

Lecture 23 -- Spinal Reflexes -- Krakauer

(referenced figures are in fourth edition of *Principles of Neural Science*)

Introduction

1. The place of spinal reflex circuits in the motor hierarchy.
2. For the accurate control of movement, a continuous flow of sensory information is important both visually and from receptors in the moving part itself. Any type of receptor in the moving body part that can give movement or position information is called a **proprioceptor**. These include the muscle spindle, the golgi tendon organ (GTO), cutaneous receptors, and joint receptors.
 - The **GTO** (Box 36-3) lies in *series* with the muscle and tendon and is sensitive to changes in *tension*.
 - The **muscle spindle** (Box 36-1A) lies in *parallel* with the muscle and tendon and is sensitive to changes in *length*. There are up to 500 muscle spindles in a given muscle, depending on the muscle size, and each can range from 0.5 to 10 mm in length. Thus, they make up 10-20% of the length of the muscle. Muscle spindles are made up of specialized cells called **intrafusal** muscle fibers.
 - Notice in Figure 36.3 that the spindles have *both* sensory and motor innervation. This allows the CNS to alter the nature of incoming sensory information. Please take note of the 3 types of intrafusal fiber, the two types of sensory afferent, and the two types of motor neurons (called **gamma** to distinguish them from alpha motor neurons innervating the extrafusal muscle fibers).
 - Ramp and hold stretches of the soleus muscle in the **decerebrate** cat. Type II afferents respond to constant changes in length whereas Type Ia fibers are sensitive to rate of change of length. Importantly, they only show linear behavior for very rapid small changes in length. This means that, overall, muscle spindles are non-linear receptors because they only show linear behavior for small changes in length. We will come back to this non-linear behavior later.
 - Response of Ia to gamma activation (Fig 36-3C). Why have gamma activation? Because it enables muscle spindles to continue sensing changes in muscle length (Fig 36.9).
3. Definition of a reflex: “ a stereotypical motor behavior, elicited by a unimodal afferent, whose magnitude and timing are determined respectively by the intensity and onset of the stimulus”
4. This definition is correct but does not convey the fact that the spinal circuits responsible for reflexes can be used for voluntary behaviors. The idea that there is one stereotypical response to one afferent input is too rigid because the reflex circuit can be modified, through interneuronal connections, to produce an alternative output. The essential point is that a given reflex circuit produces a stereotypical behavior when stimulated under artificial circumstances such as a tendon tap or a decerebrate preparation, but that the same circuit can act in conjunction with other modifiable connections in a normal animal to produce a different behavior. Patients who suffer spinal cord injuries will develop abnormally enhanced reflexes: they become spastic

and hyperreflexic. These reflexes are disengaged from descending control and are a hindrance rather than useful.

Reflexes are highly adaptable and control movements in a purposeful manner.

Examples of adaptability :

- wrist muscles (Fig 36.1A)
- thumb loading (Fig 36.1B)
- classical conditioning of the finger flexion-withdrawal reflex (Fig 36.2)

How is such flexibility achieved ?

1. Spinal circuits consist of primary afferents, zero or more interneurons, and motor neurons. These circuits are highly adaptable because they can be modified by segmental and descending input.
2. Modifiable spinal circuits allow simplification of descending commands because spatio-temporal details can be taken care of at the level of the spinal cord.
3. Interneurons are the building blocks of spinal reflex circuits. Their presence allows the use of the same spinal circuit in a reflex or in a voluntary movement.
4. Types of interneuron: Ia interneuron (Fig 36-5A), the Renhaw cell (Fig 36-5B), the Ib inhibitory interneuron (Fig 36-7A).
5. Interneurons can be connected in various ways:
 - Divergence: **Flexion withdrawal reflex** (Fig.36-2)
 - Convergence & **Gating**: not all spinal circuits are active all the time. Higher centers determine which spinal circuits will be incorporated into a behavior depending on the task. The descending control signal acts on the interneuron to either inhibit it or excite it and thus modifies the effect the interneuron has on a nearby motorneuron and therefore allows other inputs to have greater or lesser effect on the motor neuron. In other words, by modulation of an interneuron(s), the contribution to a behavior of a particular spinal circuit can be changed, e.g. **state-dependent reflex reversal, the Ib inhibitory interneuron** (Fig. 36.7).

The monosynaptic stretch reflex (Fig. 36-2B).

1. Allows short-latency responses to unexpected perturbations (36-12 A & B).
 - alpha/gamma co-activation
 - Compensation for irregularities in the velocity of muscle shortening during isometric finger flexion.
2. Is an example of a negative feedback system
3. Linearizes the properties of muscle so it behaves more like a spring and so makes anticipatory control easier.

Spasticity.

Hyperreflexia: due to strong facilitation of the monosynaptic Ia pathway

Hypertonus: increased resistance to velocity-dependent muscle stretch

Relevant reading: chapter 36 in “Principles”