COGS 107B
Monday 2pm Sections

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Key Points - Spatial Cognition

- Convergence, Divergence, Reentry
- Frame of Reference
- Allocentric Cell Types (3)
Understanding Visualizations

A. Spikes on trajectory

1. Place cell

2. Grid cell

B. Rate maps
Understanding Visualizations
Population Coding

- Spatial location 'b'
- Place field
- Population vector at 'b'
- Firing Rate (Hz) at location 'b'
- Neuron ID
A neurotransmitter, upon binding to a post-synaptic receptor, begins a 2nd messenger cascade that changes the kinetics of a voltage-gated Ca++ channel. The neurotransmitter is of what type?

A. ionotropic
B. metabotropic
C. it's not possible to know
D. cationotropic
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Neuromodulators - Slide 5
Name 4 neuromodulatory neurotransmitters and two properties common to all neuromodulatory systems
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**NTs:** NE, 5-HT, DA, HA, ACh  
**Properties:**  
– small groups of neurons  
– widespread, unmyelinated projections  
– long lasting effects through phosphorylation  
– input from many regions, including PFC  
– low firing rates  
– influence the response to other inputs as opposed to directly mediating inhibitory or excitatory responses
characteristics of brain neuromodulatory systems:

1. small groups of neurons (10’s of thousands) sharing the same neurotransmitter (i.e., neuromodulator)

2. projections, via unmyelinated fibers, to widespread regions of the brainstem and forebrain

3. neurotransmitter binding to receptors generates, through phosphorylation, long-lasting (100+ ms) changes in properties of voltage-gated ion channels

4. firing activity of neuromodulatory neurons is strongly impacted by sleep/wake state (exception for dopamine)

5. neuromodulatory neurons receive input from a number of different sources, but all receive input from prefrontal cortex

6. low firing rates (mean approx. 0-6 Hz)

7. influence the neuronal responses to ionotropic excitatory and inhibitory inputs as opposed to directly mediating excitatory or inhibitory responses (i.e., alter the ‘functional anatomy’ of the brain)
NE acting on a neuron only slightly changes its membrane potential, but nevertheless doubles that neuron's response to input from another neuron. This is one example of how neuromodulatory systems change the operation of brain circuits or, in other words, how they sometimes change the _____ _____ of the brain.
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functional anatomy
Name three cell types that each exhibit spatially–specific firing according to the allocentric frame of reference.
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Head Direction Cells, Grid Cells, Place Cells
tracking directional heading in the allocentric (world-centered) frame of reference: ‘head direction’ cells
- firing is tuned to the orientation of the animals head relative to the boundaries of the environment
- different neurons have different preferred directions (all directions are represented)

mapping position in the environment by path integration: ‘grid cells’
- neurons of the medial entorhinal cortex exhibit multiple firing fields in any given environment
- such fields are arranged according to the nodes of a set of ‘tesselated’ triangles
- grids, like head-direction tuning and place cells firing fields rotate with the boundaries of the environment

tracking position in the world-centered (allocentric) frame of reference: the ‘place cell’
- firing is tuned to the position of the animal in the environment (the place ‘field’)
- different neurons map different positions (all directions are represented)
- rotation of the environment boundaries = rotation of the place fields
According to Professor Nitz, neurons in this part of the rat brain exhibit spatially-specific firing that bears a route-centered frame of reference.

A. anterodorsal thalamus  
B. parietal cortex  
C. the entorhinal cortex  
D. IT cortex
According to Professor Nitz, neurons in this part of the rat brain exhibit spatially-specific firing that bears a route-centered frame of reference.

A. anterodorsal thalamus
B. parietal cortex
C. the entorhinal cortex
D. IT cortex
parietal cortex neurons in behaving rats map path segments (e.g., start pt. to first R turn)

parietal cortex: a rather abstract frame of reference – the space defined by the route (i.e., the space defined by sequence of behavior changes and the spaces separating them)
This region/nucleus of the brainstem serves as the convergence point for cortical inputs to the cerebellum. _______ _______
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Pontine Nuclei
the cortex-cerebellum-cortex loop: role in timing and adjustment of motor patterns

- inhibitory projection
- excitatory projection

- cerebral cortex
  - convergence
  - divergence
  - convergence = coordination across muscles of the body

- pontine nuclei (mossy fibers)
  - convergence

- cerebellum – granule cells

- cerebellum – Purkinje cells
  - divergence

- cerebellar nuclei (base of cerebellum – each contains homunculus)

- inferior olive (climbing fibers - ‘error’ signal induces learning)

- vestibular and proprioceptive inputs

- ventrolateral thalamus (and brainstem and spinal cord)
  - divergence

- motor cortex
Circle the appropriate word. The [GPi] / [GPe] is part of both the direct and indirect pathways through the basal ganglia. Medium spiny neurons of this region utilize [D1] / [D2] dopamine receptors which [enhance] / [suppress] their response to cortical excitatory inputs.

QUESTION NOT ON EXAM
True / False
Dopamine neurons fire more action potentials when expected reward is less than actual reward.
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True
DA neuron activity is, at least in part, driven by positive errors in reward expectation (i.e., getting more value than expected given a specific condition.)
True / False
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True
the local field potential (LFP):
a measurement, like the membrane potential, of charge differences (voltages) between two regions of the brain – maximal fluctuations in voltage are produced by common fluctuations in membrane potential among a population of neurons
Two types of voltage-gated Ca++ channels and two types of K+ channel are implicated in the intracellular membrane potential oscillations of thalamic and cortical neurons which accompany LFP 'slow-waves' in the thalamus and cortex.

Name them. _______ _______ _______ _______
Two types of voltage-gated Ca++ channels and two types of K+ channel are implicated in the intracellular membrane potential oscillations of thalamic and cortical neurons which accompany LFP 'slow-waves' in the thalamus and cortex.

\[ \text{Ih \& It} \quad - \quad \text{Ca}^{++} \text{ channels} \]

\[ \text{K+ leak channels and Ca}^{++} \text{ dependent} \quad - \quad \text{K+ channels} \]
Slow-waves (delta waves, 0.5-4 Hz) and spindles (12-16 Hz) that define NREM sleep are a reflection of burst-pause activity patterns of thalamic and cortical neurons — burst-pause activity results from the ‘deinactivation’ of I_h and I_i voltage-gated ion channels and their interaction with Ca++-dependent K+ channels — the former are deinactivated only when membrane potentials reach a certain level of hyperpolarization (< -65 mV) are depolarizing influences which counteract the hyperpolarizing influence of the Ca++-dependent K+ channel.

During waking, NE, 5-HT, and ACh all cause certain K+ channels (K+ ‘leak’ channels) to close — this depolarizes thalamic and cortical neurons tonically and renders I_h and I_i Ca++ channels inoperative because the membrane potential never gets hyperpolarized enough to de-inactivate them.

During REM sleep, ACh by itself depolarizes thalamic and cortical neurons.

During NREM sleep VLPO neurons likely inhibit ACh neurons.
This region of the brain contains the rare type of neuron that fires most action potentials during NREM or 'slow-wave' sleep.

A. suprachiasmatic nucleus
B. basal forebrain
C. Locus coeruleus
D. VLPO
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A. suprachiasmatic nucleus  
B. basal forebrain  
C. Locus coeruleus  
D. VLPO
VLPO neurons are unusual in firing faster during NREM sleep as compared to waking – some continue firing in REM sleep