TBIOL 140: Introductory Biology 3: Plant and Animal Anatomy and Physiology

Demo Lesson: Nerves and the neuronal action potential

Learning objectives:
LO#1. Describe the anatomy of the neuron and mechanisms underlying the membrane potential (***Bloom's taxonomy levels: "remember", "understand"***)
LO#2. Explain how the neuronal action potential is generated, propagates in a neuron, and transfers to another neuron (***Bloom's taxonomy levels: "understand", "apply"***)
LO#3. Examine how destruction of myelin sheath will affect the action potential, its propagation and neuron communication (***Bloom's taxonomy levels: "apply", "analyze"***)

Learning outcomes
1. By the end of the lesson the students **need to know:**
- The main anatomical structures of the neuron and its membrane (*LO#1*)
- How the membrane potential is maintained (*LO#1*)

2. After participation in the lesson and completion all the required assignments the students **will be able to**:
- Describe the mechanisms underlying the neuronal action potential (*LO#2*)
- Explain how the neurons communicate with each other (*LO#2*)
- Evaluate how neuronal damage (such as demyelination) might affect the transmission of the nerve impulses (*LO#3*)

Learning outcome assessment
Learning outcome #1:
- Pre-class assignment: overview of the nervous system and the anatomy of a neuron (slides 9-12; see attached file)
- In-class worksheet, part 1 (slide 4; see attached file)
- In-class short ungraded quizzes "Concept Check" (slides 13, 21, 30, 35, 41)
- Final short ungraded quiz "Quick Review" (slides 42-43)
- Small-group discussions (slides 5, 16-18, 27)
- All-class discussions (slides 5, 9-12, 15, 16-18, 23-24, 27, 37)

Learning outcome #2:
- In-class worksheet, parts 2 and 3 (slides 27, 37; see attached file)
- Homework assignment: evaluation of how demyelination affects the action potential transfer (see attached file)
- Small-group discussions (slides 5, 16-18, 27)
- All-class discussions (slides 5, 9-12, 15, 16-18, 23-24, 27, 37)

Time format: 80 min

Handouts: in-class worksheet, "A-B-C-D" cards (see attached files)

Activities: in-class worksheet, small-group discussions, all-class discussions, in-class short ungraded quizzes ("Concept Check" and "Quick Review")

Notes: (a) pre-lecture assignment is due at the beginning of class and should be submitted online (see attached file); (b) the slides for the lesson are attached, all the activities on slides are marked in blue; (c) Primary text used in preparation of lesson and slides: Freeman, S. Biological Science. 6th Ed. (2016). Pearson Education.

Lesson plan

Part 1. Nervous system, nerves, anatomy of a neuron (20 min)

Concepts covered: 1.1. Nervous system (overview): neuron as individual nerve cells, types of neurons, nerves, central and peripheral nervous systems; 1.2. The anatomy of a neuron

Concepts covered / slides / time	Activities	Learning goals
1.1. Nervous system (overview) *Slides 4-8 (8 min)*	➢ **In-class worksheet part 1 (Associations game).** The students fill out part 1 of their worksheet and write down all the associations with the term "Nervous system" they come up with. The students then compare their associations in pairs, small groups, and finally present them to the class. ➢ The instructor addresses the presented associations and presents **main terms/concepts** which will be discussed during the lecture.	• To 'warm-up' • To indirectly review the students' prior knowledge of the topic
1.2. The anatomy of a neuron *Slides 9-12 (10 min)*	➢ **All-class discussion of the pre-class assignment.** The instructor presents the distribution of student answers using an online tool (Canvas, Blackboard, or any online survey tool) and discusses with the class the main structures of a neuron and how CNS integrates sensory information.	• To help students to "have some of their prior knowledge in an active form in their memory so that they can focus on processing information, i.e. integrate the new knowledge with their prior knowledge.." (Kolari and Savander-Ranne, 2007)
Concept Check *Slide 13 (2 min)*	➢ **Short ungraded quiz.** The students answer the questions using their 'A-B-C-D' cards (correct answers are in blue): **Q1.** The specialized accessory cells of the central nervous system that wrap around some axons to provide electrical insulation. (A) Schwann cells (B) Axon terminal **Q2.** Neuron which carries signals to the effector (a muscle, gland, etc.). (A) Efferent motor neuron (B) Afferent sensory neuron **Q3.** A short extension from a neuron's cell body that receives signals from other neurons. (A) Axon (B) Dendrites	• To help students follow the material • To assess if learning outcome #1 is being reached

Part 2. Membrane potential (15 min)

Concepts covered: 2.1. Membrane, the inside and outside of the cell, resting membrane potential; 2.2. How is the membrane potential maintained?

Concepts covered / slides / time	Activities	Learning goals
2.1. Membrane and membrane potential *Slides 14-18* *(10 min)*	➢ **All-class guided discussion.** The instructor presents a picture of the membrane. In the guided dialog/discussion the students familiarize themselves with the main components of the membrane potential. *Questions to be discussed:* - What do you see? (just a description without analysis) Expected answers: ions Na, K, Cl, some channels, inside of the cell, outside of the cell, etc.) - What does it mean? (which ion is predominant, what direction each ion is moving, etc.) The students answer the questions using their 'A-B-C-D' cards.	• To build vocabulary for further understanding of the mechanisms underlying the membrane potential
2.1. How is the membrane potential maintained? *Slides 19-20* *(4 min)*	➢ The instructor addresses the students' answers from the previous discussion and describes/makes conclusions on the mechanisms underlying maintaining the resting membrane potential. ➢ The instructor then introduces K+ leak channels and the sodium-potassium pump and how they work.	• To identify the role of each membrane's structure and component in maintaining the membrane potential
Concept Check *Slide 21* *(1 min)*	➢ **Short ungraded quiz.** The students answer the questions using their 'A-B-C-D' cards (correct answers are in blue): **Q1**. A typical neuron has a resting membrane potential of about: (A) +70 mV (B) +70 V (C) -70 mV (D) -70 V **Q2**. Potassium channel that allows potassium ions to leak out of a neuron in its resting state: (A) Axon terminal (B) Leak channel (C) The sodium–potassium pump	• To help students follow the material • To assess if learning outcome #1 is being reached

Part 3. Action potential and its propagation in a neuron (30 min)

Concepts covered: 3.1. Action potential, main phases; 3.2. How do action potentials propagate?

Concepts covered / slides / time	Activities	Learning goals
3.1. Action potential (overview)	➢ **All-class short discussion**. What do you see on the graph? What do you think is happening to the membrane potential here? ➢ The instructor introduces the term "action potential" and its main phases	• To understand and be able to explain the processes

Slides 22-29 *(14 min)*	➢ **Small-group discussion. In-class worksheet part 2.** The class is divided into three groups (3 tables, 3 rows, etc.). Each group is assigned a different phase of the action potential (depolarization, repolarization, or hyperpolarization). Students discuss the questions in their worksheet and fill out table 1. *Questions to be asked:* For each phase, please describe the following: - Charges on each side of the membrane - Changes in membrane potential (becomes more/less positive, negative, or no changes) ➢ **All-class short discussion**. A designated person from each group presents the answers; students from other groups fill out the rest of the table in their worksheet. ➢ The instructor addresses all the answers and (1) introduces the concept of voltage-gated channels and their role in making action potential happen, and (2) emphasizes that action potential is an "all-or-none" event.	involved in action potential
Concept Check *Slide 30* *(2 min)*	➢ **Short ungraded quiz.** The students answer the questions using their 'A-B-C-D' cards (correct answers are in blue): **Q1**. A rapid, temporary change in electrical potential across a membrane, from negative to positive and back to negative. (A) Resting potential (B) Action potential **Q2**. Match each ion's movement with the type of graded potential it creates Na+ entry -> (A) Depolarization (B) Hyperpolarization K+ exit -> (A) Depolarization (B) Hyperpolarization **Q3**. Return to a normal membrane potential after it has changed; a normal phase in an action potential. (A) Depolarization (B) Repolarization (C) Hyperpolarization	• To help students follow the material • To assess if learning outcome #2 is being reached
3.2. How do action potentials propagate? *Slide 31-34* *(10 min)*	➢ The instructor explains the direction of action potential and principles of its propagation to the axon terminal. ➢ **All-class guided discussion.** The class watches a short animation on ion channels work during the action potential propagation. *Questions to be discussed:* - What ion channels are open during (a) the resting potential phase, (b) when the threshold potential is reached? - What differences do you observe at different points of the axon? ➢ The instructor introduces the key factors affecting the speed of action potential conduction and demonstrates action potentials in myelinated axons	• To understand and be able to explain how an action potential propagates in a neuron

Concept Check *Slide 35* *(2 min)*	➢ **Short ungraded quiz.** The students answer the questions using their 'A-B-C-D' cards (correct answers are in blue): **Q1**. One of the periodic unmyelinated sections of a neuron's axon at which an action potential can be regenerated: (A) Nodes of Ranvier (B) Axon terminal **Q2**. A stimulating electrode placed halfway down an axon artificially depolarizes the cell above threshold. In which direction will an action potential travel: (A) to the axon terminal (B) to the cell body (C) to both **Q3**. Place the following neurons in order of their speed of conduction, from fastest to slowest: (A) myelinated axon, diameter 20 μm (1) (B) unmyelinated axon, diameter 20 μm (3) (C) unmyelinated axon, diameter 200 μm (2)	• To help students follow the material • To assess if learning outcome #2 is being reached

Part 4. Synapse, neuron communication (10 min)

Concepts covered: synapse, transmitters transfer, postsynaptical potentials

Concepts covered / slides / time	**Activities**	**Learning goals**
Synapse, transmitters transfer, postsynaptical potentials *Slide 37-40* *(9 min)*	➢ **Small-group-discussion and work with the worksheet**. The students watch a 1-min video on neuron communication and answer to the corresponding questions in their worksheet: https://www.biointeractive.org/classroom-resources/molecular-mechanism-synaptic-function *Questions to be asked:* - What ions do release at the axon terminal? - What activates receptors on a second neuron? ➢ **All-class-discussion.** The students then share their answers with the class ➢ The instructor addresses the students' answers and further explains the process of transferring information at synapses	• To familiarize the students with neuron communication • To be able to further explain the mechanisms underlying information transfer at synapses
Concept Check *Slide 41* *(1 min)*	➢ **Short ungraded quiz.** The students answer the questions using their 'A,B,C,D'-cards (correct answers are in blue): **Q1**. What channels do open at presynaptic membrane when the action potential arrived to the axon terminal? (A) Voltage-gated Na+ channels (B) Voltage-gated Ca 2+ channels **Q2**. Changes in the membrane potential of a postsynaptic cell that make the cell more likely to produce an action potential: (A) excitatory postsynaptic potentials (B) inhibitory postsynaptic potentials	• To help students follow the material • To assess if learning outcome #2 is being reached

Part 5. Conclusion and Review: quick review and homework. (5 min)

Concepts covered / slides / time	**Activities**	**Learning goals**
Quick Review *Slides 42-44* *(4 min)*	➢ **Final short ungraded quiz.** The students answer the questions using their 'A,B,C,D'-cards (correct answers are in blue): **Q1**. Neurons that conduct signals away from the central nervous system are classified as: (A) afferent (B) associative (C) sensory (D) motor **Q2**. When a neuron is not stimulated: (A) the outside of the neuron is negatively charged and the inside is positively charged (B) the outside of the neuron is positive and the inside is negative (C) both outside and inside of the neuron are negatively charged (D) both outside and inside of the neuron are positively charged **Q3**. Which cells wrap around an axon forming a myelin sheath: (A) other neurons (B) Schwann cells (C) axons of other neurons (D) dendrites of other neurons **Q4**. Which of the following is **not** involved in the process of synaptic transmission: (A) the release of a neurotransmitter from synaptic vesicles at the pre-synaptic neuron (B) the destruction of the post-synaptic membrane after the neurotransmitter has come in contact with it (C) diffusion of the neurotransmitter across the synaptic cleft (D) destruction of the neurotransmitter after transmission of the impulse has taken place ➢ **Learning outcomes review**	• To help students assess their understanding of the topic • To assess if learning outcomes #1 and #2 are reached by the end of the class
Homework *Slide 45* *(1 min)*	➢ **Brief introduction to homework "What will happen if the myelin sheath is destroyed?"** The homework is posted online for the students. It contains a worksheet with several quick questions on how demyelination cause diseases like multiple sclerosis. (the file is attached)	• To help students apply and evaluate their knowledge in new situations • To assess if learning outcome #2, (specifically for LO #3) is reached by the end of the class

References:

Freeman, S. Biological Science. 6th Ed. (2016). Pearson Education. 1360 p.
Kolari, S., & Savander-Ranne, C. (2007, September). Pre-lecture assignments-a method for improving learning in engineering education. In *Proceedings of the International Conference on Engineering Education 2007, ICEE 2007*.