Neuroscience at Penn State

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The growing consensus among both scientists and the public that few things in life are more important than a complete understanding of what drives our behavior has fostered interest in neuroscience worldwide and at Penn State. Further support is based on the promise that progress in neuroscience can some day help to remedy the increasing prevalence and socioeconomic cost of neurological and psychiatric disorders of the brain. A recent detailed cost analysis of brain diseases in Europe has concluded that, on average, 23 percent of the years of healthy life are lost to diseases of the brain. Furthermore, among the years of life lived with disabilities, 50 percent are due to disorders of the brain (Olsen and Leonard, 2003). The most common causes for disabilities are—in decreasing order of socioeconomic impact—uni- and bipolar depressive disorders; Alzheimer’s and other forms of dementia; diverse forms of drug abuse, particularly alcoholism; schizophrenia; epilepsy; stroke; and diverse forms of congenital neurological disorders, as well as accidental injuries of the brain and spinal cord. Even more disturbing, there is strong evidence that the prevalence and economic burden of these disorders is rapidly increasing as a function of the aging population and the continuing change in life style.

What is Neuroscience?

A clear definition of neuroscience may be elusive because the term is meant to be all-inclusive and therefore can mean different things to scientists from different fields. The term includes all the scientific disciplines concerned with the development, structure, function, chemistry, pharmacology, clinical assessment, and pathology of the nervous system. With special reference to the human brain, neuroscience tries to explain in molecular and cellular terms the mechanisms of learning and memory, consciousness, and the molecular basis of emotions. Acquiring a thorough understanding of brain function at this level undoubtedly represents one of biology’s greatest remaining challenges.

The Emergence of Neuroscience as a Scientific Discipline

During the 20th century, one of the most significant developments within the life sciences was the rapid growth of scientific disciplines known as neuroanatomy, neurophysiology, neurology, the behavioral sciences, and physiological psychology (for a comprehensive review see Cowen et al. 2000). The roots of these scientific subjects go back to three or four decades near the turn of the 19th century, which were shaped by a number of highly influential scientists including the neuroanatomist Ramon y Cajal (1852–1934), the physiologist Charles Scott Sherrington (1857–1952), the neurologist Charcot (1825–1893), the neurologist Hughlings Jackson (1835–1911), the developmental neurobiologist Wilhelm His (1831–1904), and finally, John B. Watson and Burrhus Frederic Skinner (1904–1990), the founders of behaviorism. As an objective and scientific approach to psychology, behaviorism eventually gave rise to cognitive neuroscience. With their varied but rigorous scientific approaches to studies of the nervous system, these scientists each in their own way contributed to the establishment of their field as an independent neuroscience discipline. Numerous dramatic and influential discoveries followed throughout the 20th century. They include the discovery of nerve-growth factor as a first target-derived substance that was able to promote the survival of neurons, the publication of the first electron-microscopic images confirming the existence of electrochemical synapses, and the elucidation of the subunit structure of the nicotinic acetylcholine receptor as an ion channel that mediates synaptic transmission. However, while each of these discoveries represented seminal contributions to the respective specialty field, they tended to be descriptive and technology driven, and their impact was limited mostly to the respective specific discipline. The discoveries of Ramon y Cajal had no influence on the thinking of Watson and Skinner, and vice versa.

The Origin of Modern Neuroscience

Compared to the traditional neuroscience disciplines described above, modern neuroscience differs dramatically in that it represents a paradigm of interdisciplinary and multidisciplinary research. Many of the triggers to integrate the different areas of neuroscience came from basic biological disciplines not traditionally associated with neuroscience. These triggers include the discovery of DNA as the inheritable substance of all living beings by Watson and Crick (1953); the gradual realization that much about the structure, function, and development of the mammalian nervous system can be learned from studying simple animal models that are amenable to efficient genetic manipulation; and subsequently, the enormous progress made in gene technology and the ease by which such technology could be transferred between laboratories and applied to problems of neuroscience. Thus, DNA technology has not only facilitated the emergence of a universal language of biochemistry, cell biology, developmental biology, molecular biology, and genetics, but it also has made problems of neuroscience broadly amenable to scientific investigation by all kinds of biologists. As part of a concerted worldwide effort, molecular cloning and genetic approaches have led to the identification of the underlying causes of virtually all the major inheritable nervous-system disorders that are due to changes in single genes. A single historical event that has been equated with the birth of modern neuroscience was the foundation of the first Department of Neurobiology in the United States at Harvard Medical School in 1966.
The formation of similar departments at other universities soon followed, along with the foundation of the Society for Neuroscience, which is still the largest and most prestigious professional organization of neuroscientists. The dramatic increase in attendance at the annual meeting of this society from 600 registered participants in 1968 to over 34,800 in 2005 is characteristic of the expansion of neuroscience research in recent history. The scientific breadth of neuroscience is further illustrated by the fact that this branch of the life sciences is represented at the National Institutes of Health by 11 of its 20 different Institutes (NINDS, NIMH, NICHD, NIDCD, NEI, NIDCR, NIA, NIAAA, NIDA, NHGRI and NCI).

Human neuroscience experienced major progress from improvements in diverse imaging methods such as Positron Emission Tomography (PET) and functional Magnetic Resonance Imaging (fMRI) and major improvements in microsurgery techniques. These techniques have led to dramatic progress in the diagnosis and neurosurgical treatment of epilepsy and brain tumors, and have aided the construction of topographical maps for all kinds of brain functions. At the other end of the spectrum, some of the most astounding advances have come from analyses of diverse animal models, including electrophysiological studies relevant for learning and memory in the sea slug *Aplysia*, genetic screens for genes underlying development of the nervous system in the fruit fly *Drosophila melanogaster*, and analyses of laboratory mice engineered to allow conditional manipulation of gene products relevant for behavior. Each of the different animal models used in neuroscience research has specific technical advantages and limitations. Importantly, many of the basic biological principles uncovered by studies in animal models were shown, time and again, to be functionally conserved from snails to flies to mammals. Studies in animal models, thereby, have contributed greatly to the rapid advancement of neuroscience and likely will continue to provide a rich source of discoveries for many years to come. Already, the concerted multidisciplinary effort has led to remarkable progress in areas of neuroscience that seemed virtually untouchable just twenty years ago. In particular, sophisticated genetic manipulation of mice, in combination with electrophysiological, pharmacological, biochemical, and behavioral testing, has identified some of the molecular substrates of learning and memory. Transgenic mice also have elucidated the etiology of neurological, neurodegenerative, and psychiatric disorders, and have uncovered the molecular and cellular brain substrate of psychoactive drugs. Thereby, neurobiology has merged with physiological psychology and psychiatry.

The combination of molecular genetics and behavioral techniques enabled researchers to describe the molecular principles underlying mechanisms of pair-wise attachment (a conceptual equivalent of love in rodents) and elucidated the molecular mechanism by which changes in maternal behavior affect inherited mechanisms of gene expression in pups that are not associated with the sequence of their DNA (epigenetic mechanisms), thereby affecting their brain development and behavior in adulthood. The multidisciplinary possibilities seem indefinite, such that neuroscience now involves all possible combinations of approaches that in one way or another contribute to the common goal of a better understanding of brain function.

**The Challenges and Potentials of Neuroscience as a Multidisciplinary Research Entity**

As evident from this historical background, modern neuroscience now spans the borderland of the natural sciences and the humanities, two camps of academia that traditionally have found themselves on opposite sides of a seemingly impassable cultural fault line. Furthermore, traditional disciplines of neuroscience such as neurology, neuroanatomy, and neurophysiology have originated as subfields of the medical sciences and thus tend to be associated with clinical departments at medical schools. While much of the recent intellectual drive in neuroscience research has come from basic science departments, which often are separated physically from medical schools, they have been quick to adopt the language of molecular biology and genetics to prob-

While neuroscientists have come a long way in bridging these divides, further unifying the language of communication and the removal of organizational and physical barriers between clinical and basic scientists holds the promise for major progress in the future. In addition, tremendous opportunities exist in integrating scientific disciplines and techniques that so far have played only marginal roles in neuroscience. In other words, the list of scientific disciplines that are now an integral part of modern neuroscience is by no means complete and the boundaries, if they exist, will continue to expand. For example, significant progress is expected from technical advancements in physics in the development of new higher-resolution imaging techniques, which are needed to study the function of proteins and neurotransmitters in individual living nerve cells in their normal context—optical imaging of live cells and tissue and functional magnetic-resonance imaging of living subjects.

Further, a major limitation in modern biology, not just in neuroscience, is the wealth of data available that remain unexplored for scientific information. Help is expected here from interactions with experts in computational biology and bioinformatics.
Neuroscience at Penn State Now

At Penn State, neuroscience research is scattered across many departments in six different colleges, including the College of Medicine at the Penn State Milton S. Hershey Medical Center and five colleges at the University Park Campus: the Eberly College of Science and the Colleges of Health and Human Development, Liberal Arts, Engineering, and Agricultural Sciences. Colin Barnstable, professor and head of the Department of Neural and Behavioral Sciences, and I currently serve as co-directors of the Penn State Neuroscience Institute, which was established in 2004 to coordinate research, education, and outreach activities among all these colleges and their departments.

Based on faculty participation in the newly established cross-campus Intercollege Graduate Degree Program in Neuroscience, research in the area currently is represented by 78 laboratories that are distributed roughly evenly between the Penn State Hershey Medical Center and the University Park Campus. While the origins of neuroscience at the Medical Center predate the beginning of graduate education in 1984 at the College of Medicine, the first sign of an organized neuroscience initiative at the University Park campus goes back no further than 1993, when Jonathan Day in the Department of Biology, Byron Jones in the College of Health and Human Development, and Andy Ewing in the Department of Chemistry came together to establish the first two undergraduate courses in neurobiology. This initiative was followed in 1996 by the foundation of the neuroscience option of the Integrative Biosciences (IBIOS) graduate program and by a gradual increase in the hiring of neuroscience faculty across all six colleges involved. Notably, among the current 34 faculty members of the Intercollege Graduate Degree Program in Neuroscience with appointments at University Park, all but four have joined Penn State within the last eleven years. Thirteen neuroscience faculty members currently hold an appointment in the Eberly College of Science, which makes this college the most prominently represented in the neurosciences at this campus. The research conducted by Eberly College of Science faculty is recognized as very timely and highly competitive for extramural funding and, as a result, our college is expected to play a leading role in the planned expansion of the neuroscience program and in the continuing evolution of neuroscience research and education as a rigorous biological-science discipline at Penn State.

Neuroscience at Penn State in the Future

The biological and biomedical sciences are among the scientific enterprises with the highest intellectual, practical, and economical influence on the future of our society. With neuroscience at the center of the life sciences, major research universities with aspirations for national prominence are competing for scientific influence and economic reward in this area. There has been significant growth in neuroscience at Penn State, and efforts are continuing in building a larger and more competitive neuroscience community here. These efforts include initiatives to strengthen the foundation for the neuroscience discipline at Penn State, as well as strategies for taking advantage of Penn State’s unique academic strength in physics and material science for collaborative research projects with the Penn State neuroscientists.

Following the recommendation of the University-wide Neuroscience Advisory Committee, Penn State has recognized that significant new resources are required to develop neuroscience as a major research enterprise. The formation of the Penn State Neuroscience Institute within the Huck Institutes of the Life Sciences in 2004 was a strong first step in this direction. The institute is expected to develop into an administrative home for teaching, research, and outreach services across the broad array of neuroscience-related disciplines, both at the University Park campus and at the Medical Center. Some goals of the institute include the enhancement of core facilities such as our biological imaging facilities, the enhancement of the newly formed Intercollege Graduate Degree Program in Neuroscience, and other new initiatives in undergraduate and graduate education. The plan for expansion includes hiring 30 to 40 new neuroscience faculty over the next ten years. A physical home for the Penn State Neuroscience Institute with ample space for new hires in neuroscience research is planned in the new Life Sciences/Material Sciences building at University Park, scheduled to be completed in 2009.

In summary, neuroscience is an exciting and rapidly evolving scientific discipline. With plans for improvement of infrastructures and increase in faculty, neuroscience is expected to become a highly progressive force in basic and biomedical research at Penn State.

Citations:
