

# Systems Neuroscience

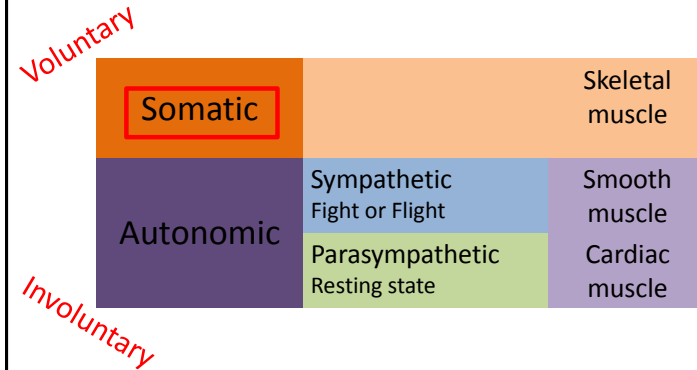
## CISC 3250

### Motor control

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 JMH 332



## Classes of motion



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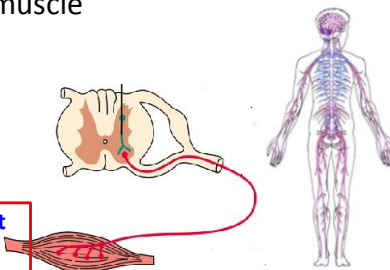
## Pathways to motion in (typically) 2 synaptic steps

- 0 Command from primary motor cortex (M1)
- 1 Synapse onto neuron in spinal cord/cranial nerve
- 2 Synapse onto muscle

**Efferent** – motor message out

**Afferent** – perceptual message in

**Cortical commands sent to contralateral side of body**

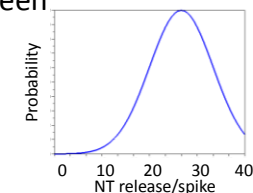


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## Precise motion in an imprecise world

Imprecise neurons

- Efferent signal for motion will present variable number of NT molecules per spike
- Number of spikes may vary between movement repetitions



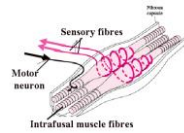
Unreliable world

- Wind blows while you pick up a bag
- You trip on unseen object while walking

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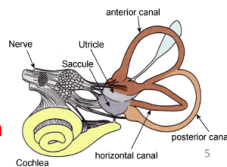
## Monitoring body motion

- Seeing body move (covered in earlier lecture)
- Skin stretch (covered in earlier lecture)
- Muscle stretch/contraction – muscle spindles



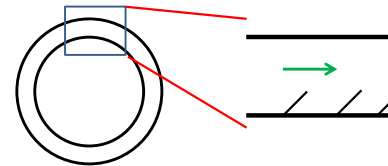
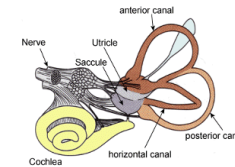
- Head rotations – inner ear; semi-circular canals

**Anterior:** Sagittal spin    **Posterior:** Coronal spin  
**Horizontal:** Axial spin



## Vestibular system

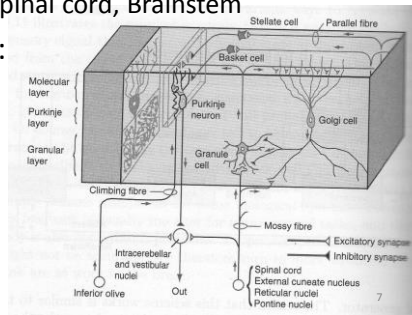
Three canals on left and right side of head: anterior, posterior, horizontal



1. Head rotates
2. Fluid flows
3. Hairs displaced

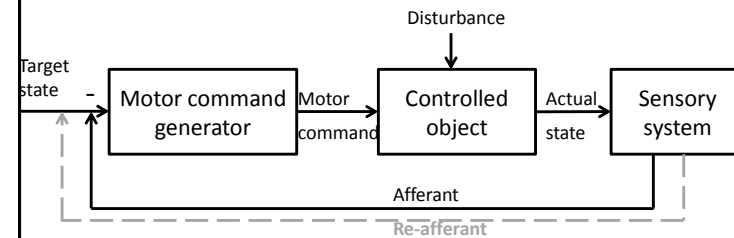
## Adjusting motion with the cerebellum

- Compare motor commands to actual motion
- Cerebellar inputs:
  - Climbing fiber from Inferior Olive (brainstem)
  - Mossy fiber from Spinal cord, Brainstem
- Cerebellar outputs:
  - Purkinje cells – inhibition to brainstem

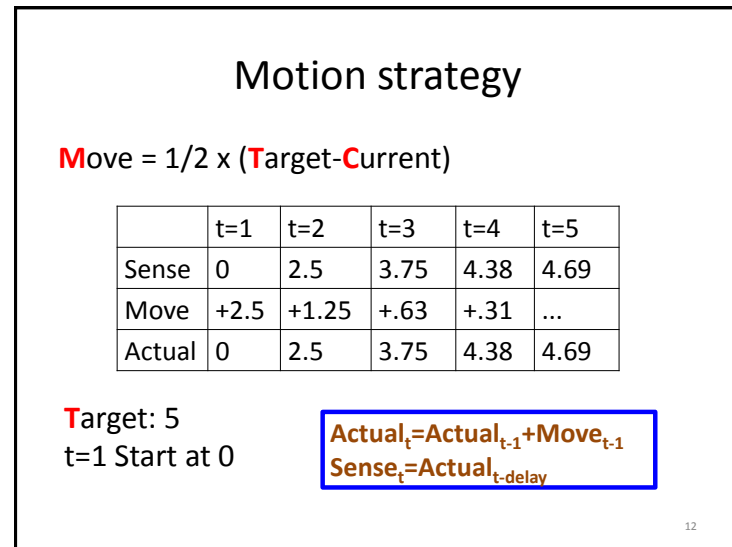
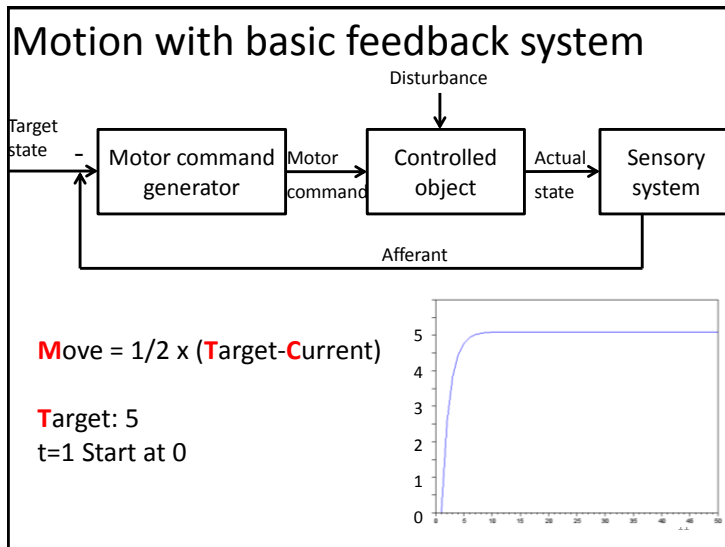
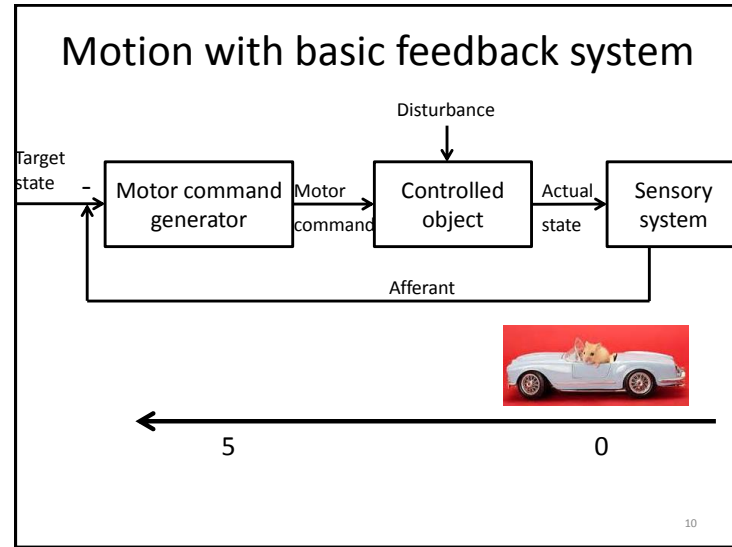
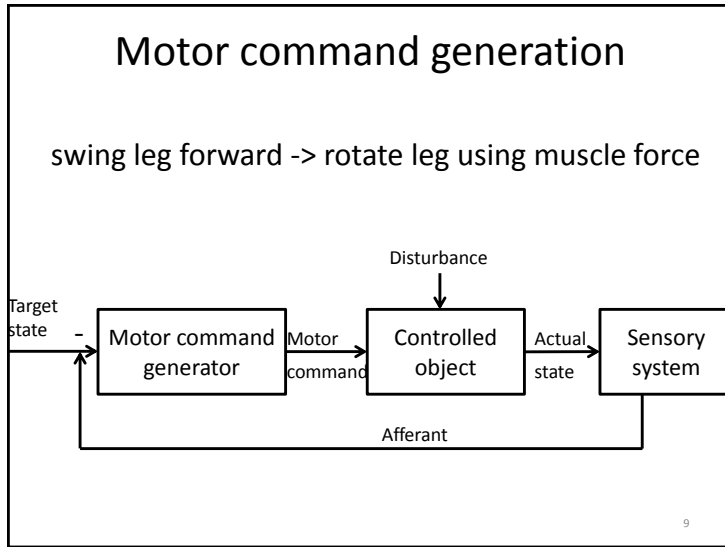


## Control theory

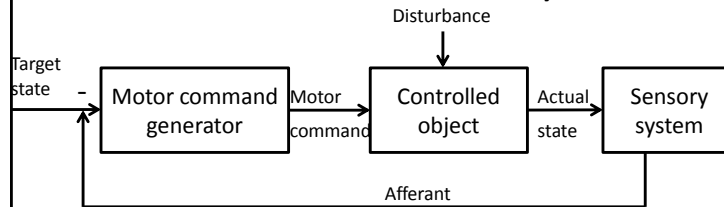
Correcting errors in motion



Afferant – muscle sensors  
 Re-afferant – visual sensors



## Motion with basic feedback system

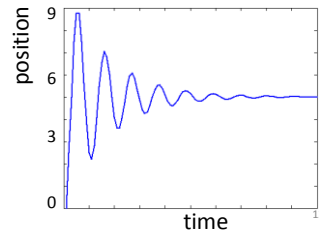


$$\text{Move} = 1/2 \times (\text{Target} - \text{Sensed})$$

Target: 5

t=1 Start at 0

Sense delay: 2 time points



## Motion strategy

$$\text{Move} = 1/2 \times (\text{Target} - \text{Sensed})$$

	t=1	t=2	t=3	t=4	t=5	t=6
Sense	0	0	0	2.5	5	7.5
Move	+2.5	+2.5	+2.5	+1.25	0	-1.25
Actual	0	2.5	5	7.5	8.75	8.75

Target: 5

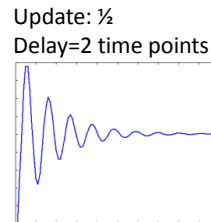
t=1 Start at 0

2 time point sensation delay

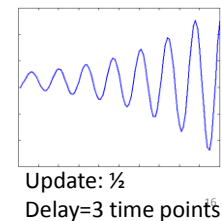
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## Delay-based Oscillations

- If sense delay and update fraction ( $1/2 \times (\text{Targ} - \text{Sens})$ ) are small, oscillations will converge to target



- If sense delay and/or update fraction ( $1/2 \times (\text{Targ} - \text{Sens})$ ) are large, oscillations will get larger and NOT converge to target



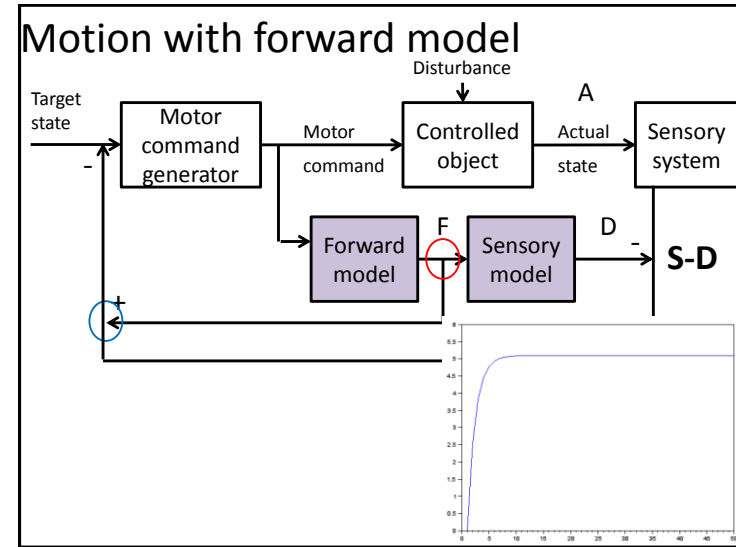
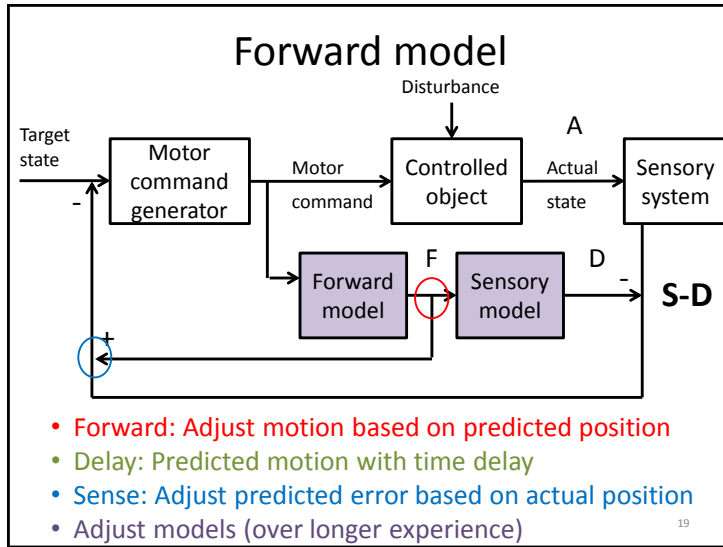
## Expanded control theory

Challenge: Waiting for afferent feedback is slow

Solutions:

- Anticipate typical motion progress – **forward model**
- Account for typical motion progress from the beginning – **inverse model**

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### Motion strategy

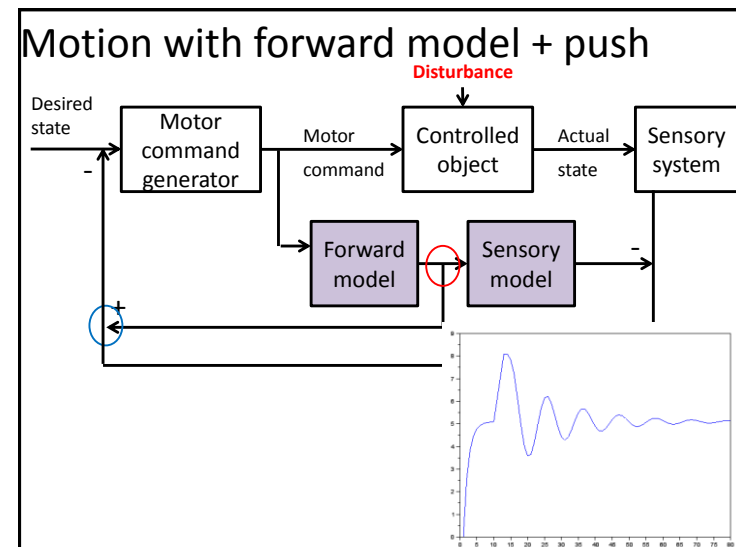
**Move = 1/2 x (Target - Forward - (Sensed - Delay))**

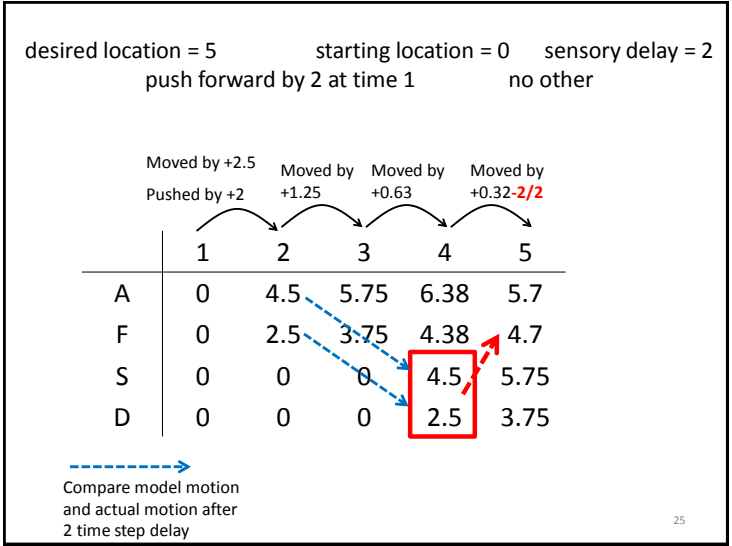
	t=1	t=2	t=3	t=4	t=5	t=6
Sense	0	0	0	2.5	3.75	4.38
Forward	0	2.5	3.75	4.38	4.69	4.85
Delay	0	0	0	2.5	3.75	4.38
Actual	0	2.5	3.75	4.38	4.69	4.85
<b>Move</b>	<b>+2.5</b>	<b>+1.25</b>	<b>+0.63</b>	<b>+0.31</b>	<b>+0.16</b>	<b>+0.08</b>

Target: 5  
 t=1 Start at 0  
 2 time point sensation delay

$Forward_t = Forward_{t-1} + Move_{t-1}$   
 $Delay_t = Forward_{t-delay}$

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