Muscle Receptors and Motor Control

Innervation of the Soleus Muscle of the Cat

<table>
<thead>
<tr>
<th>AFFERENT</th>
<th>Fiber type</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>Ia fibers</td>
<td>50 spindle primary endings</td>
</tr>
<tr>
<td>40</td>
<td>Ib fibers</td>
<td>45 Golgi tendon organs</td>
</tr>
<tr>
<td>50</td>
<td>II fibers</td>
<td>50 spindle secondary endings</td>
</tr>
<tr>
<td>[200-400]</td>
<td>IV fibers</td>
<td>pain, vasculature</td>
</tr>
</tbody>
</table>

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<tr>
<th>EFFERENT</th>
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<tbody>
<tr>
<td>150</td>
<td>alpha motor neurons</td>
<td>25,000 extrafusal muscle fibers</td>
</tr>
<tr>
<td>100</td>
<td>gamma motor neurons</td>
<td>300 intrafusal fibers in 50 spindles</td>
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</tbody>
</table>
The GTO is “in series” with the muscle. It can be activated by contraction of the muscle or by pulling on the tendon.

The GTO (Ib) provides a signal related to muscle force.

Effect of Contraction of a Single Motor Unit

Muscles used for fine control (e.g. muscles of hand and neck) have relatively more spindles (#/gram) than other muscles.

Soleus, Lat. Gastrocnemius

The spindle is situated ‘in parallel’ with the extrafusal fibers. Stretching the muscle stretches the spindle.
Nuclear chain fibers
Nuclear bag fibers

Muscle fibers, unlike neurons, have more than one nucleus – they are multinucleated.

Primary "annulospiral" endings
Secondary ("flower spray") endings

Ia fibers
Type II fibers

The Ia axon is sensitive to muscle stretch (length)
Muscle spindle afferents provide signals related to muscle length (static aspect) and rate-of-change of length (dynamic aspect).

Dynamic vs static transduction properties appear to depend on the physical characteristics of the intrafusal muscle fibers rather than the nerve terminals.

Gamma motor neuron activity is said to “bias” the spindle, i.e. make it more sensitive or more active at a given length.

Intrafusal fibers do not generate action potentials. Their contraction is modulated by temporal summation of end-plate potentials.
Note: To interpret the Ia input in terms of muscle length, the CNS must take account of the gamma activity or gamma bias. It must use some kind of efference copy for this.
Coactivation of alphas and gammas allows the spindle to adjust its length to the changing length of the muscle.
Myotatic Reflex and Reciprocal Innervation (Inhibition)

Dorsal horn
Dorsal root ganglion cell
Muscle spindle
Agonist muscle
Antagonist muscle
Inhibitory interneuron
alpha motor neurons
Motor end plate

Note that the gamma motor neurons are not targets of the Ia input.

Myotatic Reflex and Automatic Load Management

A. Initial Equilibrium
B. New Load
C. New Equilibrium
The myotatic reflex as a regulator of muscle length

With respect to muscle length, the Ia feedback is negative because an increase in spindle output results in a decrease in muscle length.

The myotatic reflex contributes to the stiffness of the muscle, i.e. its resistance to lengthening.

Increasing the sensitivity of the spindle by gamma bias would increase the 'stiffness' of the reflex.

Spasticity: Hypertonia, Hyperreflexia

The Myotatic Reflexes are Hyperexcitable

Spasticity can result from abnormally high gamma activity.

Because this has its effect via the Ia afferents, spasticity goes away if the dorsal roots are cut.