Muscle

解剖學暨細胞生物學研究所

黃敏銓

基醫大樓6樓 0646室
mchuang@ntu.edu.tw
<table>
<thead>
<tr>
<th>Single-cell contractile units</th>
<th>Multicellular contractile units</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Myoepithelial cells</td>
<td>• Smooth muscle</td>
</tr>
<tr>
<td>– Expel secretion from glandular acini</td>
<td>• Striated muscle</td>
</tr>
<tr>
<td>• Pericytes</td>
<td>– <strong>Skeletal muscle</strong></td>
</tr>
<tr>
<td>– Surround blood vessels</td>
<td>– <strong>Visceral striated muscle</strong></td>
</tr>
<tr>
<td>• Myofibroblast</td>
<td>Tongue, pharynx, diaphragm, esophagus</td>
</tr>
<tr>
<td>– A dominant cell type in formation of a scar</td>
<td>– <strong>Cardiac muscle</strong></td>
</tr>
</tbody>
</table>
Skeletal muscle

• **Muscle fibers:** extremely elongated, multinucleate contractile cells, bound by collagenous supporting tissue
  - Individual muscle fiber: 10-100 \( \mu \text{m} \) in diameter, may reach up to 35 cm in length

• **Motor unit:** the motor neuron and the muscle fibers it supplies
  - Vitality of skeletal muscle fibers is dependent on the maintenance of their nerve supply
Skeletal muscle

Muscle fibers (cells)

Muscle fiber (muscle cell)

Myofibril

Sarcomere

Thick filament (myosin filament)

Molecule: myosin

Thin filament (actin filament)

Molecules:
Actin
Tropomyosin
Troponin complex
Skeletal muscle

Connective tissues: endomysium, perimysium, epimysium

- Small fasciculi: external muscles of the eye
- Large fasciculi: the muscle of the buttocks

* Fasciculus = Fascicle
Skeletal muscle
— fasciculus

- Muscle cells (fibers)
- Endomysium
  1. Reticulin fibers
  2. Collagen
- N: nerve bundle
- V: blood vessel

Trichrome stain x150
Basal lamina stained by silver stain

Reticular fiber
Skeletal muscle — fasciculi of the tongue

Masson’s trichrome stain x300

TS: transverse section  P: perimysium  C: capillaries
Red: skeletal muscle cells  Blue: collagen
Skeletal muscle: rich blood supply

Perfusion method x 128
Skeletal muscle and its embryogenesis
— mature skeletal muscle

- Elongated, unbranched cylindrical cells
- Numerous flattened nuclei just beneath the sarcolemma
Skeletal muscle
— transverse section

- nuclei
- Skeletal muscle fiber (100 μm in diameter)
- perimysium
- capillaries (7 μm in diameter)
Skeletal muscle
— transverse section

Myofibrils (肌原纖維): 每一個小黑點代表一肌原纖維的橫切面

Iron haematoxylin x 1200
Skeletal muscle

平行排列的肌原纖維呈現横紋
Skeletal muscle

— 橫紋的形成

arrangement of the contractile proteins

I bands: Isotropic in polarized light
A bands: Anisotropic in polarized light
Z bands: Zwischenscheiben

Heidenhain’s haematoxylin x 1200
Skeletal muscle

N: nucleus  Mt: mitochondria  M: myofibrils
Skeletal muscle

G: glycogen granules
S: smooth membrane system
Mi: mitochondria
A: A band
H: H band
I: I band
M: M line
**Sarcomere**: the functional unit of the myofibril

1. Thick filaments: myosin attached to M line
2. Thin filaments: actin attached to Z line
Skeletal muscle
— sliding filament theory

Contracted state:
I and H bands narrow
Z bands are drawn closer
Skeletal muscle — the conducting system

Transverse tubular system (T system): Triad: T tubule + 2 terminal cisternae

T tubule: membrane invagination

Location: A-I band junction

Two T tubules per sarcomere

Function: synchronous contraction of all sarcomeres
**Td**: Triad  
**T**: T tubule  
**TC**: terminal cisternae  
**SR**: sarcoplasmic reticulum  
**M**: mitochondria
Skeletal muscle — the conducting system

transverse section

SR: sarcoplasmic reticulum
T: T tubule
M: mitochondria
ICS: intercellular space
L: external lamina
Skeletal muscle — type I and type II

Activity of succinate dehydrogenase → relative amount of mitochondria

A : aerobic fibers (type I)
I : intermediate fibers (type IIa)
An: anaerobic fibers (type IIb)
**Skeletal muscle — type I and type II**

**Aerobic (type I, red) muscle fibers**
1. Small in cross-section
2. Contain abundant mitochondria
3. Large content of myoglobin: oxygen binding protein: red color
4. Have a rich blood supply
5. Slow twitch motor units: 維持姿勢之較長且慢的收縮: 四肢及背部長肌

**Anaerobic (type II, white) muscle fibers**
1. Large in cross-section
2. Contain few mitochondria
3. Little of myoglobin: white color
4. Have a poor blood supply
5. Rich in glycogen and glycolytic enzymes
6. Predominate in the biceps and triceps
7. Fast twitch motor units: 快速大力的收縮: 眼球轉動及手指運動
Smooth muscle

Shape: elongated, spindle-like
Nucleus: one nucleus, centrally located
Smooth muscle fasciculi

Fasciculi are functional contractile units
Collagen is stained blue
Smooth muscle bowel wall

Highly regular and packed closely
Central nucleus in cross-sectioned muscle fiber
Smooth muscle in the ileum

G: parasympathetic ganglia

Peristalsis (蠕動)
Contraction band
Thin filament
Thick filament
Dense body:
  • $\alpha$-actinin
  • Actin filaments
  • Intermediate filaments
smooth muscle cells

Spindle-shaped and elongated central nuclei

S: supporting tissue
smooth muscle

N: gap (nexus) junction: for excitation spread
J: junctional complex (filaments attachment site at the membrane)
C: caveolae (membrane invaginations)
S: vesicular and tubular structures (analogous to sarcoplasmic reticulum)
D: dense body (analog of the striated muscle Z line)

Sarcolemmal invaginations, vesicles, caveolae: analogous to T system
Dense bodies provide an attachment site for thin filaments and intermediate filaments.
Cardiac muscle

Cell branched, central nucleus, cell junctions, cross striations
Longitudinal section of cardiac muscle
Cross-sectioned Cardiac muscle

- Central nucleus
- Branched cell
- Rich blood supply
Cardiac muscle

D: intercalated discs

C: capillaries

Toluidine blue x 640
Cardiac muscle

D: intercalated discs
Intercalated disc:
Fascia adherens (adherens junction)
Macula adherens (desmosomes)
Gap junctions (nexus junctions)
Cardiac muscle

The intercalated disc is an interdigitating junction

FA: fascia adherens
D: desmosome
(macula adherens)
N: gap junction
Cardiac muscle

Diad: T tubule + sarcoplasmic reticulum

T tubule: located at the level of Z line
Cardiac muscle

M: mitochondria（多且大）
G: glycogen
T: T tubules
SR: sarcoplasmic reticulum
Skeletal muscle  Cardiac muscle
Purkinje fibers: large cells with less myofibrils, more glycogen, clear cytoplasm
Purkinje fibers: modified cardiac muscle fibers for conduction