Lecture 14, Mar 14, 2023

Cardiac Muscle

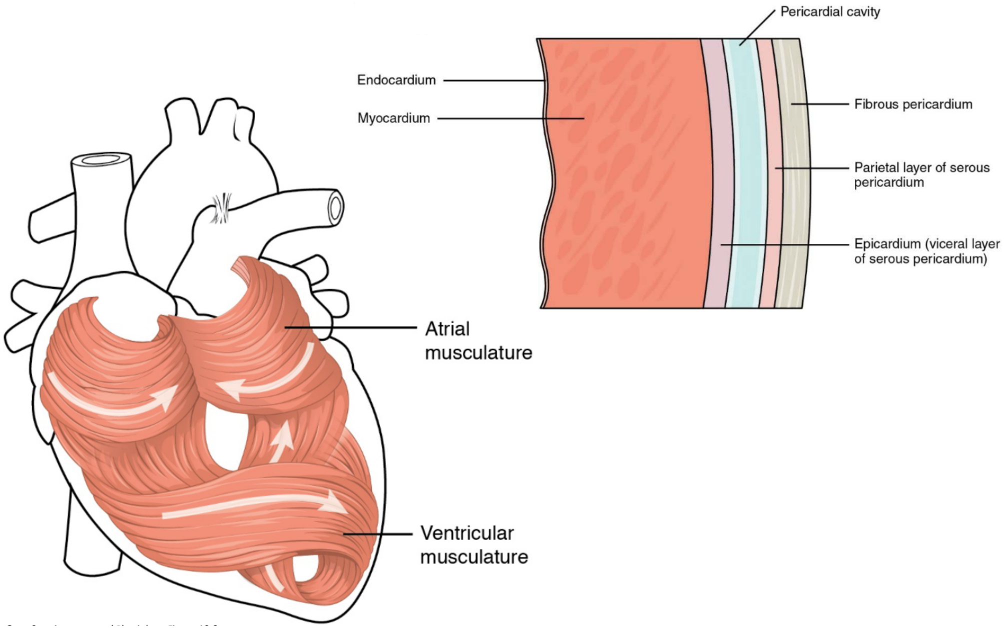

Figure 1: Arrangement of cardiac muscle in the heart

- Controlled by the autonomic nervous system
  - Both types are striated muscles, but the heart is involuntarily controlled
- Cardiac muscles are myogenic (they initiate themselves, without the need of a signal from the nervous system)
  - The nervous system just modifies the contraction strength and speed
- Unlike skeletal muscles the length of fibre controls the strength and the calcium concentration
- Hormones also modify the effect of cardiac muscle
- The SR isn't as developed, so the ECF is playing a larger role in bringing calcium in
- Gap junctions exist, unlikely in skeletal muscle
  - Gap junctions in an electrical synapse let ions pass from one cell to another if they are open
  - Once an action potential is started, it spreads through the whole heart
- While skeletal muscles are linear, cardiac muscle has branches; they are connected by desmosomes and gap junctions
- Cardiac muscle cells only have a single nucleus while a skeletal muscle cell can have multiple nuclei
- RMP is about -80 mV
- There are 2 sub-types of voltage gated calcium channels: L-type (long-lasting) and T-type (transient)
  - Different areas of the heart have different types of channels, to allow for different patterns of action potential

Types of Action Potentials

- Ventricular myocyte action potential (main muscle in the heart)
  0. Membrane depolarization
     - This happens very fast
  1. Rapid, transitory repolarization
     - Potassium channels open, but only a small number of them open for a short period of time
  2. Plateau phase
     - Other potassium channels open

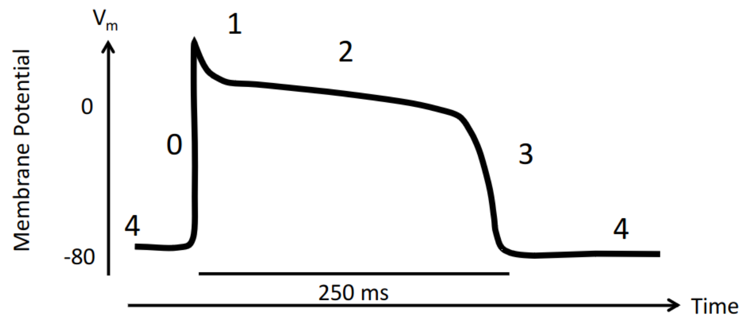

Figure 2: Shape of ventricular myocyte action potential

    - Calcium channels also open
    - Since these act against each other, this makes the membrane potential change slowly
    - The length of this phase can be altered by hormones
    - Functionally this causes a very long refractory period, which matches the contractile response of the heart; this way we won't get a tetanic response (because that does not pump blood)
  3. Repolarization
    - More potassium channels open, overwhelming the calcium channels, which are now closing
  4. Electrical diastolic phase
    - Kind of like a resting membrane potential (for this type of action potential)
    - Heart relaxes in this phase

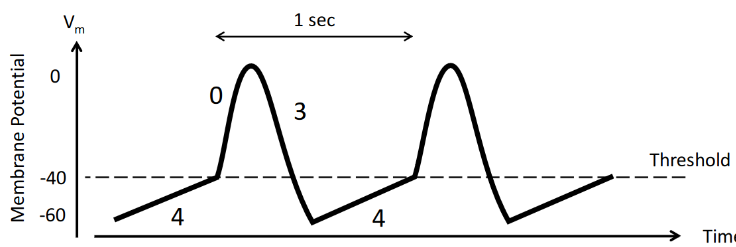

Figure 3: Shape of the nodal cell action potential

- Nodal cell (aka pacemaker) potential (autorhythmic cells that drive the heartbeat; these start the action potential that spreads through the heart)
  0. Membrane depolarization
    - This is only caused by calcium, not sodium
    - The slope isn't as steep due to this reason
    - In this phase, it's the L-type (long-lasting) calcium channels that depolarize the membrane
  1. Repolarization
    - Potassium leaks out of the cell
    - Highest permeability occurs right at the peak of the potential, and then decreases to allow for repolarization
  2. Minimum diastolic potential
    - There is no more resting potential; the cell membrane potential is always changing
    - The membrane potential hits a minimum, then slowly depolarizes until it hits a threshold, at which point it repeats the cycle
    - Sodium channels open in this phase, which is what leads to the gradual depolarization
      * This is unlike normal cells in which the sodium channels only open when the membrane is depolarized, not hyperpolarized
    - As the potential gets close to the threshold, T-type (transient) calcium channels open to provide a final boost to get to the threshold potential

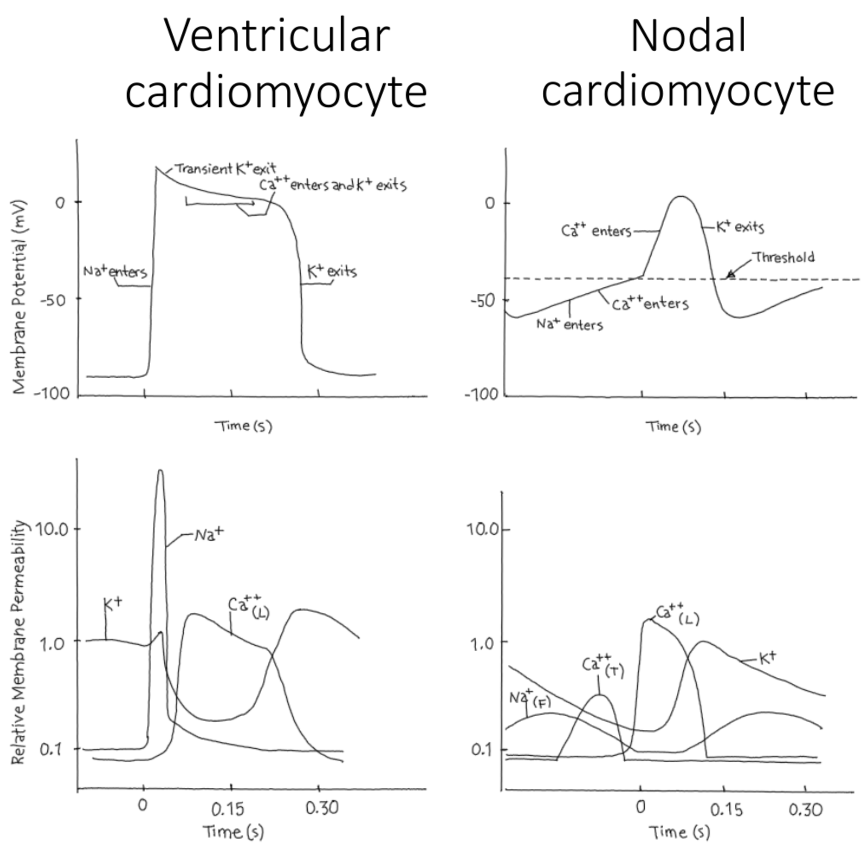

Figure 4: Comparison of the two types of action potentials and the ion permeabilities causing them

- Skeletal muscle cells are made of only 12-15% mitochondria; cardiac muscles are about 35% mitochondria