This exercise introduces the nervous system and its functions. It introduces these topics:

- The relevance of the nervous system to psychology.
- The two basic specialized functions of the nervous system: Communication (transmitting information) and integration (combining information). Coding: All mental and behavioral activity is coded or represented in the nervous system.
- The functions of neurons ("nerve cells"): the specialized cells in the nervous system, which are designed for communication and integration of information.

The exercise outlines the division of the nervous system into two major parts:

- The central nervous system (CNS). The brain inside the skull and the spinal cord inside the vertebral column (backbone) form the CNS.
- The peripheral nervous system (PNS): The sensory part of the PNS brings information to the central nervous system from the senses (eyes, ears, balance, gut, joint position, etc.). The motor part takes information from the central nervous system to control the action of muscles and glands.

After you have finished the exercise you should understand

- Why most psychologists accept the idea that mental and behavioral activity depends on brain activity.
- What communication and integration are and how they occur.
- What coding in the nervous system means.
- How the PNS carries information into the CNS from the senses and out of the CNS to control muscles and glands.

The Nervous System and Psychology

Development creates your body and your mind by a continuous interaction between the action of genes and of environment. For psychology, the most important result of development is the nervous system. As far as anyone knows, activity in the nervous system is the proximal ("closest to" ~immediate, direct,) cause of all psychological and behavioral processes.

This means that the nervous system has a unique pattern of activity in it for each behavior you do, each mental process you produce, and each experience you have. "Mental" illness, personality, learning, memory, perception, etc. all appear to reflect specific patterns of activity in the nervous system. Therefore, many psychologists believe that the study of the nervous system is very useful for understanding psychological processes.

Figure 1-2a shows the two main parts of the nervous system, the Central Nervous System (CNS) and the Peripheral Nervous System (PNS). The CNS consists of the brain in the skull and spinal cord in the spinal column ("backbone"). The PNS consists of the nerves from the senses (eyes, ears, skin, balance, etc.) to the CNS and the nerves from the CNS to the muscles and (many) glands of the body.

Figure 2-2a shows a drawing of the main parts visible on the surface of this organ system for the mind. Link to a brief history of this idea.
The nervous system is specialized for communication and integration of information. All organ systems have specialized functions. For example, the respiratory system gets oxygen from the air and removes carbon dioxide from the body. The cardiovascular (cardio = heart, vascular = blood vessels) system is specialized to move blood throughout the body. The specialized function of the nervous system is to manage the body's information. It sends information from one place to another -- communication -- and it coordinates information from many different sources -- integration. (Masterton, 1970). As far as anyone knows, these two specialized functions are based on the codes that stand for and produce all your actions, feelings, and thoughts.

Match the following with the part of the nervous system they fit best.

Q1A. The Central Nervous System collects information from all parts of the head and body and uses it to select appropriate responses.
Q1B. what is happening in your brain as you read this.
Q1C. The Peripheral Nervous System connects from the senses(e.g., ears, eyes) to the Central Nervous System and from the Central Nervous System to the muscles and glands.

1. communication  2. integration  3. proximal cause

For psychology, the most important question about the nervous system is: "How does the nervous system code or represent psychological and behavioral processes?" For example, what happens in the brain that:

1. lets you remember the practical joke you pulled on your brother last year, or that elephants live in Africa and South Asia?
2. makes you feel happy or sad?
3. lets you anticipate (~expect) the consequences of what you.
4. lets you plan tasks you need to do (buying groceries so you won't run out; planning time to balance work, studying, and fun, etc.)?
5. makes injuries more painful or less painful under different conditions?
The list is as long as the list of things people do and feel.

The nervous system uses two basic codes:

1. **place codes**: where activity is in the brain; This works as a code because different parts of the brain do different things. Such codes are usually called labeled line codes or anatomical codes.
2. **pattern codes**: the pattern of activity of the brain in time and space

Although many psychologists do their work that ignores the nervous system, many (most?) would agree that mental events reflect patterns of activity in the brain. For this reason, more and more psychologists have started to use information and ideas about the nervous system as tools in their psychological work. The relation between brain processes and psychological processes is reciprocal. Psychological processes show what to look for in the nervous system, and processes in the nervous system show how psychological processes may work.

Which of the following is a reason that many psychologists are interested in how the nervous system works?

Q2A. T F Mental processes reflect and are coded by patterns of activity in the brain.
Q2B. T F Once the way the brain is well understood, psychology will be unnecessary, because the study of brain function is more scientific.
Q2C. T F Understanding how the brain codes a mental process can help understand how that mental process works psychologically.
Q2D. T F Mental processes are the proximal cause of brain activity.

The nervous system is made of specialized nerve cells called neurons. The human brain contains an estimated 100 billion (10¹¹) to 1 trillion (10¹²) neurons (far too many to count individually). Neurons are specialization for communication and integration, both in how they work and how they connect to each other. Neurons use electrical signals to integrate information they get from other neurons. They use electrical and chemical signals to communicate with other neurons.

The nervous system has another kind of specialized cell called glia. In the past, glial cells were described as protecting and supporting the neurons. Recent research has shown that they also modify the action of neurons and contribute to the brain's integrative functions (Gallo & Chittajallu, 2001).
Methods of studying the nervous system

Many methods and techniques show that brain activity codes or represents mental and behavioral activity. They include:

! **Brain anatomy** is the starting point for all other methods. The modern study of anatomy began in 16th-century Italy. Until about 1975 human brain anatomy could be studied only in post-mortem (after death) specimens. Figure 3-2a is an example. Then instruments appeared that created computer-generated images of the structure and function of the normal living brain without invading the body surgically (see below).

! **Brain damage in different parts of the brain** produces different mental and behavioral disturbances. This is the oldest method for studying brain organization and function. The earliest case in modern medical history is that of Phineas Gage. In 1848 he suffered an industrial accident, which severely damaged the front end of his brain. Remarkably he recovered and lived another 12 years. Although he recovered most of his physical abilities, his personality was completely and permanently changed. He became a psychopathic liar and lost most of the social inhibitions needed to function with other people. Subsequently, neurologists (physicians who specialize in brain diseases) and psychologists have shown that lesions (~damage) in different brain areas produce different disturbances in mental and behavioral function, as illustrated in Figure 4-2a. Link to the a website devoted to Phineas Gage.

! **Electrical, chemical, and, recently, magnetic stimulation in different parts of the brain** elicit (~trigger) different behavioral and mental reactions when delivered to different locations. A very important experiment (Olds & Milner, 1953) showed that electrical stimulation through fine electrodes in a brain area called the hypothalamus was a strong reinforcer. (This discovery was an accident in two ways. The electrodes were way off target, and Olds and Milner were looking for effects on learning and memory. They noticed the rats returned repeatedly to the place where they got the stimulation and realized this was reinforcement.) Rats and other animals press a lever thousands of times an hour for many hours to turn on 0.5-second pulses of weak electrical stimulation, as shown in Figure 5-2a.

! **Measurement of electrical and chemical activity** from different parts of the brain shows activity changes in different parts of the brain during different mental and behavioral activity. The EEG (“brain waves” or
electroencephalogram), first discovered in 1929, uses silver disk electrodes on the scalp (Figure 6-2a) to detect weak electrical activity from the outer surface of the brain just below the electrodes. Figure 7-2a shows 2-second segments of the EEG during waking, light sleep, and deep sleep.

The newest of these techniques, the computerized PET and fMRI scans, can follow second-by-second changes in activity in the brain of normal, conscious humans. Figure 8-2a shows activity changes in the human brain during speech. The yellow and red areas indicate high activity, the green indicates average activity, and the blue indicates low activity.

[Mark EACH item True (T) or False (F)] Schizophrenia is a severe “mental” disease. If the brain is the basis of all mental and behavioral activity, you can expect that __. Hint A Hint B Hint C Hint D
T F Q4A. brains of people with this disease show evidence of damage
T F Q4B. medication can help relieve symptoms of schizophrenia
T F Q4C. the abnormal mental activity in schizophrenia makes measurements of brain function with scanning methods impossible
T F Q4D. measurements of brain activity of people with schizophrenia will show some differences from those of normal people

Link to a fact sheet summarizing information about schizophrenia.
Link to an extensive source of information about schizophrenia.
Link to as summary of brain scanning used to study behavioral and psychological functions.

The Main Parts of the Nervous System

The nervous system has several subsystems, with different specialized functions. Figure 9-2a summarizes the two main divisions of the nervous system: the Peripheral Nervous System (PNS) (peripheral ~ edge) and Central Nervous System (CNS) and the sub-divisions of the PNS. Figure 9-2a shows the location of the PNS and CNS in the body. The subdivisions of the CNS are described in asgn2c-e.

The main thing to understand about CNS is this: Activity in the Central Nervous System is the basis of all mental and behavioral activity, as far as anyone can tell. It contains >99% of all the neurons (~nerve cells) and consists of:

! the spinal cord running down the middle of the vertebral column (“backbone”), which carries out the simpler levels of behavioral organization.
! the brain in the skull, which carries out the higher, more complex mental and behavioral activities.

The Peripheral Nervous System (PNS) gets all information into the brain (and therefore to the mind) and controls directly all responses you make, because it:

! connects the senses (hearing, touch, etc.,) to the CNS
! connects the CNS to the muscles and glands

The PNS consists of the nerves going to and from the central nervous system. A nerve is a bundle of nerve fibers (called axons, the part of neurons that carries signals from one place to another; see below).

Match the following with the part of the nervous system they fit best.
Q5A. contains most of the neurons in the human nervous system
Q5B. the brain in the skull and the spinal cord in the vertebral column
Q5C. connects the brain and spinal cord to sense organs (e.g., the ear) and muscles and glands
Q5D. muscles and glands

1. peripheral nervous system 2. central nervous system 3. not part of nervous system
Properties of Neurons

This exercise describes neurons briefly; Exercise asgn2f describes them in more detail. The “typical” neuron (nerve cell), illustrated in Figure 10-2a, has three specialized parts, in addition to the cell body (or soma), which carries out the basic life processes. These three parts are:

1. Several dendrites, which form the receiving end of a neuron. Most neurons have many, branching dendrites, which are covered with connections from other neurons. The dendrites converge at a single place, where the signals from other neurons are summed. Dendrites are designed both in shape and function to combine information they get from other neurons, so they are specialized for integration.

2. A single, wire-like axon which usually branches several times. The axon is long (up to 1.5 meters [5 feet]) long, but it is thin (less than 25 microns [1/1,000 inch]), like a wire. (Axons work very differently from the way metal wires work.) Axons are designed for communication both in shape and function. They carry information from the senses to the CNS, send information from one part of the CNS to another, or send signals from the CNS to muscles and glands.

3. Many axon terminals at the end of the axon branches. They make the connection from one neuron to the next.

Connections from one neuron to another are called synapses. Figure 11-2a is a diagram of a synapse. Synapses are formed by the axon terminal of one neuron and the dendrite of another. Between them is a tiny space called the synaptic cleft.

Synapses have several important features.

"Synapses are the only places where one neuron (normally) affects another."

"The axon terminal sends signals across the synaptic cleft to the dendritic membrane of another neuron by releasing chemical neurotransmitters."

"Psychologically active chemicals, which include recreational drugs and medications for "mental" illness, work by modifying transmission by specific neurotransmitters in specialized systems in the brain."

Match the descriptions of structures and functions of neurons with the part of a neuron they go with best.

Q6A. carries neural signals reliably from over long distances.
Q6B. axon terminal of one neuron, dendritic membrane of another neuron, and tiny cleft between them.
Q6C. connection from one neuron to another. Q6D. combines signals from many other neurons.
Q6E. the sending part of the connection from one neuron to another.
1.axon 2. dendrite 3.axon terminal 4.synapse

Neurons in the CNS code information by:

1. by responding only to a limited range of stimuli; the neuron's adequate stimulus.
2. by sending signals to specific location in the brain: labeled line or anatomical coding.
3. by the pattern of neural signals, both in individual neurons and across groups of neurons; this is called pattern coding.

For example, a neuron in your brain codes something about vision, if it responds only when light gets to the eyes. When such a neuron becomes active, it activates other neurons in the visual areas of the brain. The location and pattern of activity in the visual areas "tells" your mind something about the visual world. A different set of neurons and brain areas codes language-related processes. You can infer this if certain neurons or brain areas respond only when you are about to say something. Activity in such neurons is the way the mental processes of language "tell" the mouth, the vocal cords, and the lungs what to do to say what you want to say.
The amount (or strength) of a neuron’s activity codes the strength of the signals it gets. A small change in a neuron's activity signals (or codes) a small change in the stimulus that triggers the activity. A large change in activity signals a large change in the stimulus. For example, a neuron in your brain’s visual system gets a little more active, it signals that the light getting to your eye changed a little. When that neuron becomes much more active, it tells your mind that the intensity (~strength) of the light in your eyes has changed a lot.

Match the functions of communication, integration, and coding to the alternatives with which they go best.

**Hint:** Does the example relate to: 1. sending information from one place to another, 2. putting together information from different sources, or 3. something that happens in the brain during some specific psychological or behavioral process?

**Q7A.** A touch on the wrist sends signals to specific place in the brain.

**Q7B.** When neurons in specific places in the brain become active, your mind can tell that your wrist is getting touched.

**Q7C.** the part of the neuron that makes lots of branches, which receive synaptic connections from many other neurons

**Q7D.** the wire-like axon

**Q7E.** Seeing a talker’s mouth helps you understand the words s/he is saying. [Hint: does this describe something happening inside the mind/brain?]?

**1. communication  2. integration  3. coding**

**Match the following functions to the parts of the neuron listed below**

**Q8A.** neurons reacting to touch on a finger send messages to brain over these

**Q8B.** neurons in brain that combine information from touch and vision do the combining on these

**Q8C.** neurons from the senses (eyes, ears, etc.) make their connections to CNS neurons using these

**1. dendrites  2. axon  3. synapses**

**The Nervous System and the Endocrine System**

*The nervous system shares the functions of integration and communication with the endocrine system.* The endocrine system consists of glands (e.g., sex glands; adrenal glands above the kidneys; thyroid in the neck) and other organs, which release hormones. Hormones are chemical messengers that the blood spreads throughout the body. Most have several different targets and affect several different functions. For example, the gonads (~sex glands) secrete sex hormones that affect development of body structure, activity of the sex organs, and brain organization and activity. Figure 12-2a shows the location of some of the glands in the endocrine system.

**Q9.** The hormones are the ___ the endocrine system uses. They get to where they act by ____.

**A. chemical messengers; the blood stream  B. glands; their targets  C. nerve impulses; nervous system  D. chemical integrations; axons**

*Compared to the endocrine system, the nervous system acts faster and is much more differentiated (~separated into parts).* This difference makes the nervous system and endocrine system complementary (One system takes up where the other leaves off.). Specifically:

! The endocrine system takes seconds to act. The nervous system can act 1,000s of times faster.

! Many hormones have different targets scattered all over the body. Neurons have very specific targets with the nervous system, often only one or a few.

! The endocrine system usually acts tonically (~for a long while: minutes, hours, days). The nervous system acts phasically (changing quickly, often in milliseconds).

! The endocrine system has "global" (overall, general) effects. The nervous system produces very many different, precise, specific actions.

! The endocrine system is especially important in keeping the internal environment within normal limits (homeostasis - see asgn4m) over longer times (minutes, hours, days). Most of the nervous system controls your actions and reactions to the continuously changing external environment. The exception is the autonomic nervous system and its brain connections. This system is essential for regulating the internal environment more quickly (in a second) than the endocrine system can.
Mark each alternative below with the number by the system(s) that it matches best.

Q10A. chemical messengers spread throughout the body via blood  HINT
Q10B. fast, immediate reaction to external stimuli  HINT
Q10C. integration and communication  HINT
Q10D. rapidly changing, precise actions  HINT
Q10E. slow, long-lasting action  HINT
1. endocrine system  2. nervous system  3. both endocrine and nervous systems

The nervous system and the endocrine system work closely together. Each affects the function of the other.

The brain controls much of the endocrine system, mainly by controlling the pituitary gland located directly underneath the brain. The pituitary is often called the master gland of the body, because it releases hormones into the blood. Pituitary hormones control many other glands, including the adrenal cortex (a stress gland) and gonads (sex glands).

Many hormones strongly affect specific parts of the brain. For example, sex hormones from the gonads activate sexual behavior by stimulating brain areas that control sexual behavior. The stress hormones from the adrenal cortex influence many parts of the brain, including parts that deal with memory as well as parts that affect the internal environment.

Q11. The nervous system and the endocrine system can coordinate their actions because
A. the brain controls many hormones through the pituitary gland  B. the brain is affected by many hormones
C. they both use chemical messengers  D. A and B are both correct
E. A, B, and C are all correct  F. none of the above; the two systems are independent of each other

The study of the nervous system is now called Neuroscience. This subject combines all different approaches to understanding what the nervous system does and how it does it, from psychology and anthropology to molecular biology and genetics. The Society for Neuroscience serves as the umbrella organization for the study of the nervous system.

Link to some examples of the way ideas from the study of the nervous system have entered popular culture. Link to an extensive overview of the brain. Click HERE to go a source with many different links to sites related to the nervous system. Link to the Whole Brain Atlas, slices through the human brain created by MRI (magnetic resonance imaging). Click HERE to go to an overview of the nervous system and how it functions. Link a website with many different resources on the brain and its diseases, including "mental" illness. Click HERE for an article about development of brain function in human babies.

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asgn2b -- NERVOUS SYSTEM:
Peripheral Nervous System

This exercise describes the peripheral nervous system (PNS) [peripheral=away from center; edge]. The following exercises(asgn1c, d, e) deal with the central nervous system. The PNS carries information from the senses to the central nervous system (CNS) and from the CNS to the muscles and glands. The PNS has two parts: the externally directed somatic system and the internally directed autonomic system. The autonomic nervous system has opposing two parts: The sympathetic division, which is especially active during emergency situations, and the parasympathetic nervous system, which controls the body’s "housekeeping."

When you finish this exercise, you should be able to explain how information comes into the CNS from the senses and how it leaves the CNS to control muscles and glands. You should be able to explain how the brain controls the internal environment of the body through the autonomic nervous system.

The peripheral nervous system (PNS) connects the central nervous system (CNS) with the senses (eyes, taste, etc.) and with the body's muscles and glands. It has two kinds of nerves:
Sensory afferent nerve fibers from the body enter the spinal cord in the dorsal roots, which go into the dorsal (back) side of the spinal cord. Motor efferent fibers to the rest of the body leave the spinal cord in ventral roots from the ventral (front or stomach) side of the spinal cord. Figure 1-2b shows a cross section through the spinal cord with dorsal sensory roots entering the back and ventral motor roots leaving from the front of the spinal cord.

Match each item to the part of the peripheral nervous system with which it goes (not all alternatives are necessarily used).

Q1A. the nervous system outside the brain and spinal cord  
Q1B. travels over dorsal (toward the back) root  
Q1C. brings information from senses to the CNS  
Q1D. carries information between CNS and muscles & many glands

1. sensory part  
2. motor part  
3. both sensory and motor parts  
4. neither sensory nor motor part

The dorsal and ventral roots reach the spinal cord by passing between vertebrae (the individual bones that make up the spinal column or "backbone"). Figure 2-2b illustrates this. For clarity, the right side shows only dorsal roots, and the left side shows only ventral roots. Both sides have both kinds of roots.

Dorsal roots that are next to each other bring in sensory information from neighboring strips on the body, as illustrated in Figure 3-2b. These strips (which really overlap) are called dermatomes (derm = skin; tome = slice). They go from the body's midline on the back to the body's midline on the front or extend down the limbs. Each strip on the skin marks an area that connects to the spinal cord (mainly) through one dorsal root. We know this because cutting a dorsal root produces a strip around the body with decreased sensitivity to and distorted perception of touch. Cutting a ventral root makes the group of muscles it goes to weaker.

Pinching a root between the vertebrae above and below it can cause sensory or motor changes in the associated dermatome. The spaces between the vertebrae are padded with disks. Sometimes people develop a "slipped disk." The disk "wears out," and the vertebrae above and below that disk begin to press on each other. This can pinch the dorsal or ventral root that goes between them.
If the ventral root is pinched, the efferent (motor) nerve may be blocked, and the muscles it (partly) controls become weak. If the dorsal root is pinched, the sensory fibers may be stimulated by irritation, or they may be blocked. This makes the person feel tingling, pain, and/or numbness in the pinched dorsal root's dermatome. A neurologist (physician specializing in diseases of the nervous system) can often identify quite accurately where the slipped disk is from where the patient reports weakness, tingling, pain, or numbness.

Q2. Sam has a shooting pain that runs down the length of his left arm. It is probably the result of
A. pinching a vertebra between its neighbors
B. pinching the left dorsal root that carries information from the dermatome that hurts
C. pinching the left ventral root that carries information from the dermatome that hurts
D. stimulating the pain area on a particular vertebra
E. A and D are both correct

Q3. The upper right panel in Figure 4-2b shows the location of Sam's shooting pain (see Q2). Which of the numbers in the lower left panel best describes the location of the problem that causes Sam's pain? 1. 2. 3. (in cord) 4. 5. (in cord)

The Peripheral Nervous Systems.

The PNS has several divisions, as summarized in Figure 5-2b. The whole PNS is divided into the somatic division and the autonomic divisions. The somatic division carries signals "from the external senses (vision, hearing, touch, etc.) to the central nervous system. " from the central nervous system to the (striated) skeletal muscles, which move the body, the arms, legs, face.

The autonomic nervous system controls the insides of the body. " It carries information from inside the body to the CNS. " controls the action of internal organs, including - the gut and the cardiovascular system (heart, arteries) - the adrenal gland, which secretes adrenalin - other glands (salivary glands, tear glands, etc.)

The autonomic nervous system plays an essential role in keeping the body's internal environment in the proper range. The body keeps temperature, salt concentration, blood sugar, oxygen, carbon dioxide level in the blood, etc. within their normal ranges. These processes keep the body in a condition called homeostasis (See asgn3Q). The autonomic nervous system also plays a major part in emotional experience and expression (see asgn3q). When you are emotionally excited, the body shows many changes: blood pressure and heart beat increase, the mouth is often dry, stomach has "butterflies" in it. These and other body actions are controlled by the autonomic nervous system.

Match the following to the part of the peripheral nervous system with which it goes.
Q4A. connects CNS to muscles that move the body and to senses that get information from the outside world.
Q4B. your body's internal reaction when you barely avoid having a bad traffic accident.
Q4C. talking.
Q4D. keeping body temperature, blood sugar, carbon dioxide level normal.
Q4E. bundles of nerve fibers in body (outside the skull and vertebral column).
1. somatic division 2. autonomic division 3. both somatic and autonomic division

The Autonomic Nervous System also has two divisions: the sympathetic and the parasympathetic. They innervate (send nerves to; act on) the internal organs, but have antagonistic (opposing) effects on them.
The sympathetic division, shown in Figure 6-2b, is the emergency system. It quickly prepares the body to put out energy and to protect it from effects of injury. It shuts the gut down, speeds up the heart, increases blood pressure, dilates (makes bigger) the pupils of the eyes, makes more glucose (blood sugar) available in the blood for energy, etc. Cannon (1929) described these reactions as preparation for fight or flight.

The parasympathetic division, shown in Figure 7-2b, is the "housekeeping" division. It cleans up the mess that the activities of living produce (just as a housekeeper cleans up a house from the mess that living in it makes). The parasympathetic division's action is (almost) always the opposite of the sympathetic division. It activates the gut for digestion, slows the heart rate, decreases the blood pressure, etc.

Match the following effects with the part of the autonomic nervous system that produces it.

Q5A. heart rate slows  
1. parasympathetic division  
2. sympathetic division

Q5B. digesting a large meal  
1. parasympathetic division  
2. sympathetic division

Q5C. the body reactions to an unexpected loud sound  
1. parasympathetic division  
2. sympathetic division

Q5D. increased blood pressure  
1. parasympathetic division  
2. sympathetic division

This exercise
1. presents an overview of the central nervous system (CNS), consisting of the spinal cord and brain.
2. explains how information gets into and out of the spinal cord.
3. how the spinal cord organizes reflexes.
4. how the spinal cord sends information to the brain.
5. how the lower parts of the brain organize complex reflexes.

When you have completed this exercise, you should understand how the CNS is organized overall, how a reflex works and how it is affected by other activity in the CNS, and how the lower part of the brain partly resembles the spinal cord in its functions and partly has specialized functions of its own.

ORGANIZATION OF THE CNS
The preceding assignment described the basic properties of the Peripheral Nervous System (PNS). This assignment describes the basic properties of the Central Nervous System (CNS) and explains the basic structure and function of the spinal cord and its enlarged front extension, the brain stem.
Figures 1-2c and 2-2c show the three main levels of the CNS:

1. **The spinal cord** is a long cylinder inside the vertebral column ("backbone"). It is about as thick as your thumb.

2. **The brain stem** expands from the front end of the spinal cord. It becomes thicker and its internal structure becomes more complex as it enters the skull.

3. **The two cerebral hemispheres** are mushroom-shaped bulges on the front end of the brain stem. In mammals, especially humans, they take up most of the space inside the skull.

**The CNS is a very complex, highly organized structure**, the most complex thing known in the universe. The following principles will help you understand how it is put together.

1. **The CNS has two kinds of tissue**: grey matter and white matter. Grey matter, which has a pinkish-grey color in the living brain, contains the cell bodies, dendrites and axon terminals of neurons, so it is where all synapses are. White matter is made of axons connecting different parts of grey matter to each other. Figure 1-2c shows that grey matter (pink) is (mostly) on the outside of the cerebral hemispheres.

2. **The left side of the CNS receives information from and (primarily) controls the right side of the body**. The right side of the CNS is linked to the left side of the body in the same way. What you see to your left (through either eye, because both connect to both hemispheres) goes to the right side of the brain. When your right hand moves, the left side of the brain is directing its action.

3. **The front part** (toward the chest and abdomen, so the lower half in animals) **of the CNS organizes and controls movement**. The back half (toward the back, so the upper half in animals) **part receives and processes information from the senses.**
4. The CNS is organized in a hierarchy (organized in graded layers, higher layers controlling lower layers, as in military ranks [general > colonel > major > lieutenant > sergeant > private]). The hierarchy has three main levels, cerebral hemispheres > brain stem > spinal cord, as shown in Figure 4-2c. Each level controls the levels below it. Unlike most hierarchies, the higher the level the more parts in it, especially in humans.

! The spinal cord is the lowest level of the hierarchy. It:

- "receives sensory neurons from the body.
- "sends motor neurons to the muscles and some of the glands in the body.
- "does simpler reflexes, the simplest, most basic integration (coordination) of different body parts.

! The brain stem is the next level of the hierarchy. It is an expansion of the front end of the spinal cord. It does for (much of) the head what the spinal cord does for the body. In addition, the brain stem:

- "receives sensory neurons from the senses on the head (eyes, ears, balance, etc., but not smell) and the internal organs of the body (stomach, intestines, lungs, heart, etc.).
- "sends motor neurons to most muscles of the head and some glands.
- "sends sensory information to higher levels of the brain and gets motor plans and instructions from higher levels, which the patterned neural signals that control spinal activity
- "coordinates more complex reflexes and actions that involve many parts of the body.
- "activates (excites, wakes up) and inhibits (depresses, puts to sleep) the rest of the brain and spinal cord.

! The cerebral hemispheres are the highest level of the hierarchy. They bulge off the end of the brain stem. The cerebral hemispheres perform the highest levels of mental activity. They:

- "extract the important information coming from the sensory input from brain stem and spinal cord (selective attention and perception)
- "compare that information to past experience (memory) and interpret it (thinking, language).
- "choose and plan doing something and tell the lower level to do it.
- "coordinate actions of different parts of the brain stem and spinal cord.

5. The cerebral hemispheres got bigger as animals evolved more complex behavioral abilities. In simple vertebrates like frogs and fishes, they are small bumps on the brain stem. In mammals, especially primates, they are much larger, completely covering most of the brain stem. The mammalian cerebral hemispheres are the only ones that have a true cerebral cortex, which forms the grey matter on the outer surface of the cerebral hemispheres Figure 5-2c shows the change in relative size of the cerebral hemispheres in the brains of several species from fish to human. Figure 6-2c show photographs of the brains of 19 different mammalian species from the on-line Brain Museum.
Match the following with the best alternatives.

Q3A. combines information from eyes, ears, spinal cord, etc., to coordinate complex automatic body reactions  
Q3B. carries out simpler reflexes for the body  
Q3C. selects overall direction of behavior and mental processes  
Q3D. the largest and most highly developed part of the brain in humans; very small part of frog and fish brains  
Q3E. the part that recognizes the letters on the screen and selects the response  
A. spinal cord  B. brain stem  C. cerebral hemispheres

**SPINAL CORD: Simple Reflexes**

The spinal cord is made of white matter on the outside and a butterfly-shaped area of grey matter on the inside as shown in Figure 7-2c. The white matter is specialized for communication, because it made up of axons ("nerve fibers"), which communicate between different parts of the spinal cord and between the spinal cord and the brain. The grey matter is specialized for integration, because it contains dendrites and axon terminals, which make the synaptic connections from one neuron to the next. Link to further description of the spinal cord.

Match the following with their location in the spinal cord

Q4A. sends information from one part of spinal cord to other parts and to the brain  
Q4B. dendrites  
Q4C. axons  
Q4D. synapses  
Q4E. connection from one neuron to the next  
1. grey matter  2. white matter

The simplest level of integration in the nervous system is the reflex. Reflexes are specific, automatic responses to their specific adequate stimuli (stimuli that normally trigger a particular response). They adapt the body to the effect of the adequate stimulus. As a general rule, reflexes (like most body reactions) try to counteract anything done to the body. All reflexes go through at least one synapse in the grey matter of the CNS, where the reflex reaction is organized. Many reflexes are organized in the spinal cord, but others depend on the brain stem above it.

The body has many reflexes. You probably recognize these:

! Patellar or "knee jerk" reflex: Tapping the patellar tendon below the knee cap elicits (triggers) straightening of the knee to kick the lower leg out.
! Withdrawal reflex: Touching something that causes pain, like a burning hot baking pan, elicits an automatic jerk of the hand away from the source of pain.
! Sneezze: A tickle in the nose elicits a complex pattern of muscle contractions in throat, chest, and abdomen, which together produce a sneeze, which tries to get rid of the stimulus that tickles.
! Salivary reflex: A sour lemon elicits salivation to dilute the acid.
! Pupillary reflex: Light in the eye makes the pupil (dark disk in middle of colored iris) get smaller to let less light into the eye. You can check this in the bathroom mirror. Cover one eye; the pupils of both eyes get bigger, which you can see in the uncovered eye. Uncover the eye, and both pupils get smaller.
! Blink reflex: A puff of air or other irritation around the eye triggers blinking. Other reflexes adjust blood pressure, heart rate, and other vital functions in response to increased or decreased demand for oxygenated blood, make eyes jump left or
Figure 8-2c. Diagram showing patellar or "knee jerk" stretch reflex.

**DIAGRAM OF KNEE JERK STRETCH REFLEX**

1. **Sensory (afferent) Nerve**
2. **Spinal Cord**
3. **Tap Stimulus**
4. **Receptor**
5. **Synapse**
6. **Leg**
7. **Motor (efferent) Nerve**
8. **Effector (muscle)**

Figure 9-2c. Diagram showing excitatory synapses that turn on the patellar or "knee jerk" stretch reflex and inhibitory synapses that shut down muscles that oppose this reflex response.

**Reflexes inhibit muscles that oppose the muscles that produce their reaction.** Figure 9-2c illustrates general principle of reflex action: Stimuli that turn on a reflex response also shut down responses that oppose it. In the patellar reflex, the sensory signals from the stretch receptors shut down the nerves that make the muscles that contract to bend the knee, at the same time that they turn on the muscles that straighten the leg.
486x725
asgn2c     p. 15

Figure 11-2c. Brain, showing brain stem and head (top) end of spinal cord

Figure 12-2c. Inner surface of the left cerebral hemisphere, showing the brain stem (cut in half) and some of structures on the inner surface of the hemispheres: the limbic lobe of the left hemisphere, and the corpus callosum, which connects the left and right

**BRAIN STEM:** More complex integration

The brain is a large expansion of the top end of the spinal cord, in the bottom of the skull cavity. Figure 11-2c shows the top of the spinal cord (lower right) expanding as it enters the skull to form the brain stem. In humans (and many other mammals), the brain stem is largely hidden by the cerebral hemispheres, which bulge off its front end.

Figure 12-2c shows a slice down the middle of the brain to give a fuller view of the brain stem. The inner surface of the left hemisphere is above and around the outside of the brain stem, which is shown in green. It shows how the brain stem extends up between the hemispheres.

The brain stem does for the face what the spinal cord does for the body and adds specialized functions as well.

1. The brain stem links the spinal cord to the

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Match the parts of the “knee jerk” stretch reflex with the parts of the reflex.

Q6A. Nerve fibers between spinal cord and stretch detecting receptors in the muscles
Q6B. muscles that contract to make leg kick out
Q6C. muscle spindles, which detect muscle stretch caused by tendon tap
Q6D. where sensory fibers connect to motor fibers
Q6E. nerve fibers between spinal cord and muscles that make leg kick out

1. receptor  2. sensory nerve  3. synapse in the grey matter of the spinal cord
4. motor nerve  5. the reflex reaction itself

Reflexes never work alone. The signal triggered by the eliciting stimulus does not just produce the reflex response. It spreads out to affect other related reflexes and reaches higher brain areas as well. For example, if you step on something sharp, the sharp stimulus not only triggers withdrawal of the leg, but activates other reflexes that adjust the body’s balance. Also you consciously experience the pain, even though this is entirely unnecessary for the reflex to occur.

Nor does the motor reaction depend only on the reflex-triggering stimulus. It can be modified by competing reflexes and by activity from the brain. For example, you can inhibit your hand from dropping something burning hot long enough to set it down. This voluntary control over the automatic withdrawal reflex depends on nerve fibers from the brain to the spinal cord, where they block the reflex signals at their synapses (connections) in the spinal cord.

When reflex systems were first studied systematically, researchers simplified them by studying them when they are artificially disconnected from most other signals. They tested experimental animals with surgically isolated spinal cords or humans whose spinal cords have been cut in accidents.

Q7. Charles Sherrington (1947) did much of the basic research on reflexes in the late 19th and early 20th centuries. He said that simple reflexes are a convenient fiction (they don’t really exist), because they

A. are modified by other reflexes and by brain activity
B. really are voluntary reactions
C. are created by damaging the nervous system
D. never act alone
E. A and D are both correct
F. A, B, C, and D are all correct

---
The cerebral hemispheres. Sensory and motor pathways (bundles of nerve fibers or axons) go through it, connecting between the spinal cord and the cerebral hemispheres.

2. The brain stem receives information from all senses (except olfaction [smell]) and organizes their reflexes.

For example, as you look at something, say some faces, your eyes jump around to aim at all the important parts of the faces these jumps are organized in the brain stem. Or, when you are standing, your body must keep on adjusting to its slight swaying. The needed adjustments are organized in the brain stem. The brain stem also receives information about the body's internal condition and organizes the vital reflexes that keep the internal condition within normal levels. These reflexes adjust breathing rate, heart rate, blood pressure, etc.

Normally, you usually don't notice the balance reflexes, yet they work all the time keeping your body erect. If they quit working, the body collapses, as has happened in a couple of rare cases (Cole, 1995). Link to an article describing a case. But you very much notice how strong these reflexes are when your balance is disturbed, as when you trip. When your foot catches on something, the other leg goes way out in front of you to try to catch your body's weight, your body flexes, and your arms go out to anticipate the fall. The reaction to tripping is completely automatic, and it requires combining sensory signals from your balance sense (in the inner ear), from your muscles and joints all over the body, and from vision. Therefore, your reaction when you trip is organized and coordinated in your brain stem.

3. The brain stem organizes simple reflexes to work together in complex patterns.

For example, as you do something like walk, the brain stem is essential for organizing the control of the muscles to make the walking smooth and well-organized. The brain stem also organizes many of the vital reflexes that manage the internal organs of the body. Vital reflexes control processes like the rate of heartbeat, blood pressure, swallowing, stomach activity, etc. Because these reflex centers are located in the lower brain stem just inside the base of the skull, a sharp blow to the base of the skull can kill by disrupting these reflexes.

4. The brain stem has extra, specialized functions.
   a. The brain stem organizes complex reactions and co-ordinates many different reflexes, so that they work together smoothly. Examples of complex reflex reactions organized in the brain stem are the startle reflex and various balance reflexes. Many things, such as a loud sound, an unexpected touch or sound, etc., can elicit a startle reflex. This reflex involves most of the body: the body, arms, and legs partially flex, neck jerks back, and a startled expression appears on the face (partially opened mouth, eyes widened, etc.).
   b. The core of the brain stem contains a structure called the reticular formation or reticular activating system. This structure is critical for "waking up" the rest of the brain (Morruzzi & Magoun, 1949; Adrian et al., 1954). Damage to it can produce long-lasting coma, in which patients are unresponsive to anything. Even strong stimulation, like pain, produces only brief arousal (Lindsley et al., 1949; Scheibel, 1980).
   c. The brain stem contains areas that block signals in the pathways leading to pain areas of the brain (Reynolds, 1969; Liebsekind et al., 1973; Gebhart et al., 1984). In addition, within the reticular formation are areas that slow down and inhibit many areas in the rest of the CNS.
   d. The brain stem contains the origin of brain systems that play major roles in motivation, reward, and movement organization. For example, electrically stimulating the median forebrain bundle produces a powerful rewarding effect (Olds, 1967). Loss of neurons from the nigrostriatal bundle causes Parkinson's Disease, which starts with a tremor and develops into a progressive loss in the ability to make voluntary movement.

Q8. A cat falling from a second story window lands on its feet. This righting reflex combines information from vision, the balance sense, and the muscles all over the body, so you can guess that it is organized in the
   A. mind   B. peripheral nervous system   C. startle response   D. brain stem above the spinal cord   E. spinal cord

The cerebellum on the back of the brain stem has been viewed as a motor coordination system, because damage to it disturbs the speed, accuracy, and strength of movements involved in balance control and motor control. Recent evidence shows that it plays a crucial role in timing activity in many other parts of the brain. Therefore, it affects many other functions, living up to its name, which means "little brain" (Baringa, 1996). For example, the cerebellum is needed for many forms of motor learning (Thompson & Kim, 1996). Recent research also suggests that autistic children have abnormal
cerebellar function as reflected in abnormal motor learning, as measured with eye blink conditioning [learning to blink to a signal (like a tone) that predicts air puff to eye] (Sears et al., 1994). Other data show that the cerebellum contributes to higher mental function through its connections to the frontal lobes. It appears to be part of a circuit that controls precise timing needed in higher mental functions as well as complex motor acts (Andreasen, 1999).

Mark the following True if it is true about the brain stem or False if it is not.

Q9A. T F an alarm clock activates part of it, which then activates the rest of the CNS
Q9B. T F does simpler reflexes that involve the arms or legs
Q9C. T F does simpler reflexes that involve vision or balance
Q9D. T F makes complex body actions work smoothly
Q9E. T F contains part of the brain's motivating and reward network

The hypothalamus in bottom of the front end of the brain stem (Figure 13-2c) connects the limbic system of the cerebral hemispheres to the body's internal responses systems: the autonomic nervous system and pituitary gland. The limbic system and hypothalamus are basic to motivation, emotion, and reward processes.

The hypothalamus is particularly important for maintaining homeostasis, which is the proper balance of the body's internal environment (e.g., body temperature, blood sugar, water and salt concentration, oxygen level). The hypothalamus helps maintain homeostasis by its control over the autonomic nervous system and the endocrine system through the pituitary gland, located in the skull just below the hypothalamus.

The pituitary gland is the "master gland of the body," because it regulates the action of many other glands, including the adrenal cortex (vital for response to stress and control of salt balance in the body), the gonads (sex glands: ovaries in females and the testicles in males), the thyroid gland (controls metabolism), etc.

Q10. The hypothalamus is particularly important in controlling the
A. stability of the internal environment of the body  Hint  B. the autonomic nervous system  Hint  
C. (parts of) the endocrine system through the pituitary gland  Hint  D. all of the above are correct

Stimulating the hypothalamus can activate many functions related to motivation, emotion, and reward, whereas damage disrupts such functions. For example, electrodes implanted in the lateral hypothalamus can activate very strong reward. Rats and other animals with such electrodes will make thousands of responses per hour to turn on 0.5-second bursts of stimulation (Olds, 1969). Such stimulation can also elicit (trigger) vigorous eating in animals that have just finished a meal (Valenstein, 1976). Repeated stimulation several times a day for several weeks will make animals eat so much that they put on a lot of fat. (Steinbaum & Miller, 1965). Damage in this same area depresses eating (Teitelbaum & Epstein, 1962). Stimulation in the hypothalamus can also trigger aggression indicating anger and/or fear, and many other functions related to motivation and emotion.

Which of the following might you expect to be associated with the hypothalamus?

Q11A A science fiction story had a man murdered by stimulating a place in the brain that was so pleasurable the man stopped eating and drinking.  Hint  
Q11B Where sex hormones act to turn on sexual behavior  Hint  
Q11C Where the brain organizes drinking in response to increased salt in the body  Hint  
Q11D Where the brain organizes protective reactions when body temperature falls below normal  Hint  
Q11E All of the above are all correct
asgn2d -- CEREBRAL CORTEX:
Primary Sensory and Motor Areas

This assignment and the next describe the basic organization of the cerebral cortex, the outer layer of the cerebral hemispheres. The cerebral cortex contains the majority of cell bodies in the human nervous system and the synapses formed axon terminals and dendrites. It is divided into three levels: primary sensory areas, sensory association areas, and higher order association areas. The assignment describes how the areas were identified and some main features of the lowest level, the primary sensory areas.

When you have completed this exercise, you should know something about the structure and organization of the cerebral cortex, and how it is divided. You should also understand how the primary sensory areas represent the senses from which they get their information.

Asgn2a claims that "From psychology's viewpoint, the most important question about the nervous system is: 'How does the nervous system code or represent psychological and behavioral processes?' One basic code is location: different parts of the brain are associated with different functions. Phrenology was the first attempt to relate different psychological processes to different areas in the brain.

At the end of the 19th century, Franz Gall (Figure 1-2d), a Viennese physician, and his disciple, Johan Spurzheim, proposed that the shape of a person's skull in the head reflected his/her mental traits. They named the study of the shape of the head phrenology (in Greek, "phren" = mind, "logy," from logos = study of). Gall claimed that each area of the cerebral cortex was associated with one of 27 mental "faculty" (~ trait, ability). If a faculty was strong, its brain area swelled up. Figure 2-2d shows a typical phrenological map of the head. The pictures represent the different mental and behavioral traits associated with the location of bulges on the skull.

Phrenology made a fundamental contribution to the understanding of the brain and how it works. Phrenology introduced the idea that the mind could be divided into separate functions, which are linked to specific parts of the brain. Therefore, phrenology is quite similar to the dominant modern idea about brain organization, with one crucial exception: The data used to support phrenological ideas was very weak and unreliable. Modern behavioral neuroscience deals with many more and simpler, more specific mental processes. Link a description of phrenological theory.

The psychological concepts that phrenology used were faculties like benevolence, veneration (~worship), cunning, etc. Modern behavioral neuroscience deals with working memory (asgn3j) and its subdivisions, visual recognition of shapes and objects (asgn2s,t), perception of motion (asgn2r,s), etc. Also, many behavioral neuroscientists claim that specialized areas of the brain are parts of complex, interactive networks rather than isolated modules. The evidence on which phrenology was based was its downfall. Gall claimed that the outer surface of a skull reflected the shape of the brain underneath. Gall established the relation between mental faculties and skull shape with people he judged to show a faculty very strongly and measuring that person's skull. Fortunately the mental assessment was much less carefully done than was the skull measurement, and the sample of skulls was quite small and biased. Objective measurement of psychological
processes (asgn1b) and random or representative sampling (asgn1j) were techniques that would first appear a century later. Finally, the evidence is quite clear that the skull’s surface does not reflect the shape of the brain inside, and the brain’s outer shape is only very weakly related to its functions.

The flaws in phrenology made it a standard example of poor science. Nevertheless, it’s contribution has been very important. Previously, philosophers and scientists believed that the brain worked as a whole, partly because of the apparent unity of conscious experience. Phrenology is the first clear statement of the idea that the brain does different things in different places. This idea is called localization of function, and it has been a dominant theme in behavioral neuroscience for about a century and a half. For more about phrenology's contribution to modern behavioral neuroscience.

Unfortunately, the concept of localization is often taken too far. Like the phrenologists, some researchers seem to claim that a specific location in the brain is the specific place where a specific psychological function takes place. For example, one area generates grammar, another recognizes faces, a third guides attention, etc. A more likely view is that a specific area is an important, even crucial, part of a brain system for a psychological function. Furthermore, brain systems for different functions are interconnected and overlap.

Q1. The main contribution of phrenology to modern psychology and neuroscience was
A. the discovery of the main categories of personality and mental traits
B. the idea that skull shape reflects how developed the brain under it is
C. the idea that different parts of the brain were involved in different psychological functions
D. A, B, and C are all correct
E. none of the above are correct. Phrenology is a deeply flawed theory, so it contributed nothing

Cerebral Hemispheres

The cerebral hemispheres are the top level of the basic hierarchy in the Central Nervous System (CNS). They bulge off either side of the rostral (front) end of the brain stem, somewhat like two mushrooms.

The hemispheres have several different parts:

1. The cerebral cortex is the 1 cm-thick layer of grey matter that forms the outer surface of the cerebral hemispheres. Figure 3-2d shows it as a pink outer layer on the hemispheres. (In the living brain it is pale pink, which turns greyish tan in preserved brains.) It is the "mushroom's cap."

The cortex is highest level of the brain and is essential for higher levels of mental function. It contains roughly half of all neurons in the human brain. Figure 4-2d shows a highly magnified slice through the cortex. It is stained with a dye that colors only the cell bodies of neurons (and glia) blue. Note how densely packed neurons are in the cerebral cortex. It also shows that the cortex has six basic layers of neurons, each having its specialized functions.
The cerebral cortex is wrinkled in many mammals, especially in humans. The grooves that make these wrinkles are called sulci, and the ridges between them are called gyri. Figure 3-2d shows sulci in cross section as narrow valleys into the cortex. Figure 5-2d, shows them as curving lines on the surface of the cerebral hemispheres.

Wrinkling packs more grey matter into the limited space inside the skull, just as crumpling a piece of paper fits it into a smaller space. Figure 5-2d shows the “typical” pattern of sulci as curving lines on the cerebral hemispheres. The sulci also divide the brain into five major subdivisions called lobes. The pattern varies among individual brains, so the sulci only rough landmarks.

2. White matter forms the inside cerebral hemispheres underneath the cerebral cortex. It is made of the axons that connect to and from each area of the cortex to other areas and to other parts of the brain. It is the “stem of the mushroom.”

3. The basal ganglia are several large, interconnected clusters of grey matter inside the white matter of the hemispheres. They link most of the cerebral cortex to the motor system of the brain, to organize and execute complex movements smoothly and efficiently. They also play an important role in simple learning.

The cerebral cortex of humans (and many other mammals):

- **T F Q2A.** has all the neurons in the cerebral hemispheres
- **T F Q2A.** is wrinkled by gyri and sulci to pack more grey matter into the skull
- **T F Q2A.** is the outer layer of the front end of the brain
- **T F Q2A.** has two lobes, the anterior and the posterior

The cerebral cortex is divided into many different areas, each of which is closely associated with its own set mental and behavioral functions. These functions are nothing like the ones phrenology proposed, and they are based on much better evidence. This division is based on several different measures. Originally they were defined by differences in the pattern of the six layers of the cortex (Figure 4-2d). These correlate with measures of brain function, measured by methods described in asgn2a.

The relation between cortical area and function is not fixed by a genetic code. Rather, it depends on the interaction between genetic and environmental processes, early in development especially.

For example, in ferrets, the visual connections were rerouted experimentally to the auditory cortex, which developed the anatomical and functional characteristics of visual cortex (Roe et al. 1990; von Melchner et al., 2000, Merzenich, 2000). A similar reorganization also happens in humans who are blind at birth and learn to read Braille (touch-based printing). Their cortical visual areas become responsive to touch. Transcranial magnetic stimulation there disturbs their ability to read, whereas it has no effect when tested on sighted people who read Braille (Büchel et al., 1998; Cohen et al., 1997).

Brain organization can change in adults. For example, professional string players, who use their fingers a lot, have much more brain devoted to the fingers than do amateur players (Elbert et al., 1995). Simply practicing a touch task using fingers for several weeks will affect both the size and function of the brain devoted to the fingers.

The front part of the cortex is associated with movement, from planning an action to doing it. The back part of the cortex is associated with sensory perceptual function. Vision, hearing, somesthesia (body sense and “touch”) are (mainly) associated with different parts of the back part of the cortex. Figure 6-2d illustrates the connections between these “main” senses and their primary areas, and between the primary area for motor control and muscles it controls.

Figure 6-2d shows that each sense (vision, hearing, etc.) sends information first and most directly to its own specialized area, called its primary sensory area.

![Figure 6-2d. Diagram showing the projection (connection) of each major sense to its primary area in the cerebral cortex.](image-url)
makes connections to) most directly to the primary visual cortex on the occipital lobe at the back of the brain. 

The auditory pathway from the ear projects most directly to the primary auditory cortex on the top edge of the temporal lobe, which is located behind and just above the ears, where the temple pieces of a pair of glasses go.

The somatosensory (soma = body) or “touch” pathways go most directly to the primary somatosensory cortex on the front edge of the parietal lobe. (Somatosensory also includes muscle, joint, and other body senses)

The most direct pathways controlling movement goes from the primary motor cortex to motor neurons in spinal cord, which control muscles directly.

Match the experience that a patient reports, if s/he is stimulated at each of the numbered locations on Figure 7-2d. 

1. 2. 3. 4. 5.

Q3A. touch Q3B. (involuntary) movement Q3C. visual Q3D. sound

Hint: What would a person report feeling when the primary touch area is stimulated?

Each primary sensory area contains a map of its sense organ. This is easiest to understand for the somatosensory system in Figure 8-2d. Figure 8-2d shows the place in the primary somatosensory cortex at which stimulation produces a sensory experience in the body part named at the right. The size of the lettering indicates the size of the somatosensory cortex from which such reactions can be produced.

For example, touching the feet activates the top end of the primary somatosensory area, so this part of the body map is called the representation of the foot. Below the foot representation, in order, are the representations of the legs, the back and chest, the arms, the hands, the face, and the mouth.

Damage in the primary somatosensory ("touch") cortex disturbs the sense of touch. The numbers on Figure 9-2d show different places on the cerebral cortex damaged in different patients. Match the number for each place with the part of the body where a patient would have defective touch perception. 

1. 2. 3. 4. 5. Q4A. hand Q4B. mouth Q4C. foot Q4D. face Q4E. back

Figure 10-2d. Penfield's classic maps of the human primary somatosensory and motor cortex, based on effects of weak electrical stimulation of the cortex during neurosurgery. The stimulation was done to identify areas of pathology to be removed and areas of function that must be avoided. Note how distorted the "homunculus" is. The hands and face are very large and the back is small relative to their real size. This difference is the basis of the high sensitivity to touch on the hands and face.

Every method described in asgn2a is used to study the organization of primary sensory and motor cortex. Most dramatic are the observations on human patients during brain surgery. In some kinds of brain surgery, the patient is awakened from anesthesia after the brain is exposed (Calvin and Ojemann, 1994; Penfield and Rasmussen, 1950). (The nerves from the head are blocked with local anesthetic.) The patient is awake because the neurosurgeon needs to locate accurately the pathological (sick) area to be removed and important healthy areas, such as the speech area, to avoid damaging them.

The electrical stimulation identifies what each area is especially important by triggering some specific reaction. If the stimulation is in a speech area, it disturbs the patient's ability to speak. If the stimulation is in part of the primary somatosensory cortex, the patient reports tingling or buzzing on a part of his/her body. This means...
that the stimulated area is especially associated with that place on the body. If the stimulation is in part of the primary motor cortex, the patient makes an involuntary movement with the part of his/her body especially associated the stimulated brain area.

Figure 11-2d shows the effect of stimulating different parts of the primary somatosensory area. Patients report tingling in the right foot when stimulated at the top end of the primary somatosensory area on the left hemisphere (each hemisphere controls the opposite side of the body). Stimulation at the bottom end of the left primary somatosensory area elicits (triggers) tingling on the right side of the face. Stimulation at places in the middle part of this area elicits tingling sensations on other parts of the body. In Figure 10-2d, stimulation between the face and foot areas of the left hemisphere elicit sensations in the right hand. Link to a description of surgery for epilepsy.

The map of the body is the way the brain codes location on the body. Touch on the foot makes neurons (nerve cells) at the top end of the somatosensory area respond. Touch to the face activates neurons at the bottom end of the somatosensory area. Touch on each finger activates cells in neighboring parts of the hand area of the cortex. Your mind interprets activity in these different parts of the somatosensory cortex as a sensory experience on the related body part.

The somatosensory map of the body is very distorted. Some small parts of the body take a lot of space on the map, and some big parts take only a small part of the map. The type size of the names of body parts illustrates the size of the area devoted to it. In Figure 8-2d above, the larger the type size, the larger the cortical areas for that body part. For example, "back" and "legs" are printed in little letters, because these parts of the body take up only a small part of the primary somatosensory cortex, even though the legs and back have a large part of the skin. In contrast, "hand" and "mouth" are printed in big letters, because these parts of the body take up a large part of the primary somatosensory cortex, even though they have a area of skin surface.

The size of the somatosensory area for each part of the body is correlated with touch sensitivity on that part of the body. Parts of the body that has a large area in the cortex are very sensitive to touch, and you can locate where to touch is on that part of the body quite accurately. For example, your fingers and mouth are very sensitive to touch, and you can locate quite accurately where on each finger or on the lip you get touched. In contrast your back is not very sensitive, and you can't locate accurately where you are touched there.

You can compare how sensitive you are to touch on different parts of the body quite easily. Take two tooth picks and have someone touch them simultaneously and gently on the skin of your index finger. Start with them rather far apart, about 1 cm between the

**Figure 11-2d.** Outline of body with hands magnified on which to record perceived location of a touch. To print a copy of the figure (Windows only), click on it with the right mouse button, then click (with left mouse button) on save image as (In Internet Explorer save picture as) on the menu and select a temporary folder for it (write the folder and its address down;to find it). To print it, open this file in an image program, like Paint in the Accessories menu of Windows.
Q6. Raccoons have five separate bulges in the lower part of its somatosensory cortex, one associated with each finger. Therefore you might expect raccoons ___.  
A. to be very sensitive to pain  
B. to recognize things by touch (with fingers) quite well  
C. not to connect information between the fingers  
D. also to have large face and mouth areas in the somatosensory cortex

The map of your visual field (what you see) in your primary visual area has the same kind of features as the somatosensory (“touch”) map. You can think of the primary visual cortex as being sort of like a TV screen and your eye as being sort of like a TV camera. Light from different parts of your visual world activates corresponding parts of the “TV screen.” The TV screen analogy to the primary visual area models only one aspect of how the visual cortex works -- how location in the visual world is coded. The map of the visual world on the visual cortex is described in more detail in Exercise asgn2s.

Like the somatosensory area, the visual map is distorted. The part of the map devoted to the middle of the visual field is much larger than the part devoted to the periphery (edges). Look straight at the end of your thumb at arm's length; it takes up about 1% of your visual field. On the primary visual cortex, your thumb is activating about half of its total area.

This enlargement makes the small part in the middle of your visual field much more sensitive to fine detail (you can see fine detail only directly where you are looking; detail vision decreased rapidly as the visual target moves away from the very center of your visual field (asgn2s explains this effect in more detail). Figure 12-2d illustrates this fact.

Q7. (Select the best answer.) When the optometrist tests your eyes with the eye chart, s/he measures how good your best detail vision is. S/he measures how well information about the letter you are looking straight at gets to ___.
A. the middle of the TV screen  
B. the 1% of the visual cortex that gets information from the letter on the eye chart you are looking at  
C. the whole visual cortex  
D. the middle 50% of the visual cortex

Damage to the primary sensory areas of the cortex disturbs conscious perception of sensory experience. For example, damage in the somatosensory area disturbs the ability to recognize or locate touch to the affected part of the body. Damage to a part of the primary visual area on the occipital cortex results in a “blind spot” for the corresponding part of the visual world. Destroying all of the primary visual cortex results in cortical blindness: visual experience is unavailable to consciousness.

Vision can still guide some behavior in cortical blindness, even without conscious awareness (Cowey, 1995; Humphrey, 1972, Natsoulas, 1997; see however Wessinger et al., 1996). With practice, monkeys with the primary visual area removed can under appropriate conditions navigate visually without bumping into things and reach accurately for small objects. People with this condition can point to and reach for objects accurately even though they report no conscious awareness of seeing. Link to a description of a patient with brain damage that produced blindsight. A similar effect occurs after damage to primary auditory cortex. (Garde & Cowey, 2000).
Q8. Helen Keller became blind (and deaf, as well) at age 2 as an aftereffect of measles, because the disease affected her brain. Because she had no conscious sense of vision, the damage responsible for her loss of sight probably destroyed entirely her

A. primary visual cortex  B. lenses  C. cerebral cortex  D. all primary sensory cortex

The primary motor area also has a map of the body surface. Stimulating the top end of the right motor cortex elicits (triggers) movement in the left foot. As the location of stimulation is moved down the motor cortex, the movements that the stimulation elicits move up the body. So stimulating the bottom end of the right motor cortex triggers movement on the left side of the face.

As in the sensory areas, the motor map of the body is distorted, enlarging the parts of your body that you can control most precisely, as is illustrated in Figure 13-2d. The size of the names of body parts indicates the size of the cortical areas to those parts. The fingers and mouth make precise movements and take up much more of the motor cortex than do areas like the trunk, where movement control is not precise.

More recent research shows that movements elicited (triggered) by stimulation underestimate the amount of motor cortex associated with movement in each part of the body (Baringa, 1995; J. Sanes et al., 1995). In this research, monkeys learn to make specific movements when signals tell them to respond. Neurons in many widely scattered parts of the motor cortex became active while monkeys make these specific movements.

This finding shows that a much broader area of the motor cortex participates in the control of specific muscles and movements. This organization makes sense when you consider the fact that even very simple movements require the coordinated action of many muscles and joints. The wide scattering allows more efficient coordination between muscles working at these different locations on the body.

A recent study using stimulation has confirmed the idea that the motor cortex is organized more by movements than as a map of the body (Helmuth, 2002). This work showed that monkeys make smooth, complex, well-directed movements when the motor cortex was stimulated with longer lasting (0.5 sec.) stimulation than was used in earlier studies.

Q9. Some new world monkeys can use their tails as an extra hand. You would expect that they have __.  
   
   A. an enlarged area at the top of the motor cortex  
   B. an enlarged area in the motor cortex for the hand  
   C. a smaller hand area in motor cortex to make room for controlling the tail  
   D. an enlarged motor cortex, in which all parts are equally bigger  
   E. A and C are both correct
When you have finished the exercise you should be able to recognize the difference in functions of the association cortex and the primary cortex. You should be able to described the main features of limbic functions and recognize the main functions of the basal ganglia inside the cerebral hemispheres.

**Association cortex is the cerebral cortex outside the primary areas** (Figure 1-2e). In humans and other primates the association cortex is by far the most developed part of the brain. It is essential for more complex mental functions. For example, association areas are necessary for perceptual activities, like recognizing objects (toasters, horses, words, etc), rather than their simple features, like edges, color, or pitch, which depend on primary sensory cortex.

**Association areas take up an increasingly larger percentage of the cerebral cortex as brain size increases among different species.** As brains get bigger among different species of animals, the cerebral cortex gets bigger even more. The extra cortex is created by more and deeper wrinkling. Most of the added cortex is association cortex. Figure 1-2e compares the relative size of association cortex in rats and humans. Association cortex is the pink area outside the primary sensory areas.

The increasing size of association areas correlates with the complexity of behavior and mental functions. Big-brained primates -- monkeys, apes, and especially humans -- have complex behavior and mental function. Their wrinkled cortex is mostly association cortex. Animal species like horses and cats, have less complex behaviors. Their medium-sized brains have less a wrinkled cortex, with a lower percentage of association cortex. Rats and rabbits have still less complex behaviors. Their smaller brains have few, shallow wrinkles in the cortex, and association cortex is a small percentage of the total area.

**Q1.** A biologist shows a class a brain that has rather large cerebral hemispheres. This brain probably

A. is wrinkled and swollen because it is preserved (“embalmed”)
B. came from an animal that probably had fairly complex behaviors
C. probably has quite a lot of association cortex compared to primary areas
D. had a lot of grey matter  
E. B, C, & D 
F. A, B, C, & D

Recall from asgn2d that the sensory systems (vision, hearing, etc.) each have their own primary area on the cortex, which gets the most direct connections from its sense. Each primary sensory area sends information to its own cortical association areas, which is next to its primary area, as shown in Figure 2-2e. The arrows show the main direction of information flow, but association areas also connect back to their primary areas providing them feedback. (The motor system is organized in the same way, but in the reverse direction: from motor association areas to the primary motor area to the motor systems in the brain stem and spinal cord.)

**Each sensory association area appears necessary for perception of objects and events for its sense.** The information that each sensory association area gets from its primary area is about simple contours, boundaries, and qualities like color or pitch. Sensory association areas combine this kind of information to represent complex objects. For example, the visual association area on the lower part of the temporal lobe plays a primary role in your ability to recognize faces, dogs, cars, trees, etc., whereas the primary visual cortex is required for detecting basic features of the visual world: edges, light and dark, location, etc.

Many data support this idea. For example, people with damage to visual association cortex (on the lower part of the temporal lobe) often suffers from visual agnosia (α = without, gnosis = knowing) (Farah, 1990). Such people
can see objects, but cannot recognize them. They may be able to describe the features of an object but still cannot name it by sight. They can recognize and name the same object placed in the hand, showing they know the word. This condition is described further in asgn2q.

Q2. A neurologist (physician who specializes in diseases of the nervous system) described a patient as "the man who mistook his wife for a hat" (Sacks, 1985). He could see his wife but perceived her head as a hat. This patient probably had damage in ___.

A. all association areas of the cortex  
B. primary visual cortex  
C. visual association cortex  
D. the sulci between the gyri where arrows cross them.

The activity of nerve cells in visual association cortex also shows that these areas are involved in a higher level of processing. For example, nerve cells in (a part of) the visual association area respond selectively to complex, patterned visual stimuli, like images of objects, abstract forms, hands, faces, or even specific faces (K. Tanaka et al., 1991). This means that when such cells respond, the brain has information telling that the specific stimulus object that triggers the active cells is getting to the sense organ.

For example, a group of neurons in a monkey’s visual association area on the temporal lobe respond only when it looks at a specific person (Young & Yamane, 1992). This suggests that activity in those neurons tells the brain/mind that the monkey looks at that specific person. So the next time you see your best friend, remember that you can see him/her because a few thousand neurons in the visual association area of your temporal lobe have become active. Give them a pat on the back for the great job they do for you, without you even asking.

The somatosensory (touch) and auditory association areas show the same kind of processes. For example, damage to the auditory association cortex (around the primary auditory cortex on the top of the temporal lobe) leaves sensitivity to sound unaffected, but disturbs recognition of what sounds mean. In the auditory association areas, neurons respond much better to complex sound patterns like bird calls and speech sounds than to simple tones. Damage to the somatosensory association cortex (on the parietal lobe behind the primary somatosensory cortex) leaves sensitivity to touch unaffected, but disrupts ability to recognize objects by touch.

Q3. You can predict that neurons in auditory association areas are most likely to respond to

A. simple pure tones  
B. complex meaningful sounds, like a door closing or a dog barking  
C. speech sounds  
D. B and C are both correct  
E. A, B, and C are all correct

The information flow in the motor system is in the opposite direction from the flow in sensory systems. Information goes from the association area to the primary motor area, which directly and indirectly controls the motor systems in the brain stem and spinal cord. The motor association area is on the frontal lobe in front of the primary motor cortex. It is essential for effective planning for actions. To execute the plans it sends signals to the primary motor area, which is more directly related to the actual execution. Damage here disturbs planning and organization of movements (Goldman-Rackic, 1994).

Mark each item True or False. Association areas for each sense ___.

T F Q4A. receive information from their own sense’s primary sensory area  
T F Q4B. are required for recognizing but not for detecting (seeing, hearing, etc)  
T F Q4C. have nerve cells that respond best to a pattern of stimulation  
T F Q4D. together with higher order association areas, takes up a much bigger percentage of a large, wrinkled cerebral cortex than of a small, smooth one.  

Higher Order Association Areas

Higher order association cortex carries out complex mental processes not associated with any particular sense. Figure 3-2e shows the primary areas and their association areas in colors and the higher order association areas in grey. Each sensory and motor association areas sends signals to higher order association areas, which combine this information to form the basis of the highest mental processes, like language, thinking, and
planning. These processes do not depend on any one specific kind of sensory information. For example, language can use vision (reading, sign language) and touch (Braille for the blind), as well as hearing. The arrows show the flow of information from primary areas to sensory association areas to higher order association areas. Link to a story about Albert Einstein's brain and how it may differ from the average brain.

Figure 4-2e shows the higher order association areas in grey and points out the location of two parts that play a crucial role in language: Broca's area at the lower back of the left frontal lobe, and Wernicke's area, at the junction of the left temporal and parietal lobes. Both are shown on the left hemisphere, because it is dominant for phonetics (speech sounds) and for grammar in 99% of right-handed people and about 2/3 of left-handed people. (These are not the only brain areas that are important in language.)

These areas were first identified in the mid-19th century from the effects of brain damage on language function. Damage in Broca's area affects speech production and understanding more complex grammar. Damage in Wernicke's area affects understanding and using words. However, the exact location of these areas and what processes they carry out is still not settled (Lieberman, 2001).

Figure 5-2e shows the unique activity in three parts of the brain during three tasks: listening to spoken words, saying words they are given to say, and generating words (thinking of words the participant can that start with a specific letter, for example: sneeze, smile, smoke, smell, smite, smear, etc).

Listening to spoken words automatically activates understanding the meaning, so Wernicke's area is activated. Saying words depends on precise control of the muscles of the face and mouth, so these areas are activated. Generating words depends on finding words and getting them ready to say, so Broca's area is activated.

Match the brain area to the best fitting items below.
1. Wernicke's area  
2. Broca's area  
3. both Wernicke's and Broca's areas

Q5A. left side of brain (for most people)  
Q5B. producing grammar  
Q5C. word understanding  
Q5D. higher order association area  
Q5E. frontal lobe

Connect to Chapter 3, Seeing the Brain Speak about language and the brain in Conversations with Neil's Brain (Calvin, W., & Ojemann, G., 1994). This exceptional book uses the case of Neil who undergoes neurosurgery to present an introduction to neuro-science and mental processes. It is written mainly as conversations with Neil, explaining the steps in his treatment.

For more information about aphasia, click HERE or HERE or HERE.

The higher order association areas on the right hemisphere's parietal and temporal lobes are part of a network of brain areas related to directing attention. Large lesions (~damage) on the back part of the right hemisphere (see Figure 6-2e) can make people completely ignore the left side of their world (Heilman, 1979). This condition often shows considerable recovery, so that patients show neglect to stimuli on their left side when they also get a competing stimulus on their right. Figure 7-2e shows a drawing of a car and of a clock that a patient with left sided neglect would make. It show how the left side of the drawings are missing or squeezed into the right side.
Figure 6-2e. A typical neglect-producing lesion (=damage) on the right hemi-sphere, showing the area on the top edge of the temporal lobe. Patients with this disorder ignore their left, so damage in this higher order association cortex can disturb many other functions indirectly: reading and writing, (they miss what is on the left side of the page); eating (ignoring food on left side of plate); getting dressed (failing to put left arm or leg into sleeve or pant leg).

Figure 7-2e. illustrates how a patient with neglect might

This part of the right association areas also appears important in recognition and expression of emotion. This problem can lead to important problems in social communication. For example, damage here can make people unable to recognize or express emotion, such as anger, fear, or sarcasm (Bear, 1983; Ross & Mesulam, 1979). These social signals play an important part in effective social behavior.

An elementary school teacher suffered a stroke in this area. Although she recovered most of her mental abilities completely, she still had difficulty recognizing and especially expressing emotion. Therefore, she had a lot of difficulty with class discipline, a problem she did not have before her stroke. Her soft, dull, monotone speech no longer made the emotional impact needed to let her pupils know she was annoyed and would not tolerate some misbehavior.

Higher order non-sensory association areas
Q6A T=A F=B take up much of the expanded cerebral cortex and brains get larger among species of animals
Q6B T=A F=B are important for mental functions that do not depend on information a single sense
Q6C T=A F=B are not involved with language, which is built on hearing
Q6D T=A F=B are not involved with attention which is close ly tied to hearing
Q6E T=A F=B on the right side plays an important role in recognizing socially important signals

The higher order association area in the very front part of the frontal lobes appears to be essential for many different complex, psychological processes. It is especially important for planning and executing actions effectively and for anticipating their consequences. Evidence for this idea comes from many sources. For example, people with damage to the frontal lobes may have normal, even superior, IQs, but their inability to plan and recognize consequences in advance prevents them from using their "intelligence" for much of anything useful. They also have trouble changing plans when a change in the environment requires a new strategy. Like Phineas Gage, they often show major personality changes, becoming impulsive, superficial, and/or socially incompetent.

Damage in the frontal lobes can affect a specific behavioral process, but the loss of a specific function can show up in many different kinds of disturbed behavior. Damasio (1994) describes a remarkable case of frontal lobe damage as shown in Figure 8-2e, Elliot, the patient, could describe what he needed to do in social and business settings, but he could not do what he had just described. Otherwise, he was completely normal or above normal mental functioning.

Elliot was a successful lawyer and businessman when he developed a brain tumor in the orbital frontal cortex (orbit=eye socket), located on the bottom of the frontal lobes just above the eyes. The tumor was successfully removed with little damage to the surrounding brain, and Elliot recovered completely, except that he could not carry out correctly ordinary personal, business, or social activities, though he could describe correctly what he needed to do.
Elliot could analyze business deals but was totally unable to do what his analysis told him to do. He made very bad deals, which he never would have done before his tumor, and managed to lose his family as well as his money. He could describe accurately what to do in different social situations, but he acted completely inappropriately in such social settings. Nevertheless, he passed virtually every test that was supposed to measure frontal lobe functioning.

Damasio finally figured out Elliot's problem from a casual remark he made. He had successfully done a test that required him to explain what to do in different situations. Elliot said that although he could explain what to do he could not do what he had just said. Further testing showed that he could not do tasks that required him to follow a plan or learn from the consequence of doing it. He apparently had lost the connection from his brain’s planning system to its motivation system. His plans could no longer control his actions.

For example, in a gambling task he chose plays with a few big wins, but in the long run it wiped out his stake. He could not switch to plays with smaller wins but was a winning strategy over the long run. People with intact orbitofrontal cortex often start on the losing play but switch to the successful play. They can inhibit their attraction to the bad plays that gave the large wins. (Interestingly their hands "knew" the winning play before they could consciously recognize it.)

Frontal lobe damage often affects personality. Damage in other parts of the frontal association areas makes personality much shallower and disturbs the ability to recognize what social situations require. (In contrast, Elliot's personality became very cool and distant. He understood, but could not make, the appropriate social response.) Brain scans show that patients with schizophrenia (a severe "mental" illness) have abnormally low activity in the frontal lobes. This is why many people with schizophrenia have difficulty monitoring what is important in their mental activity and behavior. As a result, many people with this devastating disease have trouble organizing even fairly simple activities, such as ordinary household chores. (Observations like these show that "mental illnesses" like schizophrenia and depression, are mental only in the sense that the main symptoms are mental. These diseases are based on abnormal brain function, just as are epilepsy, Alzheimer's disease, strokes, etc. Asgn5d,e, and f explain why schizophrenia is a brain disease in more detail.) Link to information about the role of abnormal frontal lobe function in schizophrenia.

Q7. Phineas Gage was one of the first people to survive a severe brain injury and have his behavior documented afterwards. Before the brain injury, he was a sober, responsible worker. Afterwards, he was not seriously disabled physically but was a completely different person: impulsive, emotional, unable to recognize the consequences of his actions, etc. These changes were the result of
A. Alzheimer's disease  B. damage to the frontal lobes  C. damage to the left hemisphere
D. damage to the primary area of the cortex  E. right parietal lobe

Link to a website devoted to Phineas Gage.

Other Parts of the Cerebral Hemispheres

This section briefly summarizes some of the functions of the limbic system (motivation and emotion, as well as conscious memory) and basal ganglia (movement organization and simple learning). These are the primitive parts of the brain (Sarnat & Netsky, 1974), and they are essential for organizing and executing the most basic functions of the nervous system: movement, motivation, and emotion. However, these basic systems have added other functions, which is quite new in evolution appearing only in mammals. Filling in a table like this may help you remember the following information and do the next question.

<table>
<thead>
<tr>
<th>Brain Area</th>
<th>Function.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limbic system</td>
<td></td>
</tr>
<tr>
<td>Hippocampus</td>
<td></td>
</tr>
<tr>
<td>Hypothalamus</td>
<td></td>
</tr>
<tr>
<td>Anterior Cingulate</td>
<td></td>
</tr>
<tr>
<td>Amygdala</td>
<td></td>
</tr>
</tbody>
</table>
The limbic system is especially important in motivation and emotion (see asgn4n, o, and z). It is mainly in the limbic lobe, which forms the inner surface of the cerebral hemisphere. The limbic lobe makes a ring around the white matter that connects between the cerebral hemisphere and the top end of the brain stem, as the rough underside of a mushroom cap circles the stem. Figure 10-2e shows the location of several parts of the limbic system on the inner surface of the left cerebral hemisphere.

The limbic system is does most of its control of behavior through the hypothalamus, at the top end of the brain stem. The hypothalamus controls the autonomic nervous system and many parts of the endocrine system through its control of the pituitary gland directly below it (see asgn4zd).

Evidence for the role of the limbic system in emotion and motivation comes from many sources. Some examples include:

1. The parts of the limbic system are connected to each other and to the hypothalamus.
2. Damage to different areas in the limbic system disrupts different motivated and emotional behaviors. For example, damage in the lateral (outside part, margin) hypothalamus makes rats unresponsive to most stimuli. They will even starve to death in the midst of plenty, because they do not make any effort to get food. However, these rats chew and swallow food put in their mouths. They act as if they like the food but don't "want" it or can't make voluntary movements to get it.
3. Electrical stimulation in the hypothalamus can elicit motivated behavior, such as eating and drinking.
4. Stimulation in the hypothalamus can also produce intense reward. Animals will repeatedly turn on electrical stimulation in these parts of the hypothalamus thousands of times per hour for many hours in a row, even at the expense of ordinary motives like eating. These areas in the hypothalamus are also activated by cocaine and amphetamine ("speed"), indicating that these areas are important links in the brain's reward or "wanting" system (see asgn4w.)

The hippocampus and related parts of the medial (inner, toward the middle) wall of the temporal lobe of the limbic system are crucial for the storage of new declarative (~conscious) memories (see asgn3l) (Squire, 1987). Especially clear evidence comes from human patients with damage to these structures. They cannot remember any new information consciously for more than a few minutes. For example, such patients cannot remember anything about a doctor or nurse who started working with them after the brain damage occurred, even after hundreds of visits with them. Mishkin and co-workers (Miskin & Appenzeller, 1987) have described an animal model of this amnesia. The role of the hippocampus and related structures in memory is described further in asgn3l.

The amygdala is important for recognizing and responding to emotional cues. This structure, deep in the temporal lobe (see Figure 11-2e), is a very important link in the limbic system. Damage to it disrupts emotional reactions, as shown in many studies with monkeys, humans, and rats. The amygdala plays a particularly important role in fear. For example, rats and other animals (including humans) with damage to the amygdala cannot learn fear reactions to signals that predict an aversive event (e.g., painful electric shock). It also plays an important role recognition of emotions, especially fear and sadness. (Hamann et al., 1996; Morris et al., 1996) People with damage in the amygdala have difficulty recognizing these emotions (Adolphs et al., 1994; Calder et al. 1996), and brain scans from normal volunteers show high activating in the amygdala while viewing faces showing emotional expressions, especially fear.
Tests of monkeys in social groups showed that removal of the amygdala makes them social outcasts from their troupe. They become social outcasts because they cannot recognize the meaning of emotionally and socially important signals from other monkeys. They can’t tell when to back off, so they get beaten up and kicked out of their troupe. For example, monkey with damage in the amygdala approach a normal monkey, even when it signals the test monkey to back off (Emery et al, 2001). Link to an article about the amygdala's possible role in social function, depression, autism, etc.

The **anterior cingulate cortex appears to play an important role in selecting and executing voluntary actions** (Posner, 1994). Complex, high-level tasks activate this area, especially if they require high performance, coordinating several activities, dealing with novelty, and response monitoring. Such tasks put a heavy demand on attention and decision-making. This brain area is also activated by positive, attractive events, which enhance voluntary responding.

Match the behavioral processes below with the part of the brain to which they are most closely related

| Q8A | increased activity here when you are memorizing the names of brain areas |
| Q8B | increased activity here when you watch a scary horror movie |
| Q8C | animals will work very hard to turn on weak electrical stimulation here |
| Q8D | increased activity here when you are successfully solving a complex task |
| Q8E | becomes more active when you get thirsty |
| Q8F | the system essential for normal motivation and emotion; it includes all the other brain areas in the list |

1. limbic system  2. amygdala  3. hypothalamus  4. hippocampus and related areas  5. anterior cingulate

The **basal ganglia** are crucial areas for integrating (combining) information from many different brain systems. They are several large areas of grey matter deep inside the cerebral hemispheres (see Figures 11-2e and 12-2e), separated from the cortex by white matter. They play an essential role in starting and executing behaviors smoothly, quickly, and efficiently. Damage to this system, disorganizes movement and make movements difficult to start or to stop.

For example, Parkinson’s disease is the result of losing of nigrostriatal bundle, a set of neurons that form a major pathway in the basal ganglia from the substantia nigra to the striatum. Some of you probably know an older person who suffers from Parkinson’s disease. The first sign of Parkinson’s disease is usually a slow shaking of the resting hand or foot. As the disease progresses, voluntary movement becomes harder to start, walking becomes a slow shuffle, and the face becomes mask-like and unexpressive. In its late stages, patients are unable to move voluntarily.

Surprisingly, patients with Parkinson’s Disease can make quick, automatic reactions to specific triggering stimuli, especially under stress. For example, a former baseball player who was paralyzed this way could quickly raise his hands to catch a ball thrown at him unexpectedly. Mohammed Ali, the former heavyweight boxing champion, is one well known figure who suffers from it; his boxing career may have helped the disorder to develop. It usually appears later in life, but some young people developed devastating cases because of an impurity that can form in certain improperly prepared "recreational" street drugs. Link to information about Parkinson's Disease.

Parts of the basal ganglia also appear to be important in storing and retrieving automatic, non-conscious memories, like memory for motor skills and habits (Petri & Mishkin, 1994). For example, rats trained to find a goal in a water maze could not recall where to go 24 hours later, if the striatum of the basal ganglia was chemically blocked after training. In contrast, they showed no loss following this treatment on the same kind of task if it required recalling the spatial location of the goal, without any specific cue for it (Packard & Teather, 1997). The first task requires learning a specific association between cue for goal area and successful
responding, which is a form of non-conscious, automatic memory of a habit (which uses unconscious memory called procedural memory). The second task requires learning a particular place, which depends on conscious memories, called declarative memory. These two memory systems are described further in asgn3I.

The basal ganglia also appear to play an important role in the emotion of disgust. People with damage in the basal ganglia show a selective defect in recognizing this emotion in pictures showing different emotions in facial expressions. (Calder et al., 2000, 2001)

Q9. Mark each of the following with T if it likely to be an effect of damage in the basal ganglia or F if it is not.

A. difficulty in consciously remembering new information for more than a few minutes
T F

B. jerky, awkward, poorly timed movements, or slowed voluntary movements
T F

C. problems falling asleep
T F

D. failing to recognize the facial expression of disgust
T F

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asgn2e -- CEREBRAL CORTEX: Association Cortex

asgn2f -- CELLS THAT MAKE UP THE NERVOUS SYSTEM

This exercise is an introduction to the way neurons in the brain work. Neurons are the brain cells that do (most of) the specialized functions of the nervous system: communication and integration. The exercise outlines:

- the codes that neurons use to signal excitation and inhibition
- the way one code integrates (combines) signals from 1,000s of other neurons
- the way the other code communicates (sends) that integrated signal to 1,000s of other neurons.

When you have finished the exercise, you should know

- the main parts of the neuron:
  - dendrites: the message-receiving part of the neuron
  - axon: the message-sending part of the neuron
  - cell body or soma: the metabolic (life process) center of the neuron

- the two main codes that neurons use, and how they work:
  - all-or-nothing impulse code on the axon, specialized for reliable transmission over distance: communication
  - graded response on the dendrites, specialized for combining signals from many other neurons: integration

Neurons carry out their specialized functions of communication and integration because their outer cell membrane has special properties. The cell membrane separates the inside of all cells (not just neurons) from the outside, and all chemicals that get into and out of the cell must go through it. As in all cells, the neuron is polarized. This means that there is an electrical difference across the cell membrane.

To measure the polarization of a cell, a very thin electrode is put inside a cell and connected to a very sensitive voltmeter, as illustrated in Figure 1-2f. (The electrode is usually a thin glass tube filled with a conducting salt solution. The tube is tapered to a very fine point (about 1 um thick), which is barely visible with a light microscope.) The meter shows that the inside of the cell has a negative voltage relative to the outside. In a neuron that is neither excited nor inhibited, this electrical difference is called the resting potential.

Figure 3-2f shows that the "typical" neuron has a resting potential of about -70 mV (about 1/20 of what a flashlight battery produces).
Q1. An electrode inside an unstimulated neuron records ___ of about -70 millivolts.
A. an electrical difference  B. a polarization  C. a resting potential  D. a cell membrane
E. A, B, and C are all correct  F. A, B, C, and D are all correct

To understand polarization, think of a flashlight battery. A battery is polarized: it has a + pole (the button at one end), which is positive relative to the - pole (the flat surface at the other end). Imagine that the cell membrane has lots of tiny “batteries” in it, as illustrated in Figure 2-2f. The positive button poles are on the outside of the cell membrane, and the flat negative pole are on inside. This would make the inside of the cell negative relative to the outside.

Of course, the cell membrane really does not have little batteries in it. The polarization is produced by chemically driven molecular “pumps.” These “pumps” push Na+ (positive sodium ions: atoms of sodium with a + electric charge) out of the cell, leaving behind negative ions, especially Cl- (chloride ions). The excess of negative ions left inside the cell makes it negative. The Na+ gets back into the cell when the cell is excited. (Na+ and Cl- are the atoms that form table salt. Dissolving table salt in water breaks it up into these two ions.)

Q2. The polarization across the membrane of a neuron (and all other living cells) is caused by
A. putting electrodes through the neuron’s cell membrane  B. tiny batteries in the cell membrane
C. pumping out positively charged atoms of sodium  D. combining positive sodium and negative chloride ions

Coding excitation and inhibition on dendrites

The cell membrane of neurons is modified to have special properties. These special properties let dendrites integrate information and let axons communicate the integrated information reliably to other neurons.

3. All the excitation and inhibition the dendrites add up by a process called summation
4. The total amount of + and - determines what the polarization across its membrane is.
   a. If the neuron gets more + (excitation) than -, then its polarization shifts toward 0.0 mV. This is called depolarization. If + is only a little more than -, the depolarization is small. If + is a lot more than -, the depolarization is large.
   b. If the neuron gets more - than +, then polarization shifts away from 0.0 mV. This is called hyperpolarization. If - is only a little more than +, the hyperpolarization is small; if - is a lot more than +, the hyperpolarization is large.

Match the following terms with what they mean.
1. excitation  2. inhibition  3. summation
Q3A. polarization on dendrites goes from -70 mV to -64 mV
Q3B. a dendrite gets 20 excitatory inputs and 20 inhibitory inputs, and its polarization shows no net change
Q3B. the input to a dendrite changes its polarization from -70 mV to -73 mV

The dendritic membrane varies smoothly, because summation on it adds up the small excitations (+) and inhibitions (-) from the many synaptic connections it gets from other neurons. Each synapse can produce a little depolarization or a little hyperpolarization. The dendritic membrane adds all of them up, and the total + and - = the membrane’s polarization at that moment. Because the dendritic membrane adds up all these different excitations and inhibitions, its polarization changes smoothly with changes in excitation and inhibition. This kind of polarization changes called a graded response.
Figure 6-2f illustrates this with six meters showing different graded responses from the dendrites. The illustrated values range from -95 mV to -45 mV, but they could take any value: -57.7 mV, -73.4 mV, -66.1 mV, or any other. The dendritic membrane's polarization changes just a little when it sums (adds up) weak signals from a few other cells. It changes a lot when it sums strong signals from many other cells. Therefore, size of the change in polarization reflects how strong the signals from other neurons reaching the dendrites are.

A dimmer switch is an analogy to graded response coding on dendrites. Dimmers can vary the brightness of a light smoothly from very bright to very dim (not just on or off). In the same way, the dendritic membrane acts like a dimmer switch, because their polarization can vary smoothly in its response to signals from other neurons. Turning the dimmer in Figure 5-2f toward -45 mV (right) increases excitation. Turning it toward -95 mV (left) has the opposite effect by increasing inhibition.

Q4. The dendrite's response to excitation and inhibition is graded. This means that
A. its polarization varies smoothly with the amount of excitation and inhibition it gets from other cells
B. it grades excitations into inhibitions from many sources
C. it contains many dimmer switches
D. strong stimulation excites its polarization, and weak stimulation inhibits its polarization.

The combined signal that summation produces on dendrites must be sent to other neurons to have an effect. The axon of the neuron does this job. It is designed to communicate this information reliably over distances that can be 1.5 meters or more (in a giraffe, 5 or 6 meters, because of its long neck).

To do this, the axon uses a "digital" or pulse code. The axon is either off or (briefly) on, as when you flick a light switch on and off. It generates brief pulses of electrical current called action potentials or all-or-nothing impulses (usually impulse, for short). All-or-nothing refers to the fact that the axon makes them all (about) the same size.

Because the all-or-nothing impulses on axons are all the same size, the size of the impulses does not transmit information. Instead, the axon uses the number of impulses per second (rate) as the code for stimulus intensity. Digital yes/no codes like this are very reliable (especially for transmission over long distances), because noise (~interference) does not affect the rate of a digital, pulse code signal.

Communications engineers discovered about 60 years ago what nature "discovered" through evolution at least 500 million years ago, when animals that probably had specialized nerve cells first appeared. Modern communications lines, like the cables that carry long-distance telephone calls, carry a digitized version of your voice. That is why a long distance call from across the continent or even across the ocean usually sounds as clear as if it were coming from next door.

Depolarization (excitation) on the dendrites must reach threshold (~minimum level) to generate any impulses. Above that threshold, the stronger the excitation is, the more impulses travel down the axon each second. Inhibition has the opposite effect. It slows the rate of the all-or-nothing impulses or stops them entirely.

Figure 7-2f summarizes this rate code. The horizontal axis is time (a few seconds). Each vertical line stands for an all-or-nothing impulse. The top line shows that the axon fires no impulses when the excitation is

Communications engineers discovered about 60 years ago what nature "discovered" through evolution at least 500 million years ago, when animals that probably had specialized nerve cells first appeared. Modern
too weak to reach threshold. The next four lines show increasing numbers of impulses as intensity of excitation increases above threshold. The bottom line show that inhibition generates no impulses.

When a neuron sends all-or-nothing impulses down its axon, neuroscientists often say that the neuron is firing. Think of the neuron as a machine gun and the all-or-nothing impulses traveling down the axon from the dendrites to the axon terminal as bullets it fires. In this machine gun, the tighter the trigger is squeezed (graded depolarization on dendrites), the more bullets it fires every second (all-or-nothing impulses on the axon). Therefore, the number of bullets that leave the machine gun every second reflects how strongly the dendrite trigger is being pulled. Link to more about the codes that dendrites and axons use.

Q5. Mo measures the activity of an axon in the optic nerve from the eye to the brain. When she shines a tiny spot of light on the eye, the rate of all-or-nothing impulses increases from 5/sec. to 10/sec. This means the light ____ the neuron. When she shines the light on a neighboring spot on the eye, the rate of all-or-nothing impulses decreases from 5/sec. to 1/sec. This means the light ____ the neuron. Hint: 
A. excited; excited
B. excited; inhibited
C. inhibited; inhibited
D. inhibited; excited
E. not enough information provided

asgn2g -- SIGNALS THAT NEURONS USE: Transmission at Synaptic Connections

This exercise describes the basic process of transmitting signals from one neuron to another: synaptic transmission. At most synapses in the brain, chemical messengers called neurotransmitters send signals from one neuron to the next. Synaptic transmission is particularly important for two reasons: 
! Behavioral change is associated with synaptic change. Learning and all other behavioral change processes depend on changes in synaptic efficiency. 
! Psychologically active chemicals (almost) all act by changing synaptic function. Psychoactive drugs and medications have selective psychological effects because: 
! they act on only one or a few of the many different types of synaptic transmission systems, 
! each brain system uses only one or a few chemical neurotransmitter systems at their synapses. Therefore, if a medication or "recreational" drug affects one chemical transmitter system, then it also acts on only those few brain systems that use it.

When you have completed this exercise, you should be able 
! to explain the steps in synaptic transmission. 
! to explain why psychologically active chemicals can have selective effects on synaptic transmission and on behavior. 
! to recognize a few major chemical neurotransmitters, their general behavioral functions, and chemicals that affect these neurotransmitters and the behavioral effects they have.

**Synapses** are the connections between neurons, where one neuron can affect the activity of another. The signals from one neuron travel down its axon (nerve fiber) to axon terminals (or terminal buttons). There, axon terminals almost touch the dendrite of another neuron to form a synapse. The "typical" synaptic connection sends signals from the axon terminal button of one neuron to the dendrite of another neuron. Figure 1-2g shows the main parts of a "typical" synapse. Most synapses use chemical neurotransmitters (often called simply transmitters) to send signals from one neuron to the next. The nervous system has many more than 50 different identified chemicals that act or

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**Figure 1-2g Parts of a synapse.**

- **Parts of a Synapse**
  - Axon Terminal
  - Synaptic Cleft
  - Dendrite
  - Pre-synaptic Membrane
  - Postsynaptic Membrane
probably act as transmitters. It is estimated that perhaps hundreds more have yet to be identified. Some of them are called neuro-modulators, because they only change the dendrites' sensitivity to other transmitters, but do not trigger signals themselves. I will ignore this difference and use only the term neurotransmitter.

Q1. Transmission from the axon terminal of one neuron to the dendritic membrane of another occurs by
A. all-or-nothing impulses   B. graded responses
C. a chemical neurotransmitter D. psychologically active drugs and medications

[Memorize and understand the next two paragraphs!] These different neurotransmitters are very important psychologically. Psychologically active drugs have selective effects on behavior because each drug affects only one or a few of the many neurotransmitter systems. For example, opiates, like morphine (the "standard" for pain relief) and heroin, depress the brain and the body because they act on a specific set of transmitters. Cocaine and amphetamine stimulate the brain, because they act on a different set of transmitters. The strong hallucinogens, like LSD, affect a third systems, and sleep-inducing medications like barbiturates act on a fourth.

Synaptic transmission has five steps:
1. synthesis: making the chemical transmitter molecules.
2. storage: putting the transmitter molecules away to protect them till needed.
3. release: letting them out of the axon terminal into the tiny synaptic cleft, the submicroscopic gap between the axon terminal of one neuron and dendrite of another.
4. binding: attaching to and activating receptor molecules on the dendrite. This excites or inhibits the dendrite's membrane, depending on the kind of synapse.
5. removal by reuptake or breakdown: promptly getting rid of the transmitter molecules so they won’t keep on stimulating the dendrite.

Figure 2-2g summarizes these five steps, which are named in red lettering.

Q2. Chlorpromazine (Thorazine®) was the first medication discovered that helped relieve symptoms of schizophrenia, a severe "mental" illness. ("Mental" illness is mental only in its symptoms; it reflects abnormal brain function, just as strokes and brain tumors do.) Chlorpromazine works
A. in 5 steps: synthesis, storage, release, binding, removal
B. by changing the size of all-or-nothing impulses on axons
C. on the threshold for membrane polarization
D. by affecting a specific chemical neurotransmitter system

Review: These steps are very important to understand, because psychologically active drugs and medications act on one or more of these steps of a synaptic transmitter system.

For example, amphetamine ("speed") blocks the removal (by reuptake) of the transmitter dopamine. Therefore, it makes dopamine synapses act as if the presynaptic axon terminal [presynaptic = before the synaptic cleft] were releasing much more dopamine. Morphine and heroin mimic the action of a family of transmitters called endorphins, because they bind to their receptor molecules and activate them.

Review: Figure 3-2g summarizes the sequence of the steps in synaptic transmission. Click HERE for a step-by-step summary of the stages of synaptic transmission.

The following briefly explains how each of the five steps in synaptic transmission works:
Synthesis. Neurons extract chemicals (often an amino acid from protein) from the blood and convert them into chemicals that serve as neurotransmitters. One or more specific enzymes (biological catalysts) convert the starting chemical into the neurotransmitter.

Storage. Neurons make extra neurotransmitter molecules, so that enough is quickly available if the neuron is strongly excited. This extra neurotransmitter is stored in little packets called vesicles.

Release. All-or-nothing impulses (or action potentials - see asgn2f on neurons) travel down the axon of a neuron and reach the axon terminal where synaptic transmission starts. There, impulses trigger the release of neurotransmitter molecules from the axon terminal into the synaptic cleft. (The synaptic cleft is the tiny gap between the axon terminal button and the dendritic postsynaptic membrane [postsynaptic = after the synaptic cleft].)

Binding. When neurotransmitters reach the dendritic membrane on the other side of the synaptic cleft, they can bind (attach) to receptor molecules specifically shaped to accept those neurotransmitter molecules. Binding activates several reactions, including a change in dendritic membrane polarization, producing depolarization if it is an excitatory synapse and hyperpolarization if it is inhibitory [depolarize = decrease in polarization; hyperpolarization = increase in polarization {hyper = extra, over}]. The binding is loose, so the neurotransmitter molecules soon are released back into the synaptic cleft.

Removal. Neurotransmitter molecules in the synaptic cleft must be removed. If they are not, transmitter molecules would accumulate in the synaptic cleft. These molecules would repeatedly bind with and be released from the receptor molecules. This would stimulate the dendrite repeatedly, as if many impulses were arriving on the axon. If this happens, the dendrite cannot tell the difference between low and high rates of firing on the axon (= weak and strong stimulation from the neuron). The transmitter molecules are either recycled or broken down into an inactive form.

Psychologically active drugs and medications act on one (or a very few) of the more than 50 chemical neurotransmitter systems at some stage of synaptic transmission. Therefore, different psychologically active drugs and medications affect different psychological processes, because they affect different neurotransmitter systems. Different neurotransmitter systems affect different brain systems, which in turn control different behaviors.

Drug A -> neurotransmitter system K -> brain system Q -> behavior X
Drug B -> neurotransmitter system L -> brain system R -> behavior Y
Drug C -> neurotransmitter system M -> brain system S -> behavior Z
Q4. [Mark EACH item True (T) or False (F)] Chlorpromazine and barbiturates (older sleeping pills) are both classed as depressants. Chlorpromazine relieves symptoms of schizophrenia, whereas barbiturates do not. The reason these medications have different effects is that

T F A. they affect different neurotransmitters
T F B. they change the order of the stages of synaptic transmission
T F C. each brain system has its own behavioral function
T F D. they are different neurotransmitters
T F E. each brain system has its own neurotransmitter system

The following are examples of the relation between different recreational drugs and the neurotransmitter systems they affect. The main point is not to memorize this, but to use them to help understand the underlying principle: *psychologically active chemicals produce their effects by changing how one (or a few) neurotransmitter systems work.*

! Alcohol (among other effects) increases the effectiveness of **GABA**, the main inhibitory neurotransmitter in the brain. Other drugs and medication also increase the activity at synapses using GABA. These include barbiturates (older type of sleeping pills) and anti-anxiety medications (like Valium and Librium). These drugs and medications act at different sites, so their combined effect on GABA transmission is much stronger than the sum of their individual effects. This makes combining these drugs and medications with alcohol very dangerous.

! **Amphetamine** and cocaine increase the effectiveness of transmission at **dopamine** synapses, mainly by preventing removal by reuptake. Therefore, much more dopamine remains in the synaptic cleft and binds more with the receptor molecules. This has the effect of increasing the stimulation to the dendrites of the post-synaptic neuron. One brain system that uses dopamine as its neurotransmitter is the "reward system" of the brain, which is what makes these recreational drugs so popular (and so addictive, especially if used for any length of time).

! **Opiates** (drugs like morphine and heroin) mimic the action of a group of transmitter substances called **endorphins**. (These transmitters are sometimes called the brain's own "morphine.") These drugs bind to one or more types of endorphin receptors on the dendrites and activate them as if they were the natural endorphin. Some systems that use endorphins as transmitters inhibit pain systems. Others activate the dopamine-using reward system.

! **Nicotine** (in tobacco) binds to and stimulates one kind of receptor molecule for **acetylcholine**. This transmitter system has recently been found closely associated with the dopamine reward system, which is an important reason for nicotine's strong addictive properties.

Match the drug with the chemical transmitter it affects

1. GABA  2. dopamine  3. endorphins  4. acetylcholine
Q5A. nicotine  Q5B. cocaine  Q5C. heroin  Q5D. alcohol

Reminder: if you are not sure, go back and check the list above. For information on how caffeine works to keep you awake, click HERE.

The following examples illustrate how some medications act to help relieve "mental" disorders.

! **Schizophrenia** is a very disruptive "mental" illness that severely disrupts people’s ability to deal with even ordinary tasks of everyday life. The first effective medication, **CPZ (chlorpromazine)**, was introduced about 45 years ago. Many others, like **HAL (haloperidol)** have been developed. They appear to work by blocking one kind of dopamine receptor. They do so by binding to the receptor molecules *without activating them*. Therefore they prevent dopamine from binding to the receptors and activating them. This is like putting chewing gum into a lock, so the key can't fit in and open it. The more tightly a medication binds to the dopamine receptor, the lower the dose needed to be effective (Creese et al., 1971).

! **Depression** often can be relieved quite successfully by one of several medications. **Imipramine (Tofranil ®)** acts to block the reuptake of norepinephrine (NE) and serotonin (5HT). **Fluoxetine (Prozac ®)** selectively blocks serotonin reuptake. **MAO inhibitors like phenelzine (Nardil ®)** block the breakdown of serotonin, norepinephrine, and dopamine.

! **Anxiety** is often helped by a group of chemicals called **benzodiazepines**, which include Librium® and Valium ®. These act to increase effectiveness of the important inhibitory neuro-transmitter, **GABA**. These medications can become addictive, especially if taken for a long time.
Match the chemical neurotransmitter system with the behavioral problem with which it seems associated

1. dopamine  2. GABA  3. serotonin (and others)

Q6A. anxiety  Q6B. schizophrenia  Q6C. depression

Reminder: if you are not sure, go back and check the list above.

To go to a website with a more detailed description of synaptic transmission, click HERE.