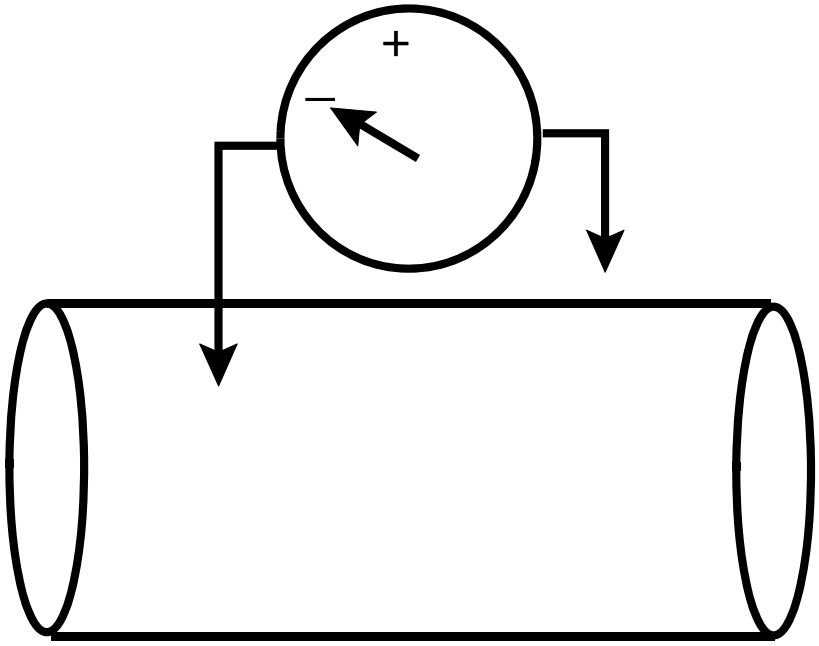
Neurophysiology: The Physiology of the Nerve Impulse

Read: Chapter 12, pages 390-415. We covered neural tissue anatomy in part 1 and now return to Chapter 12 to cover neurophysiology.

A. The Resting Neuron

1) Resting Membrane (Transmembrane) Potential

Definition -

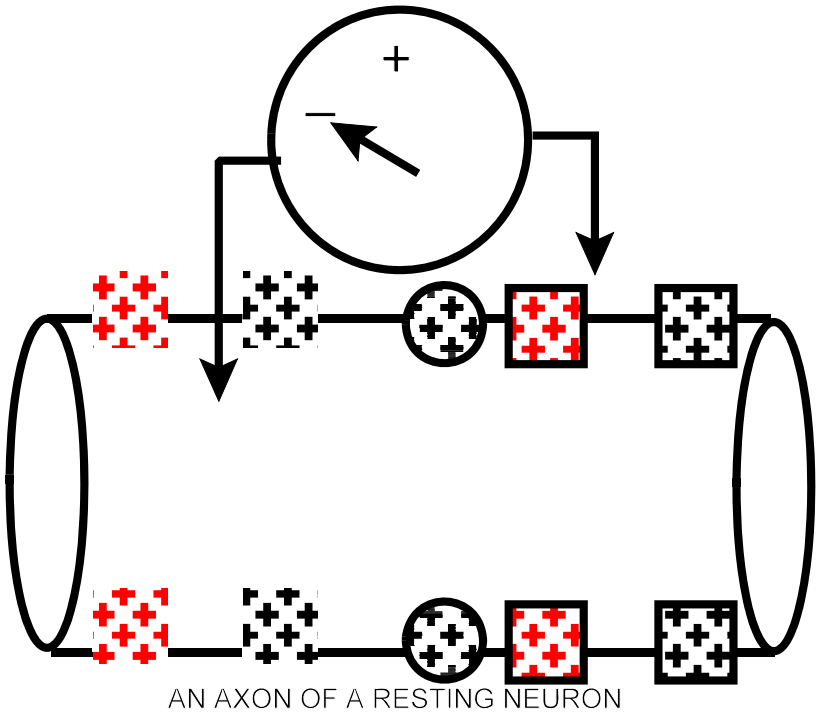


AN AXON OF A RESTING NEURON

2) Distribution of ions across the resting membrane

CATIONS:

ANIONS:



AN AXON OF A RESTING NEURON

3) Ion transport mechanisms across the resting membrane

a) In what direction does Na+ move across them membrane by simple diffusion? K+?

b) What is the role of active transport in the distribution of ions across the membrane?

c) Why is the RMP -70 mVolts?

B. Development of An Action Potential (Nerve Impulse)

Action potential -

SUMMARY TABLE 12–3 GENERATION OF ACTION POTENTIALS

STEP 1: Depolarization to Threshold

- A graded depolarization brings an area of excitable membrane to threshold (−60 mV).

STEP 2: Activation of Sodium Channels and Rapid Depolarization

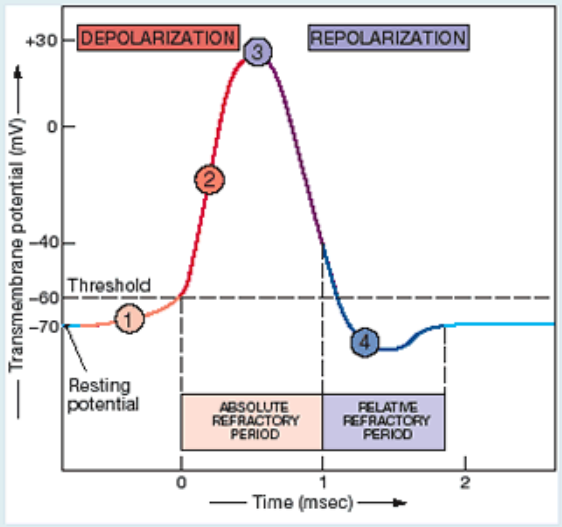
- The voltage-regulated sodium channels open (sodium channel activation).
- Sodium ions, driven by electrical attraction and the chemical gradient, flood into the cell.
- The transmembrane potential goes from −60 mV, the threshold level, toward +30 mV.

STEP 3: Inactivation of Sodium Channels and Activation of Potassium Channels

- The voltage-regulated sodium channels close (sodium channel inactivation occurs) at +30 mV.
- The voltage-regulated potassium channels are now open, and potassium ions diffuse out of the cell.
- Repolarization begins.

STEP 4: Return to Normal Permeability

- The voltage-regulated sodium channels regain their normal properties in 0.4–1.0 msec. The membrane is now capable of generating another action potential if a larger than normal stimulus is provided.



- The voltage-regulated potassium channels begin closing at −70 mV. Because they do not all close at the same time, potassium loss continues, and a temporary hyperpolarization to approximately −90 mV occurs.
- At the end of the relative refractory period, all voltage-regulated channels have closed, and the membrane is back to its resting state.

Resting Neuron -

Application of a Threshold Stimulus

Depolarization

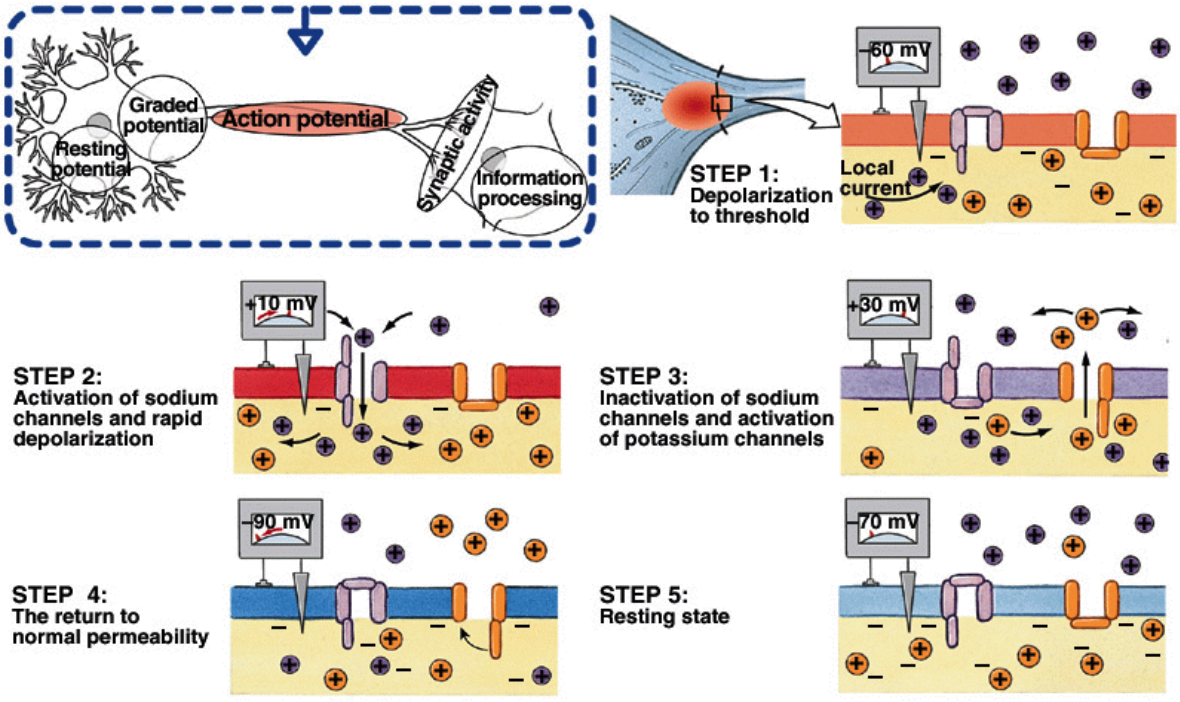
Repolarization

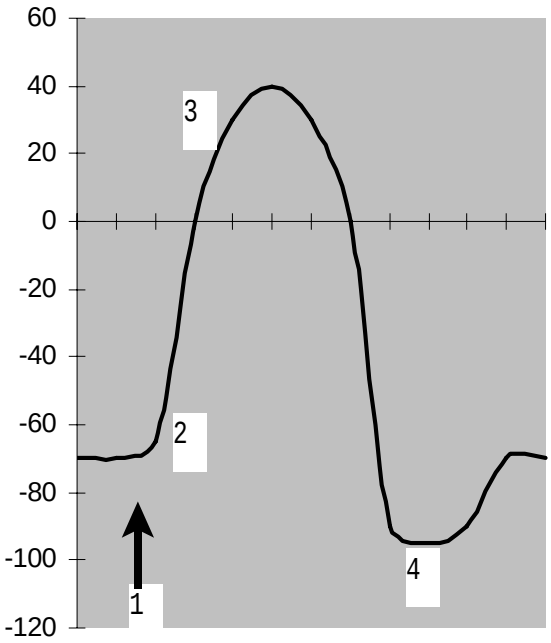
Refractory Periods

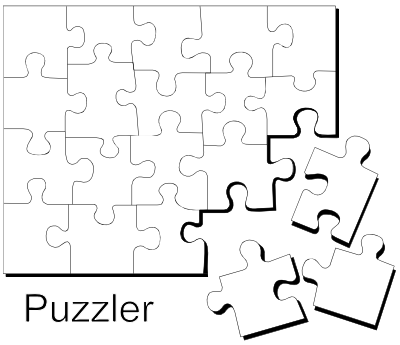
Absolute RP -

Relative RP -

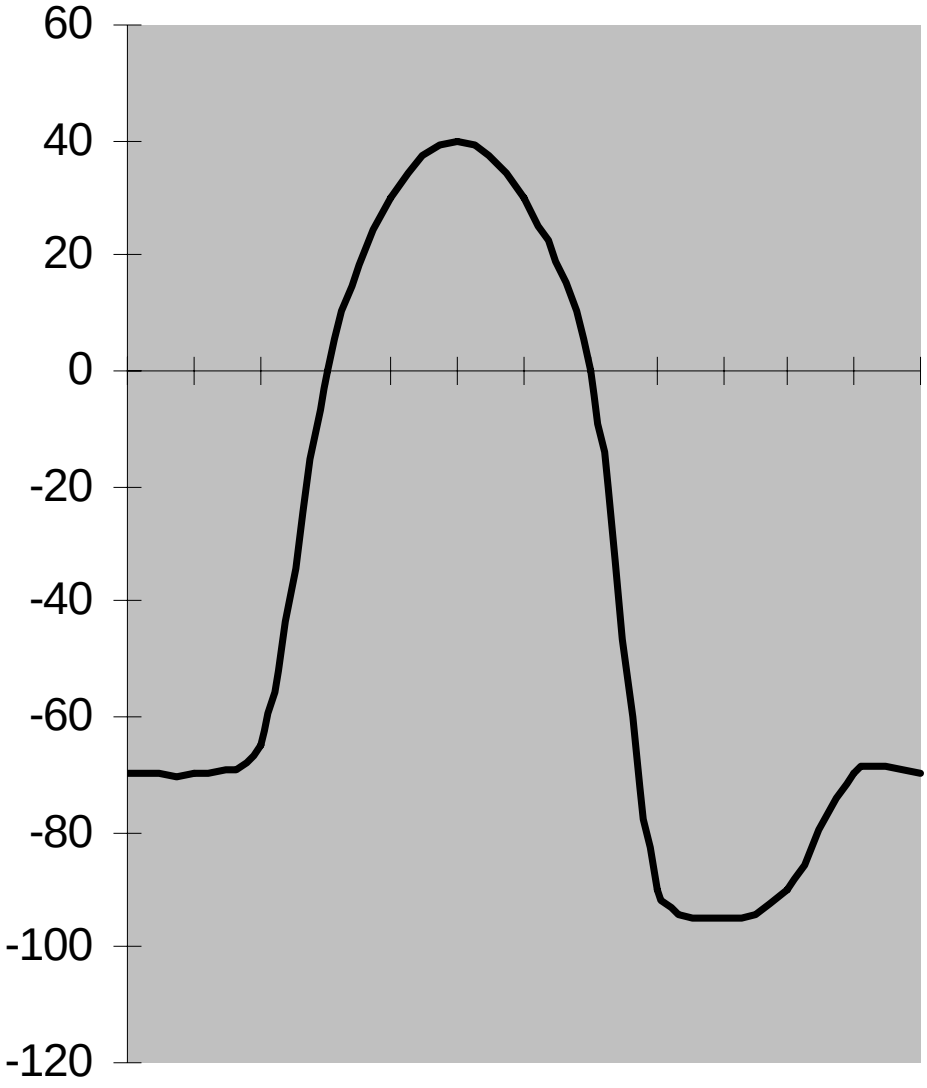
SUMMARY OF ACTION POTENTIAL EVENTS







Label the action potential recording (below) with the following terms: stimulus, depolarization, repolarization, Na+ influx, K+ efflux, Na VRCs open, K+ VRCs open, Na VRCs close, Na+ VRCs reset, absolute refractory period, relative refractory period



C. Propagation of an Action Potential on a Neuron

1) Resting Axon

2) Application of a threshold stimulus

3) Conduction of the action potential

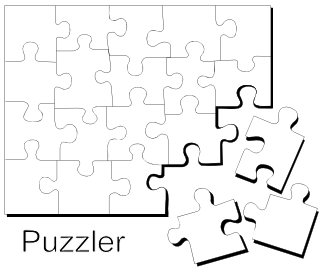
Wave of depolarization is initiated:

Wave of depolarization spreads to adjoining area followed by wave of repolarization:

Wave of depolarization reaches axon terminus and dissipates (dies out):

D. Factors that Affect the Speed of Action Potential Conduction

E. All-or-None Principle of Neurons



The body is always being presented with stimuli of different strengths. The question remained for some time, how does the nervous system encoded the strength of a stimulus in the language of nerve impulses? Two hypotheses existed for some time:

Hypothesis 1: **The frequency of action potentials increases with stimulus strength**

Hypothesis 2: **The voltage of the action potential increases with stimulus strength**

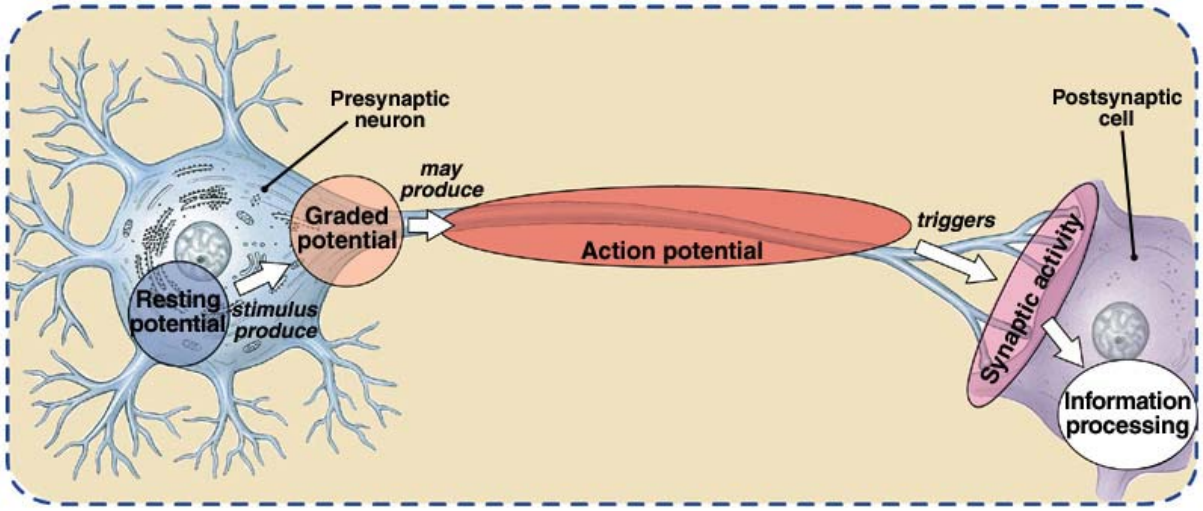
Suppose you were testing the temperature of water running from a faucet and adjusting the water temperature. Your first trial felt too hot but the second trial was comfortably warm. Which best describes the difference in how the nervous system signaled the difference in sensory stimuli in trials 1 and 2?

(A) The frequency of action potentials was higher in trial 1 than trial 2 and the voltage of the action potential was not different in the two trials.

(B) The voltage of action potentials was higher in trial 1 than trial 2 and the frequency of action potentials was not different in the two trials.

IV. Communication Among Neurons in the Nervous System

A. Processes that Occur in a Single Neuron



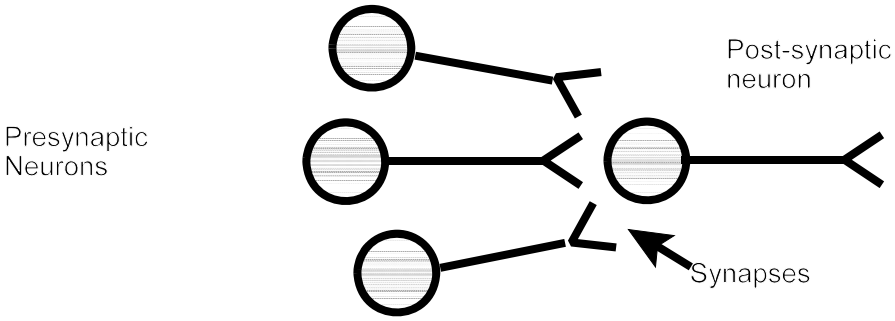
1) Graded Potentials

Events on the dendrite and cell body membranes:

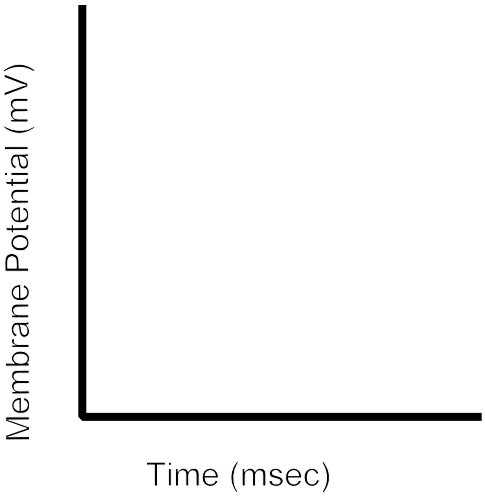
a) Excitatory post-synaptic potentials (EPSPs)

b) Inhibitory post-synaptic potentials (IPSPs)

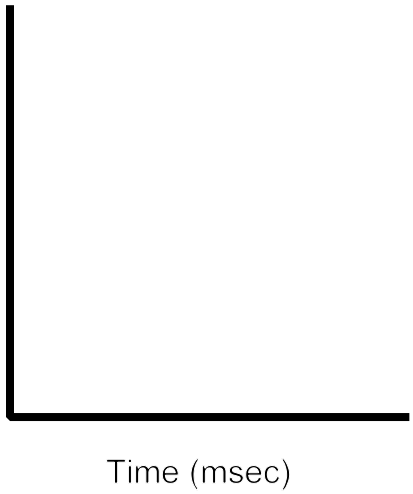
c) Integration (summation) of Presynaptic Inputs



Spatial Summation



Temporal Summation

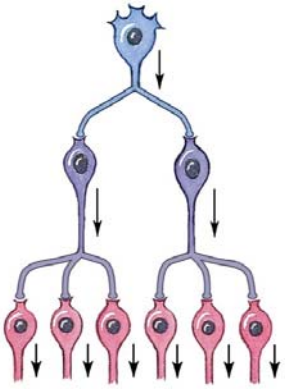


2) Action Potential Propagation

3) Synaptic Transmission

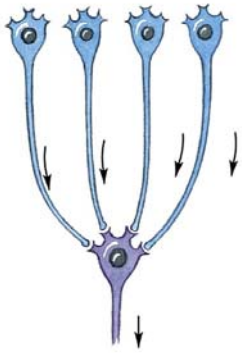
B. Organizing Multiple Neurons into Circuits (Pathways)

1) Divergence



(a) Divergence

2) Convergence

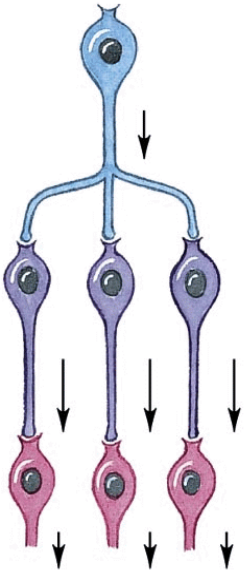


(b) Convergence

3) Serial

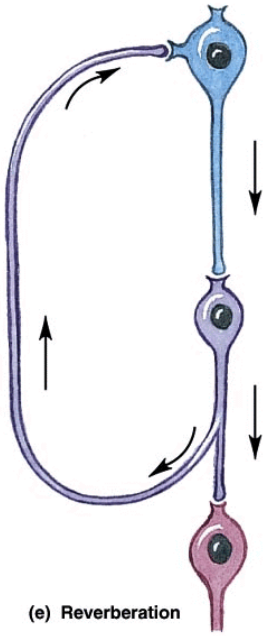
(c) Serial processing

4) Parallel



(d) Parallel processing

5) Reverberating



(e) Reverberation

ASSIGNMENTS

Lecture Guide

1) Which neuron would conduct an action potential most quickly? Explain.
   A) neuron with a small diameter, unmyelinated axon
   B) neuron with a large diameter, myelinated axon
2) What is the meaning of each of the following terms: neuron, nerve cell, fiber, axon, synapse, and neurilemma.
3) What are the different types of neurons? How is each different from the other?
4) What is the resting membrane potential? Explain why the RMP is -70 mVolts.
5) What is an action potential? How does it differ from the RMP?
6) What part(s) of a neuron conduct action potentials? Graded potentials? Release neurotransmitters?
7) Draw a graph showing action potential recording. Label the recording with the important events: depolarization, stimulus, repolarization, Na VRGs open, K VRG open, Na VRG close, absolute refractory period, relative refractory period.
8) Describe the conduction of an action potential. Use the terms unidirectional and all-or-none principle.
9) How does the nervous system encode stimulus strength? Explain.
10) Describe graded potentials? What type of ion channels and chemicals are responsible for these phenomena?
11) Define: presynaptic neuron, postsynaptic neuron, synapse, neurotransmitters, neurotransmitter receptors
12) Where and how does summation occur in a neuron?
13) Distinguish among different patterns of neuron organization: divergence, convergence, parallel, serial, and reverberating.

Textbook Chapter 12 (pages 419-420)

Level 1 Reviewing Facts and Terms: 8, 9
Level 2 Reviewing Concepts: 14, 16, 21, 22, 23, 25
Level 3 Critical Thinking and Clinical Applications: 27, 28, 30

Study Guide Chapter 12 (pages 213-226)

(L1) Multiple Choice: 1-4, 6-8, 10-18, 21, 23-26, 29, 31
Completion: 2, 3, 6, 7, 9, 17
Drawing/Illustration: Figures 12.1, 12.2

(L2) Concept Map II
Matching part 1: 1, 2, 3, 6, 9
Multiple Choice: 2-5, 9, 10, 12, 16
Completion: 4, 5, 6, 7, 11, 14, 15
Short Essay: 1, 2, 4-6, 8, 9

(L3) Critical Thinking: 2