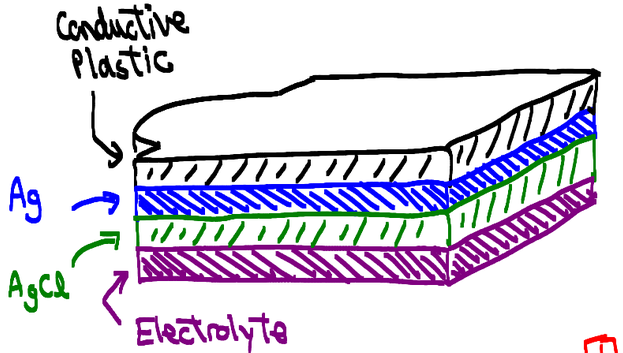
Lecture 9: EEG + Photoplethysmography

1. EEG
2. Photoplethysmography

- Exam #1 this Thu (Feb 6)
  - * Lecture 1-8 material
  - See course website for
    - → HW, PreLab, Quiz solns
    - → Last year's exam + solns
- Lab3 report due next Fri (Feb 14)
- PreLab 4 due at next week's lab session

0. Review

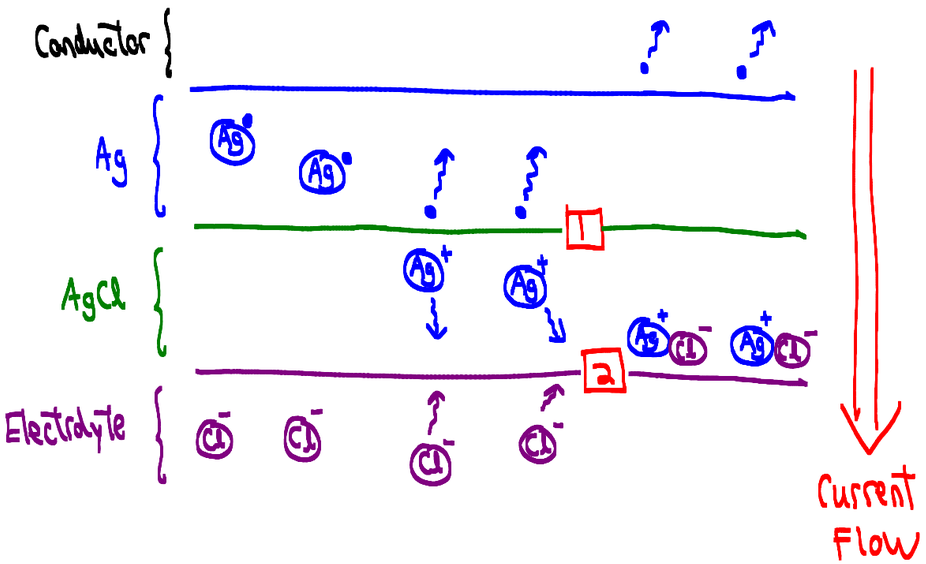
① Ag/AgCl Electrodes



★ Chemical reactions

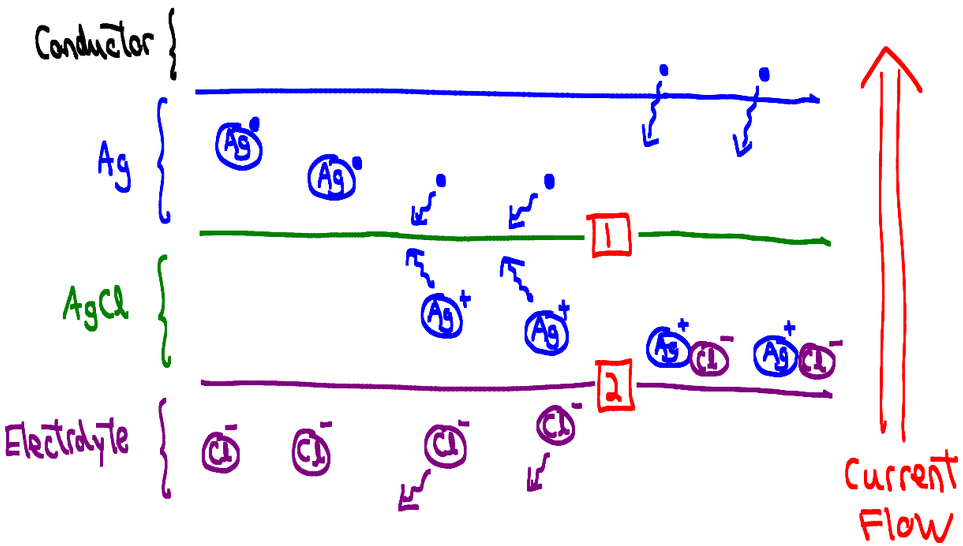
[1] Oxidation

[2] Association

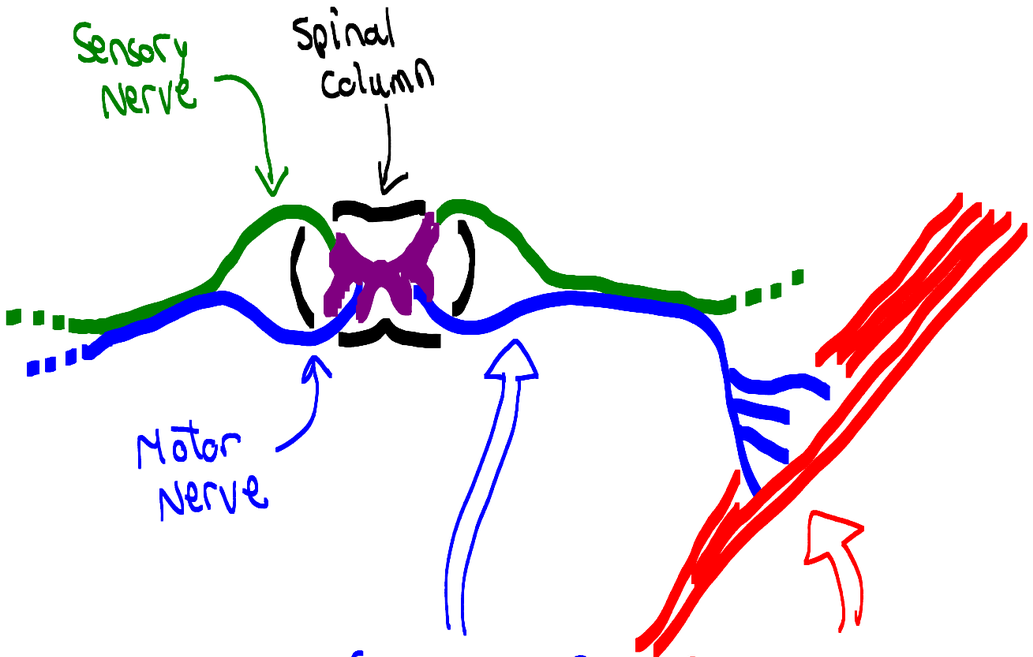


[1] Reduction

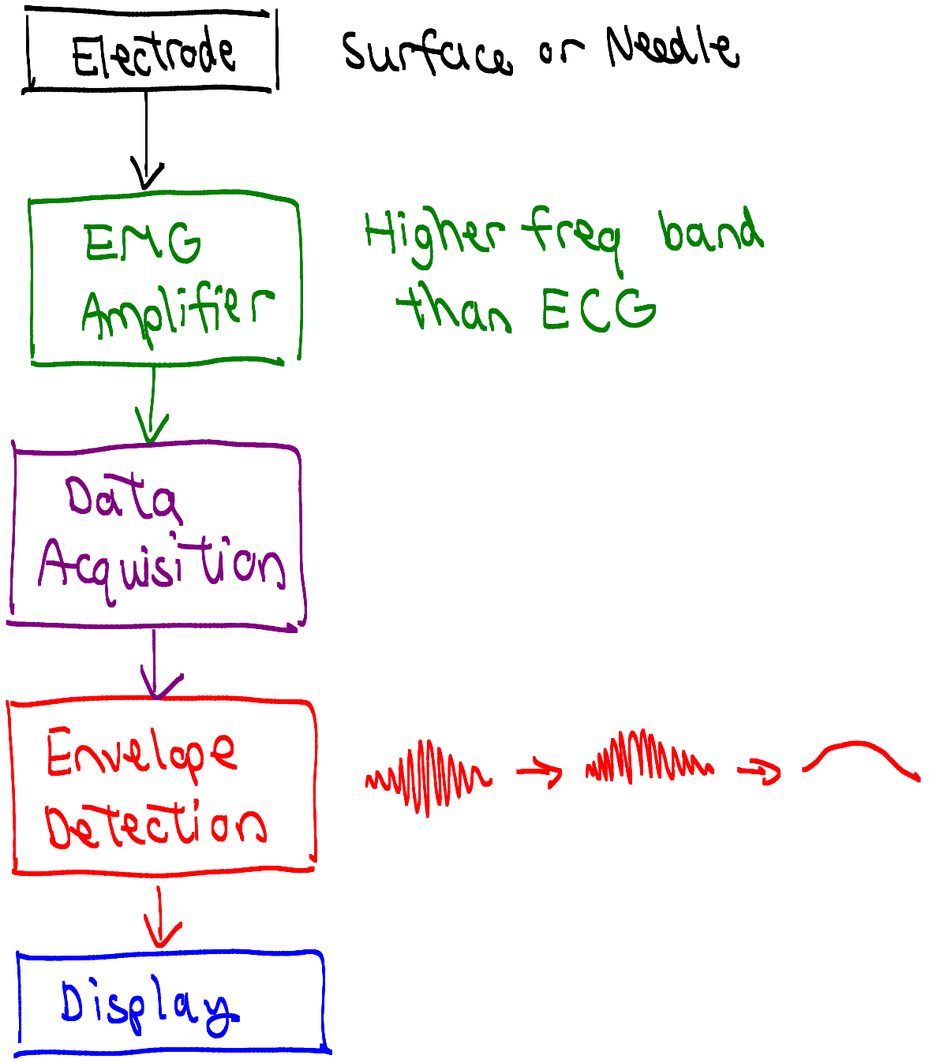
[2] Dissociation



② EMG (Electromyography)



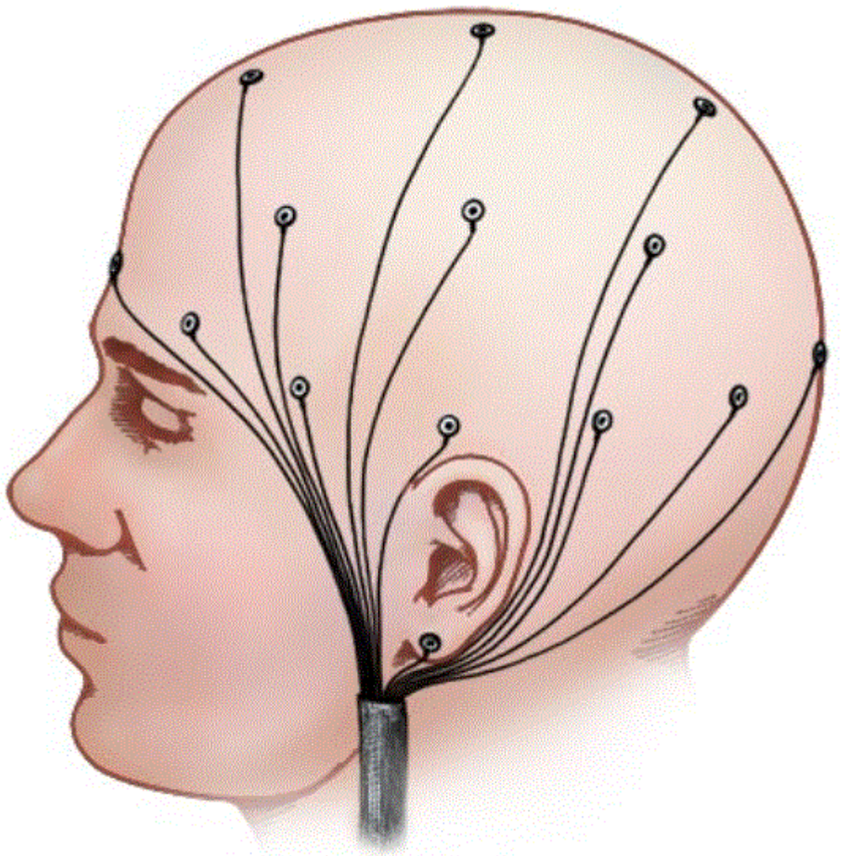
SMU = [Single motor neuron] + [bundle of muscle fibers]



1. EEG Electroencephalography

A. Significance

- Measure electrical activity of the brain
- Cannot measure a single neuron
  - ⇒ too weak
  - → electrode size
  - use many scalp electrodes
    - Used for:
      - → Patient monitoring [stroke, Coma, epilepsy]
      - → Neuroscience [Brain activity, sleep disorders]



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B. Basic Brain Anatomy

① Cerebrum

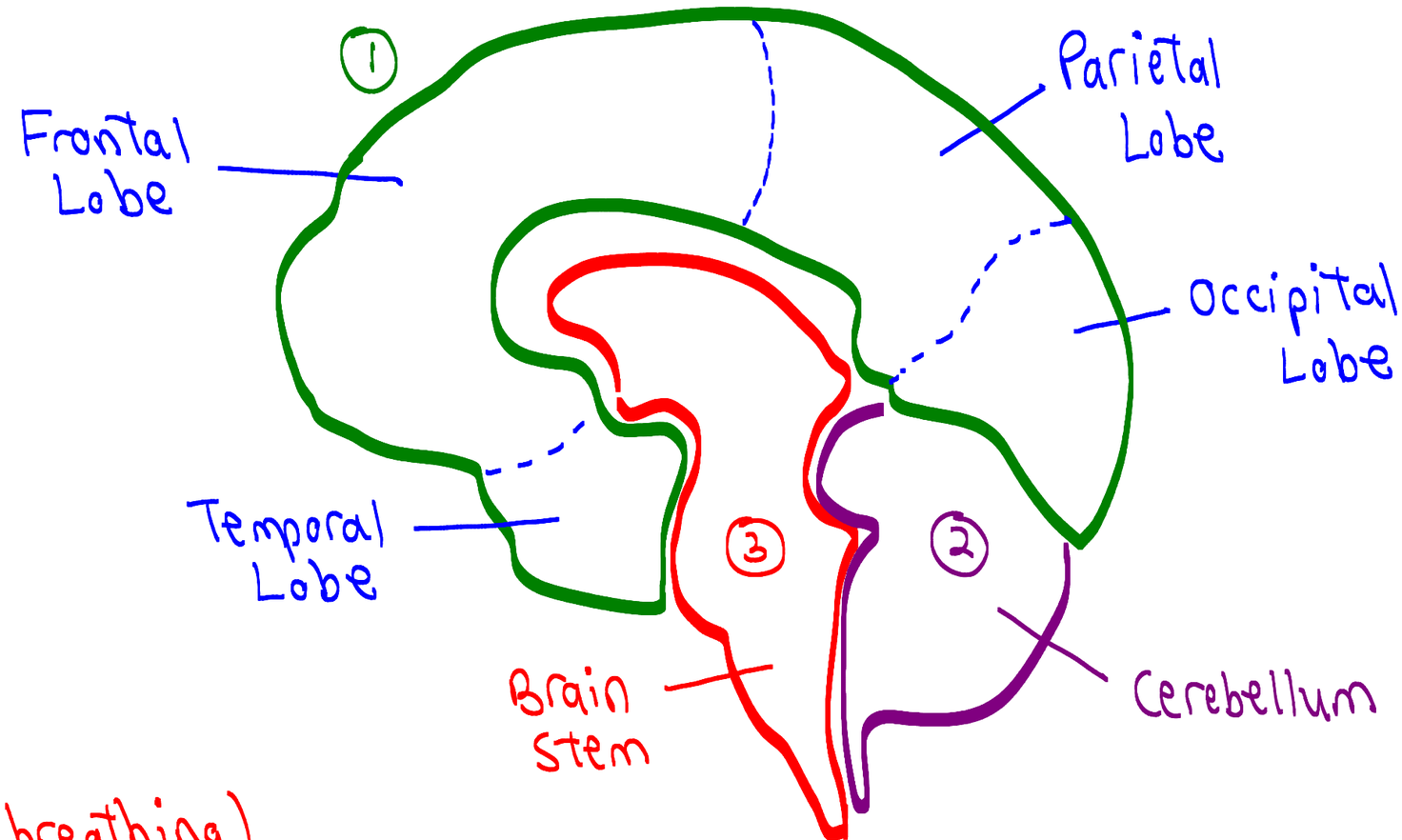
- Conscious functions
- Surface is the cortex

② Cerebellum

- Balance
- Voluntary muscular control

③ Brain Stem

- Autonomous functions (eg. breathing)
- Reflexes



C. Electrode Placement

★ 10-20 Standard

↑ ↑

% of distance (front-back, left-right) across scalp

F : Frontal Lobe

T : Temporal Lobe

P : Parietal Lobe

O : Occipital Lobe

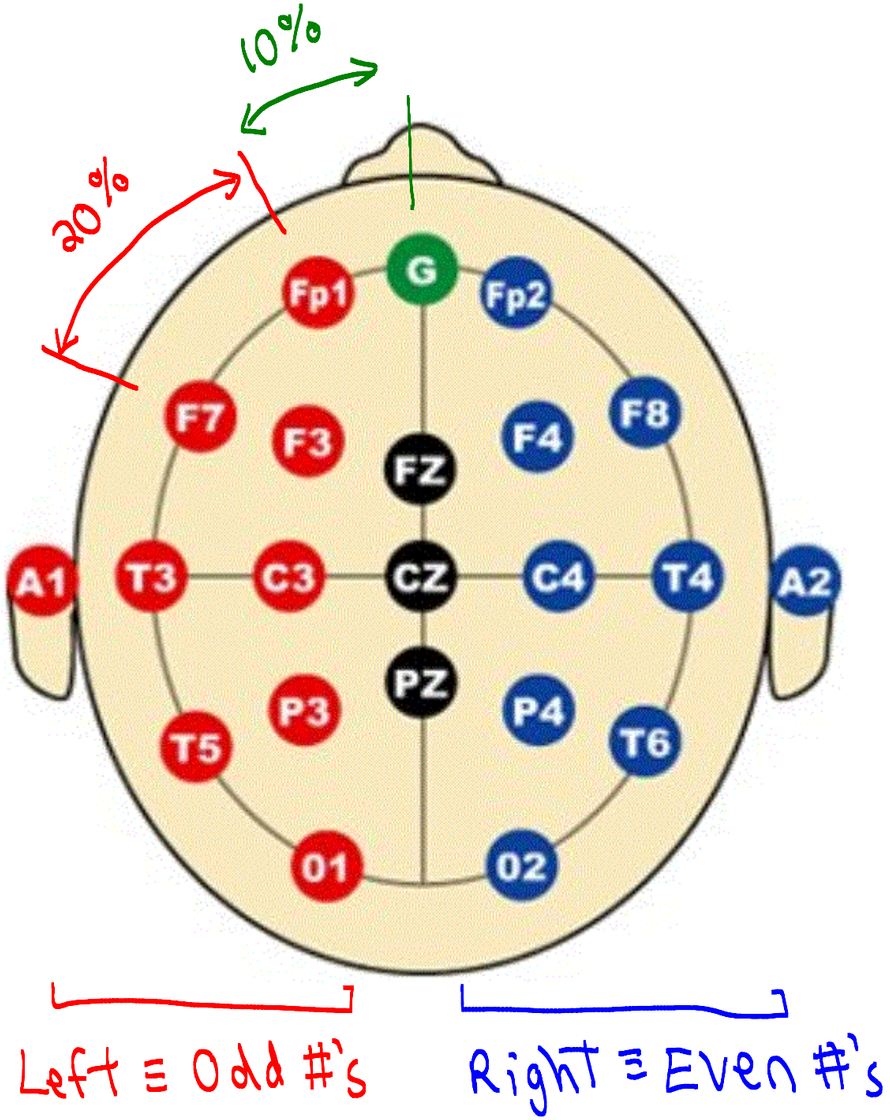
C : "Central"

Z : Mid-line

A : Ear

Pg : Nasopharyngeal

Fp : Frontal polar



Normal EEG Waves

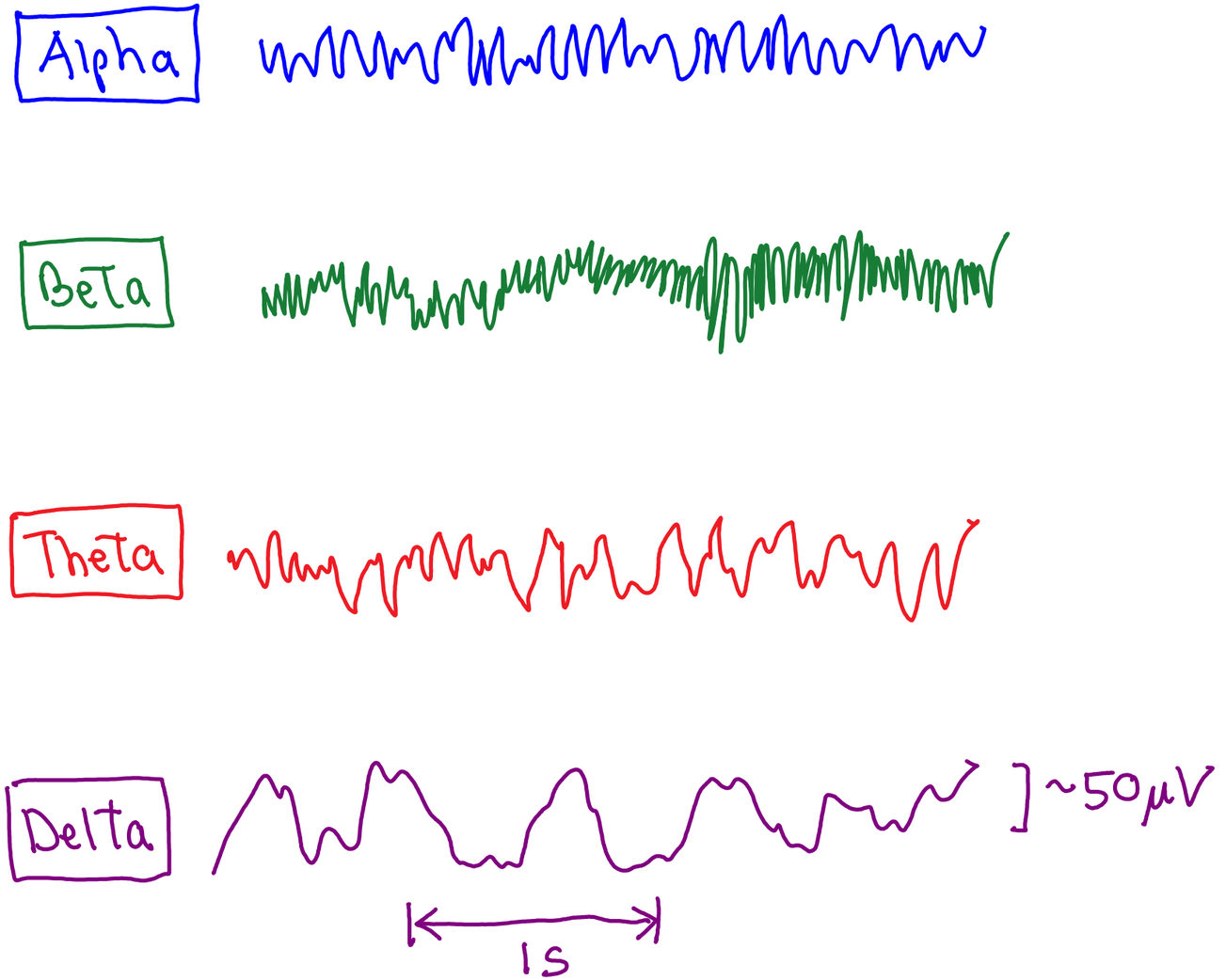
Disappear during sleep!

Alpha 8-13 Hz
Awake, resting state
20-200 μV

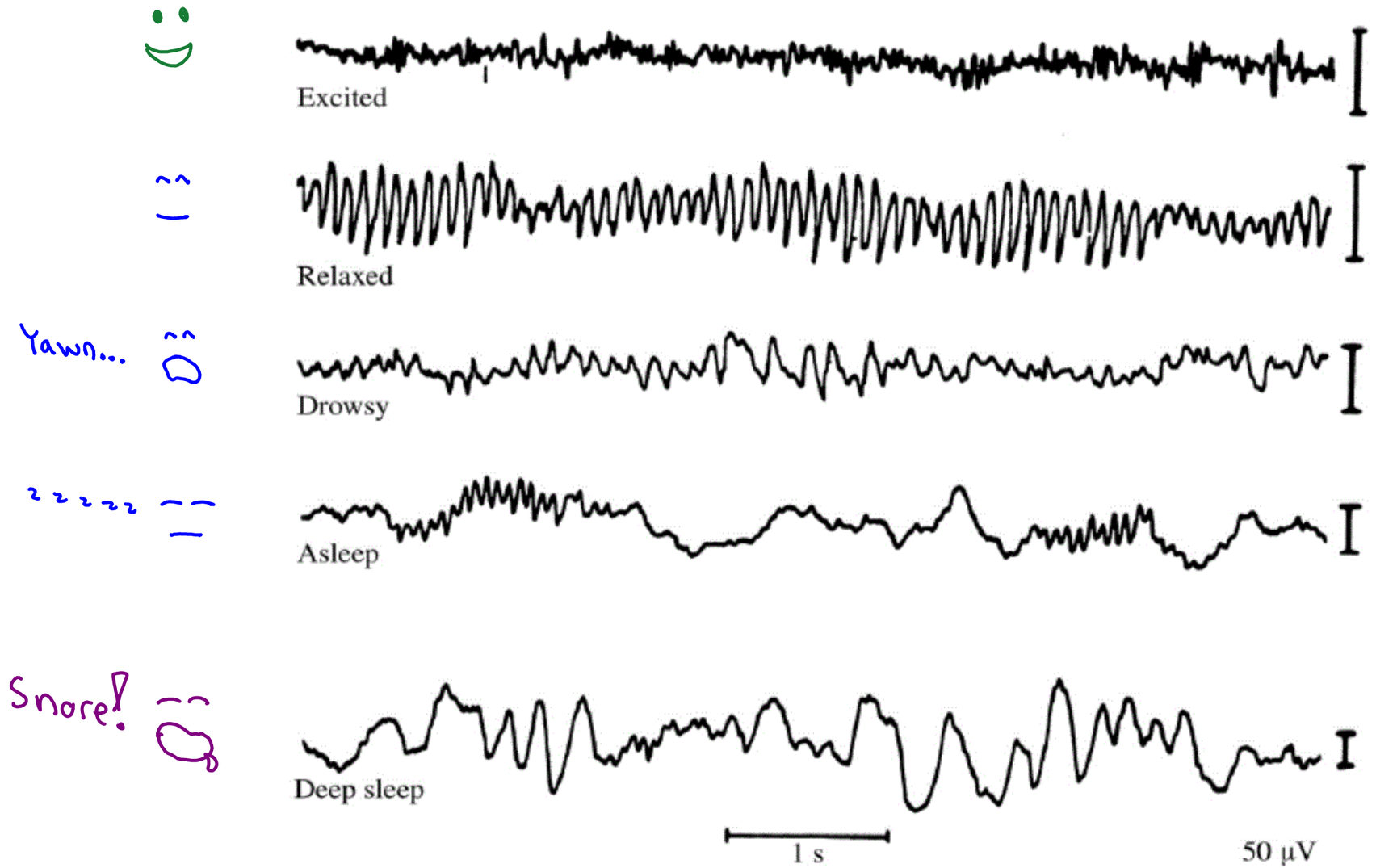
Beta 14-30 Hz
Beta I: similar to alpha
Beta II: Agitation

Theta 4-7 Hz
Frustration

Delta Below 3.5 Hz
Deep sleep...



- EEG waveforms of a subject falling asleep...



(webster Fig 4.29)

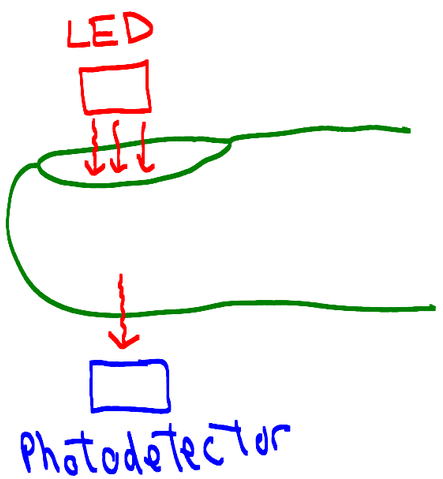
2. Photoplethysmography

A. Intro

- Plethysmography = Measurement of changes in volume

- Photoplethysmography

  → use light to measure heart rate



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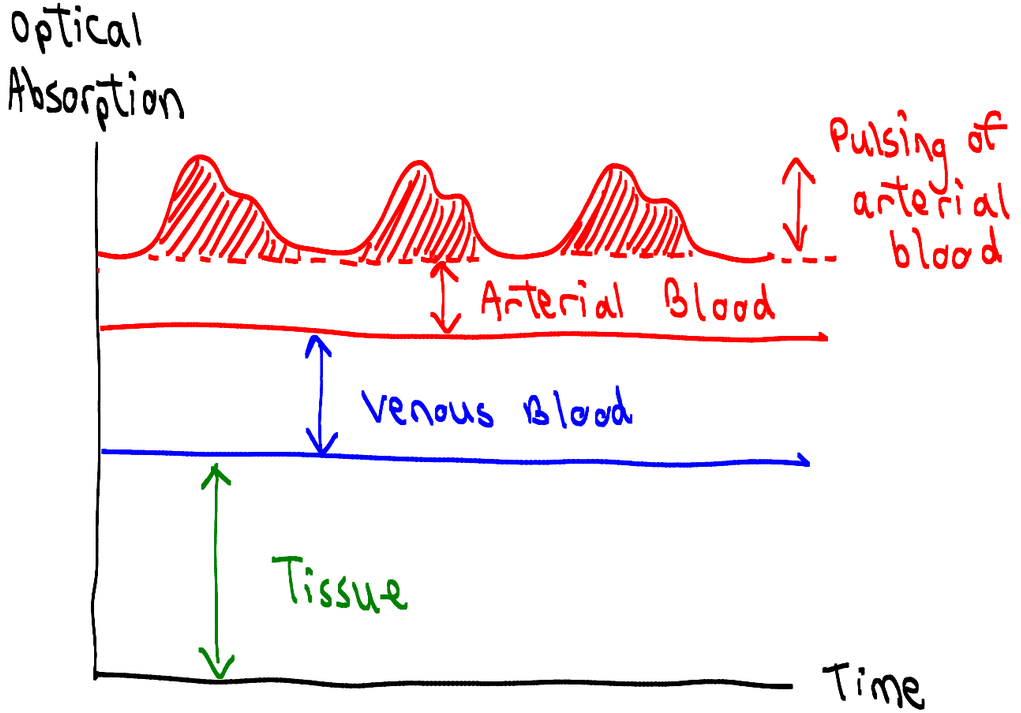
- **Basic idea of photoplethysmography**

→ Arterial pulsations fill the capillary bed in finger tip

⇒ Change in blood volume affects transmitted light (mostly due to absorption)

⇨ Measure the transmitted light [usually use infrared (e.g. 940 nm)]



NOTE: Photoplethysmography is OK to monitor heart rate, but CANNOT accurately measure blood volume change.

Why? ⇒ Difficult to derive an accurate and reliable relationship between the optical signal and blood volume.

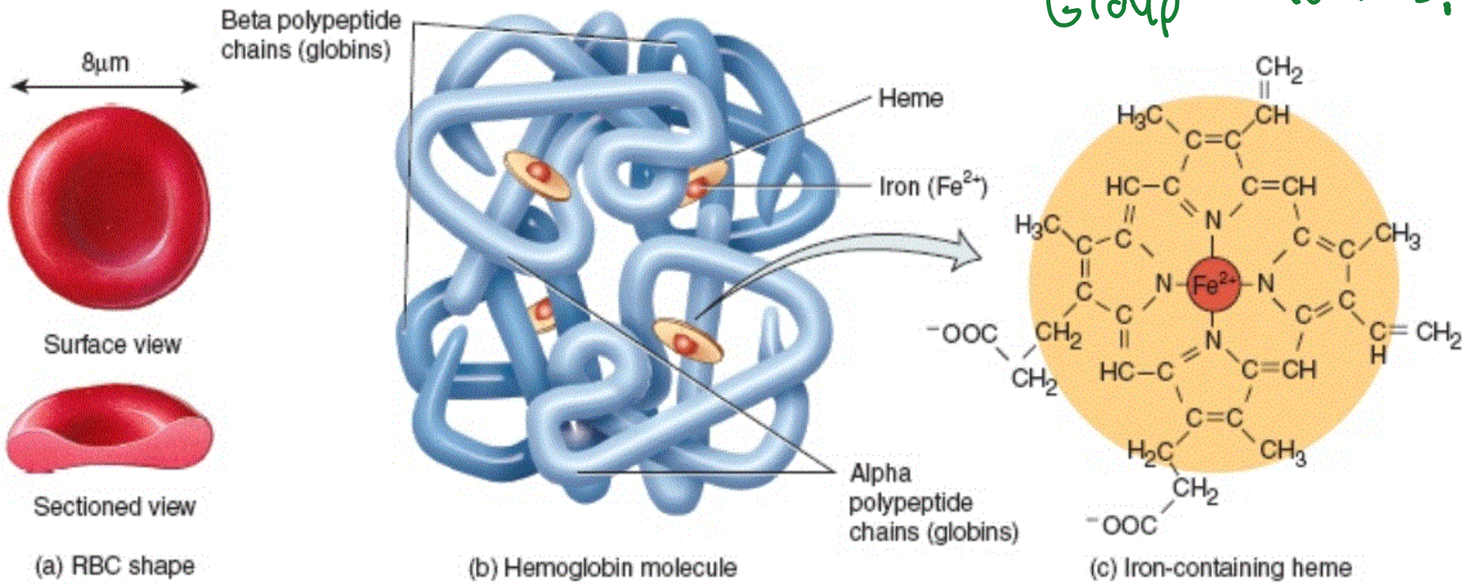
C. Pulse Oximetry

- Measures arterial oxygen saturation (SO_2)
- Uses TWO wavelengths
- More wavelengths are used for other blood-gas measurements such as oxygen tension (PO_2) and carbon dioxide tension (PCO_2)

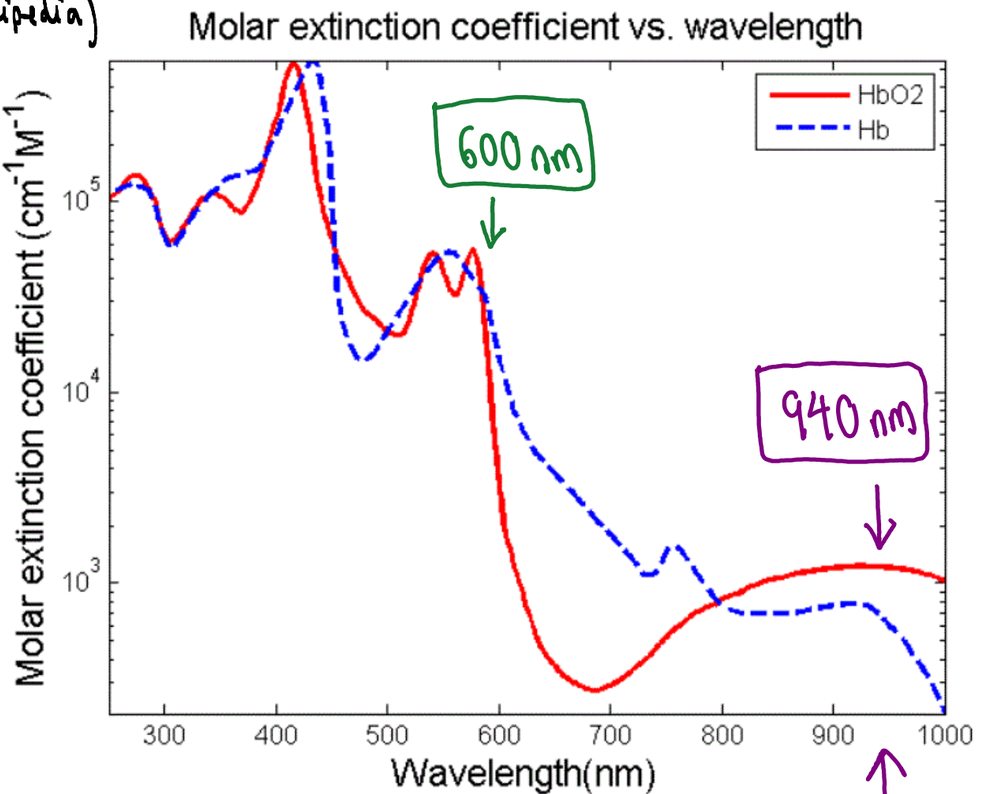
Red blood cell (RBC)

Hemoglobin (Hb) Molecule

Heme Group ← O_2 binds to this!



(wikipedia)



Equally absorbed by HbO_2 and Hb

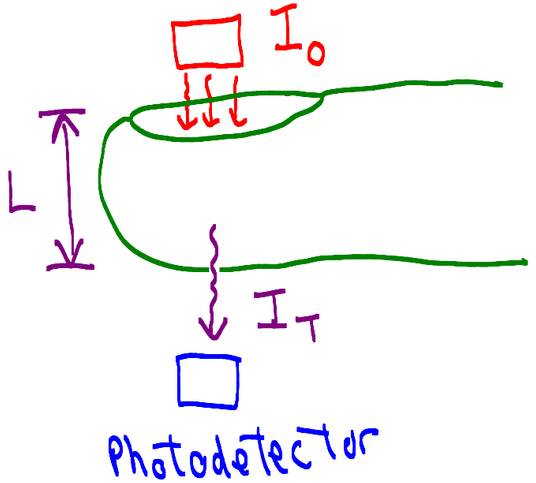
More strongly absorbed by Hb with O_2 (HbO_2)

- **Oxygen Saturation**

C_o = Concentration of oxyhemoglobin

C_d = Concentration of deoxyhemoglobin

$$SO_2 = \frac{C_o}{C_o + C_d}$$



Transmitted light intensity depends on absorption by both oxy and deoxy-hemoglobin!

$$I_T(\lambda) = I_0(\lambda)\, e^{-(\alpha_o(\lambda)\cdot C_o + \alpha_d(\lambda)\, C_d)\, L}$$

Optical absorption coefficient depends on λ!

Q: How to get SO_2 from I_T?

A: use TWO wavelengths!

$$\lambda_1: \quad \ln\left(\frac{I_{T1}}{I_1}\right) = -\left(\alpha_o(\lambda_1)\cdot C_o + \alpha_d(\lambda_1)\cdot C_d\right)L$$

$$\lambda_2: \quad \ln\left(\frac{I_{T2}}{I_2}\right) = -\left(\alpha_o(\lambda_2)\cdot C_o + \alpha_d(\lambda_2)\cdot C_d\right)L$$

$$\begin{bmatrix} -\ln\left(\frac{I_{T1}}{I_1}\right) \\ -\ln\left(\frac{I_{T2}}{I_2}\right) \end{bmatrix} = \begin{bmatrix} \alpha_o(\lambda_1) & \alpha_d(\lambda_1) \\ \alpha_o(\lambda_2) & \alpha_d(\lambda_2) \end{bmatrix} \begin{bmatrix} C_o L \\ C_d L \end{bmatrix} \Rightarrow SO_2 = \frac{C_o}{C_o + C_d}$$

Two measurements

Known values

Solve for these using linear algebra