Origins of Biopsychology

I. Introduction

II. Course Overview

III. History of Behavioral Neuroscience
Biopsychology

- Seeks to describe the physiological mechanisms of the body that mediate our movement and mental activity.
- “Mental activity” includes a vast array of things including feeling, thinking, consciousness, communication, learning, and memory.
- A.k.a. psychobiology or behavioral neuroscience
Two Sides to the Mind-Body Question

• Dualism: The belief that the mind and body (or the mind and the brain) are separate entities.
  – Often assumes the existence of a non-material soul or spirit
  – Most popular view throughout history
  – May be “wired” to view ourselves this way

• Monism: The belief that the mind and body (or the mind and the brain) are one.
  – Mind and brain are almost synonymous
  – The mind is a product of the brain
  – Most common view among biopsychologists
III. History of Behavioral Neuroscience

A. Aristotle (384-322 BC)
   – dualist

B. Hippocrates (460-370 BC)
   – monist

C. Descartes (17th Century)
   – modified dualist

D. Galvani (17th Century)
   – frog muscles contract with electricity
III. History of Behavioral Neuroscience (Continued)

E. Müller (19th Century):
   – doctrine of specific nerve energies
   – advocate of experimentation

F. Flourens (19th Century)
   – experimental ablation

G. Broca (19th Century)
   – aphasia
III. History of Behavioral Neuroscience (Continued)

E. Fritsch and Hitzig (19th Century)
   – stimulation of dog cortex produces body movement

F. Darwin and Wallace (19th Century)
   – theory of evolution and common descent
Natural Selection

• The process by which inherited traits that confer a selected advantage become more prevalent in the population. (Huh?)
• “selected advantage” = increase an animal’s likelihood of living or reproducing
• In other words... if genetically-influenced traits give an animal an edge, you’ll see more animals with those traits in the future
Which one is human?
Lateralization of Function versus Localization of Function

- **Localization of Function**: The tendency for a function to be located in a particular area of the brain (i.e., a great deal of advanced visual processing occurs in the occipital lobe).

- **Lateralization of Function**: The tendency for a function to be primarily located on one side of the brain (i.e., Broca’s area is typically in the left frontal lobe).
Cells of the Nervous System

I. Introduction

II. Neurons

III. Ways of Classifying Neurons

IV. Nervous System Support Cells

V. Communication within a Neuron

VI. Communication among Neurons

VII. Major Neurotransmitters
I. Introduction

• How many neurons does the average adult brain have?
• How long would it take to count to this number?
How Long Would it Take to Count to 100 Billion?

• 60 seconds per minute × 60 minutes per hour × 24 hours/day × 365.25 days/year = 31,557,600 seconds per year

• $100,000,000,000 \div 31,557,600 = \boxed{3168.8\text{ years}}!$
II. Neurons
Basic Structures of a Neuron

- **Dendrites**
- **Soma (cell body)**
- **Axon (inside myelin sheath)**
- **Myelin sheath**
- **Terminal buttons**

Direction of messages
III. Ways of Classifying Neurons

- By number of processes
  - Unipolar
  - Bipolar
  - Multipolar
Other Classification Systems

• By function: sensory, motor, & interneuron
• By direction of information flow: afferent (towards CNS) versus efferent (away from CNS)
• By neurotransmitter released: serotonergic, dopaminergic, etc...
• By effect: excitatory versus inhibitory
IV. Nervous System Support Cells

[Diagram showing neurons, astrocytes, blood vessels, and metabolic pathways involving glucose, lactate, and glycogen.]
Has Science Missed Half the Brain? Neglected Cells Hold Keys to Thought and Learning

The First Nanochips Have Arrived

Dusty Clues to Hidden Planets
V. Communication within a Neuron
The Resting Potential
Important Ions in and around a Typical Neuron

• $A^-$ Large Protein Molecules
• $K^+$ Potassium (a.k.a. Kalium)
• $Na^+$ Sodium (a.k.a. Natrium)
• $Cl^-$ Chloride (a.k.a. Chloride)

• NOTE: There are other ions in and around a typical neuron that we aren’t mentioning.
Two Forces Operating on Ions

• Force of Diffusion
  – Ions move from areas of high concentration to areas of low concentration

• Force of Electrostatic Pressure
  – Ions of similar charge (- - or + +) repel
  – Ions of opposite charge (- +) attract
The diagram illustrates the process of sodium-potassium transport across a cell membrane. Three sodium ions (Na⁺) are pumped out of the cell, while two potassium ions (K⁺) are pumped into the cell. This transport is facilitated by a sodium-potassium transporter located in the membrane.

The sodium ions are located outside of the cell, and the potassium ions are located inside the cell.
Factors Contributing to the Resting Potential of a Neuron

- Large number of negatively charged protein molecules ($A^-$) inside
- Semi-permeable membrane allows more Potassium ions ($K^+$) to leak out than Sodium ions ($Na^+$) to leak in (net result: more positive ions leave the cell)
- Sodium-Potassium pump three Sodium ions ($Na^+$) out for every two Potassium ions ($K^+$) it pulls in (net result: more positive ions leave the cell)
Graded Potentials

(a) Depolarizing stimulus

(b) Hyperpolarizing stimulus

Membrane potential (voltage, mV)

Time (ms)

Resting potential

Depolarization

Hyperpolarization

Inside positive

Inside negative

Copyright © 2004 Pearson Education, Inc., publishing as Benjamin Cummings.
The Action Potential

1. Sodium channel opens.
2. Sodium ions enter the cell.
3. Sodium channels become refractory, no more Na⁺ enters the cell.
4. K⁺ continues to leave the cell, causing the membrane potential to return to resting level.
5. K⁺ channels close, Na⁺ channels reset.

Membrane potential (mV)

Threshold of excitation

+40

0

-70
VI. Communication among Neurons
The Synapse
Transparency 37
Release of Neurotransmitter

Undocked synaptic vesicle

Cluster of protein molecules in membrane of synaptic vesicle

Docked synaptic vesicle

Cluster of protein in presynaptic membrane

Entry of calcium opens fusion pore

Fusion pore widens, membrane of synaptic vesicle fuses with presynaptic membrane

Molecules of neurotransmitter begin to leave terminal button

Presynaptic membrane

"Omega" figures

Copyright © 2002 by Allyn and Bacon
Receptors at the Synapse

- Receptor: Protein molecule embedded in a membrane that has a binding site for one or more neurotransmitters
  - The binding site is like a key slot
  - Neurotransmitter is like the key
Ionotrophic Receptor

• Receptor contains an ion channel (or door) that opens or closes when neurotransmitter (NT) attaches to its binding site

• Example: door to your house (ionotrophic receptor) has a key slot (binding site on the receptor) that opens when you put in and turn the key (neurotransmitter)
Metabotropic Receptor

- Receptor doesn’t contain an ion channel
- When Neurotransmitter attaches to binding site, a G-protein changes
- Altered G-protein can affect near by ion channels or activate “second messengers”
- Second messengers: 1) affect near by ion channels and/or 2) activate DNA to perform cellular functions
Metabotropic Receptor Example

• Putting a key (neurotransmitter) into a key slot (binding site on the receptor) causes a nearby elevator to turn on and open its doors (G-protein or second messenger opens a nearby ion channel) and sends a message that the elevator is operating to a control center elsewhere in the building (G-protein affects other cellular processes)
(A) Ligand-gated ion channels

(B) G-protein-coupled receptors
Schematic Illustration of an NMDA Receptor, with Its Binding Sites

- Polyamine
- Glutamate
- Calcium channel
- Zn$^{2+}$
- Glycine
- Mg$^{2+}$
- PCP
Structures of the Nervous System

I. Divisions of the Nervous System
II. Orienting within the Brain
III. The Developing Brain
IV. The Adult Brain
V. Brain Plasticity
I. Divisions of the Nervous System
Organization of the Nervous System

The Nervous System

Central Nervous System
- The body's master control unit
  - Spinal Cord
    - A column of nerves between the brain and peripheral nervous system
  - Brain
    - Divided into three major parts: the lower part or hindbrain, the midbrain, and the forebrain

Peripheral Nervous System
- The body's link to the outside world
  - The Autonomic Nervous System
    - Regulates involuntary bodily processes, including heart rate, respiration, digestion and pupil contraction; operates automatically without conscious direction
  - The Somatic Nervous System
    - Carries sensory information from sensory organs to the central nervous system (CNS) and relays motor (movement) commands to muscles; controls voluntary movements

Sympathetic Nervous System
- Mobilizes bodily resources in response to threat by speeding up heart rate and respiration and drawing stored energy from bodily reserves

Parasympathetic Nervous System
- Replenishes bodily resources by promoting digestion and slowing down other bodily processes
II. Orienting within the Brain
Anatomy Directions
(See figure 3.2, Page 65)

Anterior/Rostral
- towards the head or front

Posterior/Caudal
- towards the rear or behind

Ventral (Inferior)
- towards the belly (below)

Dorsal (Superior)
- towards the back (above)

Medial
- close to the neuraxis

Lateral
- away from the neuraxis

Ipsilateral
- on the same side

Contralateral
- on the opposite side
Convolutions of the Cortex

- Bump or ridge = gyrus (plural is gyri)
- Groove = sulcus (plural is sulci)
- Big groove = fissure
Figure 2.13  The Basal Ganglia Are Located Deep Within the Cerebral Hemispheres  The basal ganglia, including the caudate nucleus, putamen, and globus pallidus, are found in the forebrain. Many anatomists include the amygdala and the substantia nigra of the midbrain as parts of the basal ganglia due to their tight connections.

Figure 2.14  The Limbic System Is Our Emotional Brain  A number of closely connected forebrain structures participate in the limbic system, which controls many emotional and motivational behaviors.
<table>
<thead>
<tr>
<th>Major division</th>
<th>Ventricle</th>
<th>Subdivision</th>
<th>Principal structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forebrain</td>
<td>Lateral</td>
<td>Telencephalon</td>
<td>Cerebral cortex</td>
</tr>
<tr>
<td></td>
<td>Third</td>
<td>Diencephalon</td>
<td>Basal ganglia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Limbic system</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thalamus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hypothalamus</td>
</tr>
<tr>
<td>Midbrain</td>
<td>Cerebral aqueduct</td>
<td>Mesencephalon</td>
<td>Tectum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tegmentum</td>
</tr>
<tr>
<td>Hindbrain</td>
<td>Fourth</td>
<td>Metencephalon</td>
<td>Cerebellum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pons</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medulla oblongata</td>
</tr>
</tbody>
</table>
Welcome to Club Brain 'Where the minds unwind'

Yo.. Check out the cerebellums on those babes... let's follow them, Bob...

Heeeeey there, ladies... wanna see a huge hypothalamus?

Go away, creep.

Give me some aspirin, will you, Phyllis? This loser's giving me a headache.

Sure. Here you go.

Hey hey hey what?!

This is your brain.

This is your brain on drugs.

You will never hear a better pick-up line.
Psychopharmacology

I. Introduction
II. Principles of Psychopharmacology
III. Sites of Action
Psychopharmacology

• The study of how drugs effect the nervous system and behavior.

• Drugs have...
  – effects: changes in behavior and/or physiology
  – sites of action: place in the body where the drug interacts with the cells, causing some kind of change
Pharmacokinetics

• Pharmacokinetics: The study of how drugs are...
  – absorbed
  – distributed within the body
  – metabolized (used) and
  – excreted (gotten rid of)
Factors Influencing Drug Effects

• Route of administration
  – Ingested vs. smoked vs. injected (Figure 4.1)

• Solubility
  – Water soluble molecules can’t cross the BBB
  – Lipid (or fat) soluble molecules can cross BBB
  – Heroin more soluble in fat than morphine
  – Given equal initial doses, more heroin gets to the brain than morphine
The graph illustrates the plasma cocaine concentration (ng/ml) over time (min) for different routes of administration:

- Intravenous (0.6 mg/kg)
- Smoked (100 mg base)
- Oral (2 mg/kg)
- Intranasal (2 mg/kg)

The graph shows the peak concentration is highest for intravenous administration, followed by smoking, oral, and intranasal routes in descending order.
Tolerance

• Refers to how with repeated use of a drug, it takes more of it to achieve the same effect.
  – Receptors on postsynaptic membrane may disappear in response to repeated cocaine use (cellular tolerance)
  – With repeated consumption, more enzymes are present in liver and blood to break down alcohol, thus less gets to cells (metabolic tolerance)
Tolerance Effects

• 100 milligrams of morphine typically causes profound sedation and even death in first time users

• Users with morphine tolerance have been known to consume 4000 milligrams (40 times more) without adverse effects

• Amphetamine users can consume up to 100 times initial dose with tolerance
Withdrawal

• Symptoms opposite to those of a drug that occur when someone stops taking a drug that they have been using repeatedly.

• For example, if drug makes you happy and euphoric, withdrawal symptoms may make you depressed and down
Sensitization

• Refers to how with repeated use of a drug, it takes less of it to achieve the same effect.
• Less common than tolerance
• Thought to occur in response to occasional or infrequent use
Agonist

- Drug that facilitates or enhances the effect of a neurotransmitter
  - Nicotine is an ACh agonist
  - Cocaine and amphetamines are dopamine agonists
Antagonist

• Drug that counter-acts the effect of a neurotransmitter
  – 1st schizophrenia meds dopamine antagonists
  – Botulinum toxin (botulism) is an ACh antagonist
Steps in the Neural Communication Process

1. Neurotransmitter (NT) is created/manufactured
2. NT is stored in synaptic vesicles
3. NT is released into the synaptic cleft when an action potential arrives
4. NT detected by autoreceptors (presynaptic)
5. NT activates postsynaptic receptors
6. NT potential terminated/stopped via reuptake or enzymatic deactivation
Would it help or hinder the effect of a neurotransmitter if you...

1. Added more of the material needed to make the neurotransmitter?
2. Interfered with the process of creating NT?
3. Prevented the NT from being stored in the vesicles?
4. Tricked the vesicles into releasing NT (without an action potential)?
5. Prevented calcium from triggering the release of NT from the vesicles?
Would it help or hinder the effect of a neurotransmitter if you...

6. Artificially activated a binding site of a receptor?
7. Blocked the binding site of a receptor?
8. Artificially activated an autoreceptor?
9. Blocked an autoreceptor so that it couldn’t detect neurotransmitter?
10. Prevented reuptake from happening?
11. Prevented the destruction of ACh?
Tyrosine $\rightarrow$ Enzyme $\rightarrow$ L-DOPA $\rightarrow$ Enzyme $\rightarrow$ Dopamine $\rightarrow$ Enzyme $\rightarrow$ Norepinephrine
Tryptophan

\[ \text{Enzyme} \]

5-hydroxytryptophan (5-HTP)

\[ \text{Enzyme} \]

5-hydroxytryptamine (5-HT, or serotonin)
ALTHOUGH CHEAPER, BOZOTOX HAD NEGATIVE SIDE EFFECTS
After this point, increasing the dose does not produce a stronger effect.
Dose-response curve for the analgesic effect of morphine

Dose-response curve for the depressive effect of morphine on respiration

Margin of safety