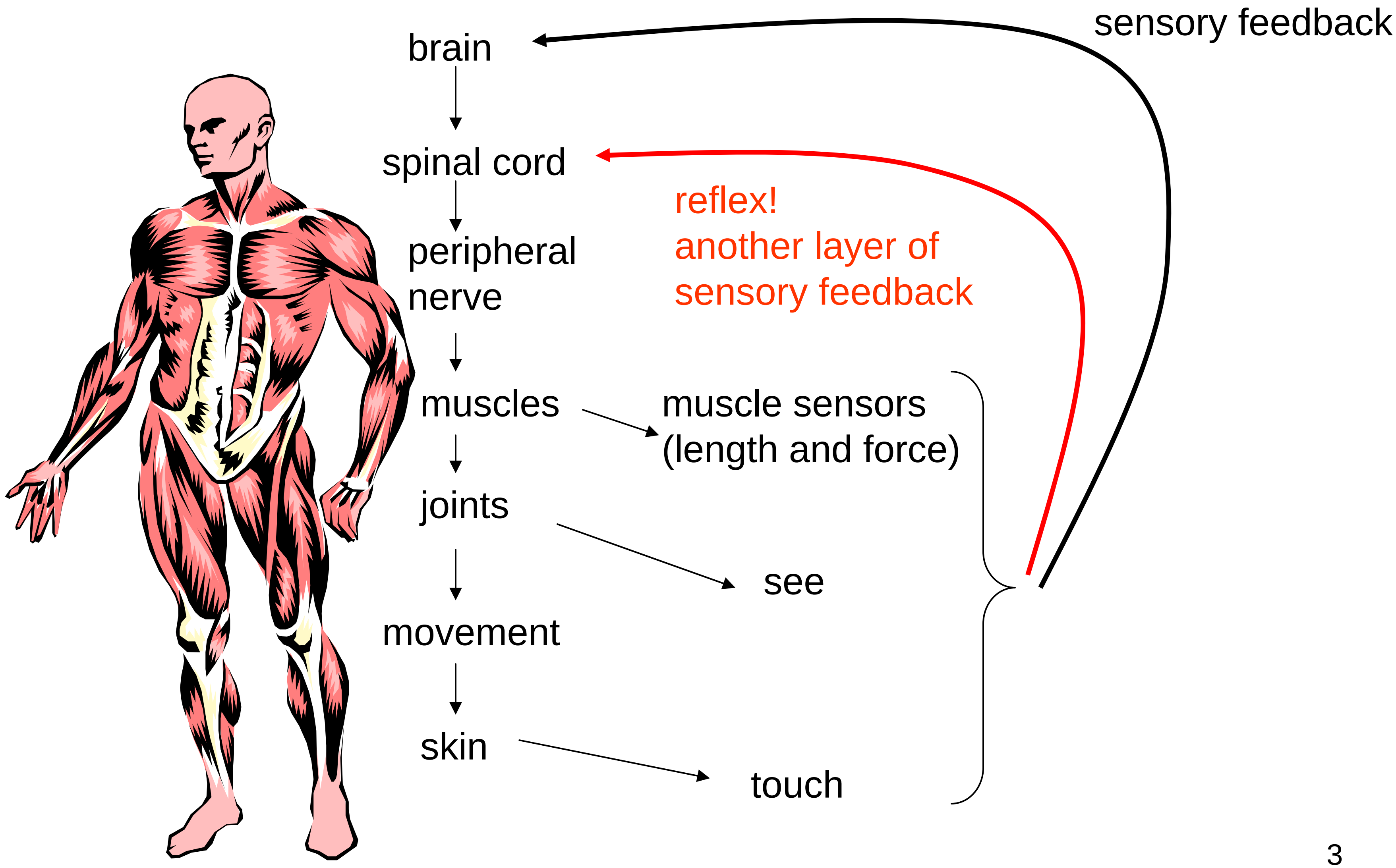
CSE 490i
Lecture 3
Neural Control of Movement
Part 1

1/23/2007

Announcements

- PS3 due Thursday morning 10:30am
- PS4 (reading assignment) posted today
- Lab2 writeup due this week (before your lab session electronically)
- Lab3 this week
- Guest lecture by Kai Miller on Thursday.
- Feedback?

Human Closed Loop System



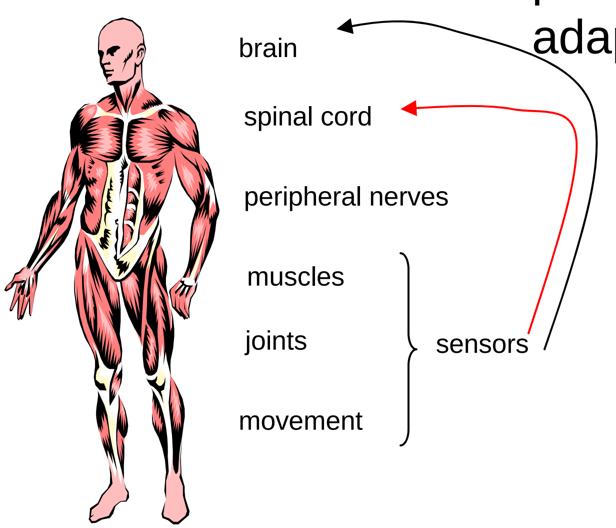
Roles of Components in Human Movement Control

Muscles: contracts (and shortens) with electrical signals

Peripheral nerves: conducts electrical signals

Spinal cord: conducts signals to muscles from brain
from sensors to brain
reflex signals comes back and **calculate** appropriate actions
reflex required because the neural conducting time is slow

Brain: computes motor output (motor cortex)
converts tasks/goals to desired output signals (premotor cortex)
processes error correction (cerebellum)
adapt to the environment/tasks, etc (everywhere)



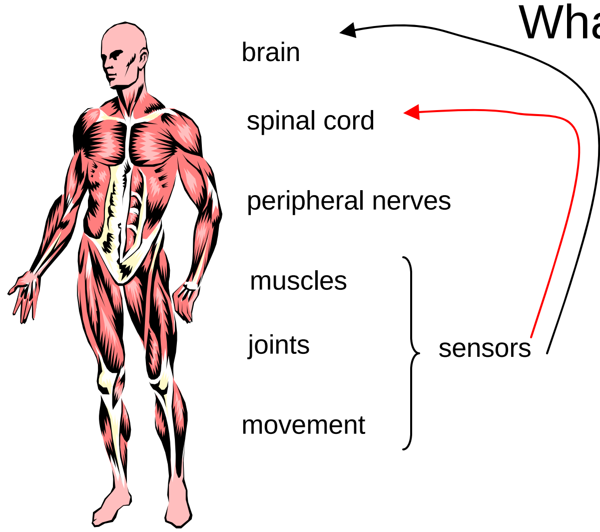
So what do the researchers in Neurobotics study?

Physiology: How do the muscles/sensors work?
Is there a way to mimic for robots or implants?

Dynamics: How do multi-joint limbs get controlled?
Modeling of dynamic behavior

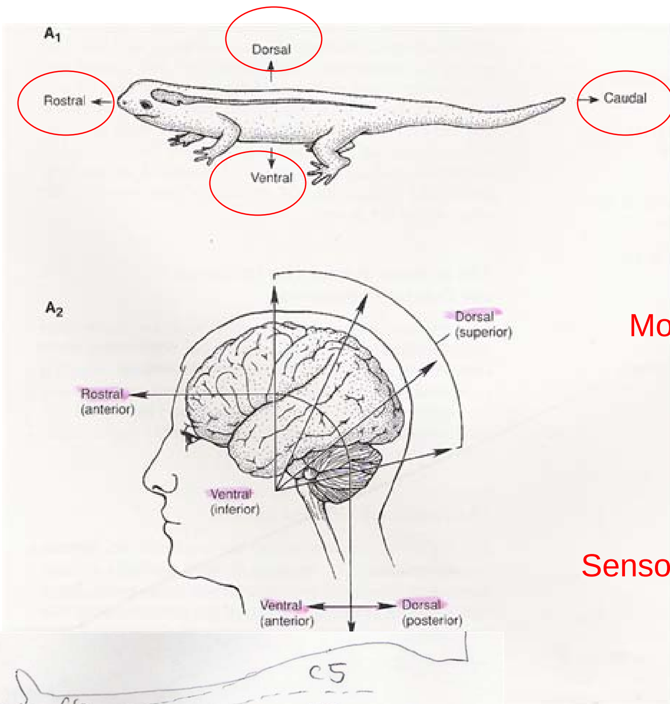
Brain Anatomy: Which part of the brain is in charge of different function?
Lesion (hole) studies, patient studies

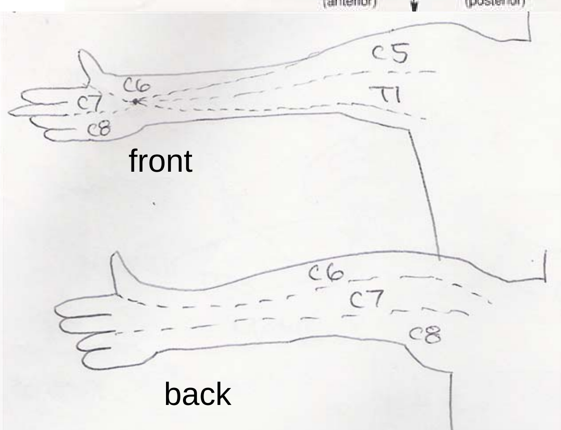
Motor Control: What does the brain control? Muscles? Endpoint?
What is the "desired" signals? Force? Position?
What is being optimized? Energy? Moving distance?
What is the adaptation structure? Long and short adaptation

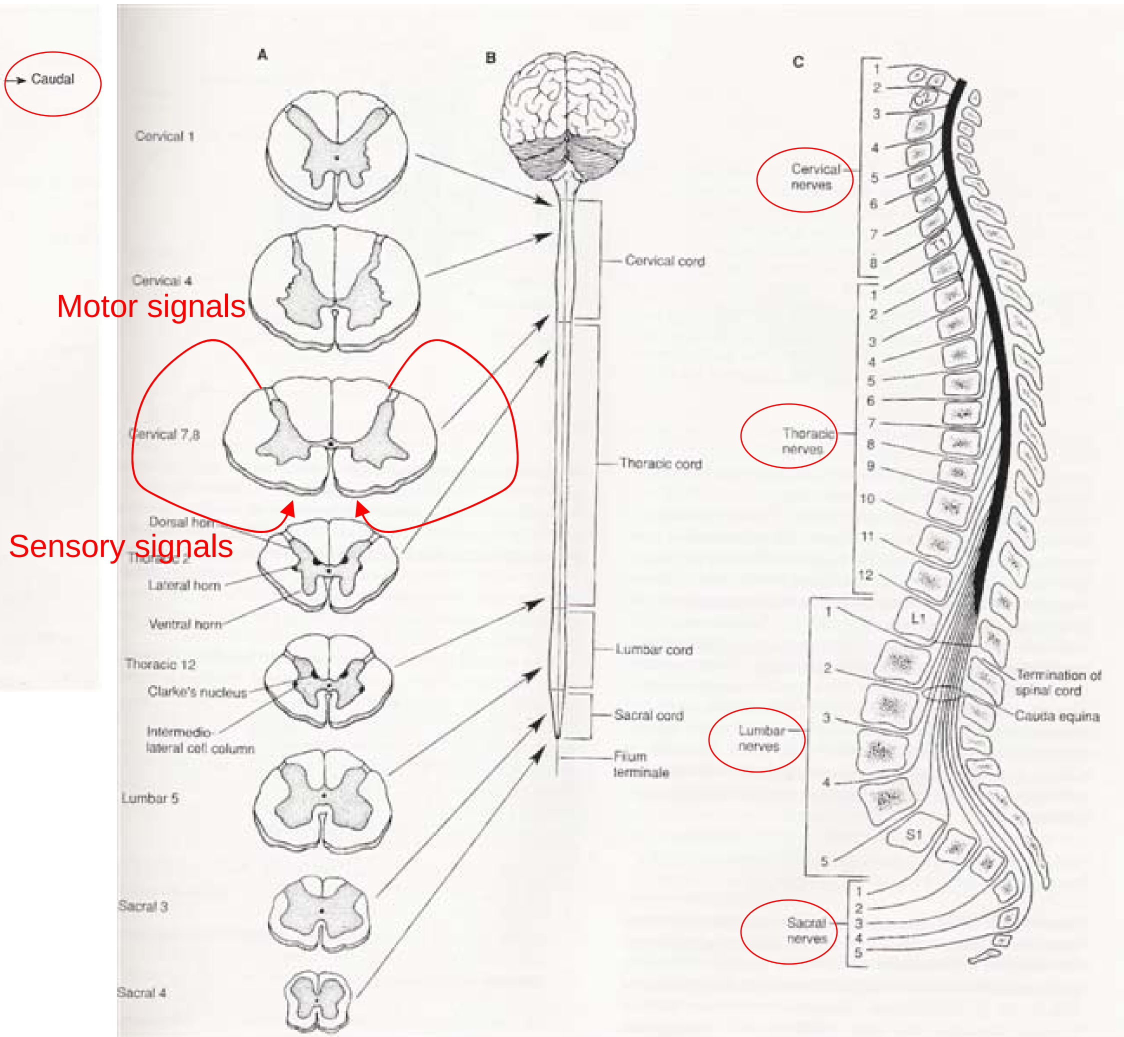


Brain-Machine Interface:
- Superman Suit
- Prosthetics
- Brain-Computer Interface
- External device induce new control/adaptation

Anatomical Terms of the Central Nervous System (CNS)

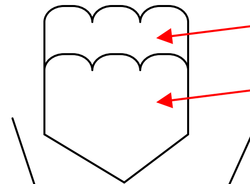






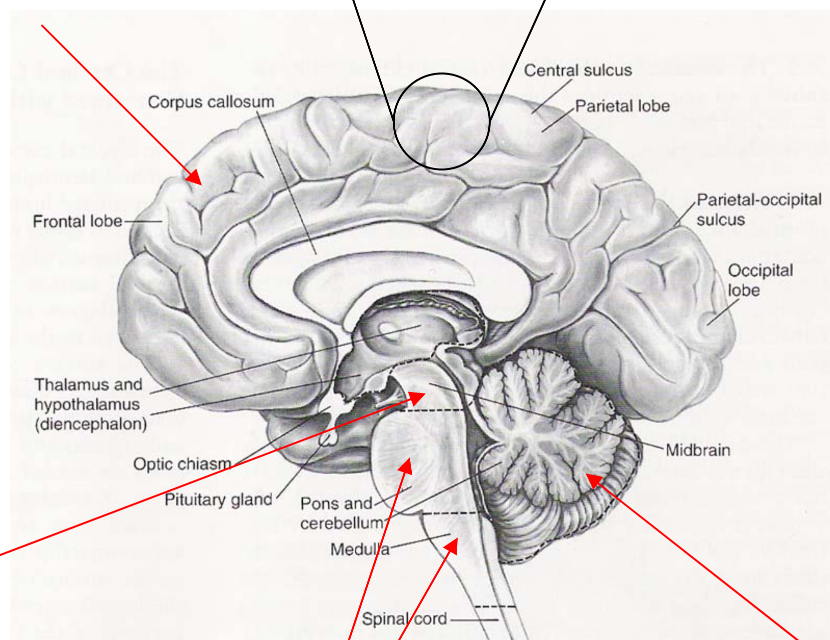
Paraplegic: lower than T2. Quadriplegic: higher than C4. In between: a variety of deficits

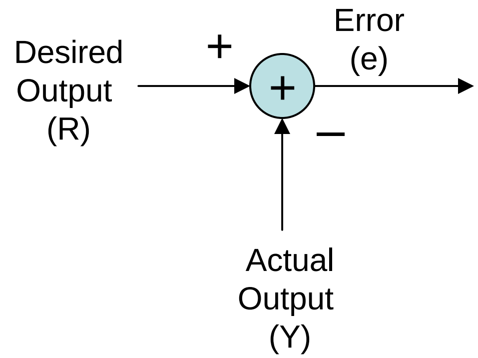
Brain (with motor systems)



Gray matter: lots of cells (neurons)
6 layers with different type of cells
While matter: lots of fibers

Cerebral Cortex (mostly called cortex):
Evolved faster than the skull
Different areas in charge of different function.





Purkinje cells in Cerebellum looks like this and takes these signals!

Basal Ganglia:
Reinforcement learning
Lesion in BG causes:
- slow movements
- uncontrolled movement
- hard to initiate movement

Ex: Parkinson's disease

Pons and Medulla:
Regulation of blood pressure, respiration, etc

Cerebellum:
Heavily involved in motor coordination
Inputs: sensory inputs from spinal cord, motor signals
Outputs: movement plan, timing, patterns
Lesion in CB causes:
- uncoordinated movements
- lose balance
- can't learn error directed movements

Cortex

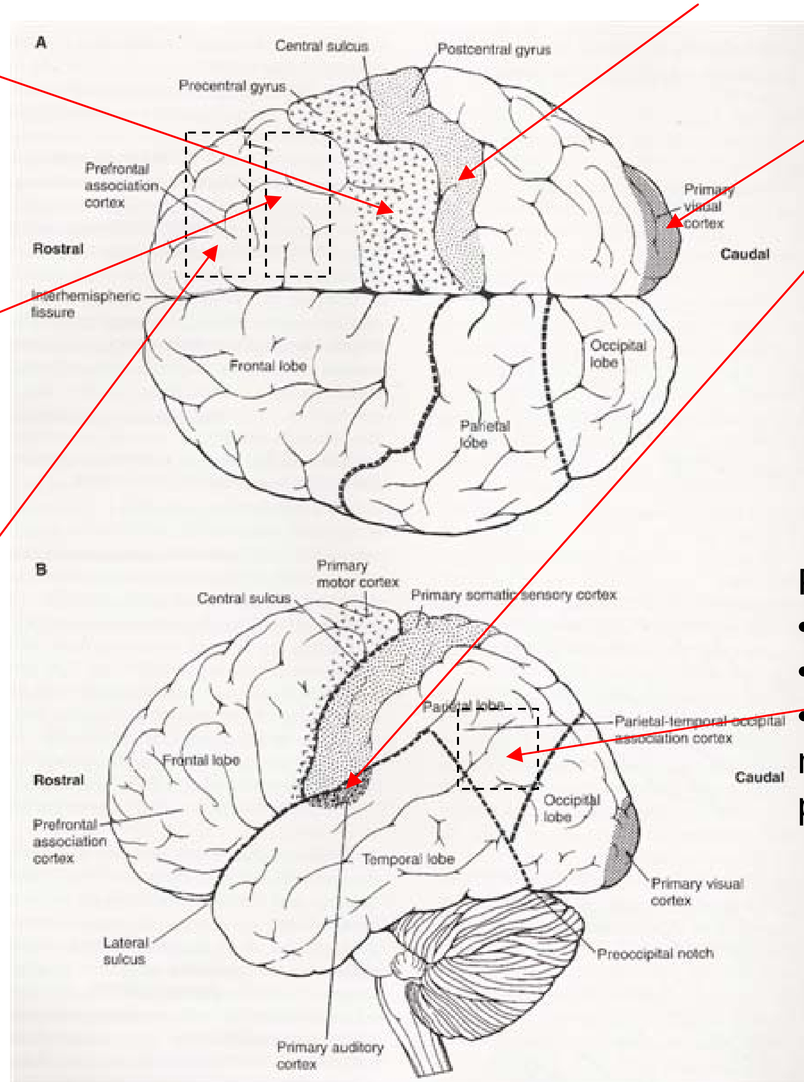
Primary motor cortex (M1):
•Output port (neurons in M1 have wires that project down through spinal cord).
•Well studied and used for Neurobotics

Primary sensory cortex (S1):
•Input port (neurons in S1 have wires that come from spinal cord.

Primary visual cortex (V1):
•Visual input port

Primary auditory cortex (A1):
•Auditory input port

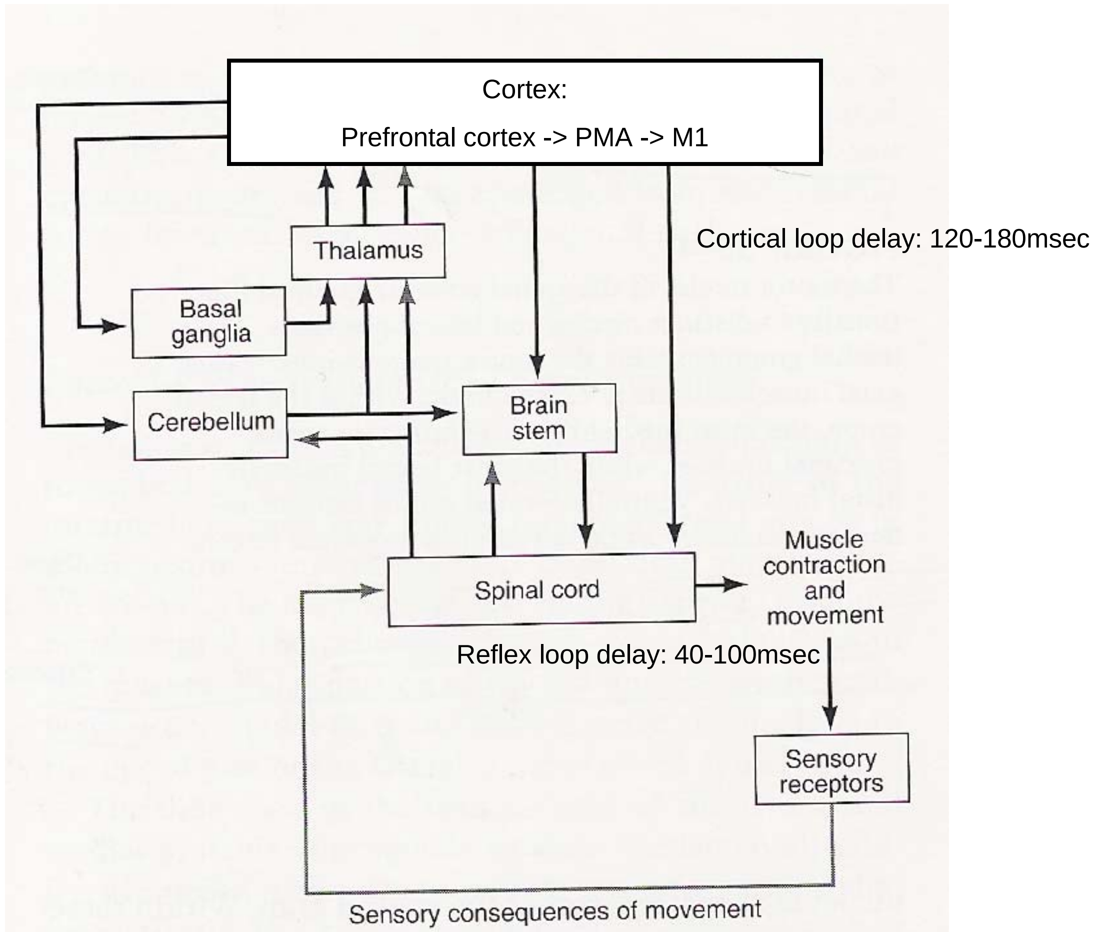
Premotor area (PMA):
•Motor sequence planning
•Projects to M1
•Active 200msec before movement onset



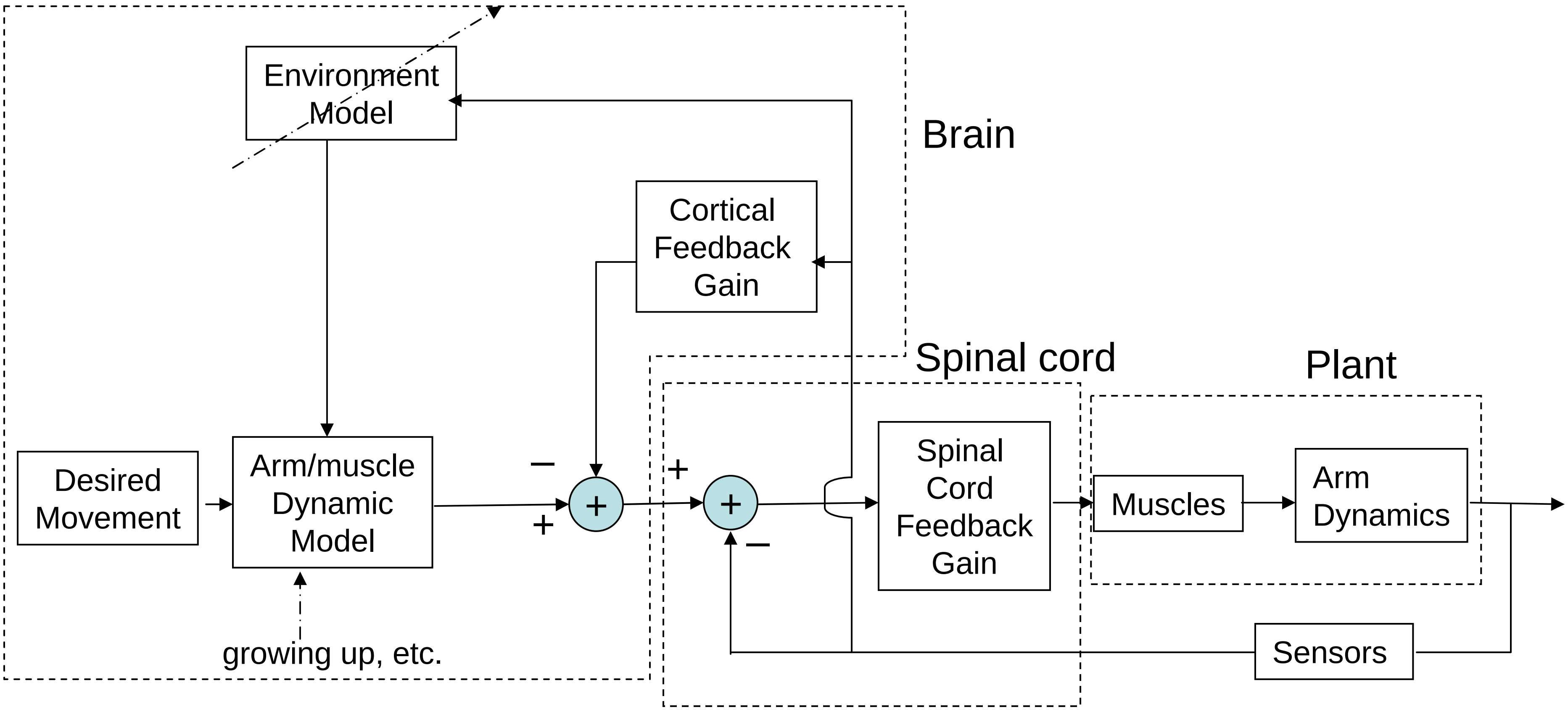
Prefrontal cortex:
•Plans voluntary movements
•Receives info from limbic system (related to motivation?)
•Projects to PMA

Posterior parietal cortex:
•Receives info from S1, V1
•Projects to PMA, prefrontal cort
•Coordinates sensory info for movement production --- perception

Box Diagram of Motor Systems in CNS

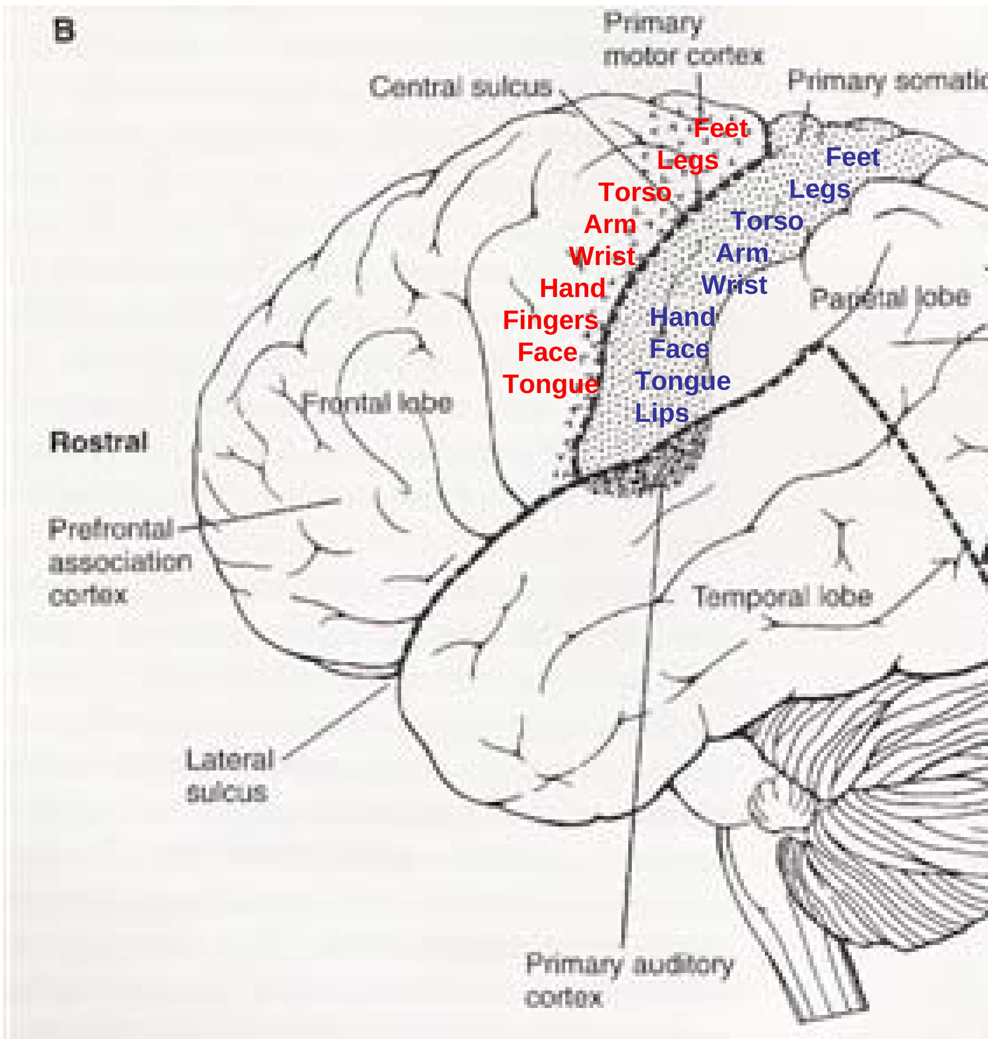


Now in terms of engineering….



- Open loop: can't keep the movement steady with perturbation
- Spinal feedback: can correct movements involuntarily (reflex)
- Cortical feedback: can correct movements voluntarily (but still can't catch a ball)
- Feedforward control (allows anticipation): build a model of the environment/arm/muscles
- Adaptation: learn the environment model (always), learn plant model (growing up, etc)

Motor/Somatotopic map



Penfield

There is a topological map in a specific order

Area size depends on the fine control ability (for M1) or sensitivity (for S1)

Specific lesions create specific deficits.
Example: stroke

Contra-lateral side deficits

Brain-machine Interface (BMI)
Brain-Computer Interface (BCI)

- Stroke, Spinal cord injuries, amputees, etc
  Movement augmentation

- Locked in
  Communication assistance