

100 points total

Your Name: _____

I. (11 points) Matching. Use each item in right hand column only once

- | | |
|---------------------------|---|
| <u>G</u> 1. statocyst | A. Ganglion in Jellyfish with several sensory systems |
| <u>C</u> 2. neuropile | B. valves on the respiratory system of Arthropods |
| <u>A</u> 3. marginal body | C. synaptic region of a ganglion |
| <u>H</u> 4. trachea | D. modified 2 nd pair of wings: balance organ used in flight |
| <u>I</u> 5. chitin | E. portion of retinula cell containing rhodopsin |
| <u>K</u> 6. transduction | F. individual units of a compound eye |
| <u>J</u> 7. rhodopsin | G. gravity sensor |
| <u>D</u> 8. haltere | H. air-filled tubes within Arthropods, function in respiration |
| <u>B</u> 9. spiracles | I. non-living hard material that forms exoskeleton of Arthropods |
| <u>E</u> 10. rhabdomere | J. light receptor molecule |
| <u>F</u> 11. ommatidium | K. the conversion of one form of energy into another form of energy |

1 point for each correct answer

II. (12 points) Matching. Options in the right hand column may be used more than once.

<u>C, D, E, G</u>	1. Annelids	A. first group to have evolved true muscle cells
<u>A, E, H, I</u>	2. Cnidarians/Coelenterates	B. Cephalopods
<u>E</u>	3. Sponges/Porifera	C. first group to exhibit segmentation
<u>B, E</u>	4. Molluscs	D. first group to evolve well developed “heads” and “brains”
<u>E, F</u>	5. Arthropods	E. have electrically excitable cells
<u>E</u>	6. Protists	F. have a chitinous exoskeleton
		G. Earthworms, Polychaetes, and Leeches
		H. First group to evolve true nerve cells
		I. Have bi-directional synapses

1–6 were each worth 2 points. Wrong answers were each worth half of the worth of one right answer, but negative.

III. (18 points) True/False

- T The story of Clever Hans, the horse that was thought to have mathematical talents, illustrates that the behavioral experimenter can readily become part of the experiment without knowing it.
- F Activation of one chemoreceptor hair on the foot of a fly is sufficient to cause the fly to empty its crop.
- F As in humans, flies determine hunger by the level of sugar in their blood.
- T Recent experiments on glass sponges show that the choanocytes are controlled by conducted electrical impulses.
- F All sensory neurons conduct APs in response to an adequate stimulus.
- F A gap junction allows only current to flow between the two cells it joins.
- T The electrical organ in most fish is derived from muscle.
- T Electroreception is a logical consequence of the fact that living organisms generate electrical currents.
- T Many weakly electric fish use both active and passive electroreception.
- T The voltage of electrical generating tissue of strong electric fish depends on the number of electroplax cells connected in series in insulated columns.
- F Homing pigeons can find their way home because they have special symbiotic magnetosensing bacteria that help the pigeon orient to the Earth’s magnetic poles.

12. F The presence of intense infrared radiation on the early earth is thought to have been a driving force in the evolution of photoreception.
13. F Each ommatidium of a compound eye sees the entire visual field of the eye.
14. T In the compound eyes of arthropods, each ommatidium sends an independent picture of what it sees into the nervous system where all inputs are summed to create a mosaic image.
15. F All muscles must conduct an AP in order to contract.
16. F The vertebrate striated muscle fiber is caused to contract by calcium release from stores within the motor axon.
17. T Hair cells do NOT conduct APs, but are still able to release neurotransmitter upon stimulus reception.
18. T The central nervous system can dampen the sensitivity of the ear.

1 point for each correct answer

IV. Fill-in-the-blank. (8 points)

Cnidarians or Coelenterates are the first group of marine invertebrates to evolve a true nervous system. Hence, they have specialized cells to conduct APs called, neurons. The next level of nervous system organization is small clusters of neurons where synaptic connections occur in high densities. These structures are called ganglia and in invertebrates they are commonly found distributed all throughout the body. Increasing complexity of the nervous system occurs as these structures fuse together in the anterior region of the animal. Concentration of the nervous system and sensory structures to the anterior region is called cephalization. Animals with more complex nervous systems have lower (*choose which*) numbers of peripheral ganglia.

Each blank was worth one point, so this one was worth a total of 5 points.

The inner hair cells are the specialized sound-transducing cells in the ear. They transduce sound waves into electrochemical signals by projections called stereocilia that are stiff, only bending when the flexible membrane that they are associated with vibrates with the propagation of sound waves. The primary ion that causes the electrochemical signal in hair cells is K⁺.

Each blank was worth one point, so this one was worth a total of 3 points.

V. (21 points) Multiple choice More than one alternative might be right.

highlighted choices are the correct answers

1. [2pts] Which type of channel is involved in the AP?
 - mechanosensitive channels
 - ligand-gated channels
 - voltage-gated channels
 - leak channels
 - chemoreceptor channels

2. [2pts] Which are the only necessary precursors to triggering synaptic transmission at a chemical synapse?
 - AP at the axon terminal
 - Depolarization of the axon terminal
 - Ca⁺⁺ influx into the axon terminal
 - Ca⁺⁺ efflux out of the axon terminal
 - Hyperpolarization of the axon terminal

3. [2pts] Which of the following properties would result in a neuron with the largest space constant?
 - high internal resistance
 - low internal resistance
 - high membrane resistance
 - low membrane resistance

4. [3pts] Which of the following describe graded potentials, such as receptor or synaptic potentials?
 - all-or-none
 - active propagation
 - propagate by opening of voltage-gated channels
 - degrade with space and time
 - their amplitude directly reflects the stimulus intensity
 - able to be regenerated
 - always depolarizing

5. [3pts] Which of the following describe electrical synapses?
- f the presynaptic neuron and the postsynaptic neuron are directly connected (cytoplasms can mix to some extent)
 - f there is a gap between the presynaptic neuron and the postsynaptic neuron
 - f an excitatory signal in the presynaptic neuron can trigger an inhibitory signal in the postsynaptic neuron
 - f they are extremely fast (almost no delay in the transmission of the signal)
 - f Ca^{++} influx is involved
 - f they are commonly found in neural circuits that mediate alarm or startle responses
6. [3pts] Which of the following describe the Cnidarian nervous system?
- f *en-passant* synapses, synapses that occur wherever two neurons intersect each other, not just at the tips of the neurons.
 - f myelinated axons
 - f bi-directional synapses
 - f true giant axons
 - f neuroid or epithelial conduction
 - f specific neural pathways with different conduction velocities
7. [2pts] Ampullae of Lorenzini are used in which sensory modality?
- f electroreception
 - f mechanoreception
 - f thermoreception
 - f photoreception
8. [2pts] Which of the following explains how an Arthropod achieves graded contractions of its muscles?
- f motor unit recruitment: more and more of the neurons that innervate one muscle are firing APs
 - f increased frequency of APs within the innervating neuron
 - f trigger muscle fibers to fire increasing frequency of APs
 - f increased release of glutamate onto all the muscle fibers of the muscle
9. [2pts] The human ear is involved in which of the following?
- f orienting the body relative to gravity
 - f detecting body movement in three dimensions
 - f sound transduction/hearing
 - f mechanoreception
 - f chemoreception

Each question's answers were weighted differently depending on the total worth of the question and how many correct choices there were. Each correct answer was worth = total # of points for question/ # of correct answers. Wrong answers counted against earned points in the amount = half of the worth of a correct answer.

VI. (30 points) Short answer. Write answer clearly in the space provided.

1. (6 points) Explain how Kenneth Roeder's approach to experiments in moth hearing of bat sonar exemplifies the ideals of neuroethological research. *Think about the types of experiments he did.*

Neuroethology – (see NC pp. 1-2) Ethology is an experimental approach to studying behavior, vs. just passively observing behavior, ethology involves setting up experiments with controls etc. Neuroethology involves ethological experiments on behavior *combined with* an attempt to gain an understanding for the underlying neural mechanisms that explain this behavior using neurobiological techniques.

3 steps Roeder took in his experiments with moth hearing that “exemplified the ideals of neuroethological research”:

1. He made a simple observation and formulated a testable hypothesis about it. Noticed whenever he came home after dark there were lots of moths clinging to his screen door. Whenever he jingled his keys the moths would drop off the screen door immediately. He knew that the sound emission of the keys had a sound spectrum that contained not only frequencies that were in the range of human hearing ability, but also super sonic components that we could not hear. He also knew that bats had recently been found to emit super-sonic pulses to find prey (e.g., moths).
Roeder formulated a hypothesis that the moths could hear the super-sonic emissions that bats made and had adaptive escape behaviors associated with detecting these sounds.
2. He set up a very simple *behavioral experiment* in his backyard. He had a speaker that emitted super-sonic sounds (bat-like sounds). At night, as a moth would fly by he would turn on the speaker and record the moth's behavior. He witnessed three behaviors that were associated with how near the moths were to the sound source: (1) tight turns, associated with being very near sound source, (2) fly straight down into vegetation, associated with being very near sound source, (3) fly straight away fast in a straight path, associated with being far from the sound source. These observations supported his hypothesis.
3. He took his moths into the lab to see if he could find further *neurophysiological* experimental evidence to support his hypothesis. He dissected out the moths' ears and recorded the impulses within each of 3 cells he found as he played super-sonic sounds. One fired continuously signaling the brain that the ear is working. Another cell fired APs whenever the super-sonic sounds were very faint (i.e., as would be the case if the pursuing bat was far from the moth). This cell seemed to mediate the fly straight away behavior. Another cell fired APs whenever the super-sonic sounds were quite loud (i.e., as would be the case if the pursuing bat was near). This cell seemed to mediate the drop into the vegetation & the tight-turns behavior.

2. (4 points) What two neuronal modifications have evolved to increase conduction velocity in neurons? Describe *how* these modifications affect the conduction velocity of the AP.

Myelination – seen most commonly in vertebrates as a means to increase conduction velocity of AP. It functions to increase the membrane resistance thereby reducing the amount of charge or current leakage across the membrane as the signal/current travels down an axon. Myelin is an axon's insulation. It also functions to decrease the capacitance of the membrane, which decreases the amount of charge that the membrane can store and thus take away from the current.

AP moves between nodes as an electrical current, essentially instantaneously, hence conduction is called saltatory (jumping). At node AP is restored by Na/K flux as in normal AP generation.

Increased axonal diameters – seen most commonly in invertebrates: giant axons. This functions to decrease the internal resistance associated with the cytoplasm inside the axon. If there is more “free space” in which the current can flow, which would be the case if the axon had a larger diameter, then there would be less impedance to the flow of current within an axon. This increases the conduction velocity of the AP by increasing the space constant of the axon.

3. (3 points) Since sensory systems communicate with the central nervous system only by means of all-or-none nerve impulses, how does the CNS comprehend the type of the stimulus (light, pressure, tastes ,etc) and its intensity?

labelled lines – input coming from a given nerve is always interpreted as being **caused** by a particular stimulus regardless of whether those APs were actually initiated by that specific stimulus or not. Ex. Visual phosphenes, when you push on your eyeball you are stimulating your photoreceptors to send APs to your brain via your optic nerve. (Even though the photoreceptors are not evolved to detect mechanical pressure, if the force is great enough they will send APs). When you push on your eyeball you perceive light flashes even though that is not what is actually causing the APs in your optic nerve.

stimulus strength or intensity is encoded by the frequency of APs that are sent along afferent nerves to your brain, **the sensory code is impulse frequency.**

4. (4 points) If we could genetically engineer a jellyfish with a nervous system that was concentrated at the apex of its bell would this be advantageous or disadvantageous? Explain your answer.

Most of you probably argued that this would be disadvantageous, but if you made a good argument for why it would be advantageous, you will receive credit also.

Here are some reasons it would be disadvantageous:

First of all, in reality, is the jellyfish nervous system concentrated in one region of its body or diffuse? It's diffuse. This is because the jellyfish has radial body symmetry and its locomotion is not unidirectional (as in a worm or an arthropod). Jellyfish locomotion is such that the jellyfish is equally likely to encounter a new environment on any portion of its body. To have the fastest reaction times to external stimuli, the jellyfish nervous system and sensory structures are distributed uniformly throughout its body. Examining nervous system structure along the evolutionary tree, you can see that concentration of the nervous system is associated with the evolution of unidirectional locomotion and bilateral symmetry. If you genetically engineer a jellyfish that is still radially symmetric and has non-unidirectional locomotion, but has its nervous system concentrated in the bell apex, then its reaction times to stimuli arriving on the opposite side of its body would be slower and this would not be advantageous.

Alternate advantageous argument: If a central ganglion at apex of bell gained control, the organism might adopt locomotion with bell apex leading and this could lead to eventual symmetry with advantages much like in bilateral symmetry.

5. (3 points) Why does a Crustacean have polyterminal neurons that synapse onto its muscle fibers instead of monoterminal neurons?

Crustacean muscle fibers do not have the ability to trigger a muscle AP like the vertebrate muscle fibers do. Instead the muscle fiber is depolarized in a graded fashion by huge numbers of small neuronal junctions from one or a few axons (excitatory and inhibitory). Thus the muscle fiber can be made to contract more or less by the frequency of neural excitation. Vertebrate muscle fibers contract in an all-or-none fashion. The value of this difference to the crustacean is that the entire anatomical muscle acts as a motor unit saving the possibly hundreds of small motor units that are in a typical vertebrate muscle. A crustacean muscle might have only 4 motor axons where a vertebrate muscle of the same size would have many times that number. Operating in this fashion the crustacean conserves the numbers of motor cells that it must use and achieves similar precision of contraction to the vertebrate.

So in a vertebrate, underneath the neuronal terminal is a region called the end plate. It is depolarized when the motor axon is stimulated. This end-plate depolarization travels outside of the end-plate region and triggers voltage-gated channels to open. In this manner the signal is propagated very quickly to the entire muscle fiber (a muscle AP), and this triggers the muscle fiber to contract simultaneously.

Since crustacean muscle fibers do not have voltage-gated channels there is no means for propagating the initial depolarization triggered by the release of neurotransmitter from the motor axon. Because this signal is a passive, graded signal it will degrade with space and time as it travels. This type of potential is rarely large enough to depolarize the entire muscle fiber, hence the entire fiber

would never contract as one unit. In order to get around not having the ability to propagate a depolarization, the motor axon that innervates the muscle fiber has branched out so that it makes several synaptic “connections” with the muscle fiber. All of these polyterminal sites of depolarization along the muscle fiber will overlap such that whenever the one motor axon innervating the muscle fiber is stimulated the entire muscle fiber will contract as unit.

6. (4 points) How do the two fundamental types of phylogenetically distinct photoreceptors differ in their response to light and anatomically (also, state the two types)? Name one major group that has each type.

Ciliary – Chordates have these, ex. in humans: rods and cones

these hyperpolarize in response to light

the upper portion (outer segment) of the cell is full of stacked discs which dramatically increases the surface area of membrane. It is within these disc membranes that the light-sensitive molecule, rhodopsin sits.

Microvillar – Annelids, Molluscs, and Arthropods have these types of photoreceptors

these depolarize in response to light

they are thought to have evolved from microvilli (like in your intestines),

their outer segment is characterized by a highly folded membrane (like a comb). It is within this highly folded area that rhodopsin sits.

7. (6 points) Compare and contrast the electroreception abilities of the shark, the strong electric fish (e.g., *Torpedo*), and the weak electric fish. Also discuss how each organism uses electroreception.

Shark – ex. of a passive electroreceptive fish. It does not actively emit an electrical pulse. It has evolved the ability only to sense the passive electrical fields that surround every living creature in water (because of the electricity that is coursing through every living organism’s body, muscle APs and nervous APs). Using ampullae of Lorenzini in it’s anterior region a shark can find it’s prey by homing in on the electrical signal that the prey emits rather than sniffing it out or seeing it.

Strong electric fish (ex. *Torpedo*) – ex. of active electroreception. This fish actively emits a very strong pulse of electricity into the water only when it is striking at prey or defeding itself (not continuously). It uses this emitted pulse to stun its prey and for defense.

Weak electric fish – ex. of active electroreception. These fish actively emit weak pulses of electricity continuously into the water. These pulses create a current or electrical halo around the fish. The fish is simultaneously emitting the electricity at one end and detecting the return current at the other end of its body. As it nears objects its electrical halo is distorted. By detecting these distortions in its electrical halo it can navigate its murky environment. It can also stun small prey items and communicate with other members of its species with its electrical halo.