

Name _____
(write your name on every sheet)

There are 28 questions.
Point values for each are given.
86 points total.

1. The dark current of photoreceptors is so named since it flows in the dark. It was initially recorded between two extracellular electrodes one placed at the outer segment, and the other placed nearer to the inner segment. What ionic current is being measured here? (3 points):

- a. Ion responsible: _____
- b. Type of channel responsible: _____
- c. Subcellular localization of channel: _____

2. Following the interaction of rhodopsin with light, which of the following play a role in stopping the downstream signaling? (3 points)

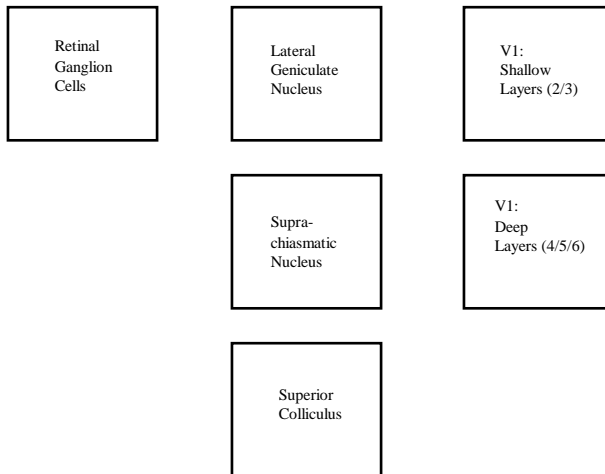
- a. The G-protein coupled receptor transducin is hydrolyzes its GTP and ceases to signal.
- b. Active rhodopsin eventually hydrolyses its GTP and ceases to signal.
- c. Active transducin is phosphorylated by opsin kinase and then inactivated by arrestin.
- d. Active rhodopsin is phosphorylated by opsin kinase and then inactivated by arrestin.
- e. Active rhodopsin is phosphorylated by opsin kinase and then endocytosed.
- f. Activation of a phosphodiesterase reduces intracellular cGMP and closes gates of cyclic nucleotide gated channels.

3. Sensory adaptation in the retina occurs since (2 points):

- a. Calcium influx through cGMP gated channels is reduced during prolonged light exposure. Resting calcium is reduced, which disinhibits guanylyl cyclase and modestly increases cGMP concentration in the photoreceptor.
- b. The center-surround structure of horizontal cells tends to reduce signals in response to only extremely bright light, always resulting in an intermediate firing pattern in retinal ganglion cells.
- c. An amacrine cell, which makes a reciprocal connection at the bipolar-retinal ganglion cell synapse, can release GABA or glycine once stimulated by the bipolar neuron. Thus, with a temporal lag, the response of the ganglion cell will be reduced.
- d. Once exposed to light, rhodopsin is photobleached and needs to be recycled before it can be used again in the photoreceptor. Thus, for seconds afterwards, any particular photoreceptor cells is not available after exposure to light.

4. Which of the following are true about the odorant receptor proteins in primary olfactory sensory neurons? (3 points)
- They are all seven transmembrane receptors.
 - Though encoded by only a few genes, they produce enormous variability in olfactory response through alternative splicing.
 - They produce enormous variability in olfactory response since they are encoded by several hundred distinct genes.
 - Though encoded by only a few genes, they produce enormous variability in olfactory response through coupling to a large number of different G-proteins.
 - They appear to play a role in glomerular targeting of olfactory sensory neurons.
 - They appear to play a role in differentiation, ensuring that newborn olfactory sensory neurons express region-appropriate olfactory receptor proteins.
5. Which of the following are true about the organization of the olfactory epithelium? (3 points)
- Olfactory sensory neurons (OSNs) provide a graded response to odorants and release transmitter onto olfactory ganglion neurons which project to glomeruli in the olfactory bulb.
 - Olfactory sensory neurons expressing a receptor appropriate to an odorant fire action potentials strongly with shorter latency; other OSNs may fire to a lesser degree, or with greater latency, since their receptor may be partially activated by the odorant.
 - Olfactory sensory neurons expressing the same olfactory receptor are restricted to certain zones or strips within the olfactory epithelium, but appear to be randomly located within that zone.
 - In the adult olfactory system, neural precursor cells differentiate into olfactory sensory neurons, replacing OSNs on a regular basis.
 - Sensory neurons expressing a specific type of olfactory receptor target two and only two glomeruli in the olfactory bulb on each side of the brain.
6. Circle the correct response: (2 points)
- (a) True or False: Release of glutamate onto the mGluR6 receptor of a bipolar cell will cause that cell to fire an action potential.
- (b) Parvocellular Ganglion cells have [Small / Large] receptive fields and constitute [More than / Less than] 50% of the ganglion cells in the retina.

7. Major pathways of visual information in primates: Draw arrows from each region specified in the drawing below showing indicating afferents projecting from one region to another (3 points).



8. In class, we have seen how optical illusions can exploit information processing in our visual system. In one illusion, a square of a certain luminance surrounded by lighter ones that appears seems darker than an square of the same luminance that is surrounded by darker colored ones. Which is the BEST explanation for this effect? (2 points)

- Photoreceptor adaptation to the different light intensities in the surround makes the square surrounded by light ones appear darker.
- Intraretinal processing by horizontal cells establish a spatial center-surround for retinal ganglion cells, thus enhancing edges and making objects surrounded by darker ones appear lighter (and vice versa).
- Intraretinal processing by amacrine cells establish a temporal center-surround for retinal ganglion cells, thus enhancing edges and making objects surrounded by darker ones appear lighter (and vice versa).

9. Which of the following are true with respect to the functional architecture of visual cortex? (2 points)

- Penetrating an ocular dominance column from shallow (pial) to deep, you will encounter cells with a preference first for one eye, then binocular cells, and then cells with a preference for the other eye, all covering the same general spatial receptive field location.
- Per degree of visual space, visual cortex devotes a larger area to processing inputs from near the fovea than the periphery.
- Retinotopy is preserved in all layers (Layer 2/3, Layer 4, etc.) of striate cortex.
- The interaction of retinotopy and orientation selectivity in visual cortex is such that, for a region of visual space (say, the upper left visual field), cells that prefer objects of various orientations in that field are found near one another in cortex.

10. Which are true about somatic sensation: (circle all that apply) (3 points)
- DRG neurons innervating Pacinian corpuscles and encoding vibration make synapses on dorsal horn neurons of the ascending anterolateral system.
 - The receptive fields of dorsal root ganglion cells are shaped by inhibitory feedback from the thalamus
 - TRPV1 channels are activated by high temperatures, capsaicin and low pH
 - Dorsal root ganglia contain the sensory neurons innervating Meissner corpuscles and Merkel cells, joint and tendon organs, and muscle spindles, but not the nociceptive (C-fiber) neurons with free nerve endings in the skin.
 - Skin near whiskers has many more Meissner corpuscles per cm² than the skin of the upper arm.
11. Dorsal root ganglia: (circle all true statements; 2 points)
- Contain the first order neurons of Meissner and Merkel receptors, joint receptors, muscle spindles but not of free nerve ending which are in the dorsal horn.
 - Are considered part of the central nervous system
 - At the level of the lumbar spinal cord are important for the knee jerk reflex
 - Are functionally equivalent to the spiral ganglion (auditory)
12. Ascending sensory pathways share—to some extent—a common architecture. Cells in layer IV of primary sensory cortex receive input from cells in a thalamic nucleus, which in turn receive input from brainstem or spinal cord neurons. Complete the list below. (5 points)

stimulus	sensory cell	relay neuron	project to thalamus	thalamus	cortex
light touch	dorsal root ganglion cell	dorsal root ganglion cell			postcentral gyrus
sound			cochlear nucleus		transverse temporal gyrus
Light				LGN	

13. If you shock the gamma efferent motor axons innervating a muscle, what would you record from the muscle's spindle afferents? If the reflex loop is intact, what would you record from the alpha motor axons innervating the same muscle? Why? (2 points)

14. Which of the following are TRUE about mechanotransduction in hair cells? (3 points)

- a. The deflection of the hair bundle in any direction leads to a depolarizing receptor potential
- b. When mechanotransduction channels open in hair cells in vivo there is a passive inward K^+ current.
- c. Hair cell mechanotransduction channels are relatively fast, opening in tens of milliseconds
- d. One mechanism for adaptation by hair cells is an adjustment of tip-link tension by myosin motors within the stereocilia.
- e. Hair cells are fragile, but like olfactory neurons can regenerate in days if killed by trauma or aminoglycoside antibiotics.

15. A hair cell makes no action potentials but nevertheless communicates the receptor potential to neurons in the spiral ganglion or vestibular ganglia. Which of the following regarding this process are true? (3 points)

- a. Transmitter is released, not by vesicles, but by a glutamate transporter running in reverse.
- b. Voltage-gated calcium channels in hair cells open at relatively negative membrane potentials—near the resting potential—to evoke vesicle release.
- c. The receptor potential is very large, peaking near +10 mV, which can open ordinary calcium channels.
- d. Hair cells are electrically coupled by gap junctions to postsynaptic fibers.
- e. Potassium entering through transduction channels in the stereocilia directly stimulates vesicle release.
- f. Hair cells continuously release vesicles, and small changes in membrane potential modulate the release rate up or down.

16. For each of the following, identify which structure performs the function listed. (3 points)

- a) Detects linear acceleration of the head: _____
- b) Is the first CNS auditory relay : _____
- c) Processes interaural time differences: _____
- d) Contains cells that might form a spatial auditory map: _____
- e) Projects to motor neurons of extraocular muscles _____

choices:

- 1) cochlear nucleus
- 2) lateral superior olive
- 3) semicircular canals
- 4) inferior colliculus
- 5) utricle
- 6) nucleus of lateral lemniscus
- 7) medial superior olive
- 8) superior vestibular nucleus
- 9) inferior vestibular nucleus

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HST 131/Neuro 200
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17 (a). Briefly describe how frequency and intensity are coded by the auditory nerve. (2 points)

17 (b). Contrast the definitions of receptive field for spiral ganglion neurons and retinal ganglion cells. (2 points)

18. The firing rate of vestibular neurons innervating the semicircular canals is largely proportional to angular *velocity* of the head (rather than angular acceleration) because of (select the *one* best answer) (2 points):

- a. the inhibitory commissural projections that interconnect the vestibular nuclei
- b. adaptation of hair cell mechanotransduction
- c. higher density of the otoconia relative to endolymph
- d. damped mechanics of the canal / cupula

19. In the VOR (for small movements without nystagmus), the motor neurons innervating the extraocular muscles must have firing rates proportional to the angular *position* of the head. Yet the vestibular ganglion neurons driving the VOR respond to angular *velocity* of the head. How is a velocity signal converted to a position signal for the VOR? (2 points)

- a. a collection of neural integrator cells in the nucleus prepositus hypoglossi
- b. adaptation of the ganglion neurons due to the cupula elasticity
- c. summation (integration) in superior and medial vestibular nucleus neurons by post-tetanic facilitation
- d. inhibitory feedback by neurons of the medial superior olive

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20. List three other properties that differ between fast twitch and slow twitch muscle fibers. (3 points)

Fast Twitch

1. Activate quickly

2.

3.

4.

Slow Twitch

1. Activate slowly

2.

3.

4.

21. Which of the following are false? (3 points)

- a) A single alpha motor neuron innervates one and only one motor fiber.
- b) Reflexes are not able to coordinate motor responses on both sides of the body.
- c) The motor unit type (fast/slow twitch) is determined by its innervating motor neuron.
- d) There are more muscle fibers per motor unit in the large muscles of the thigh than the intrinsic muscles controlling the fingers.
- e) Fiber type grouping in the muscle suggests that the individual is suffering from primary damage to the muscle.

22. Match the correct lesion with the symptoms presented (5 points):

- A. M1 lesion
- B. Cerebellar lesion: left cerebellar cortex/hemisphere
- C. Left corticospinal tract lesion, red nucleus spared
- D. Right corticospinal tract and red nucleus lesion, medial brainstem system spared
- E. Cerebellar lesion: right cerebellar cortex/hemisphere
- F. Right corticospinal tract lesion, red nucleus spared
- G. PM or SMA lesion
- H. Left Corticospinal tract and red nucleus lesion, medial brainstem system spared
- I. Cerebellar lesion: flocculonodular node.

___ A patient has difficulty performing simple balance tasks, and cannot read while turning his head back and forth.

___ A patient's posture is affected such that upon noxious stimulation, he brings his left arm and leg towards his body and rotates them backward.

___ A patient finds she has ataxic movements in her right arm and hand while dribbling a basketball, but can use her left arm and hand without any difficulty.

___ A patient can bend her arm about the elbow and wrist, but has trouble completing a task in which using the 2 joints in combination is necessary (such as retrieving a piece of candy behind a transparent barrier).

___ Following a period of weakness lasting several days, a patient develops a persistent flexion of the right arm, while the right leg remains extended.

23. Indicate all the following that are true about motor control (3 points):

- a. Most corticospinal axons synapse on alpha motorneurons.
- b. Motor cortex, unlike sensory cortex, varies in its properties along the radial axis (perpendicular to the cortical).
- c. Neurons sensitive to the direction of limb movements can be found in both M1 and PMA.
- d. An M1 neuron encoding the kinematics of an arm movement would be expected to fire at a similar rate for the same changes in joint angles, regardless of the force required to make the movement.
- e. The direction-tuning of M1 neurons tends to be rather narrow, implying that only a few specific neurons may be required to complete precise movements.
- f. As you go from premotor to motor areas of the cortex, there is a trend toward less anticipatory "set" neural activity.

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24. Climbing fibers and Mossy fibers are the main input to the cerebellum. For each of the following, indicate whether the statement is true for climbing fibers (C), mossy fibers (M), both (B), or neither (N). (3 points)

___ Fibers bifurcate in the molecular layer and run in opposite directions, parallel to the long axis of the lobules.

___ Form excitatory synapses

___ Excitation leads to complex spikes in Purkinje neurons

___ Arise in the inferior olivary nucleus

___ Synapse on Purkinje neurons

___ Form inhibitory synapses

25. Draw the direct and (separate drawing) indirect pathways from cortex through striatum and back again, indicating the nuclei involved, the neurotransmitters used by the projection neurons from each nuclei, and the net effect on voluntary movement. (6 points)

26. Which of the following are true: (2 points)

- a. Since projection neurons in the striatum are GABAergic, inhibitory interneurons are not present in the caudate and putamen.
- b. Medium spiny neurons of the putamen project to both external and internal subdivisions of the globus pallidus.
- c. Both pharmacological subtypes (D1 and D2) of dopamine receptors are present on medium spiny neurons of the putamen involved in the direct pathway promoting motor movement.
- d. Both pharmacological subtypes (D1 and D2) of dopamine receptors are present on medium spiny neurons of the globus pallidus involved in the direct pathway promoting motor movement.

Amyotrophic Lateral Sclerosis:

27. Although only some cases of Amyotrophic Lateral Sclerosis seem to be inherited, one important recent discovery has identified a gene that plays a role in ALS. This conclusion is supported by experiments using transgenic animals with similar deficits in the gene. (4 points)

- (a) Identify the gene (1): _____
- (b) Is it sex-linked or autosomal (0.5): _____
- (c) Cell type(s) in which gene is expressed (0.5): _____
- (d) Type of mutation that accounts for most cases (0.5): _____
(null, nonsense, missense)
- (e) Normal cellular function of the gene (short answer) (1.5): _____

28. Indicate which of the following are cardinal symptoms of Parkinsonism (5 points):

- A. Muscle fatigue
- B. Rigidity
- C. Dementia
- D. Akinesia
- E. Hemifacial spasms
- F. Tremor
- G. Gait disorder
- H. Nystagmus
- I. Bradykinesia
- J. Loss of coordination and balance