260-2017-11-06-action

Rick Gilmore

2017-11-05 08:21:08

Prelude (6:09)

Some of the best athletic feats ever captured on video.Incredible!

Today's Topics

- Wrap up on pain
- The neuroscience of action

The Real Reason for Brains

Daniel Wolpert
The real reason for brains

The neuroscience of action

- What types of actions are there?
- How are they produced?
    - By the muscles
    - By the nervous system

Nervous system "output" includes

- Movements
- Autonomic responses
- Endocrine responses

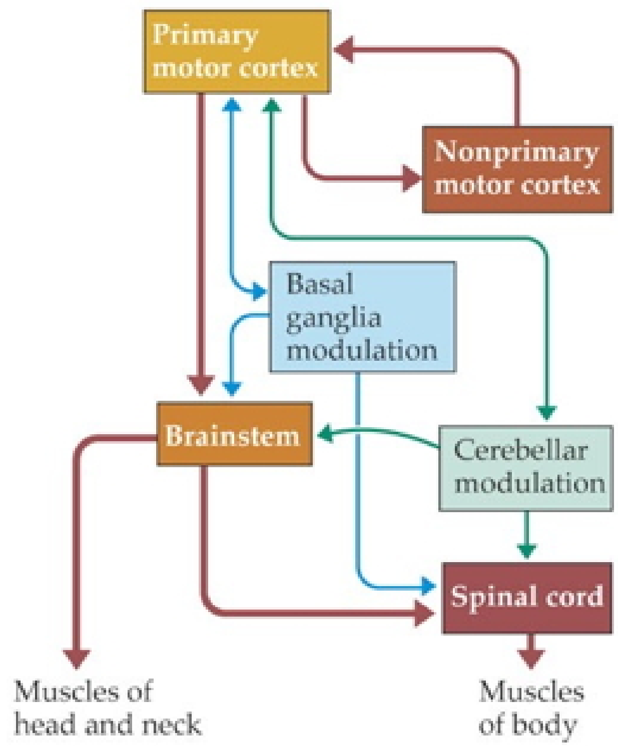
Types of actions

http://www.kidport.com/reflib/science/humanbody/muscul

Types of actions

- Reflexes
  - Simple, highly stereotyped, unlearned, rapid
- vs. planned or voluntary actions
  - Complex, flexible, acquired, slower
- Discrete (reaching) vs. rhythmic (walking)
- Ballistic (no feedback) vs. controlled (feedback)

Multiple, parallel controllers



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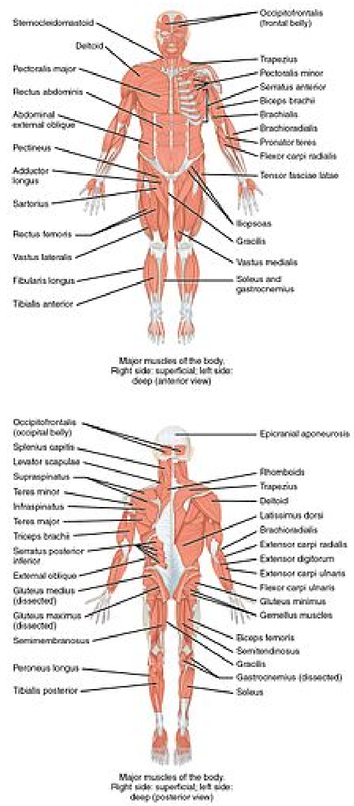
Key "nodes" in network

- Primary motor cortex (M1)
- Non-primary motor cortex
- Basal ganglia
- Brain stem
- Cerebellum
- Spinal cord

Muscle classes

- Axial
  - Trunk, neck, hips
- Proximal
  - Shoulder/elbow, pelvis/knee
- Distal
  - Hands/fingers, feet/toes

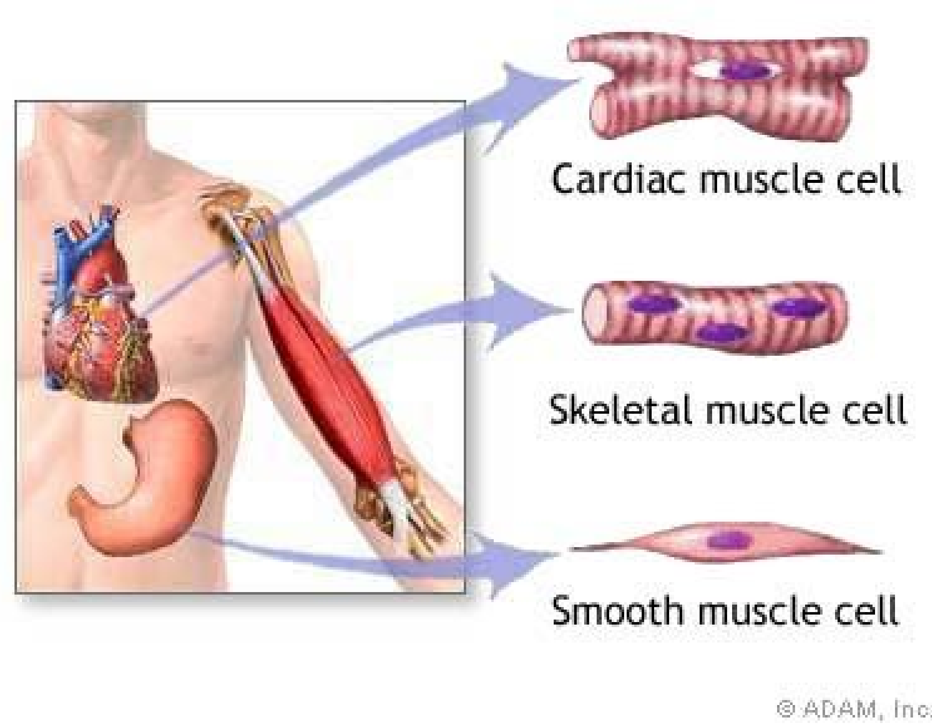
Muscles


Sternocleidomastoid
Deltoid
Pectoralis major
Rectus abdominis
Abdominal external oblique
Pectineus
Adductor longus
Sartorius
Rectus femoris
Vastus lateralis
Fibularis longus
Tibialis anterior
Occipitofrontalis (frontal belly)
Trapezius
Pectoralis minor
Serratus anterior
Biceps brachii
Brachialis
Brachioradialis
Pronator teres
Flexor carpi radialis
Tensor fasciae latae
Iliopsoas
Gracilis
Vastus medialis
Soleus and gastrocnemius
Major muscles of the body.
Right side: superficial; left side:
deep (anterior view)
Occipitofrontalis (occipital belly)
Splenius capitis
Levator scapulae
Supraspinatus
Teres minor
Infraspinatus
Teres major
Triceps brachii
Serratus posterior inferior
External oblique
Gluteus medius (dissected)
Gluteus maximus (dissected)
Semimembranosus
Peroneus longus
Tibialis posterior
Epicranial aponeurosis
Rhomboids
Trapezius
Deltoid
Latissimus dorsi
Brachioradialis
Extensor carpi radialis
Extensor digitorum
Extensor carpi ulnaris
Flexor carpi ulnaris
Gluteus minimus
Gemellus muscles
Biceps femoris
Semitendinosus
Gracilis
Gastrocnemius (dissected)
Soleus
Major muscles of the body.
Right side: superficial; left side:
deep (posterior view)

Muscle types

- Smooth
  - Arteries, hair follicles, uterus, intestines
  - Regulated by ANS (involuntary)
- Striated (striped)
  - Skeletal
  - Voluntary control, mostly connected to tendons and bones
- Cardiac

Muscle types

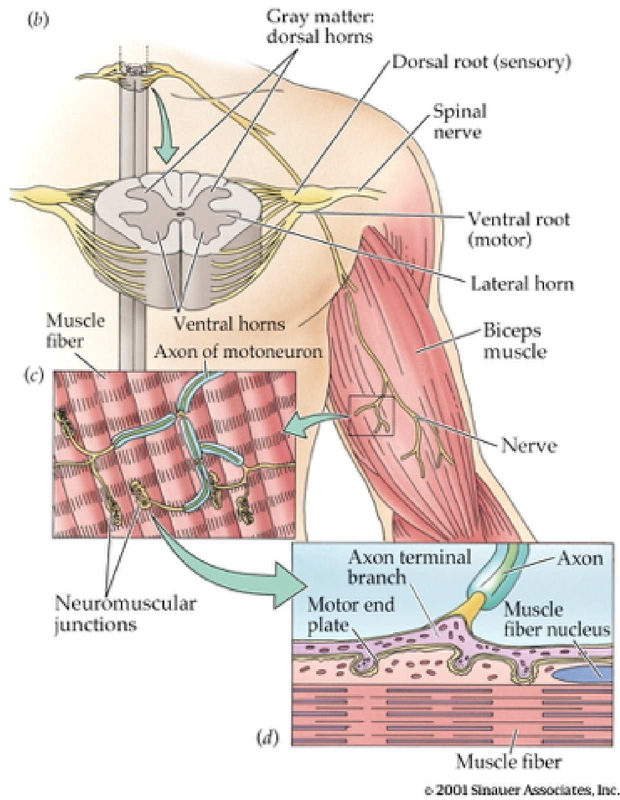


http://graphics8.nytimes.com/images/2007/08/01/health/a

How skeletal muscles contract

- Motor neuron soma located in ventral horn of spinal cord
- 'motor unit' = one motor neuron + all muscle fibers it connects with
- Motor neurons create specialized synapse = neuromuscular junction
    - Releases ACh

From spinal cord to muscle



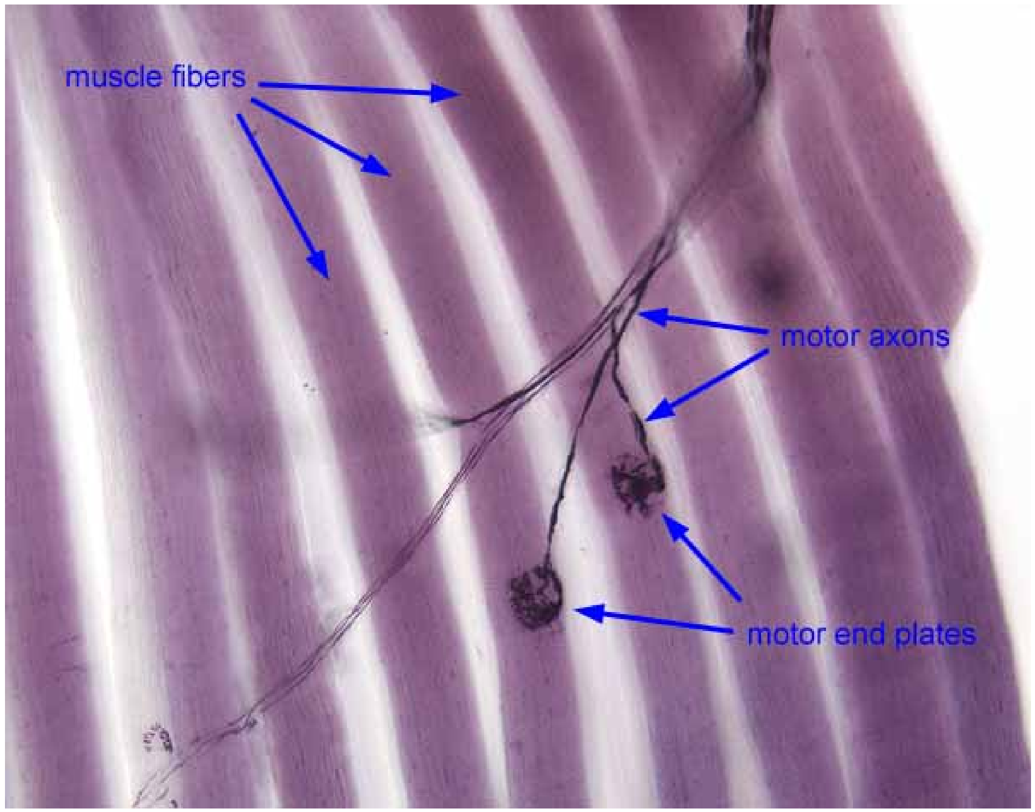
How skeletal muscles contract

- Nicotinic ACh receptor (nAChR) binds ACh
    - *Nicotine* also binds to this receptor
    - nAChR's found in muscle (also in ANS and CNS)
- *Rate* of motor neuron firing ~ force produced ('rate coding')

nAChR activation produces excitatory endplate potential

- Na+ influx/K+ efflux
- Muscle fibers depolarize
- Depolarization spreads along fibers like an action potential
- Intramuscular stores release Ca++

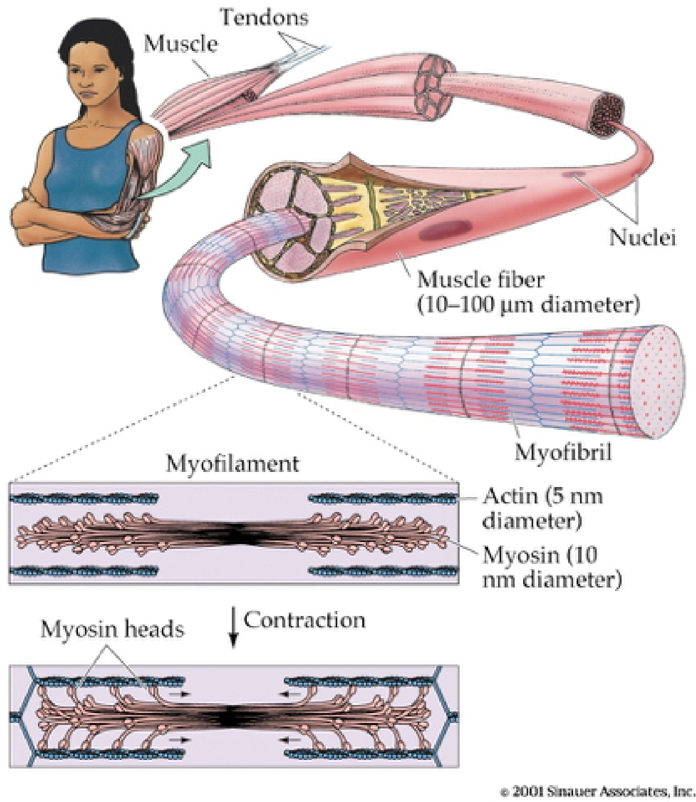
Motor endplate



How skeletal muscles contract

- Myofibrils (w/in sarcomere)
    - Actin & mysosin proteins
    - “Molecular gears”
- Bind, move, unbind in presence of Ca++, ATP

Anatomy of muscle fibers

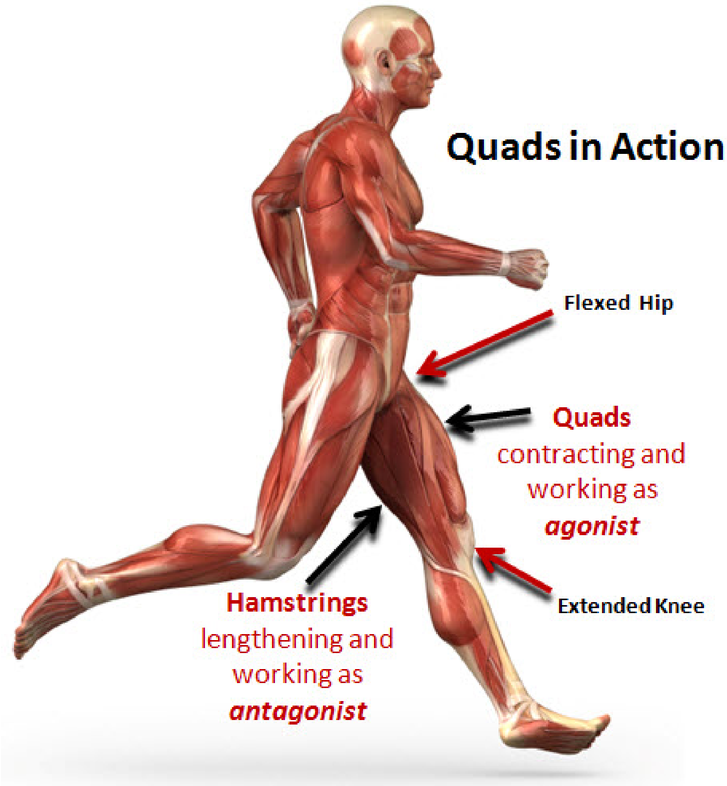


Anatomy of motor endplate

Muscle contraction

Muscle Contraction Process Molecular Mechanism 3D Animation

Agonist/antagonist muscle pairs



http://2.bp.blogspot.com/-TpOC4my_NBc/T0J-MhEv29I/AAAAAAAAF88/dYLv7QzFwmg/s1600/Hamstring-Quad4.jpg

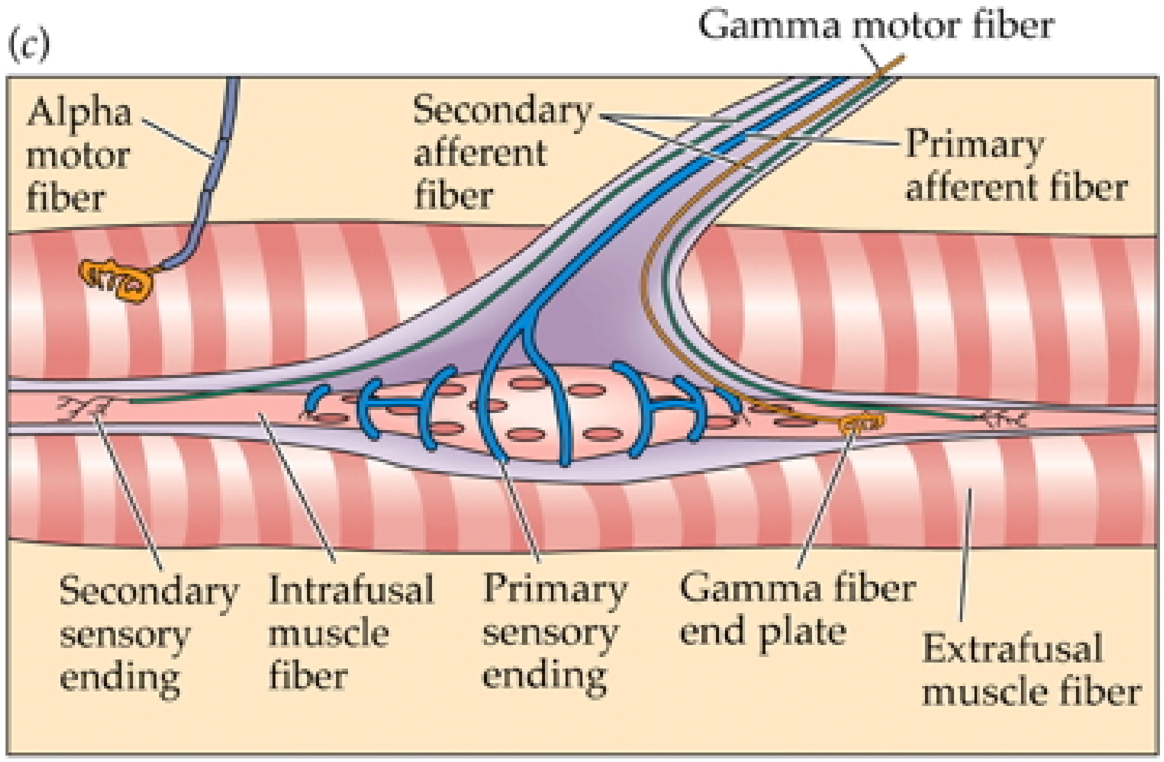
Meat preference?

Muscle fiber types

- Fast twitch/fatiguing
    - Type II
    - White meat
- Slow twitch/fatiguing
    - Type I
    - Red meat

Muscles are sensory organs, too!

Two muscle fiber types



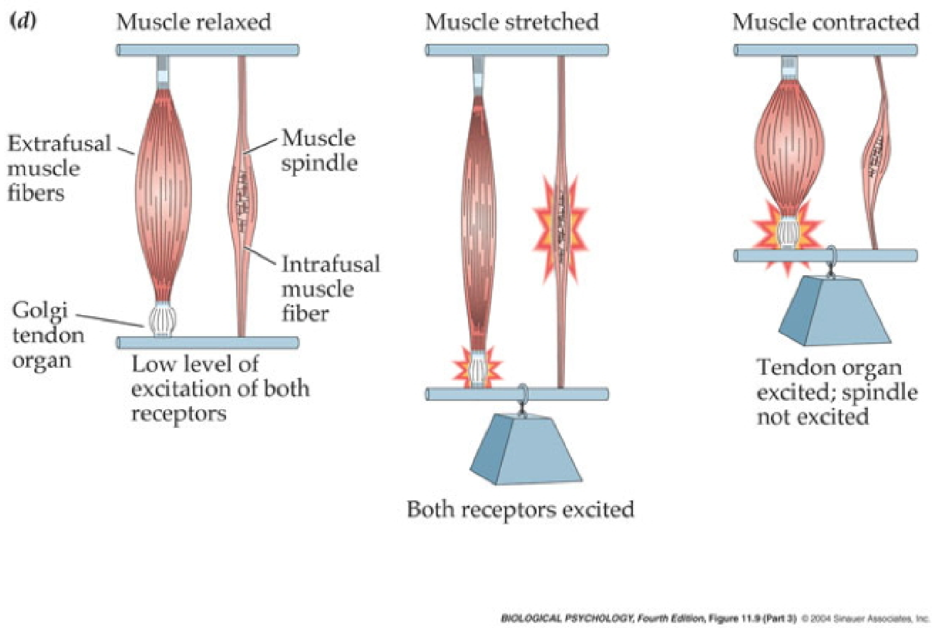
Two muscle fiber types

- Intrafusal fibers
  - Sense length/tension
  - Contain muscle spindles linked to Ia afferents
  - ennervated by gamma (γ) motor neurons
- Extrafusal fibers
  - Generate force
  - ennervated by alpha (α) motor neurons

Monosynaptic stretch (myotatic) reflex

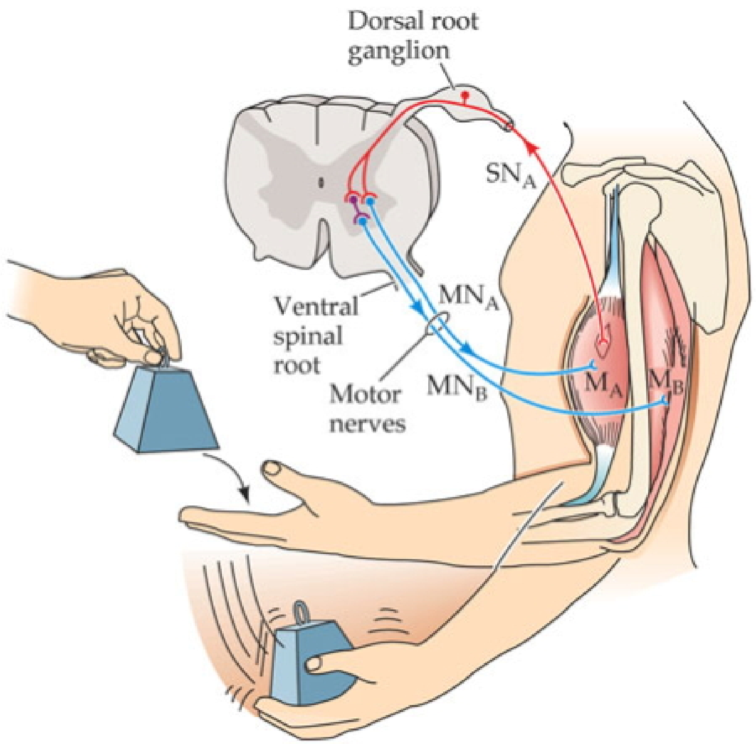
- Muscle stretched (length increases)
- Muscle spindle in intrafusal fiber activates
- Ia afferent sends signal to spinal cord
  - Activates alpha (α) motor neuron
- Muscle contracts, shortens length

Monosynaptic stetch (myotatic) reflex



- Gamma (γ) motor neuron fires to take up intrafusal fiber slack

Monosynaptic stretch (myotatic) reflex



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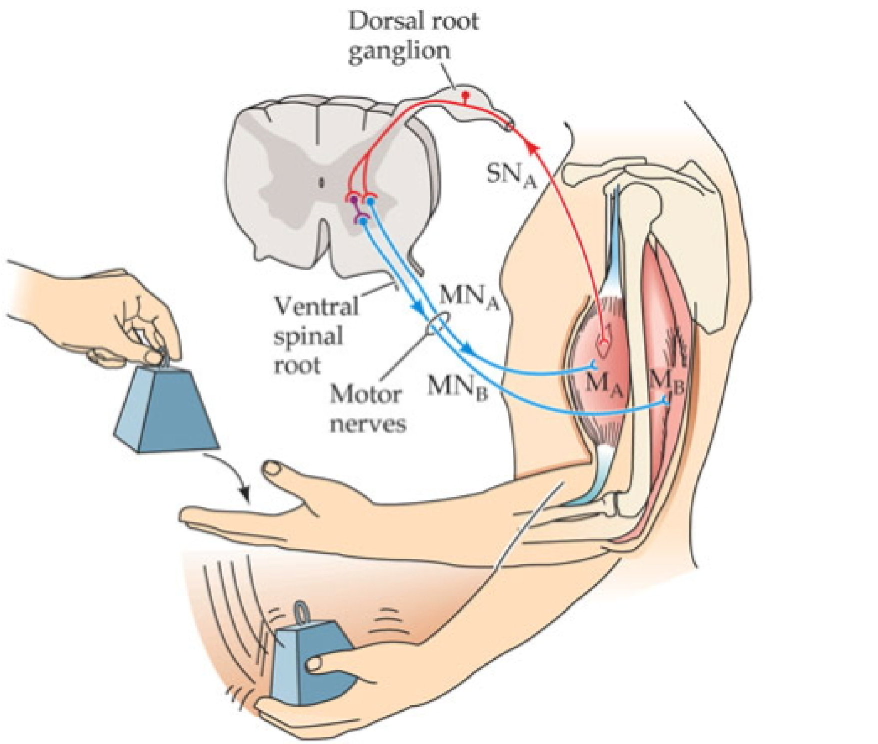
Why doesn't antagonist muscle respond?



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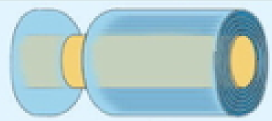
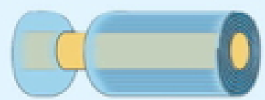
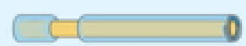
Why doesn't antagonist muscle respond?

- Polysynaptic inhibition of antagonist muscle
- Prevents/dampens tremor

Brain gets fast(est) sensory info from spindles

TABLE 8.2 *Fibers That Link Receptors to the CNS*

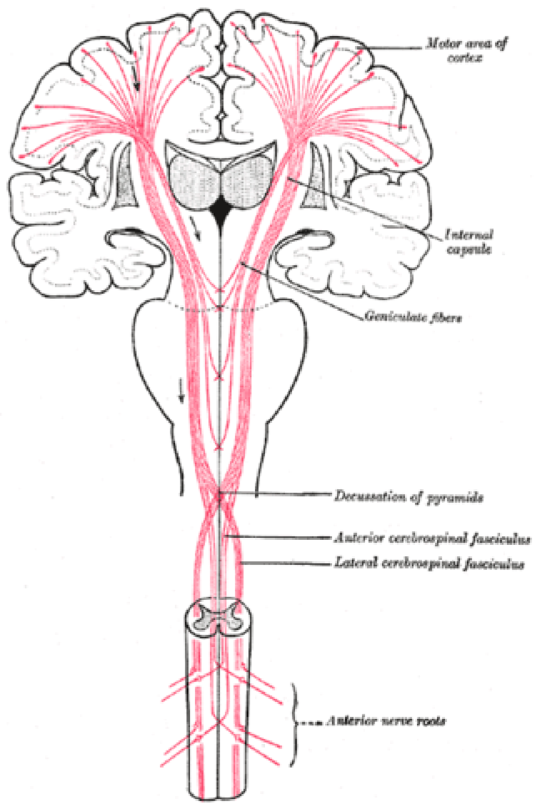
Sensory function(s)	Receptor type(s)	Axon type	Diameter (μm)	Conduction speed (m/s)
Proprioception (see Chapter 11)	Muscle spindle	 Aα	13–20	80–120
Touch (see Figures 8.12 and 8.13)	Pacinian corpuscle, Ruffini's ending, Merkel's disc, Meissner's corpuscle	 Aβ	6–12	35–75
Pain, temperature	Free nerve endings; VRL1	 Aδ	1–5	5–30
Temperature, pain, itch	Free nerve endings; VR1, CMR1	C	0.02–1.5	0.5–2

BIOLOGICAL PSYCHOLOGY, Fourth Edition, Table 8.2

How the brain controls the muscles

- Pyramidal tracts
  - Pyramidal cells (Cerebral Cortex Layer 5) in primary motor cortex (M1)
  - Corticobulbar (cortex -> brainstem) tract
  - Corticospinal (cortex -> spinal cord) tract
- Crossover (decussate) in medulla
  - L side of brain ennervates R side of body

Corticospinal tract

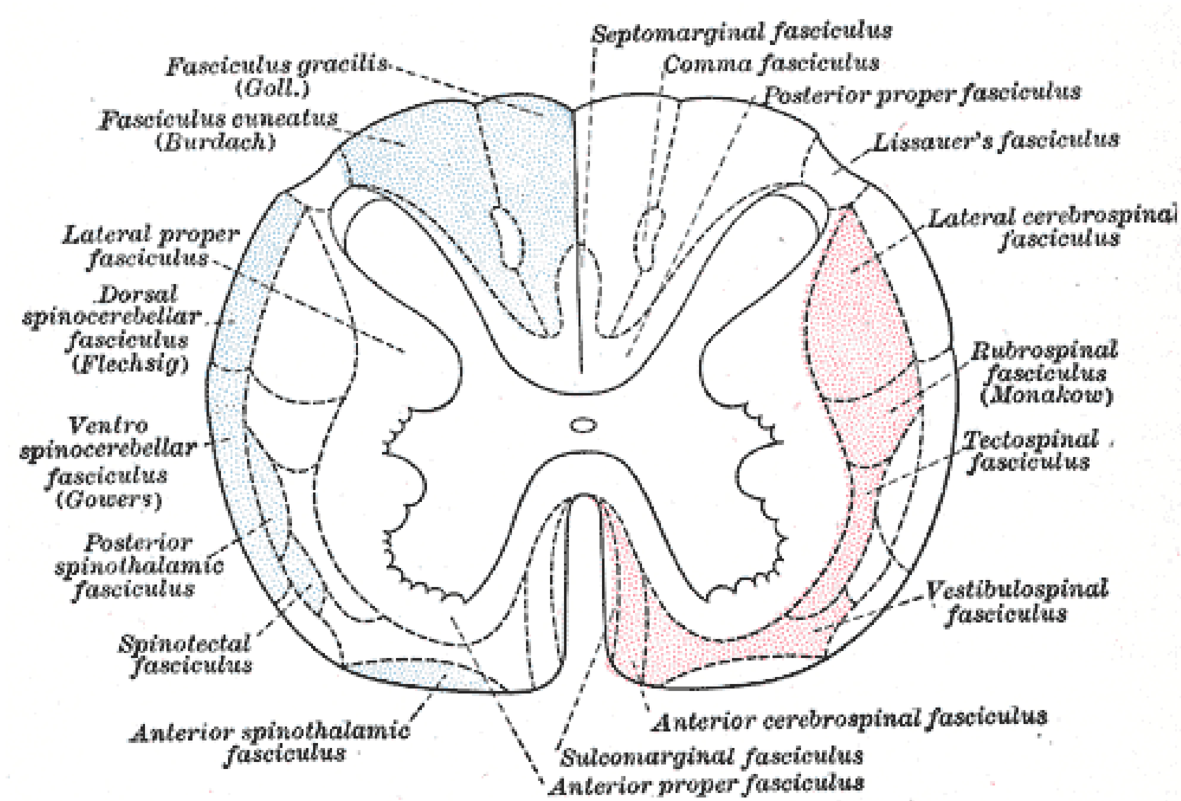


https://commons.wikimedia.org/wiki/File:Gray764.png#/me

How the brain controls the muscles

- Extrapyramidal system
  - Tectospinal tract
  - Vestibulospinal tract
  - Reticulospinal tract
- Involuntary movements
  - Posture, balance, arousal

Extrapyramidal system

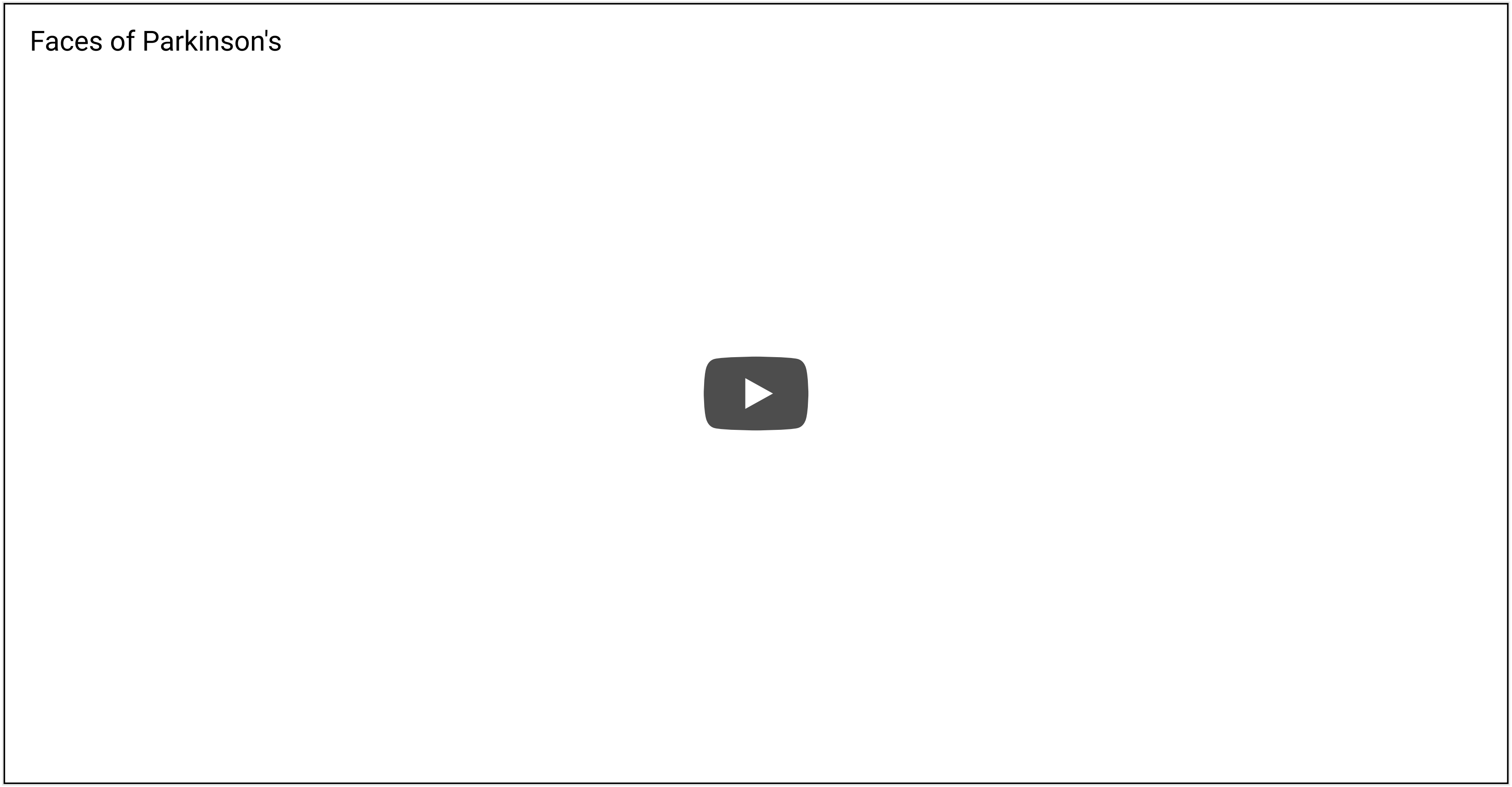


https://upload.wikimedia.org/wikipedia/commons/b/be/Gra

Disorders

- Parkinson's
- Huntington's

The Faces of Parkinson's



Parkinson's

- Slow, absent movement, resting tremor
- Cognitive deficits, depression
- DA Neurons in substantia nigra degenerate
- Treatments
  - DA agonists
  - DA agonists linked to impulse control disorders in ~1/7 patients (Ramirez-Zamora et al. 2016)
  - Levodopa (L-Dopa), DA precursor

Huntington's

http://cp91279.biography.com/1000509261001/100050926 guthrie-centennial-1.jpg

Huntington's

- Formerly Huntington’s Chorea
  - "Chorea" from Greek for "dance"
  - “Dance-like” pattern of involuntary movements
- Cognitive decline
- Genetic + environmental influences
- Disturbance in striatum
- No effective treatment

Huntington's

A family struggles with Huntington's Disease

Final thoughts

- Control of movement determined by multiple sources
- Cerebral cortex + basal ganglia + cerebellum + spinal circuits

Next time…

- Review for Exam 3

References

Ramirez-Zamora, Adolfo, Lucy Gee, James Boyd, and José Biller. 2016. "Treatment of Impulse Control Disorders in Parkinson's Disease: Practical Considerations and Future Directions." *Expert Review of Neurotherapeutics* 16 (4): 389–99. doi:10.1586/14737175.2016.1158103.