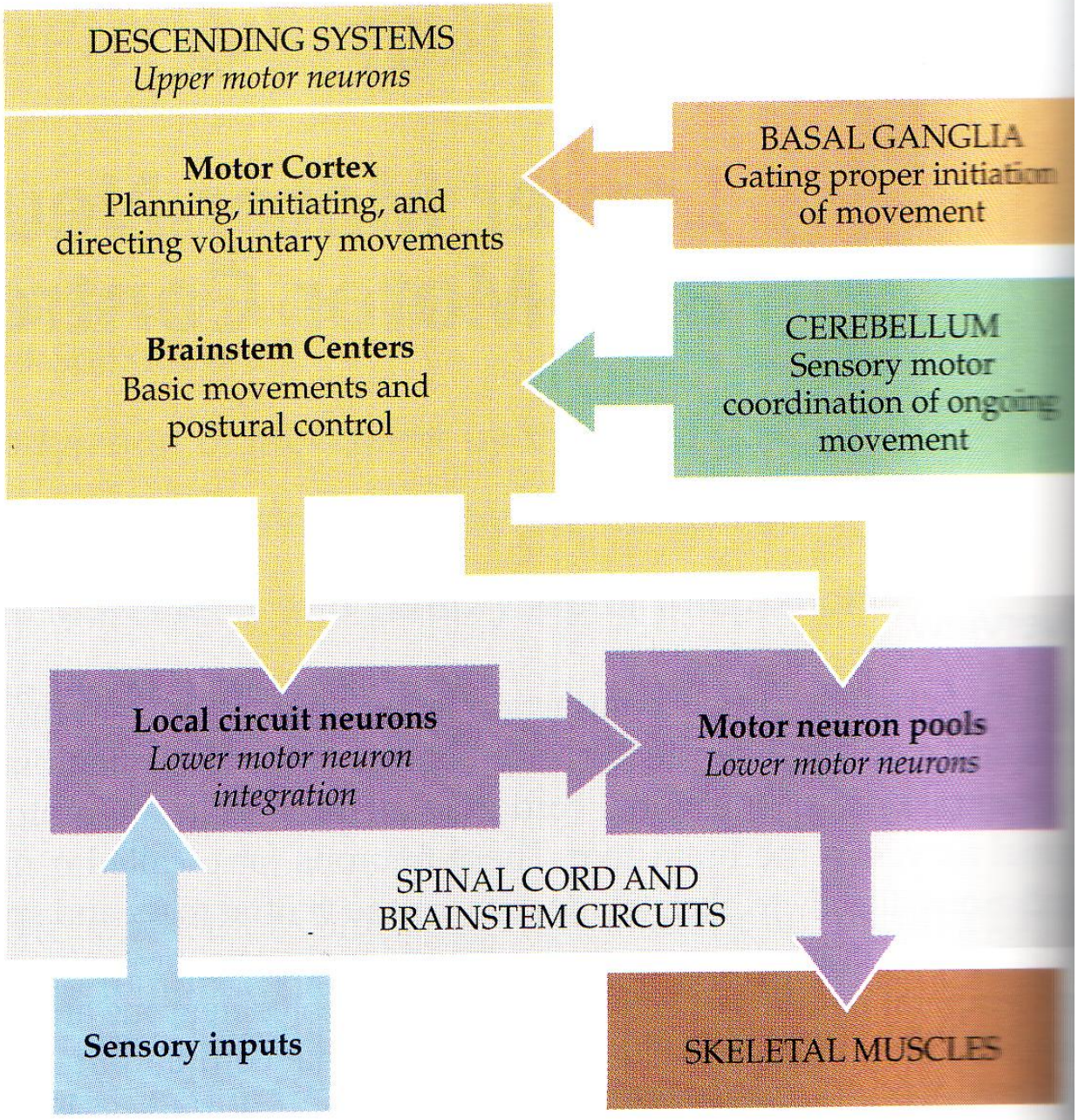
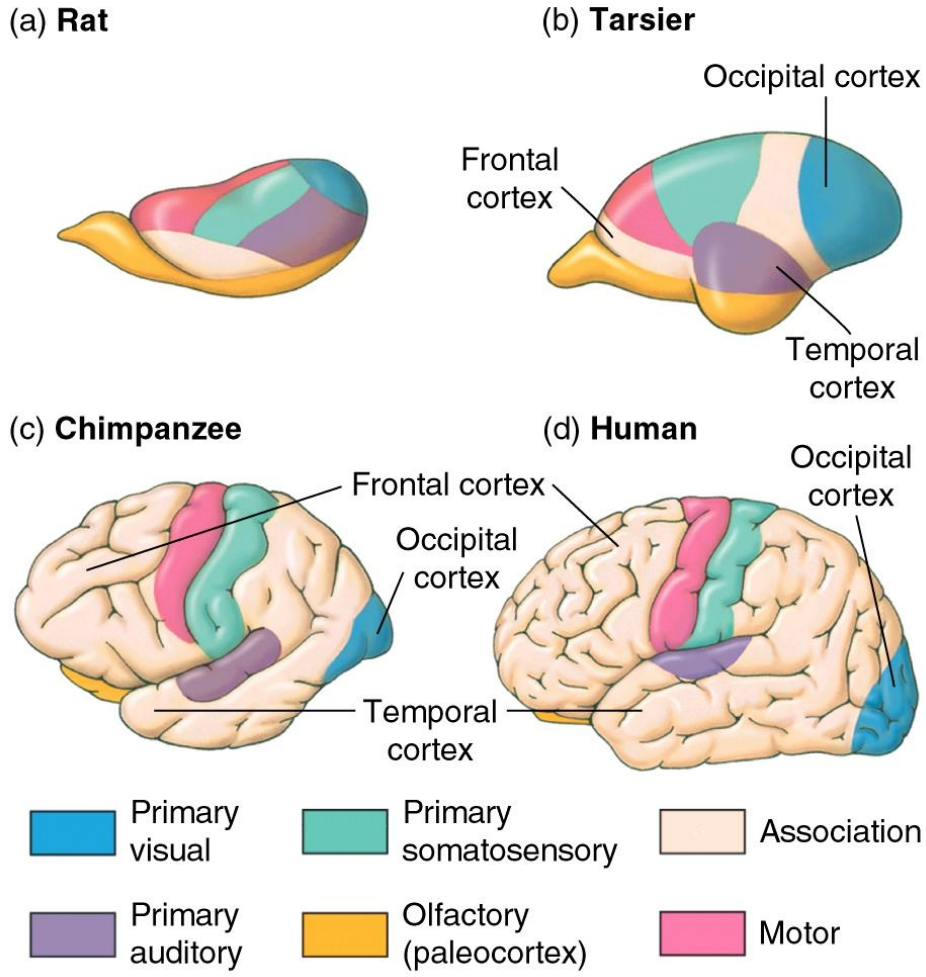
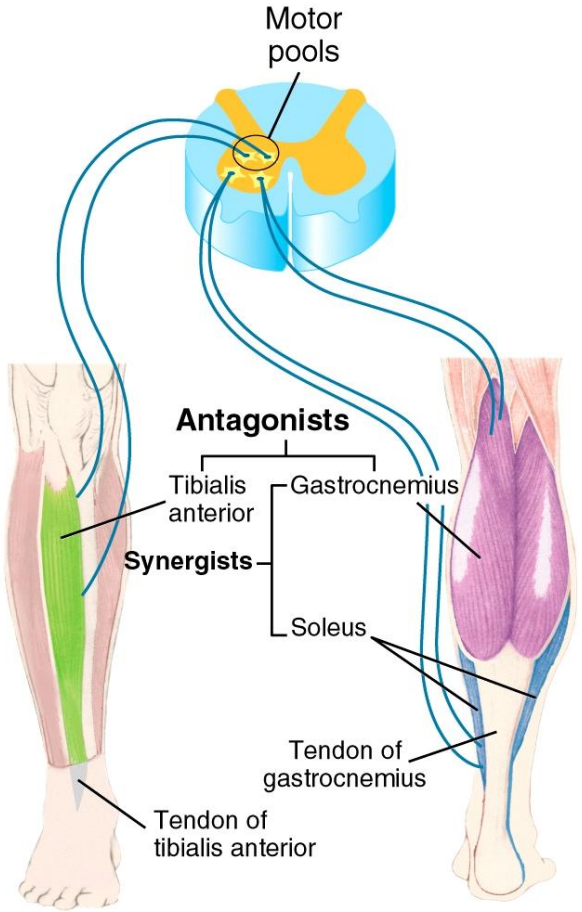
Chapter 16:
Lower Motor Neuron Circuits

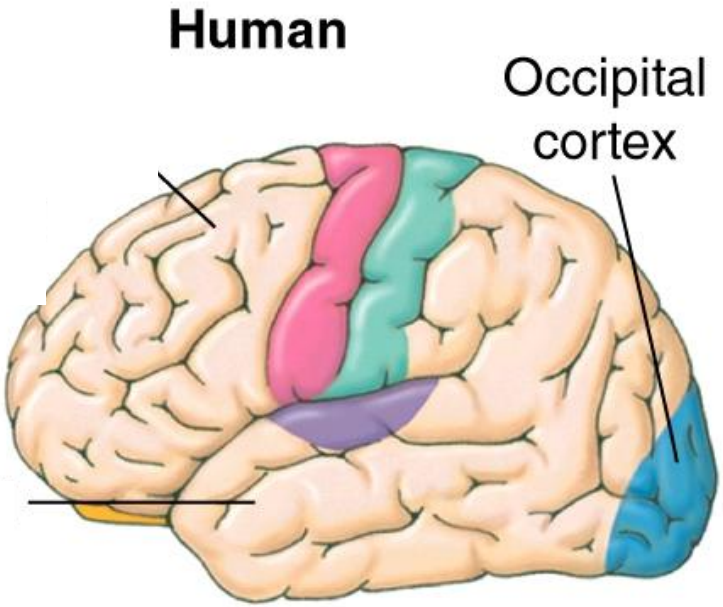

DESCENDING SYSTEMS
Upper motor neurons
Motor Cortex
Planning, initiating, and directing voluntary movements
Brainstem Centers
Basic movements and postural control
BASAL GANGLIA
Gating proper initiation of movement
CEREBELLUM
Sensory motor coordination of ongoing movement
Local circuit neurons
Lower motor neuron integration
Motor neuron pools
Lower motor neurons
SPINAL CORD AND BRAINSTEM CIRCUITS
Sensory inputs
SKELETAL MUSCLES

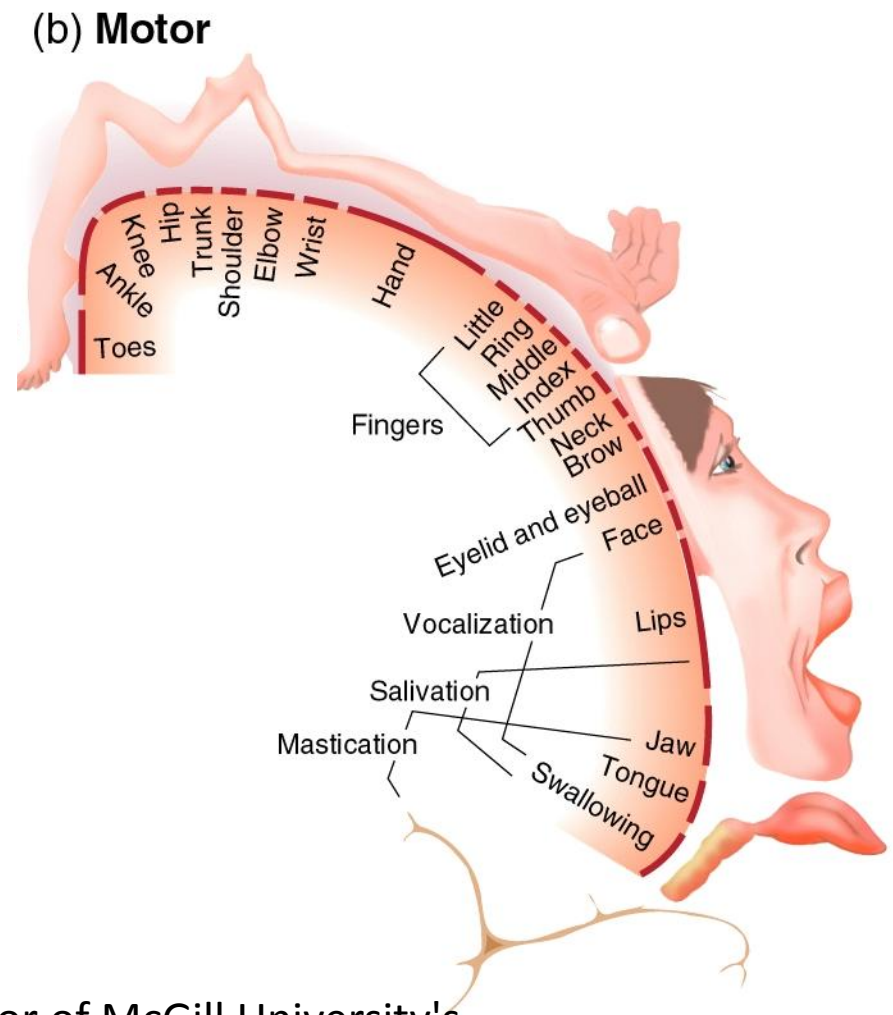
Upper motor neurons: CNS (premotor & primary motor cortex)

Lower motor neurons: Motor neurons from the spinal cord









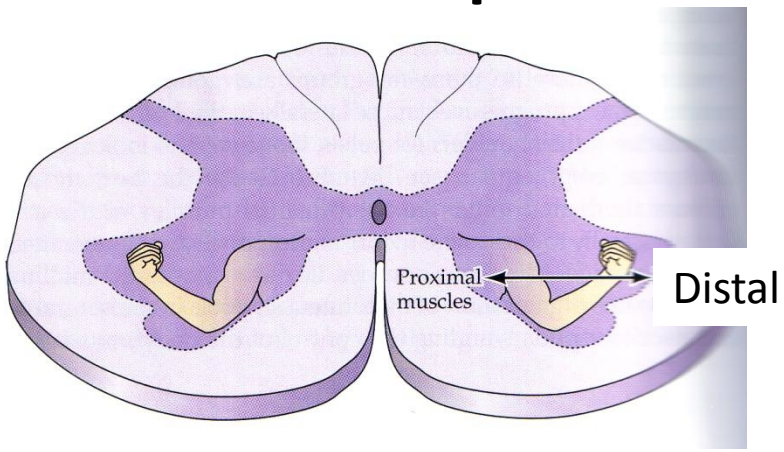
Wilder Penfield

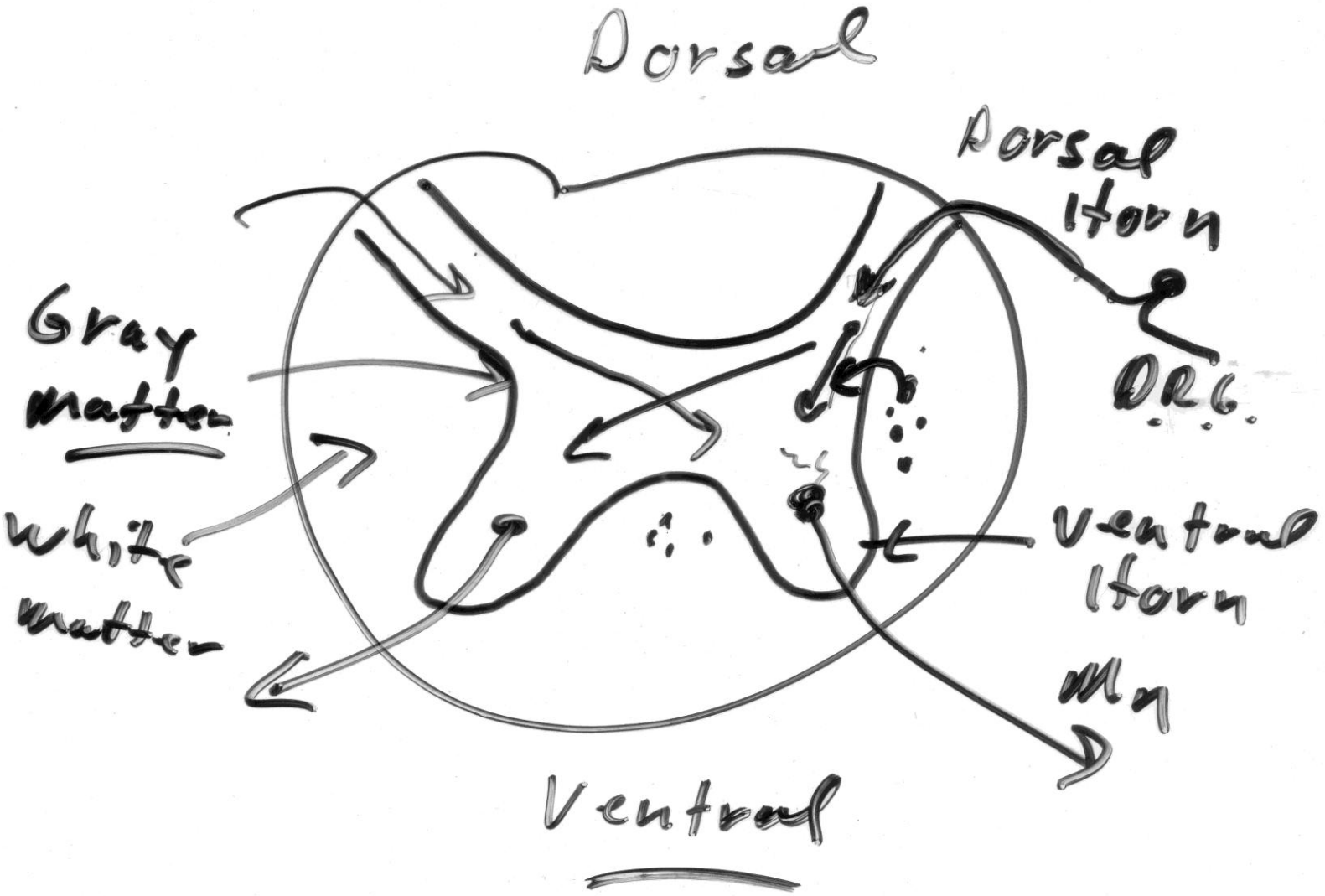
WWW I

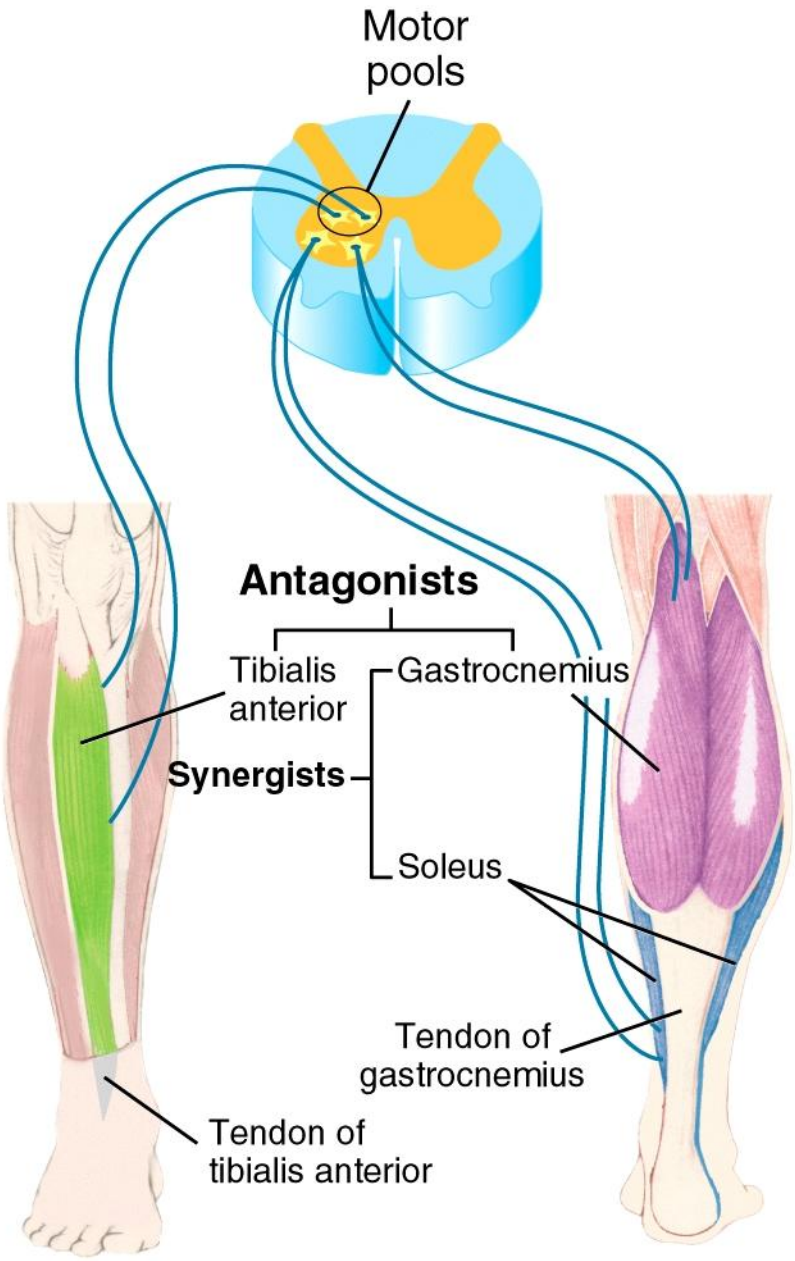
1934 he founded and became the first Director of McGill University's world-famous Montreal Neurological Institute and the associated Montreal Neurological Hospital

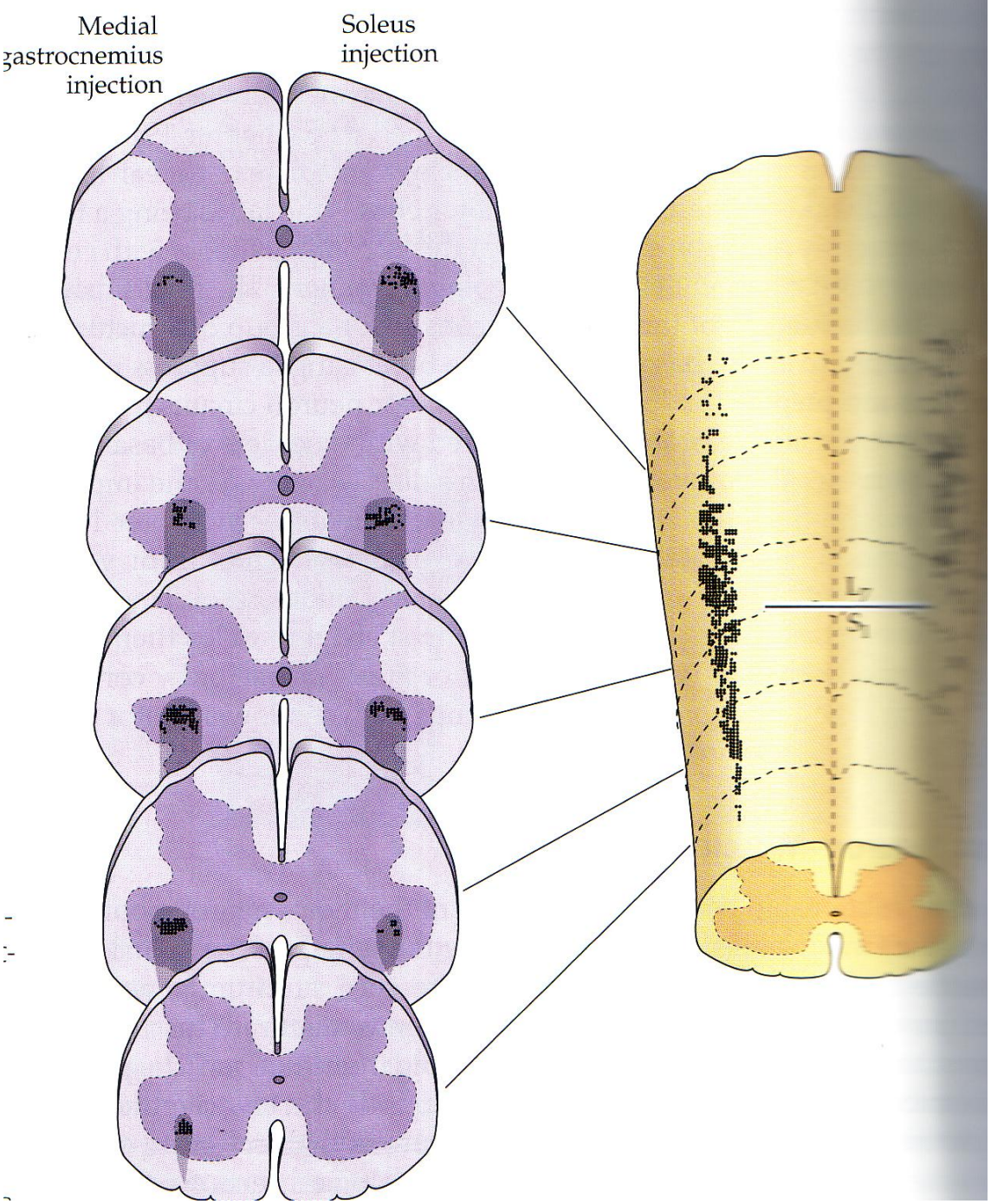
Published 1951 the homunculus

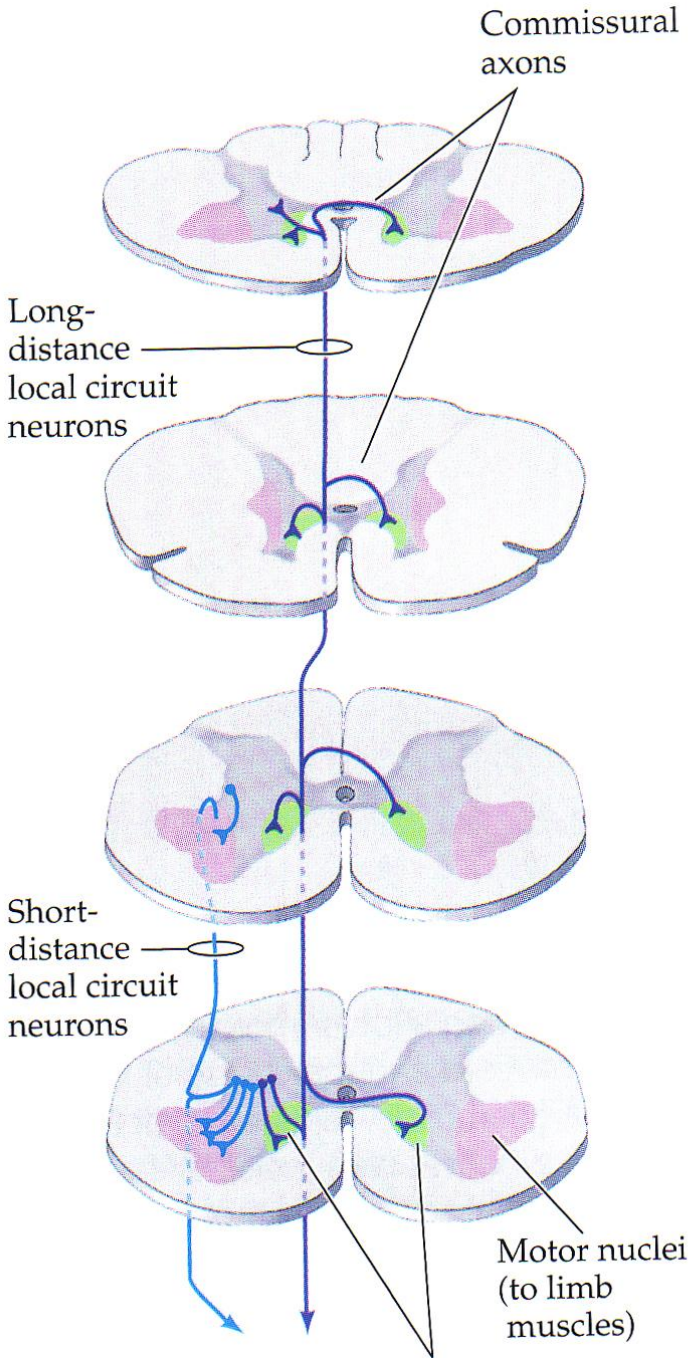
Spinal cord cross section




Dorsal
Dorsal horn
Gray matter
DRG
White matter
Ventral horn
Ventral


Motor pools
Antagonists
Tibialis anterior
Gastrocnemius
Synergists
Soleus
Tendon of gastrocnemius
Tendon of tibialis anterior


Medial
gastrocnemius
injection
Soleus
injection
L7
S1


Commissural axons
Long-distance local circuit neurons
Short-distance local circuit neurons
Motor nuclei (to limb muscles)

Motor unit

- Alpha motor neuron and muscle

Types

Slow, fast fatigable, fast fatigue-resistant

----muscle fiber types match

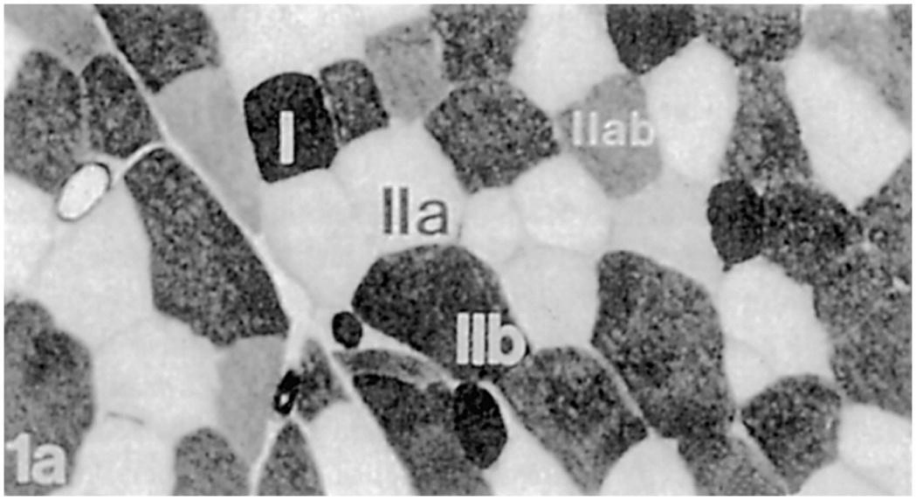
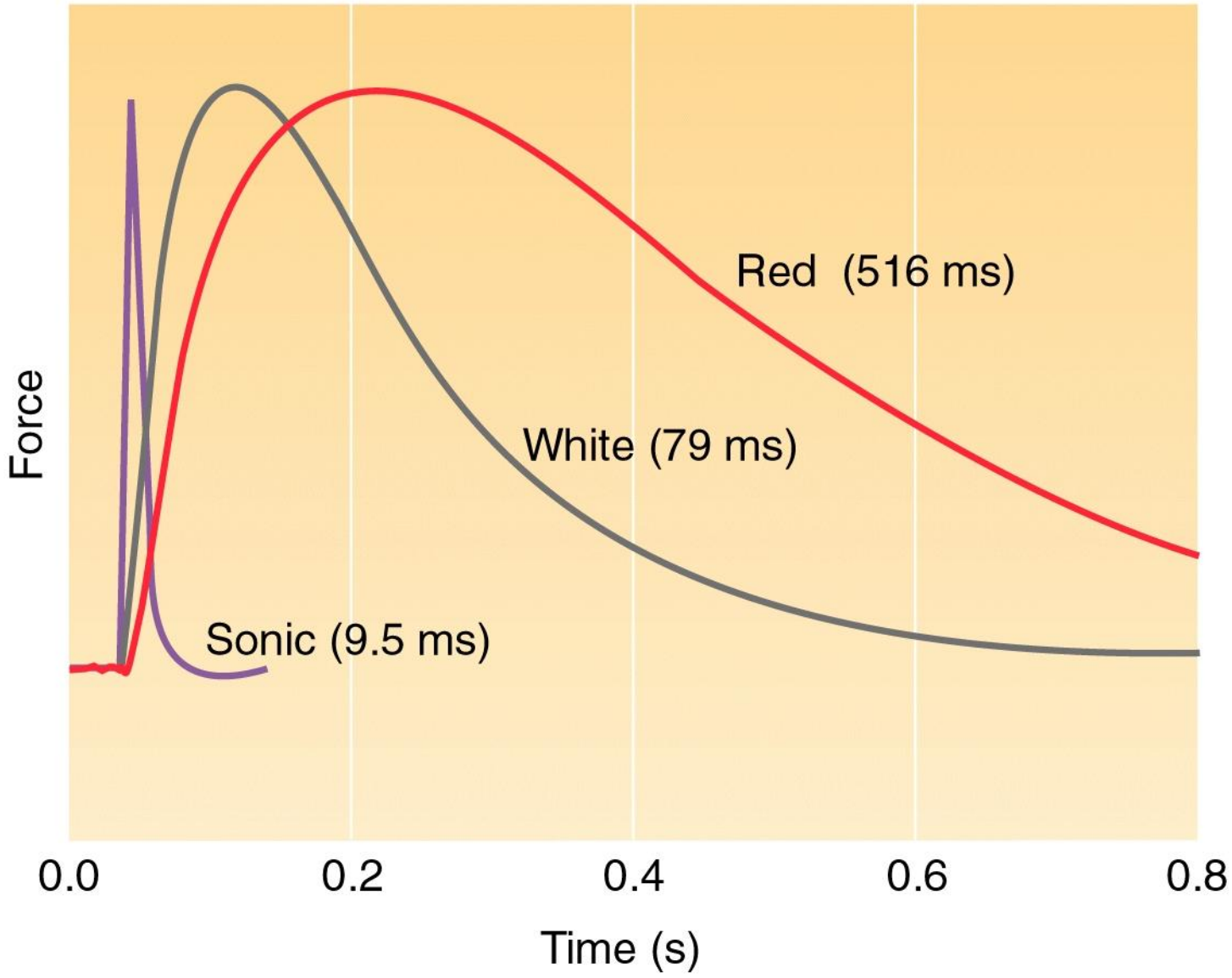


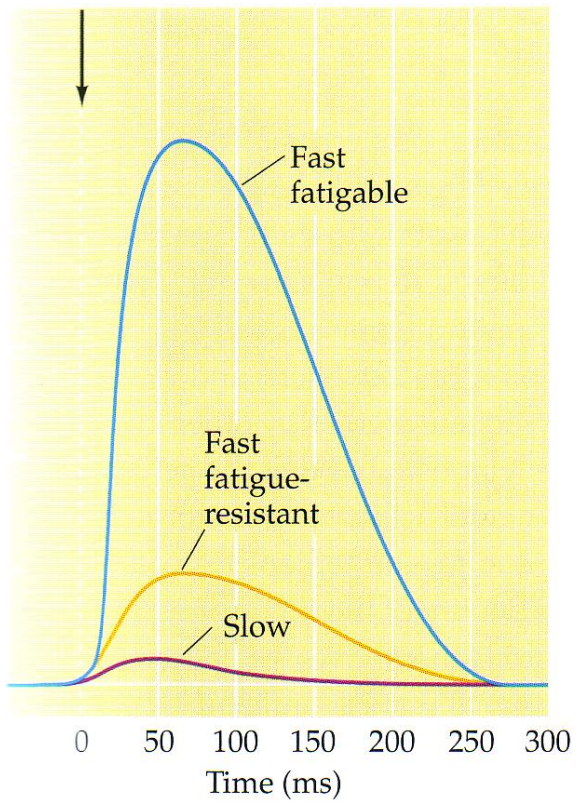
Table 10-1 **Properties of twitch (phasic) fibers in mammalian skeletal muscles**

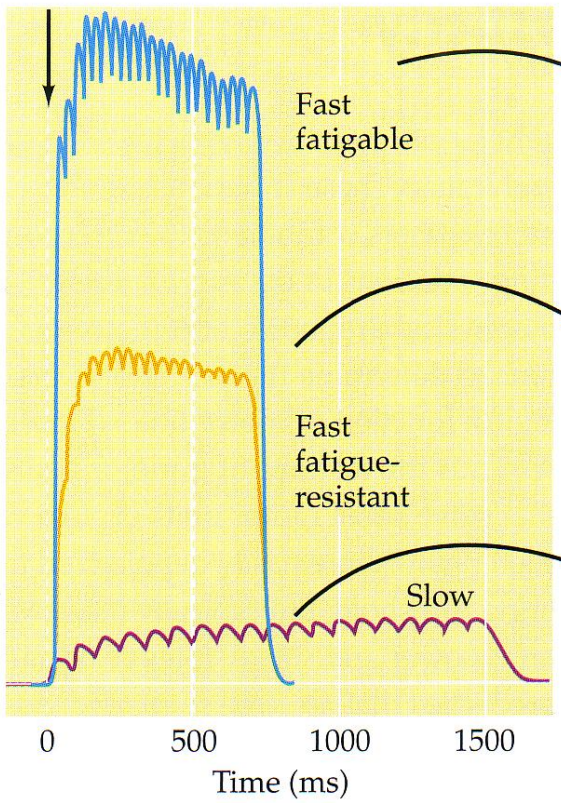
Property	Slow oxidative (type I)	Fast oxidative (type IIa)	Fast glycolytic (type IIb)
Fiber diameter	↓	↔	↑
Force per cross-sectional area	↓	↔	↑
Rate of contraction (V_{max})	↓	↑	↑
Myosin ATPase activity	↓	↑	↑
Resistance to fatigue	↑	↔	↓
Number of mitochondria	↑	↑	↓
Capacity for oxidative phosphorylation	↑	↑	↓
Enzymes for anaerobic glycolysis	↓	↔	↑

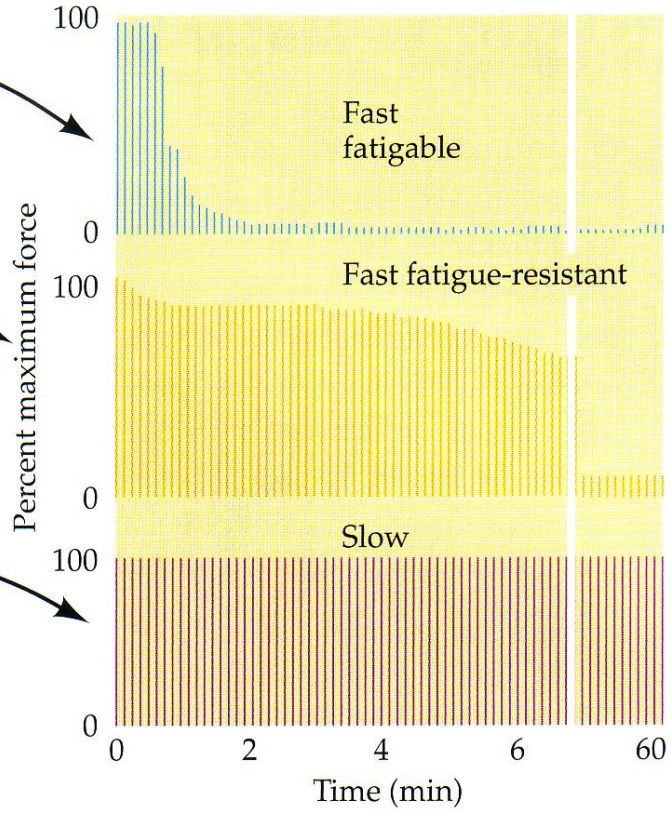
Source: Adapted from Sherwood, 2001. Key = ↓ Low ↔ Intermediate ↑ High

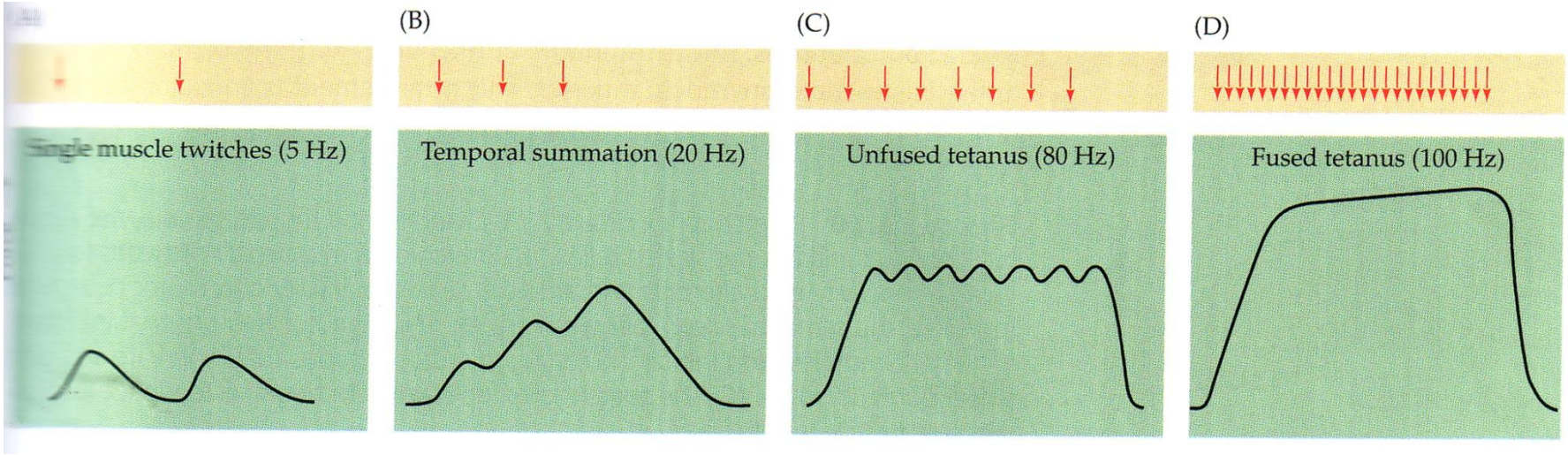
(b) Twitch tension over time



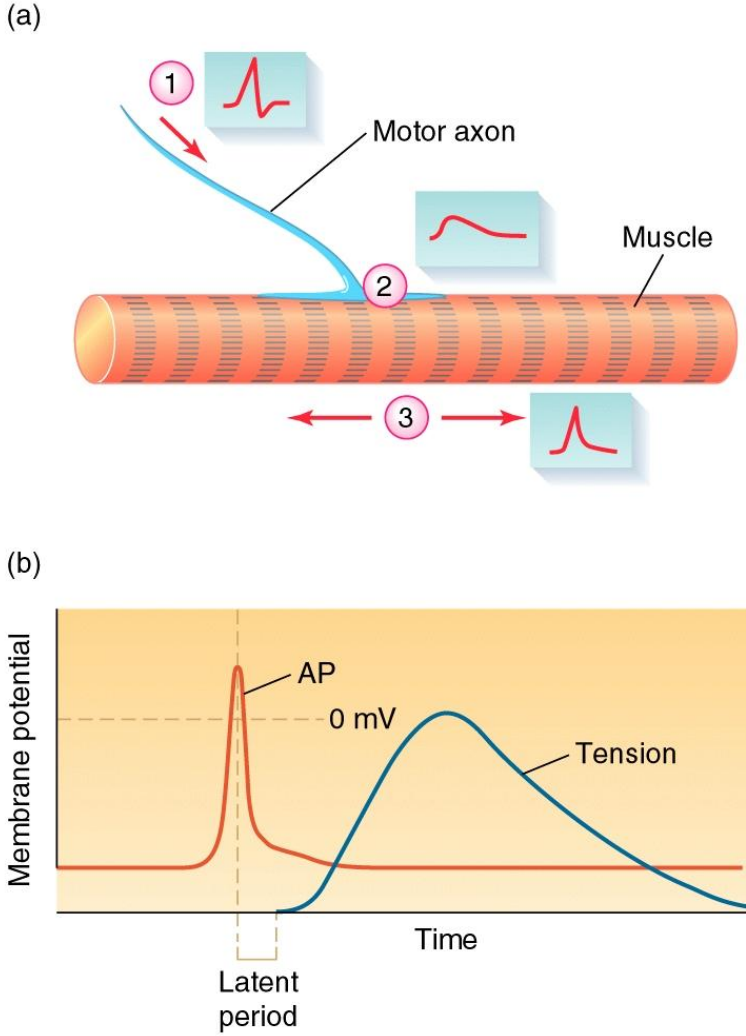

Fast
fatigable
Fast
fatigue-
resistant
Slow
0
50
100
150
200
250
300
Time (ms)

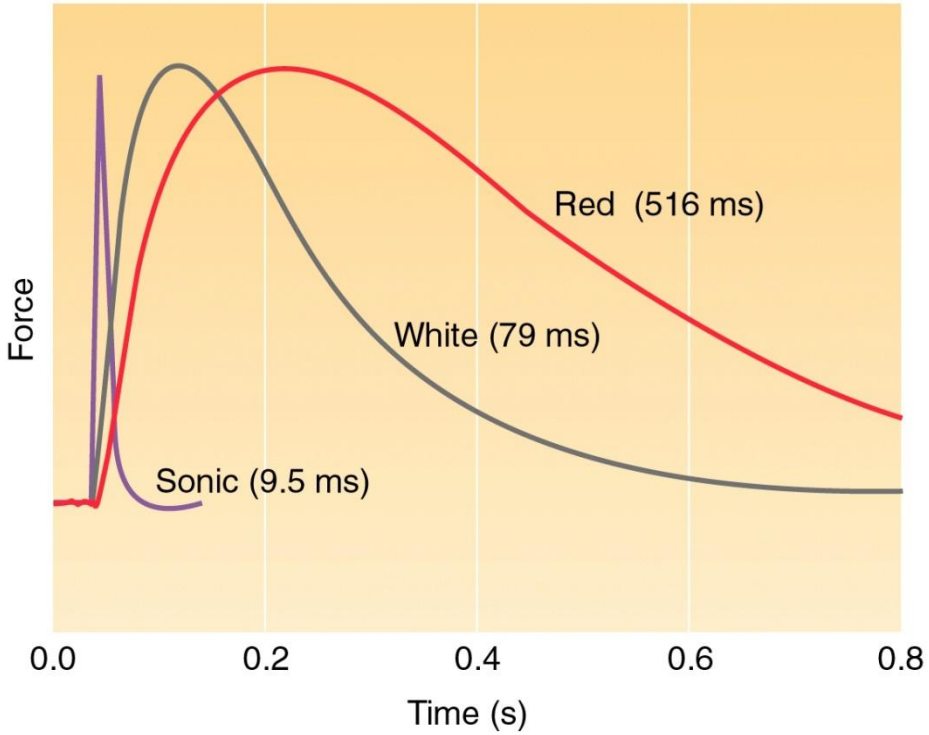

Fast
fatigable
Fast
fatigue-
resistant
Slow
0
500
1000
1500
Time (ms)

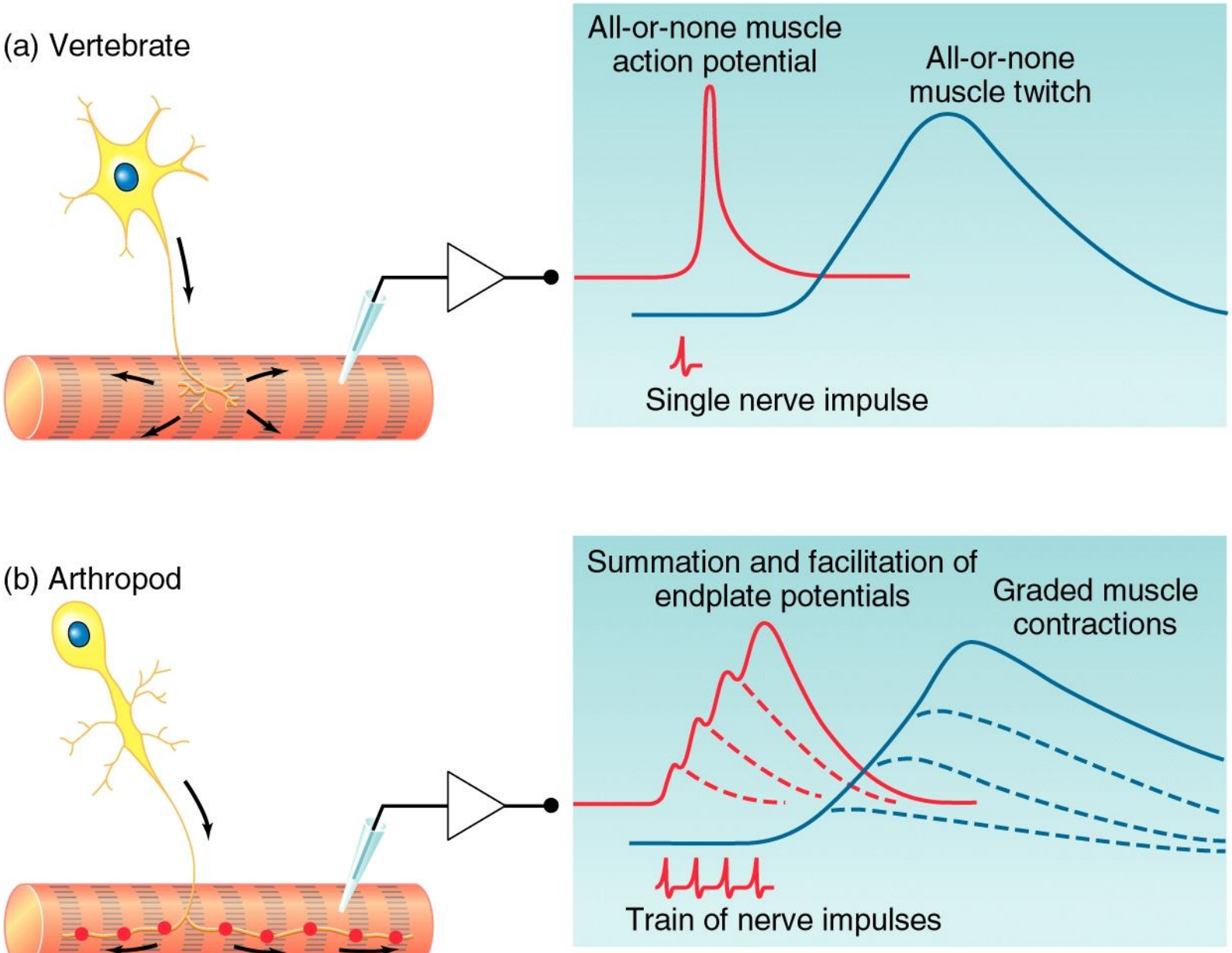

Percent maximum force
100
0
Fast
fatigable
100
0
Fast fatigue-resistant
100
0
Slow
0
2
4
6
60
Time (min)


(B)
(C)
(D)
Single muscle twitches (5 Hz)
Temporal summation (20 Hz)
Unfused tetanus (80 Hz)
Fused tetanus (100 Hz)

Muscle responses: force and electrical events (think comparative: vertebrate vs. invertebrate)

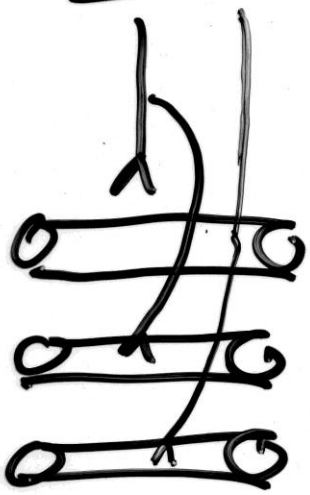





(a) Vertebrate
All-or-none muscle action potential
All-or-none muscle twitch
Single nerve impulse
(b) Arthropod
Summation and facilitation of endplate potentials
Graded muscle contractions
Train of nerve impulses

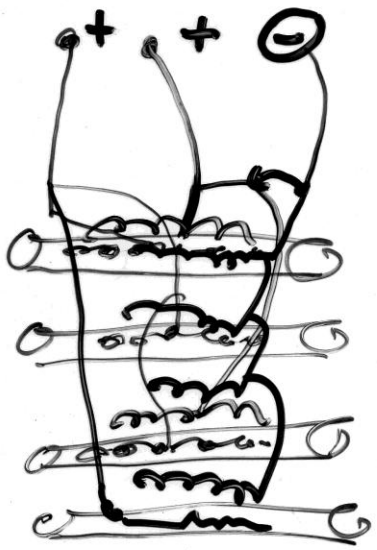
LIST OF DIFFERENCES

Vert

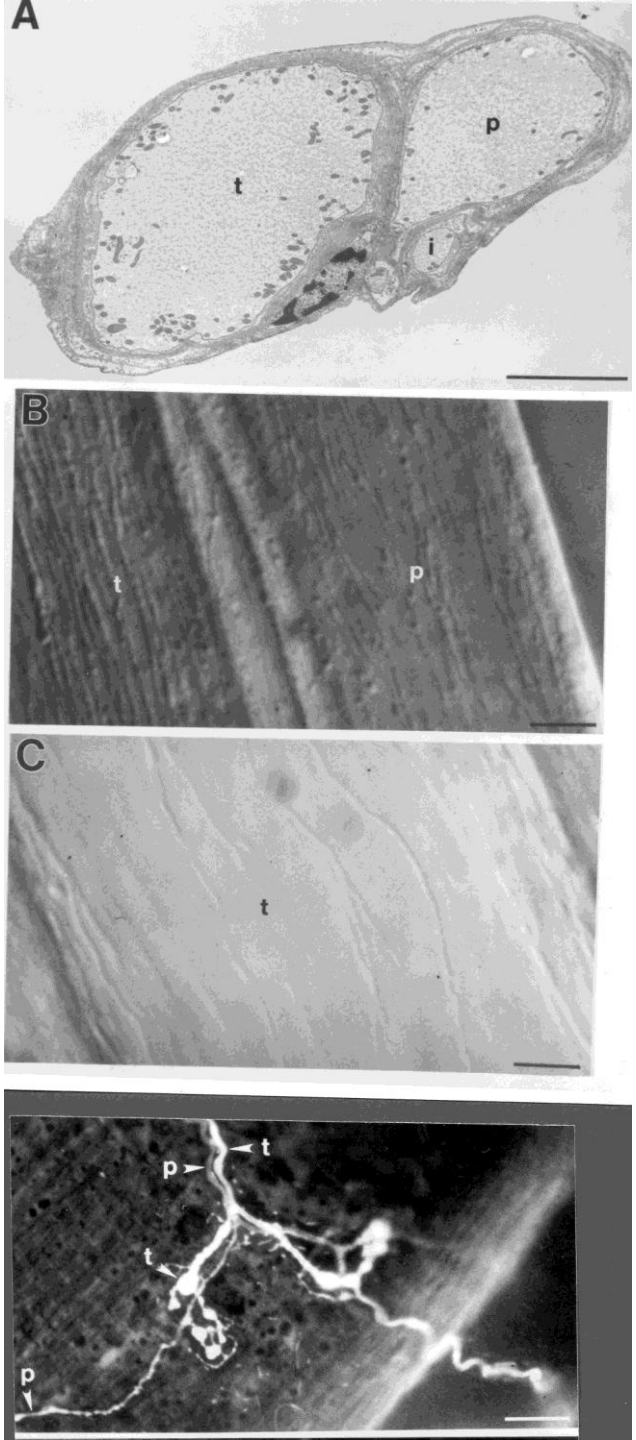


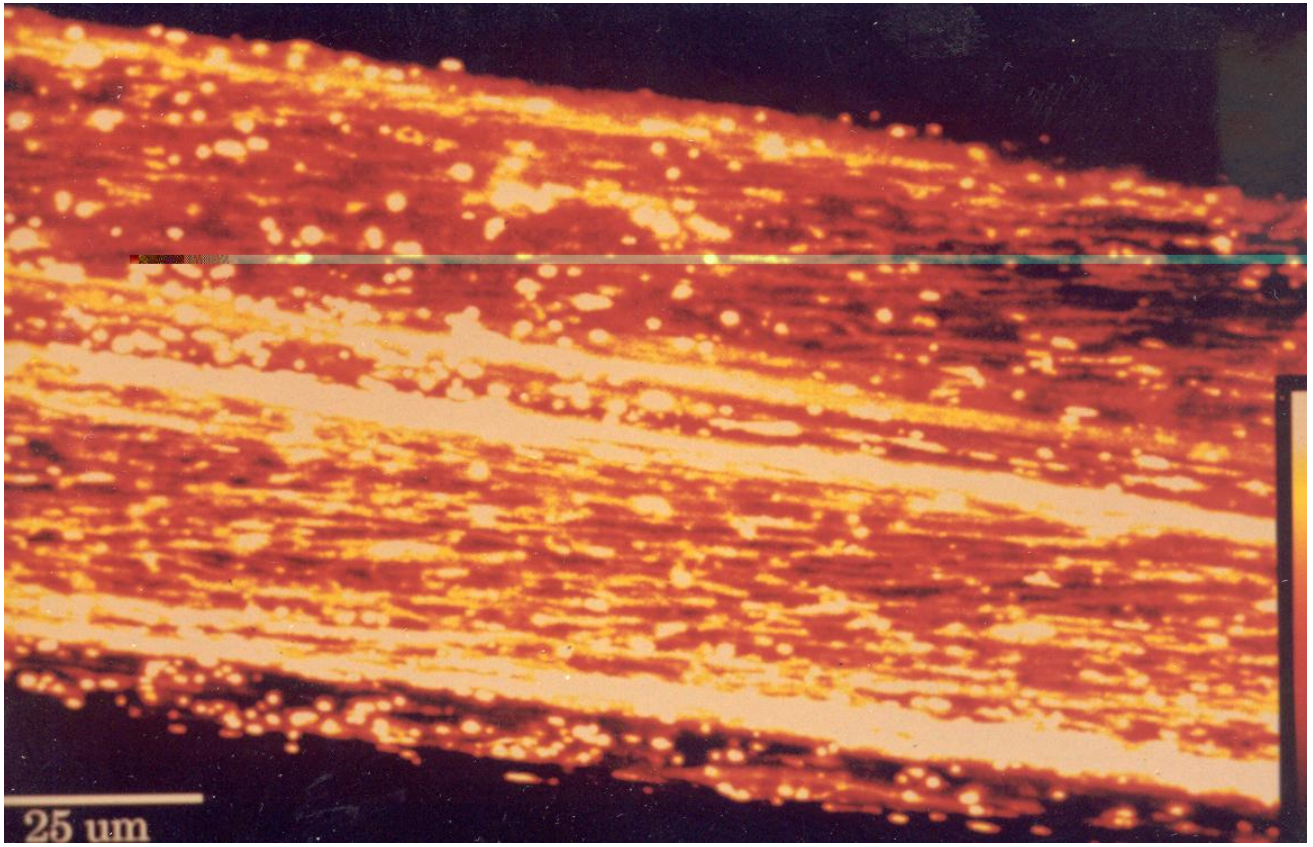
- Ach ⊕
- Belly
- → Ap

Invert

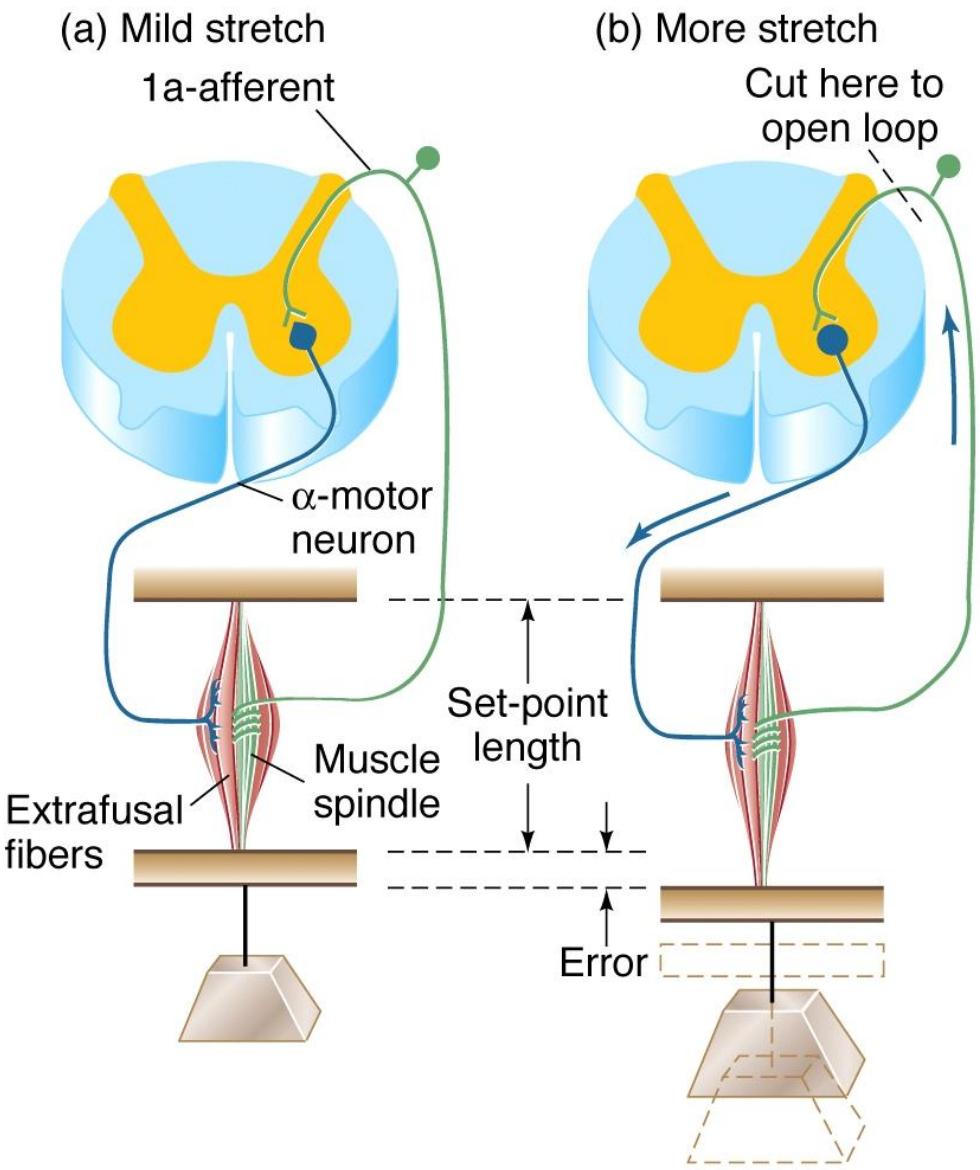


- → glutamate ⊕ EPSP
- → GABA ⊖ IPSP
- → multiterminal
- → poly neuronal
- → Graded
- presynaptic Inhibition

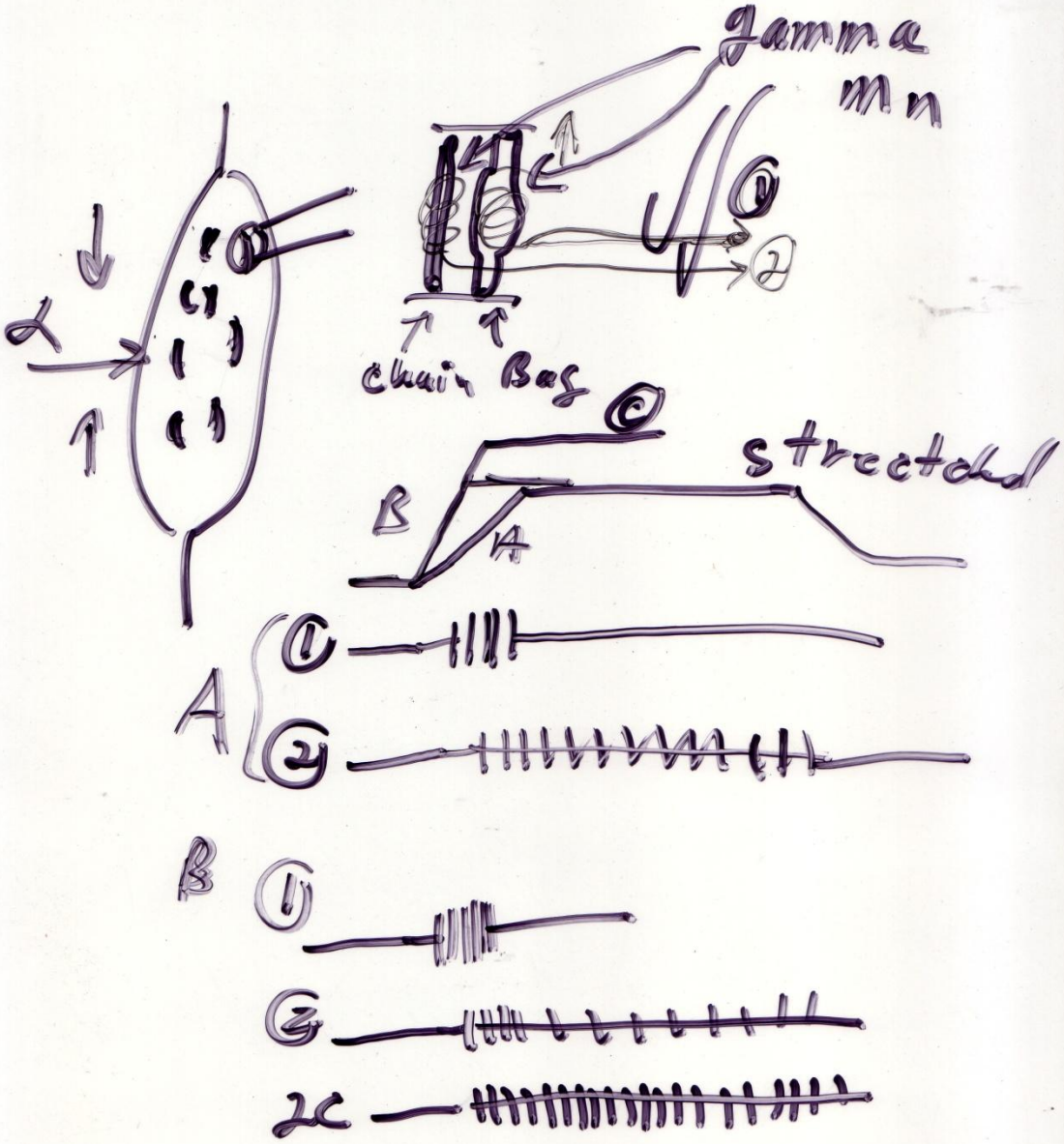

A
t
p
i
B
t
p
C
t
t
p
t
p


25 um

Muscle Stretch Reflexes (page 408 text)



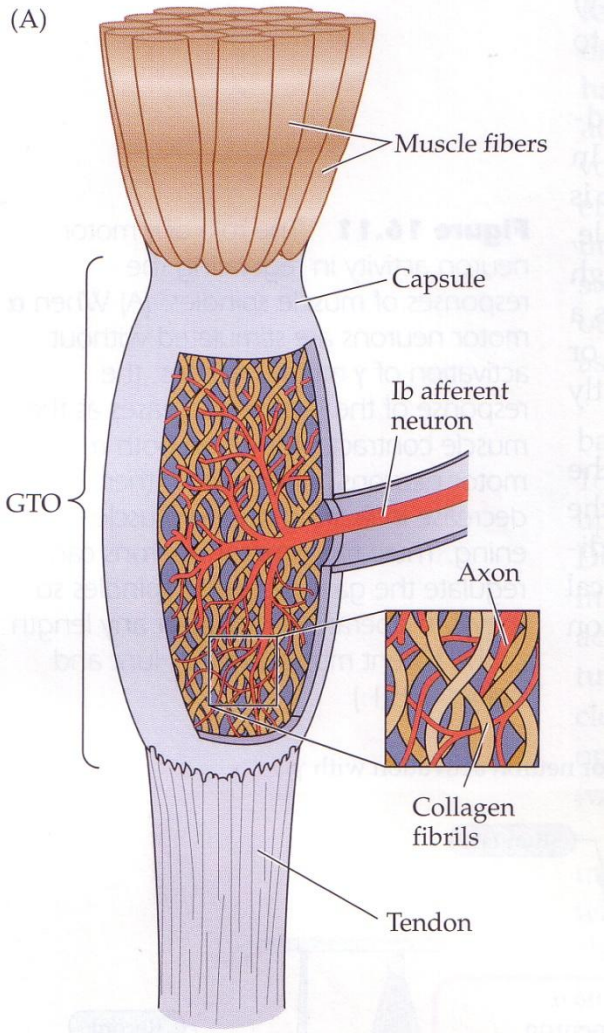
The electrical activity and control

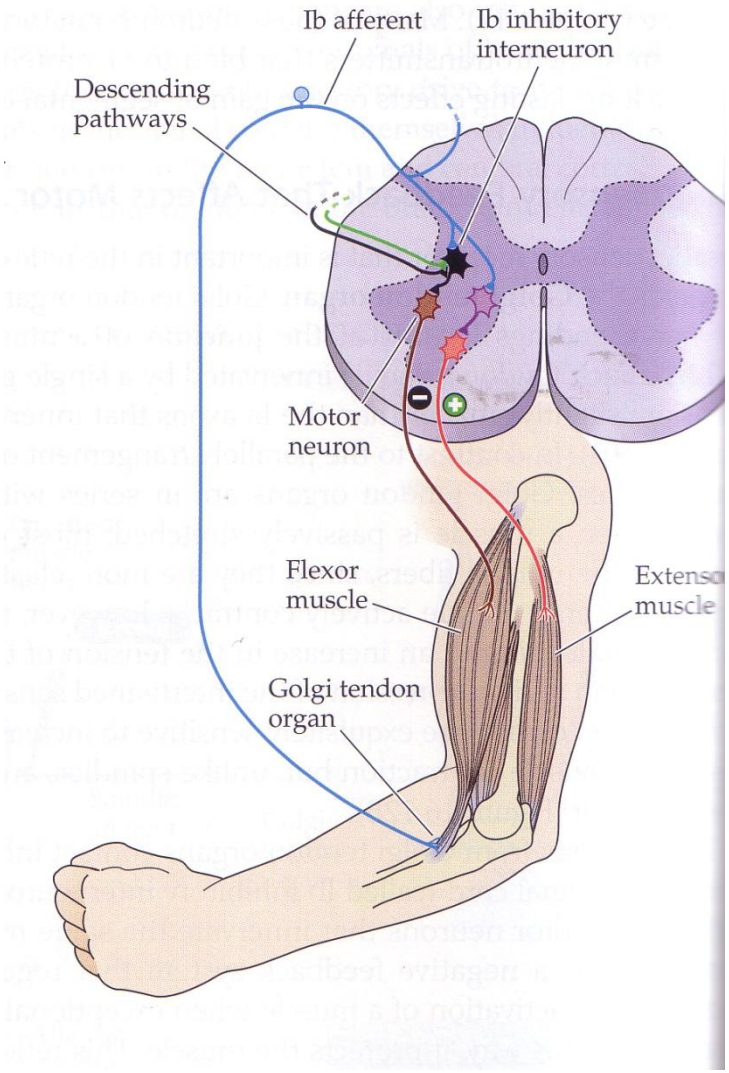

gamma
mn
Chain Bag
stretched
B
A
A
B
2c

Crayfish Tail
Muscle receptor organ

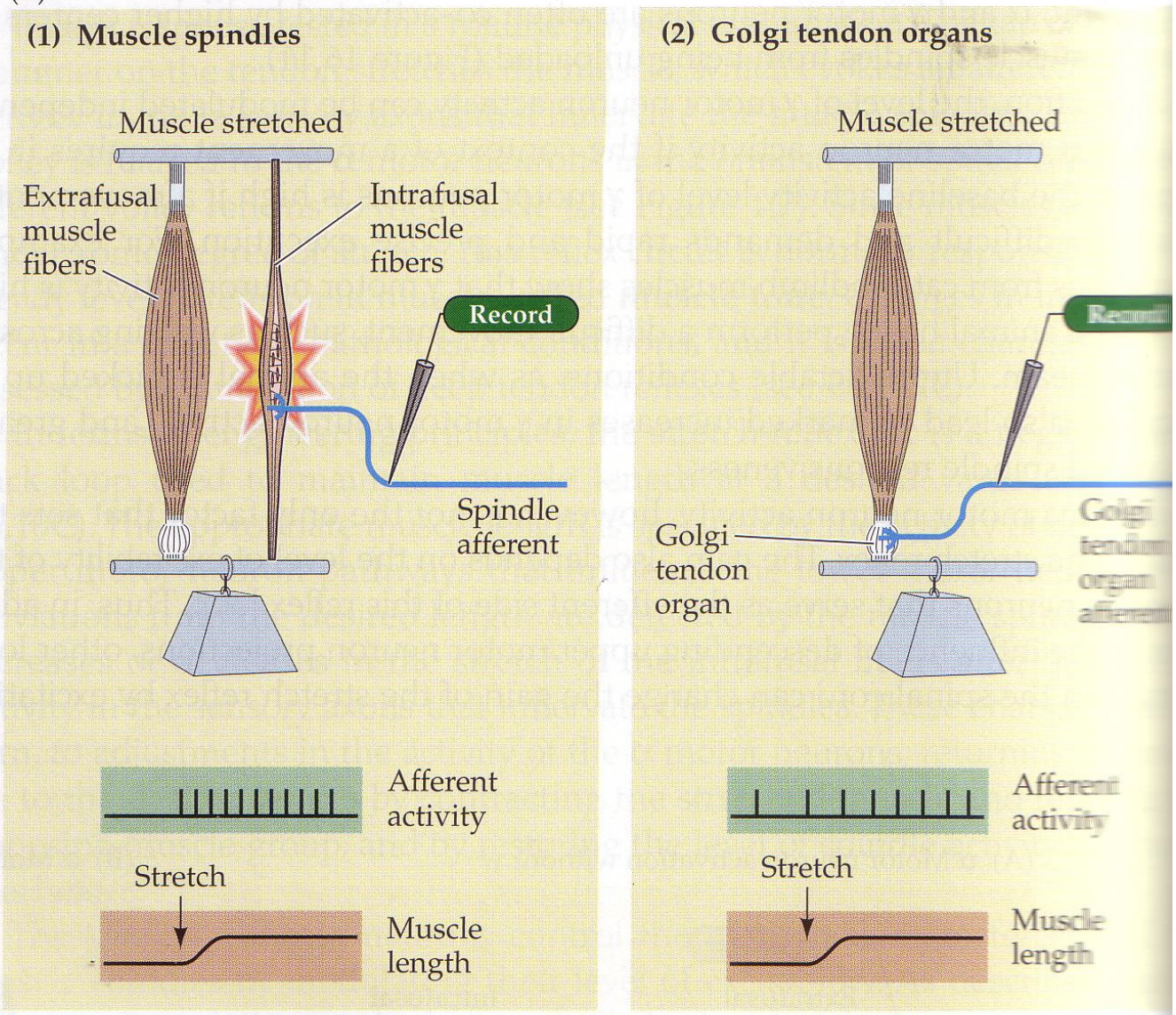
M.R.O.

Same Exp.

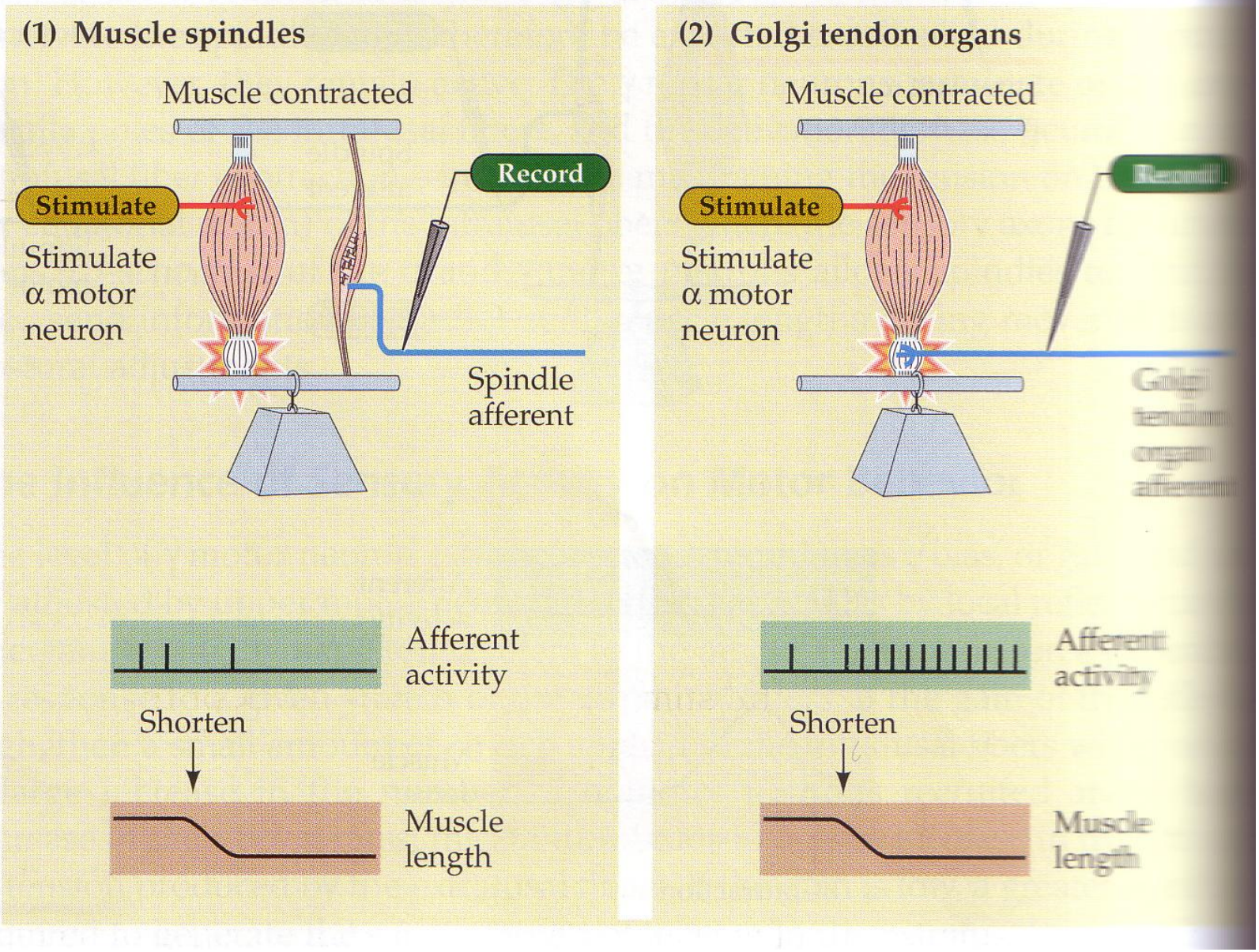

(A)
Muscle fibers
Capsule
Ib afferent neuron
GTO
Axon
Collagen fibrils
Tendon


Ib afferent
Ib inhibitory interneuron
Descending pathways
Motor neuron
Flexor muscle
Golgi tendon organ

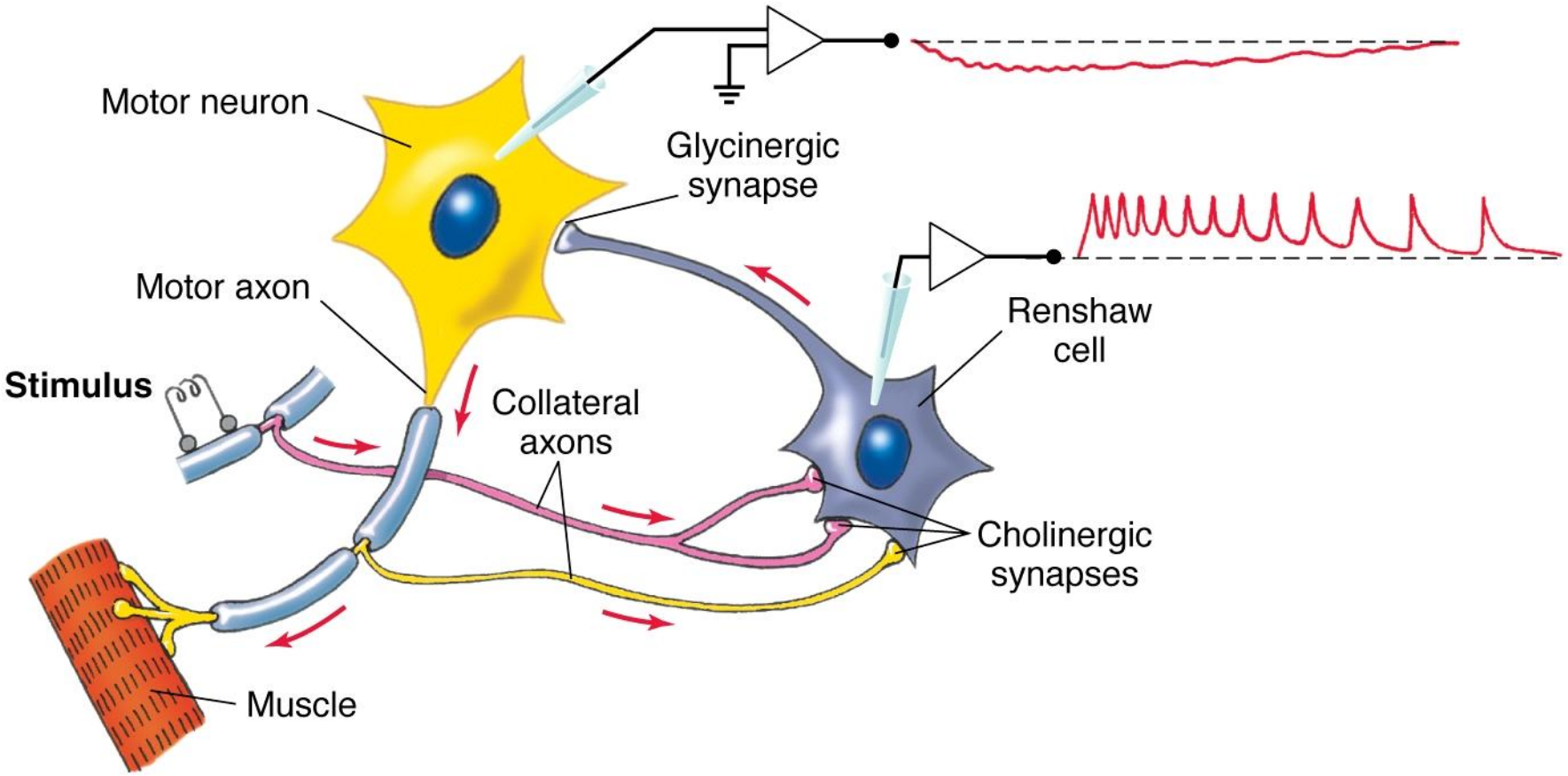
(B) MUSCLE PASSIVELY STRETCHED

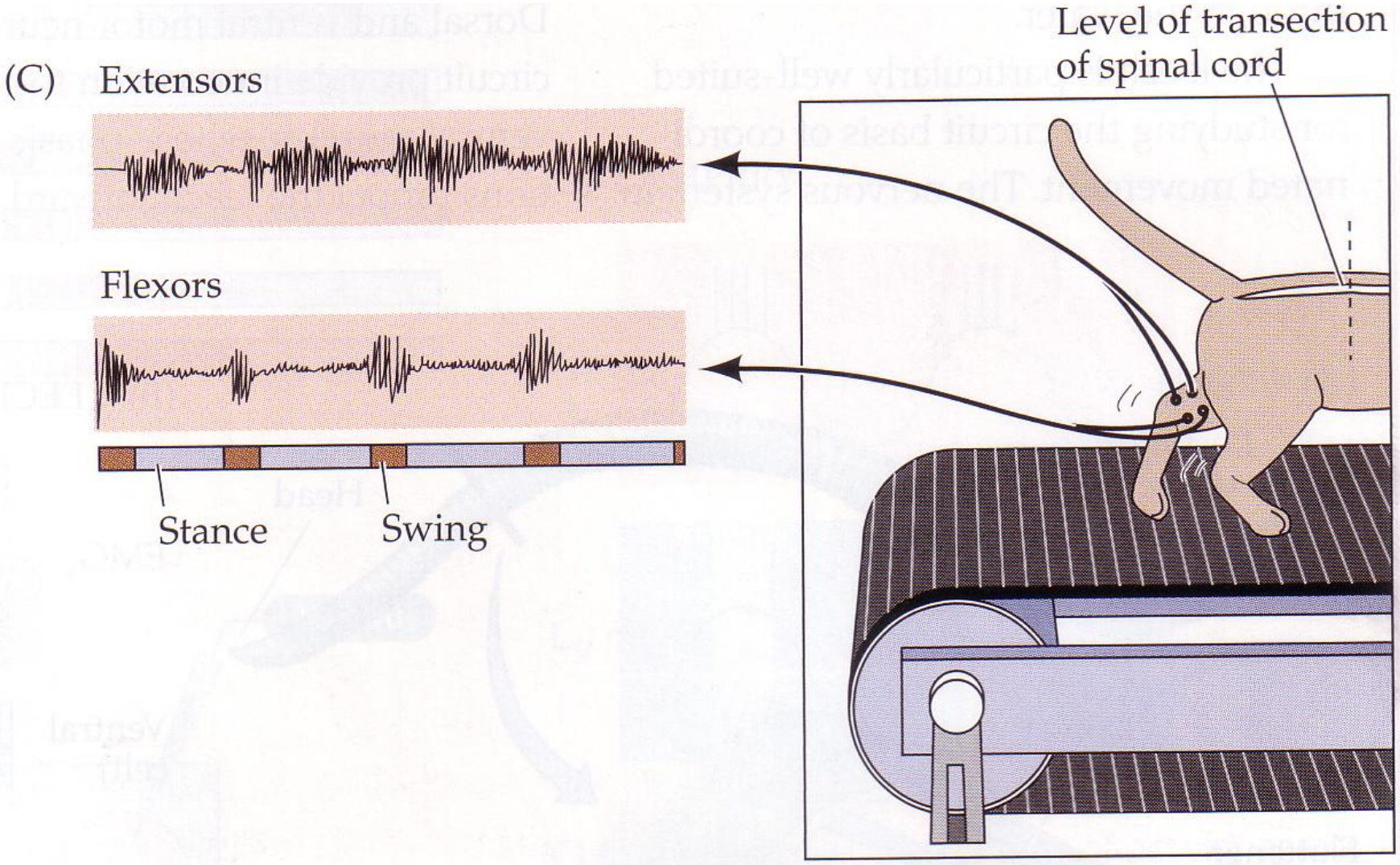


MUSCLE ACTIVELY CONTRACTED

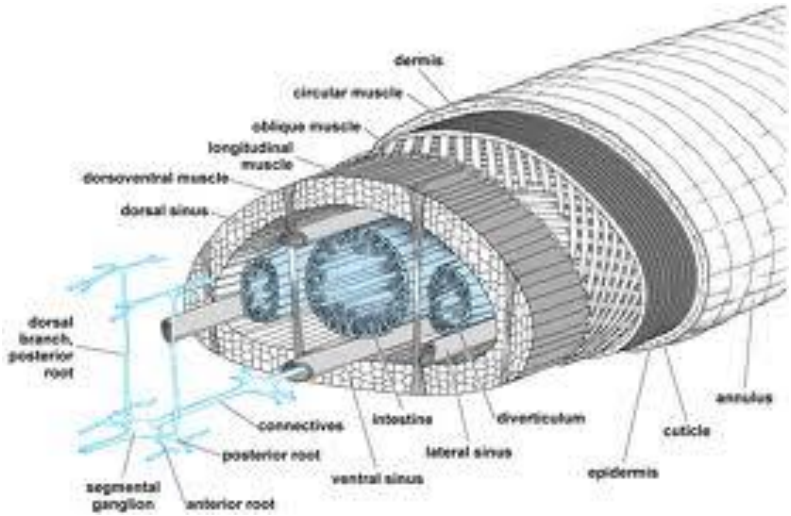


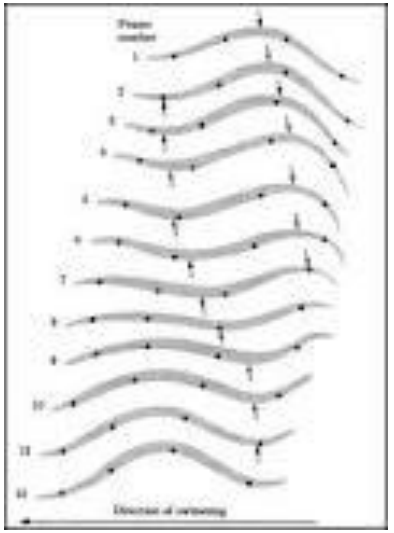
Within the spinal cord circuits: (mammal)



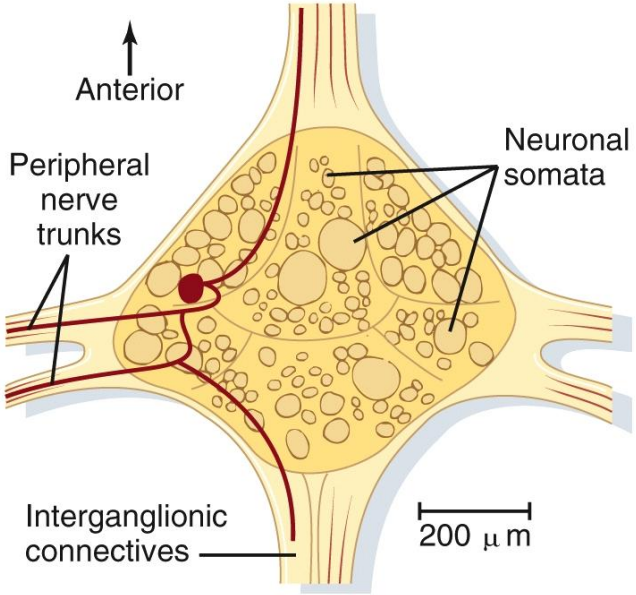

(C)
Extensors
Flexors
Stance
Swing
Level of transection
of spinal cord

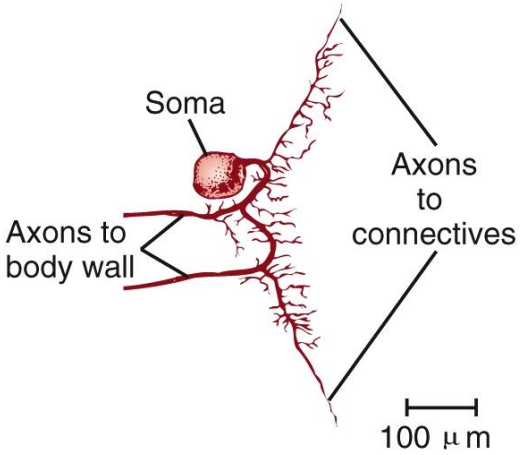
LEECH

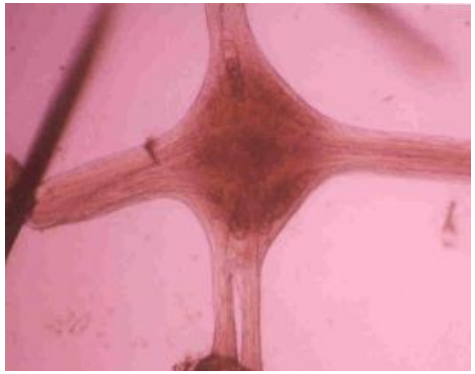


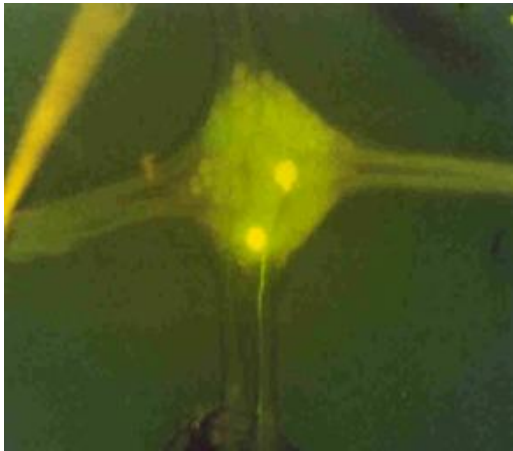


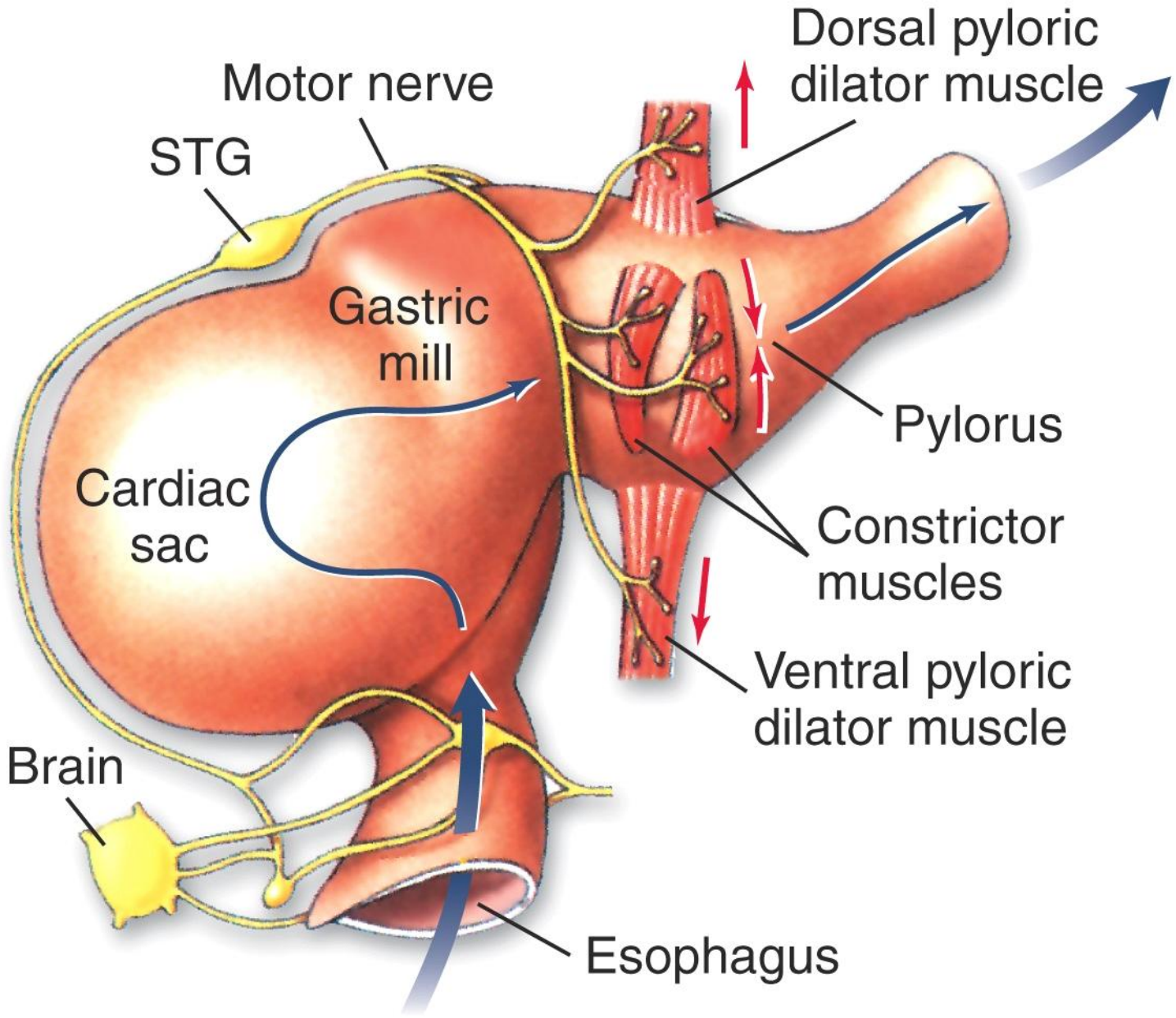
(a) Segmental ganglion of *Hirudo*










Dorsal pyloric
dilator muscle
Motor nerve
STG
Gastric
mill
Pylorus
Cardiac
sac
Constrictor
muscles
Ventral pyloric
dilator muscle
Brain
Esophagus

Diseases of motor unit:

Amyotrophic lateral sclerosis (**ALS**) (**Lou Gehrig's disease)** a form of motor neurone disease caused by the degeneration of upper and lower neurons, located in the ventral horn of the spinal cord and the cortical neurons that provide their efferent input.

Peripheral nerve damage (peripheral neuropathy)
Mononeuropathy-Mononeuropathy and radiculopathy is most often due to trauma of some type.
Radiculopathy-Radiculopathy indicates damage to nerve root(s), and typically occurs as a component of several spinal diseases.
Polyneuropathy-Polyneuropathy is a common condition. It is not always easy to determine its cause. In this condition the longest peripheral nerve fibers are usually first. Peripheral neuropathy can affect either the axon, or myelin sheaths (demyelinating), or both.

Mononeuritis Multiplex "Mononeuritis multiplex" is a relatively rare presentation of certain disorders that damage nerves primarily by interfering with blood flow to nerves or plexi or by an autoimmune process damaging either the myelin or axon.

Continue of diseases of motor unit:

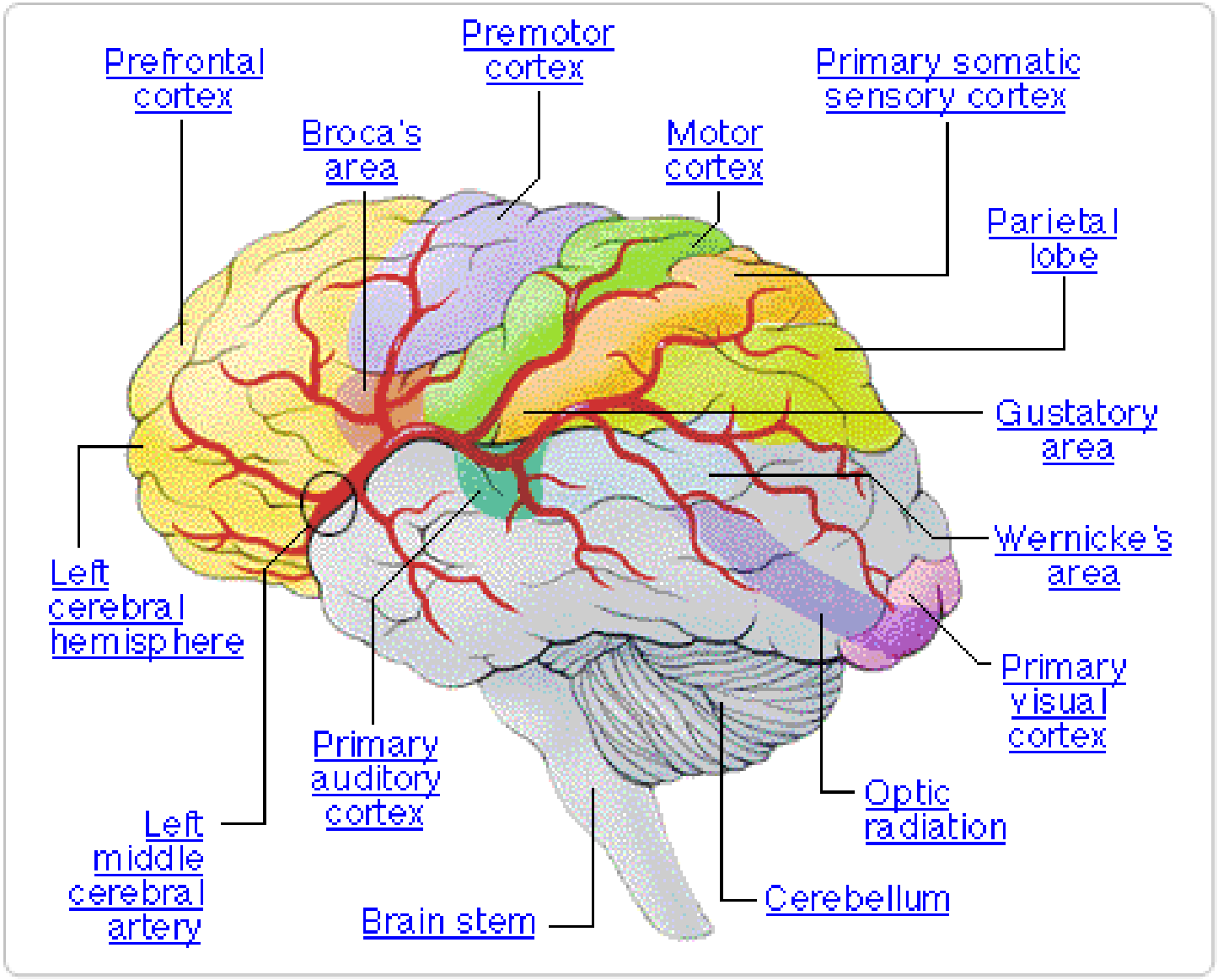
End-plate (neuromuscular junction)
Acetylcholine is the neurotransmitter at this synapse that couples motor nerve activity with response in the muscles. Botulinum toxin or a block of nicotinic ACh receptor (such as curare).

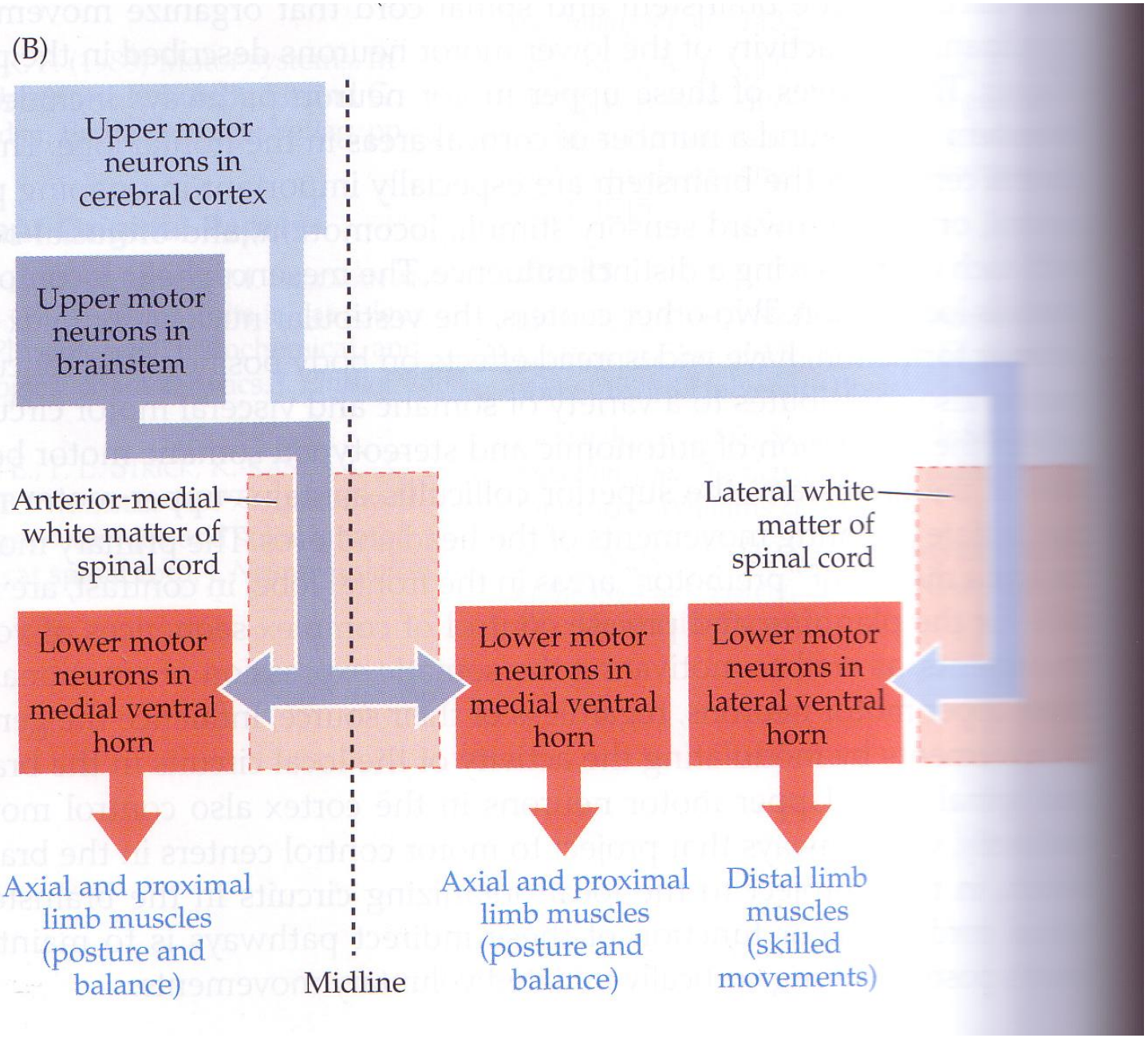
Myasthenia gravis.
Myasthenia gravis is the most common disorder affecting neuromuscular transmission. This condition is autoimmune, with antibodies directed against nicotinic acetylcholine receptors of the neuromuscular junction. It is not extremely common (about 1:10,000) and incidence is highest in young adult women. * thymic tumors.

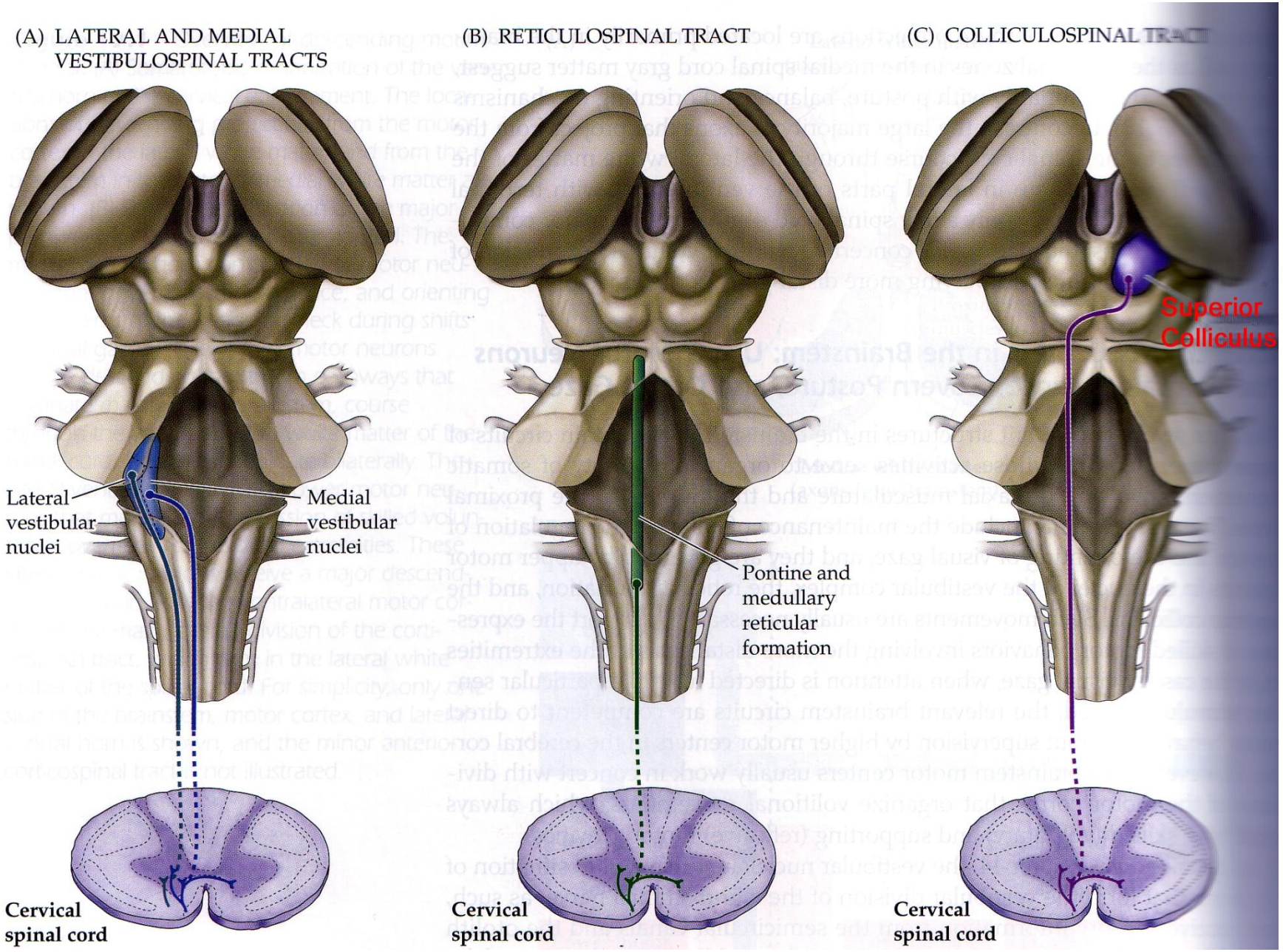
Myasthenic syndrome. There is another interesting and uncommon disorder of neuromuscular transmission -- the myasthenic syndrome or Lambert Eaton Syndrome (LEMS).

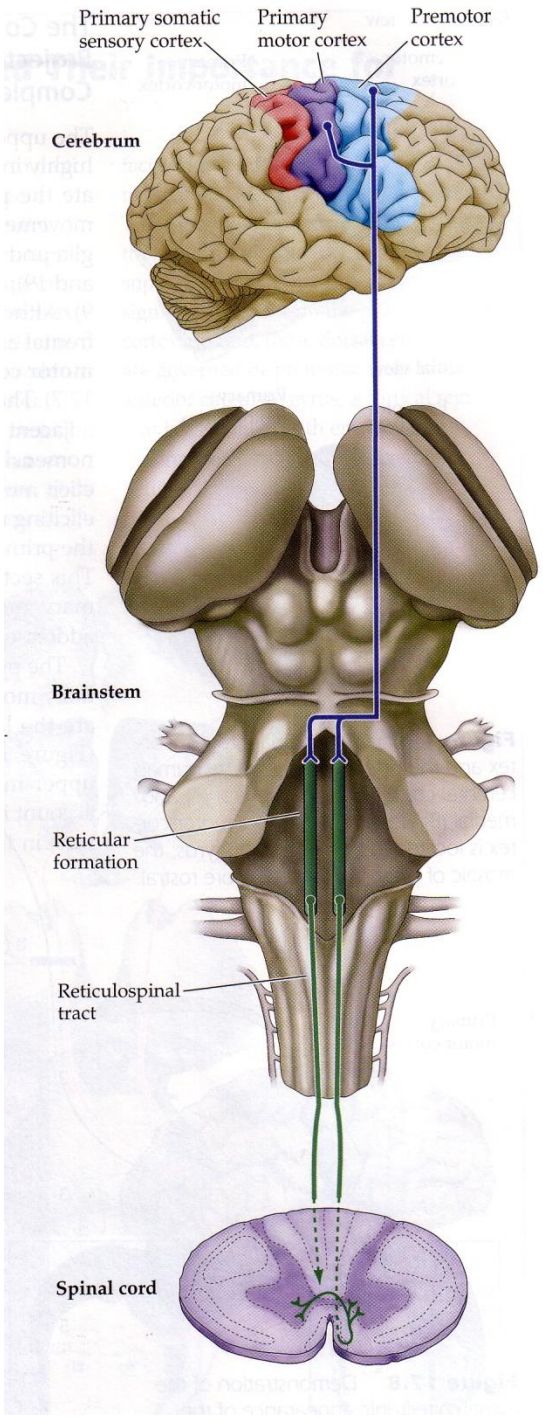
Muscle Disease (myopathy)
There are many things that can go wrong in muscles

Chapter 17: Upper motor neurons




(B)
Upper motor neurons in cerebral cortex
Upper motor neurons in brainstem
Anterior-medial white matter of spinal cord
Lateral white matter of spinal cord
Lower motor neurons in medial ventral horn
Lower motor neurons in medial ventral horn
Lower motor neurons in lateral ventral horn
Axial and proximal limb muscles (posture and balance)
Midline
Axial and proximal limb muscles (posture and balance)
Distal limb muscles (skilled movements)

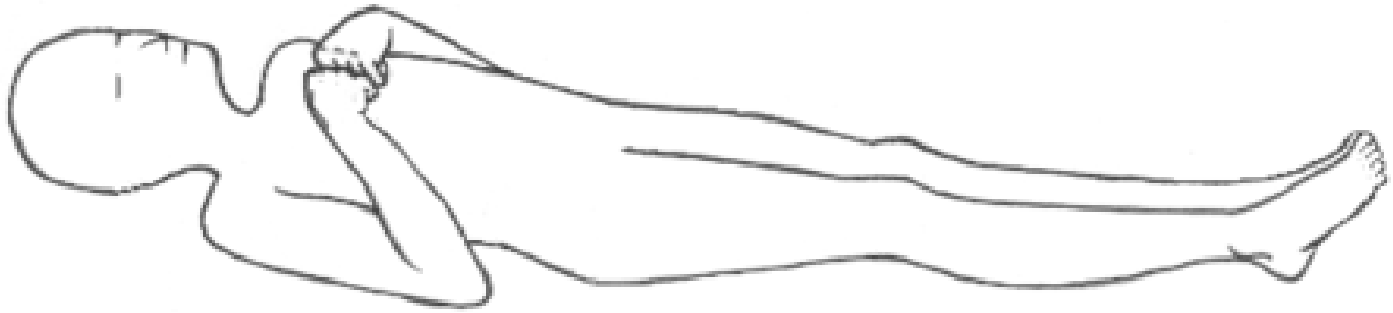

(A) LATERAL AND MEDIAL VESTIBULOSPINAL TRACTS
Lateral vestibular nuclei
Medial vestibular nuclei
Cervical spinal cord
(B) RETICULOSPINAL TRACT
Pontine and medullary reticular formation
Cervical spinal cord
(C) COLLICULOSPINAL TRACT
Superior Colliculus
Cervical spinal cord


Primary somatic sensory cortex
Primary motor cortex
Premotor cortex
Cerebrum
Brainstem
Reticular formation
Reticulospinal tract
Spinal cord

Decorticate

Decorticate posturing is also called **decorticate response**, **decorticate rigidity**, **flexor posturing**, or, colloquially, **mummy baby**

Decorticate posturing indicates that there may be damage to areas including the cerebral hemispheres, the internal capsule, and the thalamus. It may also indicate damage to the midbrain.



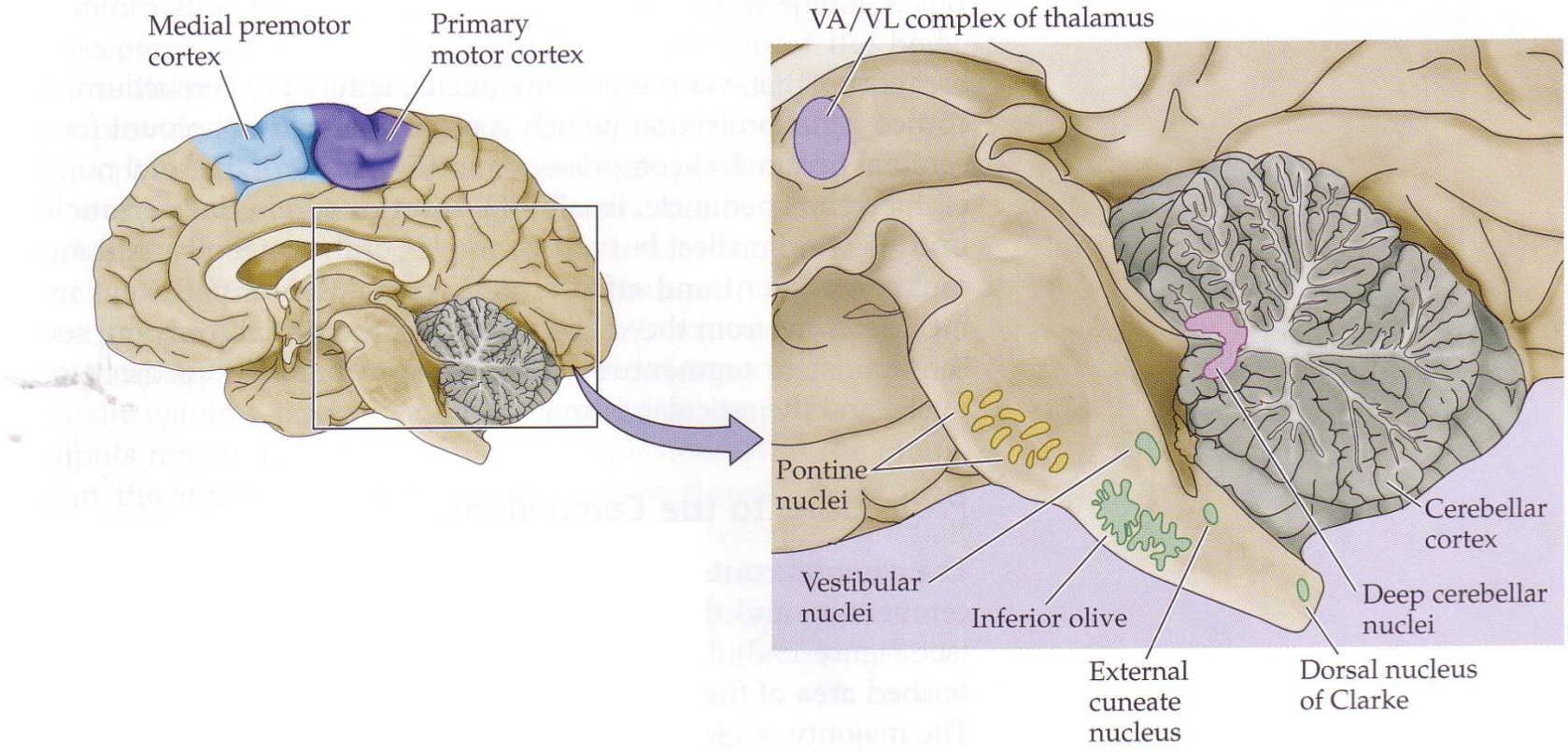
Decorticate posturing, with elbows, wrists and fingers flexed, and legs extended and rotated inward

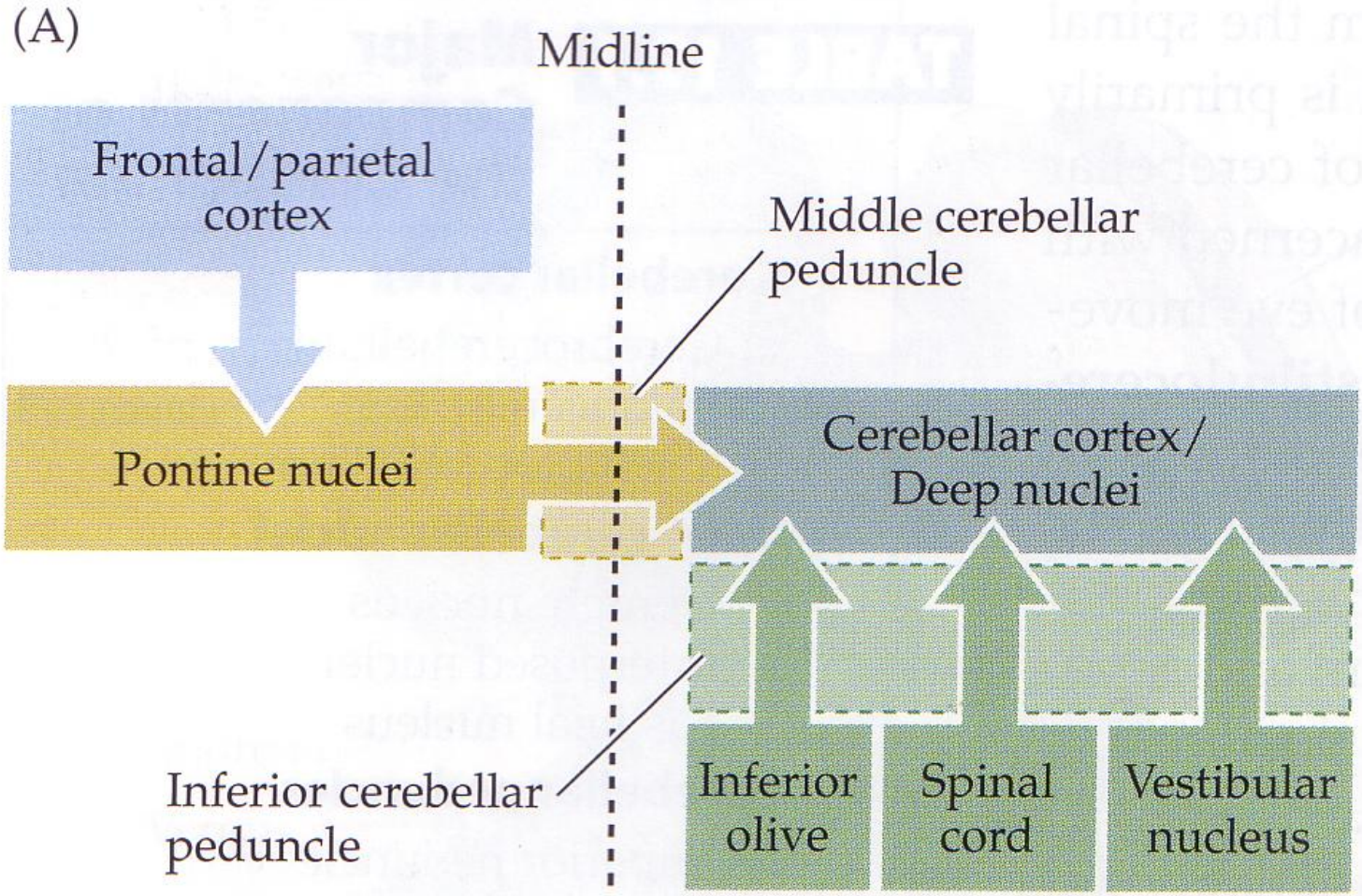
Decerebrate

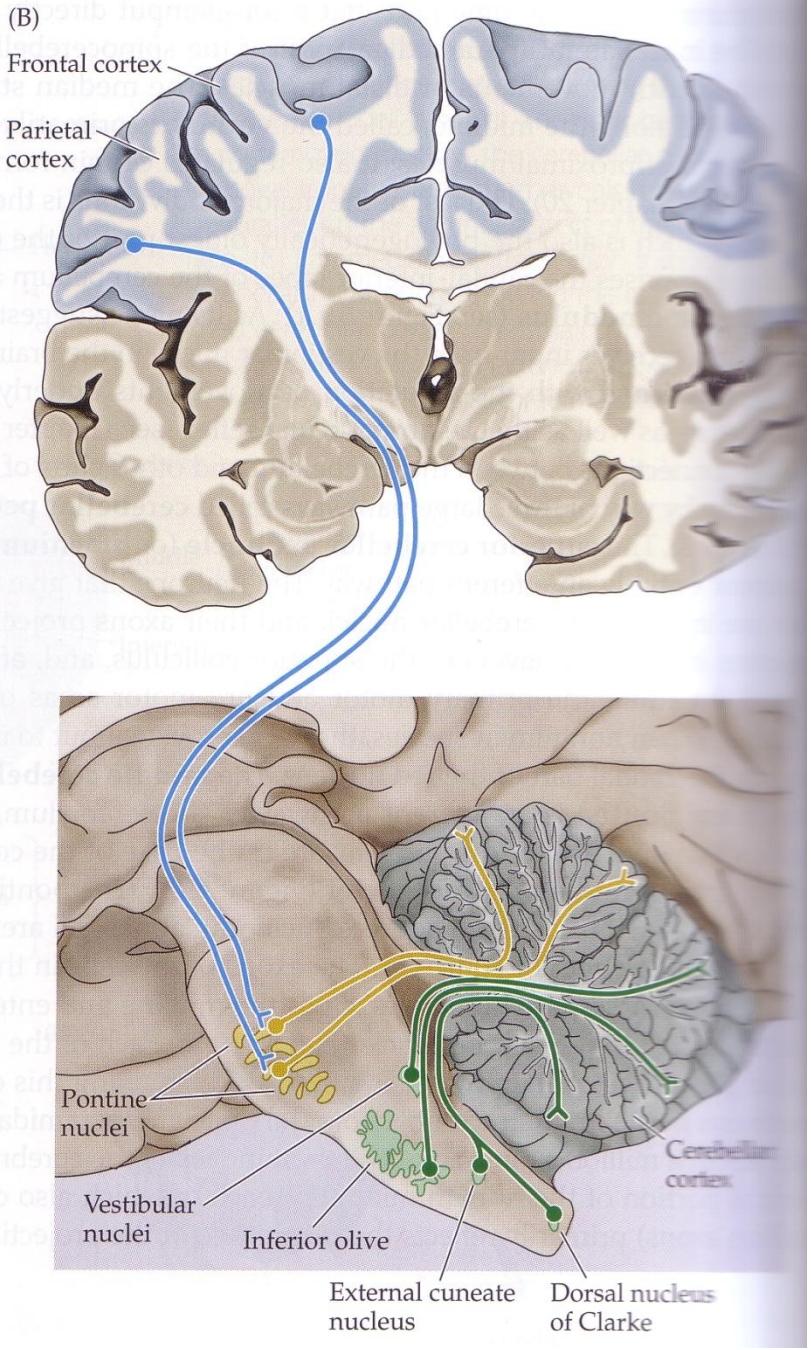
Decerebrate posturing is also called **decerebrate response**, **decerebrate rigidity**, or **extensor posturing**. It describes the involuntary extension of the upper extremities in response to external stimuli.

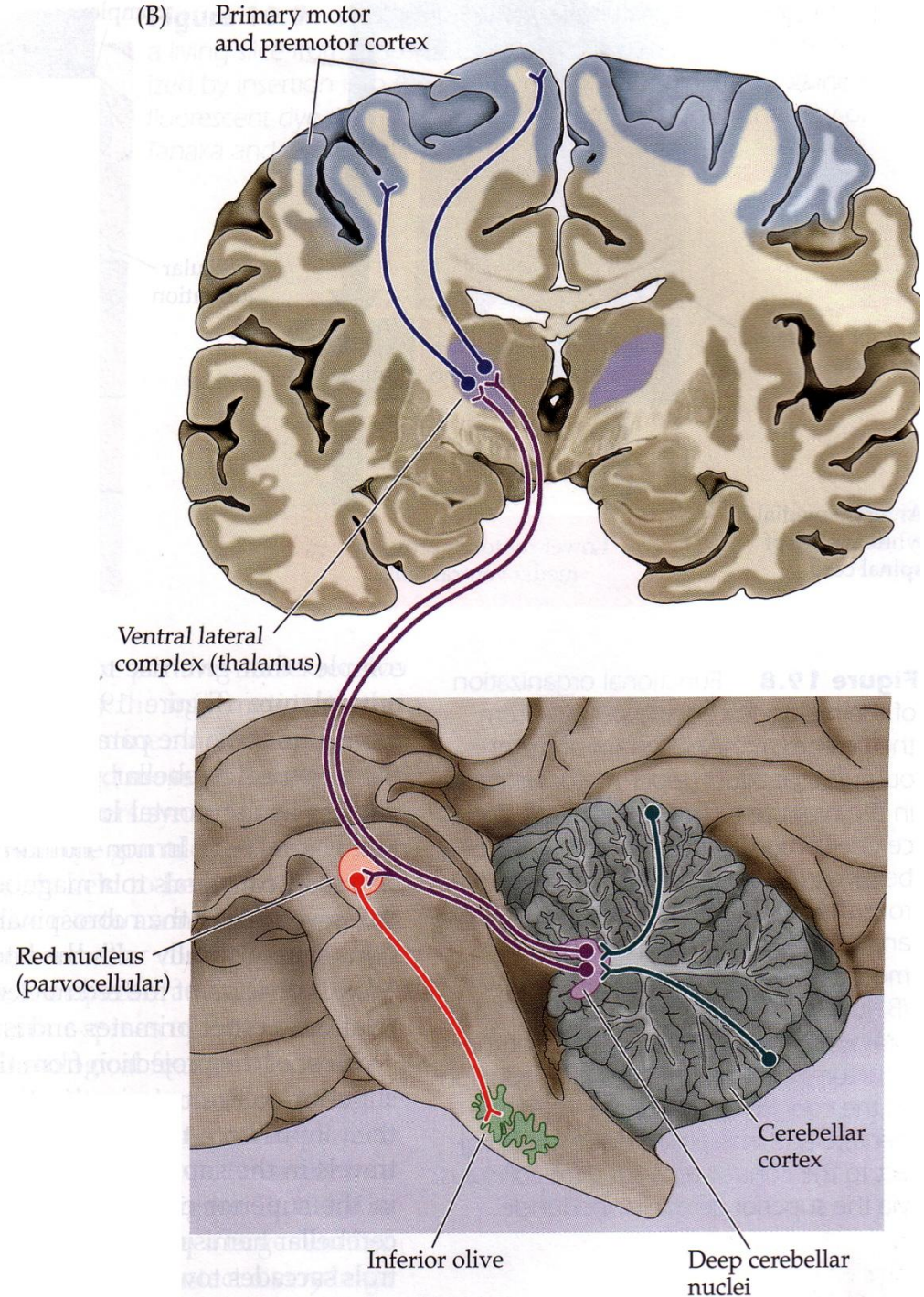
Decerebrate rigidity or abnormal extensor posturing.

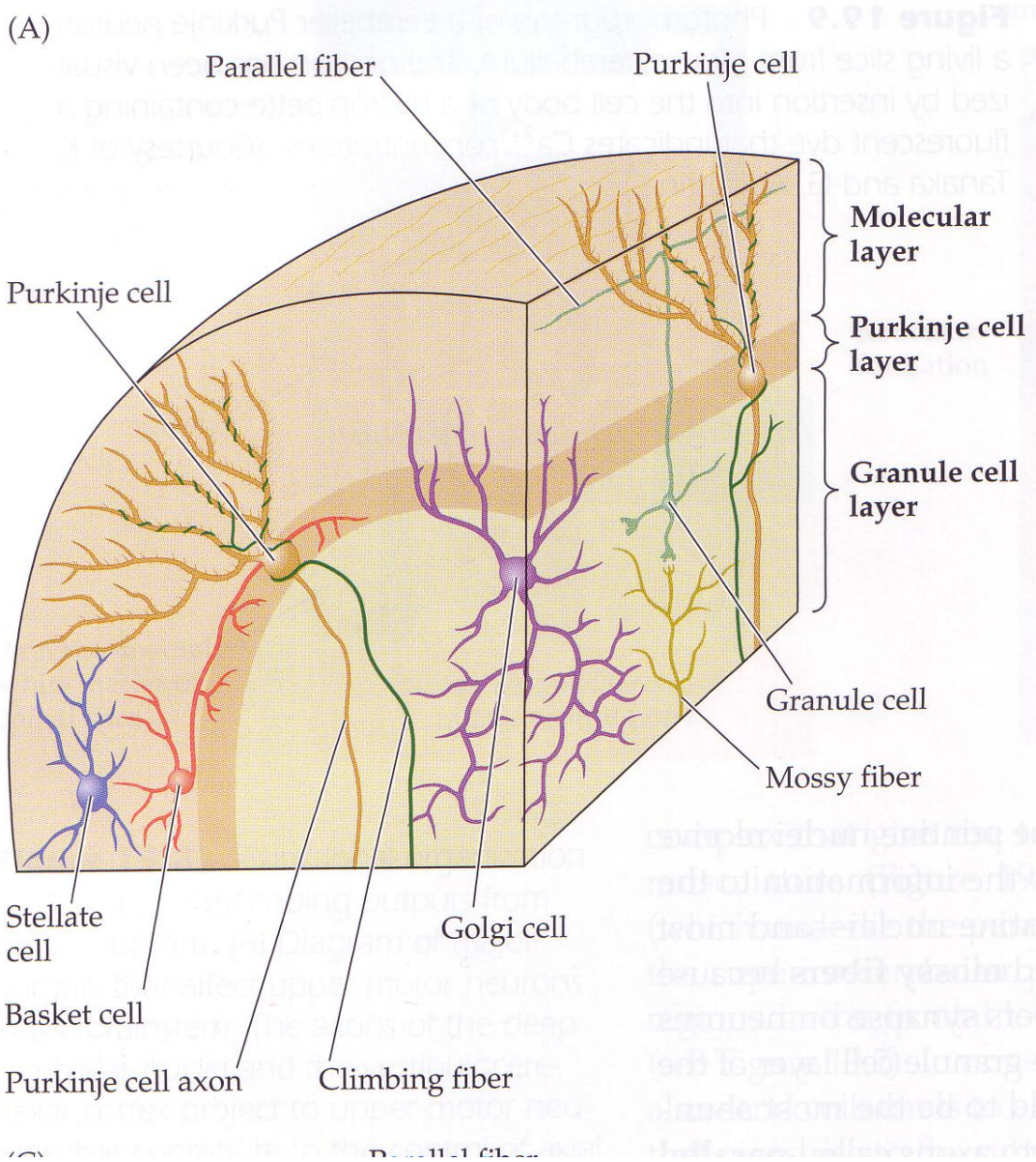
Chapter 19: Modulation of Movement

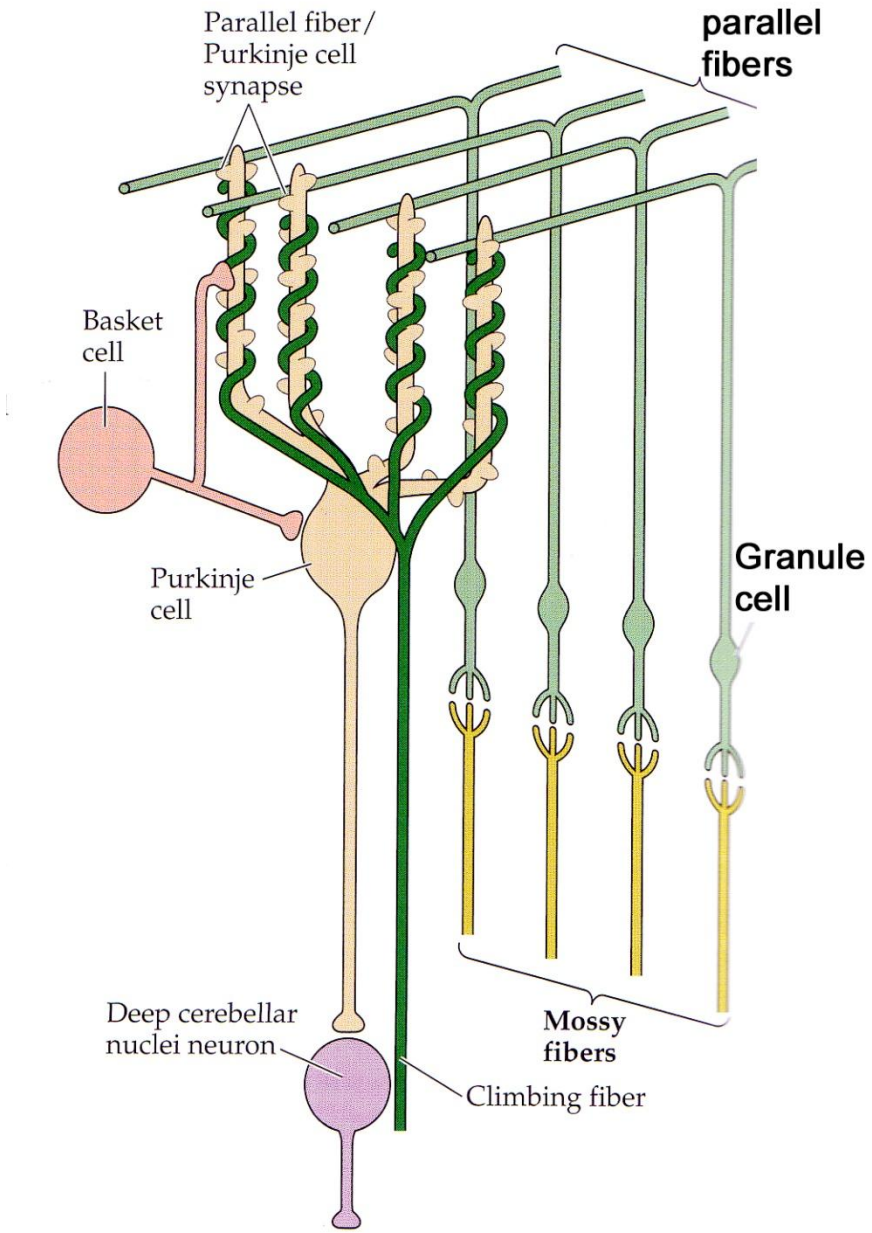


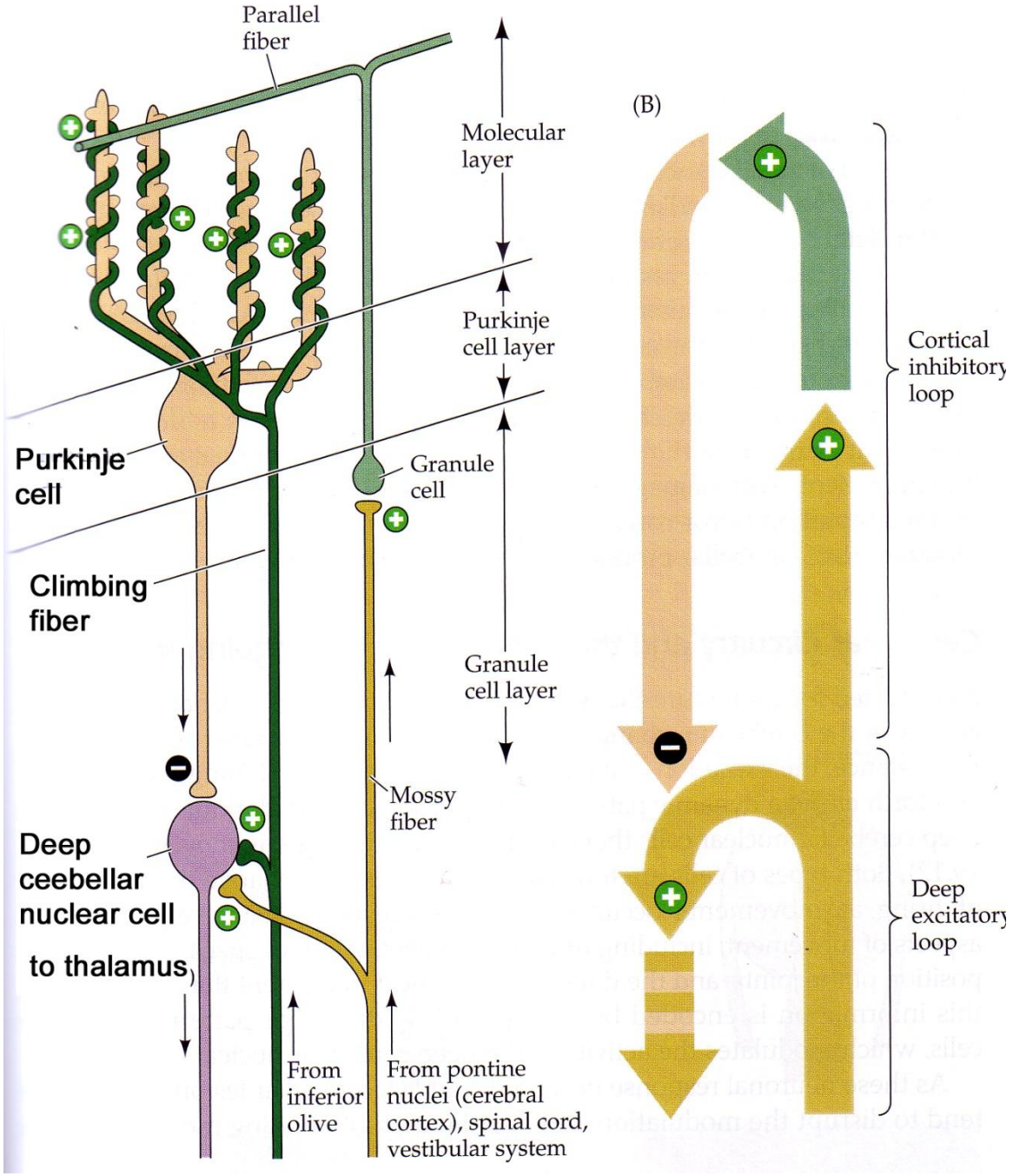

(A)
Midline
Frontal/parietal cortex
Middle cerebellar peduncle
Pontine nuclei
Cerebellar cortex/ Deep nuclei
Inferior cerebellar peduncle
Inferior olive
Spinal cord
Vestibular nucleus


(B)
Frontal cortex
Parietal cortex
Pontine nuclei
Vestibular nuclei
Inferior olive
External cuneate nucleus
Dorsal nucleus of Clarke


(B)
Primary motor
and premotor cortex
Ventral lateral
complex (thalamus)
Red nucleus
(parvocellular)
Cerebellar
cortex
Inferior olive
Deep cerebellar
nuclei


(A)
Parallel fiber
Purkinje cell
Molecular layer
Purkinje cell layer
Granule cell layer
Purkinje cell
Granule cell
Mossy fiber
Stellate cell
Basket cell
Golgi cell
Purkinje cell axon
Climbing fiber


Parallel fiber/
Purkinje cell
synapse
parallel
fibers
Basket
cell
Purkinje
cell
Granule
cell
Deep cerebellar
nuclei neuron
Mossy
fibers
Climbing fiber


Parallel fiber
Molecular layer
Purkinje cell layer
Granule cell layer
Purkinje cell
Granule cell
Climbing fiber
Mossy fiber
Deep ceebellar nuclear cell
to thalamus
From inferior olive
From pontine nuclei (cerebral cortex), spinal cord, vestibular system
(B)
Cortical inhibitory loop
Deep excitatory loop

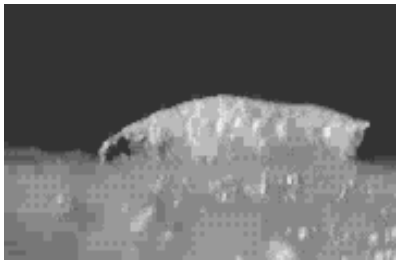
Critical Period

- Central circuits are well defined after a critical period, which is due to the sensory input early in the life.

- The central circuits are altered by hormones and neuromodulators throughout development.

Comparative

Drosophila



- Sensory input early in developmental stages.
- The central circuits are altered by hormones and neuromodulators.
- Challenge in the field is: Integration of sensory input that controls the muscular movement in a coordinated fashion.

Neuromodulators

- Recovery of locomotion by using selective agonists and antagonists of neurotransmitters involved in sensory-CNS-motor circuits.

(Chau et al., 2002)

contd…

- Rapid changes in the neural circuit activity can be induced by neuromodulators.

  Eg: aggressive behavior of D*rosophila*

  (Baier et al., 2002)

- 3 common neuromodulators:

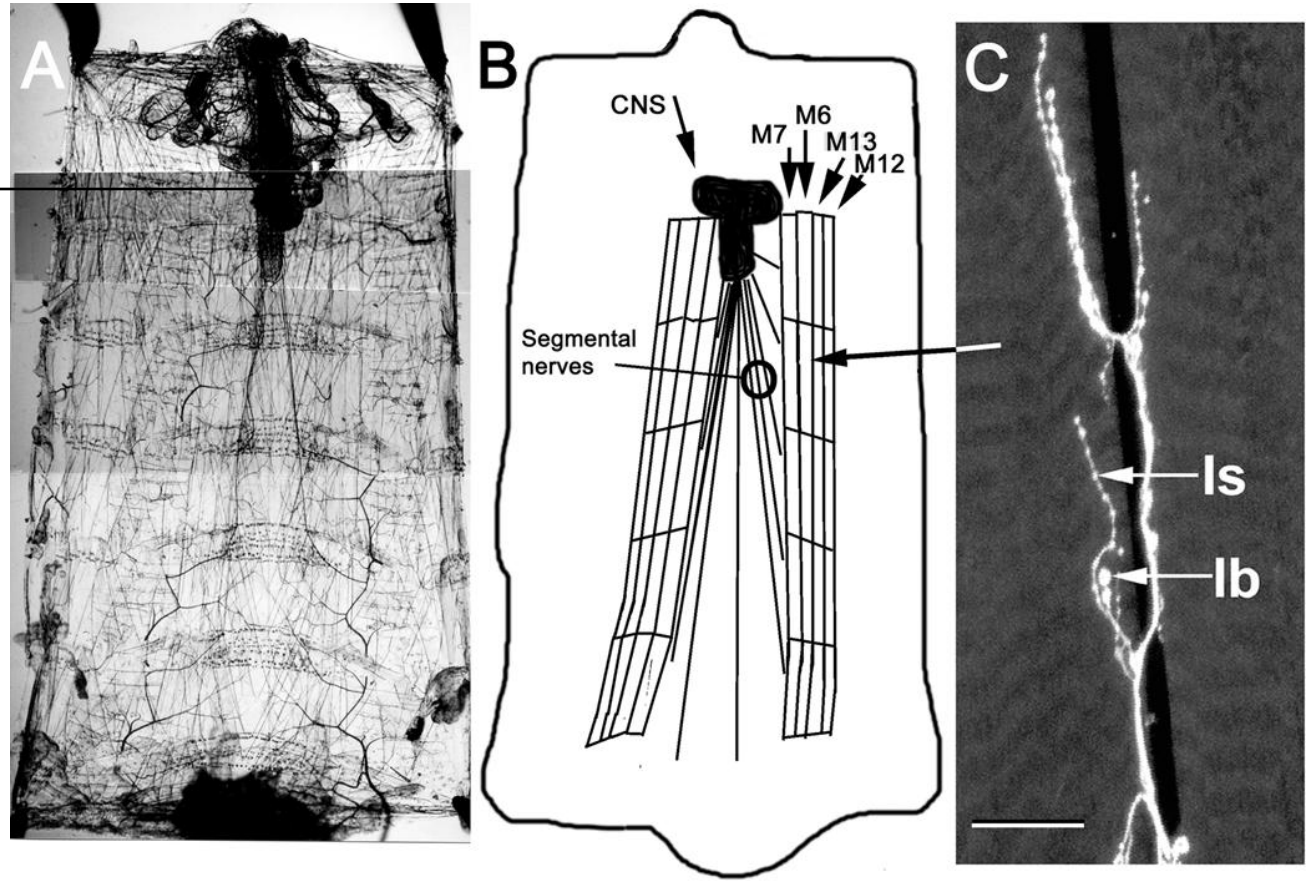
  Serotonin

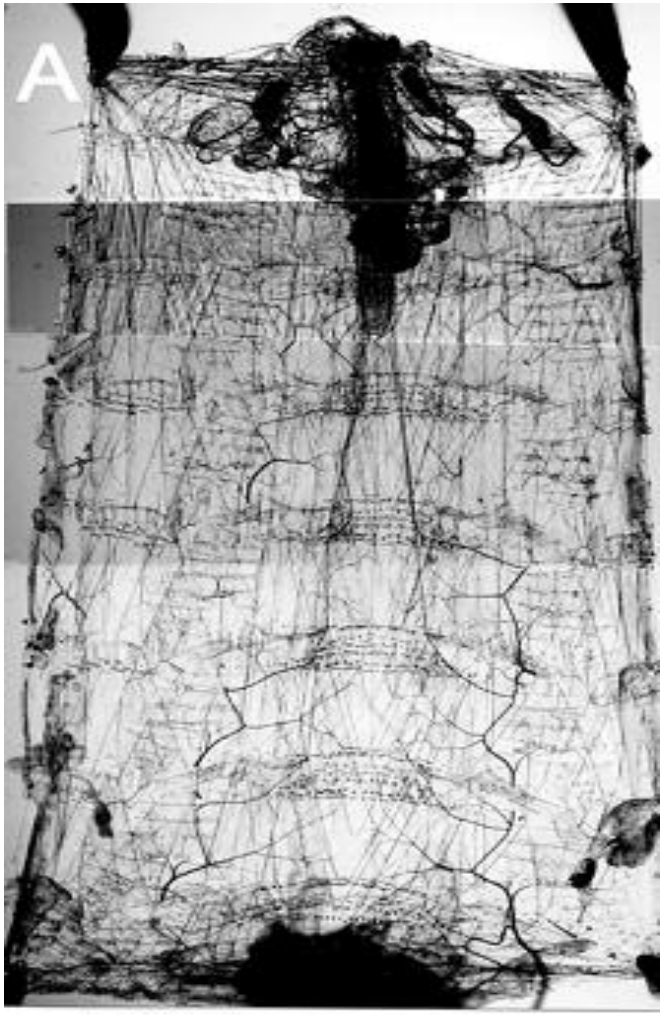
  Octopamine

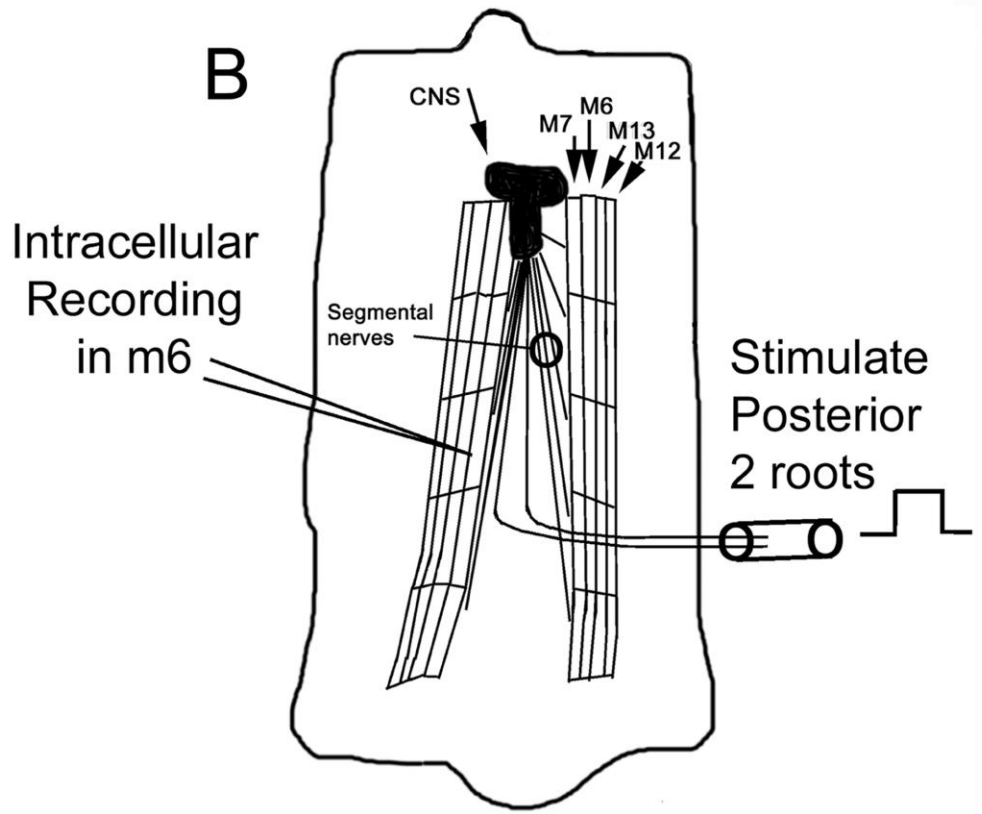
  Dopamine

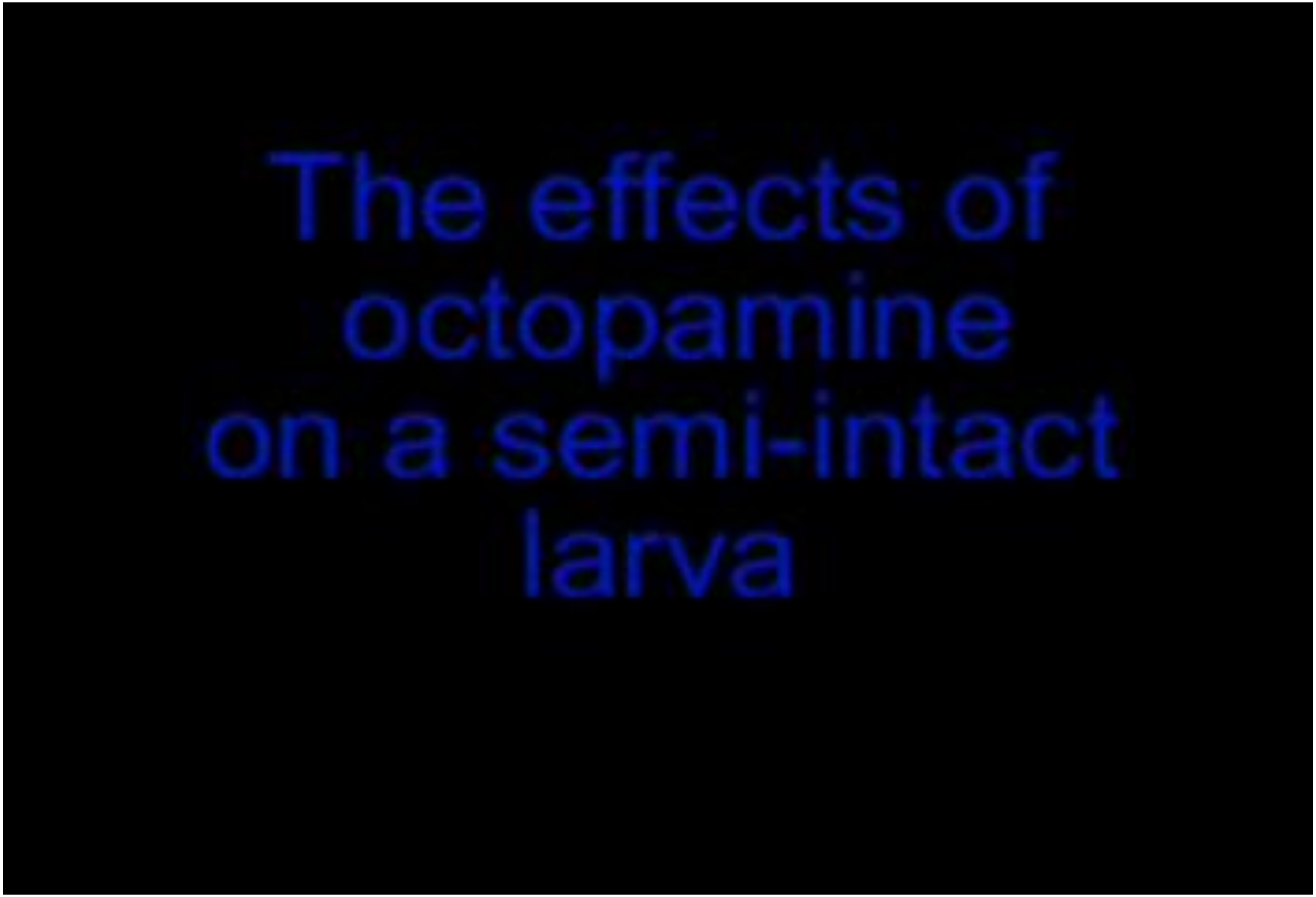
- In *Drosophila*
- 5-HT modulate the heart rate and voltage dependent potassium channels.
- DA is known to alter the sexual behavior in adult flies.
- OA is expressed in stress conditions.

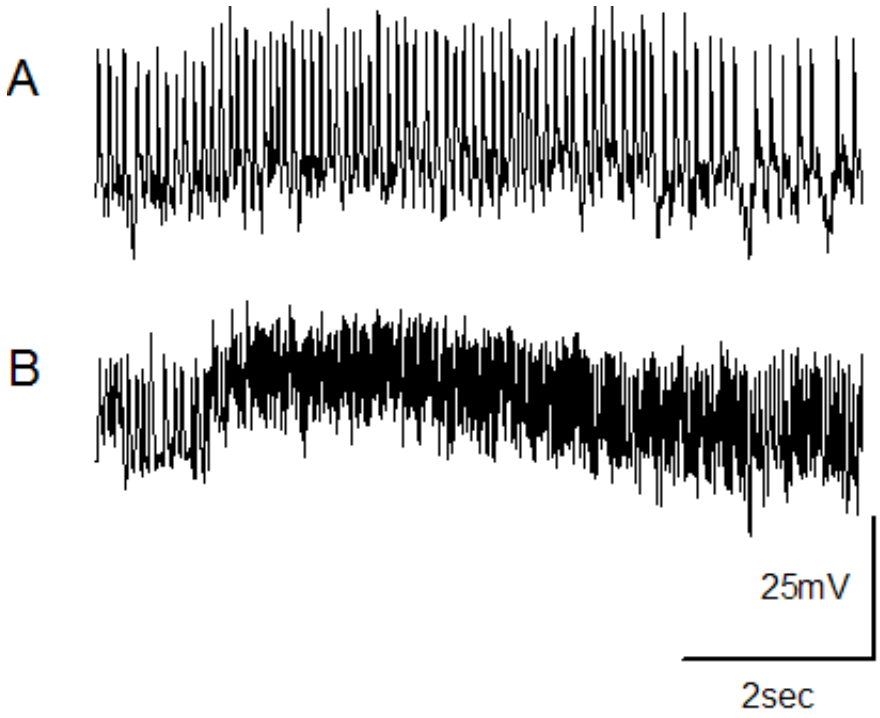
Preliminary Studies

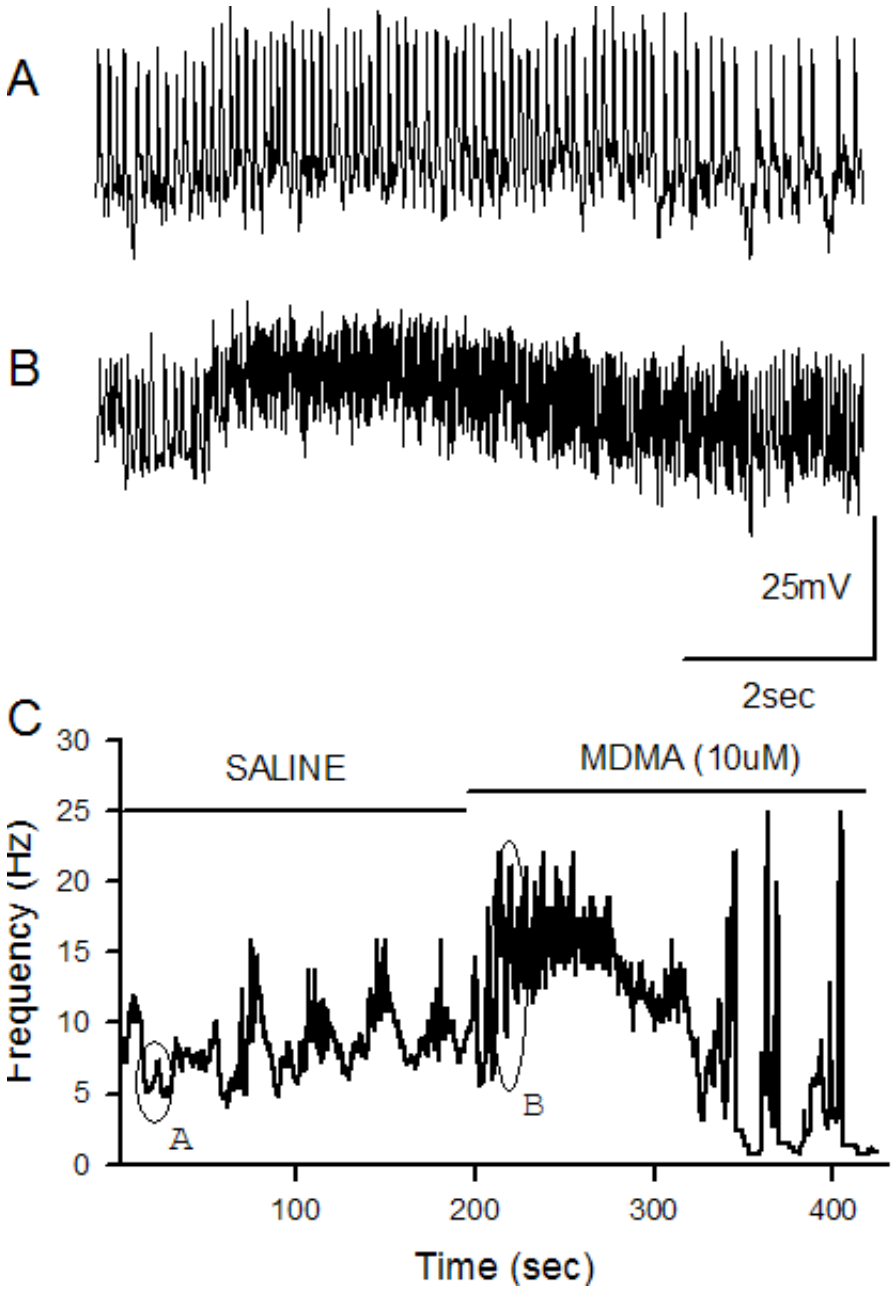


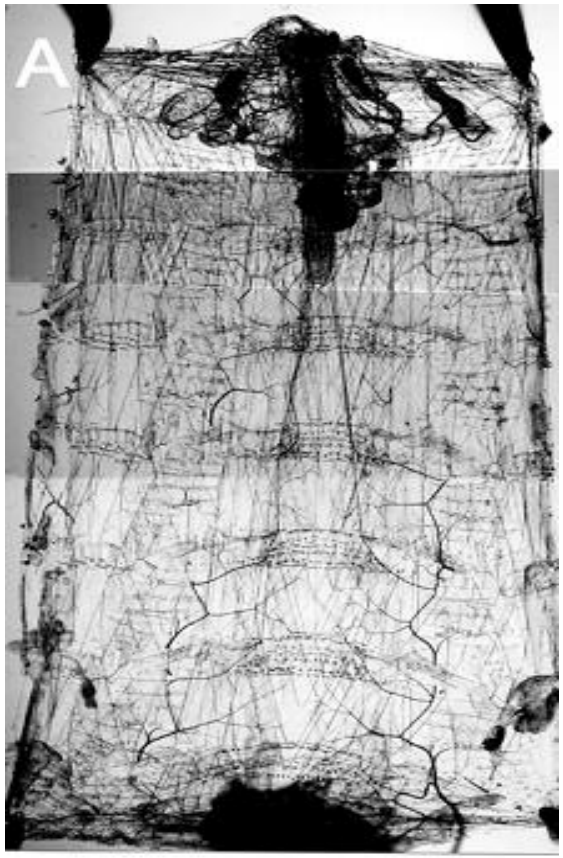

A

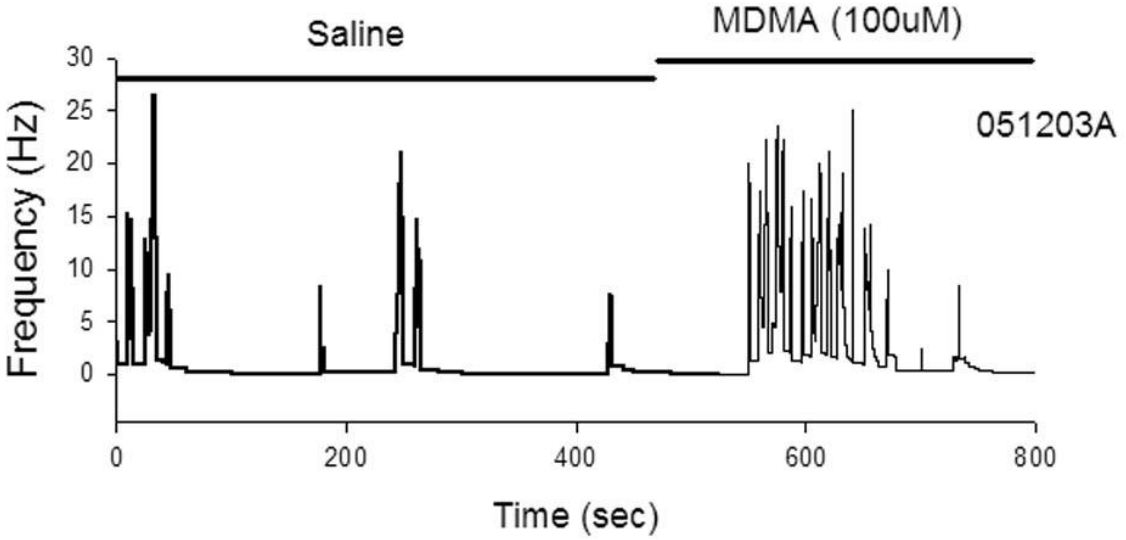

B
CNS
M7
M6
M13
M12
Intracellular
Recording
in m6
Segmental
nerves
Stimulate
Posterior
2 roots

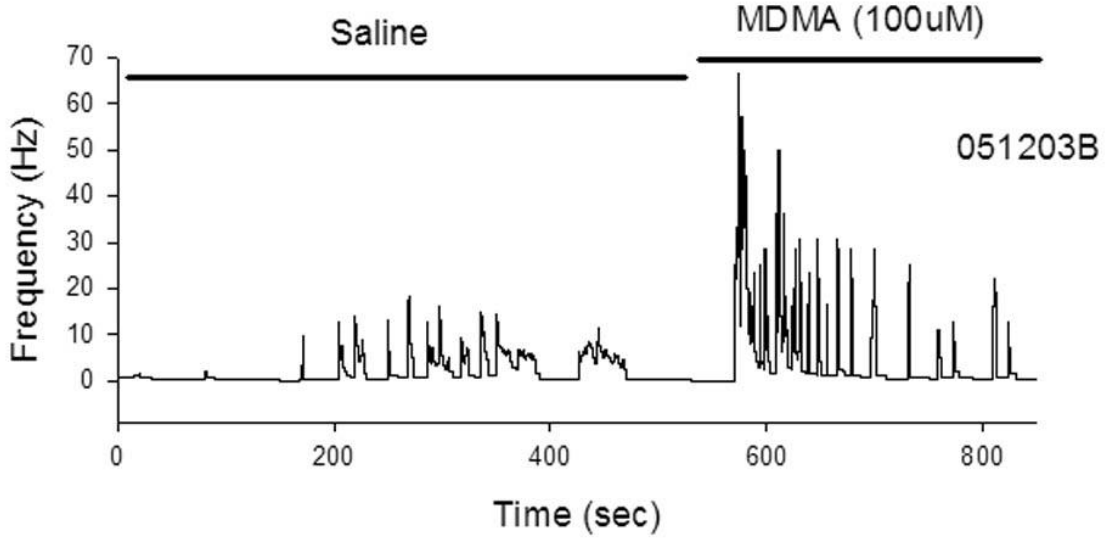

The effects of
octopamine
on a semi-intact
larva


A
B
25mV
2sec


A
B
25mV
2sec
C
SALINE
MDMA (10uM)
Frequency (Hz)
30
25
20
15
10
5
0
A
B
100
200
300
400
Time (sec)


A


Saline
MDMA (100uM)
051203A
Frequency (Hz)
30
25
20
15
10
5
0
0
200
400
600
800
Time (sec)


Saline
MDMA (100uM)
051203B
Frequency (Hz)
70
60
50
40
30
20
10
0
0
200
400
600
800
Time (sec)