UNIT 1 STRUCTURE OF MUSCLE AND ASSOCIATED TISSUES

Structure

1.0 OBJECTIVES

After reading this unit, you will be able to:

- describe the detailed structure of different types of muscles like skeletal muscle, cardiac muscle and smooth muscle;
- illustrate the structure of associated tissues like epithelial, nervous and connective tissue;
- explain the construction and organisation of muscle; and
- distinguish between different types of muscles and between different types of fibers.

1.1 INTRODUCTION

Meat is broadly defined as animal tissue used as food. Most often it refers to skeletal muscle and associated fat, but it may also refer to lung, liver, kidney brain etc. The term 'muscle' is derived from a Latin word — '*musculus*' that means 'little mouse'. It is so named because some muscles like biceps pop up as though a mouse is dashing about under the skin. The structure and composition of muscle affect the quality of meat. With the advancement of science, the study of animal flesh has gained importance. Here in this chapter we are going to deal the same under heading "structure of muscle and associated tissues".

1.2 STRUCTURE OF MUSCLE

Muscle is the major component of meat. A variable quantity of other tissues like connective, nervous and epithelial tissues also present in meat. There are three distinct types of muscle i.e., skeletal, cardiac and smooth muscle and out of these three, skeletal muscle is the principal source of muscle tissue in meat. However, a small amount of smooth muscle is also present in meat as a component of blood vessel while cardiac muscle is confined to heart only.

The proportion of muscle varies from 25 per cent (lamb) to 50 per cent (turkey) of the live weight. Skeletal and cardiac muscle are referred to as striated muscle because of the transverse banding pattern. Skeletal muscle is also referred to as voluntary muscle while smooth and cardiac muscles are called as involuntary muscles.

1.2.1 Skeletal Muscle

Skeletal muscle constitutes about 35-65% of the carcass weight of meat animals. Most skeletal muscles are attached directly to bone but some of them are attached indirectly to bones through ligaments, fascia, cartilage and skin. In the animal body there are more than 600 muscles and they vary widely in shape, size and activity. A thin connective tissue sheath covers each muscle; nerve fibers and blood vessels enter and exit the muscles with the connective tissue networks.

(i) Skeletal Muscle Fiber: Muscle fiber is a highly specialised cell and is the structural unit of skeletal muscle tissue. Muscle fibers constitute 75 to 92 per cent of the total muscle volume. Mammalian and avian skeletal muscles are composed of a large number of long, cylindrical (thread like), unbranched multinucleated cells called muscle fiber which taper slightly at both ends and are arranged parallel to each other.

Muscle fibers vary in length and diameter. The fibers measure between 0.01 to 0.10 mm (10 to 100 μ m) in diameter and are several centimeters long. The diameter varies within the same species and even within the same muscle.

(ii) Sarcolemma: Each muscle fiber is completely surrounded by a plasma membrane which is called the sarcolemma. It is composed of protein and lipid material. It is relatively elastic to sustain contraction, relaxation and stretching. Sarcolemma comprises of plasmalemma, basal lamina and a thin layer of collagenous fibrils. It folds in to give a system of tubules that form a network through the fiber and this is called T-tubules or transverse tubules. The T-tubules and sarcoplasmic reticulum form a functionally continuous system. Motor nerve fibers are implanted in small invaginations of the sarcolemma i.e., myoneural junction.

(iii) Sarcoplasm: The cytoplasm of muscle fiber is called sarcoplasm. It is the intracellular colloidal substance in which all the organelles like nuclei, mitochondria and sarcoplasmic reticulum are suspended. The sarcoplasm contains water (75%-80%), lipid droplets, variable quantities of glycogen granules, ribosomes, numerous proteins, nonprotein nitrogenous compounds and a number of inorganic constituents.

(iv) Nuclei: Skeletal muscle fibers are multinucleated. The nuclei lie just below the sarcolemma and at the periphery of the fiber. They are ellipsoidal in shape with their longest axis oriented parallel to the long axis of the fiber. The number of nuclei per fiber is not constant but it increases in the vicinity of the myoneural junction.

(v) Myofibrils: Myofibrils are long, thin, cylindrical rods, usually 1 to 2 μm in diameter. They constitute 75-85% of the fiber volume. They lie in parallel to form a cell and their long axis is parallel to the long axis of the fiber. The myofibrils are bathed by the sarcoplasm and extend the entire length of the muscle fiber. A muscle fiber from meat animals with a diameter of 50 μm will have at least 1000 myofibrils.

There are two types of filaments within the myofibrils — thick and thin filaments. Cross-sections of myofibrils show a well-ordered array of dots and these dots are actually the myofilaments. The myofilaments are commonly known as the thick and thin filaments. These thick and thin filaments are aligned parallel to each other and they also overlap in certain regions along with their longitudinal axes. This arrangement of myofilaments gives a characteristic banding or a striated appearance to the myofibril and that's why the skeletal muscle is called as striated muscle. This banding effect takes the form of alternating light and dark areas. They are respectively also known as I band (isotropic zone) and A band (anisotropic zone). I band is bisected by a dark thin band called the Z line. The distance between two adjacent Z-lines is known as sarcomere which is the structural and functional unit of myofibril. Sarcomere is the basic unit of the muscle's contraction- relaxation cycle. The sarcomere includes both an A band and the two half of I bands located on either side of the A band. Sarcomere length is not constant. At rest, the sarcomere length is nearly 2.5 μm (micrometer) in mammalian muscle. In the central region of the A band, there is a slightly less dense area which is called as H zone. Additionally, a narrow dense band, bisects the centre of the A band and this zone is known as M line. On either side of the M line, there is a narrow and relatively less dense area which is known as pseudo H-zone.

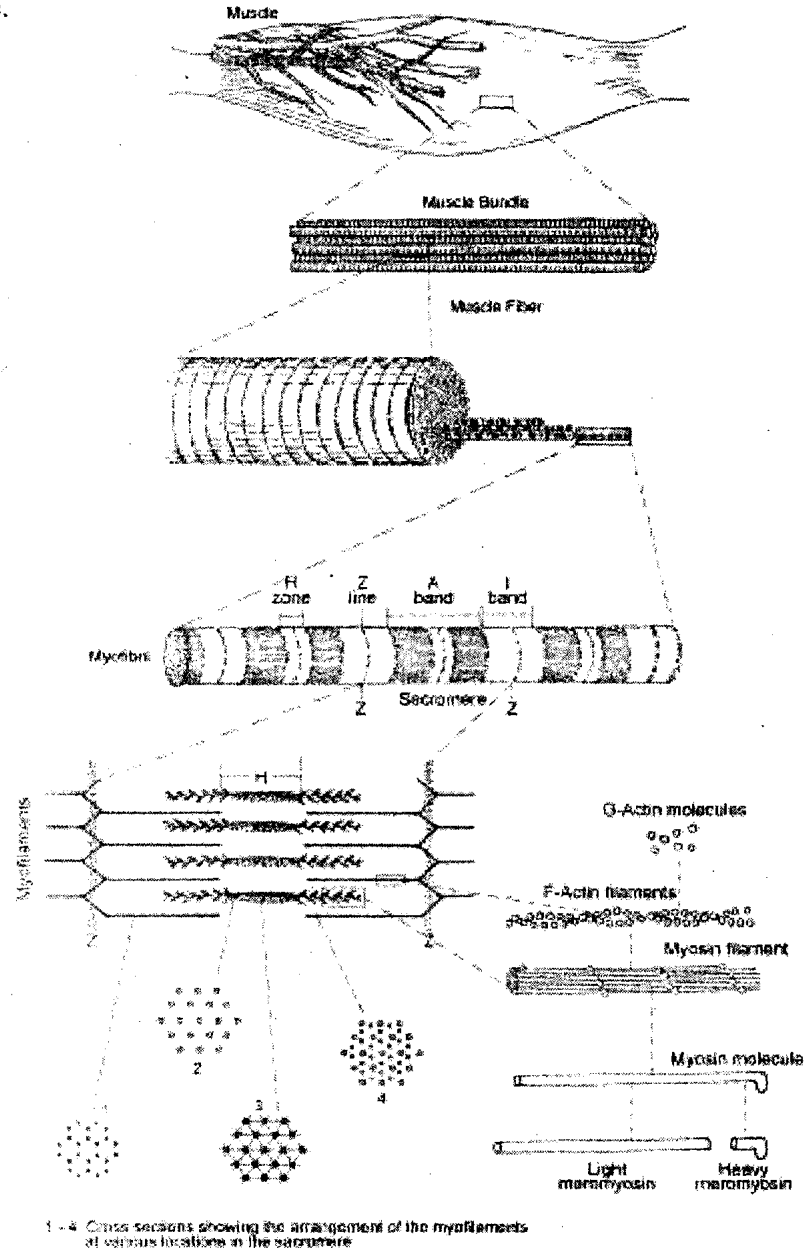

Fig. 1.1: The organisation of skeletal muscle from the gross structure to the molecular level

(vi) Myofilaments: The thick filaments of vertebrate muscles are approximately 14 to 16 nm (nanometers) in diameter and 1.5 μm long. The main component of thick filament is 'myosin' and these filaments are therefore, referred to as myosin filaments. Myosin constitutes about 50-55 per cent of the myofibrillar protein. The isoelectric pH of myosin is 5.4. Each myosin filament contains about 200-300 myosin molecule which are again divided into two heavy chains and four light chains. Myosin molecule is an elongated rod shaped with a thickened portion at one end. This thickened portion is called as head region and the long rod-like portion is called as tail region. The head portion is double headed and project laterally from the long axis of the myosin filament. The region in between head and tail is called as neck. The enzyme trypsin can spilt the myosin molecule at neck region and results in two fraction-light meromyosin and heavy meromyosin.

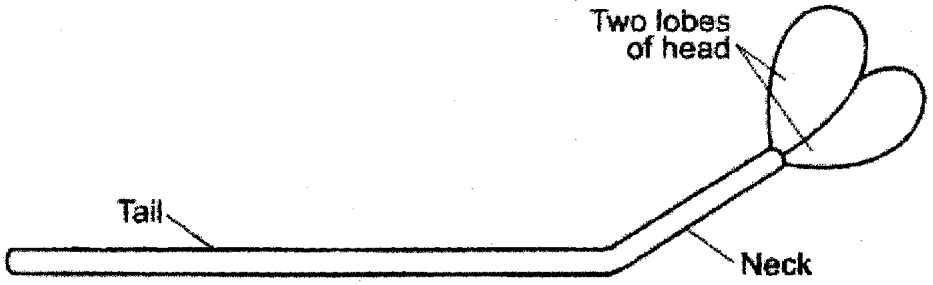

Fig.1.2: Myosin molecule

The thin filaments are about 6 to 8 nm in diameter and they extend approximately 1.0 μm on either side of the Z line. They consist primarily of the protein 'actin' and are referred to as the actin filaments. 20-25% of the myofibrillar protein is actin which is rich in proline (amino acid). The amino acids form the globular molecule i.e., G-actin (globular actin) which again polymerizes to form F-actin (fibrous actin). G-actin is the monomeric form and F-actin is the polymeric form. Two strands of F-actin form a super-helix which is the characteristic form of actin filament. The isoelectric pH of actin is 4.7.

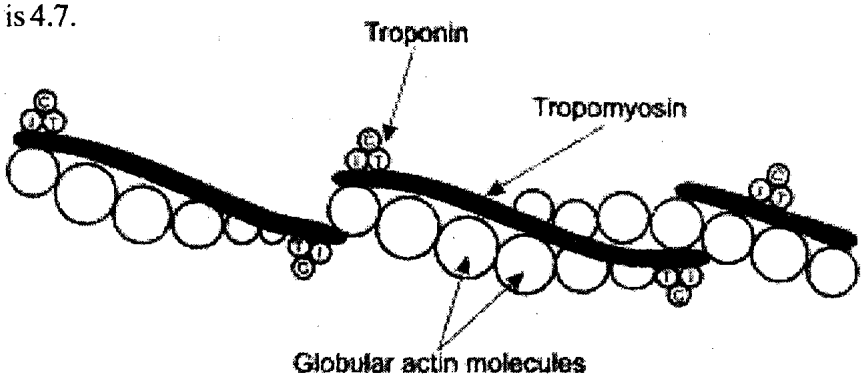

Fig.1.3: Arrangement of actin, tropomyosin and troponin in the actin filament

The proteins actin and myosin constitute approximately 75 to 80 per cent of the myofibrillar protein and the remaining fraction consists of the 'regulatory proteins' such as tropomyosin, troponin, M protein, α-actin, C protein and β- actin. Tropomyosin, troponin and actinin are associated with the actin filament. Tropomyosin helps in attachment of actin filament to Z-line and it extends along the helical groove in the actin filament. Troponin is of three types-C, I and T. Troponin C has calcium binding site, troponin I inhibits actomyosin ATPase and troponin T binds to troponin C and tropomyosin. α-actinin is a component of the Z-line and it promotes the lateral association of F-actin. β-actinin is located at the end of the actin filaments and inhibits polymerization of G-actin. M proteins compose the M-line. C protein is found in the myosin filament and binds the myosin molecules together into the bundle that forms myosin filament.

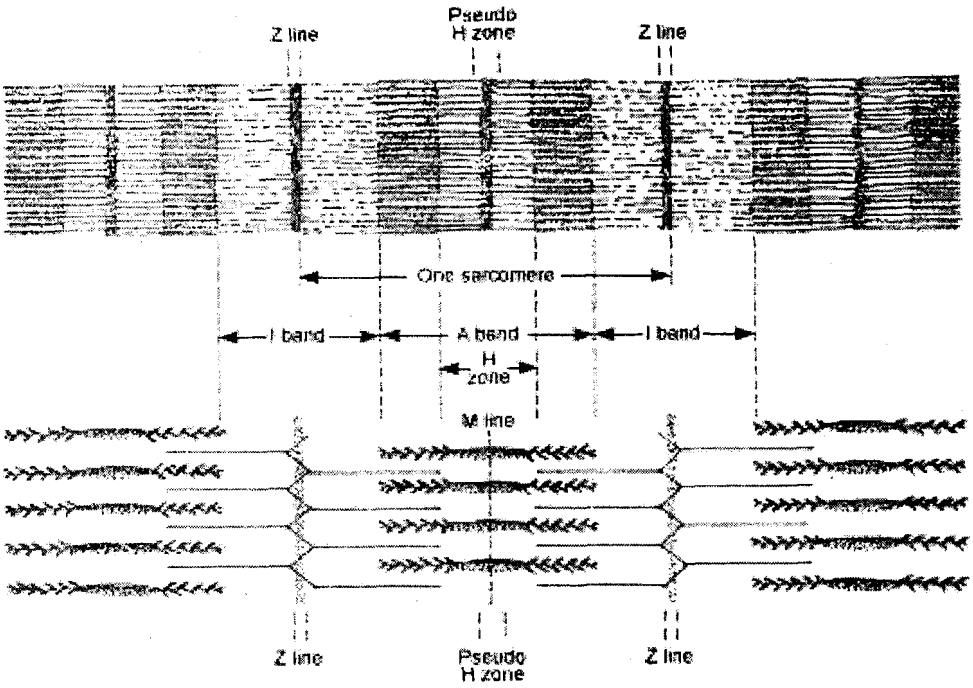

Fig.: 1.4 Electron photo micrograph of myofibril and sarcomere

Table 1.1: Percentage-wise contribution of different myofibrillar proteins

Myofibrillar protein	Percentage
Myosin	50-55
Actin	20-25
Tropomyosin	8-10
Troponin	8-10
M protein	4-5
C protein	2-2.5
α-actinin β-actinin	2-2.5

(vii) Sarcoplasmic reticulum and T tubules: The sarcoplasmic reticulum is a membranous system of tubules and cisternae (flattened reservoirs for Ca^{2+}) that forms a network around each myofibril. It is the storage site of calcium ion.

The T (Transverse) tubules are associated with the sarcolemma. Relatively thin tubules, oriented in the direction of the myofibrillar axis, constitute the L (Longitudinal) tubules of the reticulum.

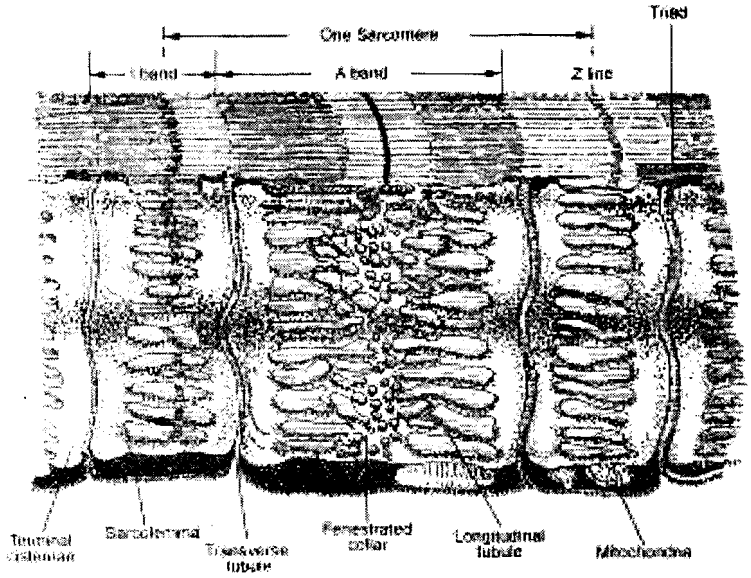

Fig.1.5: Sarcoplasmic reticulum and T tubules

The longitudinal tubules form a perforated sheet that is called a 'fenestrated (window like opening) collar' (in the H zone region of the sarcomere). The longitudinal tubules join with a pair of larger, transversely oriented, tubular elements called 'terminal cisternae' (at the junction of A and I bands) and form a structure called as triad.

(viii) Mitochondria: Mitochondria are located in the sarcoplasm and are referred to as the 'power-house' of the cell. They contain the enzymes of oxidative metabolism. The number and size of mitochondria vary in muscle fibers. Mitochondria are relatively abundant at the periphery of the fiber near the poles of the nuclei and are especially abundant at the myoneural junctions.

(ix) Lysosomes: Lysosomes are located in the sarcoplasm and contain a number of enzymes. Lysosomal enzymes are a group of proteolytic enzymes which have effects on some of the muscle proteins that might contribute to meat tenderization during postmortem ageing.

(x) Golgi complex: Golgi complex are located in the sarcoplasm near the nuclei. They consist of flattened vesicles which apparently function as the 'concentrating and packaging' apparatus for the metabolic products. The muscle fiber has numerous golgi complexes.

1.2.2 Smooth Muscle

The walls of arteries, lymph vessels, gastro intestinal tract and reproductive tracts are composed of smooth muscles. Smooth muscle fibers vary in size and shape depending upon their location. They vary from extremely flattened ellipsoids to triangular and polyhedral shapes. The smooth muscle fiber has a single centrally located nucleus. The sarcoplasmic reticulum is less developed than that in skeletal muscle. The myofilaments of smooth muscle are arranged in pairs that run parallel to the longitudinal axis of the fiber. Actin and myosin are present in the smooth muscles in the same proportion as in skeletal muscle but there are no striation. These are involuntary in nature. These fibers are long, unevenly thickened in the centre and tapering on both the sides. There is no M or Z-lines.

Smooth muscle fibers occur either singly or in bundles. Each fiber is surrounded by a delicate network of reticular fibers that support and bind them in place. Smooth muscle, compared to skeletal muscle, is poorly supplied with blood.

1.2.3 Cardiac Muscle

Cardiac muscles are found in the heart and involuntary in nature. Cardiac muscle has properties that resemble characteristic properties of both skeletal and smooth muscle. It has a single centrally placed nucleus, generally. The fibers of cardiac muscle are branched and shorter than the fibers of skeletal muscle. The sarcoplasm of cardiac muscle contains numerous glycogen granules. The mitochondria of cardiac muscle are especially large and numerous. Thick and thin filaments are aligned to give a striated appearance identical to that of skeletal muscle. The intercalated discs are present in the position of Z-lines.

The myocardium is the contractile layer of the heart and contains the bulk of the cardiac muscle. Blood and lymph vessels and nerve fibers enter and exit the myocardium via the connective tissue between muscle bundles.

1.3 STRUCTURE OF ASSOCIATED TISSUES

We have already studied that meat is primarily composed of muscle but there are some other tissues associated with muscle. These associated tissues are connective

tissue, nervous tissue and epithelial tissue. The muscle and the connective tissues contribute exclusively to the meat and these are the gross compositional components of meat animal's carcass.

1.3.1 Epithelial Tissue

Epithelial tissue in meat is associated with blood and lymph vessels and edible organs such as the kidney and liver. However, epithelial tissues form the linings of external and internal body surface and organ systems. These are usually removed during the slaughter and processing operations. These tissues have little intracellular material and these are classified according to shape of the cells and number of layers forming the epithelium.

1.3.2 Nervous Tissue

Nervous tissue contributes very little to meat (less than 1%) but plays an important role in stunning and bleeding of the animal. Thereby this tissue also affects the meat quality. The neuron (nerve cell) comprises the bulk of nervous tissue. It consists of a cell body and axon. Cytoplasm of the neuron is the neuroplasm. Nucleus is centrally placed in the neuroplasm.

Nerve fibers are composed of groups of the neuronal axons and the assembly of groups of fibers into fascicles results in the formation of 'nerve trunks'. Fascicles of nerve fibers are held together by sheaths of connective tissue and the nerve trunk itself is ensheathed in a connective tissue covering.

1.3.3 Connective Tissue

Connective tissues are the components of the skeleton, organs, blood and lymph vessels and of the sheaths that surround structures such as tendons, muscle, nerve trunks, muscle fibers. Connective tissue has two components — connective tissue proper and connective tissue cells.

The connective tissues generally have relatively few cells and considerable extra-cellular substance. This extra-cellular substance of the connective tissue proper varies from a soft jelly to a tough fibrous mass. The connective tissue proper is characterised by the presence of distinct fibers i.e., 'fibrous connective tissue'.

(i) Connective Tissue Proper: The 'connective tissue proper' envelopes muscle fibers and bundles and finally the muscles themselves. The connective tissue proper consists of a structureless mass called the 'ground substance' in which the cells and extra-cellular fibers are embedded.

The ground substance is a viscous solution containing soluble glycoproteins. These glycoproteins are also known as usually referred to as 'mucoproteins or mucopolysaccharides'. Hyaluronic acid is a mucopolysaccharide which is a very viscous substance found in joints (synovial fluid) and between connective tissue fibers. Another mucopolysaccharide is chondroitin sulfate which is found in cartilage, tendons and adult bone. The extracellular fibers are of three types-collagen, elastin and reticulin.

a) Collagen

Collagen is the most abundant protein in the animal body (20-25% of total protein) and it is the principal structural protein of connective tissues and is a major component of tendons, ligaments and to a lesser extent that of bones and cartilage. Collagen is not uniformly distributed among skeletal muscles. Muscles of the limbs are less tender than that of back because link muscles are having more collagen.

Collagen is a glycoprotein that contains small quantities of the sugars. Glycine is the most abundant amino acid in collagen. Hydroxyproline and proline are another two important amino acids of collagen. Collagen contains approximately 13-14% hydroxyproline which does not occur in other animal protein (to any significant extent). Thus collagen quantity in any tissue is determined by assessing the amount of hydroxyproline.

Collagen fibers are composed of variable number of collagen fibrils. Tropocollagen molecule is the structural unit of collagen. Individual fibers are colourless but their aggregations are white in colour. These fibers are almost completely inextensible. The relative insolubility and high tensile strength of collagen fibers result from "intermolecular cross linkages'. As the animal grows older the number of cross linkages increase. Coincidently, collagen is more soluble in young animals and becomes less soluble as the animal ages.

b) Elastin

Elastin is less abundant than collagen. It is present throughout the body in ligament and the walls of arteries as well as in the frame work of a number of organs including muscle. Elastin fibers are extensible.

Aggregation of elastin fibers has a characteristic yellow colour. Elastin is highly insoluble because of its nonpolar amino acids and desmin cross links. Elastin is highly resistant to digestive enzymes and thus contributes nothing to the nutritive value of meat. The cervical ligament i.e., *ligamentum nuchae* in the neck of the ruminant is the aggregation of elastin fibers.

c) Reticulin

Reticulin is composed of small fibers that form delicate networks around cells, blood vessels, neural structures and epithelium.

(ii) Connective Tissue Cells : Connective tissue cells like fibroblasts, undifferentiated mesenchymal cells and adipose cells are related to the meat properties. Fibroblasts synthesize the precursors of the extracellular components of connective tissues, namely, tropocollagen, tropoelastin and the ground substance.

The mesenchymal cells are undifferentiated cells that can become one of several different cell types, depending upon the specific stimulus. Cells which accumulate lipids are precursors of adipose cells.

The accumulation of numerous adipose cells results in the formation of 'adipose tissue', also known as fat. Many such sites, known as adipose tissue depots, are present in the animal body.

Check Your Progress 1

1) Fill in the blanks

   a) ....., ... and ..... are three kinds of muscle tissues.

   b) Sarcolemma forms a network of tubules called.....

   c) Myofilaments are referred to as .....and.....filaments of myofibrils.

   d) The sarcomere is the repeating structural unit of the .....

   e) The thick filaments consist of the protein.....and the thin filaments consist of the protein.....

   f) The regulatory proteins include .....

g) ..... is present in the greatest quantity on the walls of arteries, lymph vessels and the gastrointestinal and reproductive tracts.

h) ..... is the principal structural protein of connective tissue.

i) Amount of ..... is assessed for determination of collagen quantity in meat.

j) Trypsin splits myosin molecules into ..... and .....

2) What do you mean by sarcomere?

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3) How collagen is related with tenderness of the meat?

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4) What are the different forms of actin?

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5) How do you differentiate between skeletal muscle and smooth muscle?

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1.4 MUSCLE ORGANIZATION AND CONSTRUCTION

Groups of muscle fibers are bound together by connective tissues in the skeletal muscles. A small amount of epithelial and nervous tissue is also associated with skeletal muscles.

1.4.1 Muscle Bundles and Associated Connective Tissues

Many individual fibers are grouped together into bundles. The number of fibers varies from one bundle to another; consequently, bundle size is variable. A number of bundles, in turn, are grouped to form a muscle. The texture of the muscle depends on the size of the bundles and the thickness of their connective tissue septa. Muscles with small bundles and thin septa have a fine texture and those with large bundles and thicker connective tissue septa have a coarse texture.

Each muscle fiber is surrounded by a delicate connective tissue layer called endomysium. Sarcolemma lies beneath this endomysium. Thus, the sarcolemma and endomysium are two separate and distinct structures even though both encase the muscle fiber. Approximately, 20 to 40 muscle fibers and the associated endomysium are grouped to form 'primary bundle'. A variable number of primary bundles are grouped together to form larger bundles known as the 'secondary muscle bundles'. Both the primary and secondary bundles are covered with the 'perimysium' which consists of sheath of collagenous connective tissue. Finally, a variable number of secondary bundles are grouped together to form a 'muscle'. Each muscle is surrounded by a sheath of connective tissue known as epimysium.

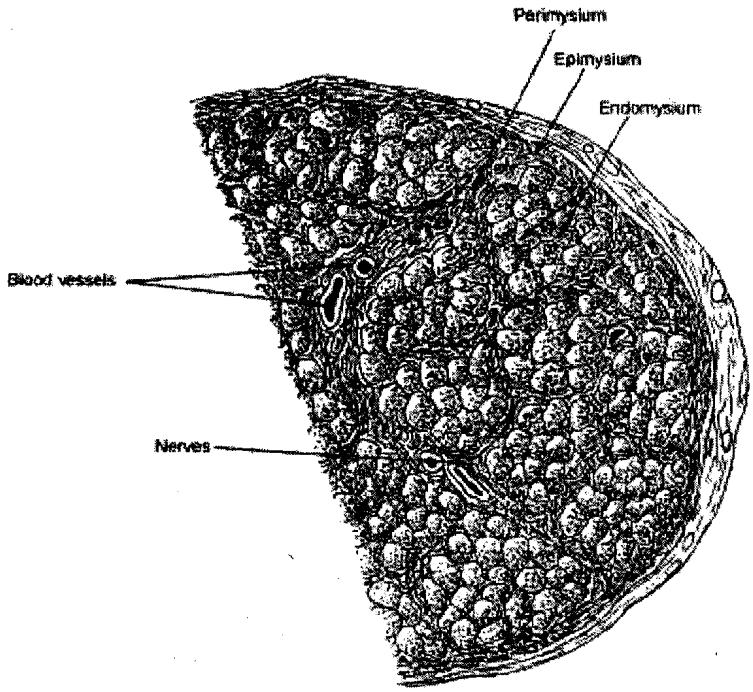

Fig. 1.6: Cross section of skeletal muscle showing connective tissue, nerves and blood vessels

The collagen fibers of the epimysium are continuous with those of the perimysial septa which, in turn are continuous with the endomysial septa. Nerve fibers and blood vessels supplying the muscles enter into the interior of the muscles through these connective tissue septa.

Like blood vessels, the lymph vessels enter and exit the muscle via the connective tissue septa. Intramuscular fat is deposited within the muscle in the loose networks of the perimysial connective tissue septa in close proximity to blood vessels. Inter muscular fat or seam fat is deposited in the connective tissue septa between the individual muscles.

Likewise, the connective tissue septa between individual muscles contain variable quantities of adipose tissue. This latter type of fat deposit is referred to as 'inter-muscular fat' or 'seam fat'.

1.4.2 Muscle and Fiber Types

Muscles are usually classified as red or white depending on their colour intensity. Few muscles are composed of all red or all white fibers but most are mixtures of red and white fibers. Depending upon the colour of muscles, meats are also called as red meat or white meat. When we say that red meat is dangerous to cardiac patient, then we talk about the mutton, chevon (goat meat) or beef. We generally use the term 'white meat' for chicken. Most muscles of meat animals contain a higher proportion of white fibers than red fibers even in muscles that are visibly red.

Thus, red muscles are those with a higher proportion of red fibers than found in white muscles, or alternatively, white muscles have fewer red fibers than do red muscles. Fibers with characteristics that are intermediate between those of the red and white types also exist in muscle and are called the intermediated fiber type.

These three types of muscle fibers differ in their structural, functional and metabolic characteristics (*Table 1.2*). The characteristics are relative to the other fiber types.

Table 1.2: Characteristics of red, intermediate and white muscle fibers

Characteristics	Red Fiber	Intermediate Fiber	White Fiber
Colour	Red	Red	White
Myoglobin content	High	High	Low
Fiber diameter	Small	Small-intermediate	Large
Contraction speed	Slow	Fast	Fast
Contractile action	Tonic	Tonic	Phasic
Number of mitochondria	High	Intermediate	Low
Mitochondrial size	Large	Intermediate	Small
Capillary density	High	Intermediate	Low
Oxidative metabolism	High	Intermediate	Low
Glycolytic metabolism	Low	Intermediate	High
Lipid content	High	Intermediate	Low
Glycogen content	Low	High	High

(Source : Forrest et.al. (1975) — Principles of Meat Science, W.H. Freeman & co.)

Check Your Progress 2

1) How do the connective tissue septa take part in muscle organisation?

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2) What are the different types of muscle fibers?

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3) What are the differences between red and white fibers?

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1.5 LET US SUM UP

Meat is defined as those tissues which are suitable for use as food. Meat is composed of muscle and variable quantities of other tissues. Skeletal muscles contribute to the bulk of meat. Smooth muscle comprises only a small proportion of meat. Skeletal muscle fibers are multinucleated. The structural unit of skeletal muscle tissue is called muscle fiber.

Many individual fibers are grouped together into bundles. A number of bundles are grouped in various patterns to form a muscle. Connective tissue septa bind the fibers and bundles together. Muscles are usually classified as red or white based on their colour intensity. Sarcoplasm of skeletal muscle contains water, lipid droplet, glycogen granules, ribosomes, proteins, non-protein nitrogenous compounds and a number of inorganic constituents. Myofibrils are bathed by the sarcoplasm and extend the entire length of the muscle fiber. The thick and thin filaments of myofibrils are known as myosin and actin filaments, respectively. Actin and myosin constitute approximately 75-80% of the proteins in the myofibril. The remaining 20-25% fraction consists of tropomyosin, troponin, two M protein, α-actinin, C protein and β-actinin. These are also called 'regulatory proteins'. Myofibrillar proteins refer to thick and thin filaments as well as regulatory proteins.

The smooth muscle fiber has a single nucleus that is centrally located within the cell. Cardiac muscle has properties that resemble to those of skeletal and smooth muscles. The connective tissues are having relatively few cells and considerably extracellular substance. The extracellular fibers consist of collagen, elastin and reticulin. Collagen is the most abundant protein in the animal body and significantly influences meat tenderness. The relative insolubility and high tensile strength of collagen fibers result from intermolecular cross linkages. Elastin is highly resistant to digestive enzymes and contributes almost nothing to the nutritive value of meat.

1.6 KEY WORDS

Meat : Meat is defined as those animal tissues which are suitable for use as food. Beef, buffalo meat, pork, lamb, mutton, chevon (goat meat), veal, horse, camel and rabbit meats are used for human consumption.

Muscle Fiber : The structural unit of skeletal muscle tissue is a muscle fiber.

Sarcolemma : The membrane surrounding the muscle fiber is called the sarcolemma.

Sarcoplasm : The cytoplasm of muscle fiber is called sarcoplasm.

Myofibrils : Myofibrils are long, thin, cylindrical rods, usually 1-2 μm in diameter.

Muscle : Muscle is composed of many individual fibers that are grouped together into bundles.

Voluntary muscle : Movement of muscle as per wish.

1.7 SOME USEFUL BOOKS

Biswas, S. (2005). *Meat and Egg Technology.* 1st edition. University Publication, WBUAFS, Kolkata. West Bengal.

Forrest, J.C. (1975). *Principles of Meat Science.* W.H. Freeman & Co., San Francisco.

Lawrie, R.A. (1998). *Lawrie's Meat Science.* 6th Edn. Woodhead Publishing Limited.

Sharma, B.D, (1999). *Meat and Meat Products Technology.* 1st Edition. JAYPEE Brothers, New Delhi.

1.8 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) (a) Skeletal, smooth, cardiac
   (b) Transverse tubules
   (c) Actin, myosin or thin, thick
   (d) Myofibril
   (e) Myosin, actin
   (f) Tropomyosin, troponin, actinin, M-protein, C protein
   (g) Smooth muscle
   (h) Collagen
   (i) Hydroxyproline
   (j) Light meromyosin, heavy meromyosin.

2) Sarcomere is the structural unit of myofibril and it is the distance between two adjacent Z-lines. It is the basic unit of muscle shortening and force generation. It includes both — an A band and two half of I bands.

3) Collagen is related with tenderness of the meat because intermolecular cross linkages of collagen result in relative insolubility and high tensile strength of the collagen. Collagen is more soluble in young animals than in the older because number of cross linkages increases with the advancement of the age of the animal. Thus the meat from young animal is more tender than older one.

4) There are two forms of actin — G-actin and F-actin. G-actin is the globular molecule which is monomeric form. F-actin is the polymeric form and fibrous in nature formed by several G-actin.

5) The differences between skeletal and smooth muscles are tabulated below:

Skeletal muscle	Smooth muscle
i. Skeletal muscle is voluntary in nature.	i. Smooth muscle is involuntary in nature.
ii. These are striped.	ii. These are smooth or unstriped.
iii. These are multinucleated.	iii. These have single nucleus.
iv. These are attached to skeleton.	iv. These are present in viscera, blood vessels, ducts, air passages etc.

Check Your Progress 2

1) There are three connective tissue covering, namely, endomysium, perimysium and epimysium. These three take part in muscle organisation in following way:
   - Each muscle fiber is covered with endomysium.
   - Many muscle fibers are grouped together to form a primary bundle and many primary bundles are grouped together to form secondary bundles. Perimysium covers each primary bundle and secondary bundle.
   - A variable number of secondary bundles are grouped together to form muscle which is covered by epimysium.

2) Different types of meat fibers are (i) Red, (ii) White and (iii) Intermediate type.

3) The differences between red and white fibers are following:

(a) Red fiber has high myoglobin, high lipid and low glycogen content. White fiber has low myoglobin and lipid and high glycogen content.

(b) Red fiber is characterised by small fiber diameter, slow contraction speed and high number of large mitochondria. Whereas white fiber is characterized by large fiber diameter, high contraction speed and less number of mitochondria.

(c) Oxidative metabolism is high and glycolytic metabolism is low in red fiber and the condition is just reverse in case of white fiber.