

Spinal cord

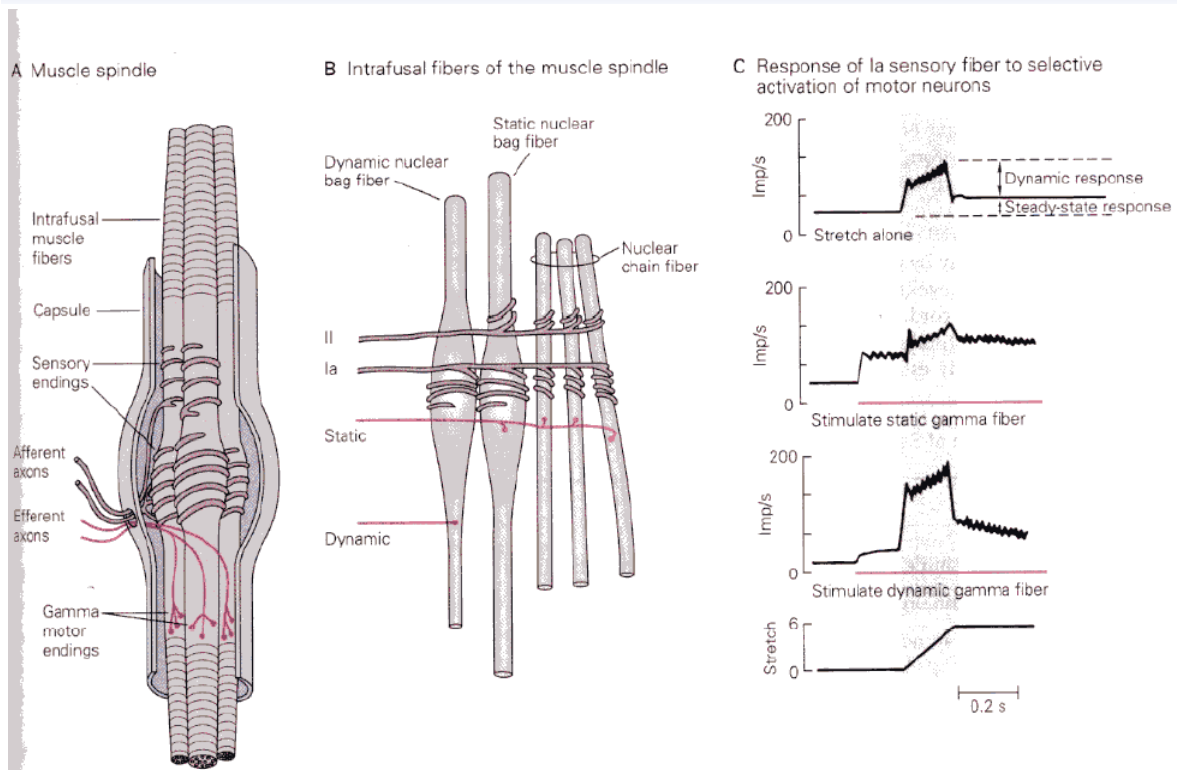
Emo Todorov

Applied Mathematics
Computer Science and Engineering

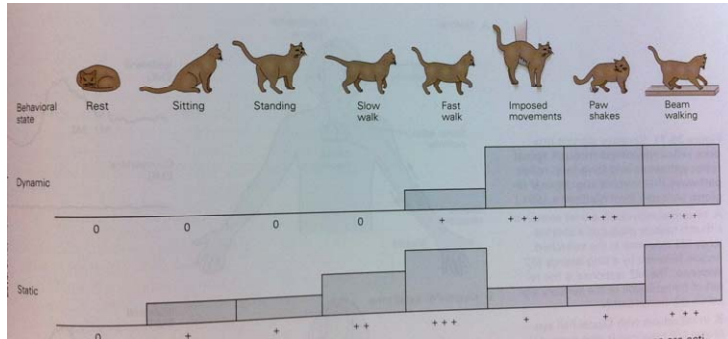
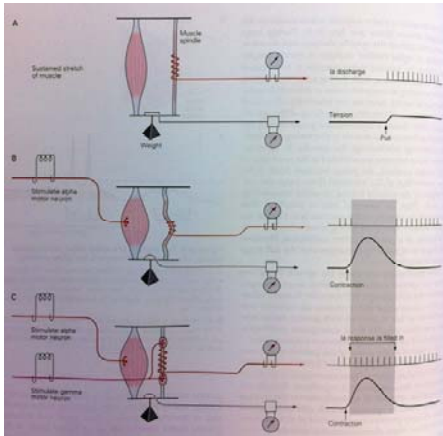
University of Washington

Muscle spindles: length and velocity sensors

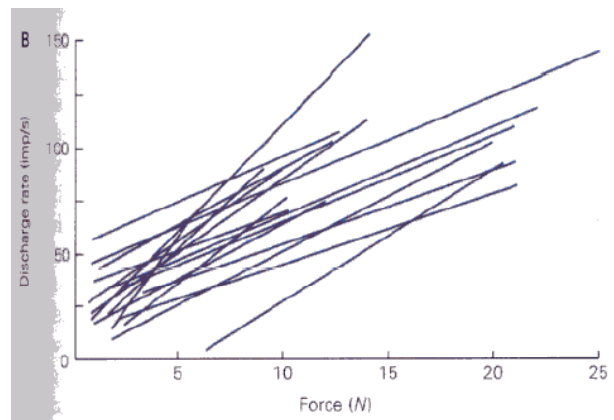
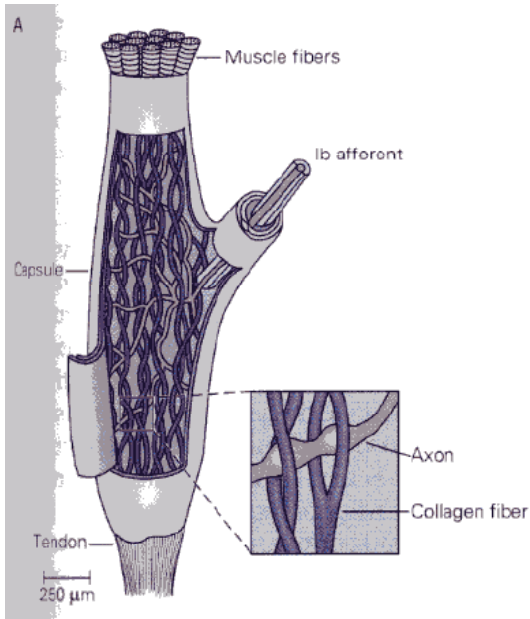
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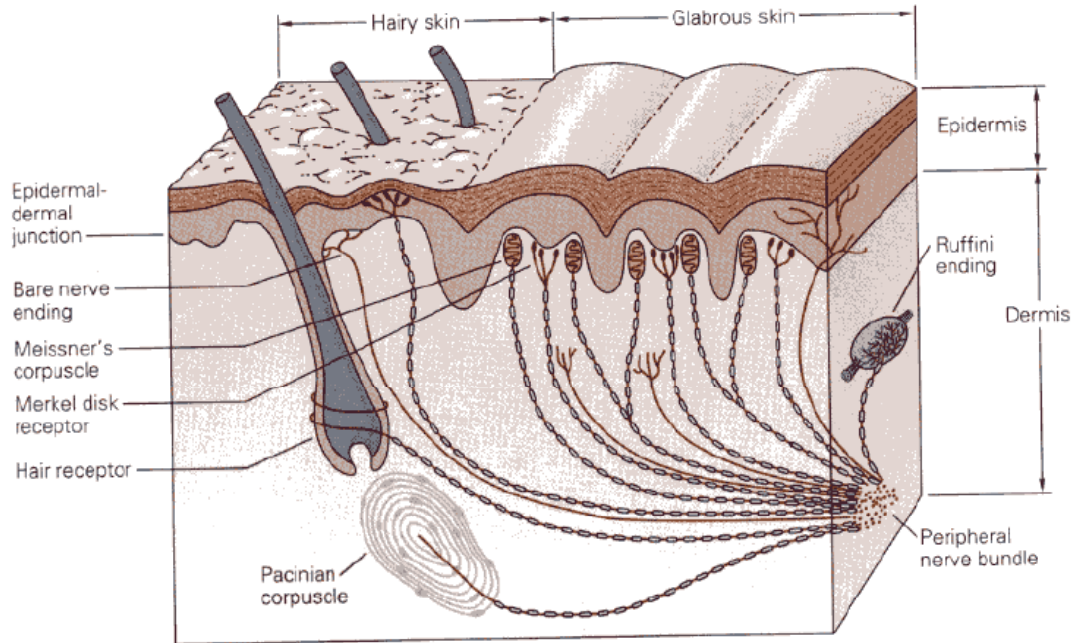
Gamma motoneurons



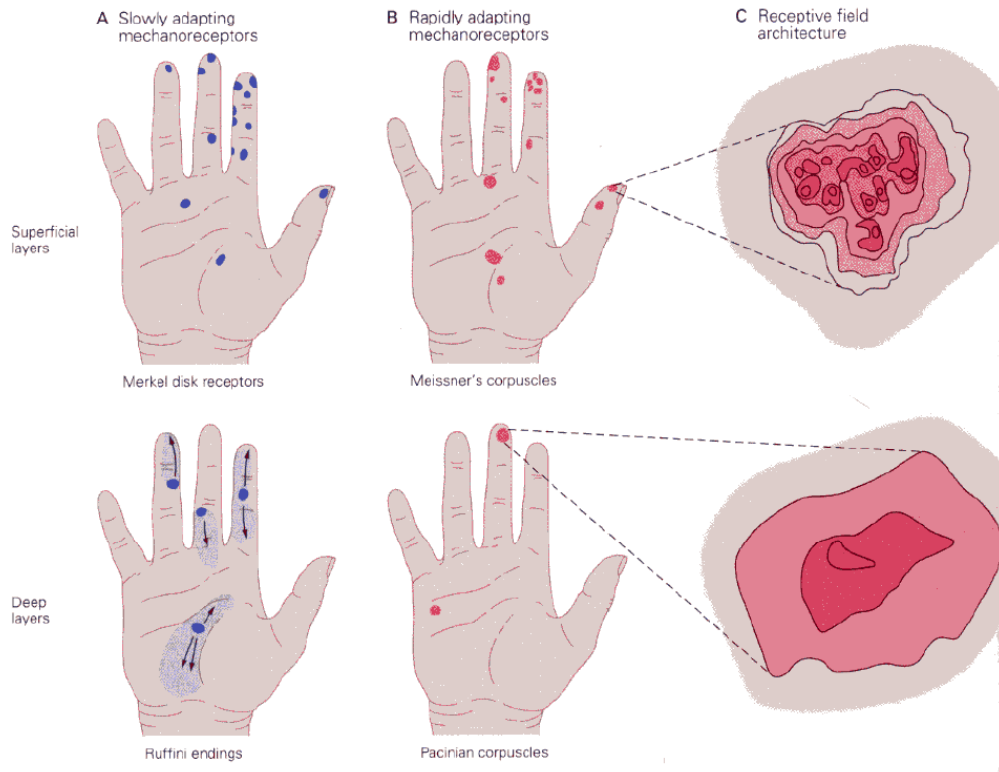
Gogli tendon organs: force sensors



Tactile sensors

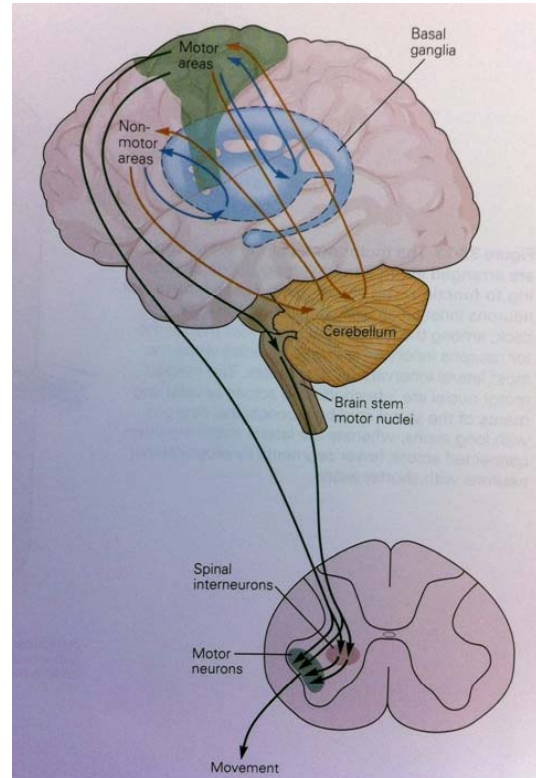
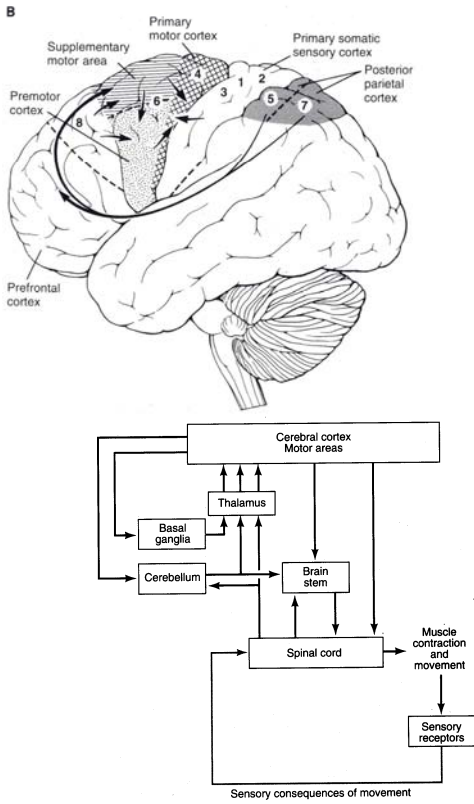


Properties of tactile sensors



Brain areas involved in motor control

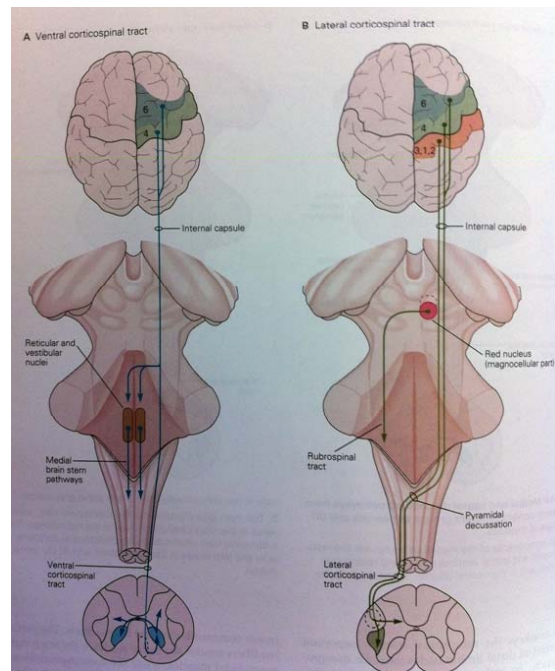
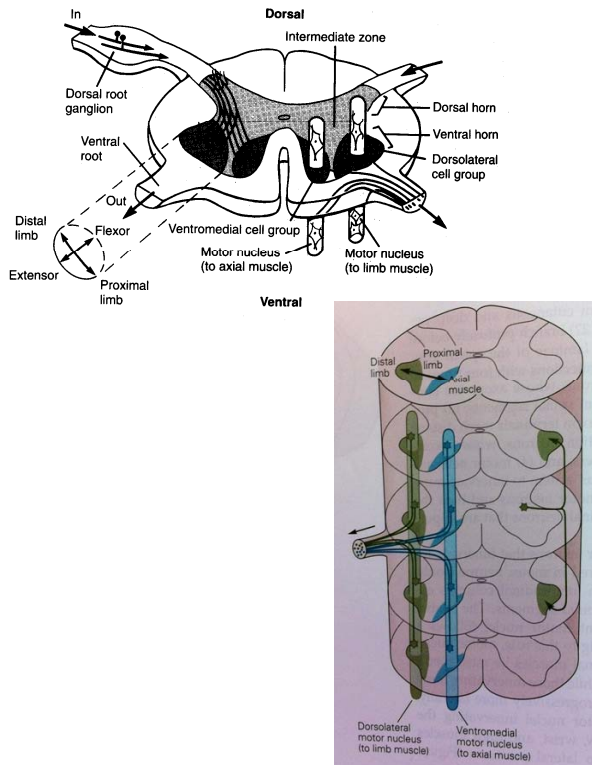
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Spinal cord connectivity

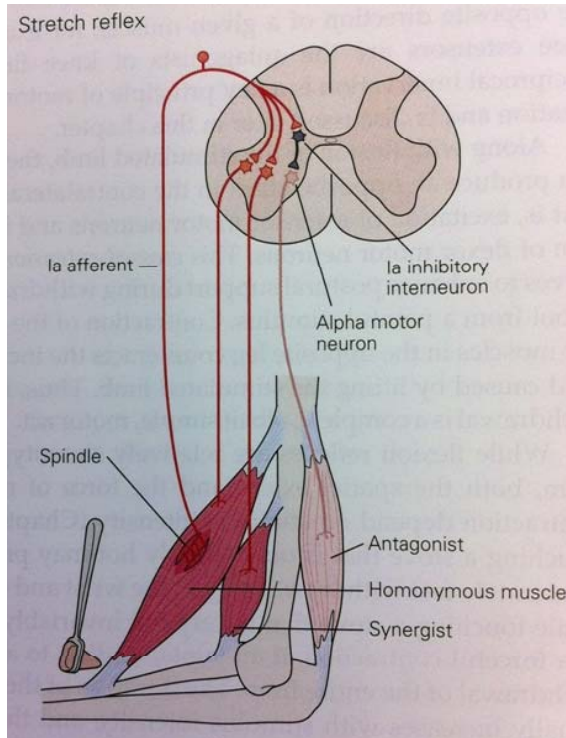
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Course of afferent fibers Location of motor nuclei



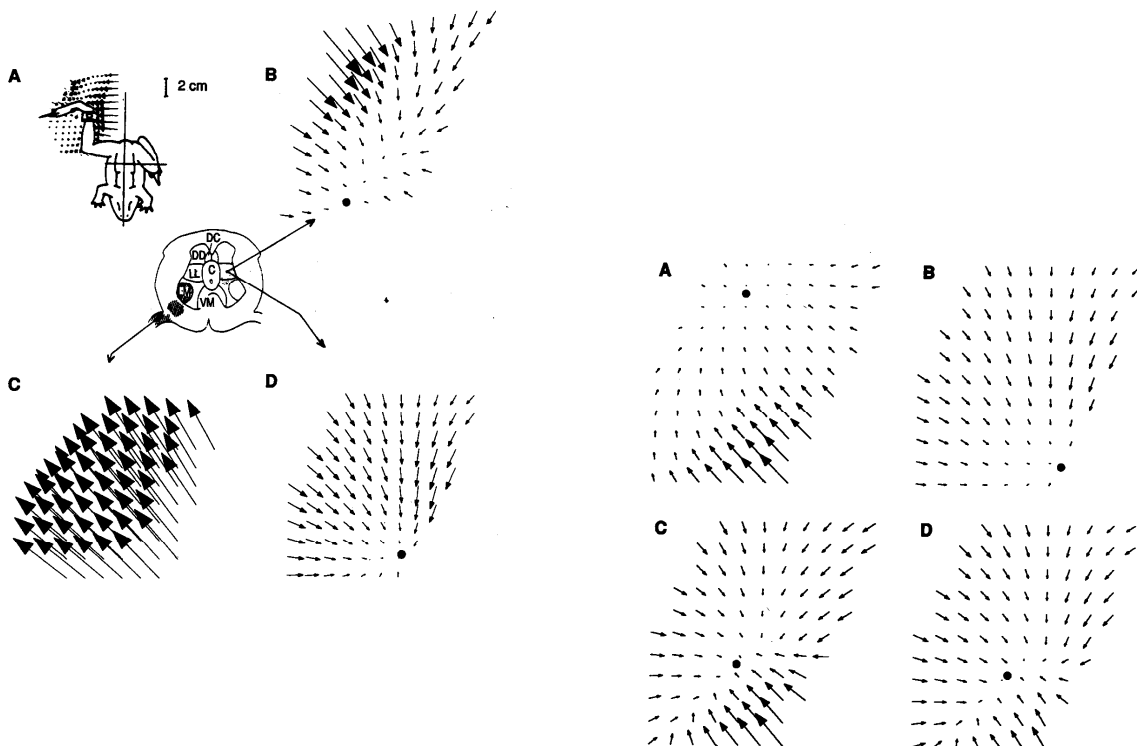
Stretch reflex

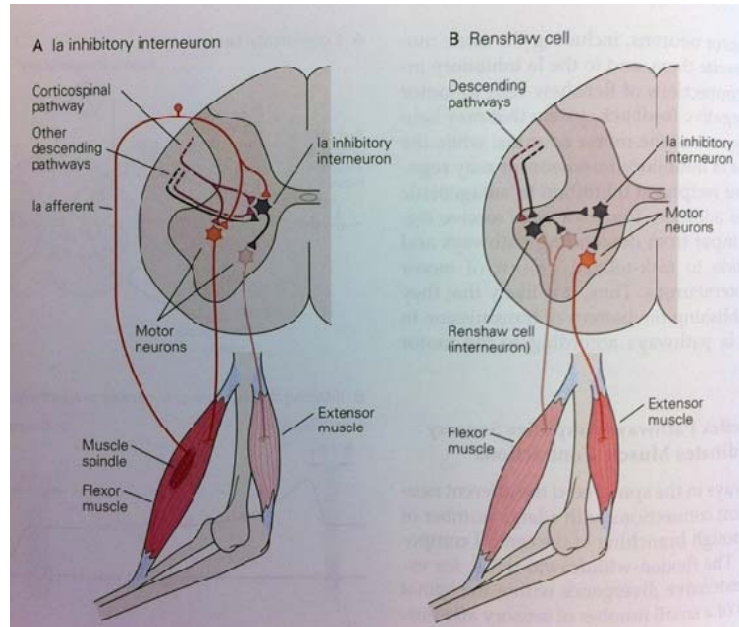
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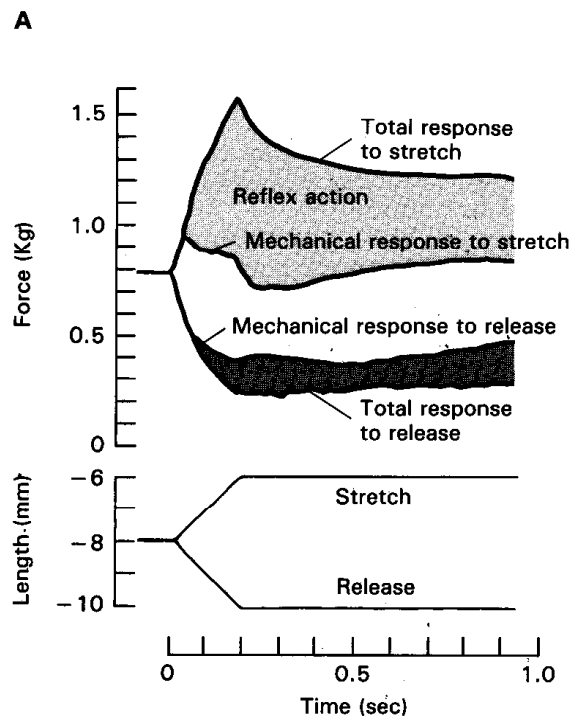
Spinal force fields in the frog

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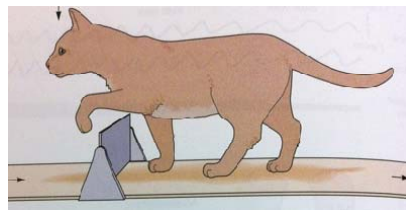
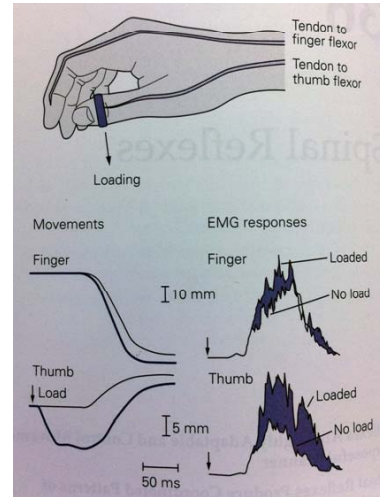
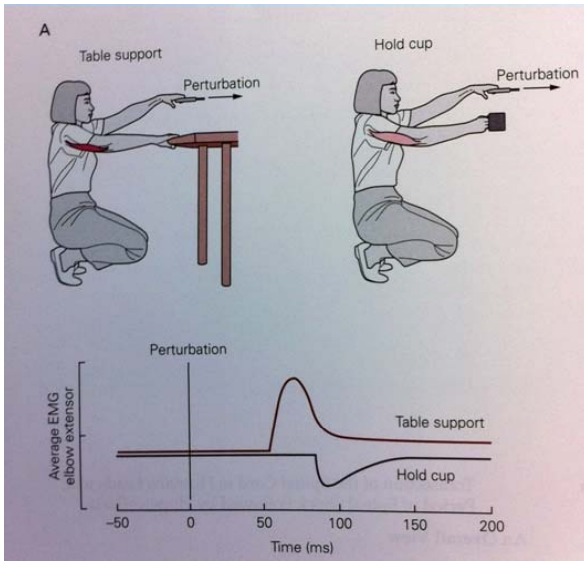




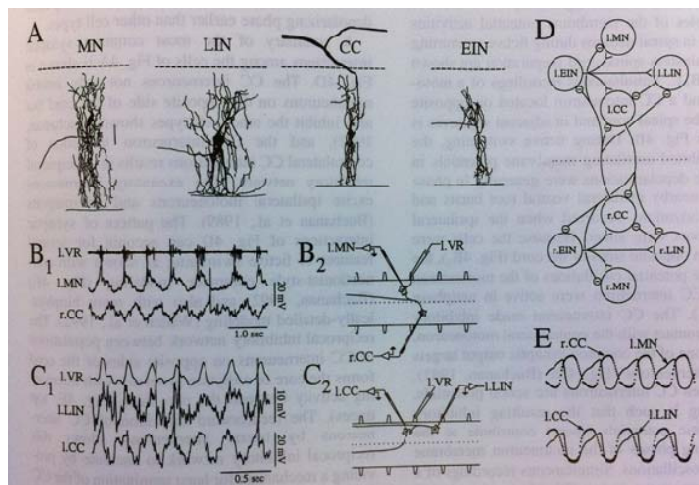
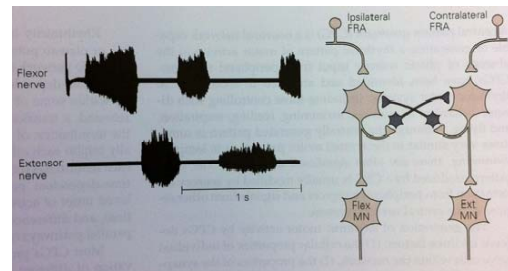
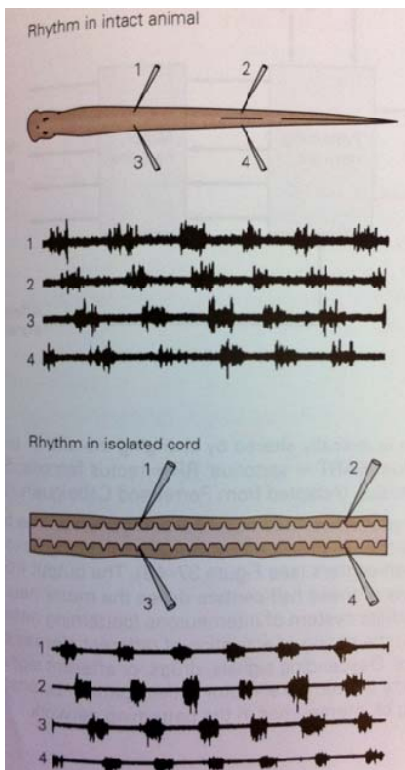
Muscle and reflex complement each other

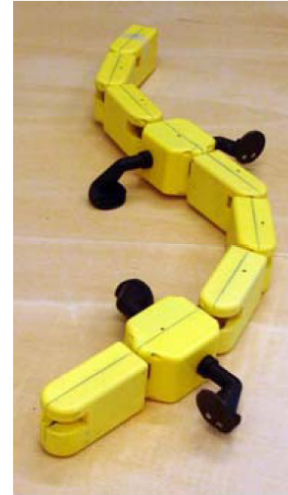
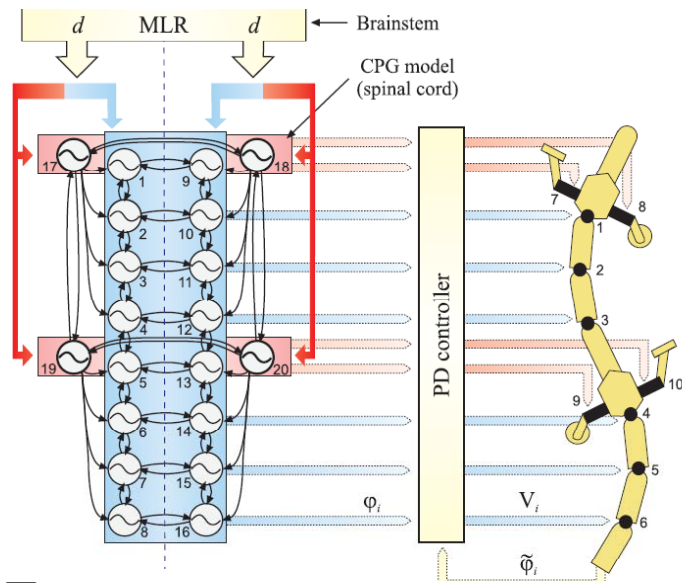


Reflexes are smart



Central Pattern Generators



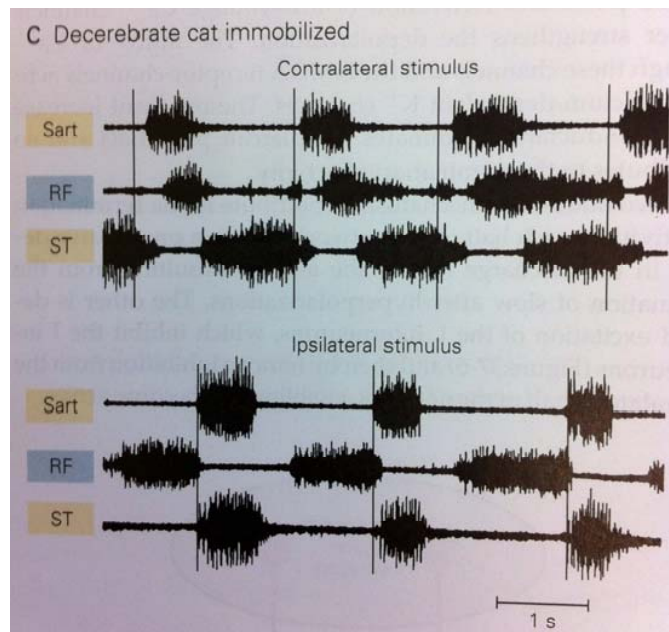


$$\dot{\theta}_i = 2\pi v_i + \sum_j r_j w_{ij} \sin(\theta_j - \theta_i - \phi_{ij})$$

$$\ddot{r}_i = a_i \left(\frac{a_i}{4} (R_i - r_i) - \dot{r}_i \right)$$

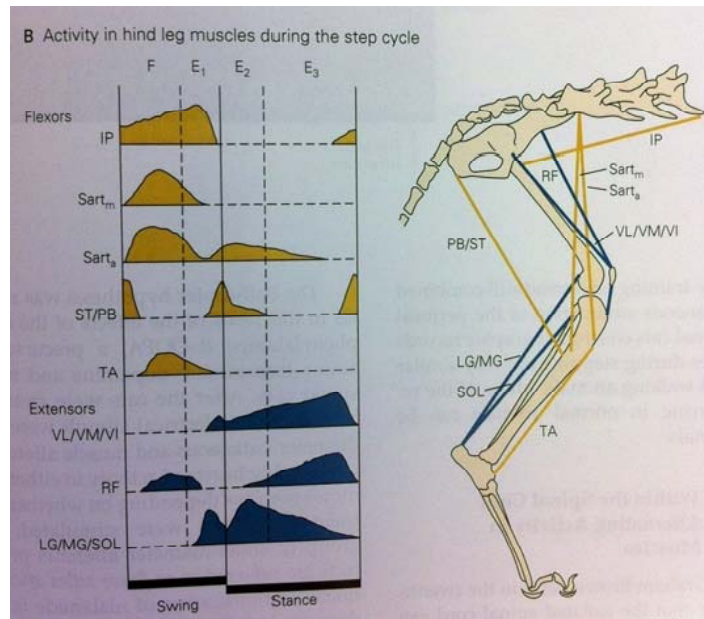
$$x_i = r_i (1 + \cos(\theta_i))$$

Walking in spinalized cats



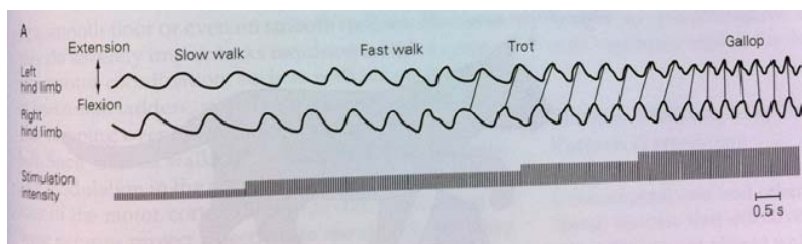
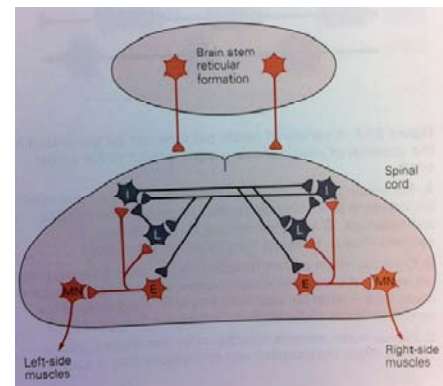
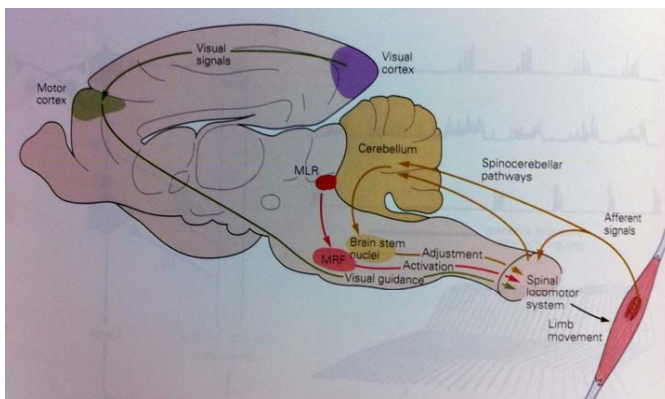
Complex patterns of muscle activity

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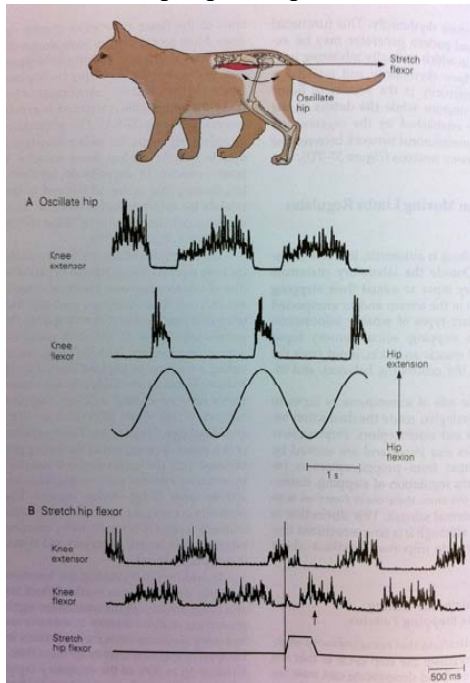
Brain-stem modulation

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Sensory modulation of walking

proprioceptive



visual

