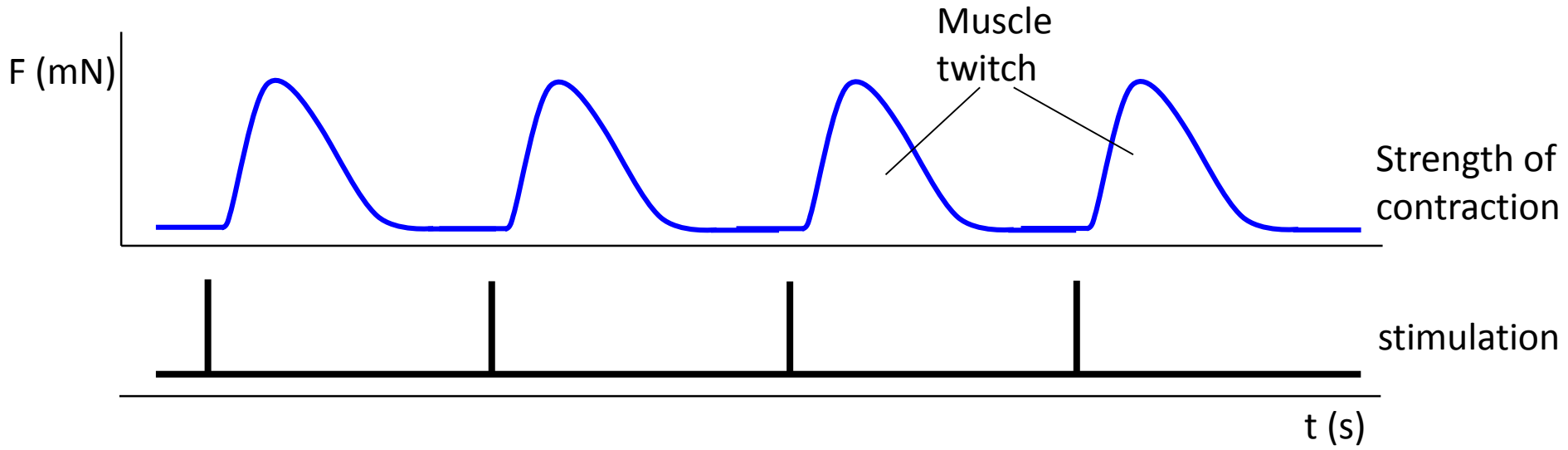
(XXVI.) Recruitment and Summation in Skeletal Muscle

Contraction of the skeletal muscle

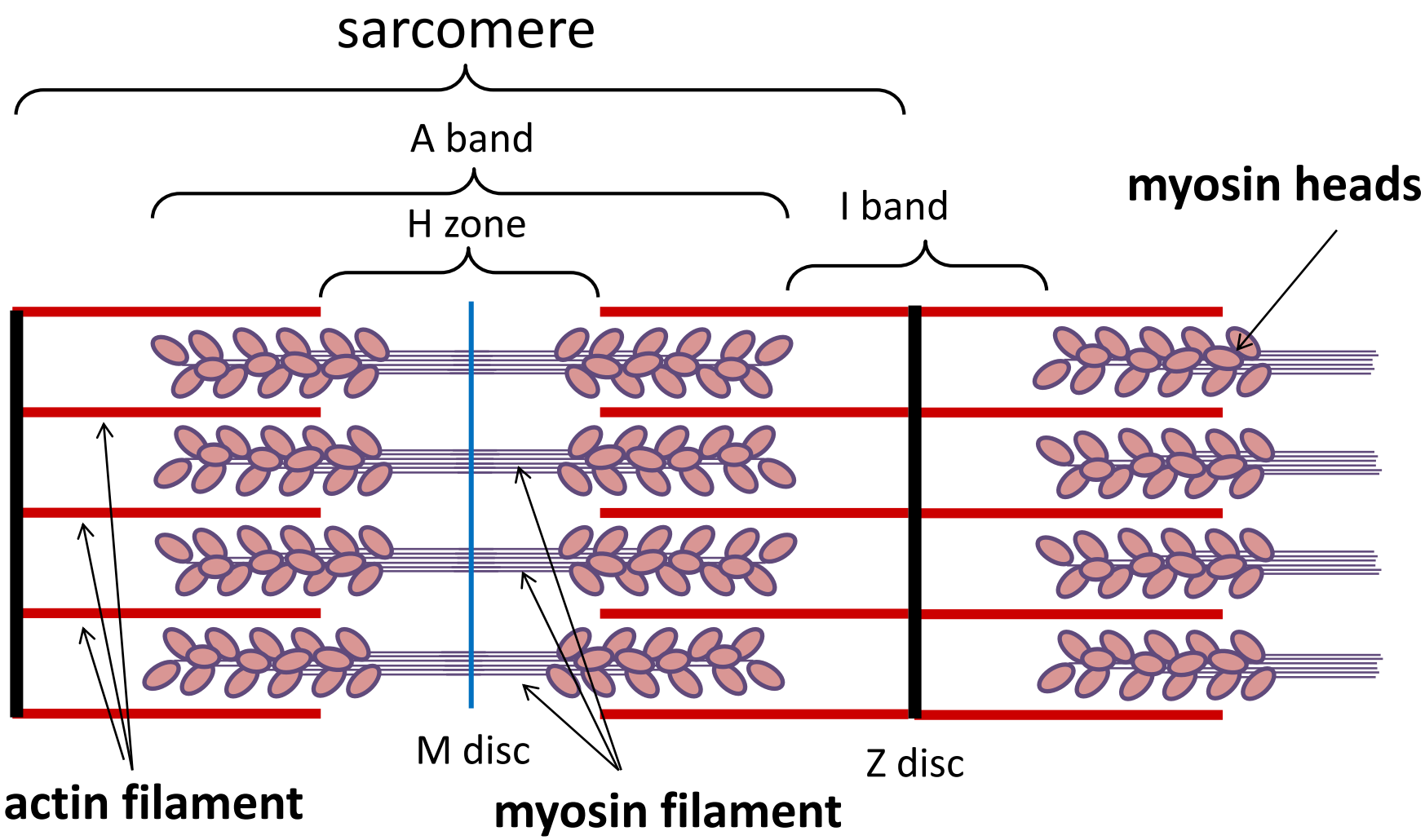
- **Myography** – method of recording of the muscle contraction
- **Motor unit**: a group of muscle fibers innervated by a single α - *motoneuron*

- **Muscle twitch** – elementary mechanical response to a single stimulus (action potential)

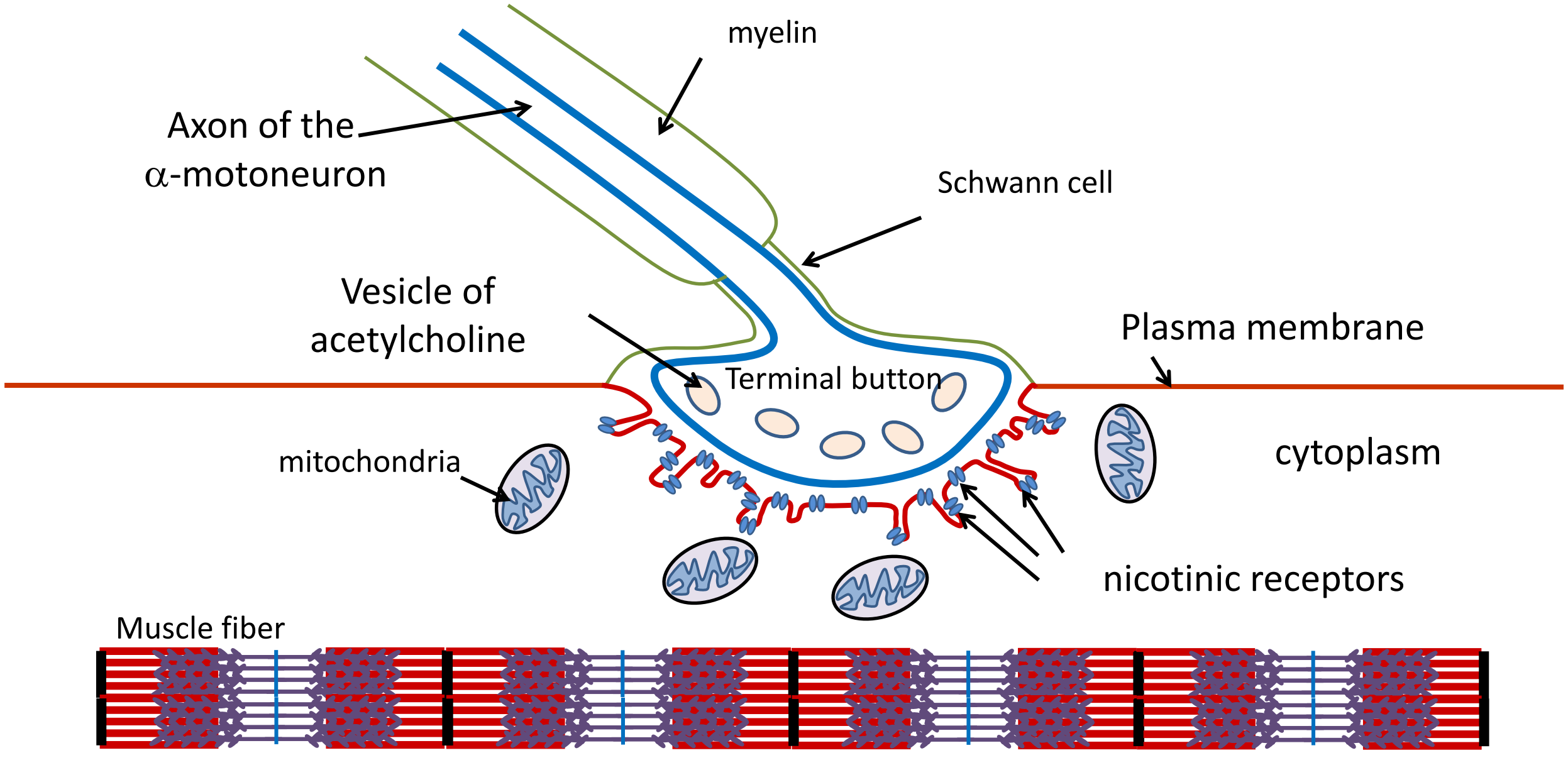
- **Types of muscle fibers:**
  - **S** (slow) – slowly get tired, used in long-term performance, many mitochondria, well vascularized, a lot of myoglobin
  - **F** (fast) – fast contraction, quickly get tired, a lot of glycogen, a little myoglobin



Morphology of the skeletal muscle fiber



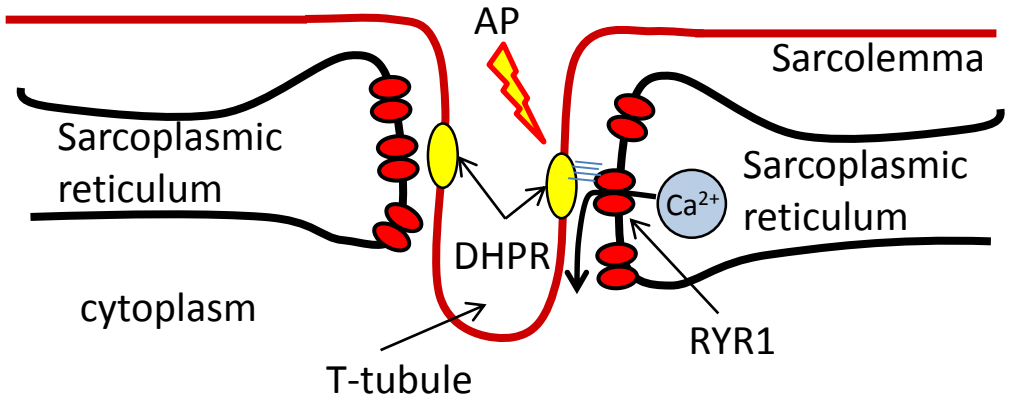
Motor end-plate



Excitation – contraction coupling

Excitation

- Action potential (AP) spreads on axon from alfa-motoneuron to neuro-moto end-plate
- Release of acetylcholine from vesicles to synaptic cleft
- Binding of acetylcholine with the nicotinic receptors placed on post-synaptic membrane
- Opening of Na^+ channels (connected with acetylcholine receptors) and intake of Na^+
- Local depolarization of the membrane
- Opening of voltage gaited channels for Na^+
- Formation of action potential

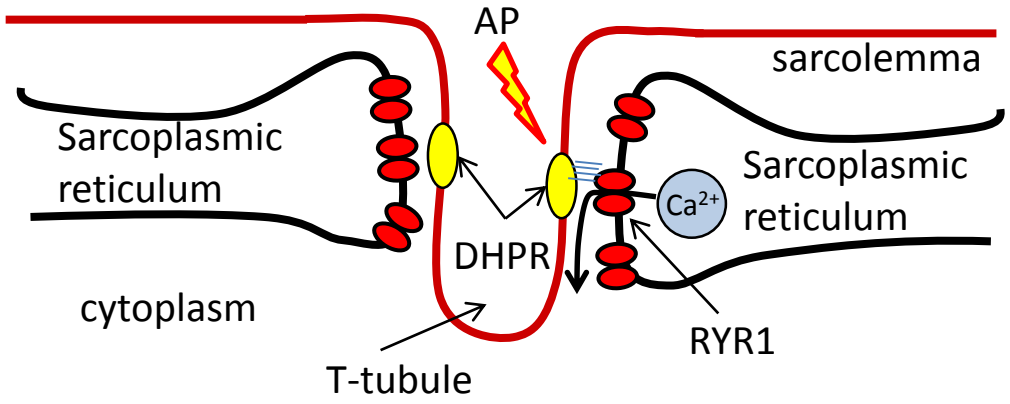


Excitation – contraction coupling

Contraction

- Spreading of action potential (AP) across fiber and into transversal tubule (T-tubule)
- Dihydropyridine receptors (DHPR) in the membrane changes its conformation
- Interaction of DHPR with ryanodine receptors (RYR1) in the membrane of sarcoplasmic reticules
- Opening of calcium channels in the sarcoplasmic reticulum and intake of Ca^{2+} into cytoplasm
- Binding of Ca^{2+} with troponin C
- Binding of myosin heads on actin
- If enough of Ca^{2+} and ATP in cytoplasm, myosin shifts along actin → contraction of muscle
- Contraction ends with decrease od Ca^{2+} concentration in the cytoplasm (Ca^{2+} is pumped by Ca-ATPase into the reticulum)

Rigor mortis – caused by ATP deficit → formation of strong link between actin and myosin



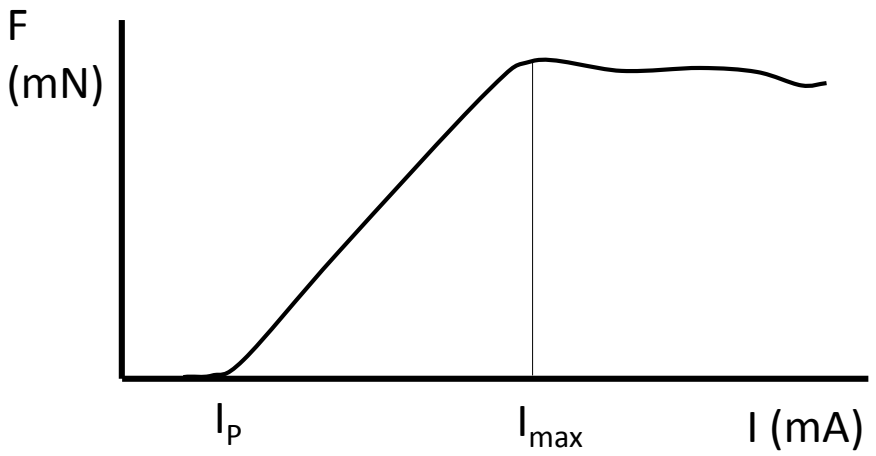
Recruitment of skeletal muscle

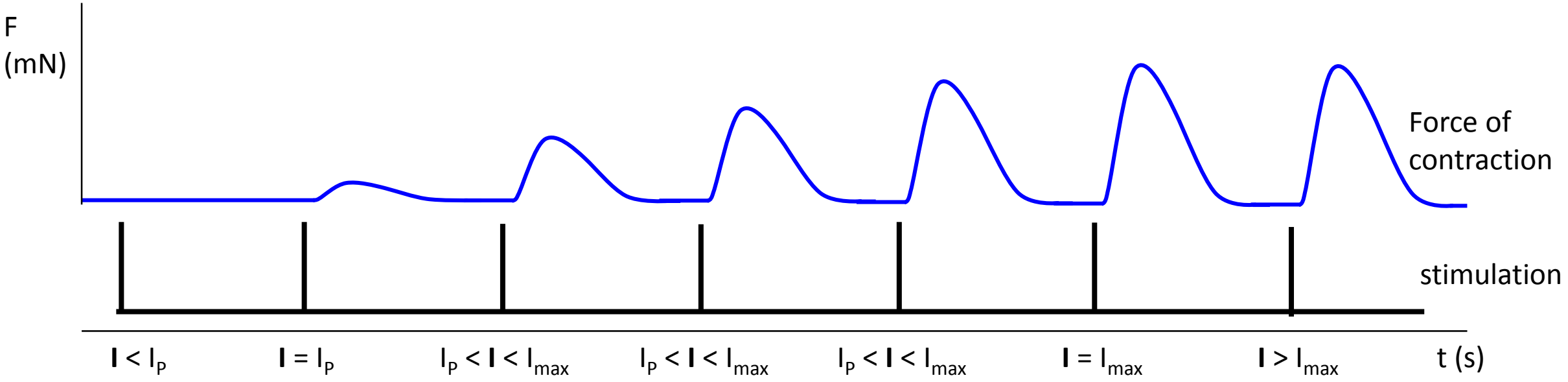
Increasing of the number of simultaneously activated motor units

I – intensity of stimulation

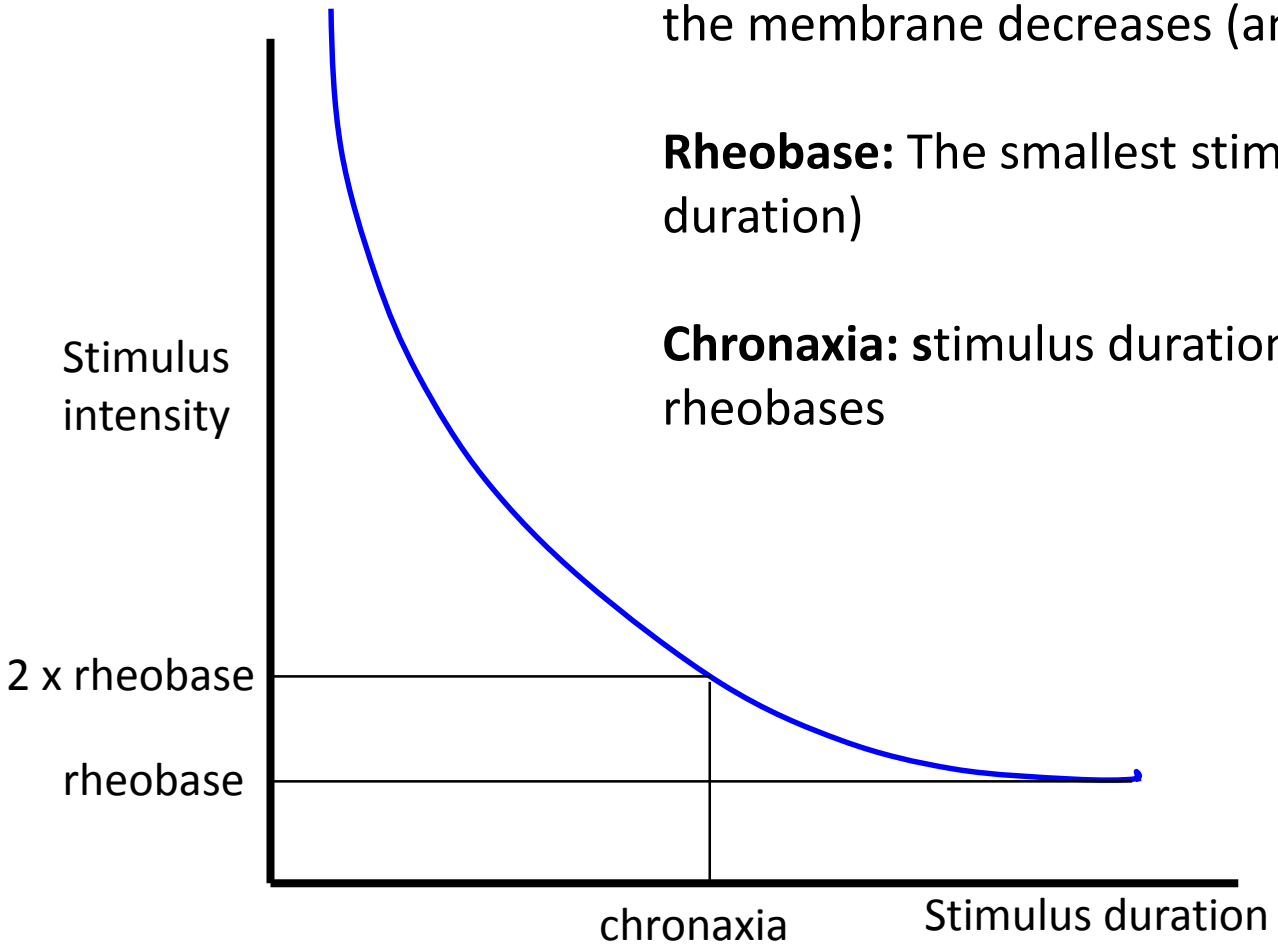
$\mathbf{I_P}$ – threshold intensity of stimulation – first fibers started their contraction

$\mathbf{I_{max}}$ – maximal intensity of stimulation – all motor units are activated





Dependence of contraction formation on the stimulus duration and strength



As the strength of the applied current increases, the time required to stimulate the membrane decreases (and vice versa) to maintain a constant effect

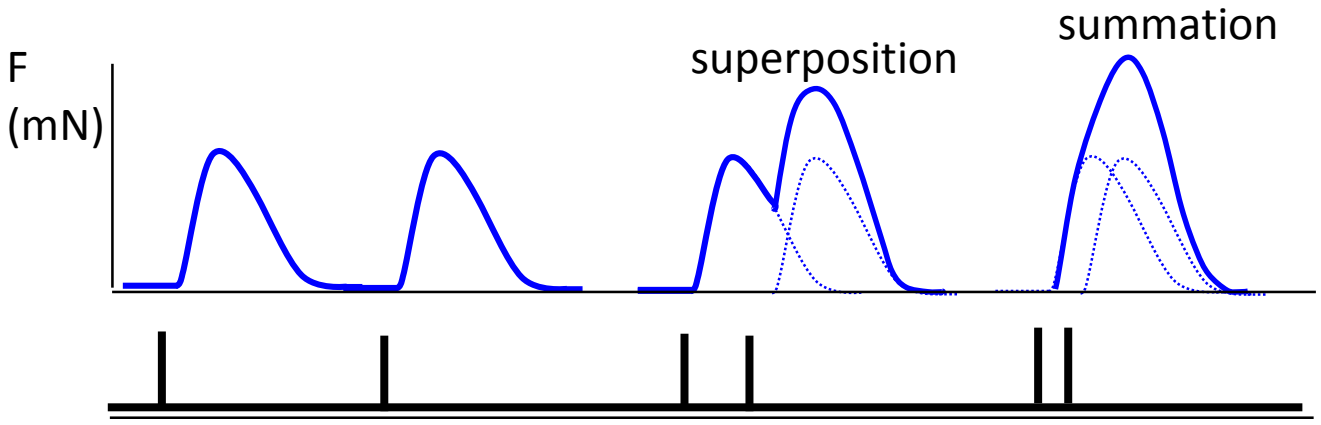
Rheobase: The smallest stimulus leading to contraction (infinite stimulus duration)

Chronaxia: stimulus duration necessary for a contraction in case of two rheobases

Summation of skeletal muscle

Summation is due to repetitive activation prior to full relaxation (higher frequency of stimulation, higher force of contraction)

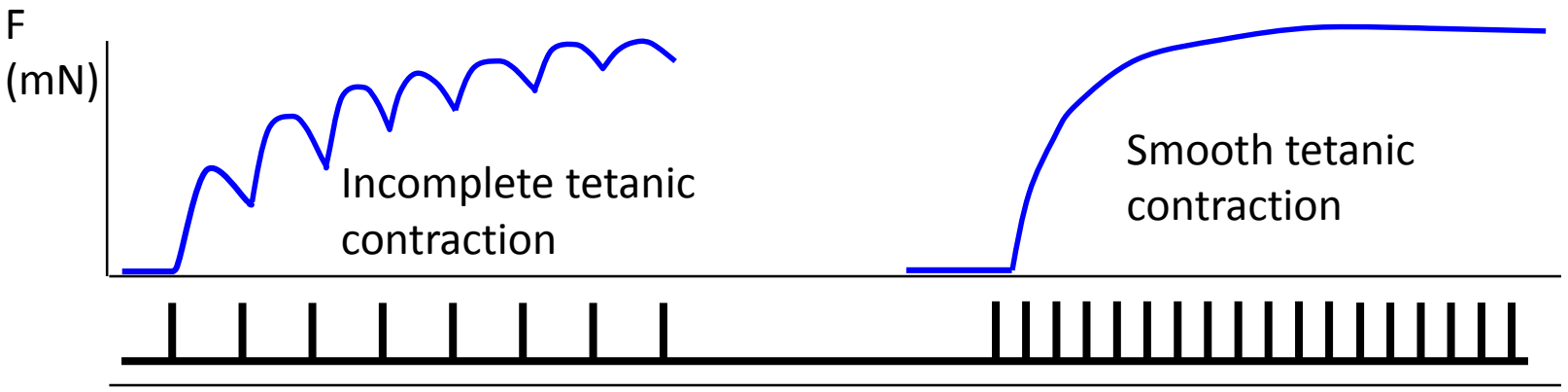
Principle: The higher the frequency of the stimulus, the higher concentration of calcium in the cytoplasm
→ increase of the contraction force



If the next stimulus arrives before the contraction is completed, both mechanical responses fuse

Superposition – if the fused contraction if double peaked

Summation – if the new contraction occurs during crescent, resulting double contraction has a single peak



Series of stimuli

Incomplete tetanic contraction – cumulative superposition

Smooth tetanic contraction – exerted by a train of stimuli during ascending phase

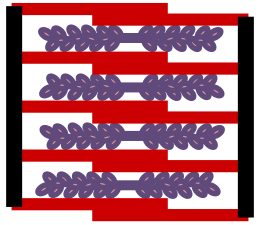
Autoregulation of the cardiac muscle

Heterometric autoregulation (Frank-Starling):

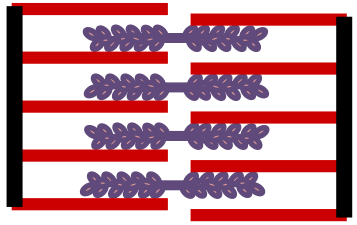
Increase of the heart filling leads to stronger contraction of the heart

Principles: 1) the relative position of actin and myosin during different stretch of muscle

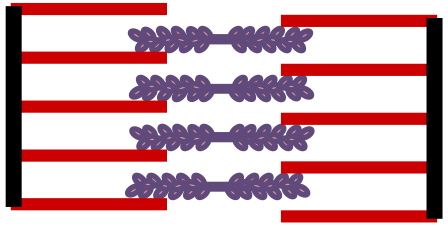
2) Fiber stretching increases sensitivity of troponin to calcium



Low heart filling



High heart filling

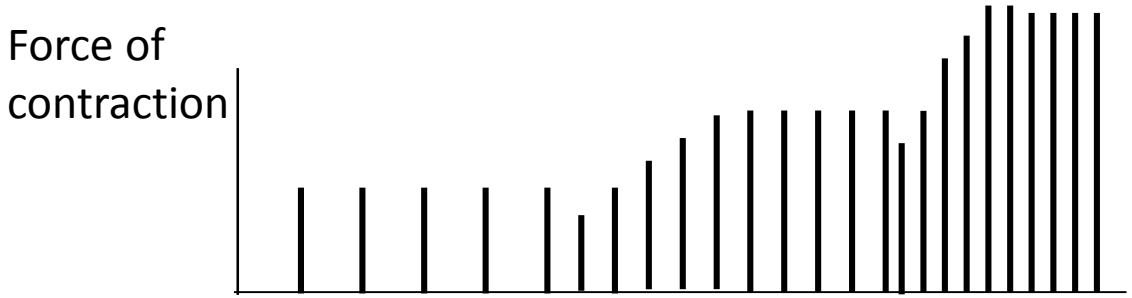


Extremal muscle stretch

Homeometric autoregulation:

Increasing heart rate leads to muscle contraction increase

Principle: Increase of ratio Intracellular/Extracellular calcium concentration



Bowditch (Staircase) phenomenon

Homeometric autoregulation is analogous to the summation of the skeletal muscle.

Cardiac muscle can not get into tetanic contraction because of long refractory phase.

Skeletal, cardiac and smooth muscle – action potential and contraction