

IMPACT OF NEUROSCIENCE IN HUMAN DEVELOPMENT

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Keywords: Neuroscience, human development, artificial intelligence, consciousness, brain, peripheral nervous system, neuron, neuronal signaling, action potential, synaptic transmission, neuronal circuits, neuronal differentiation, axon guidance, synapses plasticity, sensation, perception, learning and memory, emotion, neurological disease, biochip, human genetic pool

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Summary

A better understanding of the impact of neuroscience on human development is essential for people to understand better the topography and course of the present scientific revolution. Neuroscience is one of the frontiers in the study of the structures and functions of the nervous system (especially the brain) in health and illness. Recently, it has become one of the fastest growing fields in science. Knowledge gained from neuroscience provides much more accurate answers to questions about human beings than other approaches, and also affects human society in many other ways.

1. Introduction

“Men ought to know that from nothing else but the brain come joys, delights, laughter and sports, and sorrows, grieves, despondency, and lamentations. And by this, in an especial manner, we acquire wisdom and knowledge, and see and hear and know what are foul and what are fair, what are unfair, what are bad and what are good, what are sweet and what are unsavory...And by the same organ we become mad and delirious,

and fears and terrors assail us...All these things we endure from the brain when it is not healthy...In these ways I am of the opinion that the brain exercises the greatest power in the man.” (Hippocrates, *On the Sacred Disease*, Fourth Century BC).

For thousands of years, people have been asking questions about the human being. How do we perceive the world around us? How do we see, hear and smell? How do we learn from past experience? How do we store and recall information derived from those experiences? How do we determine when to act and what actions to carry out? Why do some things feel good and others hurt? What is the nature of anger and madness? What is consciousness? What is intelligence? What is the seat for the soul? How are those aspects of human lives that most specifically define humanity instantiated in the function of the brain? What are the reasons behind these brain diseases? How can we cure them? These are but some of the questions being asked, and neuroscience is in the frontier of disciplines seeking the answers.

Except for satisfying curiosity and the constant hunger for knowledge, a more significant role of neuroscience lies in its contributions to human development. A general goal for human development is to enhance the quality of life. The concept of “quality of life” is determined by a set of many interrelated factors that cut across many disciplines with varied perspectives and paradigms. As discussed in the theme article for this section (see chapter *Sustainable Human Development in the Twenty First Century: An Evolutionary Perspective*), these factors include the prevailing culture, health status, economic performance, political and social conditions, building of human capacity and capabilities, and institutional development, among others. People expect to live longer, healthier and more productive lives. They should be able to enjoy good health, have access to knowledge and educational opportunities, and be treated with respect, in a socially equitable and dignified manner.

Discovering the truth about the human being itself is one of the essential issues for that purpose. In the twentieth century, biomedical research has been established as one of the major forces that are pushing human development forward. Advances in medical science have greatly improved survival and health status around the world. People are expecting to live much longer than before. According to WHO statistics for 1999, while the world’s population grows at an annual rate of 1.7%, the population aged over 65 increases by 2.5% per year. The fastest growing populations in most countries of the world are those of the oldest old. Now, too much attention should perhaps not be paid to causes of death at the oldest ages, but rather to the fact that there is an urgent need to improve the disability-adjusted life years (DALY) for the population. The DALY has brought a critical reality to light, and has shown that psychiatric disorders and neurological diseases are amongst the most important contributors to the global burden of the diseases, and a great danger for the quality of life. For the younger generations, mental retardation, and numerous neuronal and psychiatric diseases, are even more damaging.

At present, discoveries from the neuroscience field not only benefit the biomedical field, but also affect the whole of human society in many other different ways. For example, the development of neural network computer programs was stimulated by basic neuroscience research on neuronal assembly. This brought about a technological

revolution. Combined with the increasing computing powers of modern computers, neural networks have been used in the fields of banking, pattern recognition, speech recognition, industries, and national defense, among others. Furthermore, those systems of artificial intelligence keep absorbing and building upon new findings from basic research in neuroscience.

The twenty-first century will be a high-tech overwhelmed century. It is an open question as to what destination the marriage of technology and neuroscience will lead human society. Scientists are now able to create smarter mice by manipulating a certain DNA sequence code for a protein subunit called NR2B, that makes part of NMDA receptors. By mating homozygous smarter mice, Tsien's group (Tang et al. 1999) has been able to produce generations of smarter mice, able to show improved intelligence in several tests. An interesting fact is that the DNA sequence of the mouse gene manipulated in these studies is 98% identical to that of humans, suggesting that if altered in humans, it might make them more intelligent. Human civilizations are based on the extraordinary power of human intelligence. If there is a way to enhance intelligence, then it may not be surprising to see a change in the evolution of human societies. Therefore, scientific findings from research groups such as that of Tsien might have lasting effects on human development.

Little by little, discoveries in the neuroscience field allow people to go further and further in understanding the workings of the brain—mind and consciousness. Can we be sure that the mind will survive explanation—that just as a rose's perfume, even when its molecular structure is deduced, it will still smell as sweet? Instead of going forward blindly, people are trying to understand better the topography and course of the symbolic cultural revolution in order to reduce its negative externalities, introduce purpose, and be able to plan for better human development in the twenty-first century.

The remainder of this article describes how neuroscience has established its position as a contributor to human knowledge, and discusses the impact it has had in the past, and may have in the future, upon the development of human individuals as well as upon the development of the whole of human society.

2. Neuroscience Before the Twentieth Century

Before the twentieth century, most of the knowledge about neuroscience was not firmly established. For example, fundamental questions were repeatedly raised about the seat of the soul, the way we perceive the world around us, the reason for our seeing, hearing and smell, the mechanism for learning from past experience, and for storing and recalling information derived from those experiences, and the way that we determine when to act and what actions to carry out. All kinds of answers were given and believed in for a long time, based on culture, and without scientific foundation. However, some key discoveries made before the twentieth century became the foundations for the development of modern neuroscience. For example, it was already considered that the brain is the seat for the soul. It had also been established that different structures in the brain were responsible for the sensations and movements of the body, as well as for learning and memory. Furthermore, the basic unit of the nervous system, the neuron, was discovered and studied before the twentieth century.

2.1 Structure of the Nervous System

As early as the fourth century BC, the father of the Western medicine, Hippocrates, had already stated his belief that the brain not only was involved in sensation, but was also the seat of intelligence. During the time of the Roman Empire, a Greek physician and writer, Galen, through animal dissections, tried to deduce function from the structure of the brain. From his observations, Galen concluded that the cerebrum must be the recipient of sensations, and the cerebellum must command the muscles, and that to form memories, sensations must be imprinted onto the brain. Through observations of patients who had brain injury, and the study of dissected animals, the basic structure of the nervous system had been intensively studied before the twentieth century.

The nervous system of all mammals has two divisions: the central nervous system and the peripheral nervous system. The central nervous system consists of the parts of the nervous system that are encased in bone: the brain and the spinal cord. The brain lies entirely inside the skull. A side view of the brain reveals three parts: the cerebrum, the cerebellum, and the brain stem.

The cerebrum is the largest part of the brain. It is split down into two cerebral hemispheres by a sagittal fissure. In general, the right cerebral hemisphere receives sensations from, and controls movements of, the left side of the body, while the left side of the cerebral hemisphere is concerned with sensations and movements on the right side of the body.

The cerebellum is primarily a movement control center having extensive connections with the cerebrum and the spinal cord. In contrast to the cerebral hemispheres, the left cerebellar hemisphere is concerned with movements of the left side of the body, and the right cerebellar hemisphere is concerned with movements of the right side of the body.

The brain stem is a complex nexus of fibers and cells that in part serve to relay information from the cerebrum to the spinal cord and cerebellum, and vice versa. The brain stem is the site where vital functions are regulated, such as breathing, consciousness, and the control of the body temperature. Damage to the brain stem usually means rapid death.

The spinal cord is encased in the bony vertebral column and is attached to the brain stem. The spinal cord is the major conduit of information from the skin, joints, and muscles of the body to the brain, and vice versa. A transection of the spinal cord results in anesthesia in the skin and paralysis of the muscles in parts of the body caudal to the cut.

The peripheral nervous system (PNS) has two parts: the somatic PNS and the visceral PNS. All the spinal nerves that innervate the skin, the joints, and the muscles that are under voluntary control, are parts of the somatic PNS. The visceral PNS, which is also called the involuntary, vegetative, or autonomic nervous system, consists of the neurons that innervate the internal organs, blood vessels, and glands. Visceral sensory axons bring information about the visceral function to the CNS, such as the pressure and oxygen content of the blood in the arteries. Visceral motor fibers command the

contraction and relaxation of muscles that form the walls of the intestines and the blood vessels, the rate of the cardiac muscle contraction, and the secretory function of various glands.

2.2 Neurons

As an organ, the brain consists of cells—neurons and glia. The special functions of the cells and how they interact specify the functions of the brain.

Early in the nineteenth century, the compound microscope and the development of methods to slice organs and fix tissues spawned a field called histology. This led to the study of the brain by using the microscope. “The gain in brain is mainly in the stain.” Nissl stain allows the neurologist to distinguish neurons and glia from one another, and to study the arrangement, or cytoarchitecture, of neurons in different parts of the brain. The study of cytoarchitecture led to the realization that each region performs a different function. Golgi stain shows that neurons have at least two distinguishable parts: a central region that contains the cell nucleus, and numerous thin tubes that radiate away from the central region.

Using Golgi stain, Ramon y Cajal was able to observe that neurons, in fact, are discrete cells, bounded by membranes, and inferred that nerve cells communicate with one another only at specialized points of appositions, contacts that Charles Sherrington was later to call synapses. Ramon y Cajal also showed an uncanny ability to infer from static images remarkable functional insights into the dynamic properties of neurons. One of his most profound insights, gained in this way, was the “principles of dynamic polarization.” According to this principle, electrical signaling within neurons is unidirectional: the signals propagate from the receiving pole of the neuron—the dendrites and the cell body—to the axon, and then, along the axon to the output pole of the neuron—the presynaptic axon terminal.

Modern neuroscience was founded based on these fundamental findings.

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Biographical Sketch

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