Chapter 3: The Brain and the Nervous System

The Brain

1. How are biological influences actualized? What bodily mechanisms produce our behavior?
2. The simple answer is that our brain and our nervous system makes that happen.

The Organism as a Machine
Organism as a Machine

1. Sixteenth and the 17\textsuperscript{th} century marked the enlightened period when people became well versed in math, physics, and other technological sciences.

2. Based on such understanding, Descartes asked seriously if brain was also a machine, and could human behavior be explained in mechanical terms.

Reflex Action Concept

1. Descartes studied the reflex action (see picture) and suggested that information from the senses reached the brain via the nerves, and the brain then reflected (thus reflex) by channeling energy into the nerve to produce actions through muscles.

2. Although brain, he argued had a lot of mechanical operations, but behavior in humans was carried out by a soul, as opposed to animals.

How do we Study the Nervous System?
Neuroscience

1. Neuroscience is the study of the nature, functions, origins of the nervous system. The approach begins with studying cells of the nervous system.

2. It is a multidisciplinary approach, and includes psychology, biology, computer sciences etc.

3. Neuroscientific investigations tells us that there are 100 billion neurons in the nervous system (NS). Each neuron makes about 50,000 connections. So the complexity of NS is enormous.

4. The other kind of bells in the NS are glia (from the word “glue”), which outnumber neurons 10:1. Their function is not incompletely understood.

Clinical Observations

1. A great deal of our understanding about the brain and the nervous system comes from clinical studies where people suffered from injuries and insults to the brain.

2. One such historical case has been of a man called Phineas Gage, who worked as railroad construction foreman.

3. During demolition, a 3-foot long steel rod pierced through his brain changing his emotional and intellectual life.
Neuropsychology

1. Neuropsychology understands brain function by examining individuals who have suffered brain damage.
2. Neuropsychologists design experiments to look at what behaviors can be performed by these patients and which others not.
3. Carrying out such experiments have lead neuropsychologists to propose different modules in the brain. Some modules carry motion perception, other color perception etc.

Experimental Techniques

Brain Lesions

Lesion (damage) in animal brains have been used as an experimental technique to study behavioral deficits as a result.

Transcranial Magnetic Stimulation

Transcranial Magnetic Stimulation (TMS) non-invasively stimulates the brain of an alert subject and changes his cognitive functions which can be reversibly studied.
Neuroimaging Techniques

**Computerized Axial Tomography**
Computerized Axial Tomography (CAT) scans brain by taking X-rays images and putting them together in a 3D format. This technique is used for identifying strokes and other problematic brain morphology.

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**Magnetic Resonance Imaging**
Magnetic Resonance Imaging (MRI) uses a large magnet and spins molecules in the brain. Signals from these molecules generate brain scans. Better resolution than CAT scans, though expensive.

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**Electroencephalography**
A recording of the electrical waves that sweep across the brain’s surface, measured by electrodes placed on the scalp. Provide temporal resolution.
Neuroimaging Techniques

Positron Emission Tomography

Positron Emission Tomography (PET) provides brain images based on radioactive positron emissions. Invasive procedure, but provides correlates of brain function during cognitive tasks.

Correlation and Causation

1. **Neuroimaging techniques** are correlational in nature and any conclusions drawn from data is not always reliable.
2. **Brain damage and neuroimaging techniques** used together lead to better understanding brain structure and function relationship.
3. To understand that different modules in the brain lead to different cognitive functions, investigators use **double dissociation**. Damage the module if one or both functions are disrupted.
The Architecture of the Nervous System

Nervous System

<table>
<thead>
<tr>
<th>Central Nervous System</th>
<th>Peripheral Nervous System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain and spinal cord</td>
<td>Nerves in the body—afferent and efferent nerves</td>
</tr>
<tr>
<td>Cranial nerves</td>
<td>Divided into somatic and autonomic division</td>
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Nervous System

Diagram of nervous system classification and components.
Central Nervous System (CNS)

<table>
<thead>
<tr>
<th>CNS</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forebrain</td>
<td>Sensory and higher order functions like thinking, consciousness etc.</td>
</tr>
<tr>
<td>Midbrain</td>
<td>Coordinates motion, relays information to other sites.</td>
</tr>
<tr>
<td>Hindbrain</td>
<td>Controls many functions including survival, heart beat, and breathing</td>
</tr>
</tbody>
</table>

The Cortex

Cortex

1. Cortex occupies 80% of total brain volume. Its thickness is 3.0 mm, and divides into six layers.
2. The surface of the cortex is convoluted (wrinkled) and enables more tissue to fit in the bony skull.
3. Divided into 2 hemispheres and 4 paired lobes, frontal, temporal, occipital, parietal, provides a convenient way to map the brain.
**Subcortical Structure**

1. **Thalamus** is a relay station for all processes except olfaction.
2. **Hypothalamus** regulates motivated behavior – eating, drinking, aggression, sexual behavior.
3. **Limbic system** is involved with learning and memory (hippocampus) and emotional behavior (especially fear: Amygdala).

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**Lateralization in the Brain**

1. Brain has two “sides”. Left and right hemispheres.
2. Brain is contralaterally organized. Left hemisphere controls actions of right side of body and vice versa.
3. Most structures are doubled (Left and right amygdale). Connected through bundled neural fibers (**corpus callosum**), information transfers from one side of the brain to the other.

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**Left & Right Brain**

<table>
<thead>
<tr>
<th>Left Brain</th>
<th>Right Brain</th>
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<tbody>
<tr>
<td>Both left and right hemispheres are tightly coordinated. And both necessary for efficient and normal brain function</td>
<td></td>
</tr>
<tr>
<td>Language, making inferences</td>
<td>Facial recognition, pattern recognition</td>
</tr>
</tbody>
</table>
Split-Brain Experiments

Since object recognition is performed by right hemisphere and language by left. Seeing the horse in the left visual field (LVF) does not lead to naming the “saddle” as an object that goes on top of the horse, however right hemisphere instructs the left hand to draw a saddle.

Projection Areas

1. The brain contains many modules or areas, in which specific information is processed. When these areas coordinate they perform complex functions.
2. On the surface of the cortex and some hidden from view, important sensory and motor projection areas are localized.

Sensory Area

The sensory or the somatosensory area receives information about the environment through receptors in our skin. Body is mapped in an inverted fashion. Some areas like fingers and lips occupy more brain areas than toes or torso.
Motor Area

Similarly, the motor area is a strip of cortex that serves as a projection area for the muscles all over the body.

Association Areas

All areas on the picture below that are not colored are called association areas. These projection areas are more complicated and process higher cognitive functions like thinking, imagination, consciousness.

Language Areas

Two other areas of interest are the Broca’s and Wernicke’s areas processing speech and language comprehension.
Cortical Damage & Disorders
1. **Apraxia** – involve disorders of motor function and represent inability to initiate or carry out complex (2+ steps) actions.
2. **Agnosia** – disorders of attention and perception include inability to identify familiar objects or a face (prosopagnosia) or neglecting one self (hemineglect).

Cortical Damage & Disorders
3. **Aphasia** – disorder of language where the individual is unable to use or comprehend speech and language. ** Fluent and nonfluent aphasias** – represent inability to comprehend and produce speech (damage to Wernicke’s and Broca’s areas).
4. **Prefrontal cortical damage** – inability to inhibit social or emotional responses (disorders of planning and social cognition).

The Origins of the Brain
Nervous System: Evolution

1. How did the nervous system evolve to the human level? Evolution changed the brain from animals that merely had neural networks (sea anemones) to peripheral ganglia (aplysia) to animals with more centralized ganglia (dolphins).

2. One aspect of brain evolution throughout the history of animal species is a shift from peripheral ganglia to more central ganglia.

3. Central ganglia (human neocortex) is a far superior organ in executing higher order and sophisticated functions.

Nervous System: Development

1. The development of the nervous system involves differentiation of primordial cells to neurons, during gestation.

2. Neuronal differentiation occurs through a process of neurogenesis. Neurons proliferate at tremendous rates forming the neural tube leading to complete formation of the brain by 5 months during gestation.

3. Connections among neurons is a selective process of pruning. Neurons are guided to reach their target sites through chemical gradient markers, guide post cells and a process of redundancy which ends in programmed neuronal death, fine tuning the connections. In some areas, neuronal death continues into the 3rd decade of life.
The Building Blocks of the Nervous System

Neurons and Glial Cells

Neurons conduct electrochemical messages between senses, muscles and internal organs. Glial cells are provide scaffolding, insulation and nutrition to neurons.

Communication Among Neurons
Neuronal Communication

1. Neurons communicate with one another and other tissues through electrochemical messages.
2. The inside and the outside of neuron membrane stands at a potential (electrical) difference of \(-70\text{mV}\), called the resting potential.

Action Potential

3. When this resting potential is perturbed (from \(-55\text{mV}\), threshold), a cascade of events take place, causing propagation of electrical current across the axon, called the action potential.

Action Potential

4. If the neuron reaches the threshold \((-55\text{mV})\) it fires else it does not, called the all-or-none law.
5. Action potential runs across the length of the axon all the way to the terminals.
6. And the intensity of action potential remains the same throughout the length of the axon.
Intensity of the Stimulus

7. To register the intensity of the stimulus, the frequency of the action potential increases. Also many neurons start firing simultaneously to process different frequencies.

Spatial & Temporal Summation

8. Action potential in a neuron can be generated by repeated stimulation called temporal summation. When summations are based on stimulations from more than one spatial locations it is called spatial summation.

Synaptic Communication

1. How does one neuron communicate with another neuron when there is physical distance between them?
2. The physical distance between the axon terminals of presynaptic neuron (A) and the dendrites of the postsynaptic neuron (B) is called a synapse.
Synaptic Communication

3. Action potential causes synaptic vesicles to expend their contents (neurotransmitters) into the synaptic cleft. These neurotransmitters bind to receptors on the postsynaptic neurons; opening them and letting the ions flow through them.

Excitation & Inhibition

4. The effect of neurotransmitter on the postsynaptic neuron can either be excitatory insuring that action potential will flow through. Or it can be inhibitory and leads to no action potential.

5. There are many (100) types of neurotransmitters. Each function differently at the synapse some cause excitation and some inhibition. Some work only in presence of certain other neurotransmitters.

“Lock and Key” Mechanism

6. Each neurotransmitter works as a “Lock and Key” mechanism. Each neurotransmitter binds to the receptor opening it.
Drugs & Neurotransmitters

7. Some drugs mimic the action of neurotransmitter and work as, **agonists**. Other drugs prevent the action of neurotransmitters and are called **antagonists**.

Interactions through the Bloodstream

Endocrine System

1. Endocrine glands secrete hormones (Greek, “to excite”) which are chemicals released in the bloodstream to affect the nervous system.
2. There are 5 different kinds of endocrine glands in the human body. They release different kinds of hormones and have different kinds of affect on the nervous system and behavior.
1. In life, we continually learn, and acquire new experiences. Are all these changes reflected as changes in the nervous system?
2. Changes in the nervous system refers to the process of plasticity.
3. During gestational periods we see a lot of plastic changes in the nervous system due to cell proliferation, new connections, pruning and cell migration. But do such changes take place as adults?
4. In adulthood, changes in the nervous system reflect changes in morphological connections. With new learning new dendritic spines grow.

5. **Cortical maps tend to reorganize** themselves after training. Monkeys auditory projection areas reorganized after training with certain frequencies (Recanzone et. al., 1993).

6. It was once thought that the brain was unable to grow new cells. However that idea has been modified. Modern day investigations show that in some parts of brain stem cells grow, that turn into neurons and take over functions of neurons that have been destroyed.
Psychological Questions
Biological Answers

1. Should all psychological questions need to have biological answers?

2. In many cases, a biological answer to a psychological question are:
   a. Not practical
   b. Not helpful
   c. Not possible

3. Many other levels of analysis need to be applied in order to answer many questions about human behavior.

Questions

1. Which of the following best describes what functional neuroimaging techniques measure?
   a. Which brain regions are active during a specific task.
   b. The pattern of increases in activity in individual brain regions during a specific task.
   c. Which brain regions are inactive during a specific task.
   d. The pattern of decreases in activity in individual brain regions during a specific task.

Questions

2. The central nervous system consists of the:
   a. Efferent nerves.
   b. Afferent nerves.
   c. Brain and spinal cord.
   d. Somatic division and autonomic division.
Questions

3. Melissa has suffered brain damage and is now unable to recognize objects by looking at them. She is, however, able to recognize objects by touching them. Melissa’s disorder is called:
   a. Apraxia.
   b. Visual agnosia.
   c. Prosopagnosia.
   d. Aphasia.

Questions

4. The most common (99%) type of neurons are:
   a. Motor neurons.
   b. Interneurons.
   c. Sensory neurons.
   d. Primary neurons.

Questions

5. The destabilization-restabilization sequence of a neuron’s cell membrane, caused by the movement of ions across the cell membrane, is called:
   a. an action potential.
   b. the resting potential.
   c. the excitation threshold.
   d. the propagation pattern.