Lecture Notes 4
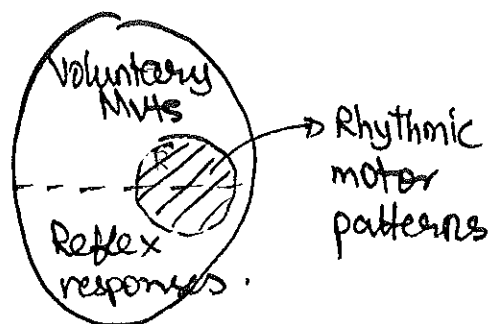
General Motor Control, Voluntary Mvts.

– Mvts produced by the nervous System.

Voluntary Mvts – most complex actions

1. Purposeful – initiated in response to a Specific stimulus or to the will

2. Goal directed learned mvts. Most voluntary mvts improve w/ practice.

   eg. infants learning to reach playing piano/tennis

     → Over time, requires less or no conscious participation

  Involves brain control.

Reflex responses :– involuntary mvt. elicited by stimulus.

   – eg. withdraw hand from hot object.

  mostly controlled @ spinal cord.

Rhythmic motor patterns – walking, running etc.

   – combination of Voluntary + Reflex.
                  ↳ initiation/termination

   –   "   " spinal + cortical control
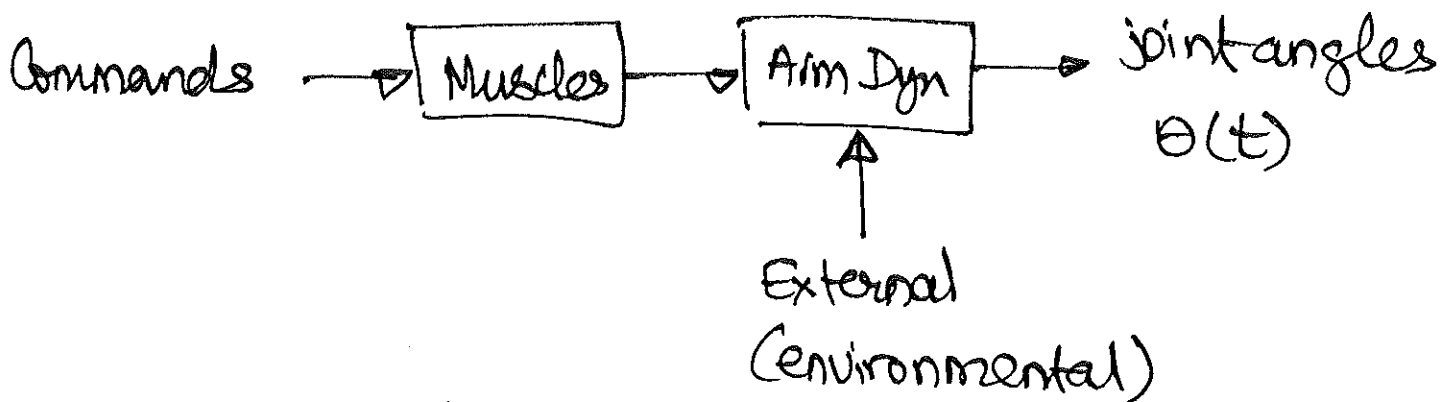   ↳ brain

Lower animals – more dependent on spinal control.

ex. Spinalized cats: brain + spinal cord not connected

only SC connected to limbs
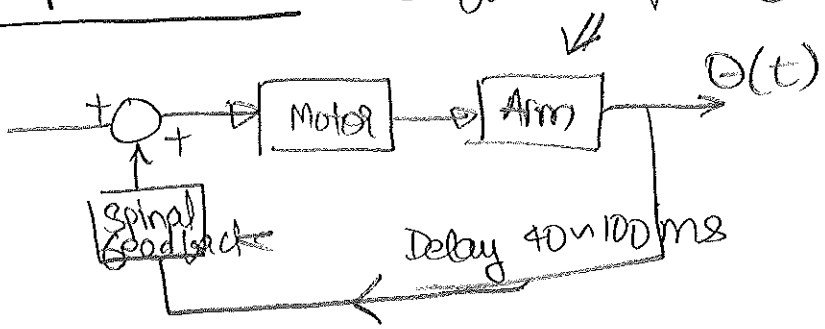
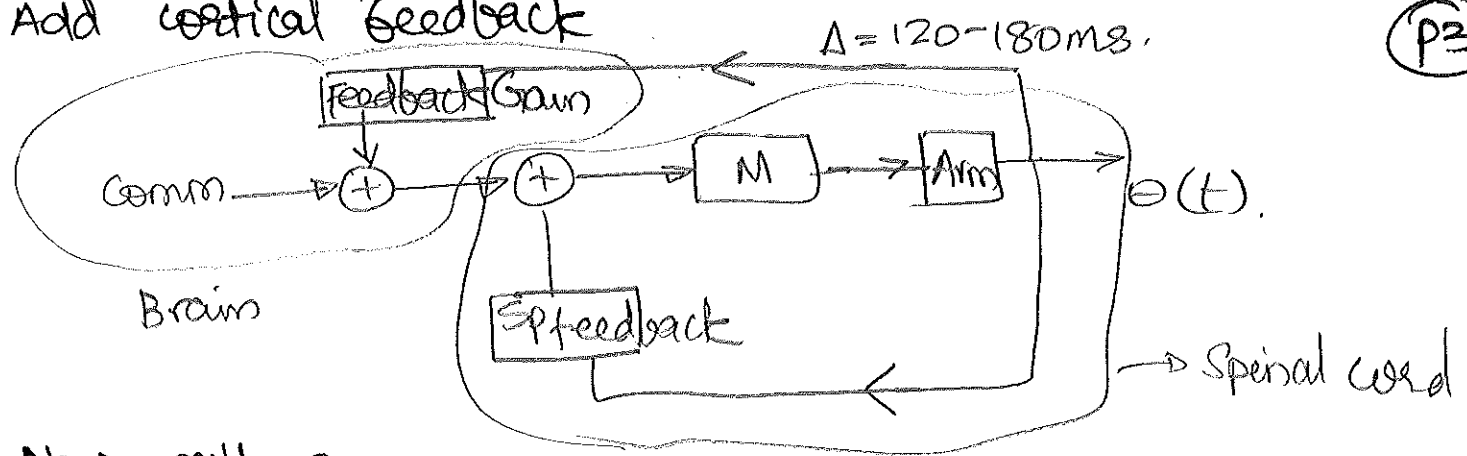– can walk on treadmill

Think in Engineering terms.

Commands —▷ | Motor | —▷ | Plant | —▷ dynamic response

Human arm movement.

Commands —▷ | Muscles | —▷ | Arm Dyn | —▷ joint angles $\theta(t)$

↑ External (environmental)

Patients w/ no feedback (deafferented) cannot keep arm steady

Add spinal cord (reflex response only.)

$\theta(t)$

+○+ —▷ | Motor | —▷ | Arm | → $\theta(t)$

| Spinal feedback |

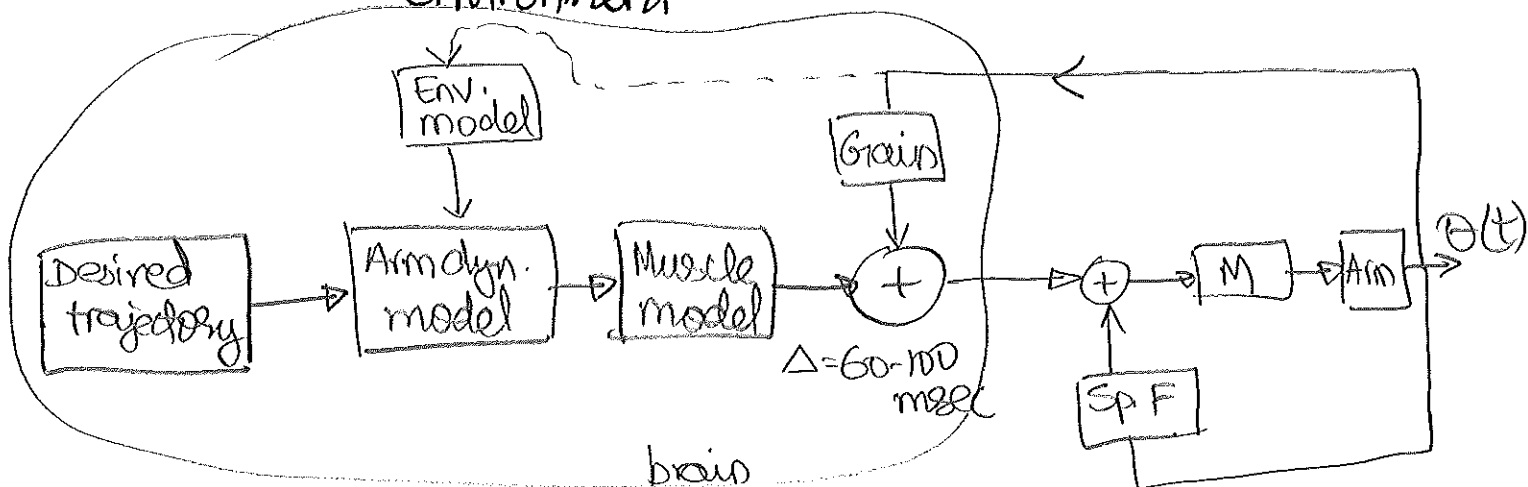Delay 40~100 ms

Add cortical feedback

Δ = 120-180ms.

Brain

→ Spinal cord

Now mvt. errors can be corrected but can never catch a
ball — anticipation

⇓

Need feedforward model/control.
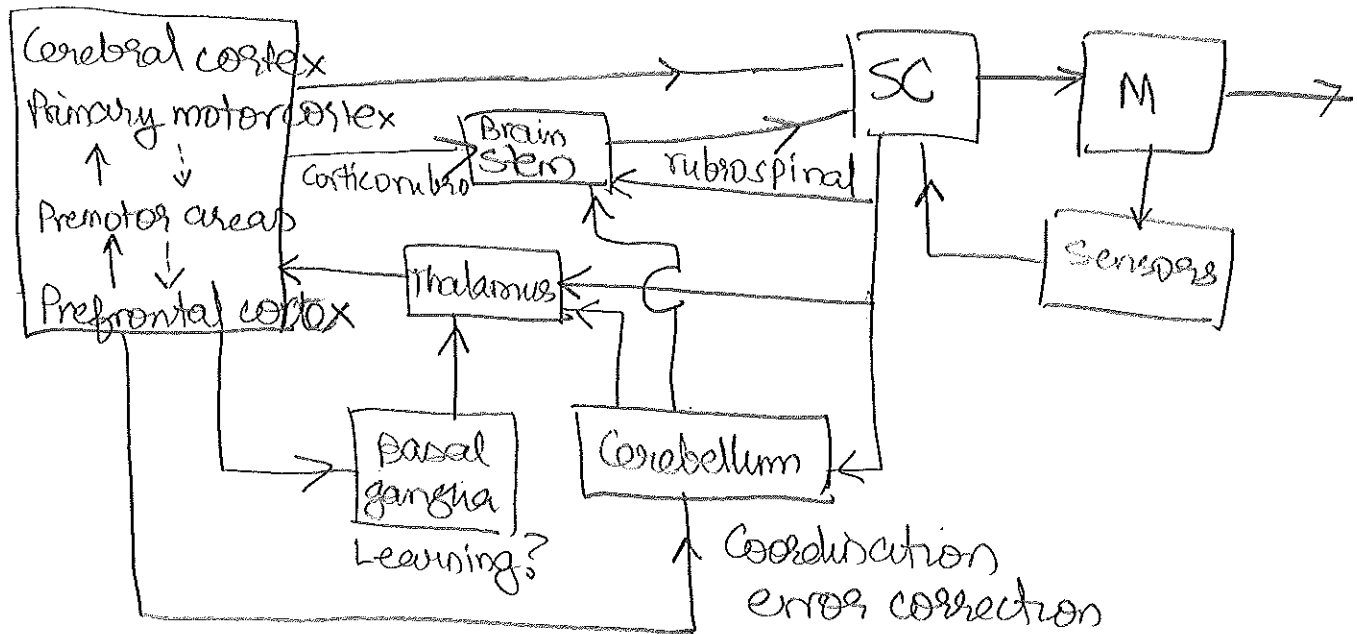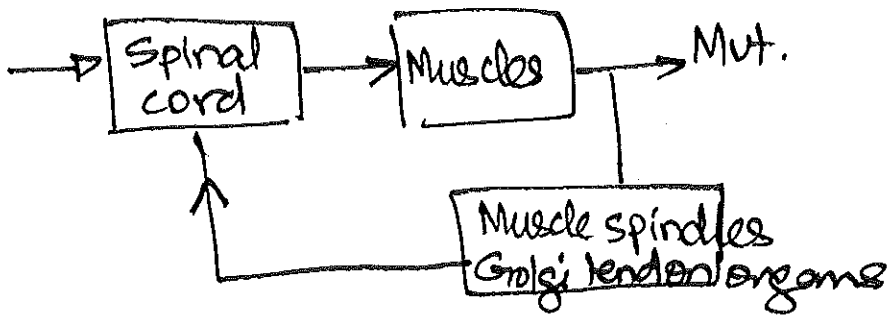- Muscle model
- Arm dyn "
- Environment "

Δ = 60-100 msec

brain

Delays: Spinal — 40~100ms.

Cortical 120-180 + 60-100ms ≅ 200-250ms.

Learning a whole cycle.

Spiral cord → Muscles → Mvt.

Muscle spindles
Golgi tendon organs

Cerebral cortex
Primary motor cortex
Premotor areas
Prefrontal cortex

Brain stem
Corticorubro
Rubrospinal
SC
M
Sensors

Thalamus
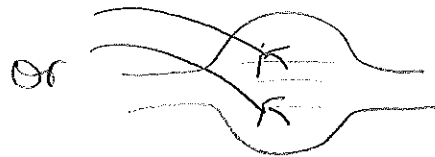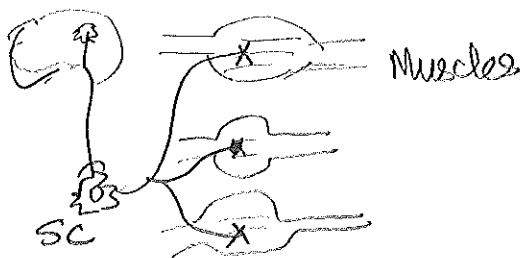
Basal ganglia
Learning?

Cerebellum

Coordination
error correction

What do they do wrt the control diagram?

Primary motor cortex

↳ One neuron controls a set of muscle fibers that (sometimes) innervates several muscles.

Muscles   or

SC

What do they encode?   Muscle model

↳ Muscle force (not position)
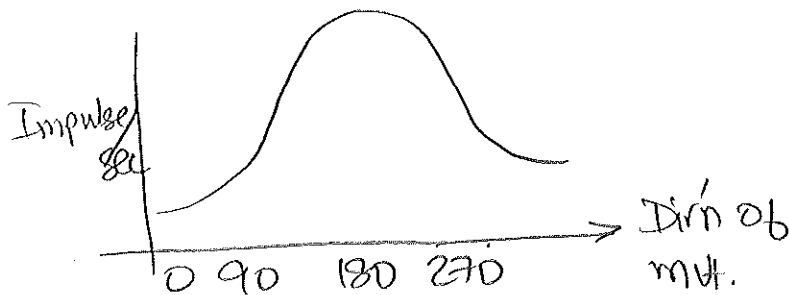
→ Direction of force produced /Mvt.
direction

Georgopolous et al 1983

Famous (classic) motor control expts (which of course
have been criticized in many ways later)

Found cells in M1 have preferred dirn of movement

- Recorded in the right M1 proximal arm area.

- Monkeys made reaching mvts in 8 dirns using
  left arm (elbow & shoulder)
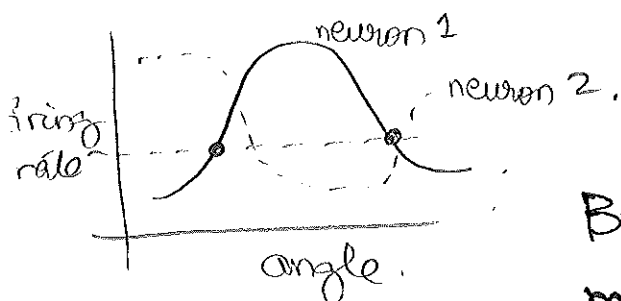
- Cells fired more toward a certain direction.

Sinusoidal
Different cells have different
Preferred dirn

So does it take one neuron to move to one dirn?

Unfortunately there is ambiguity for sine waves (Two
Solns for the same firing rate)
  ⤷ Use multiple neurons.

The more neurons ⟹ the less
              ambiguity

Brain uses a population of neurons to encode
mvt dirn.

Going back to the engineering block diag.

Where does the desired traj lie?

In PMA + prefrontal cortex.

- neurons begin firing 200 ∞ 1000 ms before mvt
onset.

Lesions in PMA

- complex mvt. cannot be executed

- mvts. become purposeless.

How about environmental adaptation?

↳ also called "internal model" of the env.

Evidence shows changes everywhere.

Next week: Muscle Physiology.