Observations by a University Anatomy Teacher and a Suggestion for Curricular Change: Integrative Anatomy for Undergraduates

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The observation that anatomical course offerings have decreased in undergraduate biology curricula is supported by a survey of undergraduate institutions in the state of Washington. This reduction, due partially to increased emphasis in other areas of the biology curriculum, along with the lack of anatomy prerequisites for admission to most medical and dental schools, has resulted in many biology majors who have little or no exposure to the anatomical sciences. This is a disservice to our students who need to understand organismal form and function to better connect our rapidly expanding knowledge of life at the cell and molecular level to our understanding of the role of organisms in ecosystems and as the primary target of natural selection in evolutionary change. Undergraduate anatomical courses can also serve as an extension of the anatomy curriculum in professional healthcare programs, where anatomical sciences are also experiencing a reduced allocation of instructional time. Given the importance of anatomical knowledge along with the many demands and constraints on biology curricula, what can we do? One suggestion, a course in integrative anatomy for undergraduates, is proposed and discussed.


Key words: anatomy curriculum; undergraduate anatomy; biology curriculum; integrative anatomy

INTRODUCTION

What anatomical sciences should be included in the curriculum of a biology department at a comprehensive state university? This was the question I set out to answer a couple of years ago during my sabbatical. There is of course no definite answer, but like most other long-time anatomy instructors, I have opinions on the matter, opinions honed primarily through experience. If teaching is both an art and a science, these opinions are more artistic than scientific. It seems little data truly address my question (Miller et al., 2002), so for now I have little choice. I must rely primarily on my experience in the classroom and what I have learned from colleagues at professional meetings and in informal discussions to best determine how anatomical sciences might be better incorporated into a modern undergraduate biology curriculum.

Context

Central Washington University (CWU) is a state-supported, comprehensive university with an on-campus student population of ~9,000. Approximately 20 faculty, with expertise in the broad range of biological subfields, comprise the Department of Biological Sciences. Historically, the department was strongest in organismal and “field” biology, an emphasis that continues in a more modern form as evidenced by strong programs in ecology and conservation biology. During the past 10–15 years, the department actively moved to strengthen its programs in the cell and molecular areas. We have largely been successful in doing this, and the numbers of students choosing our cell and molecular specialization continue to grow.

Although it is extremely gratifying to see the ecological, cell, and molecular aspects of our program mature, we have paid little attention to the “middle” level of the biological hierarchy—the biology of the organism. As an anatomist, this is of concern, and led me to bring together my fellow anatomists and physiologists to take a look at what we are doing...
and where we might want to go with our “form and function” curriculum.

Here, I concentrate on the vertebrate anatomical sciences and will set the stage by outlining what changes I have witnessed in my 30 years of taking and teaching courses in human anatomy, embryology, histology, and comparative anatomy.

**OBSERVATIONS**

**Limited Undergraduate Anatomical Course Offerings**

In 1987, when I was first hired as an assistant professor at CWU to teach embryology and human anatomy and physiology (A&P), the Biology Department offered both courses regularly, as well as courses in histology and comparative anatomy. Of these courses, only A&P has enjoyed strong and increasing enrollments over the years. We are now frequently faced with overenrolled sections and are planning how to better accommodate the increasing number of students we anticipate. Our other anatomical offerings—embryology, histology, and comparative anatomy—became relegated to every-other-year offerings with limited numbers of students.

Each of these courses offers a different perspective on animal form. The anatomy portion of A&P is of course restricted to the study of a single species and is, primarily due to time constraints, limited to adult human anatomy. Although we allocate a minimal amount of time to tissues, virtually no developmental anatomy is covered, and any evolutionary perspective is mostly an afterthought or aside. Our embryology course has been called upon to integrate the more recent contributions to developmental biology and has thus become a hybrid of classic developmental anatomy and molecular developmental biology. We fear it is not enough of either.

Histology, although remaining primarily a survey course of the basic tissue types and an introduction to histological technique, suffers from low enrollments due to prerequisite requirements and irregular scheduling. Comparative vertebrate anatomy continues to emphasize the evolution of vertebrate form through hands-on dissection and study of ancestral and derived vertebrate morphologies. It has, however, been losing enrollments as more premedical and predentistry students opt for human A&P. After all, they will be doctors and dentists; why should they concern themselves with non-human species?

As pressures mount to better manage departmental course offerings relative to enrollment pressure and budgetary constraints, the loss of formal courses in embryology, histology, and comparative vertebrate anatomy appears likely here at CWU. I suspected we were not alone, and in an effort to see, I surveyed the biology departments of 13 four-year undergraduate institutions in the state of Washington. Included are public and private schools, small liberal arts colleges and universities, and large research universities, as well as comprehensive similar to CWU. Online course catalogs were used to determine which courses are being offered.

Of the 13 departments surveyed, only CWU currently offers four separate majors-level courses in anatomical science. One biology department has no anatomy courses listed as part of its curricular offerings (Fig. 1). Fewer than half of the surveyed departments offered histology, embryology, and majors-level human anatomy (including both stand alone and A&P) courses. Comparative vertebrate anatomy is the most widely offered anatomical course, listed by 9 of the 13 biology departments (Fig. 2).

Although far from definitive, these data support my supposition that anatomical course offerings have been reduced in undergraduate biology curricula. Assuming that biology programs in Washington state are representative, these data do indicate that anatomical coursework in undergraduate biology departments is limited.

**Undergraduate Students Are Not Well Served**

As most medical and dental schools do not explicitly require anatomical coursework as a prerequisite to admission, and none is required for either CWU’s B.A. or B.S. degrees (A&P can be taken as an option in the B.A.), many of our biology majors finish their degree with little or no exposure to the anatomical sciences. Even those students who do manage to schedule one of our anatomical courses within their program receive only a limited view of the scope of anatomical science, e.g.,

![Figure 1.](image)

Number of majors-level anatomical courses offered by Washington state biology departments.

![Figure 2.](image)

Number of Washington state biology departments offering specific types of majors-level anatomical courses. Percentages are calculated based on the sample size of 13 departments.
human anatomy with no developmental or evolutionary perspective or comparative anatomy with no human exposure.

Although this distresses me as an anatomist, I believe it is a true disservice to our students for three primary reasons. First, the form and function of individual organisms are the link between our rapidly expanding knowledge of life at the cell and molecular level and our understanding of the role of organisms in ecosystems. Molecular biology and ecology are more robust approaches to understanding life on earth if they are practiced in the context of organisms. Second, natural selection remains the cornerstone mechanism of biological evolution, and although a hierarchical view of the units of selection is warranted, it is still safe to say that selection works primarily at the organismal level. It is the organism that either lives or dies, reproduces or does not. To understand evolution, one must understand the organism.

These two reasons alone are enough to suggest that form and function courses deserve a central place in a modern biology curriculum, but a third reason is important for a subset of biology students. Those who are planning on attending professional healthcare programs in medicine, dentistry, physical therapy, etc. no doubt benefit from such classes. Traditionally, the benefit to such students is the promise of being better prepared for the preclinical, basic science component of professional healthcare programs. The reasoning is simple. We tell students that they will be faced with tremendous course loads as a beginning student in professional healthcare programs. The more knowledge and understanding of anatomy, embryology, and histology they take into the program with them, the better equipped they will be to survive the onslaught. As to whether this is really true, data are scarce; some support this seemingly logical premise, others do not (Rarey, 2001; Forester et al., 2002; Peterson and Tucker, 2005).

One alternative, and perhaps better, way we might view the potential importance of undergraduate anatomy courses for prehealth professional students is less as an extension of the curriculum currently being employed in medical, dental, and physical therapy schools. Those who are planning on attending professional healthcare programs in medicine, dentistry, physical therapy, etc. no doubt benefit from such classes. Traditionally, the benefit to such students is the promise of being better prepared for the preclinical, basic science component of professional healthcare programs. The reasoning is simple. We tell students that they will be faced with tremendous course loads as a beginning student in professional healthcare programs. The more knowledge and understanding of anatomy, embryology, and histology they take into the program with them, the better equipped they will be to survive the onslaught. As to whether this is really true, data are scarce; some support this seemingly logical premise, others do not (Rarey, 2001; Forester et al., 2002; Peterson and Tucker, 2005).

Curriculum revisions of various sorts are being proposed and employed to compensate for loss of class time (Drake, 1998; Joslin, 2008; Drake et al., 2009; Holla et al., 2009). Some of the pedagogical revisions are probably long overdue anyway, and although there is little doubt that to some extent, less can be more, there are limits. Why not view undergraduate anatomical coursework as a part of, as an extension of, the curriculum currently being employed in medical, dental, and physical therapy schools?

**DISCUSSION**

**No Going Back to the Future**

We could return to the “good ol’ days” and give students the full complement of courses they need to gain a robust perspective on and appreciation for the importance and power of the anatomical sciences. Keep human anatomy and comparative anatomy, bring back embryology and histology, and add neuroanatomy for good measure. Although students with these courses under their belt (assuming they are well taught) could really hit the ground running in preclinical professional classes, it will not happen.

There are simply too many demands on biology curricula, too few dollars to hire enough faculty, and as long as four years remains the standard undergraduate programs length, not enough time for the students. And even if it were possible, it is simply not necessary. Much of what students have historically done in these classes was “learn the parts”—anatomy in its most basic and, except for those of us with the odd appreciation for so much detail, most mind-numbing form. Current science education research is pointing more and more to the importance of providing students the perspective and tools to figure things out rather than engaging them in exercises in memorization (Miller et al., 2002; Terrell, 2006; AAMC-HHMI, 2009). The task for faculty at undergraduate universities is to provide our anatomy students this perspective and these tools.

**A Suggestion—Integrative Anatomy**

How many anatomy courses can we expect undergraduate biology students to take? Four seems nearly impossible, three is improbable, and even two is difficult. If we can realistically expect all or most undergraduates to take a single course in anatomy, what would that course be? Perhaps a course that integrates several anatomical perspectives, that introduces the student not only to gross human anatomy but also to the basic tissue types and to enough evolutionary morphology and embryology to give context to adult form. Such an Integrative Anatomy course will not, cannot, and should not cover everything. A student will not “learn all the parts,” but will hopefully come away with skills (dissection, three-dimensional visualization), language (directional terms, roots, derivations), and perspective (tissue, gross, developmental, evolutionary). Such students will be better able to appreciate animal form and function; interrelate organisms to molecules, cells, and ecosystems; formulate meaningful anatomical questions; and postulate how those questions might be answered. Students moving on to professional programs will not merely be ready to contend with preclinical anatomical courses, but rather will continue in an extended anatomical curriculum.

To appropriately design such a course, several things need to happen. First is distillation—getting rid of great quantities of anatomical detail. Students will not come away knowing every bump on every bone, nor will they know the origin, insertion, and action of every muscle. But as in any distillation, you do not want to get rid of everything, and you do want to keep the primary essence. Second is shifting the emphasis from memorization toward critical thinking. Note that a shift implies a different balance, not an elimination. At some level, terms and basic concepts must be memorized (Pandey and Zimitat, 2007), but anatomy courses based primarily on memorization with little critical thinking and context are more likely to produce technicians rather than scholars.

Third is the need for appropriate text and laboratory support materials. Students cannot be expected to purchase texts and laboratory manuals for human anatomy, comparative anatomy, histology, and embryology. Not only is this economically unfeasible, but it is unnecessary and undesirable considering the goals of such a course. Such materials can be developed, but until there is a market, one is faced with selecting some basic materials and supplementing from other sources. Luckily, the plethora of internet resources makes this possible and perhaps even preferable.
Most importantly, this approach, or another better one, needs to be accepted by the anatomical community. This would best result from discussion, communication, and comparison among undergraduate anatomy educators, and between them and anatomy educators in preclinical health professions programs. Any hope of viewing anatomical sciences curriculum across the undergraduate–professional divide must begin with a bigger picture than individual programs or levels.

Trial Run

I offered my first Integrative Anatomy course during the 2009 Spring quarter here at CWU. Our quarters are essentially ten weeks long, and this course met for lecture three times per week and included three two-hour laboratories per week for a total of 30 hours of lecture and 60 hours of laboratory. I used a comparative anatomy text (Kardong, 2009) and laboratory manual (Kardong and Zalisko, 2009) along with an abbreviated atlas of human anatomy (Hutchinson et al., 2007) and many histological images gathered from the internet. Students actively engaged in the dissection of dogfish sharks and cats, and studied prospected human cadavers.

The core of the course was comparative and evolutionary, but instead of setting the human aside as some “special case,” the overall evolutionary context included human anatomy. I made histological analysis explicit, introduced the four basic tissue types, and reinforced them within the context of appropriate organ systems (e.g., connective tissues with skeletal system and epithelial tissues with digestive system). Embryology has always been an integral component of most comparative anatomy courses because of the insight that knowledge of organogenesis gives us into the evolution of form and function. This tradition takes on even more significance in light of our expanding knowledge of the influence of development on evolutionary change (evo-devo).

Students in this course received a broad perspective on vertebrate (including human) anatomy, histology, and embryology in an evolutionary perspective, and I believe those headed into professional healthcare programs will be well prepared. Do I know this? Of course not. All I have now are my opinions and observations, and feedback from the 20 students who took the course.

Although many of the comments from the course evaluations were similar to those from students in my previous offerings of Comparative Anatomy, the feedback on the integrative nature of the course was positive. “I like the way everything was connected and similar to the human.” “I liked the mix of gross anatomy and histology and think we covered just the right amount to be difficult but not overwhelmingly so.”

Not everyone agreed that we covered “just the right amount.” As always, several students voiced concern about the amount of material to be mastered. “The bone practical was overwhelming. The sheer amount of information that had to be memorized was too much. I would suggest either pairing down the lists significantly or splitting the bone practical into two parts—the skull and everything else.” This is a valid criticism of a long-standing problem with teaching anatomy and will require continued consideration and modification.

Perhaps, the most satisfying comment came via email from a student who went on to veterinary school: “Especially thank you for the histology portion!! It has made microanatomy that much less stressful, and everything makes so much more sense knowing how and from where certain features were derived.”

A true assessment will take more time, greater numbers, and the acquisition of data. In the meantime, I will continue to distill material, shift toward critical thinking, and design course materials. What I do know is that undergraduate courses in anatomical sciences can play an important role in a modern, comprehensive undergraduate biology curriculum, and can serve as an initial component of the anatomical curriculum in professional healthcare programs. As anatomists, we need to make this case to our departments, our administrators, our admissions people, and ourselves.

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