Perspective

West Virginia Human Whole-Body Donors in Undergraduate Biology Education at Radford University

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Abstract: The use of human whole-body donors is the gold standard in anatomy education, and dissection is a standard pedagogical tool in gross anatomy courses in medical schools, physical therapy schools, and other health science graduate and professional training programs. However, undergraduate students studying anatomy and physiology rarely have the opportunity to work with real human tissues. The Biology Department at Radford University in Southwest Virginia is noteworthy for using whole-body donors from the West Virginia University Human Gifts Registry in all of its undergraduate anatomy and physiology courses. Radford University also uses whole-body donors in non-Biology courses and in student research projects. This report details the educational uses and impacts of WV whole-body donors at Radford University over the past seven years.

Keywords: Anatomy; Anatomy pedagogy; Healthcare education; Human body donors; Physiology; Undergraduate education

Introduction

Radford University (RU) is a mid-sized, primarily undergraduate public university located in the city of Radford, Virginia, with a satellite campus in Roanoke. Originally a women's college that focused on training students for historically traditional women's careers such as education and nursing, RU continues to have a strong role in educating future healthcare professionals in Southwest Virginia and the surrounding regions. The Biology Department at RU offers anatomy and physiology (A&P) classes to students throughout the university, fulfilling curricular requirements for a wide range of majors. Human whole-body donors are used in all A&P classes on the Radford campus, a high-impact and effective method (see Aziz *et al.* 2002 and Saltarelli *et al.* 2014, and references therein) that is standard for medical schools, but rare in undergraduate curricula (McLachlan 2004; Estai and Bunt 2016; Sparacino *et al.* 2019). The RU Biology Department has been procuring whole-body donors from the West Virginia University Human Gifts Registry since 2016, and there are typically 5-6 donor bodies in use in the teaching laboratories at any given time. The donor bodies are prosected by faculty and students (more information below) and are then used in multiple courses by hundreds of undergraduate students before they are cremated and returned to West Virginia after approximately two years. This report details the uses and impacts of WV whole-body donors in undergraduate education at Radford University.

Undergraduate Curriculum

The Biology Department at RU includes eight faculty members who teach A&P classes on a regular basis - the department's largest subject area, by faculty and student numbers. Since 2016, over 3,000 RU undergraduates in many majors including Biology, Chemistry, Nursing, Science Education, Anthropological Sciences, Respiratory Therapy, pre-Physical Therapy, and other Allied Health

concentrations have learned anatomy from WV whole-body donors (Table 1).

Table 1. Total enrollments in Radford University Biology courses that utilize West Virginia whole-body donors.

Course	Total enrollment, Fall 2016-Spring 2023
BIOL 310, Human Anatomy & Physiology I*	1,987
BIOL 311, Human Anatomy & Physiology II*	1,422
BIOL 322, A&P for Pre-Nursing students**	752
BIOL 350, Comparative Vertebrate Anatomy	76
BIOL 405, Histology	58
BIOL 481, Advanced Human Anatomy	43
All Courses	4,338

**The majority of students who take Human Anatomy & Physiology I (BIOL 310) also take Hunan Anatomy & Physiology II (BIOL 311) and vice-versa, thus these numbers represent course enrollments rather than individual students.*
***This course was discontinued in 2021. Radford University pre-Nursing students now take a more traditional two-semester sequence of Human Anatomy & Physiology I and II.*

Human Anatomy & Physiology I & II

The Radford University two-semester, introductory Human Anatomy and Physiology course sequence, Human A&P I (BIOL 310) and Human A&P II (BIOL 311), is typically taken by 300+ undergraduate students each academic year. These courses follow a systems-based approach. Donor bodies are used during lab sessions, with students studying the human bodies to identify anatomical structures through hands-on, experiential activities. During labs, which are taught entirely by faculty (the Biology Department does not offer a graduate program, so graduate students and graduate teaching assistants are not available), the instructor introduces structures in the bodies to small groups of students at a time, or to the entire group using overhead, live-feed video cameras. Students then work in groups to identify, examine, and review the structures on their own, with the instructor stepping in as needed for clarification; this approach allows for peer-to-peer teaching during lab. Student knowledge is assessed with practical exams, wherein structures are marked on the bodies with pins for student identification.

Advanced Human Anatomy

In addition to introductory Human A&P courses, Radford undergraduate students also benefit from learning experiences with whole-body donors in upper-level electives. One of these specialized electives is Advanced Human Anatomy (BIOL 414), which was designed as a "mini medical gross anatomy" course. In this class, upperclassmen who have succeeded in introductory A&P courses learn more detailed human anatomy by completely dissecting a donor body themselves over the course of a semester.

For hundreds of years, whole-body dissection has been the gold standard for learning human anatomy, and it is traditionally part of the first-year medical school curriculum (McLachlan 2004; Korf *et al.* 2008). Most anatomy educators still favor cadaver dissection as the best way for students to learn anatomy (Patel and Moxham 2005; Korf *et al.* 2008; Estai and Bunt 2016). However, this hands-on, integrative, active, and effective student-centered approach to learning anatomy (Yeager 1996; Azer and Eizenberg 2007; Davis *et al.* 2013) is exceedingly rare in undergraduate curricula because of the substantial resources required as well as difficulty integrating dissections into typical undergraduate systems-based A&P courses (Estai and Bunt 2016).

An RU Advanced Human Anatomy class includes 12-18 students working in groups of 4-6, each group dissecting a donor body. Students work their way through the body region by region (back, thorax, abdomen, limbs, etc.), which allows them to gain a more complete understanding of how the structures of various systems are related spatially and functionally, compared to what they learned in systems-based introductory A&P courses. Specialized dissection techniques are used to preserve anatomical structures so that the donor bodies can subsequently be used as prosections in the Human A&P I and II labs as described above. For example, to open the body cavities of the trunk, the clavicles are bisected, the ribs are cut bilaterally along the sides of the thorax, and the incisions are continued downward through the muscles of the lateral abdominal wall. The anterior diaphragm is transected from the lower ribs, and the anterior rib cage and sternum remain attached to the anterior abdominal muscles. This allows the entire anterior body wall to remain intact and attached to the body, but to be reflected inferiorly to allow access to the body cavities for student study.

Although we do not allow photography of whole-body donors as a rule out of respect for their privacy and dignity, students in Advanced Human Anatomy develop "atlases" for their donor bodies, creating labeled photographs of their dissections that can then be shared with students in other A&P courses (Fig. 1). Photography for the atlases is strictly monitored by the

instructor, and donor confidentiality is carefully preserved: no identifying information, including photographs of the donors' faces, is shared. These atlases also include information about health, disease, pathologies, and anatomical variations that students discover during dissection. Some recent examples include quadruple heart bypass surgery, an immense abdominal aortic aneurysm with stent repair, an accessory abductor digiti minimi muscle, gallstones and pancreatic stones, and a "wandering spleen". Encountering pathologies, anatomical variants, and evidence of past medical incidents and procedures challenges students to a) consider the immense amount of anatomical variation present in human populations and b) apply their anatomical and physiological knowledge to infer potential causes and sequelae of the conditions they discover in the donor bodies. Since medical records are not provided with the whole-body donors, only cause of death, documentation and explanation of each donor's unique anatomy is valuable for all students studying the donor bodies.

Most of the students enrolled in Advanced Human Anatomy at RU intend to pursue post-graduate education in the health sciences (e.g. MD, DO, PA, or PT programs, etc.), and many have described this class as one of the most impactful and useful in their undergraduate career. For example, RU graduate Brandi Clemons (c/o 2023) reflects "Upon starting PT school, I felt I had the knowledge and skills necessary to carry out a complete cadaver dissection which would not have been true had I not taken Advanced Anatomy. This class put me a step above my peers who had never been in a cadaver lab before." Blake Flinchum (c/o 2018) reports "The experience of receiving such an in-depth course typically reserved for graduate/medical students is unforgettable and something that very few get to experience… There is no better way to learn anatomy and physiology than working in a cadaver lab. I feel as if this course better prepared me for entering the workforce and an internship with the Office of the Chief Medical Examiner of Virginia."

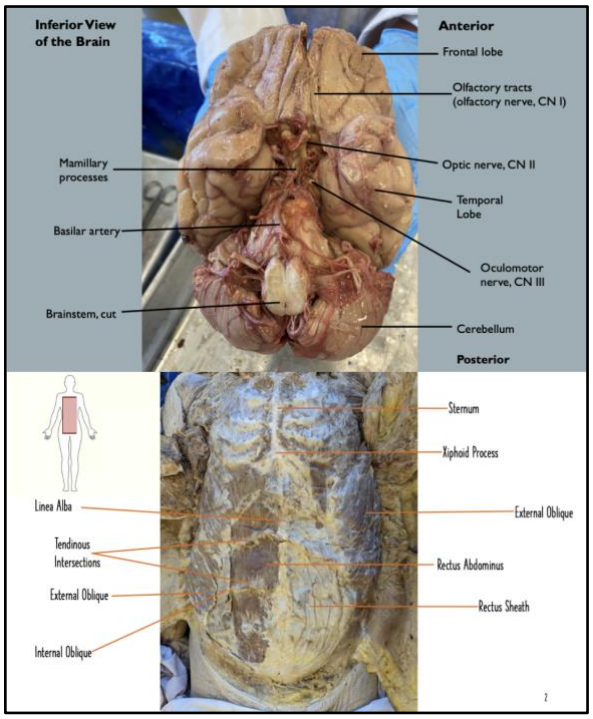

Figure 1. Pages from photographic atlases created by two groups of Radford University Advanced Human Anatomy students based on their dissections.

Histology

Tissues from WV donors have also been used for teaching histology and histotechniques. RU's Histology course (BIOL 405) is an advanced elective for students who have already completed one or two organismal A&P courses, and focuses on building proficiency with the compound light microscope and tissue processing – from sample collection, to sectioning, to staining. In this course, students generate research questions based on sequelae identified in the whole-body donors, collect and process tissues, and analyze the slides they make using light microscopy. Students compare typical and atypical morphology from donors with different pathologies and conditions, and then present their results to the class. In some cases, the pathologies were generally well-known, but in many cases, students explored questions that were not well-published.

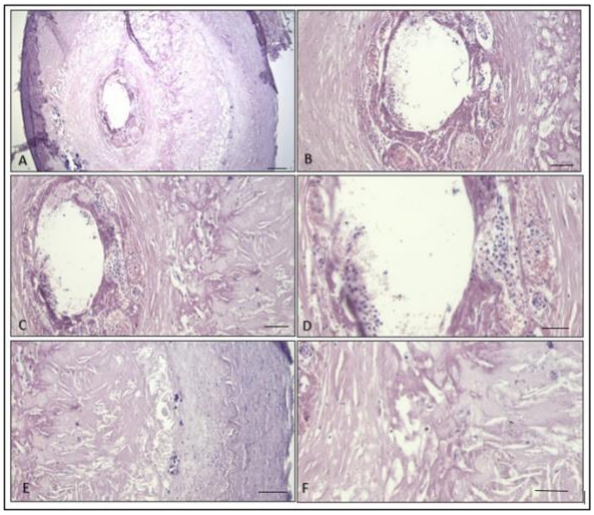

Figure 2. Image from a Radford University student team's Histology project. The project, *Complications of Renal Artery Stenosis and Atherosclerotic Renal Artery Stenosis in the Unilateral Atrophic Kidney*, demonstrated the morphological effects of cardiovascular disease on the renal artery supplying an atrophied cadaver kidney. Image series of low (A) through high (F) magnification of H&E-stained cross sections of the renal artery wall demonstrating the presence of sclerotic plaques and resulting decreased luminal diameter.

In 2021, two teams of Histology students studied the effects of cardiovascular disease on kidney microstructure (Fig. 2). After studying pre-prepared slides of healthy and unhealthy kidneys, one team compared the right kidney from a donor with typical kidneys and no record of cardiovascular disease with that of a donor with cardiovascular disease who had an atypical, atrophied right kidney. A second team studied healthy vs. stenotic arteries, and compared the renal arteries supplying typical and atrophied kidneys from the whole-body donors. Students biopsied the tissues, created their own slides, and compared renal and vascular microanatomy between the two donor tissues, and determined that the donor with cardiovascular disease lacked typical nephrons in the atrophied kidney and that this was likely due to ischemia to the organ as a result of stenosis in the artery.

Comparative Vertebrate Anatomy

RU students majoring and minoring in Biology outside of the traditional Human A&P curriculum have benefited from donor bodies as well. In Comparative Vertebrate Anatomy (BIOL 350), which typically enrolls students interested in pre-veterinary and environmental/wildlife concentrations, students begin with dissections of dogfish sharks and end with dissections of mammals including cats, rats, and humans. Donors that have been dissected by Advanced Human Anatomy students, research students, and A&P instructors have been incorporated into the Comparative Vertebrate Anatomy curriculum in order to introduce concepts that are difficult to illustrate without whole bodies to examine. In addition to the concepts of homology, analogy, and homoplasy, donor bodies have been used to directly compare bipedal and quadrupedal tetrapods, and discuss effects that bipedalism has on the organization of the skeletal and muscular systems. Similarly, Comparative Anatomy students are able to compare, for example, the cardiovascular and central nervous systems of humans and other animals, and consider aspects of their development and evolution, by directly observing and comparing these organs *in situ*. These hands-on learning experiences enhance understanding of what are often very difficult concepts for students.

Non-Biology Courses at Radford University Incorporating Whole-Body Donors

Students from programs throughout Radford University are able to learn from experiences with WV donor bodies - even if their coursework does not involve Biology classes - through group visits to the Biology Department's A&P laboratories. For example, Anthropological Sciences students have examined osteoarthritic joints as part of a Bioarchaeology class. Likewise, an Honors seminar exploring the anatomy and psychology of human running visited to examine, in real human bodies, the muscles they were learning about. Students in a Religion and Death class have gained a deeper understanding of the physical process of death and its impacts by seeing and learning about the whole-body donors, and reflecting on their experiences with them. Occupational Therapy students have performed detailed dissections on whole-body donors' hands to familiarize themselves with the anatomy they would be helping patients with. The A&P faculty in the Biology Department at RU are grateful to be able to enrich the educational experience of students from across the University by sharing this invaluable resource with them.

Peer Teaching Assistants in the Anatomy & Physiology Laboratories

In order to meet the RU Biology Department's mission to provide extensive opportunities for hands-on and experiential learning, open lab sessions are offered in the A&P laboratories outside of regular course

meetings. These open labs provide supervised opportunities for students in all anatomy and physiology-related courses to study the whole-body donors, as well as models and other materials. The peer teaching assistants (Peer TAs) who staff open labs are undergraduate students who have previously excelled in Human A&P courses and shown enthusiasm for working with the whole-body donors. Peer TAs can earn course credit in Apprentice Teaching (BIOL 493).

The use of Peer TAs in undergraduate A&P courses has been shown to benefit both the TAs and the students they work with (Sparacino *et al.* 2019). Many of the students who take on Peer TA roles at RU are majoring in Nursing or other pre-health concentrations. The experience helps them develop skills necessary for ethical teamwork and leadership in healthcare, and to build their professional resumes, while solidifying and deepening their knowledge of human A&P. Peer TAs are also important for supporting students currently enrolled in A&P courses. Students can study during open lab times and review information with Peer TAs, who offer a valuable peer perspective on tackling course expectations.

Student Projects and Independent Research

Undergraduate Research Projects

In addition to the undergraduate curriculum, WV whole-body donors at Radford University are also used in undergraduate research. Many RU students in the sciences conduct independent research projects under the mentorship of a faculty member, and results are typically presented at university, regional, or even state-wide forums. For example, as an Honors capstone project, Biology major Claire Dundon carried out gross and microscopic comparisons of a typical donor brain vs. one from a donor who died of dementia, attempting to identify signature characteristics of Alzheimer's disease (Fig. 3). She performed craniotomies, measured and compared brain sizes and dimensions, biopsied the hippocampus and infratemporal cortex, and then stained and examined these tissues using light microscopy. Ms. Dundon was able to determine that the dementia patient displayed three of the distinguishing characteristics of Alzheimer's dementia (brain atrophy, plaques, and neurofibrillary tangles). Planned future student research projects include examining human donor tissues for the presence of microplastics across various organ systems.

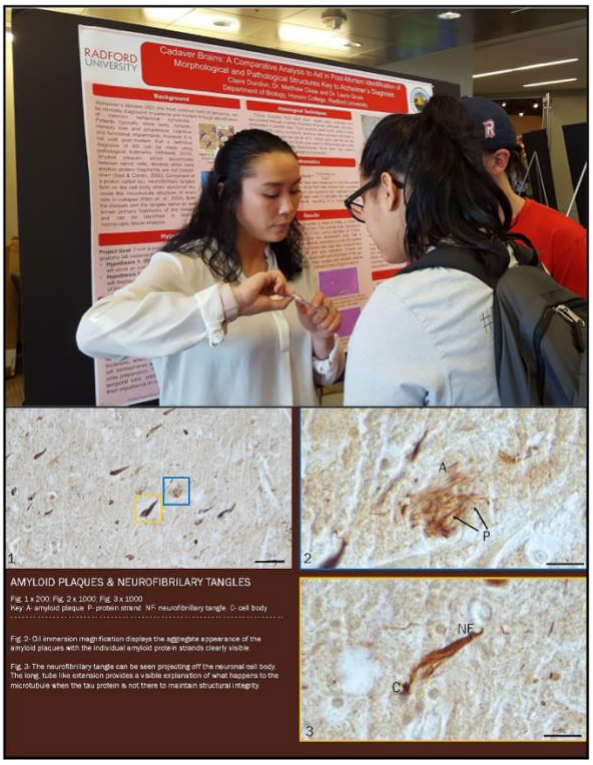

Figure 3. Undergraduate researcher Claire Dundon's project examining gross and histological properties of WV donor brain samples. Above: The student presented her research at a university-wide student research forum and a Virginia Collegiate Honors Council conference. Below: Light micrographs of silver-stained hippocampal tissue from a donor with dementia showing the presence of amyloid plaques and neurofibrillary tangles, two signs of Alzheimer's disease. The image, including labels, scale bars, and description, is from the student's original report; photo used with permission.

West Virginia whole-body donors at RU have also been used in Human Biology (BIOL 104), an introductory-level course for non-science majors. Students in this class conduct a semester-long original group research project in which they collect data to test a hypothesis related to the human body. Although they are not required to work with the whole-body donors, some do wish to, and design their research projects around them. For example, one group measured the diameter of limb muscles on donor bodies to quantify levels of right-left asymmetry, and another tested whether gyri vary in width in different lobes of the cerebrum among donors with brain pathologies (dementia and hemorrhagic stroke) vs. a comparatively healthy brain. These projects, although modest in scope, provided unusual and impactful experiential learning experiences for undergraduate students, especially given that they were not STEM majors.

Students were able to ask questions and formulate hypotheses about human anatomy, and then test them using real data they collected themselves, gaining a rare appreciation for the nature, complexity, and variability of the human body, while learning about the scientific method.

Donor Body Dissection by Undergraduate Students

Radford undergraduates who have shown a particular interest in, and aptitude for, working with the donor bodies in A&P classes may be invited to help faculty members with prosections outside of formal class settings. Typically, 2-4 students participate in extracurricular dissections each semester, earning credit for Biology Directed Study and Research (BIOL 491). Students find this work very helpful for keeping their A&P knowledge fresh in their minds as they continue their education. Students participating in dissection have sometimes used this opportunity to create educational materials for others. For example, one student (who also served as a Peer TA) designed a method for preparing serial coronal sections of donor brains using readily available materials. A bread loaf slicer was used to section the brains approximately 1 cm thick, and the serial sections were then vacuum-sealed into transparent plastic sleeves and placed in a binder. Structures visible in each slice were labeled for other students to study (the brain slices were eventually cremated along with the rest of the donor and returned to the WV University Human Gifts Registry). Independent, faculty-supervised dissections have also been used by students to fulfill requirements for the Honors program at RU, as senior capstone projects or as enrichment activities supplemental to standard coursework.

Conclusions

West Virginia whole-body donors have provided thousands of Radford University undergraduate students with uniquely impactful educational experiences, whether through a semester spent dissecting a donor body completely, or a single class visit to the A&P laboratories. Students benefit from having multiple whole-body donors to learn from, which allows them to gain an appreciation for the sight and feel of real human tissues as well as for the great variation, both typical and pathological, that exists in the human form (Aziz *et al.* 2002). This is a critical perspective for anyone who plans a career caring for *living* people's bodies, whether as a nurse, physician, dentist, physical therapist, emergency medical technician, or any of the other health-related careers that RU students go on to pursue. Experiences working with human whole-body donors have also been beneficial to students with other career ambitions, including veterinary science, forensics, science education, athletic training, bioengineering, anthropology, and still others outside the realm of the sciences. As Victoria Leeks, RU class of 2018 and now an autopsy technician at a Virginia State Medical Examiner's office, reports, "The use of human cadavers ranks as one of the top exciting and impactful hands-on experiences not only for my education, but for reaching my career goals." The anatomy and physiology faculty in the Biology Department at Radford University are proud of our contributions to science education and healthcare in this region, and we wish to express our profound gratitude to the West Virginia donors whose incredible generosity has made this work possible.

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