BIOENG-311
Review – Systems

Week 14

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Key motifs covered in this course (*systems*)

- **Neural firing** and **population code** as an encoding of information
- **Neural tuning** as a description of function
- **Topography**: Retinotopy, V1 pinwheels, face patches, tonotopy, somatotopy
- **Brain disorders**: aphasia, neglect, lesions/stroke (e.g. S.M., H.M.), visual agnosia, achromatopsia, prosopagnosia, PD, …
- Computational models
  - as a **tool**. E.g., connectomics, data processing
  - as a **codification** of mechanisms. E.g., Hodgkin Huxley, GLM, Deep Nets
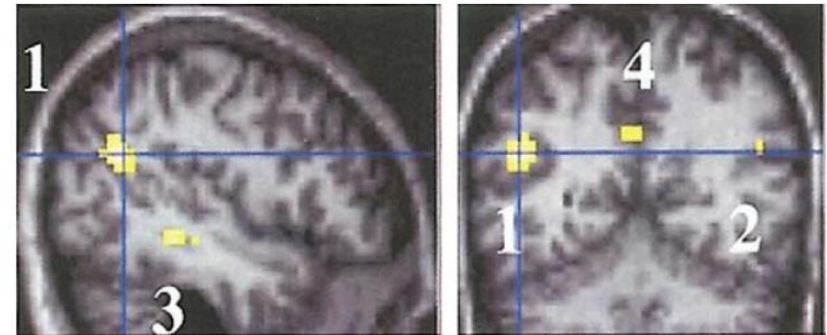
Neural code

- What is the primary way of transmitting information between neurons?
  → spikes

- Which of the following devices most likely generated this image?
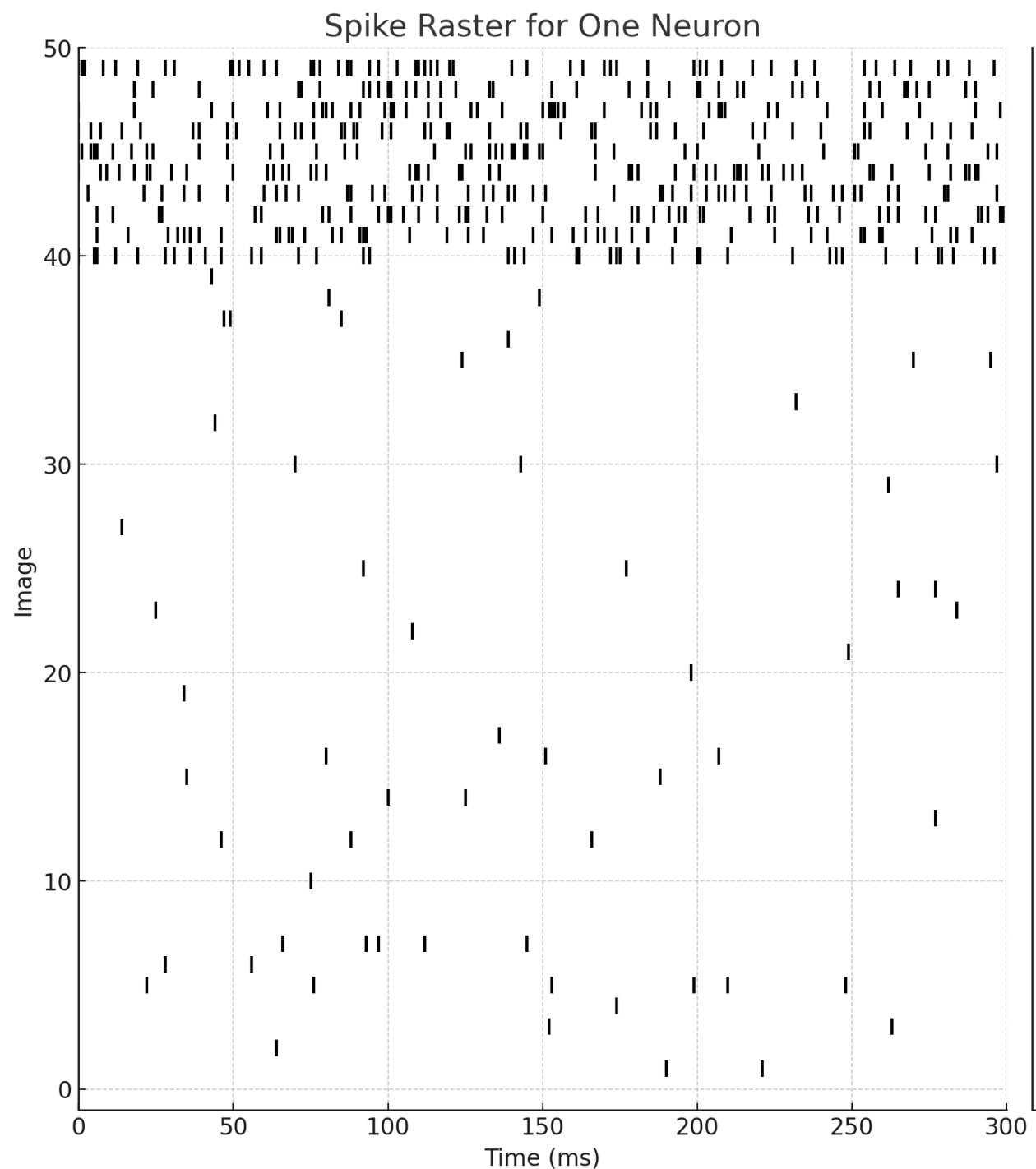 [ ] electrodes [ ] Calcium imaging
  [x] fMRI [ ] optogenetics

- What is the temporal resolution of electrode recordings?
  [x] milliseconds [ ] seconds [ ] minutes [ ] hours

Neural code

Imagine you recorded this data from a neuron in high-level visual cortex (IT).
1. What is the data?
2. What are the axes?
3. What stimulus does this neuron most respond to?

→ 1. spiking data for a single neuron across different images
→ 2. x-axis is time in milli-seconds, y is the image number
→ 3. more active for flowers over other categories

Spike Raster for One Neuron

Neural code

- We want to test which stimulus properties a neural population encodes. Describe how can we use linear decoding to quantify this?

  → **split** data into train/test split (cross-validated)
  → **fit** linear decoder on train split (from neural firing rate to stimulus property)
  → **evaluate** decoder on test split, measure how well we can predict different properties
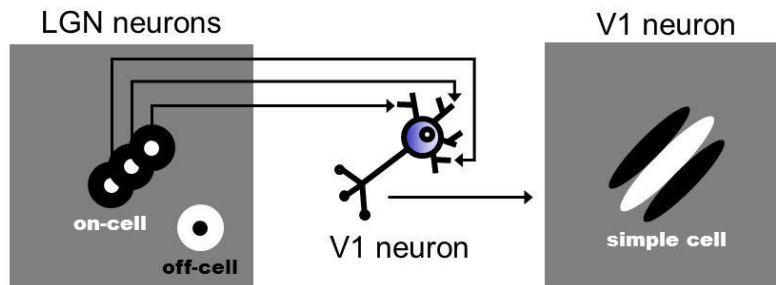
Vision

- Which has a higher resolution, fovea or periphery? Because of which cell type?

  → Fovea has a higher resolution than periphery
  → High density of cones (periphery has more rods instead)

- How do humans perceive a scene in high resolution?

  → Multiple saccades → That fixation can now be processed at high resolution

- Which hemisphere processes the left visual field?
  [ ] Left hemisphere [x] Right hemisphere

Vision

- Why is a V1 neuron only sensitive to a small part of the visual field?

  → Receptive field of ~1°. Each V1 neuron only receives limited visual input.

- Where in visual cortex are neurons sensitive to ~8-12°?

  → Inferotemporal cortex (IT)

- Describe the function of each of the three factors of the following Gabor function $f(x, y) = \frac{1}{2\pi\sigma_x\sigma_y} \cdot \exp\left(-\frac{x^2}{2\sigma_x^2} - \frac{y^2}{2\sigma_y^2}\right) \cdot \cos(kx - \varphi)$

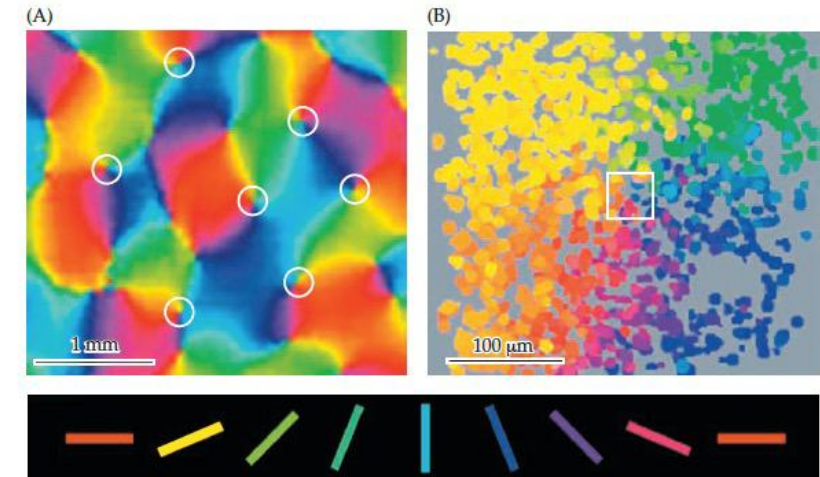 → 1. normalization 2. receptive field location 3. spatial phase

Vision

- Sketch the LGN-to-V1 simple-cell model of edge detection
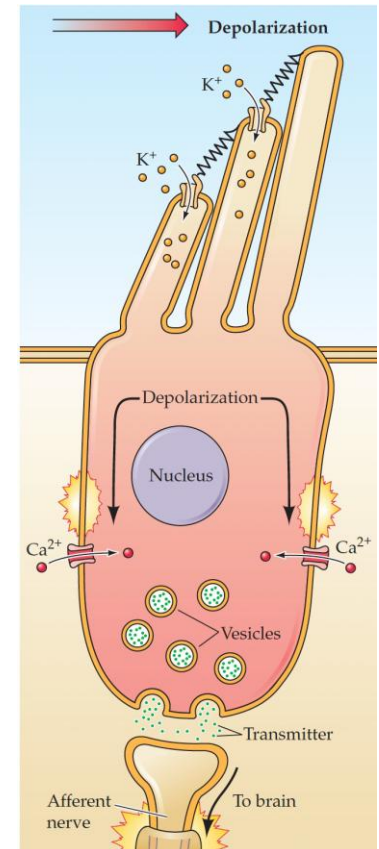

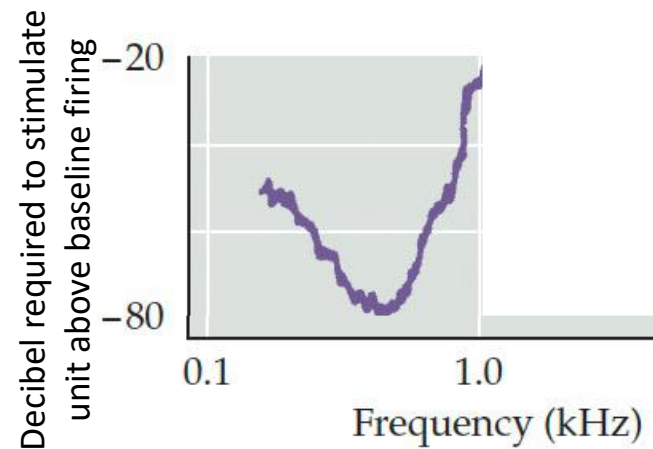- Which brain area is this plot most likely from?
  [ ] M1
  [x] V1
  [ ] A1

- What are the two streams in vision? Give a one-word description each
  → Ventral stream: objects / what   → Dorsal stream: motion / how / where
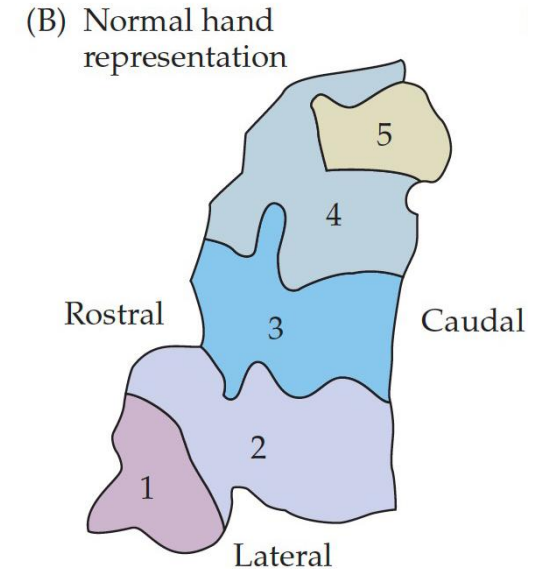
Audition

- What differences in sound do different hair cells respond to? How are they organized along the cochlear?

  → Different frequencies
  → From high to low frequency sounds

- What transmitter is released at the base of hair cells?

  → Glutamate

- What is a neural tuning curve in the context of audio?

  → Characteristic input
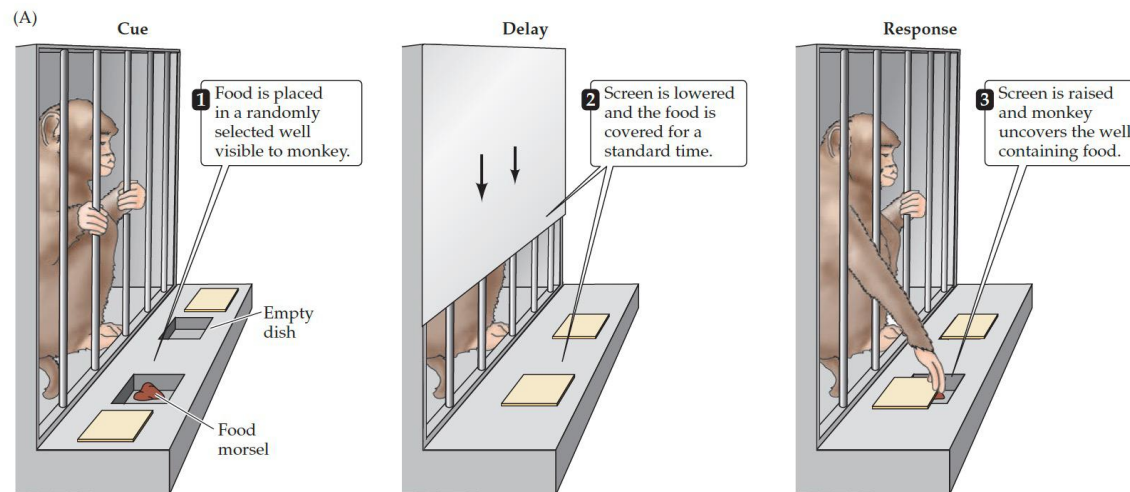 → Sound frequency to which neurons most responds

Somatosensation

- What is depicted here?

    → Homunculus
    → Size of skin parts scaled by how many neurons process sensing

- Imagine this is the functional organization of neurons in someone's somatosensory cortex, where the different numbers correspond to different digits of their hand. What would this organization look like several years after amputating their index finger (digit 2)?

    → The neurons corresponding to digits 1 and 3 would "grow" into the space (neural adaptation)

(B) Normal hand representation

Rostral   Caudal

5
4
3
2
1
Lateral

Memory and Learning

- Name two types of memory and their associated time course

  → Sensory: milliseconds to seconds

  → Working/short-term: seconds to minutes

  → Long-term: days to years

- Describe an experimental task to study working memory

(A)

Cue

1 Food is placed in a randomly selected well visible to monkey.

Empty dish

Food morsel

Delay

2 Screen is lowered and the food is covered for a standard time.

Response

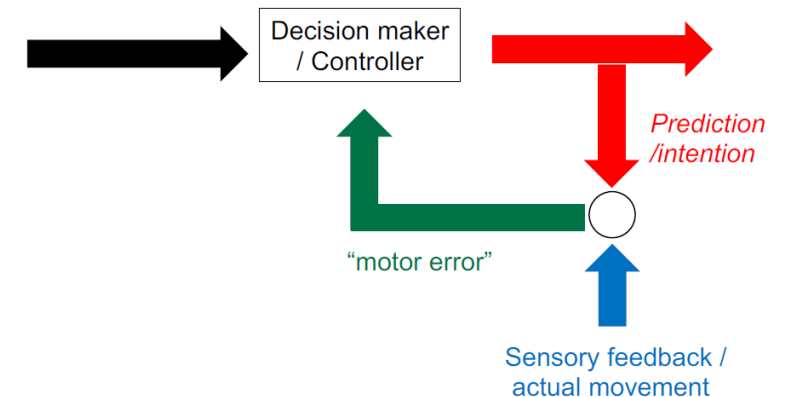3 Screen is raised and monkey uncovers the well containing food.

Memory and Learning

- Which brain region in patient H.M. was abnormal?

  → Hippocampus

- Which memories did H.M. have trouble with? Which were normal?
  → Difficulty: new memories (anterograde amnesia) and recent ~2y
     memories before hippocampal removal (retrograde amnesia)
  → Normal: childhood memories >2y ago

- Name a brain disorder that can also lead to memory deficits.
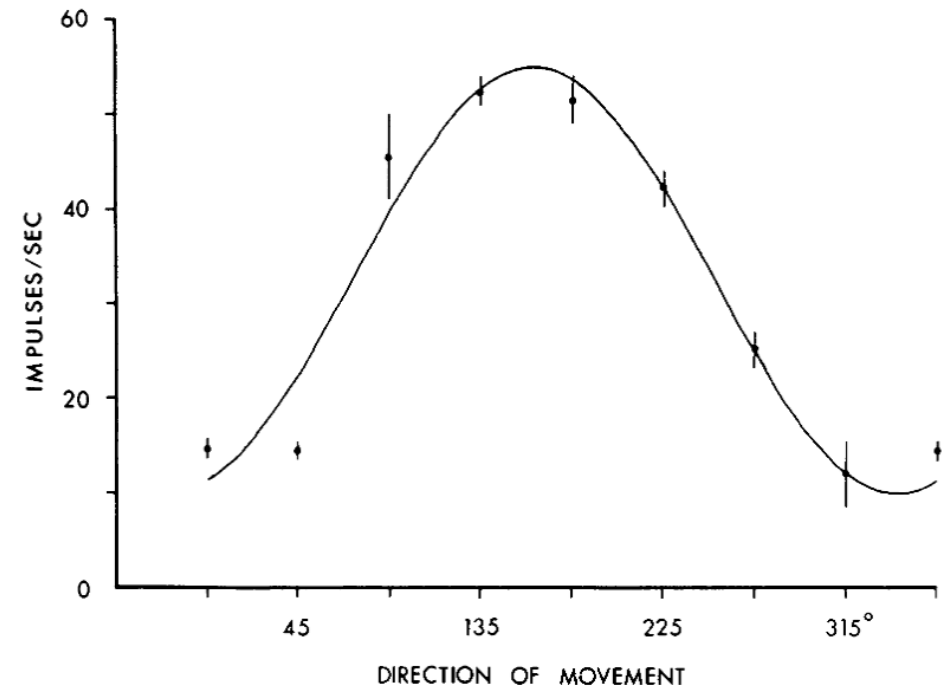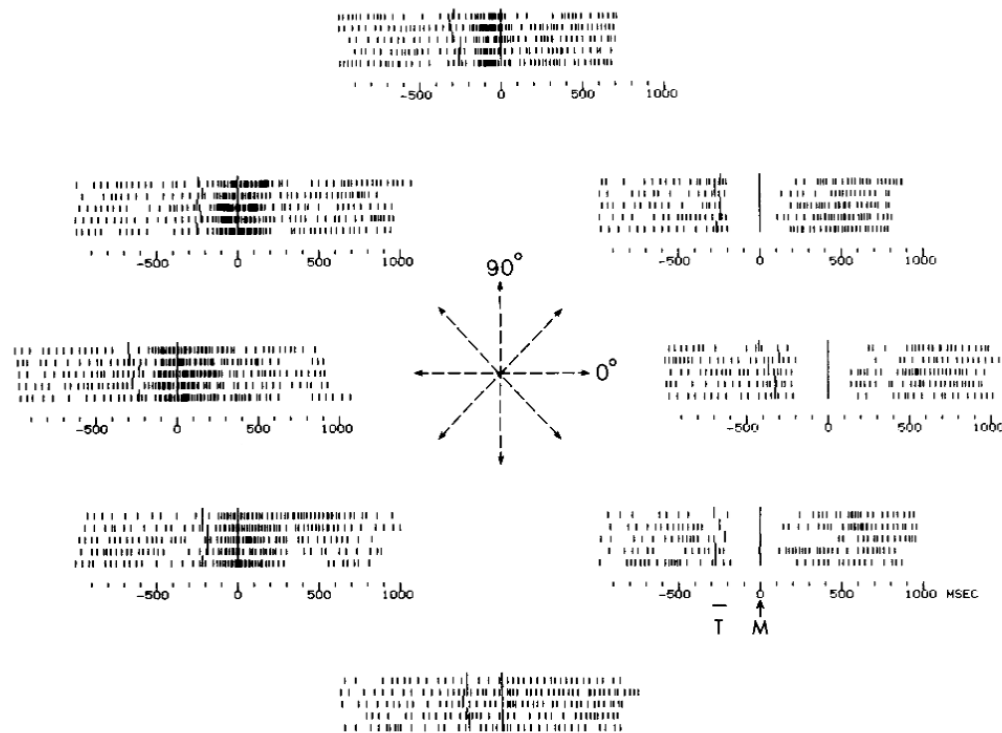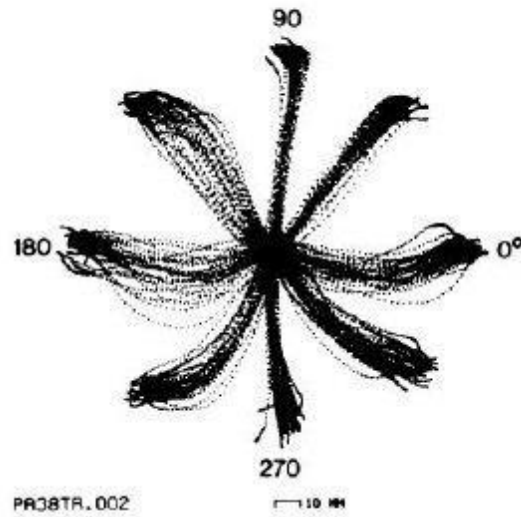 → Alzheimer's   → Dementia

Motor Control

- Name four regions involved in motor control

  → spinal cord   → motor cortex   → cerebellum   → basal ganglia   → brainstem

- Which types of neurons activate muscles?

  → α motor neurons

- Fill in the two gaps

  - The cerebellum **receives input from regions of the cerebral cortex** that plan and initiate complex and highly skilled movements;

  - it also **receives input from sensory systems that monitor the course of movements**

  - This arrangement enables a comparison of **an intended movement** with the **actual movement** and a reduction in the difference, or **"motor error."**
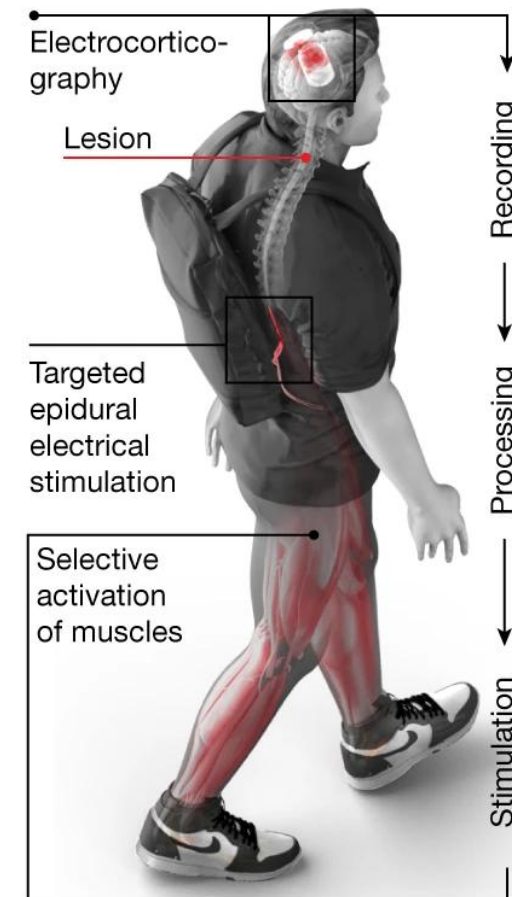
Motor Control

- Given these recordings of a neuron during joystick movement, sketch the neuronal tuning curve
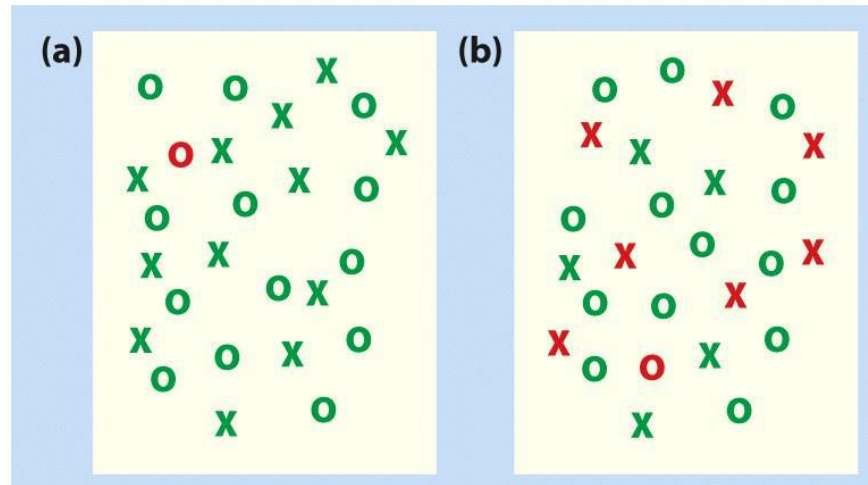
Motor Control

- Where would you stimulate a paralyzed individual to make them walk again?

  → Spinal cord below the lesion
  → Muscle motor neurons

Cognition

- Which types of attention are associated with each of these tasks? Name one key feature each

→ **Bottom-up attention**
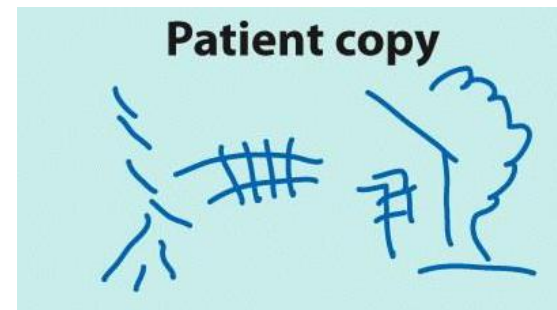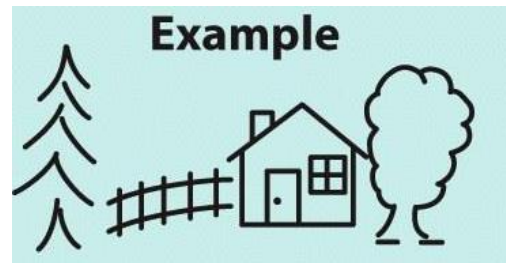→ Single feature difference
→ No effect of set size

→ **Top-down attention**
→ Multiple feature differences
→ Linear effect of set size on reaction time

Cognition

- How would an individual with neglect copy this image of a house? You may choose between **spatial** and **object** centered neglect, but name which you are sketching.

Example

Patient copy

Patient copy

Cognition

- What functions are impaired in individuals with global aphasia? What functions are not impaired?

  → Any verbal behaviors impaired (language comprehension/production)
  → Intact non-verbal intelligence

- Describe or sketch a Sally-Anne False-Belief Task

AI Brain Models