Spinal reflexes and motor control

The CIRCUITRY of the myotatic reflex as a regulator of muscle length.

The myotatic circuitry makes the muscle more difficult to stretch, i.e. it appears to make the muscle “stiffer.”

One can speak of the stiffness of the myotatic circuitry. How much additional force is produced by each additional unit of stretch.

Muscles that face changing loads have the myotatic machinery.

Gamma motor neurons keep the spindle “on the air” as the whole muscle shortens, allowing it to continue to function as a transducer of muscle length.

But, this is not the only function of the gamma innervation of the spindle!!!

Intrafusal fiber

Extrafusal fiber

The Gamma Loop

1. γ motor neurons activated
2. Annulospiral ending stretched
3. Ia activated
4. α motor neuron activated
5. Muscle contracts

So the gammas could in principle control the alphas by themselves

Merton’s Follow-up Length Servo Hypothesis

Gamma motor neuron activity alone specifies a new equilibrium (desired) length by imposing stretch on the annulospiral ending. The muscle shortens until there is just the right amount of Ia and alpha activity to hold the muscle at the specified length.
Servomechanism: An automatic device for the control of a large power output by means of a small power input or for maintaining correct operating conditions in a mechanism. It is a type of feedback control.

Prediction: If Merton is right, $\gamma$ and Ia discharge should accelerate before the $\alpha$ activity increases.
Feedback Signal

Muscle (Controller)

Mass of load

Muscle length

Spindles (transducers)

Motor neurons

Muscular force

α

γ

External forces

Control Signal

EMG

The follow-up length servo hypothesis cannot be correct.

Prediction: If Merton is right, γ and Ia discharge should accelerate before the α activity and EMG activity increase.

The gamma motor neurons have at least two identifiable functions:

- They keep the spindle ‘on the air’ as a stretch receptor as the extrafusal fibers vary in length.
- They participate in servo-assisted contraction by increasing their discharge beyond that needed to keep the spindle ‘on the air’.

Alpha-gamma co-activation could implement servo-assistance.

The low-power spindle machinery not only keeps the spindle “on the air” but via the gamma loop boosts the excitation of the high-power extrafusal muscle.

Prediction of the servo-assistance idea: during isotonic contraction, Ia activity should increase as the muscle shortens.
The Length-Tension Diagram of a Muscle

γ-loop acceleration of Ia input to α motor neurons could also help compensate for the decrease in contraction force accompanying muscle shortening.

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<th>% Maximum force</th>
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<td>100</td>
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<td>80</td>
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<td>40</td>
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Sarcomere length (μm)

1.5
2.0

Equilibrium Point Model

K_L = K_R
K_L < K_R
K_L > K_R

K = Stiffness or spring constant

Stimulate spinal interneurons

Bizzi’s Experiment

The angle of a joint is a function of the forces developed by the muscles acting across the joint. When the forces are equal and opposite (no net force), the joint angle is stable. This represents an equilibrium point or position.

Equilibrium-point models of motor control postulate that joint angles are changed by changing the stiffness of the antagonist muscles to specify a new equilibrium position.
Recall…pain signals enter dorsal horn and synapse immediately

Circuitry of the Withdrawal Reflex

Flexor-Crossed Extensor Reflex

Hopping requires “dynamic rewiring” of the flexor-crossed extensor circuitry.

Long Spinal Reflexes

Inputs: vestibular, neck proprioceptors
Organized by circuits of propriospinal neurons
Inputs from: Vestibular system, Neck vertebrae

Propriospinal pathway