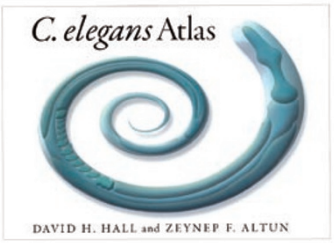
Gray's Anatomy for worms



C. elegans Atlas

By David H. Hall and Zeynep F. Altun

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Reviewed by Jonathan Hodgkin

This book provides a lavishly illustrated survey of the anatomy of the nematode worm *Caenorhabditis elegans*. It will undoubtedly be useful and illuminating for the thousands of scientists who use *C. elegans* as their primary research organism, or to those contemplating a move into *C. elegans* research. It should also be of considerable value to anyone interested in biological structure at the cellular and subcellular levels, or in the representation of complex three-dimensional objects.

C. elegans Atlas is a companion to the online WormAtlas project and much of its material can be viewed at http://www.wormatlas.org/. However, the *Atlas* itself is much more convenient, more considered and more informative. In these days when the death of print is so frequently predicted, this publication demonstrates the advantages of book over computer screen. Its format is helpful, with ring-bound landscape pages that lie flat and can be easily examined and discussed. Eight chapters deal successively with the major organ systems, and each includes well referenced textual passages describing organization, development and function. The authors have also gone to great lengths to provide colour-coded summary drawings, which effectively convey the solid shapes and topology of many of the cells and organs described. Inferring these shapes from stacks of serial electron microscopy sections or from light microscope images is not always easy and most nematode researchers are likely to gain new information about their favourite worm organs from the pictures provided here.

Several sources of information were used to create the *Atlas*. First was the remarkable effort initiated by Sydney Brenner in the 1960s to obtain a diagram of the complete neuronal wiring of the worm. This was ambitious but feasible, because *C. elegans* has a simple and largely invariant nervous system of just 302 neurons. Also, the adult worm is small enough to be reconstructed from serial sections of electron micrographs and laboriously identifying all the neuron profiles, synapses and neuromuscular junctions in each picture. That huge task, carried out by Brenner's collaborators, resulted in a landmark 1986 publication documenting the anatomy and connectivity of almost the entire nervous system. Many thousands of electron micrographs were created and used in the initial project, and these also contained information about other anatomical structures in the worm. The invaluable archive of photographic plates and prints was eventually transferred from Cambridge to New York, where it has provided a valuable resource for the activities of WormAtlas, under the direction of David Hall. Much additional EM work has been carried out by Hall and others, which adds to the total archive.

Second, light microscopy provides a complementary source of information. Cells can be identified in the living animal, and their shapes correlated with the fixed and sectioned material used for the EM analysis. This approach has become even more powerful in the past ten years, with the advent of fluorescent protein labelling technology. Green fluorescent protein (GFP) is a tool perfectly suited for the tiny and transparent *C. elegans*, so it is not surprising that its earliest use in biology, by Martin Chalfie (who consequently shares this year's Nobel Prize in Chemistry) and collaborators in 1994, was to label *C. elegans* neurons. Since then, hundreds of different GFP-tagged reporter genes have been created for the worm, each of which allows fluorescent visualization of a specific cell or set of cells. Confocal microscopy can then be used to create exact three-dimensional images of living cells or their subcellular components. The *Atlas* contains dozens of GFP-based images, often side by side with corresponding EM sections, so the resulting summary drawings can be seen to be accurate renditions.

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The detail in this book is unprecedented, beautiful, unique in biology and challenging. *C. elegans* has an advantage over other multicellular model organisms in possessing more researchers than cells, but it is sobering to look at the detailed structures revealed in this book and contemplate how much more there is to understand about the anatomy of any one of these cells or its constituents. To give one example, the pharyngeal grinder is an intricate, toothed structure in the head of the worm, which works like a minute food processor, efficiently breaking up and macerating bacterial cells. The *Atlas* conveys some idea of the grinder's complexity, but one would need a three-dimensional working model to fully appreciate its shape, how it is created and how it functions.

Nevertheless, a two-dimensional atlas cannot possibly include everything. Full understanding of the worm anatomy requires not only the three spatial dimensions but also a temporal dimension. This Atlas deals comprehensively with the adult hermaphrodite worm, but we still need complete anatomies of the different larval stages and the adult male worm. These, however, are projects for the future, perhaps best deferred to a time when the dream of automated reconstruction from serial sections can finally be realized.

The book is beautifully produced, a true labour of love, and maintains an extremely high level of accuracy. I did not find any serious errors, except for the comical misrepresentation of the UK Medical Research Council, who funded so much of the initial phases of *C. elegans* research, as the 'Media Research Council'.

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