Unit 3: The Nervous System

Introduction

Everything you do, everything you feel, every thought that you have, every sensation that you experience, involves the activity of your nervous system. Your nervous system is composed of well over 100 billion cells called neurons, and neurons have one particular characteristic that makes them so special—they are able to communicate with each other. Your nervous can therefore be thought of as an amazingly complex communications network, a network whose operation can only be understood by understanding how neurons send signals to one another. In this unit, we will study how neurons communicate with each other, and the way in which the nervous system as a whole is organized. We will then take a tour of the brain, looking at its different parts and the functions that they serve, and then will discuss some issues regarding brain functioning and some common misconceptions about the brain.

READING: Chapter 4

Read before or as you progress through the lesson.

In this unit, we will be looking at the following topics:

1. The Basic Unit of the Nervous System: The Neuron
2. Structure of the Nervous System
3. A Tour of the Brain—1
4. A Tour of the Brain—2
5. Issues and Misconceptions
Part 1: The Neuron (pp. 105–114)

Parts
Dendrites: Receivers of signals
Axon: Transmitter
Axon terminals, synaptic knob, myelin sheath

Synapse
Nerve impulses (action potentials)
Electrical transmission within cells
Chemical transmission between cells
Neurotransmitters
All-or-none law (lecture)
Coding information within the nervous system
  • Changes in RATE of signal production
  • Changes in WHICH neurons are involved
Drug effects: LSD and morphine (lecture)
Part 1 Lectures

All-or-None Law

**AUDIO LECTURE:** Click here for the lecture on the “All-or-None” Law as it applies to synapses.

Drug Effects

**AUDIO LECTURE:** Click here for the lecture on drug effects as they relate to LSD and morphine.
Part 2: Structure of the Nervous System (pp. 102–104)

Divisions
CNS: Brain and spinal cord
PNS: Peripheral nervous system
Nerve: A bundle of axons in the peripheral nervous system
Somatic PNS: Motor and sensory nerves
Autonomic PNS

Spinal Cord and its Functions (lecture)
Information transmission
Spinal reflexes: A model of a simple brain
  - Sensory input translated into adaptive motor output
  - Balance of excitation and inhibition
  - Interactions with other parts of the nervous system
An adaptive spinal reflex: Praying mantis copulation (lecture and video segment)
Part 2 Lectures

Spinal Cord

**AUDIO LECTURE:** Click here for the lecture on the Spinal Cord and its Functions.

An Adaptive Spinal Reflex

**VIDEO:** Click here for the video on an adaptive spinal reflex as demonstrated by praying mantis copulation.
Part 3: A Tour of the Brain I (pp. 118–122)

WEBSITE ACTIVITY: For wonderful pictures of the brain and its parts, check out the Whole Brain Atlas.

Mapping the brain
Lesion method
Brain stimulation: Needle electrodes
PET scans and MRI

The brain stem
Pons: Some regulation of states of consciousness
Medulla: Basic life support functions

Cerebellum
Helping to regulate posture and movement (lecture)

Thalamus
The sensory switching station

Hypothalamus and limbic system
Regulating basic motivation and emotion
Pleasure centers in the hypothalamus
Our biological clock
Regulating the endocrine system

Amygdala
Regulating the flight or fight response

Hippocampus
The gateway to storage of conscious memories
Part 3 Lectures

Cerebellum

**AUDIO LECTURE:** Click here for a lecture on the cerebellum’s role in regulating posture and movement.
Part 4: A Tour of the Brain II

WEBSITE: For wonderful pictures of the brain and its parts, check out the Whole Brain Atlas.

Cerebral Cortex (pp. 122–130)

Humans do not have the largest brains of any species. The large whales, for examples, have larger brains than do humans. Humans, however, have the largest brains relative to body size of any species. And the largest part of the human brain is the cerebral cortex.

Lobes, Hemispheres, Corpus Collosum

Primary Sensory Motor Areas (lecture)
Visual and auditory cortex
Motor and somatosensory cortex
Mapping the body
Phantom limbs (video segment)

Association Areas: Evidence from Cortical Damage (lecture)
Apraxia: Disordered motor planning and execution
Agnosia: Disordered visual recognition
Prosopagnosia: Disordered face recognition (video segment)
Aphasia: Disordered language ability
  • Expressive: Broca’s area
  • Receptive: Wernicke’s area
Prefrontal cortex: Planning and personality (lecture)
The curious case of Phineas Gage (video segment)

Hemispheric Specialization (pp. 126–130)
Research with split-brain patients
Left: verbal skills, sequential analysis
Right: visual/spatial pattern analysis
Part 4 Lectures

Primary Sensory Motor Areas

**AUDIO LECTURE:** Click here to hear the lecture on primary sensory motor areas.

Phantom Limbs

**VIDEO:** Click here to see the video segment on phantom limbs.

Association Areas: Evidence from Cortical Damage

The cerebral cortex in general makes up a larger percentage of the human brain than is the case for any other species. In addition, WITHIN the cerebral cortex, humans possess the largest percentage of cortex OUTSIDE the primary sensory-motor areas. These other areas of the cortex that are involved in the higher mental processes, are called association areas. Much of our knowledge of the functions of different association areas derives from studying people who have experienced damage to different parts of the cortex.

**VIDEO LECTURE:** Click here for the lecture on evidence from cortical damage.

Prosopagnosia: Disordered Face Recognition

**VIDEO LECTURE:** Click here for the video segment on disordered face recognition.

Prefrontal Cortex: Planning and Personality

**VIDEO LECTURE:** Click here to hear the lecture on how the prefrontal cortex guides planning and personality.

**VIDEO LECTURE:** Click here to learn about the curious case of Phineas Gage.
Part 5: Issues and Misconceptions

Where is conscious awareness?: The interpreter (p. 131) (lecture, video segment)

“His” and “her” brains? (pp. 132–134)

Do we only use 10% of our brains?

How does the brain change with age? (lecture)

Age changes: number of neurons, cell size, number of synapses, myelinization

Should we be teaching more to the right hemisphere? (lecture)

Activity: Are you left brained or right brained? Take the quiz! Then watch the lecture. (lecture)

Recovery from brain damage: The story of constraint-induced therapy (lecture)
Part 5 Lectures

Where is Conscious Awareness? The Interpreter

VIDEO LECTURE: Click here for the lecture on conscious awareness.

VIDEO: Click here for the video segment on conscious awareness.

How Does the Brain Change with Age?

AUDIO LECTURE: Click here for the lecture on how the brain changes with age.

[6-25-04—these lectures have now been collapsed since they're on the same video.]

Should We Be Teaching More to The Right Hemisphere?

AUDIO LECTURE: Click here for the lecture on teaching to the right hemisphere.

Are You Left Brained or Right Brained?

WEBLINK ACTIVITY: Are you left brained or right brained? Take the quiz!

VIDEO LECTURE: Click here to watch the video lecture on right brained and left brained.
Recovery from Brain Damage: The Story of Constraint-Induced Therapy

Stroke—damage to the brain caused by the blockage of blood vessels within the brain or bursting of a blood vessel within the brain—is a common cause of death. Even if the stroke patient lives, he or she is likely to experience significant impairment in some aspect of functioning. The specific nature of the impairment depends upon the specific location and the extent of the neurological damage.

Recovery early. Until recently, the accepted wisdom amongst neurologists and therapists was that most recovery from the effects of a stroke was likely to occur within the first six months following the stroke, and certainly by 18 months after the stroke the possibility of further recovery was considered remote. This view was based upon knowledge of the way in which the brain changes with age. Specifically, as you have learned already, neurogenesis (the process of forming new neurons) is essentially complete well before birth, and the peak period for formation of new synapses is prior to two years of age.

Accordingly, extended therapy for stroke victims—particularly those who have movement impairments (such as a very limited ability to use a particular limb)—has tended to focus on compensation rather than recovery. A patient who lost most of the ability to use his right hand and arm, for example, would work in therapy on learning to perform tasks with the left hand and arm.

The past decade, however, has seen the beginnings of what may turn out to be a revolution in therapeutic treatments for victims of stroke (and other neurological disorders). This new form of therapy, developed initially by Dr. Edward Taub of the University of Alabama, is called Constraint Induced Therapy (CIT), and the study of the different lines of research that have contributed to the development of the therapy makes for an instructive scientific case study.

Hubel and Wiesel

One line of very basic research that contributed in an important, but indirect, way to the development of CIT was the work by Hubel and Wiesel (H&W) in the 1960s and early 1970s on the functioning of neurons in the visual cortex of the cat. One series of studies by Hubel and Wiesel focused on the effects of early visual experience on the distribution of monocular and binocular neurons. Monocular neurons are neurons whose level of activity is affected only by visual input to one eye. A “left-eye” neuron, for example, may change its rate of firing if certain patterns of light are presented to the left eye but would be unaffected by patterns of light presented to the right eye. Binocular neurons, in contrast, are affected by the patterns of light received by both eyes. Note that this discussion is focusing on neurons within the visual cortex, not on sense receptors within the eyes themselves.

Basic organization. Hubel and Wiesel started by surveying what percentage of neurons in particular parts of the visual cortex of the adult cat were left-eye neurons (affected only by patterns of light presented to the left eye), right-eye neurons, and binocular neurons. They next conducted a similar survey of the visual cortex of the newborn kitten. The important finding was that, even though newborn kittens have had no visual experience, the percentages of left-eye, right-eye, and binocular neurons were the same as in the adult cat. This finding suggested that
the basic organization of the visual cortex was initially established without any dependence upon visual experience.

Could the functioning of neurons in the visual cortex, however, be affected by later visual experience?

In order to address this question, H&W raised kittens from birth with a patch over one eye. A survey of the visual cortex when these animals were adults revealed the eye patching’s dramatic effect. If the patch was over the left eye, for example, the number of left-eye neurons in the adult cat would be many fewer than normal. At the same time, the number of right-eye neurons would increase. These changes in the neurons’ functioning corresponded with evidence that the animals no longer could see well with the eye that had been patched since birth.

**Importance of timing.** Further work demonstrated that these effects were highly dependent on exactly when the animal’s eye was patched. With cats, it was discovered that a patch put on at birth but then removed at 4 weeks of age had no effect at all. Similarly, if the patch was not put on until 12 weeks of age (and not removed until adulthood), there was no effect on the numbers of left-eye, right-eye, and binocular neurons. However, if a patch was put over one eye from 4 to 8 weeks of age, the number of neurons responding to input from that eye declined while the number of neurons controlled by input from the other eye increased.

These findings suggested that visual experience could affect the basic functioning and organization of neurons in the visual cortex, but only during a critical period during the development of that part of the brain. In the case of cats, the critical period corresponded to the period from 4 through approximately 8 or 10 weeks of age.

H&W next investigated whether the effects of eye patching could be reversed in any way. In other words, they decided to examine whether they could rehabilitate the animals whose vision had been affected by eye patching. The only method that proved to be effective involved reverse patching, but even the reverse patching had to be done early in life.

**Reverse patching.** For example, consider the case of a kitten whose left-eye was patched from 4 to 8 weeks of age. H&W knew that if nothing were done, the animal would never see well through its left eye (even though the eye would remain unpatched for the rest of the animal’s life). The animal’s ability to see with the left eye could, however, be improved by patching the right eye for a period of time. This reverse patching could turn back the effects of the initial patching, but only if the reverse patching were done within, or soon after, the critical period. If the reverse patching procedure was used after the animals were 12 weeks of age, the reverse patching produced no effects.

**Competition.** These findings suggested that visual experience affects a competition-like process among nerve pathways for control of neurons in the visual cortex, but also suggested that there was only a limited time during which the competition occurred. Thus, for example, patching the left eye from 4 to 8 weeks weakened the pathways from the left eye to various neurons—which permitted nerve pathways originating in the right eye to “win” the competition for control of those neurons. In the absence of reverse patching, the game was over for control of those neurons. Reverse patching, however, could reverse these effects by weakening the pathways to
these neurons from the right eye while strengthening the previously weakened pathways from the left eye.

**Not for adults.** Note that although H&W found effects of reverse patching, their work also was consistent with the view that similarly dramatic changes could not occur in the brains of mature animals. Thus, their work supported a compensation, rather than recovery, perspective on therapeutic interventions with stroke victims suffering from movement limitations.

**Recent Research**

Some recent research suggests the motor and somatosensory cortex of adult animals and humans can be reorganized.

In the early 1980s, the view that reorganization in the mature brain was impossible began to change. Merzenich found that if he cut off a monkey’s finger, the part of the monkey’s somatosensory cortex that had responded to that finger eventually began to respond to input from other fingers—as if pathways originating in other fingers had begun to take over these neurons which had lost their original function. Ramachandran found something similar, but more dramatic, in studies of humans who had lost a hand. Ramachandran was mainly interested in phantom limbs, and he found that even years after the injury, many patients still had a phantom of the missing hand. He also discovered, however, that if he lightly stoked the side of the patient’s face, the patient would sometimes say that he felt his face being stroked and felt the phantom hand being stroked. Apparently, nerve pathways beginning with the sense receptors in the face now had some control over neurons in the somatosensory cortex that had originally been regulated by input from the missing hand.

**Effect of neglect.** Some of the most important evidence came from a very controversial research project begun in the 1970’s by Edward Taub. Taub was aware that stroke victims often neglect the use of a limb if their ability to use of the limb has been reduced. This means that even if patients could use the limb a little bit, they would not use it at all, preferring to do things with the limb that had not been affected by the stroke. Taub decided to examine the effects of neglect on brain organization in monkeys. In order to get monkeys to neglect a limb, he severed the sensory pathways from that limb to the cortex (by cutting the relevant sensory nerves in the spinal cord). This is a process called deafferentation. Taub found that the procedure did, in fact, cause the monkeys to neglect a limb in a manner analogous to what is often observed in human stroke victims.

**Silver Springs Monkeys Case.** Taub’s plan was to examine the brains of the monkeys as well. However, before he could get to that phase of his project, his work became the center of an animal rights controversy. One of the founders of PETA (People for the Ethical Treatment of Animals, an animal rights organization that opposes ALL medical research with animals, is against hunting and fishing, and equates the life of a rat with that of a human) got a job in Taub’s lab and then brought a lawsuit to stop the research. The suit also charged Taub with animal cruelty. Taub lost his job, and the case became famous as the “Silver Springs Monkeys” case. Eventually, PETA lost the suit and researchers were permitted to examine the effects of deafferentation on the organization of the somatosensory cortex of the monkeys. The findings, which were dramatic and surprising at the time, were that even in monkeys who experienced
deafferentation as adults, the cortical areas that would normally respond to input from the
deafferented limb now responded to input from other parts of the body, usually parts of the face.
Thus, the study provided important evidence that reorganization of the cortex was possible in
adult primates.

**Constraint-Induced Therapy**

In recent years, Taub put together the evidence that the adult brain has greater potential for
reorganization than had previously been thought, along with the technique of reverse patching
used by H&W, to develop constraint-induced therapy. With this form of therapy, patients have
their good limbs restrained, forcing them to use the limb that had been affected by the stroke.
The therapy is intense, and difficult. Patients work 8, 10, and even 12 hours per day struggling to
use their affected limb. The results have been encouraging, to say the least. Even patients whose
strokes had occurred years before have benefited from the intensive three- and four-week therapy
programs.

**WEBLINK:** There is a good discussion of some of this research in a recent article in *Scientific
American*.

You will also see a patient undergoing CIT in the video segment focusing on this new form of
therapy.

**VIDEO:** Click here to watch the video on *recovery from brain damage*. 