beaked . . . . *Lepidochitona raymondi* (fig. 111)

LIST OF CHITONS

Class AMPHINEURA

Order *Polyplacophora*

D *M *Cryptochiton stelleri* (Middendorff)
M *Ischnochiton cooperi* (Carpenter)
D *M *Ischnochiton magdalenensis* (Hinds)
M *Ischnochiton mertensii* (Middendorff)
M *Ischnochiton regularis* (Carpenter)
D *M *Katharina tunicata* (Wood)
*M *Lepidochitona hartwegii* (Carpenter)
D *M *Lepidochitona (Tonicella) lineata* (Wood)

M *Lepidochitona raymondi* Pilsbry
D B *M *Mopalia ciliata* (Sowerby)
M *Mopalia lignosa* (Gould)
D B *M *Mopalia muscosa* (Gould)
D *M *Nuttalina californica* (Reeve)
D M *Placiphorella velata* Carpenter

Class GASTROPODA

These animals are the dominant and conspicuous animals over much of the area which we are to study, and the number of common genera and species which we must be able to recognize in the field is large. They present themselves, naturally, therefore, as a group for careful study of methods of identification. Although revisions are badly needed the gastropods of the Pacific Coast have been extensively studied and numerous valuable works of references are available. Unfortunately none of these gives keys which are available for the fauna of this

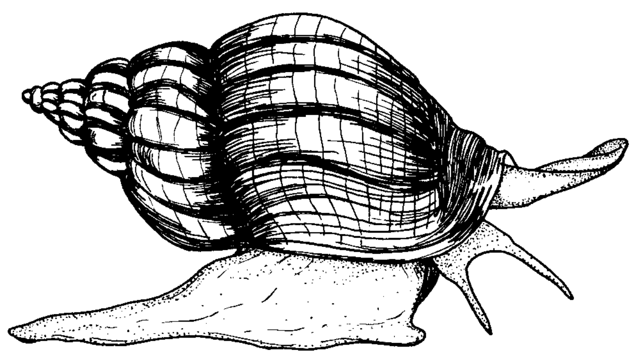


Fig. 112.—A marine snail, the whelk (Buccinum) (after Buchsbaum).

coast, and we shall have to depend for identification upon the key given below. Identification may be checked with the excellent illustrations in (1) Oldroyd, (2) Manual of Conchology by Tryon and Pilsbry, and (3) Packard. When still in doubt as to the correctness of your identifications, reference may be made to authentic named collections in charge of the teaching assistant.

There are five main groups or types of gastropods which are given various names and are variously grouped by different authors. They are (1) the *Aspidobranchia* (often called *Scutibranchia* or *Diotocardia)* including the limpets of various kinds, the abalones, and a number of typical snail-like forms of which *Calliostoma* is our best example; (2) the *Pectinibranchia* (often called *Ctenobranchia* and *Monotocardia)* including the vast majority of marine shelled gastropods; (3) the *Tectibranchia,* including the sea hares (no common Moss Beach examples); (4) the *Nudibranchia,* the nudibranchs; and (5) the *Pulmonata,* including most land and fresh-water snails, and slugs, but with only two local marine representatives, *Gadinia* and *Arctonchis.*

On the basis of the twisted condition of the nervous system the first two of the groups above are often placed together in an order (or subclass), the *Streptoneura* or *Prosobranchia,* and commonly spoken of as prosobranchs or streptoneurous gastropods. The remaining three groups are also often included in a single order (or subclass), the *Euthyneura,* and spoken of as euthyneurous gastropods, those whose nervous system is symmetrical. The tectibranchs and nudibranchs are often included in the single order, Opisthobranchia, as in Hegner.

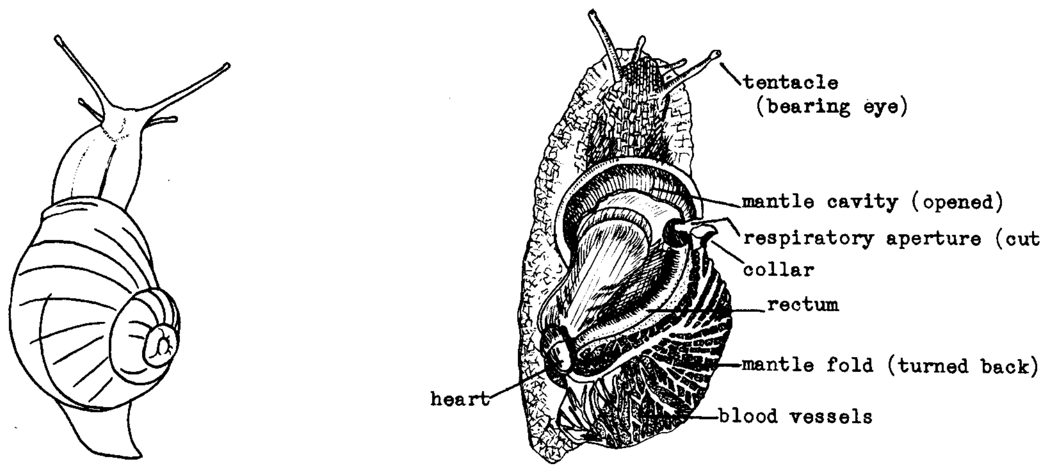


Fig. 113.—Helix, a terrestrial pulmonate (after Selenka): A, with shell in place; B, shell removed; mantle chamber ("lung") opened by cutting mantle fold anteriorly and turning it back.

On the specimen given you, *Helix aspersa,* a pulmonate (fig. 113), identify the foot, the head, bearing the tentacles, the fold of body-wall known as the mantle, and the mantle cavity, the marginal thickening of the mantle called the collar which in some species (*Ilyanassa*) is drawn out to form the siphon, lying, in life, in the siphonal canal, an extension of the shell. By means of forceps introduced through the mouth pull out the characteristic feeding organ of the Mollusca, the radula. Examine it under the microscope. See demonstration mount of radula of a limpet.

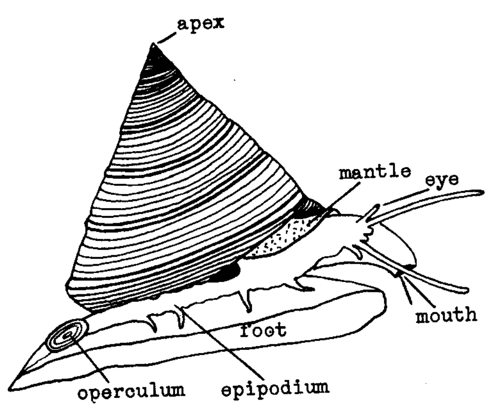


Fig. 114.—Calliostoma, a scutibranch (after Eales).

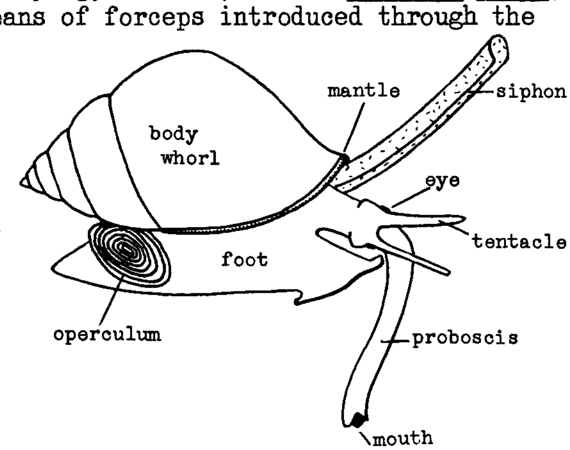


Fig. 115.—A pectinebranch (after Eales).

The shell of a typical pectinibranch consists of the body whorl (fig. 115), which opens by the aperture, and the whorls of the spire ending in the apex. The groove between two successive whorls is known as the suture. The axis of the shell around which the shell is coiled is known as the columella (see sectioned shell); the hollow center sometimes present in the columella is the umbilicus (fig. 122) and a thickening partially or completely filling the opening of the umbilicus below as the callus.

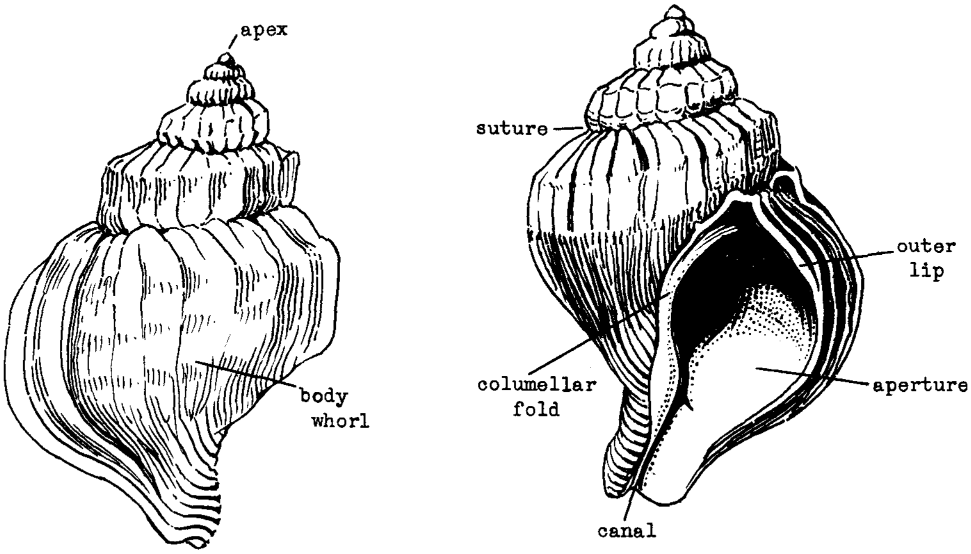


Fig. 116.—A dextrally coiled gastropod shell, Buccinum baeri morchianum Fisher (after Oldroyd).

Here as in the bivalves identification depends upon characters of the shell. To gain familiarity with certain important characters and at the same time learn the names of certain species to be encountered later, make out the following characters on the demonstration specimens:

Canal: (1) lacking (*Tegula*), (2) open (*Thais*), (3) closed (*Purpura*).
Aperture: (1) smooth (*Littorina*), (2) crenulate (*Tritonalia*).
Inner lip: (1) toothed (*Thais lamellosa*), (2) corrugated (*Searlesia*), (3) smooth (*Littorina*).
Sutures distinct: (*Calliostoma costatum*)
Shell: (1) low-spired (*Homalopoma*), (2) moderately high-spired (*Calliostoma*), (3) acute spire (*Epitonium* or *Bittium*), (4) with spiral ridges (*Calliostoma*), (5) with radiating ridges (*Epitonium*), (6) with slits (*Haliotis*), (7) with under-shelf (*Crepidula*).

Using the key below, identify as many specimens as time allows. Check some at least of your identifications with Mrs. Oldroyd's work, or if *Acmaea*, with Mrs. Grant's paper. Learn the names of as many as possible of the genera found at Moss Beach.

KEY TO THE MARINE SHELLED GASTROPODS
(See also Vokes, 1934, for small species)

A. Shell with more or less elevated, coiled spire 1
B. Shell with flattened spire, not rising above level of surface or only slightly so and with a row of perforations near left margin 46
C. Shell without a coiled spire, cap-shaped (plates XII-XV) 25
D. Irregularly twisted tube masses . . . . Vermetidae

1. Aperture rounded, entire; no indication of a canal (figs. 121, 122) 15
1. Aperture produced, forming a canal or rudiment thereof (fig. 116) 2

2. Canal rudimentary; spire greatly elevated; 5-7 flat spiral threads on each whorl . . . . *Bittium* (fig. 117,A)
2. Canal obvious 3

Fig. 117.—A, Bittium eschrichtii (Middendorf); B, Nassarius (= Alectrion)

3. Canal short, distal end of canal marked by a decided notch (fig. 117,B) 4
3. Canal elongated, with or without notch 9

4. Notch conspicuous; a deep spiral furrow in body whorl to left of canal (fig. 117,B) . . . . *Nassarius (= Alectrion)*
4. Notch inconspicuous; without deep furrow 5

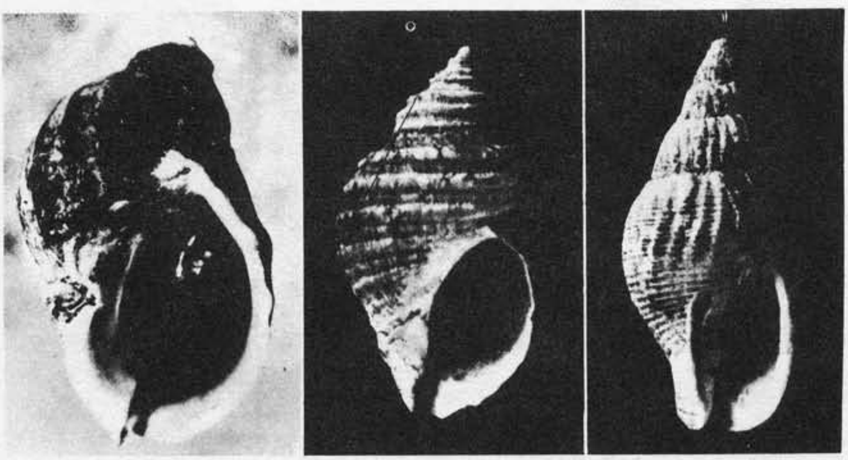
5. Shell with smooth, polished, evenly convex surface; body whorl making up more than 3/4 of shell; aperture greatly elongated, with a broad, conspicuous white callus on the columella and a broad shallow notch at base of aperture (canal) . . . . *Olivella biplicata*
5. Not so 6

6. Upper limit of aperture at or above middle of shell 7
6. Upper limit of aperture well below middle of shell 8

7. Sculpturing of conspicuous, uniform, spiral ridges separated by narrow, deep furrows (fig. 118); body whorl with about 10 spirals; upper end of aperture near middle of shell . . . . *Thais canaliculata*
7. Sculpturing (often obsolete or obscure) of low, unequal, spiral, rounded ribs, nodulated by growth lines, separated by wide, shallow depressions; upper end of aperture well above middle of shell . . . . . . *Thais emarginata* (fig. 119,A)

Fig. 118.—Thais canaliculata (Duclos)

8. Shell with inconspicuous longitudinal grooves; faint (obsolete) furrow on body whorl; color dark; mud-flat dweller . *Ilyanassa*



A B C

Fig. 119.—A, Thais emarginata Deshays; B, T. lima (Martyn); perhaps only a variety of T. emarginata; C, Amphissa columbiana Dall. (All from Guberlet.)

8. Shell with smooth polished surface; spire approximately half as long as body whorl; shell with 7 whorls; upper end of aperture more or less clearly angular . *Mitrella (= Columbella)*

9. Shell with three heavy flanges extending entire length of shell; canal usually closed . . . . *Purpura*
9. No such flanges; canal usually open 10

10. Edge of outer lip bearing a prominent spine . . . . . . *Acanthina*
10. No such spine 11

11. Sculpturing of numerous, small, obliquely longitudinal ridges; lip distinctly thickened near canal . . . *Amphissa* (fig. 119,C)
11. Sculpturing absent, or, if present, of less numerous, larger, and not oblique ridges 12

12. Inner margin of outer lip corrugated transversely along its whole length (fig. 120,A) 13
12. Inner margin of outer lip smooth, or sculptured with a few discrete teeth 14

13. Corrugations of lip extend far into aperture; shell large . . . . *Searlesia* (fig. 120,A)
13. Corrugations only suggested; shell sculptured with faint, spiral threads undulated by prominent, radiating ridges; shell smaller . . . . "The Oyster Borer," *Urosalpinx*

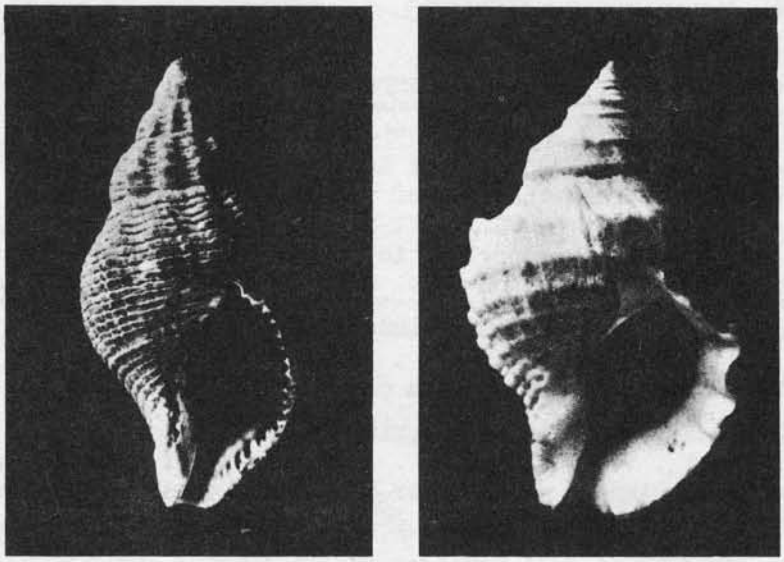


Fig. 120.—A, Searlesia dira (Reeve); B, Thais lamellosa (Gmelin). (Both from Guberlet.)

14. Shell large; outer lip variable in thickness; sculpturing of conspicuous, radiating lamellations, fluted by widely separated spiral ribs (sculpture often obsolete); aperture flaring at top, pinched at bottom; spire about equal to body whorl . . . . *Thais lamellosa* (fig. 120,B)
14. Shell small; outer lip usually thin, spire greatly elevated; sculpturing of conspicuous, close-set spiral ribs, either without radiating sculpture, or with rounded radially arranged swellings—*Tritonalia* (a difficult group of several species); for species see 47

15. Spire greatly elevated; sculpture of 12-14 sharp-cut, radiating ridges . . . . *Epitonium* (fig. 121)
15. Spire relatively low 16

16. With pearly luster or white inside 19
16. Without pearly luster inside; inner side of outer lip brown or purplish 17

17. Callus broad and flattened; umbilicus closed 18
17. Callus thin and thread-like; umbilicus open (fig. 122); shell tiny . . . . *Lacuna* spp.

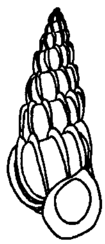


Fig. 121.—Epitonium.

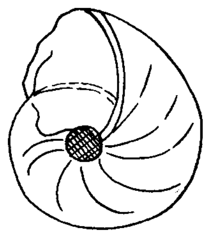


Fig. 122.—Lacuna. Much enlarged, showing open umbilicus.

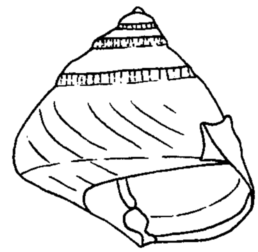


Fig. 123.—Tegula funebralis Adams.

18. Larger; shell of three whorls; broad band of white cutting diagonally across the face of the lip to its edge . . . . *Littorina planaxis*
18. Smaller; higher in proportion to width, with four whorls in shell; no white band on lip . . . . *Littorina scutulata*

19. With small nodes or teeth on the columellar callus (fig. 123) 20
19. Aperture smooth, without teeth or nodes on the callus 22

20. Color black; outer lip overlapping the whorl above (fig. 123) . . . . *Tegula funebralis*
20. Color brown, tan or gray; outer lip merely touching the whorl above, not overlapping it 21

21. Umbilicus closed; base rounded; whorls convex; shell turban-like (more pyramidal in young) . . . . *Tegula brunnea*
21. Umbilicus open; base flat; whorls flat; body whorl angular; shell pyramidal . . . . *Tegula montereyi*

22. Umbilicus closed 23
22. Umbilicus open 22a

22a. Very large; whitish . . . . *Polynices lewisii* (fig. 124)
22a. Small; reddish . . . . *Margarites* spp.

23. Shell ivory to reddish-brown; large, over 3/8 of an inch in diameter; ribs spiral, heavy, well-marked; spire moderately high, acute 24
23. Shell reddish; small, less than 3/8 of an inch in diameter; ribs spiral, fine, not prominent; spire low, broad; (resembling a young *Tegula*) . . . . *Homalopoma*

24. Body whorl rounded; base convex; sutures more or less distinct; color reddish, with blue tinges at apex . . . . *Calliostoma costatum* (fig. 125,A,B)
24. Body whorl acutely angular; base flat; sutures indistinct; color old ivory; shape pyramidal . . . . *Calliostoma canaliculatum* (fig. 125,C)

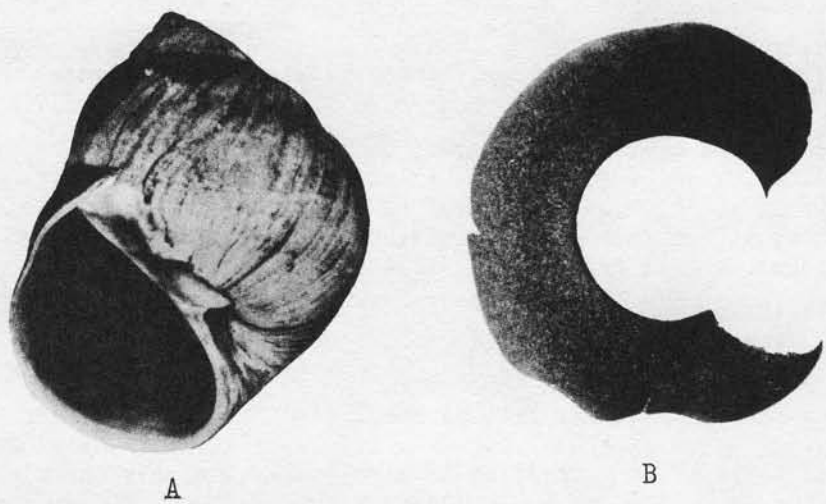


Fig. 124.—Polinices lewisii (Gould) (from Guberlet): A, shell, considerably reduced; B, sand collar containing eggs.

25. Shell not perforated at apex 26
25. Shell perforated at apex (keyhole limpets) 44

Fig. 125.—Calliostoma (after Oldroyd): A and B, C. costatum (Martyn); C, C. canaliculatum (Martyn).

26. With a shelf on under side 27
26. Without such a shelf 28

27. Shell black or dark brown, peaked; apex recurves; common on *Tegula* . . . . *Crepidula adunca*
27. Shell white; peak reduced or absent; under stones and in crevices; variable in shape and proportions . *Crepidula nummaria*

28. Shell thick and very irregular; typically subcircular . . *Hipponix*
28. Shell thin and more or less regular 29

29. With no distinct external or internal color markings (Plate XIII, no. 8) 30
29. With a distinct color pattern, at least internally 35

30. Usually over 3/8 of an inch long; apex at or near center . . . 33
30. Less than 1/4 of an inch long 31

31. Usually on *Tegula* 32
31. Usually on narrow eel grass; brown; bilaterally compressed . . . . . . *Acmaea paleacea* (Plate XII, no. 6; Plate XIV, no. 9)

32. Black; broad oval; sides convex; on *Tegula funebralis* . . . . *Acmaea asmi* (Plate XII, no. 1; Plate XIV, no. 1)
32. Light in color, usually covered by coralline; sides parallel; rare; on *Tegula brunnea* (occasionally on coralline-covered rocks). *Acmaea triangularis* (Plate XII, no. 7; Plate XIV, no. 4)

33. White inside and out 34
33. Dark brown inside and out; corneous; usually on *Egregia* . . . . . . *Acmaea insessa* (Plate XII, no. 2; Plate XV, no. 13)

34. Outer surface radially ribbed; shell flat; outline circular . . . . *Gadinia*
34. Outer surface not ribbed; shell high; outline nearly circular . . . . *Acmaea mitra* (Plate XII, no. 10; Plate XIII, no. 8; Plate XIV, nos. 7 and 8)

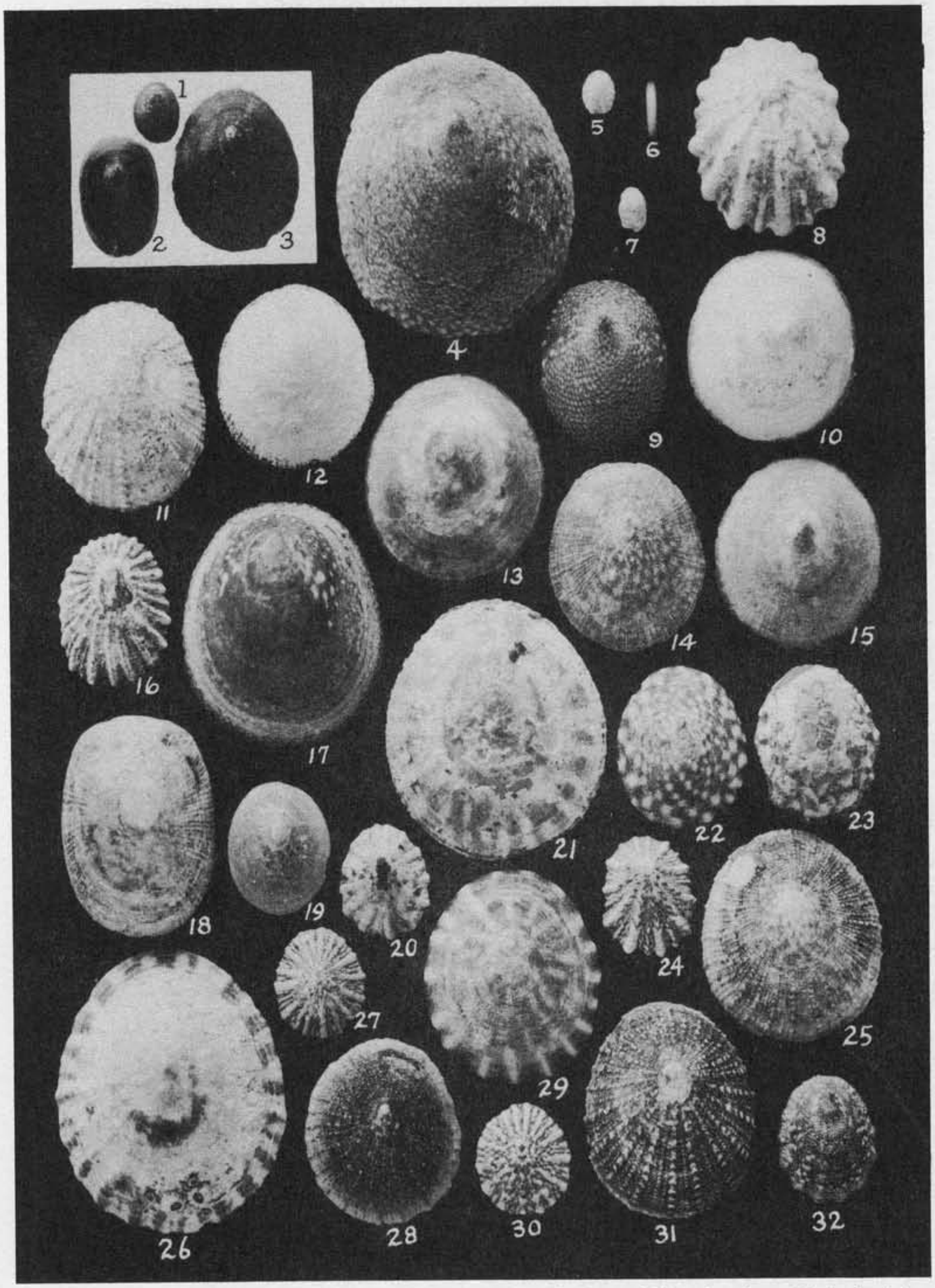
35. Apex less than one-third of length from nearest (anterior) end (Plate XIV, no. 17) 36
35. Apex at least one-third of length from end 39

36. Anterior (short) surface concave (Plate XIV, no. 17) unless corroded by fungus 37
36. Anterior surface straight or convex 38

37. Ribs broad and undulating, branching; margin crenate; interior generally dark, with lighter owl-shaped apical marking; very large and heavy; lower; apex very near anterior end . . . . *Lottia gigantea*
37. Ribs rounded, unbranched, prominent to obsolete (Plate XIV, nos. 11-19); margin ruffled; inner surface with elongated, solid, dark-brown area on white background; border dark (Plate XIII, nos. 21, 22); higher; apex seemingly at least farther from anterior end. . . . . *Acmaea digitalis* (Plate XII, nos. 23, 32; Plate XIV, nos. 11-14, 16-19)
(See Plate XIV, nos. 23-27, for hybrids with *pelta*)

38. Heavily ribbed, with projecting marginal points (Plate XII, no. 8); inner surface with irregular dark markings on porcelanous ground (Plate XIII, nos. 7, 11-13); ribs often spinulescent (Plate XII, no. 24)
. . . . . *Acmaea scabra* (Plates XII, XIII, Plate XIV, nos. 20-22)
38. Ribs fine, thread-like (Plate XII, no. 9); posterior surface markedly arched convexly (Plate XV, nos. 18, 19); interior milk-white, with plain, broad, dark border, and apical spot (Plate XIII, no. 23). . . . . *Acmaea persona*

PLATE XII



Shells of various species of <u>Acmaea</u> in dorsal view. Natural size. Listed alphabetically by species:

1, <u>A. asmi</u>
20,30, <u>A. cona</u>
23,32, <u>A. digitalis</u>
13,15, <u>A. fenestrata cribraria</u>
2, <u>A. inessa</u>
18, <u>A. instabilis</u>
11,12,25,28,31, <u>A. limatula</u>
10, <u>A. mitra</u>
19, <u>A. ochracea</u>
6, <u>A. paleacea</u>
3,26, <u>A. pelta</u>
4,9,17. <u>A. persona</u>
5, <u>A. rosacea</u>
8,16,24, <u>A. scabra</u>
21,22,29, <u>A. scutum</u>
16, <u>A. triangularis</u>

39. Height at apex less than one-third of width (Plate XV, nos. 10, 16) 40
39. Height at apex at least one-third of width 42

40. Width distinctly more than three-fourths of the length of shell (Plate XII, nos. 29, 31); shell very low 41
40. Width about three-fourths of length of shell; striations straight, unbranched, continuous from apex to margin, with interspaces equal in width to striations (Plate XII, 19); external color pinkish or dark, spotted with white; interior blue and brown; shell very fragile . . . . *Acmaea ochracea* (Plate XII, no. 19; Plate XIII, no. 2; Plate XIV, nos. 28, 29)

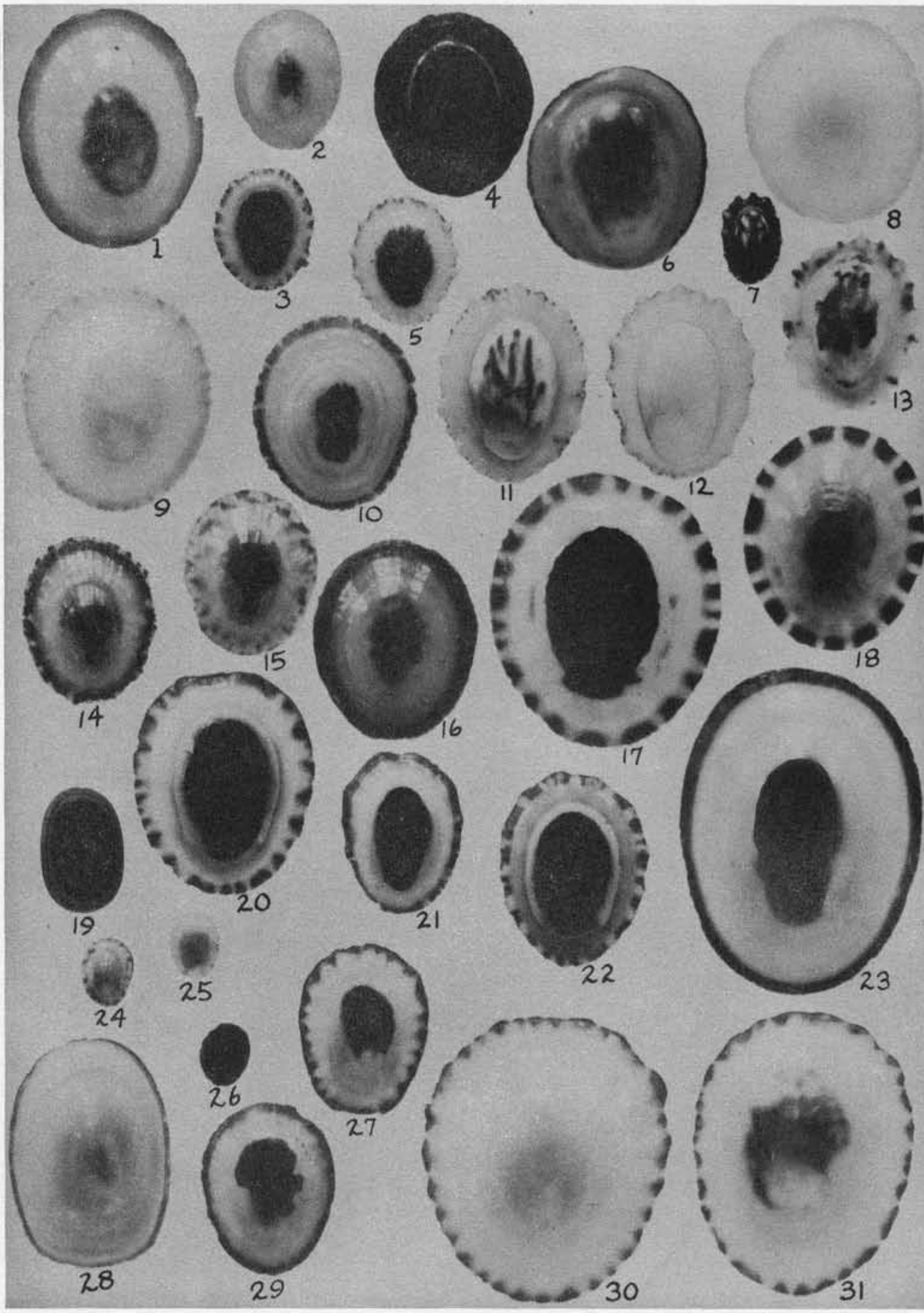
41. Shell with thread-like ribs (Plate XII, no. 14), with interspaces wider than ribs (ribs often obsolete); external coloration plain dark, or dark and white in varying patterns (Plate XII, nos. 21, 22, 29); internal color bluish-white with brown markings (Plate XIII, nos. 17, 18); large; common . . . . *Acmaea scutum* (Plate XV, nos. 10-12)
41. Shell with imbricated ribs alternating with 2-4 riblets (Plate XII, nos. 25, 31); margin finely serrate (Plate XV, nos. 14, 15); rare . . . *Acmaea limatula* (Plate XIII, nos. 9, 10, 14, 15)

42. Sides compressed, making elliptical outline (Plate XII, no. 18); bottom rocker-like; external surface grooved; color brown, often marked by white spot at apex; inner surface white with pale brown spot at apex, and narrow brown border; rare; on *Laminaria Andersonii* . . . *Acmaea instabilis* (Plate XII, no. 18; Plate XIII, no. 28)
42. Sides not compressed (except in young of *A. pelta* on seaweed); outline subcircular to ovoid 43

43. Outer surface with large, rough ribs, unless corroded; dense white within; usually with narrow, scalloped, brown border; often with brown blotch behind apex; large; common; very variable . . . . . *Acmaea pelta* (Plate XII, no. 26; Plate XIII, nos. 20, 27, 29-31; Plate XV, nos. 1-6) (See Plate XIV, nos. 23-27 for hybrids with *digitalis*)
43. Outer surface corroded and satiny, or very finely striate; inner surface suffused with brown, and highly nacreous; rare . . . . *Acmaea fenestrata* (Plate XII, nos. 13, 15; Plate XIII, nos. 4, 6; Plate XV, nos. 7-9)

44. Perforation one-third as long as shell, with a lateral projection of the shell modifying otherwise perfectly oval slit; shell less than 2 cm. long, low, narrow; in life, shell nearly hidden by mantle protruding from perforation; mantle surface at least 4 times as great as shell surface . . . . *Megatebennus* spp.
44. Perforation less than one-twelfth as long as shell; mature shell more than 25 mm. long; apex elevated 45

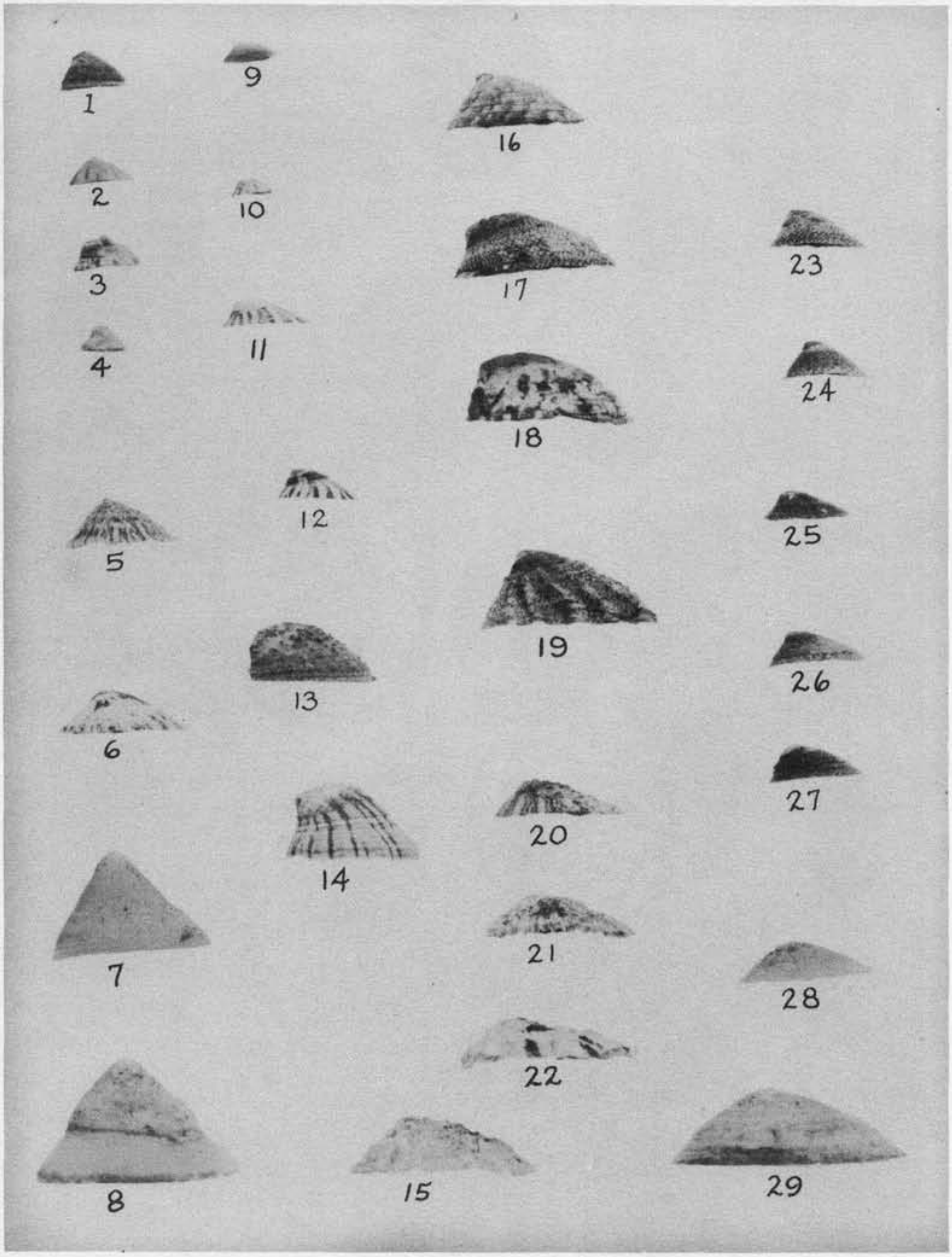
PLATE XIII



Inside view of shells of various species of *Acmaea*. Natural size. Listed alphabetically by species:

26, *A. asmi*
3, *A. cona*
21,22,24, *A. digitalis*
4,6, *A. fenestrata*
19, *A. insessa*
28, *A. instabilis*
9,10,14,15, *A. limatula*
8, *A. mitra*
1,2, *A. ochracea*
20,27,29-31, *A. pelta*
23, *A. persona*
25, *A. rosacea*
7,11-13, *A. scabra*
16-18, *A. scutum*

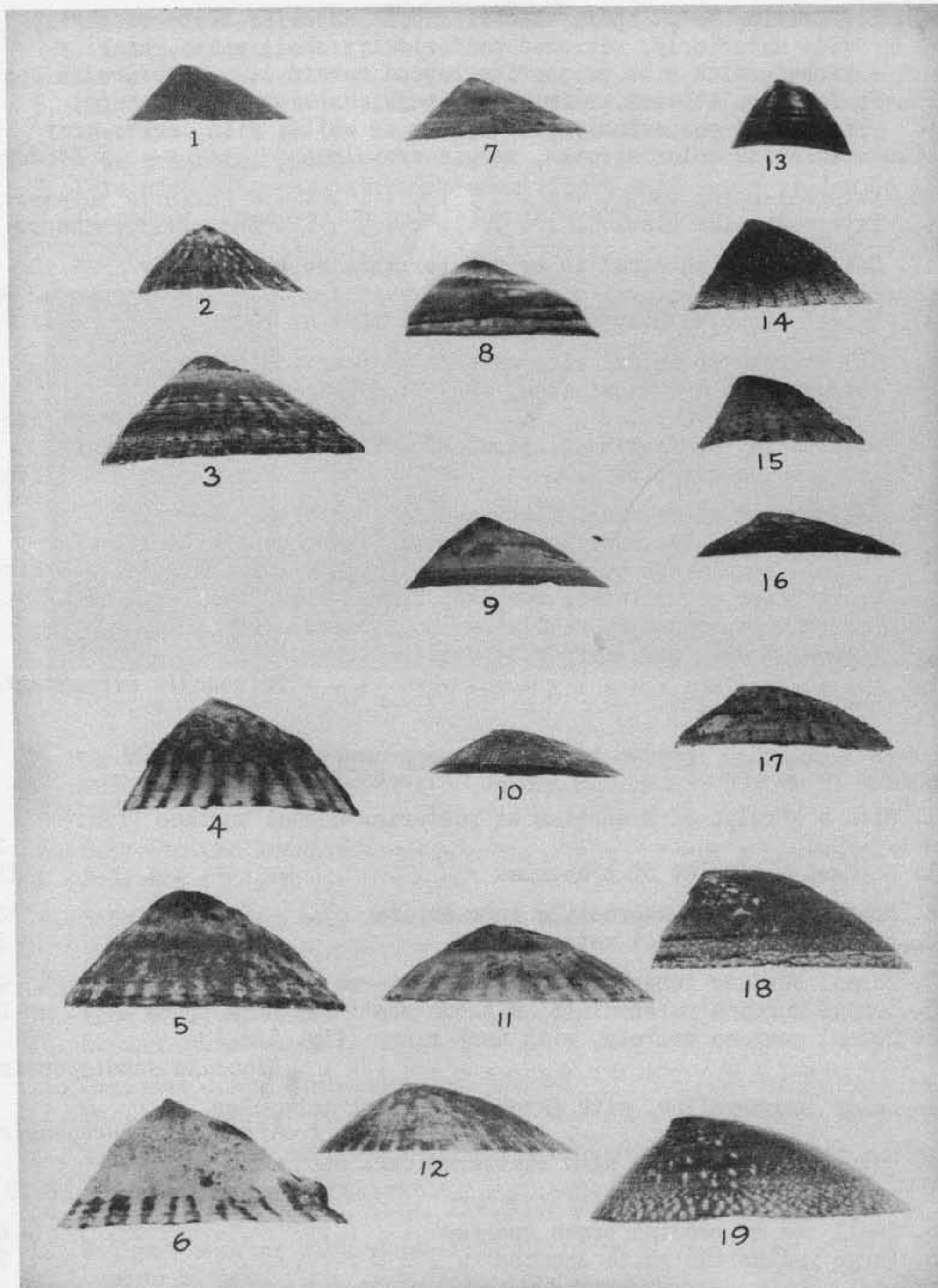
PLATE XIV



Shells of various species and one hybrid of the genus Acmaea seen in lateral view. Natural size. Listed alphabetically by species:

1, A. asmi
5,6, A. cona
3,10-14,16-19, A. digitalis
7,8, A. mitra
28,29, A. ochracea
9, A. paleacea
23-27, A. pelta x A. digitalis
2, A. rosacea
15,20-22, A. scabra
4, A. triangularis

PLATE XV



Shells of various species of Acmaea in lateral view:

1-6, A. pelta
7-9, A. fenestrata cribraria
10-12. A. scutum
13, A. insessa
14-17, A. limatula
18-19, A. persona

45. Perforation below apex, extending down anterior slope of shell, wide anteriorly, narrowed posteriorly; shell white, heavily ribbed, with ribs projecting beyond margin . . *Puncturella* spp.
45. Perforation at apex, eliminating peak, subcircular in shape, truncated posteriorly; shell gray or white, with darker gray radiating color streaks, margin crenulate . . . . *Diadora*

46. External color red . . . . *Haliotis rufescens*
46. External color black . . . . *Haliotis cracherodii*

47. Height of spire equal to or greater than height of body whorl 48
47. Height of spire distinctly less than that of body whorl 49

48. Sculpturing of spiral ribs crossed by longitudinal ribs of equal size and prominence, producing effect of basket weave . . . . *Tritonalia interfossa*
48. Sculpturing of flattened spiral ribs without prominent longitudinal cross ribs . . . . *Tritonalia gracillima*

49. Sculpturing of regular, flattened, spiral ribs not markedly interrupted by longitudinal growth lines; grooves shallow; shell regular in outline . . . . *Tritonalia lurida*
49. Sculpturing of elevated, rounded, spiral ribs, undulated by prominent, rounded, revolving longitudinal swellings; grooves deep and sharp cut; outline irregular . . . . *Tritonalia circumtexta*

KEY TO THE MORE COMMON NUDIBRANCHS

1. With a circlet of branchiae on posterior dorsal surface (fig. 126,A) 2
1. Without a circlet of branchiae 12

2. Branchial plumes retractile into cavity 3
2. Branchial plumes not retractile 8

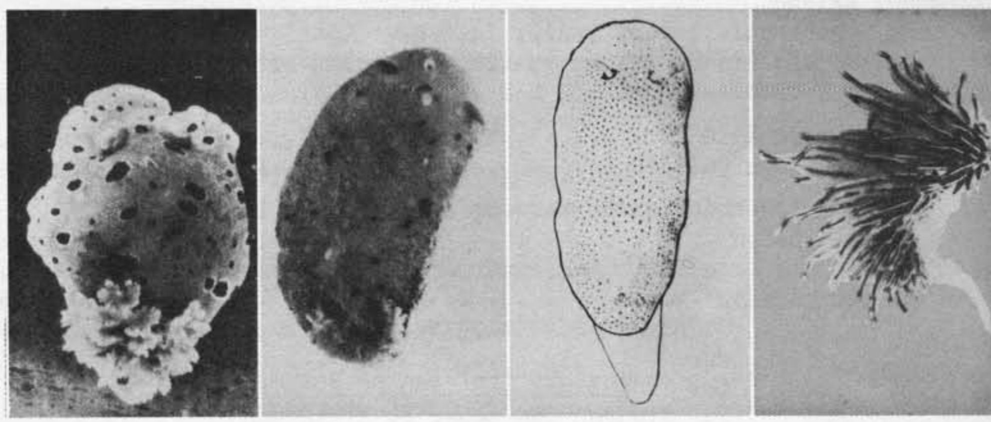
3. Dorsal surface tuberculate, with scattered dark spots 4
3. Dorsal surface tuberculate, without scattered dark spots 5
3. Dorsal surface velvety, with dark rings (fig. 126,A) . . . . *Diaulula sandiegensis*

4. Color lemon-yellow, with patches of black tubercles . . . . *Archidoris montereyensis*
4. Color bright orange, with scattered dark spots and patches . . . . *Anisodoris nobilis* (fig. 126,B)

5. Small red or reddish brown species 6
5. Large yellow and white species 7

6. Two conspicuous black spots, one in front of branchia, and one behind sense organs . . . . *Aldisa sanguinea*
6. No conspicuous black spots, but with minute red or brown papillae; often found on red sponges . . . . *Rostanga pulchra*

7. Yellow with white-tipped, scattered papillae; rhinophores dark; branchiae whitish yellow . . . . *Dendrodoris fulva*
7. Pale yellowish white with dark rhinophores and a row of lemon-yellow spots on low tubercles on each side from rhinophore to branchial plume . . . . *Cadlina flavomaculata*
7. Pale with numerous tubercles each tipped with lemon-yellow; a band of lemon-yellow outlining foot and mantle (fig. 126,C) . . . . *Cadlina marginata*



A B C D

Fig. 126.—Common nudibranchs (from Guberlet): A, Dialula sandiegensis (Cooper); B, Anisodoris nobilis (MacFarland); C, Cadlina marginata MacFarland; D, Hermissenda crassicornis (Eschscholtz).

8. Body striped longitudinally . . . . *Polycera atra*
8. Body not striped 9

9. Body brown with many small bluish-white spots dorsally . . . . *Triopha maculata*
9. Body pink or white 10

10. Body entirely pink . . . . *Hopkinsia rosacea*
10. Ground color white 11

11. Papillae long, club-like, red-tipped . . . . . . *Laila cockerelli*
11. Papillae short, red . . . . *Triopha carpenteri*

12. Without cerata or dorsal gills; mantle dark red with fine white longitudinal lines . . . . *Pleurophyllidia californica*
12. With gills or cerata (fig. 126,D) 13

13. Without cerata; with plume-like gills on ridges along either side of back . . . . *Tritonia festiva*
13. With cerata (fig. 126,D) 14

14. Cerata brilliantly colored; body with brilliantly colored areas . . . . *Hermissenda crassicornis* (fig. 126,D)
14. Cerata and body without brilliant coloring 15

15. Cerata very numerous; feeding on sea anemones . . . . *Aeolidia papillosa*
15. Cerata larger, less numerous; feeding on *Tubularia* . . *Alderia* sp.

A KEY TO THE COMMON GENERA OF FRESHWATER SNAILS

1. Shell dextral 2
1. Shell sinistral 4

2. Shell spired 3
2. Shell planispiral; very small; flat or slightly depressed above, deeply umbilicate below; aperture somewhat expanded . . . . *Planorbula (= Planorbis)*

3. Large; operculate . . . . *Viviparus*
3. Small; not operculate . . . . *Fossaria (= Lymnaea)*

4. Spired; spire acute or depressed; aperture contracted above, rounded below . . . . *Physella (= Physa)*
4. Planispiral; base funicular; aperture suddenly expanded and thickened; few whorls . . . . *Helisoma*

KEY TO THE SHELLED LAND PULMONATES
(For figures see paper by Nicholson)

A. Shell minute:

1. Elongate:

   1'. Length $2\frac{1}{2}$ mm.; dark brown to black; dull . . . . *Vertigo californica*
   2'. Length 6 mm.; yellowish-brown; glossy . . *Cochlicopa lubrica*

1. Depressed:

   1'. Widely umbilicated; 3 whorls; diameter 1.5 mm.; ash-gray to white in color . . . . *Striatura milium*
   2'. Moderately umbilicated; 4 whorls; diameter 2 mm.; dark brown (horn) in color . . . . *Punctum conspectum*
   3'. Slightly umbilicated; $4\frac{1}{4}$ whorls; diameter 2 mm.; light horn to white in color . . . . *Pristiloma nicholsoni*

B. Shell 6-8 mm. in diameter; depressed; moderately, but deeply, umbilicated; 5 whorls; light to dark brown in color; oblique . . . . *Polygyra loricata*

C. Shell 14-18 mm. in diameter; depressed; moderately umbilicated; 6 whorls; dark to yellowish-brown; hirsute; some with parietal tooth . . . . *Polygyra columbiana*

D. Shell 20-30 mm. in diameter; depressed; widely umbilicated; 5 whorls; greenish-yellow in color . . . *Haplotrema vancouverensis*

E. Shell 25-40 mm. in diameter; depressed.

1. Imperforate (no umbilicus); 4 whorls; globose; yellowish to russet; banded; diameter 25-40 mm. . . . . *Helix aspersa*
2. Minutely umbilicated; 5 whorls; pale horn color to ash-yellow; superior chestnut narrow band; diameter 25-40 mm. . . . . *Helminthoglypta nickliniana*
3. Moderately umbilicated
   1'. $6\frac{1}{2}$ whorls; brown on top, black beneath; body whorl angulated; 35-38 mm. . . . . . . *Helminthoglypta infumata*
   2'. 7 whorls; light brown to yellowish in color with superior chestnut band; body whorl rounded; often dark brown; 34-40 mm. . . . . *Helminthoglypta arrosa*

FIELD KEY TO THE LOCAL LAND SLUGS
(For figures see paper by Waste, 1938)

1. Respiratory orifice anterior to middle of mantle . . . . *Prophysaon andersoni*
1. Respiratory orifice posterior to middle of mantle 2

2. Tip of tail excavated, with a mucus pit . . . *Ariolimax columbianus*
2. Tip of tail conical, not excavated 3

3. Central oval area on mantle marked by a groove . . . *Milax gagetes*
3. Mantle without demarcated central area, but ornamented with closely concentric grooves over whole surface 4

4. Conspicuous irregular stripes on body . . . . *Limax maximus*
4. Body at most spotted, never striped 5

5. Color pattern a mosaic of black, gray, or buff-colored areas bounded by anastomosing grooves; slime yellow . . . *Limax flavus*
5. Body coloration and reticulation of the integument not in correspondence; slime not yellow 6

6. Larger, adults about 40 mm. long; secreting abundant milky slime when touched; color of back variable usually gray, or ocherous buff with dark gray patches shading rarely to almost uniform black . . . . *Agriolimax agrestis*
6. Smaller; hardly reaching a length of 30 mm., secreting very little milky slime; color uniform . . . . *Agriolimax campestris*

LIST OF SPECIES OF LOCAL GASTROPODA EXCLUSIVE OF THE PULMONATES

Order Streptoneura (Prosobranchiata)

Suborder Aspidobranchiata (Diotocardia)

D *M	*Acmaea asmi* Middendorf
D *B *M	*Acmaea digitalis* Eschscholtz
TB D B M	*Acmaea fenestrata* (Reeve)
D M	*Acmaea insessa* (Hinds)

Suborder Aspidobranchiata (Diotocardia) *(Continued)*

M *Acmaea instabilis* (Gould)
M *Acmaea limatula* Carpenter
D *M *Acmaea mitra* Eschscholtz
M *Acmaea ochracea* Dall
D M *Acmaea paleacea* (Gould)
D *B *M *Acmaea pelta* Eschscholtz
B *M *Acmaea persona* Eschscholtz
D *B *M *Acmaea scabra* (Gould)
D B *M *Acmaea scutum* Eschscholtz
M *Acmaea triangularis* Carpenter
M *Astraea inaequalis* (Martyn)
D M *Calliostoma canaliculatum* (Martyn)
D *M *Calliostoma costatum* (Martyn)
M *Calliostoma tricolor* Gabb
D M *Diodora aspera* (Eschscholtz)
D M *Haliotis cracherodii* Leach
D M *Haliotis rufescens* Swainson
D *M *Homalopoma carpenteri* (Pilsbry)
D M *Lottia gigantea* Sowerby
*M *Margarites lirulatus* (Carpenter)
*M *Margarites pupillus* (Gould)
M *Margarites salmoneus* (Carpenter)
M *Margarites succincta* (Carpenter)
M *Megatebennus bimaculatus* (Dall)
D *M *Tegula brunnea* Philippi
D *M *Tegula funebralis* Adams
M *Tegula ligulata* (Menke)
M *Tegula montereyi* Kiener
M *Tegula pulligo* (Martyn)

Suborder Pectinibranchiata (Monotocardia)

D *M *Acanthina spirata* Blainville
M *Aletes squamigerus* (Carpenter)
M *Alvania hartmanae* Vokes
D M *Amphissa bicolor* Dall
M *Amphissa columbiana* Dall
M *Amphissa versicolor* Dall
D M *Barleeia haliotiphila* Carpenter
M *Barleeia oldroydi* Bartsch
D *M *Bittium eschrichtii* (Middendorff)
M *Bivonia compacta* Carpenter
TB M *Cerithidea californica* (Haldeman)
M *Cingula californica* Tryon
M *Cingula montereyensis* Bartsch
M *Clathrodrillia incisa* (Carpenter)
M *Conus californicus* Hinds
D *M *Crepidula adunca* Sowerby
B M *Crepidula convexa glauca* Say
M *Crepidula lingulata* Gould
D *M *Crepidula nummaria* Gould

Suborder Pectinibranchiata (Monotocardia) *(Continued)*

D M *Cypraeolina pyriformis* (Carpenter)
M *Diala acuta* Carpenter
D M *Epitonium indianorum* (Carpenter)
*M *Epitonium tinctum* (Carpenter)
M *Epitonium wroblewskii* (Morch)
D *M *Hipponix antiquatus* (Linnaeus)
D *Hipponix tumens* Carpenter
*B *Ilyanassa (Nassarius) obsoleta* (Say)
D *M *Lacuna marmorata* Dall
M *Lacuna porrecta* Carpenter
M *Lamellaria*
D B *M *Littorina planaxis* Philippi
D *B *M *Littorina scutulata* Gould
M *Marginella* (?)
M *Mitra*
D *M *Mitrella (= Columbella) carinata* (Hinds)
*M *Mitrella gouldii* (Carpenter)
*M *Mitrella tuberosa* (Carpenter)
*M *Nassarius mendicus* Gould
M *Nassarius perpinguis* Hinds
M *Odostomia oregonensis* Dall and Bartsch
TB *M *Olivella biplicata* (Sowerby)
M *Phasianella compta* Gould
M *Pseudomelatoma torosa* (Carpenter)
D M *Purpura foliata* Martyn
D *M *Searlesia dira* (Reeve)
M *Spiroglyphus lituellus* Morch
D M *Thais canaliculata* (Duclos)
D *M *Thais emarginata* Deshayes
D *B M *Thais lamellosa* (Gmelin)
D *M *Tritonalia circumtexta* Carpenter
*M *Tritonalia foveolata* Hinds
M *Tritonalia gracillima* Stearns
*M *Tritonalia interfossa* Carpenter
D *M *Tritonalia lurida* Middendorff
M *Tritonalia painei* Dall
M *Tritonalia subangulata* Stearns
D M *Trivia*
M *Turbonilla*
*B *Urosalpinx cinereus* (Say)
M *Velutina laevigata* Muller
F *Viviparus japonicus* von Martens
F *Viviparus malleatus* Reeve

Order Opisthobranchiata

Suborder Tectibranchiata

TB *Actaeon punctocaelata* (Carpenter)
M *Haminoea vesicula* (Gould)
TB *Phyllaplysia taylori* Dall
B *Tethys californica* (Cooper)

Class PELECYPODA

On a fresh or preserved clam locate the hinge at the dorsal side, the gape at the ventral side of the shell, the siphons, exhalent (dorsal) and inhalent, either separate, as in *Macoma*, or united to

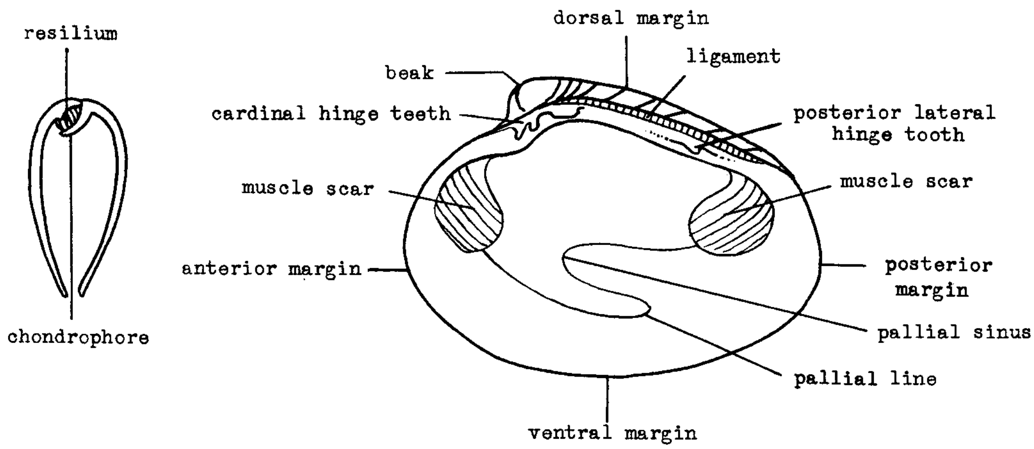


Fig. 127. The pelecypod shell, terminology (after Keen and Frizzell): A, cross section; B, right valve.

form a "neck," as in *Mya* or *Schizothaerus*. Remove one valve to see the mantle folds and the relations of the siphon to them. Within the mantle chamber make out the gills two pairs of labial palps, located on either side of the mouth, the visceral mass and foot, making up the body proper, and the anterior and posterior adductor muscles running between the two valves of the shell.

The major divisions (orders) of the Pelecypoda are based in part at least on the structure of the gills. We shall deal with two orders. The *Filibranchia* are characterized by gills in the form of parallel filaments and by a holdfast, typically of numerous threads, known as a byssus. Here belong the jingles (*Pododesmus*, fig. 129,A), the marine mussels (*Mytilus* and *Modiolus*) and the pectens or scallops (*Pecten*, *Hinnites*, fig. 129,B).

The great majority of pelecypods belong to the order Eulamellibranchia. This includes the oysters, the clams, the freshwater mussels, the boring clams and the shipworms (*Teredo*). They are characterized by lamellar gills composed of completely joined filaments.

See slides of permanent mounts of sections of *Mya* and *Mytilus* to show these two types of gill structure and study pieces of the gills of each from freshly collected specimens. On these last note also the powerful ciliary action.

The common names ordinarily used for groups of pelecypods are not derived from the names of the orders but are true vernacular names, such as oysters, scallops, rock oysters or jingles, sea mussels, freshwater mussels, clams, etc.

Classification of pelecypods to genus and species is based largely on characters of the shell. On the shell given you, orient yourself by remembering that the hinge is dorsal and that the umbo lies nearest the anterior end and the beak (fig. 127) is often inclined toward it. On the exterior of the shell note the concentric growth lines and the radiating striae. On the inner surface locate the pallial line (fig. 127) connecting the anterior and posterior muscle scars, and the pallial sinus (fig. 127), marking the position of the siphonal muscles in life. At the dorsal margin see the hinge teeth (fig. 127) and the remnants of the ligament.

The cardinal teeth are directly under the umbo and the lateral teeth either in front of or behind the umbo, if in front they are antero-laterals, if behind posterior-laterals.

Understand the following commonly encountered terms which are illustrated by demonstration specimens; integripalliate, lacking a pallial sinus (*Clinocardium*); sinupalliate, with a pallial sinus (*Protothaca*); dimyarian, with two adductor muscles; isomyarian, with adductor muscles approximately equal in size (*Protothaca*); heteromyarian, with adductor muscles strikingly unequal (*Mytilus*); monomyarian, with a single adductor muscle (*Ostrea, Pecten*); chondrophore (fig. 127), shelf-like process of left valve to which is attached the ligament (*Mya*); myophore (fig. 128), a more or less extended, inwardly directed, process to which muscles are attached in the boring clams. Identify your specimen by means of the key which follows.

Read the introduction to Illustrated Key to West North American Pelecypod Genera, by Keen and Frizzell, and identify several specimens by it. This excellent publication should be owned if possible and consulted extensively.

Each student should sample also Weymouth, Oldroyd, and Packard.

KEY TO THE MORE COMMON PELECYPODA

1. Two valves distinctly different due to attachment by one valve; one or both valves markedly rough and irregular (fig. 129,A,B) 34
1. Two valves approximately alike, not especially irregular; attached by byssus or not at all 2

2. Brown to black; valves elongated, with umbo at or very near end 3
2. Light colored; valves not especially elongated or if so not with umbo near end 8

3. Rock borers; narrow 4
3. Attached to rocks or piles, or half buried in mud 5

4. Smooth externally . . . . "The Smooth Pea-Pod Borer," *Botula californiensis*
4. With fine, transverse ridges over most of shell; color uniform . . . . "The Rough Pea-Pod Borer," *Botula falcata*
4. With coarser, oblique ridges at posterior end; color obscured over part of shell; shell wider than in *Botula* but with posterior end markedly pointed . . . . *Lithophaga plumula*

5. Hinge and beaks at extreme tip (*Mytilus*) 6
5. Hinge and beaks at side or subterminal (*Modiolus*) 7

6. Larger; narrower with a few longitudinal ribs; growth lines prominent; brown to black-brown . . . . "The California Sea Mussel," *Mytilus californianus*
6. Smaller; broader; smooth; black . "The Bay Mussel," *Mytilus edulis*

7. Large; without ribs; width nearly uniform; buried portion dark brown, polished; free portion yellowish, hairy . . . . *Modiolus (= Volsella) rectus*
7. Smaller; with prominent radiating, longitudinal ribs; hinge end narrowed . . . . *Modiolus demissus*

8. Both valves swollen anteriorly and sculptured for boring rocks (fig. 129,C) 32
8. Not so (except for *Petricola pholadiformis* which is sculptured anteriorly) 9

9. With radiating ribs 10
9. Without ribs but often striated 14

10. Each valve with flat expansions in front of and behind umbo; monomyarian . . . . *Pecten*
10. No such expansions; dimyarian 11

11. Ribs of approximately same type and size throughout; shell suborbicular or subquadrate 12
11. With a few large anterior ribs and numerous narrow ribs on remainder of shell; shell elongated . . *Petricola pholadiformis*

12. Very small, shell subquadrate . . . . *Glans carpenteri*
12. Shell larger, suborbicular 13

13. Ribs broad and prominent; growth lines not marked; margin scalloped; integripalliate . . . . "The Basket Cockle," *Clinocardium nuttallii (= Cardium)*
13. Ribs narrow; growth lines prominent; margin not scalloped but often distorted; sinupalliate . ."The Rock Cockle," *Protothaca (= Venerupis = Paphia) staminea*
14. Concentric growth lines prominent, often protruding; shape irregular, often distorted owing to its being a nestler . . . 15
14. Not so 17

15. Growth lines in form of thin prominently projecting flanges, ... *Irus (= Venerupis) lamellifera*
15. Not so 16

16. Median cardinal tooth (fig. 127) prominent, plate-like; growth lines close set and relatively regular; shell without periostracum; tips of siphons bright purple . . . ."The Rock Dweller," *Petricola carditoides*
16. Without cardinal teeth; growth lines irregular in shape and distribution; shell chalky, covered with a brown periostracum, some remnants of which are present in nearly all old shells; siphon tips red . . . . *Saxicava pholadis*

17. In colony of compound ascidians; higher than long . . . . *Mytilimeria nuttallii*
17. Not associated with ascidians 18

18. Small, less than an inch long 19
18. Not so 24

19. Marine 20
19. In freshwater; teeth minute or obsolete; suborbicular . *Musculium*

20. 5 mm. long or less 21
20. More than 5 mm. long when adult 23

21. Shell rosy; with transverse chondrophore in both valves; nestling in barnacle beds . . . . Unidentified
21. Shell white; without transverse chondrophore 22

22. Sinus deep, dorsally directed; lateral teeth not conspicuous . . . . *Gemma gemma*
22. Sinus not noticeable or anteriorly directed; lateral teeth conspicuous, ridge-like . . . . *Psephidia*

23. Nestler in pholad holes; teeth prominent; shell short, oval, smooth with gleaming green periostracum . . . . *Kellia (= Chironia) laperousii*
23. Often in kelp holdfasts; almost three times as long as high; teeth inconspicuous . . . . *Lyonsia californica*

24. Long-oval, much elongated; with a prominent ridge running downward from the teeth on the inside of each valve . . . . "The Razor Clams," *Siliqua*
24. Not so 25

25. Both valves bent to the right at the posterior end . . . . "The Bent-Nosed Clam," *Macoma nasuta*
25. Not so 26

26. Without chondrophore 27
26. With chondrophore (fig. 127) or pseudochondrophore 29

27. Thick; subquadrate; gaping widely . "The Geoduck," *Panope generosa*
27. Thin, ends rounded or pointed 28

28. Larger, up to 4 inches long; posterior end somewhat pointed; without conspicuous periostracum . . . . *Macoma secta*
28. Smaller, up to 2 inches long; both ends rounded; with conspicuous brown periostracum . . . . *Macoma irus (= inquinata)*

29. A vertical chondrophore on each valve; a brown tent-shaped cardinal tooth on left valve; gaping widely behind . . . ."The Giant Clam," *Schizothaerus*
29. A conspicuous horizontal chondrophore on one or both valves . . 30

30. Umbo at or near center 31
30. Umbo near posterior end; both ends truncate . . . . *Platyodon cancellatus*

31. Posterior end truncate, with faint external striations; commensal with Callianassa . . . . *Cryptomya californica*
31. Posterior end somewhat pointed, without external striations . . . . *Mya arenaria*

32. Sculpture fine to moderate, confined to a triangular section of anterior half of shell, consisting of fine concentric ridges undulated by fine radial ridges; with one or more conspicuous accessory plates along dorsal margin (fig. 128) . 33
32. Sculpture coarse, over anterior half of shell, consisting of coarse concentric ridges prolonged into spines at regular intervals which are therefore in radiating rows; without conspicuous accessory plates . . . . *Zirfaea*

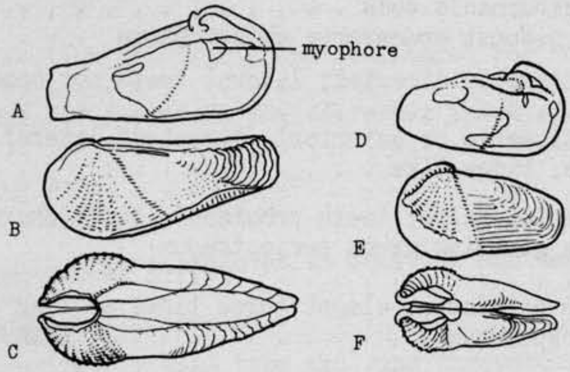


Fig. 128. Rock borers (after Keen and Frizzell): A-C, Parapholas californica (Conrad); D-F, Pholadidea penita Conrad.

33. Dorsal margin doubled and reflected both anterior and posterior to beaks; posterior half of shell divided approximately in half by a conspicuous radiating angle which marks change in direction of concentric lines; a conspicuous posterior extension of brown periostracum; siphon tips pale lavender . . . . *Parapholas californica* (fig. 128,A-C)

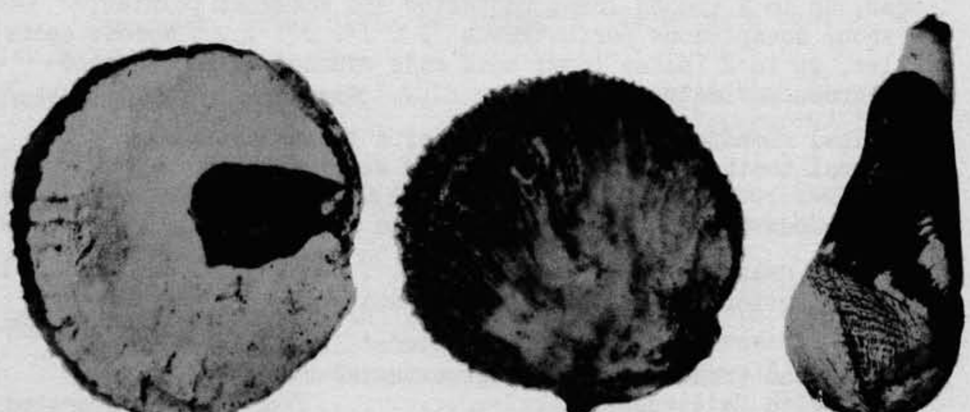


Fig. 129. A, Pododesmus macroschisma (Deshayes); B, Hinnites multirugosus (see Gale) (= "giganteus Gray"); C, Pholadidea penita Conrad. (All from Guberlet.)

33. Dorsal margin doubled only anterior to beaks; without conspicuous radiating angle; no posterior extension of periostracum; siphon tips white with faint brownish tinge . . . . *Pholadidea penita* (figs. 128,E-F, 129,C)

34. Lower valve with hole or deep notch near hinge . . . . "The Rock Jungle," *Pododesmus* (fig. 129,A)

34. Both valves entire 35

35. Large, approximately circular, with distinct wings on either side of umbo; purplish within; with radiating ribs; left valve and younger portions of right valve distorted . . . . "The Rock Scallop," *Hinnites* (fig. 129,B)

35. Small, with pointed beak; elongate to circular; surface of upper valve laminated or irregularly plaited . . . ."The Western Oyster," *Ostrea lurida*

LIST OF PELECYPODA

Order Filibranchiata

*M *Botula californiensis* Philippi
*M *Botula falcata* Gould
D *M *Hinnites multirugosus* (Gale) (= "*H. giganteus* Gray")
M *Lithophaga plumula* Hanley
*B *Modiolus (= Volsella) demissus* Dillwyn
*M *Modiolus rectus* Conrad
D *M *Mytilus californianus* Conrad
*B *Mytilus edulis* Linnaeus
D *M *Pododesmus macroschismus* Deshayes
Septifer bifurcatus (Conrad)

Order Eulamellibranchiata

*B *Bankia setacea* (Tryon)
TB B M *Clinocardium nuttallii* (Conrad) (= *Cardium corbis*)
B *Cryptomya californica* (Conrad)
B *Gemma gemma* (Totten)
M *Glans carpenteri* (Lamy) (= *Cardita subquadrata*)
D M *Irus (= Venerupis) lamellifer* (Conrad)
D *M *Kellia (= Chironia) laperousii* (Deshayes)
B *Macoma inconspicua* (Broderip and Sowerby) (= *M. balthica*)
*B TB *Macoma irus* (Hanley) (= *M. inquinata*)
*B TB M *Macoma nasuta* Conrad
TB *Macoma secta* Conrad
M *Milneria minima* (Dall)
*F *Musculium*
*B M *Mya arenaria* Linnaeus
D M *Mytilimeria nuttallii* Conrad
B *Ostrea gigas* Thunberg, Japanese Oyster
*B M *Ostrea lurida* Carpenter
TB *Panope generosa* Gould, The Geoduck
M *Parapholas californica* (Conrad)
*M *Petricola carditoides* Conrad
B *Petricola pholadiformis* Lamarck

Order Eulamellibranchiata *(Continued)*

D M *Pholadidea parva* Tryon
D *M *Pholadidea penita* (Conrad)
M *Platyodon cancellatus* Conrad
*B D *M *Protothaca* (variously *Paphia* or *Venerupis*) *staminea* (Conrad)
D M *Psephidia lordi* Baird
TB *Sanguinolaria nuttallii* (Conrad)
D *M *Saxicava pholadis* (Linnaeus)
TB *Saxidomus nuttallii* Conrad
B TB *Schizothaerus nuttallii* (Conrad)
B *Siliqua lucida* Conrad
B *Siliqua patula* (Dixon)
TB *Tellina bodegensis* Hinds
*B *Teredo navalis* Linnaeus
M *Zirfaea pilsbryi* Lowe (= *Z. gabbi*)

PHYLUM ENTOPROCTA (Kamptozoa, Calyssozoa)

This group has usually been included with the Bryozoa, but differs from it fundamentally in structure. The term entoproct refers to the inclusion of the anus within the circle of tentacles (the anus is outside in the true or ectoproct Bryozoa). Externally, the simplest way to distinguish the two is to note whether the tentacles are folded into the center when withdrawn (as in a hydroid), in which case it is an entoproct, or whether the whole anterior end of the body is introverted into the basal part, with the tentacles still pointing forward, in which case it is an ectoproct. The nodding movement of individual zooids is also characteristic of the Entoprocta. The Entoprocta are much less common than the Ectoprocta, but will probably be collected as they are often found forming small, moss-like patches on coralline algae.

PHYLUM BRYOZOA (Ectoprocta)

Under the low power of the microscope see that the colony or zoarium is composed of numerous individuals. Make yourself familiar with the terms defined below which commonly occur in keys and descriptions. Each individual consists of a zooecium (pl. zooecia) and a polypide. The zooecium is a chamber or sack, the proximal portion of the individual, and is covered externally by a secreted wall of calcareous, chitinous, or rarely, gelatinous, or membranous nature. The polypide is the distal half of the individual, when extended, including the lophophore (which bears the tentacle) and the alimentary tract. The polypide is retractile within the zooecium. The opening at the end of the zooecium when the polypide is withdrawn is the orifice (Plate XVI,B). The front wall of the zooecium is often called the aperture. Do not confuse this with the orifice.

Avicularia (sing. avicularium) are bird's-head-like appendages of the zooecia of certain species. Vibracularia (vibracula) are long seta-like appendages of the zooecia of certain species. The ooecium (pl. ooecia) or ovicell is an expanded chamber, above a zooecium, in which the embryos develop.

Zoaria may be creeping, erect, suberect, encrusting, flexible, or stiff. They may be articulated (divided into internodes by joints or nodes) or nonarticulated (Plate XVI).

See expanded living individuals. Seek to identify common species by means of the key which follows.

A PRELIMINARY KEY TO THE BRYOZOA AND ENTOPROCTA OF THE MOSS BEACH REGION

1. Individuals composed of distinct stalk and body regions and connected by stolons; individuals separately moveable. ENTOPROCTA (base of stalk bulbous) . . . . *Pedicellina (Barentsia) gracilis* (Plate XVI,A)
1. Colony (zoarium) composed of individuals (zooecia) not readily divisible into stalk and body regions; individuals usually not movable. ECTOPROCTA 2

2. Colony gelatinous; zooecia without calcareous skeletons. CTENOSTOMATA 3
2. Zooecia with calcareous skeletons 4

3. Zoarium brownish, covered with branched reddish, spine-shaped projections which arise from between the zooecia; zooecia hardly discernible; colony resembling seaweed . . . . *Alcyonidium cervicornis*
3. Zoarium gray or colorless, without spines; zooecia with distinct outlines . . . . *A. mytili*

4. Zooecia tube-like, with orifice at one end (Plate XVI,C,D); colony branching. CYCLOSTOMATA 5
4. Zooecia box-like, orifice on "front" (Plate XVI,B,E). CHEILOSTOMATA 6

5. Zooecia uniserial, with joints between each; joints black, giving characteristic speckled appearance to older parts of colony (Plate XVI,C) . . . . *Crisidia franciscana*
5. Zooecia biserial; joints few, not present between each zooecium (Plate XVI,D) . . . . *Crisia pacifica*

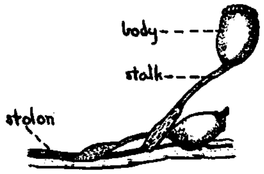
6. Zoarium encrusting rocks, algae, shells, other Bryozoa, etc. . . 7
6. Zoarium not encrusting, but forming a branching mass 17

7. Front almost entirely occupied by large orifice 8
7. Orifice covers not more than half of the front 9

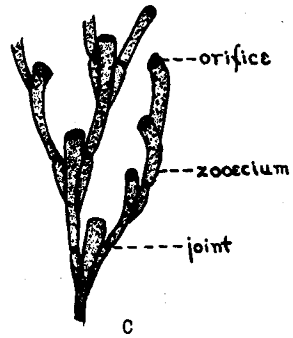
8. Avicularia sessile, in spaces between zooecia . . *Callopora horrida*
8. Avicularia stalked, among spines surrounding orifice (Plate XVI,F) . . . . *Caulorамphus spinifer*

9. Front wall calcareous, crossed by somewhat irregular rows of large pores . . . . *Cribrilina* sp.
9. Front wall calcareous, not traversed by rows of pores, but sometimes with scattered small ones 10
9. Front wall membranous, with small semicircular orifice; zooecium oblong, margins slightly raised . . . . *Membranipora membranacea* (fig. 130,A)

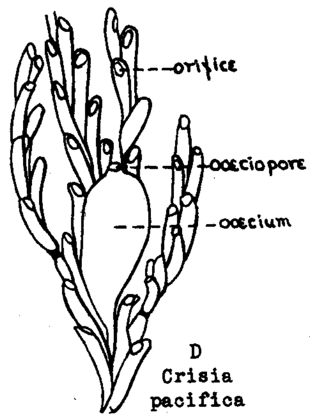
PLATE XVI



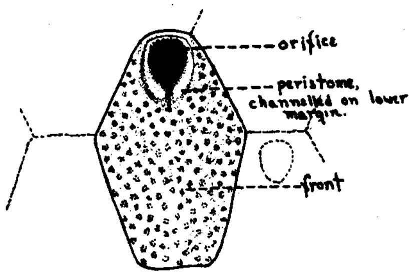
A
Pedicellina gracilis



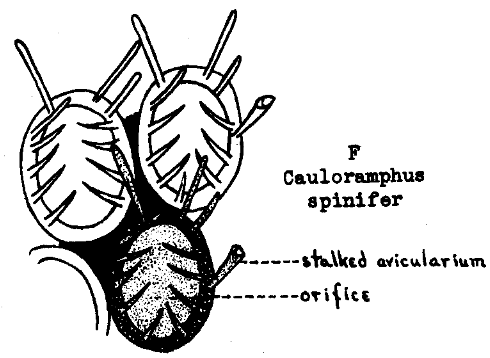
C
Crisidia franciscana



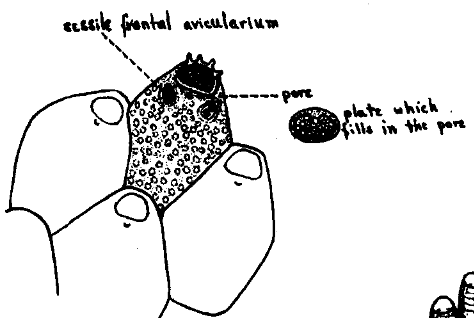
D
Crisia pacifica



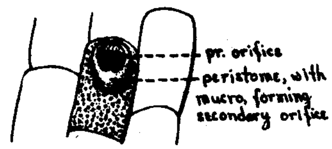
B
Schematic zooecium



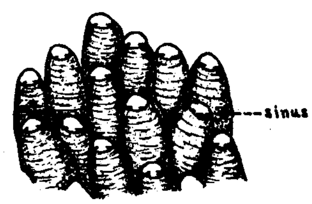
F
Cauloramphus spinifer



E
Microporella ciliata



H
Mucronella sp.



G
Hippothoa hyalina

Bryozoa and Entoprocta (figures partially after Robertson)

10. Zooecium possesses a special semicircular pore, with a sieve-plate in it, below the orifice; orifice semicircular, with straight lower margin (Plate XVI,E) 11
10. Zooecium without special pore 12

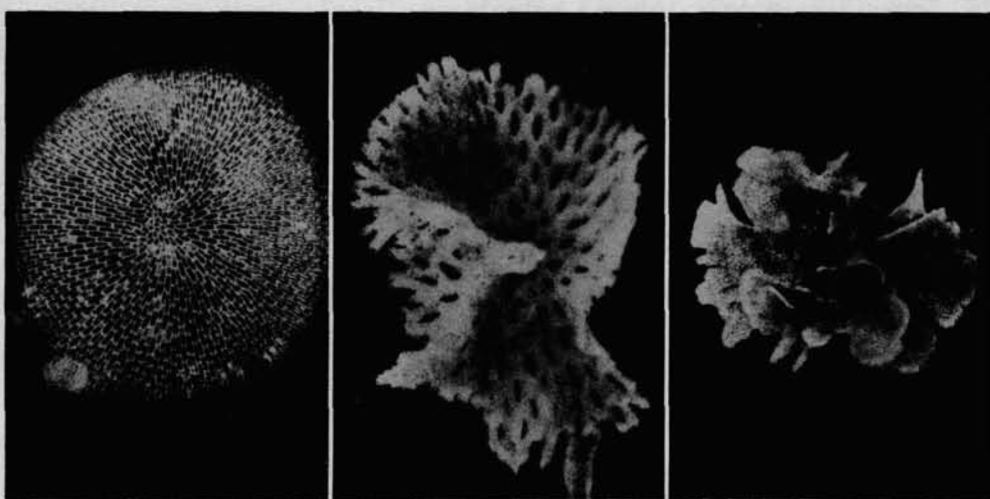


Fig. 130. Bryozoan colonies (from Guberlet): A, Membranipora membranacea (Linnaeus); B, Retepora pacifica Robertson; C, Flustra lichenoides Robertson.

11. Zooecium bears spines above the orifice . . . . *Microporella ciliata* (Plate XVI,E)
11. Zooecium does not bear spines . . . . *M. californica*
12. Orifice simple, usually contracted near the lower margin, covered with brown operculum; color of zoarium in life old rose . . . . *Eurystomella bilabiata*
12. Not as above 13
13. Orifice simple, with narrow sinus on lower margin; zooecium with transverse ridges (Plate XVI,G) . . . . *Hippothoa hyalina*
13. Secondary orifice developed by growth of peristome (Plate XVI,H) 14
14. Orifice with deep sinus on lower margin; zooecia erect or sub-erect, heaped together . . . . *Costazzia incrassata*
14. Orifice without sinus on lower margin; zooecia not erect . . . 15
15. Peristome elevated, forming secondary orifice channeled on lower margin (Plate XVI,B); primary orifice dentate 16
15. Peristome elevated, forming secondary orifice, which has a mucro or tooth on its lower margin (Plate XVI,H) . . . . *Mucronella* sp.
16. Zooecium with two spines on upper margin of orifice and two or three large blunt protuberances below the orifice . . . . *Smittina collifera*
16. Zooecium spineless, with no large protuberances . . . . *Smittina reticulata*

17. Branching regular; one or more main trunks, from which periodic whorls of branches are given off; colony has the appearance of having been twisted into a spiral . . . . *Bugula californica*
17. Branching much less regular than above; branches do not come off in whorls 18

18. Zooecia have only lateral avicularia; joints occur usually between every three zooecia . . . . *Menipea occidentalis*
18. Zooecia have frontal avicularia as well as lateral ones. More than three zooecia between each joint . . . . *Scrupocellaria californica*

LIST OF ENTOPROCTA AND BRYOZOA

KAMPTOZOA (ENTOPROCTA)

Barentsia (= Pedicellina) gracilis Lomas

BRYOZOA (ECTOPROCTA)

Order Phylactolaemata

Plumatella (fresh water)

Order Gymnolaemata

Suborder Ctenostomata

D *M *Alcyonidium cervicornis* Robertson
Alcyonidium mytili Dalyell

Suborder Cyclostomata

Crisia pacifica Robertson
Crisidia franciscana Robertson

Suborder Cheilostomata

D *M *Bugula californica* Robertson
Callopora horrida Hincks
Cauloramphus spinifer Johnston
Costazzia incrassata Lamarck
Cribrilina sp.
Eurystomella bilabiata Hincks
Hippothoa hyalina Linn.
Menipea occidentalis Trask
B TB D *Membranipora membranacea* Linn.
Microporella californica Busk
Microporella ciliata
Mucronella sp.
Scrupocellaria californica Trask
Smittina collifera Robertson
Smittina reticulata Macgillivray

PHYLUM PHORONIDEA

This is a very small phylum with but two genera (*Phoronis* and *Phoronopsis*) and relatively few species. Under favorable conditions they occur in great numbers as in Elkhorn Slough, Bolinas Bay, and Tomales Bay. In the upper end of Tomales Bay students have estimated that over a billion individuals were living in one acre. Six species have been reported from the Pacific Coast, two from British Columbia, one from Humboldt Bay and Puget Sound, and three from southern California. Just which species (one, two, or more) occur in central California is not known. The special paper of T. H. Bullock represents the only attempt to identify these animals in this vicinity.

Study preserved specimens. Keep in mind that while they are elongated worm-like animals the mouth and anus open close together and that terms of orientation such as anterior and posterior must be used with caution. Note the lophophore, the great double semicircular whorl of tentacles with incoiled ventral edges, the cilia on which serve to set up currents which bring plankton to the mouth.

If time permits, study sections to get some idea of the interesting anatomy of this type. Consult Borradaile and Potts or Cambridge Natural History for figures.

PHYLUM BRACHIOPODA

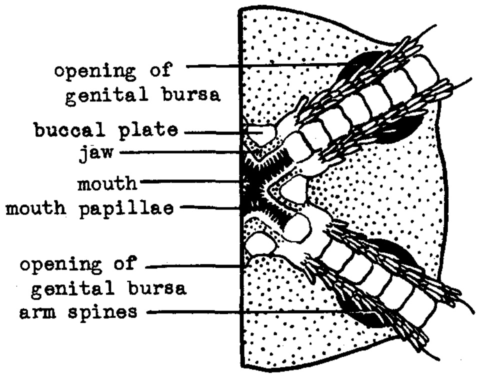
A very few small individuals of this small phylum are found at the lowest tide levels in this region. They belong to a species, *Terebratalia transversa* (Sowerby), found in large numbers in deeper waters or in shallow waters farther north.

The two-valved shell suggests a pelecypod mollusk but they are entirely different structural types. Superficially they are easily differentiated by the unequal valves of the shell which are dorsal and ventral instead of right and left.

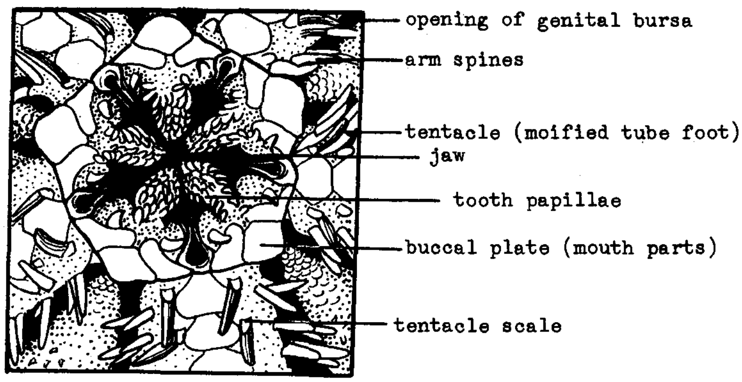
PHYLUM ECHINODERMATA

The present-day echinoderms fall into five distinct classes, the Asteroidea or sea stars (starfishes), the Ophiuroidea or brittle stars, the Echinoidea or sea urchins, the Holothuroidea or sea cucumbers, and the Crinoidea or crinoids (sea lilies). All save the last class have representatives in the local fauna. Make certain that you are able to recognize and distinguish the members of these classes. Since only the class Asteroidea is represented by a number of species, we shall confine our laboratory study to the sea stars.

On a sea star make out the radiating rays or arms, the oral surface with the central mouth, the ambulacral groove, in the oral surface of each arm containing the tube feet (podia or ambulacral appendages). On the aboral surface locate the anus and the madreporic plate and note the absence of tube feet. Note the spines; their shape, size, and arrangement are of importance in classification. Using a lens seek minute pincer-like organs, the pedicellariae. These are more strikingly developed on the sea urchin. Examine the living demonstration specimen under the microscope.



A



B

Fig. 131. Mouth parts of brittle stars: A, Ophioderma; B, Ophiopteris.

Scrape away the outer body layers and the spines to expose the plates of the skeleton of one entire arm and the area around mouth and anus.

Using Pratt when available, attempt to determine the family of one species. Meanwhile, identify your specimen, using the key below.

On a brittle star locate mouth with "jaws" (fig. 131) and oral papillae, buccal plates, genital bursae, tentacles (modified tube feet), disk scales, radial plates, dorsal arm plates.

Identify your specimen using the key below.

KEY TO THE ECHINODERMS

Holothuroidea (Sea Cucumbers)

1. Pale (usually white) in color; lacking tube feet; small in size . . . . *Leptosynapta albicans*
1. Colored; tube feet present 2

2. Tentacles 20 or more, fairly short, each somewhat resembling a flower; size of animal large . . . . . . *Stichopus californicus*
2. Tentacles about 10; tentacles longer, dendritic (tree-like in branching) 3

3. Dorsal and ventral surfaces of body markedly distinguished from each other; small; red in color . . . . . . *Thyonepsolus nutriens*
3. No distinction of dorsal and ventral surfaces; some species large, some small . . . . *Cucumaria* spp.

Echinoidea (Sea Urchins)

1. Body very flattened; spines short; below intertidal zone . . . . "The Sand Dollar," *Dendraster excentricus*
1. Body not greatly flattened; spines long. "Sea Urchins" 2

2. Small (2 inches or less in diameter); purple; spines relatively short . . . . *Strongylocentrotus purpuratus*
2. Large; red or purple; spines longer . . . . *Strongylocentrotus franciscanus*

Ophiuroidea
(Brittle Stars, with long mobile arms)

1. Disk with overlapping scales 2
1. Disk with granules or granule-like spines; radial plates covered; lowermost spines claw-like near tip of arm . . . . *Ophiopholis aculeata* var. *kennerlyi* (Clark, p. 132)

2. A single dorsal arm plate to each segment 3
2. Many dorsal arm plates of varying size; four mouth papillae, first twice as long as each of the others . . . . . *Ophioplocus esmarki*

3. Smaller, disk usually less than 5 mm. wide; radial plates in contact save at proximal tip, three pairs of oral papillae, first as long as next two together; dorsal arm plates not in contact, less than twice as wide as long . *Amphipholis pugetana*
3. Larger, disk usually about 10 mm. wide; radial plates separated by smaller disk scales save at bases; a single pair of oral papillae; dorsal arm plates broadly in contact, twice as wide as long . . . . *Amphiodia occidentalis*

Asteroidea (Sea Stars)

1. Leathery outer covering . . . ."The Leather Star," *Dermasterias imbricata*
1. Spiny outer covering 2

2. About twenty arms
   . . . "The 20-rayed or Sunflower Star," *Pycnopodia helianthoides*
2. Not more than six arms 3

3. Small, $\frac{1}{2}$ to $2\frac{1}{2}$ inches in diameter 4
3. Large, with five arms 6

4. Five arms; spines of aboral surface in elongated groups (pseudo-paxillae) . . . . young of *Henricia leviuscula*
4. With six arms; spines as usual 5

5. Small, usually less than one inch in diameter; arms slender; spinulation sparse; common in tide pools of mid-tide horizon . . . . *Leptasterias pusilla*
5. Larger, reaching a diameter of $2\frac{1}{2}$ inches; arms stouter, somewhat swollen at base; spinulation close-set; common in tide pools of low-tide horizon . . *Leptasterias aequalis* (fig. 132,A)

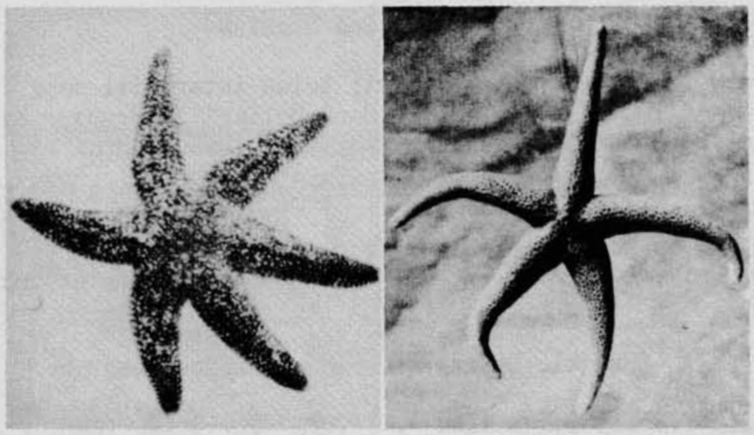


Fig. 132. Sea stars (from Guberlet): A, Leptasterias; B, Henricia leviuscula (Stimpson).

6. Disk very broad; arms short and triangular . . *Patiria (Asterina)*
6. Disk smaller; arms long, subcylindrical 7

7. Arms slender; spines very tiny, in groups (pseudopaxillae); color an even orange red . . . . *Henricia leviuscula* (fig. 132,B)
7. Spines more conspicuous; body and arms stouter 8

8. Spines conspicuous, forming a network
   . . . . "The Ochre Starfish," *Pisaster ochraceus*
8. Very large; spines conspicuous but not forming a network
   . . . . *Pisaster giganteus*
8. Spines very short and inconspicuous, forming a network; pale pink in color . . . . *Pisaster brevispinus*

LIST OF ECHINODERMS

HOLOTHUROIDEA

M *Cucumaria* spp.
M *Leptosynapta albicans* (Selenka)
M *Stichopus californicus* (Stimpson)
M *Thyonepsolus nutriens* Clark

ECHINOIDEA

M *Dendraster excentricus* (Eschscholtz)
*M *Strongylocentrotus franciscanus* (Agassiz)
*M *Strongylocentrotus purpuratus* (Stimpson)

OPHIUROIDEA

M *Amphiodia occidentalis* (Lyman)
M *Amphipholis pugetana* (Lyman)
M *Ophiopholis aculeata kennerlyi* (Lyman)
M *Ophioplocus esmarki* Lyman

ASTEROIDEA

M *Dermasterias imbricata* (Grube)
*M *Henricia leviuscula* (Stimpson)
*M *Leptasterias aequalis* (Stimpson)
*M *Leptasterias pusilla* Fisher
*M *Patiria miniata* (Brandt)
*M *Pisaster brevispinus* (Stimpson)
*B *M *Pisaster ochraceus* (Brandt)
M *Pisaster giganteus* (Stimpson)
M *Pycnopodia helianthoides* (Brandt)

PHYLUM CHORDATA

SUBPHYLUM HEMICHORDA

Class ENTEROPNEUSTA

One species of this group (*Mesoglossus intermedia*) has been found in small numbers at Moss Beach. The Enteropneusta are worm-like animals (our species small, generally not more than an inch long) which can be distinguished from other worm-like creatures by the division of the body into three parts; proboscis, collar, and trunk. The species which has been found at Moss Beach is small and is taken on the under sides of rocks lying in coarse sand in protected tidal channels or lagoons.

SUBPHYLUM UROCHORDA (TUNICATA)

There are three classes in this subphylum, the Larvacea, Thaliacea, and Ascidia. The first consists of small pelagic forms which will not be encountered in this course. The Thaliacea are also pelagic, but are larger and more common. Some may occasionally be seen floating in the water or washed ashore. They are soft, jelly-like, transparent, colorless except for a relatively small "nucleus." *Salpa* is the genus commonly encountered. The Ascidia are attached to rocks or piling and form a conspicuous element in our littoral fauna. Some of them are solitary; they are sac-like and possess two orifices at or near the distal end: one, the incurrent or <u>branchial orifice</u>, the other the excurrent or <u>atrial orifice</u>. The majority of species, however, are colonial. The individuals, called zooids, may be merely united by their outer layer (test) or their cavities may be variously united. One common arrangement is the fusion of several atrial orifices into a common <u>cloacal</u> orifice, the branchial orifices remaining separate, arranged in a circle around the cloaca. The <u>stigmata</u> referred to in the key are internal gill openings between the branchial and atrial cavities. See Borradaile and Potts or another text for other internal characters mentioned in the key.

Many different species of compound ascidians are known. Many of them form smooth, lobed colonies and are often spoken of as sea pork (fig. 135).

A KEY TO THE MORE COMMON LITTORAL ASCIDIANS OF THE MOSS BEACH AREA

By Robert L. Fernald

1. Individuals fixed and solitary. ASCIDIAE SIMPLICES 2
1. Many individuals more or less completely embedded in a common cellulose mass. ASCIDIAE COMPOSITAE 4

2. Long, club-shaped; peduncle or stalk at least as long as body; prevailing color dark red . . . . *Styela montereyensis*
2. Without peduncle; sac-like 3

3. Test translucent and without color; plates surrounding the atrial and branchial orifices . . . . *Chelyosoma productum*
3. Test tough and coated with foreign material; basic red-brown color with bright-red siphon tips . . . . *Halocynthia* sp.

4. Zooids with basal portions only embedded in common test; connected by stolons. "Social Ascidians" 5
4. Zooids entirely embedded in common cellulose mass 6

5. Individuals mound-like, 2 to 4 mm. in diameter; colored various shades of red . . . . *Metandrocarpa michaelseni*
5. Individuals ovoid, 2 mm. by 3 mm.; pale greenish-yellow; test transparent; attached to rocks, coralline algae, etc. . . . . *Perophora annectens*
5. Individuals elongate, club-shaped, 2 to 4 cm. high; test transparent; pink internal organs clearly visible. *Clavelina huntsmani*

6. Colony broken up into few or many club-shaped masses each with a peduncle about twice as long as the more or less rounded head . 7
6. Colony otherwise 9

7. Sand-encrusted 8
7. Test free of sand, transparent; yellow-orange zooids (common) . . . . *Macroclinum pellucidum*

8. Common cloacal orifice in small heads; zooids with 16 series of stigmata; atrial orifice with flat, truncate, languet; stomach cylindrical with seam on left surface but free from foldings (fig. 133,A) . . . . *Macroclinum par-fustis*
8. No common cloacal orifices; zooids characterized by 8 series of stigmata; atrial and branchial siphons of about equal length; wall of stomach with 6 or 7 longitudinal folds (fig. 133,B) . . . . *Amaroucium aequali-siphonis*

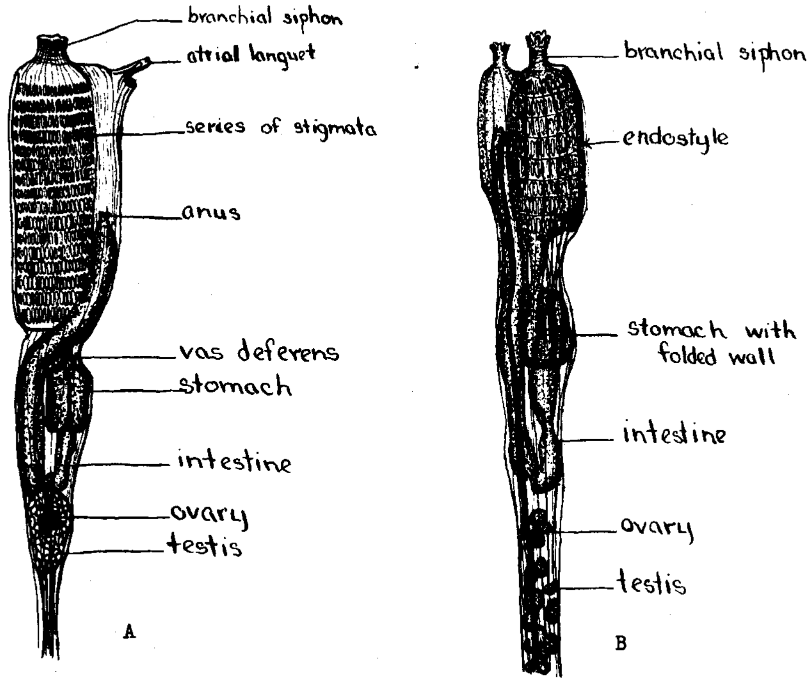


Fig. 133.—A, Zooid of Macroclinum par-fustis (enlarged); B, zooid of Amaroucium aequali-siphonis (enlarged). (Both after Ritter and Forsyth.)

9. Numerous calcareous spicules present in test 10
9. Spicules absent 11

10. Colony 1 to 4 mm. thick; white or flesh-pink in color; zooids with 4 series of stigmata; spicules with blunt rays (fig. 134,A) . . . . *Didemnum carnulentum*

Fig. 134.—A, spicule of Didemnum carnulentum (enlarged); B, spicule of Trididemnum della vallei (enlarged). (Both after Ritter and Forsyth.)

10. Colony 1 to 2 mm. thick; gray or buff in color; zooids with 3 series of stigmata; spicules with longer rays often split at the tips (fig. 134,B) . . . . *Trididemnum della vallei*

11. Zooids divided into three body regions—thorax, abdomen, and post-abdomen (fig. 136,A); atrial orifice without lobes but with long, tapering languet; 8 to 14 series of stigmata; stomach cylindrical with longitudinal folds sometimes branching or discontinuous (fig. 136,A); abundant . . . . *Amaroucium californicum* (fig. 135)
11. Zooids divided into two body regions—thorax and abdomen . . . 12

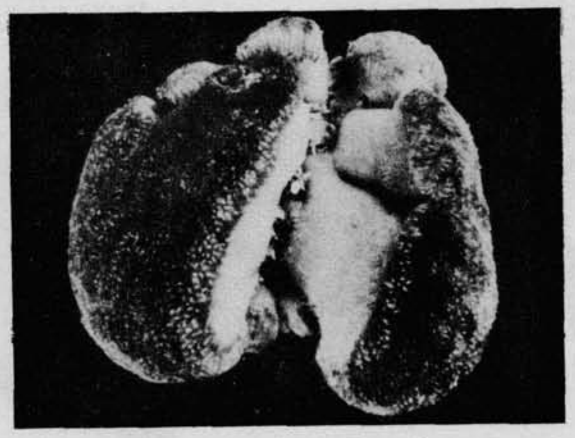


Fig. 135.—Amaroucium californicum (from Guberlet).

12. Atrial siphon as long as, or longer than the branchial siphon; 3 to 5 series of stigmata 13
12. Atrial siphon not well developed; four series of stigmata . . 15

13. Colony hard, much sand embedded in the test; brown to claret in color; zooids in systems; atrial siphon longer than branchial; three series of stigmata; abundant . . . . *Eudistoma psammion*
13. Colony not hard, relatively free of sand; lighter than *E. psammion*, zooids not in systems 14

14. Colony thick and encrusting, pedunculate or lobate; color opaque white through yellow-brown to light vermillion; three series of stigmata . . . . *Eudistoma diaphanes*
14. Colony thick and encrusting or lobate; five series of stigmata . . . . *Distoma lobata*

15. Colony soft and encrusting, pedunculate or capitate; wide color variation; zooids may or may not be in systems; atrial languet well developed; stomach ovate, wall not folded but with a network of ridges on inner surface (fig. 136,B); very abundant . . . . *Distaplia occidentalis*
15. Colony soft, thin, and encrusting; systems if present, irregular; atrial orifice large with simple opening; stomach smooth walled . . . . *Diplosoma* sp.

Species accounts of the above may be found in Ritter and Forsyth, 1917, Acidians of the Littoral Zone of Southern California. Univ. Cal. Publ. Zool., 16: 439-512.

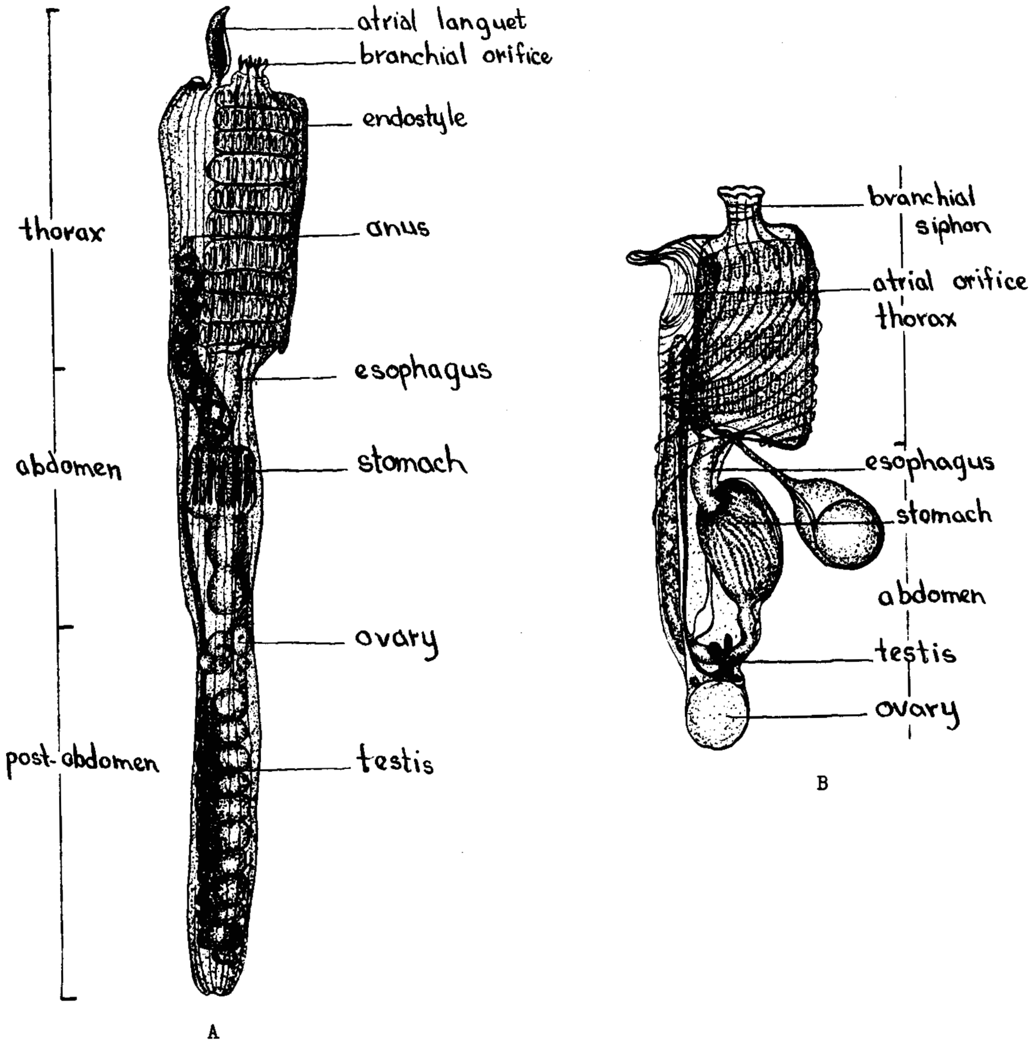


Fig. 136.—A, zooid of Amaroucium californicum (enlarged); B, zooid of Distaplia occidentalis (enlarged). (After Ritter and Forsyth.)

SUBPHYLUM CRANIATA or VERTEBRATA

We have designated our field as Invertebrate Zoology. The vertebrates, however, have very important relations to the invertebrates and as predators and in other ways powerfully influence their lives and the conditions under which they live them. For that reason we give brief consideration to them here.

Class PISCES

Studies at the seashore are largely made, perforce, at low tide. During low tide most of the animals concerned are not functioning fully but are largely passive, keeping alive under adverse conditions of exposure, by means of various types of adaptations, until the returning tide gives them again the normal conditions of submergence under which they are equipped to live. During the falling of the tides, also, many of the animals important in the life of the seashore swim out with the tides. The picture gained from low-tide studies is, therefore, very partial for both these reasons and every attempt should be made to visualize the true conditions of life during high tide.

As aids to this we have recourse to the tide pools, or under fortunate conditions to the glass-bottomed boat or the diving bell. The last two give us, as does the tide pool to much lesser extent, some idea of the importance of the fishes in the interrelated communities of the intertidal zone. They figure largely as predators, putting a premium on numbers, or swiftness, or defensive weapons, or protective devices and behaviors of many kinds.

We shall not devote any time to the study of the fishes. The ones commonly encountered by us will be the small spotted sculpins of the tide-pools (*Oligocottus maculosus*) sometimes called rock-pool johnnies. This and other common species may be identified by the key which follows. For further details or for other species see Keys to the Fishes of Washington, Oregon, and Closely Adjoining Regions, by L. P. Schultz, University of Washington Publications in Biology, 2: 103-228.

FIELD KEY TO THE FISHES COMMONLY SEEN OR TAKEN AT MOSS BEACH
(Figure references are to Walford, Fish Bulletin 28, 1930)

1. Elongated, eel-like 2
1. Not so 4

2. No paired fins; median fins vestigial; gill opening a small hole; head bilaterally flattened
. . . . "Green Moray," *Gymnothorax mordax* (Walford fig.)
2. Pectoral fins present; median fins fin-like; gills opening as in other fishes; head dorsoventrally flattened
. . . . "Blenny Eels," "Eels," 3

3. Median fins prominent; tail fin distinct; pectoral fins longer than eye . . . . *Cebidichthys violaceus* (Walford, fig. 110)

3. Median and tail fins narrow, inconspicuous; pectoral fins very short . . . . *Xiphister mucosus* (Walford, fig. 109)

4. Body very deep and thin (Surf Fishes, "Perch"); commonest species with longitudinal stripes of dull orange and blue
. . . "The Striped Perch," *Taeniotoca lateralis* (Walford, fig. 81)
4. Body not deep and thin 5

5. With a ventral sucker 6
5. Without sucker 7

6. Tadpole-like rock-pool fish, with large flat head, and a single dorsal fin
. . . . . . "Cling Fish," *Caularchus meandricus* (Jordan, fig. 651)
6. Head smaller, normal in shape; two dorsal fins
. . . . "Pretty Goby," *Lepidogobius lepidus*

7. Two dorsal fins 8
7. A single continuous dorsal fin from head to tail; small spotted tide-pool fish
   . . . . "Spotted Kelp-Fish or Senorita," *Gibbonsia elegans*

8. Without scales 9
8. With scales 12

9. Small rock-pool fish 10
9. Large, dark in color with extreme variation in color and pattern . "Cabezone," *Scorpaenichthys marmoratus* (Walford, fig. 102)

10. With abundant cirri, giving woolly appearance
   . . . . "Woolly Sculpin," *Clinocottus analis*
10. With few if any cirri 11

11. With ugly depressed head bearing a strong perpendicular spine with two or three hooks; greenish above, abruptly white below; pectorals and caudal banded with black
   . . . . "Smooth Sculpin," *Leptocottus armatus*
11. Commonest rock-pool fish; head normal, spine very short; with many color shades and patterns
   . . "Rock-Pool Johnny," *Oligocottus maculosus* (Jordan, fig. 566)

12. Three large projecting spines in anal and 12 or 13 in anterior dorsal; anal with few rays; a single lateral line
   . . . . "Rock Cods," *Sebastodes* spp. (Walford, figs. 90-101)
   (Many species, usually separated with difficulty.)
12. No projecting spines; anal with about 20 rays, dorsal with about 21; five lateral lines; males and females different in shape and color (see Walford)
   . . . . "California Sea Trout," *Hexagrammos decagrammus*

Class <u>AVES</u>

In contrast to the fishes, birds are most active in the intertidal zone during low tides when they pick up great numbers of invertebrates. Most important, no doubt, are the gulls which in addition to being scavengers eat great numbers of small animals, notably sand crabs (*Emerita*) and the mud crab (*Hemigrapsus oregonensis*) and are, therefore, the terminal animals of a number of food chains. Several gulls occur along our shores as seen from the list below, but only one, the Western Gull, is a summer resident.

Other birds feeding largely on shore animals are the curlews, the sandpipers, the oyster catchers, and some ducks such as the scoters.

The curlews and sandpipers feed largely upon dwellers in the mud and sand and the list of animals involved is probably a large one, consisting chiefly of species of Crustacea and Polychaeta.

One animal which occurs in enormous numbers at times and serves as a most important key industry animal, since it is fed upon by most of the birds mentioned, is the sand crab (*Emerita analoga*). Only a little observation will show the gulls to be regular hunters for these crustaceans. Likewise even the curlews and smaller shore birds can be seen joining the feast, shearing off the legs and eating them when the animal itself is too large for them.

As for the scoters they put on a truly amazing performance in their search for these sand-dwelling plankton feeders. Washing up with a wave they follow the backwash of it down the sandy beach for a short distance, digging madly for *Emerita,* then waddle clumsily down to repeat the process on another wave.

Besides these birds which feed directly on the invertebrates there are several which feed on the fish which themselves feed on the invertebrates. Important among these are the pelicans and several species of cormorants (see list below).

Finally we might mention birds of entirely different food habits, the plant feeders, which affect the invertebrates only indirectly. An interesting bird of this type to be seen at Dillon Beach and at Año Nuevo Island is the black brant, which seems to feed entirely on extensive local growths of an *Ulva*-like green algae.

A list of the common and scientific names of the commoner species of birds of the types mentioned here is given below. For distinctions between the species see Hoffmann, Guide to the Birds of the Pacific States.

Gulls:

Glaucous-winged Gull (*Larus glaucescens* Naumann)
California Gull (*Larus californicus* Lawrence)
Western Gull (*Larus occidentalis* Audubon)
Ring-billed Gull (*Larus delawarensis* Ord)
Herring Gull (*Larus argentatus smithsonianus* Coues)
Bonaparte Gull (*Larus philadelphia* [Ord])

Terns:

Caspian Tern (*Hydroprogne caspia imperator* [Coues])
Forster Tern (*Sterna forsteri* Nuttall)

Oyster catcher (*Haematopus bachmani* Audubon)

Curlews:

Long-billed Curlew (*Numenius americanus* Bechstein)
Hudsonian Curlew (*Phaeopus hudsonicus* [Latham])

Scoters:

White-winged Scoter (*Melanitta deglande* [Bonaparte])
Surf Scoter (*Melanitta perspicillata* [Linnaeus])

Pelicans:

Brown Pelican (*Pelicanus occidentalis* Linnaeus)

Cormorants:

Double-crested (Farallon) Cormorant (*Phalacrocorax auritus* [Lesson])
Brandt's Cormorant (*Phalacrocorax penicillatus* [Brandt])
Baird's Cormorant (*Phalacrocorax pelagicus* Pallas)

Brant:

Black Brant (*Branta nigricans* [Lawrence])

Class MAMMALIA

Important in the pelagic communities are the whales, which we may see blowing offshore. They are feeders on invertebrates, consuming vast quantities of them. The smaller porpoises are predators on fishes. Other fish feeders commonly noted on our trips are the Steller Sea Lion (*Eumetopias jubata*) and the Harbor Seal (*Phoca richardii*).

Finally and most important, so far as the intertidal fauna is concerned, is man. His activities as clam digger, abalone hunter, and collector of mussels, marine snails, and sea urchins have sadly impoverished the faunas. One has only to visit a biological preserve such as Año Nuevo Island, south of Pescadero, to realize the effect of man's activities on the large gastropods. There the red abalone (*Haliotis rufescens*) is abundant and the black abalone (*Haliotis cracherodii*) forms solid layers overlapping under especially favorable ledges, even well above the low-tide level, while family groups of the giant limpet (*Lottia*) are seen on every favorable rock surface.

FIELD STUDIES

These studies are designed to give the student a firsthand knowledge of living invertebrate animals in their natural habitats, of their behavior and interrelations, their adaptations as correlated to the various factors of the environment, and the influence of physical conditions upon their local distribution.

Naturally such studies are largely in the nature of field trips with an all-too-brief period in the field during which those animals needed for further study are collected and as complete observations and records as possible are made of the ecological settings characteristic of the different animals seen, of their distribution within the ecologically varying environment, and of the major differences in this environment which seem to be responsible for the different distributions.

The approach and spirit of these studies is, therefore, essentially ecological whereas the method can rarely, if ever, be the quantitative and experimental one characteristic of modern ecology. This is due in part to limitations of training and equipment but essentially to lack of time.

It might be said that we make ecological surveys or reconnaisances and seek to set up preliminary hypotheses as to the role of different factors in determining the distribution of the animals, hypotheses based only on readily observable and relatively obvious facts with regard to such features for example as degree of exposure as determined by vertical level of occurrence, by the nature and arrangement of the substrate, by position with regard to wave impact, wind, rain, sun, etc.

These field trips are interspersed with the laboratory studies according to a logic of necessity. Groups are studied in the laboratory not according to any taxonomic order but as best to prepare for the field trips as they occur. The order of the field trips in turn is determined by various factors chiefly those of season, weather and tide. Hence the schedule of events will differ not only as between the spring semester and the intersession but also for each from year to year. Examples of such schedules will be found in Appendix A.

The conditions of study vary greatly as between the spring semester when the student is carrying other courses and the intersession when for six weeks nothing else intervenes and only time and tides must be considered. These courses (Zoology 112, and S112 and S119) will be considered separately therefore. First, however, come certain general instructions for field work.

GENERAL DIRECTIONS FOR FIELD WORK

Equipment needed: Geologist's pick (if possible); forceps; containers of various sizes (preferably screw-topped); hard-backed notebook with automatic pencil; if possible a magnifying glass (the magnifying glass and, if possible, the forceps to be attached in some way); and some sort of bag or basket for carrying equipment and specimens.

General Suggestions: Plan your program beforehand, especially if at the seashore, as every minute of low tide must be made to count. Go out at once to the tide line. Follow the tide out. Collect back as the tide drives you in. Take great care not to be caught by the tide.

Methods of Collecting: Do not collect unless you plan to use the specimens for (1) study or identification, or (2) for your class or personal collection. Do not collect great numbers of the same species.

Destroy as little as possible either of animal life or of the natural conditions of the environment. Replace overturned stones to their original position, since the fauna living on the under side or under the stone cannot survive when exposed to air and wave action.

<u>Field Notes</u>: If specimens are taken merely for immediate study or practice in identification, field notes are perhaps not necessary. Any specimen to go into a permanent collection, however, should be accompanied by certain information to make it of value to any future student. Experience has shown that most collections ultimately come to be used for study whether that was the original intention of the collector or not. Many troublesome errors and difficulties have arisen because of the lack of information with regard to specimens in such collections as well as from accidents and carelessnesses in making and preserving field records of collections designed for study. <u>No</u> collection should be made, therefore, which lacks the essential information with regard to the specimens in it, least of all a collection made in connection with a study of natural history.

It is an exceedingly difficult thing to insure the correlation of specimens and notes in general collecting where time is greatly limited by the tides and organisms occur in profusion. There are two common ways of keeping these notes. One, perhaps the safest, but by no means the easiest, or the most commonly used, is to write the information in pencil and drop it into the container with the specimen, or wrap it with the specimen if several are in one container. When the collection is put into permanent form later the information thus obtained must be copied on the label in (or on) the bottle and on the museum or collection record, whether card or journal. The second method is to drop into the container or wrap with or attach to the specimen a number written at the time or, better yet, already prepared, and, after the same number to give the desired information in a field notebook or on cards used for that purpose. The last method, while easier, involves the danger of loss of the notes, in which case the number means nothing, and also the danger of mixing numbers and notes due to haste in the field must be guarded against. Experience will dictate your choice of methods. Your problem is to obtain essential information at the time of collection and keep it in such a way as to insure that it will be correlated with the particular specimen concerned and ultimately preserved as a permanent record and in part, at least, placed with the specimen itself as a museum label.

There is almost no limit to the amount of available information which might prove valuable to the student of distribution, variation, or ecology if connected with a specimen. Points commonly noted are (1) exact locality, including county, (2) date, including hour if of any significance, (3) exact location (as regards tide level, or altitude for example), (4) environmental situation (underside of rock), (5) any organisms or organic remnant apparently associated with it ("with polychaete worms, no. 63, in hole of boring clam," for example), (6) anything unusual in the behavior or stage of the animal, and (7) the collector's name. The absolute minimum must include locality, date, location and environmental situation, and name of collector.

The difficulty of collecting and keeping proper notes under the conditions of wet hands, lack of place to sit, presence of rain or spray, lack of time, difficulty of keeping specimens separate, must again be emphasized to make clear the necessity of careful planning and discipline of the will to accomplish the required end. Such notes will be required with the collections which are to be turned in as a part of the required work of the course and for the various ecological and observational studies. They can only be obtained by limiting the objective, making it sharply definite, and refusing to be deflected from it. For that reason the earlier trips will usually have more general objectives and records will be confined to those having to do with ecologic features noted.

A shell bag or fishing creel is convenient for carrying vials, bottles, etc. A wise provision against loss by breakage on the rocks is to use tins to hold vials and even bottles. Another danger is the losing of corks and the consequent loss or mixing of specimens. <u>See that corks are in tightly</u> or, better yet, use screw-top vials and jars in so far as possible.

The most rewarding places for collecting are, (1) deep shaded tide pools near low-tide level, (2) on and in seaweed, particularly in its holdfasts,

(3) in the crevices and cavities of rock and within rock, particularly if the rock be soft, porous, or covered with coralli ıs algae, (4) under rocks, and (5) in sand and mud if they are not subject to constant movement by the tides.

Small rocks, especially favorable pieces from larger rocks, and holdfasts of kelp or *Laminaria*, from the outer low-tide level may be brought in and the animals removed and cared for at leisure. This requires but the one set of notes in the field for many specimens. Also numerous specimens from the same exact environment (a low-level tide pool, for example) may be placed in a single container with the proper notes and be sorted later. Care must be taken, however, to segregate certain types of organisms. Most worms, for example, secrete mucus and tend to form a tangled, often inextricable, mass with other organisms. This is particularly true of nemertean worms, which should be kept separately. Certain other animals, particularly crabs, tend to tear others. Voracious animals, such as large isopods, often devour smaller forms and the spines of echinoderms form a place of escape and entanglement for many smaller, mobile animals. Intelligent care will be necessary, therefore, if satisfactory collections are to be obtained by putting numerous specimens in the same container in the field.

PRESERVATION AND STUDY

On return to the laboratory the first move should be to get material segregated and either into fixative or into dishes of clear seawater, taking care always to maintain the correlation between specimens and field notes. As a routine it is worth while to observe under the microscope, while still living, any small animal, or developmental stage, not already studied, as this will often bring out much of beauty and interest otherwise lost. If time permits and there is any probability that your specimens are to be used for future systematic studies, careful color notes will be of value.

Well-known animals may be preserved at once or steps taken in that direction. Others should be preserved when they have been studied and the proper notations made. For methods of preservation see Bulletins 39-42 of the United States National Museum (bound together).

THE SPRING SEMESTER

(Zoology 112)

You will be given a tentative schedule of exercises for the semester. Fasten this in your syllabus and note on it at the time such changes as may be announced from time to time.

You will note that the exercises consist of a number of field trips interspersed with laboratory exercises designed to give you a knowledge of the animals to be studied in the field. The field trips constitute the heart of the course. The dates of a number of these trips will be determined by tides and hence no regular schedule, as regards days of the week, is possible. These irregularities are unavoidable and have been cut to a minimum. Please note them at once and make provision for them in your program.

The field trips usually undertaken are listed below in the order in which they are considered in the pages which follow. It will be seen that they sample three major environments, marine (intertidal), freshwater, and terrestrial, and one, the estuarine, intermediate between the first two. This order while a logical one cannot be followed chronologically because of seasonal requirements and the tides. The schedule of exercises should be consulted for the chronological sequence.

These studies should be cumulative and comparative. Each new situation should be compared to the others and differences and similarities should be noted as to environmental conditions, faunas, and their interrelationships.

FIELD TRIPS OF THE SPRING SEMESTER

Marine

A. Point Richmond in San Francisco Bay. Tide flats and a rocky beach in an enclosed bay.
B. Halosaccion Flats, Moss Beach, San Mateo County. A flat rock surface on the open sea, exposed at intermediate tides.
C. Dillon Beach, Marin County. A three-day trip permitting comparison of the faunas of (1) an exposed rocky shore (Tomales Point), (2) partially protected rocky shores (Bodega Bay near Dillon Beach) and (3) protected tide flats in an enclosed bay (head of Tomales Bay).

Estuarine

D. Lake Merritt, Oakland. A brackish-water, estuarine lake subject to great annual shifts in salinity but not usually subject to tidal shifts of level.
E. Fruitvale Bridge, Alameda Estuary, Oakland. Fauna of under-bridge piling in a tidal estuary.

Freshwater

F. Fauna of a freshwater pond or lake.
G. Fauna of some seasonal pond or pool.

Terrestrial

H. Strawberry Canyon, Berkeley Hills. Terrestrial habitats and faunas of a wooded canyon.

DIRECTIONS FOR THE FIELD TRIPS OF THE SPRING COURSE AND THE LABORATORY EXERCISES IMMEDIATELY PREPARATORY TO THEM

A. The Animals of Point Richmond, a Rocky Shore with Tidal Flats in an Enclosed Bay

Preliminary Laboratory Study.—This study is a necessary preliminary to the first field trip. A list of the animals commonly encountered will be posted. A study collection of these animals will be on display to enable you to get a preliminary familiarity with their appearance and names. Your work in the field will be to find and observe as many as possible of these animals in their natural habitats and associations. Several species of decapods form a conspicuous part of this fauna. Specimens of these will be distributed through the class and they should be identified by means of the accompanying key. Do the same for such other specimens as are available. Keys follow to the decapods, isopods, amphipods, limpets (*Acmaea*) and annelids. These keys cover only the species reported from Point Richmond; consult the index for more complete keys for these animal groups found in the preceding section.

Field Trip to Point Richmond

Purpose: (1) To learn the various animals of this region as they exist under natural conditions, i.e., each in its normal ecologic setting ("niche"); (2) to determine their distribution with regard to physical and biotic factors;

(3) to learn their groupings by zones or other environmental situations; and (4) to obtain as clear an idea as possible of their interrelationships in such groupings, especially their food relations.

Procedure: (1) Make field notes with diagrams or sketches. (2) Collect such animals as are necessary to identify species using the keys which follow and where needed those in the preceding section.

A second trip will probably be necessary to complete these studies for those who have no previous knowledge of the fauna.

Report: The report, if any, will be in the form of a synthetic vertical section of the shore at Point Richmond showing the relative location of all important habitats or associations, accompanied by lists of the species found in each of these different habitats or associations. A discussion of the reasons for the distribution of the different types is optional.

If this trip follows the one to Halosaccion Falts (see below) it should raise many questions as to the great differences in the faunas of the two regions.

A Sample Set of Questions on the Point Richmond Fauna

(1) Name three major factors which probably account for the sparse nature of the fauna. (2) Which large and important phylum of animals was not found represented at all? (3) What conditions probably account for their absence? (4) Where were the oysters largest and most abundant? (5) What differences in physical conditions were correlated with this abundance? (6) What predator was confined to the area of the abundance of oysters? (7) What could be shown to be the usual explanation of the occurrence of shells of gastropods at intertidal levels where the living species were not found? (8) What is the most important predator (or scavenger of freshly killed animals) in each of the following situations: (a) under stones fitting closely against the substrate? (b) in the small, high, rock-bottomed tide pools during low tide? (c) over the higher rock surfaces during high tide? (9) List the animals found in the zone of pebbly beach. (10) Which if any of these occurred in the sandy beach—a few inches away? (11) How do you explain this great difference? (12) Name a different amphipod characteristic of each of the following locations: (a) high-tide pools in rock; (b) under surface of smooth stones resting on substrate, low in tidal zone; (c) felted mass of algae over surface of rock outcrop in mussel zone; (d) algal debris at or near high-tide line. (13) What biotic reason might you give for the absence of relatively large predators such as the larger sea anemones and starfishes both of which are present at the yacht harbor? (14) What two physical conditions may also be concerned? (15) Which two species are diagnostic of the higher splash zone? (16) Which two of the lower splash zone or the highest tide line? (17) What three vicissitudes must be met by animals living in small high-tide pools? (18) What is the present status in the mussel-bed succession? (19) Judging from the situations in which you found them name as many as you can of the more than a dozen species whose numbers would probably be greatly increased if the mussel beds were fully developed. (20) On a line, representing the beach line from the middle of the pebbly beach (small stones between mud flats and sand beach above) to the fixed boulders at the point, indicate by brackets where you would expect to find each of the following: (a) *Hemigrapsus oregonensis*; (b) *Hemigrapsus nudus*; (c) *Thais lamellosa*; (d) chitons. (21) Choose four species whose niches seem best defined by our study and attempt to state the factors involved. (22) Which one species had the widest intertidal range? What makes possible this wide range? (23) Which species common here are absent at Halosaccion Flats? Attempt to explain the absence of each species.

A KEY TO THE DECAPODA OF POINT RICHMOND

1. Antennae long (generally at least as long as carapace); body elongated, not flattened 2
1. Antennae short (much less than half the length of carapace); body short and broad, greatly flattened (True Crabs) 5

2. Abdomen twisted, carried in a mollusk shell . . . . Hermit Crabs, *Pagurus* spp. (figs. 97, 98)
2. Abdomen symmetrical, exposed 3

3. Abdomen not narrowed behind; one cheliped of male very large; living in burrows in mud or muddy sand . . . . Ghost Shrimp, *Callianassa* (fig. 96)
3. Abdomen narrowed behind at base of tail fan; chelipeds all slender; not burrowing . . . . True Shrimps 4

4. Small (less than one and one-half inches long); rostrum long, slender . . . . *Spirontocaris paludicola* (figs. 85, 87,D)
4. Larger (one and one-half to two inches); rostrum short, dorsally flattened; a circular black area on either side of 6th abdominal segment . . . . *Crago nigromaculata*

(Other species of *Spirontocaris* and *Crago* may possibly be found. See Key, p. 104.)

5. Body nearly square 6
5. Body more or less oval, much broader than long 8

6. Back with numerous transverse lines . . . . Striped Shore Crab, *Pachygrapsus crassipes*
6. No lines on back 7

7. Tips of legs without hairs; body usually purple or dark red . . . . Purple Shore Crab, *Hemigrapsus nudus*
7. Tips of legs hairy; body usually yellowish-green . . . . Mud Crab, *Hemigrapsus oregonensis*

8. Margin between eyes (the front) extending forward (produced), with five nearly equal teeth . . . . Red Crab, *Cancer productus*
8. Front not produced, five teeth unequal 9

9. Hairy; with red spots on ventral surface; antennae conspicuous, as long as width of front . . . . Rock Crab, *Cancer antennarius*
9. Smooth; not spotted below; antennae very short . . . . Edible Crab, *Cancer magister*

A KEY TO THE ISOPODA OF POINT RICHMOND

1. Uropods terminal (fig. 61); largely above high-tide mark . . . . *Ligia occidentalis*
1. Uropods lateral (fig. 58); or ventral (fig. 54); not above high tide . . 2

2. Uropods valve-like, inflexed (fig. 54); pleopods largely branchial; color green or brown . . . . *Pentidotea* (fig. 56)
2. Uropods forming with terminal segment of abdomen a caudal fan (fig. 58); color gray or white 3

3. Abdomen usually of 6 segments 5
3. Abdomen usually of 2 segments 4

4. Smaller; caudal fan spreading (fig. 58,A); surface not densely granular; . . . . *Exosphaeroma*
4. Larger; caudal fan not noticeably spreading; surface densely granular . . . . *Sphaeroma pentodon*

5. Size moderately large; color speckled or dark gray; not boring in wood . . . . *Cirolana* (fig. 58,C-E)
5. Size minute; body white, eyes black; boring in wood . . . . *Limnoria*

A KEY TO THE *AMPHIPODA* OF POINT RICHMOND

1. Body laterally compressed as usual in amphipods; prominent side plates covering bases of legs (fig. 63) 2
1. Body not laterally compressed (fig. 70); no side plates 10

2. Antennule (fig. 63) very short, only as long as first two segments of peduncle of antenna; habitat usually above high-tide mark; large . . . . *Orchestia traskiana*
2. Antennule at least as long as entire peduncle of antenna; habitat intertidal or lower 3

3. Third uropod (fig. 63) extending posteriorly beyond second uropod (study under microscope); antennule with an accessory flagellum . . . 4
3. Third uropod not extending beyond second; antennule without accessory flagellum 6

4. Eye round or irregularly round; outer ramus of the third uropod several times as long as the tiny inner ramus . . . . *Melita* sp.
4. Eye bean-shaped; outer ramus of third uropod not more than three times as long as inner ramus 5

5. Inner ramus of third uropod at least two-thirds as long as outer ramus . . . . *Gammarus pribilofensis*
5. Inner ramus of third uropod less than one-half as long as outer ramus . . . . *Gammarus confervicolus*

6. Third uropod with two prominent upward-pointing hooks at the tip of the outer ramus; color in life green or gray stippled with small brown spots . . . . *Ampithoë valida*
6. No such hooks on third uropod 7

7. Antennule longer than antenna . . . . *Neopleustes pugettensis*
7. Antennule shorter than antenna 8

8. Antenna with dense tufts of bristles; antennule two-thirds to three-fourths as long as antenna . . . . *Allorchestes plumulosus*
8. Bristles of antenna fewer, not in tufts; antennule little more than half the length of antenna 9

9. Color black and gray, sometimes with transverse white stripes; conspicuous in high-tide pools . . . . *Hyale pugettensis*
9. Color pale; size small; not common . . . . *Allorchestes angustus*

10. Body somewhat flattened (fig. 70); living in tubes . *Corophium insidiosum*
10. Body very slender, abdomen reduced to stump; appearance very unlike that of other amphipods . . . . *Caprella* sp. (Plate XI, no. 5)

A KEY TO THE SPECIES OF *ACMAEA* OF POINT RICHMOND

1. Apex near one end of shell (refer to Plates XII-XV) 2
1. Apex at least one-third of length from end 4

2. With well-developed ribs (radiating ridges on shell) and irregular margin 3
2. With fine striations and entire margin . . . . The Speckled Limpet (rare), *A. persona*

3. Ribs close together, rough; margin serrate; inner, central area porcelaneous, white or mottled . . . . The Rough Limpet, *A. scabra*
3. Ribs well separated, rounded; margin crenate; inner area shiny, with one central brown spot; apex usually overhanging . . . . The Mask Limpet, *A. digitalis*

4. Elevated; profile with straight sides 5
4. Very low; profile convex . . . . The Plate Limpet, *A. scutum*

5. Shell heavy; inside with a considerable white area . . . . The Shield Limpet, *A. pelta*
5. Shell thinner; black externally and brown internally . . . . The Owl Limpet (rare), *A. fenestrata*

A KEY TO THE ANNELIDA OF POINT RICHMOND

(Refer to plates, figures, and explanations of terms under Phylum Annelida in preceding section)

1. Non-segmented; tough-skinned, finely tuberculated; with an introvert terminated by dentritic branchiae (fig. 13,E); in rock crevices. SIPUNCULOIDEA . . . . *Physcosoma*
1. Segmented worms, with parapodia (figs. 13,A and 14) more or less developed and variously modified; often with accessory head and body appendages. POLYCHAETA 2

2. Body dorsally covered with overlapping scales (fig. 17,B). POLYNOIDAE . . . . Polynoids
2. Body without scales 3

3. Head completely covered by feathery tentacles (fig. 16); body in a calcareous tube. SERPULIDAE . . . . Serpulids
3. Head completely covered by a conspicuous spiny operculum (fig. 19); body in a tube which is not calcareous. SABELLARIIDAE . . . . Sabellarids
3. Head otherwise; body generally not in a tube 4

4. Anterior end of body with long filamentous outgrowths, usually extending forward over head. CIRRATULIDAE (fig. 17,H) . . . . Cirratulids
4. Filamentous outgrowths, if present, not concentrated near anterior end . 5

5. Prostomium bearing tentacles or palpi and often accompanied by peristomial cirri (fig. 15) 6
5. Prostomium plain, without tentacles or palpi, and not accompanied by peristomial cirri 10

6. Prostomium with conspicuous tentacles or palpi 7
6. Prostomium with minute, inconspicuous tentacles (fig. 17,F); proboscis actively everted when disturbed 9

7. Prostomium with tentacles, but without palpi; small, very active, mud-flat dwellers. PHYLLODOCIDAE (fig. 17,E) . . . . *Eteone* (fig. 28,C)
7. Prostomium with a pair of long, prehensile, tentacular palpi (fig. 17,J) SPIONIDAE . . . . *Boccardia*
7. Prostomium with a pair of thick, fleshy, palpi (fig. 15) 8

8. Parapodia distinctly biramous; prostomium with only paired antennae; dorsal cirri never articulated. NEREIDAE . . . . Nereids
8. Parapodia uniramous; prostomium with a median antenna in addition to paired antennae; dorsal cirri often articulated (fig. 17,D); mostly minute. SYLLIDAE . . . . Syllids

9. Prostomium angular (fig. 27,A); recurved cirri between branches of parapodia (fig. 27,B); pearl-gray in life; in sand. NEPHTYIDAE . *Nephtys*
9. Prostomium pointed, annulated; parapodia tiny, without recurved cirri. GLYCERIDAE . . . . Glycerids (fig. 17,F)

10. Most of dorsum covered by interlacing, cirriform branchiae; prostomium shovel-like. ORBINIIDAE . . . . *Naineris* (fig. 25,A)
10. Without branchiae; prostomium pointed or rounded 11

11. Parapodia reduced; bluish-red in life; in mud flats. CAPITELLIDAE . . . . Capitellids
11. Parapodia more or less normal; orange to reddish-metallic in life; in sands or sandy mud. LUMBRINEREIDAE . . . . . Lumbrinereids (fig. 17,A)

B. The Animals of Halosaccion Flats, a Horizontal Rock Exposure at About Mid-Tide Level, on the Open Coast, Moss Beach, San Mateo County

Location: The name Halosaccion Flats is our own, given because of the presence of the peculiar, finger-like, gas-inflated green algae in great numbers near the center of the rocky flat which lies (see Map I) just south of Moss Beach Point and immediately north of the lagoon-like cove we have designated Seal Cove.

Physical Conditions: These have been largely stated: A rocky substrate of fairly hard slaty shale, with relatively few crannies but cut at intervals by narrow crevices which are tidal channels at intermediate tides but contain long, narrow tide pools at low tides, often containing accumulations of sandy gravel. The precipitous seaward face of the rock, rising about two feet above low-tide level, receives the full force of the waves and is cut at intervals by tidal channels, most of which do not penetrate far. Shoreward at the northern end the reef rises to near high-tide level. Shoreward also are protected channels and tide pools with a sloping rocky or sandy beach rising to the sheer cliff.

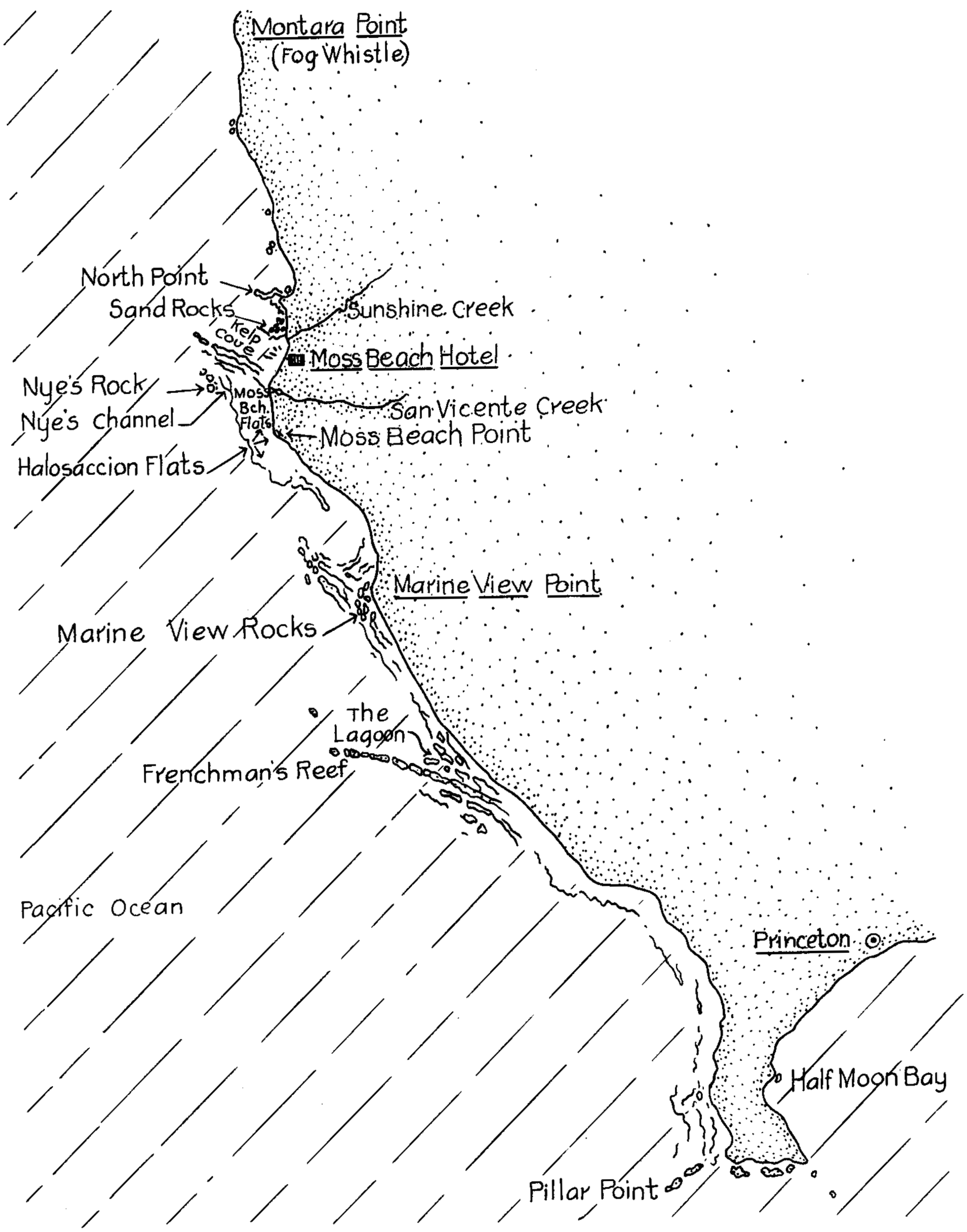
Physical habitats of diverse types are found, therefore. The factor of exposure, varying primarily with vertical height with regard to the low-tide line, is variously affected by the nature and arrangement of the substrate. Thus we have tide pools; shallow, gravel-filled crevice pools; deep protected tidal channels; outer exposed tidal channels; ledges; exposed rock surfaces with varying relations to wave impact, etc.

Special Biotic Features: (1) Living seaweed forming a close growth over most of the horizontal rock surface, (2) close-set aggregates of a sea anemone (*Bunodactis elegantissima*) which cover themselves with pieces of shell and gravel, (3) a *Mytilus-Mitella* zone on the high northern shoulder.

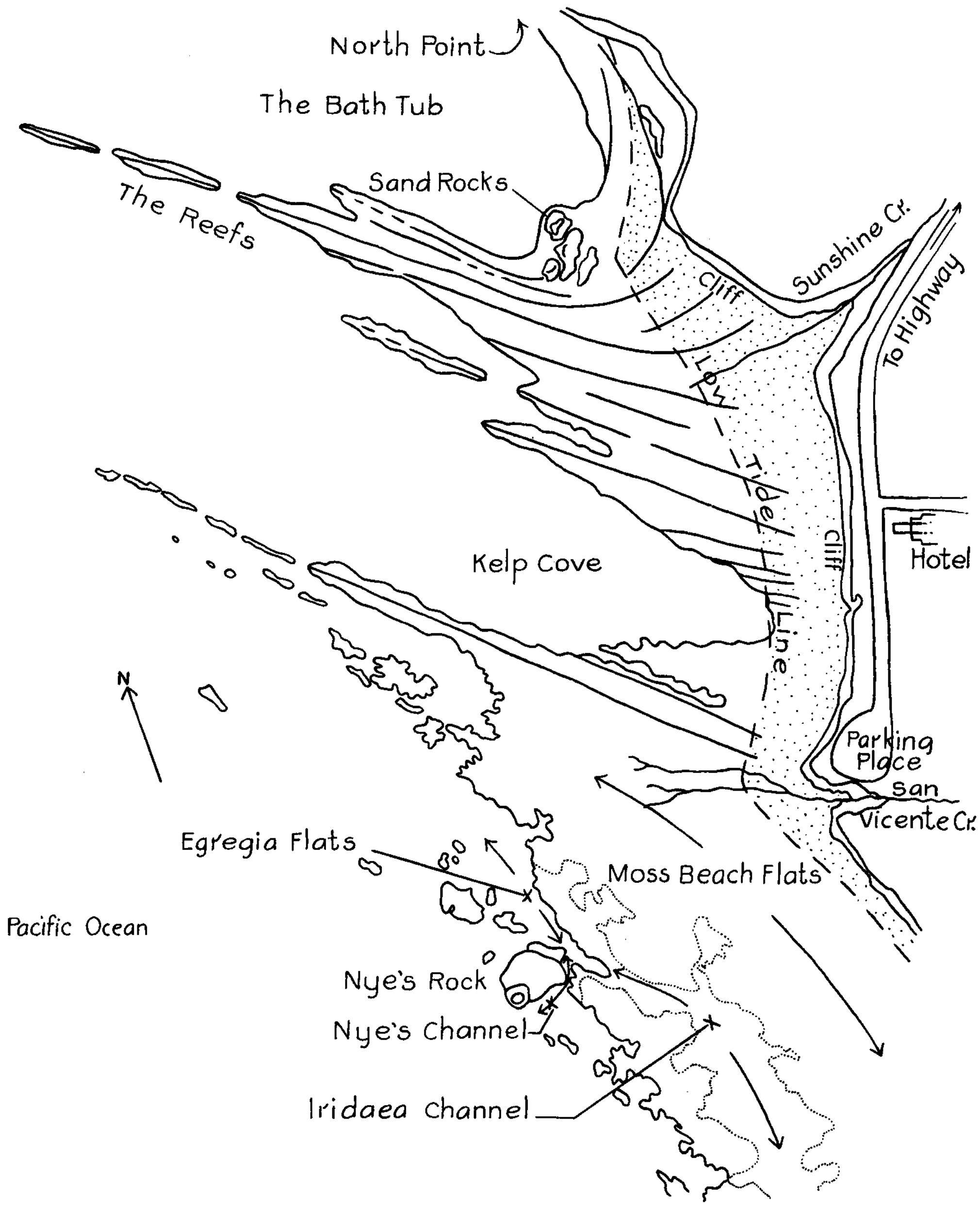
Purposes of Study: Familiarity with members of fauna and their names; experience in the observation of animals in the field in terms of the effects of ecological factors on the distribution and success of species and on the faunal associations.

Procedures: If this is the first field trip it will be preceded by a laboratory study of the animals most commonly to be encountered. Go out to the sea-front to take advantage of the low tide. Study the animals at the lowest tidal exposure first. Look under ledges. Break off overhanging ledges to get a more intimate knowledge of the dwellers on the surface and in the crannies and burrows. Distinguish between borers, nestlers, and cranny dwellers. Work back across the horizontal surface, noting differences of faunas, if any, (1) between the seaward and landward sides; (2) correlated with different algal types; (3) of the narrow crevice pools; (4) of the gravel-bottomed high-crevice pools; (5) of protected inner tidal channels and tide pools; (6) of the higher northern shoulder; (7) of the rocks between the reef and the beach slope; (8) of the beach slope; (9) of the crevices at the foot of the cliff.

If this follows the Point Richmond trip, differences between the two faunas should be noted and an attempt made to explain these. Some of the differences are those to be expected between bay and open shore faunas. Others are due to special conditions in the two situations. Attempt to distinguish between these two types of differences.



Map I. Moss Beach and vicinity (using many local names)



Map II. Moss Beach shore area (local names)

Sample questions:

1. What phylum well represented here was absent at Point Richmond?
2. Differences in what two important ecologic factors might be thought to explain this difference?
3. Which two phyla were represented most extensively in the fauna of the horizontal algae-covered flat?
4. Can you give any reason for the absence of large individuals and species here?
5. Contrast the assemblages found in crevice pools and surface growth. What explains the differences?
6. Compare the limpets (*Acmaea*) of the flat and of the inner shore rocks and high shoulder. How would you explain this situation?
7. Attempt to explain the occurrence of the patches of *Bunodactis*. Why not more extensive?
8. What seems to restrict the occurrence of *Anthopleura* in this area?
9. Describe the home habits of *Lophopanopeus* in the larger, more shoreward crevice pools.

C. Comparison of Faunas of Exposed Rocky Shore (Tomales Point), Partially Protected Rocky Shore (Bodega Bay) and Protected Tidal Mud and Sand Flats (Tomales Bay)

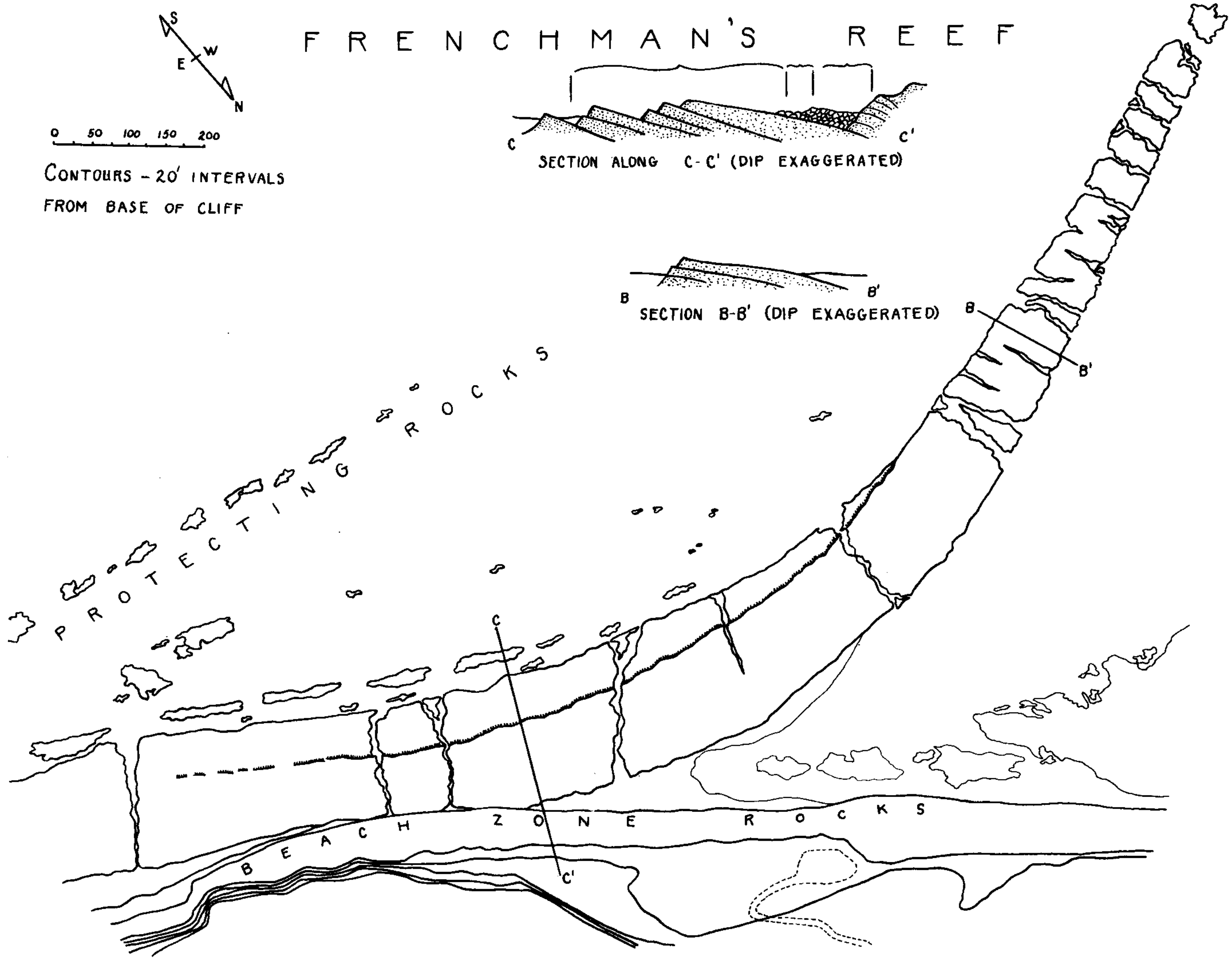
Location: The class will have its laboratories and living quarters at Dillon Beach, Marin County, California (see Map IV) on the shores of Bodega Bay near the mouth of Tomales Bay.

Purposes: This will be by far the most important field trip of the course. It will usually come relatively late in the semester and enable the student to focus the knowledge gained from the preceding field trips and laboratory studies in an intensive study of three faunal assemblages not far apart spatially but ecologically distinct. The opportunity given by continuous study for the three days makes it possible to identify the unknowns collected by all, thus giving a relatively complete picture of these rich faunas, and to compare notes and impressions as to ecological features and relationships.

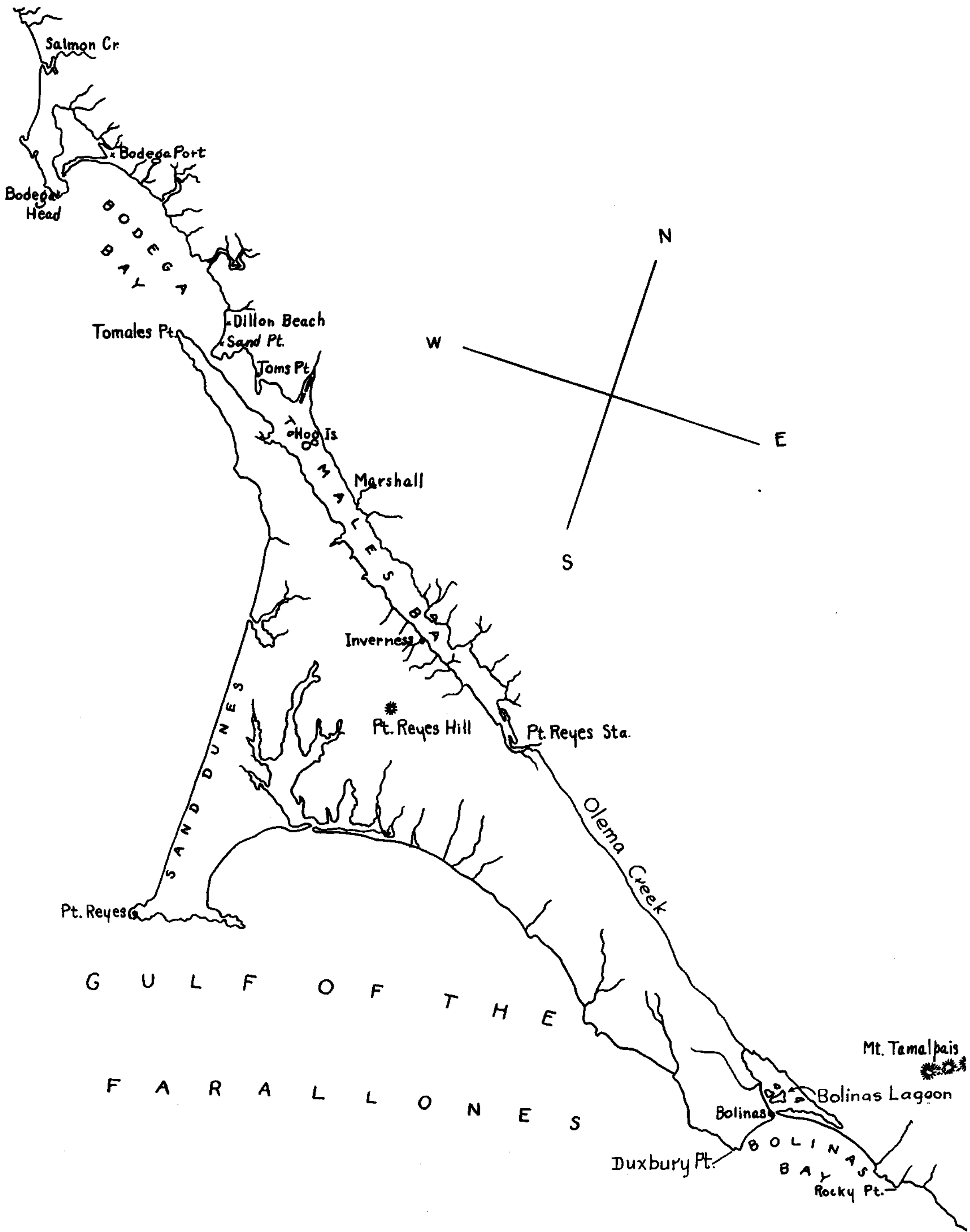
Procedure: One morning the class will visit an area of tumbled rocks whose bases are exposed at low tide at a point known as "The Second Sled Road" (see Map V) along the shore of Bodega Bay north of Dillon Beach. Here a relatively rich and diversified fauna will be found in tide pools, on rock surfaces, among algae, in gravel and sand about roots of eelgrass, etc. This will suggest in some ways the fauna of Halosaccion Flats. Differences from it should be noted and explanations for these differences sought. Again it should be compared with that to be seen at Tomales Point a more exposed region where rocky formations abound with deep tidal channels, tide pools, etc.

Another morning will be devoted to the fauna of the tidal channels, tide pools, and rocks of Tomales Point. Among other things make certain that you investigate fully the association of animals in a well-developed mussel bed such as will be found here on the higher rocks. Be able to explain the role of each type of animal in the association or what advantages it receives by the association.

Finally one morning will be given to the faunas of animals to be found at various levels of the tidal flats of muddy sand just inside the mouth of Tomales Bay (map V). Here the numbers of species are not so great as in the faunas so far studied but there is a wealth of individuals. Particularly important here are the giant clam, *Schizothaerus*, the bent-nosed clam, *Macoma nasuta*, *Phoronopsis* sp., whose pale-green lophophores practically cover the ground for several acres, polychaete worms of several interesting types especially *Clymenella*, and capitellids. At certain levels in a restricted area the mud shrimp, *Upogebia*, will be found, while *Callianassa* occurs in great numbers at somewhat



Map III, Frenchman's Reef (local names)



Salmon Cr.
Bodega Port
Bodega Head
BODEGA BAY
Dillon Beach
Sand Pt.
Tomales Pt.
Toms Pt.
Hog Is.
TOMALES BAY
Marshall
N
W
E
S
Inverness
Pt. Reyes Hill
Pt. Reyes Sta.
SAND DUNES
Olema Creek
Pt. Reyes
GULF OF THE FARALLONES
Mt. Tamalpais
Bolinas Lagoon
Bolinas
BOLINAS BAY
Duxbury Pt.
Rocky Pt.

Map IV.

higher levels. In the time available get as clear a picture as possible of these major types in their natural setting, and the other species which will be encountered, and of the varying ecologic ranges of the different species, seeking to assign environmental causes for the limitations of these ranges.

In identifying species use the keys to the various groups as listed in the index. Report any species not listed in the syllabus and turn these in with information as to place of collection.

D. Lake Merritt: A Brackish Water Estuarine Lake

Lake Merritt has been formed from a branch of Alameda Estuary. Its level is controlled by tide gates and hence the factor of the tides is eliminated. During the rainy months the salinity is very low. During the summer and fall it reaches a concentration (30 parts per 1000) not far below that normal for seawater (34 parts per 1000). An abundant algal growth, chiefly green algae and diatoms, furnishes a rich food supply. As a result a few species, adjusted to low and varying salinity and not adapted to withstand exposure or wave action, flourish and occur in great numbers except during periods of high salinity.

Such species are the tube worm *Mercierella enigmatica*, the associated amphipods *Corophium bonellii* and *Gammarus confervicolus*, the polychaete, *Neanthes succinea*, the crab, *Rhithropanopeus harrisii*, all of which live among the masses of tubes of *Mercierella*, the endoproct bryozoan, *Barentsia* (= *Pedicellina*), common as a mossy growth over the tube-worm masses, especially near the exit of the lake, and the horse mussel, *Modiolus demissus*.

Several other species, while typically marine, invade the lake at times of high salinity but maintain a precarious existence during the remainder of the year. Such are the soft-shell clam, *Mya*, the barnacles, the encrusting bryozoan, *Membranipora*, the mud snail, *Ilyanassa obsoleta*, the oyster drill, *Urosalpinx*, the tunicate, *Ciona intestinalis*, and various other species.

Procedure: Study the fauna to be found on the sides of the pier of the Municipal Boathouse. See a boat lifted in the shops near by and observe the enormous numbers of gammarids leaving it as it leaves the water and the thick encrustation of *Mercierella* tubes. Observe *Modiolus* in life in the mud near the inner end of the pier and the young *Mya* just west of the boathouse. Can you distinguish as to niche, between *Nereis* and *Neanthes*.

Tows will be made which should be studied on return to the laboratory. These will probably contain very numerous larvae of *Mercierella* in various stages of development, trochophores, polytrochs, and young worms. Also veliger larvae, probably of *Mya*, possibly also of *Modiolus*, may be found in great numbers. In late spring or summer entomostraca, especially copepods, are present in great numbers, as also rotifers.

Mud from the bottom will show great numbers of worms, chiefly of the genus *Streblospio*.

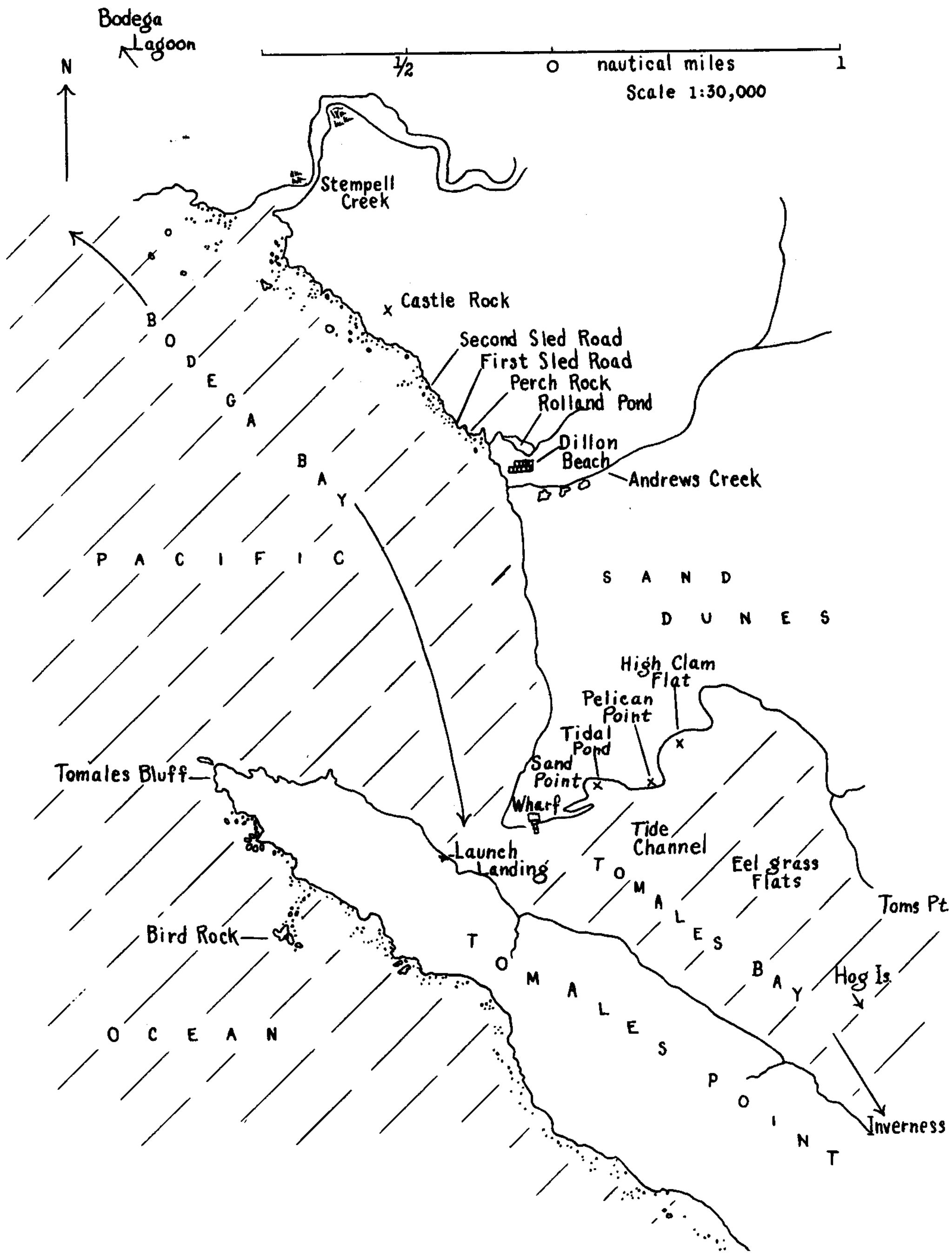
Break apart one of the tube-worm masses and study the relations between the different animals in this association.

Be responsible for a knowledge of this fauna, the food habits of all its elements, and the chief physical and biotic features responsible for the abundance of each.

Keys for the identification of amphipods and polychaetes are given below. Identifications of other groups must be made by the general keys.

A KEY TO THE AMPHIPODS OF LAKE MERRITT AND OAKLAND ESTUARY

1. Side plates typical (fig. 63), body compressed 2
1. Side plates 2-4 fused; a small, broad species common among hydroids in Oakland Estuary . . . . *Metopa*
1. Side plates reduced; dorsoventrally flattened; tube-builders . . *Corophium*



Map V. Dillon Beach and vicinity

2. Outer branch of uropod 3 broadened and much longer than that of uropods 1 and 2 (Family Gammaridae) 3
2. Outer branch of uropod 3 not broadened and not longer than that of uropods 1 and 2; in moist but not in wet places (Family Talitridae) . . . . *Hyallela*

3. Antenna 1 at least one-half as long as body; eyes not crescent-shaped; dorsal groups of spinules only on fifth pleon segment; Lake Merritt . . . . *Melita*
3. Antenna 1 not one-half as long as body; eyes crescent-shaped; pleon segments 4-6 with dorsal groups of spinules; Lake Merritt . . . . *Gammarus confervicolus*

A KEY TO THE ANNELIDS OF LAKE MERRITT

1. In closely packed, calcareous tubes; head covered by feathery tentacles (fig. 16); operculum spiny . . . . *Mercierella enigmatica*
1. Not so 2

2. Larger; head with a pair of fleshy palpi, 2 small anterior antennae and 4 pairs of peristomial cirri (fig. 15) 3
2. Smaller; head with 2 long, prehensile palpi or without palpi 4

3. First few segments provided dorsolaterally with oblique wrinkles; posterior notopodia with only pointed setae . . . . *Neanthes succinea*
3. First few segments smooth dorsally, without oblique wrinkles; posterior parapodia with some blunt setae . . . . *Nereis vexillosa*

4. Anterior end of prostomium with 4 small antennae; palpi absent (figs. 28,B,C) 7
4. Anterior end of prostomium without antennae; posterior margin provided with conspicuous prehensile palpi (fig. 17,J) 5

5. Prehensile palpi accompanied by a pair of foliaceous appendages; a dorsal collar on segment 3; in muddy tubes . . . . *Streblospio lutincola* (fig. 34,A)
5. Prehensile palpi not accompanied by foliaceous appendages; without dorsal collar 6

6. Pale white; minute; constructing erect tubes which project from crevices; dorsal branchiae not present anterior to segment seven . *Polydora*
6. Salmon to red in life; inhabiting burrows constructed in clay banks or in crevices; dorsal branchiae present on segments 3 to 5 as well as more posteriorly . . . . *Boccardia* (17,J)

7. Slender, thread-like; yellowish or somewhat green; first segment well-developed dorsally . . . . *Eteone californica*
7. Depressed, short; pale or white; first segment dorsally reduced . . . . *Eteone lighti*

E. Pile Communities and Zonation as Seen at Fruitvale Bridge

Laboratory Preparation: A group of invertebrates which is an important part of the Fruitvale Bridge fauna but which has not been previously encountered in any abundance in this course is the hydroids. The Hydrozoa should therefore be studied in the laboratory not long before the field trip.

Field Procedure: Collections and notes must be made from boats. The animals taken will be studied and identified in the laboratory on the same day. Materials needed are several screw-top jars, several vials for individual specimens, forceps, scalpel.

Observe and record the vertical and horizontal distribution of the animals found. What factor usually determines vertical distribution? You will find some types here at higher levels than would ordinarily be expected. What are these types? Do you find any difference in this regard between central and marginal piles? What is the factor thus modifying the action of the factor which usually determines vertical distribution?

Note especially the hydroids and the anemones. Attempt to distinguish the different genera of hydroids and the different species of anemones in the field. Collect specimens to enable you to check your field determinations. Be able to place each in its characteristic zone. Learn to see the highly modified amphipods (Caprellidea) which are abundant on the hydroids. Study these in the laboratory. Are the caprellids different on different genera of hydroids? Where do you find nudibranchs and their coiled egg masses?

Some of the piles will be covered with muddy debris. This is made up of tubes of great numbers of small amphipods. Many species of animals seek shelter in and about the mud tubes. Collect some for later study. Does the location of these piles give you any clue as to why they, and not others, bear this association?

Select a pile which shows zonation especially clearly. Working in teams of three or four, study the zonation carefully, designating the various zones, measuring their extent and relation to low tide level. Keep notes on the animals found to be characteristic of each zone. Seek to determine the factors, physical and biotic, influencing the zonation.

As time allows, stop at other neighboring piles. Compare them with your first pile. Study the piles on the other side of the estuary. Account for differences in the fauna of the different piles.

F. A Permanent Freshwater Pond or Lake

The laboratory preparation for this trip requires introductory studies of some of the invertebrate groups whose members are largely inhabitants of fresh water. Such are the Rotifera, the Cladocera, the Ostracoda, and the Copepoda.

Purposes: To get a comprehensive picture of the fauna, food chains, and food cycle of a freshwater pond or lake.

Procedure: Collect as completely as possible from various habitats in the pond. Especially important are (1) floating plants; (2) the surface of floating wood, etc.; (3) under the bark of floating branches and logs; (4) the fine roots of trees; (5) plants growing in the water at various levels; (6) the bottom mud. Tows will be made near the surface, some inches below, and near the bottom. Mud will be taken from the bottom for making cultures.

Identify your collections, using the keys in the preceding section. Sample the fauna of the tow and the bottom mud and identify the animals found there.

Insects need not be identified beyond the family or order groups, thus, belostomid bugs, dytiscid beetles, damsel-fly larvae, dragon-fly larvae, chironomid larvae, phantom larvae (*Corethra*). Use Needham in Ward and Whipple, or A Guide to the Study of Freshwater Biology (1930) by Needham and Needham, and works dealing with individual groups which are listed in the bibliography.

The common, small, somewhat transparent leeches belong to the genus *Glossiphonia* and are predators on the snails rather than bloodsuckers as are typical leeches exemplified by the larger species (Genus *Hirudo*).

Consider carefully the food habits of each species or group found. Fit them into food chains and these into a food cycle for the pond. Put the food cycle in the form of a diagram. This is to be turned in for criticism and evaluation.

Some Animals of a Permanent Pond Listed According to Food Habits

Plankton Feeders: Protozoa, sponges, rotifers, Cladocera, Bryozoa, Musculium (pelecypod), Copepoda.

Predators: *Hydra*, *Dugesia* (= *Planaria*), leeches, water mites, spiders, dragon-fly larvae, water bugs (back-swimmers, water boatmen, Belostomatidae), water-striders (Gerridae), beetles and their larvae (Dytiscidae, Hydrophilidae), ghost larvae (*Corethra*), fishes, Amphibia, reptiles, birds.

Plant Feeders: Isopoda, snails, aphids, amphibian larvae, some fishes.

Plant Scavengers (including detritus feeders): nematodes, oligochaetes, Ostracoda, Isopoda, Amphipoda, may-fly nymphs, bloodworms (larval Chironomidae), mosquito larvae, gnat larvae (Simuliidae).

Animal Scavengers: Ostracoda, Isopoda, Amphipoda, water-striders (Gerridae), Gyrinidae.

G. A Temporary Pond

Life in all small bodies of water is subject to relatively rapid seasonal changes due to changes in temperature and other climatic factors. The life of a permanent pond or lake undergoes also a vastly slower series of changes, known as geoglogical succession owing to the fact that physical conditions change slowly, each body of water tending to become more and more sedimented and ultimately passing through a marsh or a bog stage to become a meadow.

The seasonal pond undergoes each year profound changes in its life since it is not only subject to the influence of climatic factors but also a change from dry land to pond and from that back to dry land through marshy stages. Only those organisms will be found in it which have a resistant stage to carry them over the dry period or such as may be introduced either by visiting animals or by wind-borne resting stages.

In such ponds the shifts of population are very rapid. First a short period of rapid development of plankton which furnishes the food basis for a rapidly pyramiding population of plankton feeders (Protozoa, phyllopods, Cladocera, copepods, rotifers) which develop in enormous numbers followed somewhat later by a horde of predators and scavengers. The predators are largely insects, waterbugs, and water beetles, larvae and adults. Important as scavengers at this stage are the ostracods, which oftentimes occur.in very great numbers in such ponds.

To get the true picture of the seasonal succession of life in such a pond would require a number of visits beginning early in the spring. We shall designate the pond to be studied, suggest the time for two earlier visits, and set aside a day for a visit by the class when the population can be thoroughly sampled.

H. Terrestrial Habitats of Strawberry Canyon

The laboratory preparation for this trip will consist of a study of invertebrate groups which are primarily terrestrial, chiefly arthropods: centipedes, millipedes, arachnids, etc. Many insects will be found. They should be placed to the order and their ecologic position with respect to other invertebrates should be noted wherever possible.

In the field investigate all habitats, especially (1) under logs, (2) under dead bark, (3) in decaying wood, (4) in damp surface debris, (5) under stones, (6) in debris and under loose stones in the creek bed. The aquatic habitats of the stream should be noted and compared with other freshwater habitats studied.

Collect animals of whose systematic position you are uncertain. Keep records of others. Keep in mind the food relations of the various species seen. Identify the slugs and isopods using the keys listed in the index.

No report will be called for but you will be held responsible for the knowledge thus gained.

THE SPECIAL PROBLEM

Each student will choose a special problem for careful study and report. This problem will deal with the classification, the anatomy, the development, the behavior, the distribution, or the ecology of some local animal or group of animals, or with the fauna of a certain circumscribed area.

The problem should be chosen and work initiated early in the course. A certain part of the laboratory time will be allotted to it. It is to be carried out and reported on as a research problem. Every effort should be made to make it as scientific as possible. All statements should be supported by the author's accurately presented findings or by definite reference to authority. Reference should be made to sources found to be useful such as previous reports on the same subject, general treatises and especially articles in scientific journals. Care should be taken to limit the scope of the problem so as to make this possible.

The following is suggested as a standard form for these reports:

Brief table of contents
Statement of problem
Brief survey of literature and previous reports
Materials and methods
General findings, including lists of species, keys, etc.
Detailed presentation of results
Discussion of results (if needed)
Summary
Bibliography

Illustrations should be placed in the body of the paper where they will be of most value. Both Zoological Record and Biological Abstracts may be used in making up the bibliography. The standard bibliographical forms should be used, as in the example below, and references made by name and year, thus Oldroyd (1924):

Oldroyd, I. S.
1924. The marine shells of the west coast of North America. Stanford Univ. Publ. Geol. Sci., 1: 1-247, pls. 1-47.

A rough draft, or at least an outline, should be turned in for criticism and suggestions as early as possible, not later than two weeks before the last laboratory period during the regular session or one week during the summer session.

The finished reports will be held for use of future students in the course. Duplicates should be made if the student desires to retain a copy. Carefully labeled examples of the species dealt with are to be turned in with each report.

THE SUMMER COURSE

(Zoology S112, S119)

In alternate years the course is given at the seashore during the six weeks of the Intersession, usually from near the middle of May to near the end of June. S112 is given at this time for undergraduates or graduates seeking a teaching certificate in zoology or biology and for other graduates who, for good reason, do not wish to take S119.

Candidates for the Ph.D. degree in the department of Zoology of the University of California at Berkeley may take S119 in fulfillment of the requirement in Marine Zoology. The subject matter will be much the same as that in S112 but greater proficiency will be expected of these students, their examinations will be fewer and separate and they will do much more intensive problem work.

The summer course has been given at two different stations, Moss Beach or Montara, San Mateo County (Map I), and Dillon Beach, Marin County (Map IV).

Each location has its advantages. Facilities for board, room, and laboratory usually decide which shall be chosen in any given year. Directions are given for each, therefore.

Board and room for the six weeks usually ranges from a minimum of from $50.00 to $55.00 where a number of students share a room to a maximum of from $70.00 to $75.00 where a single room is desired. This includes the use of the laboratory and at Dillon Beach transportation across the bay on two or three trips and to the tide flats on two or three trips.

As noted above, undergraduates and those graduates not taking the course to fulfil the marine zoology requirements for the doctorate will take S112. This has a unit value of 3 but the amount and nature of the work done during the six weeks is the equivalent of a five-unit course and students desiring the additional two units may enroll for two units of S119 (without additional laboratory fee).

Those desiring six units or those who have taken Zoology 112 may enroll for problem work (S199 or S224), the number of units to be arranged with the instructor, who is enabled to act for the registrar and the comptroller.

The course given at the beaches, has the same general aims as the regular course. Much of the general discussion in the early part of the syllabus, as well as the laboratory directions, will be applicable to it. The program of the summer course will naturally be very different because of the short period of time involved.

The detailed program will vary from year to year with the incidence of the tides, but the projects will remain much the same.

The first necessity is to learn the fauna, its distribution, in general, and the major physical features which determine this distribution. Following this, problems of a more definite nature will be attempted. Since advantage must be taken of all low tides and since the lowest tides usually occur during the first or the second week of the course, these will necessarily be especially strenuous, the very early morning being devoted to field study and collecting and the remainder of the day to the identification and study of the animals collected on those field trips. Those exercises which are to be carried on independently should be undertaken early in the course and plans made for their completion.

During the remainder of the course, in addition to continuing the study of the fauna as a whole, more emphasis will be placed on problems of a general or specific nature.

GENERAL PURPOSES OF S112 and S119

1. The gaining as rapidly as possible of the ability to identify from the specimen or the name the common invertebrates of the region, chiefly those of the marine littoral. This is a necessary preliminary to other types of study. To facilitate the gaining of this knowledge preliminary lists will be posted and named collections put on demonstration. Relatively early in the course an identification test will be given.
2. The study of those characters used in the identification of the various groups of invertebrates.
3. Experience in the identification of animals by means of keys.
4. A knowledge of the ecologic niches (the characteristic environmental settings) of all the common animals seen.
5. A knowledge of the grouping of the different species in faunas of specific areas and habitats.
6. A knowledge of the grouping of species in associations and their interrelationships in associations, most obviously their relations in food chains and cycles.
7. A knowledge of the distribution and density of population of certain species and of groups throughout the region as a whole with a view to understanding some of the factors which limit their distribution.
8. A knowledge of the habits and behavior of certain species.

Read those portions of the introduction dealing with the use of scientific names and systems of classification, and with field and laboratory methods.

Read Flattely and Walton, The Biology of the Seashore; and Ricketts and Calvin, Between Pacific Tides; papers by MacGinitie on feeding habits and natural history of a number of marine animals; also MacGinitie on Littoral Marine Animal Communities; Shelford et al., Some Marine Biotic Communities of the Pacific Coast of North America; Hewatt, Ecological Studies on Selected Marine Intertidal Communities of Monterey Bay; Newcombe, Certain Environmental Factors of a Sand Beach; and other articles listed in the bibliography as dealing with ecology and natural history.

Collections should be made on all field trips of animals not already known or not in the demonstration sets. Those belonging to the Mollusca and decapod Crustacea should be identified at once and those at all common learned in preparation for the identification tests. Others should be preserved for future identification in connection with scheduled exercises. Polychaetes should be killed by adding formalin, a few drops at a time, and preserved.

1. AS GIVEN AT MOSS BEACH

Exercises 1 to 16 deal with the marine littoral fauna of Moss Beach and San Mateo County. Exercises 13, 14, 15, and 16 should be begun at the earliest possible oportunity. Read instructions under individual projects, p. 204, study the exercises and organize your program accordingly.

The diversity of fauna of Moss Beach and vicinity is due to the wide variety of physical conditions within a relatively narrow area, especially to the diversity in nature and arrangement of the substrate. Maps I and II give the local names which it will be necessary to learn in order to discuss the different faunas.

The following points should be identified at the outset in preparation for work in the field: North Point, Sand Rocks, Sunshine Creek, the Reefs, Kelp Cove, Moss Beach Flats, San Vicente Creek, Moss Beach Point, Nye's Channel, Nye's Rocks, Egregia Flats, Halosaccion Flats, Seal Cove, Marine View Point, Marine View Rocks, Frenchman's Reef, the Lagoon.

Read the account by Charles Reed of the geology of the Moss Beach Region.

General Purposes of These Exercises (1-16)

1. Knowledge of all marine littoral invertebrate animals of the region.
2. Knowledge of the fauna of various specific habitats.
3. An appreciation of the factors responsible for major differences in faunas, as between Moss Beach Flats and Frenchman's Reef for example.
4. A study of the distribution of certain species or groups with a view to determining the limiting factors.
5. The behavior of certain groups or species.

These have been separated out into exercises in an effort to make them specific. They actually overlap, forming part of a continuous program necessarily altered by the nature of the tide and the weather and other considerations. These exercises should be read over to gain a comprehensive picture and to allow for greater efficiency in their prosecution.

Exercise 1. A Preliminary Survey of Moss Beach and the Fauna of Moss Beach Flats

If the time before low tide permits there will be a brief survey of the important local landmarks.

After this follow up the receding tide across Moss Beach Flats to Nye's Rocks and Channel and Egregia Flats, collecting any animals not known to you and keeping notes on those destined for your collection, together with notes on the faunas of the different habitats.

Learn the names of as many animals in the field as possible.

When the tide has driven you from profitable collecting grounds take your collections to the laboratory for identification, preservation, or study under the microscope.

Do not bring in specimens of species known to you and not needed for your collection or sea urchins and sea stars (except the small individuals of *Leptasterias* and *Henricia*.

Exercise 2. Halosaccion Flats

Ecological distribution of a meager fauna in an area of little diversification.

Exercise 1 should have given you some general idea of the animals to be encountered, their range of size, and ordinary distribution in a region of diversified environmental conditions.

In this exercise we shall confine our efforts to a circumscribed area of the flat central portion of Halosaccion Flats (Maps I and II). Study the environmental conditions, both physical and biotic. Consider such factors as intertidal range, nature of substrate, position and disposition of the substrate, degree of exposure to sun, wind, wave impact, predators, etc.

Distinguish all the different habitats represented, determine the specific assemblages in each, seek to understand presences and absences in terms of definite physical or biotic conditions.

Is the fauna as a whole characterized by any conspicuous absences? If so, how is this explained in the light of the ecological features? Is it conspicuous as a whole for largeness or smallness of the species involved or the individuals of the species? If so, set up an hypothesis to explain this feature.

Exercise 3. Fauna of Sand Rocks and Vicinity

Location: Sand Rocks just beyond the Reefs which form the northern boundary of Kelp Cove (see Map II).

Physical Conditions: An area of varied physical conditions involving several very distinct habitats (and their intergrades) such as (1) high tide pools (in top of Sand Rocks); (2) sheer, soft rock surfaces (sides of Sand Rocks) exposed to tidal and wave action; (3) a rock surface sloping upward toward the shore composed of granite interspersed with softer areas and ending in a sheer or overhanging shoreward face; (4) tiny tide pools contained in the surface of this rock layer; (5) a shaly low low-tide bottom exposure; (6) the inner ends of nearly upright reefs of hard rock (The Reefs) extending out some distance; (7) a region of rocks and small boulders near low tide line; and (8) a sandy inner beach of coarse sand.

Biotic Conditions: These are correspondingly varied, from areas practically devoid of life to those with heavy growths of large seaweeds.

Purpose: Experience in thinking in terms of ecologic factors as determining habitats and ecologic niches. We are using the term ecologic niche to refer to the sum total of environmental conditions, physical and biotic, to which a particular species is adapted and which are necessary to its continued existence. A habitat on the other hand is a kind of place, a place or region characterized by certain major environmental features. A habitat will possess a characteristic fauna, each species of which has its own niche. Thus, for example, a tide pool will contain a number of different species each with its own niche. Since the distribution of ecologic conditions within a habitat may spatially limit an ecologic niche we may, for convenience, connect certain niches with places within the habitat, but this is not true of many niches and not really correct for any niche. To completely define a niche would involve an immense amount of quantitative and experimental investigation of the physical and biotic ecological factors not yet begun for the species we study. However, we are usually able to discern one or more obvious features of each niche which give it objective reality and allow us to give it a preliminary definition and to use it in discussion.

Procedure: Study each of these habitats and its characteristic fauna. Be able to discuss the distribution of the different groups and species in this area in terms of the ecologic factors involved. Be able to make a field key to the species of *Acmaea*, and to answer such questions as the following: Why are the gastropods (aside from *Acmaea*) absent from the Sand Rocks? Which genus is dominant on the sides of Sand Rocks? What is the dominant species in the tide pools in the top of Sand Rocks? Where did you find zonation?

There will be no report but a written test will be given covering the information gained in Exercises 1-3.

You have now seen three different habitats or locales each with its own characteristics and variations. You should begin to form a picture of the ecologic ranges of certain species, such as those of the genus *Acmaea* (see Exercise No. 12), the hermit crabs (see the key, p. 113 and the special paper by Harris), and the flat-topped crabs of the genus *Petrolisthes* (see special paper by Fields and Benton).

Sample Questions on Sand Rock and Vicinity

1. What species not found or rare at Sand Rock and vicinity were found on Halosaccion Flats proper?
2. Name species found abundantly in the vicinity of Sand Rock that were rare or not found on Halosaccion Flats proper.
3. Suggest one general reason for the fact that the latter list is longer than the former.
4. What were the most important plant feeders; scavengers; predators; plankton feeders, in the Sand Rock vicinity?
5. Name animals characteristic of Sand Rock proper that were not found among smaller rocks around its base.
6. List differences in fauna between loose rocks on sandy substratum closer in and farther out.
7. Which of the three major factors seems most important here? Illustrate.
8. On the basis of today's observations how could you distinguish the niches of the three shore crabs?
9. What evidences did you note of vertical zonation of the species of *Acmaea*?
10. Which was the most abundant polychaete?
11. What two features of the situation probably account for its abundance?
12. What are the advantages and disadvantages for *A. scabra* of sandrock as against granite rock?
13. Why so few barnacles and no mussels on sandrocks?
14. Why so few littorines?
15. What structural character of *Cirriformia luxuriosa* not found in *C. spirabrancha* is correlated with its habit of life?
16. Name three genera of isopods encountered. Characterize the very distinct ecologic niche of each. Which two may be found together? Where and why?
17. With what other animal did the presence of *Acanthina* seem to correlate?
18. Why were borers not abundant? Nestlers?
19. What terebellid worm was abundant? Give some features of its niche.

Exercise 4. Frenchman's Reef

Location: Between Marine View and Pillar Point (see Maps I and II).

Physical Features: A rocky reef, with a relatively flat top, extending into the open sea, exposed on its high side to direct wave action and cut by numerous, deep, narrow, tidal channels (see Map III) with steep, often overhanging walls; numerous high tide pools; ledges under exposed horizontal rock strata; a protected, shallow lagoon between shoreward end and shore on north side.

Biotic Features: Very great abundance of algae except on high central shoreward portion; beds of narrow eelgrass and *Laminaria*, etc., on protected side; sea urchin beds and mussel bed near outer end.

Procedure: Study first the deep tidal channels and the fauna of the seaweeds and eelgrass of the protected sides. On the return study and attempt to explain shoreward changes in fauna on the reef surface. On the way out or back study the under-rock fauna of the lagoon, comparing it with that of Iridaea Channel and Marine View Rocks. Hydroids should be collected wherever found and taken back to the laboratory for study and identification (at least ten species should be found).

A colony of the sea anemone, *Corynactis*, occurs under one of the high ledges about halfway out. Be certain to see it.

Attention should be paid to three species of limpets each confined to a single plant species: *A. paleacea* on the eelgrass (*Phyllospadix*), *A. insessa* on *Egregia*, and *A. instabilis* on the stalks of *Laminaria;* all found on the north side of the reef.

Some Questions on Frenchman's Reef

1. List nine or more habitats or subhabitats each with an essentially distinct fauna. Give one to three characteristic species for each.
2. Name five extremely stenotopic species of sessile gastropods.
3. What advantages probably explain the abundance of *Plumularia* on the bases of the brown algae near the laminarian zone?
4. At many points a fauna characteristic of the lowest littoral or the sublittoral was encountered at relatively high levels. How could you explain this in terms of physical factors?
5. What biotic factor (associated with a physical feature of the subhabitat) operates with regard to the hydroids?
6. What factors do you conceive to operate to determine the distribution of *Strongylocentrotus purpuratus?*
7. What major difference with regard to *S. franciscanus?*
8. Name four types belonging to as many phyla which are found competing for space in certain favorable spots? What makes these spots favorable?
9. Name five genera of hydroids encountered. Which was most abundant?
10. What arthropods seem adapted for life on this particular hydroid?
11. What highly stenotopic pelecypod was encountered?
12. Why the relative scarcity of limpets (biotic factor)? Of barnacles? Of *Tegula* except near inner end of reef?

Exercise 5. Iridaea Channel

Location: Iridaea Channel (see Map II), really lagoon-like, is a lower area in Moss Beach Flats which drains at low tides through Nye's Channel and Egregia Flats.

Physical Features: Protection from strong tidal or wave action and from exposure except at extreme low tide. Numerous rocks resting in gravelly sand containing much organic detritus.

Procedure: Learn the fauna and attempt to explain it on the basis of physical features of the environment. Be able to name another location where the same general conditions prevail. What two factors seem most significant in determining the nature of this fauna?

Some Questions on Iridaea Channel

1, What other spots have furnished a somewhat similar fauna? Which one especially, at Frenchman's Reef?
2. List five physical features and two biotic features which conspire to bring together the characteristic fauna.

3. Be able to list (1) the in-rock dwellers, as borers, nestlers or cranny dwellers; (2) the on-rock dwellers both those of exposed and of under surfaces; (3) the under-rock dwellers; and (4) the dwellers in the under-rock substratum.
4. Have in mind the food habits of each and, in so far as possible, the reasons for their presence there.
5. For each of the following name one or more species which are conspicuous in, or characteristic of, the fauna:

Brachyurous anomurans	Larger snail-like gastropods	Surface-dwelling pelecypods
Anomurous anomurans	Asteroids	Cranny-dwelling gastropods
Brachyurans	Limpets	Rock-dwelling brachyurous anomurans
Chitons	Barnacles	Ophiuroids
Errant polychaetes	Isopods	Holothuroids
Sedentary polychaetes	Rock-boring pelecypods	
Aberrant annelids	Nestling pelecypods	
Small snail-like gastropods		

6. What two types of prochordates (chordate invertebrates) are found?
7. What was the largest animal? What correlation between its size and its location?
8. What important predators were not seen by us?
9. Why were barnacles less numerous than on Nye's Rock?
10. What species of *Acmaea* is found only here? What does the nature of its shell and the places where it is found suggest as to the factors limiting its distribution?

Exercise 6. Marine View Rocks and Seal Cove

Location and Ecologic Features: Most important controlling physical condition is the presence of a broken line of outer rocks and reefs which more or less completely protects (1) the area of rocks of various sizes lying in gravel or sand which is Marine View Rocks (Map I); and (2) Seal Cove just north of it and between it and Halosaccion Flats already visited. These outer reefs support a heavy growth of many types of seaweed which are frequently torn away and carried in over the Marine View Rocks, and along the shoreward side of Seal Cove, where they break down and decay, furnishing food for many animals.

Note similarities between conditions and fauna at Marine View Rocks and other areas studied. One rock rises high enough to have a sample of a formation different from that found elsewhere in the vicinity. What gastropod marks this formation and why does it occur at that particular spot?

Seal Cove is particularly interesting for the occurrence there in numbers of two species which occur rarely or not at all in the other localities visited. These are *Olivella biplicata,* to be found in the sand at the end of surface trails, made presumably at night, and a large cirratuled worm, *Cirriformia spirabrancha,* whose slender, greenish tentacles resemble nemerteans.

Locate these two and attempt to explain their abundance here and their absence or rarity elsewhere.

Exercise 7. The Fauna of a High Rock Exposed on Its Outer Face to Violent Wave Action

Location: Nye's Rock (see Map II), separated from the high outer front of Moss Beach Flats by a deep narrow tide channel, Nye's Channel.

Physical Features: Rock sufficiently hard to withstand wave action but still penetrable by borers and sea urchins; base below low low tide, hence in Laminarian zone; high enough on seaward face to be exposed except at high water; with two lower shoreward shelves.

Biotic Features: A relatively rich growth of seaweeds of various types; mussel beds at certain areas and levels.

Habitats: A great number of habitats, some protected from wave action, others exposed to its greatest violence or to the scouring effect of tidal channels, tide pools, crannies, mussel beds, close set algal growths, Laminaria, etc.

Procedure: Make as complete as possible a study of the fauna. Note differences between exposed and protected sides. Seek an explanation for the location of the different species or associations, especially for the mussel and *Mitella* beds and the sea urchins.

Exercise 8. Fauna of a Tidal Cave

Drake's Cave, really a tunnel, furnishes excellent opportunities for a study of the influence of light or its absence. Attempt to segregate the influences of reduced light from those of the peculiar water flow resulting from the configuration of the cave and its varying diameter.

Before the field trip read the special problem report by Groody and Villee on "The Biology of Drake's Cave." Check your findings against theirs as to the fauna and its distribution. Are the differences real or simply differences in sampling? If real, have you any explanation for them?

Exercise 9. Under-Rock Faunas

Purpose: To visualize the importance of the factor of protection.

Procedure: Choose a rock resting on or partly embedded in sand or gravel, one small enough to be turned over, but yet of considerable size and so located as to be relatively stable.

Note carefully the physical location of the rock with regard to tide level, protection from wave action, etc., also whether embedded in or resting on the substrate, or with space between it and the substrate.

Overturn the rock and make immediate notes of the active population which almost at once seeks protection elsewhere.

Carefully list and evaluate the remaining fauna of the lower surface of the rock and of its crevices and crannies if any.

Attempt to arrange the total fauna thus listed on various bases: (1) as to the reasons for their presence there, (2) their food relations, etc.

Exercise 10. Rock Dwellers

At a low tide choose a small rock from Egregia Flats or break off a small piece from the shoreward bank of Nye's Channel.

Collect and make careful record of the surface-dwelling animals.

Break it open and identify and list (1) the crevice and cranny dwellers, (2) the rock borers and (3) the nestlers.

Attempt to explain the presence of each species in its particular location.

Exercise 11. Fauna of a Seaweed Holdfast

By means of a geologist's pick separate from the rock a holdfast of one of the larger algae (*Laminaria, Egregia,* etc.) found at low tide level along the front of Moss Beach Flats, Nye's Channel, or on Egregia Flats.

In the laboratory break it open and list the different species present.

Attempt to explain the presence of the different species.

Exercise 12. The Distribution and Habits of the Limpets of the Genus Acmaea

Purpose: The genus *Acmaea* offers an unusual opportunity for the study of numerous species of the same genus living in the same general habitat. Fourteen species occur in this area, of which ten should have been encountered by all. The purpose of this study is to consider the structural differences of these species, their interrelationships within the genus, their habitats and habits of life insofar as time allows with a view to discovering what correlation, if any, is to be found between these structural characters and the habitats and habits of life of the different species. The following ten species will be used for the study, all of them common except *Acmaea persona* and *A. instabilis* which will be pointed out to you:

1. *Acmaea asmi*	6. *Acmaea paleacea*
2. *Acmaea digitalis*	7. *Acmaea persona*
3. *Acmaea insessa*	8. *Acmaea scabra*
4. *Acmaea mitra*	9. *Acmaea scutum*
5. *Acmaea pelta*	10. *Acmaea instabilis*

(Other species occurring but not so favorable for such studies are: *Acmaea fenestrata, A. limatula, A. ochracea,* and *A. triangularis.*)

Procedure: Make careful notes as to the characteristic location of these species as seen by you during low tides. Look for characters of general shape, color, and marginal ornamentation which seem to have an adaptive relation to the particular niche which each occupies.

Read introductory portions of thesis of Dr. Avery Grant and papers on homing behavior by Hewatt, and by Villee and Groody.

If time of tides allows (as during the summer) observe their behavior on a nocturnal low tide. Again look for correlations between their feeding behavior, their "home" locations, and their structural characteristics. To what extent is there competition between species?

Exercise 13. A Collection of Mollusks, Crustacea and Polychaetes

Purposes: (1) Training in collecting, preserving and labelling of invertebrates. (2) The additional familiarity with the species involved.

Directions: The utmost care, accuracy and neatness is to be used in all the work involved in collecting the specimens, in making ecologic notes, in correlating these notes with the specimens, in preparing the specimens, in their identification, and in labelling them properly. The work should be conducted at all times as if the materials were to be used for purposes of scientific research as, indeed, may well be the case.

The specimens turned in should, in general, be only those collected by the student involved. If specimens are obtained from others the collector should be cited on the label and it should be clear who is responsible for the ecologic data. Any other procedure or attitude vitiates the whole situation.

Juveniles or worn or damaged specimens should not be used except under unusual conditions.

Collections will be evaluated on the basis of completeness, correctness of identification, excellency of the preparations, neatness in organization and labelling, accuracy and completeness of data furnished and especially on the general and specific indications of scientific attitude and method.

Read carefully the general directions for collecting and for the keeping of field notes, and also the section on the use of scientific names.

Identifications should not be made lightly. Read the section on the identification of invertebrate animals. Where the species is uncertain the specimen should be labelled with the generic name followed by sp.? Thus: *Tegula* sp.? If it is believed to be a certain species but the identification is in doubt, a question mark in parentheses should follow the author's name, thus: *Tegula funebralis* Adams (?).

COLLECTIONS

Mollusca

Chitons: Minimum, 5 species. For permanent preservation chitons should be placed in a mixture of equal parts of water, alcohol and glycerine. For our purposes fixation in 5% formalin after flattening on a glass slide or other flat surface will be satisfactory. Specimens thus fixed may be left in formalin. Pelecypods: Minimum, 9 genera. Remove soft parts, using hot water if necessary. Gastropods: Minimum, 30 species in at least 15 genera. Bodies are best removed after leaving for some days in 30% alcohol. This is too expensive and time consuming for our purposes and it may be accomplished by placing them in hot (not boiling) water. This may slightly alter the color and surface of the shell hence making them unfit for a permanent collection.

Polychaeta

Minimum, 15 species in 10 genera. For permanent preservation specimens should be anaesthetized, fixed in special fixatives and preserved in alcohol. For our purposes they may be preserved in formalin and identified in connection with the laboratory study of this group.

Crustacea

Minimum requirements: Copepoda, mounts of at least 5 species, including at least one from each of the common orders. Amphipoda, at least 8 species. Isopoda, at least 6 species. Macrura, at least 3 species. Anomura, at least 6 species in at least 4 genera. Brachyura, at least 10 species in at least 6 genera.

Organization of collections. Specimens should be arranged in a species list by phyla and classes and by collection numbers. When turned in they must be so arranged as to be easily inspected and checked. Labels should be made with India ink. See page 175 for instruction as to contents of label. Full scientific names should be used.

Exercise 14. Collection of a Single Group and a Study of Its Ecological Distribution

This should be begun as early as possible in the course to allow for studies at low tide. Choice of group should be approved by the instructor. The degree of emphasis on the taxonomic or the ecological phase of the exercise will be determined in some cases by the size of the group involved, in others by the interest of the student.

Groups suggested are: the hydroids, the Bryozoa, the sea anemones, the seastars, the true crabs, the shrimps, the Anomura, the species of *Petrolisthes*, the species of *Pagurus*, the *Acmaea*, the small gastropods, the species of *Crepidula*, the amphipods, the isopods, harpacticoid copepods, the polychaetes in general or any group within them such as the Nereidae, the Phyllodocidae, the Spionidae, the Cirratulidae, etc.

Exercise 15. Fauna of Small Tide-Pools with Emphasis on Behavior and Feeding Habits

Location: A small, permanent, relatively high tide pool. A particular pool will be assigned for this study.

Procedure: Visit the pool at various times and under different conditions as regards tides, etc. Do not disturb unnecessarily the inhabitants or remove any of them at any time during the study. Station yourself so as not to cast a shadow on the pool.

Make a careful survey and census of the population keeping a faunal list with approximate numbers of individuals. Make a diagram to show distribution of the inhabitants. Species not sufficiently seen to allow for diagnosis may be described and identifications will be supplied by the staff.

Note and record any activities observed during a period of 15-30 minutes after the original disturbance, if any, has quieted down. Attempt to explain these movements.

Devise experiments to determine reactions of different animals to various types of stimuli.

Introduce a small piece of mussel previously prepared so as to avoid disturbances. By this method seek (1) to determine the numbers and locations of carnivorous animals, (2) to understand and record their feeding behavior, (3) to determine whether sight, chemical sense or touch enables them to find their food.

By varying this device seek to determine which are facultative carnivores and which obligatory. By using tiny fragments of dead seaweed detect plant scavengers if any. By using whole tiny organisms seek to determine which, if any, of these carnivores are predators. By using different animal bodies seek to determine whether they have favorite foods. Interpret negative results with caution.

Consider also relations with other species present only during high tide. Attempt thus to build the food chains involved. Do they form a cycle? Visit the pool numerous times on different days, preferably on sunny days and after the water has become warm. Before leaving the pool remove any debris or food particles which you might have added. Leave the pool as undisturbed as when you found it.

Make an effort to determine (1) to what degree the fauna changes from day to day, (2) to what extent the animals concerned have permanent locations.

Turn in a report covering all the points studied.

Please make this an entirely individual study and report avoiding discussion or conference.

Make the study and report an exercise in the scientific method.

Exercise 16. The Fauna of the High Tidepools between Sand Rocks and North Point and the Problem of the Distribution of the Red Copepods (*Tigriopus californicus*)

These tide pools vary in size from a few inches in depth and diameter to deep pothole pools on the top of sand rocks and elsewhere. The substratum also varies from soft shaley sandstone through conglomerate to granite. Other physical factors possibly concerned are elevation, exposure to sunlight, etc.

The dominant animals of these pools are three, *Pachygrapsus crassipes*, *Boccardia probiscidea*, whose waving tentacles are readily seen on close observation, and the red copepod, present in varying numbers or absent. Some of the pools are inhabited by the cirratulid worm, *Cirriformia luxuriosa*, whose dark tentacles form conspicuous patches.

Study the distribution of the copepods with a view to determining why they are absent or nearly so in some pools and present in others. Important among the factors to be considered are predatory animals and food requirements. Previous studies have shown the copepod adapted to withstand extreme ranges of temperatures and salinity as would be expected of an animal living in small high tide pools.

On the basis of early observations propose an hypothesis. Make observations at later times, organize your evidence, and criticize your hypothesis in the light of the evidence. Incorporate this in a report to be turned in not later than the end of the fourth week.

Exercise 17. The Identification of Polychaeta

Identify and label all the polychaete worms collected using the key on page 34. Refer to Hartman (thesis and various papers), and Fauvel, Errantia (1923) and Sedentaria (1927) in Faune de France.

Co-operate with the staff (1) in accumulating a correctly labelled series of well-preserved reference specimens, and (2) in gathering all animals seemingly not in our lists or new to the region to be sent to Dr. Hartman for identification.

Exercise 18. Fauna of Tidal Flats in an Enclosed Bay (Tomales Bay near Dillon Beach, Maps IV and V)

For directions see Exercises 28, 30, 31, and 32.

Read: MacGinitie, "Ecological Aspects of a California Marine Estuary (Elkhorn Slough)" and "Littoral Marine Communities"; Shelford and Towler, "Animal Communities of San Juan Channel and Adjacent Waters"; Shelford et al. "Some Marine Biotic Communities of the Pacific Coast of North America"; Alice Mulford, report of special problem on "Distribution of *Callianassa*."

Individual Projects

All members of the S112 class will do the following as individual projects:

1. Either Exercise 13, 14, or 15, with collection (or report if 15).
2. An intensive study of the behavior of some one common species.

A special problem (see suggested subjects below) may be done either in addition to the above or, with the instructor's permission, in place of 1 or 2. If additional credit is desired for special problem work the student should enroll for extra units early in the course.

S119

Each member of the S119 group will carry out at least one special problem. The number of possible problems is almost endless. A careful study of any species from any one of several points of view would produce results of interest and value. In addition there are many problems of various types dealing with groups and local faunal assemblages.

Suggestions for Special Problems

Distribution and behavior of the two littorines, especially factors differentially affecting the two species. A collection of nemerteans with notes on their behavior and distribution for Dr. Coe. Further studies on *Tegula funebralis* (see paper by Gorbman). The distribution of *Tegula brunnea*, limiting factors and an analysis of population. Behavior and habits of the large sand flea, *Orchestoidea corniculata*. *Orchestoidea californica*, its behavior and distribution (Half Moon Bay) and limiting factors. Is it a separate species? Fauna of Montara tidal caves. Habits and behavior of *Olivella biplicata*; food. Anatomy of *Olivella* with a view to its availability for use as type for the study of streptoneury, asymmetry and extreme torsion. Classification and ecologic distribution of any common family of polychaete worms such as (1) Lumbrineridae and Glyceridae, (2) Opheliidae and Orbiniidae, (3) Nereidae, (4) Phyllodocidae and Nephthyidae, (5) Syllidae, (6) Terebellidae, (7) Polynoidae, (8) Sabellidae, etc. The anemones, with a key for their identification. Structural and ecologic differences between the two large anemones, *Anthopleura xanthogrammica* and *Bunodactis*. A key to the hydroids of Frenchman's Reef with notes on their distribution. The fauna of the inner lagoon of Frenchman's Reef. Taxonomy and biology of the common flatworm. Fauna of a sandy beach (Montara Beach). A practical key to the common Bryozoa. The harpacticoids. Stages in the development of the isopod, parasitic in barnacles at Marine View Rocks. *Alloniscus*, the high beach isopod, its habits and ecology. Marine and beach dwelling insects, their behavior and ecology. Authentically named demonstration collection of Polychaeta. *Botula falcata* and *B. californica*; distribution; borers or nestlers? If borers, how accomplished? Anatomy of pholad compared with that of typical clam and an attempt to determine adaptive features of anatomy. *Acmaea limatula*; distribution; limiting factors. Same for *A. fenestrata*. Halosaccion Flats: (1) Distribution of polychaetes; (2) distribution of decapods, especially hermits. Feeding habits of *Acanthina*. Further studies on ecologic segregation of the species of *Pagurus* (see paper by Morgan Harris). Further study on homing of *Acmaea scabra* (see papers by Hewatt, and by Villee and Groody).

2. AS GIVEN AT DILLON BEACH AND VICINITY

Dillon Beach lies on the shore of Bodega Bay not far north of the mouth of Tomales Bay (Maps IV and V) and within reach of numerous diverse faunas.

The bold rocky outer coast of Tomales Point affords excellent opportunities for the study of animals of tide pools, tide channels, and exposed rocks rising from the low tide line. Just off this shore lies Bird Island, which supports a fauna less reduced by human collecting than that of the shore. Tomales Bay has many tidal mud- and sand flats supporting rich faunas. Within reach, also, are numerous other interesting marine faunas. Such are those of Bodega Head to the north (Map IV), Duxbury Reef, Bolinas Bay and Bolinas Lagoon to the south (Map IV), and Moss Beach south of San Francisco (Maps I, II).

Tomales Bay, as its long, narrow, straight shape would indicate, is a fault bay. Bolinas Bay and the creek which runs into it from the north are continuations of the same fault line, the San Andreas Rift, which traverses San Francisco.

The fault line marked by the bay separates the Point Reyes block from the mainland. This block is supposed to have been an island during much of Tertiary times, perhaps connected with the Farallons. Its mesozoic granites are exposed along the western shore of the Point, where we shall collect.

The eastern shore of Tomales Bay is a part of the bed of the ancient Merced Sea (Pleiocene). Along most of this shore the Merced deposits have been eroded, exposing the older Franciscan deposits (Jurassic?) like those about Berkeley. In the northeastern portion, however, and along the shores of Bodega Bay, the Merced deposits remain. The conspicuous rocky outcrops east of Dillon Beach formed part of the shores of the Merced Sea, and the rocks which we study at Perch Rock Point and Second Sled Road must be from the Merced or from Franciscan deposits.

The sand dune area south of Dillon Beach partly closing up the mouth of Tomales Bay consists of much younger (Pleistocene and Recent) alluvial deposits.

Consult Dickerson (1922, Proc. Calif. Acad. Sciences) for a detailed account of the geology of the region.

Read the general statements with regard to the summer course (p. 193) and individual projects (p. 214). Begin as soon as possible the reading of appropriate chapters in Flattely and Walton and in Ricketts and Calvin, especially those dealing with the tides. Consult also the schedules given you and the list of low tides and begin to plan your program. Study Maps IV and V and make yourself familiar with the local names in preparation for field trips.

A list follows of field studies which may be made with Dillon Beach as headquarters. Not all these are possible in any one six-week period and during the tides available. A tentative schedule will be issued each year listing those field trips to be attempted and the dates as well as the laboratory exercises to be interspersed among them. Keep this schedule and amend it from time to time on the basis of announcements to be made.

FIELD STUDIES FROM DILLON BEACH

Exercise 19. Ecologic Distribution of the Polychaete Worms

A large number of species of polychaetes belonging to many genera and families are to be found in this diversified area. See Dr. Hartman's thesis for a list of species and something of the ecologic distribution of some of them. Polychaetes should be collected whenever found and, after microscopic observation and identification, properly preserved and labelled. If it is not possible to identify them at the time preserve them for future identification. About the end of the second week a period will be devoted to the identification of polychaetes.

Please co-operate with the staff in its efforts to accumulate a well-preserved, correctly-identified, study collection and also in the accumulation of rare forms or those new to this locality. Since the summer course has been given at Dillon Beach only once previous to 1941, much remains to be known of the polychaete fauna and its distribution.

There is a distinct value in identifying and becoming familiar with a wide range of types in a group. It gives a picture of the range of structural diversity, the results of a long evolution. Here, in the realm of taxonomy, a rare species is just as important as a common one, or more so. To the student of ecology, however, the species which occur in considerable numbers are the important ones since they have a proportional effect upon the communities of which they form parts.

Make certain, therefore, that you collect and identify all of the species of polychaetes which occur in any considerable numbers, keeping as complete a record as possible of this occurrence and ecologic distribution. Be prepared to report on the ecologic distribution of at least a dozen such common polychaetes.

Exercise 20. The Ecologic Distribution of the Limpets of the Genus *Acmaea*

Read introductory portions of the thesis of Dr. Avery Grant and papers on homing behavior by Hewatt, and by Villee and Groody. Identify in the field or on return from it all species of the genus *Acmaea*. Place them ecologically with regard to (1) vertical location, (2) nature of substrate, and (3) food.

Keep this in mind on all field trips and be able to combine your total findings into a chart or diagram.

Exercise 21. The Ecologic Distribution of *Callianassa*, *Upogebia*, and *Emerita* Considered in the Light of Their Adaptative Structure and Behavior

Read papers by MacGinitie on the natural history of these three decapods (Anomura) with highly specialized structure and habits.

A. Laboratory Study

Purpose: (1) To understand the correlations between special structure, behavior, and environmental location, that is, the structural adaptations, of these three anomuran decapods adapted to a life in the substrate, and (2) to see how differently the fundamental decapod type of structure has been modified in the three species.

Procedure: Remove and arrange in parallel series all the appendages of the right side of the three species. Care must be taken in removing the peraeopods to obtain the gills with them. Each peraeopod is provided with a gill attached near its proximal articulation.

Make a table for these appendages, with separate columns for the three species in the order *Callianassa*, *Upogebia*, *Emerita*, to bring out all differences. Attempt to correlate differences of structure with differences in behavior and these with life-habit differences. Is *Upogebia* more like *Callianassa*? If so why? Which of the two is most like *Emerita*? Do you think this is to be explained in terms of relationship? If not, on what basis do you explain it?

B. Field Studies

The sandy beaches from Sand Point up to Second Sled Road Point and beyond abound in sand crabs, the adults scattered but numerous, the young in countless thousands. These should be observed from the first field trip. Be able to describe their method of swimming, walking and digging in, the type of trail they make and the part played in these different activities by the different thoracic appendages. Read: MacGinitie, "Movements and Mating Habits of the Sand Crab."

See if you can discern by your own observations an animal which preys on them. This will best be made out when the tide is coming in. Be able to present your evidence in convincing form.

Make yourself familiar with the holes and burrows of the ghost shrimp in the upper end of Tomales Bay. See the various associated organisms especially the gobies, the pinnotherid crabs and *Cryptomya*. Preliminary reading: Mulford, Distribution of *Callianassa californiensis* Dana at Sand Point; MacGinitie, "The Natural History of *Callianassa*." Run a transect from the inner eelgrass associes to the sand dunes noting the change of fauna enroute. Be able to draw a diagrammatic section showing this change in fauna in relation to increasing height of surface of substrate.

In running the above transect individuals of *Upogebia* may have been encountered at the lower levels. If not, make a search at or very near the low-tide level along the inner channels to locate these mud-shrimps. Attempt to state how spatially and ecologically they are isolated from *Callianassa*.

In this connection read MacGinitie, "Natural History of the Mud-Shrimp."

Exercise 22. Fauna of a Sandy Beach and Scattered Elevated Rocks in Sand

Location: Perch Rock Point just at northern edge of the Dillon Beach settlement.

Physical conditions: Facing the open sea to the west, hence subjected to wave action, violent at times of storm. Rocks relatively hard with few if any crevices or crannies. Beach relatively long with gentle even slope from low tide level to the rocky cliff. Rocks irregular in shape but generally sloping to a narrow top, bottoms buried for unknown depth in sand. Sand washed out about bases of most rocks, leaving temporary tide pools. Two major habitats, rocks and sand.

Biotic conditions: Living seaweed small in quantity: very little on rocks, a few scattered clumps of *Egregia* in sand. A certain amount of dead seaweed is present. That at upper level should be investigated for plant scavengers. Algal film seemingly lacking on upper rocks. Two striking rock communities, one dominated by *Mytilus californianus*, the California Mussel, the other almost pure sea anemones.

The following animals are among those present:

Rock Fauna

Anemones, large and small
Tegula funebrale Adams
T. canaliculata Duclos
Thais emarginata Deshayes
Littorina scutulata Gould
Littorina planaxis Philippi
Acmaea digitalis Eschscholtz
Acmaea pelta Eschscholtz
Acmaea scabra Gould
Acmaea scutum Eschscholtz
Acmaea limatula Carpenter (rare)
Mytilus californianus Conrad
Ligia (The Rock Louse)
Katharina
Mopalia ciliata Sowerby
Balanus glandula, the common acorn barnacle
B. cariosus, the thatched barnacle
Chthamalus, the tiny barnacle
Mitella, the leaf barnacle

In Mussel Bed

Thais canaliculata Duclos
Petricola (rare)
Nereis vexillosa Grube
Petrolisthes, the flat-topped crabs
Pachycheles, the big clawed crabs
Pagurus
Cirolana
Amphipods

Sand Fauna

Nainereis
Nephtys caeca Fabricius
Nereis vexillosa Grube
Emerita analoga, the sand crab
Orchestoidea, the sand flea

Others

Pisaster ochraceus, the ochre seastar
Pachygrapsus, the lined shore crab
Hemigrapsus nudus, the purple shore crab
Epialtus productus, the kelp crab
Cancer antennarius, the rock crab

Purpose: To gain familiarity with the members of the fauna, their names, their ecological niches, their interrelationships.

Procedure: Identify as many of the animals as possible in the field, use their names again and again until they become familiar. Bring those not identified to the laboratory for identification. Keep careful notes as to distribution and associations and of any biotic or physical factors which seem to explain them.

Be able to answer such questions as the following:

What is the dominant animal in the most conspicuous animal association of the area? What other animals are present in this association? What is their relation to it? What other sedentary animal is present in considerable concentration? Does it seem to compete with the other association? Make a field key to the species of *Acmaea*. What evidence did you note of differences in niche of these species? What is the most important sand dwelling organism? What plant scavengers were noted? Where are the different polychaetes to be found?

Do you find any clams? Reasons?

How does the method of progression of *Emerita* differ from that of most crabs? Can you differentiate their trails?

Exercise 23. Hard Rocks in Intertidal Zone (Second Sled Road Point)

Recognize as many animals as possible in the field. Collect and identify those not thus recognized. Get as clear a picture as possible of the distribution of the animals of this locality in relation to the diversified physical and biotic factors involved.

Attempt to classify the general area into more or less definite habitats each marked by a characteristic faunal assemblage. Such, for example, would be the beds of narrow-leaved eelgrass (*Phyllospadix*).

Find the outcrop of softer rock and collect the borers, nestlers, and cranny dwellers in it for study in connection with Exercise 26.

Exercise 24. An Outer Exposed Rocky Shore (Tomales Point)

This area offers the richest fauna of any habitat to be studied in the Dillon Beach locality and approaches that of Frenchman's Reef. Especially to be studied are (1) the tide pools, (2) the tidal channels, (3) under rock assemblages, (4) the mussel beds, here at climax.

Exercise 25. The Fauna of a Rocky Island (Bird Island), with Tide Pools, Tidal Caves and Tidal Channels

Get as complete a picture of the fauna, its distribution and the ecologic features involved as is possible in the brief time available. Biotic features require attention. Such are the luxuriant growth of seaweed and the negative one of the relative absence of the disturbing presence of man. Be able to explain various features of the fauna in the light of these factors as well as the physical conditions.

The tide pools are on the flat rock at the southwestern end of the islands, the tidal cave at the northern end, the tidal channels along the western shore.

On top of the high flat-topped plateau which forms the eastern half of the island is a colony of nesting cormorants and the nests of gulls, etc. These are interesting as forming end organisms of some of our food chains.

Exercise 26. The Fauna of a Long Narrow Reef Extending into the Open Sea and Cut by Deep, Narrow Tidal Channels
(Frenchman's Reef, San Mateo County, Maps I and III)

This region is discussed elsewhere, Field Trip C, p. 183 and Exercise 4, p. 197.

Attempt to segregate in your mind some eight or ten very different types of habitats found here and their characteristic assemblages. Where elsewhere have you found the same or similar faunal assemblages? Have they been correlated with similar environmental conditions? If so, you can begin to formulate general statements as to the animals to be found under given sets of environmental conditions.

Make a special effort to see and to collect for identification as many hydroids as possible as well as certain species of *Acmaea* not common elsewhere (*A. paleacea, A. instabilis,* and *A. insessa*).

Exercise 27. Boring, Nestling and Cranny-Dwelling Animals

A number of pelecypods are able to bore into relatively hard substrata or occur in cavities in substrata so hard as to seem to indicate that they have bored into it. It is not known just how this boring is accomplished. Some have thought it was purely mechanical abrasion, others that it was due to the dissolving action of some secreted acid and, more recently it is believed that carbonic acid may be involved.

As a result of the action of the borers, including the purple sea urchin, many of the softer intertidal rocks are full of holes and crannies in addition to those which might normally arise from fracturing and weathering. These holes and crannies furnish protected sites for a large array of species of various groups. Some of them live within the shells left by preceding species. Such have been termed nestlers in distinction to the cranny dwellers which live in the cavities of one kind or another in the rock. Sometimes we may have a series of successive nestlers. For example, a tiny young *Kellia* in a *Saxicava* shell, itself in a *Protothaca* shell which lies within the shell of *Pholadidea*, the original borer.

The conditions concerned vary all the way from deep, almost entirely shut off cavities to shallow ledges or surface cavities. We shall encounter conditions favorable for such studies in several localities. Some of the rocks in the vicinity of the Second Sled Road are soft enough to permit of their being occupied by borers. The same is true of many of the rocks at Frenchman's Reef and especially of many near the lagoon. At Duxbury Reef also will be found situations for the study of these borers, nestlers and cranny dwellers.

Keep notes concerning them as encountered at different times and make lists of all the species by phyla which fall under these different categories. Attempt to determine the food habits of all of them. Refer to various papers by MacGinitie.

Exercise 28. Ecological Distribution as Seen on the Sand Flats and Sandy Mud Flats on the Eastern Shore Just Inside the Mouth of Tomales Bay

Just inside Tomales Bay on the northeastern shores are extensive areas of sandy mud flats already sampled in Exercise 21. Here wave action is largely eliminated and sedimentation active. Here tidal currents while not violent, except in certain relatively limited channels, are prolonged bringing an immense amount of water over a given area of bottom.

This area supports a fauna which seems to belong to the *Macoma* formation as defined by Shelford and Tower (1925) with general and special modifications due to local conditions. We shall sample this fauna in general on this trip, compare it with another tidal flat (Exercise 29 on Bolinas Lagoon) and study more intensively two of its subdivisions (Exercises 29 and 30), and finally consider it in terms of ecologic variation and succession in Exercise 31.

In preparation for these exercises and during their prosecution make yourself familiar with the ideas and terminology in the article by Shelford and Towler and read MacGinitie's "Littoral Marine Communities" and his "Ecological Aspects of a California Marine Estuary (Elkhorn Slough)."

The three important associes, studied separately, are at different levels as regards the tides. The eelgrass associes or *Macome-Schizothaerus* associes (perhaps same as the *Macoma-Synapta* associes of Shelford) is lowest, being mostly a few inches under water at low low tide due in part to the very slow run-off in this area. The *Phoronopsis* or *Macoma-Phoronopsis* associes is just a few inches above low low tide level, while the *Callianassa* or *Macoma-Callianassa* associes, already studied, is much higher. These should be studied with the idea of an ecological succession in mind whose climax may be the sand dune formation.

In narrow zones are other associes. Among these should be studied the *Clymenella* associes which form narrow zones between the others. More broadly distributed than the limits of these associes but less widely than *Macoma* is the abundant horse clam *Schizothaerus nuttallii* and the much less common geoduck, *Panope generosa.*

Study the distribution of the three types of clams, and of *Phoronopsis*, *Clymenella* and other common polychaetes. Turn in a map showing their distribution.

Exercise 29. Bolinas Lagoon

This may be combined with a study of the fauna of Duxbury Reef (Exercise 27) since the tides are much later in the lagoon. It should be sampled at least at two points, one very near the mouth where a *Phoronopsis-Urechis-Macoma* association should be studied, the other high up the lagoon where the mud-crab is the dominant animal as is the case at numerous points along the lower reaches of Tomales Bay.

Get a clear picture of the other members of the associes there and seek to place them in terms of food chains or a food cycle.

Exercise 30. The Eelgrass Flats

These outer flats near the mouth of Tomales Bay, separated from the shore flats by a tidal channel are subject to fluctuation in level and consequently in fauna and flora. Whether this is a seasonal variation or associated with the extensive shifts in location of sand deposits which are caused by differences in wind and tide is not known. In 1935 they supported a luxuriant growth of eelgrass (*Zostera*) and various seaweeds and were never completely exposed even at the lowest tides. In the spring of 1940 they were a few inches above low-tide level and the eelgrass and large algae were largely lacking.

Whatever their condition they should be studied and their fauna well known. If these outer flats are lacking in extensive plant growth this may be found and should be studied in lower areas near the shore, bordering on the *Macoma-Phoronopsis* association.

Go prepared for wading in several inches of mud and water.

Collect and make notes on the ecologic distribution of the rich but monotonous fauna of this habitat. There are really three important habitats or zones here, (1) the mud below, (2) the water, and (3) the luxuriant growth of eelgrass and large algae (*Ulva*, etc.). Do not neglect the fauna of the mud. Material will be collected and brought to the laboratory to allow for the study of the sub-macroscopic fauna of the water and the algae masses and the eelgrass.

Be on the lookout for holothurians and *Edwardsiella* (an 8-tentacled anemone). Note those species present here only because the large seaweeds give them sites above the muddy bottom.

Exercise 31. *Phoronopsis* and the *Macoma-Phoronopsis* Associes

Laboratory Study: *Phoronopsis* represents a small group of uncertain systematic position, the Phoronidea. The U-shaped intestine and lophophore suggest bryozoan affinities but the well-developed blood vascular system and the entirely different embryology render this relationship unlikely. We shall consider it a phylum as does Borradaile and Potts.

Study whole specimens dissecting to get an idea of the structure of the lophophore, etc. Study serial sections to see the body cavity, the circulatory system, the finer structure of the lophophore, etc.

On living individuals see the ciliary action of the lophophore.

Field Studies: Where the substrate has been built up (by ordinary deposition or mud transportation) to the level of low tides the plant growths are inhibited and here are to be found luxuriant clans of *Phoronopsis,* with *Macoma secta* less abundant.

The class will attempt a preliminary population study in this area. Working in teams of two, two areas six inches square will be chosen by each team, half of these so as to avoid any clam holes which perhaps crowd out a certain number of *Phoronopsis* and certainly obscure their openings. Six-inch square, open-ended metal boxes will be pushed in surrounding these areas and a careful count made and checked, of the holes visible at the surface. The earth will then be removed on all sides of the box and the number of individuals within the box carefully counted. This should give the correction necessary to make surface counts accurate. How do you explain the discrepancy, if any, both where clams are present and where not? To what extent, if any, do the clams seem to reduce the *Phoronopsis* population?

Half of the teams will now measure off areas of a yard square and on the basis of a count of the clam openings present, estimate the population of clams, remembering that *Macoma* has two separate siphons, one smaller than the other.

The other half will measure off areas of six inches square using the metal boxes and after attempting to determine the number of clams involved from surface counts carefully excavate to determine definitely the number actually present.

Exploratory transects will be run to determine the limits of the particular *Phoronopsis* clan and an estimate made of the number per acre (43,560 square feet).

Exercise 32. Ecologic Succession

Study again the relation of the shore tide flats from the lowest algae grown portion to the sand dunes with the possibility in mind that the sand encroaching on the upper end of the bay is responsible for the change, locally at least, (1) from *Zostera* associes to the *Macoma-Phoronopsis* associes, (2) from this to the *Clymenella* associes, (3) from it to the *Macoma-Callianassa* associes, (4) from this to the Staphylinid-beetle associes and (5) from it in turn to the sand dunes. Or is the succession in the other direction with wind and current resulting in the encroachment of the marine on the sand dunes?

See again the special paper by Alice Mulford on the distribution of *Callianassa.*

Exercise 33. Estuarine Faunas on Piles and Mud Flats

Estuaries or deep estuarine bays have characteristic faunas which are rich in individuals but low in number of species. Here food is abundant and wave action is negligible but inhibiting factors are (1) lowered salinity and (2) great amounts of sediment and often of polluting materials in the water.

The study will be made at Inverness on the west side of the inner end of Tomales Bay. Here piles offer surface for sessile animals and broad mud flats afford favorable substrate for others which live within the substrata.

Make certain that you know all species involved and are able to discuss their distribution in terms of ecological factors.

Exercise 34. Commercial Oyster Beds at Bivalve on Tomales Bay

These beds will be visited to see the methods of commercial oyster culture, the ecological conditions favorable to it and the associated fauna. Especially interesting are the introduced species.

Exercise 35. The Plankton

A surprising number of littoral marine invertebrates are plankton feeders. No true understanding of the food relationships, food chains, and food cycles is possible from the low tide investigations to which we are largely confined. We shall therefore devote at least one period to a study of the floating population, the organisms concerned, and something of their relation to the animals already studied.

Identify common forms to the group and seek to understand their place in the food cycle. Supplementary aids to this end will be supplied. Refer also to Johnstone, Scott and Chadwick, The Marine Plankton.

Be on the lookout for larval forms which should be brought to the attention of the instructor for demonstration to the class.

Exercise 36. Individual Study of a Small Tide Pool

See Exercise 15 for directions.

Exercise 37. Individual Study of the Fauna of a Limited Area of Rock Surface in the Intertidal Zone

As an alternative individual exercise if the tide pools are not available, as is frequently the case due to movements of sand, study a limited area of one of the rocks at Perch Rock Point or Second Sled Rock, or a limited especially interesting area of beach or tide flat.

Exercise 38. The Fauna and Food Cycle of a Freshwater Pond (Rolland Pond)

A small segregated body of water lends itself to this purpose much better than the marine littoral with its tidal changes. Even here, however, there are interrelations with nonaquatic or amphibious organisms which should be brought into the food cycle so far as ascertainable.

Begin this study early in the course and continue it from time to time.

Read Exercise F on page 191.

Turn in your food cycle as finally conceived.

Exercise 39. The Fauna of a Coastal Stream (Salmon Creek or Upper Stemple Creek)

This is to be an entirely individual problem.

The individuals should scatter out along the creek, each working along.

Make a collection of macroscopic and microscopic life in connection with notes on ecological features.

In your report place each species found in its individual niche in a food cycle and attempt to explain the special adaptations of each species to its niche. In Salmon Creek note especially the peculiar shrimps, *Sycnaris* (see special paper by Lee).

Exercise 40. Terrestrial Fauna

Terrestrial faunas in general are less rich in numbers of species and of individuals than are those of the seashore. Also their constituent species are less easily observed since the necessities of food-getting and protection require either great speed or retiring life habits.

Conditions such as those furnished by a wooded canyon, where moisture abounds and many types of cover are available, make for relatively rich and diversified fauna. Study such a fauna referring to page 192 for suggestions as to the types to be expected.

We shall take advantage also of the near-by sand dunes to study terrestrial life under much more severe conditions. These conditions result in limitation of the number of species to a few highly specialized types. The detection of these would be a baffling problem indeed were it not that many of them leave trails to indicate their activities. As it is, we shall find it an intriguing problem to determine the animals of this community, especially so, since I know of no investigations of this fauna. For studies of sand dune communities elsewhere, see Chapter 19 of Chapman's Animal Ecology or Pierce, Dwight and Pool (1938, 1939).

Make numerous visits to the dunes, keeping a record of all trails and animals observed. Some visits should be made at early morning and evening hours and at least one at night, using flashlights. Excavate wherever trails seem to end and elsewhere to determine the in-ground fauna in general. Gain as complete as possible a picture of the community, its constituents and interrelationships.

Individual Projects

Instructions as regards individual projects and special problems for S112 and S119 will be found on pp. 193 and 204.

There is great need for systematic, faunistic, and distributional studies in the Dillon Beach area, the results of which will be of value to future classes. The summer session course has been held here only once, in 1935, and very much remains to be known of the fauna and its ecologic distribution. Following is a list of a few of the many problems which suggest themselves.

Taxonomic

The pelecypods
The amphipods
The harpacticoid copepods
Other benthonic copepods
The isopods
The sponges
The tunicates
The Bryozoa
Phoronopsis: Are there two species? Their distinguishing characters?
The terebellid polychaetes
The Nereidae

Faunistic

The sand-dwelling polychaetes
Polychaetes of the eelgrass flats
Polychaetes of the shore tidal flats
A survey of the shore tide flats eastward around the eastern shoulder of Tomales Bay
The fauna of the sand flats in front of Dillon Beach
The fauna of the sand flats at Perch Rock Point
The fauna of the sandy beach from Dillon Beach to Sand Point
The fauna of Štemple Creek Lagoon
The fauna of the narrow-leaved eelgrass beds (Second Sled Road and elsewhere)

Ecologic Distribution and Other Ecologic Studies

The *Clymenella* associes, its constituent species and distribution

The degree of intergradation between the *Clymenella* associes and other associes and an attempt to explain the segregation of these associes

The relative abundance and distribution of *Panope* as compared to *Schizothaerus*

Schizothaerus as a dominant animal and its influence on other members of the association

Distribution of *Phoronopsis* and factors limiting it

Evidence as to the degree of correlation between color and pattern of *Acmaea digitalis* and *Acmaea scabra* and that of their backgrounds (*Balanus, Mytilus, Mitella,* etc.)

The smaller gregarious sea anemones (*Bunodactis elegantissima*) of the Perch Rock Point rocks: Are they different structurally from the solitary anemones (*Anthopleura xanthogrammica*)? What are the ecologic features characteristic of the sites of each? What differences as to behavior? As to food?

Succession of animals settling on glass slides exposed below low-tide level at Sand Point

APPENDIX A

SAMPLE SCHEDULES

ZOOLOGY 112: SCHEDULE, 1940

January

26. F. ..... Decapoda
27. S. ..... Amphipoda

February

2. F. ..... Pelecypoda
3. S. ..... Animals at Point Richmond
4. Su. .... Field Trip to Point Richmond (2:00 p.m. at beach)
5. M ..... Field Trip to Point Richmond (2:00 p.m. at beach)
9. F. ..... Free
10. S. ..... First Mid-Term including tests on identification and ecology and behavior of animals of Point Richmond

16. F. ..... Polychaeta
17. S. ..... Coelenterata
20. T. ..... Field Trip to Fruitvale Bridge (be at bridge at 2:00 p.m.)
or
21. W. ..... Same as above at 2:30 p.m.
23. F. ..... Free
24. S. ..... Free

March

1. F. ..... Copepoda
2. S. ..... Entomostraca completed
8. F. ..... Rotifera
9. S. ..... Free
15. F. ..... Free
16. S. ..... Gastropoda
22. F. ..... Spring Recess
23. S. ..... Spring Recess
29. F. ..... Terrestrial Arthropoda
30. S. ..... Field Trip to Strawberry Canyon

April

5. F. ..... Second Mid-Term
6. S. ..... Field Trip to Lake Merritt
12. F. ..... Free
13. S. ..... Field Trip to Freshwater Pond
19. F. ..... Marine Gastropods
20. S. ..... Continued: Polychaeta
21. Su. }
26. F. } ... Field Trip to Dillon Beach for three tides
27. S. ..... Free

May

3. F. ..... Free
4. S. ..... Property clearance

S112 AND S119, SCHEDULE, 1939

May

15. M. .... Adjustment of rooms, etc. 7:30 p.m. Preliminary meeting.
16. T. 8:30 a.m. S119 (alone) for orientation
    9:00 a.m. S112 and S119. General introduction, Laboratory study of Decapoda
    2:00 p.m. Gastropoda
17. W. 8:30 a.m. Pelecypoda
    2:00 p.m. Polychaeta

May (Continued)

18.	Th.	(-0.5, 4:07 a.m.)	Trip on S.S. Scripps and study of plankton taken
19.	F.	(-0.8, 4:58 a.m.)	Halosaccion Flats
		3:00 p.m.	Test on Halosaccion Flats
20.	S.	(-1.0, 5:40 a.m.)	Sand Rocks and Vicinity
		3:00 p.m.	Test
21.	Su.	(-1.1, 6:25 a.m.)	Frenchman's Reef
22.	M.	(-0.9, 7:10 a.m.)	Moss Beach Flats, especially Iridaea Channel
23.	T.	(-0.7, 8:06 a.m.)	Special problems
		2:00 p.m.	Lecture by Prof. E. T. Schenck, Palaeontologist, Stanford University
24.	W.	(-0.4, 9:00 a.m.)	Special problems
		2:00 p.m.	Chitons
25.	Th.	(0.0, 9:40 a.m.)	Special problems
		2:00 p.m.	Lecture by Dr. Robert C. Miller, Director of the Museum and Aquarium of the California Academy of Sciences on "The Pacific Ocean a Balanced Aquarium"
26.	F.	8:30 a.m.	Gastropoda completed
		2:00 p.m.	Amphipoda, Isopoda
27.	S.	--	Nothing scheduled
28.	Su.	--	Nothing scheduled
29.	M.	10:00 a.m.	Mid-Term
		2:30 p.m.	Lecture
30.	T.	8:30 a.m.	Decapoda completed
		2:00 p.m.	Lecture by Dr. Avery R. Grant on speciation in the genus Acmaea
31.	W.	(-0.6, 3:40 a.m.)	Special problems

June

1.	Th.	(-0.7, 4:25 a.m.)	Special problems
2.	F.	(-0.8, 5:00 a.m.)	Marine View Rocks and Seal Cove
		2:00 p.m.	Polychaeta
3.	S.	(-0.8, 5:40 a.m.)	Polychaeta of Moss Beach Flats
4.	Su.	(-0.6, 6:15 a.m.)	Unscheduled
5.	M.	(-0.4, 7:00 a.m.)	Special problem
6.	T.	(-0.1, 7:40 a.m.)	Special problem
7.	W.	8:30 a.m.	Freshwater Ecology, Entomostraca
		2:00 p.m.	Ostracoda, Cladocera
8.	Th.	8:30 a.m.	A Freshwater Pond
		2:00 p.m.	Rotifera
9.	F.	....	Special problems
10.	S.	....	Special problems
11.	Su.	....	Free
12.	M.	8:30 a.m.	Terrestrial Arthropoda
		2:00 p.m.	Field trip in Sunshine Creek Valley
13.	T.	8:30 a.m.	Bryozoa
		2:00 p.m.	Porifera
14.	W.	8:30 a.m.	Coelenterata
15.	Th.	8:30 a.m.	Special problems
16.	F.	(-0.8, 4:00 a.m.)	Special problems
17.	S.	(-1.1, 4:40 a.m.)	Special problems
18.	Su.	(-1.2, 5:15 a.m.)	Nye's Rock and Channel
19.	M.	(-1.2, 6:00 a.m.)	Frenchman's Reef
20.	T.	(-1.0, 6:45 a.m.)	Special problems
21.	W.	(-0.6, 7:40 a.m.)	Problems and collections to be in by noon
22.	Th.	9:30 a.m.	Practical Examination
		2:00 p.m.	Property checked in and packed
23.	F.	8:30 a.m.	Final Examination

S112 AND S119
TENTATIVE SCHEDULE, 1941

May

19.	M.	....	Housing arrangements
		7:15 p.m.	First meeting for general discussion
20.	T.	8:30 a.m.	S119 alone for orientation
		9:00 a.m.	S112. Introductory
		9:30 a.m.	S112, S119. Decapoda
		2:00 p.m.	Decapoda
21.	W.	8:30 a.m.	Isopoda; 2:00 p.m. Amphipoda
22.	Th.	8:30 a.m.	Polychaeta; 2:00 p.m. Polychaeta
23.	F.	8:30 a.m.	Gastropoda; 2:00 p.m. Pelecypoda
24.	S.	8:30 a.m.	Chitons
25.	Su.	(-0.3, 5:10 a.m.)	
26.	M.	(-0.5, 5:40 a.m.)	Field trip to Perch Rock Point, Ex. 21
27.	T.	(-0.5, 6:15 a.m.)	Ex. 21 completed; 3:00 p.m. test on fauna of Perch Rock Point
28.	W.	(-0.6, 6:50 a.m. + 1)	Field trip to tide flats, Ex. 27
29.	Th.	(-0.6, 7:30 a.m.)	Field trip to Second Sled Road, Ex. 22
30.	F.	(-0.4 at 8:10 a.m.)	Individual projects
31.	S.	(-0.3 at 9:00 a.m.)	Individual projects

June

1.	Su.	(-0.1 at 9:50 a.m.)	
2.	M.	9:30 a.m.	Mid-Term; 2:30 p.m. Bryozoa
3.	T.	8:30 a.m.	Sponges; 2:00 p.m. Pelecypoda
4.	W.	8:30 a.m.	Copepoda; 2:00 p.m. Cladocera and other Branchiopoda
5.	Th.	8:30 a.m.	Laboratory portion of Ex. 20 on *Callianassa, Upogebia,* and *Emerita*; 2:00 p.m. Coelenterates
6.	F.	8:30 a.m.	Coelenterates; 2:00 p.m. Gastropoda
7.	S.	(-0.7 at 3:35 a.m.)	Individual projects
8.	Su.	(-1.2 at 5:15 a.m. [4:28 + 50])........	Field trip to tide flats, Ex. 29
9.	M.	(-1.4 at 5:15 a.m.)	Field trip to Tomales Point, Ex. 23
10.	T.	(-1.5 at 6:00 a.m.)	Field trip to Bird Island, Ex. 24
11.	W.	(-1.4 at 6:50 a.m.)	Second field trip to Tomales Point
12.	Th.	(-1.1 at 7:40 - 45)................	Field trip to Frenchman's Reef, Ex. 25
13.	F.	(-0.7 at 8:25 a.m.)	Individual projects
14.	S.	(-0.2 at 9:15 a.m.)	Individual projects
15.	Su.		
16.	M.	8:30 a.m.	Identification of polychaetes
17.	T.	8:30 a.m.	Ostracoda and Rotifera; 2:00 p.m. Rolland Pond, Ex. 37
18.	W.	8:30 a.m.	Completion of study of freshwater pond
19.	Th.	8:30 a.m.	Terrestrial arthropods; 2:00 p.m. Sand-dune animals, Ex. 39
20.	F.	8:30 a.m.	Further on terrestrial arthropods
21.	S.	....	Individual projects
22.	Su.		
23.	M.	(-0.3, 4:50 a.m.)	Individual projects
24.	T.	(-0.5, 5:20 a.m.)	Tide flats, Ex. 30 and 31
25.	W.	(-0.6, 5:55 a.m.)	Optional field trip to oyster bed, Ex. 33
26.	Th.	(-0.7, 6:30 a.m.)	Optional field trip to Duxbury Reef and Bolinas Lagoon, Ex. 26 and 28; 2:30 p.m. Practical Examination. Property check
27.	F.	(-0.6, 7:10 a.m.)	10 a.m. Final Examination

APPENDIX B.

THE CLASSIFICATION OF INVERTEBRATES FOLLOWED IN THIS TEXT
(Modified from Hyman, Borradaile and Potts, and others)

- Phylum PROTOZOA[1]
    - Classes MASTIGOPHORA
      SARCODINA
      SPOROZOA
      INFUSORIA
- Phylum PORIFERA
    - Classes Calcarea
      Demospongiae
      Hexactinellida
- Phylum COELENTERATA
    - Class HYDROZOA
        - Order HYDROIDA
            - Suborders GYMNOBLASTEA (ANTHOMEDUSAE)
              CALYPTOBLASTEA (LEPTOMEDUSAE)
        - Order Siphonophora
        - Three other orders (see Hyman)
    - Class SCYPHOZOA
    - Class ANTHOZOA
        - Subclasses ALCYONARIA
          ZOANTHARIA (Sea Anemones)
- Phylum CTENOPHORA
- Phylum PLATYHELMINTHES
    - Class TURBELLARIA
        - Orders Acoela
          Rhabdocoela
          Tricladida
          Polycladida
    - Classes TREMATODA
      CRESTODA
- Phylum NEMERTEA
- Phylum ROTIFERA
- Phylum Gastrotricha
- Phylum NEMATODA
- Phylum Nematomorpha

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[1]Explanation of meaning of four different ways of printing group names:

1. Those groups in UNDERLINED CAPITALS are given specific treatment in the exercises, or form an essential part of the classification of such groups.
2. Those groups in CAPITALS are not given specific treatment but should be known to all students of invertebrate zoology. In some cases, such as the Protozoa, these are very important groups which are not considered because they form the subject matter of other courses. In other cases the groups are of moderate importance, but are rarely encountered in the collections dealt with here; in still other cases the animals are important but these group names are little used.
3. Those group names in underlined lower case refer to animals given in the lists but either the animals are of subordinate importance here or these group names are little used.
4. Those groups in lower case and not underlined do not appear in the exercises or lists, but are included here, because, in most cases, they are of equal taxonomic rank with better-known groups.

Phylum Acanthocephala
Phylum ANNELIDA
- Class Archiannelida
- Class POLYCHAETA
  - (Families given in keys and list)
- Class OLIGOCHAETA
- Classes HIRUDINEA
  - ECHIUROIDEA
  - SIPUNCULOIDEA

Phylum ONYCHOPHORA (or subphylum of Arthropoda)
Phylum ARTHROPODA
- Subphylum CRUSTACEA
  - Class BRANCHIOPODA
    - Orders Anostraca
      - Notostraca
      - Conchostraca
      - CLADOCERA
  - Class OSTRACODA
  - Class COPEPODA
    - Orders CALANOIDA
      - CYCLOPOIDA
      - HARPACTICOIDA
  - Class CIRRIPEDIA
    - Orders Thoracica
      - Acrothoracica
      - Apoda
      - Rhizocephala
      - Ascothoracica
  - Class MALACOSTRACA
    - Subclasses Leptostraca
      - Hoplocarida
      - Syncarida
    - Subclass Pericarida
      - Orders Mysidacea
        - Cumacea
        - Tanaidacea
      - Order ISOPODA
        - Suborders FLABELLIFERA
          - VALVIFERA
          - ONISCOIDEA
      - Order AMPHIPODA
        - Suborders GAMMARIDEA
          - Hyperiidea
          - Caprellidea
    - Subclass Eucarida
      - Order Euphausiacea
      - Order DECAPODA

CLASSIFICATIONS OF THE DECAPODA

Parker and Haswell	Borradaile and Potts	Pratt; Schmitt	
Suborders:	Suborders:	Suborders:	Sections:
Macrura	Penaeidea	Natantia	Penaeidea
	CARIDEA		CARIDEA
	Palinura	Reptantia	Palinura
	Astacura		Astacura
ANOMURA	ANOMURA		ANOMURA
BRACHYURA	BRACHYURA		BRACHYURA

Subphylum MYRIAPODA
Classes CHILOPODA
DIPLOPODA
Symphyla
Pauropoda

Subphylum INSECTA
(Divisions too numerous to give here—see texts)

Subphylum ARACHNIDA
Classes Scorpionida
Xiphosura
Acarina
Phalangida
(Several other terrestrial classes)
PYCNOGONIDA

Subphyla (?) Tardigrada
Pentastomida

Phylum MOLLUSCA
Class AMPHINEURA
Orders POLYPLACOPHORA
Aplacophora

Class GASTROPODA
Order STREPTONEURA (Prosobranchiata, prosobranchs, or strepotoneurous gastropods)
Suborder DIOTOCARDIA (Aspidobranchiata, Aspidobranchs)
Tribe Rhipidoglossa
Section Zygobranchiata (with paired gills; zygobranchs: abalones, keyhole limpets)
Section Azygobranchiata (with single gill; azygobranchs; *Tegula*, *Calliostoma*)
Tribe Docoglossa (true limpets, *Acmaea*)
Suborder MONOTOCARDIA (Pectinibranchiata; pectinibranchs: all other snail-like forms)
Order OPISTHOBRANCHIATA (opisthobranchs)
Suborder TECTIBRANCHIATA (tectibranchs: sea hares)
Suborder NUDIBRANCHIATA (nudibranchs)
Order PULMANATA (pulmonates: land snails and slugs)
(Opisthobranchiata and Pulmonata are considered by some to be suborders of the order Euthyneura)

Opposed Terms

Streptoneurous vs Euthyneurous	Zygobranchs vs Azygobranchs
Prosobranchs vs Opisthobranchs	Tectibranchs vs Nudibranchs
Pectinibranchs vs Aspidobranchs	Pulmonates vs Gill-breathing gastropods

Class SCAPHOPODA
Class PELECYPODA

Orders Protobranchiata
Filibranchiata
Eulamellibranchiata
Septibranchiata

Class CEPHALOPODA

Phylum KAMPTOZOA (Endoprocta)
Phylum BRYOZOA

Orders Phylactolaemata
Gymnolaemata

Phylum BRACHIOPODA
Phylum Chaetognatha
Phylum PHORONIDEA
Phylum ECHINODERMATA

Classes ASTEROIDEA
OPHIUROIDEA
ECHINOIDEA
HOLOTHUROIDEA
CRINOIDEA

Phylum CHORDATA

Subphylum HEMICHORDATA
Subphylum UROCHORDATA

Classes Larvacea
Ascidiacea
Thaliacea

Subphylum CEPHALOCHORDATA
Subphylum CRANIATA

Class PISCES
Class Amphibia
Class Reptilia
Class AVES
Class MAMMALIA

APPENDIX C.

ATTEMPT AT A FIELD KEY TO SOME OF THE COMMONER ALGAE OF MOSS BEACH
(For further identification see mounted specimens and monographs by Setchell and Gardner)

A. Green Algae
B. Brown Algae
C. Red Algae (oftentimes blackish or brownish)

<u>A. Green Algae</u>

1. Made up of slender filaments 2
1. Broad, flat, thin, bright green. Sea Lettuce . . . . *Ulva*

2. A fine, green felting over tops of rocks covered only at high tide . . . . *Enteromorpha*
2. Small, but thick, felted masses; common on Moss Beach Flats, scattered . . . .? *Cladophora*

<u>B. Brown Algae</u>

1. With naked, stout, cylindrical stipe or "stem," blades only at its apex; found chiefly in outer zone of breakers 2
1. No conspicuous unbranched stipe 3

2. Stipe less than two feet long, erect, with a crown of many short blades. Sea Palm . . . . *Postelsia palmaeformis*
2. Stipe averaging two feet or more, with a single long blade . . . *Laminaria*
2. Stipe very long, up to 60 feet, stipe hollow and ending in a swollen, hollow bulb; many long blades . . . . *Nereocystis*

3. Unilateral branching along one side of long cylindrical stipe; blades broad, with a bulb-like float at base; edges of blades with scattered tag-like outgrowths . . . . *Macrocystis*
3. Bilateral branching along sides of flattened rachis; blades small; interspersed with bladder-like floats . . . . *Egregia*
3. Dichotomously branched fronds; branches less than a centimeter wide . . . . *Fucus furcatus*

<u>C. Red Algae</u>

1. Fronds cylindrical 2
1. Fronds more or less flattened 3

2. Forming low, stiff, reddish-brown masses, seldom more than an inch in height; densely branched, covered with very tiny, spinose branches . . . . *Endocladia*
2. Fronds blackish, elongated, hanging, several inches in length, ultimate branches several millimeters long, all of about same length . *Microcladia*

2. Fronds longer, more open, ultimate branches thicker, scattered . . . . *Gastroclonium*

3. Fronds very broad, little-branched, iridescent in color . . . . *Iridopsis (Iridaea)*
3. Fronds narrower, much branched 4

4. Fronds only slightly flattened, finely branched and delicate, bright red; often epiphytic . . . . *Microcladia*
4. Fronds flattened, dichotomously branched, varying from broad red blades to narrow, much-branched brownish blades . . . . *Gigartina*

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