Nervous System Problem Set

The problems in this handout are dependent on you understanding the lectures we emailed later this week so make sure to review those lectures. We highly recommend that in addition to these lectures, which serve more as a review, you review Campbell Chapters 48-50. The nervous system can have many components that are similar but not identical, having a potential for confusion especially if this is your first time.

Part 1 (MC):

1. Which best describes an afferent neuron?
   a. The cell body is in the CNS and the peripheral axon terminal is in the skin.
   b. The cell body is in the dorsal root ganglion and the central axon terminal is in the spinal cord.
   c. The cell body is in the ventral horn of the spinal cord and the axon ends on skeletal muscle.
   d. The dendrites are in the PNS and the axon terminal is in the dorsal root.
   e. All parts of the cell are within the CNS.

2. Which incorrectly pairs a glial cell type with an associated function?
   a. astrocytes; formation of the blood–brain barrier
   b. microglia; performance of immune function in the CNS
   c. oligodendrocytes; formation of myelin sheaths on axons in the PNS
   d. ependymal cells; regulation of production of cerebrospinal fluid
   e. astrocytes; removal of potassium ions and neurotransmitters from the brain's extracellular fluid

3. If the extracellular Cl^- concentration is 110 mmol/L and a particular neuron maintains an intracellular Cl^- concentration of 4 mmol/L, at what membrane potential would Cl^- be closest to electrochemical equilibrium in that cell?
   a. +80 mV
   b. +60 mV
   c. 0 mV
   d. −86 mV
   e. −100 mV

4. Consider the following five experiments in which the concentration gradient for Na^+ was varied. In which case(s) would Na^+ tend to leak out of the cell if the membrane potential was experimentally held at +42 mV?

Experiment	Extracellular Na^+ (mmol/L)	Intracellular Na^+ (mmol/L)
A	50	15
B	60	15
C	70	15
D	80	15
E	90	15

a. A only
b. B only
c. C only
d. A, B, and C
e. D and E

5. Which is a true statement about the resting membrane potential in a typical neuron?
   a. The resting membrane potential is closer to the Na^+ equilibrium potential than to the K^+ equilibrium potential.
   b. The Cl^- permeability is higher than that for Na^+ or K^+.
   c. The resting membrane potential is at the equilibrium potential for K^+.
   d. There is no ion movement at the steady resting membrane potential.
   e. Ion movement by the Na^+/K^+-ATPase pump is equal and opposite to the leak of ions through Na^+ and K^+ channels.

6. If a ligand-gated ion channel permeable to both Na^+ and K^+ was briefly opened at a specific location on the membrane of a typical resting neuron, what would result?
   a. Local currents on the inside of the membrane would flow away from that region.
   b. Local currents on the outside of the membrane would flow away from that region.
   c. Local currents would travel without decrement all along the cell's length.
   d. A brief local hyperpolarization of the membrane would result.
   e. Fluxes of Na^+ and K^+ would be equal, so no local currents would flow.

7. Which ion channel state correctly describes the phase of the action potential it is associated with?
   a. Voltage-gated Na^+ channels are inactivated in a resting neuronal membrane.
   b. Open voltage-gated K^+ channels cause the depolarizing upstroke of the action potential.
   c. Open voltage-gated K^+ channels cause afterhyperpolarization.
   d. The sizable leak through voltage-gated K^+ channels determines the value of the resting membrane potential.
   e. Opening of voltage-gated Cl^- channels is the main factor causing rapid repolarization of the membrane at the end of an action potential.

8. Two neurons, A and B, synapse onto a third neuron, C. If neurotransmitter from A opens ligand-gated ion channels permeable to Na^+ and K^+ and neurotransmitter from B opens ligand-gated Cl^- channels, which of the following statements is true?
   a. An action potential in neuron A causes a depolarizing EPSP in neuron B.
   b. An action potential in neuron B causes a depolarizing EPSP in neuron C.
   c. Simultaneous action potentials in A and B will cause hyperpolarization of neuron C.
   d. Simultaneous action potentials in A and B will cause less depolarization of neuron C than if only neuron A fired an action potential.
   e. An action potential in neuron B will bring neuron C closer to its action potential threshold than would an action potential in neuron A.

9. Which correctly associates a neurotransmitter with one of its characteristics?
   a. Dopamine is a catecholamine synthesized from the amino acid tyrosine.
   b. Glutamate is released by most inhibitory interneurons in the spinal cord.
   c. Serotonin is an endogenous opioid associated with "runner's high."
   d. GABA is the neurotransmitter that mediates long-term potentiation.
   e. Neuropeptides are synthesized in the axon terminals of the neurons that release them.

10. Which of these synapses does not have acetylcholine as its primary neurotransmitter?
    a. synapse of a postganglionic parasympathetic neuron onto a heart cell
    b. synapse of a postganglionic sympathetic neuron onto a smooth muscle cell
    c. synapse of a preganglionic sympathetic neuron onto a postganglionic neuron
    d. synapse of a somatic efferent neuron onto a skeletal muscle cell
    e. synapse of a preganglionic sympathetic neuron onto adrenal medullary cells

Part 2 (MC):

1. Choose the *true* statement:
   a. The modality of energy a given sensory receptor responds to in normal functioning is known as the "adequate stimulus" for that receptor.
   b. Receptor potentials are "all-or-none," that is, they have the same magnitude regardless of the strength of the stimulus.
   c. When the frequency of action potentials along sensory neurons is constant as long as a stimulus continues, it is called "adaptation."
   d. When sensory units have large receptive fields, the acuity of perception is greater.
   e. The "modality" refers to the intensity of a given stimulus.

2. Using a single intracellular recording electrode, in what part of a sensory neuron could you simultaneously record both receptor potentials and action potentials?
   a. in the cell body
   b. at the node of Ranvier nearest the peripheral end
   c. at the receptor membrane where the stimulus occurs
   d. at the central axon terminals within the CNS
   e. There is no single point where both can be measured.

3. Which best describes "lateral inhibition" in sensory processing?
   a. Presynaptic axo–axonal synapses reduce neurotransmitter release at excitatory synapses.
   b. When a stimulus is maintained for a long time, action potentials from sensory receptors decrease in frequency with time.
   c. Descending inputs from the brainstem inhibit afferent pain pathways in the spinal cord.
   d. Inhibitory interneurons decrease action potentials from receptors at the periphery of a stimulated region.
   e. Receptor potentials increase in magnitude with the strength of a stimulus.

4. What region of the brain contains the primary visual cortex?
   a. the occipital lobe
   b. the frontal lobe
   c. the temporal lobe
   d. the somatosensory cortex
   e. the parietal lobe association area

5. Which type of receptor does *not* encode a somatic sensation?
   a. muscle-spindle stretch receptor
   b. nociceptor
   c. Pacinian corpuscle
   d. thermoreceptor
   e. cochlear hair cell

6. Which best describes the vision of a person with uncorrected nearsightedness?
   a. The eyeball is too long; far objects focus on the retina when the ciliary muscle contracts.
   b. The eyeball is too long; near objects focus on the retina when the ciliary muscle is relaxed.
   c. The eyeball is too long; near objects cannot be focused on the retina.
   d. The eyeball is too short; far objects cannot be focused on the retina.
   e. The eyeball is too short; near objects focus on the retina when the ciliary muscle is relaxed.

7. If a patient suffers a stroke that destroys the optic tract on the right side of the brain, which of the following visual defects will result?
   a. Complete blindness will result.
   b. There will be no vision in the left eye, but vision will be normal in the right eye.
   c. The patient will not perceive images of objects striking the left half of the retina in the left eye.
   d. The patient will not perceive images of objects striking the right half of the retina in the right eye.
   e. Neither eye will perceive objects in the right side of the patient's field of view.

8. Which correctly describes a step in auditory signal transduction?
   a. Displacement of the basilar membrane with respect to the tectorial membrane stimulates stereocilia on the hair cells.
   b. Pressure waves on the oval window cause vibrations of the malleus, which are transferred via the stapes to the round window.
   c. Movement of the stapes causes oscillations in the tympanic membrane, which is in contact with the endolymph.
   d. Oscillations of the stapes against the oval window set up pressure waves in the semicircular canals.
   e. The malleus, incus, and stapes are found in the inner ear, within the cochlea.

9. A standing subject looking over her left shoulder suddenly rotates her head to look over her right shoulder. How does the vestibular system detect this motion?
   a. The utricle goes from a vertical to a horizontal position, and otoliths stimulate stereocilia.
   b. Stretch receptors in neck muscles send action potentials to the vestibular apparatus, which relays them to the brain.
   c. Fluid within the semicircular canals remains stationary, bending the cupula and stereocilia as the head rotates.
   d. The movement causes endolymph in the cochlea to rotate from right to left, stimulating inner hair cells.
   e. Counterrotation of the aqueous humor activates a nystagmus response.

10. Which category of taste receptor cells does MSG (monosodium glutamate) most strongly stimulate?
   a. salty
   b. bitter
   c. sweet
   d. umami
   e. sour

Part 3 (Short Answer):

1. Neurons are treated with a drug that instantly and permanently stops the Na^+/K^+-ATPase pumps. Assume for this question that the pumps are not electrogenic. What happens to the resting membrane potential immediately? Over time?

2. Extracellular K^+ concentration in a person is increased with no change in intracellular K^+ concentration. What happens to the resting potential and the action potential?

3. A person has received a severe blow to the head but appears to be all right. Over the next week, however, he develops loss of appetite, thirst, and loss of sexual capacity but no loss in sensory or motor function. What part of the brain do you think may have been damaged?

5. Some cells are treated with a drug that blocks Cl^- channels, and the membrane potential of these cells becomes slightly depolarized (less negative). From these facts, predict whether the plasma membrane of these cells actively transports Cl^- and, if so, in what direction.

6. If the enzyme acetylcholinesterase was blocked with a drug, what malfunctions would occur in the heart and skeletal muscle?

7. The compound tetraethylammonium (TEA) blocks the voltage-gated changes in K+ permeability that occur during an action potential. After experimental treatment of neurons with TEA, what changes would you expect in the action potential? In the afterhyperpolarization?

8. A resting neuron has a membrane potential of -80 mV (determined by Na+ and K+ gradients), there are no Cl- pumps, the cell is slightly permeable to Cl-, and ECF $[Cl^-]$ is 100 mM. What is the intracellular $[Cl^-]$?
(Use the Nernst equation $V = 61/z \bullet \log([X]_{out}/[X]_{in})$

9. Five days after having a stroke, a nurse assesses the patients muscle strength and determines that he has right-sided weakness. What part of the brain was likely damaged?

The following questions involve the following case study:

Mrs. Gutteman was brought to the hospital after a bus crash. When paramedics arrived on the scene, Mrs. Gutteman was unconscious with cuts on her arms, face and scalp. Paramedics observed that she had a right hemiparesis (muscle weakness), with a near complete paresis of her right upper extremity and partial paresis of the right lower extremity. Doctors noted that she was able to follow commands from medical personnel. With difficulty, she could speak haltingly, using only simple words. A head CT scan also revealed an extensive subarachnoid hemorrhage (leakage from broken blood vessels).

10. Based on the observed signs in this case, which cerebral hemisphere is most likely involved? **(Left or Right)**. Which specific part of the injured hemisphere is likely to cause the muscle weakness?

11. Injury to which part of the brain is likely responsible for Mrs. Gutteman's speech difficulty?

12. Mrs. Gutteman was unconscious for a while. How can this be explained given the injury to a cerebral hemisphere?