ANATOMY OF *Movement*

REVISED EDITION

Blandine Calais-Germain

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Anatomy of Movement presents a dynamic, integrated approach to the study of the physical structures of the musculoskeletal system and their functional relationship to the movements of the human body.

In clear and concise text illustrated with more than a thousand graphic drawings, the author guides the reader on a lively tour of the muscles, bones, ligaments and joints of the arms, legs and trunk. The focus throughout the book is on anatomy not for its own sake, but in its functional relationship to the actual movements of the body in dance, exercise, and other physical disciplines.

Blandine Calais-Germain is the celebrated author of *Anatomy of Movement, Anatomy of Movement: Exercises, The Female Pelvis: Anatomy and Exercises,* and *Anatomy of Breathing.* Her lifelong involvement with dance, both as performer and teacher, led to an interest in other physical disciplines and to more formal study of the complex and integrated movements of the body. She studied physiotherapy at the French School of Orthopedics and Massage in Paris, and subsequently developed an innovative method for teaching the physical structures of anatomy in relation to movement, which she teaches at workshops in France to students from all over the world.

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Blandine Calais-Germain

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Dedicated to Marie, Patrick, Jacques, Francois

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Foreword

Anatomists, for many centuries, were concerned almost exclusively with precise description of the body's structures. Inevitably, they began by treating the locomotor system in the same way as the internal organs, i.e., actual functions were either unknown or described independently of structure.

Gradually, around the beginning of the 20th century, anatomists began paying more attention to the actions of muscles and joints. Such functional studies remained at an elementary level for several decades. More recently, some researchers began looking at biomechanical properties (such as elasticity and resistance) of the locomotor system. However, these studies were focused on isolated components in the laboratory, not on how muscles and joints are used in "real life." Functional aspects were often viewed in terms of "efficiency," i.e., how to make the body an obedient instrument of various physical disciplines.

In physiotherapy, body movements are analyzed in terms of both neurophysiological and mechanical components, thus allowing better definition of therapeutic effects and the real mechanisms of movement.

Many people interested in physical disciplines such as dance, mime, theater, yoga, relaxation, etc. have come to physiotherapy looking for quantitative as well as qualitative analytical studies which would facilitate their practice. In this way, Blandine Calais-Germain began by studying dance and ended up studying physiotherapy.

The complementary nature of these two ways of dealing with human body movements is obvious. Blandine quickly realized that dancers could benefit greatly from a better understanding of their "inner" bodies. She devised a novel teaching method to serve this purpose: the simultaneous representation of physical structures and their possible movements, designed to facilitate actual execution by the dancer.

Not only dancers, but also professionals involved in other physical disciplines, came in increasing numbers to her classes. The emphasis in these classes (and this book) is on anatomy not for its own sake, but for better understanding of body movements.

I have taken great pleasure in witnessing the birth of this concept, the first classes, and now the publication of this book which embodies Blandine's many years of experience as a dancer and teacher. I am delighted that the fruits of this experience will now be made widely available to others. Having worked closely with Blandine when she was a student of physiotherapy, I can attest to her skills as a therapist, her intelligence, and her love for teaching.

The drawings in this book are all original, and the emphasis is always on description and understanding of natural postures and movements. The book will be particularly useful to those who, by profession, deal with integrated or complex movements of the body. For those who deal with human anatomy in any way, it will provide a useful and thought-provoking resource. I wish for this book the great success it deserves.

Dr. Jacques Samuel
Director, French School of Orthopedics and Massage
Paris, France

Preface

I would like to briefly describe the content and organization of this book.

This is intended simply as an introductory text. The emphasis is on basic human anatomy as it relates to *external body movement.* Therefore, we will be concerned mainly with bones, muscles, and joints. There will be no description of the skull, visceral organs, circulatory system, central nervous system, etc.

The book is designed to be as compact as possible, and to avoid repetition. Thus, format may vary from one chapter to the next. Parts of the body that are affected by the same muscles may be described together. Reference may be given to a previous page where a certain structure or function is described in more detail.

For consistency and ease of orientation, drawings usually show structures from the right side of the body. Exceptions are clearly indicated.

Joints are sometimes drawn without the adjacent bones, so that the articular surfaces can be more clearly seen. Similarly, each muscle is drawn in isolation (without surrounding muscles) to make its function more obvious.

Chapter 1 provides basic orientation and terminology, and should be read first. Subsequent chapters are arranged in a logical order (starting with the trunk, moving down the arm, and then down the leg), and I recommend that they be read in this order. However, the reader with previous knowledge of anatomy may start at any chapter.

The index will be helpful for locating the page where a particular structure is first mentioned, or described in detail.

CHAPTER ONE

Introduction

Anatomical position

The anatomy of movement, in the human body, mainly involves interaction of three systems:

- the **bones** of the skeleton,
- linked together at the **joints,**
- are moved by action of the **muscles.**

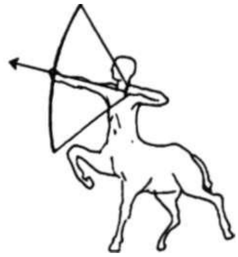
Description of movements can be difficult.
Various parts of the body can move in many different directions. Often more than one joint is involved.
For consistency, the following conventions are generally followed:

- we begin by considering each joint in isolation;
- three perpendicular planes are used for reference;
- movements are described in relation to a standard "anatomical position" in which the body is standing upright, the feet parallel, the arms hanging by the sides, and the palms and face directed forward (see illustration). This position is not a common posture, but it is helpful for reference purposes to describe the starting point of a movement.

Example: flexion of the wrist is a movement that takes the hand forward from the anatomical position

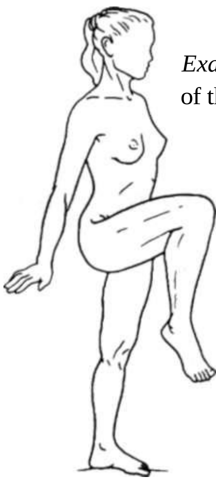
Planes of movement

The **median plane** divides the body into symmetrical right and left halves.

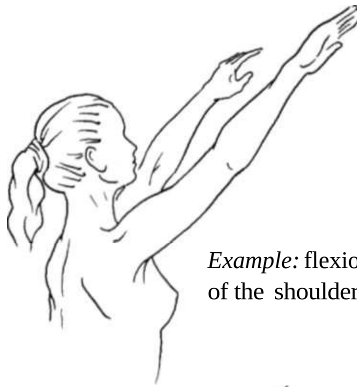


Any plane parallel to the median plane is called a **sagittal plane.** Movements in this plane can be seen from the side.

A movement in a sagittal plane which takes a part of the body forward from anatomical position is called **flexion.**



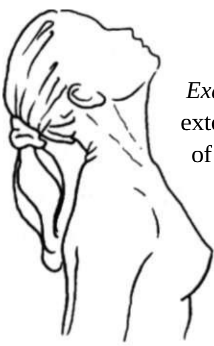
Example: flexion of the hip



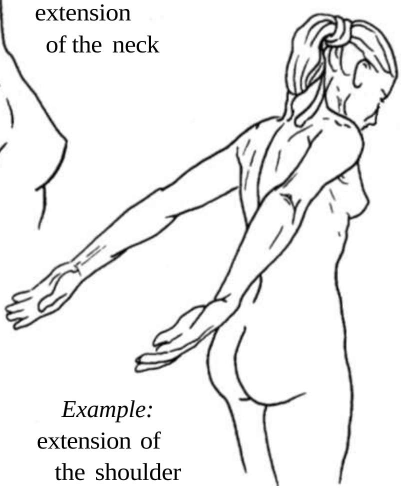
Example: flexion of the shoulder

Exception: flexion (dorsiflexion) of the ankle

A movement in a sagittal plane which takes a part of the body backward from anatomical position is called **extension.**



Example: extension of the neck



Example: extension of the shoulder

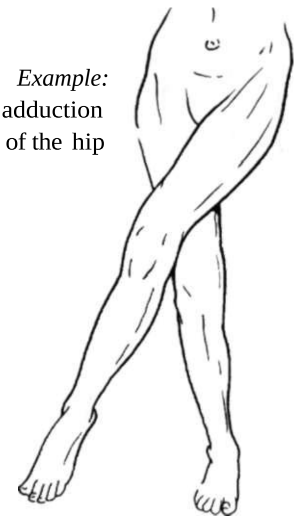
Exception: flexion of the knee

Exception: extension (plantarflexion) of the ankle

A coronal or **frontal plane** is any plane perpendicular to the median plane. It divides the body into anterior and posterior parts.

Movements on the frontal plane can be seen from the front.

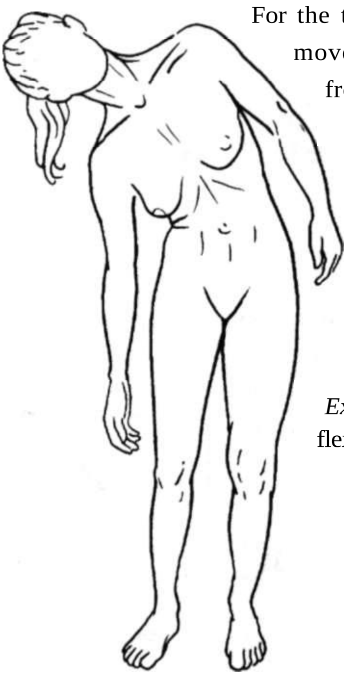
A movement in a frontal plane which takes a part of the body toward the median plane is called **adduction.**



Example: adduction of the hip

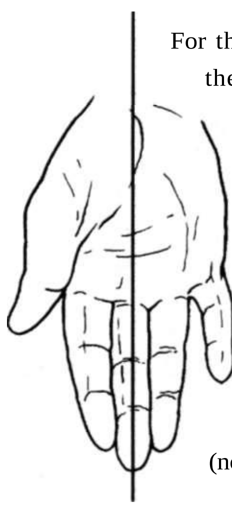
The opposite type of movement (away from the median plane) is called **abduction.**

Example: abduction of the shoulder



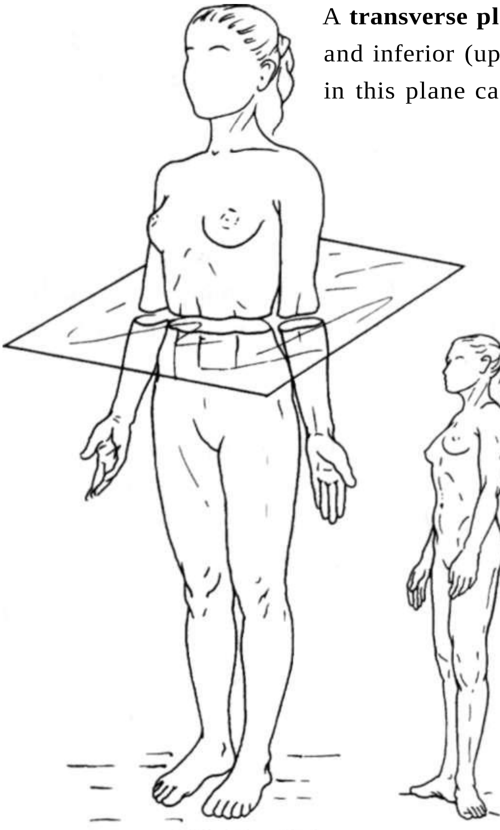
For the trunk or neck, movement in the frontal plane away from the median plane is called **lateral flexion** or **sidebending.**

Example: right lateral flexion of the trunk



For the fingers or toes, the reference used is the axis of the hand (middle finger) or foot (2d toe).

Example: abduction of the fifth finger moves it away from the axis of the hand (not from the median plane)



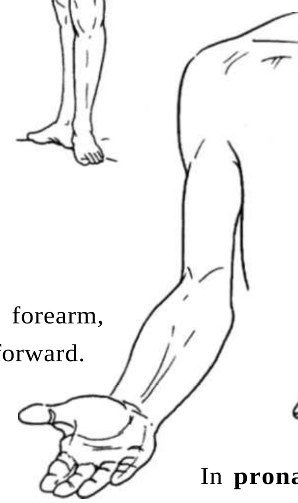
A **transverse plane** divides the body into superior and inferior (upper and lower) parts. Movements in this plane can be seen from the top or bottom.

A movement in a transverse plane which takes a part of the body outward is called **lateral rotation.**

Example: lateral rotation of the hip (the part being moved here is the front of the thigh)

The opposite type of movement (inward) is called **medial rotation.**

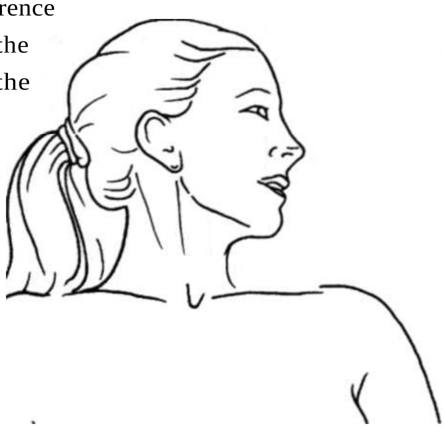
Example: medial rotation of the shoulder (the part being moved is the front of the upper arm)



In **supination** of the forearm, the palm faces upward or forward.

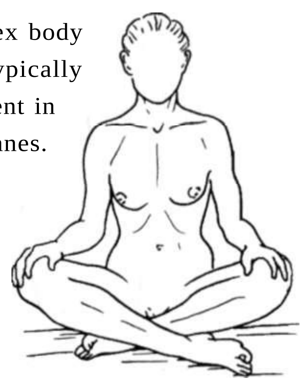
In **pronation** of the forearm, the palm of the hand faces downward or backward.

For the trunk or neck, we refer simply to right or left rotation. The reference point is the front of the chest or head.



Complex body movements typically involve movement in all three planes.

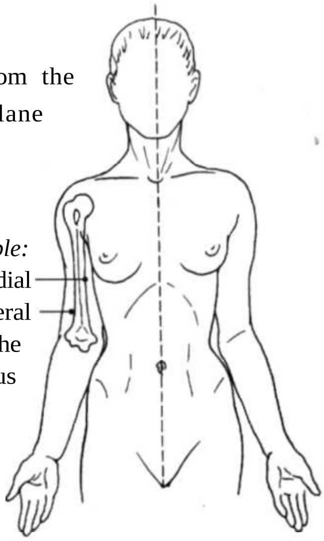
Example: sitting in the "tailor's position" involves flexion, abduction, and lateral rotation of the hip joints



Other anatomical reference terms

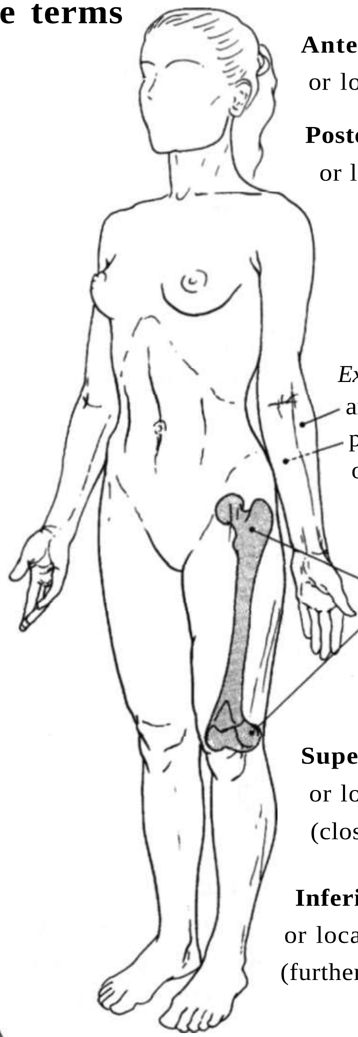
Medial: closer to the median plane

Lateral: further from the median plane



Anterior: facing toward or located at the front

Posterior: facing toward or located at the back

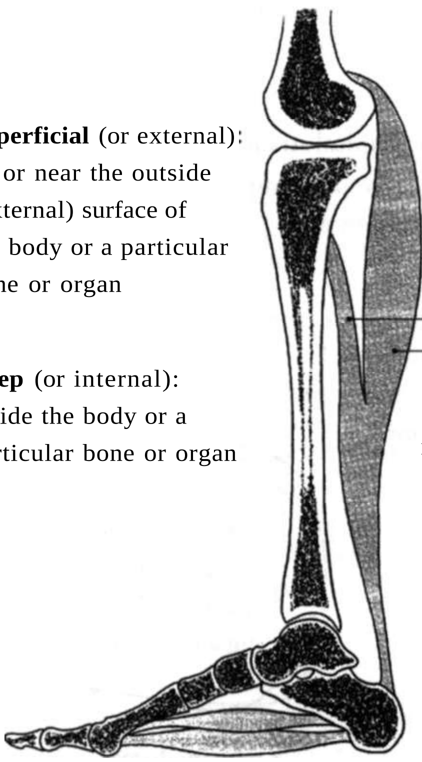


Superior: facing toward or located at the top (closer to the head)

Inferior: facing toward or located at the bottom (further from the head)

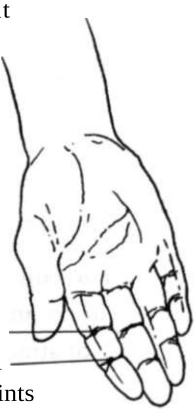
Superficial (or external): on or near the outside (external) surface of the body or a particular bone or organ

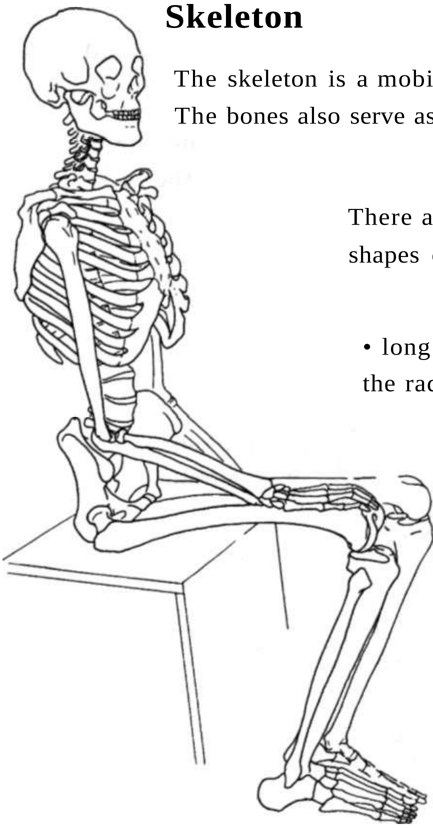
Deep (or internal): inside the body or a particular bone or organ



Proximal: closer to the trunk, or some major joint

Distal: further from the trunk, or some major joint



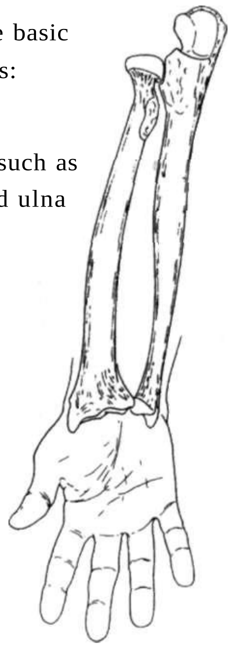


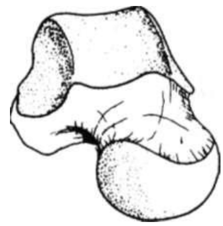
Skeleton

The skeleton is a mobile framework of bones providing rigid support for the body. The bones also serve as levers for the action of muscles.

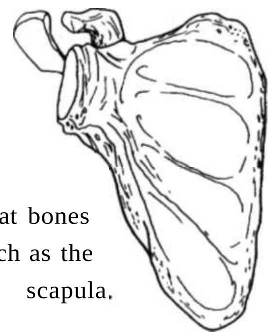
There are three basic shapes of bones:

- long bones such as the radius and ulna



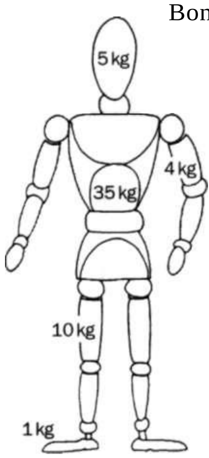


- short bones such as the talus (ankle bone)



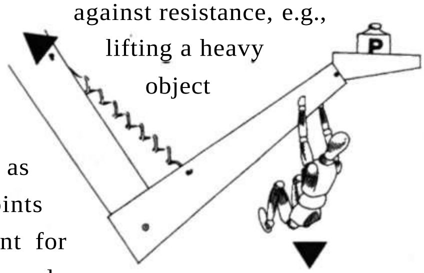
- flat bones such as the scapula.

Bone tissue consists of about two-thirds mineral components (mostly calcium salts), which give rigidity, and one-third organic components, which give elasticity.
Both these qualities are essential. Without rigidity bones would not keep their shape, but without some elasticity they would shatter too easily.

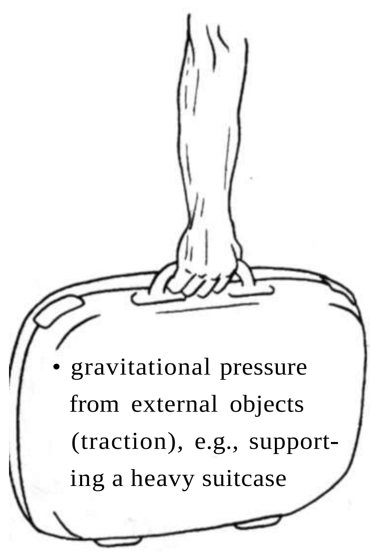


Bones are subjected to several types of mechanical strain:

- gravitational pressure from the body itself. Bones (particularly those of the feet, legs, and back) must support the weight of the body.
- movement (muscle contraction) against resistance, e.g., lifting a heavy object



The bones act as levers and points of attachment for the muscles.

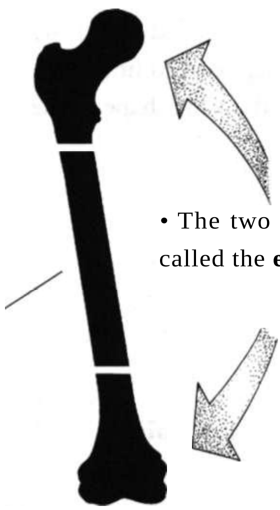


- gravitational pressure from external objects (traction), e.g., supporting a heavy suitcase
- twisting forces.

Bones

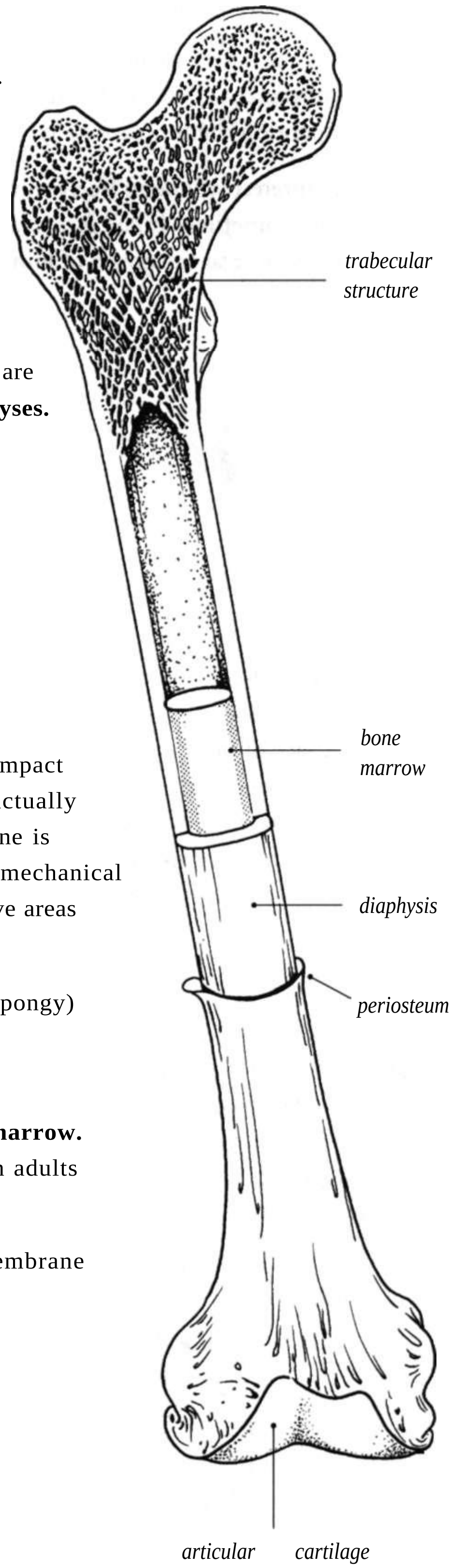
The structure of the bones shows us that
they are made to withstand all these types of strain.
We can see how by looking at a bone in cross section.

A long bone,
in this case the femur,
consists of three parts.



• The two ends are called the **epiphyses.**

• The central shaft is called the **diaphysis.**



The diaphysis is a hollow tube with walls made of compact bone. The hollow structure gives light weight and is actually sturdier than a solid structure would be. Compact bone is thickest in the middle section of the diaphysis where mechanical strains are greatest. It also predominates in the concave areas of the curved ends.

A cross section of the epiphysis shows a **trabecular** (spongy) **structure.** Fibers are arranged in rows along the lines of greatest mechanical stress.

The hollow part of the diaphysis contains the **bone marrow.** The marrow is red in children, but becomes yellow in adults as much of it is replaced by fatty tissue.

The external surface of the bone is covered with a membrane called the **periosteum.**

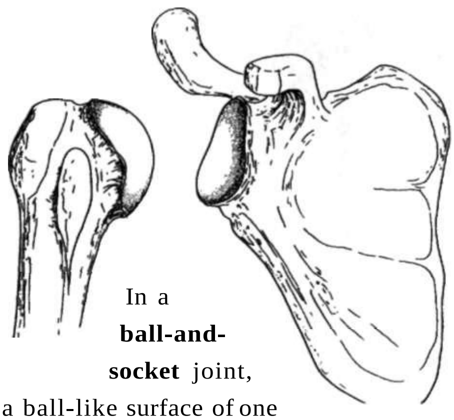
The articular surfaces of the bones are covered with **articular (hyaline) cartilage.**

Joints

Joints are areas where bones are linked together. They have varying degrees of mobility.

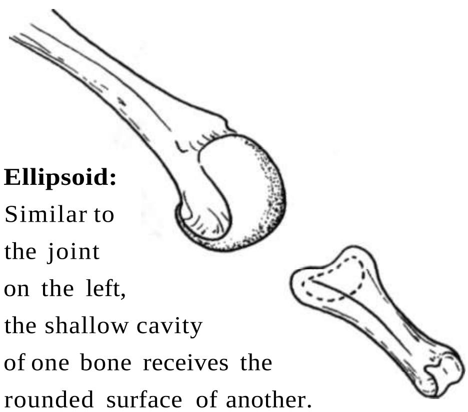
In some joints the bones are linked simply by fibrous connective tissue or cartilage. This allows little or no movement. These joints are not of great interest in a book about movement, but we will mention them occasionally.

Our primary interest will be in freely-movable joints called **diarthroses,** or **synovial joints.** These surfaces (sometimes called facets) are shaped so as to fit together but also allow movement. There are many general categories of joints, based on the shape of the articulating surfaces.



In a **ball-and-socket** joint, a ball-like surface of one bone fits into a cup-like depression of another bone. This type of joint, also called an enarthrodial or spheroidal joint, allows movement in all directions.

Examples: shoulder

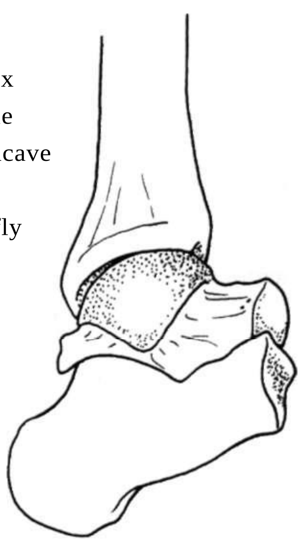


Ellipsoid: Similar to the joint on the left, the shallow cavity of one bone receives the rounded surface of another. This allows movement in all three planes described on pages 8-10.

Examples: metacarpophalangeal

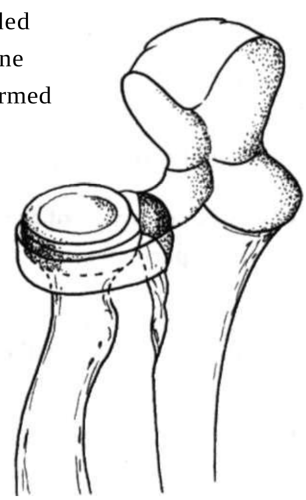
Hinge: The convex surface of one bone fits against the concave surface of another. Movement is chiefly in one plane.

Examples: ankle



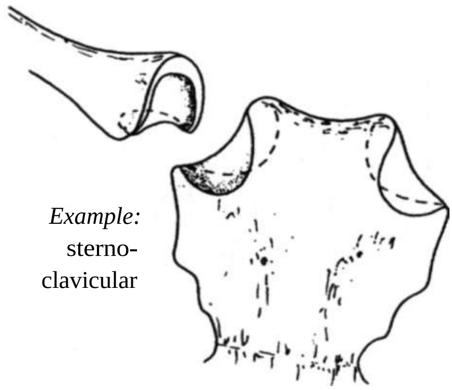
Pivot: The rounded surface of one bone fits into a ring formed partly by another bone. Movement is chiefly in one direction, like the hinge of a door.

Examples: radioulnar



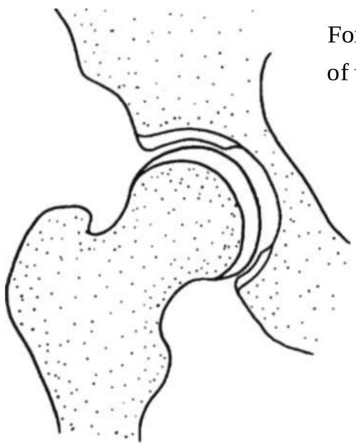
Saddle: Both surfaces are saddle-shaped, i.e., convex in one direction and concave in the other.

This permits movement in two planes.



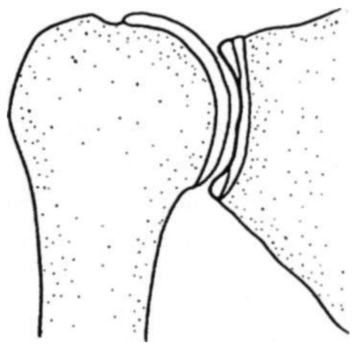
Example: sterno-clavicular

The articulating surfaces in a joint do not always make a snug fit. Some joints are more stable than others.



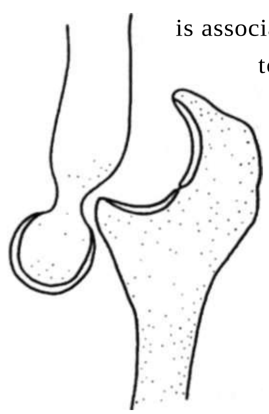
For example, the ball-and-socket structure of the hip is deep and snug-fitting.

By contrast, the ball-and-socket of the shoulder is shallow, looser and less stable.



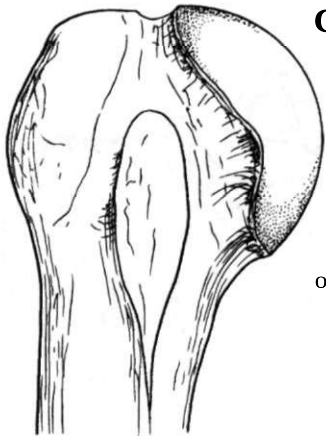
Between the articulating ends of the two bones in a joint is a gap which is not opaque to X-rays. This corresponds to the articular cartilages and synovial cavity. When you look at the X-ray, you can only see the thickness of the cartilages in the joint. The cartilages themselves are not visible on X-ray. Thus, it looks like there is a free space between the two bones.

In a dislocation or subluxation, a bone is moved from its normal position in a joint because of some trauma. There is associated damage to ligaments, etc.



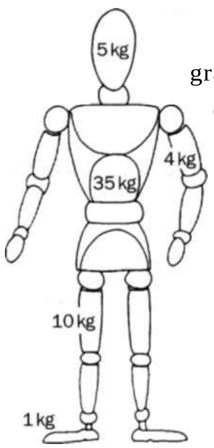
Cartilage

Articulating surfaces of bones are covered with a shiny, whitish connective tissue called cartilage. It contributes to the synovial capsule and also protects the underlying bone tissue.



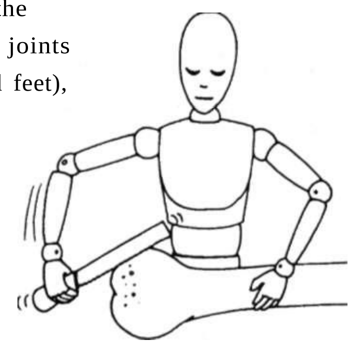
Example: cartilage of the head of the humerus

When movement occurs, joint cartilage is subjected to two types of stress:



gravitational pressure (particularly in the weight-bearing joints of the legs and feet),

...and friction from the movement itself.

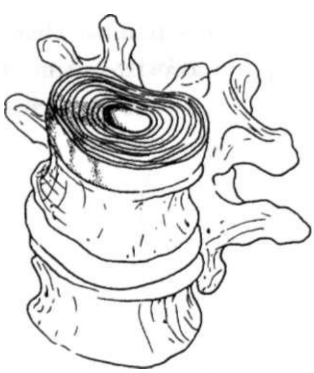


Cartilage is well-adapted to these stresses, being strong, resilient, and smooth. Thus it can allow some sliding of the bones relative to each other.

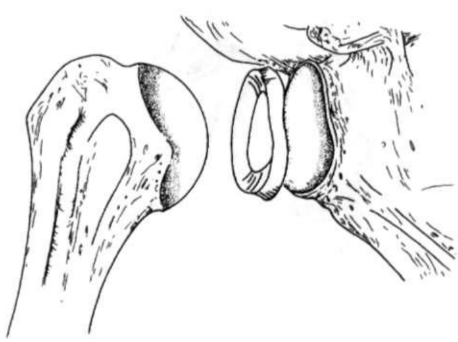
Nevertheless, cartilage may be damaged either by trauma or excessive wear (e.g., when the ends of the articulating bones do not provide a good "fit"). Rheumatoid arthritis and osteoarthritis are two common diseases involving damage to joint cartilage, accompanied by inflammation, pain, and stiffness of the joint and surrounding muscles.

Joint cartilage (like all cartilage) does not contain blood vessels. It receives nutrients from the synovial fluid and the bone it covers.

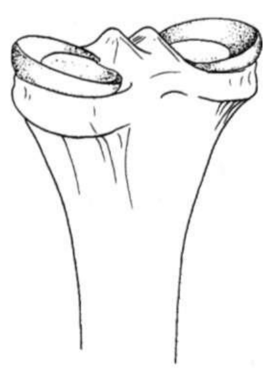
Fibrocartilage contains high concentrations of collagenous (white) fibers and is specially adapted for absorbing shock. It is found in the intervertebral discs and in the menisci (articular discs) of the knee and other large joints.



intervertebral discs



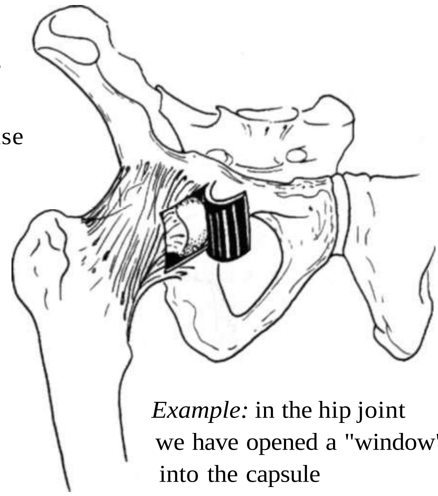
fibrocartilagenous padding
(e.g., in shoulder joint)



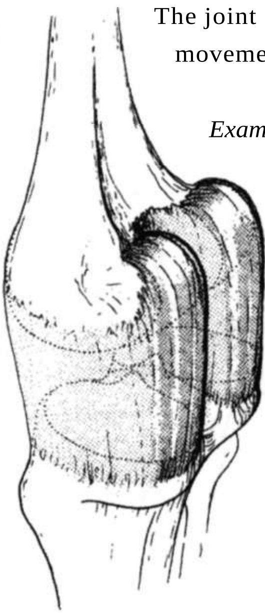
menisci

Joint capsule

This sleeve-like structure encloses the joint, prevents loss of fluid, and binds together the ends of the articulating bones. The outer layer of the capsule is composed of dense connective tissue and represents a continuation of the periosteum.



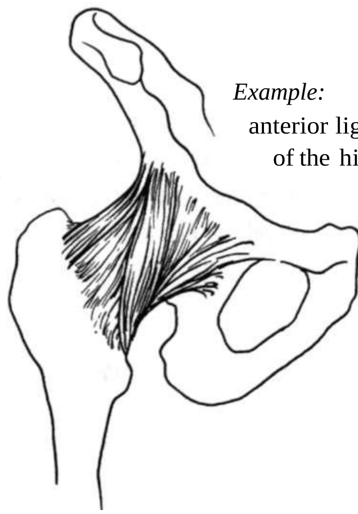
Example: in the hip joint we have opened a "window" into the capsule



The joint capsule is stronger where movement must be prevented.

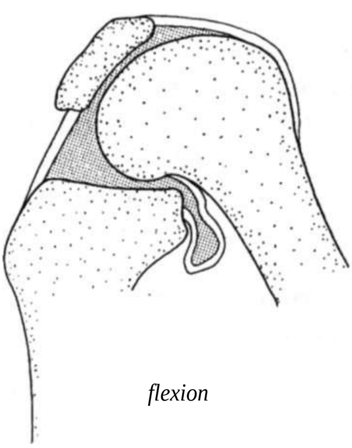
Example: the knee joint (starting from anatomical position) allows only flexion. The capsule is strongly reinforced posteriorly to prevent extension.

Fibers of the outer capsule are often arranged in parallel bundles (called **ligaments;** see following section) to reinforce joints and prevent unwanted movement.

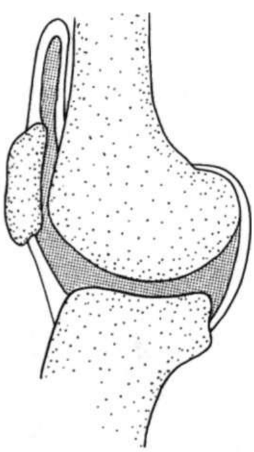


Example: anterior ligaments of the hip joint

The capsule may be arranged loosely or in folds where movement is possible.



flexion

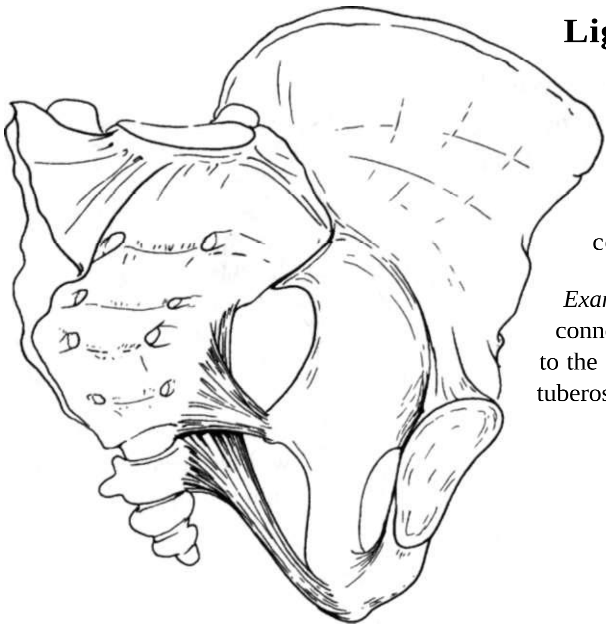


extension

Example: the capsule of the knee is loose in the front to allow flexion, and becomes folded during extension

The interior of the capsule is covered by a **synovial membrane,** which covers the deep surface of the capsule and folds over at the capsular insertions. Its principal function is to secrete **synovial fluid** (shown as gray in the drawing) that fills the articular cavity.

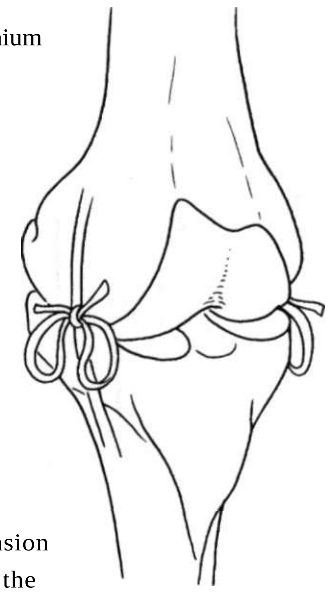
This fluid lubricates the joint and provides nutrients to the cartilage.



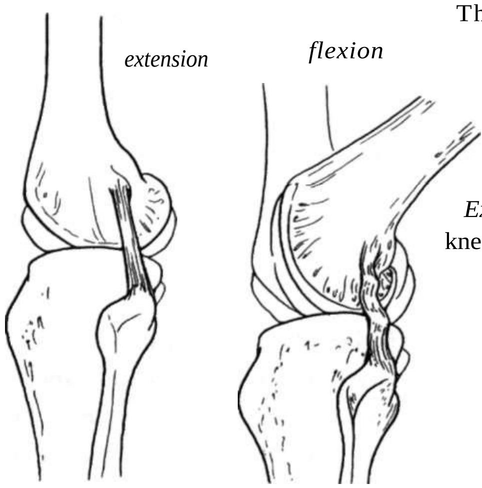
Ligaments

Ligaments are dense bundles of parallel collagenous fibers. They are often derived from the outer layer of the joint capsule, but may also connect nearby but non-articulating bones.

Example: the ligament connecting the sacrum to the spine and tuberosity of the ischium



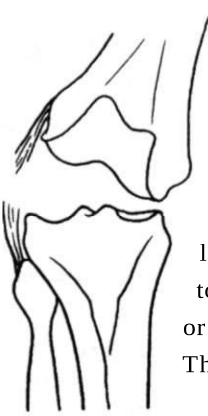
The ligaments function chiefly to strengthen and stabilize the joint in a passive way. Unlike the muscles, they cannot actively contract. Nor (except for a few ligaments which contain a high proportion of yellow elastic fibers) can they stretch.



They are placed under tension by certain positions of the joint and slackened by others.

Example: the fibular (lateral) collateral ligament of the knee is pulled tight in extension, and loosened in flexion

Ligaments contain numerous sensory nerve cells capable of responding to the speed, movement, and position of the joint, as well as to stretching or pain.



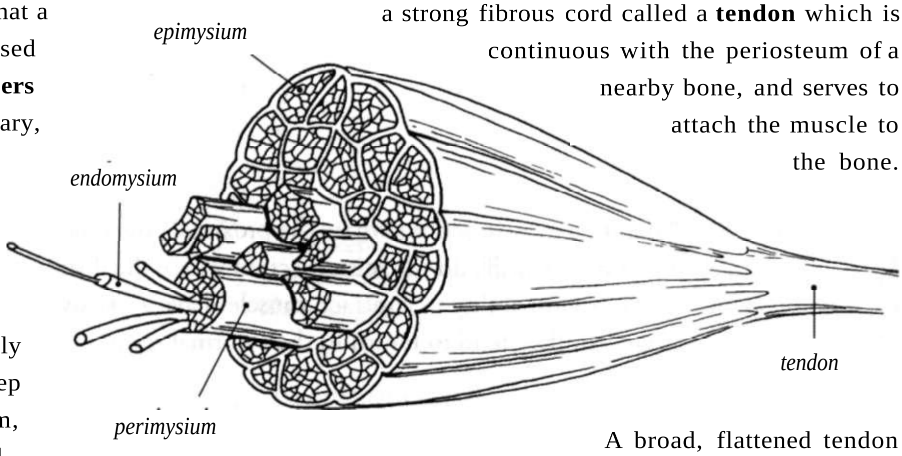
The sensory cells constantly transmit such information to the brain, which in turn sends signals to the muscles via motor neurons. This is called the **proprioceptive sense.**

Nevertheless, excessive movement of the joint can lead to ligamentous stretching to the point of straining or tearing the ligament. This is called a **sprain.**

Muscles

Essentially all movements of the human body result from contraction of muscles. In this book we are concerned with external movements, and will therefore focus on the skeletal muscles (also known as voluntary or striated muscles) which attach to bones. We will not discuss smooth muscle or cardiac muscle.

In a microscopic cross section, we see that a muscle is composed of bundles of **fibers** (primary, secondary, tertiary), held together and compartmentalized by fibrous partitions called (on a progressively smaller scale) deep fascia, epimysium, perimysium, and endomysium.



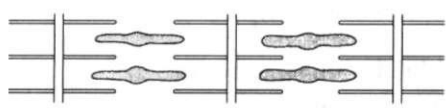
They can be extended beyond the muscle to form a strong fibrous cord called a **tendon** which is continuous with the periosteum of a nearby bone, and serves to attach the muscle to the bone.

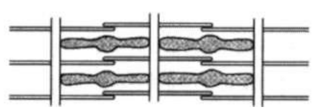
A broad, flattened tendon is called an **aponeurosis.**

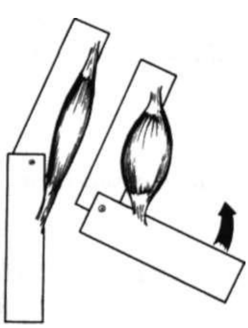
These connective tissue partitions (which are continuous with each other) allow easy movement of one muscle or muscle group relative to another.

Each muscle cell, also called a muscle fiber, contains extremely long **myofibrils.** Each of these contains a contractile element in its central part, the sarcostyle. It is striated with dark and light colored bundles arranged in alternating fashion. The structure of these bundles appears (under extreme magnification) to consist of **filaments:**

- dark bundles, thick filaments, which are rounded in the middle (consisting of myosin, a type of protein)
- light bundles, thin filaments, linked to each other through their central part, consisting of actin (another type of protein).

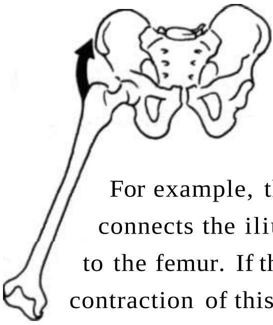






At rest, the actin and myosin filaments are not connected. When the muscle contracts, they unite, and pull each other. This causes a thickening (diameter) and shortening (length), which makes it possible for the muscle to pull the bones to which it is attached.

Typically, a muscle is attached to two different bones. For a given body movement, one bone (called the **origin)** is fixed in some way, and the other (called the **insertion)** moves as a result of muscle contraction. The origin is often the proximal bone, and the insertion the distal bone, but there are many exceptions.



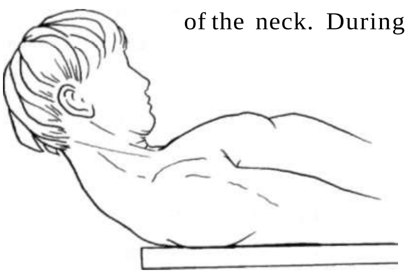
For example, the gluteus medius connects the ilium (large hip bone) to the femur. If the ilium is fixed, contraction of this muscle results in abduction of the femur.

On the other hand, if one is standing with the weight on the leg, the femur becomes the fixed point, and contraction of the muscle results in lateral flexion of the pelvis.

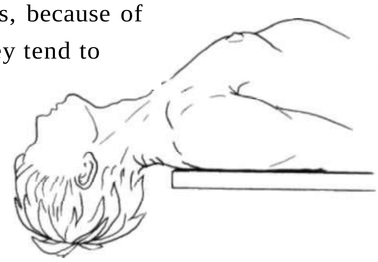
Muscle elasticity

In this book, we will describe muscle actions where the proximal attachment is the fixed point. For some muscles or regions, we will add the muscle action where the distal attachment is the fixed point. Besides their (active) ability to contract, muscles have a (passive) property of elasticity. When stretched, they tend to return to their normal resting length.

For example, the anterior neck muscles, when they contract, are flexors of the neck. During extension of the neck, these muscles become stretched.



When this happens, because of their elasticity, they tend to return the head to its anatomical position.



Muscle shapes

Muscles attach to bones in several ways:

- directly via muscle fibers (usually in a broad insertion)
  Example: subscapularis (p. 126)
- via an aponeurosis (broad tendon)
  Example: quadratus lumborum (p. 93)
- via a regular tendon
  Example: coracobrachialis (p. 129)
- via the tendon passing under a fibrous band.
  Example: tibialis anterior (p. 286)

Some muscles have several origins (called "heads"), which may be on more than one bone.

Example: biceps brachii has two heads (p. 147), triceps brachii has three heads (p. 148), and quadriceps femoris has four heads (p. 238)

Typically, the proximal insertion of the muscle is called origin and the distal one is called insertion.

Example: the psoas muscle (p. 92) has its origin on the vertebrae and its insertion on the femur

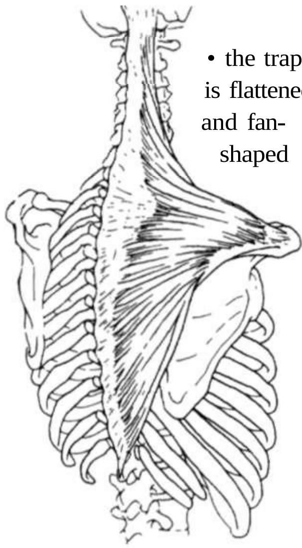
A muscle can have several origins,

Example: flexor digitorum superficialis originates from both the radius and ulna (p. 177)

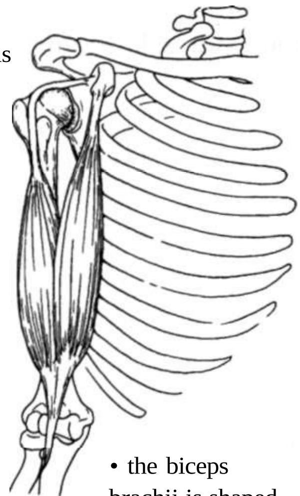
. . .and several insertions.

Example: the interosseous muscles insert on the phalanges and extensor tendons of fingers (p. 180)

The fiber bundles of muscles are arranged in many shapes:

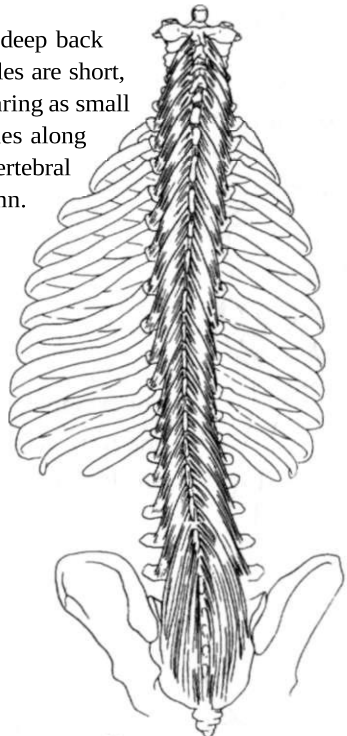


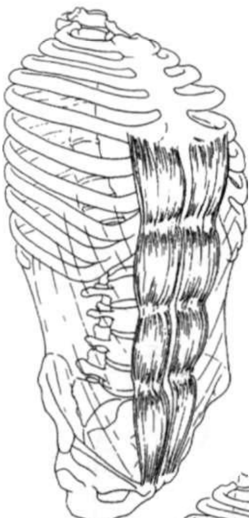
• the trapezius is flattened and fan-shaped



• the biceps brachii is shaped like a long spindle

• the deep back muscles are short, appearing as small bundles along the vertebral column.

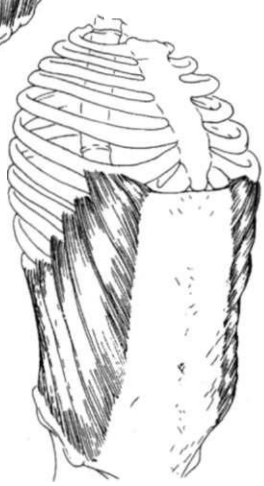




Depending on the orientation and attachment of their fibers, muscles may act in one or several directions.

Example: the fibers of the rectus abdominis run essentially parallel to each other.

This muscle flexes the trunk.



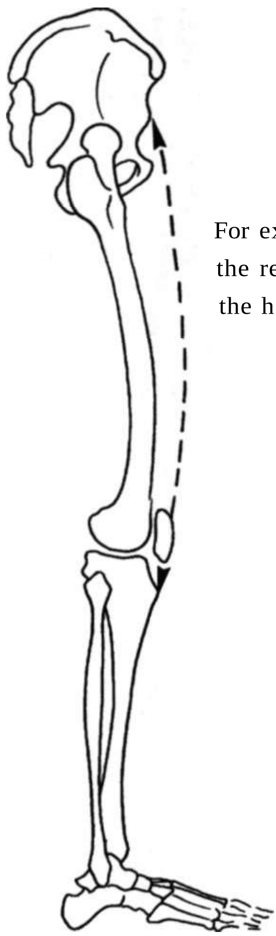
Example: fibers of the external oblique are arranged like a fan.

This muscle can produce anterior flexion, sidebending, or rotation of the trunk.

Long muscles are usually kinetic, i.e., able to produce highly visible external motion. Short, deep muscles (e.g., those inserting on the vertebrae or foot bones) tend to be responsible for precise, small-scale adjustments rather than gross movements.

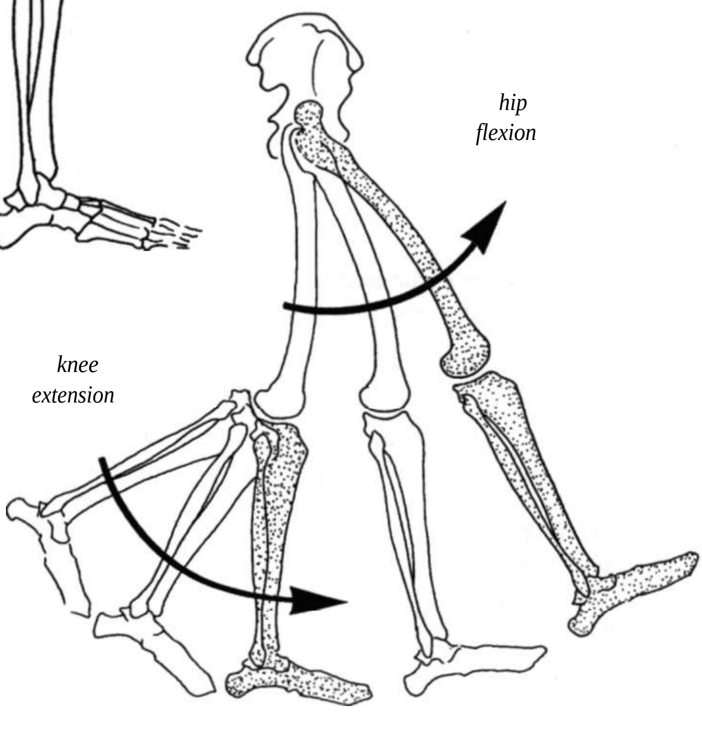
A muscle which crosses and affects a single joint is called **monoarticular.**
A muscle which crosses (and moves) more than one joint is called **polyarticular.**

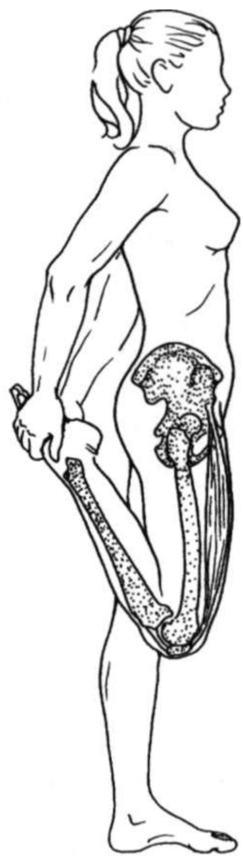
To stretch a muscle, you move it in a manner that is the opposite of its usual action around each of its joints.



For example,
the rectus femoris crosses
the hip and knee joints...

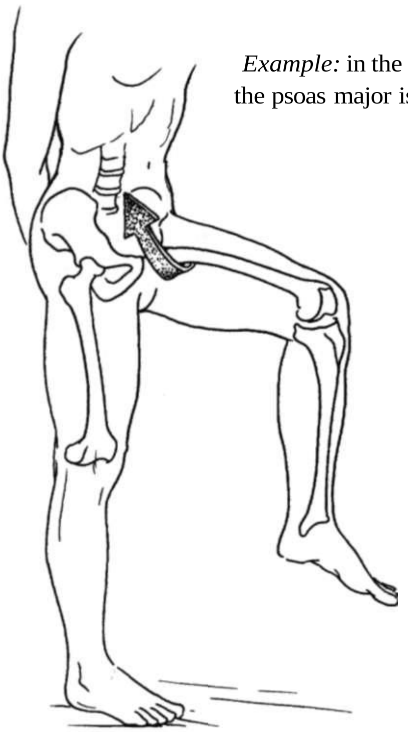
...and is both
a flexor of the hip
and an extensor of the knee.



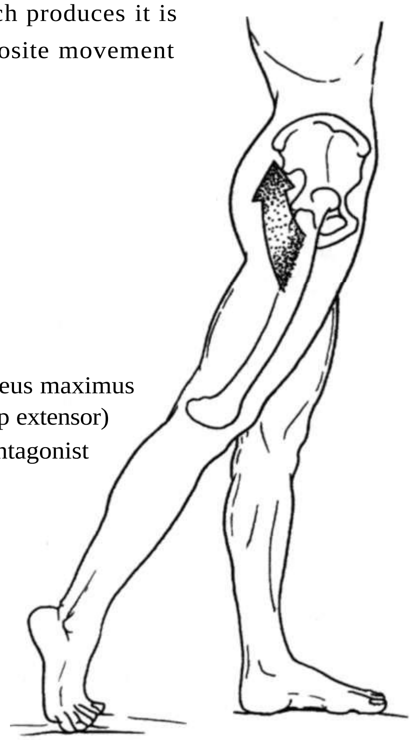


Conversely,
it will be stretched
in situations involving
simultaneous extension
of the hip and flexion
of the knee.

When we speak of a particular movement, the muscle which produces it is called an **agonist,** and the muscle which produces the opposite movement is called an **antagonist.**

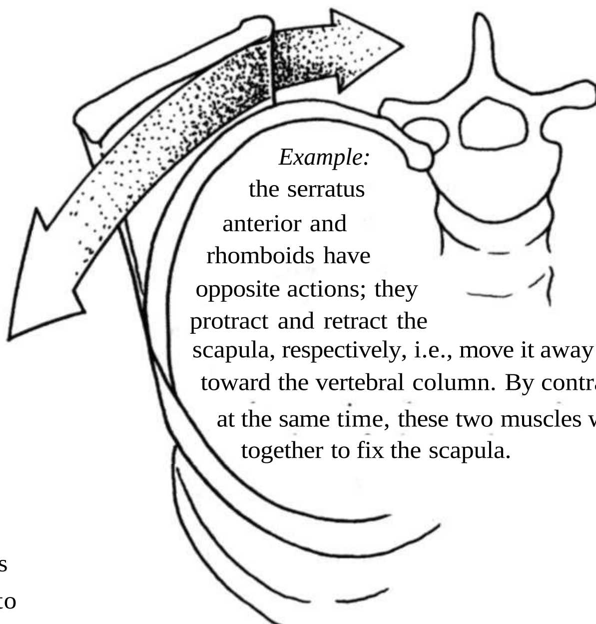


Example: in the case of hip flexion, the psoas major is the agonist...

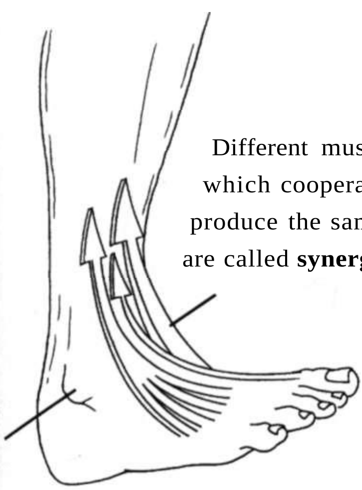


...and the gluteus maximus (a hip extensor) is the antagonist

Mutually opposing muscles often function together to fix or stabilize a bone.



Example: the serratus anterior and rhomboids have opposite actions; they protract and retract the scapula, respectively, i.e., move it away from and toward the vertebral column. By contracting at the same time, these two muscles work together to fix the scapula.



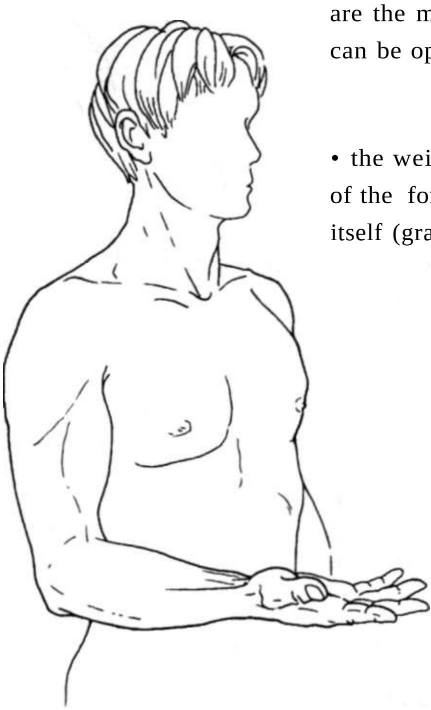
Different muscles which cooperate to produce the same action are called **synergetic.**

Example: in dorsiflexion of the ankle, three muscles work synergetically: tibialis anterior, extensor hallucis longus, and extensor digitorum longus

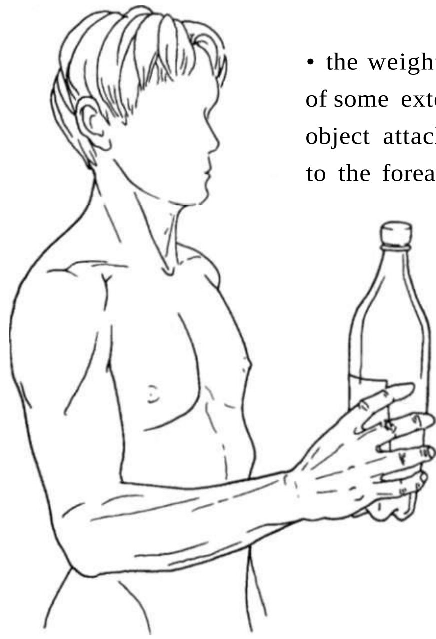
When a muscle contracts, it tends to draw its origin and insertion points closer together. Anything that opposes this tendency is called **resistance.**

For example, the brachialis and biceps brachii are the major flexors of the elbow. Their action can be opposed by several types of resistance:

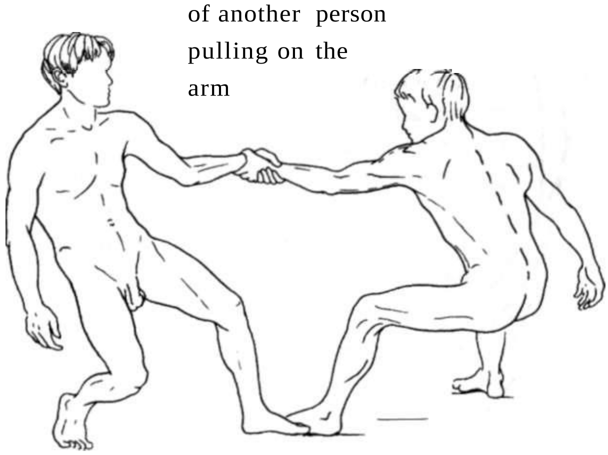
• the weight of the forearm itself (gravity)



• the weight of some external object attached to the forearm

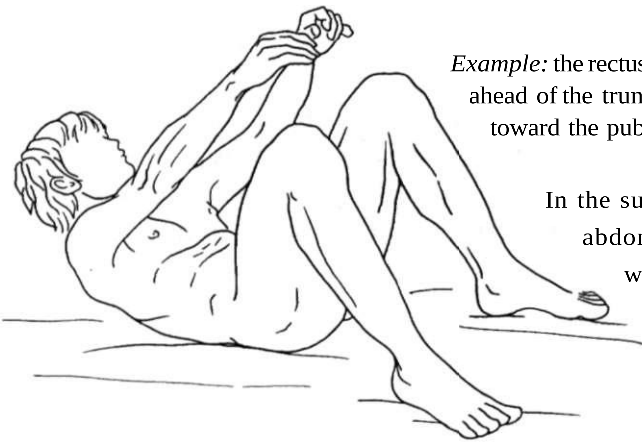


• the force of another person pulling on the arm



• contraction of antagonist muscles (in this case the triceps brachii, the major elbow extensor).

When a muscle contracts, a movement occurs. However, the movement may be caused by forces other than the muscle itself.



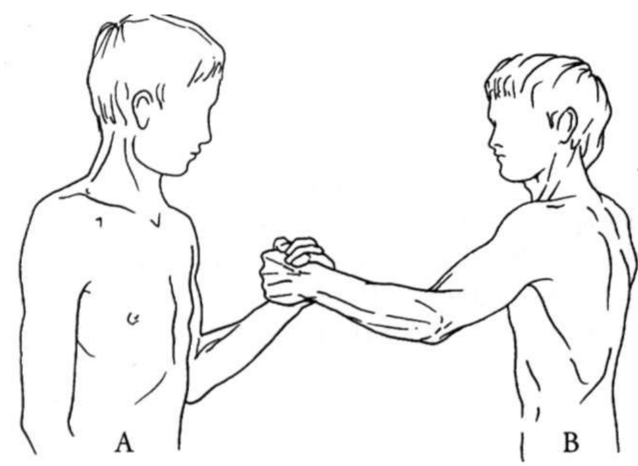
Example: the rectus abdominis flexes ahead of the trunk, moving the sternum toward the pubis

In the supine position, the rectus abdominis flexes the trunk while the weight of the trunk resists the flexion.

However, in a standing position, the rectus abdominis is not active. Instead, gravity causes the trunk to fall forward.

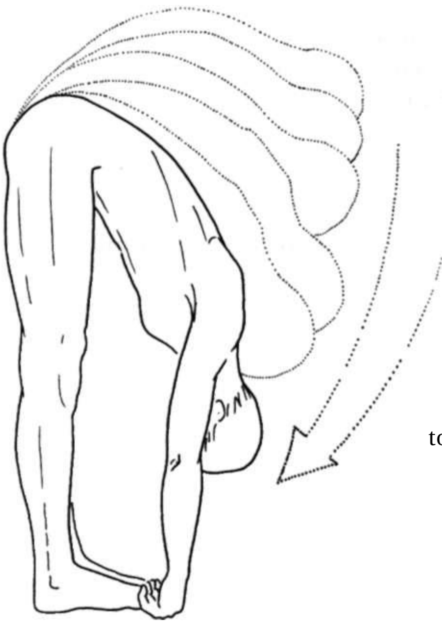
When a movement occurs because of an active muscle, the muscle insertions are moved closer together. This type of contraction is called **concentric.**

In the example of the supine position above, a concentric contraction of the trunk flexors occurs.



Another example: two people (A and B) pull each other (elbows are flexed). As we can see, A wins. This is a **concentric contraction** of A's elbow flexors.

In some cases, a muscle works without initiating the action itself; instead, it "applies the brakes" to the action. Without the work of this muscle braking the action, it would occur faster.

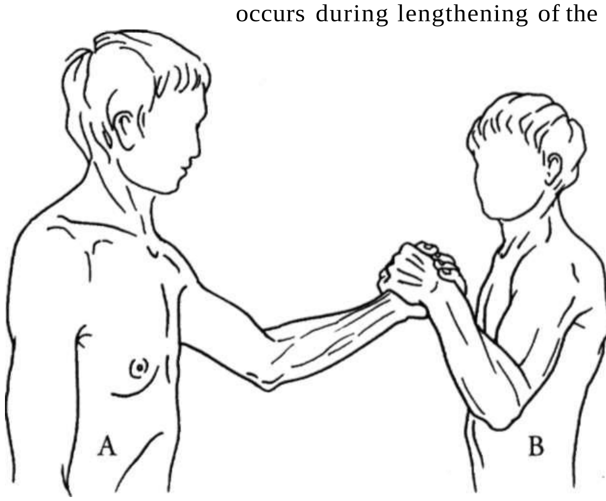


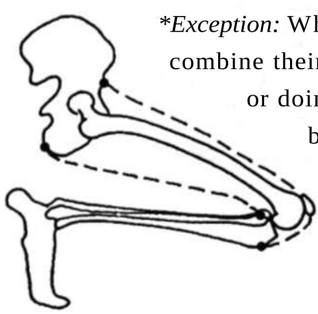
Let's go back to the example of trunk flexion. In the standing position, the trunk flexors don't initiate flexion; gravity does. If the muscles didn't work, the flexion would consist of a "falling" forward.

To slow down flexion, the extensors of the trunk must contract in order to restrain or "brake" this flexion.

If the muscles which oppose a movement apply the brakes, their contraction is called **eccentric.** This occurs during lengthening of the muscles.*

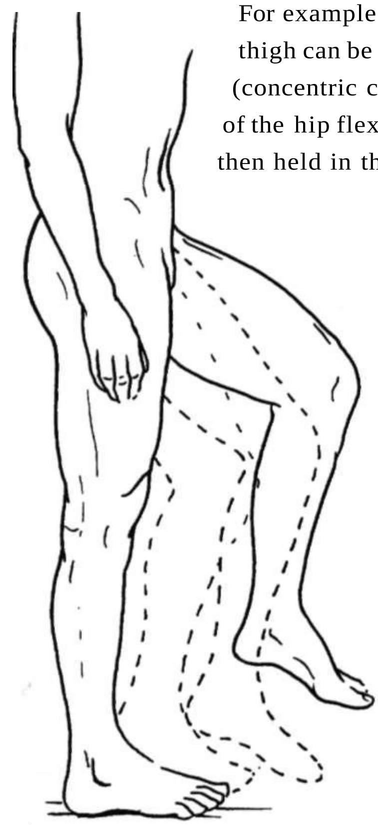
Example:
when A "loses" and brakes the pull of **B,** an **eccentric contraction** of As elbow flexors occurs



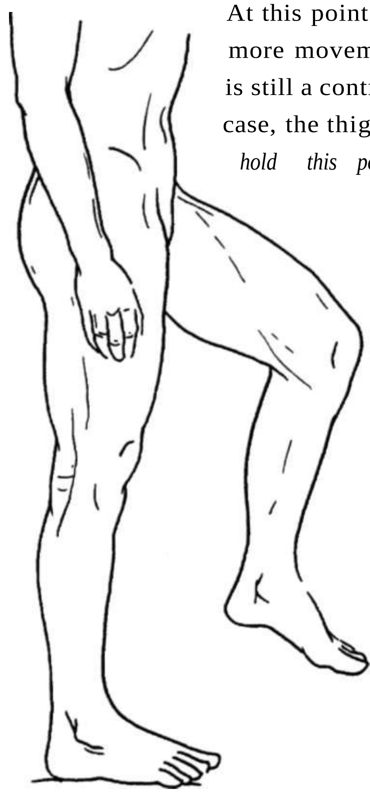


**Exception:* When the rectus femoris and hamstring muscles combine their actions by flexing the hip and knee (e.g., when squatting or doing a "grand plie"), the bones involved change their position, but the muscles do not lengthen or shorten. The hip and knees "cancel out" each other's actions.

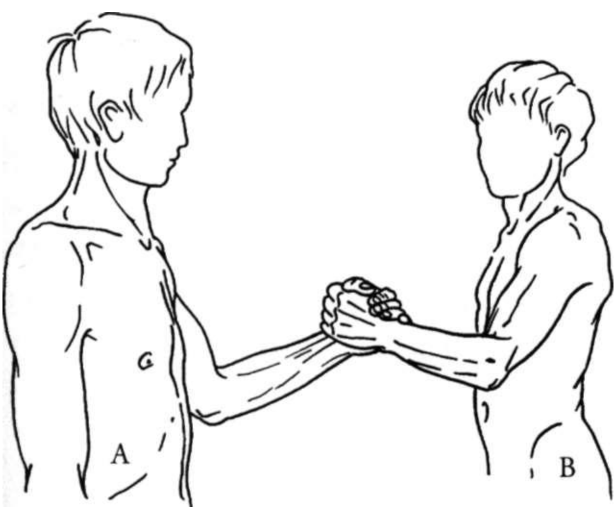
It is also possible that a muscle is contracted even though no movement is taking place.



For example, the thigh can be flexed (concentric contraction of the hip flexors) and then held in this position.



At this point, there is no more movement, but there is still a contraction (in this case, the thigh flexors) to *hold this position.*



When a position is fixed by a muscular contraction, we call this contraction **isometric.**
The insertions of the muscles do not move.

A and B are in balance:
This is an **isometric contraction.**

In real life, these different types of contraction are combined during various movements.

For example, if we apply the illustration above to the knee, the following would happen when stretching the knee: isometric contraction at the hip flexors and isotonic (concentric) contraction of the knee extensors.

CHAPTER TWO

The Trunk

The trunk is the central part of the body. In this book, we will examine only its locomotor functions, not its internal organs.

The trunk serves a double function, which is connected to its bony structure, the vertebral column.

On one hand, the trunk can bend and perform curved movements, like those of a serpent or a measuring tape (unlike the limbs, which perform angular movements like those of a folding measuring stick). This mobility of the trunk is due to the flexibility of the vertebral column, which has twenty-six "levels" of articulation.

On the other hand, the vertebral column contains a tunnel for the nerves: the spinal cord and the nerve roots, which exit the spinal cord. Weakness in the vertebrae may therefore affect not only the joints, but also the spinal cord and nerves as well. Thus, the trunk must be able to align and stabilize the vertebral segments when the body is motionless, and especially when it is carrying a load.

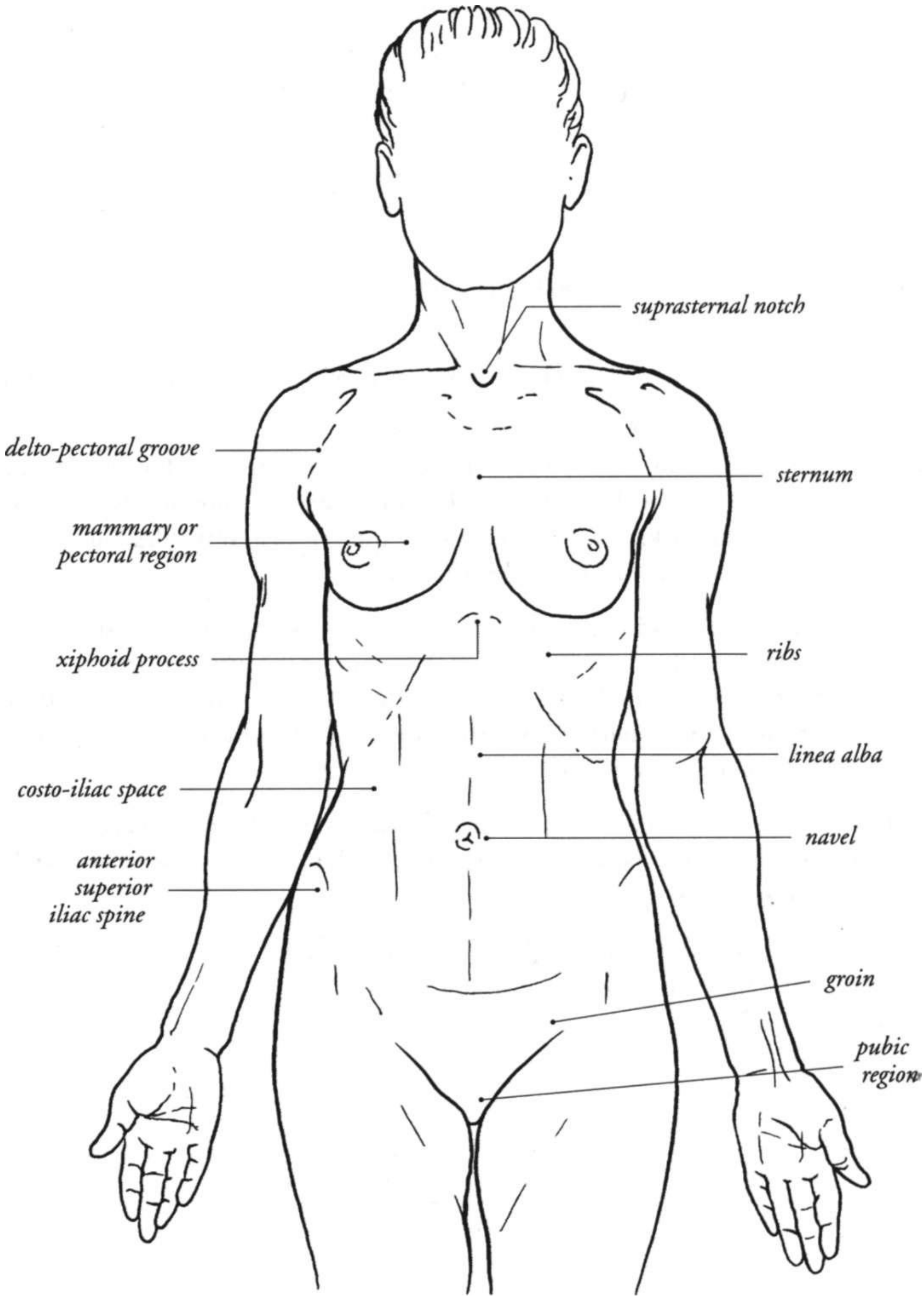
This dual function depends on a finely integrated system of mostly polyarticular muscles, which are either deep (composed of numerous small bundles) or superficial (usually arranged like broad sheets).

Movements of the pelvis are difficult to separate from those of the vertebral column. Therefore it too will be included in this chapter.

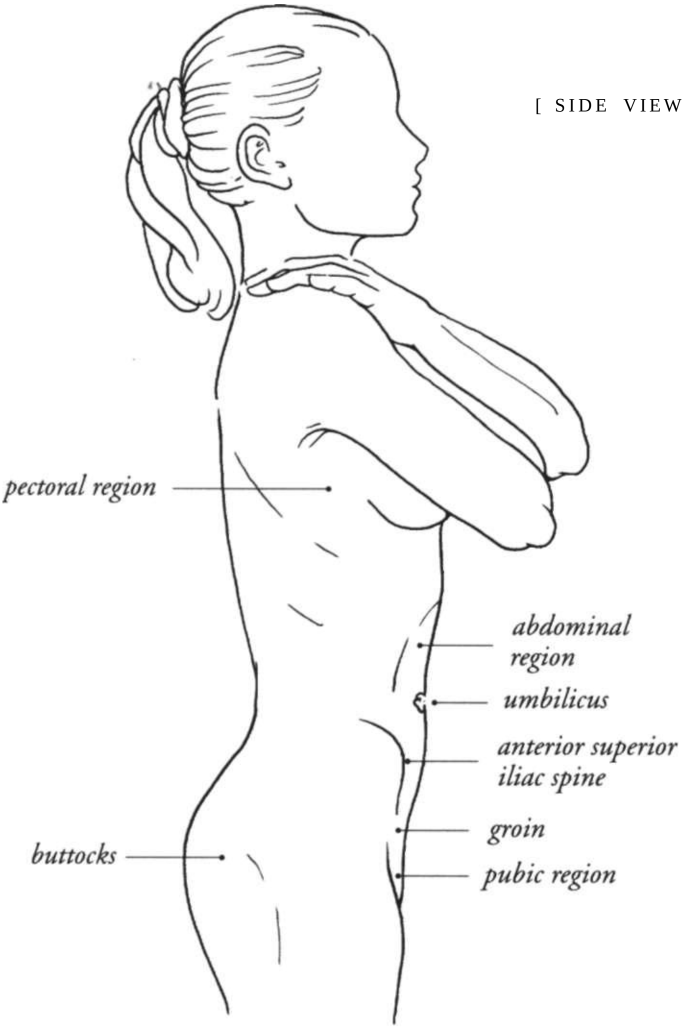
Landmarks

Some visible and palpable landmarks of the trunk are shown below.

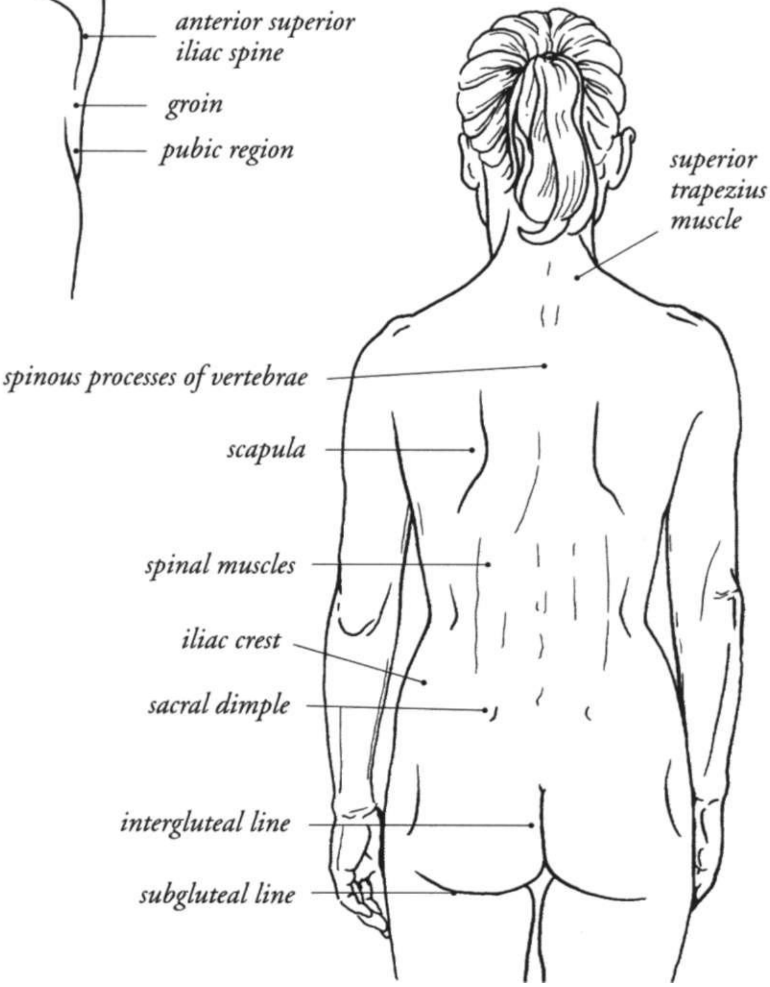
[FRONT VIEW]



[SIDE VIEW]

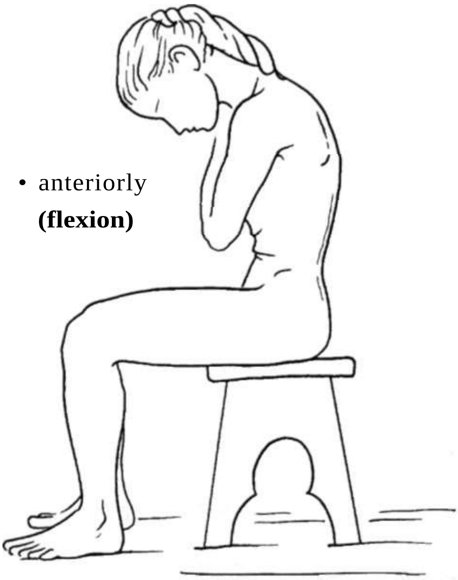


[BACK VIEW]

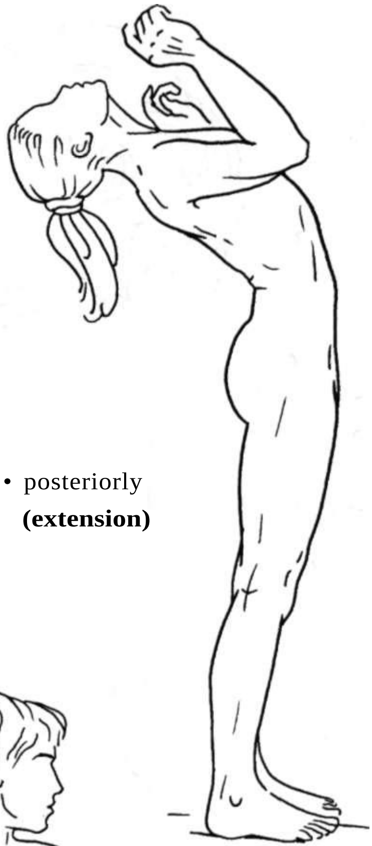


Movements of the trunk

Thanks to the mobility of the vertebral column, the trunk can move in several directions, as seen on pages 8-10.



• anteriorly **(flexion)**



• posteriorly **(extension)**

• on its own axis **(rotation)**

• laterally **(lateral flexion** or **sidebending)**

Range of movement varies depending on vertebral level due to several factors:

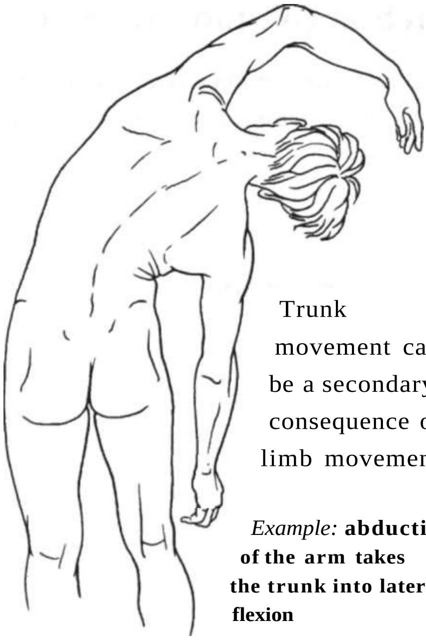
• shape of the vertebrae

• thickness of intervertebral discs (the thicker the disc, the greater the mobility)

• the thoracic vertebrae articulate with ribs, which limit their mobility (see p. 58-63).

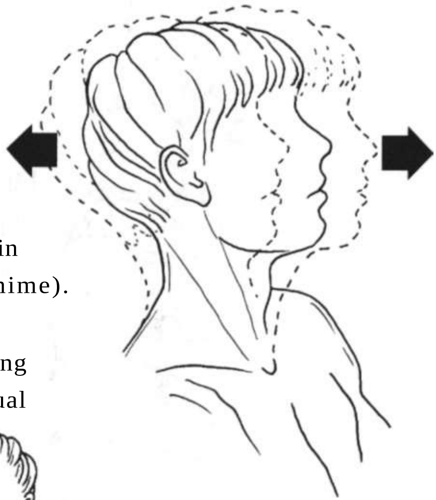
Do not confuse these movements with those in which the trunk moves as a single unit at the hip joint.

Example: **hip flexion without flexion of trunk**



Trunk movement can be a secondary consequence of limb movement.

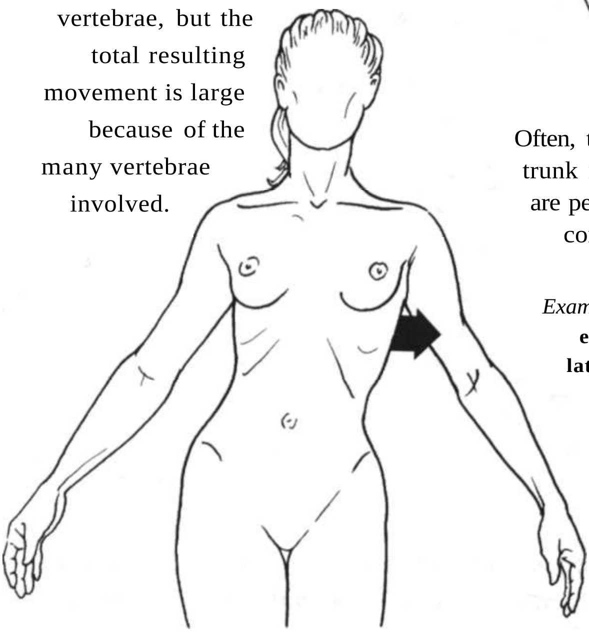
Example: **abduction of the arm takes the trunk into lateral flexion**



The trunk provides the base for translation movements (called "isolations" in dance or mime).

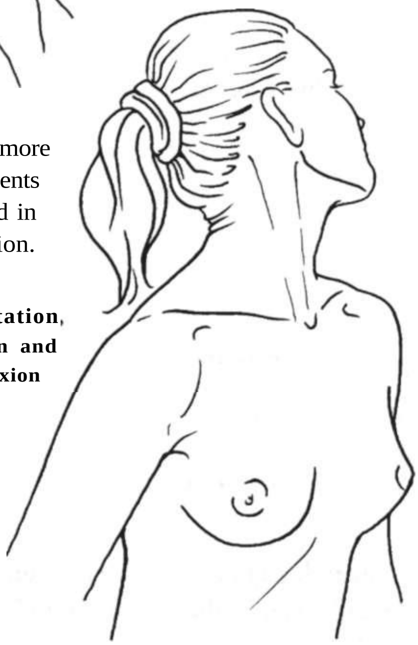
Example: **front-to-back or side-to-side movements of the head and pelvis while using a hula-hoop**

These involve minimal sliding displacements of individual vertebrae, but the total resulting movement is large because of the many vertebrae involved.



Often, two or more trunk movements are performed in combination.

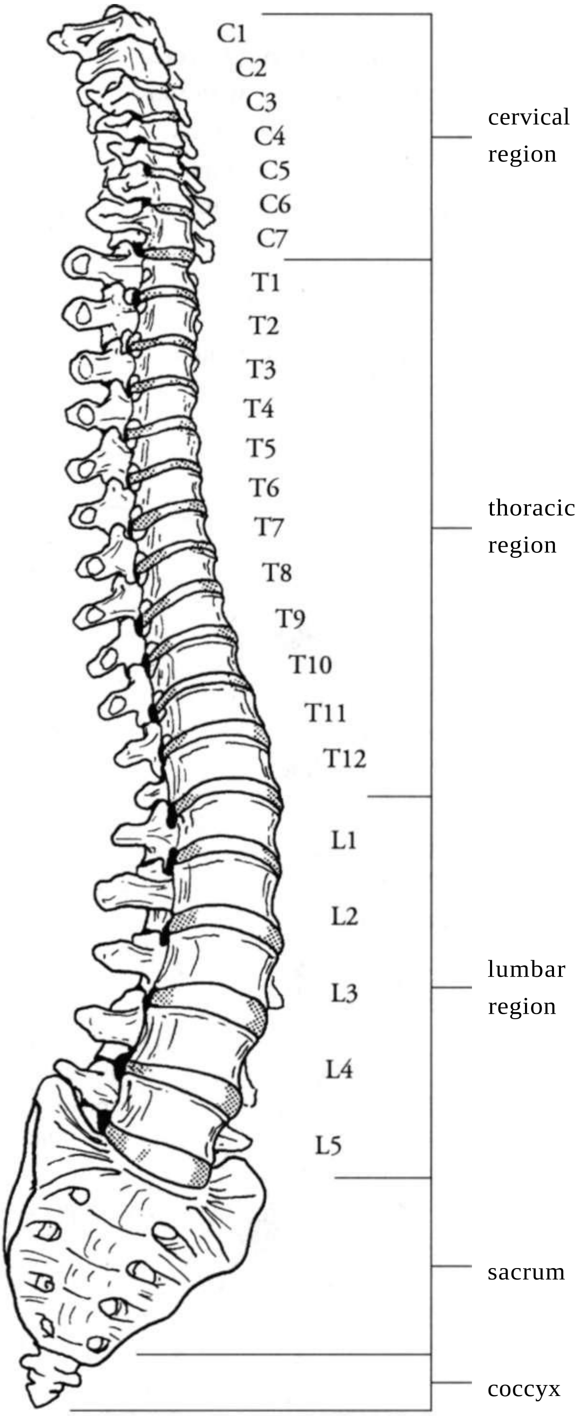
Example: **rotation, extension and lateral flexion**



Vertebral column (or spine)

The spine forms a mobile bony stem which constitutes a part of the skeleton of the **trunk.** From top to bottom, it consists of several areas:

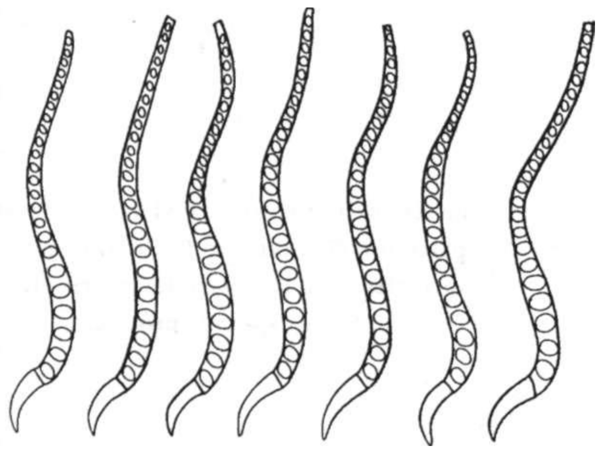
- seven **cervical** vertebrae
- twelve **thoracic** vertebrae
- five **lumbar** vertebrae
- the **sacrum**
- the **coccyx** or tailbone



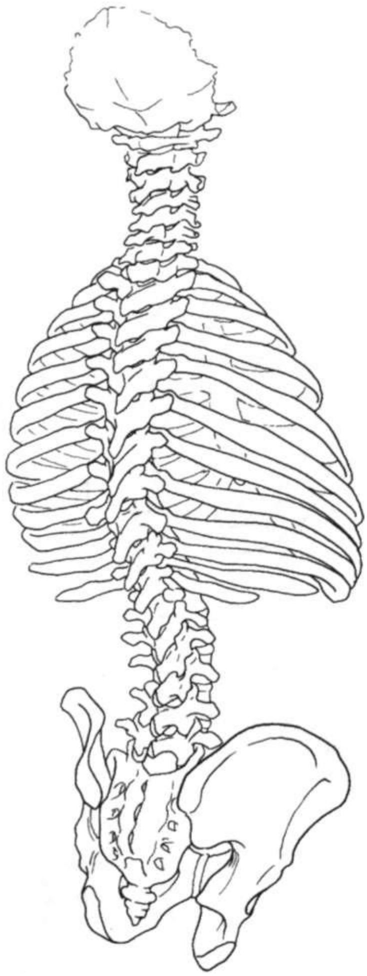
Within each region, vertebrae are numbered sequentially from top to bottom. For convenience, we usually refer to them by a letter plus a number. *Examples:* C7 = seventh cervical vertebra; T3 = third thoracic vertebra; L2 = second lumbar vertebta; S1 = first sacral vertebra, etc.

There are several characteristic curvatures of the vertebral column:

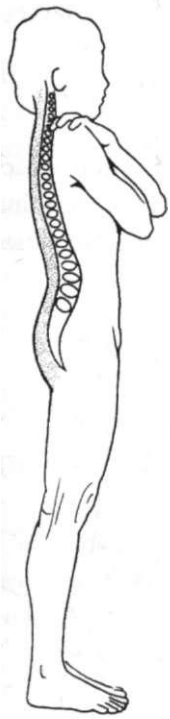
- sacrum, convex toward the back
- concave lumbar region (the term **lordosis** can refer either to an exaggeration of this curvature, or to the normal condition)
- convex thoracic region **(kyphosis)**
- concave cervical region.



Exact form of these curvatures varies from person to person; this is normal. For example, kyphosis is almost non-existent in some individuals.

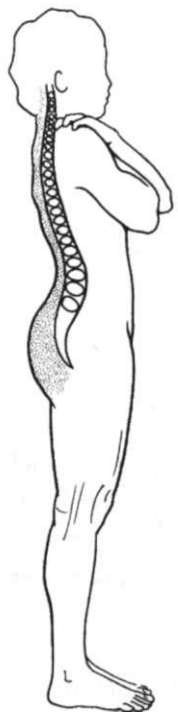


The vertebral column is attached to other skeletal structures: the base of the cranium, the ribs, and the pelvis (ilium).



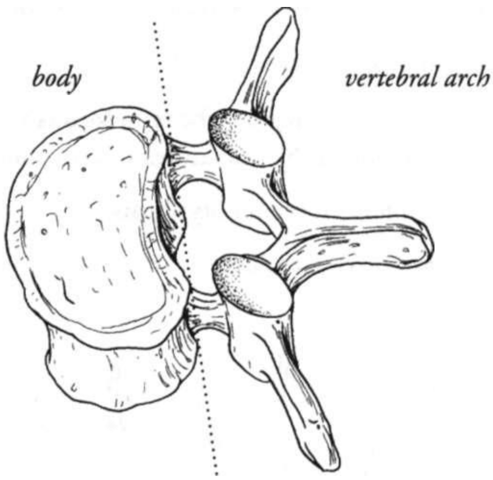
External appearance of these curvatures can be affected by overlying "soft" structures.

Example: **a person with large buttocks may appear to have more pronounced lordosis than a person with small buttocks. However, X-rays could reveal identical lumbar curvatures, as shown in these two illustrations.**

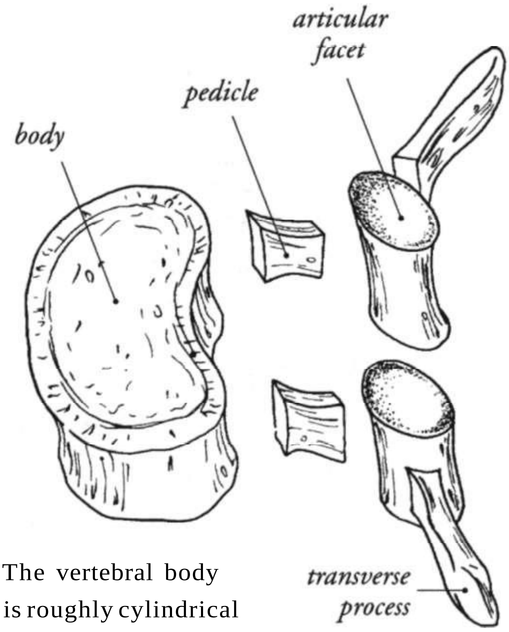


Vertebral structure

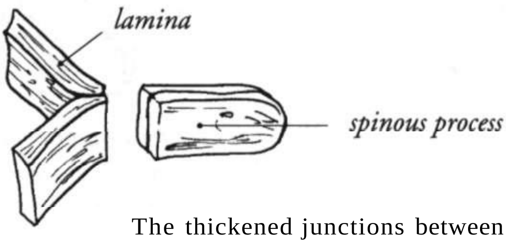
Each vertebra consists of two main parts: the massive **body** (anterior), and the **vertebral arch** (posterior).



This page shows a typical vertebra. Depending on its position in the spine, its shape and size will vary (see also p. 54-71).



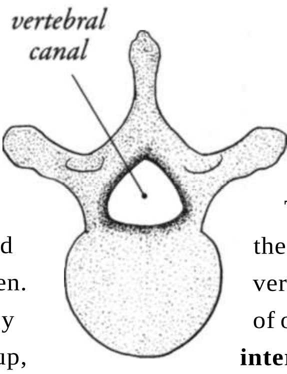
The vertebral arch can be divided into many parts. It is connected to the body by two **pedicles.** Two **lamina** unite posteriorly to form a **spinous process.**



The vertebral body is roughly cylindrical and consists of six surfaces.

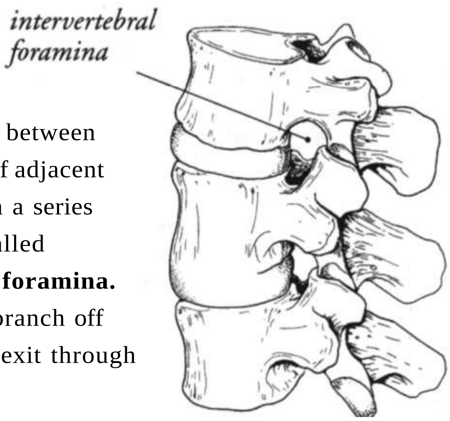
The thickened junctions between the pedicles and laminae have superior and inferior cartilaginous **articular facets** and a laterally-projecting **transverse process.**

The vertebral holes stacked on top of each other form a bony pipe. This is the spinal canal, through which the spinal cord passes.



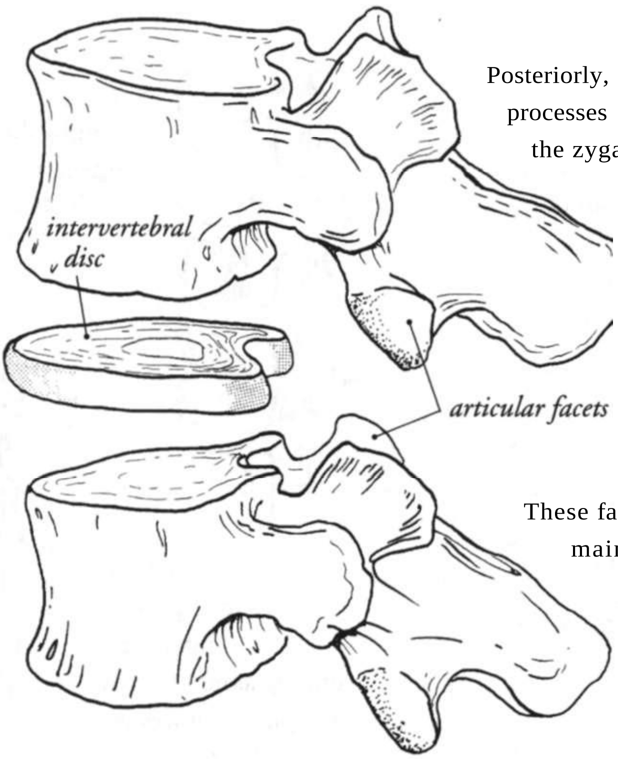
The opening between the body and the arch is called the vertebral foramen. As foramina of many vertebrae are lined up, they form the **vertebral canal** through which the **spinal cord** passes.

The spaces between the pedicles of adjacent vertebrae form a series of openings called **intervertebral foramina.** As spinal nerves branch off the spinal cord, they exit through these foramina.



Each vertebra is attached to its neighbor by three joints (except for the atlas-axis joint; see p. 70).

Anteriorly, the bodies are joined by the fibro-cartilaginous **intervertebral disc.**



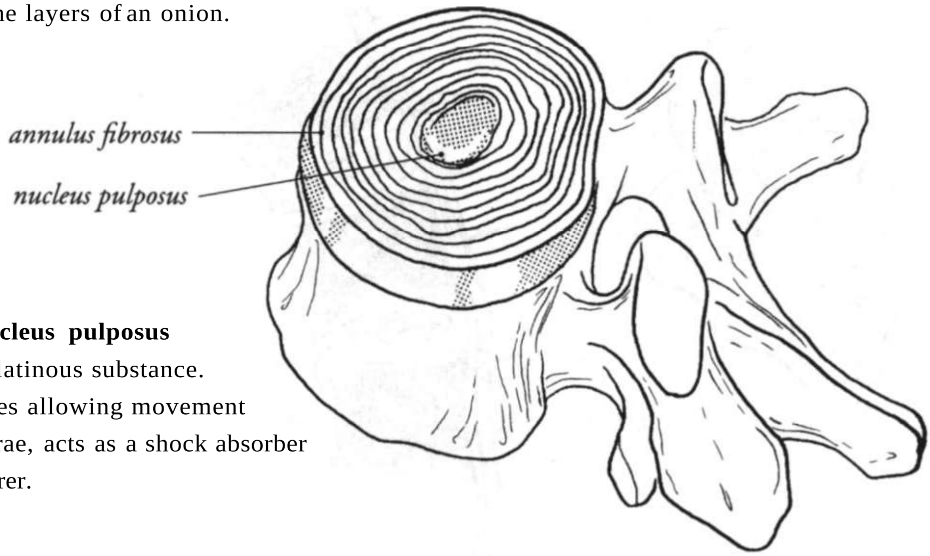
Posteriorly, between the articular processes of the vertebrae are the zygapophyseal joints.

The two inferior articular facets of the top vertebra contact the two superior articular facets of the bottom vertebra.

These facets are small, and serve mainly to guide movements. They are covered with cartilage and held together by a capsule and a number of small ligaments (see p. 39).

In cross section, we can see that the disc contains two distinct types of material:

The peripheral area, called the **annulus fibrosus,** is composed of concentric rings of fibrocartilage arranged like the layers of an onion.

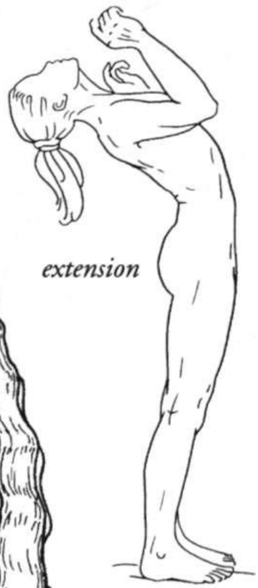


The central **nucleus pulposus** is made of a gelatinous substance. The disc, besides allowing movement between vertebrae, acts as a shock absorber and weight bearer.

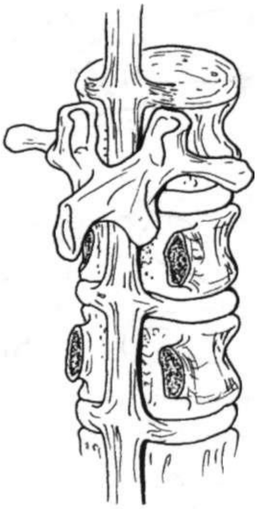
Ligaments of the spinal column

There are three ligaments extending the length of the vertebral column.

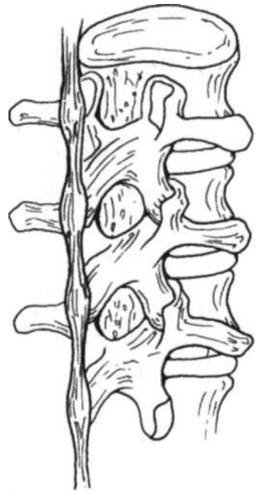
The **anterior longitudinal ligament,** attached to the front of the vertebral bodies, acts as a brake to extension.



extension

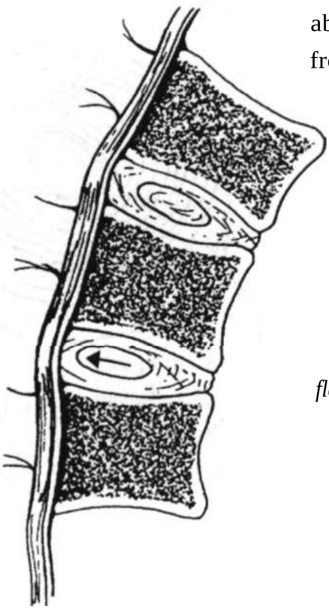


The **posterior longitudinal ligament,** attached to the back of the bodies...



...and the **supraspinous ligament,** running along the tips of the spinous processes, act as brakes to flexion.

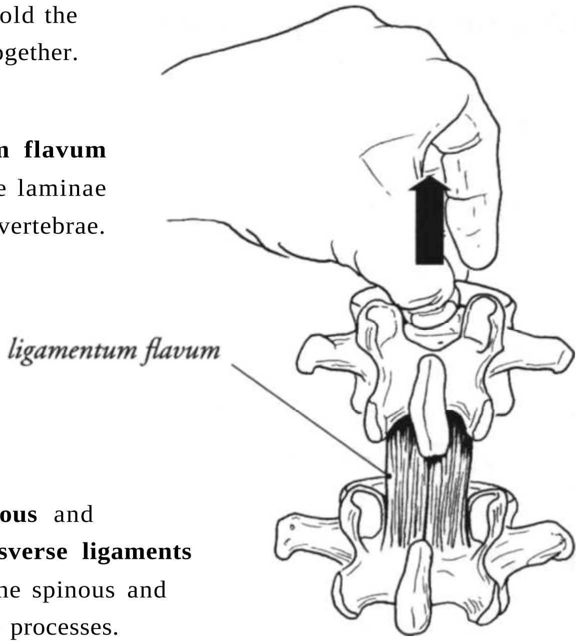
In flexion, the posterior longitudinal ligament absorbs the thrust from the disc nuclei.



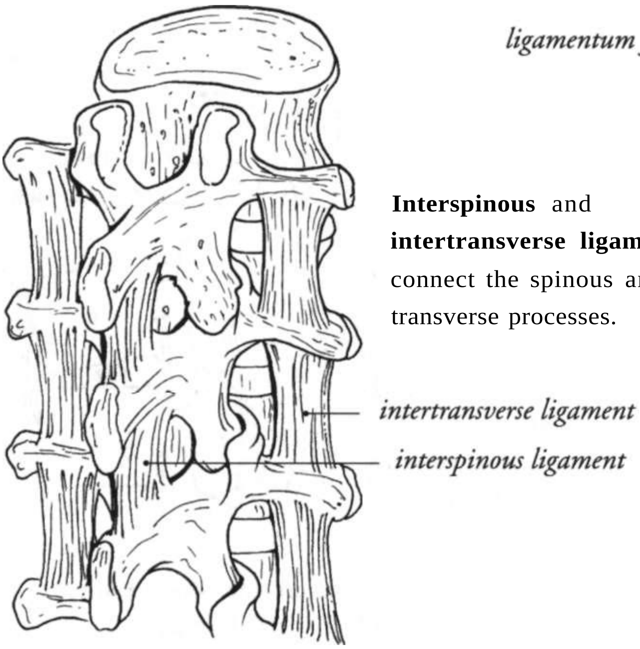
flexion

The other ligaments are discontinuous and hold the posterior arches of the individual vertebrae together.

The **ligamentum flavum** connect the laminae of adjacent vertebrae.

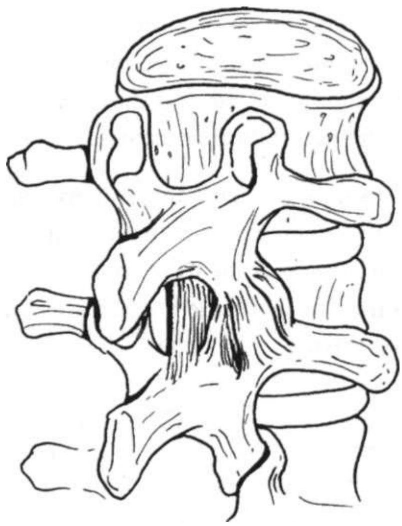


Interspinous and **intertransverse ligaments** connect the spinous and transverse processes.



These ligaments ate elastic, and can be pierced by a syringe during a spinal tap.

The surfaces of the articular processes are linked together through a capsule insetted on its circumference. The inside of this capsule is reinforced by an extension of the ligamentum flavum and, at the back, by a posterior ligament.

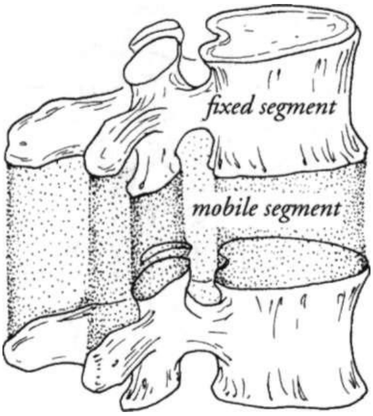


Left sidebending stretches the right intertransverse ligaments.

Other ligaments, specific to certain regions, will be mentioned later.

Movements of the vertebrae

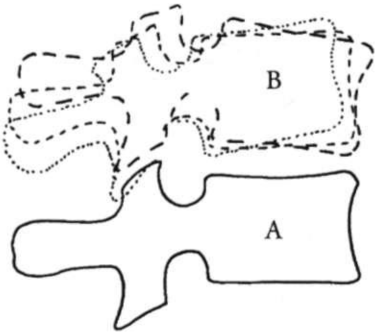
We can think of the vertebral column as a series of fixed segments (the vertebrae) having mobile connections (discs, ligaments).



Movements of individual vettebrae are compounded such that the entire structure has considerable mobility in three dimensions.

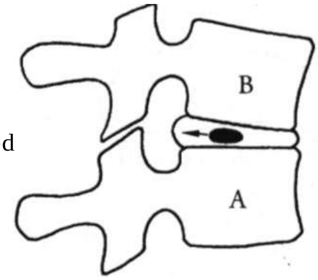
Type and extent of mobility varies with different spinal regions, depending on size and shape of vertebrae, and other factors.

Let's look at what happens between two vertebrae during movement, assuming that the top vertebra (B) is mobile, while the bottom vertebra (A) is fixed.



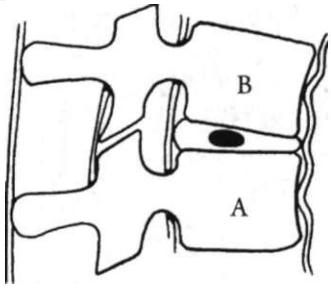
In **flexion,** B tilts toward the front. The superior articular facets slide on the inferior ones.

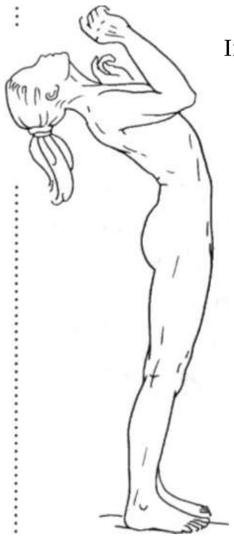
The disc is compressed anteriorly and expanded posteriorly,



...and its nucleus moves slightly toward the back.

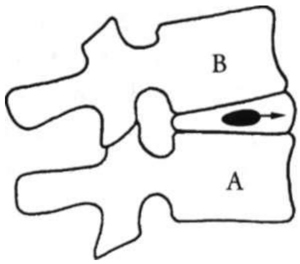
The various parts of the vertebral arches are pulled apart, and the ligaments connecting these parts are stretched.





In **extension,** the opposite occurs. B tilts toward the back.

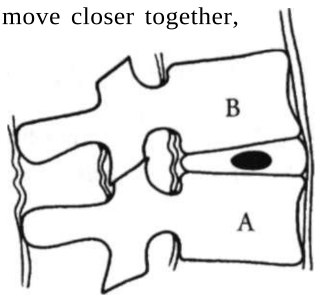
The disc is compressed posteriorly and expanded anteriorly,



...and its nucleus moves forward.

The articular facets ate pressed together, the arches move closer together,

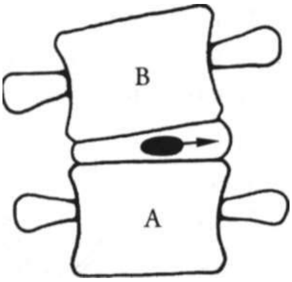
...and the posterior ligaments are relaxed.



The anterior longitudinal ligament is stretched.

What happens in **lateral flexion?** Let's consider left sidebending as an example.

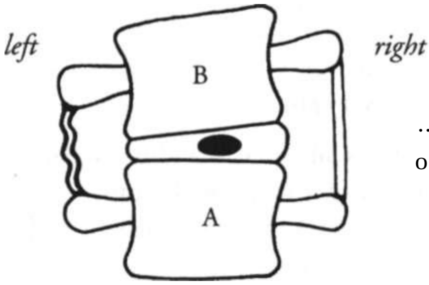
The left sides of A and B move closer together,



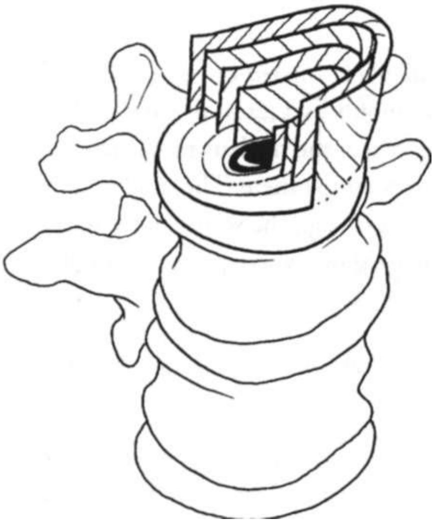
.. .while the fight sides move farther apart.

The disc is expanded (and its nucleus moves) to the right side.

On the left side, the transverse processes and articular facets come closer together, and the associated ligaments are relaxed;



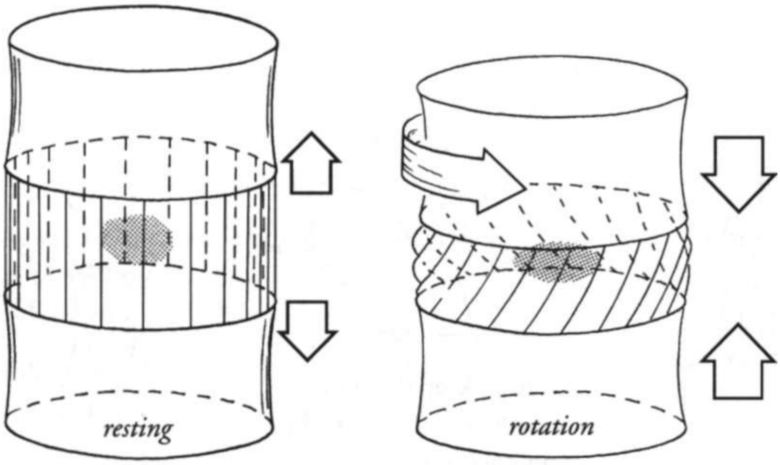
.. .the opposite occurs on the right side.



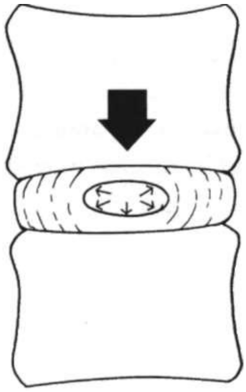
In **rotation,** the fibers of the disc, whose orientation alternates from one layer to the next, are under torsion (twisting).

They are moving in two different directions from layer to layer, such that one layer is stretched and the next layer is relaxed.

Because of the effect of the torsion, and the ensuing tension on the fibers, the distance between the vertebrae is diminished. The nucleus is therefore slightly compressed.



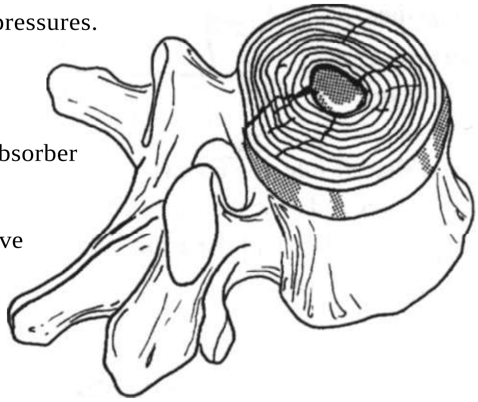
All of the connecting ligaments ate stretched by rotation.



The intervertebral disc serves as shock absorber

The disc often receives pressure from the vertebral body above. The nucleus, because of its central location and gelatinous composition, tends to distribute the pressure it receives in every direction.

Thus, the fibers of the annulus receive both horizontal and vertical pressures.



As long as fluid remains in the nucleus, the disc performs its role as a shock absorber very efficiently.

Unfortunately, due to the aging process and/or excessive wear and tear, the disc may partially lose this property, i.e., cracks develop in the annulus through which the fluid of the nucleus can escape.

This condition is termed a herniated or **ruptured disc.** It happens most commonly as a result of chronic flexion movements, during which the nucleus moves toward the back and fluid can escape there. The fluid may then compress the nerve roots, e.g., the sciatic nerve which exits from the lumbar region, where pressures on the veitebral column ate most intense.

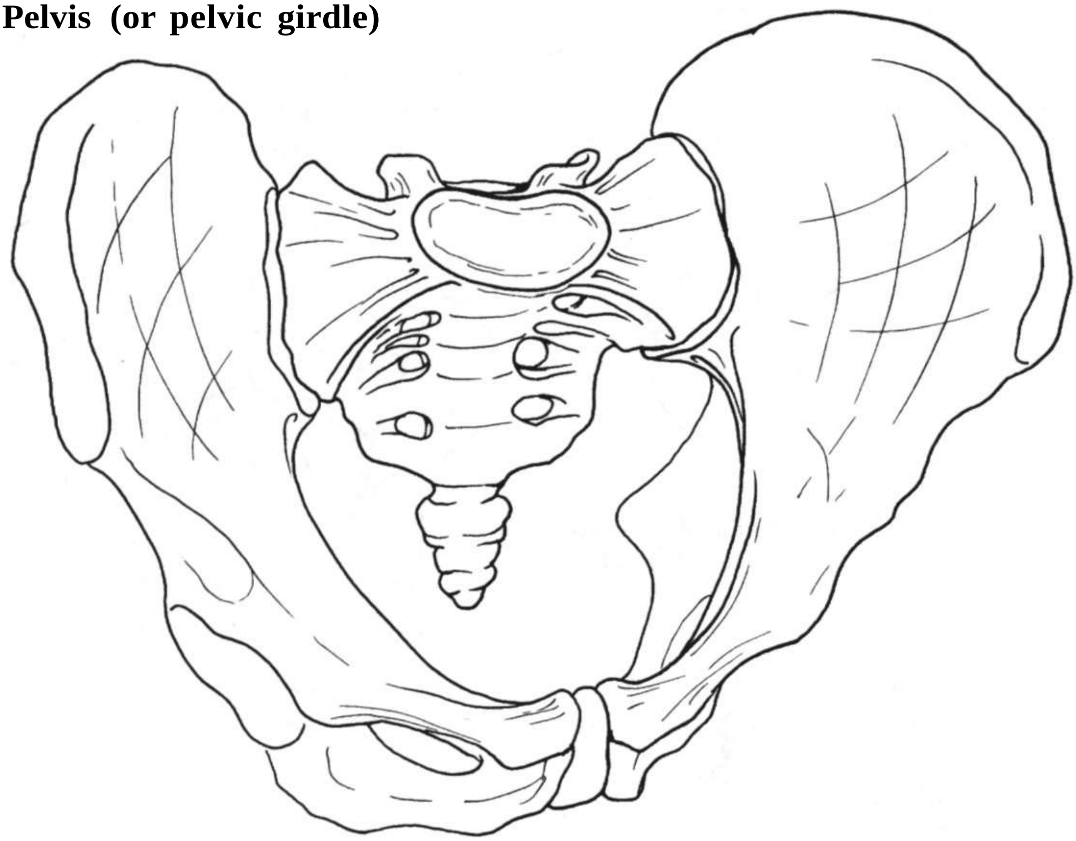
This situation, combined with chronic or sudden extreme tension on the posterior longitudinal ligament, can result in chronic lumbar backaches

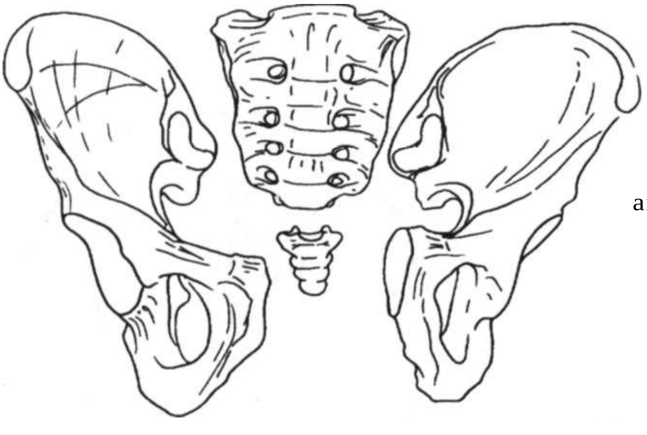
To avoid these problems, it is important to avoid "loaded" vertebral flexion, e.g., flexing the lumbar spine while lifting a heavy object.

Instead, keep the spine straight and flex at the hip and knee joints only.

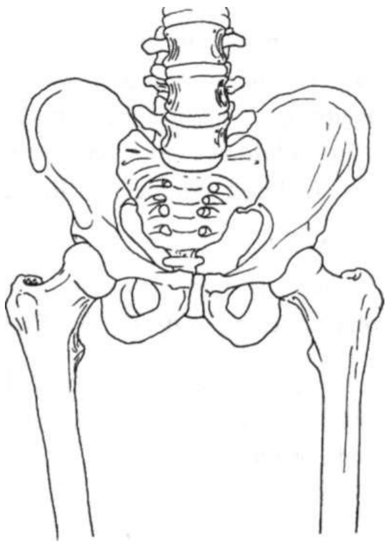
In fact, it is preferable to avoid loaded lumbar flexions in any type of physical exercise, even if you are not lifting any object.

Pelvis (or pelvic girdle)





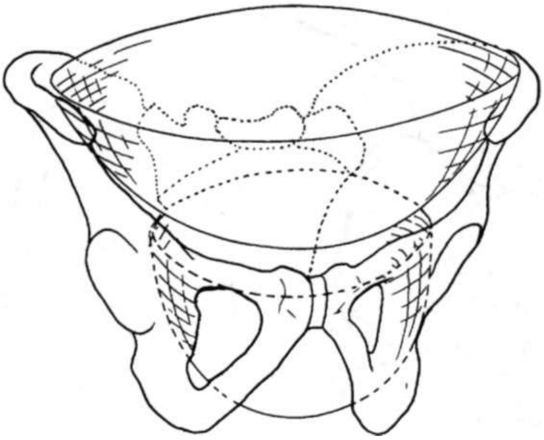
The pelvis (meaning "basin") is a ring-shaped structure consisting of four main bones: the **sacrum,** two **hipbones,** and the **coccyx.**



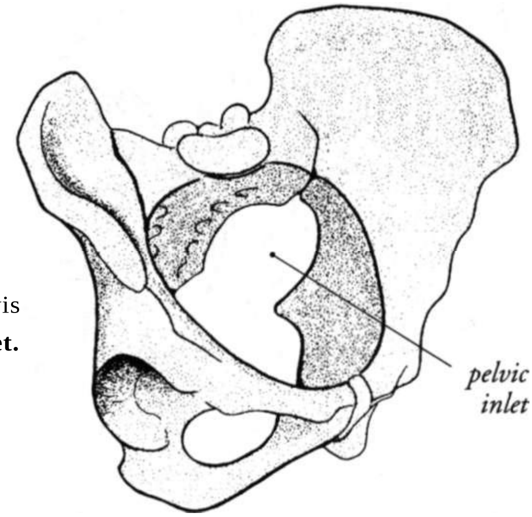
There are associated muscles (e.g., those making up the pelvic floor) and ligaments above.

The pelvis receives the weight of the upper body and passes this weight on to the lower limbs via its articulations with the femurs.

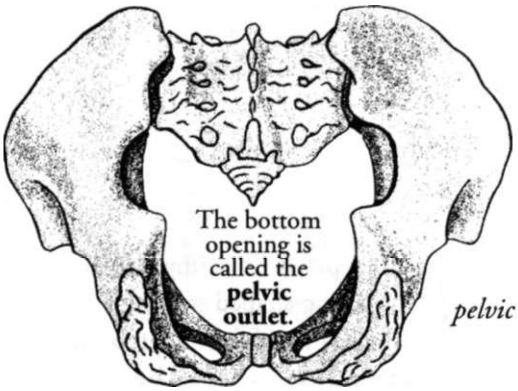
Conversely, it must absorb stresses from the lower limbs, e.g., in walking or jumping.



The shape of the bones forms a **greater (false) pelvis** at the top and a **lesser (true) pelvis** at the bottom.



The top opening of the lesser pelvis is called the **pelvic inlet.**

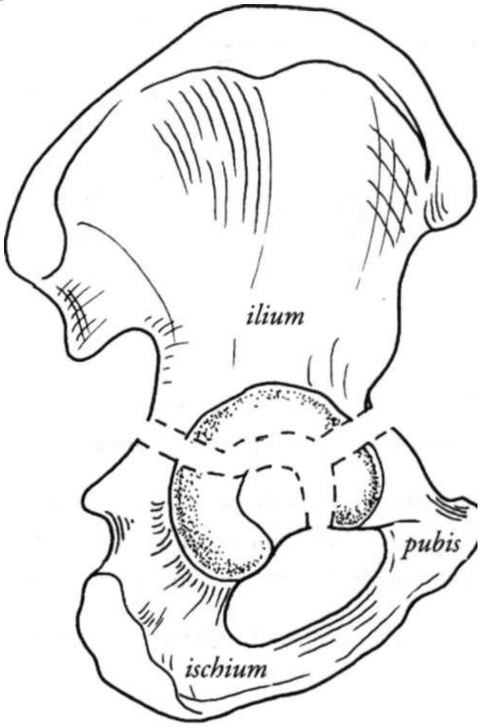


The hip bones of the pelvis

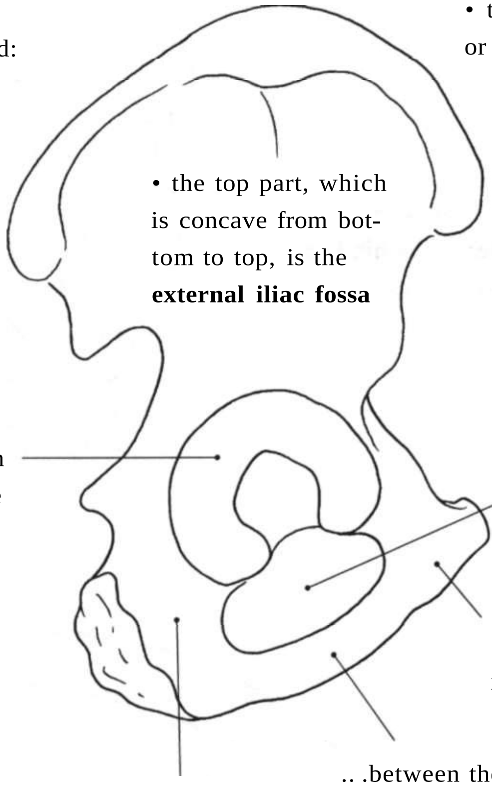
The hip bones are flat and consist of a superior and inferior part, which are twisted against each other (a little bit like a propeller). In the adult, each hip consists of three bones that are fused together: the **ilium, ischium,** and **pubis.**

These bones fuse at a cartilage in the shape of a Y, located in the center of the socket.

The hip has two surfaces (medial and lateral) and four edges (superior, inferior, anterior, and posterior).



On the lateral surface of the hip bone, we find:



• the superior border or **iliac crest**

• the top part, which is concave from bottom to top, is the **external iliac fossa**

• in the middle is an area in the form of a hollow sphere, called the **acetabulum,** which receives the head of the femur (see p. 202)

• the lower part is like a bony arch, which surrounds a hole called the **obturator foramen**

• the anterior area is the **pubis**

the posterior area is the **ischium**

.. .between the two: the **ischio-pubic ramus.**

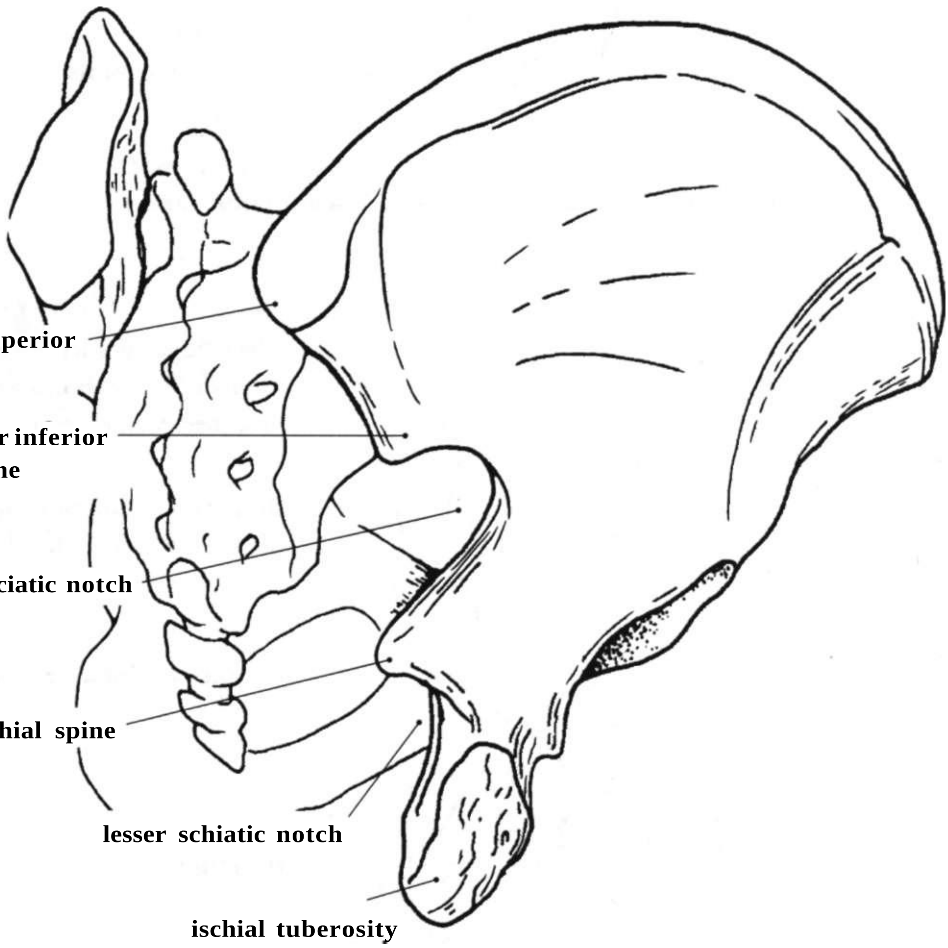
The anterior border has a number of depressions and protuberances, especially:

the **anterior superior iliac spine,** the most forward part of the iliac crest,

the **anterior inferior iliac spine,**

the **pubic tubercle.**

Seen from a three-quarter posterior view,
we find the posterior border of the hip bone,
which shows various protuberances
and depressions, notably:

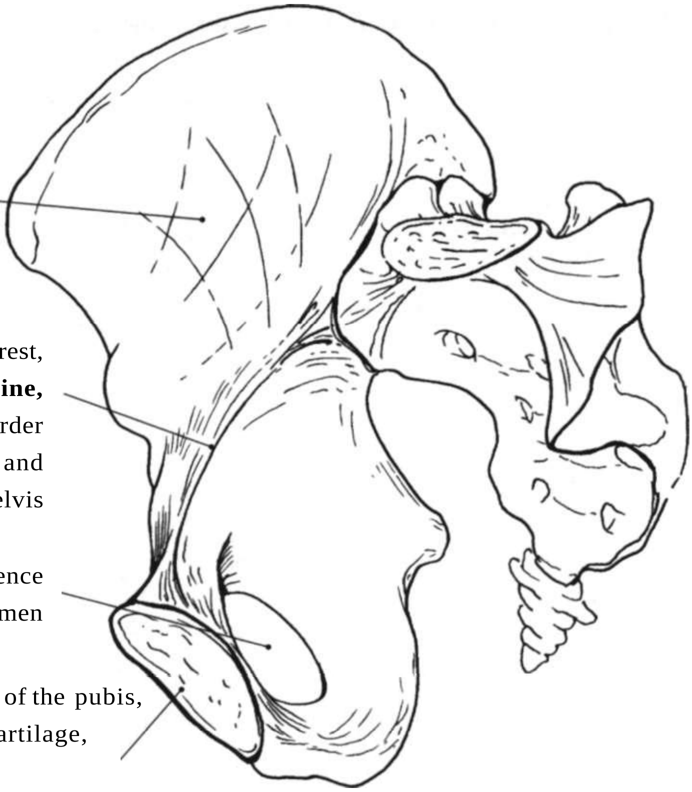


On the medial surface, we find:

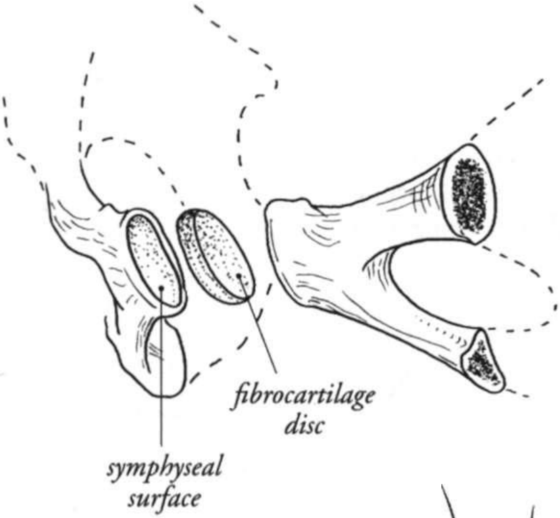
the **internal iliac fossa**

an oblique crest, the **iliopectineal line,** which forms the border between the lesser and greater pelvis

the internal circumference of the obturator foramen



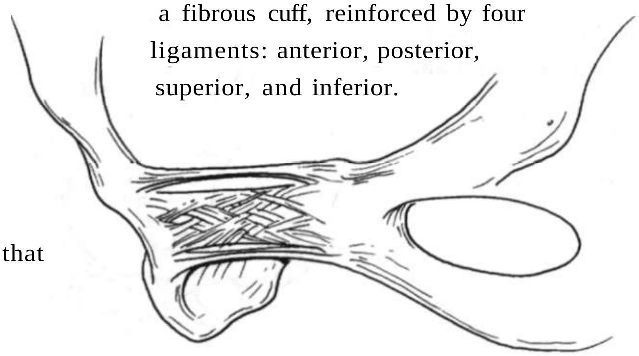
an articular surface located in front of the pubis, in the shape of an oval covered by cartilage, which unites the two pubic bones. This is the pubic symphyseal surface.



The articulation between the two pubic bones is called the **pubic symphysis.**

Between the two surfaces is a fibrocartilage disc which attaches to the articular surfaces.

The entire structure is covered by a fibrous cuff, reinforced by four ligaments: anterior, posterior, superior, and inferior.

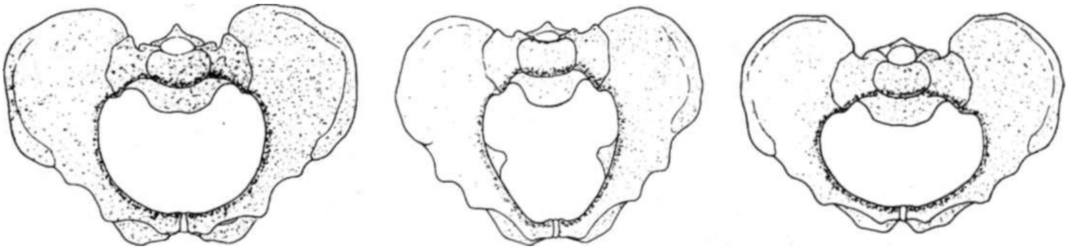


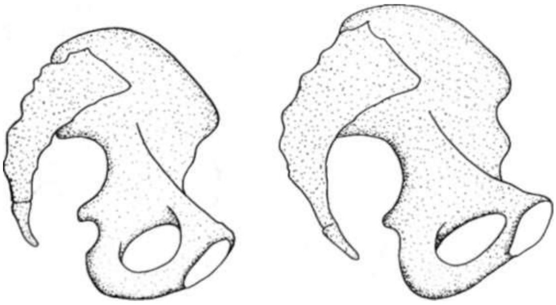
This is a joint with very little mobility. Only small gliding, compression, and twisting movements ate possible here. During childbirth, the joint loosens so that the pelvis can open up further.

The shape and proportions of the pelvis vary considerably in normal individuals.

For example, the pelvic inlet may have a round shape,

...or be compressed in either direction (center, right).



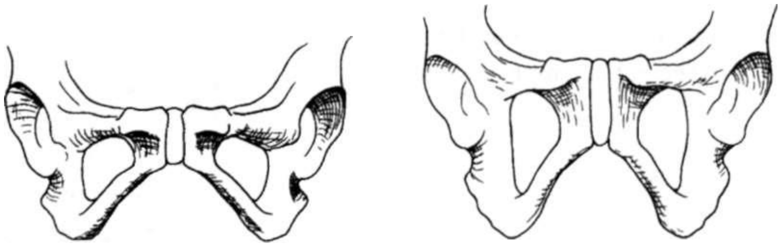


The curve of the sacrum may be more or less emphasized, and the hip bones more or less developed.

[SIDE VIEW]

The gap between the two ischial tuberosities may be bigger or smaller.

[FRONT VIEW]



The sacral crest or posterior superior iliac spines may protrude in some individuals. This condition, combined with lack of "padding" by muscles and adipose tissue, can result in difficulty doing floor exercises, particularly rolling on a hard surface.

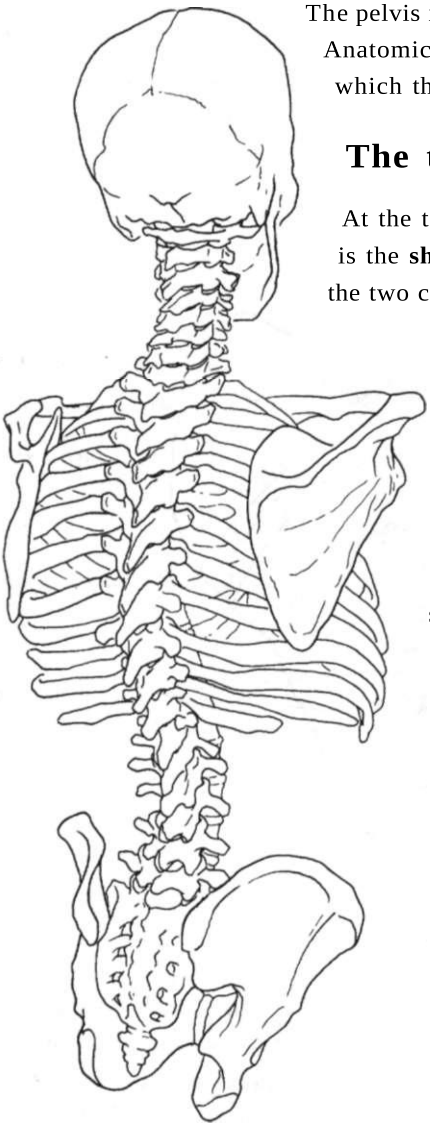
male pelvis

There are obvious differences in pelvic shape between males and females.

Essentially, the male pelvis is narrower and the female pelvis is wider, with larger pelvic inlet and outlet.

female pelvis

These differences are all related to the ability of women to carry and deliver a child.



The pelvis is sometimes also called the pelvic girdle. Anatomically, girdles are bony and articular structures by which the limbs ate attached to the trunk.

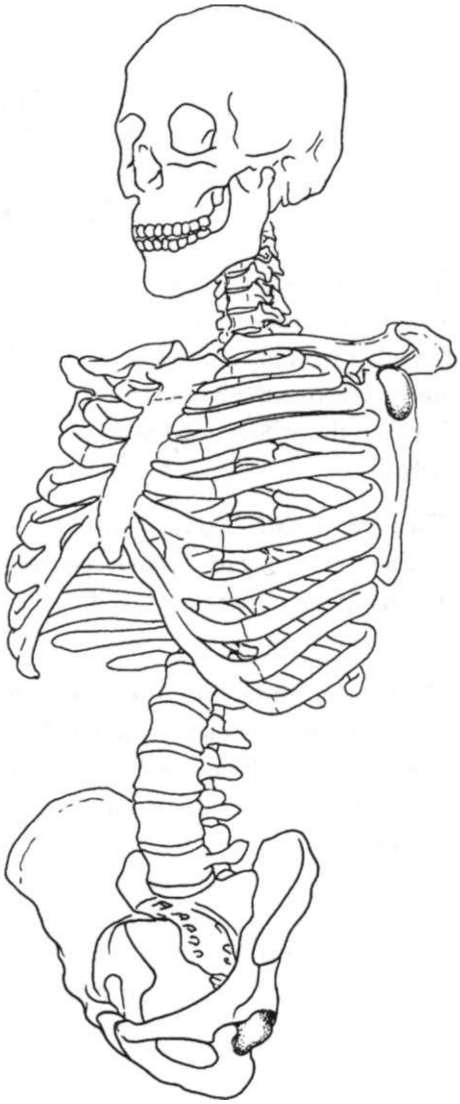
The two girdles

At the top of the trunk, lying on top of the ribs, is the **shoulder girdle,** which consists of the sternum, the two clavicles, and the two scapulae.

Through this structure, the upper limbs are attached to the trunk.

Its main feature is its mobility.
It is not linked via joints to the spinal column, but instead is linked to the thoracic cage.

(For more information, see p. 110-115.)



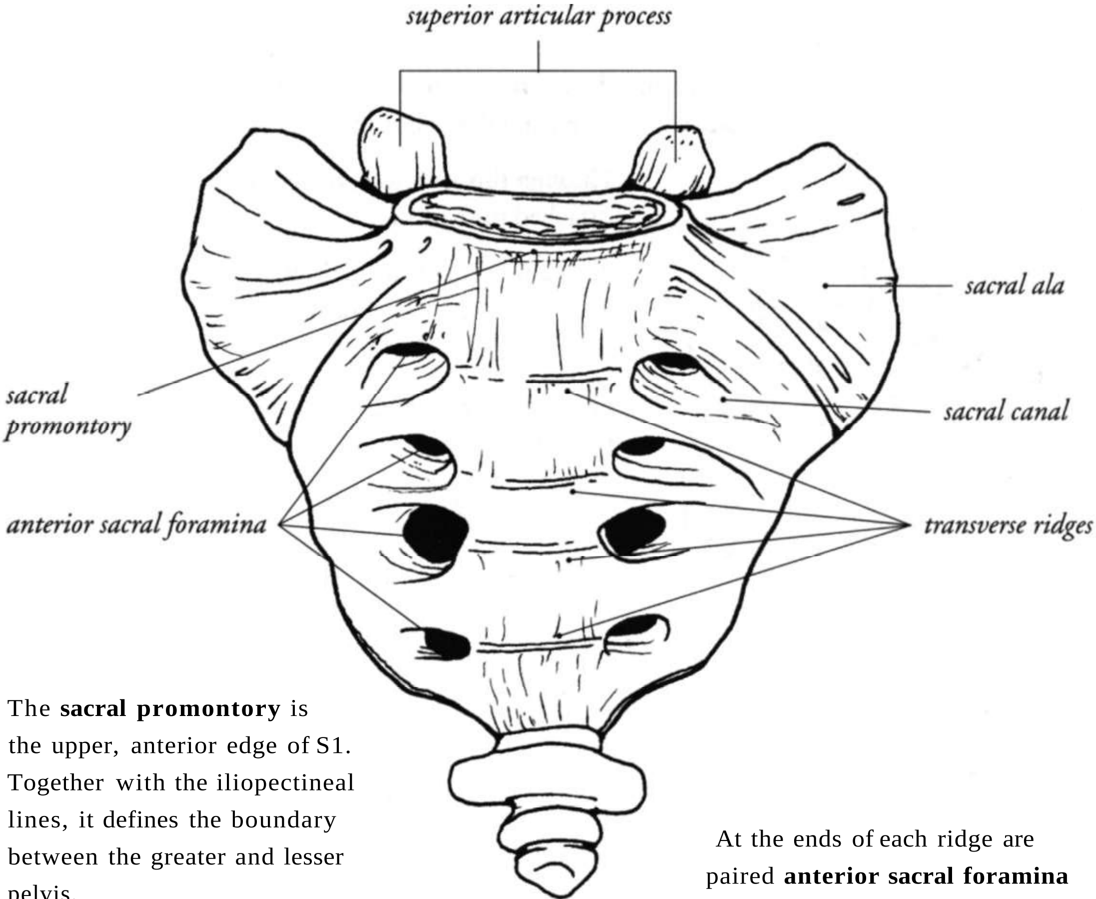
At the bottom of the trunk is the **pelvic girdle,** or pelvis, which consists of the sacrum and the two hip bones.

Through this structure, the lower limbs are attached to the trunk. Because the articulations between these bones are not very mobile, it is a very stable structure. The pelvic girdle is attached to the trunk via the sacro-lumbar joint, which connects it to the spinal column.

(For mote information, see p. 43-53 in this chapter.)

Sacrum

The sacrum is the posterior, wedge-shaped component of the pelvic ring, located between the two ilia. It is composed of five expanded, fused vertebrae (S1-S5) whose individual components are readily visible.

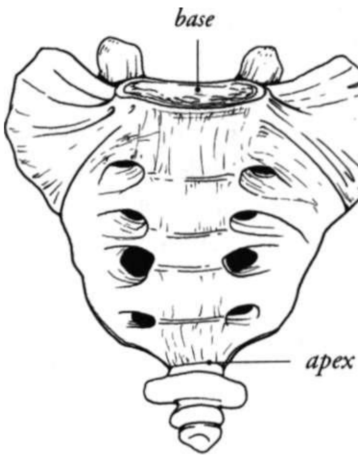


The **sacral promontory** is the upper, anterior edge of S1. Together with the iliopectineal lines, it defines the boundary between the greater and lesser pelvis.

The anterior surface is smooth and concave. There are four **transverse ridges,** which represent intervertebral discs.

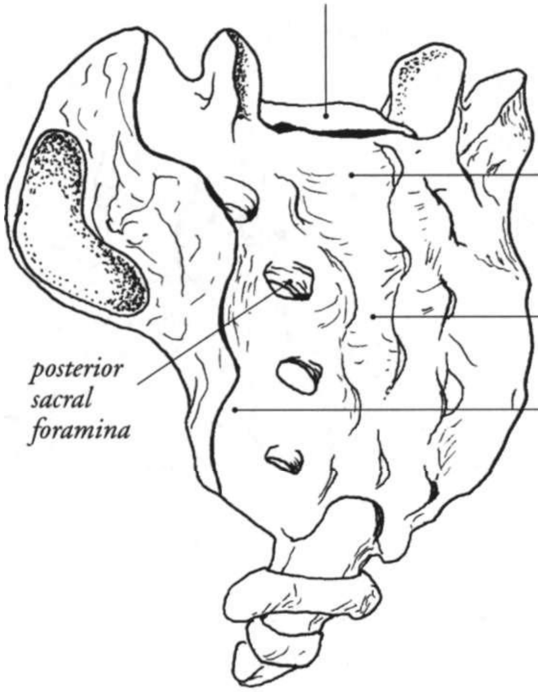
At the ends of each ridge are paired **anterior sacral foramina** (corresponding to intervertebral foramina), through which the anterior branches of the sacral nerves pass.

The superior surface of S1, called the base of the sacrum, articulates with L5. The inferior surface of S5, which articulates with the coccyx, is called the apex of the sacrum.

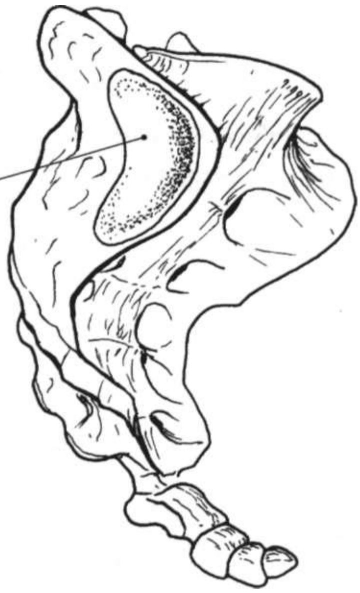


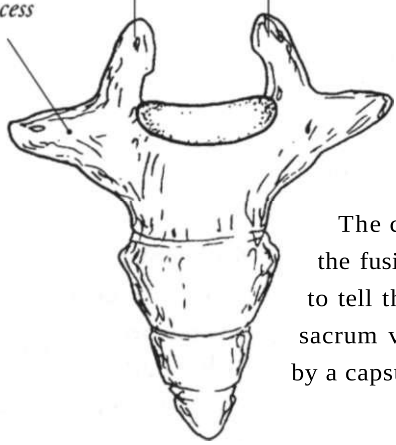
The convex posterior surface is much rougher.

The **posterior sacral foramina** are continuous with the anterior foramina; posterior branches of the sacral nerves exit here. The **median sacral crest** and paired **lateral sacral crests** represent the spinous and transverse processes of the vertebrae. The spinal cord enters through the **sacral canal.**



The **auricular** ("ear-shaped") **surfaces** are best seen in side view. These articulate with the auricular surfaces of the ilia.





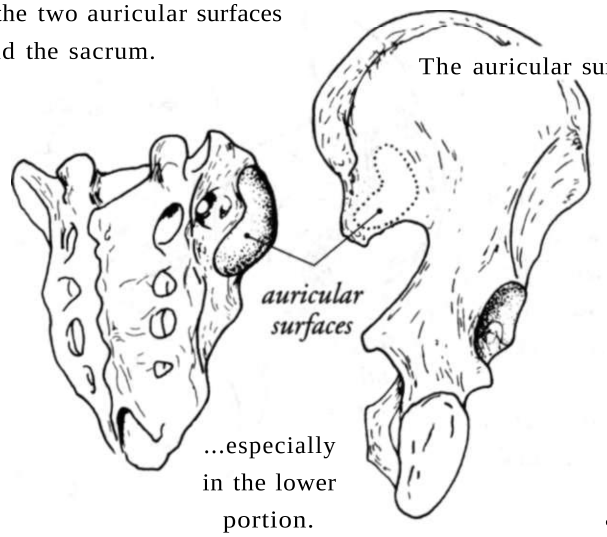
Coccyx

The coccyx is a small triangular bone consisting of the fusion of three to five vertebrae. (It is not possible to tell them apart.) The coccyx articulates with the sacrum via an **oval-shaped surface.** It is supported by a capsule and ligaments (this joint is often fused).

Sacroiliac joint

This joint consists of the two auricular surfaces on top of the ilium and the sacrum.

The auricular surface of the sacrum is slightly concave.



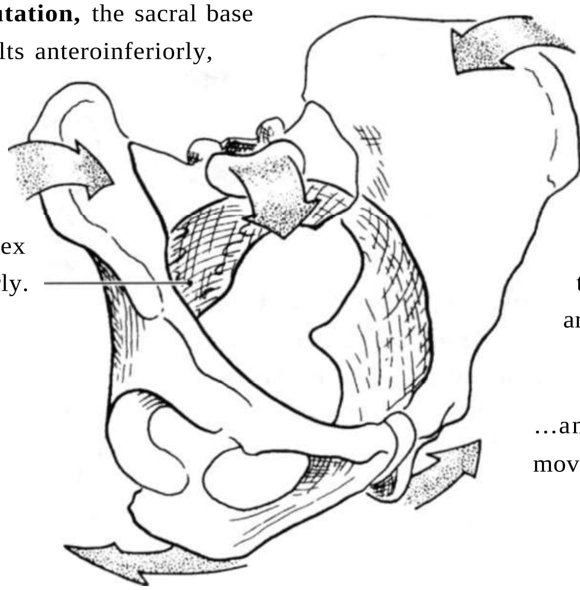
The auricular surface of the hip bone is slightly convex...

...especially in the lower portion.

This arrangement allows for an important movement between the sacrum and the two ilia, called nutation and counternutation.

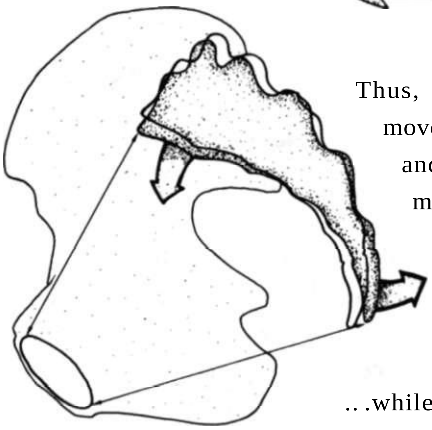
In **nutation,** the sacral base tilts anteroinferiorly,

.. .and the sacral apex tilts postefosuperiorly.



In one type of movement, which we shall call "adduction" of the pelvis, the sacrum goes into nutation, the iliac "wings" are pulled medially,

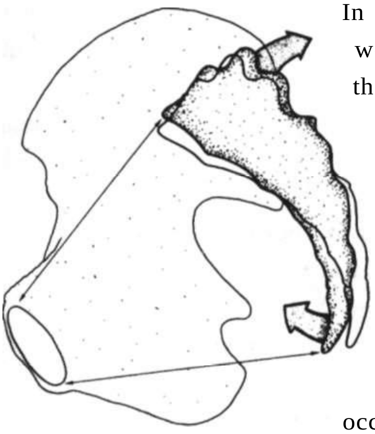
...and the ischial tuberosities move laterally.



Thus, the sacral promontory moves toward the pubis, and the sacral apex moves away from the pubis,

.. .while the ischial bones move away from each other, increasing the distance between them.

In summary: during adduction, the diameter of the pelvic outlet increases and the pelvic inlet decreases from front to back.



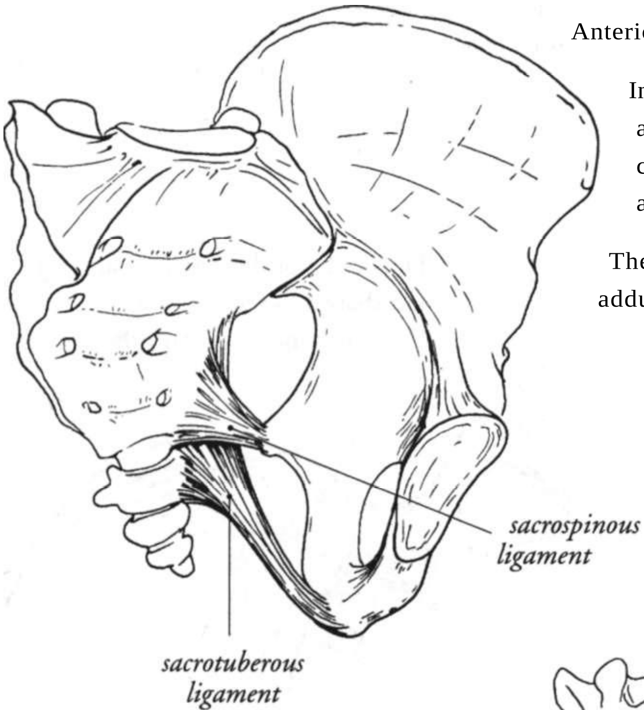
In the opposite movement, which we will call "abduction" of the pelvis, the sactum moves in **counternutation,** as the sacral base tilts backward and upward and the sacral apex tilts forward and downward. The iliac wings move away from the midline and the ischial bones move toward each other.

In summary: during abduction, the pelvic inlet becomes larger from front to back, and the diametet of the pelvic outlet becomes smaller

The dimensional changes between the pelvic inlet and outlet occur especially during childbitth: At the beginning of the baby's engagement in the pelvis, there will be a sacral counternutation, and when the baby comes out (expulsion), a nutation.

Sacroiliac ligaments

Each sacroiliac joint is reinforced by a capsule and a strong network of ligaments:



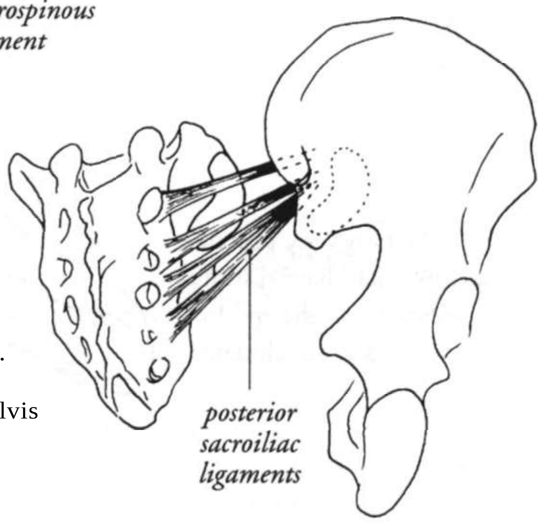
Anteriorly, there are two fasciae (not shown).

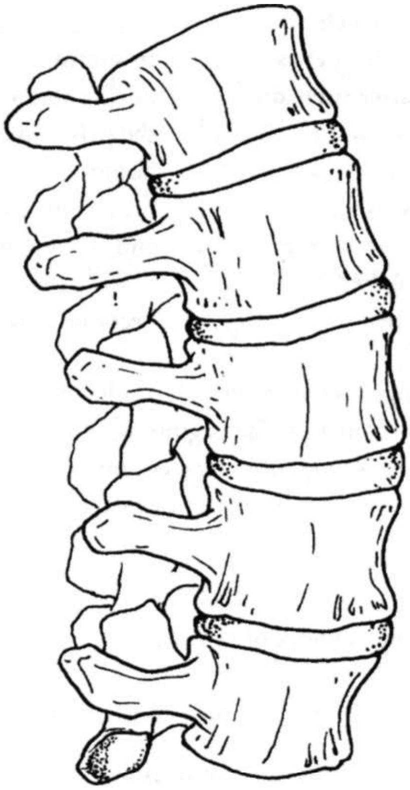
Inferiorly, the **sacrospinous** and **sacrotuberous ligaments** connect the sacrum to the ischial spine and ischial tuberosity respectively.

These ligaments tend to oppose adduction" of the pelvis.

There are also a series of **posterior sacroiliac ligaments** connecting the ilium to the lateral sacral crest.

These tend to oppose "abduction" of the pelvis





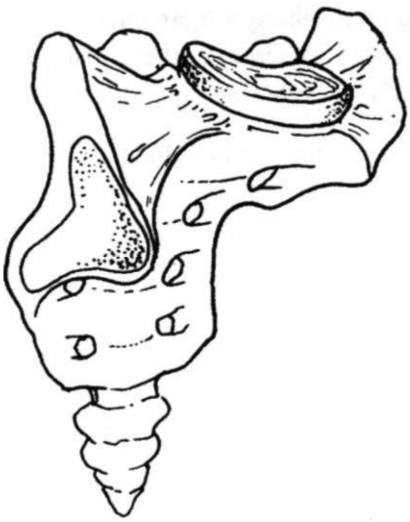
Lumbar spine

This is the next structure above the sacrum.
It is concave at the back.
This is the "loin" area
between the pelvis and the ribcage.

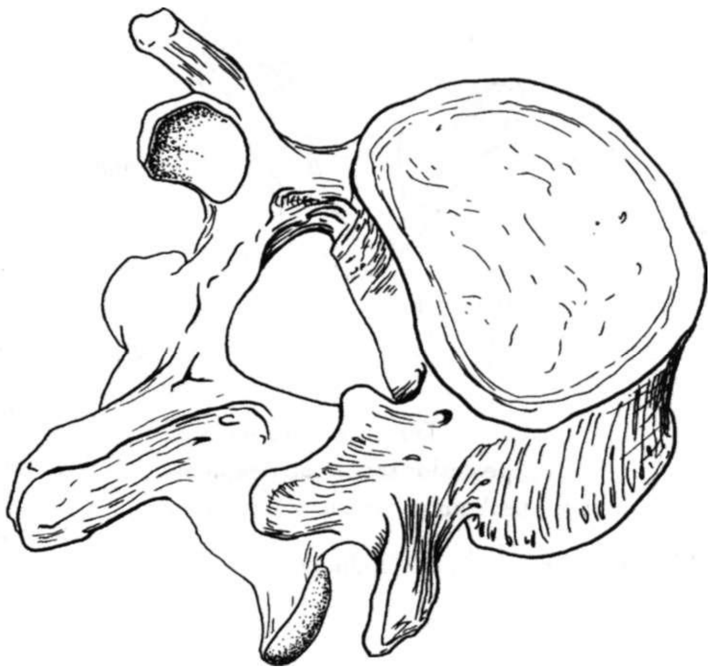
Lumbar vertebrae

The lumbar vertebrae are large,
and become larger
at the bottom of the lumbar spine.

The discs are thick,
about one-thitd the thickness
of the vertebral bodies.
This increases mobility.

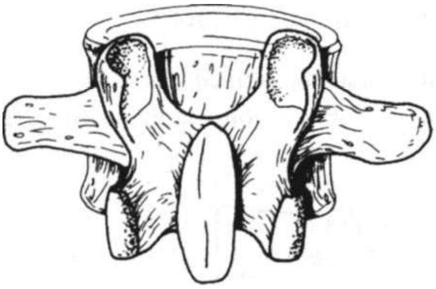


The bodies of the vertebrae are large,
and shaped like a lima bean.
They are concave posteriorly.

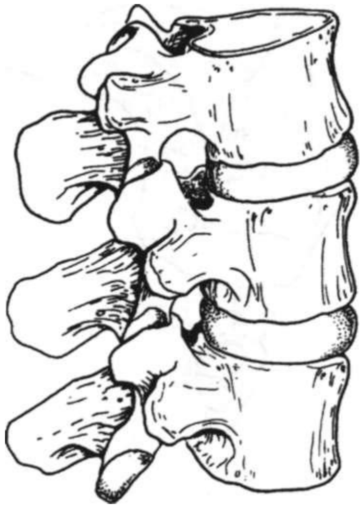


The transverse processes
are long and have distinct
tubercles on the end for
muscle attachment.

The articular processes project above and below the vertebral body, with a narrow part in-between: the isthmus.

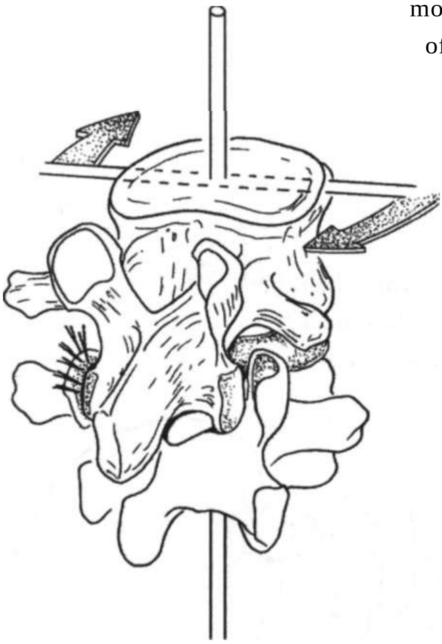


The superior articular processes of the vertebrae have a concave cylindrical form. They point medially (and slightly backward).



The inferior articular processes have a convex cylindrical form. They point laterally (and slightly forward). These bony projections articulate with the neighboring vertebrae and are stacked on top of each other.

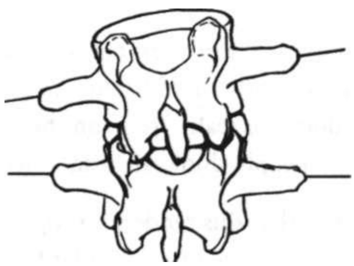
Their articular facets are vertical and somewhat sagittal.* These characteristics make rotation very difficult (below),



...but facilitate movements of flexion,

extension,

and sidebending.



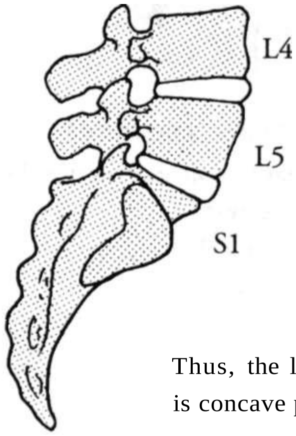
The top lumbar vertebrae are sagittal. They become more and more frontal towards the lower lumbar vertebrae. At the lumbosacral junction, they are completely frontal.

To summarize the mobility of the lumbar vertebrae: good range of motion for flexion, extension, and sidebending, limited ROM for rotation.

Between the sacrum and the 5th lumbal vertebra we find the...

Lumbosacral joint

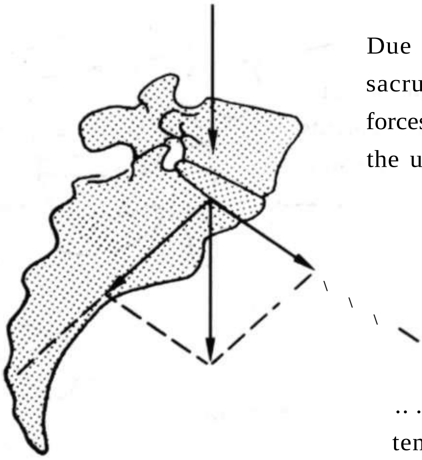
The sactal base is tilted forward to a variable degree (considerably, in some individuals).



Also, the body of L5 and the disc between L5 and S1 are slightly thicket anteriorly than posteriorly (this also applies to the L4/L5 joint).

Thus, the lumbosacral joint is concave posteriorly.

Due to the oblique orientation of the sacrum, there are two perpendicular forces resulting from the weight of the upper body at L5.

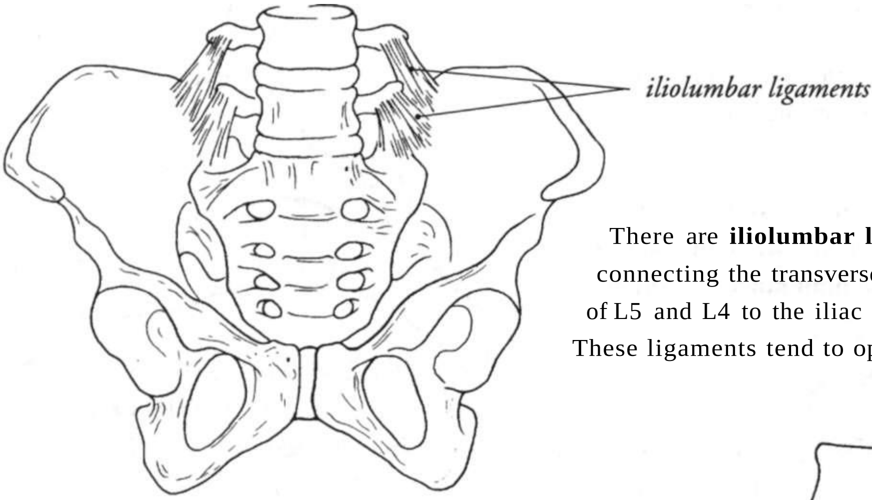


One is directed along the axis of the sacrum,

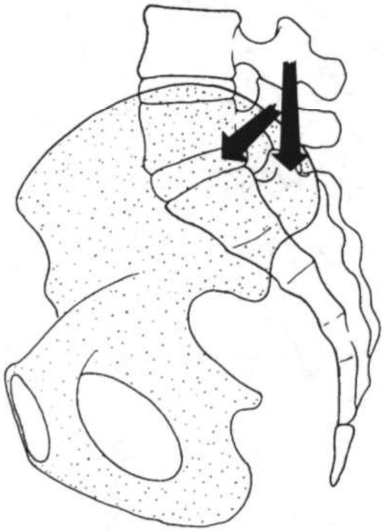
.. .while the other tends to make L5 slide forward.

This second force can be significant if the sacral base is greatly tilted (right). In other words, L5 does not really "rest" on the sacral base, as many people think. It "wants" to slide forward.

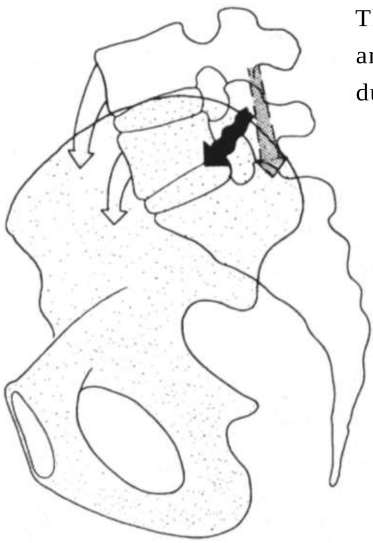
Notice that this tendency is opposed by the contact between the articular facets of S1 and the inferior articular processes of L5.



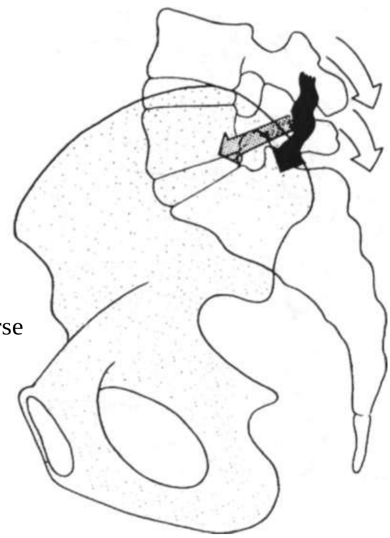
There are **iliolumbar ligaments** connecting the transverse processes of L5 and L4 to the iliac crest. These ligaments tend to oppose sidebending.



From the side, you can see that the ligament from L4 is oriented posteroinferiorly, while that from L5 runs more anteroinferiorly.



Thus, the L4 ligament is stretched and the L5 ligament relaxed during flexion...

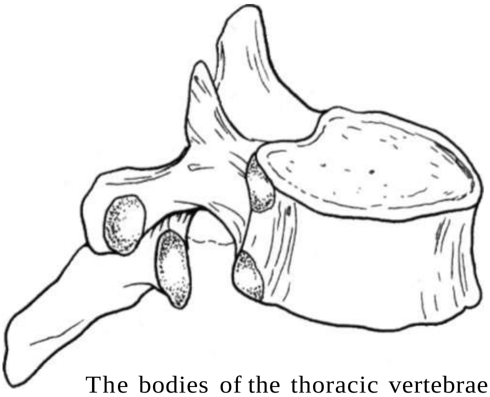


...while the reverse occurs during extension.

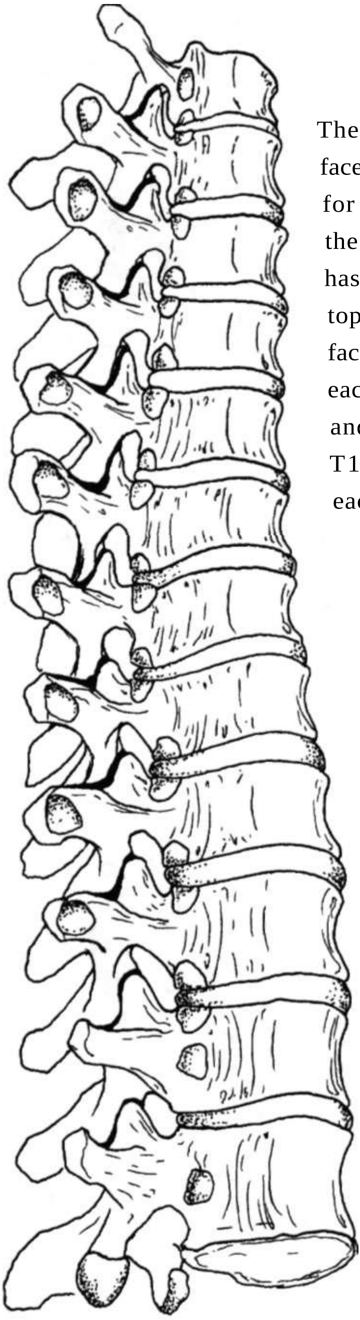
Thoracic spine

The thoracic spine articulates with the ribs.
It consists of twelve vertebrae,
the thoracic vertebrae.

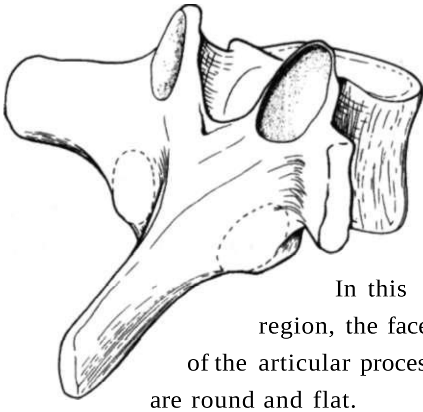
In contrast to the lumbar region, the thickness of the discs is only about one-sixth that of the bodies; this tends to limit range of motion.



The bodies of the thoracic vertebrae are cylindrical, and almost found in cross section.

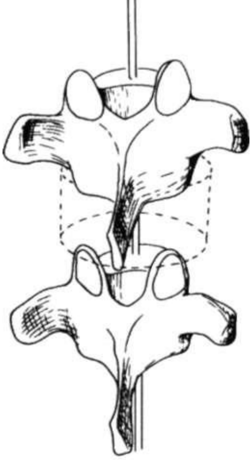


There are posterior facets on the bodies for articulation with the heads of ribs. T1 has a facet near the top, and an inferior facet. T2 through T9 each have superior and inferior facets. T10 through T12 each have one facet.



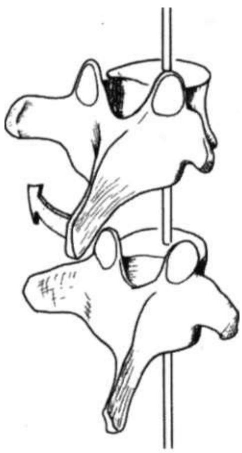
In this region, the facets of the articular processes are round and flat.

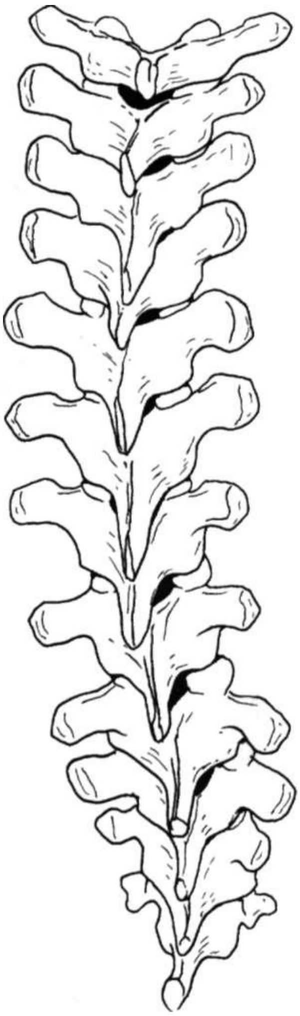
The articular facets are oriented postero-superolaterally on the superior articular processes, and anteroinfero-medially on the inferior processes. This arrangement permits flexion, extension, and sidebending.



These facets are located approximately on the circum-ference of a circle whose center would be the center of the vertebral body.

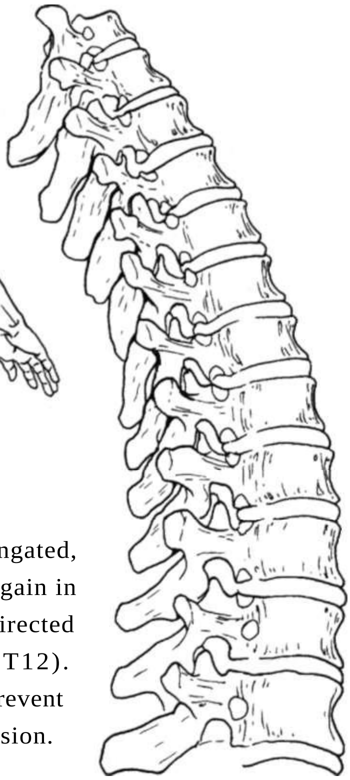
This facilitates rotation.





The laminae are flat, rectangular, and taller than they are wide. They are stacked on and overlap each other like tiles on a roof.

The transverse processes decrease in length from top to bottom (left), and those of T1 through T10 have anterior facets for articulation with the tubercles of ribs.



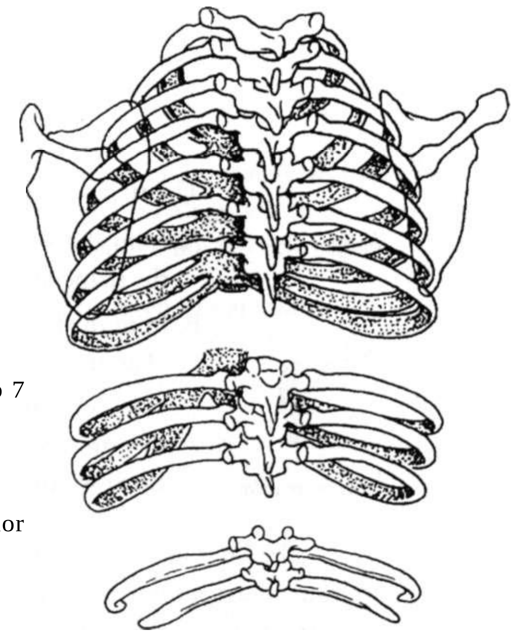
The spinous processes are elongated, laterally compressed, and (again in contrast to the lumbal region) directed inferiorly (except for Tl 1 and T12). These characteristics help prevent hyperextension.

The vertebral attachment to the rib cage tends to limit mobility of the thoracic spine.

This is particularly true for T1 through T7 between the scapulae, whose cot responding ribs (the "rrue ribs") are connecred directly to the sternum by short pieces of cartilage which allow little mobility.

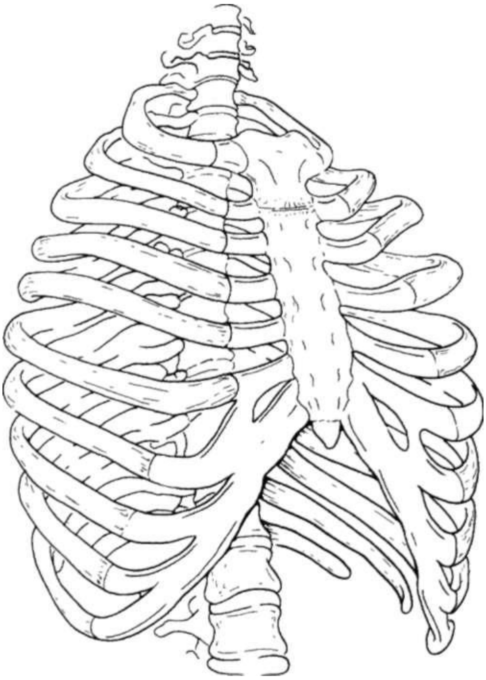
Ribs 8, 9, and 10 (the "false" ribs) have longer costal cartilages which attach to the cartilage of rib 7 rather than directly to the sternum. The mobility of T8, T9, and T10 is correspondingly greater.

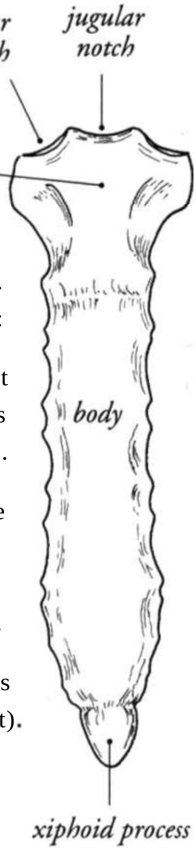
Ribs 11 and 12 (the "floating" ribs) have no anterior attachment at all, so the mobility of T11 and T12 is greatest.



Thoracic cage

The thoracic cage consists of the thoracic vertebrae at the back, and the ribs and sternum in the front.





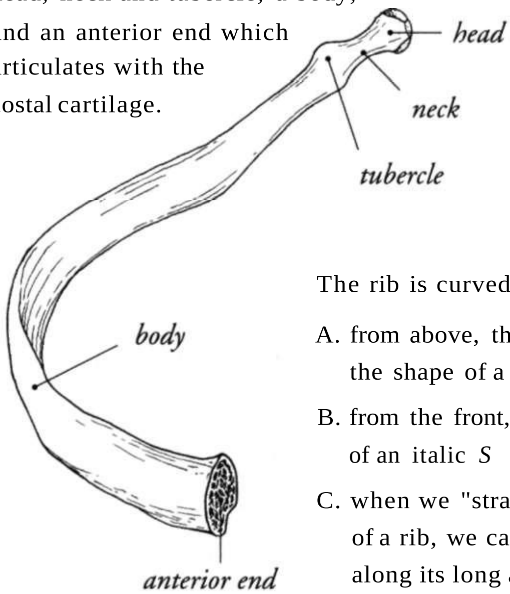
The **sternum** is a flat bone located at the front of the thorax. It consists of three parts:

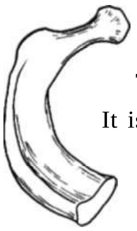
1. manubrium: The top part of the manubrium articulates with the clavicles (see p. 110).

2. body: The lateral edge has another 7 notches, which articulate with the first 7 costal cartilages.

3. xiphoid process (not always present).

The **ribs** are elongated, flattened, and twisted bones. Each rib consists of a posterior end with three parts: head, neck and tubercle; a body; and an anterior end which articulates with the costal cartilage.





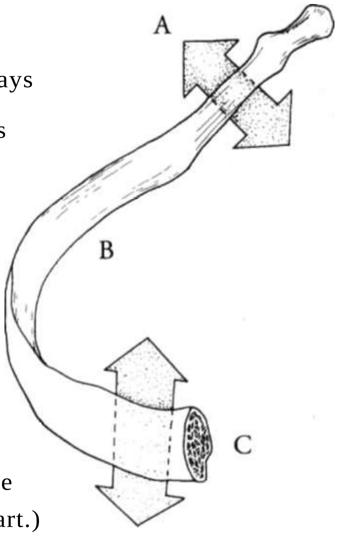
The first rib is the smallest. It is flattened from top to bottom.

The rib is curved in three different ways

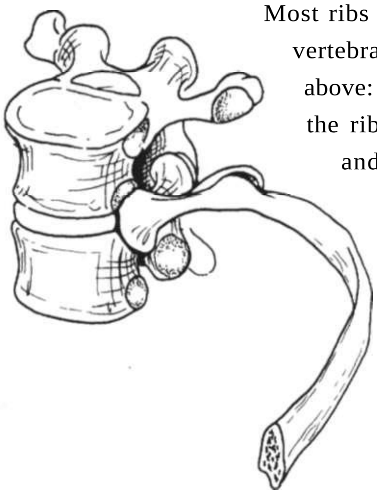
A. from above, the edge of the rib has the shape of a bucket handle

B. from the front, it has the shape of an italic *S*

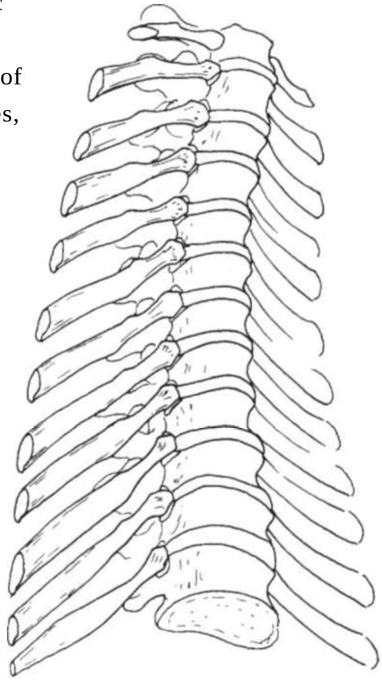
C. when we "straighten" part of a rib, we can see torsion along its long axis.



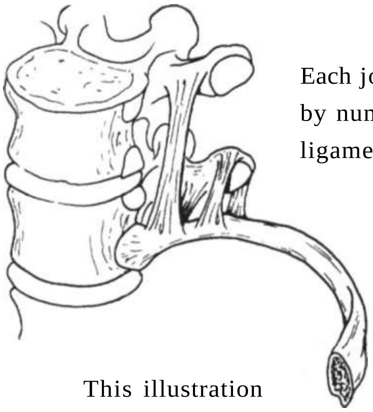
The rib is like a curved blade "under tension." (During a sternotomy, a surgical procedure where the sternum is cut, one can see how the ribs move apart.)



Most ribs articulate with two thoracic vertebrae at three points, as noted above: the two facets on the head of the rib contact the vertebral bodies, and the tubercle contacts the transverse process.

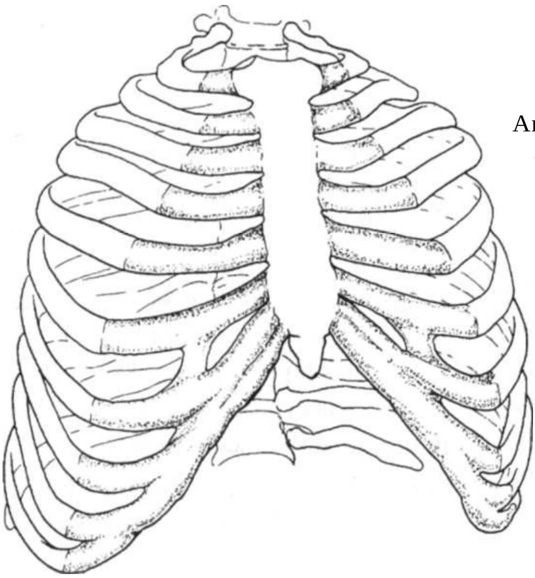


Exceptions are ribs 1, 11 and 12, which only contact one vertebral body, and ribs 11 and 12, which do not rest on a transverse process.



Each joint is stabilized by numerous small ligaments.

This illustration depicts the joints as if pulled apart from each other.



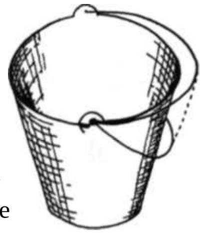
Anteriorly, each rib is attached to the sternum via its **costal cartilage,** which increases the elasticity of the thoracic cage.

The first seven ribs are short and attach directly to the sternum. These ribs are called **true ribs.**

The three following cartilages, which are longer, all attach to the 7th rib. These are called **false ribs,** and have greatef mobility.

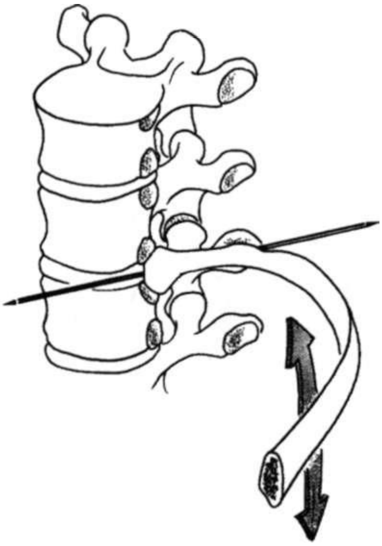
The two lowest ribs do not have a cartilage. These are called **floating ribs.**

Movements of the ribs



The movements of a rib can be compared to those of a bucket handle.

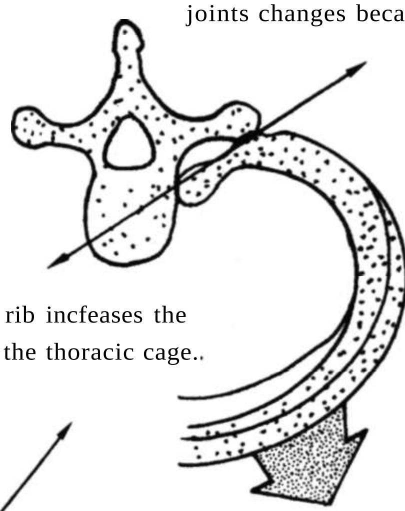
As the rib moves up or down, the diameter of the thoracic cage ("bucket") is changed



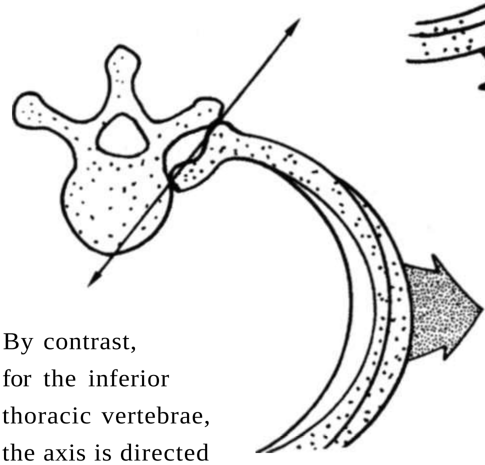
Posteriorly, the rib pivots on an axis passing through the center of two joints:

- one, with two facets, articulates with the vertebral body
- another articulates with the transverse process of the vertebra.

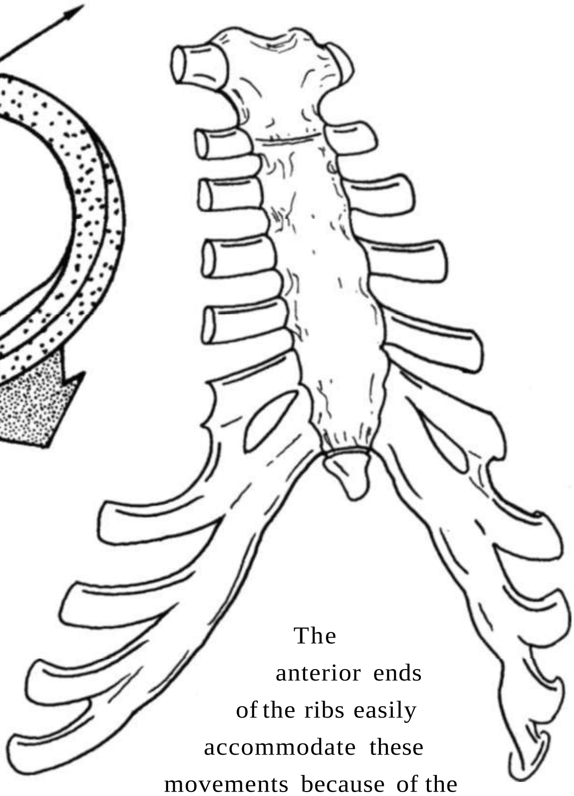
At different levels, the spatial relationship of these two joints changes because the shape of the vertebra changes.



For the superior thoracic vertebrae, the axis is directed more laterally, and elevation of the rib incfeases the anterior diameter of the thoracic cage..

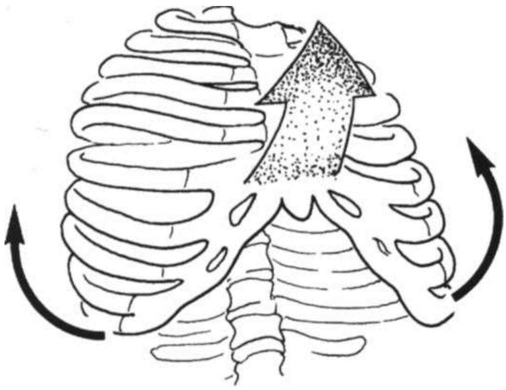


By contrast, for the inferior thoracic vertebrae, the axis is directed more posteriorly, and elevation of the rib increases the lateral diameter of the thoracic cage.

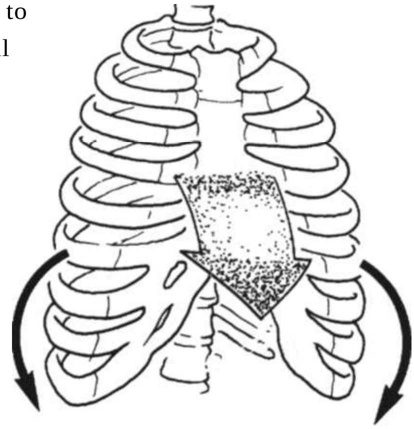


The anterior ends of the ribs easily accommodate these movements because of the flexibility of the costal cartilages, which varies depending on the level of the rib. However, this flexibility can decrease with age, thus reducing overall mobility.

During **costal inhalation,** the ribs are elevated. Therefore, the diameter of the upper thoracic cage is increased in an anterior direction, while that of the lower cage is increased in a lateral direction.



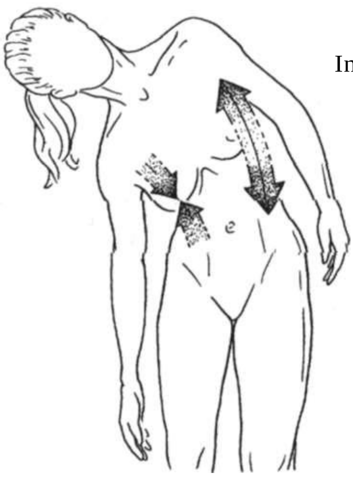
The reverse occurs during **costal exhalation,** when the ribs move down. The costal cartilages undergo some torsion (twisting on their own axis) on inhalation, then return to their normal shape on exhalation.



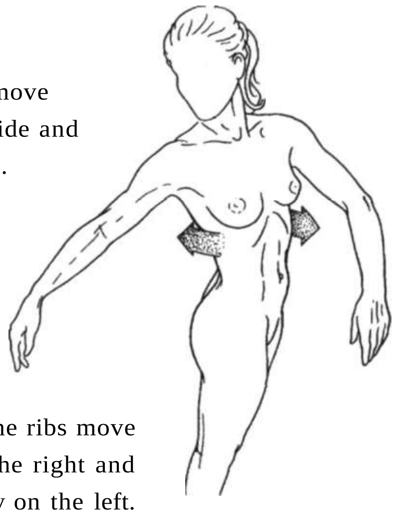
Obviously, spinal movements also affect the orientation of the ribs:

The ribs in front move closet together during thoracic flexion,

...and farther apart during extension.



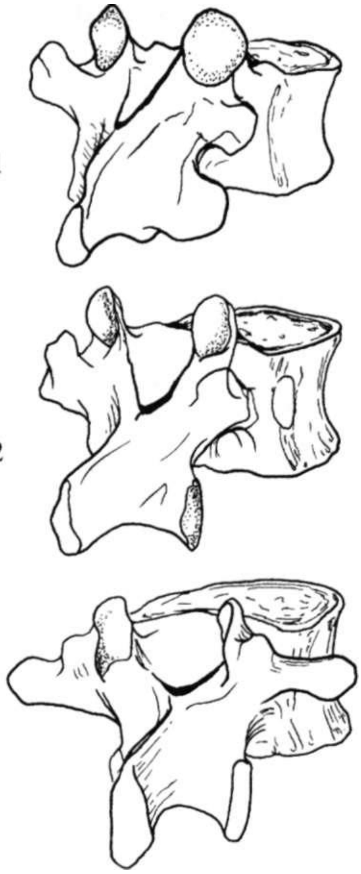
In right sidebending, the ribs move closer together on the right side and farther apart on the left side.



In right rotation, the ribs move posteriorly on the right and anteriorly on the left.

Thoracolumbar junction

The junction between the thoracic and lumbar spinal regions has some interesting features.



T11

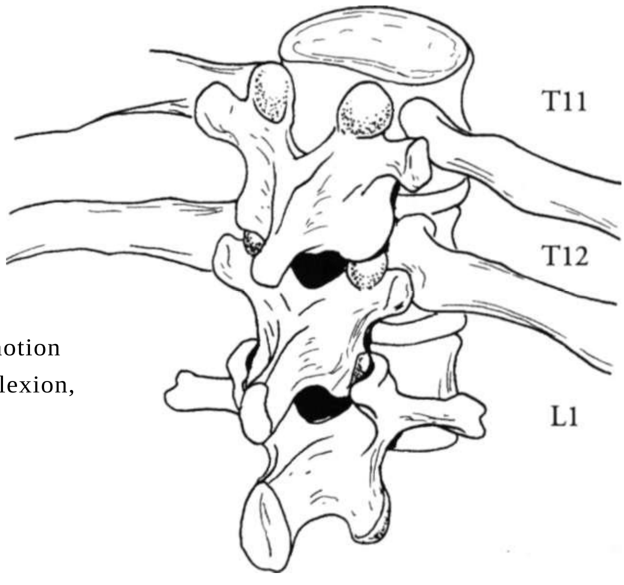
T12

L1

T12 resembles T11 in its upper half, but resembles L1 in its lower half, i.e., the spinous process is shortened (which facilitates extension), and the inferior articular facets are large and convex (which restricts rotation).

At T12/L1, the junction between the thoracic and lumbar spinal regions, mobility of the spine is characterized by good flexion, extension, and sidebending, but very little rotation.

Because T11 and T12 are both attached to floating ribs, and because of the shape of the spinous process and inferior articular processes on T11, there is good range of motion in all directions at the T11/T12 joint: flexion, extension, sidebending, and rotation.



Starting from the bottom of the spine, the T11/T12 joint is the first important rotational joint.

Hyper-rotation is possible at this location.

Cervical spine

The cervical spine forms the skeleton of the neck.
We will study two regions.

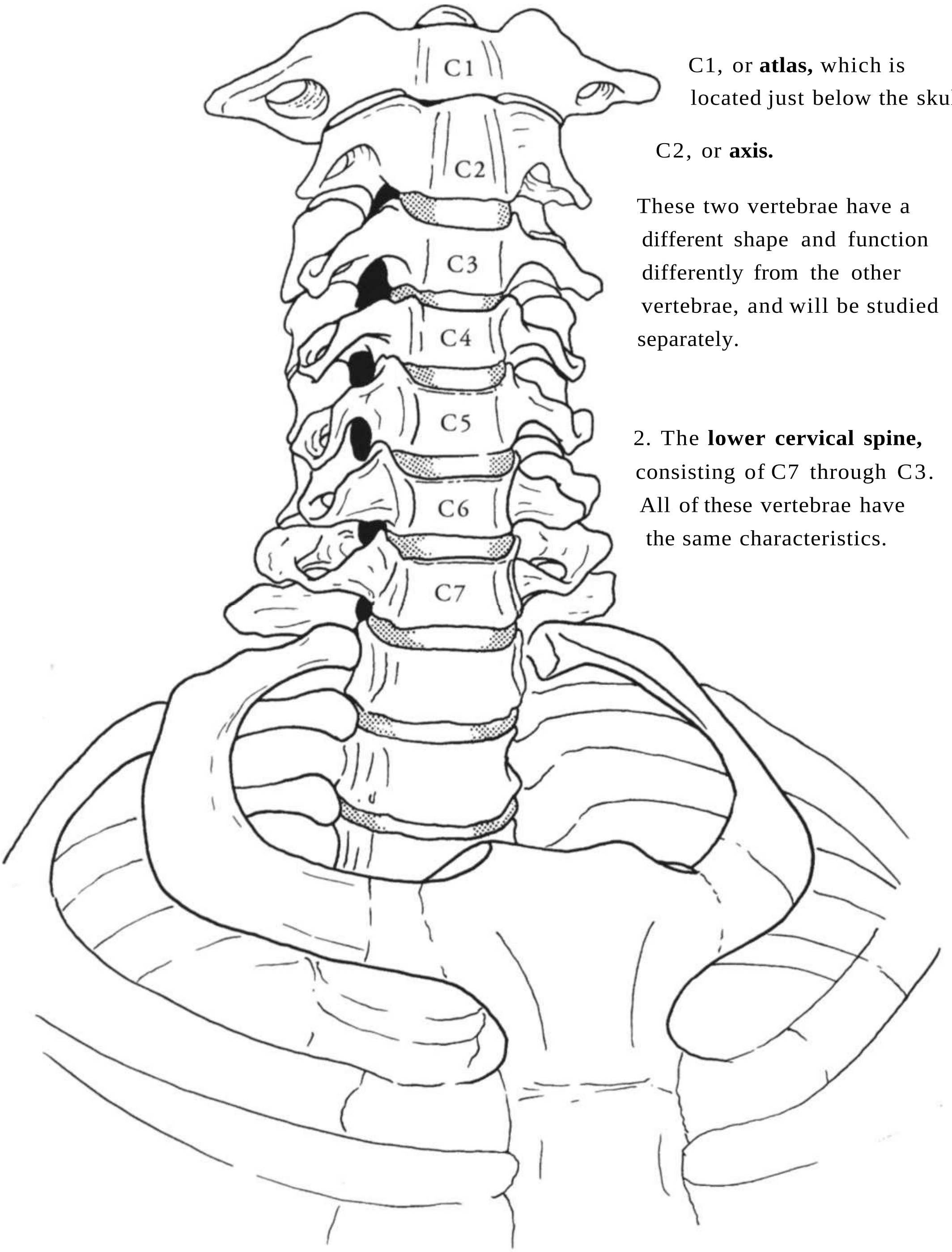
1. The **suboccipital cervical spine,** which consists of the two top vertebrae:

   C1, or **atlas,** which is located just below the skull

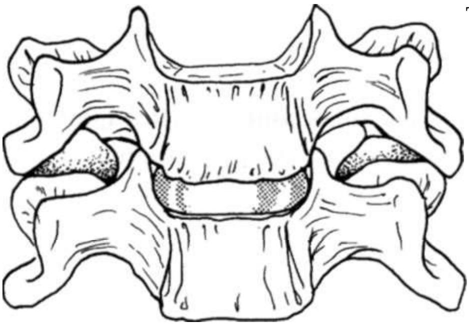
   C2, or **axis.**

   These two vertebrae have a different shape and function differently from the other vertebrae, and will be studied separately.

2. The **lower cervical spine,** consisting of C7 through C3. All of these vertebrae have the same characteristics.



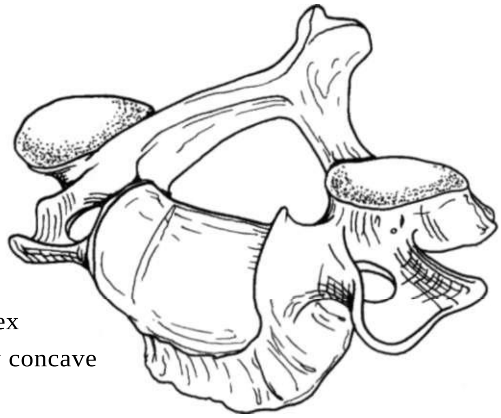
Cervical vertebrae



The bodies of cervical vertebrae are small.
The discs are about one-third as thick as the bodies.
Both of these factors tend to increase mobility.

Sidebending is somewhat restricted by the rectangular shape of the bodies, as seen in cross section.

The superior surfaces of the cervical vertebral body project upward on the sides. (These projections are called uncinate processes.) The inferior surfaces are shaped to articulate with the superior ones.

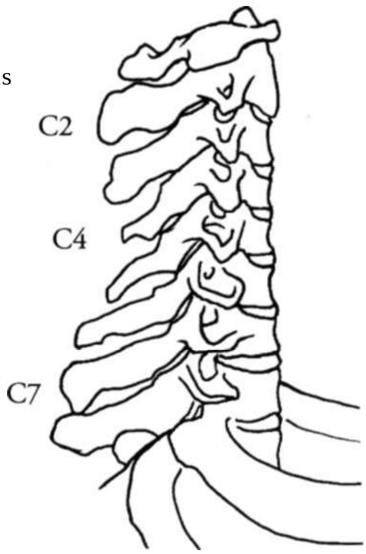


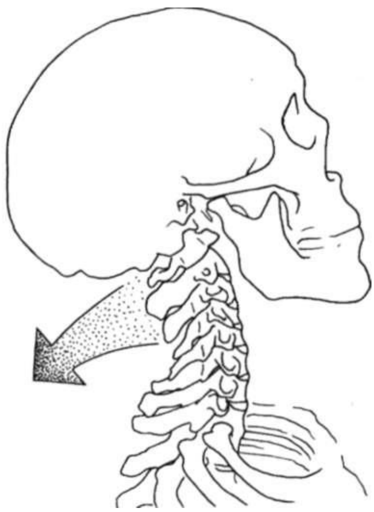
This bony configuration provides mobility as well as stability. The vertebral bodies are "stacked" laterally.

Additionally, the superior surfaces are slightly convex and tilted forward. The inferior surfaces are slightly concave and lifted backwatd.

The lengths of the spinous processes vary.

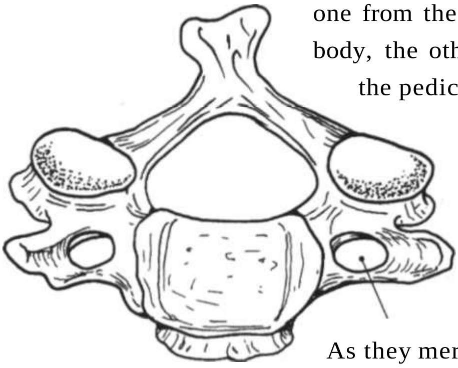
Those in the middle cervical area are short, especially C4, which permits good extension of the cervical spine.



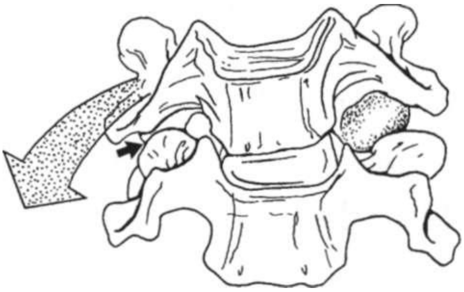


However, at the bottom part of the cervical spine (the area of C6 and C7), extension is mote limited because these two spinous processes are long and restrain extension.

Each of the cervical transverse processes has two roots:



one from the side of the body, the other from the pedicle.

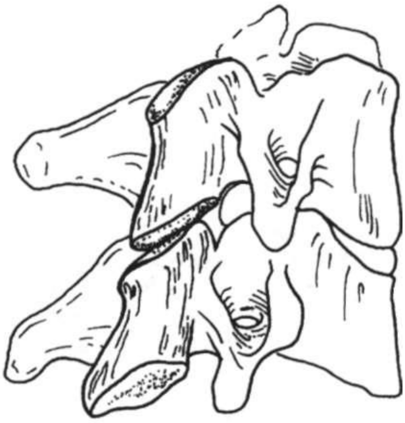


They ate thick and tend to limit side-bending when they come in contact.

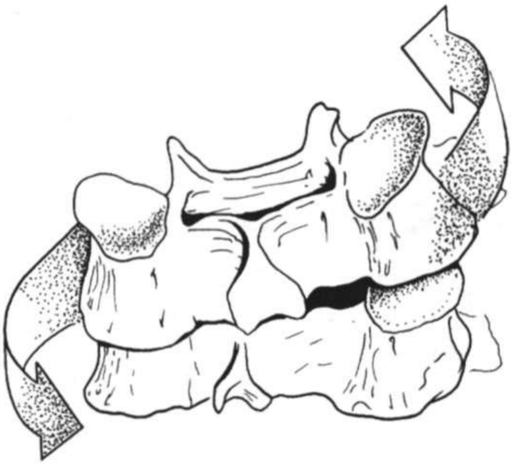
As they merge, the two roots form a medial opening called the **transverse foramen,** and a small lateral groove.

The **vertebral artery** passes through the transverse foramina of CI-C6. Spinal nerves pass through the lateral grooves.

Thus, correct alignment of the cervical spine is important for protection of these soft tissues.



The superior articular facets face posterosuperiorly, and the inferior facets anteroinferiorly, at an angle of 45°.



Sidebending of the cervical spine is always accompanied by a certain amount of rotation.

For example, during left sidebending, the left facet moves inferiorly and slightly posteriorly, while the right facet moves superiorly and slightly anteriorly. The combination of these two movements results in slight left rotation.

The **suboccipital spine** is the top part of the cervical spine.

This is the area where movements which are independent of the head are made, like nodding the head "yes" and shaking it "no."

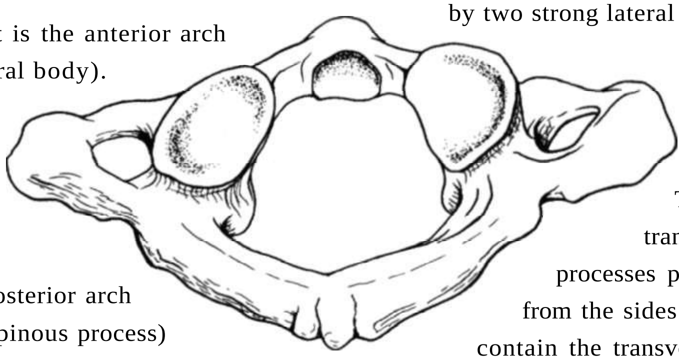
It consists of two unique vertebrae: the atlas and the axis.

The atlas

This is the first vertebra at the top of the spine.

It is not shaped like the other vertebrae. It is essentially a bony ring, reinforced by two strong lateral masses.

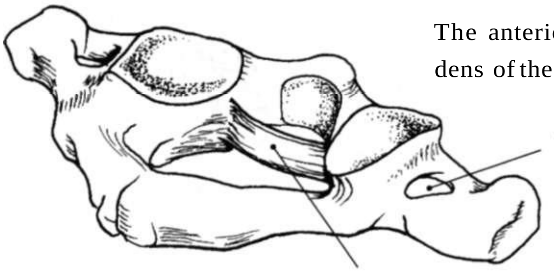
In front is the anterior arch (the atlas has no vertebral body).



In back is the posterior arch (the atlas has no spinous process)

The large transverse processes project from the sides. They contain the transverse foramina, through which the vertebral artery passes.

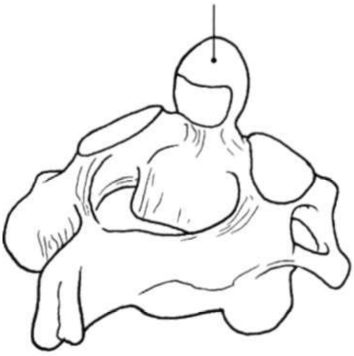
The **transverse ligament of the atlas,** which attaches to the inside of the lateral masses, divides the ting of the atlas into two parts.

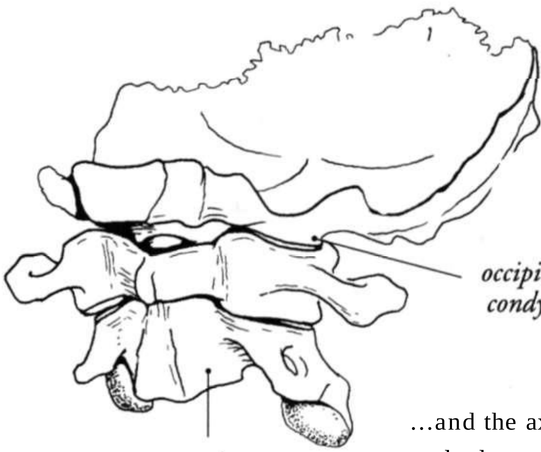


The anterior part surrounds the dens of the axis (see p.70)

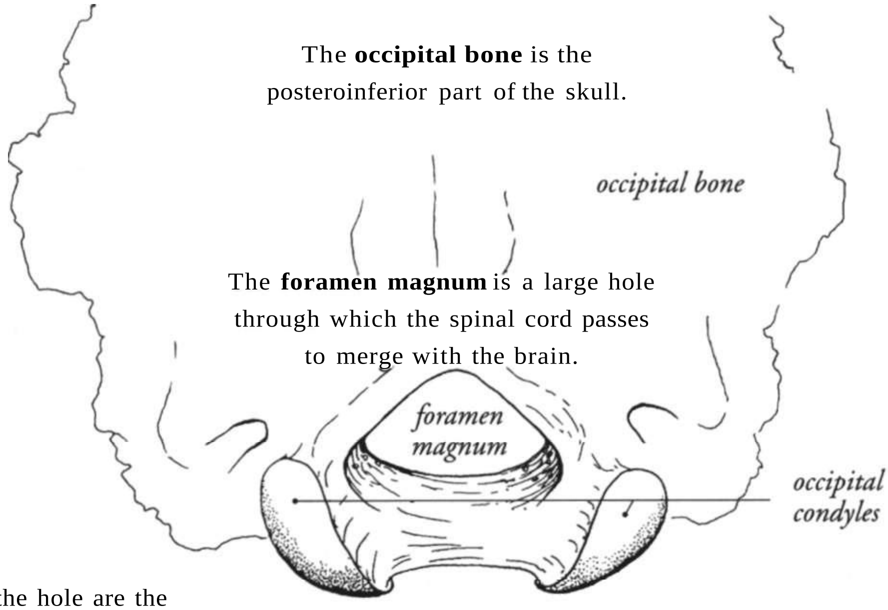
The posterior part contains the vertebral foramen, through which the spinal cord passes.

The upper and lower surfaces of the lateral masses have facets for articulation with the occipital condyle at the top...





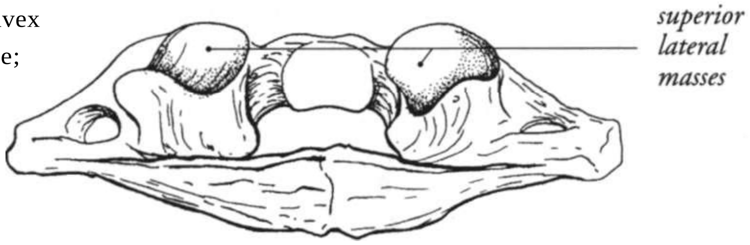
...and the axis at the bottom.



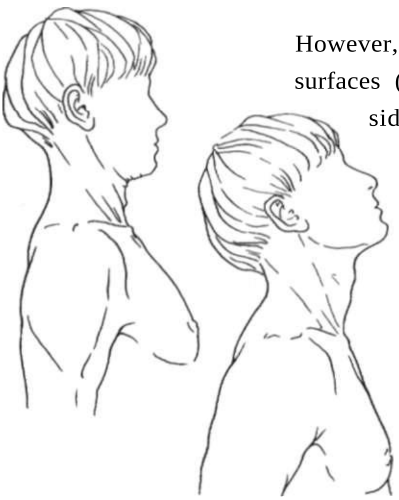
The **occipital bone** is the posteroinferior part of the skull.

The **foramen magnum** is a large hole through which the spinal cord passes to merge with the brain.

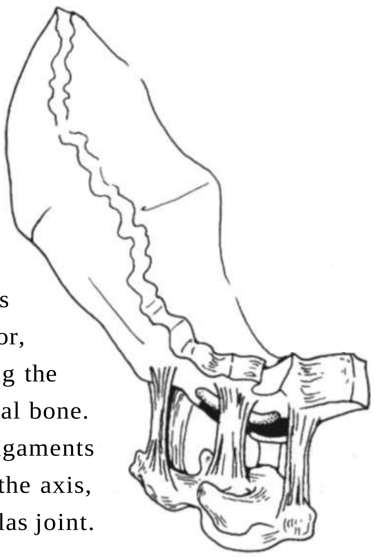
On each side of the hole are the **occipital condyles,** oval, convex surfaces coveted with cartilage; the corresponding superior articular facets of the atlas are concave.



These articulating surfaces lie essentially on the outside of an imaginary sphere whose center is inside the skull. Thus, the occipital-atlas joint could be viewed as a ball-and-socket joint, potentially allowing movement in any direction.



However, the shape of the joint surfaces (longer front-to-back than side-to-side) and presence of ligaments favors flexion/ extension and restricts other movements.

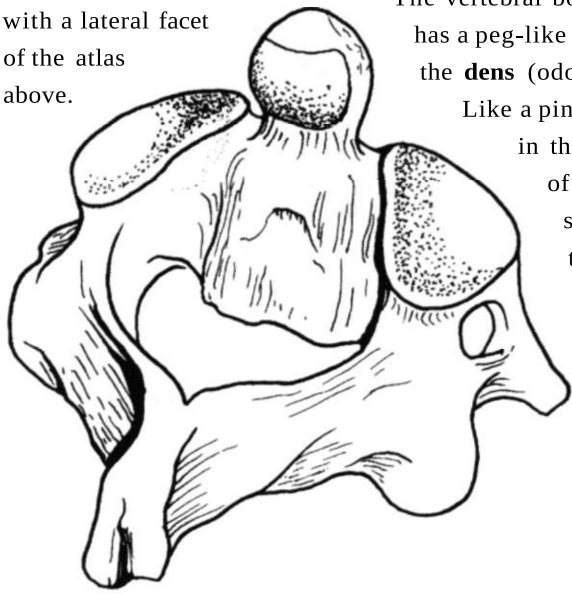


There are four ligaments (two lateral, one anterior, one posterior) linking the atlas to the occipital bone. These same ligaments continue inferiorly onto the axis, and help stabilize the axis-atlas joint.

The axis
and its connection with the atlas

The axis is the second cervical vertebra.
It has the shape of a typical cervical vertebra,
except that on the top,
there ate certain bony particularities
which help it to articulate with the atlas.

Each side of the vertebral body has an oval convex surface, which articulates with a lateral facet of the atlas above.



The vertebral body of the axis has a peg-like process: this is the **dens** (odontoid process). Like a pin, it is lodged in the anterior part of the ring-like structure of the atlas.

Thus, there is no disc between the atlas and axis, just two freely movable joints (see p. 14, diarthrosis).

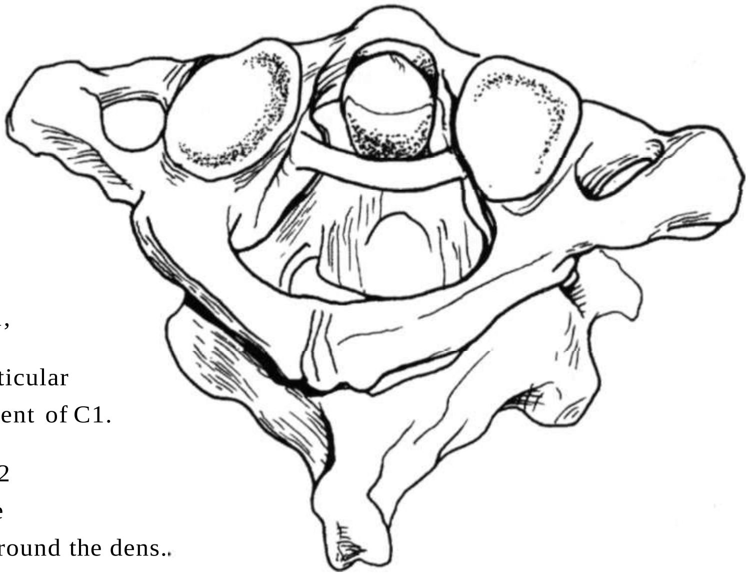
The articulating surfaces of atlas and axis are convex, i.e., they do not fit into each other. It is a hinge with permanent mobility.

There ate two articulations between the atlas and dens:

• The dens fits anteriorly against the anterior arch of C1,

• and posteriorly against an articular surface of the transverse ligament of C1.

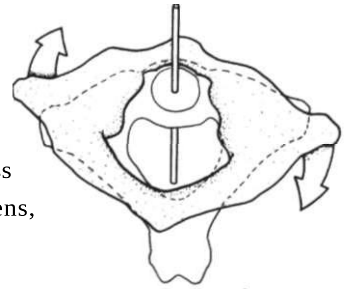
Thus, the pivot joint of C1-C2 consists of a ting-like structure covered by cartilage rotating around the dens..

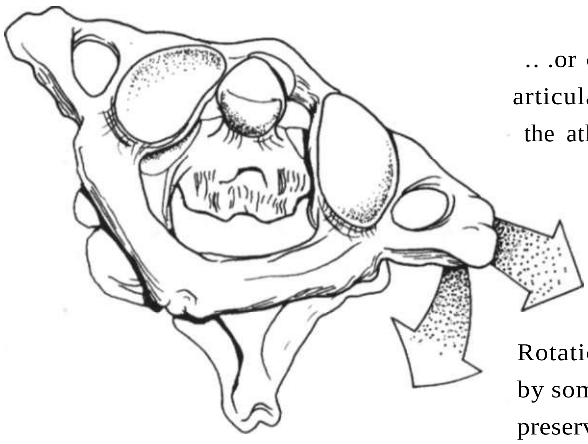


The atlas (C1) presses on the axis (C2) and turns around its pivot.

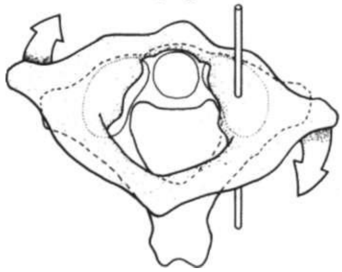
At this level, rotation is the most important movement (as in shaking your head "no"). This consists of a rotation and a gliding movement:

The axis of rotation can pass either through the dens,



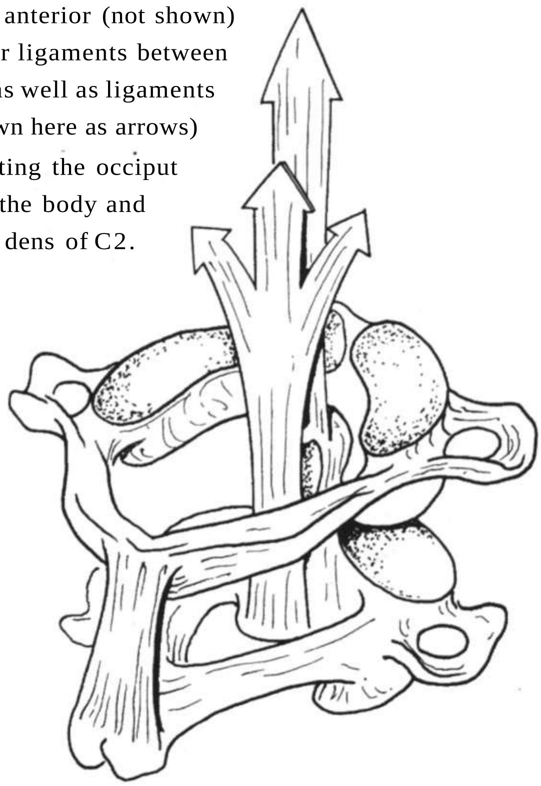


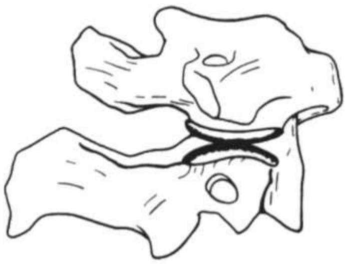
.. .or one of the articular facets of the atlas and axis.



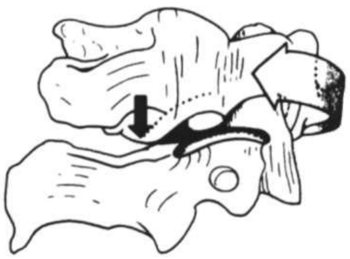
Rotation of C1 on C2 is accompanied by some lateral gliding of C2 which helps preserve the integrity of the spinal canal.

There are anterior (not shown) and posterior ligaments between C2 and C1, as well as ligaments (shown here as arrows) connecting the occiput to the body and dens of C2.



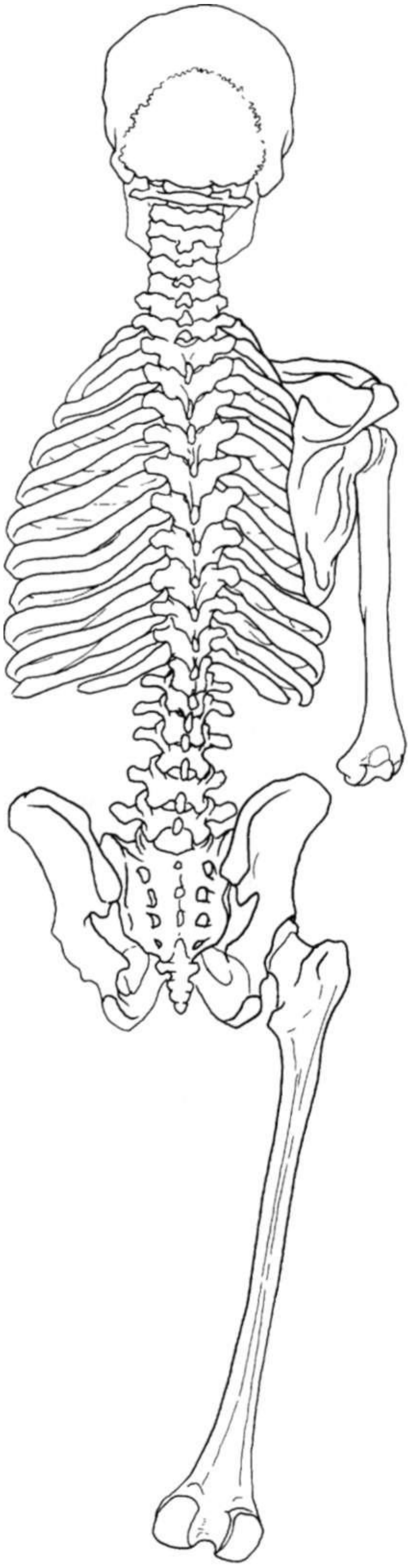


Due to the convexity of the articular facets of both C1 and C2,



.. .C1 tends to move slightly closer to C2 during rotation.

Muscles of the trunk and their bony attachments



Ribs:

longissimus thoracis
iliocostalis
serratus posterior
latissimus dorsi
scalenes
intercostal muscles
levatores costarum
transversus thoracis
diaphragm
abdominal muscles

Vertebrae:

spinal muscles
splenius
levator scapulae
serratus posterior
rhomboid
latissimus dorsi
trapezius
longus colli
pre-cervical muscles
scalenes
levatores costarum
diaphragm
psoas
quadratus lumborum
abdominal muscles

Cranial bones:

(mainly occipital and temporal bones)
sternocleidomastoid (SCM)
pre-cervical muscles
suboccipital muscles (deep neck muscles)
semispinalis and longissimus capitis
splenius capitis
trapezius

Shoulder girdle, humerus:

levator scapulae
rhomboid
latissimus dorsi
ttapezius
sternocleidomastoid (SCM)

Pelvic girdle:

muscles of the lumbar spine
latissimus dorsi
psoas
quadratus lumbofum
abdominal muscles
muscles of the pelvic floor

Femur:

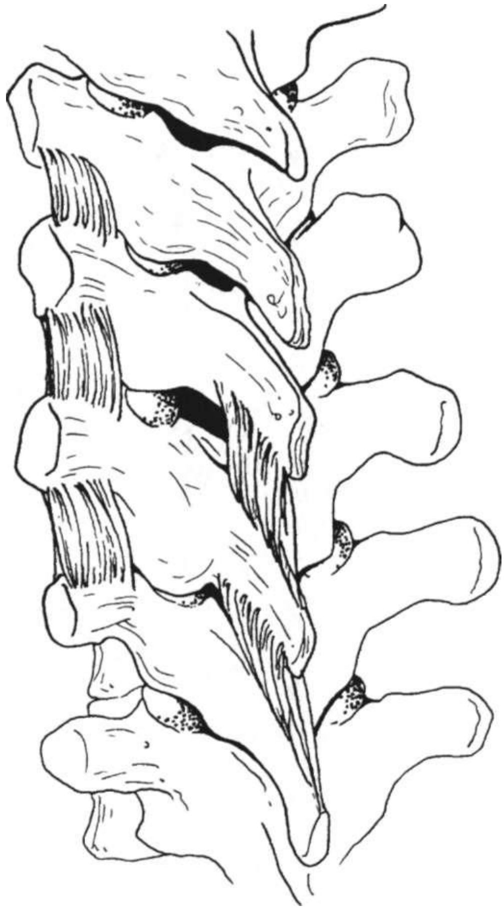
psoas

Posterior muscles of trunk and neck

The back side of the trunk contains numerous muscles, which are arranged in several layers. The deepest ones attach only to the vertebrae and consist of small bundles, which pass from one vertebta to the next.

The **intertransverse** muscles connect one transverse process to the next, posterior to the intertransverse ligament.

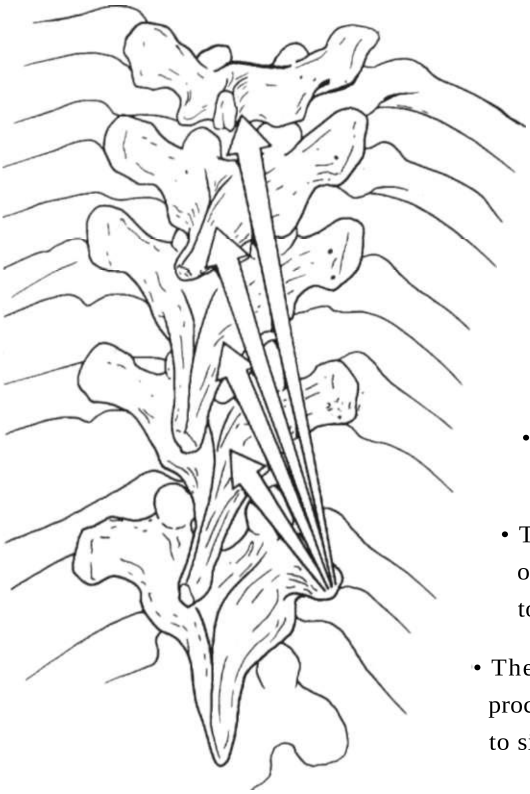
Action: sidebending



The **interspinalis** muscles connect adjacent spinous processes, on either side of the ligament.

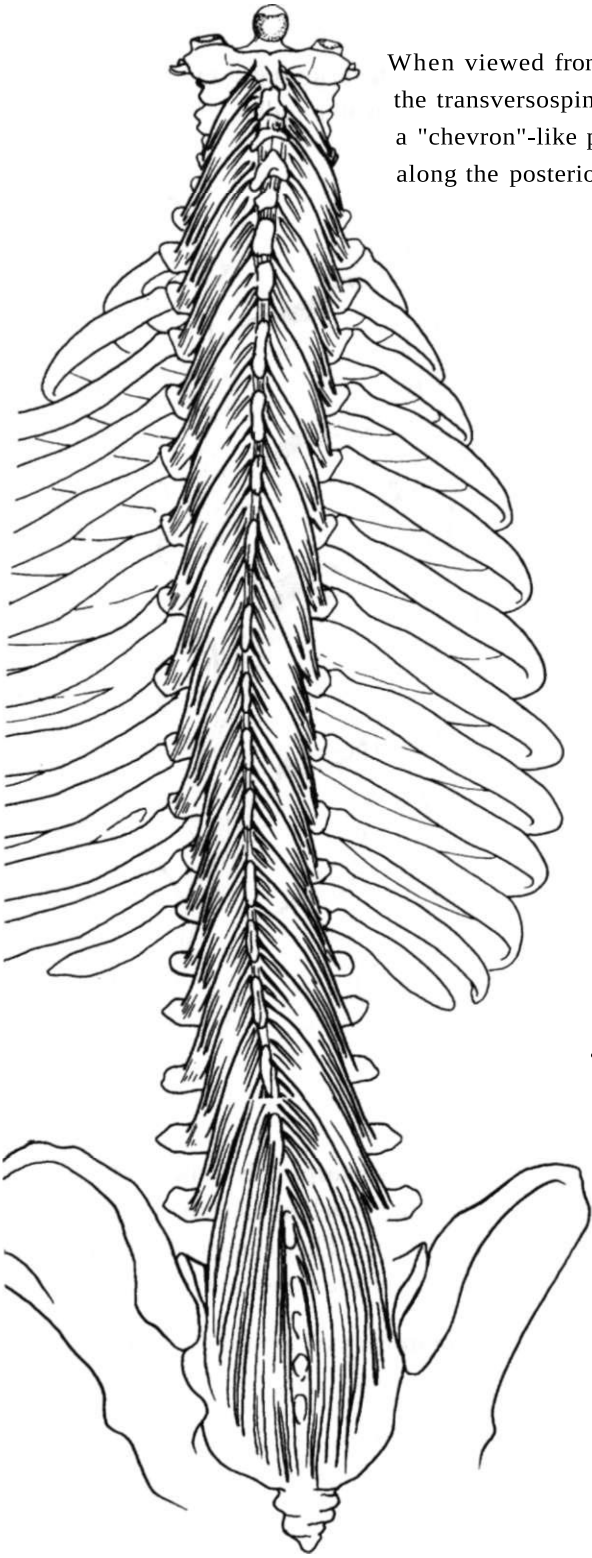
Action: extension

Innervation: **posterior branches of spinal nerves** (C3-S4)

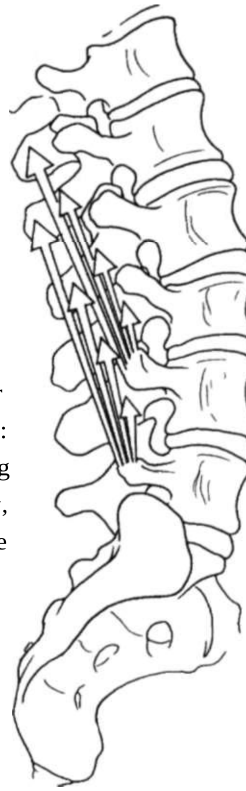


The **transversospinalis** muscles attach to the back of the vertebrae all along the spine, from sacrum to axis. They consist of three bundles, which arise at the transverse processes:

- The **rotatores** pass toward the lamina of the vertebra above.
- The **multifidus** pass to the spinous processes of the vertebrae that are located two to four levels above.
- The **semispinalis** muscles pass to the spinous processes of the vertebrae that are located four to six levels above, covering the other layers.



When viewed from behind, the transversospinalis form a "chevron"-like pattern along the posterior spinal column.

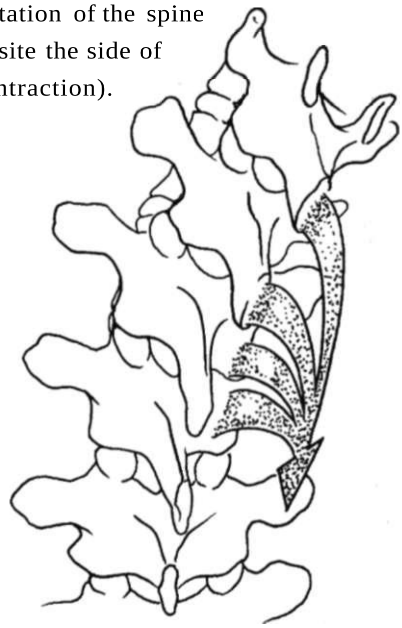


Actions: The muscle fibers run diagonally:

- from inferior to superior: when contracting bilaterally, they move the vertebrae into extension

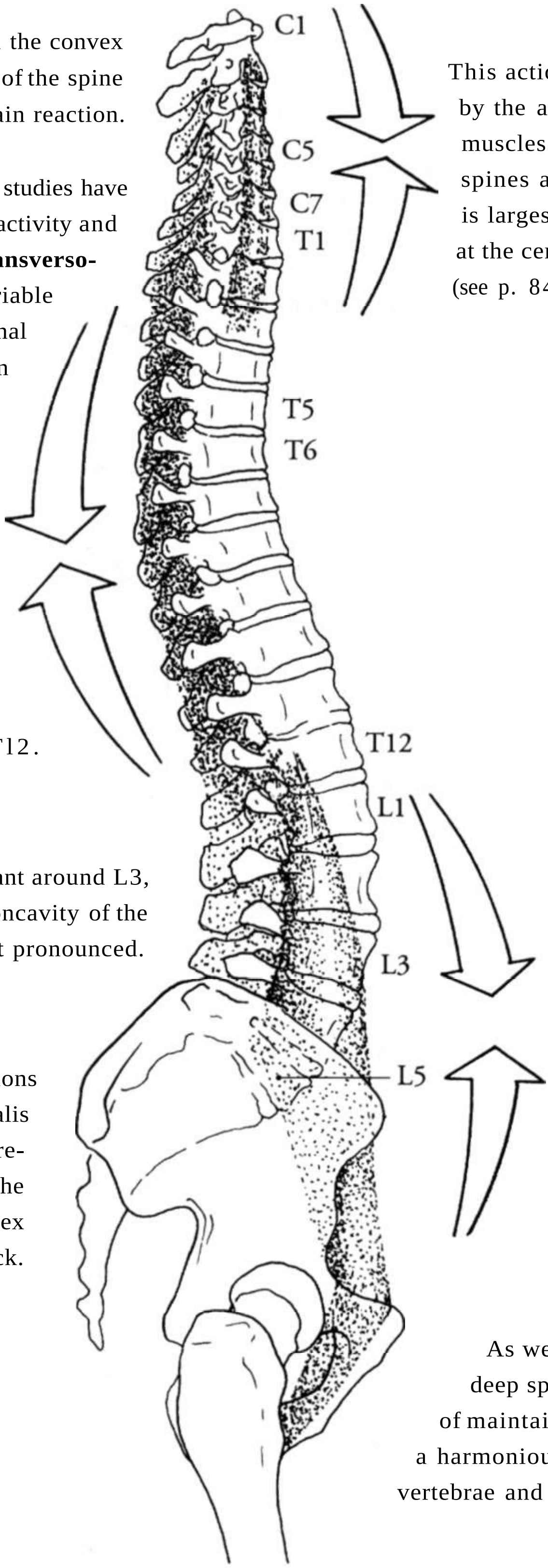
- from medial to latetal: sidebending

- from anterior to posterior: rotation of the spine (opposite the side of contraction).



Innervation: **posterior branches of spinal nerves** (C3-S4)

Role of deep spinal muscles in keeping trunk erect



Muscles located in the convex sagittal curves of the spine elicit a chain reaction.

Electromyographic studies have shown that the activity and importance of the **transverso-spinalis** muscles are variable depending upon spinal level, particularly in terms of "elongating" (straightening) the spine:

It is important around T6, where the posterior convexity of the thoracic spine is most pronounced.

It is less significant at T12.

It is also less significant around L3, where the posterior concavity of the lumbar region is most pronounced.

As shown here, the actions of the transversospinalis muscles are more pre-dominant where the spine is most convex in the back.

This action is completed by the actions of two other muscles located where the spines anterior convexity is largest: the **longus colli** at the cervical level (see p. 84)...

... and the **psoas** at the lumbar level (p. 92).

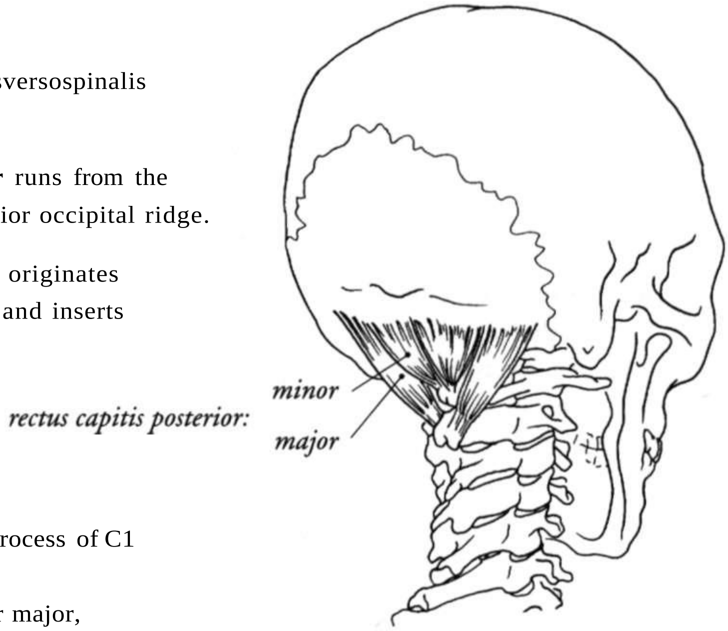
As we can see, this group of deep spinal muscles is capable of maintaining stability and a harmonious alignment of the vertebrae and intervertebral discs.

Deep neck muscles

These are analogous to the transversospinalis but insert on the occiput.

Rectus capitis posterior minor runs from the posterior arch of C1 to the inferior occipital ridge.

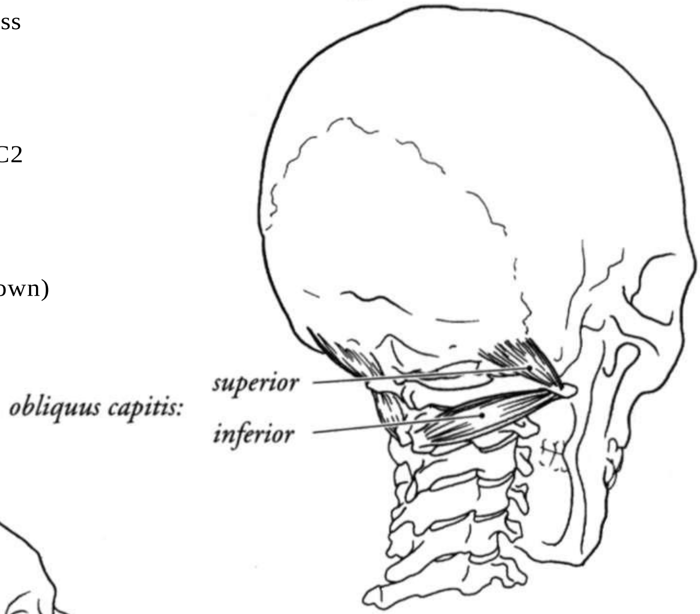
Rectus capitis posterior major originates from the spinous process of C2 and inserts just lateral to the minor.



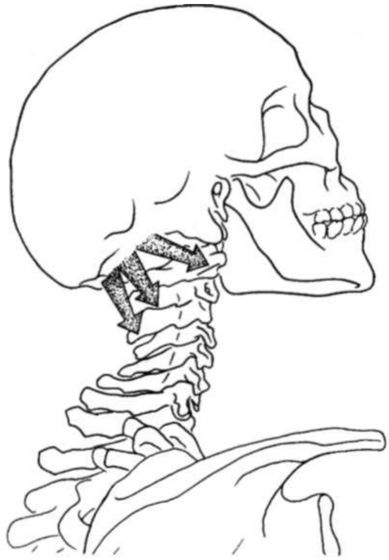
Obliquus capitis superior originates from the transverse process of C1 and inserts on the occiput lateral to rectus capitis posterior major, just posterior to the mastoid process of the temporal bone.

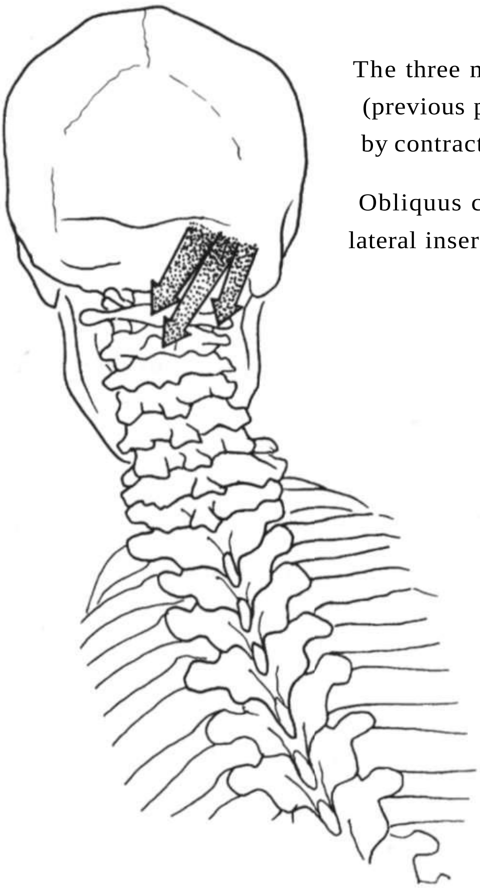
Obliquus capitis inferior runs from the spinous process of C2 to the transverse process of C1.

Action: extension, sidebending, and rotation of C1 on C2 (not shown)



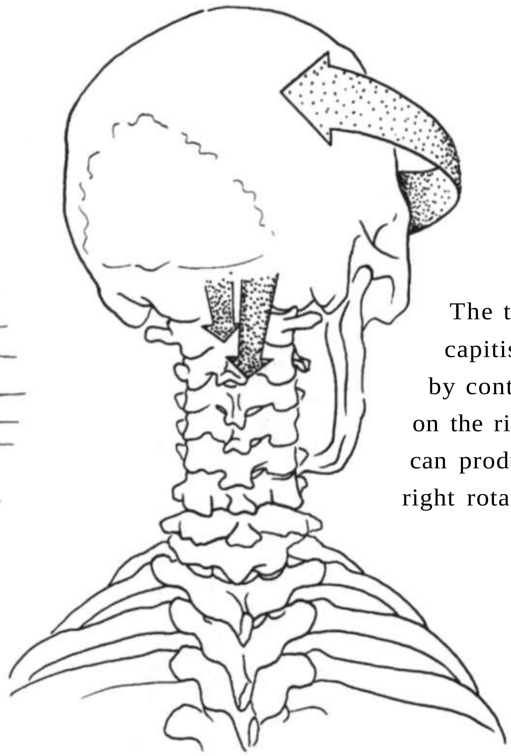
Action: these three muscles help produce extension at the C1/ C2 joint when they contract bilaterally



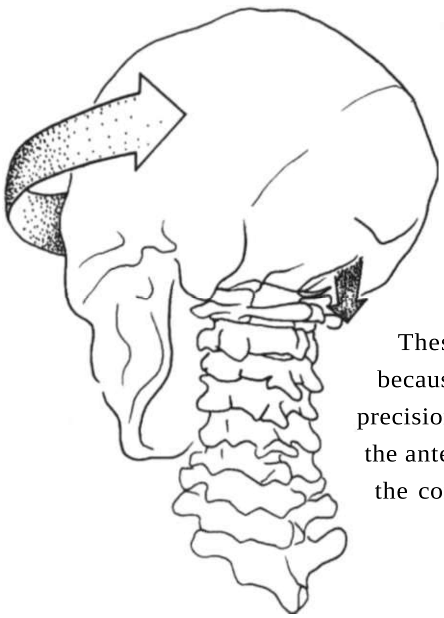


The three muscles that insert on the occiput (previous page) bend the head to that side by contracting unilaterally.

Obliquus capitis superior, with the most lateral insertion, does this most effectively.



The two rectus capitis muscles, by contracting on the right, can produce right rotation.



Obliquus capitis superior can produce left rotation by contracting on the right.

These deep muscles have limited lever action because of their small size, but allow great precision of movement. In cooperation with the anterior neck muscles (p. 85), they regulate the correct orientation of the head on the neck.

Intermediate back and neck muscles

The group of posterior muscles shown on this page forms a layer superficial to those described on the previous pages. These muscles are sometimes referred to collectively as the sacrospinalis or erector spinae.

There are three muscles in this group: iliocostalis (most lateral), longissimus, and spinalis (most medial; see p. 80). Each of these is further divided into three subcomponents.

(The iliocostalis has been "cut away" on the right side of the illustration to reveal the longissimus.)

Longissimus capitis originates from the transverse processes of T3 to C4 and inserts on the mastoid process of the temporal bone.

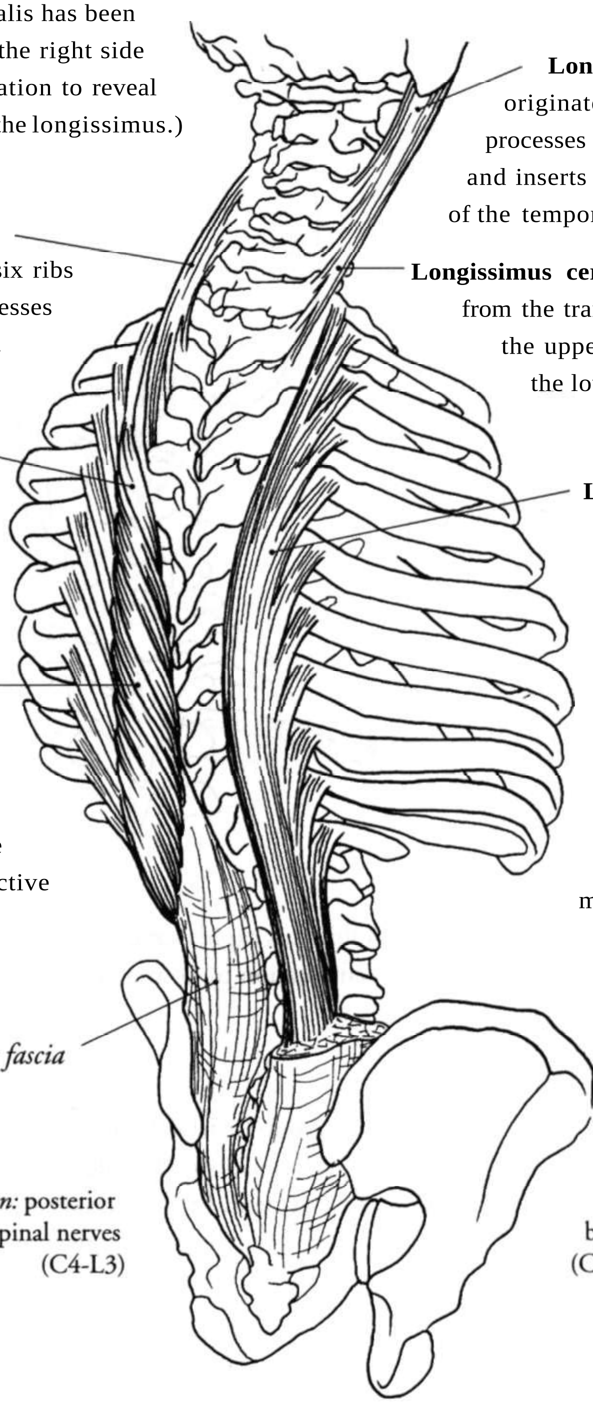
Iliocostalis cervicis runs from the upper six ribs to the transverse processes of the lower cervicals.

Longissimus cervicis runs from the transverse processes of the upper thoracic vertebrae to the lower cervical vertebrae.

Iliocostalis thoracis runs from the lower six to the upper six ribs.

Longissimus thoracis originates from the lumbar transverse processes and inserts on the thoracic transverse processes and posterior aspect of ribs 9 and 10. It fills the groove formed where the thoracic vertebrae meet the ribs.

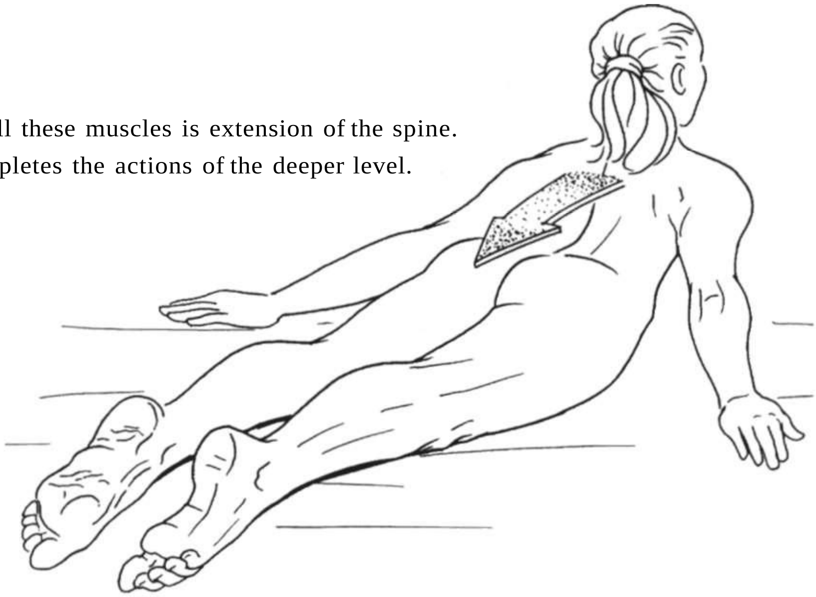
Iliocostalis lumborum originates from the iliac crest via the lumbar fascia (a sheet-like structure made of dense connective tissue), and inserts on the lower ribs.



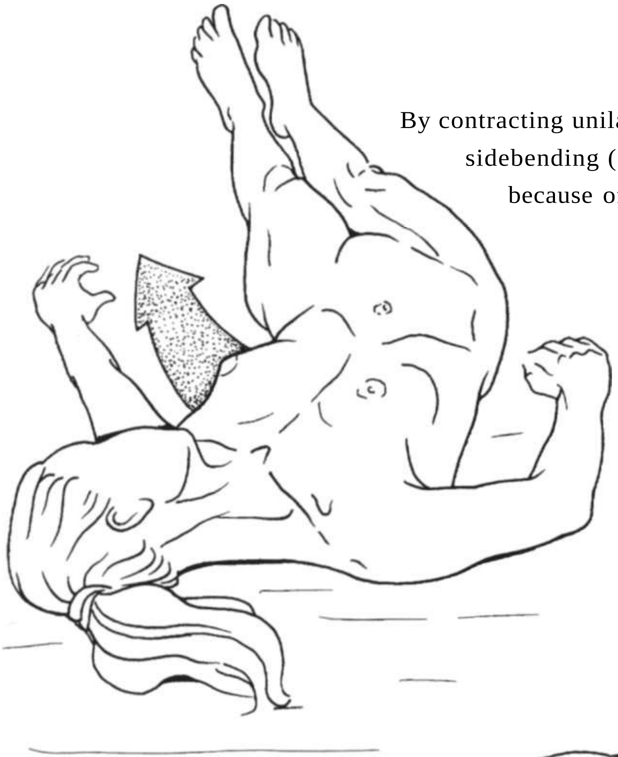
Innervation: posterior branches of spinal nerves (C4-L3)

Innervation: posterior branches of spinal nerves (C2-L5)

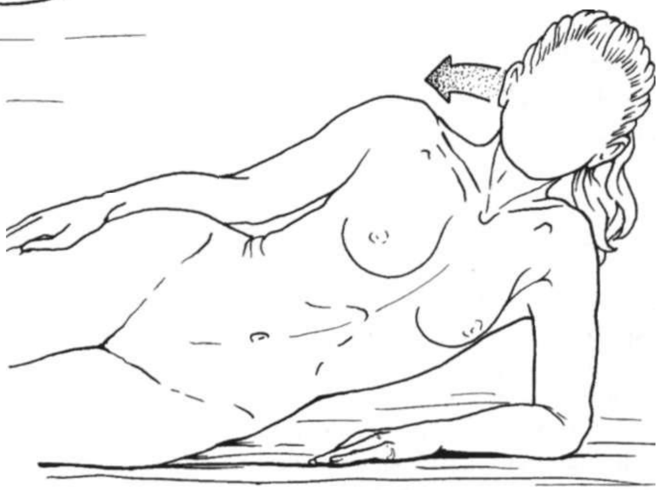
The main action of all these muscles is extension of the spine. This completes the actions of the deeper level.



By contracting unilaterally, they also contribute to sidebending (especially iliocostalis lumborum, because of its position) and rotation.

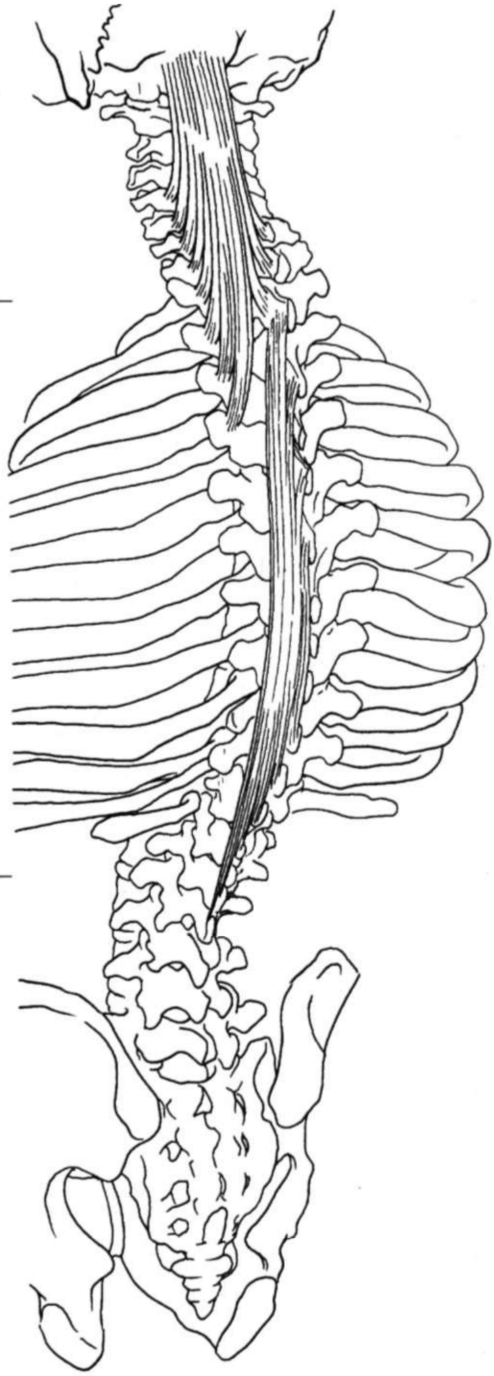


Longissimus capitis contributes to extension of the head (bilateral contraction), or sidebending of the head (unilateral contraction).



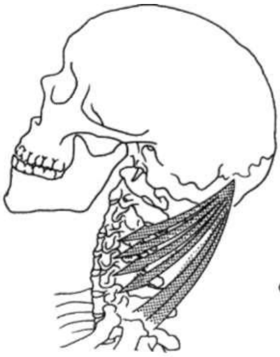
Innervation: **posterior branches of spinal nerves (C2-L5)**

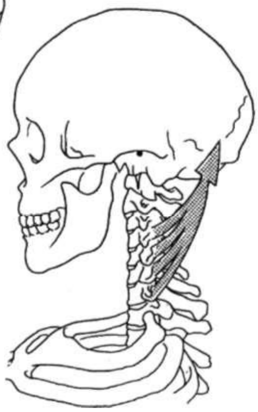
A second layer of muscles, located along the spinal column, covers the muscles described on the previous pages.



Spinalis capitis and **semispinalis capitis** can be considered together. They originate respectively from the spinous processes of C7—Tl and the transverse processes of C4—T4, and insert on the occiput.

Actions: if they contract bilaterally, while the cervical spine is fixed, they extend the head. If they contract unilaterally, with the spine fixed, they can contribute to sidebending or rotation.





On the other hand, if they contract bilaterally with the head fixed, they tend to straighten out the cervical spine.

Innervation: posterior branches of spinal nerves (C1-C5)

Spinalis thoracis runs from the spinous processes of T1 through T10 to the spinous processes of T11 through L2.

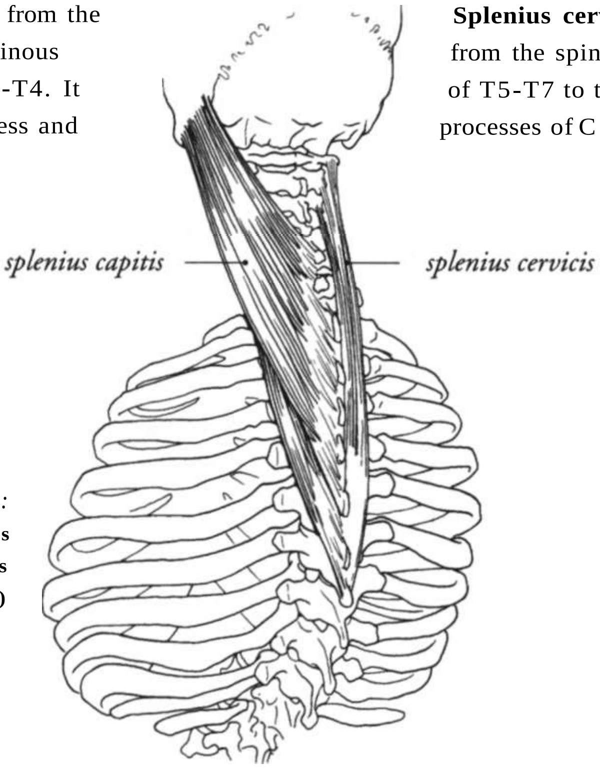
Action: extends the spine in the thoracic region

Innervation: posterior branches of spinal nerves (C2—T10)

The back muscles described thus far (and some later) form a deep muscle layer, also referred to as the **spinal muscles.** They have a short lever arm, hence not much power to do certain activities, e.g., extension of the spine from the horizontal position. However, they work very precisely. In the vertical position, they work together to keep the spine straight, rebalancing each other slightly at every vertebral level. In a standing person, they are almost constantly working. This is because they are very active muscles, able to work without fatiguing for long stretches of time. For example, the head "sits on the neck" for an entire day with the help of these muscles.

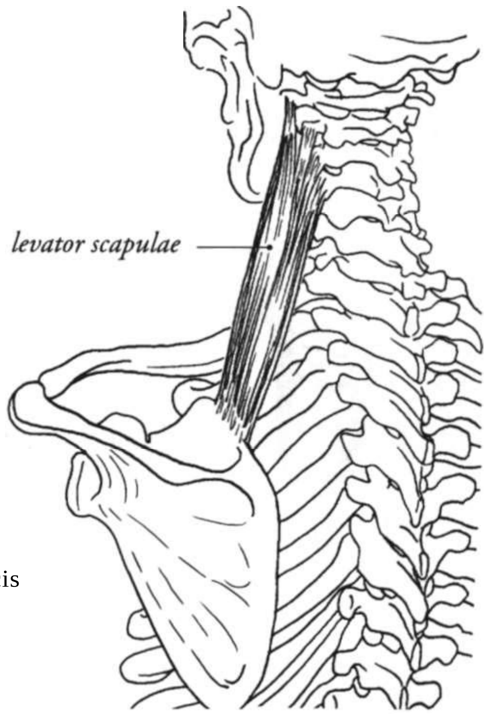
Splenius capitis originates from the nuchal ligament and the spinous processes of C7 through T3-T4. It inserts on the mastoid process and adjacent occipital bone.

Splenius cervicis runs from the spinous process of T5-T7 to the transverse processes of C1-C3.



Innervation:
posterior branches of spinal nerves (C1-C8)

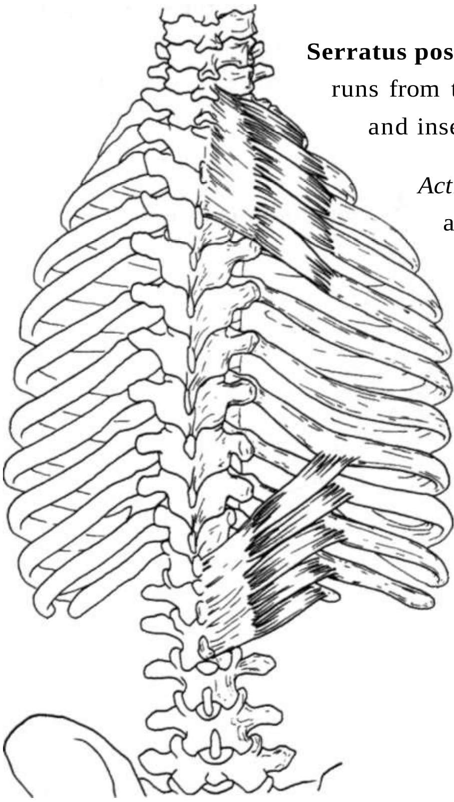
Actions: contracting bilaterally, these muscles extend the head and cervical spine. Contracting unilaterally, they cause sidebending and rotation toward the contracting side.



Levator scapulae (see p. 123) runs from the transverse processes of C1-C4 to the medial scapula.

Actions: acts primarily on the scapula; however, when the scapula is fixed, its actions can reinforce those of the splenius cervicis

The next layer consists of the **posterior serratus muscles.**



Serratus posterior superior
runs from the spinous processes of C7 to T3 and inserts on the first five ribs.

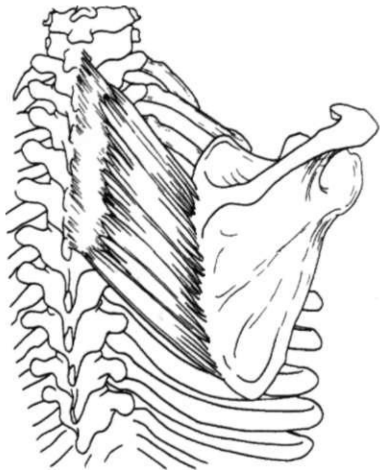
Action: elevates the ribs and thereby aids in inspiration

Innervation: **branches of first four intercostal nerves (T1-T4)**

Serratus posterior inferior
runs from the spinous processes of T l2 to L2 and inserts on the last four ribs.

Action: depresses these ribs and thereby aids in expiration

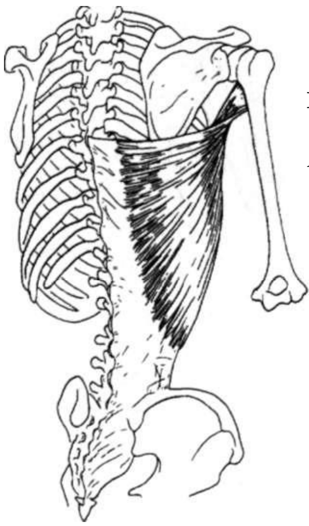
Innervation: **superior branches of the last four intercostal nerves**



The following three muscles act primarily on the shoulder joint and will be discussed later in that context. However, when the shoulder is fixed, they can also act on the spine.

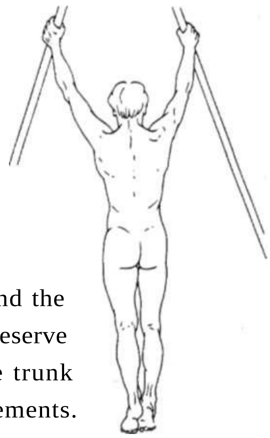
Rhomboids (see p. 123)

Action: when the scapula is fixed, the contraction of these muscles pulls the vertebrae laterally



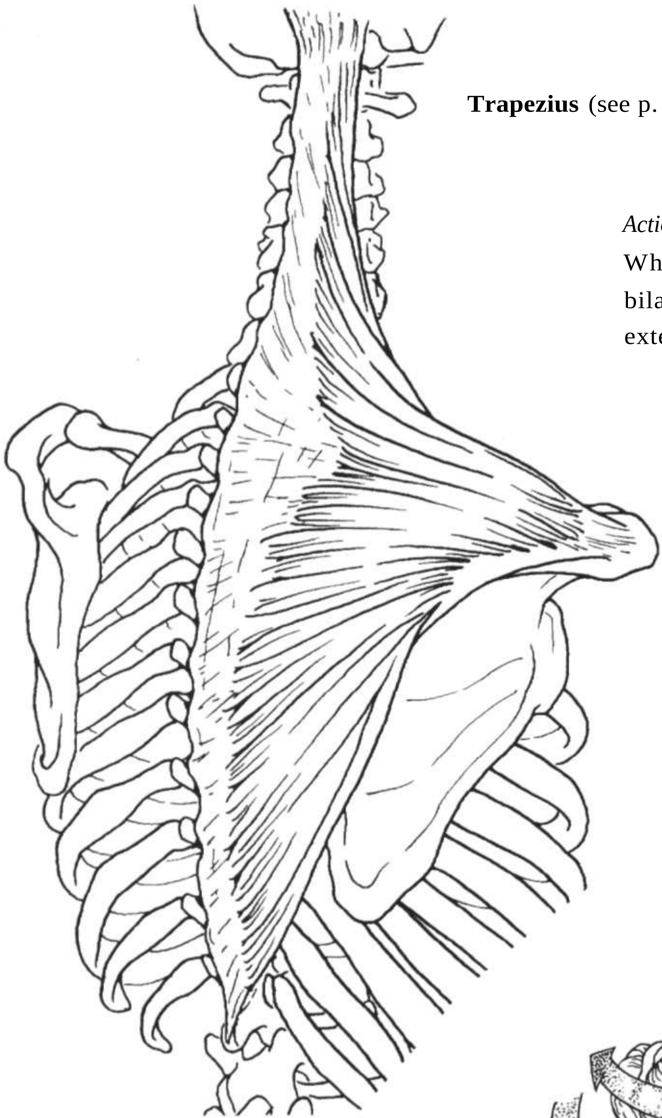
Latissimus dorsi (see p. 131)

Action: when acting bilaterally, this muscle extends the thoracolumbar spine



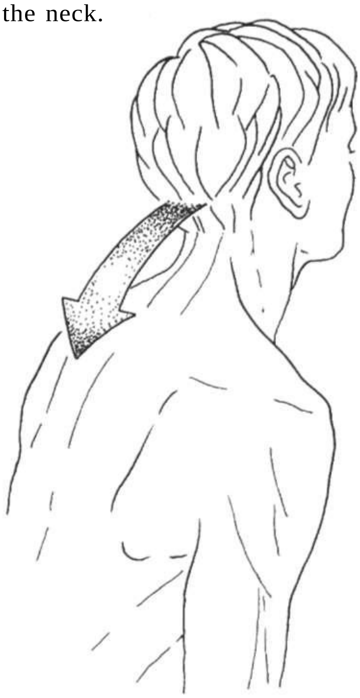
By wrapping around the posteroinferior trunk, it helps preserve the structural integrity of the trunk during certain movements.

Trapezius (see p. 124)

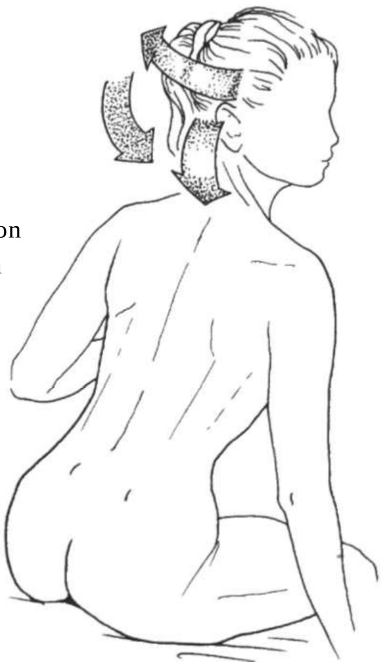


Actions:

When the shoulder bones are fixed, bilateral contraction of the trapezius extends the neck.

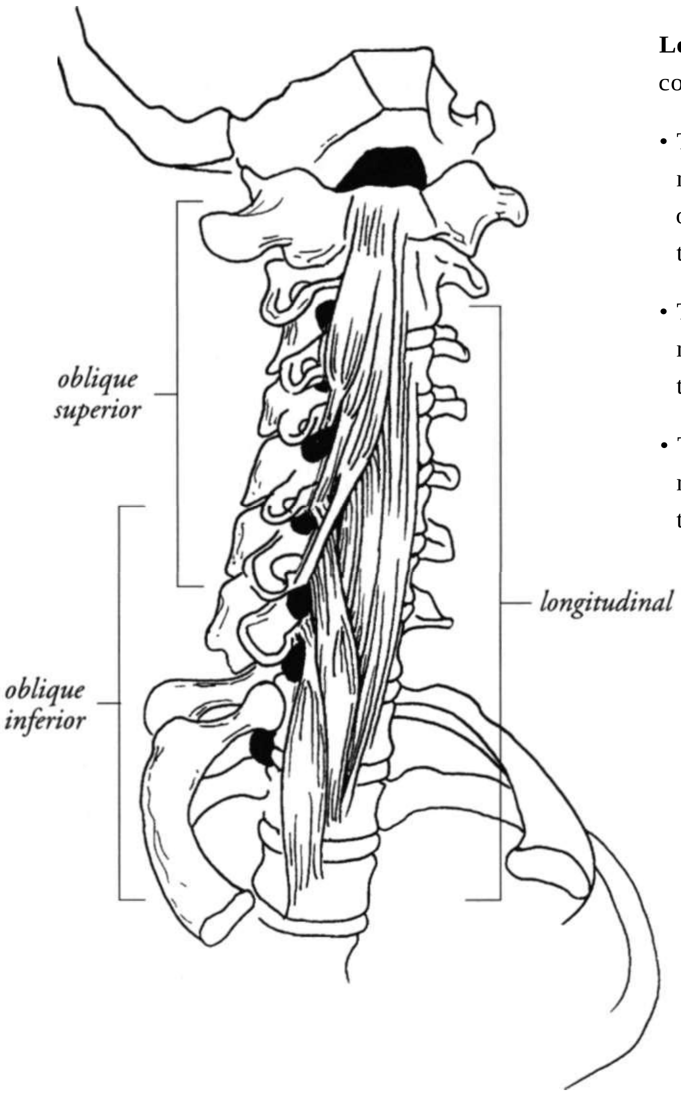


Unilateral contraction of its superior portion can assist in ipsilateral sidebending, or contralateral rotation of the head.



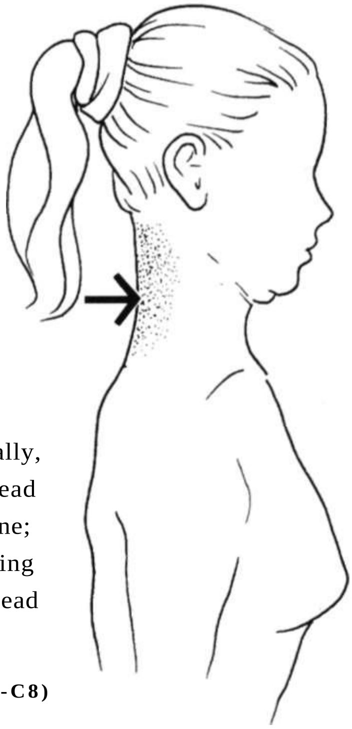
Anterior and lateral neck muscles

Several deep muscles which run along the cervical spine can be found on the anterior and lateral sides of the neck.



Longus colli is a deep muscle consisting of three portions.

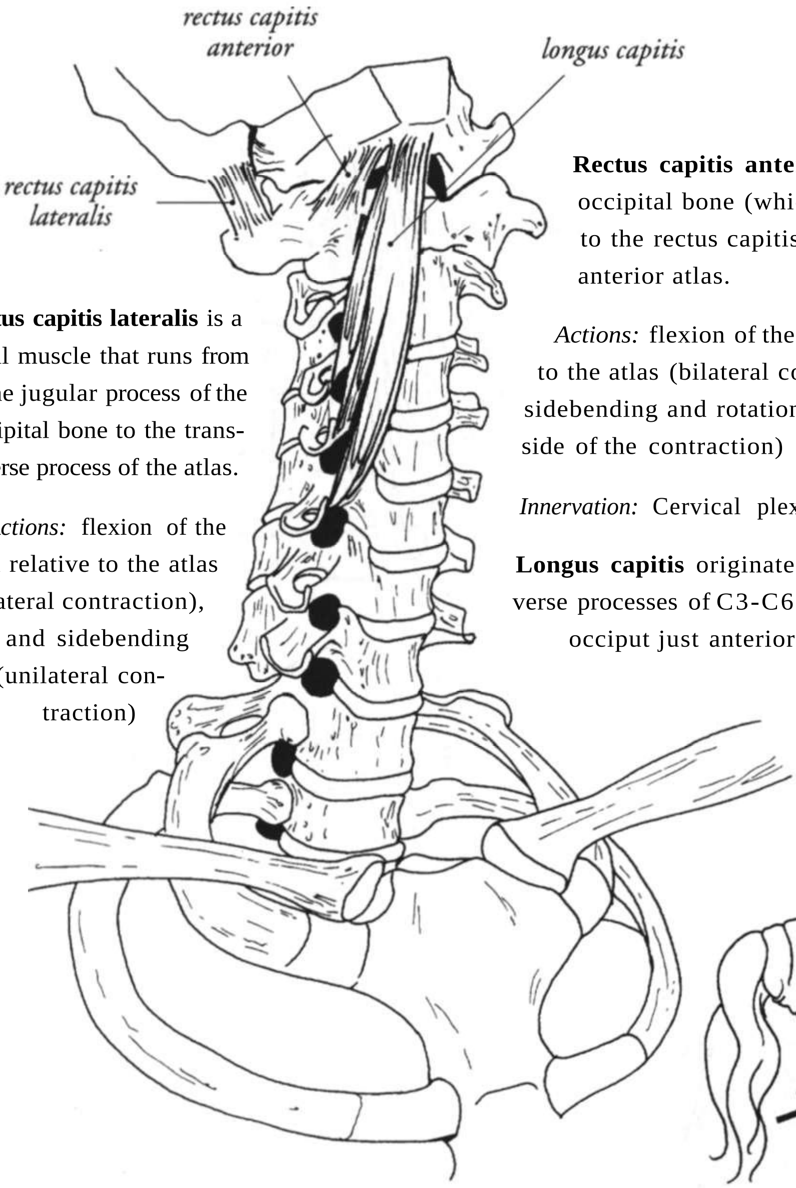
- The longitudinal portion runs from the bodies of C2 through T3 to the bodies of C4-C7.
- The oblique superior portion runs from the anterior arch of C1 to the transverse processes of C3-C6.
- The oblique inferior portion runs from the bodies of T1-T3 to the transverse processes of C5-C7.



Actions: contracting bilaterally, longus colli flexes the head and straightens the cervical spine; unilaterally, it assists in sidebending and flexion of the head

Innervation: **cervical plexus (C2-C8)**

The following muscles attach to the cervical spine and the occiput (the bone at the posterior base of the skull).



Rectus capitis lateralis is a small muscle that runs from the jugular process of the occipital bone to the transverse process of the atlas.

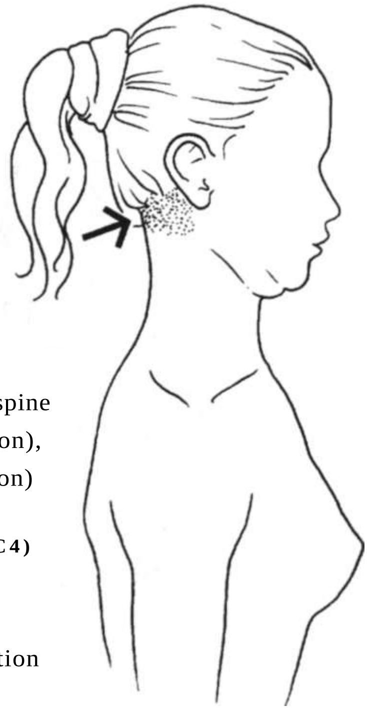
Actions: flexion of the head relative to the atlas (bilateral contraction), and sidebending (unilateral contraction)

Rectus capitis anterior runs from the occipital bone (which lies anterior to the rectus capitis anterior) to the anterior atlas.

Actions: flexion of the head relative to the atlas (bilateral contraction), and sidebending and rotation (unilateral, on the side of the contraction)

Innervation: Cervical plexus (C1)

Longus capitis originates from the transverse processes of C3-C6 and inserts on the occiput just anterior to the rectus.



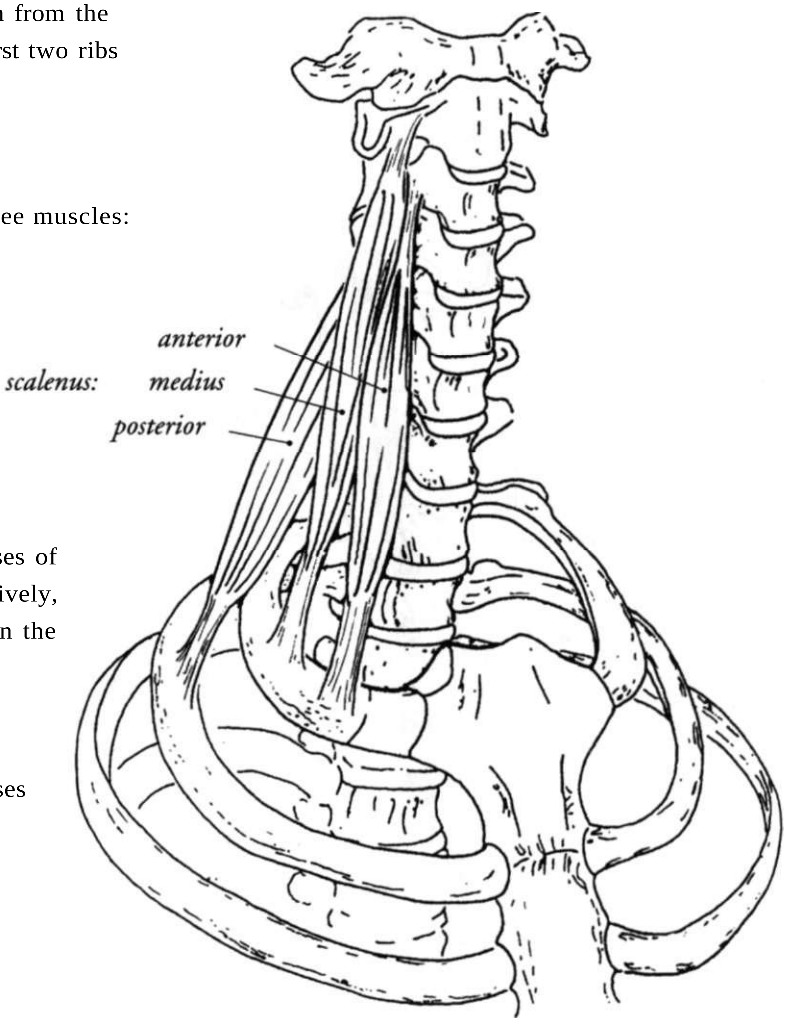
Actions: helps straighten the upper cervical spine and flex the head (bilateral contraction), or sidebend the head (unilateral contraction)

Innervation: **cervical plexus (C1-C4)**

Longus colli and longus capitis work together with the scalenes to stabilize the cervical spine, which becomes fixed during inspiration (see p. 87).

The following muscles run from the cervical vertebrae to the first two ribs

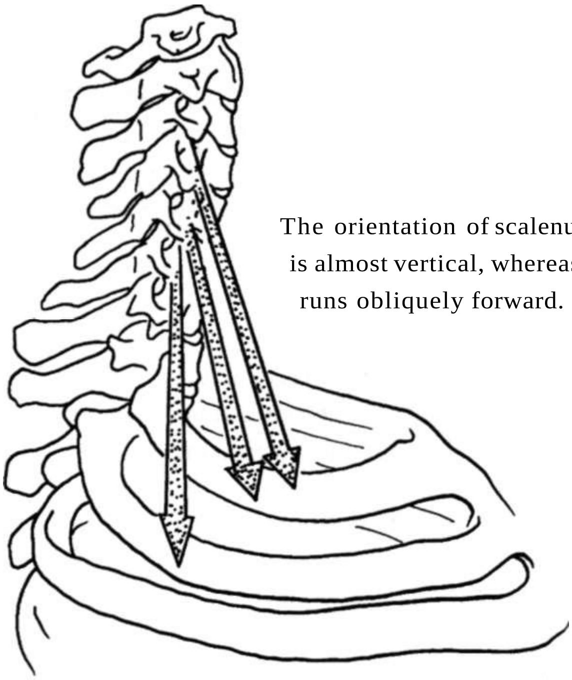
The **scalenes** consist of three muscles:



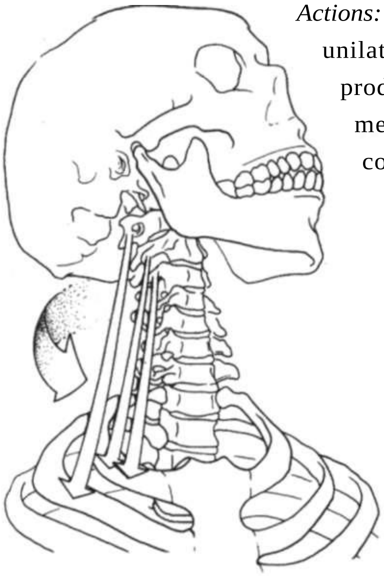
Scalenus anterior and **scalenus medius** originate from the transverse processes of C3-C6 and C2-C7 respectively, and insert close together on the anterior part of rib 1.

Scalenus posterior runs from the transverse processes of C4-C6 to the lateral surface of rib 2.

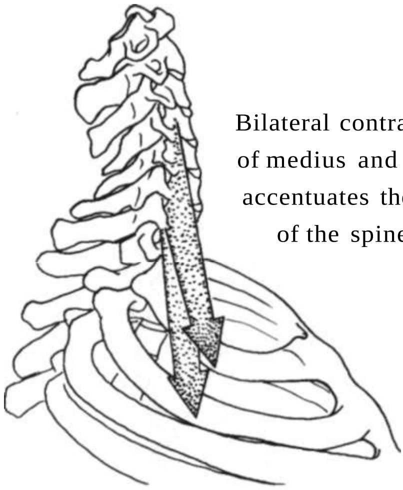
Innervation: brachial plexus (C4-C8)



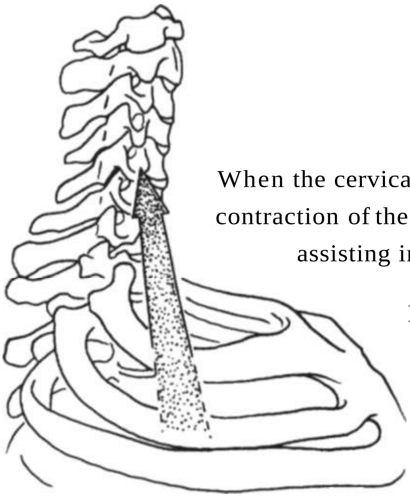
The orientation of scalenus posterior is almost vertical, whereas scalenus anterior runs obliquely forward.



Actions: when the ribs are fixed,
unilateral contraction of the scalenes (especially posterior) produces sidebending of the cervical spine;
medius and anterior also produce some contralateral rotation.



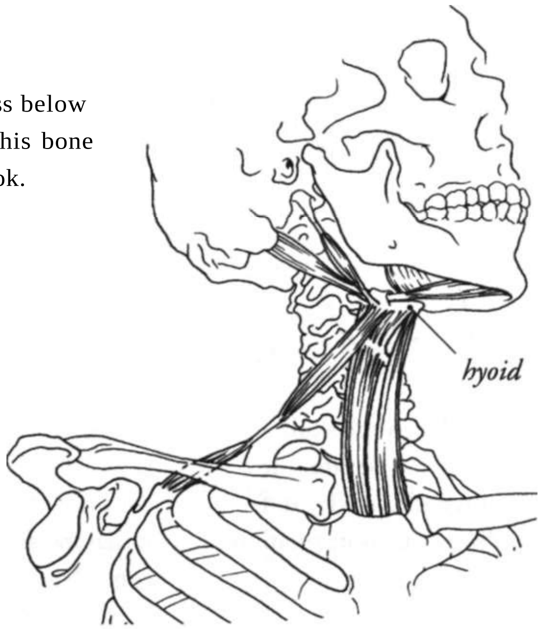
Bilateral contraction of medius and anterior accentuates the curvature of the spine.



When the cervical (and upper thoracic) spine is fixed, contraction of the scalenes elevates ribs **1** and 2, assisting in inspiration.

Longus colli and the scalenes play an important role in stabilizing the cervical spine during this action.

Here, we will simply list all the muscles that pass below and above the hyoid bone. A detailed study of this bone and its muscles are beyond the scope of this book.



Suprahyoid muscles:

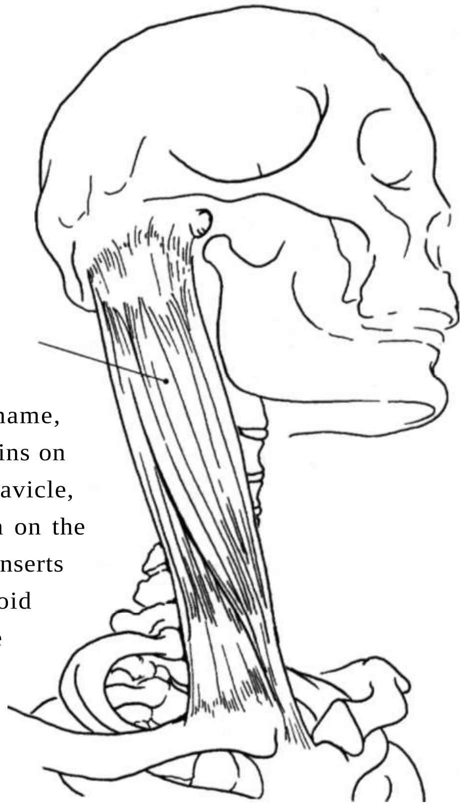
- hyoglossus
- geniohyoid
- mylohyoid
- digastric
- stylohyoid

Infrahyoid muscles:

- sternohyoid
- thyrohyoid
- omohyoid

Among other actions, these muscles assist with the flexion of the head above the neck and thorax.

Superficial to the muscles mentioned on the previous pages lies another muscle:

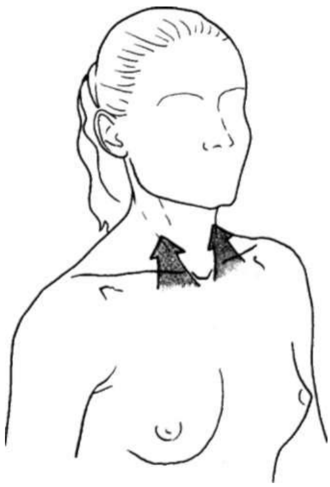


Sternocleidomastoid (SCM) is the largest and most important anterior neck muscle.

It can be clearly seen externally when the head is turned.

As reflected in its name, it has dual origins on the sternum and clavicle, near their junction on the manubrium. It inserts on the mastoid process and the curved superior occipital line.

Innervation: **spinal accessory (11th cranial nerve) cervical plexus (C1-C2)**



Actions: When the skull is fixed, SCM elevates the sternum and clavicle, and thereby assists in inspiration.

When the thoracic cage is fixed, unilateral contraction of SCM causes ipsilateral sidebending and contralateral rotation of the head, as well as extension.

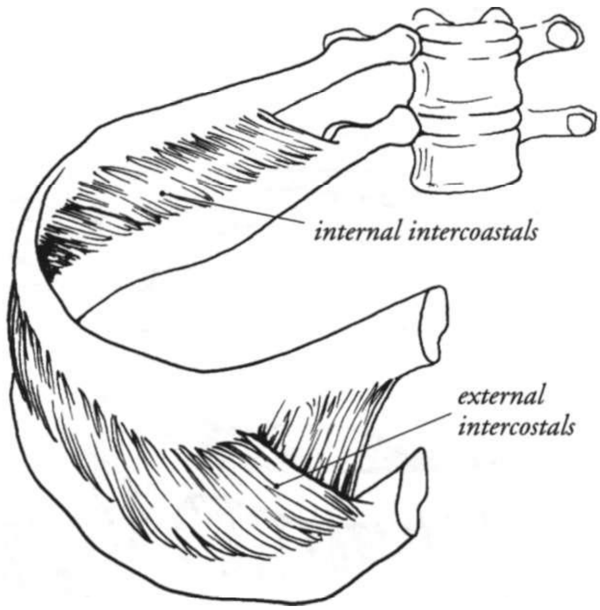
Bilateral contraction results in extension of the head, accentuating cervical lordosis.

Muscles of the thorax

The **intercostal muscles**
occupy the spaces between adjacent ribs, and are arranged in two thin layers.

The fibers of the **internal intercostals** run downward and backward to the upper border of the rib below.

The **external intercostals** run downward and *forward to* the rib below.

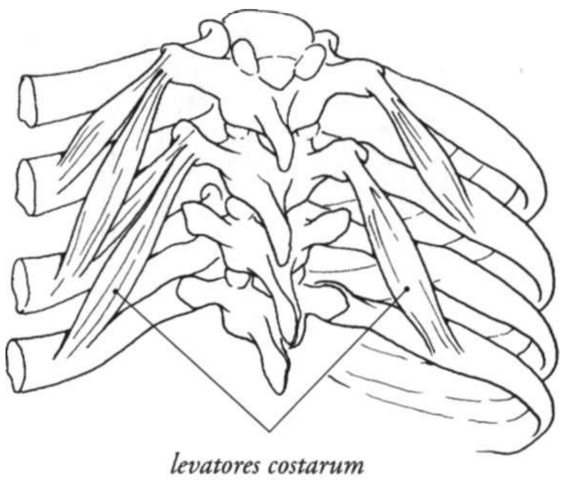


Actions: The intercostals form a muscular sheet, which joins the ribs to each other, making the thoracic cage a contiguous entity. Thus a muscle, e.g., the anterior scalene, pulling on the first rib, will also pull the entire ribcage, because of the intercostals

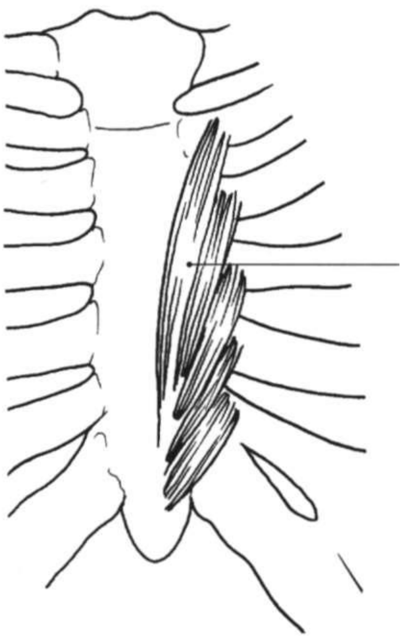
Innervation: **1st—11th intercostal nerves**

Levatores costarum run from the transverse process of a thoracic vertebra to the tubercle of a rib located one or two levels below.

Action: assists in rotation of the spine or elevation of the ribs, depending on which end is fixed



Innervation: **posterior branches of the spinal nerves**



Transversus thoracis originates from the posterior surface of the lower sternum and xiphoid process, and runs superolaterally to insert on the cartilages of ribs 2 through 6.

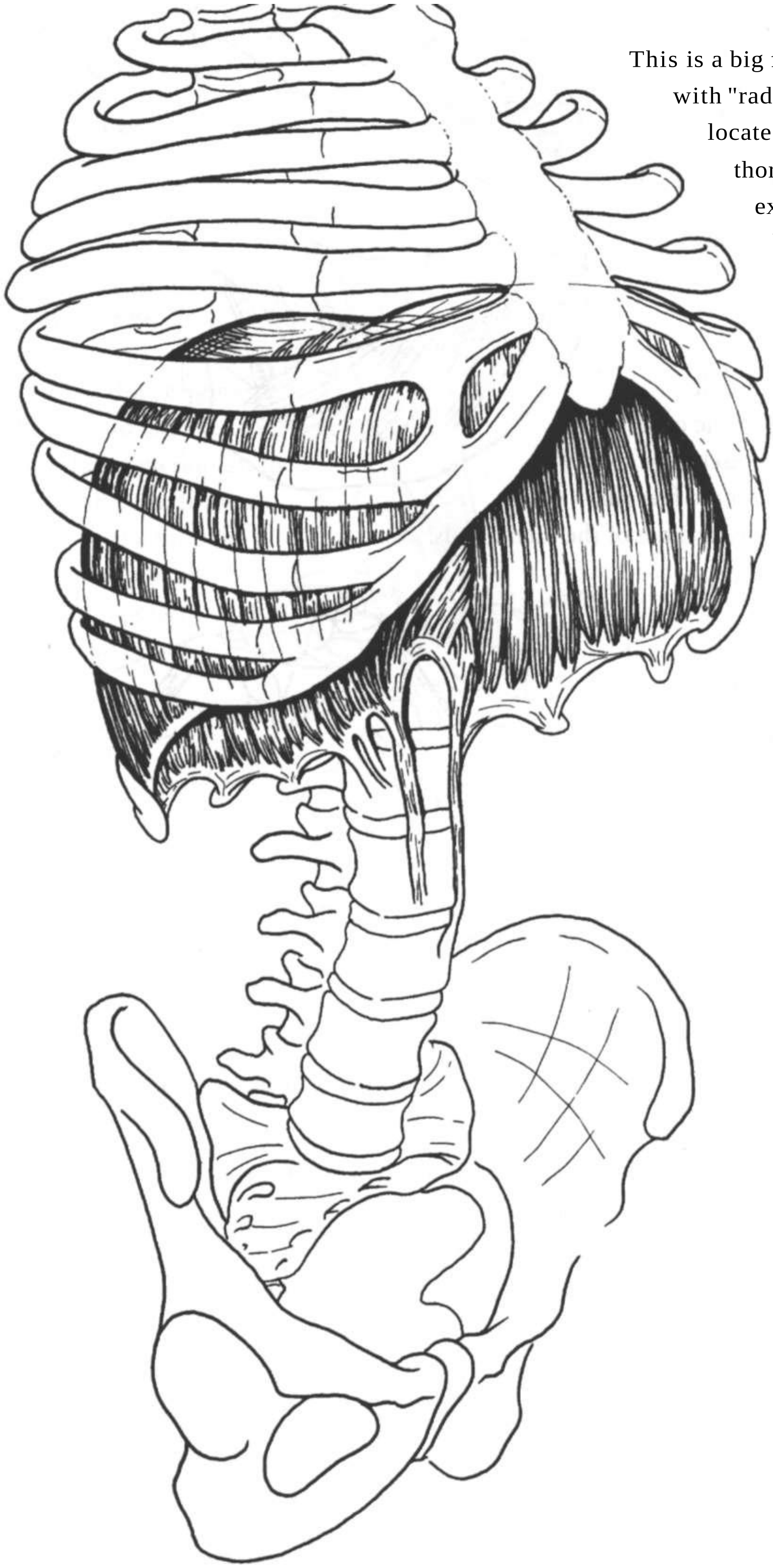
Action: contraction lowers these ribs, assisting in expiration

Innervation: **2nd-6th intercostal nerves**

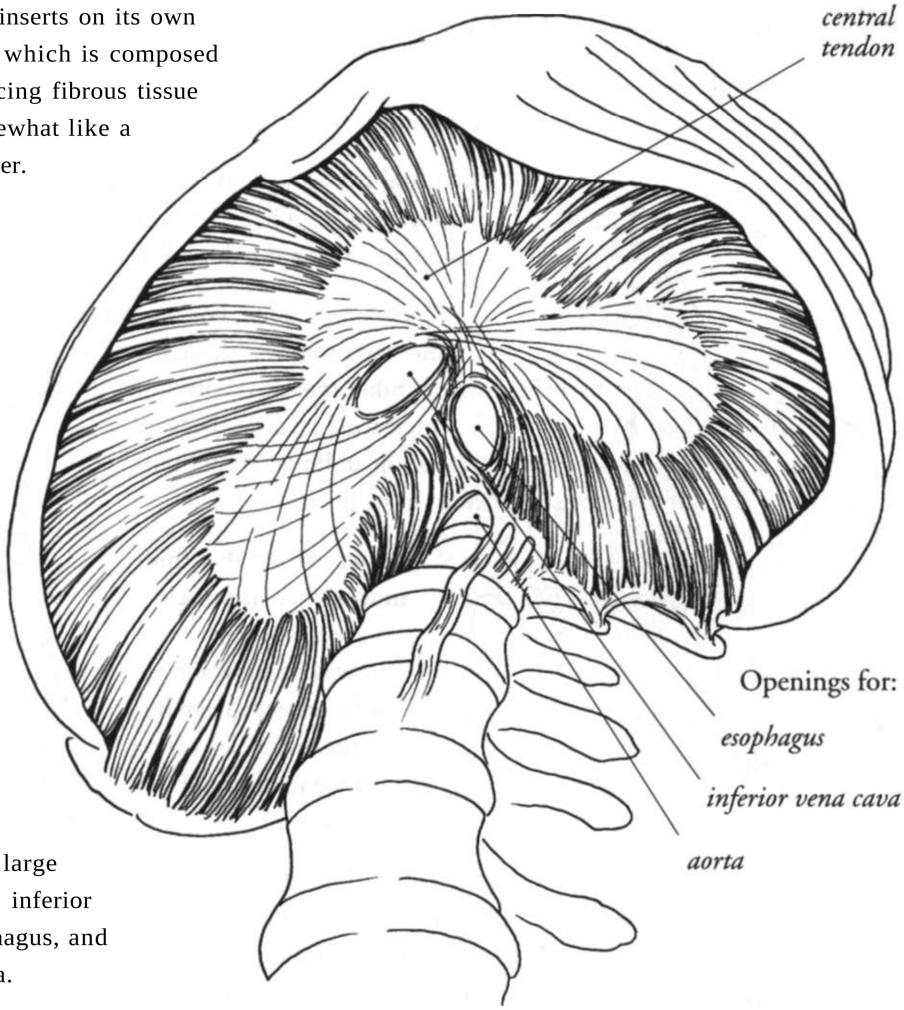
Pectoralis major and serratus anterior are described together with the muscles of the shoulder (see p. 120, 130).

Diaphragm

This is a big flat muscle, with "radiating" fibers, located inside the thoracic cage. It extends like a dome between the thoracic and abdominal cavities.



The diaphragm inserts on its own **central tendon,** which is composed of strong interlacing fibrous tissue and shaped somewhat like a three-leafed clover.



In the middle and near the vertebral column, the diaphragm is pierced by three large openings for the inferior vena cava, esophagus, and descending aorta.

The muscular portion of the diaphragm has three major origins, all inserting on the central tendon:

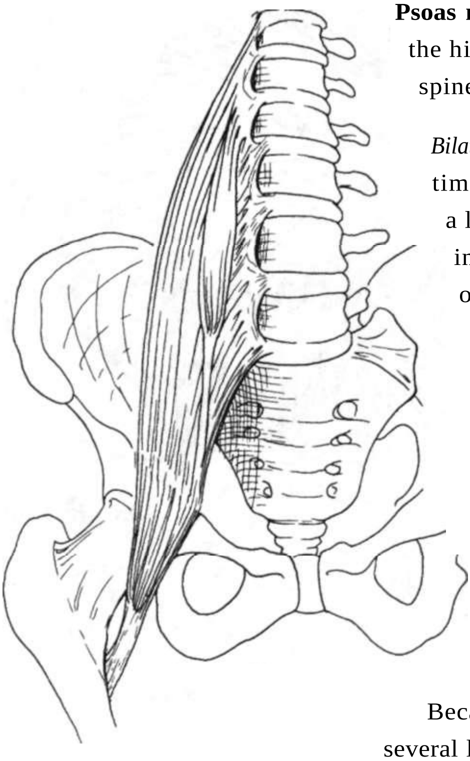
- The **sternal origin** is from the xiphoid process.
- The **costal origin** is from the deep surfaces of ribs 7-12 and their cartilages; the fibers of attachment interdigitate with those of the transversus abdominis muscle.
- The **vertebral origin** consists of a "right crus" arising directly from the bodies of L1-L3, a "left crus" arising from the bodies of L1-L2, and five **arcuate ligaments.**
  - —The single median arcuate ligament joins the two crura at the midline and arches over the abdominal entrance of the aorta.
  - —The paired medial arcuate ligaments extend from the body of L1 to its ttanverse processes, arching over the psoas major muscle.
  - —The paired lateral arcuate ligaments extend from the transverse processes of L1 to rib 12, arching over the quadrates lumborum muscle.

Action: The diaphragm is the principal muscle of inspiration (see p. 100).

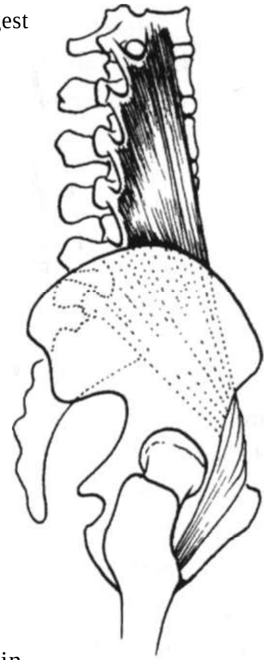
Innervation: phrenic nerves (C3-C5)

Posterior muscles of trunk

Starting from the sides of the lumbar vertebrae, we find two muscles, psoas major and quadratus lumborum.



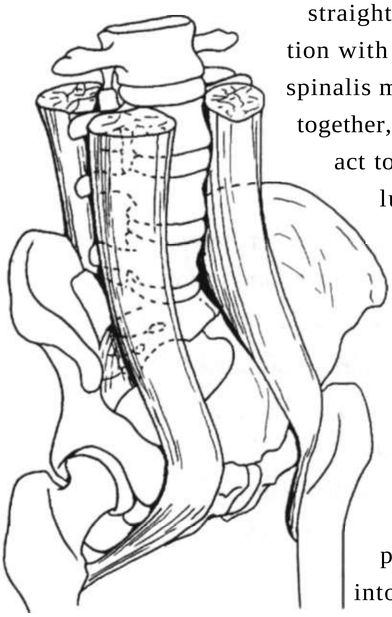
Psoas major is described on page 234 in connection with the hip muscles. Here, we shall consider its action on the spine, i.e., when the thigh is fixed.

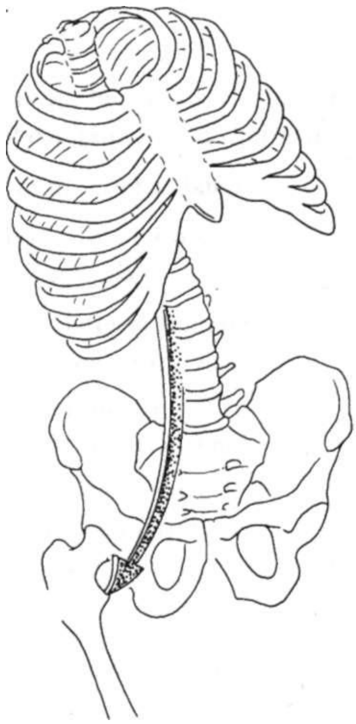


Bilateral contraction: For the longest time, the psoas was described as a lumbar muscle involved in increasing lordosis, because of the oblique orientation of its fibers.

But we can see that this multi-articular muscle (which passes over eight joints, six of which ate intervertebral) can have a more complex action on the level of the lumbar spine.

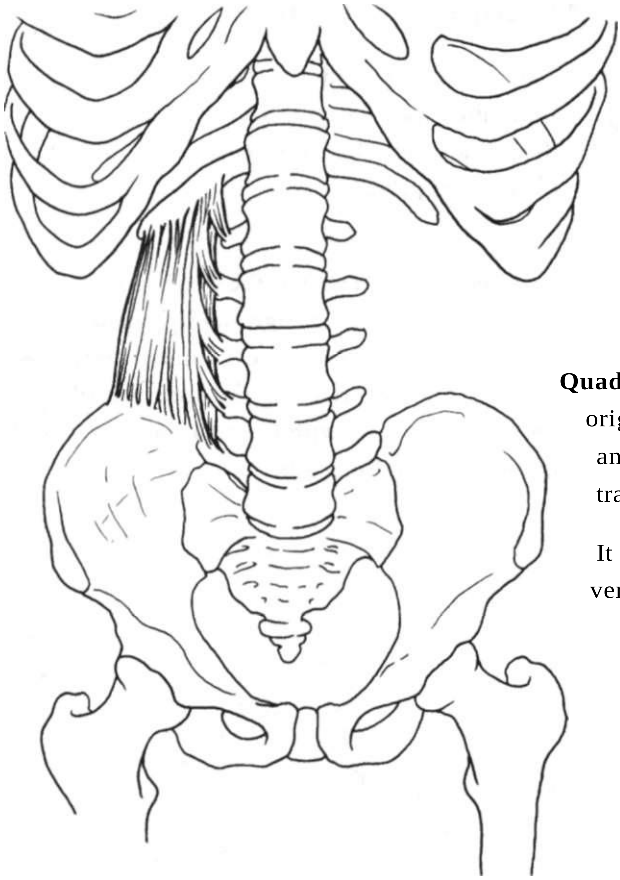
Because of its placement on several levels in the convex area of the lumbar spine, this muscle participates in straightening the spine, in combination with the posterior transversospinalis muscles. By contracting together, these four bundles can act to erect (straighten) the lumbal spine, father than increasing lordosis. This was discovered in electromyographic recordings taken from moving subjects.





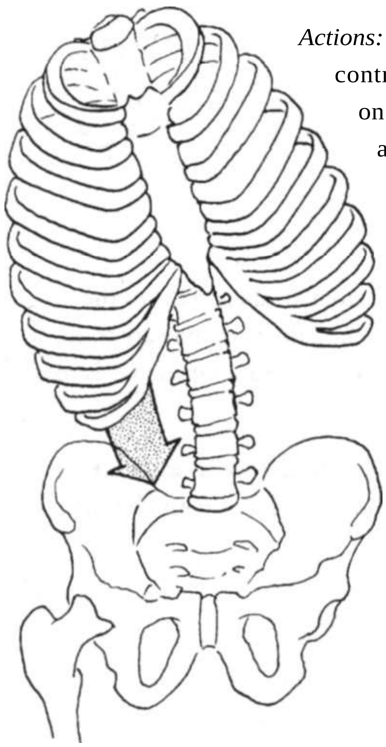
Unilateral contraction: The psoas muscle's unilateral action consists of pulling the lumbar spine into sidebending, flexion, and rotation of the side opposite the contraction.

Innervation: **lumbar plexus** (L1-L3)



Quadratus lumborum
originates from the posterior iliac crest, and inserts on rib 12 and the transverse processes of L1-L5.

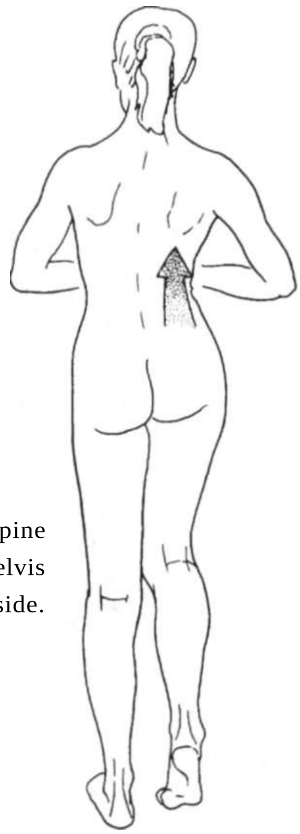
It is composed of both vertical and oblique fibers.



Actions: When the pelvis is fixed, contraction of this muscle pulls on rib 12 and the other ribs along with it. This causes sidebending of the lumbar spine and ribcage.

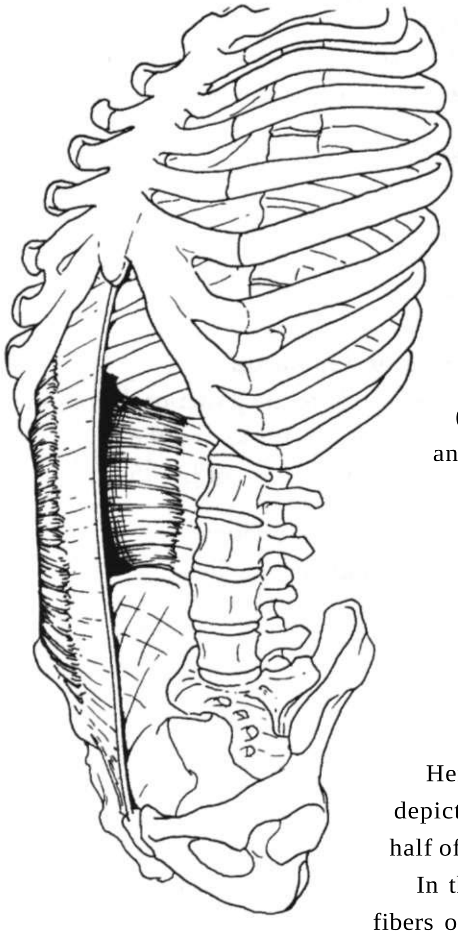
It is also an expiratory muscle.

When the ribs and spine are fixed, it raises the pelvis on one side.



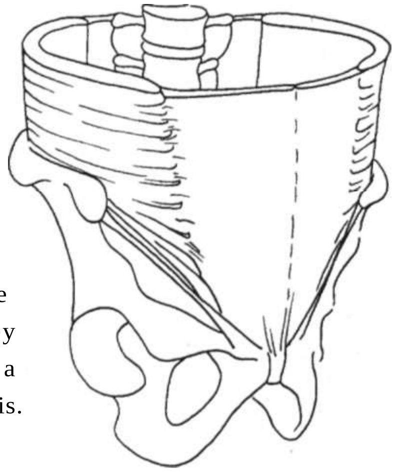
Innervation: **lumbar plexus** (T12/L1-L3)

Abdominal muscles

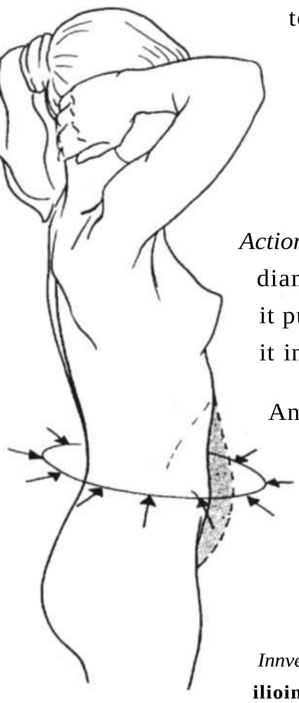


There are four paired muscles in the abdominal wall. They fill all the space (front, sides, and back) between the ribcage and pelvis.

Transversus abdominis is the deepest of the four. It attaches below to the **inguinal ligament** and the iliac crest; posteriorly to the five lumbar vertebrae; above to the inner surfaces of the last seven ribs (where it interdigitates with fibers of the diaphragm); and anteriorly to the **linea alba.**



Here is a schematic depiction of the lower half of the transversus. In this depiction, the fibers of the transversus are essentially horizontal. They terminate anteriorly in a broad aponeurosis.

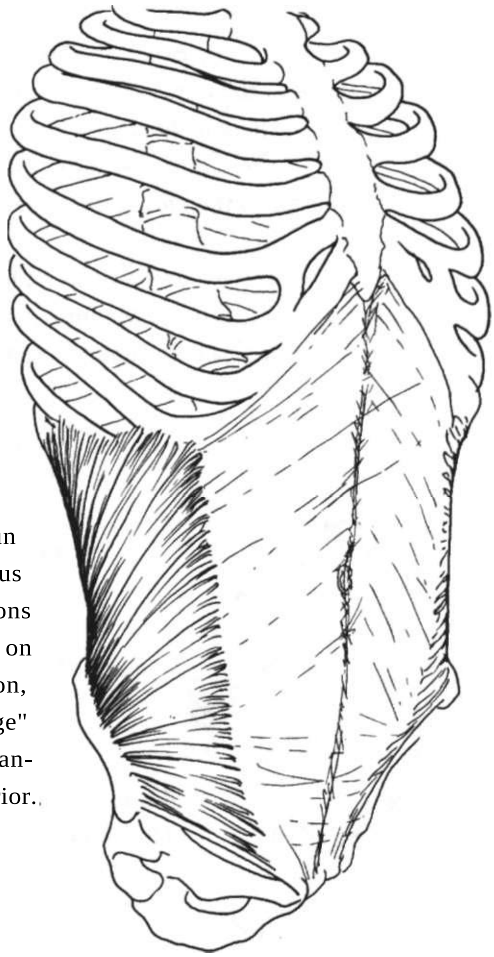


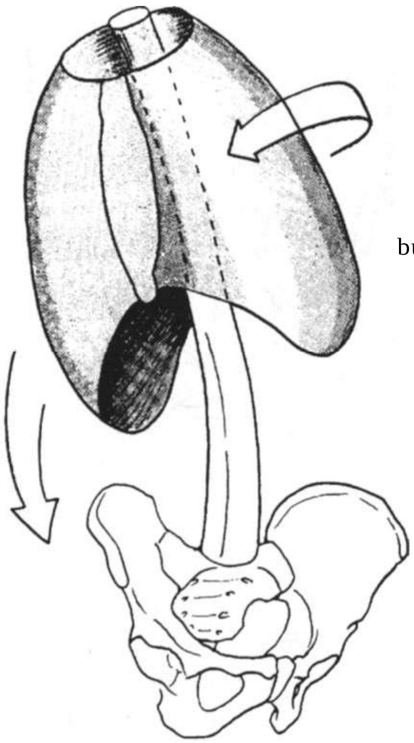
Actions: Contraction of these circular fibers reduces the diameter of the abdomen. When the vertebrae are fixed, it pulls in the belly. When the anterior aponeurosis is fixed, it increases lordosis of the lumbar spine.

An easy way to feel the action of the transversus is to wrap your hands around the sides of your abdomen and cough.

Innvervation: **intercostal nerves (T7-T12), ilioinguinal and iliohypogastric nerves (L1)**

The **internal oblique** lies between the transversus and external oblique. It is attached below to the inguinal ligament and the iliac crest; posteriorly to the lumbodorsal fascia; above, to the lower four ribs; and anteriorly to a very broad aponeurosis.



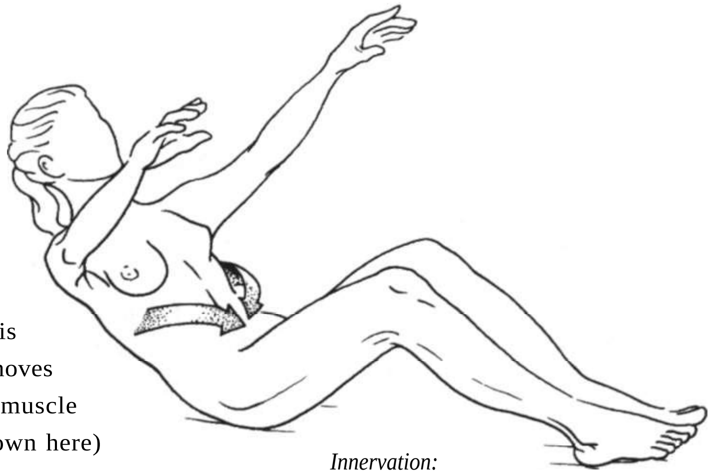


The fibers run in various directions depending on their location, but the "average" direction is anterosuperior.

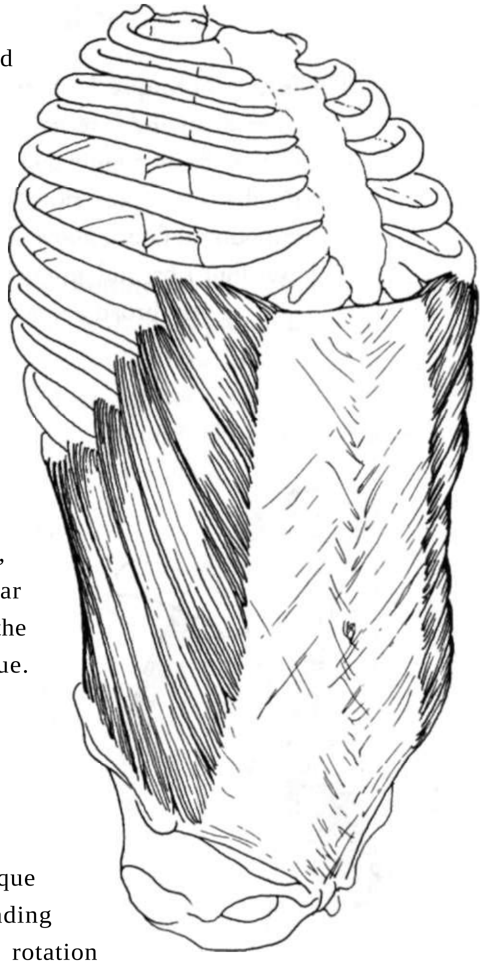
Actions: Unilateral contraction of the internal oblique results in sidebending or ipsilateral rotation of the spine and ribcage. If the pelvis is fixed, it acts on the ribs, and vice versa.

When the pelvis is fixed, bilateral contraction causes compression of the abdomen and assists in flexion of the trunk.

When the vertebrae and the pelvis ate fixed, it lowers the ribs and moves them backward. This is how the muscle is involved in expiration (not shown here)

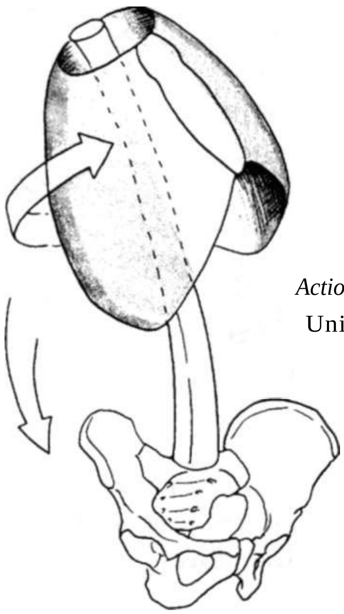


Innervation:
intercostal nerves (T9-T12),
ilioinguinal and iliohypogastric nerves (L1)



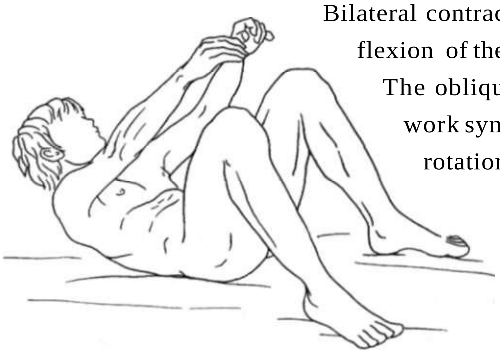
The **external oblique** is attached above to the outer surfaces of ribs 5-12 (where its fibers intertwine with those of the serratus anterior) and to the ilioinguinal ligament. In front and below, it forms a broad aponeurosis ending at (and contributing to) the linea alba and inguinal ligament.

The average direction of the fibers is anteroinferior, i.e., perpendicular to those of the internal oblique.

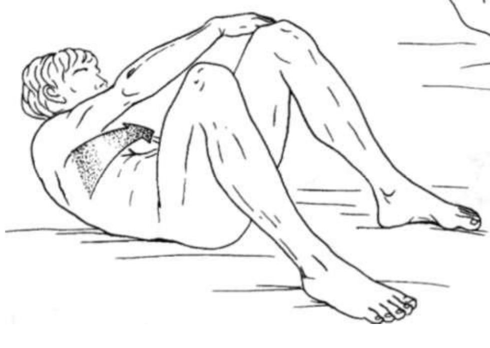


Actions:

Unilateral contraction of the external oblique results in side-bending and contralateral rotation of the spine and ribcage.



Bilateral contraction causes flexion of the trunk. The oblique muscles work synergetically in rotation of the trunk.



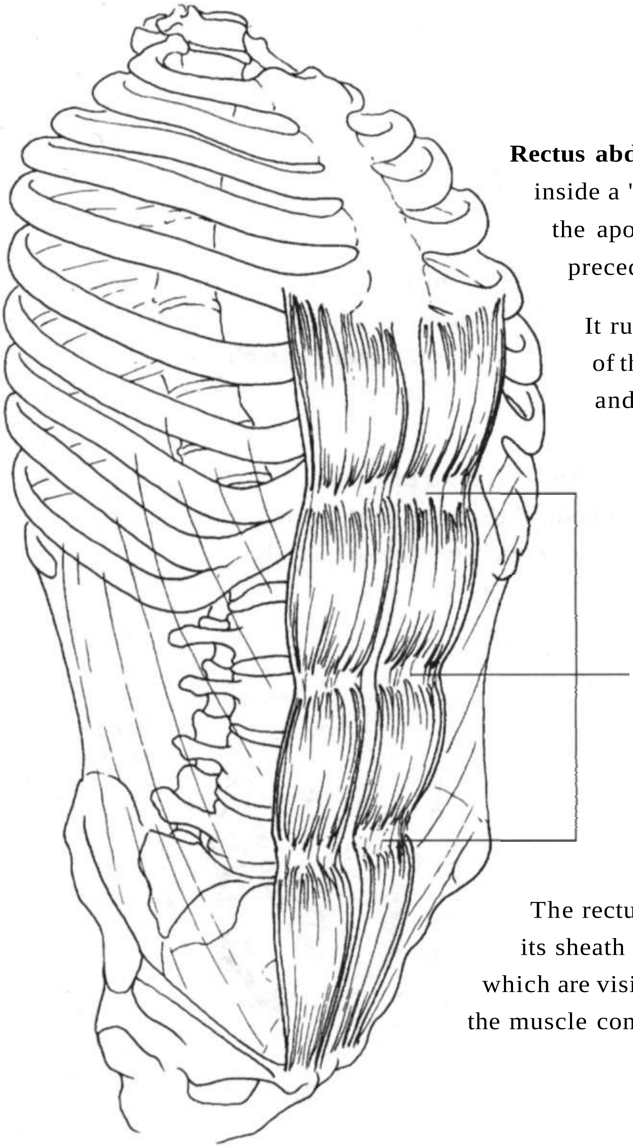
For instance, rotation of the trunk to the left (combined with flexion) involves simultaneous contraction of the left internal oblique and right external oblique.

Innervation: intercostal nerves (T5-T12), ilioinguinal and iliohypogastric nerves (L1)

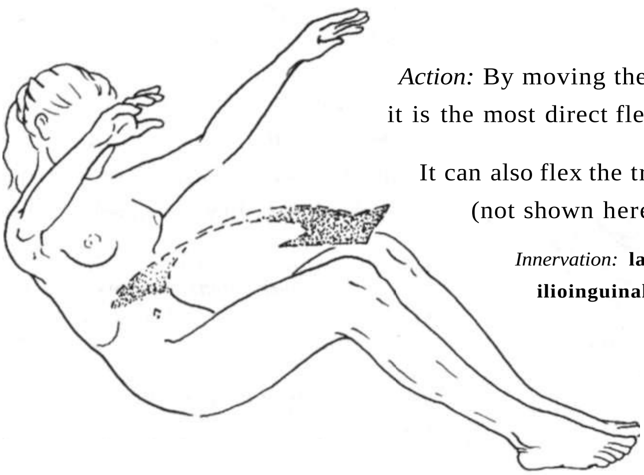
When the pelvis is fixed, it lowers the ribs; it is then an expiratory muscle (not shown here).

Rectus abdominis is located anteriorly, inside a "rectus sheath" formed by the aponeuroses of the three preceding muscles.

It runs from the crest and symphysis of the pubis to the xiphoid process and cartilages of ribs 5-7.



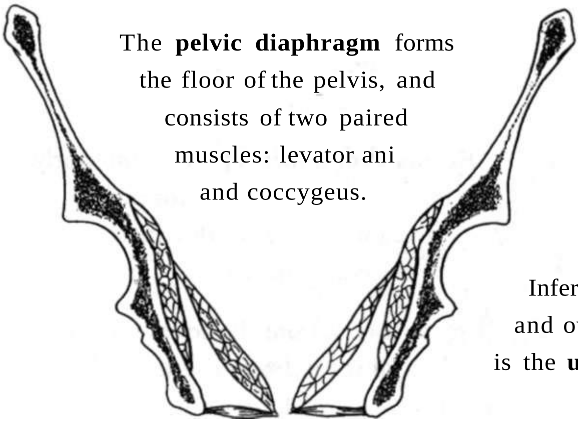
The rectus adheres to the anterior layer of its sheath at three tendinous intersections, which are visible as transverse grooves when the muscle contracts.



Action: By moving the sternum toward the pelvis, it is the most direct flexor of the trunk.

It can also flex the trunk by tilting the pelvis backward (not shown here).

Innervation: **last four intercostal nerves (T5-T12), ilioinguinal and iliohypogastric nerves (L1)**



The **pelvic diaphragm** forms the floor of the pelvis, and consists of two paired muscles: levator ani and coccygeus.

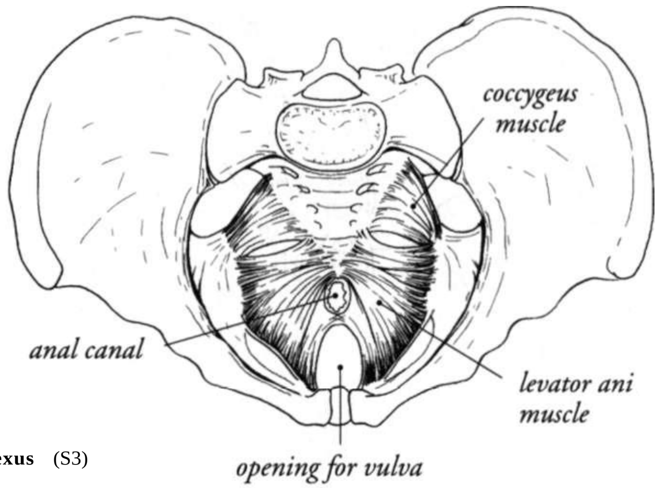
Inferior to the pelvic diaphragm, and overlapping it anteriorly, is the **urogenital diaphragm.**

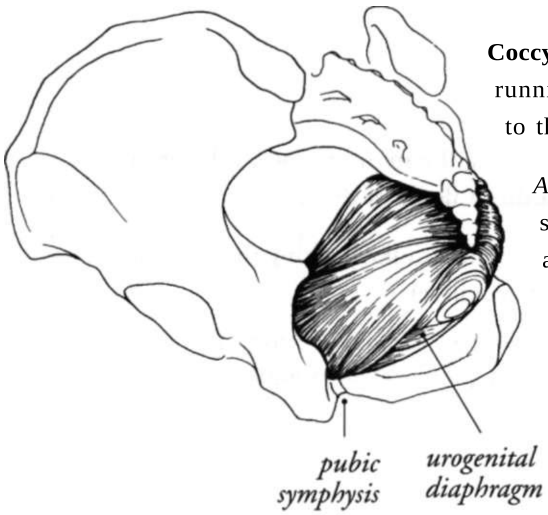
Levator ani originates from fascia covering the obturator internus, along a line extending from the posterior body of the pubis to the ischial spine. The fibers from the left and right sides of this muscle run inferomedially and meet each other at the midline. Some posterior fibers insert on the coccyx and lower sacrum.

Levator ani contains an opening for the anal canal.

The anterior portion of this muscle is different in the female pelvis, where it has an opening to accommodate the vulva (as shown in the illustration). In the male pelvis, this area is closed (not shown here).

Innervation: **accessory branch of sacral plexus** (S3)





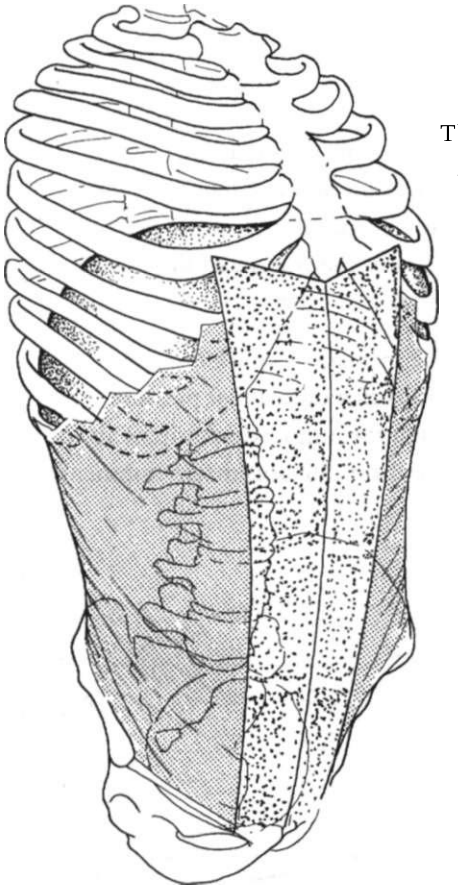
Coccygeus is posterior to levator ani, running from the ischial spine to the coccyx and lower sacrum.

Actions: Both of these muscles support the weight of the pelvic organs, and are involved in continence. They also rotate the sacrum backward.

Innervation: **accessory branch of pudendal plexus** (S4)

Note: These muscles play no role in the positioning of the pelvis on top of the legs, since they do not insert into the femurs.

Abdominal cavity

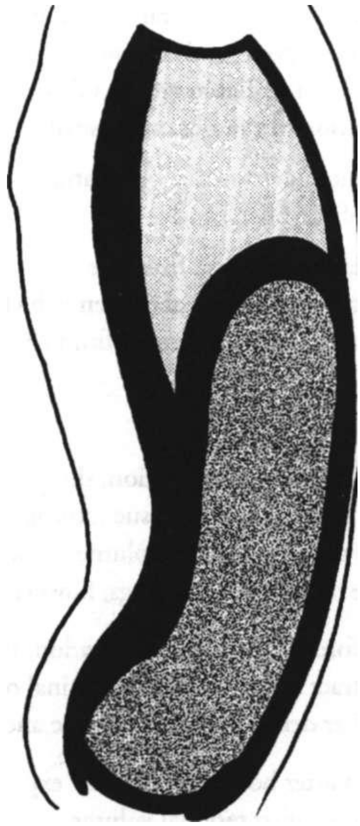


The abdominal cavity is inferior to the thorax and contains the abdominal organs.

It is bounded:

- above by the diaphragm, lower ribs, costal cartilages and sternum
- posteriorly by the lumbar vertebrae
- laterally and anteriorly by the abdominal muscles
- inferiorly by the pelvis and the pelvic and urogenital diaphragm.

Diaphragm and abdominal muscles in respiration



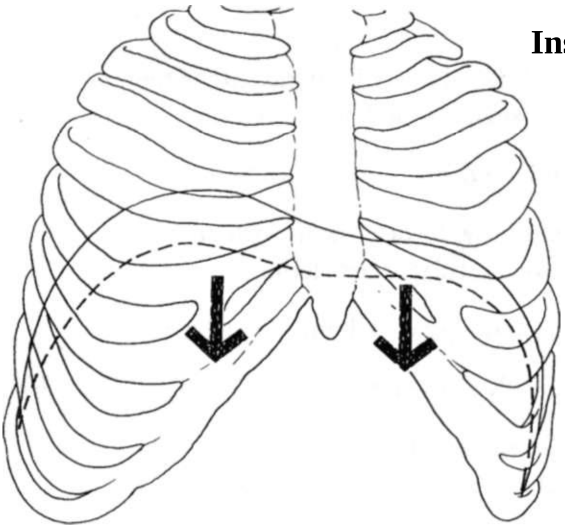
The two large cavities of the trunk, thorax and abdomen, function differently.

The abdomen can be compared to a liquid-filled, flexible container which can change its shape but not its volume (i.e., is non-compressible).

By contrast, the thorax can be compared to a gas-filled container which can change its shape and is compressible.

The diaphragm is like a plunger that moves between these two cavities. In cooperation with the abdominal muscles, it helps control the shape, volume, and pressure of both cavities during many activities (breathing, speaking, coughing, defecating, childbirth, hiccups, etc.)

How the diaphragm and abdominal muscles are involved in breathing



Inspiration

During normal inspiration, contraction of the diaphragm lowers its dome and thereby increases the volume of the thorax and lungs.

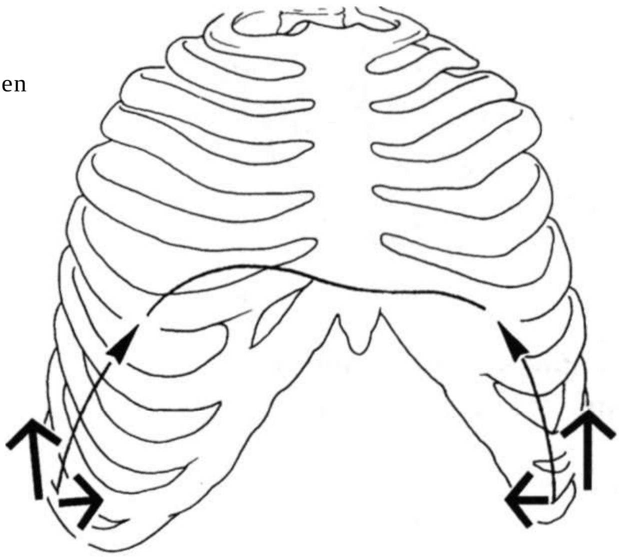
The increase in volume results in a decrease of pressure inside the lungs, which causes air to enter from the outside environment.

On the other hand, contraction of the abdominal muscles can cause the abdomen to maintain its shape and resist lowering of the diaphragm.

In this case, the central tendon becomes the fixed point and contraction of the fibers of the diaphragm results in elevation of the ribs, because of

(a) the superomedial orientation of the fibers, and

(b) lateral pressure from the contents of the abdomen, which ate being compressed from above.



Expiration

During normal expiration, the diaphragm simply relaxes (i.e., the dome moves upward) and the elastic lung tissue returns to its normal size after being stretched during inspiration. The decrease in lung volume results in an increase in pressure, and air is expelled through the nose or mouth. The lungs, however, do not empty completely.

In "forced" (or active) expiration, the expiratory muscles, especially the abdominal muscles, contract and press the abdominal organs upward against the thorax and lower ribcage, further decreasing lung volume and increasing the pressure which drives air out.

No matter how hard "forced" expiration is done, some air will always remain in the lungs. This is called residual volume.

CHAPTER THREE

The Shoulder

The shoulder is the area where the arm is attached to the thorax. In contrast to the hip, it involves more than one joint. This complex structure has two important functions:

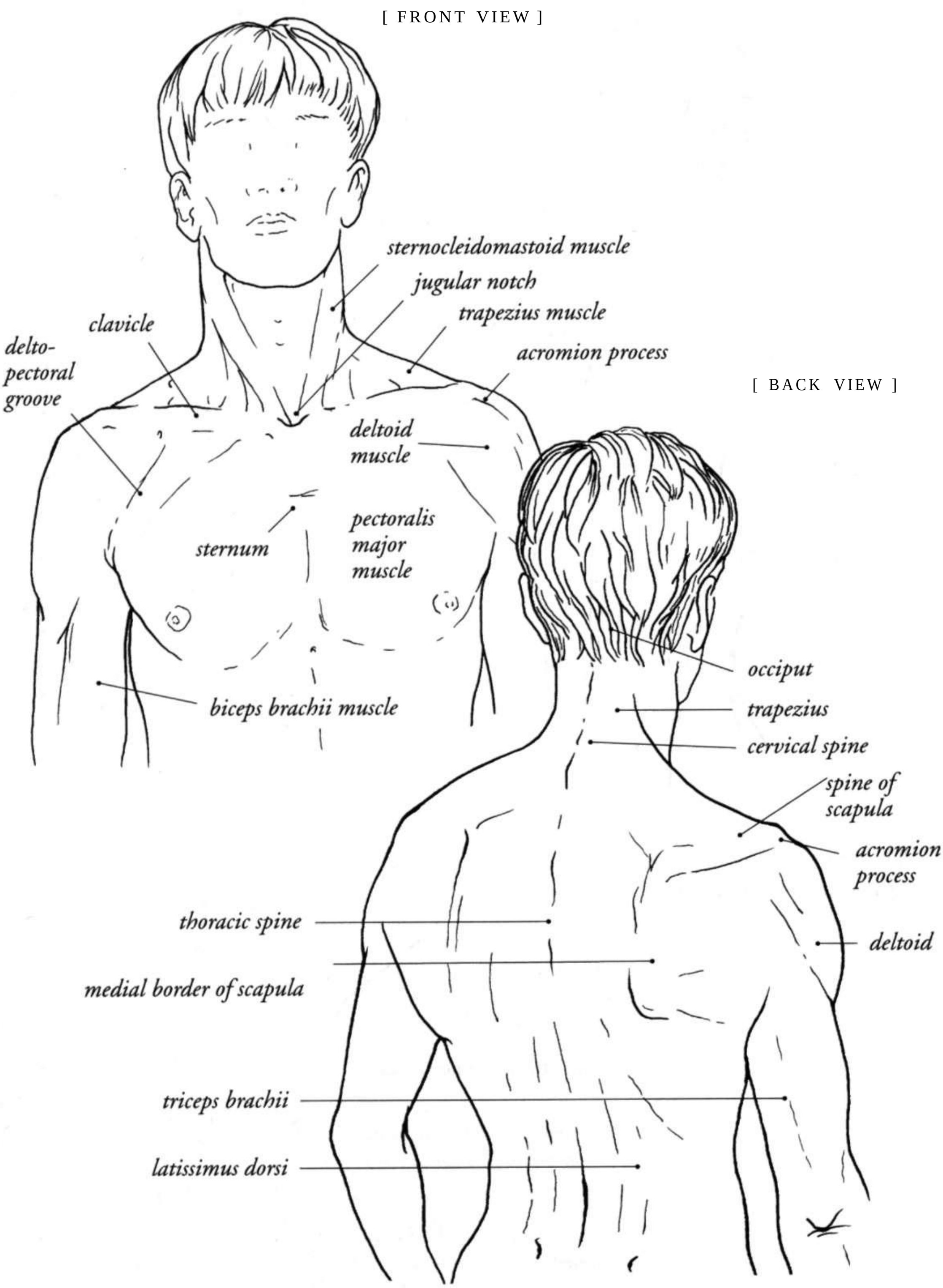
- It must be very flexible, to allow the hand and arm the huge range of motion which they require.
- It must provide a strong, stable fixed point for certain actions (lifting a heavy object, pushing against resistance, etc.)

The primary joint of the shoulder is the **glenohumeral joint** between the head of the humerus and glenoid cavity of the scapula. However, the scapula itself is an extremely mobile bone, and is connected to the axial skeleton (i.e., sternum) only by the long, thin clavicle. Thus, two other joints are involved in movements of the shoulder: the **acromioclavicular joint** between the distal clavicle and acromion process of the scapula, and the **sternoclavicular joint** between the medial clavicle and manubrium of the sternum.

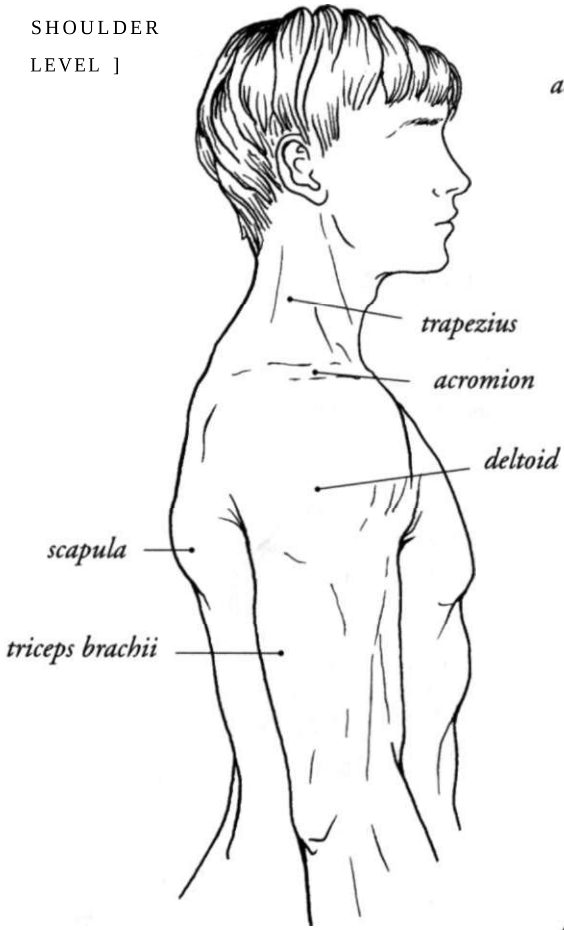
The shoulder thus comprises three joints, plus important gliding planes. We can distinguish functional areas: the **scapulothoracic** and the **scapulohumeral.**

Landmarks

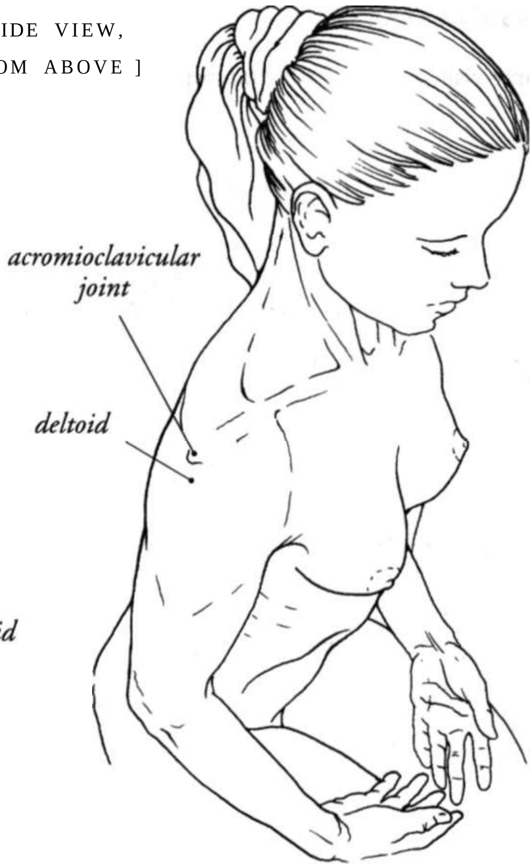
Some visible and palpable landmarks of the shoulder are shown below.



[SIDE VIEW, SHOULDER LEVEL]

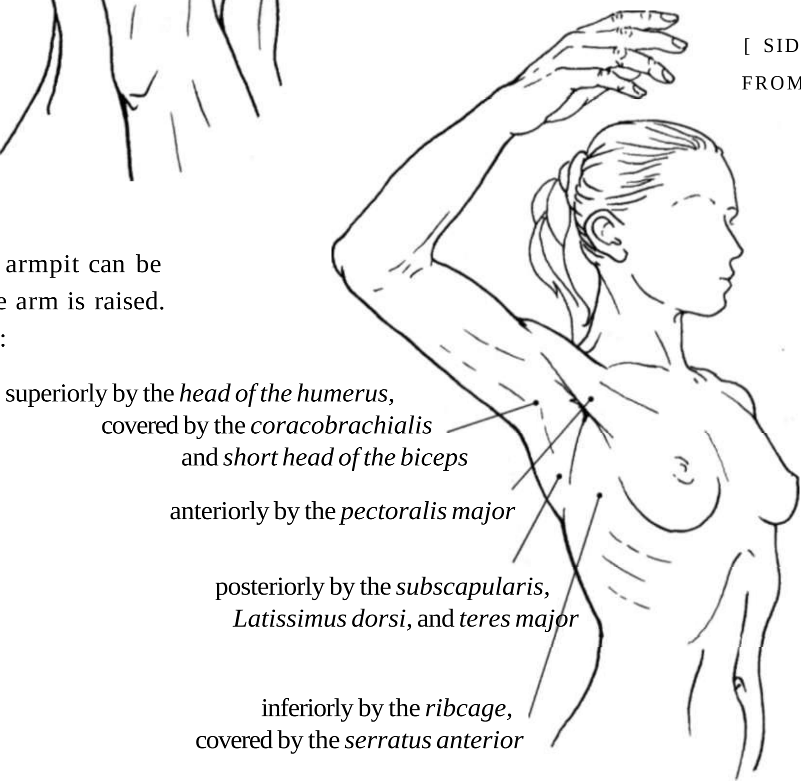


[SIDE VIEW, FROM ABOVE]



The **axilla** or armpit can be seen when the arm is raised. It is bounded:

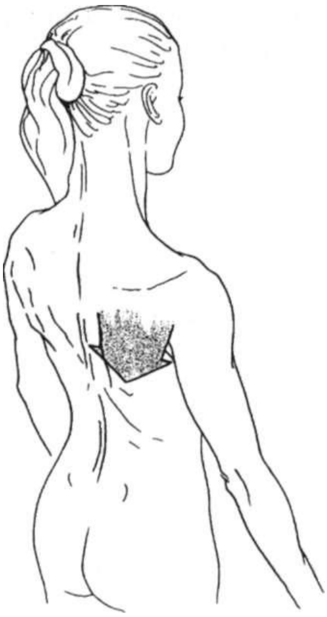
[SIDE VIEW, FROM BELOW]



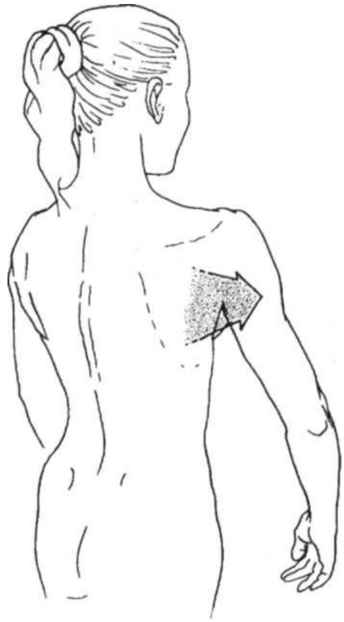
Global movements of shoulder

There are two types of movement, because the two functional areas either work individually or together to make them possible. First, we can observe how the shoulder moves on the thorax. These movements make the shoulder:

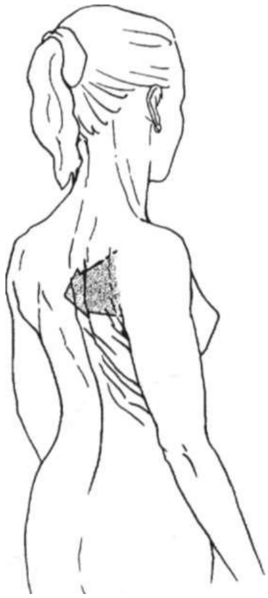
go up: **elevation**



down: **depression**

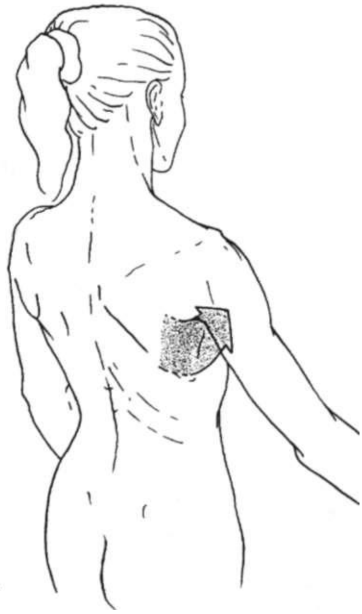


move away from the spine (this movement also brings the shoulder forward): **abduction**



move closer to the spine: **adduction**

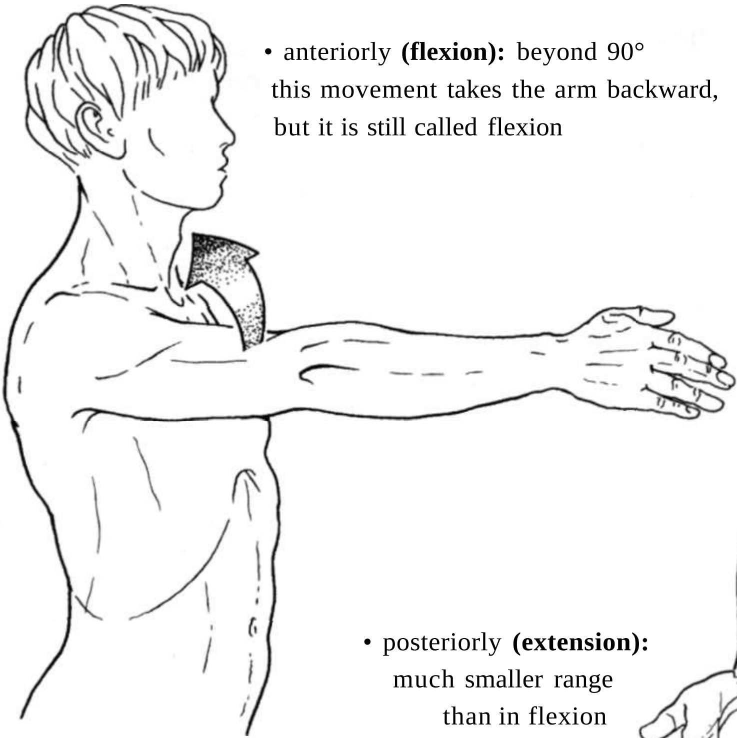
tilt by moving the inferior angle of the scapula toward midline: **medial rotation**



tilt by moving the inferior angle away from midline: **lateral rotation.**

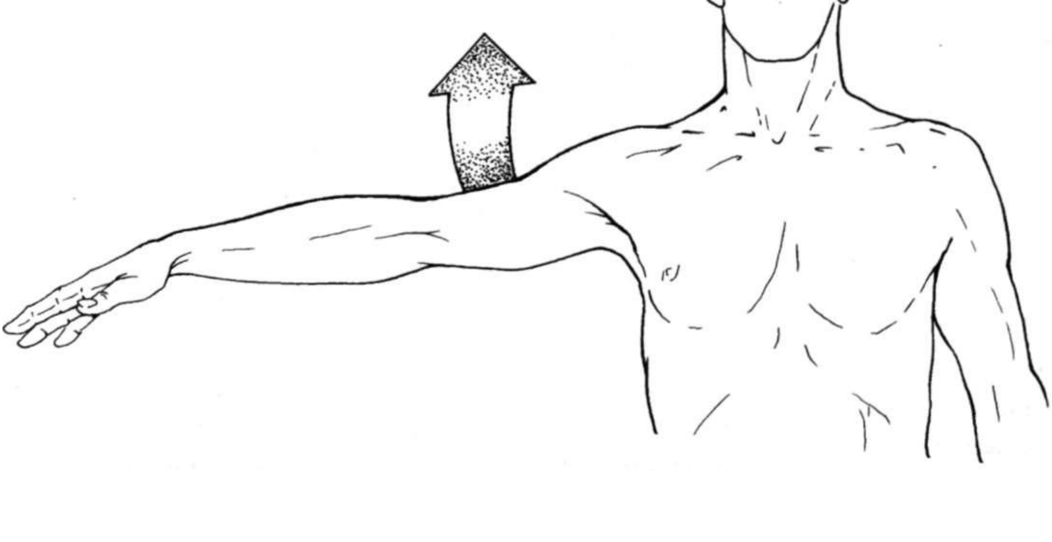
Second, we can see how the combined actions of the scapula and arm allow the arm to move in many ways:

• anteriorly **(flexion):** beyond 90°
this movement takes the arm backward, but it is still called flexion

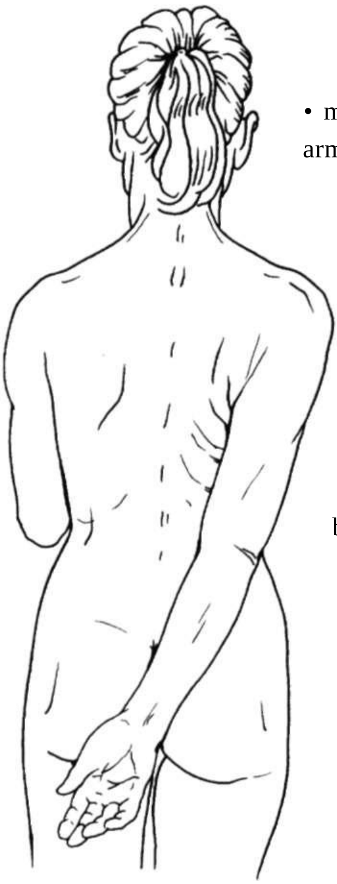


• posteriorly **(extension):** much smaller range than in flexion

• laterally **(abduction):** beyond 90°
this movement takes the arm closer to the midline, but it is still called abduction

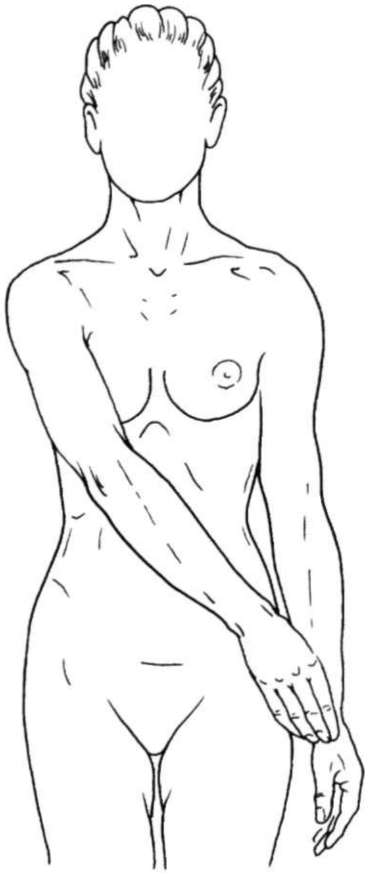


• medially **(adduction):**
arm moves closer to body

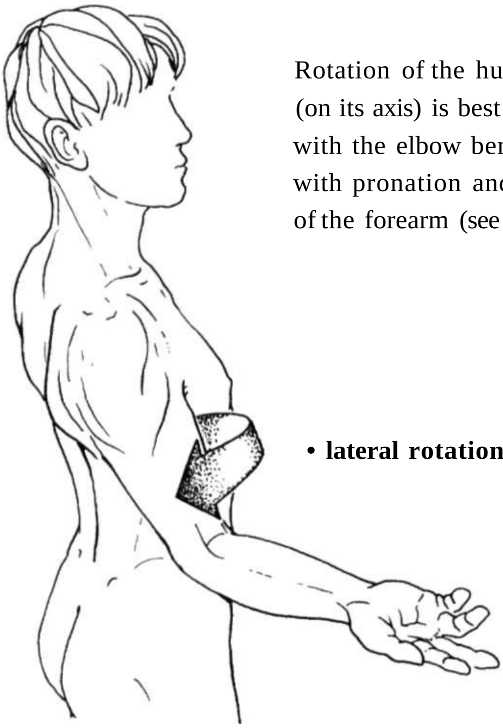


Adduction
is combined
with extension
to move the arm
behind the body...

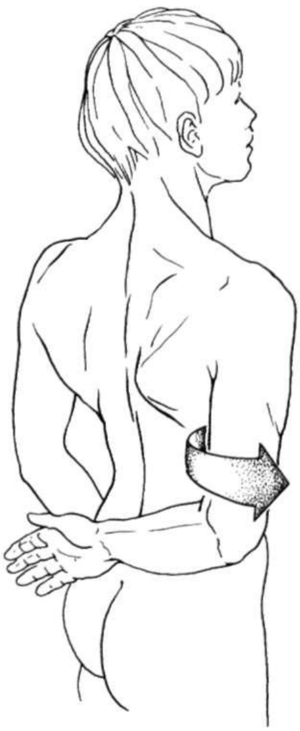
...or with flexion
to move the arm
in front of the body.



Rotation of the humerus
(on its axis) is best visualized
with the elbow bent, to avoid confusion
with pronation and supination
of the forearm (see p. 149):

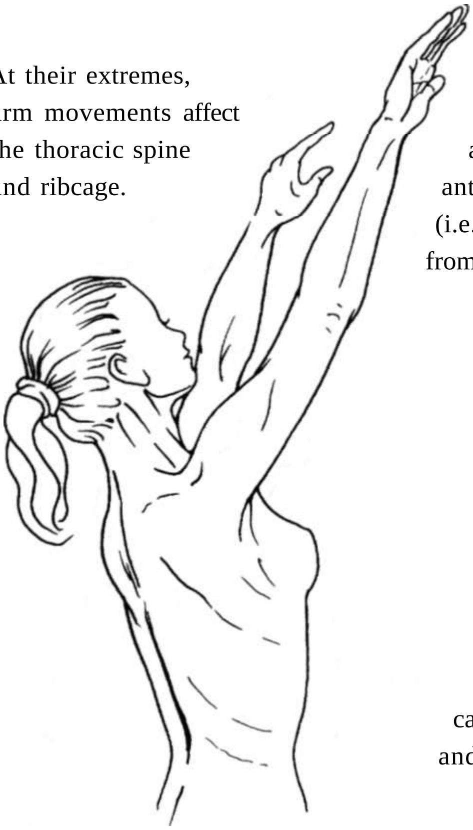


• **lateral rotation**

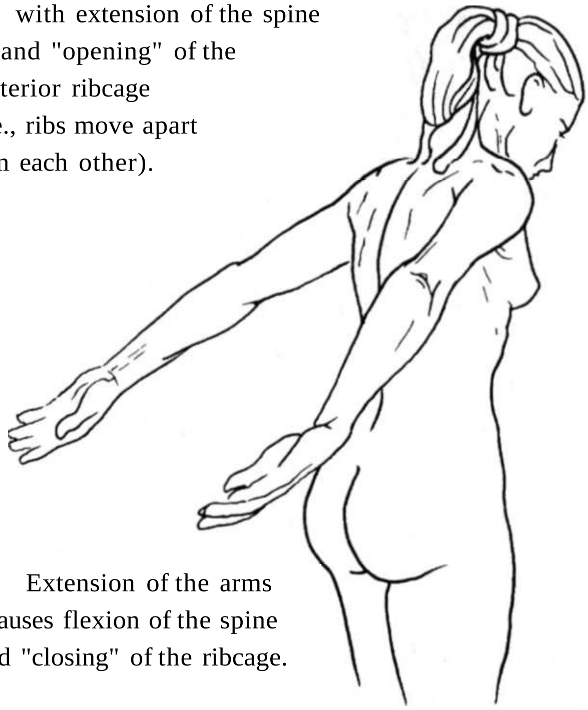


• **medial rotation**

At their extremes, arm movements affect the thoracic spine and ribcage.



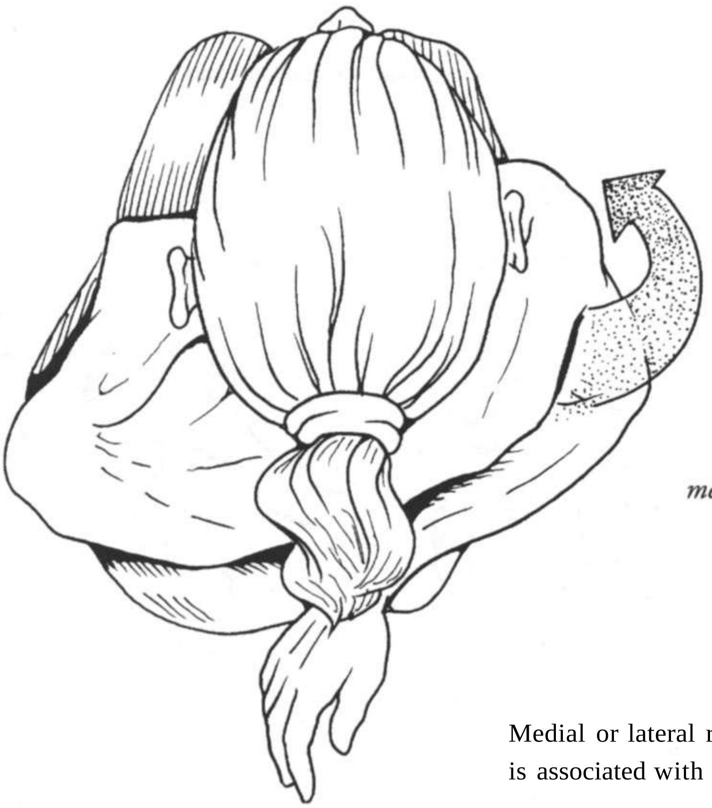
Flexion of the arms is associated with extension of the spine and "opening" of the anterior ribcage (i.e., ribs move apart from each other).



Extension of the arms causes flexion of the spine and "closing" of the ribcage.

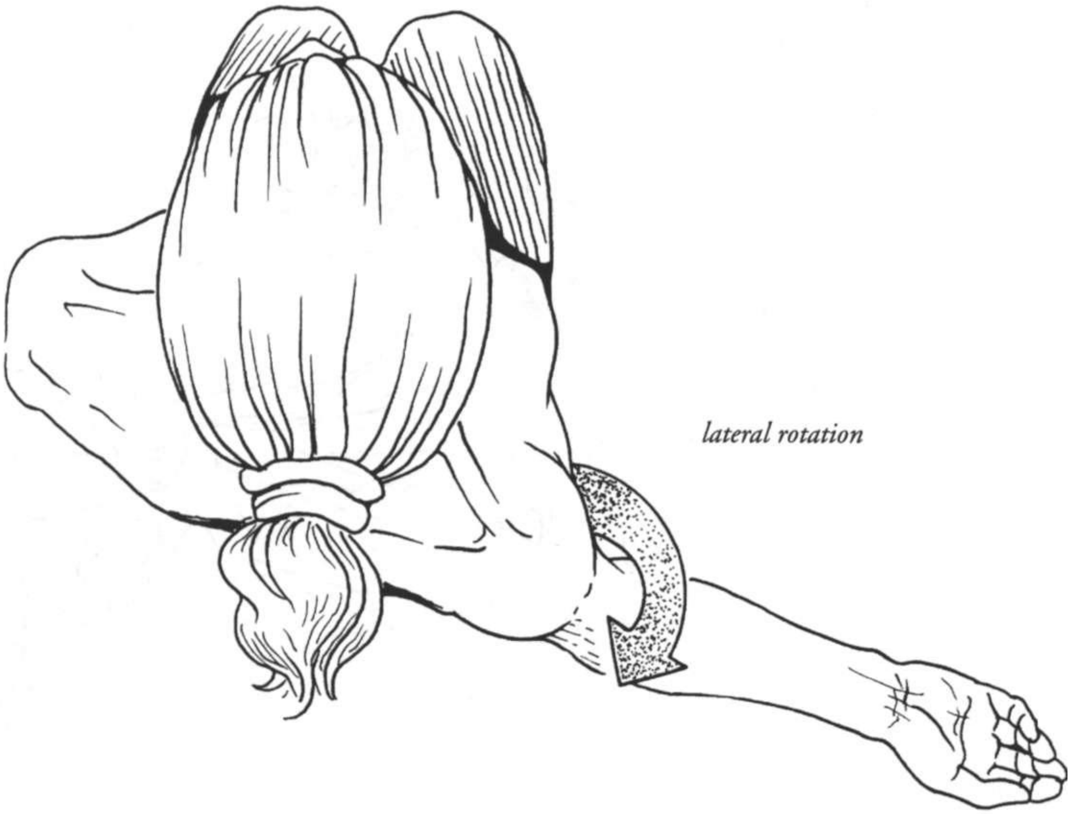
Adduction is associated with ipsilateral sidebending and closing of the ipsilateral hemithorax...

...while abduction causes contralateral sidebending and opening of the ipsilateral hemithorax.



medial rotation

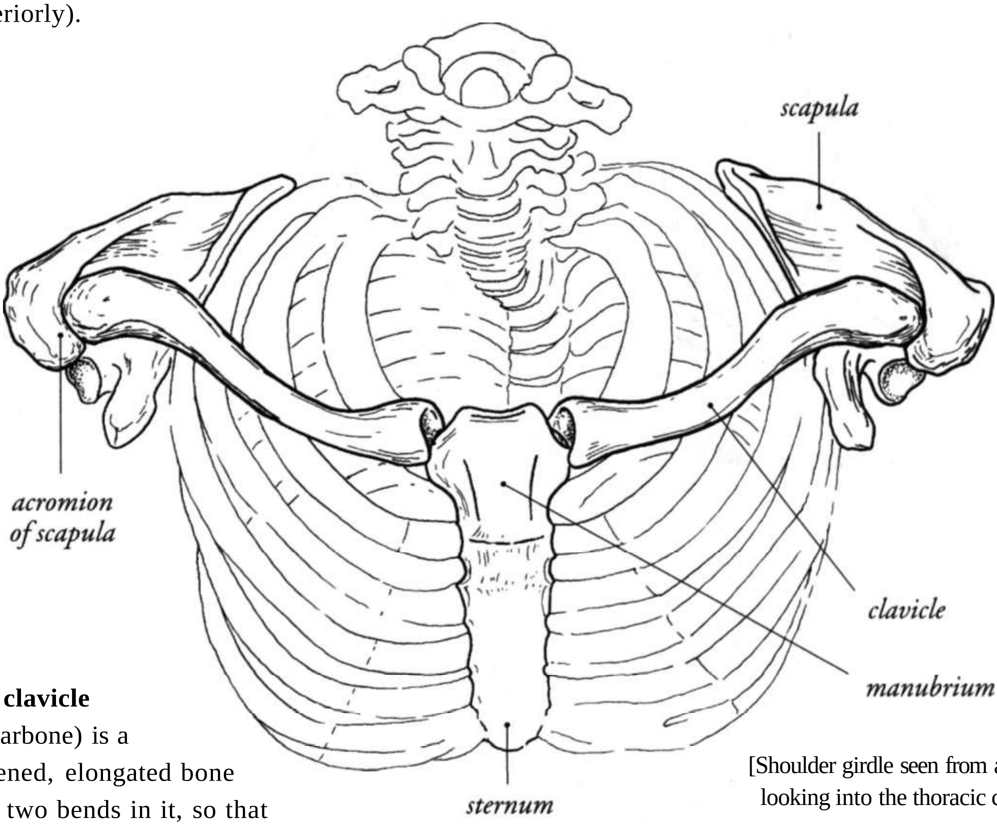
Medial or lateral rotation of the humerus is associated with similar rotation of the spine.



lateral rotation

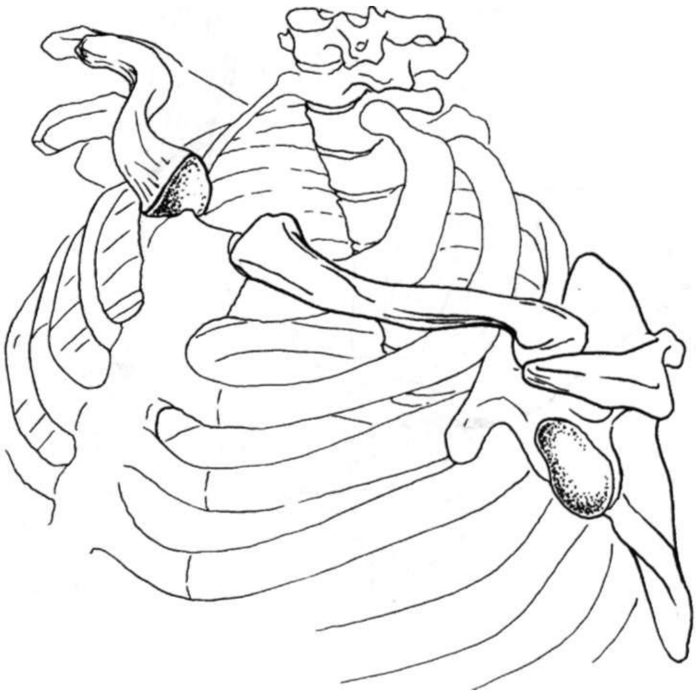
Shoulder girdle

The shoulder girdle consists of the scapulae (posteriorly) and the clavicles and sternum (anteriorly).



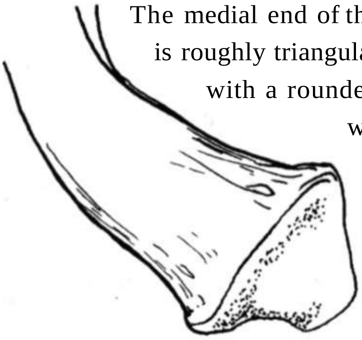
[Shoulder girdle seen from above, looking into the thoracic cage]

The **clavicle** (collarbone) is a flattened, elongated bone with two bends in it, so that it is roughly S-shaped when viewed from above or below.

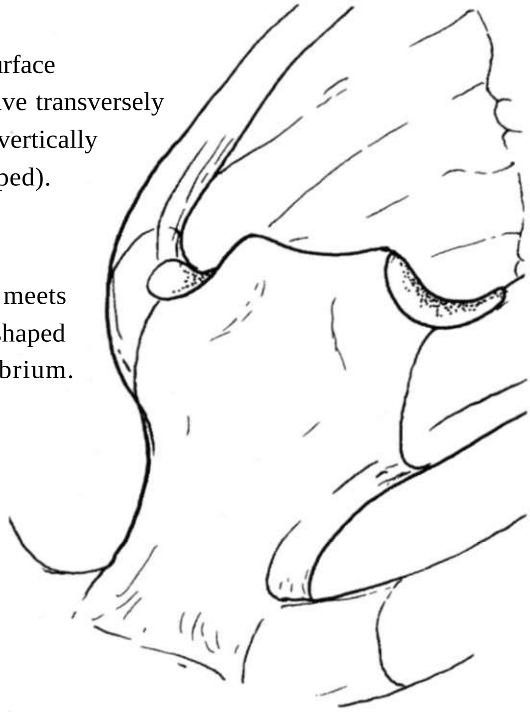


It articulates medially with the manubrium of the sternum. Laterally, it articulates with the acromion of the scapula.

Sternoclavicular joint

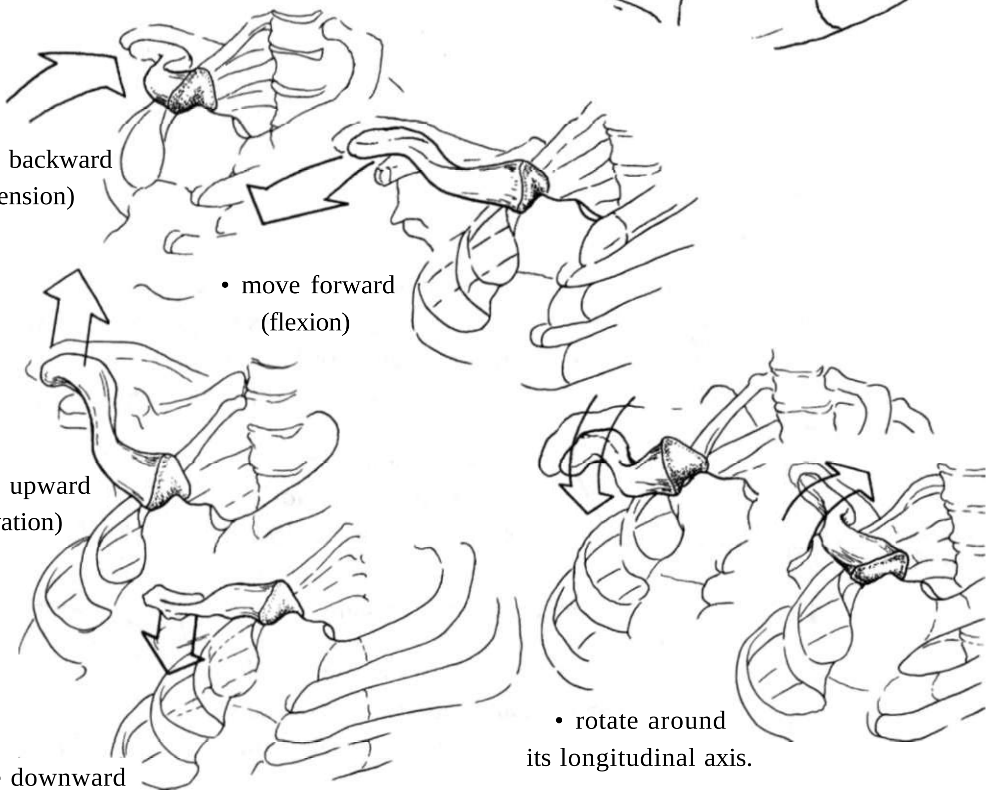


The medial end of the clavicle is roughly triangular, with a rounded articular surface which is concave transversely and convex vertically (saddle-shaped).



It meets an inversely-shaped articular surface on the manubrium.

The saddle shape of the joint allows the clavicle to:

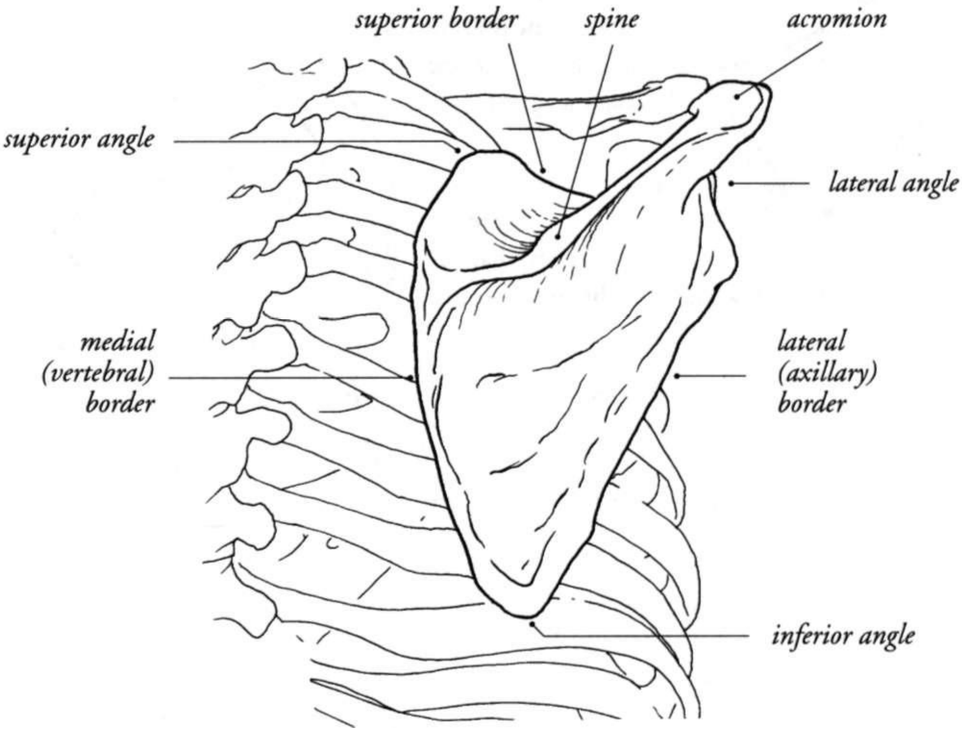


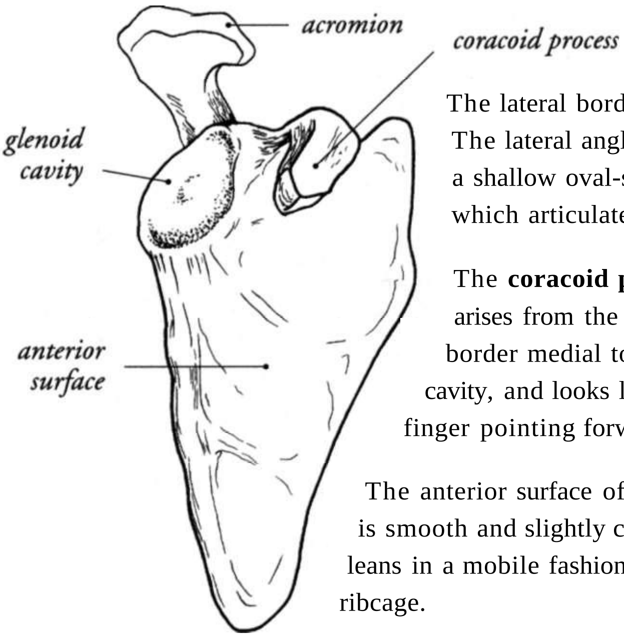
- move backward (extension)
- move forward (flexion)
- move upward (elevation)
- move downward (depression)
- rotate around its longitudinal axis.

These movements generally occur secondarily in association with movements of the scapula. There are anterior and posterior ligaments (not shown).

Scapula

The scapula, or shoulderblade, is a flat triangular bone with two surfaces (anterior and posterior), three borders, and three angles.

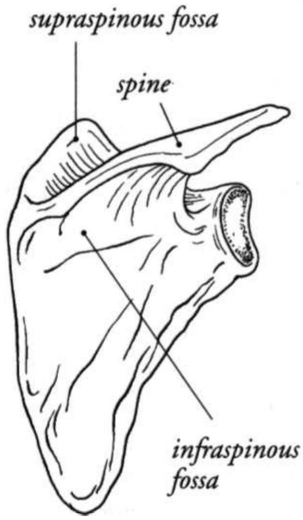




The lateral border is much thicker than the medial border. The lateral angle contains the **glenoid cavity,** a shallow oval-shaped depression which articulates with the head of the humerus.

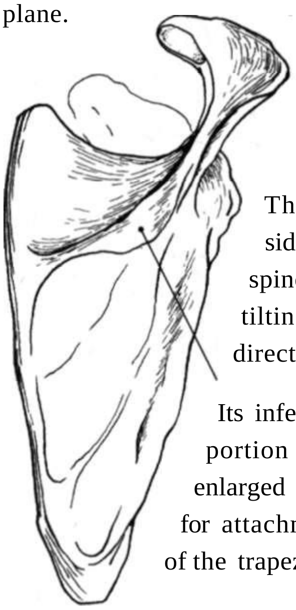
The **coracoid process** arises from the superior border medial to the glenoid cavity, and looks like a bent finger pointing forward.

The anterior surface of the scapula is smooth and slightly concave, and leans in a mobile fashion against the ribcage.



The posterior surface is convex. The **spine** is a strong, sharp ridge running diagonally near the superior border. There are depressions above and below it called the supraspinous and infraspinous fossae.

The scapular spine is a triangular ridge, which starts roughly perpendicular to the scapular plane.



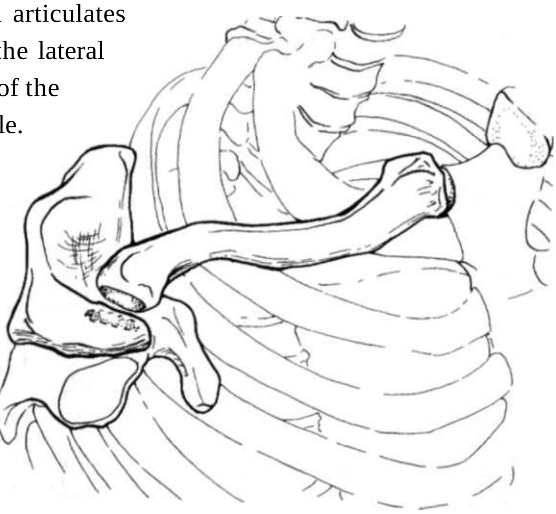
The posterior side of the spine is thick, tilting in two directions.

Its inferior portion has an enlarged tubercle for attachment of the trapezius.

The lateral end of the spine is enlarged and flattened to form the **acromion process.** Note that the acromion is oriented perpendicular to the spine.

The posterior surface of this process can easily be palpated through the skin.

Its anterior surface projects beyond the glenoid cavity; its anterior side consists of an oval articular surface, which articulates with the lateral edge of the clavicle.



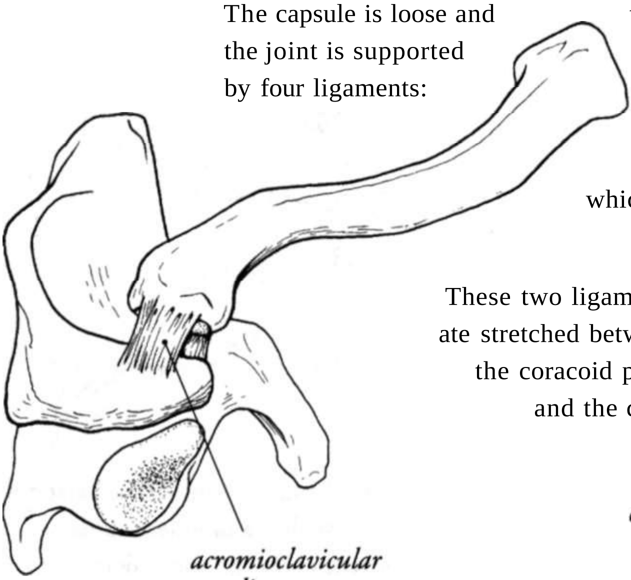
Acromioclavicular joint

The acromion and the lateral end of the clavicle each has a small oval surface where they articulate. Sometimes this joint includes a meniscus (fibrous disk). The shape of the articular surfaces allows some gliding movement, as well as opening and closing of the angle formed by the two bones.

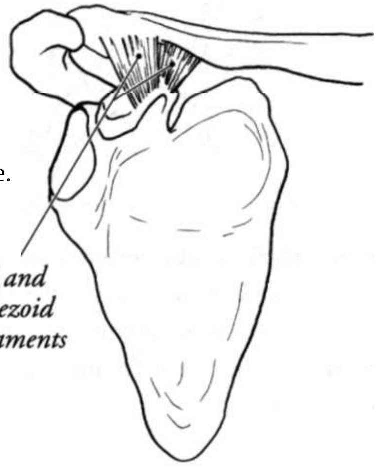
The capsule is loose and the joint is supported by four ligaments:

the superior and inferior acromioclavicular ligaments, which inhibit the opening of the angle between the two bones;

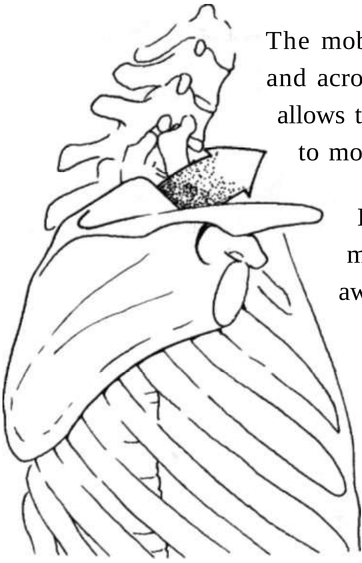
and the conoid and trapezoid ligaments, which inhibit the closing of the angle.



These two ligaments ate stretched between the coracoid process and the clavicle.



Movements of shoulder girdle on ribcage

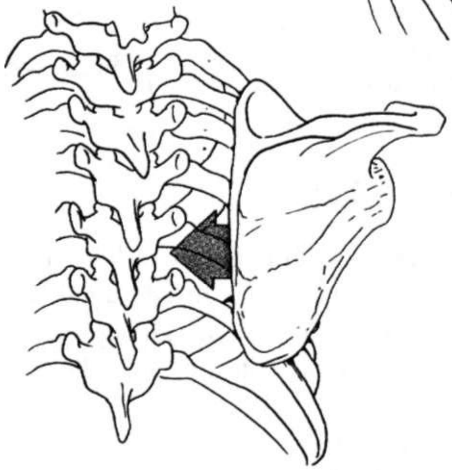


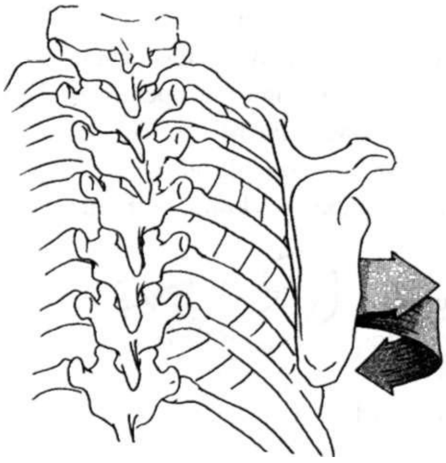
The mobility of the sternoclavicular and acromioclavicular joints allows the scapula to move in various directions.

In **elevation,** the scapula moves upward and away from the ribcage.

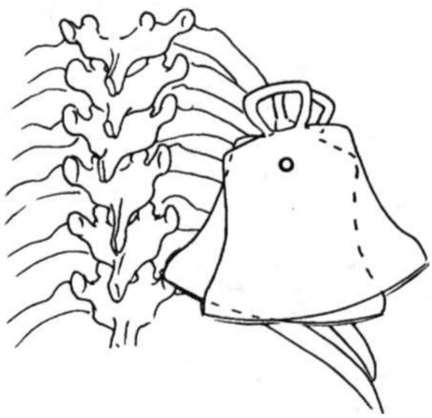
In **depression,** it moves downward and fits mote snugly against the ribcage.

In **retraction (adduction),** the medial border moves closer to the vertebral column.

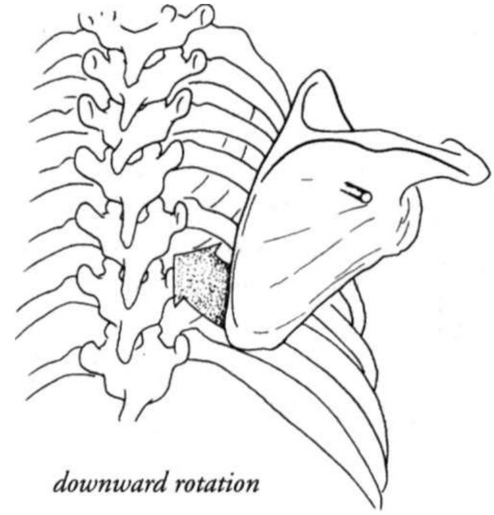




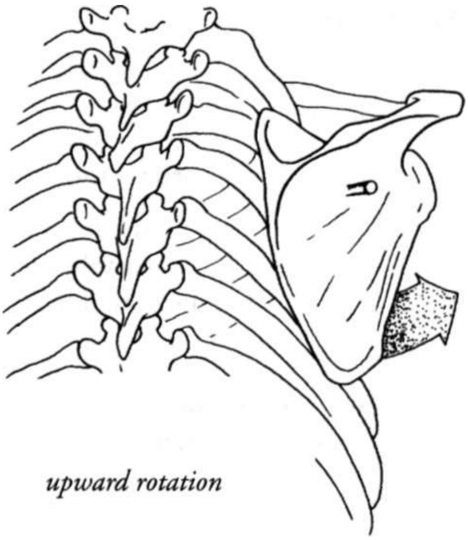
In **protraction (abduction),** the medial border moves away from the vertebral column, and the scapula moves anteriorly at a 45° angle as it glides on the convex thorax.



Rotation: a bell-like movement. To understand this movement, visualize a mobile scapula positioned above the ribcage and moving around an axis, which is vertical to the ribcage and passes under the middle of the scapular spine. The scapula pivots around this axis.

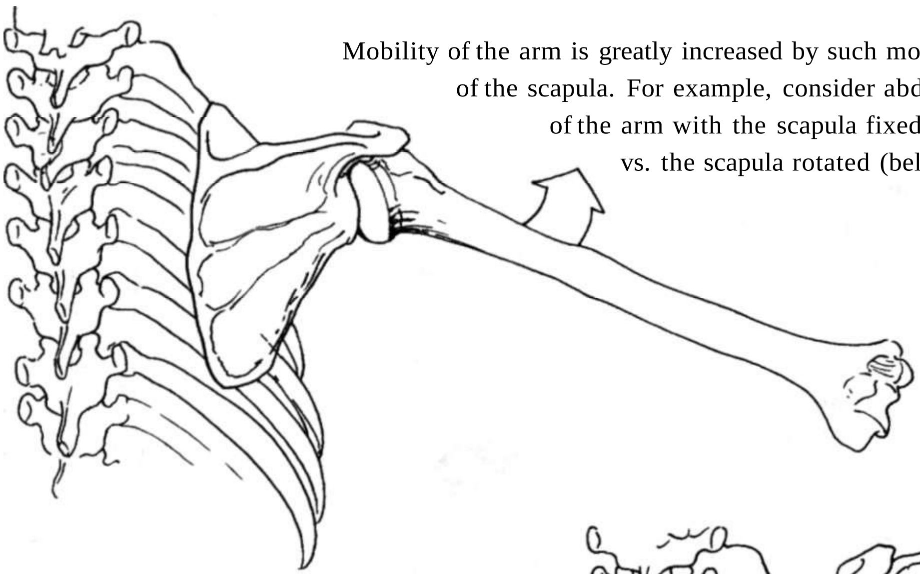


downward rotation

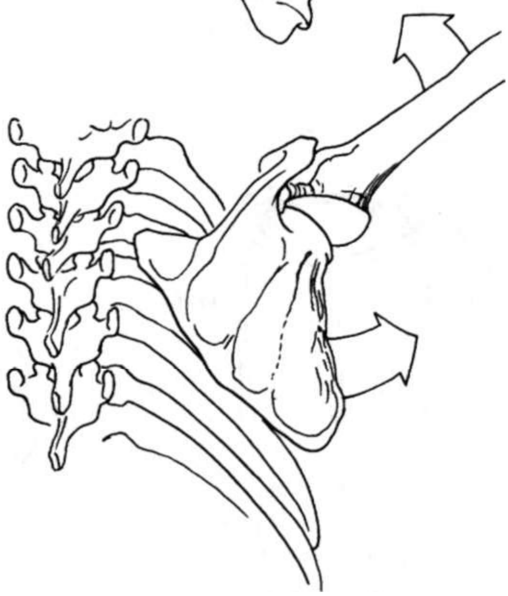


upward rotation

The glenoid cavity of the scapula can point in many directions.
This greatly increases the range of motion of the glenohumeral joint.



Mobility of the arm is greatly increased by such movements of the scapula. For example, consider abduction of the arm with the scapula fixed (left) vs. the scapula rotated (below).



The free movement of the scapula is aided by the presence of some fatty layers ("gliding planes"). One is located between the serratus anterior muscle and the ribcage (see p. 121), another between the subscapularis and the serratus anterior muscles.

Humerus

This is the long bone of the upper arm.

Landmarks of the proximal end include:

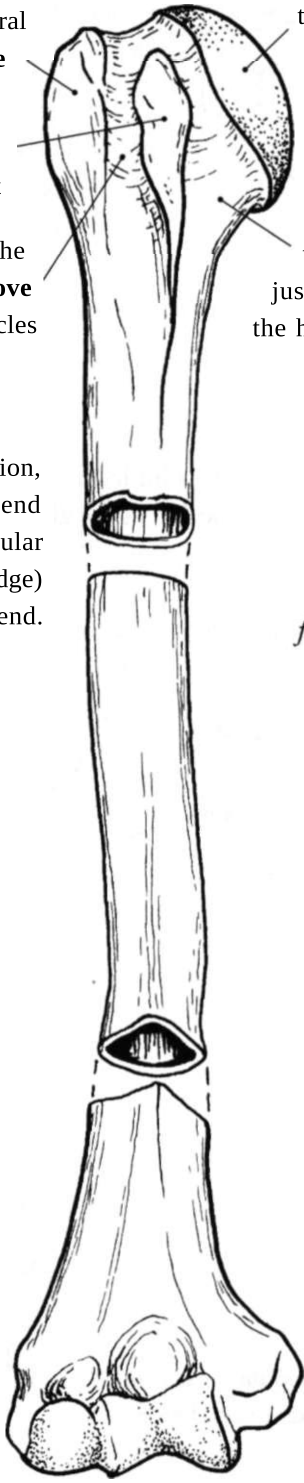
the lateral **greater tubercle**

the anterior **lesser tubercle** for muscle attachment

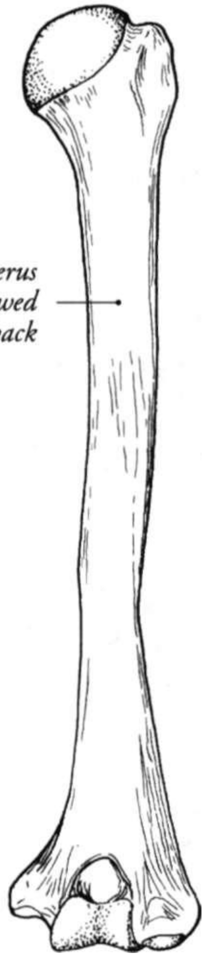
the **bicipital (intertubercular) groove** running between the rwo tubercles

the medial **head** (whose spheroid surface articulates with the glenoid cavity of the scapula)

the **anatomical neck** just below the head.

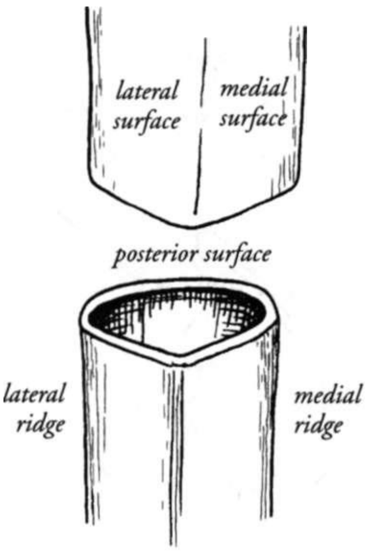


The shaft itself, in cross section, is circular near the proximal end but becomes more triangular (with a pronounced anterior ridge) near rhe distal end.



The distal end is enlarged and forms articulating surfaces for the bones of the forearm at the **elbow** joint.

The triangular shape of the humerus here allows us to distinguish three surfaces and three ridges:

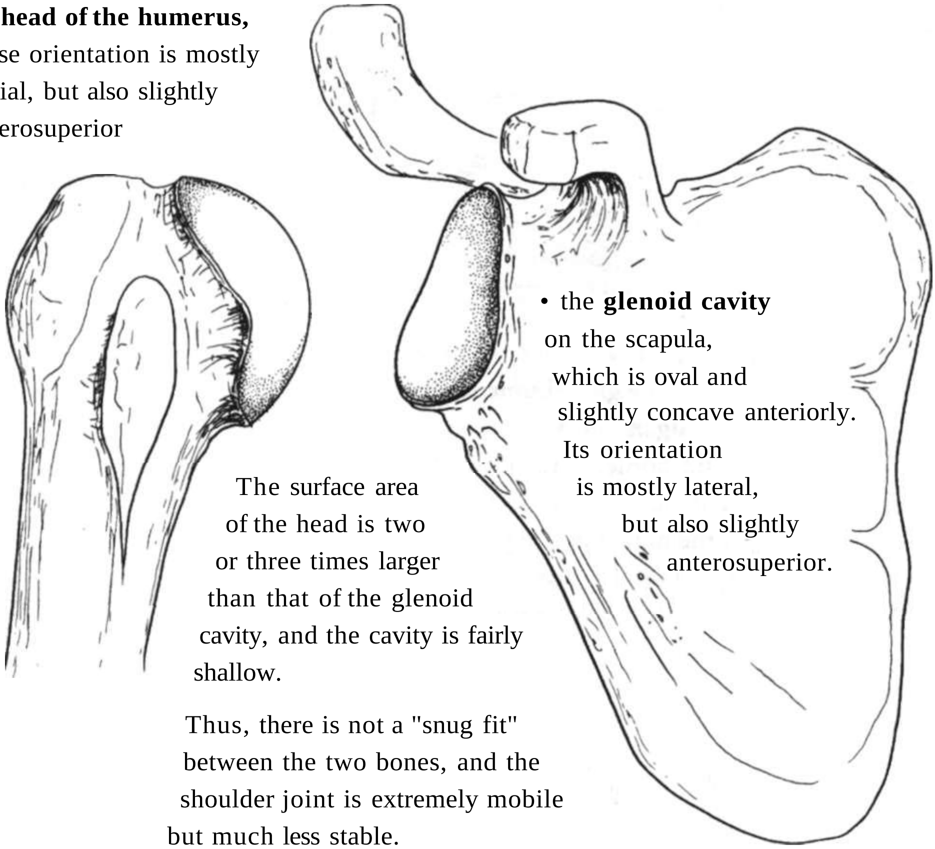


(extends the bicipital groove at top and bifurcates at bottom)

Glenohumeral joint

This is the primary joint of the shoulder, which unites the head of the humerus with the glenoid fossa of the scapula. The articular surfaces consist of:

* the **head of the humerus,** whose orientation is mostly medial, but also slightly posterosuperior

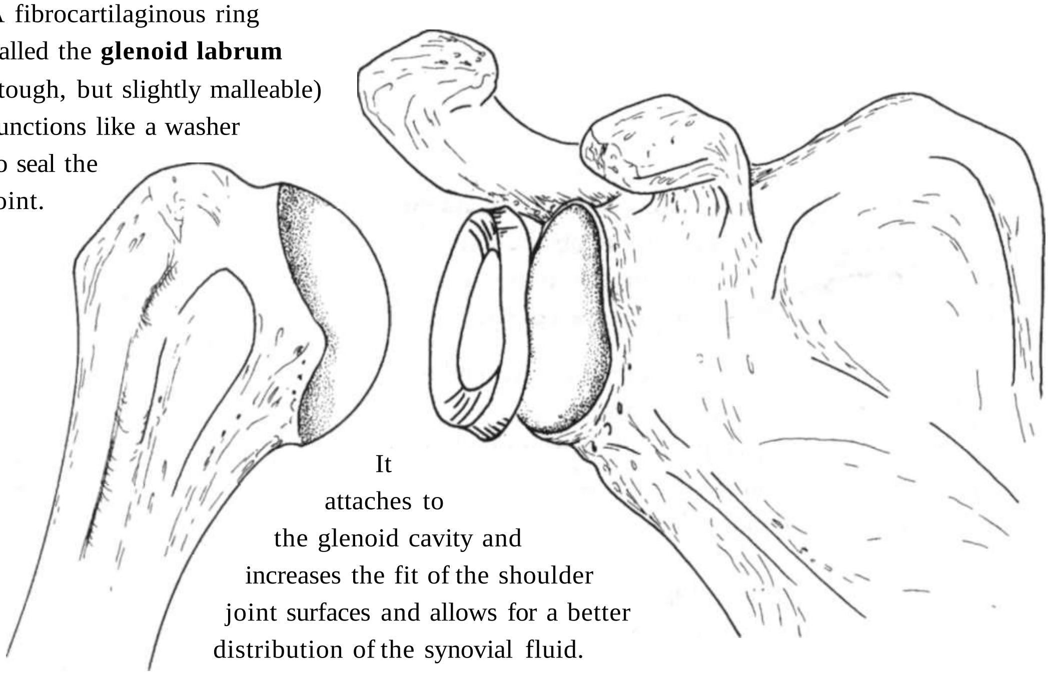


* the **glenoid cavity** on the scapula, which is oval and slightly concave anteriorly. Its orientation is mostly lateral, but also slightly anterosuperior.

The surface area of the head is two or three times larger than that of the glenoid cavity, and the cavity is fairly shallow.

Thus, there is not a "snug fit" between the two bones, and the shoulder joint is extremely mobile but much less stable.

A fibrocartilaginous ring called the **glenoid labrum** (tough, but slightly malleable) functions like a washer to seal the joint.



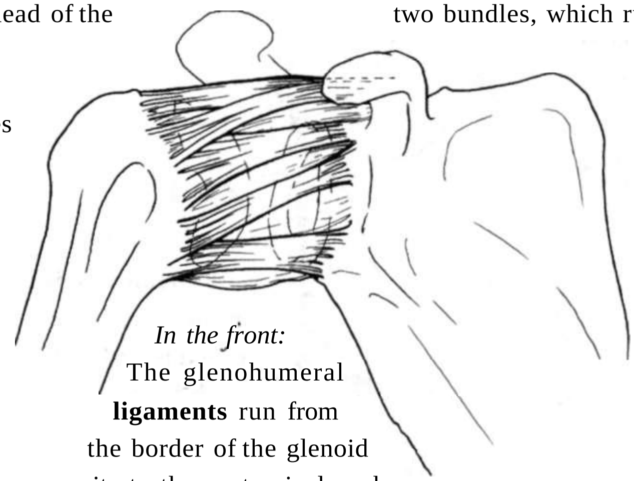
It attaches to the glenoid cavity and increases the fit of the shoulder joint surfaces and allows for a better distribution of the synovial fluid.

The capsule of the glenohumeral joint attaches to the scapula, on the outer rim of the glenoid cavity.

This capsule is reinforced at the top and front by ligaments.

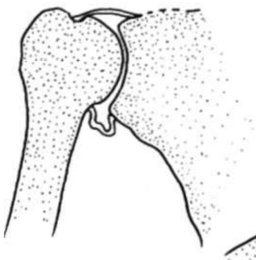
Anterosuperiorly, it goes all the way up to the coracoid process, and encircles the origin of the long head of the biceps at its origin.

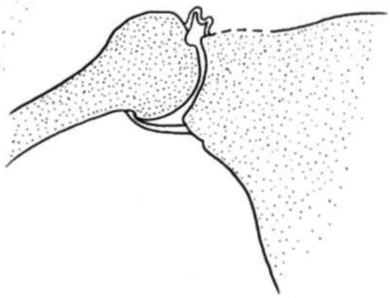
At the top: The **coracohumeral ligament** runs from the coracoid process and forms two bundles, which run to the greater and lesser tubercle of the humerus. This is the strongest ligament of this joint.



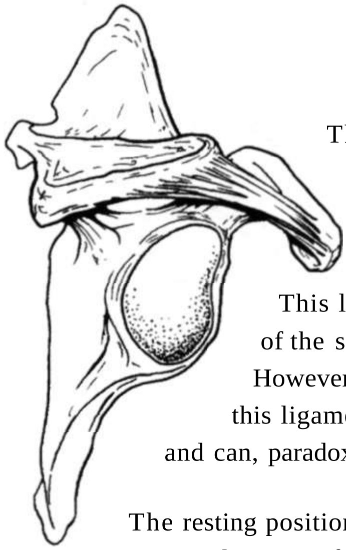
The capsule attaches around the head of the humerus. It has many folds, especially in its inferior portion, which gives it a good range of motion for anterior flexion and abduction.

In the front: The glenohumeral **ligaments** run from the border of the glenoid cavity to the anatomical neck of the humerus. They consist of three bundles: superior, middle, and inferior. There are weak areas between these ligaments.





In summary, the capsuloligamentary structure of the shouldet is not very strong. The glenohumeral part of the shoulder is stabilized especially by the deepest muscles, which fotm a cuff of "active ligaments" around the shoulder, called the rotator cuff (see p. 126-128).



The **coracoacromial ligament** stretches across the scapula and attaches to the acromion and the caracoid process.

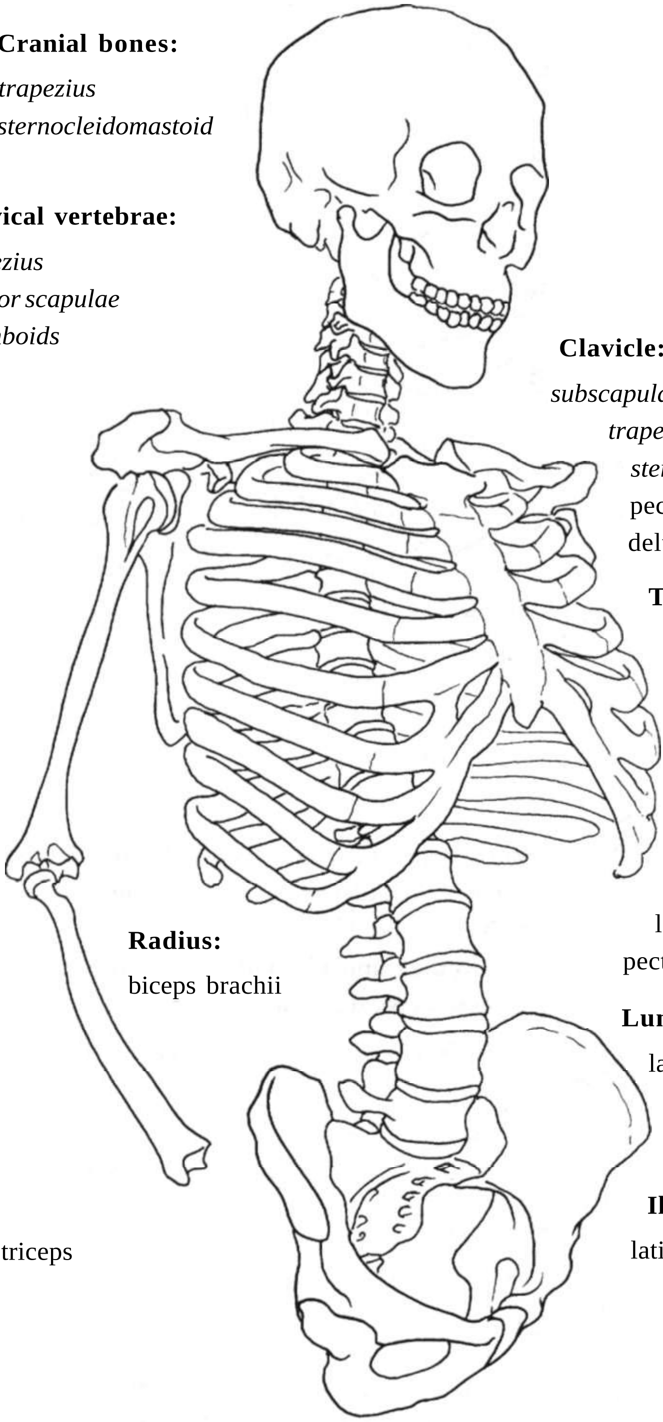
This ligament protects the tendon of the supraspinatus. However, if the humerus is lifted too much, this ligament can rub against the tendon and can, paradoxically, cause it to wear out.

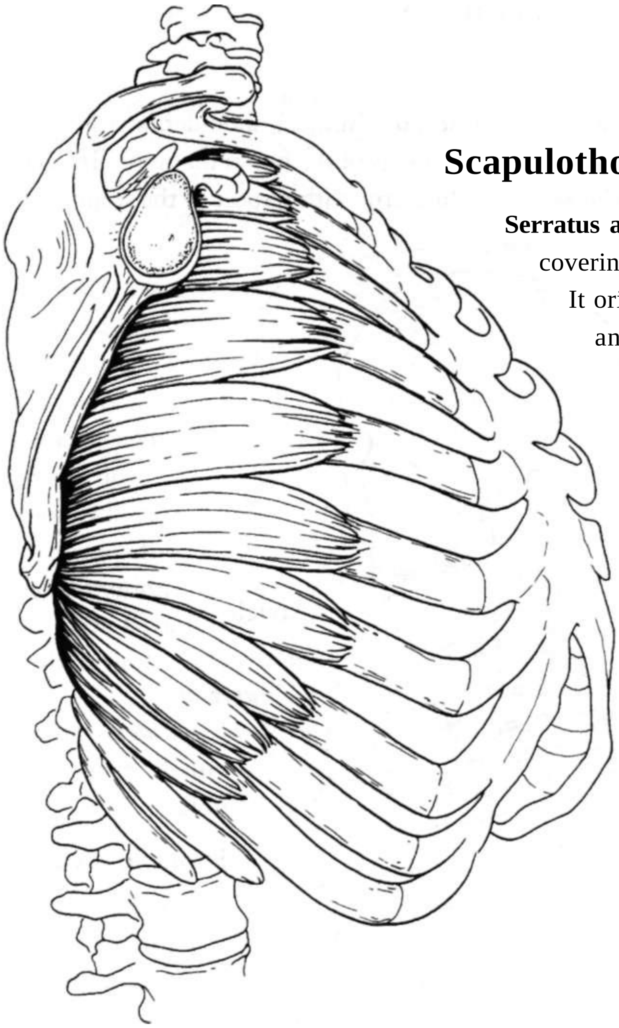
The resting position of the joint (i.e., allowing maximal relaxation of the ligaments) is where the arm is in slight flexion, abduction, and internal rotation.

Shoulder muscles with bony attachments

These bones are grouped into two categories:

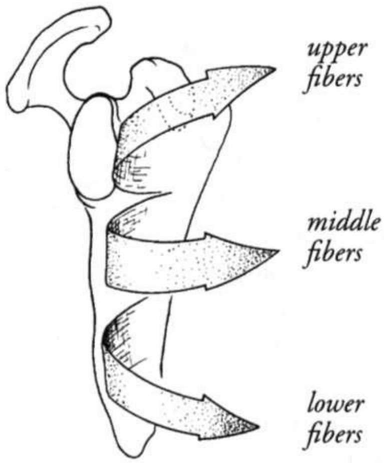
- scapulo-thoracic shoulder, which consists of the bones that mobilize the scapula and clavicle with respect to the thorax *(italicized)*
- scapulo-humeral shoulder, which consists of the bones that mobilize the humerus with respect to the scapula.

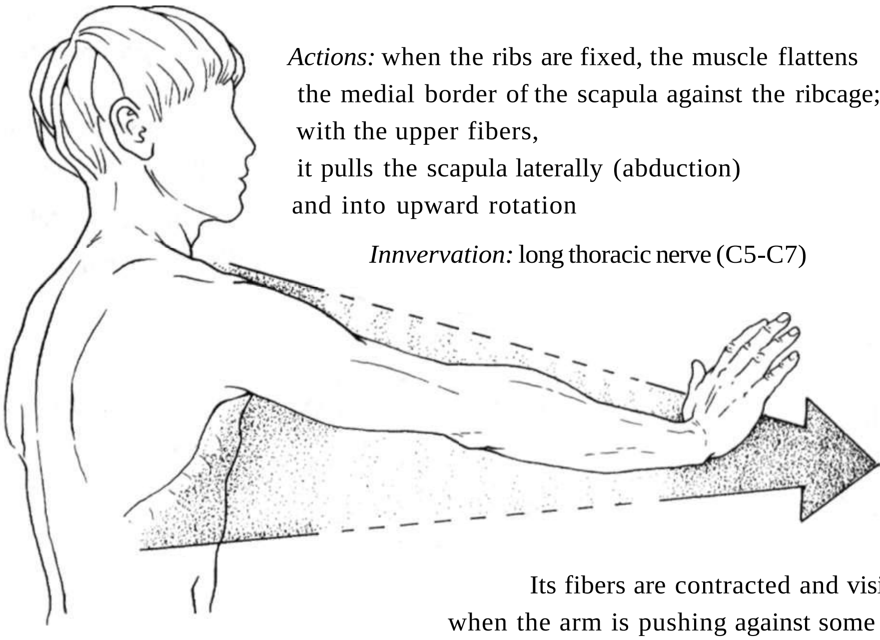




Scapulothoracic muscles

Serratus anterior is a broad, thin muscle covering the lateral ribcage. It originates from the upper ten ribs, and inserts along the entire medial border of the scapula.

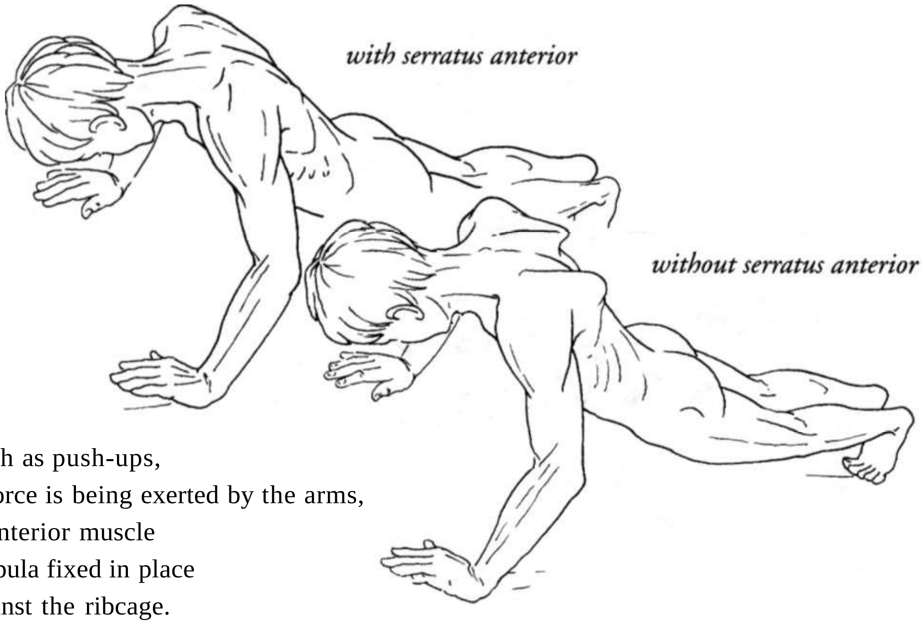




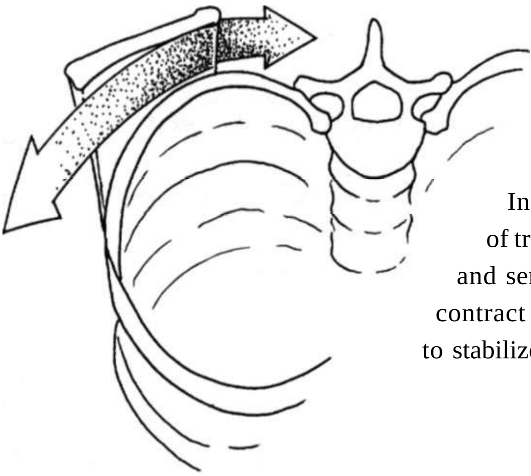
Actions: when the ribs are fixed, the muscle flattens the medial border of the scapula against the ribcage; with the upper fibers, it pulls the scapula laterally (abduction) and into upward rotation

Innvervation: long thoracic nerve (C5-C7)

Its fibers are contracted and visible when the arm is pushing against some resistance.



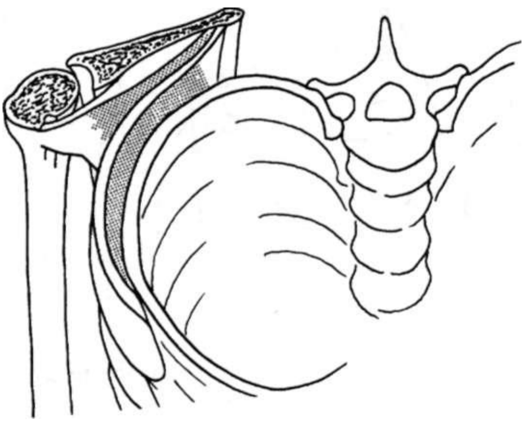
In actions such as push-ups,
where great force is being exerted by the arms,
the serratus anterior muscle
keeps the scapula fixed in place
and tight against the ribcage.



In such situations, the middle fibers
of trapezius (an adductor)
and serratus (an abductor)
contract simultaneously
to stabilize the scapula.

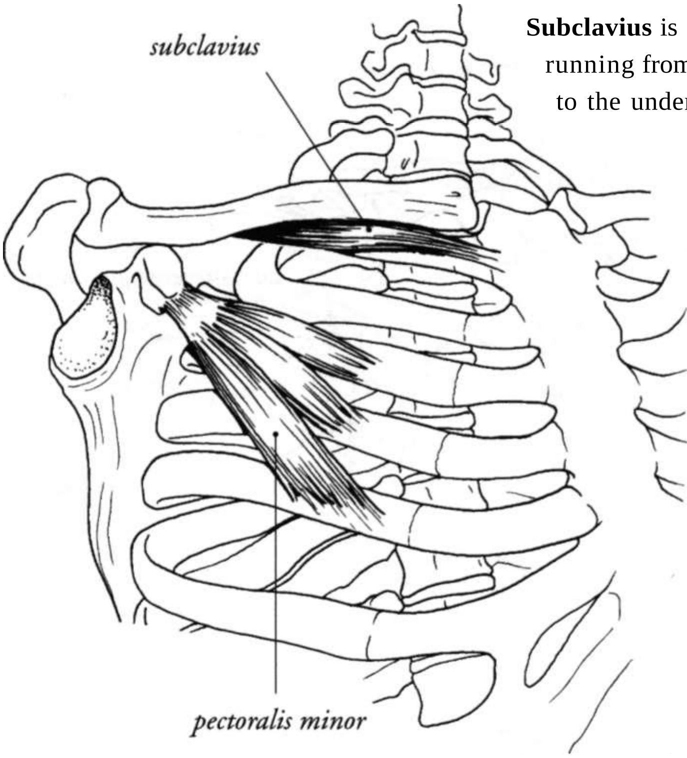
There are some fatty layers ("gliding planes")
separating serratus from the ribcage
and from the subscapularis muscle.

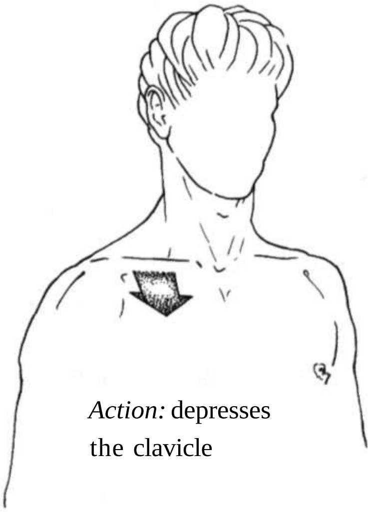
These increase the mobility of the scapula
and are important in many complex
movements of the shoulder.



If the scapula is fixed,
the lower fibers of serratus anterior
lift the middle ribs, acting as inspiratory muscles
(not shown here).

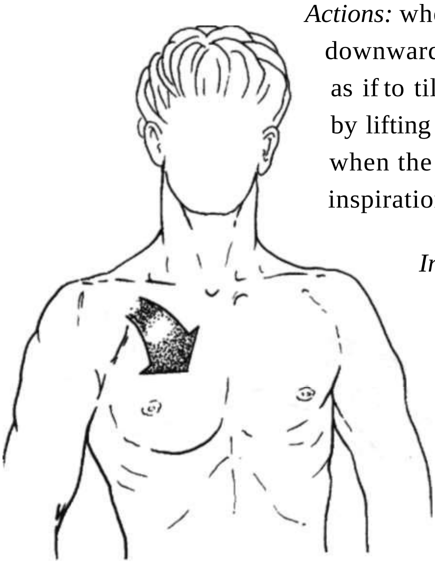
Subclavius is a small muscle running from rib 1 and its cartilage to the underside of the clavicle.





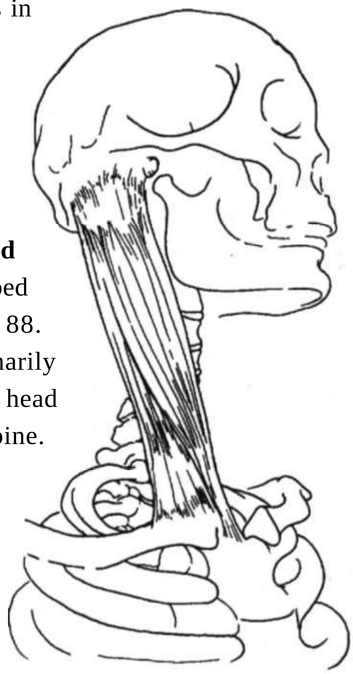
Action: depresses the clavicle

Pectoralis minor originates from ribs 3-5 and inserts on the coracoid process.



Actions: when the ribs are fixed, it pulls the scapula downward and forward, as if to tilt the scapula above the ribcage by lifting the inferior angle upward; when the scapula is fixed, it assists in inspiration by elevating the ribs

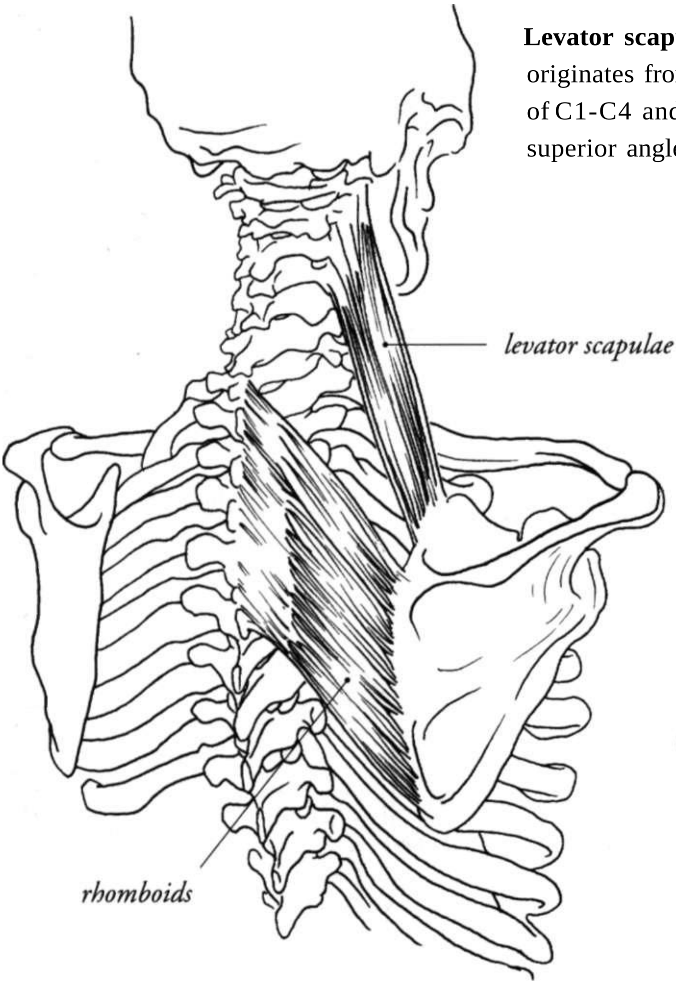
Innervation: medial pectoral nerve (C7-T1)



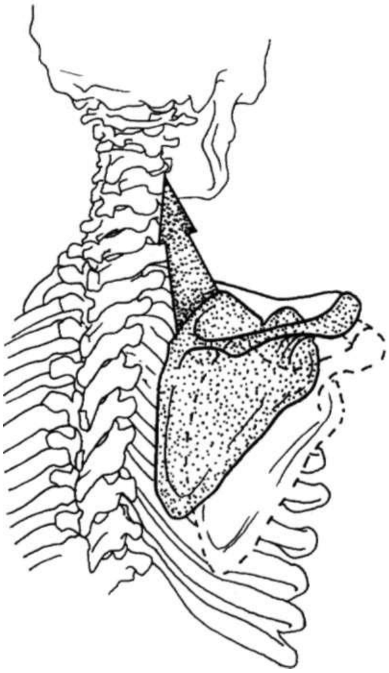
Sternocleidomastoid (SCM) is described on page 88. It acts primarily on the head and cervical spine.

If the head is fixed, however, SCM can elevate the area where the clavicle and sternum meet, and thereby assist in inspiration.

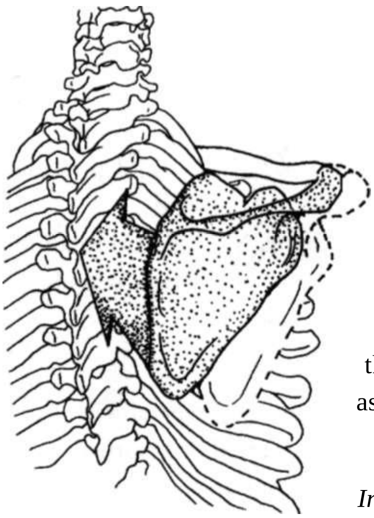
Levator scapulae
originates from the transverse processes of C1-C4 and inserts on the superior angle of the scapula.



Actions: elevates the scapula and rotates it downward; when the scapula is fixed, it acts on the cervical spine, as explained on page 81

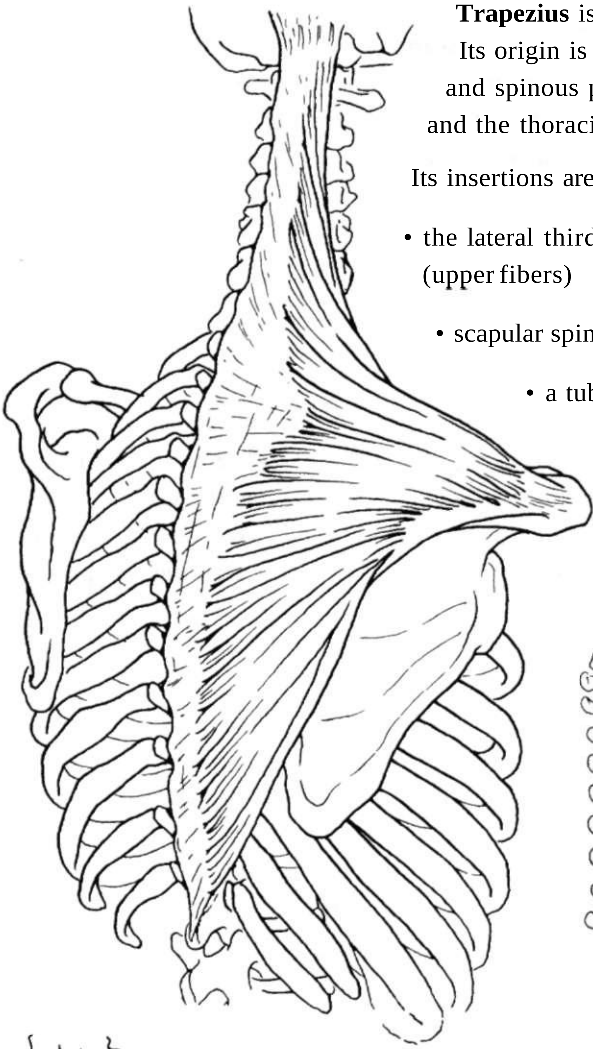


The **rhomboids** (major and minor)
originate from the spinous processes of C7 and T1-T4 and insert on the medial border of the scapula.



Actions: adduct the scapula and rotate it downward; when the scapula is fixed, they act on the thoracic spine, as explained on page 82

Innervation: dorsal scapular nerve (C4-C5)

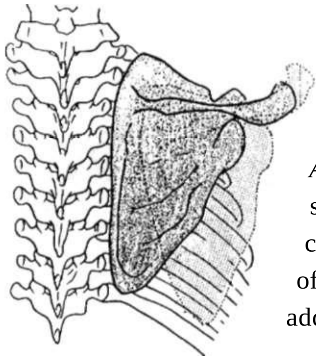


Trapezius is a large, important, diamond-shaped muscle. Its origin is on the occiput, nuchal ligament, and spinous processes of the cervical vertebrae and the thoracic vertebrae down to T12.

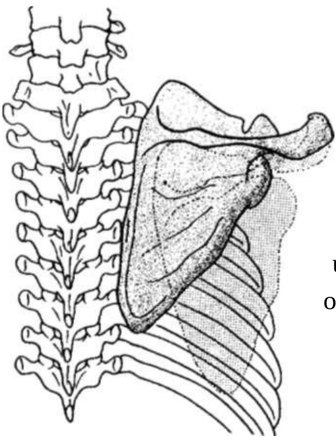
Its insertions are on:

- the lateral third of the clavicle and acromion (upper fibers)
- scapular spine (middle fibers)
- a tubercle at the medial end of the scapular spine (lower fibers).

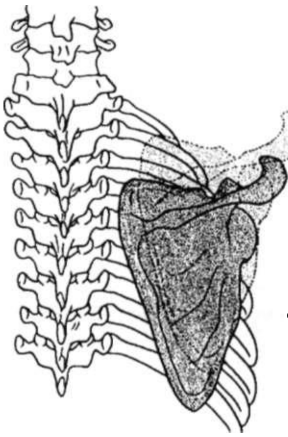
The orientation of these fibers ranges from inferolateral to superolateral.



Actions: simultaneous contraction of all the fibers adducts the scapula



The upper fibers by themselves act in elevation and upward rotation of the scapula.



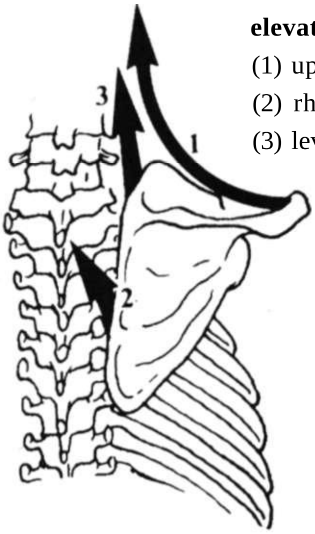
The lower fibers by themselves act in depression and upward rotation of the scapula.

Innervation: spinal accessory nerve and cervical plexus (C2-C4)

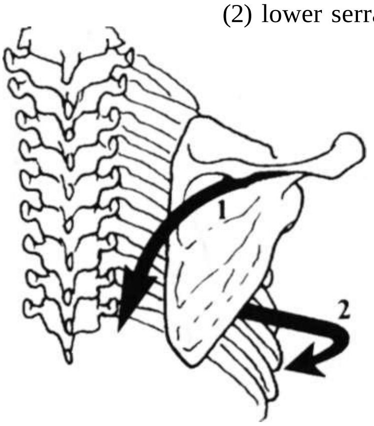
The upper fibers are frequently over-solicited in work (e.g., at a computer or typewriter) involving prolonged suspension of the arms. When force needs to be exerted or absorbed by the arm, the middle fibers of trapezius (adductor) act together with serratus anterior (abductor) to stabilize the scapula (see p. 121).

Muscles involved in specific movements of the scapula

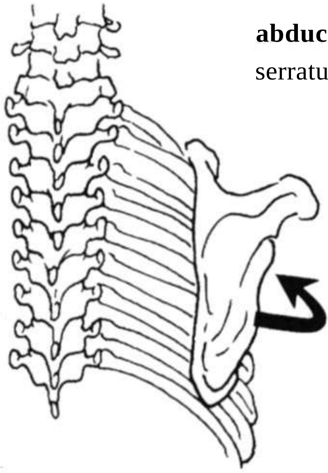
elevation:
(1) upper trapezius
(2) rhomboids
(3) levator scapulae



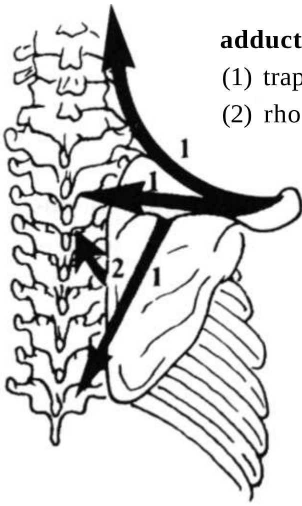
depression:
(1) lower trapezius
(2) lower serratus anterior



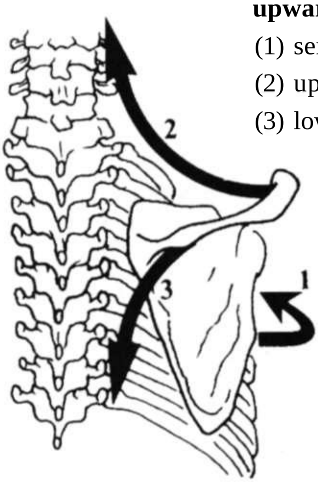
abduction:
serratus anterior



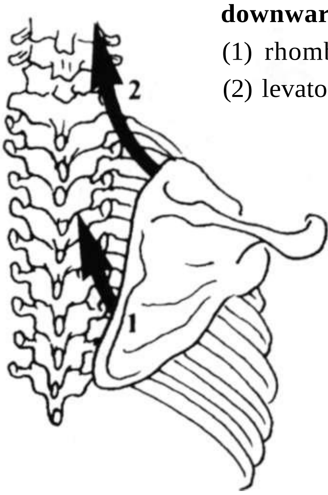
adduction:
(1) trapezius
(2) rhomboids



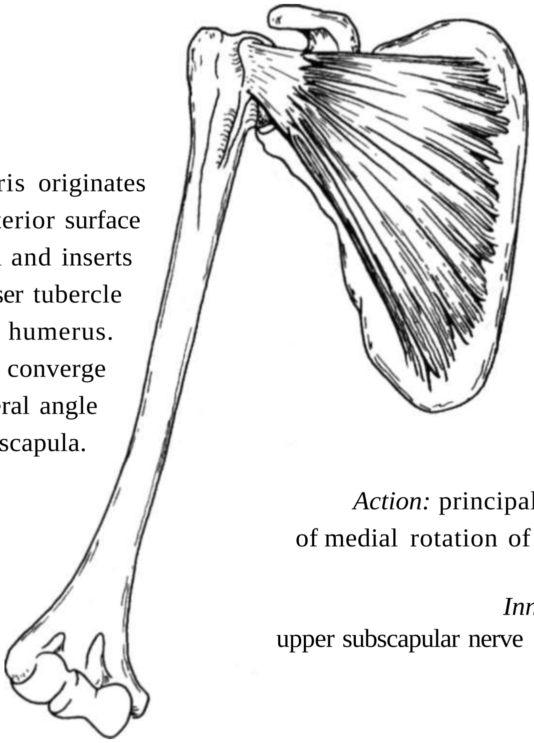
upward rotation:
(1) serratus anterior
(2) upper trapezius
(3) lower trapezius



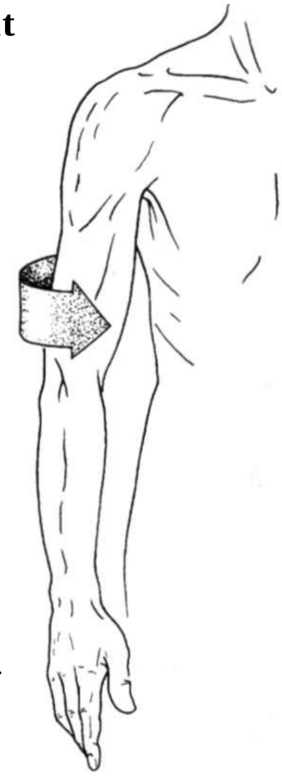
downward rotation:
(1) rhomboids
(2) levator scapulae



Deep scapulohumeral muscles of shoulder joint



Subscapularis originates from the anterior surface of the scapula and inserts on the lesser tubercle of the humerus. Its fibers converge at the lateral angle of the scapula.



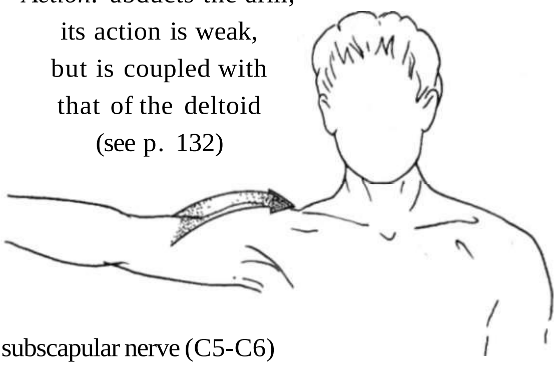
Action: principal muscle of medial rotation of the arm

Innervation: upper subscapular nerve (C5-C6)

Supraspinatus originates from the supraspinous fossa on the posterior scapula. Its tendon passes under the acromioclavicular joint and the ligament which connects the coracoid process to the acromion, and inserts on the highest point on the greater tubercle.

There is a large bursa (closed sac of synovial fluid) surrounding its tendon and separating it from the inferior surface of the acromion and deltoid muscle. This bursa acts as an auxiliary component of the glenohumeral joint. Adhesions here can restrict mobility of the shoulder.

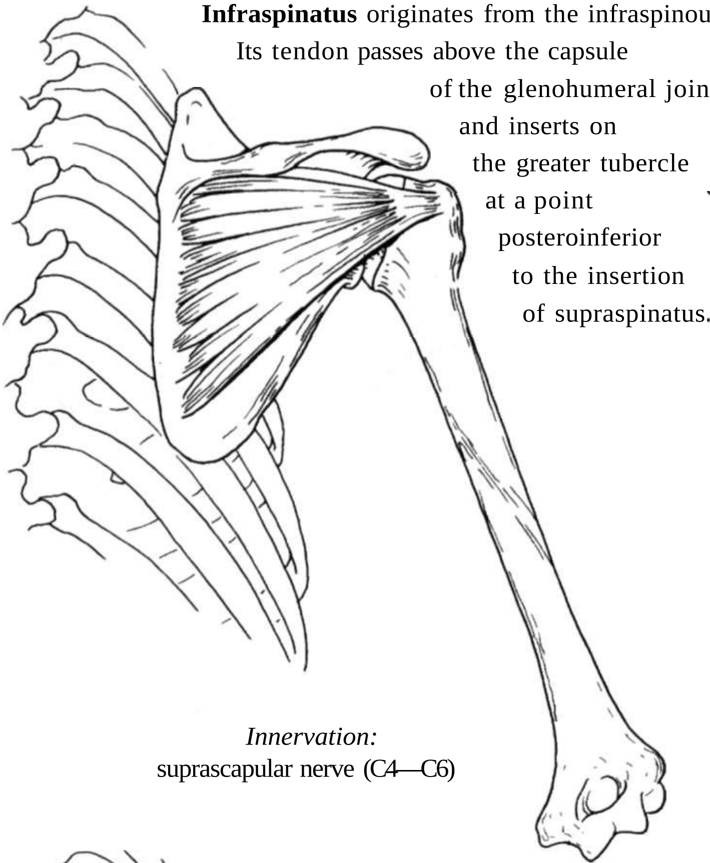
[Viewed from back and above]

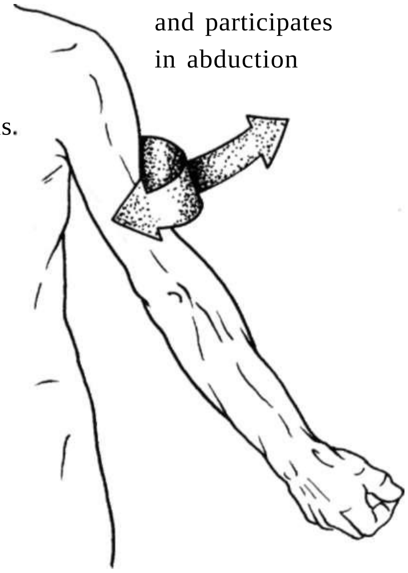


Action: abducts the arm; its action is weak, but is coupled with that of the deltoid (see p. 132)

Innervation: subscapular nerve (C5-C6)

Infraspinatus originates from the infraspinous fossa. Its tendon passes above the capsule of the glenohumeral joint and inserts on the greater tubercle at a point posteroinferior to the insertion of supraspinatus.

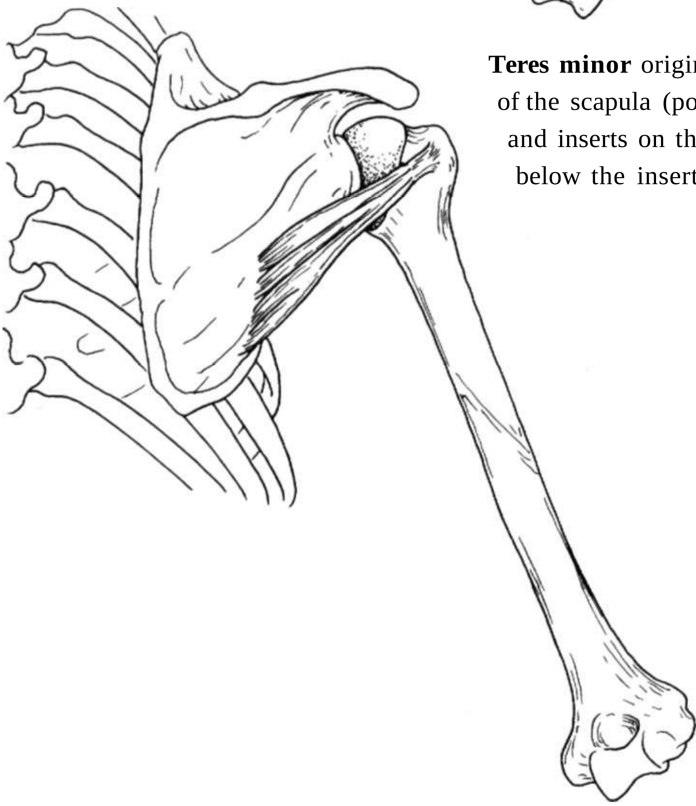


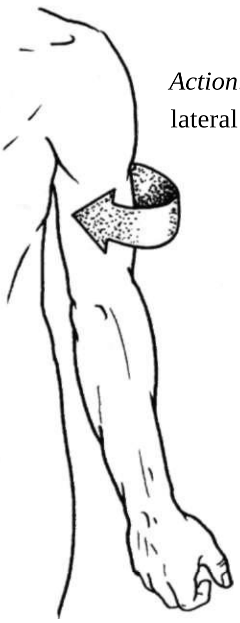


Actions: lateral rotation and participates in abduction

Innervation:
suprascapular nerve (C4—C6)

Teres minor originates from the lateral border of the scapula (posterior surface) and inserts on the greater tubercle below the insertion of infraspinatus.





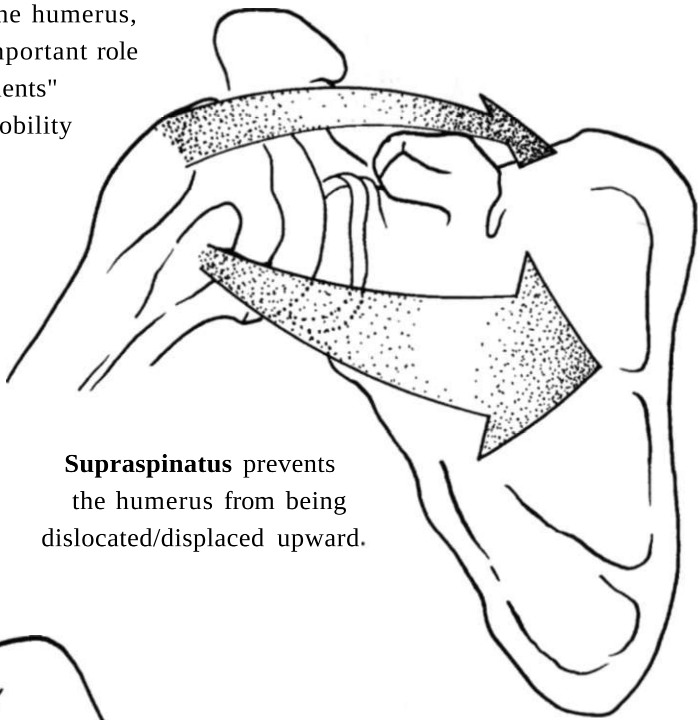
Action:
lateral rotation

Innervation:
axillary nerve (C5-C6)

Rotator cuff muscles

Collectively, these four deep muscles—subscapularis, supraspinatus, infraspinatus, and teres minor—are called the rotator cuff muscles.
Their tendons surround and reinforce the shoulder-joint capsule on three sides.

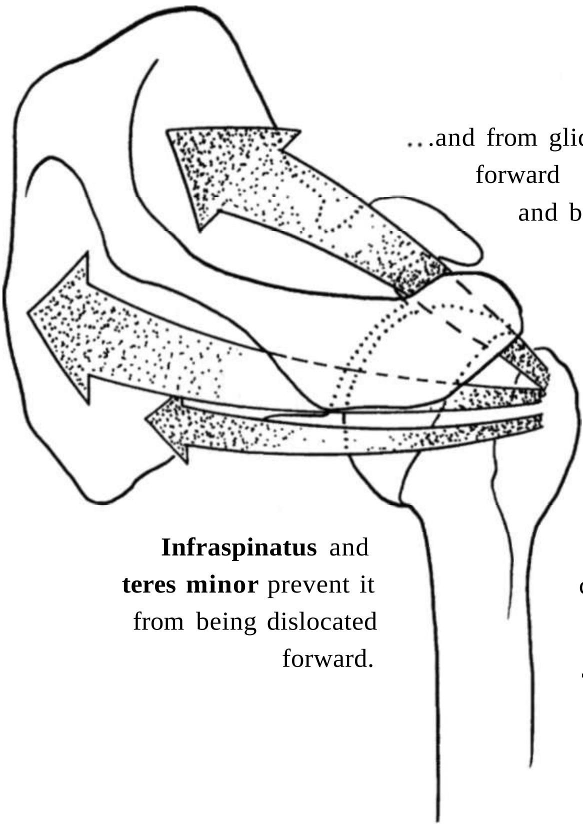
Apart from their action of mobilizing the humerus, they play an important role as "active ligaments" in providing mobility to the joint.



Supraspinatus prevents the humerus from being dislocated/displaced upward.

Subscapularis prevents the head of the humerus from gliding backward...

...and from gliding forward and backward.



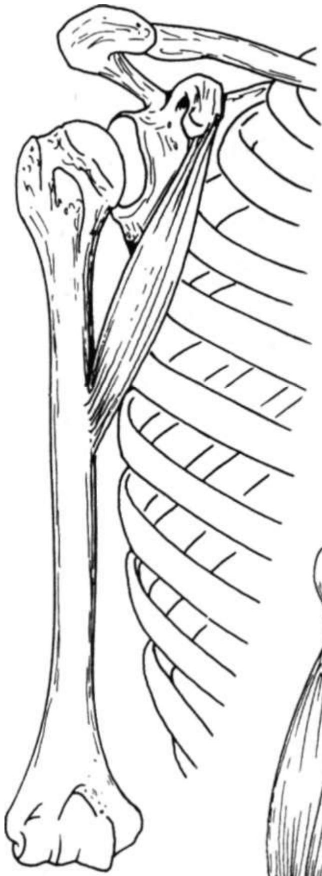
Infraspinatus and **teres minor** prevent it from being dislocated forward.

This shows that the shoulder is a joint whose bony structure and passive attachments (capsule, ligaments) are only weak stabilizing structures.

The main stabilizing force comes from the action of these periarticular muscles.

This action can be upset, which is why the shoulder is often a problem area causing joint pain.

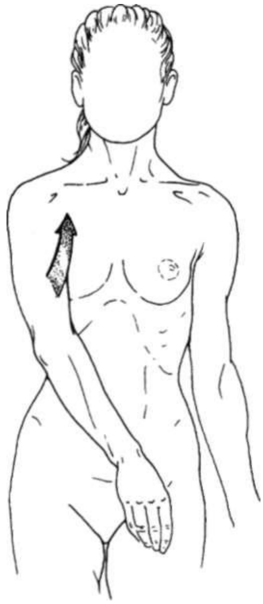
Scapulohumeral muscles of shoulder

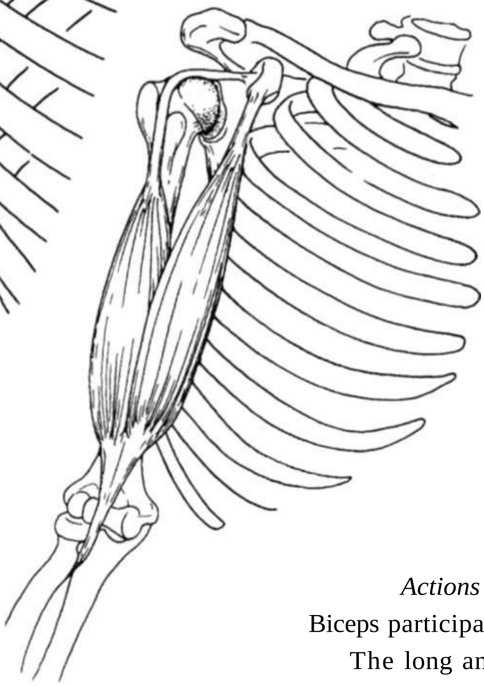


Coracobrachialis
arises from the coracoid process and inserts on the medial surface of the humeral shaft, near the middle.

Action: flexes and adducts the arm

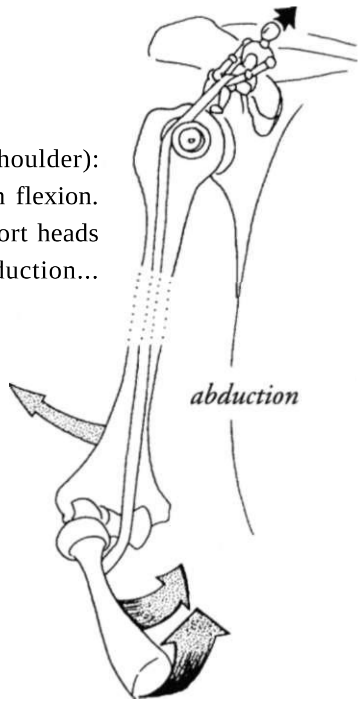
Innervation:
musculocutaneous nerve (C6-C7)

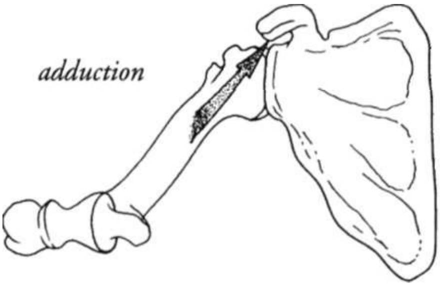




Biceps brachii is discussed on page 147 in connection with the elbow.

Actions (at shoulder):
Biceps participates in flexion.
The long and short heads are also involved in abduction...





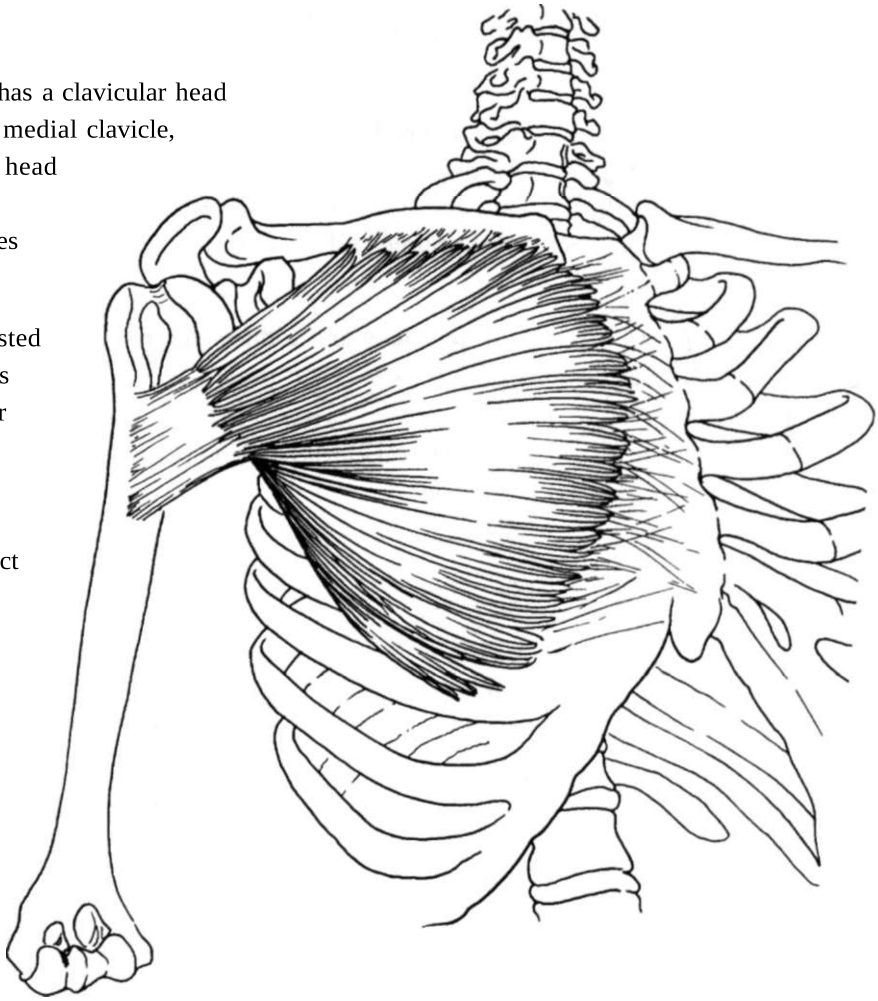
...and adduction of the arm, respectively.

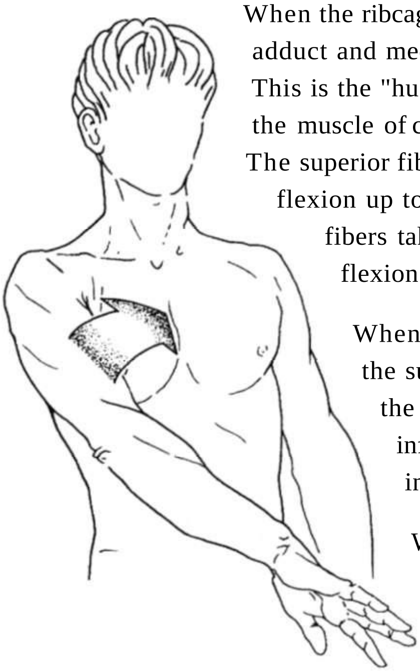
Triceps brachii is discussed on page 148 in connection with the elbow.

Action (at shoulder): participates in adduction of the arm

Pectoralis major has a clavicular head from the anterior, medial clavicle, and a sternocostal head from the sternum and costal cartilages 1-6 and rib 7.

The tendon is twisted such that the fibers from the clavicular head insert below those from the sternocostal head on the lateral aspect of the bicipital groove.

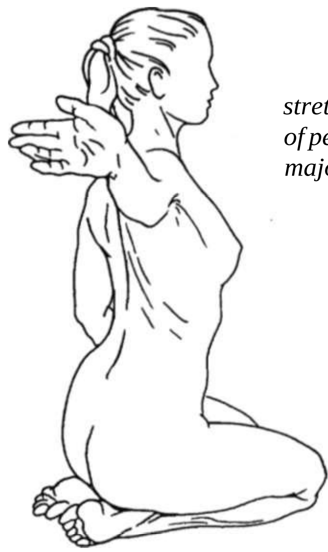




When the ribcage is fixed, all the fibers adduct and medially rotate the arm. This is the "hugging" muscle, the muscle of chest suspension. The superior fibers are involved in flexion up to 60°, then the inferior fibers take over and continue flexion up to 0° (see p. 135).

When the shoulder is fixed, the superior fibers lower the clavicle and the inferior fibers participate in inspiration.

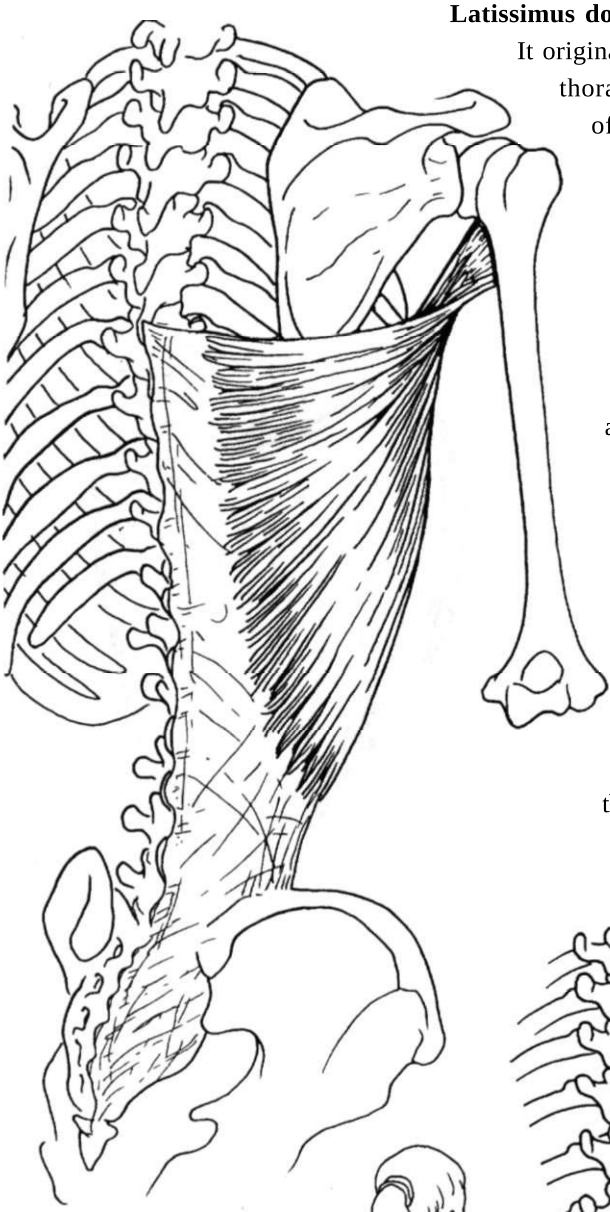
When the shoulder is fixed while the arm is flexed, all the fibers are involved in inspiration



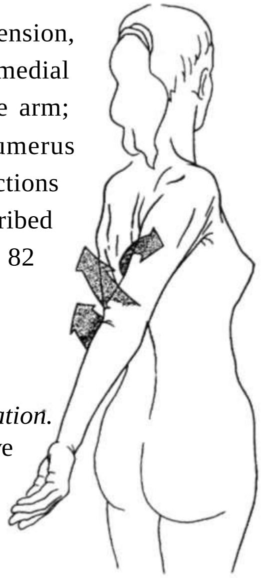
stretching of pectoralis major

Innervation: lateral and medial pectoral nerves (C5-T1)

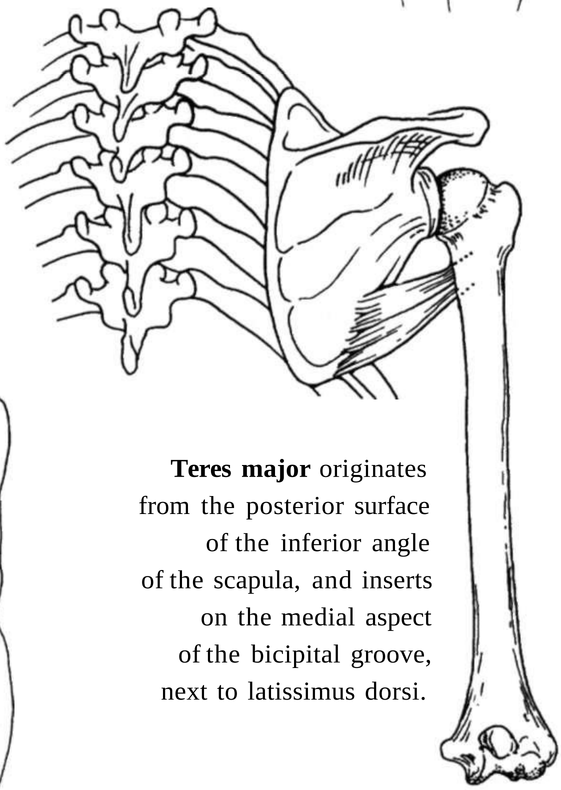
Latissimus dorsi means "widest back muscle." It originates from the sacral and iliac crests, thoracolumbar fascia, spinous processes of T7-T12, and posterior surfaces of the four lower ribs. The tendon wraps around the medial side of the humerus, makes a twist, and inserts on the bicipital groove.



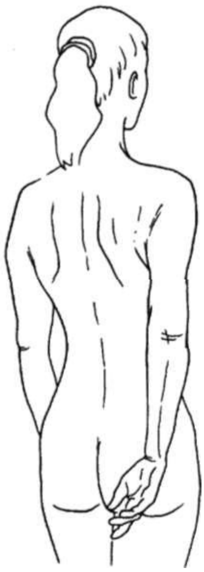
Actions: extension, adduction, and medial rotation of the arm; if the humerus is fixed, its actions are as described on page 82



Innervation. thoracodorsal nerve (C6-C8)



Teres major originates from the posterior surface of the inferior angle of the scapula, and inserts on the medial aspect of the bicipital groove, next to latissimus dorsi.



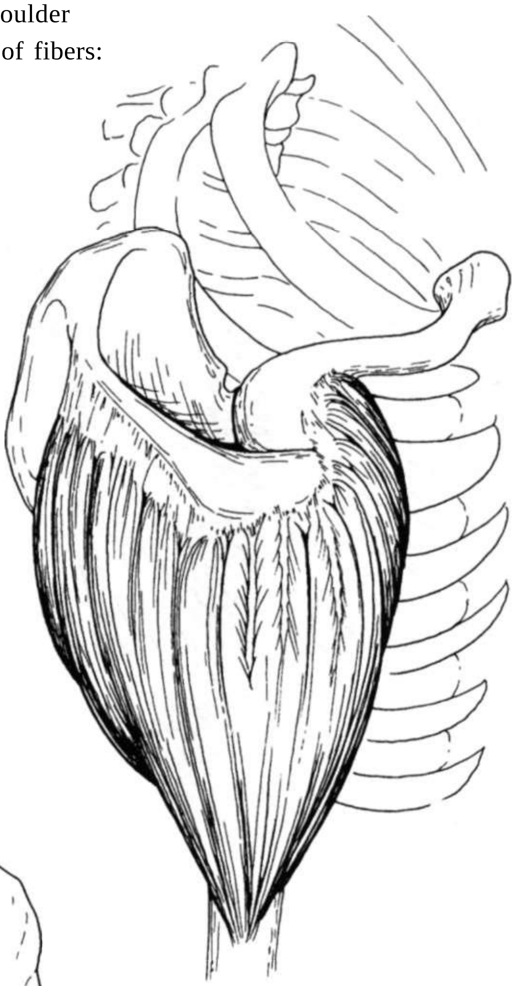
Actions: same as latissimus dorsi, but much less powerful

Innervation: lower subscapular nerve (C6-C7)

Deltoid is a superficial muscle which gives the shoulder its characteristic shape. It consists of three groups of fibers:

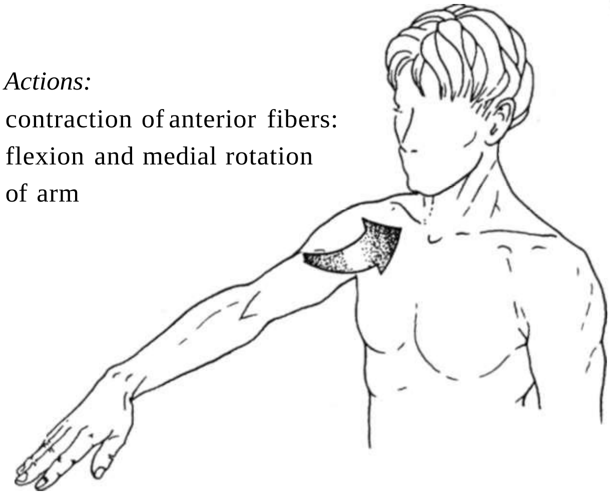
- The middle fibers attach to the lateral border of the acromion.
- The posterior fibers attach to the spine of the scapula (inferior portion of the posterior border).
- The anterior fibers attach to the clavicles (lateral third of the anterior scapular border).

These three groups of fibers converge toward the middle of the arm and insert on the lateral surface of the humerus.

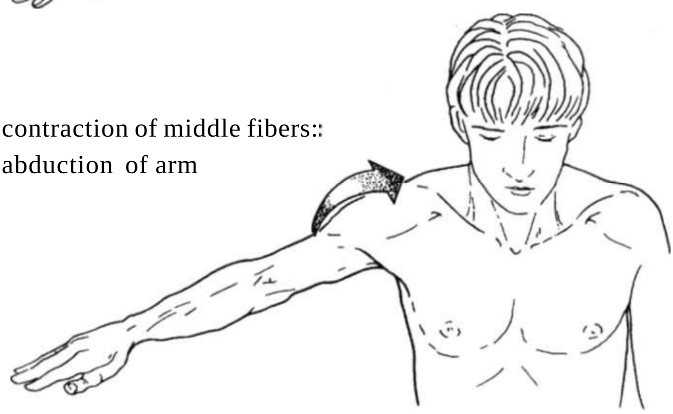


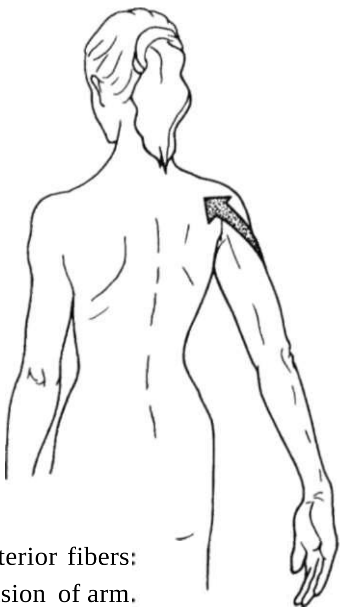
Innervation: axillary nerve (C5-C6)

Actions:
contraction of anterior fibers: flexion and medial rotation of arm



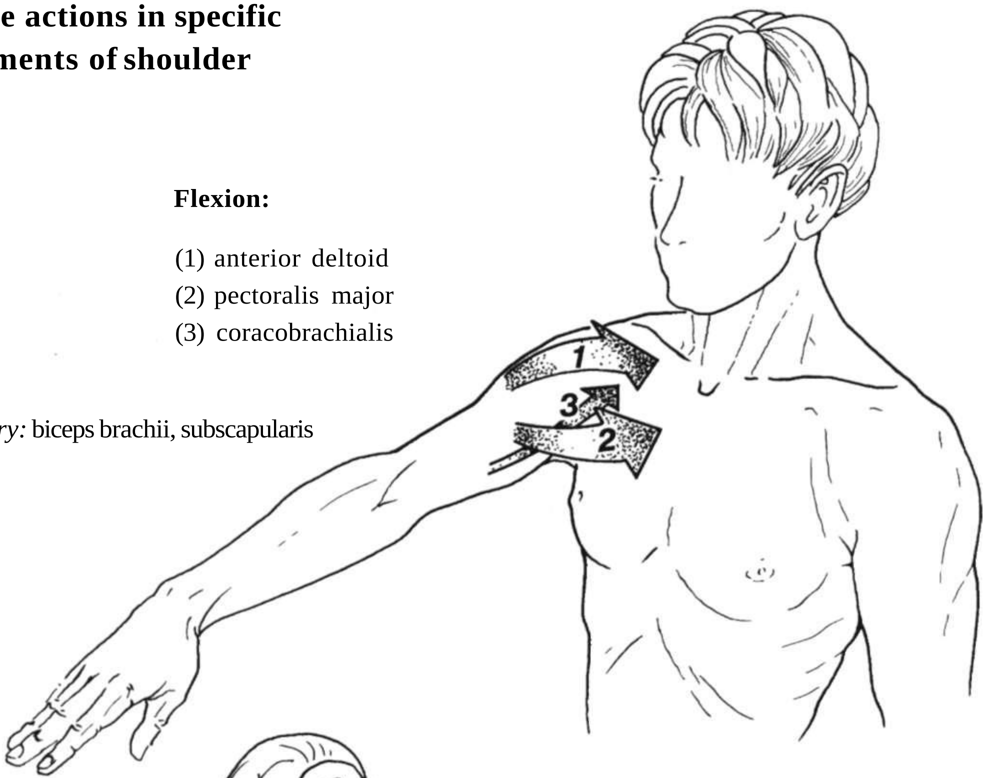
contraction of middle fibers:: abduction of arm





contraction of posterior fibers: extension of arm.

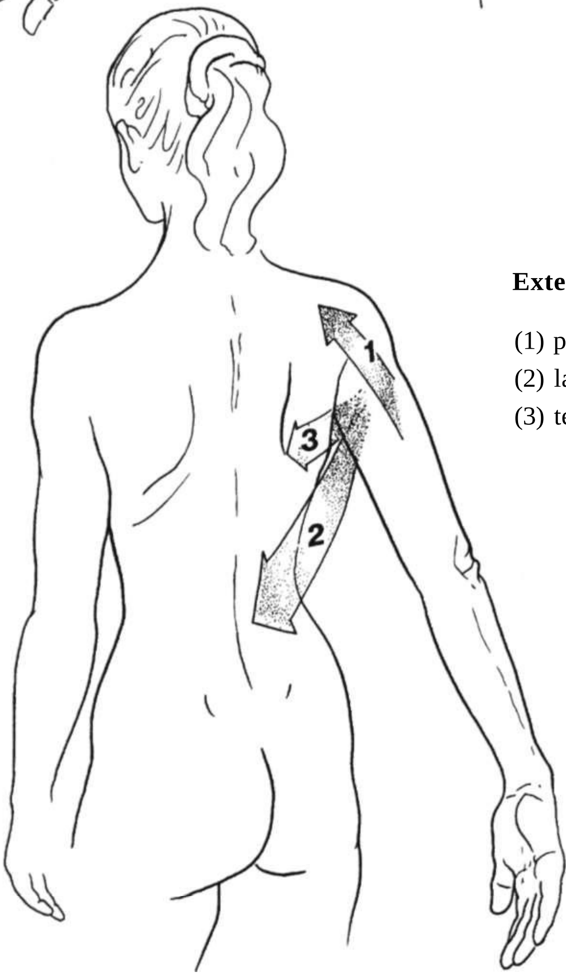
Muscle actions in specific movements of shoulder



Flexion:

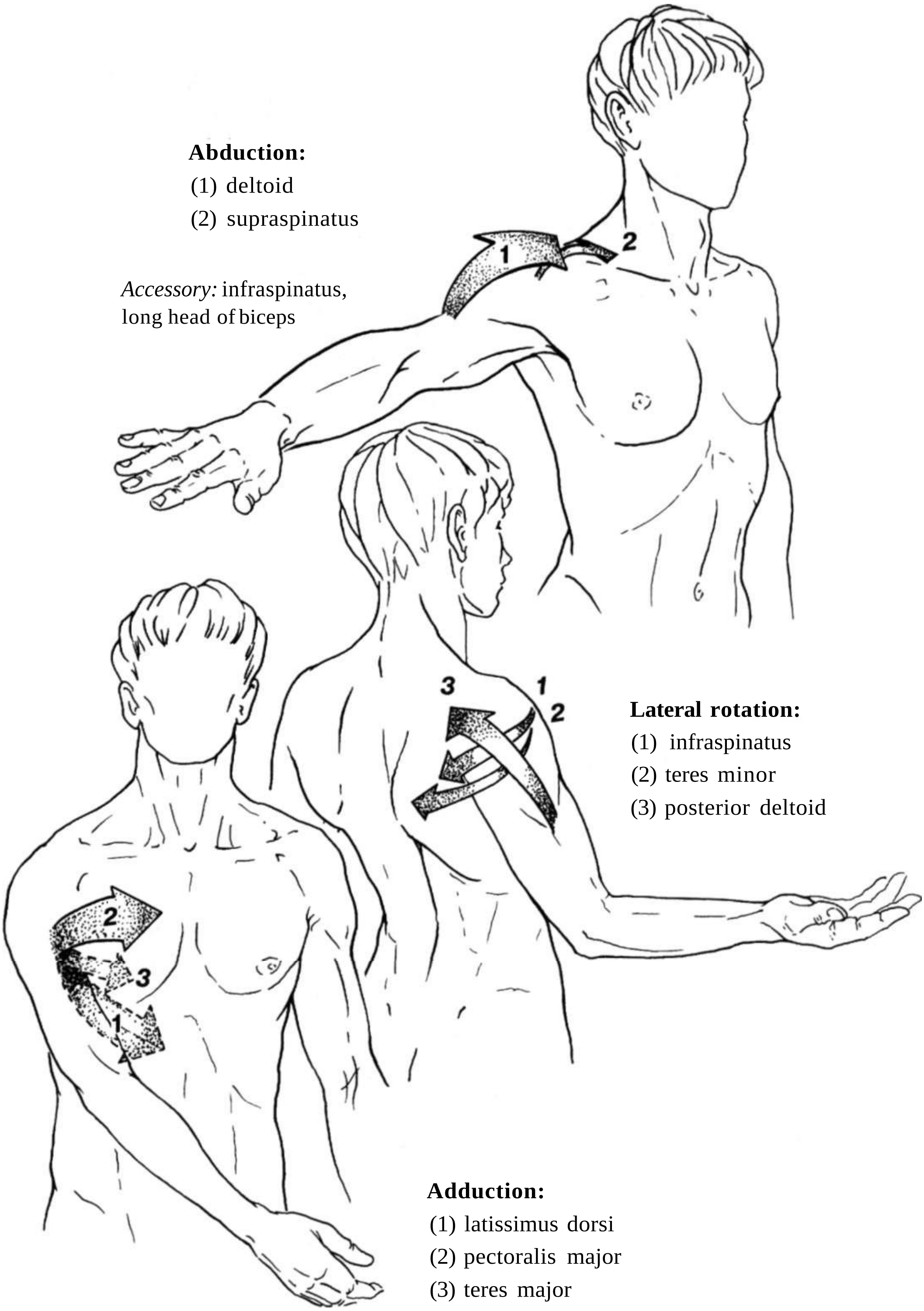
(1) anterior deltoid
(2) pectoralis major
(3) coracobrachialis

Accessory: biceps brachii, subscapularis



Extension:

(1) posterior deltoid
(2) latissimus dorsi
(3) teres major



Abduction:
(1) deltoid
(2) supraspinatus

Accessory: infraspinatus, long head of biceps

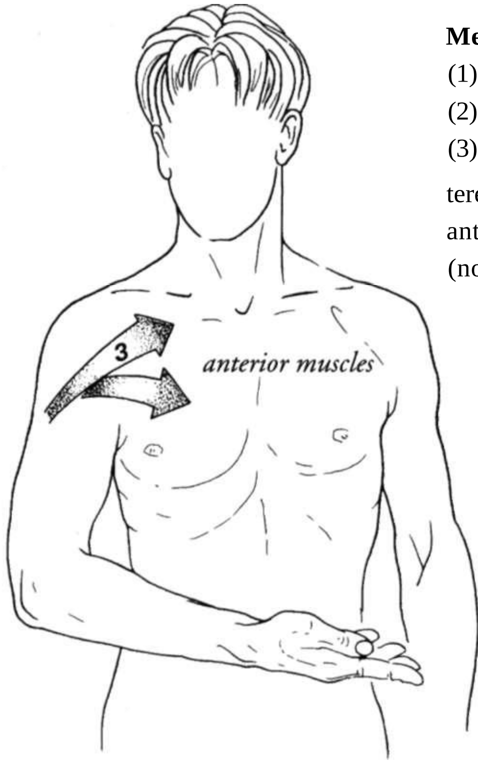
Lateral rotation:
(1) infraspinatus
(2) teres minor
(3) posterior deltoid

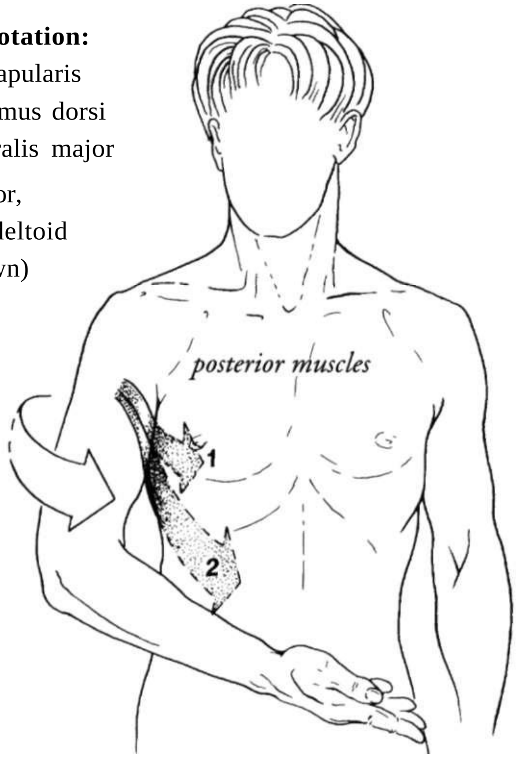
Adduction:
(1) latissimus dorsi
(2) pectoralis major
(3) teres major

Accessory: teres minor, short head of biceps, long head of triceps, coracobrachialis

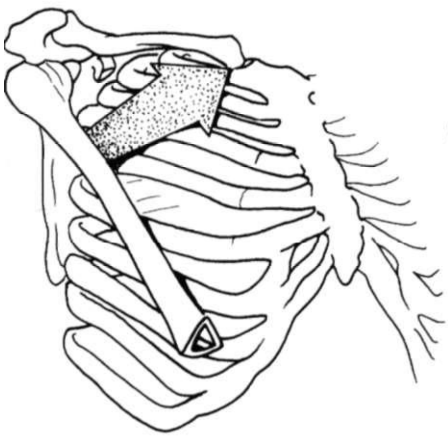
Medial rotation:
(1) subscapularis
(2) latissimus dorsi
(3) pectoralis major

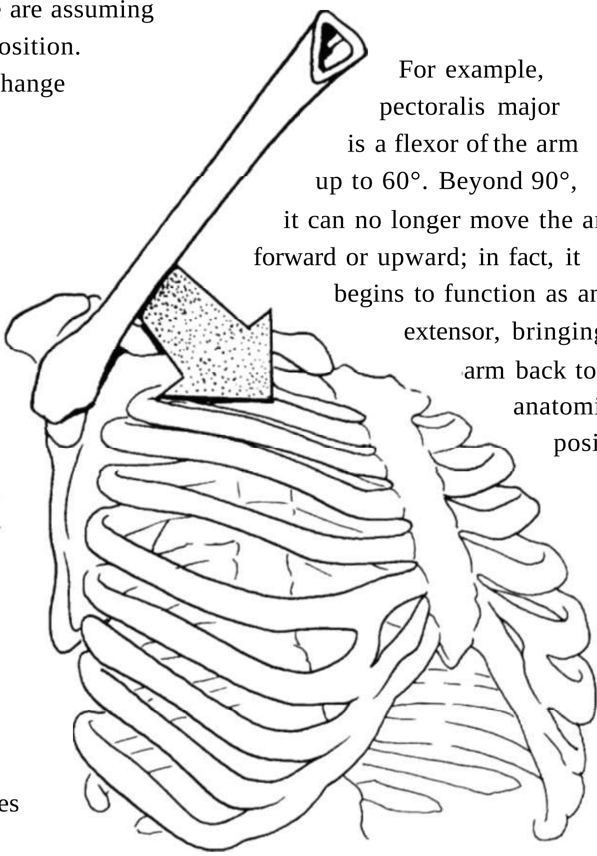
teres major,
anterior deltoid
(not shown)





In noting the muscle actions above, we are assuming that the arm starts out in anatomical position. In different positions, muscle actions change and may even be reversed.





For example, pectoralis major is a flexor of the arm up to 60°. Beyond 90°, it can no longer move the arm forward or upward; in fact, it begins to function as an extensor, bringing the arm back toward anatomical position.

We can see that the muscle actions are not equally distributed because the adductor and medial rotator muscles are predominant.

CHAPTER FOUR

The Elbow

The elbow is a joint that serves two functions:

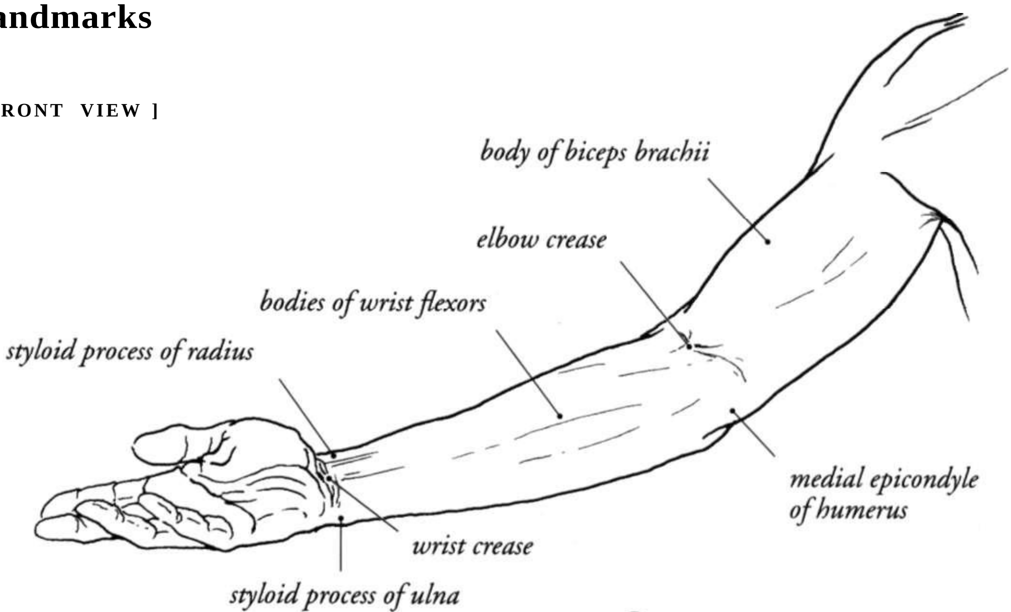
First, it allows the upper limb to fold on itself and to extend, so that the distance between the shoulder and hand can be shortened or lengthened. Through this action, you can, for example, flex your elbow to lift your hand to your mouth, or extend your elbow to reach lower parts of your body or objects located farther away from the shoulder. This is the *flexion-extension* action of the elbow.

Second, the elbow also participates in rotating the forearm around its longitudinal axis, multiplying the possible positions of the hand. This is the *pronation-supination* action of the elbow.

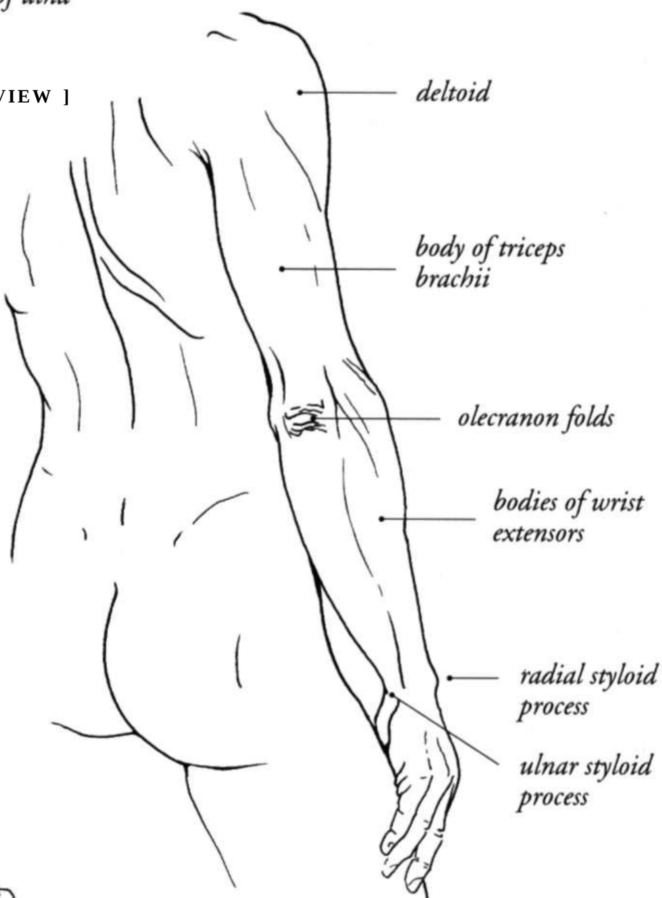
This chapter is accordingly organized into two parts, considering each function in turn.

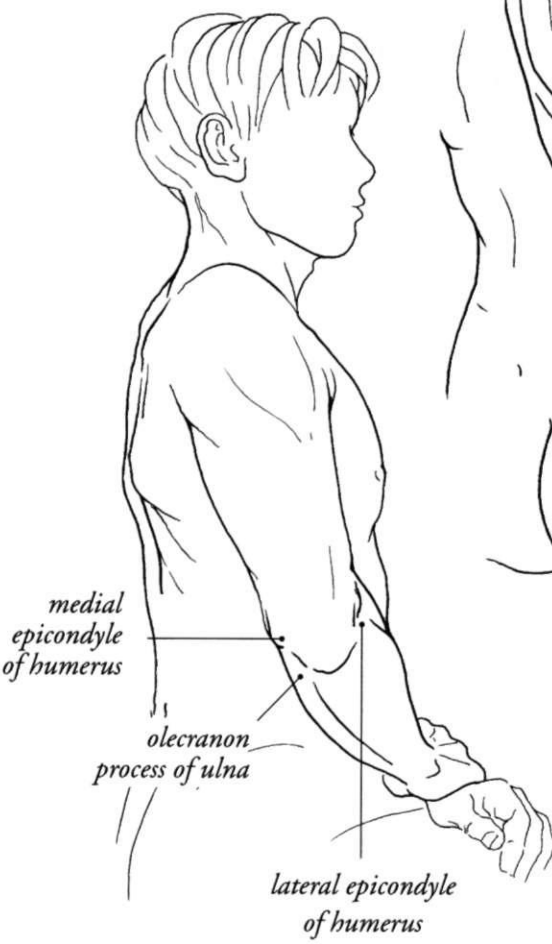
Landmarks

[FRONT VIEW]



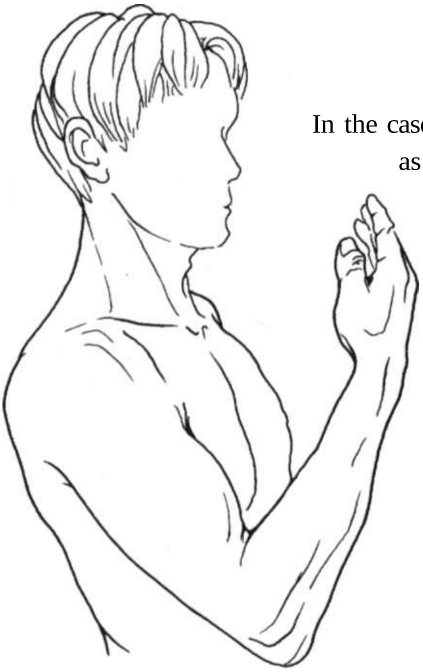
[BACK VIEW]





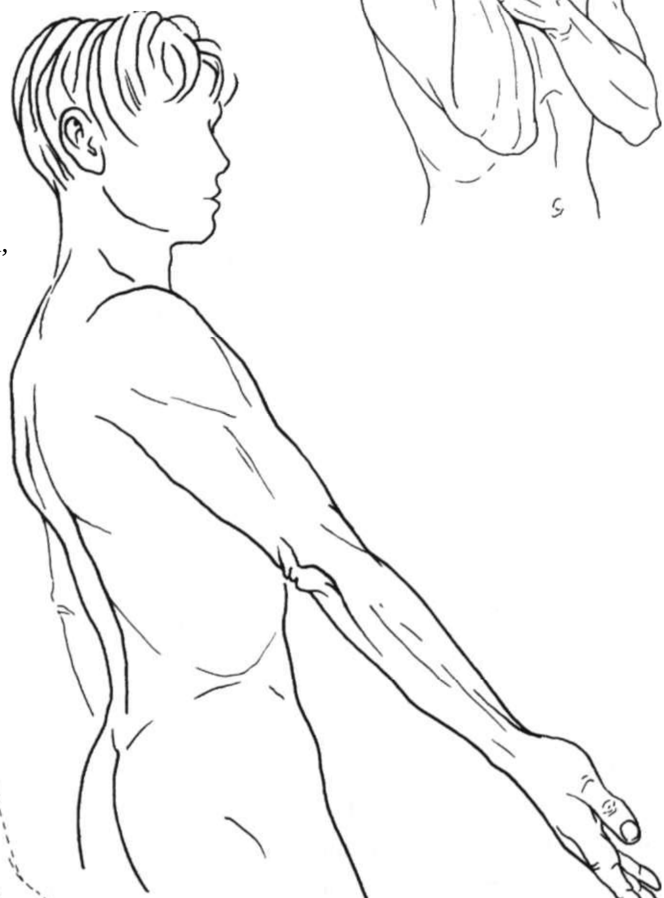
[BACK VIEW, ELBOW FLEXED]

Flexion/extension of the elbow

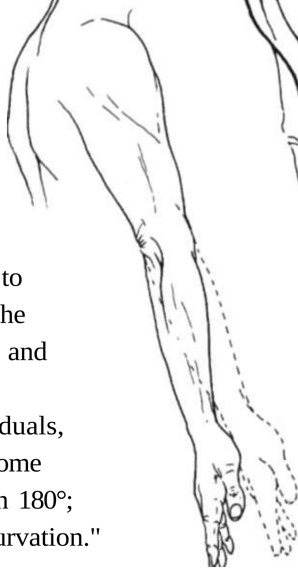


In the case of the elbow joint, **flexion** can be defined as a movement that decreases the angle between the anterior surfaces of the arm and forearm.

In active flexion, the movement is limited by contact between the bodies of the muscles involved. In passive flexion, the angle may become slightly smaller since the muscles are more compressible.



Extension of the elbow is a return from flexion to anatomical position, i.e., an increase in the angle between the arm and forearm.



Generally, increase of the angle past 180° is impossible due to contact between the olecranon process and its fossa. In a few exceptional individuals, the angle can become slightly larger than 180°; this is called "recurvation."

Radius and ulna

RADIUS ULNA

The forearm consists of two bones: the radius and the ulna.

These are long bones, each of which has three parts: a shaft and two ends or extremities.

The bones are triangular shaped and therefore have three surfaces and three edges.

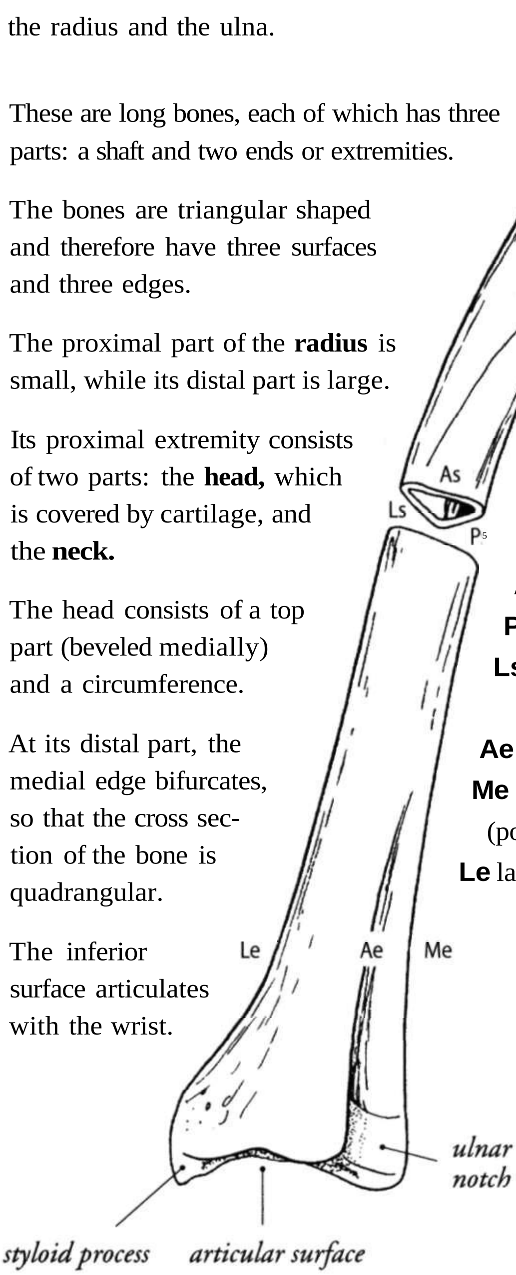
The proximal part of the **radius** is small, while its distal part is large.

Its proximal extremity consists of two parts: the **head,** which is covered by cartilage, and the **neck.**

The head consists of a top part (beveled medially) and a circumference.

At its distal part, the medial edge bifurcates, so that the cross section of the bone is quadrangular.

The inferior surface articulates with the wrist.

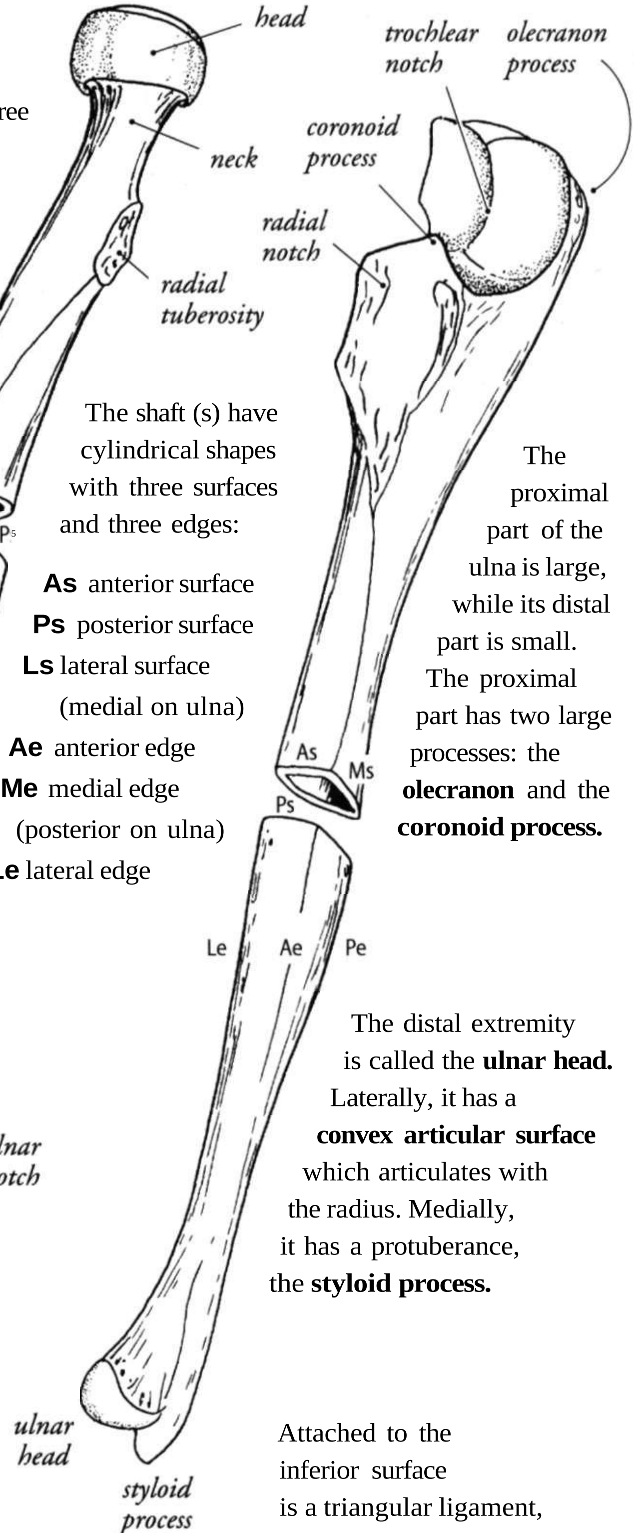


Its bifurcation has a concave articular surface which articulates with the ulna. This is the **ulnar notch** of the radius.

There is another protuberance at the lateral distal end of the radius: the **styloid process.**

The shaft (s) have cylindrical shapes with three surfaces and three edges:

As anterior surface
Ps posterior surface
Ls lateral surface (medial on ulna)
Ae anterior edge
Me medial edge (posterior on ulna)
Le lateral edge



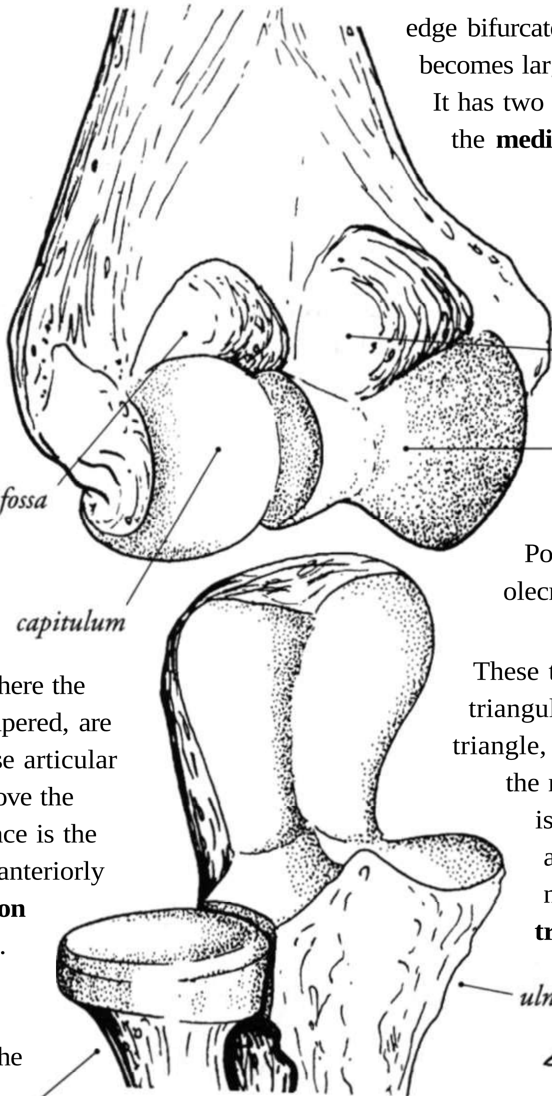
The proximal part of the ulna is large, while its distal part is small. The proximal part has two large processes: the **olecranon** and the **coronoid process.**

The distal extremity is called the **ulnar head.** Laterally, it has a **convex articular surface** which articulates with the radius. Medially, it has a protuberance, the **styloid process.**

Attached to the inferior surface is a triangular ligament, which connects the ulna to the bones of the wrist.

Bones and articulating surfaces for flexion and extension of elbow

At the distal end of the humerus the anterior edge bifurcates and the bone flattens out, becomes larger, and curves forward. It has two lateral bony projections, the **medial** and **lateral epicondyles.**

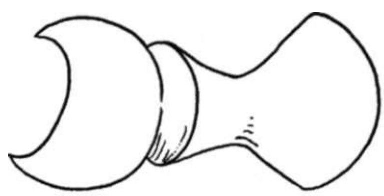


Posteriorly, there is an olecranon fossa (not shown).

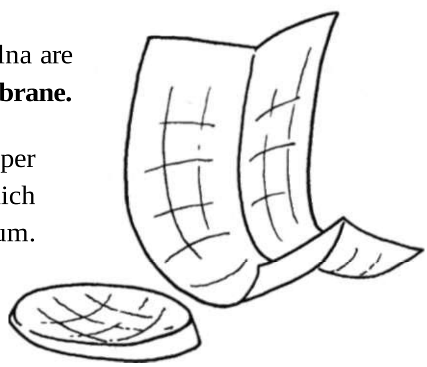
These two protuberances delimit a triangular space. At the base of this triangle, there are two articular surfaces: the medial pulley-shaped surface is oblique medioinferiorly and articulates with the trochlear notch of the ulna. This is the **trochlea of the humerus.**

Hollow areas, where the bone becomes tapered, are common on these articular surfaces. Just above the trochlear eminence is the **coronoid fossa** anteriorly and the **olecranon fossa** posteriorly. Just above the capitulum is the **radial fossa** of the humerus.

The lateral rounded surface with a diameter of about 1cm is the **capitulum.**



The surfaces between the shafts of the radius and ulna are connected via a thin layer: the **interosseous membrane.**

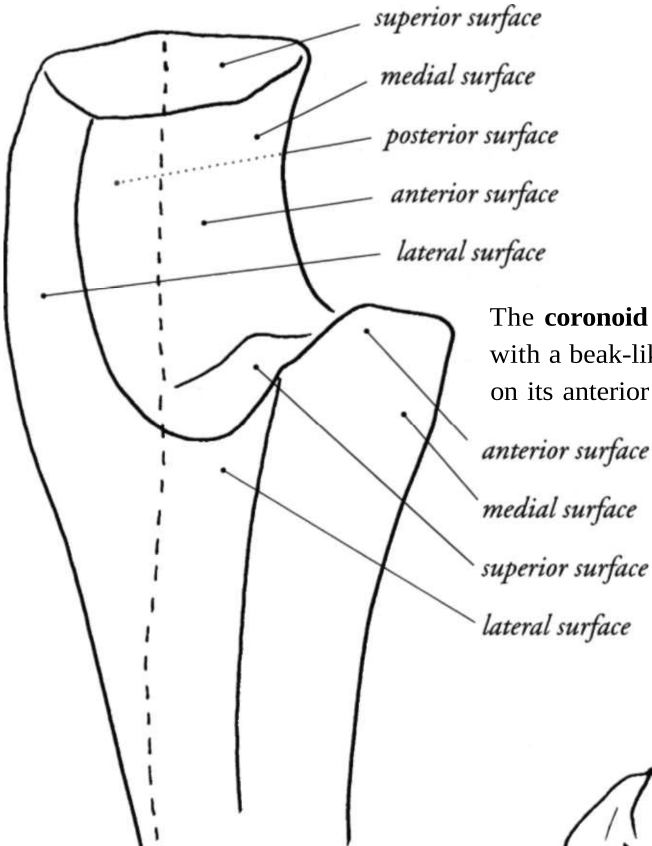


At the head of the radius, on its upper surface, is a shallow cup or **fovea** which articulates with the capitulum.

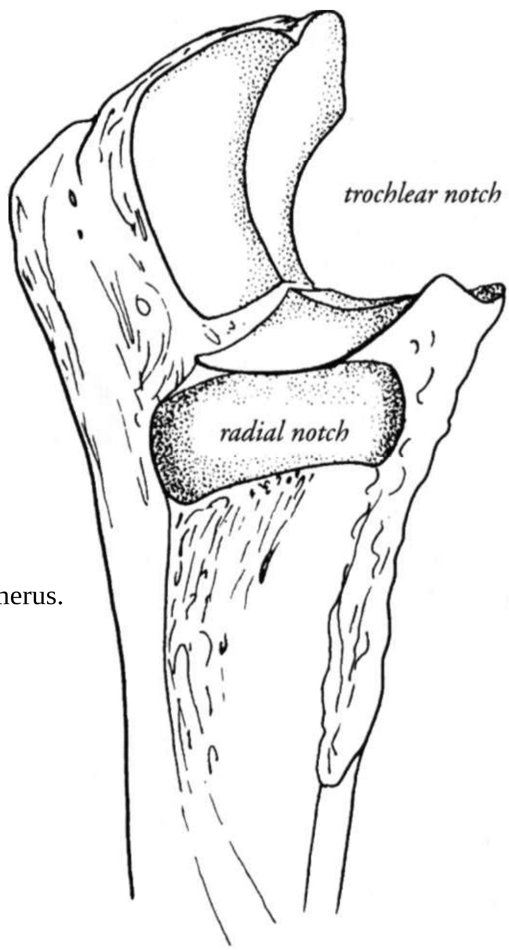
The radius is lined by a beveled layer, which articulates with the interosseous membrane.

Proximal end of the ulna

The **olecranon** consists of five surfaces, including a beak-like projection on its superior surface.



The **coronoid process** has four surfaces, with a beak-like projection of its own on its anterior surface.



The anterior surface of the olecranon and the superior surface of the coronoid process form an almost continuous surface in the shape of a hollow cylinder. This is the **trochlear notch** of the ulna.

It is covered with cartilage and separated into two grooves by a longitudinal ridge. This notch articulates with the trochlea of the humerus.

From an anatomical point of view, the **radial notch** of the ulna is not part of the elbow joint because it is not contained in the same capsule. It is described in more detail on page 150.

Joint capsule of elbow

Three bones—the humerus, ulna, and radius—come together to form the capsule of the elbow joint.

The capsule attaches to the circumference of the coronoid and olecranon fossae of the humerus and connects with the medial and lateral epicondyles without encircling them. It attaches to the circumference of the neck and the radius. It also attaches to the circumference of the trochlear notch of the unla.

The capsule is taut in front (especially laterally), but loose in back (facilitating flexion).

[The illustration at left shows the joint with bones spread apart slightly to better view the capsule.]

Ligaments of elbow

The anterior and posterior elbow ligaments are minor ligaments:

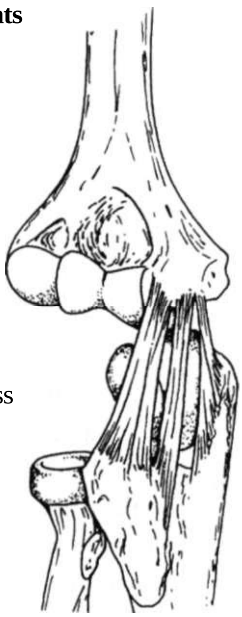
• anteriorly, they are fan-shaped and reinforce the capsule

Thus, they allow flexion and extension.

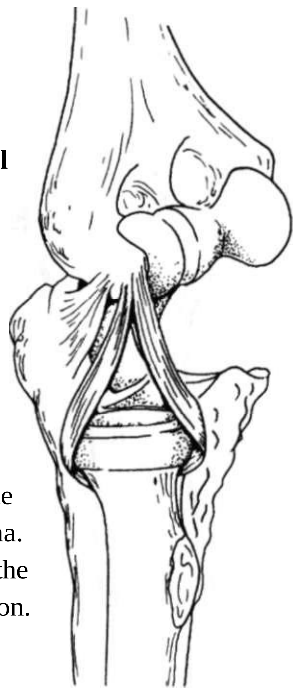
• posteriorly, their fibers cross over (as shown here on a flexed elbow).

The **collateral ligaments** are the most important ligaments of the elbow:

The **ulnar collateral ligament** arises from the medial epicondyle and attaches below to the medial coronoid process and olecranon.



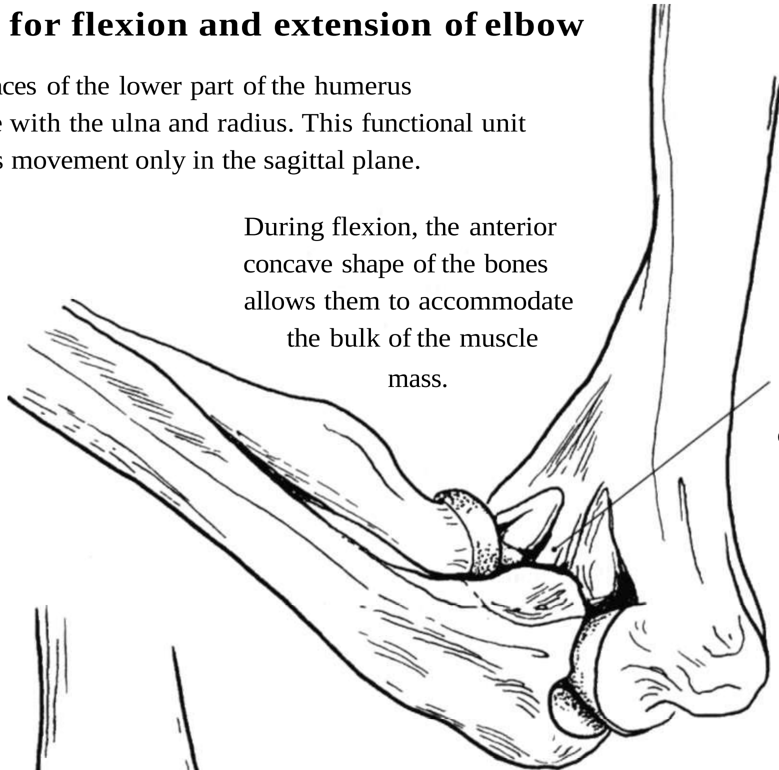
The **radial collateral ligament** is formed by three fasciae that arise from the lateral epicondyle. Two slips encircle the head of the radius, one anteriorly and the other posteriorly, before inserting at the radial notch of the ulna. The third inserts on the lateral olecranon.



Both collateral ligaments prevent any lateral movement of the elbow joint.

Bones for flexion and extension of elbow

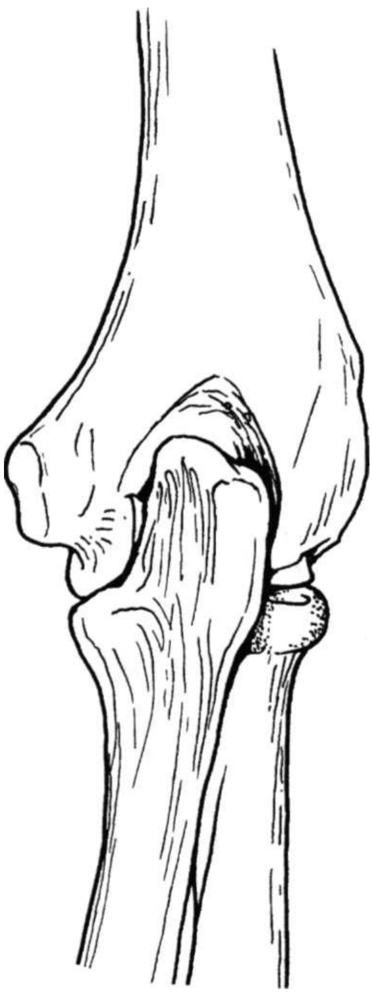
The surfaces of the lower part of the humerus articulate with the ulna and radius. This functional unit facilitates movement only in the sagittal plane.



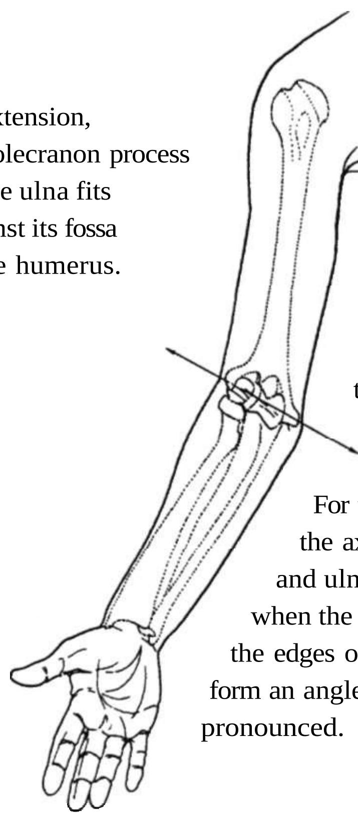
During flexion, the anterior concave shape of the bones allows them to accommodate the bulk of the muscle mass.

The head of the radius fits into the radial fossa of the humerus.

The "beak" of the coronoid process fits into the coronoid fossa.



In extension, the olecranon process of the ulna fits against its fossa on the humerus.

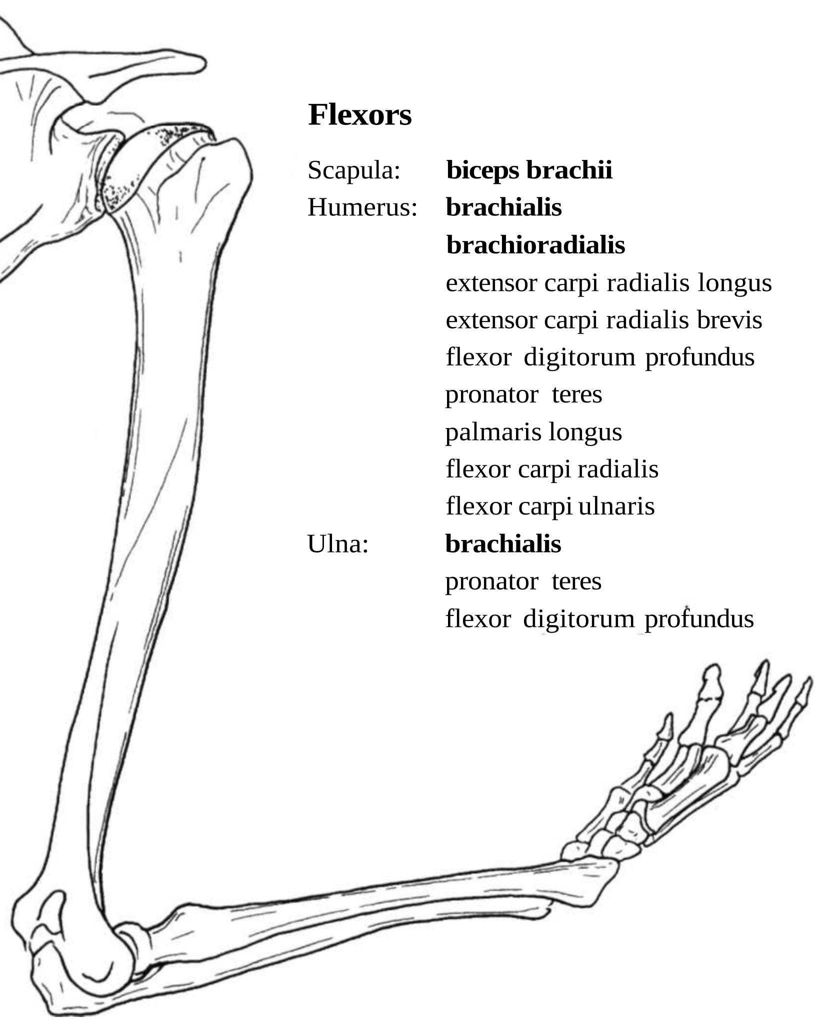


The axis of the trochlea is directed obliquely superolaterally; the medial side is lower than the lateral side.

For this reason, the axes of the humerus and ulna are not quite parallel when the elbow is extended, i.e., the edges of the arm and forearm form an angle that is more or less pronounced.

Muscles for flexion/extension of elbow with their many bony attachments

Two muscle groups are presented here:
the principal muscles (in **boldface)**
and the secondary muscles,
most of which will be described in Chapter 5 on the wrist and hand.



Flexors

Scapula: **biceps brachii**
Humerus: **brachialis**
brachioradialis
extensor carpi radialis longus
extensor carpi radialis brevis
flexor digitorum profundus
pronator teres
palmaris longus
flexor carpi radialis
flexor carpi ulnaris
Ulna: **brachialis**
pronator teres
flexor digitorum profundus

Radius: **biceps brachii**
brachioradialis

Bones of the hand:
extensor carpi radialis longus
extensor carpi radialis brevis
flexor digitorum profundus
palmaris longus
flexor carpi radialis
flexor carpi ulnaris

Extensors

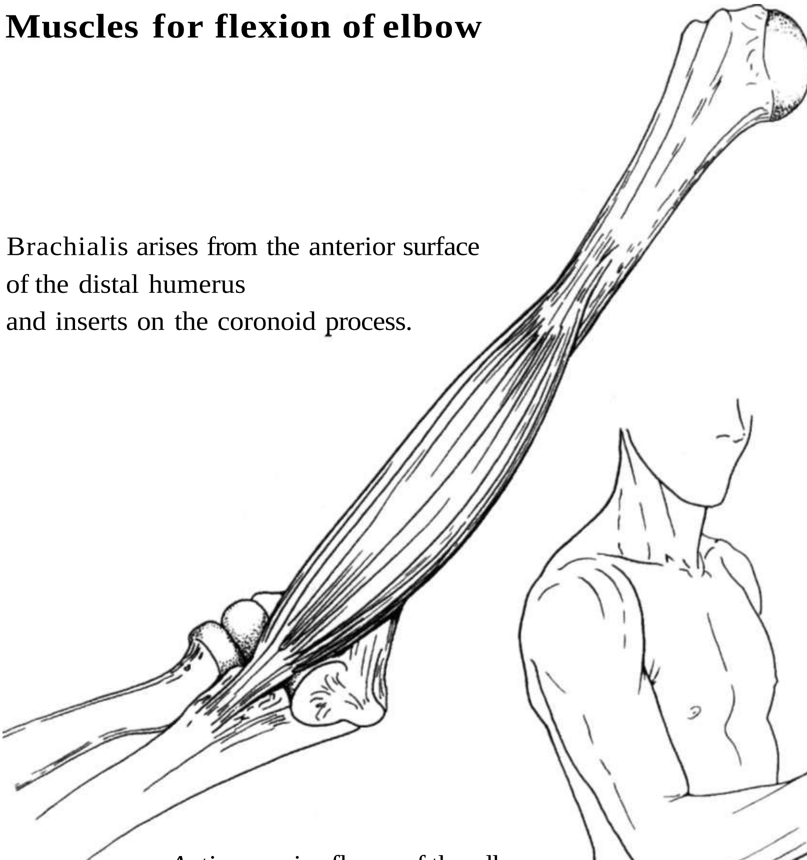
Scapula:
triceps brachii

Humerus:
triceps brachii
anconeus
extensor digitorum
extensor digiti minimi
extensor carpi ulnaris

Ulna:
triceps brachii
anconeus

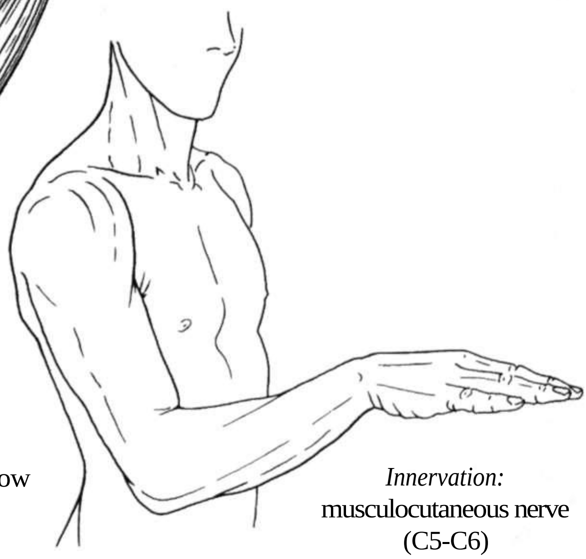
Bones of the hand:
extensor digitorum
extensor digiti minimi

Muscles for flexion of elbow

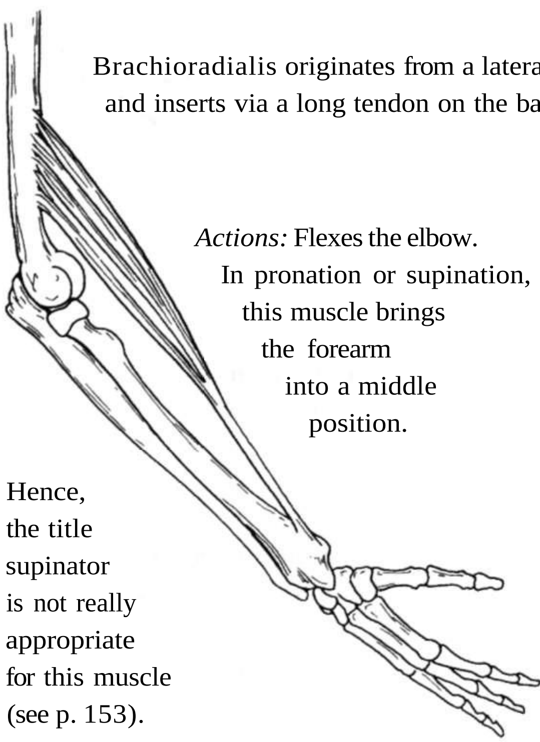


Brachialis arises from the anterior surface of the distal humerus and inserts on the coronoid process.

Action: major flexor of the elbow



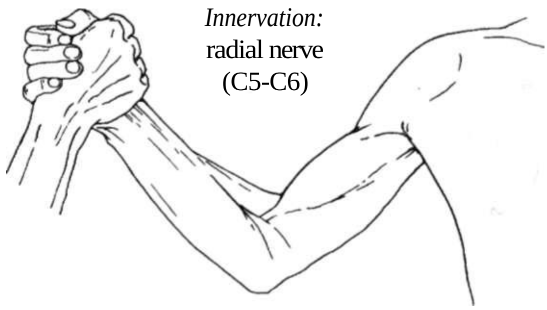
Innervation:
musculocutaneous nerve
(C5-C6)



Brachioradialis originates from a lateral ridge on the distal humerus, and inserts via a long tendon on the base of the radial styloid process.

Actions: Flexes the elbow. In pronation or supination, this muscle brings the forearm into a middle position.

Hence, the title supinator is not really appropriate for this muscle (see p. 153).

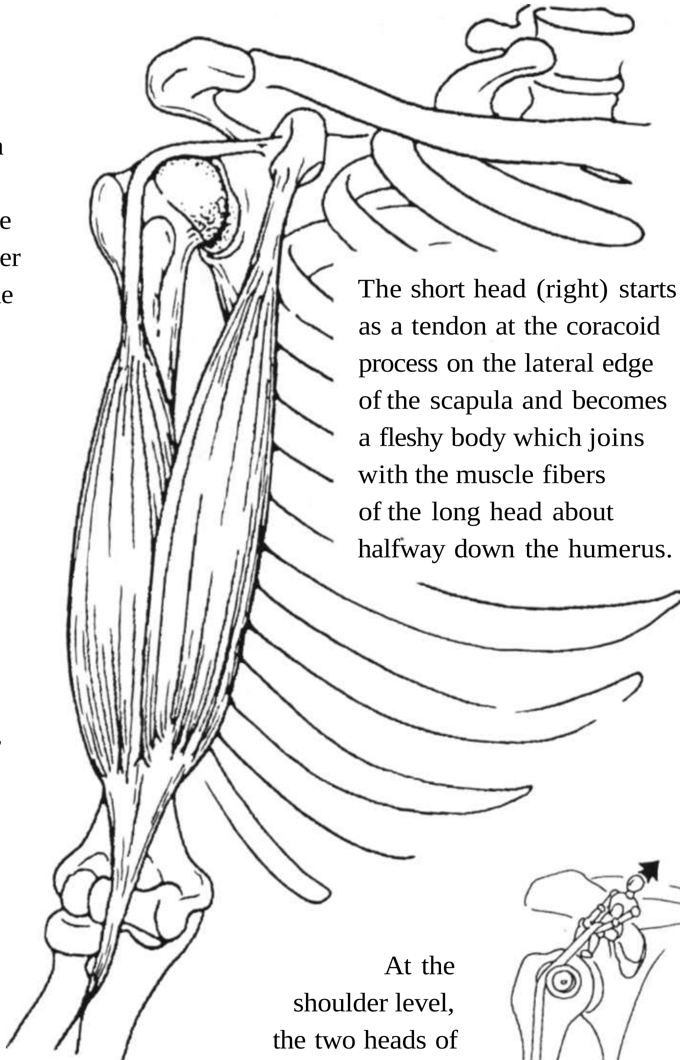


Innervation:
radial nerve
(C5-C6)

Its contraction can be seen along the radius when the elbow is flexed and the forearm is pronated or supinated.

Biceps brachii has two origins.

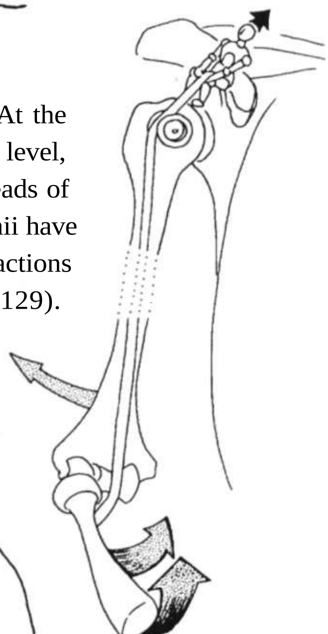
The long head (left) arises from a tubercle above the glenoid cavity of the scapula, travels through the shoulder joint, between the greater and lesser tubercles, and along the bicipital groove before merging with the body.



The short head (right) starts as a tendon at the coracoid process on the lateral edge of the scapula and becomes a fleshy body which joins with the muscle fibers of the long head about halfway down the humerus.

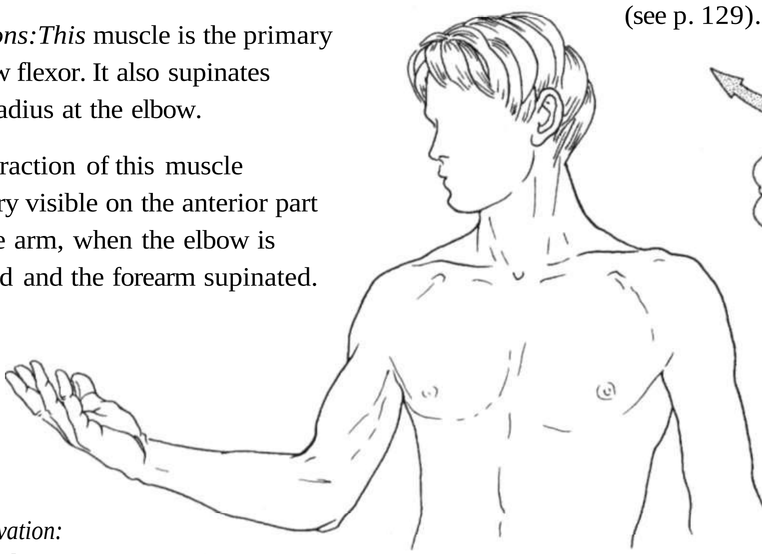
The two heads then continue downward and form one tendon, which passes anterior to the elbow joint and inserts at the bicipital tuberosity of the radius.

At the shoulder level, the two heads of biceps brachii have different actions (see p. 129).



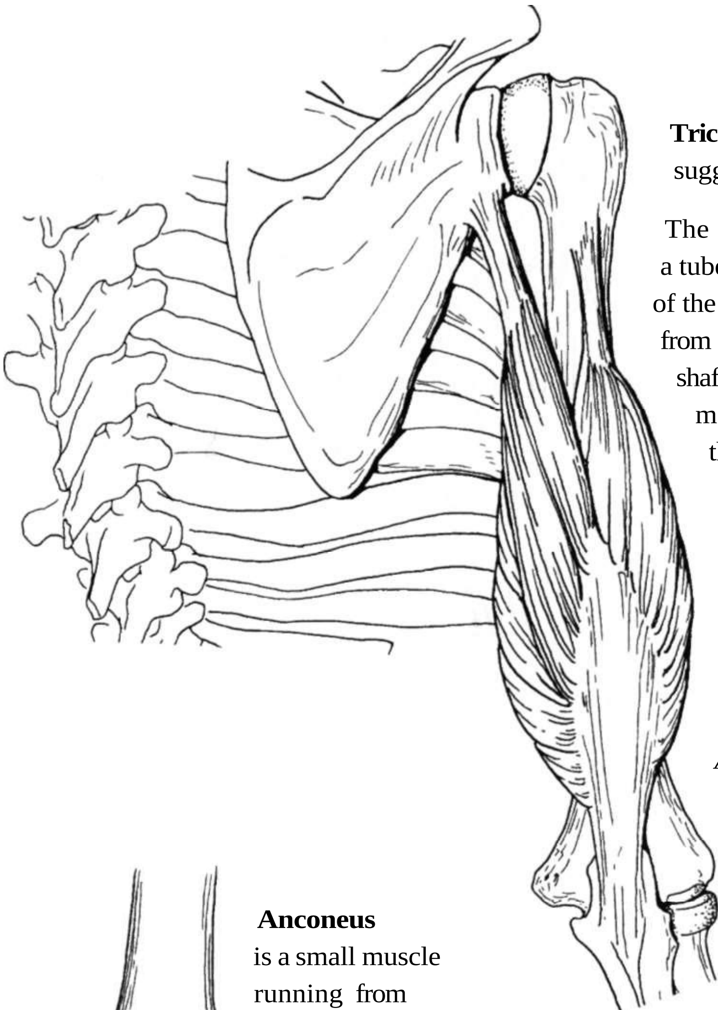
Actions:This muscle is the primary elbow flexor. It also supinates the radius at the elbow.

Contraction of this muscle is very visible on the anterior part of the arm, when the elbow is flexed and the forearm supinated.



Innervation:
musculocutaneous nerve (C5-C6)

Muscles for extension of elbow



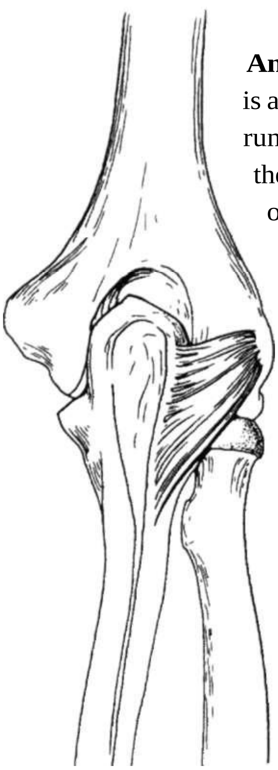
Triceps brachii, as the name suggests, consists of three heads.

The long head comes from a tubercle below the glenoid cavity of the scapula, the lateral head is from the lateral posterosuperior shaft of the humerus, and the medial head (better called the deep head) is from the posteroinferior humerus, where it is covered up by the body.

Triceps has a single broad insertion by a tendon onto the olecranon.

Action: This is the major elbow extensor.

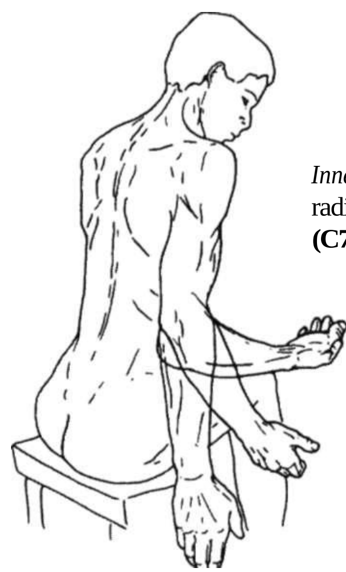
The long head also participates in extension of the arm due to its attachment to the scapula.



Anconeus is a small muscle running from the lateral epicondyle of the humerus to the superior ulna.

Action: extends the elbow; plays a small role as an abductor during pronation of the ulna (see p. 149)

Innervation:
radial nerve
(C7-C8)

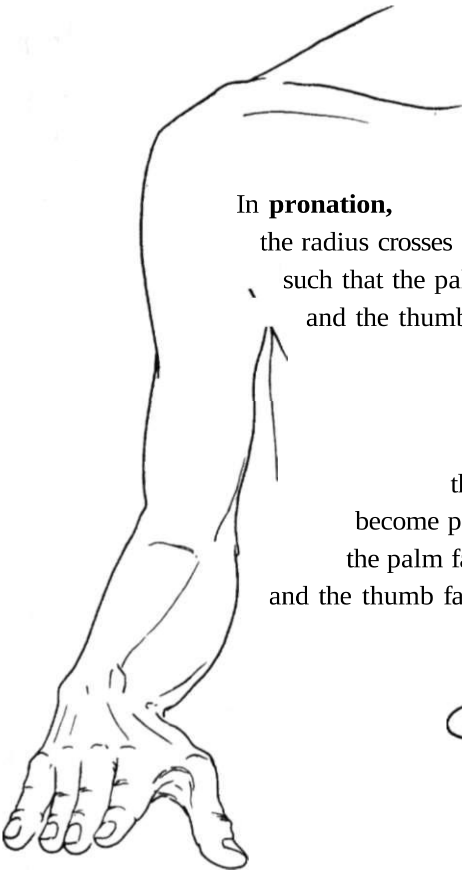


Innervation:
radial nerve
(C7-C8)

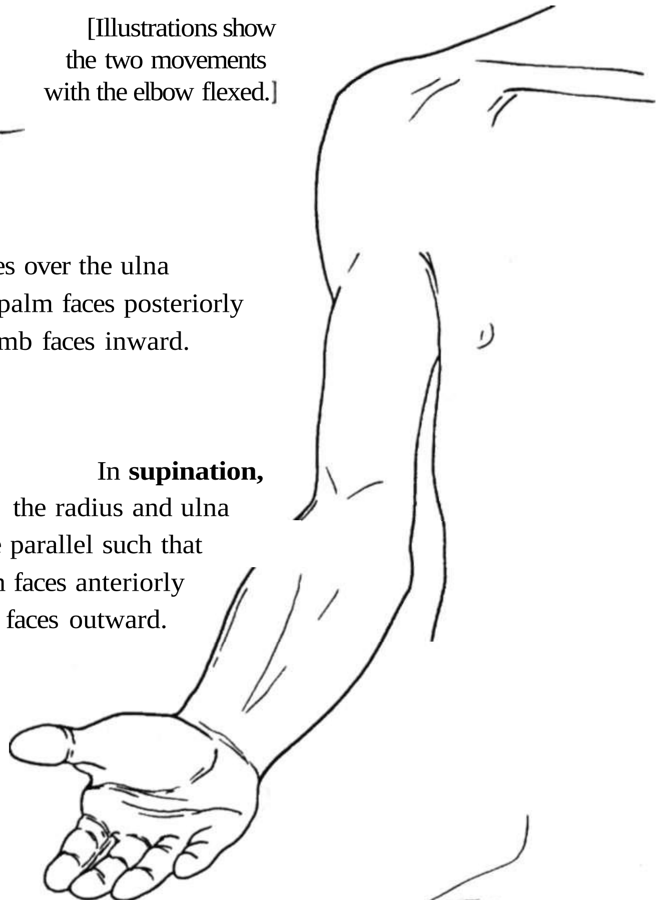
Pronation/supination of elbow and forearm

These movements involve changes in the elbow joint and in the relationship between the radius and ulna.

[Illustrations show the two movements with the elbow flexed.]

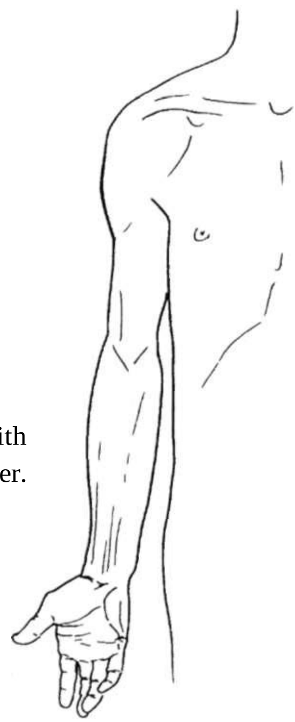


In **pronation,** the radius crosses over the ulna such that the palm faces posteriorly and the thumb faces inward.



In **supination,** the radius and ulna become parallel such that the palm faces anteriorly and the thumb faces outward.

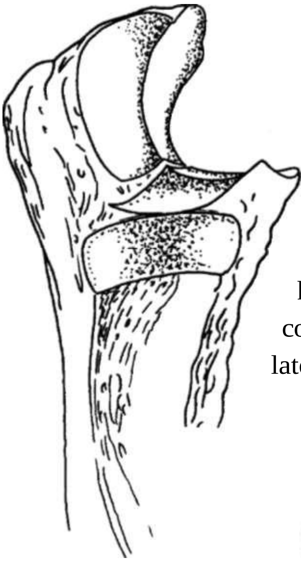
If the elbow is fully extended, it is easy to confuse pronation with medial rotation of the shoulder joint...



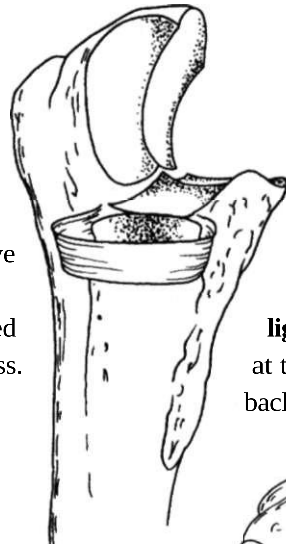
.. .and supination with lateral rotation of the shoulder.

For this reason, it is best to study these movements with the elbow flexed.

Pronation and supination are possible because of the interplay of articular surfaces and ligaments at the proximal and distal ends of the forearm.

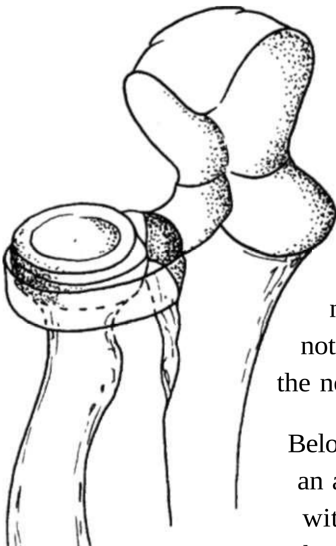


At the proximal end, as we have seen, the ulna has a concave **radial notch** located lateral to the coronoid process.

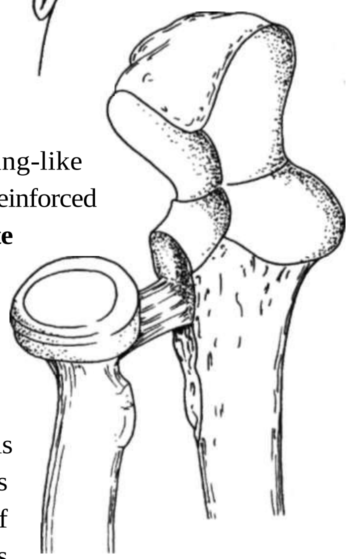


The **annular** (or transverse carpal) **ligament** attaches at the front and back of this notch.

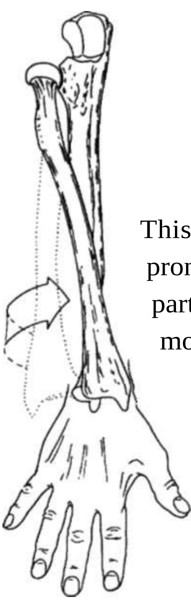
The notch and ligament are both lined with synovial membrane, and form a ringlike structure around the radial head.



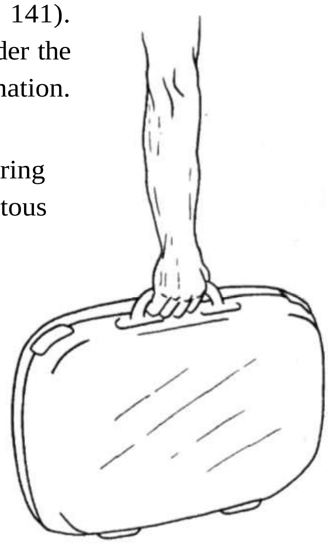
At its base, this ring-like structure is reinforced by the **quadrate ligament** connecting the radial notch of the ulna to the neck of the radius.



Below the radial head is an area that articulates with the capitulum of the humerus. This was described in the section on elbow extension and flexion (p. 141). It allows the radial head to turn under the capitulum during pronation and supination.



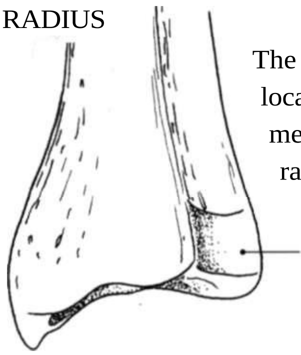
This ring allows easy rotation of the radial head during pronation, with a little bit of "give" in the ligamentous part of the ring. This serves as a brake for extreme movements.



The ring is somewhat funnel-shaped (wider at the top than the bottom), which helps resist downward movement of the radius when the forearm is supporting a heavy weight.

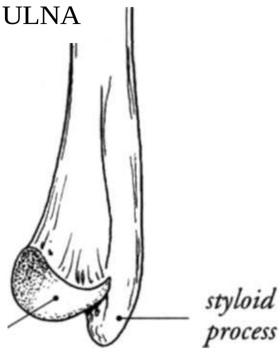
At the distal end, the two bones of the forearm have several surfaces.

RADIUS

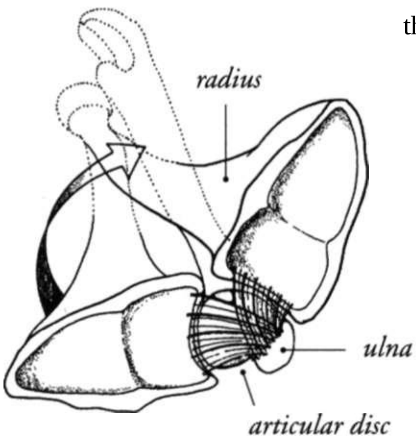


The **ulnar notch** is located where the medial edge of the radius bifurcates.

ULNA



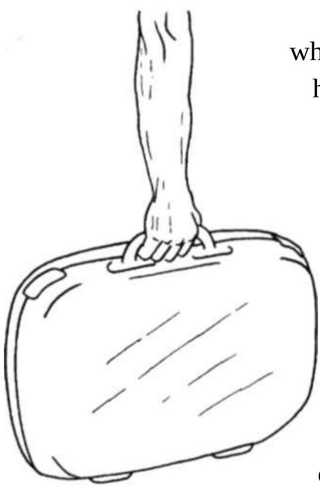
The distal radioulnar joint consists of the convex ulnar head fitting into the concave ulnar notch of the radius. This facilitates rotation of the base of the radius around the head of the ulna.



There is another mobile connection between ulna and radius: the **articular disc.** This structure runs from the styloid process of the ulna to the ulnar notch of the radius. Its anterior and posterior edges are thick, which gives it a concave shape. Both surfaces are covered by cartilage.

This disc is both an articular surface (with the inferior surface of the ulnar head and therefore with the wrist) and a connecting structure. Like a window wiper, it sweeps the ulnar surface during pronation and supination.

During pronation, the posterior portion of the disc becomes taut; during supination, the anterior portion becomes taut.



The **interosseous membrane,** which connects the shafts of the radius and ulna, has diagonal fibers oriented in both directions.

This membrane is very sturdy and consists of two layers:

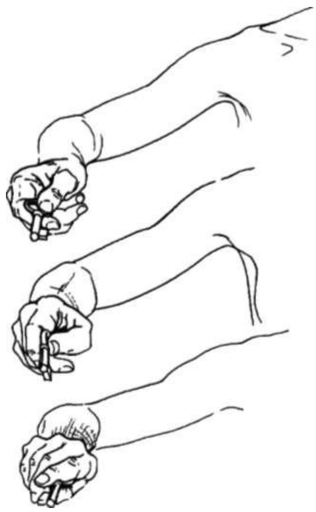
- oblique middle fibers inferomedially
- oblique superior fibers superomedially.

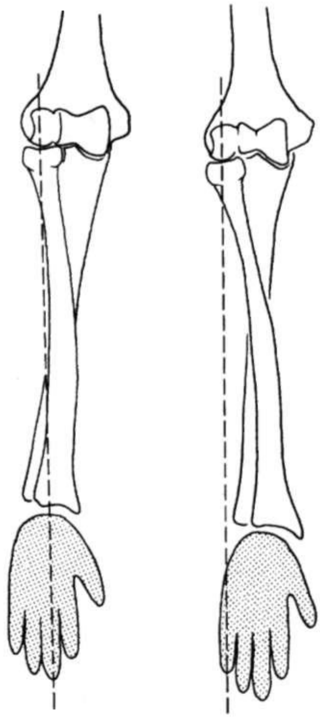
This membrane is relaxed in pronation and taut in supination, and thus acts as a brake on supination. It also prevents longitudinal displacement of the two bones, e.g., when carrying a heavy object.

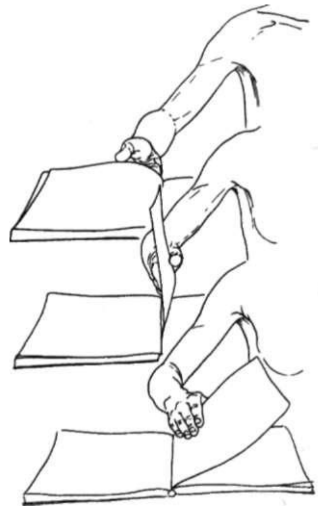
How shape of bones affects pronation/supination

Pronation involves a conical movement of the radius around the ulna. The proximal end of the radius pivots on itself, but with a slight "give" due to the suppleness of the annular ligament. Its distal end glides anteromedially around the head of the ulna.

For the ulna, there are two slightly different types of pronation:



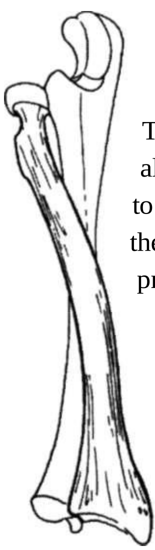




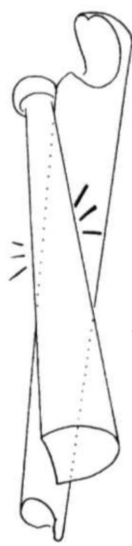
In the first (e.g., turning a key), the axis for movement of the hand passes through the middle finger, and the ulna moves slightly in conjunction with the radius. Anconeus is involved in this movement.

In the second (e.g., flipping the page of a book), the axis of the hand passes through the fifth finger, and the ulna remains fixed.

The ulna and radius, in anatomical position, are both concave anteriorly.



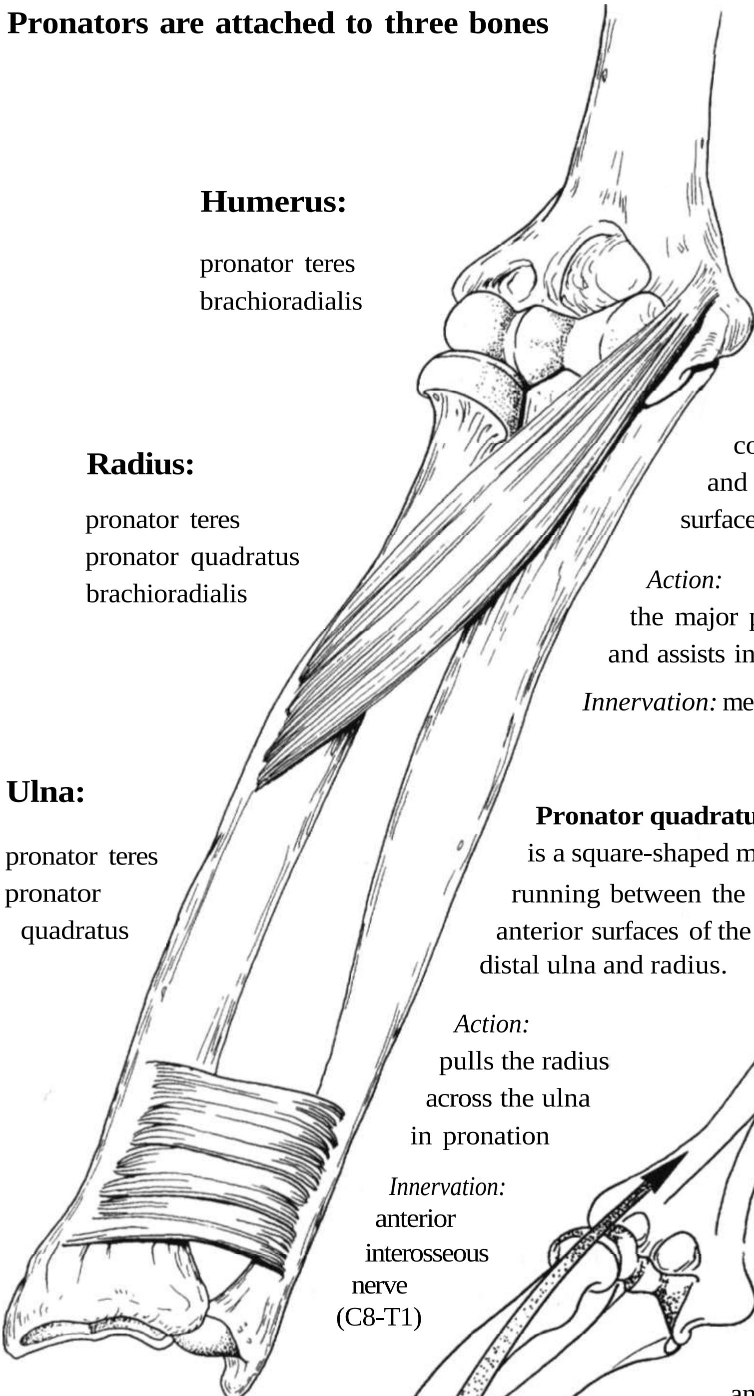
This curvature allows the radius to cross over the ulna during pronation.



If both bones were straight, they would contact each other too soon and normal pronation would be impossible.

Fractures or other injuries can alter these curvatures and thereby interfere with pronation. This is a point of concern in certain disciplines (e.g., martial arts) involving unusual stresses on the forearm.

Pronators are attached to three bones



Humerus:

pronator teres
brachioradialis

Radius:

pronator teres
pronator quadratus
brachioradialis

Ulna:

pronator teres
pronator quadratus

Pronator teres arises from two fasciae on the medial epicondyle of the humerus and coronoid process of the ulna, and inserts on the midlateral surface of the radius.

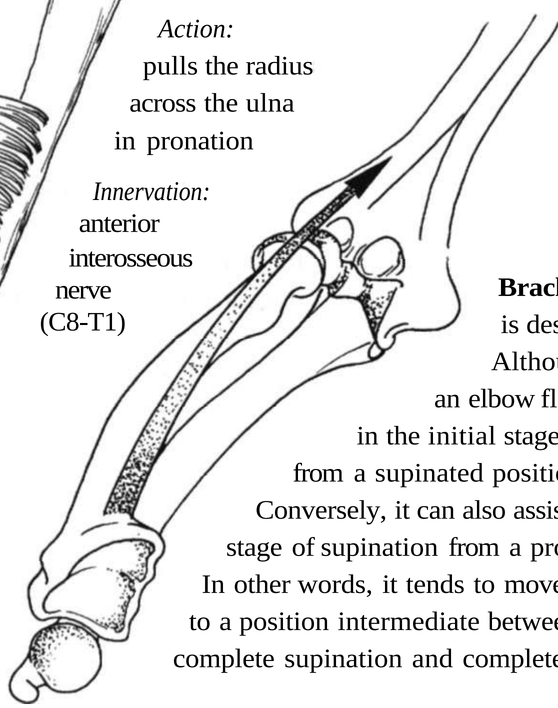
Action:
the major pronator of the forearm, and assists in flexion of the elbow

Innervation: median nerve **(C6-C7)**

Pronator quadratus is a square-shaped muscle running between the anterior surfaces of the distal ulna and radius.

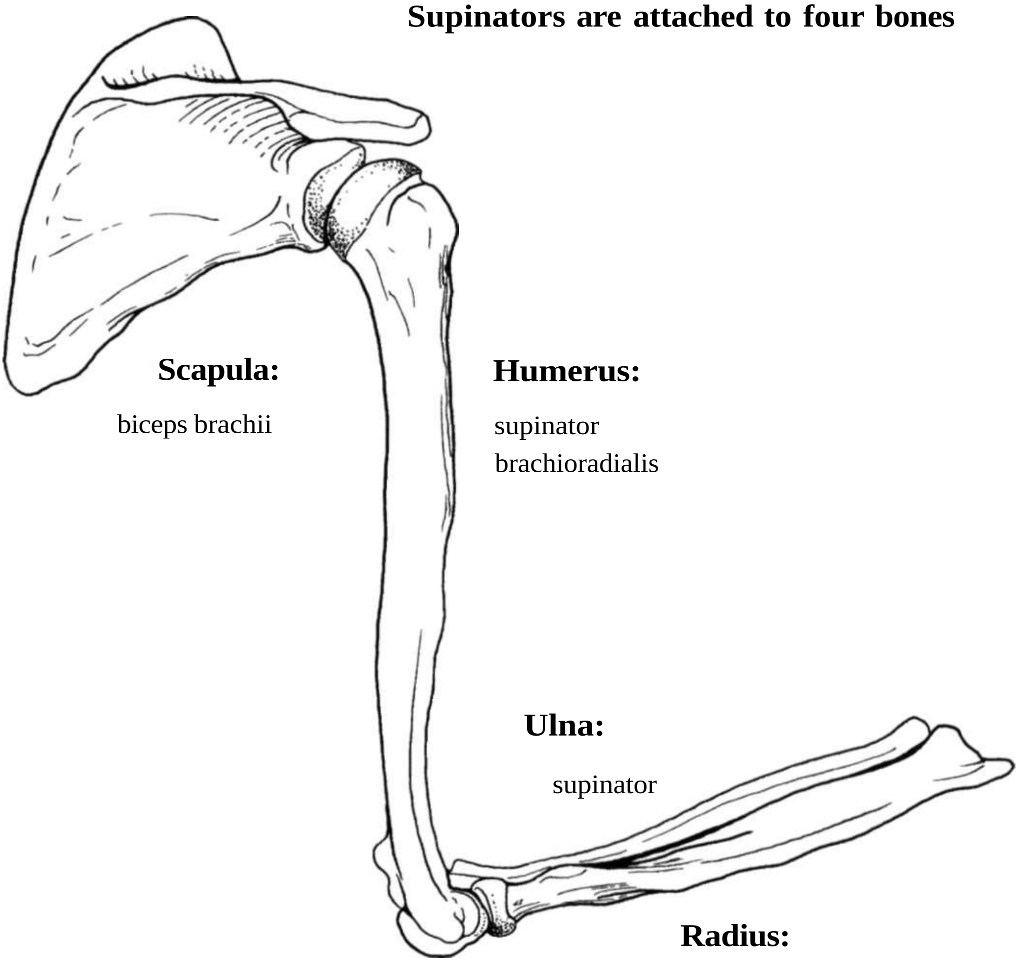
Action:
pulls the radius across the ulna in pronation

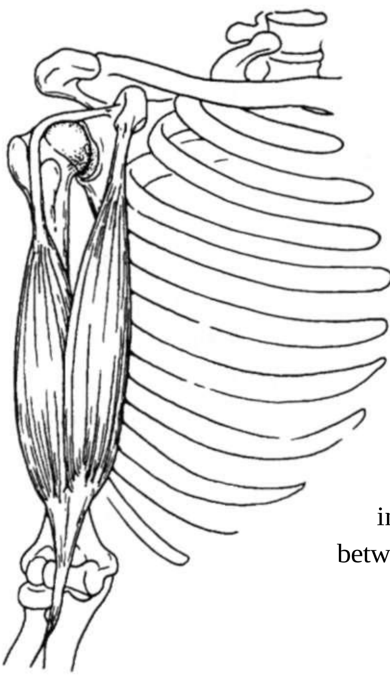
Innervation:
anterior interosseous nerve (C8-T1)



Brachioradialis is described on page 146. Although primarily an elbow flexor, it can assist in the initial stage of pronation from a supinated position. Conversely, it can also assist in the initial stage of supination from a pronated position! In other words, it tends to move the radius to a position intermediate between complete supination and complete pronation.

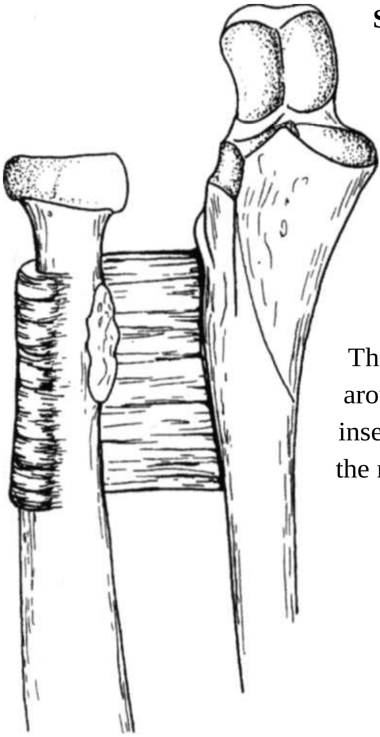
Supinators are attached to four bones





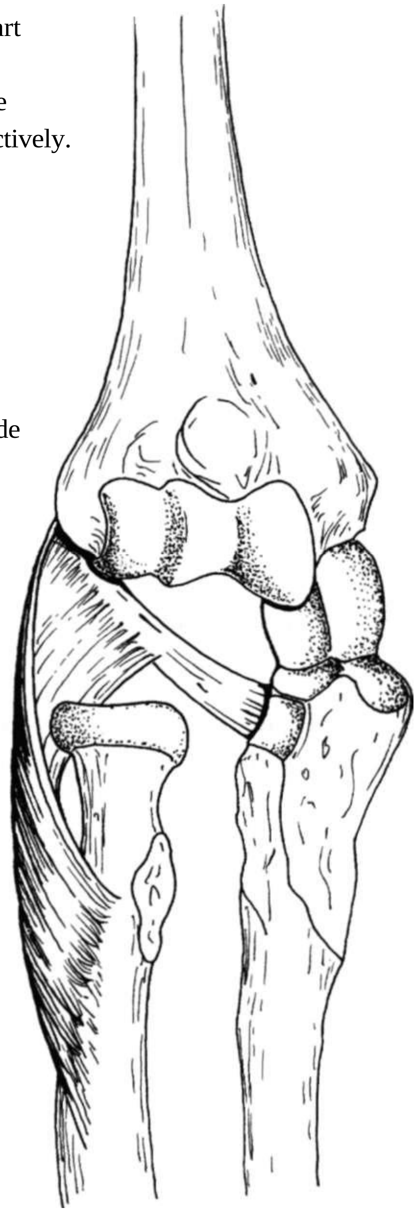
Biceps brachii (see p. 147)
is the most powerful supinator.
It acts by "unfurling"
the proximal part of the radius.

Brachioradialis (see p. 146)
acts as a supinator only
when it is in a pronated position.
In this case, it moves the forearm
into position halfway
between pronation and supination.



Supinator has two layers,
a deep one (shown at left)
and a superficial one (below right)
These layers originate from
the superolateral part
of the ulna and
the lateral epicondyle
of the humerus, respectively.

This muscle wraps
around the radius,
inserting between
the neck (deep fibers),

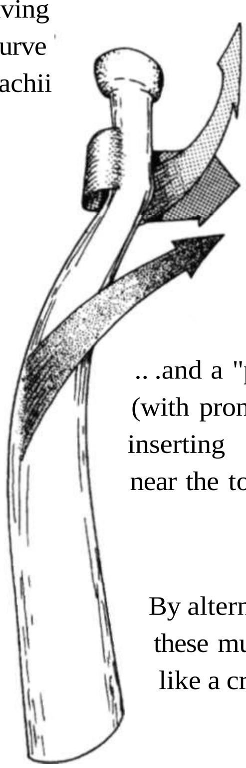


. . . and the lateral side
of the bone
(superficial fibers).

Action: supinates
the forearm

Innervation: deep radial
nerve (C5-C6)

The radius can be
visualized as having
a "supinating curve"
(with biceps brachii
and supinator
inserting
near the top),



.. .and a "pronating curve"
(with pronator teres
inserting
near the top).

By alternately contracting,
these muscles turn the radius
like a crank.

CHAPTER FIVE

The Wrist & Hand

The **hand,** located at the extremity of the upper body, is a very versatile tool.

This is due to the enormous *mobility* of the fingers, which are equipped with a complex system of tendons—witness the hands of a pianist, for example.

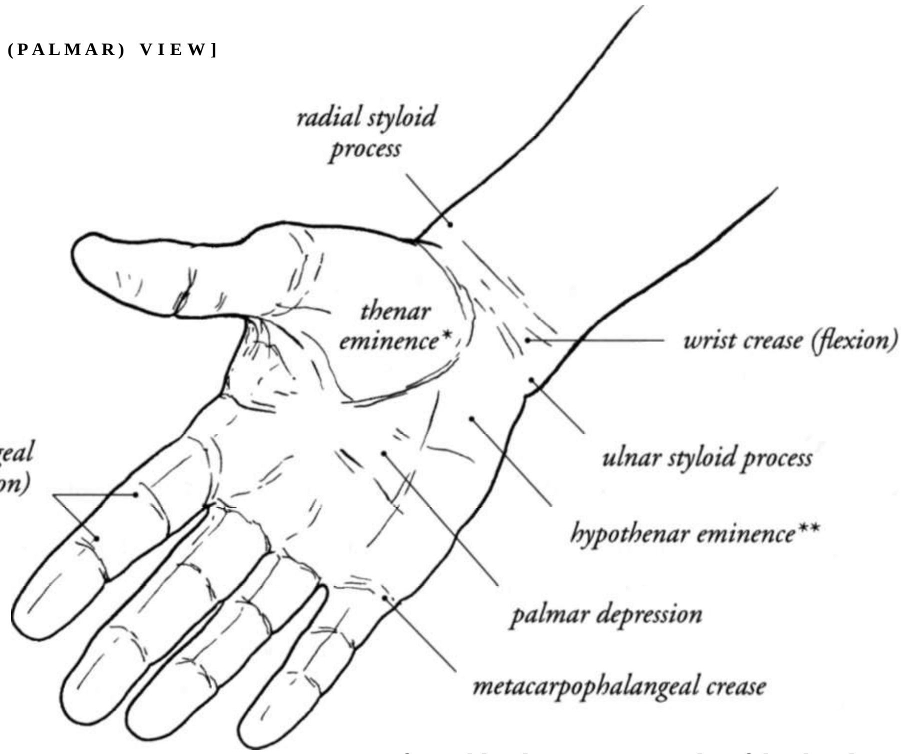
The other factor contributing to the hand's versatility is the *arrangement of the thumb* vis-a-vis the fingers. The *opposable thumbs* makes it possible to grasp objects and to accomplish many different tasks, ranging from fine precision (threading a needle) to great strength (lifting a heavy object, pulling on a partner).

The hand is linked to the forearm via the carpal bones, which form the area of the **wrist.** In this chapter, we will describe the wrist and hand together since they share many muscles.

Because the thumb plays such a major role in the bone and muscle structure of the hand, it will be dealt with separately at the end of the chapter.

Landmarks

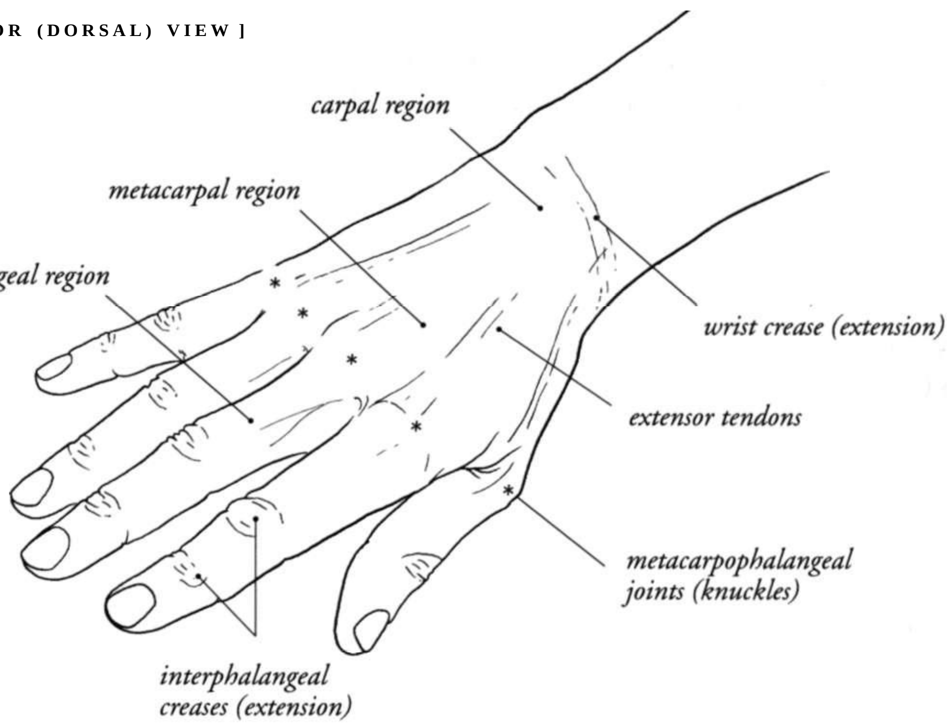
[ANTERIOR (PALMAR) VIEW]



***formed by the intrinsic muscles of the thumb**

****formed by the intrinsic muscles of the little finger**

[POSTERIOR (DORSAL) VIEW]

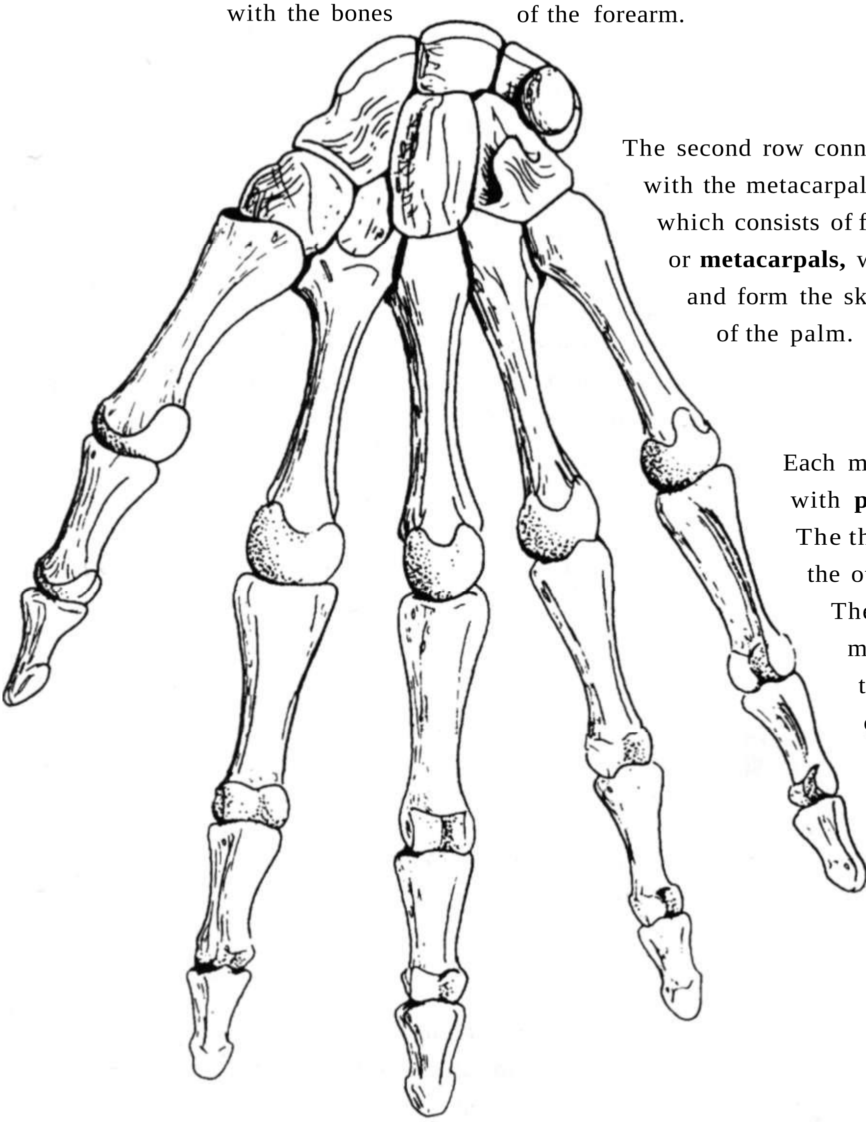


Bones

The skeleton of the hand, shown here with the palm facing forward, consists of three bony areas:

At the top are the **carpal bones,** consisting of eight small bones. The carpals are arranged in two rows of four bones each.

The first row connects with the bones of the forearm.

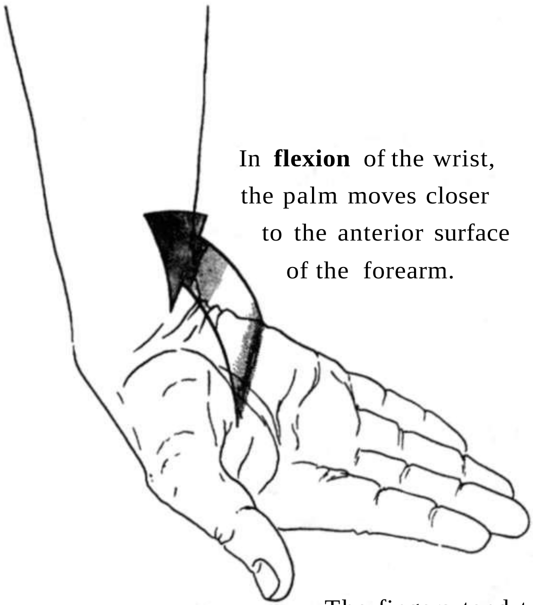


The second row connects with the metacarpal region, which consists of five long bones or **metacarpals,** which flare out and form the skeleton of the palm.

Each metacarpal connects with **phalanges.** The thumb has two, the other fingers three. The phalanges make up the skeleton of the fingers.

The metacarpals and phalanges flare out like a fan.

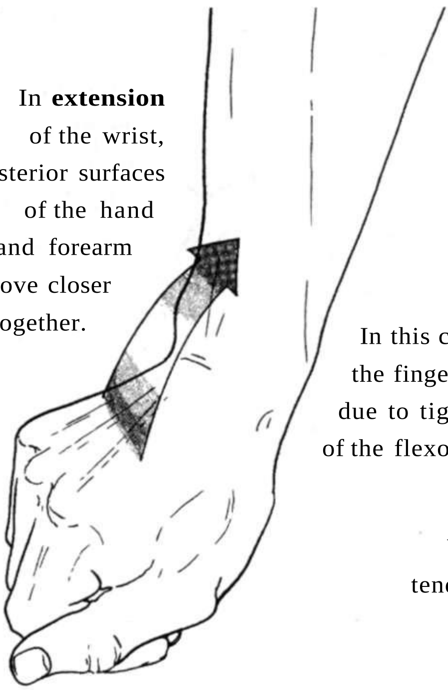
Movements of the wrist



In **flexion** of the wrist, the palm moves closer to the anterior surface of the forearm.

The fingers tend to stretch during this movement, due to tightening of the extensor tendons.

You can feel this tightening on the back of the hand when flexing the fingers,



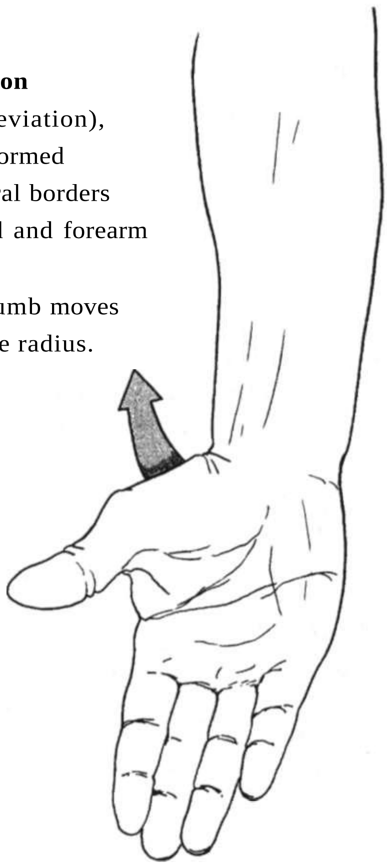
In **extension** of the wrist, the posterior surfaces of the hand and forearm move closer together.

In this case, the fingers tend to flex, due to tightening of the flexor tendons.

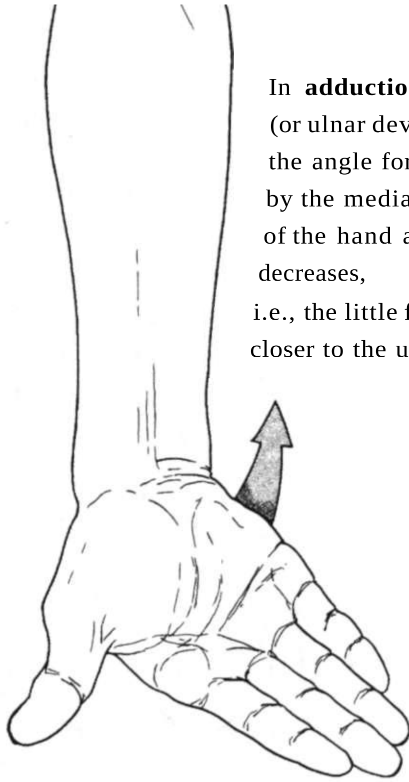
You can feel these tendons on the palm when extending the fingers.

Flexion and extension of the wrist have roughly the same range of motion.

In **abduction**
(or radial deviation),
the angle formed
by the lateral borders
of the hand and forearm
decreases,
i.e., the thumb moves
closer to the radius.



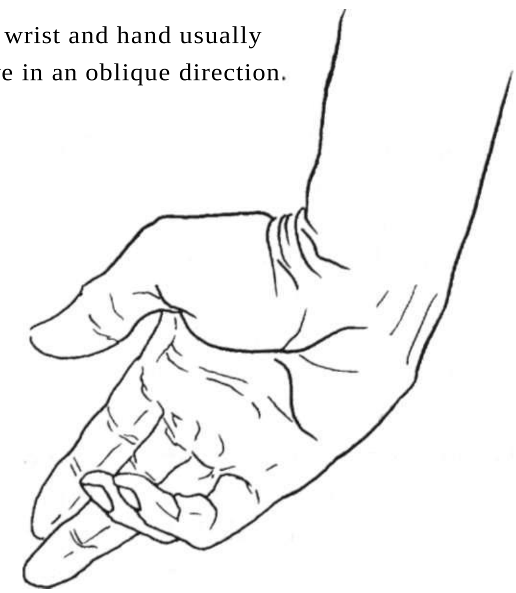
In **adduction**
(or ulnar deviation),
the angle formed
by the medial borders
of the hand and forearm
decreases,
i.e., the little finger moves
closer to the ulna.



The range of motion for adduction
is greater than that of abduction.

The wrist and hand usually
move in an oblique direction.

Because of the muscles involved,
adduction tends to be combined
with flexion...



...whereas abduction tends
to occur together with extension.

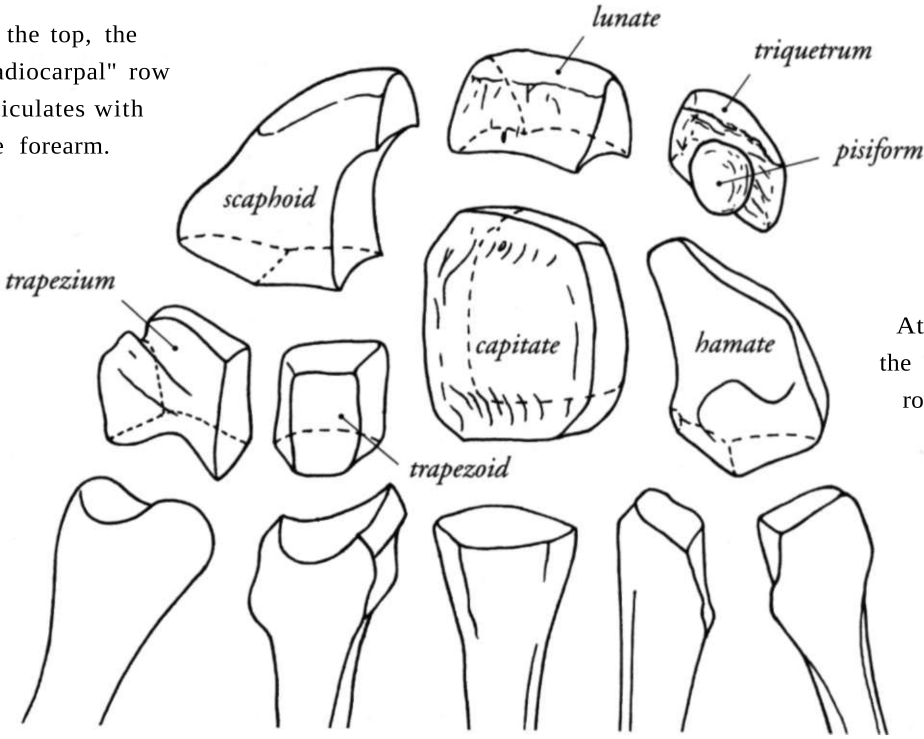
[Movements of the fingers are described on p. 169.]

Carpal bones

The wrist, which is only 3cm in height and 5cm in width, consists of two rows, each containing four bones.

[RIGHT HAND, PALMAR VIEW]

At the top, the "radiocarpal" row articulates with the forearm.



At the bottom, the "metacarpal" row articulates with the metacarpals.

The **scaphoid** articulates superiorly with the radius and inferiorly with the trapezium and trapezoid.

The **lunate** articulates superiorly with the radius and articular disc and inferiorly with the capitate.

The **triquetrum** articulates superiorly with the articular disc. Inferiorly, it contacts the hamate and capitate.

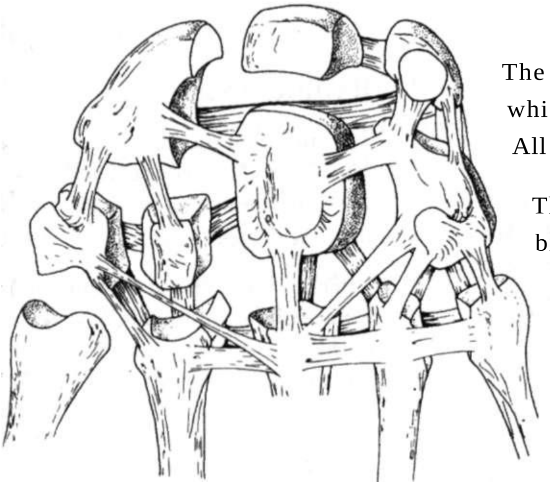
The **pisiform** is a small round bone which sits on the anterior surface of the triquetrum. It does not articulate with the forearm nor with the hamate, but does serve for attachment of some ligaments.

The **trapezium** has a sharp anterior crest. It joins metacarpal I.

The **trapezoid** is the most symmetrical of the carpal bones, being shaped like a pyramid with the top cut off. It articulates with metacarpal II.

The **capitate** is the largest carpal and has an anterior tubercle. It articulates primarily with metacarpal III and has two facets on the inferior corners which contact metacarpals II and IV.

The **hamate** has a prominent anterior projection called the "hook." The inferior surface of the hamate has two facets oriented in different directions which articulate with metacarpals IV and V.



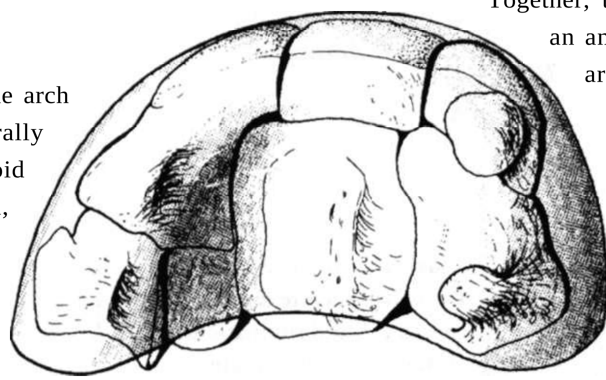
The wrist consists of small bones which articulate with each other laterally. All the surfaces are covered by cartilage.

There are many small ligaments binding the carpals to one another and to the metacarpals.

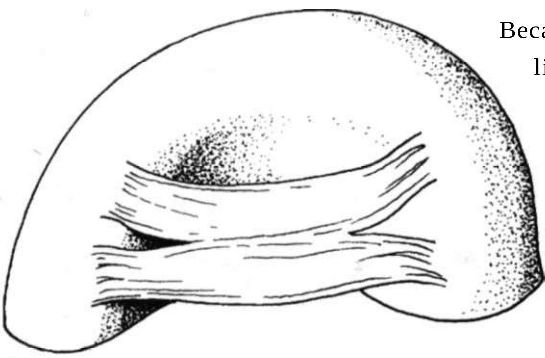
Carpal arch

There are eight carpal bones. Together, the carpals form an anteriorly-concave arch.

The sides of the arch consist laterally of the scaphoid and trapezium,



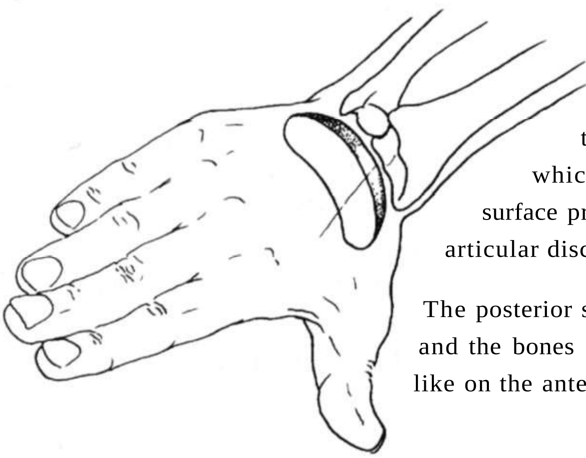
...and medially of the triquetrum, pisiform, and hamate.



Because of the annular (or transverse carpal) ligament which runs anterior to the carpus, this concave space is transformed into a tunnel, the **carpal tunnel.**

The small intrinsic muscles of the hand and palmaris longus attach above this ligament.

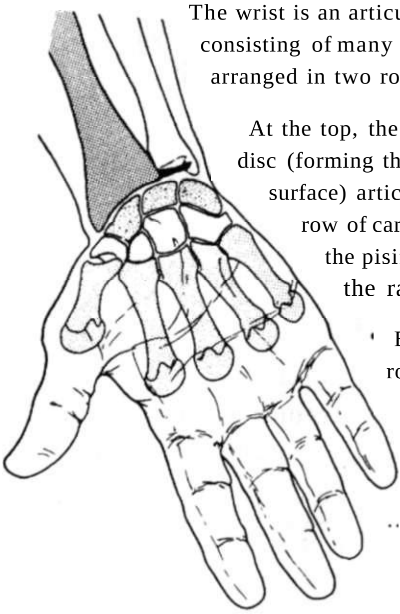
The tendons of the long muscles of the hand pass below it.



Superiorly, the scaphoid, lunate, and triquetrum present a large convex surface which articulates with the smaller concave surface presented by the distal radius and articular disc to form an ellipsoid joint.

The posterior surface is convex and the bones are bound together here, like on the anterior surface, by many ligaments.

Articular surfaces of wrist joint



The wrist is an articular region consisting of many bones arranged in two rows:

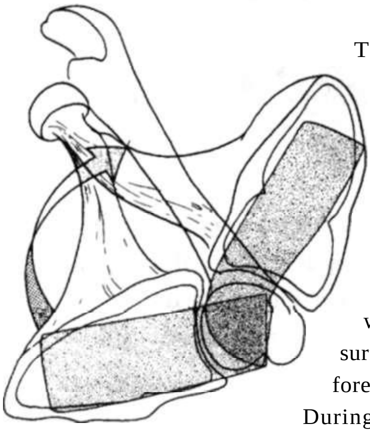
At the top, the radius and the articular disc (forming the articular radiocarpal surface) articulate with the proximal row of carpal bones (except the pisiform). This is called the radiocarpal joint.

Below, this proximal row articulates with the second row of carpal bones. This is called the midcarpal joint.

Radiocarpal joint

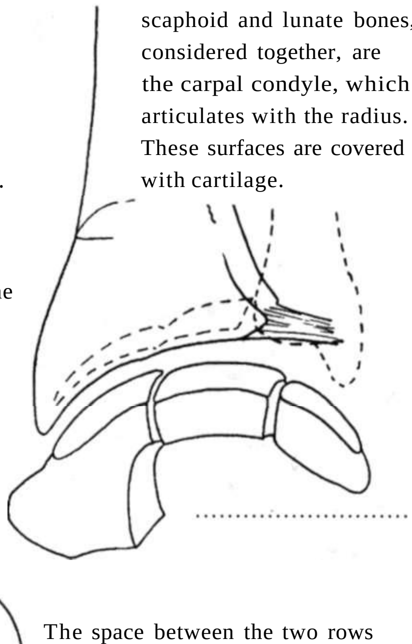
The surface of the radiocarpal articulation has a concave oval shape, whose posterior edge is slightly lower than the anterior edge.

Laterally, it consists of the inferior surface of the radius, and medially of the inferior surface of the articular disc, covered by cartilage.



The articular disc maintains the wrist structure during pronation and supination. If the wrist were to directly articulate with the two bones of the forearm, it would fold on itself during pronation.

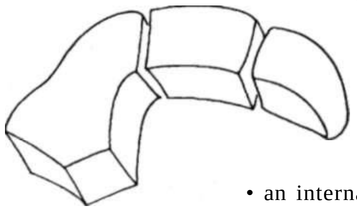
Through the articular disc, the wrist forms a quasi-continuous surface with the radius, whether the forearm is pronated or supinated. During both movements, it "wipes" the ulnar head like a windshield wiper.



The superior surfaces of the scaphoid and lunate bones, considered together, are the carpal condyle, which articulates with the radius. These surfaces are covered with cartilage.

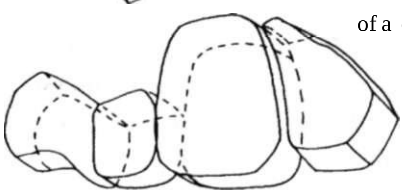
Midcarpal joint

The midcarpal joint consists of the inferior surfaces of the scaphoid, lunate, and triquetrum proximally, and the superior surfaces of trapezium, trapezoid, capitate, and hamate distally.



The space between the two rows has the shape of the letter S, where we can distinguish two parts:

- an internal part, which consists of a concave and a convex surface



- an external part, which consists of two flat surfaces superiorly and inferiorly.

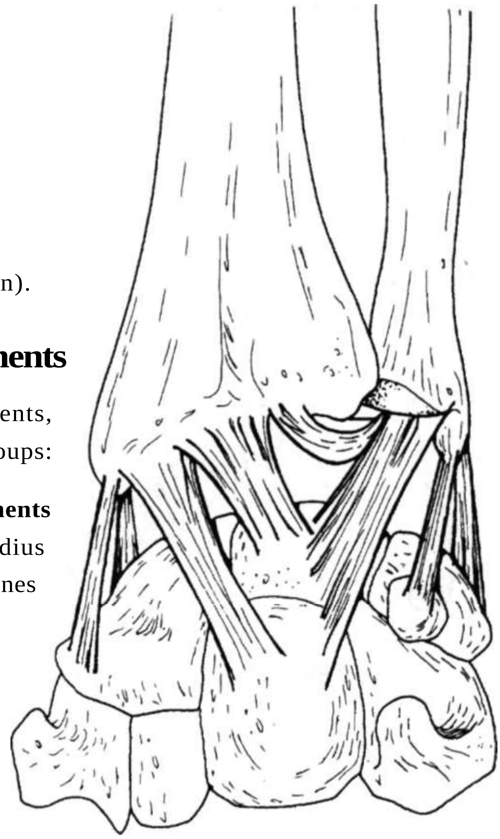
Joint capsules

The radiocarpal joint is surrounded by a capsule,
which is attached to the joint circumference.
It is very loose from front to back, but taut laterally.
It is lined by a synovial membrane.
There is an articular capsule at each midcarpal joint.
The capsules are more or less joined to each other
and the synovial membrane is continuous (not shown).

Ligaments

The radiocarpal joints have many small ligaments, which can be subdivided into three groups:

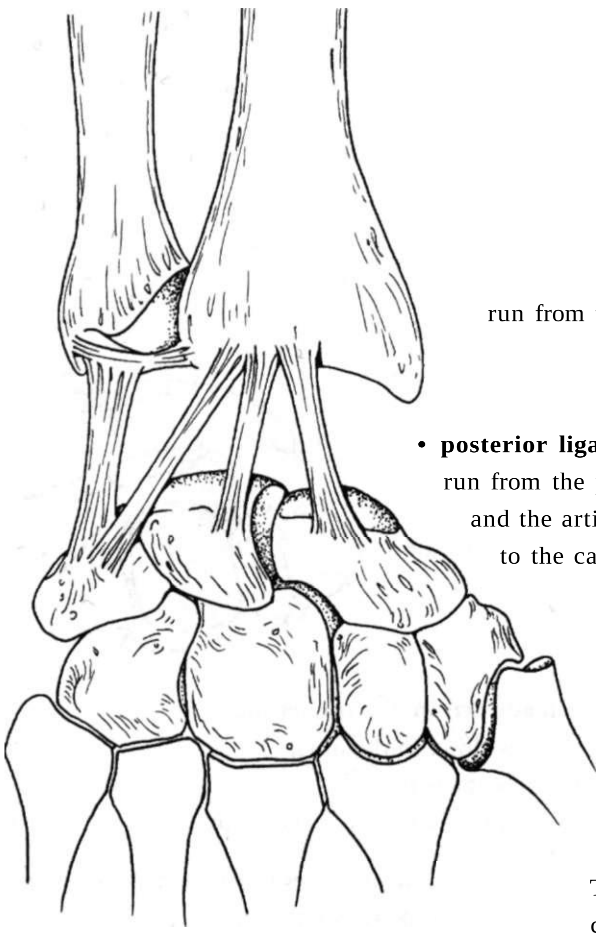
- **anterior ligaments**
  run from the anterior surface of the distal radius to the carpal bones



[FRONT VIEW]

- **lateral ligaments**
  run from the styloid processes of the radius and ulna to the carpal bones

- **posterior ligaments**
  run from the posterior surface of the distal radius and the articular disc to the carpal bones.

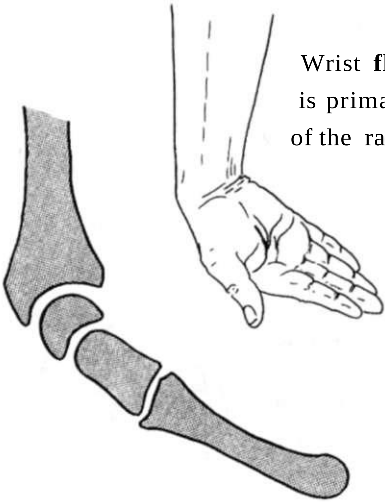


[BACK VIEW]

The ligaments at the midcarpal joints connect neighboring bones.
They are reinforced by bundles of ligaments from the radiocarpal joint.

Movements of the wrist

The movements of the wrist involve two rows of joints.

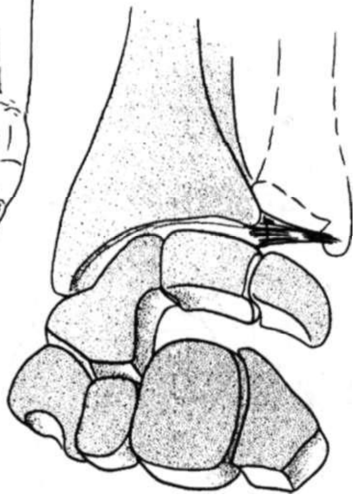


Wrist **flexion** is primarily a function of the radiocarpal joint.

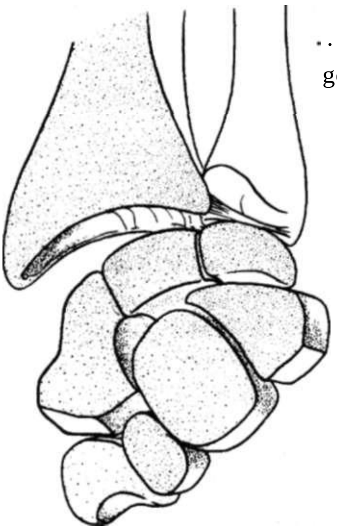
Extension involves the midcarpal joint to a greater extent, since the posterior border of the distal radius limits extension at the radiocarpal joint.

In **abduction,** the scaphoid moves closer to the radius. This movement is limited by the radial styloid. Medially, the proximal and distal rows of carpals move apart.

The proximal carpal row goes into flexion-pronation...



...while the distal row goes into extension-supination.



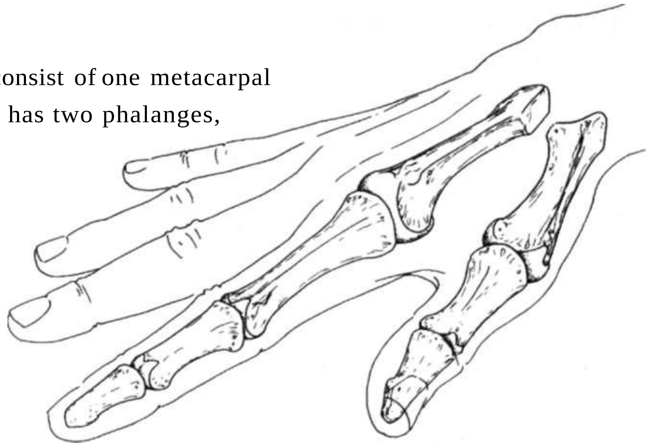
In **adduction,** the triquetrum moves closer to the ulna, while the scaphoid moves away from the radius.

Movement is less restricted here because the ulnar styloid is not as prominent as the radial styloid.

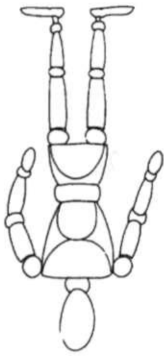
The lateral carpals move apart during adduction.

Metacarpals and phalanges

There are five bony structures which consist of one metacarpal and several phalanges each (the thumb has two phalanges, the other fingers have three each).

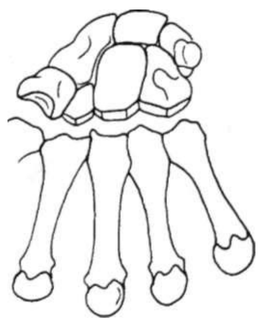


Each of these bones consists of three parts:



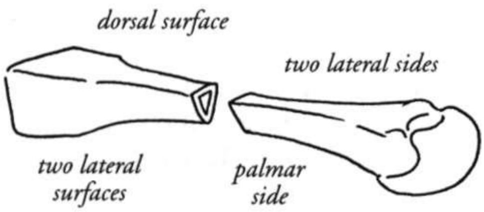
The bony structures studied here are those of fingers 2 through 5. The structure of the thumb is studied on page 183.

The metacarpals

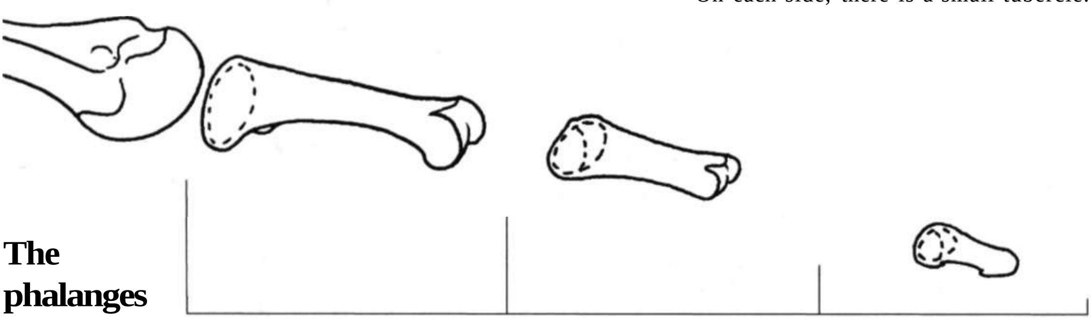


The base of each metacarpal is roughly quadrangular, with facets for articulation with a carpal and the adjacent metacarpals.

The shaft is roughly triangular, with three surfaces and three sides.



The head has one cartilaginous articulating surface, which is rounded from front to back and laterally. On each side, there is a small tubercle.



The phalanges

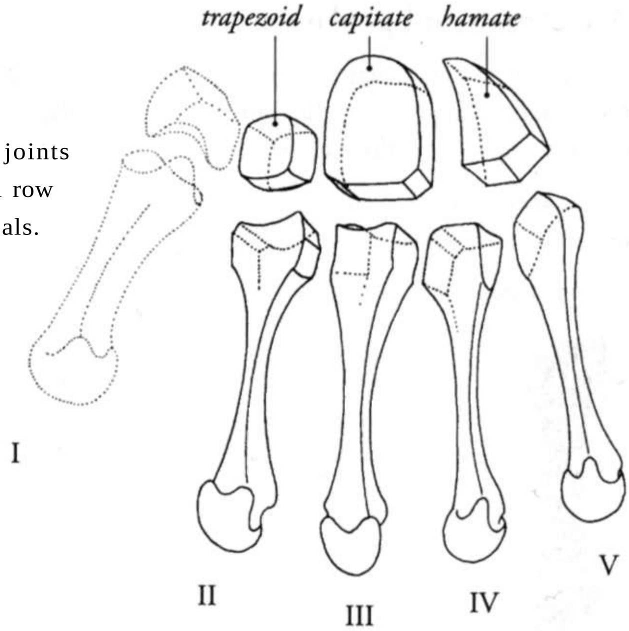
The **proximal phalanx** of each finger has a concavely rounded base for articulation with the metacarpal, and a pulley-shaped head.

The base of the **middle phalanx** is concave but with a median crest to match the shape of the head of the proximal phalanx. The head has the same surface as the proximal phalanx.

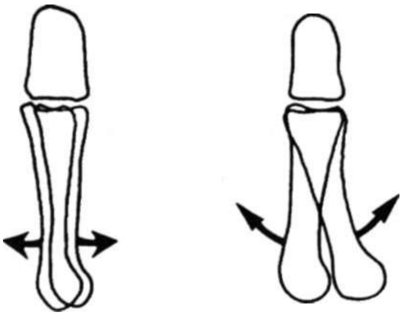
The base of the **distal phalanx** is identical to the base of the second phalanx. Its palmar head has a protuberance for the finger tip area.

Carpometacarpal joints (without thumb)

These are the joints between the distal row of carpals and the metacarpals.

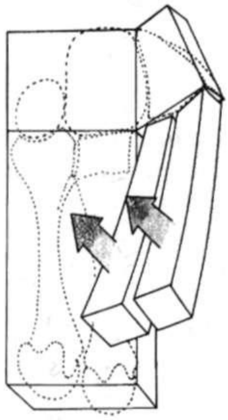


The articular surfaces are straight. They allow slight sliding/gliding and flexion/extension movements.

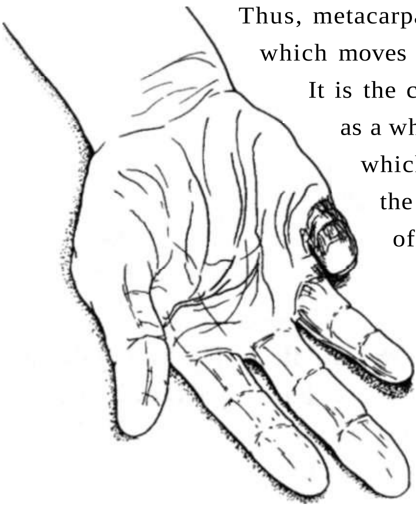


The range of these movements increases progressively from metacarpal II through V.

As a result of the anterior curvature of the carpals, the plane of carpometacarpal joints IV and V is oblique to that of joints II and III.



Thus, metacarpals IV and V can flex, which moves them toward the thumb. It is the carpometacarpal movements as a whole which bring about the anterior depression of the hand.

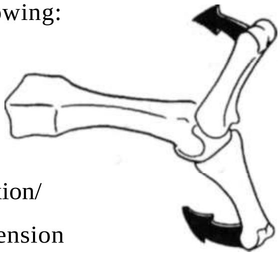


This depression is made complete by the opposition of the thumb.

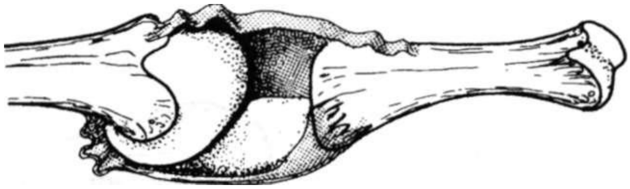
Metacarpophalangeal joints

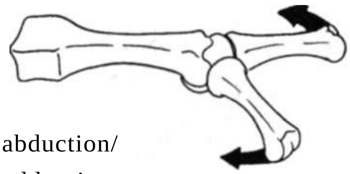
[The third finger serves as the example here.]
These are essentially hinge joints,
allowing:

Range of passive extension is greater than that of active extension.



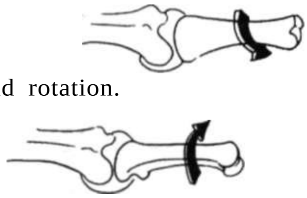
flexion/
extension



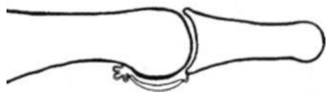


abduction/
adduction..

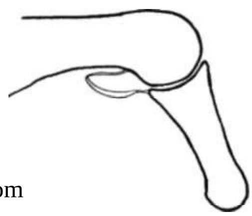
The joint capsule is slack at the front and back, taut at the sides, and reinforced on the palmar surface by the **palmar ligament,** a dense band of fibrocartilaginous tissue. This ligament attaches to the edge of the phalanx and forms a hinge there.



and rotation.



When the joint is extended, the ligament stretches over the surface of the phalangeal base

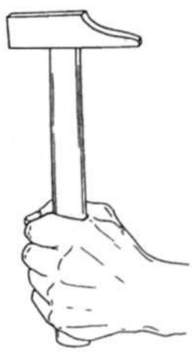


When the joint is flexed, it folds due to its hinge-like structure and the folds of the capsule.

The capsule is reinforced by collateral ligaments which run from the tubercle of the metacarpal head to the lateral sides of the base of the phalanx. Since they originate from the dorsal side of the metacarpal head, which is somewhat narrower than the palmar side, these ligaments are slack in extension and taut in flexion.

Consequently, movements of abduction/adduction and rotation are impossible when the joint is in full flexion.

When the metacarpophalangeal joints are in extension or slight flexion, passive abduction/adduction and rotation allow the hand to adapt itself to grasp a variety of shapes.

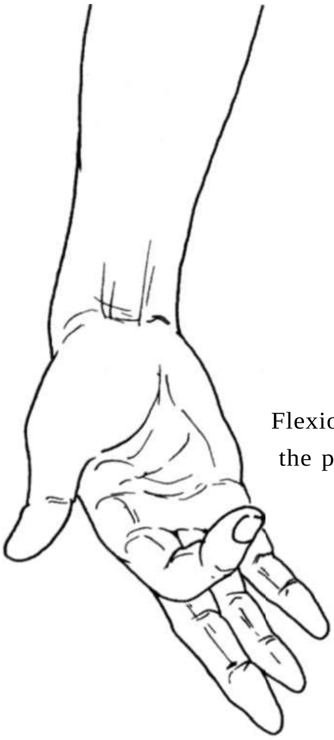


When these joints are in a more flexed position, they become less flexible but also more stable, which is helpful for feats requiring strength or force.

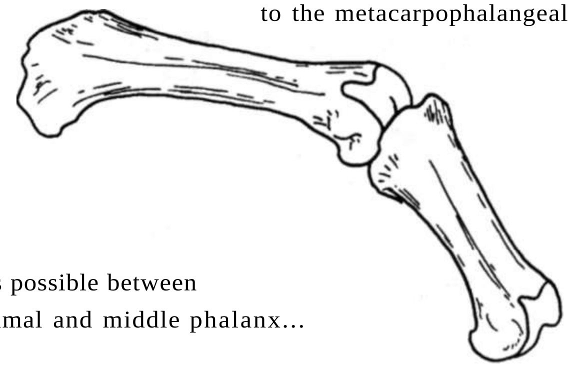
The collateral ligaments expand like a fan toward the palmar ligament.

Interphalangeal joints

The articular surfaces of these joints can be compared to a convex double-track, which articulates with a concave double-track. They allow for anterior and posterior movements (in the sagittal plane).

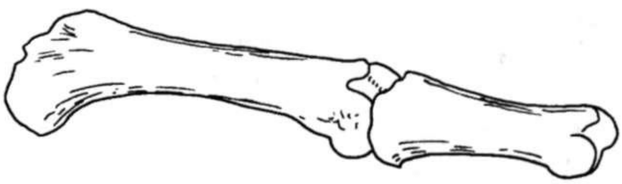


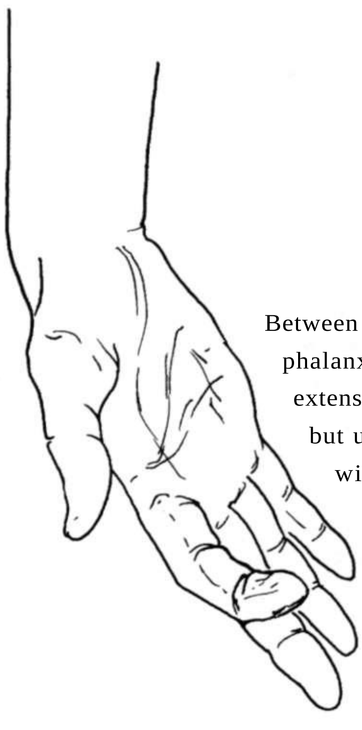
The capsule and ligaments are arranged similarly to the metacarpophalangeal joints.



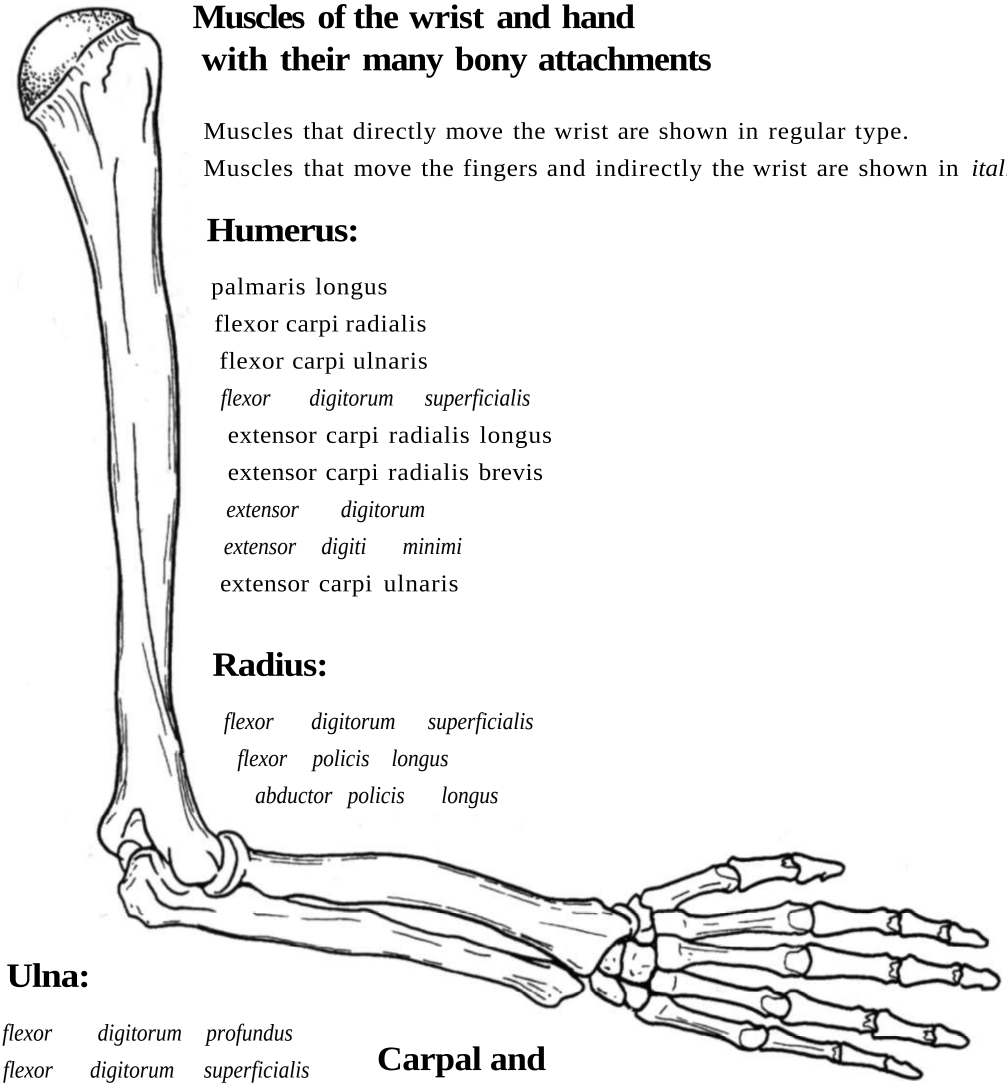
Flexion is possible between the proximal and middle phalanx...

...but extension is usually limited to 180°.





Between the middle and distal phalanx, flexion is possible; extension is also possible, but usually within a limited range.



Muscles of the wrist and hand with their many bony attachments

Muscles that directly move the wrist are shown in regular type.
Muscles that move the fingers and indirectly the wrist are shown in *italic.*

Humerus:

palmaris longus
flexor carpi radialis
flexor carpi ulnaris
flexor digitorum superficialis
extensor carpi radialis longus
extensor carpi radialis brevis
extensor digitorum
extensor digiti minimi
extensor carpi ulnaris

Radius:

flexor digitorum superficialis
flexor policis longus
abductor policis longus

Ulna:

flexor digitorum profundus
flexor digitorum superficialis
flexor policis longus
flexor carpi ulnaris
abductor pollicis longus
extensor pollicis longus
extensor pollicis brevis
extensor indicis
extensor carpi ulnaris

Carpal and metacarpal joints:

palmaris longus
flexor carpi radialis
flexor carpi ulnaris
extensor carpi radialis longus
extensor carpi radialis brevis
extensor carpi ulnaris
abductor pollicis longus

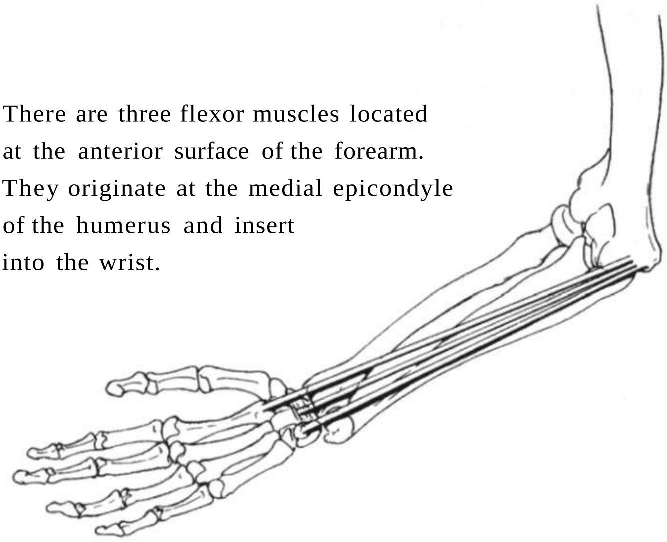
Phalanges:

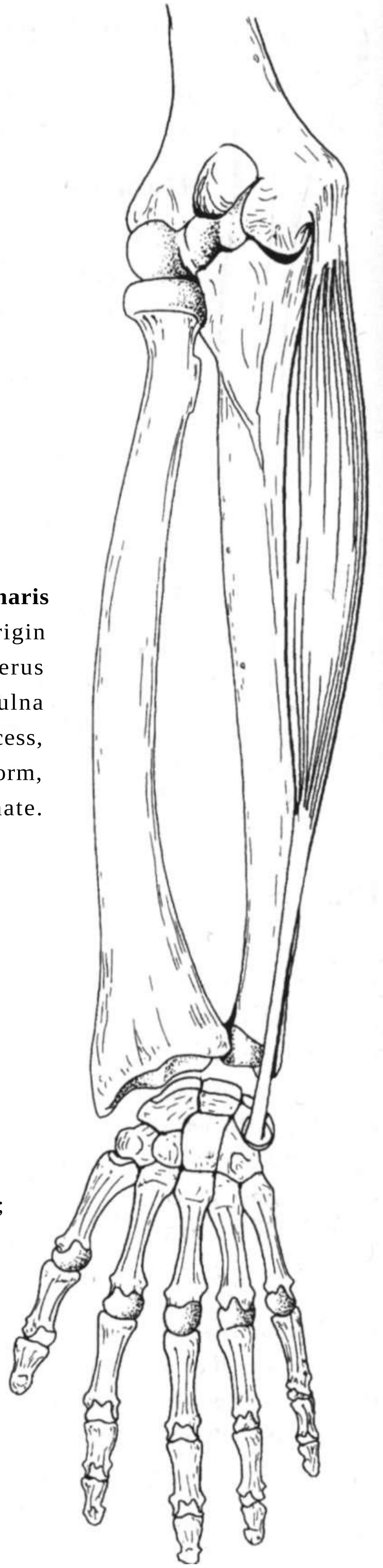
flexor digitorum profundus
flexor digitorum superficialis
flexor policis longus
extensor pollicis longus
extensor pollicis brevis
extensor digitorum
extensor indicis
extensor digiti minimi

In addition, there are muscles that only attach to the bones of the hand, the *intrinsic muscles of the hand.* The muscles that move the thumb and form the mound on the palm at the base of the thumb are called the *thenar eminence.* The muscles that move the little finger and form a fleshy eminence on the palm along the ulnar margin are called *hypothenar eminence* There are also intrinsic muscles located between the metacarpals, called the *interosseous* and *lumbrical* muscles.

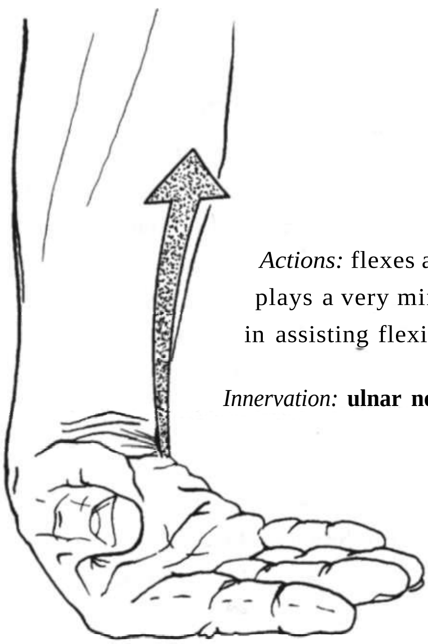
Flexors of the wrist

There are three flexor muscles located at the anterior surface of the forearm. They originate at the medial epicondyle of the humerus and insert into the wrist.



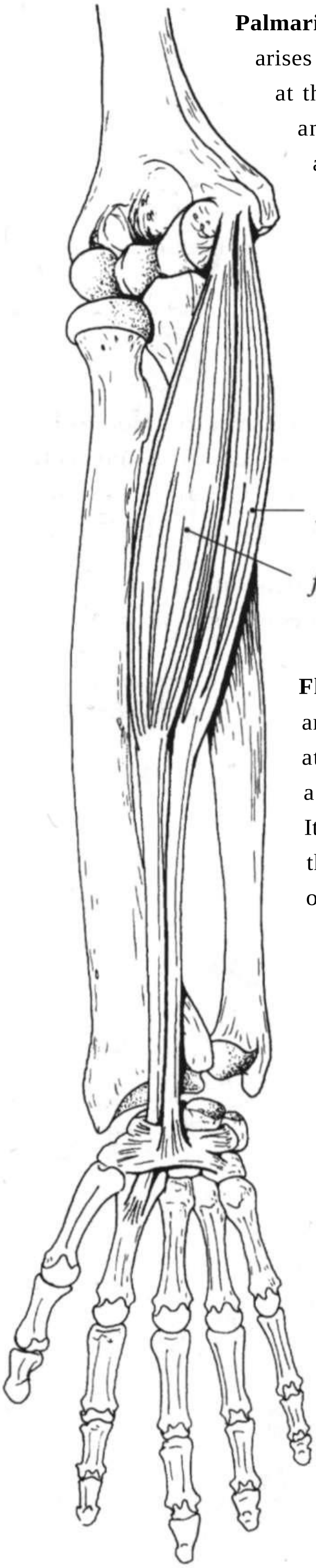


Flexor carpi ulnaris
runs from the common flexor origin at the medial epicondyle of the humerus and descends along the medial ulna and styloid process, inserting on the pisiform, and also the hamate.



Actions: flexes and adducts the wrist; plays a very minor role in assisting flexion of the elbow

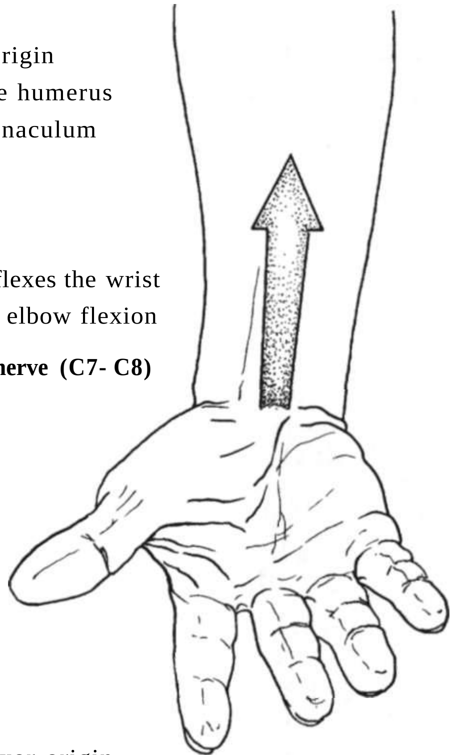
Innervation: **ulnar nerve (C7-C8)**



Palmaris longus
arises from the common flexor origin
at the medial epicondyle of the humerus
and inserts on the flexor retinaculum
and palmar aponeurosis.

Actions: flexes the wrist
and assists weakly in elbow flexion

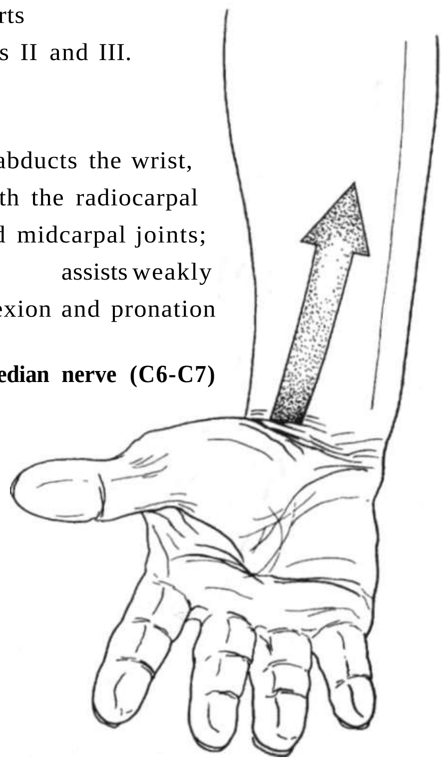
Innervation: **median nerve (C7- C8)**



Flexor carpi radialis
arises from the common flexor origin
at the medial epicondyle of the humerus
and then runs down the forearm.
Its tendon runs through
the carpal tunnel and inserts
on the bases of metacarpals II and III.

Actions: flexes and abducts the wrist,
acting on both the radiocarpal
and midcarpal joints;
assists weakly
in elbow flexion and pronation

Innervation: **median nerve (C6-C7)**

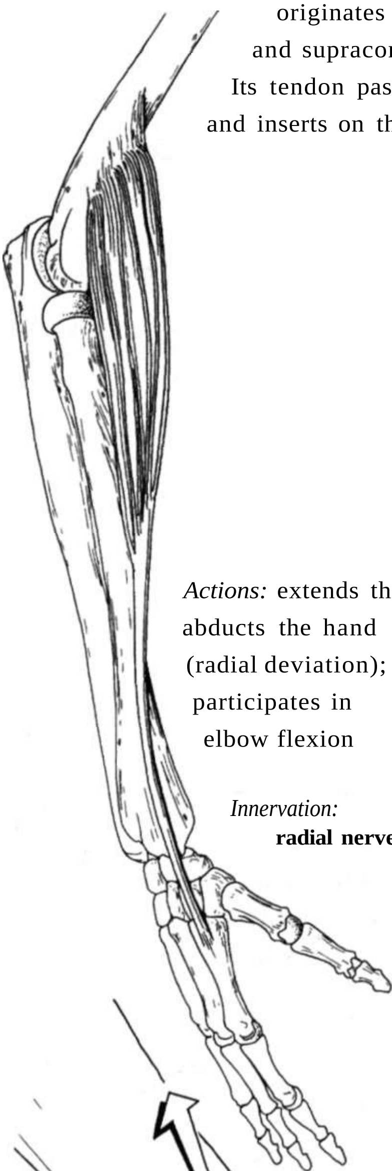


Extensors of the wrist

Radialis muscles

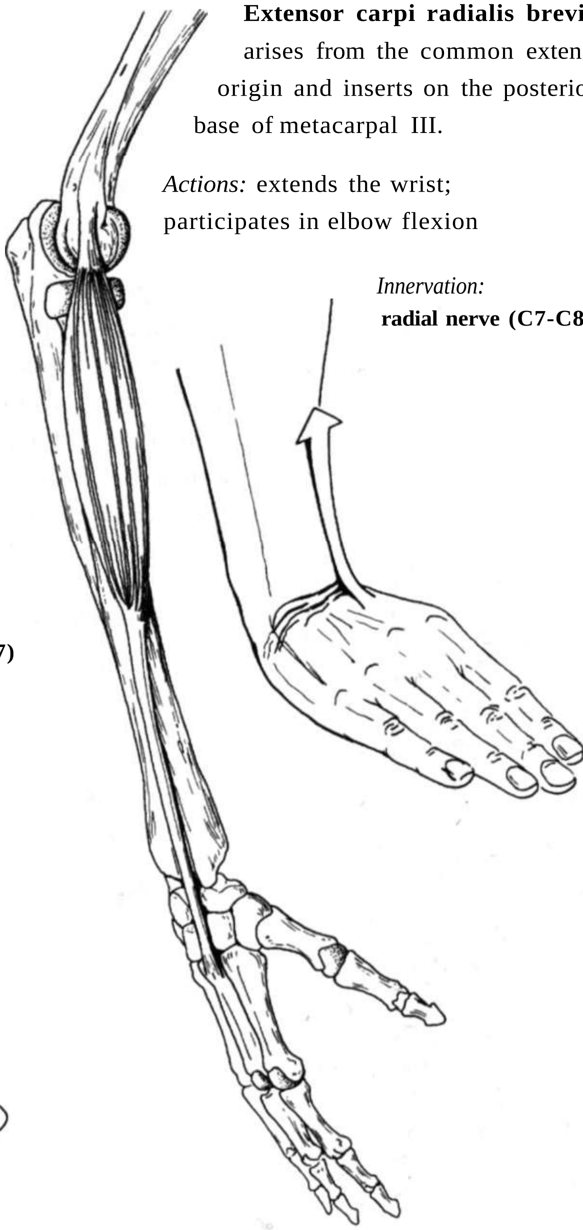
These two muscles pass lateral to the radius, through a fibrous sheath at the level of the wrist, and end on the posterior side of the hand.

Extensor carpi radialis longus
originates from the lateral epicondyle (common extensor origin) and supracondylar ridge of the humerus.
Its tendon passes under the extensor retinaculum and inserts on the posterior base of metacarpal II.



Actions: extends the wrist, abducts the hand (radial deviation); participates in elbow flexion

Innervation:
radial nerve (C6-C7)

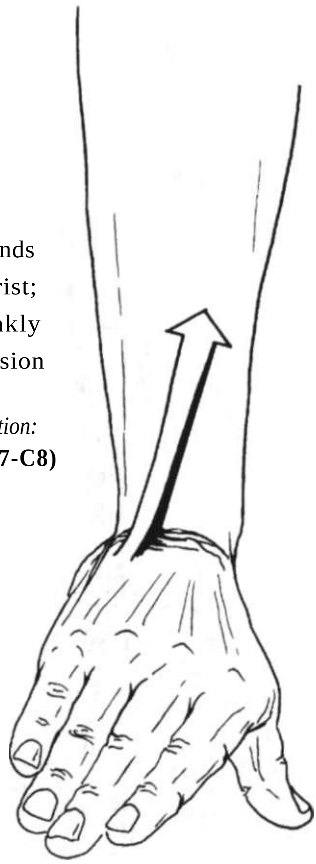


Extensor carpi radialis brevis
arises from the common extensor origin and inserts on the posterior base of metacarpal III.

Actions: extends the wrist; participates in elbow flexion

Innervation:
radial nerve (C7-C8)

Extensor carpi ulnaris
originates from the common extensor origin and the posterior border of the ulna, passes under the extensor retinaculum, and inserts on the posterior base of metacarpal V.

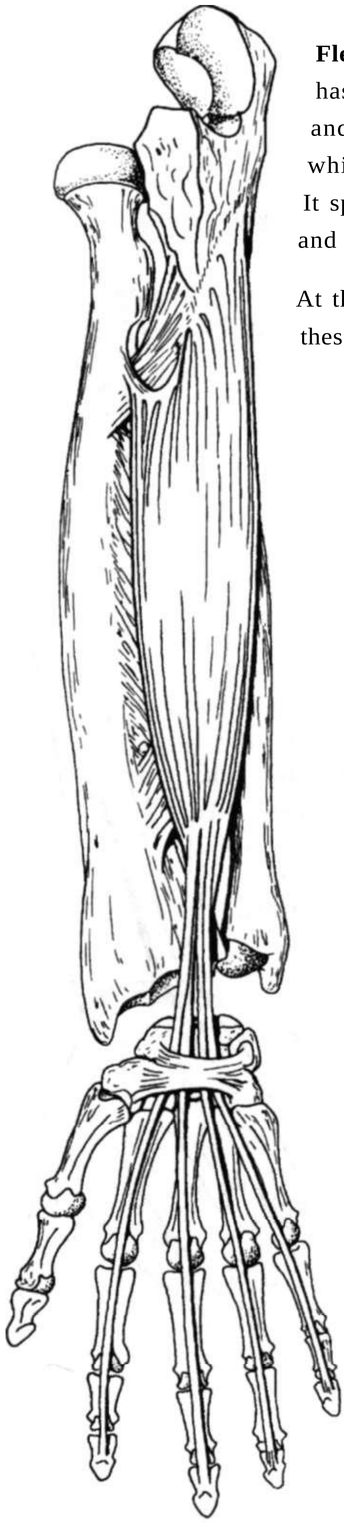


Actions: extends and adducts the wrist; participates weakly in elbow extension

Innervation:
radial nerve (C7-C8)

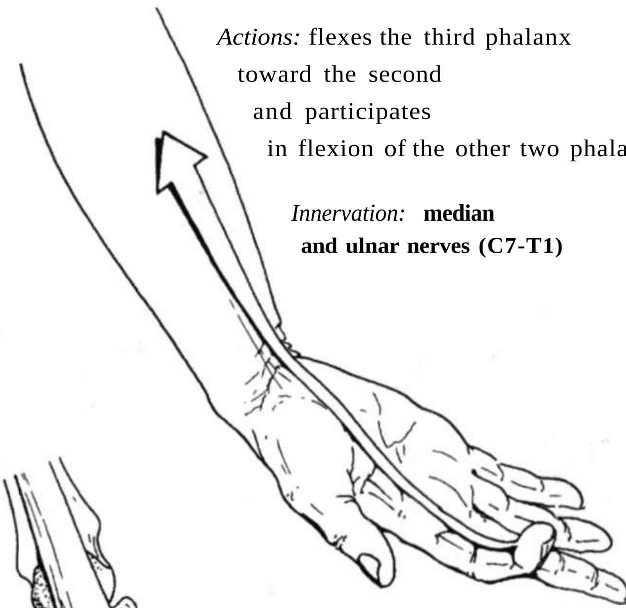
Extrinsic flexors of the fingers

These are two muscles whose mass is arranged on top of each other on the anterior surface of the forearm and whose tendons end on the phalanges.



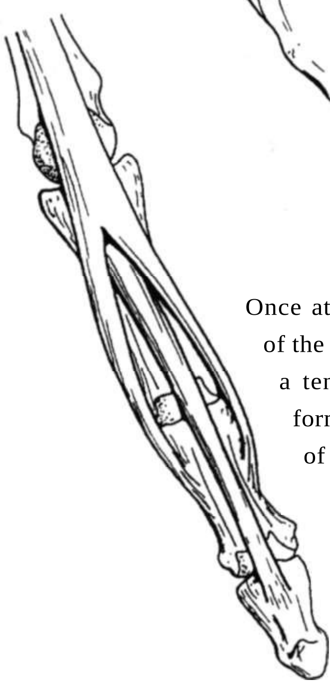
Flexor digitorum profundus has a broad origin on the anterior and medial ulna, and the medial half of the interosseous membrane which connects the ulna and radius. It splits into four tendons which pass through the carpal tunnel and insert on the distal phalanges of fingers II through V.

At the level of the metacarpals, these tendons attach to the lumbrical muscles.



Actions: flexes the third phalanx toward the second and participates in flexion of the other two phalanges

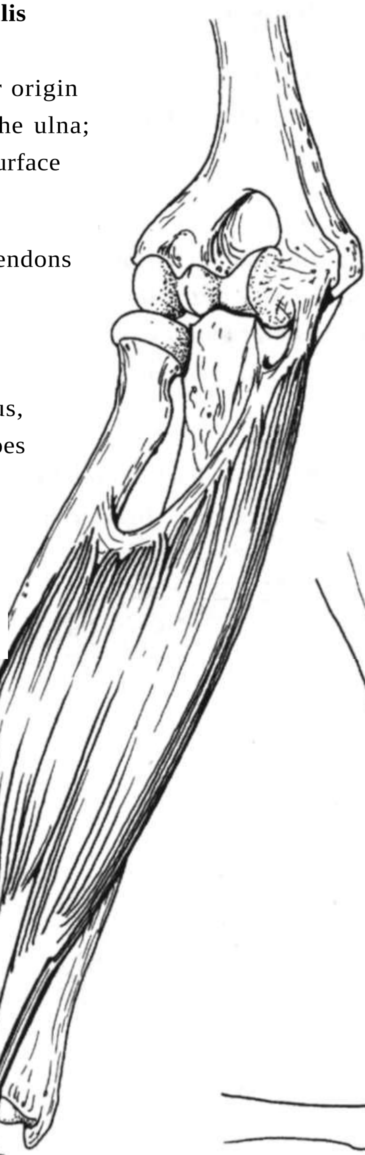
Innervation: **median and ulnar nerves (C7-T1)**



Once at the level of the middle phalanx, a tendon passes through a notch formed when the tendon of the flexor digitorum superficialis splits in two.

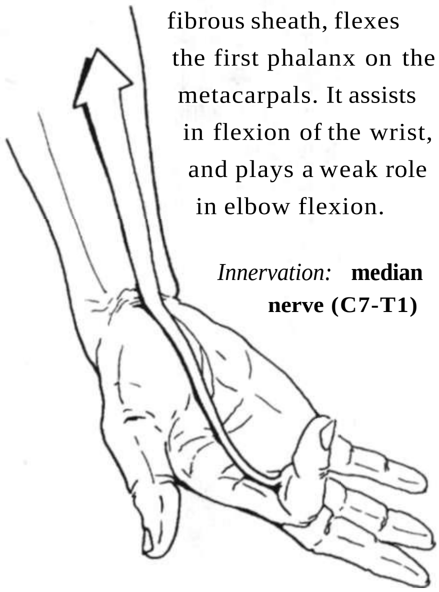
Flexor digitorum superficialis has two heads: one from the common flexor origin and the coronoid process of the ulna; the other from the anterior surface of the radius.

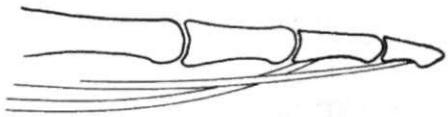
The muscle splits into four tendons which pass through the carpal tunnel (superficial to the tendons of flexor digitorum profundus, of course), split into "Y" shapes (to accommodate passage of other flexor tendons), and inserts bilaterally on the middle phalanges of fingers II through V.



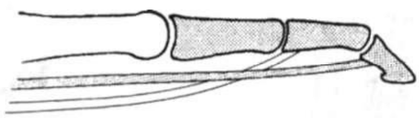

Actions: flexes the second phalanx toward the first, and, due to the fibrous sheath, flexes the first phalanx on the metacarpals. It assists in flexion of the wrist, and plays a weak role in elbow flexion.

Innervation: **median nerve (C7-T1)**

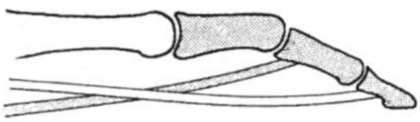




Side view of a finger, showing the tendons of the flexor muscles



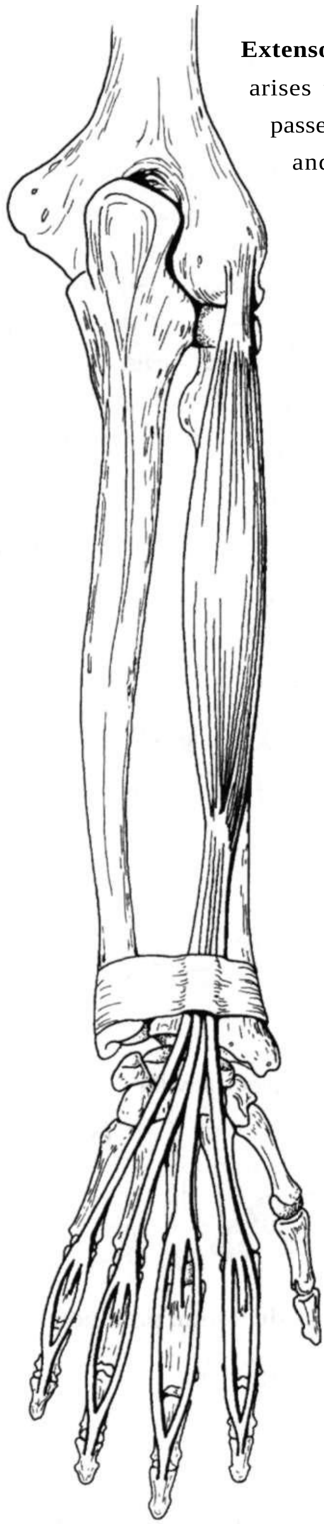
Action of flexor digitorum profundus



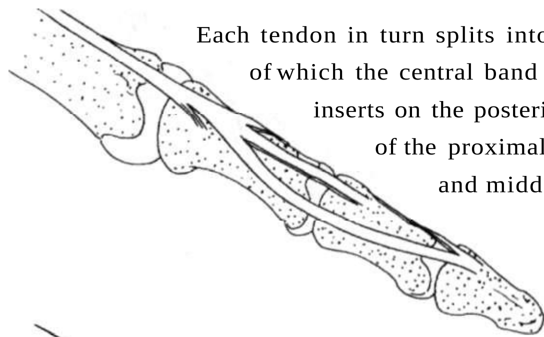
Action of flexor digitorum superficialis

Extrinsic extensors of the fingers

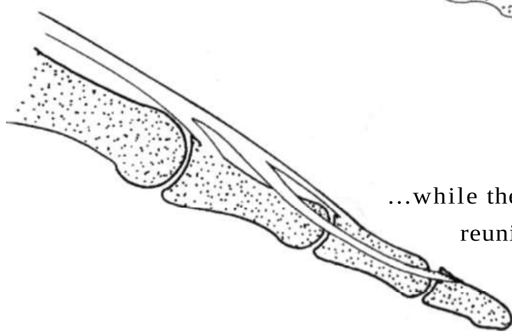
These three muscles are located on the posterior side of the forearm. Their tendons insert on the posterior side of the hand.



Extensor digitorum
arises from the common extensor origin, passes down the back of the forearm, and splits into four tendons.



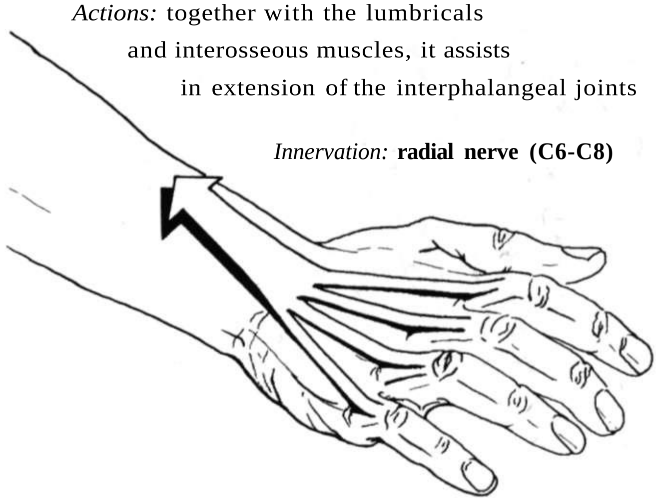
Each tendon in turn splits into three bands, of which the central band inserts on the posterior base of the proximal and middle phalanges...



...while the two lateral bands reunite at the base of the distal phalanx.

Actions: together with the lumbricals and interosseous muscles, it assists in extension of the interphalangeal joints

Innervation: **radial nerve (C6-C8)**

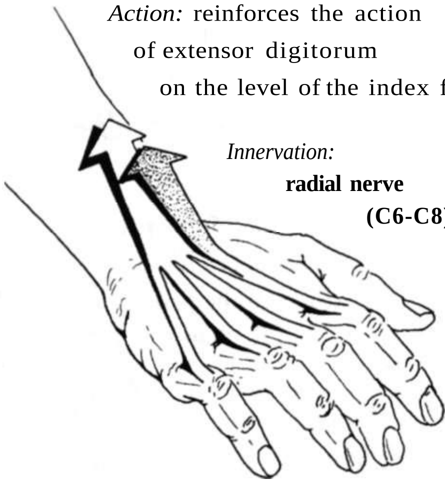


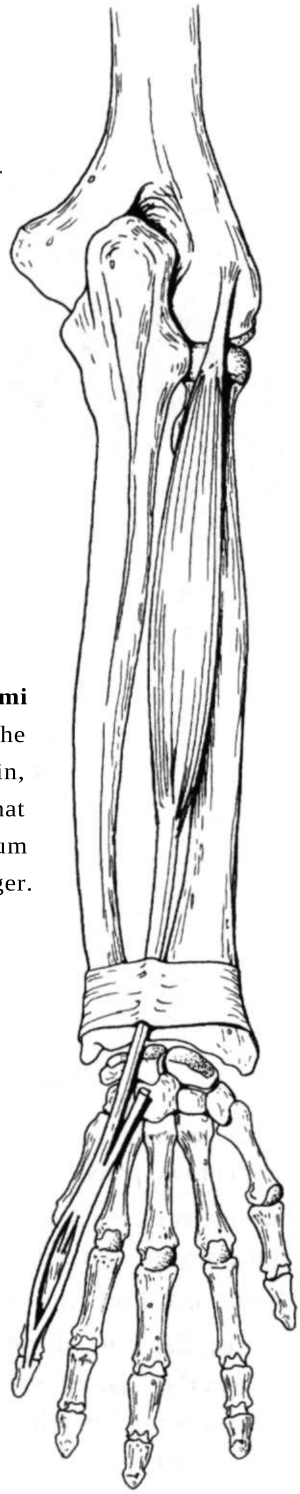
Extensor indicis

arises from the posterior ulna and interosseous membrane, below the origin of extensor pollicis longus. Its tendon joins that of extensor digitorum leading to the index finger.

Action: reinforces the action of extensor digitorum on the level of the index finger

Innervation:
radial nerve (C6-C8)



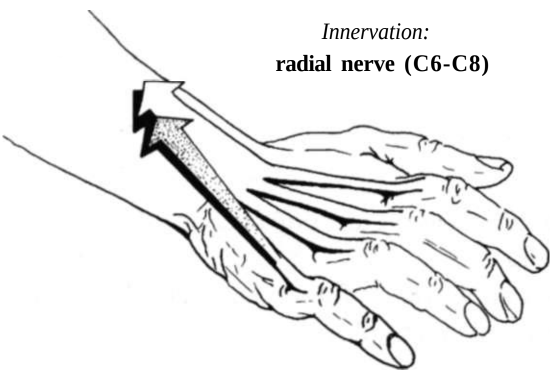


Extensor digiti minimi

originates from the common extensor origin, and its tendon joins that of extensor digitorum leading to the little finger.

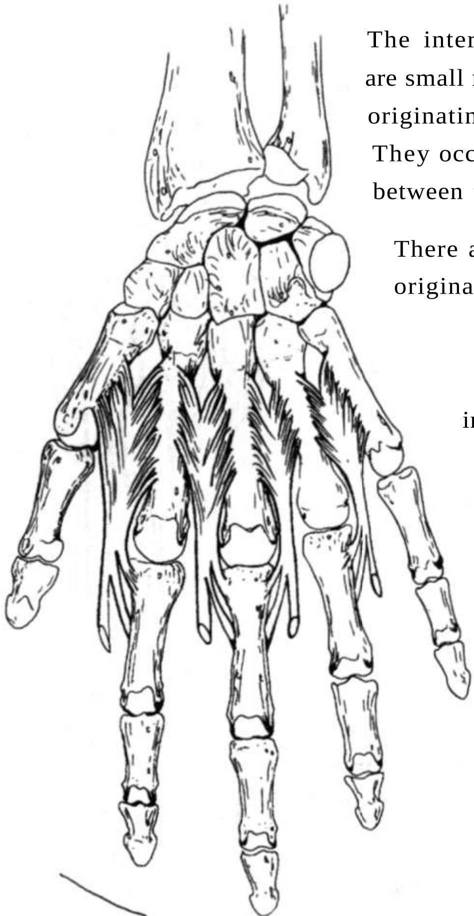
Action: reinforces the action of extensor digitorum on the level of the little finger

Innervation:
radial nerve (C6-C8)



Intrinsic muscles that move the fingers

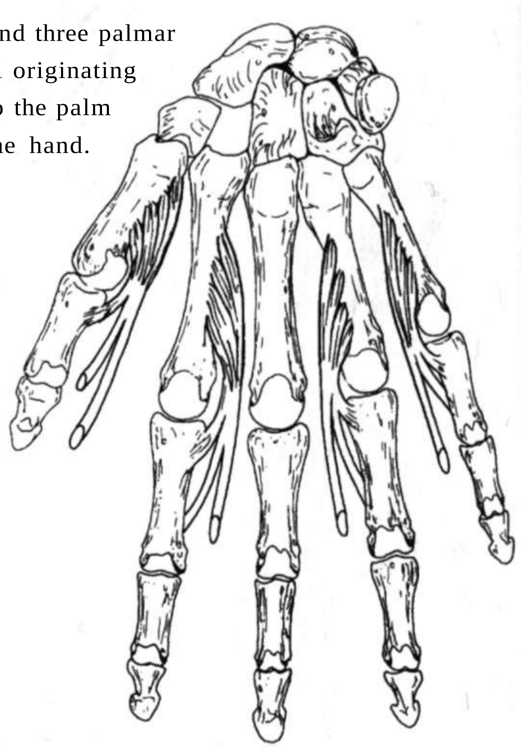
The intrinsic muscles of the hand are those that attach solely to the bones of the hand.

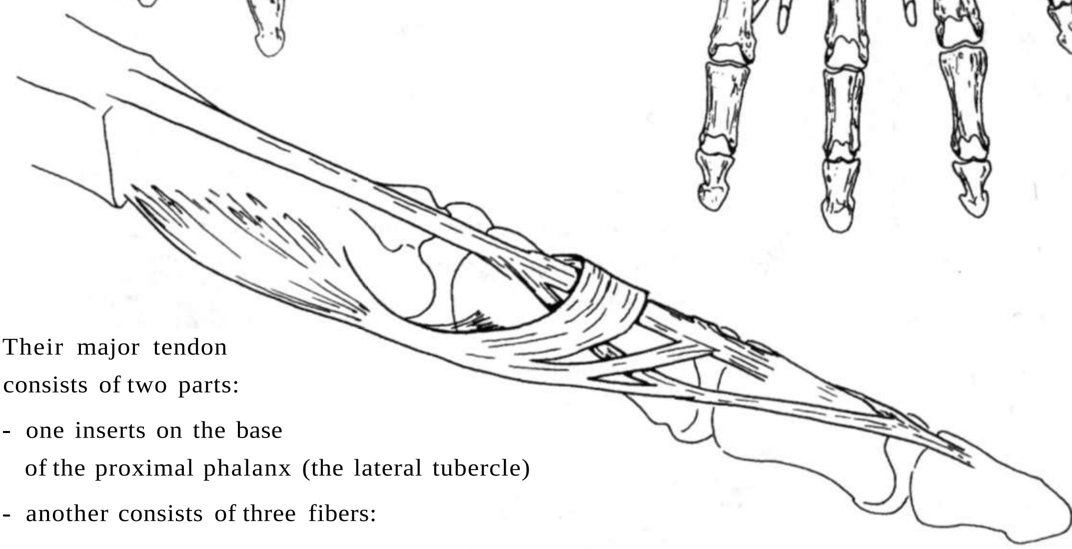


The interossei are small muscles originating from the metacarpals. They occupy the spaces between the metacarpals.

There are four dorsal interossei originating close to the back of the hand.

... and three palmar interossei originating closer to the palm of the hand.



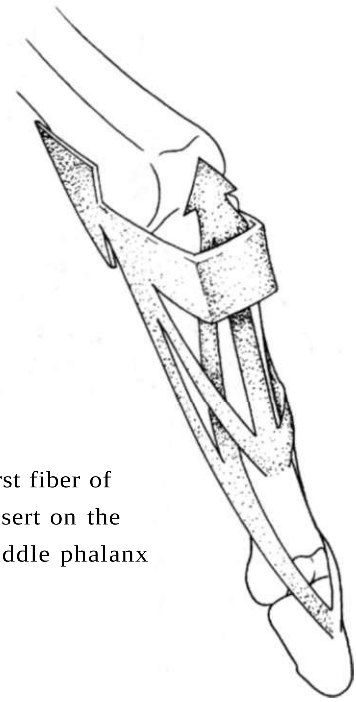


Their major tendon consists of two parts:

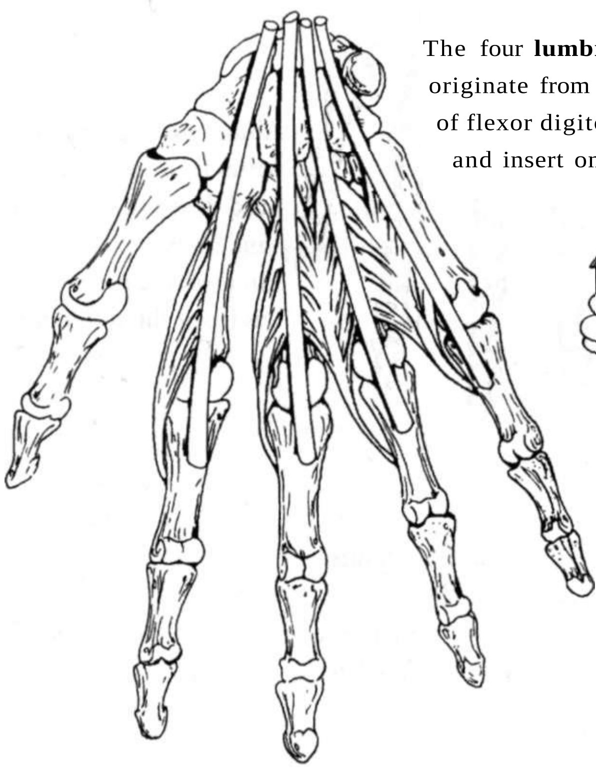
- one inserts on the base of the proximal phalanx (the lateral tubercle)
- another consists of three fibers:
  - the first skirts the phalanx and joins the identical fibers on the adjacent interosseous
  - the second and third insert on the edges of the extensor digitorum tendon at the level of the proximal and middle phalanges.

Actions: the dorsal interossei abduct and the palmar interossei adduct the fingers

Innervation: **ulnar nerve (C8-T1)**



Acting together bilaterally, the first part of the tendon and the first fiber of the second part flex the proximal phalanx. The two fibers that insert on the extensor tendon pull on the proximal phalanx and extend the middle phalanx toward the proximal, and the distal phalanx toward the middle.



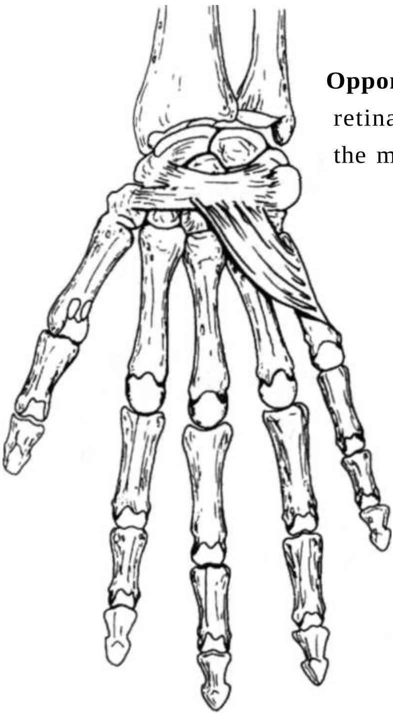
The four **lumbricals** originate from the tendons of flexor digitorum profundus, and insert on the tendons of extensor digitorum.

Actions: collectively, the lumbricals flex the metacarpophalangeal joints and extend the interphalangeal joints

Innervation: **ulnar nerve (C8-T1)**

Intrinsic muscles of 5 th finger

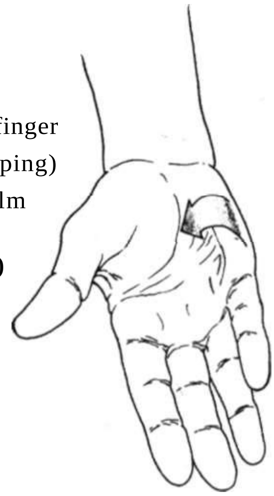
The bodies of the **hypothenar muscles** provide the bulk of the hypothenar eminence on the medial side of the palm.

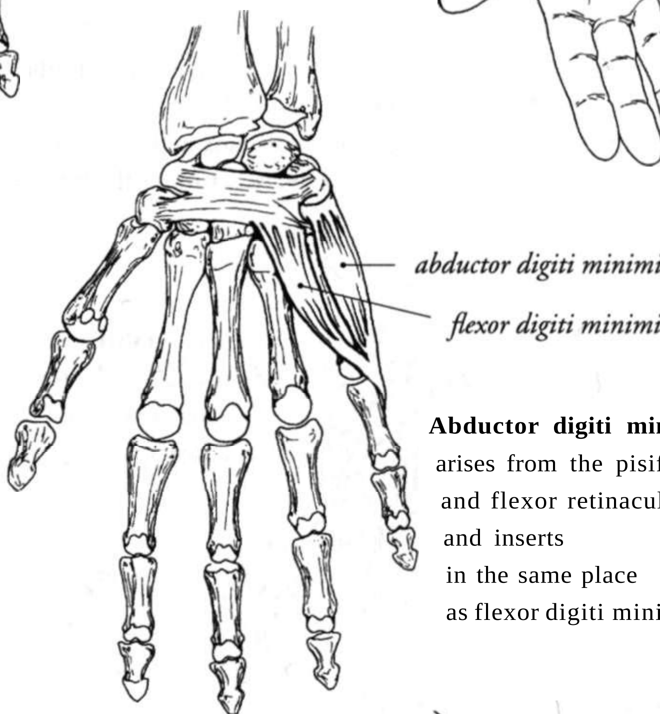


Opponens digiti minimi originates from the flexor retinaculum and hamate hook, and inserts on the medial surface of metacarpal V.

Action: helps move the little finger toward the thumb (for grasping) and create the curvature of the palm

Innervation: **ulnar nerve (C8-T1)**

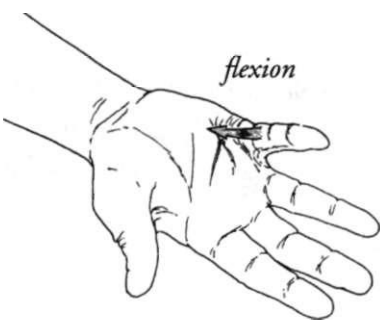




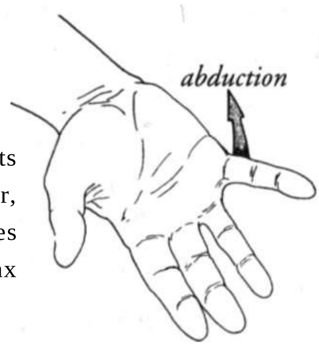
Flexor digiti minimi
has the same origin as opponens, and inserts on the base of the proximal phalanx of finger V.

Abductor digiti minimi
arises from the pisiform and flexor retinaculum, and inserts in the same place as flexor digiti minimi.

Action: flexes the little finger



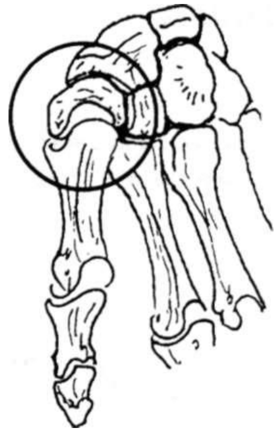
Actions: abducts the little finger, and flexes its proximal phalanx



Innervation: **ulnar nerve (C8-T1)**

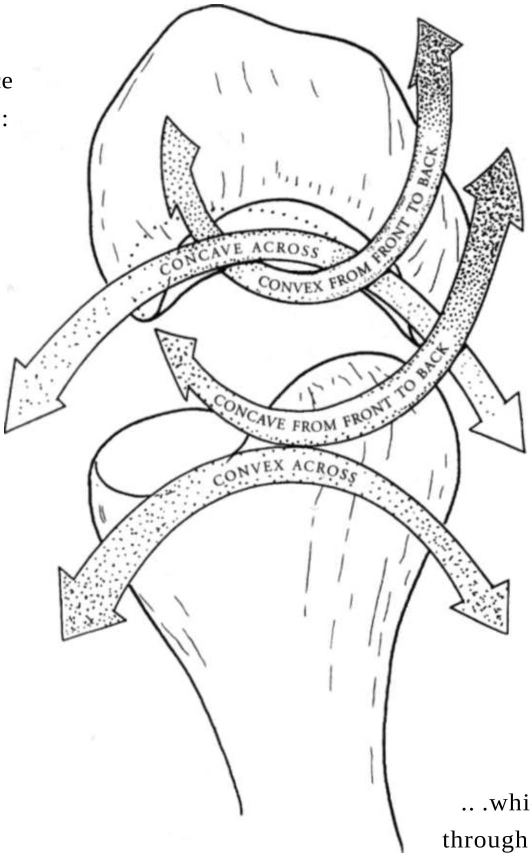
Innervation: **ulnar nerve (C8-T1)**

Carpometacarpal articulation of thumb



The inferior surface of the trapezium is:

- concave across
- convex from front to back.



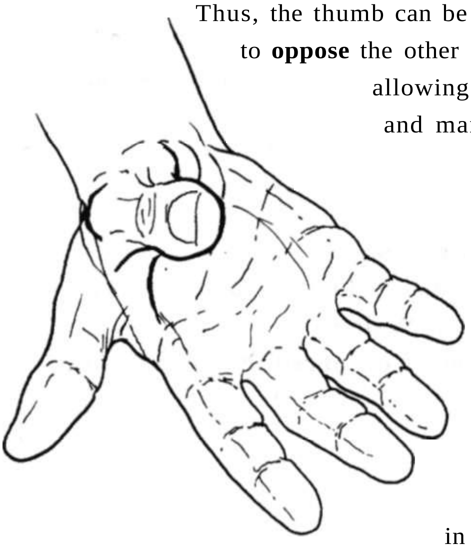
The superior surface of metacarpal I, which articulates with it, is:

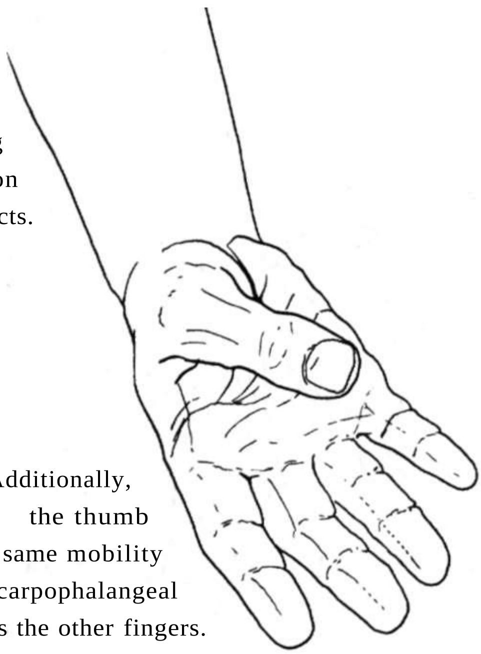
- concave from front to back
- convex across.

Together, the two structures form a saddle joint...

.. .which allows the thumb to move through the three planes of movement described on pages 8-10.

Thus, the thumb can be moved to **oppose** the other fingers, allowing grasping and manipulation of objects.



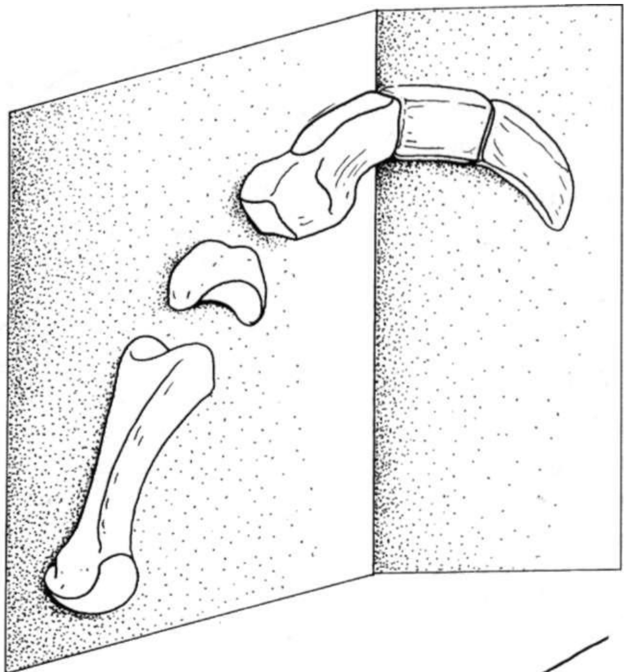


Additionally, the thumb has the same mobility in its metacarpophalangeal and interphalangeal joints as the other fingers.

Thumb

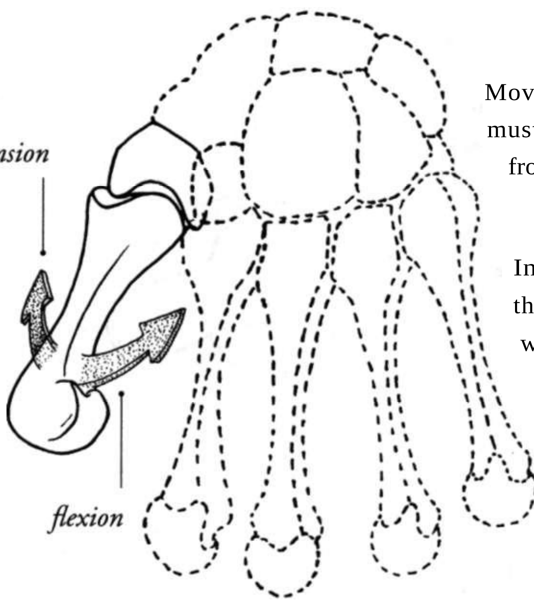
The thumb has a specific orientation vis-a-vis the rest of the hand:

• the scaphoid bone is positioned at a 40° angle anteriorly to the carpal plane



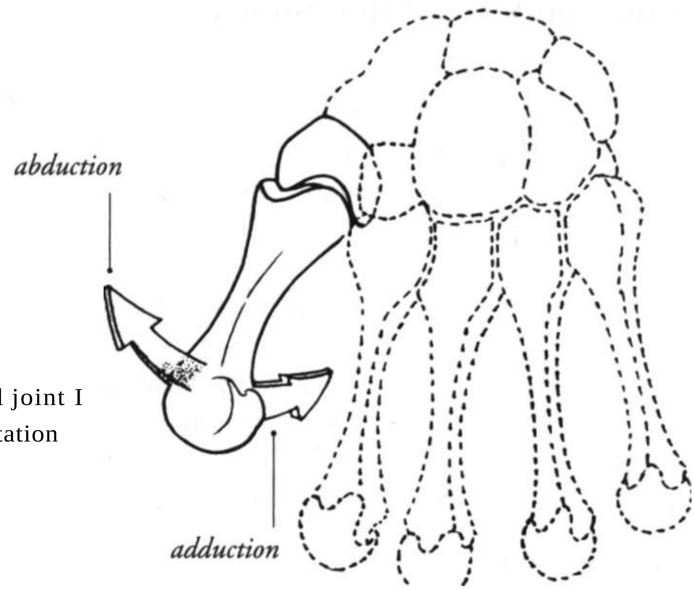
• the first metacarpal is positioned at a 20° angle to the second metacarpal and placed at a 40° angle anteriorly.

Thus, in a hand at rest, the thumb faces the other fingers at a right angle.



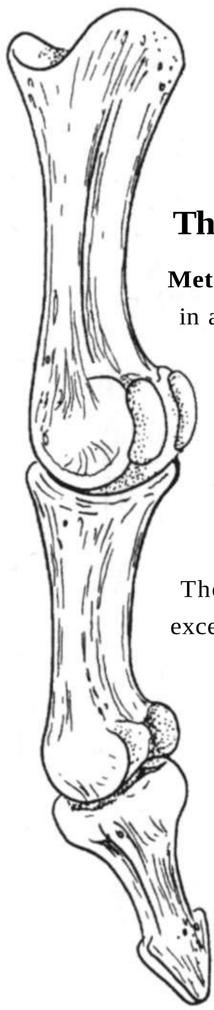
Movements of the thumb (i.e., metacarpal I) must be defined differently from those of the other fingers.

In **extension,** the metacarpal moves posterolaterally, while in **flexion** it moves anteromedially, closer to the palm.



In **abduction,**
it moves anterolaterally,
while in **adduction**
it moves posteromedially.

The capsule of carpometacarpal joint I is slack, allowing some axial rotation in addition to the movements described above, and further enhancing the thumb's mobility.



Thumb joints

Metacarpophalangeal joint I differs from II through V in a few respects:

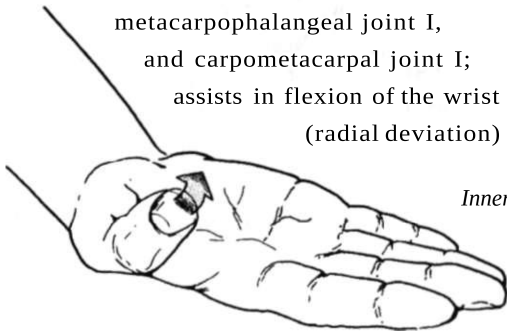
- It is more massive.
- The capsule is not as taut and allows some axial rotation.
- Two small sesamoid bones are embedded in the palmar fascia, and serve for tendon attachment.

The **interphalangeal joint** is similar to those of fingers II through V, except for being more massive.

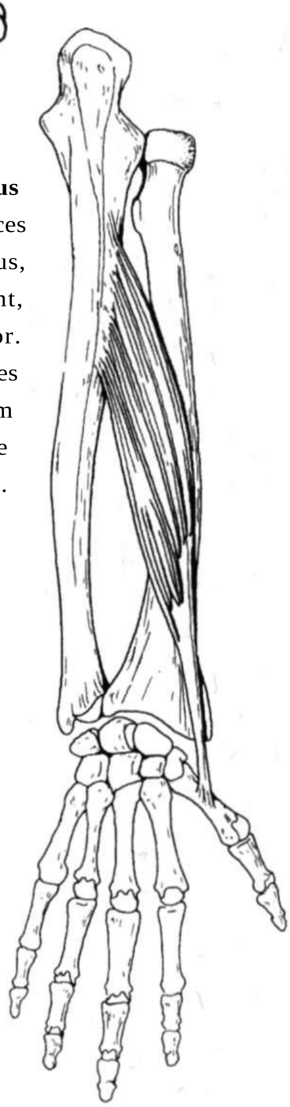
Extrinsic muscles of the thumb

Flexor pollicis longus
originates from the anterior radius.
Its tendon passes through the carpal tunnel
and inserts on the base of the distal phalanx of the thumb.

Actions: flexion of interphalangeal joint I,
metacarpophalangeal joint I,
and carpometacarpal joint I;
assists in flexion of the wrist and abduction
(radial deviation)



Innervation: **anterior interosseous nerve (C7-C8)**



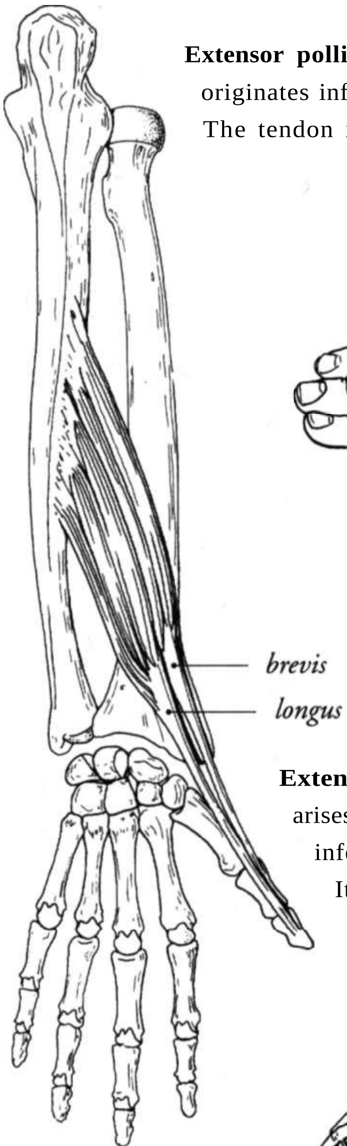
Abductor pollicis longus
arises from the posterior surfaces
of the ulna, radius,
and interosseous ligament,
inferior to supinator.
The tendon passes
under the extensor retinaculum
and inserts on the lateral base
of metacarpal I.

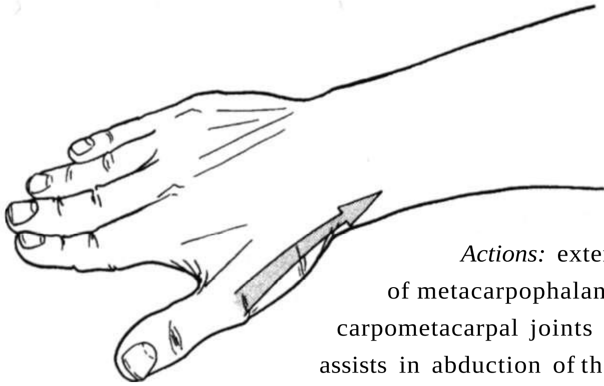
Actions: anteromedial movement
of the thumb; also
assists in flexion of the wrist
and abduction (radial deviation)

Innervation: **radial nerve (C7-C8)**

Extensor pollicis brevis

originates inferior to abductor pollicis longus.
The tendon inserts on the base of the proximal phalanx of the thumb.



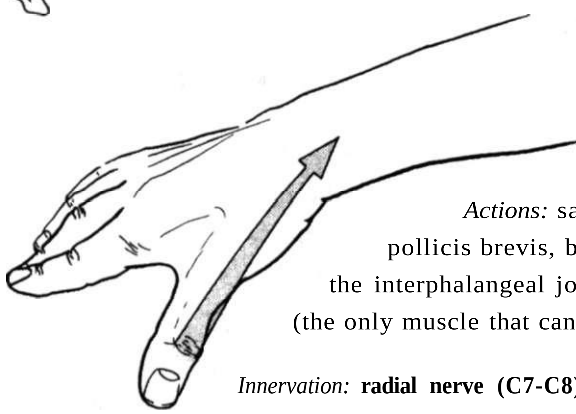


Actions: extension of metacarpophalangeal and carpometacarpal joints of thumb; assists in abduction of thumb

Innervation: **radial nerve (C7-T1)**

Extensor pollicis longus

arises on the posterior ulna and interosseous membrane, inferior to extensor pollicis brevis.
It inserts on the base of the distal phalanx of the thumb.



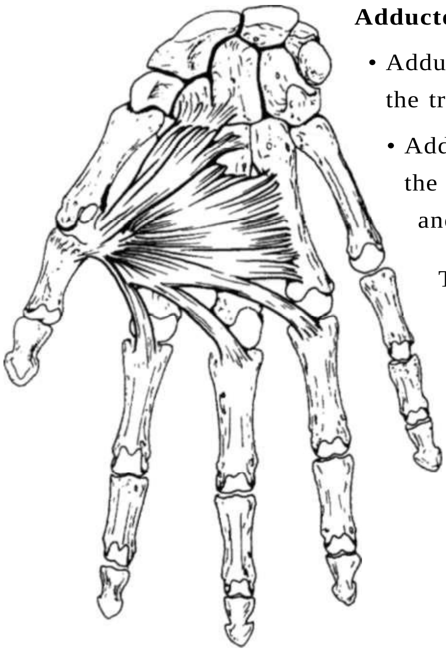
Actions: same as extensor pollicis brevis, but also extends the interphalangeal joint of the thumb (the only muscle that can do this)

Innervation: **radial nerve (C7-C8)**

When the thumb is fully extended, a depression known as the "anatomical snuffbox" can be seen at the posterior base of the thumb.

It is bordered laterally by the tendons of abductor pollicis longus and extensor pollicis brevis, and medially by the tendon of extensor pollicis longus.

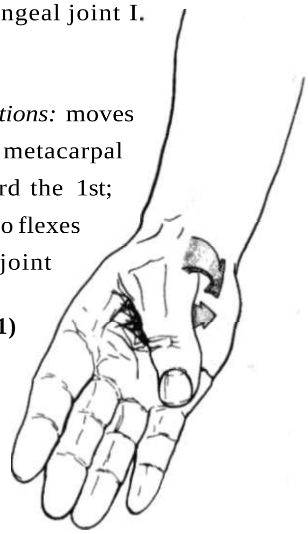
Intrinsic muscles of the thumb



Adductor pollicis has two fibers:

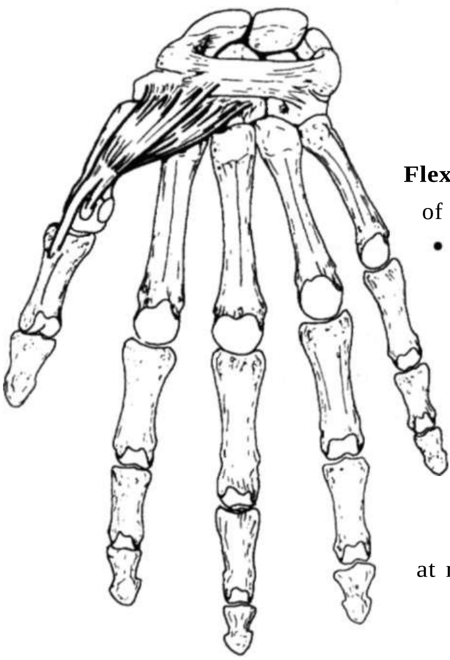
- Adductor pollicis obliquus arises from the trapezoid and capitate bones.
- Adductor pollicis transversus arises from the 2nd and 3rd metacarpals and the corresponding metacarpophalangeal joint.

The two fibers insert on the medial base of the proximal phalanx of the thumb, and the medial sesamoid bone located at metacarpophalangeal joint I.



Actions: moves the 2nd metacarpal toward the 1st; also flexes the metacarpophalangeal joint

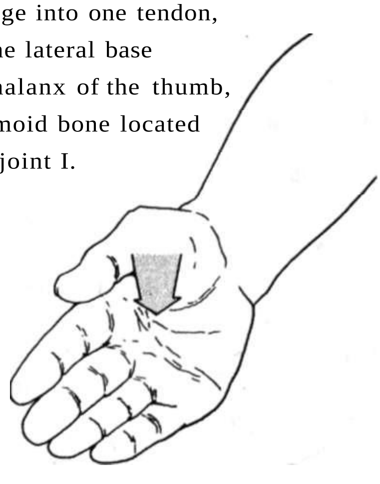
Innervation: **ulnar nerve (C8-T1)**



Flexor pollicis brevis consists of two layers:

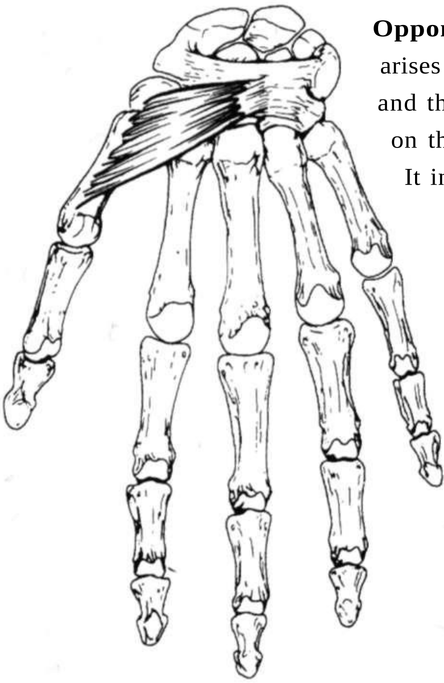
- a deep layer, which arises from the trapezoid and capitate
- a superficial layer, which arises from the trapezium and the flexor retinaculum.

The two layers merge into one tendon, which inserts on the lateral base of the proximal phalanx of the thumb, and the lateral sesamoid bone located at metacarpophalangeal joint I.



Actions: moves the metacarpals anteromedially and in medial rotation, and flexes the proximal phalanx of the thumb

Innervation: **median and ulnar nerves (C8-T1)**



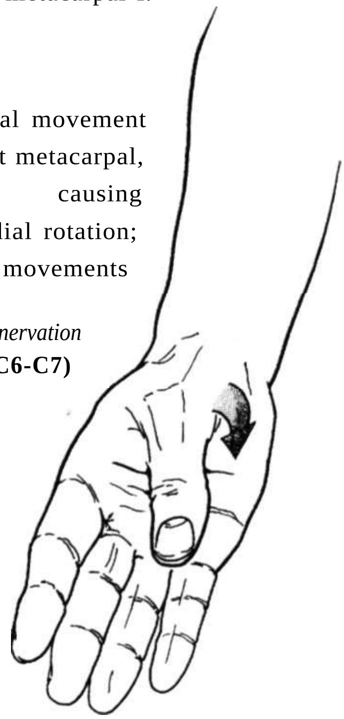
Opponens pollicis

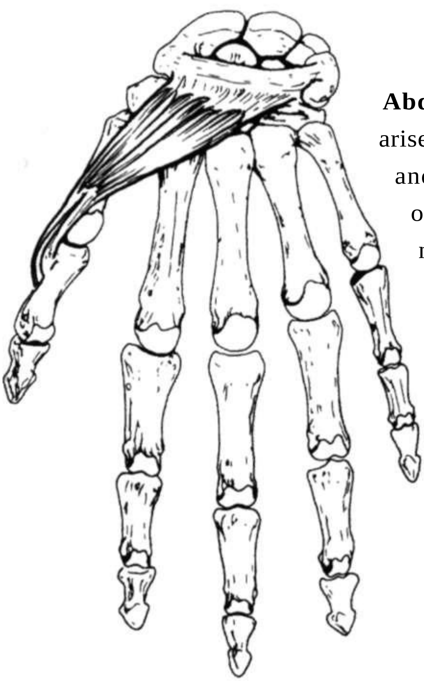
arises from the crest of the trapezium
and the flexor retinaculum
on the anterior medial surface of the first metacarpal.
It inserts on the lateral shaft of metacarpal I.

Actions: anteromedial movement
of the first metacarpal,
causing
a strong medial rotation;
important in grasping movements

Innervation

median nerve (C6-C7)





Abductor pollicis brevis

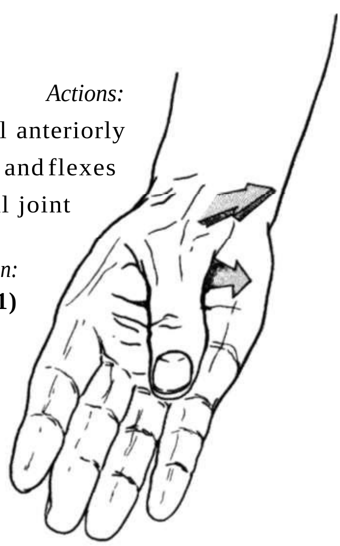
arises from the flexor retinaculum, scaphoid, and trapezium,
and inserts on the lateral base
of the proximal phalanx of the thumb
next to flexor pollicis brevis.

Actions:

pulls the metacarpal anteriorly
and flexes
the metacarpophalangeal joint

Innervation:

median nerve (C8-T1)



CHAPTER SIX

The Hip & Knee

The **hip** is the proximal joint of the lower limbs and connects the femur to the pelvis. It is surrounded by thick muscles, and therefore difficult to palpate or localize.

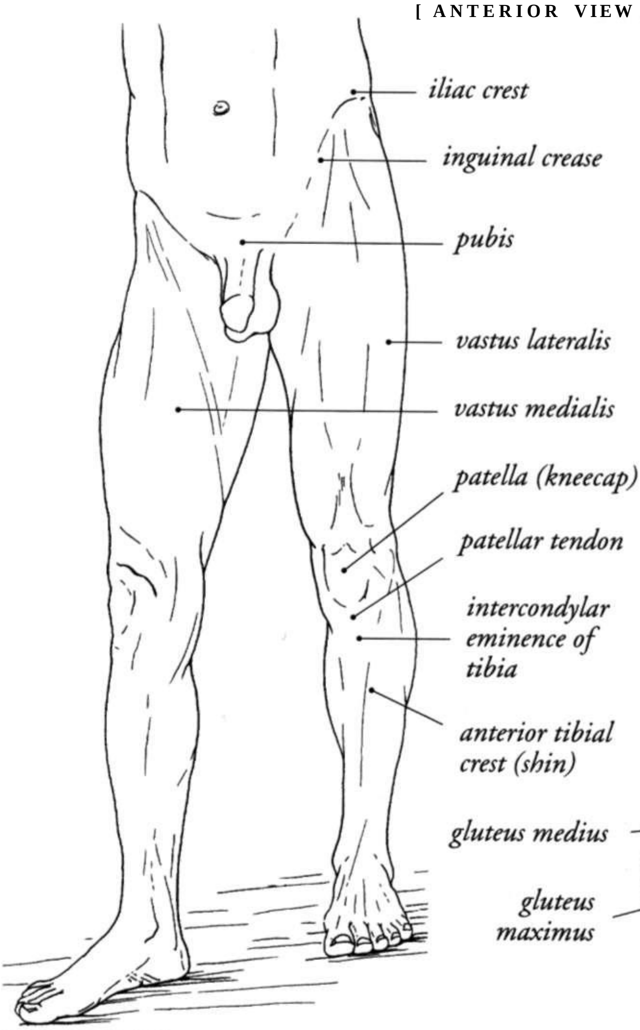
The stability and powerful musculature of this joint are essential for standing and walking. Many physical disciplines require good range of motion (ROM) at the hip. Restrictions in ROM here are common, and typically affect nearby structures such as the lower back, knee, and foot joints. To work with the hip, we therefore need to understand this joint in order to more easily isolate its movements.

The **knee,** an intermediate joint on the lower limb, is primarily capable of flexion and extension. Its mobility allows it to vary the distance between the foot and the trunk to a large degree. Its stability is not due to bone structure, which is rather weak, but rather to the arrangement of ligaments and muscles. The knee receives considerable stress, both from above (body weight) and below (impact of the foot on the ground, footwear).

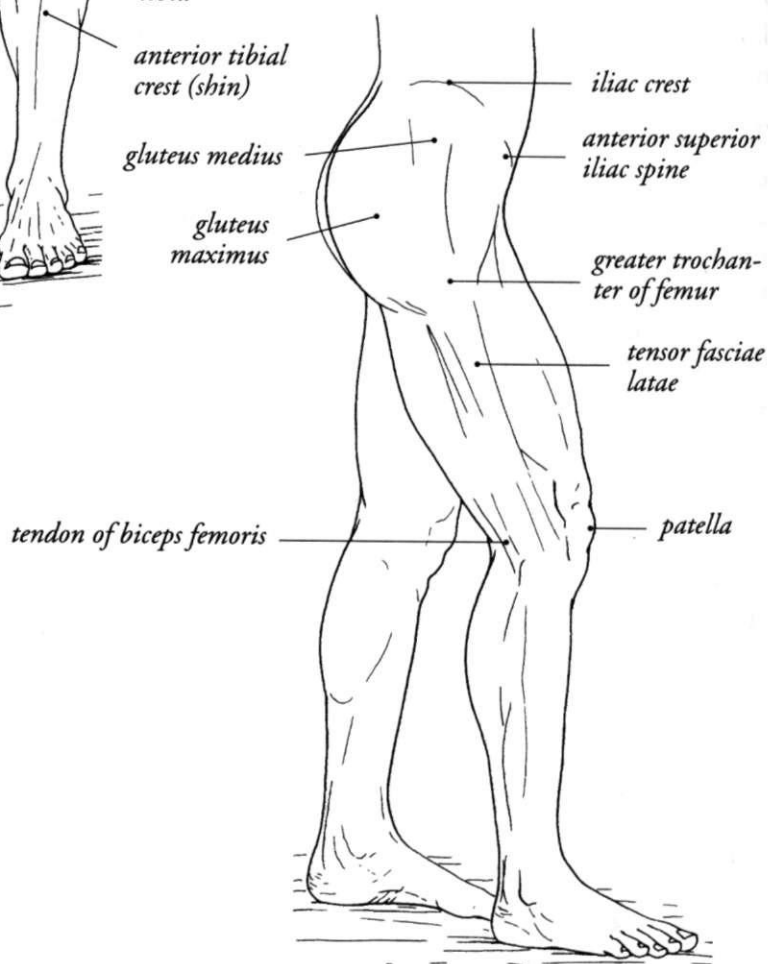
This chapter looks at the hip and knee together, because these two joints have many muscles in common.

Landmarks

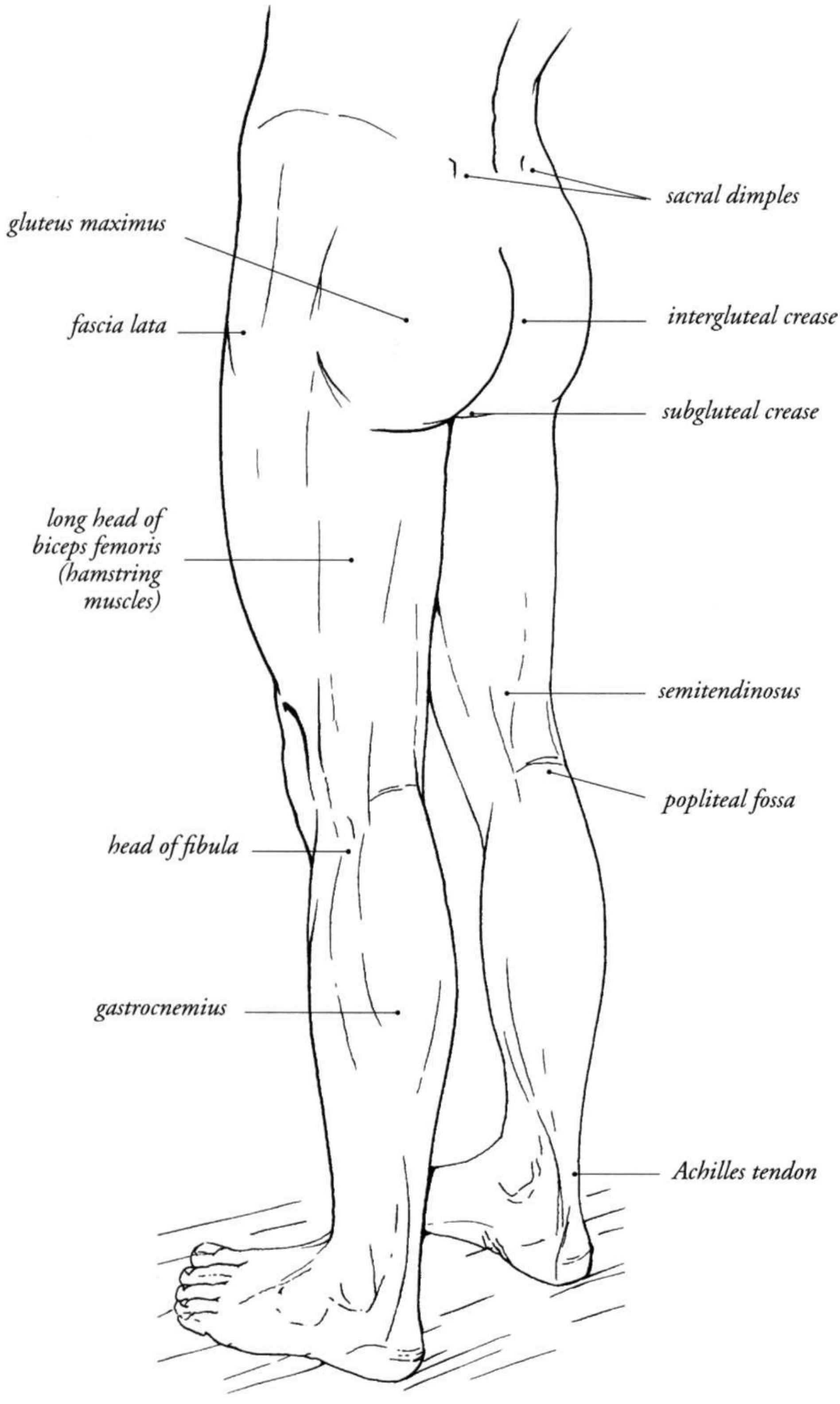
[ANTERIOR VIEW]



[SIDE VIEW]



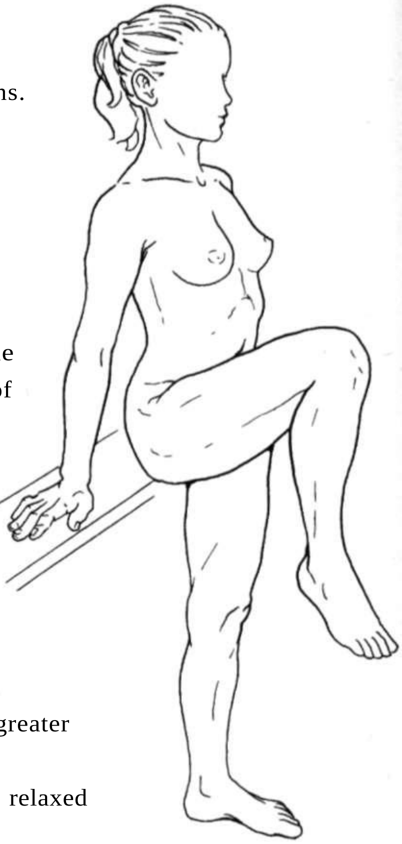
[POSTERIOR VIEW]



Movements of hip

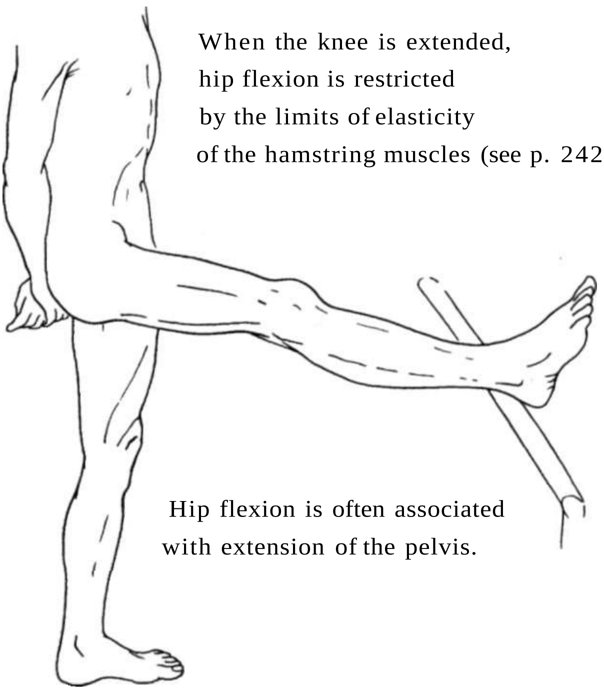
The shape of its articulations (see p. 201-202) allows the hip joint to be moved in many different directions. For ease of study, the movements of the hip are described with respect to the planes they intersect (see p. 8-10).

We assume first that the pelvis is fixed and the femur is moving.



Flexion is the movement in which the angle between the anterior surfaces of the thigh and the trunk decreases. ROM for hip flexion is greater when the knee is also flexed.

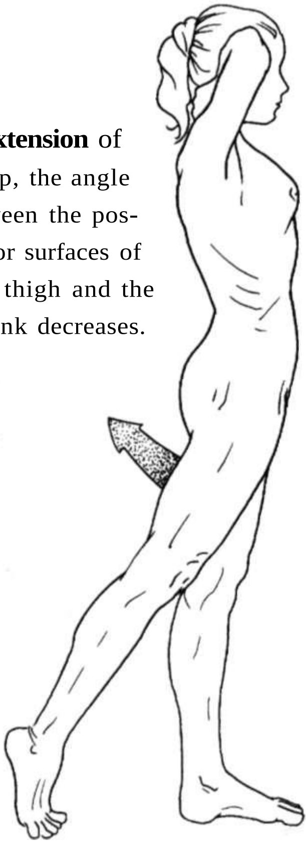
ROM for passive flexion is greater than for active flexion since the flexing muscles are relaxed and can be compressed.



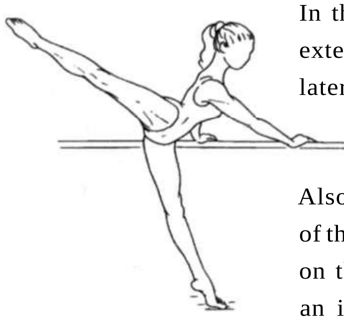
When the knee is extended, hip flexion is restricted by the limits of elasticity of the hamstring muscles (see p. 242).

Hip flexion is often associated with extension of the pelvis.

In **extension** of the hip, the angle between the posterior surfaces of the thigh and the trunk decreases.



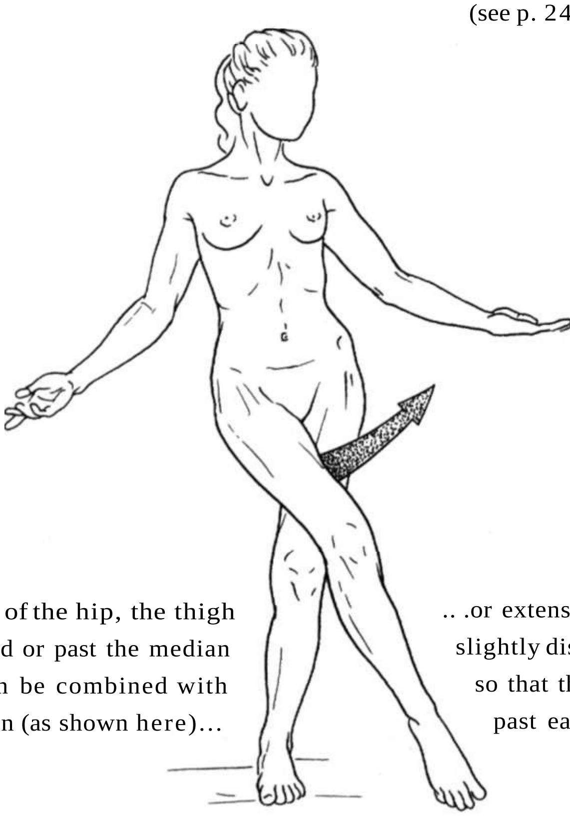
ROM for extension is limited compared to that for flexion, and this movement is often confused with or increased by lumbar lordosis (see p. 35).



In the "grande arabesque," extension is combined with lateral rotation of the hip.

Also, flexion and rotation of the pelvis (see p. 198) on the opposite side can give an impression of extension.

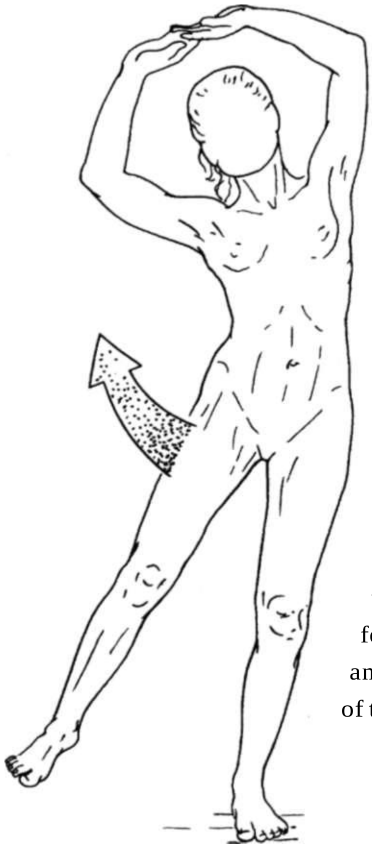
ROM for hip extension is greater when the knee is extended, but is reduced when the knee is flexed, because of the limits of elasticity of the rectus femoris muscle (see p. 240).

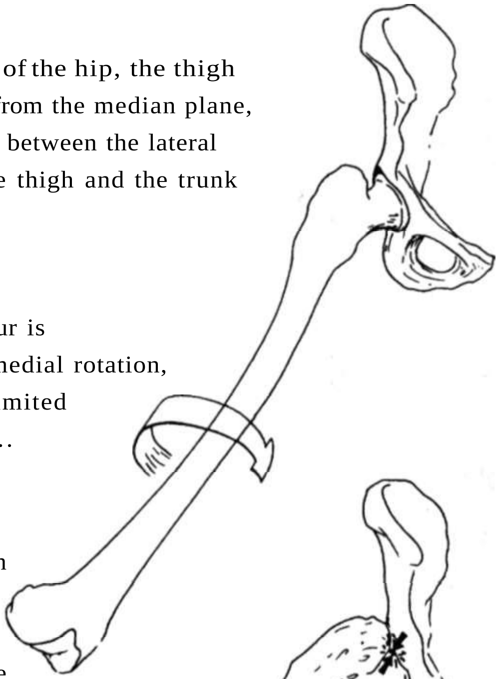


In **adduction** of the hip, the thigh moves toward or past the median plane. It can be combined with slight flexion (as shown here)...

.. .or extension, with the other leg slightly displaced accordingly, so that the two legs can move past each other.

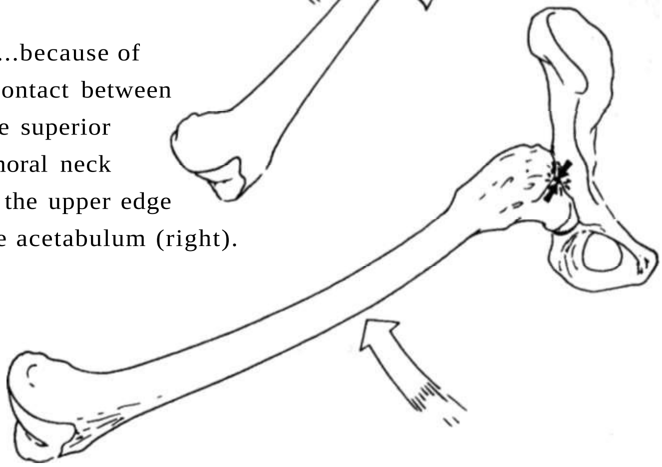
In **abduction** of the hip, the thigh moves away from the median plane, and the angle between the lateral surfaces of the thigh and the trunk decreases.

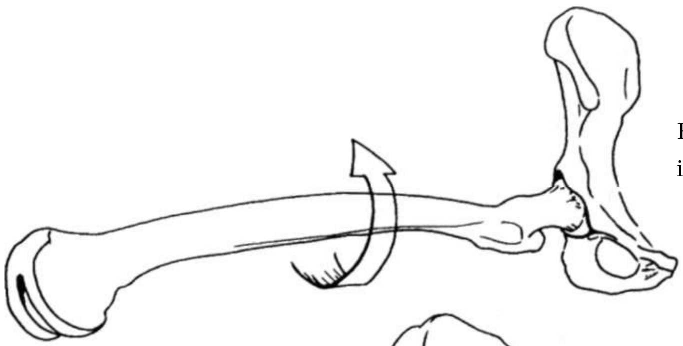




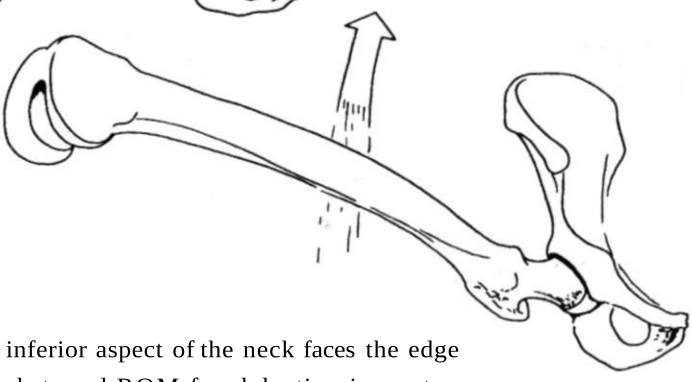
When the femur is in neutral or medial rotation, abduction is limited to about 40°...

...because of contact between the superior femoral neck and the upper edge of the acetabulum (right).





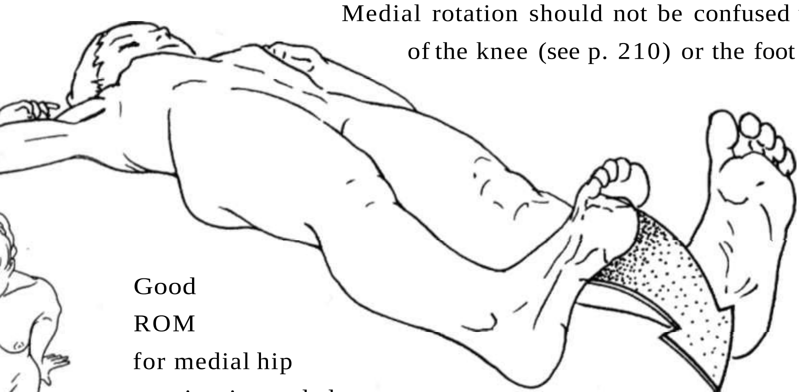
However, with the femur in lateral rotation...



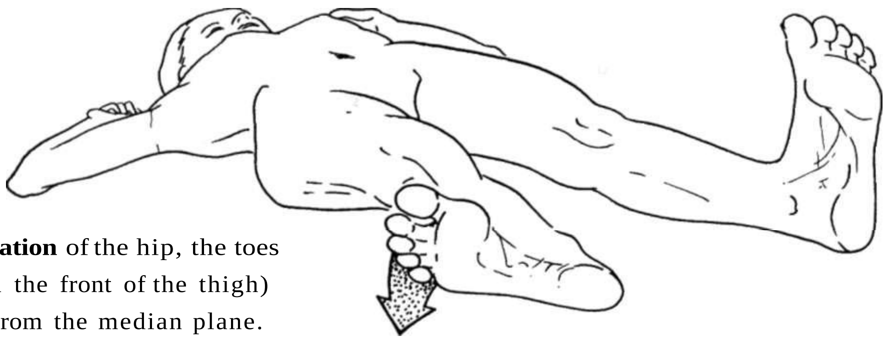
.. .the inferior aspect of the neck faces the edge of the socket, and ROM for abduction is greater.

In **medial rotation** of the hip, the femur rotates on its own long axis, and the toes of the foot (or an imaginary spot on the front of the thigh) move closer to the median plane.

Medial rotation should not be confused with rotation of the knee (see p. 210) or the foot (p. 261).



Good ROM for medial hip rotation is needed to assume the position shown at left without forcing lateral rotation at the knee joint.

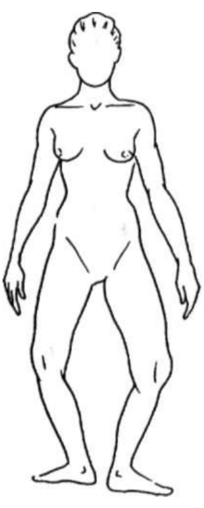


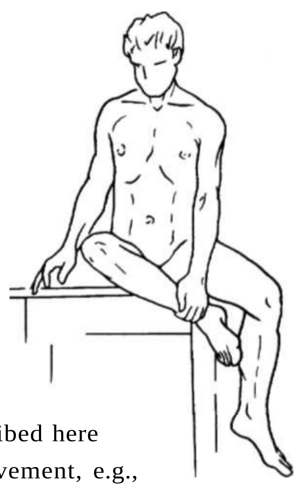
In **lateral rotation** of the hip, the toes (or a spot on the front of the thigh) move away from the median plane.

Good ROM for lateral rotation is needed for the "en dehors" position of ballet...

...or for assuming the "lotus position" without stressing the knee and ankle joints.

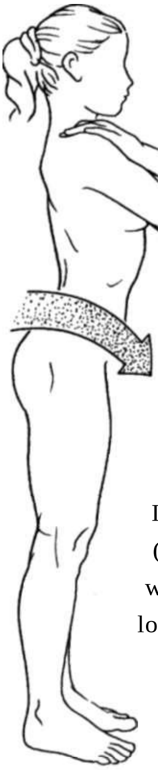
When the hip is flexed, ROM for lateral rotation is greater because the ilio-femoral ligament is slack.



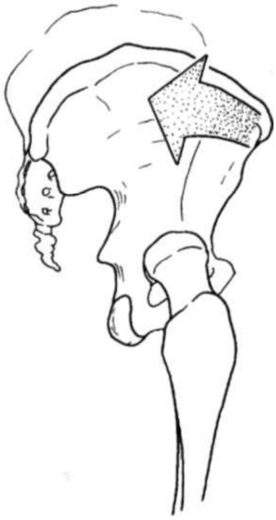


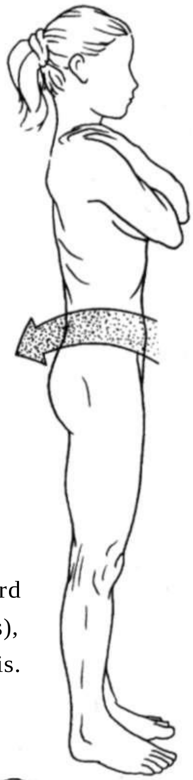
Most often, the hip movements described here combine several directions in one movement, e.g., abduction + lateral rotation, or flexion + abduction

Let us now consider the possible movements *of the pelvis* at the hip joint, assuming that the femur is fixed. We will focus on the anterior superior iliac spine (ASIS) as a reference point.

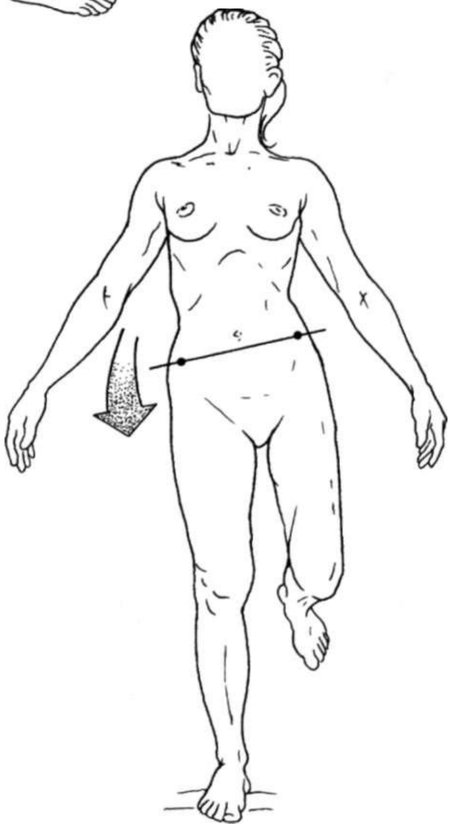


It can move forward (**flexion** of the pelvis), which tends to increase lordosis of the lumbar spine.

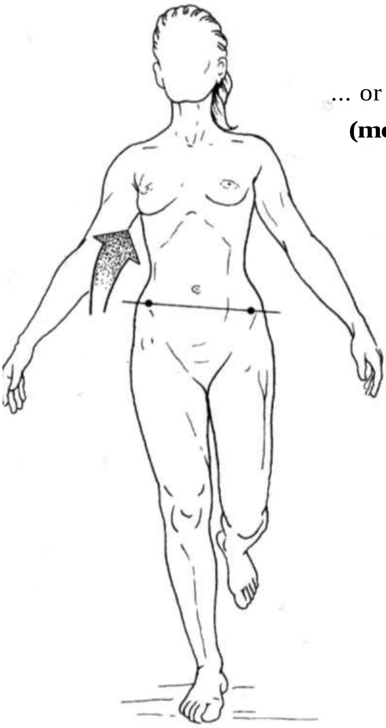




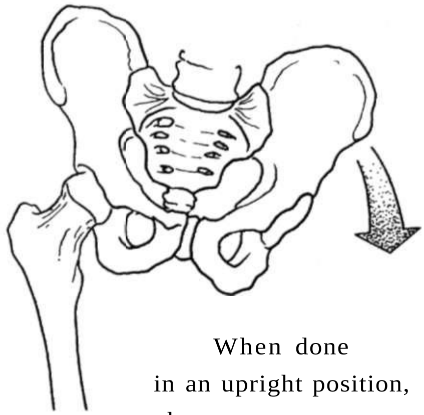
The ASIS can move backward (**extension** of the pelvis), which decreases lumbar lordosis.



It can move inferolaterally **(lateral flexion)...**

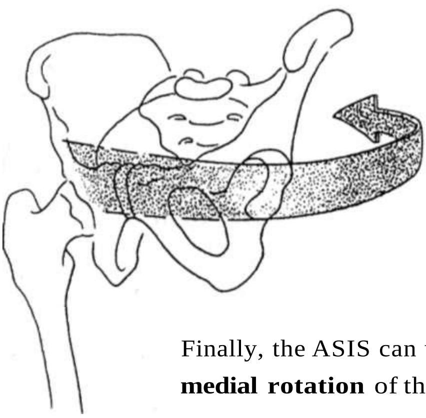


... or superomedially
(medial flexion).

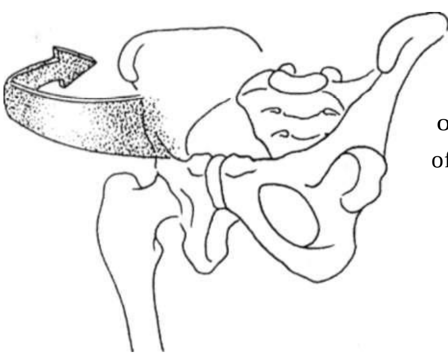


When done
in an upright position,
these two movements
are associated
with sidebending
of the lumbar spine.

Note that in these
two illustrations,
you can observe the
movement of the pelvis
on the supported hip
and not on the
unsupported hip.

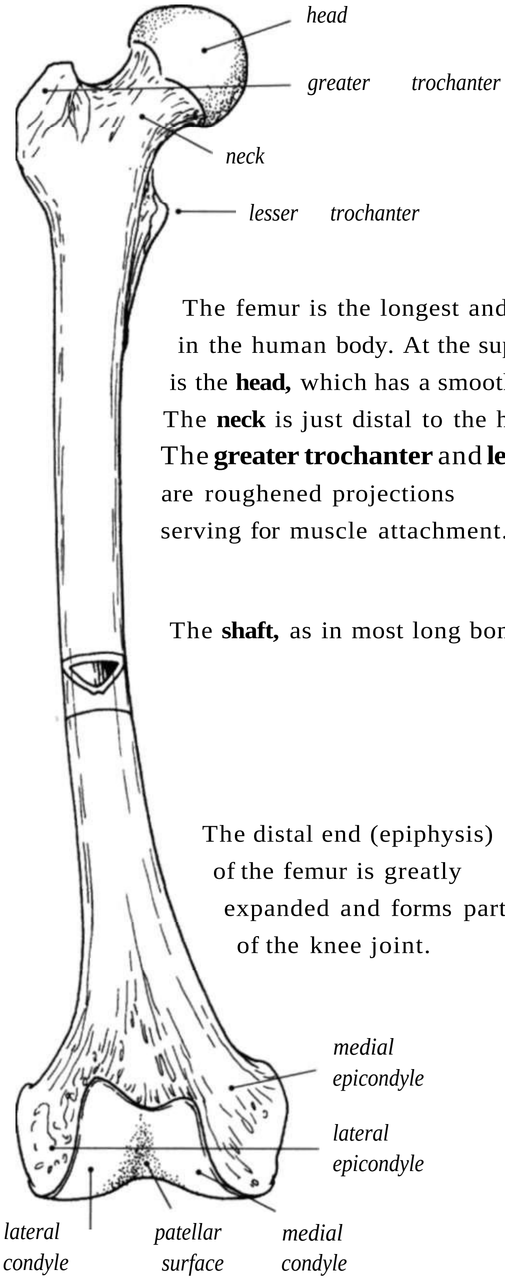


Finally, the ASIS can undergo limited
medial rotation of the pelvis...

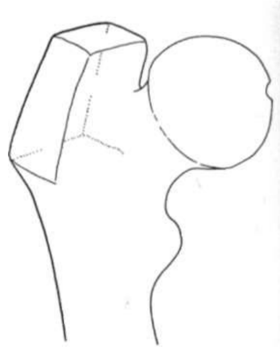


or **lateral rotation**
of the pelvis.

Femur



The greater trochanter has five surfaces: anterior, lateral, posterior, medial, and superior.

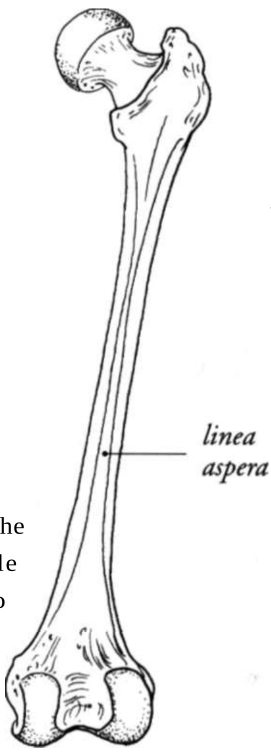


Many deep thigh muscles attach to the greater trochanter.

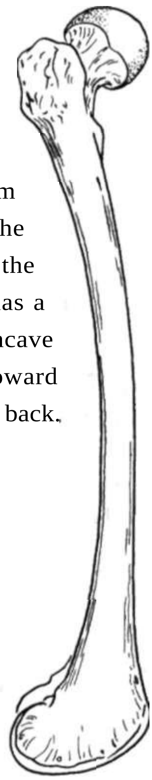
The femur is the longest and heaviest bone in the human body. At the superior end is the **head,** which has a smooth, spherical surface. The **neck** is just distal to the head. The **greater trochanter** and **lesser trochanter** are roughened projections serving for muscle attachment.

The **shaft,** as in most long bones, is roughly triangular in cross section.

The distal end (epiphysis) of the femur is greatly expanded and forms part of the knee joint.



Viewed from the side, the shaft of the femur has a slight concave bent toward the back.

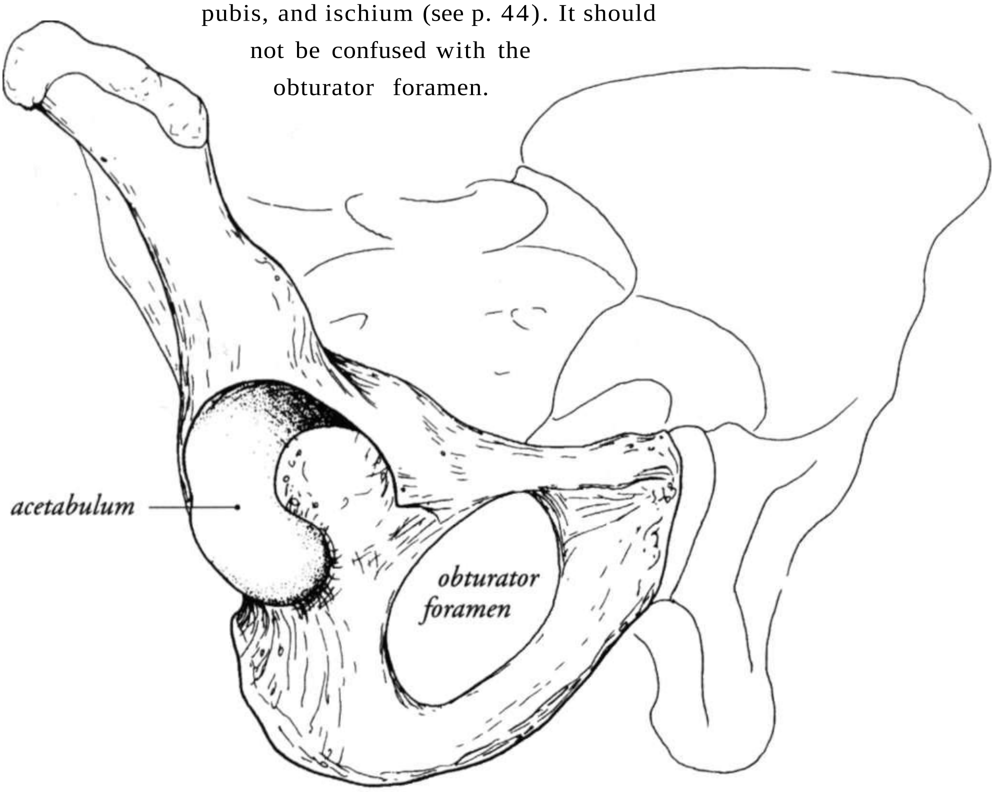


On the posterior shaft of the femur is a prominent double ridge, the **linea aspera,** to which nine muscles attach. This ridge is bifurcated superiorly and inferiorly.

[POSTERIOR VIEW]

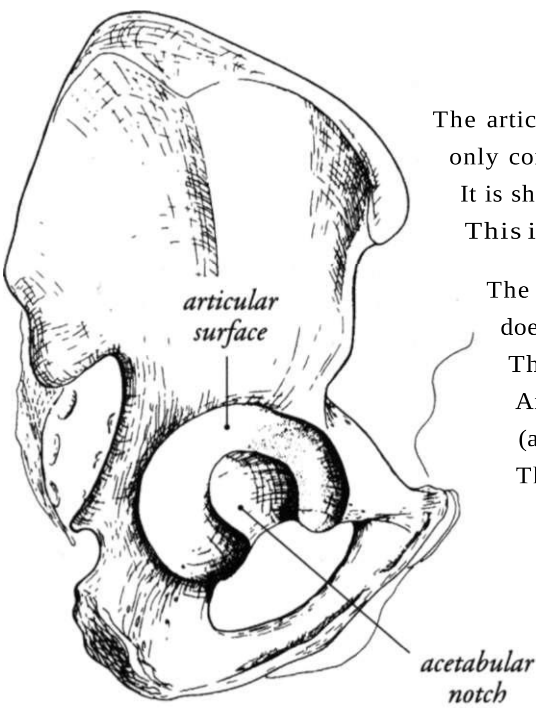
Hip (coxo-femoral) joint

On the lateral surface of the hip bones is the acetabulum (Latin for "small bowl"), a deep socket formed by the junction of the ilium, pubis, and ischium (see p. 44). It should not be confused with the obturator foramen.

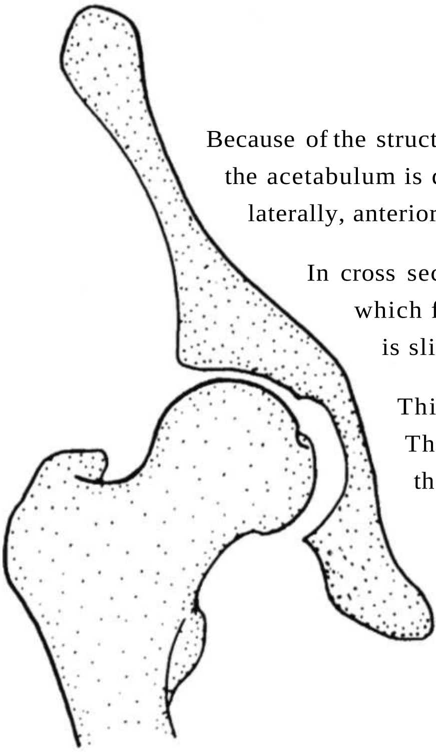


The articular surface of the hip only constitutes part of the acetabulum. It is shaped like a croissant. This is the **lunate surface of the acetabulum.**

The deeper portion of this cavity does not articulate with the femur. This is where the **ligamentum teres** is located. Anteroinferiorly, the surface is interrupted (at the ends of the croissant). The croissant is also sometimes cut posteriorly.



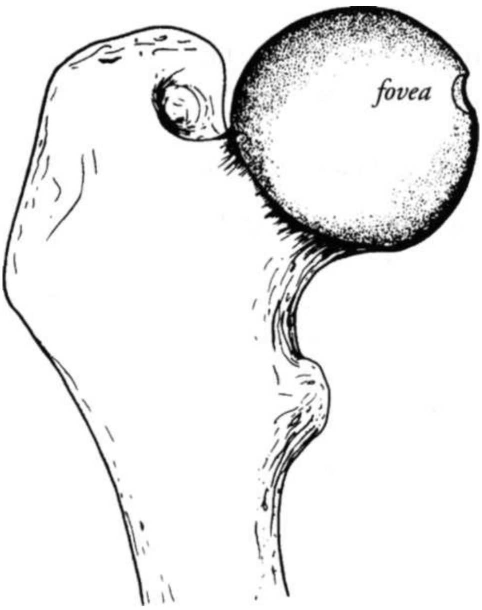
Articular surfaces of hip



Because of the structure of the pelvis, the acetabulum is directed laterally, anteriorly, and inferiorly.

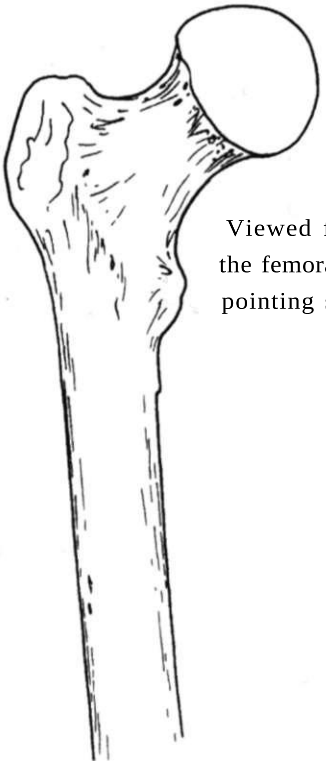
In cross section, we see that the upper part of the socket, which fits against the head of the femur, is slightly oblique rather than horizontal.

This angle varies with the individual and with age. The more the angle deviates from horizontal, the less stable is the joint.

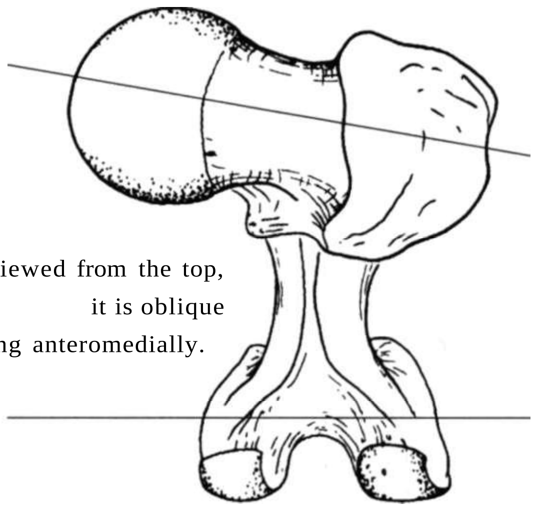


The femoral head, the articulating surface of the femur, represents about two-thirds of a sphere and is covered with thick cartilage except at the fovea where the **ligamentum teres**, which connects the femoral head to the acetabulum, is attached.

The head of the femur sits on top of the **femoral neck.**

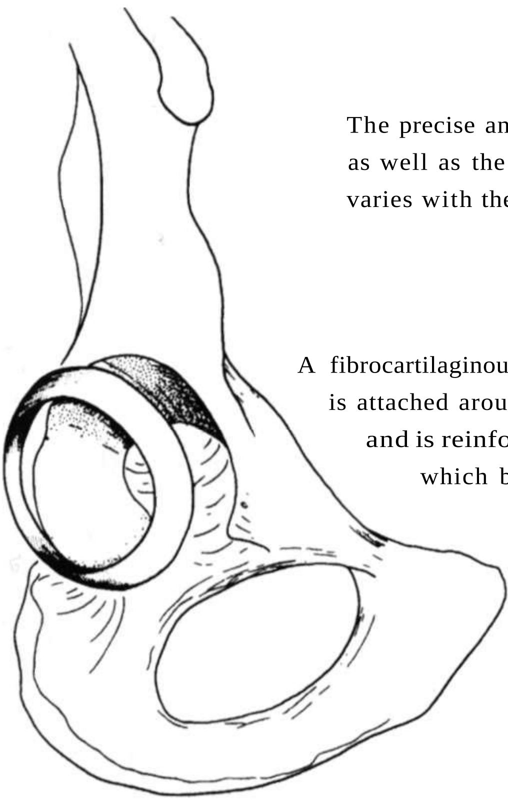


Viewed from the front,
the femoral neck is oblique
pointing superomedially.



Viewed from the top,
it is oblique
pointing anteromedially.

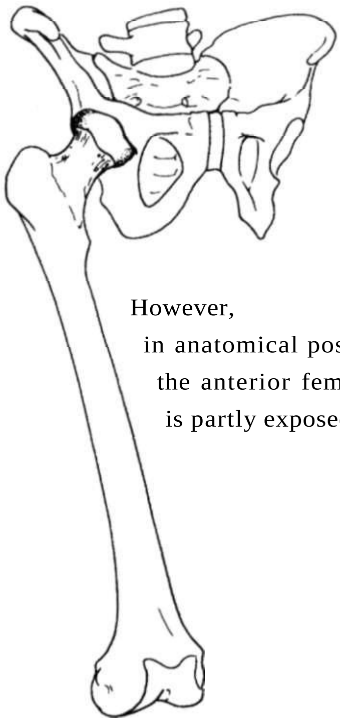
The precise angle of the head,
as well as the length of the femoral neck,
varies with the individual and with age.



A fibrocartilaginous ring called the **labrum**
is attached around the rim of the acetabulum
and is reinforced by a **transverse acetabular ligament**
which bridges the inferior opening of the notch.

The labrum
helps hold the femoral head in place,
and increases the effective depth of the socket.

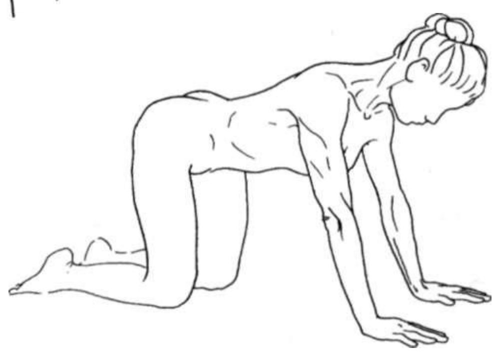
How head of femur articulates with socket

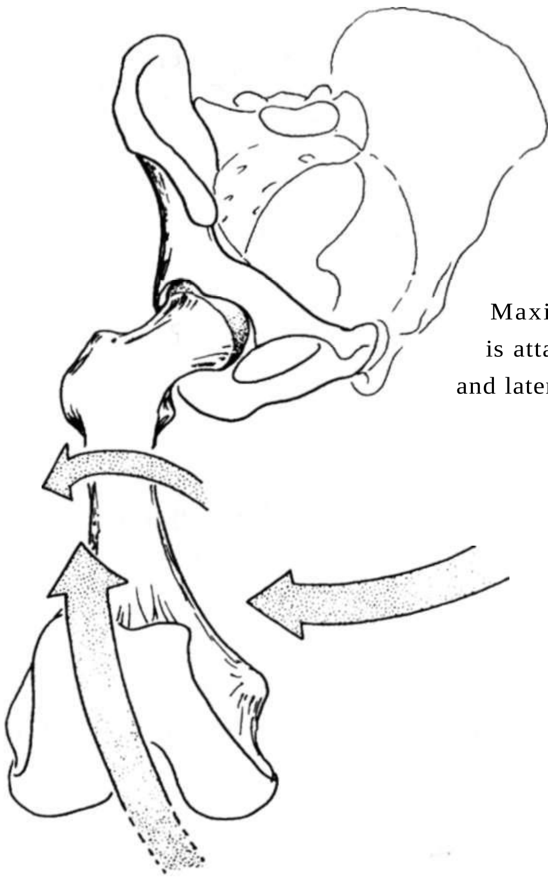


The surfaces of the hip (with the additional fibrocartilagenous ring) form an "encased" articular structure.

However, in anatomical position, the anterior femoral head is partly exposed.

The head fits better into the socket when the femur is flexed to a 90° angle relative to the trunk, as in a kneeling position.

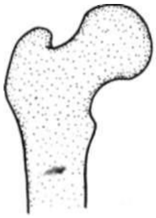




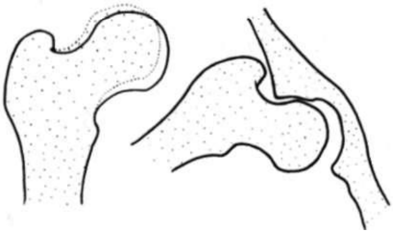
Maximal contact between the articular surfaces is attained by a combination of flexion, abduction, and lateral rotation.

We often assume this position spontaneously when at rest.

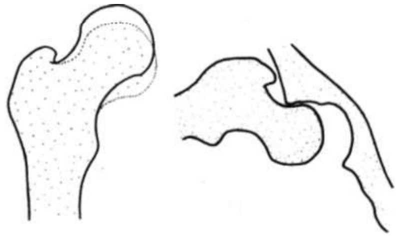
Variations of hip



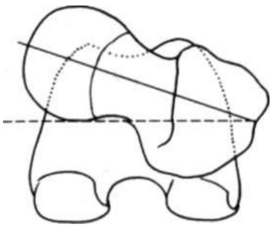
The average angle between the femoral neck and shaft is 135°.



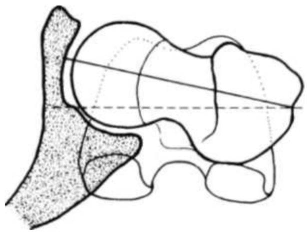
In some individuals this angle is smaller, a condition called **coxa vara** in which the range of abduction is reduced.



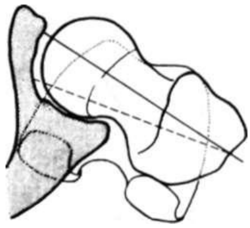
When the angle is greater than 135° **(coxa valga)**, the range of abduction is increased.



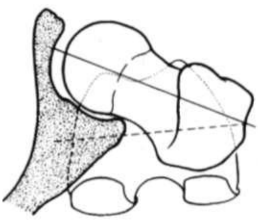
Seen from above, the neck is oriented anteriorly at an angle of 10 to 30°.



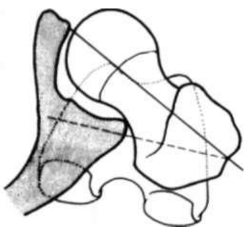
When this "anteversion" angle is small, the head fits into the socket well in anatomical position,



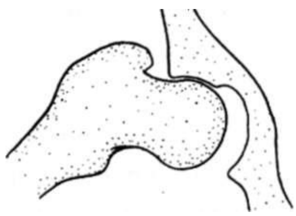
and maintains good articular contact even in lateral rotation.



When the anteversion angle is large, the anterior part of the head is more exposed in anatomical position,

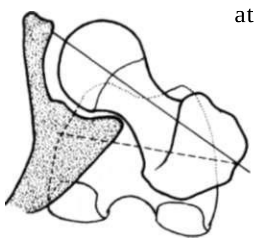


and the posterior part loses contact with the socket in lateral rotation.

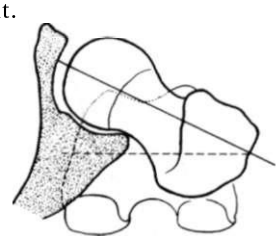


Lateral rotation is more restricted in these individuals by contact between the neck and the lateral edge of the acetabulum. Curvature and length of the femoral neck also affect mobility at the hip joint.

A neck that is more con cave, and longer, will facilitate abduction...



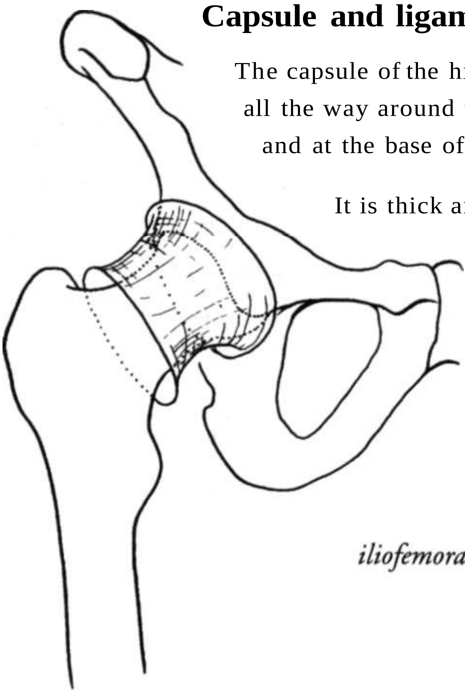
and lateral rotation.



With a shorter, less concave neck, both these motions are restricted by contact with the edge of the acetabulum.

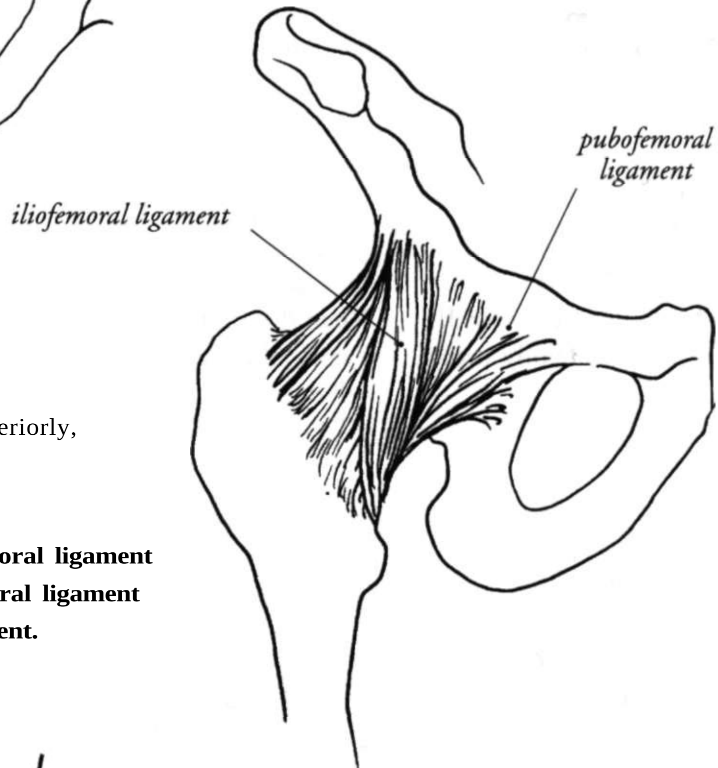
Obviously, there are intrinsic limitations to ROM at the hip joint due to the shape of the articulating bones, which may be greater or less in specific individuals. It is important to be aware of this variation when teaching dance or other physical disciplines. In fact, people with limited movement of the hip joint due to bony restrictions may injure themselves while trying to achieve certain positions, by putting too much stress on the superior joints (lumbar spine) or inferior joints (knee).

Capsule and ligaments of hip joint



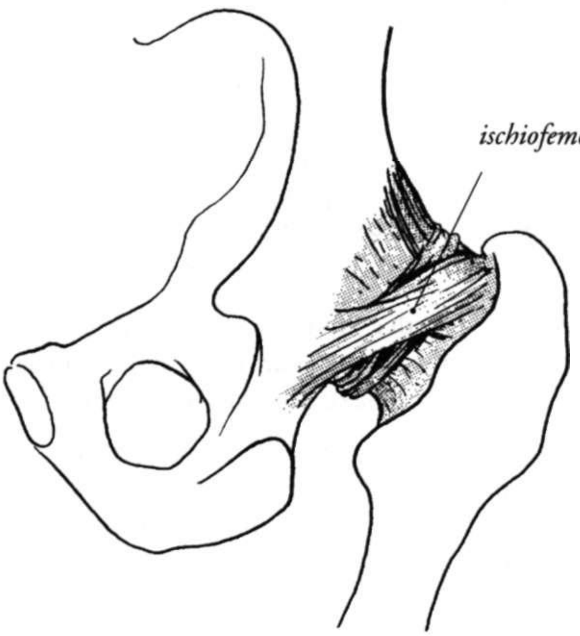
The capsule of the hip joint attaches firmly all the way around the rim of the acetabulum and at the base of the femoral neck.

It is thick and tough, and is reinforced by ligaments.



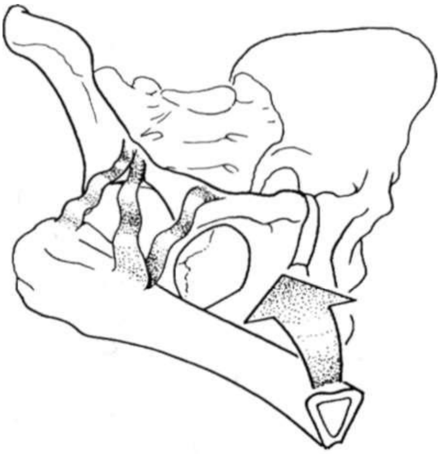
Two ligaments are arranged anteriorly, consisting of three fasciae which form the shape of an N:

* superior fascia of the **iliofemoral ligament**
* middle fascia of the **iliofemoral ligament**
* fascia of **pubofemoral ligament.**

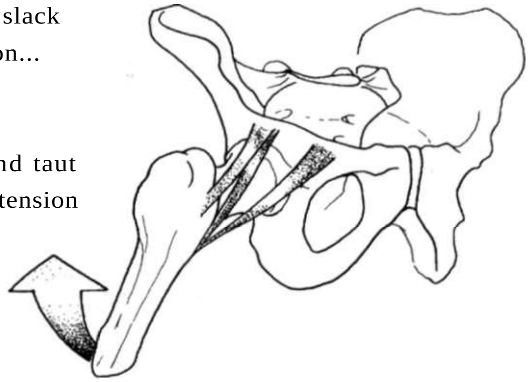


Posteriorly, the **ischiofemoral ligament** is arranged like a spiral. It is much weaker than the others. Deep circular fibers reinforce the middle of the capsule, which give it an hourglass shape.

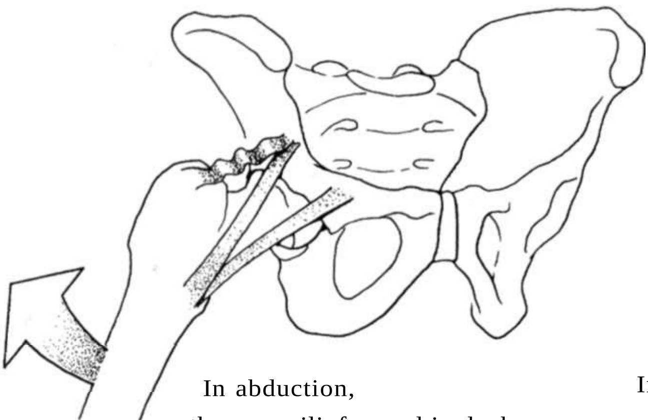
During movements of the hip, the anterior ligaments display varying degrees of tightness.



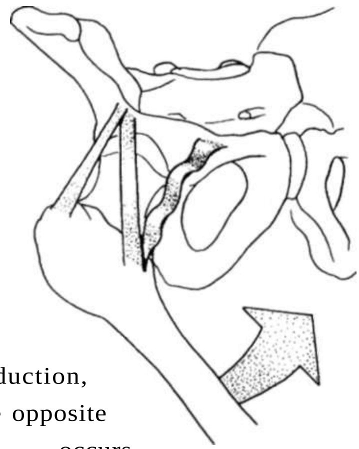
The iliofemoral (both branches) and pubofemoral ligaments become slack in flexion...



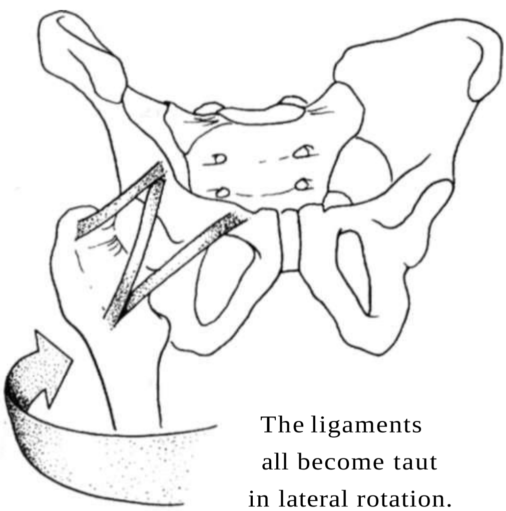
...and taut in extension



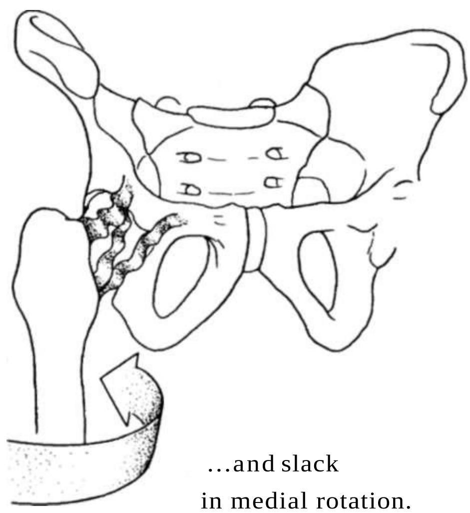
In abduction, the upper iliofemoral is slack while the pubofemoral is taut.



In adduction, the opposite occurs



The ligaments all become taut in lateral rotation.



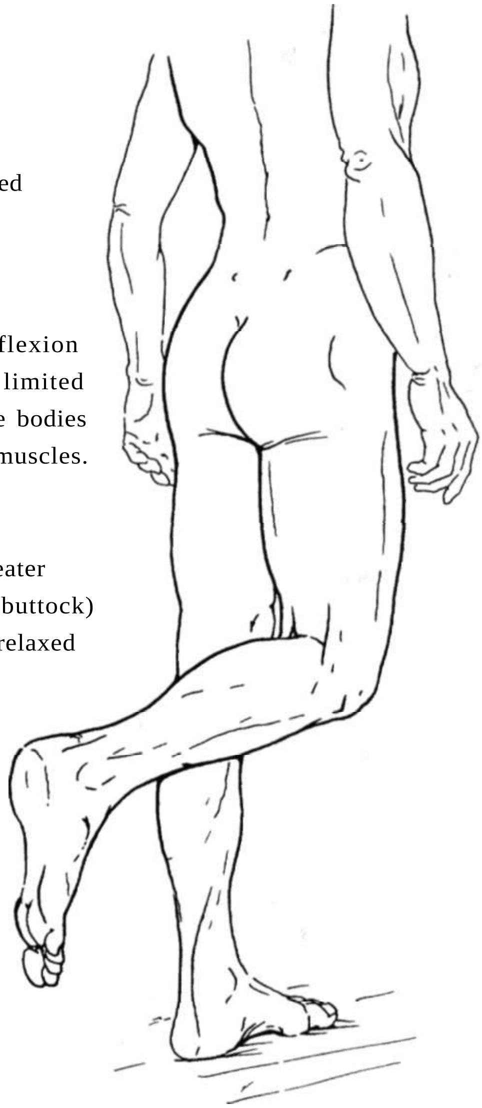
...and slack in medial rotation.

In summary, flexion and medial rotation loosen the ligaments, while extension and lateral rotation make them taut.

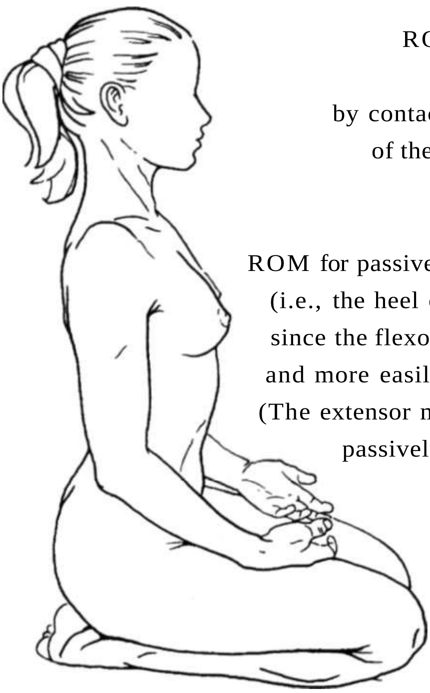
Movements of the knee

The knee is primarily a hinge joint.

Flexion decreases the angle formed by the posterior thigh and leg.



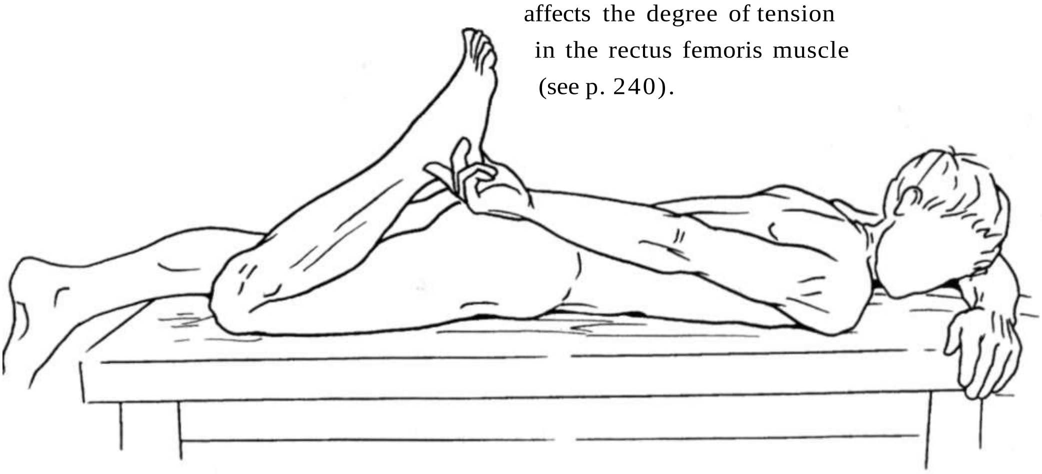
ROM for active flexion is limited by contact between the bodies of the contracting muscles.

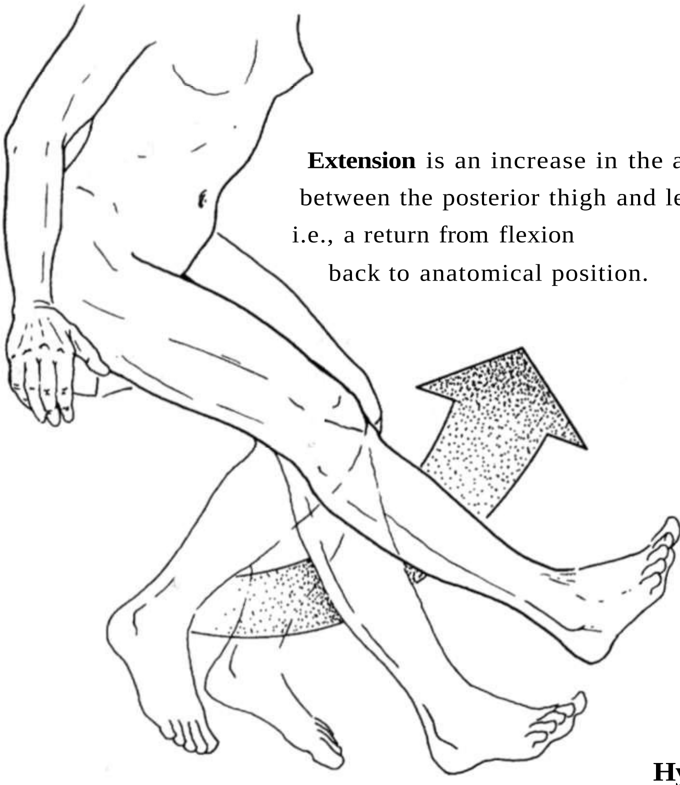


ROM for passive flexion is greater (i.e., the heel can touch the buttock) since the flexor muscles are relaxed and more easily compressed. (The extensor muscles are passively stretched.)

In addition, ROM for flexion is greater when the hip joint is flexed and smaller when the hip is extended. Why?

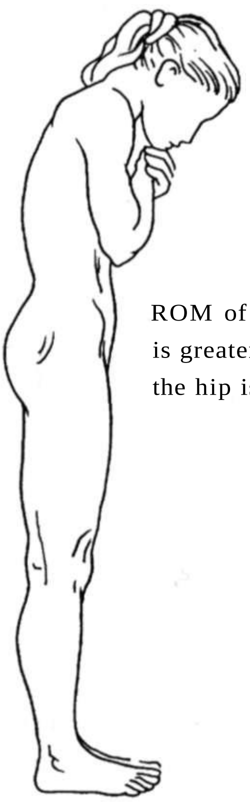
Because position at the hip joint affects the degree of tension in the rectus femoris muscle (see p. 240).



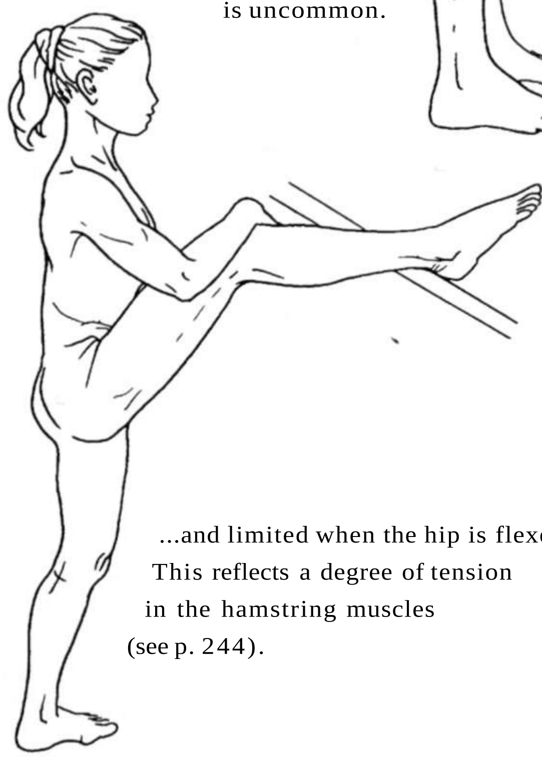


Extension is an increase in the angle between the posterior thigh and leg, i.e., a return from flexion back to anatomical position.

Hyperextension, or "genu recurvatum" (an increase of this angle significantly beyond 180°), is uncommon.

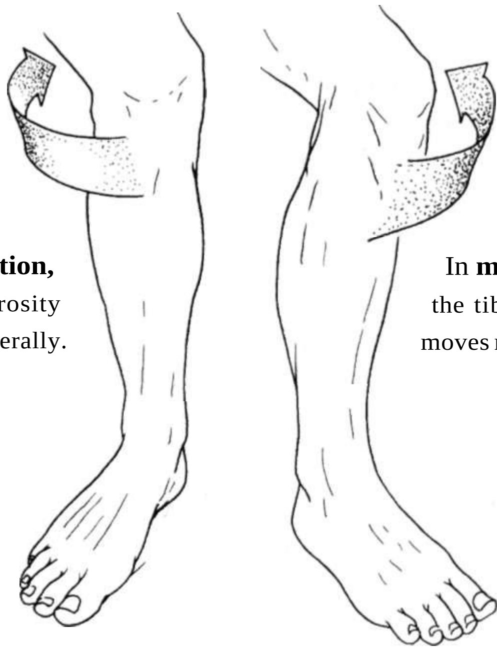


ROM of knee extension is greater when the hip is extended...



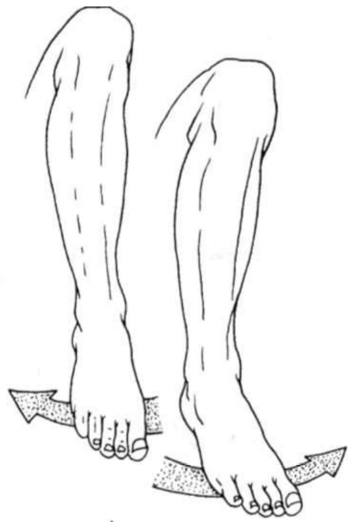
...and limited when the hip is flexed. This reflects a degree of tension in the hamstring muscles (see p. 244).

To describe rotation, we will assume that the femur is fixed.



In **lateral rotation,** the tuberosity moves laterally.

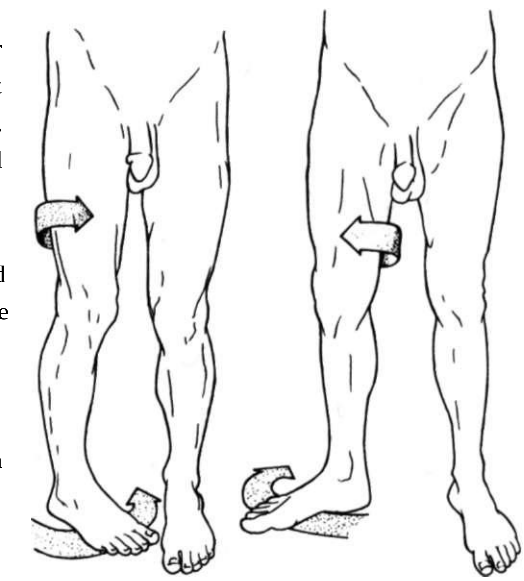
In **medial rotation,** the tibial tuberosity moves medially.



It is also important not to confuse knee rotation with abduction/adduction of the foot. This is the reason for focusing on movement of the tibial tuberosity (see above) rather than the foot.

Rotation can occur to an appreciable extent only when the knee is flexed, and the ligaments are relaxed (see p. 222).

If the knee is extended and you see the tuberosity moving medially or laterally, this is rotation not at the knee but at the hip.



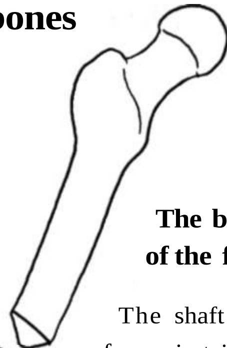
Note that these rotations occur automatically during knee flexion and extension, although ROM is small then and involves both bones (not just the mobile tibia below the femur, as shown above). These rotations are primarily due to the shape of the articular surfaces (see p. 223).

The knee joint consists of three bones

The femur articulates with the patella, which is called the femoropatellar joint.

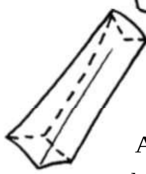
The femur articulates with the tibia, which is called the femorotibial joint.

The patella does not articulate with the tibia. We will study it in detail on page 225. Here, we will just take a look at the femorotibial joint.



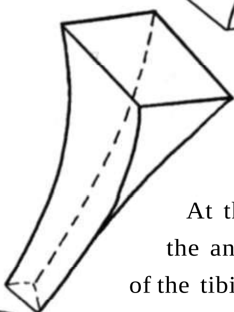
The base of the femur:

The shaft of the femur is triangular in cross section (see p. 200).



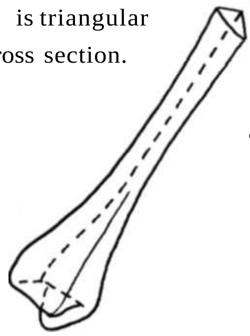
At the bottom: the posterior edge of the femur's distal end bifurcates such that its shape in cross section changes to a square, which expands: thus, the base of the femur looks like the trunk of a pyramid.

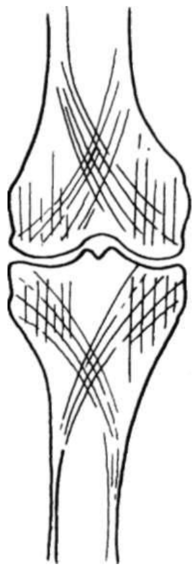
The top of the tibia:



At the top: the anterior edge of the tibia's proximal end also bifurcates and changes to an expanding square shape. Its top looks like an upside-down pyramid.

The shaft of the tibia is triangular in cross section.





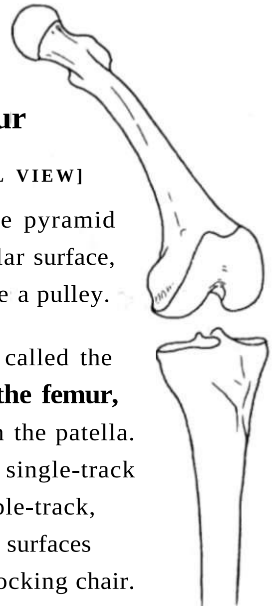
Thus, the two bones are both expanded where they come together and form a massive structure, like the ends of two columns. This increases their stability and weight-bearing ability.

The fibers of the alveolar (spongy) tissue inside are oriented diagonally and vertically, as well as horizontally, which increases their strength.

Surfaces of knee joint

Surfaces of femur

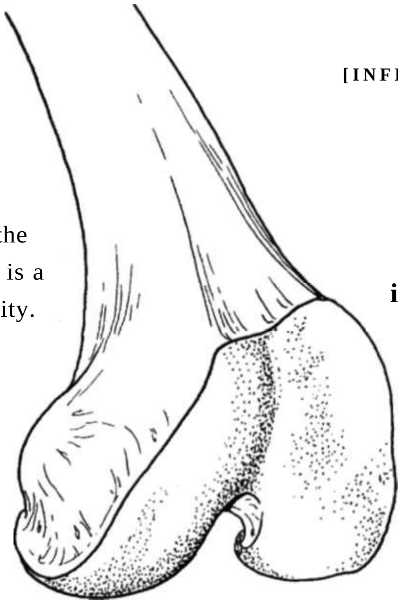
[INFEROANTERIOLATERAL VIEW]



The base of the pyramid is a rounded articular surface, shaped roughly like a pulley.

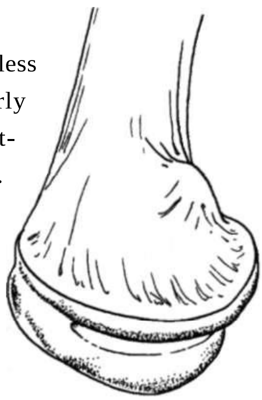
The anterior portion is called the **intercondylar fossa of the femur,** which articulates with the patella. Posteroinferiorly, the single-track pulley becomes double-track, and the shape of the surfaces is like the legs of a rocking chair.

Above and posterior to the two condyles is a bony tuberosity.

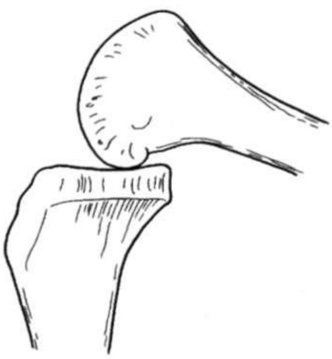


These are the **medial and lateral condyles of the femur,** which articulate with the condyles of the tibia.

The condyles are less curved anteriorly (good for weight-bearing function)...



.. .and more curved posteriorly (good for flexion movement).



Overall, the medial condyle is more curved than the lateral condyle, which helps explain the automatic rotations of the knee during flexion/extension (see p. 223).

Prolonged standing with the knee in slightly flexed position puts stress on the small articular surface of the condyles, and can damage the cartilage.

Surfaces of tibia

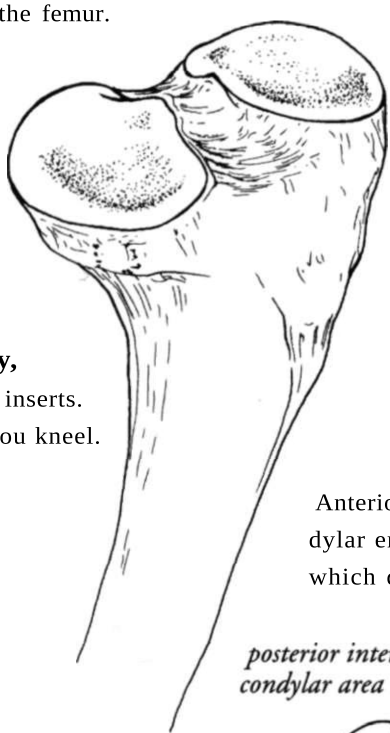
The superior surface (base of the pyramid) of the tibia is called the **tibial plateau.**

The lateral and medial **condyles of the tibia,** protected by cartilage, are concave for articulation with the convex condyles of the femur.

The lateral surface of the tibial plateau has a tubercle, called **Gerdy's tubercle,** where the fascia lata inserts.

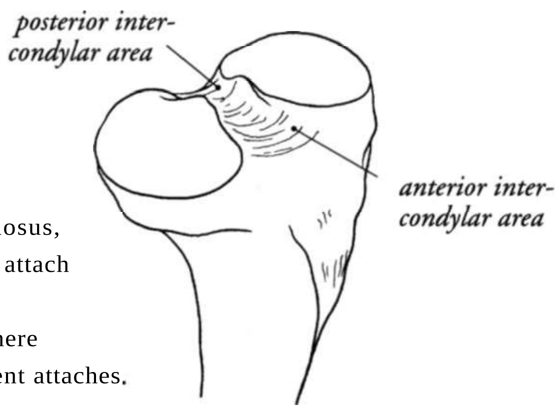
Its anterior surface has a prominence, the **anterior tibial tuberosity,** where the quadriceps muscle inserts. You can feel this area when you kneel.

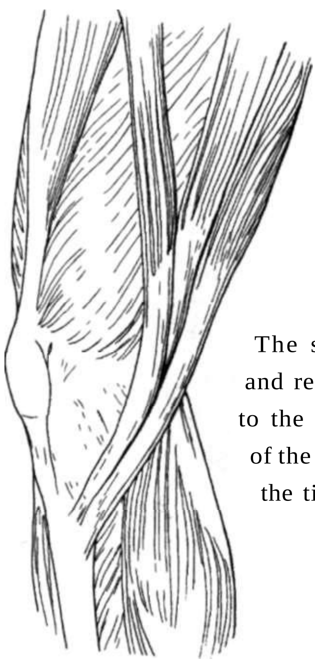
[ANTEROLATERO-SUPERIOR VIEW]



At the center of the tibial plateau, the edges of the condyles are raised and form the **intercondylar eminence.**

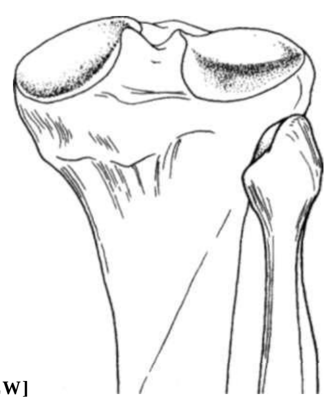
Anterior and posterior to the intercondylar eminence are two hollow surfaces, which do not articulate with the femur:





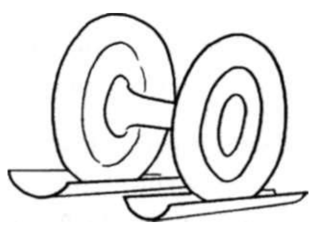
The sartorius, semitendinosus, and rectus femoris muscles attach to the upper medial shaft of the tibia. This is also where the tibial collateral ligament attaches.

The tibial condyles are concave transversely, but from front to back the lateral condyle is slightly convex while the medial one is concave.



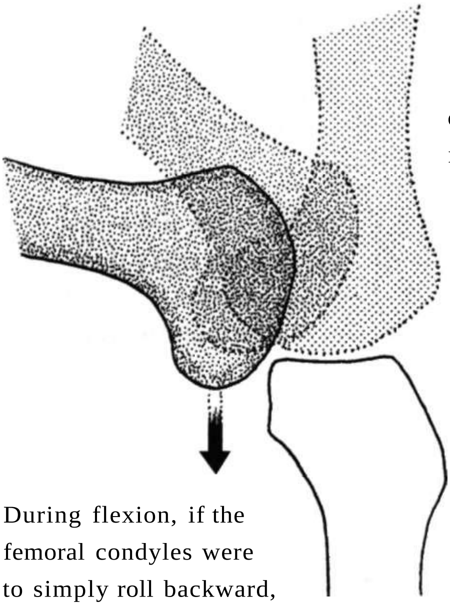
[POSTERIOR VIEW]

The femorotibial articulation looks like a double-wheel structure fitting into a set of two tracks.

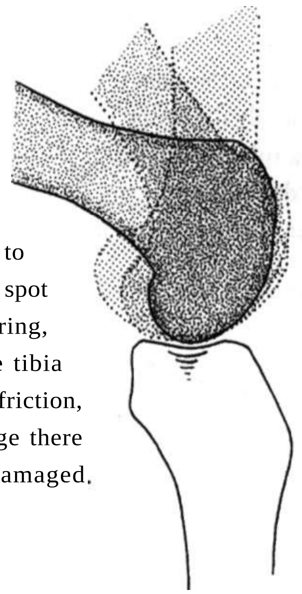


Displacement of condyles during movement of knee

There are two mechanisms associated with the movements of flexion and extension of the knee: rolling and gliding.

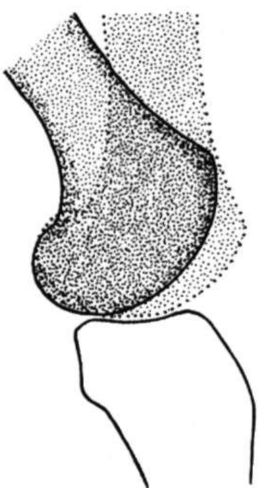


During flexion, if the femoral condyles were to simply roll backward, the femur would slip off the tibia.

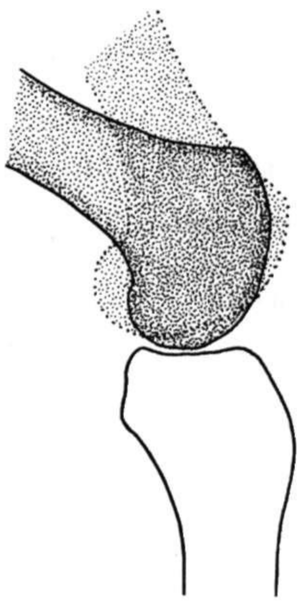


If they were to glide in one spot like a ball bearing, a single spot on the tibia would receive all the friction, and the cartilage there would be damaged.

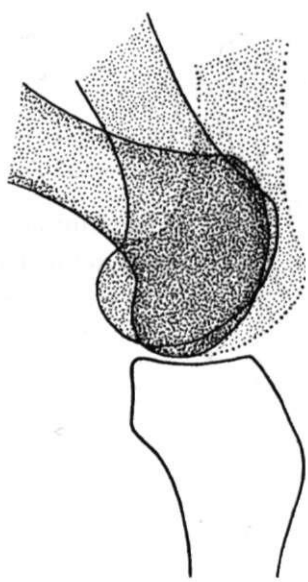
The movement of the knee in the sagittal plane can therefore be described in the following way:



In **flexion,** the femoral condyle first rolls (15-20°) on the tibial condyle,



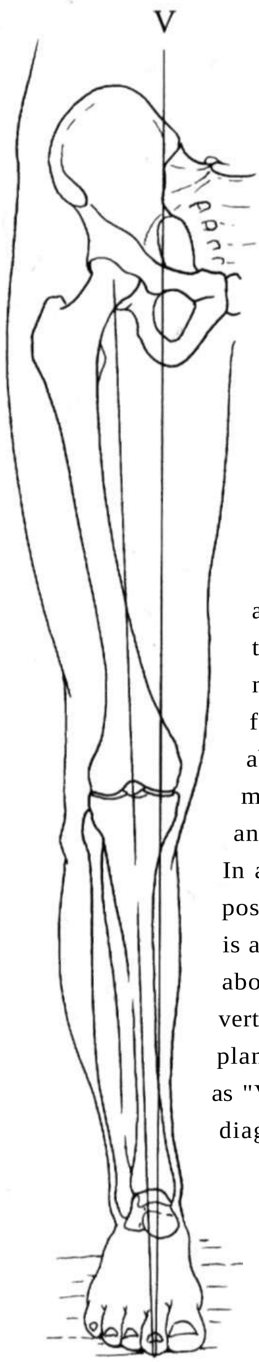
then glides...



producing a combined "rolling-gliding" movement.

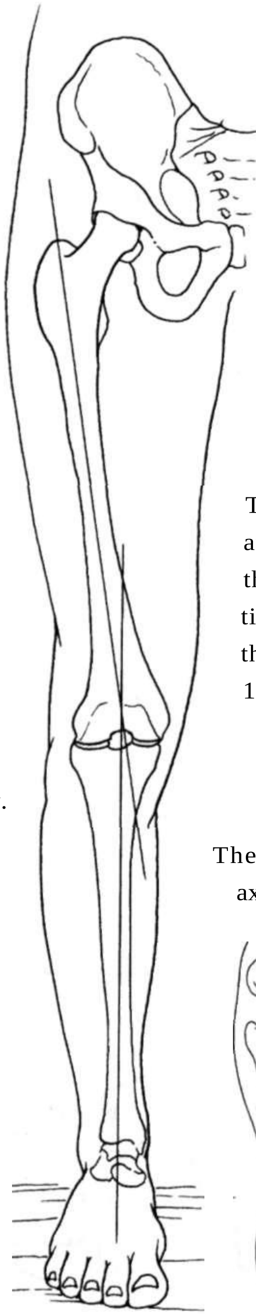
The opposite occurs in **extension** of the knee: first gliding, then rolling. During this movement, the lateral condyle rolls more than the medial condyle, which leads to automatic rotation of the knee (see also p. 223).

For the lower limb, in anatomical position, we can consider three different axes.



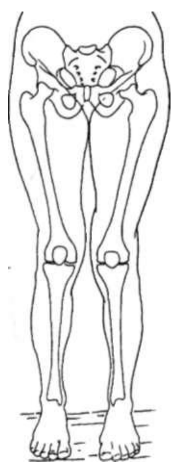
The first ("mechanical axis") passes through the middle of the femoral head above and the middle of the ankle joint below. In anatomical position, this axis is at an angle of about 3° from a vertical (sagittal) plane (shown as "V" in the diagram).

If you stand on one foot, this axis moves farther from the sagittal plane.



The second and third axes are those passing through the shafts of the femur and tibia, which form an angle that is usually between 170° and 175°.

The lateral angle formed by these two axes varies from person to person:

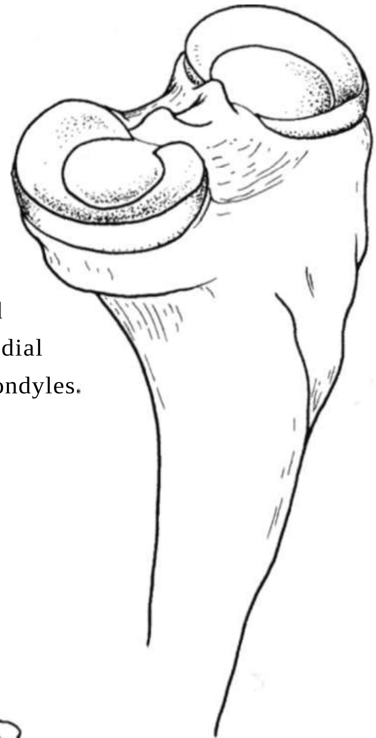


It can be less than 180° (genu valgum or "knock knees"),

.or greater than 180° (genu varum or "bow-legs").

Menisci

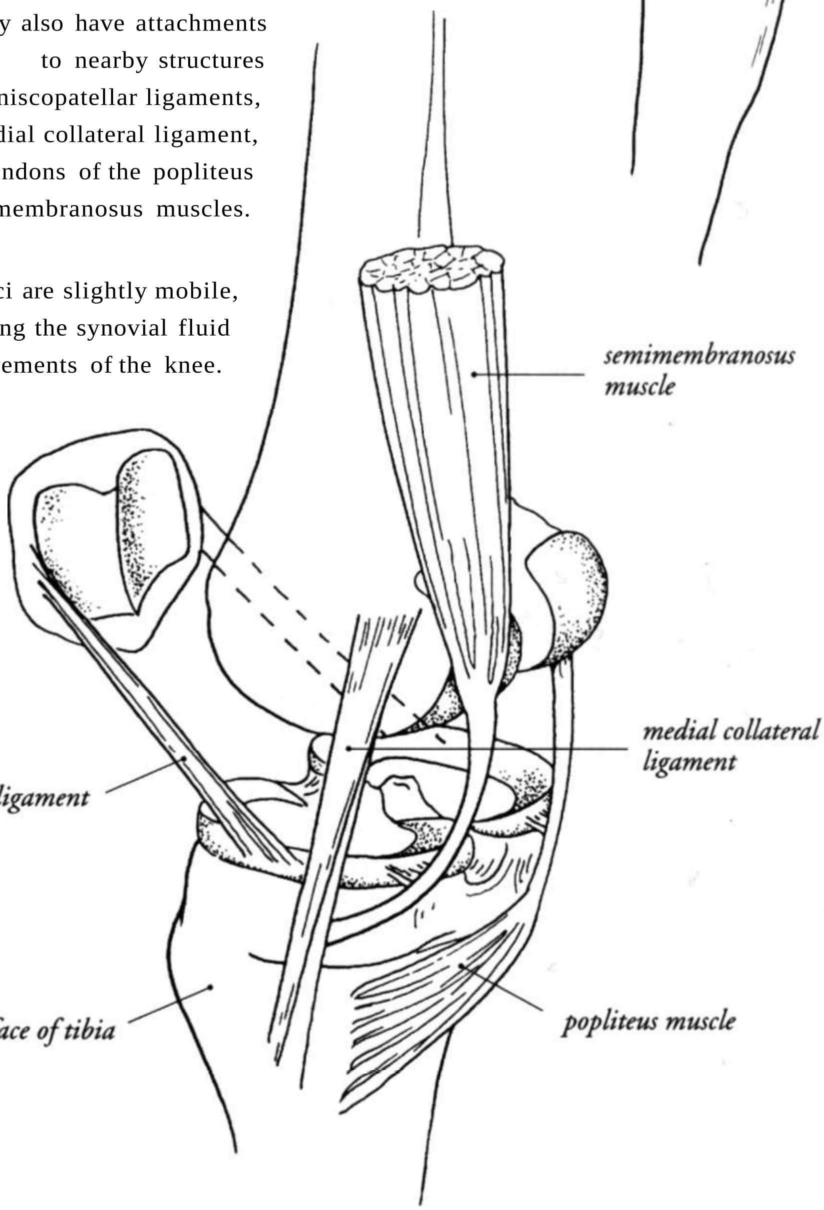
The **menisci** (singular: meniscus) are two croissant-shaped intra-articular discs made of fibrocartilage.



Their shallow central tips are attached to the intercondylar eminence of the tibia, and their thicker margins are attached to the peripheral edges of the medial and lateral tibial condyles.

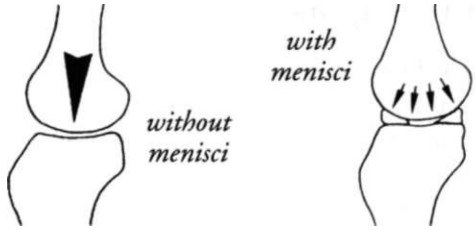
They also have attachments to nearby structures such as the meniscopatellar ligaments, medial collateral ligament, and tendons of the popliteus and semimembranosus muscles.

The menisci are slightly mobile, and aid in spreading the synovial fluid during movements of the knee.



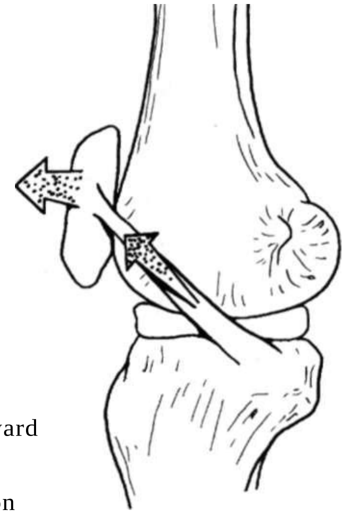
[RIGHT KNEE, POSTEROMEDIAL VIEW]

The menisci have several functions:

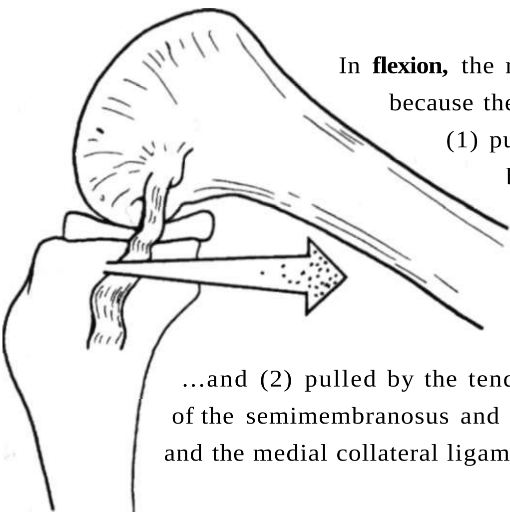


- As they move around, they increase the distribution of synovial fluid.
- They increase the weight-bearing surface, which results in a better distribution of pressure as they move around.
- Like wedges, they increase the concave shape of the tibial condyles and therefore provide better stability.

How the menisci move during knee movements



In **extension,** the menisci move forward because they are (1) pushed in that direction by the femoral condyles, and (2) pulled by the meniscopatellar ligaments, which are in turn pulled upward by movement of the patella.

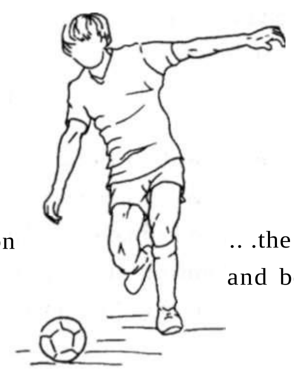


In **flexion,** the menisci move backward because they are (1) pushed in that direction by the condyles...

...and (2) pulled by the tendons of the semimembranosus and popliteus muscles, and the medial collateral ligament.

In **rotation,** the ipsilateral meniscus moves forward because of pressure from the condyle and is held back by the meniscopatellar ligament.

These movements are all necessary for normal function of the knee joint. In some cases (particularly rapid extension movements, as in soccer),

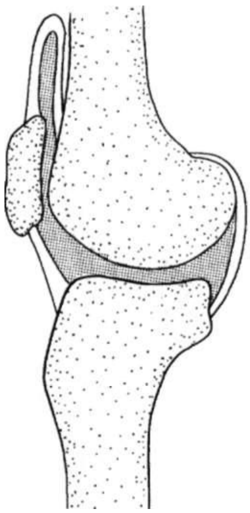


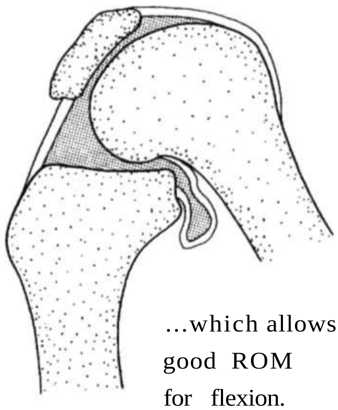
.. .the menisci may not move fast enough, and become crushed or torn.

Knee capsule

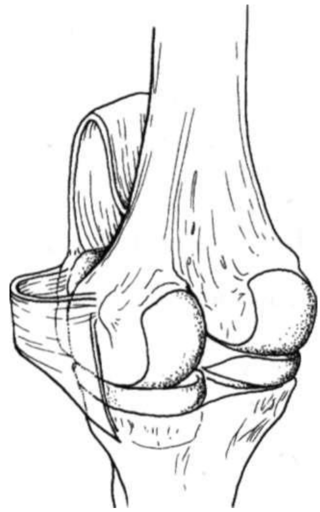
The knee joint is held by a thick **capsule,** which attaches just outside the articular surfaces of the three bones involved. The patella is contained in the anterior capsule. Thus the patella, femur, tibia, and capsule enclose a single synovial cavity within which synovial fluid circulates.

The capsule is very slack anteriorly...



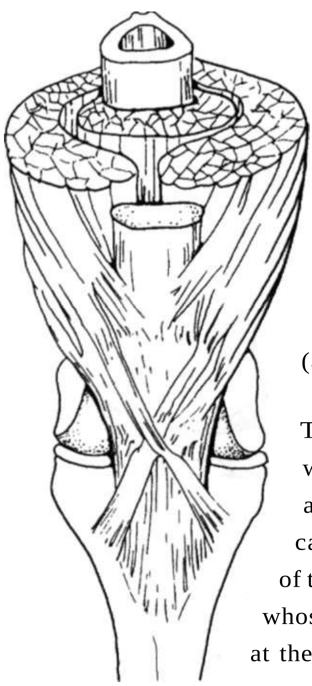


...which allows good ROM for flexion.



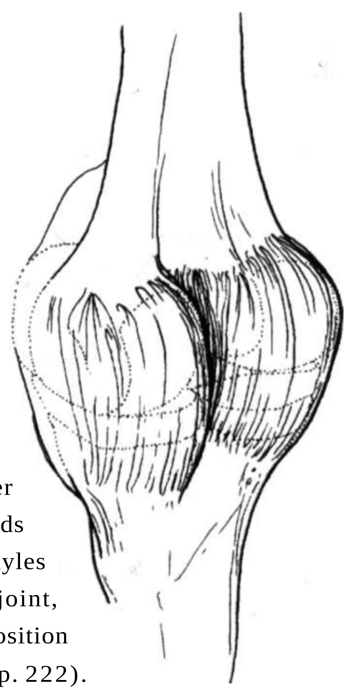
In extension, therefore, the capsule forms deep folds at the front and sides.
In cases of prolonged immobilization of the joint, these folds can develop adhesions which subsequently limit flexion.

In terms of bone morphology, the knee is not a very well-fitted joint. Therefore, its ligaments are essential to its stability.



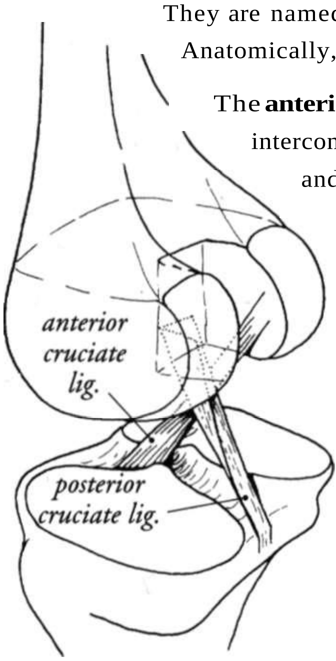
The patella (see p. 224) is attached to the femoral condyles and the menisci by small ligaments (actually thickenings of the capsule).

The strong **patellar ligament,** which contains the patella and inserts on the tibial tuberosity, can be viewed as a continuation of the tendon of the quadriceps muscle, whose fibers cross over each other at the knee joint.



Posteriorly, the knee capsule is thicker and forms two strong bands connecting the femoral and tibial condyles These resist hyperextension of the joint, and provide "passive stability" in the standing position (see p. 222).

The joint is also held in place by two **cruciate** ("crossed") **ligaments** located in the intercondylar fossa of the femur.
They are named according to where they attach to the tibia.
Anatomically, they are outside the joint capsule.

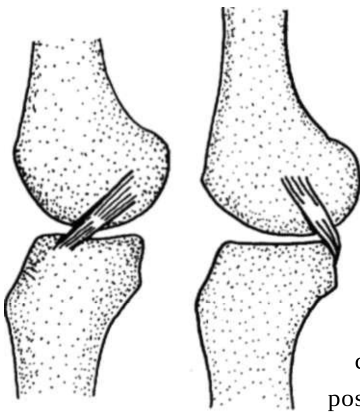


The **anterior cruciate ligament** is attached to the anterior intercondylar area of the tibia. It runs posterosuperolaterally and attaches to the medial aspect of the lateral femoral condyle.

The **posterior cruciate ligament** attaches to the posterior intercondylar area of the tibia. It runs anterosuperomedially and attaches to the lateral surface of the medial femoral condyle.

Their principal role is to prevent anteroposterior displacements of the two bones.

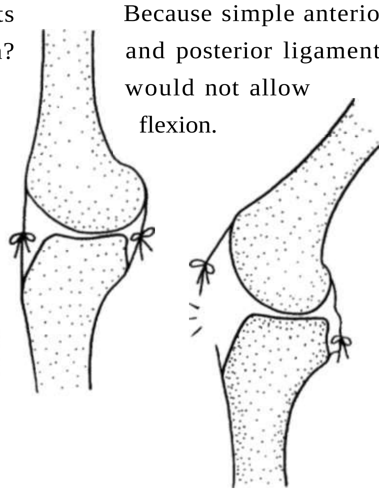
The anterior cruciate ligament tends to resist anterior displacement of the tibia on the femur...



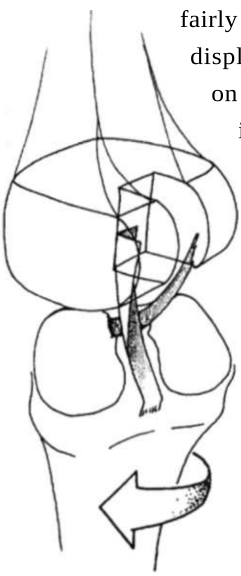
.. .while the posterior cruciate ligament resists posterior displacement.

Why have obliquely-oriented ligaments perform this braking action?

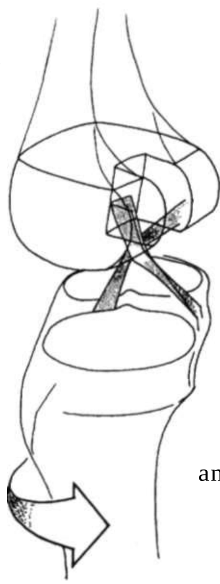
Because simple anterior and posterior ligaments would not allow flexion.



In both flexion and extension, the cruciate ligaments remain fairly taut, and displacement of the tibia on the femur is minimal.



In lateral rotation, the cruciates slacken somewhat.

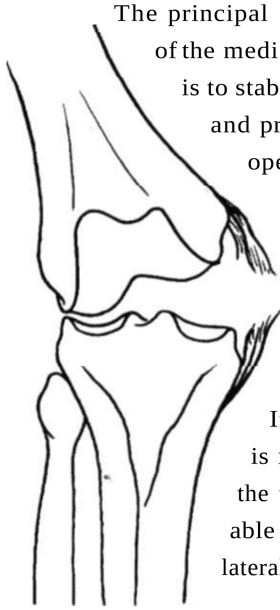


In medial rotation, they press against each other, and therefore become more taut.

On the sides, the joint capsule is reinforced by two **collateral ligaments.**

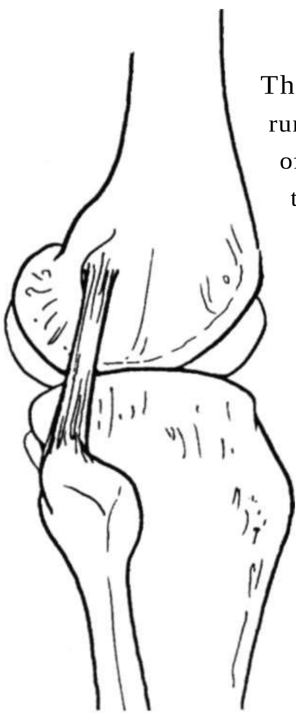
The **medial (tibial) collateral ligament** runs from the medial condyle of the femur to the medial condyle and upper medial shaft of the tibia.

Its lower attachment is slightly anterior relative to its upper attachment.



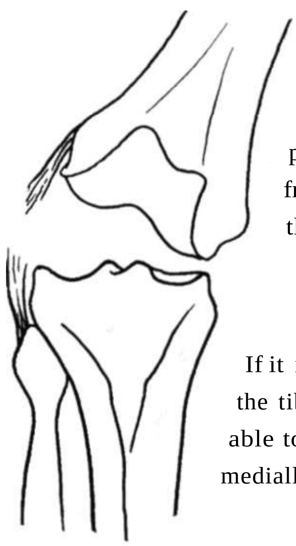
The principal function of the medial collateral is to stabilize the joint and prevent it from opening on the medial side.

If this ligament is ruptured, the tibia will be able to move laterally.



The **lateral (fibular) collateral ligament** runs from the lateral condyle of the femur to the head of the fibula.

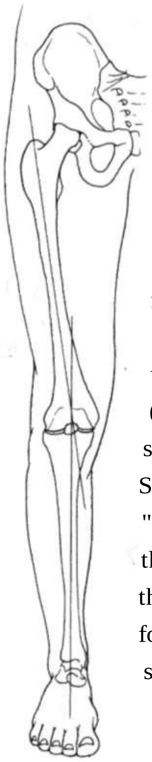
Its lower attachment is slightly posterior relative to its upper attachment.



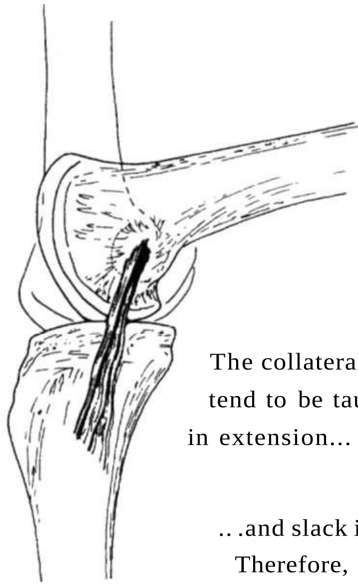
The principal function of this ligament is to prevent the joint from opening on the lateral side.

If it ruptures, the tibia will be able to move medially.

The medial collateral is considerably thicker and stronger than its lateral counterpart. Why?

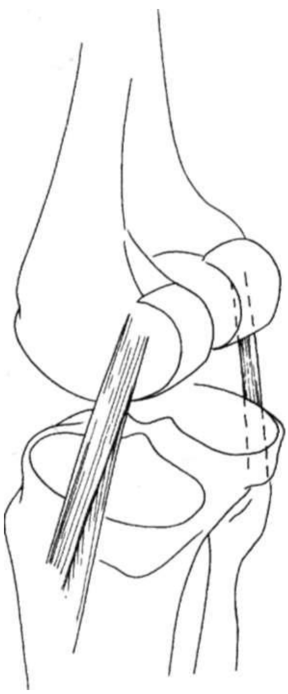


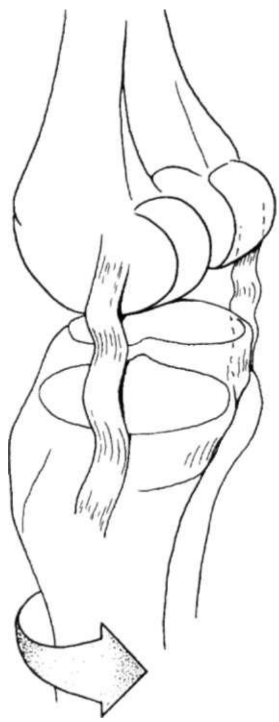
In the average person, the lateral angle formed by the femur and tibia is slightly less than 180° (genu valgum, see p. 215). Since the joint "gapes" more on the medial side, there is a need for stronger stabilization on that side.



The collaterals tend to be taut in extension...

...and slack in flexion. Therefore, they resist hyperextension.



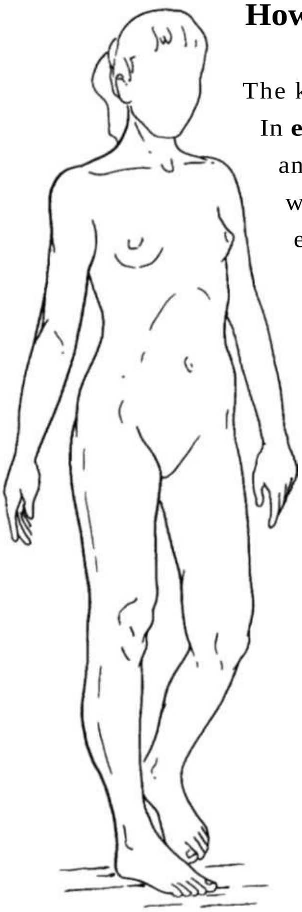


On leg bones, which have been "pulled apart" for illustrative purposes...

we see that the collaterals become slack in medial rotation of the tibia due to their orientation...

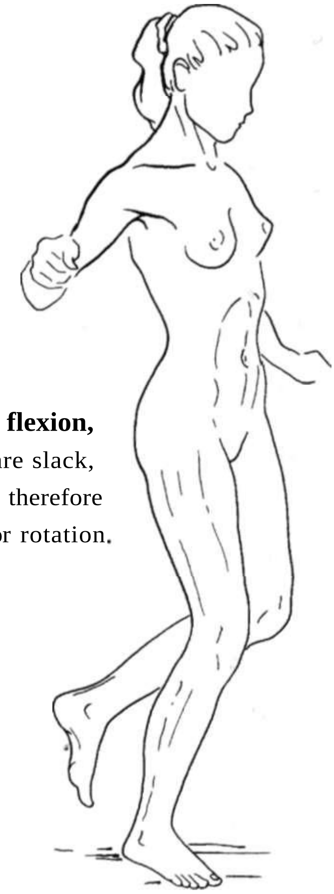
...and taut in lateral rotation. Thus, they resist excessive lateral rotation of the tibia.

How ligaments stabilize the knee

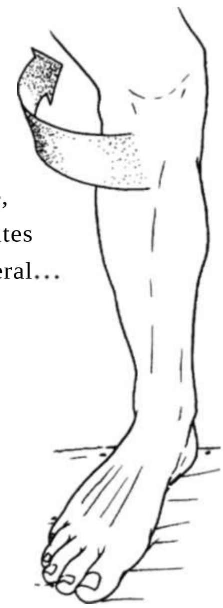


The knee ligaments act together to stabilize the joint
In **extension,** all the ligaments are taut,
and the joint can be passively stabilized
without any muscular action,
e.g., when balancing on one foot.

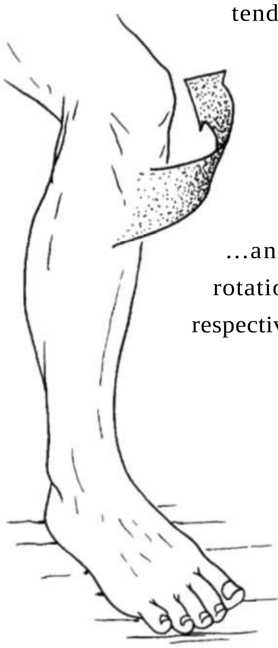
Here, the joint is "locked"
in slight hyperextension
by the tautness of the ligaments
(particularly the thickened
posterior portion
of the joint capsule).



In **flexion,**
most of the ligaments are slack,
and the joint therefore
has some capacity for rotation.



As noted above,
the collaterals and cruciates
tend to limit lateral...

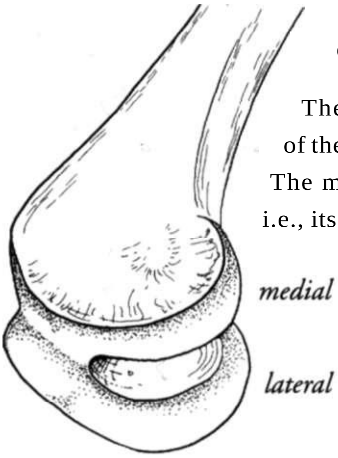


...and medial
rotation,
respectively.

But they are more restrictive
in the extended
than in the flexed position.

While balancing on one foot
with the knee flexed,
several muscles are used
to stabilize the body:

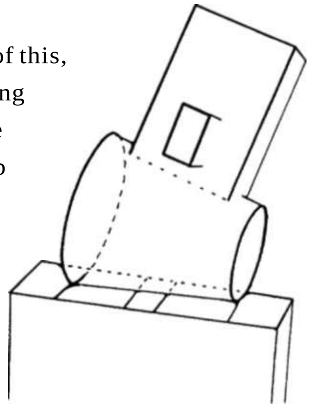
- quadriceps to prevent the knee from flexing more
- rotator muscles to prevent or slow down excessive rotation
  - — medially: vastus medialis, sartorius, gracilis, semitendinosus
  - - laterally: vastus medialis, biceps femoris, tensor fascia latae (see also muscle actions on p. 254)



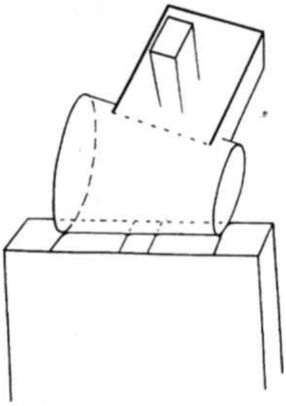
Some "automatic" rotation of the knee occurs during flexion/extension. Why is this?

The primary explanation involves the shape of the femoral and tibial condyles. The medial femoral condyle is more curved than the lateral one, i.e., its radius of curvature is smaller.

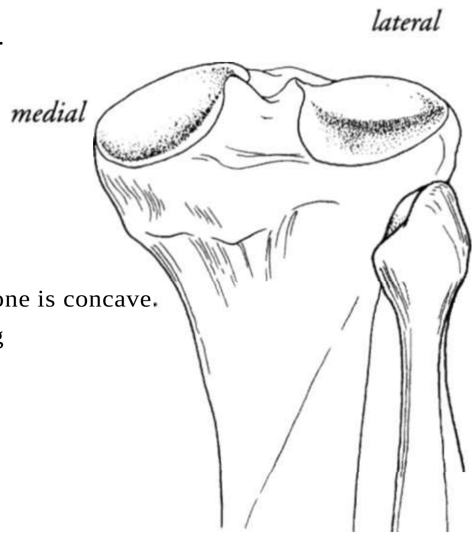
To understand the implications of this, visualize the two condyles as fitting inside a truncated cone, and the femoral shaft as a rectangular slab with a projection which we shall use as a reference landmark.



During extension, the shaft of the femur is directed forward.

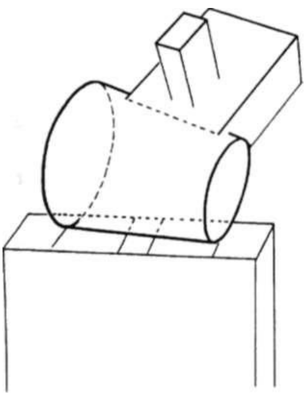


During flexion, due to the shape of the cone, the landmark becomes directed somewhat laterally.



[POSTERIOR VIEW]

The tibial condyles are also not totally symmetric; both are concave transversely, but from front to back the lateral condyle is slightly convex while the medial one is concave. Therefore, the lateral tibial condyle allows more rolling than does the medial one.

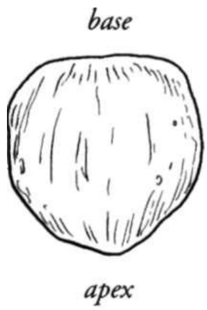


During flexion, the lateral femoral condyle rolls backward more than the medial one does, which accentuates the lateral orientation of our landmark, i.e., the lateral rotation of the femur.

The secondary explanation for automatic rotation of the knee is that the medial collateral ligament is stronger than the lateral one (see p. 221). This reinforces the tendency of the medial femoral condyle to be less mobile than the lateral one.

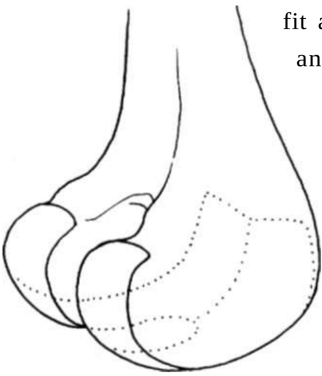
Patella

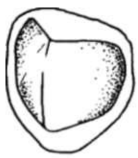
This is a sesamoid bone, located anterior to the distal end of the femur, which develops within the tendon of the quadriceps muscle (right).



Its anterior surface sits directly beneath the skin and is easily palpable.

The two articular facets on its posterior surface fit against the patellar surface of the femur, and are separated by a vertical ridge.

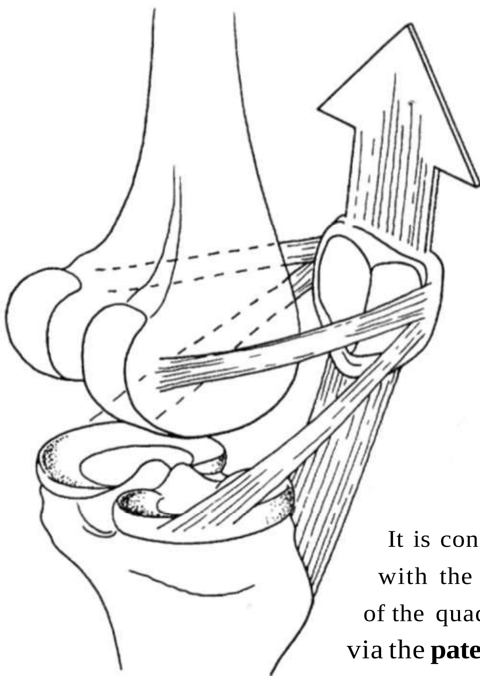




The patella is both attached to the knee and is mobile on top of it.

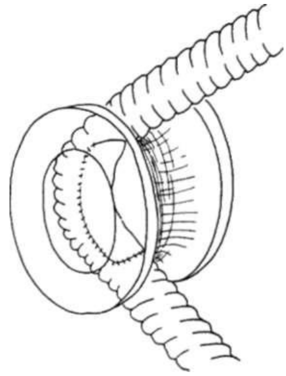
It is connected:

- with the femoral condyles via the lateral and medial patellar ligaments
- with the menisci via the meniscopatellar ligaments.

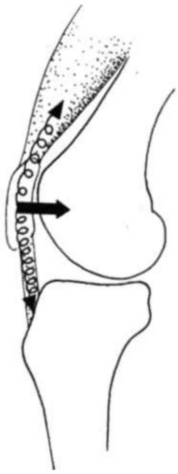


It is connected with the tendon of the quadriceps femoris via the **patellar ligament.**

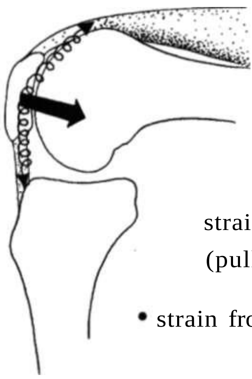
What exactly does the patella do? Its primary function is to protect the quadriceps tendon, in which it is contained. During movement, this tendon slides in the groove between the femoral condyles, like a rope in a pulley.



This causes intense strain on the patella:



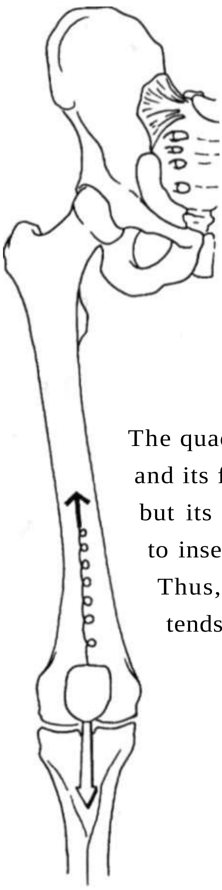
- strain from being pressed against the groove during flexion due to the pulling action of the quadriceps muscles...



...this pressure can be 400 kg or more during squatting, and even more when carrying a heavy object

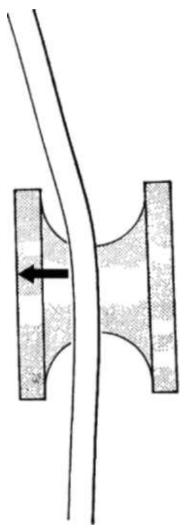
strain from stretching (pulling forces from different directions)

- strain from constant usage.

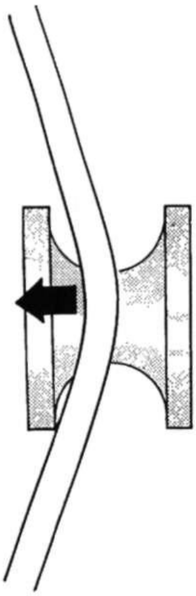


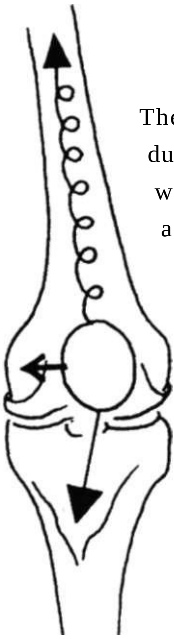
The patella is not stable laterally.

The quadriceps follows the femoral shaft and its force is slightly oblique, but its tendon runs straight down to insert on the tibia.
Thus, contraction of the quadriceps tends to pull the patella laterally...



...just as a pulley would move sideways if its rope came down at an angle.

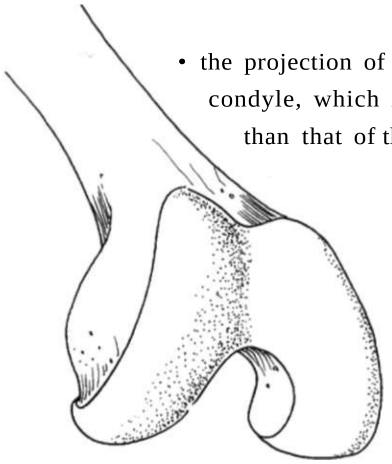




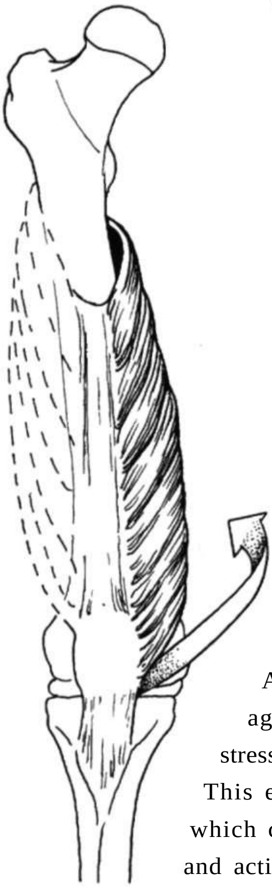
The lateral instability of the patella is maximal during active extension or slight flexion when the patella is not firmly pressed against the patellar surface of the femur; during full flexion the patella is better "locked" in place.

This instability is accentuated during lateral rotation of the tibia when the lower as well as upper part of the tendon become obliquely oriented.

The tendency of the patella to move laterally is counteracted by two mechanisms:



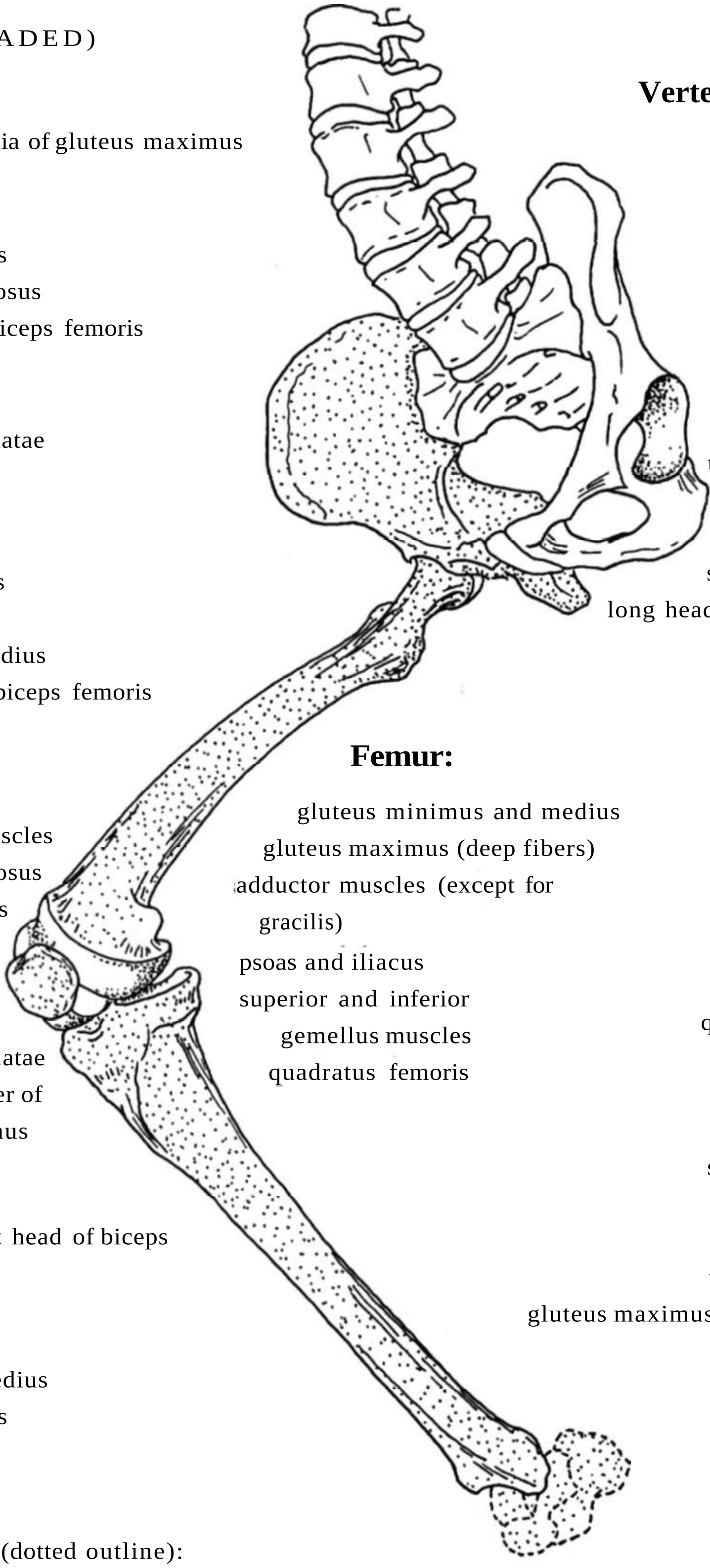
• the projection of the lateral femoral condyle, which is more pronounced than that of the medial condyle



• the contraction of the vastus medialis muscle, which pulls the tendon medially.

As you can see, the articulation of the patella against the femur is subjected to major strains and stresses, particularly on the lateral side. This explains the frequency of arthritis here, which can compromise proper gliding of the patella and active extension of the knee.

Muscles of the hip and knee with their many bony attachments



KNEE (SHADED)

Sacrum:

superficial fascia of gluteus maximus

Ischium:

semitendinosus
semimembranosus
long head of biceps femoris
gracilis
sartorius
tensor fasciae latae
rectus femoris

Femur:

vastus medialis
vastus lateralis
vastus intermedius
short head of biceps femoris
popliteus

Tibia:

quadriceps muscles
semimembranosus
semitendinosus
gracilis
popliteus
sartorius
tensor fasciae latae
superficial layer of gluteus maximus

Fibula:

long and short head of biceps femoris

Patella:

vastus intermedius
vastus medialis
vastus lateralis
rectus femoris

Calcaneus (dotted outline):

gastrocnemius

HIP

Vertebrae T12/L5:

psoas

Sacrum:

piriformis
gluteus maximus

Ischium:

rectus femoris
sartorius
tensor fasciae latae
gluteus muscles
semitendinosus
semimembranosus
long head of biceps femoris
adductor muscles
obturator muscles
gemellus muscles
quadratus femoris

Femur:

gluteus minimus and medius
gluteus maximus (deep fibers)
adductor muscles (except for gracilis)
psoas and iliacus
superior and inferior gemellus muscles
quadratus femoris

Coccyx:

gluteus maximus

Patella:

quadriceps muscles

Tibia:

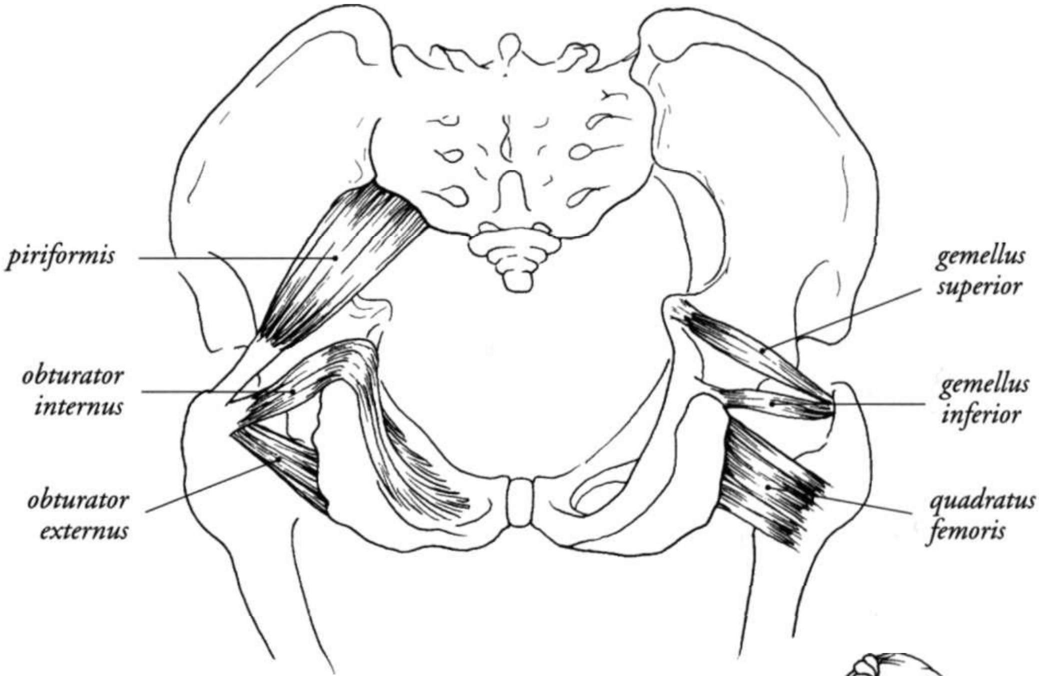
semitendinosus
semimembranosus
gracilis
sartorius
tensor fasciae latae
gluteus maximus (superficial layer)
rectus femoris

Fibula:

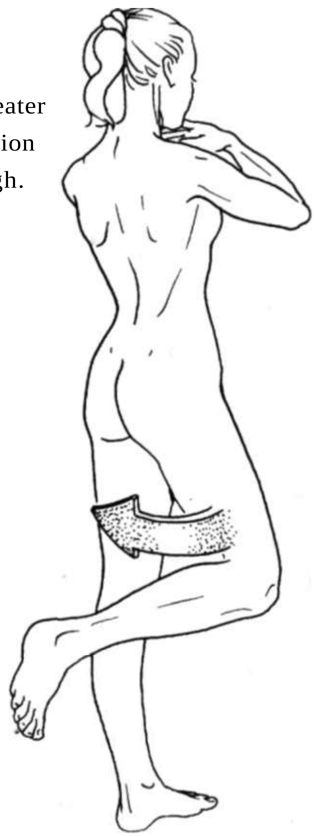
long head of biceps femoris

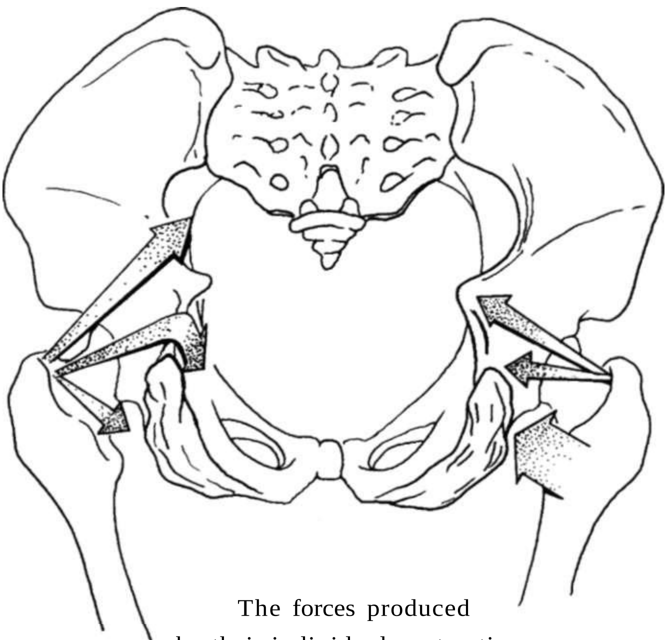
Muscles of the hip

A group of six deep hip muscles are shown in this inferior view of the pelvis.

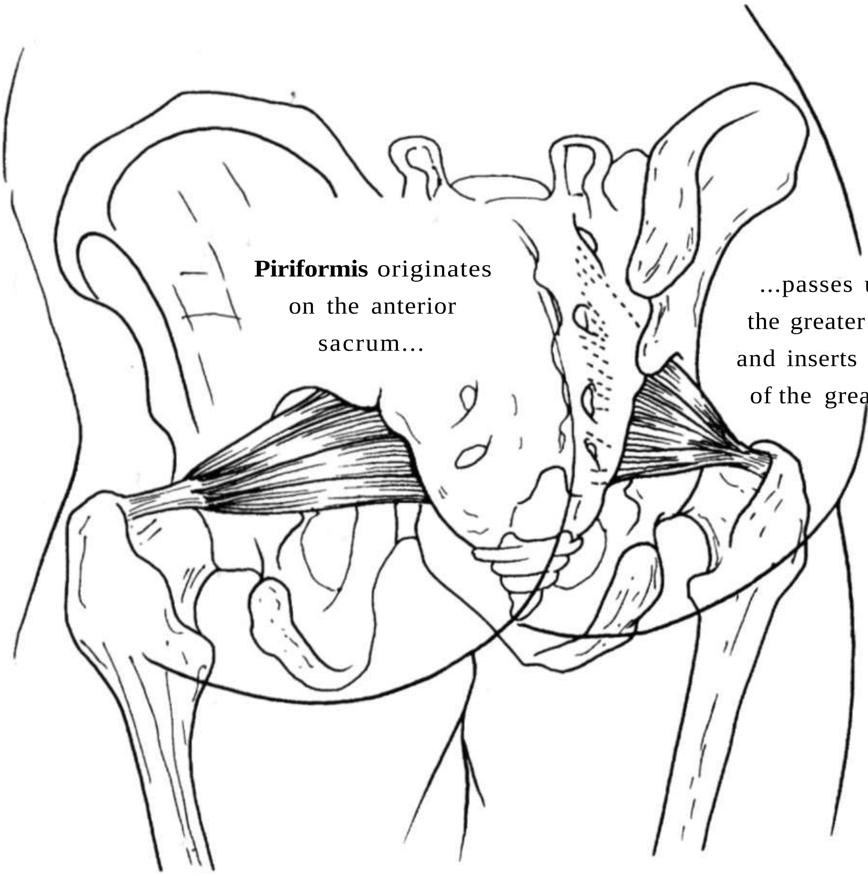


They all insert on or near the greater trochanter of the femur and function in lateral rotation of the thigh.





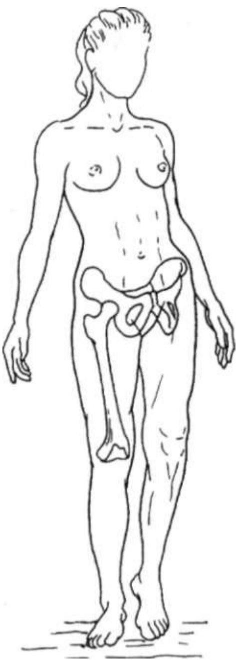
The forces produced by their individual contractions are illustrated above.



Piriformis originates on the anterior sacrum...

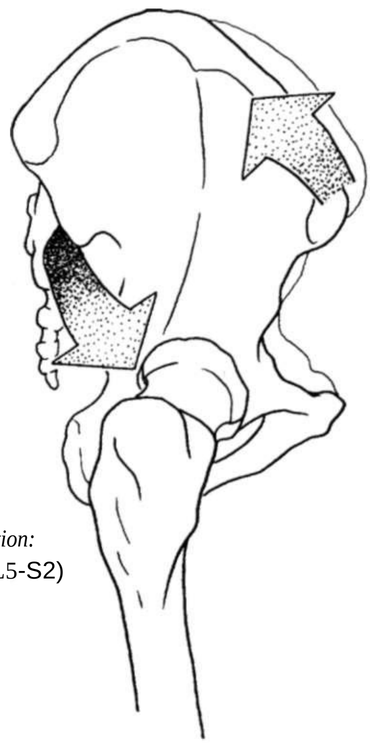
...passes under the greater sciatic notch, and inserts on the top of the greater trochanter.

Actions: If the sacrum is fixed, piriformis laterally rotates, abducts, and flexes the femur.

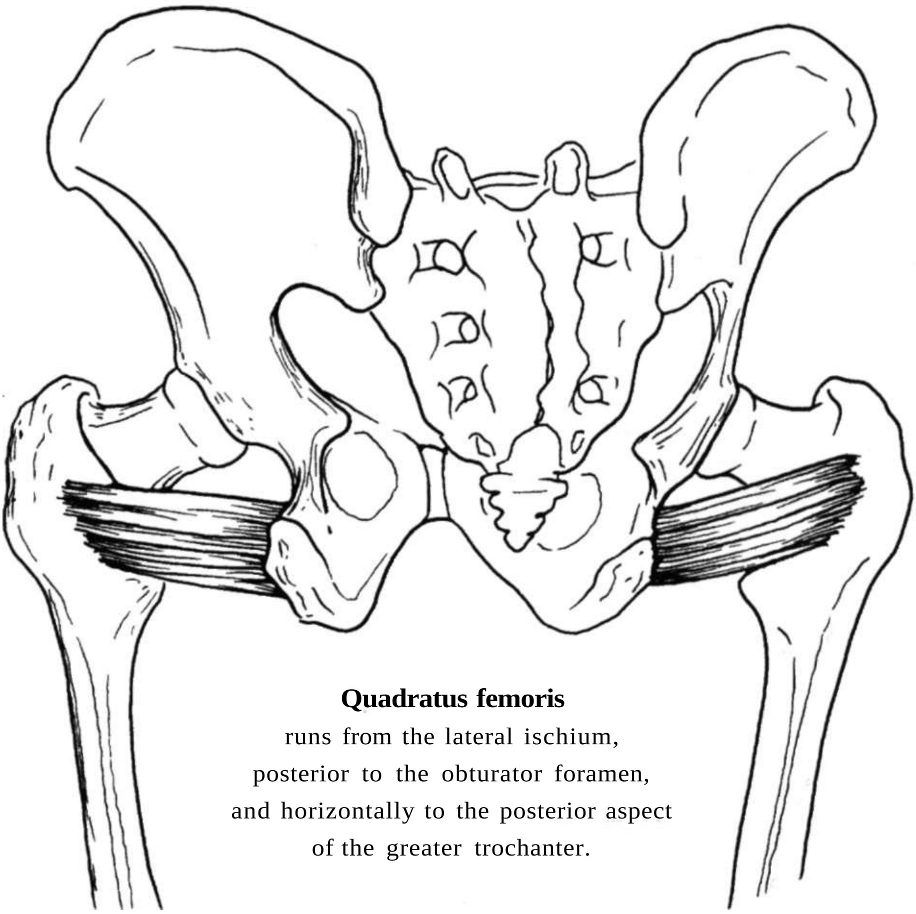


If the femur is fixed, it contributes to extension of the pelvis (bilateral contraction)...

.. .or to medial rotation of the pelvis (unilateral contraction).

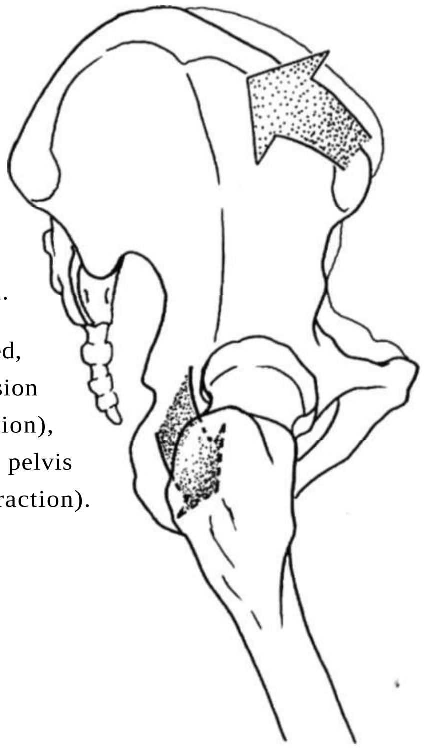


Innervation:
sacral plexus (L5-S2)



Quadratus femoris

runs from the lateral ischium, posterior to the obturator foramen, and horizontally to the posterior aspect of the greater trochanter.

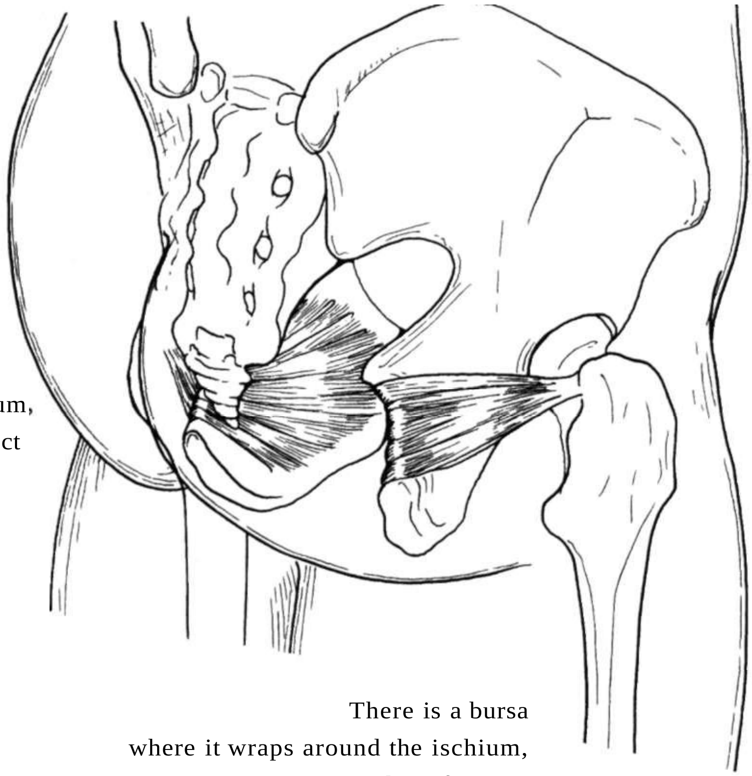


Actions: If the pelvis is fixed, quadratus femoris laterally rotates the thigh.

If the femur is fixed, it contributes to extension of the pelvis (bilateral contraction), or to medial rotation of the pelvis (unilateral contraction).

Innervation:
inferior gluteal nerve, sacral plexus (L5-S2)

The following four muscles insert into the medial surface of the greater trochanter, at the level of a depression called the **trochanteric fossa.**

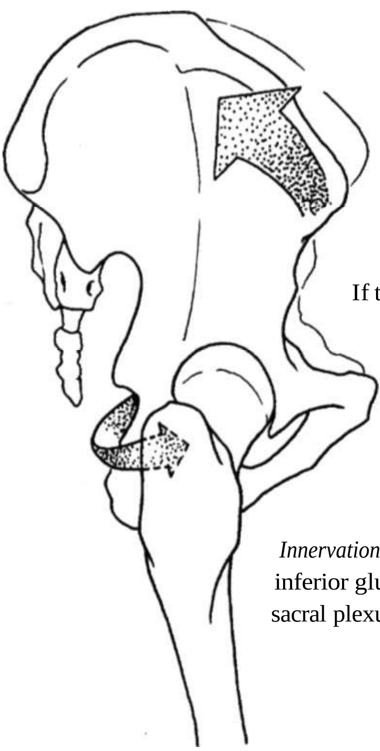


Obturator internus

arises from the obturator membrane and adjacent portions of the ischium and ilium.

Its fibers pass posteriorly through the lesser sciatic notch, make a sharp bend around the body of the ischium, and insert on the medial aspect of the greater trochanter.

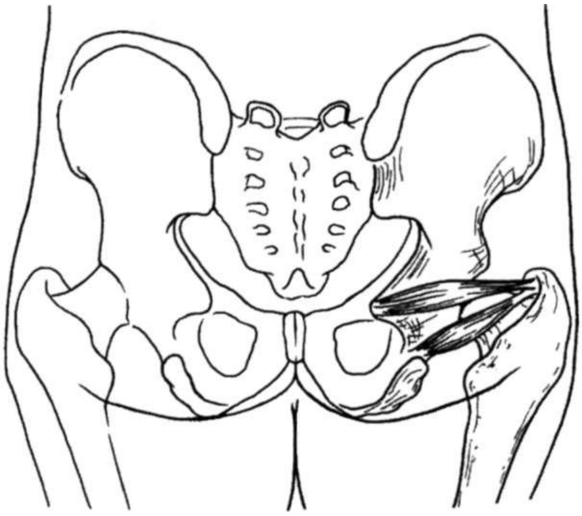
There is a bursa where it wraps around the ischium, to reduce friction.



Actions: If the pelvis is fixed, this muscle laterally rotates, flexes, and abducts the thigh.

If the femur is fixed, the muscles act in extension (bilateral contraction) and in medial rotation or medial flexion (unilateral contraction) of the pelvis.

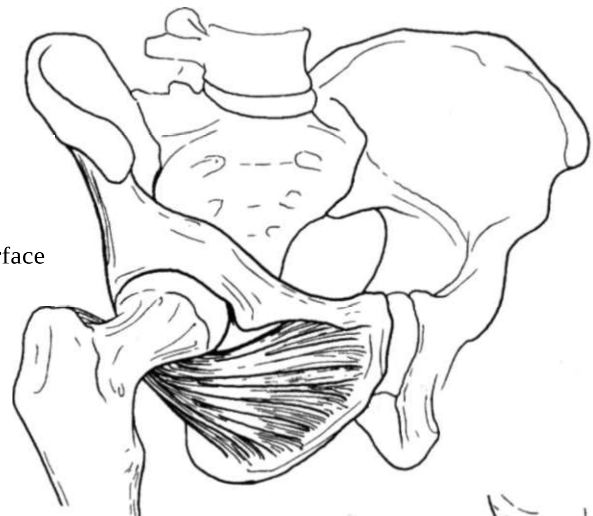
Innervation: inferior gluteal nerve, sacral plexus (L5-S2)

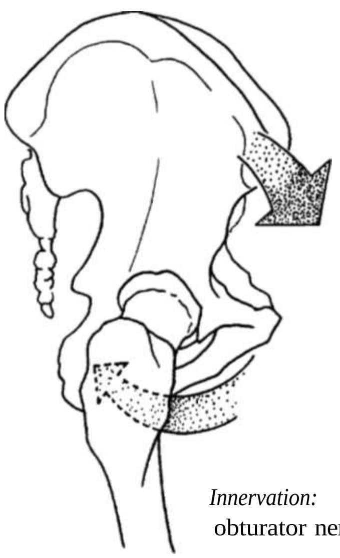


Gemellus superior and inferior are small muscles located above and below the distal borders of obturator internus, at the level of the lesser sciatic notch. They reinforce the actions of obturator internus.

Obturator externus arises from the external surface of the obturator membrane, passes posterior to the femoral neck, and inserts on a fossa on the medial surface of the greater trochanter.

Actions: If the pelvis is fixed, it laterally rotates, flexes, and abducts the femur.





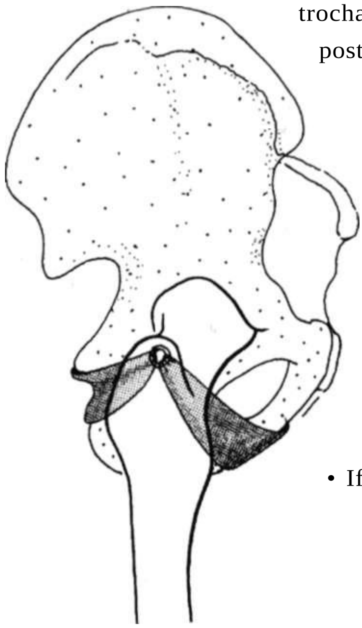
If the femur is fixed, it functions in flexion of the pelvis (bilateral contraction)...

...and also medially rotates and flexes the pelvis (unilateral contraction).

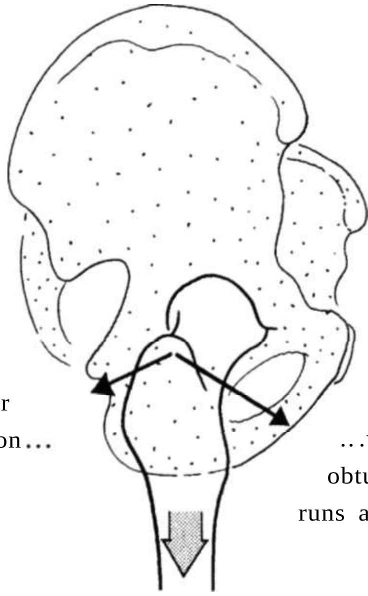
Innervation: obturator nerve (L1-L4)

How obturator and gemellus muscles support the hip

Viewing the hip from the right side, we observe that:



Obturator internus and the gemelli run from the greater trochanter in a posteroinferior direction...



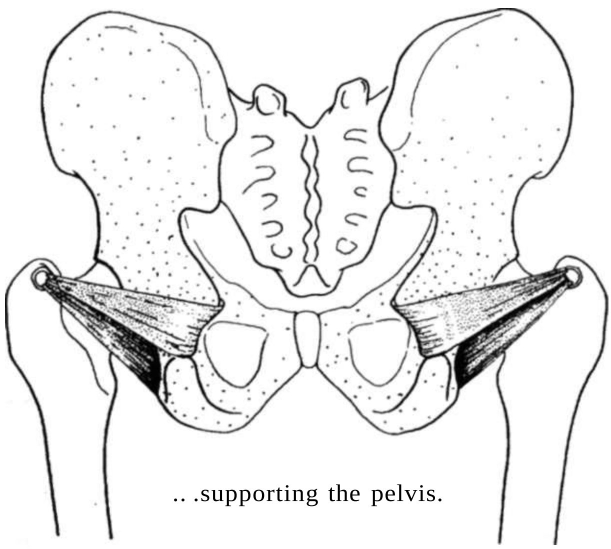
...while obturator externus runs anteroinferiorly.

The combined action of the obturators and gemelli, therefore, can be understood as follows:

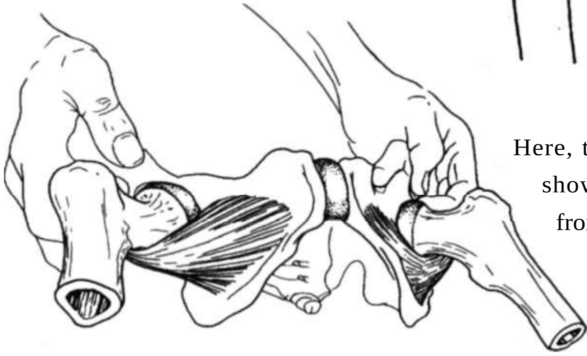
- If the pelvis is fixed, they will pull the femur down relative to the pelvis.
- If the femur is fixed, they will lift the pelvis relative to the femur.

Either way, they tend to "pull apart" the hip joint, on a very small scale. This is a decompressive effect which is quite beneficial for certain painful conditions (e.g., worn-down cartilage).

The obturators and gemelli have been compared to a "hammock"...



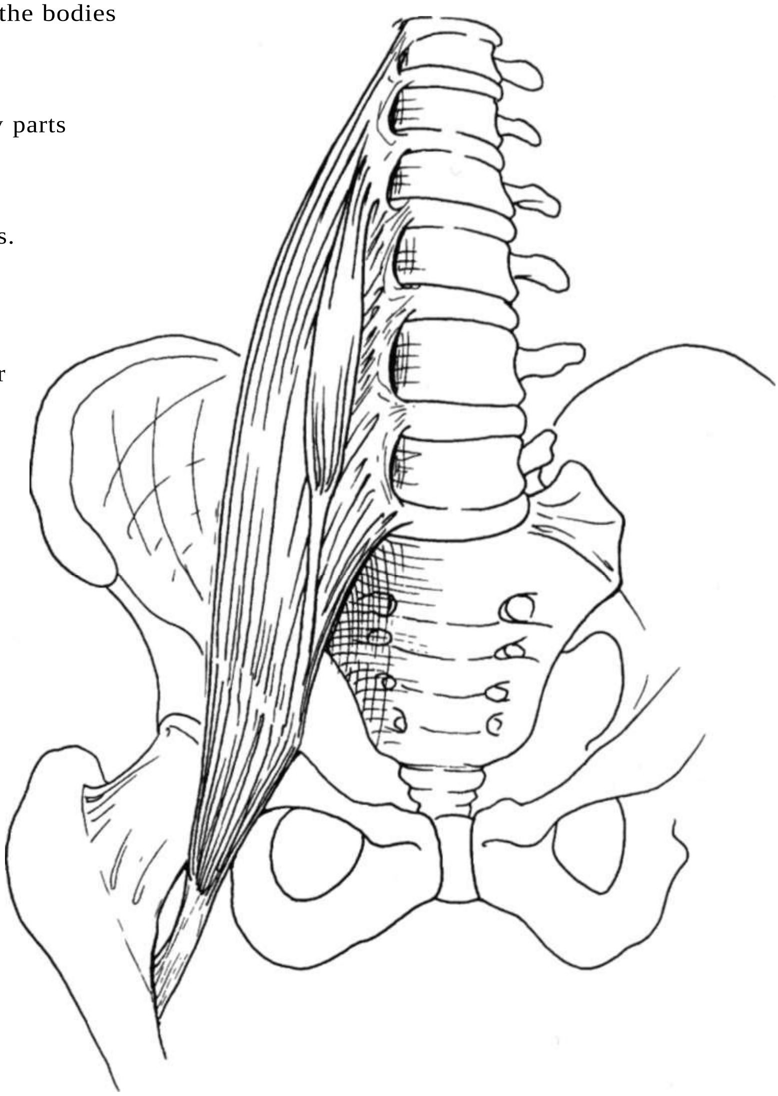
...supporting the pelvis.



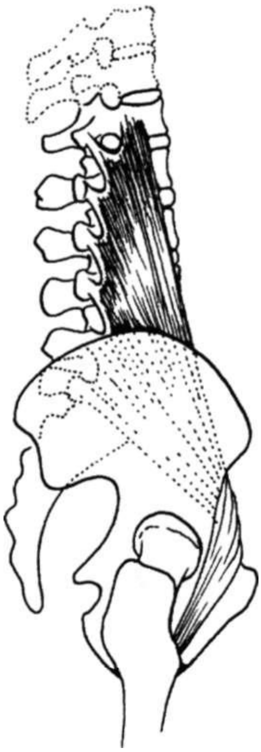
Here, the pelvis is tilted backward, showing the two external obturator muscles from the bottom.

In this view, you can see how the muscles wrap under the femoral head and neck before heading superiorlaterally.

Psoas major arises from the bodies
of T12 through L5,
and from arches of fascia
which connect the boney parts
of the vertebral bodies
but do not attach
to the intervertebral disks.



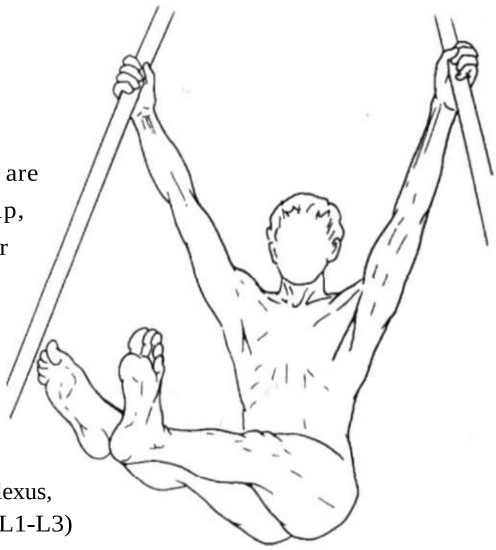
It runs anterior
to the pelvis,
posterior to the
inguinal ligament,
and inserts
on the lesser trochanter.



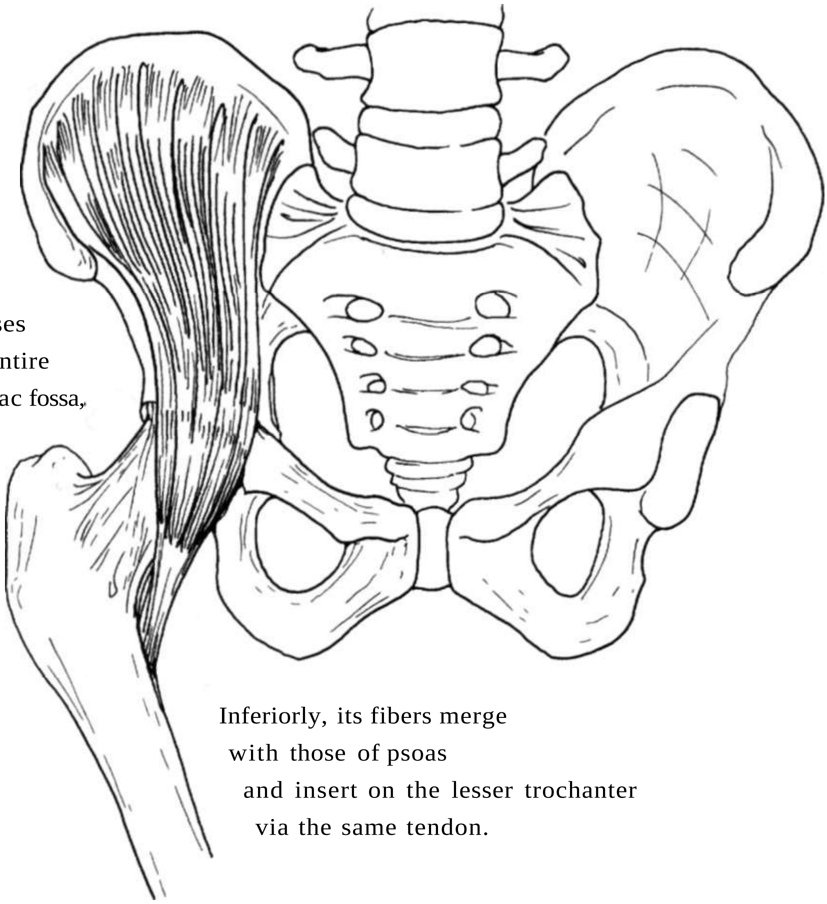
There is a bursa to reduce friction
where it bends at the
anterior pelvis.

Actions: When the vertebrae are
fixed, the psoas flexes the hip,
and works as a weak adductor
and lateral rotator.

Its effect on the lumbar spine
when the femur is fixed was described on page 92.

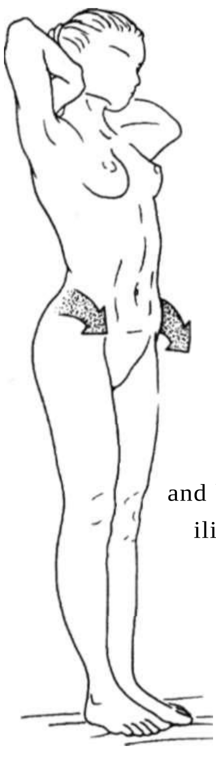


Innervation: lumbar plexus,
femoral nerve (L1-L3)



Iliacus arises
from the entire
internal iliac fossa,

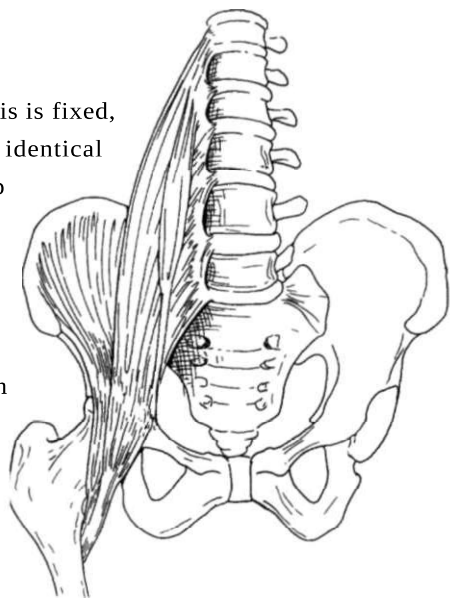
Inferiorly, its fibers merge
with those of psoas
and insert on the lesser trochanter
via the same tendon.



Actions: When the pelvis is fixed,
the action of iliacus is identical
to that of psoas in flexing the hip

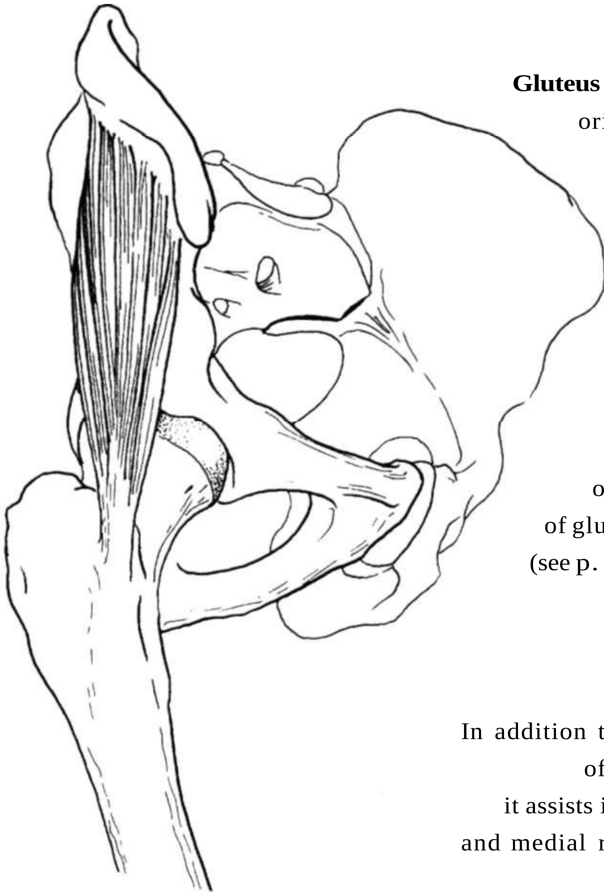
When the femur is fixed, iliacus
acts in flexion of the pelvis
(bilateral contraction).

Because they share the same tendon
and have the same action on the thigh,
iliacus and psoas are often described
as a single muscle ("iliopsoas").



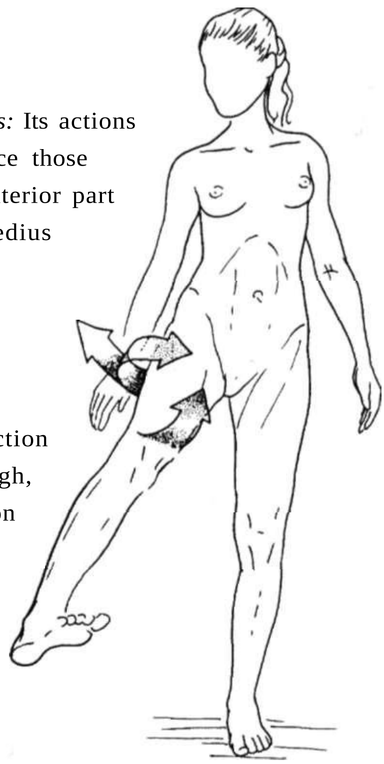
However, it is important to remember that
their superior attachments are quite different.
When the femur is fixed, iliacus acts on the pelvis,
whereas psoas acts on the lumbar spine.

Innervation: lumbar plexus,
femoral nerve (L2-L4)

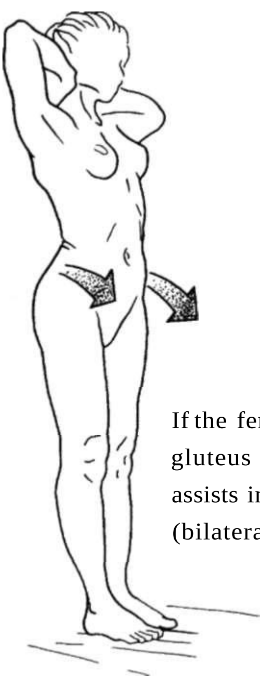


Gluteus minimus is a small muscle originating from the external iliac fossa and inserting on the anterior aspect of the greater trochanter.

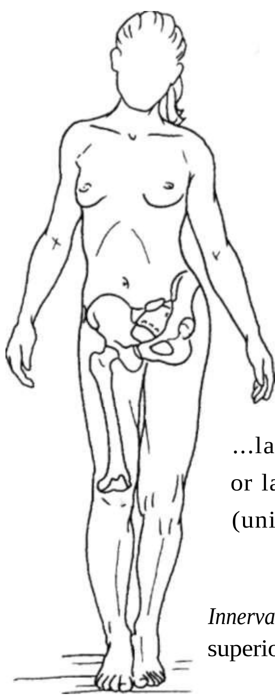
Actions: Its actions reinforce those of the anterior part of gluteus medius (see p. 237).



In addition to abduction of the thigh, it assists in flexion and medial rotation.

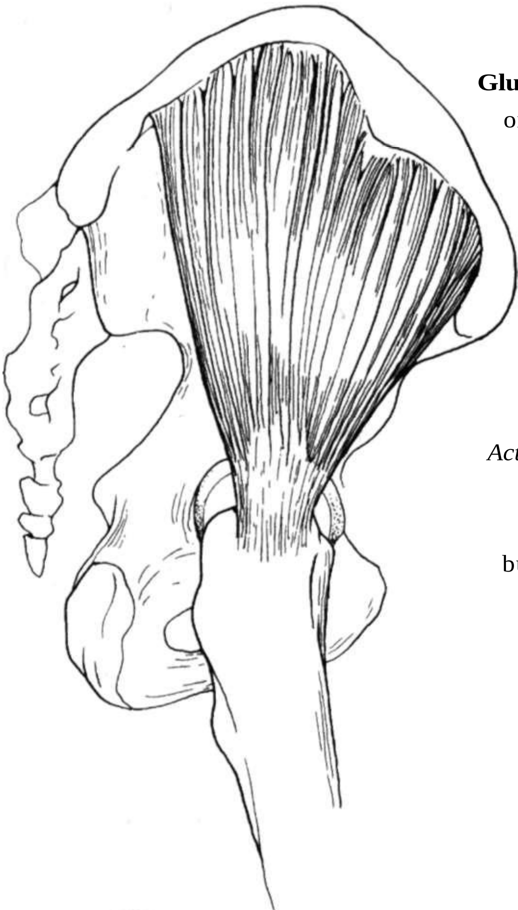


If the femur is fixed, gluteus minimus assists in flexion (bilateral contraction)...

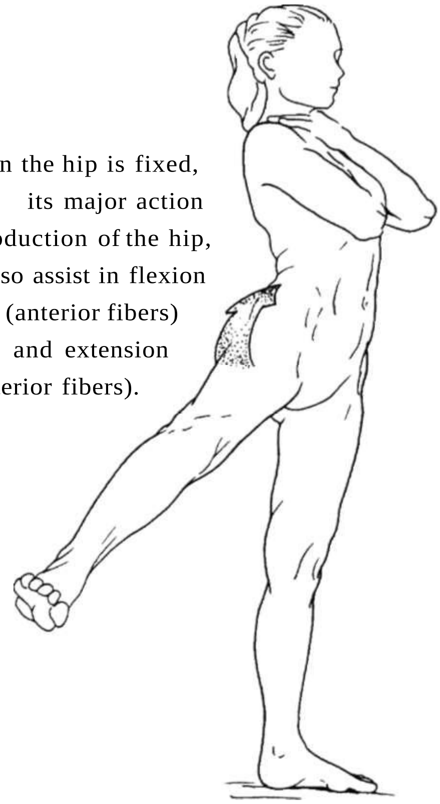


...lateral flexion, or lateral rotation of the pelvis (unilateral contraction).

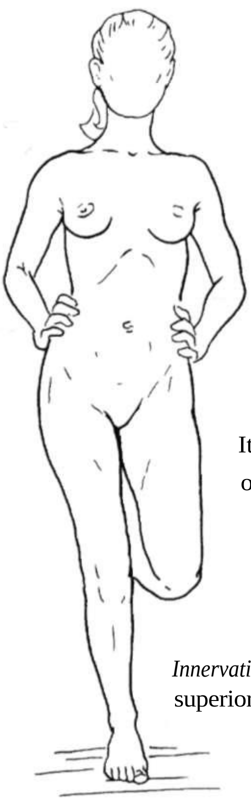
Innervation:
superior gluteal nerve (L4-S1)



Gluteus medius has a broad origin on the external iliac fossa. Its fibers converge and insert on the lateral aspect of the greater trochanter.



Actions: When the hip is fixed, its major action is abduction of the hip, but it can also assist in flexion (anterior fibers) and extension (posterior fibers).



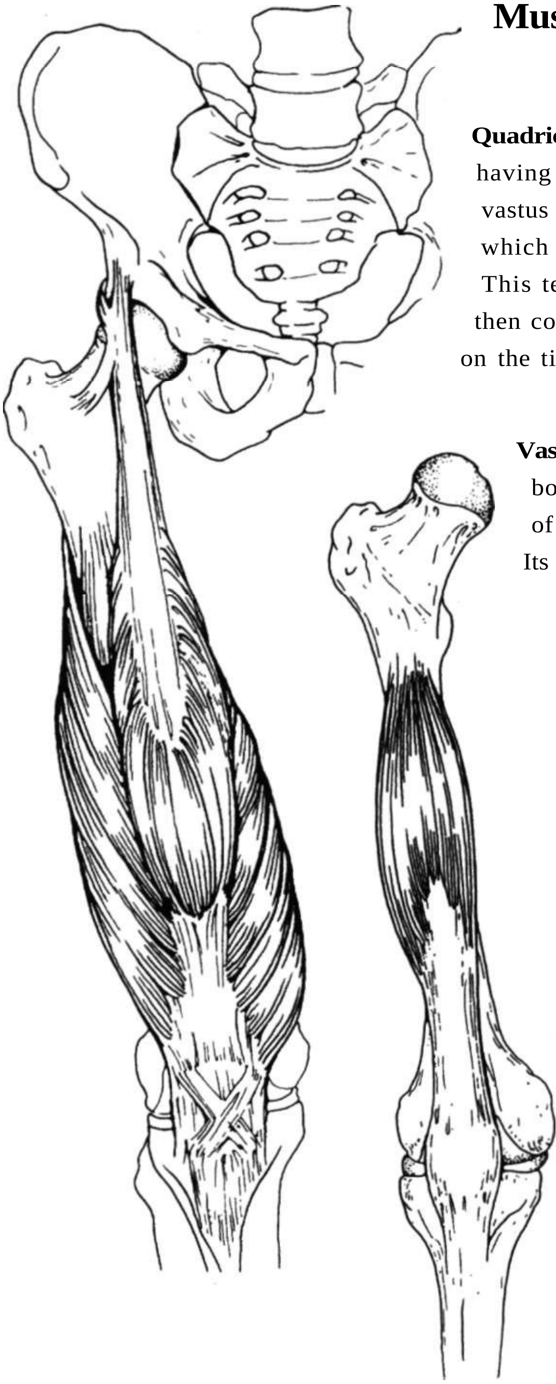
When the femur is fixed, gluteus medius is involved in both flexion and extension of the pelvis, depending on whether the anterior or posterior fibers contract (bilateral contraction).

Its main action is visible when a person stands on one leg: It mostly acts in lateral flexion of the pelvis.

Innervation:
superior gluteal nerve (L4-L5)

With unilateral contraction, it acts in lateral flexion of the pelvis, and also stabilizes the pelvis during walking (see p. 255) or standing on one foot.

Muscles of the hip and knee



Quadriceps femoris is a massive muscle having four bodies (rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius) which converge into a single quadriceps tendon. This tendon inserts on and surrounds the patella, then continues as the patellar ligament to insert on the tibial tuberosity.

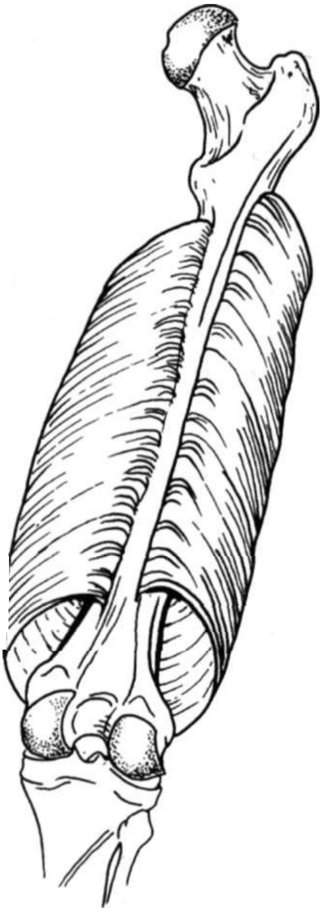
Vastus intermedius, the deepest of the muscle bodies, originates from the upper two-thirds of the anterior femoral shaft. Its fibers follow the axis of the femur.

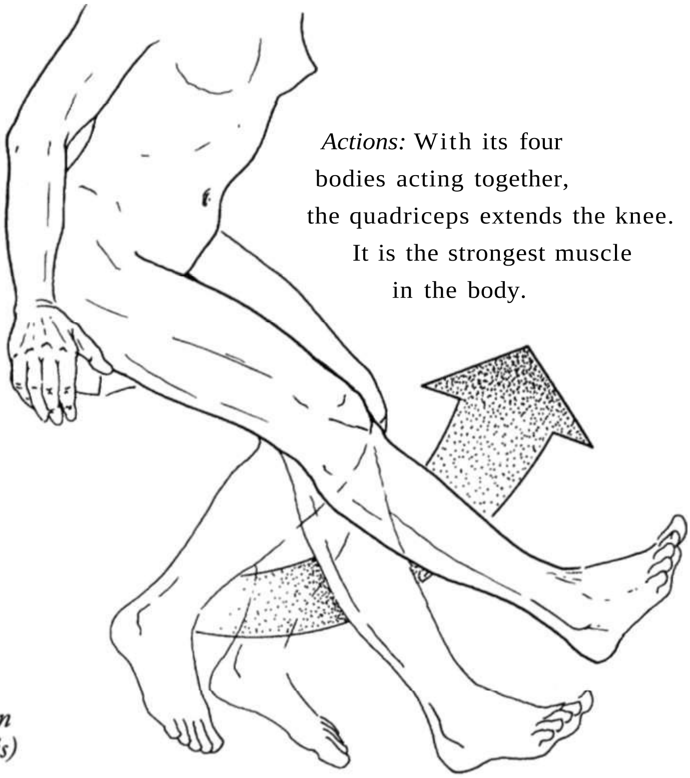
Vastus intermedius is covered by **vastus lateralis** and **medialis,** which arise from either side of the linea aspera on the posterior femoral shaft, then wrap around the sides to meet anteriorly, superficial to vastus intermedius.

Rectus femoris arises from the anterior inferior iliac spine and part of the ilium near the acetabulum, and passes superficial to the three vasti to insert on the common tendon. Thus, unlike the vasti, it crosses the hip as well as the knee.

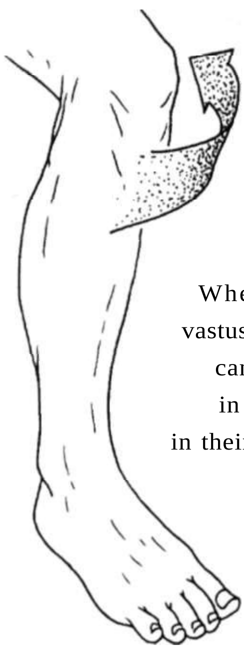
Innervation:
femoral nerve (L2-L4)

This posterior view of the femur shows the origin of the vastus muscles along the linea aspera (see p. 200). Vastus medialis has its origin on the medial surface of the femur, whereas vastus lateralis has its origin on the lateral surface of the femur. From there, they run on both sides of the femur toward the anterior thigh.

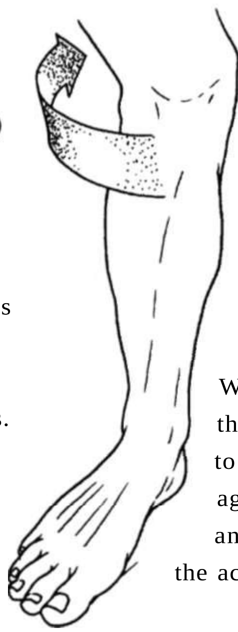




Actions: With its four bodies acting together, the quadriceps extends the knee. It is the strongest muscle in the body.



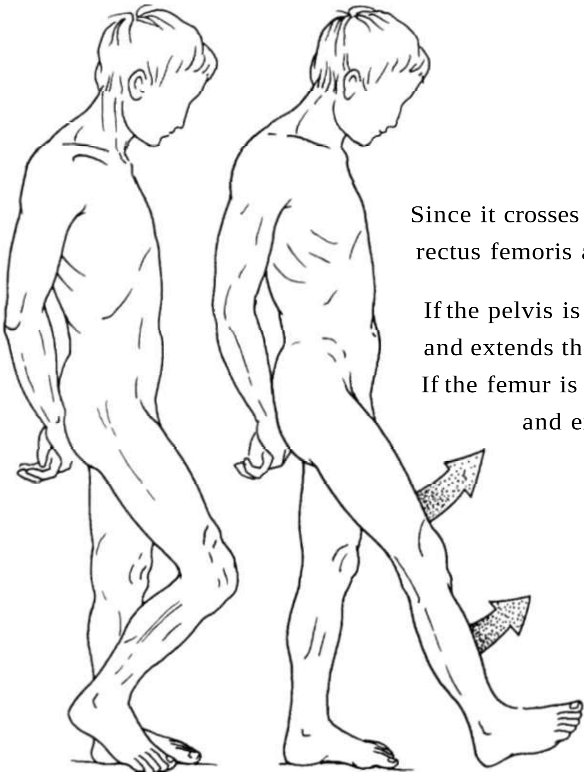
medial rotation (vastus medialis)



lateral rotation (vastus lateralis)

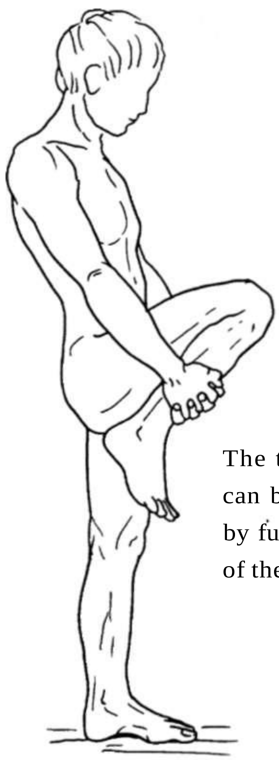
When the knee is flexed, vastus medialis and lateralis can play a small part in rotating the tibia in their respective directions.

When the knee is extended, the two muscles act to stabilize the knee against lateral displacement, and thereby actively complement the actions of the ligaments.

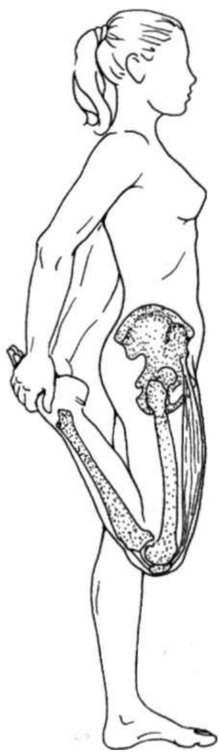


Since it crosses the hip and knee, rectus femoris acts on both joints.

If the pelvis is fixed, it flexes the hip and extends the knee (e.g., in walking).
If the femur is fixed, it acts in flexion of the pelvis and extends the knee.

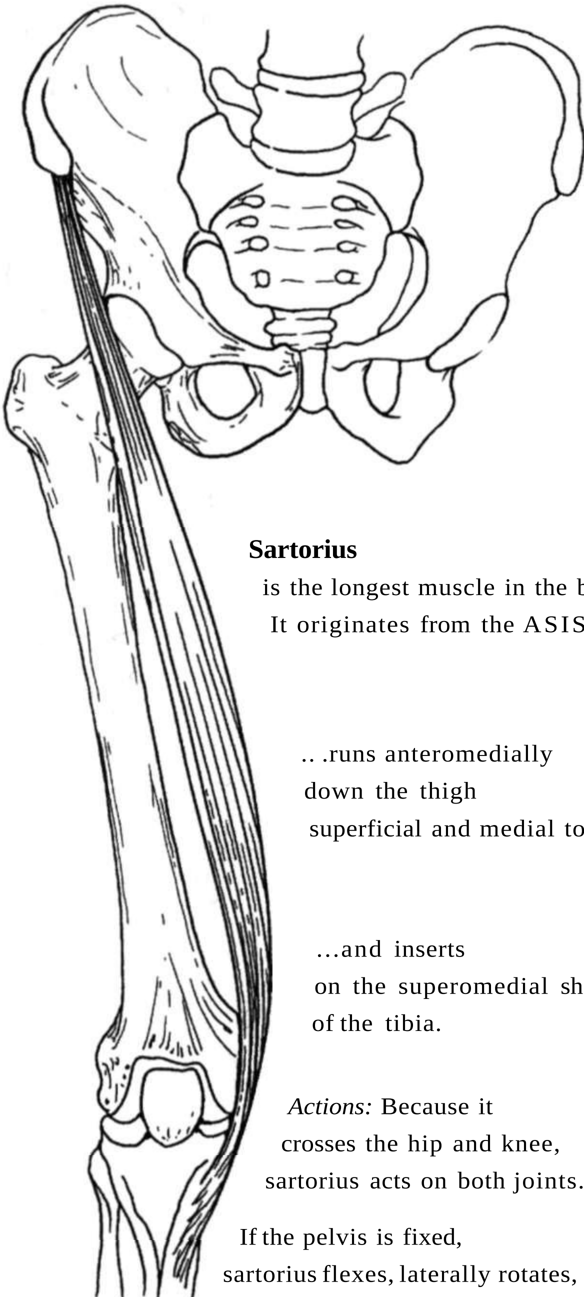


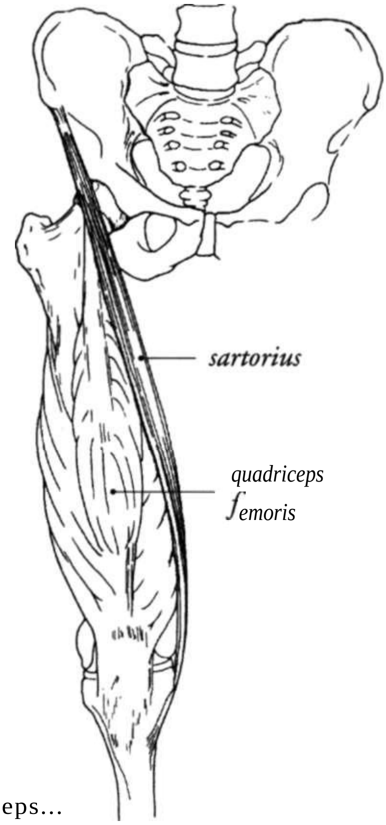
The three vasti can be stretched by full flexion of the knee and hip.



For stretching rectus fermoris, the hip must be in extension and the knee in flexion.

When the rectus femoris is shortened, it is often one of the muscles responsible for a flexed hip position, i.e., flexion of the pelvis.





Sartorius

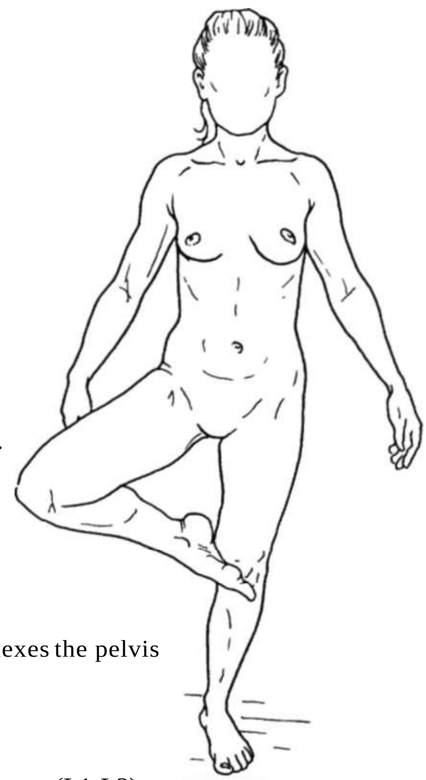
is the longest muscle in the body.
It originates from the ASIS...

.. .runs anteromedially
down the thigh
superficial and medial to quadriceps...

...and inserts
on the superomedial shaft
of the tibia.

Actions: Because it
crosses the hip and knee,
sartorius acts on both joints.

If the pelvis is fixed,
sartorius flexes, laterally rotates,
and abducts the femur,
and flexes and medially rotates the tibia.

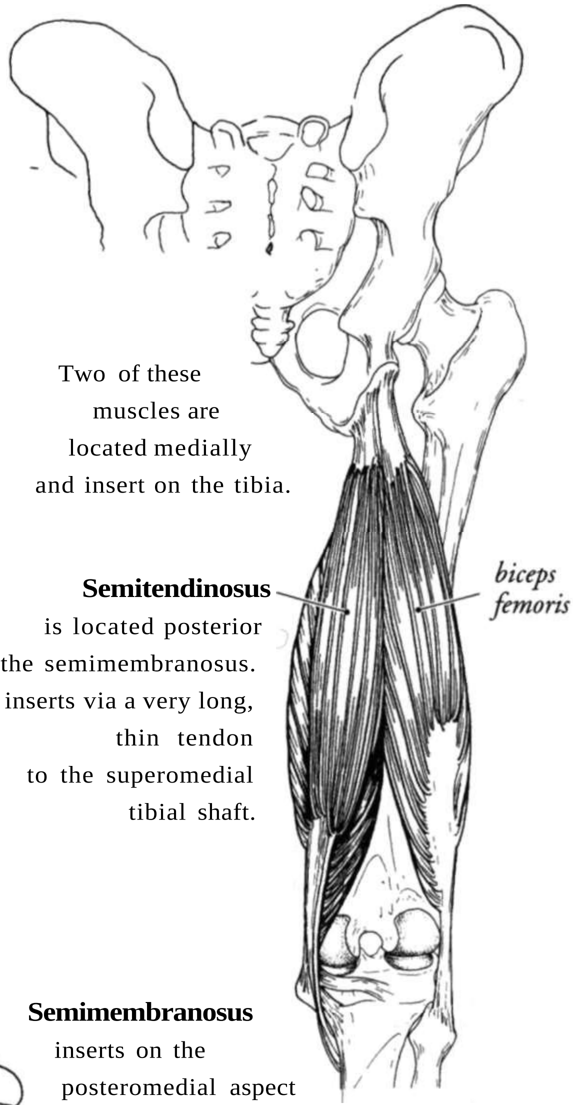


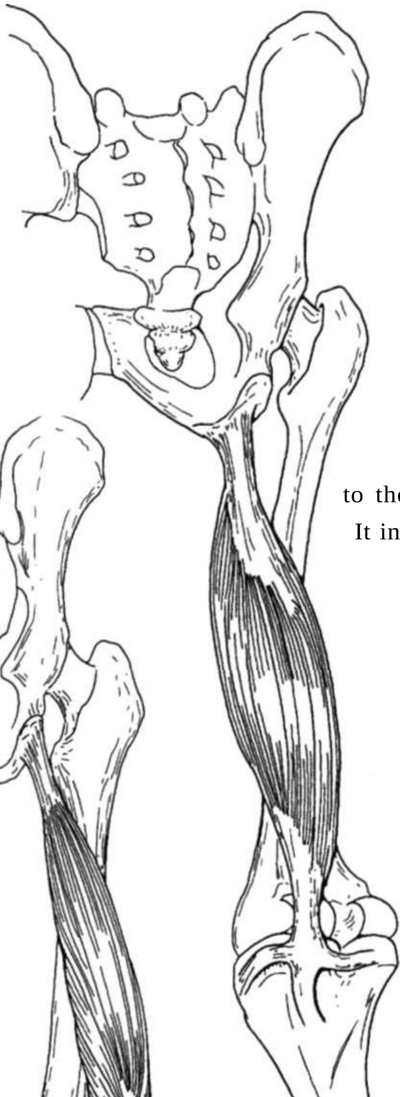
If the leg is fixed, it:

- anteverts the pelvis (bilateral contraction)
- anteverts, medially rotates, and laterally flexes the pelvis (unilateral contraction).

Innervation: femoral nerve (L1-L3)

The hamstrings are a group of three posterior muscles working together to flex the knee and extend the thigh. They all arise from the ischium, posterior to the hip bone, and insert on the bones of the lower leg.





Two of these muscles are located medially and insert on the tibia.

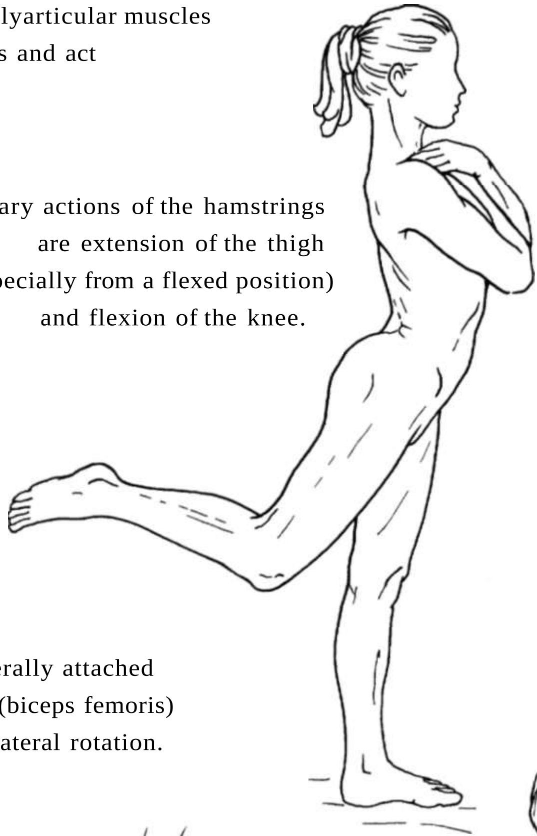
Semitendinosus is located posterior to the semimembranosus. It inserts via a very long, thin tendon to the superomedial tibial shaft.

Semimembranosus inserts on the posteromedial aspect of the tibial condyle.

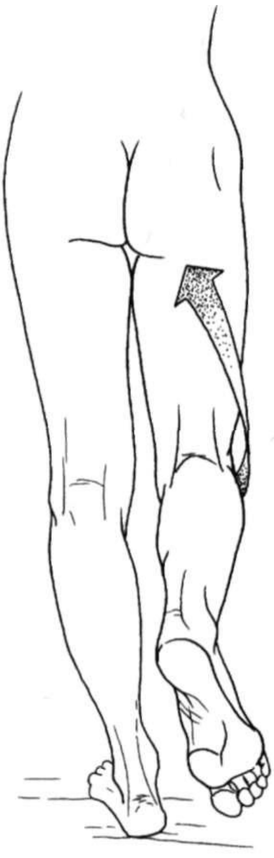
Biceps femoris is located laterally. The two heads of this muscle merge inferiorly and insert via a common tendon to the head of the fibula. This tendon is bifurcated by the lateral collateral ligament of the knee.

Innervation:
common tibial nerve (L5-S2)

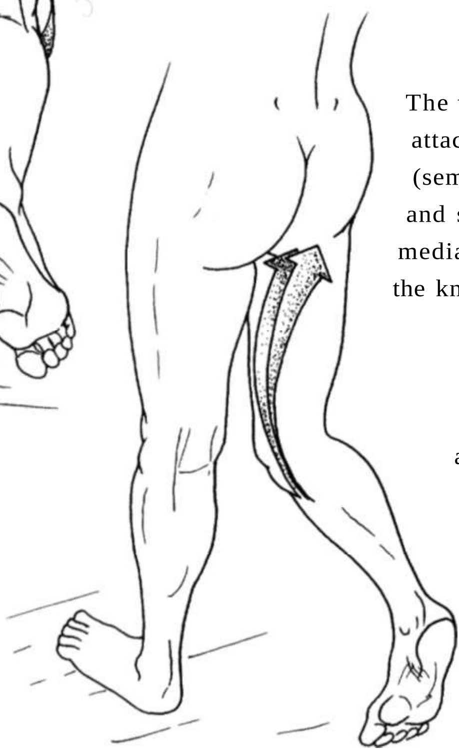
Collectively, the hamstrings are polyarticular muscles of the hip and knee, i.e., they cross and act on more than one joint.



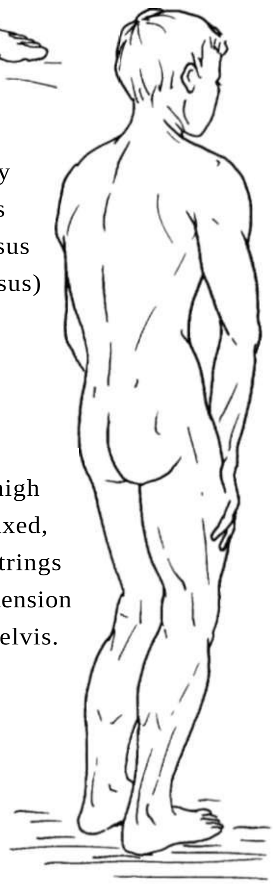
Actions: The primary actions of the hamstrings are extension of the thigh (especially from a flexed position) and flexion of the knee.



The laterally attached muscle (biceps femoris) acts in lateral rotation.

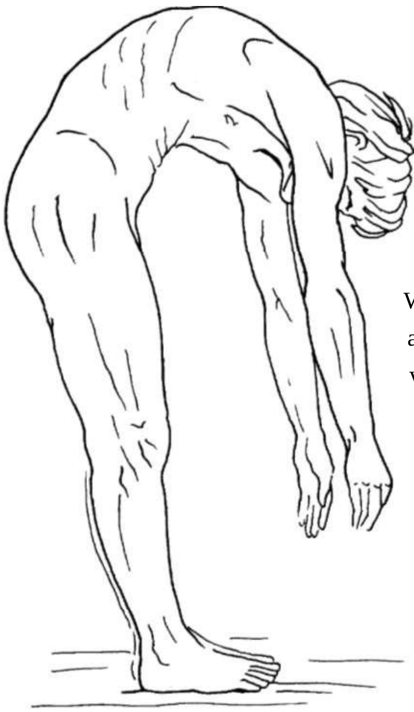


The two medially attached muscles (semimembranosus and semitendinosus) medially rotate the knee.



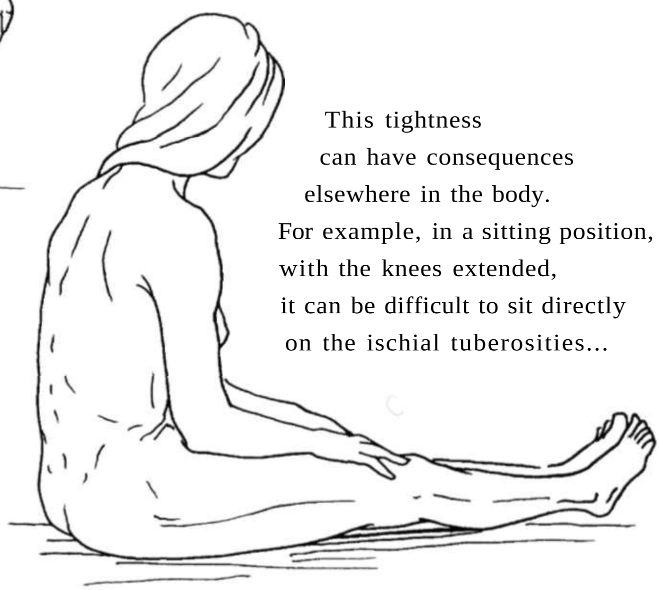
If the thigh and leg are fixed, the hamstrings act in extension of the pelvis.

In the flexed knee, the tendons of the hamstrings delimit the **popliteal fossa,** which is readily visible posteriorly.

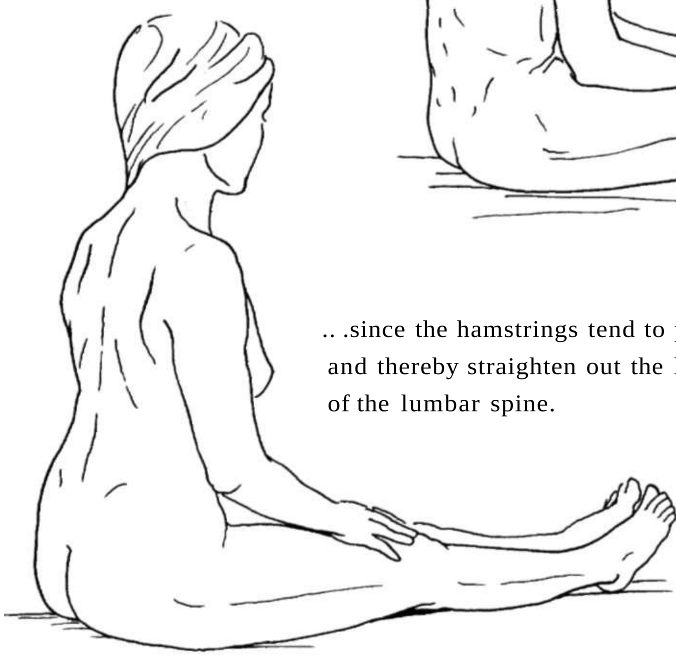


Touching the toes, e.g., in warm-up exercises, causes flexion of the hip and extension of the knees, which stretches the hamstrings.

When the hamstrings are tight, this is very difficult, and it may prevent a person from touching the floor when bending down from a standing position.



This tightness can have consequences elsewhere in the body. For example, in a sitting position, with the knees extended, it can be difficult to sit directly on the ischial tuberosities...



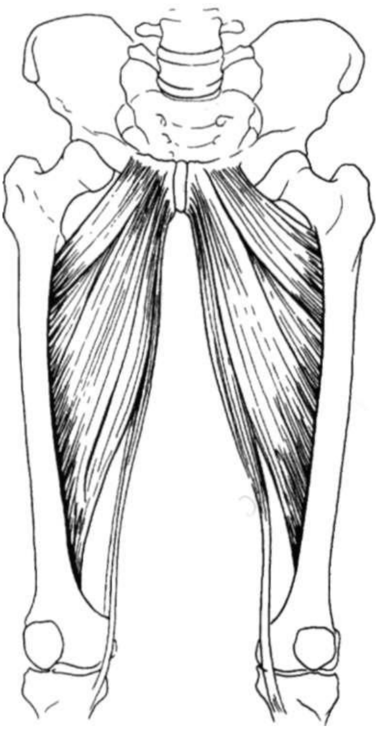
.. .since the hamstrings tend to pull the pelvis into extension and thereby straighten out the lordosis (curvature) of the lumbar spine.

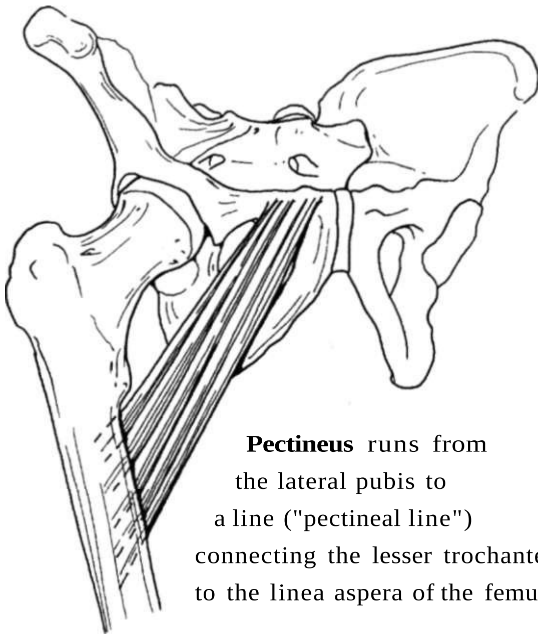
In this way, tight hamstrings can lead to increased flexion of the lumbar region and indirectly to disc problems at that level (see p. 42).

It is important to be aware of this problem and do appropriate warm-up exercises on the floor, especially for beginners.

Adductors

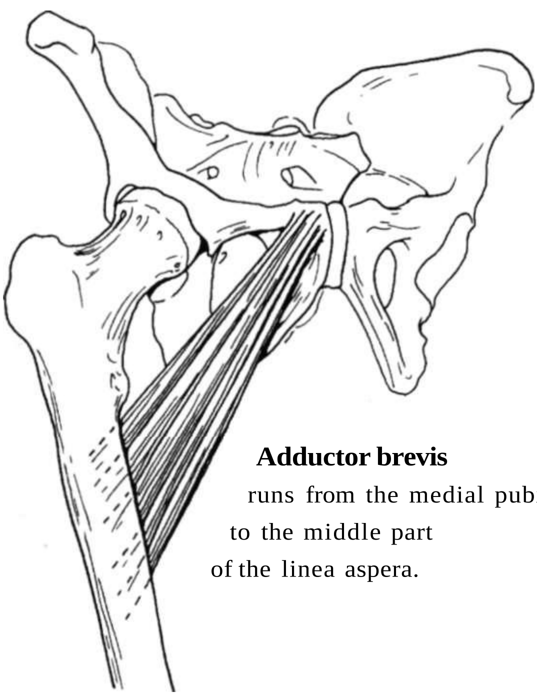
The adductors are a group of five muscles having their bodies on the medial thigh.





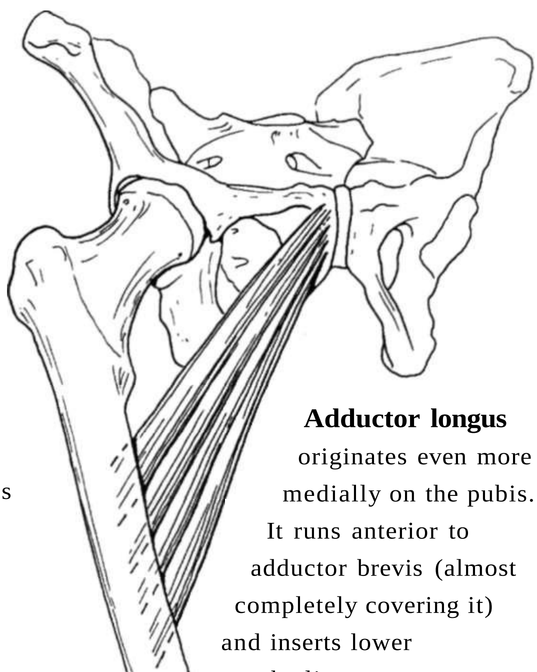
Pectineus runs from the lateral pubis to a line ("pectineal line") connecting the lesser trochanter to the linea aspera of the femur.

Innervation: femoral nerve (L2-L3), obturator nerve (L2-L4)



Adductor brevis runs from the medial pubis to the middle part of the linea aspera.

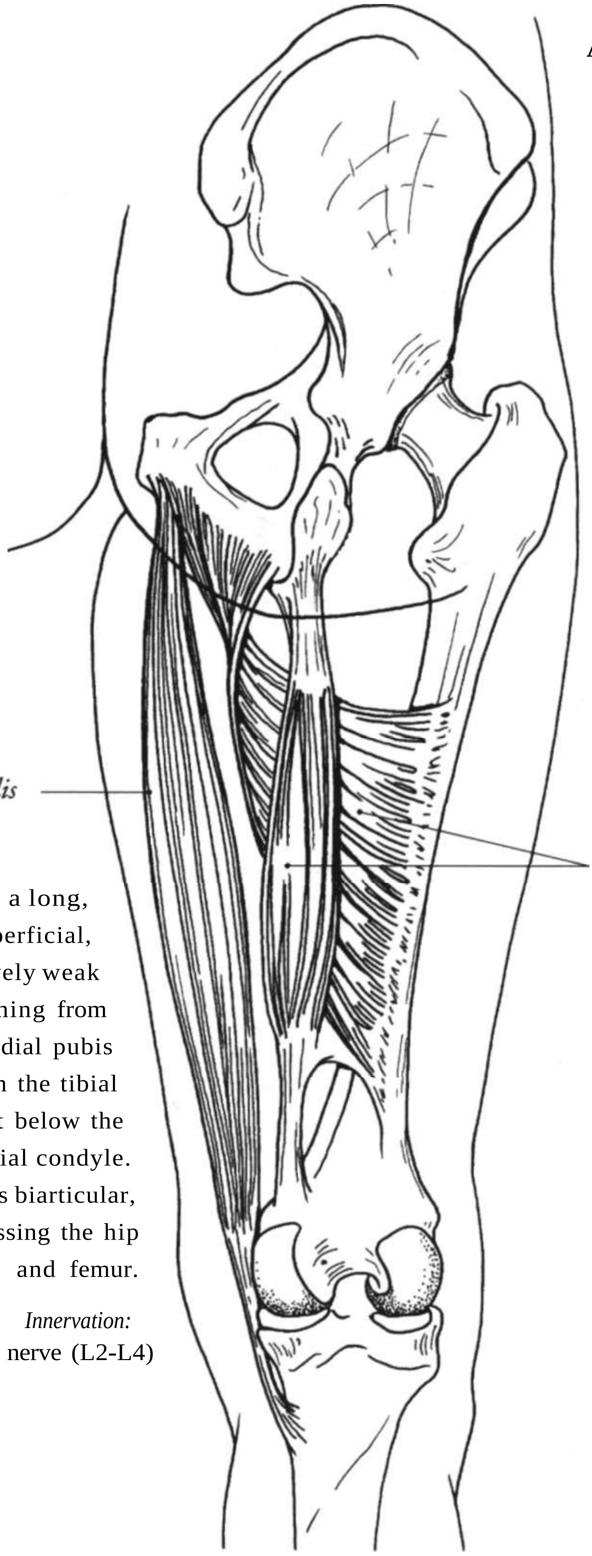
Innervation: obturator nerve (L2-L4)



Adductor longus originates even more medially on the pubis. It runs anterior to adductor brevis (almost completely covering it) and inserts lower on the linea aspera.

Innervation: obturator nerve (L2-L4)

This illustration shows the two adductor muscles, viewed from the back. They are easily distinguished from one another.



Adductor magnus, the largest and strongest of the adductor group, is really a compound muscle innervated by two different spinal nerves.

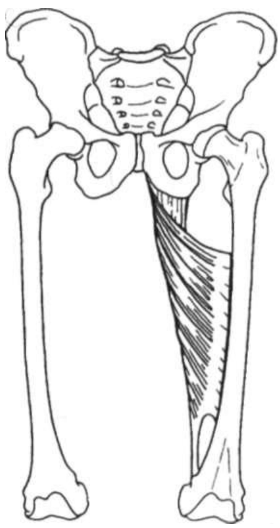
Its anterior portion originates from the ischiopubic ramus, runs inferomedially, and has a very broad insertion on the linea aspera.

The posterior portion originates from the ischial tuberosity, runs straight down, and inserts just above the medial femoral condyle.

Innervation: obturator nerve, sciatic nerve (L3-L5)

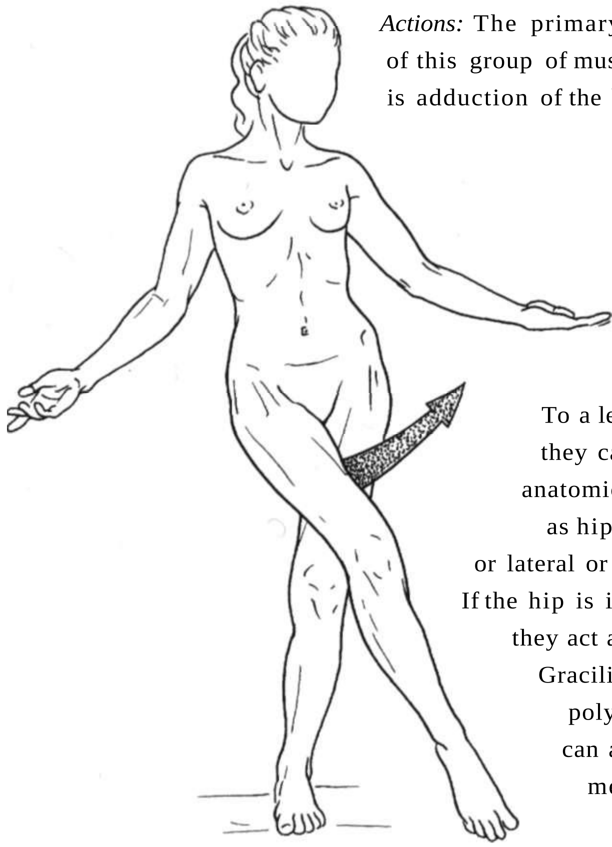
Gracilis is a long, thin, superficial, comparatively weak muscle running from the inferomedial pubis to a spot on the tibial shaft just below the medial condyle. Gracilis is biarticular, crossing the hip and femur.

Innervation: obturator nerve (L2-L4)

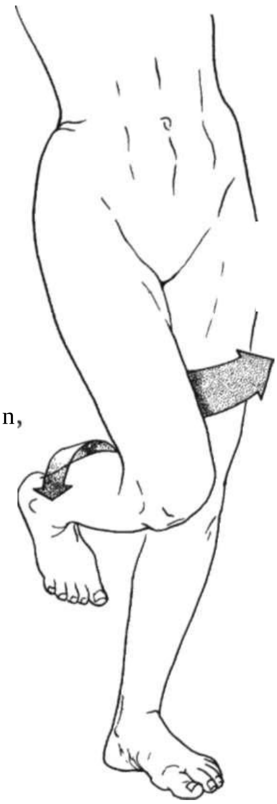


Frontal view of adductor magnus running from the ilium to the femur

Actions: The primary action of this group of muscles is adduction of the hip.

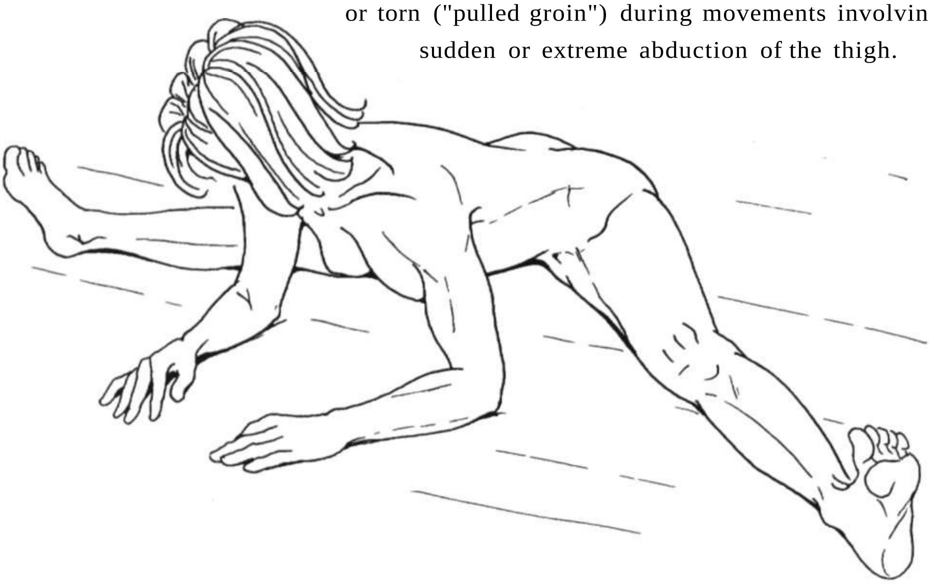


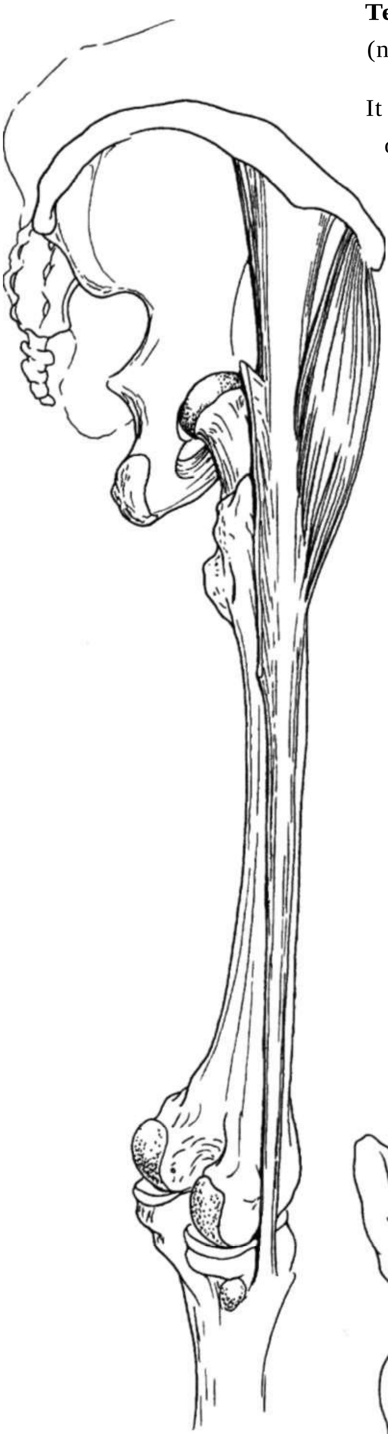
To a lesser degree, they can act from anatomical position as hip flexors or lateral or medial rotators. If the hip is in flexed position, they act as extensors. Gracilis, which is polyarticular, can also flex and medially rotate the knee.



If the femur is fixed, the adductors are involved in flexion, medial flexion, lateral rotation, or (in the case of gracilis and the posterior portion of adductor magnus) medial rotation of the pelvis.

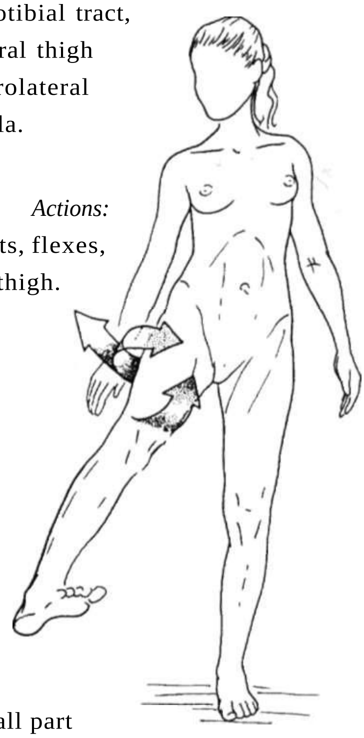
These muscles, especially gracilis, are frequently strained or torn ("pulled groin") during movements involving sudden or extreme abduction of the thigh.



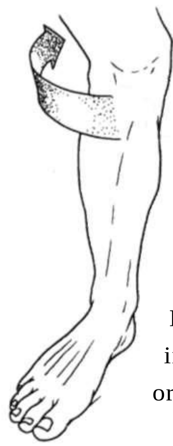


Tensor fasciae latae originates from the anterior iliac crest (near the ASIS) and runs inferiorly and slightly posteriorly.

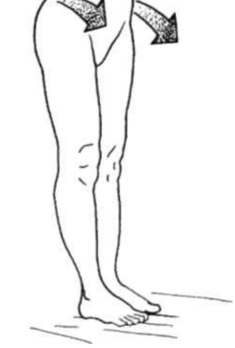
It inserts not on a bone, but rather on a band of strong fibrous tissue, called the **fascia lata** or iliotibial tract, which runs down the lateral thigh and attaches to the superolateral tibia and head of the fibula.



Actions:
This muscle abducts, flexes, and medially rotates the thigh.

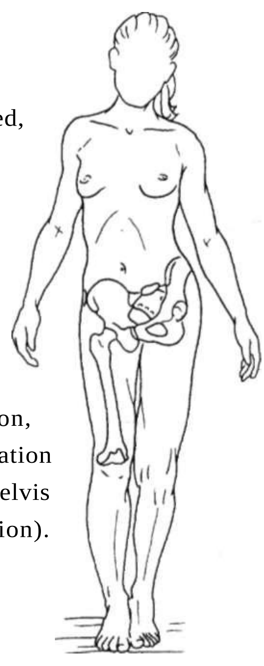


It plays a small part in knee extension or lateral rotation of the flexed knee.

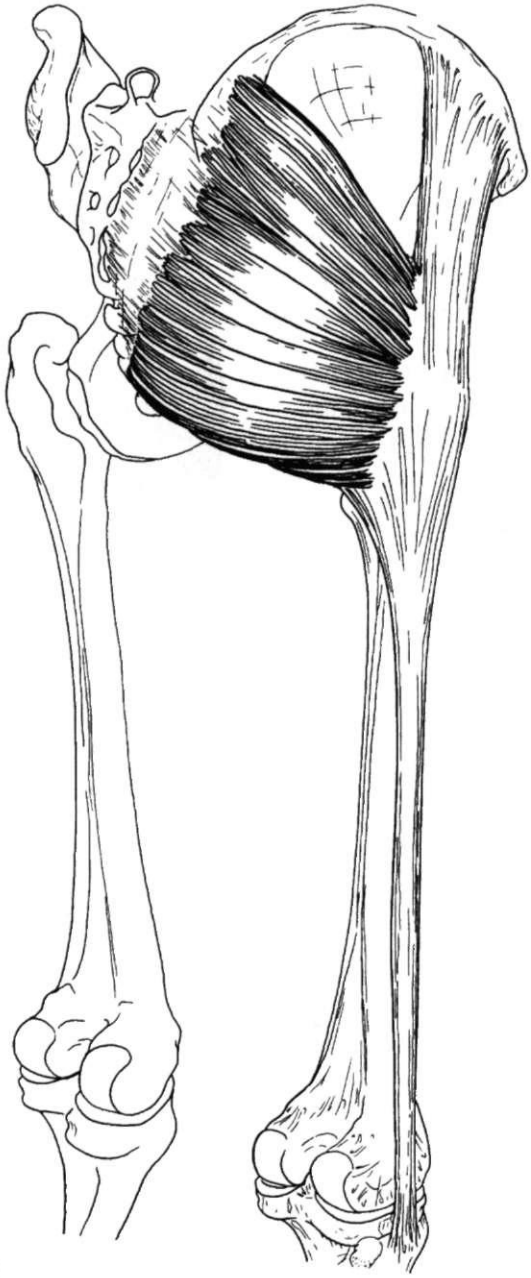


If the thigh and leg are fixed, it acts in flexion (bilateral contraction)...

...lateral flexion, or lateral rotation of the pelvis (unilateral contraction).

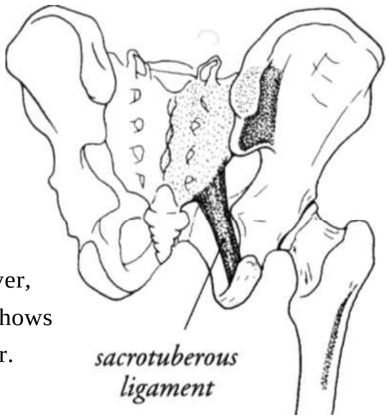


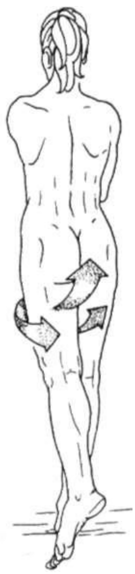
Gluteus maximus is one of the largest and strongest muscles of the body. It has two layers: a deep layer and a superficial layer.



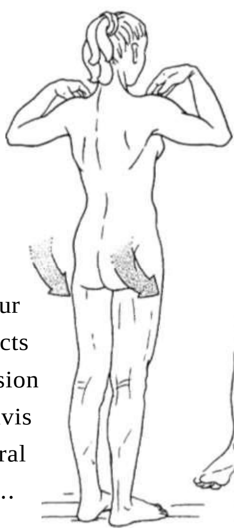
It arises on the posterior sacrum and coccyx as well as the posterolateral iliac fossa. The deep layer inserts on the superior linea aspera of the femur, while the superficial layer inserts on the fascia lata.

Insertion of gluteus maximus: light gray shows the superficial layer, darker gray shows the deep layer.





Actions of deep layer:
When the hip bone is fixed, it pulls the femur backward (hip extension), into lateral rotation and slight adduction.



When the femur is fixed, it acts in extension of the pelvis (bilateral contraction)...

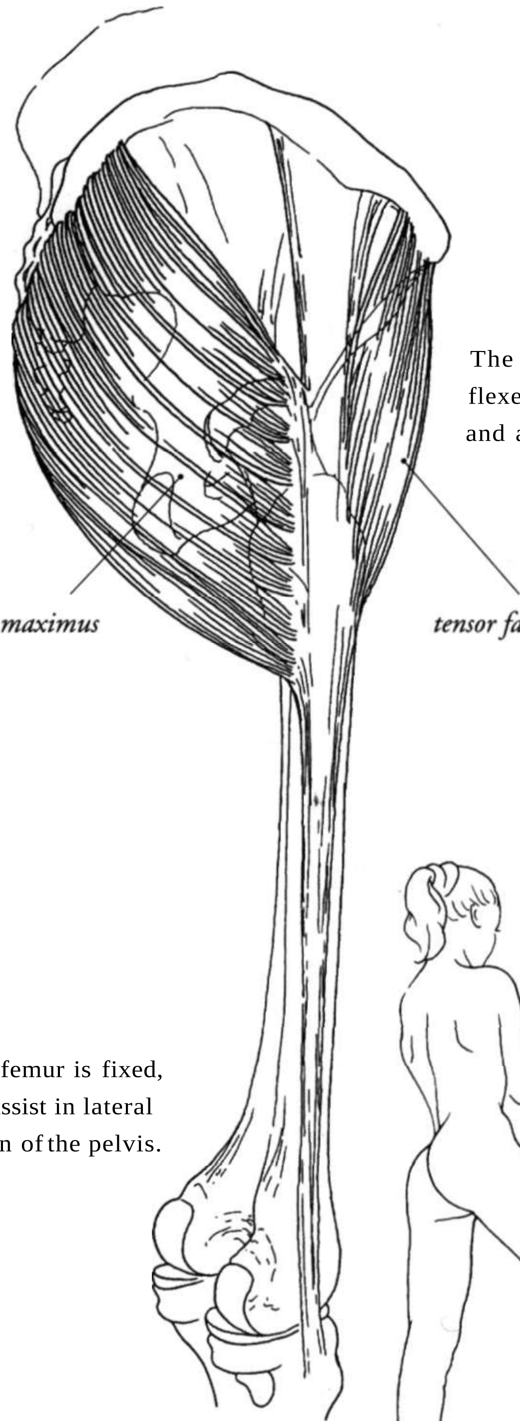
. .and in extension, medial rotation, and medial flexion of the pelvis (unilateral contraction).

The action of the superficial layer is discussed together with the tensor fasciae latae on the following page.

The "pelvic deltoid muscle"

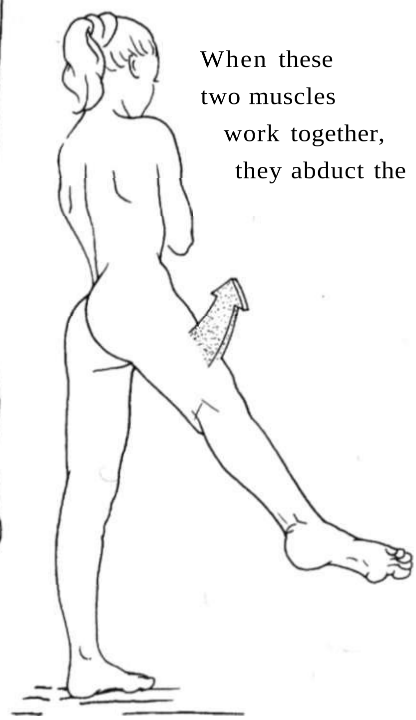
The superficial layer of gluteus maximus (in back), and tensor fasciae latae (in front), insert onto the iliotibial tract from opposite directions.

The superficial layer of gluteus maximus acts on the femur by extending, externally rotating, and abducting it.



The tensor fascia latae flexes, medially rotates, and abducts the femur.

If the femur is fixed, they assist in lateral flexion of the pelvis.

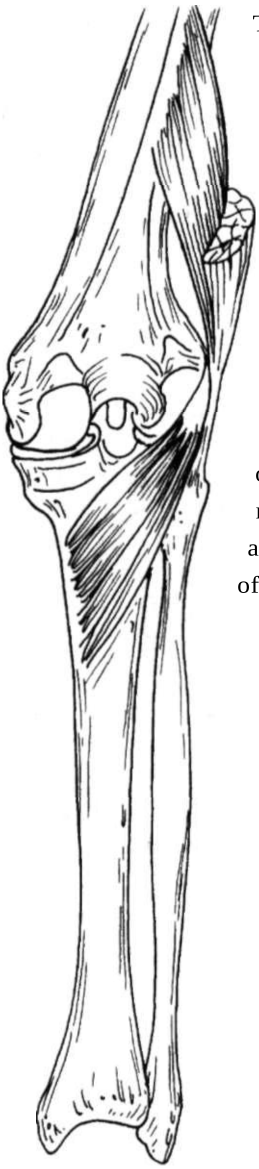


When these two muscles work together, they abduct the hip.

They assist gluteus medius in maintaining the position of the contralateral pelvis while standing on one foot (see p. 215)

Muscles of the knee

Most muscles acting on the knee also act on the hip, and they have been described above. We need to mention only three muscles which do not cross the hip.

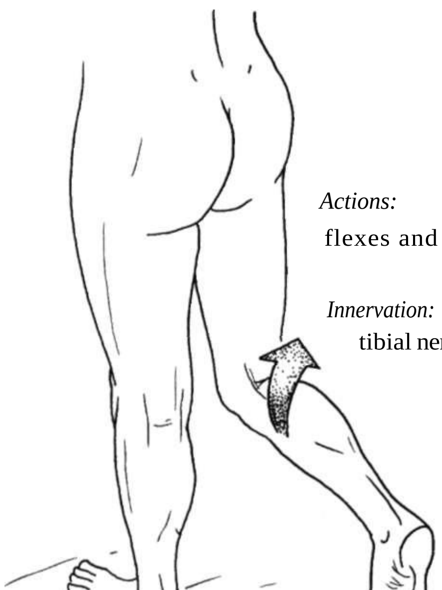


The short head of **biceps femoris** arises from the femoral shaft. It merges with the long head of the biceps (p. 242) at the common tendon, which inserts on the head of the fibula.

Actions:
flexes and laterally rotates the knee

Innervation:
common peroneal nerve (S1-S2)

Popliteus originates from the lateral aspect of the lateral femoral condyle, runs inferomedially, and inserts on a triangular area of the posterosuperomedial tibial shaft.



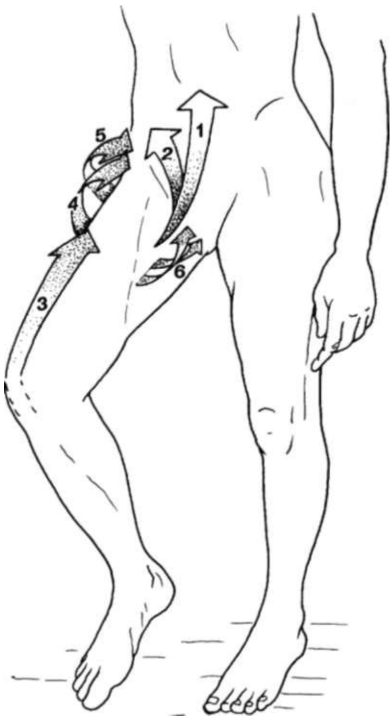
Actions:
flexes and medially rotates the knee

Innervation:
tibial nerve (L4-S1)

The **gastrocnemius** are part of the triceps muscles of the calf. They are discussed in detail with the muscles of the ankle on page 292. They flex the knee.

Summary of muscle actions of the hip

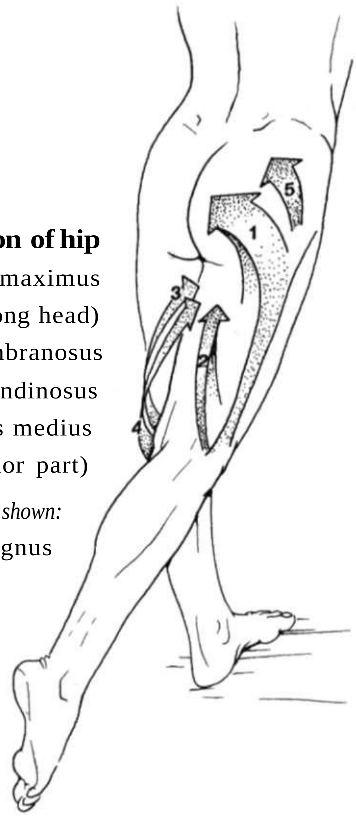
The arrows represent the actions produced by the various muscles.



Flexion of hip

1) psoas
2) iliacus
3) rectus femoris
4) tensor fasciae latae
5) gluteus minimus and medius (anterior part)
6) adductor longus & brevis

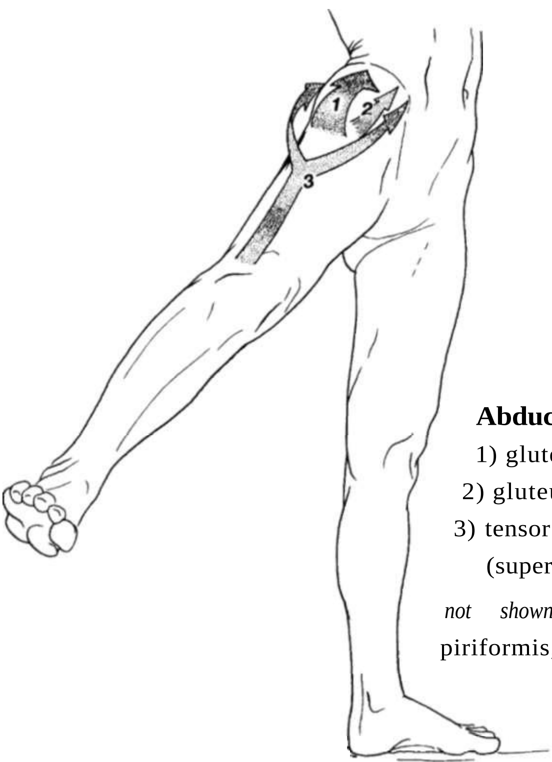
not shown:
gracilis, sartorus, pectineus



Extension of hip

1) gluteus maximus
2) biceps femoris (long head)
3) semimembranosus
4) semitendinosus
5) gluteus medius (posterior part)

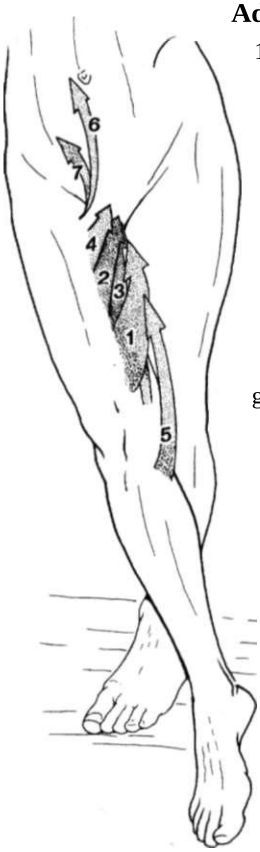
not shown:
adductor magnus



Abduction of hip

1) gluteus medius
2) gluteus minimus
3) tensor fasciae latae, gluteus maximus (superficial part)

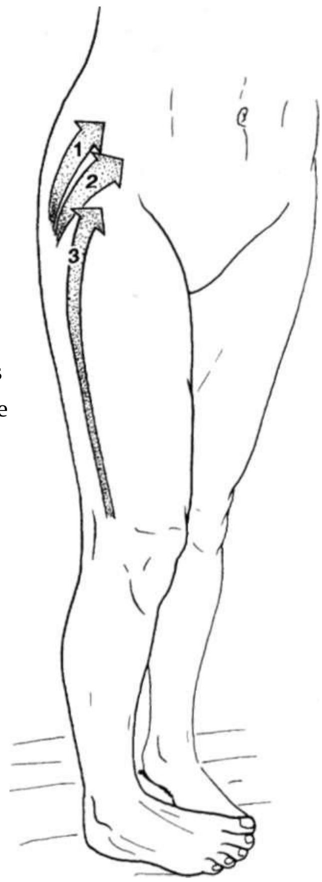
not shown:
piriformis, obturators, gemelli, sartorius



Adduction of hip

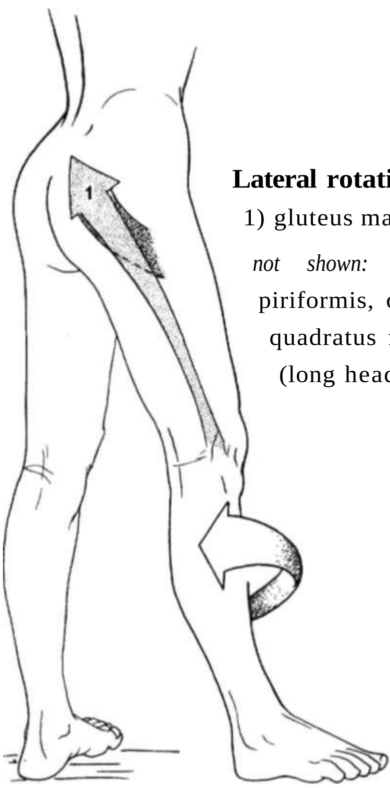
1) adductor magnus
2) adductor brevis
3) adductor longus
4) pectineus
5) gracilis
6) psoas
7) iliacus

not shown:
biceps femoris (long head),
gluteus maximus (deep part)



Medial rotation of hip

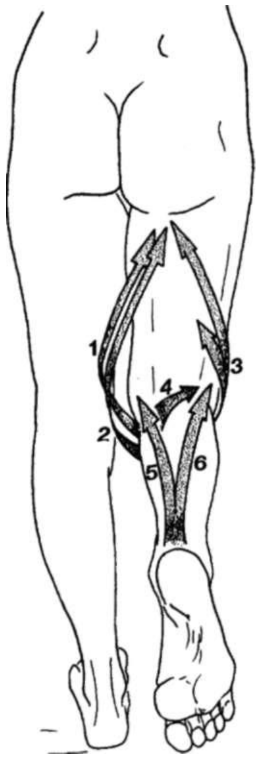
1) gluteus medius
2) gluteus minimus
3) tensor fasciae latae



Lateral rotation of hip

1) gluteus maximus

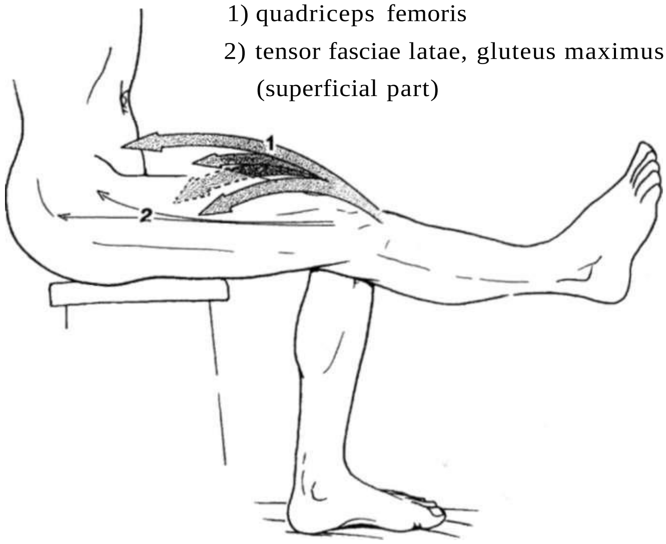
not shown:
piriformis, obturators, gemelli,
quadratus femoris, biceps femoris
(long head), adductors



Flexion of knee
1) semitendinosus
2) semimembranosus
3) biceps femoris (long head)
4) popliteus
(5, 6) gastrocnemius (medial & lateral)

not shown:
sartorius, gracilis

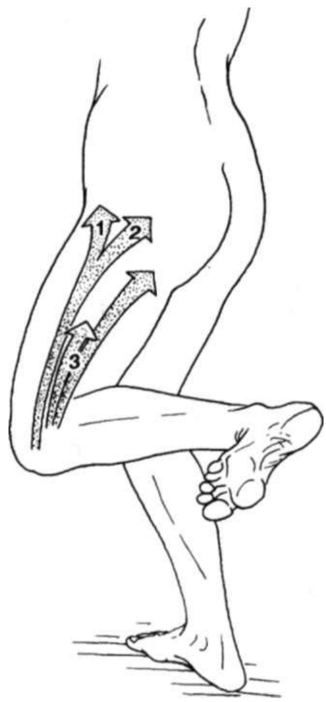
Extension of knee
1) quadriceps femoris
2) tensor fasciae latae, gluteus maximus (superficial part)



Medial rotation of knee
1) sartorius
2) semitendinosus
3) semimembranosus
4) gracilis

not shown:
popliteus

Lateral rotation of knee
1) tensor fasciae latae
2) gluteus maximus (superficial part)
3) biceps femoris (long and short heads)

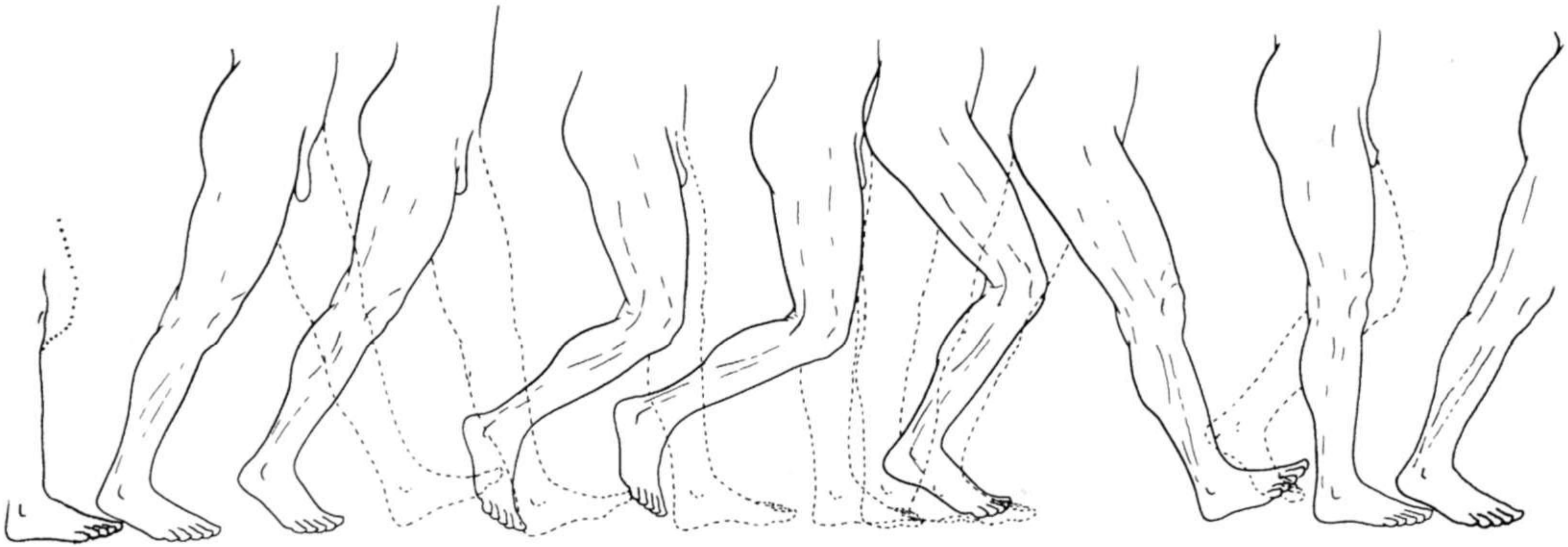


Actions of muscles of the hip and knee in walking

1
The leg propels the body forward.

3
The leg, free from the body's weight, does an oscillating movement which takes the foot forward.

5
The body's weight shifts onto the leg again.



Contraction of quadriceps, hamstrings, gemelli, gluteus maximus.
2

Contraction of rectus femoris (flexes hip, then extends knee), completed by contraction of entire quadriceps (extends knee).
4

Contraction of lateral stabilizing muscles of hip and knee.
6

CHAPTER SEVEN

The Ankle & Foot

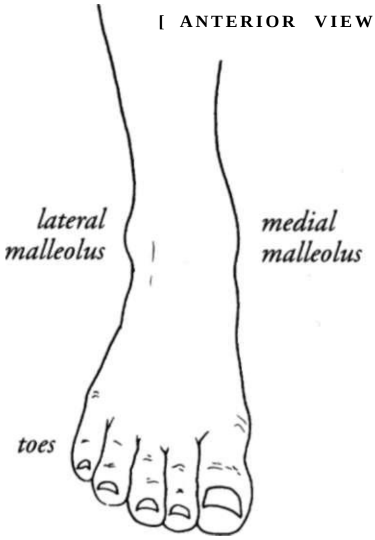
The **foot,** adapted to a bipedal posture, serves a double function: bearing the weight of the entire body, and performing the dynamic movements necessary for walking. This requires both strength and flexibility.

The foot contains 26 bones, 31 joints, and 20 intrinsic muscles. Unfortunately, malformation of the foot is common due to mechanical stresses from excess weight and poorly-fitted shoes. By understanding its structure and function, we are better able to avoid injury.

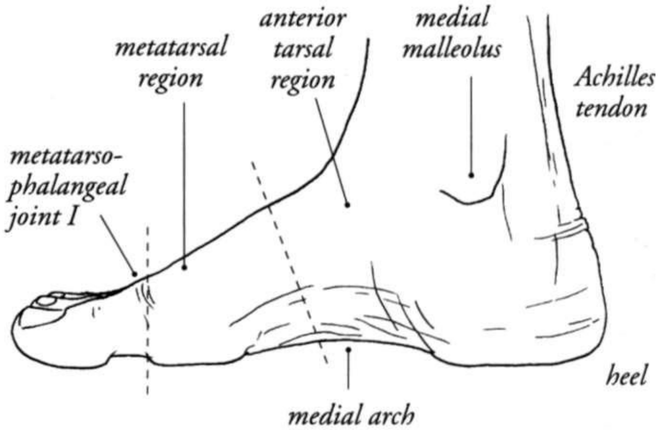
The **ankle** joint combines the malleability of the foot with the strength of the leg bones. In this chapter, we will describe both the foot and the ankle joint because the muscles which act on the ankle joint also act on the foot.

Landmarks

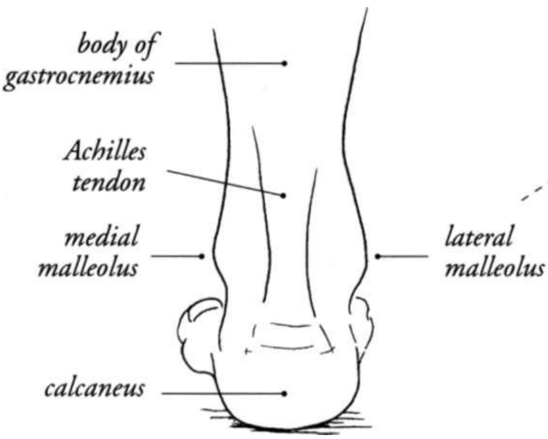
[ANTERIOR VIEW]



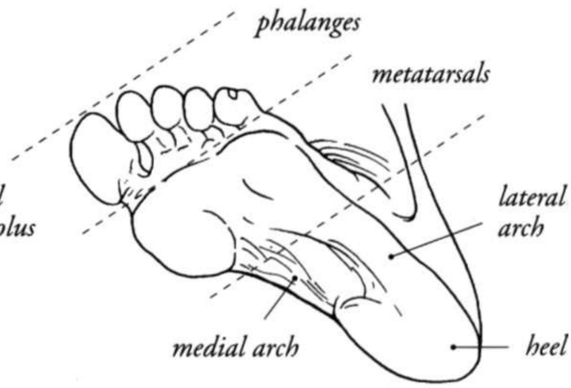
[MEDIAL VIEW]



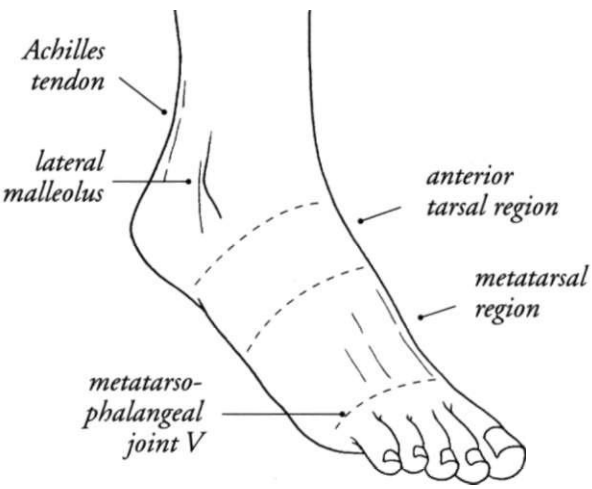
[POSTERIOR VIEW]



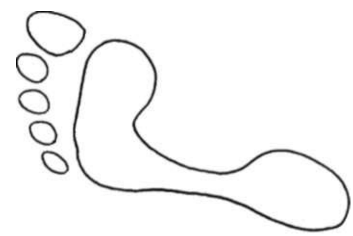
[INFERIOR VIEW]



[LATERAL VIEW]



As you can see on a wet footprint, the medial arch and proximal phalanges do not normally come in contact with the ground...



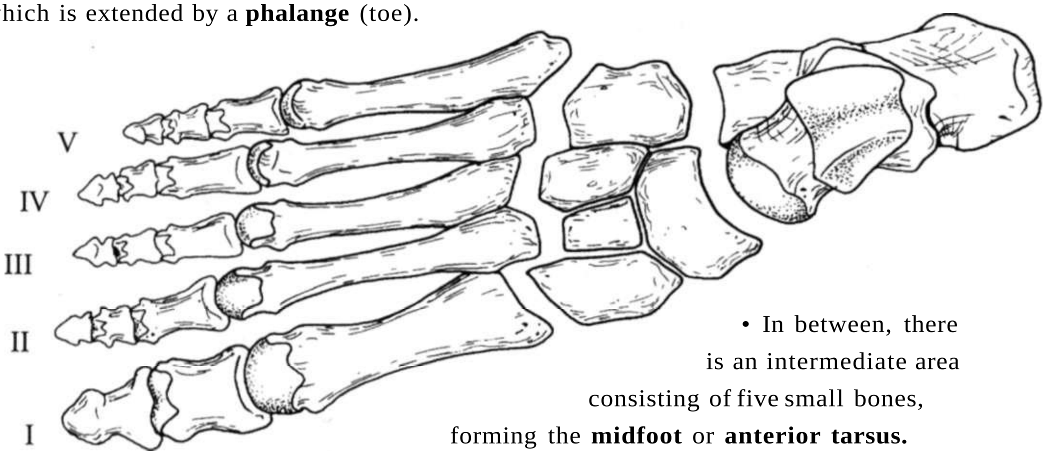
... while the heel, lateral arch, distal metatarsal region, and distal phalanges do contact it.

Arrangment of bones in foot

A skeletal top view of the foot shows three regions (from front to back):

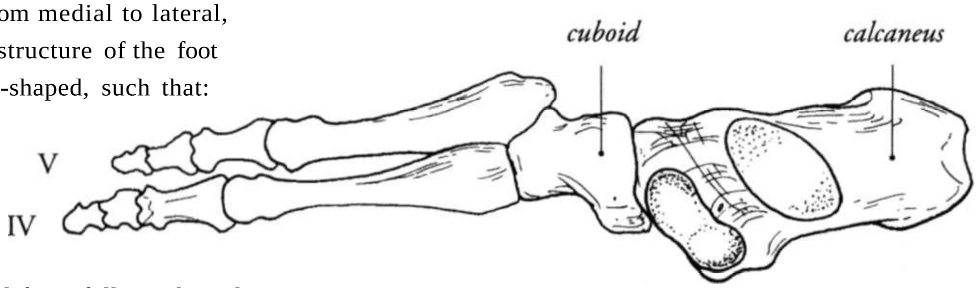
- In front, there are five slender bones arranged next to each other and flaring outward like "spokes" (numbered I-V from medial to lateral). Each spoke consists of a **metatarsal** which is extended by a **phalange** (toe).

In back, there are two sizeable bones sitting on top of each other: the **talus** and the **calcaneous.** This part of the foot is known as the **hindfoot** or **posterior tarsus.**

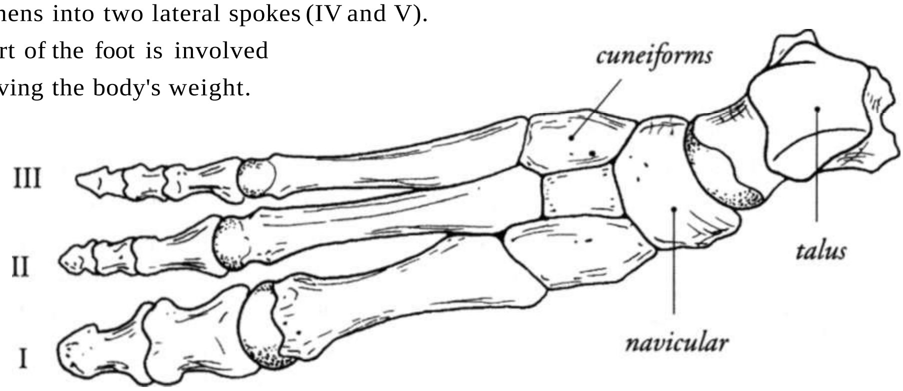


- In between, there is an intermediate area consisting of five small bones, forming the **midfoot** or **anterior tarsus.** The bones are the **navicular,** the **cuboid** and three **cuneiforms.** This area between the front and back is a junction zone where a lot of torsion occurs. This helps the foot adjust to the surface of the ground.

Viewed from medial to lateral, the bony structure of the foot looks fork-shaped, such that:



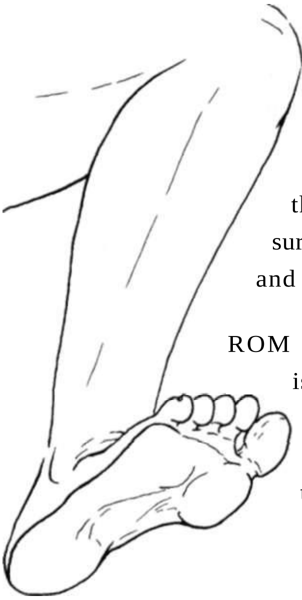
- A "lateral foot" follows the calcaneus. It lengthens into two lateral spokes (IV and V). This part of the foot is involved in receiving the body's weight.



- A "medial foot" follows the talus. It lengthens into three medial spokes (I-III). This part of the foot is involved in propulsion.

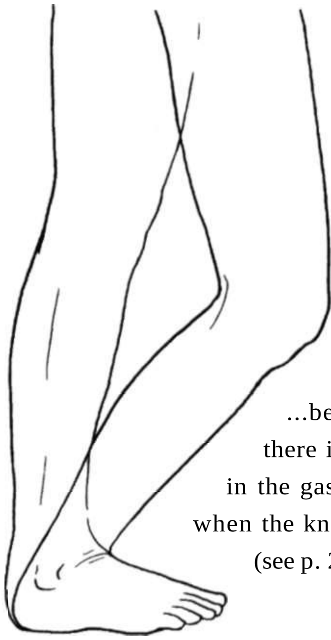
Movements of the foot

We can speak of the following movements in reference to the entire foot, or to some specific region or joint.

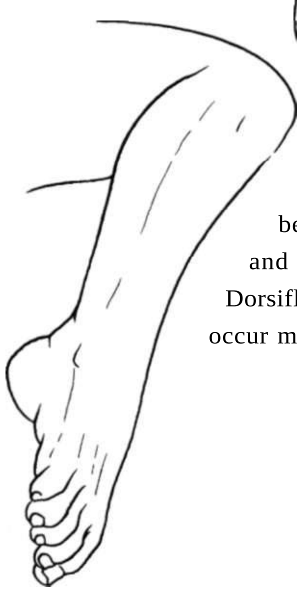


Dorsiflexion, also called flexion, is a decrease in the angle between the superior (dorsal) surface of the foot and the anterior leg.

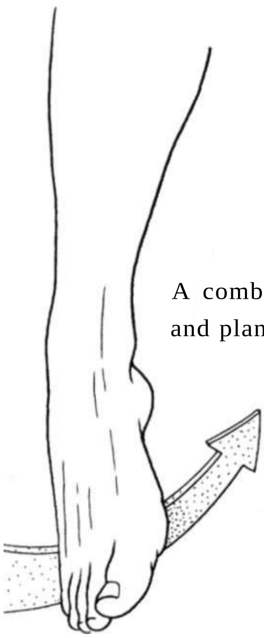
ROM for dorsiflexion is greater when the knee is flexed, and less when the knee is extended..



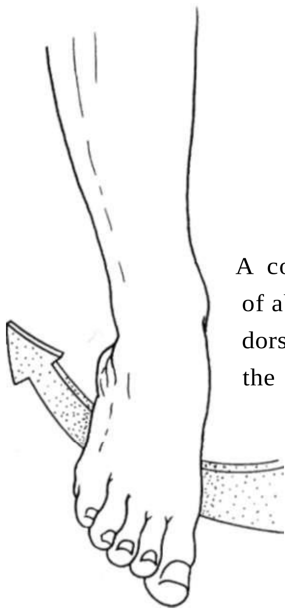
...because there is greater tension in the gastrocnemius when the knee is extended (see p. 293).



Plantar flexion, also called extension, is an increase in the angle between the dorsal surface of the foot and the anterior leg. Dorsiflexion and plantar flexion occur mainly at the ankle joint.

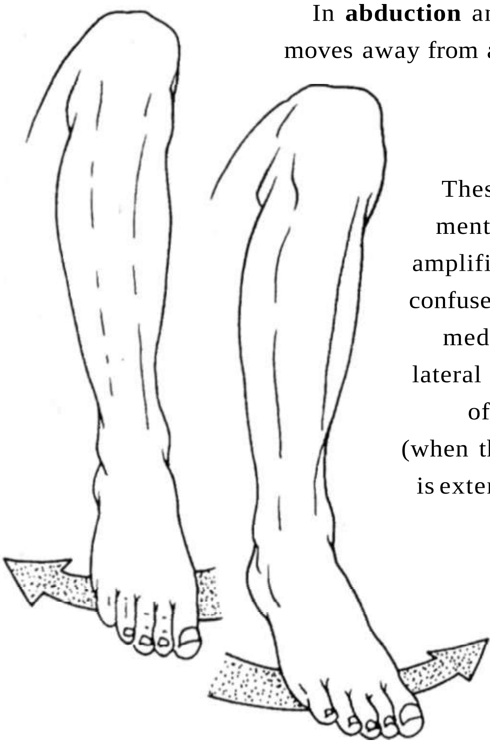


A combination of adduction and plantar flexion, in which the sole is directed toward the median plane, is called **supination.**

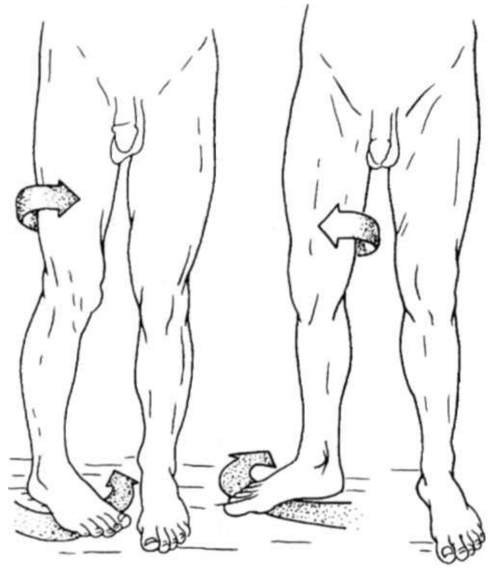


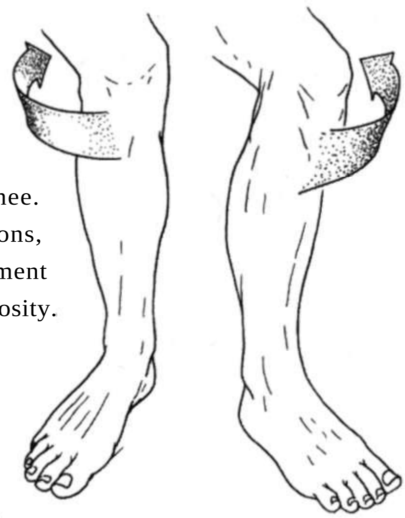
A combination of abduction and dorsiflexion, in which the sole of the foot is directed away from the median plane, is called **pronation.**

In **abduction** and **adduction,** the distal end of the foot moves away from and toward the median plane, respectively.



These movements can be amplified by or confused with medial and lateral rotation of the hip (when the knee is extended)...





or rotation of the flexed knee. In either of these situations, you will notice movement of the tibial tuberosity.

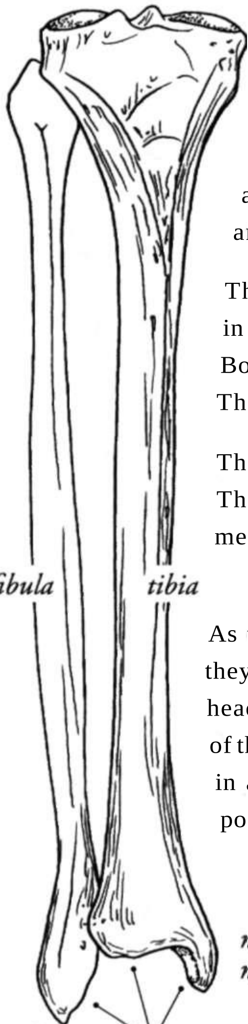
In practice, the following three types of movement are combined automatically:

Adduction, supination, and plantar flexion combine to produce **inversion.**

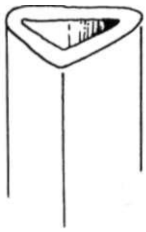
Adbuction, pronation, and dorsiflexion combine to produce **eversion.**

These combined movements of the foot are due to the bony surfaces and orientation of the axes of movement. They are executed simultaneously while walking (see also p. 271).

Two long bones form the skeleton of the leg, tibia, and fibula



The **fibula,** on the lateral side of the leg, is a thin bone, triangular in cross section. It is twisted on itself and its edges are therefore not really straight. This gives the bone a certain suppleness, i.e., its curvature can be slightly modified.



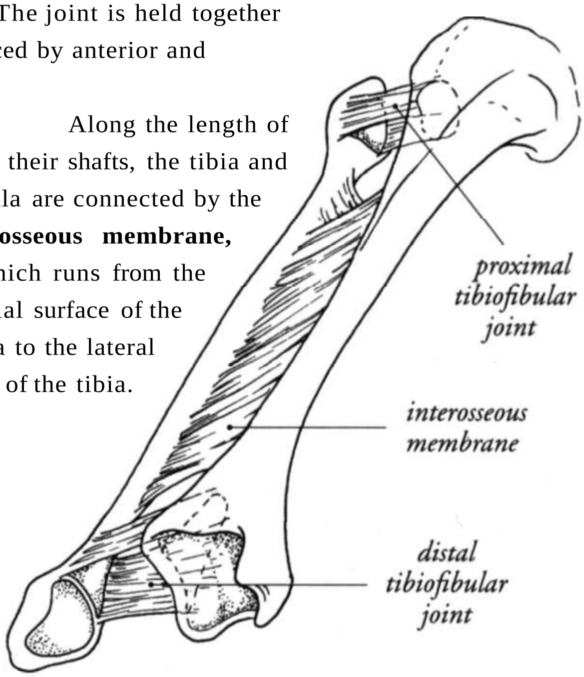
It consists of three main parts: the head, shaft, and lateral malleolus. The bone is shaped like a spear and is easily palpable.

The **tibia,** on the medial side, is also triangular in cross section, with three surfaces and three edges. Both the distal and proximal ends are large. The proximal end is part of the knee joint (see p. 213).

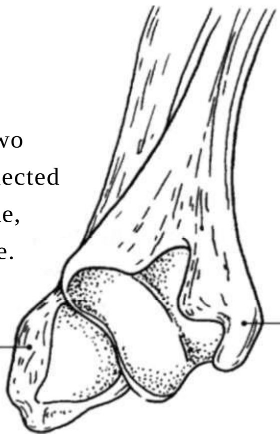
The anterior edge of the bone bifurcates superiorly and inferiorly. The distal end of the bone is massive in size, and ends in the medial malleolus, which has anterior and posterior edges, and a peak.

As they move, the bones contact each other at two points: proximally, they form a synovial joint (see p. 14), consisting of an oval surface on the head of the fibula and a corresponding surface posterior to the lateral part of the tibial plateau. The joint is held together in a capsule, reinforced by anterior and posterior ligaments.

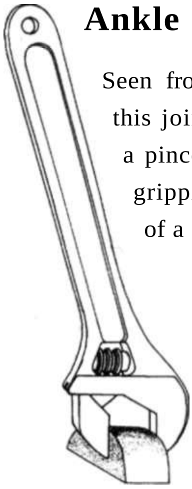
Along the length of their shafts, the tibia and fibula are connected by the **interosseous membrane,** which runs from the medial surface of the fibula to the lateral edge of the tibia.



Distally, it is a syndesmosis (fibrous joint) in which the two bones are connected by fibrous tissue, but no cartilage.

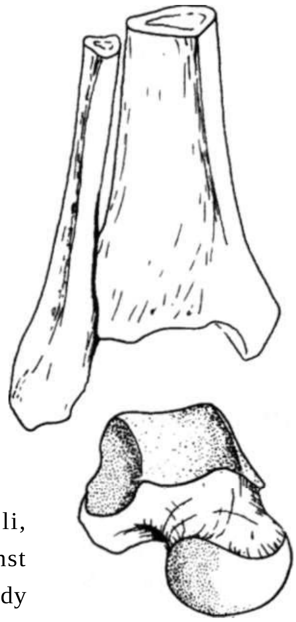


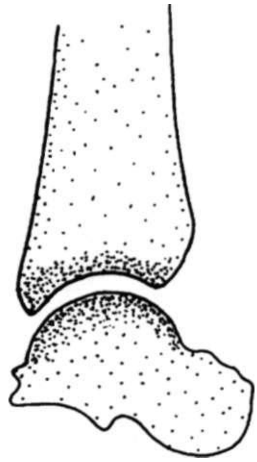
The bones are held together by anterior and posterior ligaments. When the ankle moves, the two bones are simultaneously stable and mobile. Distally, they "clasp" the talus (the uppermost tarsal bone).



Ankle joint

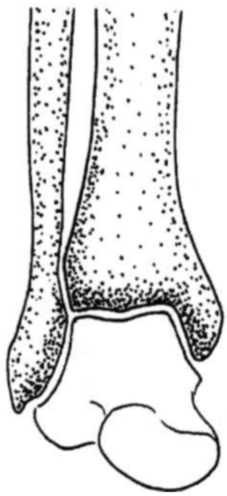
Seen from the front,
this joint resembles
a pincer or crescent wrench
gripping a section
of a hemisphere.

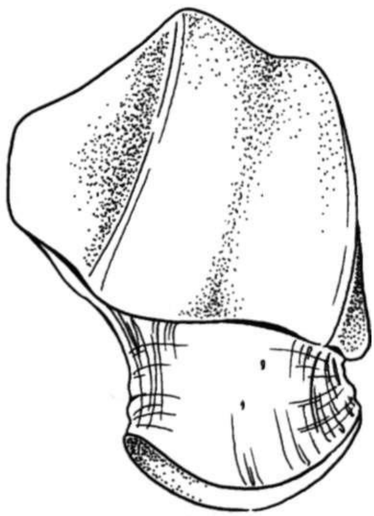




The lateral and medial malleoli, and distal tibia, fit against the three facets of the talar body (see below).

Seen from the side, the cartilaginous superior and inferior articulating surfaces appear concave and convex, respectively.



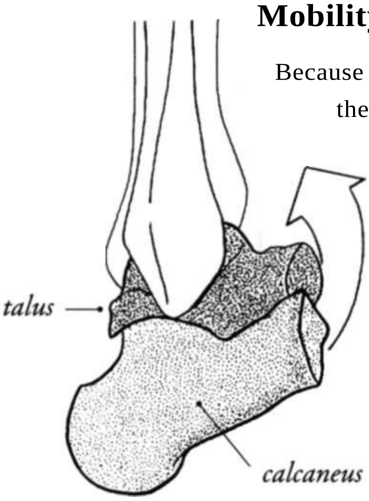


The two malleoli provide a snug fit around the talus. The lateral malleolus extends farther down and is more obliquely oriented than the medial malleolus.

In cross section, we see that there is a slight ridge on the articulating surface of the distal tibia, and a corresponding groove on talus.

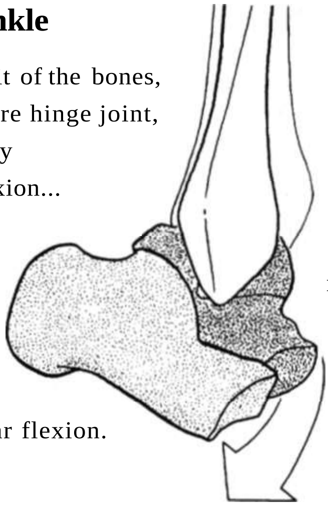
We should also note that the superior talus is wider anteriorly than posteriorly.

Mobility of the ankle



Because of the tight fit of the bones, the ankle is a pure hinge joint, capable only of dorsiflexion...

...and plantar flexion.

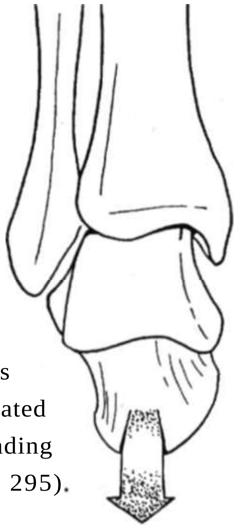


At this level, these are the most important movements of the foot. The axis of movement passes through the two malleoli.

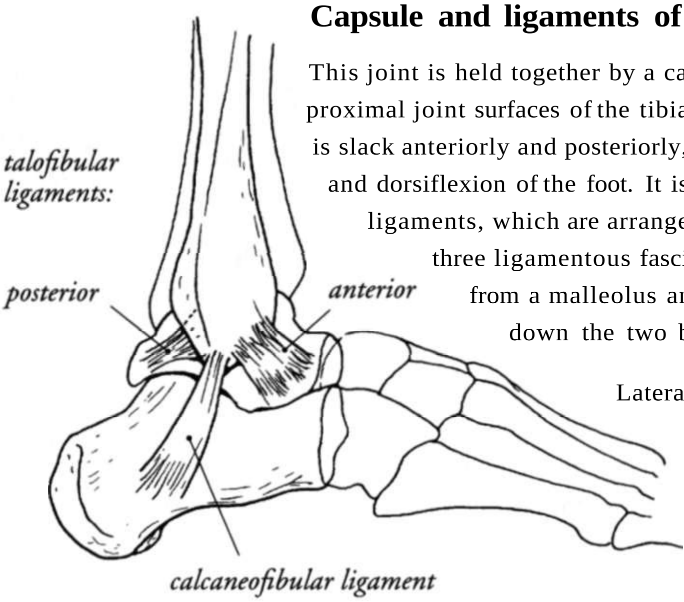
Stability of the bones

Of all the joints in the foot, this one allows the greatest range of motion (ROM). In dorsiflexion (left), the anterior (wider) part of the superior talus moves into the "pincer," and the joint is more stable.

In plantar flexion (right), the posterior (narrower) part of the talus is in the "pincer," and the joint is therefore less stable. This lack of stability is compensated for in part by support from surrounding muscles and ligaments (see p. 295).



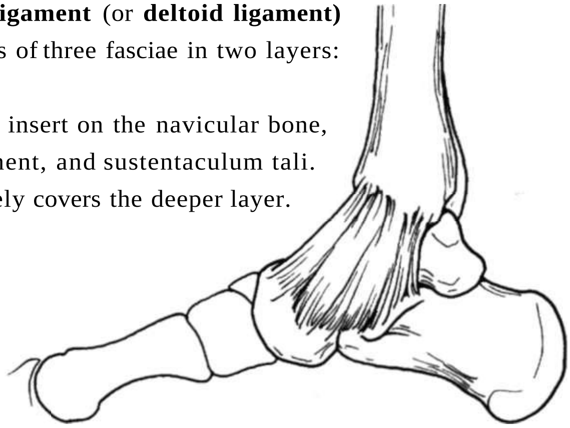
Capsule and ligaments of the ankle



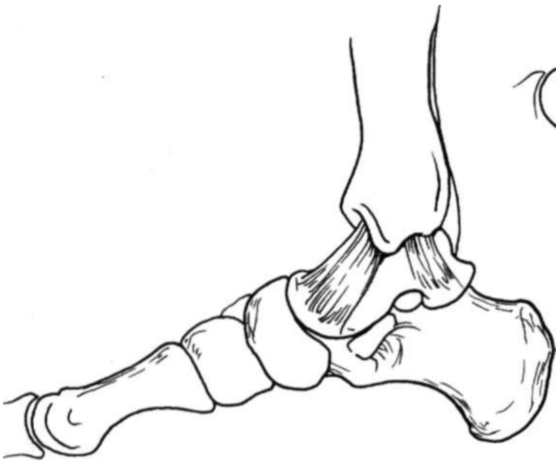
This joint is held together by a capsule which attaches to the proximal joint surfaces of the tibia, fibula, and talus. The capsule is slack anteriorly and posteriorly, allowing for plantar flexion and dorsiflexion of the foot. It is primarily reinforced by lateral ligaments, which are arranged roughly symmetrically: three ligamentous fasciae on each side arise from a malleolus and run obliquely down the two bones of the hindfoot.

Laterally, the **anterior** and **posterior talofibular ligaments** end on the talus and tie it directly to the bones of the leg, while the **calcaneofibular ligament** runs down to the lateral calcaneus, which is thus involved in ROM of the ankle.

Medially, the **medial collateral ligament** (or **deltoid ligament)** consists of three fasciae in two layers:

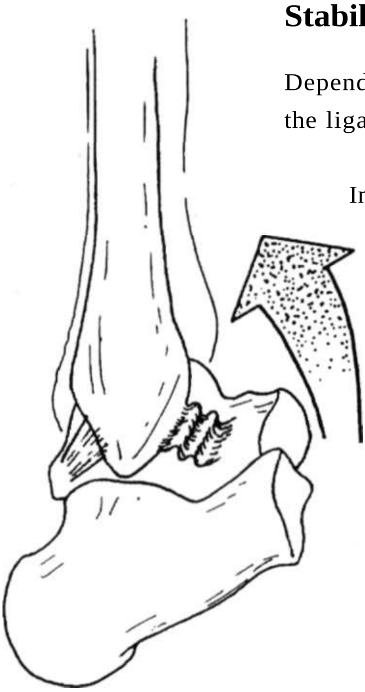


- a superficial layer with fibers that insert on the navicular bone, calcaneonavicular ligament, and sustentaculum tali. This layer completely covers the deeper layer.



- a deep layer with anterior fibers, which insert on the talus (see p. 266), and posterior fibers, which insert on the anteromedial side of the talus.

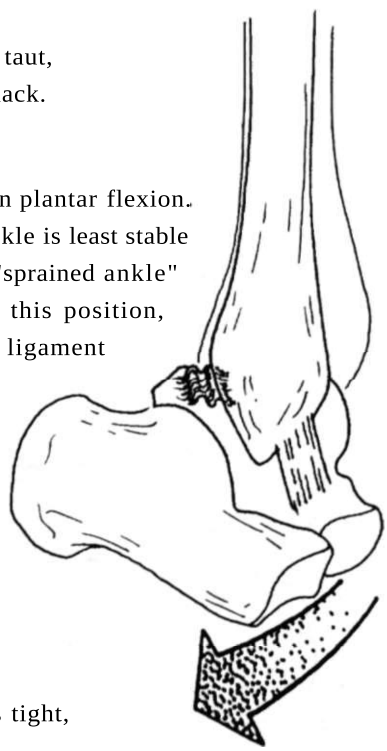
Stabilization of the ankle



Depending on the position of the ankle, the ligaments become more or less taut.

In dorsiflexion, the posterior ligaments are taut, and the anterior ones are slack.

The reverse is true in plantar flexion. Since the ankle is least stable in plantar flexion, a "sprained ankle" occurs most commonly in this position, and the anterior talofibular ligament is the one most often injured.

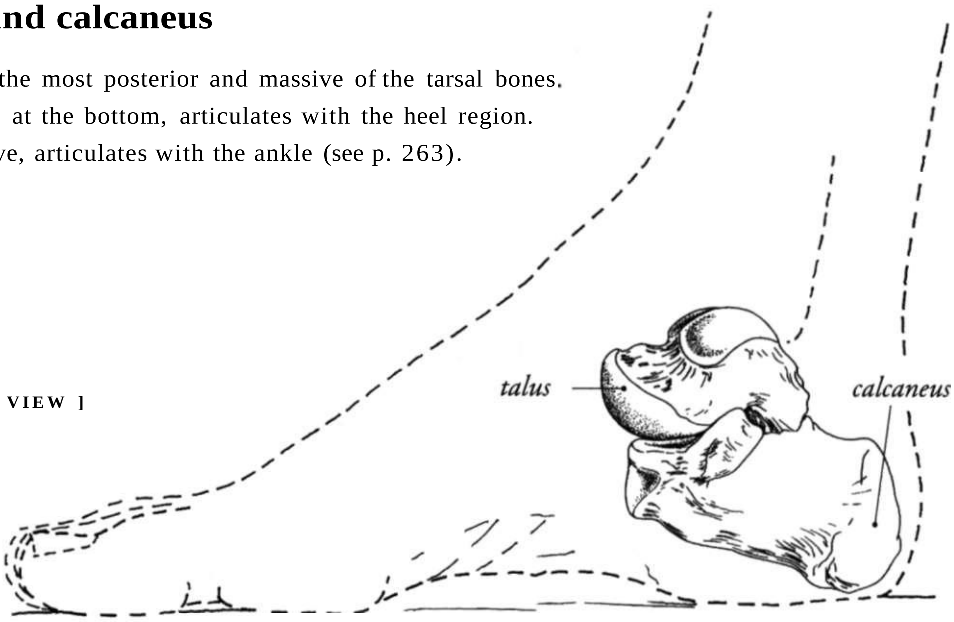


The stability of the ankle is also assisted by muscular action, which helps adjust the "pincer" action, making it more or less tight, during active movement of the ankle (see p. 295).

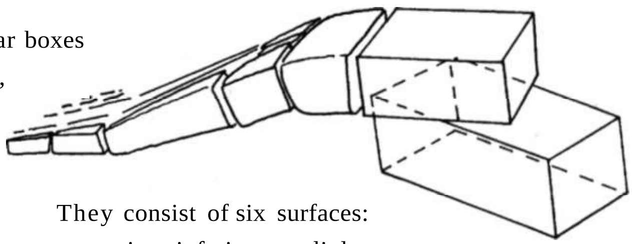
Talus and calcaneus

These are the most posterior and massive of the tarsal bones. Calcaneus, at the bottom, articulates with the heel region. Talus, above, articulates with the ankle (see p. 263).

[MEDIAL VIEW]



These bones are like two rectangular boxes set at an angle on top of each other, with the talus pointing medially and the calcaneous pointing laterally.

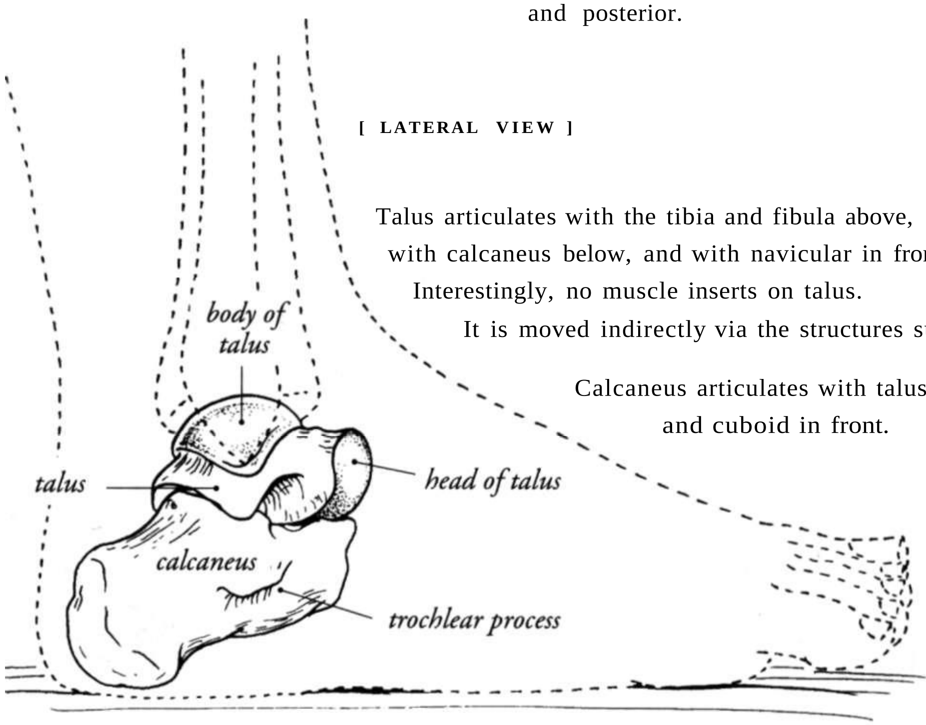


They consist of six surfaces: superior, inferior, medial, lateral, anterior, and posterior.

[LATERAL VIEW]

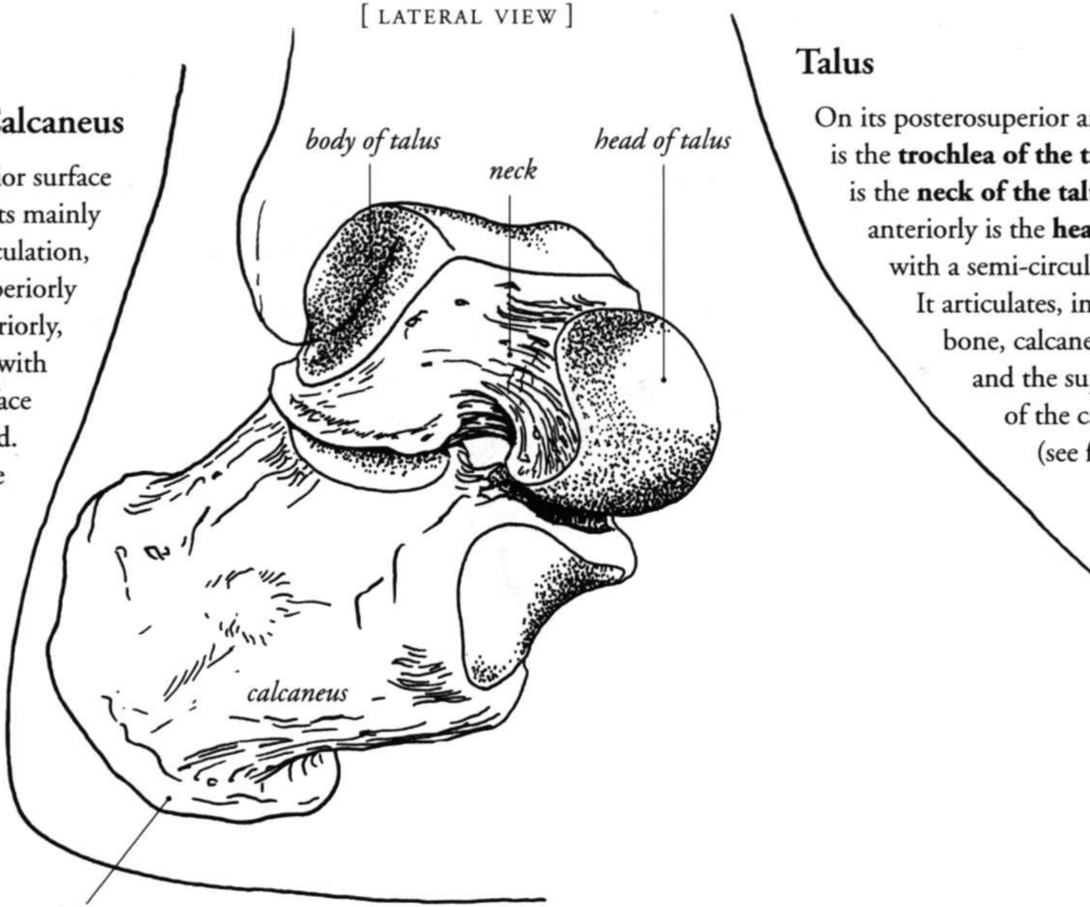
Talus articulates with the tibia and fibula above, with calcaneus below, and with navicular in front. Interestingly, no muscle inserts on talus. It is moved indirectly via the structures surrounding it.

Calcaneus articulates with talus above and cuboid in front.



On this page and the next, we will take a closer look at these two bones from different angles.

[LATERAL VIEW]



Calcaneus

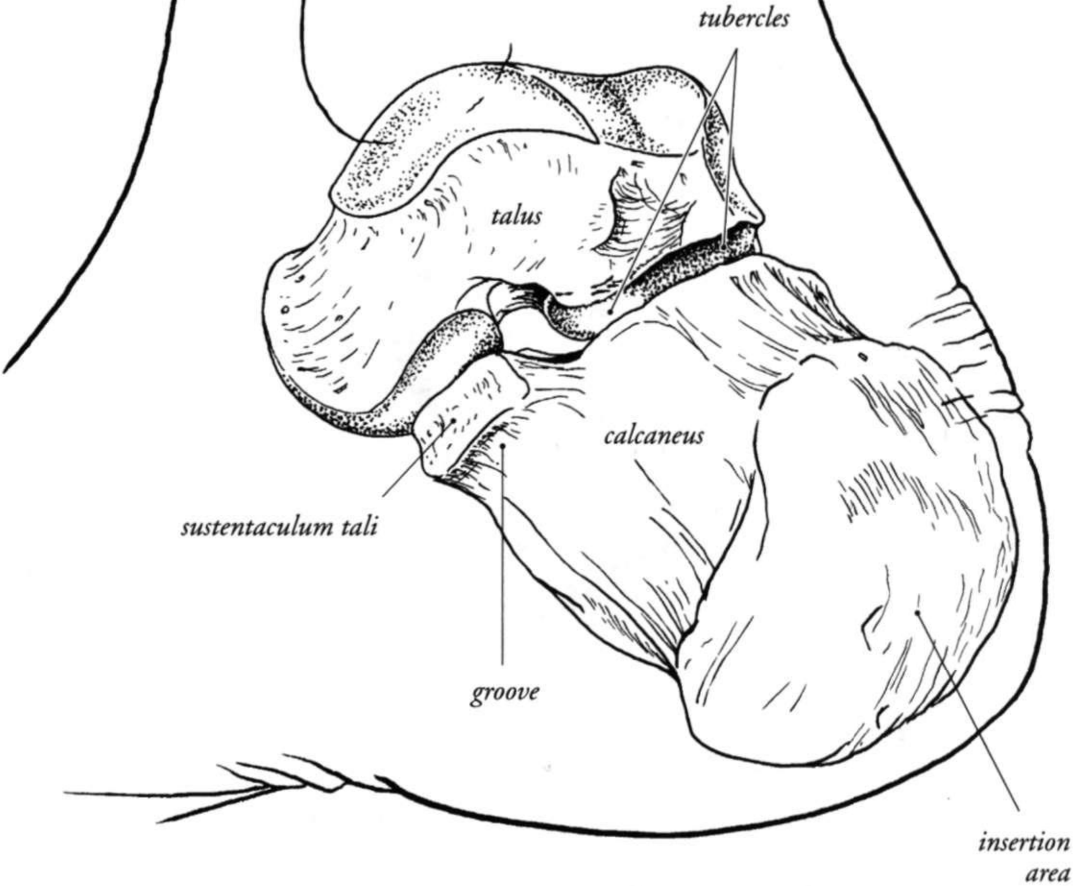
The anterior surface consists mainly of a triangular articulation, which is concave superiorly and convex inferiorly, and articulates with the posterior surface of the cuboid. Its inferior surface has two tuberosities (medial and lateral), which contact the ground. At the lateral, more anterior surface of the calcaneus is a bony eminence, the **trochlear process**, which separates the peroneus tendons.

Talus

On its posterosuperior and lateral surfaces is the **trochlea of the talus**. More anteriorly is the **neck of the talus**. And even further anteriorly is the **head of the talus** with a semi-circular articular surface. It articulates, in turn, with the navicular bone, calcaneonavicular ligament, and the superior surface of the calcaneus (see following pages).

[MEDIAL VIEW FROM BACK]

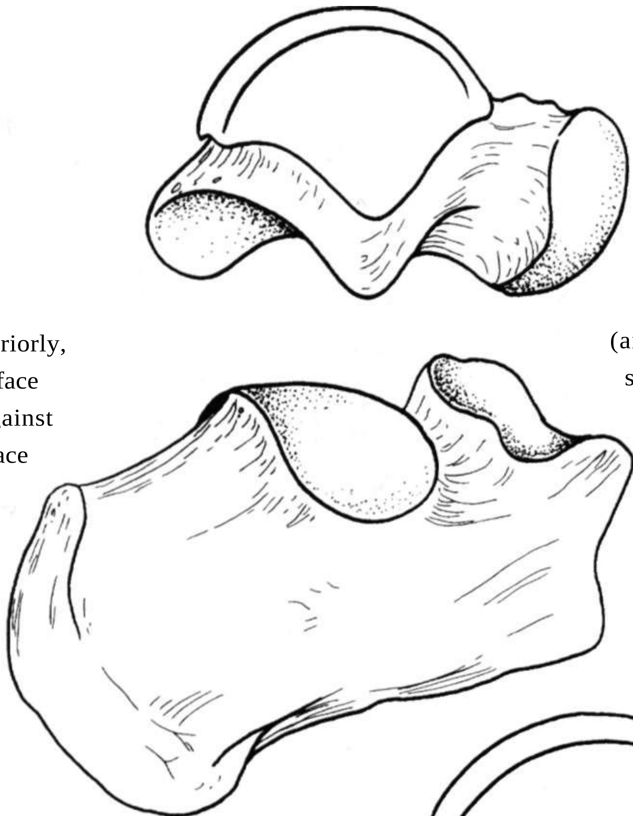
The posterior surface of **talus** constitutes the back of its trochlea. Inferiorly, there are two lateral tubercles, which are separated by a groove where the flexor hallucis longus tendon passes.



On **calcaneus,** we see a prominent projection called the **sustentaculum tali** (helps support talus), a groove for passage of various tendons, blood vessels and nerves, and a large insertion area for the Achilles tendon.

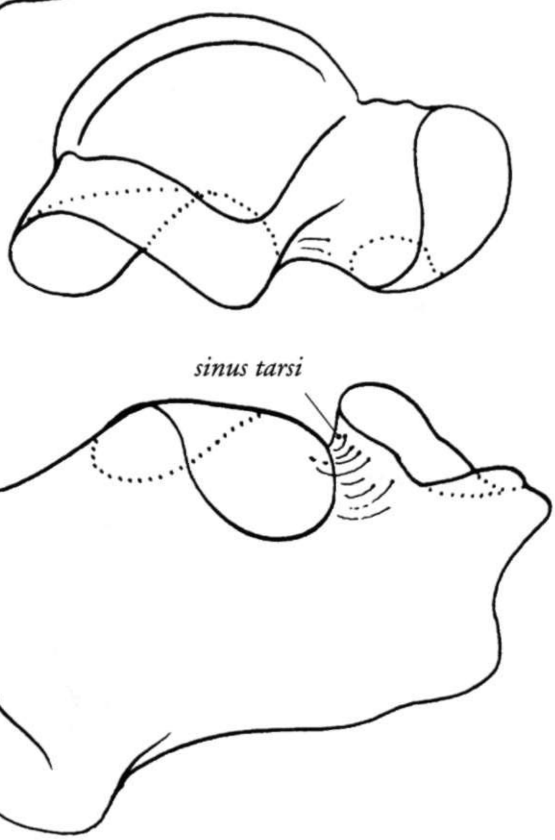
Subtalar (talocalcaneal) joint

Talus sits slightly obliquely on calcaneus, since the long axes of the two bones are oriented (respectively) somewhat medially and laterally.



Anteriorly, a convex surface of talus fits against a concave surface of calcaneus (and partly on the sustenaculum tali)...

...while posteriorly, a concave surface of talus fits against a convex surface of calcaneus.

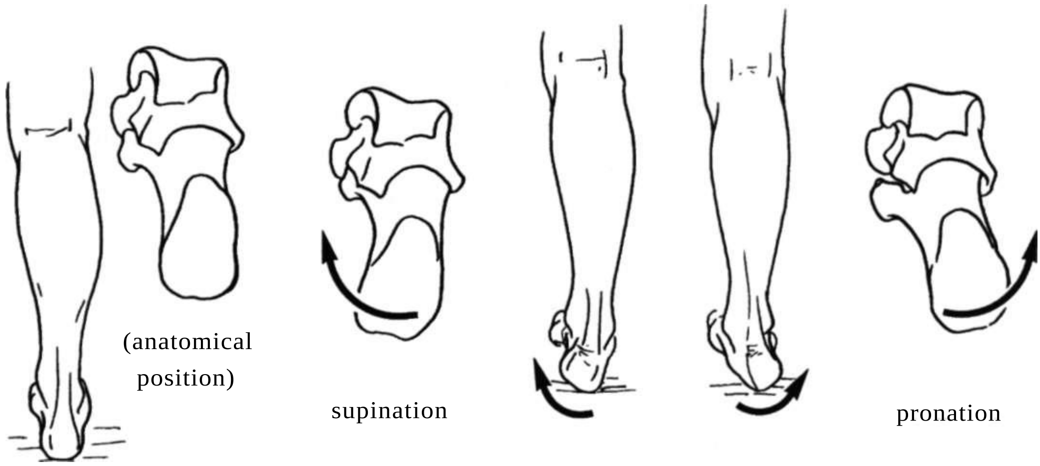


The **sinus tarsi** is a groove between the two bones which contains the strong **interosseous talocalcaneal ligament** and blood vessels.

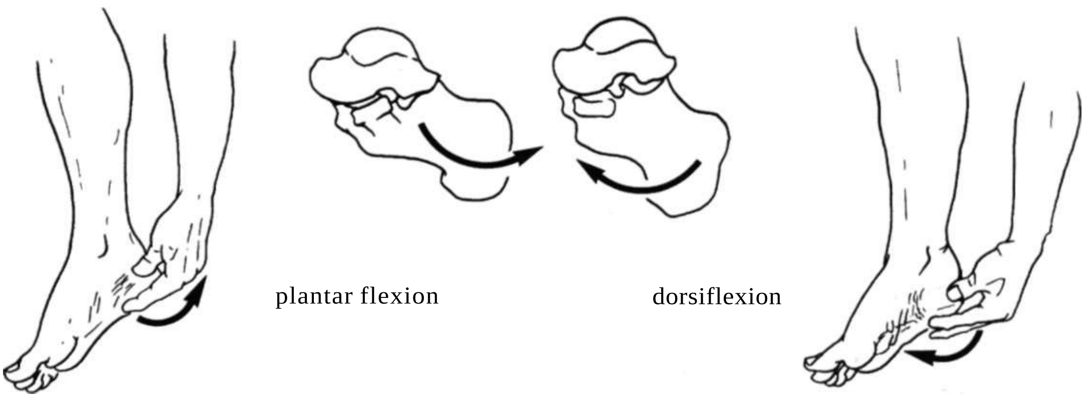
Mobility of subtalar joint

The subtalar joint sits below the ankle, at a vertical angle.
This gives it greater ROM than the ankle, but its ROM is still limited.
We will look at possible movements in three different planes, with and without support.

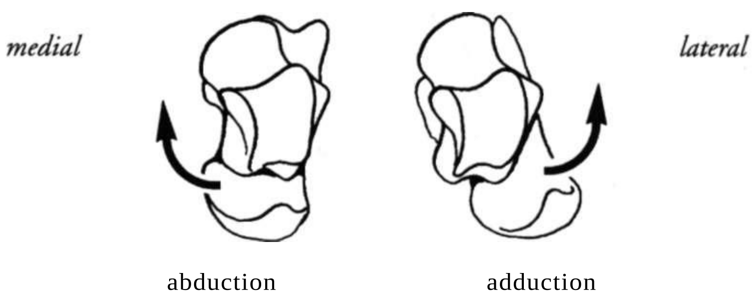
Frontal plane (back view, with support): calcaneous is tilting sideways below the talus



Sagittal plane (without support): calcaneous is moving front to back



Transverse plane (view from above): calcaneous is moving while turning under the talus



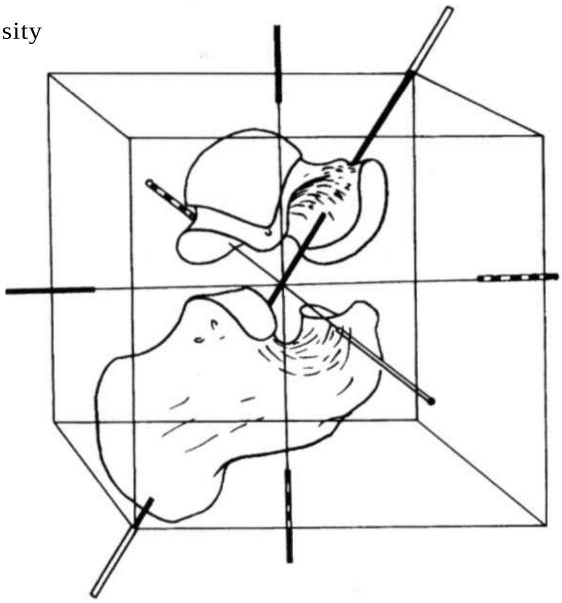
Actually, because of the structure of the articulating surfaces, these movements tend to be combined around an imaginary line called the axis of Henke (a German anatomist).

axis of Henke

This axis enters the posterolateral tuberosity of calcaneus,

...runs anterosuperomedially,

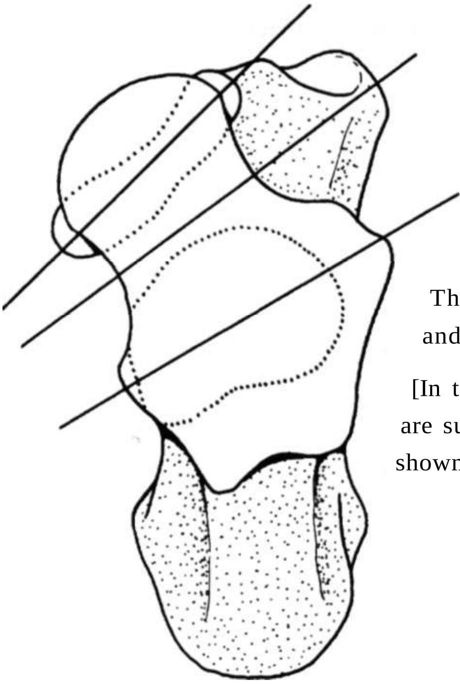
...and exits through the medial neck of talus.



This axis therefore runs obliquely from back to front, bottom to top, lateral to medial.

The movement called **inversion** occurs around this axis, and is a combination of adduction, supination, and plantar flexion.

The opposite movement, **eversion,** is a combination of abduction, pronation, and dorsiflexion.



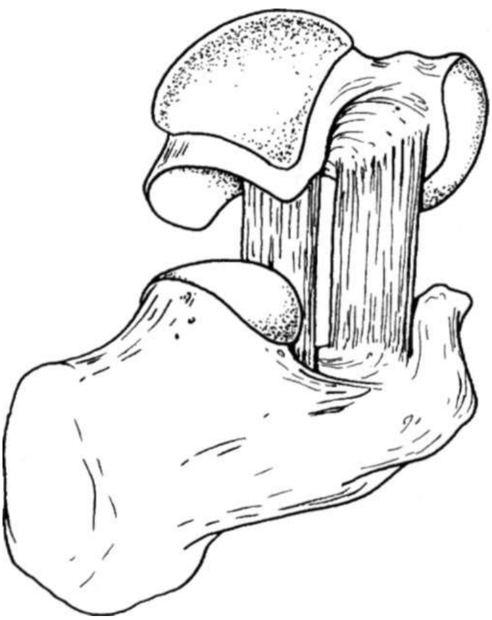
The long axes of the two articulating surfaces and the sinus tarsi are directed anterolaterally.

[In this see-through view, the two bones are superimposed, with their articulating surfaces shown by the dotted outline.]

Capsule and ligaments of subtalar joint

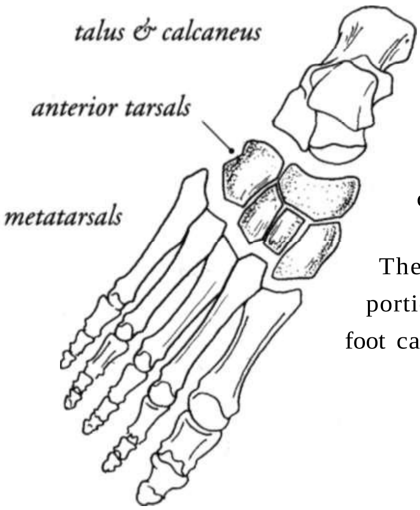
The surfaces are held together by

- two capsules:
  - — posteriorly, a capsule which attaches to the circumference of the surfaces
  - anteriorly, a capsule shared with the transverse tarsal joint.



Because the surfaces (on the talus) and the capsules are continuous, the movements of the anterior subtalar and the transverse tarsal joints are inseparable.

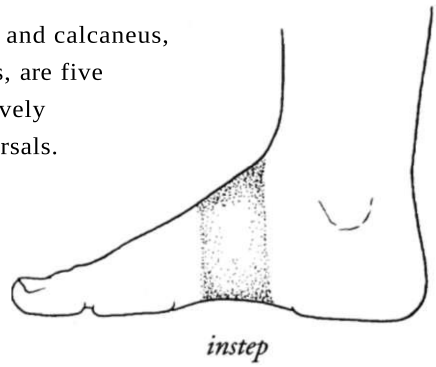
- ligaments:
  - The **interosseous talocalcaneal ligament** forms a double row of ligaments passing along the tarsal tunnel.
  - There is also an anterior and a posterior ligament.



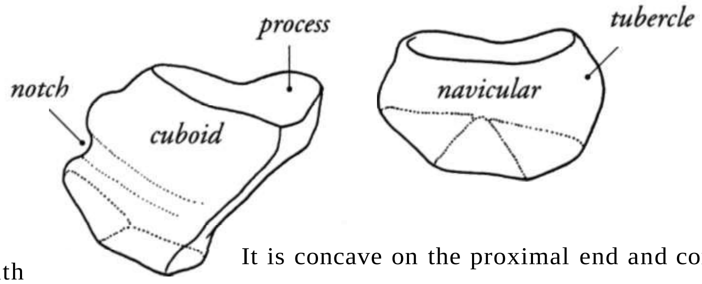
Anterior tarsal bones

Between the talus and calcaneus, and the metatarsals, are five small bones collectively called the anterior tarsals.

They correspond to the portion of the external foot called the **"instep."**



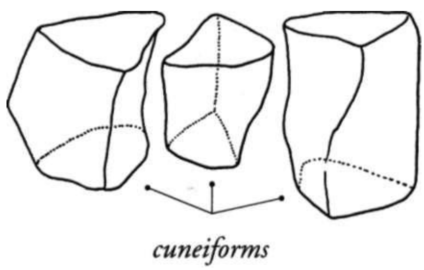
Navicular articulates with talus. Medially, it has an externally palpable tubercle for insertion of tibialis posterior (see p. 290).



Cuboid does not actually bear much resemblance to a cube.

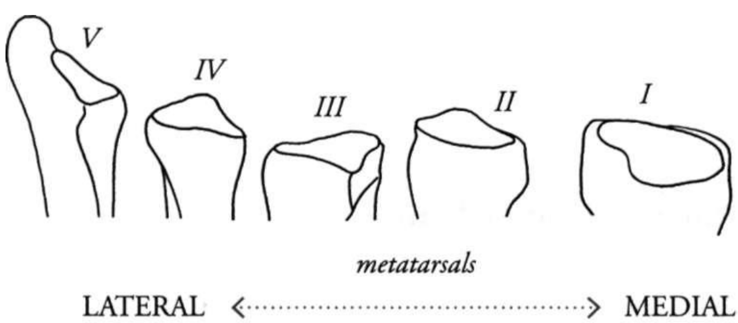
It is concave on the proximal end and convex on the distal end, where there are three facets for articulation with the cuneiforms.

It has facets for articulation with calcaneus (proximally), lateral cuneiform and navicular (medially), and metatarsals IV and V (distally). A proximal process fits under calcaneus and helps maintain the lateral arch of the foot. A lateral notch continues as a groove on the inferior surface and accommodates the tendon of peroneus longus (see p. 288).



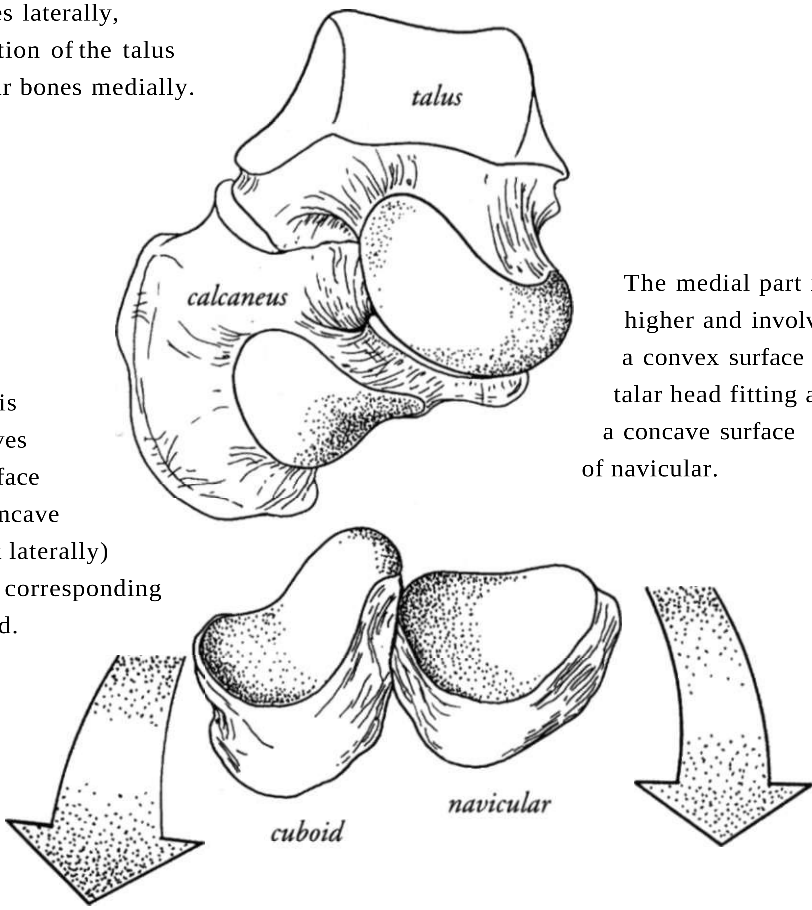
The **cuneiforms** are three small wedge-shaped bones with the sharp edges directed inferiorly. They articulate proximally with navicular and distally with metatarsals I—III. Together with cuboid and the metatarsals, they constitute the transverse arch of the foot.

The anterior tarsals, and their many gliding joints, allow a reasonable degree of flexibility, though less than that of the corresponding wrist bones.



Transverse tarsal joint (Chopart's joint)

This joint is located between the posterior and medial foot. It comprises the articulation of the calcaneous and cuboid bones laterally, and the articulation of the talus and the navicular bones medially.

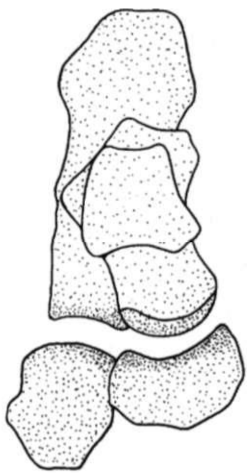


The medial part is higher and involves a convex surface of the talar head fitting against a concave surface of navicular.

The lateral part is lower and involves an S-shaped surface of calcaneus (concave medially, convex laterally) fitting against a corresponding surface of cuboid.

This shows the tarsal region from the front. The two posterior bones are shown in anatomical position. The two anterior bones, cuboid and navicular, are tilted 90° to the back to show their posterior surface.

Seen from above, the transverse tarsal joint is curved rather than straight.



Midtarsal joint mobility

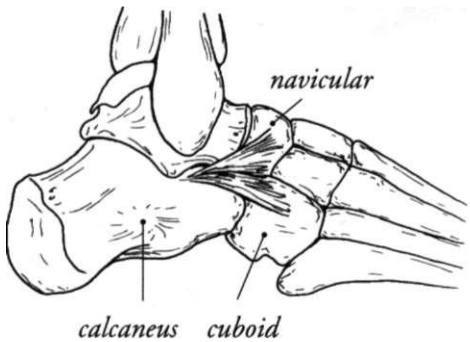
The basic movements here are inversion and eversion. The dominant movement in this joint is **abduction-adduction.**

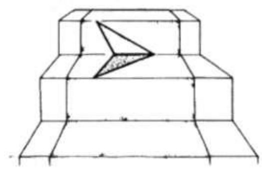
Capsules and ligaments of transverse tarsal joint

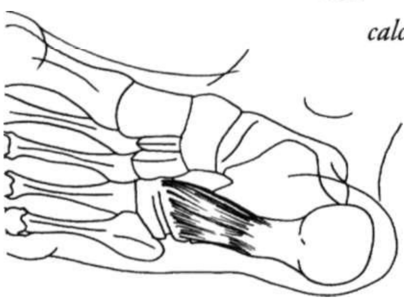
Superiorly, the joint is reinforced by the **talonavicular** and **calcaneocuboidal ligaments.** A medial capsule unites with the capsule of the anterior subtalar joint (see p. 269). A lateral capsule unites the calcaneous with the cuboid bone.

These capsules are reinforced by many ligaments.

Laterally, the **bifurcate ligament** runs from calcaneus and spreads out vertically on navicular and horizontally on cuboid (the surfaces of these two bones are roughly perpendicular at this junction).

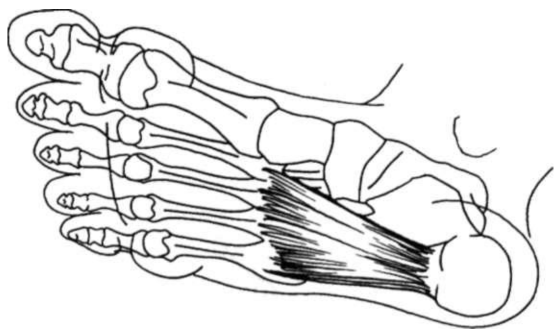


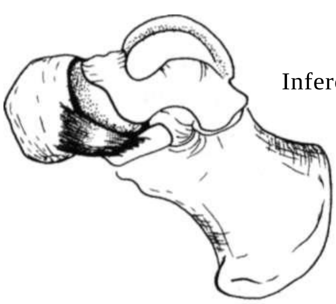




Inferiorly, the transverse tarsal joint is reinforced by three ligaments. The two layers of **plantar calcaneocuboid (short plantar) ligament** run from the calcaneus to the proximal cuboid, and to the base of the metatarsals.

The **long plantar ligament** (located superficial to the short plantar ligament) runs from calcaneus to a ridge on cuboid, passes over the groove (thereby forming a groove for the peroneus longus tendon), and continues on to attach to the bases of metatarsals II-V. The long plantar ligament is quite strong and helps support the arches of the foot.

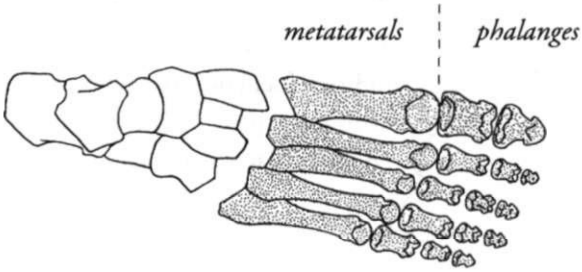


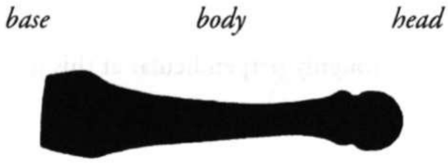


Inferomedially, the **plantar calcaneonavicular ligament** runs from the sustentaculum tall to navicular, and helps support the talar head.

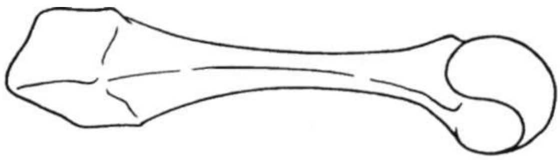
Metatarsals and phalanges

These are five parallel "spokes" made of small bones, which flare out anteriorly. Every spoke consists of a **metatarsal,** as well as **phalanges,** which form the skeleton of the toe.





Each **metatarsal** consists of a proximal base, a body, and a distal head.

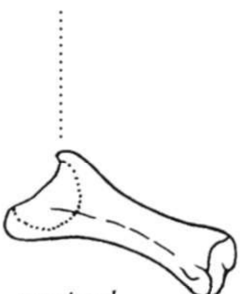


The **base** is roughly quadrangular, with facets for articulation with the tarsals and adjacent metatarsals.

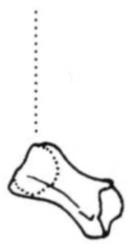
The **head** is convexly rounded, with a cartilaginous surface for articulation with the proximal phalanx, and a tiny tubercle on each side.

The **body** is triangular in cross section, like most long bones.

The proximal **phalanx** of each toe has a concavely rounded base for articulation with the metatarsal, and a pulley-shaped head.



The base of the middle phalanx is concave but with a median crest to match the shape of the head of the proximal phalanx.

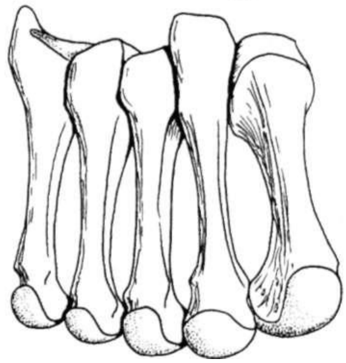


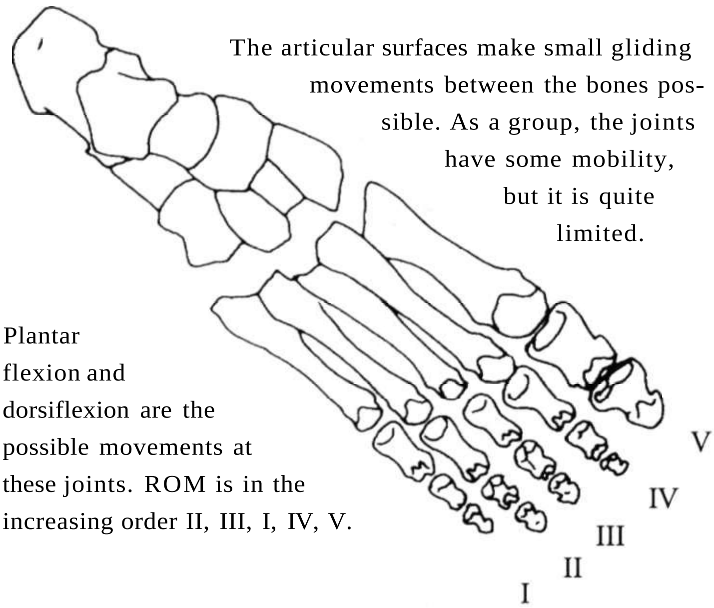
The head of the distal phalanx is flared to support the toenail superiorly, and has an inferior tubercle to support the fleshy part of the toe.

Tarsometatarsal joints

This group consists of the joints formed between the tarsal and metatarsal bones. This "articular line" joins the distal cuneiform and cuboid bones with the proximal bases of the metatarsal bones.

Collectively, the junction is irregular, not straight.





The articular surfaces make small gliding movements between the bones possible. As a group, the joints have some mobility, but it is quite limited.

Plantar flexion and dorsiflexion are the possible movements at these joints. ROM is in the increasing order II, III, I, IV, V.

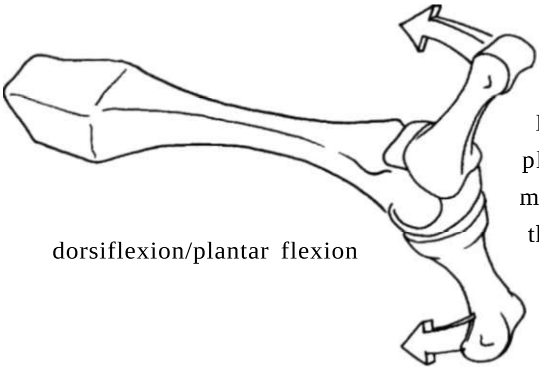
The second spoke has very little mobility. It represents the axis of movement for pronation and supination of the foot.

These joints are supported by capsules, each of which is connected to neighboring capsules.

The capsules in turn are reinforced by many small ligaments, dorsal (shown at left) and plantar (not shown), which serve to connect the bones to one another.

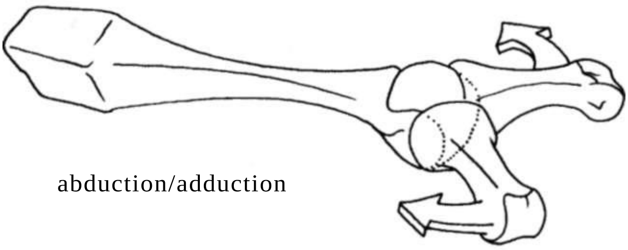
Metatarsophalangeal joints

At each metatarsophalangeal joint the head of the metatarsal articulates with the base of the proximal phalanx at each of the five "spokes" of the forefoot. The articular surfaces have the shape of a small condyle, which allows movement in all three planes, as described on pages 8-10.

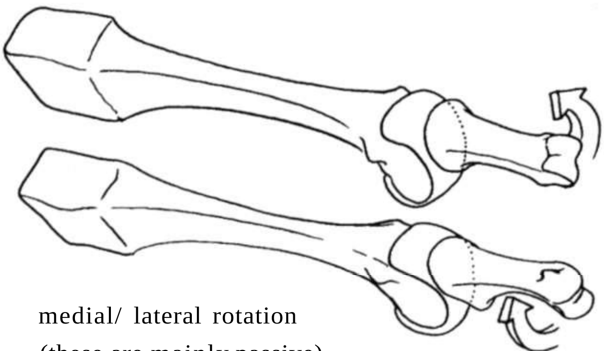


dorsiflexion/plantar flexion

Dorsiflexion has greater ROM than plantar flexion (the cartilage of the metatarsal is more developed on the dorsal side), and the associated muscles are stronger.



abduction/adduction

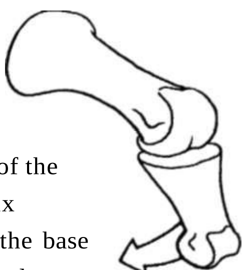


medial/ lateral rotation
(these are mainly passive)

For going uphill, or up the stairs, strong dorsiflexion is needed.

Interphalangeal joints

The proximal interphalangeal joint is a hinge.



Here, the head of the proximal phalanx articulates with the base of the middle phalanx.

It allows plantar flexion but not dorsiflexion.

The distal interphalangeal joint is also a hinge...

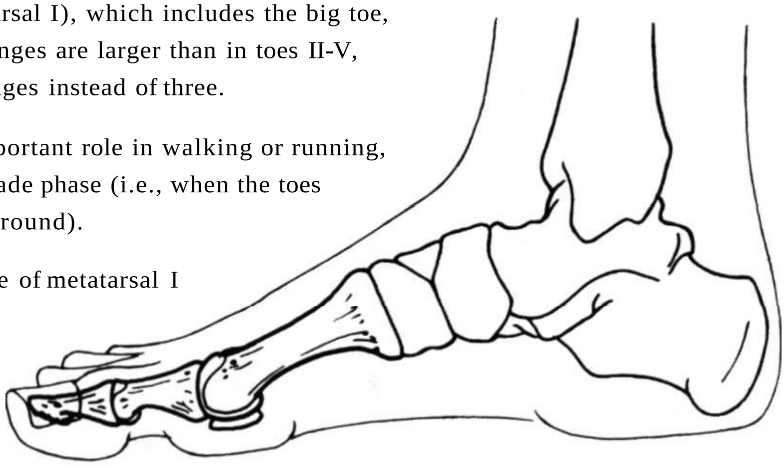
...but allows both plantar and dorsiflexion.

Particularities of 1st and 5 th "spokes"

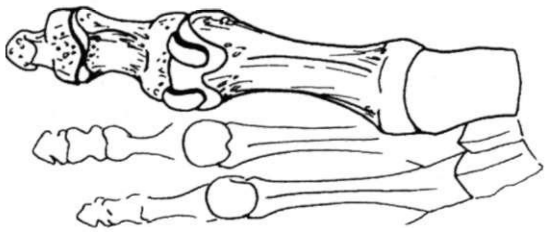
In the first spoke (metatarsal I), which includes the big toe, the metatarsal and phalanges are larger than in toes II-V, and there are two phalanges instead of three.

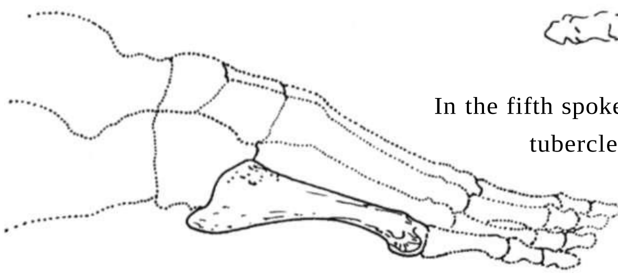
The big toe plays an important role in walking or running, especially in the digitigrade phase (i.e., when the toes are in contact with the ground).

The disproportionate size of metatarsal I can lead to instability or medial pain when on tiptoe or during prolonged walks.



Two small sesamoid bones are located in the plantar cartilage on the head of metatarsal I. They act as shock-absorbers during weightbearing.



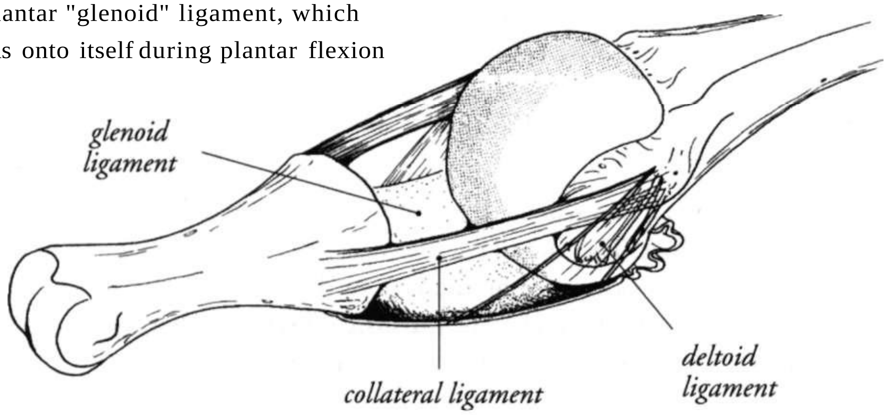


In the fifth spoke, there is an externally-palpable tubercle (for muscle attachment) on the lateral base of metatarsal V.

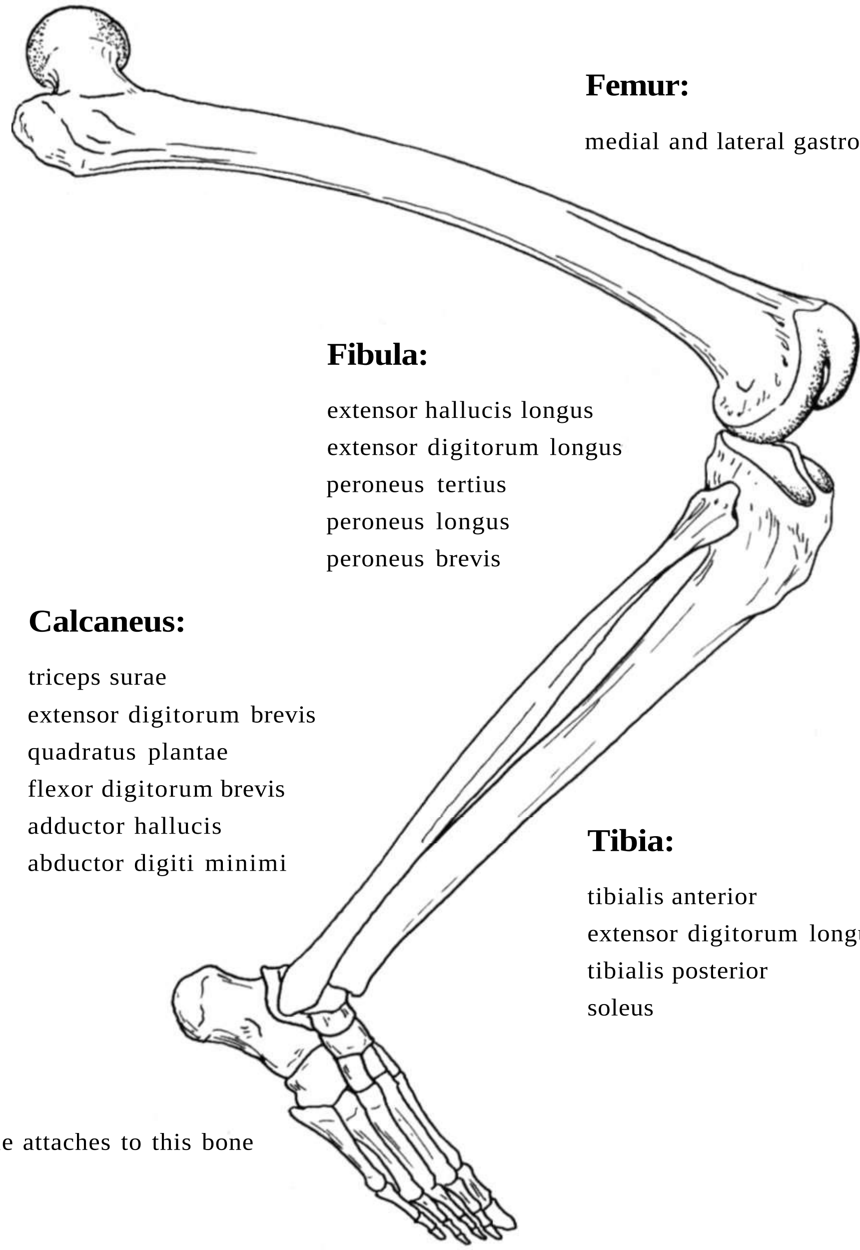
Joint capsules and ligaments

Ligaments of the metatarsophalangeal and interphalangeal joints have the same general plan. The joints are held by a capsule, which is attached to the neighboring structures and reinforced by ligaments:

- two collateral ligaments, inserting on proximal tubercles of the distal bone
- a fan-shaped "deltoid" ligament, running from the tubercle to the glenoid ligament.
- a plantar "glenoid" ligament, which folds onto itself during plantar flexion



Ankle and foot muscles with their many bony attachments



Femur:

medial and lateral gastrocnemius

Fibula:

extensor hallucis longus
extensor digitorum longus
peroneus tertius
peroneus longus
peroneus brevis

Calcaneus:

triceps surae
extensor digitorum brevis
quadratus plantae
flexor digitorum brevis
adductor hallucis
abductor digiti minimi

Tibia:

tibialis anterior
extensor digitorum longus
tibialis posterior
soleus

Talus:

no muscle attaches to this bone

Other bones of the foot:

All extrinsic muscles of the foot (except the triceps surae muscles) and all the intrinsic muscles of the foot.

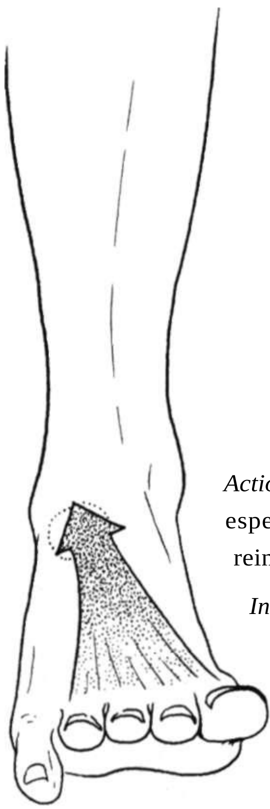
The **extrinsic muscles** of the foot originate on the femur, tibia, or fibula, and insert on the bones of the foot via long tendons. They are all polyarticular, acting on the ankle and foot (or on the knee, in the case of the gastrocnemius muscle). As they course down the leg, their tendons run anterior or posterior to the ankle. The **intrinsic muscles** are short muscles which run between nearby foot bones. They are mostly on the plantar side of the bones, and comprise the fleshy mass of the sole.

Intrinsic muscles of the foot

Extensor digitorum brevis
is the only dorsal intrinsic muscle.

It arises from the anterosuperolateral calcaneus and divides into four bodies.

The medial tendon inserts on proximal phalanx I, while the other three merge laterally with the tendons of extensor digitorum longus, inserting on toes II-IV.



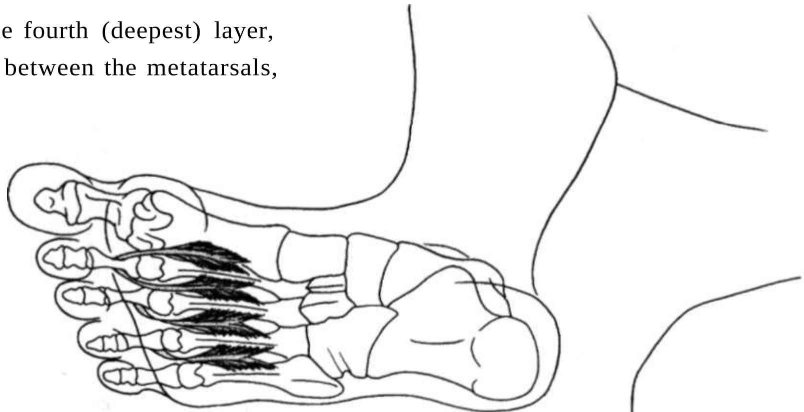
Actions: dorsiflexion of toes I-IV, especially at the level of the proximal phalanx; reinforces the action of extensor digitorum longus

Innervation: deep peroneal nerve (S1-S2)

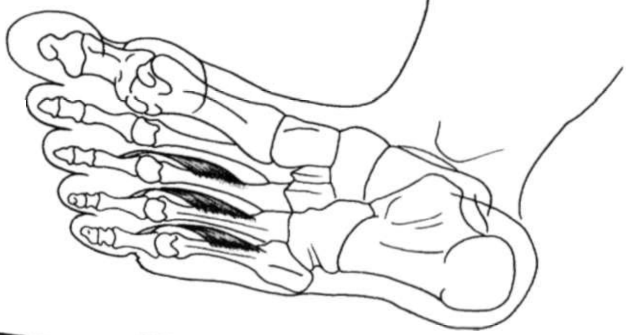
Middle group

On the sole of the foot, the intrinsic muscles can be subdivided into three groups: middle, medial, and lateral. These first two pages describe the middle group. Collectively, these muscles occupy several layers, but each of the following illustrations shows each muscle layer separately.

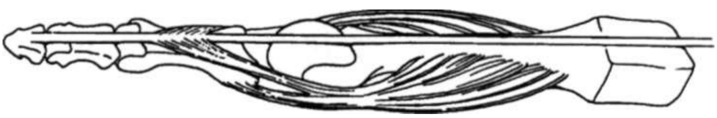
The **interossei** form the fourth (deepest) layer, and occupy the spaces between the metatarsals, where they originate.



There are four dorsal interossei (i.e., arising closer to the dorsal surface of the foot)...

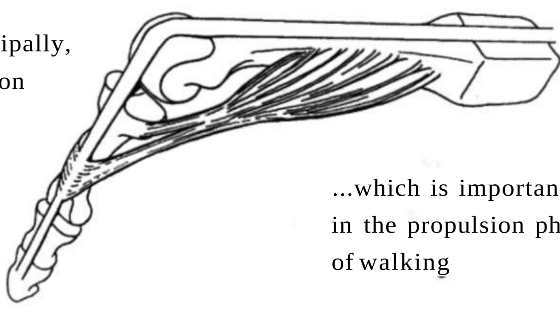


.. .and three plantar interossei (closer to the plantar surface).

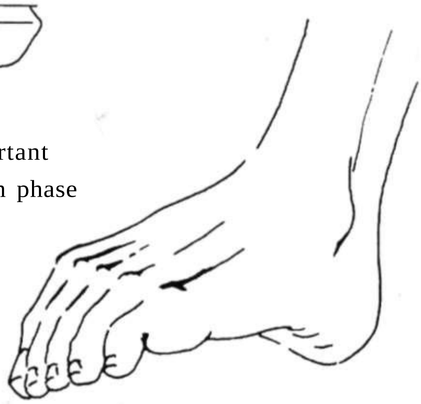


They insert at the base of the proximal phalanges (plantar side) and at the extensor digitorum longus tendon (dorsal side, as shown in simplified drawing above).

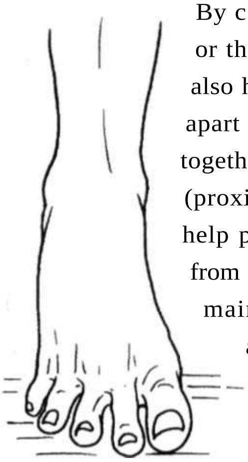
Action: principally, plantar flexion of proximal phalanges...



...which is important in the propulsion phase of walking

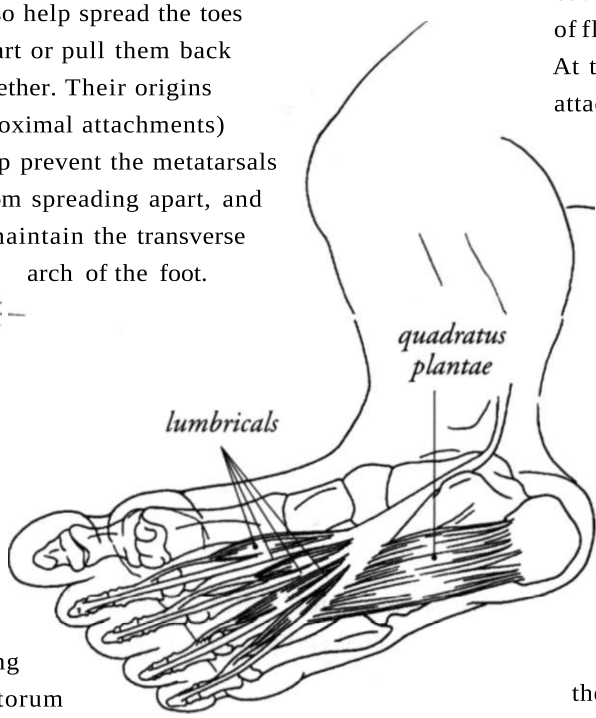


Innervation: lateral plantar nerve (S1-S2)



By contracting on one side or the other, the interossei also help spread the toes apart or pull them back together. Their origins (proximal attachments) help prevent the metatarsals from spreading apart, and maintain the transverse arch of the foot.

The interossei are covered by the tendons of flexor digitorum longus. At the hindfoot, a muscle attaches to these tendons:



Quadratus plantae (also called flexor digitorum accessorius) arises from the body of calcaneus, and inserts on the posterolateral border of the flexor digitorum longus tendon near its division into four parts. It belongs to the second layer.

Actions: redirects the pull of the flexor digitorum longus tendons to be more in line with the axes of the toes

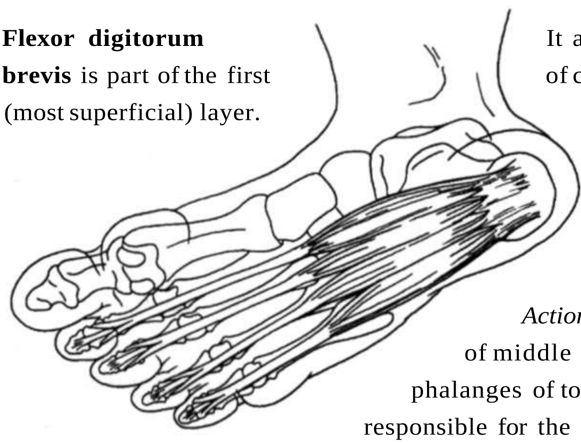
Innervation: lateral plantar nerve (S1-S2)

The **lumbricals** are four small muscles (in the second layer) running from the flexor digitorum longus tendons to the dorsal parts of the extensor digitorum longus tendons.

Action: minimal; they mostly "fine tune" the actions of other toes muscles

Innervation: medial and lateral plantar nerves (L5-S2)

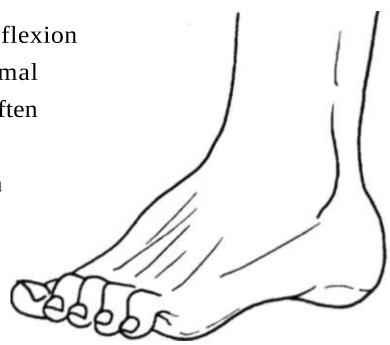
Flexor digitorum brevis is part of the first (most superficial) layer.



It arises from the posteroinferior tuberosity of calcaneus, splits into four parts, and inserts laterally on middle phalanges II-V. Each tendon is "perforated" to allow passage of the flexor digitorum longus tendons to the distal phalanges.

Action: plantar flexion of middle and proximal phalanges of toes II-V; often responsible for the condition called "clawfoot," particularly when action of the interossei is weak

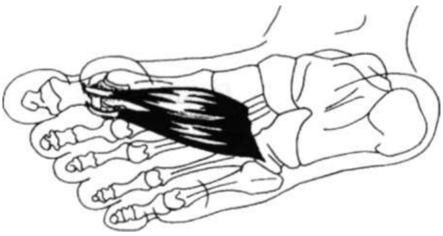
Innervation: medial plantar nerve (L5-S1)



Medial group

There are three muscles which insert on the proximal phalanx of the big toe and, in passing, on the sesamoid bone.

Flexor hallucis brevis (third layer) originates from cuboid and the two lateral cuneiforms and inserts via two tendons on either side of proximal phalanx I.

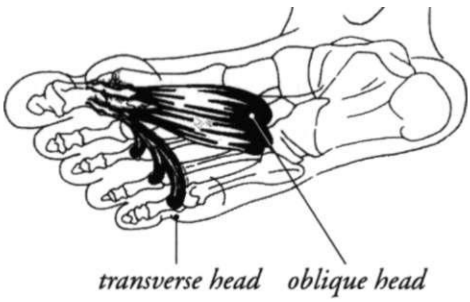


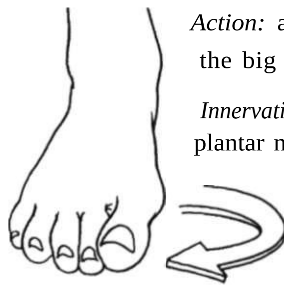
Action: plantar flexion of proximal phalanx of big toe

Innervation: medial plantar nerve (L5-S1)

Adductor hallucis has two layers. The oblique adductor arises on the cuboid, and the transverse adductor on the metatarsaophalangeal joints III-V. Both layers merge in a tendon, which inserts on the lateral base of proximal phalanx I.

This is the muscle that is primarily responsible for "hallux valgus," a malformation in which metatarsal I is permanently adducted and prosimal phalanx I abducted, such that the big toe overlaps the second toe.



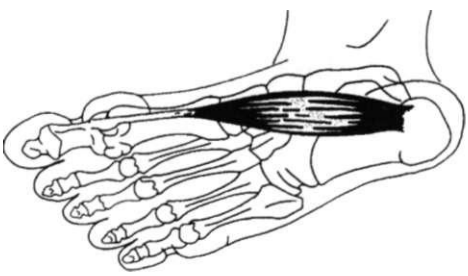


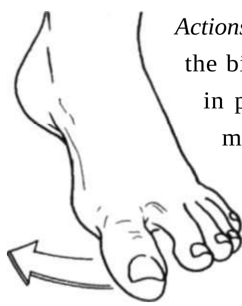
Action: adducts the big toe*

Innervation: medial plantar nerve (S1-S2)

Abductor hallucis is the most superficial of the three muscles. It originates at the medial tuberosity on the medial surface of the calcaneous and inserts on the medial base of the proximal phalanx I.

This muscle actively supports the medial arch and assists in keeping the big toe properly aligned by opposing "hallux valgus."





Actions: abducts the big toe; assists in plantar flexion of the metatarsophalangeal joint

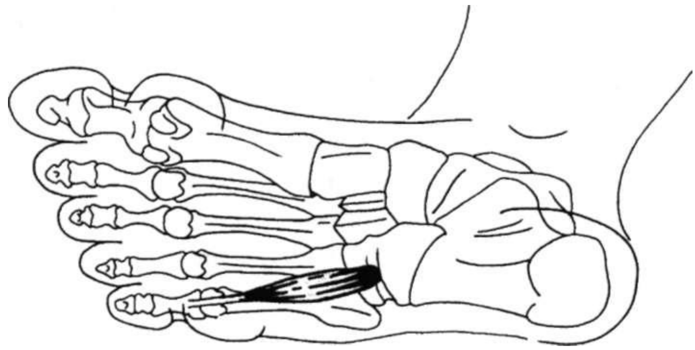
Innervation: lateral plantar nerve (L5-S1)

**Note:* When we speak of adduction or abduction of toes, the reference is the axis of the 2ND toe, not the median plane of the body.

Lateral group

There are three small muscles on the lateral side of the foot.

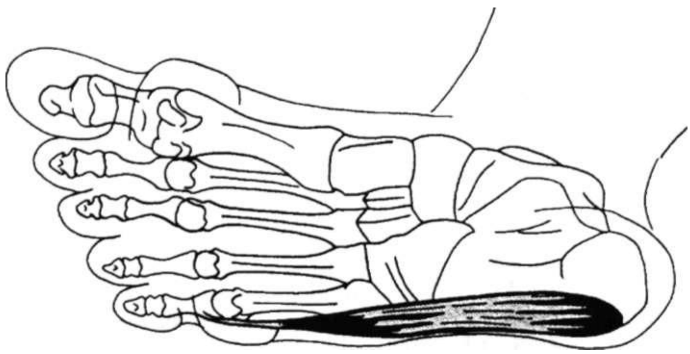
Flexor digiti minimi brevis (third layer) arises from the base of metatarsal V and inserts on the base of proximal phalanx V.



Action: plantar flexion of little toe

Innervation: lateral plantar nerve (S1-S2)

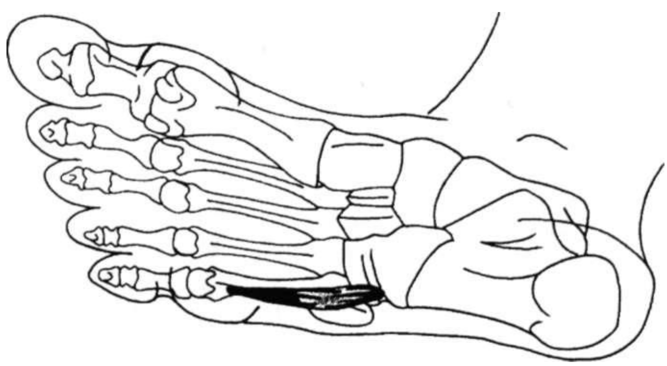
Abductor digiti minimi (first layer) originates from the posteroinferior calcaneus and inserts laterally on the base of proximal phalanx V.



Actions: abduction and plantar flexion of little toe; supports lateral arch

Innervation: lateral plantar nerve (S1-S2)

Opponens digiti minimi originates from cuboid and inserts on the lateral side of metatarsal V.



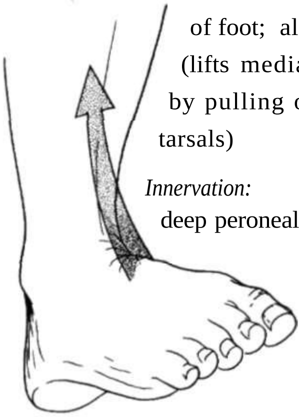
Actions: orients metatarsal V toward the other metatarsals and resists the spreading of the anterior portion of the foot

Innervation: lateral plantar nerve (S1-S2)

Extrinsic anterior muscles

On the anterior surface of the leg are three long muscles whose tendons run anterior to the ankle, where they are held in place by the **extensor retinaculum.**

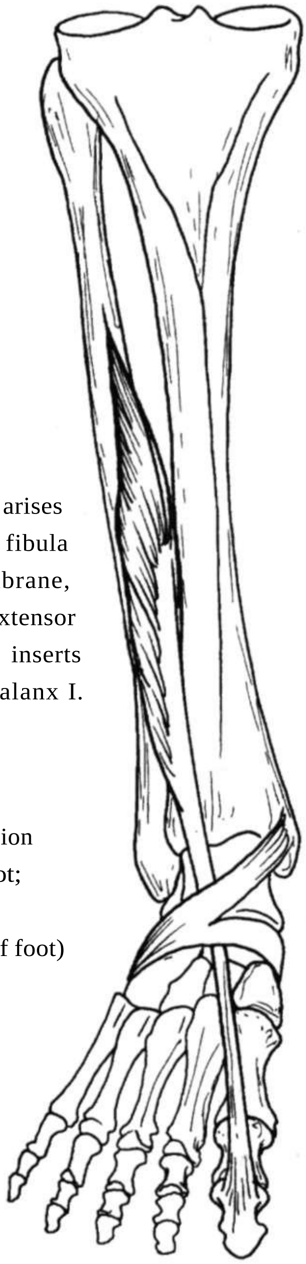
Tibialis anterior originates from the lateral condyle and superolateral shaft of tibia, passes under the extensor retinaculum, and inserts on the medial cuneiform (inferomedial surface) and base of metatarsal I. This muscle is the strongest dorsiflexor.



Actions: dorsiflexion of foot; also supination (lifts medial edge of foot by pulling on anterior tarsals)

Innervation: deep peroneal nerve (L4-S1)

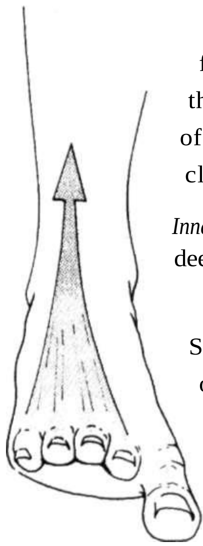
Extensor hallucis longus arises from the central medial fibula and interosseous membrane, passes under the extensor retinaculum, and inserts dorsally on distal phalanx I.



Actions: dorsiflexion of big toe and foot; also supination (lifts medial edge of foot)

Innervation: deep peroneal nerve (L4-S1)

Extensor digitorum longus originates from the lateral tibial condyle, most of the anterior fibular shaft, and interosseous membrane. Its tendon passes under the extensor retinaculum, splits into four parts, and inserts on toes II-V. Each of the four tendons further splits into two slips attaching to the sides of the middle phalanx, and a central slip attaching to the base of the distal phalanx.

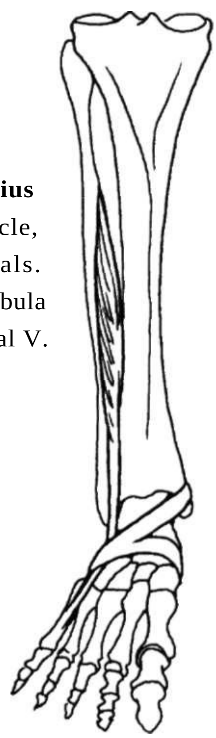


Action: dorsiflexion of toes II-V, foot, and ankle; it mainly acts on the proximal phalanx and is one of the muscles responsible for the clawing" action of the toes

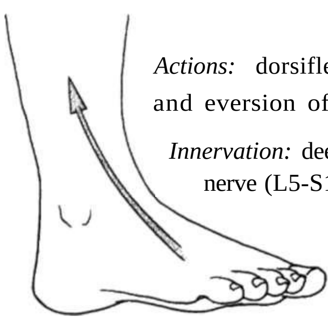
Innervation:
deep peroneal nerve (L4-S1)

Short muscles of the foot that insert on the tendon of extensor digitorum longus, complementing its action:

- extensor digitorum brevis (p. 281)
- interossei (p. 282)



Peroneus tertius
is an insignificant muscle, absent in some individuals. It arises from the anteroinferior fibula and inserts on metatarsal V.



Actions: dorsiflexion and eversion of foot

Innervation: deep peroneal nerve (L5-S1)

Extrinsic lateral muscles

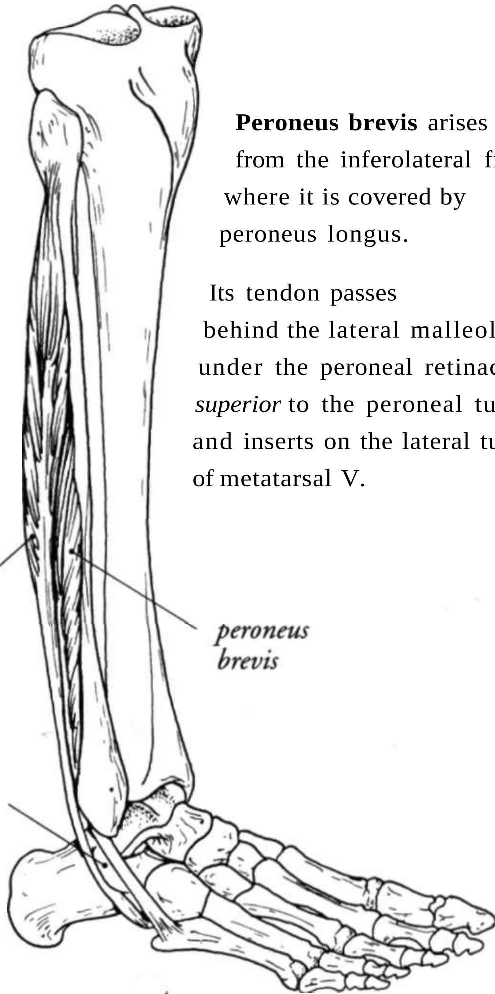
There are two muscles on the lateral side of the leg that attach to the fibula: the **peroneus muscles.**

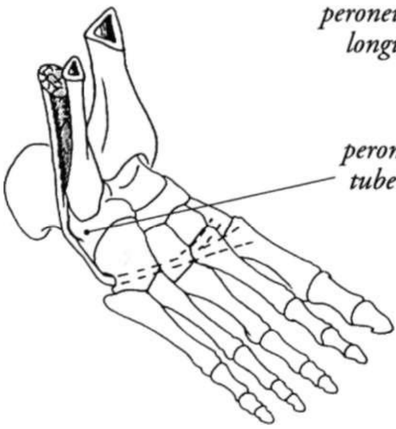
Peroneus longus arises from the head and superolateral shaft of fibula.

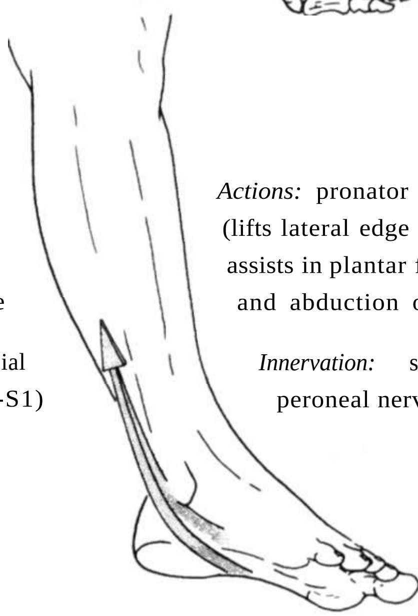
Its tendon follows a complicated path behind the lateral malleolus, under the peroneal retinaculum, *inferior* to the peroneal tubercle of calcaneus, along the groove of the plantar (inferior) cuboid, and finally inserts inferiorly on the base of the medial cuneiform and base of metatarsal I.

Peroneus brevis arises from the inferolateral fibular shaft, where it is covered by peroneus longus.

Its tendon passes behind the lateral malleolus, under the peroneal retinaculum, *superior* to the peroneal tubercle, and inserts on the lateral tubercle of metatarsal V.







Actions: pronator (lifts lateral edge of foot and lowers medial edge); plantar flexes ankle

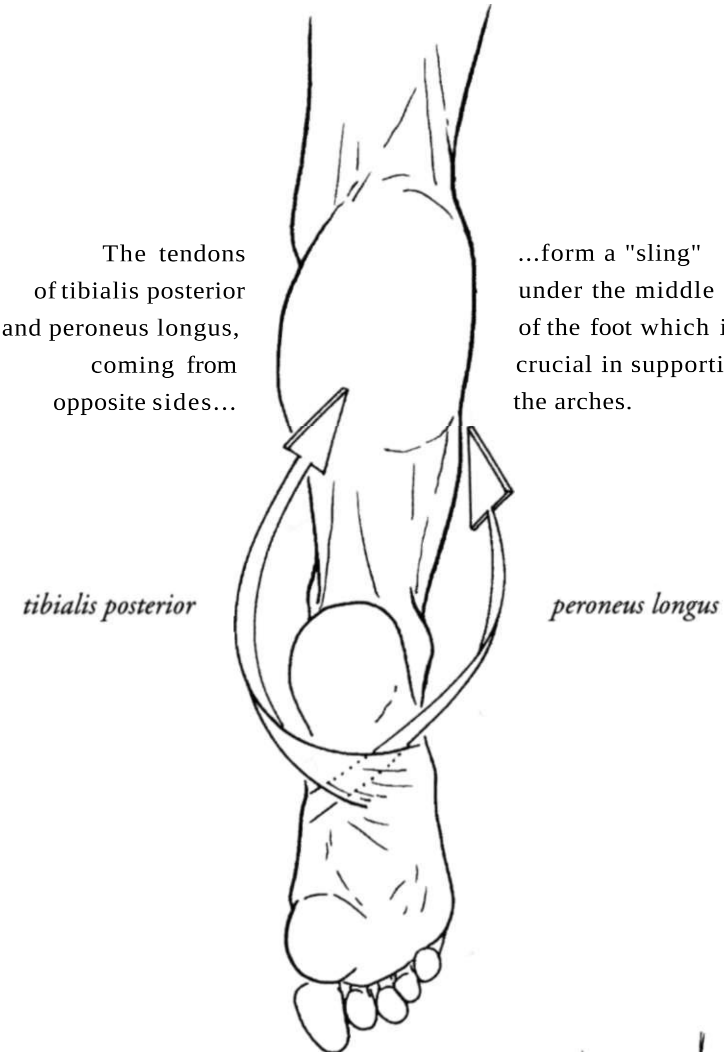
Innervation: superficial peroneal nerve (L5-S1)

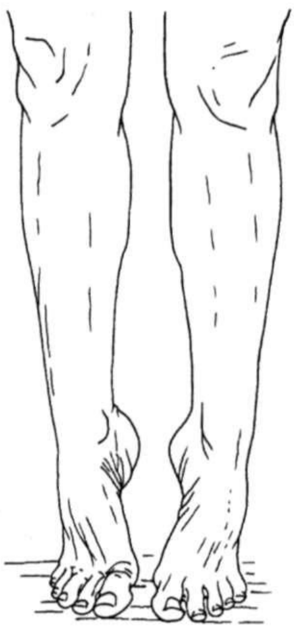
Actions: pronator (lifts lateral edge of foot); assists in plantar flexion and abduction of foot

Innervation: superficial peroneal nerve (L5-S1)

The tendons of tibialis posterior and peroneus longus, coming from opposite sides...

...form a "sling" under the middle part of the foot which is crucial in supporting the arches.



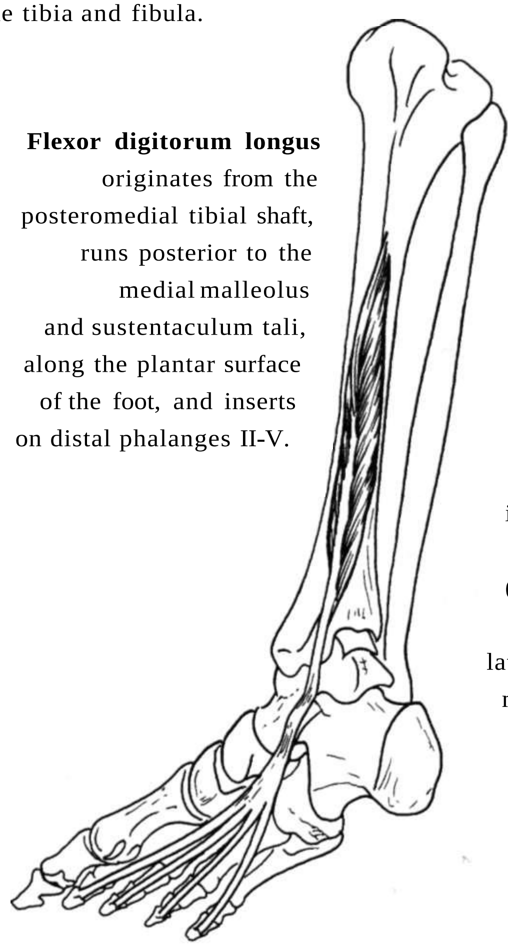


Peroneus longus and brevis both strengthen and support the lateral arch, stabilizing the ankle and preventing loss of balance laterally, especially when standing on one foot or on tiptoe.

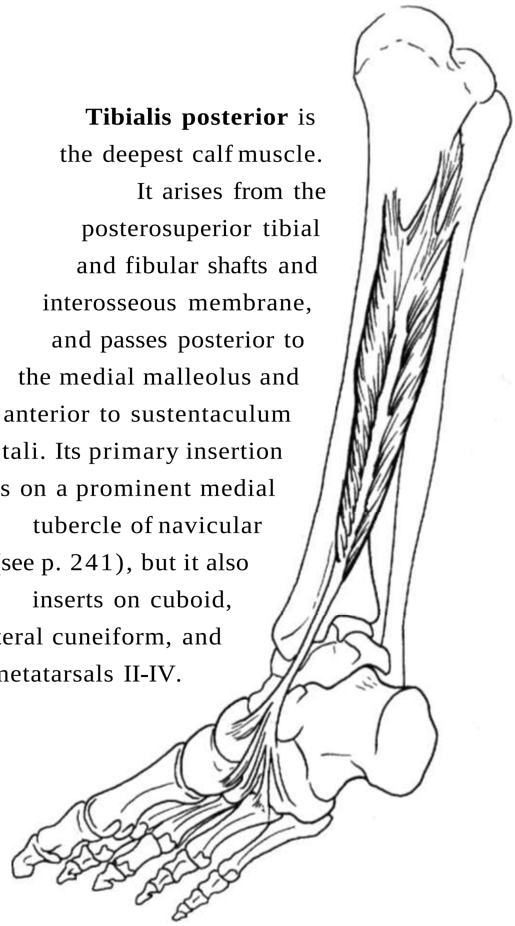
Extrinsic posterior muscles

The posterior group of leg muscles is the most important muscle group. It has two layers, the deeper one consisting of three muscles located next to each other on the posterior surfaces of the tibia and fibula.

Flexor digitorum longus originates from the posteromedial tibial shaft, runs posterior to the medial malleolus and sustentaculum tali, along the plantar surface of the foot, and inserts on distal phalanges II-V.

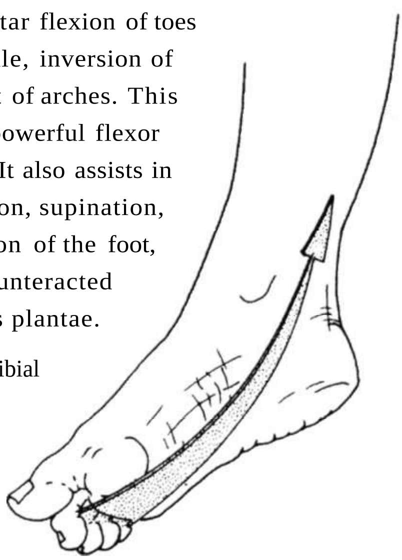


Tibialis posterior is the deepest calf muscle. It arises from the posterosuperior tibial and fibular shafts and interosseous membrane, and passes posterior to the medial malleolus and anterior to sustentaculum tali. Its primary insertion is on a prominent medial tubercle of navicular (see p. 241), but it also inserts on cuboid, lateral cuneiform, and metatarsals II-IV.



Actions: plantar flexion of toes II-V and ankle, inversion of foot, support of arches. This is the most powerful flexor of toes II-V. It also assists in plantar flexion, supination, and adduction of the foot, the latter counteracted by quadratus plantae.

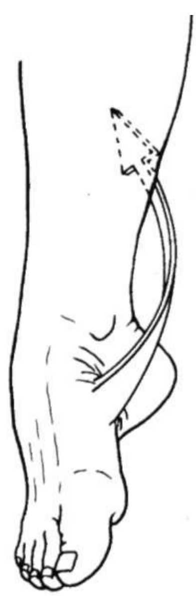
Innervation: tibial nerve (S1-S3)



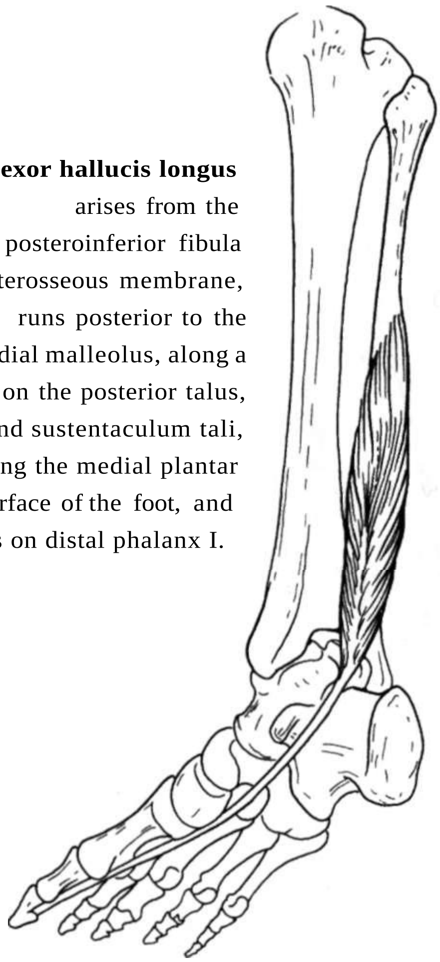
Actions: plantar flexion, inversion, support of arches (see p. 295)

The role of tibialis posterior, in conjunction with peroneus longus, in forming a "sling" for the middle foot, was noted on the preceding page.

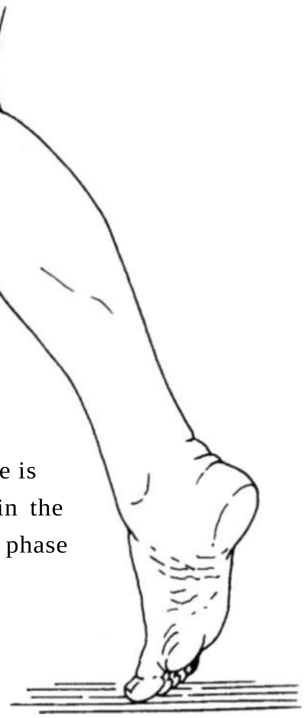
Innervation: tibial nerve (L4-L5)



Flexor hallucis longus arises from the posteroinferior fibula and interosseous membrane, runs posterior to the medial malleolus, along a groove on the posterior talus, behind sustentaculum tali, along the medial plantar surface of the foot, and inserts on distal phalanx I.

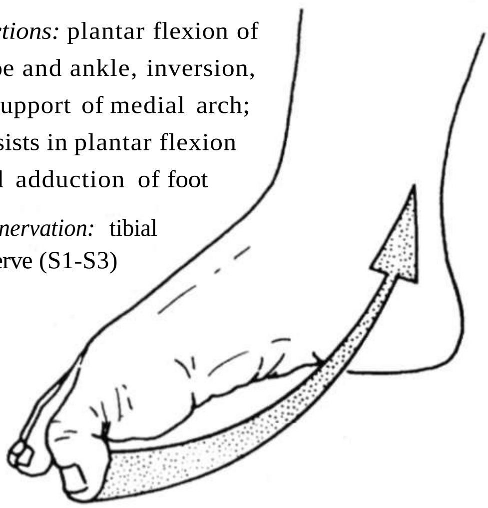


This muscle is important in the propulsion phase of walking.



Actions: plantar flexion of big toe and ankle, inversion, support of medial arch; assists in plantar flexion and adduction of foot

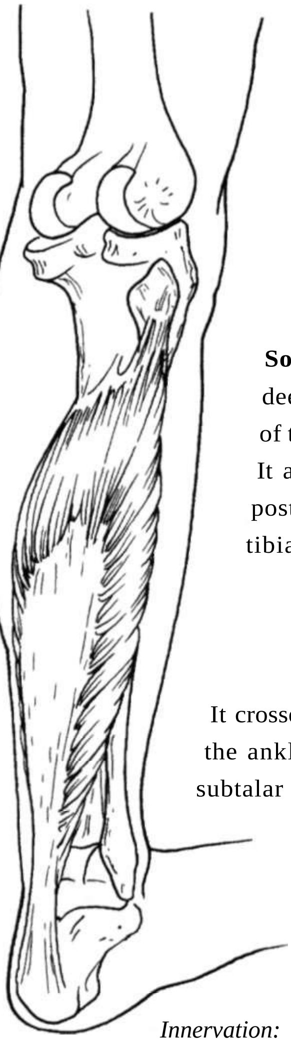
Innervation: tibial nerve (S1-S3)



It also has a very important role in stabilizing the foot when standing on tiptoe, since the pushing action of the big toe offsets the anterior loss of balance. It also helps stabilize the ankle (see p. 295).

The superficial group of posterior calf muscles is known collectively as the **triceps surae.**

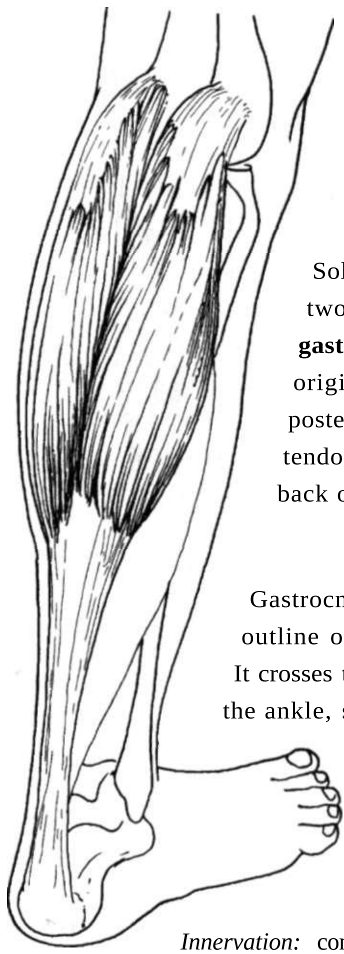
This is the strongest muscle group of the leg. It consists of three muscular heads, all of which terminate on the **Achilles tendon,** which then attaches to the posterior surface of the calcaneus.



Soleus is the deepest head of triceps surae. It arises from the posterosuperior tibia and fibula.

It crosses two joints: the ankle and the subtalar joint.

Innervation: common tibial nerve (L5/S2)

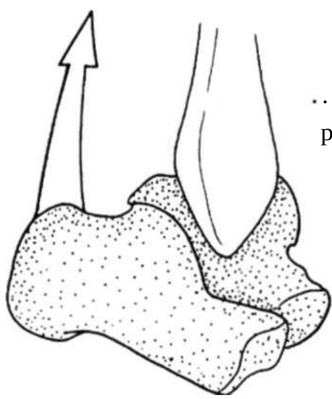


Soleus is covered by the two superficial heads of **gastrocnemius,** which originate at the distal posterior femur from a tendon attaching to the back of each condyle.

Gastrocnemius shapes the outline of the posterior calf. It crosses three articulations: the ankle, subtalar joint, and knee.

Innervation: common tibial nerve (S1-S2)

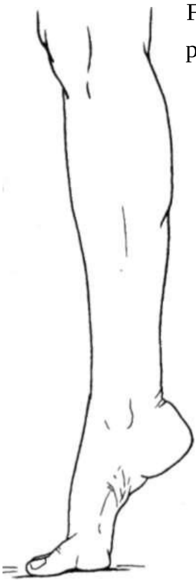
Actions of triceps surae: Together, the three muscles pull the calcaneus into plantar flexion under the talus, with a tendency to inversion*...



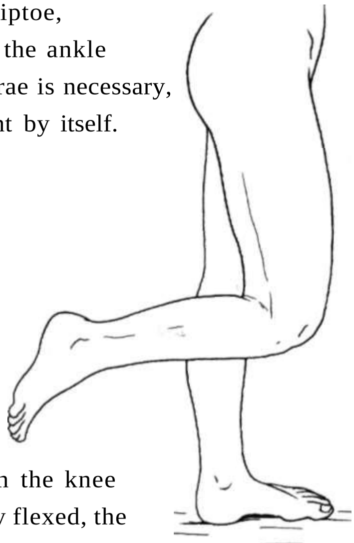
. . .and indirectly pull the talus into plantar flexion. This second action is actually more important than the first because it gives the joint more mobility.

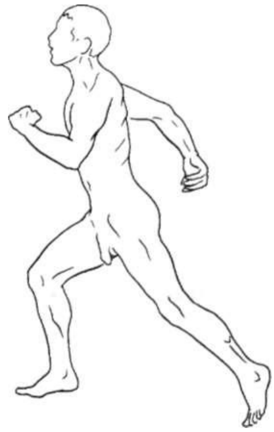
*Why inversion? It is linked to the articular surfaces of the subtalar joint. Plantar flexion corresponds to adduction and supination (see p. 271).

Since gastrocnemius crosses the knee, the position of the knee affects its efficiency as a plantar flexor of the ankle.



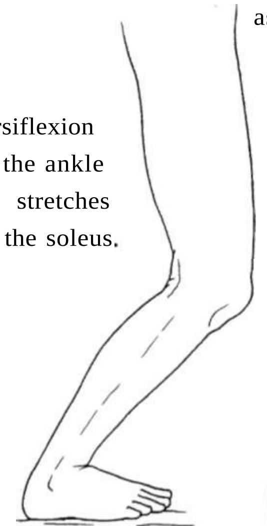
For standing on tiptoe, plantar flexion of the ankle by the triceps surae is necessary, but not sufficient by itself.





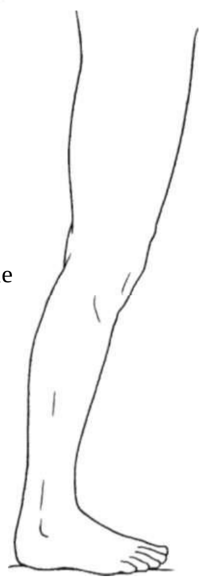
When the knee is very flexed, the gastrocnemius is slack and therefore inefficient as an ankle flexor.

When the knee is extended or only slightly flexed (the position taken by the "propelling leg" at the start of a race), the gastrocnemius is more taut and more efficient as an ankle flexor.

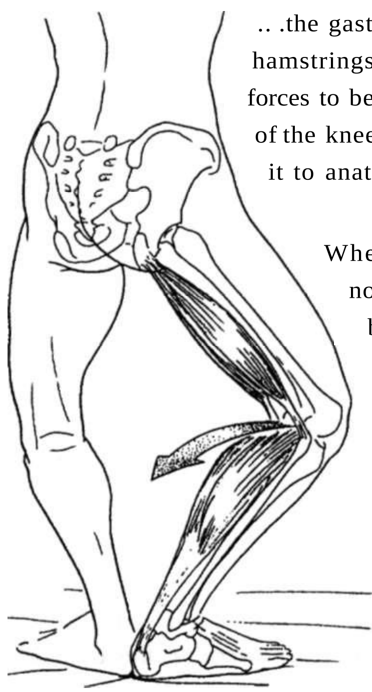


Dorsiflexion at the ankle stretches the soleus.

Interestingly, when the knee is flexed and the leg and foot are bearing the weight of the body...



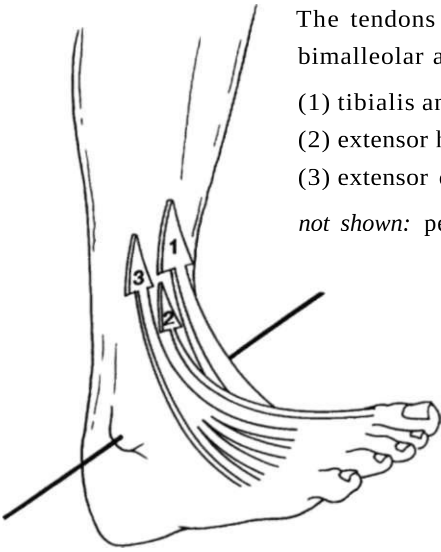
To stretch the gastrocnemius, we must add extension of the knee.



.. .the gastrocnemius and hamstrings combine their forces to become *extensors* of the knee, i.e., returning it to anatomical position.

When the foot is not bearing the body's weight, these muscles act as *flexors* of the knee.

Actions of extrinsic foot muscles on the ankle



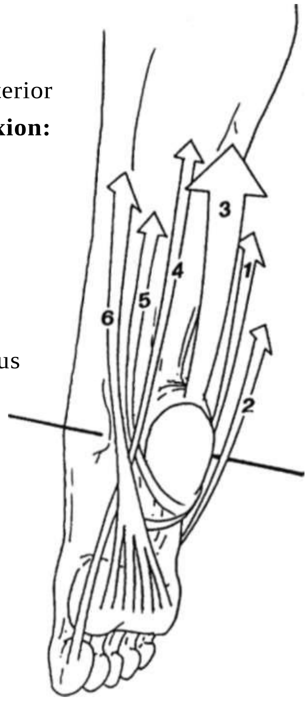
The tendons passing anterior to the bimalleolar axis perform **dorsiflexion:**

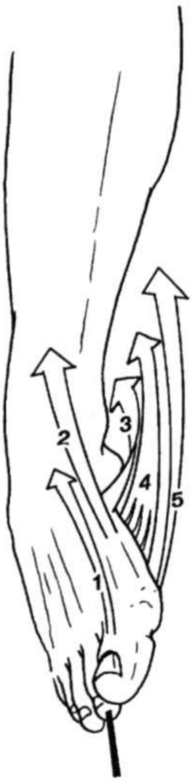
(1) tibialis anterior
(2) extensor hallucis longus
(3) extensor digitorum longus

not shown: peroneus tertius

The tendons passing posterior to it perform **plantar flexion:**

(1) peroneus longus
(2) peroneus brevis
(3) triceps surae
(4) flexor hallucis longus
(5) tibialis posterior
(6) flexor digitorum longus





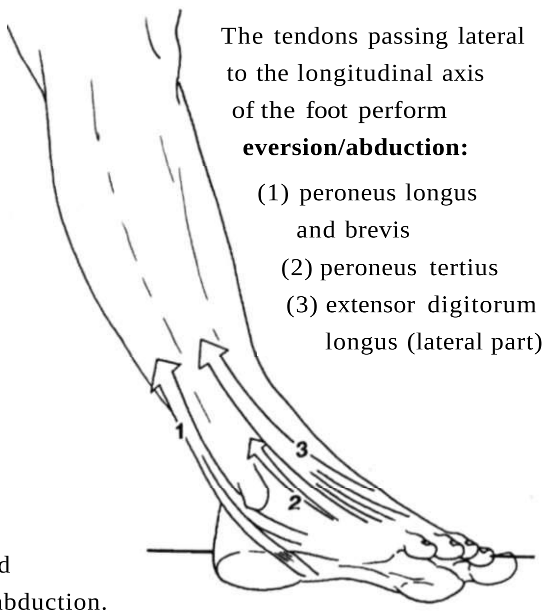
The tendons passing medial to the longitudinal axis of the foot (axis through 2nd toe) perform **inversion/adduction:**

(1) extensor hallucis longus
(2) tibialis anterior
(3) tibialis posterior
(4) flexor digitorum longus
(5) flexor hallucis longus

We could add triceps surae, whose action adds an inversion (see p. 292).

The tendons passing lateral to the longitudinal axis of the foot perform **eversion/abduction:**

(1) peroneus longus and brevis
(2) peroneus tertius
(3) extensor digitorum longus (lateral part)



Notice that opposing actions are not "balanced." Plantar flexion is dominant over dorsiflexion, and inversion/adduction is dominant over eversion/abduction.

Stability of ankle joint

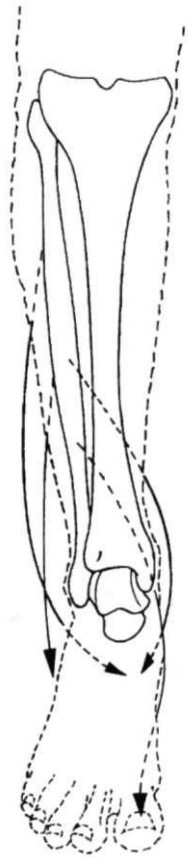
As explained on page 264, the talus fits more snugly into the "pincer" (formed by the distal tibia and fibula) during dorsiflexion than plantar flexion.

plantar flexion

dorsiflexion

To compensate for the loss of stability during plantar flexion, the shape of the "pincer" is modified by four muscles which tend to pull down the fibula:

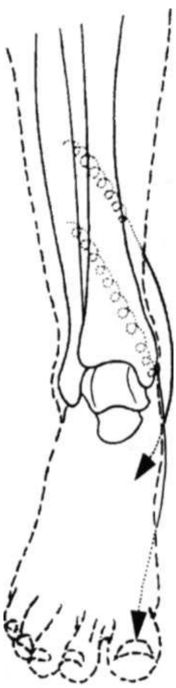
- peroneus longus
- peroneus brevis
- flexor hallucis longus
- tibialis posterior.



malleolus raised

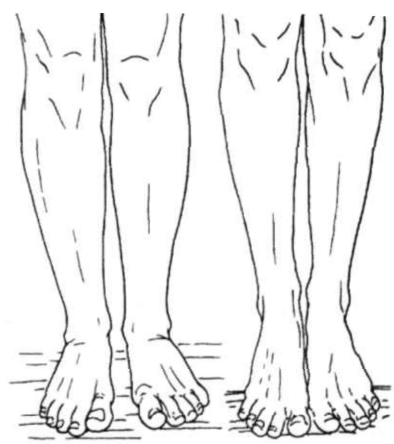
malleolus lowered

The fit of the pincer on the plantar-flexed talus is improved when the lateral malleolus is lowered.



A related factor is the "tightening" of the two sides of the "pincer," produced in part by flexor hallucis longus and tibialis posterior.

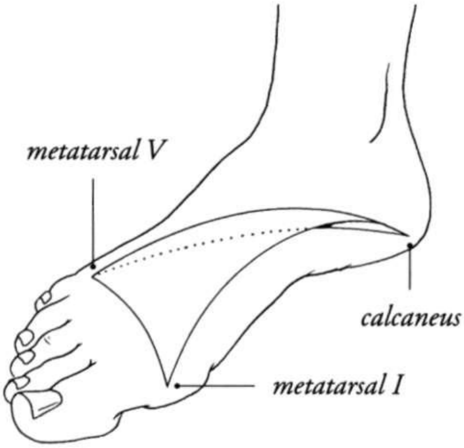
Also, when the fibula is lowered, the distal tibiofibular ligaments come under tension, which automatically tightens the "pincer."



These effects on the "pincer by muscles and ligaments stabilize the ankle during plantar flexion, e.g., standing on tiptoe.

Arches of the foot

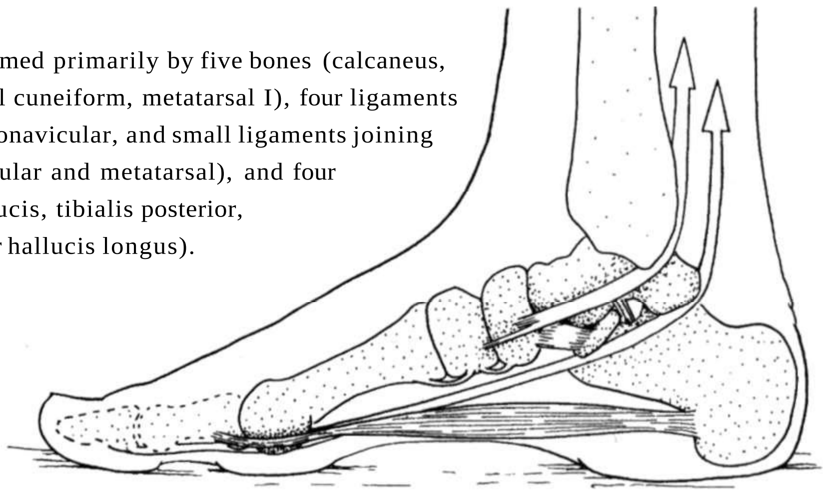
The foot has three arches (which could also be called "trusses"*). They rest on three points of support. The arches therefore constitute a flexible slat, which serves as a shock absorber and adapts the foot's shape to the ground.



When standing, the weight of the body is essentially distributed among three points:

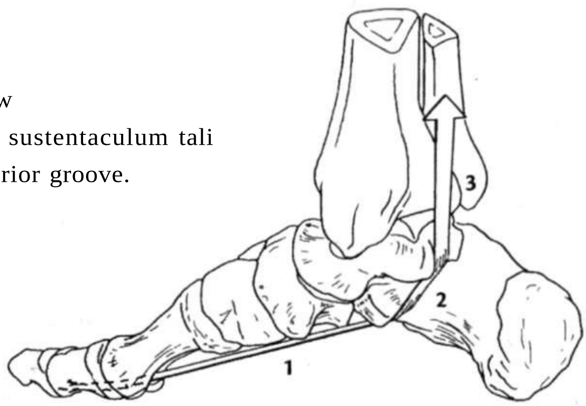
- The posteroinferior tuberosity of calcaneus receives most of the weight.
- The secondary weight-bearing point is the head of metatarsal I, a relatively massive bone.
- The third point, the head of metatarsal V, supports the least weight.

The **medial arch** is formed primarily by five bones (calcaneus, talus, navicular, medial cuneiform, metatarsal I), four ligaments (talocalcaneal, calcaneonavicular, and small ligaments joining the cuneiform to navicular and metatarsal), and four muscles (abductor hallucis, tibialis posterior, peroneus longus, flexor hallucis longus).

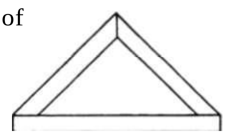


Flexor hallucis longus has three functions with respect to the medial arch:

1. stretches the arch like the string of a bow
2. supports calcaneus by passing under the sustentaculum tali
3. supports talus by passing along its posterior groove.



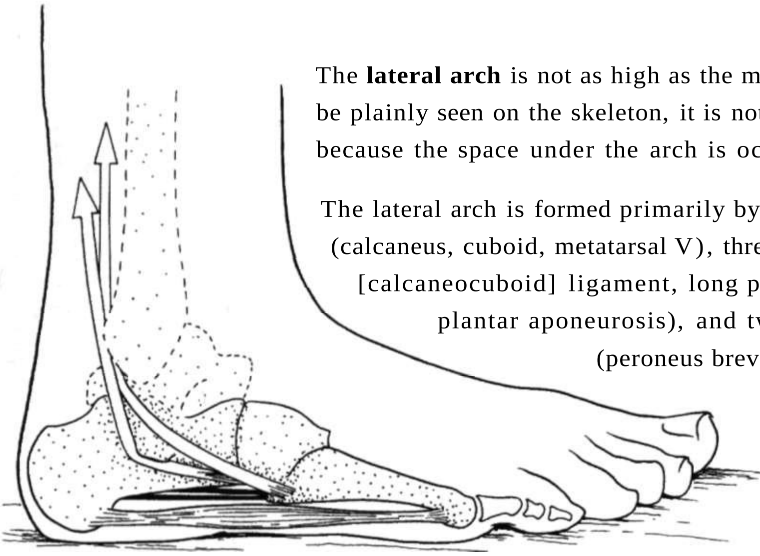
* In architecture, a supporting structure in the shape of a triangle (a truss) has the following stress distribution:

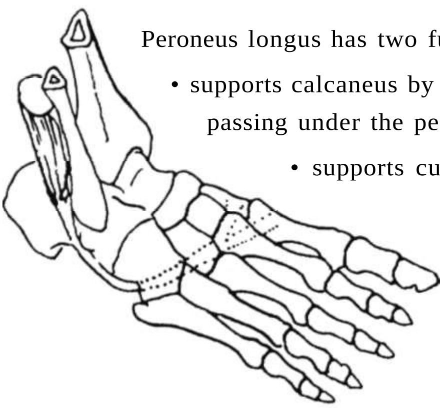


The weight on the top part causes compression stress (on the top) and stretching stress (on the bottom). Due to the relative elasticity of the lower part, a very heavy weight can be supported.

The **lateral arch** is not as high as the medial one. Although it can be plainly seen on the skeleton, it is not obvious on the whole foot because the space under the arch is occupied by muscles.

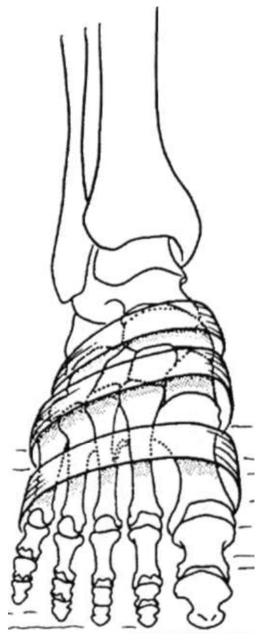
The lateral arch is formed primarily by three bones (calcaneus, cuboid, metatarsal V), three ligaments (short plantar [calcaneocuboid] ligament, long plantar ligament, plantar aponeurosis), and two muscles (peroneus brevis, peroneus longus).





Peroneus longus has two functions here:

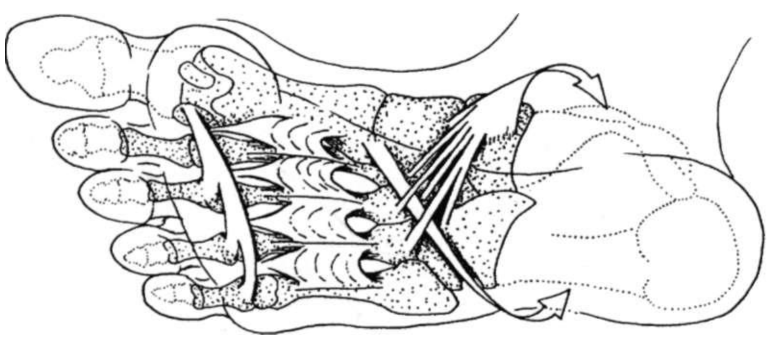
- supports calcaneus by passing under the peroneal tubercle
- supports cuboid.



The **transverse arch** is most visible around the middle of the metatarsals. It is represented in this drawing as straps.

As you would expect, it is higher on the medial (navicular) side than the lateral (cuboid) side.

Its muscular support comes primarily from adductor hallucis (transverse head), peroneus longus, tibialis posterior, and the interossei.



Muscle actions of ankle and foot during walking

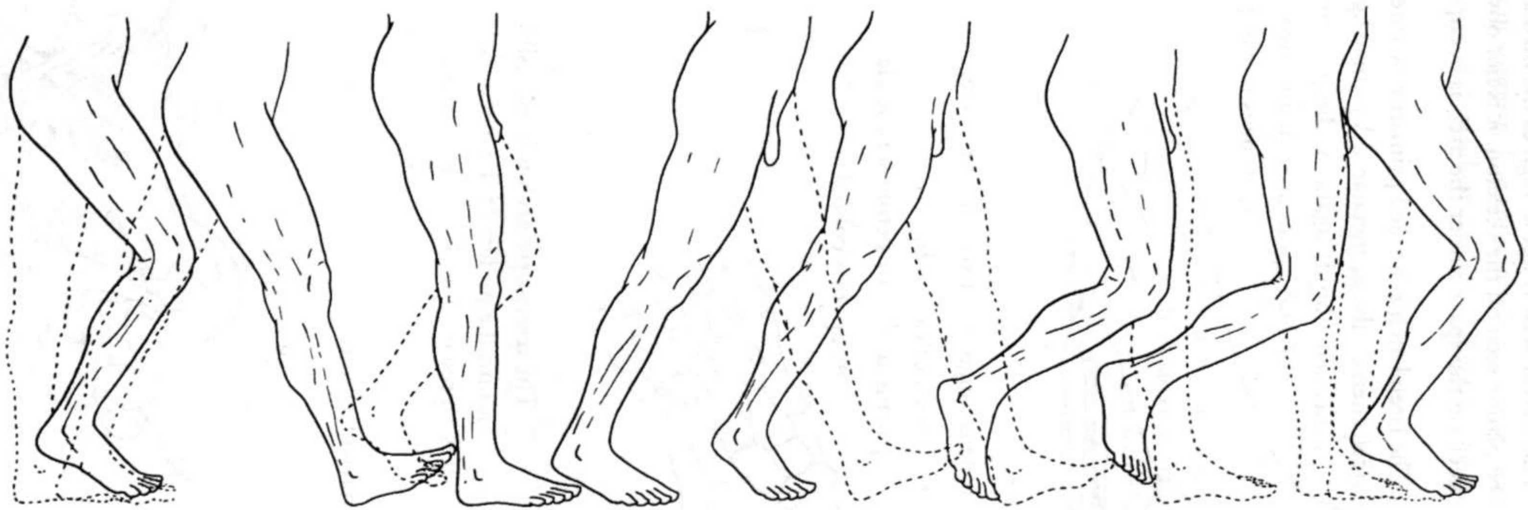
foot hits the ground heel-first, then rolls forward

body's weight on foot, foot in full contact with ground

heel leaves ground; propulsion by distal foot

toes leave ground (big toe last)

entire foot is off the ground; foot moves rapidly forward



contraction of dorsiflexors during rolling movement

contraction of muscles supporting the three arches

contraction of triceps surae and other plantar flexors; contraction of intrinsic plantar muscles

contraction of flexor digitorum longus, then flexor hallucis longus

brief moment of muscular relaxation while foot is off ground; contraction of dorsiflexors to prevent toes from touching ground during forward movement of foot

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