Week 5 notes: Nerve and muscle physiology

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1 Overview

- **Physiology**: the science of how things work
  - a.o.t. **Kineology** (?): study of movement
  - a.o.t. **Anatomy**: ???
- Basic cell structure
  - Nucleus
  - Mitochondria
  - Microtubules
  - Endoplasmic reticulum
    - Protein synthesis
    - Sarcoplasmic reticulum (specific to muscles)
      - Where muscle cells store calcium ions (important for muscle contraction)
  - Cytoplasm/cytosol
    - Negative potential relative to outside the cell
    - Very strong electric field across cell membrane: 12kV/mm (means cell membrane is a very strong insulator)
  - Cell membrane
    - Selectively permeable to certain ions via specialized transport proteins
- Why electric potential (-90mV in generic cells)?
  - **Resting potential** or **membrane potential**

  - Keep some salt out, otherwise draws in too much water (don't want high osmolality)
  - Aids in transport of other molecules
  - Potassium usually leaks out, sodium leaks in
  - Sodium-potassium pump to actively pushed sodium outside of the cell and potassium back into
    * A third of your resting energy goes into this

1.1 Nerves

- Neurons:
  - Types:
    * Motor: innervates muscle tissue
    * Sensory: picks up stimuli from special receptors, brain stem to spinal cord
    * Interneuron: connects two neurons: handles reflexes
  - Parts:
    * Cell body: close to dendrites, normal cell functions
    * Dendrites: talk to neighbor neurons, get inputs from outside the cell, from sensory receptors or other neurons, greatly increase surface area
    * Axon hillock: part that connects cell body to axon
    * Axon: long fiber coming off of cell body
      · This is what people refer to as a nerve (e.g., median nerve)
      · Axons may be several feet long; the actual nerve cells are near the spinal cord
      · Carries electric impulses called **action potentials**
    * Axon termination: synapse
- Action potential
  - Sudden change in voltage; all the same size; like an impulse in physics
  - Generating one of these is called the nerve "firing"
  - Sometimes "graded potentials": small changes in potential, but not above some threshold

  - When the graded potential goes over some threshold, then the impulse happens because the voltage-sensitive sodium channels in the cell membrane starts a positive feedback system (rare existence in nature)
  - The impulse ends when the potassium gates open, both potassium and sodium leave the cell
  - Overshoot baseline, **refractory period** for a few milliseconds in which the sodium channels cannot operate
  - Action potential travels down the axon, refractory period leads to one-way movement
  - End of axon is synapse
  - Strong stimulus generates multiple action potentials (rather than a large one)
  - Speed of AP propagation is faster on a wider axons

- Chemical transmission to next neuron/muscle through synapse via neurotransmitters
  - Excitatory or inhibitory

- **Myelinated nerves**
  - Myelin are made of Schwann cells: insulated bundles of fat
  - When not insulated, high concentration of voltage potential; only have to generate action potential at fewer nodes (optimization); saves energy as well as speeding things up
  - Unmyelinated 1.5m/s, myelinated to 120m/s
  - Only about a third of nerves are myelinated: don't need all of them; perception of pain slowly
  - Reflexes controlled by myelinated nerves
  - De-mylenating disease: **multiple sclerosis** (slower conduction velocity and greater energy consumption; often tired)

- Reflexes:
  - Myelinated nerves used
  - Brain is not involved; only to spinal cord and back to muscle nerve

- Neuromuscular junction:

  - **Motor unit** is the quantum of the neuromuscular system
    * Motor neuron and all muscle fibers innervated by it
    * All signaled by a single motor neuron
  - Muscle fibers: similar electrically to neurons, contraction due to electric signal passing over it

1.2 Muscles

- Smooth: deep inside, intestines and blood vessels, airways; no voluntary excitation; does not fatigue; almost always working
- Cardiac: more like skeletal muscle (striated); the entire heart contracts at the same time; involuntary; innervation only influences rate of contraction; long action potential; always relaxes after contraction
- Skeletal muscle: what we will mostly be talking about, striated
- Muscle anatomy:
  - Individual muscle cells called sarcomeres; a bundle of proteins
  - Muscle fibers are made of many myofibrils; many sarcomeres in series
  - Sarcomeres are bounded by "walls" z-lines
  - Bands are composed of overlapping myofilaments
  - Thin (actin) and thick (myosin) filaments
  - Troponin and tropomyosin block attachment of myosin head to actin at rest
  - When an electric impulse comes along, then the two attach to each other
  - Then using ATP, "sliding filament theory of muscle contraction": filament ratchets and pulls along
  - Sarcomere becomes shorter; thick filaments don't become shorter, but thin filaments shrink
  - No energy (ATP) prevents muscle from relaxing (rigor mortis); takes energy to relax
  - With fatigue rate of force development and relaxing grow longer
- Types of muscle fibers:

  - Type I: slow twitch
    - Less sarcoplasmic reticulum; slower to reclaim calcium; slow conduction velocity; small fibers; few fibers per motor unit; responsible for fine movements
    - Able to extract oxygen from blood; resistant to fatigue; relatively flow but efficient ATP production
  - Type II: fast twitch: take Type I and invert everything
    - Fast relative to Type I, but still slow compared to nerves
    - Primary energy supply is sugar stored in muscle, glycolysis; only a small supply and produces lactic acid

- Motor unit recruitment:
  - **Size principal**:
    - Smaller motor units recruited first, Type I; slowly more motor units recruited until Type II motor units

- Modes of muscle contraction
  - Three modes: concentric (muscle shortens while doing work), isometric (muscle remains the same length while doing work), eccentric (muscle lengthens while doing work, opposing outside forces while lengthening)
  - You can do more work eccentrically than concentrically; good for rehab
  - Eccentric has more of a role in muscle damage and reformation (unfamiliar bout of eccentric exercise)
    - Muscle damage is normal physiology, not injury
    - In eccentric action, sarcomeres get pulled apart
    - **Delayed-onset muscle soreness** (DOMS)
    - Protective effect (for ~6 months)
    - This is how you gain strength
  - Fast-enough action potentials cause smooth muscle contraction (called tetanus; no not that tetanus)

- Agonist and antagonist muscles
  - **Agonist**: pulls in the direction about joint
  - **Antagonist**: responsible for other direction

  - Co-contraction for stability
- Length-tension relationship: force-generating potential gets maximized somewhere along the length; because of amount of overlap between thick and thin filaments
- Series elastic component (e.g., tendons); must stretch out before any force transmittted on the bone
- Measurements of muscles
  - EKG/ECG: electrocardiography, electrical activity of heart
  - EMG: same but for skeletal muscle
  - EEG: brain
  - EOG: eye
  - MMG/AMG: sliding muscle filament sounds
  - EGG: stomach

2 Journal club

- Lot of big names on this paper
- Title IX: equal funding for both men and women in athletics
- Weak hypothesis: there would be a difference
- Definition of ACL injury for purposes of this study: only non-contact during game or practice for their team
- Figure 7 is incorrectly labeled

3 Other

- Dendrites are incredibly dense when born, but get pruned off over time
- Memory works like DRAM: read involves a write operation
- Most of atrophy is when type II muscles become type I
  - Turning type I to type II is much harder; even harder to try to get both at the same time
- We are PWM