

Chapter 3



The Nervous System

Class 6
September 29, 2009

Organization of the Nervous System

- Central nervous system (CNS) – brain and spinal cord
 - Afferent = toward the CNS/ Efferent = away from the CNS
- Peripheral nervous system – nerves that lie outside the central nervous system
 - Somatic nervous system– voluntary muscles and sensory receptors
 - Autonomic nervous system (ANS) – controls automatic, involuntary functions
 - Sympathetic – Go (fight-or-flight)
 - Parasympathetic – Stop

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The nervous system has two main divisions, central and peripheral.

The central nervous system consists of the brain and spinal cord, while the peripheral nervous system consists of nerves that lie outside the brain and spinal cord.

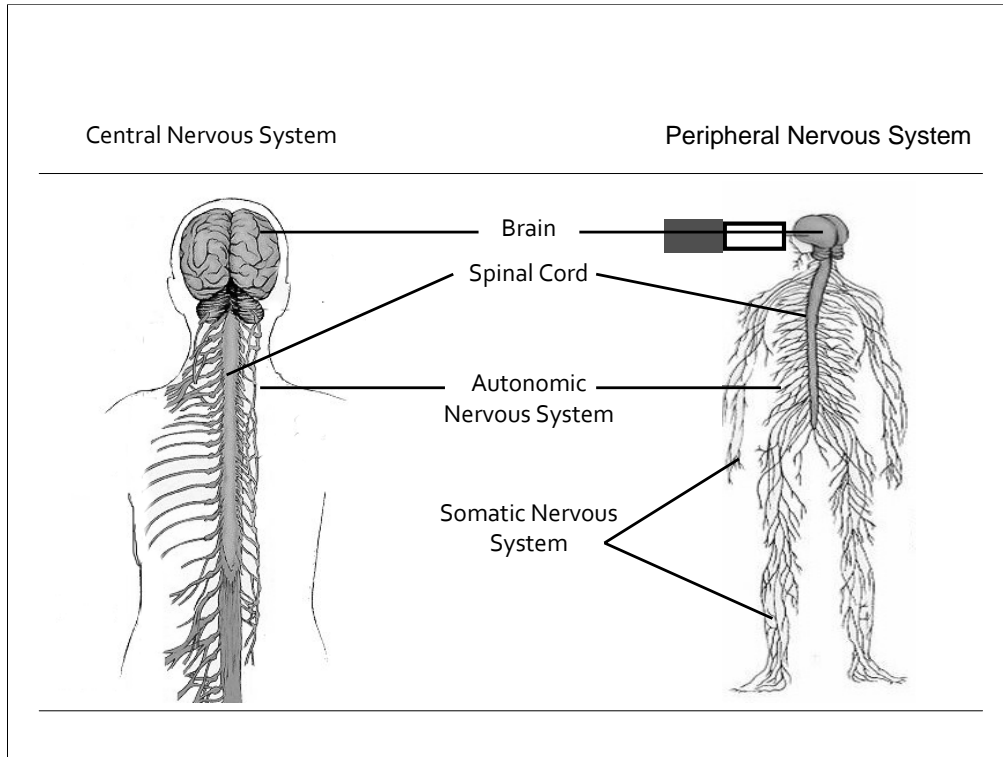
In the peripheral nervous system, afferent nerve fibres send information toward the CNS, while efferent nerve fibres send information away from the CNS.

There are two divisions of the peripheral nervous system, the somatic, or voluntary portion, and the autonomic, or involuntary portion.

The autonomic portion of the peripheral nervous system governs involuntary, visceral functions...such as heart and breathing rate, blood pressure, etc.

When a person is autonomically aroused, these speed up. This speeding up is controlled by the sympathetic division of the autonomic nervous system...the sympathetic nervous system mobilizes the body's resources for emergencies and creates the fight-or-flight response.

The parasympathetic division, in contrast, activates processes that conserve bodily resources...slowing heart rate, reducing blood pressure, etc.



Introduce the parts of the nervous system:

The nervous system is subdivided into two parts: the central and peripheral nervous systems.

The peripheral nervous system is made up of both cranial and spinal nerves whose branches are present in virtually all parts of the body. These nerves pick up sensory information and carry it to the central nervous system, as well as emit motor actions controlled by the central nervous system.

The central nervous system is composed of the *brain* and the *spinal cord*.

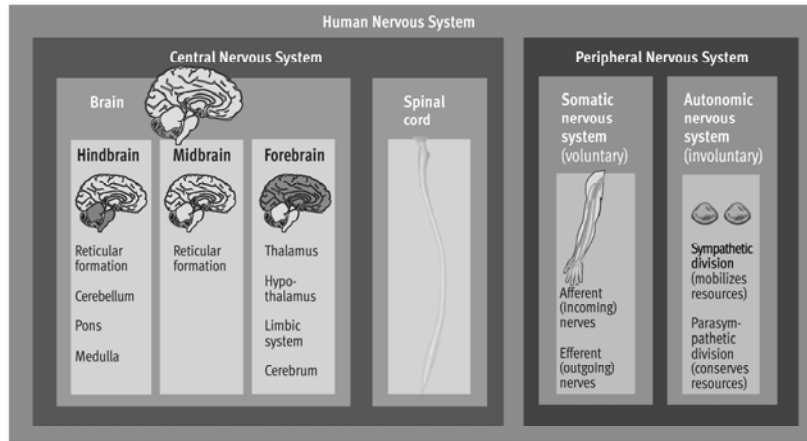
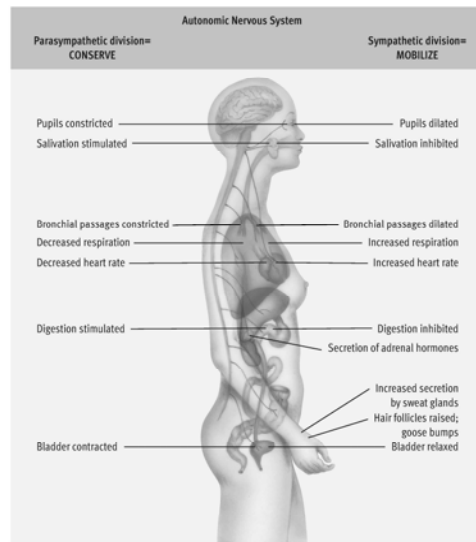


Figure 3.6
Organization of the human nervous system. This overview of the human nervous system shows the relationships of its various parts and systems. The brain is traditionally divided into three regions: the hindbrain, the midbrain, and the forebrain. The reticular formation runs through both the midbrain and the hindbrain on its way up and down the brainstem. These and other parts of the brain are discussed in detail later in the chapter. The peripheral nervous system is made up of the somatic nervous system, which controls voluntary muscles and sensory receptors, and the autonomic nervous system, which controls the involuntary activities of smooth muscles, blood vessels, and glands.

Parasympathetic
(paralyzed)

STOP



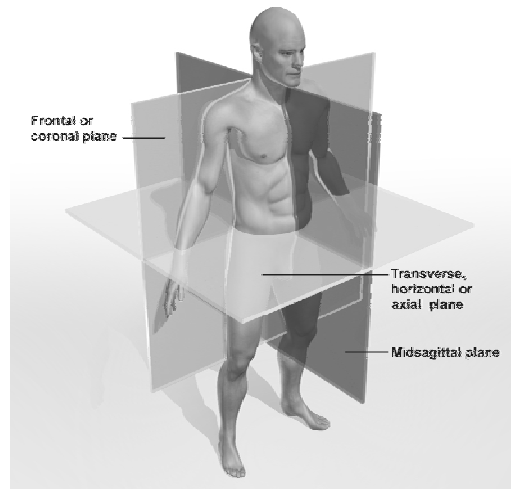
Sympathetic
(speed)

GO

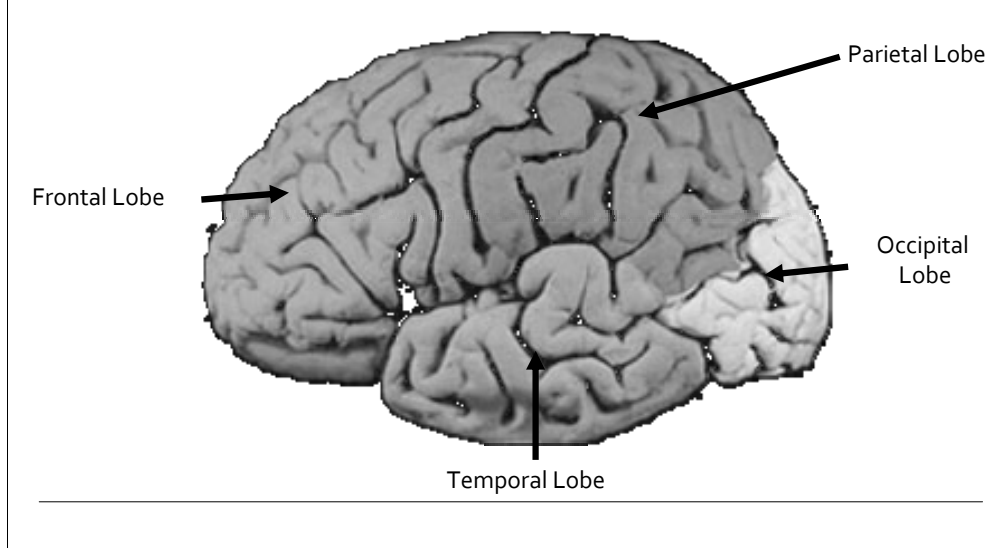
Figure 3.8

The autonomic nervous system (ANS). The ANS is composed of the nerves that connect to the heart, blood vessels, smooth muscles, and glands. The ANS is divided into the sympathetic division, which mobilizes bodily resources in times of need, and the parasympathetic division, which conserves bodily resources. Some of the key functions controlled by each division of the ANS are summarized in this diagram.

Anatomical Planes



Lateral view of the cerebral cortex



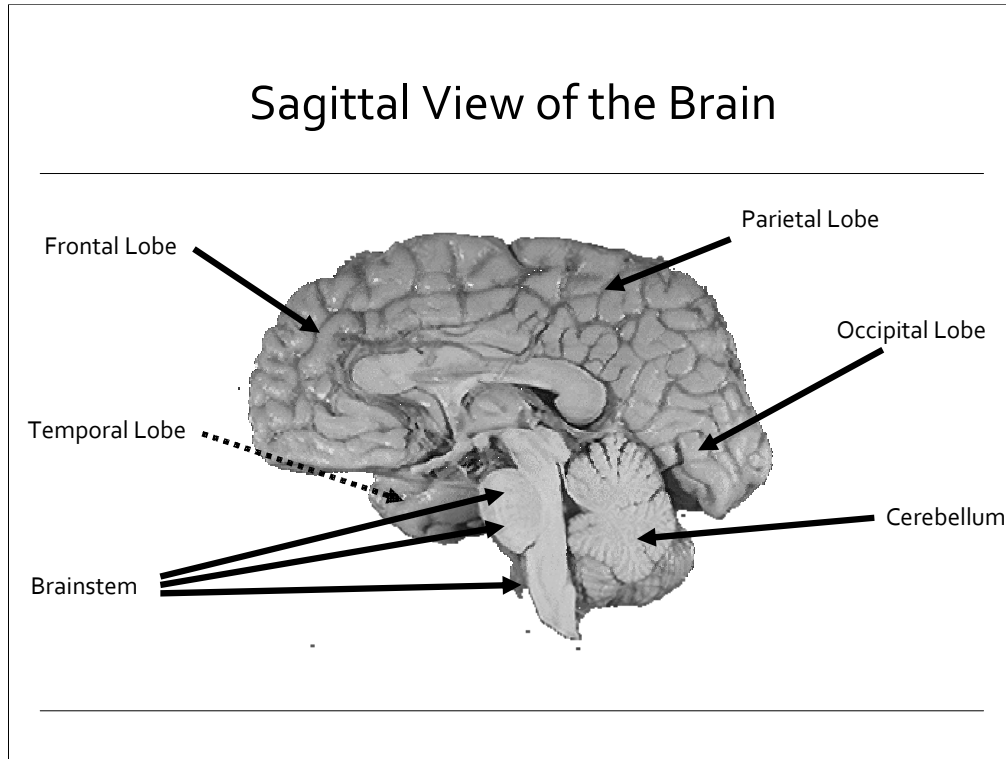
Review the lobes and introduce the temporal lobe:

This is a lateral, or side view of the brain.

This view shows the four lobes of the cerebral cortex: frontal, parietal and occipital as mentioned before.

The view also shows the temporal lobe. This lobe is involved in auditory processing (i.e. music and speech), visual processing, and memory.

Sagittal View of the Brain



Introduce the parts of the brain:

This is a mid-sagittal view or an image of the brain as if it were cut right down the middle of your head.

The major parts of the brain (which is part of the central nervous system) are:

Brainstem: The brain stem plays a vital role in basic attention, arousal, and consciousness. All information to and from our body passes through the brain stem on the way to or from the brain. (midbrain, pons, medulla oblongata)

Cerebellum: Important for coordination, balance, and control of voluntary movements.

Cerebrum: The cerebrum includes the cerebral hemispheres and the diencephalon (thalamus and hypothalamus).

- Only three of the four lobes of the cerebral cortex are identified here.

The **frontal lobes** are involved in motor function, problem solving, spontaneity, memory, language, initiation, judgment, impulse control, and social and sexual behavior. The frontal lobes are extremely vulnerable to injury due to their location at the front of the cranium (plug helmets!).

The **parietal lobes** process sensory information (i.e. touch). They are also involved in spatial processing (i.e. forming mental map).

The **occipital lobe** is involved in visual processing (i.e. color discrimination, movement processing, form processing).

The lobe that cannot be viewed from this sagittal image is the **temporal lobe**.

Brainstem

- Essential for life
- breathe,
- pump blood,
- sleep,
- wake up, and
- digest food



Cerebellum

- Coordination of complex movements and balance.



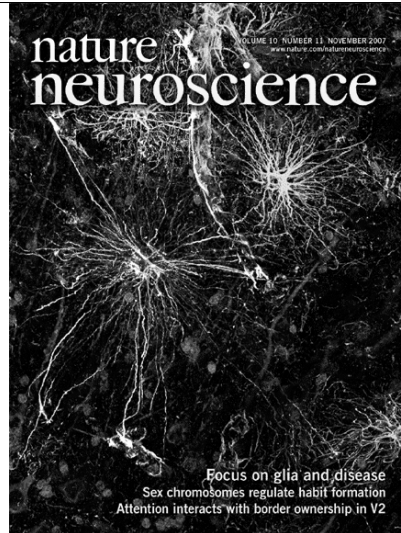
Limbic System

- Emotions
- Memories



Communication in the Nervous System

- Two types of brain cells:
 - Glia – structural support, insulation, and communication
 - Neurons – communication
 - Soma – cell body
 - Dendrites – receive
 - Axon – transmit away



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Behaviour depends on rapid information travel and processing...the nervous system is the body's communication network, handling information just as the circulatory system handles blood.

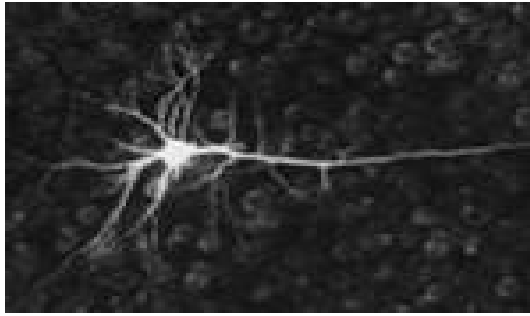
The basic components of the nervous system are living cells called neurons and glia.

Glia are cells that provide structure and insulation for neurons...neural "glue."

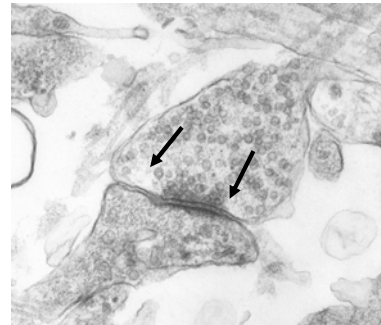
Neurons are cells that receive, integrate, and transmit information...permitting communication in the nervous system.

A "typical" neuron consists of a soma, or cell body; dendrites, which are feeler-like structures specialized to receive information; and an axon, which is a long, thin fibre that transmits signals away from the soma to other neurons, or to muscles or glands...the basic flow of information is as follows...the dendrite receives a signal, the signal passes through the soma and down the axon to the dendrites of another neuron.

Introduction to Neural Transmission



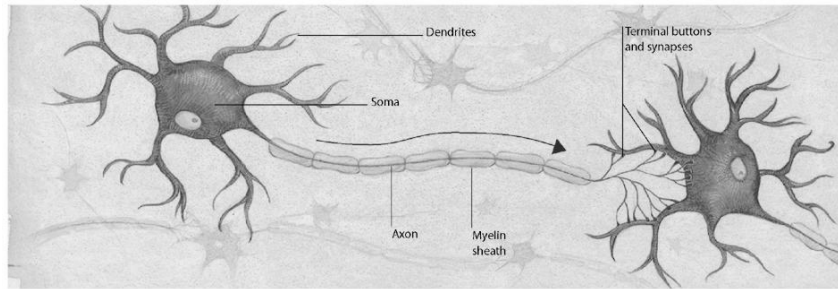
Neuron



Synapse

Neuron and Neural Impulse

Figure 3.1 - Structure of the neuron.



PLAY
ANIMATION

The Neural Impulse: Electrochemical Beginnings

- Hodgkin & Huxley (1952) - giant squid
 - Fluids inside and outside neuron
 - Electrically charged particles (ions)
 - Neuron at rest – negative charge on inside compared to outside
 - -70 millivolts – resting potential

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Alan Hodgkin and Andrew Huxley in the 1950's discovered the mechanics of neural transmission by studying giant squid...which have axons that are about 100 times larger than human axons.

Found that fluids inside and outside the neuron contain electrically charged particles, or ions.

Also found that when a neuron is "at rest" the inside has more negative ions than the outside. The stable negative charge of a neuron when it is inactive is its resting potential.

The Neural Impulse: The Action Potential

- Stimulation causes cell membrane to open briefly
- Positively charged sodium ions flow in
- Shift in electrical charge travels along neuron
- The Action Potential
- All – or – none law

16 16

When a neuron is stimulated, channels in the cell membrane open briefly, allowing the positive ions outside the cell to flow into the electronegative inside...this shift in the electrical charge travels along the axon and is referred to as an action potential. Either an action potential occurs, or it doesn't. Once an action potential is initiated, it goes full force.

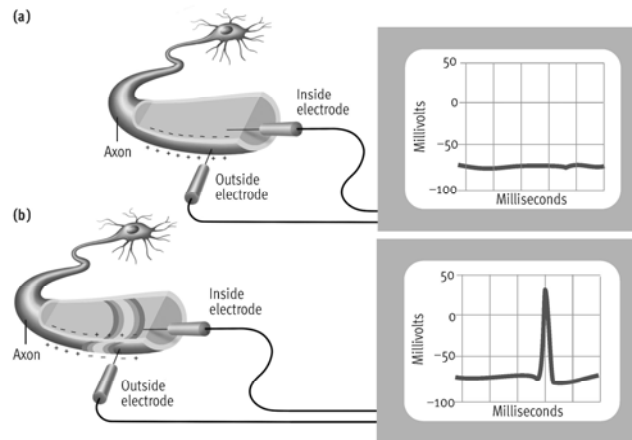


Figure 3.2

The neural impulse. The electrochemical properties of the neuron allow it to transmit signals. The electric charge of a neuron can be measured with a pair of electrodes connected to an oscilloscope, as Hodgkin and Huxley showed with a squid axon. Because of its exceptionally thick axons, the squid has frequently been used by scientists studying the neural impulse. (a) At rest, the neuron's voltage hovers around -70 millivolts. (b) When a neuron is stimulated, a brief jump occurs in the neuron's voltage, resulting in a spike on the oscilloscope recording of the neuron's electrical activity. This change in voltage, called an *action potential*, travels along the axon like a spark traveling along a trail of gunpowder.

The Synapse: Chemicals as Signal Couriers

- Synaptic cleft
- Presynaptic neuron
 - Synaptic vesicles
 - Neurotransmitters
- Postsynaptic neuron
 - Receptor sites

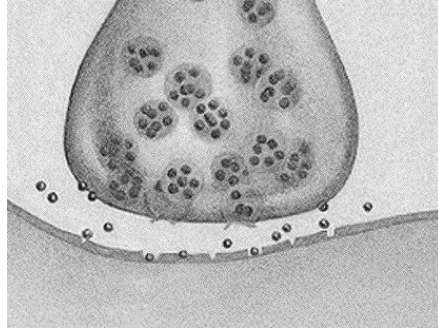
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Neurons don't actually touch at a synapse, instead they are separated by a microscopic gap between the terminal button of one neuron and the cell membrane of another neuron - the synaptic cleft.

Electrical signals can't jump this gap. Instead, the neuron that is sending the message across the gap (the presynaptic neuron) releases neurotransmitters into the synaptic cleft. This occurs when the action potential gets to the terminal button and causes the synaptic vesicles (storage sacs for the neurotransmitter) to fuse with the membrane at the end of the axon and spill its contents into the synaptic cleft.

The neurotransmitters diffuse across the space where they find open receptor sites on the postsynaptic neuron. These sites recognize and respond to some neurotransmitters, but not to others.

Synaptic Transmission



Mac Users

**PLAY
ANIMATION**

Neural Communication: Insulation and Information Transfer

- Myelin sheath – speeds up transmission
- Terminal Button – end of axon; secretes neurotransmitters
- Neurotransmitters – chemical messengers
- Synapse – point at which neurons interconnect

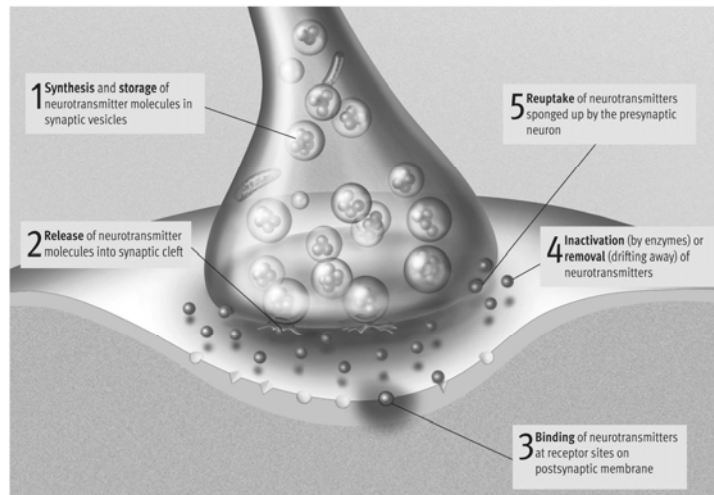
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For efficient neural transmission to take place, many axons are covered with an insulating material called myelin. Myelin sheaths speed up transmission of signals that move along axons. Multiple sclerosis is a myelin degeneration disease, causing loss of muscle control, etc. due to loss of transmission efficiency in the nervous system when the myelin sheaths deteriorate.

At the end of an axon, the terminal buttons are small knobs that secrete chemical messengers called neurotransmitters. When the signal gets to the end of the axon, it causes these chemical messengers to be released into the synapse...the junction of two neurons. The chemicals flow across the synapse and stimulate the next cell.

Figure 3.4

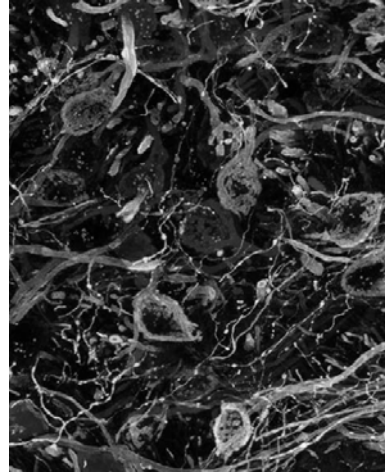
Overview of synaptic transmission. The main elements in synaptic transmission are summarized here, superimposed on a blowup of the synapse seen in Figure 3.3. The five key processes involved in communication at synapses are (1) synthesis and storage, (2) release, (3) binding, (4) inactivation or removal, and (5) reuptake of neurotransmitters. As you'll see in this chapter and the remainder of the book, the effects of many phenomena—such as pain, drug use, and some diseases—can be explained in terms of how they alter one or more of these processes (usually at synapses releasing a specific neurotransmitter).



Signals:

From Postsynaptic Potentials to Neural Networks

- One neuron, signals from thousands of other neurons
- Requires integration of signals
 - PSPs add up, balance out
 - Balance between IPSPs and EPSPs
- Neural networks
 - Patterns of neural activity
 - Interconnected neurons that fire together or sequentially
- Synaptic connections
 - Elimination and creation
 - Synaptic pruning



Brainbow - Jeff Lichtman and Joshua Sanes, Harvard Brain Center

22 22

One neuron may receive signals from thousands of other neurons, across thousands of different synapses.

Each neuron must integrate the many signals arriving at the same time before it “decides” to fire.

EPSPs together add up...enough can cause the cell’s voltage to reach the threshold at which the action potential will begin.

EPSPs and IPSPs may balance out, as well, and the neuron would remain at rest.

Thus, the state of the neuron is a weighted balance.

Thought occurs through the firing of millions of neurons in unison. Our perceptions, thoughts, and actions depend on patterns of neural activity in interconnected neurons that fire together or sequentially – neural networks.

The links in these networks are constantly changing, with synaptic pruning or the elimination of old or unused synapses playing a larger role than the creation of new synapses in the sculpting of neural networks. For example, the number of synapses in the human visual cortex begins to decline after the age of 1 year.

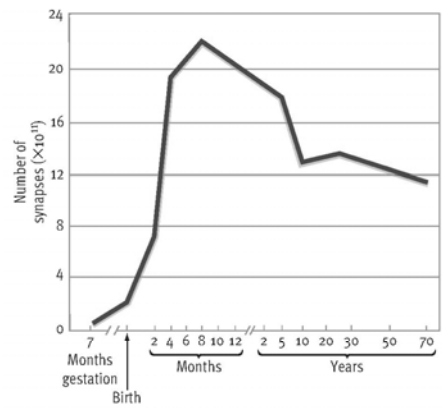


Figure 3.5

Synaptic pruning. This graph summarizes data on the estimated number of synapses in the human visual cortex as a function of age (Huttenlocher, 1994). As you can see, the number of synapses in this area of the brain peaks around age one and then mostly declines over the course of the life span. This decline reflects the process of *synaptic pruning*, which involves the gradual elimination of less active synapses.

Source: Data based on Huttenlocher, P. R. (1994). Synaptogenesis in human cerebral cortex. In G. Dawson & K. W. Fischer (Eds.), *Human behavior and the developing brain*. New York: Guilford Press. Graphic adapted from Kolb, B., & Whishaw, I. Q. (2001). *An introduction to brain and behavior*. New York: Worth Publishers.