Chapter 1

INTRODUCTION

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This book, the second edition of *Invertebrate Medicine*, represents a concerted effort by a group of dedicated authors on the topic of invertebrate animal medicine. It has been substantially expanded from the first edition to reflect the tremendous growth of the pertinent literature and work that is being accomplished in the fields of invertebrate animal medicine, disease investigation, conservation, husbandry, and animal welfare. With the increased merging of animal and human medicine ("one health" or "one medicine"); the growing importance of invertebrates in biomedical research; and the many ongoing efforts to preserve habitat, protect at-risk species, and learn more about how invertebrates help define and connect ecosystems, this new edition is both warranted and timely.

Six new chapters ("Coral Reef Systems," "Butterfly Houses," "Honeybees," "Conservation and Preservation," "Welfare," and "Sources of Supplies") have debuted and three first edition appendices ("Neoplasia," "Euthanasia," and "Reportable Diseases") have been expanded into full chapters. The "Laws and Regulations" chapter has been broadened, with the addition of a new author, to include more international information.

This is not an invertebrate zoology text and is by no means comprehensive with regard to the anatomy, physiology, natural history, and taxonomy of the myriad of invertebrate taxa. This is a veterinary text about invertebrate animals. It includes pertinent biologic information as well as the state-of-the-science information pertaining to medicine and the clinical condition.

What sort of topic is invertebrate medicine? And what exactly are invertebrates? Ruppert and Barnes (1994) have said that the invertebrates are a group of unrelated taxa that share no universal "positive" traits. Undergraduate and graduate courses are dedicated to invertebrate zoology or even to specific parts of this topic, such as entomology, malacology, or protozoology. Simply put, the invertebrates are a collection of animals, comprising more than 95% of the earth's species, unified by the lack of a vertebral column.

Relatively recent and interesting genetic research has produced some intriguing ideas about intertaxonomic relationships regarding invertebrates and vertebrates. With the complete genetic sequencing for a number of species, including the fruit fly (*Drosophila melanogster*), an important biomedical research nematode (*Caenorhabditis elegans*), humans (*Homo sapiens*), and more recently an annelid worm (*Platyneries dumerlii*), some theories on animal evolution and phylogenetic relationships are being revisited and revised (Telford, 2004; Wolf et al., 2004; Federov and Federova, 2006). The more traditional "Coelomata hypothesis," linking animals (many invertebrates and all vertebrates) possessing a coelom, may be giving way to the "Ecdysozoa hypothesis," which places molting invertebrates, such as arthropods and introvertans (nematodes and other pseudocoelomates), in the same broad taxonomic group (Telford, 2004). Based largely on the comparison of small nonprotein-coding DNA segments called introns, researchers have learned that annelid worms may be more closely related to humans than they are to either insects or nematodes (Raible et al., 2005).

Detailed accounts and discussion of these theories, and invertebrate taxonomy and phylogeny in general, are beyond the scope of this medical text. Still, this is an active area of sophisticated research, the results and subsequent deliberations of which are worth being aware of for the clinician or caregiver charged with invertebrate animal health, welfare, and husbandry.

Depending on the text or investigator, there are currently over 30 recognized phyla of invertebrates (not including the protozoans). Many of these might be considered obscure, but for no better reason than they may contain few species, microscopic representatives, or lack obvious economic value to humans. In reality, each phylum and its members are important to the diversity and survival of the planet, even if the group is only studied by a small number of investigators. Unfortunately, very little is known about the veterinary aspects of many of these taxa, and writing a comprehensive text for all invertebrate phyla would currently be a daunting and somewhat inefficient task. Consequently, I have elected to include the most economically important and "visible" metazoan taxonomic groups. Exclusively parasitic taxa (e.g., trematodes, cestodes, and acanthocephalans) are only touched upon. Table 1.1, which lists the major taxonomic groups (along with brief descriptions) that do not have their own chapter, has been included in an effort to remind

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Table 1.1. Invertebrate phyla and major classes not reviewed in this book

Placozoa: A monotypic phylum containing only the species *Trichoplax adhaerens*. This primitive amoeboid metazoan is flattened, less than 3 mm in diameter, and exhibits extracellular digestion of detritus and algae.

Orthonectida: A very small phylum (about 20 species) of very small (no larger than 1 mm) internal parasites of other invertebrates such as bivalves, polychaetes, tunicates, turbellarians, and nemerteans.

Dicyemida: This phylum contains about 75 species of very thin renal parasites of cephalopods.

Nemertea: This diverse phylum contains approximately 1150 species of *ribbon worms*, which tend to be much larger and longer than flatworms. Unlike flatworms, nemerteans have a true coelomic circulatory system. Most are marine, but there are a few freshwater and terrestrial forms. Nemerteans are predators and use a long, eversible proboscis to capture and retain prey.

Mollusk groups

Aplacophora: This class consists of about 300 species of small, vermiform, marine animals that live at depths of between 200 and 7000 m.

Polyplacophora: Commonly known as the *chitons*, these interesting mollusks are mobile but spend most of their time tightly adhered to rocky substrates. There are approximately 800 exclusively marine species described. All have eight valves or plates (hence the name of the class) that overlap and are connected by soft tissue and surrounded by a muscular "girdle." Most species could rest in your palm, but one, *Cryptochiton* sp., the stocky gumshoe chiton, can reach a length of about 40 cm.

Scaphopoda: Known as the "tusk" or "tooth" mollusks because of their shell shape. The approximately 500 species are all marine, and most are burrowers with the head facing down within the substrate.

Echiura: Commonly known as the *spoon worms*, most of the 150 species either live in U-shaped burrows or between rocks closely associated with the marine environment. Most are deposit feeders, and some are an important food source for fishes. The name comes from the large and flared prostomium that resembles a spoon or small scoop.

Sipuncula: The sipunculids, or *peanut worms*, are a group of about 150 marine burrowing species. Most are smaller than 10 cm, but some can reach 70 cm in length. They possess an interesting feeding structure termed the *introvert* that can be expelled from or retracted into the main body or trunk.

Onychophora: This group of tropical, terrestrial animals (110 known species) is commonly referred to as *velvet worms* or *walking worms*. They are segmented and aligned with arthropods. In fact, some workers include the phyla Onychophora, Tardigrada, and Arthropoda in the superphylum Panarthropoda. Velvet worms prey on smaller arthropods by capturing them with slime ejected from paired glands near the mouth.

Tardigrada: If the *water bears*, as they are commonly known, grew larger (most are less than 1 mm long), they would surely be common and popular pets and display animals. There are marine, freshwater, and terrestrial representatives among the 800-plus species in this group of taxonomically mysterious animals. They have features in common with the arthropods but are different enough to warrant their own phylum. Perhaps their most interesting attribute is their ability to undergo cryptobiosis and form desiccated *tuns*, which can withstand adverse environmental conditions. In fact, some tardigrades may live as long as 100 years with the aid of cryptobiosis.

Gastrotricha: Many of the 500 species belonging to this microscopic phylum are interstitial. Most look like miniature bowling pins atop two small pegs. There are freshwater and marine forms.

Nematomorpha: The *horsehair worms* superficially resemble nematodes but are very long and free-living as adults. The larvae usually parasitize either crustaceans or insects. Approximately 325 species have been described.

Priapulida: This small phylum containing just 18 species is all marine and benthic. They are cylindrical and resemble a small cactus.

Loricifera: This interesting and microscopic marine phylum (all appear to be interstitial) was not known to science until 1983. Many of the 100 or so known species have not yet been described due to the difficulty of examining fresh, living specimens. These little creatures are so dogged in their attachment to sand grains that only freshwater will dislodge them, causing osmotic damage and distortion of their anatomy.

Kinorhyncha: The *mud dragons* somewhat resemble the Gastrotricha in general shape but have an oral feeding structure called the *oral styles* at the end of a movable introvert. Most are microscopic and are either interstitial or benthic on mud and sand. There are approximately 150 species and all are marine.

Gnathostomulida: Virtually all 80 known species are marine, interstitial, and less than 1 mm long. They are vermiform and were not known to science until 1956.

Rotifera: Most occur in freshwater, but there are marine and terrestrial (primarily in water films) species. They are defined and frequently identified by the ciliated corona or *wheel organ* near the head. Some rotifers are extremely important in freshwater and marine food chains (in some cases, hundreds may be found in a liter of water) and are also commonly reared to support invertebrate and finfish aquaculture. There are approximately 2000 described species.

Acanthocephala: A totally parasitic group containing 1150 species. They are commonly known as thorny-headed worms, and some are important parasites of wild and domestic vertebrates. Most use other invertebrates as intermediate hosts.

Kamptozoa: Also known as Entoprocta, the 150 species are nearly all marine. Most are stalked, and some people refer to them as *nodders* because of the zooid's tendency to nod or rock at the end of the stalk. Although some zoologists still classify them as bryozoans, these animals differ in their complete lack of a coelomic cavity. Some zoologists feel the morphological similarities between the groups are convergent.

Cycliophora: This small (in size and species number) phylum was not introduced to science until 1995. The single described species, *Symbion pandora*, exhibits a commensal lifestyle with a lobster (*Nephrops* sp.). Other as yet undescribed species are commensal with other crustaceans, including the American lobster, *Homarus americanus*. They are suspension feeders and have a complex reproductive cycle with both asexual and sexual life stages. None of the life stages are over 0.5 mm long.

Phoronida: There are just 14 species in two genera of these sessile marine creatures. These vermiform animals live in chitinous tubes that they secrete. Although externally they are bilaterally symmetrical, internally the left side is dominant. They feed by means of a lophophore and are grouped into the superphylum Lophophorata along with the bryozoans and brachiopods.

Brachiopoda: The brachiopods, or *lamp shells*, are an interesting group of 350 extant marine species that grossly resemble bivalve mollusks. Thousands of species are known from the fossil record, in part due to their mineralized valves that are preserved well. They are not related to mollusks, and the hard valves that protect the soft body are oriented opposite that of the bivalve's. They feed with the aid of a lophophore, placing them in the superphylum Lophophorata. Most are the size of small *cherrystone* clams and frequently turn up in shops specializing in fossils. Most species occur in colder waters.

Table 1.1. (*continued*)

Bryozoa: Known as the *moss animals*, these are common animals that can be found on many marine substrates (there are a few freshwater species), including rocks, algae, pilings, and even living animals such as sea turtles. With nearly 5000 species, this phylum is the best known of the Lophophorata and is studied as part of nearly all basic invertebrate zoology courses. The vast majority are colonial, although there is one solitary genus. From a distance, they may look more like plants than animals to casual observers. Some colonies are polymorphic, whereas other species are monomorphic. They are filter feeders, using the lophophore to trap and retain small food items.

Arthropoda

Pycnogonida: Known commonly as the *sea spiders*, this class of arthropods contains about 1000 known species. They are all marine and widely distributed, with most occurring in benthic habitats. Very few species are larger than 1 cm, and although they resemble a true spider, they are not close relatives.

Xenoturbella: This flatworm-like group of benthic, ciliated, marine organisms was first discovered in the early years of the 21st century but initially and incorrectly considered a free living turbellarian. Later, it was erroneously linked to other taxonomic groups, including hemichordates and echinoderms. In the 1990s, based on *Xenoturbella bocki* samples that were “contaminated” by food the animal was consuming, the group was reclassified as a bivalve mollusk. Recent molecular work has elevated this cryptic and small group of animals into their own phylum of deuterostomes (bilaterally symmetrical animals like the echinoderms, hemichordates, and chordates, which possess radial cleavage, an ectodermal mouth, and anal opening originating from the blastopore). Unique and unusual traits include lack of a gut or defined coelomic cavity, absence of gonads or excretory organs, and a nerve net system without a cephalic or central ganglionic region.

Taxonomy and descriptions largely from Ruppert et al. (2004).

Table 1.2. Habitats and approximate metazoan species numbers

Phylum	Benthic Marine	Pelagic Marine	Benthic Freshwater	Pelagic Freshwater	Terrestrial	Ectosymbiotic	Endosymbiotic
Porifera	###	–	#	–	–	#	–
Placozoa	#	–	–	–	–	–	–
Orthonectida	–	–	–	–	–	–	#
Dicyemida	–	–	–	–	–	–	#
Cnidaria	###	##	#	#	–	#	–
Ctenophora	#	#	–	–	–	–	–
Platyhelminthes	###	#	###	–	##	#	####
Nemertea	##	#	#	–	#	#	–
Mollusca	#####	#	###	–	###	#	#
Annelida	####	#	##	–	###	##	–
Echiura	##	–	–	–	–	–	–
Sipuncula	##	–	–	–	#	–	–
Onychophora		–	–	–	##	–	–
Tardigrada	#	–	##	–	#	–	–
Arthropoda	####	###	####	###	#####	###	###
Gastrotricha	##	–	##	–	–	–	–
Nematoda	###	#	###	#	###	###	###
Nematomorpha	–	–	–	–	–	–	##
Priapulida	#	–	–	–	–	–	–
Loricifera	#	–	–	–	–	–	–
Kinorhyncha	##	–	–	–	–	–	–
Gnathostomulida	#	–	–	–	–	–	–
Rotifera	#	#	##	##	#	#	#
Acanthocephala	–	–	–	–	–	–	###
Kamptozoa	##	–	#	–	–	#	–
Cycliophora	–	–	–	–	–	#	–
Phoronida	#	–	–	–	–	–	–
Brachiopoda	##	–	–	–	–	–	–
Bryozoa	###	–	#	–	–	–	–
Chaetognatha	#	#		–	–	–	–
Hemichordata	#			–	–	–	–
Echinodermata	###	#		–	–	–	–
Xenoturbella	#	–	–	–	–	–	–
Chordata (Cephahochordata and Urochordata)	###	#	–	–	–	–	–
Chordata (Vertebrata)	###	###	##	###	####	#	#

#, 1–100;
##, 100–1000;
###, 1000–10,000;
####, 10,000–100,000; and
#####, over 100,000.
Modified from Pearse et al. (1987), p. 7; with taxonomic and number updates from Ruppert et al. (2004).

readers of the diversity of the invertebrate animal kingdom. Table 1.2 provides a snapshot of animal diversity with regard to the number of described species and habitat. I encourage interested readers to obtain one or more of the general invertebrate zoology texts listed under the section "General Invertebrate Zoology Resources," where detailed descriptions of the various groups in Table 1.1 and throughout this book can be found.

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