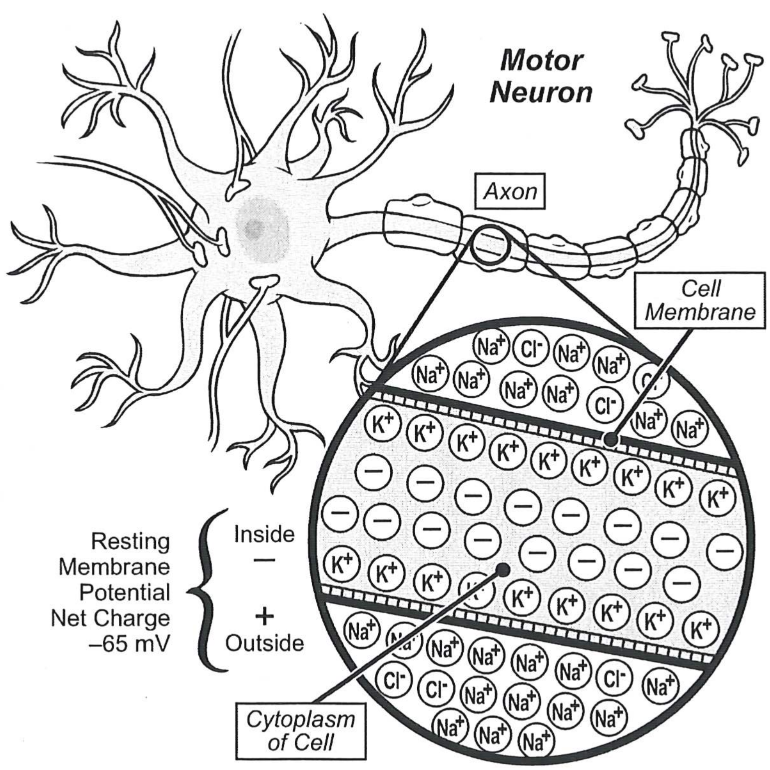
Section 4.1
Nervous System

Section Overview

Tasting, smelling, seeing, hearing, thinking, dreaming, breathing, heart beating, moving, running, sleeping, laughing, singing, remembering, feeling pain or pleasure, painting, writing...you couldn't do any of these things without your nervous system!

Your nervous system is made up of your brain, your spinal cord, and an enormous network of nerves that thread throughout your body, it's the control center for your entire body. Your brain uses information it receives from your nerves to coordinate all of your actions and reactions. Without it, you couldn't exist!



Resource List

- *Inquiry Into Life*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod4.html

Lesson 4.1A
Neurons—Electric Cells

Overview

As you read this lesson, your nervous system is performing a complex series of electrical events, all propagated along **neurons**. Neurons, along with neuroglial cells, are specialized cells that make up the nervous system.

The nervous system is divided into two functional divisions—the peripheral nervous system (PNS), made up of motor and sensory neurons, and the central nervous system (CNS). Neurons are found in both systems. These two systems will be explored in future lessons.

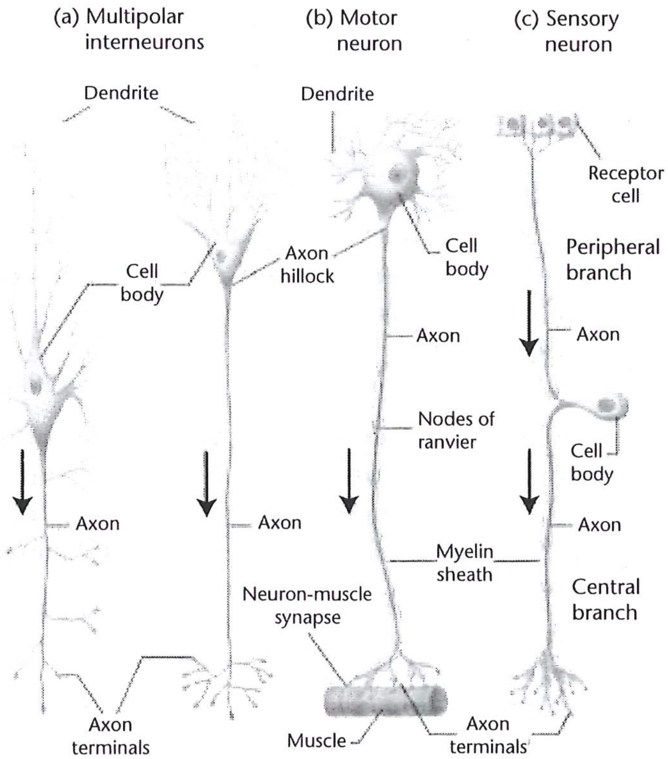
Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*

Neurons: Structure and Function

There are three kinds of neurons: **motor neurons**, **sensory neurons**, and **interneurons**.

1. Motor neurons carry impulses (individual electrical events called action potentials) from the **central nervous system** (brain and spinal cord) to muscles and organs (i.e., the heart)
2. Sensory neurons carry impulses from the **sensory receptors** (any cell that detects external or internal stimulation, such as those in the retina of the eye that detect light) to the central nervous system
3. Interneurons carry impulses from sensory neurons to motor neurons, and are located solely in the central nervous system



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Look at types of neurons in Figure 17.2 on page 321 of your *Inquiry Into Life* textbook.

Neuron Structure

Throughout the body, neurons are organized in different ways, and their structures and functions are subtly different. The following questions will help you focus on their differences and similarities. Use the diagram in your *Inquiry Into Life* textbook for comparison.

In each drawing, locate the cell bodies. Now note the extensions from the cell bodies. At the top of the illustrations, you'll see that the extensions are either **axon** or **dendrites**. The extensions at the bottoms of each illustration are all dendrites.

The arrows indicate the direction an impulse travels along the neuron. In all cases, it's from the top to the bottom of the cell.

The movement of the impulse in relation to the extensions can be used to write a general rule about the direction of impulse travel in neurons:

> Impulses travel from dendrites toward the cell body and then down the axons.

Use the diagrams in your *Inquiry Into Life* text and the above rule to trace the path of an impulse from receptor to effector. Effectors are located at the end of motor neurons. They respond to impulses that travel down the axons of motor neurons.

Myelin Sheath

The **myelin sheath** is an important component of neuron structure. Cells that have a myelin sheath are described as myelinated. Myelinated axons enable the neuron to quickly transfer or propagate an impulse. In the human body, myelinated axons carry impulses at about 2 metres/second. Non-myelinated dendrites carry impulses about 50 to 100 times more slowly than myelinated axons.

Myelinated axons are found in long nerves that connect sensory organs, for example, the skin on your toes, to the central nervous system. A disease called multiple sclerosis (MS) attacks the protective myelin covering of neurons, and sometimes destroys it. This damage interrupts the normal movement of nerve impulses along the axons. The symptoms of MS vary greatly from person to person, ranging from problems with vision and coordination to partial or even complete paralysis.

Guided Practice 4.1A 1
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

Vocabulary terms to know for this lesson:

- axon
- cell body
- central nervous system
- dendrite
- effector organs
- interneurons
- myelin sheath
- motor neurons
- neuron
- sensory neuron
- sensory receptors

Guided Practice 4.1A 2
Types of Neurons

Select the best answer to each question.

1. Of the three types of neurons, the one with long axons and short dendrites is:

   A. sensory neuron

   B. motor neuron

   C. interneuron

   D. neuroglial cell

2. The structure in neurons that improves the speed of impulse travel is:

   A. axon

   B. sensory receptor

   C. effector

   D. myelin sheath

3. The neuron that is located entirely within the CNS is:

   A. sensory neuron

   B. motor neuron

   C. interneuron

   D. neuroglial cell

4. Cell bodies are outside the CNS in a:

   A. sensory neuron

   B. motor neuron

   C. interneuron

   D. neuroglial cell

5. Which is found only in some neurons?

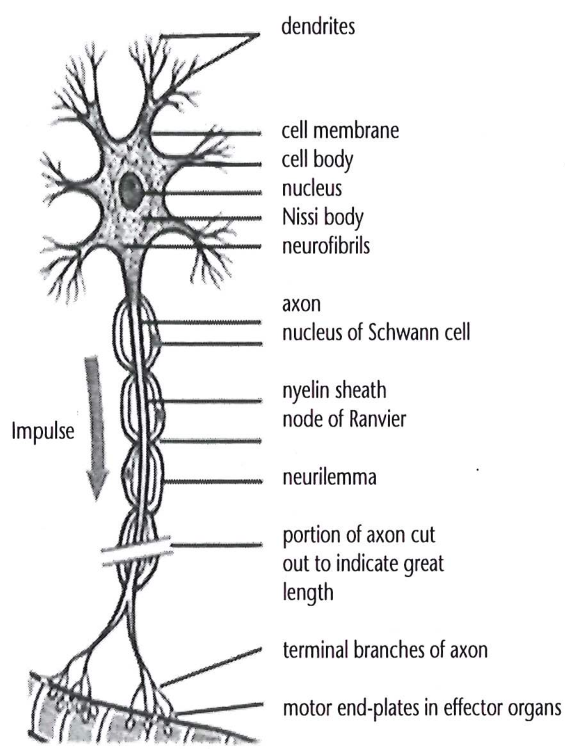
   A. cell bodies

   B. axons

   C. dendrites

   D. myelin

6. Which type of neuron is illustrated in this drawing?



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   A. sensory neuron

   B. motor neuron

   C. interneuron

   D. neuroglial cell

Guided Practice 4.1A 3
Comparison of Neuron Types

Using information from this lesson and your *Inquiry Into Life* textbook, complete the following table.

	Sensory Neuron	Interneuron	Motor Neuron
Relative length of dendrite			
Axons with myelin?			
Dendrites with sensory receptors?			
Position of cell body relative to other cell parts			
Location of cell body			
Attached to effector?			
Names of main cell parts present			

Summary

There is no section assignment for this lesson.

Completing this lesson has helped you to:

- recognize various neurons from drawings
- explain how neurons are connected, structurally and functionally
- describe anatomical differences between neurons

Lesson 4.1B
Impulse Transmission

Overview

For the human body to work properly, it must be able to gather external and internal information, send the information to a processing centre to be deciphered, and send appropriate responses to various muscles and organs. This is largely accomplished by neurons "firing" in a controlled and predictable manner. The biochemical events that occur inside and along the surface of neurons, called the **action potential**, is the primary means of sending information through the body. In this lesson you will learn how the neuron manages this complex and yet simple process, and how some neurons increase the speed of impulse travel.

Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod4.html
- *Biology 12 Media CD*

The Resting Membrane Potential

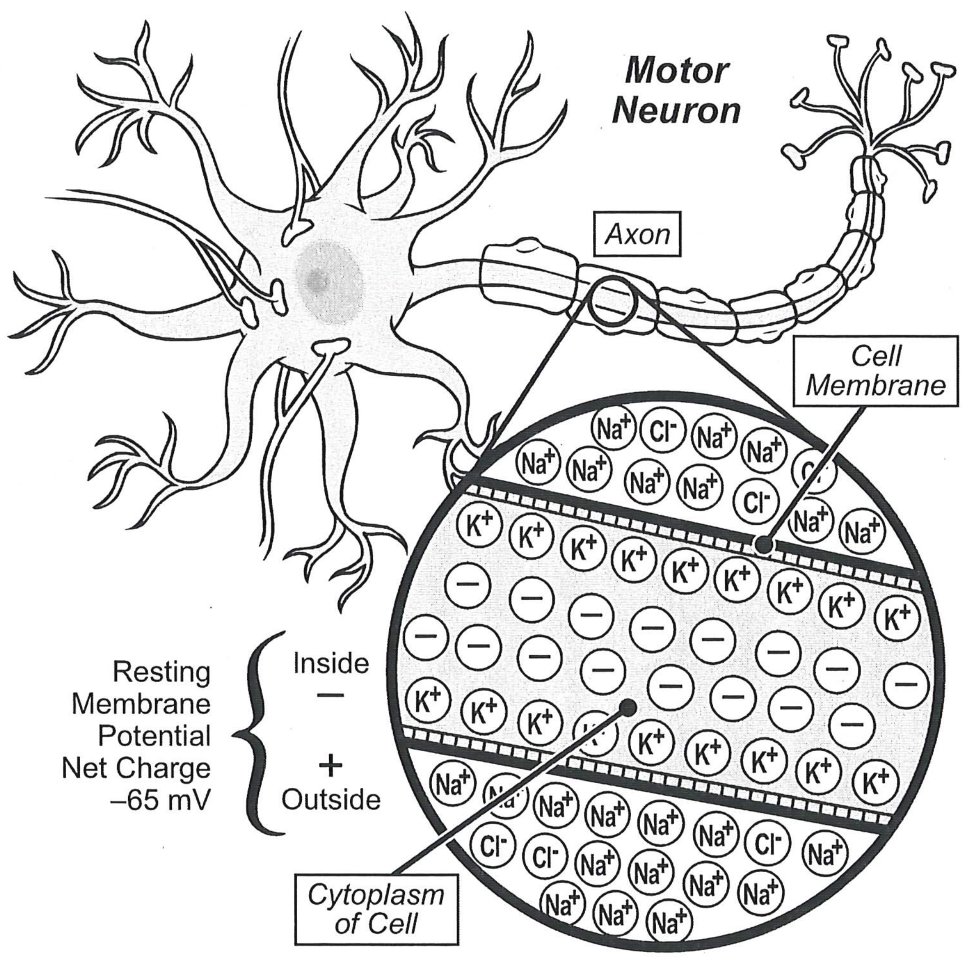
Individual neurons carry impulses in only one direction, and from a particular source towards the central nervous system. All neurons work exactly the same way. When you accidentally bump your eye, you see "stars" or tiny pinpricks of light. The bump caused neurons that normally carry light messages to send a message to the brain, and the brain only interprets messages from this part of the body as light.

To understand how a neuron carries an impulse, we need to understand how various ions move around in the neuron.

Scientists have learned a great deal about neurons by studying squid, because these animals have extremely large axons—in some cases, the size of a pencil. Small electrical probes (microprobes) can be placed inside and along the surface of these large neurons.

Scientists had hypothesized that electrical events along the neuron's surface were responsible for carrying impulses. By carrying out these experiments with squid, they were able to observe electrical potentials and changes while neurons were both at rest and carrying an impulse.

At rest, axon surfaces have a tiny electrical potential of –65 millivolts (a single dry cell has an electrical potential, from one end to the other, of 1500 millivolts or 1.5 volts) between the outside and the inside of the membrane



The diagram shows a motor neuron with a shortened axon. Notice that one piece of the axon is redrawn in the bottom of the diagram. Pay particular attention to:

- the location of the inside and outside of the membrane
- the distribution of K^+, Na^+, and organic anions (shown as ⊖).
- the relative number of each ion (note the uneven balance between positive and negative ions outside, and then inside)
- the potential difference (measured in millivolts) between the outside and the inside of the membrane, shown on the right of the drawing

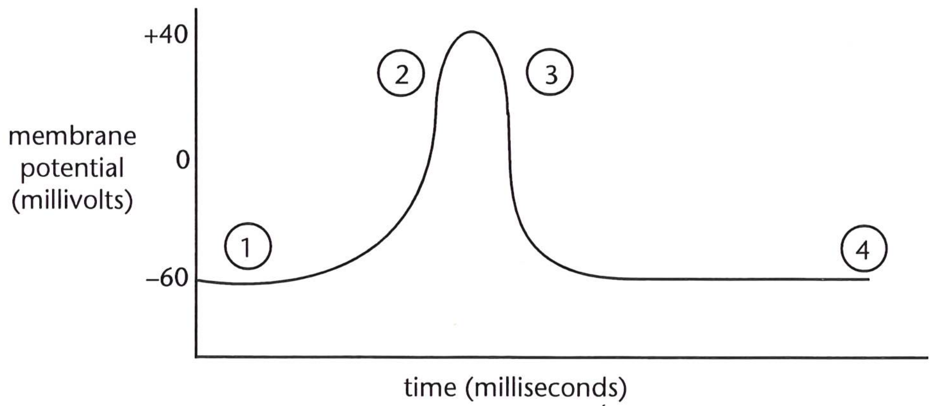
These conditions create a condition called **Resting Membrane Potential** (RMP).

Guided Practice 4.1B 1
Check Your Understanding

1. Which ions are important in the resting membrane potential?
2. What is the potential difference between the outside and inside of a neuron at resting membrane potential?
3. Is conduction along an axon caused by a chemical or electrical phenomenon?

The Action Potential

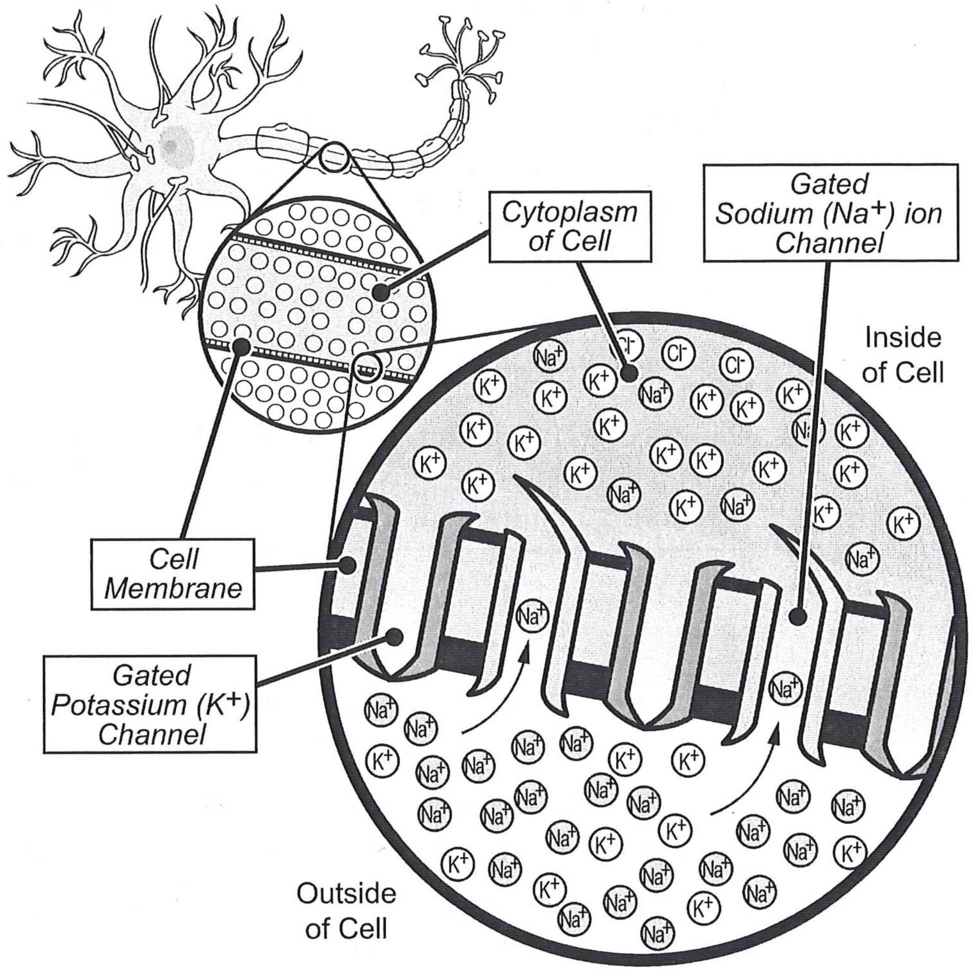
When at rest, a neuron's membrane maintains an uneven distribution of ions. When a receptor is stimulated (e.g., light in the retina, pressure on fingertip, etc.) above the threshold level, the neuron goes into action potential. To understand the events taking place in the neuron, more data were obtained by studying squid membranes as they actually carried impulses. As impulses travelled past microprobes, the electrical potential varied. When this data is presented in a graph, it looks like this:



Here's what happened.

1. The membrane is at resting membrane potential.
2. As an impulse passes the microprobe, the potential reverses to +40 millivolts (this is called **depolarization**).
3. As the impulse moves on, the membrane returns to resting potential (this is called **repolarization**).
4. During the period after repolarization, the membrane is in a **refractory period**.

How can events inside the axon change the ion distribution to account for these changes in potential?



Notice in this diagram that the membrane has two types of protein molecules called gated channels. One allows the controlled movement of Na^+, and the other K^+. Since the distribution of Na^+ at RMP is greater on the outside, opening the Na^+ gates allows the Na^+ to rush in by diffusion. This occurs at the beginning of the stage called **action potential** (AP), the series of events that occur as an impulse travels past a point on the membrane. The inward rush of Na^+ causes a higher distribution of positive charges on the inside, which accounts for the reverse in polarity (to +40mV) across the membrane. (**depolarization**)

Immediately after the Na^+ gates open, the K^+ gates open and potassium rushes out, again by diffusion. This causes the polarity of the membrane to revert to its RMP (repolarization).

To regain true RMP, ion distribution the Na^+ and K^+ must be reversed. To do this, the membrane uses another protein molecule—a Na^+/K^+ pump. These molecules pick up the misplaced ions and, with the expenditure of ATP, the molecule changes shape and pumps the ions back into their normal RMP configuration. The time it takes to recover RMP is known as the **refractory period**. During RMP the Na^+/K^+ pump works to maintain the imbalance of ions characteristic of resting membranes.

Note:
This use of ATP is an **active process**, which means energy must be used up in the process. This prevents impulses from travelling in both directions—an important feature of axons.

If you have access to a computer and the Internet, go to the *Biology 12 Web site* Lesson 4.1B Impulse Transmission:

- to see a short animation of this process.
- to see a detailed animation of the action potential.

Have you ever wondered why sleeping on your arm causes it to tingle? Lying on your arm restricts blood flow, meaning there is a lack of oxygen supply to the neurons. Without oxygen, in the cells cannot manufacture ATP. Since ATP is required for action potential, the neuron is unable to carry impulses to the brain. Your brain interprets this as numbness or a tingling feeling.

Action Potential Details

The time taken for an action potential to pass one site on a membrane is about 4 milliseconds. At maximum capacity, this amounts to 250 impulses per second. The actual number is a bit lower because there are inefficiencies in delivering ATP to any one site and that slows the process.

Since the neuron's capacity to carry impulses is limited, increased stimulation of a neuron beyond this is not noticed. This means that once you have applied a maximum amount of pressure to your fingertip, pressing harder will not cause the brain to produce a sensation of more pressure.

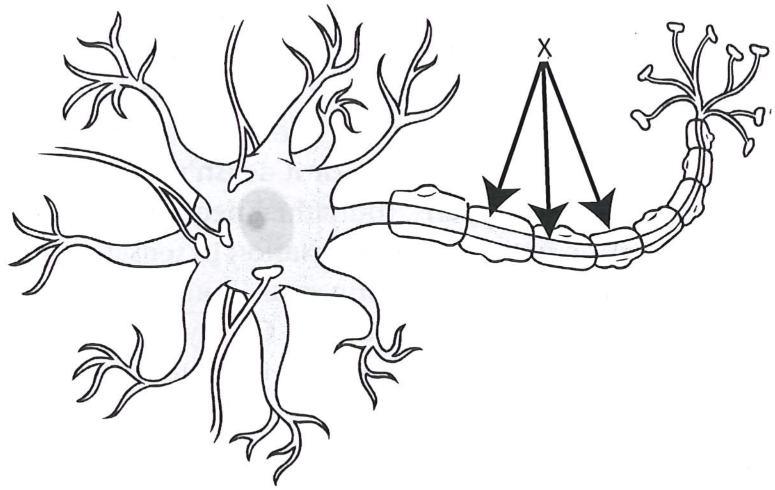
Greater stimulation, or increased pressure, is translated as more axons firing, rather than one axon firing harder. Also, below a certain stimulus a neuron will not fire. This is known as a **threshold**. This important principle in action potential is called the **all-or-none response**. The neuron either reaches threshold stimulation and fires (initiates an impulse), or it doesn't reach threshold stimulation and nothing happens. Individual neurons cannot vary the way they carry action potentials. For variation in sensation to occur, various numbers of neurons fire. Hitting your thumb with a hammer causes a huge number of neurons to fire. Gently touching the hammer only stimulates a few. The brain interprets the number of neurons firing as variation in stimulation.

Propagation of Action Potential

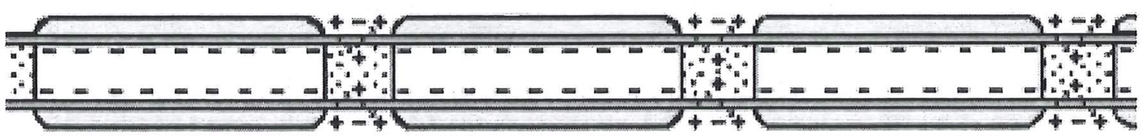
Let's consider what happens at a particular site on a neuron when it is in AP. The disruption of ion balance at that site stimulates the adjacent membrane (in RMP). Specifically, as Na^+ ions leak into the cell's cytoplasm in AP, Na^+ ions from the adjacent part of the membrane diffuse in to replace them. This weakens the RMP at that site, which in turn stimulates the membrane at that site to go into AP. The wave of AP down the neuron is the moving impulse. As you can imagine, this process is too slow to account for the high speed of impulse travel within the nervous system. Consider how long it would take for information from the tail of a whale to reach its brain. Far too long to allow for its graceful movements.

Saltatory Conduction

To allow for quick impulse travel (up to 700 kilometres per hour) impulses actually jump along the neuron. Refresh your memory of axon structure with this diagram.



Notice the structures labelled X in the diagram. These are **Schwann cells**, which collectively produce a sheath called the myelin sheath. The little gaps that interrupt the Schwann cells are called the **nodes of Ranvier**.



The Na^+ and K^+ gates in myelinated axons are concentrated at these nodes. As an impulse travels along the neuron, it actually jumps from node to node, by a process called **saltatory conduction**. This jumping accounts for the great speed of conduction in long axons.

If you have access to a computer and the *Biology 12 Media CD*, you may choose to view an animation illustrating how an action potential is set up in a neuron.

Go to your:

Biology 12 Media CD > Module 4 > **How Does an Action Potential Occur?**

Guided Practice 4.1B 2
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

Vocabulary terms to know for this lesson:

- action potential
- all-or-none response
- depolarization
- recovery period
- repolarization
- resting membrane potential
- saltatory conduction
- threshold

Guided Practice 4.1B 3
Impulse Transmission

Fill in the blank with the correct term.

1. Nerve impulses are actually action potentials travelling along ____________________.

2. The two ions responsible for altering the resting membrane potential to an action potential are ____________________ and ____________________.

3. When the neuron is not in action potential, it is said to be in ____________________.

4. The unequal distribution of Na^+ and K^+ on either side of the membrane is due to the action of the ____________________.

5. The first event in the action potential after the neuron is stimulated is ____________________.

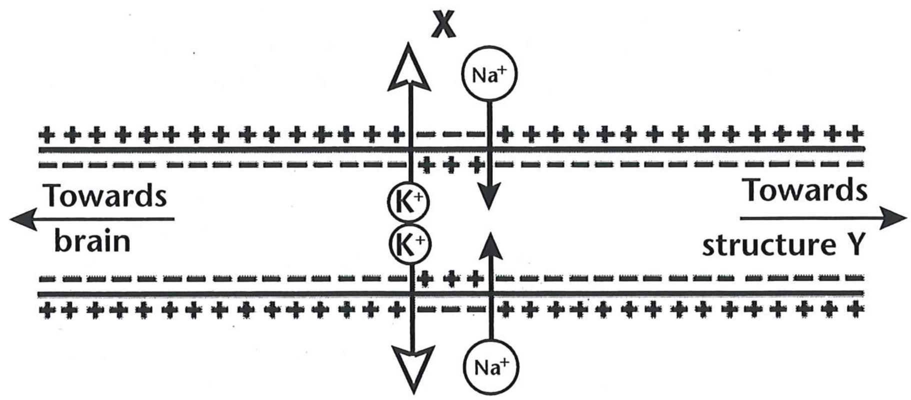
6. This is immediately followed by ____________________.

7. For the cell to restore its RMP, the correct ion distribution is attained by the action of the ____________________.

8. Jumping action potential along the neuron is called ____________________ and requires the presence of ____________________.

9. The initial movement of Na^+ and K^+ is due to the transport mechanism called ____________________ but the final movement of these ions into their RMP distribution is accomplished by ____________________.

Use the following image to answer questions 10–12.



10. The partial neuron depicted in the diagram is called a ____________________.

11. The ____________________ would be found at the location labelled Y?

12. The ____________________ is missing from this axon.

Guided Practice 4.1B 4
Action Potential

Indicate the correct sequence of events in an action potential by writing in the correct order (#1–#7) in the left-hand column.

Sequence	Statement
	Sodium gates open
	More K^+ ions outside, more Na^+ ions inside
	Na^+/K^+ pump restores original distribution of ions
	K+ gates open
	More Na^+ outside, more K^+ ions inside
	Cell depolarized
	Cell repolarized

Summary

There is no section assignment for this lesson.

Completing this lesson has helped you to:

- explain the transmission of a nerve impulse through a neuron, using these terms: resting and action potential, depolarization and repolarization, sodium and potassium gates, sodium-potassium pump, recovery period, threshold (all-or-none response)
- relate the structure of a myelinated nerve fibre to the speed of impulse conduction

Lesson 4.1C
Synaptic Transmission

Overview

Impulse transmission occurs in two ways—neuron transmission, which is electrochemical, and synaptic transmission, which is chemically controlled. Synaptic transmission takes place at the gaps between neurons, or between neurons and effectors. Synaptic transmission is controllable, which means the impulse can be tuned or ignored. Synaptic transmission is influenced by neurohormones, such as adrenalin or drugs that can mimic or enhance the effect of natural neurotransmitters. Common drugs such as aspirin, and opiates, including cocaine or morphine, work in this way.

Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod4.html

Structure of Synapses

Synapses are small gaps that separate communicating neurons or motor neurons from effector organs. Impulses travelling along neurons must first cross these gaps before they cause the next (postsynaptic) cell to be stimulated.

Open your *Inquiry Into Life* textbook to Figure 17.5 on page 324.

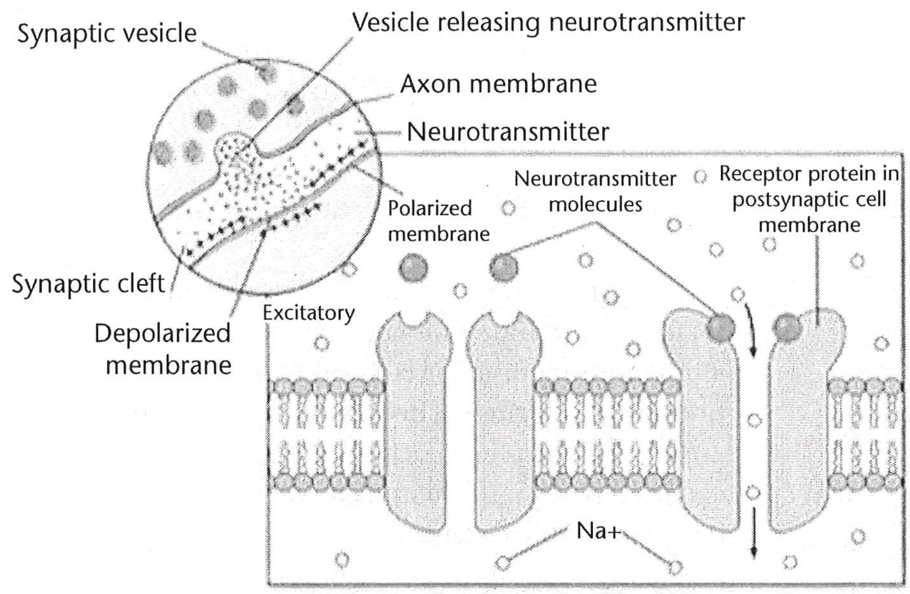
In the diagram in the top left corner, notice the axon of a sensory neuron and the entire interneuron. Normally the interneuron is connected to other interneurons, or perhaps to motor neuron cell bodies.

In the diagram in the top right corner, you'll notice the swelling at the end of the axon. This is called the **axon bulb**. The axon bulb contains vesicles loaded with protein molecules called **neurotransmitters**. The two neurons do not touch each other. Instead they are separated by a tiny gap called the **synaptic cleft**. If the **postsynaptic cell** is a muscle cell, then the gap is called a neuromuscular junction.

If you have access to the Internet, you should also check out the diagrams in the Essential Study Partner on the *Biology 12 Web site* Lesson 4.1 C Synaptic Transmission. Compare these diagrams to those of the synapse structure on page 324 in the *Inquiry Into Life* textbook.

How Synapses Work

An action potential travels along a neuron. When it reaches the axon bulb, it causes the bulb membrane to increase its calcium ion (**Ca^{++}**) permeability. This causes Ca^{++} to rush into the axon bulb, where vesicles containing neurotransmitters are located. These vesicles then fuse with the membrane, causing the neurotransmitter molecules to be released into the cleft. Once released, they quickly diffuse across the tiny cleft to the postsynaptic cell membrane where receptors embedded in the postsynaptic membrane attach to the neurotransmitter. These receptors are actually Na^+ gates, which are opened by the presence of the neurotransmitter. Once open, Na^+ rushes into the cell, causing the postsynaptic cell to go into action potential. The postsynaptic cell then carries the impulse along its length.



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In the illustration, notice how the presence of the neurotransmitter alters the shape of the **receptor molecules**, allowing the Na^+ to move into the cell. Remember that the shape of protein molecules is a factor of how they functioning. This movement initiates an action potential.

Neurotransmitters Are Short-lived and Work in One Direction

Neurotransmitters exist in the cleft for only a brief time. Almost immediately enzymes released into the cleft from the postsynaptic cell break them down (e.g., **cholinesterase** breaks down acetylcholine). In some synapses, the neurotransmitter is reabsorbed and recycled back into vesicles. Removing the neurotransmitter from the cleft prevents continued stimulation of the postsynaptic cell.

It is important to understand that the mechanism for transmission across a synapse is one way. Only the presynaptic bulb can release neurotransmitters, and only the dendrites have receptor sites. Otherwise the presynaptic cell could be stimulated into action potential.

If impulses could travel in different directions along an axon, they would cancel each other because the refractory periods of the two impulses would prevent the further transmission in either direction.

Controlling Synaptic Transmission

Think of the neuron-to-neuron connection like a land-line telephone system that allows one person to call another. A message is carried along a phone line (or cell link) and is picked up by the receiving phone, which rings. The person at the other end has the option of answering the phone or not. If that person has call display, he or she can screen calls. In the nervous system, an impulse initiated at a receptor or in the central nervous system (CNS). The impulse travels along the neuron until it reaches the receiving neuron. The impulse must then cross a small gap (like the receiving phone), which may cause the postsynaptic cell to respond by going into action potential, or may inhibit the postsynaptic cell, reducing its ability to respond.

Synapses may be excitatory (stimulating the postsynaptic neuron to fire) or inhibitory (reducing the ability of the post-synaptic neuron to fire). For a message to be initiated on the postsynaptic neuron, the combination of many presynaptic neurons may occur. The neuron takes all these together and sums them up in a process called **integration**.

You can probably relate to these examples of integration:

1. Have you noticed that while playing a sport, you might be slightly injured but not notice?
2. After you put on your watch, glasses, or hat, do you have to check to see if they are on after some time has passed?
3. When you work in a noisy environment, are you oblivious to the noise after a while? This may be most apparent when the noise finally stops.

In these examples, inhibitory neurons are firing on interneurons that normally would be stimulated by excitatory neurons firing from various sensory receptors. The action of the inhibitory neurons cancels the input from excitatory neurons, causing the CNS to be unaware of the input. This action frees the CNS from input that would be burdensome and confusing, distracting it from the main task at hand.

Neurotransmitters and the Drug Connection

The following chart summarizes the various types of neurotransmitters found in the nervous system. Note specific neurotransmitters do not work in synapses not intended for them.

Neurotransmitter	Site of Activity
Noradrenalin/ adrenalin*	Sympathetic Nervous System
Acetylcholine	Parasympathetic Nervous System
Seratonin	Central NS—produces happy feelings, prevents depression
Dopamine	CNS—produces sensation of pleasure, controls movement
Gastrin*	Digestive System
Cholecystokinin*	Digestive System
Vasopressin*	Circulatory System
Oxytocin*	Reproductive System
Corticotropin*	Endocrine System

Note:
Neurotransmitters with an asterisk are produced by endocrine glands. Those will be covered in a later section.

The brain produces more than fifty chemicals that could be classified as drugs, which means they alter mechanisms within the brain. Many artificially produced drugs are designed to alter normal mechanisms within the central nervous system. Cocaine and Prozac are two examples.

Cocaine blocks the reuptake of dopamine, increasing pleasurable feelings. It is addictive because it becomes required for a person to feel pleasure. Withdrawal causes an overwhelming sense of displeasure.

Prozac blocks the reuptake of serotonin, causing a prolonged happy feeling. Seratonin reduces anxiety, fear, insomnia (sleeplessness) and restlessness, and people who produce low amounts of serotonin may suffer from depression. Prozac counteracts this condition.

Aside from depression, many neurological disorders are caused by the body's reduced ability to produce appropriate neurotransmitters. Parkinson's disease is one example of this. People who suffer from Parkinson's display a stiffness in their legs, which impairs their gait. They also display a lack of expression, and will have tremors, particularly in their hands. Two famous people with Parkinson's are actor Michael J. Fox and boxer Mohammed Ali. This disease is caused by the brain's diminished ability to produce dopamine, which helps to control movements. Drugs that simulate the action of dopamine have been somewhat successful in relieving the symptoms. No known cure exists, despite active attempts to fine one.

Guided Practice 4.1C 1
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

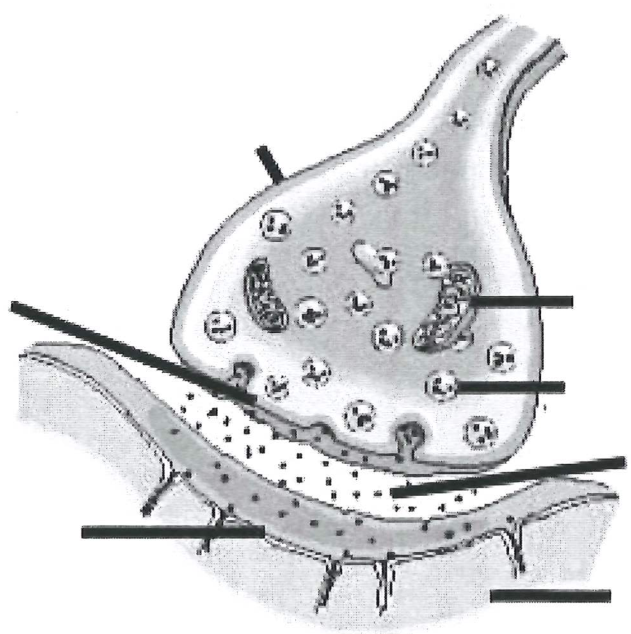
Vocabulary terms to know for this lesson:

- axon bulb
- cholinesterase
- integration
- neurotransmitter
- neurotransmitter receptor
- postsynaptic neuron
- presynaptic neuron
- synapse
- synaptic cleft

Guided Practice 4.1C 2
Synapse Structure and Synaptic Transmission

Label the diagram using the provided terms.

1. axon bulb
2. synaptic vesicles containing neurotransmitters
3. mitochondrion
4. synaptic cleft
5. postsynaptic membrane
6. postsynaptic neuron
7. presynaptic neuron
8. presynaptic membrane



Guided Practice 4.1C 3

Synaptic Transmission

What is the role of each of the following structures in synaptic transmission?

1. vesicles in axon bulb
2. neurotransmitter
3. receptor molecule
4. Ca^{++}
5. enzymes (i.e., cholinesterase)

Summary

There is no section assignment for this lesson.

Completing this lesson has helped you to:

- identify the major components of a synapse
- explain the process by which impulses travel across a synapse
- demonstrate knowledge of how neurotransmitters are broken down in the synaptic cleft

Lesson 4.1D
Reflex Actions

Overview

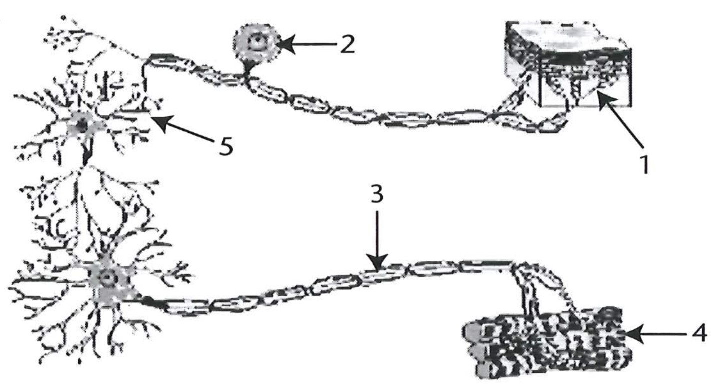
In this lesson you will learn about the basics of reflexes and the neural structures responsible for this primitive action, and you will perform some simple experiments to discover how reflexes work.

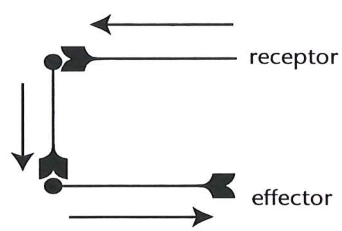
Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod4.html

Design of Reflex Arcs

A **reflex arc** is a simple neural pathway consisting of a sensory neuron, an interneuron in the CNS, and a motor neuron. Study the following two diagrams. The one on the left depicts these three neurons. The simplified diagram on the right shows the path of a single action potential through the reflex arc.





The five components of a reflex arc are:

1. sensory receptor in sensory organ (skin)
2. cell body of sensory neuron
3. axon of motor neuron
4. effector organ (muscle)
5. interneuron in CNS

Notice that when the receptor is stimulated, it initiates an action potential that travels from a sensory neuron to an interneuron, and then to motor neuron. The brain does not have to be involved to activate the muscle. Stimulating the receptor causes a contraction in the muscle.

The Purpose of Reflex Arcs

Reflex arcs ensure quick responses to environmental input. In many animals, almost all responses are reflexive. Their CNS has little or no input into the majority of their movements. This makes their movements very predictable.

As animals evolved and became more complex, more of their activity required input from the brain. This allowed for variation in response based on more complex inputs from a variety of sources. In complex animals, including humans, the majority of actions are controlled by the brain, although we still have many reflex responses. These reflexes allow quick responses to immediate threats that can be avoided by reflexive actions. Many reflexes maintain fluid motion as input from one part of the body causes an immediate response from another part.

The lab activity in Section Assignment 4.1 is designed to help you explore our reflexes. As you observe reflexes in your own body, consider how such responses ensure that you respond quickly and smoothly when necessary.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 4.1 D Reflex Actions to view this short animation that demonstrates how reflex arcs are designed and work.

Guided Practice 4.1D 1
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

Vocabulary terms to know for this lesson:

- reflex arc
- reflexive response

Guided Practice 4.1D 2
Review Questions

Select the best answer.

1. The main advantage of a reflexive response is to:
   - A. minimize the time required to react
   - B. relieve the brain of tedious tasks
   - C. involve the spine in responses
   - D. make sure all effectors are working properly

2. The correct order of neuron firing in a reflex arc is:
   - A. motor, inter-, sensory
   - B. sensory, inter-, motor
   - C. inter-,motor, sensory
   - D. sensory, motor, inter-

3. Which of the following is not controlled reflexively?
   - A. deciding which route to take home
   - B. ducking a baseball flying toward you
   - C. blinking the eye when a loud noise occurs
   - D. yelling out in pain

Summary

Now do Section Assignment 4.1A Part A: Reflex Arcs Laboratory.

Completing this lesson has helped you to:

- describe what a reflex arc is
- explain how an impulse travels through the neural pathway
- understand the general functions of reflexes
- relate the structure of a reflex arc to its functions

Lesson 4.1E
Divisions of the Nervous System

Overview

To this point you have focused on the cellular design of the nervous system. In this lesson you will consider its macroscopic design.

Your nervous system does most of its work without you being aware of what it is doing. If you consciously had to monitor and adjust each of the various systems in your body and the events that take place, your brain would be too distracted to perform necessary functions.

Automatic functions of the nervous system are carefully choreographed by the autonomic nervous system (ANS). Let's look at the division of labour of the nervous system.

By the end of this lesson you won't be a brain surgeon, but you will be able to impress your friends with your understanding of the general design of the nervous system.

Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod4.html

The Overall Design of the Nervous System

The following chart and diagram summarize the divisions of the nervous system. Refer to them as you read the material in this section.

Human Nervous System

Central Nervous System (CNS)	**Peripheral Nervous System (PNS)**
Brain and spinal cord	Everything else
interneurones	sensory and motor neurones

Peripheral Nervous System (PNS):

Somatic Nervous System	**Autonomic Nervous System**
Voluntary	Involuntary
Input from sense organs	Input from internal receptors
Output to skeletal muscles	Output to smooth muscles & glands

Autonomic Nervous System:

Sympathetic Motor System	**Parasympathetic Motor System**
'Flight' or 'flight' responses	Relaxing responses
Neurotransmitter: noradrenaline	Neurotransmitter: acetylcholine
'Adrenergic System'	'Cholinergic System'

To help us understand the nervous system, scientists have artificially divided it into two main divisions—the **central nervous system** (CNS) and the **peripheral nervous system** (PNS). Keep in mind that the two are closely connected and continually communicate with each other.

The CNS processes information received from various sensory neurons. The spinal cord was once thought to be simply a highway for information to and from the brain, but we now know it has memory functions. Spinal cord learning is easily understood if you consider how you learned to walk, to ride a bike, or play the piano. Initially the brain was fully engaged in those activities as you learned them. Once mastered, the brain releases control and the spine takes over. This makes it possible to eat a sandwich while riding a bike, talk while playing a game, or walk and chew gum at the same time.

The PNS can be further subdivided into two divisions—the **somatic** and **autonomic nervous systems**. Both control motor functions, and they determine how our muscles and organs respond to output from the CNS.

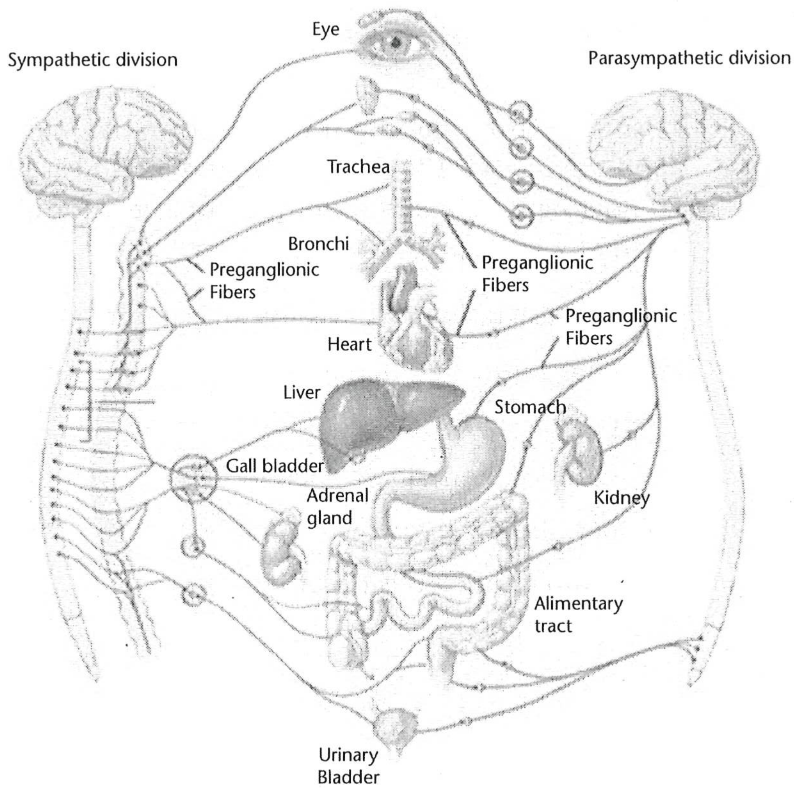
The somatic nervous system includes all neurons involved in controlling voluntary muscle movement. **Voluntary** means that something is under conscious control. **Involuntary** means the opposite. Think about each of the following activities. Blinking, coughing, and digesting a sandwich are involuntary. Planning strategy in a game, reading, and holding your breath while hiding are voluntary actions. Voluntary muscle is made up of striated muscle, which appears to have a banded or striated appearance when studied under a microscope.

The control of various organs is done entirely by the autonomic nervous system. These organs are involved with secreting hormones, pumping blood, breathing, and digesting food, to name a few, and all of them are under involuntary control. This frees up the brain make conscious decisions about when do homework or watch TV, deciding whether to eat a donut or granola bar, and so on.

Notice that some autonomically controlled functions are muscular. These include contractions of the **smooth muscle** found in the walls of the bladder and the blood vessels, and the **cardiac muscle** found in the walls of the heart.

The autonomic nervous system is divided into **sympathetic** and **parasympathetic motor systems**. These control the way your body responds to different control commands from the ANS. Generally, if things aren't going well, the sympathetic motor fibres work overtime to make sure your body manages the difficulty. If things are running smoothly, then the parasympathetic fibres send messages that allow your body to relax, digest your meal, and feel relaxed.

On page 338 in your *Inquiry Into Life* textbook, study Figure 17.17 titled Autonomic system structure and function. It looks very similar to this:



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The Vagus Nerve

The vagus nerve partly controls feelings of nervousness, such as those experienced in a difficult social situation. Symptoms such as loss of speech control, butterflies in the stomach, and excessive perspiration. Some people may even faint or suddenly urinate when they experience a sudden shock.

If you have access to the Internet, visit the *Biology 12 Web site* Lesson 4.1 E Divisions of the Nervous System to find out more about the vagus nerve and how to control the response to these situations.

Guided Practice 4.1E 1
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

Vocabulary terms to know for this lesson:

- autonomic nervous system
- central nervous system (CNS)
- parasympathetic division of PNS
- peripheral nervous system (PNS)
- sympathetic division of the PNS
- vagus nerve

Guided Practice 4.1E 2
Review Questions

Answer the following questions.

1. What kinds of tissue are controlled by the autonomic nervous system?
2. What three similarities do the two subdivisions of the ANS have in common?
3. What important physiological balance is controlled reflexively by the ANS?
4. Which ANS subdivision has long pre-ganglionic fibres and short post-ganglionic fibres?
5. Which division controls emergency situations?
6. Name the neurotransmitters used in the synapses of each division.
7. Where do the neurons that control each division originate?
8. How would each of the following respond in the given situation?

   A. bronchioles if you are worried about writing an exam?

   B. liver while you are watching the TV?

   C. intestine while you are swimming?
9. Why are you taught as a beginning swimmer that it is not a good idea to swim right after eating?
10. Which large cranial nerve in the parasympathetic nervous system has branches to most of the internal organs?
11. Consider the action of both sympathetic and parasympathetic neurons on the genitals. It would appear that both are required for their correct functions during copulation. What type of situations would prevent their correct functioning?

12. What physiological advantage results from having synapses in the ganglia?

13. Can you think of a situation you have experienced that initiated a sympathetic nervous system release of adrenalin and caused you to feel a characteristic adrenalin rush?

Guided Practice 4.1E 3
CNS and PNS

Complete the following tables by writing Yes or No beneath the headings CNS and PNS, or inserting the correct descriptor.

	CNS	PNS
Environmental stimuli		
Internal stimuli ('thinking')		
Reflex response		

	Autonomic	Somatic
Running		
Digesting Food		
Thinking		
Voluntary or Involuntary		
Effectors		

	Sympathetic	Parasympathetic
Feeling butterflies		
Neurotransmitter type		
Learning in distance ed		
Meeting a date for the first time		
Effectors		

Summary

There is no section assignment for this lesson.

Completing this lesson has helped you to:

- contrast the locations and functions of the central and peripheral nervous systems
- differentiate between the functions of the sympathetic and parasympathetic divisions of the autonomic nervous system

Lesson 4.1F
The Brain

Overview

The brain is the most complex organ in the body. It is responsible for our thoughts, memory, and emotions, and it controls functions such as hormone secretions by organs throughout the body. In this lesson you will become more familiar with some of the basic structures and functions of the brain.

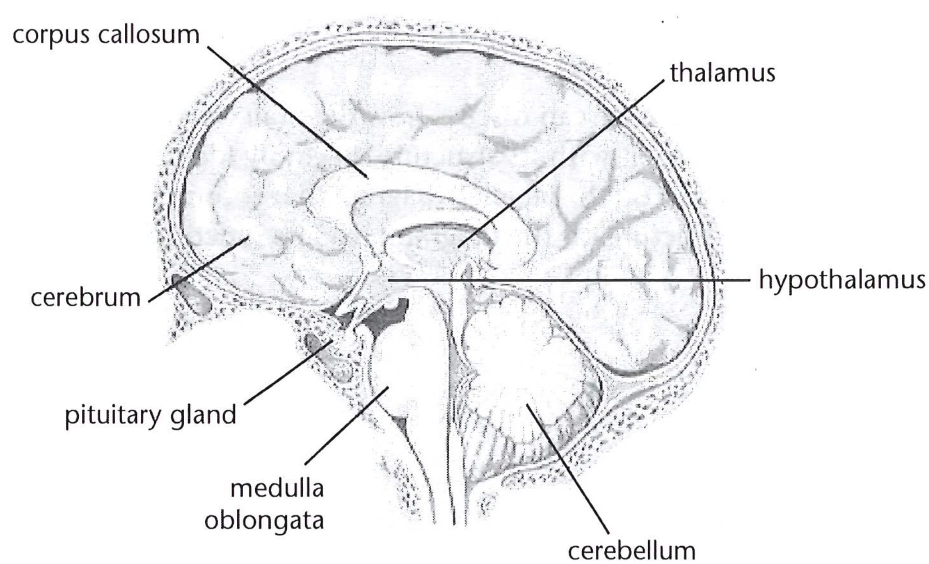
Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod4.html

The Brain

Before we can discuss how the brain works, you need to familiarize yourself with its structure. Begin by identifying the structures in the chart on the labelled diagram that accompanies it. As you identify each structure on the diagram, read its function.

Structure	Function
cerebrum	sensation, thought processes, motor control
cerebellum	organizes outgoing motor impulses so motions are coordinated and fluid
hypothalamus	connects the brain with the endocrine organs by **releasing hormones** that influence pituitary secretions
thalamus	receives and routes all incoming sensory information to the upper brain
corpus callosum	connects the two sides of the brain; information moving from one half (hemisphere) of the brain to the other is routed through the corpus callosum
medulla oblongata	controls basal metabolic functions (e.g., breathing, blood pressure, and heart rate, and many reflexive actions, such as coughing, vomiting, hiccupping, and swallowing)
pituitary	releases hormones that control the endocrine system; because of this, the brain controls such functions as sexual maturity, the menstrual cycle, metabolic rate, and water concentration in the blood



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Read the section titled *The Brain* starting on page 328 in the *Inquiry Into Life* textbook. The glossaries at the end of this lesson and in the *Inquiry Into Life* textbook will also help you become familiar with the structures of the brain.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 4.1 F The Brain to review the brain's structure. For another look at the structure of the brain, take a look at this virtual fetal pig dissection. Click on the link and review the entire dissection of the nervous system.

You can also use a search engine and the key words "brain structures" to find images of the brain on the Internet.

Neuro-Endocrine Control

The brain is responsible for direct nervous control of muscles, memory, thought processes, emotions, and sensory awareness. It also controls the body by directing the release of hormones. The centre of this control is in the hypothalamus and the **pituitary gland**.

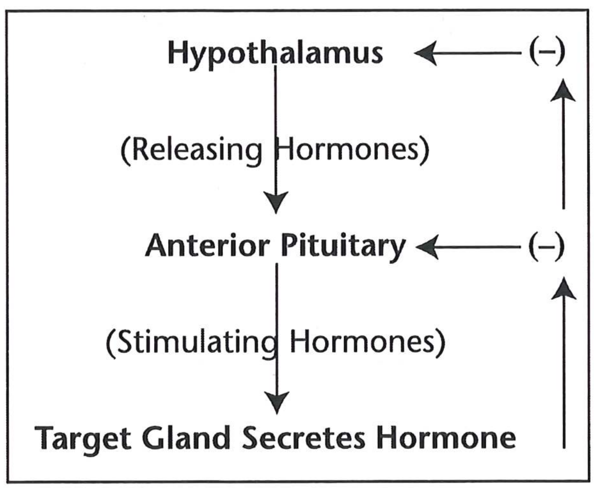
The hypothalamus receives information from the brain and monitors hormone levels in the blood. It responds to this information by releasing the appropriate hormones, which are then transported to the pituitary via axons that connect the two parts of the brain. Both are called endocrine glands because they produce hormones that are released directly into the blood stream and carried to a particular type of tissue. Some hormones control a broad range of tissues and others are very specific.

Take a look at the diagram of the pituitary gland in Figure 20.2 on page 397 of your *Inquiry Into Life* textbook. Notice that the pituitary had two portions—the anterior pituitary (closer to front of the brain) and the posterior pituitary. The function of anterior pituitary is more diverse than that of the posterior pituitary.

Feedback Loop

The brain's **neuro-endocrine control** of the body is carried out by the release of hormones. Short-term concentrations of hormones are adjusted by a mechanism called a **feedback loop**. Most homeostatic control operates in this way.

Recall that in feedback loops, an alteration of normal conditions will set off a string of connected events that eventually lead to the system being rebalanced. Feedback loops are usually negative because the body is working to reverse a condition that is out of balance.



This flowchart summarizes a feedback loop in which the hypothalamus first produces a releasing hormone (RH), under direction of the brain. This RH causes the anterior pituitary to release a **stimulating hormone** (SH), which in turn causes a **target gland** to produce a particular hormone. This hormone has an **inhibitory affect** on both the hypothalamus and the anterior pituitary, slowing the output of each respective hormone. This is **negative feedback** because it inhibits production. In a few cases, a feedback loop can be positive. This will be discussed in a later lesson.

The Adrenal Gland

The body has two adrenal glands, one top of each kidney. These glands secrete a variety of hormones that generally help the body cope with short- and long-term stress. In the case of short term stress, the body has a **fight-or-flight response**. This allows the body to defend itself or to run away from the threat. Think about how you respond to a loud, unexpected noise. Your heart rate suddenly increases, and your body might even flinch or jump. That's the work of your adrenal glands.

To help the body cope with long-term stress, the adrenal glands focus on organizing the body's physiological settings.

The following chart summarizes the adrenal glands and their two types of responses.

Region of Adrenal Gland	Hormone Secreted	Target
adrenal cortex	cortisol aldosterone sex hormones	all tissues kidneys skin, muscles, bones, and sex organs
adrenal medulla	epinephrine (adrenalin) and norepinephrine (noradrenalin)	cardiac and other muscles

Guided Practice 4.1F 1
Study Flash Cards

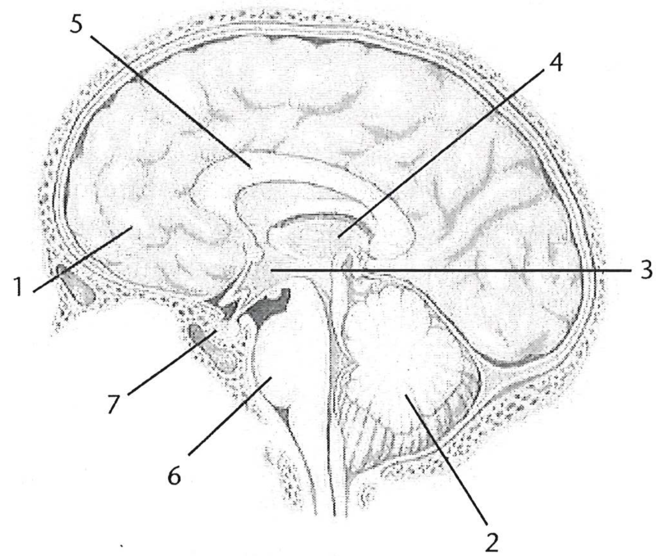
Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

Vocabulary terms to know for this lesson:

- adrenal cortex
- adrenal medulla
- brain stem
- cerebellum
- cerebrum
- corpus callosum
- frontal lobe
- hypothalamus
- inhibitory affect
- medulla oblongata
- negative feedback
- occipital lobe
- parietal lobe
- pituitary
- target gland
- temporal lobe
- thalamus

Guided Practice 4.1F 2
The Brain

For each structure on the following diagram of the brain, write the function in the appropriately numbered space.



Structure	Function
1.	
2.	
3.	
4.	
5.	
6.	
7.	

Guided Practice 4.1F 3
Adrenal Gland

For this scenario, describe the response of the adrenal gland.

> You are driving home late at night and you are sleepy. Suddenly a deer jumps in front of your car. You brake and swerve to miss it. You pull over to the side of the road and tremble uncontrollably for a few minutes.

If you have access to the Internet, take the multiple choice quiz found on the *Biology 12 Web site* Lesson 4.1 F The Brain for feedback on your understanding of the nervous system.

Summary

Now do Section Assignment 4.1 Part B: The Brain.

Completing this lesson has helped you to:

- identify structures of the brain and their functions
- identify the source gland for adrenalin and explain its role in the fight-or-flight response
- explain how the hypothalamus and pituitary gland interact as the body's neuro-endocrine control centre