# The Johns Hopkins Hunterian Laboratory Philosophy: Mentoring Students in a Scientific Neurosurgical Research Laboratory

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## Abstract

After over 50 years of scientific contribution under the leadership of Harvey Cushing and later Walter Dandy, the Johns Hopkins Hunterian Laboratory entered a period of dormancy between the 1960s and early 1980s. In 1984, Henry Brem reinstituted the Hunterian Neurosurgical Laboratory, with a new focus on localized delivery of therapies for brain tumors, leading to several discoveries such as new antiangiogenic agents and Gliadel chemotherapy wafers for the treatment of malignant gliomas. Since that time, it has been the training ground for 310 trainees who have dedicated their time to scientific exploration in the lab, resulting in numerous discoveries in the area of neurosurgical research. The Hunterian Neurosurgical Laboratory has been a unique example of successful mentoring in a translational research environment. The laboratory's philosophy emphasizes mentorship, independence, self-directed learning, creativity, and people-centered collaboration, while maintaining productivity with a focus on improving clinical outcomes. This focus has been served by the diverse backgrounds of its trainees, both in regard to educational status as well as culturally. Through this philosophy and strong legacy of scientific contribution, the Hunterian Laboratory has maintained a positive and productive research environment that supports highly motivated students and trainees. In this article, the authors discuss the laboratory's training philosophy, linked to the principles of adult learning (andragogy), as well as the successes and the limitations of including a wide educational range of students in a neurosurgical translational laboratory and the phenomenon of combining clinical expertise with rigorous scientific training.


Established in 1904 by Harvey Cushing and later led by Walter Dandy, the Hunterian Neurosurgical Laboratory of the Johns Hopkins Hospital was founded with the goal of investigating the causes and symptoms of disease.[1,2] After decades of investigators' scientific contributions, including describing the anatomy and functions of the pituitary gland, and investigations on cerebrospinal fluid circulation, the Hunterian laboratory entered a period of dormancy.[1] During this time, the focus of neurosurgery research shifted to optimizing surgical operations as technology advanced in the operating room.[1]

### Reemergence and Structure of the Hunterian Laboratory

In 1984, Henry Brem reinstituted the Hunterian Neurosurgical Laboratory, with a vision to change the armamentarium of therapeutic options for brain tumor patients. This commitment was supported by the National Institutes of Health (NIH), the university, and multiple donors. Since then, 310 trainees have dedicated between four weeks and three years to learning and conducting research in the lab (Table 1). The structure of the laboratory is similar to other successful labs: It is headed by a main principal investigator who is supported by a combination of departmental faculty, postdoctoral fellows, and graduate students. In the case of the Hunterian program, however, an organized rotation of neurosurgical residents, medical students, undergraduate students, and high school students contribute significantly to the laboratory's scholarly output. Throughout each year, postdoctoral fellows and neurosurgical residents are assisted in their research projects by younger students. The laboratory uses a total of 5,375 square feet of research space with additional office space and imaging and operating facilities.

The laboratory has included students whose educational homes are local, elsewhere in the United States, or international. Over 400 peer-reviewed papers have been published (Figure 1). Of the 310 trainees, 228 have continued on to careers in the medical field, with 37 either in high school or obtaining undergraduate education as of 2015 (Table 2). The Hunterian Laboratory functions as an incubator for training physician–scientists and researchers. We seek to share its approaches with other laboratories dedicated to education and translational research.

### Common Barriers to Biomedical Research

There are several barriers to biomedical research that are thought to influence the decreasing number of physician–scientists. These include economic factors such as the increasing financial burden that medical graduates shoulder and the substantial costs associated with conducting biomedical research[3,4] in the context of an increasingly challenging funding environment. A lack of sufficient training and mentorship is often cited as a significant deterrent to research.[3,5] Furthermore, there is a substantial regulatory burden required for biomedical research, which requires effective organization and consistent oversight.[3] The Hunterian Laboratory has overcome these barriers through an established research philosophy and

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Table 1

**Demographic Characteristics of 310 Alumni of the Hunterian Neurosurgical Laboratory of the Johns Hopkins Hospital, 1984–2014**

| Demographic characteristic | No. (%) |
|---|---|
| **Gender** | |
| Male | 216 (69.7) |
| Female | 94 (30.3) |
| **Race** | |
| Caucasian | 171 (55.2) |
| African American | 29 (9.4) |
| Asian | 56 (18.1) |
| Other | 39 (12.6) |
| Latino | 15 (4.8) |
| **Trainee educational status**[a] | |
| High school | 31 (10.0) |
| Undergraduate | 65 (21.0) |
| Postbaccalaureate | 16 (5.2) |
| Masters | 2 (0.6) |
| Medical | 145 (46.8) |
| Graduate | 7 (2.3) |
| Resident | 9 (2.9) |
| Postdoctoral fellow | 33 (10.6) |
| Unknown | 1 (0.3) |
| **Citizenship** | |
| National | 257 (82.9) |
| International | 53 (17.1) |

[a]Educational status is defined as the status of the student when he or she first joined the laboratory.

an efficient organizational framework. The laboratory frequently collaborates with the School of Medicine to subsidize medical students who dedicate time to neurosurgical research. Additionally, through the proactive and cooperative philosophies of the laboratory, resources are shared among investigators, which results in decreased operating costs.

## The Laboratory Philosophy and Basic Principles of Andragogy

The question of how adults learn has been an important one in the field of education since the 1920s.[6] In 1973, Malcolm Knowles[7] defined andragogy as "the art and science of helping adults learn." Six core adult learning instincts have been described: a drive to seek knowledge, strong self-directed will, accumulating experience for the formation of the self, coping effectively with real-life learning, obtaining task-centered knowledge in life context, and learning for sustained satisfaction and enhanced quality of life.[7]

There are various philosophies concerning laboratory research and the manner in which it is carried out.[8–10] The Hunterian Laboratory has incorporated the principles of andragogy to facilitate successful learning in the students' research experiences (Table 3). The laboratory's philosophy emphasizes mentorship, independent and self-directed learning, creativity, and a diversity of backgrounds. Through this philosophy and strong legacy of scientific contribution, the laboratory has maintained a positive and productive research environment that supports highly motivated students and trainees.

## Mentoring in the Research Environment

The success of academic research programs is dependent on achieving a good match between the student and mentor regarding both research interests and temperament.[11] Mentoring has been shown to make a tremendous impact on students' educational development, and with a strong mentor relationship, undergraduates can learn significantly from their research experience.[12]

The Hunterian Laboratory has promoted the importance of mentorship which stemmed from Dr. Brem's experience as an undergraduate student under the guidance of Herbert S. Rosenkranz, PhD, at Columbia University, where he discovered the mutagenicity of haloalkanes.[13] Despite Brem's inexperience, he was able to scientifically contribute and enhance the environmental testing standards at that time. As a predoctoral student working with Judah Folkman, MD, at Harvard Medical School, he worked with Dr. Robert Langer, then a postdoctoral fellow, to isolate the first inhibitor of angiogenesis and developed techniques for studying angiogenesis inhibitors still used today.[14] Brem's early introduction into encouraging mentor relationships and successful scientific endeavors were the cornerstone on which the mentoring framework for the laboratory was developed. The Hunterian Laboratory has ensured successful mentorship through clearly defined responsibilities of the mentor, establishment of an organizational framework, strong dedication to teaching, promoting peer-to-peer mentorship, clearly defined projects, and team building.

### The mentor's responsibility

Pita et al[15] described five strategies to mentoring undergraduate students: being available to the student, fostering community, being attentive, encouraging participation in the broader research community, and being understanding. The Hunterian Laboratory strives to fulfill these requirements by creating a safe, dynamic, and structured work environment (List 1).

### Organizational framework

The laboratory includes postdoctoral fellows, medical residents, graduate students, medical students, undergraduates, and high school students who work with the principal investigators. Senior members of the laboratory conduct research year-round with more junior students working part-time throughout the year.

The Johns Hopkins University School of Medicine's Scholarly Concentration program is a faculty-mentored, stipend-supported, scholarly experience for first-year medical students. This required component of the curriculum provides the infrastructure for students to develop an area of interest and encourages the acquisition of skills for self-directed, lifelong learning and scholarship. Many medical students are introduced to the laboratory through this program. The program includes the following six areas of study: basic science; clinical research; history of medicine; medical humanities; bioethics and the healing arts; and public health and community service. Students who select the Hunterian Laboratory for their scholarly concentrations fulfill the basic science and clinical research areas of study.

Projects are selected according to the laboratory's focus of research as well as through collaborative interest from the student. Other opportunities include presenting at laboratory meetings, participating in clinical research projects, and shadowing in the clinic or operating room. These allow students to broaden their exposure to the medical field and to better understand the impact of their research efforts.

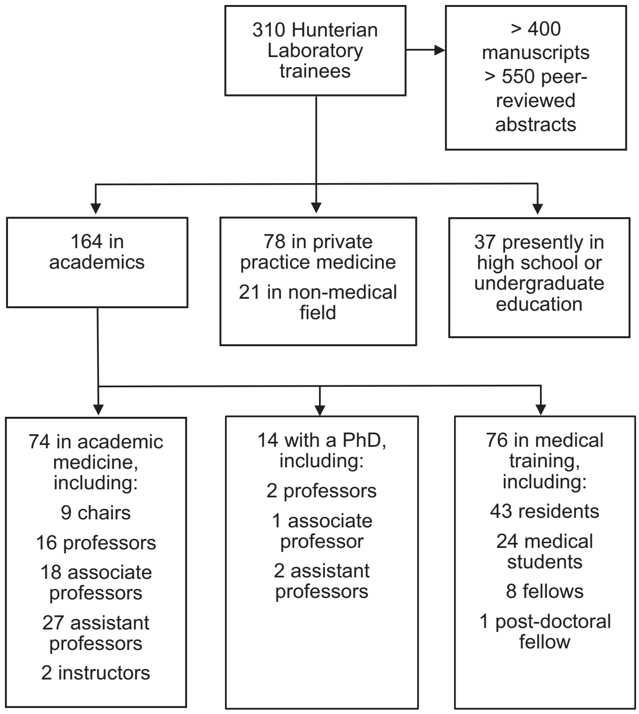


**Figure 1** Scholarly productivity and employment and training status of 310 alumni of the Hunterian Neurosurgical Laboratory of the Johns Hopkins Hospital, 2015.

Many neurosurgical residents at Johns Hopkins have worked in the laboratory for their two years of required research during their seven-year residency training. Residents are encouraged to dedicate 50% of their time to predefined and funded projects and 50% to innovative, high-risk projects, often in collaboration with other laboratories.

Other students join either through the Office of Academic Advising or through collaborative contacts. Although the motivation of students who join our laboratory is high, there is no suggestion that it differs from other students placed in other laboratories through similar mechanisms. We believe that the scholarly productivity of our students is due, at least in part, to the outstanding opportunities afforded to them and the lab's strong commitment to mentoring. In addition, the Hunterian Laboratory overcomes common impediments by obtaining necessary funding (via the NIH, neurosurgical foundation-sponsored fellowships, independent grants and donors, and institutional grants), offering administrative assistance to formulate institutional protocols, and contributing materials and equipment.

### Dedication to teaching

The Hunterian Laboratory dedicates significant time and effort to teaching trainees. Laboratory mentors often attend the Johns Hopkins Neurosurgery Interest Group meetings to discuss current research projects in an effort to inspire medical students to join the Hunterian Laboratory. Trainees then receive education in various areas, including responsible research conduct, general compliance, bloodborne pathogens, and Health Insurance Portability and Accountability Act compliance (as necessary).

Trainees are taught experimental research design to ensure properly controlled experiments that answer a focused question. Students are also introduced to ethics and conscientious concerns involved in experimental design. Technical laboratory training is project specific and includes surgical techniques, immunohistochemistry methods, imaging techniques, and data analyses. Collaborative etiquette with other laboratories and core facilities is strongly encouraged; trainees learn to establish and maintain solid professional contacts across departments and disciplines. Students also attend and participate in university-wide, national, and international conferences to present their research. As such, students have attended over 100 conferences and presented over 550 peer-reviewed abstracts.

### Peer-to-peer mentorship

Peer mentoring is currently receiving more attention as a strategy to provide a more enriched research experience.[16] Because of the inherent equality between the mentor and mentee,[17] these relationships are more likely to offer friendship, flexibility, and feedback on such topics as work–life balance and career planning. Peer mentoring is thought to enhance professional support, a sense of well-being, and career development.[18,19] On a more personal level, peer mentoring can improve interpersonal and communication skills, expand on qualities such as patience and compassion, and may boost self-esteem.[20]

To provide high-quality research experiences, the laboratory has implemented peer and near-peer mentoring groups. The mentorship groups are established with careful planning in regard to personal mentoring styles, experience in the laboratory, and projects being

## Table 2

**Current Employment and Educational Status of 310 Alumni of the Hunterian Neurosurgical Laboratory of the Johns Hopkins Hospital, as of 2015**

| Employment or education | No. (%) |
|---|---|
| **Academic medicine** | 74 (23.9) |
| Chair | 9 (12.2) |
| Professor | 16 (21.6) |
| Associate professor | 18 (24.3) |
| Assistant professor | 27 (36.5) |
| Instructor | 2 (2.7) |
| **Private practice medicine** | 78 (25.2) |
| **Medical training**[a] | 76 (24.5) |
| Medical student | 24 (31.6) |
| Resident | 43 (56.6) |
| Postdoctoral fellow | 9 (11.8) |
| **PhD** | 14 (4.2) |
| Professor | 2 (15.4) |
| Associate professor | 1 (7.7) |
| Assistant professor | 2 (15.4) |
| **Other** | 21 (6.8) |
| **Not applicable**[b] | 37 (11.9) |
| **Unknown** | 10 (3.2) |

[a]Includes medical students, residents, and fellows.
[b]Includes high school students and undergraduate students.

Table 3

**Principles of Andragogy and Implementation in the Hunterian Neurosurgical Laboratory of the Johns Hopkins Hospital[a]**

| Knowles's[7] principles of andragogy | Implementation in the Hunterian Laboratory |
|---|---|
| Drive to seek knowledge | Involve trainees in mutual planning of their intended focus of research<br>• Conduct cause/effect discussions<br>• Perform literature review of the pertinent specific topic<br>• Engage in experimental design discussions |
| Strong will to direct the self | Encourage learners to formulate individualized learning objectives<br>• Encouragement to review the literature and determine a goal based on their skill set or a skill set they would like to learn<br>Help students identify resources and devise strategies to achieve their objectives<br>• Encourage collaboration with investigators in other departments, universities, industry, and so forth to achieve a predetermined skill set or goal |
| Drive to accumulate experience for the formation of the self | Link proposed project with individuals' specific academic and/or career goals; involve students in evaluating their own learning to develop their skills of critical self-evaluation<br>• Evaluate experimental projects with the student<br>• Discuss positive/negative data in a positive atmosphere<br>• Determine longevity of a project<br>• Determine the student's involvement in future experiments |
| Drive to cope effectively with real-life learning | Support students in carrying out their objectives<br>• Encourage the students' individual curiosity and research questions<br>• Serve as a reference and a guide for all questions and help the student determine the merit or disadvantage for each question<br>• Guide trainees through project and professional setbacks |
| Drive to acquire task-centered knowledge in life context | Establish an effective and fun learning climate for students<br>• Foster a positive work environment<br>• Have individual meetings to discuss specific project details<br>• Foster mentorship, particularly peer mentorship<br>Have laboratory meetings for participation in overall goals |

[a]Andragogy is defined as the principles of adult learning.[7]

investigated. Small to medium open office spaces maximize daily interaction among all members of similar projects. This scaffold gives students a social group to work within and a sense of teamwork. Also, the workload flows better and more ideas are generated from increased communication.

These groups also benefit the more established students, giving them the opportunity and responsibility to teach and mentor within the laboratory setting. This dedication to teaching has led several trainees to teach neuroanatomy during their neurosurgical residency. Not only does this experience enhance the teaching and mentorship skills of our resident trainees, it also encourages medical students to pursue research early in their academic careers. Oftentimes, new projects have been proposed and carried out as a result of these peer mentorship relationships.

**Team building**

Building an effective team is essential to conducting high-quality research and requires a trusting environment in which collaboration, knowledge transfer, and idea sharing occur. These then lead to innovation and discovery.[21] Although developing trust is typically a slow and long-term process, open and consistent communication can establish trust more quickly.[21] Several factors vital to maintaining a high-functioning team are clearly defined and common goals, assigned roles and responsibilities, mutual respect and commitment to the team, an interactive (rather than authoritarian) approach to training, and strong leadership.[21–25] These operational principles translate into a results-oriented approach and flexible work environment, where timetables and score keeping are prized less than posing valuable research questions and obtaining high-quality results. These practices ensure a respectful and nonjudgmental workplace where creativity and collaboration automatically stimulate trainees and mentors into natural teams.

Team building at the Hunterian Laboratory is maintained through continuous communication and idea sharing, frequent interactions, and regular acknowledgment of trainees' accomplishments. Communication has been achieved through an "open door" policy between trainees and mentors. Flexible meetings allow researchers to discuss new ideas, ask questions, voice concerns, troubleshoot challenges, and refine research methodology. Frequent interactions—both formal and informal—are also important to effective team building. The laboratory organizes regular small-group meetings as well as large, formal laboratory presentations. The laboratory hosts lunches, dinners, and an annual pool party, where current students and Hunterian alumni can share experiences, support networking, and form new collaborations.

Acknowledgment of accomplishments is a vital component to creating a high-performing team. The Hunterian Laboratory regularly acknowledges the work of its trainees through formal announcements at the Neurosurgery Department's weekly grand rounds, authorship in peer-reviewed journals, letters of recommendation, and awards, such as the annual Harvey Cushing Medical Student Research Award, given to exceptionally productive students in the laboratory. These formal and informal team-building activities have helped maintain a positive environment in the laboratory.

**Clearly defined projects**

Basic science and translational projects under investigation in the laboratory are frequently long-term and are carried out over months and years. Although research projects with long-term goals are customary practice in a preclinical laboratory, short-term research experiences are the most practical form of research exposure for the majority of high school, undergraduate, and medical students, with the goal of sparking their interest for research.[26] It is important

List 1

**Mentor Responsibilities for the Hunterian Neurosurgical Laboratory of the Johns Hopkins Hospital**

- Time commitment
- Administrative duties
- Organization of projects (including both laboratory and written)
- General training
    - Compliance training
    - Safety training
    - Experimental design
    - Ethics
    - Statistics
    - Bloodborne pathogen training
    - Additional as needed
- Specific training (particular to project)
    - Radiation training
    - Microsurgical techniques
    - Health Insurance Portability and Accountability Act training
    - Additional as needed
- Laboratory meetings/presentations
    - Presentation assignment and training
    - Progress reports and project presentations

for the mentor to work with students to develop a feasible project with specific and answerable questions to fit limited time constraints. On the basis of preliminary insights, the laboratory therefore selects short-term projects with more defined goals for these students. This benefits the student with a rewarding and tangible accomplishment while also benefiting the laboratory with extra information and frequently a different perspective on the long-term topic.

## Early Exposure to Conducting Research

Physician–scientists are vital to advancing the field of medicine through the translation of basic science research findings into practical clinical applications.[27] The number of physician–scientists has continually decreased over the past several decades,[27–30] and inadequate exposure to research may play a significant role.[26,30,31]

Siemens et al[30] found that students who conducted research prior to medical school were more likely to pursue additional research opportunities during medical school. Similarly, students involved in laboratory research during high school and/or college were more likely to enroll in MD–PhD programs compared with MD program enrollees.[32] Early exposure to research increases the likelihood that medical students will later pursue careers in research and/or academic medicine.[28] Even short-term research training may increase a student's belief in his/her own capability to achieve a specific research goal.[26] The majority of students feel that research experiences during medical school help stimulate their interest in research and allow the development of important research skills.[5]

Ultimately, undergraduate research has been shown to provide an exceptional experience for students and encourages research at later stages of training and careers.[30] Cited benefits include personal and professional gains, critical thinking, improved problem solving, developing new skills, clarification or confirmation of a certain career path, communicating and disseminating new information, enhanced career or graduate school preparation, contributing to medical knowledge, and shifts in attitudes to inquiry-based learning.[5,28,30,31,33,34] These skills translate clinically by enhancing the physician's approach toward evidence-based medicine. Scientific inquiry leads to the ability to identify important questions, critically appraise the literature, and apply evidence to patient assessment and management.[35]

To capitalize on the benefits of early exposure to scientific research, the Hunterian Laboratory has consistently recruited students, from high school to medical school. Over the past 30 years, the lab has mentored 241 such students, which have constituted the majority (78%) of the lab's alumni (Table 1). These students' refreshing interest, steadfast perseverance, and inspiring ingenuity have resulted in several important findings. Many students have become physician–scientists in a wide variety of fields highlighting the value of early research exposure.

## Collaboration and Diversity of Research Topics

As defined by Chrislip and Larson,[36] collaboration is "a mutually beneficial relationship between two or more parties who work together toward common goals by sharing knowledge, learning, responsibility, authority and accountability for achieving results." When faced with finite resources, collaboration can allow for access to resources and equipment,[37] special expertise and knowledge,[38] and greater rewards.[39] Collaboration of scientists in research has become the norm, with an increase in growth, thanks to federal initiatives.[40] The National Science Foundation reported that the amount of research and development funding shared by multiple institutions grew more rapidly from 2000 to 2009 than did overall academic research and development expenditures.[40]

The treatment of brain tumors is multidisciplinary, often involving neurosurgeons, neurologists, oncologists, and radiation oncologists. Similarly, the study of brain tumors requires knowledge of multiple specialties. The Hunterian Laboratory has teamed up with over 40 other laboratories at Johns Hopkins to achieve out-of-the-box thinking and, ultimately, groundbreaking results. Collaborative efforts have also included student representation from over 30 international laboratories.

As a result, the laboratory has examined a variety of research topics ranging from basic research to translational work to clinical trials. Projects have included work on intracranial glioma and intramedullary spinal cord tumors,[41,42] developing biodegradable polymers for controlled delivery of

Table 4
**Survey Results for 215 Alumni of the Hunterian Neurosurgical Laboratory of the Johns Hopkins Hospital, 2015**

| Question | No. (%) agree or strongly agree |
|---|---|
| I was satisfied with my research experience in the Hunterian lab | 212 (98.6) |
| I would recommend working in the Hunterian lab to others | 211 (98.1) |
| I was satisfied with the mentorship I received in the Hunterian lab | 203 (94.4) |
| My experience in the Hunterian lab encouraged me to conduct future research | 186 (86.5) |
| My experience in the Hunterian lab encouraged me to mentor students | 178 (82.8) |

chemotherapeutic agents, investigating immune modulators,[43–47] and developing nanotechnology and microchips for therapeutic utilization.[48–50] In recent years, "bench to bedside" research has been emphasized to develop new treatments; this effort has led the laboratory to be at the forefront of brain drug delivery, antiangiogenesis, immunotherapy, and vasospasm and stroke research. Preclinical studies carried out in the Hunterian Laboratory have laid the foundation for phase I, II, and III clinical investigations of therapeutic agents for malignant glioma.

## Our Impact

To examine the effect that the Hunterian Laboratory's philosophy has had on trainees, we surveyed our alumni in February 2015. Of the 280 (90%) alumni for whom contact information could be obtained, we received 215 responses (77%). Despite their different backgrounds, training levels, and amount of time spent in the laboratory, almost all respondents (212; 99%) expressed full satisfaction with their research experience, and nearly all (211; 98%) would recommend the laboratory to others (Table 4). The majority of respondents (203; 94%) were satisfied with the mentorship received, and their experience encouraged them to maintain a research component in their careers and to mentor others in a likewise fashion. Many alumni highlighted a number of aspects that contributed to their experience in the laboratory and their decision to remain in research. Multiple alumni wrote that working in a fun, caring, and positive environment was essential to their learning. Additionally, they reported a great sense of common purpose and support that helped enable them to persevere. Finally, many alumni were inspired to pursue academic medicine after seeing mentors who were successfully able to balance research with clinical duties and family.

## Concluding Remarks

The importance of a laboratory's philosophy in the success of a research laboratory cannot be underestimated. The Hunterian Laboratory's philosophy integrates principles of andragogy, mentorship, people-centered collaboration, a breadth of research interests, and a diversity of backgrounds to create a unique and successful environment for trainees interested in research. Because of this template, alumni have been satisfied with their work, which has included significant scientific advances, translational research success, and improvements in clinical outcomes.

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