Psychophysics & Signal Detection Theory

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Perception (PSY 345 / NEU 325)
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Lec. 3

Chapter 1

Outline for today:

- Weber-Fechner law (review)
- Stephen's power law
- Psychophysics
- Signal Detection Theory

The Dawn of Psychophysics

Ernst Weber (1795–1878)

Weber Fraction

• ratio of change magnitude to stimulus magnitude that is required for detecting the change

change in stimulus $\longrightarrow dR$

stimulus intensity $\longrightarrow R$

Any two comparisons with the *same* Weber fraction should be equally detectable.

eg. $\frac{1}{20}$ = .05 is just as noticeable as $\frac{0.2}{4}$ = .05

The Dawn of Psychophysics

Ernst Weber (1795–1878)

Weber Fraction

• ratio of change magnitude to stimulus magnitude that is required for detecting the change

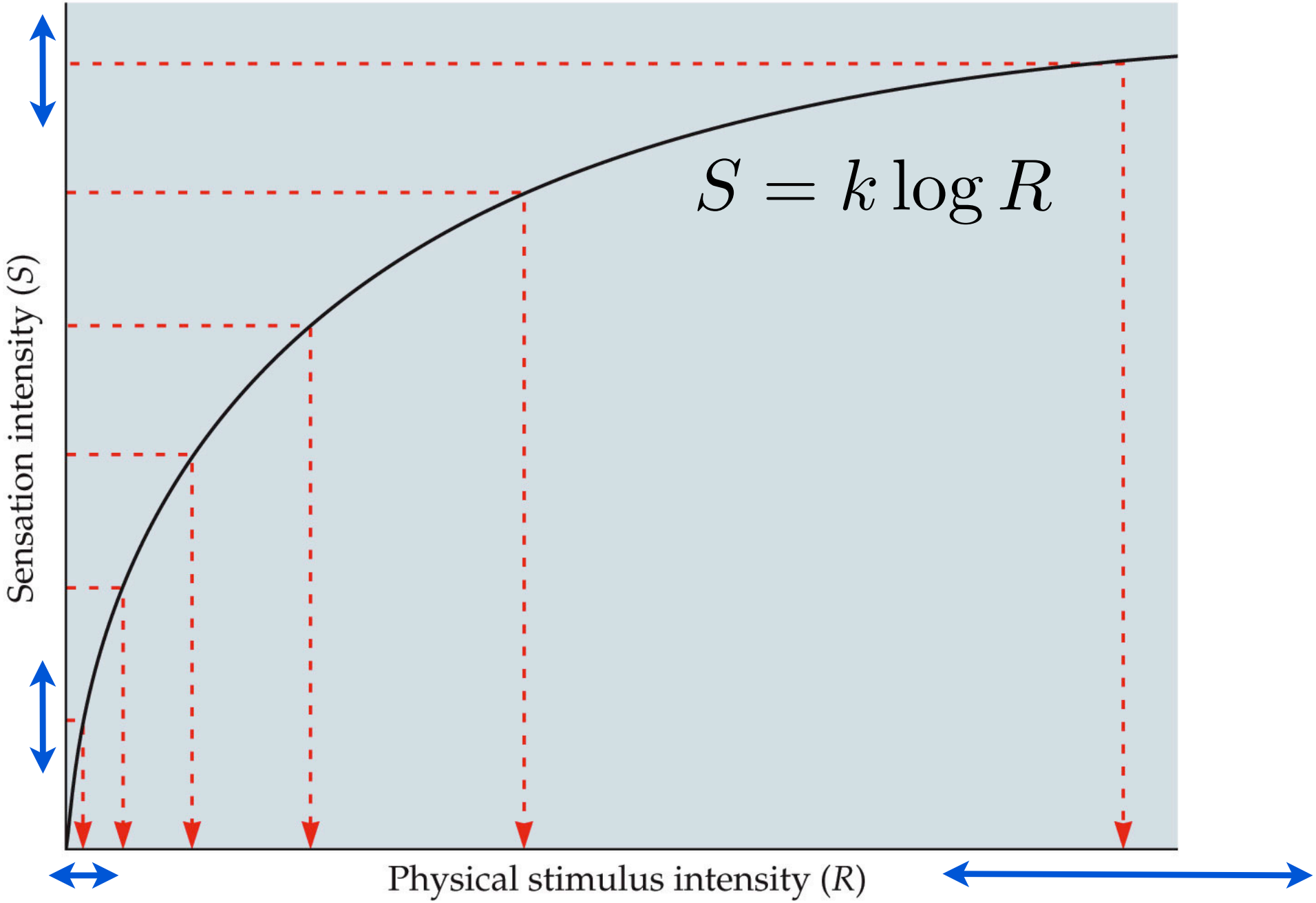
change in stimulus $\longrightarrow dR$

stimulus intensity $\longrightarrow R$

Just-Noticeable Difference (JND)

• smallest magnitude change (“dR”) that can be detected

Look at Fechner's law again:



A little math (don't freak out)

Fechner's law:

$$S = k \log R$$

S: percept intensity

R: stimulus intensity

differentiate both sides

Weber's law:

$$dS = k \frac{dR}{R}$$

dS: change in percept intensity

dR: change in stimulus intensity

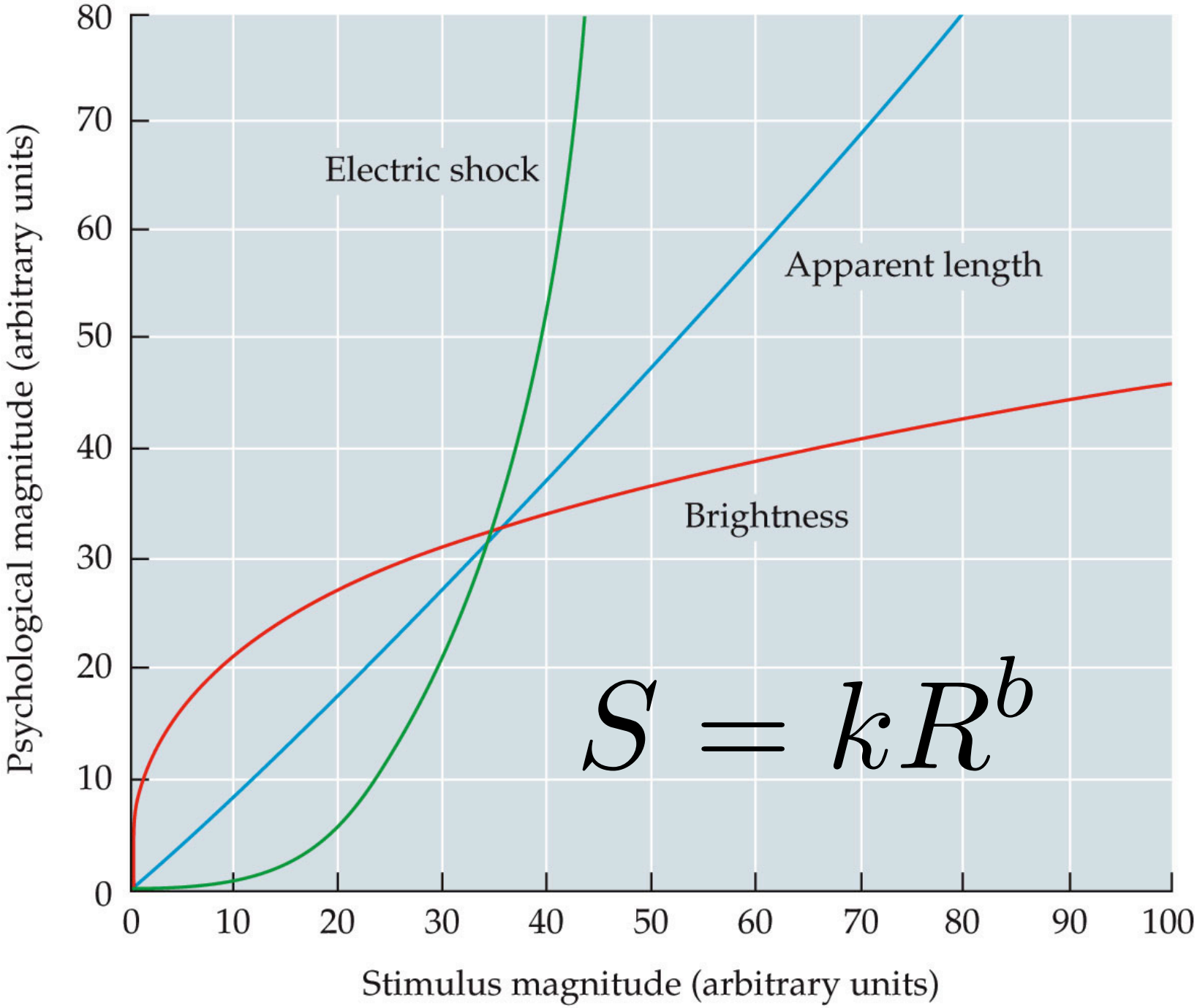
So detectability ("how much the percept changes") is determined by the ratio of stimulus change dR to stimulus intensity R.

(so, it's really the same law!)

Weber-Fechner Law

my rating: this is super deep + important!

Stevens' Power Law

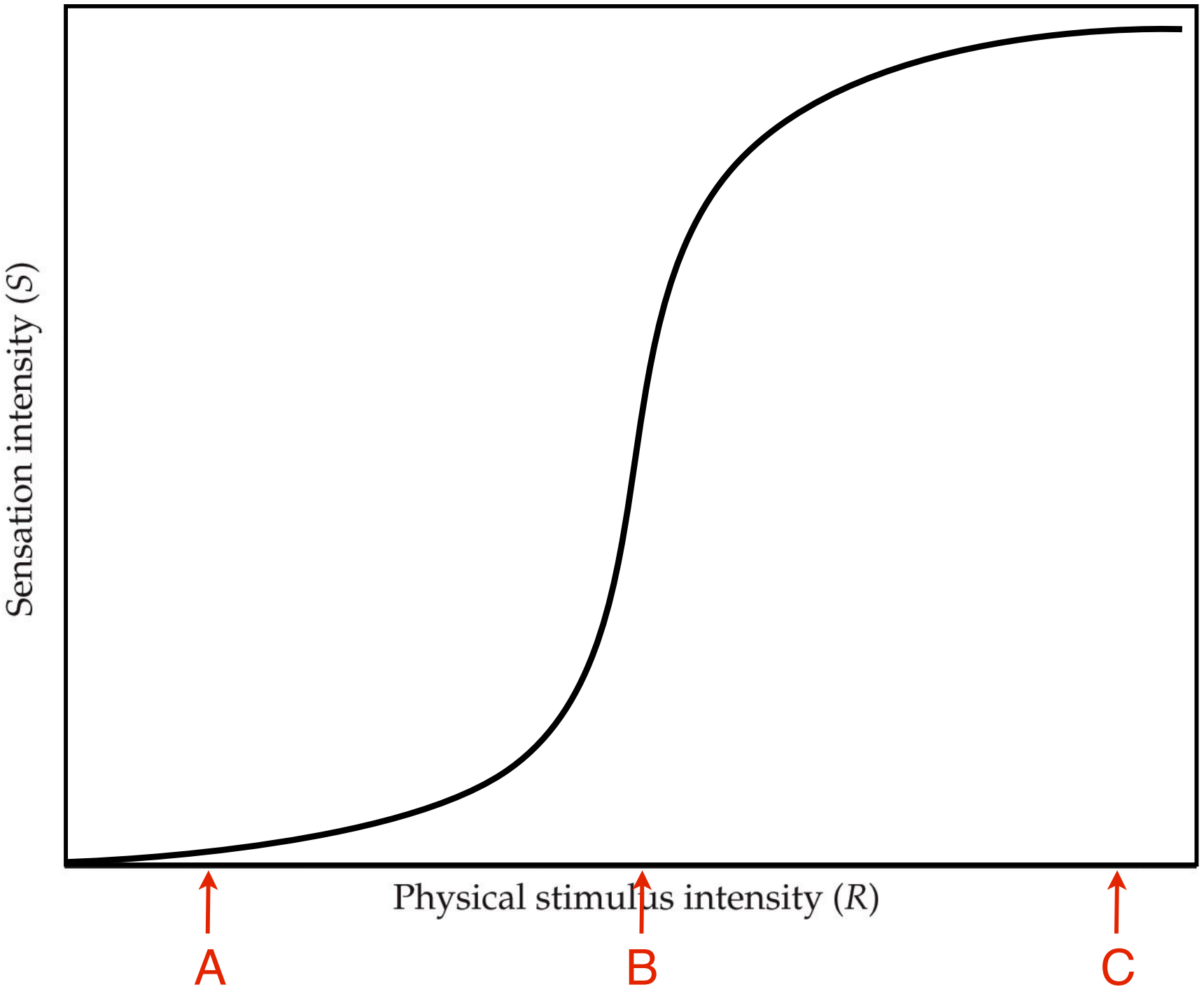


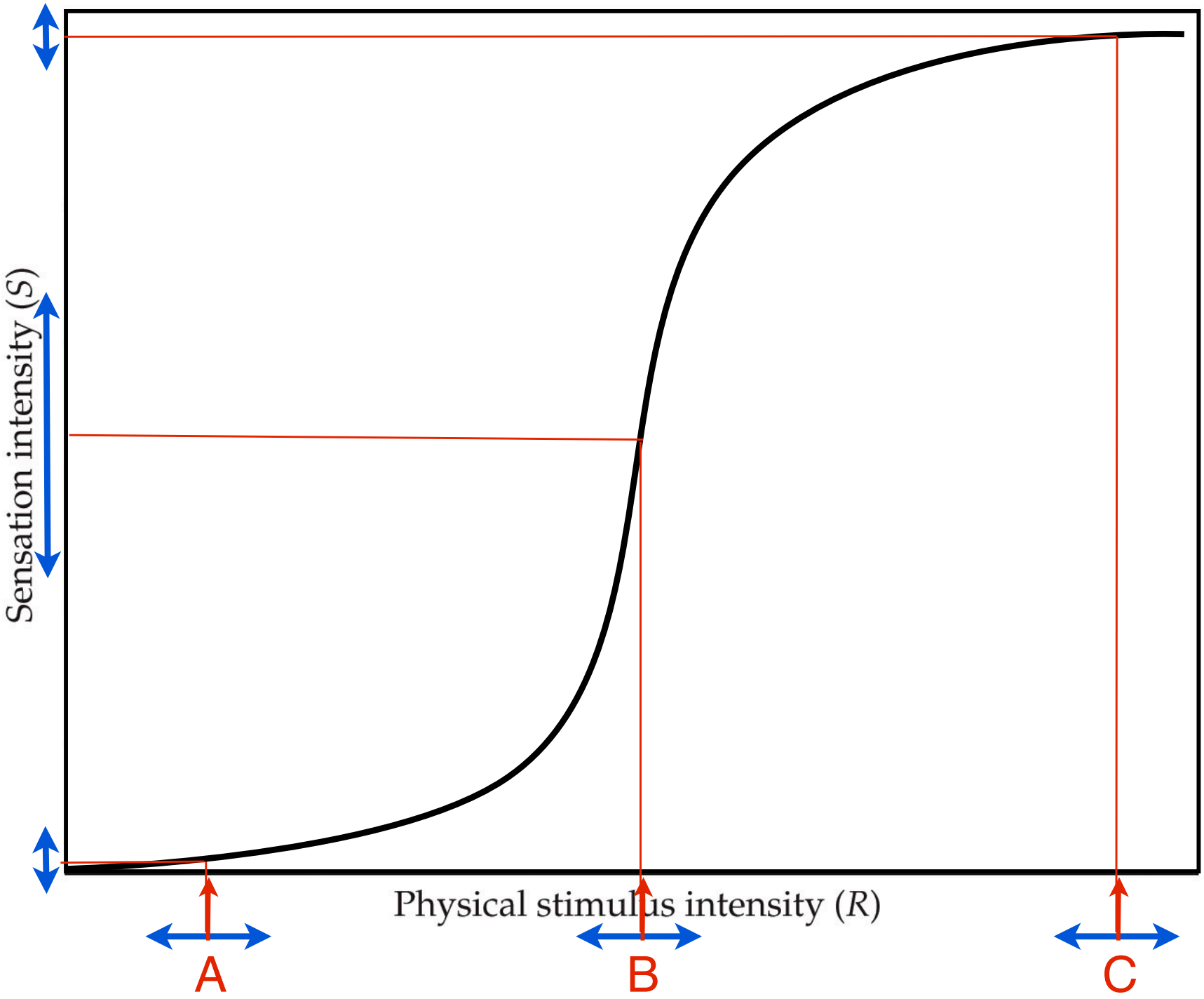
Stevens' Power Law

- subjective
- based on rating data
- no "right" answer: just a mapping between one unknown scale ('pain') and another unknown scale ('numbers')

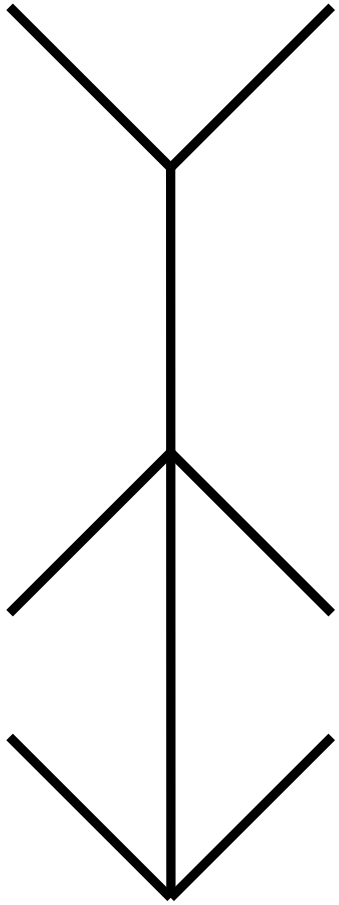
(my rating: "meh")

Test yourself: at which intensity are changes most detectable?

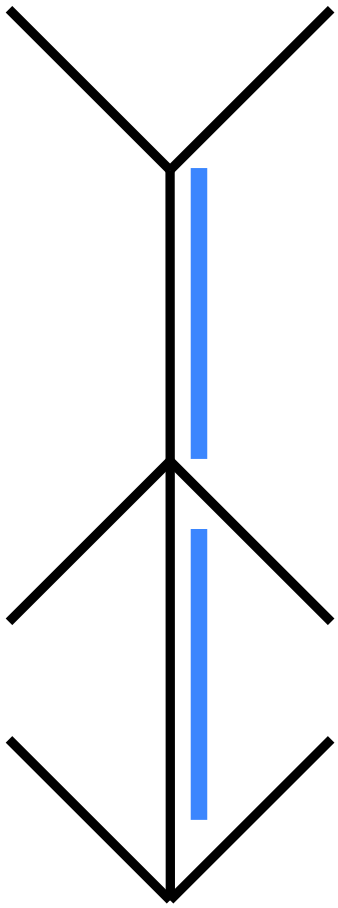



Sensation intensity (S)
Physical stimulus intensity (R)
A
B
C

How to measure perception?



müller-lyer illusion



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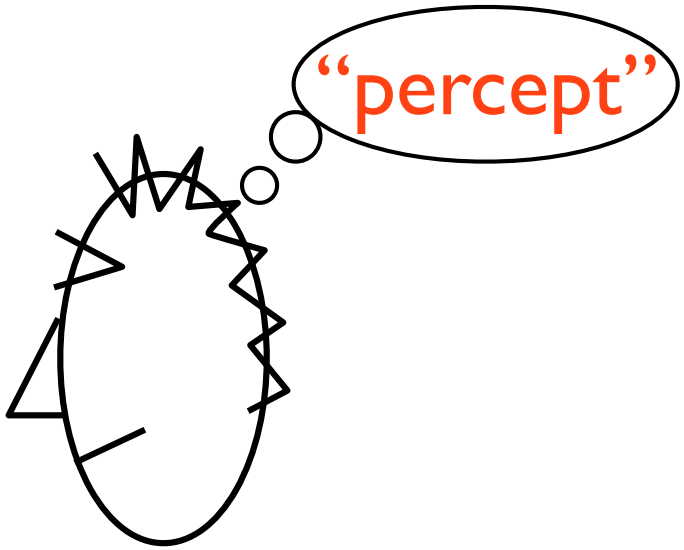


“percept” is internal

Psychophysics

- detection (yes/no)
- discrimination (e.g., bigger than)
- estimation (report the stimulus exactly)

All provide indirect measure of internal mental state!

Table 1.1

Absolute thresholds in the real world

Sense	Threshold
Vision	Stars at night, or a candle flame 30 miles away on a dark, clear night
Hearing	A ticking watch 20 feet away, with no other noises
Vestibular	A tilt of less than half a minute on a clock face
Taste	A teaspoon of sugar in 2 gallons of water
Smell	A drop of perfume in three rooms
Touch	The wing of a fly falling on your cheek from a height of 3 inches

Source: From Galanter, 1962.

SENSATION & PERCEPTION 5e, Table 1.1

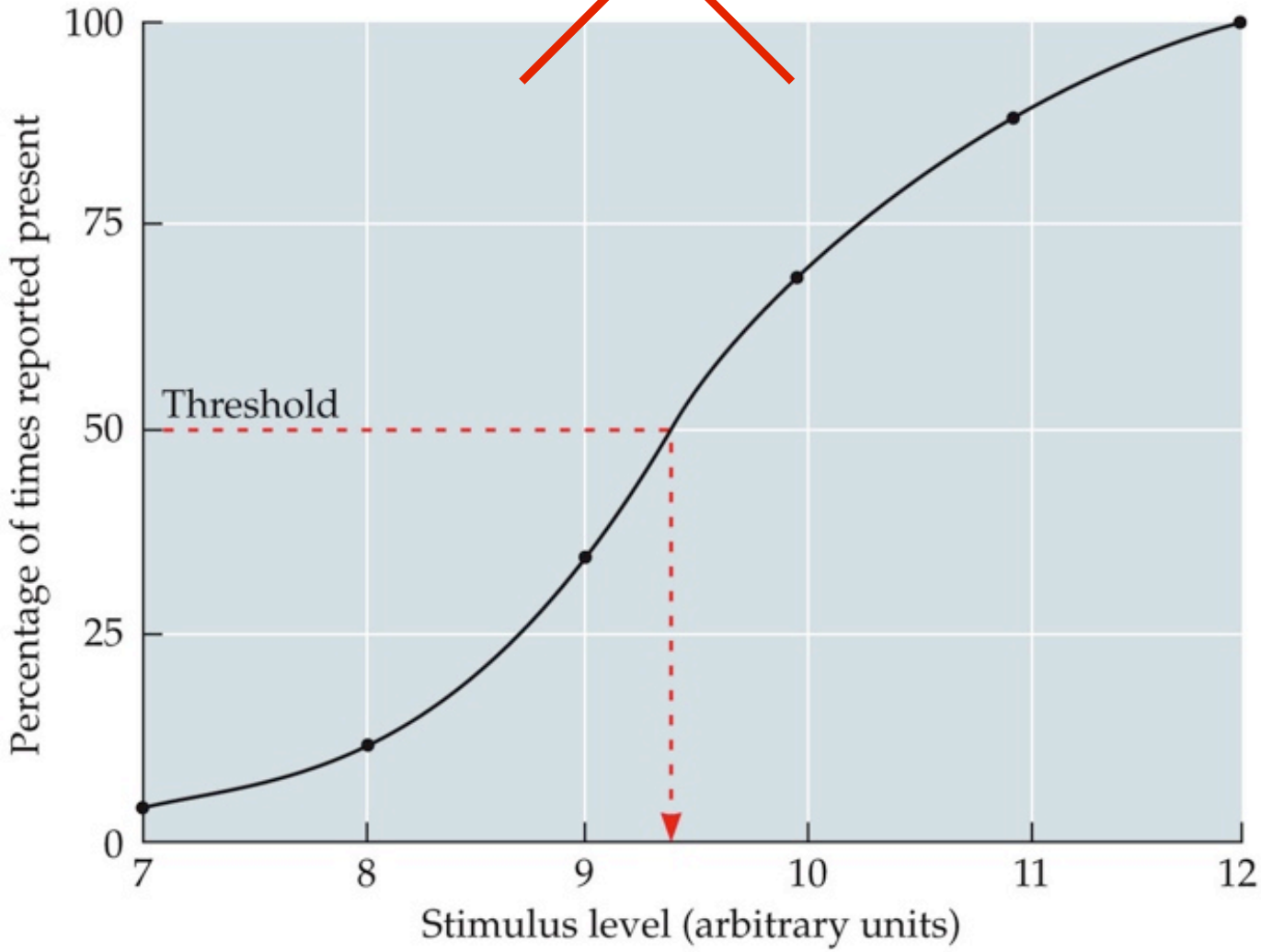
Detection

perfect threshold

Detection

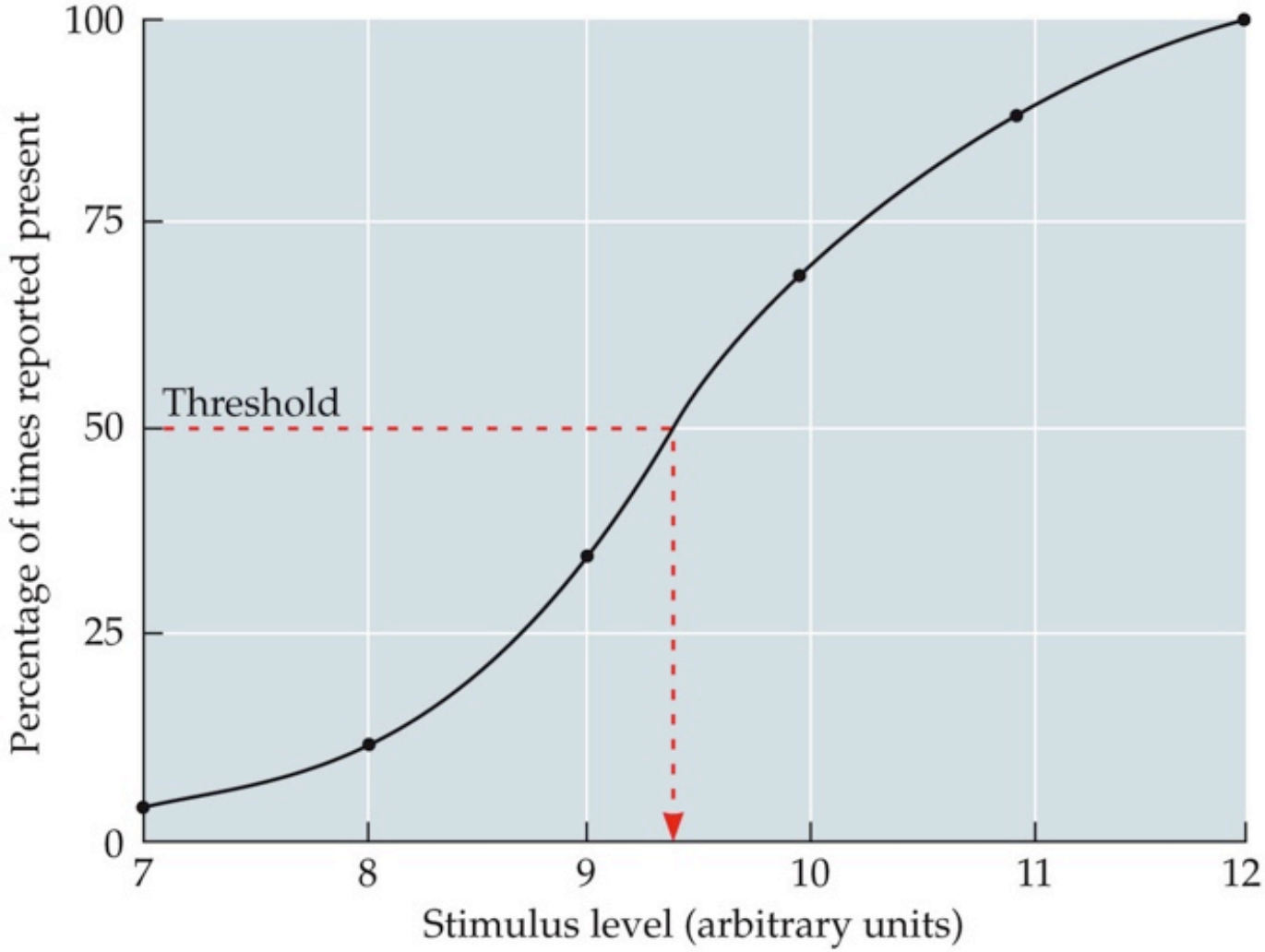
perfect threshold

noise



psychometric function

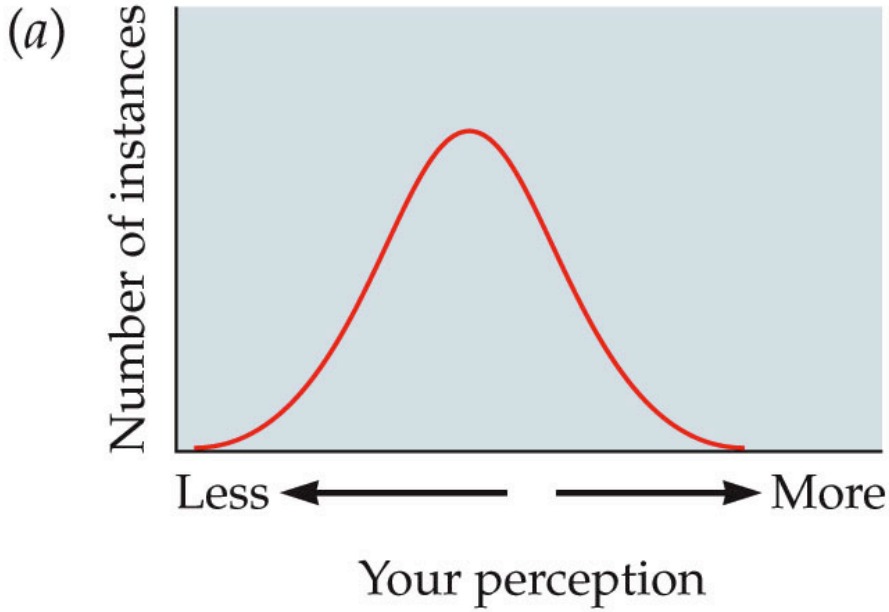
- relates physical quantity to the probability of detecting it

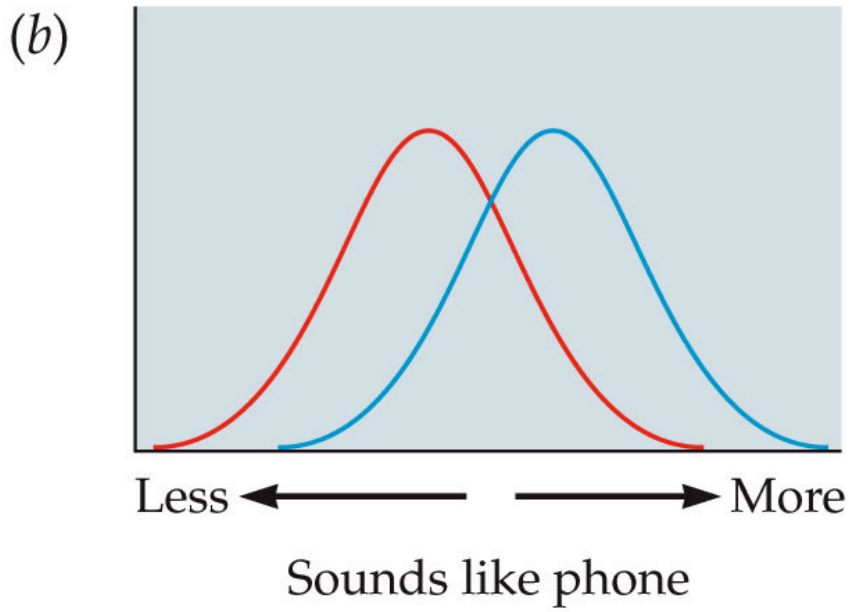


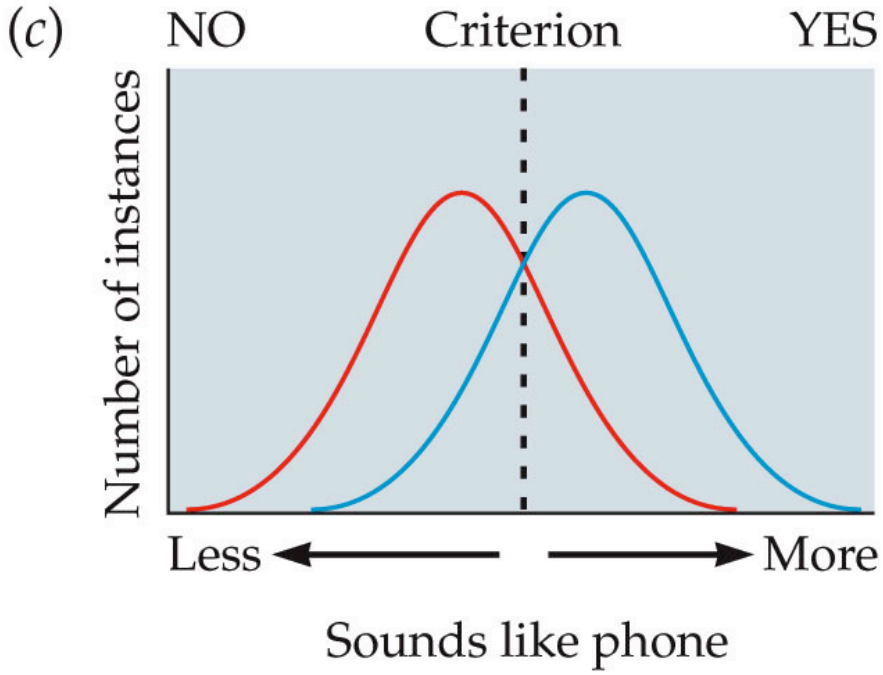
Signal detection theory: A psychophysical theory that quantifies the response of an observer to the presentation of a signal in the presence of noise

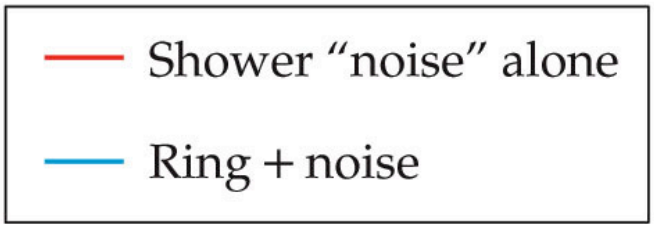
(On board)

Detecting a stimulus using the signal detection theory (SDT)

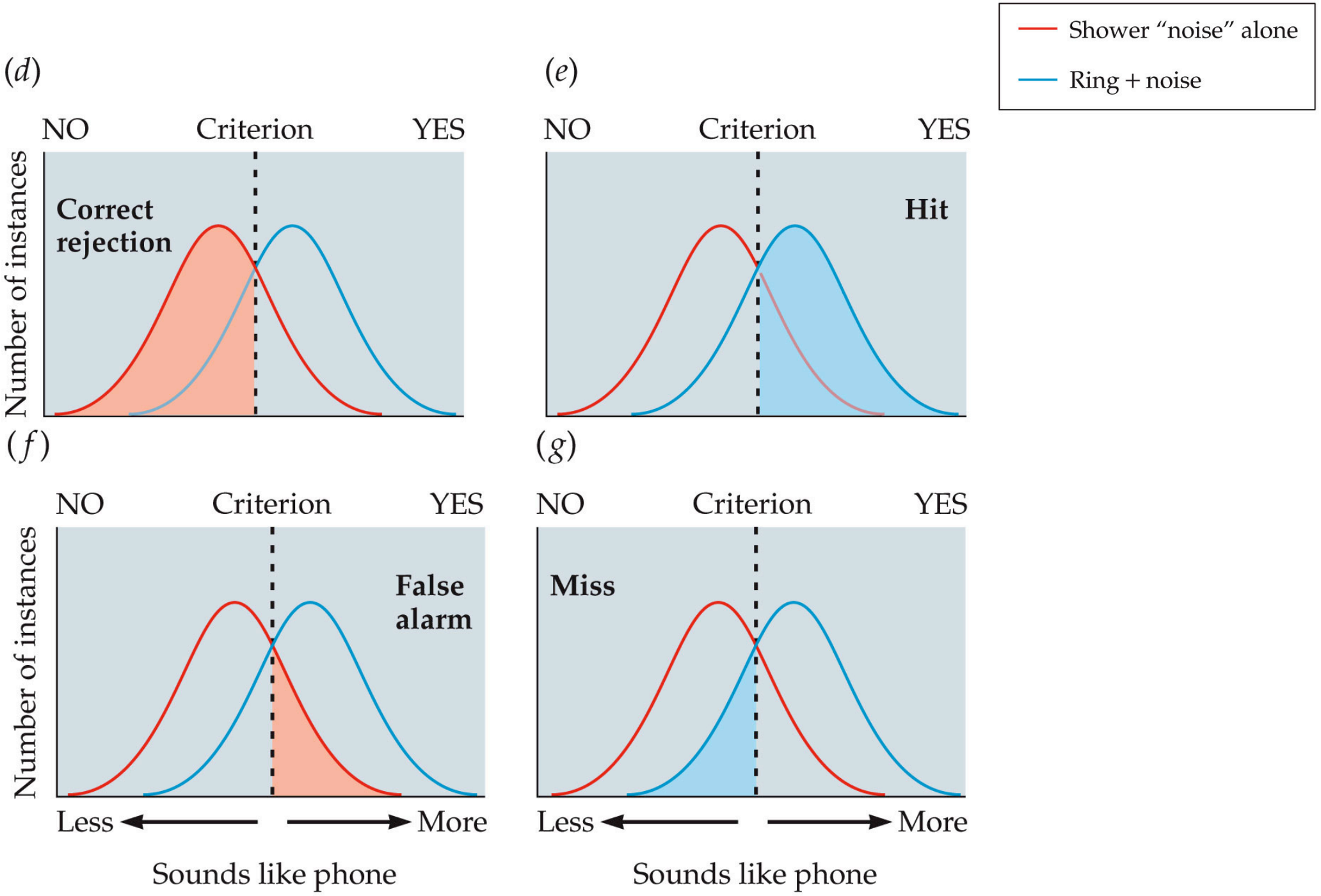




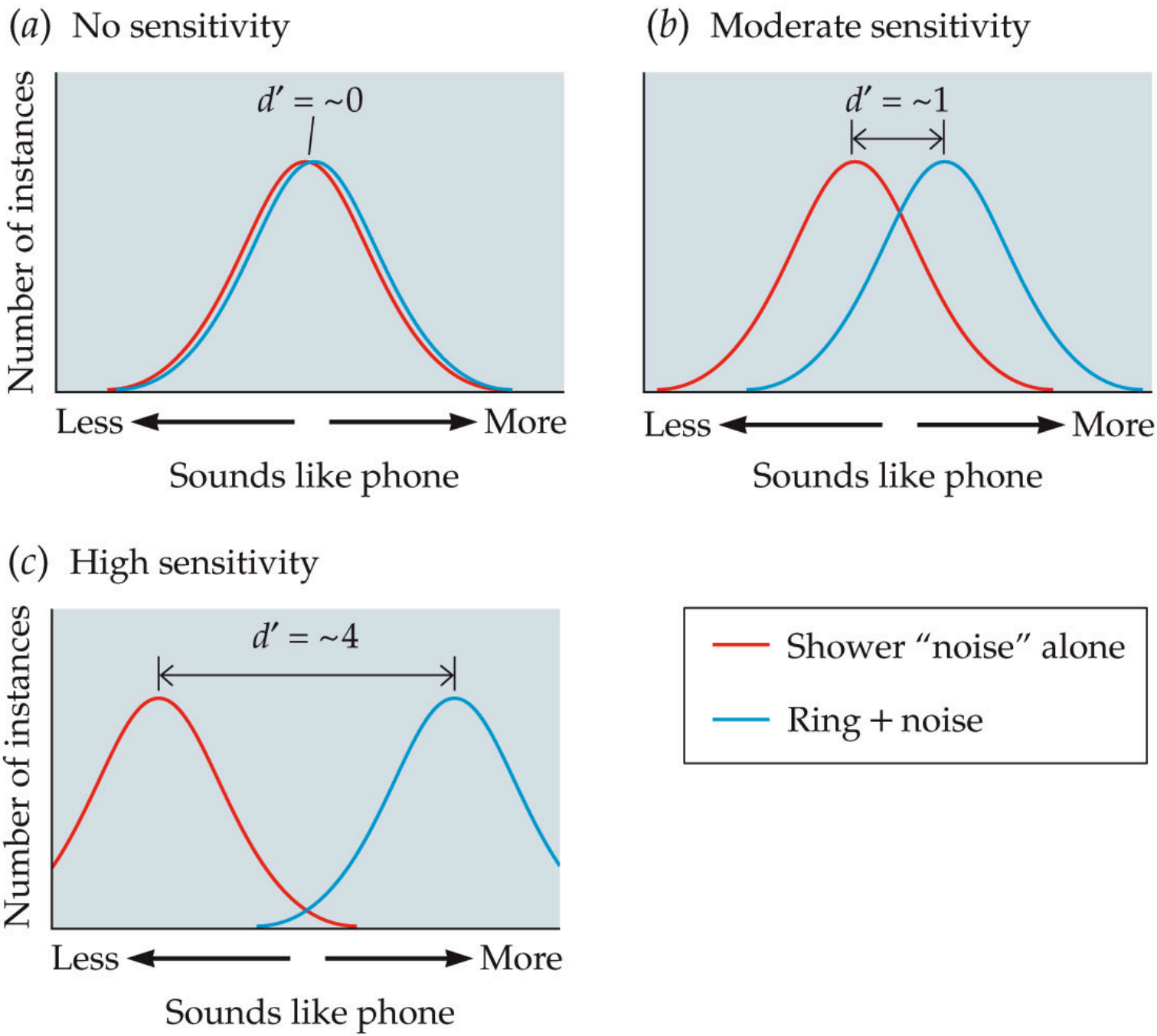




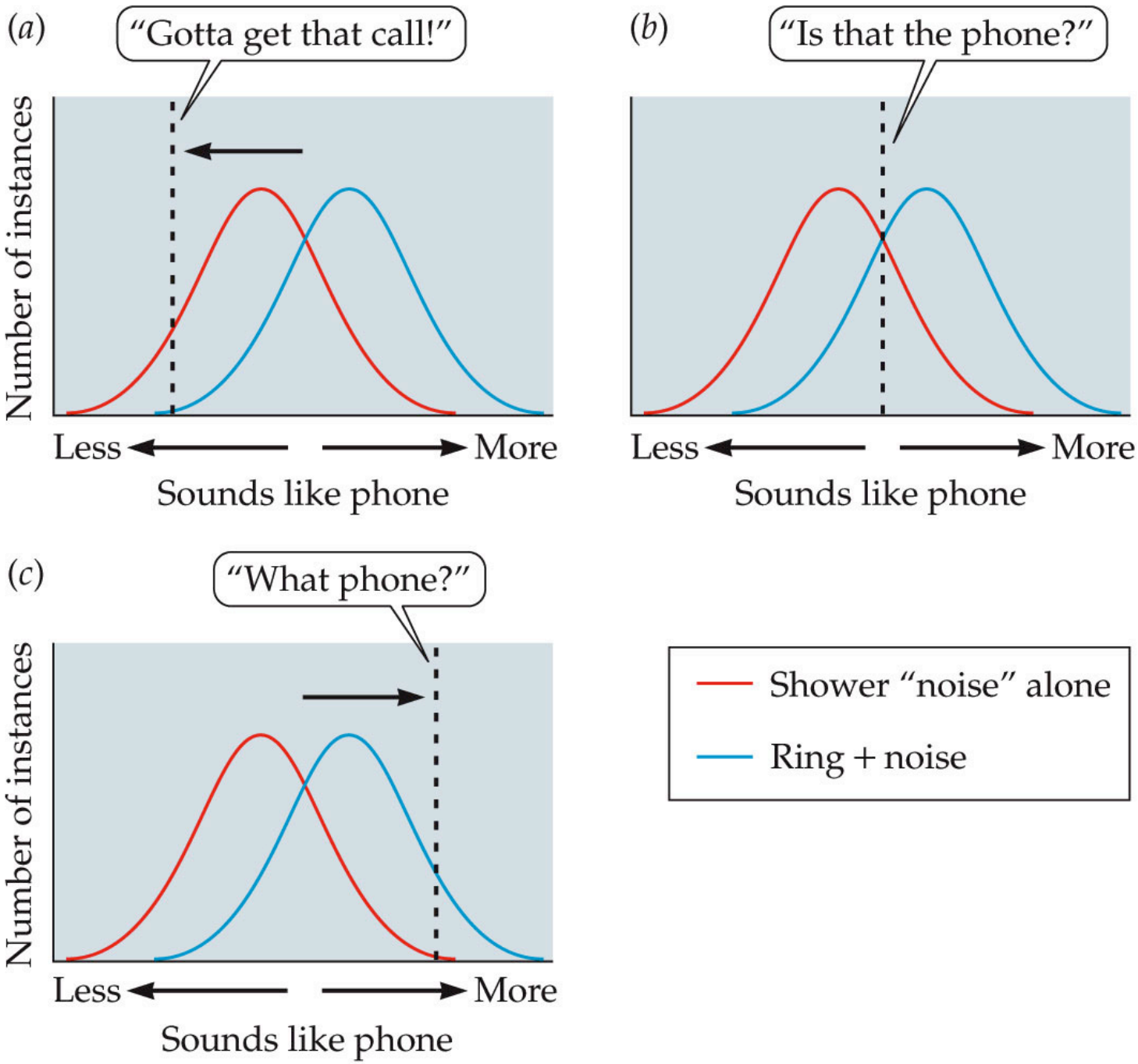
Detecting a stimulus using the signal detection theory (SDT)



Sensitivity to a stimulus: The separation between the distributions of response to noise alone and to signal plus noise



For a fixed d', shifting the response criterion



note about book figures:

- The x axis in signal detection plots shouldn't be "your percept". It should have physical units like "sound intensity"

Signal detection theory

- **Hit**: Stimulus is presented and observer responds "Yes"
- **Miss**: Stimulus is presented and observer responds "No"
- **False alarm**: Stimulus is not presented and observer responds "Yes"
- **Correct rejection**: Stimulus is not presented and observer responds "No"

Signal Detection Theory Terms to know:

“noise” distribution: values arising when stimulus not present

“signal” distribution: values arising when signal + noise present

Type I error: rate of “false alarms”, or false positives

Type II error: rate of “misses”, or false negatives

psychometric function: describes probability of saying “I heard it” as function of stimulus intensity

Chapter 1 Summary

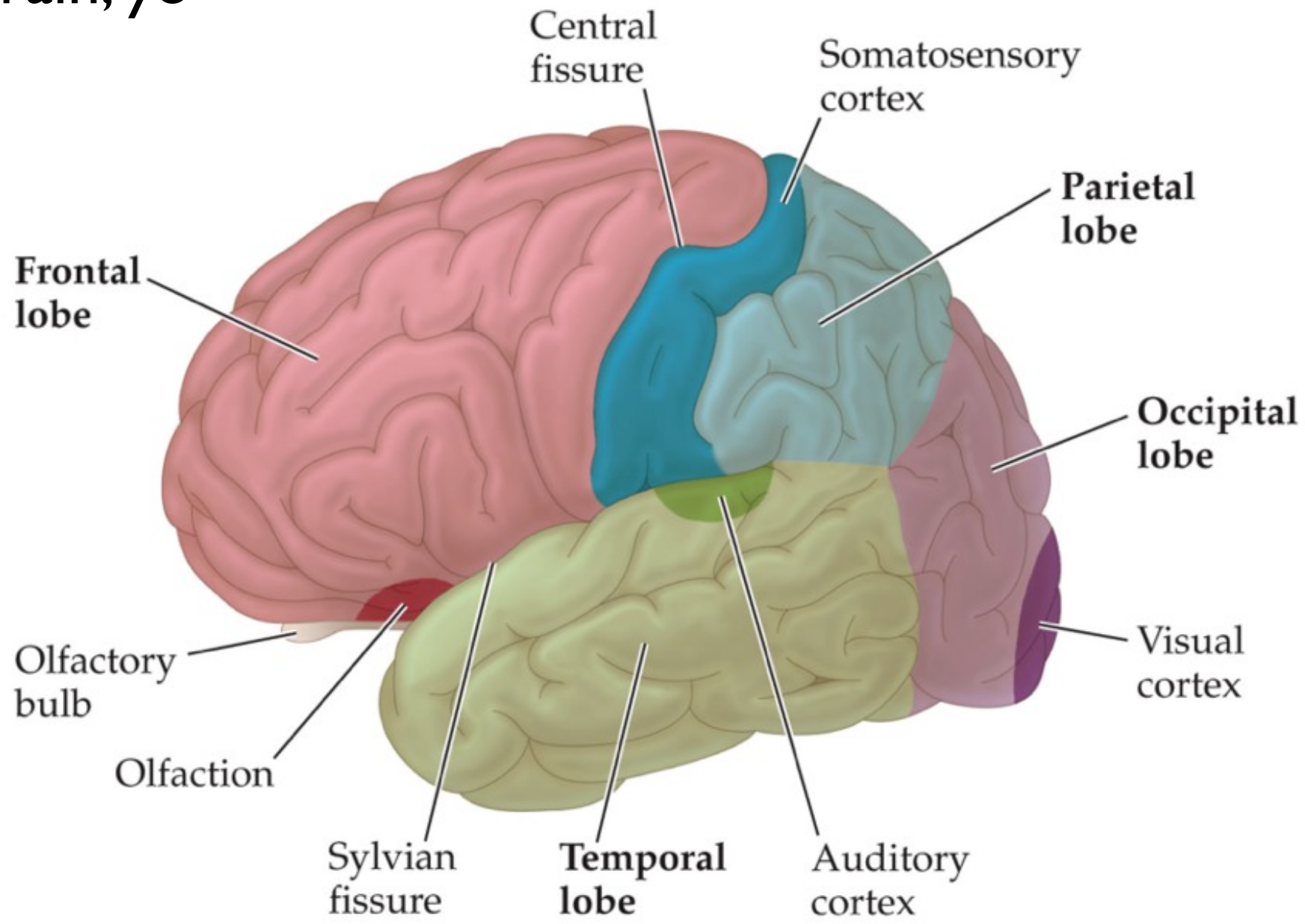
- Weber-Fechner law
- Stevens' power law
- psychophysics
- psychometric function
- signal detection theory: threshold, criterion, Hit/Miss, FA/CR, d' (i.e., "d-prime")
- spikes, synapses, neurotransmitter

You can safely ignore (for now)

- method of constant stimuli / method of adjustment
- ROC curves
- Fourier analysis (though we will come back to it!)
- Cranial nerves (Fig 1.20)
- brain anatomy (Fig 1.21, but we will come back as needed)

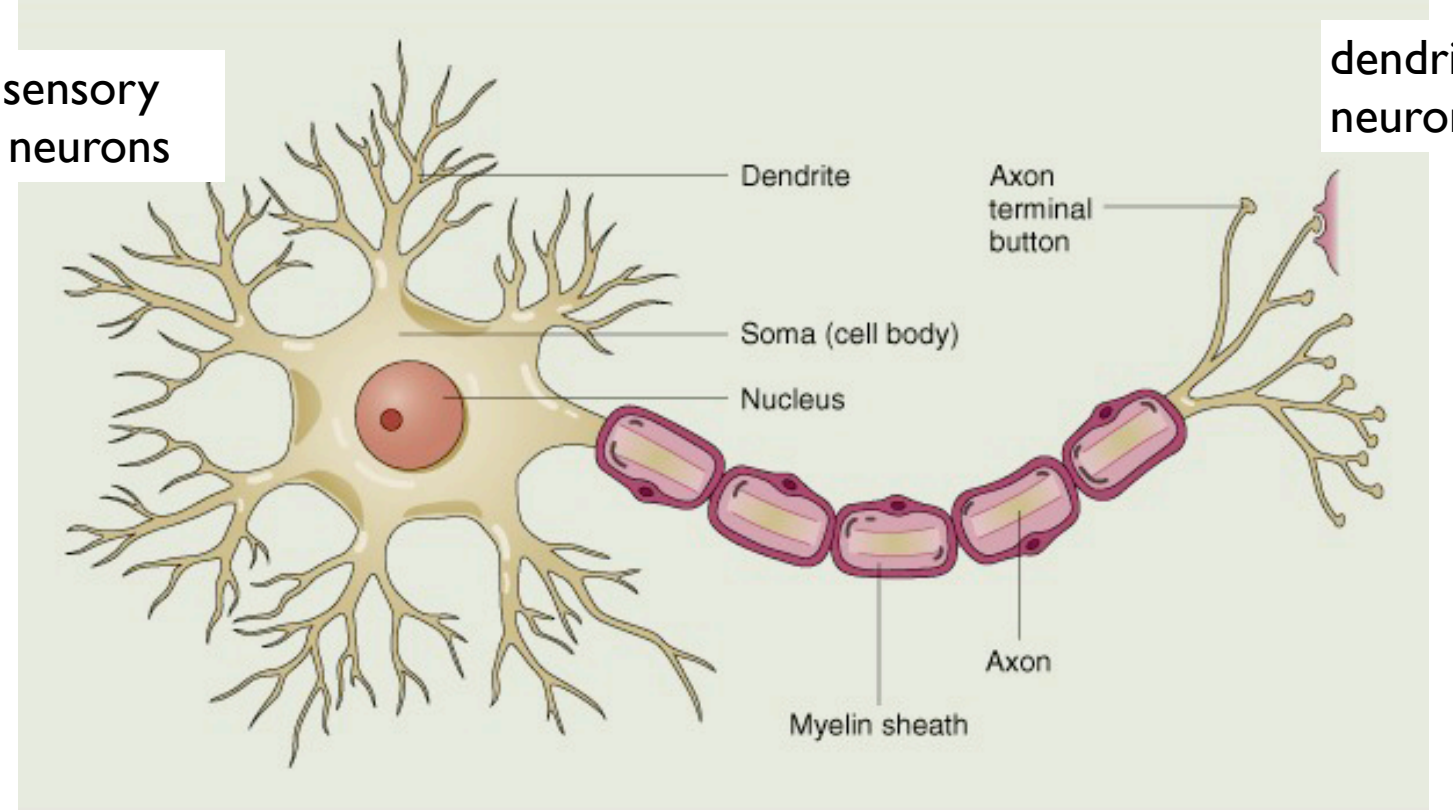
Brief Neuroscience Intro:

the brain, yo


Central fissure
Somatosensory cortex
Parietal lobe
Frontal lobe
Occipital lobe
Olfactory bulb
Visual cortex
Olfaction
Sylvian fissure
Temporal lobe
Auditory cortex

neuron

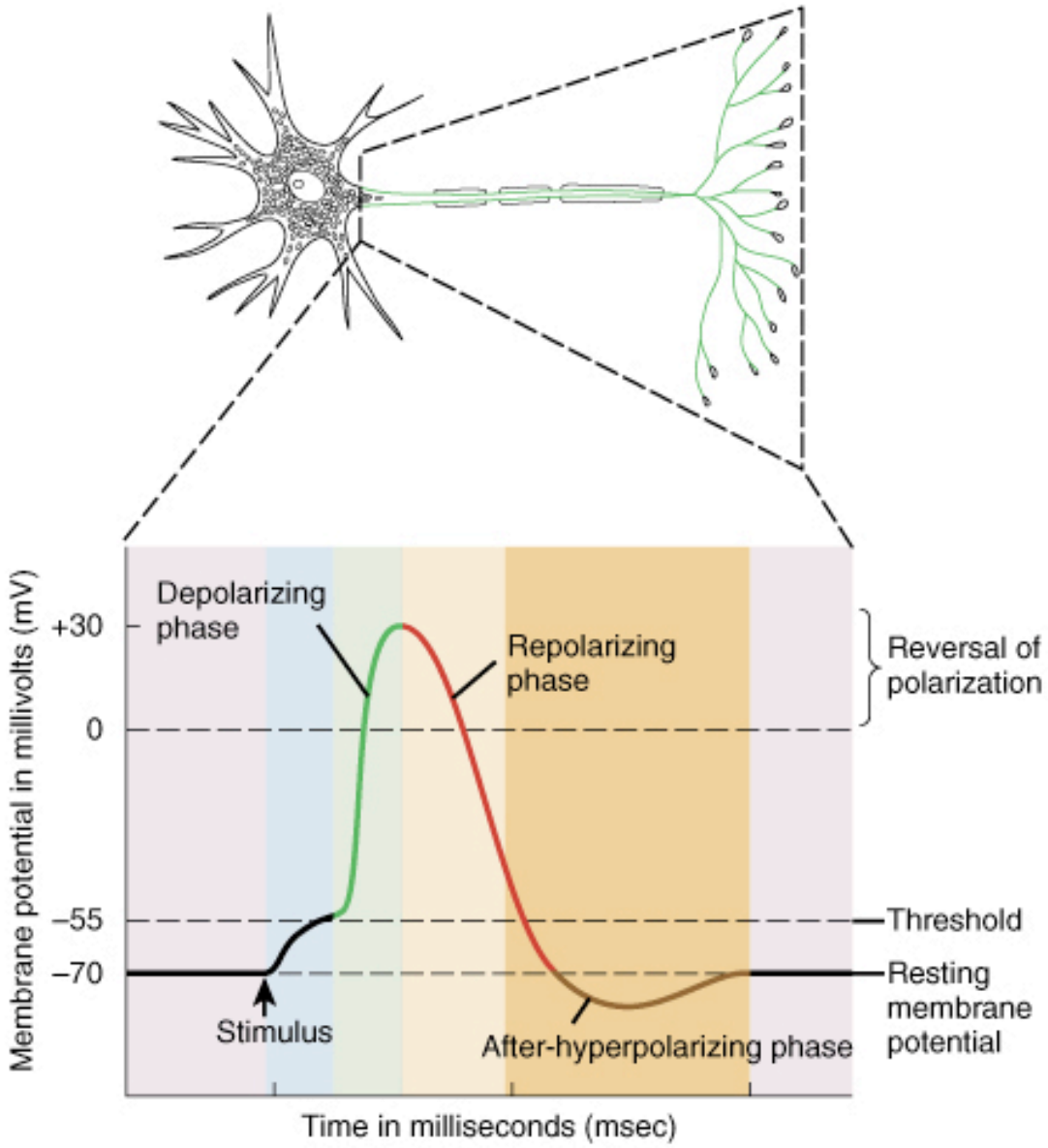
axons of sensory receptor neurons



dendrites of target neurons

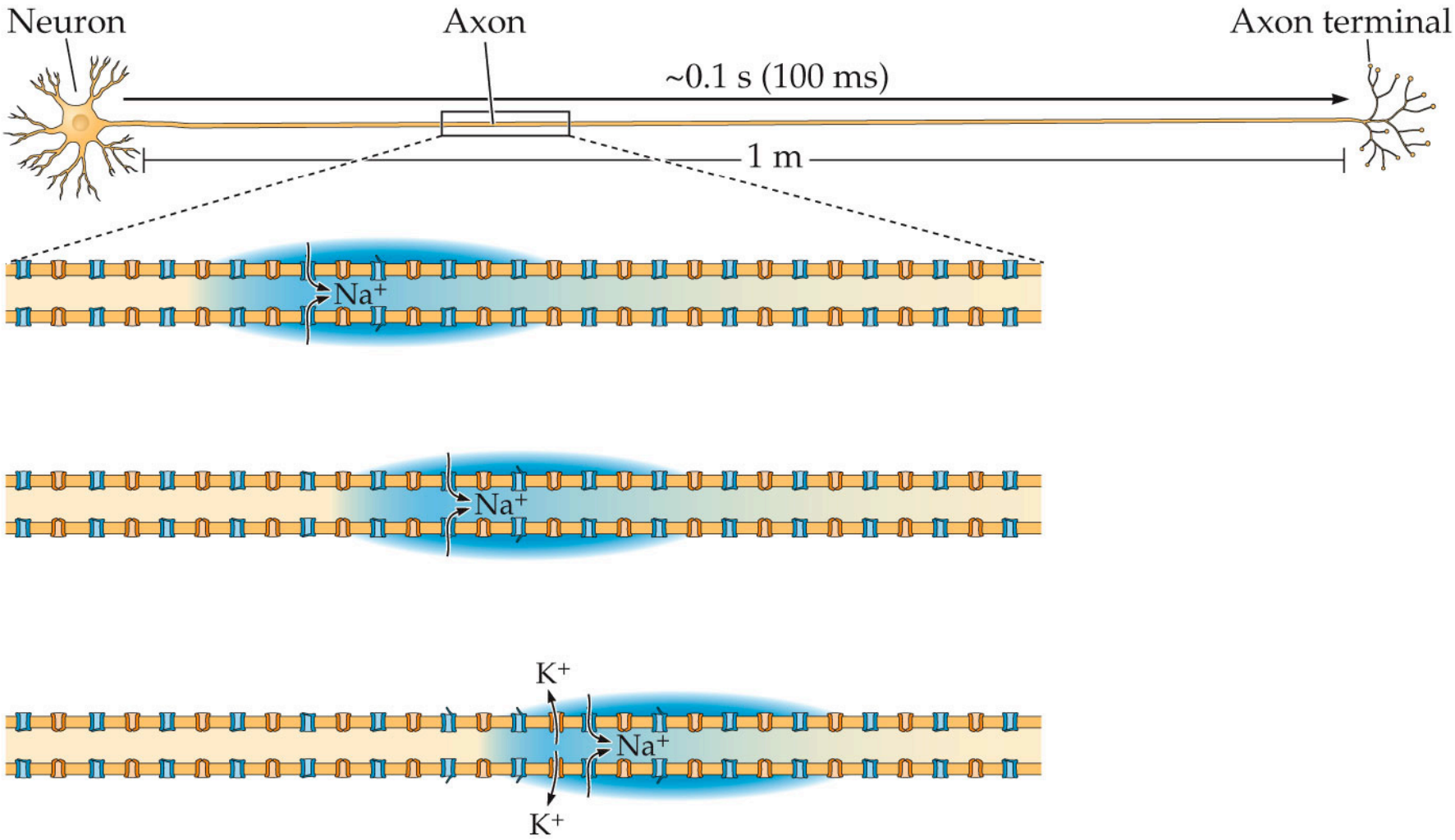
- membrane is *polarized*: voltage difference between inside and outside (neuron is like a battery)

Spikes - currency of the nervous system

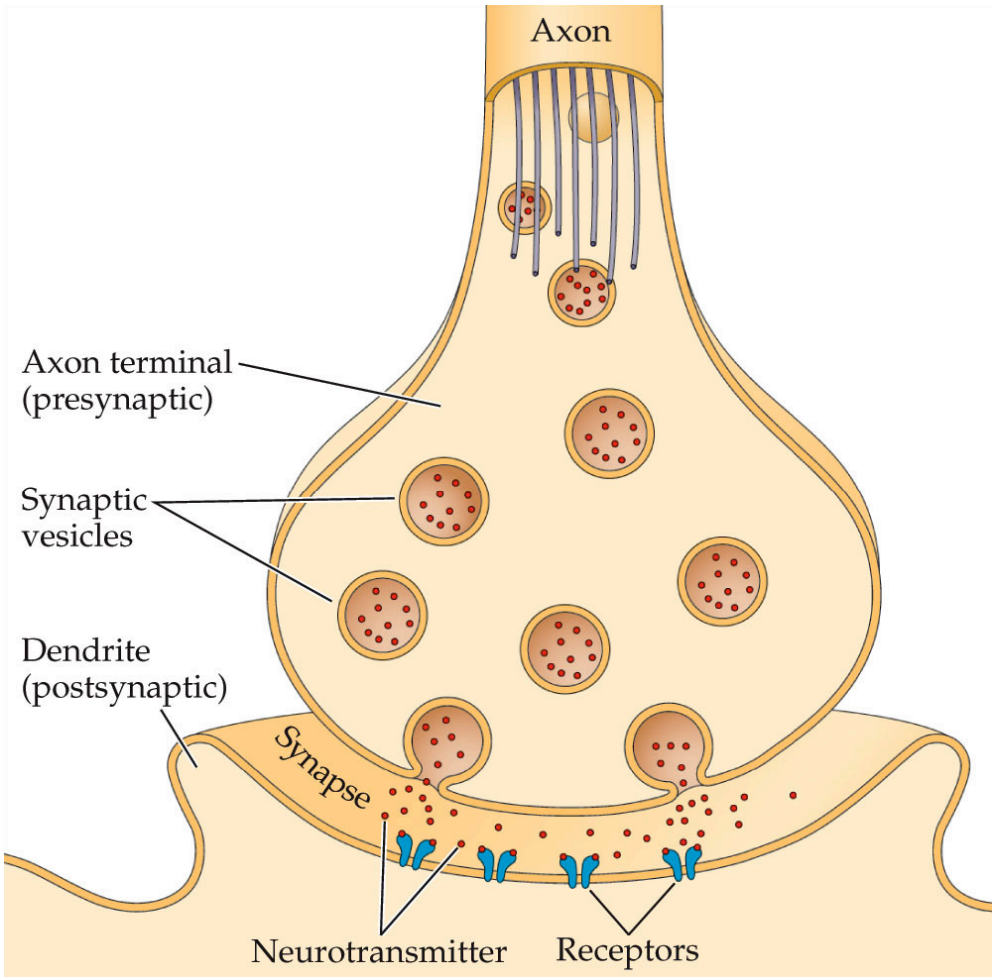


- channels open
- current flows in
- membrane becomes *depolarized*

spike propagation



synapse



- action potential triggers release of vesicles
- transmitter molecules bind to receptor
- post-synaptic electrical signal

measuring neural activity

- Invasive methods
  - electrophysiology (electrodes)
  - imaging (voltage sensitive dyes)

- non-invasive methods
  - fMRI (functional magnetic resonance imaging)
  - EEG (electroencephalography)
  - MEG (magnetoencephalography)

Next: Read Chapter 2