260-2017-04-03-action

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Prelude

Prelude

Today's Topics

- The neuroscience of action

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

Remember

- Nervous system "output" includes
  - Movements
  - Autonomic responses
  - Endocrine responses

Types of actions

http://www.kidport.com/reflib/science/humanbody/muscularsystem/images/Reflexes.jpg

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

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

http://classroom.sdmesa.edu/eschmid/F08.12a.L.150.jpg

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/adam/19917.jpg

How skeletal muscles contract

- Motoneuron (ventral horn of spinal cord)
- Neuromuscular junction
  - Releases ACh

From spinal cord to muscle

How skeletal muscles contract

- Motor endplate
  - Nicotinic ACh receptor
- Excitatory endplate potential
  - Muscle fibers depolarize
  - Depolarization spreads along fibers like an action potential
  - Sarcomeres are segments of fibers
  - 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

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

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

Monosynaptic stretch (myotatic) reflex

- Muscle stretched (length increases)
- Muscle spindle 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

Why doesn't antagonist muscle respond?

Why doesn't antagonist muscle respond?

- Polysynaptic inhibition of antagonist muscle
- Prevents/dampens tremor

Brain gets fast(est) sensory info from spindles

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#/media/File:Gray764.png

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/Gray672.png

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/1000509261001/1000509261001_1733824754001_woody-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

Final thoughts

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

Multiple, parallel controllers

Cerebellum as predictor of future sensory states? (Ito 2008)

http://venturebeat.com/wp-content/uploads/2009/10/star-trek-holodeck.jpg

Next time...

- Exam 3 review

References

Ito, Masao. 2008. "Control of Mental Activities by Internal Models in the Cerebellum." *Nature Reviews Neuroscience* 9 (4): 304–13. doi:10.1038/nrn2332.

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.