Presentation 3:

Biomechanical Principles

by:

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MULTIMEDIA SYMPOSIUM OVERVIEW

This multimedia symposium was developed for the specific purpose of providing individuals who sit for the Certified Strength and Conditioning Specialist® (CSCS®) certification exam with a review of facts, concepts, and theories that are relevant to strength training and conditioning.

You are encouraged to simultaneously listen and watch the symposium video presentation, view the PowerPoint® slide show, follow along in the presentation outline, and add your own notes in the spaces within the outline (more paper may be necessary).

To maximize the value of the multimedia symposium when preparing for the CSCS exam, you may find it helpful to first study the Essentials of Strength Training and Conditioning (2nd edition) text. Further, candidates who perform well on the CSCS exam typically have considerable practical experience in strength training and conditioning athletes (e.g., designing programs, teaching proper exercise technique, performing testing sessions) and a strong academic background in the exercise sciences (i.e., anatomy, physiology, biomechanics, etc.). For additional suggestions for preparing for the CSCS exam, go to www.nsca-cc.org.

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BIOMECHANICS TERMINOLOGY

I. Functional Anatomy

II. Kinesiology

FUNCTIONAL ANATOMY

I. Anatomic Orientation (Figure 1)

A. Anatomical position
   1. Standing erect
   2. Eyes, head, and toes directed anteriorly
   3. Upper extremities at side with palms facing anteriorly
4. Feet together with toes pointing anteriorly

B. Planes of movement (Figure 2, continued on the next page)
### Biomechanical Principles

**Presentation 3**

<table>
<thead>
<tr>
<th>Lower back—sagittal</th>
</tr>
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<tbody>
<tr>
<td><strong>Flexion</strong></td>
</tr>
<tr>
<td>Exercise: sit-up</td>
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<tr>
<td>Activity: get out of bed</td>
</tr>
<tr>
<td><strong>Extension</strong></td>
</tr>
<tr>
<td>Exercise: back machine</td>
</tr>
<tr>
<td>Activity: lift boxes of supplies</td>
</tr>
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<thead>
<tr>
<th>Lower back—transverse</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left rotation</strong></td>
</tr>
<tr>
<td>Exercise: medicine ball side toss</td>
</tr>
<tr>
<td>Activity: baseball swing</td>
</tr>
<tr>
<td><strong>Right rotation</strong></td>
</tr>
<tr>
<td>Exercise: torso stack machine</td>
</tr>
<tr>
<td>Activity: chopping wood</td>
</tr>
</tbody>
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<thead>
<tr>
<th>Hip—frontal</th>
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<tbody>
<tr>
<td><strong>Adduction</strong></td>
</tr>
<tr>
<td>Exercise: sideward shuffle</td>
</tr>
<tr>
<td>Activity: riding a horse</td>
</tr>
<tr>
<td><strong>Abduction</strong></td>
</tr>
<tr>
<td>Exercise: skating slide board</td>
</tr>
<tr>
<td>Activity: sidestepping around an obstacle</td>
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<tr>
<td><strong>Adduction</strong></td>
</tr>
<tr>
<td>Exercise: cardio-kickbox inward sweep kick</td>
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<tr>
<td>Activity: soccer kick</td>
</tr>
<tr>
<td><strong>Abduction</strong></td>
</tr>
<tr>
<td>Exercise: cardio-kickbox outward sweep kick</td>
</tr>
<tr>
<td>Activity: stepping over a fence</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ankle—sagittal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dorsiflexion</strong></td>
</tr>
<tr>
<td>Exercise: pushup with invert on a large ball</td>
</tr>
<tr>
<td>Activity: SCUBA diving</td>
</tr>
<tr>
<td><strong>Plantarflexion</strong></td>
</tr>
<tr>
<td>Exercise: walking</td>
</tr>
<tr>
<td>Activity: standing on tiptoes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower back—frontal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left tilt</strong></td>
</tr>
<tr>
<td>Exercise: side tilt with bar on shoulders</td>
</tr>
<tr>
<td>Activity: walking with a suitcase in the right hand</td>
</tr>
<tr>
<td><strong>Right tilt</strong></td>
</tr>
<tr>
<td>Exercise: side bend with dumbbell in one hand</td>
</tr>
<tr>
<td>Activity: carrying a toolbox in left hand</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hip—sagittal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flexion</strong></td>
</tr>
<tr>
<td>Exercise: high stepping</td>
</tr>
<tr>
<td>Activity: self defense kick</td>
</tr>
<tr>
<td><strong>Extension</strong></td>
</tr>
<tr>
<td>Exercise: cross country ski machine</td>
</tr>
<tr>
<td>Activity: walking uphill</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hip—transverse</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal rotation</strong></td>
</tr>
<tr>
<td>Exercise: sand box</td>
</tr>
<tr>
<td>Activity: swing dancing</td>
</tr>
<tr>
<td><strong>External rotation</strong></td>
</tr>
<tr>
<td>Exercise: skate board</td>
</tr>
<tr>
<td>Activity: ice skating turn</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Knee—sagittal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flexion</strong></td>
</tr>
<tr>
<td>Exercise: interval sprints</td>
</tr>
<tr>
<td>Activity: rock climbing</td>
</tr>
<tr>
<td><strong>Extension</strong></td>
</tr>
<tr>
<td>Exercise: step class</td>
</tr>
<tr>
<td>Activity: walking upstairs</td>
</tr>
</tbody>
</table>

<table>
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<tr>
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</tr>
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<tbody>
<tr>
<td><strong>Inversion</strong></td>
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<tr>
<td>Exercise: medicine ball catch with feet</td>
</tr>
<tr>
<td>Activity: walking across a hillside (uphill foot)</td>
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<tr>
<td><strong>Eversion</strong></td>
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<tr>
<td>Exercise: walking in sand</td>
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<tr>
<td>Activity: walking across a hillside (downhill foot)</td>
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</tbody>
</table>

1. Sagittal
   a. Movements
      i. Extremities
      ii. Vertebral column
2. Frontal
   a. Movements
      i. Extremities
      ii. Vertebral column

3. Transverse/horizontal
   a. Movements
      i. Extremities
      ii. Vertebral column

II. Neural System
   A. Motor unit (Figure 3)
B. Proprioceptors (“feedback system”)

1. Muscle spindle (Figure 4)

2. Golgi tendon organ (Figure 5)
III. Skeletal System (Figure 6)

- Axial skeleton
- Appendicular skeleton

IV. Muscle Attachments

- Origin
- Insertion
V. Muscle Functions (Figure 7)

A. Agonist

B. Antagonist

C. Synergist

D. Stabilizer
VI. Functional Movement

A. Triplanar movement
   1. Functional movement does not occur in only one plane of motion
   2. Exercise and sports movements require motion in multiple planes

B. Muscle function
   1. Muscles do not function in isolation
   3. Several muscles function to produce complementary movements to complete a given task

KINESIOLOGY

I. Lever Systems (Figure 8)

A. Lever
   1. In the body, the bones are the levers
   2. In the body, the joints are the axes
B. Three forces of a lever

1. Axis (fulcrum)

2. Effort (moving) force
   a. Tends to create the desired movement; in the body the muscle activity is the effort force
   b. Effort arm: the perpendicular distance from the axis to the effort force

3. Resistive force
   a. Tends to oppose the desired movement; the weight of a body part or an external weight is the resistive force
   b. Resistance arm: the perpendicular distance from the axis to the resistive force

C. Lever classification

1. First class lever (Figure 9)

   a. Advantage
   b. Disadvantage
2. Second class lever (Figure 10)

![Second class lever diagram]

- **Advantage**
- **Disadvantage**

3. Third class lever (Figure 11); *note: the speaker mentions the side lateral raise as another example than what is seen in Figure 11*

![Third class lever diagram]

- **Advantage**
- **Disadvantage**
D. Torque (Figure 12)

1. Rotary effect of force

2. Torque = force x moment arm

3. Torque varies throughout exercise movements; *note: the speaker mentions these exercises as other examples than what is seen in Figure 12:*
   
   a. Leg extension
   
   b. Front dumbbell shoulder raise

E. Mechanical advantage (MA) = the ratio of effort arm to resistance arm

1. MA greater than one: effort force is greater than the resistive force

2. MA less than one: effort force is less than the resistive force
3. Examples

a. Elbow joint: the mechanical advantage is the greatest at 90° elbow flexion (Figure 13)

![Image of elbow joint mechanics](image1)

b. Knee joint: the patella optimizes the perpendicular distance from the axis to the line of force to allow maximal torque capabilities (Figure 14)

![Image of knee joint mechanics](image2)

II. Strength

A. Contributory factors

1. Neural: muscle force is varied by altering the amount of motor unit activity

   a. Motor unit recruitment: motor units are activated in a set sequence
b. Motor unit firing rate: frequency of action potentials

c. Methods to increase force production

2. Muscular: muscle force development depends on the mechanical properties of muscle and its architecture

a. Length-tension relationship: force varies with the amount of myosin-actin overlap (Figure 15)

b. Force-velocity relationship: concentrically, movement velocity is inversely proportional to the force (Figure 16)
c. Force-time relationship: strength varies based on the time and duration of muscle activation (Figure 17)

i. Starting strength: the ability to develop force at the beginning of a muscle action

ii. Rate of force development (RFD): the ability to quickly achieve maximal force at the beginning of a muscle action

iii. Maximum strength

iv. Strength endurance: the ability to maintain muscle activity for long durations (static vs. dynamic vs. explosive)

v. Deceleration strength: force required when returning to rest
d. Muscle fiber architecture

i. Three element model (Figure 18)

![Three element model diagram](image1)

a) Contractile component (CC) (Figure 19)

![Contractile component diagram](image2)

b) Series elastic component (SEC)

c) Parallel elastic component (PEC)
ii. Muscle pennation: variation of fiber alignment in relation to the line of pull (Figure 20)

![Diagram of muscle pennation types]

- Fusiform
  - Rapid shortening
  - Large ROM
- Unipennate
- Bipennate
- Multipennate
- Longitudinal/Strap
  - Slower contractile velocity
  - Larger CSA
  - Greater force production

e. Cross-sectional area (CSA): the force a muscle can exert is related to its cross-sectional area rather than to its volume; greater CSA equals greater muscle force production
f. Joint angle: changes in strength throughout the joint range of motion affect force capability (Figure 21)

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<thead>
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<th>ELBOW FLEXION</th>
<th>Angle (°)</th>
<th>Torque (N·m)</th>
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<td>N/A 110 130 134 120 101 79 51 25</td>
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i. Length-tension relationship

ii. Variation in leverage over the joint range of motion
B. Types of forces

1. Gravity: resistance due to weight in a vertical direction; center of gravity

2. Ground reaction force

3. Tension

4. Compression

5. Shear

6. Axial loading

III. Power

A. Force-velocity relationship (already discussed)

B. Power-time relationship (Figure 22): power production decreases with activity duration

![Power-Time Graph]
C. Applications based on exercise mode

1. Plyometrics: quick movements involving a prestretch or counter-movement that activate the stretch shortening cycle (SSC) (Figure 23)

2. Weightlifting (i.e., clean and jerk, snatch, and their variations)

3. Speed training
   a. Rationale for using speed training to increase power
      i. Involves the stretch shortening cycle (SSC)
ii. Requires speed-strength: the application of maximal force at high velocities (e.g., sprint training)

b. Types of sprint training

i. Technique training

ii. Sprint-assisted training

iii. Resisted sprinting

IV. Kinetic Chain Terminology

A. Closed kinetic chain: distal end of the “chain” of joints is fixed (Figure 24)

1. Multi-joint ≠ closed chain

2. Weight bearing ≠ closed chain
B. Open kinetic chain: proximal end of the “chain” of joints is fixed (Figure 25)

C. Importance

D. Application example (sprinting)

APPLICATION OF BIOMECHANICS

I. “SAID” principle

II. Free Weight Exercises
   A. Kinetic chain (exercise examples and applications)
   B. Range of motion (exercise examples and applications)
   C. Speed of movement (exercise examples and applications)
III. Variable Resistance Exercises

A. Developed to match the muscular torque to the resistance of the exercise

1. Cam exercise machines (Figure 26)
2. “Universal®” (i.e., pivot) exercise machines (Figure 27)

![Diagram of a universal exercise machine showing effort lever arm, resistance lever arm, lift height, and weight stack.]

3. Type of machines to compensate for flaws of cam or pivot machines

B. Can machines equate to the human strength curves?

1. Mismatch for most individuals

2. Exercise machines were designed for the average person
   a. Limb lengths
   b. Points of muscular attachment
GLOSSARY OF TERMS

**Acceleration**—the rate at which speed changes

**Agonist**—the muscle most directly involved in creating movement

**Anatomical position**—the body standing erect with arms down and palms forward

**Angle of pennation**—the angle between the overall muscle and its fibers ($0^\circ = \text{no pennation}$)

**Angular displacement**—the angle through which an object rotates

**Angular velocity**—an object’s rotational speed (radians/sec or deg/sec)

**Antagonist**—a muscle that can slow down or stop a movement

**Biomechanics**—the mechanical analysis of biological systems

**Concentric muscle action**—when a muscle shortens because its contractile force is greater than the resistive force

**Eccentric muscle action**—when a muscle lengthens because its contractile force is less than the resistive force

**Fluid resistance**—the resisting force encountered by an object moving through a fluid or by a fluid moving past or around an object

**Friction**—the resistive force encountered while attempting to move two surfaces in contact relative to each other

**Frontal plane**—a vertical plane dividing the standing body into anterior and posterior halves

**Fulcrum**—the pivot point of a lever

**Inertial force**—the force required to accelerate an object (equals the mass of the object times its acceleration)

**Isometric muscle action**—when muscle length does not change because the contractile force is equal to the resistive force

**Lever**—an object that, when subjected to a force whose line of action does not pass through its pivot point, exerts force on any object impeding its tendency to rotate

**Lordosis**—an arched back
**Mechanical advantage**—the ratio of the movement arm through which an applied force acts to that through which a resistive force acts (e.g., a pliers with 9” handles with 1.5” jaws has a mechanical advantage of $9/1.5 = 6$; a 10 pound squeeze on the handle generates a $6 \times 10$ pound = 60 pound squeeze at the jaws)

**Moment arm**—the perpendicular distance from the line of action of a force on a lever to its fulcrum

**Muscle force**—force generated by biochemical activity which tends to draw the opposite ends of a muscle towards each other

**Pennate muscle**—a muscle whose fibers have a featherlike arrangement

**Power**—the time rate of doing work (equals work/time or force x velocity)

**Resistive force**—force which acts contrary to muscle force (i.e., gravity, inertia, friction)

**Rotational power**—rotational work per unit time or torque times angular velocity

**Rotational work**—the product of torque and angular displacement

**Sagittal plane**—a vertical plane dividing the standing body into left and right halves

**Specificity**—the concept that training is most effective when resistance exercises bear key similarities to the sports activity in which the improvement is sought; to train in a specific manner to achieve a specific outcome

**Strength**—the maximal force that can be exerted under specified conditions

**Synergist**—a muscle that assists indirectly in a movement

**Tendon**—a fibrous attachment between muscle and bone that blends into and is continuous with both the muscle sheath and the connective tissue surrounding the bone

**Torque**—the tendency of a force to rotate an object about a fulcrum (equals the magnitude of the force times the length of its moment arm); ability to create a turning effect

**Transverse plane**—a horizontal plane dividing the standing body into superior and inferior halves

**Weight**—the downward force on an object due to gravity (equal to the object’s mass times the local acceleration of gravity)

**Work**—the product of the force exerted on an object and the distance the object moves in the direction in which the force is exerted
PRESENTATION REFERENCES


## INDEX TO IMAGE REFERENCES

<table>
<thead>
<tr>
<th>IMAGE NO.</th>
<th>TITLE OF IMAGE</th>
<th>IMAGE REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F4</td>
<td>Muscle Spindle</td>
<td>© 2006 NSCA Certification Commission.</td>
</tr>
<tr>
<td>F5</td>
<td>Golgi Tendon Organ</td>
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</tr>
<tr>
<td>F8</td>
<td>Components of a Lever</td>
<td>© 2006 NSCA Certification Commission.</td>
</tr>
<tr>
<td>F14</td>
<td>Changes in Mechanical Advantage at the Knee Joint</td>
<td>© 2006 NSCA Certification Commission.</td>
</tr>
<tr>
<td>F15</td>
<td>Length-tension Relationship</td>
<td>© 2006 NSCA Certification Commission.</td>
</tr>
<tr>
<td>F17</td>
<td>Force-time Relationship</td>
<td></td>
</tr>
<tr>
<td>F20</td>
<td>Muscle Pennation</td>
<td></td>
</tr>
<tr>
<td>F22</td>
<td>Power-time Relationship</td>
<td></td>
</tr>
<tr>
<td>F23</td>
<td>Illustrations of Plyometric Exercises/Drills</td>
<td></td>
</tr>
</tbody>
</table>

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MUSCULAR ANATOMY

A Supplement to “Biomechanical Principles”
by
David H. Potach, MS, PT, CSCS,*D; NSCA-CPT,*D

SCAPULAR/DELTOID REGION

The movements of the shoulder girdle are accomplished by combinations of posterior and anterior muscles that run between axial and appendicular skeletons. Muscles which insert on the appendicular skeleton but originate from the axial skeleton are considered extrinsic muscles of the limb; muscles that both originate from and insert upon the appendicular skeleton are intrinsic muscles of the limb.

I. Superficial Extrinsic Muscles of the Back/Shoulder

A. Trapezius

1. *Trapezium* = irregular four-sided figure

2. Origin: superior nuchal line; external occipital protuberance (of the occipital bone); ligamentum nuchae

3. Insertion:
   a. Part I (uppermost fibers): lateral 1/3 of clavicle
   b. Part II (lower cervical/upper thoracic fibers): acromion (of scapula)
      i. Thickest portion of trapezius
   c. Part III (lower thoracic fibers): scapular spine

4. Actions:
   a. Part I: elevation of scapula; upward rotation of scapula
   b. Part II: retraction (adduction) of scapula
   c. Part III: depression of scapula; upward rotation of scapula
   d. Superior + inferior fibers (parts I & III): upward rotation of scapula
      i. Upward rotation is similar to shrugging one's shoulders
      ii. Upward rotation occurs when the acromion of the scapula moves upward
iii. The inferior angle of the scapula moves laterally and slightly up during upward rotation
e. This large, flat, triangular muscle covers the posterior aspect of the neck and superior half of the trunk. The superior fibers of the trapezius elevate the scapula (i.e., pull it posteriorly toward the median plane), and its inferior fibers depress the scapula and lower the shoulder. The superior and inferior fibers act together in the superior rotation of the scapula. The trapezius muscles brace the shoulders by pulling the scapulae posteriorly, hence, weakness of these muscles results in drooping of the shoulders.

B. Latissimus Dorsi
1. *Latissimus dorsi* = widest of the back
2. **Origin:** spinous processes of T-6 through S-2 (via thoracolumbar fascia); posterior iliac crest; lower three ribs
3. **Insertion:** lesser tubercle on anterior aspect of humerus
   a. Fibers converge, then turn 180 degrees to insert on lesser tubercle of humerus
4. **Actions:**
   a. Extension (of the humerus)
   b. Adduction (of the humerus)
   c. Medial rotation (of the humerus)
5. The latissimus dorsi covers the inferior half of the back (T-6 to the iliac crest). This muscle is used when chopping wood, climbing, paddling a canoe and swimming (particularly the crawl). When climbing, these muscles raise the trunk; they raise the trunk to the arm, which occurs when performing chin-ups.
The next muscle, although it belongs and is listed with the deep intrinsic muscles, is more functionally suited to be included with the latissimus dorsi as its actions mimic those of the latissimus dorsi.

6. Teres Major
   a. **Origin**: inferior 1/3 of lateral border of scapula
   b. **Insertion**: lesser tubercle (on anterior aspect of humerus)
      i. Passes anterior to long head of triceps to crest of lesser tubercle
      ii. Just medial to insertion of latissimus dorsi muscle
   c. **Actions**:
      i. Adduction of humerus
      ii. Medial rotation of humerus
   d. Teres major is an important stabilizer of the head of the humerus in the glenoid cavity during abduction of the arm, i.e., it steadies the head of the humerus in its socket

II. Deep Extrinsic Muscles of the Shoulder

A. Levator Scapulae
   1. *Levator scapula* = elevator of the scapula
   2. **Origin**: transverse processes of upper cervical vertebrae (C1-C4)
   3. **Insertion**: superior angle/upper vertebral border of scapula (superior to scapular spine)
   4. **Actions**:
      a. Elevation of scapula
      b. Downward rotation of scapula
         i. Tilts glenoid cavity inferiorly by rotating the scapula

B. Rhomboids (minor and major)
   1. Named for the shape of the muscle, i.e., shaped like a rhomboid, an oblique parallelogram
   2. **Origin**:
      a. Minor: lower ligamentum nuchae & spinous processes of C-7 to T-1
      b. Major: spinous processes of T-2 to T-5
3. **Insertion**: vertebral border of scapula (spine to inferior angle)

4. **Actions**:
   a. Retraction (adduction) of scapula
   b. Downward rotation of scapula (depression of the glenoid cavity)
   c. Fixation of scapula to body wall

5. Major is about two times wider than minor. The rhomboids are used when forcibly lowering the raised upper limbs, e.g., when driving a stake with a sledge hammer.

### III. Intrinsic Muscles of the Shoulder

A. **Deltoid**

1. **Deltoid** = triangular, i.e., it is shaped like the inverted Greek letter delta
2. **Origin**: scapular spine; posterior and lateral edge of acromion; lateral 1/3 of clavicle
   a. Approximates insertion of trapezius
3. **Insertion**: deltoid tuberosity (just above middle of humerus); fleshy portion (of muscle) surrounds humeral head anteriorly, laterally and posteriorly
4. **Actions**:
   a. **Middle**:
      i. Especially strong, but has a short range of action. Action = abduction (following initiation of movement by supraspinatus muscle)
   b. **Anterior**: flexion of the humerus at the shoulder joint
      i. Internal (medial) rotation of humerus – minor movement for the deltoid
   c. **Posterior**: extension of the humerus at the shoulder joint
      i. External (lateral) rotation of humerus – minor movement for the deltoid
5. To make these movements, the deltoid works with other muscles, e.g., the anterior portion works with the pectoralis major and coracobrachialis when flexing the humerus at the shoulder. The middle portion acts with the supraspinatus when abducting the arm. Deltoids are used everyday when swinging the arms during walking.

B. Deep intrinsic muscles

1. Supraspinatus
   a. *Supraspinatus* = superior to the spine (of the scapula)
   b. **Origin**: supraspinous fossa of scapula
   c. **Insertion**: greater tubercle of humerus
      i. Crosses over the top of the humeral head to insert on the superior aspect of the greater tubercle
   d. **Actions**:
      i. Abduction of humerus (with deltoid)
      ii. Stabilization of glenohumeral joint (with other rotator cuff muscles)
   e. The supraspinatus is the most commonly torn part of the rotator cuff
   f. The supraspinatus acts strongly when a heavy weight is carried with the upper arm adducted (e.g., when carrying a heavy suitcase)

2. Infraspinatus
   a. *Infraspinatus* = inferior to spine of the scapula
   b. **Origin**: infraspinous fossa of scapula
   c. **Insertion**: greater tubercle of humerus
      i. Passes transversely across the posterior aspect of humeral head to insert into the upper part of the posterior aspect of the greater tubercle
   d. **Actions**:
      i. External rotation of humerus
      ii. Stabilization of glenohumeral joint (with other rotator cuff muscles)
   e. Infraspinatus occupies most of the infraspinous fossa of the scapula
3. Teres Minor
   a. **Origin**: middle 1/3 of lateral border of scapula
   b. **Insertion**: greater tubercle of humerus
      i. Passes posterior to origin of long head of triceps to insert into the lower part of the posterior aspect of the greater tubercle
   c. **Actions**:
      i. External rotation of humerus
      ii. Stabilization of glenohumeral joint (with other rotator cuff muscles)
   d. Teres minor is an elongated, tapering muscle (often inseparable from infraspinatus), which lies along the inferior border of the infraspinatus.

4. Subscapularis
   a. **Subscapularis** = underside of scapula
   b. **Origin**: subscapular fossa, comprising anterior aspect of the scapula
   c. **Insertion**: lesser tubercle (on anterior aspect of humerus)
   d. **Actions**:
      i. Internal rotation of humerus
      ii. Stabilization of glenohumeral joint (with other rotator cuff muscles)

**PECTORAL REGION**

The pectoral region contains four muscles, all of which are attached to the pectoral girdle and are associated with movements of the pectoral girdle and upper limb.

**I. Pectoral (Shoulder) Girdle**

A. Connects the upper limb to the axial skeleton (skull, vertebral column, ribs)
B. Formed by:
   1. Clavicle
   2. Scapula
C. Although very mobile, the pectoral girdle is supported and stabilized by pectoral muscles

II. Pectoral Muscles

A. Pectoralis Major
   1. *Pectus* = chest; *major* = greater
   2. Origins:
      a. Clavicular head: anterior surface of the medial 1/2 of clavicle
      b. Sternocostal head:
         i. Anterior surface of sternum
         ii. Upper six costal cartilages
         iii. Aponeurosis of external oblique muscle
   3. Insertion: lateral lip of intertubercular groove of humerus
   4. Actions:
      a. Adduction of humerus
      b. Internal rotation of humerus
      c. When acting alone:
         i. Clavicular head: flexion of humerus
         ii. Sternoclavicular head: horizontal adduction

B. Pectoralis Minor
   1. *Pectus* = chest; *minor* = lesser
   2. Origin: ribs 3 to 5 near their costal cartilages
   3. Insertion: coracoid process (of scapula)
   4. Action: stabilization of scapula
      a. Pectoralis minor draws the scapula inferriorly and anteriorly against the body wall
      b. Pectoralis minor also rotates the scapula, tilting the glenoid cavity inferiorly (downward or inferior rotation)
C. Serratus Anterior
1. *Serratus* = saw; *anterior* = front
2. **Origin**: external surfaces of lateral parts of ribs 1 to 8
3. **Insertion**: anterior surface of medial border of scapula
4. **Actions**:
   a. Protraction of scapula; holds it against the body wall
   i. Protraction is similar to continuing the bench press movement past the perceived range of motion
   b. Upward rotation of scapula
5. Because it is active during punching, serratus anterior has been called the “boxer's muscle.” By fixing the scapula to the body, it acts as an anchor for this bone to produce movements of the humerus.

**ARM REGION**

There are four muscles in the arm; three flexors in the anterior compartment and one extensor in the posterior compartment.

I. **Anterior Muscles of the Arm**

A. Biceps Brachii
1. *Biceps* = two heads (i.e., two origins for this muscle); *brachii* = arm
2. **Origin**:
   a. Short head: coracoid process (of scapula)
   b. Long head: supraglenoid tubercle (of scapula)
3. **Insertion**: radial tuberosity
4. **Actions**:
   a. Supination of forearm
   b. Flexion of forearm (only when it is supinated; palm facing up)
5. **Relationships:**
   a. Biceps brachii is an important flexor of the elbow, but is more importantly the chief supinator of the forearm. There is no pronator corresponding in strength or mechanical advantage to biceps brachii; consequently, supination is a much stronger movement than pronation.
      i. Screws are made to turn clockwise, enabling insertion of the screw via supination by a right-handed person.
   b. Biceps brachii has no attachment to the humerus

6. When the elbow is extended, the biceps is a simple flexor of the forearm; it is also a powerful supinator when the forearm is flexed and when more power is needed against resistance (e.g., turning a screw into hard wood). The biceps barely operates at all during flexion of the prone forearm.

**B. Brachialis**

1. *Brachialis* = arm
2. **Origin**: distal half of anterior surface of humerus
3. **Insertion**: coronoid process and tuberosity (of ulna)
4. **Action**: flexion of forearm (in all positions)
5. **Relationships**:
   a. Lies posterior to (deep to) biceps brachii. This is the main flexor of the forearm. It flexes the forearm in all positions and in slow or quick movements. When the forearm is being extended slowly, the brachialis steadies the movement by slowly relaxing. It always contracts during flexion of the elbow joint and is primarily responsible for maintaining flexion. Because of this, it is the “workhorse” among the flexor muscles of the elbow.

**C. Brachioradialis**

1. *Brachi* = arm; *radialis* = attachment on the radial side (thumb side) of the wrist
2. **Origin**: upper 2/3 of supracondylar ridge (of humerus)
3. **Insertion**: styloid process (of radius)
   a. Becomes tendinous at mid-forearm
4. **Actions:**
   a. Flexion of forearm
      i. Occurs when forearm is pronated, i.e., when the palm of the hand faces the floor

   **II. Posterior Muscles of the Arm**

   A. **Triceps Brachii**
      1. *Triceps* = three heads (three origins for this muscle); *brachii* = arm
      2. **Origin:**
         a. Long head: infraglenoid tubercle (of scapula)
         b. Lateral head: upper 1/2 of posterior surface of humerus. The long and lateral heads of the triceps form a distinctive horseshoe shape in lean individuals.
         c. Medial head: lower 1/2 of posterior surface of humerus. The medial head actually lies between the long and lateral heads of the triceps (i.e., between the two sides of the “horseshoe”).
      3. **Insertion:** proximal end of olecranon process (of ulna)
      4. **Action:** extension of the forearm
         a. Triceps brachii is the chief extensor of the forearm
         b. Long head steadies the head of abducted humerus
      5. Because the long head of the triceps crosses the shoulder joint, it also aids in both extension and adduction of the arm
TRUNK REGION

The abdominal wall serves four primary functions. It protects the abdominal organs (e.g., liver). It is a repository for fat, especially for males. It aids in respiration and its muscles produce movements of the vertebral column.

I. Anterior Muscles of the Trunk

A. Rectus Abdominis
1. *Rectus* = straight or strap-like; *abdomino* = belly
2. **Origin**: pubic symphysis and pubic crest
3. **Insertion**: xiphoid process (of sternum) and costal cartilages 5 to 7
4. **Action**: flexion of trunk
   a. Primary flexor of lumbar vertebrae

B. External Oblique
1. *External* = closer to surface; *oblique* = diagonal
2. **Origin**: outer surfaces of ribs 5 to 12 (lower 8)
   a. Interdigitates with serratus anterior insertion
   b. Interdigitates with latissimus dorsi origin
3. **Insertions**:
   a. Linea alba
   b. Pubic tubercle
   c. Anterior 1/2 of iliac crest
4. **Actions**:
   a. Flexion of trunk
      i. When both act together
   b. Flexion and rotation of trunk to opposite side
      i. When acting separately
5. **Relationships:**
   a. Largest and most superficial of the three flat abdominal muscles
   b. Its fibers run inferoanteriorly and medially
      i. Similar to the direction one's fingers would be when inserting a hand into a pocket

C. **Internal Oblique**
   1. *Internal* = deep; *oblique* = diagonal
   2. **Origins:**
      a. Anterior 2/3 of iliac crest
      b. Lateral 1/2 of inguinal ligament
   3. **Insertions:**
      a. Inferior borders of ribs 10 to 12
      b. Linea alba
      c. Pubis
   4. **Actions:**
      a. Flexion of trunk
         i. When both act together
      b. Flexion and rotation of trunk to same side
         i. When acting separately and with a fixed pelvis (hip)
      c. Flexion and rotation of trunk to opposite side
         i. When acting separately and with a fixed thorax
   5. **Relationships:**
      a. Intermediate of the three flat abdominal muscles
         i. External oblique = most superficial
         ii. Transversus abdominis = innermost
      b. Fibers run superoanteriorly and at right angles to those fibers of external oblique
D. Transversus Abdominis

1. *Transverse* = horizontal; *abdomino* = belly
2. **Origins:**
   a. Internal surfaces of costal cartilages 7 to 12 (lower six)
   b. Iliac crest
   c. Lateral 1/3 of inguinal ligament
3. **Insertions:**
   a. Linea alba (with internal oblique)
   b. Pubic crest
4. **Action:** compression and support of abdominal organs
5. **Relationships:**
   a. Innermost of the three flat abdominal muscles
   b. Fibers run horizontally

II. **Posterior Muscles of the Trunk – Muscles of the Back**

A. **Erector Spinae**

1. *Erector* = to erect; *spinae* = spinal column
2. **Origin:**
   a. Broad tendon connected to the:
      i. Iliac crest
      ii. Sacrum
3. **Insertions:**
   a. All of the ribs
   b. Tips of transverse processes of all thoracic vertebrae
   c. Spinous processes of upper lumbar vertebrae and all thoracic vertebrae
4. **Actions:**
   a. Bilateral action
      i. Extension of the head and vertebral column
   b. Unilateral action
      i. Lateral flexion of the head and vertebral column
c. Erector spinae muscles are the chief extensors of the vertebral column
   i. Extend vertebral column from flexed to straight position
   ii. Extend vertebral column back, past straight

B. Quadratus Lumborum
1. \textit{Quad} = four; \textit{lumb} = lumbar region of back
2. Origins:
   a. 12\textsuperscript{th} rib (inferior border)
   b. Transverse processes of lumbar vertebrae
3. Insertions:
   a. Iliolumbar ligament
   b. Iliac crest
4. Actions:
   a. Extension of vertebral column
      i. Primarily for stabilization
   b. Lateral flexion of vertebral column
HIP AND THIGH REGION
Part I: Anterior Muscles

The primary purpose of the lower limb is to provide locomotion, bear the weight of the body, and maintain equilibrium (balance). It consists of four primary components: the hip, the thigh, the leg and the foot. Although there are major differences, the parts of the lower limb are similar to those of the upper limb, i.e., the anatomy from the hip to the foot is similar to that from the shoulder to the hand.

The hip and thigh area include the structures between the iliac crest and the knee. The hip is the region between the iliac crest and the greater trochanter of the femur. The thigh includes the area between the greater trochanter of the thigh and the knee, i.e., between the hip and knee.

I. Muscles of the Thigh
   A. Anterior thigh muscles
      1. Iliopsoas (composed of psoas major and iliacus muscles)
         a. Psoas Major
            i. Psoa = muscle of loin; major = greater
            ii. Origin: sides of T-12 to L-5 vertebrae and intervertebral discs between them
            iii. Insertion: lesser trochanter (of femur)
            iv. Action: flexion of thigh at hip joint (major action)
               a) Stabilization of hip joint
               b) Flexion of the trunk
         b. Iliacus
            i. Iliacus = pertaining to the ilium (hip)
            ii. Origins:
               a) Iliac crest
               b) Iliac fossa
               c) Anterior sacroiliac ligaments
            iii. Insertion: tendon of psoas major (to lesser trochanter)
               a) Inserts on lateral side of psoas major
iv. **Action**: flexion of thigh at hip joint (main action)
   a) Stabilization of hip joint
   b) Flexion of the trunk

c. Iliopsoas is the strongest flexor of the thigh at the hip joint

2. **Tensor Fasciae Latae**
   a. *Tensor* = tightener; *fascia* = band; *latus* = wide
   b. **Origin**: anterior superior iliac spine; part of iliac crest
   c. **Insertion**: iliotibial tract (that attaches to lateral condyle of tibia)
   d. **Actions**:
      i. Tightens the fascia lata (a band of connective tissue that surrounds the thigh muscles)
         a) Enables thigh muscles to act with increased power
      ii. Tightens iliotibial tract
         a) Enables gluteus maximus muscle to keep knee joint in the extended position
      iii. Abduction of thigh at the hip joint
      iv. Medial (inward) rotation of thigh at the hip joint
      v. Flexion of thigh at the hip joint

3. **Sartorius**
   a. *Sartor* = tailor
      i. Sartorius is so named because it crosses the legs in the tailor's squatting position
   b. **Origin**: anterior superior iliac spine
   c. **Insertion**: superior part of medial surface of tibia
      i. The insertion of the sartorius, along with the gracilis and the semitendinosus, is part of the *pes anserinus* (*pes* = foot; *anserinus* = goose), a common fan-like insertion into the tibia.
d. **Actions:**

i. At the hip
   a) Flexion of thigh at the hip joint
   b) Abduction of thigh at the hip joint
   c) Lateral rotation of thigh at the hip joint

ii. At the knee
   a) Flexion of leg at knee joint

iii. Sartorius only assists with these actions

e. **Relationships:**

i. Longest muscle in the body

ii. Most superficial muscle in the anterior thigh

4. **Quadriceps Femoris**

a. *Quad* = four; *capital* ("ceps") = heads; *femoris* = thigh

b. Four parts (heads)

i. Rectus Femoris
   a) *Rectus* = straight
   b) **Origin:** anterior inferior iliac spine
   c) **Insertions:**
      i) Tibial tuberosity via patellar ligament
      ii) Patellar base
   d) **Actions:**
      i) Extension of leg at knee joint
      ii) Steadies hip joint
      iii) Helps iliopsoas with flexion of thigh at hip joint

ii. Vastus Lateralis
   a) *Vastus* = large; *lateral* = toward outside (away from the midline)
   b) **Origin:** greater trochanter and lateral lip of linea aspera of femur
c) **Insertions:**
   i) Tibial tuberosity via patellar ligament
   ii) Patellar base

d) **Action:** extension of leg at knee joint

iii. Vastus Medialis
   a) *Vastus* = large; *medial* = toward midline
   b) **Origin:** intetrochanteric line and medial lip of linea aspera of femur
   c) **Insertions:**
      i) Tibial tuberosity via patellar ligament
      ii) Patellar base
   d) **Action:** extension of leg at knee joint

iv. Vastus Intermedius
   a) *Vastus* = large; *intermedius* = middle
   b) **Origin:** anterior and lateral surfaces of femur
   c) **Insertions:**
      i) Tibial tuberosity via patellar ligament
      ii) Patellar base
   d) **Action:** extension of leg at knee joint

c. **Relationships:**
   i. Tendons of the four parts of the muscle unite to form the qudriceps tendon, which attaches to and surrounds the patella and continues as the patellar tendon (or ligament) to attach to the tibial tuberosity
   ii. All parts of quadriceps femoris, acting through the patellar ligament, extend the leg at the knee joint
   iii. Used during climbing, running, jumping, and rising from a chair
B. Medial thigh muscles

1. Adductor Longus
   a. \textit{Longus} = long
   b. \textbf{Origin}: body of pubis, inferior to pubic crest
   c. \textbf{Insertion}: middle 1/3 of linea aspera of femur
   d. \textbf{Action}: adduction of thigh
   e. \textbf{Relationship}: most anterior adductor muscle

2. Adductor Magnus
   a. \textit{Magnus} = large
   b. There are two portions to this muscle
      i. Adductor part
      ii. Hamstring part
   c. \textbf{Origins}:
      i. Inferior ramus of pubis
      ii. Ramus of ischium (adductor part)
      iii. Ischial tuberosity
   d. \textbf{Insertions}:
      i. Adductor part
         a) Gluteal tuberosity
         b) Linea aspera
         c) Supracondylar line
      ii. Hamstring part
         a) Adductor tubercle of femur
   e. \textbf{Actions}:
      i. Adduction of thigh
      ii. Flexion of thigh at hip joint (adductor part)
      iii. Extension of thigh at hip joint (hamstring part)
3. Gracilis
   a. *Gracilis* = slender
   b. **Origin**: body and inferior ramus of pubis
   c. **Insertion**: superior part of medial surface of tibia
      i. The insertion of the gracilis, along with the sartorius and the semitendinosus, is part of the *pes anserinus* (*pes* = foot; *anserinus* = goose), a common fan-like insertion into the tibia.
   d. **Actions**:
      i. Adduction of thigh at hip joint
      ii. Flexion of leg at knee joint
      iii. Assists with medial rotation of leg at knee joint
   e. **Relationships**:
      i. Most superficial of the adductors
         a) Therefore it is the most medial muscle of the thigh
      ii. Weakest adductor muscle
         a) Gracilis can be removed without noticeable loss of function
         b) Surgeons often transplant gracilis to replace a damaged muscle
      iii. Only adductor muscle to cross the knee joint
GLUTEAL REGION

The gluteal region lies posterior to the pelvis. The region is bounded superiorly by the iliac crest and inferiorly by the inferior (lower) border of the gluteus maximus muscle. The gluteal muscles consist of the larger, more superficial gluteals (maximus, medius, and minimus) and a smaller, deeper group which are primarily lateral rotators of the thigh (piriformis, obturator internus, gemelli, quadratus femoris, and obturator externus).

I. Gluteal Muscles

A. Gluteus Maximus

1. *Gloutos* = rump; *maximus* = greatest

2. Origins:
   a. Iliac crest
   b. Sacrum and coccyx
   c. Sacrotuberous ligament

3. Insertions:
   a. Iliotibial tract (to lateral condyle of tibia)
   b. Gluteal tuberosity of femur
      i. Very few fibers insert here (less than 1/4 the total number of fibers)

4. Actions:
   a. Extension of thigh at hip joint
      i. Its main function is to bring the thigh from a flexed position into line with the body (e.g., climbing stairs)
      ii. Gluteus maximus is used very little during “normal” walking
   b. Lateral rotation (assists)
   c. Stabilization of knee joint
      i. Due to its large insertion into the iliotibial tract, gluteus maximus also helps keep the knee in extension, thereby securing stability
5. Relationships:
   a. Gluteus maximus is one of the strongest muscles in the body
   b. It is particularly well developed in humans (i.e., the upright position)
   c. When standing (during hip extension), gluteus maximus covers the ischial tuberosity; while seated (during hip flexion), the inferior border of the muscle slides superiorly, leaving the ischial tuberosity a subcutaneous structure
   d. Gluteus maximus provides a very gross-type movement
      i. One nerve fiber innervates a very large number of muscle fibers (compared to the muscles of the eye)
   e. If gluteus maximus is paralyzed, an individual will have difficulty walking up stairs or an incline or standing from an upright position
      i. Actions of the hamstring muscles will allow movement along flat surfaces

B. Gluteus Medius
   1. *Gloutos* = rump; *medius* = middle
   2. Origin: external surface of ilium, between anterior and posterior gluteal lines
   3. Insertion: lateral surface of greater trochanter of femur
   4. Actions:
      a. Abduction of thigh at hip joint
      b. Medial rotation of femur at hip joint
      c. Steadies pelvis

II. Lateral Rotators of the Thigh

A. Piriformis
   1. *Piriform* = pear-shaped
   2. Origin:
      a. Sacrum
      b. Sacrotuberous ligament
      c. SI joint capsule
3. **Insertion:**
   a. Trochanteric fossa of the femur

4. **Actions:**
   a. External hip rotation (when thigh is extended)
   b. Hip abduction (when thigh is flexed)
   c. SI and hip joint stabilization

B. Obturator Internus
C. Superior Gemellus
D. Inferior Gemellus
E. Quadratus Femoris
F. Obturator Externus

**HIP AND THIGH REGION**

**Part II: Posterior Muscles**

The three large muscles in the posterior compartment of the thigh are collectively termed the hamstring muscles. The hamstrings have a common origin at the ischial tuberosity. The hamstrings span both the hip and knee joints and therefore act at both joints; however, they are not able to perform both movements fully at the same time.

**I. Posterior Thigh Muscles**

A. **Semitendinosus**
   1. *Semi* = half; *tendin* = tendon (“half-tendon” for its long inferior tendon)
   2. **Origin:** ischial tuberosity
   3. **Insertion:** superomedial tibia
   4. **Actions:**
      a. Extension of thigh at hip joint, from a straight to an extended position
      b. Flexion of leg at knee joint
      c. Medial rotation of leg at knee joint
B. Semimembranosus

1. **Semi** = half; **membran** = membrane ("half-membrane" for its superior membranous portion)

2. **Origin**: ischial tuberosity

3. **Insertion**: posterior part of medial condyle of tibia

4. **Actions**: (same as semitendinosus)
   a. Extension of thigh at hip joint, from a straight to an extended position
   b. Flexion of leg at knee joint
   c. Medial rotation of leg at knee joint

5. **Relationships**:
   a. Lies deep to both semitendinosus and biceps femoris

C. Biceps Femoris

1. **Origins**:
   a. Long head: ischial tuberosity
   b. Short head: lateral lip of linea aspera and lateral supracondylar line
   c. Short head of biceps femoris lies deep to long head of biceps femoris and semitendinosus

2. **Insertion**: lateral side of fibular head

3. **Actions**:
   a. Flexion of leg at knee joint
   b. Lateral rotation of leg at knee joint
   c. Extension of thigh at hip joint, from a straight to an extended position (e.g., when starting to walk)
**LEG REGION**

The leg is the inferior part of the lower limb, between the knee and ankle joints. While the entire lower limb is commonly referred to as the leg, only the area between the knee and ankle joints is the anatomical leg. The tibia and fibula are the bones of the leg, with the tibia being the primary weight bearing bone of the leg.

I. **Muscles of the Leg**

A. **Anterior compartment**

There are four muscles of the anterior compartment, all of which are primarily concerned with dorsiflexion of the ankle joint and extension of the toes. Only one of these four muscles will be discussed here.

1. **Tibialis Anterior**
   a. *Tibialis* = tibia; *anterior* = front
   b. **Origin:** superior 1/2 of lateral surface of tibia
   c. **Insertions:**
      i. Base of 1<sup>st</sup> metatarsal bone
      ii. Medial cuneiform bone
   d. **Actions:**
      i. Dorsiflexion of foot at ankle joint
      ii. Inversion of foot
   e. **Relationships:**
      i. Chief muscle to dorsiflex and invert the foot
      ii. Used when walking to prevent stubbing of the toes as the advancing limb swings forward

B. **Lateral compartment (peronei) – evertors of the foot**

1. The primary function of the evertors of the foot is to resist inversion of the foot, especially in the plantar flexed position, when the ankle is least stable

2. **Peroneus Brevis**
3. Peroneus Tertius
   a. Actually part of the anterior compartment

4. Peroneus Longus
   a. *Perone* = fibula; *longus* = long
   b. **Origin**: head and superior 2/3 of lateral surface of fibula
   c. **Insertions**:
      i. Base of 1st metatarsal bone
      ii. Medial cuneiform bone (located behind the first metatarsal)
         a) These insertions are near those of tibialis anterior
   d. **Actions**:
      i. Eversion of foot
      ii. Plantarflexion, weak movement

C. Posterior compartment

1. Gastrocnemius
   a. *Gaster* = belly; *kneme* = leg
   b. **Origins**:
      i. Lateral head: lateral aspect of lateral condyle of femur
      ii. Medial head: popliteal surface (area of the “back of the knee”) of femur, superior to medial condyle of femur
   c. **Insertion**: posterior calcaneus, via Achilles tendon
   d. **Actions**:
      i. Plantarflexion of foot at ankle joint
      ii. Flexion of leg at knee joint
      iii. Raises heel during walking
   e. **Relationships**:
      i. Most superficial posterior leg muscle
      ii. In order for gastrocnemius to perform plantarflexion, the knee must be in extension. Any muscle that crosses two joints cannot simultaneously act maximally at both joints. Therefore, to plantarflex, gastrocnemius must not be flexing the knee.
iii. The two heads form a single muscle less than halfway down the calf, where it becomes a wide, flat tendon

2. **Soleus**
   a. *Sole* = fish (so named due to its resemblance to sole, a flat fish)
   b. **Origins:**
      i. Posterior aspect of head of fibula
      ii. Superior 1/4 posterior surface of fibula
      iii. Soleal line of the tibia
      iv. Medial border of tibia
   c. **Insertion:** posterior calcaneus, via the Achilles’ tendon
   d. **Action:** plantarflexion of foot at ankle joint (primary action)
   e. **Relationships:**
      i. Soleus is the largest muscle of the leg
      ii. It is a very powerful muscle, but it has slower contractions than gastrocnemius