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Структура пособия соответствует современным стандартам медицинского образования в России и важнейшим европейским стандартам. Английская и латинская терминология приведены в соответствии с Международной анатомической номенклатурой.

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LIST OF ABBREVIATIONS

Art., art. — articulatio
Artt., artt. — articulationes
For., for. — foramen
Lig., lig. — ligamentum
Ligg., ligg. — ligamenta
M., m. — musculus
Mm., mm. — musculi
N., n. — nervus
Nn., nn. — nervi
R., r. — ramus
Rr., rr. — rami
S., s. — sulcus

PREFACE

The creation of the manual «Myology» in English meets the requirement of modern Russian medicine and education. Nowadays many English-speaking oversea students study in Medical Universities of Russia. Besides, many Russian school leavers have a good command of the English language so they will be able to use this manual taking into consideration the fact that many Russian specialists in medicine work abroad after graduating from the universities or take part in different international conferences and symposiums.

The English version of the manual is based on the Russian manual by professor Gay-voronskiy I.V. «Normal Human Anatomy» which has been published in Russia 9 times and is approved by the Ministry of education of Russia.

This manual introduces the main principles of Russian Anatomy School such as: detailed study of the general aspects and items of Anatomy including the development of organs and anomalies of the development. If we compare theoretical approaches to Anatomy in Russia and in other countries we`ll see that our approach is based on the system descriptions of organs, i. e. we describe separately Skeletal system, Articulations, Muscular system etc. Moreover, we use Latin terminology while describing the organs and discuss clinicoanatomical and functional problems. As for the manuals in other countries many of them describe Anatomical systems in accordance with the regional and topographical principles.

The structure of our manual meets the requirements of modern standards of medical education in Russia which in their turn correspond to the major European standards. After each chapter we give test questions and clinicoanatomical problems. The English and Latin terminology is given in accordance with International Anatomical Nomenclature.

The authers srongly believe that the manual will allow future doctors to form the morphological foundation for the further study of theoretical and clinical disciplines. We also hope that it will be of great help to Anatomy teachers.

ПРЕДИСЛОВИЕ

Создание учебного пособия «Миология» на английском языке является требованием современной системы медицинского образования в России. В настоящее время в медицинских университетах нашей страны обучаются студенты из различных регионов дальнего зарубежья. Кроме того, многие выпускники российских школ хорошо владеют английским языком, поэтому они также смогут пользоваться данным пособием, принимая во внимание, что зачастую русские специалисты в медицине после окончания университета уезжают работать за рубеж или принимают участие в различных международных конференциях и симпозиумах.

Английская версия пособия базируется на русском учебнике профессора И. В. Гайворонского «Нормальная анатомия человека», который был издан в России 9 раз и одобрен Министерством образования Российской Федерации.

Данное пособие познакомит читателей с главными принципами Русской анатомической школы, которые заключаются в подробном изучении общих вопросов, в том числе развития органов и аномалий развития. В России преподавание анатомии ведется с функционально-клинических позиций и основано на описании органов по системам, т. е. отдельно изучается опорно-двигательная система, артросиндесмология, миология и другие системы. Также при описании строения органов акцентируется внимание на латинской терминологии. Что касается зарубежных руководств по анатомии человека, многие из них основываются на регионально-топографическом принципе без использования латинской терминологии.

Структура данного пособия соответствует современным стандартам медицинского образования в России, которые, в свою очередь, соответствуют важнейшим европейским стандартам. После каждой главы мы приводим контрольные вопросы и ситуационные клинические задачи. Английская и латинская терминология приведена в соответствии с Международной анатомической номенклатурой.

Авторы выражают уверенность, что данное пособие позволит будущим докторам сформировать морфологический фундамент для последующего изучения теоретических и клинических дисциплин. Мы также надеемся, что оно принесет определенную пользу и преподавателям анатомии человека.

1. GENERAL MYOLOGY

Myology — is the science of muscles. In the human body two types of muscle tissue are distinguished: smooth (non-striated) and striated. The latter includes the skeletal and cardiac muscles. Smooth muscle tissue forms the muscular layer of the wall of the vessels and of the most internal organs. Cardiac muscle forms the middle layer of the heart wall – myocardium. Striated muscle tissue forms the skeletal muscles which will be described in the chapter «Myology».

Smooth and striated muscle tissue differ in structure. Smooth muscle tissue looks like homogeneous mass, which divides in the layers. But striated skeletal muscle tissue consists of many separated structures called muscles. Each skeletal muscle is an individual organ having specific form and structure, typical architecture of the vessels and nerves; it is constructed from the fascicles of striated muscle fibers connecting by loose connective-tissue, and covered from the outside by proper fascia.

About 639 muscles are in the human body: 317 of them are paired, 5 of them are unpaired. Each muscle possesses a specific size and form, has a certain number of the sources of blood supply and innervation, and typical sites (gates), through which the nerves and vessels pass into or from a muscle.

There are 2000 capillaries per 1 mm^2 of a muscle. The distribution of the blood vessels, density of capillaries, and the size of a muscle part supplied by blood vessels, depend on the functional load. In the relaxing or resting muscle, the most part of the capillaries is closed for the bloodstream. During the muscle contraction all capillaries open, therefore a working muscle has the 30 times better blood supply than the relaxing muscle.

The main property of the muscles is ability to contract. Skeletal muscles form active part of the locomotor system. They are attached to the bones or to the skin, therefore they act on the synovial joints, setting them in motion, or effect the skin, changing its tension.

Skeletal muscles are voluntary, i.e. their contractions occur consciously, and depend on wish. The movements can be produced rapidly and energetically. All movements of the body occur due to the actions of the voluntary muscles: they move the body in space and keep the balance of body; they produce the different movements of the limbs, they move the ribs, providing respiration; they provide the abdominal pressure, produce movements of the veretbral column and hand, and chewing movements. Besides, they provide facial expressions, speech, swallowing, defecation and urination; they produce the movements of eyeballs. Thus, striated muscle tissue forms the diaphragm, muscles of the head, neck, trunk, limbs, larynx, pharynx, upper part of the oesophagus, muscles of tongue, palate, perineum, eyeball and middle ear.

In adult man the weight of the skeletal muscles is about 40 % of the total body weight, in adult woman it is about 35 %, i. e. in women the musculature is a little less developed. The weight of the limbs` musculature can reach 80 % of the total weight of all skeletal muscles (the weight of the musculature of lower limbs is about 52—53 %, while the weight of the musculature of upper limbs is about 27—28 %).

The muscles of a newborn are already formed anatomically, but they are poorly developed. Their weight forms 20—22 % of the total body weight.

During prenatal development, the muscle fibers significantly increase, hence in a newborn they are almost 5 times thicker than in a two-months featus. During the feeding with breast milk, the abdominal musculature of an infant growth rapidly; later, in a child age, the mass of the masticatory muscles, of the muscles of the tongue, palate, pharynx increases because of the increased function of the corresponding organs. In work-induced hypertrophy, the muscle fibers are thickened, but their number can even decrease.

The structure of the skeletal muscles has age features. Muscle fibers of newborns have a distinct transverse striation, they are significantly thinner than in adult. The neurovascular apparatus of newborns` muscles is well-developed, while connective-tissue of the muscles is little developed. During the second year of life the average thikness of the muscle fibers is 10—14 mcm, in a four-year child it is 14—20 mcm. The growth of fibers in the thickness continues until 30—35 years.

Analizing the above information, we can see that, during the period of life from the birth until 18—20-year age, the relative weight of the skeletal muscles increases by 2 times. If the muscles are subjected to constant physical load, their relative weight increases by 3 times. For example, in weightlifters, the weight of musculature reaches 50—60 % of the body weight. In elderely, the muscles become weaker, they gradually atrophy; the muscle fibers are replaced by connective-tissue because of the decrease of physical load. The relative weight of skeletal musculature decreases up to 30 %.

The elascticity of muscles in children is 2 times greater than in adult, therefore, muscle ruptures in children are rare.

The physical labor or intensive muscular activity in sportmen increase metabolism in muscle tissue. As a result, the structure of a muscle changes, and the size of a muscle increases, hence the work-induced hypertrophy appears. In people with decreased physical load and reduced motor activity, the muscles become weak and loose, and their size decrease.

1.1. The Structure of Muscles

A skeletal muscle as an organ consists of the muscular and tendinous parts, and also it includes connective-tissue sheaths and proper vessels and nerves.

The structural and functional unit of the muscular part of a muscle is a striated muscle fiber (fig. 1.1). It is round in cross section. The thickness of striated fibers changes with age, and it is various in different muscles. In adult person the thickness of striated fibers is 38–61 (up to 70) mcm, but in sportsmen (especially in weightlifters) it is 100 mcm. The length of a muscle fiber is from several millimeters to 10–15 cm.

A striated muscle fiber is covered form outside by membrane termed sarcolemma. It contains nusclei, sarcoplasm, different organelles of general purpose and special contractile structures called myofibrils. Striated muscle fibers are multinuclear fibers, each of them may have up to 120 nuclei. Each fiber includes from 100 to 1000 myofibrils arranged along a fiber. The diameter of a myofibril is 1–2 mcm. Under light microscope, in a striated muscle fiber we can see alternating dark and light areas which look like striation. These features in the refraction of light are caused by the characteristics of the myofibril structure.

The myofibril consists of protofibrils (one myofibril may contain up to 1500–2000 protofibriles). Protofibrils are constructed from macromolecules of specialized muscle proteins: actin and myosin. The molecules of myosine are thicker, they correspond to the dark areas (possess double refraction of light). The molecules of actin are thin, and they correspond to the light areas. During the muscle contraction, actin filaments enter the spaces between myosin filaments, change their configuration, and concatanate together.

Striated muscle fibers can differ in chemical composition, metabolism, rate and duration of contraction. The differences in color of muscle fibers were seen about 300 years ago, and the red and white fibers were distinguished. Then the differences in chemical composition and metabolism between these types of fibers were revealed. It is known, that white fibers contain relatively less sarcoplasm and great myofibrilles. The muscles with predomination of white fibers are intended for precise and dynamic work (e. g. muscles of forearm). Red muscle fibers are thinner, and contain much sarcoplasm, but less myofibriles. That is why they possess less rate, but great force of contraction. Red muscle fibers are rich in myoglobin and contract slower than white fibers. The muscles with predomination of red muscle fibers generally active in static work with prolonged tension (e. g. gluteal muscles).

The muscles fibers, that are arranged parallelly to each other and connected by loose connective-tissue, form a primary bundle. The layer of connective-tissue, surrounding the individual muscle fibers or primary bundles, is called endomysium, *endomysium*. The primary bundles are connected with other primary bundles to form the secondary bundles. The secondary bundles are connected to form larger bundles which comprise the muscle. The thickness of muscle bundles depends on the number of their fibers. In some muscles the bundles are so large, that are visible even to unaided eye (e. g. the gluteus maximus, deltoideus).

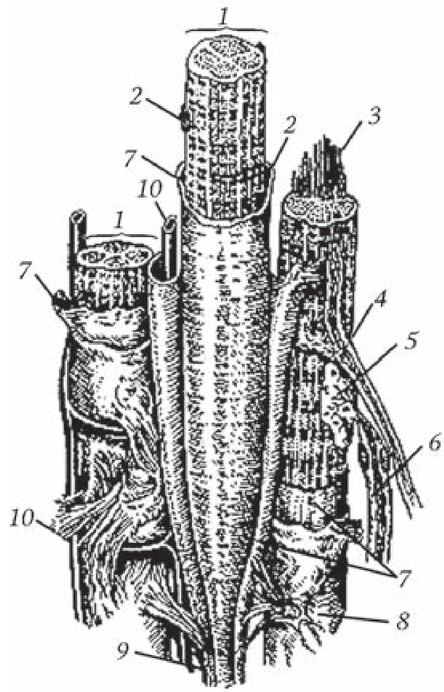

Fig. 1.1. Scheme of structure of striated fiber:

1 — muscle fiber; *2* — nucleus; *3* — myofibrils; *4* — vegetative nerve fiber; *5* — neuro-muscular synapsis; *6* – somatic (motor) nerve fiber; *7* — sarcolemma; *8* — endomysium; *9* — tendon fiber; *10* — blood capillary

The loose connective-tissue, surrounding all muscle bundles, is called perimysium, *perimysium*. It contains intramuscular arteries, vessels and nerves. The layer of connective-tissue, covered muscle from outside, is called epimysium, *epimysium*. The connective-tissue links the muscle fibers, forming the bundles, and provides their movements relatively to each other during contraction.

The tendinous part of a muscle consists of the fibers of dense connective-tissue. Connective-tissue sheaths of a muscle continue to cover the tendon, and here they are divided into endotendineum, peritendineum and epidentineum.

The tendon fibers are slightly convoluted, therefore, during stretching they can be lengthened by 4 % of their initial length. Because of this, the contraction of muscles transfer to a bone not immediately (firstly the stretching of tendon bundles occurs). The tendons possess high resistance. The limit load during the stretching of tendons is 600–1200 kg/cm^2. The tendon of triceps surae (Achilles tendon) withstands the load up to 400 kg, and the tendon of quadriceps femoris — up to 600 kg.

The tendinous part of a muscle is firmly connected with the muscular part because the tendon fibers penetrate the striated muscle fibers, passing between myofibrilles. Also the tendon is firmly attached to the bone, cartilage or fascia. If the muscle is attached to the bone, its fibers spread into the periosteum, and then penetrate into the osseous tissue. Usually at the place of the muscle`s attachment to the bone, the latter has a projection, which makes the area of the muscle effect on the bone larger.

The metabolism of muscles is very intensive, therefore they are rich in blood supply. Each muscle receives the blood through several arteries which ramify in the endomysium and anastomose with each other. Blood capillaries pass parallel to muscle fibers to supply them with oxygen and nutrients. The density of capillary bed varies in different muscles and depends on the muscle functions. So, red muscle fibers have thicker capillaries network in comparison with the white muscle fibers.

Each muscle is innervated by the sensory, motor and sympathetic nerve fibers. The sensory nerve fibers pass from proprioceptors located both in the muscular and tendinous parts of the muscle. The proprioceptors transmit the information about the tone and degree of muscle contraction into the central nervous system. Proprioceprtive impulses are necessory for coordination of the muscle activity. In damage of proprioceptors the coordination of movements is disrupted.

Sympathetic nerve fibers transmit nervous impulses from the nervous centers which regulate metabolism in muscles and provide trophic function. They change the blood supply of muscles according to performed work.

Motor nerve fibers transmit nervous impulses, which cause the contraction of striated muscle fibers, to muscles. The rupture of the nerve, coming to the muscle, leads to paralysis. Besides, the muscle atrophies because of the interruption in the regulation of its blood supply and metabolism. Usually one motor nerve fiber, arising from one cell of the spinal cord, simultaneously innervates many muscle fibers. But the number of nerve fibers is specific for each muscle and determined by functional features of the muscle. In gluteal muscle (static muscle) one nerve fiber innervates more than 500 muscle fibers, while in antebrachial muscles (dynamic muscle) one nerve fiber innervates only several dozen of muscle fibers; in the rectus lateralis muscle of eyeball one nerve fiber innervates about 19 muscle fibers. According to the innervation features of each muscle, the functional muscle unit, termed myon, is distinguished.

Myon is a collection of striated muscle fibers innervated by one nerve fiber. The striated muscle fibers of one and the same myon are not always placed near each other, usually the fibers of one myon alternate with the fibers of other myons.

Individual muscles or groups of muscles are covered from outside by proper fasciae. The proper fascia is a dense connective-tissue sheath; it belongs to accessory apparatus of muscles. Its function will be described below.

1.2. Functional Purpose of Skeletal Muscles

The main purpose of the muscles is to perform the movements. The muscles provide locomotor and working activity. For this they transform chemical energy into mechanical energy, generating much heat.

The muscles are attached to the bones, covering them, therefore the configuration of the human body depends on position of muscles and their development. Thus, the skeletal muscles have form-building function, providing gracefulness and beauty of the human body.

The muscles play a great role in cognitive human activity. They contain great number of proprioceptors which determine the body`s position in space, the condition of muscle tone and the degree of muscle contraction. The importance of proprioceptors increases in people lacking vision or hearing.

Skeletal muscles help to heart work. They are rich in blood supply, and during muscle contraction the bloodstream in the muscle vessels increases by 20—30 times. The muscle works like pump. The contraction of the muscles helps the blood flow not only through proper muscle vessels, but also through large extraorganic veins. This function explains the gradual appearance of cardiovascular insufficience in case of paralysis of the trunk and limbs muscles.

At last, the muscles, which are attached to skin, provide facial expressions, i.e. they are exponents of the inner world of a person. This function is especially important in clinical practice for examination of a patient and diagnostic.

1.3. Form of Skeletal Muscles

The form of skeletal muscles varies (fig. 1.2). In spite of this, all the muscles can be classified into 3 basic groups: long, short and wide.

The long muscles are mainly placed on the limbs; most commonly, they are fusiform. The middle thickened part of the muscle is called belly, *venter*. In most cases the muscle has two tendons, *tendo*, on its both ends; they serve for attachment of the muscle to the bones. More rarely, the muscle fibers are immediately attached to the bone, or muscle fibers are attached to the bone together with tendon fibers. Ususally the tendon of a fusiform muscle has the form of a long, narrow, cylindrical connective-tissue cord. The tendon is whitish and shiny, while the muscular belly is red-brown. The tendon possesses very high endurance. The connective-tissue fascicles of the tendons are strongly attached to the periosteum, or firmly linked with the fascia or joint capsule.

The short muscles are placed in the trunk (they are between adjacent vertebrae, ribs). Usually these muscles start from the bones by the muscular fibers. Their length is about 3–5 cm.

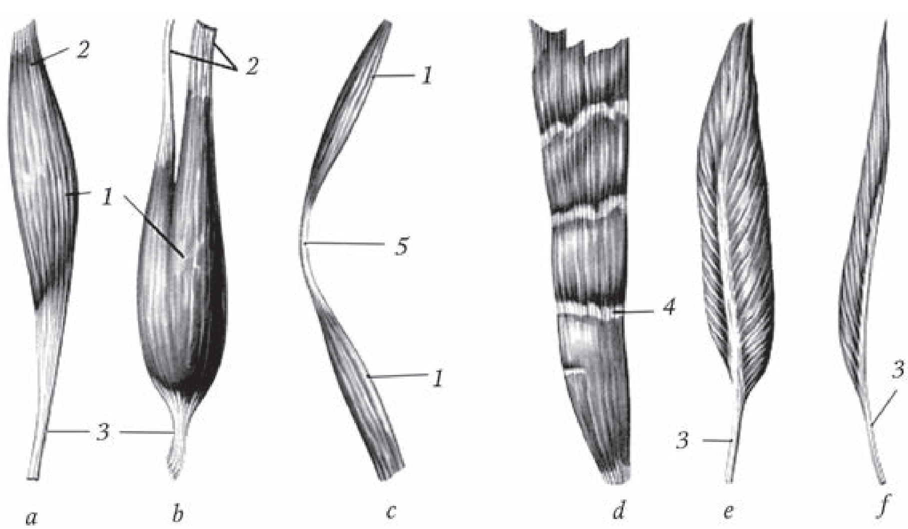

Fig. 1.2. Form of muscles:

a – fusiform; *b* – biceps; *c* – digastric; *d* – belly with tendinous intersections; *e* – bipennate; *f* – unipennate; *1* – belly; *2* – head; *3* – tendon; *4* – tendinous intersections; *5* – intermediate tendon

The wide muscles are also chiefly placed in the trunk. They form the superficial layers of the back and chest, and the musculature of the abdominal and gluteal regions. Usually the wide muscles have muscular beginning; the muscular fibers are attached to the periosteum by very short fibrous fibers which are closely linked with intermuscular connective-tissue. The wide muscles end in a very strong sheet termed aponeurosis, *aponeurosis*.

Rarely the muscles have a complex form. The complexity of form can be caused by the splitting of the muscle beginning into several separated parts called heads. So, the muscle can have not one head but two, three and even four heads, which start from different parts of the skeleton or from different points of one and the same bone. All the heads then merge into one common belly. The muscles, having such a form, are called biceps (*m. biceps)*, triceps (*m. triceps)*, quadriceps (*m. quadriceps)*.

The common belly can continue into several tendons attached to different bones (e.g. flexor digitorum superficialis and profundus, *mm. flexores digitorum superficialis et profundus*)

The intermediate tendon can divide the muscular belly into two parts to form digastric muscle (*m. biventer)*. Also the muscular belly can be divided into several parts by several tendinous intersections (*intersectiones tendineae*) formed by short fibrous fibers (e.g. rectus abdominis, *m. rectus abdominis*).

The form of muscle depends on fascicular orientation. If the fasciculi are parallel to each other, the muscle has a simple form. The muscles also may have oblique fascicular orientation relatively to the tendon; they are often placed in the limbs. If the fasciculi are attached to the tendon from both sides and converge at an acute angle, the muscle is bipennate (*m. bipennatus)*. If the fasciculi are attached only to one side of the tendon, the muscle is unipennate (*m. unipennatus)*. Somitemes the fasciculi in the muscle combine all the types of fascicular orientation, mentioned above; such muscles have very compex architecture (e.g. deltoid, *m. deltoideus*).

The muscle contraction acts on the bones, to which the muscle is attached. Ususally one of the point of the muscle attachment is fixed (*punctum fixum*) it is considered to be the origin of the muscle. The other point of the muscle attachment is mobile (*punctum mobile)*; it is the insertion of the muscle. Typically, the origin of the trunk muscles is closer to the median plane, and their insertion is distant. The origin of the muscles of the limbs is proximally, and their insertion is distally.

However, depending on function, *punctum fixum* may play the role of *punctum mobile*, and vice versa. For example, when the muscles of the upper arm flex the forearm, their origin is in the upper arm, and their insertion is in the forearm. But if the forearm is fixed, these muscles draw the upper arm together with trunk closer to the forearm; in this case their origin is in the forearm, and their insertion is in the upper arm.

1.4. Priniples of Classification of Muscles

The skeletal muscles of human body are classified according to the following criteria: the region of localization, anatomical and topographical relations, the form of the muscle, fascicular orientation, relation of the muscle to the joints, the function of the muscle, the origin of the muscle.

1. **According to the regions of the human body,** the muscles can be divided into the muscles of the head, neck, trunk and limbs. The muscles of the trunk, in their turn, are divided into the muscles of the back, chest and abdomen. The muscles of the upper limb are grouped into the mucles of the shoulder girdle, the muscles of the upper arm, forearm and hand (in accordance with the parts of the skeleton). The muscles of the

lower limbs are divided into the muscles of the pelvic girdle, the muscles of the thigh, leg and foot.

2. **According to the anatomical and topographical position** the muscles are classified into superficial and deep, external and internal, medial and lateral.

3. **According to the form** the muscles are divided into simple and coplex. The simple muscles include fusiform and quadrilateral muscles. They can be short or long. The complex muscles are the multi-headed muscles (two-headed, three-headed, four-headed), multi-tendon muscles, biventer and wide muscles. The muscles with specific geometrical form – round, square, deltoid, trapezoid, rhomboid, etc. – are also cosidered to be the complex muscles.

4. **According to fascicular orientation** the muscles can have parallel, oblique, circular and transverse orientation of fascicles. The unipennate and bipennate muscles also belong to the muscles with oblique fascicular orientation.

5. **According to the relations to the joints** the muscles can cross one or more joint. The muscles, crossing more than one joint, move not only the part of the skeleton to which they are attached, but they can change the position of the whole limb or of the part of the trunk.

6. **According to the function** the muscles can be classified into the flexor and extensor, adductor and abductor, rotator, sphincter and dilator muscles. The rotators are divided into pronators (rotating medially) and supinators (rotating laterally).

Apart from the types of motions, the muscles are divided (according to the function) into synergists and antagonists.

The synergists are the muscles, simultaneously performing one and the same function (movement) and mutually increasing the action of each other (e. g. adductor longus and adductor brevis of the thigh). In clinical practice it is important to distinguish obligate (main) and optional (accessory) muscles among the synergic muscles. During operations it is necessary to preserve the obligate muscle to prevent the impairement of the function.

The antagonists are the muscles performing opposite functions (i. e. opposite movements). For example, the biceps brachii flexes the elbow, but the triceps brachii extend the elbow.

7. **According to origin (development)** the muscles are grouped into the muscles developed from myotomes of branchial (visceral) arches and from myotomes of embryo`s trunk part. The innervation of the muscles indicates their origin: the muscles, developed from myotomes of branchial arches, are supplied by the cranial nerves; the muscles, developed from myotomes of trunk part, are innervated by posterior and anterior rami of the spinal nerves. The muscles innervated by the dorsal rami of the spinal nerves, are derived from the dorsal regions of myotomes. The muscles innervated by the anterior rami of the spinal nerves, are derived from the ventral regions of myotomes. During the development some muscles may change their position. The derivatives of the ventral regions of the myotomes may migrate over the derivatives of their dorsal parts or may migrate from the trunk to the limbs. Such muscles are called trukofugal. The derivatives of the limb buds may migrate to the trunk (trunkopetal muscles). The muscles which don`t change their position, are called autochthonous muscles.

1.5. Principles of Muscle Work

As any individual striated muscle fiber, the whole muscle becomes shorter and thicker during contraction, drawing the points of the origin and insertion closer together.

If the muscle terminates in the fibrous layer of the skin, it wrinkles the skin. The muscle, blending with the joint capsule, pulls the capsule during the movements at the joint.