الجمهورية الجزائرية الديمقراطية الشعبية

جامعة جيجل

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HISTOLOGY

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Muscular Tissues

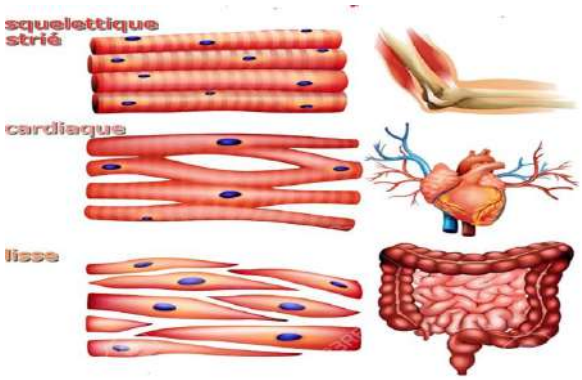
Muscular tissues constitute the «flesh» of the body and the major part of the walls of hollow organs. They are tissues whose cells are called **muscle fibres** (elongated elements).

- • **Role**: they are specialised in the production of mechanical work, which ensures the movements of the organism.
- • **Properties of muscle fibres**:

■ Excitability,
■ Conductivity,
■ Contractility (via myofibrils).

There are three types of muscular tissues:

	Size	*Nucleus*	*Striations*	*Contraction*
Striated Skeletal	up to 50 cm	multiple	transverse	Voluntary/involuntary
Cardiac	100 to 200 µm	single	transverse	involuntary
Smooth	20 to 600 µm	single	absent	involuntary

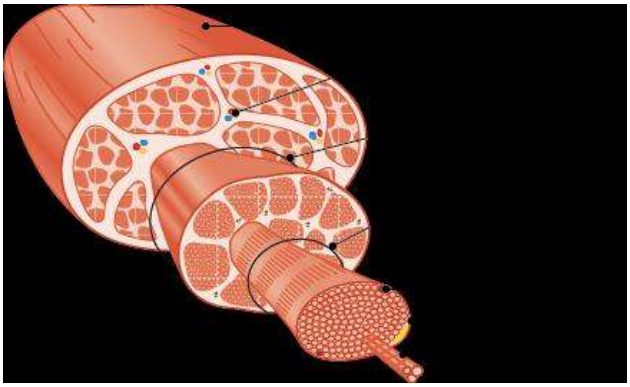


I. STRIATED SKELETAL MUSCLE TISSUE

- • **Location**: associated with the bones of the skeleton.
- • **Origin**: mesoblast (myotomes).
- • **Colour**: red, due to rich vascularisation and the presence of myoglobin.
- • **Role**: brief, rapid, voluntary/involuntary contractions.

Structure of a Striated Skeletal Muscle

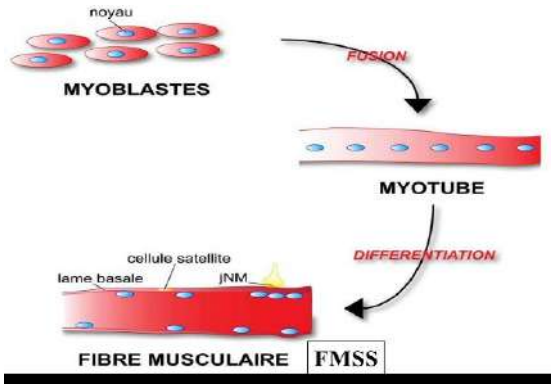
Dissociation of the tissue yields striated skeletal muscle fibres (S.S.M.F.), generally very long, which correspond to the muscle fibres. These elements are associated with connective tissue to form organs.



Myogenesis

Myogenesis (from the Greek *myo* «muscle» and *genesis* «birth») is a biological phenomenon leading to the formation of muscular tissues. It occurs first during embryonic development, then during certain repair phenomena (e.g. after muscle damage).

- – Each myotomal cell
- – will differentiate into a myoblast
- – which subsequently migrates, aligns, and fuses to form a myotube
- – The latter then differentiates into a S.S.M.F.

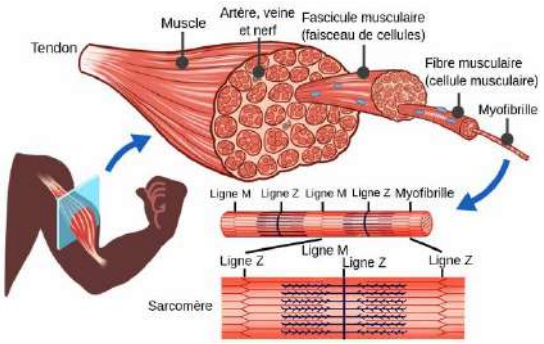


Myotomal cells	single	N/A
Myoblast	single central	granular sarcoplasm
Myotube	multiple central	peripheral myoplasm
S.S.M.F.	multiple peripheral	central myoplasm

STRIATED SKELETAL MUSCLE FIBRE (S.S.M.F.)

Structure

Shape: cylindrical or fusiform.



Ultrastructure

The sarcolemma is formed by a plasma membrane lined with an external basal lamina.

- ■ **The sarcoplasm** is peripherally located.

  It is the fundamental cytoplasm composed of:

  - – multiple oval nuclei,
  - – a perinuclear Golgi apparatus, poorly developed,
  - – sarcosomes,
  - – a sarcoplasmic reticulum,
  - – T-systems,

- ■ **Myoplasm**

  Located in the central axis of the S.S.M.F.

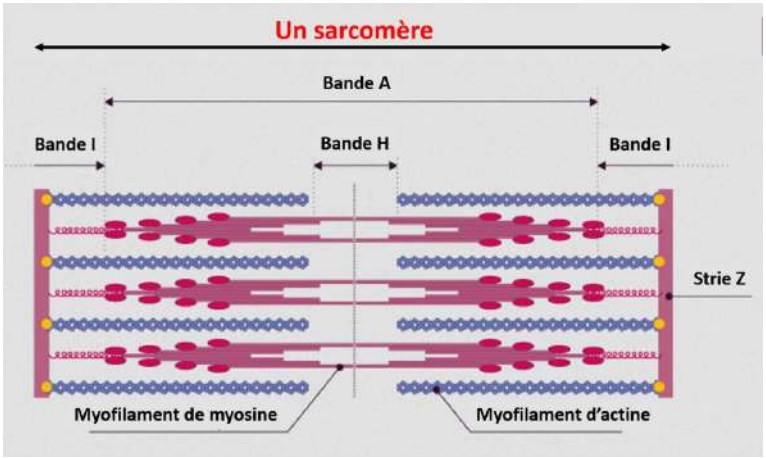
■ ■ Myofibrils are grouped into longitudinal parallel bundles.

Myofibrils are present as:

- – Leidig columns in longitudinal section,
- – Cohnheim's fields in transverse section.

STRUCTURE AND ULTRASTRUCTURE OF THE SARCOMERE OF THE S.S.M.F.

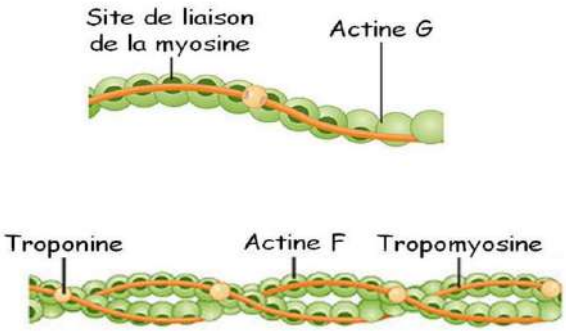
Each myofibril is divided into several sarcomeres.



Light Microscopy (Structure of the Sarcomere)

Under the light microscope, the sarcomere presents:

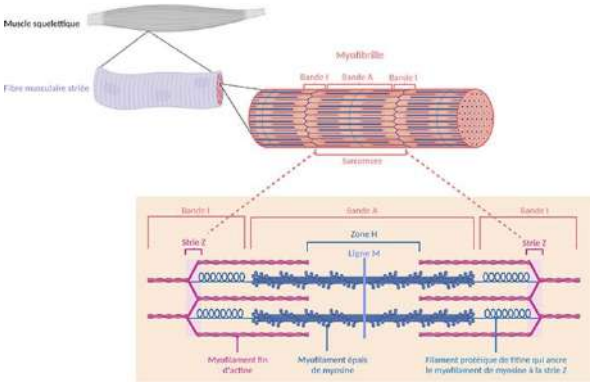
- • 2 Z lines at the extremities of the sarcomere,
- • 2 half I bands (isotropic) or light bands,
- • 1 A band (anisotropic) or dark band,
- • 1 H band located in the median portion of the A band,
- • 1 M line dividing the A band, H band and the sarcomere.



Electron Microscopy (Ultrastructure of the Sarcomere)

Under the electron microscope, thin myofilaments and thick myofilaments are observed.

– – Thin myofilaments: present everywhere except at the level of the H band.



a) Thin Myofilaments

Composed of:

Actin:

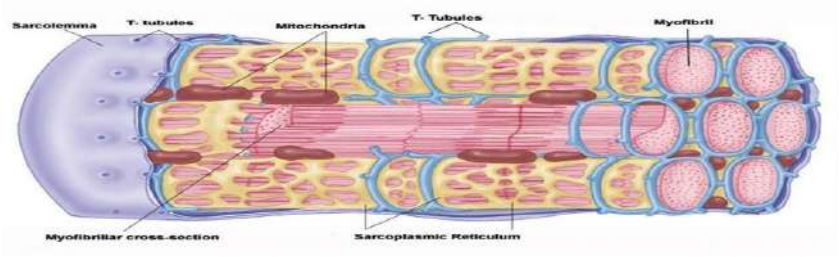
- ■ It exists in either globular (G) or fibrillar (F) form.
- ■ The conversion from the G to the F form occurs by polymerisation in the presence of ATP.
- ■ F-actin forms 2 helical strands.
- ■ The actin/troponin ratio is 1/7.

Troponin:

- ■ A globular molecule located between the actin molecules.
- ■ A sensitising factor that binds calcium and allows unmasking of the myosin-binding sites on actin.

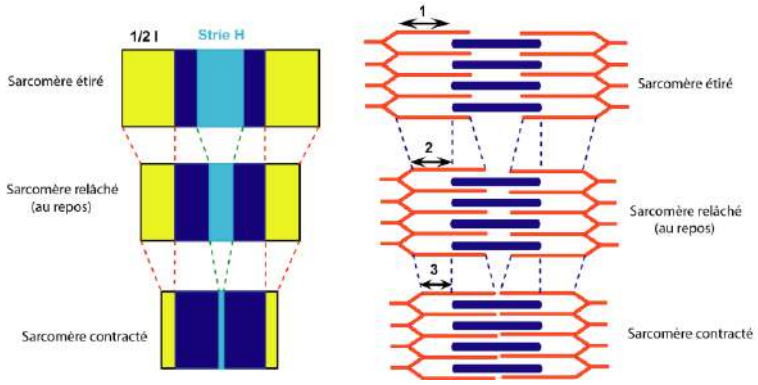
Tropomyosin:

- ■ The backbone of the thin myofilament onto which actin and troponin molecules insert.
- ■ A relaxation factor that inhibits the ATPase activity of myosin.



b) Thick Myofilaments

Present only at the level of the A band.



Myosin:

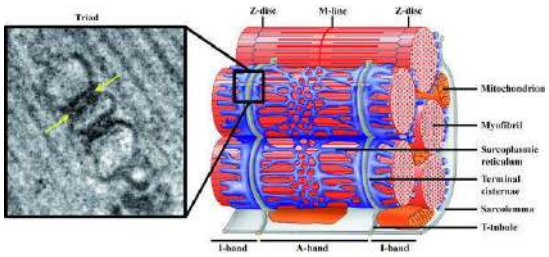
Formed by an HMM and an LMM.

Light meromyosin (LMM),

Heavy meromyosin (HMM).

LMM constitutes the backbone of the thick myofilament.

Myosin has ATPase activity.

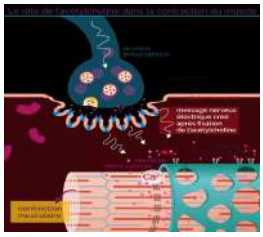


Molecular Architecture of the Myofibrils

Each thick myofilament is at the centre of a hexagon.

The vertices are occupied by thin myofilaments.

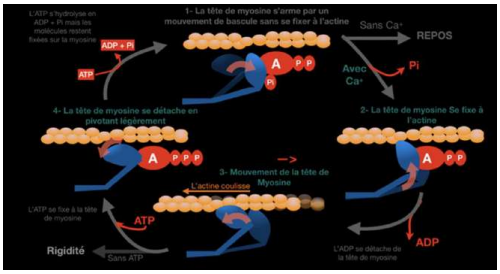
At rest there is no contact between the myofilaments.



Relationships of the Myofibrils with the Sarcoplasmic Elements

❖ Sarcosomes:

- • They are mitochondria,
- • they are parallel to the axis of the myofibrils,
- • they play an energetic role in contraction.



❖ T-Systems (Transverse System):

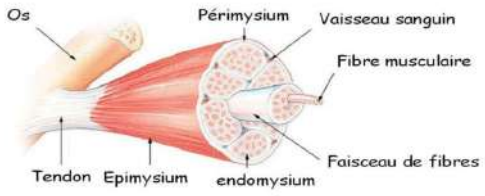
Tubules arising from invagination of the plasma membrane.

They completely surround the myofibril.

Observed between the A and I bands.

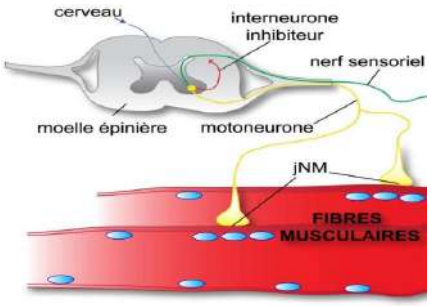
Always in contact with the extracellular environment.

They constitute a pathway for calcium.



❖ Sarcoplasmic Reticulum:

- • Network of longitudinal tubules surrounding the myofibrils.
- • Variable structure depending on whether it encircles the A or I band.
- • Ends in terminal cisternae.
- • 2 terminal cisternae + 1 T-system = a triad.
- • There are 2 triads / sarcomere.

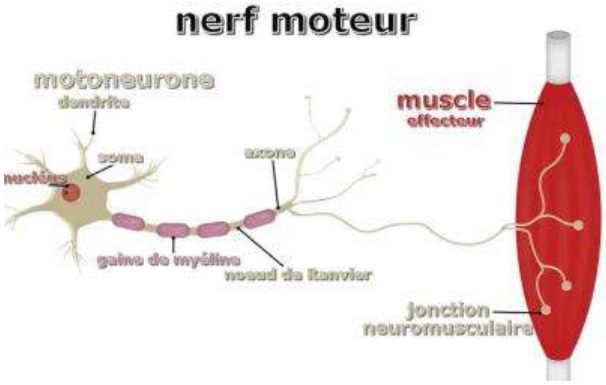


Mechanism of Muscle Contraction

- • The nerve impulse arrives at the motor end plate.
- • The nerve impulse propagates along the plasma membrane then
- • into the T-system and into the terminal cisternae of the Sarcoplasmic Reticulum, which release calcium towards each sarcomere.

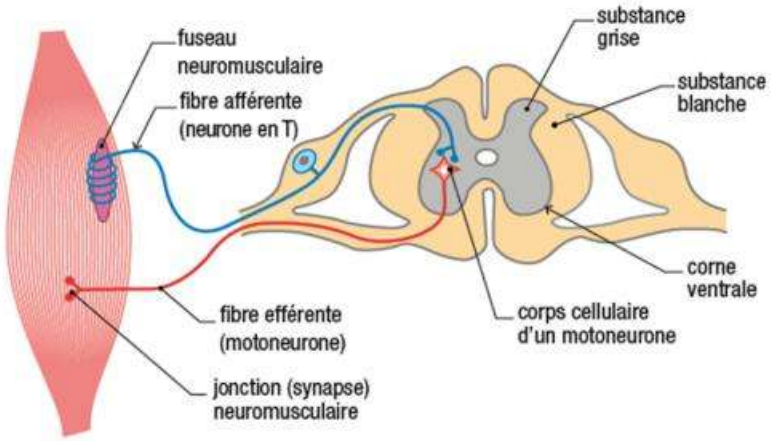
→ **Muscle stretch**: the I and H bands widen; the A band remains always unchanged.

→ **Maximal muscle contraction**: the I and H bands disappear; the Z lines come into contact with the extremities of the A band.



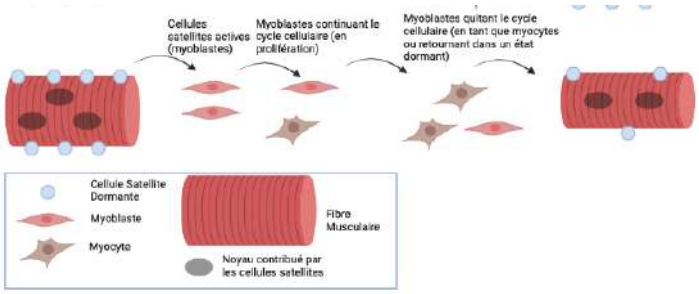
At the Electron Microscope Level

- ■ Binding of calcium to troponin C,
- ■ Disruption of the troponin I–actin bond,
- ■ Displacement of tropomyosin,
- ■ Release of myosin–actin binding sites blocked by tropomyosin,
- ■ Activation of myosin ATPase,
- ■ Hydrolysis of ATP (ATP → ADP + Pi),
- ■ Binding of actin to myosin,
- ■ The myosin head is perpendicular to the thin myofilament,
- ■ Detachment of ADP + Pi from the myosin head,
- ■ 45° rotation of the myosin head,
- ■ Sliding of myofilaments relative to each other within the A band,
- ■ Displacement of the actin myofilament,
- ■ This constitutes the contraction of the myofibril,
- ■ Binding of ATP,
- ■ Dissociation of the acto-myosin complex,
- ■ Relaxation of the sarcomere.



Connective Tissue Associated with Striated Skeletal Muscle

- • Each fibre is surrounded by connective tissue: **endomysium**.
- • Each bundle is surrounded by connective tissue: **perimysium**.
- • The muscle is surrounded by connective tissue: **epimysium**.



Vascularisation of the Striated Skeletal Muscle

- • The striated muscle is richly vascularised.
- • The arterioles of the perimysium branch into capillaries.
- • The capillaries surround the S.S.M.F. within the endomysium.

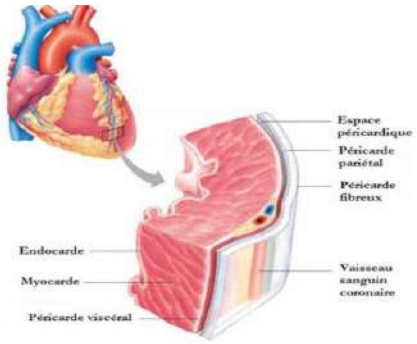
Innervation of the Striated Skeletal Muscle

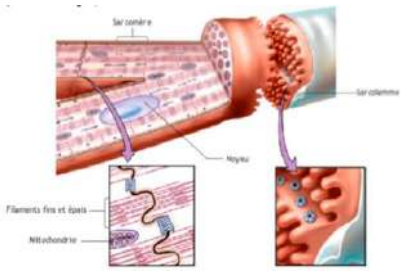
The neuromuscular junction is situated at the level of the motor end plate. The motor end plate is a synapse, placed at the centre of the S.S.M.F. The nerve stimulates the S.S.M.F. and releases a neurotransmitter (acetylcholine) into the synaptic cleft.

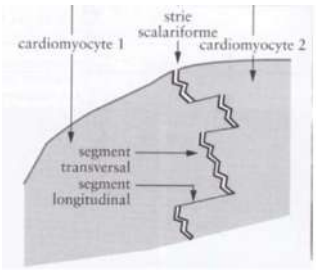
Motor unit: the set of S.S.M.F. under the control of a single motoneurone.

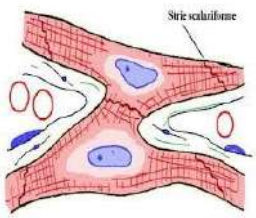
1) Motor Innervation

- • A NI departing from the brain propagates along the spinal cord and then along a motor nerve (motoneurone).
- • The motor nerve branches and each branch innervates one S.S.M.F.
- • Each muscle is innervated by a motor nerve.









- • The motor unit is composed of 4 to several hundred S.S.M.F.
- • Muscles requiring great precision have small motor units (few S.S.M.F. per motoneurone).
- • A powerful motor muscle (quadriceps of the thigh) has several hundred S.S.M.F. per motor unit.
- • S.S.M.F. contract simultaneously upon excitation of the motoneurone.

2) Sensory Innervation

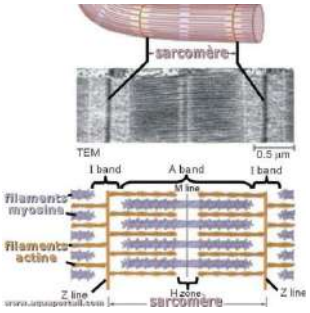
Carried out by sensory nerve fibres that synapse at the level of mechanoreceptors of the muscle:

- – the neuromuscular spindles,
- – the Golgi neurotendinous organs.

a) Neuromuscular Spindle

Sensory receptors of the muscle presenting small S.S.M.F. and nerve fibres.

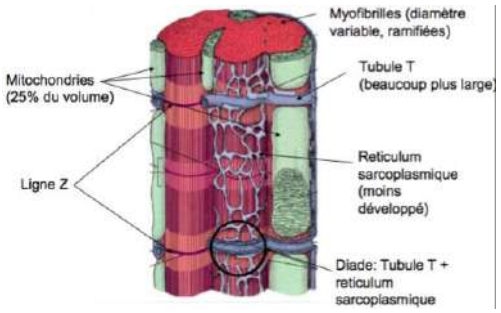
The neuromuscular spindle protects against inadequate stretching and provides information on muscle length.



b) Golgi Neurotendinous Organs

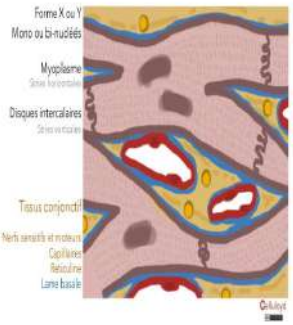
Sensory receptors located between the tendon and the skeletal muscle.

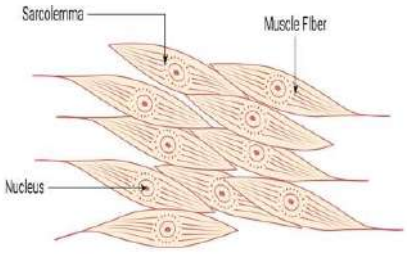
The Golgi tendon organ protects against inappropriate tension and contraction of the muscle.



Regeneration

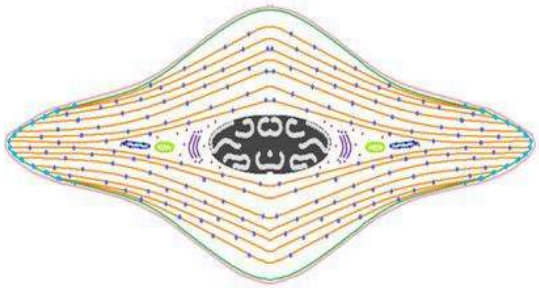
- • Skeletal muscles are subject to physical stress and injuries (trauma).
- • Regeneration occurs via satellite cells located between the plasma membrane and the basal lamina.
- • Satellite cells hold promise for cell therapies aimed at repairing muscles, as in the case of muscular dystrophies.
- • They are the myogenic precursors necessary for muscle regeneration.





Smoot Muscle Cell

II. STRIATED MYOCARDIAL MUSCLE TISSUE



- – Location: heart.
- – Origin: mesenchymal cells.
- – The striated myocardial muscle tissue is located between the epicardium and the endocardium.
- – The endocardium contains the nodal tissue.

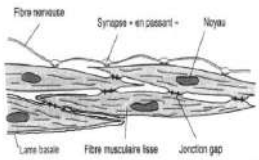
- • **Myocardial muscle tissue**:
  Formed of anastomosed striated myocardial muscle fibres (M.M.F.).
- • **Nodal tissue**:
  Formed of cardionector cells, poor in myofibrils, ensuring conduction of the nerve impulse.
  - – Cardionector cells control and regulate contraction of M.M.F.
  - – The nodal tissue is responsible for cardiac automatism.

Striated Myocardial Muscle Fibres (M.M.F.)

Size of M.M.F.: reduced (100 to 200 µm in length).

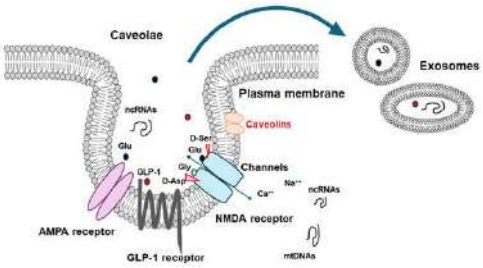
Distribution of M.M.F.:

Under light microscopy they form a network of anastomosed fibres parallel to each other and connected by intercalated discs (= Z lines).



Shape of the Striated Myocardial Muscle Fibres

- • Prismatic with extremities presenting bifurcations allowing adjacent myocardial fibres to be connected.
- • Each M.M.F. consists of a sarcoplasm, a myoplasm, and a sarcolemma that surrounds them.



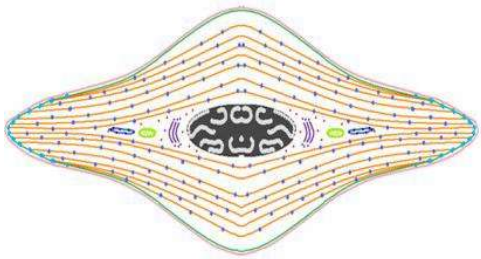
Structure and Ultrastructure of the M.M.F.

❖ Sarcolemma

Constituted by a plasma membrane lined with an external basal lamina.

❖ Intercalated Discs (Stries scalariformes)

These are specialised attachment zones uniting two adjacent M.M.F. at the level of the sarcolemma.



Under the electron microscope:

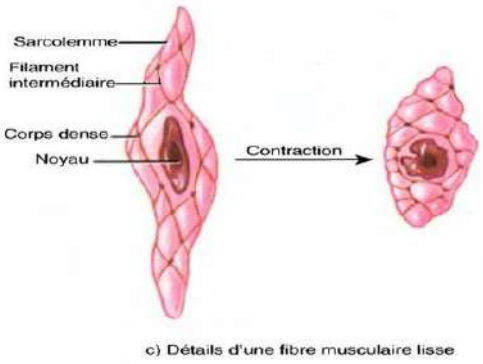
- • **Longitudinal segment**:
  Gap junctions that facilitate the passage of membrane excitation.
- • **Transverse segment**:
  Z lines of the terminal sarcomeres that transmit contraction from one fibre to the next. Also contains desmosomes and adherens junctions.

❖ Sarcoplasm:

❖ Myoplasm:

Axial topography. Presents a sarcoplasmic spindle-shaped form containing:

- – – Single central nucleus,
- – – Juxtanuclear Golgi apparatus,
- – – Rod-shaped sarcosomes,
- – – Glycogen and lipid inclusions,
- – – Myoglobin and lipofuscin pigments,
- – – Sarcoplasmic reticulum,
- – – T-system.



c) Détails d'une fibre musculaire lisse

- • Occupies the totality of the fibre, except the axial sarcoplasm.
- • The myoplasm is constituted of peripheral myofibrils, parallel to each other and oriented along the longitudinal axis of the M.M.F.

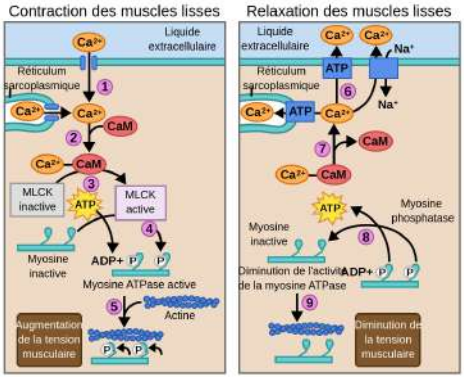
■ ■ Myofibrils are formed of several sarcomeres.

■ ■ The myofibrils of myocardial muscle fibres are structurally similar to those of striated skeletal muscle fibres; however, the sarcomeres are shorter and the I bands narrower.

Under the Light Microscope

Under the Electron Microscope

Myofilaments and contractile molecules of the same nature as those of striated skeletal muscle are observed.



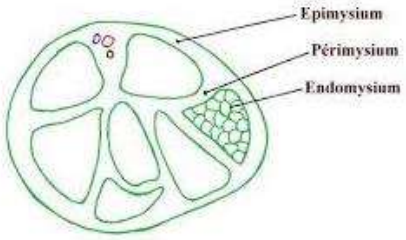
Relationship of Myofibrils with the Sarcoplasmic Organelles

❖ Sarcosomes:

- • Very numerous.
- • Associated with the myofibrils.

❖ T-System (Transverse System):

- • Tubules wider than those of the S.S.M.F.
- • They completely surround the sarcomere.
- • Observed at the level of the Z lines.
- • They constitute a pathway for calcium.



❖ Sarcoplasmic Reticulum:

- • Less developed than that of the S.S.M.F.
- • Surrounds the sarcomere on all sides between the 2 Z lines.
- • Ends in terminal cisternae.
- • 1 terminal cisterna + 1 T-system = a diad.
- • There are 2 diads per sarcomere.

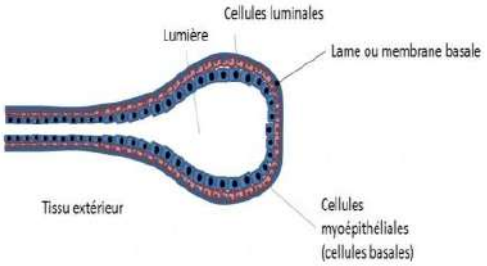
Contraction of the M.M.F.

- • Compared to the contraction of skeletal muscle.
- • Skeletal muscle requires a nervous stimulus, whereas cardiac muscle excites itself; it is myogenic.
- • Characteristics of the contraction:

  Involuntary, brief, rhythmic, automatic, continuous.

Vascularisation of the M.M.F.

- • The loose connective tissue is irrigated by an extensive network of blood capillaries.
- • The vascularisation of the myocardial muscle is important.
- • Permanent contraction requires a huge and continuous demand for ATP and oxygen.



Regeneration of the M.M.F.

- • In case of injury, repair occurs via the endomysium (loose connective tissue).
- • There are no mesenchymal cells nor satellite cells.

III. SMOOTH MUSCLE TISSUE

Smooth muscle tissue participates in digestion, respiration, and circulation.

- • **Location**:
  Walls of blood vessels, viscera, and skin muscles.
- • **Origin**: Mesenchymal.
  During differentiation, mesenchymal cells elongate and taper, then progressively accumulate myofilaments.
- • **Shape**:
  Smooth muscle fibres are:
  - – Elongated or elliptical,
  - – fusiform,
  - – with tapered extremities.
- • **Size**:
  - – 20 µm for blood vessels,
  - – 500 µm for the gravid uterus.

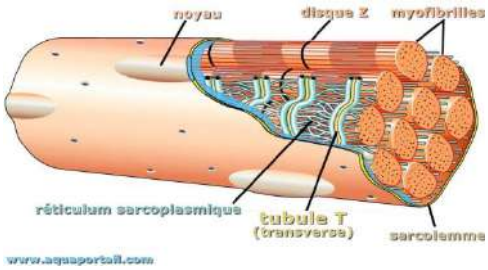
Structure and Ultrastructure of the Smooth Muscle Fibre

❖ The Sarcolemma

- • External basal lamina,
- • Plasma membrane,
- • Anchoring plaques.

Fibres communicate with each other via Gap junctions. These junctions allow the diffusion of excitation from one fibre to another.

❖ Caveolae



- • Small invaginations of the plasma membrane.
- • They function as the T-systems of S.M.F.
- • They control calcium entry into the S.M.F.
- • They are in contact with the sarcoplasmic reticulum.

❖ Sarcoplasm

- • Single and central nucleus,
- • Sarcoplasmic cones containing the organelles,
- • Sarcosomes in very low quantity,
- • Vesicular Golgi apparatus,
- • Poorly developed sarcoplasmic reticulum,
- • Juxtanuclear diplosome,
- • Pigment inclusions,
- • Lipid and glycogen inclusions.

❖ Myoplasm

- • Set of peripheral and longitudinal myofibrils.

The myofibrils are constituted of:

- • Thin myofilaments attached to anchoring plaques of dense bodies,
- • Thick myofilaments,
- • Intermediate myofilaments.

a. Thin Myofilaments

- • They insert at the level of the dense bodies and anchoring plaques.
- • They are formed of actin, tropomyosin, and calmodulin instead of troponin.

b. Thick Myofilaments

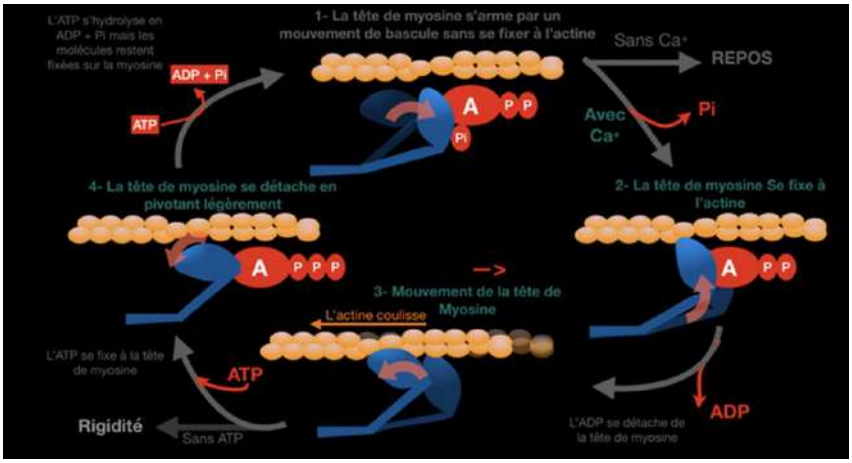
- • Composed of myosin that differs from that of striated muscle fibres.
- • They form by polymerisation of myosin molecules only when the fibre is excited.
- • Less numerous than in the S.S.M.F. (approximately 1 for 12 thin myofilaments).

c. Intermediate Myofilaments

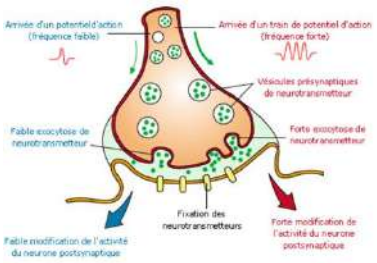
- • Formed of desmin and vimentin.

Contraction of Smooth Muscle Fibres

- • The contraction is involuntary, slow, and discontinuous.
- • It differs from that of striated muscle.
- • Calcium is stored in the sarcoplasmic reticulum,
- • then released towards calmodulin.
- • The calcium–calmodulin complex activates myosin, which then binds to actin.
- • The actin–myosin interaction is identical to that in striated muscle.



- • During contraction the nucleus shortens.
- • The entire set of smooth muscle fibres contracts as a single unit.
- • Contraction resembles muscular waves.
- • During contraction the muscular tension may remain constant in an organ.



Vascularisation

- • **Endomysium**: Avascular connective tissue surrounding the smooth muscle fibres.
- • **Perimysium**: Vascularised connective tissue surrounding bundles of smooth muscle fibres.
- • **Epimysium**: Connective tissue surrounding the muscle.

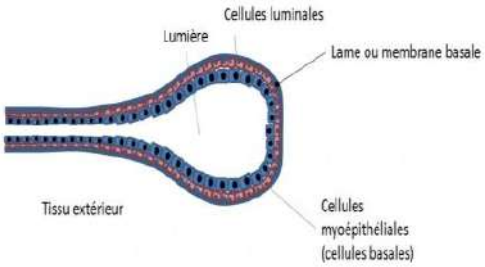
Regeneration

- • By differentiation of mesenchymal cells.
- • By mitosis of pre-existing smooth muscle fibres.

Atypical Muscle Cells

→ Myoepithelial Cells

- • **Origin**: ectoblast.
- • **Location**: included between the basal lamina and the glandular cells of the acini of certain exocrine glands (e.g. salivary glands).
- • **Role**: they contract and release the products of glandular secretions.
- • They present multiple processes (rich in myofilaments).



→ Pericytes

- • **Location**: cells that surround capillaries via their long processes.
- • **Role**: contraction; they regulate blood flow at the level of capillaries and venules, and ensure metabolic regulation.