

EDITORIAL

So you have to teach invertebrate biology...

1 | THE 25TH ANNIVERSARY OF INVERTEBRATE BIOLOGY

The cover of this special 25th Anniversary issue features the stunning photographs of marine invertebrates by Dr. Arthur Anker. It is designed to convey the same message as the following editorial on teaching: Revel in the wondrous diversity.

Identities and sizes of the animals on the cover are left as puzzles for readers to test their knowledge: To what phylum or subphylum, class and family, does each belong? Roughly how big are they? Answers may be found at the end of the editorial, or via an interactive puzzle on the American Microscopical Society website (<https://www.amicros.org>).

2 | ON TEACHING INVERTEBRATE BIOLOGY

"Don't be an invertebrate biologist if you can help it. But if you can't help it, go ahead."

(Adapted from a quotation about ornithologists attributed to Frank Chapman; Janovy, 1985, p. 1.)

I didn't always love teaching invertebrate biology. The diversity was formidable, the classification complex and perpetually in flux, the anatomical terms overwhelming, and the broad generalizations that might appeal to first- and second-year undergraduates riddled with exceptions. To teach at that level demands that you lie. But to engage dewy-eyed undergraduates with the grand vista of animal diversity, and not send them screaming off into the distance, some oversimplification—sometimes extensive—is required. You have to make peace with that.

Like so many academics who were students in the 1960s and 1970s, I saw teaching as the price one paid for the privilege of doing research at a top-tier university. It took me nearly two decades to learn otherwise. For those who don't care much, invertebrate biology can easily be taught as an intricate tableau of anatomical and taxonomic terms. Simple to teach (just follow the textbook), simple to test (the more diverse and complex the terms to be memorized, the better), and, in the end, dispiriting to both students and instructor. It's rather like being forced to learn Latin with no obvious reason for doing so.

During my early years, I found teaching invertebrate biology hard. It's not like I didn't try. I only had to co-teach one term of a two-term course for honors students, the Mollusca and Crustacea parts.

But trying to cover even that fraction of invertebrates felt more like a duty than a passion. That's not to say I did a bad job. I just didn't find it terribly inspiring, and the students probably didn't either.

My relationship with teaching changed radically when I had to replace a retired colleague who had taught our one-term introductory Survey of Invertebrates course for decades. I had studiously avoided teaching it because I thought it way too superficial. But being responsible for that whole course—for the entire story from start to finish—changed everything.

First, I had to choose a textbook, which is almost as difficult as choosing a spouse—there are *soooo* many variables to consider. The best texts were far too detailed for a one-term course at a prairie university, and most of those targeted at one-term courses still had too much detail or just didn't seem that inspiring.

I kept remembering a book I had pulled off my father's bookshelf as a high-school student: *Animals Without Backbones* (Buchsbaum, 1938; Figure 1). "It was the first biology textbook ever reviewed by *Time* [<http://content.time.com/time/subscriber/article/0,33009,772212,00.html>] and was also featured with illustrations in *Life*" (University of Chicago Press, n.d.). Even back then, I was enchanted by the fascinating line drawings, particularly those of flatworm regeneration. If a book like that had effectively stimulated my own love of invertebrates so long ago, why not use one like it to engage a new generation?

So 30 years later, I chose a derivative version of that legendary text: the superb *Living Invertebrates* (Pearse et al., 1987; Figure 1). Ten years old, its classification was a bit dated. And important details were sometimes cryptically located in figure legends, so some specifics could be hard to find. But the book was utterly engaging. It still had those glorious illustrations, the marvelously clear prose, and a judicious "just-right" amount of information. Drawings showed only the essential features of animals, which didn't cause students to tremble from information overload. Crucially, it dawned on me that—for an introductory course—the parts of crayfish ... or the basic building blocks of cnidarians, or ctenophores, or flatworms, or echinoderms ... haven't changed significantly for over a century. So, this engaging text would serve well. It would inspire students to read beyond the assigned pages for pleasure. I wanted that for my course. (If *Living Invertebrates* is hard to obtain, a 3rd edition of *Animals Without Backbones* [Figure 1] could suffice.)

Second, I had to decide what the overarching story of the course would be. The advent of cladistics, with increasingly resolved and robust phylogenetic trees, made this easy. In the 1980s and 1990s, studies of animal relationships were suddenly fashionable again.



FIGURE 1 Three versions of a legendary invertebrate biology text: *Animals Without Backbones*, 1st edition (Buchsaum, 1938); *Living Invertebrates* (Pearse et al., 1987); *Animals Without Backbones*, 3rd edition (Buchsaum et al., 1987)

Molecular phylogeneticists were desperate to get their hands on obscure groups, like acoel flatworms, remipedes, pterobranchs, and pycnogonids. More and more, biologists were becoming interested in the new tree topologies that were appearing in top-tier journals and radically changing our narrative about the history of life. Who can forget the first time acoel flatworms appeared on the cover of *Science* (19 March 1999, to highlight Ruiz-Trillo et al., 1999)? Then there was the glorious extended debate in *Nature* over whether the enigmatic *Xenoturbella bocki* was (a) an aberrant protobranch bivalve (Israelsson, 1997; Norén & Jondelius, 1997), (b) a peculiar basal deuterostome with affinities to Ambulacraria that ate protobranch bivalve eggs (Bourlat et al., 2003), or (c) part of the sister group to all remaining bilaterians (Cannon et al., 2016). Those were exciting times. They still are. And we should share that excitement with our students.

This big story—the stepwise acquisition of ever more diverse and wonderful adaptations—can truly inspire both instructor and students. Even simplified for an introductory course, the stories of new forms and functions weave together answers to the three fundamental questions in biology (adapted and condensed from Huxley, 1942, p. 40): How do things work? How do they develop? How did they evolve? And it's valuable for students to hear that each of us is part of a long lineage of biologists who have contributed to this big story. Now it's their turn to contribute.

Third, I had to make peace with terminology, a huge challenge. Emphasize it too much and you stifle student interest. But some basic vocabulary is necessary. It took me a while to figure out how to "sell" the extensive terminology of invertebrate biology. To do so, I reminded students that foreign languages have vocabularies distinct to their culture, and so we needed a vocabulary to converse about the "culture" of invertebrate diversity. Furthermore, I wanted students to realize that having words for things enhances our ability to see them. To demonstrate this, I would show them a photo of Arctic pack ice and another of a diverse coral reef under water. Then I had them imagine an Inuit hunter and a Tahitian standing together in the Arctic, or snorkeling together in the tropics, and asked: Who sees more in the ice and snow? In a coral reef? The many Inuit terms for ice and snow are legendary, and Tahitians have many terms for corals.

Finally, and perhaps most importantly, I knew I had to share with students what I personally found most exciting about invertebrate biology. So, I searched constantly for the coolest examples I could find—wonderous forms, extraordinary adaptations, amazing behaviors, and bizarre lifestyles—that I used to bring invertebrates alive when I reviewed lecture material at the end of each taxon. It's so much easier now with the internet.

These four things—a superbly crafted textbook, advances in phylogenetics that made stories about invertebrate relationships alive and exciting, a minimal emphasis on terminology, and near-endless cool examples—transformed my experience of teaching from one of work to one of passion. Now I could present with conviction one of the greatest stories ever told: the history of animal life on this planet. It's an origin story best told via the 97% of animal life represented by invertebrates and, of course, peppered with fascinating examples. Each class reinforced this message: studying invertebrates is a joy. The message to me as a teacher remains: Never forget that the story of animal evolution and diversity really is extraordinary, and constantly share with students what you personally love about it.

3 | ANSWERS TO PUZZLE QUESTIONS POSED ABOUT THE COVER COLLAGE

Below are the common names, taxonomic names (when known), higher classification, and sizes of the animals portrayed on the cover of this anniversary issue. Numbers refer to numbered images in Figure 2. The classification follows WoRMS (www.marinespecies.org, Jan. 2021, unless the taxon name is in quotes). Sizes are approximate (maximum dimensions unless noted otherwise).

1. Non-snapping alpheid shrimp (*Coronalpheus natator*; Arthropoda, Malacostraca, Decapoda, Caridea, Alpheidae; 2 cm)
2. Horseshoe crab (*Tachypleus gigas*; Arthropoda, Chelicerata, Merostomata, Limulidae; 20 cm)
3. Unidentified ribbon worm (Nemertea, Hoplonemertea, Monostilifera; extended length >10 cm)



FIGURE 2 Key to taxa in the cover image (see text for details)

4. Porcelain crab (*Petrolisthes donadio*; Arthropoda, Malacostraca, Decapoda, Anomura, Porcellanidae; 1.5 cm carapace width)
5. Pelagic blue button (*Porpita porpita*; Cnidaria, Hydrozoa, Porpitiidae; 2 cm)
6. Trochid snail (*Calliostoma* cf. *javanicum*; Mollusca, Gastropoda, Vetigastropoda, Calliostomatidae; 3 cm)
7. Unidentified inarticulate brachiopod (Brachiopoda, Linguliformea; 4 cm including peduncle)
8. Leopard sea anemones (*Nemanthus* sp.?; Cnidaria, Anthozoa, Nemanthidae; 1 cm column diameter)
9. Fire worm (*Hermodice carunculata*; Annelida, Errantia, Amphinomididae; 10 cm)
10. Hairy crab (*Pilumnus vespertilio*; Arthropoda, Malacostraca, Decapoda, Brachyura, Pilumnidae; 3 cm)
11. Lancelet (*Branchiostoma* sp.; Chordata, Cephalochordata, Branchiostomatidae; 3 cm)
12. Jewel-beetle amphipod (*Thamneus* cf. *rostratus*; Arthropoda, Malacostraca, Amphipoda, Hyperiidea, Brachyscelidae; 1 cm)
13. Doridoid sea slug (*Halgerda wasinensis*; Mollusca, Gastropoda, Heterobranchia, Discodorididae; 3 cm)
14. Cumacean (*Eocuma* sp.?; Arthropoda, Malacostraca, Peracarida, Cumacea, Bodotriidae; 0.7 cm)
15. Feather duster worm (*Branchiomma* sp.; Annelida, Sedentaria, Sabellidae; 7 cm)
16. Innkeeper worm (*Ochetostoma* sp.; Annelida, "Echiura", Thalassematidae; 7 cm)
17. Orange gum drop sea slug, ventral view (*Berthellina ilisima*; Mollusca, Gastropoda, Heterobranchia, Pleurobranchida, Pleurobranchidae; 3 cm)
18. Boxer shrimp (*Stenopus scutellatus*; Arthropoda, Malacostraca, Decapoda, Stenopodidea, Stenopodidae; 4 cm)
19. Acorn worm (*Saccoglossus bromophenolosus*; Hemichordata, Enteropneusta, Harrimaniidae; 6 cm)
20. Sea apple sea cucumber (*Pseudocolochirus violaceus*; Echinodermata, Holothuroidea, Cucumariidae; 15 cm)
21. Frog crab (*Raninoides benedicti*; Arthropoda, Malacostraca, Decapoda, Brachyura, Raninidae; 5 cm)
22. Galeommatid clam (*Scintilla* sp.?; Mollusca, Bivalvia, Euheterodonta, Galeommatidae; 1 cm)
23. Electric brittle-star (*Ophiothrix* sp.; Echinodermata, Ophiuroidea, Ophiotrichidae; disc diameter 1 cm)
24. Segmented worm rolled in a spiral (*Nereis* cf. *riisei*; Annelida, Polychaeta, Nereididae; 4 cm)
25. Polyclad flatworm (*Pseudoceros bifurcus*; Platyhelminthes, Rhabditophora, Polycladida, Pseudocerotidae; 3 cm)
26. Planktonic juvenile of a tube-dwelling anemone (Cnidaria; Anthozoa; Ceriantharia; 0.5 cm)
27. Chilean mole crab, face view (*Emerita* cf. *analoga*; Arthropoda, Malacostraca, Decapoda, Anomura, Hippidae; 2 cm)
28. Unidentified tropical sponge, French Polynesia (Porifera, Demospongiae; 15 cm)
29. Mantis shrimp, face view (*Squilla aculeata*; Arthropoda, Malacostraca, Stomatopoda, Squillidae; 10 cm)
30. Unidentified male ovigerous sea spider (Arthropoda, Chelicerata, Pycnogonida; trunk length <1 cm)
31. Heart urchin (*Lovenia* sp.; Echinodermata, Echinoidea, Loveniidae; 5 cm)
32. Unidentified deepwater peanut worm ("Sipuncula"; 4 cm)
33. Unidentified anthurid isopod (Arthropoda, Malacostraca, Isopoda, Anthuridae; 1 cm)

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A. Richard Palmer^{1,2} 

¹Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada

²Bamfield Marine Sciences Centre, Bamfield, British Columbia, Canada

Correspondence

A. Richard Palmer, Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada.

Email: rich.palmer@ualberta.ca

ORCID

A. Richard Palmer  <https://orcid.org/0000-0002-7579-3899>

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