Structure of the striated muscle

general properties
Structure of the striated muscle membrane systems

1. Myofibrillum (contractile proteins)
2. Sarcoplasmic reticulum (SR) – longitudinal tubule
3. SR – terminal cisternae
4. Transverse tubule
5. Sarcolemma
6. Mitochondrion
The electro-mechanical coupling

- Stimulus arrives to the NMJ
- Action potential on the muscle fiber (sarcolemma → T-tubules)
- Calcium release from the SR
- Activation of the contractile proteins → contraction

Calcium reuptake into the SR → relaxation
The characteristics of the action potential

• The resting potential
  – Value between -80 and -90 mV
  – Significant resting K⁺ and Cl⁻ conductance

• The potential change
  – duration 2-3 ms
  – amplitude 110-120 mV
  – Fast (TTX-sensitive) Na⁺ channels open → depolarization
  – Slow K⁺ channels open → repolarization
  – pronounced after-depolarization
Role of the membrane potential-change

- The depolarization will cause shortening, independent of
  - the formation of an action potential (K⁺-contracture)
  - the presence of extracellular Ca²⁺ → Ca²⁺ originates from intracellular stores

- Note
  - Contracture = shortening (force production) without an AP
  - Contraction = shortening (force production) evoked by an AP
Excitation-contraction coupling on striated muscle

- T-tubule sarcolemma
- Sarcoplasmic reticulum (SR)
- Longitudinal tubule
- Terminal cisternae
- Contractile proteins
- SERCA pump
- Ca²⁺
- DHPR
- RyR
- Parv
- TnC
- Excitation-contraction coupling on striated muscle
Structure of the triad

**Triad** = a T-tubule & two TC

**DHPR** = dihydropyridine receptor, L-type voltage-gated calcium channel, voltage-sensor

**RyR** = ryanodine receptor, SR calcium channel
Structure of the striated muscle
the contractile proteins
# Protein Composition of the Myofibril

<table>
<thead>
<tr>
<th>Név</th>
<th>Hely</th>
<th>Méret (kDa)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myosin</td>
<td>Thick filaments</td>
<td>485000</td>
<td>44</td>
</tr>
<tr>
<td>Actin</td>
<td>Thin filaments</td>
<td>42000</td>
<td>22</td>
</tr>
<tr>
<td>Tropomyosin</td>
<td>Thin filaments</td>
<td>68000</td>
<td>5</td>
</tr>
<tr>
<td>Troponin (TnC, TnI, TnT)</td>
<td>Thin filaments</td>
<td>70000</td>
<td>5</td>
</tr>
<tr>
<td>Titin</td>
<td>Gap filaments</td>
<td>1000000</td>
<td>10</td>
</tr>
<tr>
<td>Nebulin</td>
<td>N line</td>
<td>600000</td>
<td>5</td>
</tr>
<tr>
<td>C-Protein</td>
<td>Thick filaments</td>
<td>140000</td>
<td>2</td>
</tr>
<tr>
<td>Myomesin</td>
<td>M line</td>
<td>*165000</td>
<td>2</td>
</tr>
<tr>
<td>α-Actinin</td>
<td>Z line</td>
<td>180000</td>
<td>2</td>
</tr>
<tr>
<td>H-Protein</td>
<td>Thick filaments</td>
<td>74000</td>
<td>&lt;1</td>
</tr>
<tr>
<td>I-Protein</td>
<td>A band</td>
<td>50000</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Filamin</td>
<td>Z band</td>
<td>480000</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Desmin</td>
<td>Z band</td>
<td>*55000</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>
Structure of the striated muscle
the thin and thick filaments
The acto-myosin cycle I.
the role of Ca^{2+}

In the presence of Ca^{2+} (upper figure)
• Tm and Tnl „move” → actin-myosin interaction

Troponin
• TnC – Ca^{2+} binding
• Tnl – Inhibition
• TnT – Tm binding

In the absence of Ca^{2+} (bottom figure)
• Tm and Tnl „inhibiting” position

A – actin   Tm – tropomyosin
M – myosin   Tn - troponin
The acto-myosin cycle II. 

the sliding filament model

ATP is needed for both the contraction and the relaxation

A – actin
M – myosin
The force generated by the muscle depends on the length of the muscle, because
- the force generated by a single cross-bridge is constant
- the number of cross-bridges depend on the relative position of the thin and thick filaments
Characteristics of muscle contraction I. summation, tetanus

Two AP-evoked contractions can sum up, because

– the refractory period of an AP is shorter than the duration of a contraction
– $[\text{Ca}^{2+}]_i$ is still increased following repolarization

Continuous summation = tetanus

– Incomplete tetanus = partial relaxation between oncoming AP-s
– Complete tetanus = no relaxation between AP-s
Characteristics of muscle contraction II.

• **Motor unit** = muscle fibers innervated by a single axon
  – Regulation of muscle force = number of active units
  – Regulation of precise movement = number of fibers in a unit
  – „Recruitment” - fatigue

• Elastic elements in series and parallel (energetics)

• Hypocalcaemic tetania

• Denervation hypersensitivity (nAchR outside the end plate)

• Muscle diseases
  – Myasthenia gravis (autoimmune antibodies against nAchR )
  – Myotonies
  – Dystrophies
  – Malignant hyperthermia, Central core disease