

understand how the human brain functions and develop treatment strategies and interventions for human neurological disease.

Neuroscience Technology

Neuroscience is not just about disease but also about rapidly evolving technology in all sectors of the community, including business, healthcare, the military and civilian communities. Artificial intelligence, smart cities, neuromarketing and bionic limbs are just a few of the emerging neuroscience technologies. For instance, high priority opportunities for Army investment for neuroscience technologies include field deployable biomarkers of neural state, fatigue prediction models, models for head impact protection and threat assessment augmentation.^[4] ‘Commanders on the battlefield could benefit from decision support that alerts them in near real time to issues with personnel neural readiness, such as unexpectedly high levels of fatigue or sleep-deprivation deficits in individuals or across units.’^[4] In the civilian world, tracking reactions of humans as they navigate cities with mobile EEG devices may allow for the development of smart cities, which ‘may work to mitigate stress and anxiety disorders.’^[4]

The global neuroscience market was valued at over >\$24 billion in 2014, a value that is expected to increase by nearly 3% per year. North America constitutes 50% of the global market.^[5] The overall worldwide market for neurotechnology products (neuroprosthetics, neuromodulation, neurorehabilitation, and neurosensing) was projected to be \$7.6 billion in 2016 and reach \$12.0 billion in 2020.^[6] Areas of market growth include neuromodulation devices (i.e. for the treatment of obesity) and emerging applications for neurotechnology devices (i.e. migraine pain, and depression). This massive growth indicates a rapidly evolving field with high wage positions for PhD trained neuroscientists. These growth areas demand comprehensive knowledge from a neuroscience educated workforce – a knowledge our program will provide.

"The Brain State"

On May 6, 2016 Virginia Governor Terry McAuliffe signed a historic \$2.2 Billion Bond Package Bill that includes \$46.7 million dedicated to the Virginia Tech Carilion Research Institute to jumpstart a far-reaching Health Sciences and Technology Innovation District in Roanoke. “We are building a foundation for biotechnology and medical research that will establish Virginia as a hotbed for companies who want to be shoulder-to-shoulder with world-class collaborators and a highly trained technical workforce,” said Virginia Gov. Terry McAuliffe. “This is a cornerstone of a new Virginia economy and will position the Commonwealth as a national leader in advanced research.”^[7] Officials hope to see this partnership with Carilion Clinic and Virginia Tech as a launching point so that the commonwealth can more easily attract investors and partnerships as it earns its new reputation of being the “Brain State.”

A partnership between the Virginia Tech Carilion Research Institute (VTCRI) with ground breaking translational Neuroscience research and the substantial investment in the School of Neuroscience promises to raise awareness of Neuroscience research occurring in southern central

⁴ *Opportunities in neuroscience for future army applications*, National Research Council, 2008

⁵ <http://www.grandviewresearch.com/industry-analysis/neuroscience-market>

⁶ <http://www.neurotechreports.com/pages/execsum.html>

⁷ <http://wsls.com/2016/05/06/gov-mcauliffe-signs-bond-bill-works-to-dub-va-as-brain-state/>

Virginia, again aligning with the University Strategic Plan to create ‘a distinctive profile of progressive and internationally recognized research.’ Furthermore, the increased density of Neuroscientists between the two locations will enhance the experience of graduate students with an interest in neuroscience across the two campuses by:

- 1) a larger breadth of Neuroscience research
- 2) increasing opportunities for access to external experts invited as speakers
- 3) increase the number of Neuroscience related seminars, journal clubs and graduate elective courses
- 4) finally and most importantly, provide a strong sense of community between a group of individuals which as future colleagues are likely to contribute to the future of Neuroscience research, policy and healthcare.

Student Demand

Graduate Education

On a national level, the field of neuroscience finds itself in an era of exceptional growth and popularity. Therefore, it is not surprising that for the past decade, the number of new neuroscience PhD graduates has outpaced every other life sciences discipline.⁸

This demand is reflected on the Virginia Tech campus. Student demand for the new PhD program in Neuroscience at

Virginia Tech is high. This is evidenced by 1) the tremendous growth of the Neuroscience undergraduate student body at Virginia Tech and 2) the high volume of email communication between our faculty/staff and potential PhD applicants interested in information regarding a Neuroscience PhD degree from Virginia Tech.

Neuroscience growth at Virginia Tech: The first undergraduate Introduction to Neuroscience course was offered at Virginia Tech in 2013 before the establishment of the School of Neuroscience. This course had 33 registered undergraduate students. The demand for this course has increased exponentially since the approval of the Neuroscience undergraduate degree with 242 registrants in the Fall 2017 and over 600 current declared Neuroscience majors as of January 2018. Notably, many neuroscience undergraduate students are actively engaging in research opportunities in preparation for graduate study. In the Fall 2017, nearly 60 undergraduate students registered for 'Undergraduate Research' with Neuroscience research faculty in the

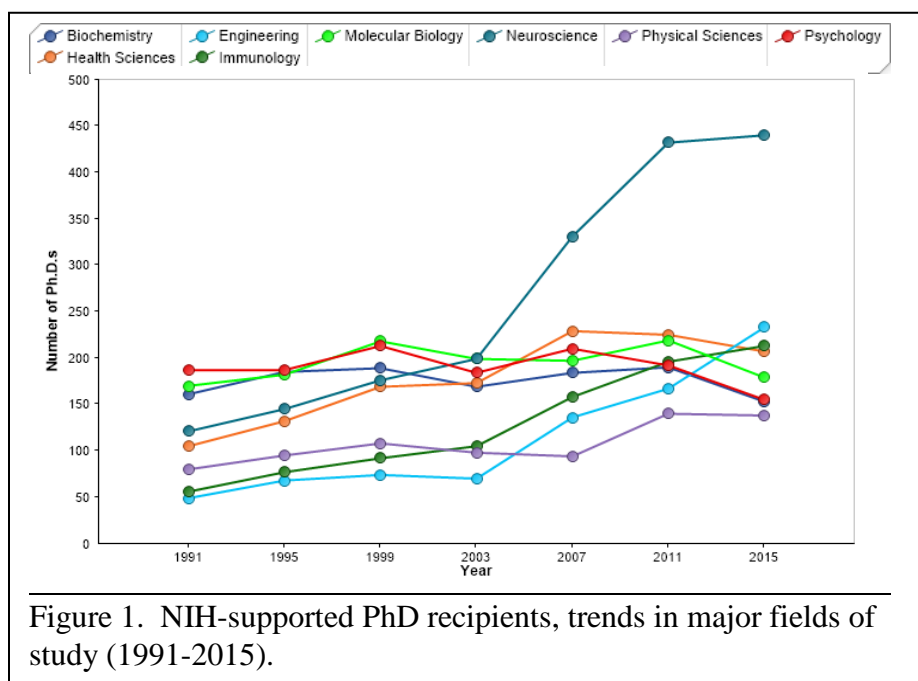


Figure 1. NIH-supported PhD recipients, trends in major fields of study (1991-2015).

⁸ <https://report.nih.gov/nihdatabook/charts/Default.aspx?chartId=267&catId=21>

School of Neuroscience, Biological Sciences, Animal Poultry Sciences, Biomedical and Veterinary Sciences and the Carilion Research Institute. The vast majority of these students (53) have declared Experimental Neuroscience as their major which prepares students for a 'hands-on' career in academic science with a primary goal to matriculate students into graduate studies.

Additional evidence of interest in a Neuroscience PhD program at Virginia Tech stems from applicants for the new Molecular and Cellular Biology Program at Virginia Tech (mcb.vt.edu). This is an interdisciplinary PhD graduate program with four regions of specialization; Cell Signaling and Cancer, Inflammation and Immunity; Microbiology; and Neurobiology. Over 50% of applicants for the start of the 2018 fall class declared Neurobiology as their primary interest.

Finally, the faculty in the School of Neuroscience have written a large number of letters of recommendation for Neuroscience majors (graduation date spring 2018) whom are seeking PhD graduate studies in the field of Neuroscience.

Market/Employer Demand

Neuroscience is a discipline that ascends conventional disciplinary boundaries, generating students that provide modern solutions to the most important questions in the life sciences. Employment opportunities for Neuroscience students are therefore widespread and include a number of careers in the life sciences that range from software design, publishing, consulting, public policy, and communication, the rapidly growing fields of neurotechnology and neuroinformatics and opportunities to specialize in conventional disciplines such as genetics, and psychology.

Moreover, there is an increasing need to communicate neuroscience information at all levels, from editing scholarly journals to educating the public. On a national level, there is an increasing need for informed regulators and policy makers. The growth of the field, together with commercialization of new products and services, will result in the expansion of career opportunities in the public and private sector, including bench scientists, entrepreneurs, analysts, consultants, and intellectual property experts. Graduates of the program will be qualified for a number of positions where a PhD in neuroscience is required or preferred, including:

- Postdoctoral Fellow or Instructor at a College, University, or Academic Health Center
- Research Scientist in the Pharmaceutical or Biotechnology Industry
- Research Scientist or Health Science Administrator in a Government Agency
- Non-research position where biomedical/health expertise and excellent communication skills are required, such as: science writer, editor, or journalist; patent agent; health science administrator at a university/government/hospital or other non-profit; public policy analyst; scientific consultant

On a national level: The U.S. Bureau of Labor Statistics (BLS) does not currently have a separate designation for PhD in Neuroscience. Nonetheless, other relevant employment categories in the BLS are appropriate for graduates holding a PhD in neuroscience.⁹ The projected job growth for all categories listed below, except Biomedical Engineer's, exceeds average national job growth which is 7%, indicating increasing demand in each of these fields. PhD's in neuroscience may fall into any of the categories listed below.

⁹ <https://www.bls.gov/ooh/> (once on the site, enter the job title or the SOC code) accessed February 2018

Job Title	SOC Code	Employment 2016	Projected Employment 2026	Percent Change 2016-2026	2016 Median Pay
<i>Medical scientists</i>	19-1042	120,000	136,100	13%	\$80,530
<i>Computer and information research scientists</i>	15-1111	27,900	28,300	19%	\$111,840
<i>Natural sciences managers</i>	11-9121	56,700	62,300	10%	\$119,850
<i>Biological Science Post-secondary teachers</i>	25-1042	62,300	71,700	15%	\$75,430
<i>Education administrators, postsecondary</i>	11-9033	180,100	198,300	10%	\$90,760
<i>Biochemists and biophysicists</i>	19-1021	31,500	35,100	11%	\$82,180
<i>Biomedical engineers</i>	17-2031	31,300	22,800	7%	\$85,620

Table 1. Employment Projections 2010 - 2020 (U.S. Bureau of Labor Statistics)

These statistics are born out in data from popular national job search engines. Current data from Indeed.com and Simplyhired.com indicates 500 - 600 current positions using the key words 'Neuroscience and PhD' with a mean income of \$82,325 (data obtained February 2018).

In the Commonwealth: According to the Virginia Economic Development Partnership (VEDP), Virginia's Life Sciences Industry employs over 25,400 people at more than 1,000 businesses. Research, Testing, and Medical Laboratories account for 46% of Virginia's Life Sciences employment and 32% of its businesses.¹⁰ Competitive operating costs, a business-friendly environment and a highly skilled workforce are driving Virginia's growing bioscience sector and fostering discoveries every day. Progressively, leading pharmaceutical, medical device and biotechnology firms are choosing to locate or develop their businesses in Virginia. This is likely due to the innovative research universities, numerous federally funded facilities, and renowned research institutes, as well as major manufacturers including Merck, Abbott, Teva, Novozymes Biologicals and Fareva.

The U.S. Bureau of Labor Statistics (BLS) provides occupation profile by state.¹¹ Again, the projected job growth for many of these careers that an individual holding a PhD in Neuroscience might chose show substantial positive projections.

Job Title	2014 Employment	2024 Employment	Percent Change 2014-2024	Annual Median Wages 2014
<i>Medical Scientists, Except Epidemiologists</i>	1,990	2,280	15%	\$94,420
<i>Computer and Information Research Scientists</i>	1,800	1,880	4%	\$119,810
<i>Natural Sciences Managers</i>	1,370	1,400	3%	\$120,630

¹⁰ <http://www.yesvirginia.org/KeyIndustries/LifeSciences>

¹¹ <https://www.careeronestop.org/Toolkit/Careers/Occupations/occupation-profile.aspx> (at site, enter SOC code or job title and state)- accessed February 2018

<i>Biological Science Teachers, Postsecondary</i>	1,590	1,940	22%	\$61,010
<i>Education Administrators, Postsecondary</i>	2,690	3,080	14%	\$90,760
<i>Biochemists and Biophysicists</i>	620	720	16%	\$85,360
<i>Biomedical Engineers</i>	370	460	25%	\$77,720

Table 2: Employment Projections 2010 - 2020 (Virginia Employment Commission)

Issues of Duplication*Statewide duplication*

Three PhD programs in the state of Virginia offer PhD programs in Neuroscience with CIP 26.1501. These include the Neuroscience graduate program at Virginia Commonwealth University (VCU), the Neuroscience PhD graduate program at George Mason University (GMU) and the Neuroscience PhD program at the University of Virginia (UVA). Given the strong interest over the last two decades in the field of Neuroscience, it makes sense at this time, with the massive growth of the undergraduate program on the Virginia Tech campus, that VT would develop a competitive Neuroscience PhD program. Like Biology, Biochemistry, Psychology, the Physical Sciences and Engineering, which are all represented at the PhD level at UVA, VCU and GMU, so Neuroscience has become a fundamental component of undergraduate and graduate education.

Enrollments¹²	Fall 2013	Fall 2014	Fall 2015	Fall 2016	Fall 2017
George Mason University	26	22	16	13	14
University of Virginia	35	32	30	32	32
Virginia Commonwealth University	25	23	23	24	19
Degrees Awarded¹³	2012-13	2013-14	2014-15	2015-16	2016-17
George Mason University	3	3	6	3	3
University of Virginia	6	7	5	4	7
Virginia Commonwealth University	3	2	3	3	4

Table. 3 Enrollments and Degrees Awarded at Comparable Programs in the Commonwealth

While there are similarities between the existing Neuroscience PhD programs in Virginia and the proposed program, several attributes of the proposed program render it unique.

- 1) Students entering the proposed program enter directly into the Neuroscience PhD program, enabling the core coursework to focus exclusively on Neuroscience. Additional restricted neuroscience electives chosen by the student and their committee enable unique neuroscience curriculum for each student.
- 2) The Neuroscience faculty in the School of Neuroscience and their specific areas of research are unique to these faculty.

¹² State Council of Higher Education for Virginia (SCHEV). *Fall Headcount Enrollment by Race/Ethnicity, Gender and Program Detail*. http://research.schev.edu/enrollment/E16_Report.asp. (Accessed [February 2018]).

¹³ State Council of Higher Education for Virginia (SCHEV). *Completion, Program Detail C1.2*. http://research.schev.edu/Completions/C1Level2_Report.asp. (Accessed [February 2018]).

- 3) Of the programs listed above, Virginia Tech is the only campus with a Neuroscience department (in this case, the School of Neuroscience). Instead faculty are interspersed in Pharmacology, Biology, Biochemistry, Psychology, etc. The large concentration of faculty, post-doctoral fellows, research technicians and support staff in the School of Neuroscience, coupled with the substantial undergraduate Neuroscience program will provide a distinctive experience for Neuroscience PhD seeking students.

Virginia Commonwealth University (VCU) PhD seeking students enter into a Biomedical Sciences Doctoral program at VCU. These students take Biochemistry, Cell and Molecular Biology during the first and second semester of the program. Students with a primary interest in Neuroscience also participate in Cellular and Molecular Neuroscience during the fall semester and Systems Neuroscience during the spring semester during year one. Research rotations are performed during the first year and can be in any discipline in Biomedical science. At the end of year one students formally transition to the PhD program in Neuroscience. The core curriculum in Neuroscience at VCU includes only two required graduate Neuroscience courses, differentiating VCU's Neuroscience PhD program from the proposed program.

University of Virginia (UVA) Students entering the PhD program in Neuroscience at UVA participate in an intensive course in integrative biosciences (BIMS 6000), laboratory rotations, and a seminar in Neuroscience during the first semester of year one. The core neuroscience curriculum begins during the second semester of year one and includes eight graded Neuroscience core credits. No other neuroscience courses, including electives are required.

George Mason University (GMU) The PhD program in Neuroscience at GMU is a 72 credit PhD program focusing on cognition and higher brain function. Students in this program take a core of 9 Neuroscience credits, a required statistics course (3-4 credits) and a research methods course (3 credits). Unlike the proposed program, students at GMU take an additional 20-21 credits of free electives graduate courses and only 24 credits of dissertation research.

Relationship to existing Virginia Tech programs

The Translational Biology Medicine and Health PhD (TBMH) program at VT is an integrative, research intensive, PhD program with a focus on translational science. The flagship first semester course for TBMH students is an 8 credit course training students in the general principles of a translational approach to basic biomedical and health sciences, biomedical interventions and health behavior and health care systems and delivery. At the end of the first semester students, choose a focus area (an additional 8 credits), which may include neuroscience, cancer, immunity and infectious disease, metabolic and cardiovascular science, development aging and repair or health implementation science. The TBMH program targets students with a broad interest in translational science. Strengths of the TBMH program include a strong foundation in principles of translational biology, medicine and health research, preparing their students to tackle some of the most challenging aspects of healthcare today. A similarity between the newly proposed program and a TBMH student that chooses a neuroscience track include an intensive, independent research project with a mentor whose research focus falls broadly into the field of Neuroscience. However, the two programs target different populations of students. Namely, the proposed program seeks students with a focused interest exclusively in Neuroscience. The core curriculum provides a comprehensive foundation in current aspects of

neuroscience. The series of core courses span from structure and function of cells to anatomy and systems neuroscience, development of the nervous system, and behavior. Upon completion of the core coursework, students will be prepared to investigate the genetic aspects of neurologic disease or the neural bases of various brain-behavior relationships including sensation, memory, attention, motivation and reward, emotion, decision-making, sleep, language and social cognition. No program in the state of Virginia and few across the nation that provide this holistic, 360-degree view of current topics in Neuroscience. All core and elective coursework offered as part of the Neuroscience PhD graduate program are unrestricted to students of existing VT graduate programs with an interest in Neuroscience, including TBMH Neuroscience Track, Psychology, Biomedical Engineering, and Biomedical Veterinary Sciences graduate programs.

Resource Needs/Savings

Program Director: The Neuroscience PhD graduate program will be managed by the program Director. The Director of the program will be a tenured faculty member in the School of Neuroscience. The director will oversee all aspects of program management but will work closely with committees comprising groups of tenure track faculty. Working together, the Director and committees will coordinate the curriculum, student advising, student research, marketing and recruitment, review application material and oversee the steering committee. The Program Director and all members of committees will be on a three-year rotation.

Faculty: The School of Neuroscience and the undergraduate major were recently established on the Virginia Tech campus (spring 2016). As such, it has undergone a tremendous growth phase over the last 18 months. This includes the addition of 10 tenure track faculty (1 full professor, 2 associate professors, 7 assistant professors). The School of Neuroscience is slated to hire an additional 5 tenure track faculty. Together, these faculty will provide research laboratories for PhD seeking students, instruct the proposed curriculum, and provide the majority of financial resources for stipends, tuition and healthcare.

Administrative Needs: The increased administrative duties for the proposed PhD in Neuroscience will be coordinated and managed within the existing framework and support of the School of Neuroscience. It is anticipated that one full time program administrator will be sufficient to manage the day to day activities for Neuroscience graduate programs. Web design and social media presence will be administered by the current School of Neuroscience web designer. Instruction will take place on the Blacksburg campus.

RESOURCE	ESTIMATED COSTS (use NA if not applicable)
Faculty	5 FTE by target enrollment year 2024-2025
Program Administrator	1 FTE by target enrollment year 2024-2025
Graduate Teaching/ Graduate Research Assistants	GRA's will be supported by grants and contracts written by faculty, and by faculty start up funds. Neuroscience PhD students may also be supported by School of Neuroscience allocated GTA positions.
Space	N/A
Library	N/A
Equipment	N/A
Other	N/A