

Lecture 2. Properties of skeletal muscles and mechanisms of their contraction

Skeletal muscles functions

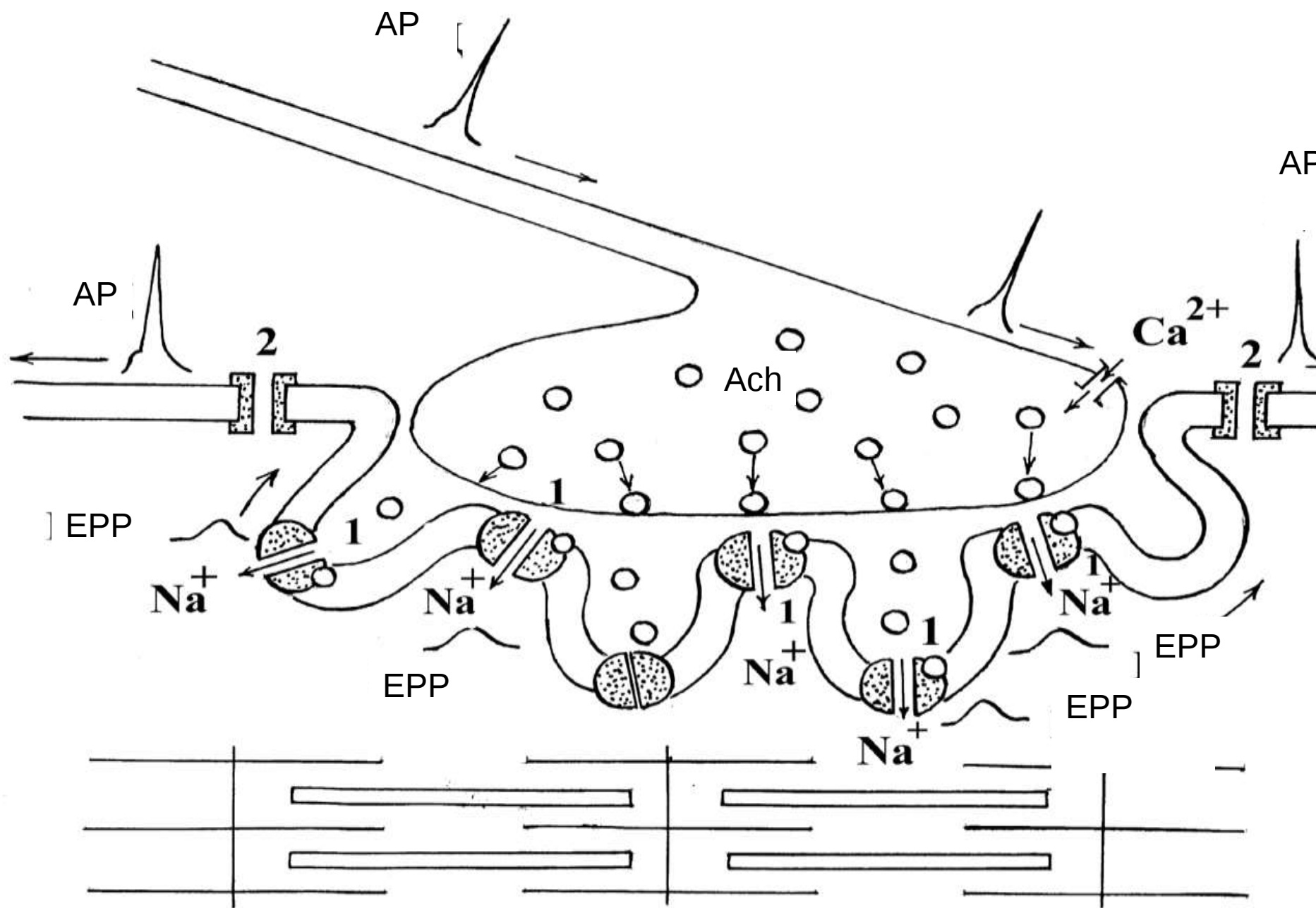
1. Maintain body posture
2. Body movements
3. Body parts movement with regards to each other
4. Thermogenesis

Sarcomere is a structural & functional unit of skeletal muscle

- Is a part of muscle fiber between 2 Z-lines
- Contains transverse tubuli (sarcoplasmic reticulum), myozin & actin fibers located in order

MOTOR UNIT

- Consists of motor neuron & a group of muscle fibers, which are supplied by axon of this motoneuron
- The number of muscle fibers in one motor unit depends on the function, which is performed by this muscle (from 10 to 30 000 fibers)



Mechanism of neuro-muscular synapse work

1. Discharge of motoneuron & AP spreading to axon ending
2. Opening of calcium voltage gated channels
3. Calcium entry
4. Acetylcholine release at motor endplate
5. Binding of acetylcholine to nicotinic acetylcholine receptors

5. Opening of sodium chemically gated channels at endplate
6. Increased sodium conductance in endplate membrane
7. Generation of endplate potential
8. Summation of endplate potentials
9. Generation of action potential in muscle fibers (due to opening of voltage gated sodium channels)

Electro-chemical interaction

- Inward spread of depolarization along T tubules
- Charge movement of the slow calcium voltage channel (dihydropyridine receptor) of the transverse tubular membrane
- Opening of calcium release channel (ryanodine receptor) in sarcoplasmic reticulum
- Calcium concentration in sarcoplasm increases 100 times

Chemo-mechanical interaction

- Myosin heads bend, allowing actin filaments to slide along myosin ones
- Sliding goes smoothly because myosin heads get attached to the subsequent active centers of actin.
- ***The higher is cytoplasm calcium concentration, the more bridges can be formed and the stronger is contraction***

Mechanism of muscle relaxation

- Calcium is pumped back into sarcoplasmic reticulum
- Calcium is released from troponin
- Cessation of interaction between actin & myosin

Energy expenditure during muscle contraction

- Na/K pump
- Sliding of myosin heads along actin filaments
- **Calcium pump**

Most energy is spent for relaxation

«All or none» law

- Single muscle fiber submit this law:
Subthreshold irritation doesn't cause contraction, and threshold irritation causes maximal contraction, i.e. the amplitude of muscle contraction doesn't depend upon the force of irritation

Types of contraction

- Isometric – tension increase without length increase
- Isotonic – length decrease at the same tension
- Mixed - auxotonic

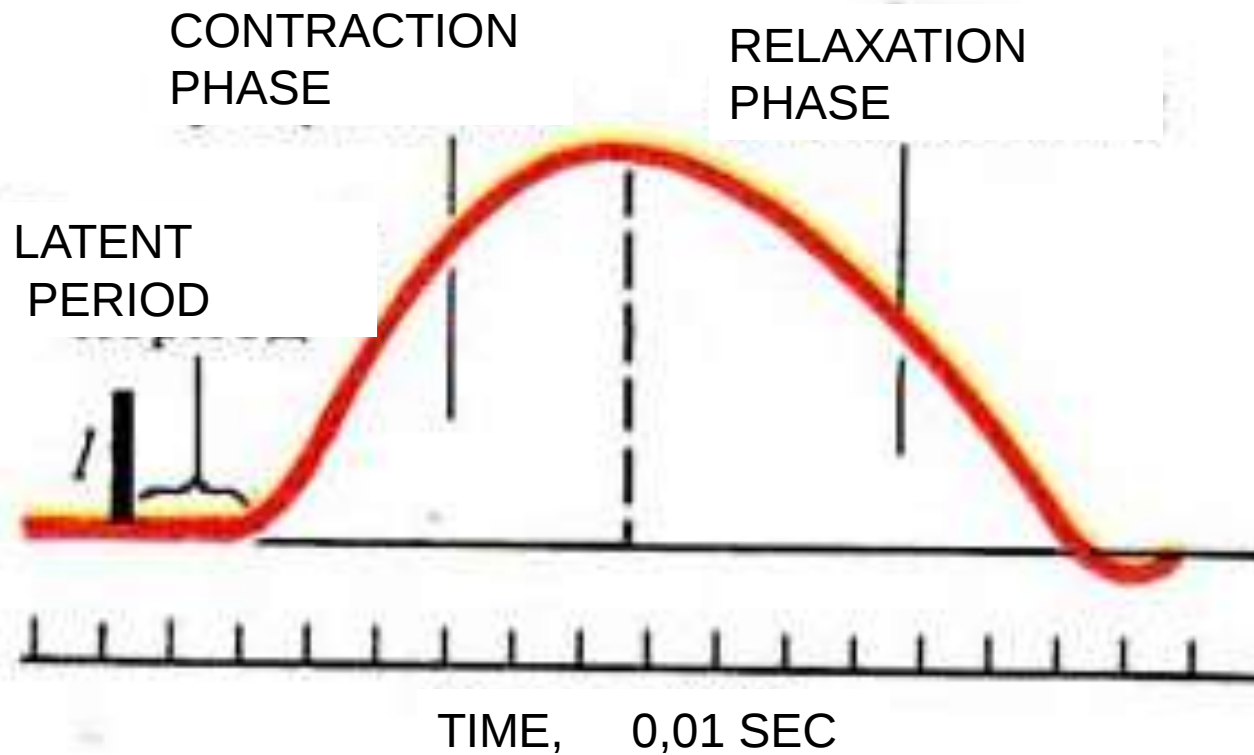
Types of muscle contraction

- Twitch
- Tetanus
- Tonus

Types of muscle irritation in experiment

- **Indirect irritation** – impulse is applied to the nervous ending of motor neuron
- **Direct irritation** – impulse is applied to the muscle directly

Single muscle contraction (twitch)



TETANUS

- Strong & long lasting contraction in response to series of irritations.
- Develops due to summation of single muscle contractions as the result of calcium concentration increase

Partial (incomplete) tetanus

- Develops when each subsequent stimulus gets into the period of muscle relaxation *so that*
- *interval between two impulses is less than the duration of single muscle contraction, but longer than contraction phase*

Holotetanus

- Each subsequent stimulus is getting into contraction phase, i.e. *interval between two subsequent stimuli is shorter than contraction phase duration, but longer than refractory period*.

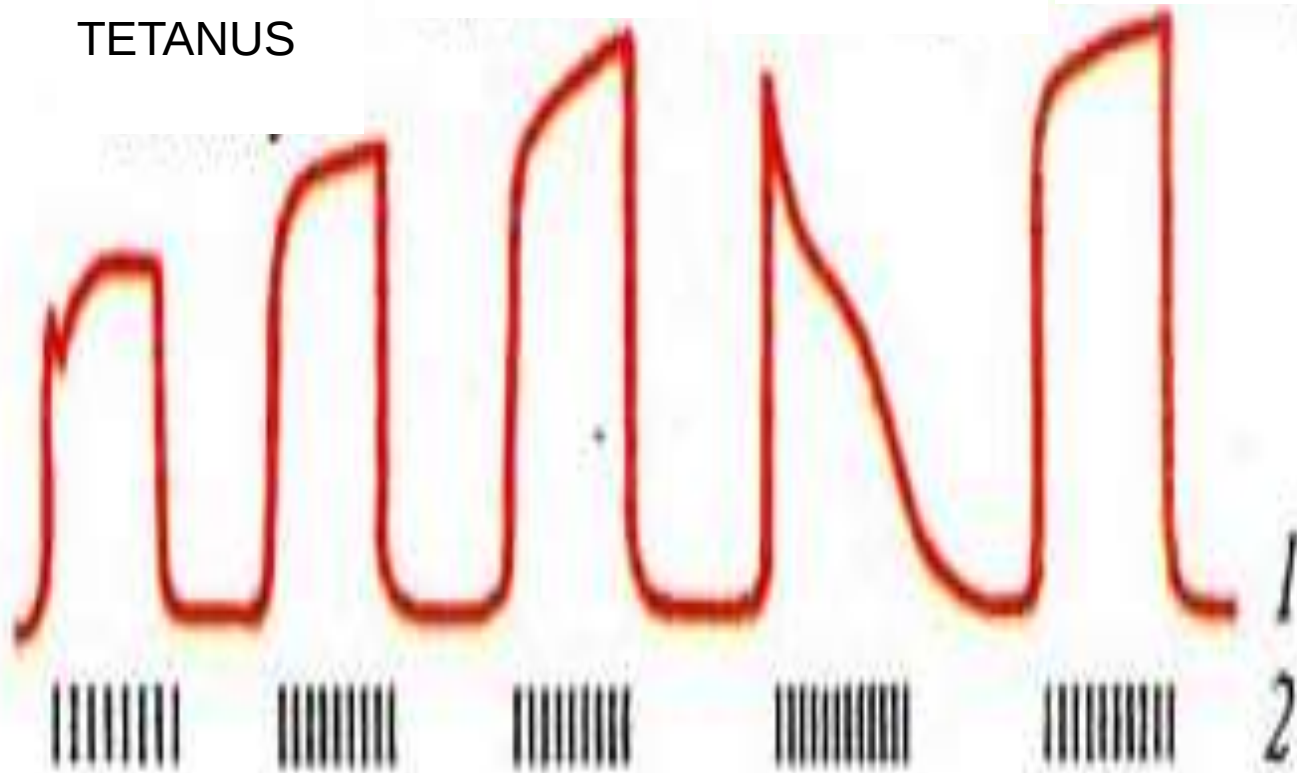
SMOOTH

OPTIMUM

PESSIMUM

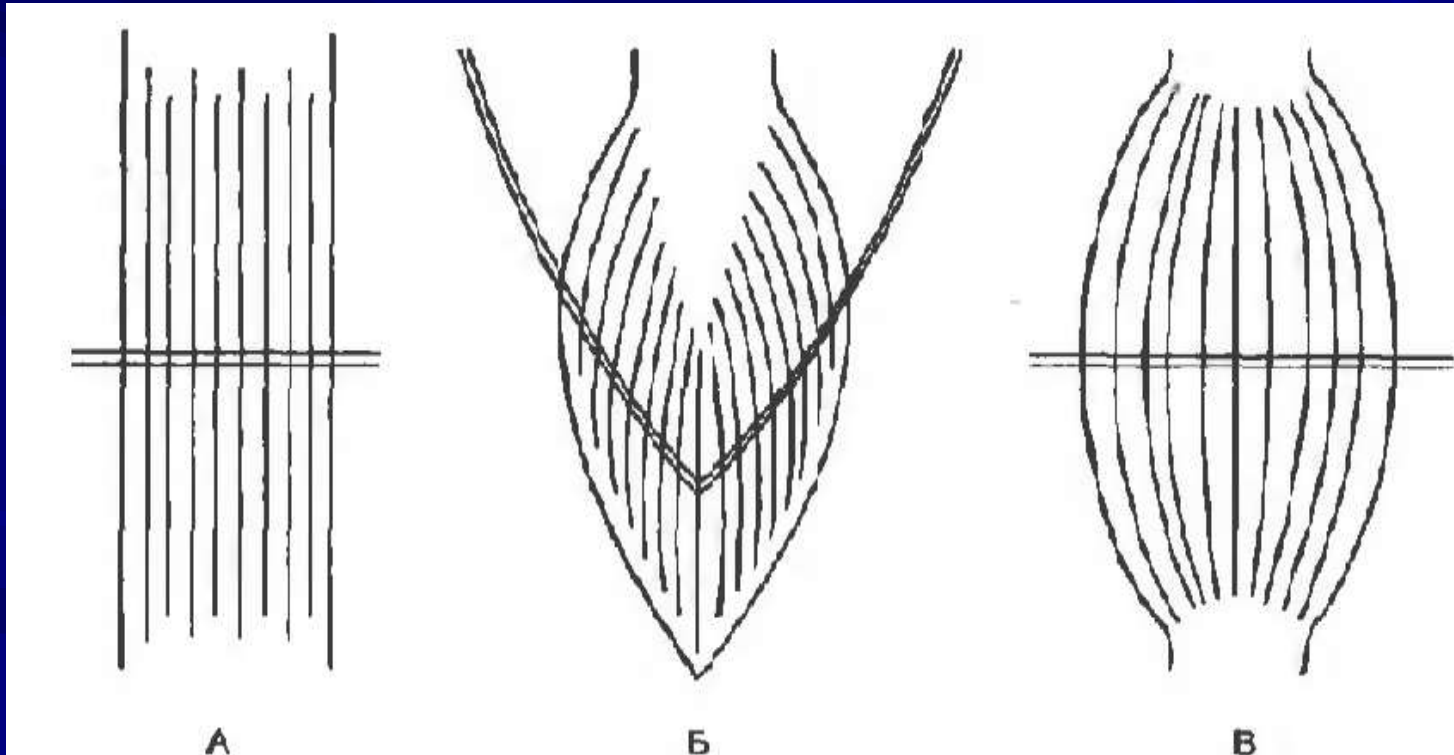
OPTIMUM

TETANUS



Muscle strength

- Depends on muscle thickness & physiological cross section



Muscle work

- Is energy spent on body movement with a certain force to a certain distance:

$$A = F \times S$$

If $F=0$, then $A=0$

If $S=0$, then $A=0$

- Maximum work is performed at middle loads

$$A_{\max} = F_{\text{med}} \times S_{\max}$$

FATIGUE

- A process of temporal decrease of muscle workability.
- Develops due to the decrease of ATP in muscle fiber or mediator in neuro-muscular synapse
- *In neuro-muscular preparation fatigue develops first of all in the synapse!*

Ergography

- A method of muscle work registration
- Ergogramme curve can show signs of fatigue:
 - ✓ *Decreased magnitude of contraction*
 - ✓ *Prolonged phase of relaxation*
 - ✓ *Decreased frequency of contraction*