Chapter 21

Attention Deficit Disorder: Brain Structure and Function

ADD/ADHD

- Attention deficit hyperactivity disorder (ADHD) is the official name for "ADD," but most people still call it ADD (attention deficit disorder)
- Ritalin – drug for ADHD
- 6% of boys and 2% of girls in school are given Ritalin

ADD/ADHD

- Behaviors indicating ADHD
  - Forgetfulness
  - Impulsivity
  - Distractibility
  - Fidgeting
  - Impatience
  - Restlessness
- Most children display some of these symptoms
- ADHD is diagnosed only when child shows most of them and has problems in at least two settings, like school and home

ADD/ADHD

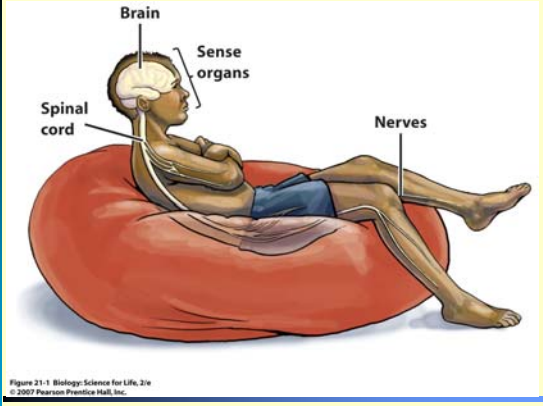
- Ritalin is a stimulant
  - Causes children to slow down and pay closer attention
- ADHD – caused by brain malfunction? If it is, then:
  - Give medication
- ADHD – caused by society? If it is, then:
  - Change environment of child

21.1 The Nervous System

- The **nervous system** receives and interprets signals
- **Neurons** – specialized cells that receive and respond to stimuli
  - Capable of carrying electrical and chemical messages back and forth b/t the brain and other parts of the body
- **Nerves** – bundles of neurons
  - Branch out from the brain and spinal cord to eyes, ears, internal organs, skin, and bones; they connect various organs to each other and link the nervous system with other organ systems

The Nervous System

- The **central nervous system (CNS)**
  - Neurons of brain and spinal cord
- Neurons in sense organs transmit signals to the CNS
- Information is processed by the CNS and then sent back to the body by other neurons
- These signals are electrical and chemical



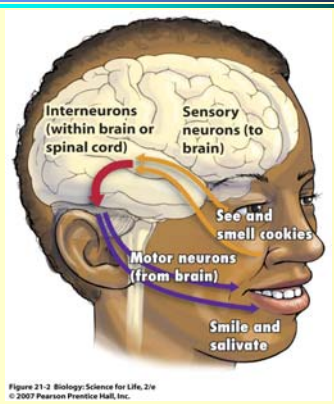
The Nervous System

- Tissues that respond to nerve signals are called **effectors** – muscle, gland, or organ stimulated by a nerve
- **Nerve impulses** – electrical charges carried by nerve cells that control the activities of muscles, glands, organs, and organ systems
- **Neurotransmitters** – chemicals released from nerve cells

The Nervous System

3 categories of neurons:

1. **Sensory neurons** carry information to the CNS
2. **Motor neurons** carry information away from CNS toward effector tissue
3. **Interneurons** are located between sensory and motor neurons



The Nervous System

- **Sensory receptors** – detect sensory input
  - These are neurons or other cells that communicate with sensory neurons
  - They detect changes in conditions inside or outside the body

The Nervous System

- **General senses**
  - Temperature
  - Pain
  - Touch
  - Pressure
  - Proprioception – body position
- **Special senses**
  - Smell
  - Taste
  - Equilibrium
  - Hearing
  - Vision

	Sense and its location	Sensory receptors	Description
General senses—throughout body	Temperature, pain, pressure, touch		The skin's sensory nerve endings react to temperature, pain, pressure, and touch. These specialized receptors respond to different levels of sensation (e.g., slight cold versus freezing cold) and send information to the brain.
	Proprioception		Specialized neurons sense joint position, tension in joints and ligaments, and muscle contractions. These neurons relay messages to the brain, along with balance information from the inner ear.

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	Sense and its location	Sensory receptors	Description
Special senses—found in complex sense organs	Smell		Paired olfactory (smell) organs with specialized receptors are located within the nasal cavity. Chemicals stimulate the receptors on hair-like projections called *cilia*. The receptors then send nerve impulses to the brain.
	Taste		A tongue's surface contains taste receptors called taste buds. When food or drink contacts the taste buds, nerve impulses travel to the brain. Taste buds are specialized to respond to one of four primary taste sensations: sweet, salty, sour, or bitter.
	Vision		Neuron receptors in the eye's retina allow for sight and relay sensory information to the brain.
	Equilibrium and hearing		The inner ear is responsible for equilibrium and hearing. Equilibrium determines the body's position in space, monitoring gravity, acceleration, and rotation. Hearing allows us to detect and interpret sound waves. Receptors for both senses are located on the cilia, which move and generate nerve impulses to the brain.

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The Nervous System

- Sensory information passed to and from the brain travels along the main nerve pathway – **the spinal cord**
- The spine, made up of vertebrae, protects the spinal cord
- Spinal nerves branch out between **vertebrae**

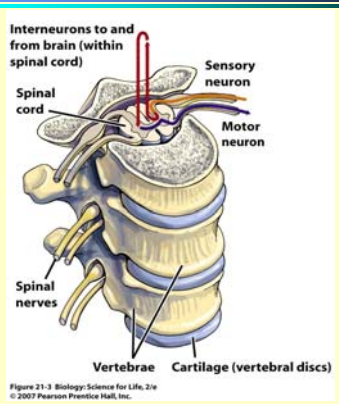

Figure 21-3 Biology: Science for Life, 2/e
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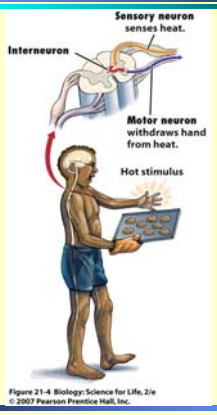
The Nervous System

- The spinal cord also is a reflex center
- **Reflexes** – automatic responses to stimuli
- **Reflex arc** – prewired circuit of neurons
  - Sensory neuron receiving stimulus
  - Interneuron transmitting information
  - Motor neuron sending message to muscle

The Nervous System

- Reflexes allow a person to react quickly to dangerous stimuli
- Withdrawal reflex – ex.: when touching something hot
  - Sensory neurons from touch receptors send the message to the spinal cord; the interneurons within spinal cord send the message to motor neurons to withdraw your hand from hot surface

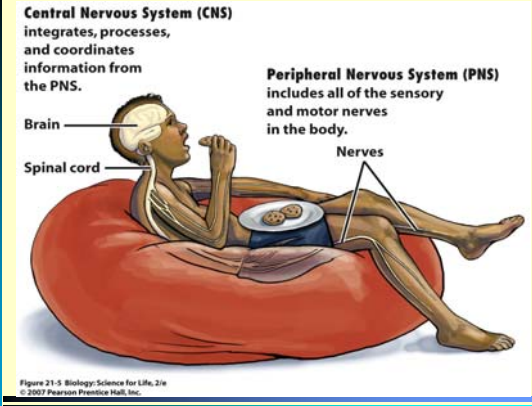


The Nervous System

- The pain stimulus travels from the spinal cord to the brain and takes a little longer than the reflex
- You have removed your hand from the heat before you feel the pain

The Nervous System

- The CNS is one of two main subdivisions of the nervous system
  - Responsible for integrating, processing, and coordinating info. received by the senses
  - Seat of functions like intelligence, learning, memory, and emotion
- The other part of the nervous system is the **peripheral nervous system (PNS)**
  - Network of nerves radiating out from brain and spinal cord that links the CNS with sense organs



21.2 The Brain

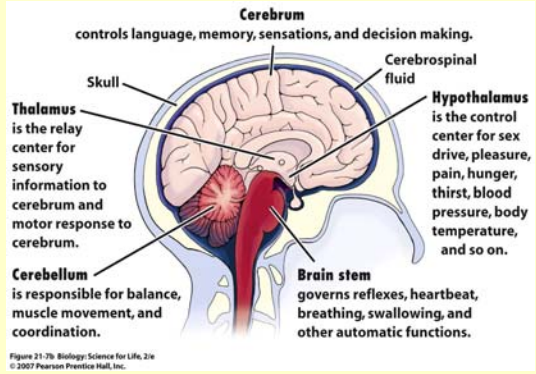
- The brain is where decisions are reached and bodily activities are directed and coordinated
- The human brain is roughly the size of a small cantaloupe
- The brain is housed in the skull and sits inside a liquid bath called the **cerebrospinal fluid** for protection and cushioning

The Brain

- There are about 100 to 200 billion neurons in the brain
- There are also **glial cells**
  - About 10 times as many as there are neurons
- Glial cells do not carry messages, but rather support neurons by
  - Supplying nutrients
  - Helping to repair the brain after injury
  - Attacking invading bacteria

The Brain

- There are several structural regions of the brain including:
  - Cerebrum
  - Thalamus
  - Hypothalamus
  - Cerebellum
  - Brain stem

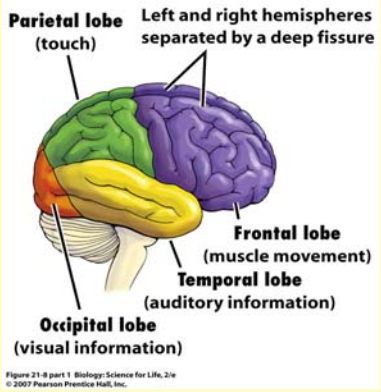


Cerebrum

- The **cerebrum** fills whole upper part of skull
  - Controls language, memory, sensations, decision making
- There are 2 hemispheres, each divided into 4 lobes

Cerebrum

1. **Temporal lobe** – involved in auditory and some visual information; memory and emotion
2. **Occipital lobe** – processes visual information from eyes
3. **Parietal lobe** – processes information from touch; self-awareness
4. **Frontal lobe** – processes involuntary muscle movements; planning and organizing future expressive behavior

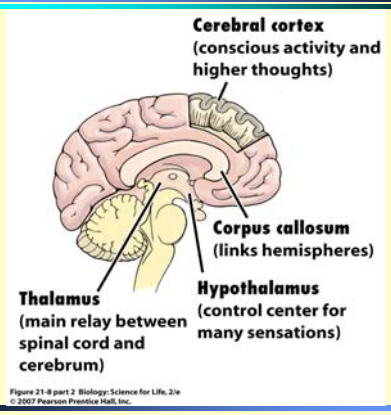


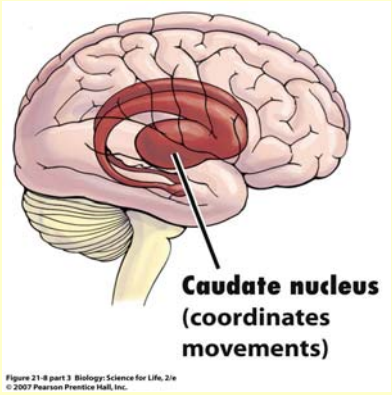
Cerebrum

- **Cerebral cortex** – wrinkled outer surface
- If unfolded, a human cerebral cortex would be the size of a 16' pizza
  - Lots of surface area in a small space
- The cerebral cortex has areas for
  - Understanding and generating speech
  - Receiving input from eyes
  - Receiving other sensory input
  - Planning

Cerebrum

- **Fissure** – deep groove dividing the cerebrum and cortex
  - Divided into right and left cerebral hemispheres
- **Corpus callosum** – bundle of nerve fibers at base of fissure – linking the two hemispheres
- **Caudate nuclei** – paired structures deep within each hemisphere that coordinate movement





Thalamus and Hypothalamus

- **Thalamus** and **hypothalamus** are inside the brain between the two hemispheres
- Thalamus – relays information between spinal cord and cerebrum
- Hypothalamus (just underneath the thalamus) controls:
  - Sex drive, release of gametes and menstrual cycle, pleasure, pain, hunger, thirst, blood pressure, and body temperature

Cerebellum

- **Cerebellum** (Latin for 'little brain")
- Controls
  - Balance
  - Muscle movement
  - Coordination

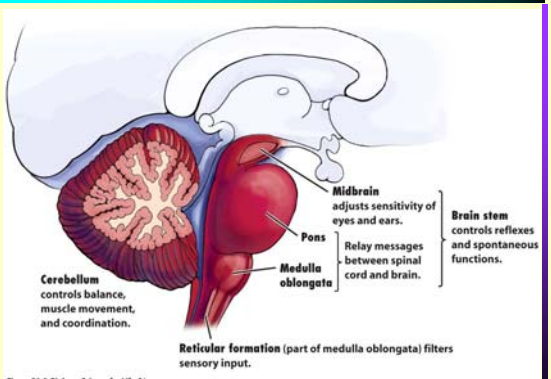
Brain Stem

- The **brain stem** is below the hypothalamus
- Governs reflexes and spontaneous functions such as heartbeat, respiration, swallowing, and coughing

Brain Stem

3 main parts of brain stem:

1. **Midbrain**: adjusts the sensitivity of the eyes to light, and the ears to sound
2. **Pons**: bridge for messages between brain and spinal cord
3. **Medulla oblongata**: continuation of the spinal cord: conveys info. b/t the spinal cord and other parts of the brain



The Brain

- Functions of the brain are divided between the right and left hemispheres
  - The left hemisphere controls the right half of the body
  - The right hemisphere controls the left half of the body
- The left hemisphere controls speech, reading and ability to solve mathematical problems
- The right hemisphere controls spatial ability and musical and artistic creation

The Brain

- The **reticular formation** is in the medulla oblongata
  - Network of neurons that radiate toward the cerebral cortex
  - Is a filter for sensory input; filters out stimuli that require no response
    - ✓Analyzes the constant onslaught of sensory info. and filters out stimuli that require no response; this prevents the brain from having to react to repetitive, familiar stimuli such as the sound of automobile traffic or the sound of your roommate's breathing while you are asleep
  - Also functions as an activating center by keeping the cerebral cortex alert; while conscious activity originates in the cerebral cortex, it can only do so if the reticular formation is keeping the cortex alert

ADD and Brain Structure and Function

- **Neurobiologists** – biologists who study the nervous system
  - Use technology to view the brain
- There may be differences in brains of ADD people

ADD and Brain Structure and Function

- A study found that people with ADD had a slightly smaller corpus callosum
- Another study found that there were similar size differences in the caudate nuclei
- Other studies show the cortex and cerebellum may be smaller in people with ADD

ADD and Brain Structure and Function

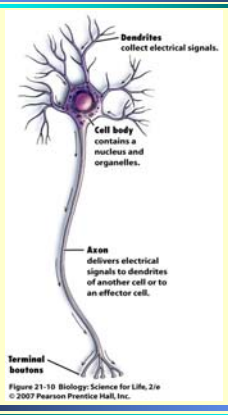
- Some research has shown that in people with ADD, the reticular formation doesn't filter effectively, allowing too much information through to the cerebral cortex
- Other research has found decreased blood flow through the right caudate nucleus in people with ADD
- These differences may be genetic, environmental or a combination of the two factors

21.3 Neurons

- Neurons are highly specialized cells that usually don't divide
- Damage to neurons can't be repaired by cell division – many times results in permanent impairment

Neuron Structure

- **Dendrites** – branches that radiate from a bulging cell body; collect electrical signals
- **Cell body** – houses nucleus and organelles
- **Axon** – long, wirelike portion of the neuron that ends in a terminal boutons; delivers electrical signals to dendrites of another cell or to an effector cell
- **Terminal boutons** – the knobby ends of axon



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Neuron Structure

- A nerve impulse usually travels down axon of one neuron and is transmitted to the dendrites of another neuron
- Many neurons have axons covered in a protective layer – **myelin sheath** – that insulates to prevent sideways transmission
  - Increases speed of transmission

Neuron Structure

- The **myelin sheath** is composed mainly of lipids and is white like animal fat
  - Supported by cells such as **Schwann cells**
- Nervous tissue of myelinated cells is called **white matter**

Axons covered in myelin sheaths

Figure 21-11a Biology: Science for Life, 2/e
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Neuron Structure

- Long stretches of myelin sheath are separated by small gaps of unmyelinated areas called the **nodes of Ranvier**
  - Nerve impulses jump from one node to the next

Nerve impulses travel more quickly on myelinated than on unmyelinated nerves.

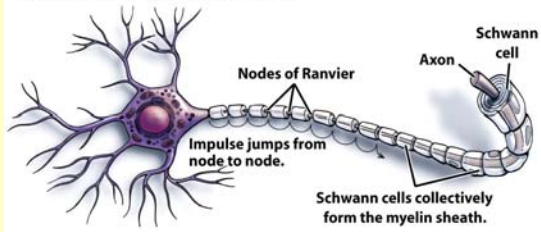

Figure 21-11b Biology: Science for Life, 2/e
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Neuron Structure

- The nerve transmission is up to 100 times faster when jumping, which occurs on a myelinated axon, than on an unmyelinated axon
- Travel rate on myelinated axons: >200mph (100m/s)
- **Gray matter** are unmyelinated neurons
  - Transmit impulses slower

Neuron Function

- Many stimuli cause neurons to fire off a response, including
  - Touch
  - Sound
  - Light
  - Taste
  - Temperature

Neuron Function

- When you touch something signals from touch sensors travel along sensory nerves from the skin through the spinal cord and into brain
- The brain sends out messages through spinal cord to motor neurons – telling muscle cells how to respond
- The signal that is transmitted along a neuron and from one neuron to the next is called action potential

Action Potential

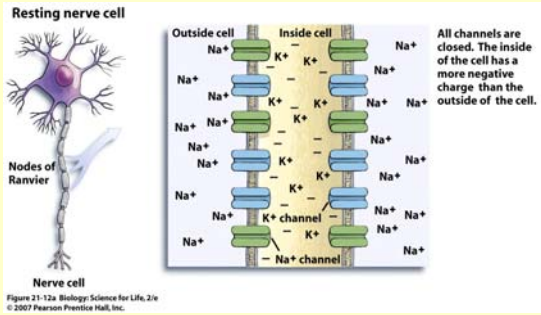
- **Action potential** transmits a signal along the length of a neuron
  - Caused by a brief reversal of the electric charge of the nerve cell membrane
- This causes a wave of electrical current to travel down the length of the neuron
- A resting neuron has a charge difference from inside to outside
  - Negative charge on inside
- Source of stored energy in membrane, since it separates the charges that want to move toward each other

Action Potential

- The difference in charge across the membrane is called **polarization**
- Caused by the concentration of potassium (K^+) inside the cell is greater than the concentration of sodium (Na^+) outside the cell

Action Potential

- Potassium channels are 'leaky' and allow potassium to passively move to the outside
- The **sodium-potassium pump** in the neuron membrane moves sodium out and potassium in
- Using ATP, the sodium-potassium pump moves 3 Na^+ out for every 2 K^+ in
- This restores the potassium levels in the cell

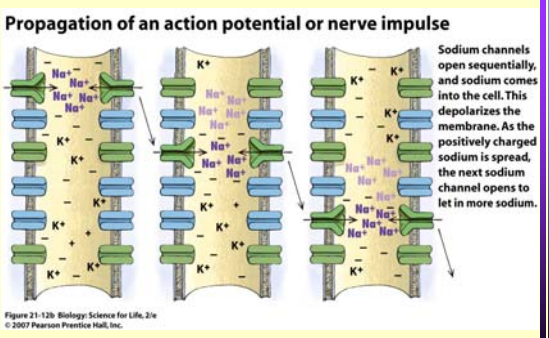


Action Potential

- When a neuron is stimulated, the sodium channel of the pump is partly opened
- Sodium enters the cell and changes the charge to less negative
- If the sodium levels reach a critical level, the gates open wide and sodium floods in
- This eliminates the charge difference across the membrane
- Causing an action potential

Action Potential

- The **depolarization** – loss of charge difference – moves in a wave down the cell
- Activates sodium channels in adjacent parts of the membrane to move the impulse along the length of the neuron



Action Potential

- Action potential declines when sodium channels close and potassium channels open
  - Potassium flows out of cell
- **Repolarization** – when potassium ions leave and internal cell state is more negative than outside
- Some neurons are inhibitory
  - Causing **hyperpolarization** in neighboring cells instead of depolarization

Synaptic Transmission

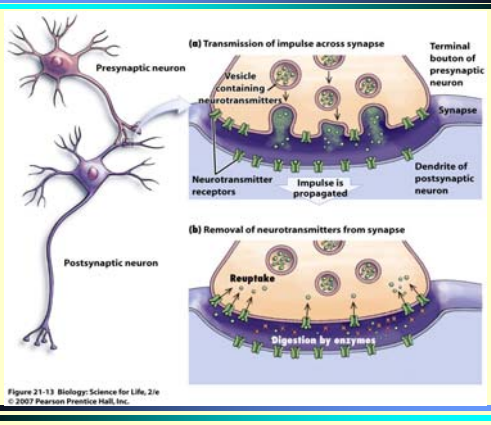
- After traveling along the axon, the signal must be passed along to the next neuron
  - Most neurons are not physically connected
- **Synapse** – the gap between two neurons
- Synapse structure:
  - Terminal boutons of **presynaptic** neuron
  - Space between both neurons
  - Cell membrane of **postsynaptic** neuron

Synaptic Transmission

- **Vesicles** are in the terminal boutons of the presynaptic neuron
- They contain neurotransmitters
- When the impulse reaches the terminal bouton of a nerve cell, the neurotransmitters are released
- The neurotransmitters diffuse across the synapse and bind to receptors on the postsynaptic cell membrane

Synaptic Transmission

- This binding stimulates the postsynaptic cell to rapidly uptake sodium
  - Sodium gates open and cell is depolarized
  - Action potential is generated
- After the neurotransmitter causes the response, it is removed from synapse by 1 of 2 ways:
  - Enzymes break down neurotransmitters
  - **Reuptake** – some neurotransmitters are reabsorbed by the presynaptic neuron



Synaptic Transmission

- By enzymatically breaking down and reuptake of neurotransmitters, there is no continuous stimulation of the postsynaptic cell

Neurotransmission, Alzheimer's, Depression, Parkinson's, and ADD

- **Alzheimer's disease** is a progressive mental deterioration with memory loss and loss of control of body functions
- **Alzheimer's disease** may involve impaired function of the neurotransmitter **acetylcholine**
  - Drugs that inhibit the enzyme **acetylcholinesterase** can improve mental function, but only temporarily

Neurotransmission, Alzheimer's, Depression, Parkinson's, and ADD

- **Depression** is a disease
  - Feelings of helplessness and despair and thoughts of suicide
- It may involve three neurotransmitters
  - Serotonin, dopamine and norepinephrine

Neurotransmission, Alzheimer's, Depression, Parkinson's, and ADD

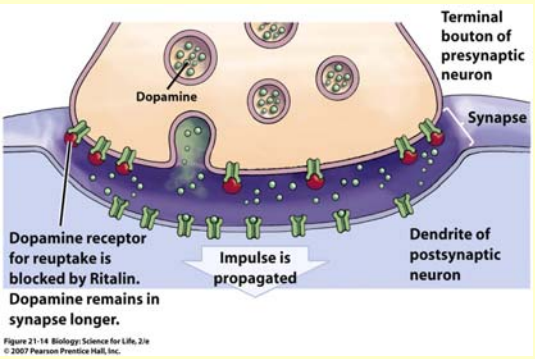
- **Parkinson's disease** is a malfunctioning of neurons that produce **dopamine**
  - The loss of dopamine causes nerve cells to fire without regulation
  - Patients have difficulty in controlling their movements and experience tremors, rigidity and slowed movements

Neurotransmission, Alzheimer's, Depression, Parkinson's, and ADD

- ADD may be due to abnormal levels of dopamine
- Dopamine controls emotions as well as complex movements
- May be due to overabundance of dopamine receptors on presynaptic cells – too much reuptake

Ritalin®

- **Ritalin** is thought to increase dopamine's ability to stimulate postsynaptic cells
  - Block reuptake receptors in presynaptic cells
  - Dopamine in synapse longer



Ritalin®

- Ritalin is legal, but other stimulants (such as cocaine and amphetamines) are illegal
- They affect heart, blood vessels, elevate blood pressure, expand airways in lungs
  - Also affects neurotransmitter action

Ritalin®

- Stimulants in high doses result in
  - Euphoric feeling
  - More energy and endurance
  - Sense of power
  - Feeling of mental sharpness
- After the stimulants wear off, user feels
  - Heightened fatigue
  - Insomnia
  - Poor concentration
  - Irritability
  - Tearfulness
  - Depression

Ritalin®

- Stimulant users may also experience
  - Personality changes
  - Skin rashes
  - Fever
  - Nausea
  - Headaches
- Abuse of stimulants can lead to
  - Psychotic episodes
  - Delusions
  - Seizures
  - Hallucinations
  - Sudden death

Ritalin®

- Many elementary children who grow up taking Ritalin still take it in college
  - At this age, many self-administer
- May be seen as less serious than other stimulants
- Recent studies indicate about 15% of college students have used Ritalin® recreationally
- There are potential side effects, as there are with all drugs

Drug	Mechanism of action	Desired mental effect	Side effect
Alcohol is a byproduct of fermen-tation. When yeast cells ferment barley, beer is pro-duced. Likewise, when yeast cells break down the sugars in grapes, wine is produced. 	• A depressant that diffuses easily across cell membranes and does not require specific receptors • Inhibits neurotransmission in the reticular formation, interfering with the activity of many neurons in the brain	• Reduced anxiety and a sense of well-being, loss of concern for social constraints	• Impaired judgment, slurred speech, unsteady gait, slower reaction times, uncontrollable emotions • Chronic alcohol abuse leads to loss of intellectual ability by damaging nerve cells. Cells in the frontal lobes (center for judgment, thought, and reason) are the first to die • Liver damage

Drug	Mechanism of action	Desired mental effect	Side effect
Amphetamines are used legally to treat obesity, asthma, and narco- lepsy. Methamphetamine is an illegal amphetamine. A crystalline form of meth-amphetamine called *ice* is smoked to produce effects similar to crack cocaine. 	• Stimulants that increase activity in the reticular formation • Mimic the actions of the neurotransmitter norepinephrine, a hormone produced in response to stress • Block reuptake and inhibit the enzyme that breaks down norepinephrine, resulting in prolonged stimulation of the postsynaptic cell	• Small doses make a person feel more energetic, alert, and confident	• Effects wear off quickly, causing sudden "crashes" from depleted neurotransmitter stores and resulting in depression and fatigue • Prolonged use results in aggressiveness, delusions, hallucinations, and violent behaviors. • Can cause blood vessels to spasm, clots to form, insufficient blood to enter the heart, fluid to build up in the lungs, and death

Table 21-2 part 2 Biology: Science for Life, 2/e

Drug	Mechanism of action	Desired mental effect	Side effect
Caffeine is a naturally occurring chemical found in plants such as coffee, tea, and cocoa. 	• A general stimulant that affects all cells, not just those of the central nervous system • Increases cellular metabolic activities	• Mental alertness, increased energy	• Insomnia, anxiety, irritability, and increased heart rate

Table 21-2 part 3 Biology: Science for Life, 2/e

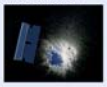
Drug	Mechanism of action	Desired mental effect	Side effect
Cocaine is extracted from the leaves of the coca plant of South America. It can be inhaled or injected. A more potent form, crack, is smoked. 	• A stimulant that increases levels of dopamine and norepinephrine by decreasing reuptake	• A rush of intense pleasure, increased self-confidence, and increased physical vigor	• Increased heart rate and blood pressure, narrowing of blood vessels, dilation of pupils, a rise in body temperature, and reduction of appetite • Crash involves deep depression, anxiety, and fatigue. • Abuse may change neurons and prevents the abuser from experiencing positive feelings without the drug

Table 21-2 part 4 Biology: Science for Life, 2/e

Drug	Mechanism of action	Desired mental effect	Side effect
Ecstasy or MDMA is a white crystalline powder that is primarily ingested in pill or capsule form. 	• A stimulant and hallucinogenic that acts to prevent serotonin reuptake • Also floods neurons with several other neurotransmitters	• Euphoria, enhanced emotional and mental clarity, increased energy, heightened sensitivity to touch, and enhanced sexual response	• Confusion, anxiety, paranoia, depression, and sleeplessness that may last for several weeks • May permanently damage neurons involved in utilizing serotonin and may also result in permanent memory damage • When combined with physical exercise, ecstasy use can lead to severe dehydration and the inability to regulate body temperature

Table 21-2 part 5 Biology: Science for Life, 2/e

Drug	Mechanism of action	Desired mental effect	Side effect
Lysergic acid diethylamide (LSD) and Mushrooms LSD is a derivative of the fun-gus *Claviceps purpurea*, which grows on rye. It is related to the compound psilocybin, found in certain mushrooms. 	• Hallucinogenic that binds to serotonin receptors in the brain, increasing the normal response to serotonin	• Heightened sensory perception and bizarre changes in thought and emotion, hallucinations	• Hallucinations can lead users to dangerous actions. • Heavy use leads to permanent brain damage, including losses of memory and attention span, and can lead to psychosis.

Table 21-2 part 6 Biology: Science for Life, 2/e

Drug	Mechanism of action	Desired mental effect	Side effect
Marijuana is the leaves, flowers, and stems of the Indian hemp plant *Cannabis sativa*. Also contains a drug called delta-9-tetrahydrocannabinol (THC). 	• Receptors for THC in the areas of the brain that influence mood, pleasure, memory, pain, and appetite. • THC is thought to work by increasing dopamine release	• Altered sense of time, enhanced feeling of closeness to others, increased sensitivity to stimuli • Large doses can cause hallucinations	• Slowed reaction time, decreased coordination, and inability to judge time, speed, and distance. Impaired short-term memory, slowed learning, decreased attention span, and lessened ability to store and acquire information • Damage to THC receptors on the hypothalamus, the area of the brain that regulates sex-hormone secretion, can decrease testosterone production and disrupt menstruation

Table 21-2 part 7 Biology: Science for Life, 2/e

Drug	Mechanism of action	Desired mental effect	Side effect
Nicotine is found in tobacco plants. Just 1 of over 1000 chemicals in cigarette smoke. It is one of the most likely to affect the brain. 	• A stimulant that triggers neuron receptors in the cerebral cortex to produce acetylcholine, epinephrine, and norepinephrine	• Increased alertness and awareness, appetite suppression, relaxation	• Cigarette smoking increases the odds of obtaining virtually every type of cancer • Also causes increased heart rate and blood pressure

Table 21-2 part 8 Biology: Science for Life, 2/e

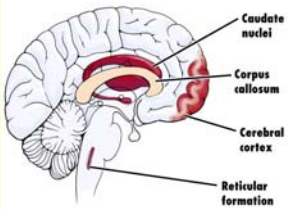
Drug	Mechanism of action	Desired mental effect	Side effect
Opiates are derived from the opium poppy. Heroin, morphine, and codeine are opiates. Morphine and codeine can be used legally to control pain. 	• Binds to opiate receptors in neurons that control feelings of pleasure • Opiate receptors have evolved to bind to opiates produced by the brain in response to exercise; these opiates are called endorphins	• A quick, intense feeling of pleasure, followed by a sense of well-being and drowsiness	• Addiction, poor motor coordination, depression • High doses can cause coma and death • Thought to change the brain's ability to respond to normal pleasures

Table 21-2 part 9 Biology: Science for Life, 2/e

21.4 The Environment and ADD

- Even though some factors are biological, there are environmental factors involved in people with ADD
- In the last decade the diagnosis of ADD has increased from 1 million to somewhere between 6 and 11 million

Biological factors that may influence ADD



Person without ADD	Person with ADD
Right caudate nucleus larger than left caudate nucleus; normal blood flow.	Two caudate nuclei same size? Decreased blood flow?
Normal size	Slightly smaller?
Normal activity	Parts of cortex less active?
Normal traffic flow	Not as effective at limiting the number of traffic signals to cortex?

Figure 21-15a Biology: Science for Life, 2/e

Societal factors that may influence ADD

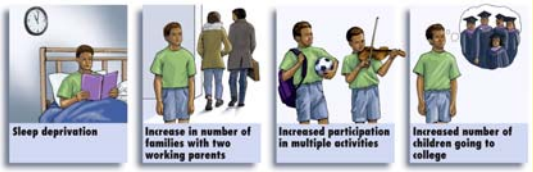


Figure 21-15b Biology: Science for Life, 2/e

Biological and societal factors may combine

Child with ADD brain + Stress → ADD behavior

Figure 21-15c Biology: Science for Life, 2/e