SENSORI-MOTOR SYSTEMS

Why do chickens bob their heads when they walk?

Why do chickens bob their heads when they walk?

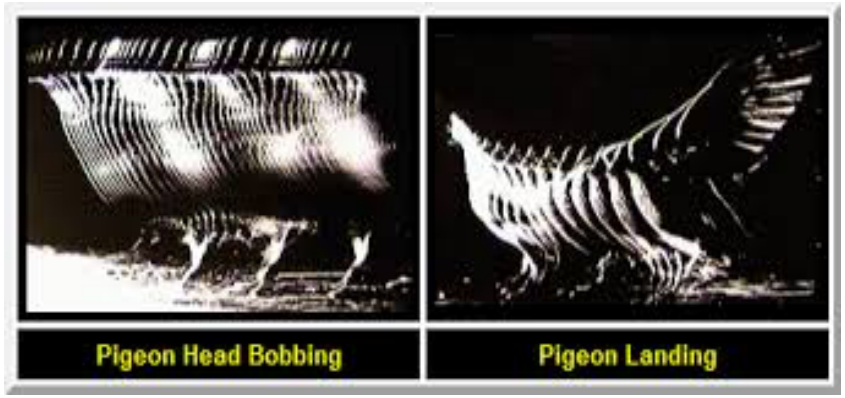
- Seriously

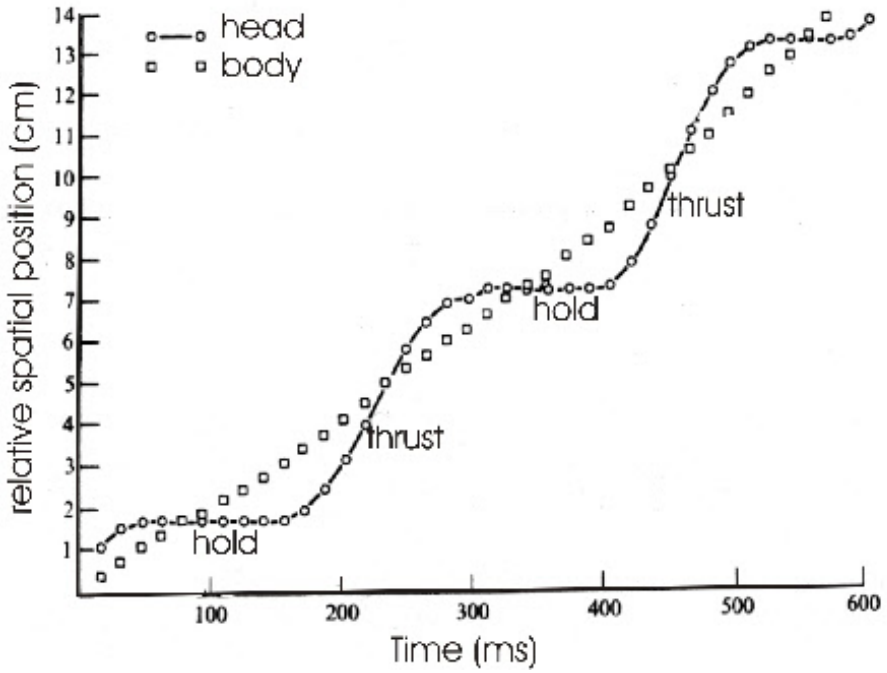
Why do chickens bob their heads when they walk?

- Seriously

Why do chickens bob their heads when they walk?

- Bobbing gone on a Treadmill (pigeons). Frost 1978

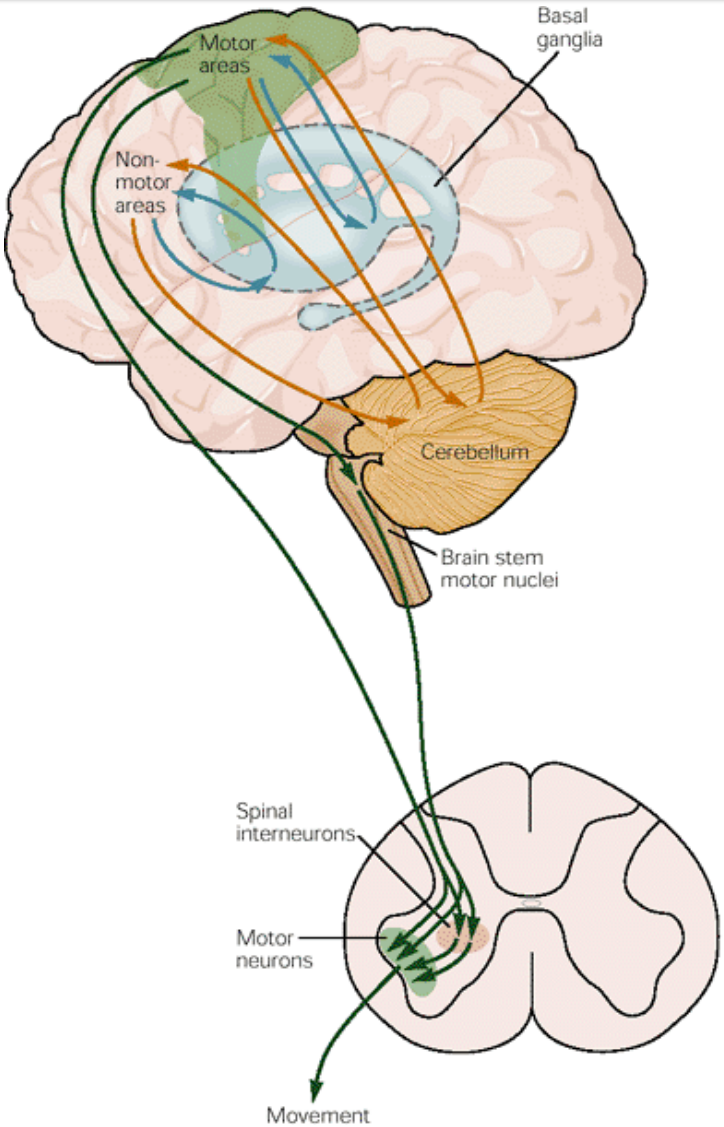


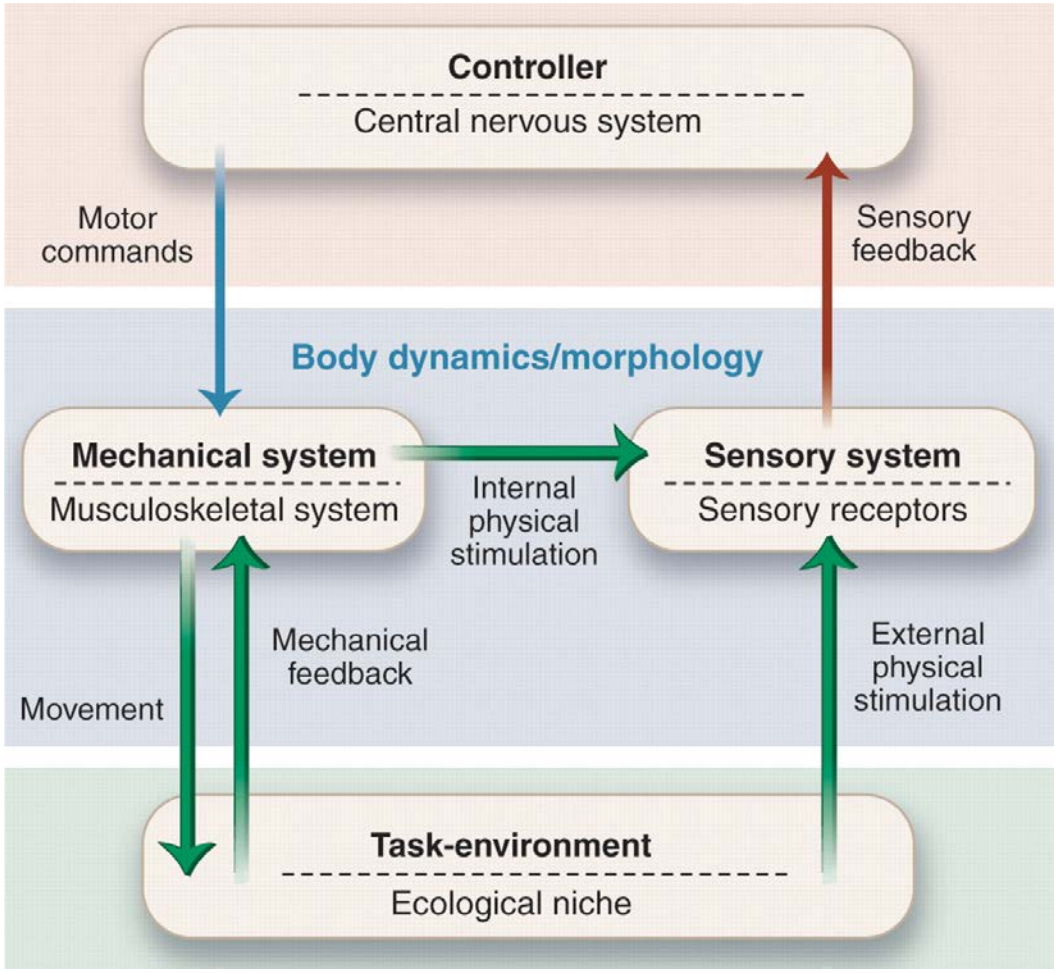


What are Sensori-Motor Systems

- Control loops subserving some function of the organism
  1. Involuntary
     1. Stability subserving
        1. Setpoint or operating range of system
        2. VOR as key example
        3. Postural control
  2. Voluntary
     1. Intentions or goals
     2. Variable setpoints and contraints
  3. *Homeostatic*

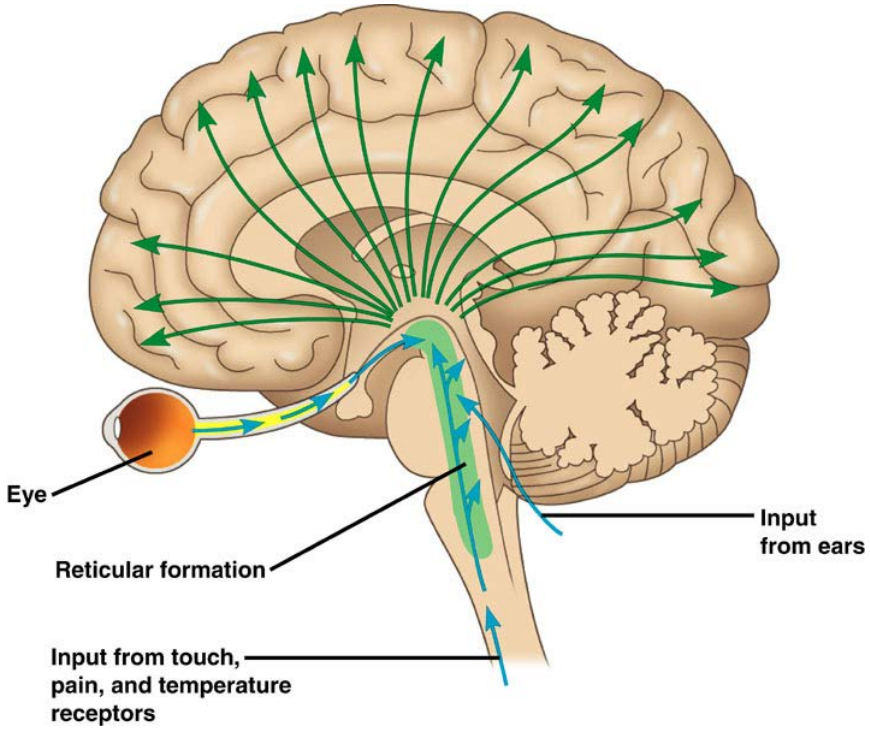
Control in the brain

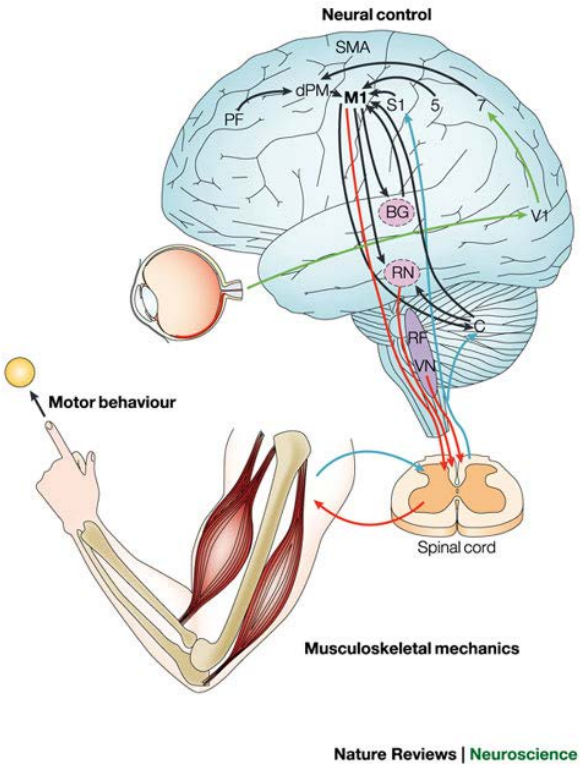




Out to cortex and back again..

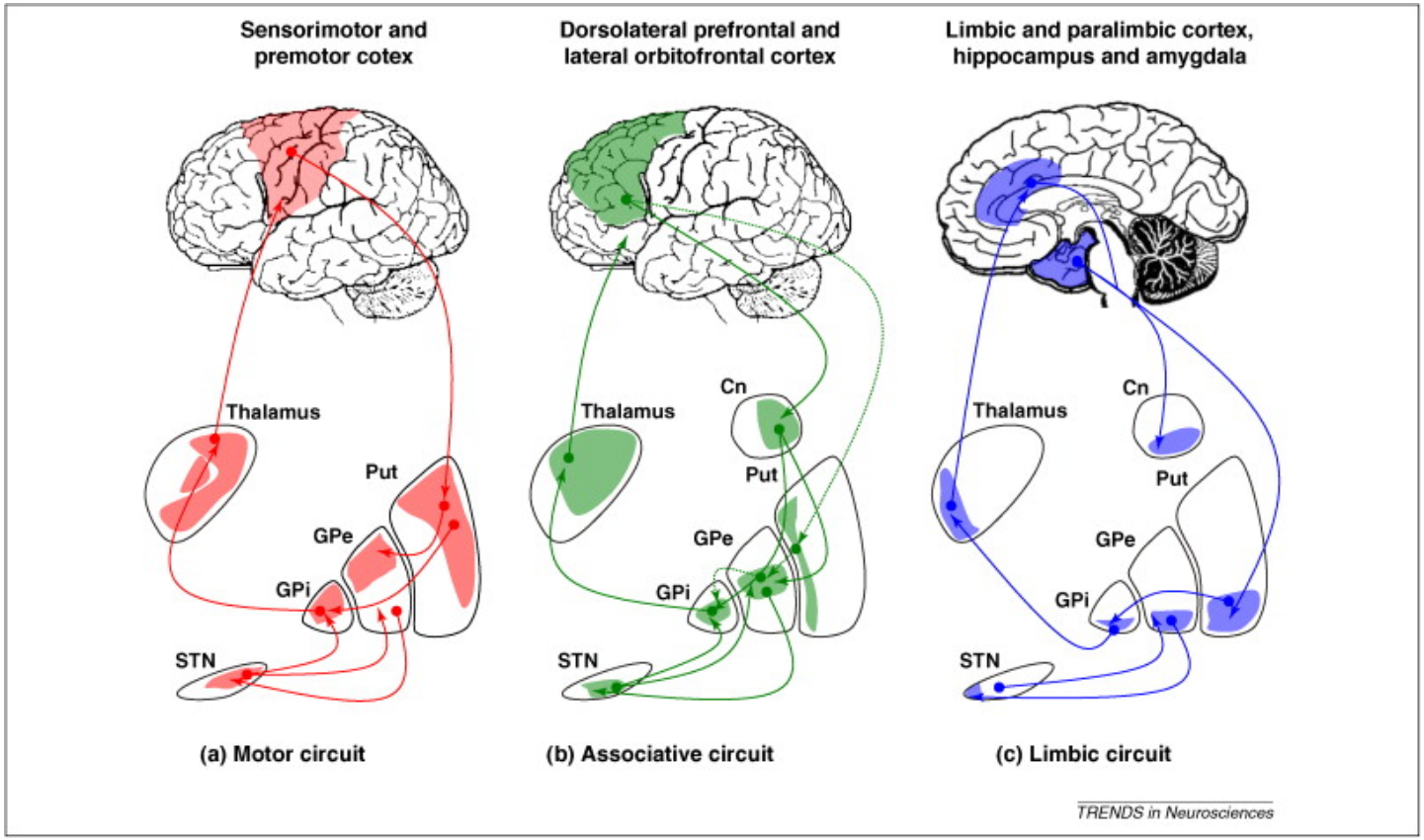
Sensory -> spinal nerves -> midbrain
-> hierarchy of nested loops -> motor





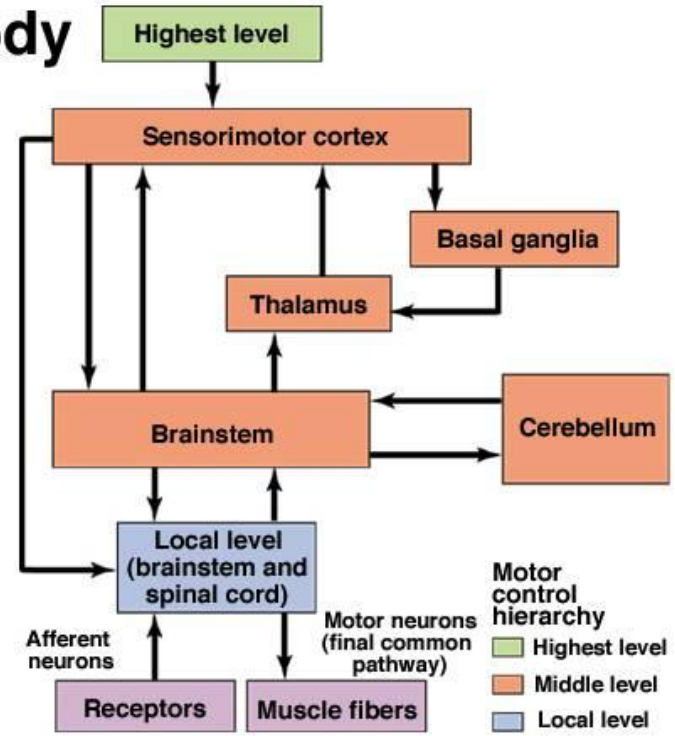
Loops!

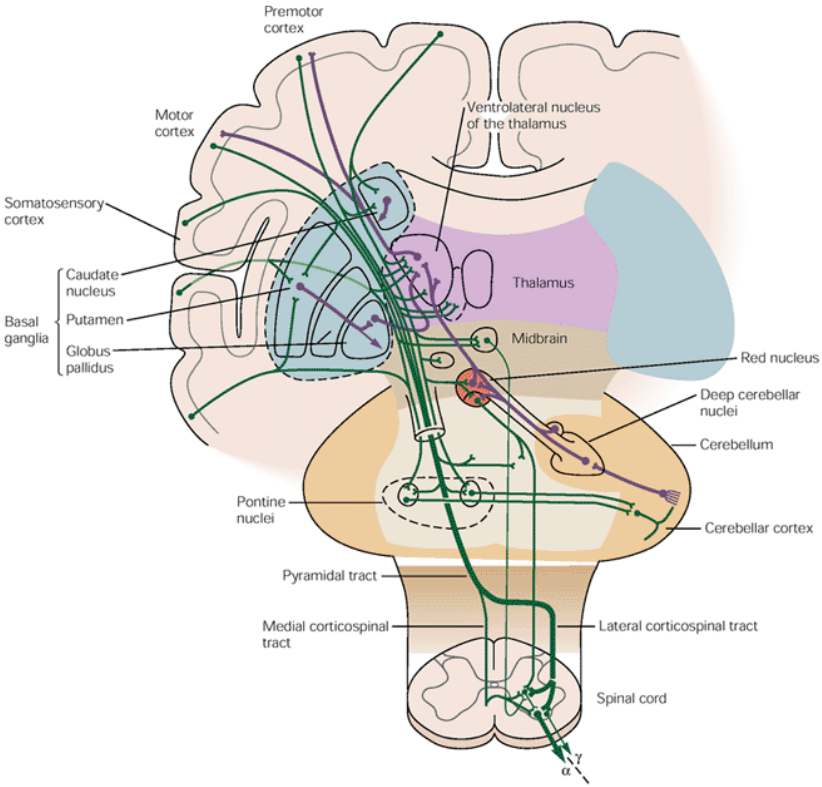
- They are everywhere...

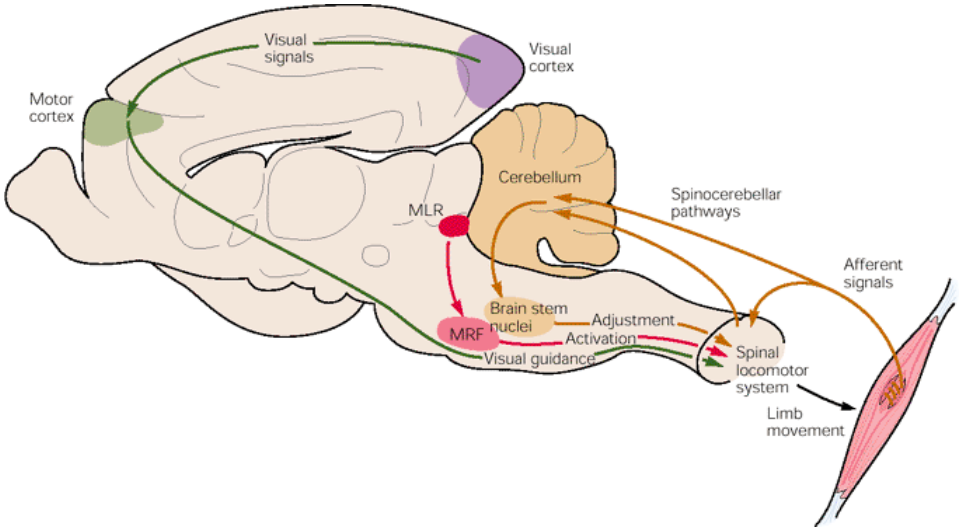


- http://www.sciencedirect.com/science/article/pii/S0166223610001050

Neural systems controlling body movement

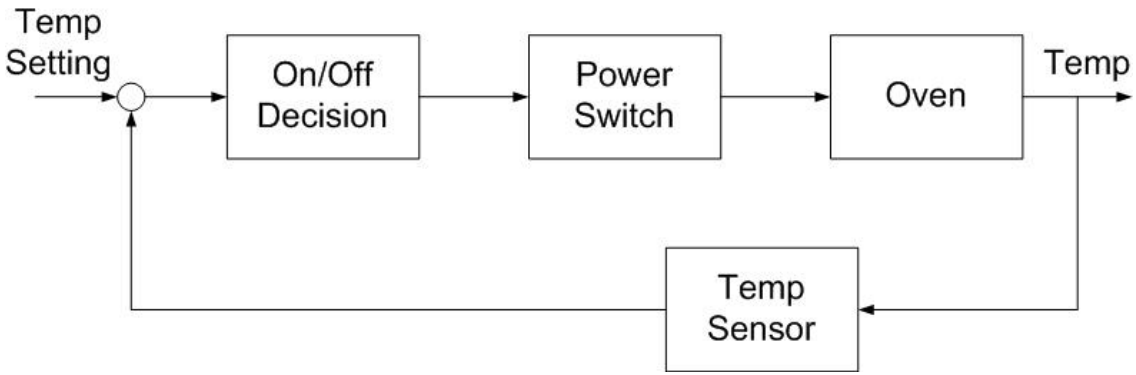


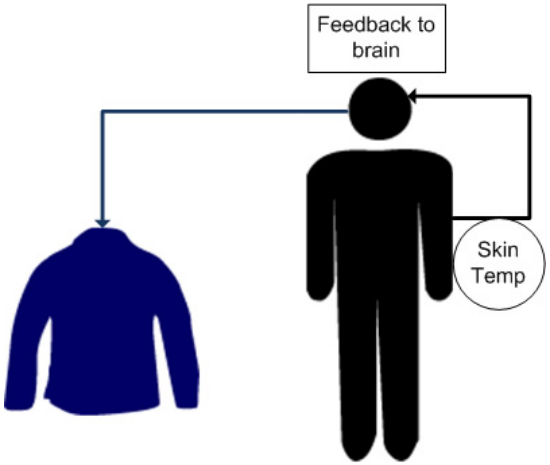




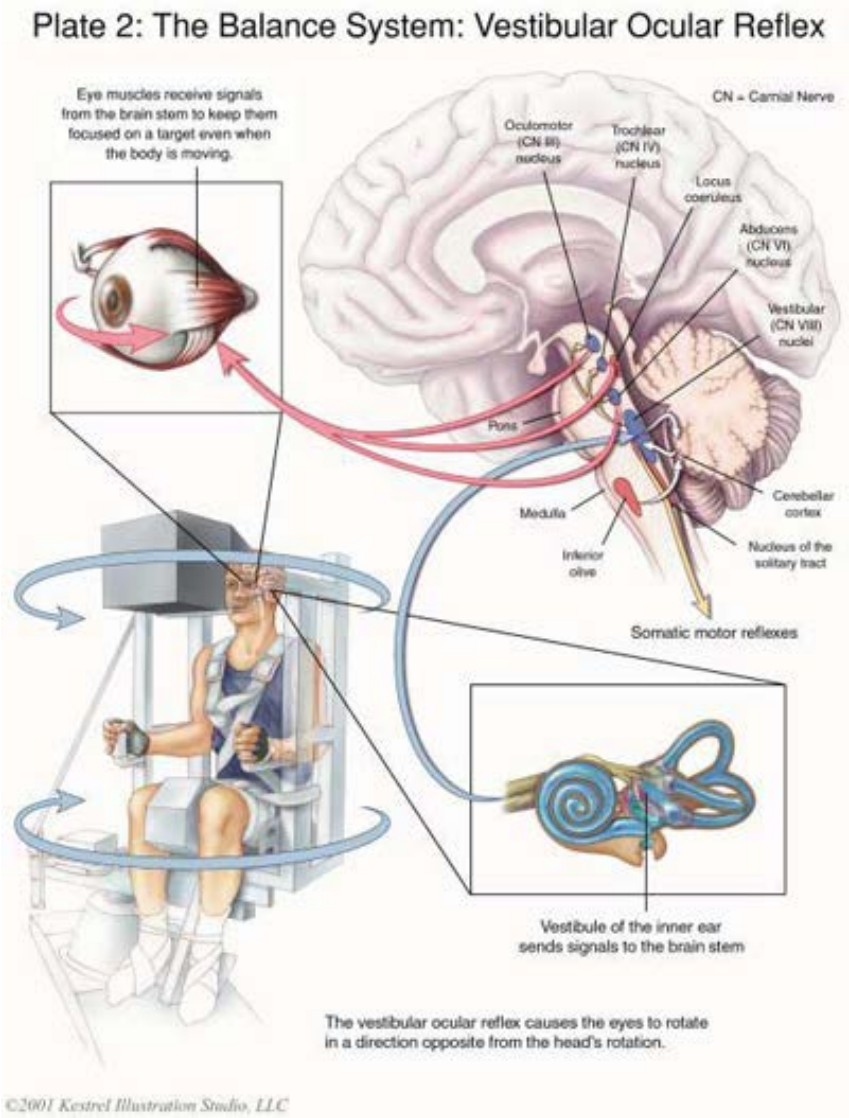
Notice the three nested loops

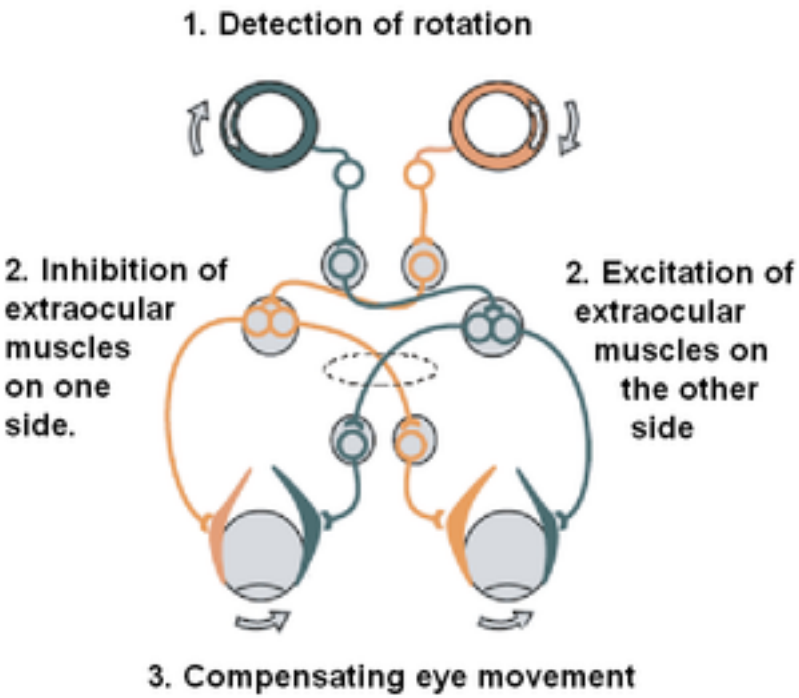
Feedback controller





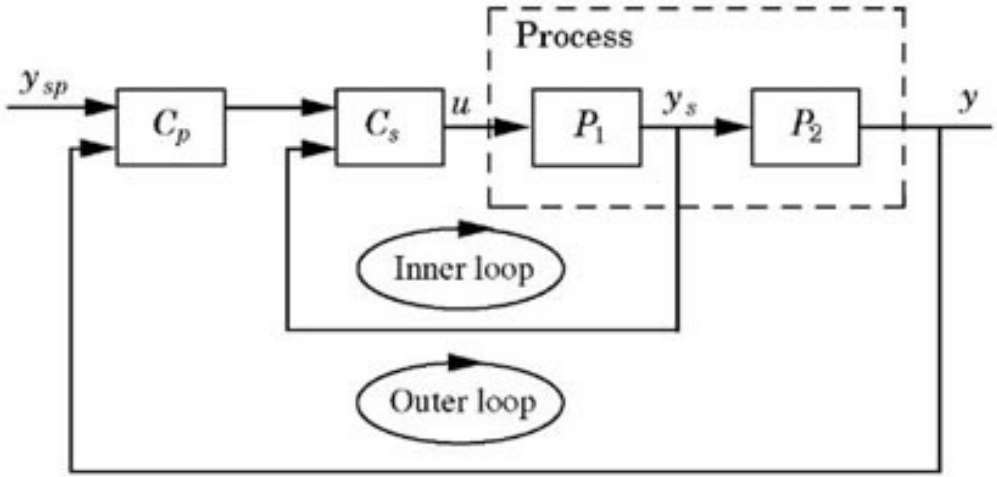
Feedback control and stability

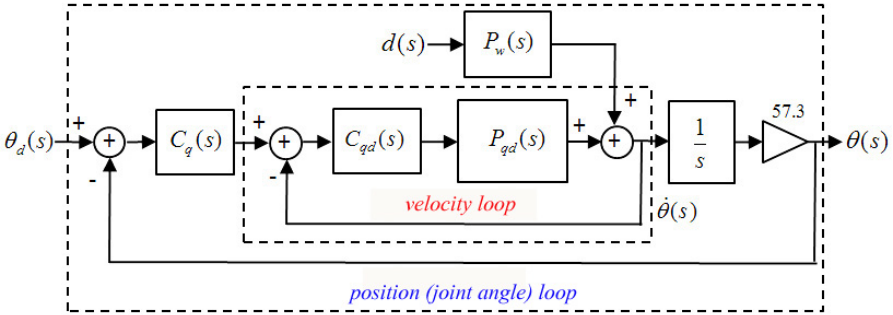




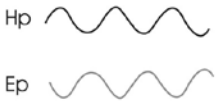
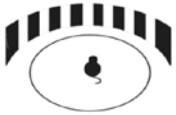
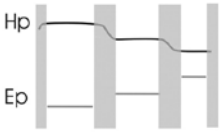
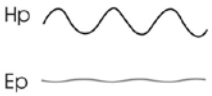
Cascade controller

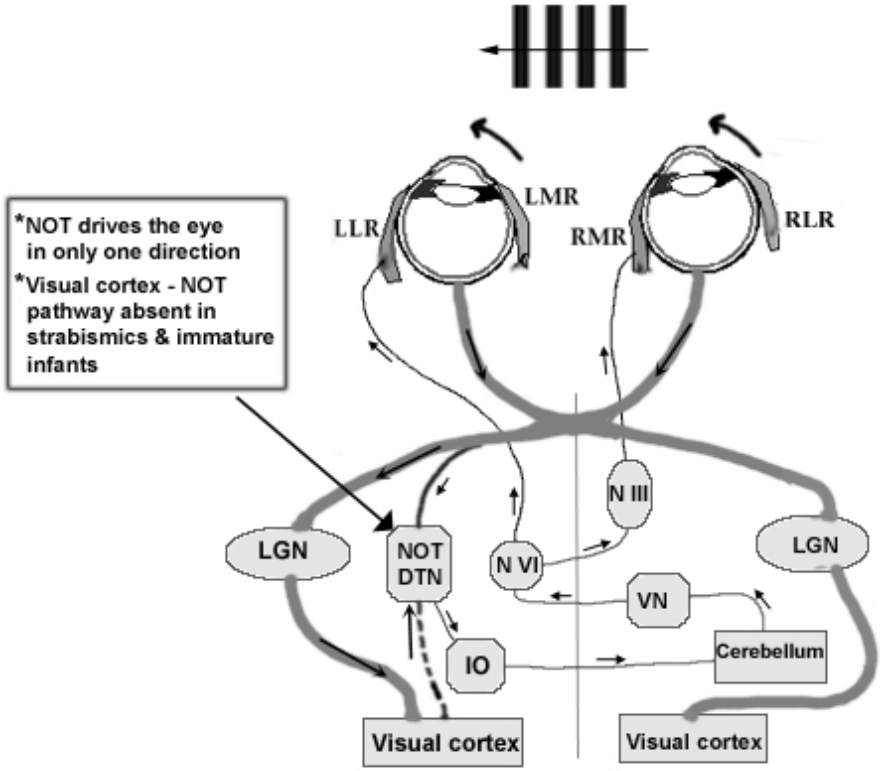
- Nested control scheme
  - Inner loop stabilizes outer loop at faster timescale





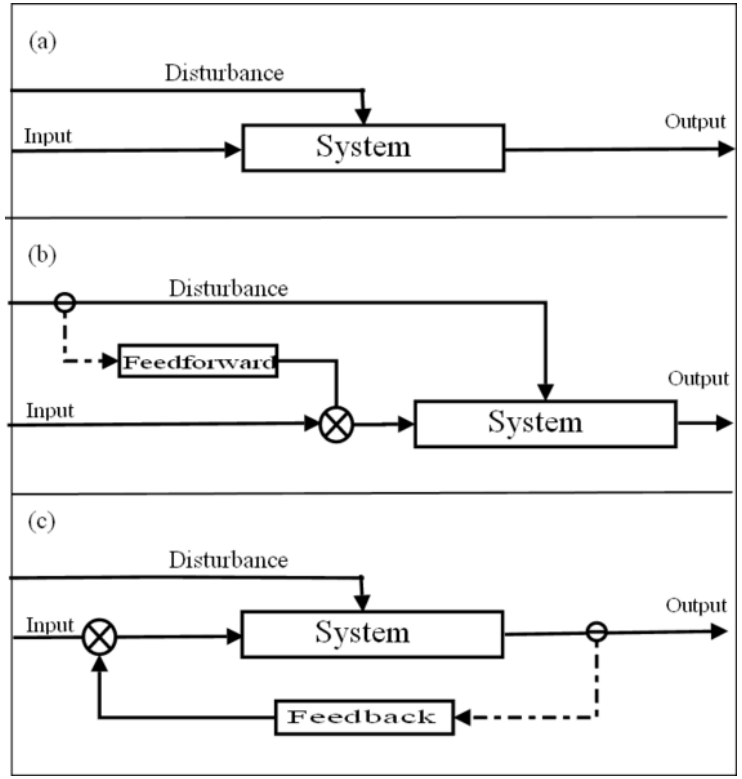
VOR gain interactions

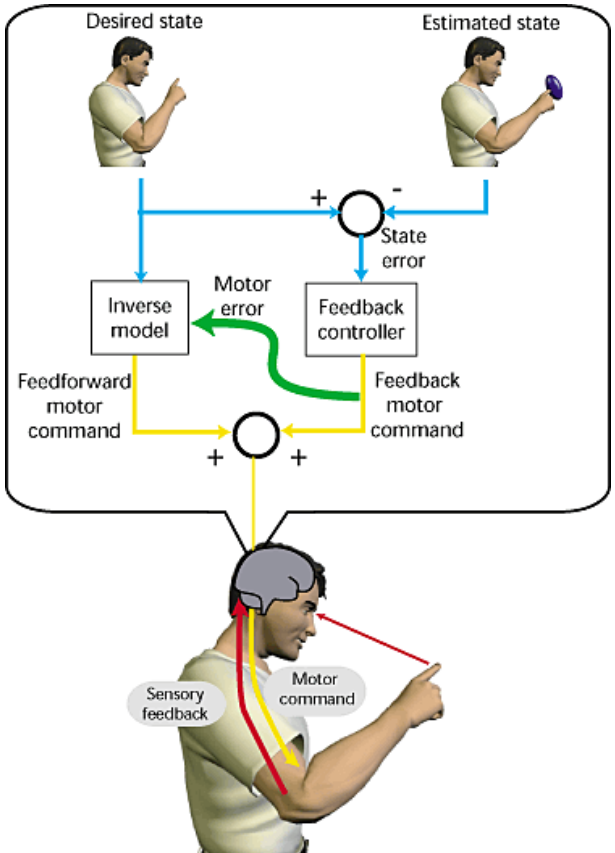
PARADIGM	Table and drum	Behavior	
Vestibulo-ocular reflex in light			Head and eye are moving.
Static eye position			Eye is driven to different Eccentricities in the orbit Neither head or eye are moving in retained sequences.
Visuo-vestibular conflict			Head is moving but eye movements are reduced or absent.
Optokinetic reflex			Head is not moving. The visual surround moves and produces eye movements



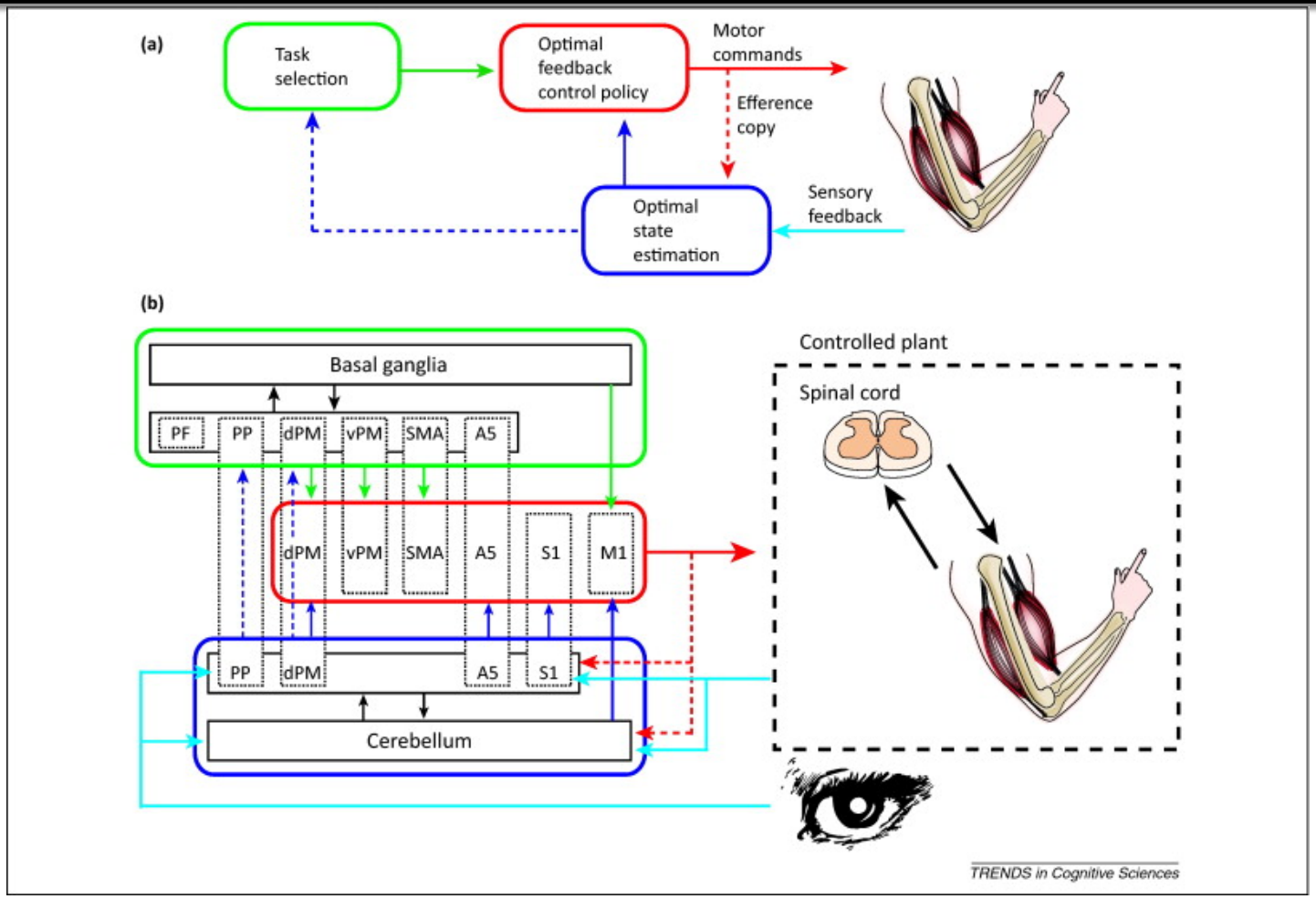
Feedforward controller

- Use internal model to mitigate delays, changing setpoints, etc





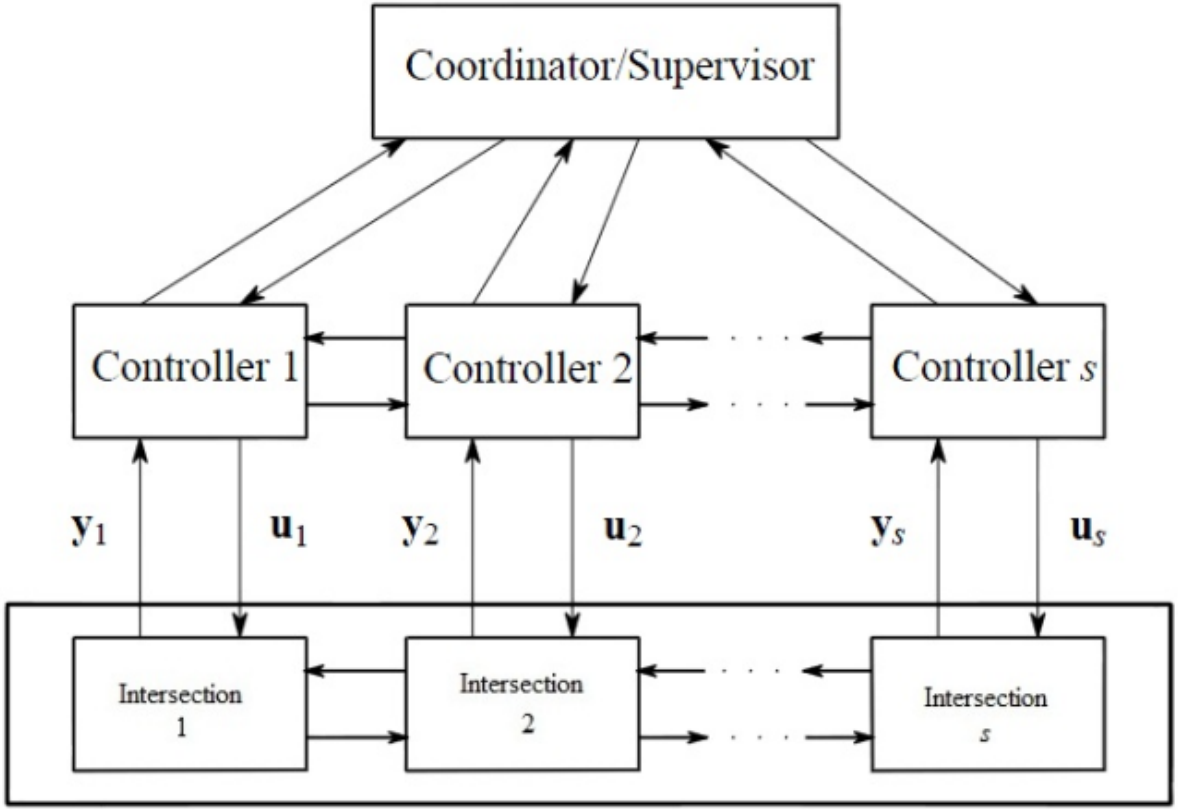
Voluntary control (reaching)



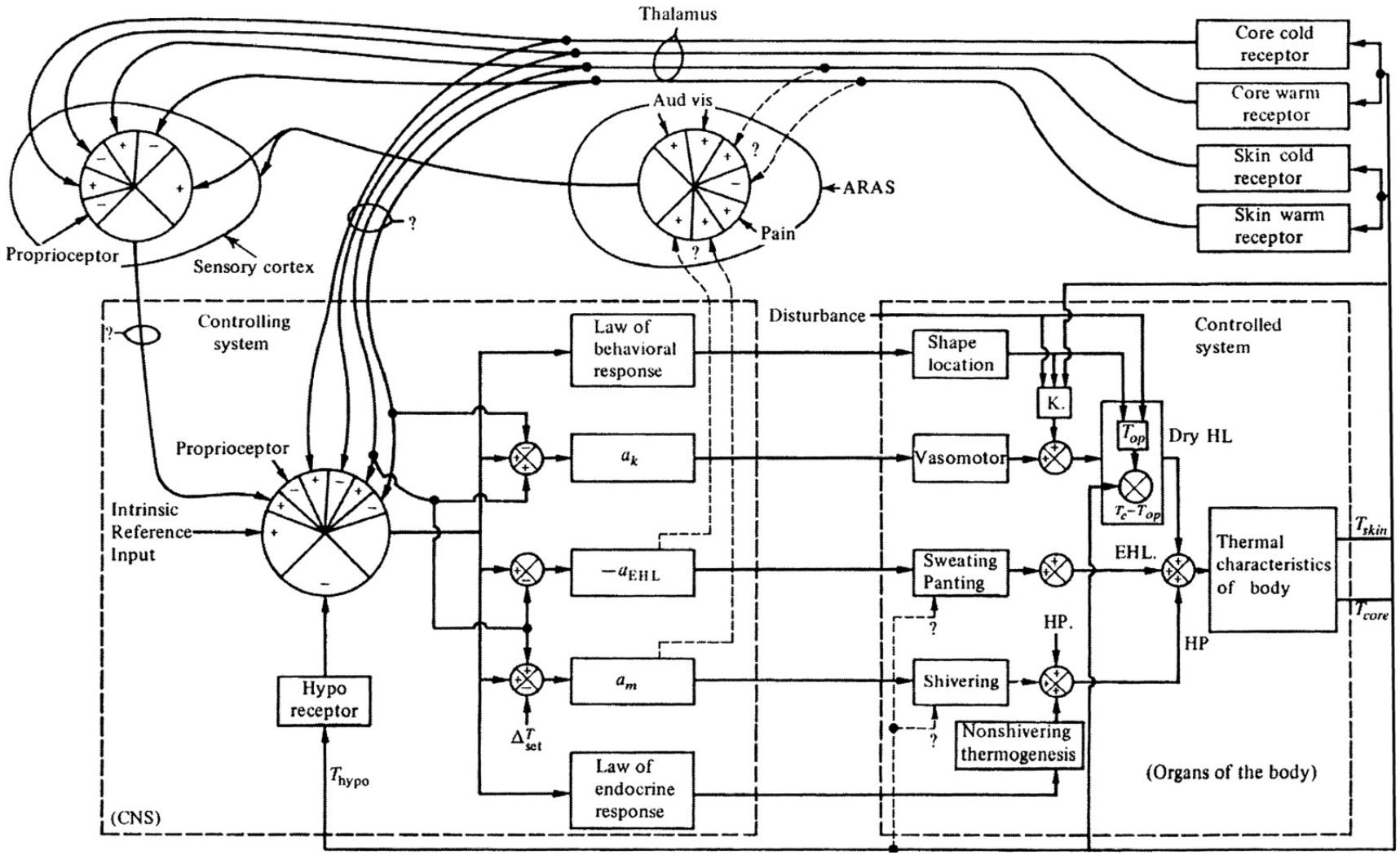
FROM: The computational and neural basis of voluntary motor control and planning. Stephen H. Scott

Hierarchical Controller

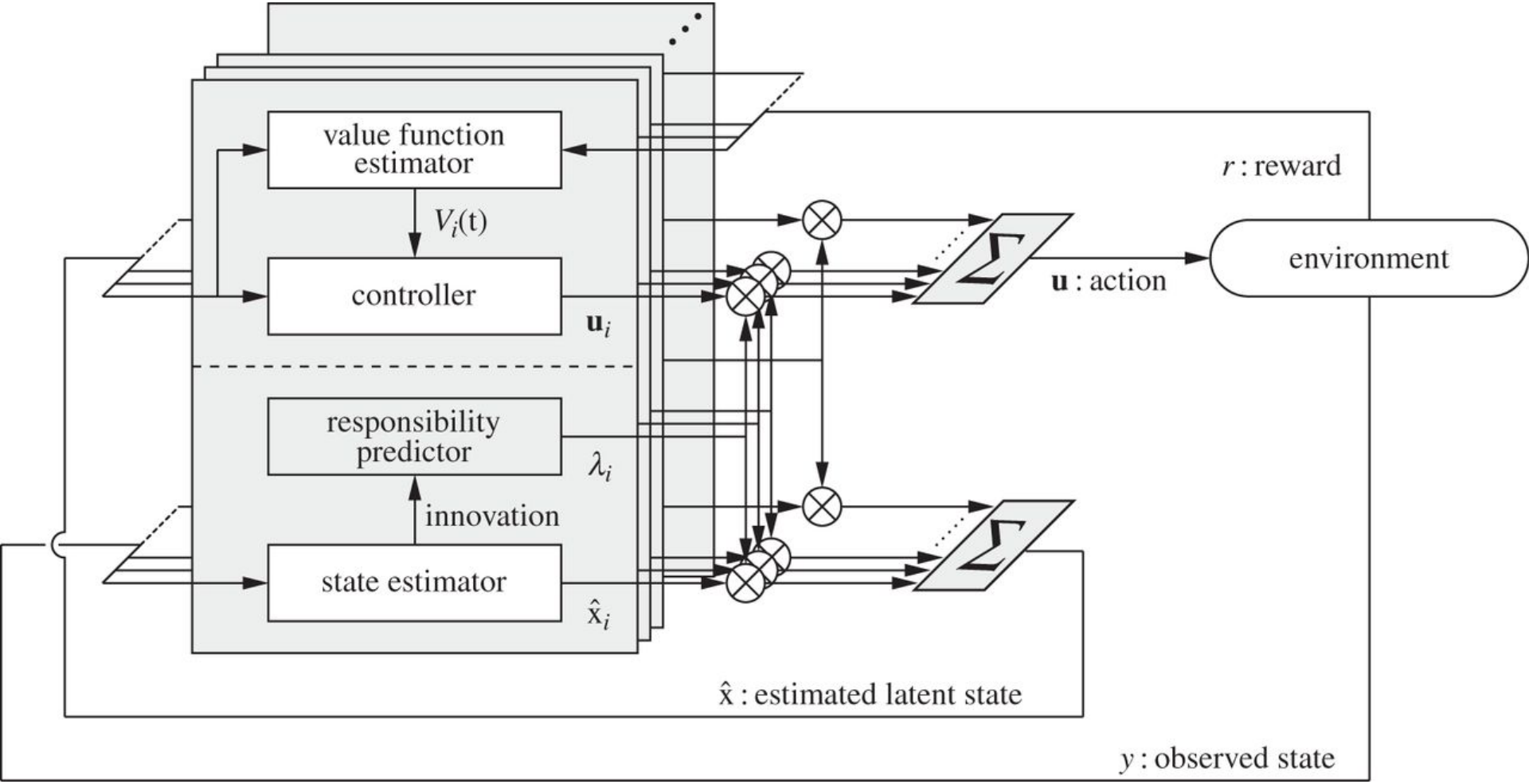
- Different behaviors coordinated and gated
  - Allows switching between completely different strategie



Temperature control (hierarchy)

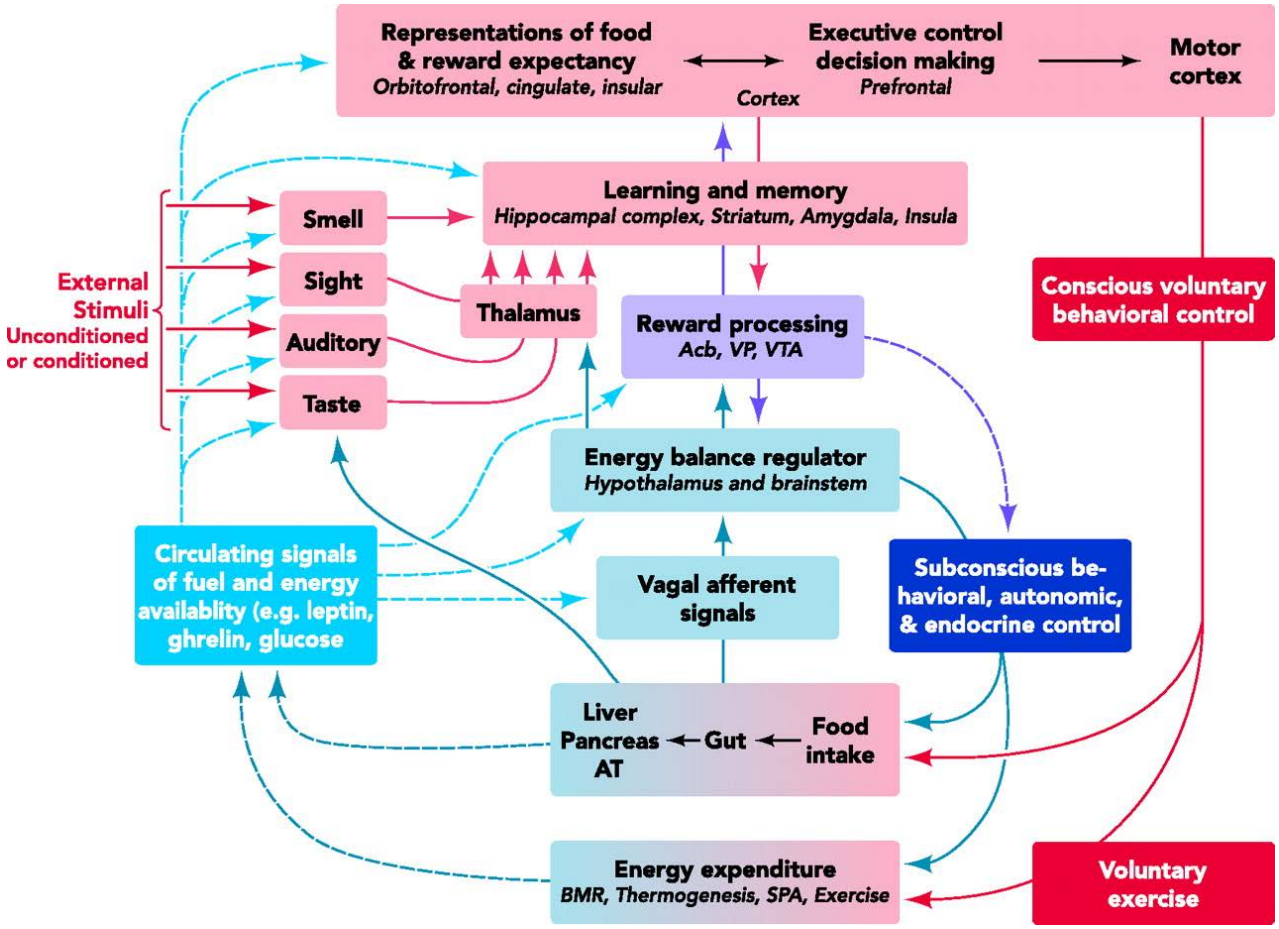


Hierarchical controller (MOSAIC)



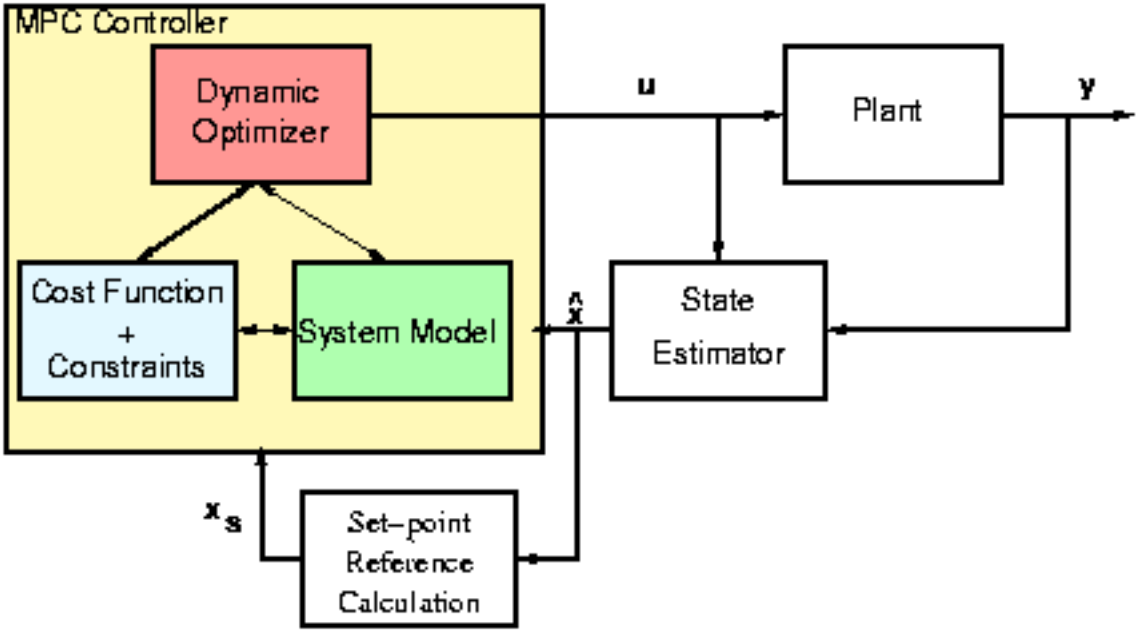
Complex coordinated – 'Need' directed

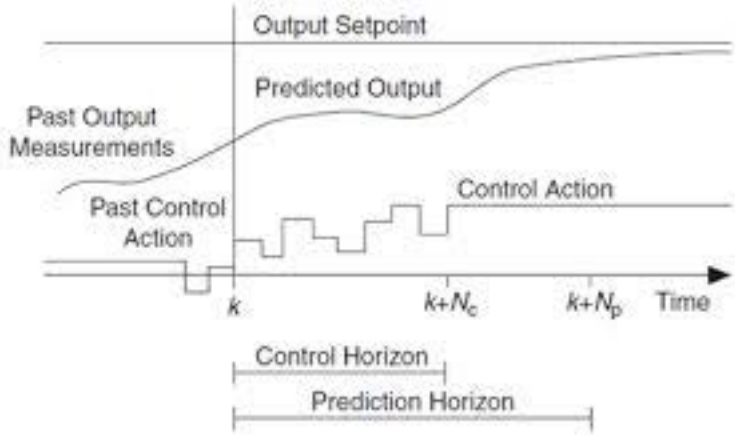
- Energetic homeostasis



Model Predictive Controller

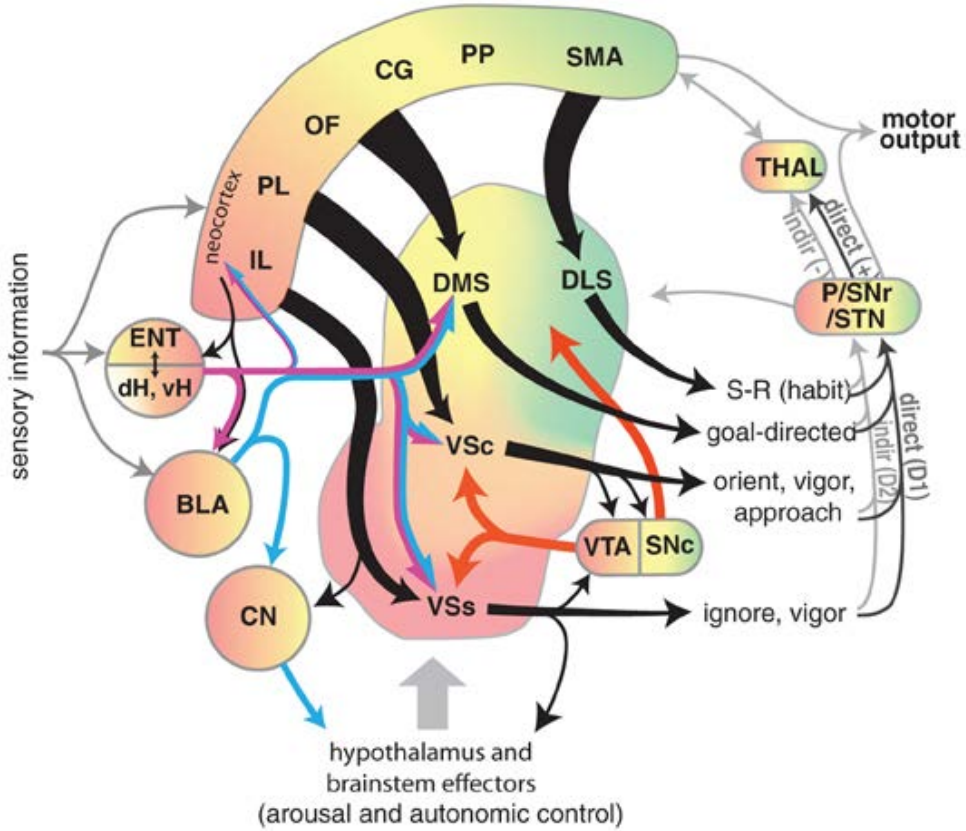
- Used extensively for tough problems
- Bounded Error Approximation to solving MDPs and Stochastic Optimal control problems





Concepts of Sensori-Motor control

- Loops
- Feedback
  - Setpoint, stabilization
- Feedforward
  - Delay handling, missing sensory information, transforming sensory information (state estimator)
- Coordination
- Cascade control
- Hierarchy
- Redundancy - Expanding degrees of freedom on output.



associations	[S, C] - Oa	[S, C] - [R, O]	S-R
association description	Pavlovian	model-based	model-free
effector coordinate system	autonomic	allocentric	egocentric
effector domain	somatic	cognitive/skeletal	skeletal
relative association speed	rapid	fast	gradual
response domain	emotive/motivation	goals	habits
response type	orient, approach, vigor	action by inference	typical response