The Mollusks

A Guide to Their Study, Collection, and Preservation

Edited by
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Preface

This volume promotes the educational mission of the American Malacological Society. The editors and contributors have brought together a broad range of topics within the field of malacology. It is our expectation that these topics will be of interest and use to amateur and professional malacologists.

The chapters in this publication have been peer-reviewed. Each chapter was reviewed by at least one of the editors and by a minimum of two outside reviewers, including at least one amateur and one professional malacologist. Chapters were then revised by authors and again reviewed by the editors, and occasionally, when warranted, by another outside reviewer. Then authors made a second round of changes and editors conducted a final review. While this review process has eliminated some errors and inconsistencies, some may remain.

If anyone does uncover any error or inconsistency in formatting, grammar, or style, the editors would appreciate it being brought to their attention. Constructive suggestions for improving this volume are welcome. Comments can be sent to the editors at <doc.fossil@gmail.com>. Website addresses, cited in this book, were active as of December 2005.

C. F. Sturm
T. A. Pearce
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Table of Contents

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CHAPTER 1

THE MOLLUSKS: INTRODUCTORY COMMENTS

CHARLES F. STURM
TIMOTHY A. PEARCE
ÁNGEL VALDÉS

1.1 INTRODUCTION

Mollusks have been important to humans since our earliest days. Initially, when humans were primarily interested in what they could eat or use, mollusks were important as food, ornaments, and materials for tools. Over the centuries, as human knowledge branched out and individuals started to study the world around them, mollusks were important subjects for learning how things worked.

Initially, nobility and the wealthy (or scientists with wealthy patrons) carried out such studies on the natural world. Later, in the 19th and 20th Centuries, a professional class of scientists developed. Governments and industry also started supporting scientists. Although in some fields, as professionalism developed, non-professionals took a back seat; in contrast, non-professionals studying mollusks have consistently made important contributions.

Just as bird watchers contribute important observations that allow professionals to study bird migration and changes in populations, so amateurs play important roles to professional malacologists. Amateurs can study the mollusks of a given region over time and see what changes occur in response to interactions with humans and natural forces. The molluscan fauna is inadequately studied in many areas; amateurs can study such areas. You may have the opportunity to describe a new species. While amateurs may not have the resources for undertaking molecular studies, they might collaborate with professionals by providing samples. In addition, many molluscan families and genera have not been subjected to a good revision in many decades. An advanced amateur could review the world literature and summarize it into a well-researched revisionary work. Though this can be a daunting task, it could be the culmination of years of demanding and painstaking work. While such a project may take years or decades, if done correctly, it will be a valuable contribution to practicing malacologists.

This book is intended for three groups of people. The first and foremost is the amateur community. Amateur malacologists are those who study mollusks out of an avocational desire, in contrast to the professional who is employed or was trained as a malacologist or biologist. Some amateurs may be classified as paraprofessionals meaning that their depth of knowledge on a particular subject may be at a professional level, however, they may not have the breadth of malacological knowledge that a professional has. We hope that this book will give amateurs the guidance and skills to deepen their interest in malacology and do so in a professional manner.

Another group of people for whom this book is intended is professional biologists, those individuals whose work, at least in part, relates to mollusks. This group would include, among others, malacologists and ecologists. The techniques outlined in this book will be of use to them in their work. If you are a biologist, and have a need for an up-to-date reference on mollusks, this book is for you. It will be of use to biologists studying both fossil and recent mollusks.

The final group of people is biology students beginning their studies of mollusks. As with the above

groups of people, this book will help open up the field of malacology to them. It will provide students with a sourcebook that they can use in their studies.

The terms conchology and malacology need clarification. Conchology has traditionally been thought of as the study of molluscan shells. Malacology is a broader term that includes the study of the animal that made the shell in addition to the molluscan shell. In this book, we use the term malacology to mean the study of mollusks and malacologist to describe anyone interested in mollusks, whether their interest is only the shell or the molluscan fauna in the broadest sense.

What is a mollusk? Among the animals, Mollusca are in a group called Spiralia or Protostomia, which also includes Annelids, Arthropods, and other small phyla. The Spiralia, which make up more than 90% of all living multicellular animals, share several developmental features including spiral cleavage of blastomeres, formation of the mouth from the blastopore, and predictable cell fates such as all mesoderm being formed from the single cell 4d. The circumpharyngeal nerve ring is present in many Spiralia. Within the Spiralia, the group Eutrochozoa includes the Mollusca, Annelida, and other small phyla, which all share a trochophore larva (top shaped larva with an equatorial ciliated band and a dorsal cilia tuft), schizocoely (formation of body cavities from multiple bilaterally paired masses of mesoderm), and paired excretory organs and ducts that open externally. Regarding the Mollusca themselves, despite the wide diversity of body forms, the groups of animals we classify as Mollusca share the following unique features (Eernisse *et al.* 1992, Haszprunar 2000):

- radula (absent in Bivalvia)
- mantle capable of secreting a calcium carbonate-based shell or spicules
- mantle cavity
- ctenidia (specialized gills having countercurrent oxygen exchange)
- osphradia (chemosensory epithelial organs) (absent in Monoplacophora and Scaphopoda)
- pericardium around the heart (not around heart in Scaphopoda)
- mesodermal origin of pericardioducts
- rhogocytes (pore cells) associated with the nephridia (kidneys)
- tetraneury (two pairs of main longitudinal nerve bundles)
- intercrossing dorsoventral muscles
- crystalline style and associated ciliated midgut digestive organs
- esophageal pouches
- broad creeping sole or narrow hydrostatic foot
- large ventral pedal glands that secrete mucus

Mollusks will share some or all of these characteristics. You may be unfamiliar with some of the terms used; many are defined in the glossary found at the end of this book.

Mollusks first appeared at the end of the Pre-Cambrian. Many lineages of mollusks have died out before Recent times. The living mollusks comprise the following classes: Solenogastres and Caudofoveata (together the Aplacophora), Monoplacophora, Polyplacophora, Scaphopoda, Cephalopoda, Gastropoda, and Bivalvia. Mollusks can be found in terrestrial, freshwater, and marine environments.

As indicated in the title, this book focuses on studying, collecting, and preserving mollusks. The study of mollusks can take place in the field, in an aquarium, or in a collection in your home or at a museum. Collection can refer to the collection of field observations or specimens. Preservation can refer to the preservation of specimens in collections, or to conserving living mollusks and their habitats.

It is also important to know what this volume does not cover. It provides only basic information on anatomy. It does not cover the biochemistry, physiology, or genetics of mollusks. Though raising and maintaining mollusks in aquaria or terraria is mentioned in a few chapters, except for Chapter 31, there is very little information on aquaculture of mollusks.

Now we give a brief overview of the remainder of this book. This overview should give you an idea

of the information to be found in each chapter and help you use this book effectively.

1.2 CHAPTER REVIEWS

The book is composed of 31 chapters. The first 14 chapters cover basic topics in malacology. The next seventeen chapters cover malacological issues related to specific groups of mollusks.

Chapter 2 presents many techniques for the collection, cleaning, and preservation of mollusks. There are also sections about tagging and narcotizing mollusks. In this chapter, Sturm, Mayhew, and Bales have tried to include not only the latest techniques, but also older and still useful methods. The Walker Dipper, first described in 1904, is illustrated here for the first time.

Chapter 3, primarily written by Burch, is on remote bottom sampling. It updates his paper presented at the annual American Malacological Union meeting in 1941. Burch relates stories about a lifetime of dredging and provides useful insights on this activity. In the second part of this chapter, Sturm discusses several other methods of sampling underwater sediments including grabs, box corers, tangle nets, and the like.

Snorkeling and SCUBA diving are covered by Cordy and Cordy in Chapter 4. This chapter will expose you to new ways of coming face to face with mollusks. While this chapter will not teach you how to dive, the authors have covered the equipment that is needed for snorkeling and SCUBA diving. The inherent risks of these activities are also covered.

Chapter 5 moves us out of the field and into our collections. If you want to learn how to help preserve your collection for the next millennium, this chapter will interest you. This chapter discusses curatorial practices and methods for archival protection of your collection. The chapter starts with a discussion of the risks to stored collections. It continues with a discussion of materials that are used in maintaining collections, stressing archival materials and practices. This chapter concludes with a list of sources for archival materials.

Moretzsohn, in Chapter 6, discusses digital imaging with flatbed scanners and digital cameras. He begins with a basic discussion of the theory behind digital imaging. He goes on to compare digital and film imaging technologies. Digital cameras and flatbed scanners are discussed. Finally, the printing and editing of digital images are reviewed. Moretzsohn also provides an extensive list of Internet sites where one can go for further information.

Geiger completes the topic of imaging with a review of traditional film photography. In Chapter 7, he begins with a discussion of the nature of light and basic photographic theory. He discusses camera equipment and accessories. There is a discussion regarding film. Special topics include infrared and ultraviolet photography, underwater photography, photography of mollusks in aquaria, and storage of images.

In Chapter 8, Rosenberg discusses the use of computer databases in managing collections. In his discussion he includes choosing a software package, the suggested fields to be included, and constructing the database. The discussion is general enough that it will apply to many different operating systems.

Chapter 9 by Sturm, Petit, Pearce, Cummings, Schwabe, and Wanniger provides an introduction to the malacological literature. The first part of the chapter discusses the various types of malacological publications: monographs, iconographies, journals, and separates, just to name a few. The rest of the chapter categorizes over 700 works by biogeographic zones and molluscan families. Thus, if you have an unknown shell from Ecuador, under the Panamic Biogeographic Zone listing, you will find a list of references to help in identifying it. Also listed are books of general interest and others for those interested in taxonomic research.

How to write a taxonomic paper is an art that is handled by Geiger in Chapter 10. Geiger shows the components of scientific papers dealing with both the new description of a genus or species and of a revisionary paper. Geiger also gives a brief overview of the International Code of Zoological

Nomenclature, a set of rules governing the naming of species. Familiarity with the code is essential for anyone describing a new genus or species; for those just interested in cataloging shells, it is useful knowing how names are determined and why a familiar name is sometimes replaced by a less familiar one.

If you are interested in finding out how researchers determine the tree of life, or how closely related different species are, Chapter 11, on cladistic analyses and phylogenetic trees, will interest you. Campbell explains cladistics and then covers some of the major techniques used in a cladistic analysis. He then concludes with a discussion of molecular biology and how it relates to modern phylogenetic analyses.

If you have ever wondered whether or not to join a malacological organization or go to a meeting, Chapter 12 will be of use to you. Here Sturm discusses the basic functions that both amateur and professional malacological associations provide. He describes the functions of such major organizations as the American Malacological Society, Conchologists of America, and others. He discusses the benefits of meetings, both local and national. Six Internet-based discussion groups are listed with directions on how to join them.

Museums are one of the places where we can go to see fossil and Recent mollusks and to learn more about them. In Chapter 13 by Sturm, you will learn about the basic roles of museums in keeping collections and conducting research: they are not just places that exhibit natural history artifacts! In addition, you will take a quick tour of 22 museums in the United States and Canada. These museums all have major malacological collections. So you can learn more about these institutions and what they have to offer, the addresses for their Internet sites are included.

If you ever wondered about museum collections and what museums do with donated specimens, Chapter 14 by Pearce will inform you. Pearce begins by discussing what makes a specimen valuable to a museum. Most specimens will have some value if they have clear and accurate locality data associated with them. Data can be intrinsic (for example color, size, and weight) or extrinsic (for example collected where, when, and by whom). The importance of the extrinsic data is emphasized, as extrinsic data are often what makes specimens of vital importance to a museum. Also covered in this chapter are ways to preserve soft tissue from molluscan specimens and how these may be of importance to a museum. Finally, if you are contemplating donating your collection to a museum, Pearce discusses the way to do this so that the collection will be of greatest use to the museum and other researchers.

With Chapter 15, we will begin exploring different molluscan groups, as well as techniques for rearing mollusks. These chapters are followed by a chapter on the marine biology of non-molluscan organisms.

Chapter 15 by Campbell is a discussion of paleomalacology. Here you will learn about some mollusks that exist only as fossils. Campbell provides a general overview of fossils and ways to collect fossil mollusks.

Chapter 16, by Scheltema, is a review of the Aplacophora (worm mollusks). These organisms comprise a fascinating group of mollusks that, while often under our feet, are rarely collected by professionals or non-professionals. Scheltema discusses the basic biology of these mollusks and their ecologic context. She goes on to discuss ways of collecting aplacophorans and techniques for studying them.

Chapter 17 deals with the smallest class of living mollusks, the Monoplacophora. Counts discusses this group, which was first known from the fossil record; the first living monoplacophoran was identified only in 1957. These mollusks are found in marine environments and at great depths. Counts covers the biology and zoogeography of these organisms. If you are fortunate enough to find a monoplacophoran, directions for their preservation are covered.

Schwabe and Wanniger write about the Polyplacophora (chitons) in Chapter 18. These mollusks

have a shell composed of 8 plates and attach tenaciously to the rocks on which they live. Schwabe and Wanniger discuss the external and internal anatomy of these organisms as well as their mode of reproduction and where they live. They include techniques for collecting and preserving the soft tissues and shells of chitons.

The Scaphopoda (tusk shells) are addressed in Chapter 19. Here Reynolds begins with a discussion of the biology of the tusk shells and goes on to review them in an ecological context. He discusses ways to collect, preserve, and maintain collections of tusk shells.

If you ever wanted to know how to preserve a giant squid, this next chapter is for you. In Chapter 20, Anderson discusses the Cephalopoda (i.e., squids and octopuses). He begins with a review of the biology and behavior of these mobile organisms. This review is followed by a taxonomic review of the class. He then goes on to discuss collecting techniques and protocols for preserving cephalopods, including *Architeuthis*, the giant squid. Although you will need hundreds of liters of preservative, an enormous vat, and weeks to months, this chapter will prepare you for the undertaking. Anderson concludes the chapter with information on identifying cephalopods and a section on the difficulties of maintaining cephalopods in an aquarium.

Chapter 21 reviews the freshwater Gastropoda. While some of these gastropods are vectors of disease, others are common aquarium inhabitants. Dillon starts off with a discussion of the biology and ecology of the freshwater gastropods. He also touches on some conservation issues relating to this fauna. He describes techniques for collecting, preparing, and storing freshwater gastropods. Dillon concludes with techniques for maintaining freshwater gastropods in an aquarium.

Pearce and Örstan discuss the terrestrial Gastropoda in Chapter 22. They begin by discussing the biology of this group. There is an extensive discussion of the habitats of the land snails and how to locate them. They continue with a discussion of field methods used in collecting land snails; you will even learn how to collect snails with a leaf blower! They conclude with an exhaustive description of processing and storing land snails as well as a discussion of record keeping.

The discussion of land snails is continued in Chapter 23. Örstan begins with a review of the literature on maintaining land snails in a terrarium. He goes on to discuss short-term maintenance of a terrarium and rearing some North American woodland snails. He concludes with a discussion of factors that can affect the health of land snails. Hans (see the frontispiece) has been raised in captivity for the past 4 years following the advice in this chapter.

The treatment of the Gastropoda concludes in Chapter 24. Here Geiger presents information on the marine Gastropoda. He begins with an extensive discussion of the shell and soft tissue anatomy of the marine gastropods. He continues with a discussion of the major groups of marine gastropods. He then discusses the various habitats where marine mollusks can be found and the ecological aspects of the marine gastropods. He concludes with a discussion of techniques for collecting and preserving marine gastropods, including the preparation of radulae.

The next three chapters cover the Bivalvia. Chapter 25 by Cummings and Bogan reviews the Unionoida or freshwater mussels. The larvae of these mollusks spend part of their lives as parasites of vertebrates. Cummings and Bogan begin with a description of the biology and ecology of the freshwater mussels. This section is followed by a taxonomic treatment of this group. They briefly touch on issues relating to conservation, a topic more fully developed in Chapter 30. They then provide an extensive description of field collecting equipment and techniques, information on identifying freshwater mussels, and methods of curating wet and dry collections of these organisms.

Korniushin, in Chapter 26, provides a similar treatment for the non-unionoid freshwater bivalves. He begins with a treatment of the Sphaeriidae, commonly known as the fingernail, pea, or pill clams because of their small size. This includes

the biology and ecology of and methods for collecting and preserving these organisms. He then briefly discusses the Corbiculidae (Asian clams) and Dreissenidae (zebra mussels).

The marine Bivalvia are discussed in Chapter 27. Coan and Scott begin with a discussion of the biology of these organisms. They then give an overview of the five groups (orders) of marine bivalves. They then discuss techniques for the collection, preservation, and study of these animals.

Chapter 28 deals with establishing and maintaining a marine aquarium. Winner begins the chapter with a discussion of the uses of and observations that can be made in an aquarium. The physical components of the aquarium are then discussed: water, plants, rocks, and food. She then describes fourteen marine organisms that she maintained in her aquaria and the observations that she made.

In Chapter 29, Gutierrez gives a brief overview of marine biology. The aim of her chapter is to introduce marine organisms that are sometimes mistaken for mollusks. Some examples are calcareous algae, annelids, brachiopods, and echinoderms.

The last two chapters cover issues of conservation. One covers freshwater mollusks while the other covers marine mollusks.

In Chapter 30, Bogan reviews the sad conservation history of freshwater Gastropoda and Bivalvia in North American streams, rivers, and lakes. He explores the patterns of extinction that have occurred and the reasons behind them. On an upbeat note, he does discuss some reversals in these trends. Bogan includes tables listing the threatened, endangered, and extinct freshwater mollusks of North America.

In the final chapter of this book, Chapter 31, Baker discusses marine molluscan fisheries. He explores the attitudes towards marine mollusks and marine conservation in the 20th and 21st Centuries. He goes on to examine specific examples involving mollusks. He extensively reviews the oyster fisheries on both coasts of the United States. Less extensively, he also discusses the fisheries for abalones, Queen Conchs, scallops, clams, mussels, and cephalopods. He includes tables listing gastropods and bivalves that are covered by state or federal regulations, common edible or commercial mollusks that are not covered by specific regulations, and information for states with marine fishery agencies.

Following Chapter 31 are two appendices and a glossary. Appendix 1 consists of four plates illustrating morphological and anatomic features of gastropods and bivalves. Appendix 2 is an expanded table of contents. It will give you a detailed overview of each chapter and help locating information in the book. In the Glossary, you will find definitions for many of the technical terms used throughout this volume.

This book is meant to be sampled piecemeal and not necessarily read from cover to cover, though one could do this. The book is meant to be sampled in portions relating to one's interests. If you are interested in bivalves, you will concentrate on Chapters 25-27. If you wish to delve into freshwater malacology, Chapters 21, 25, and 26 would be on your reading list. If you are interested in field techniques, read Chapters 2-4, 6-7, and the chapters for the organisms in which you have an interest.

We hope that you will find the information and discussions in this book helpful. As with all books of this type, compromises had to be made. The authors and editors sought to present a balanced handbook of techniques and background information. In preparing each chapter, the authors attempted to be comprehensive in approach while presenting only what they felt would be useful. If there are areas or topics that you feel were slighted or overlooked, let us know.

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the workshop were offered by Paul Drez (1947-2004), William Frank, Ross Mayhew, Timothy Pearce, Michael Penziner, Richard Petit, Robert Prezant, Gary Rosenberg, and Evangelos Tzimas. Presenters at that workshop included Kevin Cummings, José Leal, Timothy Pearce, Richard Petit, and Gary Rosenberg. Robert Prezant deserves special thanks, for presenting CFS with the opportunity to organize this workshop.

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CHAPTER 2

FIELD AND LABORATORY METHODS IN MALACOLOGY

CHARLES F. STURM
ROSS MAYHEW
B. R. BALES (1876-1946)

2.1 INTRODUCTION

Your first exposure to the world of mollusks may have been picking up a seashell on a beach while you were on vacation. It may have been finding a snail or slug in your garden. It may have taken many years before you decided to pursue a more in-depth interest in these organisms. This chapter will introduce you to ways to collect, clean and prepare mollusks.

Part of this chapter was a paper written by B. R. Bales and presented for him by R. Tucker Abbott at the Eleventh Annual Meeting of the American Malacological Union in 1941 (Bales 1942). This paper with minor alterations was reprinted in Abbott *et al.* (1955, 1966) and Jacobson (1974). While much of what Bales had to say is still relevant, some of his suggestions have not stood the test of time and are no longer considered appropriate in the context of current curatorial practices. In this chapter we (CFS and RM) copy and paraphrase from Bales' paper. In addition, we have added information that updates his views and we add information that was not in his original work. Due to our use of Bales' original paper, we have included him as an author; to do otherwise would be tantamount to plagiarism.

In addition to the recommendations in this chapter, you will find additional information in Chapters 3 to 5, and 15 to 27. Bergeron (1971), Lipe and Lipe (1993), and Weil (1998) are other works in which you can find advice and opinions on how to collect, clean, and maintain a molluscan collection.

2.2 COLLECTING BASICS

Other than being given a collection, there are three basic ways to build a collection. You can buy specimens, trade for them, or collect them yourself.

2.2.1 Purchasing. If you chose to purchase shells, you first have to find a dealer. They can be found advertising in publications such as *American Conchologist*, *La Conchliglia,* and *Of Sea and Shore.* A comprehensive worldwide listing of dealers can be found in *Tom Rice's A Sheller's Directory of Clubs, Books, Periodicals and Dealers* compiled by Tom Rice (2003) and at several good Internet sites such as <www.manandmollusc.net> and <www.conchologistsofamerica.org/home>.

There are several advantages to purchasing shells from a dealer. First, they are already cleaned. Second, they are identified. Most important, you can obtain material from places that you may never be able to collect from yourself, and from fishing boats and other sources inaccessible to the average collector.

The drawbacks to purchasing shells are two-fold. First, having good locality data is usually important, and the locality data of purchased shells may be sparse or suspect. Knowing that you are buying from a reliable dealer helps to minimize this risk. Second, you lose the ability to study the organisms in their natural habitat.

Dealers use a grading system to indicate the quality of their material. The international standard dictates that "Gem" specimens are absolutely perfect to the naked

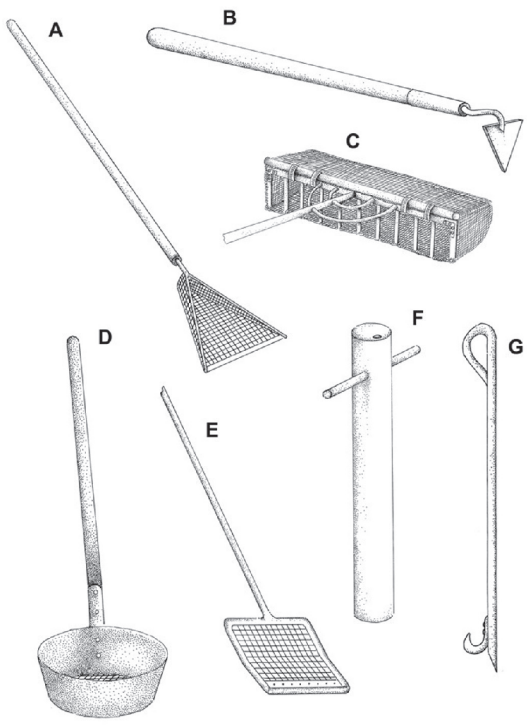

Figure 2.1 Collecting devices and aids.
A. Allison Scoop, B. Ferriss Hoe, C. Davis Rake Drag, D. Walker Dipper, E. van Eeden Scoop, F. Clam tube or clam gun, G. Bales Hook.

eye, "F++ or Gem-", which some dealers call "F+++" specimens, are so close to perfect that any flaws have to be searched for, "F+" indicates a specimen with minor flaws that do not detract much from its aesthetic appeal, "F" (stands for "Fine") specimens have significant flaws, Good specimens are not good at all, and Fair and Poor are recognizable as that species, but just barely. That said, grading is subjective, and there is an understandable temptation to over-grade. If you see a dealer's list with mostly gem designations, beware. *Caveat emptor* is a useful watch-phrase. When placing an order from a dealer you are unfamiliar with, it is best to start small. Make a few modest purchases, and if you agree with the dealer's grading of the shells and the quality of the associated data, you can make larger purchases with confidence. Often dealers will learn your interests and notify you of material in which you might be interested.

2.2.2 Trading. Trading has several rewards. One can trade shells and/or publications for other shells and/or publications. The benefits (and hazards) are the same as with purchasing from dealers. In addition, if you are not trading for a specific shell, you will have the excitement that comes with receiving a shipment of unknown material. As with purchasing from dealers, when you trade with someone, make your first trades modest ones of material that you can afford to lose. If all goes well, mutual trust will develop and larger trades will ensue with confidence. Often, but not always, the material you trade for has been self-collected and therefore the collection data may be more complete and reliable than with purchased material.

2.2.3 Self-collecting. In spite of building a collection by purchasing or trading shells, eventually you may desire to start field collecting yourself. You may decide to collect shells in which the animals have died (dead collecting) or living material (live collecting). Section 2.4 deals with some techniques that you can use to collect mollusks.

The simplest way to self-collect is to look for dead material. You can walk along the beach picking up seashells, an activity known as beachcombing. A particularly good time to try beachcombing is after a storm. Sometimes you will find material from deeper water thrown up on the beach. Also, pelagic material may be blown onto the beach by the storm's winds.

You might walk along the shores of a lake, pond, or river and search for freshwater material. Sometimes you may be lucky and find a shell midden. This is a pile of shells left behind by an animal such as a raccoon or muskrat after it has eaten a meal of mussels. Section 2.4 describes some of the techniques of field collecting.

You might also be interested in collecting terrestrial gastropods. These can be found under rocks or leaf litter. Techniques for collecting these mollusks are covered below and in Chapter 22, Sections 22.4 and 22.6.

2.3 COLLECTING EQUIPMENT

Many different tools or implements may come in handy from time to time, and, while you may

achieve a measure of success with very little equipment (such as a spade, a kitchen strainer, some vials and collecting jars, rubber boots, snorkeling equipment, sharp eyes, and plenty of patience), you will eventually find that some specialized tools will be necessary as you progress in the study of malacology (i.e., the study of mollusks as living animals), or conchology (i.e., the study of the calcareous exoskeletons of mollusks, otherwise known as "shells"). What follows now are descriptions of some such tools.

2.3.1 Allison scoop. Allison (1942) described a scoop for collecting *Campeloma* (a freshwater gastropod) from stream bottoms. The scoop was triangular in shape, had a wire basket with a reinforced leading edge and it was attached to a pole (Figure 2.1A). By varying the size of the scoop and the mesh size of the basket, this scoop can be modified to collect a wide variety of mollusks.

2.3.2 Ferriss hoe. Walker (1904) described an implement called the Ferriss hoe. This is a garden hoe with its blade trimmed to 75 mm (3 in) at the top and tapering to a sharp point. The handle is trimmed to the length of a walking cane (Figure 2.1B). This device is a good tool for turning over logs and rocks, breaking up rotting logs, and digging through rotting leaves and around stumps. It is also long enough to pull down tree branches.

2.3.3 Davis rake drag. Davis (1964) described a type of dredge to be used from the shoreline. He took a garden rake and to the crossbar of the rake he attached a 6-8 mm ($^1/_4$ in) wire mesh that looped around and was attached to the ends of the tines. He then attached a pipe, filled with sand, to the crossbar to give the device added weight (Figure 2.1C). A rope was attached to the handle of the rake. The device was then thrown out into the water and pulled back so that the wire basket and tines would bite into the substratum. The rope was pulled drawing the device back to shore. The device was then tilted, emptied, and the contents examined for specimens.

2.3.4 Screens, dippers, and nets. To collect the smaller specimens from shallow water, a screen comes in handy. Once you progress beyond kitchen strainers, these may be constructed or purchased in many sizes and forms. The size of the screen and height of the sides depend upon the individual user. It should not be so large that it taxes the strength, for it should be remembered that to be successful in screening, the collector must be persistent and many hours are usually spent in this manner. It is a fascinating form of collecting and the time flies all too soon. Seldom will the collector stop sifting without trying "just one more screenful" of material.

Some collectors prefer several graduated sizes of screen (brass, aluminum, stainless steel, or zinc-coated mesh are best, since they are corrosion-resistant), but most prefer just two; the inside screen to be 6-8 mm mesh ($^1/_4$ inch) and the outer one of 3-4 mm mesh ($^1/_8$ inch). If you are interested in microshells at all, a third one, of 1 mm or smaller mesh (0.04 in or less) will be necessary. This one will catch most of the smallest shells. The inner screen with the larger mesh should fit snugly into the outer one with the smaller mesh, but not too snugly. Allowances should be made for the natural swelling of the frames, although much swelling will be avoided by painting the frames. Some collectors nail a small cleat to the ends of the outer screen to obtain a firmer grasp. The same results may be obtained by sawing a narrow horizontal slit in the end of the frame. The size of frame and mesh being of individual preference, it is sometimes advisable to try out several before the ideal one is found, and even then, many collectors change from time to time as the occasion demands. You might also find soil sieves useful. These are nested sieves about 20 cm (8 inches) in diameter. They are generally made of brass. They can be purchased from general scientific and forestry supply companies (see the appendix in Chapter 5 for a list of such companies).

One form of screen that is sometimes used has no upright frame on one side and is held in place on the bottom of a body of water by the collector's foot. The sand, mud, marl, or other material is raked or drawn into the screen by the use of a hoe, rake, or other utensil. This type of screen avoids having to lift the material and to deposit it in the screen for those who like to adhere to a less energetic regimen while collecting.

A handy device often used consists of a small round sieve that has been attached to a long handle. It is easily made from a 12-15 cm (5 or 6 inches) gravy strainer to be had at most hardware or discount stores. They have two bent prongs in front that must be bent backward so as not to interfere with the use of the net. No device equals this when working in waist or chest deep water. You might also want to make and use a Walker Dipper (see Figure 2.1D, Chapter 21, Freshwater Gastropoda, and Walker 1904).

When collecting the specimens on various types of aquatic grasses (eel, turtle, etc.), a net made of mosquito or other fine netting sewn around a butterfly net hoop is extremely useful, especially if you wish to be as ecologically sensitive as possible, leaving the grasses in place instead of collecting them and washing the mollusks into fine (the 24-mesh) screens using fresh water.

2.3.5 van Eeden scoop. Another variation of scoop was described in van Eeden (1960) (Figure 2.1E). The scoop was designed for collecting freshwater gastropods. It is a square frame made from a 5 mm iron rod. The square is 25 cm on a side. The frame is angled upwards about 30 degrees two thirds of the way back from the leading edge. The leading edge is reinforced with iron or tin sheeting. A wire screen of appropriate mesh size is attached to the frame. The frame in turn is attached to a handle of appropriate length (2-3 m).

2.3.6 Shovels. Some collectors use a shovel to dig up clams. Commonly, these shovels have a blade 75-100 mm wide (3-4 inches). The blade is longer than it is wide, and it is slightly curved. These shovels are sometimes called clam guns. Insert the shovel so that it curves away from where you believe the clam to be and start digging. Dig and scoop the sediment away from the clam burrow; keeping the shovel blade parallel to the clam burrow. When you see part of the clam reach down and grab it. It is important not to dig towards the clam; doing so may damage it.

2.3.7 Clam tube. There is another device also called a clam gun or sometimes a clam tube. This is a metal or plastic tube, 75-150 mm in diameter (3-6 inches) and 1 to 1.5 meters long (3-4 feet). It is closed on one end with a cap that has a handle and small vent hole (Figure 2.1F). When you locate a clam burrow, place the tube over the burrow. Rock the tube back and forth and twist it so that it drills into the sediment. When you believe that the shell is within the tube, cover the vent hole. Doing so creates a suction effect when you withdraw the tube from the ground. You will pull up a plug of sediment that should include the clam. Empty the contents onto a screen, wash them, and remove the shell. This device works best in muddy and sandy substrates; it does not work well in bottoms composed of gravel and rock.

2.3.8 Hammer. A geologist's or bricklayer's hammer with a chisel end can be quite useful in several respects. You can scrape through leaf litter, dig into the upper layers of soil, turn over rocks (which of course should always be replaced as they were, before leaving the scene), use it in the pursuit of paleomalacology (fossil collecting), chip away the soft rocks in which burrowing species such as many of the family Pholadidae (e.g., *Barnea* and *Zirfaea* spp.) live, and the chisel end comes in handy when taking apart pieces of sunken wood that may harbor ship worms (Families Teredidae and Xylophagidae)**.** It is useful to paint part of these tools a bright yellow or orange. Otherwise, you will learn the hard way how easily such tools can be overlooked when put down in the field and searched for at a later time.

2.3.9 Bales hook. According to Bales, one of the most important tools is a device made from a 15 mm ($^5/_8$ inch) metal rod. One end is looped to make a handle and the other is formed into a point. About 75 or 100 mm (3 or 4 inches) above the point, a curved hook is welded onto the rod giving a form similar to an elephant hook (Figure 2.1G). With such a device, you have an implement that can be used as a walking stick, to turn over rocks, to pull things closer to you, and to pull down branches when looking for arboreal snails. Estwing makes a similar tool called the Gem Scoop®. Instead of a hook, it has a small basket. Of course, many collectors make their own tools as best as they can, given their budget and circumstances, so the implements

described in this chapter can be taken as a starting point - an assemblage of ideas and advice, for you to adopt or adapt as you see fit.

2.3.10 Water pumps. When the ocean floor is of rock that is more or less honeycombed with small potholes, it is surprising what fine specimens of the smaller varieties may be obtained by the use of a common bilge pump, which is standard equipment on small boats. The end of the pump is placed in a sand-filled pocket in the rock. The sand as well as the mollusks that have taken refuge in the hole are pumped with the water onto a screen; the sand and water flow through, leaving the specimens all ready for the collector.

2.3.11 Bags and collecting containers. Very important to the collector's outfit is your collecting bag, and this may consist of almost anything from an old tin can, a burlap or nylon sack, a pocket handkerchief or some such makeshift affair, to a real game bag or collecting bag. They are usually made from lightweight canvas and carried in some cases by a strap over the shoulder. Such bags are useful when extra heavy specimens are anticipated. A bag that may be tied or secured about the waist is much handier and has the advantage of always being in place and does not drop in front of the collector when he or she stoops to secure a specimen. Many collectors favor a bag containing partitions: one compartment for tools, vials and other equipment apart from the shells that are collected, and others for samples of various sorts. You might even find that a carpenter's apron makes a useful collecting bag.

When collecting small mollusks, a good supply of glass or plastic vials of various sizes, will prove most useful. These should be cylindrical and of the screw top sort without a narrow neck. Nylon mesh bags are often useful when collecting larger shells such as bivalves. You should be careful to keep shells from different habitats separate, labeling the vials and containers in the field using pencil and strong paper, and/or a grease pencil applied to the container. Basic information will include date, locality, collector, and as a good and brief a description of the habitat as possible. In the heat of collecting, especially when racing the tide, it is easy to mix things up and difficult to take detailed notes, but care nevertheless should be taken to keep facts and specimens straight. Any details that you note regarding the habitat can be jotted down afterwards while they are fresh in the memory.

Freshly taken specimens should never be placed, even temporarily, in a rusty metal container or in contact with rusty chains or other rusty objects for it is remarkable how soon they will become rust stained. It is almost impossible to remove these stains without damaging the shell in the process. Sturdy plastic buckets serve the same purpose at a very reasonable cost, and are easier on fragile species than metal ones.

2.3.12 Glass-bottomed bucket. A useful adjunct to shallow water collecting is the glass-bottomed bucket (first used by sponge collectors), or an equivalent device - sometimes called a water glass or water bucket. Collectors often use one that is square or oblong. An easy way to construct one is to make the frame or box of not too heavy wood and fasten the glass or plexiglas to the open bottom by means of quarter rounds available at any lumberyard. A bead of silicone caulking is placed around the opening between the wood and plexiglas. This ensures a watertight seal. Visualization will be improved if the inside is painted dull black. You can also take a plastic or metal bucket and cut out the bottom leaving a 10 mm ($^1/_2$ inch) rim. To this rim, a circular piece of Plexiglas can be attached with silicone caulking. When in use, frequent wetting of the inside of the glass makes vision clearer and eliminates fogging.

2.3.13 Lights for night collecting. If you have never collected at night, hunting by the aid of artificial light is a revelation. Many mollusks (such as *Conus*) hide wherever they can in the daytime and mainly venture out to feed at night. This is also true of *Marginella*, *Cypraea*, *Hydatina,* and the like. While specimens may be taken by the combined use of water glass (see above) and flashlight, you might also try snorkeling or SCUBA (see below and Chapter 4, Snorkeling and SCUBA Diving). Use a bright waterproof flashlight and make certain that you have spare batteries. Extremely good underwater lights can be purchased for less than