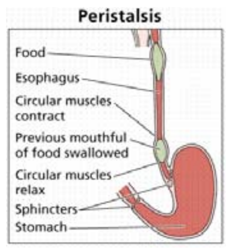
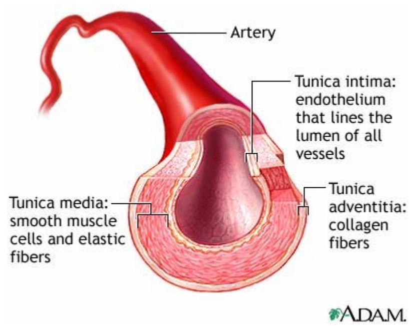
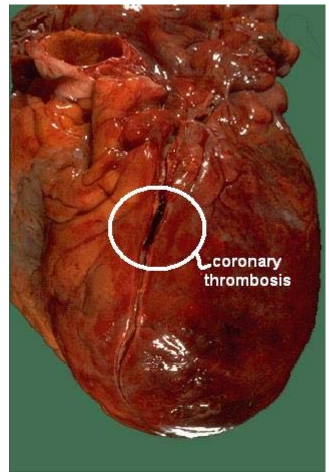
Other Kinds of Vertebrate Muscle







86

Smooth Muscle

-Lacks sarcomeres, isn't striated

-Walls of hollow organs – visceral functions
(GI tract, urinary bladder, uterus, blood vessels)

-Heterogeneous

-Innervated by autonomic NS

-Each fiber is individual cell with one nucleus

-No T-tubules

-Organized into bundles of actin and myosin anchored to dense bodies or to the plasma membrane

-Can be single-unit or multi-unit → Neurogenic (walls of blood vessels, iris)

-Myogenic and electronically linked via gap junctions
(peristaltic waves in GI tract)

87

Smooth Muscle

-Autonomic NT released from varicosities along axon, not at motor endplate, affecting many cells

-Poorly developed SR, calcium mostly across plasma membrane

-Several ways to regulate calcium concentration (no troponin)

-One is via calcium-calmodulin complex that then binds to caldesmon, removing caldesmon from blocking actin binding sites

-Some smooth muscle responds to stretch (vessels, GI)

-Processes all very slow and require little energy

88

Smooth Muscle

-Latch state

prolonged contraction, low energy use (0.3% striated)

Low rate of cross-bridge cycling

Mechanism not well-understood

(a) Vertebrate smooth muscle

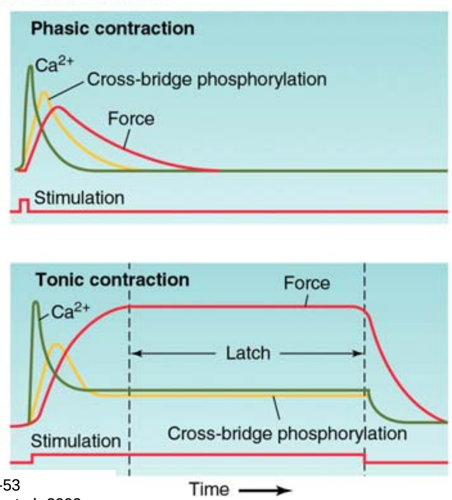
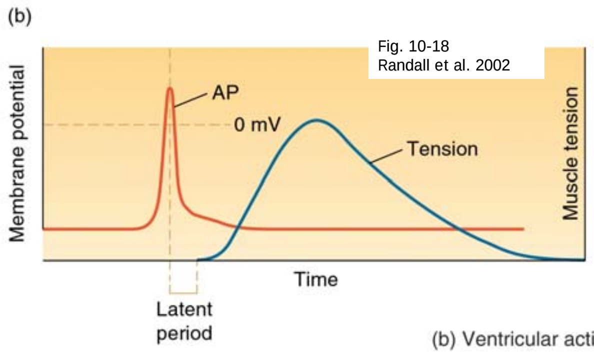


Fig. 10-53
Randall et al. 2002



Skeletal muscle

Cardiac muscle

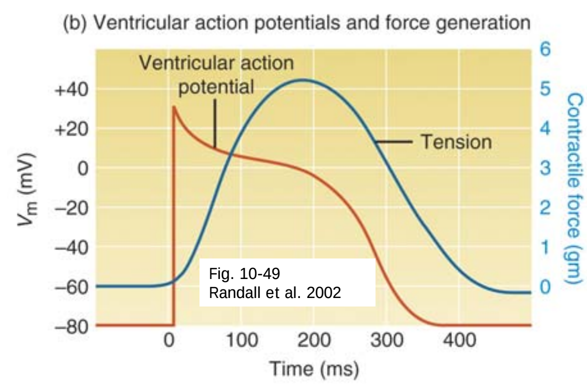


TABLE 17.3 Characteristics of the three major types of muscles in vertebrates *(Part 1)*

	Skeletal	Multiunit smooth
Structure	Large, cylindrical, multinucleate fibers	Small, spindle-shaped, uninucleate cells
Visible striations	Yes	No
Mechanism of contraction	Thick myosin and thin actin filaments slide by each other	Thick myosin and thin actin filaments slide by each other
Cross-bridge action regulated by Ca^{2+} ions	Yes	Yes
Innervation	Somatic nervous system initiates contractions	Autonomic nervous system initiates contractions
Spontaneous production of action potentials by pacemakers	No	No

Sources: After Silverthorn 2004; Randall et al. 2002; and Sherwood 2004.

TABLE 17.3 Characteristics of the three major types of muscles in vertebrates *(Part 2)*

	Single-unit smooth	Cardiac
Structure	Small, spindle-shaped, uninucleate cells	Branched uninucleate fibers, shorter than skeletal muscle fibers
Visible striations	No	Yes
Mechanism of contraction	Thick myosin and thin actin filaments slide by each other	Thick myosin and thin actin filaments slide by each other
Cross-bridge action regulated by Ca^{2+} ions	Yes	Yess
Innervation	Autonomic nervous system modulates contractions	Autonomic nervous system modulates contractions
Spontaneous production of action potentials by pacemakers	Yes	Yes

Sources: After Silverthorn 2004; Randall et al. 2002; and Sherwood 2004.

TABLE 17.3 Characteristics of the three major types of muscles in vertebrates *(Part 3)*

	Skeletal	Multiunit smooth
Hormones influence function	No	Yes
Gap junctions present	No	No (few)
Transverse tubules	Yes	No
Sarcoplasmic reticulum	Abundant	Sparse
Source of Ca^{2+} ions for regulation	Sarcoplasmic reticulum	Extracellular fluid and sarcoplasmic reticulum
Troponin and tropomyosin	Both present	Tropomyosin only
Ca regulation	Ca and troponin; tropomyosin–troponin complex moves to expose myosin-binding sites on actin	Ca and calmodulin; phosphorylation of myosin light chains
Speed of contraction (reflecting myosin ATPase activity)	Varies from fast to slow depending on fiber type	Very slow

Sources: After Silverthorn 2004; Randall et al. 2002; and Sherwood 2004.

TABLE 17.3 Characteristics of the three major types of muscles in vertebrates *(Part 4)*

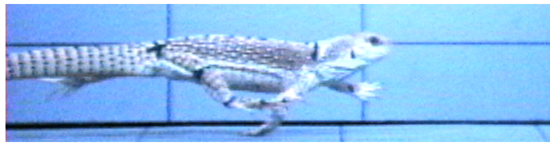
	Single-unit smooth	Cardiac
Hormones influence function	Yes	Yes
Gap junctions present	Yes	Yes
Transverse tubules	No	Yes
Sarcoplasmic reticulum	Sparse	Moderate
Source of Ca^{2+} ions for regulation	Extracellular fluid and sarcoplasmic reticulum	Extracellular fluid and sarcoplasmic reticulum
Troponin and tropomyosin	Tropomyosin only	Both present
Ca regulation	Ca and calmodulin; phosphorylation of myosin light chains	Ca and troponin; tropomyosin–troponin complex moves to expose myosin-binding sites on actin
Speed of contraction (reflecting myosin ATPase activity)	Very slow	Slow

Sources: After Silverthorn 2004; Randall et al. 2002; and Sherwood 2004.

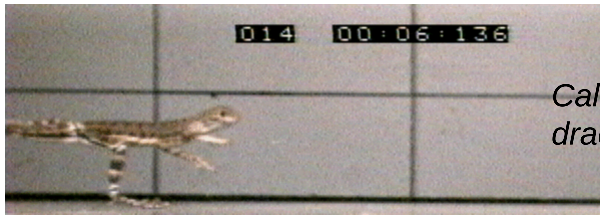
Movement and Behavior

Nervous System and Muscle

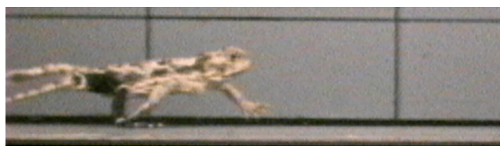
integration, control, feedback



Dipsosaurus dorsalis



Callisaurus draconoides



Phrynosoma platyrhinos

Thanks to Duncan Irschick and Steve Reilly

Animal Behavior,
Neurobiology

~Behavior Initiation

Complex

Bring together nervous, endocrine, muscular systems, etc.

Respond to situation(s)
Parallel Processing

Reflexes / Learned / Plasticity

→ Complicated Neuronal Circuitry

Simple Reflexes – basis of neuronal circuitry

Reflex Arc, Stereotypic Behavior

e.g., stretch reflex (patellar tendon)

- Tonic tension in muscle
- Important for maintenance of posture via negative feedback

- Only 2 neurons required

- monosynaptic reflex

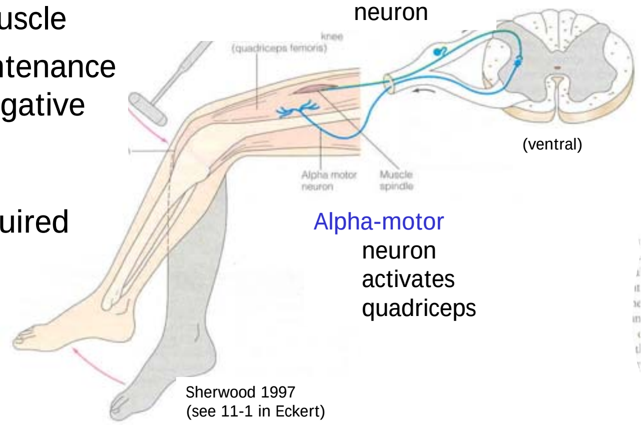


Figure 8-26 **Patellar Tendon Reflex (a Stretch Reflex)** Tapping the patellar tendon with a rubber mallet stretches the muscle spindles in the quadriceps femoris muscle. The resultant monosynaptic stretch reflex results in contraction of this extensor muscle, causing the characteristic knee-jerk response.

Simple Reflexes

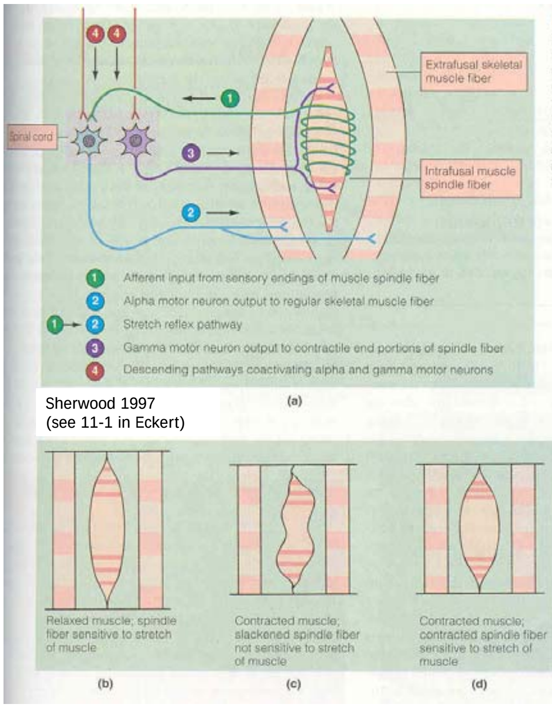
Stretch receptor = muscle spindle organ

- contains intrafusal fibers (as opposed to extrafusal)

- Sensitive to stretch (stretch -> APs)

- Need to be reset for new muscle length
- Gamma-efferent neurons innervate spindle

99



Sherwood 1997
(see 11-1 in Eckert)

Figure 8-25 **Muscle Spindle Function** (a) Pathways involved in the monosynaptic stretch reflex and coactivation of alpha and gamma motor neurons. (b) Status of a muscle spindle when the muscle is relaxed. (c) Status of a muscle spindle when the muscle is contracted upon alpha motor neuron stimulation. (d) Status of a muscle spindle when both the muscle and muscle spindle are contracted upon alpha and gamma motor neuron coactivation.

1. 1a-afferent neuron
2. Alpha-motor neuron
3. Gamma-motor neuron

c. Contracted muscle without 'reset' muscle spindle

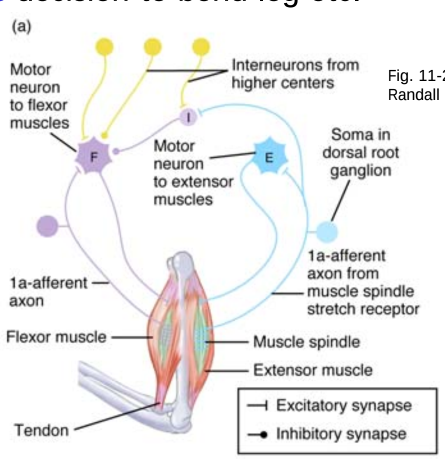
100

Simple Reflexes +

Other neurons become involved as well:

- 1a-afferents inhibit the antagonist muscle (Knee flexor ~hamstring)
- Conscious decision to bend leg etc.

- Limb



(b) Divergence

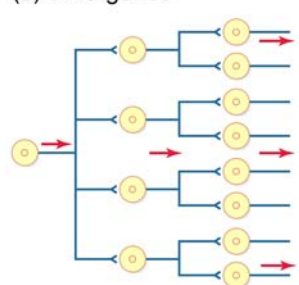
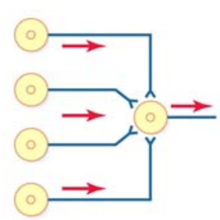


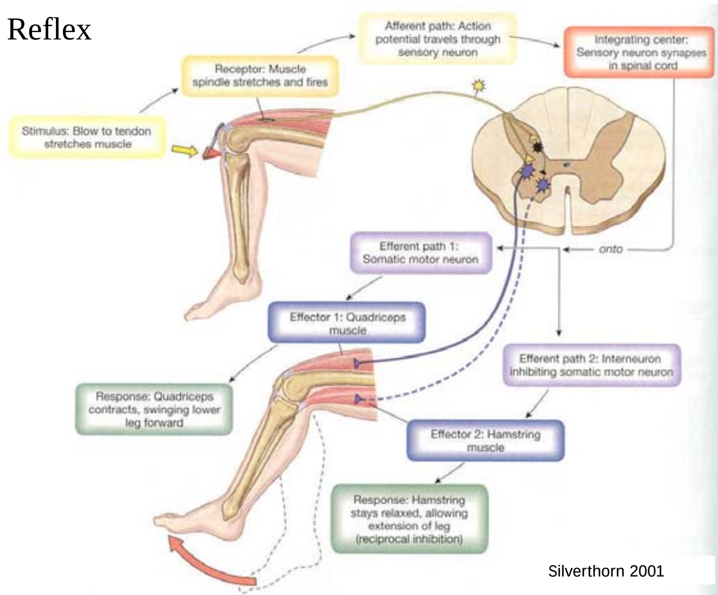
Fig. 11-2
Randall et al. 2002

(c) Convergence



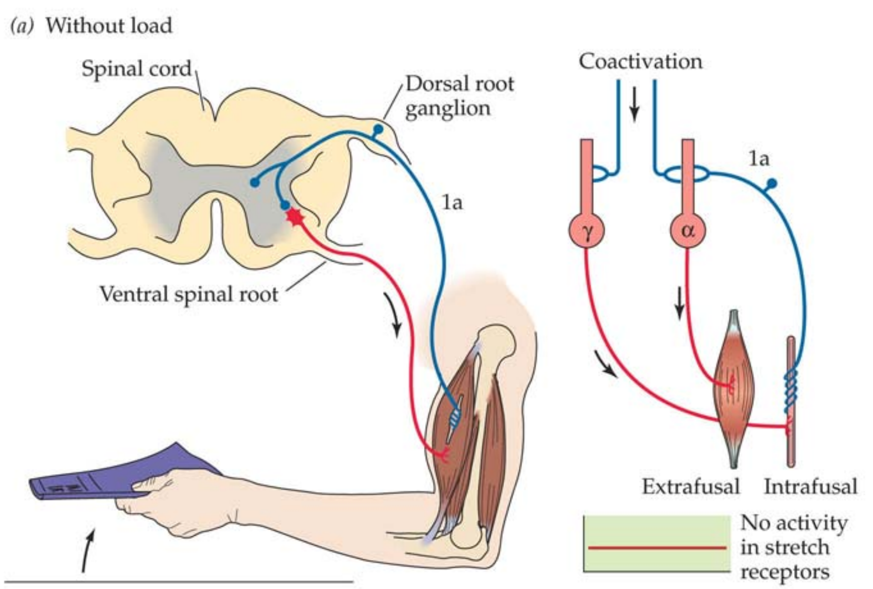
101

Stretch Reflex

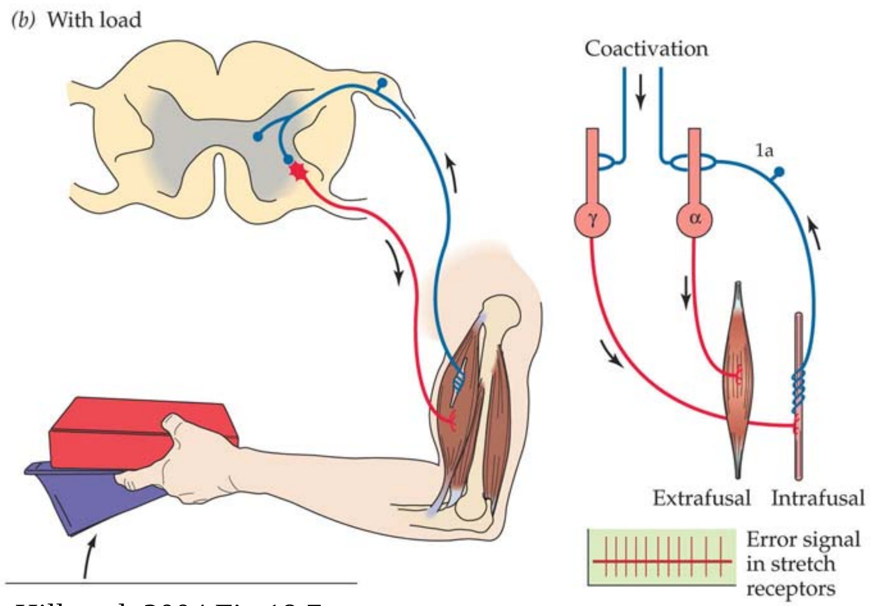


Silverthorn 2001

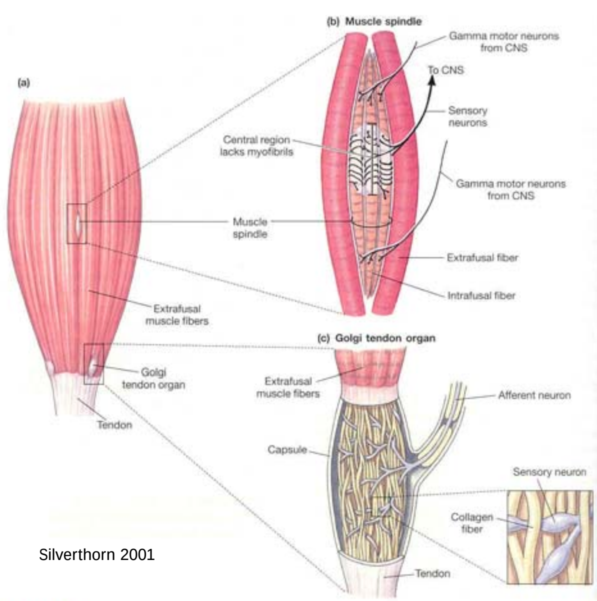
■ **Figure 13-7 The knee jerk reflex** The knee jerk or patellar tendon reflex is a monosynaptic spinal reflex in which a blow to the patellar tendon causes contraction of the quadriceps muscle (pathway 1). An integral part of the response is the polysynaptic reflex inhibition of the hamstring muscles (pathway 2).



Hill et al. 2004 Fig 18.7



Hill et al. 2004 Fig 18.7



■ Figure 13-3 **Sensory receptors in muscle** (a) Buried among the normal contractile fibers (extrafusal fibers) of the muscle are stretch receptors known as muscle spindles. Golgi tendon organs are receptors that link the muscle and the tendon. Contraction in extrafusal fibers is controlled by alpha motor neurons, and contraction of the muscle spindles is controlled by gamma motor neurons. The Golgi tendon organ does not contract. (b) The central region of the muscle spindle lacks myofibrils and cannot contract. Sensory nerve endings wrap around the central region and fire when the central section of the muscle spindle stretches. The ends of the muscle spindle contain myofibrils that contract in response to commands carried by gamma motor neurons. (c) The Golgi tendon organ consists of sensory neurons interwoven among collagen fibers. If the collagen fibers are stretched, they pinch the sensory neurons and trigger action potentials.

105

Golgi Tendon Reflex:

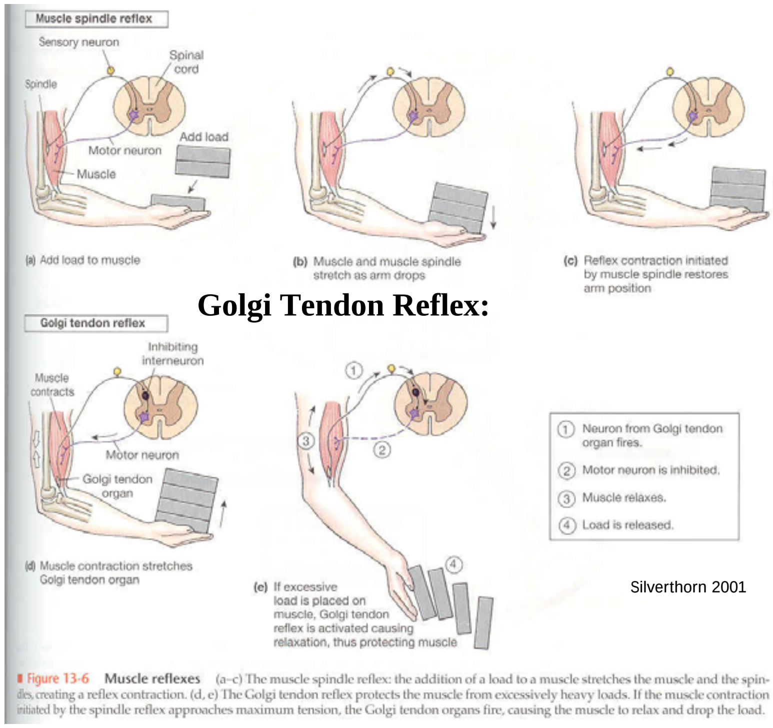


Figure 13-6 Muscle reflexes (a–c) The muscle spindle reflex: the addition of a load to a muscle stretches the muscle and the spindles, creating a reflex contraction. (d, e) The Golgi tendon reflex protects the muscle from excessively heavy loads. If the muscle contraction initiated by the spindle reflex approaches maximum tension, the Golgi tendon organs fire, causing the muscle to relax and drop the load.

Silverthorn 2001

106

Law of Nerve-Specific Energy

Action Potentials and Graded Potentials don't convey specific information.

Rather, the geographic connections, summation of different inputs, and modulation are important for correct response

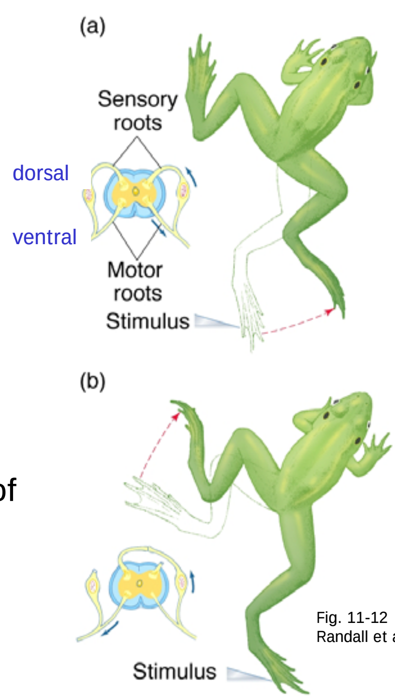


Fig. 11-12
Randall et al. 2002

107

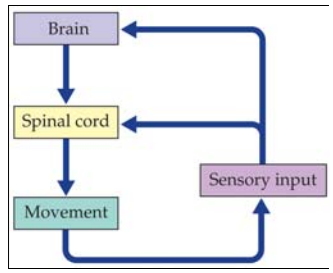
Peripheral vs. Central Control

CPG = central pattern generator

-neuronal network producing repetitive output

Walking, swimming, flying, breathing

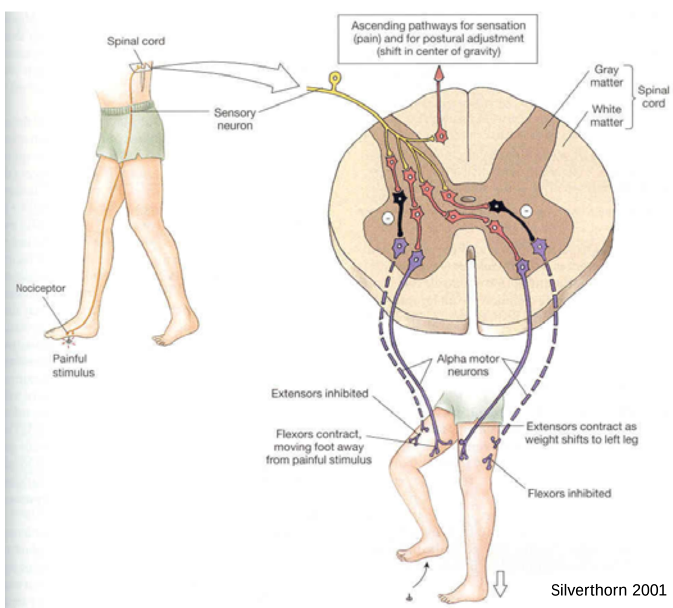
Toad walking with no afferents
- awkward
- flaccid muscles



Sensory feedback
Higher centers can override

Some patterns at level of spinal cord if stimulate initially (cats on treadmill)

108

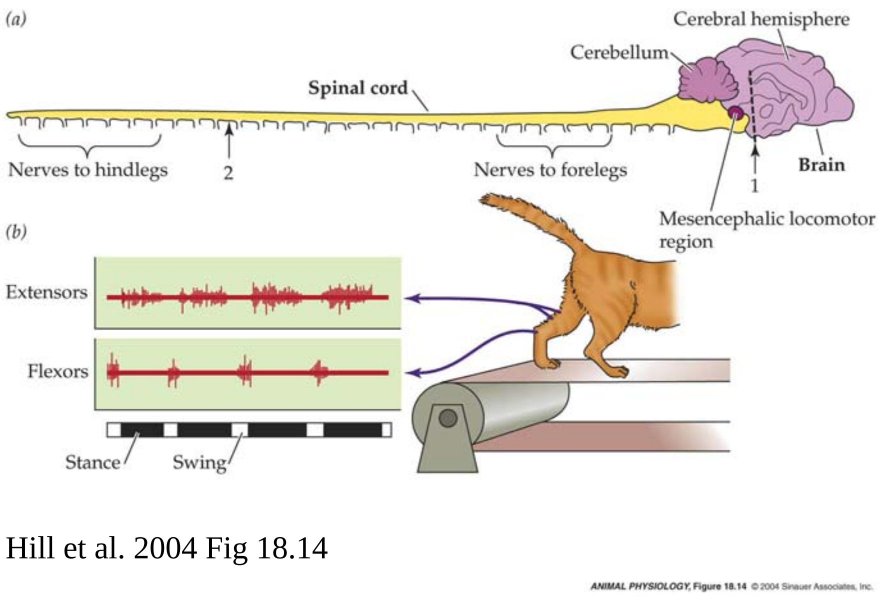


Silverthorn 2001

Figure 13-8 Flexion reflex and the crossed extensor reflex Coordination of reflexes with postural adjustments is essential for maintaining balance. When the right foot encounters a painful stimulus, a polysynaptic withdrawal reflex causes the right flexor muscles to contract. Reciprocal inhibition keeps the right extensor muscles relaxed. The crossed extensor reflex, activated by the same sensory pathway, straightens the left leg so that it will support the sudden addition of weight.

109

Central Pattern Generators in Cat Spinal Cord

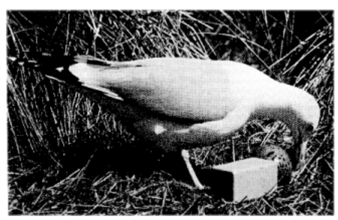


Hill et al. 2004 Fig 18.14

Fixed Action Patterns...

Herring Gull Egg Retrieval

http://salmon.psy.plym.ac.uk/year1/ETHEXPT.HTM#Egg%20retrieval



Baerends & Kruijt found that herring gulls:
prefer the **larger** of two eggs of the same colour
prefer the **speckled** egg over an unspeckled egg of the same colour
- prefer natural coloured (brown speckled) eggs over brown unspeckled eggs
- prefer green speckled eggs over green unspeckled eggs

prefer **green** eggs over brown eggs