Muscle

Muscles are tissues with elastic properties, able to contract and then relax after an exciting stimulus. They thus transform chemical energy into kinetic energy, and therefore ensure movement both within the organism an the movement of the entire organism. Muscles belong to the locomotor system and are divided into several classes - striated muscle, smooth muscle, cardiac myocardium. All these system contain contractile proteins.

General muscle structure

Skeletal muscle is composed of muscle tissue of mesenchymal origin, containing **specialized cell types**. Muscle structures are connected by **ligaments**. We distinguish **slow** muscles (performing static work, less powerful, less tiring - e.g. postural muscles) and **fast** muscles (allowing fast, intense but short-term performance - e.g. arm muscles).

A muscle contains several parts: [1]

- **Origin** (origo) – the place where the muscle begins.
- **Insertion** (insertio) – place of muscle attachment.
- **Muscular belly** (venter musculi) – the most massive part of the muscle.
- **Tendon** (tendo) – an organized collagenous ligament that fastens a muscle most often to a bone, sometimes to the skin or a joint.
- **Fascia** (band) – flexible fibrous covering of a muscle. They are part of the **osteofascial septa**, which form the spatia between the periosteum of the bone and the superficial fascia. **Pathological processes** can spread here.

Functional division of muscles

Muscles are functionally divided into: [1]

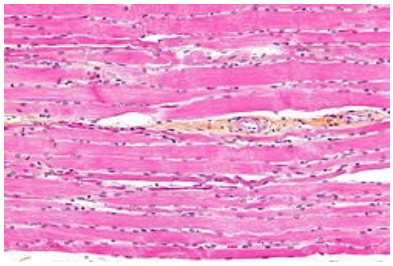
- **Main muscles** – the most important muscles for the given movement.
- **Auxiliary muscles** – muscles acting together with the main muscle.
- **Fixation muscles** – muscles that strengthen the moving part of the body.
- **Neutralizing muscles** – canceling unwanted movements of the main and auxiliary muscles.

Due to their different functions, the muscles are classified into groups:

- **Synergists** – when several muscles work together on one movement.
- **Antagonist** – when muscles act in opposite motion on each other.
- **Agonists** – muscles for movement in certain direction acting as initiators and executors.

Striated muscle

Striated muscle is the basis component of **skeletal muscle**. Thanks to the alternation of actin-myosin complexes, transverse striations are visible microscopically. There are around 600 skeletal muscles in the human body.



Skeletal muscle (HE)

Skeletal muscle is made up of **long cylindrical multinucleated cells (syncytium)** that are 60-100 μm wide. [2]

The nuclei in the muscle fiber are concentrated under the cytoplasmatic membrane, which is why skeletal muscle can be easily distinguished from other types under the microscope. Skeletal muscle fibers contain a set of contractile proteins **actin and myosin**, which allow the muscle to contract by sliding against each other. Part of the actin myofilament are regulatory proteins – **troponin a tropomyosin**.

Skeletal muscle cells are grouped into primary bundles (fasciculi), secondary bundles and finally bundles of higher orders. The structures are connected by ligaments, which are referred to as the **epimysium** (the layer surrounding the entire muscle), the **perimysium** (the layer surrounding the fiber bundles) and the **endomysium** (enclosing the individual muscle fibers). **Blood vessels** then penetrate the fibrous septa forming a rich capillary network.

A myofibril (set of actin and myosin myofilaments) is divided into regular sections, so-called **sarcomeres**, which are the basic functional unit. These sarcomeres contain characteristic lines and zones:

File:Sarkomera.jpg
The structure of the sarcomere

[3]

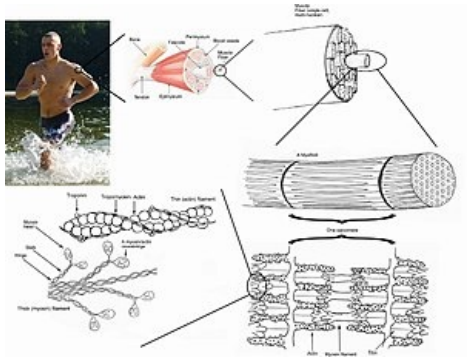
- **Z-discs** – bound the sarcomere. Thi sarkomeru. **Thin actin filaments** are anchored in these discs.
- **M-lines** – run through the center of the sarcomere and anchor the **thick myosin filaments** in their center.
- **I-band (isotropic)** – part of the sarcomere where actin filaments do not overlap with myosin filaments.

- **A-band (anisotropic)** – the darker part of the sarcomere where myosin filaments are located (including the section where mysoin overlaps with actin).
- **H-zone** – lighter part of the sarcomere where only myosin filaments are found.

During contraction, the I-band and H-zone shorten, the A-band remains the same.

Molecular principle of striated muscle contraction

It consists in the sliding of heavy myosin filaments along actin filaments. The myosin molecule consists of a long section formed by two coiled polypeptide chains, at the ends of which are globular heads. In the neck part of this molecule, there is a place that, by conformational change, can tilt the head towards the long part and thus induce a lever-like movement. At the same, this head is oriented against the actin filament. An actin filament is a double helix of filamentous **F-actin**, formed by monomers of globular **G-actin**. On both sides of the double helix there are **tropomyosin** molecules with **troponin** molecules. Troponin contains three subunits:


Skeletal muscle

- **Tn-C** − Ca^{2+} cation binding site;
- **Tn-T** − site where troponin binds to tropomyosin;
- **Tn-I** − site that covers the active sites of actin for interaction with myosin.

The presence of **Ca^{2+}** cations, which are released from the **sarcoplasmatic** (smooth endoplasmatic) **reticulum** after the transfer of excitation from T-tubules (T tubule = invagination of the sarcolemma) in response to an incoming depolarizing stimulus, is absolutely necessary for filament interaction. The binding of Ca^{2+} to the Tn-C subunit of troponin induces a **conformational change**, when tropomyosin slides even further into the actin grooves. This enables the myosin head to bind to the active site (the myosin "rests" on actin) and activates the ATPase. **ATP** is consumed for the production of ADP + Pi and the myosin head tilts in the longitudinal axis of the sarcomere - the filaments move and contract. A stable **rigor complex** is created. With the participation of additional ATP, the state relaxes.

Rigor mortis occurs when the cell runs out of ATP. Thus, the connection cannot relax. [3]

Types of contraction

We distinguis two basic types of contraction:

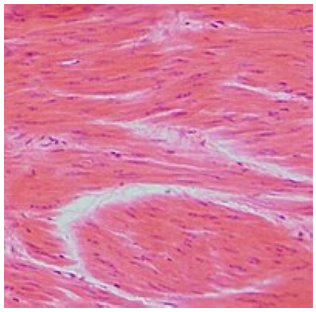
- **An isotonic contraction** changes the length of the muscle, but the tension is the same (e.g. lifting a load).
- **An isometric contraction** changes the tension of the muscle, but the length is the same (e.g. carrying a load).

Energy sources for muscle activity

The unequivocal source of energy for the muscle is **ATP**, which is supplied by oxidative phospholyration. Short-term performance is ensured by anaerobic **glycolysis** (lactate production with subsequent muscle soreness). Other energy stores are reactions of **ADP with creatine phosphate**, which is dephosphorylated. During long-term work **free fatty acids** are used, during short-term work, **glucose** is the most important. [4]

Smooth muscle

Smooth muscle forms the walls of some organs, intestines and blood vessels (except capillaries). The cells are much smaller (2–5 × 20–200 µm, max. 500 µm) and spindle-shaped. It does not have transverse striations in the light microscope. It is not controllable by will. Its contraction is slow and lasts a long time.


Smooth muscle(HE)

Smooth muscle cells are more elongated, spindle-shaped with single nucleus. Here, actin and myosin filaments run diagonally across the cell or form networks, they are not arranged in sarcomeres. Smooth muscle cells form:

- **Unit smooth muscles** connected by nexus, thanks to which the action potential propagates. The cells then function as a functional syncytium (co-cellular), where the contraction propagates.
- **Multiunit smooth muscles**, where the cells are not connected to each other and contractions practically do not propagate.

The principle of contraction is, with several differences, similar to that of skeletal muscle. Smooth muscle does not have neuromuscular plates, irritation spreads with the help of nexus or increased concentration of mediators in the intercellular space. The action arises either in so-called **pacemaker cells** or by the exchange of Ca^{2+} and Na^{+} ions. [5]

Cardiac muscle

It is located only in the heart and ensures its constant mechanical activity. Muscle is made up of **cardiomyocytes** (15 x 85−100 μm), which are connected to each other, thus enabling uniform transmission of action potentials through all cells. [6], Cardiomyocytes contain one to two nuclei located in the center, abundant mitochondria and there are characteristic **intercalary discs** at the junctions of the cells [6]. Under the microscope, transverse striations are visible due to the presence of sarcomeres.

The principle of contraction is again the same as for skeletal muscle.

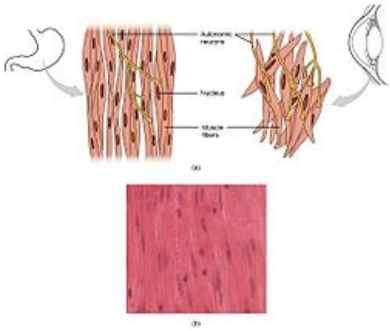
Links

Related Articles

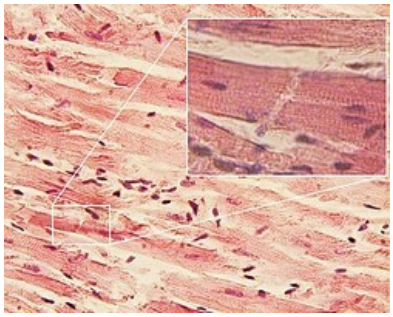
- List of muscles
- Muscle spindle
- Golgi tendon body
- Contraction of heart muscle

References

1. ČIHÁK, Radomír. *Anatomie I.* 2nd edition. Praha : Grada, 2001. 516 pp. pp. 321-322, 325. ISBN 978-80-7169-970-5.
2. JUNQUIERA, L. Carlos – CARNEIRO, José – KELLEY, Robert O. *Základy histologie.* 1st edition. Jinočany : H & H 1997, 2000. 502 pp. pp. 184-186. ISBN 80-85787-37-7.
3. TROJAN, Stanislav, et al. *Lékařská fyziologie.* 4. edition. Praha : Grada, 2003. 772 pp. pp. 92-95. ISBN 80-247-0512-5.
4. TROJAN, Stanislav, et al. *Lékařská fyziologie.* 4. edition. Praha : Grada, 2003. 772 pp. pp. 103. ISBN 80-247-0512-5.
5. TROJAN, Stanislav, et al. *Lékařská fyziologie.* 4. edition. Praha : Grada, 2003. 772 pp. pp. 104-108. ISBN 80-247-0512-5.
6. JUNQUIERA, L. Carlos – CARNEIRO, José – KELLEY, Robert O. *Základy histologie.* 1st edition. Jinočany : H & H 1997, 2000. 502 pp. pp. 198-200. ISBN 80-85787-37-7.



Smooth muscle



Myocardium with intercalary disc detail

References

- TROJAN, Stanislav, et al. *Lékařská fyziologie.* 4. edition. Praha : Grada, 2003. 772 pp. pp. 104-108. ISBN 80-247-0512-5.

- JUNQUIERA, L. Carlos – CARNEIRO, José – KELLEY, Robert O. *Základy histologie.* 1. edition. Jinočany : H & H 1997, 2000. 502 pp. pp. 184-204. ISBN 80-85787-37-7.

- ČIHÁK, Radomír. *Anatomie I.* 2. edition. Praha : Grada, 2001. 516 pp. pp. 321-327. ISBN 978-80-7169-970-5.