Skeletal Muscle
Types of muscle

- Skeletal muscle: moves the skeleton by pulling on the tendons that are connected to the bones.
• Cardiac muscle-pumps blood through the heart and blood vessels
• Smooth muscle—various functions in many diverse organs (arrector pili muscle, iris, uterus, stomach, ductus deferens)
Function of skeletal muscle

- Locomotion
- Maintain posture
- Support of soft tissues
- Regulation of orifices
- Maintain body temperature
Muscle fiber microanatomy

- Sarcolemma - plasma membrane of muscle cells
- Sarcoplasm - cytoplasm of muscle fibers
- Skeletal muscle fibers have multiple nuclei
  - fusion of multiple myoblasts
- Myofibrils - bundles of myofilaments
- Myofilaments - two types:
  - Actin - thin filaments
  - Myosin - thick filaments
• Sarcoplasmic reticulum- SR-ER in muscle fibers (release Ca for muscle contraction)
• Terminal cisternae-widened ends of the SR
• Transverse tubules (T-tubules)
• Triad-two terminal cisternae and the t-tubule between them
T-tubule brings action potentials into interior of muscle fiber.

Sarcolemma

Thin filament

Thick filament

Triad

Sarcoplasmic reticulum stores Ca^{2+}.

Lateral sacs
Sarcomere

- The functional unit of skeletal muscle
- Sarcomeres are connected in series to make myofibrils
- ~10,000 of sarcomeres make a myofibril
- Each sarcomere contracts shortening the length of the entire myofibril
Fig 9.4

(a) Organization of thick and thin filaments
I-band = light band - contains actin = thin filament
A-band = dark band - contains myosin = thick filament
Z-line/disc - the ends of the sarcomere - actin connects to the z-bands
Fig 9.6
Structures of the Sarcomere

Z disks
H-band
I-band
A-band
M line

H-band = myosin only
I-band = actin only
A-band = all of the myosin
Thin filaments

- Contains actin, tropomyosin, and troponin
- Tropomyosin blocks the active site on actin
- Troponin holds tropomyosin in place
- Calcium binds to troponin causing dissociation of the troponin-tropomyosin complex
Thick filament

- Contain bundles of myosin molecules
- The tail of myosin is attached to the center of the sarcomere, M-line
- The head of myosin attaches to actin if Ca is present in the sarcoplasm
Sliding filament theory

- When a skeletal muscle contacts:
  - The I-bands get shorter
  - The z-lines move closer together
  - The myofilaments (actin & myosin) stay the same length
  - The two myofilaments move along side of each other
• Myosin attaches to actin
• Actin is pulled closer to the center of the muscle cell
• Actin is connected to the z lines
• The z lines are pulled closer together
Fig 9.7

Sarcomere at rest

M-line

Z-line

Thick filament

Thin filament

Contraction and filament sliding
Motor neuron release neurotransmitter Ach

Changes in sarcolemma permeability to ions

Generation of electrical impulse called and action potential
Excitation - Contraction in Skeletal Muscle

1. Somatic motor neuron releases ACh at neuromuscular junction.
2. Net entry of Na⁺ through ACh receptor-channel initiates a muscle action potential.
Intracellular Ca$^{2+}$ triggers contraction
Fig 9.11

Steps in the initiation of a contraction

1. ACh released, binding to receptors
2. Action potential reaches T-tubule
3. Sarcoplasmic reticulum releases Ca²⁺
4. Active-site exposure, cross-bridge binding
5. Contraction begins

Steps that end the contraction

6. ACh removed by AChE
7. Sarcoplasmic reticulum recaptures Ca²⁺
8. Active sites covered, no cross-bridge interaction
9. Contraction ends
10. Relaxation occurs, passive return to resting length
Sliding filament theory

• Contraction-myosin binds to actin pulling it towards the M line
Connective tissue of muscle

- Epimysium-surrounds the entire muscle
- Perimysium-surrounds fascicles
- Fasicle-a bundle of muscle cells
- Endomysium-surrounds individual muscle cells
- Epimysium & perimysium are attachment sites for nerves & blood vessels
(d) MYOFIBRIL

- Surrounded by: Sarcoplasmic reticulum
- Consists of: Sarcomeres (Z line to Z line)
(c) MUSCLE FIBER

Surrounded by:
Endomysium

Contains:
Myofibrils

Fig 9.5
(b) MUSCLE FASCICLE

- Surrounded by: Perimysium
- Contains: Muscle fibers
Fig 9.5

(a) SKELETAL MUSCLE

*Surrounded by:*
Epimysium

*Contains:*
Muscle fascicles
Fig 9.5
Tendons & aponeuroses

- Tendons attach skeletal muscle to bone, skin, or another muscle
- Aponeuroses - a wide flat tendon
Organization of muscle fibers

• Muscle fascicles are organized six different ways:
• Parallel-parallel to the long axis of the muscle
• Convergent-converge from a wide area to a small area
• Circular-concentrically arranged around a opening
• **Unipennate**- at an angle on one side of the tendon

• **Bipennate**- at an angle on both sides of the tendon

• **Multipennate**- converge from a wide area to a small area. The tendon branches within the muscle
(c) Unipennate muscle (Extensor digitorum muscle)
(d) Bipennate muscle (Rectus femoris muscle)
(e) Multipennate muscle (Deltoid muscle)
Origins/Insertions/Actions of muscles

- Origins & insertions—the point on the skeleton where the tendon of a muscle attaches to the skeleton
- Origin—usually proximal to the insertion
- Actions—sarcomeres contract to pull the insertion closer to the origin
  - Move the skeleton (flexion, elevation, etc)
(c) Third-class lever

Movement completed
Motor unit

- All of the muscles fibers controlled by a single motor neuron
- Can range from 2 to 2,000 muscle fibers per motor unit
Exercise-muscle hypertrophy

- Exercise causes skeletal muscles to develop more myofibrils per sarcomere.
- Hypertrophy of each muscle cell makes the entire muscle larger.
- Increased concentrations of mitochondria & glycolytic enzymes.
Sources of ATP in Muscle Tissue

1) Immediate – Creatine Phosphate

2) Short Term – Glycolysis (Lactic Acid)

3) Long Term – Oxidative Phosphorylation
1) Creatine Phosphate

- Takes P from creatine and sticks it on ADP
Muscle Fatigue

Depletion of $O_2$ - decrease in ATP available.

Depletion of glucose or glycogen - decrease in ATP available.

Slows Na$^+$/K$^+$ pumps.

Lactic Acid Build-Up.

Motor neuron exhaust ACh: "junctional fatigue".

CNS (origin of signals) "central fatigue", mentally exhausted.
Types of skeletal muscle fibers

- FYI
- Slow red fibers
- Fast white fibers
- Intermediate fibers
- They vary in their blood supply, oxygen consumption, enzymes but that’s physiology
1. Slow Twitch: Aerobic

- Slow onset of contraction
- Slower to fatigue
- More mitochondria
- More capillaries
- Myoglobin
- Smaller diameter
- Endurance activities
- Postural muscles

FYI

2. Fast Twitch: Anaerobic

- Fast onset of contraction
- Faster to fatigue
- Faster SR uptake of Ca$^{2+}$
- High glycogen stores
- Less mitochondria/blood
- Larger diameter
- Power lifting
- Sprint
Fascicle arrangements

• Models
• Cadaver
Muscle fibers, sarcolemma, nuclei, a-band, I-band
Sliding filament theory

- Animations from CD