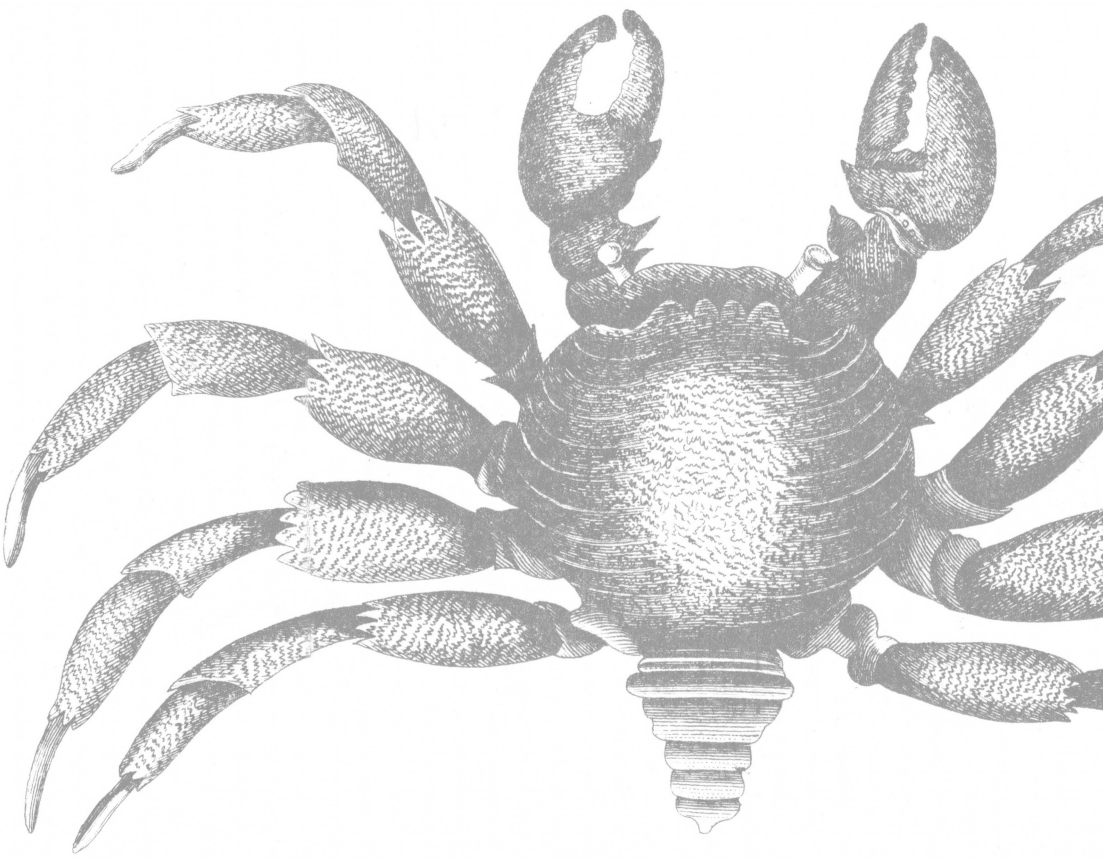
Walking Sideways



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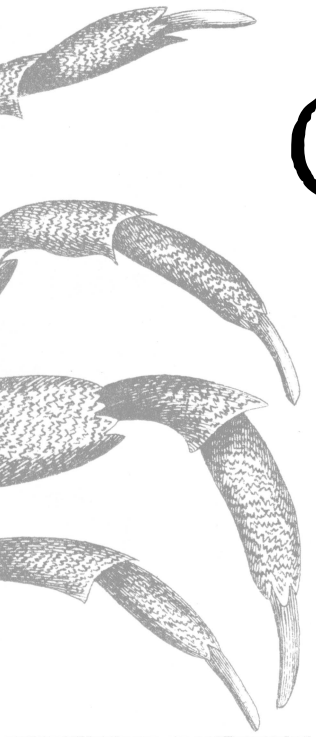

THE REMARKABLE WORLD OF CRABS

JUDITH S. WEIS

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Preface

If we live out our span of life on the earth without ever knowing
a crab intimately, we have missed a good friendship.
WILLIAM BEEBE, 1932

I find crabs fascinating to study and love to watch them. Other people who are not biologists also seem to be interested in crabs for many reasons—they like to go crabbing, they look at them in aquariums or when scuba diving, or they just like to eat them. Some people may be a bit afraid since some crabs can give a nasty pinch. People are curious about the lives of crabs because they seem so alien and different from us. What is life like living inside a shell that you have to shed frequently? What is it like living on the bottom of the ocean? How do you coordinate moving with so many legs? In this book I attempt to provide information about these fascinating creatures that live in such a very different world than we do. I have tried to provide basic biological information at a level understandable by the general public, while including lots of up-to-date scientific information.

As a seven-year-old, summering on Shelter Island, New York, I discovered a fascination with marine life that is still with me. While standing in shallow water one day I came upon a hermit crab walking along in a large whelk shell that was covered with barnacles, seaweed, boat shells, and other forms of clinging sea life. This whole collection of living things walking along in the water seemed like the most amazing thing. My mother, cousin, and friends did not find it nearly as wonderful and exciting as I did, but

this formative experience in my early life may have led to my becoming a marine biologist. Despite a crab being the central character in this formative experience, my early career as a marine biologist was not spent studying them, but fish instead. Dr. Evelyn Shaw took me on as an undergraduate for summer research at Woods Hole Oceanographic Institution, where I did my first bit of research (on fish). The following year, the Marine Biological Laboratory's course in marine ecology, taught by such luminaries as Eugene Odum, Howard Sanders, and Laurence Slobodkin, expanded my knowledge of coastal ecology, including fish and crabs. My research work as an undergraduate at Cornell and graduate student at NYU focused on fish. It was only after several years on the faculty at Rutgers that my interests expanded beyond fish to crabs. Spending a summer at the (now-defunct) New York Ocean Sciences Laboratory in Montauk, New York, I made the acquaintance of Jim Hsiang, then a graduate student, who was studying fiddler crabs. He took me along on a collecting trip to a place in Accabonac Harbor called "Louse Point" and showed me the marsh area where he collected them. Watching these crabs wave, dig burrows, and walk around in the air at low tide, I was intrigued. I hesitatingly started to study them, and was insecure because I knew so little. But with the help and encouragement of an old friend, Linda Mantel, who has been a "crab lady" (as she describes herself) for all of her career, I got to know them better. From then on, crabs (especially fiddler crabs) have been an important part of my research program, along with fish, and Louse Point has become an important place for both research and recreation. It has been fascinating to see how crabs and fish are similar and different in the ways they respond to their environment.

The idea for this book was initially generated when I was writing *Do Fish Sleep?* (Rutgers University Press, 2011). That book used a question-and-answer format to cover all aspects of fish biology; as I was developing the questions and answers, in the back of my mind I kept thinking, "I could do this with crabs." This book, though not in a question-and-answer format, covers many of the same topics. Here you will find information about basic biology, the vast diversity of places where crabs live, how they live and adapt to their environment, their amazing behaviors, their incredible migrations, the dangers they face, their ecology, and the ways they can change colors, communicate, and reproduce. Chapters are also devoted to how people can interact with crabs, and how they can catch and eat crabs

(with some famous dishes and specialties). Some space is devoted to issues of the sustainability of crab fisheries and attempts at conservation so that readers may become better informed about these vital issues. I hope that the book, written in a nontechnical, readable style, will convey my enthusiasm about the fascinating lives of crabs and that it will stimulate readers to learn more and contribute to the conservation of these wonderful creatures.

Acknowledgments

I want to thank my husband, Peddrick (Pete) Weis, who has been a research colleague for decades and a strong supporter throughout the development of this book. Pete also is responsible for taking some of the photographs included here and preparing the photos taken by others, as well as reading and commenting on the first draft. I am grateful to all those who contributed their photos, to Gregory Jensen who informed me about the writings of Oppian (-170 AD) on crabs, and to Ray Toste and Jeff Stephan for their discussions about and insights into crab fisheries of the Pacific Northwest and Alaska.

Many graduate students who worked in my lab have provided stimulation and interesting new information about crab biology. Thank you all for your enthusiasm, good work, and good company. Research associate Dr. Terry Glover provided invaluable insights into animal behavior and statistics.

I want to thank our granddaughters, Emily and Jessica Miner, for not being afraid of crabs or saying "EEEEWWW!!" when we find them on the beach.

I am grateful to the National Science Foundation, National Oceanic and Atmospheric Administration, Environmental Protection Agency, U.S. Geological Survey, New Jersey Sea Grant Program, New Jersey Department of Environmental Protection, and the Meadowlands Environmental Research Institute for supporting our research.

I appreciate all the work and help of Heidi Lovette of Cornell University Press, who was interested in this topic from the beginning and was invaluable to me through the review process. Scott Van Sant contributed many useful suggestions as a reviewer of the manuscript. Many thanks to Susan Specter, also of the Press, who shepherded the book through the publication process.

I also appreciate the hard work of all the environmental groups that are working to protect crabs and their habitats, wherever they are.

Walking Sideways

CHAPTER ONE

Introducing Crabs

Scientists in a research submarine exploring the deep-sea hydrothermal vents south of Easter Island made an amazing discovery in 2005: on the sea floor they found an unusually large crab (about 6 inches long) with its legs and claws all covered with hair. Then they noticed more of the strange crabs, mostly at depths of about 7,200 feet. Many were hiding underneath or behind rocks, and, at first, all the scientists could see were the hairy tips of their arms sticking out.

The crabs were living on recent lava flows where warm water seeps out of the sea floor. Hydrothermal vents often form near mid-ocean ridges, where hot lava rises up, causing the earth's crust to split apart and heated water to gush up from the sea floor. Ever since deep-sea hydrothermal vents were discovered as a new geological feature in the 1970s, marine biologists have been fascinated by the unique animals that live there, thriving in the deep waters that are both extremely dark and low on oxygen. Many new species that are deep-sea vent specialists have since been discovered and described. What made the discovery of these crabs so spectacular was their large size and their unusual hairy form, since most crabs have a hard, shiny outer shell. When the scientists collected some of the crabs to bring them back for identification, they found that they had discovered not only a new species (which they named *Kiwa hirsuta*) that is a distant relative to hermit crabs but an entirely new family since these crabs were so distinct from any other known crabs. Because of its hairy legs, the crab was nicknamed the "Yeti crab," after the shaggy abominable snowman of the Himalayas, the Yeti.

What is it that makes a crab recognizable as a crab? For most people, a crab is generally something with a hard shell and ten legs, with the first pair

acting as claws. But this also describes other animals such as lobsters and shrimps. A crab is usually (but not always) wider than it is long, which may have something to do with its habit of walking sideways. It does not have a distinct major tail section, except when seen from below, because this section can be folded up underneath the main body of the animal. Crabs are distinctive creatures and it is remarkable that new groups of animals of this size are still being discovered, but many still are, especially in the deep sea.

The Census of Marine Life, a global network of researchers from over eighty countries, conducted a ten-year study throughout the world to assess the diversity, distribution, and abundance of life in the oceans. They conducted field work in polar regions (Arctic and Antarctic Oceans), continental margins, continental shelves, the deep sea, coral reefs, midocean ridges, seamounts, hydrothermal vents and seeps, whale falls, sunken wood, and near shore. Over 2700 scientists spent over 9000 days at sea on more than 540 expeditions, plus many more days in labs and archives. Using the latest technological advances in remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), sonar, and imaging systems, scientists were able to explore previously inaccessible places, including the deepest and darkest areas of the ocean.

The world's first comprehensive Census of Marine Life, released in 2010, included thousands of newly discovered species, mostly from the deep sea. About sixty-five new species of crabs were found, many of which were galatheid crabs (also known as squat lobsters) from deep-sea seeps and hydrothermal vents. An estimated 5000 additional specimens have not yet been named and classified. According to Myriam Sibuet, vice-chair of the Scientific Steering Committee: "The Census enlarged the known world. Life astonished us everywhere we looked. In the deep sea we found luxuriant communities despite extreme conditions. The discoveries of new species and habitats both advanced science and inspired artists with their extraordinary beauty. Some newly discovered marine species have even entered popular culture, like the yeti crab painted on skateboards."

A year earlier, four new species of king crabs (family Lithodidae) were discovered. King crabs are among the largest crabs, so one would think they would be well known by now. But the deep sea is still largely unknown. One of the new species, however, lives in shallow water near the Galapagos Islands, so it is especially surprising that it was not known before. It is clear that many more species of marine animals of all kinds remain to be discovered. Another study of the king crabs from the New Zealand, Australian,

and Ross Sea (Antarctic) regions found twenty-three new species, doubling the number of previously known species from that part of the world. Five new species were found exclusively from New Zealand, five from Australia, and four common to both regions. One new species (*Paralomis stevensi*) was discovered in 2006 in the stomach of an Antarctic toothfish.

Almost 2 miles deep in the North Pacific, Brad Stevens, then a biologist with the National Marine Fisheries Service in Alaska, found new crabs while exploring the Patton Seamount in the submersible *Alvin*, some 250 miles south of Kodiak, Alaska. The big surprise was finding a spider crab called *Macroregonia macrocheira,* which has no common name, because it's so rare. It was first described from seamounts north of Hawaii in 1979, so they were surprised to see it near Alaska. It had never been seen that far north. It turned out to be the most abundant crab on Patton Seamount. This spider crab has very thin legs that are about a foot and a half long. Stevens thinks the spider crab lives on the sea bottom throughout the North Pacific but is seldom seen because it lives so deep. He thinks it exists all across the seafloor of the North Pacific and probably has walked, over generations, across the ocean.

In 2008, an expedition to a tiny island in the South Pacific's Republic of Vanuatu found hundreds of new species, including many new species of crabs. Over 150 scientists from twenty countries collected species as part of the survey, studying caves, mountains, reefs, shallows, and forests. Marine biologists from the National Taiwan Ocean University discovered a new species of crab off the southern Taiwanese coast in January 2010. With a bright red shell covered with small white spots, the crab resembles a large strawberry. Scientists said that the new species is similar to a previously discovered species, *Neoliomera pubescens*, which is native to Hawaii, Polynesia, and Mauritius, but it has a broader (1 inch), clam-shaped shell that makes it a distinct new species.

In 2012, four new species of brightly colored freshwater crabs were found on the Philippine Island of Palawan. Approximately 50% of all species living on Palawan are unique to this island and live nowhere else. The crabs are unable to spread elsewhere, as they skip the larval stage in seawater and depend on freshwater at all stages of their development. Although they are newly discovered, they are already under threat from several mining projects.

In 2011, researchers from the Smithsonian catalogued almost as many crab species on tropical coral reef areas measuring just 20.6 square feet as in all of Europe's seas. Instead of the usual collecting techniques, the team used DNA barcoding to quickly identify a total of 525 crustaceans (including

168 crab species) from dead coral chunks taken from seven sites in the tropics, including the Indian, Pacific, and Caribbean oceans. Reflecting the diversity of life found in coral reef ecosystems, over a third of the species were found only once, and 81% were found in only one location. The many recent discoveries of new crabs noted here—typically large and easily identifiable animals—makes it clear that our knowledge of these sideways-walking crustaceans is still actively and productively expanding.

INTRODUCING CRUSTACEANS

To introduce crabs, one must first introduce crustaceans and arthropods. Crustaceans include crabs, lobsters, shrimp, krill, barnacles, and related species, many of which are tiny floating plankton. There are approximately 40,000 crustacean species, most of which are aquatic. They range in size from almost microscopic to weighing over ten pounds. Crustaceans are the only primarily aquatic group in the phylum Arthropoda, which also includes insects, centipedes, and spiders. Like other arthropods, crustaceans have a segmented body, jointed limbs, and an external shell or exoskeleton (or cuticle) made primarily of a tough material called chitin. Most of the larger species strengthen and harden their exoskeleton with calcium carbonate. The exoskeleton covers the entire outside of the animal and even lines the front and rear parts of its digestive system. Because of having this hard exoskeleton, arthropods can grow only periodically, after they have molted or shed the old shell and before a new one has hardened. Like other arthropods, crabs have bodies that are segmented; that is, composed of repeating sections. While this segmentation is obvious in other types of arthropods, in crabs it is visible only from underneath.

Within the class Crustacea is the order Decapoda ("ten feet"). Decapods are a large and diverse order, containing crabs, lobsters, and shrimp. In addition to ten feet, they have two pairs of antennae and a pair of crushing jaws called mandibles. The order Decapoda contains nearly 15,000 species, many of which are crabs. The greatest numbers of marine decapods are found in the tropics, just north of the equator. Within that area, the greatest diversity is in the Western Indo-Pacific, where there are many families not found in other parts of the world. Crabs, like all other plant or animal species, have a scientific name consisting of two parts: a capitalized genus name and a lowercase species name, which are generally Latin words and are in italics. For

example, *Callinectes sapidus* is the common blue crab of the Eastern United States. Having a scientific name allows everyone worldwide to know exactly which species is being referred to. Popular names—or common names—will not serve that purpose because many different species may share a common name, for example, "mud crab." Likewise, one species may have more than one common name, such as "green crab" in the United States and "shore crab" in Europe. (Since the crab is not always green, the Europeans have a better name.)

Crustaceans are classified depending on various traits; important ones are how the body is divided and into how many segments. Primitive crustaceans have little differentiation between body segments. Decapods (which include crabs), for example, have a fused head-thorax region and an abdomen. Some other groups have three body regions: a head, a thorax, and an abdomen. A crab's head has appendages for sensing and feeding. The five pairs of appendages on the head are *antennules* (with chemical detectors), *antennae* ("feelers" for touch), *mandibles* (jaws), and two pairs of *maxillae*, which are used in feeding. The head also has eyes, which are on moveable stalks. Its thorax region has eight pairs of appendages: three pairs of maxillipeds, also used in feeding, one pair of legs (the first pair) with claws (*chelae or chelipeds*), and four pairs of walking legs. A firm piece of exoskeleton, called the *carapace*, covers the head-thorax on top and the gills on the sides (Fig. 1.1.). The carapace protects the vital organs inside the body such as the digestive system, heart, reproductive organs, and excretory organs. The abdomen has small appendages called *pleopods* (or swimmerets), and a tail called the *telson*. In lobsters and shrimp, the telson plus the last pair of pleopods (known as *uropods*), forms a tailfan that is easy to see, but it is missing in crabs. There are three subgroups of decapods. One contains lobsters, shrimp, and crayfish, whose abdomen extends out behind; we do not cover this subgroup in this book except for occasional references. The two other subgroups—the focus of this book—are two types of crabs.

The two groups of crabs are the "true crabs" or Brachyura (estimated over 6700 species) and the Anomura (estimated about 2500 species). Unlike in lobsters, whose abdomen (tail) is a large muscular structure behind the rest of the body, the abdomen of true crabs is greatly reduced and tucked underneath their body, so that when viewed from above, all you see is the carapace (see Fig. 1.1). Their body is usually broader than it is long, and they have smaller antennae. Their body is usually rounded or squarish, but some have an unusual shape, such as the crab in Figure 1.1 with long spines sticking

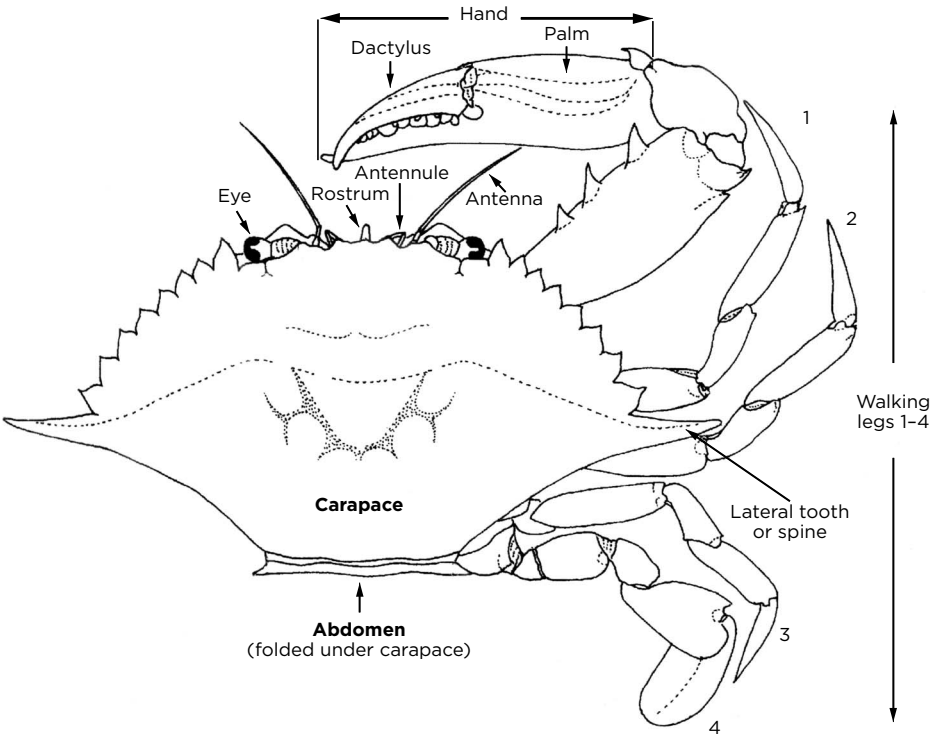

Figure 1.1. Brachyuran (true) crab anatomy, dorsal view. Illustration from UN FAO.

out on the sides. While lobsters and shrimp have five pairs of swimmerets or pleopods on the abdomen (tail) that they use in swimming, crabs, with their smaller abdomens tucked underneath, have very small pleopods that are used only in mating and for egg attachment (not seen in Fig. 1.2). Most crabs are marine, although freshwater and terrestrial species exist as well. The brachyurans are the most highly specialized group of crustaceans.

The anomurans are a large group of marine, freshwater, and terrestrial decapods that exhibit great diversity. While most are called *crabs*, some are called *lobsters*. They include 17 families, over 200 genera, and nearly 2500 species, of which just over half are hermit crabs that live in snail shells. Anomurans have their abdomen not extending straight out (like lobsters) and not tucked totally underneath them (like true crabs). In some it is asymmetrical and curved, soft and unprotected by a hard cuticle (see Fig. 1.3), which is the reason many of them take up residence in empty snail shells and are called "hermit crabs." There are two distinctly different types of

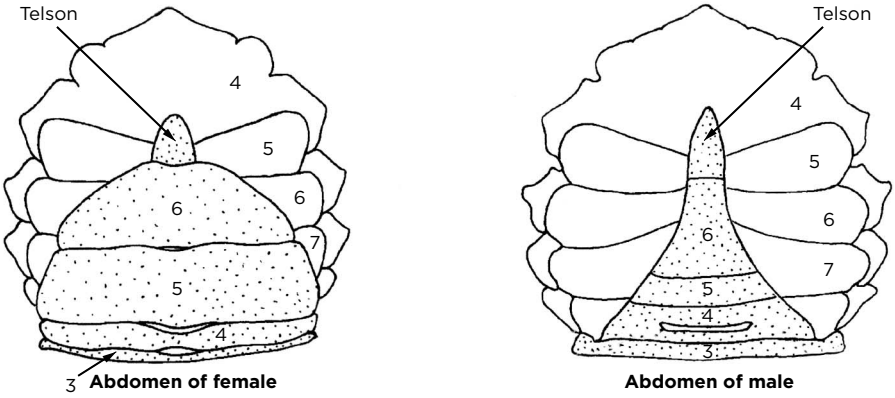

Figure 1.2. Brachyuran (true) crab anatomy, ventral view. Numbers refer to the segments of the thorax and the abdomen. Illustration from UN FAO.

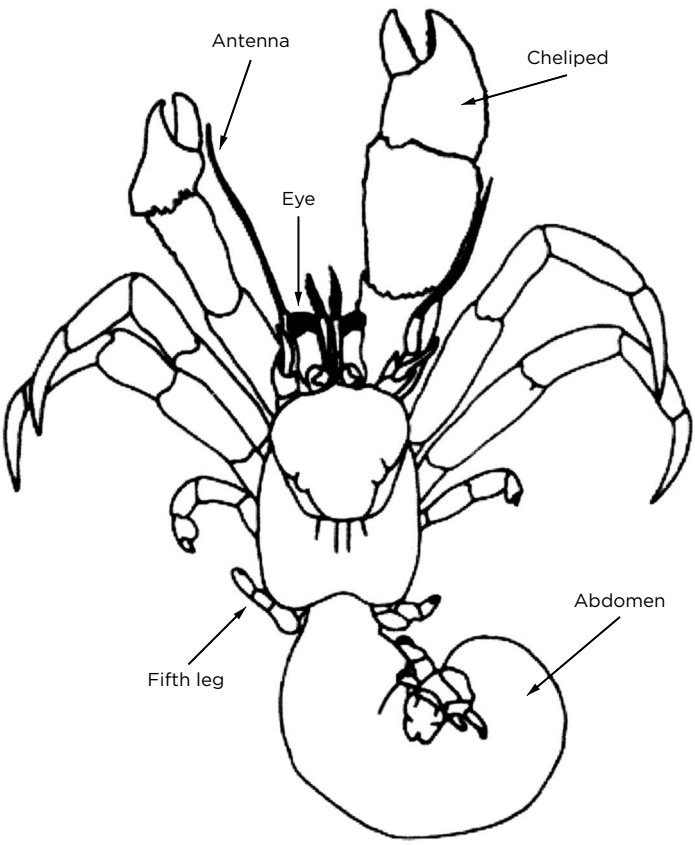

Figure 1.3. Anomuran (hermit crab) anatomy. Illustration by Joanne Taylor, Museum Victoria.

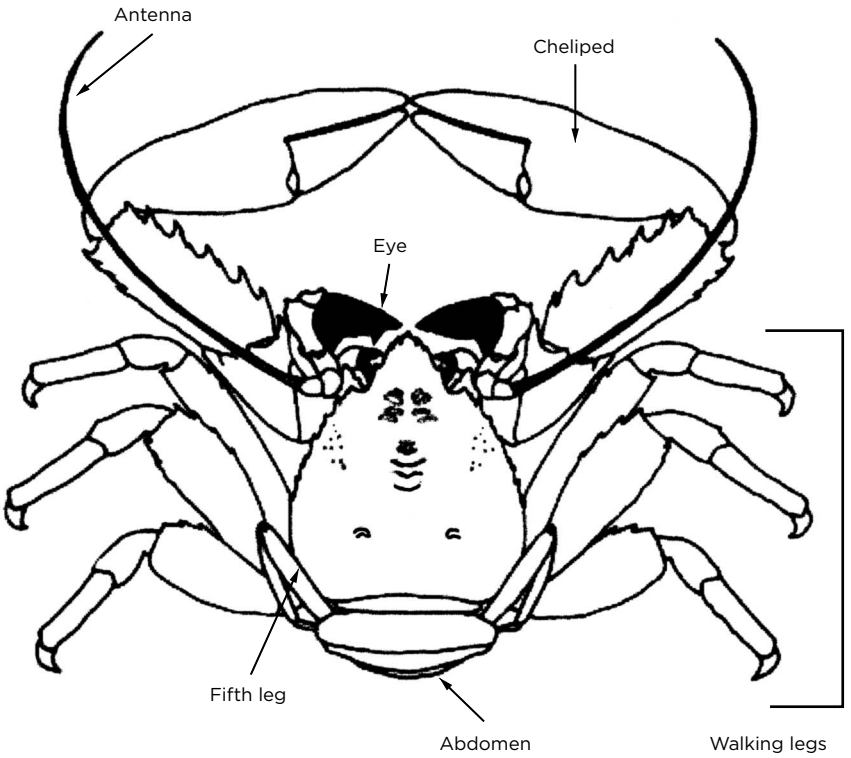

Figure 1.4. Anomuran (false crab) anatomy. Illustration by Joanne Taylor, Museum Victoria.

anomurans: the hermit crabs that live in snail shells and the "false" crabs, so called because they look superficially similar to true crabs (Brachyura). Both anomuran types have their fifth pair of legs greatly reduced—too small to be used for locomotion—and function in other ways. In false crabs, three pairs of legs are used for walking, and the reduced pair may be hidden inside the gill chamber (under the carapace) and used to keep the gills clean. In hermit crabs, only two pairs of legs (and the claws) are used for walking. The other (small) walking legs are used to hold onto their snail shell from the inside. Among the false crabs are porcelain crabs, king crabs, and mole crabs, all of which can be distinguished from brachyurans by counting the legs—they appear to have six rather than eight walking legs because the last pair is reduced (see Fig. 1.4). Their abdomen is tucked under the body as in brachyurans, but it is not as flat. King crabs have a thick shell but a soft bulbous abdomen, and they burrow backward into the sand. Mole crabs (also known as sand crabs; Fig. 1.5) also burrow backward, using their tail and walking legs to bury themselves in open sandy beaches where the water from break-

Figure 1.5. A handful of mole crabs (*Emerita talpoida*). Photo by S. Bland, North Carolina Division of Parks and Recreation.

ing waves runs down the beach. Mole crabs have a rounded domed smooth carapace and large feathery antennae that they raise up to strain food from this moving water. Porcelain crabs also feed by filtering plankton or detritus from the water, in this case using their second maxillipeds rather than antennae. Galatheid crabs are anomurans that superficially look more like lobsters and are sometimes called "squat lobsters." Some species of galatheids (red crabs) swarm in the upper surface of the ocean, while most others are found on the bottom in the very deep sea. Red crabs can be important food for large fish.

ORIGIN OF DECAPODS

Where did crabs come from? The ancestral crustacean was probably marine and small, and arose from trilobite-like ancestors near the beginning of the Cambrian period (542–488 million years ago). Since trilobites have shells, they are well preserved in the fossil record. The earliest decapods were probably shrimplike and evolved during the Late Devonian period (416–359 million years ago), and over millions of years evolved into modern shrimps and lobsters. Much later, a group of lobsters evolved into anomurans and then, perhaps, brachyurans. The earliest clearly crab fossils date from the Jurassic period (about 199–145 million years ago), although the earlier Carboniferous fossil, *Imocaris,* known only from its carapace, may be a primitive crab.

A LITTLE ABOUT LOBSTERS

The 400 species of lobsters are decapod crustaceans, belonging to the Astacidea, along with crayfish. These bottom-dwellers are found in all of the world's oceans, as well as in estuaries and even freshwater, where crayfish are common. Like crabs, lobsters have ten appendages—two claws and eight walking legs—with a carapace covering the thorax. The main anatomical difference between lobsters and crabs is that a lobster's tail (abdomen) extends out behind, while a crab's tail is tucked up underneath. A lobster can snap its tail to propel itself quickly backward—a movement that is most often used to escape potential predators. Like crabs, lobsters have compound, stalked eyes, chemosensory antennae, and sensory hairs on various parts of the body to detect touch and motion. The antennae are particularly sensitive, responding to environmental chemical cues regarding food, potential mates, and predators.

The largest lobster ever recorded was an American lobster (*Homarus americanus*) caught off the coast of Nova Scotia, Canada, that weighed 44.4 pounds and was almost 4 feet long. Scientists think it was at least 100 years old. Spiny lobsters have much smaller claws and can grow to 3 feet or more in length. The Norway lobster (*Nephrops norvegicus*) may be the smallest type of lobster, reaching only 10 inches from the eyes to the tail.

The radiation of crabs into many diverse groups took place in the Cretaceous period (145–65 million years ago; the time of the dinosaurs). An early Cretaceous hermit crab fossil was found perfectly preserved within an ammonite (an extinct group of mollusks with a spiral shell resembling a nautilus). As hermit crabs evolved, they developed a dependence on ammonite and gastropod shells for protective covering as their tails became soft and they needed to house their vulnerable abdomens within shells. As the most common mollusks shifted from ammonites to gastropods, hermit crabs coevolved to inhabit these newer shells.

Anomurans apparently evolved first in shallow waters and then moved into deeper waters. The giant king crabs are found in deep waters at temperatures just above freezing; they thrive in some of the coldest waters, living and growing slowly, probably to a very old age. Only in the cold water near the poles can king crabs be found in shallower water. They apparently evolved from hermit crabs similar to the familiar modern shoreline animals.