Brain And Human Behavior

FEM 4100

Units 1 – 10

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INTRODUCTION TO THE MODULE

Information on the course

Department: Human Development & Family Studies
Course Name: Brain and Human Behavior
(Otak dan Tingkah Laku Manusia)

Course Code: FEM 4100
Credit Hours: 3 (3+0)
This course comprises three hours of lectures a week, which adds up to
42 hours of lectures per semester. In order to complete the course
requirement, each student is expected to complete an equivalent of six
to nine hours of reading a week and complete related assignments.

Course Description

This course emphasizes on the detailed analysis of the brain and how it
influences human behavior. It discusses the neuron structure, brain
anatomy and its functions, communication within the brain and across
the nervous system as well as brain damage and recovery.
## Suggested Student Centered Learning Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Readings</th>
<th>Student Centered Learning</th>
</tr>
</thead>
</table>
| 1    | Introduction  
* discuss syllabus  
* roots of brain-based research | Pinel, ch. 1 | |
| 2-3  | The Anatomy Of The Brain  
* nervous system overview  
* detail brain regions | Ch. 2 | Assignment 1: *The strange tale of Phineas Gage* (4%)  
Assignment 2: *Label the brain parts.* (2%) |
| 4-5  | Neural Impulse Conduction  
* neurophysiology basics  
* chemical neurotransmission | Ch. 3 | Assignment 3: *How does Einstein's brain differ from most of us?* (3%)  
Assignment 4: *How do murder a neuron?* (6%) |

**Assignments 1-4 due.**  
Midsemester examination (chapters 1-3)

| 6    | Brain Development  
* fertilization to birth  
* neurogenesis | Ch. 7 | Assignment 5: *Optimizing the brain potential.* (5%) |
| 7-8  | Perception:  
Mechanism, Awareness & Attention  
* principles of perception - seeing, hearing, touch, smell, and taste | Chapter 4 - 5 | Assignment 6: *Beware of what you wish for!* (8%) |
| 9    | The Sensorimotor System  
* the principles of sensorimotor control  
* the spinal cord *motor cortex, basal ganglia, and cerebellum | Chapter 6 | Assignment 7: *A critical look at acupuncture.* (3%) |

**Assignments 5 - 7 due.**
<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Readings</th>
<th>Student Centered Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-11</td>
<td>Circadian Rhythms, Sleep &amp; Dreams</td>
<td>Chapter 7</td>
<td><strong>Assignment 8:</strong> Does hypnosis work? Can we avoid being hypnotized? (3%)</td>
</tr>
<tr>
<td></td>
<td>* Suprachiasmatic nucleus</td>
<td></td>
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<td></td>
<td>* EEG waves and sleep</td>
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<td></td>
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<tr>
<td></td>
<td>* REM and dreams</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>* Sleep disorders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Language, Cognition &amp; Intelligence</td>
<td>Ch 14</td>
<td><strong>Assignment 9:</strong> Do most of us have some amount of dyslexia? (3%)</td>
</tr>
<tr>
<td></td>
<td>* Brain hemispheric differences</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Dyslexia and dysgraphia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Memory Storage &amp; Information Processing?</td>
<td>Ch. 9</td>
<td><strong>Assignment 10:</strong> Do we want to maximize our memory power or is it more blessed to forget? (5%)</td>
</tr>
<tr>
<td></td>
<td>* synaptic plasticity and long-term potentiation (LTP)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>* amnesia disorders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Psychological Disorders</td>
<td>Ch. 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* brain injury and tumors</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>* neurodegenerative diseases</td>
<td></td>
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</tbody>
</table>

Assignments 8 - 10 due
Final Examination  (Chs. 7-10)
Evaluation Criteria and Procedures

Your final grade will be calculated based on a semester total of 100 percent. The points are determined as follows:

**Mid-Term Exam**
Total marks: 25%
Topics 1 – 3
Consists of
- 30 multiple choice questions (15%) and 5 short answer questions (choose 5 from 8 questions) (15%)

**Final Exam**
Total marks: 30%
Topics 4 – 10
Consists of
- 30 multiple choice questions (15%) and 5 short answer questions (choose 5 from 8 questions) (15%)

**Assignments:**
Total marks: 45%
- Consists of 10 response papers and exercises. Please refer to descriptions in the assignment section for the details on the assignments and marks allocated.

Suggestions for student activities include several types of activities:

1. **Module activities and self-tests:** Designed as a supplement in the text to enhance the student’s understanding of the content and to assist them in their preparation for their examinations.
2. Assignment Activities: (Total Marks 45%)
Designed to reinforce the material in the module. Individual works are suggested throughout the manual. You have a total of ten assignments, which adds up to 45% of the course marks. Each assignment should be about 4-6 pages in length, single-spaced, typed in Arial 11-point font, with 1 inch margin. In order to receive useful feedback from me, which will help you improve your assignments and maximize your marks for each assignment, please e-mail your assignments directly to me. Refer to the tentative schedule of events and complete the assignments according to the suggested weeks, in order to pace your work and optimize your learning.

Assignment One: The strange tale of Phineas Gage (5%)

Phineas Gage worked as the foreman of a railway construction gang in Vermont. At just twenty-six years old, Gage was already a success story. He was well liked by the men in his charge, and his superiors were impressed with his skill at handling dangerous explosives. He was their most efficient and capable man. Gage had a combination of intelligence and athletic ability that made him perfect for the task of clearing rock from the path of the coming railroad.

On September 13, 1848, an explosion drove a three-foot long iron rod at high speed into Gage’s left cheekbone, through his skull and out the top of his head. It landed nearly 300 feet away. Amazingly, Gage survived the terrible blow. His men picked him up and took him by ox cart to a nearby hotel, where they summoned one of the town’s physicians, Dr. John Harlow. Gage was still conscious at the time of the exam and able to answer questions about his accident, but his survival was not yet assured. Dr. Harlow did not have the benefit of antibiotics in treating Gage. However, he was knowledgeable enough about infection to understand its life-threatening risk and kept vigilant watch over Gage’s wound, cleaning and draining it regularly. Gage’s youth and previous health proved stronger forces than the infection, and within two months he was cured. Or was he?? Describe what remained and what changed with Phineas Gage after the incident.

Mounting research indicates that deficiencies in the frontal or pre-frontal regions of the brain often correlate with various forms of violence and impulsivity that can lead to criminal acts. Deficiencies in other brain areas play a role in contributing to behaviors that are categorized as “criminal.” Read on scientific literature talks about the concept of a “criminal brain” and relate them to Gage’s story.
Assignment Two: Label the brain parts (2%)
Assignment Three: How was Einstein's Brain Different from the rest of the other genius? (3%)

Einstein died of a ruptured aneurysm of the abdominal aorta in 1955 at the age of 76 years. Thomas Harvey, a doctor at the hospital where Einstein died, removed the famous scientist's brain and kept it with him over the next four decades. Harvey wanted to know what made Einstein a genius. Scientists have long sought to understand the nature of genius and before computers and imaging technology, they had few options other than studying the actual brain.

Within 7 hours of his death, his brain was removed at necropsy, fresh weight was measured, perfusion of 10% formalin by injection into the internal carotid arteries was carried out, and the whole brain was then freely suspended in 10% formalin for fixation and subsequent study. No significant neuropathology was seen on examination (gross or microscopic). After fixation, caliper measurements were made directly from the brain. The cerebral hemispheres were cut into approximately 240 blocks, each about 10 cm cubed. The blocks were embedded in celloidin, and histological sections were made.

Harvey gave some of the pieces to Harry Zimmerman, and placed the remainder in two formalin-filled jars, which he stored in the basement of his house in Princeton. In the early 1980s, Diamond heard about the existence of Einstein's brain. Diamond published her findings under the title "On the brain of a Scientist: Albert Einstein" in an obscure journal called Experimental Neurology in 1985. From then on, many other scientists examined Einstein's brain. Discuss the findings and conclusions made regarding the uniqueness of Einstein's brain?
Assignment Four: How do you murder a neuron? (6%)

<table>
<thead>
<tr>
<th>TECHNIQUE</th>
<th>RESULT</th>
<th>EXPLAIN WHAT HAPPENS</th>
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<tbody>
<tr>
<td>Starve it</td>
<td>Heart Attack Arteriosclerosis  Thrombosis or embolism  Starvation Insulin overdose</td>
<td>Cells that are without oxygen may release excessive glutamate (Please read section on neurotoxins for examples).</td>
</tr>
<tr>
<td>Suffocate it</td>
<td>Heart Attack Arteriosclerosis  Thrombosis or embolism  Drowning  Carbon monoxide poisoning</td>
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<tr>
<td>Squish it</td>
<td>Crush skull Insert something into skull that takes up space  Hydrocephaly  Hematoma  Use the skull to stop a brain that is moving at high speed</td>
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<tr>
<td>Poison it</td>
<td>Heavy Metals Mercury Lead Arsenic</td>
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<tr>
<td>Cut it</td>
<td>Gun shot wound or other projectile entering brain or nervous system Surgery</td>
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<tr>
<td>Infect it</td>
<td>Syphilis Rabies Mumps Herpes Chicken Pox</td>
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<tr>
<td>Mutate it</td>
<td>Down’s Syndrome  Huntington’s Chorea</td>
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<tr>
<td>Over stimulate it</td>
<td>Grand mal seizures</td>
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<tr>
<td>Expose it</td>
<td>Multiple sclerosis  Amyotrophic lateral sclerosis</td>
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<tr>
<td>Attack it</td>
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</table>
Assignment Five: Optimizing the brain potential. (5%)

Dr Berry Brazelton of Harvard University believes that all babies are born geniuses. Lewis Lipsitt, professor at Brown University, agreed that the newborn period is that in which man has the greatest learning capacity. About fifty years ago, Dr Makoto Shichida and Dr Glen Doman announced to the world that they have discovered the secret of making any baby a genius! Describe these secrets.

Today billions of money have been spent on brain based research. This research is driven by the idea that today's power no longer lies in weapon, but in optimizing the brain potential. Drawing on the recent findings on brain development and the details described by Shichida and Doman, discuss the strategies you can come up with to optimize your child's brain potential.

Assignment Six: Beware of What You Wish For! (8%)

If you could see better, what would you see? If you could hear better, what would you hear? If your chemical senses, taste and smell, were better than they are, how would you be affected? Describe five types of extrasensory perceptions that people have experienced.

What is the difference between telepathy, clairvoyance, precognition, retrocognition, deja vu and mediumship? Can you communicate with your loved ones over a distance without using the conventional means, like a telephone? Or have you ever had a dream that came true? Or called a friend at the exact moment he was calling you? Or have you ever felt that "I've been through this before." Most of us have had some sort of paranormal experience. Describe evidences about the existence of ESP (personal experiences or experiences of people you know or read about).
Assignment Seven: A Critical Look at Acupuncture

(3%)
More than two thousand years ago the Chinese developed the idea that an imbalance between the two vital forces, yin and yang can cause discomfort, illness, and pain. To treat such problems they developed acupuncture, a unique therapy which uses needles inserted at special points in channels where the vital forces were thought to flow. One of the most controversial aspects of Chinese medical research today is the question as to whether the ‘meridians’, or energy channels which are supposed to link the hundreds of prescribed acupuncture points in the body, actually exist, or whether they are just a convenient way of memorizing the points at which the needles should go in. But without the meridian theory, it is difficult to explain the effect of acupuncture in producing anaesthesia or therapy in some far removed part of the body: for instance, placing needles in the arm and knee to treat a stomach ulcer. How does acupuncture work? What might explain the elevated endorphin levels that acupuncture patients exhibit?

Assignment Eight: Does hypnosis work? Can we avoid being hypnotized? (3%)

The practice of hypnotism dates back centuries. Some people swear that it works! Different cultures have different names of it. Perhaps in South-East-Asia, it is well-known as “pukau”. Whether you’re a skeptic or a believer, hypnosis is an interesting phenomenon. Describe how it works. In Freudian terms and other techniques you might have read. Check it out – and let us know if you start to purr like a cat when your hypnotist tells you to.
Assignment Eight: Do most of us have some amount of dyslexia? (5%)

Dyslexia is an inability to read or write despite normal or superior intelligence. It may be developmental or acquired. It is a common disorder, affecting about 15% of males and about 5% of females. Surface dyslexia occurs when patients lose their lexical skills, whereas deep dyslexia occurs when patients lose their phonetic reading skills. Although we may not be legally diagnosed as dyslexic, most of us have some form of dyslexia. What causes dyslexia? Describe the different types of dyslexia and its symptoms. What are some form of dyslexia that you or someone you know might suffer?

Assignment Ten: Do we want to maximize our memory power or is it more blessed to forget? (5%)

Many of us wish we have perfect memory, especially when we have to memorize our texts for an examination. If our brains were computers, we could simply add a chip to upgrade our memory. The most effective study strategies require processing the meaning of information. Emotional experiences stimulate the amygdala, resulting in more vivid memories than nonemotional experiences. Context is a potential aid for memory reconstruction when you are actively trying to recall something, such as the details of a crime. Of the many types of memory improvement techniques that you read in the internet, describe three types that you find the most interesting.

The ability to forget information is as crucial to remembering. Sometimes you really want to forget, like a memory of being physically abused by your father. Such forgetting is motivated as a means of protecting yourself from painful or unpleasant memories. Forgetting may also result from errors in how the memory was framed or how it was recalled (retrieval failure). Which of the many types of amnesia do you find the most interesting? Have you ever known anyone who had the symptoms of amnesia? Describe what you might feel if you woke up one morning and had amnesia.
How to do well in this class

**Attend face-to-face meetings and participate.** Attendance, per se, is not part of your grade, but attending class is essential for you to do well. In addition to talking about ideas not in your module, you'll hear discussions about people and the disorders. These will make the material "come alive."

**Read the text before coming to class.** Our class time will be lecture/discussion based. It's harder to discuss this material well if you haven't read it first. When you read the chapter first you'll have a better understanding of class material, and the questions that you ask will be more useful for you and your classmates.

**Get involved!** As you read the text or listen to class discussions, make it interesting and become involved! Relate the ideas to yourself, your friends, and your families. Think about those places where the material applies -- and those where it doesn't. Wonder about what puts people at risk, as well as what makes others resilient in the worst possible situations. Actively read the material by thinking about, applying and using it, rather than only passively reading it.

**Visit your text's website.** Pearson at http://www.ablongman.com offers a variety of services, such as companion websites, to make your learning the material easier. Take the online quizzes to assess how you're doing; check out the video segments; use the flashcard and notes, etc. These will help you process the material more deeply and check your understanding of it.

**Read over your notes every day.** Doing so will eliminate the "need to cram," which is almost impossible with this much information. It's hard to forget something that you use every day.

**Put time and energy into this course.** For a 4000 level course, you should spend a minimum of 2-3 hours outside of class for every credit hour required for the class, in order to do well. For a class like this one that meets 3 hours/week, you need to spend an additional 6-9 hours on the course each week.
Get together with other students to study together. Helping someone else understand something is an excellent way to learn. And, if you get lost somewhere along the way, it's helpful to have some friends who can help you out. Besides, it's fun and can increase your motivation for the understanding the course content!

Check out these websites for helpful study skills information. There are numerous sites containing information on test-taking, time management, note-taking (both in class and from the text), etc.

* Study Strategies (University of Minnesota - Duluth): http://www.d.umn.edu/student/loon/acad/strat/
* Academic Success Center (George Washington University): http://gwipec.gwu.edu/counsel/asc/

How-to-Study.com
Texts and Suggested Readings:

Main Text:

Additional References:

Weblinks:

Web Link P.4 Advanced Biological Psychology Tutorials
http://psych.athabascau.ca/html/Psych402/Biotutorials/
Athabasca University
I would highly recommend referring to these tutorials for every section of the course. The diagrams and explanations are very good. So are the self-testing materials.

Web Link P.5 Neuroscience Tutorial
http://thalamus.wustl.edu/course/
The Washington University School of Medicine
An illustrated guide to the essential basics of clinical neuroscience created in conjunction with the first-year course for medical students.

Web Link P.6 Biocompare.com
This site has a news page with articles of new research in biology (including neuroscience. You can subscribe to get a periodic email message with a listing of article links. These are brief and often very interesting.

Web Link P.7 Neuropsychology Central
http://www.neuropsychologycentral.com/
site I have been able to find. It has information about all strands of neuropsychology as well as links to organizations, newsgroups, jobs, assessment procedures and free neuropsychology software.

Web Link P.8 World Wide Web Virtual Library for Neuroscience
http://neuro.med.cornell.edu/VL/
A collection of neuroscience references

Web Link P.9 Cognitive Neuroscience Resources (Archives)
http://www.cnbc.cmu.edu/Resources/archives.html
A list of links providing resources for the cognitive neuroscientist

Web Link P.10 Yahoo Neurology
http://dir.yahoo.com/Health/Medicine/Neurology/
Yahoo is one of the Internet’s premier search engines–this is the result of its best website matches for neuroscience

Web Link P.11 Wisconsin/Michigan State Brain Collection
http://brainmuseum.org/
A collection of images of mammalian brain sections

Web Link P.13 The Harvard Brain
http://hcs.harvard.edu/~husn/BRAIN/index.html
An impressive Internet magazine on the brain, designed and written by Harvard neuroscience undergraduates.

Web Link P.14 Brain and Mind: Electronic Magazine on Neuroscience
http://www.epub.org.br/cm/home_i.htm
Includes an online course in the history of Neuroscience.
Unit 1
Introduction To Brain & Human Behavior

LEARNING OUTCOME
At the end of this unit, you will be able to:
1. Describe the evolution of the scientific method
2. Describe the disciplines of neuroscience
3. Describe the nature of physiological psychology and the goals of research.
4. Describe the biological roots of physiological psychology.
5. Describe blindsight, the split brains, and unilateral neglect.
6. Describe the role of natural selection in the evolution of behavioral traits.
7. Discuss the evolution of the human species and a large brain.

"The more you use your brain, the more brain you will have to use."
George A. Dorsey

"Brain: an apparatus with which we think we think."
Ambrose Bierce

"If little else, the brain is an educational toy."
Tom Robbins
INTRODUCTION

The human brain is packed solid with billions of nerve cells each communicating with over miles and miles of living wires (the nervous system) which operates the whole body.

The ancient wondered – why can a thought/an emotion be experienced but not seen or touched? They found that inanimate was attributable to a spirit of vital force that could be neither seen or understood (known as animism today).

People view themselves in the dualistic term, with mind traditionally seen as an entity distinct from the physical world of matter and governed by entirely separate sets of principles. The roots of dualism are from the writings of the Greek philosopher Anaxagoras.

Plato elaborated on the concept, maintaining that the mind, or soul was the instrument with which knowledge is pursued – superior to the physical body & sense.

Monism is a belief that the world consists of matter and energy and that the mind is a phenomenon produced by the workings of the nervous system.

The field of biopsychology is relatively new; however, it is flourishing. This is partly because biopsychology relates to a number of current neuroscience disciplines. Biopsychologists draw from:
- neuroanatomy — structure of the nervous system
- neurochemistry — chemistry of the nervous system
- neuroendocrinology — hormones and nervous system
- neuropathology — diseases of the nervous system
- neuropharmacology — drugs and the nervous system
- neurophysiology — electrical activity of the nervous system

The emphasis in biopsychology is upon the nervous system and behavior or cognition, whereas neuroscience emphasizes the nervous system in some specialized way.

1.1 EVOLUTION OF THE SCIENTIFIC METHOD

1.1.1 Schools of Psychology

Behaviorism (John Watson)

- Behaviorism, the school of psychology founded by John B. Watson, views observable, measurable behavior as the only appropriate subject matter for psychology. Behaviorism emphasizes the environment as the key determinant of behavior.
Structuralism (Wundt)

- Wilhelm Wundt and his student Edward Titchener are associated with the early school of thought known as structuralism, the view that the purpose of psychology is to identify the basic elements of conscious mental experience using the process of introspection.

Functionalism (James)

- The first American psychologist was William James. He was also the founder of functionalism, the view that behavior and mental processes must be studied as wholes. Functionalism is also concerned with how behavior and mental processes are used to adapt to the environment. He was greatly influenced by Darwin's ideas.

Gestalt psychology (Wertheimer)

- Gestalt psychology, a forerunner of the cognitive school, emphasizes that the mind interprets information in terms of patterns rather than as individual bits of information. It goes by the philosophy that "The whole is greater than the sum of its parts."

Psychodynamic theory (Freud)

- According to Freud's theory of psychoanalysis, an individual's thoughts, feelings, and behavior are determined primarily by the unconscious—the part of the mind that one cannot see and cannot control. The tension created by conflicts between these unconscious processes and the demands of society is the driving force behind individual development.

Revise your first year notes on the following theories.

(a) Explain the main ideas in behaviorism.
(b) Define structuralism and explain its role in the early development of psychology.
(c) Describe how Freud explain human behavior.
1.1.2 Scientific Method

Converging Operations

The use of multiple approaches to address a single question:

- Korsakoff’s syndrome – a condition characterized by severe memory loss and most commonly seen in alcoholics, Jimmie G. – an alcoholic with Korsakoff’s syndrome.
- Korsakoff’s is also seen in malnourished persons who had little or no alcohol.
- Thiamine-deficient rats exhibit memory deficits.
- Alcohol accelerates the development of brain-damage in thiamine-deficient rats.
- Korsakoff’s syndrome is the result of thiamine deficiency, but the damage is accelerated by alcohol.

By exploring the possible causes of Korsakoff’s using multiple approaches, converging operations, findings are more accurate.

Scientific Inference

- The empirical method that biopsychologists use to study the unobservable.
- Scientists measure what they can observe and use these measures as a basis for inferring what they cannot observe.

Critical Thinking

- The ability to evaluate scientific claims by identifying potential omissions or weaknesses in the evidence.
- Morgan’s Canon – when several explanations are possible, give precedence to the simplest one.
1.2

DISCIPLINES OF NEUROSCIENCE

Seven disciplines in neuroscience are:

<table>
<thead>
<tr>
<th>DISCIPLINE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Neuroanatomy</td>
<td>The study of the structure of the nervous system</td>
</tr>
<tr>
<td>2. Neurochemistry</td>
<td>The study of chemical bases of neural activity</td>
</tr>
<tr>
<td>3. Neuroendocrinology</td>
<td>The study of interactions between the nervous system and the endocrine system</td>
</tr>
<tr>
<td>4. Neuropathology</td>
<td>The study of nervous system disorders</td>
</tr>
<tr>
<td>5. Neuropharmacology</td>
<td>The study of effects of drugs on neural activity</td>
</tr>
<tr>
<td>6. Neurophysiology</td>
<td>The study of functions and activities of the nervous system</td>
</tr>
</tbody>
</table>

1.2.1 Biopsychology

Biopsychology is also known as:
- Psychobiology,
- Behavioral biology,
- Behavioral neuroscience

Hebb (1949) proposed that psychological phenomena might be produced by brain activity. Biopsychology is an integrative discipline, knowledge from other disciplines of neuroscience is applied to the study of behavior.

Each discipline studies a different aspect of the nervous system that informs our understanding of what produces and controls behavior.

Biopsychological Research

Human and nonhuman subjects: Simpler brains makes it more likely that brain-behavior interactions will be revealed
Comparative approach – gain insight by making comparisons with other species
Fewer ethical restrictions

Divisions of Biopsychology

Six major divisions are:

<table>
<thead>
<tr>
<th>DIVISION</th>
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<tr>
<td>1. Physiological psychology</td>
<td>The study of neural mechanisms of behavior and direct manipulation of the brain</td>
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<td>2. Psychopharmacology</td>
<td>The study of effects of drugs on the brain</td>
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<td>3. Neuropsychology</td>
<td>The study of brain damage in humans</td>
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<td>5. Cognitive neuroscience</td>
<td>The study of neural bases of cognition</td>
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<td>6. Comparative psychology</td>
<td>Comparing different species to understand evolution, genetics, and adaptiveness of behavior</td>
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Based on material in the textbook or any other knowledge you have about the brain and behavior, fill out the right-hand column, stating the relationship each neuroscience field has with biopsychology. The first answer is given.

### Neuroscience Field Relationship to Biopsychology

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<tr>
<td>1. Neuroanatomy</td>
<td>The structure of the brain is related to behavior. Examples include brain size and cognition (although not always proportional), cerebral convolutions and cognition, and areas of brain and cognition.</td>
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<td>2. Neurochemistry</td>
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<td>3. Neuroendocrinology</td>
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<td>4. Neuropathology</td>
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<td>5. Neuropharmacology</td>
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<td>6. Neurophysiology</td>
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<td>7. Neural cell biology</td>
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1.3 THE NATURE OF PHYSIOLOGICAL PSYCHOLOGY

Generalization is a type of scientific explanation; a general conclusion based on many observations of similar phenomena.

Reduction is a type of scientific explanation; a phenomena is described in terms of the more elementary processes that underlie it.

1.3.1 Understanding Human Consciousness

Blindsight is the ability of a person who cannot see objects in his or her blind field to accurately reach for them while remaining unconscious of perceiving them; caused by damage to the mammalian visual system of the brain.

Split Brains

![Diagram of split brain operation]

Figure 1.1. The split brain operation. A window has been opened in the side of the brain so that we can see the corpus callosum being cut at the midline of the brain.

The corpus callosum is the largest commissure of the brain; interconnecting the areas of the neocortex on each side of the brain. Epilepsy occurs when nerve cells in one side of the brain become overreactive, and the overreactivity is transmitted to the other side by the corpus callosum.

The split-brain procedure involves cutting the corpus callosum, a band of axons that interconnect the two hemispheres of the brain. Split-brain operation is brain surgery that is occasionally performed to treat a form of epilepsy; the surgeon cuts the corpus callosum, which connects the two hemispheres. After the surgery, the two hemispheres are
disconnected and operate independently; their sensory mechanisms, memory and motor systems can no longer exchange information.

Under appropriate testing conditions, the different functions of the two hemispheres (language in the left, odor on the right) can be demonstrated in a split-brain patient.

Cerebral hemispheres are the two symmetrical halves of the brain; constitute the major part of the brain. They receive sensory information from the opposite sides of the body and control movement of the opposite sides.

Unilateral neglect is a syndrome in which people ignore objects located anywhere. Most often, it is caused by damage to the right parietal lobe.

1.3.2 Biological Roots of Physiological Psychology

The second section involves the understanding of physiological events that underlie our psychological existence. The biological roots of physiological psychology are traced back to the work of Descartes and Darwin.

The Pneuma Theory

The theory, which attributed the functions of mind to invisible spirits, emerged during the rise of Greek civilization:

- Hippocrates (6 century, B.C.) theorized that the brain was the controlling mechanism of all mental & emotional faculties.
- Galen, Greek physician (6 century) – suggested that the inability to vocalize is a proof of the relationship between the nervous system & behavior (based on research on a pig’s larynx).

Luigi Galvani, Italian physician (1780) – discovered that electric current applied to the muscle of a frog produce muscle movement. He correctly theorized that the nerves are capable of conducting electricity (identified that the nature of pneuma was a unique substances he called animal electricity).

Descartes & the brain

Descartes rejected the Greek notion that human fate is subject to the whim of invisible & unknowable force. He theorized that many behaviors formerly thought to be beyond the scope of conventional scientific investigation, eg. Basic sensory experiences, could be explained mechanistically, the same way you might explain the working of a complicated machine.

As Descartes observed, some movements of the human body were automatic and involuntary. He called these reflexes (from the Latin reflexor, “to bend back upon itself. A reflex is an automatic, stereotyped movement produced as the direct result of a stimulus. A Model is a mathematical or physical analogy for a physiological process; for example, computers have been used as models for various functions of the brain.

Johannes Muller was a forceful advocate of the application of experimental techniques to physiology. The Doctrine of specific nerve energies is based on Muller’s conclusion that
because all nerve fibers carry the same type of message, sensory information must be specified by the particular nerve fibers that are active.

Experimental ablation is the research method in which the function of a part of the brain is inferred by observing the behaviors an animal can no longer perform after that part of the brain is damaged. Through this method, Pierre Flourens, a nineteenth-century French physiologist claimed to have discovered the regions of the brain that control heart rate and breathing, purposeful movements and visual and auditory reflexes.

Paul Broca, a French Surgeon, applied the principle of experimental ablation to the human brain. Broca’s observation lead him to conclude that a portion of the brain of the cerebral cortex on the left side of the brain performs functions that are necessary for speech.

Natural Selection and Evolution

The human brain is perhaps one of the most exciting exhibits of evolution. Emphasize how evolution may explain many features of our brains. The following website is useful: Clues to the evolution of human’s large brain by the Wellcome Trust:

http://www.wellcome.ac.uk/en/genome/geneandbody bigotry7008.html

Functionalism and the Inheritance of Traits

Functionalism is a belief that characteristics of living organisms perform useful functions. The principle holds that the best way to understand a biological phenomenon (a behavior or a physiological process) is to try to understand its useful functions for the organism.

Natural selection is the process by which inherited traits that confer a selective advantage (increase an animal’s likelihood to live and reproduce) become more prevalent in a population.

Mutation is an accidental change in the genetic information contained in the chromosomes of sperm or eggs, which can be passed on to an organism’s offspring; provides genetic variability.

Selective advantage is a characteristic of an organism that permits it to produce more than the average number of offspring of its species. The animal is more likely to live long enough to reproduce and hence to pass on its chromosomes to its own offspring.

Evolution of the Human Species

Evolution is a gradual change in the structure and physiology of a plant and animal species, generally producing more complex organisms, as a result of natural selection. New species evolve when organisms develop novel characteristics that can take advantage of unexploited opportunities in the environment.

Evolution of Large Brains

Human beings possessed several characteristics that enabled them to compete with other species, agile hands, excellent color vision, mastery of fire, their upright posture and bipedalism, and their linguistic abilities. All these characteristics required a large brain.
Neoteny is a slowing of the process of maturation, allowing more time for growth; an important factor in the development of large brains. The mature human head and brain retain some of their infantile characteristics including their disproportionate size.

**Evolution of the human brain**
- human brain — weighs 1,350 grams: less than whale or elephant brains at 5,000–8,000 grams
- no relationship between brain size and intelligence
- larger animals have larger brains — more tissue to control (e.g., male brains larger on average than female brains)
- brain size as a percentage of body weight NOT adequate (e.g., shrew has highest brain/body ratio, but NOT most intelligence)
- focus on cerebral hemispheres
- number of **convolutions** — folds in the cerebral surface — relate to greater surface area of cerebral cortex

**ACTIVITY 1.2**
(a) Explain the function of split brain operations.
(b) Explain natural selection. Discuss the evolution of the human brain.
1. _______ is the belief that natural phenomena such as winds and tides are caused by spirits.

2. _______ is the belief that the mind and body are separate entities.

3. Transection of the _______ may be useful for reducing the symptoms of _______.

4. A reflex is considered to be a(n) _______ movement elicited by a(n) _______.

5. Galvani showed that _______ of a frog nerve caused _______ of the attached muscle.

6. Pierre Flourens is known _______.

7. Experimental ablation involves _______.

8. Mutations involve _______.

9. _______ are physicians trained to diagnose and to treat central nervous system diseases.

10. Rene Descartes asserted that _______.
Suggested Text and References

Required Reading:


Suggested Readings


Suggested Web Sites

Wikipedia on Biological Psychology:
http://en.wikipedia.org/wiki/Biopsychology

Brain and Behavior Course
http://www.nyu.edu/classes/azmitia/lecture/

Broca’s Classic Paper on Patient Tan
http://www.yorku.ca/dept/psych/classics/Broca/perte-e.html

The Descent of Man by Charles Darwin
http://www.yorku.ca/dept/psych/classics/Darwin/Descent/index.html

Split-Brain Syndrome
http://www.uwm.edu/~johnchay/sb.htm

Founders of Neurology
http://www.uic.edu/depts/mcne/homepage/neurofounders.html
Self-check

1. Animism
2. Dualism
3. corpus callosum; epilepsy
4. involuntary; external stimulus
5. electrical stimulation; contraction
6. for his development and use of the experimental ablation technique
7. the intentional damage to a portion of the brain.
8. accidental changes in the chromosomes.
9. Neurologists
10. the mechanical nature of animals is controlled by environmental stimuli.
Unit 2  • Anatomy of the Brain

LEARNING OUTCOME

At the end of this topic you will learn about:

1. Describe the appearance of the brain and the terms used to indicate directions and planes of section.
2. Describe the basic features of the nervous system, the central nervous system.
3. Describe the blood supply to the brain, the meninges, the ventricular system, and flow of cerebrospinal fluid through the brain and its production, the peripheral nervous system.
4. Describe the telencephalon, one of the two of the two major structures of the forebrain.
5. Describe the two major structures of the diencephalon.
6. Describe the two major structures of the midbrain, the two major structures of the hindbrain, and the spinal cord.
7. Describe the peripheral nervous system, including the two divisions of the autonomic nervous system.
INTRODUCTION

There are two parts of a nervous system:
1. Central nervous system (CNS)
2. Peripheral nervous system (PNS)

The central nervous system is located inside of the skull and spine. It comprises:
1. Brain (in the skull)
2. Spinal Cord (in the spine)

The peripheral nervous system is located outside of the skull and spine. It connects the central nervous system to all other parts of the body. It serves to bring information into the CNS and carry signals out of the CNS.

The peripheral nervous system comprises two parts:
1. Somatic Nervous System
   - Afferent nerves (sensory)
   - Efferent nerves (motor)
2. Autonomic Nervous System
   - Sympathetic and parasympathetic nerves
     - Sympathetic and parasympathetic nerves generally have opposite effects
The autonomic is a two-stage neural path. It is the path when neuron exit the CNS synapses on a second-stage neuron before reaching the target organ.
The sympathetic nerves are located at the thoracolumbar section. In a "fight or flight" reaction, they are on the second stage neurons that are far from the target organ.

The parasympathetic nerves lie on the craniosacral section. In a "rest and restore" action, they are the second stage neurons which are near the target organ.

2.1 BASIC FEATURES OF THE NERVOUS SYSTEM

The neuraxis is an imaginary line drawn through the center of the length of the central nervous system, from the bottom of the spinal cord to the front of the forebrain.
With respect to the central nervous system, the anterior located near or toward the head. With respect to the central nervous system, the posterior is located near or toward the tail.

The rostral is located "toward the beak"; with respect to the central nervous system, in a direction along the neuraxis toward the front of the face. The caudal is located "toward the tail"; with respect to the central nervous system, in a direction along the neuraxis away from the front of the face.

The dorsal is located "toward the back"; with respect to the central nervous system, in a direction perpendicular to the neuraxis toward the top of the head or the back.

The ventral is located "toward the belly"; with respect to the central nervous system, in a direction perpendicular to the neuraxis toward the bottom of the skull or the front surface of the body.

The lateral is toward the side of the body, away from the middle. The medial is toward the middle of the body, away from the side. The ipsilateral is located on the same side of the body. The contralateral is located on opposite side of the body.

![Figure 2.1: Planes of section as they pertain to the human central nervous system.](image)
We can slice the nervous system three ways:

(a) Cross section or Frontal section is a transverse cut like a salami. With respect to the central nervous system, a slice taken at right angles to the neuraxis it is a slice through the brain parallel to the forehead.

(b) Horizontal section is a slice through the brain parallel to the ground.

(c) Sagittal section is a slice through the brain parallel to the neuraxis and perpendicular to the ground. The midsagittal is the plane through the neuraxis perpendicular to the ground; divides the brain into two symmetrical halves.

2.1.1 Meninges, Ventricles and CSF

The brain is the best protected organ in the body. The first layer of protection is the skull, which acts as armour shielding the brain from blows. Next come the meninges, three membranes that surround the brain to keep it from being damaged by contact with the inside of the skull.

Meninges (singular: meninx) consist of three layers which encase the central nervous system:

(a) Dura mater ("hard mother") is the tough outermost membrane of the meninges; flexible, unstretchable.
(b) Arachnoid membrane (from the Greek arachne, meaning “spider”) are the weblike middle layer of the meninges, located between the dura mater and the inner pia mater.

(c) Pia mater (“pius mother”) is the layer of the meninges adjacent to the surface of the brain; thin and delicate. Adheres to CNS surface.

It is these membranes that become infected when someone gets meningitis. It is because the meninges are in direct contact with the brain that meningitis is so dangerous.

Figure 2.3: (a) The relation of the nervous system to the rest of the body. (b) Detail of the meninges that cover the nervous system. (c) A closer view of the lower spinal cord and cauda equina.

Subarachnoid space - The fluid-filled space that cushions the brain; located between the arachnoid membrane and the pia mater.
Cerebrospinal fluid (CSF) - A clear fluid, similar to blood plasma, that fills the ventricular system of the brain and the subarachnoid space surrounding the brain and spinal cord. For even more protection, the brain (and the spinal cord) are bathed in the cerebro-spinal fluid. The fluid serves as cushion.

This fluid circulates through a series of communicating cavities called ventricles. Cerebrospinal fluid also circulates between the pia mater and the arachnoid mater of the meninges. In addition to cushioning blows, this fluid reduces the pressure at the base of the brain by causing the nerve tissue to “float”.

Cerebro-spinal fluid is secreted by the choroid plexus in the upper ventricles and absorbed by the venous system at the base of the brain. As this fluid flows downward, it carries away toxic wastes and moves hormones between widely separated regions of the brain.

The Ventricular System and Production of CSF

The ventricle is one of the hollow spaces within the brain, filled with cerebrospinal fluid. The lateral ventricle is one of the two ventricles located in the center of the telencephalon. The third ventricle is located in the center of the diencephalon. The fourth ventricle is the ventricle located between the cerebellum and the dorsal pons, in the center of the metencephalon.

The cerebral aqueduct is a narrow tube interconnecting the third and fourth ventricles of the brain, located in the center of the mesencephalon. The choroids plexus is the highly vascular tissue that protrudes into the ventricles and produces cerebrospinal fluid.

Arachnoid granulation is the small projections of the arachnoid membrane through the dura mater into the superior sagittal sinus; CSF flows through them to be reabsorbed into the blood supply.

The superior sagittal sinus is a venous sinus located in the midline just dorsal to the corpus callosum, between the two cerebral hemispheres.

An obstructive hydrocephalus is a condition which all or some of the brain’s ventricle are enlarged; caused by an obstruction that impedes the normal flow of CSF.

ACTIVITY 2

List the contributions of each of the cerebrum’s lobes, if any, to the following activities:

(a) Baking a cake
(b) Reading a novel
(c) Playing a card game
(d) Lifting weights
2.2

THE CENTRAL NERVOUS SYSTEM

The neural tube is a hollow tube, closed at the rostral end, that forms from ectodermal tissue early in embryonic development and serves as the origin of the central nervous system.

The ventricular zone is a layer of cells that line the inside of the neural tube; contains founder cells that divide and give rise to cells of the central nervous system.

Radial glia are special glia with fibers that grow radially outward from the ventricular zone to the surface of the cortex, provide guidance for neurons migrating outward during brain development.

Founder cells are cells of the ventricular zone that divide and give rise to cells of the central nervous system.

The symmetrical division is the division of a founder cell that gives rise to two identical founder cells; increases the size of the ventricular zone and hence the brain that develops from it.

The asymmetrical division of a founder cell that gives rise to another founder cell and a neuron, which migrates away from the ventricular zone toward its final resting place in the brain.

2.1 Five Divisions of the Brain

The brain or encephalon (Greek for “in the head”), is the control center of the central nervous system, responsible for behavior. The brain is located in the head, protected by the skull and close to the primary sensory apparatus of vision, hearing, equilibrioception (balance), sense of acceleration, taste, and olfaction. While all vertebrates have a brain, most invertebrates have either a centralized brain or collections of individual ganglia.

It has five major divisions, which comprises:

(a) telencephalon,
(b) diencephalon,
(c) mesencephalon,
(d) metencephalon and
(e) myelencephalon.

Telencephalon

The telencephalon (tel'ə nəs'ə fə lən) is the name for the forebrain, a large region within
the brain to which many functions are attributed. Many people refer to it as the cerebrum; however, it is technically referred to as the telencephalon.

As a more technical definition, the telencephalon refers to the cerebral hemispheres and other, smaller structures within the brain, although the telencephalon is one of the larger divisions (in terms of number). It is the anterior-most embryological division of the brain that develops from the prosencephalon.

Function:
- Determines Intelligence
- Determines Personality
- Interpretation of Sensory Impulses
- Motor function
- Planning and Organization
- Sense of Smell
- Touch Sensation

Location:
- The telencephalon is the anterior portion of the brain, rostral to the midbrain.

Structures:
The telencephalon is composed of the following sub-regions;
- Limbic system
- Cerebral cortex or cortices of the cerebral hemispheres.
- Basal ganglia
- Corpus striatum
- Olfactory bulb

The reticular formation is found in the myelencephalon and metencephalon. The metencephalon also contains the pons and cerebellum. The mesencephalon houses the inferior and superior colliculi (the tectum), and the substantia nigra and red nucleus (the tegmentum).

The diencephalon consists of the thalamus, a large collection of sensory relay nuclei, and the hypothalamus, a limbic structure that controls the pituitary gland. The telencephalon is the most expansive, containing the cerebral cortex, most of the limbic system, and basal ganglia.

Approximately 90% of the cerebral cortex is neocortex in the human brain. The neocortex can be divided into frontal, parietal, temporal, and occipital lobes. The limbic system is comprised of the hippocampus, cingulate cortex, amygdala, septum, and mammillary bodies. The basal ganglia are comprised of the caudate, putamen, and globus pallidus.
1. Telencephalon
   - Cerebral cortex
   - Limbic system
   - Basal ganglia
2. Diencephalon
   - Thalamus – sensory relay nuclei
   - Hypothalamus
     - Regulation of motivated behaviors
     - Controls hormone release by the pituitary
3. Mesencephalon
   - Tectum (dorsal surface)
     - Inferior colliculi – audition
     - Superior colliculi – vision
   - Tegmentum (ventral) – 3 ‘colorful’ structures
     - Periaqueductal gray – analgesia
     - Substantia nigra – sensorimotor
     - Red nucleus – sensorimotor
4. Metencephalon
   - Many tracts
   - Pons – ventral surface
   - Cerebellum – coordination
5. Myelencephalon – medulla
   - Composed largely of tracts
   - Origin of the reticular formation
2.2.1 Cerebrum

The largest structure of the human brain, consisting of the two cerebral hemispheres connected by the corpus callosum and covered by the cerebral cortex. The most rostral of the three major divisions of the brain; includes the telencephalon and diencephalon.

Cerebral Cortex is a thin layer of gray matter on the surface of the cerebral hemisphere, folded into gyri with about two-thirds of its area buried in fissures. The cerebral cortex integrates higher mental functions, general movement, visceral functions, perception, and behavioral reactions.

It is the layer of gray matter that constitutes the outer layer of the cerebrum and is responsible for integrating sensory impulses and for higher intellectual functions. It is divided into four lobes, roughly defined by major surface folds; sometimes the limbic system, or limbic lobe, is considered to be a fifth lobe. The frontal lobe controls motor activity and speech, the parietal controls touch and position, and the temporal lobe handles auditory reception and memory. The occipital lobe at the back of the brain holds the brain’s major visual-reception area. The limbic lobe controls smell, taste, and emotional responses.

Seen from the outside, the most obvious component of the human brain is the intricately folded cerebral cortex that covers the pair of cerebral hemispheres, which conceal most of the rest of the brain. The convolutions, or gyri, of the cortex, and the fissures or sulci that separate them, vary enormously from brain to brain, and from one hemisphere to the other in each individual.

The surface layer of gray tissue of the cerebrum, frequently called the gray matter. The large size of the cerebral cortex in humans distinguishes them from other animals. Specific parts of the cortex control specific functions, including sensation, voluntary muscle movement, thought, reasoning, and memory.

The total area of cortex in man is estimated at nearly a square meter; it is about 4 mm thick, and it contains 10,000 million or more nerve cells (neurons). The number of synapses (connections between nerve fibres and other neurons) is even more staggering; there are, on average, around 10,000 synapses on every cortical neuron.

Convolutions serve to increase surface area. Longitudinal fissure is a groove that separates right and left hemispheres. Convolutions are the numerous folds or wrinkles in the cortex; they consist of:

(a) Sulci (small grooves) – A groove in the surface of the cerebral hemisphere, smaller than a fissure. The surface of the cerebral cortex is folded in large mammals where more than two-thirds of the cortical surface is buried in the grooves, called "sulci".

(b) Fissures (large grooves) – A major groove in the surface of the brain, larger than a sulcus.
(c) Gyri (bulges between adjacent sulci or fissures) – A convolution of the cortex of the cerebral hemispheres, separated by sulci or fissures.

** Corpus callosum** is the largest hemisphere-connecting tract. The thick band of nerve fibers that connects the two cerebral hemispheres and makes possible the transfer of information and the synchronization of activity between them.

**Cerebral hemispheres** are the right and left halves of the cerebrum, covered by the cerebral cortex and connected by the corpus callosum. One of the two major portions of the forebrain, covered by the cerebral cortex.

**Figure 2.4(b): Anatomical Subdivisions of the Brain**

### 1.1 The Forebrain

The forebrain surrounds the rostral end of the neural tube. Its two major components are the telencephalon and the diencephalon.

**Telencephalon**

The telencephalon includes most of the two symmetrical cerebral hemispheres that make up the cerebrum. The cerebral hemispheres are covered by the cerebral cortex and contain the limbic system and the basal ganglia. The latter two sets of structures are in the subcortical regions of the brain.
The gray, convoluted covering of the cerebral hemispheres that is responsible for higher mental processes including language, memory, and thinking and are referred to as gray matter. Andreasen and others indicated that the amount of gray matter is positively correlated with human intelligence.

Beneath the cerebral cortex runs millions of axons that connect the neurons of the cerebral cortex with those located elsewhere in the brain. The large concentration of myelin gives the tissue an opaque white appearance – white matter.

Three types of areas of the cerebral cortex receive information from sensory organs:

(a) **Primary visual cortex**: receives visual information, is located at the back of the brain, on the inner surfaces of the cerebral hemispheres (primarily the calcarine fissure).

(b) **Primary auditory cortex**: receives auditory information, is located on the lower surface of a deep fissure in the side of the brain – the lateral fissure.

(c) **Primary somatosensory cortex**: a vertical strip of cortex just caudal to the central sulcus, receives information from the body senses such as touch, pressure and temperature register.

The **primary motor cortex** is the region of the posterior frontal lobe that contains neurons that control movements of skeletal muscles.
The **association areas** house memories and are involved in thought, perception, and language.

![Diagram of the cerebral cortex](image)

**Figure 2.6:** The cerebral cortex.

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**The Frontal Lobes**

The anterior portion of the cerebral cortex, rostral to the parietal lobe and dorsal to the temporal lobe. This includes everything in front of the central sulcus (front of the brain). Functions include:

(a) **Motor cortex:** control voluntary body movements.

(b) **Broca’s area:** speech production.

(c) **The frontal association areas:** memory search, reasoning, thinking, motivation, planning for the future, impulse control, and emotional responses

The **motor cortex** is the strip of tissue at the rear of the frontal lobes that controls voluntary body movement. It was discovered by Fritsch and Hitzig. Wilder Penfield applied electrical stimulation to the motor cortex of conscious human patients undergoing neurosurgery and mapped the primary motor cortex in humans.

**Plasticity** is maintained throughout life. This allows the brain to adapt to changes such as brain damage.

**Frontal association areas** consists of association areas involved in thinking, motivation, planning for the future, impulse control, and emotional responses.

Dopamine-sensitive neurons in the **cerebral cortex** are found primarily in the frontal lobes. The dopamine system is associated with pleasure, long-term memory, planning and drive. Dopamine tends to limit and select sensory information arriving from the **thalamus** to the fore-brain. Poor regulation of dopamine pathways has been associated with schizophrenia.
The so-called executive functions of the frontal lobes involve the ability to recognize future consequences resulting from current actions, to choose between good and bad actions (or better and best), override and suppress unacceptable social responses, and determine similarities and differences between things or events.

The frontal lobes also play an important part in retaining longer term memories which are not task-based. These are often memories with associated emotions, derived from input from the brain’s limbic system, and modified by the higher frontal lobe centers to generally fit socially acceptable norms (see executive functions above). The frontal lobes have rich neuronal input from both the alert centers in the brainstem, and from the limbic regions.

The Parietal Lobes

The region of the cerebral cortex caudal to the frontal lobe and dorsal to the temporal lobe (Top rear of the brain). The lobes that contain the somatosensory cortex and other areas that are responsible for:

(a) body awareness
(b) attention
(c) motor control
(d) spatial orientation

The somatosensory cortex is the strip of tissue at the front of the parietal lobe where touch, pressure, temperature, and pain register in the cerebral cortex.

The parietal lobe integrates sensory information from different modalities, particularly determining spatial sense and navigation. For example, it comprises somatosensory cortex and the dorsal stream of the visual system. This enables regions of the parietal cortex to map objects perceived visually into body coordinate positions.

The Temporal Lobes

The region of the cerebral cortex rostral to the occipital lobe and ventral to the parietal and frontal lobes (in front of the ears).

The lobes that contain the primary auditory cortex, Wernicke's area (hearing), and association areas for interpreting auditory information, vision, memory
Primary auditory cortex: The part of the temporal lobes where hearing registers in the cerebral cortex.

The lobes that contain the primary auditory cortex (the part of the temporal lobes where hearing registers in the cerebral cortex), Wernicke's area (hearing), and association areas for interpreting auditory information, vision, and memory.

The temporal lobe is involved in auditory processing and is home to the primary auditory cortex. It is also heavily involved in semantics both in speech and vision. The temporal lobe contains the hippocampus and is therefore involved in memory formation as well.

The Occipital Lobes

The region of the cerebral cortex caudal to the parietal and temporal lobes. This is located posterior to the central sulcus (at the back of the head). The lobes that contain the primary visual cortex and association areas are involved in the interpretation of visual information.

Primary visual cortex is the area at the rear of the occipital lobes where vision registers in the cerebral cortex. Each eye is connected to the primary visual cortex in both right and left occipital lobes.

Sensory association cortex are those regions of the cerebral cortex that receive information from regions of the primary sensory cortex. Perception takes place here and memories are stored here.

Motor association cortex (premotor cortex) is the region of the frontal lobe rostral to the primary cortex; also known as the premotor cortex. Controls overall motor behavior.

Prefrontal cortex is the region of the frontal lobe rostral to the motor association cortex. This region is involved in formulating plans and strategies.

Corpus callosum is a large bundle of axons that interconnects corresponding regions of the association cortex on each side of the brain.

Neocortex is the phylogenetically newest cortex, including the primary sensory cortex, primary motor cortex, and association cortex.

Limbic cortex is the phylogenetically old cortex, located at the medial edge of the cerebral hemispheres; part of the limbic system.

Cingulate gyrus is a strip of limbic cortex lying along the lateral walls of the groove separating the cerebral hemispheres, just above the corpus callosum.
Limbic System

- The Limbic System

A group of brain regions including the anterior thalamic nuclei, amygdala, hippocampus, limbic cortex, fornix, cingulate, septum, mammillary bodies and parts of the hypothalamus, as well as their interconnecting fiber bundles. These structures in the brain are collectively involved in emotion, memory, and motivation.

Hippocampus is a forebrain structure in the limbic system (in the temporal lobe) that plays a central role in the formation of long-term memories. This includes the hippocampus proper, dentate gyrus, and subiculum.

Fornix is fiber bundle that connects the hippocampus with other parts of the brain, including the mammillary bodies of the hypothalamus.

Mammillary bodies are a protrusion of the bottom of the brain at the posterior end of the hypothalamus, containing some hypothalamic nuclei. These serve as relay stations in reflexes related to the sense of smell.

The amygdala is a structure in the limbic system (in the interior of the rostral temporal lobe), containing a set of nuclei. It plays an important role in emotion, particularly in response to aversive stimuli.
Figure 2.8: The hippocampus

Basal Ganglia

Basal ganglia are a group of subcortical nuclei in the telencephalon, including the caudate nucleus, the globus pallidus, and the putamen.

Parkinson’s disease is caused by degeneration of the caudate nucleus and putamen. Parkinson’s disease includes weakness, tremors, rigidity of the limbs, poor balance and difficulty initiating movements.

Diencephalon

Thalamus (Greek thalamos, “inner chamber”)

The largest portion of the diencephalon, located above the hypothalamus; contains nuclei that project information to specific regions of the cerebral cortex and receive information from it. The structure, located above the brainstem, that acts as a relay station for information flowing into or out of the higher brain centers. The thalamus has two lobes, connected by a bridge of gray matter called the massa intermedia, which pierces the middle of the third ventricle.
The thalamus comprises many different pairs of nuclei, most of which project to the cortex. Some are sensory relay nuclei—nuclei that receive signals from sensory receptors, process them, and then transmit them to the appropriate areas of sensory cortex. For example, the lateral geniculate nuclei, the medial geniculate nuclei, and the central posterior nuclei are important relay stations in the visual, auditory, and somatosensory systems, respectively.

The thalamus seems to be a relay for sensory input as well as an important part of other pathways, including motor and sensory pathways and those between different parts of the cortex and the cerebellum and other subcortical structures.

Projection fibers are sets of axons that arise from cell bodies located in one region of the brain and synapse on neurons located within another region.

The thalamus is divided into several nuclei:

(a) Lateral geniculate nucleus is a nucleus of the thalamus that receives fibers from the retina and projects fibers to the primary visual cortex.

(b) Medial geniculate nucleus is a nucleus of the thalamus that receives fibers from the auditory system and projects fibers to the auditory cortex.

(c) Ventrolateral nucleus is a nucleus of the thalamus that receives inputs from the cerebellum and sends axons to the primary motor cortex.

Hypothalamus (Greek hypo-, cognate to Latin sub- "under")

The hypothalamus is a group of nuclei in the diencephalon situated under the thalamus. It is a small but influential brain structure that controls the pituitary gland and regulates hunger, thirst, sexual behavior, body temperature, and a wide variety of emotional behaviors.

It plays an important role in the regulation of several motivated behaviors. It exerts its effects in part by regulating the release of hormones from the pituitary gland, which dangles from it on the ventral surface of the brain. It also:

(a) Controls the autonomic nervous system.

(b) Controls the anterior and posterior pituitary glands.

Organizes behavior such as fighting, feeding, fleeing, and mating. Two other structures appear on the inferior surface of the hypothalamus—the optic chiasm and the mamillary bodies. The optic chiasm is the point at which the optic nerves from each eye come together. The mamillary bodies are a pair of spherical hypothalamic nuclei located on the inferior surface of the hypothalamus, just below the pituitary gland. The hypothalamus apparently does not play much of a role in language.
Figure 2.9: The pituitary gland. Hormones released by the neurosecretory cells in the hypothalamus enter capillaries and are conveyed to the anterior pituitary gland.

The optic chiasm is a connection between the optic nerves where half of the fibers of the optic nerve cross to the contralateral side.

The anterior pituitary gland is the “master gland”. The anterior part of the pituitary gland; an endocrine gland whose secretions are controlled by the hypothalamic hormones.

The neurosecretory cell is a neuron that secretes a hormone or hormone-like substance.

The posterior part of the pituitary gland is an endocrine gland that contains hormone-secreting terminal buttons of axons whose cell bodies lie within the hypothalamus.
Mesencephalon

The midbrain, a region of the brain that surrounds the cerebral aqueduct; includes the tectum and tegmentum.

The mesencephalon; the central of the three major divisions of the brain. The structures of this brain region act primarily as relay stations through which the basic physiological functions of the hindbrain are linked to the cognitive functions of the forebrain.

Tectum ("roof")

The dorsal part of the midbrain; includes the superior and inferior colliculi.

Superior colliculi are protrusions on top of the midbrain; part of the visual system. In mammals they are primarily involved in visual reflexes and reactions to moving stimuli.

Inferior colliculi are protrusions on top of the midbrain; part of the auditory system.

Tegmentum

Tegmentum ("covering") consists of the portion of the mesencephalon beneath the tectum. It includes the rostral end of the reticular formation, several nuclei controlling eye movements, the periaqueductal gray matter, the red nucleus, the substantia nigra and the ventral area.

The reticular formation is a large network of neural tissue located in the central region of the brain stem, from the medulla to the diencephalons.

Periaqueductal gray matter is the region of the midbrain surrounding the cerebral aqueduct; contains neural circuits involved in species-typical behaviors such as fighting and mating; involved in sensitivity to pain.

Red nucleus is a large nucleus of the midbrain that receives inputs from the cerebellum and motor cortex and sends axons to motor neurons in the spinal cord.

Substantia nigra ("black substance") is a darkly stained region of the tegmentum that contains neurons that communicate with the caudate nucleus and putamen in the basal ganglia. Degeneration of the substantia nigra is involved in Parkinson's disease.

The Hindbrain

The most caudal part of the brain; includes the metencephalon and myelencephalon.

Metencephalon

The metencephalon consists of the pons and the cerebellum.
Cerebellum

Cerebellum ("little brain") is a major part of the brain located dorsal to the pons, containing the two cerebellar hemispheres, covered with the cerebellar cortex; important component of the motor system. The brain structure that executes smooth, skilled body movements and regulates muscle tone and posture.

The cerebellar cortex is the cortex that covers the surface of the cerebellum. The deep cerebellar nuclei is nuclei located within the cerebellar hemispheres, receive projections from the cerebellar cortex and send projections out of the cerebellum to other parts of the brain.

The brainstem is the structure that begins at the point where the spinal cord enlarges as it enters the brain.

The cerebellar peduncle is one of three bundles of axons that attach each cerebellar hemisphere to the dorsal pons.

Pons

Pons ("bridge") is the region of the metencephalon rostral to the medulla, caudal to the midbrain, and ventral to the cerebellum; a structure in the brainstem that plays a role in body movement and even exerts an influence on arousal, sleep and dreaming.

The reticular formation is a structure in the brainstem that plays a crucial role in arousal and attention and that screens sensory messages entering the brain.

Myelencephalon

The medulla oblongata is the most caudal portion of the brain, located in the myelencephalon, immediately rostral to the spinal cord. The part of the brainstem that controls vital functions such as the cardiovascular system, respiration, and skeletal muscle tone (breathing, coughing, and swallowing).

Spinal Cord

The cord of nervous tissue that extends caudally from the medulla, the base of the brain through the neck and spinal column, that transmits messages between the brain and the peripheral nervous system and is protected by bone and spinal fluid.

- Gray matter – inner component – primarily cell bodies
- White matter – outer – mainly myelinated axons
- Dorsal – afferent, sensory
- Ventral – efferent, motor

The spinal root is a bundle of axons surrounded by connective tissue that occur in pairs, which fuse and form a spinal nerve.

The cauda equina is a bundle of spinal roots located caudal to the end of the spinal cord.
A caudal block is the anesthesia and paralysis of the lower part of the body produced by injection of a local anesthetic into the cerebrospinal fluid surrounding the cauda equina.

The dorsal root is the spinal root that contains incoming (afferent) sensory fibers. The ventral root is the spinal root that contains the outgoing (efferent) motor fibers.

**Figure 2.9: The spinal cord.** (a) A portion of the spinal cord, showing the layers of the meninges and the relation of the spinal cord to the vertebral column. (b) A cross section through the spinal cord. Ascending tracts are shown in blue; descending tracts are shown in red.
2.3

THE PERIPHERAL NERVOUS SYSTEM

Figure 2.10: The autonomic nervous system and the target organs and functions served by the sympathetic and parasympathetic branches.
2.3.1 Spinal Nerves

The spinal nerves begin at the junction of the dorsal and ventral roots of the spinal cord. The nerves leave the vertebral column and travel to the muscles or sensory receptors they innervate, branching repeatedly as they go.

Afferent axon is an axon directed toward the central nervous system, conveying sensory information.

The dorsal root ganglion is a nodule on a dorsal root that contains cell bodies of afferent spinal nerve neurons.

Efferent axon is an axon directed away from the central nervous system, conveying motor commands to muscles and glands.

2.3.2 Cranial Nerves

Twelve pairs of peripheral nerves attached directly to the brain that serve sensory and motor functions of the head, neck, and shoulders.

Vagus nerve ("wandering") is the largest of the cranial nerves, conveying efferent fibers of the parasympathetic division of the autonomic nervous system to organs of the thoracic and abdominal cavities.

The olfactory bulb is the protusion at the end of the olfactory nerve that receives input from the olfactory responses.

2.3.3 The Autonomic Nervous System (ANS)

The somatic nervous system is the part of the peripheral nervous system that controls the movement of skeletal muscles or transmits somatosensory information to the central nervous system.

Autonomic nervous system is the portion of the peripheral nervous system that controls the body’s vegetative functions.

The ANS consists of two anatomically separate divisions:
- The sympathetic division
- The parasympathetic division

Sympathetic Division of the ANS

Sympathetic division is the portion of the autonomic nervous system that controls functions that accompany arousal and expenditure of energy.
Sympathetic ganglia are nodules that contain synapses between preganglionic and postganglionic neurons of the sympathetic nervous system.

A sympathetic ganglion chain is one of a pair of groups of sympathetic ganglia that lie ventrolateral to the vertebral column.

The preganglionic neuron is the efferent neuron of the autonomic nervous system whose cell body is located in a cranial nerve nucleus or in the intermediate horn of the spinal gray matter and whose terminal buttons synapse upon postganglionic neurons in the autonomic nervous system.

Postganglionic neurons are neurons of the ANS that form synapses directly with their target organ.

The adrenal medulla is the inner portion of the adrenal gland, located atop the kidney, controlled by sympathetic nerve fibers; secretes epinephrine and norepinephrine.

Parasympathetic Division of the ANS

The parasympathetic division is the portion of the autonomic nervous system that controls functions that occur during a relaxed state. It supports activities involved with increases in the body’s supply of stored energy including salivation, gastric and intestinal motility, secretion of digestive juices, and increased blood flow to the gastrointestinal system.

Color and label the appropriate structure and also list at least two of its major functions:

(a) the cerebral cortex, including the four lobes
(b) the thalamus, and hypothalamus
(c) the hippocampus
(d) the amygdala
(e) the cerebellum
(f) the pons, and medulla
1. What does the term neuraxis refer to?
2. What is another term for rostral?
3. What is the tough protective sheath that covers the brain and that lies closest to the skull termed?
4. What is the middle layer of the meninges termed?
5. The brain is cushioned by ______ fluid, which is contained within the ______
6. CSF is reabsorbed via the ______
7. The process of apoptosis is required because ______
8. Primary auditory cortex is located within which cortical lobe?
9. Which cortical lobe contains the primary visual cortex?
10. The planning and execution of movements is a function performed by association cortex in which cortical lobe?
11. What would damage to portions of the limbic cortex alter?
12. What is considered to be the body’s “master gland”?
13. Which structures comprise the midbrain?
14. Where is the pons located?
15. What is the gray matter in the spinal cord comprised of?
16. What does the autonomic nervous system control?
Suggested Text and References

Required Reading

Suggested Readings


1.2 Suggested Web Sites

Neuroscience Images
http://synergy.mcg.edu/pu/PT413/images/images.html

The Global Spinal Cord
http://www.anatomy.wisc.edu/sc97/text/SC/contents.htm

Harvard Brain Atlas
http://www.med.harvard.edu/AANLIB/home.htm

Medical Neuroscience
http://www.indiana.edu/~m555/
Self-check

1. an imaginary line drawn through the spinal cord up to the front of the brain.
2. anterior.
3. dura mater
4. arachnoid membrane
5. cerebrospinal; subarachnoid space
6. arachnoid granulations.
7. because the brain overproduces neurons during embryonic development.
8. temporal
9. occipital
10. frontal
11. emotion.
12. anterior pituitary
13. tectum and tegmentum
14. immediately ventral to the cerebellum.
15. cell bodies and dendrites.
16. smooth muscle, cardiac muscle, glands, "vegetative" processes.
Label the following parts of the Nervous System:
Unit 3  ▶  Neural Impulse Conduction

LEARNING OUTCOME

At the end of this unit, you will be able to:

1. Name and describe the parts of a neuron and explain their functions.
2. Describe the supporting cells of the central and peripheral nervous systems and explain the blood-brain barrier.
3. Briefly describe the role of neural communication in a simple reflex and its inhibition by brain mechanisms.
4. Describe the measurement of the action potential and explain the dynamic equilibrium that is responsible for the membrane potential.
5. Describe the role of ion channels in action potentials and explain the all-or-none law and the rate law.
6. Describe the structure of synapses, the release of the neurotransmitter, and the activation of postsynaptic receptors.
7. Describe postsynaptic potentials: the ionic movements that cause them, the processes that terminate them, and their integration.
INTRODUCTION

The human brain is the organ that moves muscles. Movement is the ultimate function of the brain. To make useful movements, the brain must know what is happening outside, in the environment.

To do so, the body has cells that specialize in detecting environmental events. They sense, perceive and act on the information. Besides perceiving and acting, we also remember and decide. All these abilities are made possible by the billions of cells found in the nervous system.

This unit describes the structure and functions of the most important cells of the nervous system. Information is gathered from the environment by specialized cells called the sensory neurons. Movements are accomplished by the contraction of muscles, which are controlled by another set of specialized cells called the motor neurons.

Between the sensory neurons and the motor neurons are the interneurons. Local interneurons form circuits with nearby neurons and analyze small pieces of information. Relay interneurons connect interneurons in one region of the brain with those of other regions.

How many neurons are there in the nervous system? A number of estimates has been made - between 100 to 1000 billion (as many as the stars in the galaxy). But, no one has successfully counted them yet! In addition, there is 100 trillion connections in the human brain.

3.1 CELLS OF THE NERVOUS SYSTEM

3.1.1 Neurons

There are three general types of neurons:

(a) Sensory neuron: A neuron that detects changes in the external or internal environment and sends information about these changes to the central nervous system.

(b) Motor neuron: A neuron located within the central nervous system that controls the contraction of a muscle or the secretion of a gland.
(c) **Interneuron**: A neuron located entirely within the central nervous system. Interneurons carry information between neurons in the brain and between neurons in the spinal cord.

Neurons are distinguished and categorized according to general function; there are receptor or sensory neurons, motor neurons and interneurons. Sensory or afferent (carrying toward the brain) neurons are specialized to be sensitive to a particular physical stimulation such as light (vision), sound (audition), chemical (olfaction), or pressure (touch).

Motor or efferent (carrying away from the brain) neurons receive impulses from other neurons and transmit this information to muscles or glands. Interneurons or intrinsic neurons form the largest group in the nervous system. They form connections between themselves and sensory neurons before transmission of control to motor neurons.

Neurons also vary according to shape. For example, some have more elaborate dendritic branching while others differ in the placement of the cell body relative to other portions of the neuron.

**Basic Structure**

The neuron (nerve cell) is the information processing and information transmitting element of the nervous system.

A specialized cell that conducts impulses through the nervous system and contains four structures or regions:

(a) Cell body or soma
(b) Dendrites
(c) Axon
(d) Terminal buttons

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**ACTIVITY**

Identify and describe the functions of the parts of the neuron:

(a) neuron
(b) cell body
(c) dendrites
(d) axon
(e) glial cells
Neurons receive signals from neurons or sensory organs, processes information and send signals to other neurons, muscles, or organs. The brain contains an average of one hundred billion neurons (50b – 300b).

- **Soma (cell body):** The part of the neuron that contains the nucleus and carries out the neuron's metabolic functions.

- **Dendrite:** A branched treelike structure attached to the soma of a neuron; receives signals/information from the terminal button of other neurons. Back propagating is when dendrites relay messages from the cell body to their own branches.

  The messages that pass from neuron to neuron are transmitted across synapses, a junction between the terminal buttons of the sending cell and a portion of the somatic or dendritic membrane of the receiving cell.

- **Axon:** The long, slender, tail-like extension often covered by a myelin sheath. It transmits signals/conveys information from the soma of a neuron to its terminal button, to be received by the dendrites or cell body of the other neurons or to muscles or glands. The basic message it carries is called an action potential.

**Afferent neurons** relay messages from the sense organs and receptors—eyes, ears, nose, mouth, and skin—to the brain or spinal cord.

**Efferent neurons** convey signals from the central nervous system to the glands and the muscles, enabling the body to move.
Three classifications of neurons:

- **Multipolar neurons**: A neuron with one axon and many dendrites; it is the most common type found in the central nervous system.

- **Bipolar neurons**: A neuron with one axon and one dendrite attached to its soma; usually sensory, their dendrites detect events occurring in the environment and communicate information about these events to the central nervous system.

- **Unipolar neurons**: A neuron with one axon attached to its soma; the axon divides, with one branch receiving sensory information and the other sending the information into the central nervous system. The dendrites of most unipolar neurons detect touch, temperature changes and other sensory events that effect the skin.

Figure 3.2: The classification of neurons.
3.1.1.1 Terminal Buttons

The bud at the end of a branch of an axon, the neuron forms synapses with another neuron. It sends information to that neuron. The terminal buttons of a neuron are the small knobs at the end of an axon that release chemicals called neurotransmitters.

The terminal buttons form the presynaptic neuron of the synapse. Another term used for the presynaptic terminal button is end bulb. Because the release of neurotransmitters expends large amount of energy, mitochondria are usually plentiful in this region of the neuron.

Receptors: Protein molecules on the dendrite or cell body of a neuron that will interact only with specific neurotransmitters

Action of neurotransmitters:
- **Excitatory:** Influencing the neurons to fire
- **Inhibitory:** Influencing neurons not to fire
3.1.1.2 **Internal Structure**

**Figure 3.4**: The principal internal structures of a multipolar neuron.

**Membrane**: A structure consisting principally of lipid molecules that defines the outer boundaries of a cell and also constitutes many of the cell organelles such as the Golgi apparatus. It consists of a double layer of lipid molecules.

Embedded in the membrane are a variety of protein molecules that have special functions:

- Detect substances outside the cell and pass information about the presence of theses substances to the interior of the cell.
- Control access to the interior of the cell, permitting some substances to enter but barring others.
- Act as transporters, actively carrying certain molecules in or out of the cell.

**Nucleus**: A structure in the central region of a cell, containing the nucleolus and chromosomes.

The **nucleolus** is responsible for the production of ribosomes, small structures that are involved in protein synthesis.

The chromosome is a strand of DNA, with associated proteins, found in the nucleus; carries genetic information.

**Deoxyribonucleic acid (DNA)** is a long complex macromolecule consisting of two interconnected helical strands; along with associated proteins, strands of DNA constitute the chromosomes.
Genes are the functional unit of the chromosome, which cause production of another complex molecule, messenger ribonucleic acid (mRNA), which receives a copy of the information stored at that location.

**Enzyme**: A molecule that controls a chemical reaction, combining two substances or breaking a substance into two parts. Enzymes work as catalysts that is they cause a chemical reaction to take place without becoming a part of the final product themselves.

**Cytoplasm**: The viscous, semi-liquid substance contained in the interior of a cell; contains small, specialized structures called organelles.

**Mitochondria**: An organelle that is responsible for extracting energy from nutrients; provides cells with adenosine triphosphate (ATP). Adenosine triphosphate (ATP) is a molecule of prime importance to cellular energy metabolism; its breakdown liberates energy.

**Endoplasmic reticulum**: Parallel layers of membrane found within the cytoplasm of a cell. Rough endoplasmic reticulum contains ribosomes and is involved with production of proteins that are secreted by the cell. Smooth endoplasmic reticulum is the site of synthesis of lipids and proteins and provides channels for the segregation of molecules in various cellular processes.

**Golgi apparatus**: A complex of parallel membranes in the cytoplasm that wraps the products of a secretory cell. **Exocytosis** is the secretion of a substance by a cell through means of vesicles; the process by which neurotransmitters are secreted. The Golgi apparatus also contains lysosomes, an organelle surrounded by membranes containing enzymes that break down waste products.

**Cytoskeleton**: Formed of microtubules and other protein fibers, linked to each other and forming a cohesive mass that gives a cell its shape. **The microtubule** is a long strand of bundles of protein filaments arranged around a hollow core; part of the cytoskeleton and involved in transporting substances from place to place within the cell.

**Axoplasmic transport**: An active process by which substances are propelled along microtubules that run the length of the axon. Movement from the soma to the terminal button is called anterograde axoplasmic transport accomplished by molecules of a protein called kinesin. Another protein, dynein, carries substances from the terminal buttons to the soma, a process known as retrograde axoplasmic transport.

### 3.1.2 Supporting Cells

In addition to neurons, the nervous system is populated with another category of cells, glial cells. Glial cells are approximately 10 times more plentiful than neurons. But since they are approximately one-tenth the size, they take up equal space. Glia is a Greek term meaning glue. Researchers originally believed that glial cells served as the putty that held the neurons together. Recent research indicates that these cells provide very important contributions.
**Glia**

The most important supporting cells of the central nervous system are neuroglia or "neural glue". They support cells of the central nervous system, fill the gaps between neurons, and support and feed neurons. There are 10 times more glial cells than neurons.

Gial cells help to make the brain more efficient by holding neurons together, removing waste products such as dead neurons, making the myelin coating for the axons, and performing other manufacturing, nourishing, and cleanup tasks. There are several types of glial cells, the three most important are **astrocytes**, **oligodendrocytes** and **microglia**.

**Astrocyte**

Astrocyte or "star cell": A glial cell that provides support to neurons of the central nervous system. It also provides nutrients and other substances and regulates the chemical composition of the extracellular fluid. It receives glucose from capillaries and breaks it down to lactate. It also stores a small amount of glucogen.

When neurons die, astrocytes clean up the debris. **Phagocytosis** is the process by which cells engulf and digest other cells or debris caused by cellular degeneration.
**Oligodendrocyte**

Glia cells function to support the processes of neurons in a variety of ways. The glial cells forming myelin sheaths are called oligodendrocytes in the central nervous system and Schwann cells in the peripheral nervous system.

Oligodendrocytes and Schwann cells form the myelin sheaths that insulate axons in the central and peripheral nervous systems, respectively. The tiny microglia and the star-shaped astrocytes remove waste materials that are created primarily when neurons die. Both glial types release chemicals in the vicinity of dying neurons (for e.g., following a stroke) and promote the growth of dendrites and axons of healthy neurons in the same area, perhaps stimulating recovery of function.

Nitric oxide speeds up the dying process when released close to weakened neurons. Radial glial cells (a type of astrocyte) guide the migration of neurons and the path of sprouting and growing dendrites and axons during embryonic development of the nervous system. Astrocytes also exchange K+ and other chemicals with neurons and act as an intermediary by transporting substances between neurons and the bloodstream.

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**Myelin sheath:** A white, fatty coating wrapped around axons.

The Myelin Sheath acts as an insulator, preventing messages from spreading between adjacent axons and enables impulses to travel much faster and more efficiently. This insulation acts to increase the rate of transmission of signals. A gap exists between each myelin sheath cell along the axon.
Since fat serves as a good insulator, the myelin sheaths speed the rate of transmission of an electrical impulse along the axon. The electrical impulse jumps from one node to the next at a rate as fast as 120 meters/second.

Multiple Sclerosis (MS) involves deterioration of the myelin sheath. Multiple sclerosis is characterized by patches of demyelination (destruction or loss of the myelin sheath) in the central nervous system. The symptoms that result from this demyelination are determined by the functions normally contributed by the affected neurons. Disruption of muscle control, speech and visual disturbances are common.

**Node of Ranvier:** A naked portion of a myelinated axon, between adjacent oligodendrocytes or Schwann cells. The Nodes of Ranvier are gaps (approximately 1 micrometer wide) formed between myelin sheath cells long the axons.

**Microglia**

The smallest glial cells; act as phagocytes and protect the brain from invading microorganisms; they are primarily responsible for the inflammatory reaction in response to brain damage.

**Schwann Cells**

Schwann cells are cells in the peripheral nervous system that is wrapped around a myelinated axon, providing one segment of its myelin sheath. In the PNS a Schwann cell provides myelin for only one axon, and the entire Schwann cell.

If damage occurs to a nerve, Schwann cells aid in the digestion of the dead and dying axons. Then the Schwann cells arrange themselves in a series of cylinders that act as a guide for regrowth of the axons.

**The Blood-Brain Barrier**

The blood-brain barrier regulates the chemicals that can enter the CNS from the blood. It helps the CNS maintain the proper composition of fluids inside and outside the neurons.

Blood-brain barrier is a semipermeable (selectively permeable) barrier between the blood and the brain produced by cells in the walls of the brain’s capillaries.

**Area postrema:** A region of the medulla where the blood-brain barrier is weak; poisons can be detected there and can initiate vomiting.
Concentrations of various chemicals in and around the cell.

The postsynaptic membrane has protein receptors in the membrane made of phospholipids (fat). Each receptor has a shape that fits at least one neurotransmitter molecule.

Imagine a molecule of neurotransmitter floating through the extra cellular space in the synapse until it reaches one of these receptors. When the neurotransmitter gets close, it fits into the protein molecule like a key in a lock. This changes the shape of the protein molecule and sets off a change in the electrical potential of the cell.

If the neurotransmitter is excitatory at that receptor, it will depolarize the cell membrane (make it more likely to transmit information) around the receptor site. You might think of this as dropping a stone into a still lake.

The ripples move away from the receptor, getting weaker and weaker. At some point, a ripple will cross the cell body and move down the axonal hillock. If the receptor is close to the axonal hillock, the ripple will still be strong when it gets there.
Axonal Hillock

The axonal hillock is a small "hill" at the beginning of the axon. It is here that the decision is made to "fire." The cell. The neuron "gun" is fired at the axonal hillock trigger. A small squeeze on the trigger will not fire the neuron. There will be a point when the trigger moves far enough to fire the neuron, and like a gun, once fired, it has to be reloaded.

The Neural Impulse
- *Neural impulse*: Brief electric surge that carries the neuron's message
- *Ions*: Charged particles that are moved across the cell membrane

3.2

COMMUNICATION WITHIN A NEURON

3.2.1 Measuring electrical potentials of axons

**Electrode**: A conductive medium that can be used to apply electrical stimulation and record electrical potentials.

**Microelectrode**: A very fine electrode, generally used to record activity of individual neurons.

**Membrane potential**: The electrical charge across a cell membrane, the difference in electrical potential inside and outside the cell.

**Oscilloscope**: A laboratory instrument that is capable of displaying a graph of voltage as a function of time on the face of a cathode ray tube.

Axons have two basic electrical potentials:
- **Resting membrane potential**: The membrane potential of a neuron when it is not being altered by excitation or inhibitory postsynaptic potentials.
- **Action potential**: The brief electrical impulse that provides the basis for conduction of information along an axon.

The membrane potential can change:
- **Depolarization**: Reduction (toward zero) of the membrane potential of a cell from its normal resting potential.
- **Hyperpolarization**: An increase in the membrane potential of a cell, relative to the normal resting potential.

**Threshold of excitation**: The value of the membrane potential that must be reached to produce an action potential.
3.2.1.1 Resting Membrane Potential

- Inside of the neuron is negative with respect to the outside
- Resting membrane potential is approximately -70 mV in the giant squid axon.
- When the membrane is polarized, it carries a charge.
- The membrane potential of a neuron at rest, about 270 millivolts. The resting membrane potential of a neuron when it is not being altered by excitatory or inhibitory postsynaptic potentials.

Ionic Basis of the Resting Potential: Ions, charged particles, are unevenly distributed. When summation at the axon hillock results in the threshold of excitation (-65mV) being reached, voltage-activated Na⁺ channels open and sodium rushes in. All forces were acting to move Na⁺ into the cell and membrane potential moves from -70 to +50mV.

Factors contributing to uneven distribution:
(a) Homogenizing
   (i) Random motion – particles tend to move down their concentration gradient
   (ii) Electrostatic pressure – like repels like, opposites attract

(b) Membrane is selectively permeable

(c) Sodium-potassium pumps contribute to resting potential are, sodium (Na⁺), chloride (Cl⁻), potassium (K⁺) and negatively charged proteins (A⁻). They are synthesized within the neuron and found primarily within the neuron.

The Neuron at Rest
- Ions move in and out through ion-specific channels
- K⁺ and Cl⁻ pass readily
- Little movement of Na⁺
- Don’t move at all, trapped inside

Equilibrium Potential: The potential at which there is no net movement of an ion – the potential it will move to achieve when allowed to move freely.
- Na⁺ = 120mV
- K⁺ = -90mV
- Cl⁻ = -70mV (same as resting potential)
- Na⁺ is driven in by both electrostatic forces and its concentration gradient
- K⁺ is driven in by electrostatic forces and out by its concentration gradient
- Cl⁻ is at equilibrium

Sodium-potassium pump – active force that exchanges 3 Na⁺ inside for 2 K⁺ outside.

Action potential

"Actional potential" is the technical term used to describe a nerve impulse. It consists of a brief, reversible polarization that propagates along an axon. It differs from a receptor potential (synaptic potential) in several respects.

Action potentials do not vary in amplitude or intensity. They are "all or nothing" events. If the intensity of a stimulus falls below the neuron’s excitation threshold, nothing happens.
But if the intensity of this stimulus exceeds this threshold, it does not matter whether it does so by a small or a large amount. Either way, an action potential will be triggered, and its amplitude and frequency will always be the same for any given cell.

Consequently, the only way a neuron can transmit information is by varying the frequency of its action potentials—the number of action potentials that it transmits per second.

**Action Potential: How Neurons Fire**

1. When the neuron is at rest, the inside is negatively charged relative to the outside.
2. When the neuron is stimulated, positively charged particles enter. The action potential is initiated—depolarized.
3. After a brief period, some positively charged particles are pumped into the neuron, and the neuron moves back toward its polarized state.
4. The neuron has finally returned to its initial polarized resting state.

**Figure 3.5: Action potential.**

Ion channels in neuronal membranes can be classified into two major categories: channels that are always open and that help to establish the neuron’s resting potential, and channels that open and close in response to specific stimuli such as neurotransmitters, second messengers, and fluctuations in the membrane’s electrical potential (voltage).

Action potentials (nerve impulses) are accompanied by the opening of ion channels that are termed “voltage-dependent” because they react to changes in membrane potential. These channels are found only on axons.

The brief electrical impulse that provides the basis for conduction of information along an axon; the sudden reversal of the resting potential, which initiates the firing of a neuron.

A weak stimulus may cause few neurons to fire and at a slow rate; a strong stimulus may cause thousands of neurons to fire at the same time and at hundreds of times per second.

**Ion channel:** A specialized protein molecule that permits specific ions to enter or leave the cell; neuron membranes contain many ion channels; each sodium channel can admit up to 100 million ions per second when open.

The following paragraphs describe the movements of ions through the membrane...
during the action potential:
- As soon as excitation is reached, the sodium channels open and Na⁺ rushes in, propelled by diffusion and electrostatic pressure; depolarization; the threshold of excitation. Voltage-dependent ion channel is an ion channel that opens or closes according to the value of the membrane potential. Rising phase: Na⁺ moves membrane potential from -70 to +50mV.
- End of rising phase: After about 1 millisecond, Na⁺ channels close.
- Change in membrane potential opens voltage-activated K⁺ channels.
- Repolarization: Concentration gradient and change in charge leads to efflux of K⁺.
- Hyperpolarization: Channels close slowly - K⁺ efflux leads to membrane potential <-70mV.

3.2.1.3 Conduction of the Action Potential

The conduction of the action potential is the movement of the message down the axon.

All-or-none law: The principle that once an action potential is triggered in an axon, it is propagated without decrement to the end of the fiber; when threshold is reached the neuron “fires” and the action potential either occurs or it does not. When threshold is reached, voltage-activated ion channels are opened.

Rate law: The principle that variations in the intensity of a stimulus or other information being transmitted in an axon are represented by variations in the rate at which that axon fires.

Cable properties: The passive conduction of electrical current, in a decremental fashion, down the length of an axon.

Saltatory conduction: Conduction of action potentials by myelinated axons; the action potential appears to jump from one node of Ranvier to the next.

The Membrane Potential: Balance of Two Forces

The Force Of Diffusion

Diffusion: Movement of molecules from a region of high concentration to regions of low concentration.

The Force of Electrostatic Pressure

When some substances are dissolved in water, they split into two parts, each with an opposing electrical charge.

Electrolyte: An aqueous solution of a material that ionizes a soluble acid, base, or salt.

Ion: A charged molecule; cations are positively charged, and anions are negatively charged.
Electrostatic pressure: The attractive force between atomic particles charged with opposite signs or the repulsive force between two atomic particles charged with the same sign.

Ions in the Extracellular and Intracellular Fluid

The fluid within and the fluid surrounding cells contain different ions; the forces of diffusion and electrostatic pressure contributed by these ions give rise to the membrane potential.

Intracellular fluid: The fluid contained within cells.
Extracellular fluid: Body fluids located outside cells.

There are four important ions in these fluids:
- Organic anions (A-): Negatively charged proteins and intermediate products of the cell's metabolic fluid; only found in intracellular fluid.
- Chloride ions (Cl-): Found in both intracellular and extracellular fluid; predominantly in intracellular fluid.
- Sodium ions (Na+): Found in both intracellular and extracellular fluid; predominantly in extracellular fluid.
- Potassium (K+): Found in both intracellular and extracellular fluid; predominantly in extracellular fluid.

Sodium-potassium transporter: A protein found in the membrane of all cells that extrudes sodium ions.

ACTIVITY 3.2
Label and describe the components of a synapse and their role in neuronal communication, as well as the inactivation of the neurotransmitters involved.

3.3 COMMUNICATION BETWEEN NEURONS

Neurons communicate by means of synapse, and the medium used for these messages is the neurotransmitter released by terminal buttons.

Neurotransmitters diffuse across the fluid-filled gap between terminal buttons and the membranes of neurons which form synapses (postsynaptic neurons).

Postsynaptic potentials are alterations in the membrane potential of a postsynaptic neuron, produced by the liberation of a neurotransmitter at the synapse.
3.3.1 The Concept of Chemical Transmission

Neurotransmitters, neuromodulators, and hormones are used to transmit information between cells and control the behavior of cells or organs. All these methods of transmission require cells that release the chemicals and specialized protein molecules (receptors) that detect the presence of these chemicals.

**Neuromodulator:** A naturally secreted substance that acts like a neurotransmitter except that it is not restricted to the synaptic cleft but diffuses through the extracellular fluid.

**Endocrine gland:** A gland that liberates its secretions into the extracellular fluid around capillaries and hence into the bloodstream; most hormones are produce in these cells.

**Target cell:** The type of cell that is directly affected by a hormone or nerve fiber.

**Binding site:** The location on a receptor protein to which a ligand binds; a molecule of the chemical fits the binding site in the way a key fits a lock.

**Ligand:** A chemical that binds with the binding site of a receptor; neurotransmitters, neuromodulators or hormones are natural ligands.

3.3.2 Structure of Synapses

Synapses can occur in three places:
- Dendrites (axodendritic)
- Soma (axosomatic)
- Axons (axoaxonic)

**Dendritic spine:** A small bud on the surface of the dendrite, with which a terminal button of another neuron forms a synapses.

**Presynaptic membrane:** The membrane of a terminal button that lies adjacent to the postsynaptic membrane and through which the neurotransmitter is released.

**Postsynaptic membrane:** The membrane located on the dendrite of the neuron that receives the information.

**Synaptic cleft:** The space between the presynaptic membrane and the postsynaptic membrane that is about 20 nm wide.

The presynaptic membrane faces the postsynaptic membrane. These two membranes face each other across the synaptic cleft. A meshwork of filaments crosses the synaptic cleft and keeps the presynaptic and postsynaptic membranes in alignment.

**Synaptic vesicle:** A small, hollow, beadlike structure found in the terminal buttons; contains molecules of a neurotransmitter.

**Release zone:** A region of the interior of the presynaptic membrane of a synapse to which synaptic vesicles attach and release their neurotransmitter into the synaptic cleft. **Cisterna:** A part of the Golgi apparatus; through the process of pinocytosis, it receives portions of the presynaptic membrane and recycles them into the synaptic vesicles.
3.3.3 Activation of Receptors

Molecules of the neurotransmitter produce depolarization or hyperpolarization in the postsynaptic membrane by diffusing across the synaptic cleft and attach to the binding sites of postsynaptic receptors.

Post synaptic receptor: A receptor molecule in the postsynaptic membrane of a synapse that contains a binding site for a neurotransmitter.

Neurotransmitter-dependent ion channel: An ion channel that opens when a molecule of a neurotransmitter binds with a postsynaptic receptor.

Ionotropic receptor: A receptor that contains a binding site for a neurotransmitter and an ion channel that opens when a molecule of the neurotransmitter attaches to the binding site.

Metabotropic receptor: A receptor that contains a binding site for a neurotransmitter; activates an enzyme that begins a series of events, opening an ion channel elsewhere in the membrane of the cell when a molecule of the neurotransmitter attaches to the binding site.

G protein: A protein coupled to a metabotropic receptor; conveys messages to other molecules when a ligand binds with and activates the receptor.

Second messenger: A chemical produced when a G protein activates an enzyme; carries a signal that results in the opening of the ion channel or causes other events to occur in the cell.

3.3.4 Postsynaptic Potentials

Postsynaptic potentials can be either depolarizing (excitatory) or hyperpolarizing (inhibitory) depending on the characteristics of the postsynaptic receptors, in particular the particular type of ion channel they open.

Excitatory postsynaptic potential (EPSP): An excitatory depolarization of the postsynaptic membrane of a synapse caused by the liberation of a neurotransmitter by the terminal button.

Inhibitory postsynaptic potential (IPSP): An inhibitory hyperpolarization of the postsynaptic membrane of a synapse caused by the liberation of a neurotransmitter by the terminal button.

3.3.4.1 Generation and Conduction of Postsynaptic Potentials (PSPs)

Neurotransmitters bind at postsynaptic receptors; these chemical messengers bind and cause electrical changes:
- Depolarizations (making the membrane potential less negative)
- Hyperpolarizations (making the membrane potential more negative)

Postsynaptic depolarizations = Excitatory PSPs (EPSPs)
Postsynaptic hyperpolarizations = Inhibitory PSPs (IPSPs)
EPSPs make it more likely a neuron will fire, IPSPs make it less likely; PSPs are graded potentials – their size varies. EPSPs and IPSPs travel passively from their site of origin.

One EPSP typically will not suffice to cause a neuron to “fire” and release neurotransmitter, summation is needed; Integration of IPSPs and Generation of Action Potentials (APs).

In order to generate an AP (or “fire”), the threshold of activation must be reached at the axon hillock; integration of IPSPs and EPSPs must result in a potential of about -65mV in order to generate an AP.

Integration
Adding or combining a number of individual signals into one overall signal

Temporal summation: Integration of events happening at different times

How synaptic vesicles can continually pour out neurotransmitters:
- Termination of postsynaptic potentials.
- The cell body of the neuron is always working to manufacture more of the neurotransmitter substance.
- Unused neurotransmitters in the synaptic cleft may be broken down into their component molecules and reclaimed by the axon terminal to be recycled and used again.

3.3.5 Termination of Postsynaptic Potentials

Postsynaptic potentials are brief depolarizations or hyperpolarizations caused by the activation of postsynaptic receptors with molecules of a neurotransmitter. They are kept by two mechanisms: reuptake and enzymatic deactivation.

Reuptake: The process by which neurotransmitter molecules are taken back from the synaptic cleft back into the axon terminal for later use, thus terminating their excitatory or inhibitory effect on the receiving neuron.

Enzymatic deactivation: The destruction of a neurotransmitter by an enzyme after its release, for example, the destruction of acetylcholine by acetylcholinesterase.

Acetylcholine (ACh): A neurotransmitter found in the brain, spinal cord, and parts of the peripheral nervous system; responsible for muscular contraction.

Acetylcholinesterase (AChE): The enzyme that destroys acetylcholine soon after it is liberated by the terminal buttons thus terminating the postsynaptic potential.
Postsynaptic Receptors

Cells can be seen as a mini version of the world. Just as the cell seems to
make decisions based on multiple inputs, in society we often make
decisions based on information from a number of people.

*Imagine the axonal hillock as a meeting of 100 people* — *(100 postsynaptic potentials)*.

1. The meeting is to decide whether to send a message encouraging another group of
   people to move to a different building (The goal is not important in this example). To
   make a decision, the meeting must have a Quorum of at least 50 people. Out of the
   people at the meeting, at least two-thirds must vote in favor of the action (be
   positive).

2. The meeting room has just a few people wandering around. (The resting potential)
   More people show up until there are 57 people in the room. The meeting begins.
   There is a vote on sending the message. Forty-five people vote for sending the
   message (EPSPs) and 12 vote against sending the message. Since the vote is more
   than 2/3 in favor, the message is sent.

3. The meeting room has just a few people wandering around. (The resting potential)
   More people show up until there are 45 people in the room. The meeting begins.
   There is a vote on sending the message. Forty people vote for sending the message
   (EPSPs) and five vote against sending the message. The vote is more than 2/3 in
   favor but there was not a quorum (not enough EPSPs) so the message is not sent.

4. The meeting room has just a few people wandering around. (The resting potential)
   More people show up until there are 57 people in the room. The meeting begins.
   There is a vote on sending the message. Twenty people vote for sending the message
   (EPSPs) and 37 vote against sending the message. Since the vote is not more than 2/3
   in favor, the message is not sent.

5. In these three situations, the number of excitatory and inhibitory potentials that
   reach the axonal hillock at the same time will be combined to determine whether
   or not the cell fires.

*Let's look at several examples of meeting outcomes.*

<table>
<thead>
<tr>
<th>Excitatory versus Inhibitory Postsynaptic Potential</th>
<th>Excitatory influences in the nervous system make things more likely to happen</th>
<th>Inhibitory influences in the nervous system make things less likely to happen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-synaptic versus Post-Synaptic</td>
<td>Terminal button of the axon</td>
<td>Dendrite or cell body side of the synapse</td>
</tr>
</tbody>
</table>
First, let's look at the terms that discriminate an EPSP from an
IPSP. Excitatory and Inhibitory. Post Synaptic Potentials
- Excitatory influences in the nervous system make things more likely to happen.
- Inhibitory influences in the nervous system make things less likely to happen.

3.3.6 Effects of Postsynaptic Potentials: Neural Integration

Neural integration: The process by which inhibitory and excitatory
postsynaptic potentials summate and control the rate of firing of a neuron.

3.3.7 Autoreceptors

Autoreceptor: A receptor molecule located on a neuron that responds to the
neurotransmitter released by that neuron. Autoreceptors have a variety of functions:
- Regulate internal processes of the cell
- Regulate synthesis of the neurotransmitter
- Regulate the release of a neurotransmitter
- Generally serve to inhibit the activity of a transmitter

3.3.8 Other Types of Synapses

Axoaxonic synapses alter the amount of neurotransmitter released by terminal buttons of the
postsynaptic axon. They produce presynaptic modulation: presynaptic inhibition or
presynaptic facilitation.

Presynaptic inhibition: The action of a presynaptic terminal button in an axoaxonic synapse;
reduces the amount of neurotransmitter released by the postsynaptic terminal button.

Presynaptic facilitation: The action of a presynaptic terminal button in an axoaxonic
synapse; increases the amount of neurotransmitter released by the postsynaptic terminal
button.

Gap junction: A special junction between cells that permits direct communication through
means of electrical coupling.

3.3.9 Nonsynaptic Chemical Communication

Neurons possess receptors for a variety of substances in the membrane of all parts of the cell.
These receptors are sensitive to neuromodulators and to hormones.
Peptides: A chain of amino acids joined together by peptide bonds. Most neuromodulators, and some hormones consist of peptide molecules.

Steroid: A chemical of low molecular weight, derived from cholesterol. Steroid hormones affect their target cells by attaching to receptors found within the nucleus.

NT molecules:
Small: Synthesized in the terminal button and packaged in synaptic vesicles.
Large: Assembled in the cell body, packaged in vesicles, and then transported to the axon terminal.

Release of NT Molecules: Exocytosis is the process of NT release. The arrival of an AP at the terminal opens voltage-activated Ca²⁺ channels. The entry of Ca²⁺ causes vesicles to fuse with the terminal membrane and release their contents. Activation of Receptors by NT: Released NT produces signals in postsynaptic neurons by binding to receptors. Receptors are specific for a given NT. A NT is a ligand of its receptor.

Ionotropic Receptors: Associated with ligand-activated ion channels.
• NT binds and an associated ion channel opens or closes, causing a PSP.
• If Na⁺ channels are opened, for example, an EPSP occurs.
• If K⁺ channels are opened, for example, an IPSP occurs.

Metabotropic receptors: Associated with signal proteins and G proteins.
• Effects are slower, longer-lasting, more diffuse, and more varied.
• NT (1st messenger) binds > G protein subunit breaks away > ion channel opened/closed OR a 2nd messenger is synthesized > 2nd messengers may have a wide variety of effects.

As long as NT is in the synapse, it is active; the activity must somehow be turned off.
Reuptake: Scoop up and recycle NT.
Enzymatic degradation: A NT is broken down by enzymes.

3.4 NEUROTRANSMITTERS

3.4.1 Small-molecule Neurotransmitters

Neurotransmitters are chemical messengers that relay neural messages across the synapse. A chemical that is released into the synaptic cleft from a terminal button (axon) of a sending neuron, crosses a synapse, and binds to appropriate receptor sites on the dendrites or cell body of a receiving neuron, influencing the cell either to fire or not to fire; has an excitatory or inhibitory effect on another neuron.

To be considered a neurotransmitter, a molecule must meet several criteria:
• It must be produced inside a neuron, found in the neuron’s terminal button, and released into the synaptic gap upon the arrival of an action potential.
• It must produce an effect on the postsynaptic neuron.
3.4.1 Amino Acids

The building blocks of proteins, usually found at fast-acting directed synapses in the CNS.

GABA: Most prevalent excitatory neurotransmitter in the CNS

Glutamate: Most prevalent excitatory neurotransmitter in the CNS

GABA: Synthesized from glutamate; most prevalent inhibitory NT in the CNS; aspartate and glycine

3.4.1.2 Monoamines

All synthesized from a single amino acid. Effects tend to be diffuse

- Catecholamines (synthesized from tyrosine)
- Dopamine
- Norepinephrine
- Epinephrine
- Indolamines (synthesized from tryptophan)
- Serotonin

3.4.1.3 Soluble-Gases and Ach

Soluble gases exist only briefly (nitric oxide and carbon monoxide). Retrograde transmission is backwards communication. Acetylcholine (Ach) is Acetyl group + choline.

Neuropeptides: Large molecules are "Endogenous opiates" that produce analgesia (pain suppression). Receptors were identified before the natural ligand was.

3.4.2 Dopamine

Normal Function: A neurotransmitter that plays a role in learning, attention, and movement. Produces sensations of pleasure and reward; used by CNS neurons in voluntary movement

Problems with Imbalance: Schizophrenia, Parkinson's disease

Substances that Affect: Cocaine, amphetamines, Ritalin, alcohol

3.4.3 Serotonin

Normal Function: A neurotransmitter that plays an important role in regulating mood, sleep (and dreaming), aggression, and appetite. Also regulates pain, and sexual behavior.

Problems with Imbalance: Depression, certain anxiety disorders, obsessive-compulsive disorder

Substances that Affect: Prozac, hallucinogenics (e.g. LSD)

3.4.4 Norepinephrine

Normal Function: A neurotransmitter affecting eating (appetite) and sleep. Also controls heart rate, sexual responsiveness, stress, and vigilance

Problems with Imbalance: High blood pressure, depression

Substances that Affect: Tricyclic antidepressants, beta blockers
3.4.5 Acetylcholine

Normal Function: Primary transmitter used by neurons carrying messages from CNS; involved in some kinds of learning and memory.
Problems with Imbalance: Certain muscular disorders, Alzheimer's disease
Substances that Affect: Nicotine, botulism toxin, curare, atropine

3.4.6 GABA

Normal Function: Most prevalent inhibitory neurotransmitter in neurons of CNS
Problems with Imbalance: Anxiety, epilepsy
Substances that Affect: Barbiturates, tranquilizers (e.g. Valium, Librium), alcohol

3.4.7 Glutamine

Normal Function: Primary excitatory neurotransmitter in CNS; involved in learning and memory
Problems with Imbalance: Brain damage after stroke
Substances that Affect: PCP ("angel dust")

3.4.8 Endorphins

Normal Function: Chemicals produced naturally by the brain that reduce pain and positively affect mood. "Runner's high" is attributed to the release of endorphins.
Problems with Imbalance: Lowered levels resulting from opiate addiction
Substances that Affect: Opiates: opium, heroin, morphine, methadone

3.4.9 Epinephrine

A neurotransmitter that affects the metabolism of glucose and energy stored in muscles to be released during exercise.

Pharmacology of Synaptic Transmission
Agonists increase or facilitate activity.
- Cocaine is a catecholamine agonist. It blocks reuptake, preventing the activity of the neurotransmitter from being "turned off"
- Benzodiazepines are GABA agonists. It binds to the GABA molecule and increases the binding of GABA.

Antagonists decrease or inhibit activity. Atropine is an ACh antagonist. It binds and blocks muscarinic receptors; many of these metabotropic receptors are in the brain; high doses disrupt memory.
1. Which portion of a neuron carries information toward the cell body?

2. What is the physical gap that carries a neural message between two nerve cells called?

3. Which type of nerve cells usually transmit sensory information?

4. Where are neurotransmitter molecules secreted from?

5. Proteins are produced by ________.

6. Which cells are the most important support cells of the central nervous system?

7. What functions do astrocytes perform?

8. What does the process of phagocytosis involve?

9. Which cells are important for the process of myelination of nerve axon membranes?

10. Movement of the axon membrane potential from -70 mV to -90 mV would be termed an ________.

11. What is the process by which similarly charged particles repel each other and are thus distributed throughout a medium termed?

12. What is the force that moves sodium ions out of the axon?

13. In a resting nerve cell, which force will push sodium ions into the cell?

14. The "all-or-none law" refers to the observation that an action potential ________.

15. Incoming stimuli that vary in intensity are coded by variations in the ________ of a neuron.

16. What is a small vesicle found in the axon terminal likely to contain?
Suggested Text and References

Required Reading


Suggested Readings


Suggested Web Sites

Action Potential Animation
http://www.fiu.edu/orgs/psych/psb_4003/figures/a_p.html

Tutorial on the Action Potential
http://pavlov.psyc.queensu.ca/~symonsl/brains/actpot.html

Action Potential Simulator
http://www.physc.med.wayne.edu/jeffram.axon3.htm

Synapse Web
http://synapse.bu.edu

Cell Membrane Animations
Self-check

1. dendrite.
2. synapse.
3. bipolar, unipolar
4. axon terminal
5. ribosomes.
6. neuroglial
7. physical support of nerve cells; provide nourishment to neurons; clean up debris within the brain; regulate the chemicals in the fluid surrounding neurons
8. the removal of neuronal debris.
9. oligodendrocytes
10. hyperpolarization.
11. electrostatic pressure.
12. the sodium-potassium transporter.
13. diffusion, electrostatic pressure
14. is produced whenever the membrane potential reaches threshold.
15. firing rate
16. neurotransmitter molecules.
Unit 4

Brain Development

LEARNING OUTCOME

At the end of this unit, you will be able to:

1. Describe the phases of neurodevelopment and postnatal cerebral development.
2. Describe neuroplasticity and factors affecting neuroplasticity.
3. Explain the importance of environment in prenatal and postnatal brain development.
4. Evaluate the relevance of neural development and disorders of neurodevelopment to their lives.

The Case of Ali

When Ali was 3 years old, he had a streptococcal infection. He exhibited eye-rolling tics, followed by blinking, head-jerking and nose-rubbing. He also developed obsessive and compulsive disorder (OCD), such as insisting on arranging his color pencils in a particular order, repeated counting, walking in circles while he counts to three and would continually touching certain objects until they feels right. His doctor treated him with amoxicillin (antibiotic), which reduced his tics, but not his OCD.
THE NEW BEGINNINGS

Biopsychological research promotes greater understanding of disorders causing mental retardation at birth, and paves the way for future treatment possibilities.

Neural development is important to everyone who plans to become a parent. Tissue destined to become the nervous system is differentiated even before a woman might know she is pregnant. Thus, every woman and her male partner need to know health recommendations regarding smoking, alcohol, and caffeine intake, if there is a reasonable chance of pregnancy. Even under ideal conditions, not every baby is born perfect.

During pregnancy, a great excess of neurons is produced—perhaps twice as many as necessary, but these are winnowed out in the final month or so of pregnancy and in the months just after birth.

So great is the profusion of primitive neurons that at least fifty thousand cells are produced during each second of most of intrauterine life to provide the necessary number.

So complex are the challenges involved in developing a brain that at least one half of our entire genome (the full catalogue of human genes on all the chromosomes) is devoted to producing this organ that will constitute only two percent of our body weight. It should be realized at this point that for the nine months of intrauterine life and for a short but indeterminate postnatal period, brain growth and development will be largely genetically determined.

However, environmental (epigenetic) factors will also be involved almost from the beginning of embryonic life, and will assume an increasingly important role. It is, in fact, the complex intertwining of genetic and epigenetic factors which guarantee the uniqueness of each individual.
PHASES OF NEURAL DEVELOPMENT

During pregnancy, the neonate and infancy undergoes several stages of neural development:
1. Induction of the neural plate
2. Incomplete closure of the neural tube
3. Closure of the neural tube
4. Neural proliferation – cell differentiation and division
5. Cell migration
6. Development of temporary connections – axon and synapse formation
7. Maturation of nerve cells
8. Development of myelin sheaths
9. Development of synaptic connections among neurons

**Neural tube**: A hollow tube, closed at the rostral end, that forms from ectodermal tissue early in embryonic development, serves as the origin of the central nervous system.

**Ventricular zone**: A layer of cells that line the inside of the neural tube, contains founder cells that divide and give rise to the central nervous system.

4.1 PRENATAL DEVELOPMENT OF THE CENTRAL NERVOUS SYSTEM

4.1.1 Induction of the Neural Plate

The induction of the neural plate undergoes the following development began with a patch of ectodermal tissue on the dorsal surface of the embryo. Through the release of special chemicals from the mesoderm (the “organizer”), the overlying ectoderm is induced to divide more rapidly, forming a thickened mass called the neural plate.

The neural plate is visible three weeks after conception. It forms three layers of embryonic cells:
- Ectoderm – outermost,
- Mesoderm – middle,
- Endoderm - innermost

A crease or fold soon appears in this plate. The crease rapidly deepens and becomes known as the neural groove. The entire embryo is lengthening as this happens.
The neural groove continues to deepen until its sides, the neural folds, arch over and fuse with each other forming a short segment of completely enclosed tube. This newly formed "neural tube" will become the nervous system.

The actual fusion of the walls to form the tube occurs first in the center of the embryo about midway between front and rear poles of the still rapidly lengthening little organism.

However, you can probably visualize how the newly formed section of neural tube rapidly begins to roof over in both a forward (anterior or rostral) and a backward (posterior or caudal) direction.

It is as if there were two zippers in the newly formed roof of the developing neural tube. As these zippers are pulled simultaneously away from each other toward the two ends of the embryo, the neural folds come together and the neural tube lengthens progressively in both directions.

Finally, the neural tube is almost completely enclosed in both directions, leaving only a small unroofed portion or opening at each end. These residual openings are called neuropores and under normal developmental conditions will soon be closed, thereby forming a complete neural tube.

During this process a front-back polarity has been established in the still-lengthening embryo. Accordingly, the small unroofed area of the neural tube at the front end is called the anterior neuropore; the one at the rear end, the posterior neuropore.

### 4.1.2 Incomplete Closure Of The Tube

The capacity of the developing nervous system to follow an incredibly complex series of developmental rules laid down progressively by the genes is remarkable.

Nonetheless, errors occur, and the roofing over of the neural groove to form the neural tube represents one point where disturbed development can severely affect the growing embryo.

Incomplete closure of the anterior or posterior neuropore represents two such developmental errors during the first trimester which radically alter the future life of the embryo/fetus and infant.

If the anterior neuropore fails to close, the resulting deficit leads to varying degrees of incomplete development of the cerebral hemispheres and brain stem.

One of the most frequent and dramatic resulting anomalies is the fetus which is born without cerebral hemispheres and usually without any skull above the level of the eyes. This is the so-called anencephalic child (a- or an- without: cephalo- brain). Strangely enough, this type of extreme anomaly may come to term and under some conditions, live for a week or two following birth.

Such a severely deformed infant has only a brain stem (the upward continuation of the spinal cord within the skull) on which to depend for its behavior. This takes care of its basic
breathing, cardiovascular, suckling and elimination reflexes. However, little else is possible for the infant and it usually dies within a few days or weeks of birth.

If incomplete closure persists at the posterior neuropore, the fetus will be born with some variant of spina bifida (bifida - split). In the most severe of these, the posterior portion of the spinal cord is totally or partially undeveloped and the entire lower back may be open. Some defects of this sort may be amenable to restorative surgery while others are not compatible with life.

There is a more subtle form of this anomaly known as spina bifida occulta (oculta - hidden) where the only residual pathology is a tract or canal, usually of microscopic size, running between the subdural space surrounding the lower tip of the spinal cord and the skin of the lower back.

Often, the only sign of such an anomaly is a little patch of hair in the middle of the lower back just above the beginning of the cleft between the buttocks. Although usually asymptomatic, this tiny canal can become infected, usually through trauma, and can form a painful pus-filled sac known as a pilonidal cyst.

4.1.3 Closure Of The Neural Tube

With successful closure of the neural tube, the anterior or rostral (rostral - front) end develops three vesicles which demarcate the territory for cerebral hemispheres and brain stem.

Of these, the first and third divide once more forming a series of five vesicles which will become the major portions of the central nervous system within the skull. These consist of the cerebral hemispheres, diencephalon, midbrain, pons and cerebellum and medulla oblongata.

Stem cells

Neural plate cells are often referred to as stem cells. Stem cells seem to have an unlimited capacity for self-renewal and can develop into different mature cell types (totipotent).

The nervous system develops from embryonic tissue called the ectoderm. As the neural tube develops specificity increases, resulting in glial and neural stem cells (multipotent). The first sign of the developing nervous system is the neural plate that can be seen at about the 16th day of development. Over the next few days, a "trench" is formed in the neural plate - this creates a neural groove.

By the 21st day of development, a neural tube is formed when the edges of the neural groove meet. The rostral (front) part of the neural tubes goes on to develop into the brain and the rest of the neural tube develops into the spinal cord. Neural crest cells become the peripheral nervous system.
At the front end of the neural tube, three major brain areas are formed: the prosencephalon (forebrain), mesencephalon (midbrain) and rhombencephalon (hindbrain). By the 7th week of development, these three areas divide again. This process is called encephalization.

4.1.4 Neural Proliferation

Neural plate folds to form the neural groove which then fuses to form the neural tube. Inside will be the cerebral ventricles and neural tube. Neural tube cells proliferate in species-specific ways – 3 swellings at the anterior end in humans will become the forebrain, midbrain, and hindbrain.

Cerebral cortex (cortex means “bark”): The outermost layer of gray matter of the cerebral hemispheres that is about 3 mm thick.

Radial glia: Special glia with fibers that grow radially outward from the ventricular zone to the surface of the cortex; provide guidance for neurons migrating outward during brain development.

Figure 4.2: Development of the central nervous system
4.1.5 Cell Migration

Once cells have been created through cell division in the ventricular zone of the neural tube, they migrate. Migrating cells are immature, lacking axons and dendrites.

1. Radial migration – towards the outer wall of the tube
2. Tangential migration – at a right angle to radial migration, parallel to the tube walls

Most cells engage in both types of migration.

Two types of neural tube migration:

1. Radial migration – moving out – usually by moving along radial glial cells
2. Tangential migration – moving up

Figure 4.3: Two types of neural tube migration.

Two methods of migration:

1. Somal – an extension develops that leads migration, cell body follows
2. Glial-mediated migration – cell moves along a radial glial network
Figure 4.4: Gliat-mediated migration

**Neural crest:** A structure dorsal to the neural tube and formed from neural tube cells; develops into the cells of the peripheral nervous system; cells migrate long distances.

**Aggregation:** The process of cells that are done migrating aligning themselves with others cells and forming structures.

**Cell-adhesion molecules (CAMs):** Aid both migration and aggregation; CAMs found on cell surfaces, recognize and adhere to molecules.

### 4.1.6 Axon Growth and Synapse Formation

Once migration is complete and structures have formed (aggregation), axons and dendrites begin to grow.

- **Growth cone:** At the growing tip of each extension, extends and retracts filopodia as if finding its way

- **Chemoaffinity hypothesis:** Postsynaptic targets release a chemical that guides axonal growth, but this does not explain the often circuitous routes often observed

**Axon growth**

To find their proper place in the brain, axons often stretch for several feet, making their way through surrounding tissues and around a myriad of obstacles until they reach their final target. The growth cone then forms a synapse, or a tiny gap where nerve messages are transmitted, with the dendrites of the target neuron.

Cell adhesion molecules are found on neuron surfaces and bind to similar proteins on nearby cells. By knocking out the genes for specific molecules, these proteins found in different combinations on different nerve fibers, help axons recognize and track along paths established by related axons.

Growing axons can also change course to follow gradients of certain "attraction" molecules that spread out from target cells and provide long-range cues. An axon's response to different molecules is determined by proteins called receptors on the surface of the growth cone that the molecules fit into much as a key fits a lock. When a molecule attaches to these receptors, it causes the growth cone to grow or stop or turn.

Cells can change the receptors and other molecules that are active at a given time. Thus, growth cones can respond to different guidance molecules at different stages during their development and change direction.
Mechanisms underlying axonal growth are the same across species. A series of chemical signals exist along the way—attracting and repelling. Such guidance molecules are often released by glia. Adjacent growing axons also provide signals.

**Pioneer growth cones:** The 1st to travel a route—follow guidance molecules.

**Fasciculation:** The tendency of developing axons to grow along the paths established by preceding axons.

**Topographic gradient hypothesis:** Seeks to explain topographic maps. Gopnick et al. (1999) describe neurons as growing telephone wires that communicate with one another.

Following birth, the brain of a newborn is flooded with information from the baby’s sense organs. This sensory information must somehow make its way back to the brain where it can be processed.

To do so, nerve cells must make connections with one another, transmitting the impulses to the brain. Continuing with the telephone wire analogy, like the basic telephone trunk lines strung between cities, the newborn’s genes instruct the “pathway” to the correct area of the brain from a particular nerve cell.

For example, nerve cells in the retina of the eye send impulses to the primary visual area in the occipital lobe of the brain and not to the area of language production (Wernicke’s area) in the left posterior temporal lobe.

The basic trunk lines have been established, but the specific connections from one house to another require additional signals.
Synaptogenesis

Synaptogenesis is the formation of new synapses. Neurons that are stimulated by input from the surrounding environment continue to establish new synapses. Synaptogenesis depends on:

- The presence of glial cells, especially astrocytes;
- High levels of cholesterol are needed – supplied by astrocytes;
- Chemical signal exchange between pre and postsynaptic neurons is needed; and
- A variety of signals act on developing neurons.

Neurons seldom stimulated soon lose their synapses, a process called synaptic pruning.

Neuron Death and Synapse Rearrangement

50% more neurons than are needed are produced, death is normal. Neurons die due to failure to compete for chemicals provided by targets:

- Increase targets leads to decreased death;
- Destruction of some cells leads to increased survival of remaining cells; and
- Increase number of innervating axons leads to decreased proportion survive.
Life-preserving chemicals

Neurotrophins promote growth and survival, guide axons, stimulate synaptogenesis. Both passive cell death (necrosis) and active cell death (apoptosis) occurs. Apoptosis is safer than necrosis. It is “cleaner”, leaving less debris and glutamate in the brain.

The central nervous system in the womb

Ten week human fetus is 1.25 cm (0.5 in.) long and consists mostly of ventricle. Twenty weeks fetus is 5 cm (2 in.) long with basic brain shape. At times during brain development, as many as 250,000 neurons are added per minute.

At birth, almost all the neurons that the brain will ever have are present. However, the brain continues to grow for a few years after birth. By the age of 2 years old, the brain is about 80% of the adult size. End product at adulthood is approximately 1400 g (3 lb)

Glia continues to divide and multiply. Glia carries out many important functions for normal brain function including insulating nerve cells with myelin. The neurons in the brain also make many new connections after birth.

Age Brain Weight

Average brain weights at different times of development:

<table>
<thead>
<tr>
<th>AGE</th>
<th>BRAIN WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 weeks of gestation</td>
<td>100 grams</td>
</tr>
<tr>
<td>Birth</td>
<td>400 grams</td>
</tr>
<tr>
<td>18 months old</td>
<td>800 grams</td>
</tr>
<tr>
<td>3 years old</td>
<td>1100 grams</td>
</tr>
<tr>
<td>Adult</td>
<td>1300-1400 grams</td>
</tr>
</tbody>
</table>

ACTIVITY 4.1

(a) Briefly explain the phases of neurodevelopment.
(b) Explain the different kinds of neural tube migration.
4.2 POSTNATAL DEVELOPMENT OF THE CENTRAL NERVOUS SYSTEM

Postnatal growth is a consequence of:
- Synaptogenesis
- Myelination – sensory areas and then motor areas. Myelination of prefrontal cortex continues into adolescence
- Increased dendritic branches

Overproduction of synapses may underlie the greater plasticity of the young brain.

4.2.1 Development of the Prefrontal Cortex

Believed to underlie age-related changes in cognitive function, no single theory explains the function of this area. Prefrontal cortex plays a role in working memory, planning and carrying out sequences of actions, and inhibiting inappropriate responses.

4.2.2 Effects of Experience on Neural Circuits

Neurons and synapses that are not activated by experience usually do not survive – use it or lose it. Humans are uniquely slow in neurodevelopment – allows for fine-tuning.

When a baby is born he has billions of brain cells, and that many of these brain cells are not connected. Relate early experience to how nature and nurture interact to modify the early development, maintenance, and reorganization of neural circuits discussed previously.

Early Studies of Experience and Neurodevelopment

Early visual deprivation:
- Fewer synapses and dendritic spines in 1st visual cortex
- Deficits in depth and pattern vision

Enriched environment:
- Thicker cortices
- Greater dendritic development
- More synapses per neuron

The impact we can have on those first 3 years a child’s brain is critical to every type of development (cognitive, emotional, & physical).

Competitive Nature of Experience and Neurodevelopment

Monocular deprivation changes the pattern of synaptic input into layer IV of V1. Altered exposure during a sensitive period leads to reorganization. Active motor neurons take precedence over inactive ones.
Effects of Experience on Topographic Sensory Cortex Maps

Cross-modal rewiring experiments demonstrate the plasticity of sensory cortices — with visual input, auditory cortex can see. Change input, change cortical topography - shifted auditory map in prism-exposed owls.

Neural activity prior to sensory input plays a role in development — ferret visual development disrupted by interference with neuronal activity prior to eye opening. Early music training influences the organization of human auditory cortex — fMRI studies

Mechanisms by Which Experience Might Influence Neurodevelopment

Many possibilities
- Neural activity regulates the expression of genes that direct the synthesis of CAMs
- Neural activity influences the release of neurotrophins
- Some neural circuits are spontaneously active and this activity is needed for normal development

4.2.3 Cerebral Hemispheres

Lateralization: The specialization of one of the cerebral hemispheres to handle a particular function; myelinization of the corpus callosum.

Left hemisphere: The hemisphere that controls the right side of the body, coordinates complex movements, and, in 95% of right-handers and 62% of left-handers, controls most functions of speech and written language.

Right hemisphere: The hemisphere that controls the left side of the body and that, in most people, is specialized for visual-spatial perception and interpreting nonverbal behavior.

Unilateral neglect: Patients with right hemisphere damage may have attentional deficits and be unaware of objects in the left visual field

Right Hemisphere’s Role In Emotion

The right hemisphere is involved in our expression of emotion through tone of voice and facial expressions; controls the left side of the face, which usually conveys stronger emotion than the right side of the face.

Lawrence Miller describes the facial expressions and the voice inflection of people with right hemisphere damage as “often strangely blank—almost robotic”
**Handedness, Culture, And Genes**

The corpus callosum of left-handers is 11% larger and contains up to 2.5 million more nerve fibers than that of right-handers. In general, the two sides of the brain are less specialized in left-handers.

Left-handers tend to experience less language loss following an injury to either hemisphere. Left-handers tend to have higher rates of learning disabilities and mental disorders than right-handers.

**ACTIVITY 4.2**

(a) Explain the effects of an enriched and deprived environment on a child’s brain.

(b) Explain the specialization of the right and left cerebral hemispheres.
4.3 NEUROPLASTICITY

Brain facts – True or false?

Mature brain changes and adapts

FACT 1: Neuroplasticity includes several different processes that take place throughout a lifetime.

Neuroplasticity does not consist of a single type of morphological change, but rather includes several different processes that occur throughout an individual’s lifetime. Many types of brain cells are involved in neuroplasticity, including neurons, glia, and vascular cells.

FACT 2: Neuroplasticity has a clear age-dependent determinant.

Although plasticity occurs over an individual’s lifetime, different types of plasticity dominate during certain periods of one’s life and are less prevalent during other periods.

FACT 3: Neuroplasticity occurs in the brain under two primary conditions:

1. During normal brain development when the immature brain first begins to process sensory information through adulthood (developmental plasticity and plasticity of learning and memory).
2. As an adaptive mechanism to compensate for lost function and/or to maximize remaining functions in the event of brain injury.

FACT 4: The environment plays a key role in influencing plasticity.

In addition to genetic factors, the brain is shaped by the characteristics of a person’s environment and by the actions of that same person.
4.3.1 Brain Plasticity: Synaptic Pruning

Over the first few years of life, the brain grows rapidly. As each neuron matures, it sends out multiple branches (axons, which send information out, and dendrites, which take in information), increasing the number of synaptic contacts and laying the specific connections from house to house, or in the case of the brain, from neuron to neuron.

At birth, each neuron in the cerebral cortex has approximately 2,500 synapses. By the time an infant is two or three years old, the number of synapses is approximately 15,000 synapses per neuron (Gopnick, et al., 1999). This amount is about twice that of the average adult brain. As we age, old connections are deleted through a process called synaptic pruning.

Synaptic pruning eliminates weaker synaptic contacts while stronger connections are kept and strengthened. Experience determines which connections will be strengthened and which will be pruned; connections that have been activated most frequently are preserved.

Neurons must have a purpose to survive. Without a purpose, neurons die through a process called apoptosis in which neurons that do not receive or transmit information become damaged and die. Ineffective or weak connections are “pruned” in much the same way a gardener would prune a tree or bush, giving the plant the desired shape.

It is plasticity that enables the process of developing and pruning connections, allowing the brain to adapt itself to its environment.

4.3.2 Injury-induced Plasticity: Plasticity and Brain Repair

During brain repair following injury, plastic changes are geared towards maximizing function in spite of the damaged brain.

In studies involving rats in which one area of the brain was damaged, brain cells surrounding the damaged area underwent changes in their function and shape that allowed them to take on the functions of the damaged cells. Although this phenomenon has not been widely studied in humans, data indicate that similar (though less effective) changes occur in human brains following injury.

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4.3.3 Effects of Experience on the Reorganization of the Adult Cortex

Tinnitus (ringing in the ears) – produces major reorganization of 1st auditory cortex. Adult musicians who play instruments fingered by hand have an enlarged representation of the hand in right somatosensory cortex. Skill training leads to reorganization of motor cortex.

4.4 DISORDERS OF NEURODEVELOPMENT

4.4.1 Autism

Autism is found in 4 of every 10,000 individuals. There are 3 core symptoms:

1. Reduced ability to interpret emotions and intentions
2. Reduced capacity for social interaction
3. Preoccupation with a single subject or activity

Intensive behavioral therapy may improve function.

Autism is heterogeneous, level of brain damage and dysfunction varies. Most have some abilities preserved – rote memory, ability to complete jigsaw puzzles, musical ability, artistic ability.

Savants are intellectually handicapped individuals who display specific cognitive or artistic abilities. 1/10 autistic individuals display savant abilities. Perhaps it is a consequence of compensatory functional improvement in the right hemisphere following damage to the left.

A brief observation in a single setting cannot present a true picture of an individual’s abilities and behaviors. Parental (and other caregivers’ and/or teachers) input and developmental history are very important components of making an accurate diagnosis.

There are no medical tests for diagnosing autism. An accurate diagnosis must be based on observation of the individual’s communication, behavior, and developmental levels.

At first glance, some persons with autism may appear to have mental retardation, a behavior disorder, problems with hearing, or even odd and eccentric behavior. To complicate matters further, these conditions can co-occur with autism.

However, it is important to distinguish autism from other conditions, since an accurate diagnosis and early identification can provide the basis for building an appropriate and effective educational and treatment program.

Early Diagnosis

Research indicates that early diagnosis is associated with dramatically better outcomes for individuals with autism. The earlier a child is diagnosed, the earlier the child can begin benefiting from one of the many specialized intervention approaches.
Diagnosis Tools for Autism

The characteristic behaviors of autism spectrum disorders may or may not be apparent in infancy (18 to 24 months), but usually become obvious during early childhood (24 months to 6 years).

The National Institute of Child Health and Human Development (NICHD) lists five behaviors that signal further evaluation is warranted:

1. Does not babble or coo by 12 months
2. Does not gesture (point, wave, grasp) by 12 months
3. Does not say single words by 16 months
4. Does not say two-word phrases on his or her own by 24 months
5. Has any loss of any language or social skill at any age.

Having any of these five "red flags" does not mean your child has autism.

Neural Basis of Autism

Genetic basis

Siblings of the autistic have a 5% chance of being autistic; 60% concordance rate for monozygotic twins. Several genes interacting with the environment may cause autism. There is evidence for a role of a gene on chromosome 7.

Brain damage tends to be widespread, but is most commonly seen in the cerebellum. Thalidomide, given early in pregnancy, increases chance of autism.

Neurodevelopmental error occurs within 1st few weeks of pregnancy when motor neurons of the cranial nerves are developing. Consistent with observed deficits in face, mouth, and eye control. Anomalies in ear structure indicate damage occurs between 20 and 24 days after conception.

4.4.2 Williams Syndrome

Occurs in 1 of every 20,000 births. Williams syndrome is marked by mental retardation and an uneven pattern of abilities and disabilities.

- Sociable, empathetic, and talkative – exhibit language skills, music skills and an enhanced ability to recognize faces
- Profound impairments in spatial cognition
- Usually have heart disorders associated with a mutation in a gene on chromosome 7 – the gene (and others) are absent in 95% of those with Williams

Williams Syndrome is a rare disorder. Like autism it is caused by an abnormality in chromosome 7, and shows a wide variation in ability from person to person.

Underdeveloped occipital and parietal cortex, normal frontal and temporal "eflin" appearance – short, small upturned noses, oval ears, broad mouths.
Williams people have a unique pattern of emotional, physical and mental strengths and weaknesses.

For parents, teachers, and care workers, learning about this pattern can be a key to understanding a Williams person and in helping them achieve their full potential.

It is a non-hereditary syndrome which occurs at random and can effect brain development in varying degrees, combined with some physical effects or physical problems. These range from lack of co-ordination, slight muscle weakness, possible heart defects and occasional kidney damage.

4.4.3 Hypercalcaemia

A high calcium level and is often discovered in infancy, and normal development is generally delayed. The incidence is approximately 1 in 25,000. By 2002 over 1300 cases were known in the UK and similar organisations have now sprung up in the USA, New Zealand, Canada, Australia and most countries in Europe.

**ACTIVITY**

(a) Explain the differences between Autism and Williams Syndrome.
(b) How can parents and teachers help children with Autism and/or Williams Syndrome?
1. The process of the growth of a fertilized egg into a mature nervous system is called ________.
2. The first major phase of neurodevelopment is formation of the ________.
3. Most cell division in the developing neural tube occurs in the ________.
4. In addition to the radial migration of developing neurons along glial cells, there is considerable ________ migration.
5. When the lips of the neural ________ fuse, the result is the neural tube.
6. The neural crest develops into the ________.
7. An exciting recent finding is that synaptogenesis depends on the presence of ________.
8. Between birth and adulthood, the size of the human brain ________.
9. The last part of the brain to achieve full myelination is the ________.
10. The growth of new neurons in adults is called adult ________.
11. The prefrontal cortex seems to play a role in ________.
12. Neurons and synapses that are not activated by experience usually ________.
13. Adult stem cells that migrate to the olfactory bulbs are created at certain sites in the ________.
14. The area of somatosensory cortex receiving input from the left hand was found to be bigger in ________.
15. Autism usually becomes apparent ________.
16. A core symptom of autism is ________.
17. Despite being intellectually handicapped, about 10% of autistic individuals display ________ abilities.
18. ________ taken early in pregnancy causes autism in the infant.
19. Considering their mental retardation, Williams people have remarkably good ________.
Suggested Text and References

Required Reading


Suggested Readings


Self-check

1. neurodevelopment.
2. neural plate.
3. ventricular zone
4. tangential
5. groove
6. peripheral nervous system.
7. astrocytes.
8. quadruples
9. prefrontal cortex
10. neurogenesis
11. working memory, planning and carrying out sequences of action.
12. do not survive.
13. ependymal layer.
14. musicians who finger stringed instruments with the left hand.
15. before the age of 3 years.
16. reduced ability to detect emotions and intentions of others, reduced capacity for social interaction and communication.
17. Savant
18. Thalidomide
19. language skills
Unit 5  Perception: Mechanism, Awareness & Attention

LEARNING OUTCOME

At the end of this unit, you will be able to:

1. Describe the process of sensation.
2. Distinguish between sensation and perception.
3. Describe the visual pathways in the brain.
4. Describe the auditory pathways in the brain.
5. Describe the gestational pathways in the brain.
6. Describe the somatosensory pathways in the brain.
7. Describe the vestibular system.
8. The principles of perception.
5.1 THE PROCESS OF SENSATION

Sensation is the process through which the senses pick up visual, auditory, and other sensory stimuli and transmit them to the brain.

Perception is the process by which sensory information is actively organized and interpreted by the brain.

Absolute threshold measures have been established by sensory psychology. Just as a threshold for a doorway is the dividing point between being outside or inside a room, the absolute threshold of a sense marks the difference between not being able to perceive a stimulus and being just barely able to perceive it. The minimum amount of sensory stimulation that can be detected 50% of the time.

Difference Threshold is the smallest increase or decrease required to produce a difference in sensation that is noticeable 50% of the time.

Just Noticeable Difference (JND)
The smallest increase or decrease in a physical stimulus that is required to produce the "just noticeable difference (JND)." The JND is the smallest change in sensation that a person is able to detect 50% of the time.

Weber's Law states the JND is based on a percentage or proportion of stimulus change rather than a fixed amount of change:
- A weight must increase or decrease by 1/50th or 2% for JND
- 2 lbs difference needed in 100 lb weight
- A tone must be .33% higher or lower
- Only applies to average sensitivities and stimuli not too strong or weak

Sensory Receptors: Highly specialized cells in the sense organs that detect and respond to one type of sensory stimuli and converts the stimuli into nerve impulses (neural).

Sensory Transduction: The process through which sensory receptors convert the sensory stimulation into electrochemical neural impulses.

Sensory Adaptation: The process in which sensory receptors grow accustomed to constant, unchanging levels of stimuli over time; smokers grow accustomed to smell of cigarettes.

Receptor Potential: A slow, graded electrical potential produced by a receptor cell in response to a physical stimulus; receptor potentials affect the release of neurotransmitters and hence modify the pattern of firing in neurons.
5.2 VISION

5.2.1 The Stimulus

Our eyes perceive the presence of light. Light is a band of the spectrum electromagnetic radiation; electromagnetic radiation with a wavelength of 380 and 760 nm is visible to us.

![Electromagnetic Spectrum Diagram](image)

Visible Spectrum: The band of electromagnetic waves visible to the human eye.

Wavelength: The distance from the peak of a light wave to the peak of the next wave.

Color vision results from the reflection of particular parts of electromagnetic spectrum by an object’s surface. For example, an object that appears to be red reflects longer waves than one that appears to be blue.

Perceived color of light is determined by:
- Hue (the specific color perceived); determined by wavelength
- Brightness; determined by the intensity of the electromagnetic radiation or light energy that is perceived
- Saturation; determined by the purity of the light wave or color

If all radiation is of one wavelength, the perceived color is pure, or fully saturated. If the radiation contains all wavelengths, it produces no hues (appears white).

5.2.2 Anatomy of the Visual System

Anatomy of the visual system covers the different parts of the eye, all the cell types in the retina and their functions. It explains how rods and cones carry out different visual processes. Eye movements called saccades are responsible for keeping our retinal image from...
fading and enable us to see a wider range of objects.

Visual transduction begins with a photon of light bleaching a pigment called rhodopsin (found in rods), which inhibits the G-protein cGMP, resulting in the flow of fewer sodium ions into the receptor cell. The receptor cell then becomes hyperpolarized and decreases its release of glutamate. Thus, the first step in visual facilitation is inhibition.

**The Eyes**

The cornea bends light rays inward through the pupil, the small, dark opening in the eye. The iris dilates and contracts the pupil to regulate the amount of light entering the eye. The lens changes its shape as it focuses images of objects from varying distances on the retina, a thin tissue containing the sensory receptors for vision.

The cones detect color, provide the sharpest vision, and function best in high illumination. The rods enable vision in dim light. Rods respond to black and white light, and they encode all other visible wavelengths in shades of gray.

**Orbits:** Bony pockets in the front of the skull.

**Sclera:** The white tissue of the eye; hold and move the eyes.

**Conjunctiva:** Mucous membranes that line the eyelid and protect the eye.

**Cornea:** Tough, transparent, protective layer; covers front of eye and bends light rays inward through the pupil.

**Lens:** Consists of a series of transparent, disk-shaped, onion-like layers behind the iris & pupil; its shape can be changed by contraction of ciliary muscles and changes shape as focusing on objects.

**Pupil:** Adjustable opening in the iris that regulates the amount of light that enters the eye.

**Iris:** Pigmented ring of muscles situated behind the cornea.

**Retina:** The neural tissue and photoreceptive cells located on the inner surface of the posterior portion of the eye; contains visual sensory receptors.

**Fovea:** A small central area of retina that mediates the most acute vision that contains only color-sensitive cones; has largest concentration of cones and provides clearest and sharpest vision.

**Optic Disk:** Location on the retina where fibers of ganglion cells exit the eye; responsible for the blind spot (point in each retina with no rods or cones).

**Optic Nerve:** Carries visual information from retina to both sides of the brain.

**Primary Visual Cortex:** Part of brain that processes visual information.
The eyes make three types of movements:

- **Vergence movements**: The cooperative movement of the eyes, which ensures that the image of an object falls on identical portions of both retinas.
- **Saccadic movements**: The rapid, jerky movement of the eyes used in scanning a visual scene.
- **Pursuit movements**: The movement that the eyes make to maintain an image of a moving object on the fovea.

**Accommodation**: Changes in the thickness of the lens, accomplished by the ciliary muscles that focus images of near or distant objects on the retina.

**Rods**: Photoreceptor cells in the retina that are sensitive to the light of low intensity; look like slender cylinders and allow the eye to respond to low light.

**Cones**: Photoreceptor cells in the retina; maximally sensitive to one of three different wavelengths of light and hence encodes color vision and enables humans to see color and fine detail; do not function in very dim light.

**Blind Spot**: Area in each eye where the optic nerve joins the retinal wall and no vision is possible.
The retina consists of several layers of neuron cell bodies, their axons and dendrites and photoreceptors. The primate retina is divided into three main sections:
- The photoreceptive layer
- The bipolar cell layer
- Ganglion cell layer

**Bipolar cell**: A bipolar neuron located in the middle layer of the retina, conveying information from the photoreceptors to the ganglion cells.

**Ganglion cell**: A neuron that receives visual information from bipolar cells; its axons give rise to the optic nerve.

**Horizontal cell**: A neuron in the retina that interconnects adjacent photoreceptors and the outer processes of the bipolar cells.

**Amacrine cell**: A neuron in the retina that interconnects adjacent ganglion cells and the inner processes of the bipolar cells.
**Photoreceptors**

Each photoreceptor consists of an outer segment connected by cilium to the inner segment, which contains the nucleus. The outer segment contains several hundred lamellae.

![Diagram of photoreceptor circuitry](image)

*Figure 5.4: Neural circuitry in the retina. Light striking a photoreceptor produces hyperpolarization, so the receptor releases less neurotransmitter. Because the neurotransmitter normally hyperpolarizes the membrane of the bipolar cell, the reduction causes depolarization. This depolarization causes the bipolar cell to release more neurotransmitter, which excites the ganglion.*

**Lamella:** A layer of membrane containing photopigments; found in rods and cones.

**Photopigment:** A protein dye bonded to retinal, a substance derived from vitamin A; responsible for the transduction of visual information.

**Opsin:** A class of protein that, together with retinal, constitutes the photopigments.

**Retinal:** A chemical synthesized from vitamin A, joins with an opsin to form a photopigment.

**Rhodopsin:** A particular opsin found in rods.
In the vertebrate retina, photoreceptors provide input to both bipolar cells and horizontal cells. Their release of neurotransmitters is regulated by the value of their membrane potential; depolarizations increase the release and hyperpolarizations decrease it.

Connections Between Eye and Brain

The rods and the cones transduce light waves into neural impulses that pass from the bipolar cells to the ganglion cells, whose axons form the optic nerve. The axons of the ganglion cells bring information to the rest of the brain.

At the optic chiasm, some of the fibers of the optic nerve cross to the opposite side of the brain before reaching the thalamus. From the thalamus, the neural impulses travel to the primary visual cortex.

Dorsal lateral geniculate nucleus: A group of cell bodies within the lateral geniculate body of the thalamus; receives inputs from the retina and projects to the primary visual cortex.

Magnocellular layer: One of the two inner layers in the dorsal lateral geniculate nucleus; transmits information necessary for the perception of form, movement, depth, and small differences in brightness to the primary visual cortex.

Parvocellular layer: One of the four outer layers of neurons in the dorsal lateral geniculate nucleus; transmits information necessary for perception of color and fine details to the primary visual cortex.

Koniocellular sublayer: One of the sublayers of neurons in the dorsal lateral geniculate nucleus found ventral to each of the magnocellular and parvocellular layers; transmits information from short-wavelength cones to the primary visual cortex.

The neurons in the dorsal lateral geniculate membrane send their axons through a pathway known as the optic radiations to the primary visual cortex.

Calcarine fissure: Horizontal fissure on the inner surface of the posterior cerebral cortex; the location of the primary visual cortex.

Striate cortex: The primary visual cortex; contains a dark-staining layer (stria) cells.

Optic chiasm: A connection between the optic nerves, located below the base of the brain, just anterior to the pituitary gland.

From the optic chiasm the axons from the ganglion cells cross through the chiasm and ascend to the dorsal lateral geniculate nucleus.

The axons from the outer halves of the retina remain on the same side of the brain. The lens inverts the image of the world projected on the retina.

Therefore, because the axons from the nasal halves of the retinas cross the other side of the brain, each hemisphere receives information from the contralateral half of the visual scene.
5.2.3 Coding of Visual Information in the Retina

5.2.3.1 Coding of Light and Dark

Receptive Field: That portion of the visual field in which the presentation of visual stimuli will produce an alteration in the firing rate of a particular neuron.

If a neuron receives information from photoreceptors located in the fovea, its receptive field will be at the fixation point, the point at which the eye is looking. If the neuron receives information from photoreceptors located in the periphery of the retina, its receptive field will be located off to one side.

At the periphery of the retina many individual receptors converge on a single ganglion cell, bringing information from a relatively large area of the retina, and hence a relatively large area of the visual field.

Foveal vision is more direct, with approximately equal numbers of ganglion cells and cones. These receptor-to-axon relationships explain the fact that our foveal (central) vision is very acute but our peripheral vision is much less precise.
Coding of Color

The cones detect color. Two major theories that attempt to explain color vision are the trichromatic theory and the opponent-process theory. Color blindness is the inability to distinguish some colors from one another rather than the total absence of color vision.

Trichromatic Theory

In the first theory of color vision, the trichromatic theory, Hermann von Helmholtz proposed that there are cones dedicated to three colors: red, green, and blue. Each cone achieves its maximum chemical response when its particular color is present in a stimulus. Research supports the trichromatic theory, but it doesn’t explain the variety of colors we see (obviously more than red, green, and blue).

Three types of cones in the retina each make a maximal chemical response to one of three colors (blue, green, or red): each cone is sensitive to one of the colors.

Figure 8.6 Color coding in the retina. (a) Red light stimulating a red cone. (b) Green light stimulating a green cone. (c) Yellow light stimulating red and green cones. (d) Blue light stimulating blue cone.

Photoreceptors: Trichromatic Coding The characteristics of photoreceptors are controlled by the particular opsins a photoreceptor contains; different opsins absorb particular wavelengths more readily.
Genetic defects in color vision appear to result from anomalies in one or more of the three types of cones. The first two kinds of defective color described here involve genes on the X chromosome.

**Protanopia:** An inherited form of defective color vision in which red and green hues are confused; “red” cones are filled with “green” cone opsin; they see the world in shades of yellow and blue; both red and green look yellowish to them. Visual acuity is normal.

**Deuteranopia:** An inherited form of defective color vision in which red and green hues are confused; “green” cones are filled with “red” cone opsin. Visual acuity is normal.

**Tritanopia:** An inherited form of defective color vision in which hues with short wavelengths are confused; “blue” cones are either lacking or faulty. They see the world in greens and reds; blue looks green and yellow looks pink. Visual acuity is normal.

**Retinal Ganglion Cells: Opponent-Process Theory**

One theory that adds significantly to our understanding of color vision is the opponent process theory. This theory holds that we have red/green and yellow/blue cones. The neurons in red/green cones increase firing when red is present and decrease when green is present. The yellow/blue cells increase when stimulated by yellow and do the opposite in response to a blue stimulus. There is a third type of cone that responds to white light, but its cells don’t fire when light is absent.

It is the relative firing of the cones that allows us to see a variety of colors. One interesting finding in opponent-process research is that, if you look for a long time at an image of one color (e.g., red), then look at something white, you will “see” the opposite color (e.g., green).

At the level of the retinal ganglion cell, the three-color code gets translated into an opponent-color system. Three kinds of cells respond by increasing or decreasing their rate of firing when different colors are present.

**Types of cells:**
- The **red/green** – firing increases when red present, green decreases firing
- The **yellow/blue** – firing increases when yellow present, blue decreases firing
- The **white/black** – firing increases when white present, black decreases firing

**Negative Afterimages**

**Negative Afterimage:** The image is seen after a portion of the retina is exposed to an intense visual stimulus; consists of colors complementary to those of the physical stimulus.

**Complementary colors:** Colors that make white or gray when mixed together.
5.2.4 Analysis of Visual Information: Role of the Striate Cortex

The Striate Cortex

The striate cortex consists of six principal layers, arranged in bands parallel to the surface. These layers contain the nuclei of cell bodies and dendritic trees that show up as bands of light or dark in sections of tissue that have been dyed with a cell-body stain.

In primates, information from the parvocellular and magnocellular layers of the dorsal lateral geniculate nucleus enters the middle layer of the striate cortex. From there it is relayed to the upper layers, where it is analyzed by circuits of neurons. Axons bringing information from the koniocellular layers form synapses with neurons in layer 3.

David Hubel and Torsten Wiesel discovered that neurons in the visual cortex did not simply respond to light; they selectively responded to specific features of the visual world during the 1960s at Harvard University.

Orientation and movement

Most neurons in the striate cortex are sensitive to orientation.

Simple cell: An orientation-sensitive neuron in the striate cortex whose receptive field is organized in an opponent fashion.

Complex cell: A neuron in the visual cortex that responds to the presence of a line segment with a particular orientation located within its receptive field, especially when the line moves perpendicular to its orientation.

Hypercomplex cell: A neuron in the visual cortex that responds to the presence of a line segment with a particular orientation that ends at a particular point within a cell’s receptive field.

Spatial Frequency

Although the early studies by Hubel and Wiesel suggested that neurons in the primary visual cortex detected edges and lines, subsequent research found that they actually responded best to sine-wave gratings.

Sine-wave grating: A series of straight parallel bands varying continuously in the brightness according to a sine-wave function, along a line perpendicular to their lengths. Sine-wave grating is designated by spatial frequency.

Spatial frequency: The relative width of the bands in a sine-wave grating, measured in cycles per degree of visual angle.

Retinal Disparity

Binocular vision provides a vivid perception of depth through the process of stereoscopic vision or stereopsis.
Retinal Disparity: The fact that points on objects located at different distances from the observer will fall on slightly different locations on the two retinas; provides the basis for stereopsis or depth perception.

Color

Cytochrome oxidase (CO) blob: The central region of a module of the primary visual cortex, revealed by a stain for cytochrome oxidase; contains wavelength-sensitive neurons; part of the parvocellular system.

The parvocellular system receives information only from red and green cones; additional information from blue cones is transmitted through the koniocellular system.

Neurons in the striate cortex respond to several different features of a visual stimulus, including orientation, movement, spatial frequency, texture, retinal disparity and color.

Modular Organization of the Striate Cortex

The striate cortex is divided into approximately 2500 modules, each approximately 0.5 x 0.7 mm and containing approximately 150,000 neurons. Neurons in each module are devoted to the analysis of various features contained in one very small portion of the visual field.

The modules actually consist of two segments, each surrounding a CO blob. Neurons located within blobs have a special function: They are sensitive to color and low spatial frequencies but are relatively insensitive to other visual features.

Outside the CO blob, neurons show sensitivity to orientation, movement, spatial frequency, texture and binocular disparity but do not respond to color.

Ocular dominance: The extent to which a particular neuron receives more input from one eye than from the other.

Blindsight

Cortical blindness: Blindness caused by damage to the optic radiations or primary visual cortex.

5.2.5 Analysis of Visual Information: Role of the Visual Association Cortex

Two Streams of Visual Analysis

Visual information received from the striate cortex is analyzed in the visual cortex. Neurons in the striate cortex send axons to the extrastriate cortex. Most information passes up the
hierarchy, each region receives information from regions located beneath it in the hierarchy, analyzes the information, and passes the results to higher regions for further analysis.

**Extrastriate cortex**: A region of the visual association cortex; receives fibers from the striate cortex and from the superior colliculi and projects to the inferior temporal cortex. Regions respond to particular features of visual information such as orientation, movement, spatial frequency, retinal disparity, or color.

**Dorsal stream**: A system of interconnected regions of the visual cortex involved in the perception of spatial location, beginning with the striate cortex and ending with the posterior parietal cortex.

**Ventral stream**: A system of interconnected regions of visual cortex involved in the perception of form, beginning with the striate cortex and ending with the inferior temporal cortex.

**Perception of Color**

**Color constancy**: The relative constant appearance of the colors of objects viewed under varying lighting conditions

**Achromatopsia**: Inability to discriminate among different hues; caused by damage to the visual association cortex.

**Analysis of Form**

**Inferior temporal cortex**: In primates, the highest level of the ventral stream of the visual association cortex; located on the inferior portion of the temporal lobe. It is here that analyses of form and color are put together and perceptions of 3D objects and backgrounds are achieved.

**Agnosia**: Inability to perceive or identify a stimulus by means of a particular sensory modality.

**Visual agnosia**: Deficits in visual perception in the absence of blindness; caused by brain damage.

**Apperceptive visual agnosia**: Failure to perceive objects even though visual acuity is relatively normal.

**Prosopagnosia**: Failure to recognize particular people by the sight of their faces.

**Associative visual agnosia**: Inability to identify objects that are perceived visually, even though the form of the perceived object can be drawn or matched with similar objects.

**Fusiform face area**: A region of the extrastriate cortex located at the base of the brain; involved in perception of faces and other objects that require expertise to recognize.
Perception of Movement

Optic flow: The complex motion of points in the visual field caused by relative movement between the observer and environment; provides information about the relative distance of objects from the observer and of the relative direction of movement.

Akinetopsia: Inability to perceive movement, caused by damage to area V5 of the visual association cortex.

Perception of Spatial Location

Balint's Syndrome: A syndrome caused by bilateral damage to the parieto-occipital region; includes optic ataxia, ocular apraxia, and simultanagnosia.

Optic ataxia: Difficulty in reaching for objects under visual guidance.

Ocular apraxia: Difficulty in visual scanning.

Simultanagnosia: Difficulty in perceiving more than one object at a time.

1. What is the difference between the absolute threshold and the difference threshold?
2. How does transduction enable the brain to understand sensory information?
3. Identify the parts of the eye and describe the role each plays in vision.
5.3 AUDITION

5.3.1 The Stimulus

Sound is produced by objects that vibrate and set molecules of air into motion; it travels approximately 700 miles per hour.

Humans are sensitive to vibrations between 30 and 20,000 times per second; vibrations of air are perceived as sounds.

In order to hear, sound requires a medium through which to move; air, water, or other solid objects can carry sound waves. This was first demonstrated by Boyle in 1660 with a watch in a jar; when air was pumped out the sound could not be heard.

![Diagram showing sound waves and eardrum](image)

**Figure 5.7**: Sound waves. Changes in air pressure from sound waves move the eardrum in and out. Air molecules are closer together in regions of higher pressure and farther apart in regions of lower pressure.

**The psychological quality of sound**

**Frequency**: The number of cycles completed by a sound wave in one second; unit of measure is the hertz (cycles per second). Pitch is a perceptual dimension of sound. It corresponds to the fundamental frequency. The pitch of a sound is determined by the frequency of the sound waves, which is measured in hertz.
Amplitude: The loudness of sound; a perceptual dimension of sound; corresponds to the intensity of the stimulus; unit of measure is the decibel. Loudness is a perceptual dimension of sound; corresponds to intensity. The loudness of a sound is determined largely by the amplitude of the sound waves and is measured in decibels.

Intensity: The degree to which the condensations and rarefactions of air differ from one another.

Timbre: The distinctive qualities of a sound; a perceptual dimension of sound; corresponds to the complexity of the stimulus. Distinguishes it from other sounds of same pitch and loudness.

Figure 5.8: The physical and perceptual dimensions of sound waves.

<table>
<thead>
<tr>
<th>Psychological Response</th>
<th>Decibel Scale</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold of pain</td>
<td>140</td>
<td>Rock band at 15 feet</td>
</tr>
<tr>
<td>Painfully loud</td>
<td>120</td>
<td>Jet takeoff at 200 feet</td>
</tr>
<tr>
<td>Prolonged exposure</td>
<td>100</td>
<td>Riveting machine</td>
</tr>
<tr>
<td>produces damage to hearing</td>
<td></td>
<td>Subway train at 15 feet</td>
</tr>
<tr>
<td>Very loud</td>
<td>80</td>
<td>Water at foot of Niagara Falls</td>
</tr>
<tr>
<td>Quiet</td>
<td>60</td>
<td>Automobile interior at 65 mph</td>
</tr>
<tr>
<td>noisy</td>
<td>40</td>
<td>Freeway traffic at 50 feet</td>
</tr>
<tr>
<td>Normal conversation</td>
<td>20</td>
<td>Quiet restaurant</td>
</tr>
<tr>
<td>Very quiet</td>
<td>0</td>
<td>Quiet office</td>
</tr>
<tr>
<td>Just audible</td>
<td></td>
<td>Library</td>
</tr>
<tr>
<td>Threshold of hearing</td>
<td></td>
<td>Whisper at 3 feet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal breathing</td>
</tr>
</tbody>
</table>

Figure 5.9: The decibel levels of various sounds.
Decibel Levels of Various Sounds

The loudness of a sound (amplitude) is measured in decibels. Each increase of 10 decibels makes a sound 10 times louder.

Any exposure to sounds of 130 decibels or higher puts a person at immediate risk for hearing damage.

![Auditory Apparatus Diagram]

Figure 5.10: The auditory apparatus.

5.3.2 Anatomy of the Ear

Sound waves enter the pinna, the visible part of the outer ear, and travel to the end of the auditory canal, causing the eardrum to vibrate. This sets in motion the ossicles in the middle ear, which amplify the sound waves.

The vibration of the oval window causes activity in the inner ear, setting in motion the fluid in the cochlea and moving the hair cells, which transduce the vibrations into neural impulses. The auditory nerve carries the neural impulses to the brain.

**Outer Ear:** Visible part of the ear consists of the pinna and the auditory Canal.

**Middle Ear:** Contains the ossicles, connect the ear drum to the oval window and amplifies sound waves.
• **Tympanic membrane**: The eardrum; vibrates when stimulated by sound waves.

• **Ossicle**: The bones of the middle ear.

• **Malleus**: The first of the three ossicles; attached to the tympanic membrane.

• **Incus**: Located between the malleus and the stapes. **Stapes**: The third ossicle; attached to the oval window of the cochlea.

**Inner Ear**

• **Cochlea**: The fluid-filled snail-shaped bony chamber of the inner ear; contains the basilar membrane and auditory receptor hair cells; divided into three sections:
  - Scala vestibuli (vestibular stairway)
  - Scala media (middle stairway)
  - Scala tympani (tympanic stairway)

• **Oval window**: An opening in the bone of the cochlea that reveals a membrane against which the baseplate of the stapes presses, transmitting sound vibrations into the fluid within the cochlea.

• **Hair Cells**: Sound receptors inside inner ear

• **Organ of Corti**: The sensory organ on the basilar membrane that contains the auditory hair cell; considered the receptive organ of the auditory system.

• **Deiter cell**: A supporting cell found in the organ of Corti; sustains the auditory hair cells.

• **Basilar membrane**: A membrane in the cochlea of the inner ear; contains the organ of Corti.

• **Tectorial membrane**: A membrane located above the basilar membrane; serves as the shelf against which the cilia of the auditory hair cells move.

• **Round window**: An opening in the bone of the cochlea that permits vibrations to be transmitted, via the oval window, into the fluid of the cochlea.

**ACTIVITY**

1. List each part of the ear and its function in hearing. How do the outer ear, middle ear, and inner ear function in hearing?
2. Describe internal and environmental causes of hearing loss.
Figure 5.11: A cross section through the cochlea, showing the organ of Corti.
Figure 5.12: Responses to sound waves. When the stapes push against the membrane behind the oval window, the membrane behind the round window bulges outward. Different high frequency and medium frequency sound vibrations cause flexing of different portions of the basilar membrane. In contrast, low frequency sound vibrations cause the tip of the basilar membrane to flex in synchrony with the vibrations.

5.3.3 Auditory Hair Cells and the Transduction of Auditory Information

Two types of auditory receptors, inner and outer auditory hair cells, lie on the inside and outside of the cochlear coils respectively. Hair cells contain cilia.

Sound waves cause both the basilar membrane and the tectorial membrane to flex up and down. The bending of the bundle of cilia causes receptor potentials. A small amount of the cations K⁺ and Ca²⁺ diffuses in the cilium. When the bundle moves toward the tail one, the increased tension on the tip links opens all the ion channels, the flow of cations into the cilium increases and the membrane depolarizes. As a result, the release of neurotransmitters increases.

Cilium: A hair-like appendage of a cell involved in movement or transducing sensory information; found on the receptors in the auditory and vestibular system.

Tip link: An elastic filament that attaches the tip of one cilium to the side of the adjacent cilium.
Insertional plaque: The point of attachment of a tip link to a cilium.

![Insertional plaque](image)

Figure 5.13: Electron micrographs of the transduction apparatus in hair cells. (a) Longitudinal section through three adjacent cilia. Tip links, elastic filaments attached to insertional plaques, link adjacent cilia. (b) A cross section through several cilia, showing an insertional plaque.

5.3.4 The Auditory Pathway

*Connections with the Cochlear Nerve* The organ of Corti sends auditory information to the brain by means of the cochlear nerve. These neurons have axonal processes, capable of sustaining action potentials. The excitatory postsynaptic potentials trigger action potential in the auditory nerve axones, which form synapses with neurons in the medulla.

*Cochlear nerve:* A branch of the eighth cranial nerve; the branch of the auditory nerve that transmits auditory information from the cochlea to the brain.

*Olivocochlear bundle:* A bundle of efferent axones that travel from the olivary complex of the medulla to the auditory hair cells on the cochlea.

*The Central Auditory System*

*Cochlear nucleus:* One of a group of nuclei in the medulla that receive auditory information from the cochlea.

*Superior olivary complex:* A group of nuclei in the medulla; involved with auditory functions, including localization of the sound source.
Lateral lemniscus: A band of fibers running rostrally through the medulla and pons; carries fibers of the auditory system.

Topotopic representation: A topographically organized mapping of different frequencies of sound that are represented in a particular region in the brain.

Core region: The primary auditory cortex, located on a gyrus on the dorsal surface on the temporal lobe.

Belt region: The first of auditory association cortex; surrounds the primary auditory cortex.

Parabelt region: The second level of auditory association cortex; surrounds the belt region.

Place code: The system by which information about different frequencies is coded by different locations on the basilar membranes.
5.3.5 Perception of Pitch

Theories of Hearing

Two major theories that attempt to explain hearing are place theory and frequency theory. Causes of hearing loss include sensorineural deafness and conduction deafness. Most hearing loss is caused by exposure to excessive noise. Some causes of hearing loss are noise, disease, birth defects, injury, and aging.

Place Theory: Each individual pitch is determined by the particular spot or place along the basilar membrane of the cochlea that vibrates the most. The pitch of a sound is related to where in the structure of the ear it is sensed. Hearing of pitches higher than 150 Hz is explained well by place theory.

Frequency Theory: The hair cell receptors vibrate the same number of times per second as the wave sounds that reach them. The frequency theory claims that hair cell receptors vibrate at the same frequency as the sound that stimulates these. The frequency theory is valid for sounds up to 1,000 Hz.

Rate code: The system by which information about different frequencies is coded by the rate of firing of neurons in the auditory system.

Cochlear implant: An electrical device surgically implanted in the inner ear that can enable a deaf person to hear.

5.3.6 Perception of Timbre

Fundamental frequency: The lowest, and usually most intense, frequency of a complex sound; most often perceived as the sound’s basic pitch.

Overtone: The frequency of complex tones that occurs at multiples of the fundamental frequency.

5.3.7 Perception Spatial Location

Humans can determine the location of a sound because auditory neurons respond selectively to different arrival times of the sound waves at the left and right ears.

Phase difference: The difference in arrival times of sound waves at each of the eardrums.

ACTIVITY 5.2
Identify the parts of the eye and describe the role each plays in vision.
5.4 OLFATION

5.4.1 The Stimulus

Olfaction, the sense of smell, is the second chemical sense. For humans, olfaction is the most enigmatic of the modalities. The stimulus for odor (known as odorants) consists of volatile substances having a molecular weight in the range of approximately 15 to 300. Almost all odorous compounds are lipid soluble and of organic origin.

The act of smelling begins when odor molecules reach the smell receptors in the olfactory epithelium at the top of the nasal cavity. The axons of these receptors form the olfactory nerve, which relays the smell message to the olfactory bulbs. From there the smell message travels to the olfactory cortex and on to other parts of the brain.

5.4.2 Anatomy of the Olfactory Apparatus

![Diagram of the olfactory system]

Figure 5.14: The olfactory system.
Olfactory epithelium: The epithelial tissue of the nasal sinus that covers the cribiform plate; contains the cilia of the olfactory receptors. Two 1-inch square patches of tissue, at the top of each nasal cavity, contain about 10 million olfactory neurons.

Odor molecules travel up the nose to the olfactory epithelium, which contains receptor cells for smells. The axons of these cells form the olfactory nerve. This nerve relays information about smells to the olfactory bulbs which pass them on to the olfactory cortex in the brain.

Olfactory bulb: The protrusion at the end of the olfactory tract; receives information from the olfactory receptors; relay messages to thalamus and orbitofrontal cortex; distinguish odors and relays information to other parts of the brain. Smell sensitivities vary for each individual.

Olfactory receptor cells are bipolar neurons whose cell bodies lie within the olfactory mucosa that lines the cribiform plate, a bone at the base of the rostral part of the brain.

![Diagram of olfactory system](image)

**Figure 5.14:** Details of the connections of olfactory receptor cells with the glomeruli of the olfactory bulb. Each glomerulus receives information from only one type of receptor cell. Olfactory receptor cells of different colors contain different types of receptor molecules.

**Mitral cell:** A neuron located in the olfactory bulb that receives information from olfactory receptors; axons of mitral cells bring information to the rest of the brain.

**Olfactory glomerulus:** A bundle of dendrites of mitral cells and associated terminal buttons of the axons of olfactory receptors.
Olfactory tract axons project directly to the amygdala and to two regions of the limbic cortex: the pyriform cortex and the entorhinal cortex. The amygdala sends olfactory information to the hypothalamus, the entorhinal cortex sends it to the hippocampus and the pyriform cortex sends it to the hypothalamus and to the orbitofrontal cortex.

5.5 GUSTATION

Gustation, the sense of taste, is related to eating and is our first chemical sense. This sense modality helps us to determine the nature of things we put in our mouths.

The primary taste sensations are sweet, salty, sour, and bitter, along with a newly discovered one for monosodium glutamate. The receptor cells for taste are found in the taste buds on the tongue and in other parts of the mouth and throat.

5.5.1 Anatomy of the Taste Buds and Gustatory cells.

The tongue, palate, pharynx, and larynx contain about 10,000 sensory receptor taste buds. There are only four qualities of taste: bitterness, sourness, sweetness, and saltiness.

Figure 5.15: The tongue. (a) Papillae on the surface of the tongue. (b) Taste buds.
Papillae: Small bumps on the tongue that contain taste buds; taste buds lie alongside some of the papillae.
  - **Fungiform papillae:** Located on the anterior to two-thirds of the tongue, contain up to eight taste buds, along with receptors for pressure, touch and temperature.
  - **Foliate papillae:** Consists of up to eight parallel folds along each edge of the back of the tongue.
  - **Circumvallate papillae:** Arranged in an inverted V on the posterior third of the tongue.

Taste receptor cells form synapses with dendrites of bipolar neurons whose axons convey gustatory information to the brain through the seventh, ninth and tenth cranial nerves.

### 5.5.2 Perception of Gustatory Information

![Neural pathways of the gustatory system.](image)

The tasted molecule binds with the receptor and produces changes in membrane permeability that cause receptor potentials. Different substances bind with different types of receptors, producing different taste sensations.

**Gustducin:** A G-protein that plays a vital role in the transduction of sweetness and bitterness.
5.5.3 The Gustatory Pathway

Chorda tympani: A branch of the facial nerve that passes beneath the eardrum; conveys taste information from the anterior part of the tongue and controls the secretion of some salivary glands.

Nucleus of the solitary tract: A nucleus of the medulla that receives information from visceral organs and from the gustatory system.

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5.6 SOMATOSENSES

Nerve endings in the skin (the sensory receptors) respond to different kinds of stimulation, including heat and cold, pressure, pain, and a vast range of touch sensations. The neural impulses ultimately register in the somatosensory cortex.

Cutaneous sense: One of the somatosenses; includes sensitivity to stimuli that involve the skin.

Kinesthesia: Perception of the body's own movements.

Organic sense: A sense of modality that arises from receptors located within the inner organs of the body.

5.6.1 The Stimuli

The cutaneous senses respond to several different types of stimuli: pressure, vibration, heating, cooling, and events that cause tissue damage (and hence pain). Some receptors report changes in muscle length to the brain, providing our sense of kinesthesia.

Additional receptors provide information about the internal organs such as the linings of muscles and the gastrointestinal system. Tactile information is carried to the brain when an object touches and depresses the skin.
Distinct nerve receptors: In skin are stimulated sending messages through nerves, spinal cord, through the brainstem, midbrain, to the somatosensory cortex.

Somatosensory cortex: Allows sensation of where and how hard you have been touched.

Two-point threshold: How far apart two touch points are so they can be felt as two distinct touches.

5.6.2 Anatomy of the Skin and Its Receptive Organs

The skin consists of subcutaneous tissue, dermis, and epidermis and contains various receptors scattered throughout these layers.

Glabrous skin: Skin that does not contain hair; found on the palms and soles of the feet.

Ruffini corpuscle: A vibration-sensitive organ located in hairy skin.

Pacinian corpuscles: A specialized, encapsulated somatosensory nerve ending that detects mechanical stimuli, especially vibrations.

Meissner's corpuscles: The touch-sensitive end organs located in the papillae, small elevations of the dermis that project up into the epidermis.

Merkel's disk: The touch-sensitive end organs found at the base of the epidermis, adjacent to sweat ducts.

Mechanoreceptors: Receptors that respond to mechanical stimulation; divided into four categories depending on the size of their receptive field in the skin and the speed with which they adapt to a constant stimulus.

Phantom limb: Sensations that appear to originate in a limb that has been amputated.

5.6.3 Pain

The sensation of pain is one of the products of the sense of touch. Pain is an important warning from the body that something is wrong. Scientists don’t yet fully understand pain, but they do know that the body produces its own pain-killing hormones called endorphins. Endorphins help explain why athletes can perform when they are in pain, and it may be the reason acupuncture works on some kinds of problems.

Pain reception is accomplished by the networks of free nerve endings in the skin. There appears to be at least three types of pain receptors.

- High threshold mechanoreceptors are free nerve endings that respond to intense pressure.
- A second free nerve ending seems to respond to extremes of heat, to acids and to the presence of capsaicin.
- Another type of nociceptive fiber contains receptors are sensitive to ATP.
Perception of pain is influenced by:
- Psychological factors
- Culture
- Endorphins (the body's own natural pain killers block pain and produce a feeling of well-being).

![Figure 5.17: Cutaneous receptors.](image)

Pain can be a valuable warning and a protective mechanism, motivating people to tend to an injury, to restrict activity, and to seek medical help if needed. Negative thinking can influence the perception of pain. Some cultures encourage individuals to suppress emotional reactions to pain. Endorphins are natural painkillers secreted by the body in response to physical injury or stress.

**Gate Control Theory**

An area in the spinal cord that acts like a "gate." Gate either lets pain message through or blocks transmission to the brain.

Slow conducting nerve fibers carry pain message. Fast conducting nerves carry other messages that can block pain messages at the gate.

Applying ice, heat, electrical stimulation, or rubbing area can block pain sensations; kissing 'boo boos' may actually help.
5.7 THE VESTIBULAR SYSTEM

The kinesthetic sense provides information about the relative position of body parts and movement of those parts. The position or motion is detected by sensory receptors in the joints, ligaments, and muscles.

The vestibular sense provides information about movement and the body’s orientation in space. The functions of the vestibular system include balance, maintenance of the head in an upright position and adjustment of eye movement to compensate for head movements.

Sensory receptors in the semicircular canals and in the vestibular sacs detect changes in the movement and orientation of the head.

**Kinesthetic Sense:** Provides information about the position of body parts in relation to each other and the movement of the entire body or its parts.

**Vestibular Sense:** Detects movement and the body’s orientation in space.

5.7.1 Anatomy of the Vestibular Apparatus

The endolymph of semicircular canals resist movements when the head begins to rotate. The inertial resistance pushes the endolymph against the cupula. Angular accelerations is thus translated into bending of the cupula.

The vestibular sacs are roughly circular and each contains a patch of receptive tissue. The receptive tissue contain hair cells. The cilia of these receptors are embedded in an overlying gelatinous mass, which contain otocinia (small crystal of calcium carbonate). The weight of the crystals causes the gelatinous mass to shift in position as the orientation of the head changes.
Vestibular sac: One of a set of two receptor organs in each inner ear that detects changes in the tilt of the head.
- Utricle
- Saccule

Semicircular canal: One of the three ring-like structures of the vestibular apparatus that detect changes in head rotation.
- Ampulla: An enlargement in a semicircular canal; contains the cupula and crista.
- Cupula: A gelatinous mass found in the ampulla of the semicircular canals; moves in response to the flow of the fluid in the canals.

Figure 5.18: The receptive organ of the semicircular canals.

5.7.2 The Receptor Cells

Each hair cell contains several cilia, graduated in length from short to long. A shearing force of the cilia opens ion channels and the entry of potassium ions depolarizes the ciliary membrane.

Hair cells: Similar to the hair cells found in the cochlea; method of transduction is also similar to hair cells of the cochlea.
5.7.3 The Vestibular Pathway

Vestibular ganglion: A nodule on the vestibular nerve that contains the cell bodies of the bipolar neurons that convey vestibular information to the brain.

Most axons of the vestibular nerve synapse within the vestibular nuclei in the medulla. Neurons of the vestibular nuclei send their axons to the cerebellum, spinal cord, medulla and pons. There also appear to be vestibular projections to the temporal cortex.

ACTIVITY 5.6

Describe the kinesthetic and vestibular senses and their contributions to balance and motor function. What kinds of information do the kinesthetic and vestibular senses provide?
5.8

PRINCIPLES OF PERCEPTION

5.8.1 Influences on Perception

Attention: The process of sorting through sensations and selecting some of them for further processing; some are automatic requiring minimal mental effort.

Inattentional Blindness: The phenomenon in which focus is shifted from one object to another. Changes in objects not receiving direct attention are not noticed.

Cocktail Party Phenomenon: When you hear your name focus follows due to assumption that other meaningful information will follow.

Focus: Information that receives focus is remembered while other stimulation received at same time is lost; hearing words spoken into both ears at same time. Only words that receive focus of attention are recalled.

5.8.2 Perceptual Organization and Constancy

The Gestalt principles of perceptual organization include the figure-ground relationship and four principles of perceptual grouping—similarity, proximity, continuity, and closure.

Perceptual constancy is the tendency to perceive objects as maintaining the same size, shape, brightness, and color despite changes in lighting conditions or changes in the retinal image that result when objects are viewed from different angles and distances.

Gestalt: A German word that roughly refers to the whole form, pattern, or configuration that a person perceives.

Figure-Ground:
When viewing the world, some object (the figure) often seems to stand out from the background (the ground).

5.8.2.1 Gestalt Principles of Grouping

Similarity: Objects that have similar characteristics are grouped together.
Proximity: Objects that are close together are perceived as belonging together.
Continuity: Figures or objects are perceived as belonging together if they appear to form a continuous pattern.
Closure: Figures with gaps in them are perceived as complete.
Perceptual Constancies

The phenomenon that allows perceived objects as maintaining stable properties despite differences in distance, viewing angle, and lighting.

Size constancy: As objects move away they seem to maintain same size.

Brightness constancy: Objects seem to maintain a constant level of brightness regardless of differences in lighting conditions.

Shape constancy: Objects are perceived as having an unchanging shape regardless of viewing angle changes that alter the retinal image.

Depth Perception

The ability to perceive the visual world in three dimensions and to judge distances accurately.

Binocular depth cues: Visual depth cues that depend on both eyes working together. The binocular depth cues are convergence and binocular disparity, and they depend on both eyes working together for depth perception.

The monocular depth cues, those that can be perceived by one eye, include interposition, linear perspective, relative size, texture gradient, atmospheric perspective, shadow, or shading, and motion parallax.

Interposition: When one object partly blocks your view of another, you perceive the partially blocked object as farther away.

Linear perspective: Parallel lines that are known to be the same distance apart appear to grow closer together, or converge, as they recede into the distance.

Relative Size: Larger objects are perceived as being closer to the viewer, and smaller objects as being farther away.

Texture gradient: Near objects appear to have sharply defined textures, while similar objects appear progressively smoother and fuzzier as they recede into the distance.
Atmospheric perspective: Objects in the distance have a bluish tint and appear more blurred than objects close at hand.

Shadow or shading: When light falls on objects, they cast shadows. You can distinguish bulges from indentations by the shadows they cast.

Motion parallax: When you ride a moving vehicle and look out the side window, the objects you see outside appear to be moving in the opposite direction. The objects also seem to be moving at different speeds—those closest to you appear to be moving faster than those at a distance. Objects very far away, such as the moon and the sun, appear to move in the same direction as the viewer.

Real motion is perceived as the brain compares the movement of images across the retina to information derived from the spatial orientation senses. Apparent motion is the result of specific characteristics of objects, such as flashing lights. The brain may also mistakenly perceive eye movement as object movement.

Puzzling Perceptions

Three types of puzzling perceptions are ambiguous figures, impossible figures, and illusions.

Ambiguous Figure: The sum of sensory parts can convey dramatically different perceptions of an object/stimulus. The perceptual systems are puzzled and view objects first one-way and then totally different.

Illusion: A false perception or a misperception of an actual stimulus in the environment. Size, shape, or the relationship of one element to another can be confused.

The Moon Illusion: Relative size appears different at the horizon than when the moon is overhead.

Influences On Perception

Individuals use bottom-up and top-down processing to apply knowledge to perceptual problems. Expectations generated by a perceptual based on prior knowledge set may predispose people to perceive sensations in a particular way.
We sometimes miss sensory events when our attention is focused on something else. Research suggests that the neural systems and rules for processing information about social stimuli are distinct from those for physical objects.

**Unusual Perceptual Experiences**

**Subliminal Perception:** The capacity to perceive and respond to stimuli that are presented below the threshold of awareness.

**Ganzfeld Procedure:** A study design with a “sender” and “receiver” placed in separate low-key rooms. Messages are attempted between receivers.

**Extrasensory Perception:** Gaining information about objects, events, or another person’s thoughts through some means other than the known sensory channels. Many types of ESP have been reported, of which include the following:

1. *clairvoyance and remote viewing* – the paranormal perception of people, places or events by means other than the normal senses.
2. *precognition or retrocognition* – the perception of other times via. This is usually considered to be the same as clairvoyance, except that the perception travels through time.
3. *abilities as 'aura' reading and medical intuition* – the perception of aspects of others which most people cannot perceive.
4. *psychometry, clairvoyance, clairaudience, clairsentience, clairalience and clairgustance* – the perception of aspects of things which most people cannot perceive, by means other than the normal senses.
5. *telepathy* – the ability to sense communications from and/or communicate with people by means other than the normal senses.
6. *out-of-the-body experiences* – is also called as spirit walking and astral projection, when used to perceive environments by means other than the normal senses.
7. *mediumship* – the ability to communicate with the spirits of persons or animals who have died. Mediumship may also include other paranormal abilities.
8. *psychokinesis* – the ability to move objects with the mind without physically manipulating the object.

**Activity 5.7**

1. What are the principles that govern perceptual organization?
2. Describe the process of depth perception and the role played by environmental cues.
1. _______ is the process through which the senses detect visual, auditory, and other sensory stimuli and transmit.

2. Weber's law refers to the fact that the just noticeable difference for ALL senses depends on _________.

3. Through a process known as ______, the receptors change or convert the sensory stimulation into neural.

4. Sensory receptors for vision are located on a thin layer of tissue at the back of the eyeball that is called _________.

5. This condition is also sometimes referred to as old eyes.

6. The specific color that an eye perceives — such as red, green, blue — is referred to as: _________.

7. The trichromatic theory states that there are three kinds of cones in the retina sensitive to these three colors: _________.

8. The number of cycles per second or the frequency of a sound wave is measured in _________.

9. The ________ contains the ossicles, the three smallest bones in the human body.

10. The olfactory epithelium is located here:

11. Each taste bud is composed of _______ receptor cells: _________.

12. The _______ sense is our sense of touch.

13. This accounts for the fact that psychological factors, both cognitive and emotional, can influence the perception of pain.

14. This detects movement and provides information about the body's orientation in space.

15. This word roughly refers to the whole form.

16. As objects that are familiar move further away, you continue to perceive them as being about the same size.
Suggested Text and References

Required Reading

Suggested Readings


Suggested Web Sites
Retina Reference
http://retina.anatomy.upenn.edu/~lance/retina/retina.html

Tutorials in Sensation and Perception
http://psych.hanover.edu/Krantz/sen_tut.html

Blindsight Demonstration
http://serendip.brynmawr.edu/bb/blindsight.html

Somatosensory Pathways
http://thalamus.wustl.edu/course/body.html

Relief of Pain and Suffering
http://www.library.ucla.edu/libraries/biomed/bis/PainExhibit/

Auditory System Function
http://penguin.d.umn.edu/undergradaudsyshuntweb/sld001.htm

Somatosensory Mapping
http://alpha.nimrlab.buscyr.edu/nmr_lab/

Self-check

1. sensation
2. a percentage of change in the stimulus.
3. transduction
4. the retina
5. presbyopia
6. hue
7. red, green, and blue
8. hertz
9. middle ear
10. the top of each nasal cavity.
11. 60 to 100
12. tactile
13. gate-control theory.
14. the vestibular sense
15. Gestalt
16. size constancy
Unit 6

The Sensorimotor System

**LEARNING OUTCOME**

At the end of this unit you will be able to:

1. Describe the principle of sensorimotor function
2. Explain the sensorimotor pathways and the control of movement by the brain
3. Explain the sensoris spinal circuits and the reflexive behavior

**INTRODUCTION**

Sensorimotor programs can be executed automatically and are systematically organized, based on three principles of sensorimotor functions. The "Sensorimotor Association Cortex" section describes the anatomy and functions of the dorsolateral prefrontal cortex and the posterior parietal cortex. These cortical areas give top-down instructions to areas of primary and secondary motor cortex.

"Secondary Motor Cortex" section covers the anatomy and functions of supplemental motor cortex, premotor cortex, and cingulate motor cortex. The secondary motor cortex receives inputs from association motor cortex and sends output to the primary motor cortex.

"Primary Motor Cortex" section reviews this area’s special features. Similar to the somatosensory cortex, the primary motor cortex has a somatotopic organization. It contains the motor homunculus. Penel uses the example of Belle, a non-human primate research subject. Researchers hooked up Belle's motor cortex to electrode arrays, which enabled her to control a robotic arm hundreds of miles away. This technology may hold promise for treating sensorimotor impairment following injury.
The section on "Cerebellum and Basal Ganglia" covers the anatomy and functions of these two subcortical motor areas. Both are described as modulating descending motor pathways. The "Descending Motor Pathways" section dissects the many pathways originating in the primary motor cortex and ending in the spinal cord. Some pathways make relays in the brain stem. All these details are given.

"Sensorimotor Spinal Circuits" section covers muscles, receptor organs, and various reflexes. The stretch reflex is the simplest and operates at the low-end of the sensorimotor hierarchy. It is a part of many movements we make. Walking, on the other hand, is a complex sensorimotor reflex that involves multiple sensory neurons, interneurons, and motor neurons acting in a coordinated manner.

Finally, the section "Central Sensorimotor Programs" explains concepts such as motor equivalence, whereby different muscle groups can perform the same sensorimotor program, and the response-chunking hypothesis, whereby complex behaviors can be reduced to series of chunked sequences.

### 6.1 CONTROL OF MOVEMENT BY THE BRAIN

#### 6.1.1 Principles of Sensorimotor Function

"Three Principles of Sensorimotor Function" are listed as follows:

1. the sensorimotor system is hierarchically organized,
2. motor output is guided by sensory input, and
3. learning changes the nature and focus of sensorimotor control.

**Hierarchical Organization**

The sensorimotor system is organized like a large effective company; the president (association cortex) issues general commands and lower levels (motor neurons and muscles) take care of details; the advantage of this hierarchical arrangement is that higher levels are left free to focus on complex functions.
Motor Output is Guided by Sensory Input

Like a large company, the sensorimotor system carefully monitors the external world and the consequences of its own actions, and it acts accordingly; only ballistic movements (brief, all-or-none; high speed movements) are not guided by sensory feedback.

Note the case of G.O., a former darts champion who suffered an infection that destroyed the somatosensory nerves of his arms; even though he still had visual feedback, he had difficulty picking up buttons or coins, difficulty adjusting to unanticipated external forces, and difficulty maintaining a constant force (e.g., holding a pen, cup, or suitcase).

Learning Changes the Locus of Sensorimotor Control

As a new company develops, more and more tasks become part of the routine and are taken over by lower levels of the organization; the same thing happens in the sensorimotor system; after much practice lower levels perform well-learned tasks with little higher involvement.

Why is the sensorimotor system like a large company in these three important respects? Is it mere coincidence? No, they are both complex behavioral systems that have evolved under the pressure to survive in competitive environments; thus it is not surprising that efficient companies and sensorimotor systems have a lot in common.
6.1.2 Posterior Parietal Association Cortex

Before an effective response can be initiated, the sensorimotor system must know the positions of various parts of the body and of objects in the external world; current thinking is that the posterior parietal cortex performs this function.

The posterior parietal cortex receives input from visual, auditory, and somatosensory systems (that is why it is considered to be association cortex); most of its output goes to secondary motor cortices.

In addition to disrupting the accuracy of movements, large lesions of posterior cortex can produce apraxia and contralateral neglect.

**Apraxia**

Apraxia is the inability to perform movements when requested to do so (in the absence of simple sensory or motor deficits, motivational deficits, or intellectual deficits); for example, an apraxic patient may have difficulty demonstrating hammering movements when asked to do so (even when they are demonstrated to him or her) but be perfectly capable of spontaneously hammering a nail.

Apraxia is almost always associated with left hemisphere damage, but its symptoms are always bilateral.

Right parietal damage often produces deficits on the WAIS block-design subtest; this is referred to as constructional apraxia.

**Contralateral Neglect**

Patients with contralateral neglect fail to respond to visual, auditory, or somatosensory stimuli from the contralateral half of the body.

Contralateral neglect is usually produced by very large right parietal lesions.

Patients with contralateral neglect seem to ignore the left sides of their own body (egocentric space), as well as the left halves of objects regardless of where they are in space.

However, there is evidence that these patients are capable of unconsciously perceiving objects in the left side of space.
6.1.3 Dorsolateral Prefrontal Association Cortex

Projections to this area are from the posterior parietal cortex; this area in turn projects to parts of the secondary motor cortex, the primary cortex, and to the frontal eye field.

Research has suggested that the prefrontal association cortex is involved in assessments of external stimuli; neurons here may be activated by the characteristics of an object, its location, or by the response that the object elicits.

Further research shows that the motor neurons firing the earliest (prior to a motor task) are located in the dorsolateral prefrontal cortex, indicating that this area may work with posterior parietal cortex in decisions regarding voluntary response initiation.

6.1.4 Secondary Motor Cortex

Recently, it has become clear that there are at least seven areas of secondary motor cortex in each hemisphere of the primate brain: two distinct areas of premotor cortex, two distinct areas of supplementary motor area, and three smaller cingulate motor areas. They all send information to primary motor cortex; all receive input from primary motor cortex; all are interconnected with one another; and all send axons to the motor circuits of the brainstem.

Functionally, each of these areas produces complex movements when stimulated; are activated both before and during voluntary movements; and are active when either side of the body is involved in a movement.
The exact role for each area of secondary motor cortex is not clear. Premotor cortex neurons often respond to both visual and touch stimuli; thus, premotor areas of secondary motor cortex appear to encode spatial relations of external cues and program movements guided by these cues.

6.1.5 Primary Motor Cortex

Primary motor cortex is in the precentral gyrus of the frontal lobe; it is somatotopically organized; its organization was discovered by Penfield, who stimulated the cortices of conscious patients during brain surgery.

Recent evidence suggests that there is not a 1:1 relationship between a location on the body and its representation on the motor homunculus; instead, the body is diffusely represented on the homunculus and that these representations can sometimes overlap.

![Figure 6.3: The Motor Homunculus](image)
The motor homunculus has a disproportionate representation of hands and mouth; in fact, two different areas of each primary motor cortex control the contralateral hand.

Each area of primary motor cortex receives feedback from the muscles and joints that it influences; one of the hand areas receives input from the skin rather than the joints and muscles of the digits; this feedback is presumably important for stereognosis.

Neurons in primary motor cortex seem to code for a preferred direction of movement; they fire most just before and during the movement; they fire most when the movement is in the preferred direction and less as the direction deviates from the preferred one.

Recently, Nicolelis and Chapin (2002) trained a monkey named Belle to move a robotic arm (located hundreds of miles away) in accordance with the activity of motor neurons in her primary motor cortex; this feat opens the door for further research on neurally-controlled prosthetic devices.

Lesions of primary motor cortex produce contralateral stereognosis; they reduce the speed and force of contralateral movements, and they make it difficult to move one body part (e.g., a finger) independently of others. They do not produce paralysis.

6.1.6 Cerebellum and Basal Ganglia

The cerebellum and basal ganglia are both important subcortical sensorimotor structures, but neither participates directly in the transmission of signals to the spinal cord.

Their role seems to be to integrate and coordinate the activity of structures at various levels of the sensorimotor system.

Cerebellum

The cerebellum (means little brain) constitutes only 10% of the brain’s mass, but it contains over half the brain’s neurons; it is organized systematically in lobes.

It receives inputs from primary and secondary motor cortex, from brainstem motor nuclei, and from somatosensory and vestibular systems. It is thought to correct deviations from intended movements.

Effects of diffuse cerebellar damage include loss of the ability to precisely control movement, to adjust motor output to changing conditions, to maintain steady postures, exhibit good locomotion, to maintain balance, to speak clearly, and to control eye movements.

Long-recognized role in motor learning, and more recently appreciated for a role in the fine-tuning and learning of nonmotor cognitive responses.

Basal Ganglia

The basal ganglia are part of a loop that receives information from various parts of the cortex and transmits it back to motor cortices via the thalamus.
Basal ganglia are involved in sequencing of movements; like the cerebellum, its role has recently been expanded to include a variety of nonmotor cognitive tasks.

Basal ganglia function compromised in patients with Parkinson’s Disease (due to loss of dopamine from substantia nigra) and Huntington’s Disease (due to loss of cells in basal ganglia).

6.1.7 Descending Motor Pathways

There are four descending motor pathways on each side of the spinal cord; two descend in the dorsolateral areas of the spinal cord:

1. the dorsolateral corticospinal tract and
2. the dorsolateral corticorubrospinal tract;

two descend in the ventromedial areas of the spinal cord:

3. the ventromedial corticospinal tract and
4. the ventromedial cortico-brainstem-spinal tract.

![Dorsolateral Motor Tracts](image)

**The Dorsolateral Motor Tracts**

*Figure 6.4: The Dorsolateral Motor Tracts*
Many axons from primary motor cortex descend through the medullary pyramids, decussates, and then continue to descend in the contralateral dorsolateral white matter of the spinal cord. This is the dorsolateral corticospinal tract.

A second group of axons from primary motor cortex descends to the red nucleus of the midbrain. Axons from the red nucleus then decussate and descend through the medulla; some terminate in the nuclei of the cranial nerves, while others continue to descend in the dorsolateral spinal cord. This is the dorsolateral corticobulbospinal tract.

Most axons in the dorsolateral corticospinal tract and all of those in the dorsolateral corticobulbospinal tract synapse on interneuron pools in the contralateral spinal gray matter that control motor neurons of distal limb muscles. Betz cells in the primary motor cortex descend contralaterally in the dorsolateral corticospinal tract and synapse on motor neurons that control the large weight-bearing muscles of the legs.

Primates and a few other mammals capable of individual digit movement have dorsolateral corticospinal tract neurons that synapse directly on motor neurons.

The Ventromedial Tracts

The axons of the ventromedial corticospinal tract descend ipsilaterally and terminate bilaterally in several segments of the spinal cord on the interneuron pools that control the motor neurons of trunk and proximal limb muscles on both sides of the body; the information delivery is more diffuse and goes to more levels than via dorsolateral paths.
The axons of the ventromedial cortico-brainstem-spinal tract also descend and terminate diffusely in the brainstem on interneurons in the tectum, vestibular nucleus, reticular formation, and the nuclei for the cranial nerves that innervate the face. From here, axons descend in the ventromedial portion of the spinal cord to influence trunk and proximal limb muscles on both sides of the body.

The different functions of these four tracts are demonstrated by the experiment of Lawrence and Kuypers (1968) on monkeys:

i) First, they cut the dorsolateral corticospinal tracts at the medullary pyramids; the monkeys lost their ability to move individual fingers and to release objects in their grasp (revealing the role of the dorsolateral corticospinal pathway in individual or fine movements of the digits); however, they had no difficulty releasing bars and branches when they were climbing.

ii) Next all of the monkeys received a second operation:

a) Half of the monkeys received a dorsolateral corticorubospinal tract transection; these monkeys could stand, walk, and climb normally; but when they sat, their arms hung limply by their sides, and they were used like rubber-handled rakes. Thus, the corticorubospinal tract seems to control the reaching movements of the limbs.

b) The other half of the monkeys received a transection of both ventromedial tracts (only their dorsolateral corticorubospinal tract remained intact); these monkeys had great difficulty walking or even sitting (a noise would make them fall over); when they fed, they did so with elbow and whole-hand
movements. Thus, the ventromedial paths seem to be involved with whole-body movements and postural control.

**ACTIVITY 6.2**
(a) Discuss three principles of sensorimotor function.
(b) Discuss the effects of damage to the posterior parietal cortex.
(c) Discuss the organization and functions of primary motor cortex.

### 6.2 REFLEXIVE BEHAVIOR

#### 6.2.1 Sensorimotor Spinal Circuits and Reflexes

**Muscles**

Review the anatomy of the motor end-plate, the neuromuscular junction, and the role of acetylcholine.

Motor units include a single motor neuron and all of the muscle fibers that it innervates; motor unit size is dependent on the movement accuracy required.

Motor pools include all motor neurons that innervate fibers of a single muscle.

Flexors (bend or flex a joint) vs. extensors (straighten or extend a limb).

Synergistic (muscles that produce the same type of movement, either flexion or extension, at a joint) vs. antagonistic (muscles whose actions oppose one another at a joint).

Dynamic contraction (one where muscles shorten to produce action at a joint) vs. isometric contraction (one where muscle tension increases, but muscle does not shorten and there is not action at joint).
**Muscle Receptor Organs**

Golgi tendon organs are embedded in tendons; muscle spindles are embedded in muscles. Because Golgi tendon organs are connected in series with muscles, they are sensitive to muscle tension; in contrast, muscle spindles are connected in parallel with the muscle fibers and they are sensitive to muscle length.

**Stretch Reflex**

You have all had your patellar tendon reflex tested by a doctor; the doctor raps the tendon of your relaxed thigh muscle; this stretches your thigh muscle and elicits an immediate compensatory contraction that makes your foot swing up; the patellar tendon reflex is a stretch reflex. Notice that this reflex is monosynaptic.

![Diagram of the stretch reflex](image)

**Figure 6.3: The stretch reflex**

The intrafusal motor neuron adjusts the length of the intrafusal muscle in relation to extrafusal muscle length to maintain the muscle spindle's sensitivity to changes in extrafusal muscle length.
The function of the muscle-spindle feedback circuit is to make automatic adjustments in muscle tension in response to external forces.

The brain sends general instructions to the motor neurons (e.g., hold the glass of water), and the muscle spindle feedback circuit automatically adjusts the activity in the motor neurons to make sure that this instruction is carried out even if there are unanticipated external influences (e.g., somebody brushing against the arm).

![Diagram of the muscle spindle system]

**Figure 6.5:** The muscle spindle system.

**Withdrawal Reflex**

Sensory neurons carrying signals evoked by a painful stimulus to a hand or foot synapse on interneurons that synapse on flexors of the same limb.

Thus, about 1.6 millisecond (the time for a signal to be transmitted across a two synapses) after the painful stimulus, a burst of action potentials can be recorded in the flexor motor nerves of the same limb, and the limb is withdrawn.

The limb is withdrawn before information about the painful event reaches the brain.
Reciprocal Innervation

When a muscle contracts, antagonist muscles automatically relax; this is mediated by inhibitory interneurons. However, there is always some degree of co-contraction, for smoother, more precise movement.

Recurrent Collateral Inhibition

When a motor neuron fires, an axon collateral (feeds onto an inhibitory interneuron in the ventral horn (i.e., onto a Renshaw cell), which synapses on the cell body of the motor neuron that activated it; thus motor neurons take an enforced rest after firing; this distributes the work load among the muscle’s motor pool).

6.2.2 Central Sensorimotor Programs

The central sensorimotor program theory suggests that all but the highest levels of the sensorimotor system have certain activities programmed into them; complex movements are produced by activating the appropriate combinations of these programs which are then executed without the need for control from higher levels in the system.

Central sensorimotor programs are capable of motor equivalence; the same task can be solved in different ways. Control of this equivalence appears to be high in the system; for example, you can sign your name using your hand or your foot...in either case, the signatures are very similar AND the secondary motor cortex for the preferred hand is activated (even when the foot signs).

Grillner (1985) showed that coordinated walking movements occurred in cats whose brains had been separated from their spinal cord if the cats were held over a treadmill; this suggests that the programs for some complex motor activities are wired into the spinal cord; these central sensorimotor programs are analogous to the protocols for a procedural automation.

The sensory information that controls central sensorimotor programs do not have to be consciously perceived.

Many complex species-typical behaviors do not have to be practiced for the central sensorimotor programs to develop; however, for many other behaviors practice is essential. This sensorimotor learning “chunks” central sensorimotor programs and transfers control to lower levels of the CNS.

Functional brain imaging (PET) during sensorimotor learning has revealed that:

i) Although posterior parietal cortex is active during performance of both new and well-practiced motor sequences, it is most active during new sequences. This is because posterior parietal cortex integrates sensory stimuli that guide motor sequences, and it is most active when stimuli are actively attended to (as would happen during learning of new motor sequences).

ii) Dorsolateral prefrontal cortex is active during performance of new motor sequences but not well-practiced motor sequences; thus, this brain area may be most involved when motor sequences are largely under conscious control.
iii) Premotor cortex is most active (contralaterally) when a motor sequence is new; supplementary motor cortex is most active (bilaterally) during well-practiced motor sequences. Thus, premotor cortex is more important when a behavior is guided by sensory stimuli whereas the supplementary motor cortex may be more important when a behavior can be performed automatically, with little sensory feedback necessary.

iv) Contralateral motor cortex and somatosensory cortex were active during both new and well-practiced motor sequences.

v) Contralateral basal ganglia were active during both new and well-practiced motor sequences.

vi) Cerebellum was active bilaterally were active during both new and well-practiced motor sequences, but was most active during new sequences.

Activity 6.2

(a) Draw the muscle spindle feedback circuit, label its parts, and explain how it works.
(b) Discuss the concept of central sensorimotor programs. Describe three of their important features.
1. Which kinds of movements are not influenced by sensory feedback?

2. Which structure is thought to be involved in the integration of the sensory information that is the basis for initiating a movement?

3. Patients with ________ have difficulty making accurate movements when asked to do so, particularly when they are asked to make them out of context.

4. Contralateral neglect typically results from damage to the ________ posterior parietal cortex.

5. The somatotopic map of the primary motor cortex is called the motor ________.

6. ________ is the ability to recognize objects by touch.

7. The ________ constitutes about 10% of the brain’s total mass but includes over half its neurons.

8. The basal ganglia receive signals from all parts of the cortex and transmit them to various areas of motor cortex via the ________.

9. The particularly large pyramidal neurons of primary motor cortex are known as ________ cells.

10. Neurons descending from the primary motor cortex in the corticospinal tract synapse in the ________ before the tract reaches the spinal cord.

11. Muscle contraction in the absence of movement is called ________ contraction.

12. Two muscles whose contraction produces the same movement of a joint are said to be ________ muscles.

13. The patellar tendon reflex is an example of a ________ reflex.

14. ________ inhibition is mediated by Renshaw cells and helps distribute the work among the motor neurons of a muscle’s motor pool.

15. Theories of sensor motor learning emphasize two kinds of changes to sensorimotor programs: transfer of control to lower levels of the neural hierarchy and ________.
Suggested Text and References

Required Reading


Suggested Readings


Suggested Web Sites

The Basic Motor Pathway:
http://thalamus.wustl.edu/course/basmot.html

Gross Anatomy of CNS Motor System:

Motor Cortex Animation
http://www.fmrib.ox.ac.uk/~stuart/image_gallery/P/manjm.html
Self-check

1. ballistic movements
2. posterior parietal cortex
3. apraxia
4. right
5. homunculus
6. Stereognosis
7. cerebellum
8. thalamus
9. Betz
10. red nucleus
11. isometric
12. synergistic
13. stretch
14. Recurrent collateral
15. chunking
Unit 7  ▶ Circadian Rhythms, Sleep & Dreams

LEARNING OUTCOME
At the end of this topic you will learn about:

1. Describe the physiological mechanisms of sleep and waking
2. Describe the physiological and behavioral description of sleep
3. Discuss the neural control of slow-wave and REM sleep.
4. Describe circadian rhythms and discuss research on the role of the suprachiasmatic nucleus in the control of these rhythms.
5. Discuss the time base of the circadian clock, control of seasonal rhythms, and changes in circadian rhythms caused by work schedules and travel.
6. Explain why do we sleep?
7. Discuss insomnia, sleeping medications, and sleep apnea.
8. Discuss narcolepsy and problems associated with REM and slow-wave sleep.
9. Review the hypothesis that sleep serves as a period of restoration by discussing the effects of sleep deprivation, exercise, and mental activity.
10. Evaluate evidence that the onset and amount of sleep is chemically controlled, and describe the neural control of arousal.
7.1 A PHYSIOLOGICAL AND BEHAVIORAL DESCRIPTION OF SLEEP

7.1.1 Stages of Sleep

The stages of non-REM sleep — stages 1 through 4 — are defined. The two principal explanations for sleep are that sleep serves as an adaptive response or that it provides a period of restoration. This is supported by studies using sleep deprivation. In humans, sleep deprivation impairs cerebral functioning. Animals that are sleep-deprived eventually die.

Slow-wave sleep does indeed reduce the brain's metabolic rate and that increased mental activity can cause an increase in slow-wave sleep the next night. REM sleep may promote brain development and learning.

Sleep-promoting substances or wakefulness-promoting substances may exist. Adenosine, released when neurons are obliged to utilize the supply of glycogen stored in astrocytes, serves as the link between increased brain metabolism and the necessity of sleep.

Four systems of neurons appear to be important for active wakefulness: the acetylcholinergic system (cortical activation); the noradrenergic system (vigilance); the serotonergic system (automatic behaviors such as locomotion and grooming); and the histaminergic neurons (cortical activation).

Antonia (muscular paralysis that prevents our acting out our dreams) is produced by a group of acetylcholinergic neurons. Sleep is related to temperature; it normally occurs only after the brain temperature has been lowered.

Sleep disturbances and disorders include: insomnia, sleep apnea, narcolepsy, sleep attacks, cataplexy, sleep paralysis, hypnagogic hallucinations, and REM without atonia. During slow-wave sleep, some people are afflicted by bedwetting (nocturnal enuresis), sleepwalking (somnambulism), or night terrors (pavor nocturnus).

Stage 1: A transition period of drowsiness between waking and sleeping; sleep spindles occur.
Stage 2: Somewhat more deeply asleep; delta waves slight
Stage 3: Slow wave sleep begins; delta waves reach 20%.
Stage 4: Delta waves reach nearly 100%.
Stage 1

- Similar to awake EEG, but slower
- Low-voltage, high-frequency
- EEG voltage increases and frequency decreases as one progresses from stage 1 through 2, 3, and 4

Stage 2

- K complexes – large negative waves
- Sleep spindles – burst of 12-14 Hz waves
- Stages 3 and 4 – delta waves, large and slow
- Progress to stage 4 sleep and then retreat to stage 1

Emergent stage 1 differs from initial stage 1:

- REMs
- Loss of body core muscle tone
- Progress through sleep stages in 90 minute cycles
- More time spent in emergent stage 1 as night progresses
- Emergent stage 1 sleep = REM sleep
- Non-REM (NREM) sleep = all other stages

Stage 3 + 4 = slow-wave sleep (SWS)

During REM:

- REMs
- Loss of core muscle tone
- Low-amplitude/high-frequency EEG
- Increased cerebral and autonomic activity
- Muscles may twitch

NREM Sleep (Non-rapid eye movement sleep)

Four sleep stages

- Lightest sleep
- Mid-sleep
- Deep sleep
- Deepest sleep

Heart and respiration slow and regular.
Little body movement.
Blood pressure and brain activity at lowest points of 24 hour period.

Non-REM sleep: All stages of sleep are non REM, except REM sleep.

REM sleep: A period of desynchronized EEG activity during sleep, at which time dreaming, rapid eye movements, and muscular paralysis occur.
80% of awakenings from REM yield reports of story-like dreams
Slow-wave sleep: Non-REM sleep, characterized by synchronized EEG activity during deeper stages.

Basic rest-activity cycle
A 90-minute cycle (in humans) of waxing and waning alertness, controlled by a biological clock in the caudal brain stem; controls cycles of REM sleep and slow-wave sleep. Rapid eye movement sleep called "active sleep"; 20-25% of a night's sleep.

Internally:
- Intense brain activity
- Brain metabolism increases
- Brain temperature rises rapidly
- Epinephrine release leads to increases in
- Blood pressure
- Heart rate
- Respiration

Externally:
- Body appears calm
- Large muscles become paralyzed
- Eyes dart around

REM Rebound
The increased amount of REM sleep that occurs after REM deprivation; intensity of REM sleep increases. Those with sleep deprivation proceed more rapidly into REM as REM deprivation increases. More time spent in REM when deprivation is over and is often associated with unpleasant dreams or nightmares.

Alcohol, amphetamines, cocaine, and LSD use suppress REM sleep results in REM rebound. Withdrawal results in REM rebounds; REM rebound suggests that REM sleep serves a special function

7.1.2 Physiological Measures of Sleep

i) By means of Electroencephalogram (EEG) - "brain waves".

ii) By means of EOG - Eye movements seen during rapid eye movement (REM) sleep.

iii) By means of EMG - Loss of activity in neck muscles during some sleep stages.

Electro-oculogram (EO): An electrical potential from the eyes, recorded by means of electrodes placed on the skin around them; detects eye movements.

Electromyogram (EMG): An electrical potential recorded from an electrode placed on a muscle.

Polysomnogram: Provides brain wave sleep recordings; outlined REM and NREM sleep patterns.
Electroencephalogram (EEG)
- **Beta activity**: Irregular electrical activity of 13–30 Hz recorded from the brain; generally associated with a state of arousal.
- **Alpha activity**: A smooth electrical activity of 8–12 Hz recorded from the brain; generally associated with a state of relaxation, eyes closed, preparing to sleep.
- **Theta activity**: EEG activity of 3.5–7.5 Hz that occurs intermittently during early stages of slow-wave and REM sleep.
- **Delta activity**: Regular, synchronous electrical activity of less than 4 Hz recorded from the brain; occurs during the deepest stages of slow-wave sleep.

### 7.1.3 Dreams

Dream content varies by culture, gender, and age; frequently connects with recent experience and may help us form memories.

**REM Dream**: An almost continually occurring dream during REM sleep; has story like qualities; more vivid, visual, and emotional than NREM dreams.

**NREM Dream**: Less frequent than REM dreams; less memorable than REM dreams

**Bizarre Dreams**: Caused by lower amounts of serotonin and norepinephrine lead to less inhibition of impulsive thoughts and actions.

**Lucid Dreams**: A dream an individual is aware of dreaming and whose content the individual is often able to influence while dreaming.

#### Interpreting Dreams

Sigmund Freud thought dreams were triggered by unacceptable repressed wishes. He believed dreams satisfy unconscious sexual and aggressive desires and so must be disguised.

- **Manifest Content**: The content of a dream as recalled by the dreamer
- **Latent Content**: The underlying meaning of the dream

In recent years, it has been seen as an expression of a broad range of the dreamer’s concerns rather than sexual impulses.

#### Activation-Synthesis Hypothesis

Dreams are the brain’s attempt to make sense of the random firing of brain cells during sleep. Cortex creates a story in an effort to make sense of the brain’s activity. Story is synthesized as a consequence of brain activity.
7.2 WHY DO WE SLEEP?

7.2.1 Recuperation theories

Recuperative theories state that sleep is needed to restore homeostasis and wakefulness causes a deviation from homeostasis.

7.2.2 Circadian theories

Circadian rhythms — those with a period of approximately one day — are controlled by biological clocks in the brain. Light serves as a zeitgeber for most circadian rhythms. Circadian theories state that sleep is the result of an internal timing mechanism and has evolved to protect us from the dangers of the night.

Circadian theory of sleep is based on the premise that sleep evolved to keep humans out of harm’s way during the dark of night and possibly from becoming prey of some nocturnal predator.

7.2.3 Comparative Analysis of Sleep

All mammals and birds sleep, therefore it must have an important function. However, it is not a special higher-order human function and not necessarily needed in large quantities. There is no clear relationship between species’ sleep time and activity level.

7.2.4 Restorative theory

Restorative theory holds that being awake produces wear and tear on the body and brain, and sleep serves the function of restoring the body and mind.

7.2.5 Default Theory of REM

REM serves no critical function, one can’t stay continuously in non-REM sleep, so we switch between REM and wakefulness. When bodily needs exist, we wake up; if there are no immediate needs we remain in REM. No REM rebound seen when lost REM periods replaced with 15-mins awake.
7.3 PHYSIOLOGICAL MECHANISMS OF SLEEP AND WAKING

7.3.1 Neural Control of Arousal

Circuit of neurons that secrete at least five different neurotransmitters play a role in some aspect of an animal's level of alertness and wakefulness - what is commonly called arousal: acetylcholine, norepinephrine, serotonin, histamine, and hypocretin.

**Acetylcholine**

One of the most important neurotransmitters involved in arousal. Two groups of acetylcholinergic neurons located in the pons and basal forebrain. They produce activation and cortical desynchrony when they are stimulated.

**Norepinephrine**

Catecholamine agonists produce arousal and sleeplessness; effects appear to be mediated by the locus coeruleus in the dorsal pons. Neurons of the locus coeruleus give rise to axons that branch widely, releasing norepinephrine throughout the neocortex, hippocampus, thalamus, cerebellar cortex, pons, and medulla.

![Figure 7.1: Activity of noradrenergic neurons in the locus coeruleus.](image)
Figure 7.2: A section through the pons of a rat, showing the location of the locus coeruleus, which contains the cell bodies of most of the brain's noradrenergic neurons. Also shown are some structures that play a role in REM sleep.

Locus coeruleus: A dark color group of noradrenergic cell bodies located in the pons near the rostral end of the floor of the fourth ventricle; involved in arousal and vigilance.

Figure 7.3: Activity of serotoninergic (5-HT-secretating) neurons in the dorsal raphe nuclei of freely moving cats during various stages of sleep and waking.
Histamine

A neurotransmitter implicated in the control of wakefulness and arousal; a compound synthesized from histidine, an amino acid.

Serotonin (5-HT)

Appears to play a role in activating behavior; almost all of the brain’s serotonergic neurons are found in the raphe nucleus. These neurons are located in the medullary and pontine regions of the brain.

Raphe nucleus: A group of nuclei located in the reticular formation of the medulla, pons, and midbrain, situated along the midline; contains serotonergic neurons.

Tuberomammillary nucleus: A nucleus in the ventral posterior hypothalamus, just rostral to the mammillary bodies, contains histaminergic neurons involved in cortical activation and behavioral arousal.

Hypocretin

A peptide also known as orexin, produced by neurons whose cell bodies are located in the hypothalamus; their destruction causes narcolepsy.

7.3.2 Neural Control of Slow-Wave Sleep

Ventrolateral preoptic area (VLPA): A group of GABAergic neurons in the preoptic area whose activity suppresses alertness and behavioral arousal and promotes sleep. Destruction of this area has been reported to result in total insomnia, coma, and eventual death in rats.

Figure 7.4: A schematic diagram of the effect of activation of the hypocretinergic system of neurons of the lateral hypothalamus on the sleep/waking flip-flop. Motivation to remain awake or events that disturb sleep activate the hypocretinergic neurons.
7.3.3 Neural Control of REM Sleep

PGO wave (pontine, geniculate, occipital): Bursts of phasic electrical activity originating in the pons, followed by activity in the lateral geniculate nucleus and visual cortex, a characteristic of REM sleep.

The Executive Mechanism

Peribrachial area: The region around the brachium conjunctivum, located in the dorsolateral pons; contains acetylcholinergic neurons involved in the initiation of REM sleep.

Carbachol: A drug that stimulates acetylcholine receptors.

Medial pontine reticular formation (MPRF): A region that contains neurons involved in the initiation of REM sleep; activated by acetylcholinergic neurons of the peribrachial area. Similarities between REM and wakefulness suggest that the same brain area might be involved in both. REM sleep is controlled by nuclei in the caudal reticular formation, each controlling a different aspect of REM.

Magnocellular nucleus: A nucleus in the medulla; involved in the atonia (muscular paralysis) that accompanies REM sleep.

Figure 7.5: A summary of the neural circuitry that is thought to be responsible for the components of REM sleep.
7.4 BIOLOGICAL CLOCKS

7.4.1 Circadian Rhythms and Zeitgebers

Circadian Rhythm: A daily rhythmic change in behavior or physiological process. Regular fluctuation from high to low points of certain bodily functions and behaviors.

Sleep debt: Deficiency caused by not getting the amount of sleep that one requires for optimal functioning. Affects psychological functions of:
- Blood pressure
- Heart rate
- Appetite
- Secretion of hormones and digestive enzymes
- Sensory acuity
- Elimination
- Body’s response to medication

7.4.2 Suprachiasmatic Nucleus

Suprachiasmatic nucleus (SCN): A nucleus, situated atop the optic chiasm, in the brain’s hypothalamus that control the timing of circadian rhythms. It contains a biological clock responsible for organizing many of the body’s circadian rhythms.

Lesions do not reduce sleep time, but they abolish its circadian periodicity; exhibit activity that can be entrained by the light-dark cycle.

Melanopsin: A photopigment present in ganglion cells in the retina whose axons transmit information to the SCN, the thalamus, and the olivary pretectal nuclei.

Zeitgebers: A stimulus (usually the light of dawn) that resets the biological clock responsible for circadian rhythms; synchronizes the endogenous system.
Intergeniculate leaflet (IGL): A part of the lateral geniculate nucleus that receives information from the retina and projects to the SCN; terminals release neuropeptide Y at the SCN.

7.4.3 Control of Seasonal Rhythms

Pineal Gland: A gland attached to the dorsal tectum; produces melatonin and plays a role in circadian and seasonal rhythms. Secretes melatonin from dusk until just before dawn; does not secrete melatonin during daylight hours.

Melatonin: A hormone synthesized from serotonin in the pineal gland. Melatonin levels display circadian rhythms controlled by the SCN plays a role in circadian and seasonal rhythms. Melatonin is not a sleep aid, but may be used to shift circadian rhythms

Environmental Cues

The ebb and flow of circadian rhythms is not strictly biological; environmental cues also play a part.
- Bright light (especially sunlight)
- Sleep-wakefulness cycle
- Daily fluctuations of body temperature
- Sleep is best when body is at lowest temperature (97-97.5)

7.4.4 Disruptions in Circadian Rhythms: Shift Work and Jet Lag

Jet lag

When traveling, you reach your destination at a time when it is daylight there, but it would have been time to go to sleep at the place you started. This can produce memory deficits that may be permanent. Supplemental melatonin has been shown to be an effective treatment for relapses of psychiatric disorders induced by jet lag.

Zeitgebers are accelerated or decelerated. Research indicates that frequent flyers, such as this airline employee, are just as likely to suffer from jet lag when crossing several time zones as travelers who are on their first intercontinental journey.

Reducing Jet Lag

- Gradually shift sleep-wake cycle prior to travel.
- Administer post-flight treatments to promote the needed shift
- Phase advance following east-bound travel with intense light early in the morning
Shift work & Subjective night

When people work during the night and sleep during the day, shift workers average 2 to 4 hours less sleep than non-shift workers of the same age.

Subjective night is the time during a 24-hour period when body temperature is lowest and when the biological clock is telling a person to go to sleep. During subjective night, energy and efficiency are at their lowest point, reaction time is slowest, productivity is diminished, and industrial accidents are significantly higher.

Zeitgebers unchanged, but sleep-wake cycle must be altered. Rotating work schedules forward from days to evenings to nights makes adjustment easier because people find it easier to go to bed later and wake up later than the reverse.

Modafinil: A wakefulness drug that will help people remain alert without the side effects of stimulants such as caffeine.

Reducing the Effect of Shift Changes

- Schedule phase delays, rather than phase advances
- Move from current schedule to one that starts later
- It is easier to stay up later and get up later than to retire and arise earlier
- Phase advances are harder, explaining why east-bound travel tends to be more problematic
- Shift workers who temporarily reside at their work places, such as workers on offshore oil rigs, appear to adjust more easily to the demands of night work than those who live at home
- Exposure to appropriately timed bright light or even light of medium intensity has been found to reset young adults' biological clocks and improve their performance

Work schedules

- Moving work schedules forward from days to evenings to nights makes adjustment easier
- Rotating shifts every three weeks lessens the effect on sleep

7.4.5 Variations in Sleep

Infants and young children have the longest sleep time and the highest of REM and slow wave sleep.

Ages 6-puberty are most consistent sleepers and wakers; sleep and awake same time daily.

Adolescents sleep patterns are influenced by their schedules; sleep longer when no schedule conflicts; poor sleep may contribute to poor school performance.

Larks and owls

Larks

- Awaken early every morning and leap out of bed with enthusiasm, eager to start the day
- Body temperature rises rapidly after they awaken and stays high until about 7:30 p.m.
- Turn in early and have the fewest sleep problems

Owls
- Fumble for the alarm clock and push the snooze button to get a few more precious minutes of sleep
- Body temperature of an owl gradually rises throughout the day, peaking in the afternoon and not dropping until later in the evening

Guthrie and others compared the performance of several hundred college students classified as larks or owls. They found that the larks made better grades in early morning classes, while the owls made higher grades in classes they took later in the day. A gene that runs the biological clock is responsible, in part, for the differences between larks and owls.

**ACTIVITY 7.2**

iii) Describe the biological and environmental factors that influence circadian rhythms.
iv) Explain how circadian rhythm disruptions influence physical and psychological functions.

### 7.5 SLEEP DISORDERS – PARASOMNIAS

**Somnambulism (sleepwalking):** Occurs during partial arousal from stage 4 sleep.

**Sleep terror:** Happens during partial arousal from stage 4 sleep usually begins with a piercing scream.

**Nightmares:** Frightening dreams that occur during REM sleep.

**Somniloquy (sleep talking):** Occurs during any sleep stage and is more frequent among children.

#### 7.5.1 Major Sleep Disorders

**Insomnia:** A sleep disorder characterized by:
- Disorders of sleep initiation and maintenance
- Difficulty falling or staying asleep
- Waking too early
- Sleep that is light, restless, or of poor quality
- Symptoms can lead to distress and impairment in daytime functioning
Hypersonnia: Disorders of excessive sleep or sleepiness

Sleep apnea: Periods during sleep when breathing stops and the individual must awaken briefly in order to breathe caused by muscle spasms or atonia or failure of the CNS to stimulate breathing.

Most commonly seen in males, the overweight, and in the elderly, the major symptoms are excessive daytime sleepiness and extremely loud snoring, often accompanied by snorts, gasps, and choking noises.

Alcohol and sedatives aggravate the condition. It can lead to chronic high blood pressure, heart problems, and even death and also mild brain damage. The interrupted sleep experienced by individuals with this disorder affects cognitive as well as physiological functioning.

Narcolepsy: Also a form of hypersonnia characterized by excessive daytime sleepiness and repeated brief uncontrollable attacks of daytime REM sleep, usually lasting 10 – 20 minutes; an incurable sleep disorder.

Cataplexy: Loss of muscle tone while awake
Sleep paralysis: Paralyzed while falling asleep or upon waking
Hypnagogic hallucinations: Dreaming while awake; appears to be an abnormality in the mechanics that triggers REM.

Dreaming and loss of muscle tone while awake suggest REM intruding into wakefulness. REM without atonia (able to act out dreams) possibly caused by damage to the nucleus magnocellularis or its output.

Hypothalamus and Sleep
During WWI, victims of encephalitis lethargica caused some to sleep continuously and others to sleep little
- Damage in posterior hypothalamus and adjacent midbrain > excessive sleep
- Damage in preoptic area and adjacent forebrain > wakefulness.

7.6 CONSCIOUSNESS

Consciousness can take many forms, while other mental processes occur simultaneously outside our awareness. Consciousness changes in cycles that correspond to our biological rhythms and the patterns of stimulation in our environment.

Everything of which we are aware at any given time
- Thoughts
- Feelings
- Sensations
- External stimuli
7.6.1 What Other Forms Can Consciousness Take?

An altered state of consciousness is a mental state other than ordinary waking consciousness, such as sleep, meditation, hypnosis, or a drug-induced state. It occurs when some aspect of normal consciousness is modified by mental, behavioral, or chemical means.

**Hypnosis**: Induced state of altered awareness, characterized by heightened suggestibility and deep relaxation

**Meditation**: Form of consciousness change induced by focusing on a repetitive behavior, assuming certain body positions and minimizing external stimulation

**Psychoactive drug states**: Chemicals that affect mental processes and behavior by their effects on the nervous system

**Meditation**

A group of techniques that involve focusing attention on an object, a word, one’s breathing, or one’s body movements. It is an effort to block out all distractions to enhance well-being and achieve an altered state of consciousness.

Includes: Yoga, Zen, and transcendental meditation

Yoga: A meditator typically assumes a cross-legged position known as the lotus and gazes at a visual stimulus

Zen: The individual counts breaths or concentrates on the breathing process. Can be helpful with physical and psychological problems (Lower blood pressure; learn how to control emotions)

**Hypnosis**

A procedure through which one person, the hypnotist, uses the power of suggestion to induce changes in a person’s thoughts, feelings, sensations, perceptions and/or behavior.

**Hypnotizability**: Degree to which an individual is responsive to hypnotic suggestions. 80-90% of people are hypnotizable to some degree; about 5% can reach deepest levels of feelings, sensations, perceptions and/or behavior.

**Misconceptions About Hypnosis**

- Hypnotized people are under the complete control of the hypnotists and will violate their moral values.
- People can demonstrate superhuman strength and perform amazing feats under hypnosis.
- Subjects are not stronger or more powerful under hypnosis.
- Memory is more accurate under hypnosis.

**Pseudomemories**: False memories constructed through guidance.
Theories of Hypnosis

Sociocognitive: Suggests the behavior of a hypnotized person is a function of that person’s expectations about how subjects behave under hypnosis.

Neodissociation theory: Suggests that hypnosis induces a split, or dissociation, between two aspects of the control of consciousness. The planning function and the monitoring function.

Theory of Dissociated Control: Maintains that hypnosis weakens the control of the executive function over other parts of consciousness.

Psychoactive Drugs

Any substance that has powerful effects on the brain and alters consciousness, mood, perception and/or thought.

Psychoactive drugs are:
- Controlled substances/approved for medical use
- Illicit drugs/drugs that are illegal
- Over-the-counter drugs

How Drugs Affect The Brain

All physical pleasure has a neurological basis brought about by increase of dopamine in limbic system known as the nucleus accumbens.

Nucleus accumbens: A surge of dopamine has a reward and motivational effect produced by psychoactive drugs. The effects of drugs cascade down involving the brain’s entire neurotransmitter system.

Hallucinogens: Alter perceptions of the external environment and inner awareness (also called psychedelics); mescaline, LSD, PCP and cannabis.

Opiates: Highly addictive; produce a sense of well-being and have strong pain-relieving properties; Heroin, Morphine, Heroin and Methadone. Mimic the effects of the brain’s own endorphins.

Chemicals in the brain with pain relieving properties. Produce feelings of well-being. Useful in pain management.

Depressants: Slow down mental and physical activity by inhibiting transmission of nerve impulses in the central nervous system; Alcohol, Barbiturates, Benzodiazepines (Tranquilizers), Valium and Librium;
Act on GABA receptors to produce a calming, sedating effect. Useful in reducing a patient's nervousness prior to undergoing a medical procedure.

Stimulants: Arouse the central nervous system, speeding up mental and physical responses; Caffeine; Nicotine; Amphetamines; Cocaine; MDMA (ecstasy); Mimics the effects of epinephrine. The neurotransmitter that triggers the nervous system. Benefits include suppression of hunger and digestion.

Amphetamines affect the parts of the brain that control attention and concentration, as well as the nucleus accumbens. This helps explain why these stimulants are useful in the treatment of attention problems in school children.

Substance Abuse

A continued use of a substance after several episodes in which use of the substance has negatively affected an individual's work, education, and social relationships.

People progress from substance "use" to "abuse" by:
- The physical pleasure
- Genetically based differences in people's responses to drugs
- Personality and social factors
- Stress related variables
- Social and cultural factors

Drug Dependence (addiction)

Physical drug dependence: A compulsive pattern of drug use in which the user develops a drug tolerance coupled with unpleasant withdrawal symptoms when the drug is discontinued.

Drug Tolerance: A condition in which the user becomes progressively less affected by the drug must take increasingly larger doses to maintain the same effect or high.

Withdrawal Symptoms: The physical and psychological symptoms that occur when a regularly used drug is discontinued; usually the exact opposite of the effects produced by the drugs. Symptoms terminate when drug is taken again.

Psychological Drug Dependence: A craving or irresistible urge for the drug's pleasurable effects; more difficult to combat than physical dependence. Drugs that may not be physically addictive may be due to psychological dependence. Learning processes (classical conditioning) are important elements in development and maintenance of psychological dependence.

7.6.2 Culture and Altered States of Consciousness

Every culture around the world have found ways to induce altered states of consciousness. They consist of trance rituals, spiritual possession, religious rites, and tribal ceremonies. These states are induced by flooding the senses with repetitive chanting, whirling in circles and/or burning strong, pungent incense.
SELF TEST

1. Awareness of one’s own perceptions, thoughts, feelings, sensations and external environment is _____.

2. Changes in awareness produced by meditation, hypnosis, and drugs are generally referred to as _____.

3. John has noticed that every night he awakens to go to the restroom at about 4:00 AM. This is an example of a(n) _____.

4. This structure in the brain regulates the biological clock in humans.

5. The most significant environmental cue that plays a role in circadian rhythms is _____.

6. When we are exposed to low levels of light the _____ begins to secrete the hormone melatonin, which acts to induce sleep.

7. If you managed a manufacturing plant that ran three rotating shifts, what could you do to help your employees remain in a more normal biological rhythm?

8. The _____ holds that being awake wears and tears on the body and brain, and sleep serves the function of restoring body and mind.

9. This theory is based on the premise that sleep evolved to keep humans out of harm’s way.

10. Jason is in a quiet period of sleep where his heart rate and respiration are slow, and his brain activity is at its lowest point. Sleep researchers would say Jason is in _____.
11. How many stages are in REM sleep?

12. Which type of brain waves dominate slow-wave sleep?

13. Darla did not get any sleep during the previous night as she was studying for her mid-term exams. Tonight when she falls asleep she will likely experience:

14. Who has the longest average sleep time?

15. Research shows that sleep deprivation:

16. In lucid dreams, people _______.

17. _______ believed that dreams function to satisfy unconscious sexual and aggressive wishes.

18. _______ are sleep disturbances in which behaviors and physiological states that normally occur only in the waking state take place during sleep.

19. These generally begin with a piercing scream.

20. Excessive daytime sleepiness and sudden, uncontrollable attacks of REM sleep are symptoms of:
Suggested Text and References

1.2 Required Reading:

1.3 Suggested Readings


1.4 Suggested Web Sites
The Sleep Well
http://www.stanford.edu/~dement/alphaindex.html

SleepNet
http://www.sleepnet.com/

Basics of Sleep Behavior
http://hsleep.medsch.ucla.edu/sleepsyllabus/

National Centers on Sleep Disorders Research
http://www.nhlbi.nih.gov/about.ncsdr/
Self-check

1. consciousness
2. altered states of consciousness
3. circadian rhythm
4. suprachiasmatic nucleus
5. bright light
6. pineal gland
7. Install appropriate bright lights and use a three-week rotational schedule.
8. Restorative theory
9. circadian theory of sleep
10. NREM sleep
11. one
12. delta
13. REM rebound
14. infants
15. has a negative impact on mood, alertness and performance.
16. attempt to influence the content of their own dreams.
17. Freud
18. Parasomnias
19. sleep terrors
20. narcolepsy
Unit 8

Language, Cognition & Intelligence

LEARNING OUTCOME

At the end of this topic you will learn about:

1. Explain the brain mechanisms related to lateralization of language, speech production and comprehension.
2. Describe Broca’s aphasia and the three major speech deficits that result from damage to Broca’s area: agrammatism, anomia, and articulation difficulties.
3. Describe the symptoms of Wernicke’s aphasia, pure word deafness, and transcortical sensory aphasia and explain how they are related.
4. Discuss the brain mechanisms that underlie our ability to understand the meaning of words and to express our own thoughts and perceptions in words.
5. Describe the symptoms of conduction aphasia and anomic aphasia, including aphasia in deaf people.
6. Describe pure alexia and explain why this disorder is caused by damage to twolanguages in the bilingual brain and describe the use of prosody in communication.
7. Describe whole-word and phonetic reading and discuss five categories of acquired dyslexia’s.
8. Explain the relation between speaking and writing and describe the symptoms of phonological dysgraphia, orthographic dysgraphia and semantic (direct) dysgraphia.
9. Describe research on the neurological basis of developmental dyslexias.
10. Explain the relationship between the concepts of language, cognition and intelligence.
8.1 SPEECH PRODUCTION AND COMPREHENSION: BRAIN MECHANISMS

8.1.1 Lateralization of language

A longitudinal fissure separates the human brain into two, distinct cerebral hemispheres connected by the corpus callosum. The sides resemble each other. Each hemisphere’s structure is mirrored by the other side. Yet, despite the strong similarities, the functions of each cortical hemisphere are different.

Verbal behavior is a laterized function. Language functions such as grammar and vocabulary often are lateralized to the left hemisphere of the brain. Most language disturbances occur after a damage to the left side of the brain. For example, dyscalculia and dyslexia are neurological syndrome associated with damage to the left temporo-parietal junction.

Although the circuits that are primarily involved in speech comprehension and production are located in one hemisphere, it would be a mistake to conclude that the other hemisphere has no role in speech. For example, holistic reasoning language functions, such as intonation and accentuation often are lateralized to the right hemisphere of the brain.

Figure 8.2: The location of the primary speech areas of the brain.
8.1.2 Speech Production

Speech consists of the mechanical processes required for vocalization, such as articulation and phonation. Language is the set of arbitrary symbols used for communication, often in the form of words strung together by syntactical rules.

**Broca's area:** A region located anteriorly in the left hemisphere in the left frontal lobe operculum. It is responsible for production of words and sentences. This area is named after Paul Broca (in 1861).

**Paul Broca:** Among the first scientists to demonstrate the existence of localized functions in the cerebral cortex; concluded that the site of damage was the part of the brain responsible for speech production.

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*Figure 8.1:* An average plot of PET scans of regional cerebral blood flow, superimposed on an MRI scan, taken while the subjects were reading words aloud. Note that the activation includes subcortical regions as well as the cerebral cortex of Broca's area. Also note that left and right are reversed.

*Figure 8.2:* The insular cortex, normally hidden behind the rostral temporal lobe.
8.1.3 Speech Comprehension

Wernicke's area

A region located posteriorly in the left hemisphere in the superior temporal gyrus. It is responsible for comprehension of spoken words and sentences. It is also involved in formulation of coherent speech and written language. This area is named after Carl Wernicke (in 1874). Wernicke's work initiated the study of this brain area and its role in language. It is particularly known to be involved in the understanding and comprehension of spoken language.

The Wernicke-Geschwind model of language

Wernicke created an early neurological model of language, that later was revived by Norman Geschwind. The model is known as the Wernicke-Geschwind model.

For listening to and understanding spoken words, the sounds of the words are sent through the auditory pathways to area 41, which is the primary auditory cortex (Heschl's gyrus). From there, they continue to Wernicke's area, where the meaning of the words is extracted.

In order to speak, the meanings of words are sent from Wernicke's area via the arcuate fasciculus to Broca's area, where morphemes are assembled.

The model proposes that Broca's area holds a representation for articulating words. Instructions for speech are sent from Broca's area to the facial area of the motor cortex, and from there instructions are sent to facial motor neurons in the brainstem, which relay movement orders to facial muscles.

In order to read, information concerning the written text is sent from visual areas 17, 18, and 19 to the angular gyrus (area 39) and from there to Wernicke's area, for silent reading or, together with Broca's area, for reading out loud.

This model is now obsolete. The neural organization of language is more complex than the Wernicke-Geschwind model of language suggests. The localization of speech in Broca's area is one of the weakest points of this model.

Nevertheless it has been very useful in directing research and organizing research results, because it is based on the idea that language consists of two basic functions: comprehension, which is a sensory/perceptual function, and speaking, which is a motor function.
8.1.4 Aphasia

Aphasia is a loss of the ability to produce and/or comprehend language, due to injury to brain areas specialized for these functions. It is not a result of deficits in sensory, intellect, or psychiatric functioning, nor due to muscle weakness or a cognitive disorder. Depending on the area and extent of the damage, someone suffering from aphasia may be able to speak but not write, or vice versa, or display any of a wide variety of other deficiencies in language comprehension and production, such as being able to sing but not speak. Aphasia may co-occur with speech disorders such as dysarthria or apraxia of speech, which also result from brain damage.
**Broca's aphasia**

An impairment in the physical ability to produce speech sounds, or, in extreme cases, an inability to speak at all. A form of aphasia characterized by agrammatism, anomia, and extreme difficulty in speech articulation.

**Apraxia of speech:** Impairment in the ability to program movements of the tongue, lips, and throat required to produce the proper sequence of speech sounds.

**Wernicke's aphasia**

Wernicke found that damage to the left posterior, superior temporal gyrus (Wernicke's area) caused language comprehension deficits rather than speech production deficits. This syndrome is known as Wernicke's aphasia.

It is an aphasia in which the person's spoken language is fluent, but the content is either vague or incomprehensible to the listener. This condition results in an impairment of language comprehension and in speech that has a natural-sounding rhythm and a relatively normal syntax, but otherwise has no recognizable meaning (a condition sometimes called fluent or jargon aphasia).

**Auditory aphasia**

**A Pure Word Deafness** is caused by bilateral damage to the posterior superior temporal lobes or disruption of connections between these areas. It exhibits itself as inability to comprehend the meaning of speech, but (in most cases) still being able to hear, speak, read, and write. It is caused by damage to Wernicke's area or disruption of auditory input to this region.

Auditory aphasia is often associated with lesions to the left superior temporal lobe. However, no such unilateral case has yet been documented without damage to the white matter tract connecting superior temporal lobes bilaterally or bilateral damage to the superior temporal lobe.

These facts, combined with the existence of cases of damage to these white matter tracts without detectable cortical damage, and with cases of pure word deafness resulting enlargement of the third ventricle alone suggest that the disorder results from damage to the left-right superior temporal circuit rather than the superior temporal area on one hemisphere or another.

**Temporal association areas:** House memories and are involved in the interpretation of auditory stimuli; there is a special association area where familiar melodies are stored.

**Cerebrovascular accident:** A stroke or brain damage caused by occlusion or rupture of a blood vessel in the brain.

**Function word:** A preposition, article, or other word that conveys little of the meaning of a sentence but is important in specifying its grammatical structure.
Content word: A noun, verb, adjective, or adverb that conveys meaning.

Agrammatism: One of the usual symptoms of Broca's aphasia; a difficulty in comprehending or properly employing grammatical devices, such as verb endings and word order.

Anomia: Difficulty finding (remembering) the appropriate word to describe an object, action, or attribute; one of the symptoms of aphasia.

A critical location for the control of speech articulation is the left precentral gyrus of the insula. The insular cortex is located on the lateral wall of the cerebral hemisphere behind the anterior temporal wall.

Figure 8.4: Results of PET scans indicating regions of the superior temporal lobe that respond to speech sounds. Red: Regions that responded to phonetic information. Yellow: Region that responded to only intelligible speech.

Figure 8.5: The brain damage that causes pure word deafness.
**Transcortical sensory aphasia:** A speech disorder in which a person has difficulty comprehending speech and producing meaningful spontaneous speech but can repeat speech; caused by damage to the region of the brain posterior to Wernicke’s area.

![Diagram of brain regions and connections](image)

*Figure 8.5:* The dictionary in the brain. Wernicke’s area contains the auditory entries of the word; the meanings are contained as memories in the sensory association areas. Black arrows represent comprehension of word. Red arrows represent translation of thoughts and perceptions into words.

- **Arcuate fasciculus:** A bundle of axons that connects Wernicke’s area with Broca’s area; damage to these axons causes conduction aphasia.

- **Agnosia:** Inability to name body parts or to identify body parts that another person names.

- **Conduction aphasia:** An aphasia characterized by the inability to repeat words that are heard but the ability to speak normally and comprehend the speech of others.

- **Anomic aphasia:** Aphasia characterized by difficulty in finding words. The speech of patients with this aphasia is fluent and grammatical, and their comprehension is excellent.

- **Circumlocution:** A strategy by which people with anomic aphasia find alternative ways to say something when they are unable to think of the most appropriate word.
8.1.4 Prosody: Rhythm, Tone and Emphasis in Speech.

Prosody: the use of changes in intonation and emphasis to convey meaning in speech besides that specified by the particular words; an important means of communication of emotion.

8.1.5 Language

A language is a means of communicating thoughts and feelings using a system of socially shared but arbitrary symbols (sounds, signs or written symbols) arranged according to rules of grammar.

It is a system of visual, auditory, or tactile symbols of communication and the rules used to manipulate them. It can also refer to the use of such systems as a general phenomenon.

Language is considered to be an exclusively human mode of communication. Although other animals make use of quite sophisticated communicative systems, none of these are known to make use of all of the properties that linguists use to define language.

The Structure of Language

- **Psycholinguistics**: the study of how language is acquired, produced, and used and how the sounds and symbols of language are translated into meaning.
- **Phonemes**: the smallest units of sound in a spoken language.
- **Morphemes**: are the smallest units of meaning in language.
- **Syntax**: the aspect of grammar that specifies the rules for arranging and combining words to form phrases and sentences.
- **Semantics**: the meaning or study of meaning derived from morphemes, words, and sentences.
- **Pragmatics**: the patterns of intonation and social roles associated with a language.

Language and Thinking

Linguistic Relativity Hypothesis

The notion that the language a person speaks largely determines the nature of that person's thoughts:

- Eakinos have 3 words for snow so they think differently about it than languages that have only 1 word for snow.
- Rosch color study of Americans and Dani demonstrated no difference in discriminating, thinking, or remembering based on number of words for colors.

Thought does influence and is influenced by language and reflects cultural differences. The use of the word "he" for both males and females. Studies confirm the word "he" is interpreted heavily in favor of males.
Learning a Second Language

A second language (L2) is any language learned after the first language or mother tongue (L1). Some languages are used primarily as second languages or lingua francas. Most people around the world speak two or more languages.

Bilingualism is associated with better metalinguistic skills and the capacity to think about language but decreased efficiency in memory tasks involving words. Most bilinguals develop compensatory strategies for word memory tasks but respond more slowly.

According to some researchers, the defining difference between a first language (L1) and a second language (L2) is the age at which the language was learned. There is no age limit on ability to learn a new language, but early starters have increased proficiency and accent. Hyltenstam & Abrahamsson (2003) stated that after childhood, in general, it becomes more and more difficult to acquire native-like-ness.

The earlier you learn second language the better you get at the language. A second language makes you reexamine your native language, its spelling rules, grammar structure, and vocabulary. Growing up in a bilingual home provides distinct advantages in adolescence and adulthood.

It is quite possible that the first language a person learns may no longer be their dominant language, that is, the one he or she uses most or the one with which he or she is most comfortable in.

**ACTIVITY 8.1**

ii) Examine the benefits of learning a second language.

9.2 READING AND WRITING

Reading is the cognitive process of deriving meaning from written or printed text. It is a means of language acquisition, of communication, and of sharing information and ideas. Effective readers use decoding skills (to translate printed text into the sounds of language), use morpheme, semantics, syntax and context cues to identify the meaning of unknown words, activate prior knowledge, use comprehension, and demonstrate fluency during reading.
Types of reading

- Whole-word reading: Reading by recognizing a word as a whole; sight reading.
- Phonetic reading: Reading by decoding the phonetic significance of letter strings; sound reading.

Writing is the representation of language in a textual medium through the use of a set of signs or symbols (known as a writing system). It is distinguished from illustration, such as cave drawing and painting, and the recording of language via a non-textual medium such as audio recording.

9.2.3 Toward an Understanding of Reading Disorders

Dyslexia is a disorder that manifests primarily as a difficulty with written language, particularly with reading and spelling. It is separate and distinct from reading difficulties resulting from other causes, such as a non-neurological deficiency with vision or hearing, or from poor or inadequate reading instruction.

Evidence suggests that dyslexia results from differences in how the brain processes written and/or verbal language. Although dyslexia is the result of a neurological difference, it is not an intellectual disability. Dyslexia occurs at all levels of intelligence; sub-average, average, above average, and highly gifted.

According to the findings of a University of Hong Kong study, dyslexia affects different structural parts of children’s brains depending on the language they read. The study focused on comparing children that were raised reading English and children raised reading Chinese. Using MRI technology researchers found that the children reading English used a different part of the brain than those reading Chinese. Researchers were surprised by this discovery and hope that the findings will help lead them to any neurobiological cause for dyslexia.

Relation to aphasia

Pure alexia: Loss of the ability to read without the loss of the ability to write; produced by brain damage. Also known as pure word blindness or alexia without agraphia.

Types of dyslexia

Surface dyslexia: A reading disorder in which a person can read words phonetically but has difficulty reading irregularly spelled words by whole-word reading.

Phonological dyslexia: A reading disorder in which a person can read familiar words but has difficulty reading unfamiliar words or pronounceable nonwords.
Direct dyslexia: A language disorder caused by brain damage in which the person can read words aloud without understanding them.

Many methods and measuring instruments have so far been employed to either prove or disprove that dyslexia has a biological basis, ranging from autopsies on the brains of deceased dyslexics, to advanced technological tools such as the computerized axial tomography (CAT) scan, magnetic resonance (MR) imaging, functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and single photon emission computerized tomography (SPECT).

Why Some Dyslexics Read ‘b’ when it is ‘d’

The word “dyslexia” means “difficulty with words or language.” A telltale sign of dyslexia is reversals. People with this kind of problem often confuse letters like b and d, either when reading or when writing, or they sometimes read (or write) words like “rat” for “tar,” or “won” for “now.”

A popular theory is that reversals are caused by a neurological deficit. In other words, there is something wrong inside the brain of the person. While many factors can contribute to dyslexia, one should not overlook the principle that perception of anything depends on our past experiences.

Before one can read or learn anything, one has to become aware of it through one of the senses. Usually one has to hear or see it. In other words, perception must take place. Subsequently one has to interpret whatever one has seen or heard. In essence then, perception means interpretation. Of course, lack of experience may cause a person to misinterpret what he has seen or heard.

In order to be able to interpret size constancy, one must have had enough exposure to wide vistas and distant horizons. In the same way, in order to be able to interpret position in space, one must have had enough exposure to relevant experiences. Relevant experiences include the ability to distinguish left and right and the ability to cross the midline.

The human body consists of two halves, a left side and a right side. The human brain also has two halves, which are connected by the corpus callosum. Mindful of the wise words of Immanuel Kant that man does not see things as they are but as he is, it is inevitable that a person will interpret everything in terms of his own sidedness.

A child or adult, who has not learned to interpret correctly in terms of his sidedness yet, who has not learned to distinguish properly between left and right, will inevitably experience problems when he finds himself in a situation where he is expected to interpret sidedness.

Direct dyslexia: A language disorder caused by brain damage in which the person can read words aloud without understanding them.
9.2.3 Toward an Understanding of Writing Disorders

Dysgraphia (or agraphia) is a deficiency in the ability to write, regardless of the ability to read, not due to intellectual impairment. People with dysgraphia often can write on some level, but often lack co-ordination, and may find other fine motor tasks such as tying shoes difficult.

Dysgraphia often does not affect all fine motor skills. People with dysgraphia can also lack basic spelling skills (having difficulties with p,q,b,d), and often will write the wrong word when trying to formulate thoughts (on paper).

In children, the disorder generally emerges when they are first introduced to writing. They make inappropriately sized and spaced letters, or write wrong or misspelled words despite thorough instruction. Children with the disorder may have other learning disabilities; however, they usually have no social or other academic problems.

Cases of dysgraphia in adults generally occur after some neurological trauma or it might be diagnosed in a person with Tourette syndrome, ADHD or an autism spectrum disorder such as Asperger’s. The DSM IV identifies dysgraphia as a "Disorder of Written Expression" as "writing skills (that) ...are substantially below those expected given the person’s ...age, measured intelligence, and age-appropriate education."

Types of dysgraphia

Dyslexic dysgraphia: With dyslexic dysgraphia, spontaneously written work is illegible, copied work is fairly good, and spelling is bad. Finger tapping speed (a method for identifying fine motor problems) is normal, indicating the deficit does not likely stem from cerebellar damage. A Dyslexic Dysgraphia does not necessarily have dyslexia. (dyslexia and dysgraphia appear to be unrelated)

Phonological dysgraphia: A writing disorder in which the person cannot sound out words and write them phonologically.

Motor dysgraphia: Dysgraphia due to motor clumsiness has illegible spontaneously written work, illegible copied work, normal spelling, and abnormal finger tapping speed.

Spatial dysgraphia: Dysgraphia due to a defect in the understanding of space has illegible spontaneously written work, illegible copied work, normal spelling, but normal tapping speed. Some children may have a combination of any two or all three of these. Symptoms in actuality may vary in presentation from what is listed here.

Orthographic dysgraphia: A writing disorder in which the person can spell regularly spelled words but not irregularly spelled ones.

Symptoms of dysgraphia
A mixture of upper/lower case letters, irregular letter sizes and shapes, unfinished letters, struggle to use writing as a communications tool, odd writing grip, many spelling mistakes (some times), decreased or increased speed of writing and copying, talks to self while writing, and general illegibility.
Developmental dyslexia: A reading difficulty in a person of normal intelligence and perceptual ability; of genetic origin or caused by prenatal or perinatal factors.

The mental processes that are involved in acquiring, storing, retrieving, and using information include sensation, perception, imagery, concept formation, reasoning, decision making, problem solving, and language.

9.3 COGNITION

Imagery: The representation in the mind of a sensory experience; visual, auditory, gustatory, motor, olfactory, or tactile. Useful in learning or maintaining motor skills; same brain areas used when rehearsing or performing a skill.

Concept: A mental category used to represent a class or group of objects, people, organizations, events, situations, or relations that share common characteristics or attributes. Concepts help us order our world and to think and communicate with speed and efficiency.

Formal Concept: A concept clearly defined by a set of rules, a formal definition, or a classification system. Also known as an artificial concept.

Natural Concept: Acquired through everyday perceptions and experiences.

Prototype: An example that embodies the most common and typical features of a concept. Usually fits close to a natural concept.

Exemplars: The individual instances, or examples, of a concept that are stored in memory from personal experience.

9.3.1 Making Decisions: Choosing among Alternatives

Representativeness Heuristic: A prototype that guides your expectations.

Decision Making: The process of considering alternative and choosing among them.

Bounded Rationality: Boundaries or limitations around the decision making process prevent it from being entirely logical.

Elimination by Aspects: A decision-making approach in which alternatives are evaluated against criteria that have been ranked according to importance. Usual ranking, from most important to least important.

Heuristic: A rule of thumb that is derived from experience and used in decision-making and problem solving, even though there is no guarantee of its accuracy or usefulness.
Availability Heuristic: A cognitive rule of thumb that says that the probability of an event or the importance assigned to it is based on its availability in memory.

Representative Heuristic: A thinking strategy based on how closely a new object or situation is judged to resemble or match an existing prototype of that object or situation.

Recognition Heuristic: A strategy in which decision-making stops as soon as a factor that moves one toward a decision has been recognized.

Framing: The way information is presented so as to emphasize either a potential gain or loss as the outcome. Positive framing leads people to prefer an option.

Intuition: Rapidly formed judgments based on "gut feelings" or "instincts." Usually based on a mental representation of the gist of a body of information rather than on its factual details. Can lead to errors in reasoning about decisions.

9.3.2 Problem Solving: Finding Paths to Desired Goals

Problem-Solving: Thoughts and actions required to achieve a desired goal that is not readily attainable.

Analogy Heuristic: Applies a solution that solved a problem in the past to a current problem that shares many features with the past problem.

Working Backward: A heuristic strategy in which a person discovers the steps needed to solve a problem by defining the desired goal and working backward to the current condition.

Means-end analysis: The current position is compared with a desired goal, and a series of steps is formulated and then taken to close the gap between the two.

Algorithm: A systematic, step-by-step procedure that guarantees a solution to a problem of a certain type if applied appropriately and executed properly.

Impediments to Problem-Solving

Functional fixedness: The failure to use familiar objects in novel ways to solve problems because of a tendency to view objects only in terms of their customary functions.

Mental set: The tendency to apply a familiar strategy to the solution of a problem without carefully considering the special requirements of that problem.

Artificial Intelligence

The programming of computer systems to simulate human thinking in solving problems and in making judgments and decisions.

Artificial Neural Networks: Computer systems that are intended to mimic human brains.
Expert Systems: Computer programs designed to carry out highly specific functions within a limited domain; work best when an assistant to a human.

**ACTIVITY**

a) Describe the various strategies for making decisions.
b) Explain the differences among the various problem-solving strategies.

### 9.4 INTELLIGENCE

An individual's ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, and to overcome obstacles through mental effort.

Intelligence is a term used to describe a property of the mind that includes many related abilities, such as the capacity to reason, to plan, to solve problems, to think abstractly, to comprehend ideas, to use language, and to learn.

There are several ways to define intelligence. In some cases, intelligence may include traits such as creativity, personality, character, knowledge, or wisdom. However, some psychologists prefer not to include these traits in the definition of intelligence.

#### 9.4.1 Intelligence: Contrasting Views of its Nature

*Intelligence: Unitary of Multifaceted?*

Charles Spearman (1924) is credited with having developed the concept of $g$. $g$ can be derived as the principal factor using the mathematical method of factor analysis. One common view is that these abilities are hierarchically arranged with $g$ at the vertex (or top, overlaying all other cognitive abilities). $g$ itself is sometimes considered to be a two-part construct, $gF$ and $gC$, which stand for fluid and crystallized intelligence.

1. **g Factor**
   - Spearman's term for a general intellectual ability that underlies all mental operations to some degree. People who are bright in one area tend to be bright in others

2. **$s$ factor**
   - Specific intellectual abilities. Spearman's influence seen in intelligence tests such as Stanford-Binet that yield one IQ score to indicate the level of general intelligence
Primary Mental Abilities: Thurstone’s seven relatively distinct capabilities that singly or in combination are involved in all intellectual activities.

- Verbal comprehension
- Numerical ability
- Spatial relations
- Perceptual speed
- Word fluency
- Memory
- Reasoning

All intellectual activities involve one or more of these areas. He believes a single IQ score obscures more than it reveals. He suggests a profile indicating strength and weak areas.

Gardner’s Study’s of Intelligence

Howard Gardner’s theory argues that intelligence, as it is traditionally defined, does not adequately cover the wide variety of abilities humans display. Gardner developed theory by studying patients with different types of brain damage affecting some forms of intelligence but left others intact. He studied savant syndrome, a combination of mental retardation and unusual talent and abilities.

In his conception, a child who masters the multiplication table easily is not necessarily more intelligent overall than a child who struggles to do so. The second child may be stronger in another kind of intelligence. Therefore, he/she may best learn the given material through a different approach, may excel in a field outside of mathematics, or may even be looking through the multiplication learning process at a deeper level that hides a potentially higher mathematical intelligence than in the one who memorizes the concept easily.

Figure 8.6: Gardner’s components of intelligence.
He believes all forms of intelligence are equally important and that cultures assign varying degrees of importance to types of intelligence. Various abilities and skills have been valued differently in other cultures and periods of history. The theory suggests that, rather than relying on a uniform curriculum, schools should offer "individual-centered education", with curriculum tailored to the needs of each child.

Gardner's theory of intelligence added such components as musical intelligence and bodily-kinesthetic intelligence as well as interpersonal intelligence.

**Sternberg's Triarchic Theory of Intelligence**

Many descriptions of intelligence focus on mental abilities such as vocabulary, comprehension, memory and problem-solving that can be measured through intelligence tests. This reflects the tendency of psychologists to develop their understanding of intelligence by observing behaviour believed to be associated with intelligence. Sternberg believes that this focus on specific types of measurable mental abilities is too narrow. He believes that studying intelligence in this way leads to an understanding of only one part of intelligence and that this part is only seen in people who are 'school smart' or 'book smart'.

According to Sternberg, there are actually three basic types of human intelligence:

1. Componential or analytical intelligence – the ability to complete academic, problem-solving tasks, such as those used in traditional intelligence tests. These types of tasks usually present well-defined problems that have only a single correct answer.

2. Experiential or creative intelligence – the ability to successfully deal with new and unusual situations by drawing on existing knowledge and skills.

3. Contextual or practical intelligence – the ability to adapt to everyday life by drawing on existing knowledge and skills. Practical intelligence is involved when dealing with everyday personal or practical problems. It may also be involved when dealing with new and unusual situations in everyday life.

![Figure 8.7: Components of Sternberg's Triarchic Theory.](image-url)
Sternberg argues that IQ-test performance and real-world success are based on two different types of knowledge:

- **Formal Academic Knowledge**: Knowledge acquired in school.
- **Tacit Knowledge**: Action oriented and acquired without direct help from others.

Educators use teaching methods designed to tap into all three types of intelligence that is effective with low achievers in school. Teachers need to emphasize the practical relevance of formal academic knowledge and help students apply it to real-world problems.

### 9.4.2 Measuring Intelligence

#### Binet-Simon Test: The first IQ Test

It was developed to aid schools in France and used a score called mental age. Based on number of items a child got right compared with the number right of various ages.

If number right equaled the average of 8-year-olds was assigned the mental age of 8 regardless of chronological age. However, there were flaws with scale; a 4-year-old with a mental age of 2 was more retarded than a 10-year-old with a mental age of 12.

#### Stanford-Binet Intelligence Scale

An individually administered IQ test for ages 2-23 with an overall IQ score. Four subscales:

- Verbal reasoning
- Quantitative reasoning
- Abstract visual reasoning
- Short-term memory

This scale could not be applied to adults.

#### Intelligence quotient

In 1912, a German psychologist William Stern proposed a simple formula for calculating an index of children's intelligence. Based on intelligence tests such as those developed by Alfred Binet and Simon Theodore. Terman perfected Intelligence quotient and published Binet-Simon Scale, with items adapted for American children.

**Norms**: Standards based on the range of test scores of a large group of people who are selected to provide the bases of comparison for those who take the test later.

**Intelligence Quotient (IQ)**: An index of intelligence, originally derived by dividing mental age by chronological age and then multiplying by 100, but now derived by comparing an individual's score with the scores of others of the same age.
Wechsler Adult Intelligence Scale (WAIS-R)

The first successful individual intelligence test for adults and the most widely used psychological tests. Scores are based on how much an individual deviates from the average score for adults not mental and chronological ages.

It compares verbal and performance (nonverbal) subtests with the overall IQ score and IQ score for each subtest area.

Verbal:
- Information
- Digit span
- Vocabulary
- Arithmetic
- Comprehension
- Similarities

Performance:
- Picture completion
- Picture arrangement
- Block design
- Object assembly
- Digit symbol

Wechsler Intelligence Scale for Children third edition published for ages 6-17. Wechsler Preschool and Primary Scale of Intelligence published for children ages 4-6½. Administered to one person at a time by a psychologist or educational diagnostician.

Group intelligence tests

Are administered to large numbers of people in a short period of time.
- California Test of Mental Maturity
- Cognitive Abilities Test
- Otis-Lennon Mental Ability Test

Culture-Fair Test Example Item

The Range of Intelligence, a bell curve AKA normal curve; the majority of scores cluster around the mean. The further away from the mean score the fewer there are; less than 2% are classified as genius or mentally retarded.

Mental Retardation: Subnormal intelligence reflected by an IQ below 70 and by adaptive functioning severely deficient for one's age:
- Mildly retarded: IQ 55-70
- Moderately retarded: IQ 40-55
- Severely retarded: IQ 25-40
- Profoundly retarded: IQ below 25
Inclusion or Mainstreaming
Educating mentally retarded students in regular rather than special schools and placing them in regular classes for part of the day or having special classrooms in regular schools. This relies heavily on behavior modification techniques.

![Normal Distribution](image)

**Figure 8.8: The Range of Intelligence**

**The IQ Controversy**
By what degree can variations in intelligence be accounted for by genetics, biology, and inheritance?

**Nature-Nurture controversy**
The debate over whether intelligence and other traits are primarily the result of heredity or environment; Sir Francis Galton initiated the debate and concluded intelligence was inherited. Environmentalists insist that intelligence is influenced primarily by one’s environment, the results of nurturing by parents, teachers, friends, etc.
**Heritability**

An index of the degree to which a characteristic is estimated to be influence by heredity. Some research using the adoption study method supports that genes/heritability influence IQ scores.

![Diagram of correlation between IQ scores](image)

*Figure 8.9: The correlation between genetics and IQ scores*

**Enriched Environment**

IQ scores can be modified with an enriched environment. These advantages persist into adulthood. The earlier children are adopted, the higher their IQ's. Infants and children of low IQ; low income mothers who attend education programs scored higher on IQ tests.

**Race and IQ**

Historically Blacks score about 15 points lower than whites on IQ tests; 1969 Jensen attributed the IQ gap to genetic differences and that environment would not change test scores.

Mid 1990s Herrnstein & Murray - lower IQ scores are 60% genetic and 40% environmental due to social ills of modern society (poverty, welfare dependency, crime, and illegitimacy).

Ramey and others suggest that racial differences are more likely due to results of poverty and lack of access to educational opportunities. Dynamic assessment supports environmental effects on IQ.
Examinees are taught the goal and format of each IQ subtest before testing. Children from middle class all ready have exposure to these concepts and thus demonstrate competency.

**Stereotype threat:** Minority individuals assume inferiority and testing becomes self-fulfilling prophecy as they disengage

**Gender Differences**

Cognitive Abilities
The differences that exist within the genders are greater than the difference between the genders. Even though gender differences in cognitive abilities are generally small, there tends to be more variation in such abilities among males than among females.

- Girls from 18 months on have a larger vocabulary
- Females outperformed males in reading and writing
- Males out performed females in science and math
- Males were nearer the bottom in writing and reading comprehension

The factors affecting this may be:
- Hormonal differences may contribute to boys higher math scores
- Social differences, a greater contributor to math score differences
- Parental expectations – boys are expected to do better in math
- Boys who do well at math are considered ‘talented’; girls who do well at math are considered ‘hard workers’.

Parent’s beliefs about their children’s talents by age 6 predict the child’s belief about their own abilities at age 17; this belief is smaller today than in previous years.

**Spatial tasks** - Males tend to perform better on some than females. Spatial abilities may be enhanced by prenatal exposure to androgens; high blood levels of testosterone are associated with good performance on spatial tasks.

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**9.4.3 Creativity**

The ability to produce original, appropriate, and valuable ideas and/or solutions to problems.

There is a weak to moderate correlation between creativity and IQ; high intelligence does not necessarily mean high creativity.

Genuine creativity rarely appears in sudden flashes. Four stages in creative problem-solving process:
1. Preparation—searching for information to help solve the problem
2. Incubation—letting the problem “sit” while the relevant information is digested
3. Illumination—being suddenly struck by the right solution
4. Translation—transforming the insight into useful action
Divergent Thinking

The ability to produce multiple ideas, answers, or solutions to a problem for which there is no agreed-on solution.

Is novel, original, and involves the synthesis of an unusual association of ideas; is flexible, switching quickly and smoothly from one stream of thought or set of ideas to another; it requires fluency, the ability to formulate an abundance of ideas.

High degree of divergent thinking demonstrated by creative thinkers; both brain hemispheres highly active during creative thinking.

Convergent Thinking

The type of mental activity measured by IQ and achievement tests and consists of solving precisely defined, logical problems for which there is a known correct answer.

Demonstrated by greater activity in the left frontal cortex. Highly creative thinking is associated with activity in both hemispheres, but with significantly higher levels in the right hemisphere (a). During thinking that is not creative (b) activity is largely restricted to the left hemisphere.

Measuring individual differences in creativity

Tests emphasize original approaches to arriving at solutions for open ended problems or for producing artistic works

Unusual Uses Test
Asks respondents to name as many uses as possible for an ordinary object (such as a brick)

Consequences Test
Asks test takers to list as many consequences as they can that would be likely to follow some basic change in the world (gravity being reduced by 50%)

Remote Associations Test
The essence of creativity is the thinker’s ability to fit together ideas that to the noncreative thinker might appear remote or unrelated.

ACTIVITY 8.3

(a) Explain the theories of intelligence proposed by Spearman, Thurstone, Gardner, and Sternberg.
(b) What does the term “bell curve” mean when applied to IQ test scores?
SELF TEST

1. The ability to mentally represent a sensory experience is

2. Furniture, trees, students and weddings are all examples of and

3. Rules of thumb that are derived from experiences and used in decision-making and problem solving because they usually work are:

4. The ______ is a thinking strategy in which the individual bases their decision upon how closely the situation matches an existing prototype.

5. Trial and error is an example of ________________.

6. ______ refers to the programming of computer systems to simulate human thinking in solving problems and in making judgments and decisions.

7. Research suggests the optimal time to learn a second language is in:

8. According to Spearman, intelligence is composed of a general ability which underlies all intellectual functions.

9. Instead of looking for underlying factors of intelligence, ______ proposed there are eight independent and equally important forms of intelligence.

10. The three types of intelligence proposed by Robert Sternberg are experiential, contextual and ____________.
11. The first successful intelligence test was the _____________.

12. Roughly about _____ of the population scores either above 130 or below 70 on the Wechsler intelligence scale.

13. Aphasia refers _____________.

14. Broca’s area is in the _____________.

15. A specific pathological difficulty in reading is termed _____________.

16. William Stern developed a method for assessing similar degrees of retardation in children of different ages when he devised the _____________.

17. Apraxia is usually associated with _____________.

18. A systematic, step-by-step procedure that guarantees a solution to a problem of a certain type is called _____________.

19. Computer systems that are intended to mimic the human brain are called _____________.

20. The smallest units of sound in a spoken language are known as _____________.

Suggested Text and References

Required Reading:


Suggested Readings


Suggested Web Sites

Sleep and Language
http://thalamus.wustl.edu/course/sleep.html

Dyslexia Web Resources
http://www.kgraphics.co.uk/text/help/d_web.htm

Aphasia: Treatment, Prevention, and Cure
http://www.healthlink.com/A.html
Self-check

1. mental imagery
2. concepts
3. heuristics.
4. representativeness heuristic
5. problem solving
6. Artificial intelligence
7. childhood.
8. g factor.
9. Howard Gardner
10. compositional.
11. Binet-Simon Test
12. 2%
13. generally to deficits in the ability to produce or comprehend language, or both.
14. left frontal lobe.
15. dyslexia.
16. intelligence quotient.
17. left-hemisphere lesions.
18. an algorithm.
20. phonemes.
Unit 9
Memory Storage & Information Processing

LEARNING OUTCOME

At the end of this unit, you will able to:

1. Describe the nature and basic forms of learning.
2. Describe the relationship between learning and synaptic plasticity.
3. Discuss the mechanisms responsible for the increase in synaptic strength that occurs during long-term potentiation.
4. Differentiate between long-term potentiation and long-term depression.
5. Review the connections between relational learning and anterograde amnesia.
6. Discuss how the reinforcement system may detect reinforcing stimuli and strengthen synaptic connections.
7. Describe the nature of human anterograde amnesia and the type of brain damage that causes it.
8. Discuss research on how learning affects neural structures, the induction of longterm potentiation, and the role of NMDA receptors.
9. Explain the distinction between remembering and forgetting.
10. Discuss the role of the medial temporal lobe in spatial memory and memory retrieval and the role of the prefrontal cortex in confabulation.
11. Outline a possible explanation of the role of the hippocampal formation in learning and memory.
9.1 THE NATURE AND TYPES OF LEARNING

Learning is the acquisition and development of memories and behaviors, including skills, knowledge, understanding, values, and wisdom. It is the product of experience and the goal of education.

Learning is the process by which experiences change our nervous system and hence alters future our behavior. Memory is the substrate for storing information about those experiences.

Learning ranges from simple forms of learning such as habituation and classical conditioning seen in many animal species, to more complex activities such as play, seen only in relatively intelligent animals.

Thus, learning does not occur if there is no change in the amount of knowledge even for a long time. Learning can be negative, if the amount of knowledge is decreasing over time.

![Diagram](image)

**Figure 9.1:** A simple neural model of classical conditioning. When the 1000-Hz tone is presented just before the puff of air to the eye, synapse T is strengthened.

**Hebb rule:** The hypothesis proposed by Donald Hebb that the cellular basis of learning involves strengthening of a synapse that is repeatedly active when the postsynaptic neuron fires.
Classical conditioning

A learning procedure; when a stimulus that initially produces no particular response is followed several times by an unconditioned stimulus that produces a defensive or appetitive response. This type of learning involves:

- Unconditioned stimulus
- Unconditioned response
- Conditioned stimulus
- Conditioned response

Instrumental conditioning

A learning procedure whereby the effects of a particular behavior in a particular situation increase (reinforce) or decrease (punish) the probability of the behavior. It is also called operant conditioning:

- Reinforcing stimulus: An appetitive stimulus that follows a particular behavior and thus makes the behavior become more frequent.
- Punishing stimulus: An aversive stimulus that follows a particular behavior and thus makes the behavior become less frequent.

Neural Circuits Involved in Reinforcement

- Medial forebrain bundle (MFB): A fiber bundle that runs in a rostral-caudal direction through the basal forebrain and lateral hypothalamus; electrical stimulation of these axons is reinforcing.
- Ventral tegmental area (VTA): A group of dopaminergic neurons in the ventral midbrain whose axons form the mesolimbic and mesocortical system; plays a critical role in reinforcement.
- Nucleus accumbens: A nucleus of the basal forebrain near the septum; receives dopamine-secreting terminal buttons from neurons of the ventral tegmental area and is thought to be involved in reinforcement and attention.

Types of learning

- Perceptual learning: The ability to learn to recognize stimuli that have been perceived before. The primary function of this type of learning is the ability to identify and categorize objects and situations.
- Stimulus-response learning: Learning to automatically make a particular response in the presence of a particular stimulus. It is the ability to learn to perform a particular behavior when a particular stimulus is present. It includes classical and instrumental conditioning. The behavior could be an automatic behavior such as a defensive reflex or it could be a complicated sequence of movements that was learned previously.
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Figure 9.2: A simple model of instrumental conditioning.

Figure 9.3: An overview of perceptual, stimulus-response (S-R), and motor learning.
• **Motor learning:** Learning to make a new response; a component of stimulus based learning. Differs from other forms of learning in the degree to which new forms of behavior are learned; the more novel the behavior, the more neural circuits in the motor system must be modified.

• **Relational learning:** Involves learning the relationships among individual stimuli such as becoming familiar with the contents of a room.

• **Spatial learning:** Learning about the about the relations among many other stimuli.

• **Episodic learning:** Remembering sequences of events that we witness.

• **Observational learning:** Learning by watching and imitating others.

**ACTIVITY 9.1**

i) Explain how classical conditioning is accomplished.

ii) Define and explain punishment. How does punishment affect behavior?

### 9.2 LEARNING AND SYNAPTIC PLASTICITY

**Synaptic plasticity** is the ability of the connection, or synapse, between two neurons to change in strength. There are several underlying mechanisms that cooperate to achieve synaptic plasticity, including changes in the quantity of neurotransmitter released into a synapse and changes in how effectively cells respond to those neurotransmitters (Gaiarsa et al., 2002).

Since memories are postulated to be represented by vastly interconnected networks of synapses in the brain, synaptic plasticity is one of the important neurochemical foundations of learning and memory.

Two known molecular mechanisms for synaptic plasticity were revealed by research in laboratories such as that of Eric Kandel:

• The first mechanism involves modification of existing synaptic proteins (typically protein kinases) resulting in altered synaptic function (Shi et al., 1999).

• The second mechanism depends on second messenger neurotransmitters regulating gene transcription and changes in the levels of key proteins at synapses. This second
mechanism can be triggered by protein phosphorylation but takes longer and lasts longer, providing the mechanism for long-lasting memory storage.

Long-lasting changes in the efficacy of synaptic connections (long-term potentiation) between two neurons can involve the making and breaking of synaptic contacts. If the strength of a synapse is only reinforced by stimulation or weakened by its lack, a positive feedback loop will develop, leading some cells never to fire and some to fire too much.

9.2.1 Induction of Long-Term Potentiation

Long-term potentiation: A long-term increase in the excitability of a neuron to a particular synaptic input caused by repeated high-frequency activity of that input.

Hippocampal formation: A forebrain structure of the temporal lobe, constituting an important part of the limbic system; includes the hippocampus proper (Ammon’s horn), dentate gyrus, and subiculum.

![Diagram of hippocampal formation](image)

**Figure 9.4**. Connections of the components of the hippocampal formation. (a) shows a photomicrograph of a horizontal section through the hippocampal formation of a rat brain. (b) Shows it intrinsic connections.

Ectorhinal complex: A forebrain structure of the temporal lobe constituting an important part of the limbic system; includes the hippocampal proper (Ammon’s horn), dentate gyrus and subiculum.

Granule cell: A region of the limbic cortex that provides the major source of input to the hippocampal formation.
Dentate gyrus: Part of the hippocampal formation; receives inputs from the entorhinal cortex and projects to the field CA3 of the hippocampus.

Perforant path: The system of axons that travel from cells in the entorhinal cortex to the dentate gyrus of the hippocampal formation.

Field CA3: Part of the hippocampus; receives input from the dentate gyrus and projects to the field CA1.

Pyramidal cell: A category of large neurons with a pyramid shape found in the cerebral cortex and Ammon's horn of the hippocampal formation.

Population EPSP: An evoked potential that represents the EPSPs of a population of neurons.

**ACTIVITY 9.1**

iii) What is a long-term potentiation?

iv) Describe the brain structure that are involved in the induction of long-term potentiation?
Associative long-term potentiation: A long-term potentiation in which concurrent stimulation of weak and strong synapses to a given neuron strengthens the weak ones.

![Image of population EPSPs recorded from the dentate gyrus before and after electrical stimulation that led to long-term potentiation.]

9.2.2 Role of NMDA Receptors

NMDA receptor: A specialized ionotropic glutamate receptor that controls a calcium channel that is normally blocked by Mg$^{2+}$ ions; involved in long-term potentiation. Found in the hippocampal formation especially in field CA1.

AP5: 2-Amino-5-phosphonovalerate; a drug that blocks NMDA receptors.

AMPA receptor: An ionotropic glutamate receptor that controls a sodium channel; when its open, it produces EPSPs.

Dendritic spike: An action potential that occurs in the dendrite of some types of pyramidal cells.

9.2.3 Mechanisms of Synaptic Plasticity

Research indicated that at least to types of modifications occur when a synapse becomes strengthened: Individual synapses are strengthened and new synapses are produced.

Strengthening of an individual synapse appears to be accomplished by an increase in the number of postsynaptic AMPA receptors present in that synapse.

CaM-KII: Type II calcium-calmodulin kinase, an enzyme that must be activated by calcium; may play a role in the establishment of long-term potentiation.

Nitric oxide synthase: An enzyme responsible for the production of nitric oxide.
Figure 9.7: A hypothetical model that describes the insertion of new AMPA receptors into postsynaptic membrane of dendritic spines after long-term potentiation. The presence of glutamate and membrane depolarization open NMDA receptors. Calcium ions enter and activate molecules of CaM-KII by attaching phosphate groups ($\delta$), a process known as phosphorylation. Linking proteins attach to the activated CaM-KII, and AMPA receptors, brought to the postsynaptic membrane in vesicles, attach to the linking proteins. The addition of new AMPA receptors results in larger postsynaptic potentials when the terminal buttons release glutamate.

Figure 9.8: A hypothetical series of changes that synapses undergo following long-term potentiation.
The findings were based on earlier work identifying the amygdala as a site at which neural changes that underlie auditory fear learning occur. Current theories suggest that memories are processed by our brain initially as fragile short-term memories (STM) and then get stored more permanently as long-term memories (LTM).

The transition from STM to LTM is mediated by the production of proteins. Nader found that fear experiences stored in the amygdala, when retrieved, return to a state that again requires protein synthesis in order to be restored. If you reactivate the fear memory and block the production of protein in the amygdala immediately afterwards, the memory is lost.

### 9.2.4 Long-term Depression (LTD)

A long-term decrease in the excitability of a neuron to a particular synaptic input caused by stimulation of the terminal button while the postsynaptic membrane is hyperpolarized.

Long term depression involves a decrease in the number of AMPA receptors in the postsynaptic membrane of dendritic spines. Disorders characterized by extreme and unwarranted disturbances in emotion or mood.

### 9.3 RELATIONAL LEARNING AND ANTEROGRADE AMNESIA

Amnesia is a condition in which memory is disturbed. The causes of amnesia are organic or functional. In simple terms it is the loss of memory.

Organic causes include damage to the brain, through trauma or disease, or use of certain (generally sedative) drugs. Functional causes are psychological factors, such as defense mechanisms. Hysterical post-traumatic amnesia is an example of this.

Amnesia may also be spontaneous, in the case of transient global amnesia. This global type of amnesia is more common in middle-aged to elderly people, particularly males, and usually lasts less than 24 hours.

Another effect of amnesia is the inability to imagine the future. A recent study shows that amnesics with damaged hippocampus cannot imagine the future. This is because when a normal human being imagines the future, they use their past experiences to construct a possible scenario.
9.3.1 Human Anterograde Amnesia

Anterograde amnesia: Amnesia for events that occur after some disturbance to the brain, such as head injury or certain degenerative brain diseases. A person with anterograde amnesia can remember events in the past and those that occurred just prior to the trauma. However, they cannot retain information encountered after the trauma.

Alzheimer’s disease patients lose recent memories first and retain oldest memories until the final stages of the disorder. The final stages of Alzheimer’s disease are associated with severe memory impairment, intellectual decline and incontinence.

Retrograde amnesia: Amnesia for events that preceded some disturbance to the brain, such as a head injury or electroconvulsive shock. People with retrograde amnesia may not be able to recall events in the past or events that occurred just prior to the brain trauma.

Korsakoff’s syndrome: Permanent anterograde amnesia caused by brain damage resulting from chronic malnutrition (thiamine). Korsakoff’s syndrome is associated with severe alcoholism or, more specifically, vitamin B deficiency. Since there is general progressive decline in this disorder, it is difficult to sort out the specific types of amnesia.

Confabulation: Refers to the tendency of an amnesic patient to make up a false memory; unintentionally reports a memory of an event that did not take place.

It is a common symptom noted in Korsakoff’s syndrome; damage to the prefrontal cortex can result in confabulation. Active confabulation showed frontal lobe hypoaactivity.

Short-term memory: Immediate memory for events, which may or may not be consolidated into long-term memory.

Long-term memory: Relatively stable memory of events that occurred in the more distant past.

Consolidation: The process by which short-term memories are converted into long-term memories.

Declarative and Nondeclarative Memory

Clearly there are two major categories of memories:

Declarative memory: Memory that can be verbally expressed, such as memory for events in a person’s past.

Nondeclarative memory: Memory whose formation does not depend on the hippocampal formation; a collective term for perceptual, stimulus-response, and motor memory.

Episodic memory: Memory of a collection of perceptions of events organized in time and identified by a particular context.
9.3.2 Anatomy of Anterograde Amnesia

Perirhinal cortex: A region of limbic cortex adjacent to the hippocampal formation that, along with the parahippocampal cortex, relays information between the entorhinal cortex and other regions of the brain.

Parahippocampal cortex: A region of limbic cortex adjacent to the hippocampal formation that, along with the perirhinal cortex, relays information between the entorhinal cortex and other regions of the brain.

Place cell: A neuron that becomes active when the animal is in a particular location in the environment; most typically found in the hippocampal formation.

Hippocampal Region: A part of the limbic system which includes the hippocampus and underlying cortical areas. Involved in the formation of semantic memories.

Memories can be retrieved without the hippocampus involvement. Specific types of memory handled by the hippocampus in the context of spatial location, such as working and reference memory. The Hippocampus is especially important in forming episodic memories. It is involved in creating intricate neural spatial maps.

Major theories of hippocampal function are presented, such as providing a cognitive map, handling configural learning, and encoding spatial arrangements of stimuli.

Semantic Memories: A memory of facts and general information; involve the hippocampus and other parts of hippocampal region; other long and short-term memories usually are intact.

Figure 9.8: The posterior (rear) hippocampus of an experienced London taxi driver, shown in red in the MRI scan on the left, is significantly larger than the posterior hippocampus of a research participant who was not a taxi driver, shown in red in the scan on the right.

Neuronal Changes and Memory

Apysia sea snail study mapped neural circuits formed as the animal learned and remembered. Donald Hebb argued in 1940’s that learning and memory must involve the enhancement of transmission at the synapses between neurons.

Long-term Potentiation (LTP): An increase in the efficiency of neural transmission at the synapses that lasts for hours or longer. It does not take place unless sending and receiving
are activated at the same time by intense stimulation. Receiving neuron must be depolarized (ready to fire) when the stimulation occurs.

**Hormones and Memory**

Strongest and most lasting emotions are usually fueled by emotion. Cahill and McCaugh two pathways for forming memories:

(a) Ordinary information.

(b) Memories fired by emotion
   i) Adrenal glands release epinephrine and norepinephrine into bloodstream.
   ii) Fight or flight response imprint powerful and enduring memories surrounding threatening situations.
   iii) Amygdala activates during emotional episodes and may explain the intensity and durability of flashbulb memories.
   iv) High levels of stress hormone cortisol interferes with memory.
   v) Estrogen improves working memory efficiency and the development and maintenance of synapses in the brain.

**9.4 REMEMBERING**

Remembering is a form of recollection or a retrieval of memory. It is not a passive process; people employ metacognitive strategies to make the best use of their memory, and priming and other context can have a large effect on what is retrieved. When we try to remember information there are several different techniques we can employ. These are called Measures of Retention.

There are several ways to classify memories, based on duration, nature and retrieval of information. In order to remember, memory must first be formed. Memory formation is an organism’s ability to record, store, retain, and subsequently retrieve information. From an information processing perspective, there are three main stages in the formation and retrieval of memory:

- **Encoding** or registration (processing and combining of received information)
- **Storage** (creation of a permanent record of the encoded information)
- **Retrieval or recall** (calling back the stored information in response to some cue for use in a process or activity)

Encoding: transforming information into a form that can be stored in memory.

Storage: The process of keeping or maintaining information in memory.

Retrieval: bringing to mind information that has been stored in memory.

**Information-processing theory** uses computer models and computer terminology to describe human cognitive functioning.
9.4.1 Atkinson-Shiffrin model

**Sensory:** Sensory memory corresponds approximately to the initial 200 - 500 milliseconds after an item is perceived. The ability to look at an item, and remember what it looked like with just a second of observation, or memorization, is an example of sensory memory.

It holds information from the senses for a period of time ranging from only a fraction of a second to about 2 seconds. Sensory memory holds a visual image, like a lightening bold, for a fraction of a second – just long enough for you to perceive a flow of movement. It codes information according to sound and holds about seven items for less than 30 seconds without rehearsal.

**Short term memory:** Some of the information in sensory memory is then transferred to short-term memory. Short-term memory allows one to recall something from several seconds to as long as a minute without rehearsal. Its capacity is also very limited.

George A. Miller conducted experiments showing that the store of short term memory was 7±2 items. Modern estimates of the capacity of short-term memory are lower, typically on the order of 4-5 items.

Memory capacity can be increased through a process called chunking. For example, if presented with the string:

| FBIPHD WAI BM |

people are able to remember only a few items.

However, if the same information is presented in the following way:

| FBI PHD TWA IBM |

people can remember a greater deal more letters. This is because they are able to chunk the information into meaningful groups of letters.

Beyond finding meaning in the abbreviations above, Herbert Simon showed that the ideal size for chunking letters and numbers, meaningful or not, was three. This may be reflected in some countries in the tendency to remember phone numbers as several chunks of three numbers with the final four-number groups generally broken down into two groups of two.

Short-term memory is believed to rely mostly on an acoustic code for storing information, and to a lesser extent a visual code. Conrad (1964) found that test subjects had more difficulty recalling collections of words that were acoustically similar (e.g. dog, hog, log, bog, log).

Memory strategies include:
1. **Chunking:** Grouping or organizing bits of information into larger unites.
2. **Rehearsal:** Purposely repeating information to maintain it in short-term memory.
3. **Maintenance Rehearsal:** Repeating information over and over again until it is no longer needed. May lead to storage of information in long term memory.

**Displacement:** The event that occurs when short-term memory is filled to capacity; each new, incoming item pushes out an existing item which is then forgotten.
Long-Term Memory (LTM): The memory system with virtually unlimited capacity that contains vast stores of a person’s permanent or relatively permanent memories.

The storage in sensory memory and short-term memory generally have a strictly limited capacity and duration, which means that information is available for a certain period of time, but is not retained indefinitely. By contrast, long-term memory can store much larger quantities of information for potentially unlimited duration (sometimes a whole life span). For example, given a random seven-digit number, we may remember it for only a few seconds before forgetting, suggesting it was stored in our short-term memory.

On the other hand, we can remember telephone numbers for many years through repetition; this information is said to be stored in long-term memory. While short-term memory encodes information acoustically, long-term memory encodes it semantically: Baddeley (1966) discovered that after 20 minutes, test subjects had the greatest difficulty recalling a collection of words that had similar meanings (e.g., big, large, great, huge).

Short-term memory is supported by transient patterns of neuronal communication, dependent on regions of the frontal lobe (especially dorsolateral prefrontal cortex) and the parietal lobe. Long-term memories, on the other hand, are maintained by more stable and permanent changes in neural connections widely spread throughout the brain.

The hippocampus is essential to the consolidation of information from short-term to long-term memory, although it does not seem to store information itself. Rather, it may be involved in changing neural connections for a period of three months or more after the initial learning.

One of the primary functions of sleep is improving consolidation of information, as it can be shown that memory depends on getting sufficient sleep between training and test, and that the hippocampus replays activity from the current day while sleeping.

Types of long-term memory include:

- **Episodic Memory**: Records events as they have been subjectively experienced.
- **Semantic Memory**: Stores general knowledge or objective facts and information.
- **Elaborative Rehearsal**: A memory strategy that involves relating new information to something that is already known.

9.4.2 Three Kinds of Memory Tasks

1. **Recall**: producing required information by searching memory
   - **Retrieval Cue**: Any stimulus or bit of information that aids in retrieval

2. **Recognition**: Identifying material as familiar or as having been encountered before. Only requires that you recognize it, not recall all the information

3. **Relearning**: Retention expressed as the percentage of time saved when material is relearned.
9.4.3 The Nature of Remembering

Memories are usually reconstructed, shorter, and more consistent with an individual's viewpoint. Puzzling features are adapted to fit expectations or familiar objects.

- **Reconstruction**: An account of an event pieced together from a few highlights; may or may not be accurate.

- **Schemas**: Integrated framework of knowledge and assumptions about people, objects, and events; affect how the person encodes and recalls information; may or may not be accurate.

- **Positive Bias**: Pleasant events are remembered more than unpleasant events; aids with current emotional well-being.

**Eyewitness Testimony**

It is highly subject to error and should be viewed with caution. U.S. Department of Justice prepared national guidelines for collecting eyewitness evidence in 1999.

Minimize identification of suspects errors by first describing the perpetrator and then searching for photos to match the description. Lineup errors are minimized through sequential viewing. Viewing members of lineup one at a time rather than all together. Mistakes are more likely if person is of another race or if a weapon was used in the crime.

Misinformation Effect is misleading information supplied after the event confounds a witness' memory. Stress of the event does not lessen ability to remember critical details while less important details may be lost. Confidence of eyewitnesses has much to do with ease of recall not accuracy of information.

** Recovering Repressed Memories**

Repressed memories may be false "recovered" memories influenced by suggestions. APA & AMA both agree repressed memories exist and that false memories can be constructed.

Hypnosis techniques often used to aid in recovery of memories. Hypnosis does not improve the accuracy of memory only the confidence in what was remembered.

Persons asked to imagine a fictitious event develop a false memory of the event. Repeated exposure to suggestions of false memories can create them. Individual differences in suggestibility may also play a role.

**Infantile amnesia**: The inability to recall events from the first few years of life likely due to limited language and hippocampus development.
Flashbulb Memories

An extremely vivid memory of the conditions surrounding one's first hearing the news of a surprising, shocking, or highly emotional event.

Easily recalled due to high:
1. Emotionality
2. Consequentiality (importance of the consequences of the event)
3. Rehearsal (how often people think or talk about the events afterward)

Appear to be forgotten at about the same rate and ways as other kinds of memories. Strong emotions present when the flashbulb memories are formed interfere with accurate encoding.

Memory and Culture

The matter and manner of recall are often predominantly determined by social influences.

Swazi herdsman can recall minute individual differences of every cow or a history of a tribe preserved orally by specialist are impressive memory feats possible because it is an integral and critically important part of the culture in which they live.

Other memory components usually no different, stories set in own cultures more easily remembered than those set in other cultures. Culturally based schemas may also influence memory and recall.

9.4.4 Serial Position Effect

The finding that, for information learned in a sequence, recall is better for the beginning and ending items than for the middle items in the sequence.

Primacy effect: The tendency to recall the first items in a sequence more readily than the middle items.

Recency effect: The tendency to recall the last items in a sequence more readily than those in the middle.

Poorer recall of information in the middle of a series because it is no longer in short-term memory. Serial position effect supports notion of separate systems for short and long-term memory.

Context dependent memory: Information is easier to recall when a person is in the same environmental context they were in when they learned it. Elements of the physical setting where information is learned are encoded along with the memory.

State dependent memory: The tendency to recall information better if one is in the same pharmacological or psychological state as when the information was encoded.

Mood dependant memory: The finding that what we remember when while in a given mood may be determined in part by what we learned when previously in that same mood.
9.5 FORGETTING

Forgetting (retention loss) refers to the apparent loss of information already encoded and stored in an individual’s long term memory. It is a spontaneous or gradual process in which old memories are unable to be recalled from memory storage. It is subject to delicately balanced optimization that ensures that relevant memories are recalled.

Forgetting can be reduced by repetition and/or more elaborate cognitive processing of information. Reviewing information in ways that involve active retrieval seems to slow the rate of forgetting.

Forgetting functions (amount remembered as a function of time since an event was first experienced) have been extensively analyzed. The most recent evidence suggests that a power function provides the closest mathematical fit to the forgetting function.
Ebbinghaus’s Curve of Forgetting: After memorizing lists of nonsense syllables retention was measured after varying intervals of time using the relearning method. Forgetting was rapid at first (58% after 20 minutes and 44% after 1 hour) then tapered off.

9.5.1 Causes of Forgetting

Encoding failure: Information is not put into long-term memory

Decay theory: Memories not used will fade with time and ultimately disappear

Interference: Information or associations stored hinder the ability to remember it
  • Proactive Interference: Information or experiences all ready stored hinder memory
  • Retroactive Interference: New learning interferes with ability to recall previous learning

Consolidation Failure: Any disruption in the consolidation process that prevents a long-term memory from forming.

Retrograde Amnesia: A loss of memory for experiences that occurred shortly before a loss of consciousness

Motivated Forgetting: Suppression or repression in an effort to protect from material that is painful, frightening, or otherwise unpleasant

Intentional forgetting: We sometimes forget information we believe to be inaccurate or useless, only to find that we do need it at a later time.

Repression: Removing unpleasant memories from one’s consciousness, so that one is no longer aware that a painful event occurred

Amnesia: A partial or complete loss of memory due to loss of consciousness, brain damage, or psychological cause
Prospective Forgetting: Not remembering to carry out some intended action; forgetting to do something that is unimportant or unpleasant.

Retrieval Failure: Not remembering something one is certain of knowing

Tip-of-the-tongue phenomenon: Trying to recall some bit of information knowing you knew it but not able to come up with it.

9.5.2 Improving Memory

Over-learning: Practicing or studying material beyond the point where it can be repeated once without error. People remember material better and longer if they over-learn it.

Massed Practice: Learning in one long practice session without rest periods
Spaced practice: Learning in short practice sessions with rest periods in between; more effective with learning than massed practice. Applies to motor skills, learning facts and information.

Method of Loci: The Method of Loci or is a technique for memorizing many things. It is a type of mnemonic link system based on places (loci, otherwise known as locations), used most often in cases where long lists of items are concerned.

The First-Letter Technique: Take the first letter of each item to be remembered and form a word, a phrase, or a sentence with those letters.

Pegword System: A peg system is a mnemonic technique for memorizing lists. It works by pre-memorizing a list of words that are easy to associate with the numbers they represent: 1 to 10, 1-100, 1-1000, etc. Those objects form the “pegs” of the system. Then in the future, to rapidly memorize a list of arbitrary objects, each one is associated with the appropriate peg.

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Pegword</th>
<th>Peg Image</th>
<th>Item to Be Recalled</th>
<th>Connecting Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>bun</td>
<td><img src="image" alt="bun" /></td>
<td>milk</td>
<td><img src="image" alt="milk" /></td>
</tr>
<tr>
<td>2</td>
<td>shoe</td>
<td><img src="image" alt="shoe" /></td>
<td>bread</td>
<td><img src="image" alt="bread" /></td>
</tr>
</tbody>
</table>

Figure 9.11: The pegword system

**Activity 9.3**

(a) Explain the various causes that have been proposed to explain forgetting.

(b) Describe various techniques for improving memory.
1. In which type of conditioning is an association formed between one stimulus and another?

2. Any event or object in the environment to which an organism responds is a ____________.

3. ______ involves transforming information into a form that can be stored in memory.

4. ______ occurs when information stored in memory is brought to mind.

5. Virtually everything we see, hear, or otherwise sense is held briefly in:

6. Short-term memory usually codes information according to:

7. This process can result in items being pushed out of short-term memory and forgotten.

8. ______ is a person’s vast storehouse of permanent or relatively permanent memories.

9. There are two main subsystems within long-term memory. These are:

10. ______ consists of motor skills, habits, and simple classically conditioned responses.

11. In ______ a person must produce required information by searching memory without the help of retrieval.
12. The tendency to recall things that are presented at the end of a sequence is called:

13. When Jacob was 2 years old, he and his family narrowly escaped death when their house was destroyed by a tornado. Despite the significance of this event, Jacob could remember nothing of it. This is called:

14. Recent research supports the hypothesis that _____ is especially important in episodic memories.

15. In the study of memory, LTP stands for:

16. This is a hormone that is released into the bloodstream when a person is emotionally aroused

17. _____ improves working memory efficiency and plays a role in the development and maintenance of synapses in memory areas of the brain, such as the hippocampus.

18. This researcher introduced the “curve of forgetting.”

19. This assumes that memories, if not used, fade with time and ultimately disappear entirely.

20. A term that would be used to describe “cramming” or learning in one long session without rest is:
Suggested Text and References

Required Reading:

Suggested Readings

Suggested Web Sites
Neural Plasticity and LTP Page
http://hallux.medschool.hscbklyn.edu/~eric/Plasticity

Medial Temporal Lobe and Memory
http://thalamus.russl.edu/course/limbic.html

Learning and Memory
http://brembs.net/

Tutorials on Learning and Memory
http://psy71.dur.ac.uk/Education/memory/index.html
Self-check

Answers:

1. classical conditioning
2. stimulus
3. Encoding
4. Retrieval
5. sensory memory
6. sound
7. displacement
8. Long-term memory
9. declarative memory and nondeclarative memory.
10. Nondeclarative memory
11. Recall
12. the recency effect.
13. infantile amnesia
14. the hippocampus
15. long-term potentiation
16. epinephrine
17. Estrogen
18. Ebbinghaus
19. decay theory
20. massed practice.
Unit 10 ➤ Psychological Disorders

LEARNING OUTCOME

At the end of this topic you will learn about:

1. Describe the symptoms Anxiety Disorders
2. Explain possible causes of Anxiety Disorders
3. Describe the symptoms Mood Disorders
4. Explain possible causes of Mood Disorders
5. Describe the symptoms Schizophrenia
6. Explain possible causes of Schizophrenia
7. Describe the symptoms Somatoform Disorders
8. Explain possible causes of Somatoform Disorders
9. Describe the symptoms Sexual Disorders
10. Explain possible causes of Sexual Disorders
INTRODUCTION TO PSYCHOLOGICAL DISORDERS

Psychological disorders are terms used to refer to a psychological or physiological pattern that is usually associated with distress or disability that is not expected as part of normal development or culture. The dysfunctions in psychological disorders are assumed to be the product of disruptions of thought, feeling, communication, perception and motivation. Not every dysfunction leads to a disorder, only those that result in significant harm.

The recognition and understanding of psychological disorders has changed over time. Definitions, assessments, and classifications of psychological disorders can vary. However, the guideline criterion listed in the ICD, DSM and other manuals are widely accepted by mental health professionals. Categories of diagnoses in these schemes may include mood disorders, anxiety disorders, psychotic disorders, eating disorders, developmental disorders, personality disorders, and many other categories.

In many cases there is no single accepted or consistent cause of psychological disorders, although they are widely understood in terms of a diathesis-stress model and biopsychosocial model. Psychological disorders have been found to be common, with over a third of people in most countries reporting sufficient criteria at some point in their life. Mental health services may be based in hospitals or in the community.

Mental health professionals diagnose individuals using different methodologies, often relying on case history and interview. Psychotherapy and psychiatric medication are two major treatment options, as well as supportive interventions.

Treatment may be involuntary where legislation allows. Several movements campaign for changes to mental health services and attitudes, including the Consumer/Survivor Movement. There are widespread problems with stigma and discrimination.

Jerome Wakefield propose the idea of mental disorder as "harmful dysfunction", meets two criteria:

i) The condition causes harm according to social values of a person's culture (suffering, unable to work); and

ii) The condition results from and underlying mechanism that fails to perform according to its natural function.

Characteristics include:

* Present distress (painful symptoms);
* Disability (impairment in important areas of functioning); and
* Significantly increased risk of suffering pain, death, disability or loss of freedom.
Insanity is a legal term that refers to judgments about whether a person should be held responsible for criminal behavior if he or she is also mentally disturbed.

Another approach is to define abnormal behavior in terms of statistical norms – how common or rare it is in the general population.

**Prevalence of Psychological Disorders**

![Figure 10.1: Percentage of Adults Affected with Psychological Disorders](image1)

![Figure 10.2: Estimated Lifetime Prevalence](image2)

**Recognizing and Avoiding 5 Cognitive Traps**

1. Setting unrealistic standards for yourself
2. Negative “what if” thinking
3. Turning a single negative event into a catastrophe
4. Judging anything short of perfection to be a failure
5. Demanding perfection in yourself and others

If happiness depends on these conditions, a stage is set for disappointment and depression
10.1 ANXIETY DISORDERS

Anxiety disorders all have unrealistic, irrational fears or anxieties of disabling intensity; frequent fearful thoughts about what might happen in the future.

Anxiety disorder is a blanket term covering several different forms of abnormal, pathological anxiety, fears, phobias. It describes nervous system disorders as irrational or illogical worry not based on fact.

Anxiety and fear are ubiquitous emotions. The terms anxiety and fear have specific scientific meanings, but common usage has made them interchangeable. For example, a phobia is a kind of anxiety that is also defined in the Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV-TR) as a “persistent or irrational fear.” Fear is defined as an emotional and physiological response to a recognized external threat.

Anxiety is an unpleasant emotional state, the sources of which are less readily identified. It is frequently accompanied by physiological symptoms that may lead to fatigue or even exhaustion. Because fear of recognized threats causes similar unpleasant mental and physical changes, patients sometimes use the terms fear and anxiety interchangeably.

Distinguishing among different anxiety disorders is important, since accurate diagnosis is more likely to result in effective treatment and a better prognosis.

10.1.1 Generalized Anxiety Disorder

People who are plagued with chronic worry for 6 months or more it may be caused by problems with finances, health, work, or ability to function socially. Affects twice as many women as men. Antidepressant drugs and cognitive and behavioral therapies may be helpful.

Symptoms include:
- Feeling tense, tired, and irritable
- Trembling, palpitations, sweating, dizziness, nausea, diarrhea

10.1.2 Panic Attacks

An episode of overwhelming anxiety, fear, or terror. About 2% of men and 5% of women in the U.S. Treatments include medication and psychotherapy.

Symptoms include
- A pounding heart
- Uncontrollable trembling or shaking
- Sensations of choking or smothering
- Feeling as if you are going to die
- Feeling as if you are “going crazy”
- The more catastrophic the belief, the more intense the panic
• Recurring panic attacks may be diagnosed with panic disorder
• Anxiety about the occurrence or consequences of future attacks
• Significant Health and Social Consequences
• Frequently visit doctors’ offices and emergency rooms
• Increased risk for abuse of alcohol and other drugs

10.1.3 Phobias

A phobia is an irrational, intense, persistent fear of certain situations, activities, things, or persons. The main symptom of this disorder is the excessive, unreasonable desire to avoid the feared subject. When the fear is beyond one’s control, or if the fear is interfering with daily life, then a diagnosis under one of the anxiety disorders can be made.

A persistent, irrational fear of some specific object, situation, or activity that poses little or no real danger. Phobics realize their fears are irrational, but feel compelled to avoid the feared situations or objects.

Life is planned around avoiding feared situations; they may not leave the house unless accompanied by a friend, family member, or when severe, not even then. Leads to avoidance of places or situations where attack occurred, affects physical, psychological, social, occupational, and interpersonal and economic areas of life.

Women are four times more likely than men to be diagnosed; begins typically in early adult years with panic attacks.

Social Phobia

An irrational fear and avoidance of any social or performance situation in which one might embarrass or humiliate oneself in front of others by shaking, blushing, sweating, or appearing clumsy, foolish, or incompetent.

The most common type of anxiety disorder; may take the form of Performance Anxiety. One third only fear speaking in public; in extremes can affect performance at work, education, or restrict social life; many turn to alcohol or tranquilizers to reduce symptom’s affect.

Specific Phobia

Marked fear of a specific object or situation; a general label for any phobia other than agoraphobia or social phobia. When facing, the phobic item or situation people experience intense anxiety even to the point of shaking or screaming; will go to great lengths to avoid the feared object or situation.

Phobic items include (ranked by frequency of occurrence)
- Situational phobias (elevators, airplanes, enclosed places, tunnels)
- Fear of natural environment (storms or water)
- Animal phobias (dogs, snakes, insects, or mice)
- Blood injection-injury phobia (fear of seeing blood or receiving an injection)
- Claustrophobia (closed spaces) and acrophobia (heights) most often treated by therapists

Agoraphobia: An intense fear of being in a situation from which escape is not possible or in which help would not be available if one experienced overwhelming anxiety or a panic attack.

Causes of Phobias

It is generally accepted that phobias arise from a combination of external events and internal predispositions. In a famous experiment, Martin Seligman used classical conditioning to establish phobias of snakes and flowers. The results of the experiment showed that it took far fewer shocks to create an adverse response to a picture of a snake than to a picture of a flower, leading to the conclusion that certain objects may have a genetic predisposition to being associated with fear.

Many specific phobias can be traced back to a specific triggering event, usually a traumatic experience at an early age. Social phobias and agoraphobia have more complex causes that are not entirely known at this time. It is believed that heredity, genetics, and brain chemistry combine with life-experiences to play a major role in the development of anxiety disorders and phobias.

Heredity is an important factor in the development of phobias. A family study of social phobia has demonstrated that the generalized form of this disorder (where the person is fearful in most types of social situations) is also familial in nature and etiologically distinct from other types of anxiety disorder.

May be caused by direct conditioning, modeling, or the transmission of information or traumatic childhood experience with the feared object or situation. Observational learning occurs when children who hear parents talk about a frightening encounter with a dog may develop a fear of dogs.

Treatment of Phobias

Principles of Learning

- **Classical conditioning**: Help patients associate pleasant emotions with feared items.
- **Behavior Modification**: Patients are reinforced for exposing themselves to fearful stimuli
- **Modeling**: Observing others who do not fear to the situation or object
Medication

Antidepressant drugs have been shown to be helpful.

10.1.4 Obsessive-Compulsive Disorder (OCD)

Obsessive-compulsive disorder (OCD) is a psychiatric anxiety disorder most commonly characterized by a subject's obsessive, distressing, intrusive thoughts and related compulsions (tasks or "rituals") which attempt to neutralize the obsessions. It is an anxiety disorder in which a person suffers from recurrent obsession or compulsions, or both.

The phrase "obsessive-compulsive" is often used in an offhand manner to describe someone who is meticulous or absorbed in a cause (see "anal retentive"). Such casual references should not be confused with obsessive-compulsive disorder; see clinomorphism.

It is also important to distinguish OCD from other types of anxiety, including the routine tension and stress that appear throughout life. Although these signs are often present in OCD, a person who shows signs of infatuation or fixation with a subject/object, or displays traits such as perfectionism, does not necessarily have OCD, a specific and well-defined condition.

To be diagnosed with obsessive-compulsive disorder, one must have either obsessions or compulsions alone, or obsessions and compulsions, according to the DSM-IV-TR diagnostic criteria. The Quick Reference to the diagnostic criteria from DSM-IV-TR (2000) describes these obsessions and compulsions, as follows:

Obsessions are defined by:

- Recurrent and persistent thoughts, impulses, or images that are experienced at some time during the disturbance, as intrusive and inappropriate and that cause marked anxiety or distress.
- The thoughts, impulses, or images are not simply excessive worries about real-life problems.
- The person attempts to ignore or suppress such thoughts, impulses, or images, or to neutralize them with some other thought or action.
- The person recognizes that the obsessional thoughts, impulses, or images are a product of his or her own mind, and are not based in reality.

Obsessions are persistent, involuntary thoughts, images, or impulses that invade consciousness and cause great distress, for example:

- Contamination by germs
- Whether they performed a specific action
- Turning off the stove or locking the door
- Aggression
- Religion
- Sex
Compulsions are defined by:

- Repetitive behaviors or mental acts that the person feels driven to perform in response to an obsession, or according to rules that must be applied rigidly.
- The behaviors or mental acts are aimed at preventing or reducing distress or preventing some dreaded event or situation; however, these behaviors or mental acts either are not connected in a realistic way with what they are designed to neutralize or prevent or are clearly excessive.

Compulsions are persistent, irresistible, and irrational urges to perform an act or ritual repeatedly, for example:
- Individuals know the act is senseless but cannot resist performing them without experiencing intolerable anxiety
- Anxiety is relieved only by doing the action
- Becomes a psychological problem only if:
  - The person cannot resist performing it
  - It is very time-consuming
  - It interferes with normal activities and relationships with others

In addition to these criteria, at some point during the course of the disorder, the sufferer must realize that his/her obsessions or compulsions are unreasonable or excessive. Moreover, the obsessions or compulsions must be:
- time-consuming (taking up more than one hour per day),
- cause distress, or
- cause impairment in social, occupational, or school functioning.

OCD often causes feelings similar to those of depression. About 75% of OCD involves cleaning and checking. Sometimes reflects superstitious thinking that must be done to ward off danger. OCD occurs in 2-3% of U.S. population with fairly similar rates reported in Canada, Puerto Rico, Germany, Korea, and New Zealand.

**Predisposition**

- Early autoimmune diseases,
- Strep infections,
- Changes in the brain caused by infection
- Twin and family studies indicate genetic factors
- Genes affecting serotonin are suspected of causing OCD

**Treatment**

Behavioral treatment that combines exposure and response prevention may be the most effective approach to OCD. This involves having clients repeatedly expose themselves to stimuli of that will provoke their obsession and prevent them from engaging in their compulsive rituals.

Medications that affect the serotonin seem to be the primary class of medication that has good effects on OCD. These medications alter the functioning of the serotonin system such
as clomipramine (Anafranil) and fluoxetine (Prozac) appear to reduce the symptoms by 50 to 70 percent. The disadvantage is that relapse rates are generally high once the medication is discontinued.

10.2 MOOD DISORDERS

Mood disorder is a condition whereby the prevailing emotional mood is distorted or inappropriate to the circumstances. They are disorders characterized by extreme and unwarranted disturbances in emotion or mood.

The two major types of mood disorders are depression (or unipolar depression) and bipolar disorder:

1. Depression (or unipolar depression), including subtypes:
   - Major depression
   - Major depression (recurrent)
   - Major depression with psychotic symptoms (psychotic depression)
   - Dysthymia
   - Postpartum depression

2. Bipolar disorder, a mood disorder formerly known as “manic depression” and described by alternating periods of mania and depression (and in some cases rapid cycling, mixed states, and psychotic symptoms). Subtypes include:
   - Bipolar I
   - Bipolar II
   - Cyclothymia

10.2.1 Culture, Gender, and Depression

In most countries rate of depression for females twice that for males, largely due to conflicting roles of wife, mother, lover, friend, etc. Boys twice as likely before puberty; after, females twice as likely; women more likely to have negative consequences from depression.
10.2.2 Major Depressive Disorder

Marked by feelings of great sadness, despair, and hopelessness as well as the loss of the ability to experience pleasure. Symptoms:
- Changes in appetite, weight, or sleep patterns
- Loss of energy
- Difficulty in thinking or concentrating
- Psychomotor disturbances
- Slowed body movements, reaction time, and speech or
- Constant movement, fidgeting, wringing of hands, and pacing
- Psychotic depression when severe
- Delusions or hallucinations

Major Depressive Disorder lasts 1 year after initial diagnosis. Generally, about 40% of patients are without symptoms, 40% are still suffering with the disorder and 20% are still depressed but not enough to warrant hospitalization. Slightly less than half of hospitalized patients are fully recovered.

Treatment

Many receive antidepressant drugs; studies reflect psychotherapy can be equally effective. 50-60% of patients will have a recurrence; recurrence greatest for females and when initial onset is before 15. May be frequent or infrequent, 20-35% of patients recurrence is chronic-lasting more than 2 years.

Medication, psychotherapy, social support, and exercise preventative. The types of medication that are used most frequently in the treatment of unipolar mood disorders fall into four general categories: selective serotonin reuptake inhibitors (SSRIs), tricyclics (TCAs), monoamine oxidase inhibitors (MAO-I), and “other,” more recently developed drugs.

**ACTIVITY**

(a) Explain the different types of mood disorders and their symptoms.
10.2.3 Bipolar disorder

A mood disorder in which manic episodes alternate with periods of depression usually with relatively normal periods in between.

Manic episode:
- Excessive euphoria
- Inflated self-esteem
- Wild optimism
- Hyperactivity
- Temporarily lose touch with reality
- Frequently have delusions of grandeur along with euphoric highs
- May waste large sums of money on get-rich schemes
- Likely become irritable, hostile, enraged, or dangerous if stopped
- May be hospitalized to protect themselves from disastrous consequences

Affects ~ 1.2% of the population. Prevalence is equal between male and female. Onset during late adolescence or early adulthood. More than 90% have recurrences. About 50% within a year of recovery. Between 70-80% return to a state of emotional stability.

Mild cognitive deficits persist following manic episode. Many manage their disorder and lead normal lives with the aid of medication. Psychotherapy helps cope with stress of chronic mental illness.

10.2.4 Causes of Mood Disorders

Biological factors

Hereditary and abnormal brain structure and chemistry.

Abnormal levels of serotonin linked to depression and suicide; production, transport, and reuptake patterns of dopamine, GABA, and norepinephrine different than "normal" people; neurotransmitter abnormalities may reflect genetic variations.

Heritability of depressive disorder is 70%, environment 30%; 50% of identical twins of bipolar and 7% of fraternal twins diagnosed with bipolar disorder; biological relatives of bipolar disorder sufferers are at increased risk for a number of other mental disorders.

Cognitive Factors

Depressed individual view themselves, the world, and future in a negative way. Interactions are seen as a series of burdens and obstacles that end in failure.

Depressed individuals view themselves as failures and may think:
- "everything turns out wrong"
- "I never win" or "it's no use"
- "Things will never get better"
Life Stressors

Vast majority of first depression episodes occur after major life stress. Women are more likely to experience a severe negative life event just prior to the onset of depression. Recurrence of depression in people with biological predisposition often occurs without major life stressor.

10.2.5 Suicide and Race, Gender, and Age

Mood disorders, schizophrenia, and substance abuse are major risk factors for suicide in all age groups. Suicide risk increases when exposed to troubling life stressor.

Suicidal behavior runs in families. Women are at more risk for suicide than men. Older people are at far greater risk than younger ones.

Figure 10.4: Suicide rates according to age group.

Almost 90% of individuals who commit suicide leave clues, such as:
- Verbally – “you won’t be seeing me again”
- Behavioral – giving away most valued possessions
- Taking unnecessary risks
- Showing personality changes
- Losing interest in favorite activities

Warning signs should be taken seriously; encourage them to get professional help or call 24-hour hotline.

ACTIVITY 10.2

(a) Explain the causal factors of mood disorder.
(b) Who is at highest risk for suicide?
10.3 SCHIZOPHRENIA

Schizophrenia is a severe psychological disorder characterized by loss of contact with reality, hallucinations, delusions, inappropriate or flat affect, some disturbance in thinking, social withdrawal, and/or other bizarre behavior.

It is a psychiatric diagnosis that describes a mental illness characterized by impairments in the perception or expression of reality, most commonly manifesting as auditory hallucinations, paranoid or bizarre delusions or disorganized speech and dysfunctional thinking.

The disorder is primarily thought to affect cognition. It also usually contributes to chronic problems with behavior and emotion. People diagnosed with schizophrenia are likely to be diagnosed with comorbid conditions, including clinical depression and anxiety disorders; the lifetime prevalence of substance abuse is typically around 40%.

Positive Symptoms
- Hallucinations
- Delusions
- Derealment
- Inappropriate affect

Negative Symptoms
- Social Withdrawal
- Apathy
- Loss of motivation
- Lack of goal-directed behavior
- Very limited speech
- Slow movements
- Poor hygiene
- Poor problem-solving
- Distorted sense of time

Social problems, such as long-term unemployment, poverty and homelessness, are common and life expectancy is decreased; the average life expectancy of people with the disorder is 10 to 12 years less than those without, owing to increased physical health problems and a high suicide rate.

Onset of symptoms typically occurs in young adulthood, with approximately 0.4-0.6% of the population affected. Diagnosis is based on the patient's self-reported experiences and observed behavior. No laboratory test for schizophrenia currently exists.

Studies suggest that genetics, early environment, neurobiology and psychological and social processes are important contributory factors. Current psychiatric research is focused on the role of neurobiology, but no single organic cause has been found. Increased dopaminergic
activity in the mesolimbic pathway of the brain is a consistent finding. Due to the many possible combinations of symptoms, there is debate about whether the diagnosis represents a single disorder or a number of discrete syndromes.

For this reason, Eugen Bleuler termed the disease *schizophrenia* (plural) when he coined the name. Despite its etymology, schizophrenia is not synonymous with dissociative identity disorder, previously known as multiple personality disorder or split personality; in popular culture the two are often confused.

The main treatment is pharmacotherapy with antipsychotic medications; these primarily work by suppressing dopamine activity. Dosages of antipsychotics are generally lower than in the early decades of their use. Psychotherapy, vocational and social rehabilitation are also important. In more serious cases—where there is risk to self and others—involuntary hospitalization may be necessary, though hospital stays are less frequent and for shorter periods than they were in previous years.

10.3.1 Brain Abnormalities in Schizophrenia

Several abnormalities in brain structure and function have been found.
- Low levels of neural activity in the frontal lobes
- Defects in neural circuitry of the cerebral cortex and limbic system
- Reduced volume in hippocampus, amygdala, thalamus, and frontal lobes
- Abnormal laterization of brain functions slow communications between left and right hemispheres

Abnormal dopamine activity is common which may result from cocaine abuse. Medication effective in reducing symptoms of schizophrenia block dopamine action. One third who take these medications do not show improvement

10.3.2 Types of Schizophrenia

*Paranoid Schizophrenia*

- Characterized by delusions of grandeur or persecution
- Convinced they have an identity other than their own or that they possess great ability or talent
- Often show exaggerated anger and suspiciousness
- Feel they are being harassed or threatened
- May become violent to defend themselves against imagined persecutors

Behavior is not as disturbed as other types. The chance for recovery is better

*Disorganized Schizophrenia*

The most serious type; results in the most severe disintegration of personality; poorest chance of recovery.
• Extreme social withdrawal
• Hallucinations
• Delusions
• Silliness
• Inappropriate laughter
• Grotesque mannerisms
• Show flat or inappropriate affect
• Frequently incoherent
• May exhibit obscene behavior
• May swallow almost any kind of object or material

**Catatonic Schizophrenia**

• Complete stillness or stupor
• Great excitement or agitation
• Frequently alternate rapidly between the two
• May assume an unusual posture
• Remain in the pose for long periods of time

**Undifferentiated Schizophrenia**

A catchall term used when schizophrenic symptoms either do not conform to the criteria of any one type of schizophrenia or conform to more than one type

**10.3.3 Risk Factors in Schizophrenia**

- Genetic factors play a major role; it develops when both a genetic predisposition and more stress than a person can handle are present
- Environmental factors increase risk
- Birth trauma, virus, malnutrition, head injury, etc.

![Diagram showing the risk factors in schizophrenia based on relationship](Image)

*Figure 10.5: Chances of developing schizophrenia according to relationship*
10.4 SOMATOFORM DISORDERS

Somatoform disorder (also known as Briquet’s syndrome) is characterized by physical symptoms that mimic disease or injury for which there is no identifiable physical cause or physical symptoms such as pain, nausea, depression, and dizziness.

These physical symptoms are present that are due to psychological causes rather than any known medical condition. People with somatoform disorders are not faking illness to avoid work or other activities. Somatoform disorders are physical symptoms which present as part of a general medical condition. However, no general medical condition, other mental disorder, or substance is adequately diagnosed.

The complaints are serious enough to cause significant emotional distress and impairment of social and/or occupational functioning. An inadequate diagnosis might be the result of inconclusive or faulty test results or in some cases intentional malpractice in which a caregiver deliberately mishandles a patient’s health care to derive some benefits.

A diagnosis of a somatoform disorder implies that psychological factors are a large contributor to the symptoms’ onset, severity and duration. It is important to note that somatoform disorders are not the result of conscious malingering or factitious disorders.

10.4.1 Hypochondriasis

Persons are preoccupied with their health and fear that their physical symptoms are a sign of some serious disease despite reassurance from doctors to the contrary; not convinced when medical examination reveals no problem.

Symptoms are not consistent with known physical disorders; may “doctor shop” seeking confirmation of their worst fears. It is not easily treated with a poor chance of recovery.
10.4.2 Conversion Disorder

A person suffers a loss of motor or sensory functioning in some part of the body. The loss has no physical cause but solves some psychological problem.

May become blind, deaf, unable to speak, or paralysis in some part of the body; Freud believed it is an unconscious process to help solve an unconscious sexual or aggressive conflict.

10.4.3 Dissociative Disorders

Disorders which, under unbearable stress, consciousness becomes dissociated from a person's identity or her/his memories of important personal events, or both.

Dissociative Amnesia

A complete or partial loss of the ability to recall personal information or identify past experiences which cannot be attributed to forgetfulness or substance abuse.

Often caused by traumatic experience or a situation creating unbearable anxiety causing the person to escape by "forgetting". However, they do not forget how to carry out routine tasks and basic personality remains intact.

Dissociative Fugue

A complete loss of memory of one's entire identity. The person may assume a new identity that is more outgoing and uninhibited than their former identity. Usually a reaction to a severe psychological stress.

May last hours, days, or months and may have no memory of initiating stressor or events during the episode.

Dissociative Identity Disorder (DID)

Two or more distinct, unique personalities occur in the same person; severe memory disruption concerning personal information about the other personalities. In 50% of cases there are more than 10 different personalities.

Frequent change usually occurs during sudden and during stress; host personality is one in charge of body most of the time.

Alter personalities may differ radically in intelligence, speech, accent, vocabulary, posture, body language, hairstyle, taste in clothes, manners, handwriting, and sexual orientation. 80% of cases host personality doesn't know alter personalities; alter personalities have varying levels of awareness of each other.

Lost time: periods with no memory when in alter personality.
Usually begins in childhood, rarely in adolescence; 90% are women, 95% history of severe physical and/or sexual abuse.

**ACTIVITY 10.4**

(a) What are somatoform disorders?
(b) Explain the different kinds of dissociative disorders.

### 10.5 SEXUAL DISORDERS

Disorders with a sexual basis that are destructive, guilt, or anxiety producing, compulsive, or a cause of discomfort or harm to one or both parities involved.

**Sexual dysfunction** or **sexual malfunction** is difficulty during any stage of the sexual act (which includes desire, arousal, orgasm, and resolution) that prevents the individual or couple from enjoying sexual activity.

Emotional factors affecting sex include both interpersonal problems (such as marital/relationship problems, or lack of trust and open communication between partners) and psychological problems within the individual (depression, sexual fears or guilt, past sexual trauma, sexual disorders, and so on).

Physical factors include:
- drugs (alcohol, nicotine, narcotics, stimulants, antihypertensives, antihistamines, and some psychotherapeutic drugs);
- injuries to the back, problems with an enlarged prostate gland, problems with blood supply,
- nerve damage (as in spinal cord injuries); or disease (diabetic neuropathy, multiple sclerosis, tumors, and, rarely, tertiary syphilis);
- failure of various organ systems (such as the heart and lungs); endocrine disorders (thyroid, pituitary, or adrenal gland problems);
- hormonal deficiencies (low testosterone, estrogen, or androgens); and
- some birth defects.

The sexually dimorphic nucleus starts the same in males and females:
- First few days after birth, area grows rapidly in males
- Growth triggered by estradiol, aromatized from testosterone
- Growth complete by 4 days after birth (castration no longer has effect)
- Size of the sexually dimorphic nucleus correlated with the rat’s testosterone levels and sexual behavior
- Lesions to the sexually dimorphic nucleus in adult rats—only slight effects dimorphic nuclei in the human hypothalamus
The hypothalamus and male sexual behavior

Bilateral medial preoptic area lesions:
- abolish male behaviors (mounting) in both sexes
- electrical stimulation or implants of testosterone into the medial preoptic area—
  induces copulatory behaviors.
- Medial preoptic area appears to underlie sexual motivation.
- Lateral tegmental field receives projections from the medial preoptic area and
  mediates copulatory behavior in rats.
- Neuropharmacological approaches—dopamine and endogenous opioids increase
  in the medial preoptic area before and during copulation.
- Copulation reduces androgen receptors in medial preoptic area.

The hypothalamus and female sexual behavior

- Ventromedial nucleus (VMN) are critical for female sexual behavior
- Estradiol primes VMN by increasing progesterone receptors
- Estradiol and progesterone injected into the VMN induces estrus in ovariectomized
  rats
- Periaqueductal gray (PAG) is also involved

10.5.1 Sexual Dysfunctions

Sexual dysfunction disorders are generally classified into four categories:
1. sexual desire disorders,
2. sexual arousal disorders,
3. orgasm disorders, and
4. sexual pain disorders.

Sexual desire disorders or decreased libido can be caused by a decrease in normal estrogen
(in women) or testosterone (in both men and women) production. Other causes may be
aging, fatigue, pregnancy, medications (such as the SSRIs) or psychiatric conditions, such as
depression and anxiety. Loss of libido from SSRIs usually reverses after SSRIs are
discontinued, but in some cases it does not.

Sexual arousal disorders were previously known as frigidity in women and impotence in
men, though these have now been replaced with less judgmental terms. Impotence is now
known as erectile dysfunction, and frigidity has been replaced with a number of terms
describing specific problems with, for example, desire or arousal.

For both men and women, these conditions can manifest as an aversion to, and avoidance of,
sexual contact with a partner. In men, there may be partial or complete failure to attain or
maintain an erection, or a lack of sexual excitement and pleasure in sexual activity.

Male Erectile Disorder — Persistent or recurrent inability to attain or to maintain until the
completion of the sexual activity an adequate erection.
Female Orgasmic Disorder — Persistent of recurrent delay in, or absence of, orgasm following a normal sexual excitement phase. Diagnosis is made based on clinicians judgment that the woman’s orgasmic capacity is less than would be reasonable for her age, sexual experience, and the adequacy of sexual stimulation she receives.

There may be medical causes to these disorders, such as decreased blood flow or lack of vaginal lubrication. Chronic disease can also contribute, as well as the nature of the relationship between the partners. As the success of sildenafil (Viagra) attests, most erectile disorders in men are primarily physical, not psychological conditions.

Orgasm disorders are a persistent delay or absence of orgasm following a normal sexual excitement phase. The disorder can occur in both women and men. Again, the SSRI antidepressants are frequent culprits — these can delay the achievement of orgasm or eliminate it entirely.

Sexual pain disorders affect women almost exclusively and are known as dyspareunia (painful intercourse) and vaginismus (an involuntary spasm of the muscles of the vaginal wall that interferes with intercourse). Dyspareunia may be caused by insufficient lubrication (vaginal dryness) in women.

Poor lubrication may result from insufficient excitement and stimulation, or from hormonal changes caused by menopause, pregnancy, or breast-feeding. Irritation from contraceptive creams and foams can also cause dryness, as can fear and anxiety about sex.

It is unclear exactly what causes vaginismus, but it is thought that past sexual trauma (such as rape or abuse) may play a role. Another female sexual pain disorder is called vulvodynia or vulvar vestibulitis. In this condition, women experience burning pain during sex which seems to be related to problems with the skin in the vulvar and vaginal areas. The cause is unknown.

Sexual dysfunctions are more common in the early adult years, with the majority of people seeking care for such conditions during their late twenties through thirties. The incidence increases again in the geriatric population, typically with gradual onset of symptoms that are associated most commonly with medical causes of sexual dysfunction.

Sexual dysfunction is more common in people who abuse alcohol and drugs. It is also more likely in people suffering from diabetes and degenerative neurological disorders. Ongoing psychological problems, difficulty maintaining relationships or chronic disharmony with the current sexual partner can also interfere with sexual function.

Treatment

Drug treatments have been highly successful for men and women, e.g. Viagra (men) and DHEA (women).

Individual and couples therapy are required to improve intimate relationships.
10.5.2 Paraphilias

a) Recurrent sexual urges, fantasies, or behaviors involving:
   - Children or non-consenting persons
   - Nonhumans, objects, or
   - The suffering or humiliation of the individual or his or her partner

b) A person must experience considerable psychological distress or impairment in functioning in an important area of life.

10.5.3 Gender Identity Disorder

Gender identity disorder is a problem in accepting one’s identity as male or female. People with gender identity disorder show a strong preference for the clothes, games, pastimes, and playmates of the opposite sex. It goes far beyond cross-gender play of other children. They often express the desire to be the opposite sex. As adults, they may feel so strongly about their preference to be the opposite sex that sex-reassignment surgery is done.

Types of transsexualism:

- Surgical sexual reassignment — surgery to change sex
- Male-to-female change — good results are obtained
- Independence of sexual orientation and sexual identity
- Sexual attraction, sexual identity, and body type unrelated

Genes strongly influence development (twin studies).

Activity 10.4

Discuss the activational effects of gonad hormones on the sexual behavior of women and men. The popular press and many scientific sources have expressed concern that estrogen like compounds in the environment may be changing how human beings mature. Here are two Web Links, one on each side of the issue, with some good information:

- Web Link 10.19 Environmental Estrogens
  http://neuroendo.org.uk/index.php/content/view/33/11/

- Web Link 10.20 Endocrine Disruptors
  http://www.sph.emory.edu/PEHSU/html/exposures/endocrine.htm
1. When anxiety disrupts normal behavioral functioning, it is generally referred to as ________.

2. Disorders characterized by recurring uncontrollable anxiety-producing thoughts and impulses are classified as ________ disorders.

3. A disorder of psychological function sufficiently severe to require treatment by a psychiatrist is a ________ disorder.

4. Schizophrenia typically begins in ________.

5. Hallucinations associated with schizophrenia often take the form of ________.

6. Studies of monozygotic and dizygotic twins suggest that schizophrenia ________.

7. Symptoms such as blunt affect, catatonia, and poverty of speech are ________.

8. The diathesis-stress theory of depression is that depression is caused by ________.

9. Depressed patients who do not experience periods of mania are said to suffer from ________ depression.

10. Lithium has often been used as a treatment for ________.

11. Sometimes, under tremendous stress, a person disconnects from his/her consciousness and becomes parts versus one whole. This category of disorders is ________.

12. ________ occurs when an individual suddenly moves away and assumes a new identity, seemingly unaware of the previous one.
13. ____ is the belief that natural phenomena such as winds and tides
An intense fear of being humiliated or criticized by others in social
situations is the basic idea behind ____.

14. An irresistible urge to perform a behavior or action that serves to reduce
anxiety is referred to as an__( )_____.

15. Extreme sadness, despair, a feeling of slowing down, and problems in
eating and sleeping characterize which of the following disorders?

16. Bizarre thinking and behaviors in addition to disturbances in perception,
emotion, and social interaction suggest the presence of

17. ____ is diagnosed when an individual has an apparent loss of
sensory or motor function with no known physical cause.

18. Memory loss, usually after a highly stressful event, is often referred to as

19. Michael has felt for years that he was born into the wrong body.
Although he is physically male, he truly believes himself to be female
inside. As a child, he wanted to play with typical girl toys and engaged
in many of the same behaviors in which little girls typically engage. As
an adult, he has grown more and more uncomfortable in his own skin,
to the point that he is becoming depressed.

20. Persistent, recurrent, and distressing problems involving sexual desire,
sexual arousal or pleasure associated with sex or orgasm are considered
Suggested Text and References

Required Reading:


Suggested Readings


Suggested Web Sites

Schizophrenia
http://www.schizophrenia.com/

Dana Brain Web
http://www.dana.org/brainweb/

All About Depression
http://depression.mentalhelp.net/

The Search for Novel Antipsychotic Drugs
http://salmen.psy.plym.ac.uk/yr2/schizo1.htm

Generalized Anxiety Disorder
Self-check

Answers:

1. an anxiety disorder.
2. obsessive-compulsive
3. psychiatric
4. adolescence or early adulthood.
5. voices.
6. is influenced by genetic factors.
7. negative symptoms of schizophrenia.
8. the interaction of a genetic susceptibility and stress
9. unipolar
10. bipolar affective disorder.
11. dissociative disorders
12. Dissociative fugue
13. social phobia
14. compulsion
15. major depressive disorder.
16. schizophrenia.
17. Conversion disorder.
18. dissociative amnesia.
19. gender identity disorder
20. sexual dysfunctions.