9.00 EXAM 1 NOTES
KOSSLYN CHAPTER 2 – *The Biology of Mind and Behavior: The Brain in Action*

Events at the level of the brain can influence many aspects of behavior, in ways not immediately apparent.

BRAIN CIRCUITS: MAKING CONNECTIONS

The Neuron: A Powerful Computer
The physical characteristics of the brain give rise to:
- Mental contents: knowledge, beliefs (including ideas, explanations, and expectations), desires (such as hopes, goals, and needs), and feelings (such as fears, guilts, and attractions)
- Mental processes – sets of operations that work together to carry out a function, such as attention, perception, or memory

All brain activity hinges on the workings of neurons – cells that receive signals from sense organs or other neurons, processes these signals, and sends the signals to muscles, organs, or other neurons; the basic unit of the nervous system.
Neurons are like computers: They accept *inputs* (typically 100s of signals at the same time), operate on them, and produce *outputs* (signals that are transmitted).

3 types of neurons:
- Sensory neurons – neurons that respond to signals from sensory organs and transmit those signals to the brain and spinal cord
- Motor neurons – neurons that send signals to muscles in order to control movement (and also to bodily organs, such as glands)
- Interneurons – neurons that are connected to other neurons, not to sense organs or muscles

A large number of neurons work together to accomplish any particular task. Neurons are organized into brain circuits – sets of neurons that work together to receive input, operate on it in some way, and produce specific output.

Structure of a Neuron: The Ins and Outs
→ ***See p. 44, Figure 1 for the Major Parts of a Neuron***

Cell body – central part of a neuron (or other cell), which contains the nucleus; controls the cell's metabolic activities and integrates inputs
Cell membrane – the "skin" that surrounds the cell
Axon – the sending end of the neuron; the long cable-like structure extending form the cell body; conducts the nerve impulse away from the cell body
- Axons can be branched, allows neurons to send a message to more than one place at a time
- Each neuron only has 1 axon

Terminal button – structure at the end of the branch of an axon that can release chemicals into the space between neurons when their neuron has been triggered
Dendrite – the treelike art of a neuron that receives messages from the axons of other neurons or from the environment

Neural Impulses: The Brain in Action
The inputs and outputs of neurons are chemicals!

Neurons are either at rest or they are sending signals – outputs – to other neurons.
When at rest, they maintain a negative charge within them; this negative charge is the Resting potential – arises because of how ions are distributed inside and outside the cell.
- During rest, more positively charged ions (consisting mostly of sodium ions) are outside the neuron than are inside it, and more negatively charged ions are inside the neuron than are in the surrounding fluid.

Please pardon any spelling errors or typos!

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A neuron "fires" when the dendrites (and in some cases, the cell body) receive appropriate inputs from other neurons. When this occurs, very small pores (channels) open in the membrane that covers the axon. When these channels open, a complex exchange of ions occurs, with some ions flowing into the cell from the surrounding fluid and some ions flowing from inside the cell to the surrounding fluid.

1. Na+ channels open after the neuron is stimulated, and Na+ ions rush into the cell; the inside of the cell then becomes positively charged.
2. The Na+ channels close, K+ channels briefly open, and K+ ions go outside the cell. The K+ ions are pushed out because of the addition of the positively charged Na+ ions.
3. Na+ pumps actively push Na+ ions back outside, and K+ ions are drawn inside until the inside and outside concentrations are returned to their original levels.
4. When the ion exchanges reach the end of the axon, they cause chemicals to be released from the terminal buttons.

Action potential – the shifting change in charge that moves down the axon (i.e.: steps 1 – 4)

- All-or-none law – states that if the neuron is sufficiently stimulated, it fires, sending the action potential all the way down the axon and releasing chemicals from the terminal buttons; either the action potential occurs or it doesn't

Most axons are covered in myelin – fatty substance that helps impulses efficiently travel down the axon

- *Multiple sclerosis (MS)* – myelin deteriorates, so action potentials "stumble" as they move down the axon

Neurotransmitters: Bridging the Gap

Synapse – the place where an axon of one neuron sends signals to the membrane (on a dendrite or cell body) of another neuron; the synapse includes the sending portions of an axon, the receiving portions of the receiving neuron, and the space between them

Synaptic cleft – gap in the synapse between the axon of one neuron and the membrane of another across which communication occurs

1. Action potential reaches the end of the axon
2. Synaptic vesicles release neurotransmitters into the synaptic cleft
    a. Neurotransmitter substance – chemical that carries a signal from the terminal button of 1 neuron to the dendrite or cell body of another
3. Neurotransmitters bind to receptors and the action potential is transmitted

Chemical Messages: Crossing the Gap

Neurotransmitter molecules are contained in small sacs (vesicles).

➔ ***See p. 47, Table 1 for Major Neurotransmitter Substances***

- Acetylcholine
- Dopamine
- Noradrenaline
- Serotonin
- GABA
- Endogenous cannabinoids – neurotransmitter substances released by the receiving neuron that then influence the activity of the sending neuron
    - Function: fine-tune activity underlying learning, memory, pain perception, attention
    - Found in: marijuana

Receptors: On the Receiving End

Once they cross the synaptic cleft, neurotransmitters will affect different types of receiving neurons in different ways.

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Each neuron has <u>receptors</u> – specialized site on a dendrite or cell body where a neurotransmitter molecule attaches itself, like a lock that is opened by one key, a receptor receives only one type of neurotransmitter.

2 general types of effects of neurotransmitter binding:

1. *Excitatory inputs* – the receiving neuron is more likely to have an action potential
2. *Inhibitory inputs* – the receiving neuron is less likely to have an action potential
    a. The excitatory and inhibitory inputs to each receiving neuron add up or cancel one another out, and only when their sum total is large enough will an action potential be initiated

<u>Reuptake</u> – process by which surplus neurotransmitter in the synaptic cleft is reabsorbed back into the sending neuron so that the neuron can effectively fire again

Unbalanced Brain: Coping with Bad Chemicals

<u>Agonist</u> – chemical that mimics the effects of a neurotransmitter by activating a type of receptor

Other drugs can increase the amount of a neurotransmitter in the synapse, sometimes by slowing down its reuptake.

- Ex: depression is treated with <u>selective serotonin-reuptake inhibitors (SSRIs)</u> – block the reuptake of the neurotransmitter serotonin (Prozac, Zoloft, Paxil are SSRIs)

<u>Antagonist</u> – chemical that blocks the effect of a neurotransmitter

Parkinson's Disease – evidence of connection between neurotransmitters and behavior

- Caused by death of cells that produce dopamine
- When given L-dopa (drug that helps produce dopamine), symptoms decrease, but L-dopa becomes less effective with continued use

Neurotransmitters are used widely throughout the brain, so their disruption would create more widespread difficulties

Glial Cells: More Than the Neurons' Helpmates

The average human brain contains 10x as many glial cells as neurons.

<u>Glial cells</u> – type of cell that helps neurons to form both synapses and connections when the brain is developing, influences the communication among neurons, and generally helps in the "care and feeding" of neurons

- Physically cushion neurons
- Clean up the remains of dead neurons
- Dispose of extra neurotransmitters and ions in the fluid surrounding neurons
- Provide nutrients to neurons

Neurons and Glia: A Mutually Giving Relationship

Neurons have synapses with glial cells, stimulate glial cells to release specific chemicals
Glial cells can directly regulate how strongly one neuron affects another
Glial cells coordinate the activity of vast sets of brain circuits
Glial cells can prod neurons to form additional synapses

Glial Networks: Another Way to Think and Feel?

Glial cells do not produce action potentials. They communicate by passing chemicals directly through their walls to adjoining glia or by releasing (into brain fluid that surrounds the cells) molecules that affect both neurons and other glia. Chemicals released by one glial cell can induce other glial cells to release chemicals → → ripple effect!

We're still not entirely sure what glial networks do, but we know that they are important for a wide range of brain functions.

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THE NERVOUS SYSTEM: AN ORCHESTRA WITH MANY MEMBERS

The Peripheral Nervous System: A Moving Story

2 parts of the <u>Peripheral Nervous System (PNS)</u>:

1. <u>Autonomic Nervous System (ANS)</u> – controls the smooth muscles in the body, some glandular functions, and many of the body's self-regulating activities, such as digestion and circulation
    - Controls activities not under conscious control
        1. <u>Sympathetic Nervous System</u> – part of the ANS that readies an animal to fight or to flee by speeding up the heart, increasing breathing rate to deliver more oxygen, dilating the pupils, producing sweat, decreasing salivation, inhibiting activity in the stomach, and relaxing the bladder
        2. <u>Parasympathetic Nervous System</u> – part of the ANS that is "next to the sympathetic nervous system and that tends to counteract its effects (ex: slows down heart rate, contracts the pupils, increases salivation, stimulated digestion, and contracts the bladder)
            - Sympathetic nervous system tends to affect all the organs at the same time. Parasympathetic nervous system tends to affect organs one at a time or in small groups.
2. <u>Sensory-Somatic Nervous System (SSNS)</u> – part of the PNS that consists of the neurons in the sensory organs (such as the eyes and ears) that convey information to the brain as well as neurons that actually trigger muscles and glands
    a. <u>Somatic Motor System</u> – consists of nerves that are attached to muscles that can be used voluntarily (striated muscles)

The Central Nervous System

2 parts of the <u>Central Nervous System (CNS):</u>

1. <u>Spinal cord</u> – flexible rope of neurons and their connections that runs inside the backbone (spinal column)
2. <u>Brain</u>

The Spinal Cord: Getting Inside the Backbone

The spinal cord is organized into 2 large tracts:

1. 1 runs along the front side (facing forward) – sends the brain's commands to the body
2. 1 runs along the back side (facing backward) – registers information about the body and conveys that to the brain

At each of 31 places, each tract is connected to eh body by a pair of spinal nerves, one that goes to the left side of the body, and one that goes to the right side.

The spinal cord can initiate some aspects of our behavior.

- Ex: <u>reflex</u> – automatic behavioral response to an event; allows you to respond immediately, bypassing the brain for more efficient signal-response
    - o Why do we need interneurons then?
        - ▪ Interneurons allow the brain to send signals to prevent a reflex response

The Visible Brain: Lobes and Landmarks

<u>Meninges</u> – three protective layered membranes that cover the brain

<u>Cerebral hemisphere</u> – a left or right half-brain; shaped roughly like a sphere

- Each hemisphere receives information from, and controls the muscles of, the opposite side of the body
- 4 lobes:
    1. occipital
    2. temporal
    3. parietal
    4. frontal

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Corpus callosum – large bundle of axons that connects the 2 halves of the brain
Cerebral cortex – the convoluted pinkish-gray outer layer of the brain where more mental processes arise; 2 mm thick; contains the cell bodies of neurons; aka gray matter

- Sulci – creases in the cerebral cortex
- Gyri – bulges between the sulci in the cerebral cortex
- The cortex is crumpled up so that more of it can be stuffed into the skull

Subcortical structures – parts of the brain located under the cerebral cortex; also contain gray matter

Spotlight on the Brain: How It Divides and Conquers
Brain system – set of brain circuits that work together to accomplish a particular task

The Cerebral Cortex: The Seat of the Mind

Occipital Lobes: Looking Good
Occipital lobes – brain lobes at the back of the head; concerned entirely with different aspects of vision

- Most of the signals from the eyes arrive at these lobes
- Contain many separate areas that work together to characterize properties of viewed objects (ex: shape, color, motion)
- Damage here can cause partial / complete blindness
- If the left occipital lobe is removed, you won't be able to see things in the right visual field

Temporal Lobes: Up to Their Ears in Work
Temporal lobes – brain lobes under the temples, in front of the ears; among its many functions are processing sound, entering new information into memory, storing visual memories, and comprehending language

Parietal Lobes: Inner Space
Parietal lobes – brain lobes at the top, rear of the brain; among their functions are attention, arithmetic, touch, registering spatial location

- Somatosensory strip – gyrus immediately behind the central sulcus; registers sensations on the body and is organized by body part
    - Larger areas of this gyrus correspond to areas of the body that are more sensitive (ex: lips, hands)

Frontal Lobes: Leaders of the Pack
Compared to the monkey brain, the human brain has much larger frontal lobes
Frontal lobes – brain lobes located behind the forehead; critically involved in planning, memory search, motor control, speech control, reasoning, emotions

- Motor strip – gyrus immediately in front of the central sulcus; controls fine movements and is organized by body part; aka primary motor cortex
    - Larger areas are dedicated to parts of the body that we control with precision (ex: hands, mouth)

Phineas Gage – metal bar through the front part of his head.

- Previously, he had been responsible and organized; afterward, he led a disorderly life.
- Couldn't stick to a decision; little self-control; profane language

The Dual Brain: Thinking with Both Barrels

Split-Brain Research: A Deep Disconnect
The most compelling evidence that the 2 half-brains perform distinct functions has come from looking at the effects of severing the corpus callosum.

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Split-brain patient – person whose corpus callosum has been severed for medical reasons, so that neural signals no longer pas from one cerebral hemisphere to the other

- Procedure often done to help patients with severe, otherwise untreatable epilepsy – disease that causes massive uncontrolled neural firing in parts of the brain, leading to bodily convulsions

The *left half* of each eye sends signals to the left hemisphere; the *right half* of each eye sends signals to the right hemisphere. Normally, this information quickly crosses over to the other hemisphere, so the entire brain receives signals from both halves of each eye. However, when the corpus callosum is cut, the signal stays in the hemisphere that initially receives the information.

Experiment: present pictures / words to only the left or right side of space

- Gazzaniga & LeDoux (1978) – presented a picture of a snow scene to the right hemisphere (controlled left hand; spatial attention; processing nonverbal cues) and at the same time, a picture of a chicken's claw to the left hemisphere (controls right hand, speech, reasoning)
  - The split-brain patient then had to select pictures that were related to these stimuli
    - Right hand (controlled by left hemisphere): selected chicken picture
    - Left hand (controlled by right hemisphere): selected shovel picture
    - Speech: said he saw the claw, picked chicken; made up a story to reason why shovel was chosen

Hemispheric Specialization: Not Just for the Deeply Disconnected

You can't simply say that the left brain is verbal / analytical; right brain is perceptual / intuitive

- Ex: left brain is actually better than the right at some aspects of interpreting sensory information; right brain is actually better than the left at some aspects of language

When the hemispheres differ in their functions, they typically differ in their abilities to eprform very narrow, specific tasks.

Beneath the Cortex: The Inner Brain

→ See p. 59, Figure 12 for Key Subcortical Brain Areas

Forebrain – cortex, thalamus, limbic system, basal ganglia

Thalamus: Crossroads of the Brain

- "switching center" → messages are received, redirected to the appropriate destination
- Sensory systems (ex: vision, hearing), motor systems that control muscles have connections here, before routing to other parts of the brain
- Role in controlling sleep, attention

Hypothalamus: *Thermostat and More*

- Sits under the thalamus
- Critical for maintaining bodily functions – eating, drinking, body temperature, blood pressure, heart rate; governs sexual behavior; regulates hormones

Hippocampus: Remember It

- Looks like a "seahorse"
- Plays a key role in allowing us to enter new information into the brain's memory banks
- H.M. – bilateral removal of hippocampus to control epilepsy; could no longer learn new facts
  - Memory for events that occurred a year or so before the operation seemed normal, but he was stuck at that stage of his life.
  - Was not particularly aware of deficit
- Although the hippocampus itself does not permanently store memories, it triggers processes that store new information elsewhere in the brain

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Amygdala: Inner Feelings
- "almond" shaped
- Plays a special role in strong emotions, ex: fear, anger
- Affects whether a person can correctly interpret emotions in facial expression

Limbic System – hippocampus, amygdala, hypothalamus

Basal Ganglia: More than Habit Forming
- Positioned on outer sides of thalami
- Involved in planning and producing movement
- Play a central role in forming / learning habits (NOT learning facts!)
- Relies on dopamine
  - People with Parkinson's Disease often have abnormal functioning of their basal ganglia
- *Nucleus Accumbens* – part of the basal ganglia; also needs dopamine for operation
  - Plays a crucial role in the brain's response to reward, anticipation of reward
  - Drugs like cocaine, amphetamine, alcohol affect the nucleus accumbens

Brainstem: The Brain's Wake-Up Call
- Medulla – lowest part of the brainstem; important in automatic control of breathing, swallowing, blood circulation
- Reticular formation – 2 main parts:
  - Reticular activating system – plays a key role in keeping you awake; making you perk up when something interesting happens
  - Other part – receives input from the hypothalamus; plays a key role in producing ANS reactions; involved in conducting impulses from muscles not under voluntary control to those under voluntary control
- Pons – bridge connecting the medulla and midbrain; connects the upper parts of the brain to the cerebellum; involved with a variety of functions, ranging form regulation of sleep to control of facial muscles

Cerebellum: Walking Tall
- Physical coordination, estimating time, paying attention
- The surface area of the cerebellum is nearly the same size as that of the entire cerebral cortex

Hindbrain – medulla, pons, cerebellum, parts of the reticular formation
Midbrain – grouping of the remaining brainstem structures

The Neuroendocrine and Neuroimmune Systems: More Brain-Body Connections
The brain has a total of 4 mechanisms that directly affect the body:
1. Somatic motor system – moving muscles voluntarily
2. Autonomic nervous system – regulates involuntary muscles, heart
3. Hormones – the brain produces hormones, controls production of hormones elsewhere in the body
4. Immune responses – the brain makes us more or less able to fight off the onslaught of disease, repairs damage to the body from injury

The Neuroendocrine System: It's Hormonal!
Hormones – chemicals that are produced by a gland and can act as a neurotransmitter substance; affect organs of the body, thoughts, feelings, behaviors
Neuroendocrine system – makes hormones that affect many bodily functions; provides CNS with information
➔ ***See p. 62, Figure 14 for The Major Endocrine Glands***

Important hormones:
- Testosterone
- Estrogen
- Cortisol

Pituitary gland – "master gland" that regulates other glands, but is itself controlled by the brain, primarily via connections from the hypothalamus

The Neuroimmune System: How the Brain Fights Disease
Hypothalamic-pituitary-adrenal (HPA) axis – system is activated by stress, injury, and infection and that works to fight off infection
- Produces cortisol, but too much cortisol can interfere with immune system (i.e.: being stressed out can make you more likely to catch a cold, etc.); damage the brain / hippocampus (interfere with storing new information in memory)

PROBING THE BRAIN

The Damaged Brain: What's Missing?
The first evidence that different parts of the brain do different things came from accidents in which people suffered damage to the brain
Lesion – region of impaired brain tissue
Stroke - most frequent cause of brain damage; occurs when blood fails to reach part of the brain (usually because a clot clogs up a crucial blood vessel), and thus neurosn in the affected area die
Researchers study patients with brain damage to learn which specific abilities are disrupted.

Recording Techniques: *The Music of the Cells*
Electroencephalograph – machine that records electrical activity in the brain
Electroencephalogram (EEG) – tracing of brain waves of electrical fluctuation over time
- When neurons fire together, the electric fields they produce can be detected by electrodes placed on the scalp.

Magnetoencephalography (MEG) – technique for assessing brain activity that relies on recording magnetic waves produced by neural activity
- Neural firings also produce magnetic fields that can be detected.
- Good for recording very fast changes in neural firing

Neither EEG nor MEG is very sensitive to activity in subcortical brain structures

Single-cell recording – technique in which tiny probes (microelectrodes) are placed in the brain and used to record neural firing rates

Neuroimaging: Picturing the Living Brain

Visualizing Brain Structure
Computer-assisted tomography (CT or CAT) – neuroimaging technique that produces a 3D image of brain structures using X-rays
Magnetic resonance imaging (MRI) – technique that uses magnetic properties of atoms to take sharp pictures of the 3D structure of the brain

Visualizing Brain Function

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The more frequently neurons fire, the more blood, oxygen, and nutrients they require. The amounts of these substances in a particular part of the brain indicate how vigorously neurons in that region are firing

Positron emission tomography (PET) – neuroimaging technique that uses small amounts of a radioactive substance to track blood flow or energy consumption in the brain (radioactive substance is taken up into different brain areas in proportion to how vigorously the neurons in each area are firing

Functional magnetic resonance imaging (fMRI) – type of MRI that detects the amount of oxygen being brought to particular places in the brain, which indicates how active those neurons are

All neuroimaging techniques provide evidence for *correlations* between performing a task and activation of a specific brain region. They do not establish that activated brain regions play a *causal* role in producing the behavior. To make this connection, we need other techniques!

Stimulation: Inducing of Inhibiting Neural Activity

1. Open skull, apply mild electric current delivered directly to parts of exposed cortex, report what person experiences while current is being applied
    a. Wilder Penfield pioneered this method; people experience different images, memories, feelings depending on the area in the brain that is stimulated
    b. Results are difficult to interpret because rwe can't be sure whether actual memories are activated, whether new experiences are being created at the time, or even whether the person is making up stories
    c. Alternatively, you can observe which activities are disrupted when current is applied
        i. This is limited because stimulating particular neurons can activate other ones, etc. etc.
    d. Nevertheless, advances in microstimulation of nonhuman animals have allowed us to stimulate a few neurons at a time and observe the direct consequences on an animal's perceptions, decisions, and actions
2. Transcranial magnetic stimulation (TMS) – technique in which the brain is stimulated from outside by putting a coil on a person's head and delivering a magnetic pulse (or series of magnetic pulses); the magnetic fields are so strong that they make neurons under the coil fire
    a. When neurons are repeatedly stimulated in this way, they become temporarily unresponsive. By showing that temporarily disrupting a particular brain area in turn temporarily disrupts a particular type of behavior, TMS lets us show that a brain area plays a causal role in a particular type of mental processing

Each of these techniques have strengths and weaknesses!
➔ ***See p. 69, Table 2 for Key Characteristics of Various Techniques Used to Study Brain Function***

GENES, BRAIN, AND ENVIRONMENT: THE BRAIN IN THE WORLD

Genes as Blueprints: Born to Be Wild?
Mendelian inheritance – the transmission of characteristics by individual elements of inheritance (now known to be genes), each acting separately
Gene – stretch of the DNA molecule that produces a specific protein
Genotype – genetic code within an organism
Phenotype – observable structure and behavior of an organism
Complex inheritance – transmission of characteristics by the joint action of combinations of genes working together; aka *polygenetic inheritance*

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Tuning Genetic Programs: The Environment Matters

Genes provide the blueprints for building cells and govern the way the brain is wired up before birth. But they cannot program the entire brain in advance! The brain will eliminate the connections that turn out not to be useful.

→ The wiring of the brain depends partly on the genes and partly on experience.

Pruning – process whereby certain connections among neurons are eliminated

- Connections that are used frequently are retained, while others that are not used frequently are pruned away.

Interactions with the environment not only select among connections established by the genes but can also cause new connections to form.

Plasticity – the brain's ability to change as a result of experience; pruning and adding new connections; most evident during:

1. Infancy, childhood
2. When the body changes so that the sensory input changes (ex: amputating a limb)
3. When we learn something new or store new information
4. As compensation after brain damage

Adult brains are not as plastic as the brains of children

- The adult brain loses plasticity with age because the functions of neurons and brain circuits become set in place with experience
- In some regions, though, adult brains can create new neurons

Our genes specify the range of what is possible, and the environment then operates to set up the brain within this range.

Genes and Environment: A Single System

Interactions with the environment cause many genes to be turned on and off, and when they are turned on, they have specific effects on your body and brain.

By regulating brain activity, genes affect behavior

Genes and the environment are *different aspects of a single system*.

Environment and Genes: A Two-Way Street

Passive interaction – occurs when genetically shaped behavioral tendencies of parents or siblings produce an environment that is passively received by the child

Evocative (or reactive) interaction – occurs when genetically influenced characteristics (both behavioral and physical) induce other people to behave in particular ways

Active interaction – occurs when people chose, partly based on genetic tendencies, to put themselves in specific situations and to avoid others

Behavioral Genetics – the field in which researchers attempt to determine the extent to which the differences among people's behaviors and psychological characteristics are due to their different genes or to differences in their environments

Heritability, Not Inheritability

Heritability – the degree to which the variability of a characteristic or ability in a population is due to genetics – given a specific environment

- If the environment were different, the heritability might be different as well.

Twin Studies: Only Shared Genes?

- Compares identical and fraternal twins to determine the relative contribution of genes to variability in a characteristic or ability
- Identical (monozygotic) twins have virtually identical genes; fraternal (dizygotic) twins share only as many genes as any other pair of siblings

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Twin studies have shown that the amount of gray matter in the brain is more similar in identical twins than in fraternal twins, which suggest that the amount of gray matter, is in part, under genetic control. (ex: frontal lobes; temporal lobe involved in language comprehension)

Adoption Studies: Separating Genes and Environment?
- Characteristics of children adopted at birth are compared to those of their adoptive parents or siblings versus their biological parents or siblings
- Especially powerful for twins separated at birth, growing up in different environments
  - It is always difficult to separate genetic from environmental influences

Evolution and the Brain: The Best of All Possible Brains?
<u>Evolution</u> – gene-based changes in the characteristics or abilities of members of a species over successive generations

Natural Selection: Reproduction of the Fittest
<u>Natural selection</u> – occurs when individuals with inherited characteristics that contribute to survival have more offspring, and over time those characteristics come to be widespread in a population
<u>Adaptation</u> – an inherited characteristic that increases an organism's ability to survive and reproduce successfully

Evolution via natural selection tends to mold the characteristics of a group of organisms to the requirements of their environment.
Important principles:
- Environment
- Variation
- Random variation

Not Just Natural Selection
Always exercise caution when trying to use the idea of natural selection to explain our present-day characteristics. Just because a characteristic exists doesn't mean that it is an adaptation to the environment or that it is the result of natural selection.