Control of Movement

Somatic motor control can divided into:

Direct control: control of muscle contraction by neurons that directly innervate the muscle, as well as the reflex circuits in the brainstem + spinal cord responsible for reflex movements.

Indirect control: control of muscles by descending commands from the brain that control + coordinate the motor neurons + motor circuits in the brain stem + spinal cord.

Somatic motor system consists of muscles that are attached to skeletal elements.

Divided into axial muscles - muscles associated with the body axis + trunk

Appendicular muscles - limb muscles

Somatic motor neurons innervate somatic muscles that have their cell body in the ventral horn of the spinal cord.

These motor neurons are also called

"primary motor neurons"

or

"α motor neurons"

or

"lower motor neurons"

"upper motor neurons" - neurons in motor cortex that send their axons down into the spinal cord to synapse on "lower motor neurons" + motor circuits in the spinal cord.

There are more individual muscles in your arms + legs than there are in your trunk. Also, the muscles of your limbs are involved in producing much finer + complex movements than the muscles of your trunk.

The spinal segments that innervate the muscles of the limbs are enlarged to accomodate the greater # of motor neurons required to innervate the muscles of the limbs.

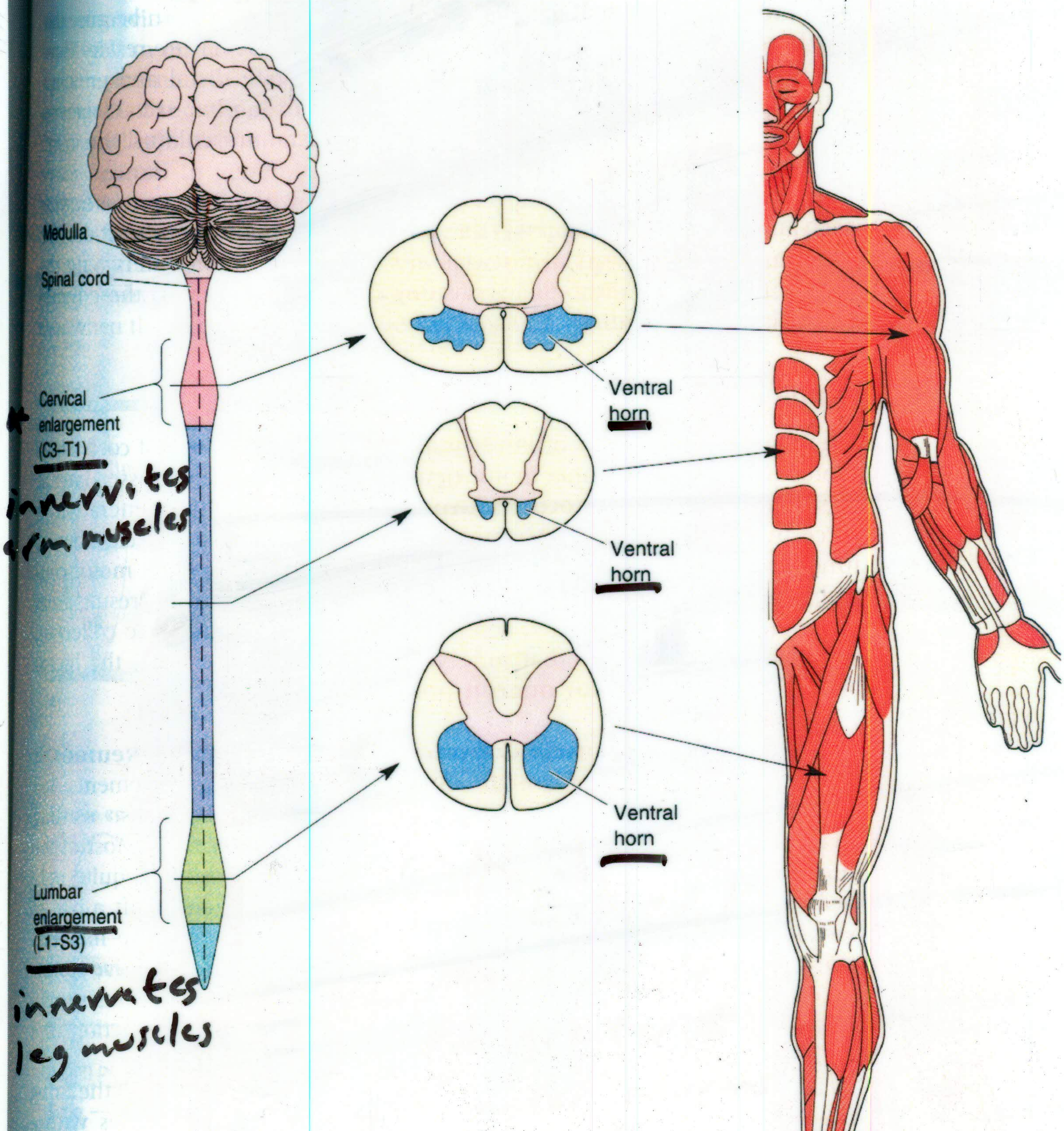


FIGURE 13.4
The distribution of motor neurons in the spinal cord. The cervical enlargement of the spinal cord contains the motor neurons that innervate the arm muscles. The lumbar enlargement contains neurons that innervate the muscles of the leg.

Each skeletal muscle is composed of many muscle fibers.

Each muscle is innervated by many primary motor neurons, that comprise the "motor neuron pool" of the muscle.

Each individual muscle fiber is innervated by only one motor neuron in the motor neuron pool.

However, an individual motor neuron may innervate many muscle fibers in the muscle.

The motor pool of the muscle + muscle fibers of the innervated muscle can be divided into "motor units."

A motor unit consists of a primary motor neuron & all of the muscle fibers it innervates.

A motor unit is the smallest voluntary contractile unit of a muscle.

Theoretically, the smallest possible voluntary contraction you can make with a muscle involves activation of a single motor unit.

When you contract a muscle there is a gradual increase in the # of motor units being activated – this is referred to as "motor unit recruitment"

In motor unit recruitment the smallest motor units of the muscle are activated first → produces a small contraction

Then to produce more force, larger motor units are activated → produces more force

This pattern of motor unit recruitment results in:

- Produces a smooth contraction of the muscle resulting in a smooth movement.
- Allows finer control of muscle contraction and finer movements.

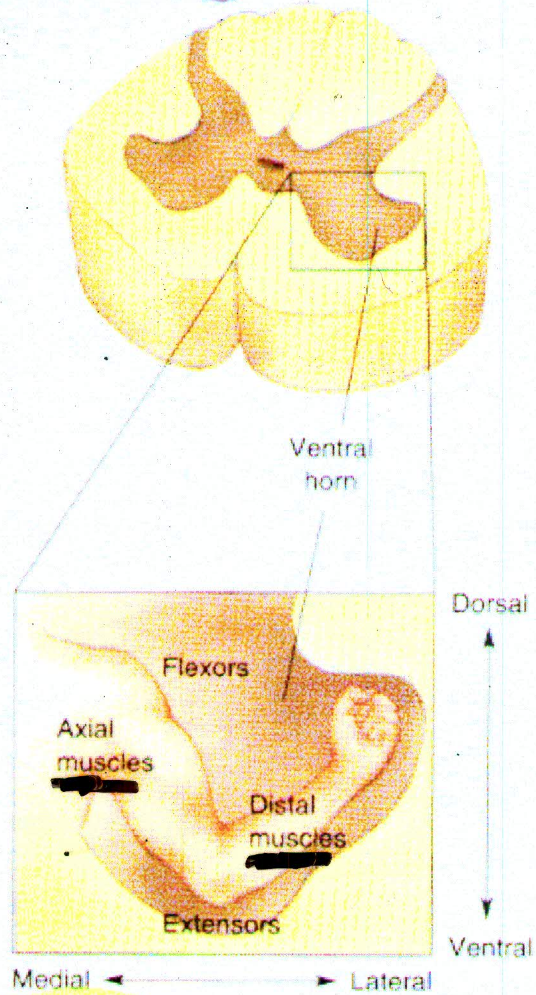


Figure 13.5

Distribution of lower motor neurons in the ventral horn. Motor neurons controlling flexors lie dorsal to those controlling extensors. Motor neurons controlling axial muscles lie medial to those controlling distal muscles.

Activation of primary motor neurons is controlled by 3 sources of inputs:

- Muscle receptors:
  - muscle spindles
  - Golgi tendon organs
- Interneurons in the spinal cord that make up the spinal motor circuits
- Motor centers in the brain that send their axons down in to the spinal cord to synapse on the primary motor neurons.

muscle Receptors

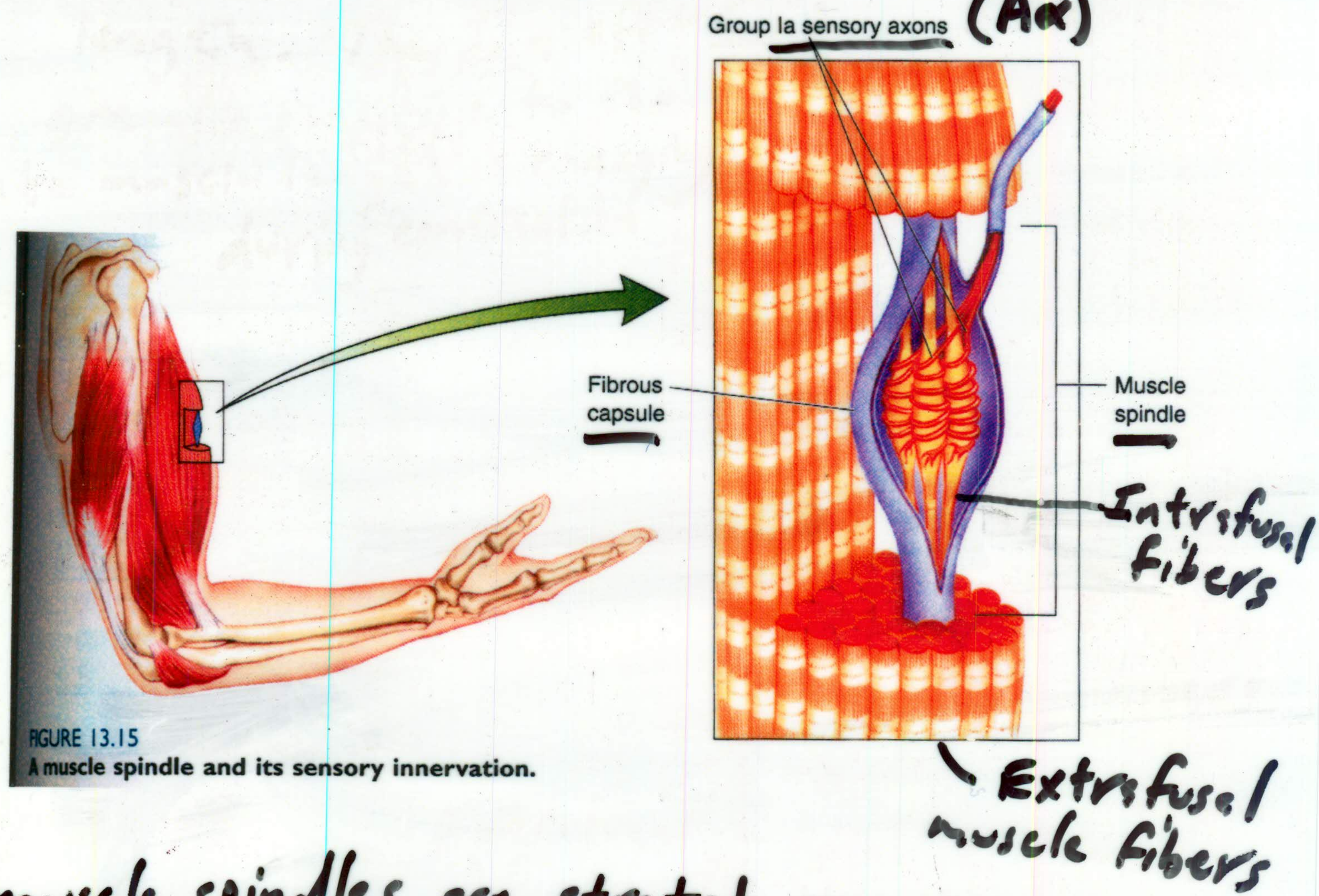


FIGURE 13.15
A muscle spindle and its sensory innervation.

muscle spindles are stretch receptors.
The Ia afferent senses the stretch in the intrafusal fibers and increase their AP firing rate as the muscle is stretched.

The muscle spindle is also sensitive to the rate at which muscle length is changing during a muscle contraction.

Faster muscle length changes

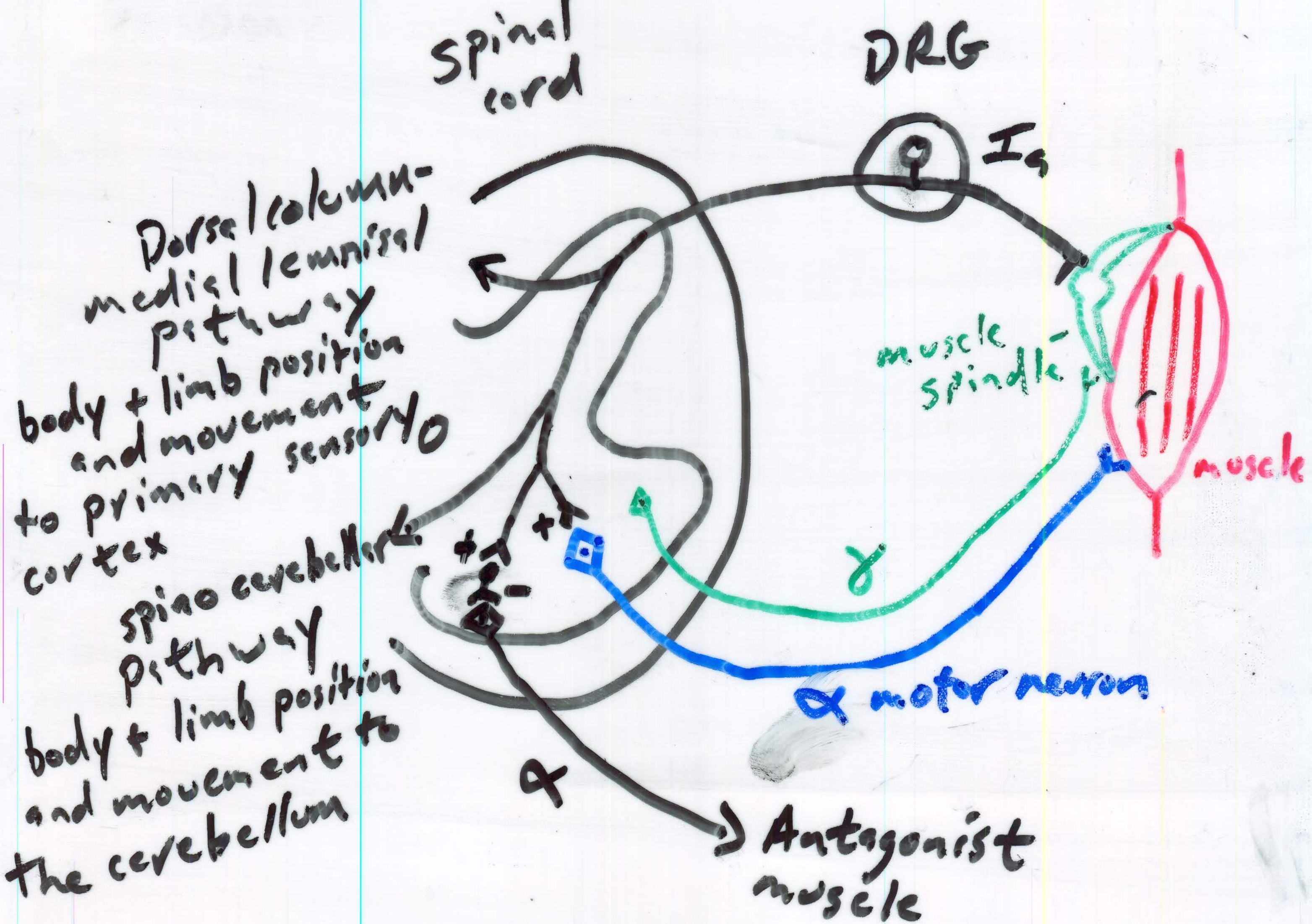
↓

Higher the freq. of APs generated by the I_a afferents.

The CNS uses the input from the I_a afferents to sense muscle length + rate at which muscle length is changing to:

- Sense limb position relative to the body
- Also to sense what a muscle is doing during a motor act so the

muscle can be coordinated with other muscles.



The excitatory input of the Ia afferent to the same muscle with the muscle spindle serves to keep the muscle partially contracted (provides muscle tone)

Reciprocal innervation of the α motor neurons of antagonist muscles inhibits contraction of the antagonist muscle.

γ motor neurons innervate contractile component of the intrafusal fiber.
Serve two functions:

— To shorten the muscle spindle in parallel with the shortening of the muscle during a contraction of the muscle.
Allows the spindle to continue to sense muscle length + rate at which muscle length is changing during contraction.

Both the α and γ motor neurons receive descending inputs from the motor cortex which are responsible for producing voluntary contraction of the muscle

— To set the sensitivity of the muscle spindle.

Under times of stress the γ motor neurons receive increased descending excitatory inputs from the brain. The increased descending excitatory inputs will cause some of the intrafusal fibers to contract and set the sensitivity of the muscle spindle to be set more tightly than normal.

This will serve to enhance your muscle spindle reflexes.

Golgi Tendon Organ

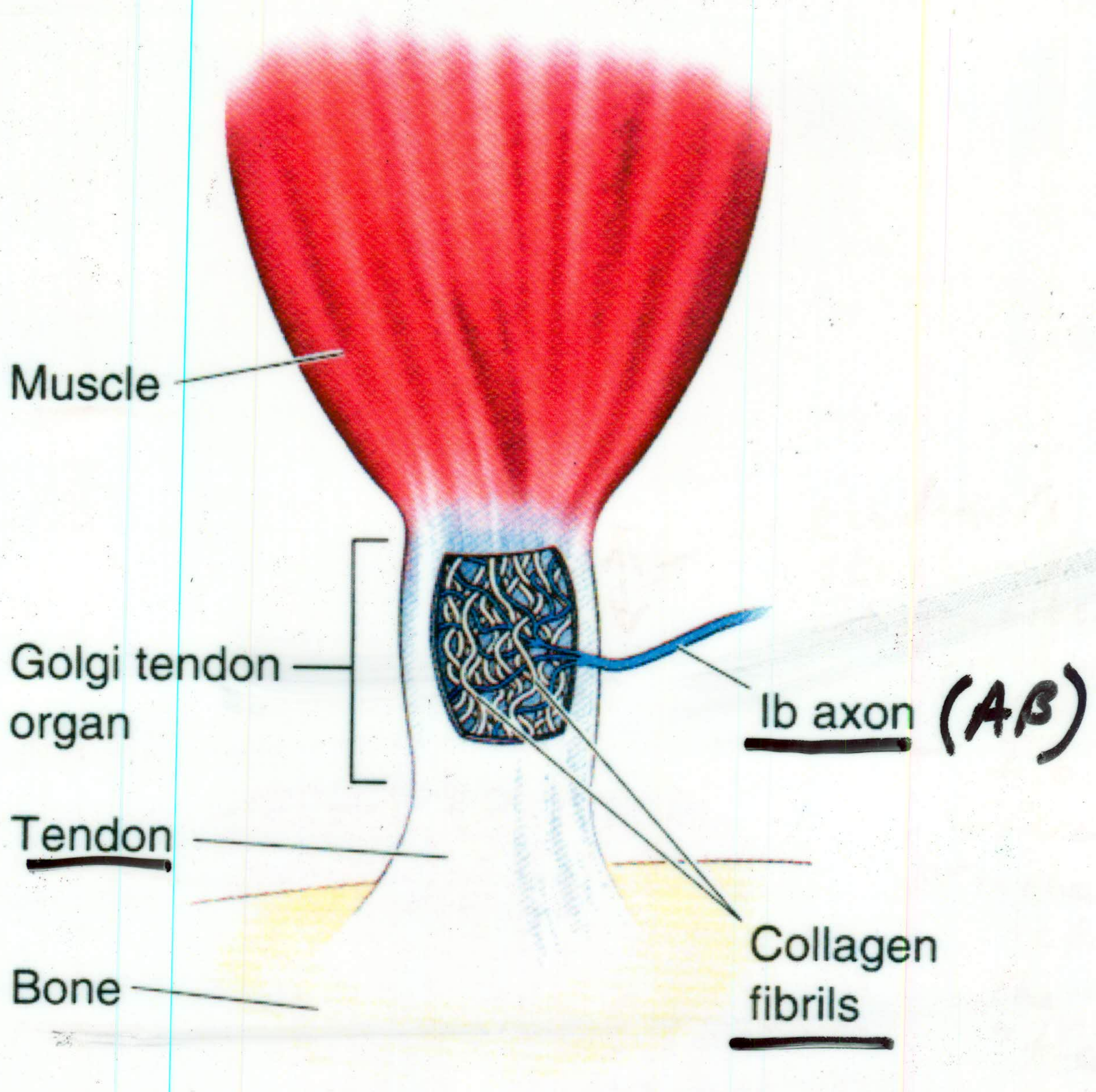
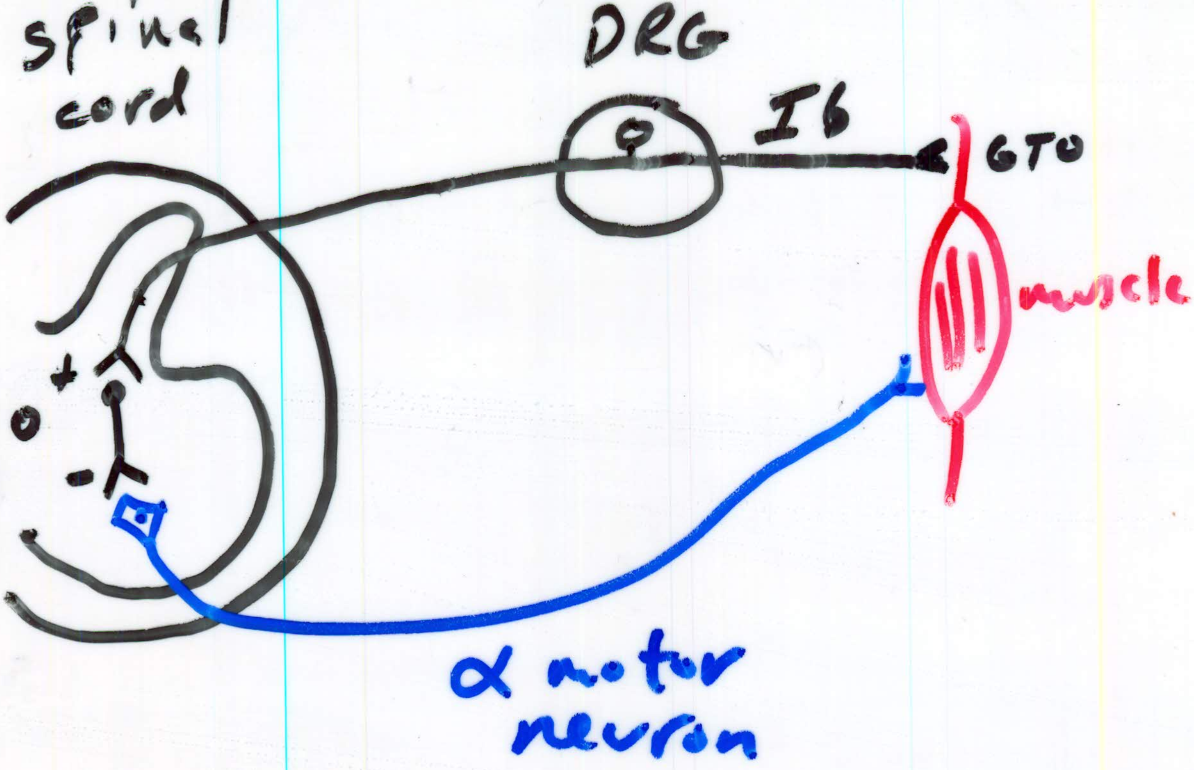


FIGURE 13.20
A Golgi tendon organ.

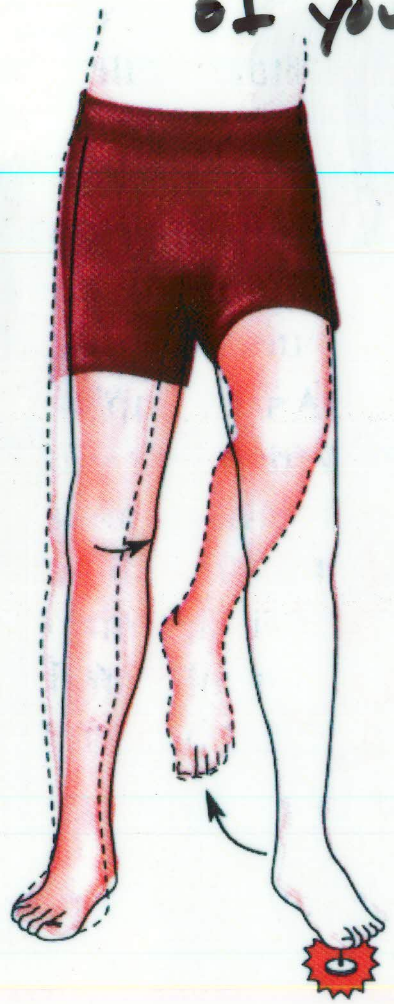


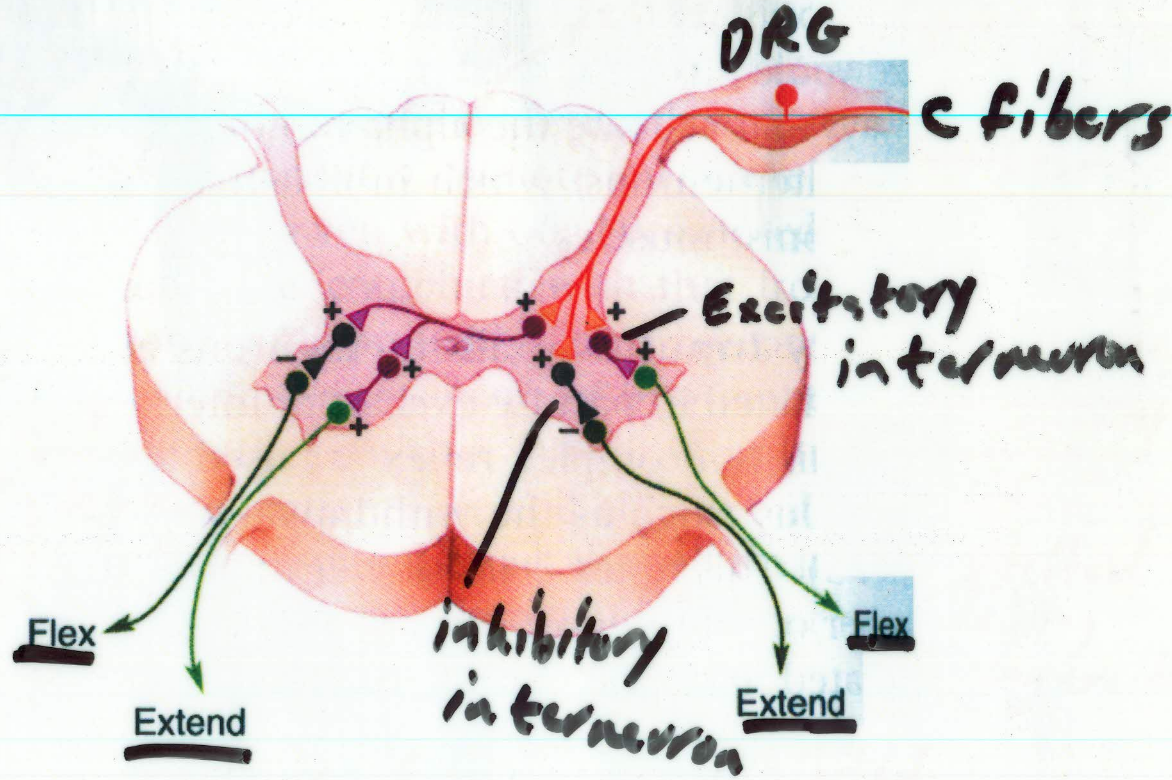
This circuit mediates the "Clasp-Knife reflex" – which serves to prevent the muscle from exerting too much force during a contraction.

The GTO circuit, together with the muscle spindle circuit, serve as a sensitive modulation system that allows you to vary the amount of force during a motor task.

Crossed Extensor Reflex Circuit.

This reflex is initiated when you lift one of your feet when you are standing





The motor circuitry for locomotion is contained entirely within the spinal cord.

It is thought that the motor circuitry for locomotion is similar to the crossed extensor reflex circuit.

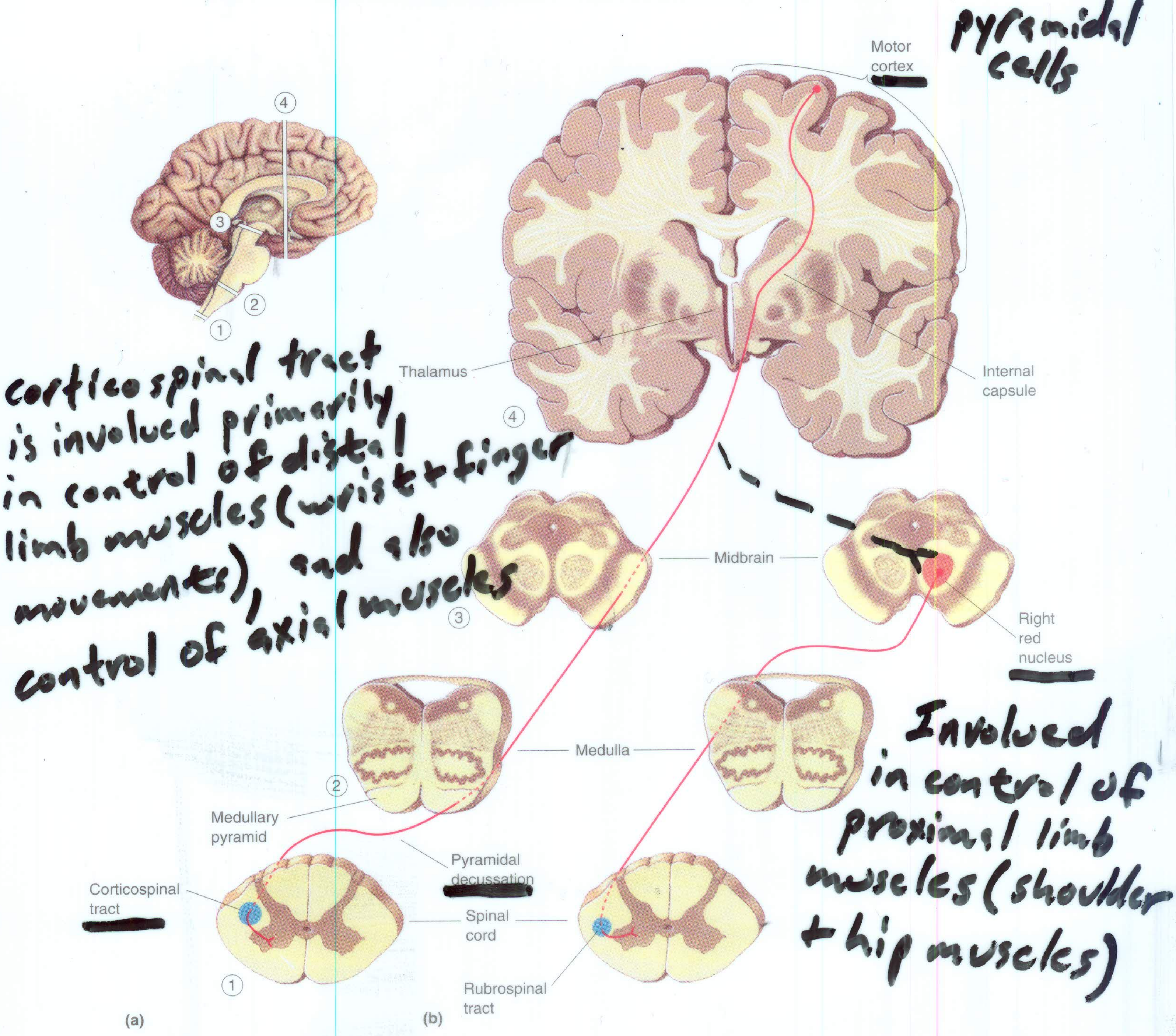
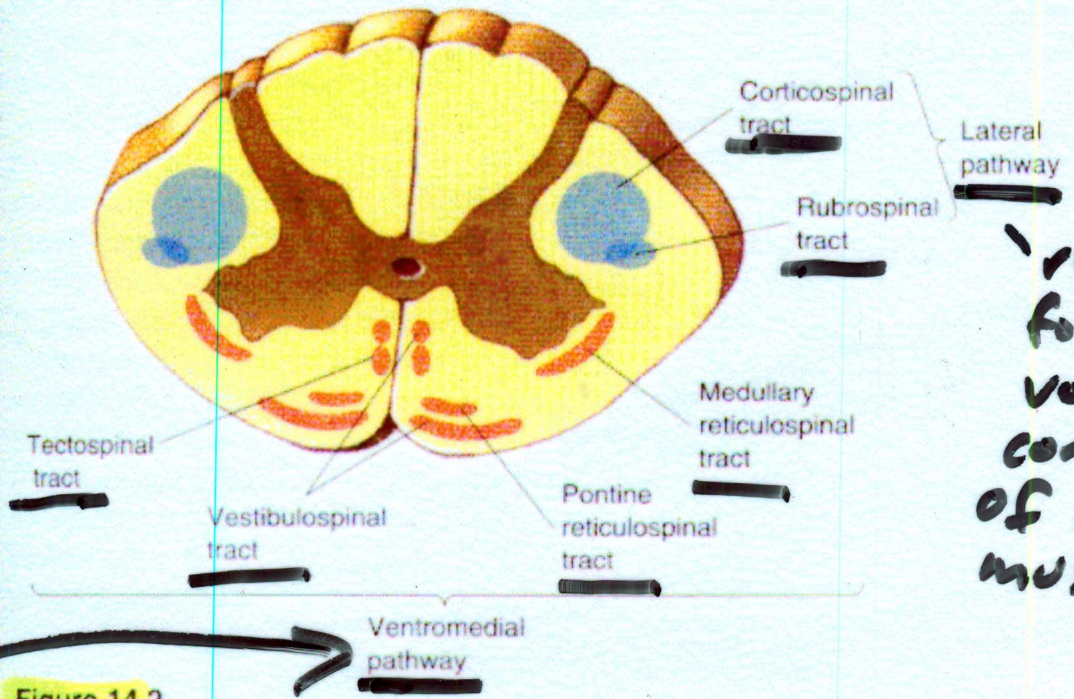


Figure 14.3
Origins and terminations of the lateral pathway. (**a**) The corticospinal tract; (**b**) the rubrospinal tract.



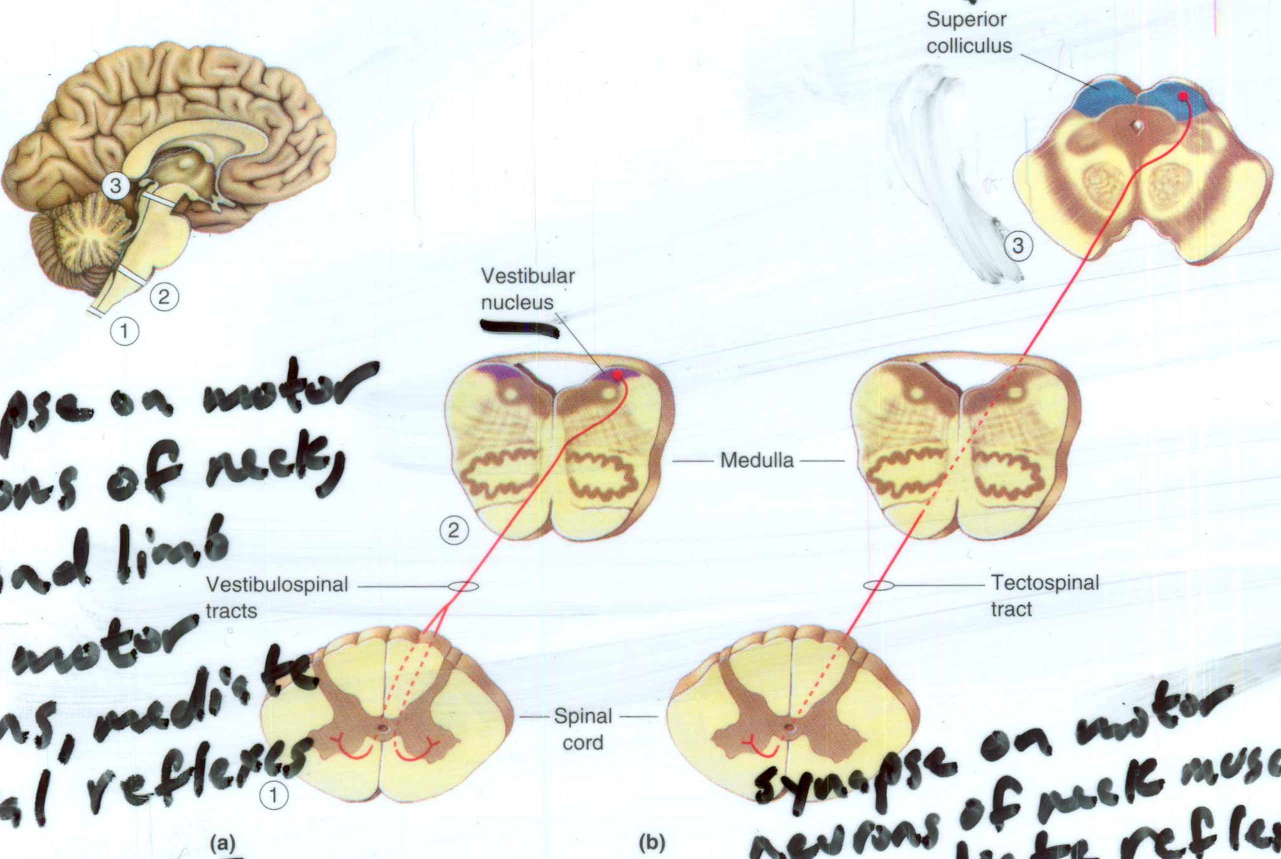
responsible for voluntary control of skeletal muscles

Figure 14.2

The descending tracts of the spinal cord. The lateral pathway, consisting of the corticospinal and rubrospinal tracts, controls voluntary movements of the distal musculature. The ventromedial pathway, consisting of the reticulospinal, vestibulospinal, and tectospinal tracts, controls postural muscles.

responsible for controlling the axial muscle reflexes involved in posture and locomotion.

Inferior +



synapse on motor neurons of neck, back, and limb muscle motor neurons, mediate postural reflexes for maintaining balance.

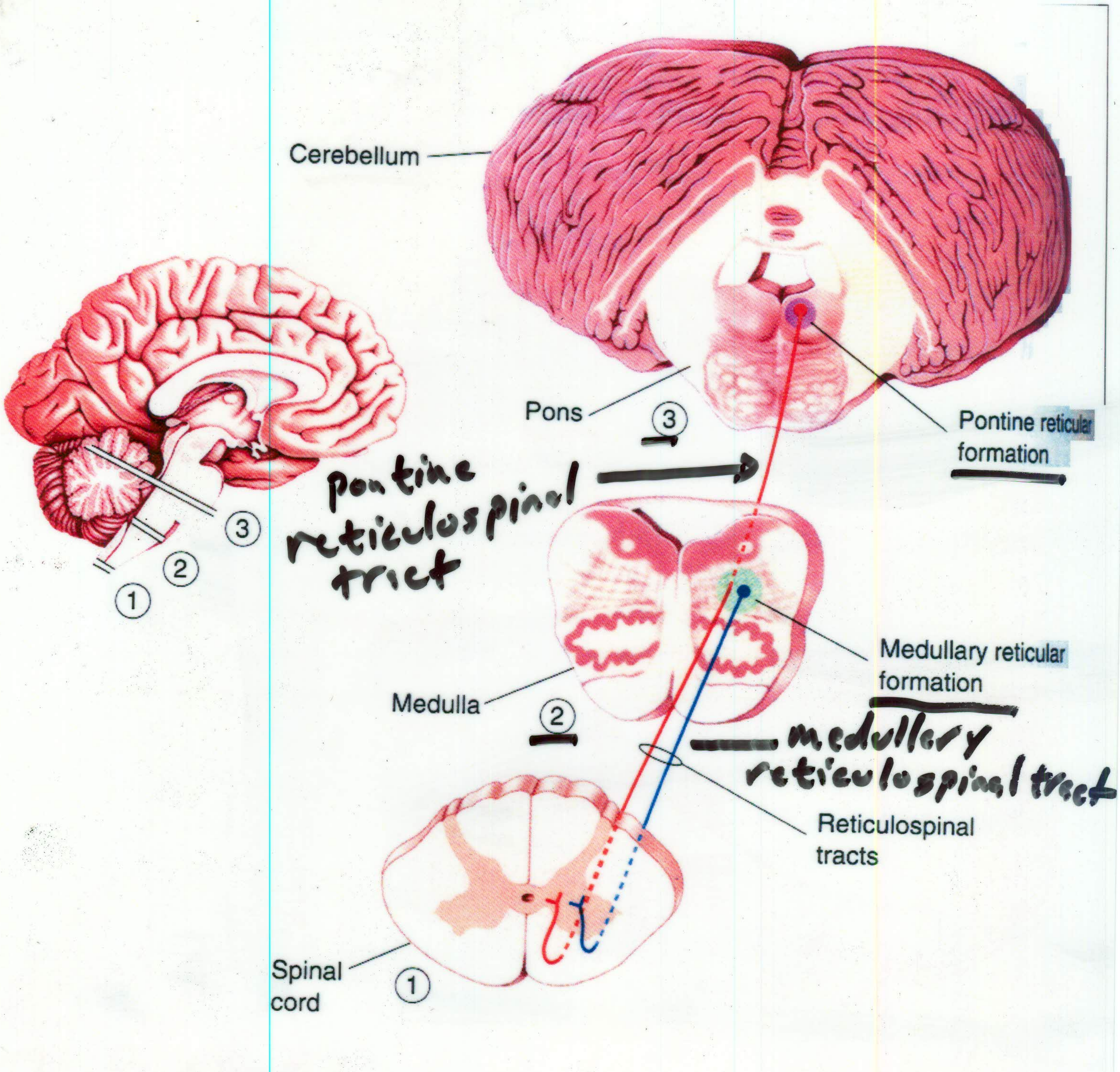
synapse on motor neurons of neck muscles mediate reflexes that orient your head to visual + auditory stimuli

Figure 14.4
Origins and terminations of (a) the vestibulospinal tract and (b) the tectospinal tract. These components of the ventromedial pathway control the posture of the head and neck.

Two divisions:

Medial vestibulospinal tract - mediates neck and trunk muscle reflexes associated with balance + posture

Lateral vestibulospinal tract - mediates limb muscle reflexes associated with balance + posture.



Cerebellum
Pons
Pontine reticular formation
③
pontine reticulospinal tract
③
②
①
Medulla
Medullary reticular formation
②
medullary reticulospinal tract
Reticulospinal tracts
Spinal cord
①

The pontine reticulospinal tract and medullary reticulospinal tract act antagonistically on the spinal motor circuits.

The PRST stimulates activity in the spinal reflex circuits that serve to maintain a standing posture.

As long as the motor neurons are kept locked in these reflex circuits they are unable to respond to motor commands from the motor cortex for voluntary movement

The MRST inhibits the spinal reflex circuits releasing the motor neurons from the spinal reflex circuits allowing them to respond to commands coming from the motor cortex

The level of activity in the pontine reticuler formation + medullary reticuler formation is modulated by inputs from the motor cortex.

So, the carry out a motor act the motor cortex increases activity in the medullary ret. formation and decreases activity in the pontine ret. formation. This will serve to release the motor neurons from the spinal reflex circuits so that they can respond to commands coming down from the motor cortex.