Chapter 13

Nervous System

The nervous system

• Nervous system – Allows for communication between cells through sensory input, integration of data and motor output

• 2 cell types: neurons and neuroglia

13.1 Overview of the nervous system

Expanding on neurons

• 3 types of neurons:
  • Sensory – takes impulses from sensory receptor to CNS
  • Interneurons – receive information in the CNS and send it to a motor neuron
  • Motor – takes impulses from the CNS to an effector (i.e. gland or muscle fiber)

• Neuron structure (Ch. 4 review):
  • Cell body – main cell where organelles and nuclei reside
  • Dendrite – many, short extensions that carry impulses to a cell body
  • Axon (nerve fiber) – single, long extension that carries impulses away from the cell body
The myelin sheath

- A lipid covering on long axons that acts to increase the speed of nerve impulse conduction, insulation and regeneration in the PNS
- Schwann cells – neuroglia that make up the myelin sheath in the PNS
- Nodes of Ranvier – gaps between myelination on the axons
- Saltatory conduction – conduction of the nerve impulse from node to node

The nerve impulse: resting potential (RP)

- Resting potential – when the axon is not conducting a nerve impulse
  - More positive ions outside than inside the membrane
  - There is a negative charge of -65mV inside the axon
  - More Na⁺ outside than inside
  - More K⁺ inside than outside

The nerve impulse: action potential

- Action potential – rapid change in the axon membrane that allows a nerve impulse to occur
- Sodium gates open letting Na⁺ in
  - Depolarization occurs
  - Interior of axon loses negative charge (+40mV)
- Potassium gates open letting K⁺ out
  - Repolarization occurs
  - Interior of axon regains negative charge (-65mV)
  - Wave of depolarization/repolarization travels down the axon
- Resting potential is restored by moving potassium inside and sodium outside
The synapse

- A small gap between the sending neuron (presynaptic membrane) and the receiving neuron (postsynaptic membrane)

- Transmission is accomplished across this gap by a neurotransmitter (e.g. ACh, dopamine and serotonin)

- Neurotransmitters are stored in synaptic vesicles in the axon terminals

How does transmission across the synapse occur?

- Nerve impulse reaches the axon terminal

- Calcium ions enter the axon terminal that stimulate the synaptic vesicles to fuse with the presynaptic membrane

- Neurotransmitters are released on diffuse across the synapse and bind with the postsynaptic membrane to inhibit or excite the neuron

A synapse and how it functions

Synaptic integration

- Integration is the summation of the inhibitory and excitatory signals received by a postsynaptic neuron

- This occurs because a neuron receives many signals
The nervous divisions

- 2 divisions:
  - Central nervous system (CNS): Brain and spinal cord
  - Peripheral nervous system (PNS): Nerves and ganglia (cell bodies)

The central nervous system

- Consists of the brain and spinal cord

- Both are protected by:
  - Bones – skull and vertebral column
  - Meninges – 3 protective membranes that wrap around CNS
  - Cerebral spinal fluid (CSF) – space between meninges is filled with this fluid that cushions and protects the CNS

- Both made up of 2 types of nervous tissue:
  - Gray matter – contains cell bodies and nonmyelinated fibers
  - White matter – contains myelinated axons

The CNS: Spinal cord

- Extends from the base of the brain and along the length of the vertebral canal formed by the vertebrae

- Functions to provide communication between the brain and most of the body

- Center for reflex arcs

- Gray matter is in the center is a butterfly shape

- White matter surrounds the gray matter
The CNS: Brain

4 major parts:
1. Cerebrum
2. Diencephalon
3. Cerebellum
4. Brain stem

1. The brain: Cerebrum – the lobes
   - Cerebrum – largest portion of the brain
   - Divided into 4 lobes/hemispheres:
     - Frontal lobe: primary motor area and conscious thought
     - Temporal lobe: primary auditory, smell and speech area
     - Parietal lobe: primary somatosensory and taste area
     - Occipital lobe – primary visual area
1. The brain: Cerebrum – the cerebral cortex
   - Cerebral cortex – thin, outer layer of gray matter:
     - Primary motor area – voluntary skeletal muscle
     - Primary somatosensory area – sensory information from skeletal muscle and skin
     - Association areas – integration occurs here
     - Processing centers – perform higher level analytical functions including Wernicke’s and Broca’s areas both involved in speech

2. The brain: Diencephalon
   - Includes the:
     - Hypothalamus – helps maintain homeostasis (hunger, sleep, thirst, body temperature and water balance) and controls pituitary gland
     - Thalamus – 2 masses of gray matter that receive all sensory input except smell; involved in memory and emotions
     - Pineal gland – secretes melatonin that controls our daily rhythms
3. The brain: Cerebellum

- Receives and integrates sensory input from the eyes, ears, joints and muscles about the current position of the body

- Functions to:
  - Maintains posture
  - Coordinates voluntary movement
  - Allows learning of new motor skills (i.e. playing the piano or hitting a baseball)

4. The brain: Brain stem

- Includes:
  - Midbrain – relay station between the cerebrum and spinal cord or cerebellum; reflex center
  - Pons – a bridge between cerebellum and the CNS; regulate breathing rate; reflex center for head movements
  - Medulla oblongata – reflex centers for regulating breathing, heartbeat and blood pressure
  - Reticular formation – major component of the reticular activating system (RAS) that regulates alertness

The reticular activating system

The limbic system

- Joins primitive emotions (i.e. fear, pleasure) with higher functions such as reasoning

- Can cause strong emotional reactions to situations but conscious thought can override and direct our behavior

- Includes:
  - Amygdala – has emotional overtones
  - Hippocampus – important to learning and memory
13.3 The limbic system and higher mental functions

The limbic system

- corpus callosum
- thalamus
- hypothalamus
- olfactory bulb
- olfactory tract
- amygdala
- hippocampus

13.3 The limbic system and higher mental functions

What parts of the brain are active in reading and speaking?

- Head cortex
- Temporal area
- Parietal area
- Hippocampal
- Information from inferior area is projected to the primary motor cortex

13.4 The peripheral nervous system

The peripheral nervous system (PNS)

- Includes cranial (12 pr) and spinal nerves (31 pr) and ganglia outside the CNS
  - Spinal nerves conduct impulses to and from the spinal cord
  - Cranial nerves conduct impulses to and from the brain

- Divided into 2 systems:
  - Somatic
  - Autonomic
13.4 The peripheral nervous system

The PNS: Somatic division

• Serves the skin, skeletal muscles and tendons

• Automatic responses are called reflexes

The PNS: Autonomic division

• Regulates the activity of involuntary muscles (cardiac and smooth) and glands

• Divided into 2 divisions:
  – Sympathetic: coordinates the body for the “fight or flight” response by speeding up metabolism, heart rate and breathing while down regulating other functions
  – Parasympathetic: counters the sympathetic system by bringing up a relaxed state by slowing down metabolism, heart rate and breathing and returning other functions to normal

Health focus: Degenerative brain disorders

• Alzheimer disease
  – Usually seen in people after 65 yrs. old
  – Starts with memory loss
  – Abnormal neurons with plaques of beta amyloid and neurofibrillary tangles
  – Difficult to treat

• Parkinson disease
  – Usually begins between the ages of 50-60
  – Characterized by loss of motor control
  – Due to degeneration of dopamine-releasing (inhibitory effect) neurons in the brain
Drugs and drug abuse

• Drugs have two general effects on the nervous system: affect the limbic system or promote the action of a certain neurotransmitter

• Most drug abusers take drugs that affect dopamine and thus artificially affect this reward circuit to the point they ignore basic physical needs in favor of the drug

• Drug abusers tend to show a physiological and psychological effect

• Once a person is physically dependent they usually need more of the drug for the same effect because their body has become tolerant

Drug abuse: Alcohol

• Alcohol – a depressant directly absorbed from the stomach and small intestine

• Most socially accepted form of drug use

• About 80% of college-aged people drink

• Alcohol denatures proteins, causes damage to tissues such as the brain and liver; chronic consumption can damage the frontal lobe

• High blood alcohol levels can lead poor judgment, loss of coordination or even coma and death

Drug abuse: Nicotine and Cocaine

• Nicotine – stimulant derived from tobacco plant
  – Causes neurons to release dopamine that helps lead to dependence
  – Adversely affects a developing embryo or fetus
  – Increases heart rate and blood pressure
  – Psychological and physiological dependency

• Cocaine – stimulant derived from a plant
  – Results in a rush sensation (5-30 minutes) and an increased sex drive
  – Results in hyperactivity and little desire for food and sleep
  – Extreme physical dependence with this drug
  – “Crack” is a street name for cocaine that is processed for smoking

Drug abuse: methamphetamine

• Powder form is called speed and crystal form is called meth or ice

• A stimulant that reverses the effects of fatigue and is a mood elevator

• High agitation is common after the rush and can lead to violent behavior

• Causes psychological dependency and hallucinations

• “Ecstasy” is the street name for a drug that has the same effects as meth without the hallucinations
Drug abuse: Heroin

- Heroin: depressant from the sap of the opium poppy plant
- Leads to a feeling of euphoria and no pain because it is delivered to the brain and is converted into morphine
- Side effects are nausea, vomiting and depression of the respiratory and circulatory systems
- Can lead to HIV, hepatitis and other infections due to shared needles
- Extreme dependency

Drug abuse and its use: Marijuana

- Marijuana: psychoactive drug derived from a hemp plant called Cannabis
- Most often smoked as a “joint”
- Mild euphoria and brain damage
- Alterations to vision and judgment as well as impaired motor coordination with slurred speech
- Heavy users may experience depression, anxiety, hallucinations, paranoia and psychotic symptoms
- Banned in the US in 1937 but recently has been legalized in a few states for medical use in seriously ill patients
  - Should marijuana be available to more patients?
  - Should people in states where it is legal for medical purposes to be prosecuted? How should this be regulated?