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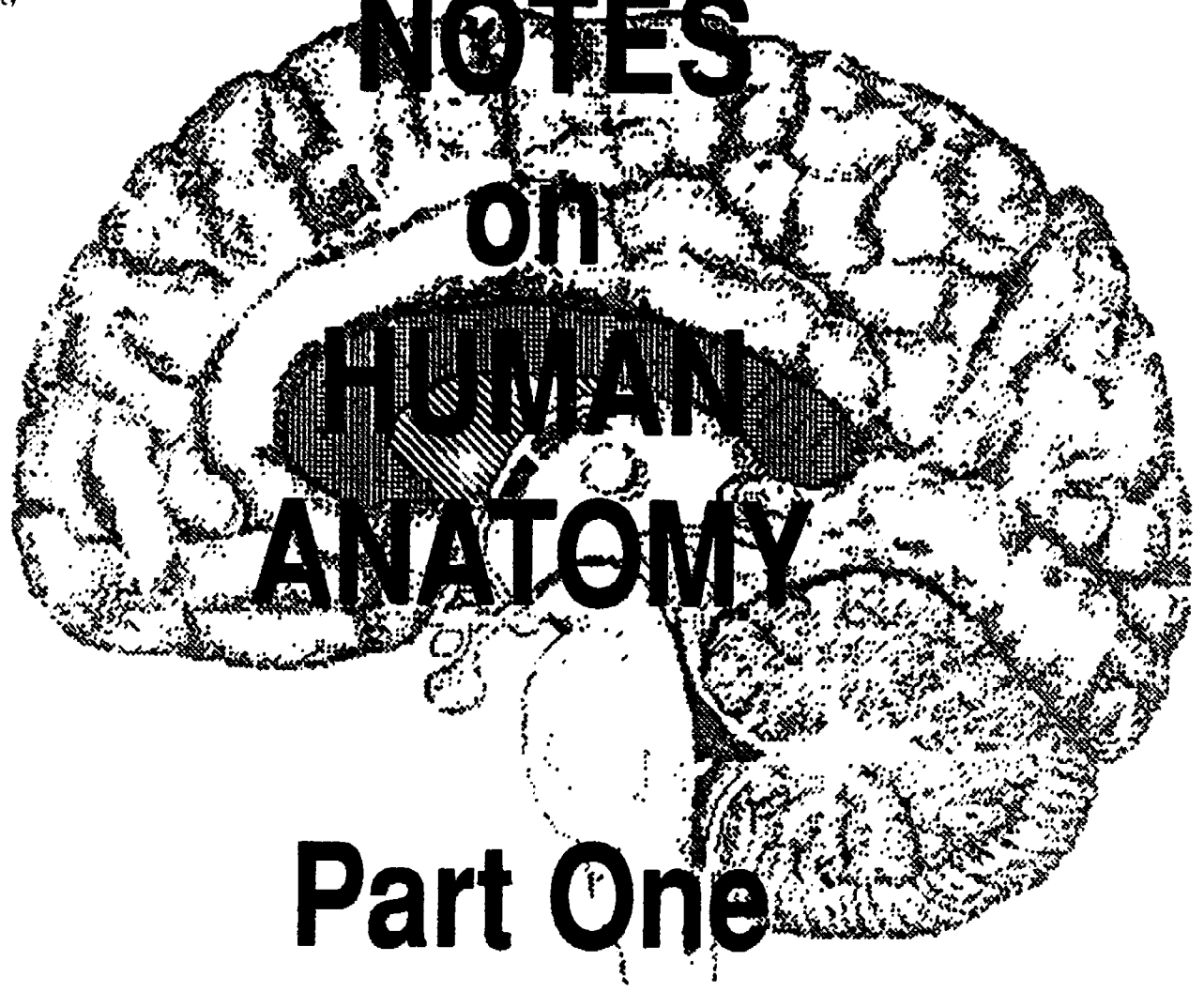
ABSTRACT

During the process of studying the specific course content of human anatomy, students are being educated to expand their vocabulary, deal successfully with complex tasks, and use a specific way of thinking. This is the first volume in a set of notes which are designed to accompany a lecture series in human anatomy. This volume includes discussions of anatomical planes and positions, body cavities, and architecture; studies of the skeleton including bones and joints; studies of the musculature of the body; and studies of the nervous system including the central, autonomic, motor and sensory systems. (CW)

LECTURE NOTES on HUMAN ANATOMY



Part One

Fourth Edition

by KATHLEEN CONREY

LECTURE NOTES on HUMAN ANATOMY

Part One

Fourth Edition

The author is a Professor of Natural Sciences at El Camino College. She holds a master's degree from the Department of Human Anatomy, University of California, San Francisco, and has been teaching human anatomy at the community college level since 1967.

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PREFACE

I have written this book to make your job as a student easier. I am writing this preface in hopes that I can help you to get beyond the goal oriented view of education (memorizing specific course content) to that of a larger view, i.e. an awareness of what the education process is and how it works.

Perhaps the most important objective of a college education is to produce graduates with trained minds.

*Perhaps the most important objective of a college education is to produce graduates with trained minds. The **process of acquiring a trained mind** is a process that operates on several different levels simultaneously. On the most obvious level, the student is exposed to a body of subject material and is expected to memorize it and to answer questions about it on examinations. For example, in anatomy you will learn the names, locations, and identifying features of all of the bones of the body, and you will be expected to identify them and answer questions about their features on examinations.*

The act of thinking requires language.

This part of the process is specifically content oriented and is usually the only process that most people are aware of when they think about a course in anatomy. It is my belief however, that there are several less obvious things happening during the content oriented learning process described above.

Learning the anatomy of the human body is a huge and seemingly impossible task.

These secondary levels to the process may be just as important or perhaps even more important than mastery of the actual course content; it may be useful to think of these secondary processes as the "hidden agenda" of a college education. They are hidden, not because they are meant to be kept secret, but because they are rarely articulated. It is my view that the student will be better able to keep his or her balance in the course and will be better able to gain satisfaction from the learning process if this "hidden agenda" is brought out into the open, demystified, and dealt with on a conscious level.

*One of the things that happens simultaneously with the study of specific course content, is that a student's **vocabulary** grows. This is an important part of the process of acquiring a trained mind, because the act of thinking requires language; ideas cannot be expressed without the accurate use of words. Acquisition of a larger vocabulary is especially important in any specialized subject area such as law or medicine. Since anatomy is a foundation course for all medically related studies, this course of study places a lot of emphasis on words and word roots.*

*Another part of the hidden agenda of studying specific course content is the expectation that by doing so a person will acquire **personal organizational skills**. This is a process that involves learning how to break a large and complex task down into smaller parts that are more manageable.*

For example, learning the anatomy of the human body is a huge and seemingly impos-

sible task. We begin by breaking the course down into six units: skeletal system, muscular system, nervous system, histology, and internal viscera (two units), allowing approximately two weeks of time per unit. Next we will focus on each in turn, beginning by breaking that unit down into smaller sections, breaking the sections down into subsections, and so on.

Break the task down to what you can do a day at a time.

Thus far you will be guided by the organization of this book and the design of the class schedule, but at some point you will need to develop a personal way of breaking the task down to what you can do a day at a time. The key word in this idea is the word personal. There is no right or wrong way to develop these management skills, the process will differ for each one of you; you will find your own unique methods. So, whenever you react to college in general and to this course in particular with the feeling that "it is impossible, there is too much information", or "how can I do it?". try to make the shift to "How can I do it?", and your answers will come, a day at a time.

It is believed that the discipline of using this particular set of skills has much to do with acquiring the ability to learn and think.

Finally, the most important part of the hidden agenda of a college education in the Western tradition is to produce graduates who have acquired a specific set of ***critical thinking skills*** *that are highly valued by Western culture. It is believed that the discipline of using this particular set of skills has much to do with acquiring the ability to learn and think rather than just memorizing information. Here is a list of these skills, starting with the most simple tool and ending with the most complex :*

1. ***define*** *(or name or identify)*
2. ***illustrate*** *(give examples or use an analogy, or visualize, or draw)*
3. ***classify*** *(organize into set and subset)*
4. ***sequence*** *properly*
5. ***compare/contrast*** *(similarities/differences)*
6. *be clear about* ***cause*** *vs* ***effect***
7. ***analyze*** *parts and functions*

Brief examples of how the above thinking skills are used in this anatomy course follow:

1. *You will be given a precise* ***definition*** *of the term "sagittal", and you will be taught how to* ***identify*** *the lunate bone of the wrist.*
2. *During lecture your instructor will give you an* ***example*** *of a muscle that has a reversible origin and insertion*
3. *The lecture on joints will be structured around the various ways in which joints are* ***classified.***
4. *The chapter in this book which describes endochondral ossification will list the steps of the process in their correct* ***sequence.***
5. *When you are studying the autonomic nervous system you will construct a chart that* ***compares*** *the sympathetic vs the parasympathetic nervous systems.*
6. *During the lecture on the pancreas you will learn to distinguish between the* ***cause*** *of diabetes and the* ***effect*** *of diabetes.*
7. *When you study the central nervous system you will* ***analyze*** *the parts of the*

CNS in terms of their embryological origin.

Your reading, listening, note taking and study efficiency will be greatly improved in any subject if you will watch for the use of these thinking skills, since recognition will immediately signal to you what information is important vs unimportant in terms of course content. You will begin to notice that all textbooks and all lectures are organized around these principles.

Furthermore, since all examination questions are also based on this specific approach to organized thinking, you can most efficiently prepare yourself for examinations by drilling yourself on information that has been first organized in these specific ways. By doing so you will discover that you have a very powerful key to academic success.

And finally, even more power will come when you begin to use these skills yourself to organize a body of information that you are thinking about or wrestling with.

In summary, keep in mind that during the process of studying specific course content in human anatomy, you are simultaneously acquiring a trained mind by the processes of expanding your vocabulary, learning to deal successfully with large and complex tasks, and then finally by learning a specific way of thinking that will liberate you from blind memorization and regurgitation.

INTRODUCTION TO ANATOMY

• In the study of anatomy it is frequently necessary to use adjectives referring to anatomical position and location, including terms for directions and planes. All of these adjectives refer to an individual or an animal which is posed in the *standard anatomical position.*

ANATOMICAL POSITION

• In bipedal animals the standard anatomical position is defined as being: in the erect stance with the arms hanging vertically by the sides, and with the face, toes, and palms forward. **See Fig. 1.**

• In quadrupeds the standard anatomical position is arbitrarily defined as being: all four feet on the ground with the head up and facing forward. **See Fig. 2.**

ANATOMICAL LOCATIONS

superior = above
inferior = below

anterior = in front
posterior = in back

proximal = nearest the center or point of attachment
distal = farthest from the center or point of attachment

medial = midline or nearer the middle
lateral = to the side

ventral = belly side or surface
dorsal = back side or surface

cephalic (cranial) = head area
caudal = tail area

ANATOMICAL PLANES

Anatomical planes are like imaginary panes of glass slicing through the body in a precisely defined three dimensional direction.

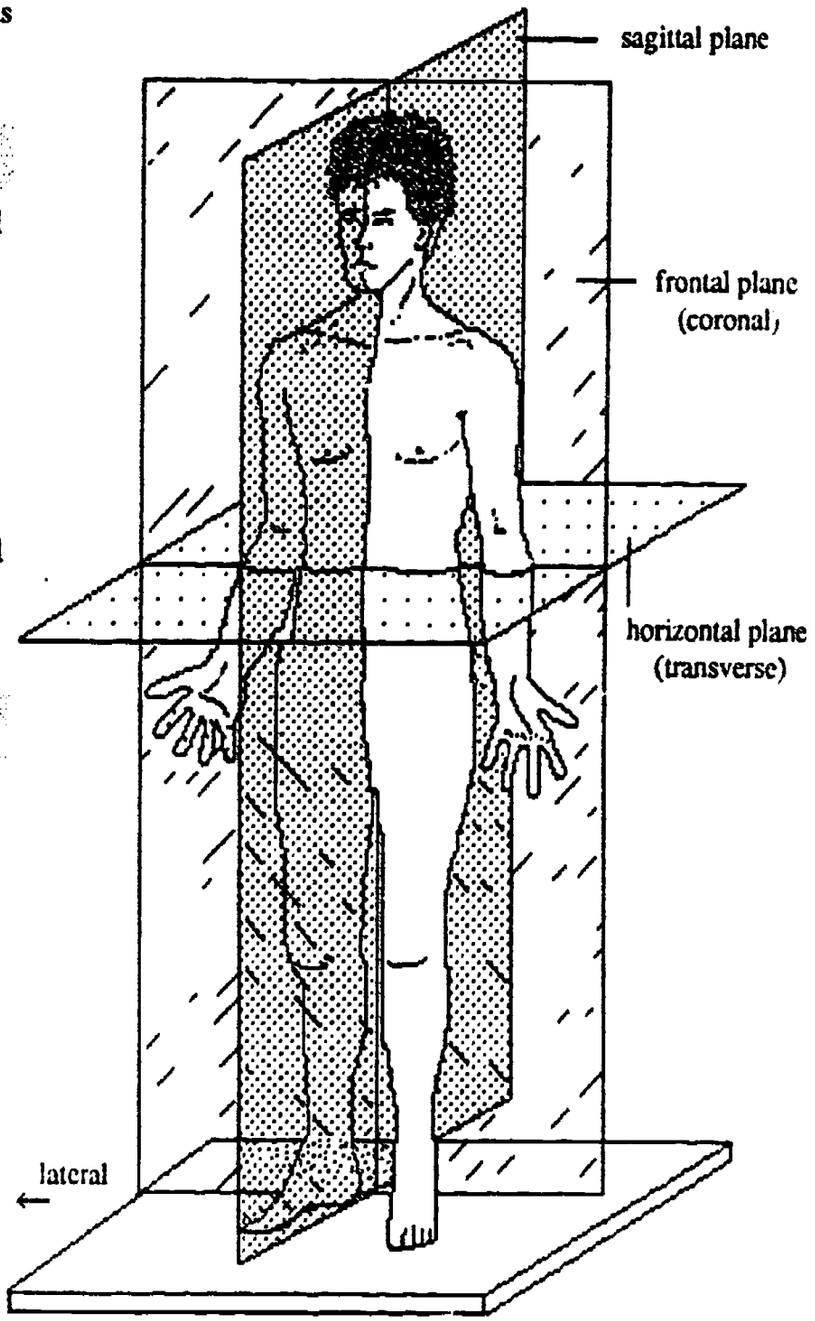


Fig. 1 - Biped in Anatomical Position

The definitions are as follows:
sagittal - a vertical plane through the long axis that divides the body into right and left (but not necessarily equal halves).

frontal - a plane parallel with the long axis and at right angles to the sagittal; it separates ventral from dorsal.

horizontal - a plane which is parallel to the horizon.

coronal - a plane that separates anterior from posterior.

transverse - a plane that cuts through the body at right angles to the long axis. A transverse cut through a body or body part is also called a cross section (abbreviated x.s.).

longitudinal - any plane or cut parallel to the long axis. It could be a sagittal section or a frontal section, or anything in between. A longitudinal section is often abbreviated "l.s.".

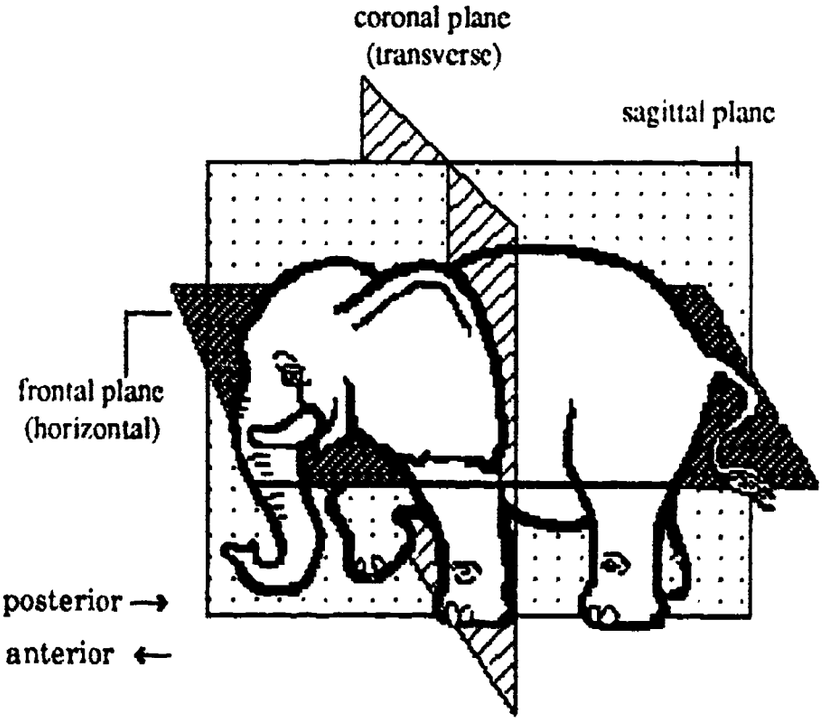


Fig. 2- Quadruped in Anatomical Position

• Study **Figures 1 and 2** and notice that for bipeds the frontal plane is also a coronal plane, while for quadru-peds the frontal plane is synonymous with the horizontal plane.

• Likewise notice that for bipeds the transverse plane is also horizontal, while for quadrupeds the transverse plane is synonymous with the coronal plane.

TORSO REGIONS

Study **Figure 3** and notice the following regions of the torso:

umbilical
epigastric
hypogastric
lumbar
inguinal (iliac)
hypochondriac

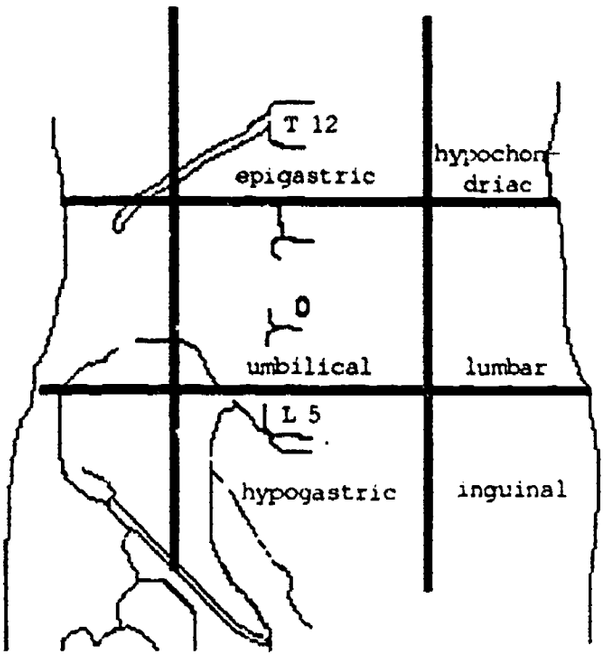


Fig. 3- Regions of the Torso

BODY CAVITIES

Study **Figure 4** and notice the following cavities:

thoracic (chest)
abdominal
pelvic
cranial
spinal (vertebral)
buccal (mouth)
nasal

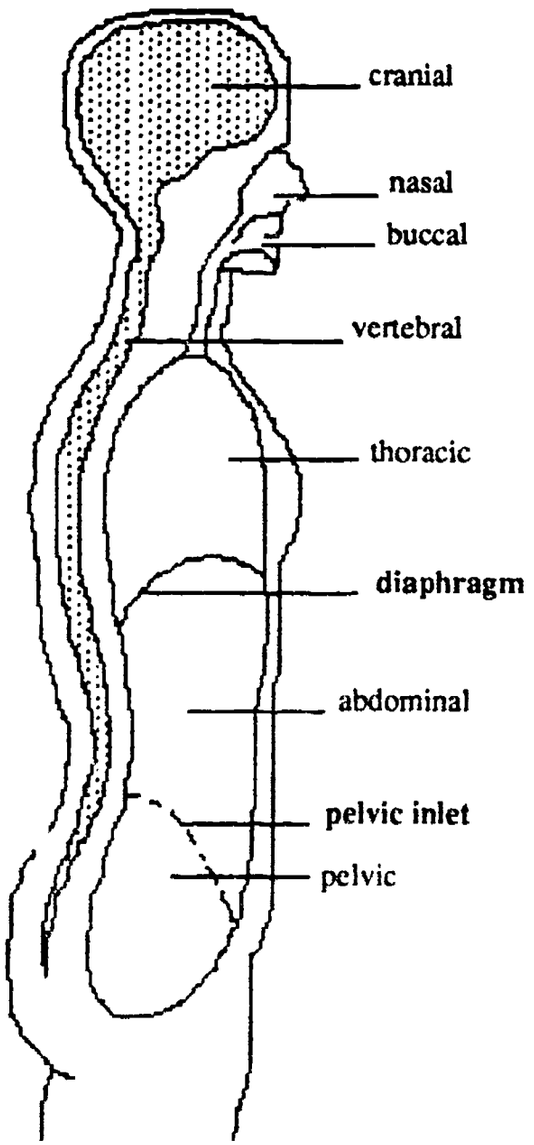


Fig. 4- Body Cavities

MISCELLANEOUS TERMS

viscera - the organs of a cavity
parietes - the walls of a cavity

peritoneum - the membrane lining the abdominal and pelvic cavities and reflected over the viscera of those cavities. Because the membrane is reflected, the peritoneum hasboth a **parietal portion** and a **visceral portion.**

pleura - the membrane lining the thoracic cavity and reflected over the surface of the lungs. Thus there is both a **parietal pleura** and a **visceral pleura.**

BODY ARCHITECTURE:

cells - the building blocks of the body.

tissues - groups of cells with similar functions. The four basic tissues are: epithelial, connective, muscle and nerve.

organs - architectural arrangements of tissues functioning together for a common purpose. Most organs are made of all four tissues, but the tissues are arranged in recognizably different patterns and in different proportions in the various organs.

systems- The organs are grouped together into functional units called systems, such as the digestive system, the endocrine system, the reproductive systems, the cardiovascular system, etc.

BONE TERMINOLOGY

EPIPHYSIS:
end area of a long bone

DIAPHYSIS:
center shaft of a long bone

CANCELLOUS BONE:
spongy bone; having a latticework architecture

COMPACT BONE:
solid layers of dense ivory like bone

SPICULES:
a needle like fragment (in cancellous bone)

MEDULLARY CAVITY:
hollow area of the diaphysis

YELLOW MARROW:
mostly fat; fills the medullary cavity in adult bones

RED MARROW:
hemopoietic tissue. In the adult it is found in the proximal epiphysis of the femur and humerus, and in the cancellous interior of short bones, vertebral bodies, and flat bones such as the sternum and cranial vault.

HEMOPOIETIC TISSUE:
blood forming tissue (forms red blood cells, platelets, and certain kinds of white blood cells)

OSTEOID TISSUE:
protein component of bone tissue (nonmineralized)

PERIOSTEUM:
connective tissue membrane covering bones (except in the areas occupied by articular cartilage); well vascularized; contains osteoblasts and blood vessels. Some of the connective tissue fibers (Sharpey's fibers) penetrate into the bone; Some of the blood vessels from the periosteum penetrate the bone by way of nutrient foramena and Volkman's canals.

PERICHONDRIUM:
connective tissue membrane covering cartilage; otherwise similar to periosteum

OSTEOBLAST:
bone forming cell

OSTEOCYTE:
resting bone cell

OSTEOCLAST:
bone removing cell

CHONDROBLAST:
cartilage forming cell

CHONDROCYTE:
resting or mature cartilage cell

EPIPHYSEAL PLATE:
The zone of cartilage between the epiphysis and the diaphysis in a growing bone long bone

INTRAMEMBRANOUS OSSIFICATION:
bone formation from a *membrane* model (precursor).

ENDOCHONDRAL OSSIFICATION:
bone formation from a *cartilage* model or precursor.

Ossification

SPECIAL TERMS

HYPERTROPHIC ZONE :
an area of cartilage in which the cells are enlarged, swollen and lined up in rows or stacks. Caused by poor nutrient diffusion due to calcification of the matrix as well as other factors.

LYSIS:
swelling and bursting of cells. Can be due to any number of causes. The area so affected is full of cellular debris and is said to be necrotic.

PERIOSTEAL BUD:
In endochondral ossification: an invasive embryonic blood vessel which originates in the periosteum and penetrates into the cartilage precursor. As it enters it drags osteoblasts with it into the interior of the cartilage.

GROWTH HORMONE:
produced in the anterior pituitary gland; stimulates growth of cartilage, bone, and a few other tissues as well.

PITUITARY DWARFISM:
Insufficient growth hormone during childhood, resulting chiefly in small stature.

GIANTISM:
Excess growth hormone before closure of the epiphyses resulting in abnormal height.

ACROMEGALY:
Excess growth hormone after closure of the epiphyses, caused by tumor of the pituitary , and resulting in overgrowth of the flat bones and bones of the hands and feet, as well as overgrowth of the skin.

INTRAMEMBRANOUS OSSIFICATION

Flat bones like the bones of the skull are formed by intramembranous ossification. These bones are first represented by little pieces of a tough fibrous connective tissue membrane which are rough patterns for the bone-to-be. Since these membranes are well vascularized and thin, osteoblast activity starts in the center of the membrane and layers of compact bone are formed.

Ossification is not complete at birth. The membranes still grow , the fontanels stay open until approximately 18 months of age, and the sutures do not close completely until approximately 8 years of age. . By this age also the bone has been remodeled by osteoclast activity in the center of the diploe activity to make it light but still structurally strong (cancellous or spongy bone), and to make more room for the marrow.

ENDOCHONDRAL OSSIFICATION

Endochondral ossification begins with a cartilage model of the future bone, This is the method of ossification used for all of the bones except the flat bones; the long bones of the body serve as a good example

BACKGROUND INFORMATION:

Development of bone from a cartilage precursor is a dynamic process. To understand the process, one must first understand that cartilage is **avascular**, i. e. it does not contain blood vessels. In fact healthy cartilage contains a chemical which acts as an active **inhibitor** of blood vessel growth. As a result cartilage cells must obtain their

nutrients by **diffusion** from the blood vessels located in the perichondrium. (Perichondrium is the term for the connective tissue membrane surrounding a piece of cartilage). In contrast to this, bone is highly vascularized, and bone growth will not occur unless there is a rich blood supply.

Secondly, one must understand that there are **osteoblasts** in the perichondrium. Thus a **collar of bone** will begin to be deposited under the perichondrium around the outside of the cartilage model , and the surrounding membrane could then just as well be called a periosteum. You will find that writers will use the terms perichondrium and periosteum loosely and interchangeably in this situation.

Third, healthy cartilage is a growing tissue. Thus, cartilage models of future bones will tend to grow larger in size over time, both in length and diameter.

THE OSSIFICATION PROCESS

Turning now to a description of the sequence of events in endochondral ossification, and the causes of these events.

As the cartilage model enlarges diffusion of nutrients to the cells in the center of the cartilage model is compromised due to three factors:

a. the nutrient **supply line** gets too long, i. e. the distance between the cells in the center of the cartilage and their source of nutrients (blood vessels in the perichondrium) becomes so great that diffusion to the the central cells is too slow.

b. the **collar of bone** deposited around the cartilage model slows diffusion and puts the cells in the center of the cartilage at the greatest risk of not getting sufficient nutrients.

c. Old cartilage tends to calcify and calcification slows diffusion.

All three of these events cause the interior cartilage cells to be **deprived of nutrients.** The distressed cells **hypertrophy** and then **lyse.** The interior of the cartilage model thus becomes **necrotic** and is no longer capable of producing the inhibitor chemical which keeps blood vessels out of the cartilage.

As a result a blood vessel from the perichondrium invades into the necrotic center of the cartilage model. The blood vessel is called a **periosteal bud. It drags osteoblasts** from the perichondrium in with it, and the osteoblasts settle down on the bits of calcified debris and start depositing **osteoid tissue.** Osteoid tissue is a protein material that is not yet mineralized. It is deposited in the form of spicules, that is, small spines or needles of bone that interlace with one another in the typical pattern seen in spongy or cancellous bone.

The area of the future bone where all this activity is taking place is the center portion of the shaft or diaphysis. Thus this area is called the **diaphyseal center of ossification.** The same identical sequence of steps will later take place first in one epiphysis, and then again, in the second epiphysis (**epiphyseal centers of ossification**).

Bone deposition spreads outward in all directions from each center of ossification, replacing cartilage as it goes. In time there will remain only a narrow band of cartilage between the diaphysis and the epiphysis. This band of cartilage is called the **epiphyseal plate** of cartilage.

Each long bone will have an epiphyseal plate of cartilage on each end. Since the cartilage in the plates is healthy and growing, the width of the epiphyseal plate is increasing. However, at the same time, bone deposition is encroaching from both sides

(from the diaphyseal side and from the epiphyseal side), thus, the observable result is that the epiphyseal plate tends to become narrower and narrower over time. It is as though there were a race between bone growth and cartilage growth, and the bone growth is winning over the long haul.

Ossification proceeds slowly over a 20-25 year period until all precursor cartilage is replaced by bone. Eventually the epiphyseal plate of cartilage is completely obliterated; this is called **closure of the epiphyses**, and growth of that bone stops. In other words, lengthwise growth of a bone is accomplished by expansion of the epiphyseal plates, and when the epiphyses close there can no longer be expansion.

As the bone is growing it is simultaneously being remodeled. A medullary cavity is hollowed out of the interior of the diaphysis, and the orientation of the bone changes when the stresses on the bone change. The cells which do the remodeling are the osteoclasts.

Bone growth is affected by many different **hormones**. Among these is an anterior pituitary hormone known as growth hormone (GH). Too much growth hormone before closure of the epiphyses will cause **giantism**. Not enough growth hormone will cause **dwarfism**. Too much GH after closure of the epiphyses will cause **acromegaly** , in which the individual does not grow any taller, but does show continued skeletal growth in certain of the short bones of the hands and feet, and in the flat bones of the sternum and skull and face. Thus in acromegaly the person's features become distorted due to over growth of some but not all aspects of the skeleton.

SUMMARY:

SEQUENCE OF EVENTS:

1. The cartilage precursor expands.

2. Diffusion is compromised in the area of the diaphysis.

3. Interior cells become necrotic.

4. A periosteal bud invades.

5. Bone is deposited in the interior of the diaphysis.

6. These same steps are repeated in each epiphysis.

7. The epiphyseal plates close, and growth stops.

CAUSE/EFFECT:

1. Diffusion: Three factors interfere with diffusion of nutrients to the cartilage precursor:
   a. As the diameter of the model increases the cartilage cells in the center get too far from the source of supply.
   b. The periosteal collar of bone acts as a barrier to diffusion.
   c. Old cartilage matrix calcifies.

2. Necrosis: When cartilage cells are deprived of nourishment they will hypertrophy (swell), arrange themselves in rows, and then lyse (burst apart and die).

3. Periosteal Bud: Dying cartilage cells no longer produce chemical inhibitors to keep blood vessels out, therefore the periosteal bud enters.

4. Interior Ossification: The invading periosteal bud drags with it osteoblasts from the

periosteum, thus ossification can begin in the interior.

5. Epiphyseal Plate: The epiphyseal and diaphyseal centers of ossification expand toward one another. The zone of growing cartilage remaining between them is called the epiphyseal plate.

6. Closure of the epiphyses occurs because the growth rate of cartilage in the epiphyseal plate is slower than the rate at which it is being replaced by bone on both edges. The result is that solid bone eventually replaces the epiphyseal plate of cartilage. and growth stops.

JOINT CLASSIFICATION

CLASSIFICATION BY STRUCTURE

I. Fibrous
II. Cartilagenous
III. Synovial

CLASSIFICATION BY FUNCTION

A. Synarthrosis
B. Amphiarthrosis
C. Diarthrosis

EXAMPLES

I. FIBROUS JOINTS

A. SYNARTHROSES.
sutures of the skull

B. AMPHIARTHROSES.
distal tibio-fibula

C. DIARTHROSES.
interosseous membranes of lower arm & leg

II. CARTILAGENOUS JOINTS

All cartilagenous joints are **Ampharthroses.** They fall into two main subgroups.

SYNCHONDROSIS
epiphyseal plates
costochondral
1st sternochondral

SYMPHYSIS
symphysis pubis;
vertebral bodies

III. SYNOVIAL JOINTS:

All synovial joints are Diarthroses. They fall into several subgroups according to type of movement or shape.

BALL AND SOCKET
hip and shoulder

HINGE
elbow, knee, jaw

GLIDING
• between the articular processes of the vertebrae;
• between carpal bones and tarsal bones;
• sternochondral joints (except for the first one).

PIVOT
atlanto-axial;
proximal radio-ulnar

SADDLE
carpometacarpal (at base of thumb)

CONDYLOID
wrist

PARTS OF A SYNOVIAL JOINT

1. Joint cavity
2. Synovial Membrane
3. Synovial Fluid
4. Articular Cartilage (hyaline type)
5. Joint Capsule (Capsular Ligament)
6. Collateral Ligaments (medial and lateral)

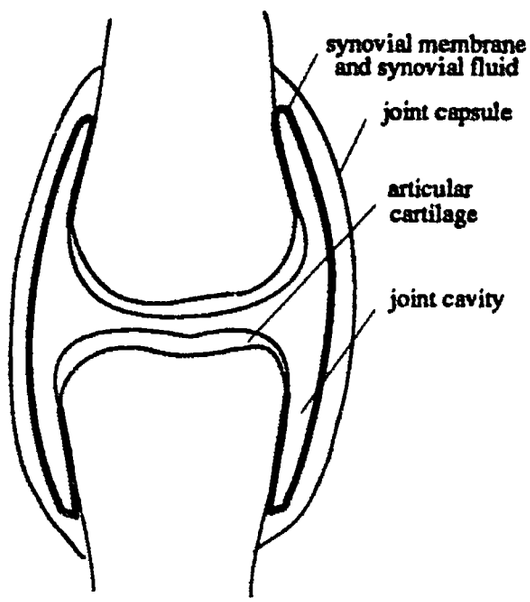


Fig. 5- Parts of a Synovial Joint

JOINT MOVEMENTS

FLEXION:
Flexion decreases the angle between two bones (brings 2 bones closer together).

EXTENSION:
Extension increases the angle between twoi bones (moves 2 bones farther apart).

There are several **special cases of flexion/ extension:**

HAND
Dorsiflexion (true extension)
Palmar flexion (true flexion)

FOOT
Dorsiflexion (true flexion)
Plantar flexion (true extension)

SHOULDER & HIP
The ball and socket joints of the shoulder and hip move so freely that the definitions of flexion and extension need to be broadened. In these locations the definition of flexion is any movement in an anterior direction and extension is any movement in a posterior direction.

ABDUCTION:
Abduction is movement away from the midsagittal axis of the body or the central axis of a part. Examples: abduction of the arm; abduction of the fingers.

ADDUCTION:
Opposite of the above

ROTATION:
Rotation is movement of a body part around an axis or pivot point. Rotation is basically either medial rotation or lateral rotation. There are several **special cases of rotation.**

HAND:
supination
pronation

FOOT
eversion
inversion

CIRCUMDUCTION:
Technically circumduction involves flexion, abduction, extension, and adduction in that sequence, as when the arm describes a cone.

OTHER SYNOVIAL SACS:

BURSAE
A bursa is a closed sac lined with synovial membrane found where soft tissues press on bone during movement. Examples: subdeltoid bursa; olecranon bursa.

TENDON SHEATHES
A tendon sheath is a closed synovial sac lying between a tendon and a bone, protecting the tendon as it moves against the bone, especially when held close to the bone by a connective tissue ***retinaculum***. Example: the hand and the foot each contain many tendon sheaths as well as several retinacula. ***Tendosynivitis*** is a condition in which the tendon sheath is inflamed and tender.

Specific Joint Features

SHOULDER JOINT

• The shoulder joint has little anatomical stability because the ***glenoid fossa*** is so shallow. Thus the shoulder is frequently dislocated. The joint capsule attaches to the rim of the glenoid fossa, and to the anatomical neck of the humerus.

• MUSCULOTENDONOUS CUFF:
The muscles surrounding the shoulder joint give it most of its strength. The tendons of four of these muscles attach to the greater and lesser tubercles of the humerus, forming a cuff around the anatomical head. This cuff group will be emphasized during the unit on muscles.

ELBOW JOINT

There is a common joint cavity for the hinge joint between the ulna and the humerus, and for the pivot joint between the head of the radius and the ulna.

COLLATERAL LIGAMENTS:
The most unusual one is the ***annular*** ligament which embraces the head of the radius and within which the radius rotates freely for pronation and supination. **See Figs. 6, 7, 8.**

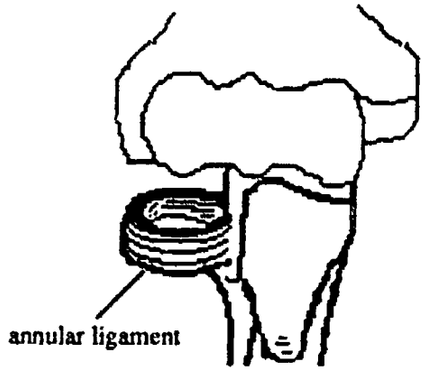


Fig. 6- Right Elbow Joint, Anterior View

Strong medial and lateral collateral ligaments strengthen the hinge joint. These ligaments can also be called the ***ulnar and radial collateral ligaments.***

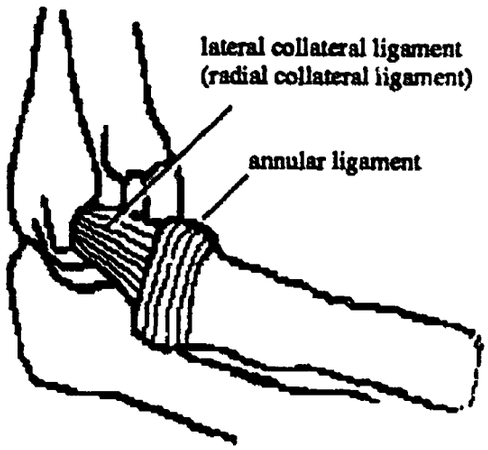


Fig. 7- Right Elbow Joint, Lateral View

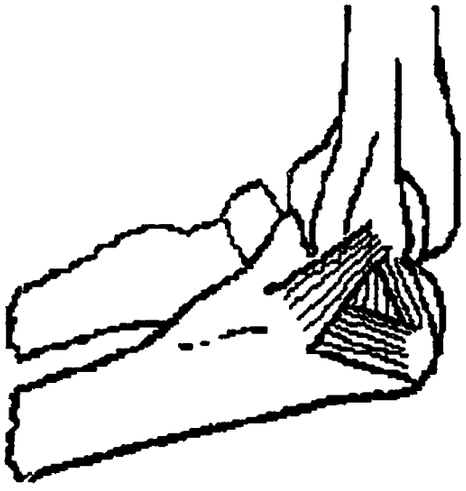


Fig. 8- Right Elbow Joint, MedialView
showing medial collateral ligaments

HIP JOINT

The head and neck of the femur are entirely enclosed in the ***joint capsule.*** Inside the joint is the ***ligamentum teres*** (also called ligamentum capitis) which is attached to the fovea capitis of the head of the femur. The ligamentum teres does not hold the joint

together, in fact it bears no strain at all, rather it provides safe passage for the vessels and nerves supplying the head of the femur. **See Figs. 9. 10.**

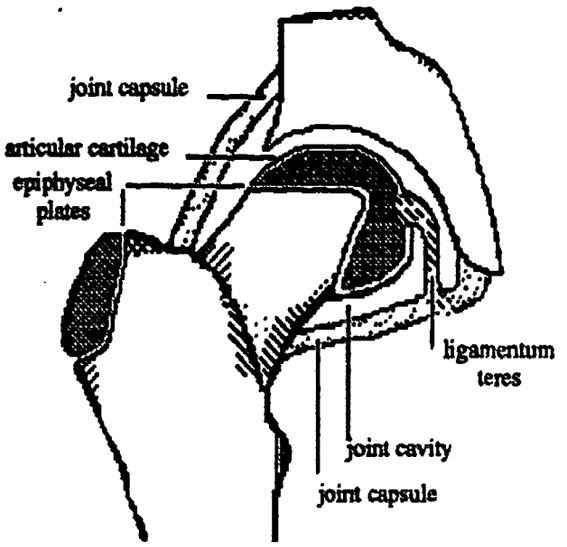


Fig. 9- Right HipJoint, Fontal Section

COLLATERAL LIGAMENTS:

The strongest reinforcement is anteriorly. The ***iliofemoral*** is the most important.

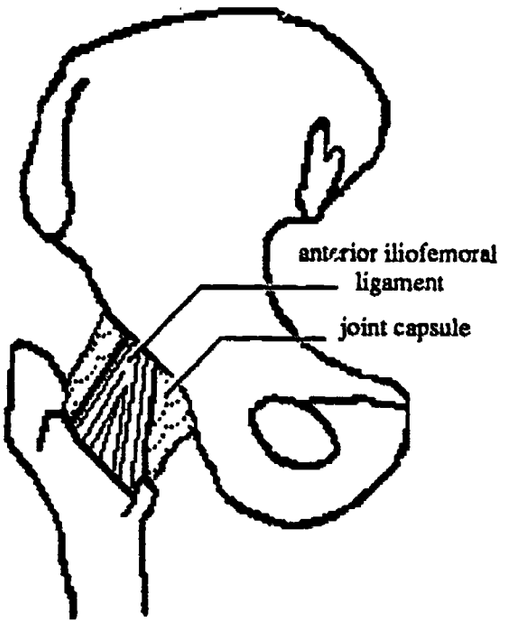


Fig. 10- Right HipJoint, AnteriorView

SACRAL JOINTS

The following ligaments are the most important ones in the sacral region:

Sacroliliac
Sacrospinous
Sacrotuberous

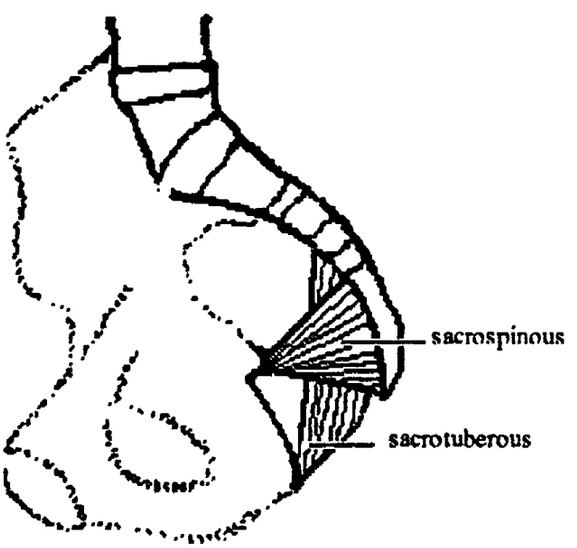


Fig. 11- Sacral Ligaments, Medial View

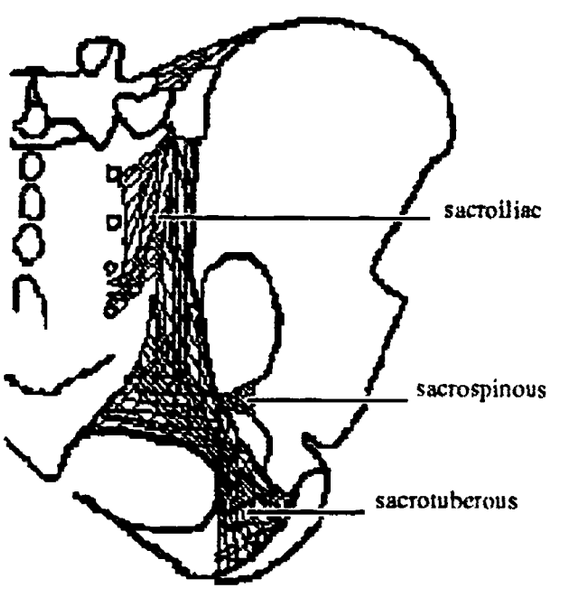


Fig. 12- Sacral Ligaments, Medial View

PATELLO-FEMORAL JOINT

The ***patellar tendon*** or ligament is part of the tendon from the quadriceps femoris muscle of the anterior thigh. The patella changes the angle of pull of this tendon. It is a gliding joint. Notice that there is no articulation between the patella and the tibia.

KNEE JOINT

• One of the most interesting features of the knee joint is that it contains several ***intracapsular*** ligaments, the most important of which are the cruciate ligaments. There is an ***anterior cruciate*** and a ***posterior cruciate***. They connect the condyles of the femur to the opposite condyles of the tibia. There are also several other menisco-femoral ligaments.

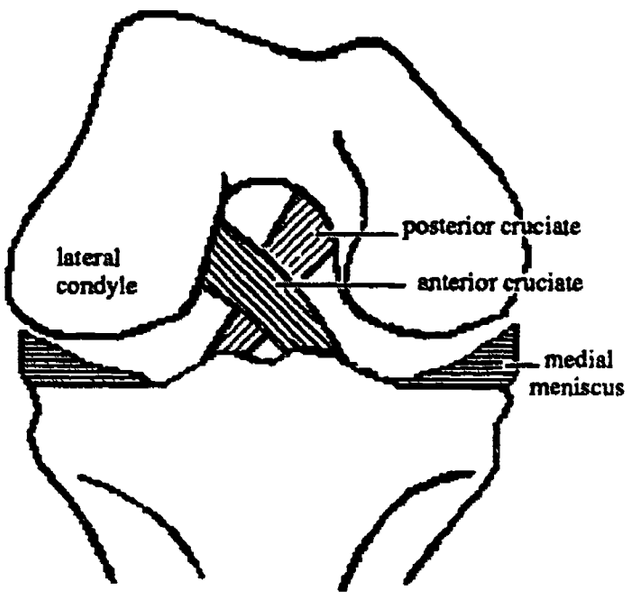


Fig. 13- Right Knee, Anterior View

• The knee joint has great weight bearing capacity and considerable stability It's stablility is largely due to the presence of halfmoon shaped **menisci** (semi..nar cartilages). These cartilages are thicker on their outside edges and much thinner on their medial borders, thus both surfaces are concave.

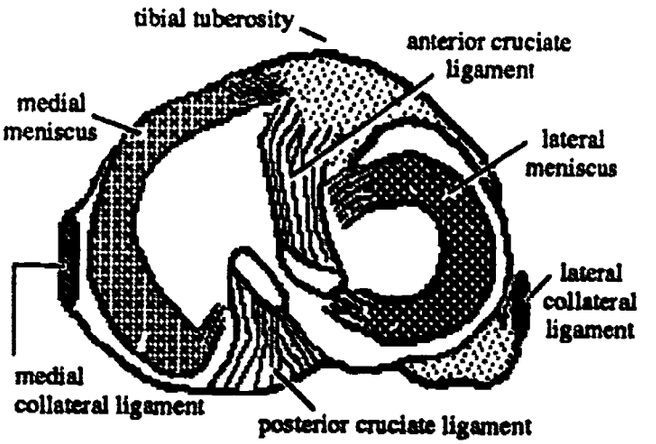


Fig. 14- Right Knee, SuperiorView

• **COLLATERAL LIGAMENTS:**
The medial and lateral collateral ligaments can also be called the ***tibial and fibular collateral ligaments***. They strengthen the joint capsule, but probably the most important source of additional strength and stability are the muscles and fascia of the thigh which extend down to the knee.

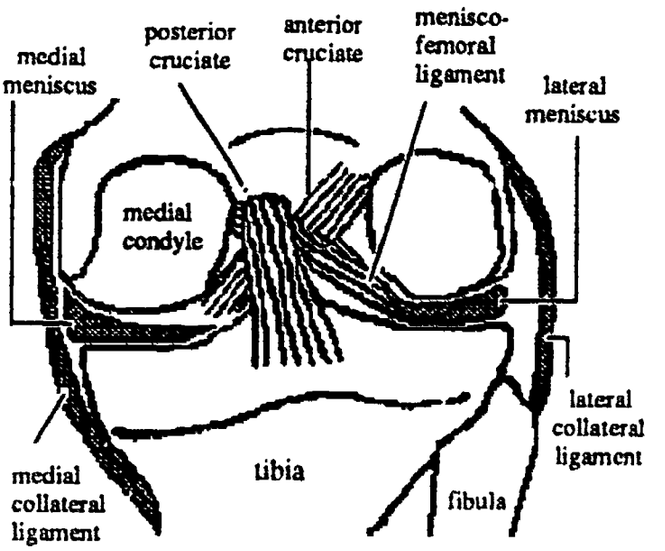


Fig. 15- Right Knee, Posterior View

MOVEMENTS AT THE KNEE:

• Mostly Flexion/Extension. The weight shifts back for flexion and forward for extension.
• There is some medial and lateral rotation. Locking the Knee refers to shifting forward to full extension plus a slight amount of medial rotation. The locked knee provides great stability.

KNEE INJURIES:

In spite of it's stability, the knee is quite prone to injury, especially when in the extended and fully weight bearing position. Damage to a meniscus is common, especially the medial meniscus since it is attached to the tibial collateral ligament, and if the ligament is torn it will often damage the meniscus as well.

• Most injury to the knee is the result of body-contact sports, but it can also happen in running if something causes the runner to turn an ankle (eversion of the foot often results in lateral flexion of the knee, which stresses the medial ligaments and the vulnerable medial meniscus).

• MOST COMMON FRACTURES:

Adduction Fracture
Abduction Fracture
Compression Fracture
Fracture of the Tibial Spine

Gross Anatomy of Muscles

INTRODUCTORY CONCEPTS

The three attributes of a muscle that are usually emphasized in a lecture and in reference books are ***action, origin,*** *and* ***insertion****. Of these three the most important attribute is* ***action****.*

ORIGIN & INSERTION

The **origin** of a muscle is the stationary end. The **insertion** is the end which is most moveable.

As a muscle shortens the insertion is pulled toward the origin, and the **action** is movement at whatever joints the muscle crosses. There are three ways to name the action: by the joint name, by the body part name, or by the name of the bone. **For example:** flexion of the hip = flexion of the thigh = flexion of the femur.

• The origin and insertion are sometimes interchangeable, depending on which end is being held still by other muscles or by gravity. For example, *rectus abdominis* can cause anterior flexion at the waist in different ways, depending on whether you are standing, or hanging by your arms from a bar, or lying on your back and bringing your hips up toward your head.

• A muscle may have two or more origins. This multiple head arrangement gives a muscle more power while still concentrating full force on a single spot. Example: *biceps brachii* or *quadriceps femoris*.

• A muscle may have two or more insertions. This arrangement spreads the action over several joints. Example: extensors and flexors of the digits.

• The origin of a muscle is often attached directly to the periosteum of a bone, without any tendon. The insertion is usually by way of a tendon. However some muscles have tendons on both ends.

• Most tendons are shaped like cords or straps. However some muscles have a thin **aponeurosis,** which is actually a broad flattened sheet-like tendon connecting muscle to muscle or muscle to bone. Examples: *aponeurosis of the external abdominal oblique* and *latissimus dorsi*.

• Tendons connect muscle to bone, whereas ligaments connect bone to bone.

ACTION

• The action of a muscle refers to the kind of movement that a muscle causes at a joint.

• Muscles do work only when they contract or shorten. Stretching is passive and does not do work.

• The **prime mover** is the primary agent causing any given movement.

• A **synergist** is a muscle which helps the prime mover in some way. It may stabilize the origin or it may cause the same action on the same joint as the prime mover.

• An **antagonist** is a muscle whose movement counteracts the action of any given sides of a joint from one another. When the prime mover is contracting the antagonist must relax. prime mover. Antagonists are on opposite sides of a joint from one another. When the prime mover is contracting the antagonist must relax.

Muscles of the Head

*The muscles of the head are divided into two groups based on common characteristics within the group. These two groups are the **muscles of facial expression** and the **muscles of mastication.***

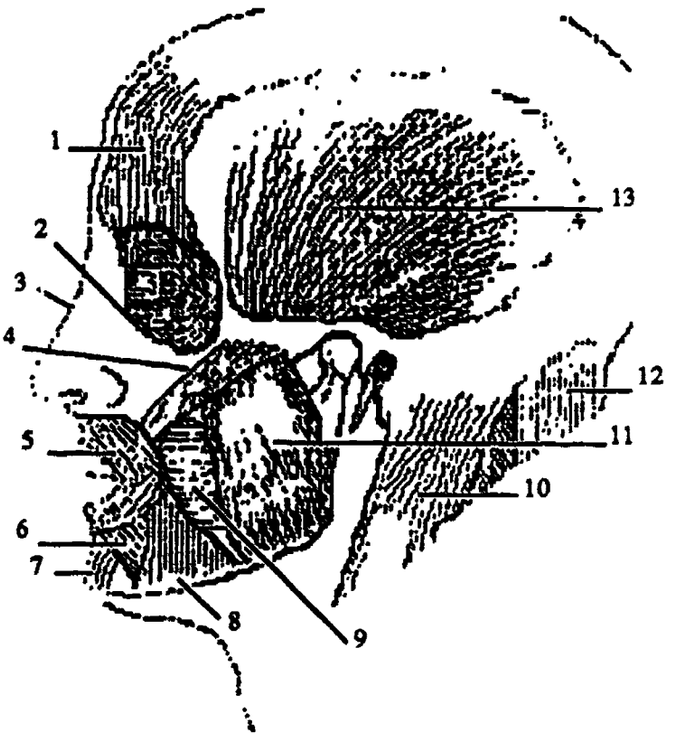


Fig. 16- Muscles of Facial Expression and Mastication

1. frontalis
2. orbicularis oculi
3. nasalis
4. zygomaticus major
5. orbicularis oris
6. depressor labii inferioris
7. mentalis
8. depressor anguli oris
9. buccinator
10. sternocleidomastoid
11. masseter
12. trapezius
13. temporalis

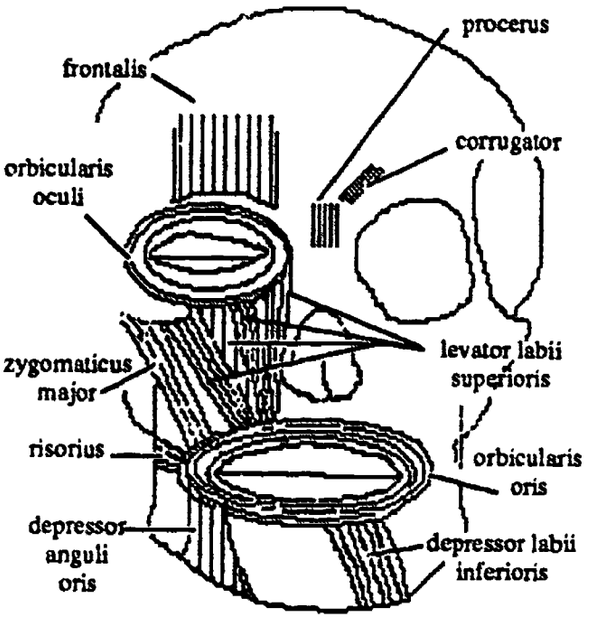


Fig. 17- Some Muscles of Facial Expression

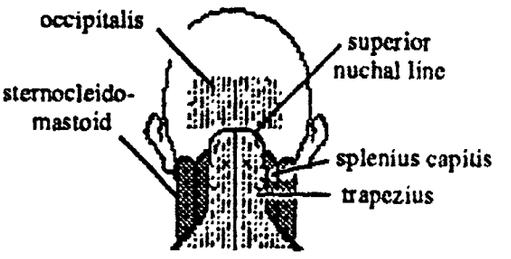


Fig. 18- Occipitalis

MUSCLES OF FACIAL EXPRESSION

The muscles of facial expression are unique in that they insert on skin rather than on bone. They are used for nonverbal communication. All of the muscles of this group are innervated by Cranial Nerve VII, the Facial Nerve.

OCCIPITALIS

I: skin in occipital region
A: wrinkles scalp in occipital region
See Fig. 18.

FRONTALIS

I: forehead at eyebrow level
A: eyebrow flash greeting
See Figs. 16, 17.

PROCERUS

I: area between inner corner of eyebrows
A: horizontal folds between eyebrows as in frowning
See Fig. 17.

CORRUGATOR
I: inner corner or eyebrow from diagonal angle above eyebrow
A: vertical folds above inner corner of eye as in frowning
See Fig. 17.

ORBICULARIS OCULI
I: surrounds eye like a sphincter
A: squinting as when light is bright
See Figs. 16, 17.

NASALIS
I: bridge of nose
A: wrinkles skin over bridge of nose as in disgust
See Fig. 17.

LEVATOR (QUADRATUS) LABII SUPERIORIS
O: 3 or 4 separate slips of muscle
I: upper lip
A: pulls lip out and up as in kissing
See Fig. 16.

LEVATOR ANGULI ORIS
I: corner of mouth, from above
A: lifts corner of mouth as in smiling
Not illustrated.

ZYGOMATICUS MAJOR
O: zygomatic bone
I: corner of the mouth
A: lifts corner of mouth as in broad smile
See Figs. 16, 17.

RISORIUS
I: corner of mouth from horizontal angle
A: slightly lifts corner of mouth as in a faint smile. **See Fig 17.**

ORBICULARIS ORIS
I: all around mouth like a sphincter
A: puckering of mouth as in kissing or pensiveness or indicating disapproval. **See Figs. 16, 17.**

DEPRESSOR ANGULI ORIS
I: corner of mouth from below
A: pulls corner of mouth down as in grief and sadness
See Figs. 16, 17.

DEPRESSOR LABII INFERIORIS
I: all along lower lip, from below
A: pulls lip down as in grief or a pout
See Figs. 16, 17.

MENTALIS
I: point of chin
A: wrinkles skin over chin as in grief, pout
See Fig 16.

BUCCINATOR
This is the deep muscle of the cheek.
A: suction. **See Fig 16.**

PLATYSMA
A: grimacing as in fear or grief
Not illustrated.

MUSCLES OF MASTICATION

All of the muscles in this group insert on the mandible. They are all innervated by the mandibular division of Cranial Nerve V, the Trigeminal Nerve. The action of all is chewing.

TEMPORALIS
O: temporal region of skull
I: coronoid process of mandible
A: chewing **See Fig 16.**

MASSETER
O: zygomatic arch
I: angle of the jaw
A: chewing **See Fig 16.**

MEDIAL PTERYGOID
O: medial pterygoid plate of sphenoid; **I:** medial aspect of angle of jaw
A: grinding movements of chewing
Not illustrated.

LATERAL PTERYGOID
O: lateral pterygoid plate of sphenoid; **I:** medial aspect of angle of jaw
A: grinding movements of chewing
Not illustrated.

Muscles of the Neck, & Deep Muscles of Torso

STRAP MUSCLES OF ANTERIOR NECK

These muscles fall into two groups, the supra- and the infra- hyoid muscles. All of the muscles attach to the hyoid bone. All of the supra hyoid muscles elevate the hyoid bone. All of the infrahyoid muscles depress the hyoid bone or the larynx. They are used during speech or swallowing. The name of the muscle often indicates its origin and insertion. **See Fig 19.**

SUPRAHYOID GROUP

STYLOHYOID
O: styloid process
I: hyoid bone

DIGASTRIC
O: mandible
I: hyoid bone

MYLOHYOID
O: mandible
I: hyoid bone

INFRAHYOID GROUP

STERNOHYOID
O: sternum
I: hyoid bone

OMOHYOID
O: scapula
I: hyoid bone **See Fig. 20.**

THYROHYOID
O: thyroid cartilage of larynx
I: hyoid bone

STERNOTHYROID
O: sternum
I: thyroid cartilage of larynx
See Fig. 19.

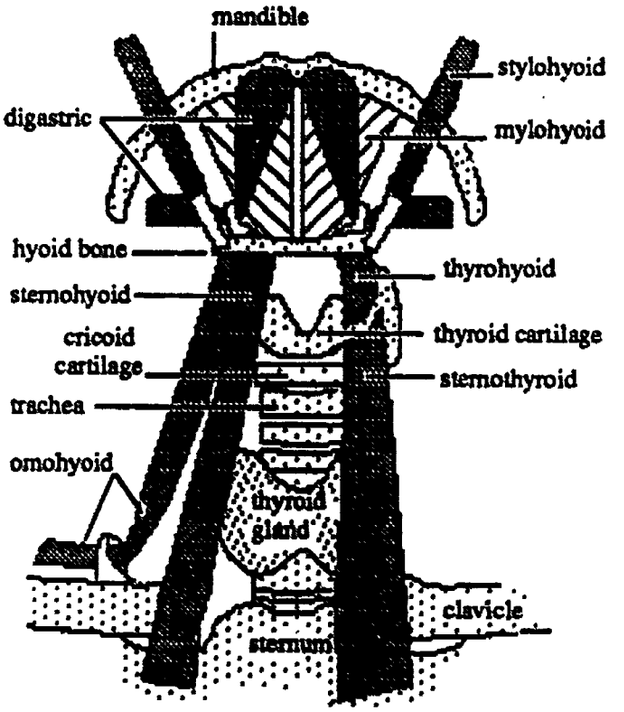


Fig. 19- Suprahyoid & Infrahyoid Muscle Groups, Anterior View
The muscles shown on the left side of the neck are deep to those shown on the right side.

POSTERIOR TRIANGLE OF NECK

Anatomists and surgeons commonly find it helpful to mentally visualize certain triangular areas of the body as an aid in learning the anatomy of the region. The posterior triangle of the neck is one example of this method.

BORDERS OF THE TRIANGLE

STERNOCLEIDOMASTOID
O: Sternum/clavicle
I: mastoid
A: anterior flexion or rotation of head and neck **See Figs. 18, 20, 33.**

CLAVOTRAPEZIUS
O: clavicle and acromion of scapula
I: superior nuchal line of occiput

A: extension or lateral flexion of head and neck. **See Figs. 18, 20, 31.**

CONTENTS OF THE TRIANGLE

Memorize the muscle positions in the triangle, from top to bottom .

SPLENIUS CAPITIS

O: spinous processes of cervical vertebrae
I: superior nuchal line of occipit
A: extension or rotation of head and neck. **See Fig. 20.**

LEVATOR SCAPULAE

O: transverse processes of cervical vertebrae
I: superior angle of scapula
A: shrug shoulder or extend head and neck, or lateral flexion of head and neck **See Figs. 20, 31.**

SCALENUS MUSCLES

Learn these (3) as having a group origin, insertion and action.
O: transverse processes of cervical vertebrae
I: 1st and 2nd ribs
A: deep inspiration (elevates the ribs)
See Figs. 20, 21.

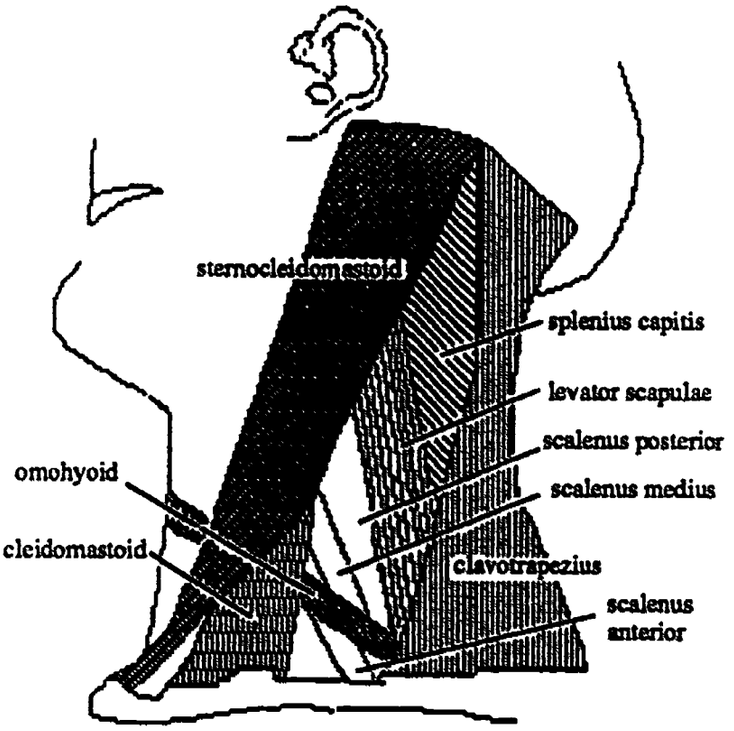


Fig. 20- Posterior Triangle of Neck

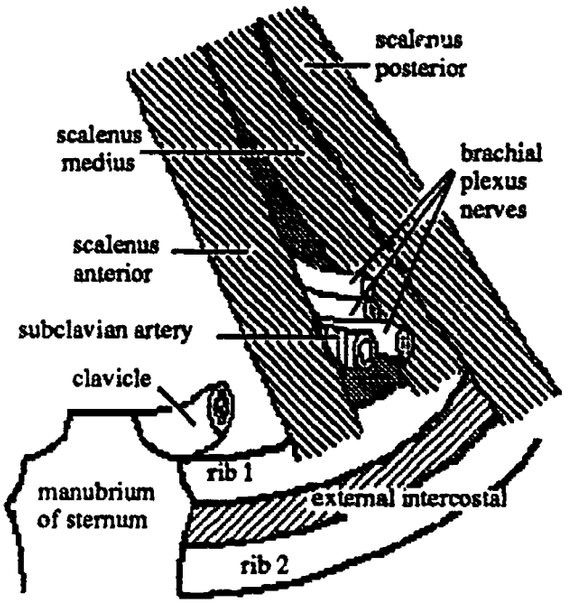


Fig. 21- Scalenus Muscles

BREATHING MUSCLES

SCALENUS MUSCLES

These were introduced with the posterior triangle of the neck.
See Figs. 20, 21.

EXTERNAL INTERCOSTALS

O: bottom edge of the upper rib
I: top edge of the lower rib
The fiber direction is diagonally downward toward the mid line.
A: elevates the lower rib. All work together to raise the rib cage for inspiration **See Figs. 21, 27.**

INTERNAL INTERCOSTALS

O: the top edge of the lower rib
I: bottom edge of the upper rib
The fiber direction is diagonally upward toward the mid line.
A: pulls the upper rib down. All work together to lower the rib cage for expiration
See Fig. 28.

DIAPHRAGM

This dome shaped muscle is unique. All the fibers start from below and rise towards a central tendinous area at the top of the dome.

O: very widespread, in a complete ring around the interior wall of the torso
I: central tendon of the diaphragm
A: Contraction causes the dome to flatten, which enlarges the thoracic cavity increasing its negative pressure and causing inspiration. During relaxation the diaphragm takes on its dome shape again, reducing the chest cavity and causing expiration. See Fig. 22.

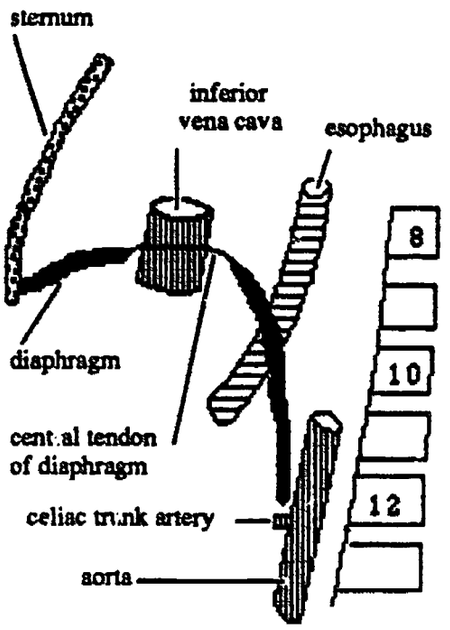


Fig. 22- Diaphragm, Midsagittal View

POSTURE MUSCLES

A posture muscle is an antigravity muscle; it holds the body erect by resisting the pull of gravity. Any muscle which acts as an extensor at a weight bearing joint is a posture muscle.

The extensors of the neck (head) and spine (back) therefore qualify as posture muscles. The ones we have covered so far are: **clavotrapezius, splenius capitis**, and **levator scapulae**. Next we will consider the deep posture muscles of the back and neck.

DEEP BACK & NECK

ERECTOR SPINAE

spinalis,
longissimus
iliocostalis

The erector spinae group is the main posture muscle of the spinal column. It is not necessary to learn the names of the muscles in small print, instead learn the action for the group as a whole. See Fig. 23.

SEMISPINALIS CAPITIS

semispinalis cervicis
semispinalis thoracis

Semispinalis capitis is the deep posture muscles (group) of the neck. Superficial head and neck posture muscles were considered previously. See Fig. 23.

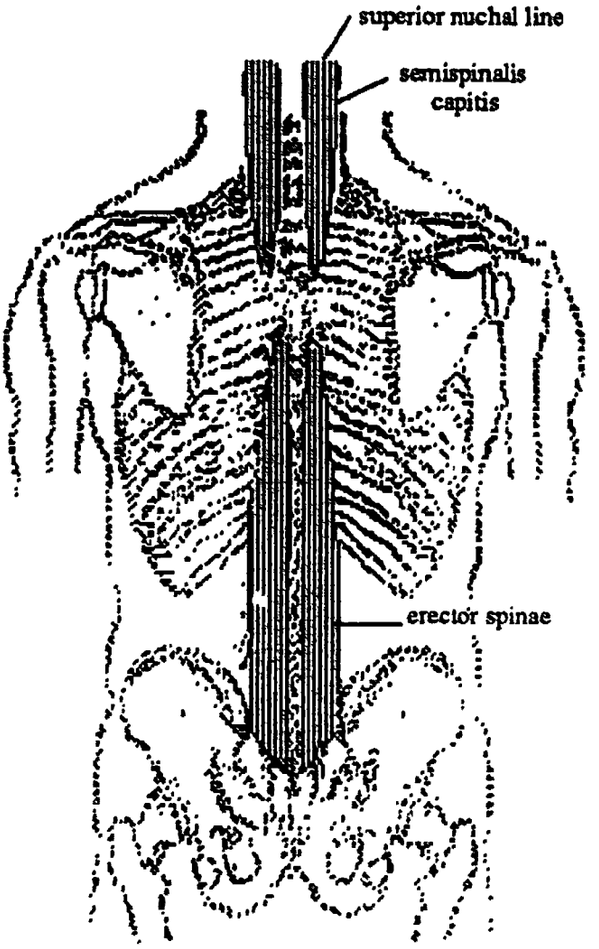


Fig. 23- Deep Muscles of the Back

Muscles of the Posterior Abdominal Wall

PSOAS MAJOR

Most people have a psoas minor, but it is insignificant and in fact is absent in about 20% of the population. If present its tendon will be seen as a flat white shinning ribbon on the anterior surface of psoas major.

O: sides of the bodies of lumbar vertebrae
I: lesser trochanter of the femur
A: flexion of the hip or flexion of the trunk
See Fig. 24.

ILIACUS

O: iliac fossa
I: lesser trochanter of the femur
A: flexion of the hip
See Fig. 24.

ILIOPSOAS

The iliacus and psoas muscles start separately, but soon their tendons fuse and have a common insertion and action. The fused portion is called the iliopsoas muscle.
See Fig. 24.

QUADRATUS LUMBORUM

O: iliac crest
I: lower ribs
A: lateral flexion of the trunk
See Fig. 24.

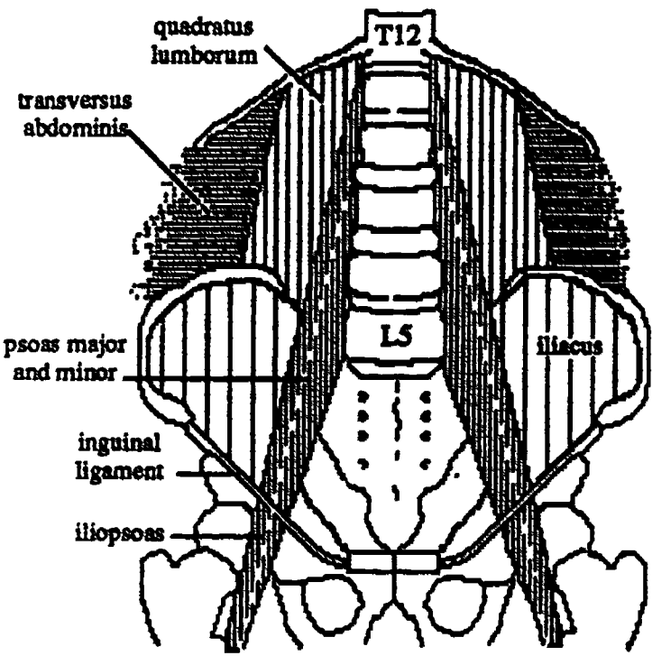


Fig. 24- Muscles of the Posterior Abdominal Wall, Anterior View

MUSCLES OF THE ANTERIOR ABDOMINAL WALL

In addition to whatever else they do, the muscles of the anterior abdominal wall all act to compress the abdomen. Compression of the abdomen is necessary to hold the viscera in place, and to aid in such functions as : forced expiration, coughing, sneezing, vomiting, defecation, urination, and parturition

RECTUS ABDOMINIS MUSCLE

There are two rectus muscles. They lie next to one another on either side of the **linea alba.** The fibers run vertically but are interrupted periodically by transverse fibrous bands called the **tendinous inscriptions** (a.k.a. tendinous interruptions; tendinous insertions). **See Fig. 25.**

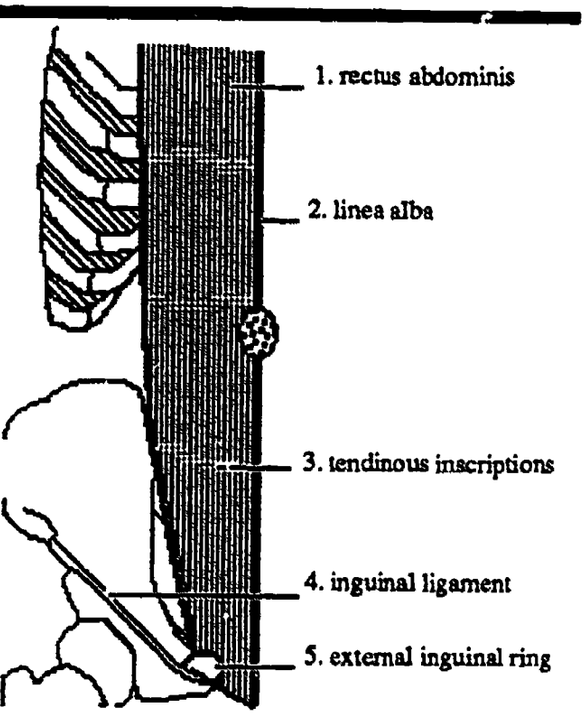


Fig. 25- Rectus Abdominis

• Sheath of the Rectus

Since there is nc bone to attach to in the front of the abdomen, the aponeuroses of the three anterior-lateral abdominal muscles pass across the surface of the rectus on their way to the midline where they meet and fuse with those of the opposite side, forming the **linea alba**

Because of this arrangement, the rectus is covered by layers of connective tissue known as the **sheath of the rectus.** The precise anatomy of these layers is important surgically: **See Fig. 26.**

- the aponeurosis of external oblique passes anterior to rectus;
- the aponeurosis of the transverse muscle passes posterior to rectus;
- the aponeurosis of internal oblique splits, half passing anterior and half posterior to the rectus.

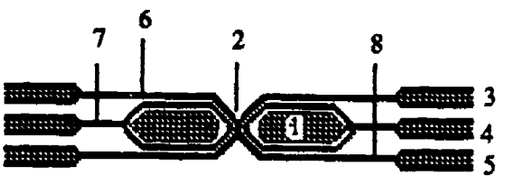


Fig. 26- Sheath of Rectus

1. rectus abdominis
2. linea alba
3. external oblique
4. internal oblique
5. transversus
6. aponeurosis of ext. oblique
7. aponeurosis of int. oblique
8. aponeurosis of transversus

• Fiber Direction

The antero-lateral abdominal muscles are layered to reinforce one another. It is not necessary to memorize the extensive origins of these lateral muscles, instead learn to recognize them by their fiber direction.

EXTERNAL OBLIQUE MUSCLE

The fibers of external oblique run diagonally down and toward the midline (imagine the direction of your fingers when putting your hands in the side pockets of a pair of jeans).
O: widespread, but basically from theexternal surfaces of the lower 8 ribs.
I: linea alba (and crest of ilium)
A: compression of the abdomen and trunk rotation. **See Fig. 27.**

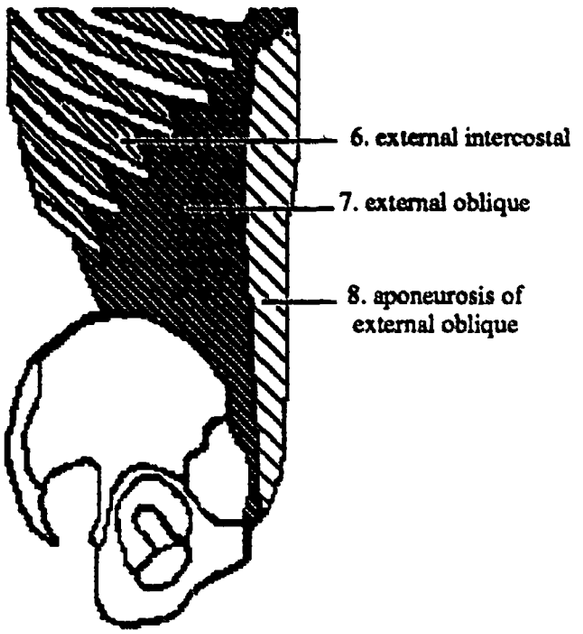


Fig. 27- External Oblique

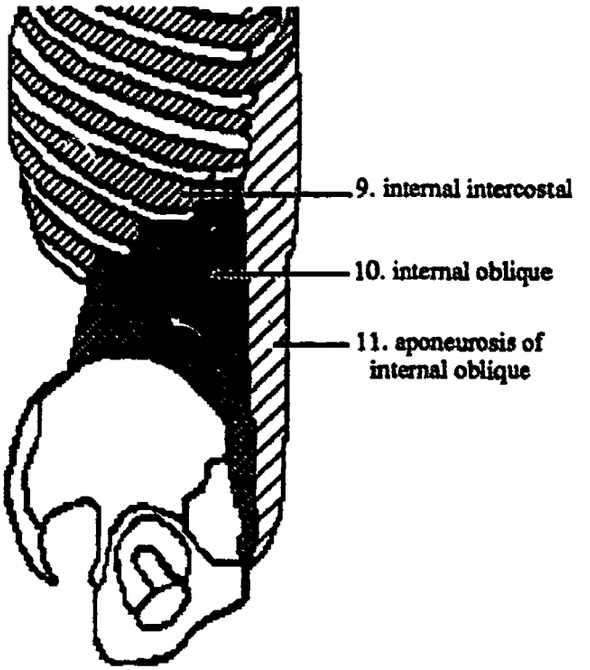


Fig. 28- Internal Oblique

INTERNAL OBLIQUE MUSCLE

The fibers of the internal oblique run diagonally up and toward the midline.
O: lateral half of inguinal ligament, iliac crest, and lower ribs.
I: linea alba
A: compression of the abdomen, and trunk rotation **See Fig. 28.**

TRANSVERSUS ABDOMINIS

The fibers of transversus run horizontally.
O inguinal ligament, iliac crest and lower ribs. **I:** linea alba
A: compression of the abdomen, and trunk rotation **See Fig. 29.**

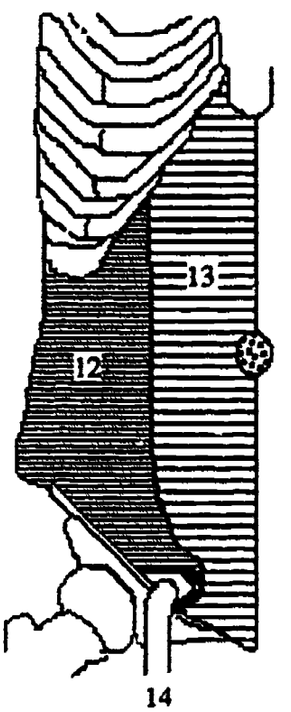


Fig. 29- Transversus Abdominis

12. transversus
13. aponeurosis
14. spermatic cord

DESCENT OF THE TESTES

• INGUINAL LIGAMENT

The inguinal ligament marks the dividing line where wall of abdomen stops and thigh begins. It extends from the **anterior superior iliac spine** to the **pubic tubercle**, and is formed by connective tissuethat blends with the lower free edge of the external oblique aponeurosis. **See Figs. 25, 30.**

• INGUINAL CANAL & RINGS

The inguinal canal is a tunnel that passes through the layers of the abdominal wall gradually one by one rather than directly through all three at once. The internal opening of the tunnel is called the **deep inguinal ring.** The superficial opening is called the **external inguinal ring.**
See Figs. 25, 30.

• GUBERNACULUM

The gubernaculum is an embryological connective tissue cord that is attached to the gonad, passes through the inguinal canal, and then attaches to the inside of the scrotum (in the male) or labia majora (in the female). In the male this cord shortens shortly before birth, pulling the testicle out of the abdomen, down thru the inguinal canal, and into the scrotum.

• SPERMATIC CORD

The spermatic cord remains attached to the testicle and therefore it occupies the inguinal canal in the male. **See Figs. 29, 30.**

• CRYPTORCHIDISM

Cryptorchidism means hidden testicle, and it refers to failure of the testicle to descend. The condition is easy to correct surgically. If not corredted, the adult male will be sterile because the temperature inside the abdomen is too high for the production of sperm cells although testosterone production will not be affected.

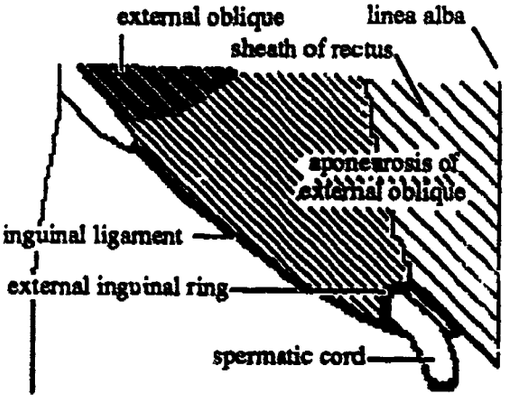


Fig. 30- Inguinal Ligament

• CREMASTER MUSCLE

As the testicle descends, some of the fibers of internal oblique get hooked around the testicle and dragged down into the scrotum. These loops of muscle are called the cremaster muscle. Contraction of the cremaster can draw the testicle up into the abdomen in infants. Sumo wrestlers have been trained since infancy so that they retain this ability as adults.

• HERNIA

A hernia is any protrusion of an internal organ into a cavity where it is not normally found.

INDIRECT HERNIA

An *indirect* hernia refers to protrusion of a loop of intestine through the inguinal canal into the scrotum. It may be caused by anything which increases abdominal pressure, and it usually only happens in males, presumably because the inguinal canal is somewhat more open in males.

DIRECT HERNIA

A direct hernia refers to a protrusion of intestine through a tear in the abdominal wall. It can be caused bya blow to the abdomen, or by weakness of the abdominal muscles.

Mooring Muscles of Scapula

• The only place in the pectoral girdle where ligaments hold bone to bone is between the clavicle and sternum, elsewhere only muscles hold the shoulder girdle in place on the axial skeleton. The reason for this highly unusual situation is the necessity for very free movement of the arm.

• All of the muscles in this group originate on the axial skeleton and insert on the scapula. Notice that they approach the scapula from every possible direction.

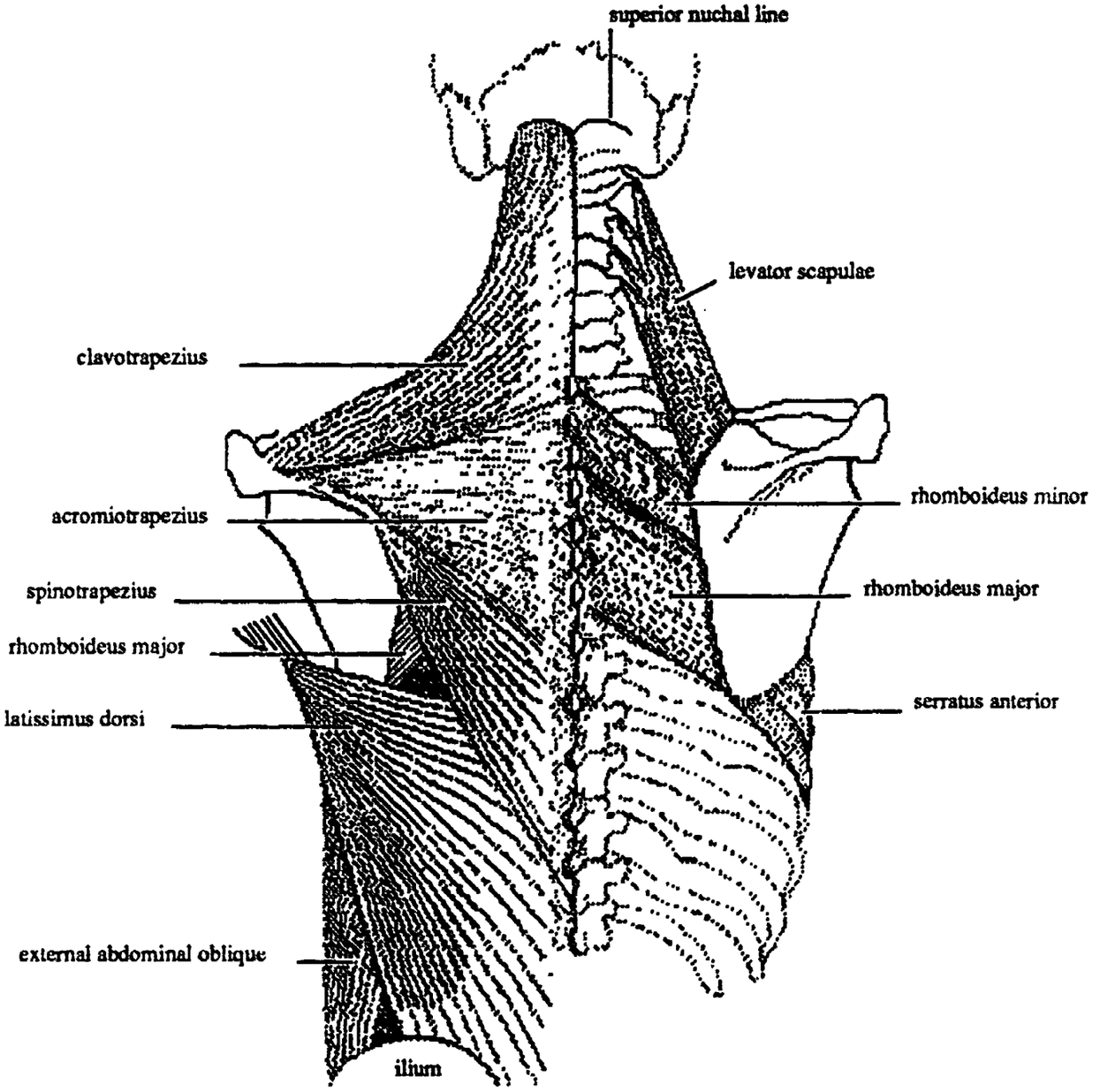


Fig. 31- Mooring Muscles of the Scapula.

Superficial muscles are shown on the left side. Deep muscles are shown on the right side.

TRAPEZIUS

This muscle has three sections that can act separately due to separate innervations.

clavotrapezius
acromiotrapezius
spinotrapezius

O: superior nuchal line, ligamentum nuchae and spinous processes of all thoracic vertebrae
I: clavicle, acromion, and spine of scapula
A: elevation, adduction, and depression of scapula. Extension and lateral flexion of head and neck.
See figs. 31, 16, 18, 20, 33.

RHOMBOIDEUS MAJOR & MINOR

O: spinous processes of thoracic vertebrae
I: vertebral border of scapula
A: adduction of scapula
See fig. 31.

LEVATOR SCAPULAE

O: transverse processes of upper cervical vertebrae
I: superior angle of scapula
A: elevates scapula (shrug shoulder). Extension and lateral flexion of neck
See figs. 20, 31.

SERRATUS ANTERIOR

O: front surface of ribs
I: vertebral border of scapula
A: abduction (protraction) of scapula (important in pushing)
See figs. 31, 32, 39.

PECTORALIS MINOR

O: front of ribs
I: coracoid process of scapula
A: stabalizes scapula **See fig. 33.**

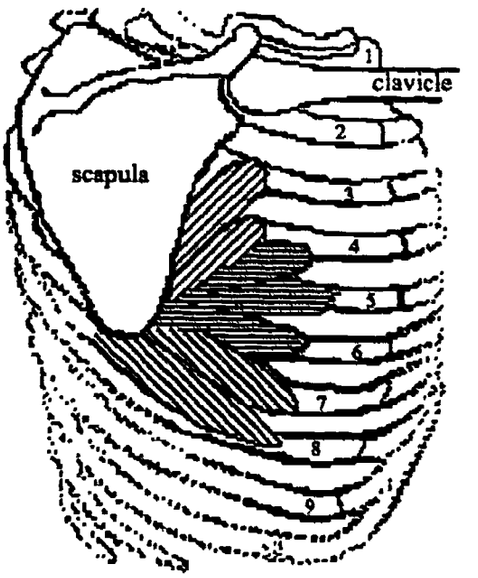


Fig. 32- Serratus Anterior

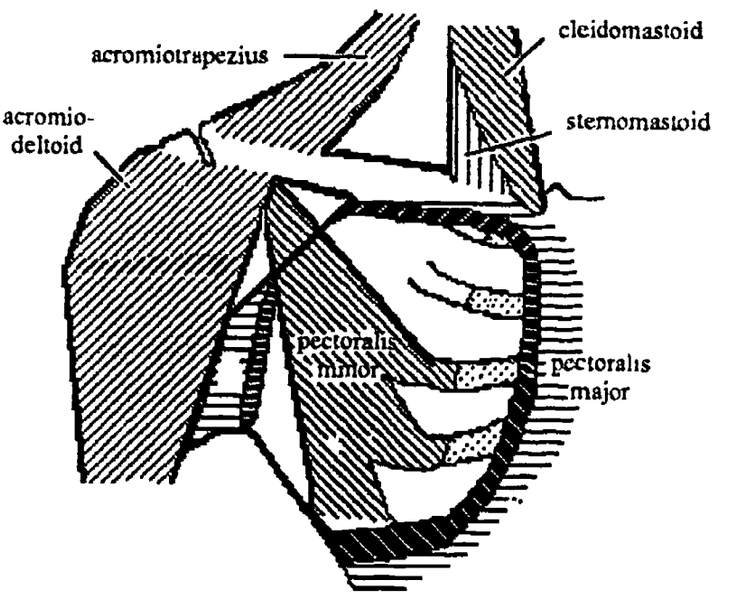


Fig. 33- Pectoralis Minor
Pectoralis major has been removed.

Muscles acting on Shoulder Joint

ROTATOR CUFF GROUP

• All of the muscles in this group originate on the axial skeleton and insert on the head of the humerus. They form a musculotendinous cuff around the head of the humerus, helping to hold it in its socket. They all act on the humerus.

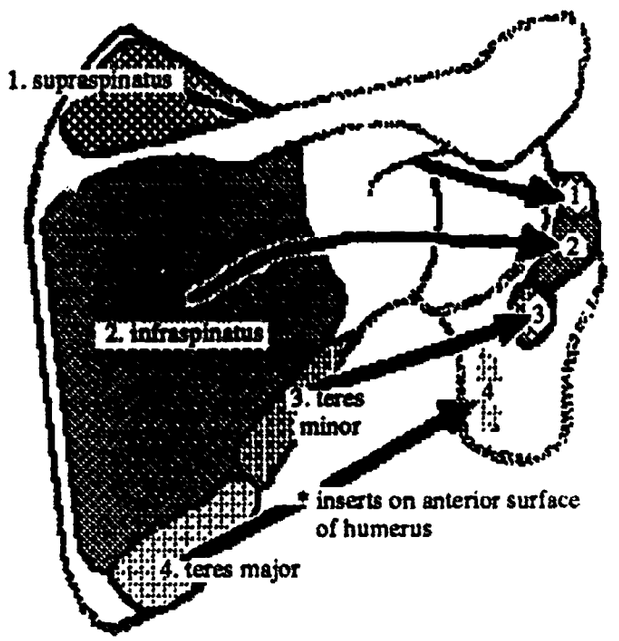


Fig. 34- Rotator Cuff Muscles
Right Arm, Posterior View

SUPRASPINATUS
O: supraspinous fossa of scapula
I: greater tubercle of humerus
A: abduction of humerus
See Figs. 34, 38, 41

INFRASPINATUS
O: infraspinous fossa of scapula
I: greater tubercle of humerus
A: lateral rotation and extension
See Figs. 34, 38, 41

TERES MINOR
O: axillary border of scapula
I: greater tubercle of humerus
A: same as infraspinatus
See Figs. 34, 38, 41

SUBSCAPULARIS
O: subscapular fossa
I: lesser tubercle of humerus
A: medial rotation of humerus and extension of humerus **See Fig. 35, 41**

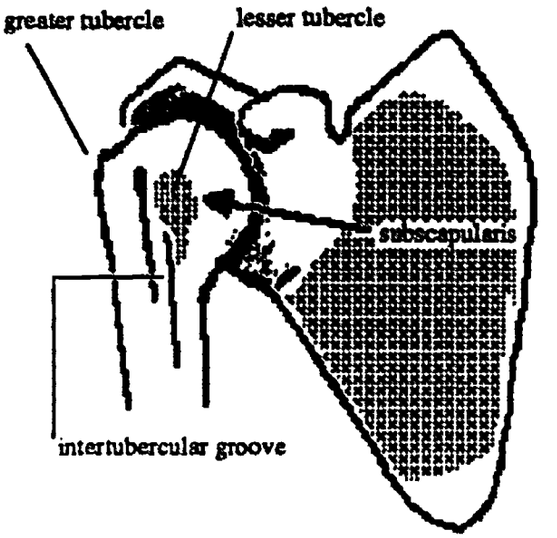


Fig. 35- Shoulder Girdle, Anterior View

MUSCLES WITH BETTER LEVERAGE

• Included in this group are the power muscles which of the arm. They all originate on scapula and/or clavicle and insert on upper shaft of humerus.

• As a rule, any muscle which is a flexor or extensor of the arm will also act as an adductor of the arm.

DELTOID
This muscle has three separate sections that can act separately due to separate innervations:

Acromiodeltoid
Clavodeltoid
Spinodeltoid

O: clavicle, acromion process of scapula, and spine of scapula
I: deltoid tuberosity of humerus

A: See Fig. 33, 36, 37, 38, 39, 41.

Acromiodeltoid: abduction

Clavodeltoid: flexion, adduction, medial rotation

Spinodeltoid: extension, adduction, lateral rotation

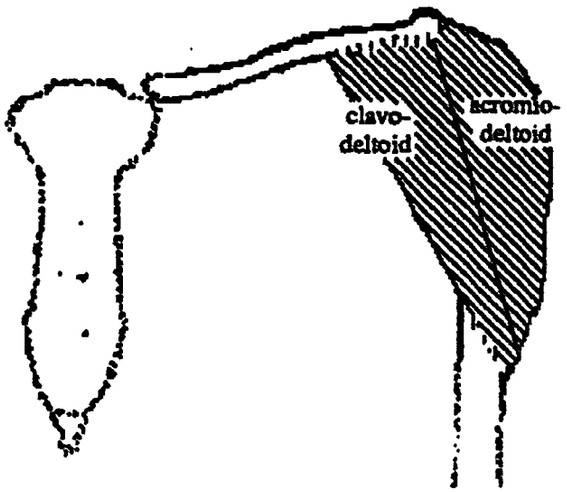


Fig. 36 -Deltoid, Anterior View

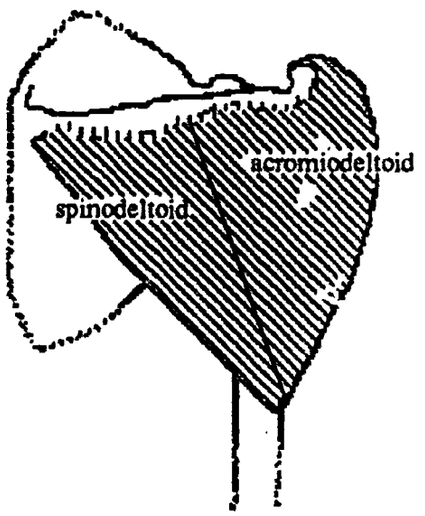


Fig. 37 -Deltoid, PosteriorView

TERES MAJOR

O: inferior angle of scapula along axillary border.

I: bicipital groove (medial crest)

A: same as latissimus dorsi

See Fig. 34, 38, 41.

LATISSIMUS DORSI

This muscle forms the posterior wall of the axilla. It is flat and sheetlike; it has a wide-spread origin and a small insertion, hence it concentrates great force on a small area.

O: low back vertebrae by way of the lumbodorsal aponeurosis

I: bicipital groove, anterior humerus

A: extension, medial rotation and adduction of humerus **See Figs. 31, 41**

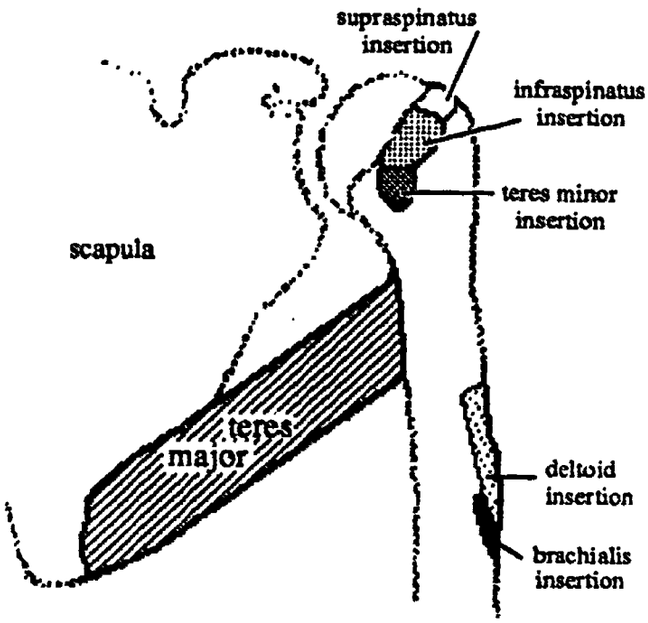


Fig. 38- Teres Major, Posterior View

PECTORALIS MAJOR

This muscle forms the anterior wall of the axilla. It has four overlapping heads

O: clavicle, sternum and ribs

I: lateral crest of the bicipital groove

A: flexion, medial rotation, adduction

See Figs. 31, 41.

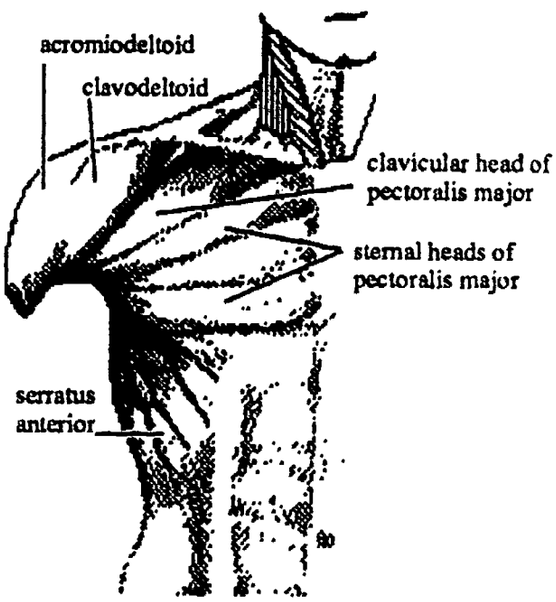


Fig. 39- Pectoralis major

CORACOBRACHIALIS
O: coracoid process of scapula
I: shaft of humerus,
A: flexion and adduction of humerus
See Figs. 40

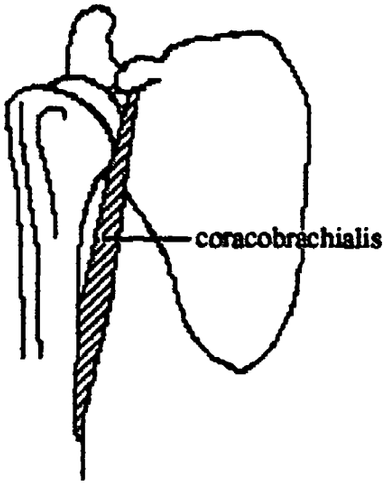


Fig. 40- Coracobrachialis, Anterior View

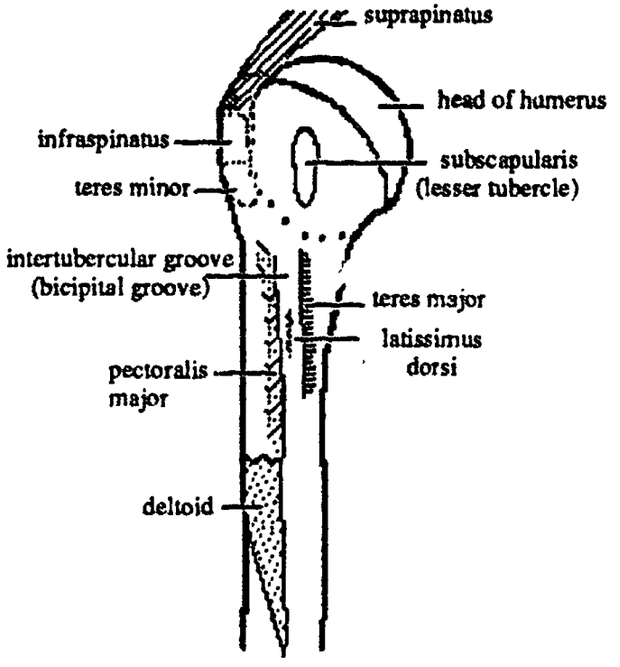
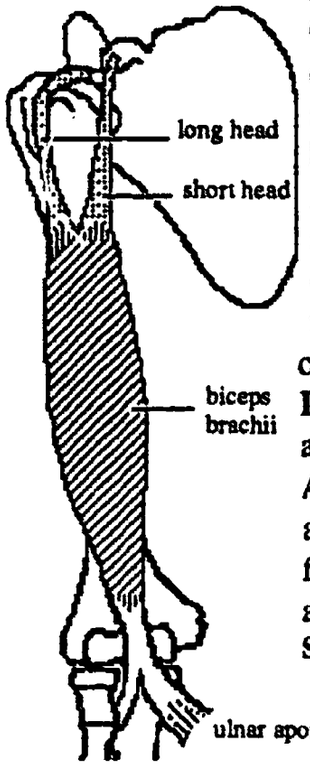


Fig. 41- Major Insertions on Proximal End of Humerus, Anterior View

Muscles Acting on the Elbow Joint

• The flexors are on the anterior side of the elbow; the extensors are on the posterior side .

• During supination and pronation of the forearm the ulna remains stationary while the radius rolls over the top of the ulna. As a result all supinator and pronator muscles must insert on the radius.



BICEPS BRACHII
O: short head: coracoid process of scapula;
long head: supraglenoid tubercle of scapula. The tendon of this head lies in the bicipital groove of the humerus.
I: tuberosity of radius and ulnar aponeurosis
A: flexion of elbow and supination of forearm, also flexion at shoulder
See Figs. 41, 42, 44.

Fig. 41- Biceps brachii
Anterior View Right Arm

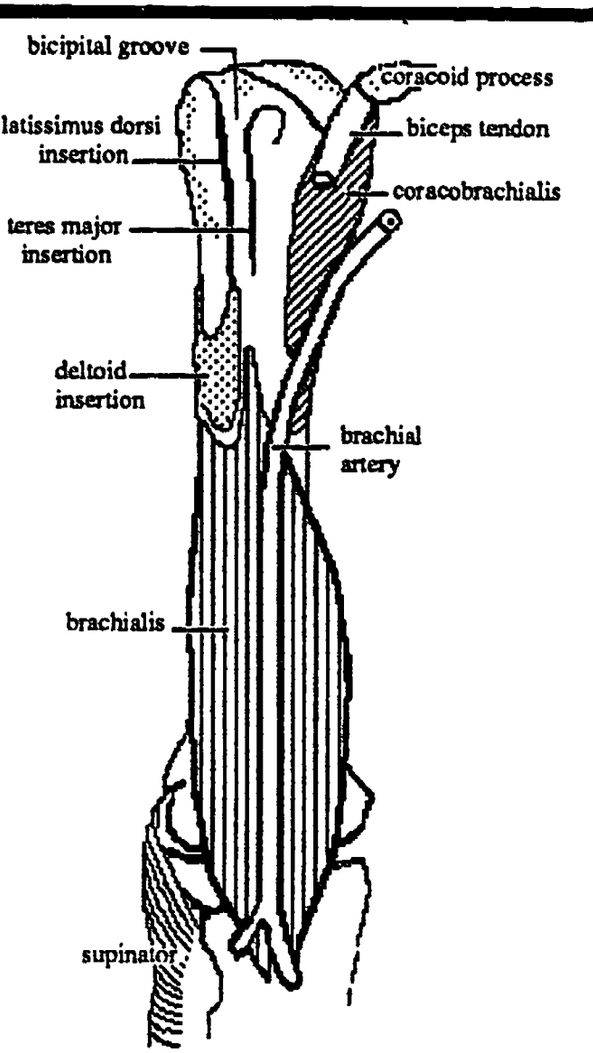


Fig. 42- Brachialis
Anterior View Right Arm

BRACHIALIS:
O: lower half of shaft of humerus
I: coronoid process of ulna and ulnar tuberosity
A: flexion of elbow
See Fig. 42

BRACHIORADIALIS
O: lateral epicondyle of humerus
I: styloid process at distal end of radius
A: flexion of the elbow and supination of forearm
See Figs. 43, 44.

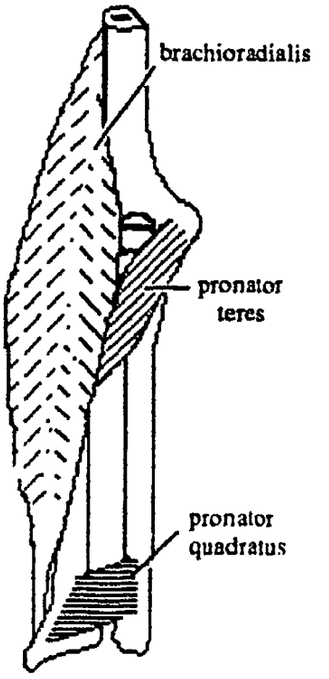


Fig. 43 Brachioradialis
Anterior View Right Arm

PRONATOR TERES
O: medial epicondyle of humerus
I: shaft of radius
A: pronation of forearm; flexion of elbow
See Figs. 43, 44.

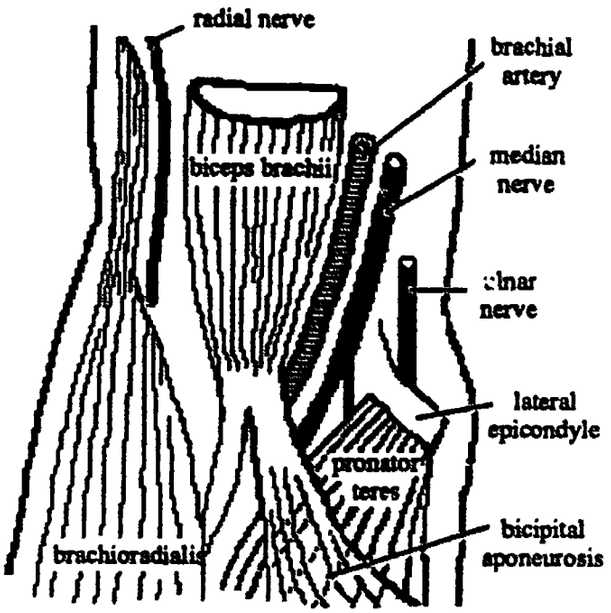


Fig. 44- Right Elbow, Anterior View

PRONATOR QUADRATUS
O: distal shaft of ulna
I: distal shaft of radius
A: pronation of forearm
See Fig. 43.

SUPINATOR
lies deep to the brachioradialis
O: lateral epicondyle of humerus
I: upper shaft of radius
A: supination of forearm
See Fig. 42.

TRICEPS BRACHII
three heads of origin
O: long head: scapula, infraglenoid
medial head: proximal humerus
lateral head: distal humerus
I: olecranon process of ulna
A: extension of elbow
See Fig. 45.

ANCONEUS
O: lateral epicondyle of humerus
I: ulna
A: extension of elbow
See Figs. 45, 46.

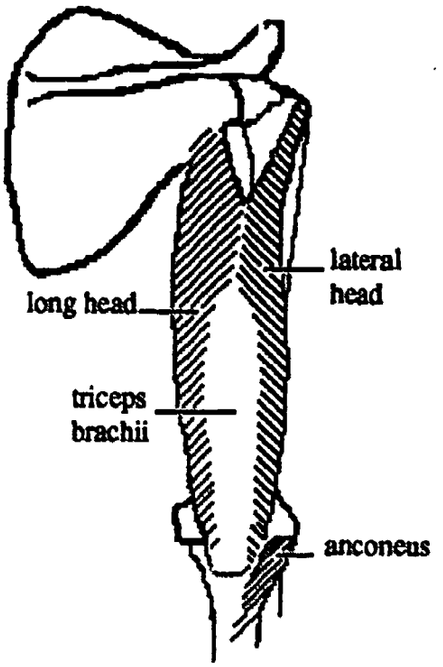


Fig. 45- Triceps Brachii,
Right Arm, Posterior View

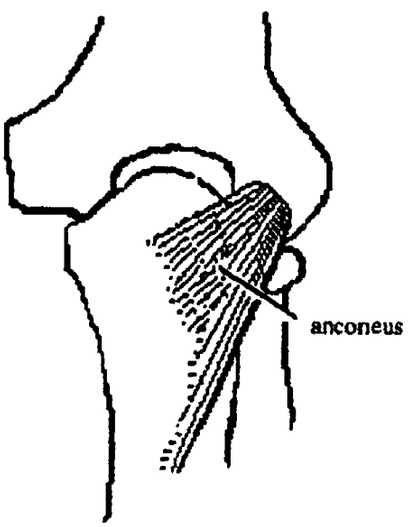


Fig. 46- Anconeus,
Right Arm, Posterior View

Muscles acting on Wrist & Finger Joints

• The muscles which originate on the medial epicondyle are flexors or pronators. The muscles which originate on the lateral epicondyle are extensors or supinators. Brachioradialis is partially an exception in that its origin is the lateral epicondyle; it is a flexor & also a supinator.

• Rule to follow when identifying muscles of the forearm: first identify and mentally set aside brachioradialis and pronator teres. They do not act on the wrist or fingers.

• The flexors of the wrist and fingers are on the anterior surface and generally originate on or near the medial epicondyle of the humerus.

• The extensors are posterior or lateral and originate on or near the lateral epicondyle.

• The flexors and extensors of the wrist and fingers have a minor action at the elbow and you do not need to memorize it.

ANTERIOR FOREARM

• All of these muscles originate on the medial epicondyle of the humerus and all act to flex the wrist and elbow.

PALMARIS LONGUS
O: medial epicondyle
I: palmar aponeurosis
A: flexion of wrist and elbow
See Fig. 49.

FLEXOR CARPI ULNARIS
O: medial epicondyle
I: wrist (carpus) on little finger side.
A: flexion of wrist and elbow and adduction of wrist
See Figs. 47, 49.

FLEXOR CARPI RADIALIS
O: medial epicondyle
I: wrist (carpus) on thumb side
A: flexion of wrist and elbow and abduction of wrist
See Fig. 49.

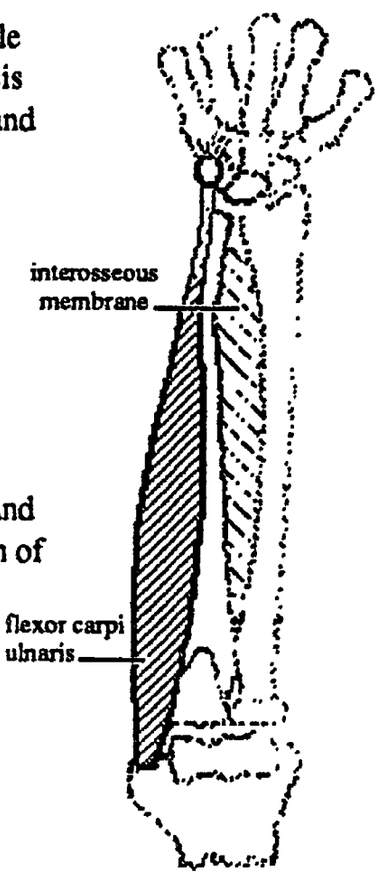


Fig. 47- Flexor Carpi Ulnaris
Right Forearm, Anterior View

FLEXOR DIGITORUM superficialis & profundus
O: medial epicondyle
I: four fingers (not the thumb)
A: flexion of fingers, wrist and elbow
See Fig. 48.

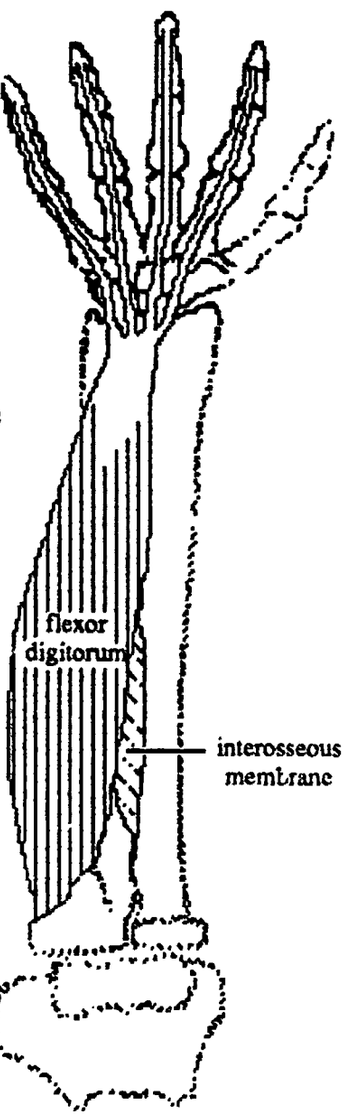


Fig. 48- Flexor Digitorum
Right Forearm, Anterior View

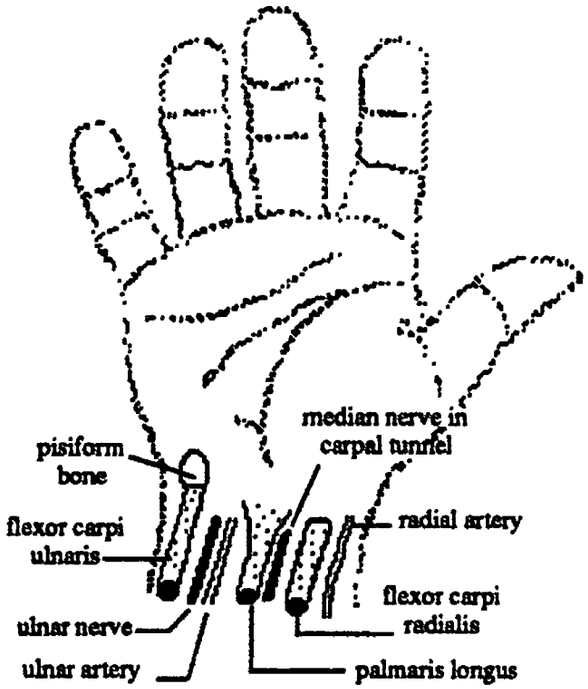


Fig. 49- Superficial Flexor Tendons
Right Wrist

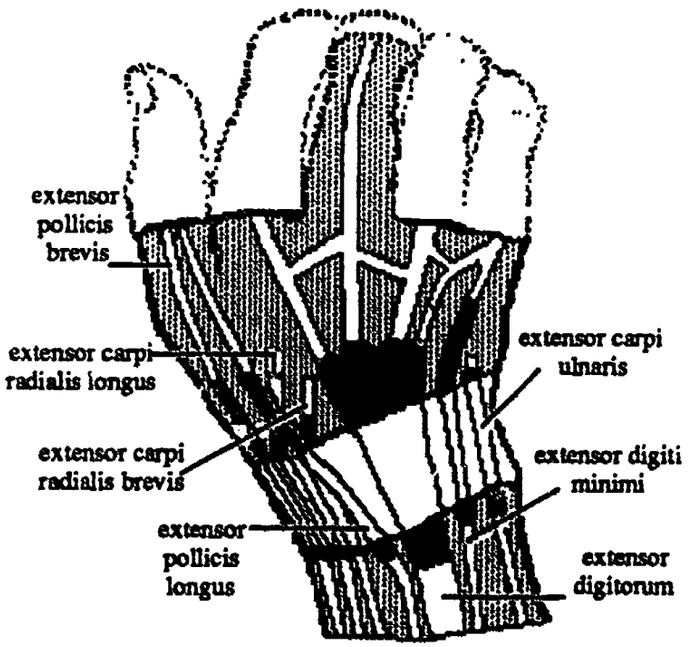


Fig. 50- Superficial Extensor Tendons
tendons are protected by tendon sheaths as they pass under the extensor retinaculum

POSTERIOR FOREARM

• *All of these muscles originate on the lateral epicondyle and all act to extend the wrist and elbow.*

EXTENSOR CARPI RADIALIS LONGUS
O: lateral epidcondyle
I: wrist, thumb side
A: extension and abduction of wrist
See Fig. 50.

EXTENSOR CARPI RADIALIS BREVIS
O: lateral epidcondyle
I: middle of wrist
A: extension of wrist
See Fig. 50.

EXTENSOR CARPI ULNARIS
O: lateral epidcondyle
I: wrist, little finger side
A: extension and adduction of wrist
See Fig. 50, 51.

EXTENSOR DIGITORUM
communis and indicis
O: lateral epidcondyle
I: all four fingers (not the thumb)
A: extension of wrist and fingers
See Fig. 50.

EXTENSOR DIGITI MINIMI (QUINTI)
O: lateral epidcondyle
I: little finger
A: extension of wrist and 5th finger
See Fig. 50.

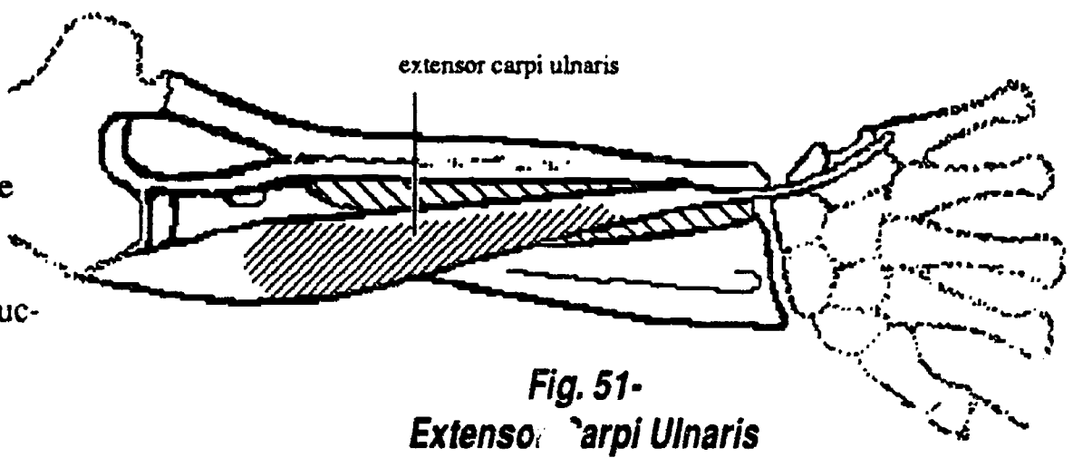


Fig. 51- Extensor Carpi Ulnaris
Right Forearm, Dorsal View

MUSCLES OF THE THUMB

• All the muscles in this group originate on the radius and all insert on the thumb. The name of the muscle indicates its action.

• The tendons of extensor carpi radialis longus and brevis tunnel under the extensors and abductor of the thumb

• When the thumb is forcibly abducted and extended a hollow fossa called the anatomical snuff box appears at the base of the thumb. It is created by the tendons of those muscles.

EXTENSOR POLLICIS LONGUS
See Fig. 50, 52.

EXTENSOR POLLICIS BREVIS
See Fig. 50, 52.

ABDUCTOR POLLICIS LONGUS

FLEXOR POLLICIS LONGUS

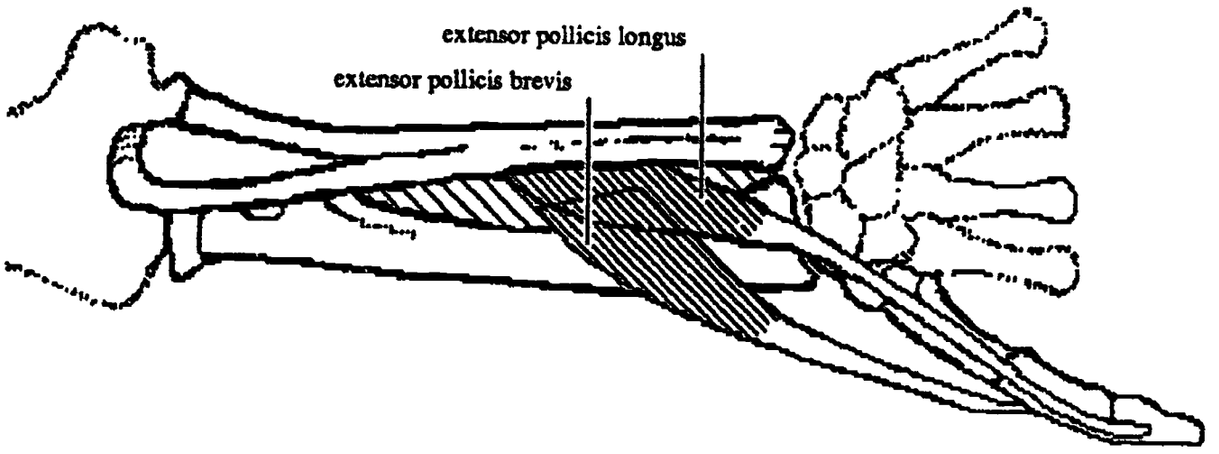


Fig. 52- Extensor Pollicis Longus & Brevis

Right Forearm, Posterior View

Extensor pollicis longus is shown as transparent where it overlies Extensor pollicis brevis.

Muscles of the Hip and Thigh

GLUTEAL REGION

The tough thick investing fascia of the lateral thigh is called the fascia lata. Part of this fascia is especially tough and thick and is called the iliotibial tract or iliotibial band. This band extends from the crest of the ilium to the lateral condyle of the tibia; it acts as a kind of tendon for two of the muscles of the gluteal group.

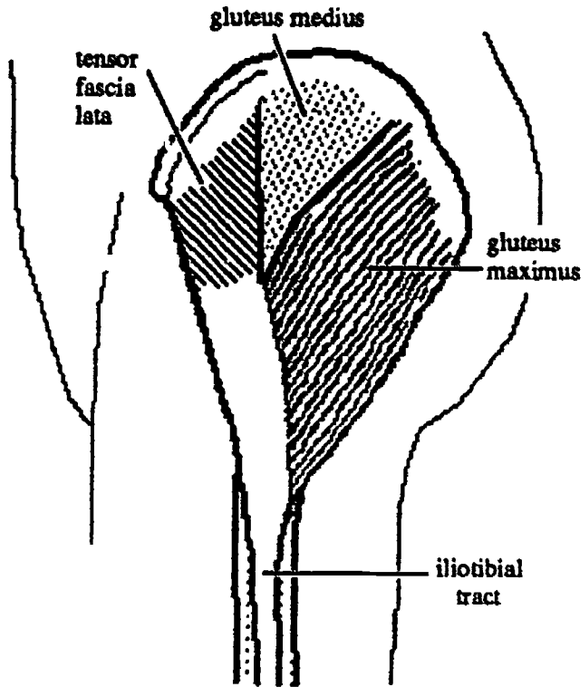


Fig. 53- Lateral View, Left Leg

TENSOR FASCIA LATA

O: anterior superior iliac spine
I: iliotibial tract
A: flexion of hip; tightens the iliotibial tract and therefore helps brace the knee & abduct the leg
See Fig. 53.

GLUTEUS MAXIMUS

The gluteus maximus in man is very large and coarse and powerful since it helps maintain the erect posture of the trunk. It is especially used in standing up from a sitting position climbing stairs or hills, in deep knee bends, and in running.
O: iliac crest, sacrum, and coccyx
I: shaft of femur below greater trochanter, & ilio tibial tract
A: extension and/or lateral rotation of the hip, also abduction of leg and bracing of the extended knee
See Figs. 53 and 60.

GLUTEUS MEDIUS

Think of this muscle as homologous to the deltoid muscle of the shoulder. It has three sections, (part 1. anterior; part 2. middle; part 3. posterior), which can act separately.
O: crest of ilium
I: greater trochanter
A: part 1: medial rotation, flexion;
part 2: abduction;
part 3: extension, lateral rotation
See Fig. 53.

GLUTEUS MINIMUS

O: posterior surface of ilium
I: greater trochanter
A: medial rotation and abduction
Not illustrated.

DEEP GLUTEAL GROUP

piriformis
gemellus superior
obturator internus
gemellus inferior
obturator externus
quadratus femoris

Learn these as a group, not individually. All of the muscles in the group are small, all pass behind the hip joint, all insert on the greater trochanter, and **all are lateral rotators of the hip.** Quadratus femoris is large and prominent in the cat. **Not illustrated.**

ANTERIOR THIGH

ILIOPSOAS

This muscle of the posterior abdominal wall is the main flexor of the hip.
See Figs 24, 59.

SARTORIUS

The Tailor's Muscle; the longest muscle of the body in humans. It is slender, strap-like (broad in the cat) and crosses the thigh diagonally, crossing both the hip and the knee joints.
O: anterior superior iliac spine
I: proximal tibia, medial side
A: flexes thigh and knee and laterally rotates thigh. It can raise the leg into the "tailor's position", hence it's name.
See Figs. 54, 55, 60, 59.

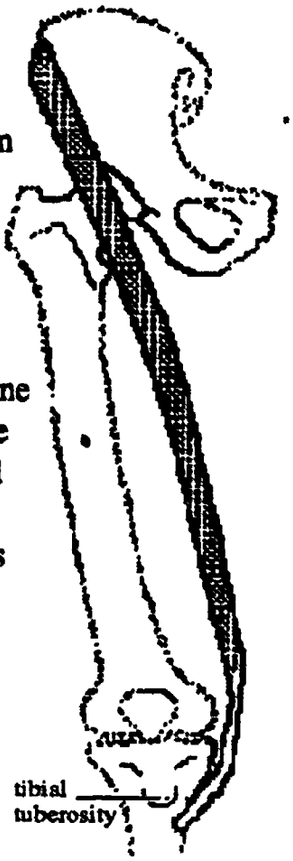


Fig. 54 Sartorius
Right Leg

QUADRICEPS FEMORIS

This muscle group has four heads of origin.
• All arise from the femur, except for the rectus which is from the ilium.
• All insert on the tibial tuberosity by way of a common tendon (the patellar tendon). The patella adds leverage to improve the angle of pull on the tibia.
• All extend the tibia; in addition the rectus helps flex the thigh.
• All are important in walking, running, climbing, jumping, and kicking. The rectus is especially important in kicking.

RECTUS FEMORIS

O: ilium
I: tibial tuberosity
A: extension of tibia, flexion of hip
See Figs 55, 56.

VASTUS INTERMEDIUS

This muscle lies deep to rectus femoris. It is not illustrated.
O: femur
I: tibial tuberosity
A: extension of tibia
Not illustrated.

VASTUS LATERALIS

O: femur
I: tibial tuberosity
A: extension of tibia
See Figs 55, 58.

VASTUS MEDIALIS

O: femur
I: tibial tuberosity
A: extension of tibia
See Figs 55, 57.

Fig. 56- Rectus Femoris

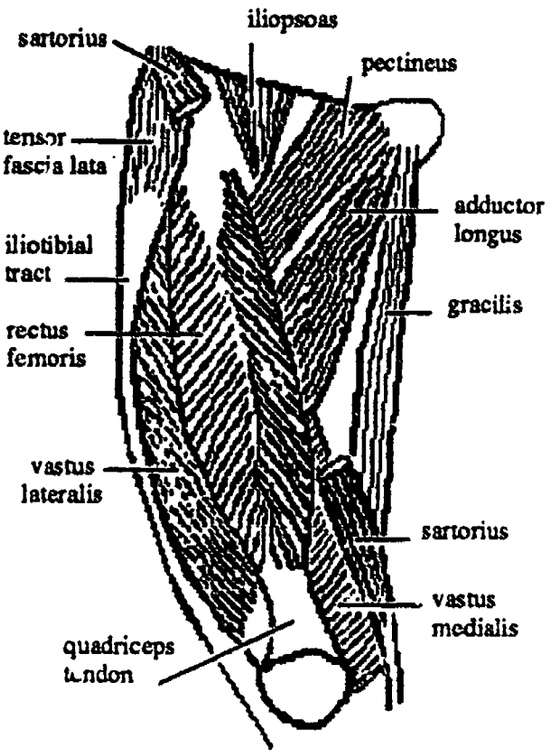


Fig. 55 Anterior Thigh, Right Leg

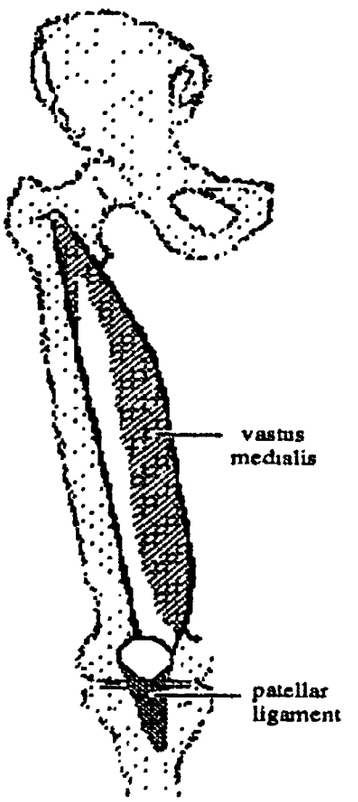


Fig. 57- Vastus Medialis
Right Leg

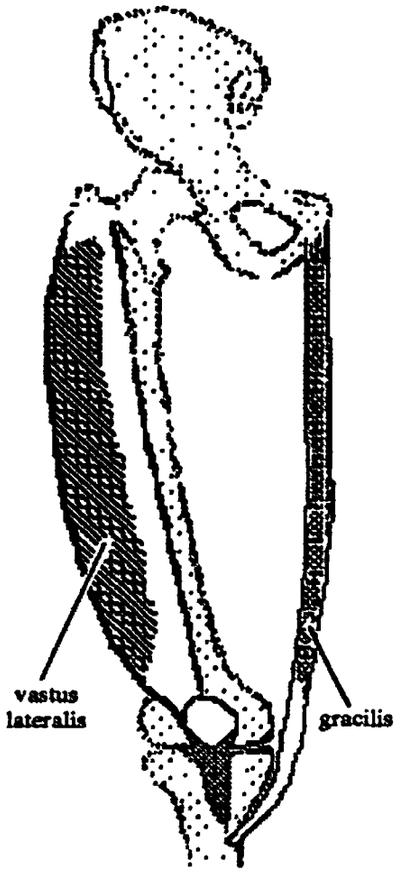


Fig. 58- Vastus Lateralis & Gracilis
Right Leg

MEDIAL THIGH
THE ADDUCTOR GROUP

- *All are adductors*
- *All originate from the pubis and/or ischium*
- *All except gracilis insert on linea aspera.*

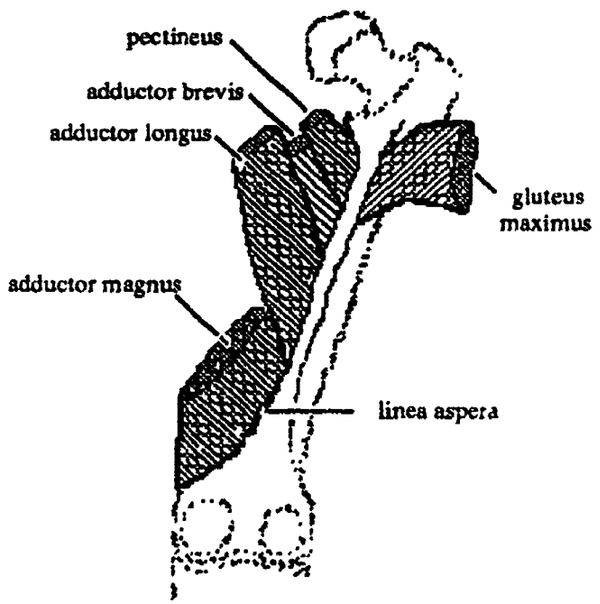


Fig. 59- Adductor Insertions
Posterior view of right thigh, hamstrings removed.

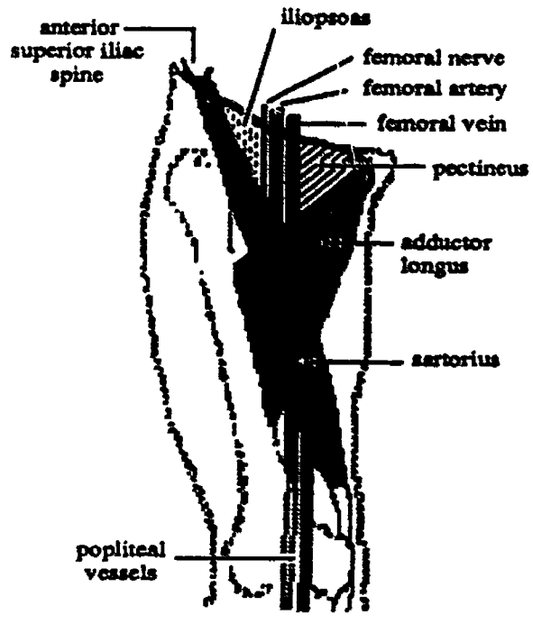


Fig. 60- Adductor Longus & Pectineus
Anterior view of right thigh.

GRACILIS
Graceful, slender, strap-like.in humans (broad in the cat).
O: pubis
I: proximal tibia, medial side
A: adduction of femur, braces the knee, also flexion of hip and knee **See Figs. 55 and 58.**

ADDUCTOR MAGNUS
O: pubis & ischium
I: linea aspera
A: adduction of femur, also flexion, lateral rotation, and extension of femur **See Fig. 60.**

ADDUCTOR LONGUS
O: pubis
I: linea aspera
A: adduction of femur, also flexion and lateral rotation of femur **See Figs. 55, 59, 60.**

ADDUCTOR BREVIS
O: pubis & ischium
I: linea aspera
A: adduction of femur, also flexion and lateral rotation of femur **See Fig. 60.**

PECTINEUS
O: pubis
I: linea aspera
A: adduction of femur, also flexion and lateral rotation of femur **See Figs. 55, 59, 60.**

POSTERIOR THIGH
THE HAMSTRING GROUP

- *All originate from ischial tuberosity.*
- *All insert on the lower leg.*
- *All extend the thigh and flex the knee; they are important in walking.*
- *All rotate the leg.*
- *All brace the knee.*

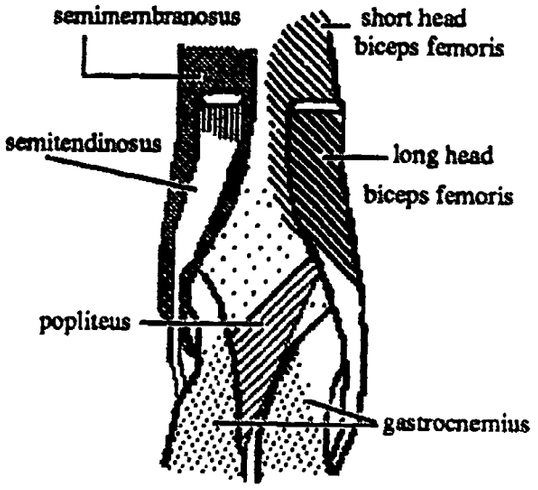


Fig. 61- Hamstring Insertions
Posterior View of Right Knee

BICEPS FEMORIS
O: two heads of origin,
long head: ischial tuberosity,
short head: linea aspera of femur
I: proximal fibula, lateral side
A: extension of hip, flexion of knee, and lateral rotation of leg **See Figs. 61 and 62.**

SEMIMEMBRANOSUS
O: ischial tuberosity
I: proximal tibia, medial side
A: extension of hip, flexion of knee, and medial rotation of leg
See Figs. 61 and 63.

SEMITENDINOSUS
O: ischial tuberosity
I: proximal tibia, medial side
A: extension of hip, flexion of knee, and medial rotation of leg
See Figs. 61 and 64.

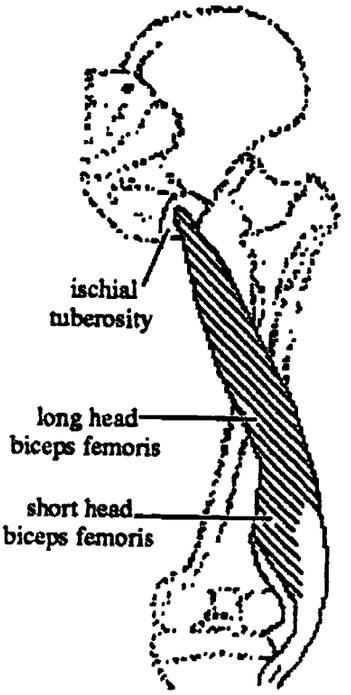


Fig. 62- Biceps Femoris
Posterior View, Right Leg

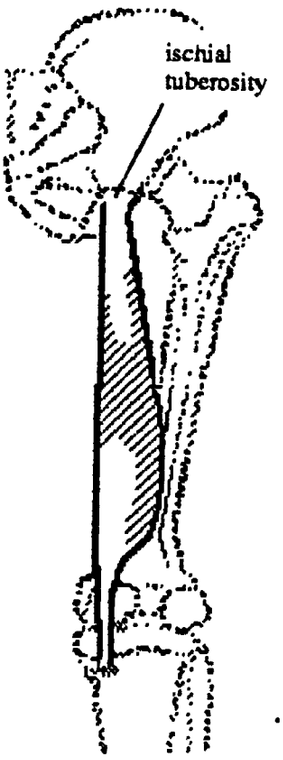


Fig. 63- Semimembranosus
Posterior View, Right Leg

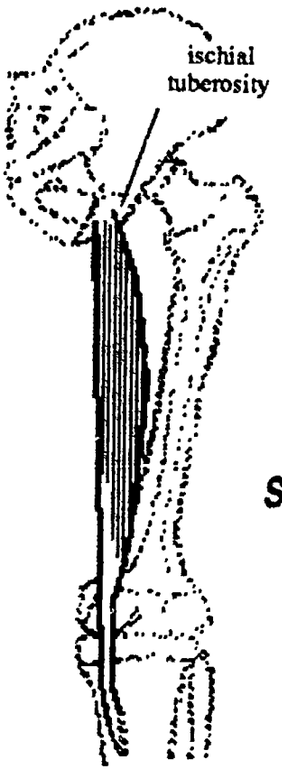


Fig. 64 - Semitendinosus
Posterior View, Right Leg

Muscles of the Lower Leg

ANTERIOR LEG FLEXORS OF THE ANKLE

The knee and toe joints are turned around 180 degrees compared to the joints of the rest of the body. This is particularly confusing when dealing with certain muscles of the lower leg that cross both the ankle and toe joints. The muscles are named for their action at the toe joints, but they do the opposite to the ankle joint. For example, the extensor digitorum flexes the ankle.

All the muscles of this group dorsiflex the ankle; some of them extend the toes as well.

TIBIALIS ANTERIOR

O: tibia
I: base of the 1st metatarsal at the medial arch of the foot
A: dorsiflexion and inversion of foot
See Figs. 65 and 67.

EXTENSOR HALLUCIS LONGUS

O: fibula
I: big toe (hallux)
A: dorsiflexion of foot, extension of hallux
See Fig. 65.

EXTENSOR DIGITORUM

O: tibia
I: four toes
A: dorsiflexion of foot, extension of toes
See Figs. 65 and 66.

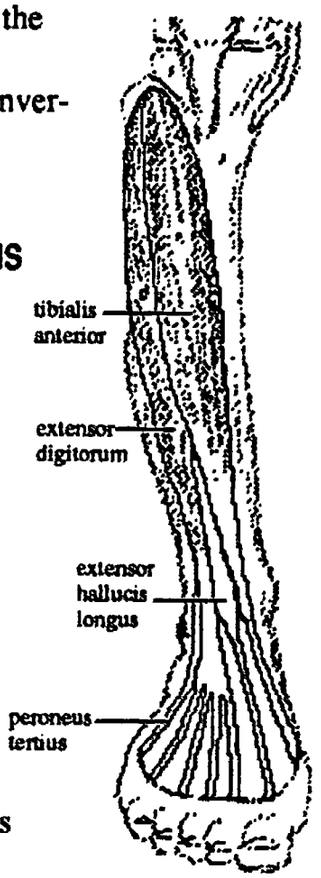


Fig. 65- Flexors of the Ankle
Right Leg, Anterior View

PERONEUS TERTIUS

This small muscle is in a different functional group than the other two peroneus muscles, because it alone crosses the front of the ankle joint.
O: fibula
I: base of 5th metatarsal
A: dorsiflexion and eversion of foot
See Figs. 65 and 66.

LATERAL CRURAL GROUP

These muscles plantar flex the ankle. Plantar flexion is actually extension.
The tendons of this group pass behind the lateral malleolus, and hence cross the ankle joint on the posterior side. This causes them to act differently than the peroneus tertius seen above.

PERONEUS LONGUS

O: fibula and interosseus membrane
I: base of the 5th metatarsal
A: plantar flexion and eversion of foot
See Figs. 66, 67, and 74.

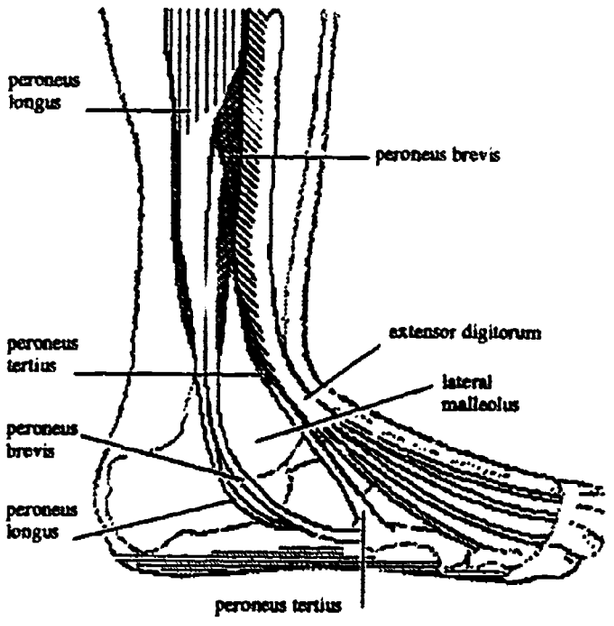


Fig. 66- Tendons of Peroneus Muscles
Dorso-lateral View of Right Foot

PERONEUS BREVIS

O: fibula and interosseus membrane
I: base of the 5th metatarsal
A: plantar flexion and eversion of foot
Figs. 66 and 67.

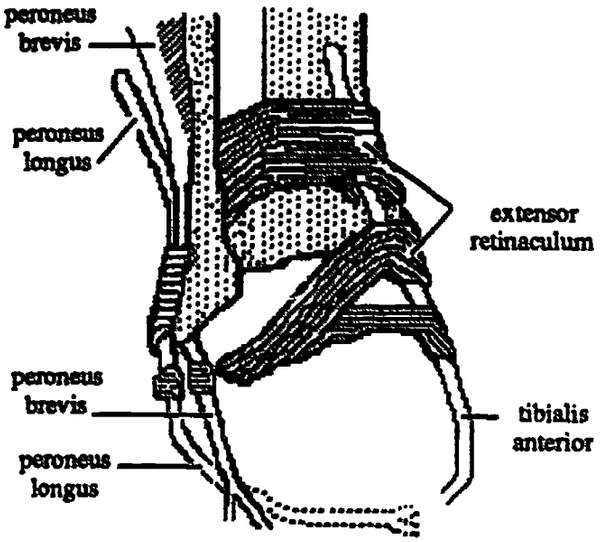


Fig. 66- AnteriorView of Right Foot
Showing common insertion for tibialis anterior and peroneus longus.

POSTERIOR LEG SUPERFICIAL GROUP

These are the calf muscles. Gastrocnemius , soleus, and plantaris have a common tendon of insertion, the tendocalcaneus (Achilles' tendon), which inserts on the calcaneus and raises the heel.

GASTROCNEMIUS

O: two heads of origin, the medial and lateral epicondyles of the femur
I: calcaneus
A: flexion of knee and extension (plantar flexion) of ankle
See Figs. 70 and 61.

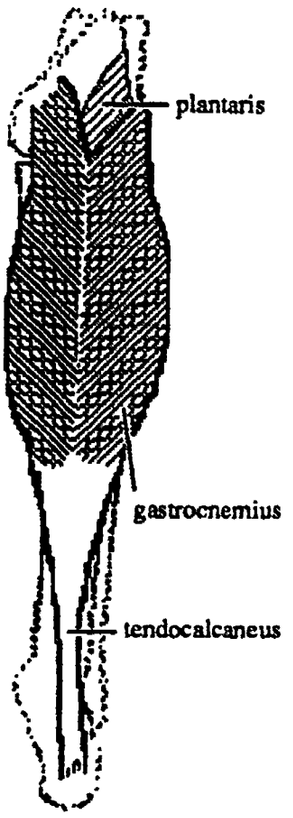


Fig. 68- Gastrocnemius
Right Calf Posterior View

SOLEUS

O: tibia and fibula
I: calcaneus
A: extension (plantar flexion) of ankle
See Fig. 69.

PLANTARIS

In humans this is a small muscle with a very long tendon.
O: lateral epicondyle of femur
I: calcaneus
A: extension (plantar flexion) of ankle and flexion of knee
See Fig. 69.

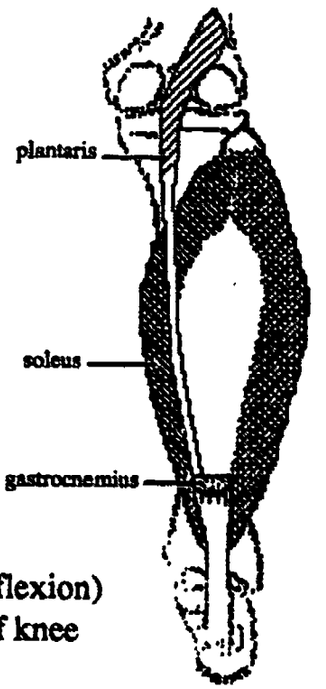


Fig. 69- Soleus and Plantaris
Right Calf Posterior View, Gastrocnemius Removed

POPLITEUS

This small muscle is confined to the floor of the popliteal fossa.
O: femur, lateral condyle
I: tibia, medial side
A: rotates lower leg medially to unlock the knee joint
See Fig. 61.

POSTERIOR LEG DEEP GROUP

The tendons of this group pass behind the medial malleolus. They all plantar flex (extend) and invert the foot.

TIBIALIS POSTERIOR

O: tibia, fibula, and interosseous membrane
I: tarsus
A: plantar flexion & inversion of foot
See Figs. 70, 73, and 74.

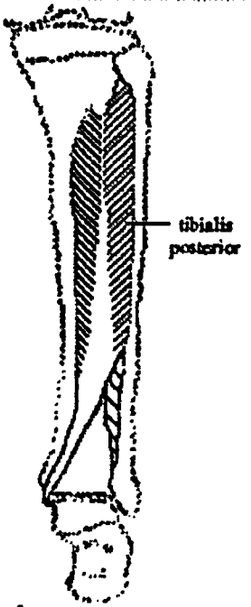


Fig. 70- Tibialis Posterior
Right Leg, Posterior View

FLEXOR DIGITORUM LONGUS
O: tibia
I: four toes
A: flexion of the toes, as well as plantar flexion & inversion of foot
See Figs. 71, 73, 74.

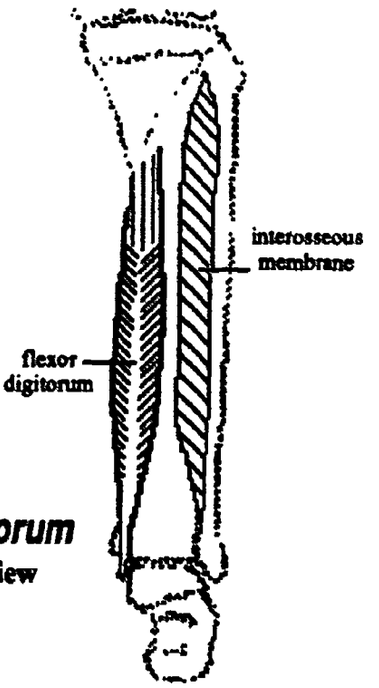


Fig. 71- Flexor Digitorum
Right Leg, Posterior View

FLEXOR HALLUCIS LONGUS
The tendon lies closest to the bone.
O: fibula
I: great toe
A: flexion of the big toe as well as plantar flexion & inversion of foot
See Figs. 72, 73, and 74.

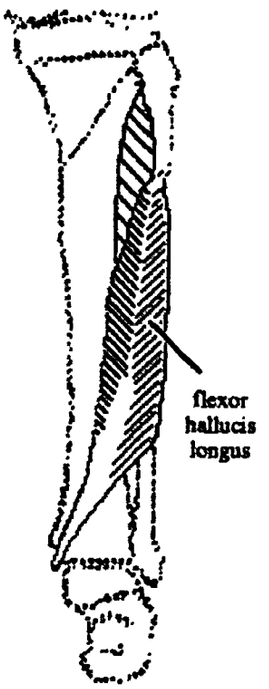


Fig. 71- Flexor Hallucis Longus
Right Leg, Posterior View

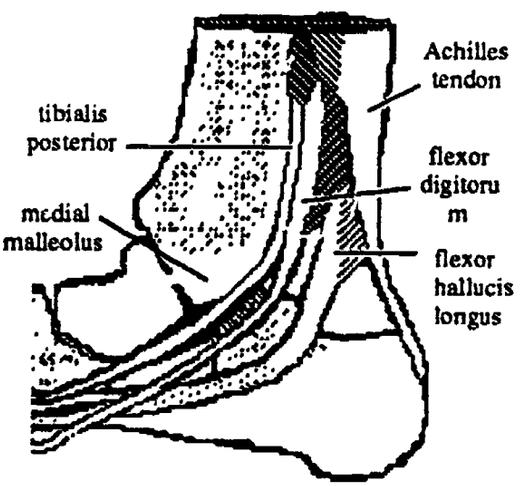


Fig. 73- Tendons of Deep Calf Muscles
Right Foot, Medial View

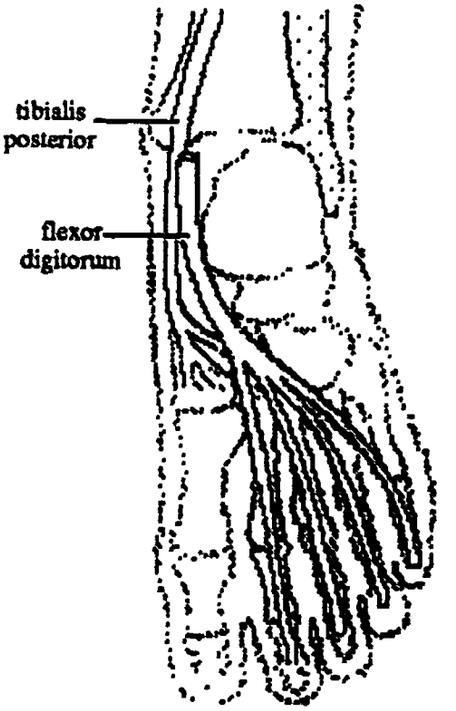


Fig. 74-A

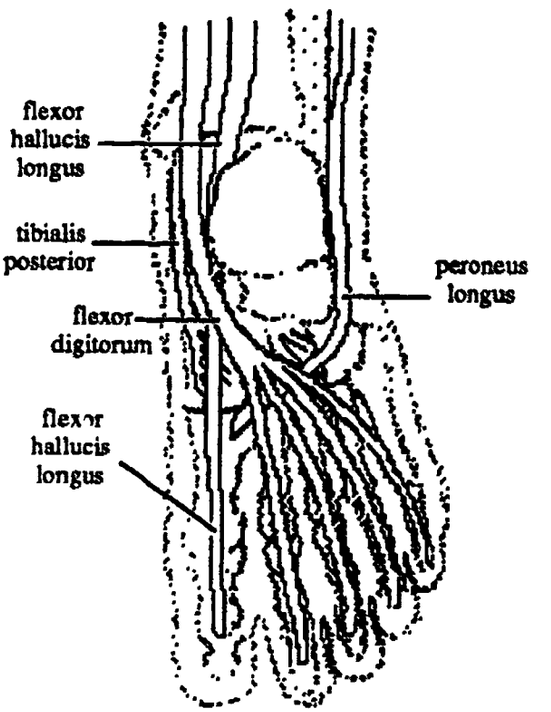


Fig. 74-B

Fig. 74 A & B- Insertions of the Deep Calf Muscles. *Figure 74A is less detailed than Figure 74B.* **Right Foot, Ventral View**

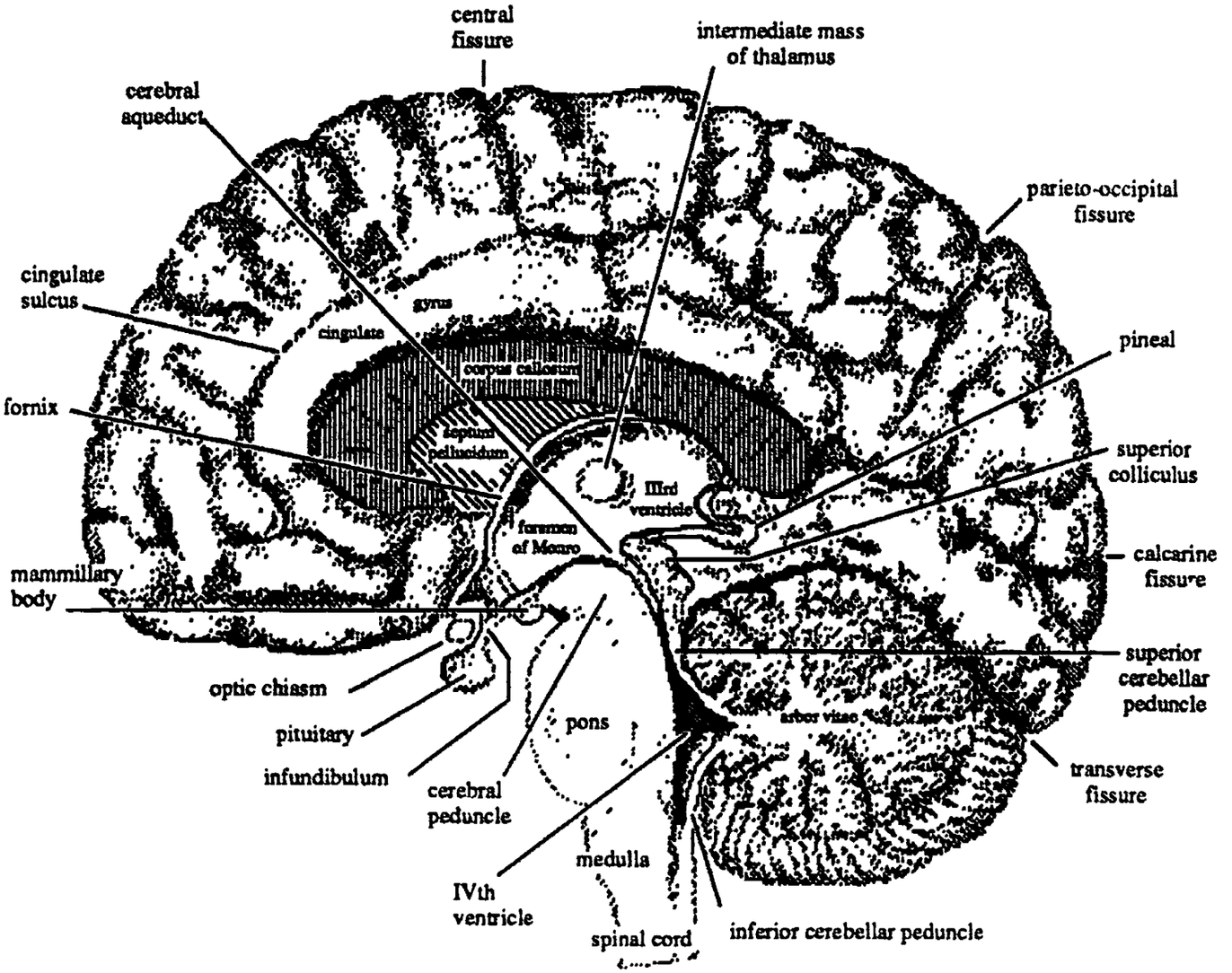


Fig. 76- Human Brain In Sagittal Section

Introduction to Nervous System
Basic Terminology and Basic Concepts

CELL TYPES

NEURONS

- cell body
- dendrite
- axon

NEUROGLIA

- Schwann cells
- oligodendroglia
- astroglia
- microglia

EPENDYMAL CELLS

PARTS OF A SYNAPSE:

- boutons terminaux;
- synaptic vesicles;
- synaptic cleft;
- presynaptic membrane
- post synaptic membrane;
- receptor sites
- transmitter esterase
- motor end plate

NEUROTRANSMITTERS:

FACILITATORS:

- Acetylcholine
- Adrenalin
- Epinephrine
- Norepinephrine

INHIBITORS:

- Serotonin
- Dopamine
- GABA

THE NERVE IMPULSE:

A nerve impulse is a traveling membrane depolarization.

PERIPHERAL NERVES:

MYELINATION

- myelin
- nodes of Ranvier
- neurilemma
- Schwann cells
- "Jelly Roll Theory of myelin formation"
- regeneration
- unmyelinated nerves;

OTHER COVERINGS:

- endoneurium
- perineurium
- epineurium

GRAY MATTER:

Gray matter areas are regions where cell bodies and dendrites predominate. The implication is that synapses are made here. Masses of gray matter are called:

- cortex
- nuclei
- ganglia

or by individual names such as:

- olive
- amygdala
- hippocampus
- hypothalamus
- thalamus

NUCLEUS:

A group of nerve cell bodies **within** the CNS; no connective tissue boundaries.

GANGLION:

A group of nerve cell bodies **outside** the CNS; encapsulated by connective tissue.

CORTEX:

A surface layer of gray matter (about 1/4 inch thick) found on the cerebrum and cerebellum.

WHITE MATTER :

White matter areas are regions where myelin is predominante. The implication is that axons are passing thru\ough the area in large numbers. Masses of white matter are called by such names as:

- tracts
- nerves
- commissures
- pathways
- fasciculi
- corona radiata

TRACTS:

Bundles of axons traveling within the CNS; not covered with connective tissue wrappings.

- ascending or afferent tracts (sensory)
- descending or efferent tracts (motor)
- Commissures

NERVES:

Bundles of axons traveling outside the CNS; covered with connective tissue wrappings. Some nerves are **afferent** and some are **efferent.**

Spinal Cord Anatomy & Spinal Nerves

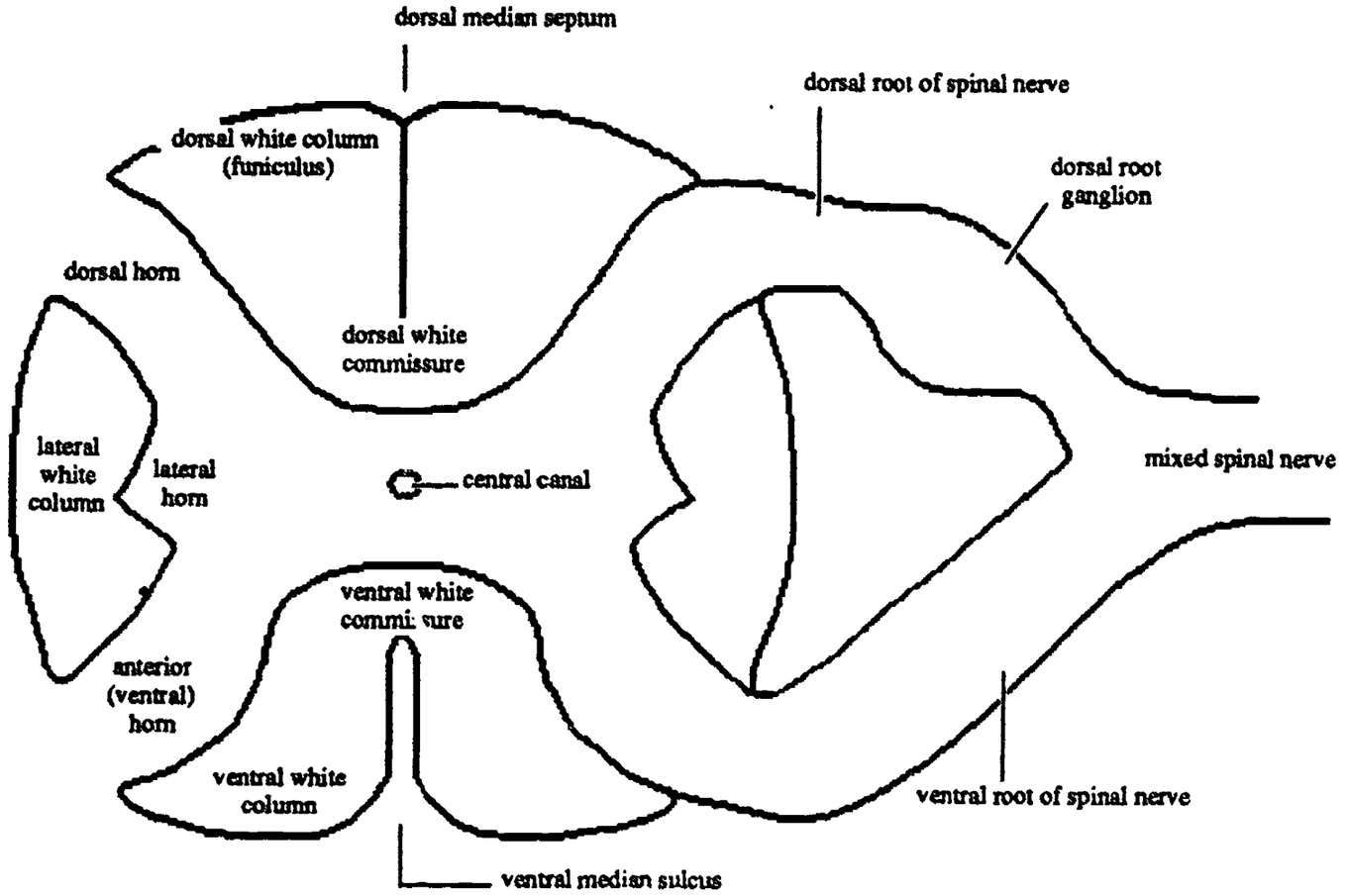


Fig. 77- Diagram of Spinal Cord in Cross Section

SPINAL REFLEX ARC

• SENSORY NERVES

DORSAL ROOT GANGLION CELLS

The receptor of a sensory nerve resides in the periphery of the body, the axon synapses with a nerve cell in the gray matter of the spinal cord, and the cell body resides outside of the cord in the dorsal root ganglion.

• INTERNUNCIAL NERVES

The cell body, axon, and synapse of an internuncial neuron all lie entirely within the spinal cord.

• MOTOR NERVES:

ANTERIOR HORN CELLS:

Anterior horn cells are the cell bodies of motor neurons which synapses with skeletal muscle cells.

LATERAL HORN CELLS:

Lateral horn cells are the cell bodies of autonomic nervous system motor neurons that synapse with cells in ANS ganglia. Lateral horn cells are also called **preganglionic motor neurons.** (Postganglionic neurons are those which start in the ganglia and synapse with smooth muscle, cardiac muscle, or gland cells.)

SPINAL CORD TERMINOLOGY

Cervical Enlargement;
Brachial Plexus;
Lumbar Enlargement,
Lumbosacral Plexus;
Conus Medullaris;
Cauda Equina;
Filum Terminale;

SPINAL NERVES AND THEIR DISTRIBUTION

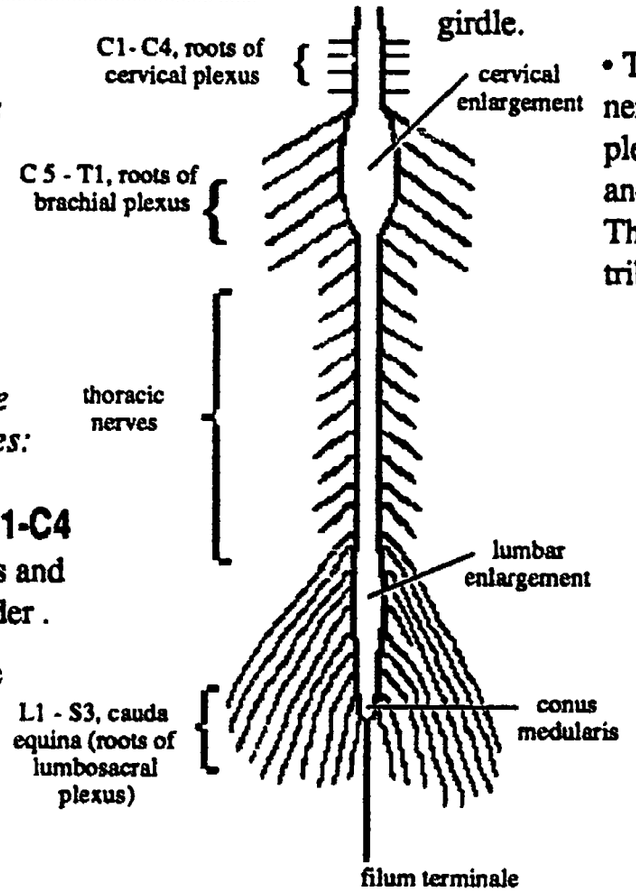
There are 8 pairs of cervical nerves, 12 pairs of thoracic nerves, 5 pairs of lumbar nerves, and 5 pairs of sacral nerves, and 1pair of coccygeal nerves. The roots of these nerves often combine in complex patterns to form plexuses (networks). There are four important plexuses:

CERVICAL PLEXUS: C1-C4

• C 1-3 supply the muscles and skin of theneck and shoulder .

• There is one major nerve from the cervical plexus (mostly C4):

PHRENIC NERVE
supplies the diaphragm



BRACHIAL PLEXUS: C_5-C_8 AND T_1

• Some branches from this plexus supply the muscles and skin of the shoulder girdle.

• There are four major nerves from the brachial plexus that supply the skin and muscles of the arm. They are named and distributed as follows:

RADIAL NERVE :
extensors of both arm and forearm

MUSCULOCUTANEOUS NERVE :
flexors of upper arm

MEDIAN NERVE :
flexors of forearm, thumb side

ULNAR NERVE :
flexors of forearm, little finger side

Fig. 78- Diagram of Human Spinal Cord & Spinal Nerve Roots
Longitudinal View

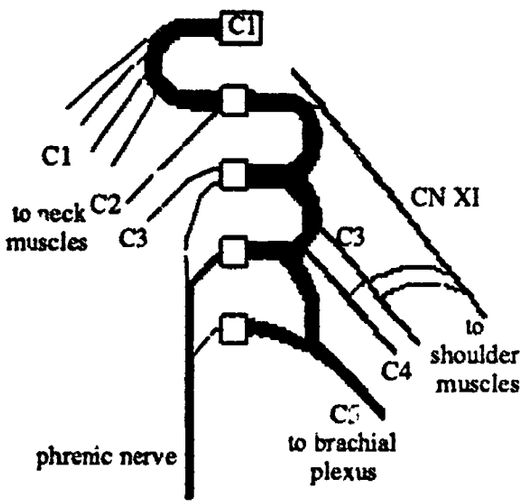


Fig. 79- Distribution of Cervical Plexus
Left Arm, Anterior View.

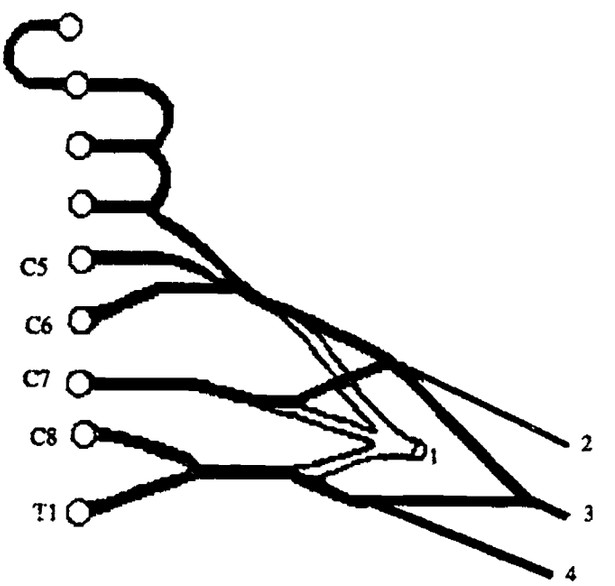


Fig. 80- Distribution of Brachial Plexus
1. radial nerve 2. musculocutaneous nerve 3. median nerve 4. ulnar nerve

THORACIC NERVES : T_2-T_{12}

The thoracic nerves (except for T1) do not form a plexus, they simply become the:

INTERCOSTAL NERVES.

LUMBOSACRAL PLEXUS:

The lumbosacral plexus is divided into two subsections, the lumbar plexus and the sacral plexus.

LUMBAR PLEXUS: L_1- L_4

FEMORAL NERVE:
anterior thigh muscles and skin (quadriceps, iliopsoas, and sartorius).

OBTURATOR NERVE:
gracilis, adductor longus, and adductor brevis

SACRAL PLEXUS: L_4-S_3)

SCIATIC NERVE
tibial and peroneal branches. Supplies gluteal region; adductor magnus; posterior thigh and all of leg and foot. Safe gluteal quadrant.

PUDENDAL NERVE:
sensory and motor to the genitalia, pelvic organs and pelvic muscles.

AUTONOMIC NERVOUS SYSTEM

There are two divisions of the ANS: sympathetic and parasympathetic. The two divisions have some things in common and they have some differences.

SIMILARITIES:

EFFECTOR ORGANS:

One important similarity is that both divisions supply the same effector organs, namely smooth muscle, cardiac muscle, and gland.

GANGLIA:

A second similarity is that both divisions use ganglia. However the ganglia have very different locations in the two divisions

MOTOR SUPPLY:

A third important feature shared by both divisions is that motor supply to the effector organ requires two motor nerves. The first of these nerves is termed a **preganglionic neuron** since it starts in the CNS and ends at a ganglion. The second of these nerves is termed a **postganglionic neuron** since it starts in the ganglion and goes to the effector.

DIFFERENCES:

GANGLION LOCATION:

PARAVERTEBRAL:
These are sympathetic ganglia. There are 22 of them on each side of the body. They are located next to the vertebral column, and are connected to one another in a chain like formation, hence: *paravertebral* chain. The term *sympathetic trunk* also refers to the chain of paravertebral ganglia.

COLLATERAL
These are sympathetic ganglia. There are three of them:

- celiac ganglion
- superior mesenteric ganglion,
- inferior mesenteric ganglion.

TERMINAL
These are parasympathetic ganglia. They are located within the wall of the organ being supplied. They are very small and will not be visible in the laboratory.

PREGANGLIONIC CELL LOCATION

THORACOLUMBAR:
For the sympathetic division the preganglionic cell body is located between sections T1-T12 and L1- L2 of the spinal cord, hence the synonym *thoracolumbar nervous system*. The cell body itself is known as a *Lateral Horn Cell.*

CRANIOSACRAL:
For the parasympathetic division the preganglionic cell body is located in either the brain stem or the sacral region of the cord, hence the synonym *craniosacral nervous system.* The specific nerves involved are: cranial nerves III, VII, IX, and X, and spinal nerves S_2-S_5.

NEUROTRANSMITTERS:

The synaptic neurotransmitter used at the postganglionic synapse differs for the two systems.

ADRENALIN
The sympathetic system uses adrenalin, epinephrine, or norepinephrine as its neurotransmitter, hence the synonym ***adrenergic nervous system.***

ACETYLCHOLINE
The parasympathetic nervous system uses acetylcholine as its neurotransmitter, hence the synonym ***cholinergic nervous system.***

HYPOTHALAMIC CONTROL:

The sympathetic nervous system is regulated by the *posterior and lateral regions* of the hypothalamus, including the area known as the *mammillary* bodies.

The parasympathetic system is regulated by the *anterior and medial regions* of the hypothalamus.

FUNCTIONAL COMPARISONS AND CONTRASTS:

The term *autonomic* implies regulation and adjustment.

The sympathetic system generally mobilizes and expends energy, and preserves the individual's existence.

The parasympathetic system generally conserves and stores energy resources and preserves the species.

EMERGENCY ACTION:

In addition to its homeostatic function, the sympathetic system is also capable of a mass discharge, causing large amounts of adrenalin to be released from the adrenal medulla. This type of mass action causes pronounced physiological changes known as the ***fight or flight syndrome.***

HOMEOSTASIS

The dramatic effects of a mass discharge of the sympathetic nervous system in stressful situations (*fight or flight syndrome* changes) should not obscure the fact that the sympathetic nervous system also functions every day, every hour, every minute to give a ***tonic balancing effect.***

The end result achieved by the ANS is homeostatic adjustment and regulation. Both divisions are *operating constantly* to keep the body in homeostasis

For example, tonic discharges to the arterioles maintain arterial blood pressure. Also, stimulation of the sympathetic nerves to the heart causes an increased heart rate without necessarily involving mass discharge to the body in any generalized way.

SPECIFIC ACTIONS:

SYMPATHETIC:

- dilates blood vessels to muscles and skin;
- constricts blood vessels to viscera;
- increases the rate & strength of heart contractions;
- increases the rate and depth of respiration;
- dilates the pupil;
- inhibits saliva flow;
- inhibits digestive secretions;
- inhibits peristalsis;
- constricts the sphincters of bladder and anus (up to a point);
- causes ejaculation followed by constriction of blood vessels to the erectile tissues.

PARASYMPATHETIC:

- constricts the blood vessels to muscles and skin ;
- dilates the blood vessels to viscera;
- decreases heart rate;
- decreases respiration;
- constricts the pupils;
- stimulates flow of saliva
- stimulates flow of all digestive secretions;
- stimulates peristalsis;
- relaxes sphincters of the bladder and anus;
- promotes sexual arousal and dilates blood vessels to the erectile tissues.

PHYSICAL CONNECTIONS:

Refer to Figure. 81.

All preganglionic motor nerves exit from the CNS along with the motor root of ordinary spinal or cranial nerves.

The preganglionic parasympathetic nerves simply stay with the spinal or cranial nerve and travel to their destination, but the preganglionic sympathetic nerves must leave the spinal nerves to get to the ganglion, and then the nerve exiting from the ganglion must rejoin the spinal nerve.

COMMUNICATING RAMI:

The nerves going to and from the ganglion travel as groups called rami. The preganglionic nerves are myelinated so they form a ***white*** **ramus communicans.** The postganglionic nerves are unmyelinated so they form a ***gray*** **ramus communicans.**

SPLANCHNIC NERVES;

Preganglionic nerves found in the abdomen and pelvis headed for the collateral or terminal ganglia (not the paravertebral ganglia. They may be either sympathetic or parasympathetic.

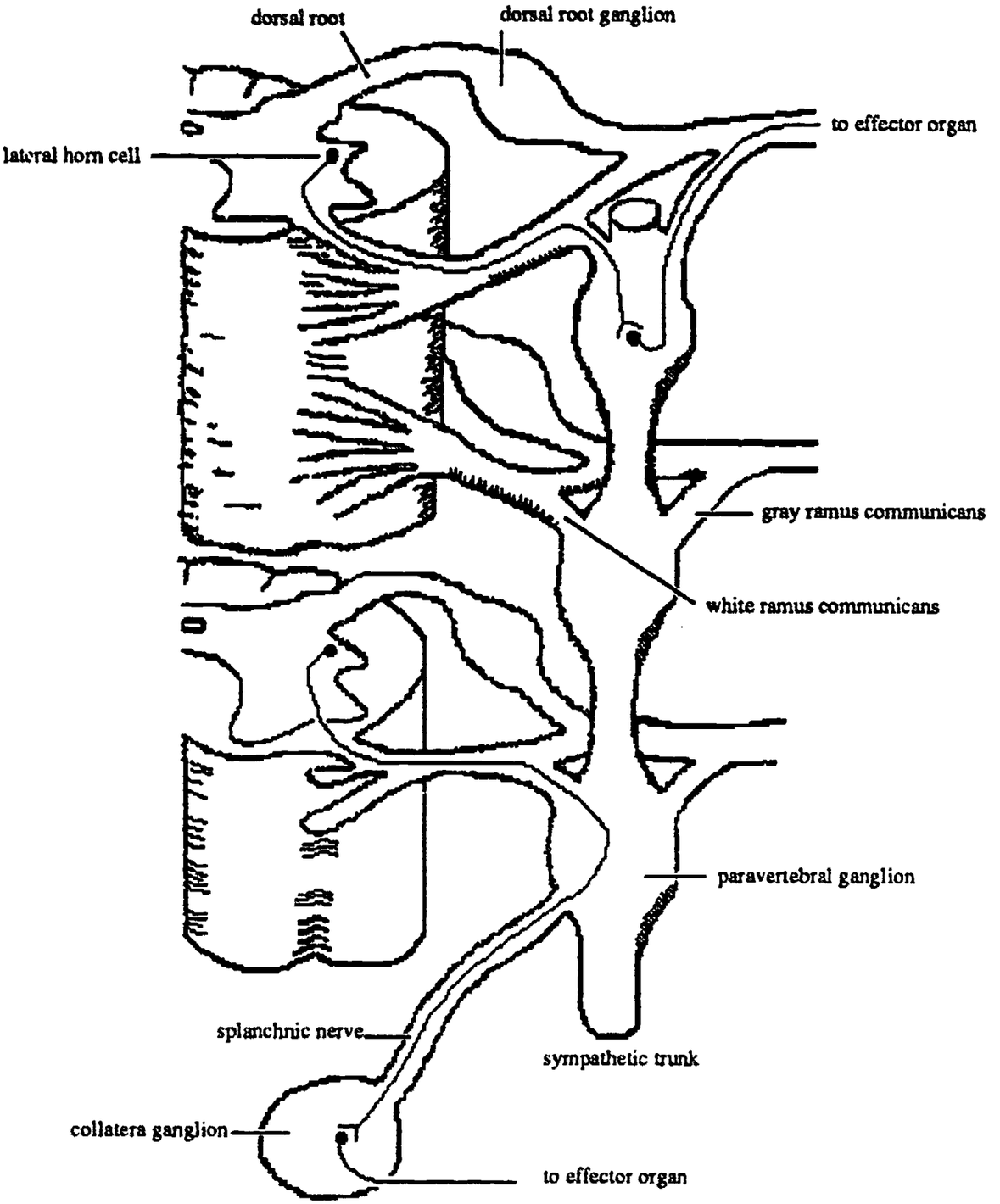


Fig. 81- Communicating Rami and Splanchnic Nerves

Cranial Nerves

Cranial nerves are typically classified as sensory, motor, and mixed. It is not usually acknowledged, but any cranial nerve which contains a motor component will also include sensory fibers from the stretch receptors (proprioceptors) in that muscle.

I. OLFACTORY:

Special sensory nerve for the sense of smell. The receptors are actually brain cells that begin in the mucous membrane of the nose and then penetrate the cribriform plate of the skull to join the olfactory bulb of the brain. This nerve is unique because it is the only known instance in which brain cells themselves interface with the environment.

II. OPTIC:

Special sensory nerve for light. The receptors are the rods and cones of the retina of the eye.

III. OCULOMOTOR:

Motor nerve:

a. Motor innervation to four of the six extrinsic (voluntary) muscles of the eye.

b. Parasympathetic innervation to the ciliary muscles of the lens and the circular (constrictor) muscles of the iris (pupil).

IV. TROCHLEAR:

Motor supply to the superior oblique muscle, one of six extrinsic (voluntary) eye muscles.

V. TRIGEMINAL:

Mixed nerve: The face is divided into three zones, each supplied by one of the three branches of the trigeminal. The mandibular branch is the one that is both sensory and motor, the other branches are just sensory. The sensory supply is for pain, touch, and temperature.

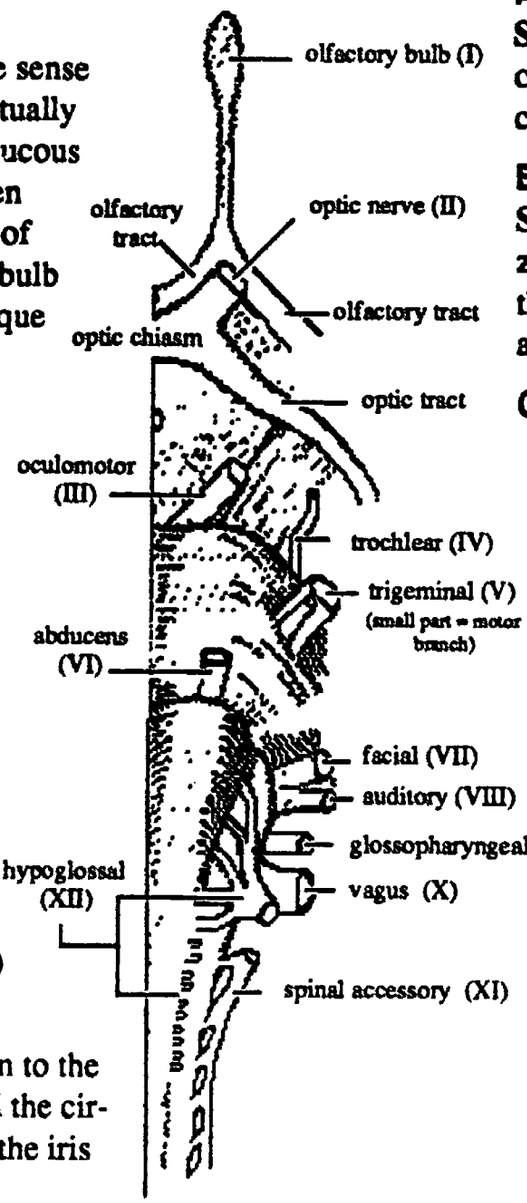


Fig. 82- Cranial Nerves
Human Brain, Left Side, Inferior View

A. OPHTHALMIC DIVISION:

Sensory from the upper 1/3 of the face, including the cornea of the eye.

B. MAXILLARY DIVISION:

Sensory from the middle zone of the face, including the maxilla and upper teeth, and the nose area.

C. MANDIBULAR DIVISION:

Sensory from the lower 1/3 of the face, including the jaw and lower teet, and

Motor to the muscles of mastication (mainly).

VI. ABDUCENS:

Motor supply to the lateral rectus muscle, which is one ofthe six extrinsic (voluntary) eye muscles.

VII. FACIAL:

Mixed nerve.

a. Sensory for **taste** from the anterior 2/3 of the tongue.

b. Motor to the muscles of facial expression.

c. Parasympathetic to the submandibular and sublingual salivary glands, tear glands, and mucous glands of nose.

VIII. AUDITORY

(also called Vestibulo-cochlear or Auditory-vestibular, or Stato-acoustic): **Sensory nerve:** two separate divisions, the ***cochlear nerve*** (from receptors in the cochlea of the inner ear), is for hearing, and the ***vestibular nerve*** (from receptors in the vestibule and semicircular canals of the inner ear), is for equilibrium.

IX. GLOSSOPHARYNGEAL:

Mixed nerve

a. Sensory for **taste** from the posterior 1/3 of the tongue. Also sensory from the carotid sinus for blood pressure regulation.

b. Voluntary motor to the muscles of the pharynx, for swallowing.

c. Parasympathetic to the parotid salivary gland.

X. VAGUS:

Mixed nerve; chiefly parasympathetic.

a. Parasympathetic to all internal organs in chest and abdomen. Slows the heart, constricts the airways, promotes peristalsis and promotes digestive secretions. Innervation for coughing, sneezing, and vomiting reflexes.

b. Voluntary motor to pharyngeal muscles for swallowing, and to larynx muscles for speech.

c. Sensory from the:

a. tongue (taste),

b. carotid &aortic bodies (blood pressu ,

c. larynx, throat, trachea, esophagus, and internal viscera of chest and abdomen (temperature and stretch receptors).

XI. SPINAL ACCESSORY:

Motor to skeletal muscles in neck area.

a. to muscles of pharynx and larynx for swallowing and speech.

b. to sternocleidomastoid and trapezius muscles.

XII. HYPOGLOSSAL:

Motor to the tongue muscles for speech and swallowing.

Ventricles, Spinal Fluid, Meninges, Blood Supply

VENTRICLES:

LATERAL VENTRICLES:

Also called ventricle I and II, there is one inside each cerebral hemisphere. Each is a fairly large cavity with a complex shape, including anterior horn, posterior horn, and lateral horn.

IIIRD VENTRICLE:

A small slit-like (extremely narrow) cavity in the center of the diencephalon.

IVTH VENTRICLE:

Lies between the cerebellum and pons in the hind brain. It is continuous with the central canal of the spinal cord. It is described as beingthe shape of a three dimensional diamond.

FORAMENA OF FOURTH VENTRICLE:

There are two lateral foramena (foramena of Luschka) and one midline foramen (foramen of Magendie). The IVth Ventricle connects with the subarachnoid space via these openings.

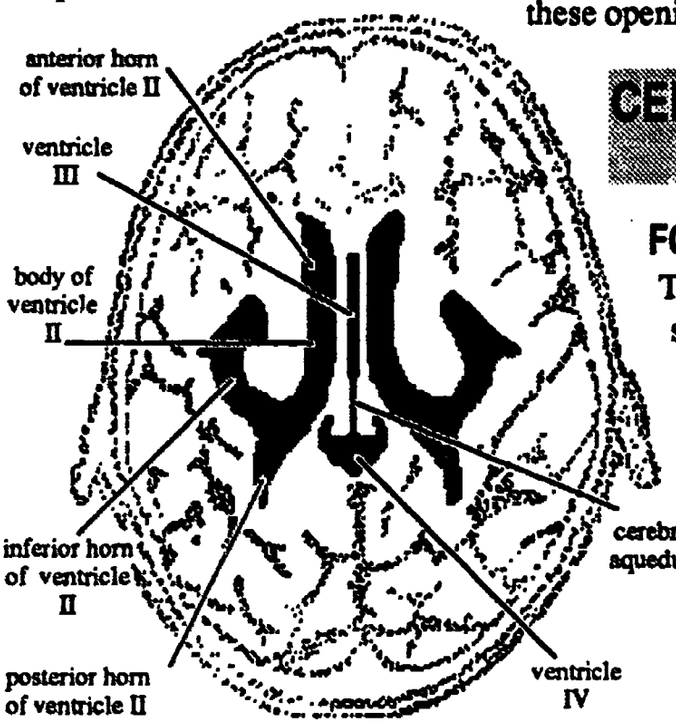


Fig. 83- Ventricles, Superior View
shown superimposed upon the cerebral hemispheres

FORAMINA & PASSAGEWAYS

INTERVENTRICULAR FORAMENA

Also called Foramen of Monro: connects each of the lateral ventricles to the IIIrd ventricle.

CEREBRAL AQUEDUCT:

Also called Aqueduct of Sylvius: connects ventricle III with ventricle IV; a long canal which passes lengthwise through the midbrain.

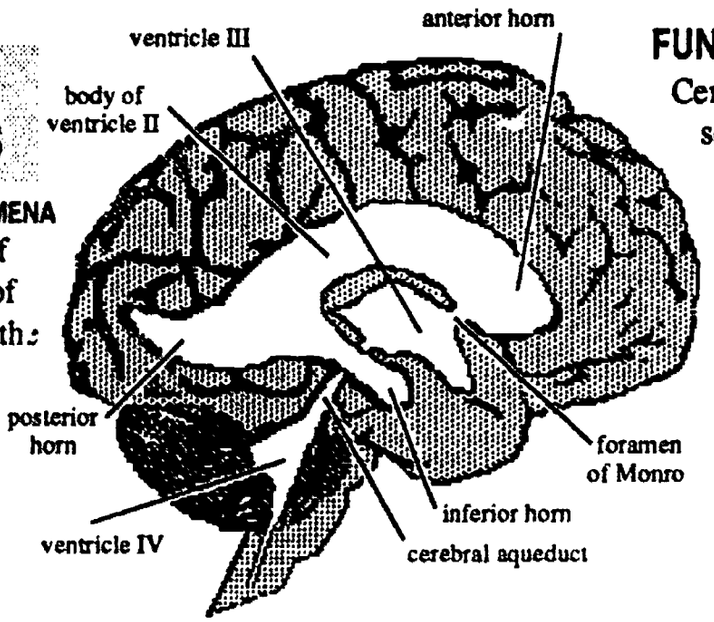


Fig. 84- Ventricles, Lateral View
shown superimposed upon the cerebral hemispheres

CEREBRAL SPINAL FLUID

FORMATION:

The **Choroid Plexus** constantly secretes cerebral spinal fluid into the ventricles. The choroid plexus is thought to be a combination of the specialized capillaries of the ventricles intertwined with the ependymal cells lining the ventricles. The process of formation is thought to be one of selective filtration or secretion.

FUNCTION

Cerebral spinal fluid serves as a shock absorber (water cushion or water jacket), protecting the brain and spinal cord. There is some evidence that it may provide a circulation pathway for certain natural chemicals or hormones.

CHARACTERISTICS OF CSF:

Cerebral spinal fluid is a clear, watery, straw colored filtrate of blood plasma. It is sterile, and normally it should be free from red and white blood cells. It contains small amounts of protein, glucose, and chloride. The volume ranges from 80-200 ml, the average for adults is 100-140 ml, with 15 ml being found in the ventricles, the rest in the subarachnoid space. Samples of the fluid are usually obtained for analysis by lumbar puncture.

CIRCULATION OF CSF:

Cerebral spinal fluid leaves each **lateral ventricle** by way of the **Foramen of Monro**; it leaves the **IIIrd ventricle** by way of the **Aqueduct of Sylvius**; it leaves the **IVth ventricle** by way of the **foramena of Luschka and Magendie**, and enters the **subarachnoid spaces**. From there it enters the **superior sagittal sinus** (vein) by way of the arachnoid villi.

REABSORPTION OF CSF:

Since the CSF is being formed constantly, it must be reabsorbed constantly, otherwise the intracranial pressure would rise, with serious consequences. Reabsorption is by way of the arachnoid villi into the venous superior sagittal sinus.

MENINGES

DURA MATER:

The outermost sheath of tough, dense, elastic connective tissue surrounding the brain and spinal cord.

The spinal dura extends all the way down to S2. It ensheathes the whole cord and the cauda equina, and extends out around the dorsal and ventral roots of the spinal nerves. There it feathers out to become the thinner epineurium covering the nerve

The dura surrounding the brain has three extensions. Each of these is a double fold of dura that projects inward into the fissures, effectively partitioning the cranial space into smaller compartments.

FALX CEREBRI

FALX CEREBELLI

TENTORIUM CEREBELLI

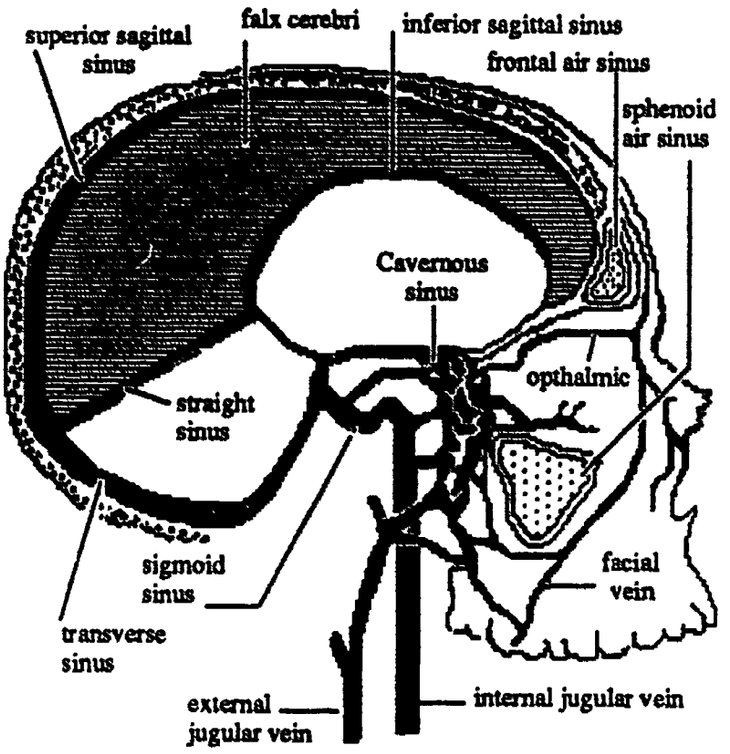


Fig. 85- Falx Cerebri and Venous Drainage of the Brain

ARACHNOID MATER:

Delicate, serous, connective tissue beneath the dura; it does not dip down into the sulci, but lies close to the dura all the way. The name implies it's spider web like appearance. The following are noteworthy features of the arachnoid:

ARACHNOID TRABECULAE

ARACHNOID VILLI (ARACHNOID GRANULATIONS)

SUBARACHNOID SPACES:

- **Lumbar Cistern**
- **Great Cistern(Cisterna Magna)**
- **Superior Cistern**
- **Interpeduncular Cistern**
- **Pontine Cistern**

PIA MATER:

Thin, delicate, highly vascular, connective

tissue that adheres to the surface of the brain and cord and dips down into all sulci. The filum terminale at the inferior end of the spinal cord is made of pia mater.

VENOUS DRAINAGE OF THE BRAIN

The blood (containing absorbed CSF) drains out of the skull by passing sequentially into the **transverse sinus, sigmoid sinus and internal jugular vein.**

If at any time this circulation pathway is blocked pressure will start building up inside the cranium. If blockage occurs in childhood, before the sutures of the skull have fused, the head will enlarge. This pathology is called ***hydrocephalus***.

BLOOD SUPPLY TO BRAIN

The arteries which supply blood to the brain are the paired vertebral arteries and the paired internal carotid arteries. Once inside the skull these four arteries join the Circle of Willis.

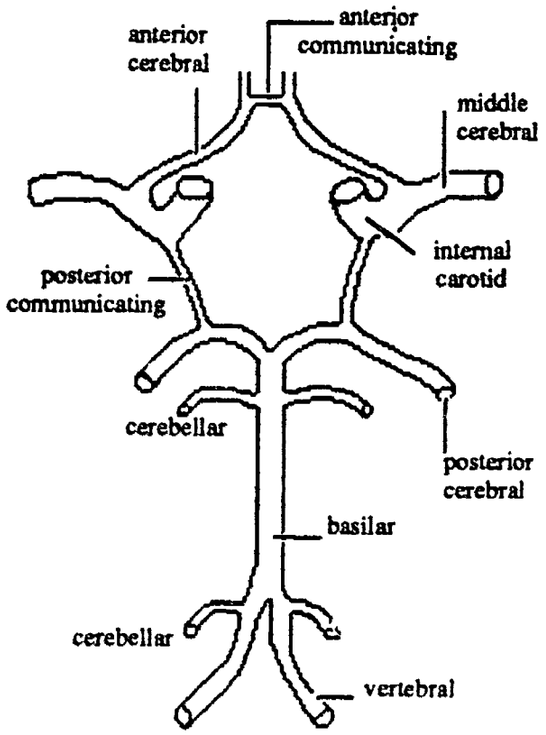


Fig. 86- Blood Supply to the Brain: The Circle of Willis

The vertebrals enter the skull via the foramen magnum. They unite on the ventral surface of the brain stem to form the single basilar artery, which then splits to form the two posterior cerebral arteries.

The internal carotid arteries enter the skull via the carotid foramena and carotid canals. Each internal carotid splits into a middle cerebral artery and an anterior cerebral artery.

The two anterior cerebrals join via the anterior communicating artery. Each middle cerebral artery joins with the posterior cerebral artery via the posterior communicating artery.

BLOOD BRAIN BARRIER

Common nutritive substances like glucose and oxygen pass freely into the brain tissue, as well as into the CSF, but if chemicals potentially capable of disrupting brain function are introduced into the bloodstream they will be screened out (except Na+, K+, and certain drugs). The only area of the brain excepted is the posterior inferior region of the brain stem (part of the medulla oblongata), which is the location of the center that controls the vomiting reflex.

Mechanisms: The present theory is that the capillaries of the brain create the barrier; there are no pores in the capillary walls in the central nervous system, therefore substances must penetrate the capillary walls directly. Another theory is that astrocytes act as middlemen, carrying substances from the capillaries to the nerve cells. Not all substances passing through the capillaries are able to enter the astrocytes.

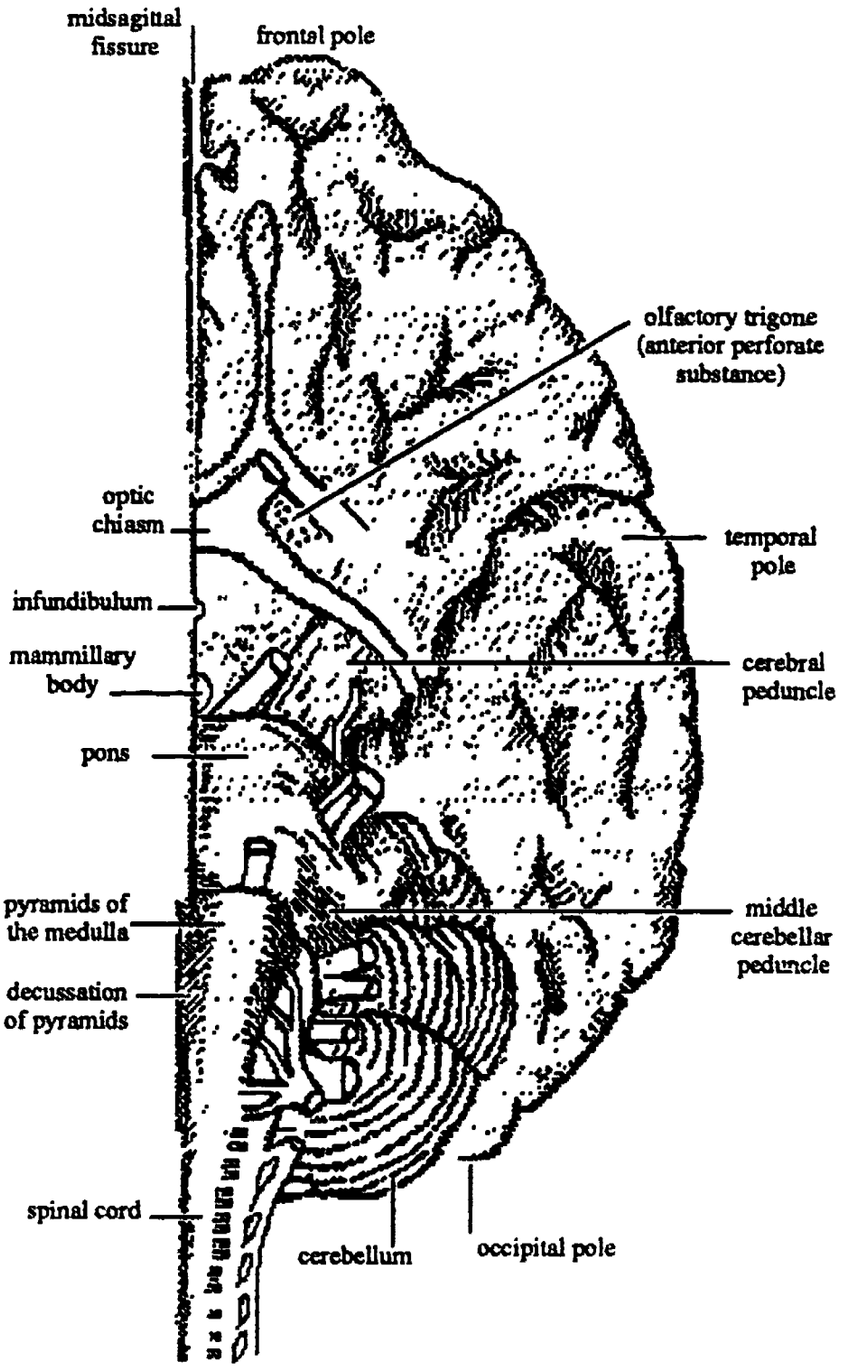


Fig. 87- Human Brain, Left Hemisphere
Inferior View

Embryology of the Brain

EMBRYOLOGICAL REGIONS:

The brain develops from the anterior end of the dorsal hollow neural tube of the embryo. This area subdivides into three regions, and each region then further subdivides. The adult structures are all derivatives of these embryological subdivisions.

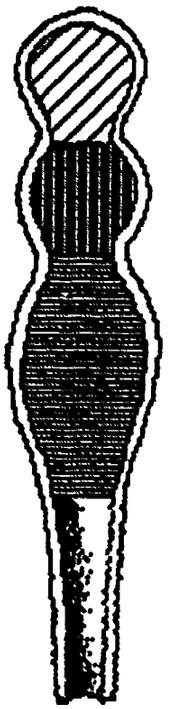


Fig. 88- Embryonic Neural Tube
Anterior End, Longitudinal Section

I. PROSENCEPHALON (FOREBRAIN)

A. TELENCEPHALON
newest part of the forebrain

NEOPALLIUM
newest part of telencephalon

RHINENCEPHALON (LIMBIC SYSTEM)
oldest part of telencephalon

B. DIENCEPHALON
oldest part of prosencephalon

II. MESENCEPHALON (MIDBRAIN)

III. RHOMBENCEPHALON (HINDBRAIN)

A. METENCEPHALON
(upper part of the hindbrain)

B. MYELENCEPHALON
(lower part of the hindbrain)

BRAIN HIERARCHY:

The "oldest" and "lower" parts of the brain are old in two senses of the word. They are the first parts to develop as the individual embryology proceeds, and secondly, they are also old in the sense that lower animals may function with, only this much of a brain.

- The more primitive or reflexive the behavior the more likely it is to be controlled by the hindbrain or midbrain.
- All of the vital functions (respiration, heart beat, vomiting, swallowing, digestion) are controlled from these older or lower centers.
- Most of the "thinking" and memory functions are centered in the newer ("higher") parts of the brain, especially the cortex.

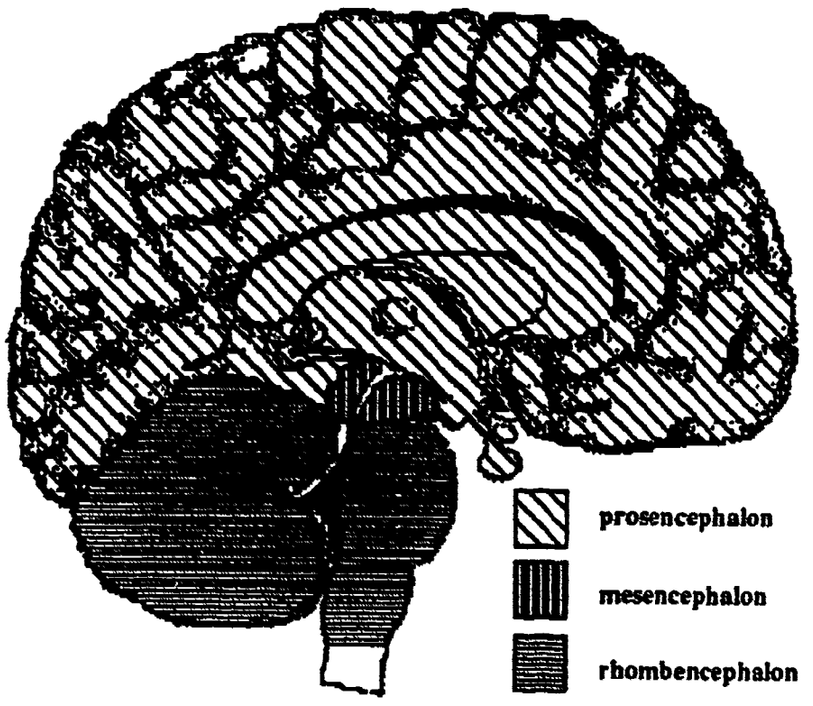


Fig. 89- Sagittal Section of Adult Human Brain
showing adult derivatives of the three primary embryonic regions

• The more "cerebral" (advanced or complex) a behavior is, the more likely it is to be controlled by the forebrain.

• The cerebral cortex of humans is more dense with cells than that of any other animal.

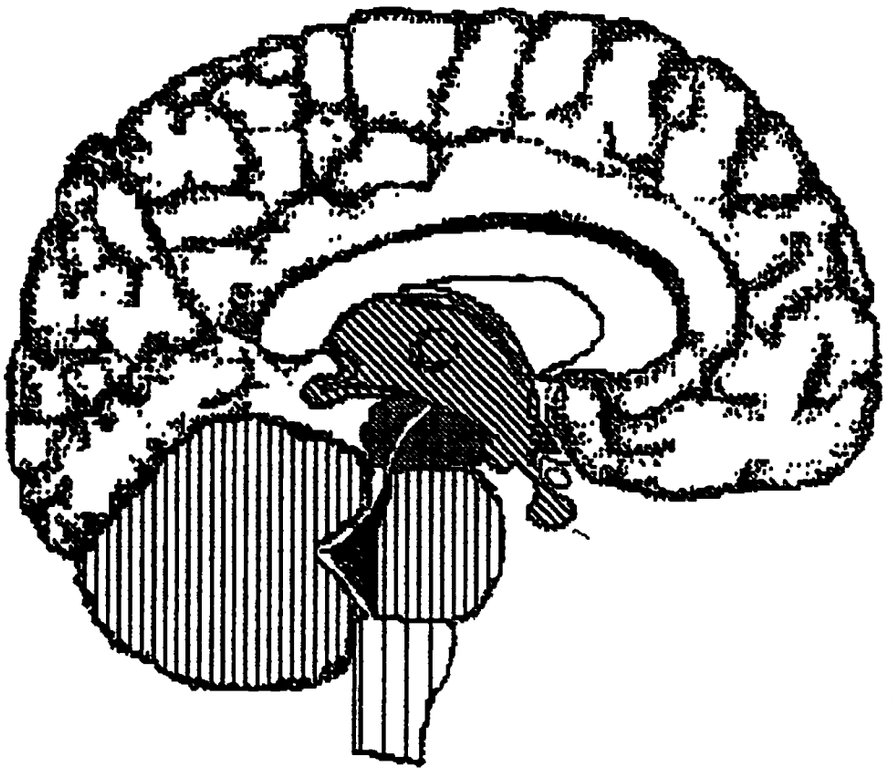


Fig. 90- Sagittal Section of Adult Human Brain
showing further subdivision of the three primary regions.

RETICULAR FORMATION:

In the core of the midbrain and hindbrain (running thru the white matter of the medulla, pons and cerebral peduncles) is the so called reticular formation, a network of neurons through which sensory pathways on the way to the cortex must pass.

The reticular formation apparently screens information, blocking irrelevant material and passing through that which is relevant, thus helping to prevent information overload.

Another function of the reticular formation is to alert higher centers that a barrage of sensory information is soon to arrive.

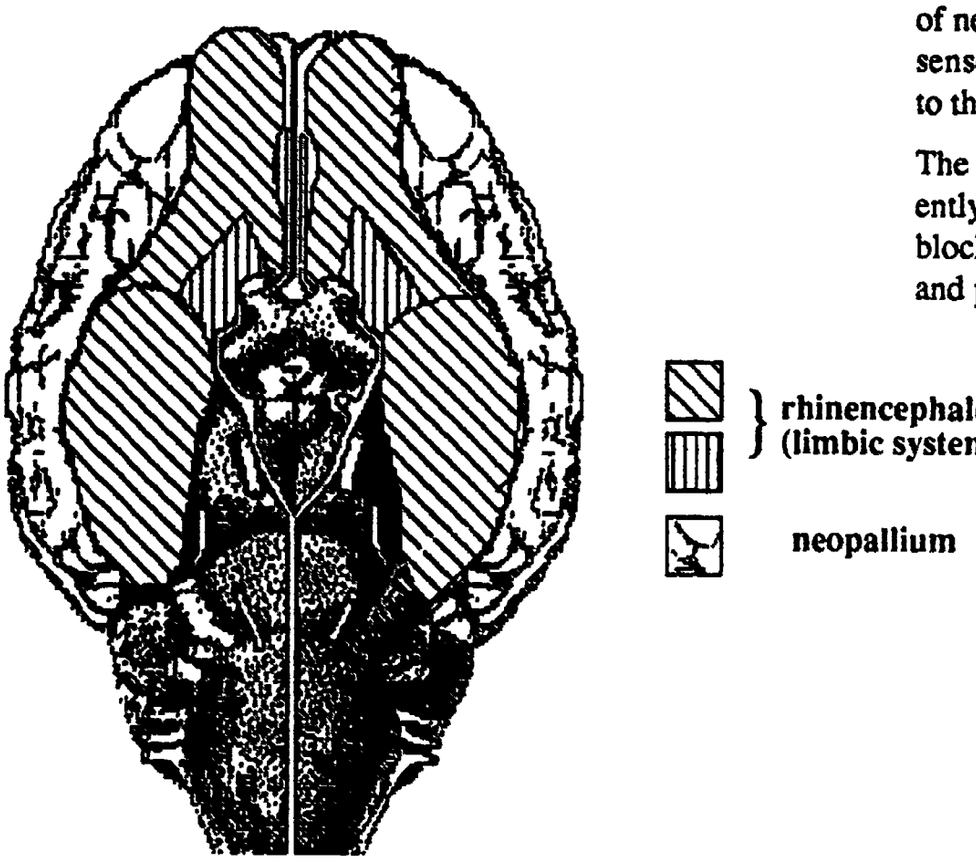


Fig. 91- Human Brain, Inferior View
showing subdivisions of the telencephalon

RHOMBENCEPHALON

MYELENCEPHALON

MEDULLA OBLONGATA

The medulla oblongata is the lowest and oldest part of the brain. It is directly continuous with the spinal cord below and the pons above. The **pyramids of medulla** are two swellings on the anterior surface of the medulla; they contain the corticospinal tracts. The corticospinal tracts physically cross from left to right and vice versa at the level of the medulla. This cross over is known as the **decussation of the pyramids.**

CRANIAL NERVE NUCLEI:

Cranial nerves IX, X, XI, XII are attached to the medulla, therefore we can say that the medulla regulates: respiration, heart beat, blood pressure (vasoconstriction), sleep, consciousness, and reflex functions such as swallowing, vomiting, sweating, and gastric secretion.

METENCEPHALON

CEREBELLUM

CEREBELLAR CORTEX:

The cerebellar cortex is the gray matter on the surface of the cerebellum. It contains the cell bodies of nerves that control muscle coordination, muscle tone, posture, equilibrium, and muscle memory (habit formation).

The cerebellum receives sensory input (cues) related to the above: i.e. proprioception from muscles, tendons, and joints; visual cues, auditory cues, vestibular organ cues, and touch cues.

CEREBELLAR PEDUNCLES:

The cerebellar peduncles are white matter tracts that connect the cerebellar cortex with other parts of the brain which are above below and across the street from the cerebellum.

superior peduncles

Connects cerebellum to midbrain.

middle peduncles:

Connects cerebellum to pons.

inferior peduncles

Connects cerebellum to medulla.

ARBOR VITAE:

The arbor vitae is a branching pattern of tracts with a fanciful resemblence a tree. These tracts are simply the continuation of the cerebellar peduncles.

PONS

The pons is mostly white matter because all ascending and descending neurons must pass through it, there is no other way for axons to travel up to higher centers or down to lower centers.

CRANIAL NERVE NUCLEI:

Cranial nerves V, VI, VII, VIII areattached to the pons in an area called the **olive.**

MESENCEPHALON

CEREBRAL PEDUNCLES

All ascending and descending neurons must pass through the white matter of the cerebral peduncles of the midbrain, there is no other way to go up to higher centers or down to lower centers. Two examples of such pathways are the corticospinal (voluntary motor) and spinothalamic (sensory) tracts.

RED NUCLEUS:

The red nucleus is a mass of gray matter where axons from the cerebral cortex synapse with axons going to the cerebellum via the superior cerebellar peduncles.

CRANIAL NERVE NUCLEI:

Cranial nerves III, IV, and 1st division of Vth are attached to the cerebral peduncles.

CORPORA QUADRIGEMINA

The corpora quadrigemina are four bodies

(two pairs) of gray matter in the midbrain. There is a pair of superior colliculi and a pair of inferior colliculi.

SUPERIOR COLLICULI:
These nuclei control visual reflexes such as: blinking, accommodation, pupillary constriction and dilation. They also control balance reflexes related to visual cues. The optic nerves go first to the lateral geniculate bodies of the thalamus, and then some of the axons continue on to the superior colliculi. The two superior colliculi are connected with one another via a band of axons called the **posterior commissure.**

INFERIOR COLLICULI:
These paired nuclei control auditory reflexes such as the **tensor tympani** and **stapedius** reflexes. They also control balance reflexes related to vestibular cues. The vestibular nerves go first to the medial geniculate bodies of the thalamus, and then some of the axons continue on to the inferior colliculi.

MEDIAL GENICULATE BODIES:
Connections for cranial nerve VIII. Fibers arrive here from the Vestibular and Cochlear nuclei of the brain stem (pons). From here fibers are sent to the auditory cortex for hearing, or to the inferior colliculus for auditory reflexes.

EPITHALAMUS (PINEAL BODY):

The pineal body is tentatively implicated as a biological clock mechanism, especially as concerns the onset of puberty, perhaps converting circadian dark/light cycles into endocrine cycles.

HYPOTHALAMUS:

Control centers (nuclei) for:

- body temperature
- control of anterior pituitary gland via production of **releasing factors**
- production of posterior pituitary hormones (**ADH and Oxytocin**)
- sleep/wake cycles
- libido (sex drive)
- hunger
- thirst
- regulation of autonomic nervous system
- regulation of emotional behavior (via limbic system connections to mammillary body nuclei).

PROSENCEPHALON

DIENCEPHALON

THALAMUS:

All afferent (sensory) fibers (except olfaction) synapse in the thalamus before being relayed to the cortex. The thalamus provides the lowest level of sensory discrimination (pleasant vs unpleasant, touch vs pain, temperature *vs* pain), but the sensation is unlocalizedunless the relay continues to the cerebral cortex.

LATERAL GENICULATE BODIES:
These nuclei are the relay stations for the optic nerve axons. From here messages are relayed to the occipital lobe of the cortex for image formation or to the superior colliculus for visual reflexes, or to the pineal gland for biological clock functions. This latter connection is still considered speculative.

TELENCEPHALON

RHINENCEPHALON (LIMBIC SYSTEM)

The rhinencephalon or "nose brain" is sometimes called the archipallium, indicating the fact that it is the oldest part of the telencephalon.

WHITE MATTER:
olfactory nerves, tracts &striae
These extend from the olfactory bulbs leading to the uncus, anterior perforate substance,amygdala, hippocampus and cingulate gyrus.

fornix
Connects amygdala and hippocampus of the limbic system to the mammillary bodies of

hypothalamus and to the brain stem, allowing the limbic system to influence the autonomic nervous system and emotional behavior.

anterior commissure
Found at the proximal end of the olfactory nerves. Connects the olfactory tracts to each other.

CORTEX: (OLFACTORY ASSOCIATION AREAS)
olfactory bulbs

anterior perforate substance
Also called the **olfactory trigone** since it is a triangular area between the olfactory tracts and olfactory striae.

uncus
The uncus is the smooth anterior end of the collateral gyrus.

hippocampus
The hippocampus is a part of the collateral gyrus which is coiled like the tail of a seahorse.

cingulate gyrus
This gyrus is above the corpus callosum and parallel to it.

NUCLEI:
amygdala
The amygdala is an almond shaped nucleus deep in the center of each temporal lobe.

NEOPALLIUM:

The neopallium is approximately 7/8 by weight of the human brain.

CORTEX:

sulci and fissures:
midsagittal fissure
This fissure is also known as the **median longitudinal fissure**. It divides the cerebral cortex into two hemispheres.

central fissure
This fissure is also known as the **fissure of Rolando**. It marks the boundary between the frontal lobe and the parietal lobe.

lateral fissure
This fissure is also known as the **Sylvian fissure**. It separates the temporal lobe from the frontal lobe.

parieto-occipital fissure
This fissure can be seen from the midsagittal view only. It marks the boundary between the parietal lobe and the occipital lobe.

calcarine fissure
This fissure can also be seen only from the midsagittal It starts at the occipital pole and runs forward at right angles to the parieto-occipital fissure.

collateral fissure
The collateral fissure runs lengthwise on the inferior surface of temporal lobe.

cingulate sulcus
The cingulate sulcus is above the cingulate gyrus, which is above the corpus callosum.

transverse fissure
The transverse fissure separates the cerebellum from the occipital pole.

lobes:
- **frontal**
- **parietal**
- **occipital**
- **temporal**
- **insula**

CORTICAL PROJECTION AREAS:
These are the *clearly localized* sensory and motor areas also known as **primary cortex**.

precentral gyrus:
This gyrus of the frontal lobe is the primary motor cortex

postcentral gyrus:
This parietal lobe gyrus is the primary sensory cortex

walls of calcarine fissure :
This cortex of the occipital lobe is the primary visual cortex.

motor speech area:
The motor speech area is in the dominant hemisphere; it is the part of the frontal lobe which is just above Sylvian fissure and just

anterior to the precentral gyrus. This area is also known as Brocca's area.

hearing projection area:
The primary hearing cortex is located on the superior gyrus of the temporal lobe.

CORTICAL ASSOCIATION AREAS:
The association areas are the areas of cortex are also known as **secondary cortex.** They immediately surrounding the primary projection area. These are the areas where memories and thoughts associated with primary events are stored.

visual association area
This is the area of the occipital lobe surrounding the calcarine fissure.

hearing association area
This is most of the temporal lobe immediately surrounding the primary hearing cortex

sensory association area
This is the part of the parietal lobe immediately posterior to the primary general sensory cortex.

language association area
This is the area of the dominant hemisphere where the temporal, occipital and parietal lobes meet. Also known as Wernicke's area.

insula:
The insula is a hidden island of cortex in the walls of the Sylvian fissure of the temporal lobe. This is the speech association area.

prefrontal cortex:
The prefrontal cortex is all of the frontal lobe anterior to the motor cortex. The prefrontal lobe is poorly understood, but is associated with such things as "intelligence", reasoning ability, emotional control, long range planning, personality, and motivation.

THE BASAL "GANGLIA"
The basal ganglia, or ***basal nuclei*** are important for the dampening and inhibiting of voluntary motor impulses so that muscles are not overactive, and movements do not overshoot their target. Rigidity and tremor are characteristic of malfunction of the basal ganglia. A band of white matter (the ***internal capsule***) runs between the caudate nucleus and the lentiform nucleus giving them a characteristic stripped appearance, giving rise to the term ***corpora striata*** (basal ganglia + the internal capsule).

caudate nucleus

lentiform nucleus
- **globus pallidus**
- **putamen**
- **substantia nigra**

WHITE MATTER:
internal capsule
The internal capsule is a tightly bundled group of axons traveling vertically between brain stem and cortex. The bundle passes through the middle of the basal ganglia and continues upwards as the corona radiata. See next listing.

corona radiata
Much of the white matter beneath the cerebral cortex is the ***corona radiata.*** When the ascending axons in the internal capsule escape the confines of the basal ganglia the axons spread (radiate) out to reach their designated area of the cortex. The same concept in reverse applies to the descending axons which after leaving the cortex must funnel into the brain stem.

corpus callosum
This very large band of axons is the brain's largest commissure; it allows the hemispheres to share information. Without this commissure therewould be essentially two brains rather than one, and each brain would be in control of the opposite side of the body. Only the dominant side (left side for most people) would have access to language.

Major Pathways of the Brain

LATERAL SPINOTHALAMIC TRACT

This is the pathway for **pain** and **temperature** sensations traveling from skin to thalamus to sensory cortex. The decussation (cross over) is at the spinal cord level so that sensations coming from one side of the body immediately cross to the other side of the cord and then travel upward towards the brain. **See Fig. 92.**

VENTRAL SPINOTHALAMIC TRACT

This is the pathway for light **touch** and **pressure** sensations traveling from skin to thalamus to sensory cortex. Again, the decussation is at the spinal cord level so that sensations coming from one side of the body immediately cross to the other side of the cord and then travel upward towards brain. **See Fig. 92.**

DORSAL SPINOTHALAMIC TRACT

This is the pathway for **proprioception, stereognosis, tactile discrimination** and some pressure sensations traveling from skin to thalamus to sensory cortex. The decussation is at the level of the medulla, which means that sensations coming from one side of the body travel upward on that same side of the cord until they reach the medulla, at which point they cross over and travel upward on the opposite side of the brain stem (medulla, pons, cerebral peduncles) towards the thalamus and cortex.

CORTICOSPINAL TRACT (PYRAMIDAL TRACT)

This is the pathway for **voluntary motor** impulses traveling from the motor cortex of the brain down through the brain stem and into the spinal cord, where they synapse on the anterior horn cells of the spinal cord. The decussation is at the level of the medulla (decussation of the pyramids), and in fact the swellings known as the pyramids of the medulla are in reality these corticospinal tracts.

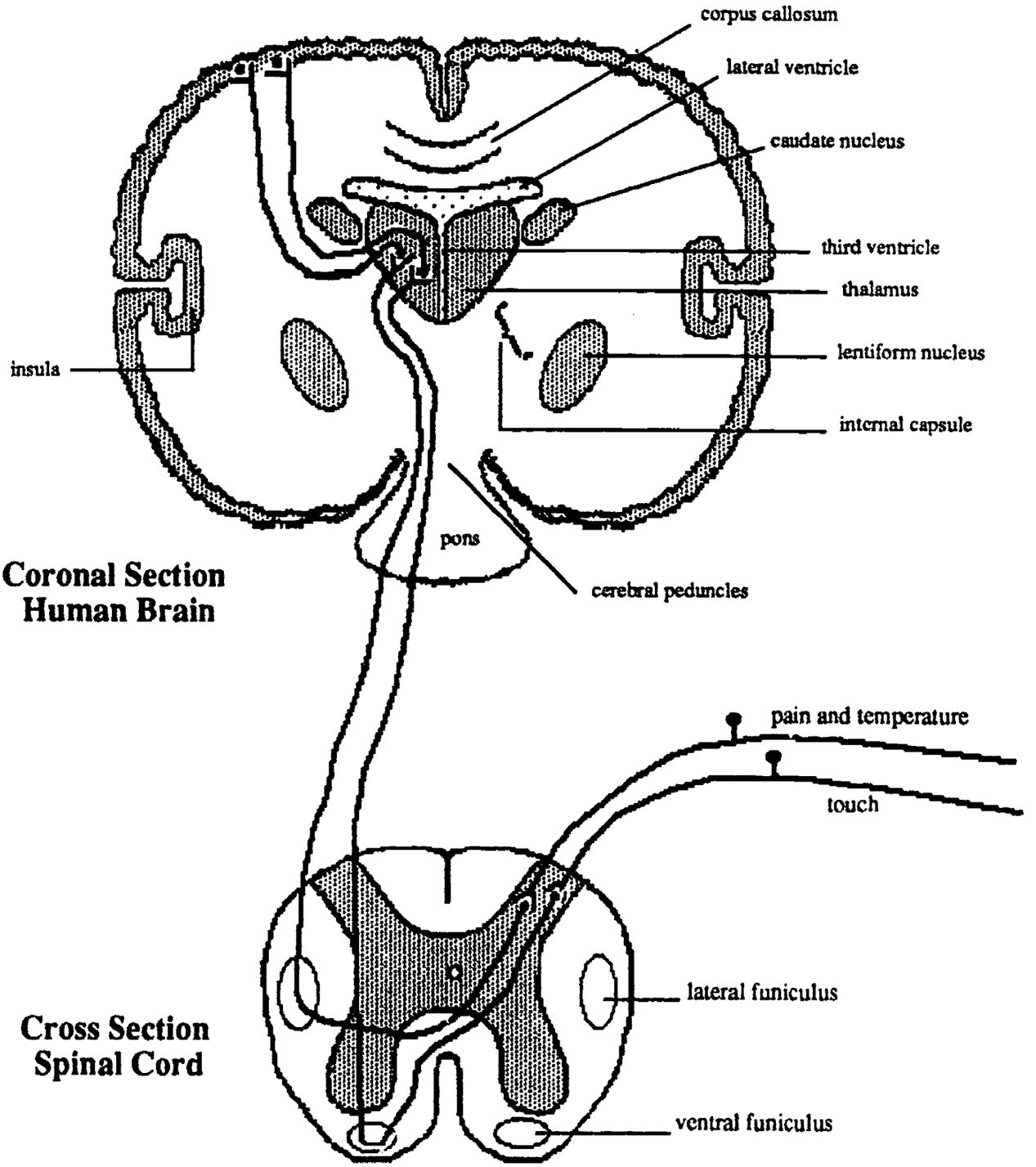


Fig. 92- Lateral and Ventral Spinothalamic Tracts

The lateral spinothalamic tract is the pathway for pain and temperature. The ventral spinothalamic tract is the pathway for light touch. Notice that each pathway requires three neurons, and that each pathway crosses to the opposite side at the level of the spinal cord.

General Sensory Receptors

BASIC TERMINOLOGY / CONCEPTS:

TRANSDUCERS:
Sense receptors are transducers; they change one form of energy (e.g. heat, sound waves, pressure) into another form of energy (into electrical signals for example). Biological transducers change one form of energy (e.g. light, heat, sound waves, pressure) into nerve impulses, which are actually electro-chemical signals acting on cell membranes.

ADEQUATE STIMULUS:
Each receptor has it's specific "adequate stimulus", i.e. the energy form which normally excites it. Usually there is no cross over stimulation unless the stimulus is very intense (e.g. very intense sound is painful).

ADAPTATION:
Most receptors adapt in the presence of a constant level of stimulus. What actually happens is that they send fewer nerve impulses, (i.e. they "fire" at a slower rate) when the level of stimulus is unchanging. Mostly we respond to change and tend to disregard a steady state. The exception to this is that pain and tendon stretch receptors do not adapt.

REFERRED PAIN:
Pain that actually originates in a visceral origin may *feel as though* it is coming from somewhere else. The explanation for this is probably as follows: the visceroceptor neuron is traveling in a mixed spinal nerve along with a peripheral sensory neuron. Both neurons probably activate the same internuncial neuron in the central nervous system. Since stimulation of sensory receptors in the viscera is relatively uncommon the brain assumes that the signal is coming from the peripheral sensory neuron, and thus *misinterprets the source* or origin of the sensation. For example: in **angina pectoris,** the source of the pain is in the heart muscle, but the pain is commonly experienced to be in the left chest, shoulder, and arm area.

CATALOG OF SENSORY RECEPTORS:

TOUCH:	Meissner's corpuscles in hairless skin Tactile discs (Merkel's discs) Hair root plexuses
PRESSURE:	Pacinian corpuscles
PAIN:	Free nerve endings in skin, connective tissue, and cornea.
COLD:	Krause's end bulbs (corpuscles)
HEAT:	Ruffini's brushes (corpuscles)
PROPRIOCEPTION:	Neuromuscular spindles (stretch receptors), are found in all muscles and joints. They give constant information to the brain regarding muscle and joint position and movement.

TENDON LOAD:	Golgi tendon organs (stretch receptors in the tendons). If a tendon is stretched to the breaking point the muscle will suddenly relax and the joint will col-lapse, preventing injury to the tendon and muscle. (clasp knife reflex)
EXTENSOR STRETCH REFLEX:	Neuromuscular spindles (stretch receptors) found in the muscles of the feet will , when stretched, cause increased contraction of the extensor muscles in the legs. This reflex is activated when the soles of the feet are pressed against the floor, causing the leg extensors to hold the individual upright.
GRAVITY:	Utricle and Saccule of the inner ear give information to the brain that allows the body to orient to gravity (ability to know up from down); recognition of head position.
ACCELERATION/ DECELERATION:	Semicircular canals of the inner ear.
SOUND:	Cochlea &organ of Corti of the inner ear.
SIGHT:	Retina, rods and cones
TASTE:	Taste buds in papillae of the tongue for sweet, sour, salty and bitter; Other flavors are a combination of taste and olfaction
SMELL:	Chemoreceptors in mucosa of upper nasal cavity
BLOOD PRESSURE:	Stretch receptors in aortic arch, carotid sinuses, and in superior and inferior venae cavae. Impulses from these receptors are carried by the glossopharyngeal nerves.
BLOOD CO_2 :	Chemoreceptors found in the *aortic body* and *carotid bodies* are sensitive to acid levels (CO_2 dissolved in water creates carbonic acid); increased CO_2 levels causes faster breathing.
BLOOD SALINITY:	Osmotic receptors in hypothalamus
BLOOD GLUCOSE:	Glucostat receptors in hypothalamus (?)
VISCERAL SENSATIONS:	Very few sense receptors exist in the viscera, touch sensibility is virtually nonexistent , warmth and cold sensibility is almost nonexistent . The few receptors that exist are called interoceptors or visceroceptors. They respond to pain and distension (internal stretch) of the viscera.

THE EYE

INTRODUCTION:

The eye has three basic layers and four basic functions.

THREE BASIC LAYERS:

• OUTER LAYER
The outer layer of the eye includes the sclera and the cornea.

• MIDDLE LAYER:
The middle layer of the eye includes the choroid layer, the iris, and the ciliary body.

• INNER LAYER:
The inner layer of the eye consists of the retina.

FOUR BASIC FUNCTIONS:

•The sclera and cornea **protect** the retina.

• The iris and choroid layer **regulate** the amount of light that hits the retina.

• The cornea, lens, and ciliary body **focus** the light on the retina.

• The retina **transduces** the light stimulus by changing it into nerve impulses.

THE OUTER LAYER:

SCLERA

The sclera is very tough thick white connective tissue; its function is to protect the retina.

CORNEA:

The cornea is the transparent front portion of the sclera. In addition to protecting the retina it is also does most of the focusing.

THE MIDDLE LAYER:

CHOROID

The choroid layer of the eye is black due to its massive amounts of melanin pigment. This black pigment protects the retina by absorbing excess light.

IRIS:

The iris is the forward extension of choroid layer. It contains less pigment than the choroid. Different eye colors in different people are the result of varying amounts of the pigment melanin in the iris.

PUPIL:
The pupil is a hole in the center of the Iris. The size of the hole will change depending on the brightness of the ambient light.

MUSCLES OF THE IRIS
(pupil size regulation)

- **Circular Layer**
  Contraction of the circular muscles of the iris will dilate the pupil.

- **Radial Layer**
  Contraction of the radial muscles of the iris will constrict the pupil.

CILIARY BODY AND LENS

Adjustment of the ciliary body will change the shape of the lens which in turn will change the focal length of the lens. This process is called the "accommodation reflex".

ELASTIC LENS

• In order to be transparent the lens has no blood vessels and no nerves, and its cells have lost all their internal structures (during embryological development), leaving them unable to replicate or to produce their own energy, and yet the lens continues to grow as the body grows.

• The lens has the most concentrated protein content of any tissue in the body. As much as 60% of the lens is made of a special class of proteins called crystallins. These special proteins perform a dual function:

a. they act as structural proteins dense

enough to bend light efficiently

b. they act as enzymes capable of converting sugars into energy to keep the cells of the lens alive.

Wistow & Piatigorsky, *Science*, June 19, 1987

SUSPENSORY LIGAMENTS

These are very delicate crystal clear strands. One end attaches to the circumference of the lens, the other end of each ligament is attaches to a ciliary muscle.

CILIARY MUSCLES

The ciliary muscles are used in the visual reflex known as *accommodation*, as in the phrase *accommodation for near vision*. They are smooth muscle, and they work by adjust the shape of the elastic lens from the resting flattened position needed for distance vision, to a rounder shape which is needed for near vision.

• Contraction of the ciliary muscles will *reduce* tension on the suspensory ligaments thus allowing the elastic lens to fatten This is the shape needed for focusing on close objects.

• Relaxation of the ciliary muscles will *increase* tension on the suspensory ligaments, stretching the elastic lens into a flatter shape. This is the shape needed for focusing on distant objects.

THE INNER LAYER:

RETINA

RODS

The rods are receptors for night vision, they contain the visual pigment rhodopsin. Rhodopsin is purple in the dark (visual purple); low intensity light causes a chemical reaction in the rhodopsin which in turn initiates a nerve impulse. The color red is not visible at night because rhodopsin is not sensitive to light waves in the red range. When exposed to bright light, rhodopsin bleaches to white and nerve impulse cease. The bleaching reaction is reversible; the bleached pigment will become purple again when protected from the light.

CONES

The cones are for color vision and acute vision. They contain a variety of visual pigments that are sensitive to all the different lengths of light waves in the visual spectrum.

MACULA LUTEA

White spot at rear of the eyeball where the retina is thicker.

FOVEA CENTRALIS

A pit in the center of the macula lutea. This is the area of most acute vision due to a high concentration of cones and the absence of rods in this area.

BIPOLAR CELL LAYER

Very short neurons. Anterior to the rods and cones. These neurons are stimulated by the chemical changes in the rods and cones. They in turn synapse with the optic nerve cells.

OPTIC NERVE FIBERS

These cells synapse with, and lie anterior to, the bipolar neurons. Light must pass through a tangle of optic nerve fibers and the bipolar layer of cells before it can strike the rods and cones of the retina. The optic nerve axons converge on the optic disk at the back of the eye.

OPTIC DISK

The optic disk is the area at the posterior pole of the eyeball where the optic nerves exit the eyeball to continue their journey to the brain. Since there is no retina at this location, the optic disk causes a " blind spot" in each eye. As long as a person has two eyes no dysfunction is caused because when light is striking the blind spot in one eye it simultaneously falls on active retina in the other eye.

EXTRINSIC EYE MUSCLES :

These are the muscles attached to the outside surface of the eyeball and used for moving the eye in the direction of sight.

They are all voluntary (skeletal) muscle as opposed to the intrinsic muscles of the eye (ciliary *muscles* and two iris muscles) which are all smooth muscle.

SUPERIOR RECTUS

LATERAL RECTUS
for abduction of the eye

MEDIAL RECTUS

INFERIOR RECTUS

SUPERIOR OBLIQUE
it runs through the trochlea

INFERIOR OBLIQUE

ACCESSORY ELEMENTS

LACRIMAL GLAND

VITREOUS HUMOR

VITREOUS CHAMBER

AQUEOUS HUMOR
This fluid is constantly secreted by the epithelium of the ciliary body.

ANTERIOR CHAMBER
POSTERIOR CHAMBER

CANAL OF SCHLEMM

CONJUNCTIVA

FAT PAD

VISUAL DEFECTS:

PRESBYOPIA
The farsightedness of aging; caused by loss of elasticity in the lens.

MYOPIA
Congenital nearsightedness; caused by an eyeball which is too long from front to back, resulting in a focal point which falls short of (in front of) the retina. The image is thus out of focus again when the light waves reach the retina.

HYPEROPIA (HYPERMETROPIA)
Congenital farsightedness; caused by an eyeball which is too short from front to back, resulting in a focal point which falls behind the retina. The image is thus not yet in focus when the light waves hit the retina.

ASTIGMATISM
Congenital difficulty in focusing due to variable thicknesses (waviness) of the cornea and/or lens.

CATARACTS
Opacity of the cornea or lens. Numerous causes. Frequently associated with the aging process.

DETACHED RETINA
The retina is held smoothly in place against the sclera by the vitreous humor. If the retina falls away from the sclera light will not focus on it and sight is lost in that area.

GLAUCOMA
Aqueous humor must drain out of the eye at the same rate at which it is produced, otherwise pressure will build up

CONJUNCTIVITIS

EXOPHTHALMIA

THE EAR

EXTERNAL EAR

The features of the external ear that are of interest include the **pinna**, the **helix**, the **lobule**, the **external auditory canal**, and the **ceruminous** glands.

MIDDLE EAR

TYMPANIC MEMBRANE

EAR OSSICLES:

Malleus
Incus
Stapes

WINDOWS:

Round
Oval

MUSCLES:

Tensor Tympani
Stapedius

EUSTACHIAN TUBE

Also known as the pharyngotympanic canal.

INNER EAR

BASIC CONSTRUCTION

Bony Labyrinth
Membranous Labyrinth
Endolymph
Perilymph
Hair Cells

ORGANS OF EQUILIBRIUM

VESTIBULE

The vestibule functions for stationary equilibrium, i.e.the sense of gravity and head position.

Bony Vestibule
Utricle
Saccule
Hair Cells
Otoliths

SEMICIRCULAR CANALS

The semicircular canals function for "dynamic" equilibrium, i.e. acceleration- deceleration.

Bony semicircular canals
Semicircular ducts
Ampullae
Endolymph

ORGAN OF HEARING (COCHLEA)

MODIOLUS

COCHLEAR DUCT

SCALA VESTIBULI

Vestibular Membrane

SCALA TYMPANI

Basilar Membrane

ORGAN OF CORTI:

Tectorial Membrane

COCHLEAR FUNCTIONS

LOUDNESS RESPONSE

Modifications of amplitude.

PITCH RESPONSE

Modifications of frequency.