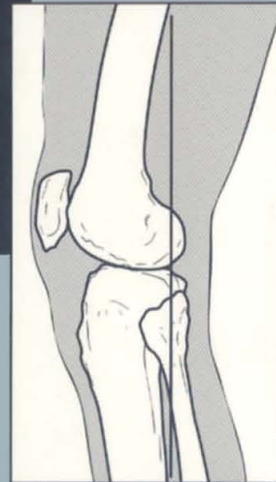
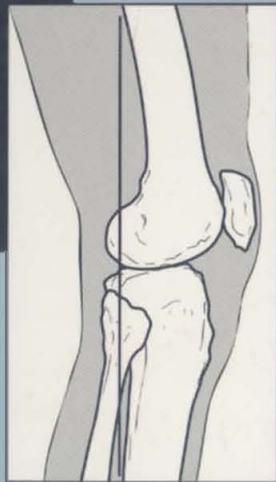
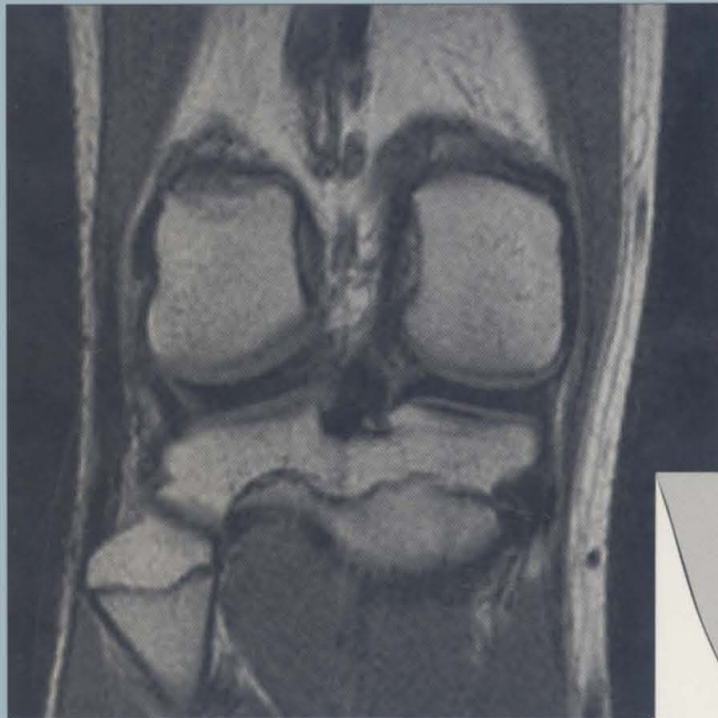


ATLAS *of* MUSCULOSKELETAL IMAGING



Thomas Lee Pope, Jr.
Stephen Loehr



Thieme

Atlas of Musculoskeletal Imaging

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Dedication

This book is dedicated to my dad and hero, the late Thomas Pope, Sr.; to my family, Roger (and Cathy) and Florence Pope; and especially to my emotional support, my wife, Lou and my sons David and Jason. Without all of them, life would be much less tolerable.

Thomas Lee Pope, Jr., M.D., F.A.C.R.

I dedicate this work to my loving wife, Laura; to Dr. C. Douglas Maynard; and to the Department of Radiology at Wake Forest University Medical Center for their encouragement, support, and patience during completion of this project.

Stephen Loehr, M.D.

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Foreword

Anatomy is important. In musculoskeletal radiology, as in real estate, it is location, location, location. Where the property is located or where the lesion is located makes all the difference in the world. In real estate, location is the major determinant of property value, whereas in the interpretation of musculoskeletal imaging, location is a major determinant in the recognition of the true nature of a lesion and a key to the development of an appropriate differential diagnosis. Where a lesion is goes a long way to telling you what it is. And by knowing precisely where it is and what is around it, the surgeon can devise an approach to the lesion and knows what to watch out for along the way. There is simply no substitute for knowledge of anatomy.

Very few radiologists involved in cross-sectional imaging, even specialists in skeletal radiology, know human anatomy so well that they can confidently interpret magnetic resonance imaging and computer tomography without feeling the need to refer to an anatomic atlas of some sort from time to time. This is particularly true when faced with an examination of an infrequently examined joint. And even more so when the area of interest is at a distance from a joint. Because of the heightened role of cross-sectional imaging in the assessment of soft tissue abnormalities (i.e., tumors, infections, and the like), such examinations are much more frequent than in the past and, indeed, in some medical centers have become an everyday occurrence. Therefore, there is a frequent need to refer to an anatomic atlas to aid in the interpretation of these examinations.

So you go to the bookcase seeking information in order to properly identify the appropriate muscles, tendons, and fascial planes, and determine the critical relationships of the lesion in question to the surrounding nerves and vascular structures. After taking down an atlas to look up the important anatomy, you often find it to be devoid of information regarding anatomy along the shaft of long bones away from the joints. Unfortunately the anatomical diagrams and accompanying images are limited to the joints and there is no illustration of the anatomy in between. This portion of the anatomy is left to your imagination!

Or maybe you are lucky enough to find an illustration of the anatomy you seek, only to realize that the illustration is of the opposite extremity—that is, the side opposite the one you

are interested in, the side opposite that in which the lesion in question is located. All illustrations are limited to a single extremity, say the right extremity, and it just so happens that you are faced with a lesion in the left extremity. There is, of course, a 50/50 chance that this will occur. You are out of luck and posed with the requirement of “mirror-image thinking.” You have to reverse the image in your mind to determine the anatomy on the side you are interested in, the side opposite that displayed in the atlas. This is not always easy; realizing, of course, that if you are not careful you could make a mistake.

This work was borne out of the preceding frustrating experiences, spawned by authors who came to the realization that there must be a better way. And there is. Why not an atlas that depicts both extremities and does away with “mirror-image” thinking? And while we’re at it, let’s illustrate the anatomy between the joints, as well. Anyone who interprets cross sectional images would immediately recognize the value of such a work.

Well, here it is. You hold it in your hands. Feast your eyes on its content. Peruse the illustrations. Yes, left and right, both sides at the joints and all points in between are there. All in all, a practical, useful, and instructive contribution.

If you do musculoskeletal imaging, if you interpret musculoskeletal images, or if you are an orthopaedist, rheumatologist, or physiatrist, I am certain this work will be of value to you in your practice. This is the atlas we’ve been waiting for. The authors are to be commended for their fine efforts. Drs. Pope and Loehr have produced an easy-to-use, comprehensive, and informative atlas that should prove to be of immeasurable value to all who have the need for precise knowledge of musculoskeletal anatomy as displayed by all forms of musculoskeletal imaging.

Lee F. Rogers, M.D.
Winston-Salem, North Carolina

Preface

This atlas was conceived at the view box while reading clinical MR images. While interpreting these images, we would invariably need to consult the standard anatomy books. However, these texts were often insufficient: The image to be interpreted showed the right extremity, but the anatomy book demonstrated the left, or vice versa. This mismatch resulted in some interesting and challenging translations from the reference book to our clinical images. Furthermore, the middle regions of the extremities usually were not included in the standard anatomy texts. Therefore, only by extrapolation from the highest or lowest images of the joint exhibited in the textbook could we estimate the anatomy in the midportion of the extremities of our images. Finally, many textbooks of anatomy do not include the origin and insertion of muscles or any discussion of the joints that are exhibited. These shortfalls prompted us to consider how we could design a text to overcome most of these problems.

The solution, in our opinion, was to create an atlas that not only demonstrated both right- and left-sided images as they are usually interpreted at the view box, but that also included the middle regions of the extremities. Such an atlas would also need to include the origin and insertion of the major muscles of each anatomic region and a brief introduction to the joint at the beginning of each chapter. *Atlas of Musculoskeletal Imaging* is the result of our ideas. The major joints, the pelvis, and selected images of the spine are included. Detailed, yet practical labeling of each anatomic image is provided. The atlas is not intended to be all-inclusive, and we have selected only the most clinically practical images.

Each chapter is organized as follows: A brief “introduction” to the anatomic area precedes the “practical protocol suggestions” section that outlines general hints about obtaining optimal images. Next is the “menu of protocols” that includes the more common technical parameters used in each anatomic area. An outline of “major osteochondral structures/landmarks” is next and lists the important structures with which to be familiar in each organ system. Finally, the “origin/insertion/innervation of major muscles” section provides a practical body of information often needed when interpreting clinical images. These sections were created because they seem to be most practical in the day-to-day clinical situations.

Our intention is for this text to serve as a practical and user-friendly guide that can be used in the day-to-day interpretation of MR images. We hope that it will find a home on the shelves beside the reading room rollerscopes or workstations, in the libraries, or in the offices of radiologists who interpret musculoskeletal MR images, and on the shelves of the offices of orthopaedic surgeons and rheumatologists who request these studies.

We solicit the suggestions of anyone who has an opportunity to use the book and look forward to hearing your comments. No book is without flaws, and this one may contain some errors that were missed. If so, please let us know, and we will ensure that they are addressed in the next edition.

Thomas Lee Pope, Jr., M.D., F.A.C.R.
Stephen Loehr, M.D.

Acknowledgments

No textbook is a single-handed endeavor, and this book is no exception. We greatly appreciate the frustration expressed by many musculoskeletal fellows and residents because they could not find a simple-to-use atlas. Without their difficulty, the idea for this book would not have been developed.

We thank Ms. Sharon Meister for her tireless dedication to excellence in transcribing the text for the book, and for coordinating and collating text. We also thank Dr. Donna Garrison and Mr. Terry Poovey, the medical editors of our department, who made sure that we all sound good on paper. Finally, we thank our Chair, Dr. C. Douglas Maynard, for creating a professional atmosphere conducive to academic productivity and cooperative interpersonal relationships, both requirements for completing projects like this one.

Thomas Lee Pope, Jr., M.D., F.A.C.R.
Stephen Loehr, M.D.

INTRODUCTION: GENERAL TECHNICAL CONSIDERATIONS

Patients undergoing musculoskeletal magnetic resonance (MR) imaging should be examined with the smallest coil that covers the body part, thereby achieving the highest signal-to-noise ratio and the best spatial resolution. For imaging of the joints and extremities, surface coils are mandatory as they improve the signal-to-noise ratio by four to six times compared to the head or body coils. The smallest field of view possible should be used. Individual variations are present among the wide range of scanners now available, and each location should determine for itself which sequences are best. The protocols described in each section were developed primarily on General Electric 1.5-T magnets. Obviously, images of diagnostic quality can be obtained with a variety of scanners, and the recommended protocols may require modification to suit the scanner at the institution and the personal preferences of the imager. The general principles regarding selection of pulse sequence and planes are most important. Furthermore, the major indicator of success is the satisfaction of the imager and the referring physician with their diagnostic results when these results are confirmed by arthroscopy, surgery, or patient outcome.

Positioning the patient properly in the MR imaging scanner is critical to obtaining diagnostic images. Technologists should pay particular attention to the placement of an extremity within the coil for an optimal selection of the slices. For best results, images should be obtained in axial, coronal, and sagittal planes. Axial MR images are probably most critical in the evaluation of a soft-tissue mass thought to be a tumor, so that the relationship of the mass to the neurovascular bundles and other important structures can be ascertained.

KEY TO ACRONYMS

Acronym	Explanation/Meaning
EPI	Echoplanar imaging
ETL	Echo-train length
FA	Flip angle (90° unless otherwise specified)
FMPIR	Fast multiplanar inversion recovery
FOV	Field of view (cm)
FS	Fat saturation
FSE	Fast spin echo
GAD	Gadolinium
GRASS	Gradient-recalled acquisition in the steady state
GRE	Gradient echo, gradient-recalled echo
IR	Inversion recovery
MPGR	Multiplanar GRASS
NEX	Number of excitations
PS	Pulse sequence
RL	Right to left
SE	Spin echo
SI	Superior to inferior
SPGR	Spoiled GRASS
ST/G	Slice thickness and gap (mm)
TE	Time to echo (msec)
TI	Inversion time
TR	Time to repetition (msec)
VAR	Variable (dependent upon size of abnormality or patient)

SUMMARY OF FAST MR TERMS

Term	Abbreviation	Explanation	Example of Manufacturer	Characteristic Feature
General				
	EPI	Echoplanar imaging		
	ETL	Echo train length		
	FOV	Field of view		
	GRE	Gradient-recalled echo		
	IR	Inversion recovery		
	MR	Magnetic resonance		
	NEX	Number of excitations		
	NSA	Number of signals averaged		
	SE	Spin echo		
	SNR	Signal-to-noise ratio		
	TE	Echo time		
	TI	Inversion time		
	TR	Repetition time		
T1-weighted sequence				
	FLASH	Fast low-angle shot	Siemens, Bruker	GRE sequence with spoiling gradient
	FFE	Fast field echo	Philips	GRE sequence with spoiling gradient
	PSR	Partial saturation recovery	Picker	GRE sequence with spoiling gradient
	FE	Field echo	Elscint	GRE sequence with spoiling gradient
	MP-RAGE	Magnetization-prepared rapid gradient echo		180° IR pulse GRE sequence with spoiling gradient
	SPGR	Spoiled gradient-recalled imaging	General Electric	GRE sequence with spoiling gradient
T2-weighted sequence				
	SSFP	Steady-state free precession	Siemens	GRE sequence with $TE > TR$
	PSIF	Reversed fast imaging with steady state precession, collection of the refocused echo	Siemens	GRE sequence with $TE > TR$
	CE-FAST	Contrast-enhanced Fourier-acquired steady-state technique	Picker	GRE sequence with $TE > TR$
	FSE	Fast spin echo		More than one echo per excitation with multiple 180° pulses
	FAIST	Fast-acquisition interleaved spin echo		More than one echo per excitation with multiple 180° pulses
	GRASE	Gradient and spin echo		Multiple 180° pulses and gradient-recalled echoes

(continued)

SUMMARY OF FAST MR TERMS (CONTINUED)

Term	Abbreviation	Explanation	Example of Manufacturer	Characteristic Feature
T1- + T2-weighted sequence and variable weighting	GREASE	Gradient echo and spin echo		GRE with multiple 180° pulses
	RARE	Rapid acquisition with relaxation enhancement		More than one phase-encoding step per excitation
	RASE	Rapid acquisition spin echo	Siemens	Half Fourier imaging
	TGSE	Turbo gradient spin echo, identical to GRASE	Siemens	FRE with multiple 180° pulses
	turboFLASH	Turbo fast low-angle shot	Siemens, Bruker	180° inversion recovery pulse plus GRE sequence
Echoplanar sequence	turboSE	Turbo spin echo, identical to FSE	Siemens	More than one echo per excitation with multiple 180° pulses
	GRASS	Gradient-recalled acquisition in the steady state	General Electric	GRE without spoiling gradient
	FISP	Fast imaging with steady-state precession	Siemens	GRE without spoiling gradient
	FAST	Fourier-acquired steady-state technique	Picker	GRE without spoiling gradient
	ABEST	Asymmetric blipped echoplanar single-pulse technique		One 90° pulse, rectangular scanning of K-space
	BEST	Blipped echoplanar signal-pulse technique		One 90° pulse, rectangular scanning of K-space
	EPISTAR	Echoplanar imaging with signal targeting and alternating radiofrequency		One 90° pulse, rectangular scanning of K-space
	Instascan	Brand name for EPI sequence	Advanced NMR Systems	One 90° pulse, rectangular scanning of K-space
	MBEST	Modulus-blipped echoplanar single-pulse technique		One 90° pulse, rectangular scanning of K-space
	mesh	Interleaved K-space scan		Meshed scanning of K-space

(continued)

SUMMARY OF FAST MR TERMS (*CONTINUED*)

Term	Abbreviation	Explanation	Example of Manufacturer	Characteristic Feature
Motion suppression technique	COPE	Cardiac-ordered phase encoding		Phase-encoding steps triggered by ECG
	FAT SAT	Fat saturation pulse		Presaturation pulse suppresses signal from fat
	FRODO	Flow and respiratory artifact obliteration with directed orthogonal pulses		Presaturation pulse suppresses signal from vessels and from tissue outside the area of interest
	MAST	Motion artifact suppression technique		
	ROPE	Respiratory-ordered phase encoding		Phase-encoding steps triggered by respiration
	STIR	Short inversion time inversion recovery		IR sequence with short T1

From Dr. Saini, with permission. Petersein J, Saini S. Appendix: Summary of fast MR terms. *Fast MR Imaging: Technical Strategies. AJR* 1995;165:1105–1109.

THE SHOULDER AND THE UPPER EXTREMITY

A. THE SHOULDER

The glenohumeral joint is commonly evaluated by magnetic resonance (MR) imaging. The major indications for MR imaging are suspected rotator cuff abnormality, glenohumeral instability, and chronic and unexplained shoulder pain. The most common pathologic processes are tendinosis, partial or complete tears of the rotator cuff tendons (injuries to the supraspinatus are by far the most frequent), glenoid labral abnormalities, biceps tendon displacement or injury, and spinoglenoid ganglia.

PRACTICAL PROTOCOL CONSIDERATIONS

The patient is routinely imaged in the supine position, with either a surface coil or paired flat coils placed above and below the shoulder in a Helmholtz configuration. The advantage of the Helmholtz configuration is the additive signal-to-noise ratio created by the two coils. Flexible quadrature and phased-array coils have also been used recently to improve the signal-to-noise ratio and increase the anatomic area covered by the study.

The patient's arm is at his or her side and is either in the neutral position or slightly externally rotated position to decrease overlapping of the infraspinatus and supraspinatus tendons. Abduction and external rotation have also been used to facilitate evaluation of partial rotator cuff tears, but this positioning is not in common use today.

Menu of Protocols: Glenohumeral Joint

Plane	Pulse Sequence	FA (degrees)	TR (msec)	TE (msec)	TI (msec)	FOV (cm)	Matrix (256X-)	ST/G (mm)	NEX	Comments
Localizer (coronal)	FMPIR		2,500	30	150	36	128	5/1.5	1	Either is acceptable
Localizer (coronal)	FSE		600	17		35	128	5/1.5	2	
Localizer (axial)	2D SPGR		30	min		20	128	5/0	2	
Coronal (oblique)	SE, double echo		2,000	20/80		14	192	4/1	1	Either is acceptable
Coronal (oblique)	FSE, double echo, (+/-1-FS)		3,000	17/102		16	192	5/1	2	
Sagittal (oblique)	SE, double echo		2,000	17/70		16	192	3/1	1	Either is acceptable
Sagittal (oblique)	FSE (+/-1-FS)		3,000	20		14	192	4/1	2	
Sagittal (oblique)	FSE (+/-1-FS)		5,500	85		16	192	4/.5	2	
Transaxial	SE, double echo		2,000	20/80		14	192	4/1	1	Either is acceptable
Transaxial	MPGR	30	450	15		14	192	4/1	1	
Transaxial	3D GRE	20	30	15		15	128	1.2/0	2	
Transaxial	FSE (+/-1-FS)		3,000	85		16	192	4/.5	2	

MAJOR OSTEOCHONDRAL STRUCTURES/LANDMARKS

- Scapula
 - Acromion
 - Spine of scapula
 - Glenoid cavity of scapula (with its articular cartilage)
 - Body of scapula
 - Coracoid process
- Infraglenoid tubercle (origin of long head of biceps tendon)
 - Proximal humerus
 - Humeral articular cartilage
 - Greater tuberosity of humerus
 - Lesser tuberosity of humerus
 - Intertubercular sulcus (for biceps tendon)
 - Clavicle
 - Acromioclavicular joint
 - Anterior glenoid labrum
 - Posterior glenoid labrum
 - Superior glenoid labrum
 - Inferior glenoid labrum

MAJOR LIGAMENTS/TENDONS/BURSAE

Tendons

- “SITS” tendons
 - Supraspinatus
 - Infraspinatus
 - Teres minor
- Subscapularis
- Long head of biceps
- Coracobrachialis

Ligaments

- Coracoclavicular (conoid and trapezoid components)
- Acromioclavicular
- Coracoacromial
- Sternoclavicular
- Coracohumeral
- Glenohumeral ligaments (focal thickenings of the anterior joint capsule)
 - Superior
 - Middle
 - Inferior

Bursae

- Subacromial/subdeltoid (most important)
- Subscapularis (normally communicates with glenohumeral joint)
- Infraspinatus
- Subcoracoid
- Coracobrachialis (not identified often on MR images)
- Latissimus dorsi
- Teres major
- Pectoralis major

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES

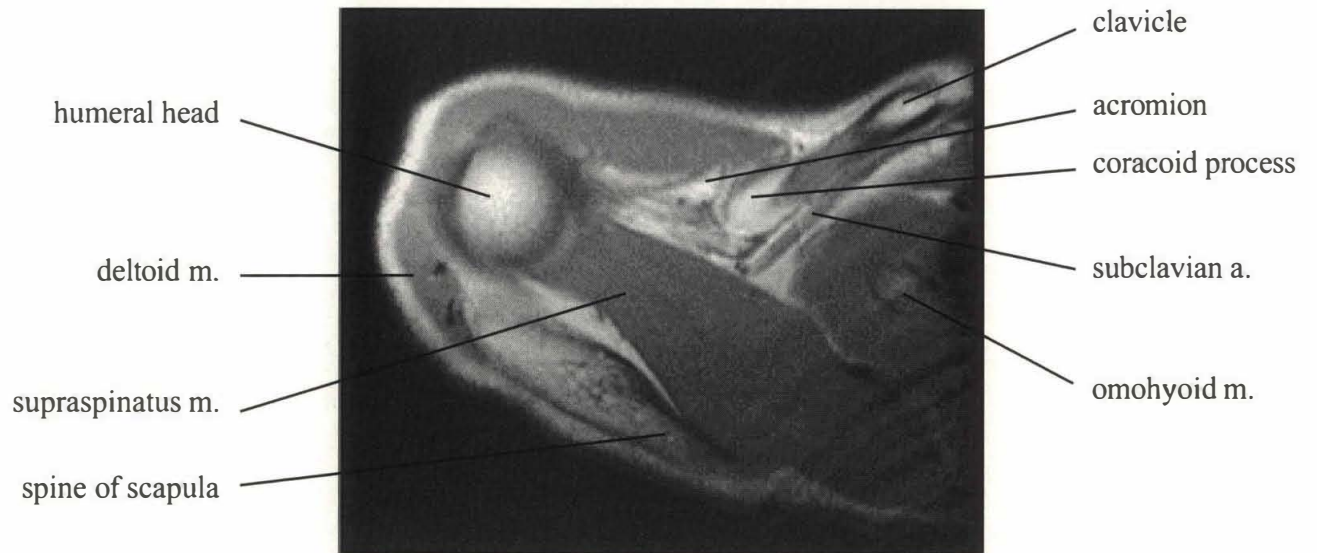
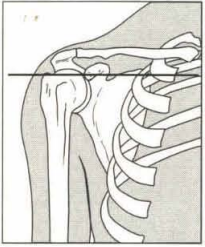
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
Dorsal Group			
-Supraspinatus (SS)	Supraspinatus fossa of scapula	Greater tuberosity of humerus	Suprascapular nerve (N.) (C5, C6)
-Infraspinatus (IS)	Infraspinatus fossa of scapula	Greater tuberosity of humerus (below SS insertion)	Suprascapular N. (C5, C6)
-Teres minor (TM)	Lateral margin of scapula	Posterior facet of greater tuberosity	Axillary N. (C5, C6)
-Deltoid	Lateral third of clavicle, acromion, scapular spine	Deltoid tuberosity of humerus	Axillary N. (C5, C6)
-Subscapularis	Suprascapular fossa	Lesser tuberosity	Subscapular N. (C5, C6)
-Latissimus dorsi	Spinous processes (T6-T12), thoracolumbar fascia of L spine and sacrum	Medial aspect of intertubercular groove	Thoracodorsal N. (C6-C8)
Ventral Group			
-Pectoralis major	Sternal half of clavicle, sternum, costochondral junctions	Lateral aspect of intertubercular groove	Medial/lateral anterior thoracic N. (C5-T1)
-Pectoralis minor	Anterior ribs 2-5	Coracoid process of scapula	Medial pectoral N. (C8-T1)
-Corabrachialis	Coracoid process of scapula	Inner surface of humerus	Musculocutaneous N.

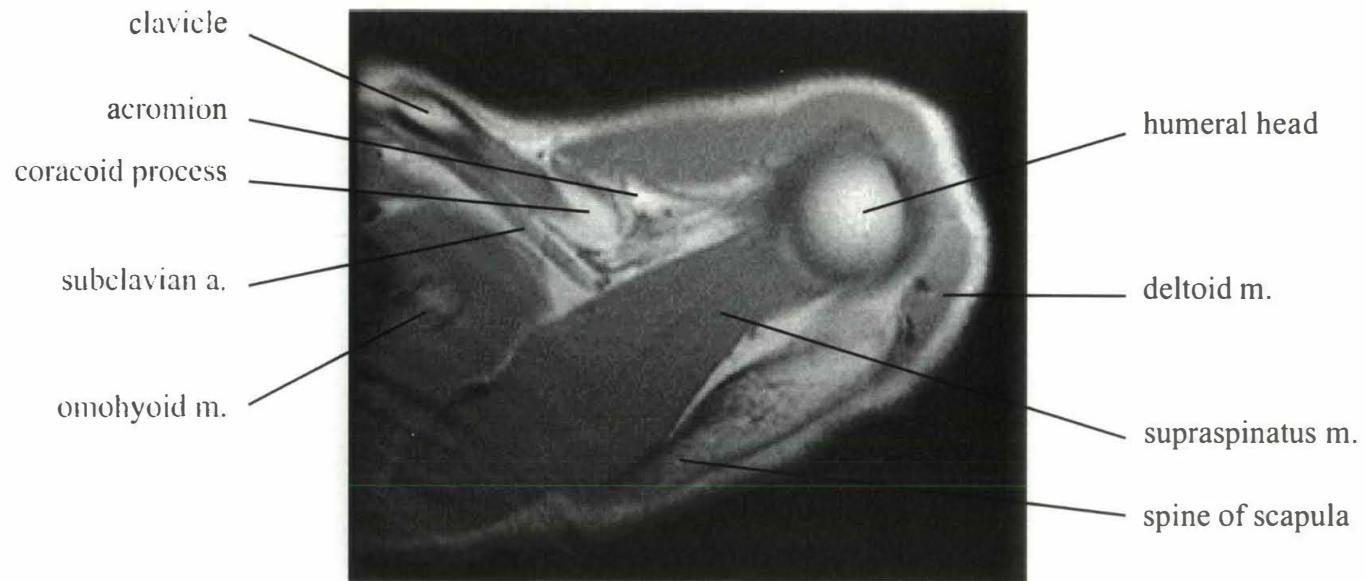
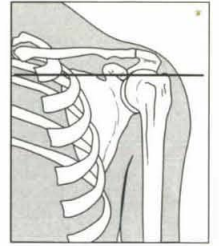
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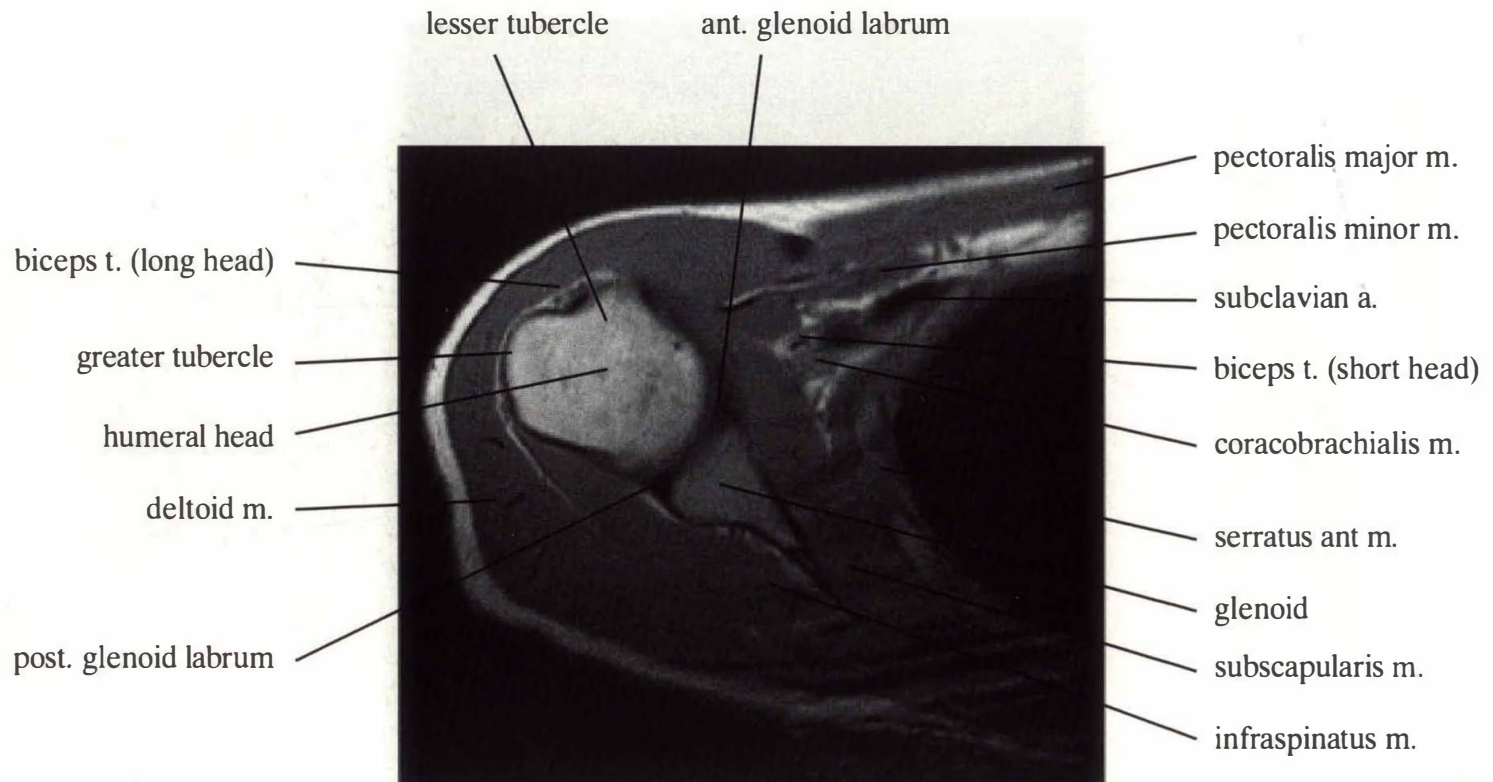
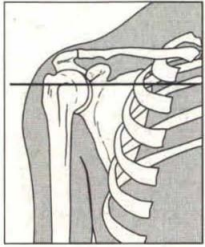
ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

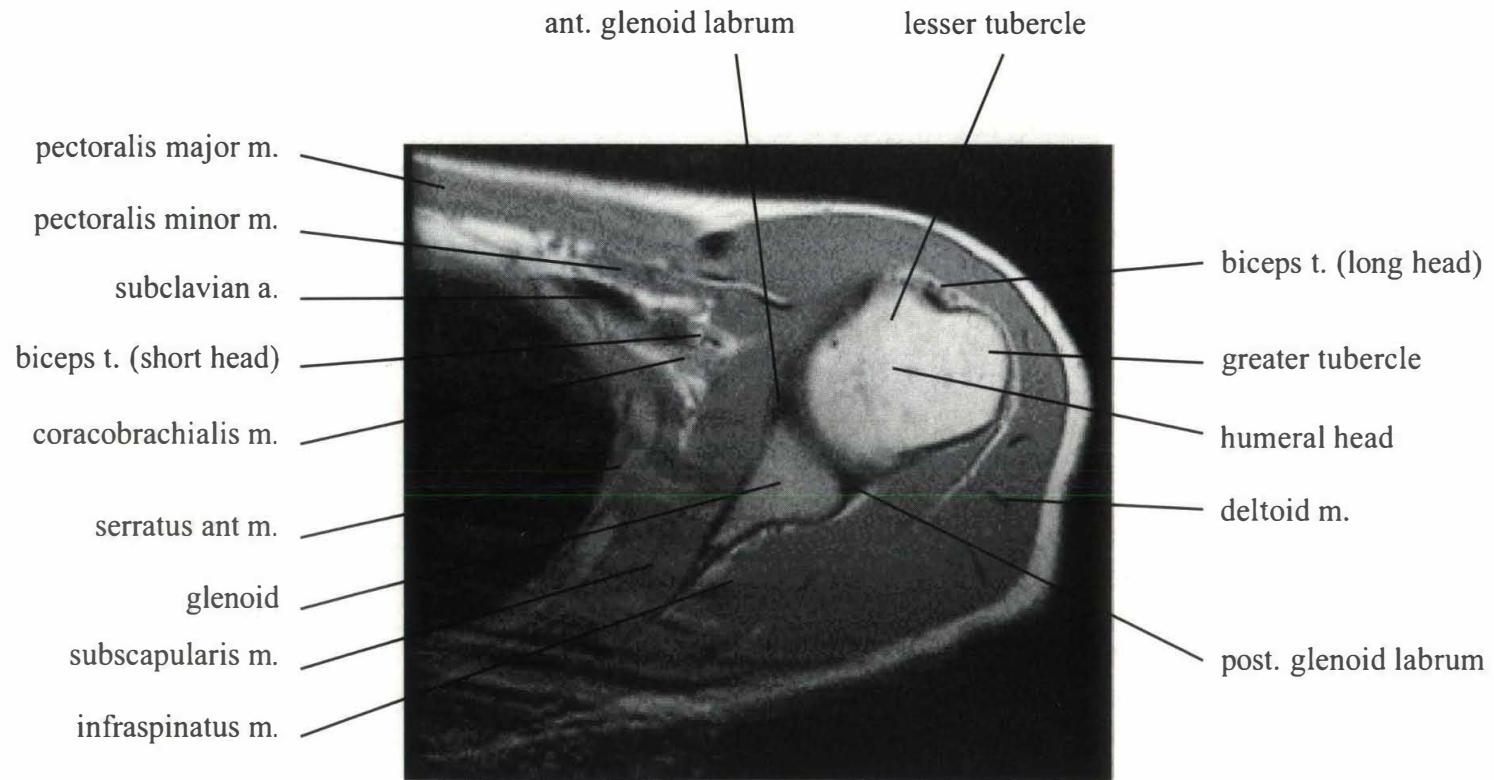
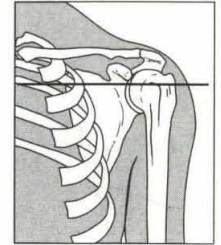
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
Other Muscles			
–Teres major	Inferior and lateral aspect of scapula	Medial aspect, intertubercular groove	Subscapular N. (C5, C6)
–Trapezius	Ligamentum nuchae, spinous processes of thoracic vertebrae	Distal clavicle, acromion, spine of scapula	Spinal accessory and C2, C3
–Levator scapulae	Posterior tubercles, transverse processes of C1–C4	Upper and medial scapula	Cervical plexus (C3–C4)
–Rhomboids			
–Major	Spinous processes of C2–T5	Posterior and medial scapula	Dorsal scapular N. (C5)
–Minor	Ligamentum nuchae, spinous processes of C7/T1	Posterior and medial scapula	Dorsal scapular N. (C5)
–Serratus anterior	Ribs 1–9	Anterior and medial scapula	Long thoracic N. (C5–C7)
–Subclavius	Anterior and medial first rib	Middle and inferior clavicle	Subclavian N.

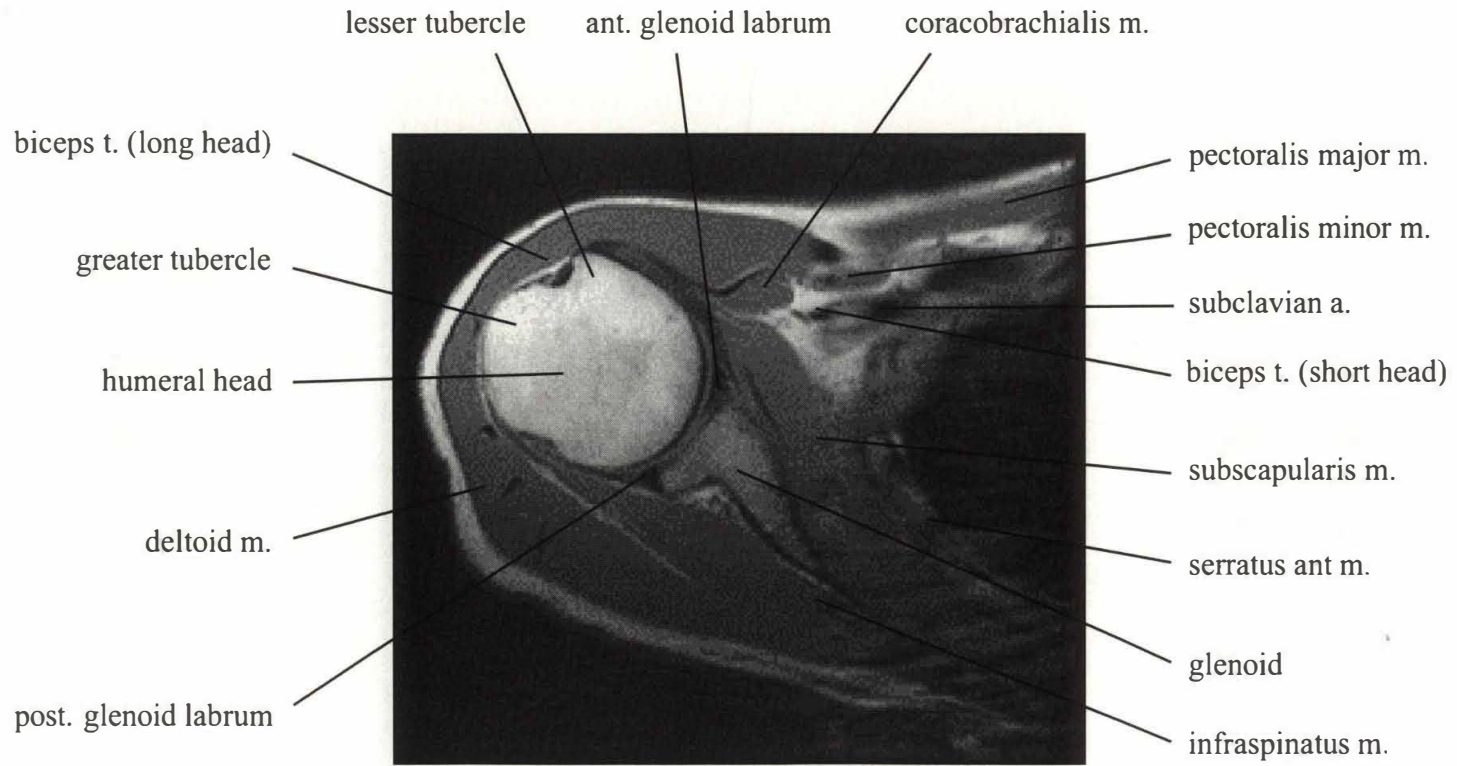
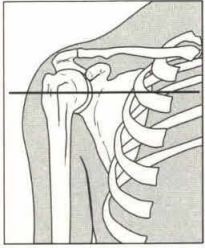
THE SHOULDER: AXIAL ANATOMY

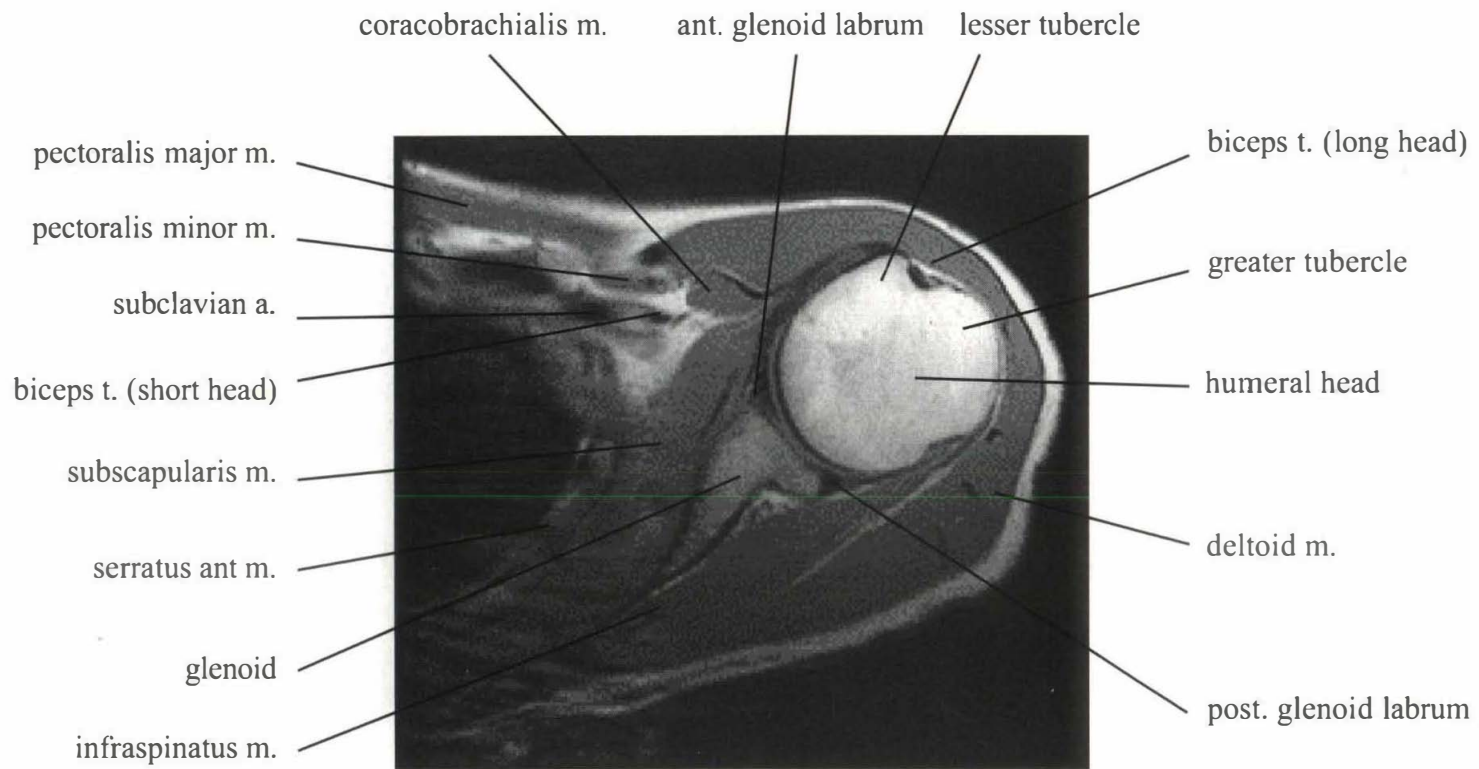
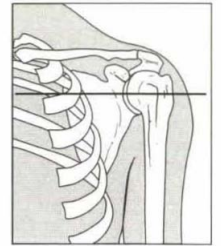


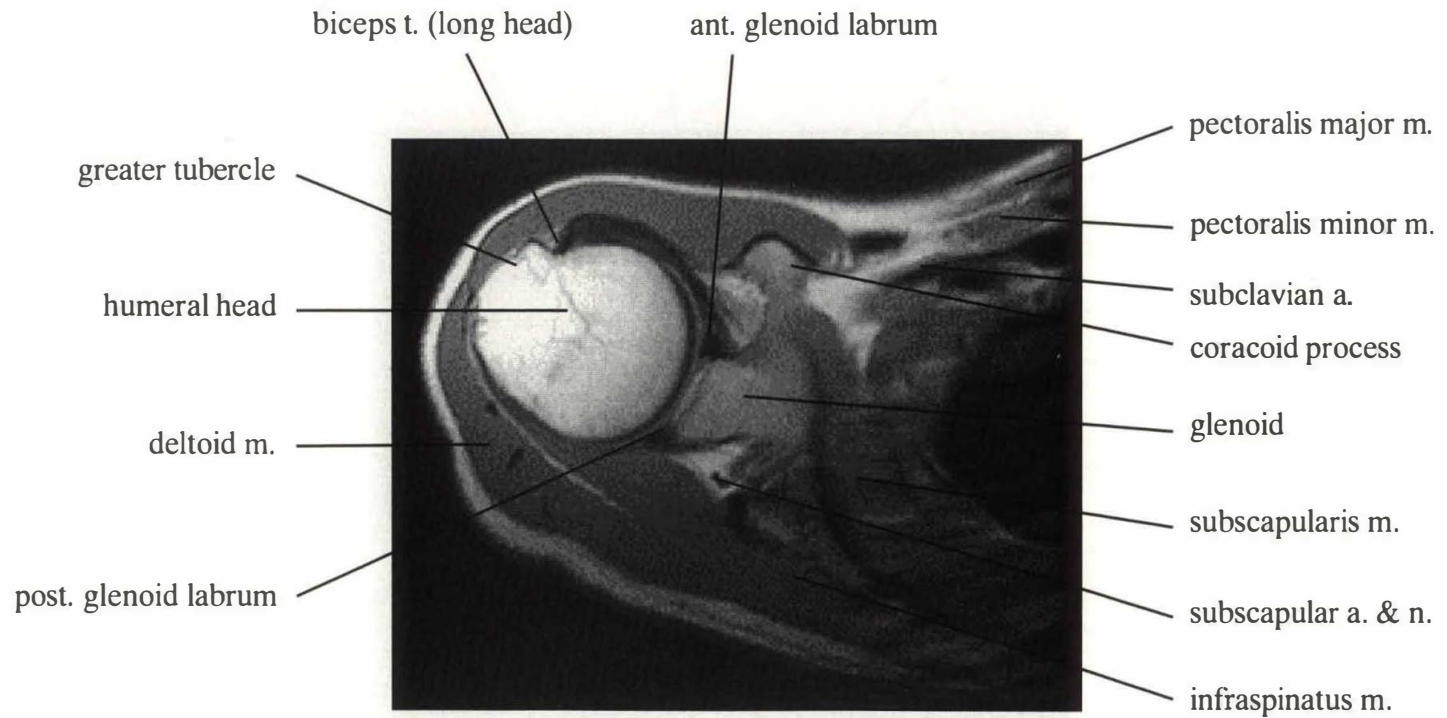
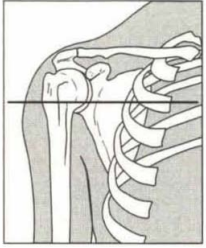


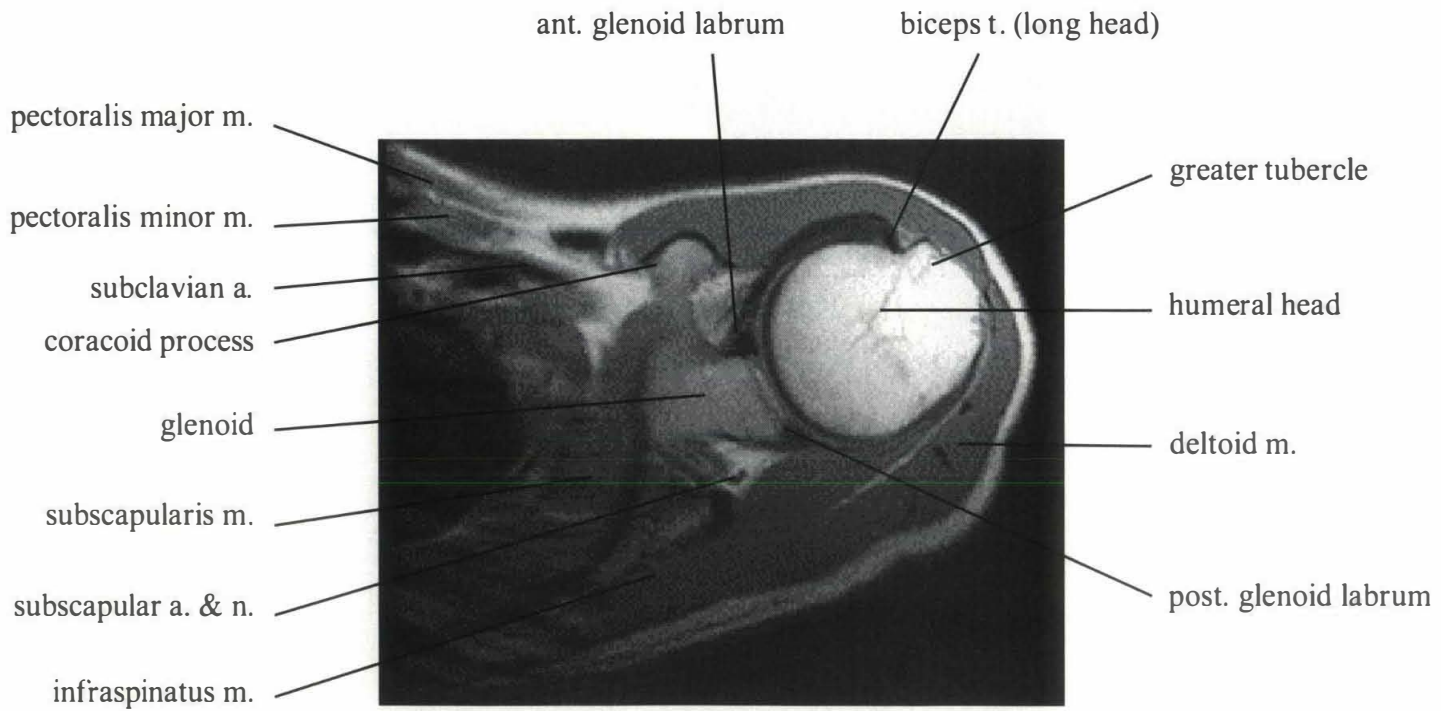
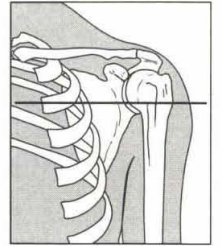


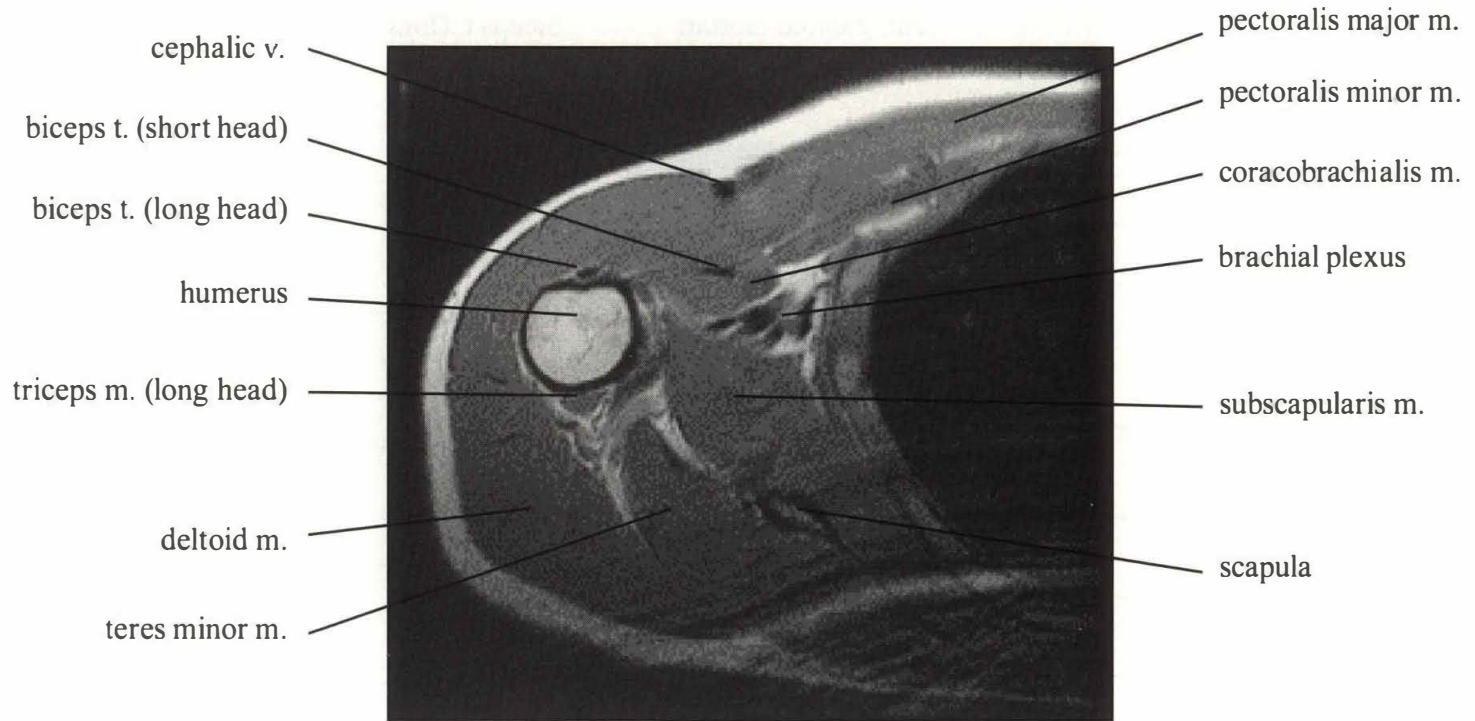
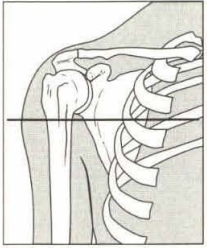


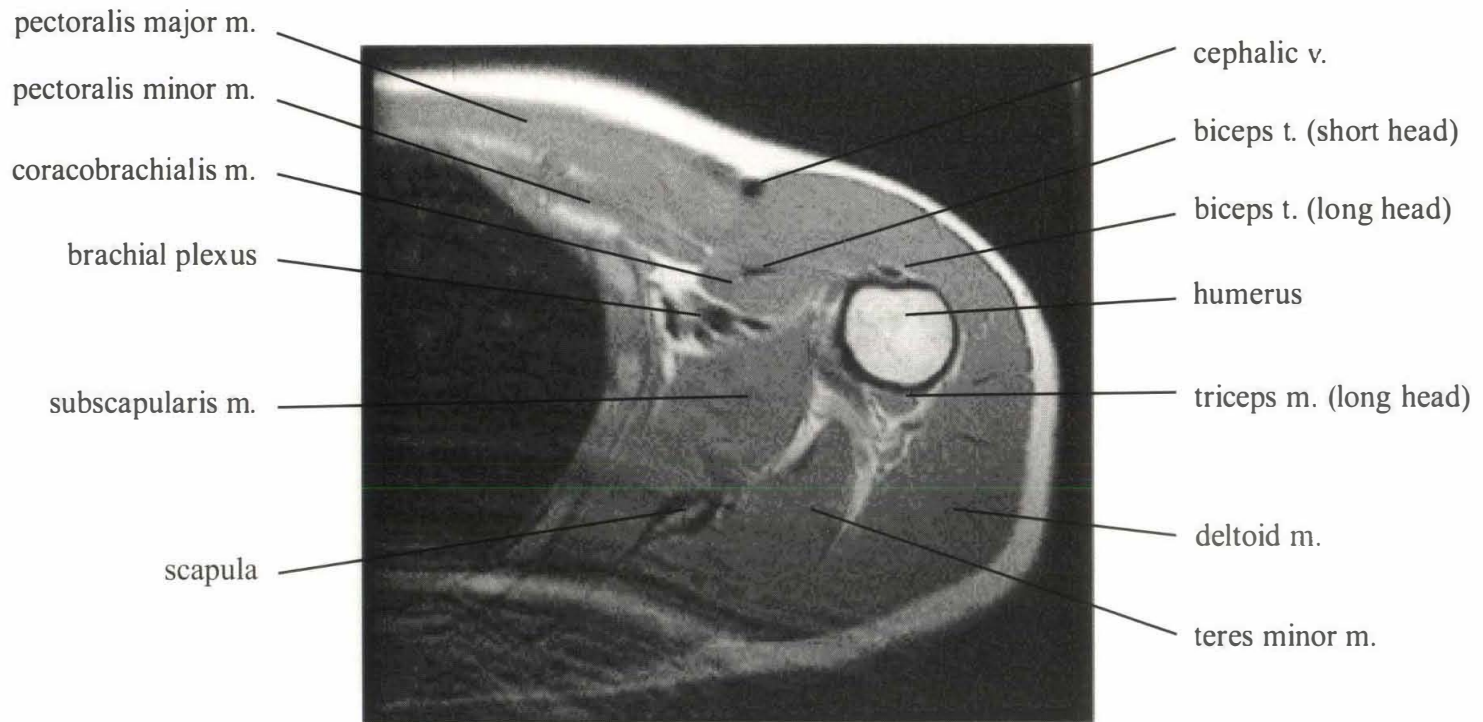
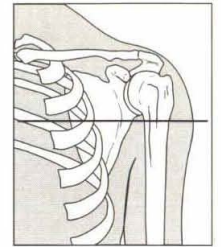




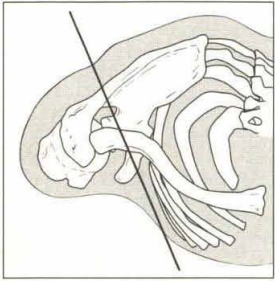


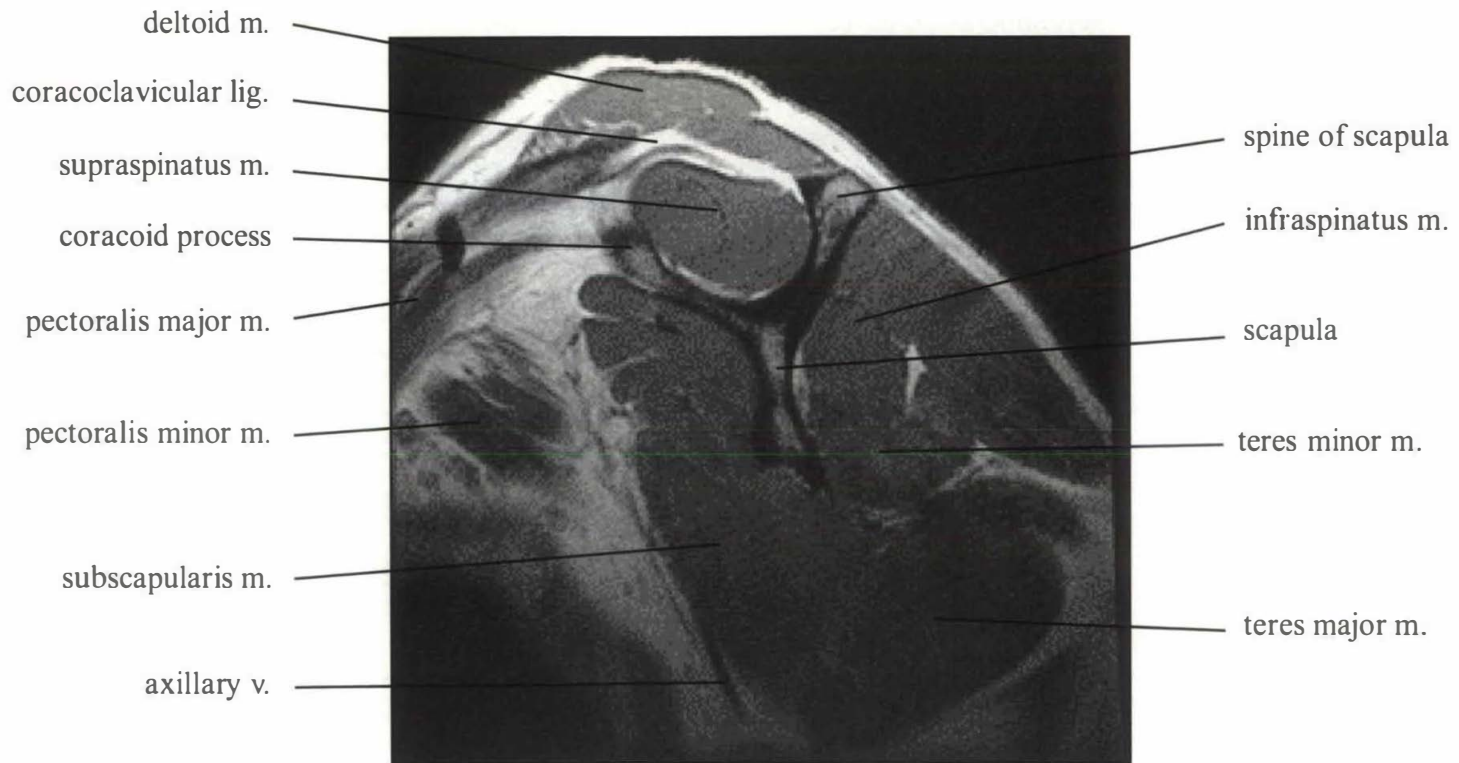
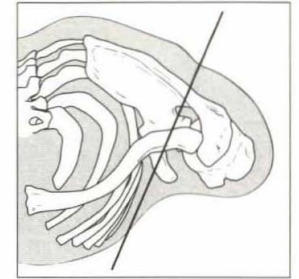






**THE SHOULDER:
OBLIQUE SAGITTAL ANATOMY**





deltoid m.

coracoclavicular lig.

supraspinatus m.

coracoid process

pectoralis major m.

pectoralis minor m.

subscapularis m.

axillary v.

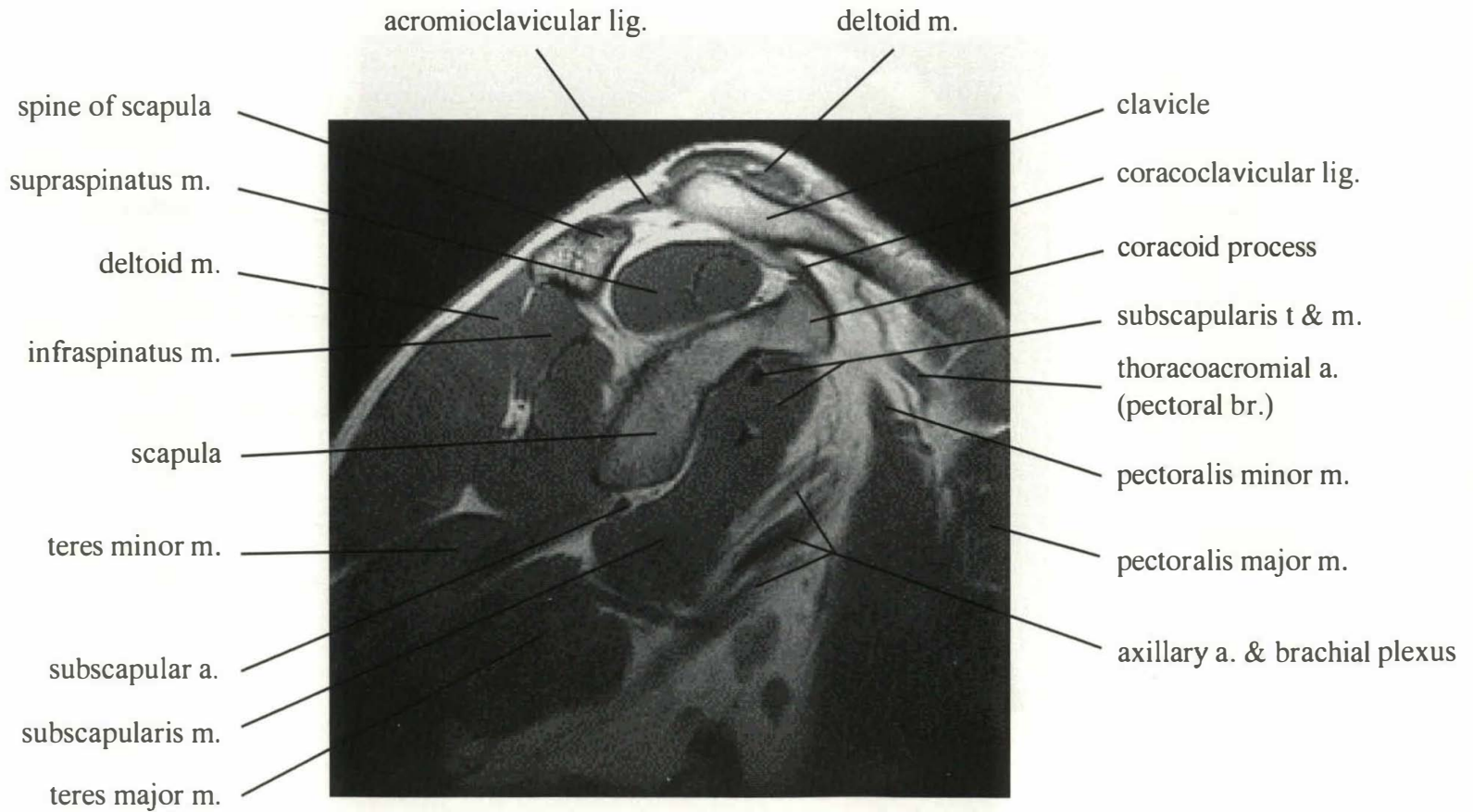
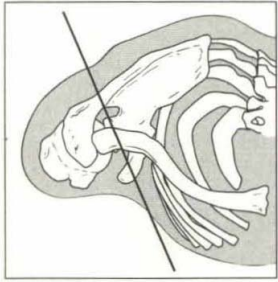
spine of scapula

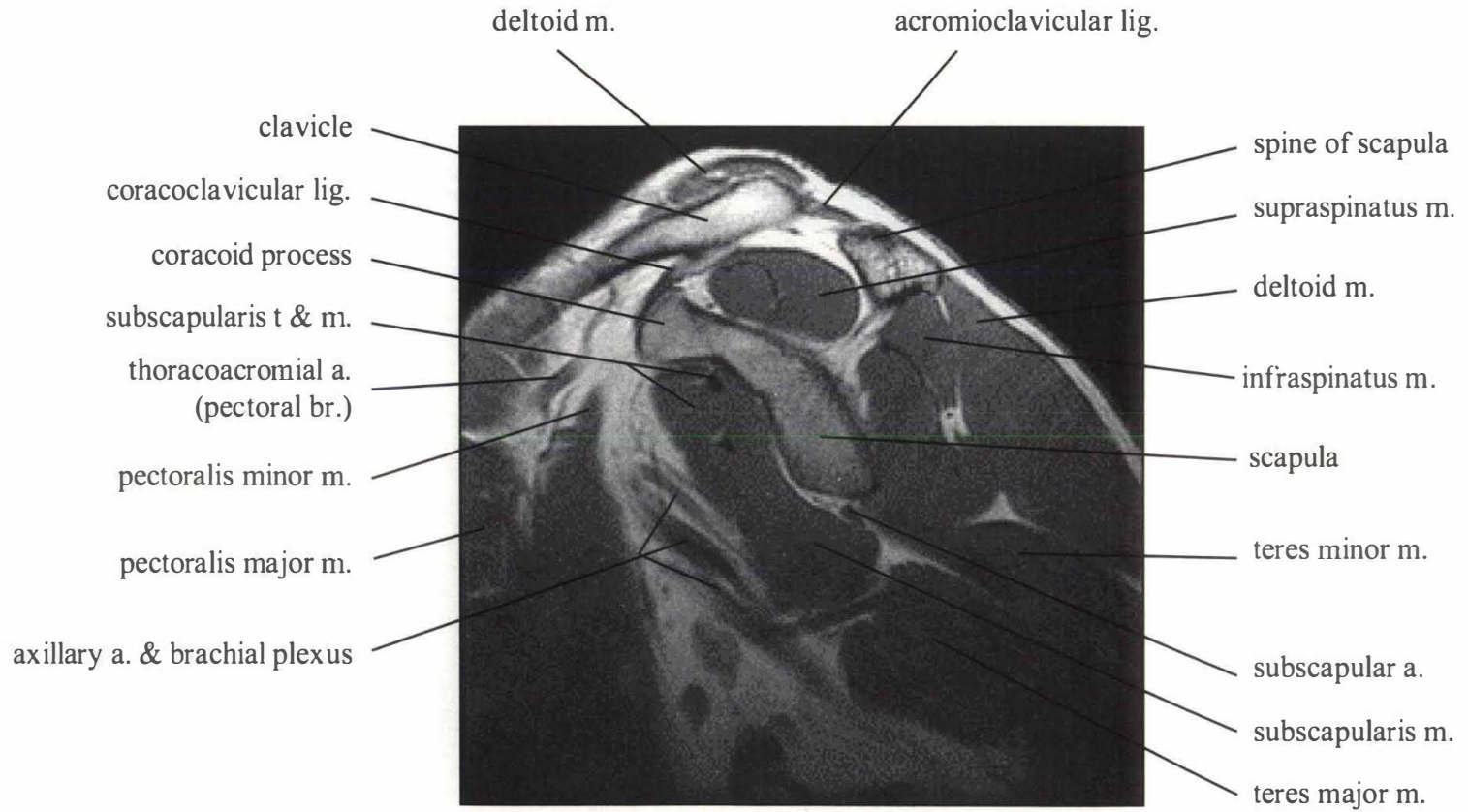
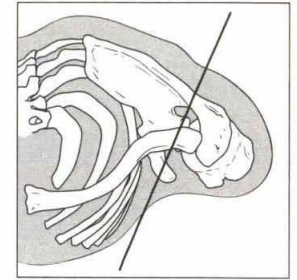
infraspinatus m.

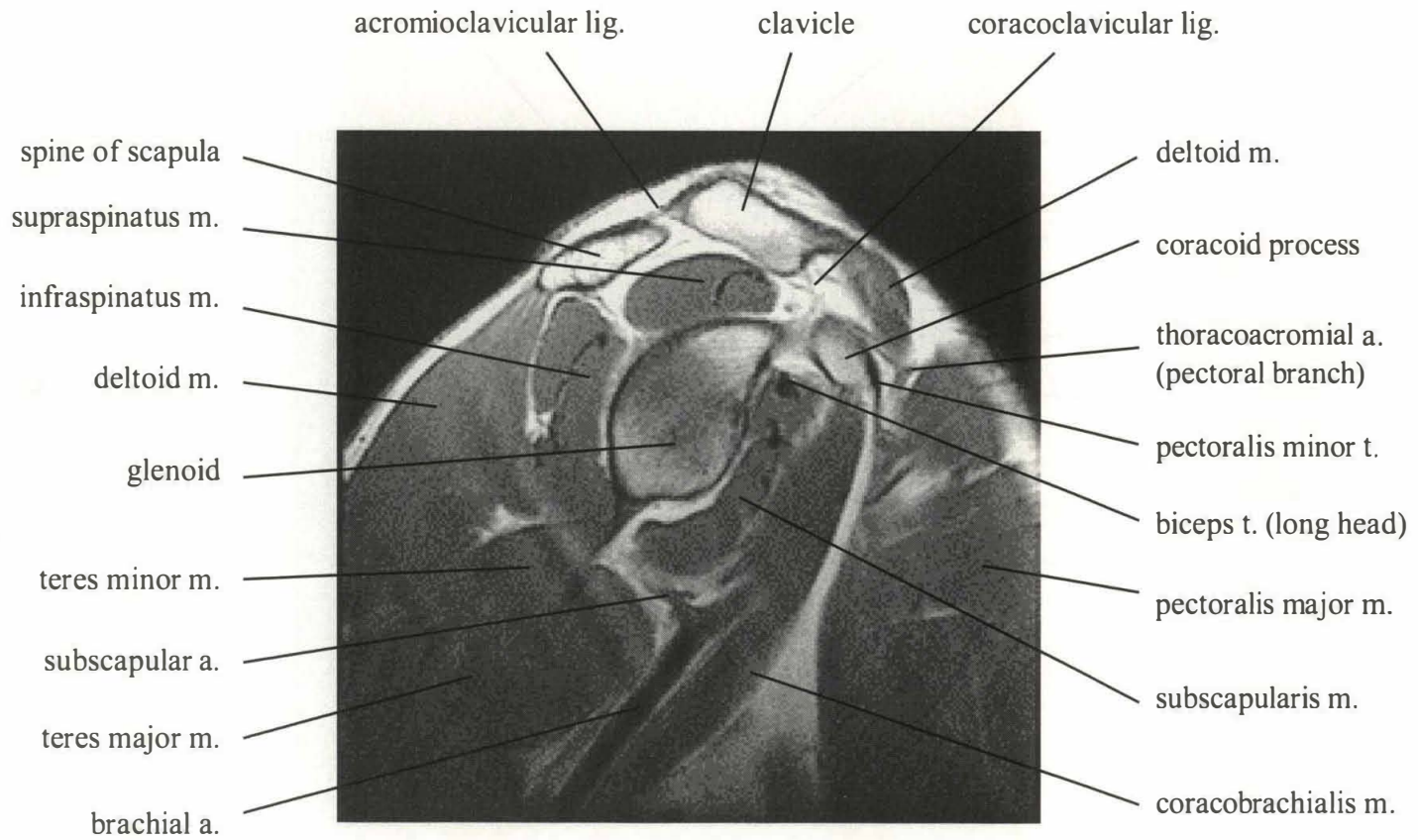
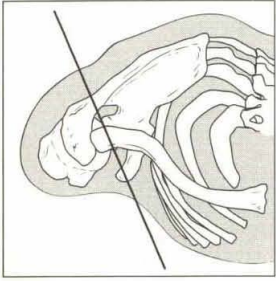
scapula

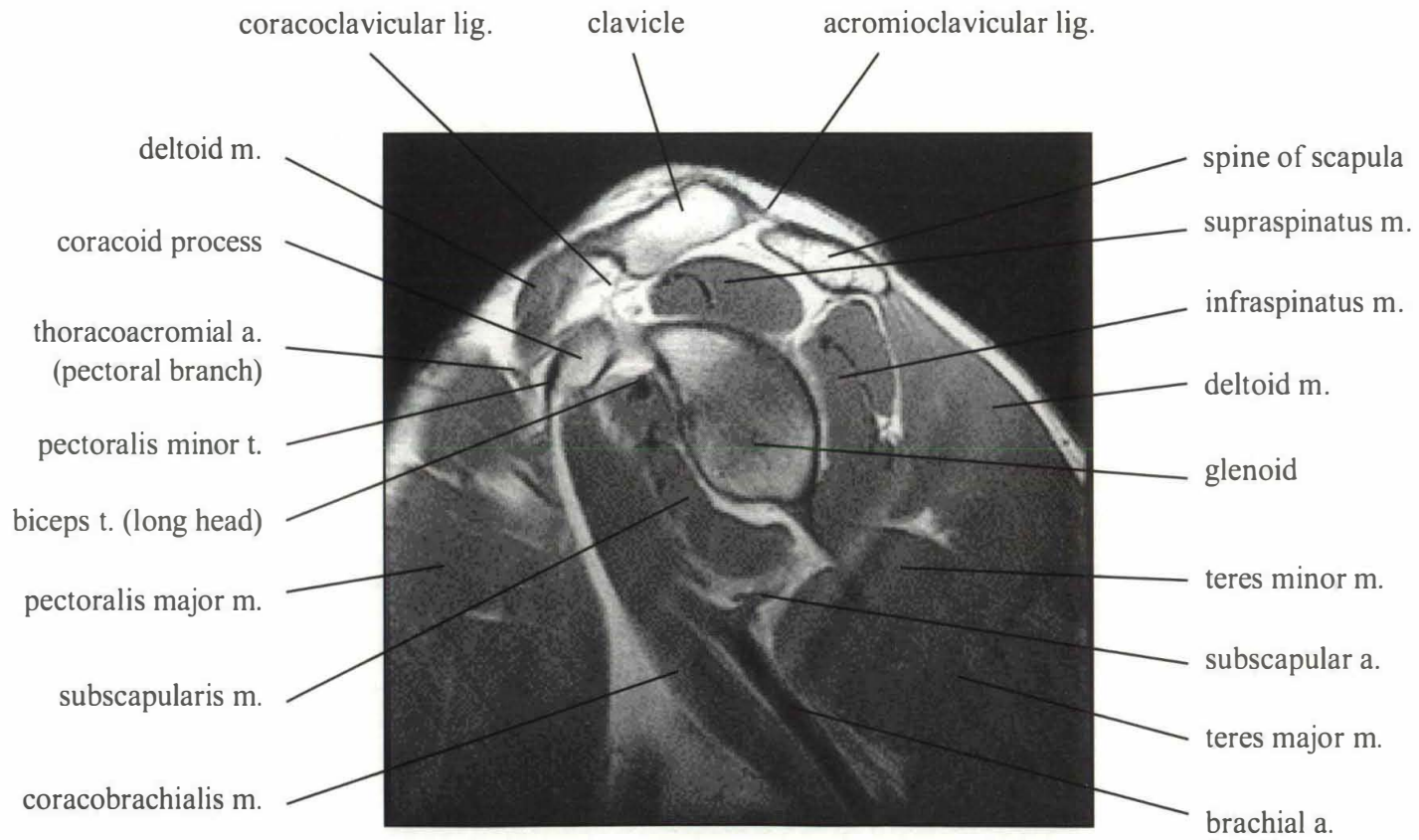
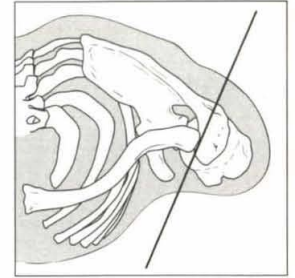
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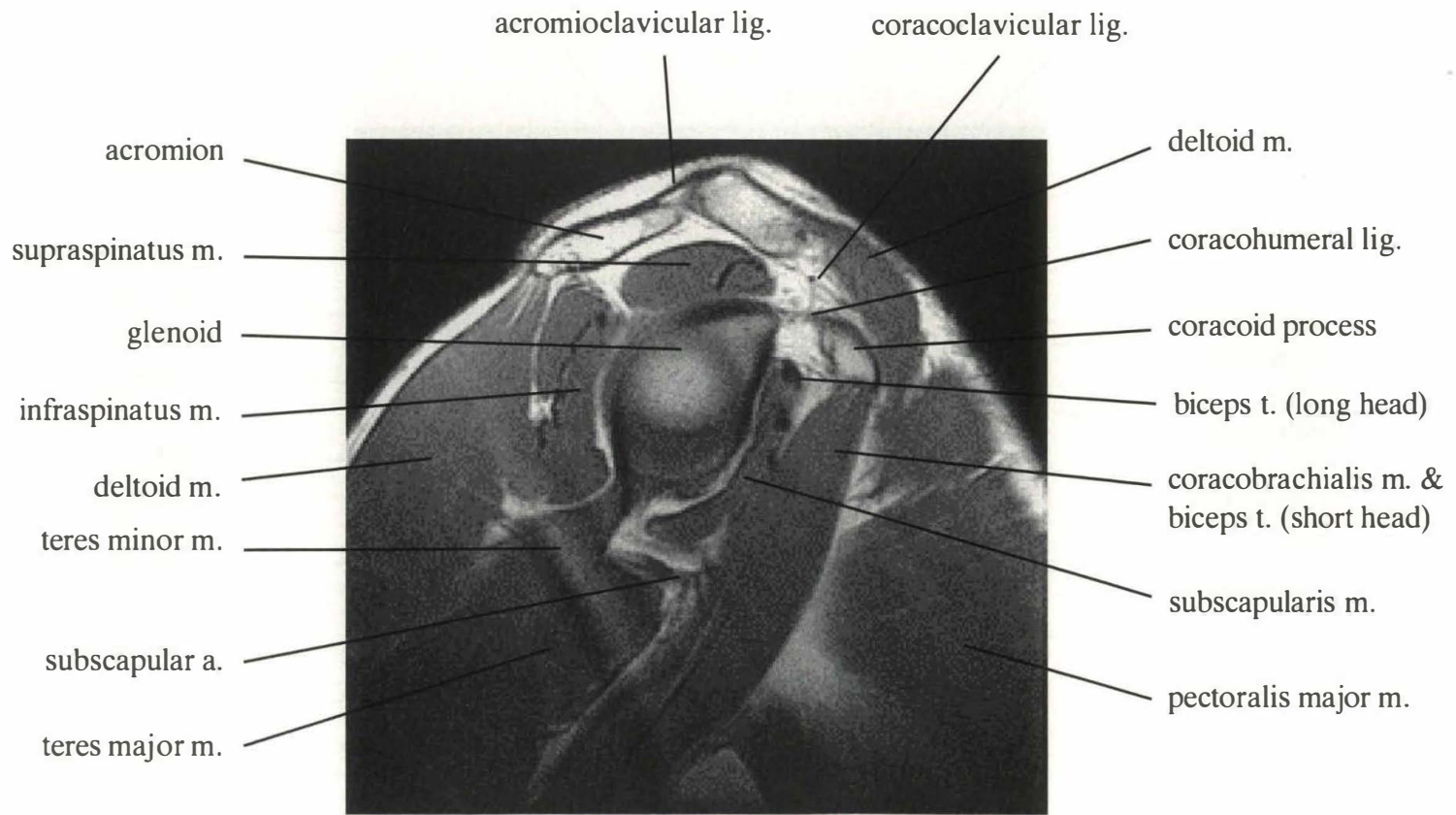
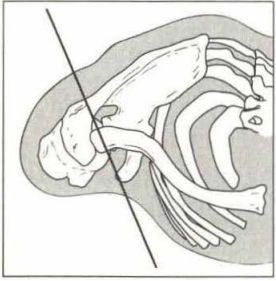
teres major m.

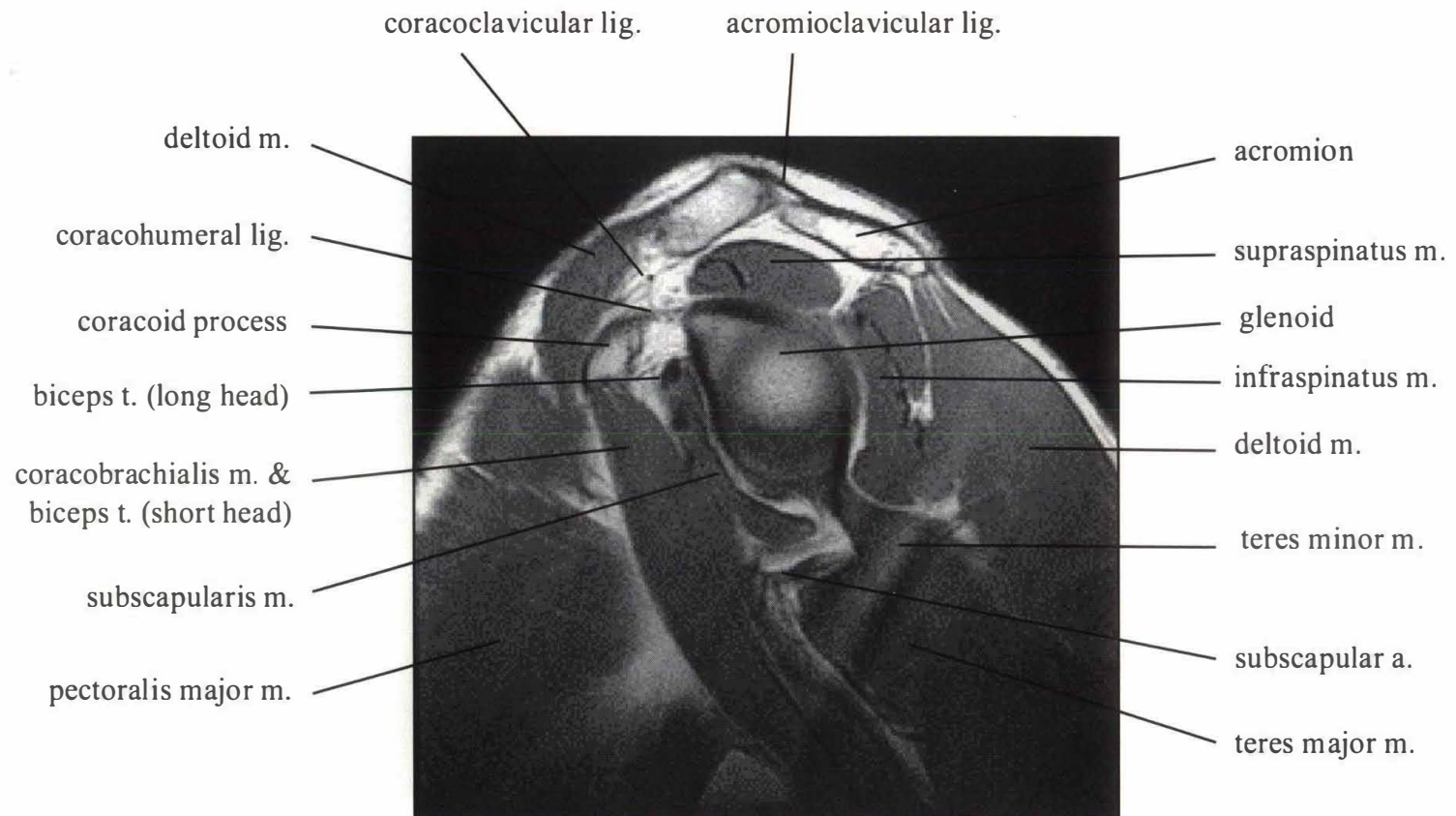
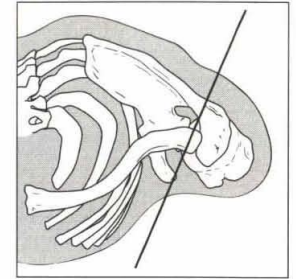


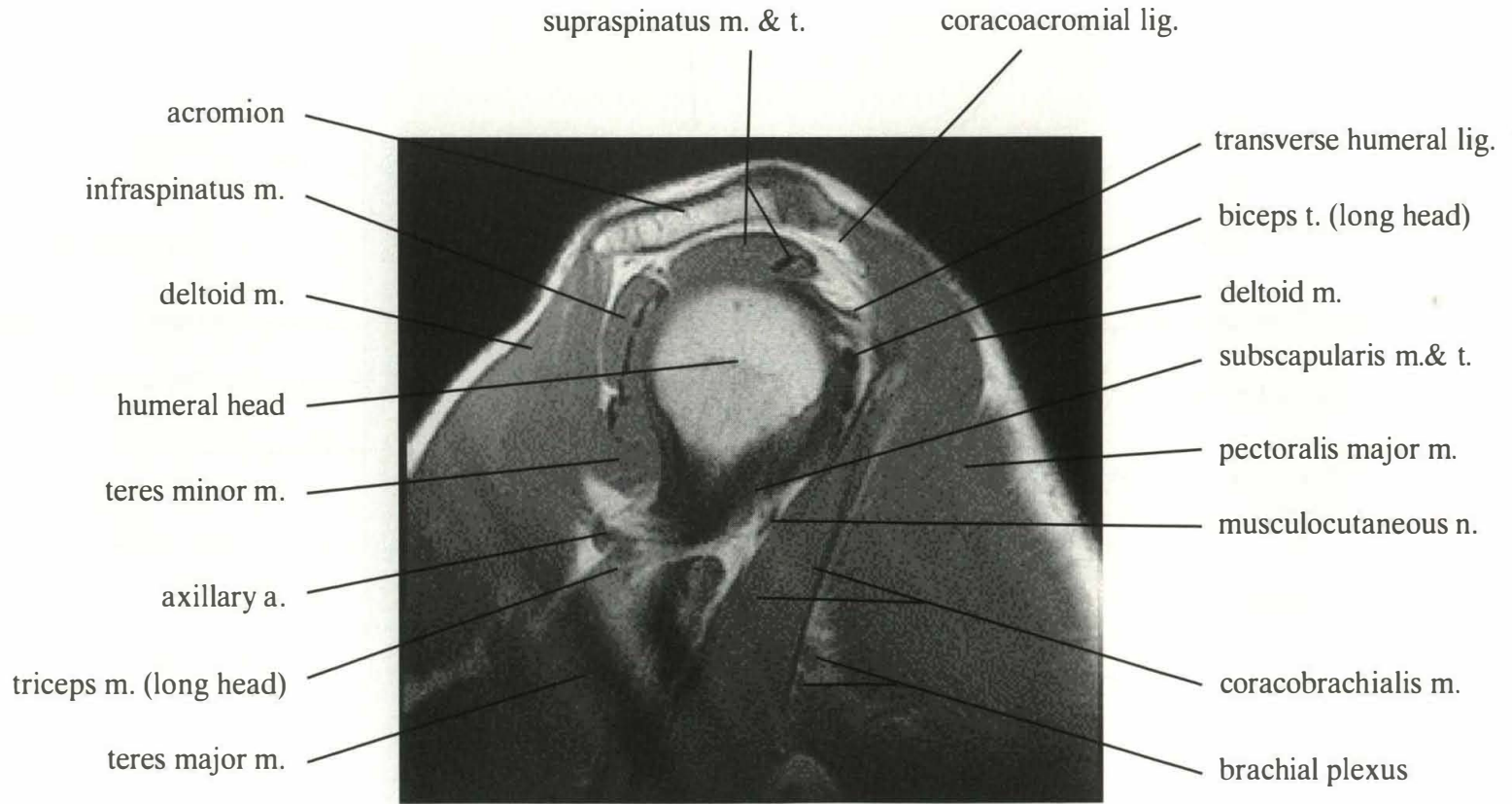
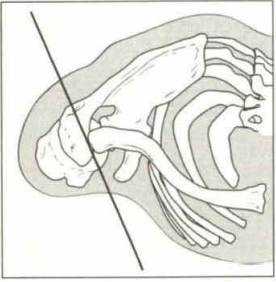


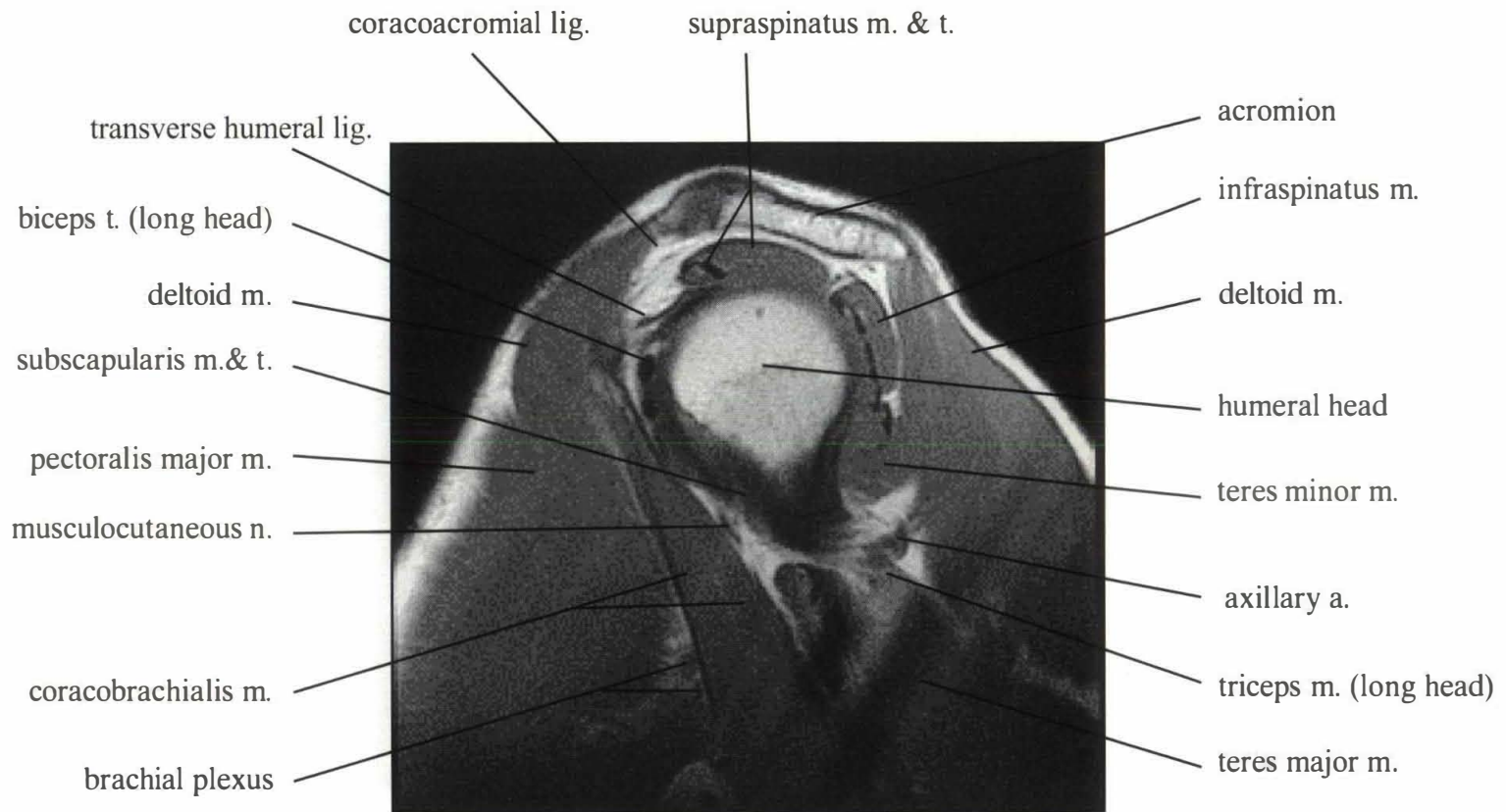
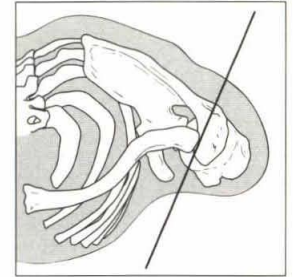


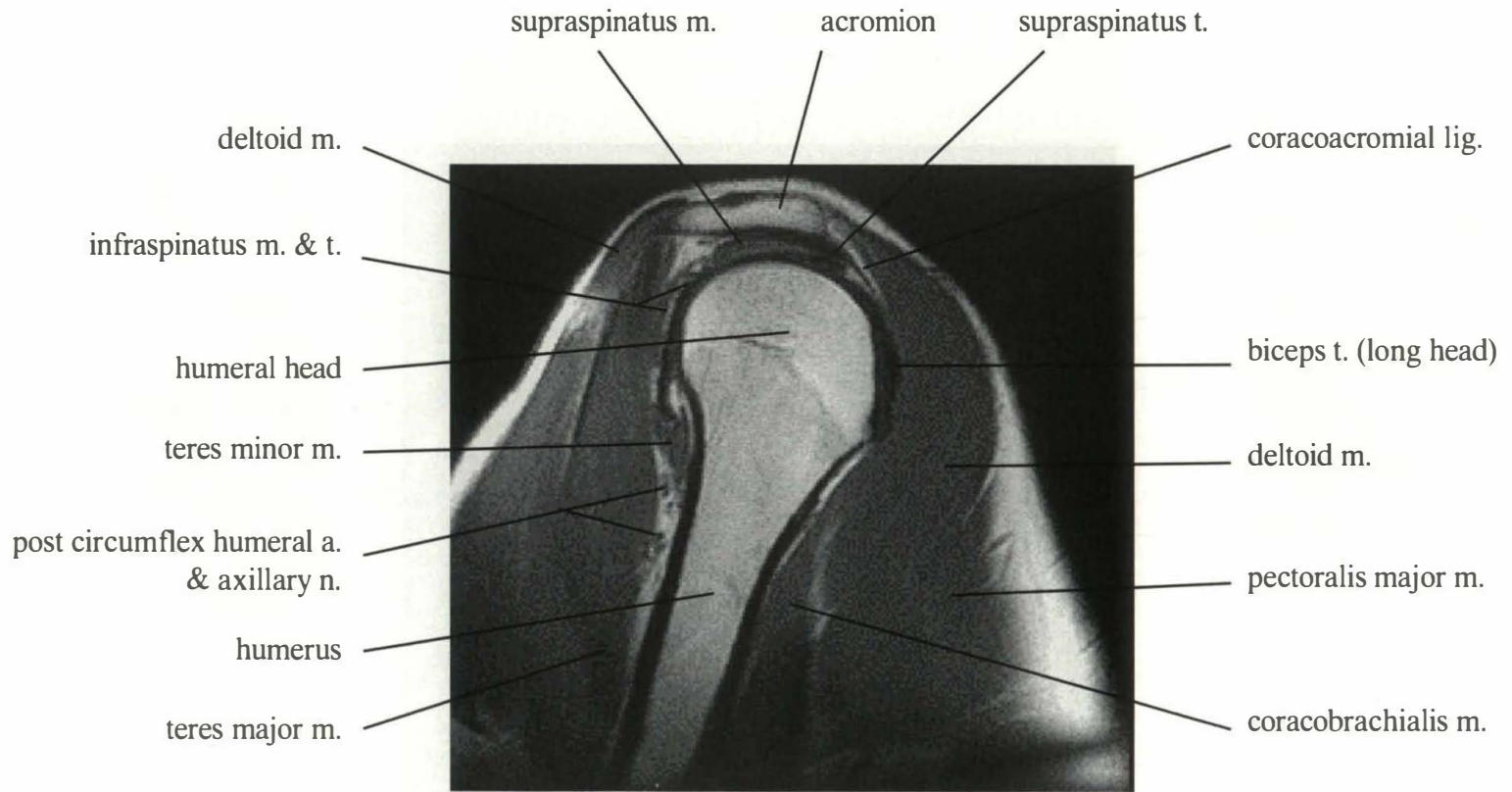
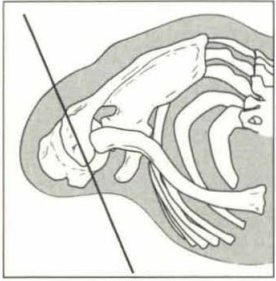


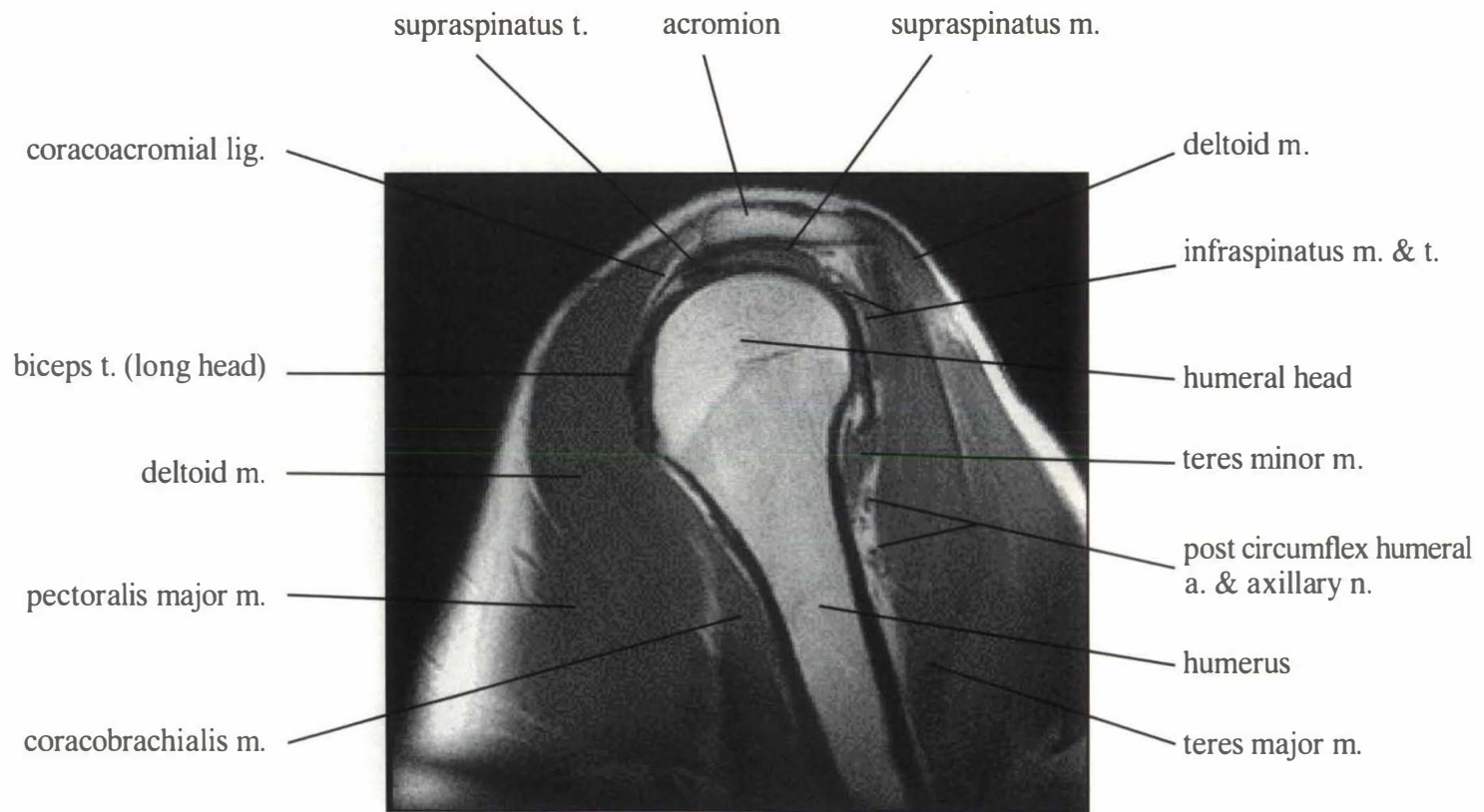
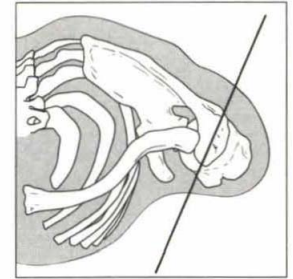


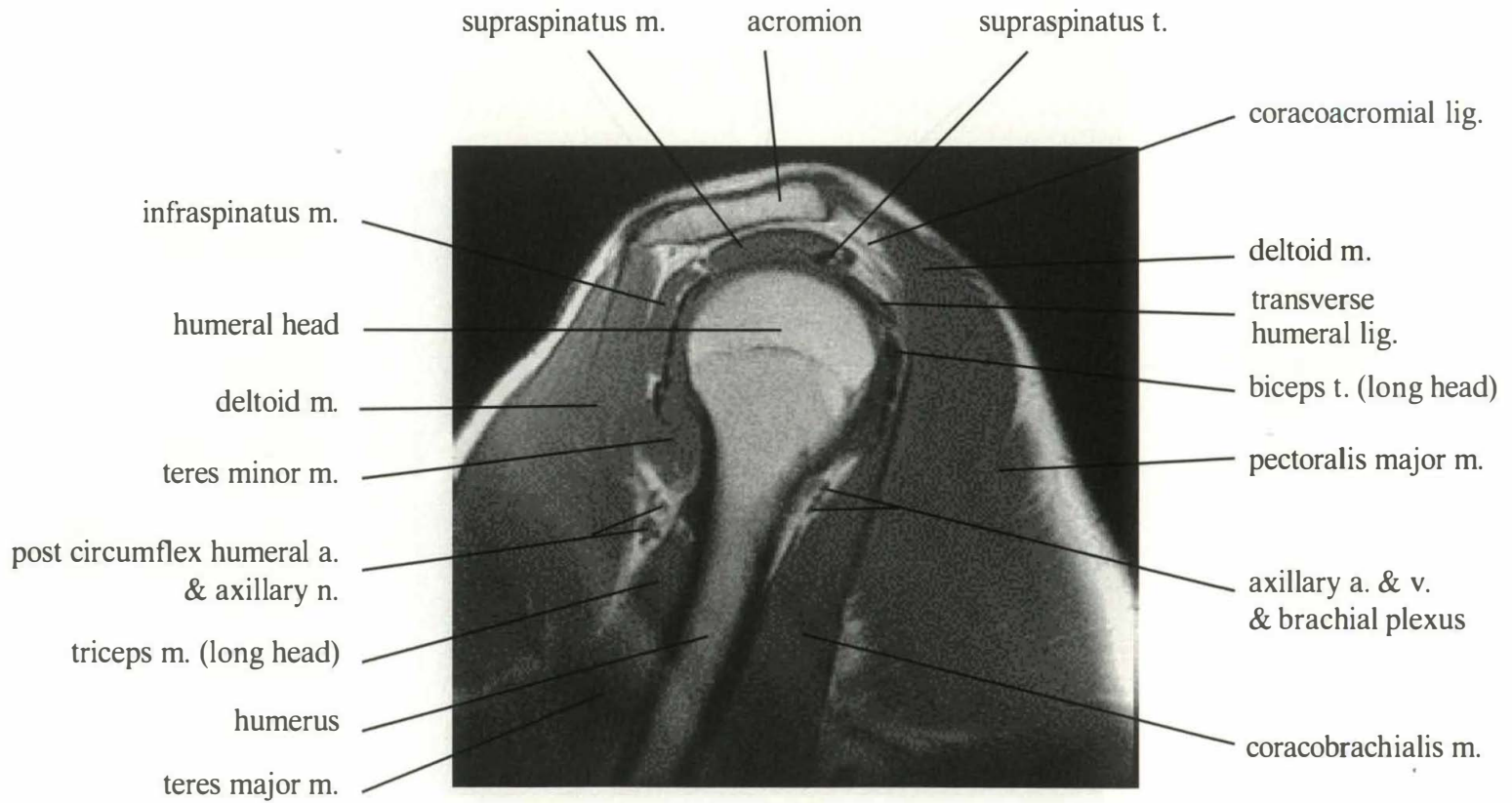
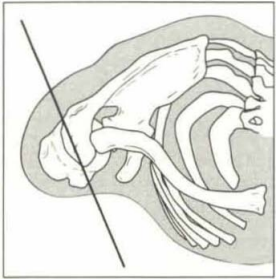


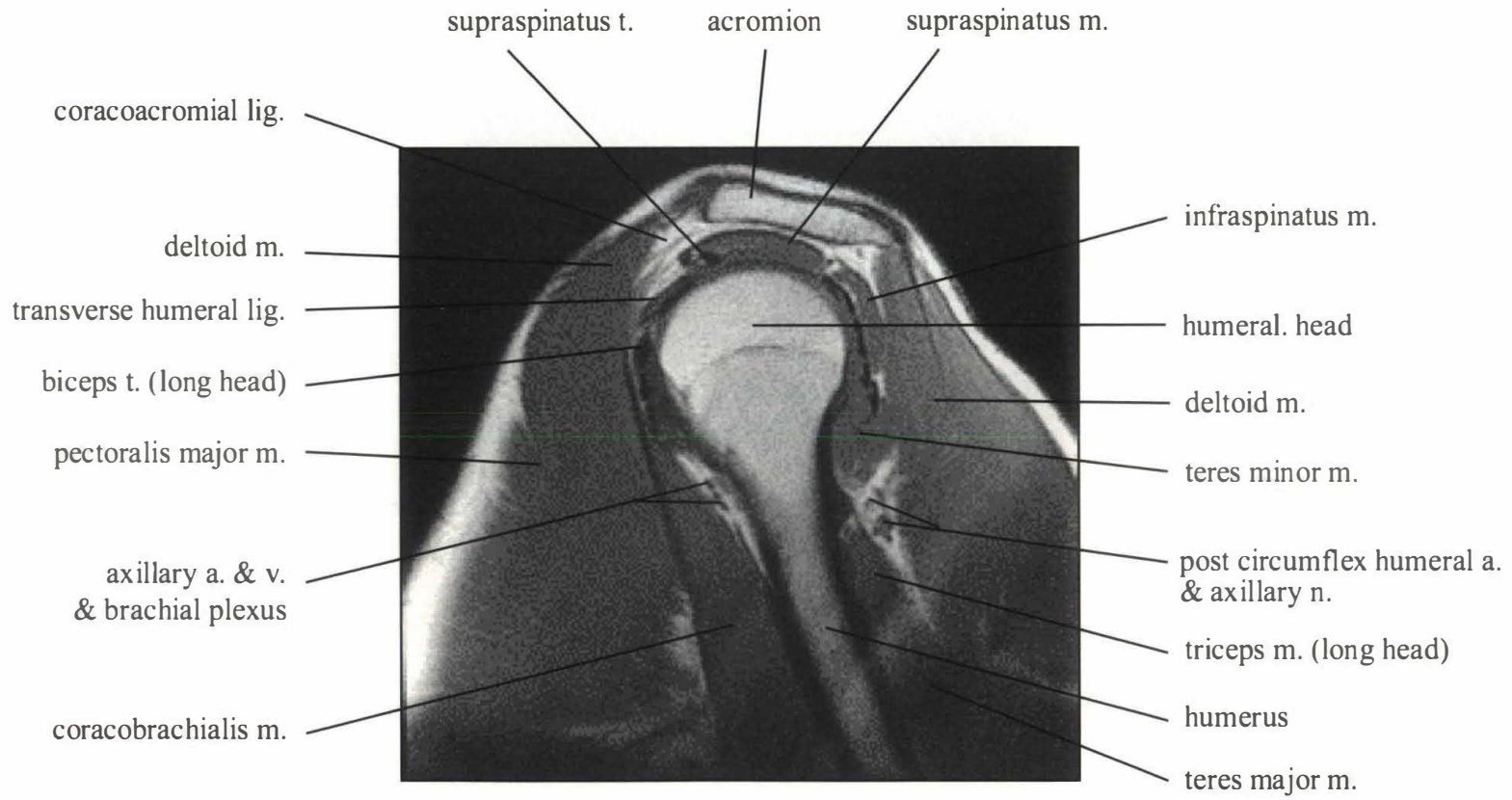
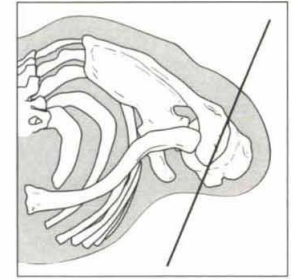


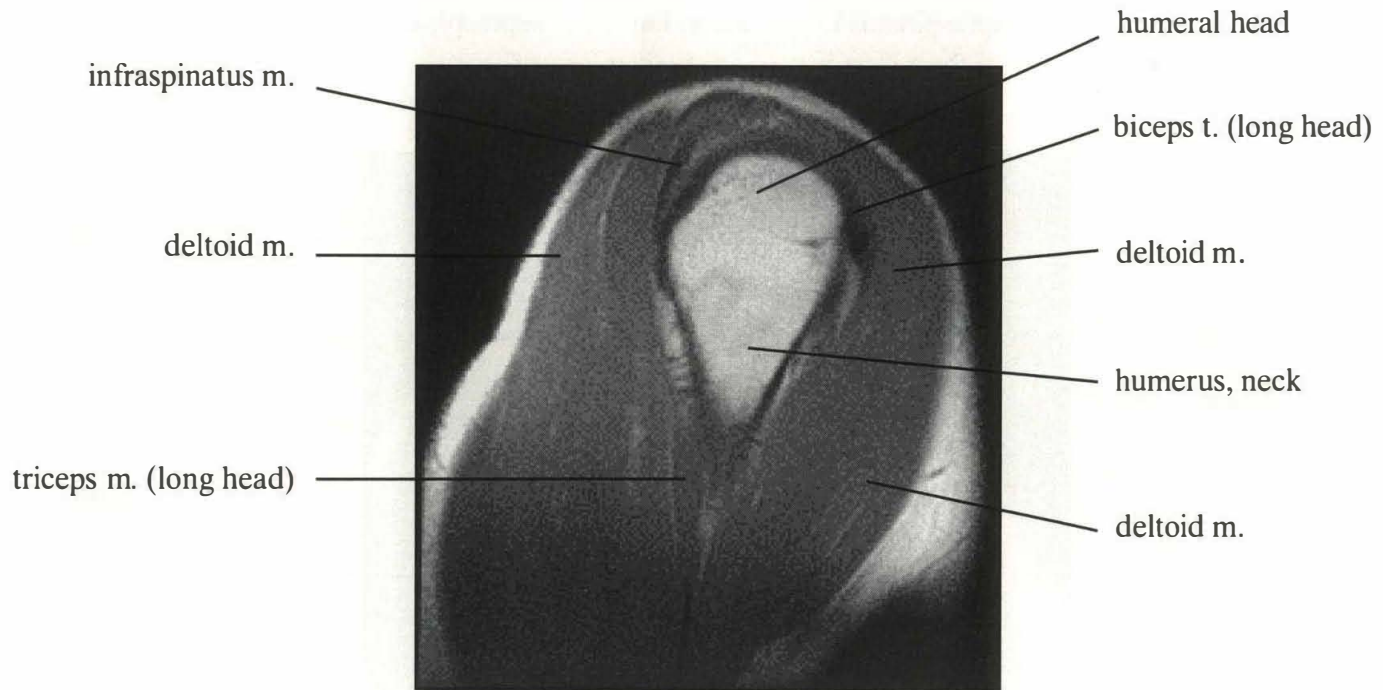
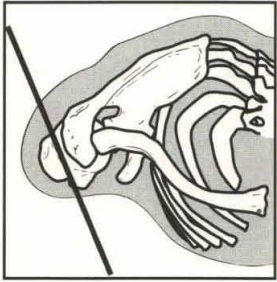


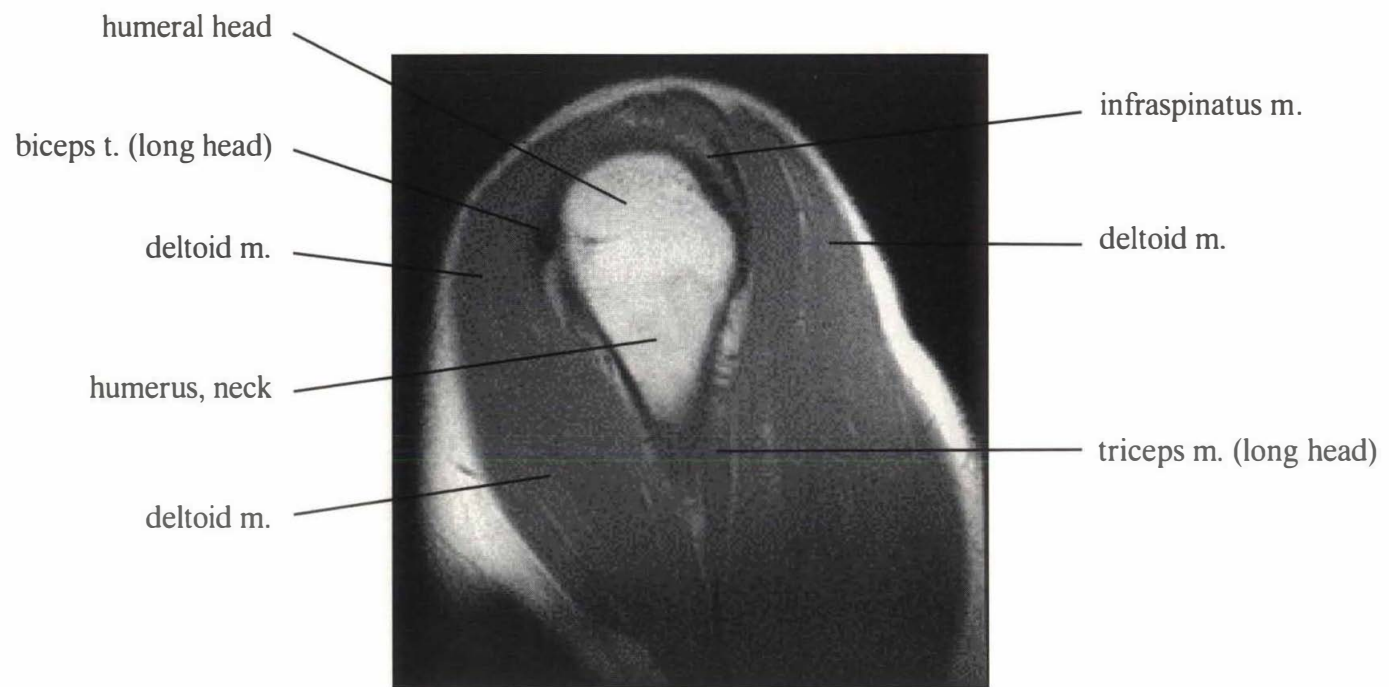
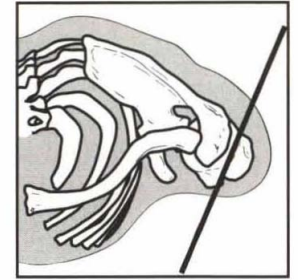




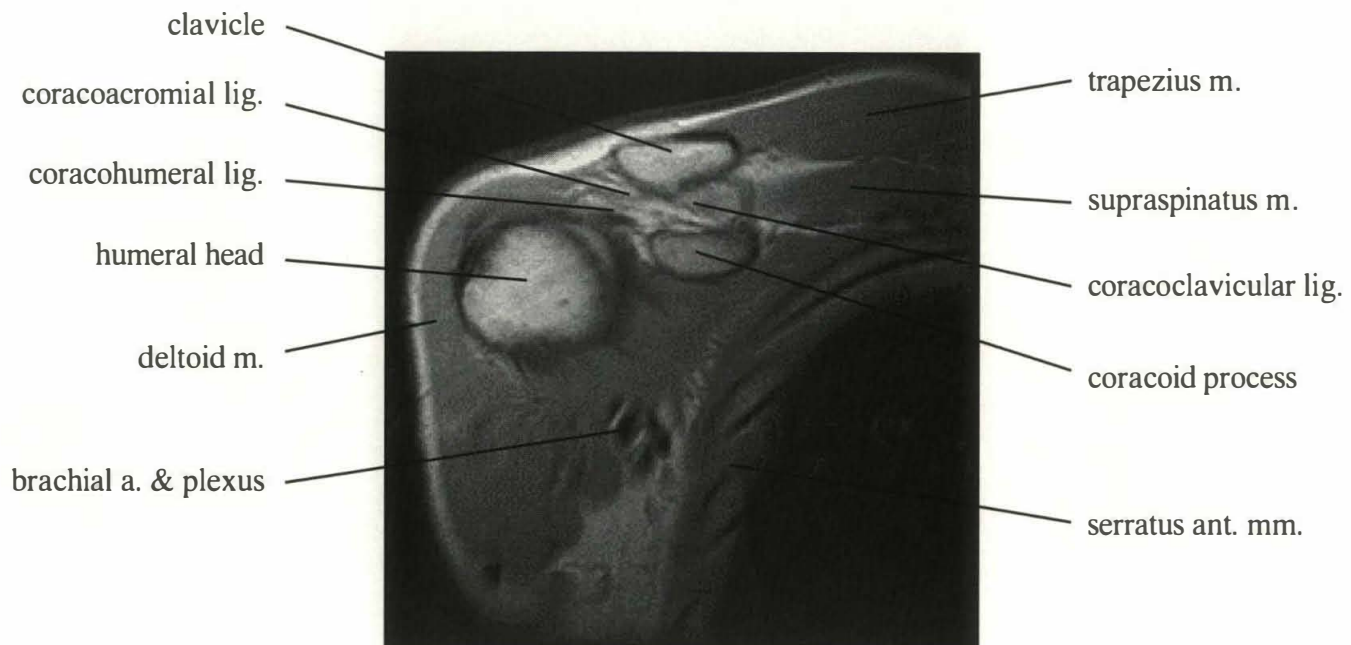
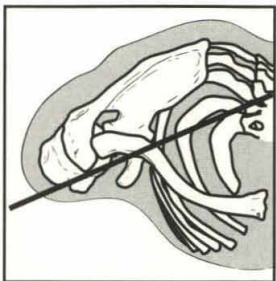


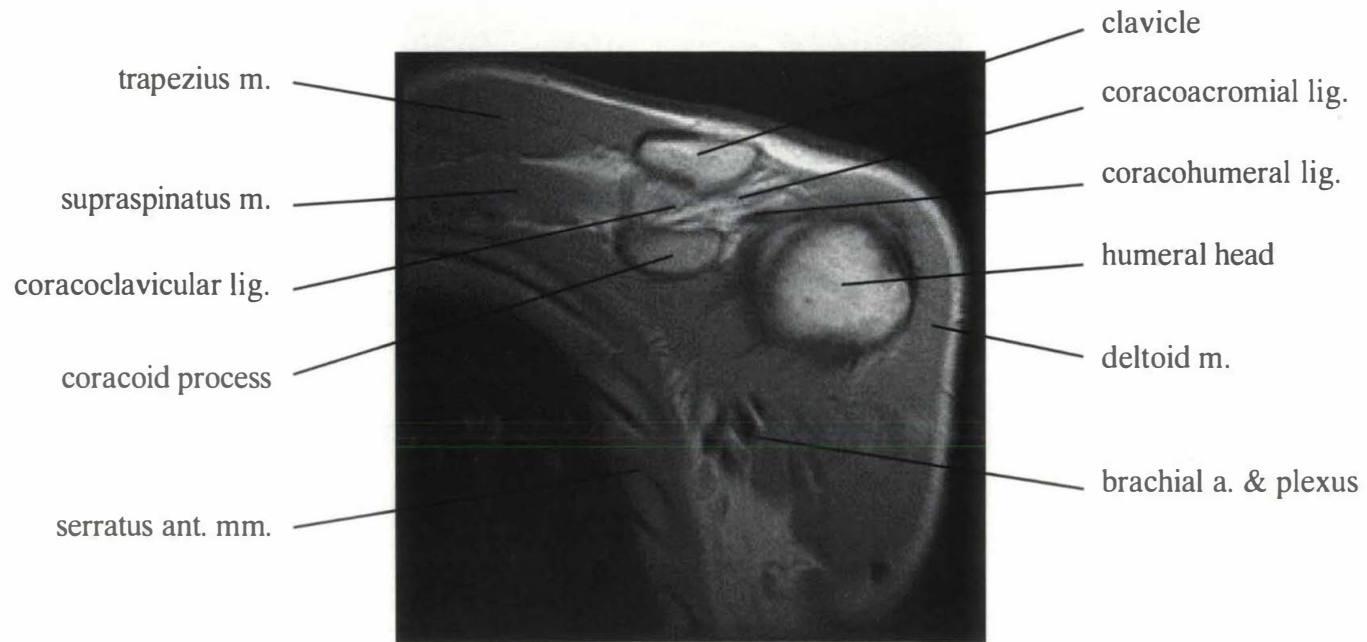
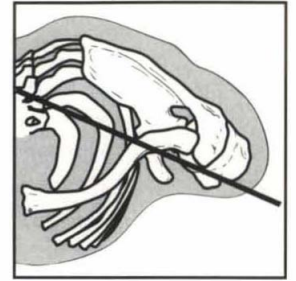


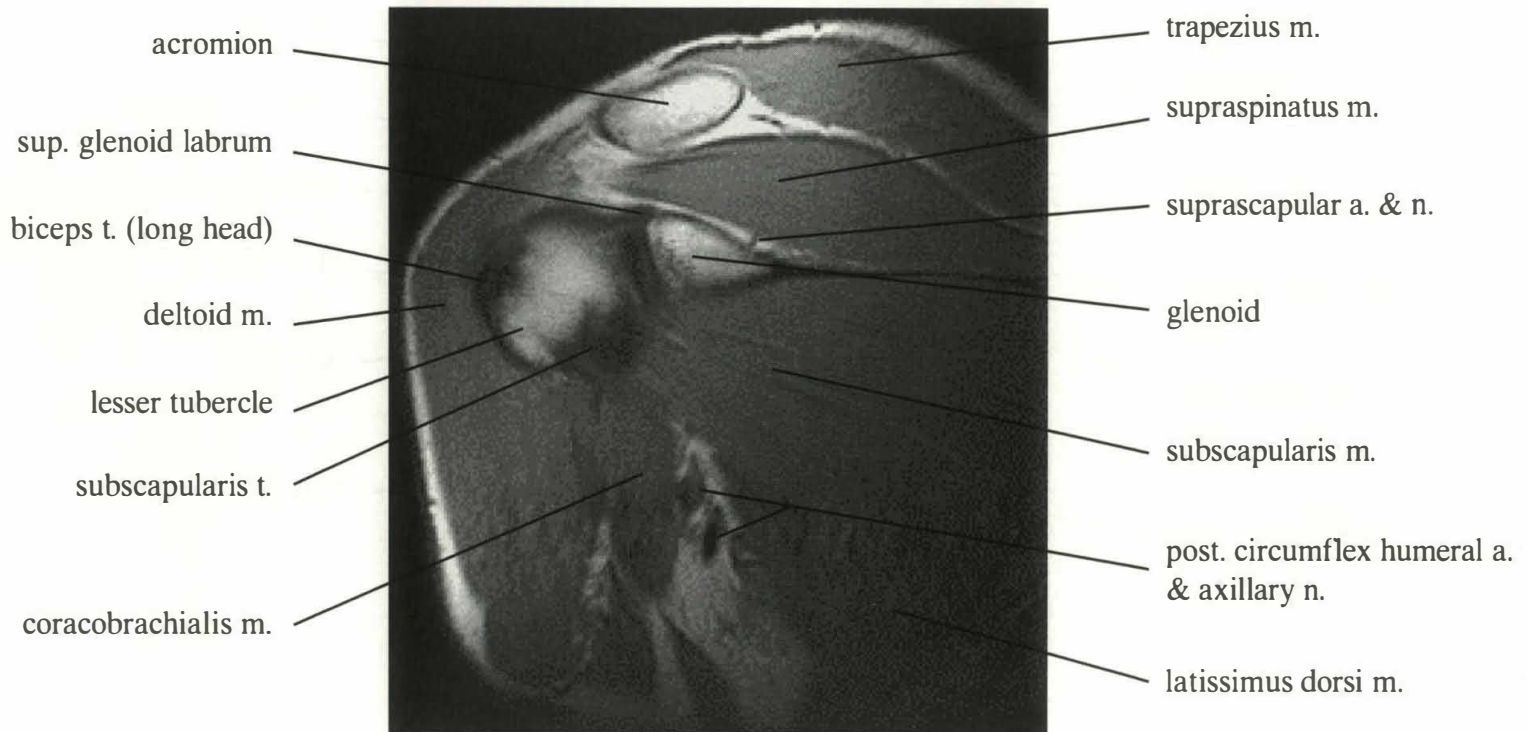
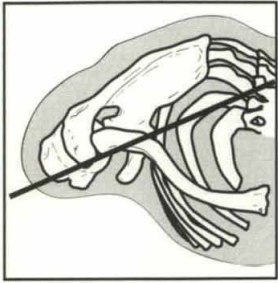


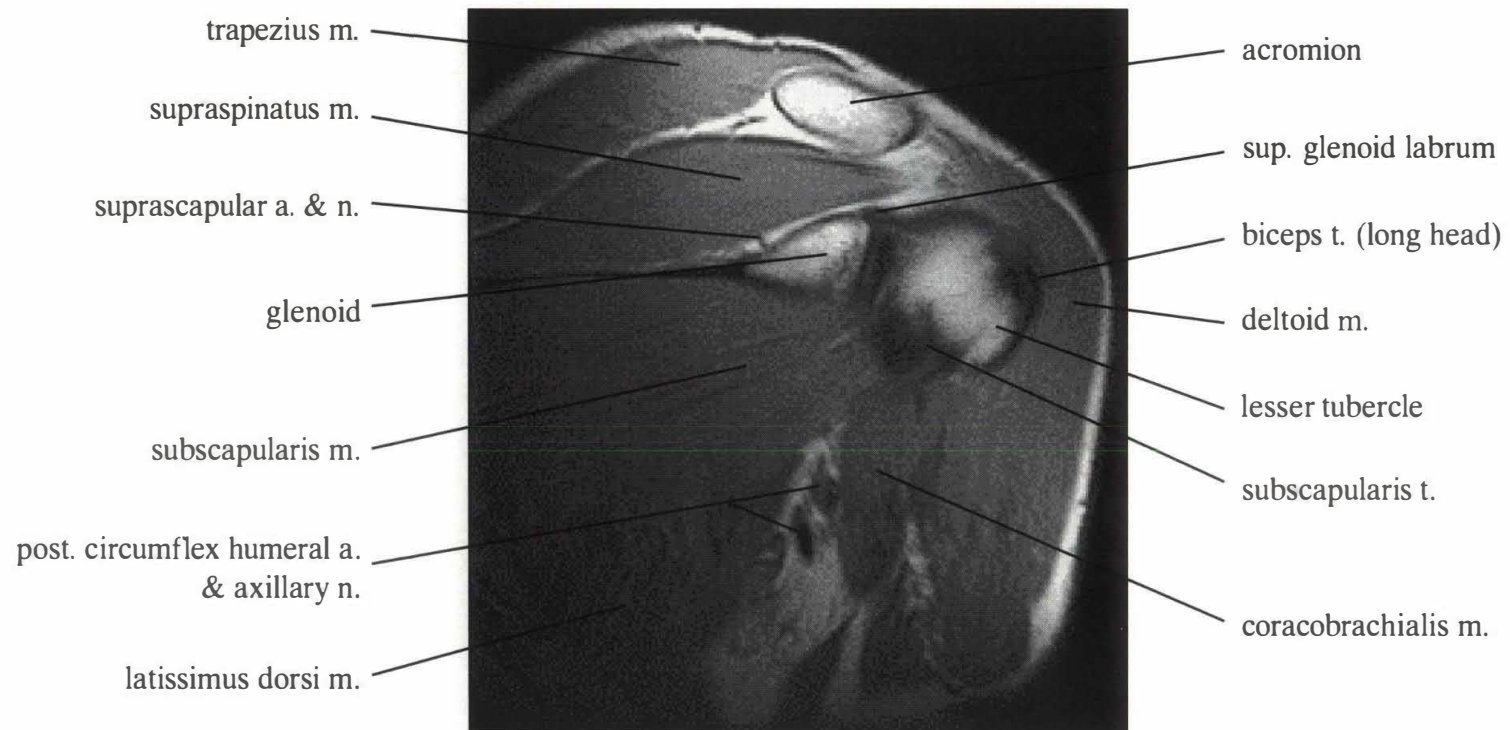
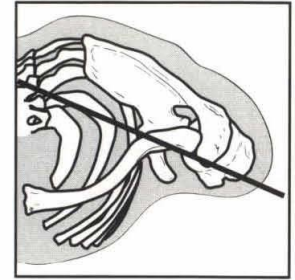


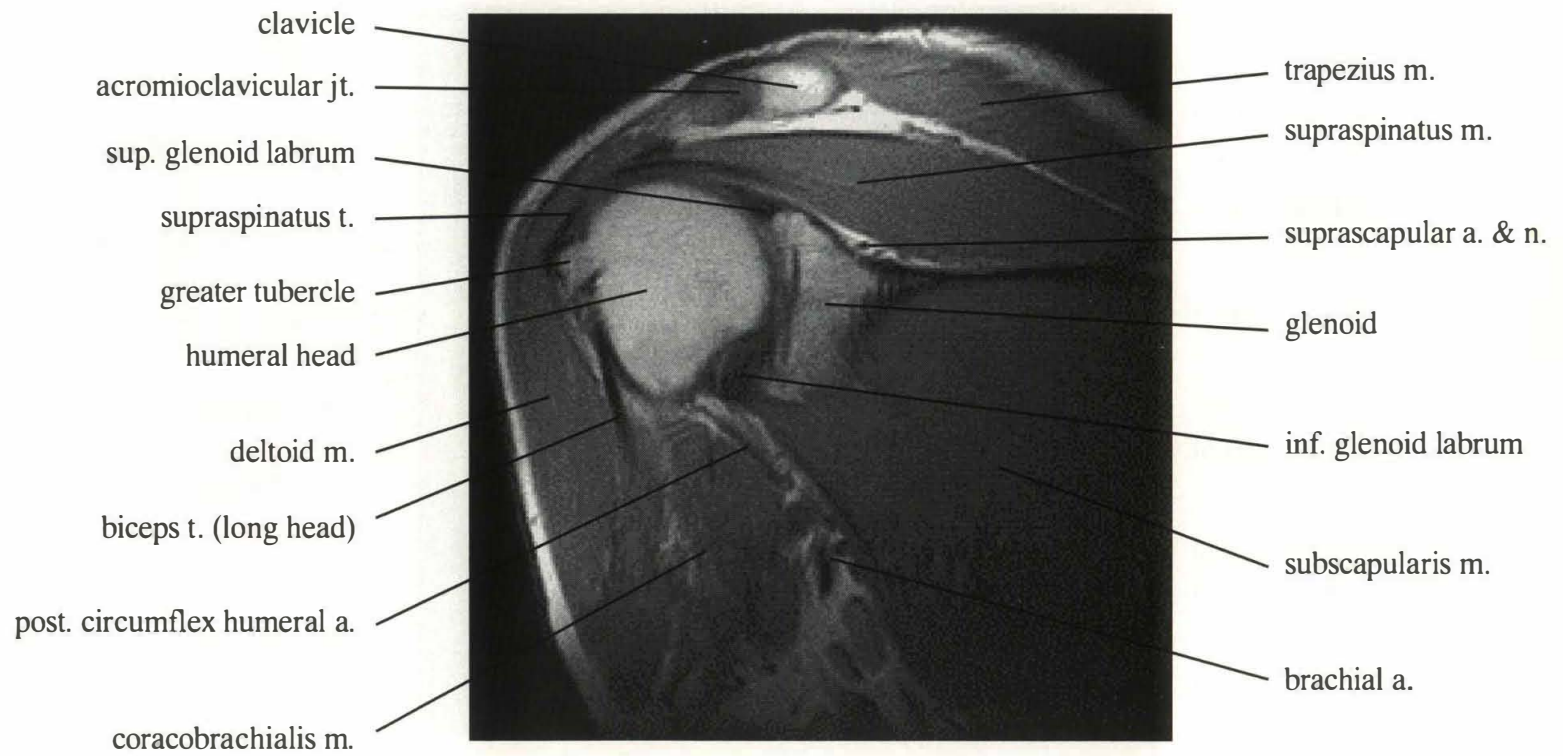
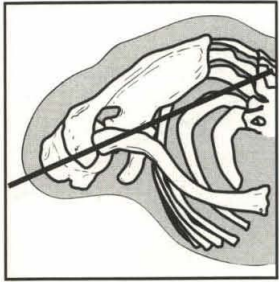
**THE SHOULDER:
OBLIQUE CORONAL ANATOMY**

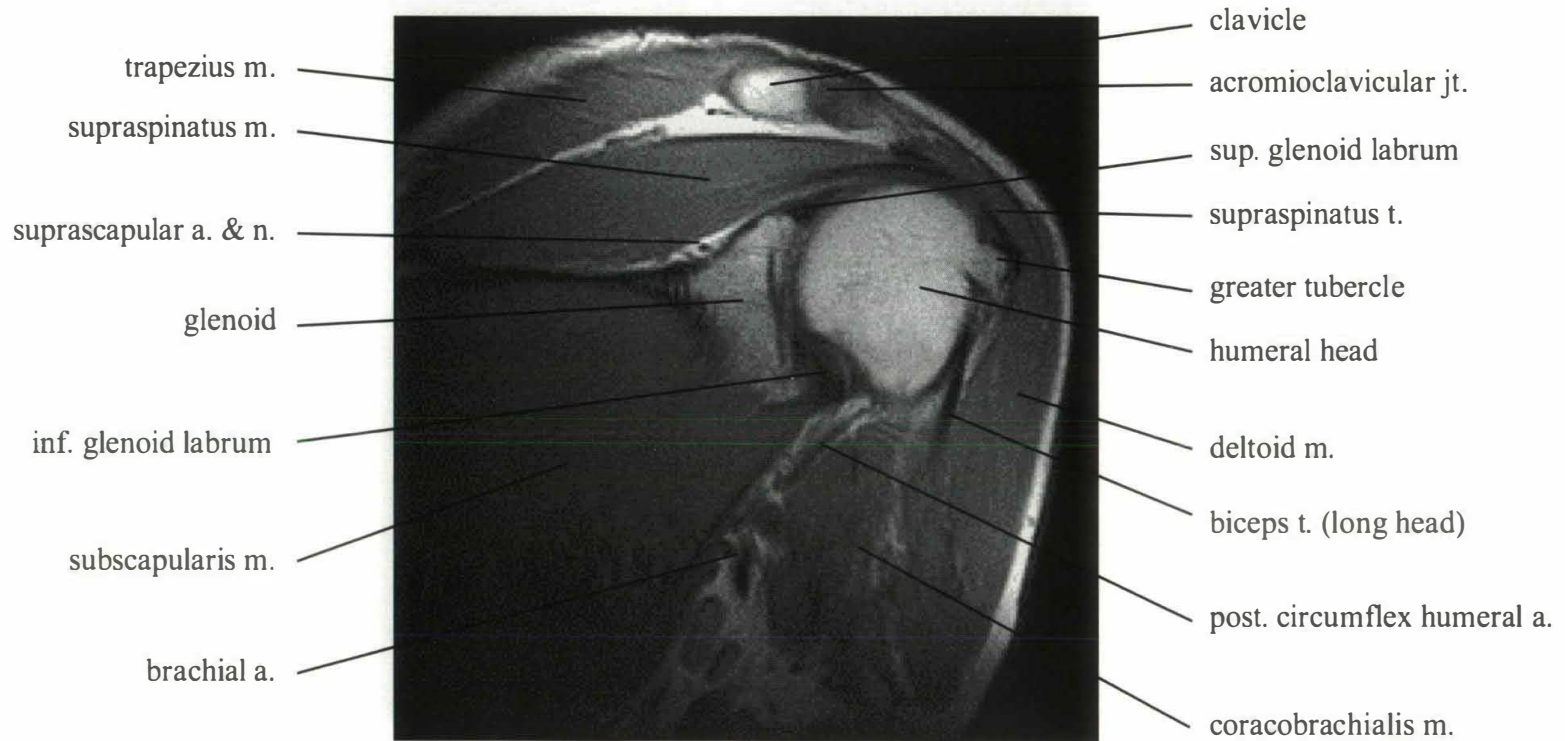
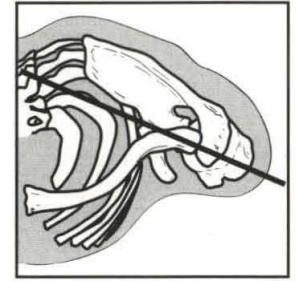


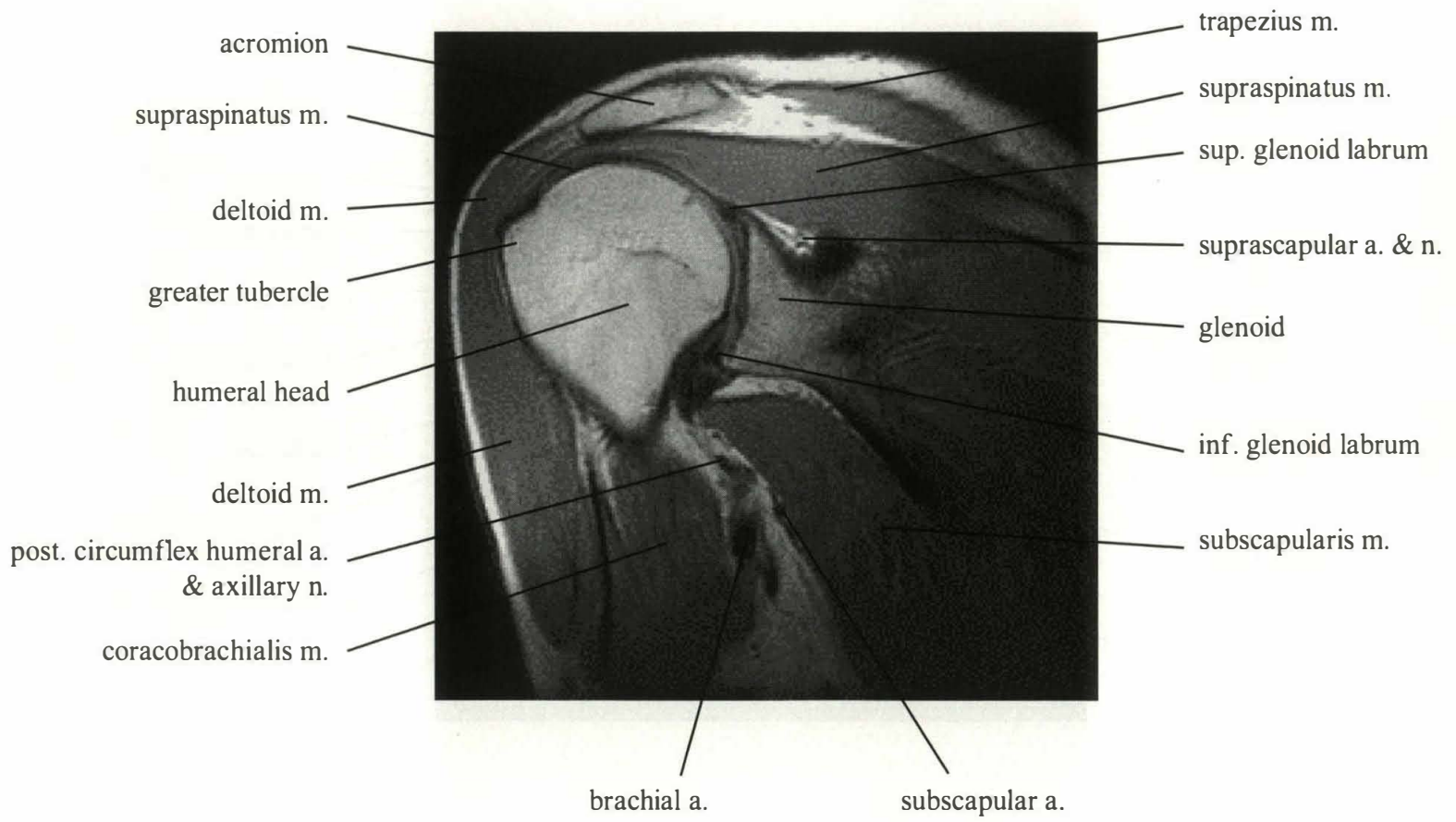
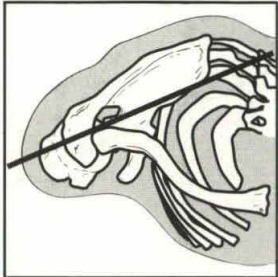


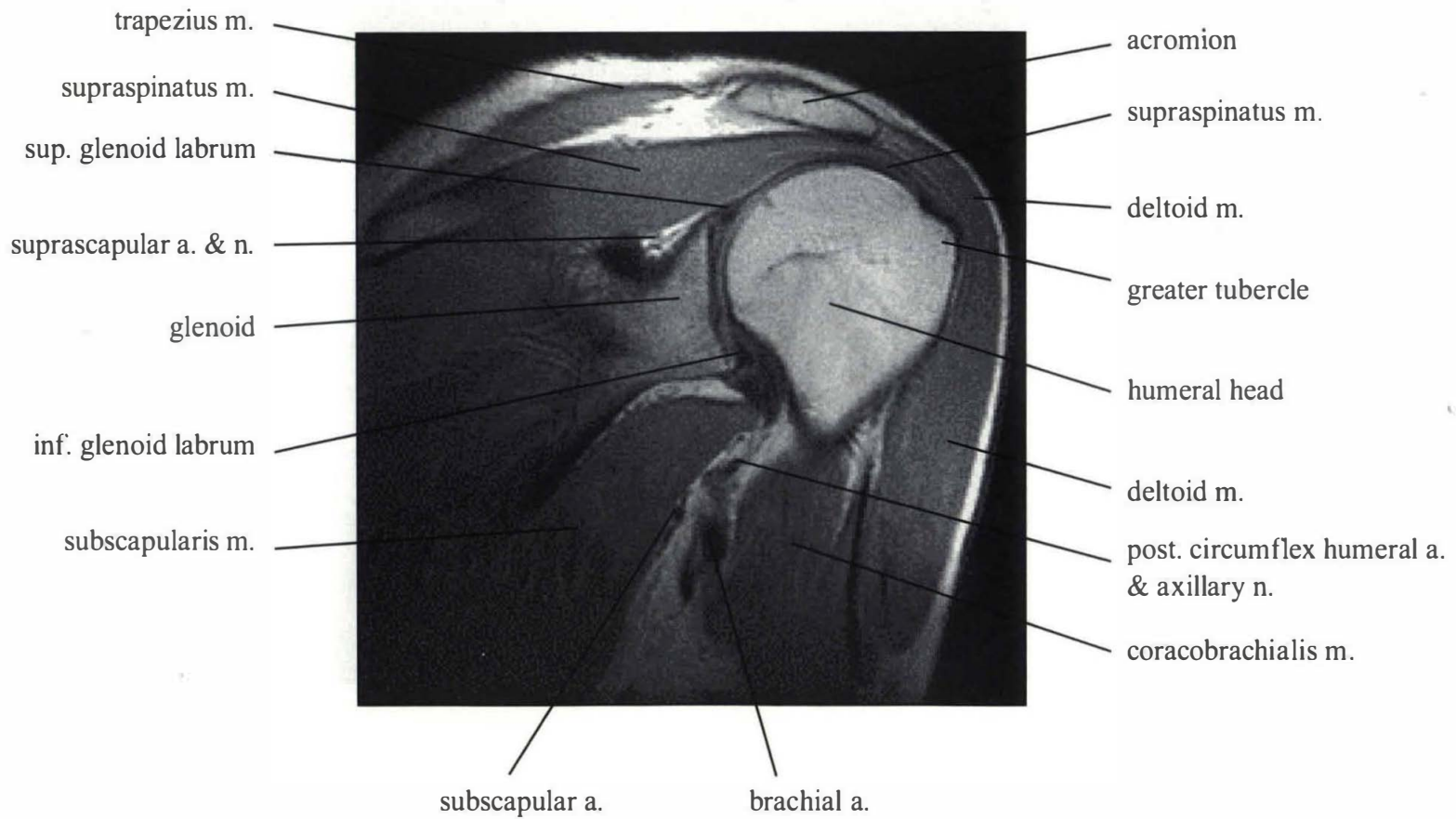
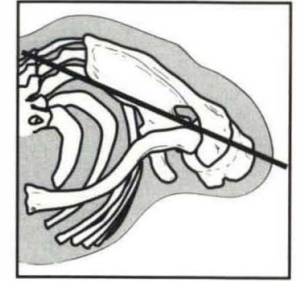


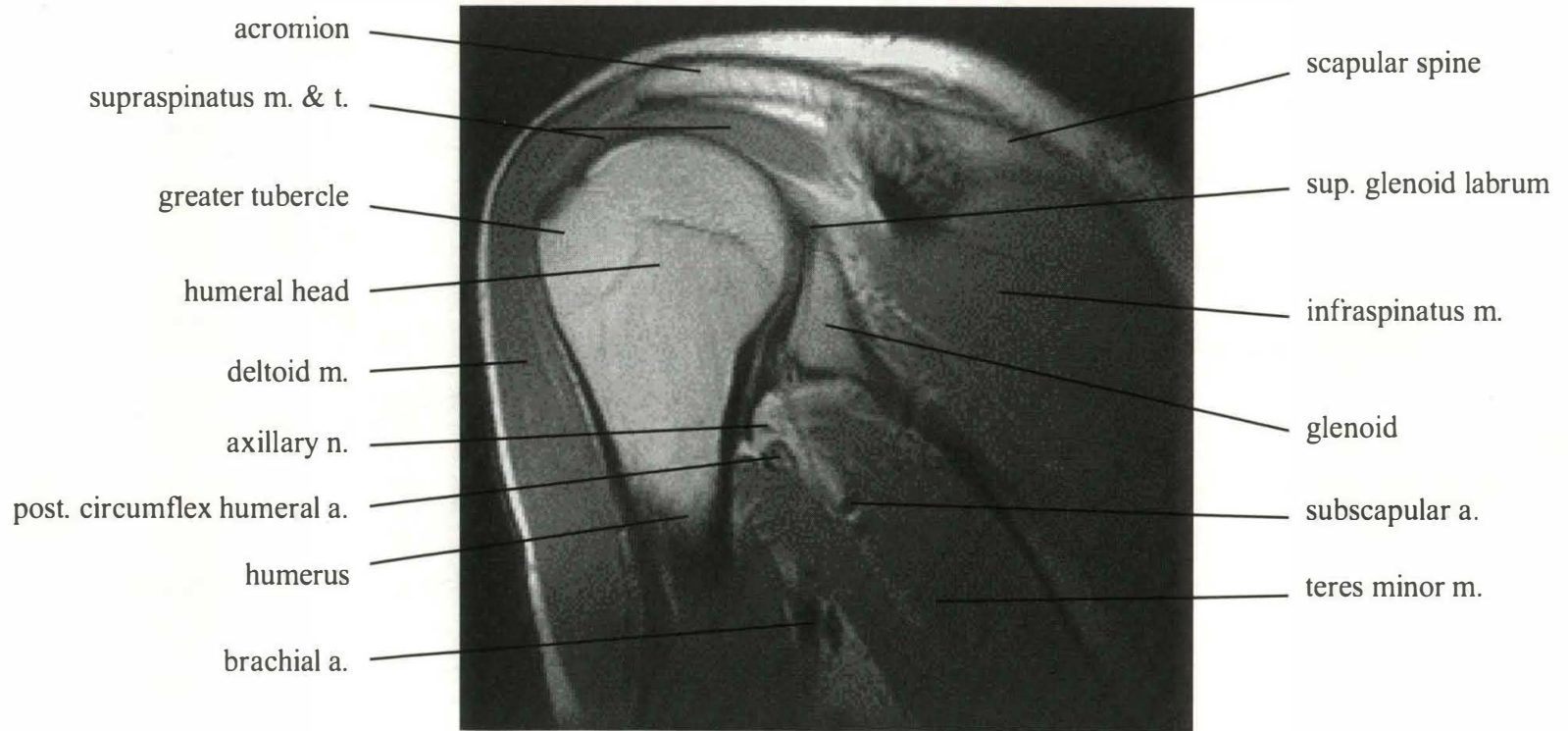
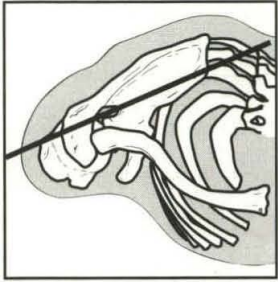


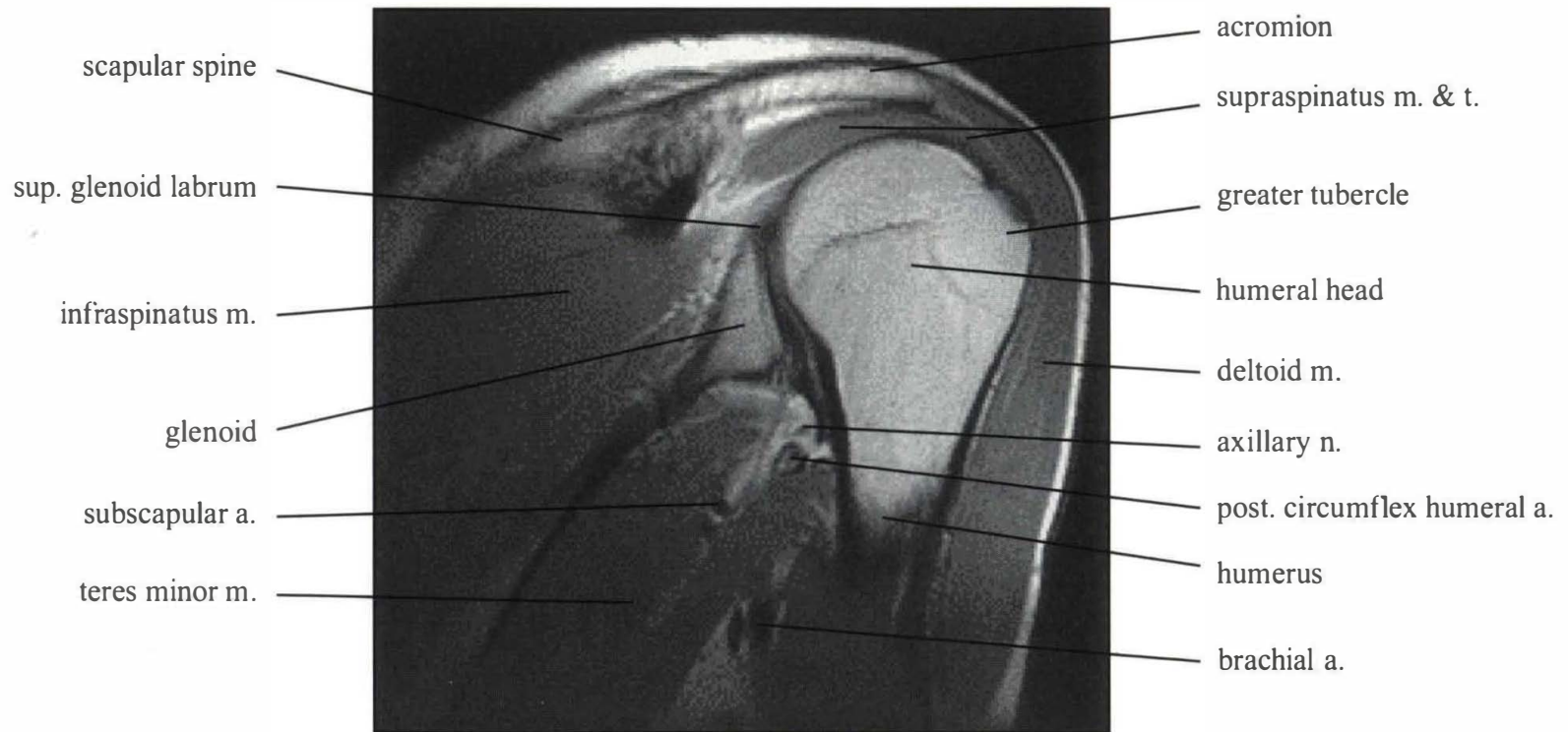
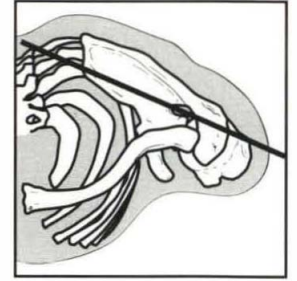


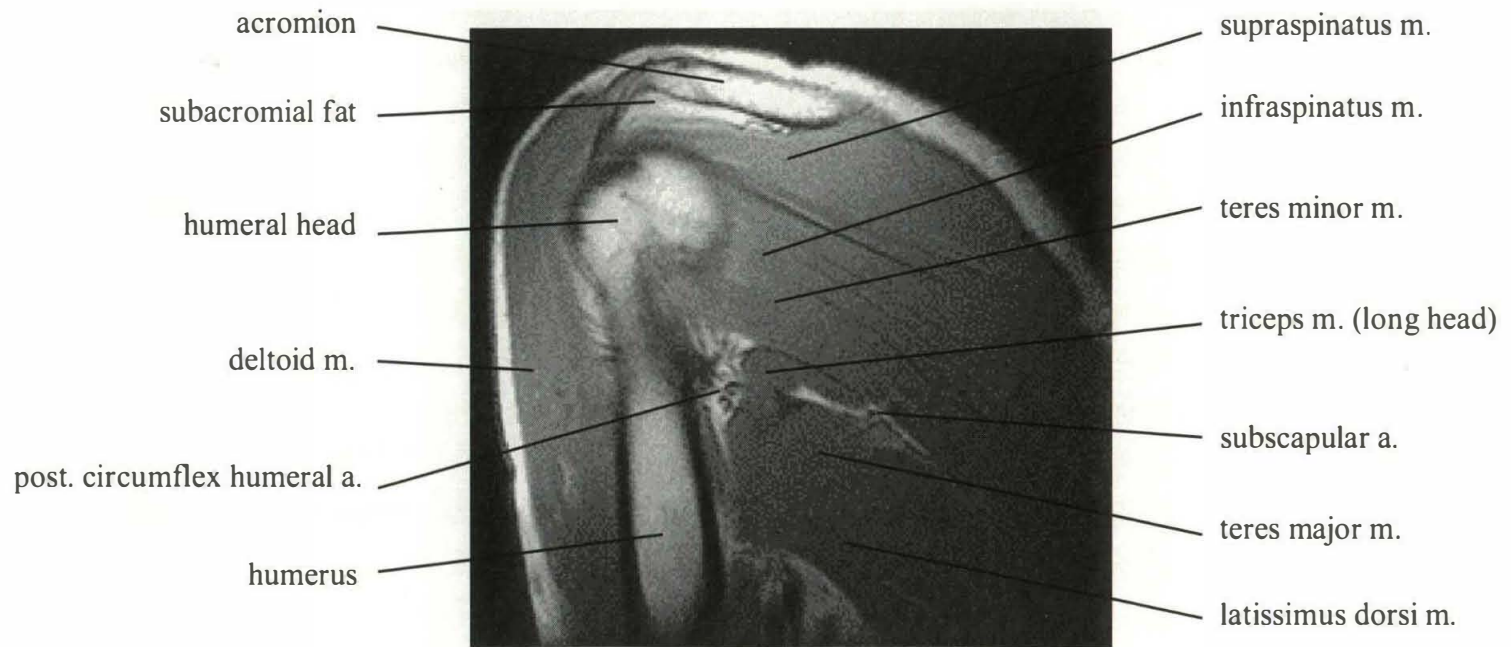
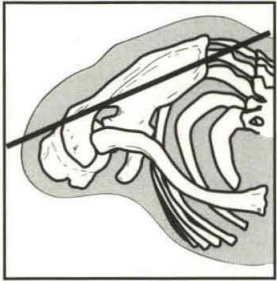


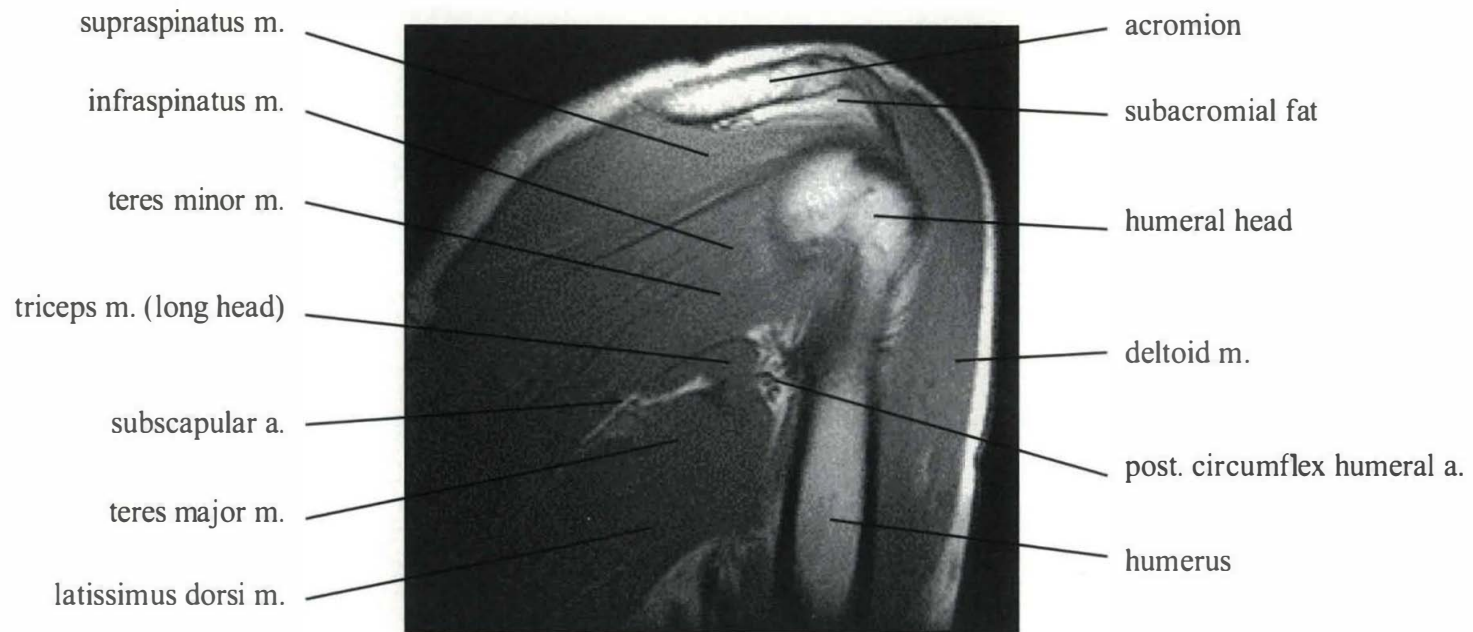
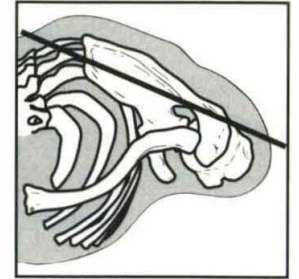


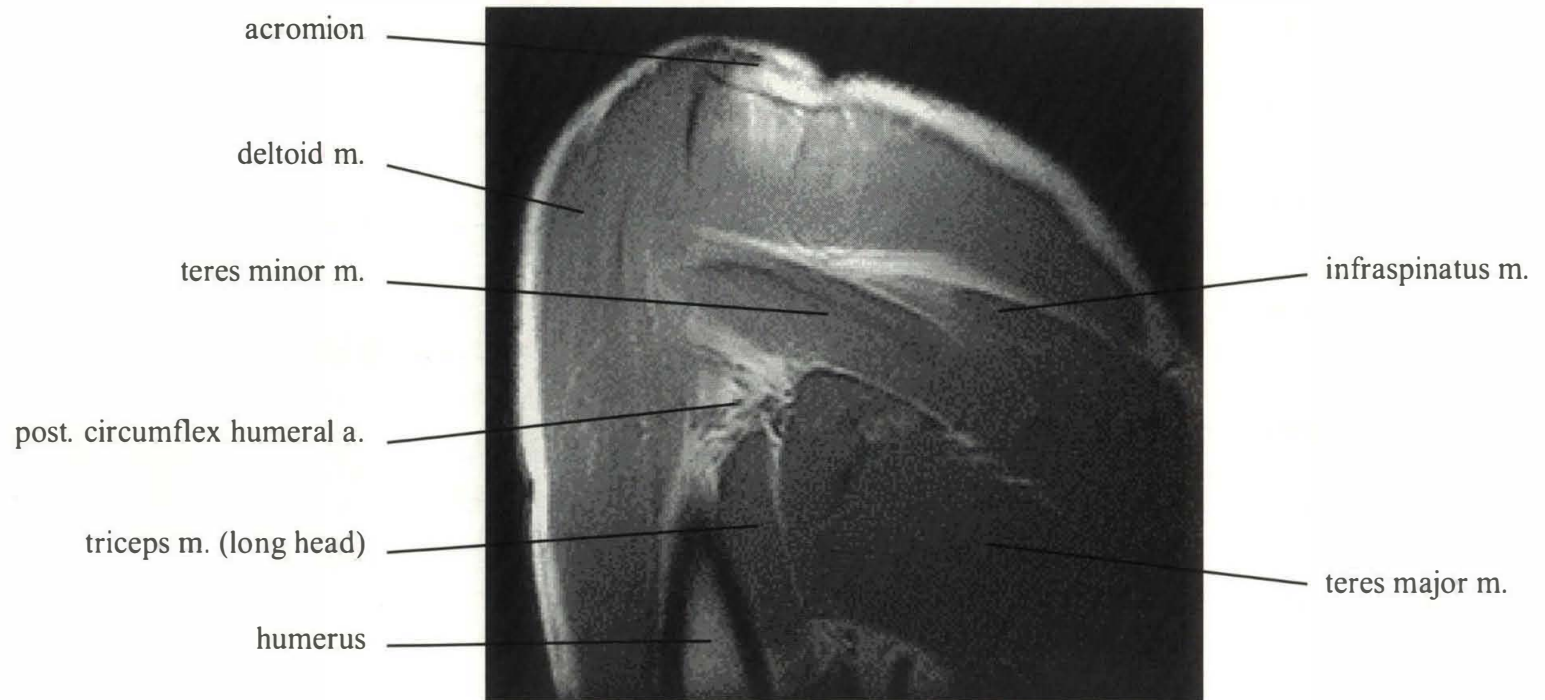
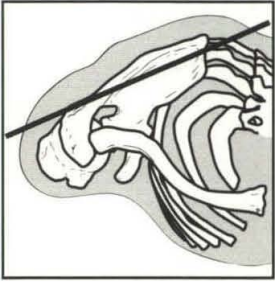


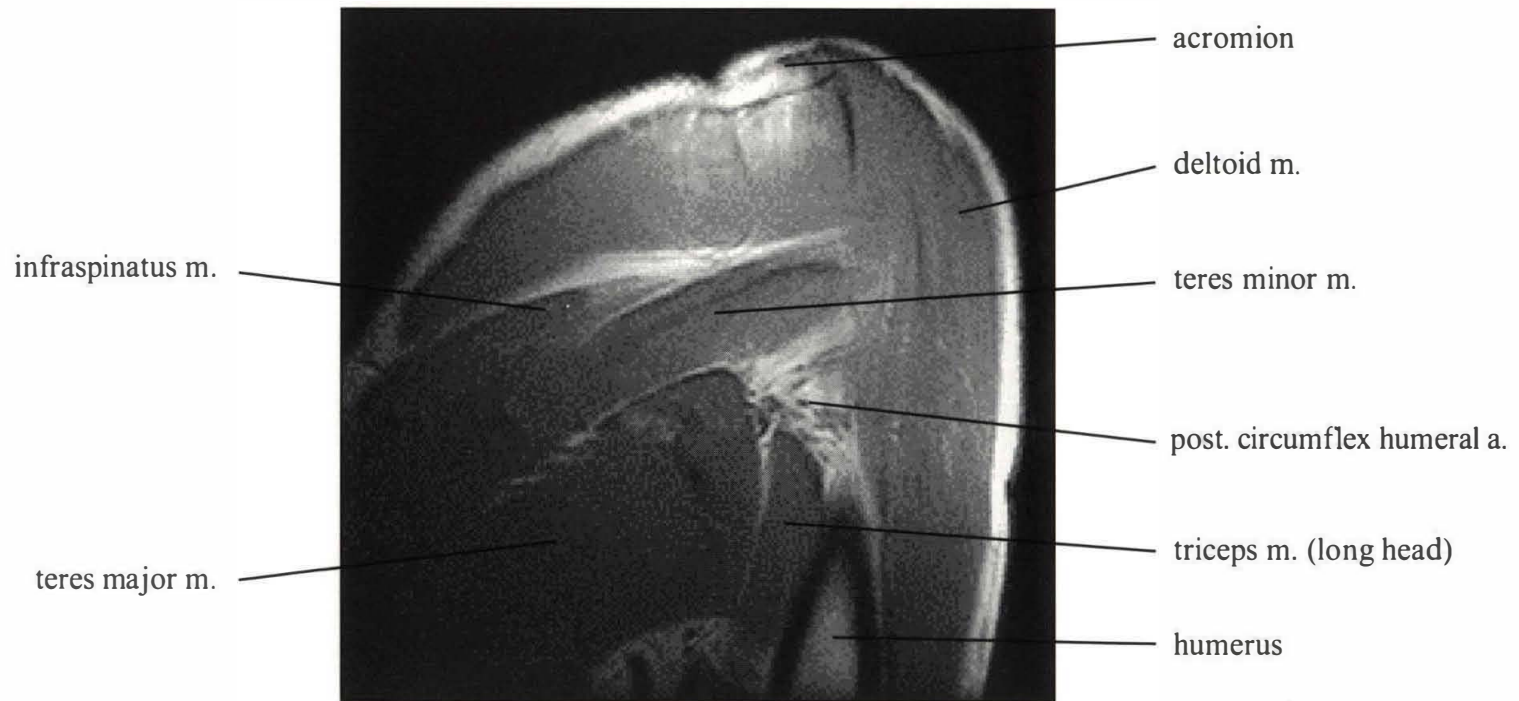
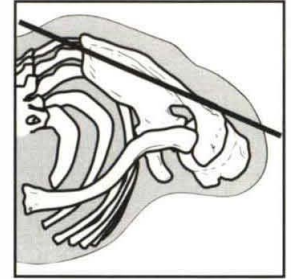












B. THE UPPER EXTREMITY

The major indications for MR imaging of the upper arm include suspected metastatic disease, avascular necrosis, infection, and primary soft-tissue tumors. Generally, these studies are monitored while the patient is in the scanner, and the images are approved before the patient leaves the MR imaging suite.

PRACTICAL PROTOCOL CONSIDERATIONS

For an MR imaging examination of the upper arm, the patient is placed in a comfortable supine position. If there is a palpable abnormality or surgical scar, or if a suspicious area is identified during physical examination, a bath oil bead or vitamin E tablet is placed at the site. For a surgical site, both the proximal and distal ends of the scar should be marked with the bead or tablet.

Whether a body or surface coil is used depends on the clinical indication for the study. In general, sagittal, coronal, and axial planes are used. The axial plane is the most important of these because it shows the relationship of any abnormality to the neurovascular bundle and other vital structures best.

Menu of Protocols: Upper Arm

Plane	Pulse Sequence	FA (degrees)	TR (msec)	TE (msec)	TI (msec)	FOV (cm)	Matrix (256X-)	ST/G (mm)	NEX	Comments
Localizer (transaxial)	SE		500	min		VAR	128	4/	1	Mark area of concern
Coronal, sagittal	SE		500	min		VAR	192	5/1.5	2	
Coronal	SE		1,000	min		VAR	192	5/1.5	2	
Coronal	FMPIR		2,500	30	150	VAR	128	5/1.5	2	
Sagittal	SE		1,000	min		VAR	192	5/1.5	2	
Sagittal	FMPIR		2,500	30	150	VAR	128	5/1.5	2	
Axial	SE, double echo, FS		3,000	19/90		VAR	192	4/1	2	
Axial, pre-GAD	SE		600	20		VAR	192	4/1	2	Repeat after GAD
Axial, pre-GAD	SE, FS		600	20		VAR	192	4/1	2	Repeat after GAD

MAJOR OSTEOCHONDRAL STRUCTURES/LANDMARKS

(See Glenohumeral Joint and Elbow)

MAJOR LIGAMENTS/TENDONS/BURSAE

(See Glenohumeral Joint and Elbow)

MAJOR MUSCLES**Compartments**

The muscles of the upper arm are divided into an anterior group and a posterior group.

- Anterior compartment
 - Coracobrachialis
 - Biceps brachii
 - Long head
 - Short head
 - Brachialis
- Posterior compartment
 - Triceps brachii
 - Long head
 - Medial head
 - Lateral head
 - Anconeus

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
Anterior Compartment			
–Coracobrachialis	Tip of coracoid process in common with short head of biceps brachii muscle	Medial surface of humerus just proximal to its mid-portion	Musculocutaneous N.
–Biceps brachii, long head	Supraglenoid tubercle of scapula	After union with short head, into radial tuberosity	Median N.

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

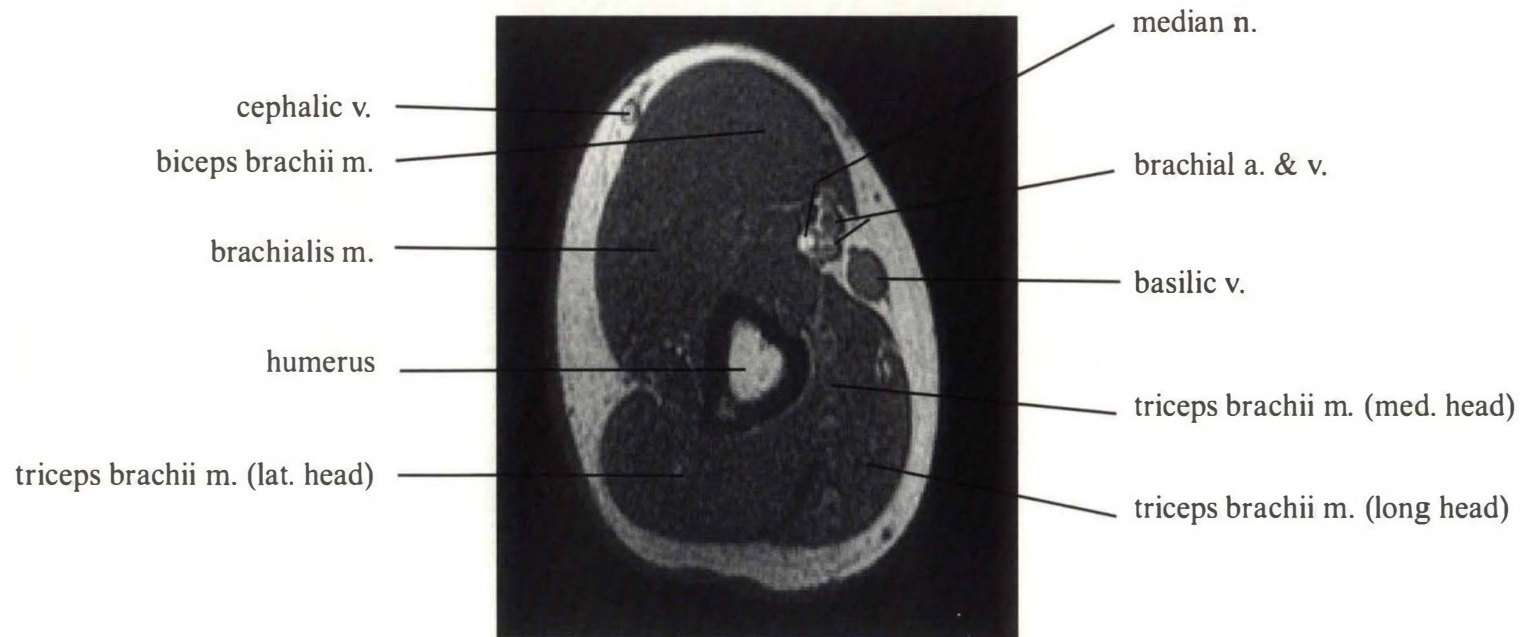
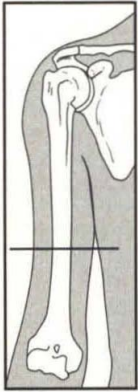
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
-Biceps brachii, short head	Tip of coracoid process in common with coracobrachialis muscle	After union with long head, into radial tuberosity	Median N.
-Brachialis	Lower half of anterior humeral surface and two intermuscular septae	Tuberosity of ulna and anterior surface of coronoid process	Median N.
Posterior compartment			
-Triceps brachii, long head	Infraglenoid tubercle of humerus	Joins lateral and medial heads in a common insertion on posterior aspect of olecranon and deep fascia of upper arm	Radial N.
-Triceps brachii, lateral head	Posterior surface and lateral border of humerus above and lateral to radial groove, lateral intermuscular septum	Joins long and medial heads in a common insertion	Radial N.

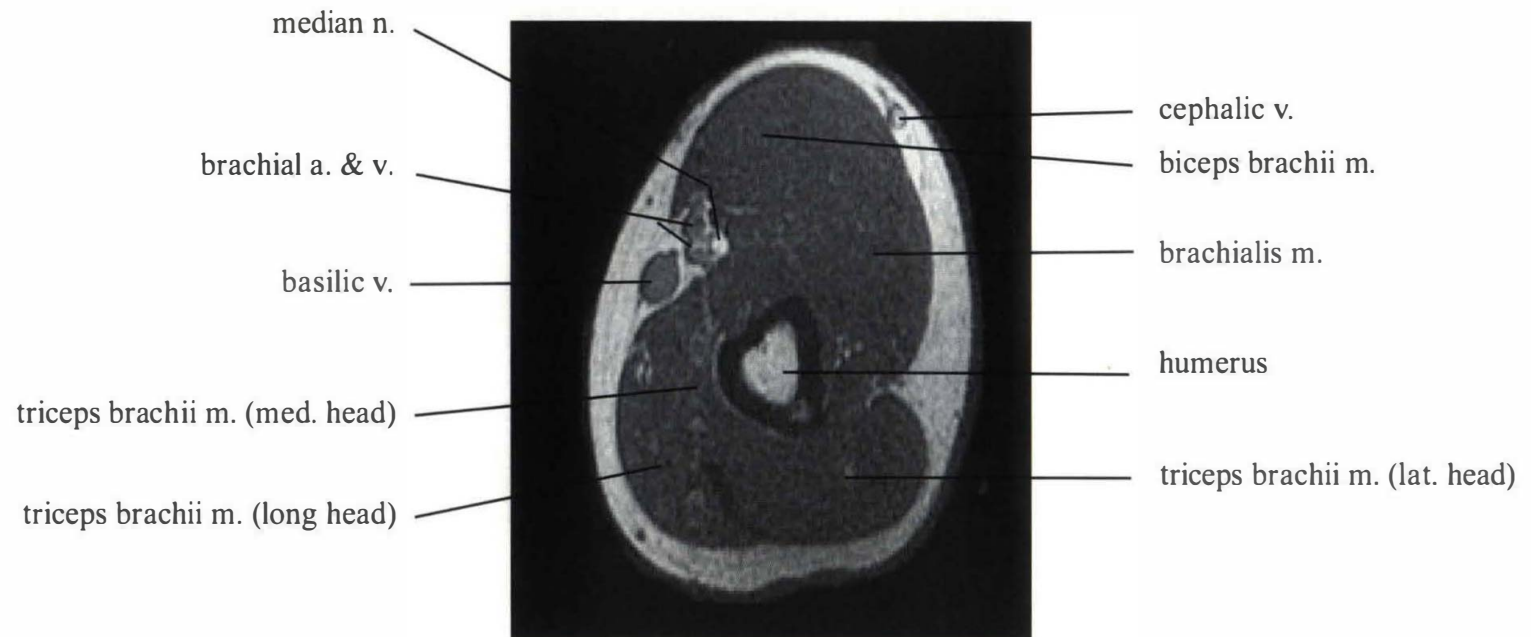
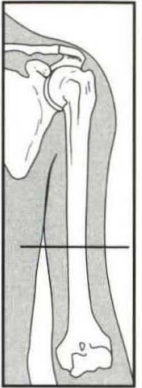
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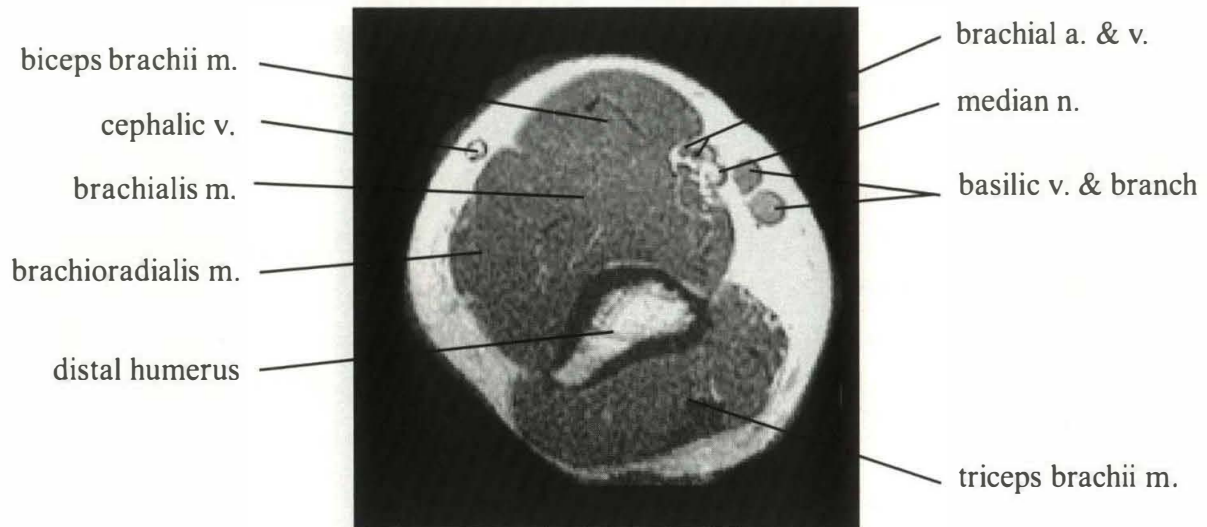
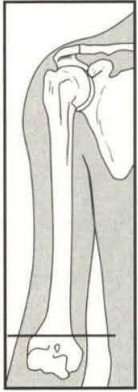
ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

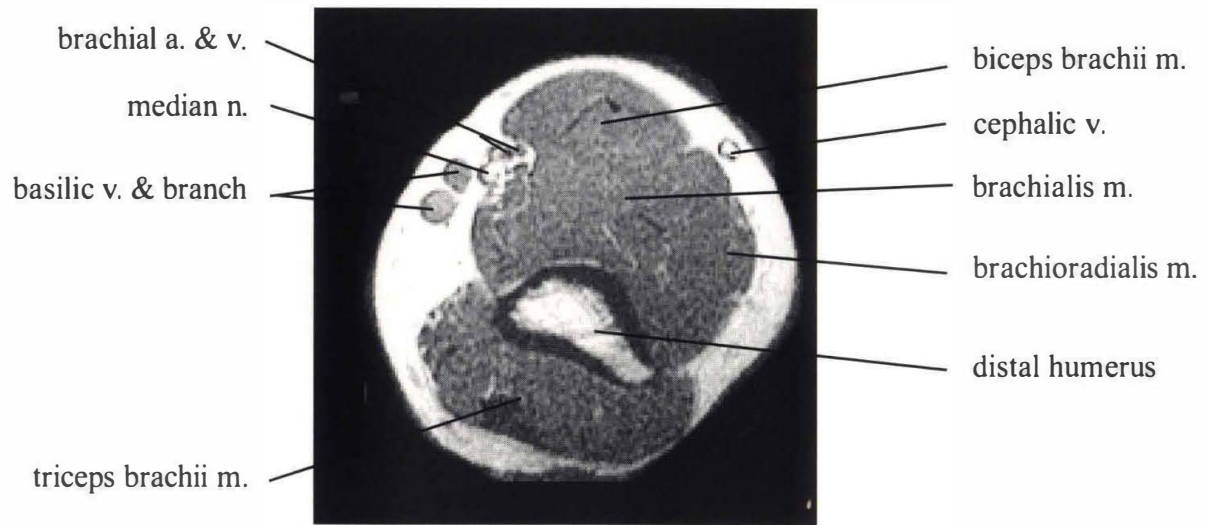
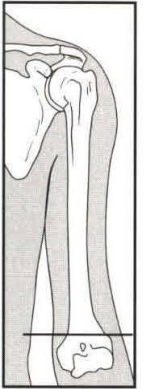
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
-Triceps brachii, medial head	Humerus medial and below radial groove and as high as insertion of teres major muscle to as low as humeral olecranon fascia, entire aspect of medial intermuscular septum	Joins lateral and long heads in a common insertion	Radial N. (Branches of ulnar N.)
-Anconeus	Lateral epicondyle of humerus	The side of olecranon and one-fourth of posterior surface of ulna	Radial N.

THE UPPER EXTREMITY: AXIAL ANATOMY

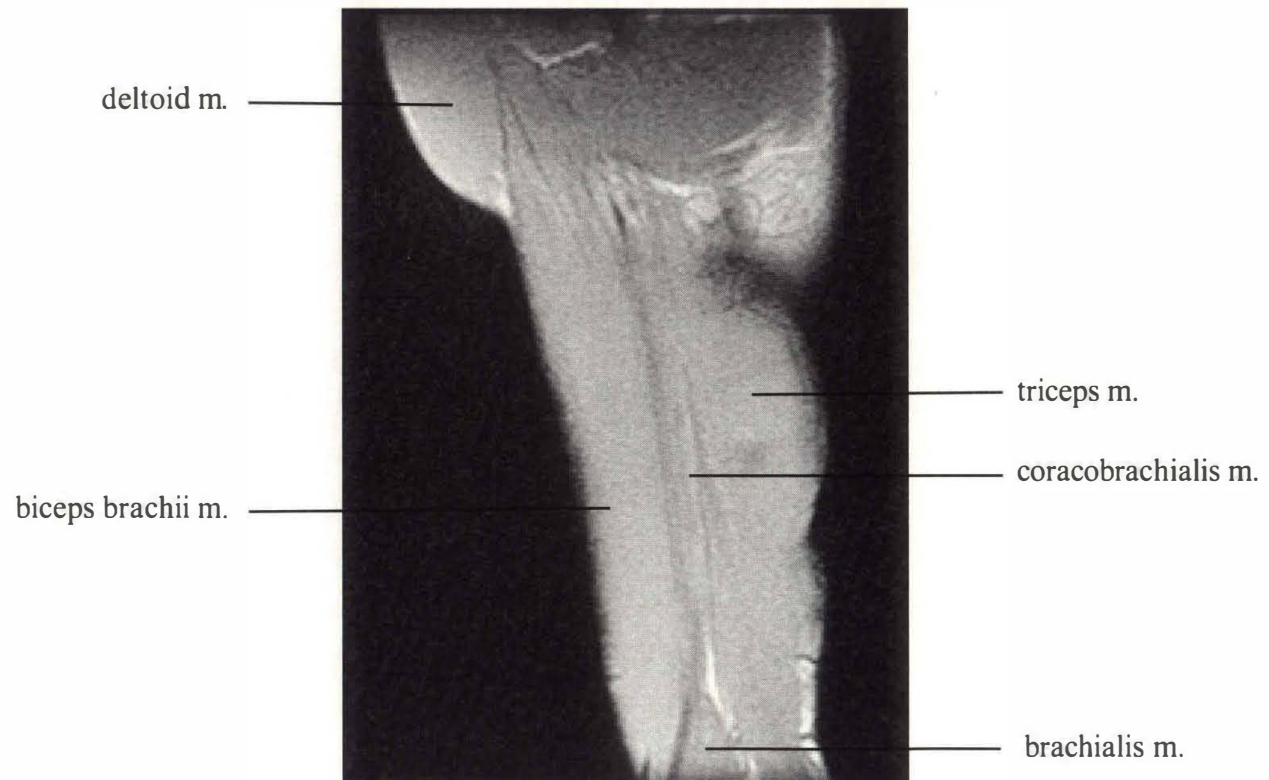
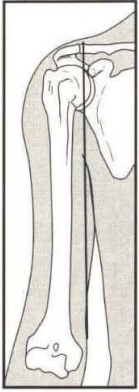


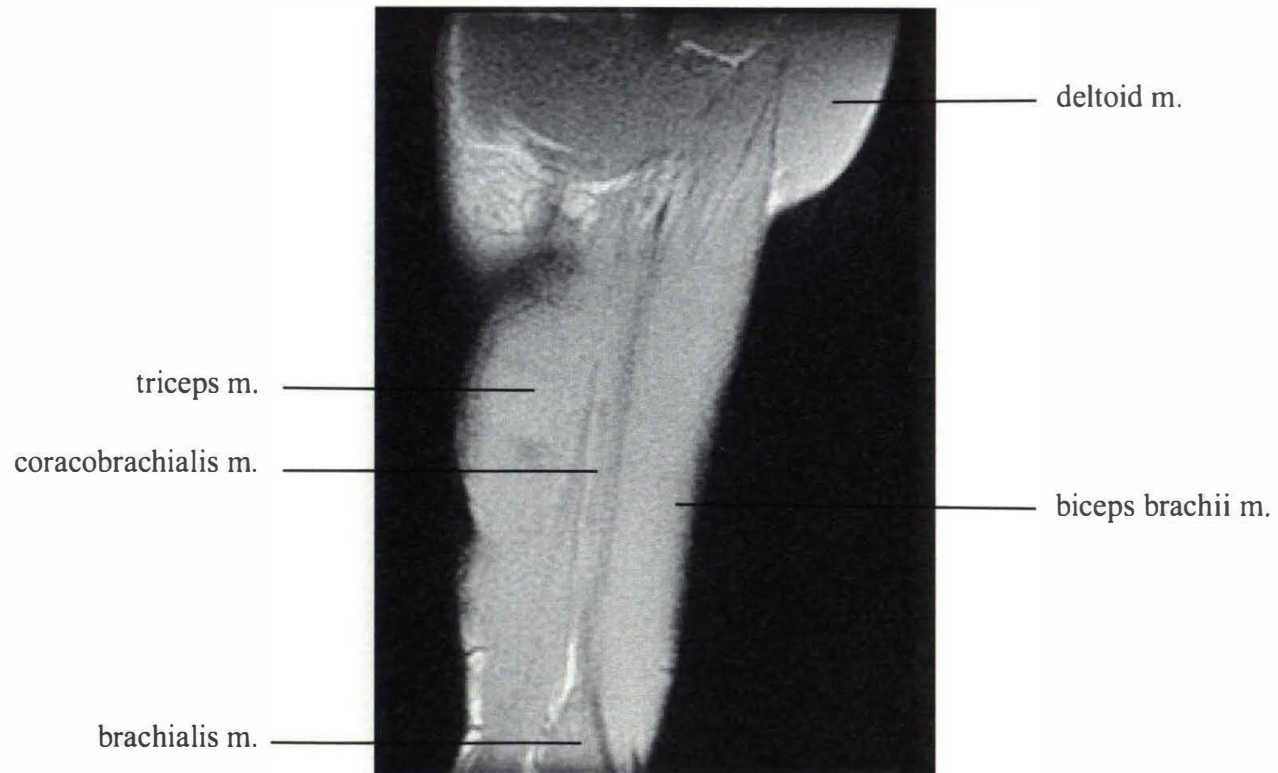
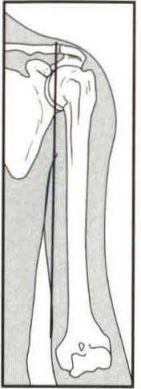


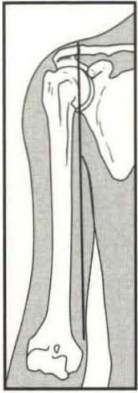


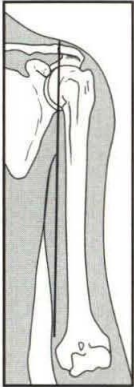


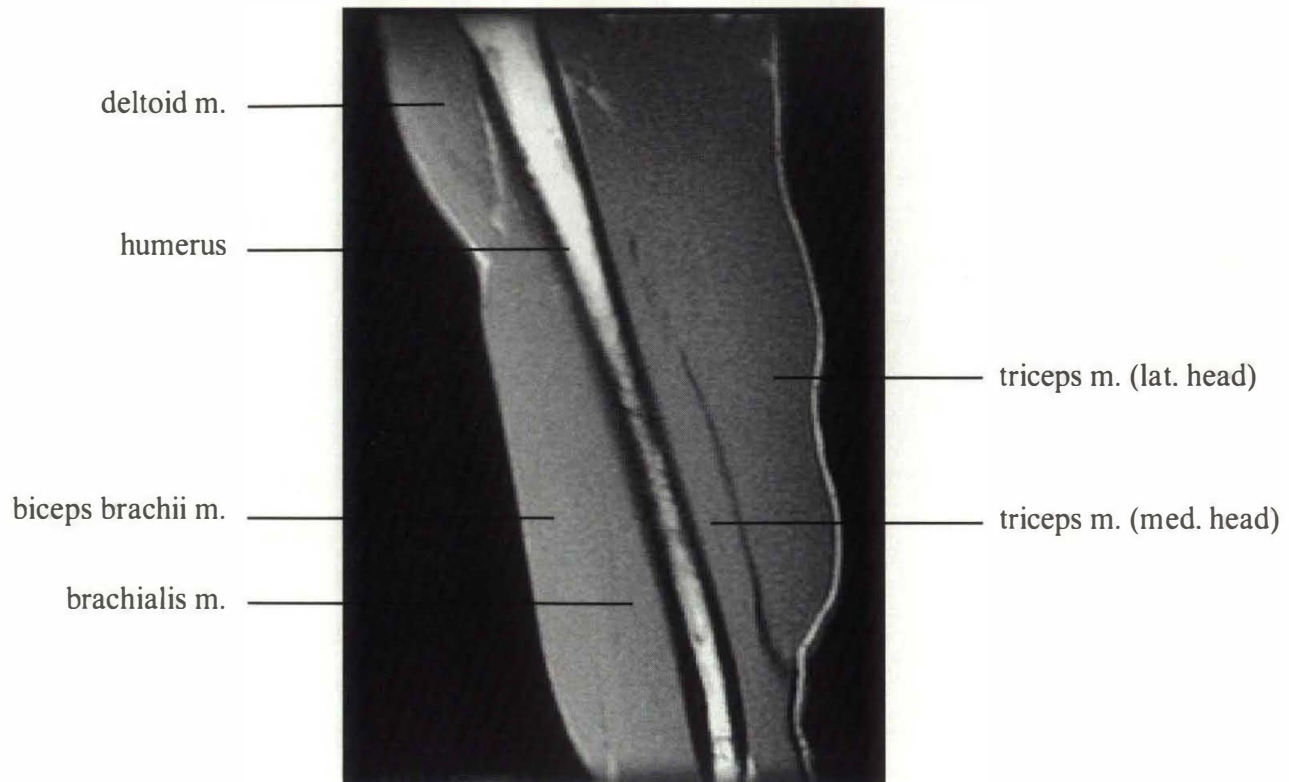
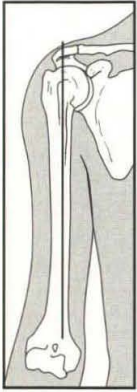
THE UPPER EXTREMITY: SAGITTAL ANATOMY

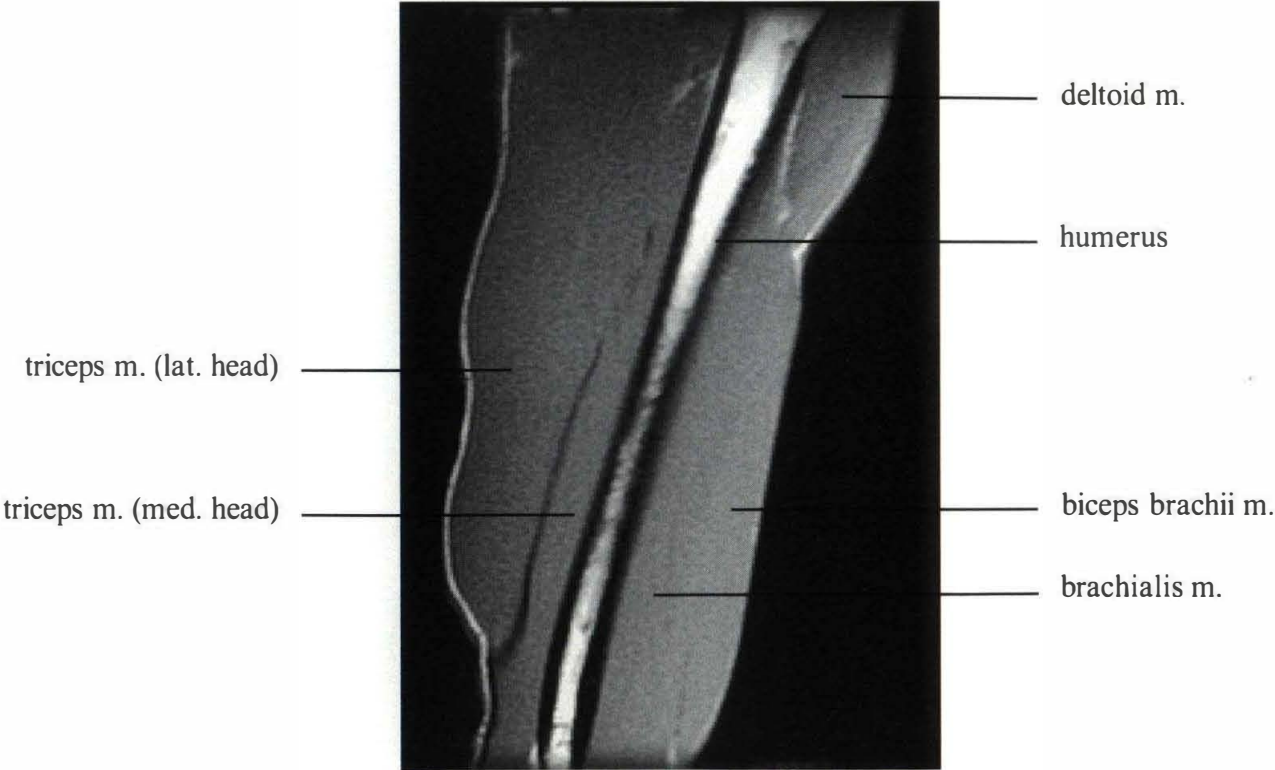
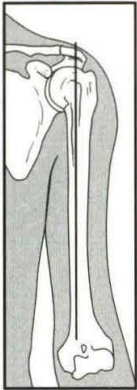


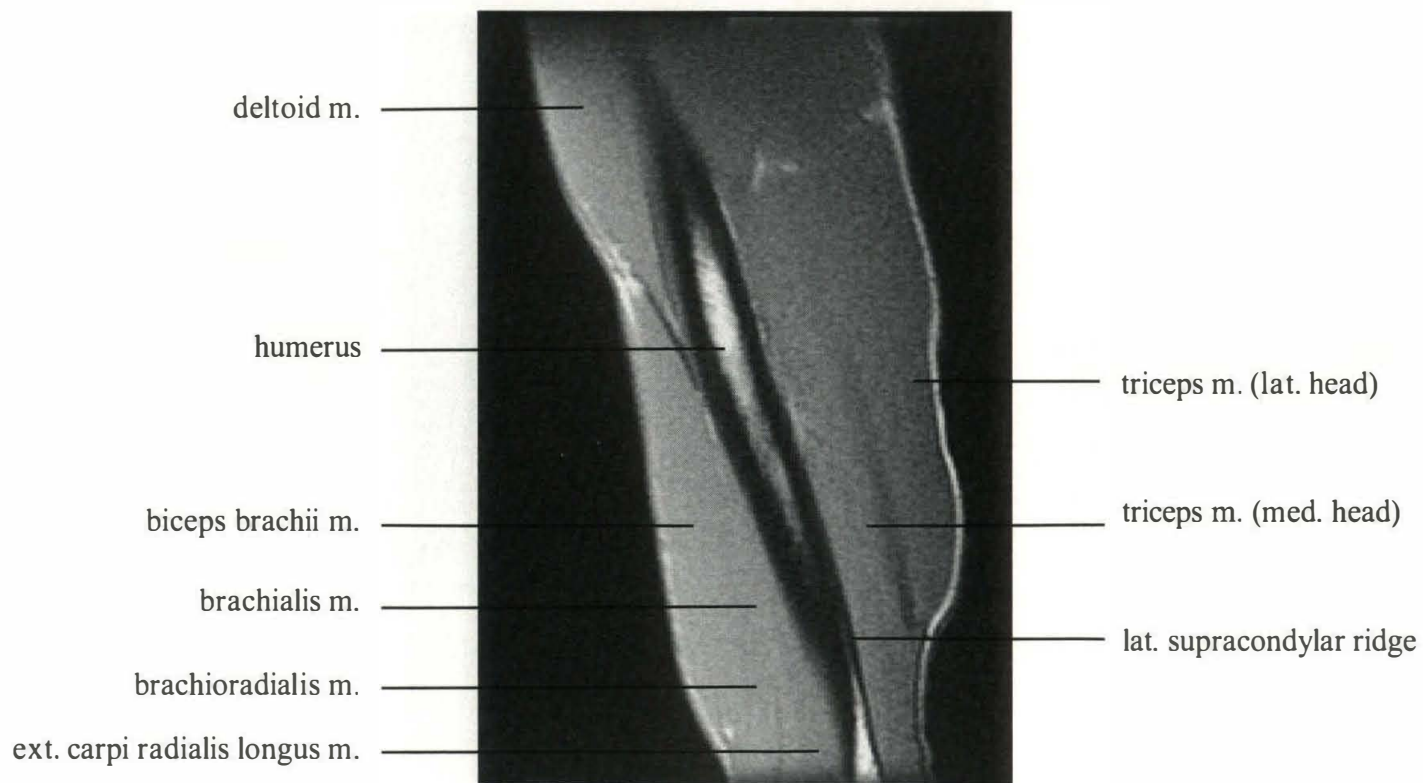
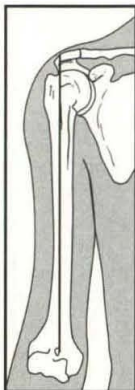


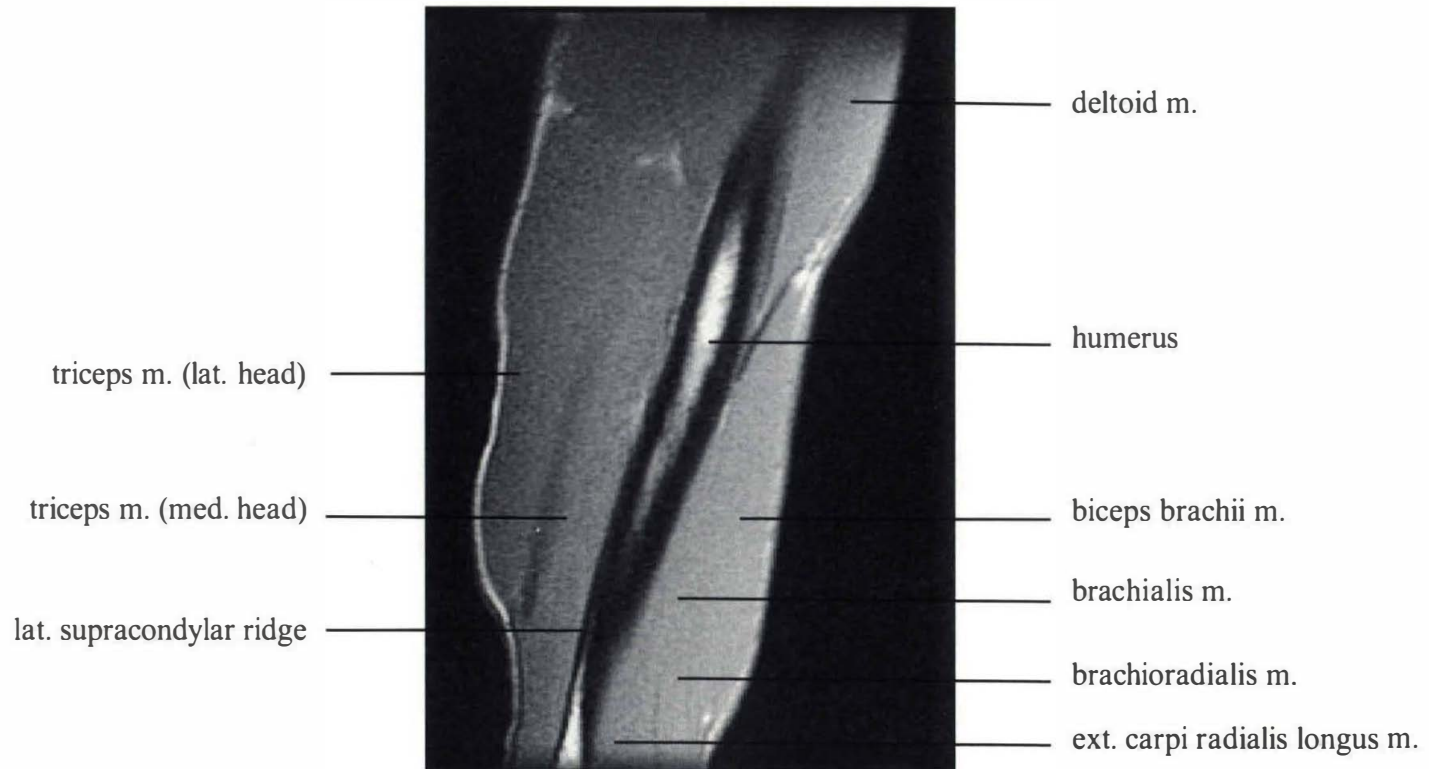
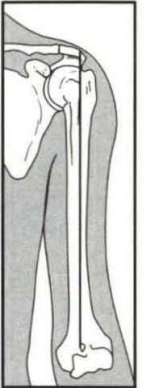


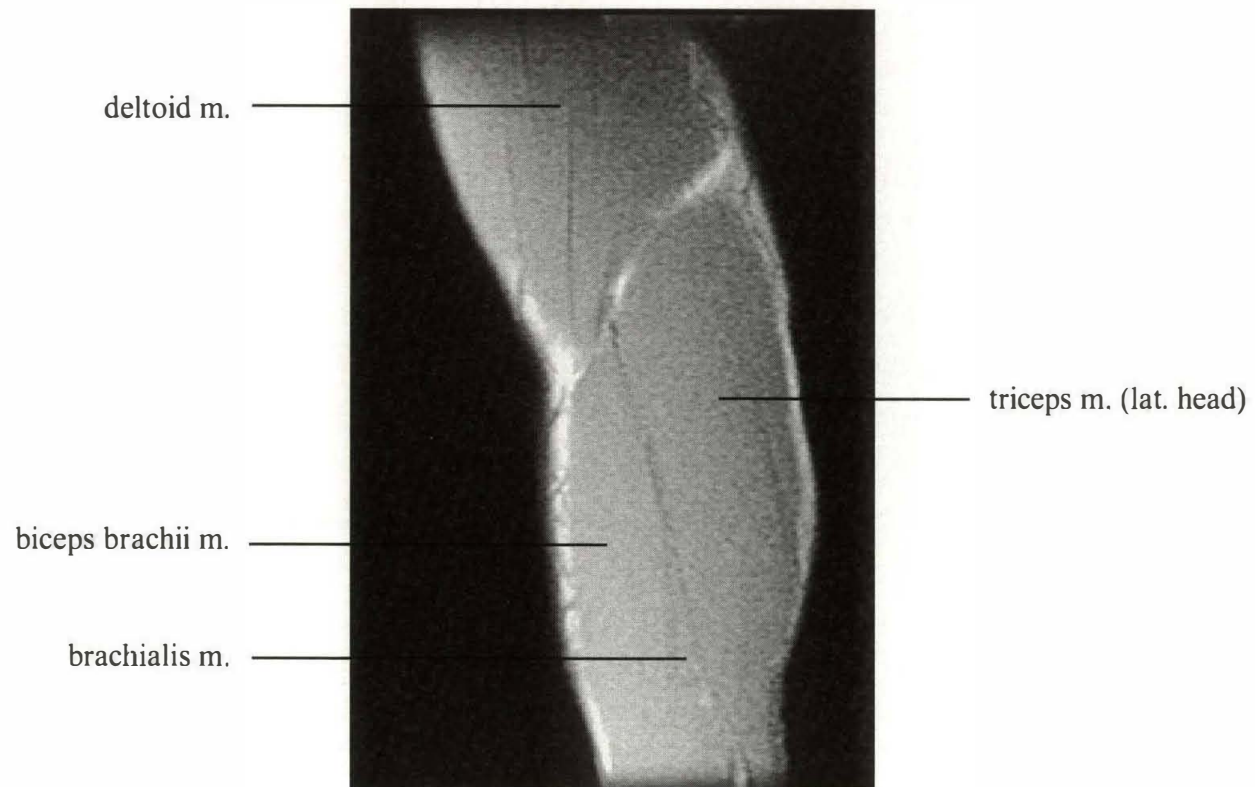
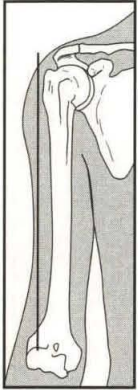










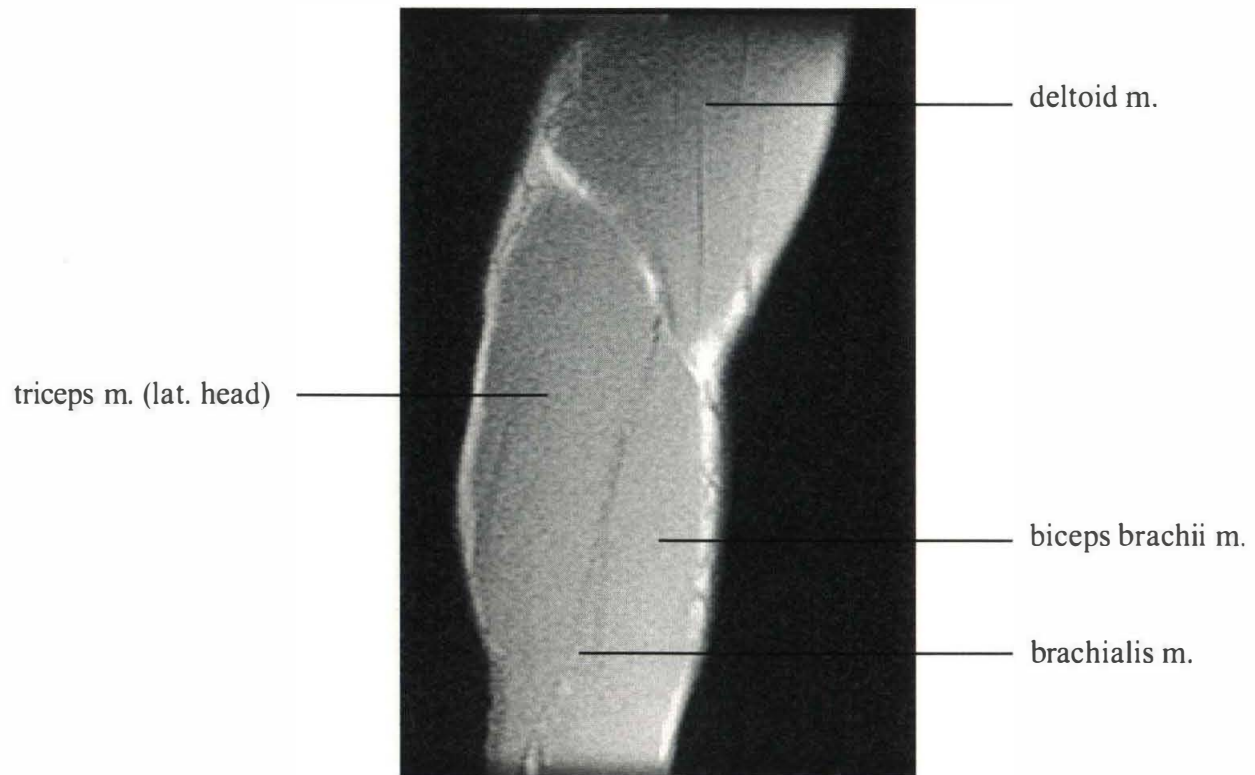
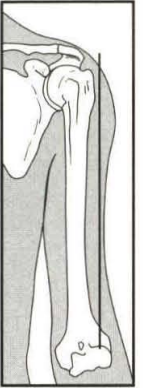


deltoid m.

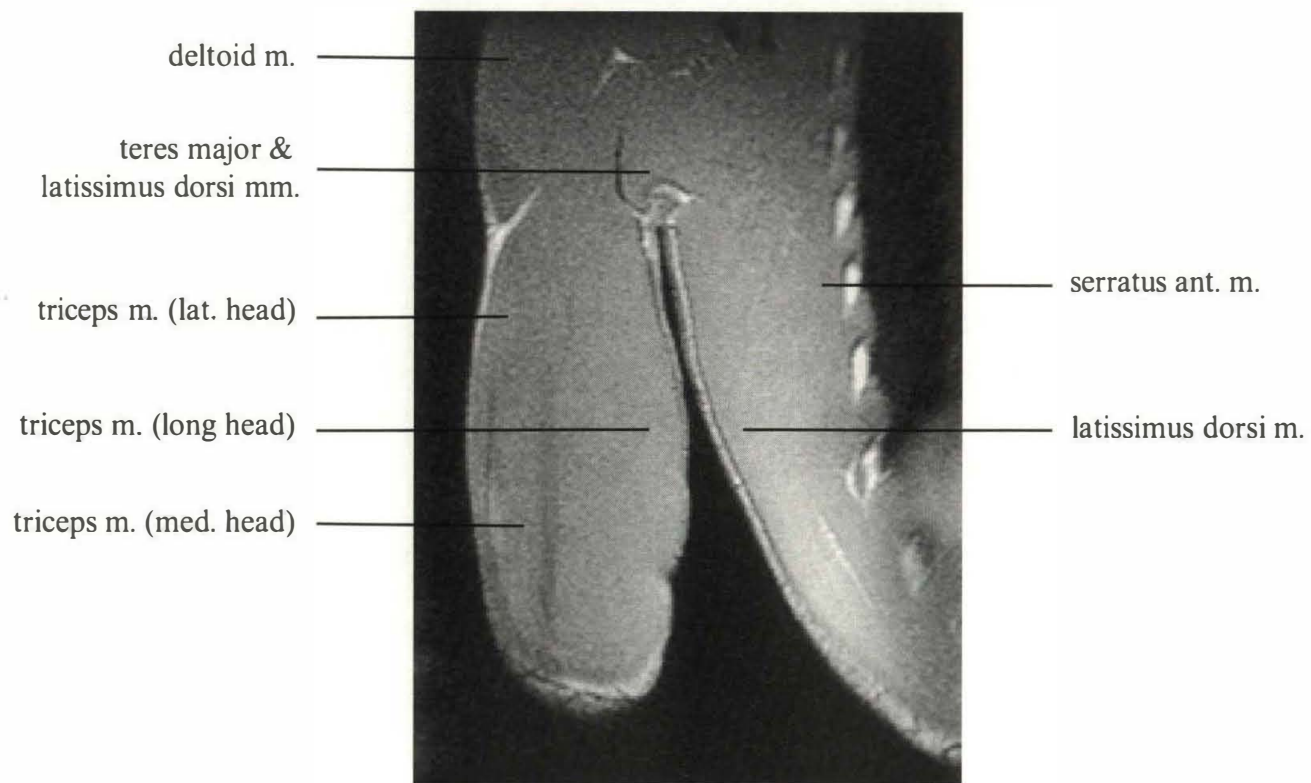
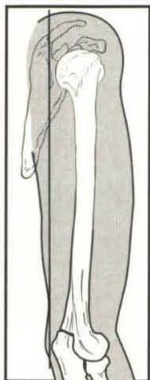
biceps brachii m.

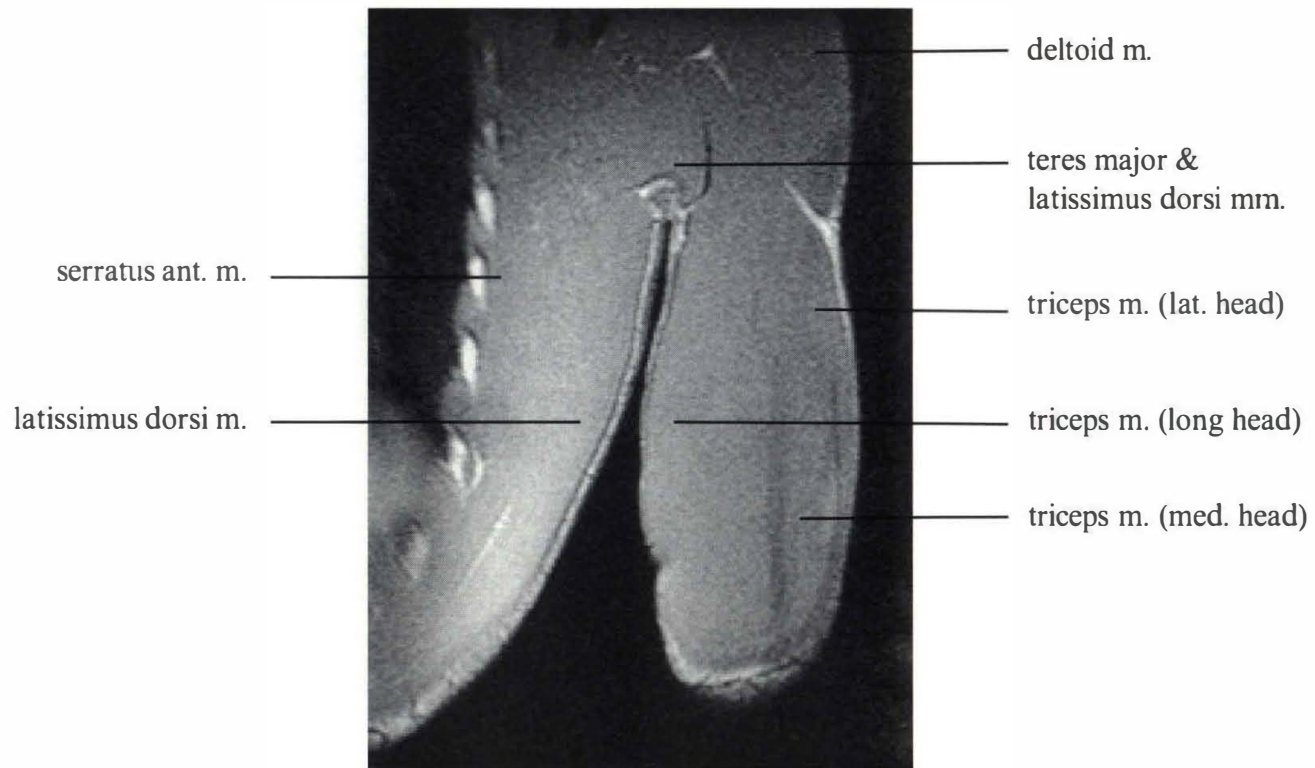
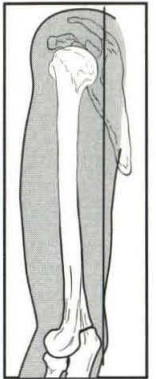
brachialis m.

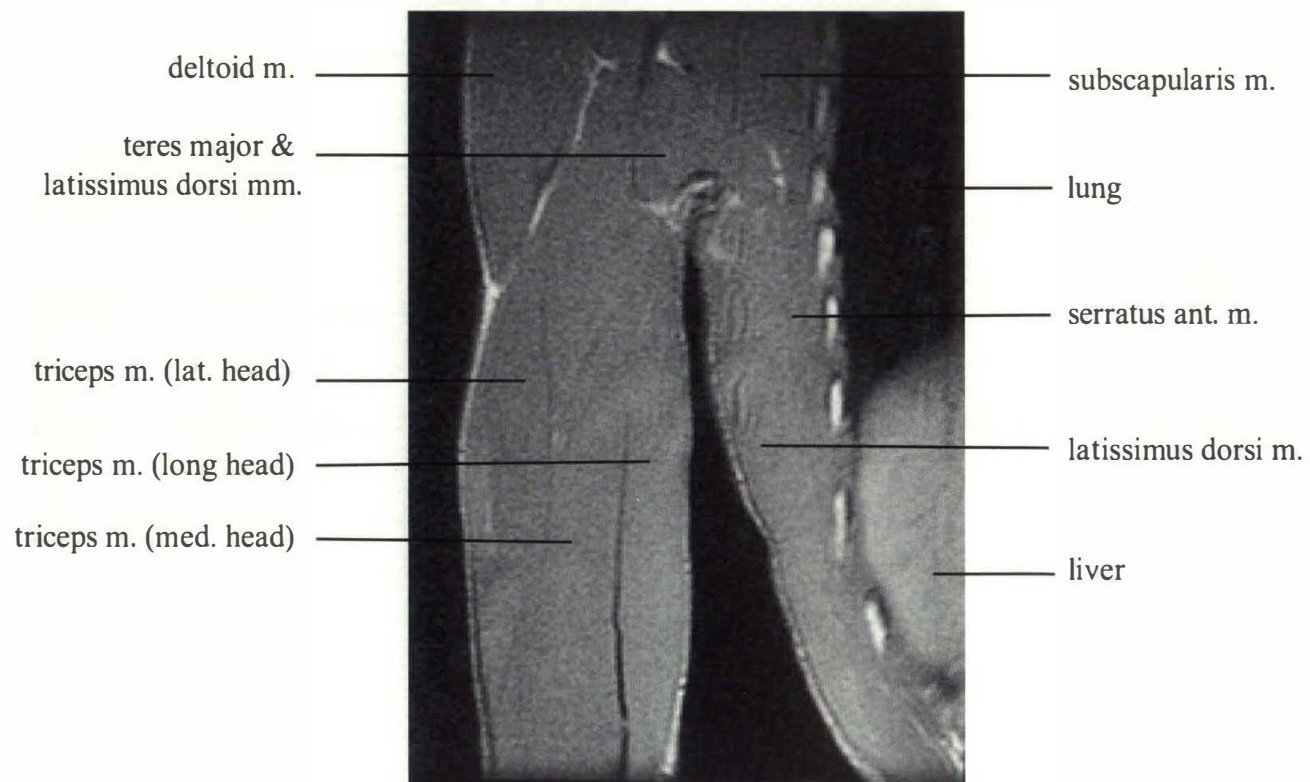
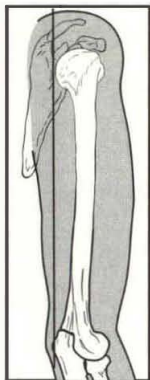
triceps m. (lat. head)

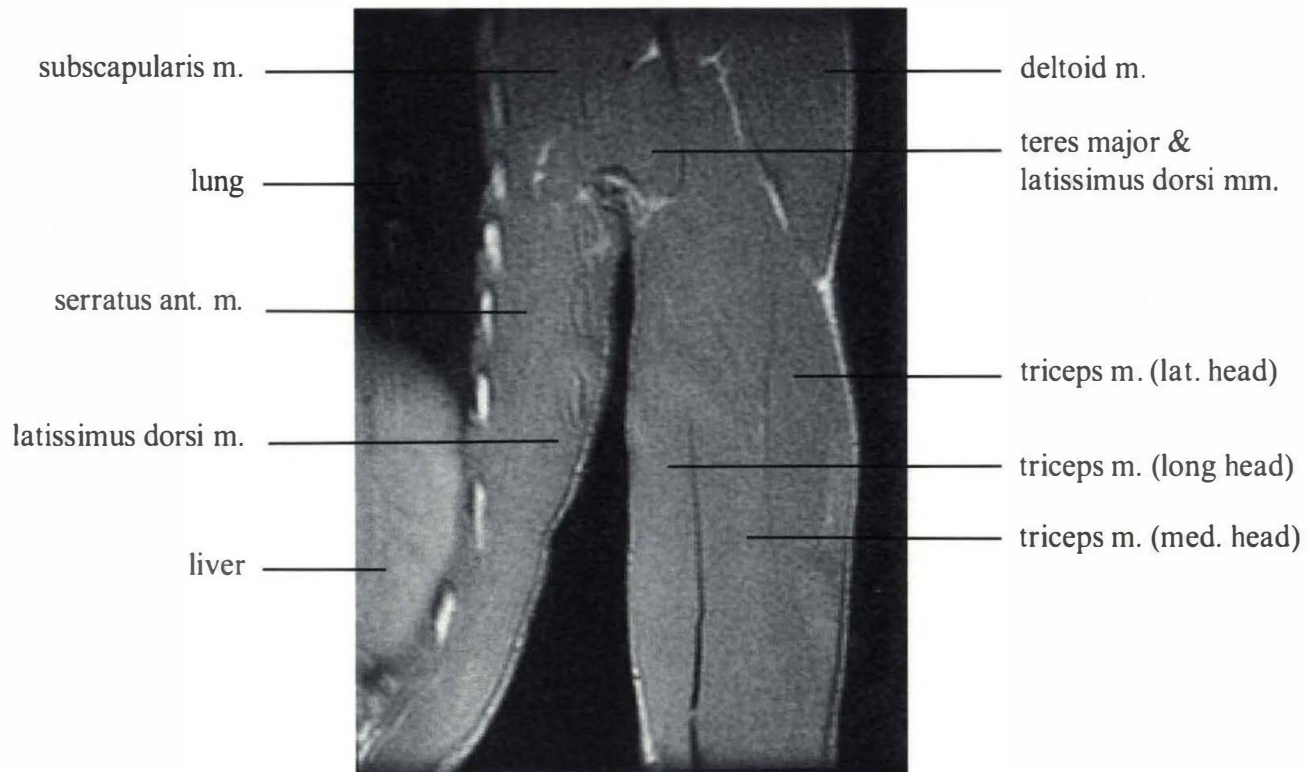
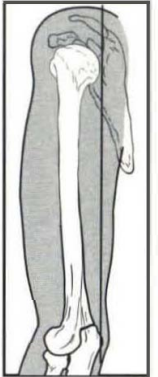


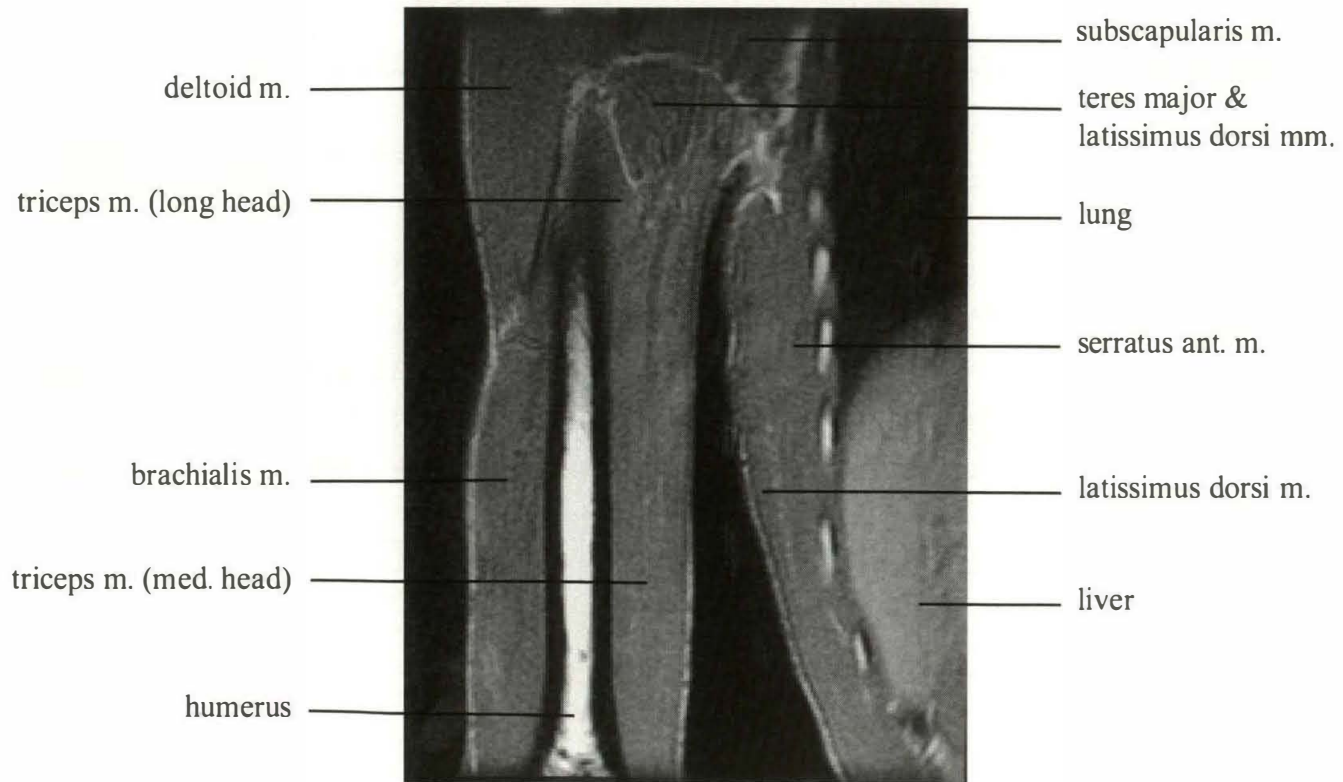
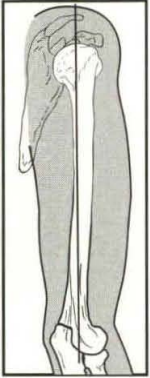
THE UPPER EXTREMITY: CORONAL ANATOMY

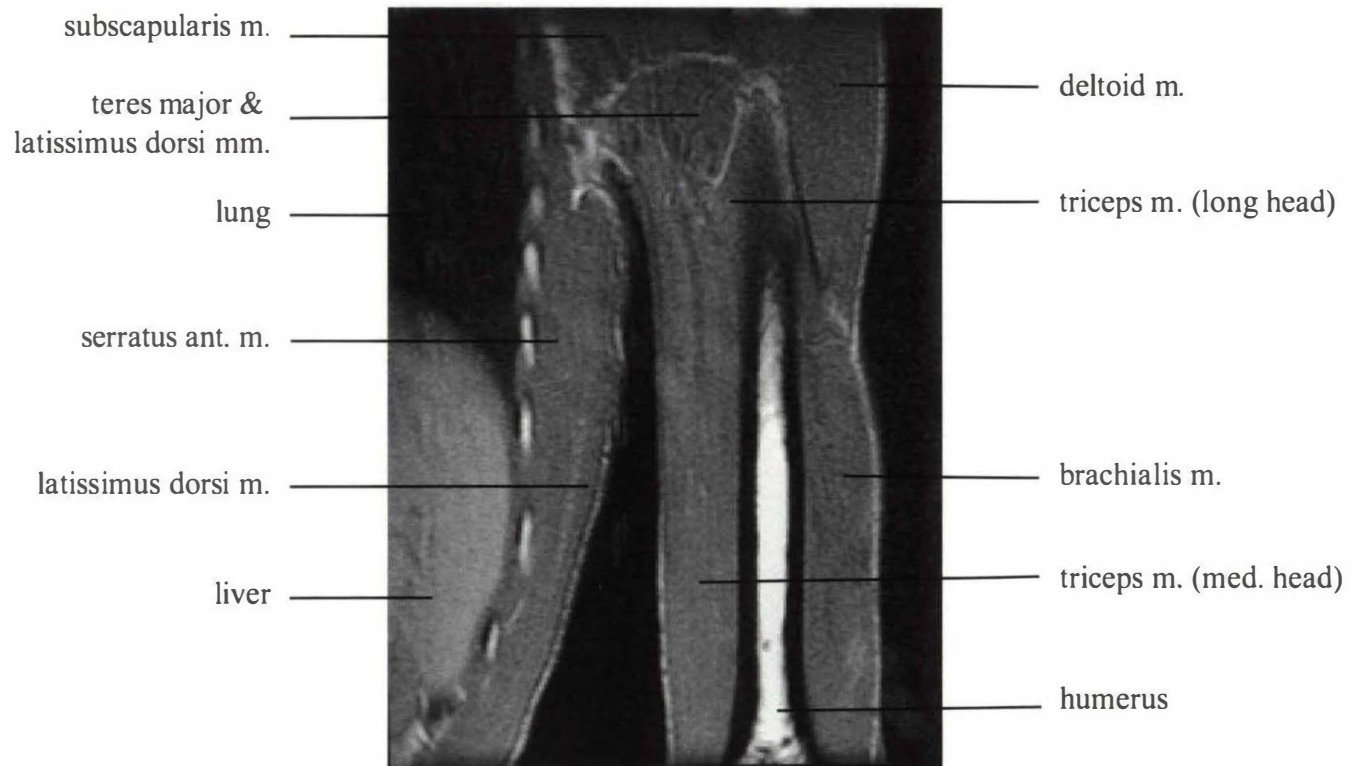
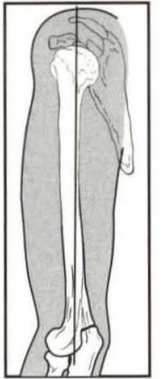


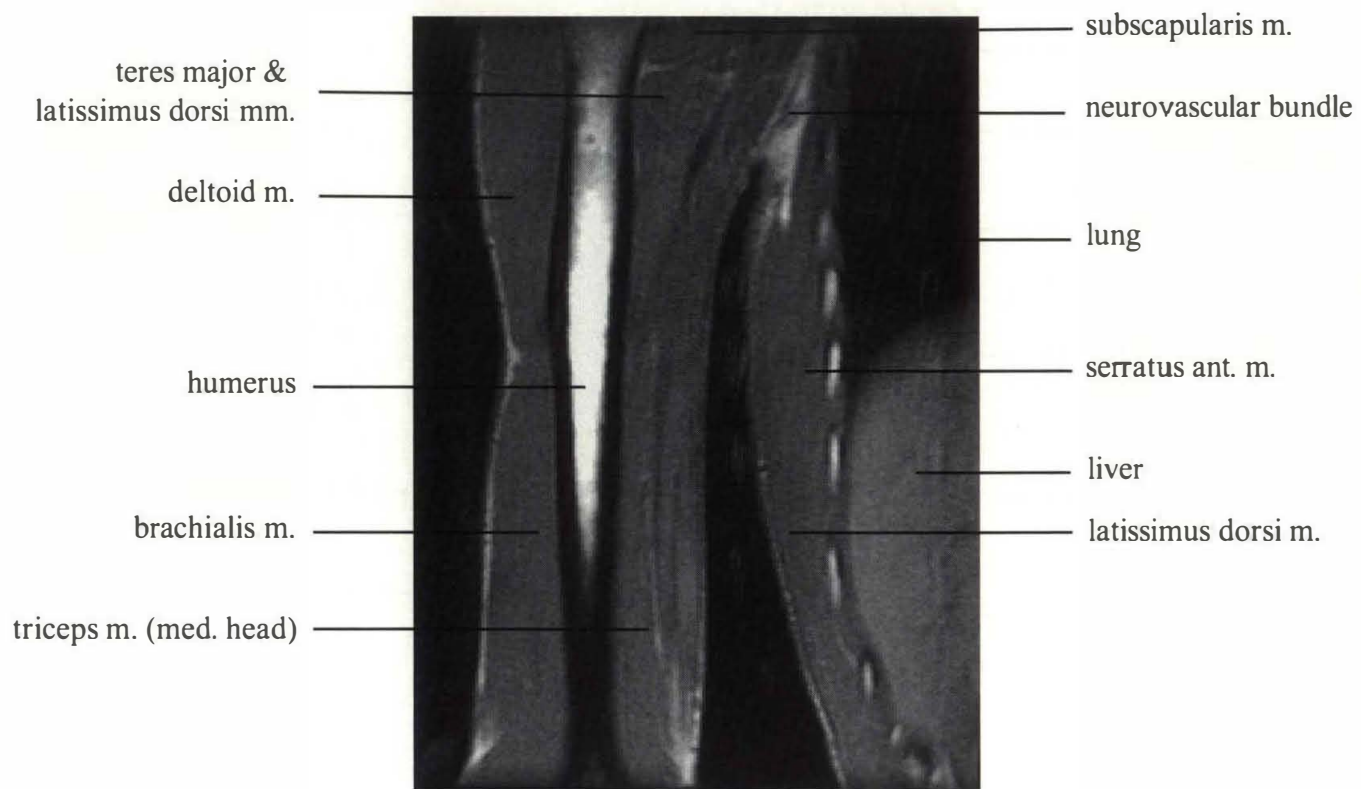
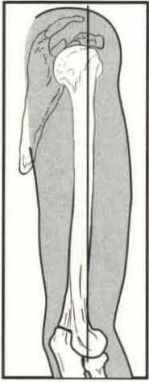


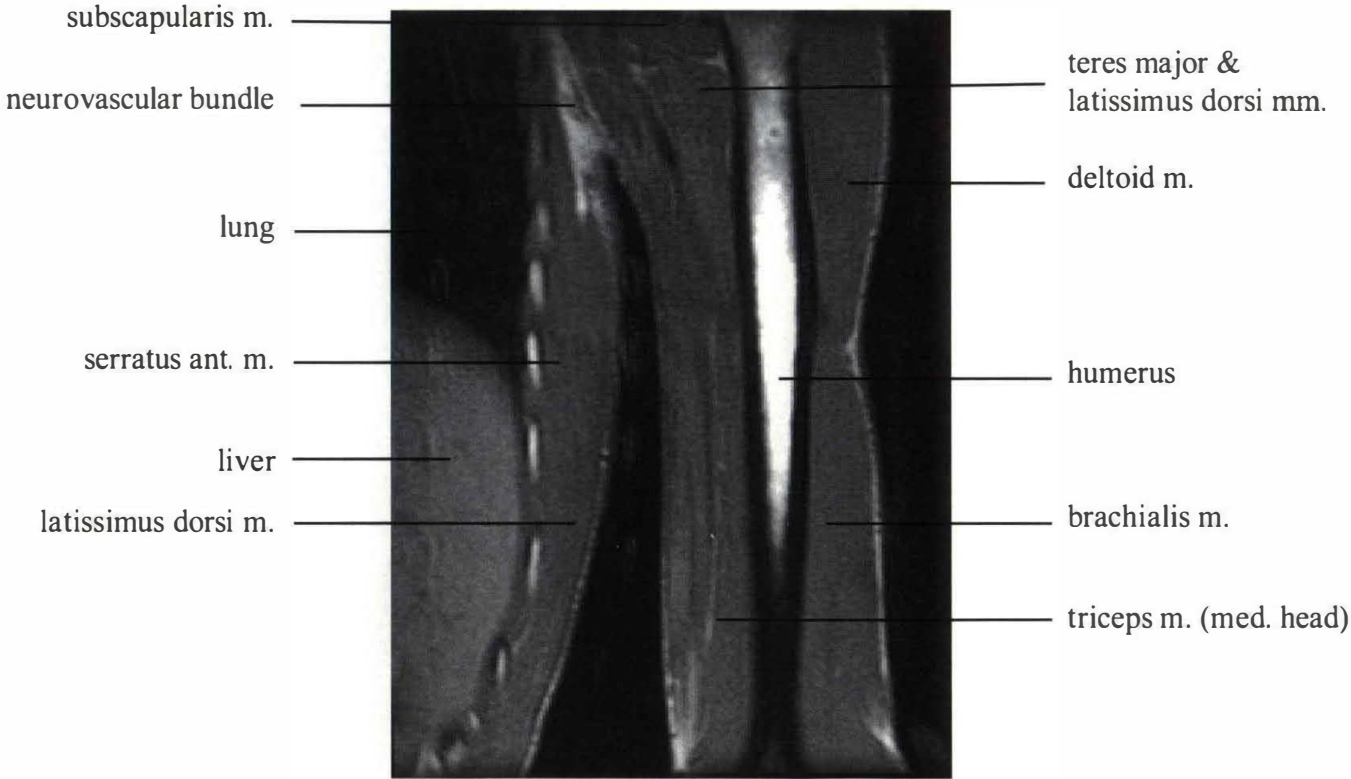
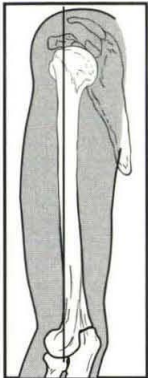


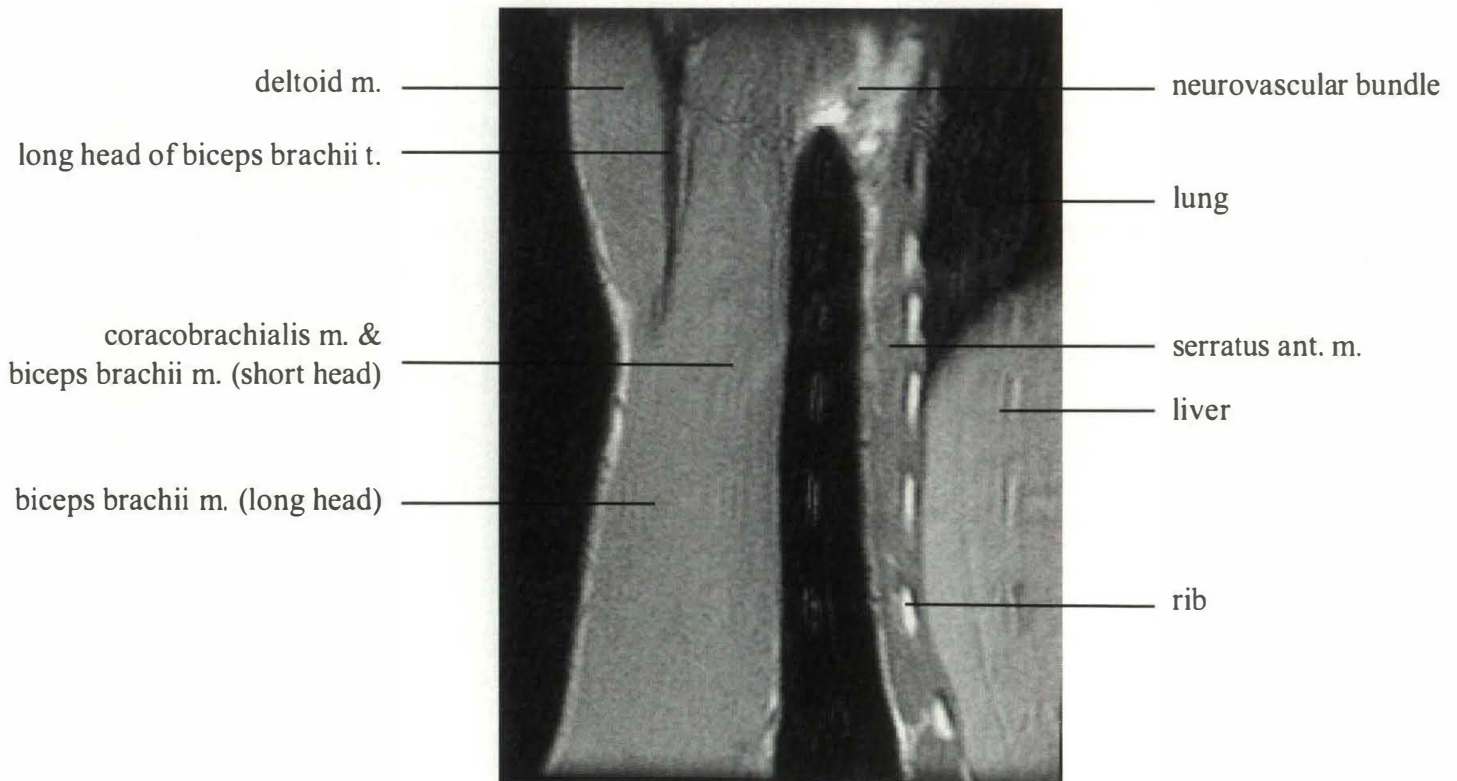
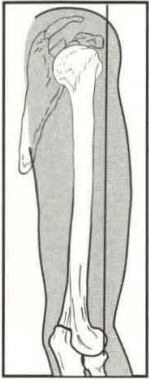


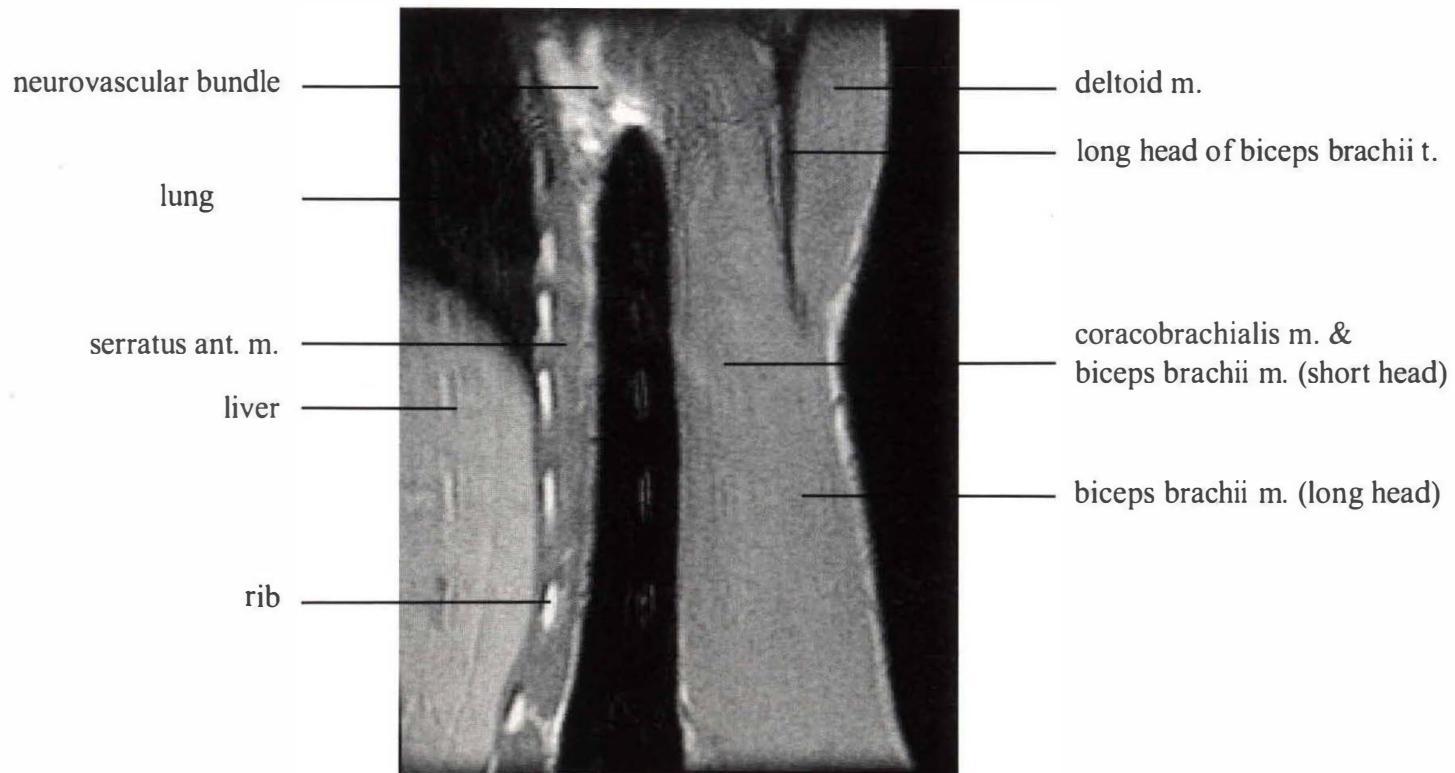
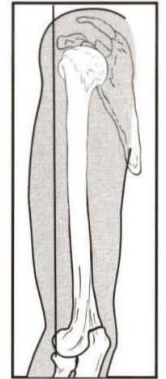












THE ELBOW AND FOREARM

Imaging of the elbow is not performed as commonly as that of other anatomic sites such as the shoulder or knee. MR imaging can evaluate all of the osseous and soft-tissue structures of the elbow. The major indications for MR imaging of the elbow are fractures when evaluation of the nonossified cartilage is necessary, fractures with suspected injury to tendons and ligaments, acute or chronic repetitive injury to the ligaments or tendons, evaluation of osteochondritis dissecans, suspected entrapment neuropathies, and, rarely, evaluation of arthritides such as rheumatoid or infectious arthritis.

PRACTICAL PROTOCOL CONSIDERATIONS

The elbow can be imaged in a variety of ways. Typically, the patient is placed in the supine position with the arm resting comfortably at his or her side. Alternatively, the patient may be semiprone with the arm extended overhead; however, this position is not as well tolerated by the patient because of the placement of the shoulder, and images may be degraded as a result of motion.

Dedicated or surface coils are mandatory to obtain diagnostic-quality images of the elbow. As in every anatomic area, if there is a suspicion of a soft-tissue mass or significant pain, a vitamin E capsule or other marker should be taped to the skin at the superior and inferior margins or the medial and lateral margins of the suspected abnormality for best results. A combination of imaging sequences can be used, and these are demonstrated in the table that follows.

Menu of Protocols

Elbow										
Plane	Pulse Sequence	FA (degrees)	TR (msec)	TE (msec)	TI (msec)	FOV (cm)	Matrix (256X-)	ST/G (mm)	NEX	Comments
Localizer (transaxial)	FMPIR		2,500	25	150	22-24	128	5/2.5	2	Excellent for edema
Localizer (transaxial)	SE		300	20		40	128	4/1	1	Either is acceptable
Sagittal, transaxial	SE		200	15		30	128	10/5	1	
Transaxial	FSE, double echo		3,000	17/102		12	192	4/1	2	Either is acceptable
Transaxial	FSE, FS		2,500	40		12-13	256	5/1	2	
Transaxial	SE		300	20		12-16	128	3/1	2	
Sagittal	FMPIR		8,000	20	150	16-18	256	5/1	2	Either is acceptable
Sagittal	SE, double echo		2,000	20/80		14-16	128	3/1	2	
Sagittal	SE		600	20		12	128	3/1	2	
Forearm										
Localizer (transaxial)	SE		300	20		VAR	128	4/1	1	Mark area of concern
Coronal, sagittal	SE		500	min		VAR	192	5/1.5	1	
Coronal	SE		1,000	min		VAR	192	5/1.5	2	
Coronal	FMPIR		2,500	30	150	VAR	128	5/1.5	1	
Sagittal	SE		1,000	min		VAR	192	5/1.5	2	
Sagittal	FMPIR		2,500	30	150	VAR	128	5/1.5	2	
Axial	SE		600	20		VAR	192	4/1	2	
Axial, pre-GAD	SE		600	20		VAR	192	4/1	2	Repeat after GAD
Axial, pre-GAD	SE, FS		600	20		VAR	192	4/1	2	Repeat after GAD

MAJOR OSTEOCARTILAGINOUS STRUCTURES/LANDMARKS

- Distal humerus
 - Medial condyle
 - Lateral condyle
 - Articular surface of trochlea
 - Articular surface of capitellum
 - Olecranon fascia
 - Coronoid fascia
 - Radial fascia
 - Medial and lateral supracondylar crests
- Proximal ulna
 - Coronoid process
 - Olecranon
 - Radial notch of ulna
- Proximal radius
 - Radial head
 - Radial neck
 - Radial tuberosity

MAJOR LIGAMENTS/TENDONS

Ligaments

- Medial collateral ligamentous complex
 - Anterior band (bundle)—from inferior aspect of the medial epicondyle to the medial aspect of the coronoid process, seen best on coronal images. The anterior bundle is the primary constraint to valgus stress and is commonly injured in athletes whose sport involves throwing
 - Posterior bundle
 - Oblique band (transverse ligament)
 - The posterior bundle and transverse ligament are deep to the ulnar nerve and make up the floor of the cubital tunnel

- Lateral collateral ligamentous complex
 - Radial collateral ligament (RCL)
 - Arises from the anterior portion of the lateral epicondyle, blending with the fibers of the annular ligament and surrounding the radial head
 - Annular ligament
 - Primary stabilizer of the proximal radial ulnar joint
 - Best evaluated on axial images
 - Lateral ulnar collateral ligament (LUCL)—variably seen

Tendons

- Anterior compartment
 - Biceps tendon
 - Brachialis tendon
- Posterior compartment
 - Triceps tendon
 - Anconeus tendon
- Medial compartment
 - Pronator teres tendon
 - Hand and wrist flexors (common flexor tendon)
- Lateral compartment
 - Supinator tendon
 - Brachioradialis tendon
 - Extensor carpi radialis longus tendon
 - Hand and wrist extensors (common extensor tendon)

Bursae

- Olecranon

MAJOR MUSCLES

The 19 muscles in the forearm are arranged in anterior (flexor) and posterior (extensor) compartments. They can be divided into groups by either their actions or layers as superficial and deep flexors or extensors, as demonstrated in the following categories.

Compartments

Grouped by Muscle Action

- Anterior compartment
 - Rotation (Radius on ulna)
 - Pronator teres
 - Pronator quadratus
 - Supinator
 - Flexion (Hand at wrist)
 - Flexor carpi radialis
 - Flexor carpi ulnaris
 - Palmaris longus
 - Flexion (Digits)
 - Flexor digitorum superficialis
 - Flexor digitorum profundus
 - Flexor pollicis longus
- Posterior compartment
 - Extension (Hand at wrist)
 - Extensor carpi radialis longus
 - Extensor carpi radialis brevis
 - Extensor carpi ulnaris
 - Extension (Digits except thumb)
 - Extensor digitorum
 - Extensor indicis
 - Extensor digiti minimi
 - Extension (Thumb)
 - Abductor pollicis longus
 - Extensor pollicis brevis
 - Extensor pollicis longus

Grouped by Layers

- Flexor muscles
 - Superficial layer
 - Pronator teres
 - Flexor carpi radialis
 - Palmaris longus
 - Flexor carpi ulnaris
 - Flexor digitorum superficialis
 - Deep layer
 - Flexor digitorum profundus
 - Flexor pollicis longus
 - Pronator quadratus
- Extensor muscles
 - Superficial layer
 - Brachioradialis
 - Extensor carpi radialis longus
 - Extensor carpi radialis brevis
 - Extensor digitorum
 - Extensor digiti minimi
 - Extensor carpi ulnaris
 - Deep layer
 - Supinator
 - Abductor pollicis longus
 - Extensor pollicis brevis
 - Extensor pollicis longus

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
Anterior Compartment			
<i>Flexor Muscles—Superficial Layer</i>			
– Pronator teres	Two heads: (1) humeral head—medial epicondyle of humerus and (2) ulnar head—medial side of coronoid process of ulna	Middle third of lateral surface of radius	Median N. (C6, C7)
– Flexor carpi radialis	Medial epicondyle of humerus	Base of second metacarpal and, frequently, a slip to base of third metacarpal	Median N. (C6, C7)
– Palmaris longus (absent in 13% of patients)	Medial epicondyle of humerus	Forms chief portion of palmar aponeurosis	Median N. (C7, C8)
– Flexor carpi ulnaris	Two heads: (1) humeral head—medial epicondyle of humerus and (2) ulnar head—medial side of olecranon, upper two-thirds of posterior ulnar border	Primarily pisiform, hamulus of hamate, and base of fifth metacarpal	Ulnar N. (C7, C8)

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Flexor digitorum superficialis	Two heads: (1) humeroulnar head—medial epicondyle, anterior epicondylar surface, ulnar collateral ligament, ulnar tuberosity, medial border of coronoid process and (2) radial head—upper two-thirds of anterior border of radius	Palmar aspect of shafts of middle phalanges of digits II–V	Median N. (C7, C8, T1)
<i>Flexor Muscles—Deep Layer</i>			
– Flexor digitorum profundus	Proximal two-thirds of medial surface face of ulna, posterior border of ulna, interosseus membrane	Bases of distal phalanges of digits II–V	Median N., anterior interosseus branch (C8, T1)
– Flexor pollicis longus	Anterior surface of radius and adjacent interosseus membrane	Base of distal phalanx of thumb	Median N., anterior interosseus branch (C8, T1)
– Pronator quadratus	Anterior surface of distal one-fourth of ulna	Anterior surface of radius	Median, anterior interosseus N. (C8, T1)

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
<i>Extensor Muscles—Superficial Layer</i>			
– Brachioradialis	Upper two-thirds of lateral epicondylar ridge of humerus	Lateral side of base of styloid process of radius	Radial N. (C5, C6, C7)
– Extensor carpi radialis longus	Common extensor tendon of lateral epicondyle of humerus, lower one-third of lateral epicondylar ridge, lateral intermuscular septum	Dorsum of second metacarpal	Radial N. (C5, C6, C7)
– Extensor carpi radialis brevis	Common extensor tendon of lateral epicondyle of humerus, intermuscular septa, and radial collateral ligament of elbow	Dorsum of base of third metacarpal	Radial or deep radial (posterior interosseus) N. (C7, C8)
– Extensor digitorum	Common extensor tendon of lateral epicondyle of humerus	By four tendons on bases of middle and distal phalanges of digits II–V	Deep radial (posterior interosseus) N. (C7, C8)
– Extensor digiti minimi	Common extensor tendon of lateral epicondyle of humerus, intermuscular septa, overlying fascia	Base of proximal phalanx of fifth digit	Deep radial (posterior interosseus) N. (C7, C8)

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

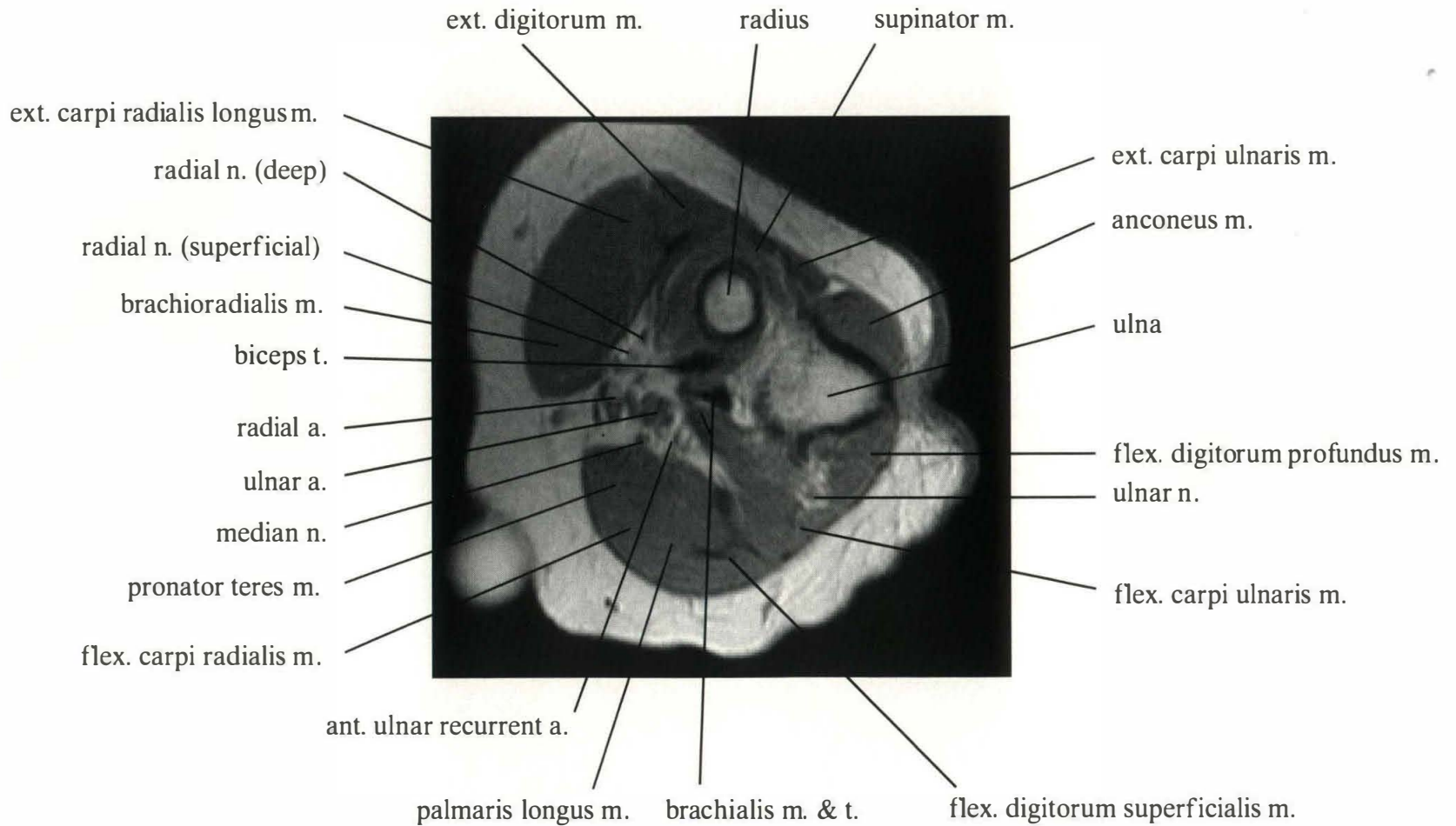
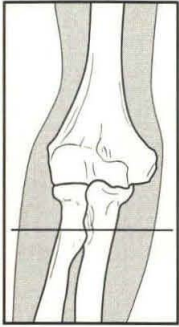
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Extensor carpi ulnaris	Two heads: (1) common extensor tendon lateral to epicondyle of humerus and (2) middle one-half of posterior border of ulna	Ulnar side of base of fifth metacarpal	Deep radial (posterior interosseus) N. (C7, C8)
<i>Extensor Muscles—Deep Layer</i>			
– Supinator	Lateral epicondyle of humerus, radial collateral ligament, annular ligament, and fossa of ulna	Lateral surface of upper one-third of radius between anterior and posterior oblique lines	Deep radial (posterior interosseus) N. (C5, C6)
– Abductor pollicis longus	Middle third of posterior surface of ulna, posterior (dorsal) surface of radius, interosseus membrane	Radial side of base of first metacarpal	Deep radial (posterior interosseus) N. (C7, C8)
– Extensor pollicis brevis	Distal end and dorsal surface of middle third of radius, interosseus membrane, and ulna (sometimes)	Base of proximal phalanx of thumb	Deep radial (posterior interosseus) N. (C7, C8)

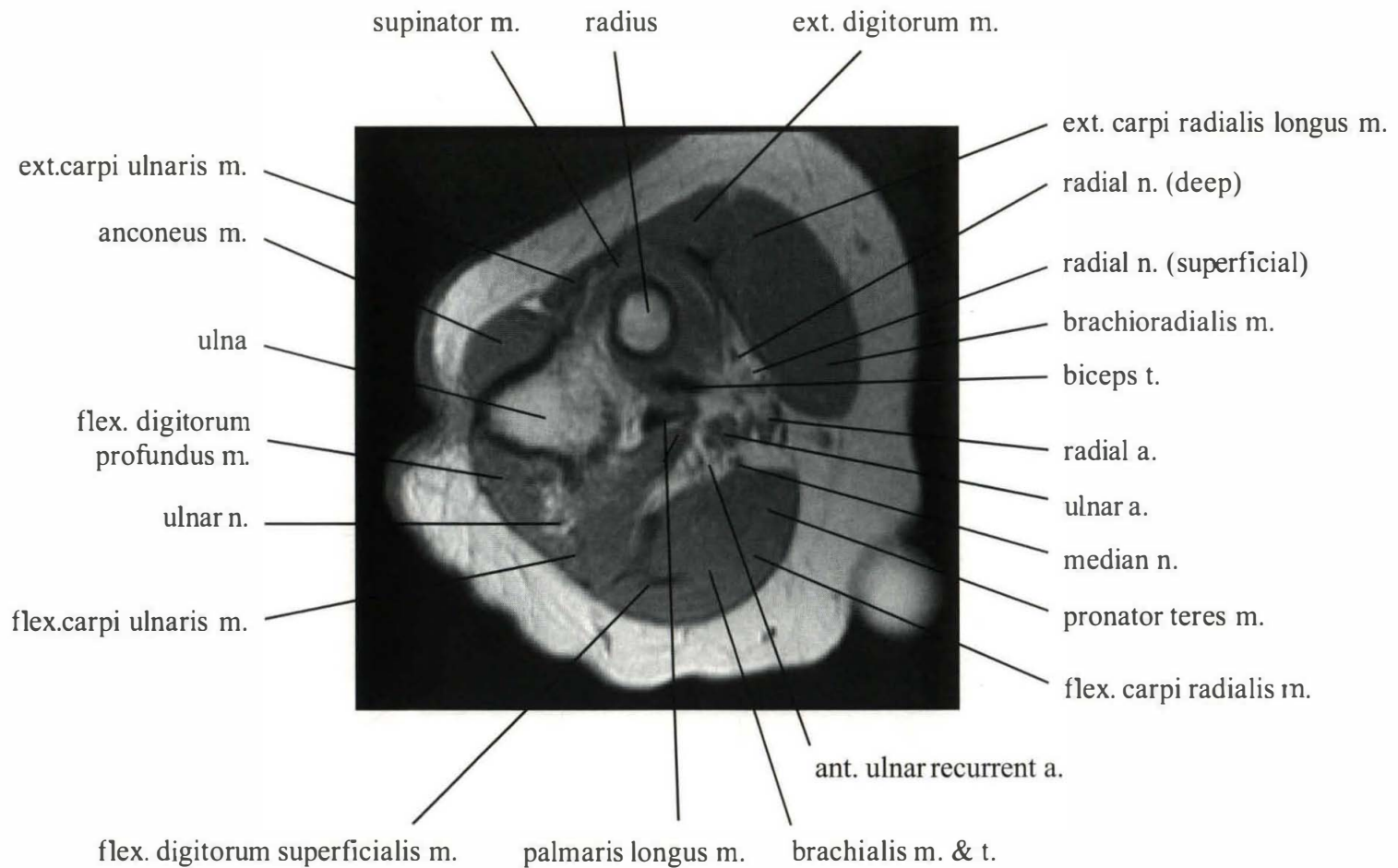
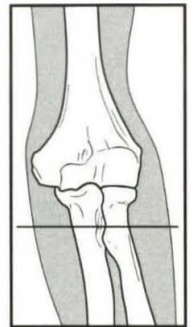
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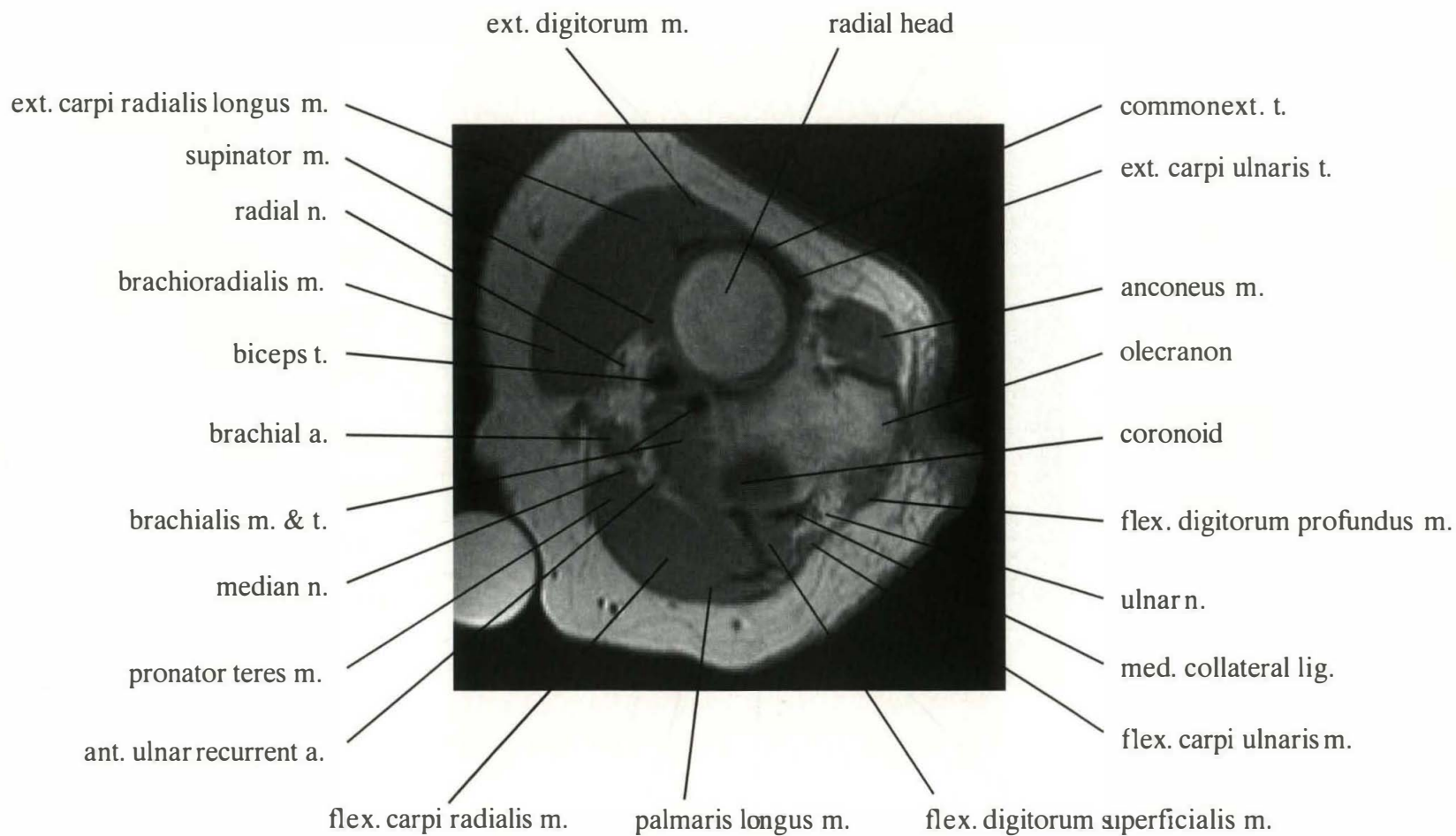
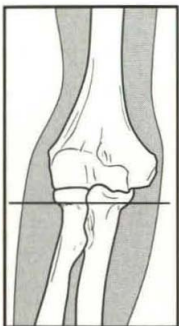
ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

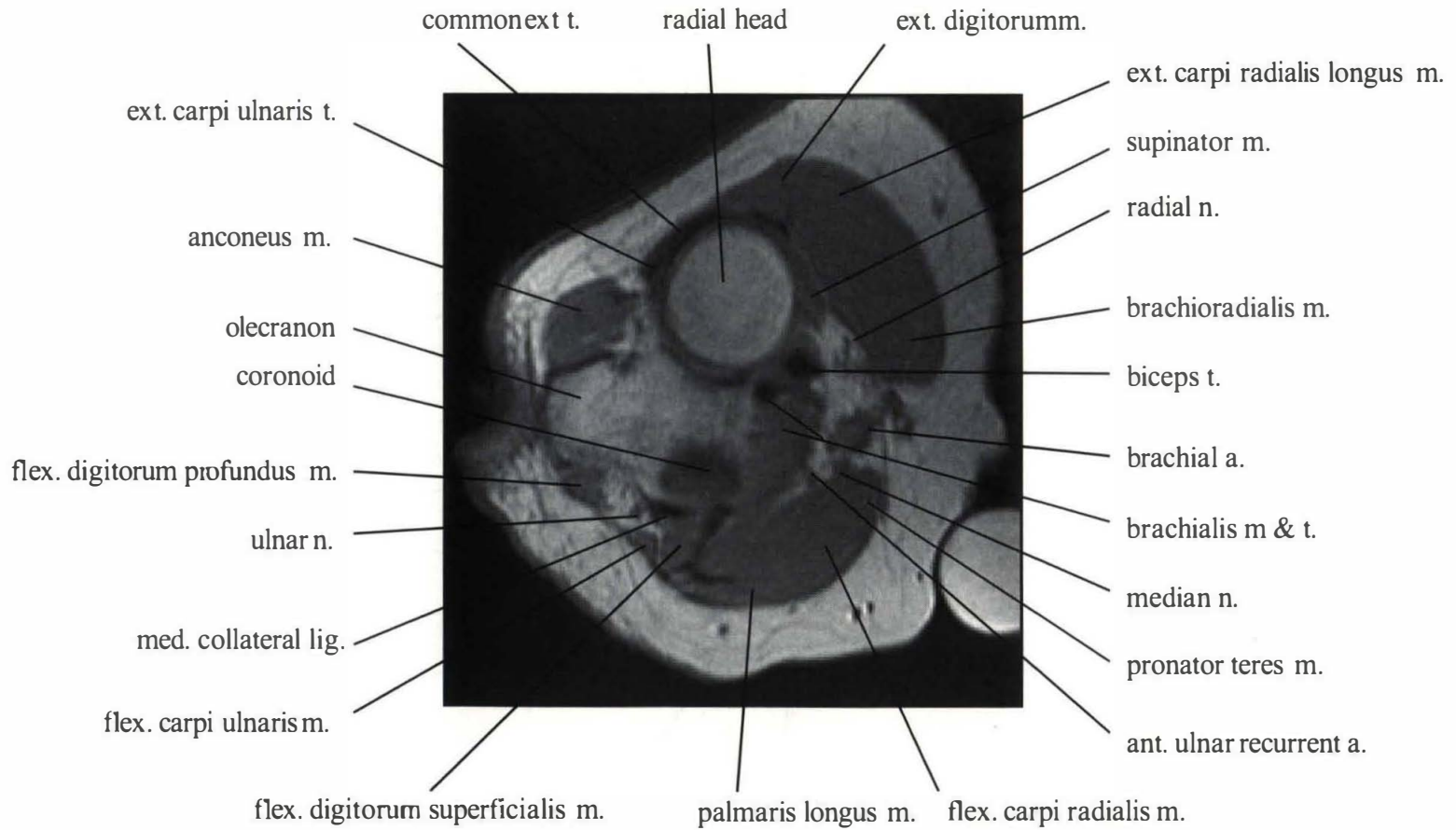
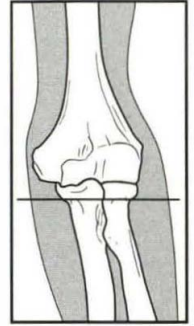
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Extensor pollicis longus	Middle third and dorsal surface of ulna, interosseus membrane distal to abductor pollicis longus muscle	Base of distal phalanx of thumb	Deep radial (posterior interosseus) N. (C7, C8)
– Extensor indicis	Posterior surface of distal third of ulna, interosseus membrane	Joins ulnar side of digital extensor muscle to insert on base of proximal phalanx of second digit	Deep radial (posterior interosseus) N. (C7, C8)

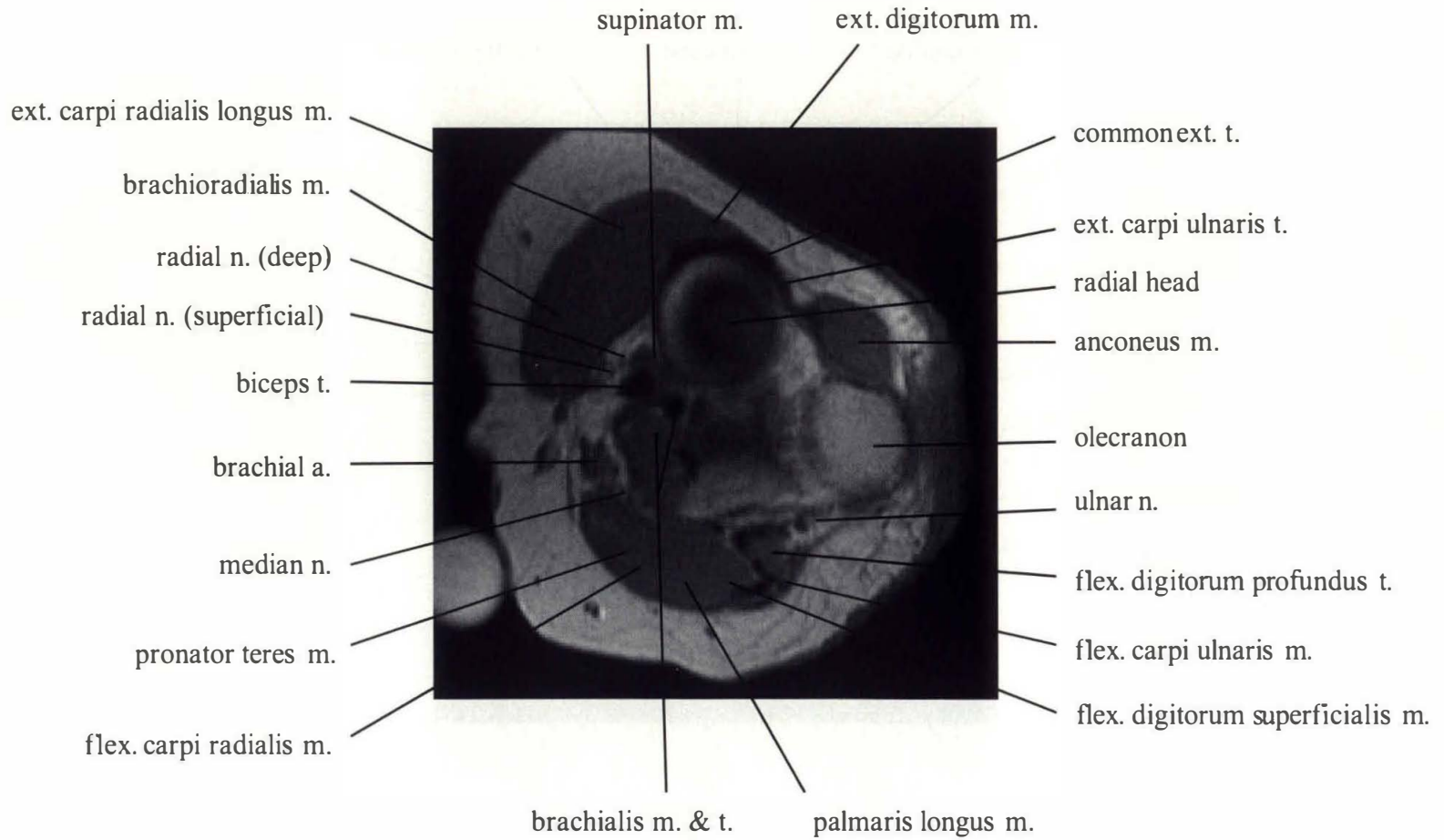
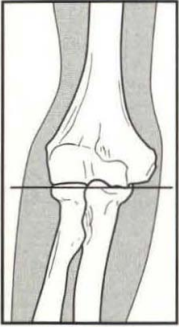
THE ELBOW: AXIAL ANATOMY

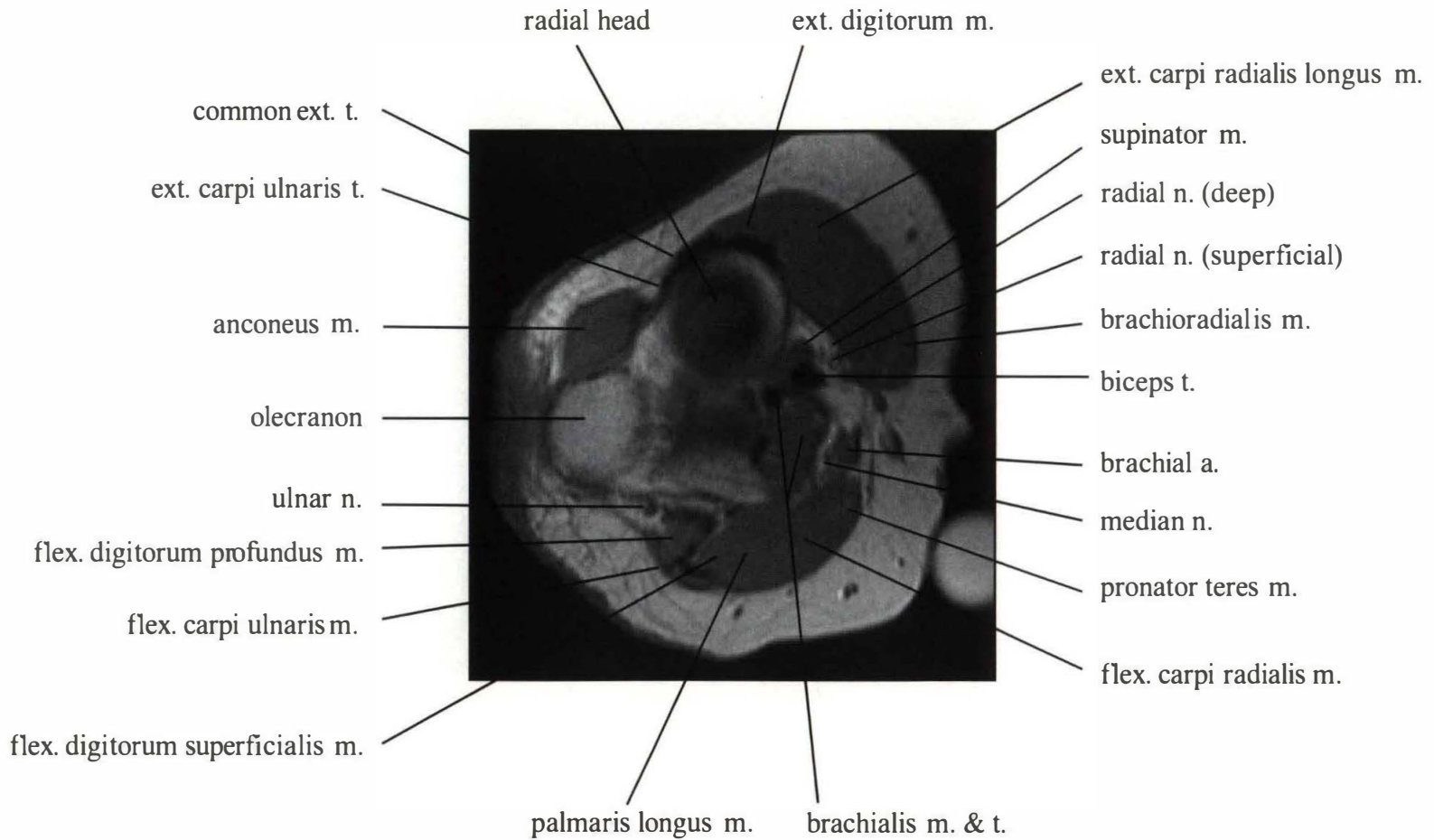
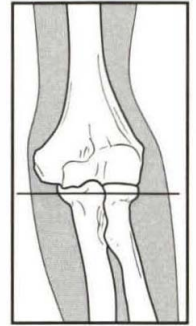


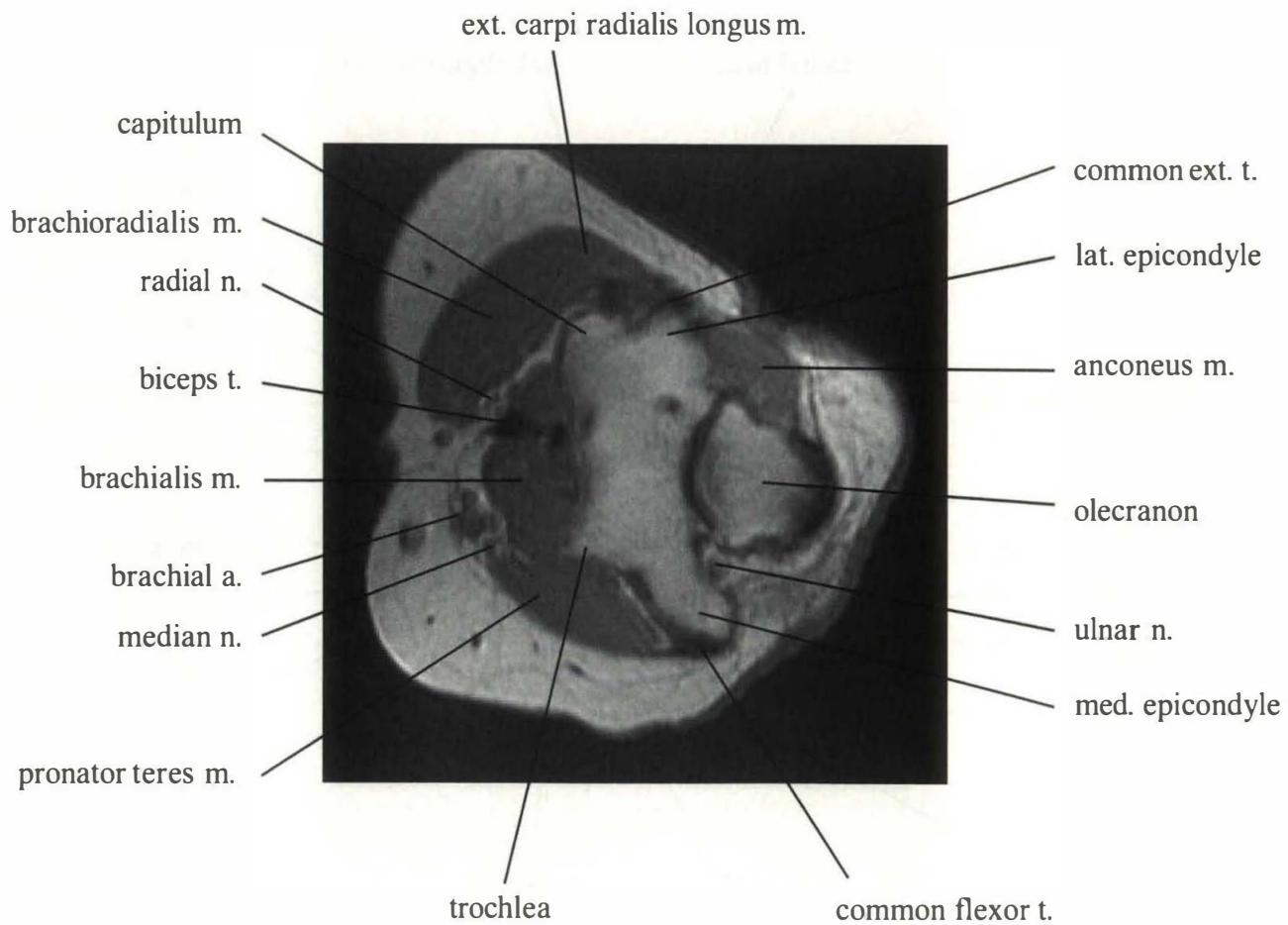
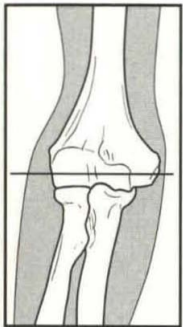


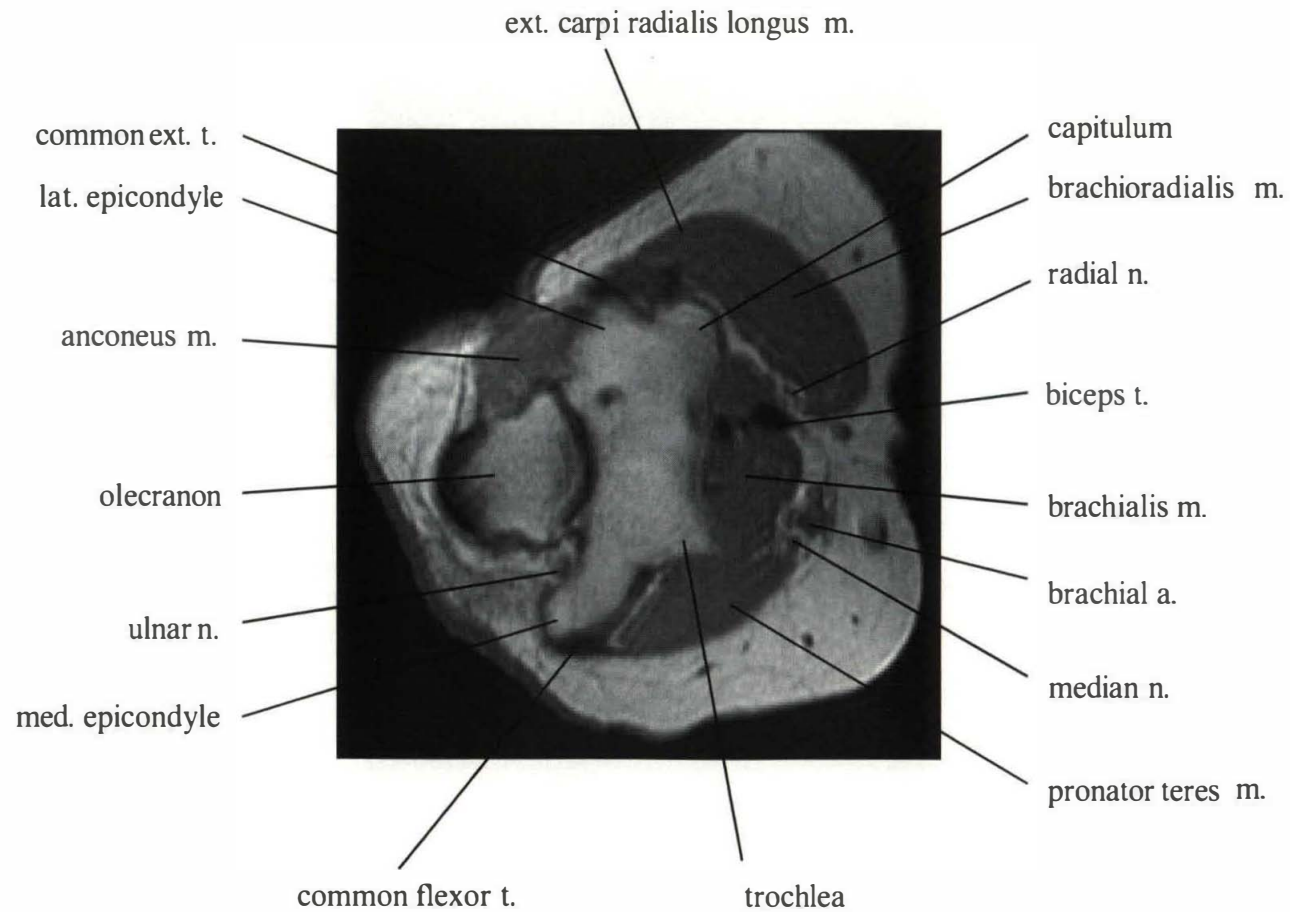
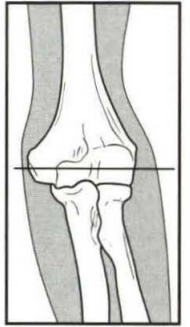


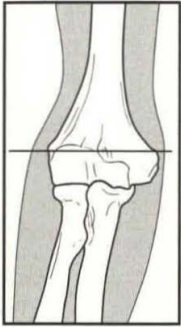












brachioradialis m.

radial n.

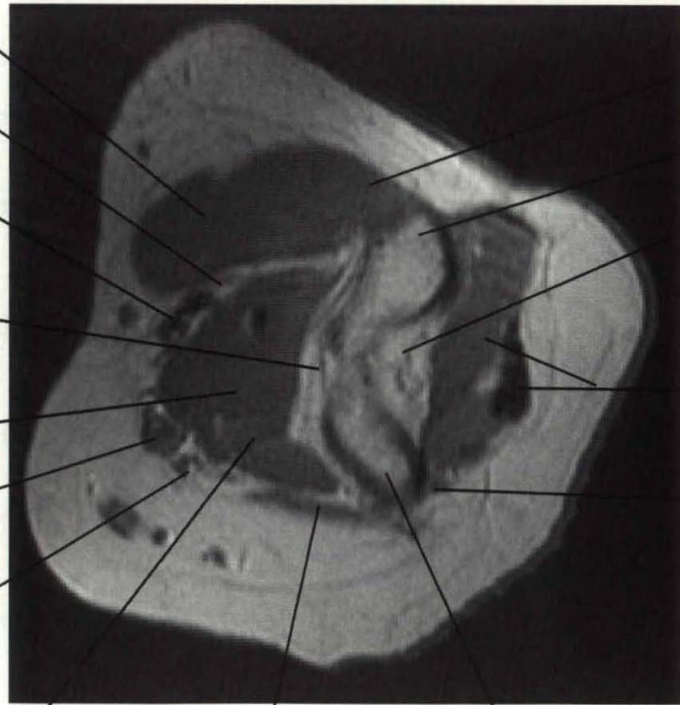
biceps t.

ant. fat pad

brachialis m.

brachial a.

median n.



ext. carpi radialis longus m.

lat. epicondyle

post. fat pad

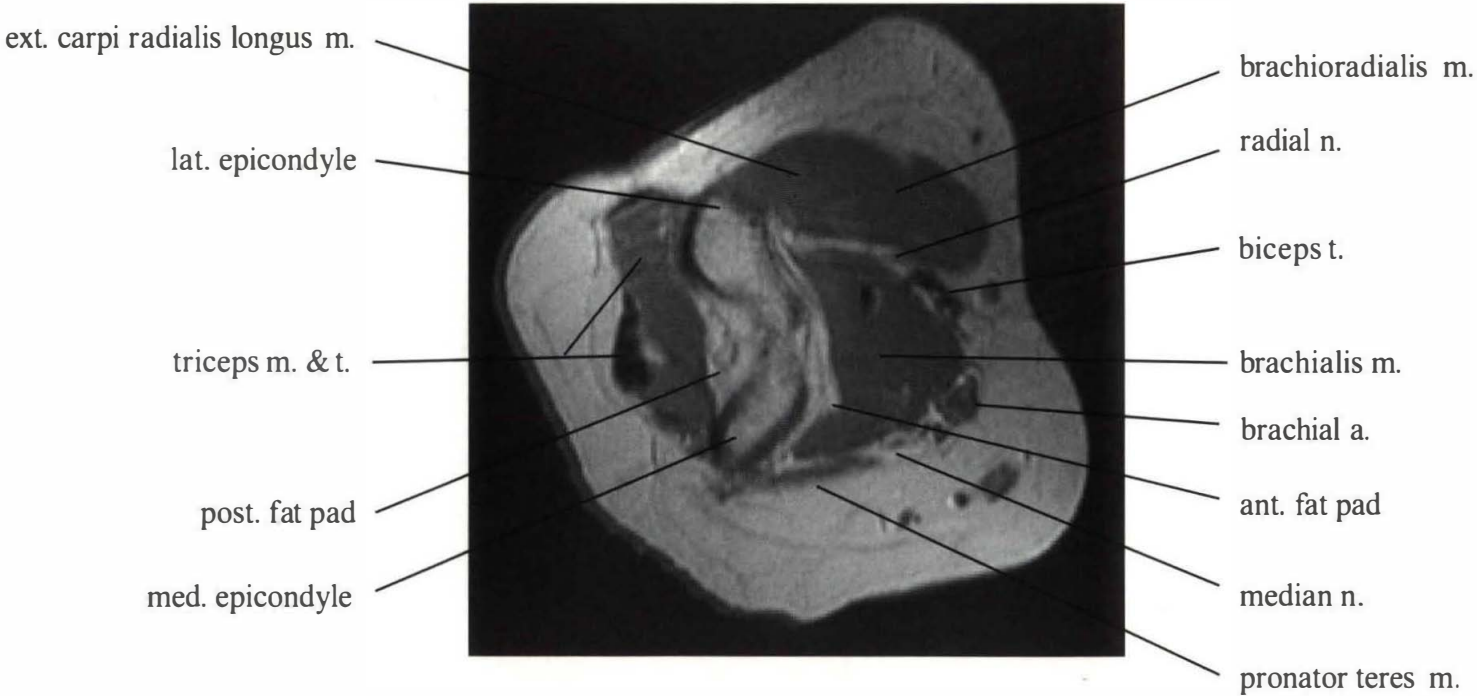
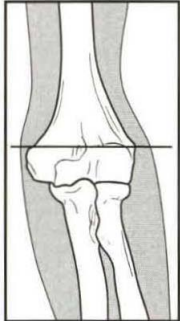
triceps m. & t.

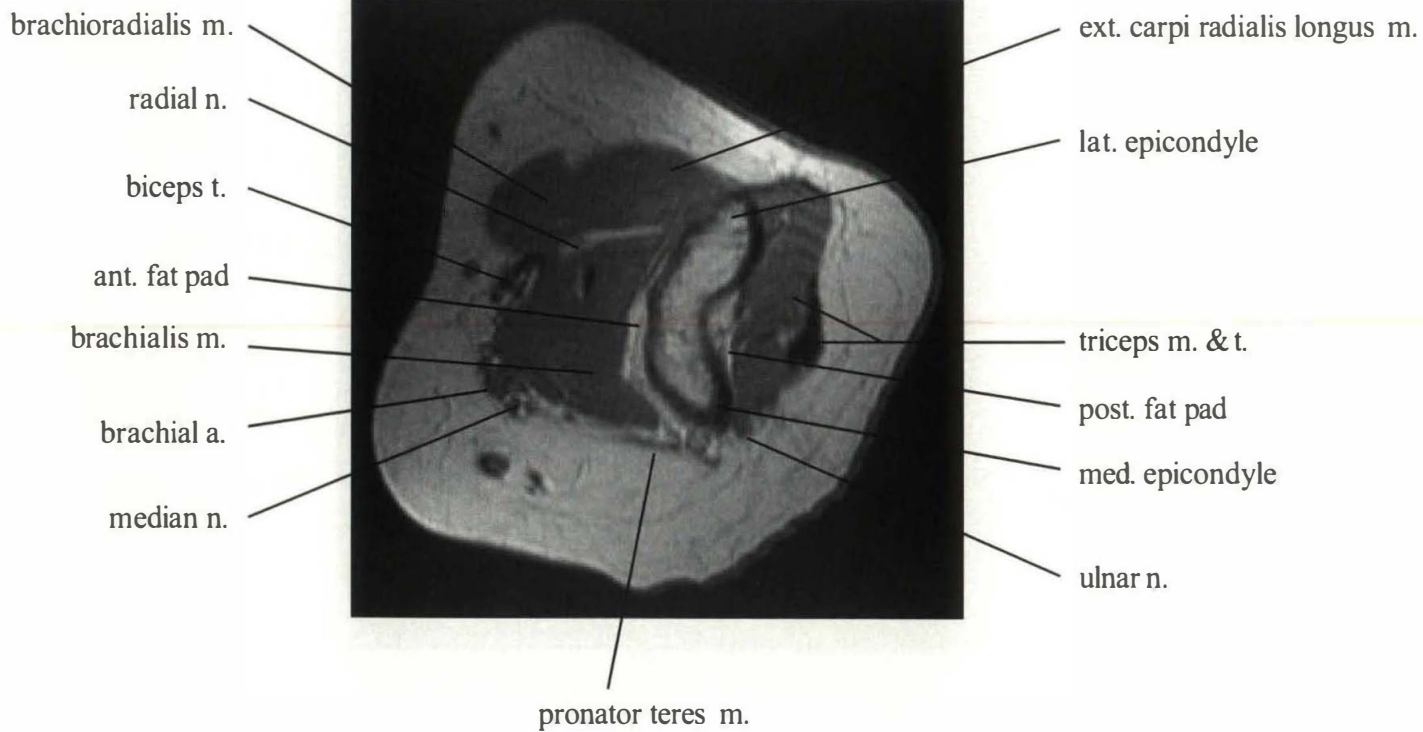
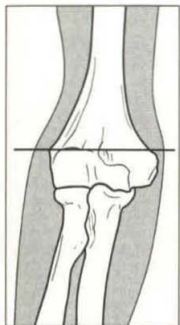
ulnar n.

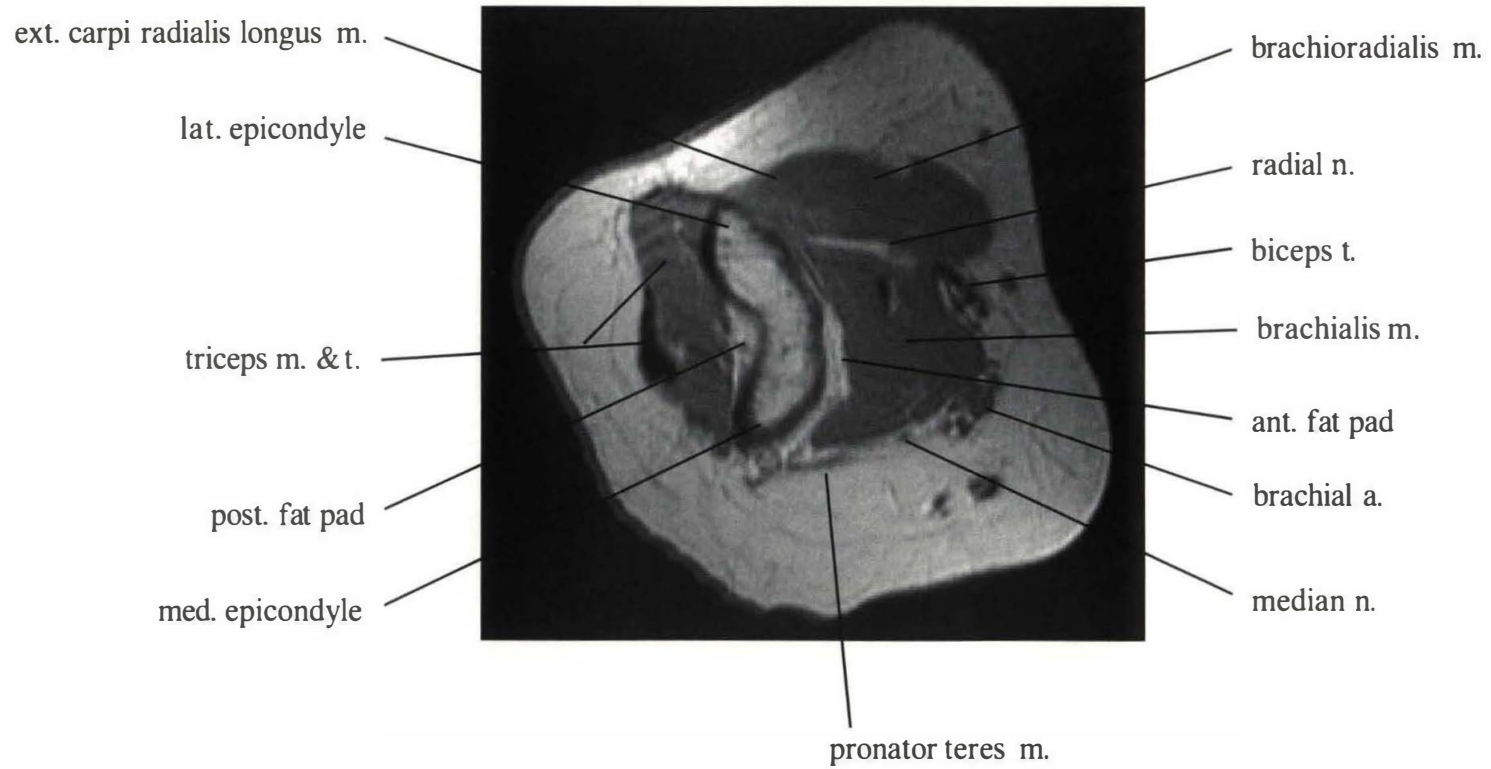
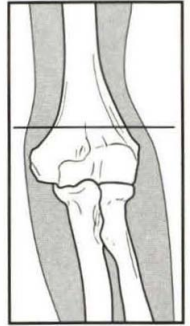
brachialis m.

pronator teres m.

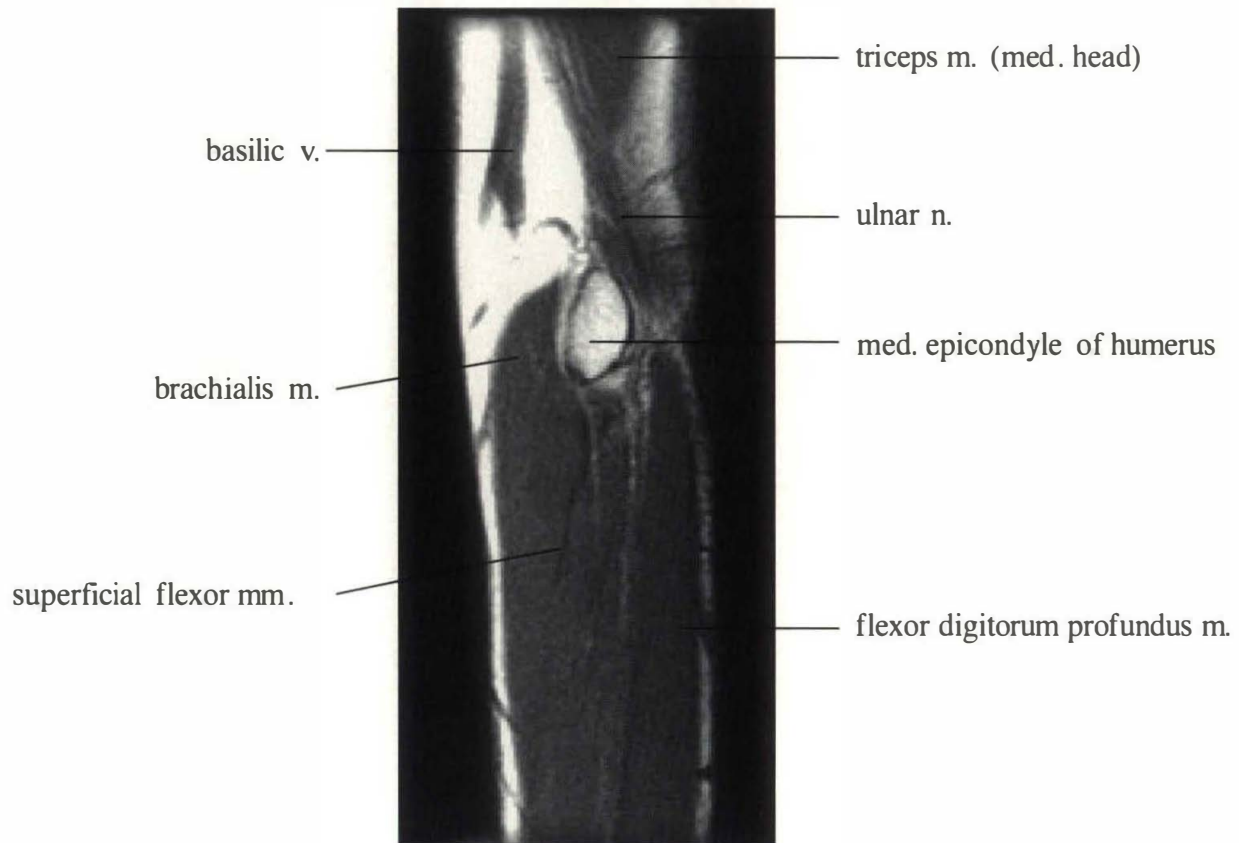
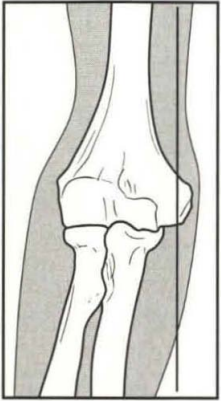
med. epicondyle

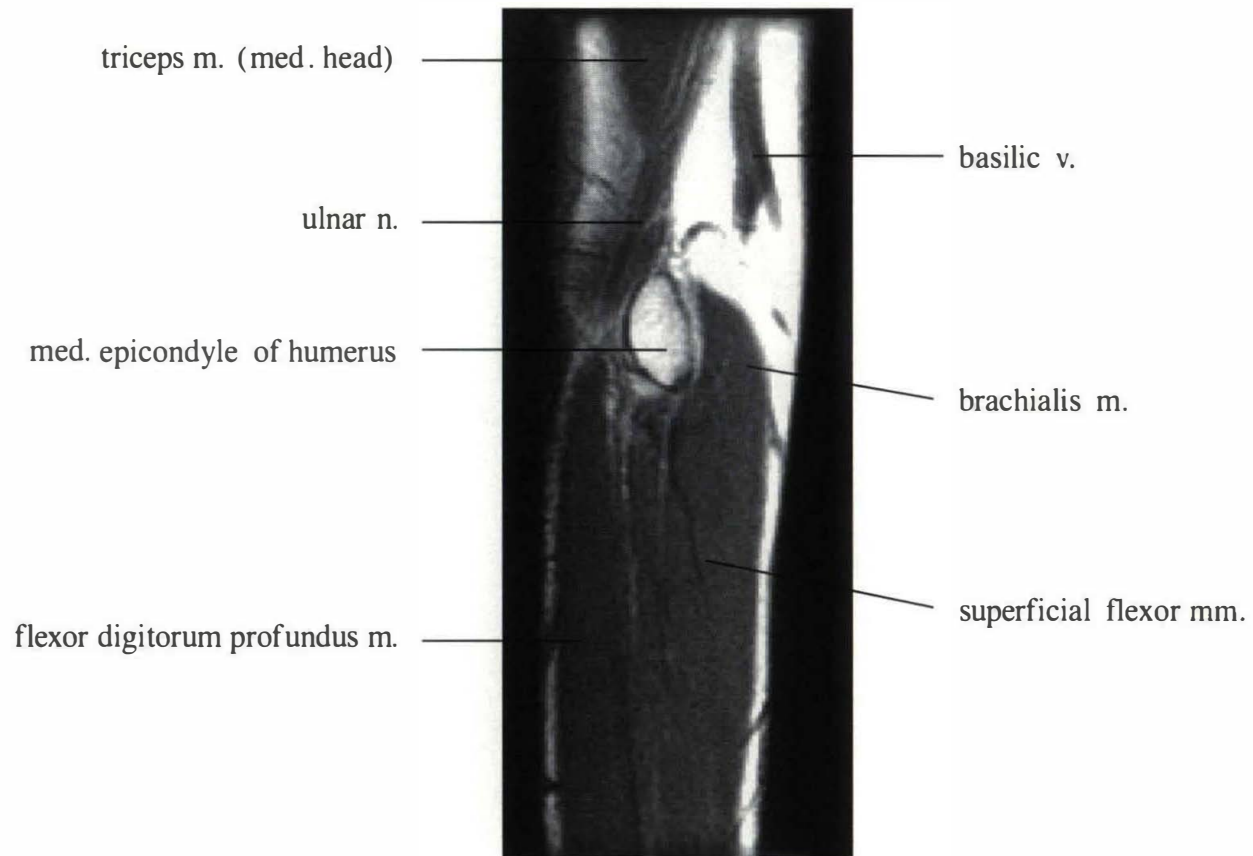
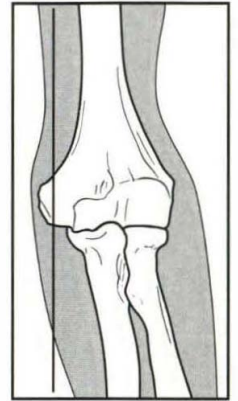


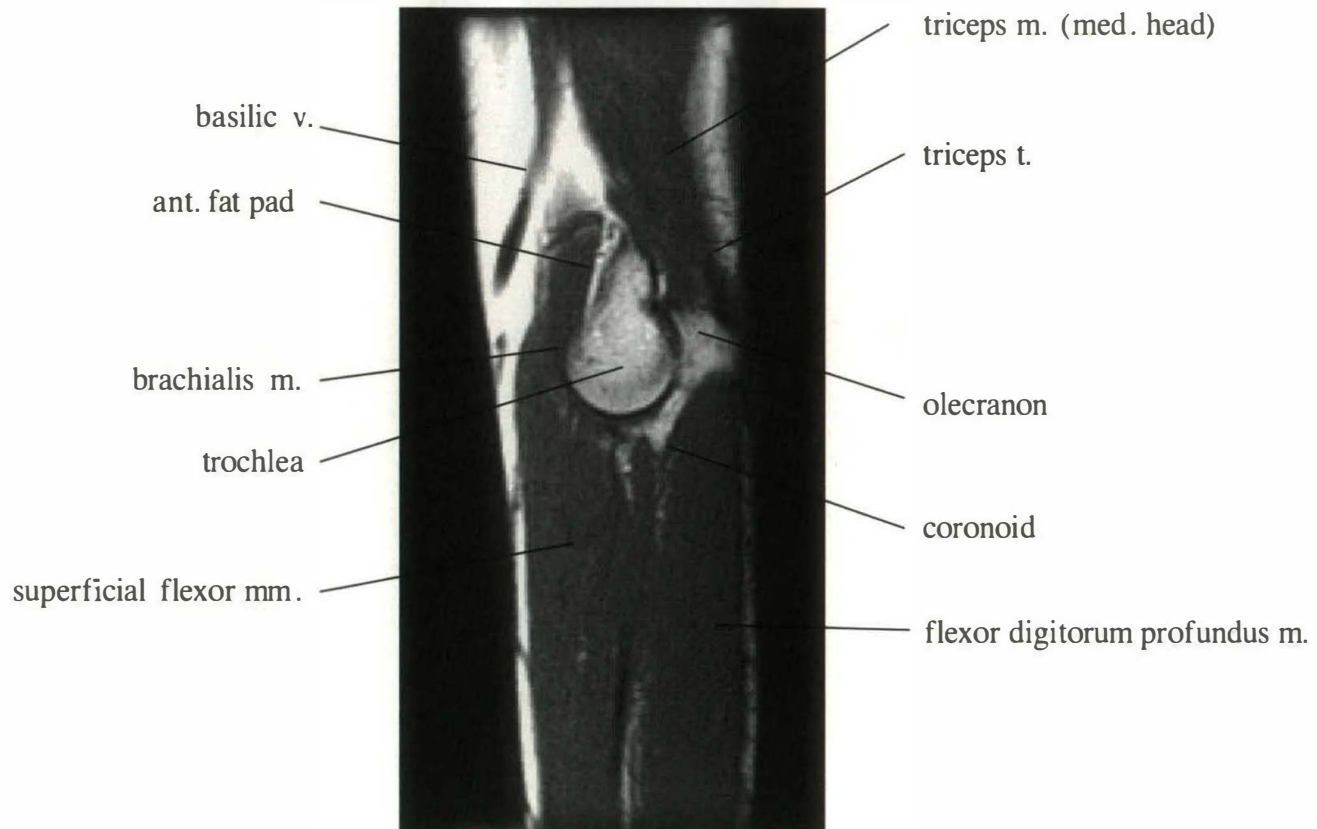
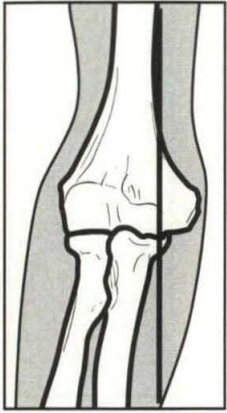




THE ELBOW: SAGITTAL ANATOMY







basilic v.

ant. fat pad

brachialis m.

trochlea

superficial flexor mm.

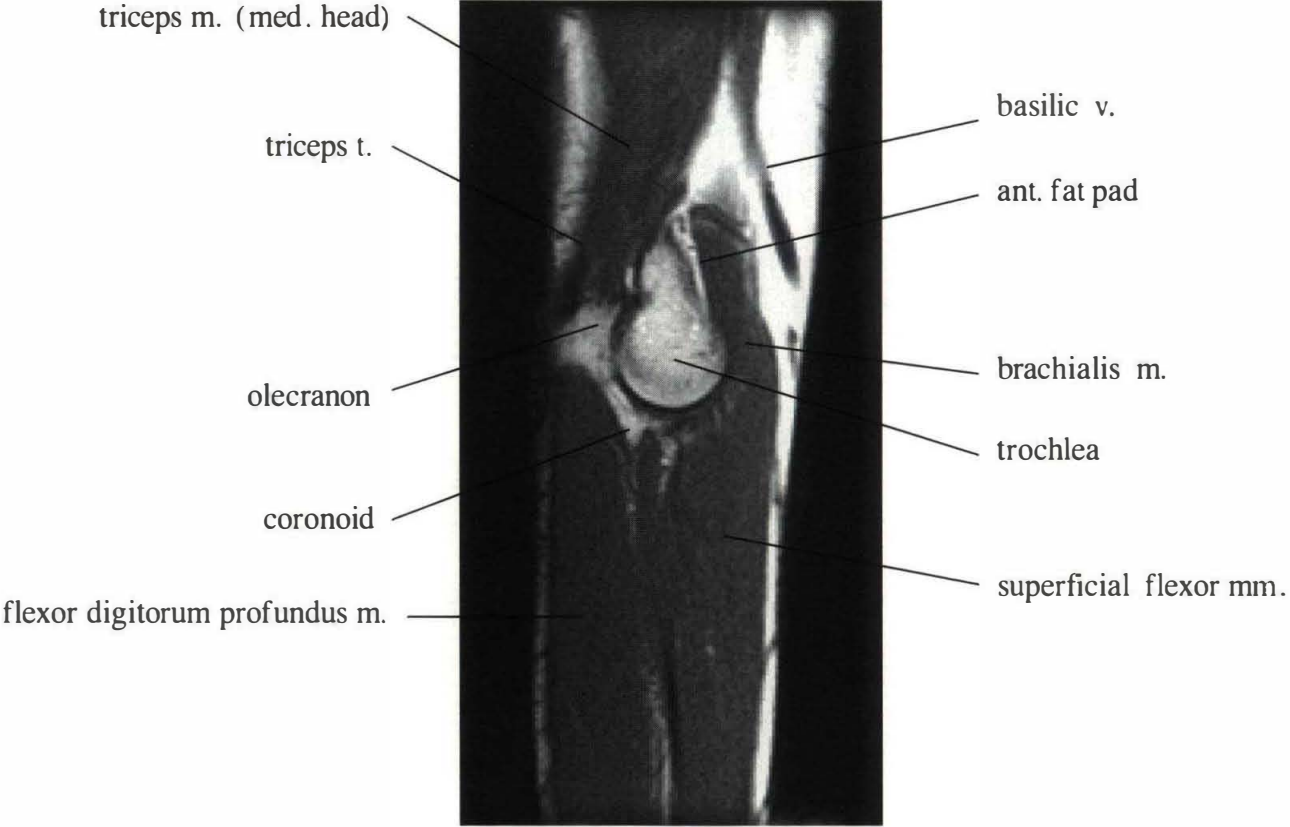
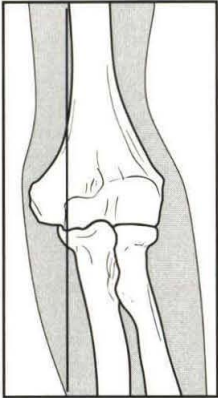
triceps m. (med. head)

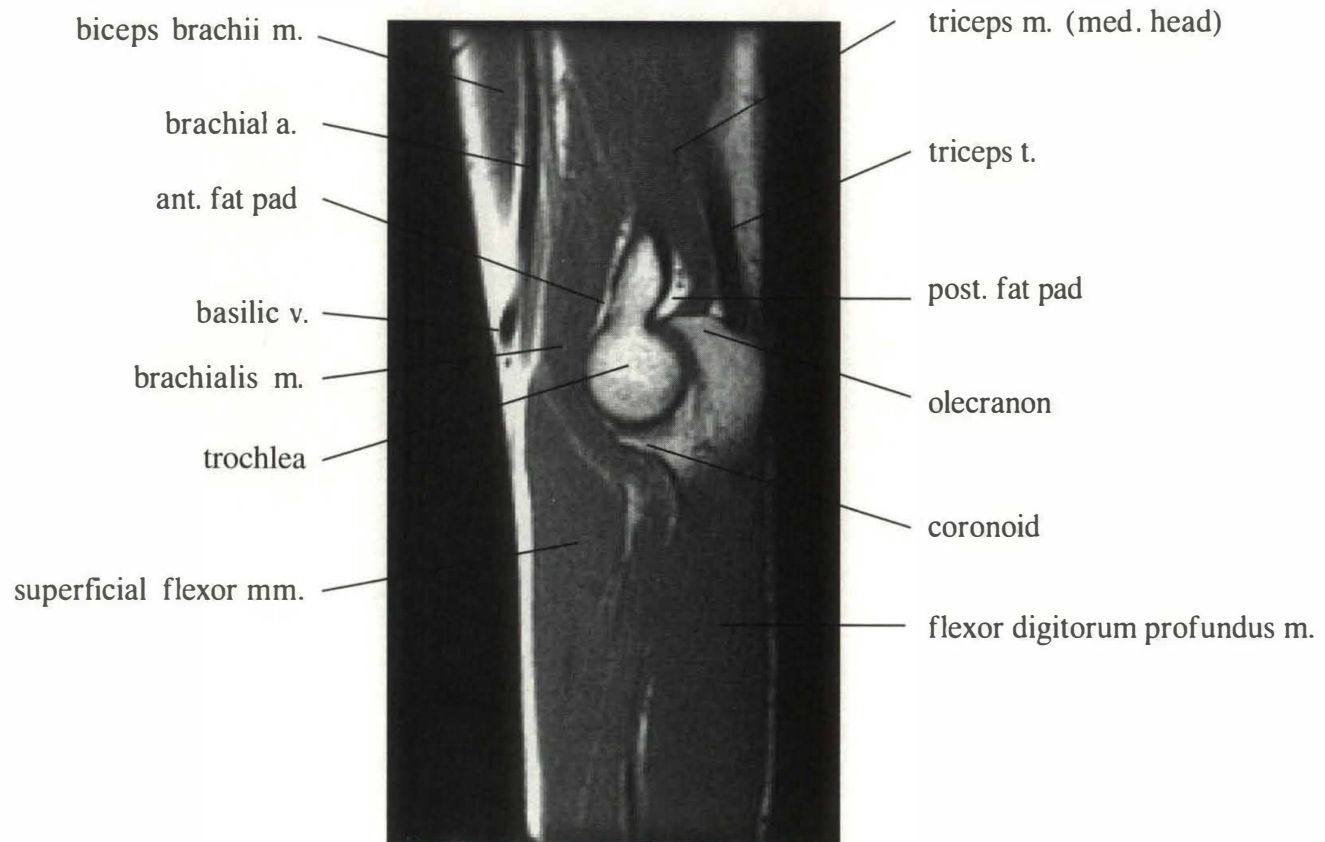
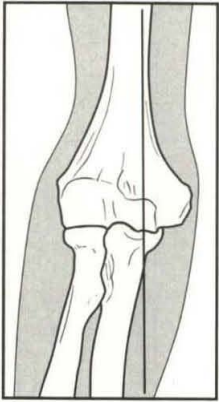
triceps t.

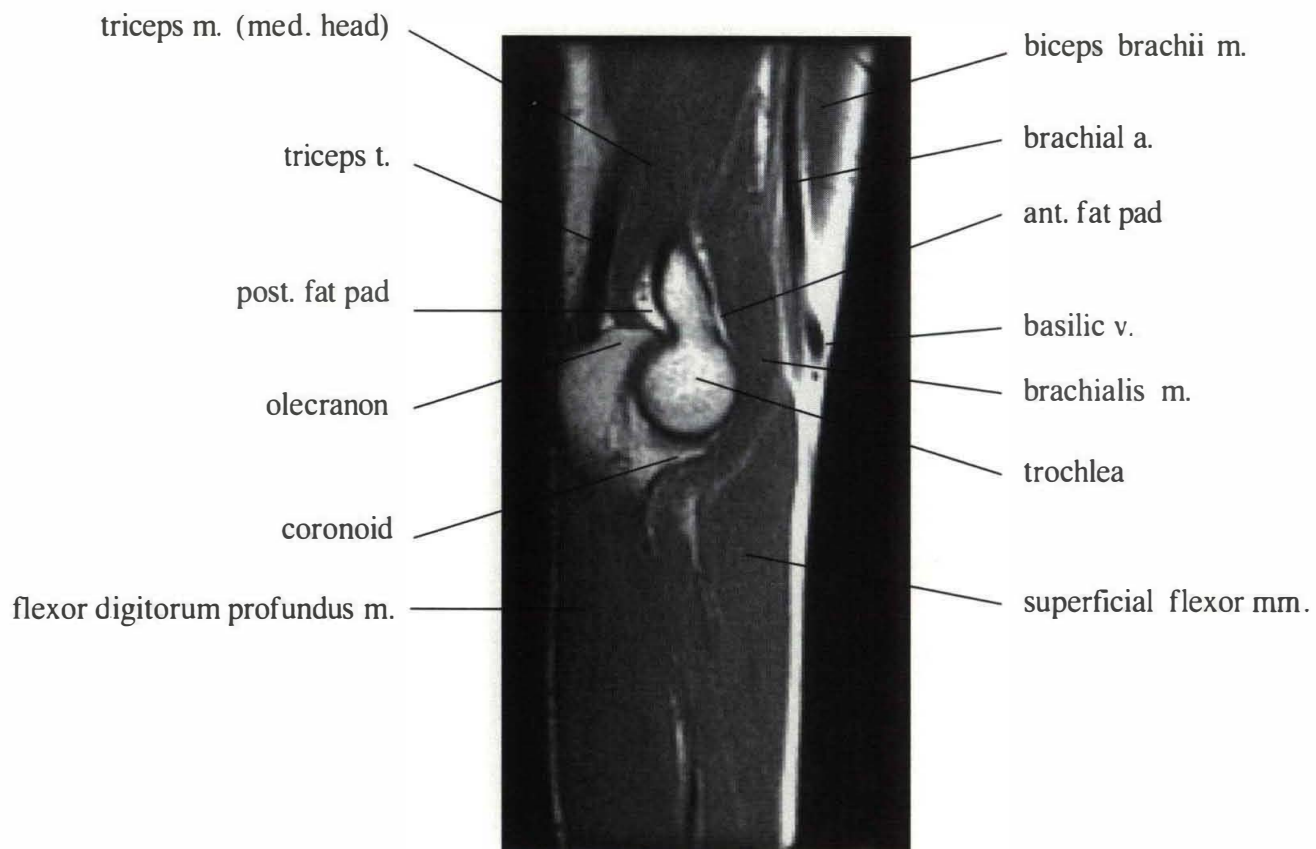
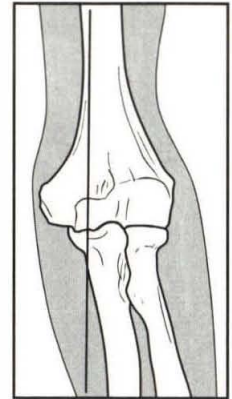
olecranon

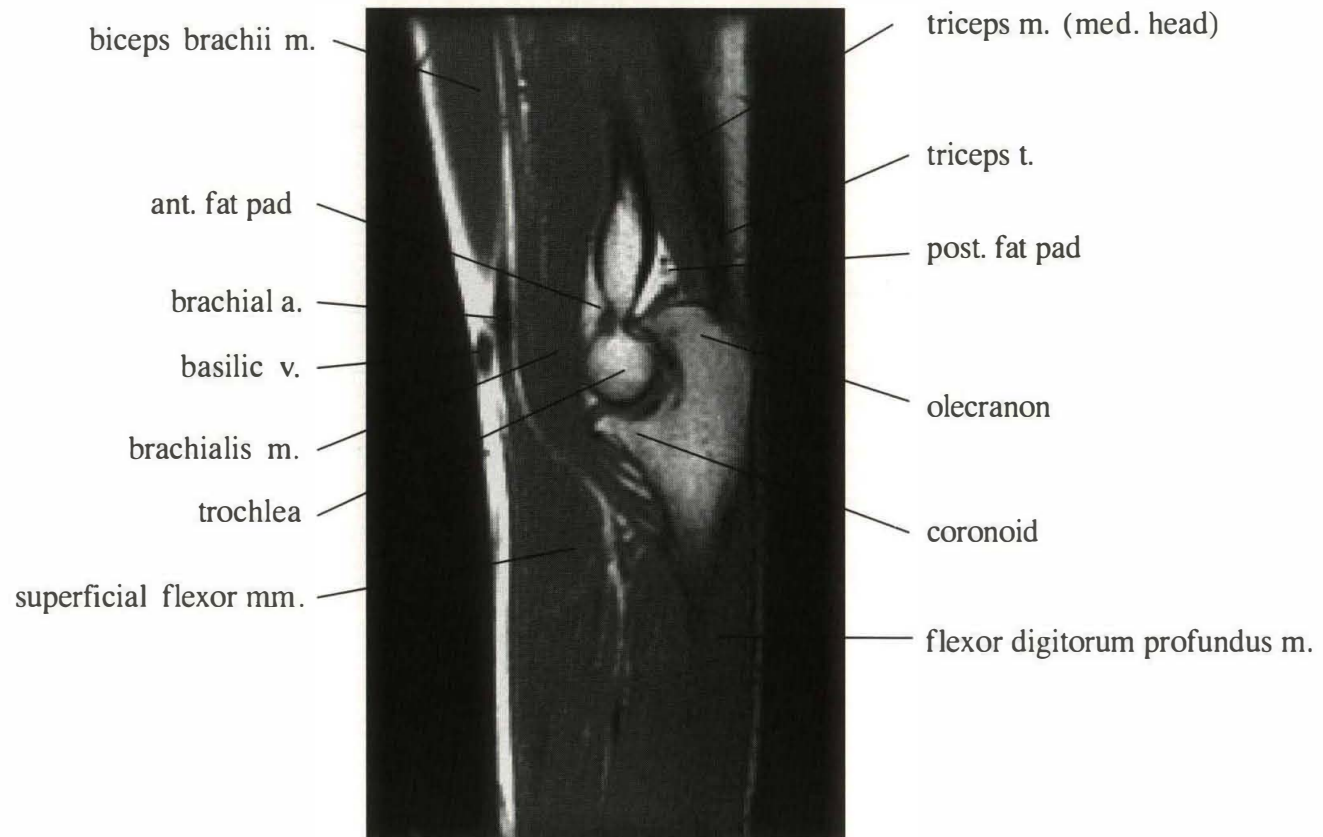
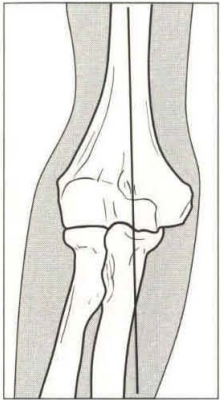
coronoid

flexor digitorum profundus m.









biceps brachii m.

ant. fat pad

brachial a.

basilic v.

brachialis m.

trochlea

superficial flexor mm.

triceps m. (med. head)

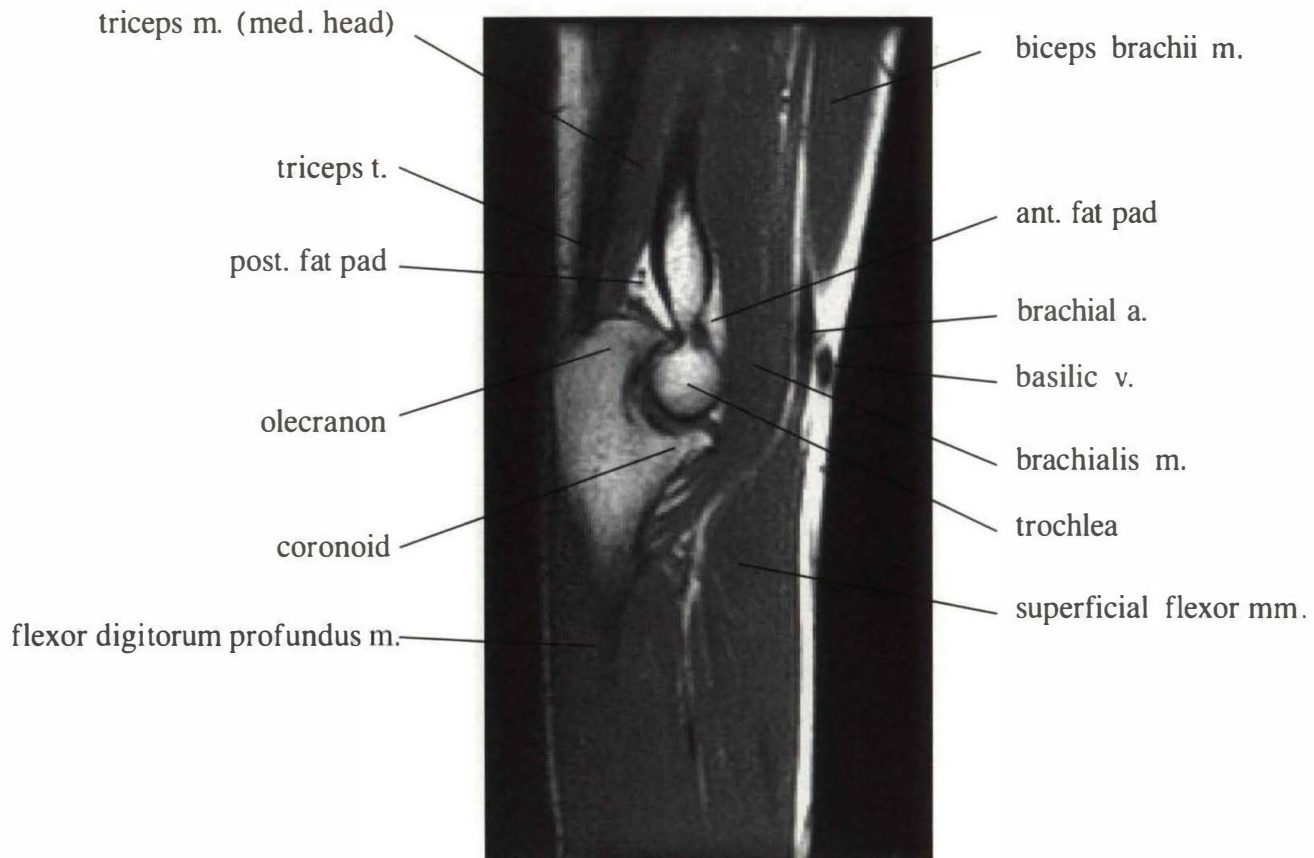
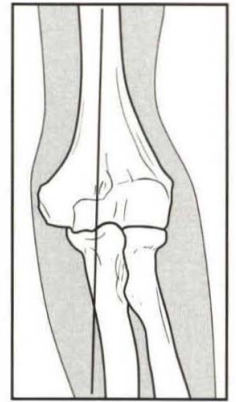
triceps t.

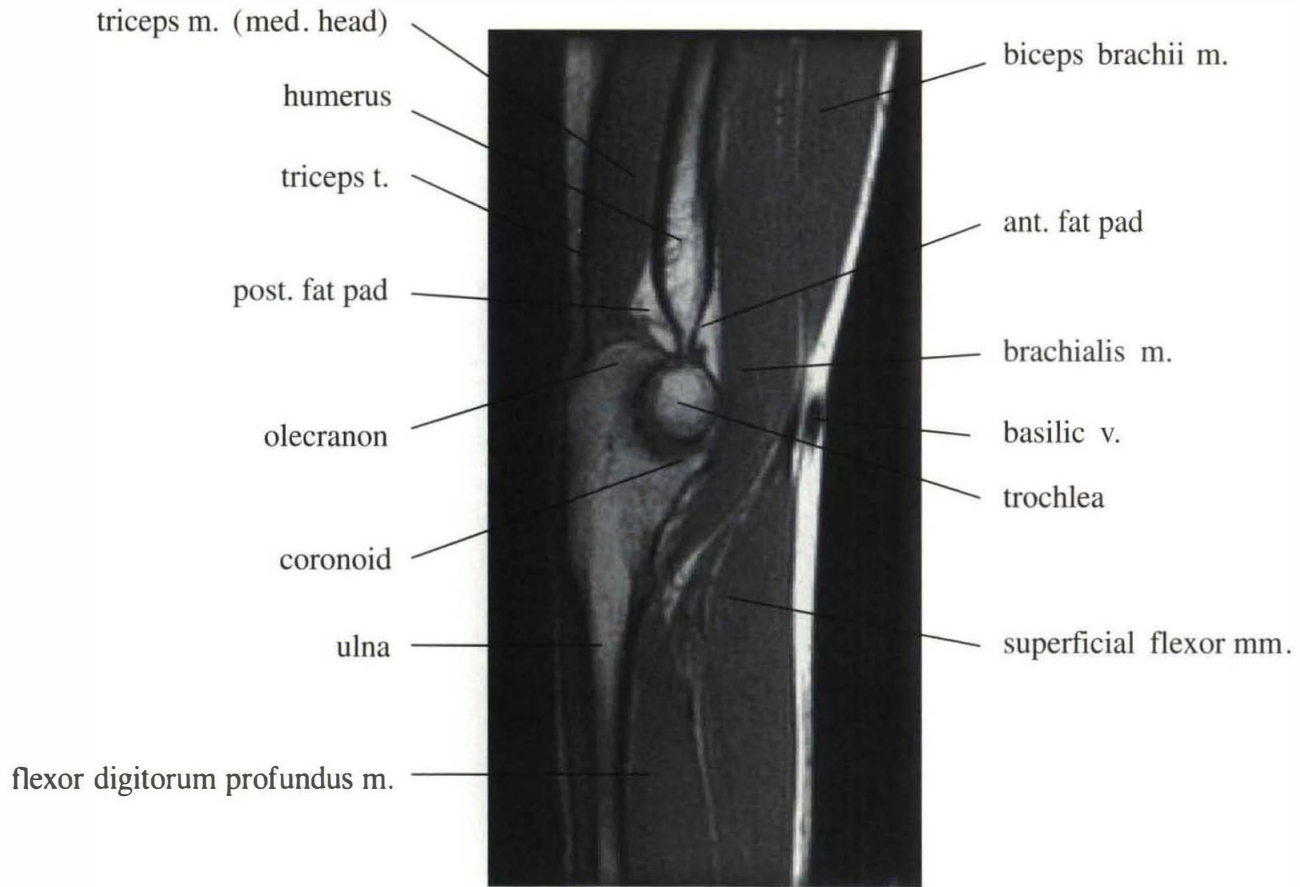
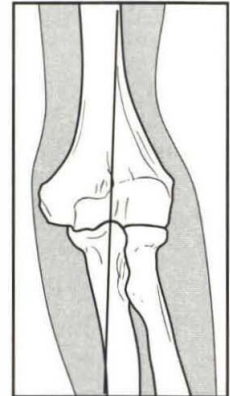
post. fat pad

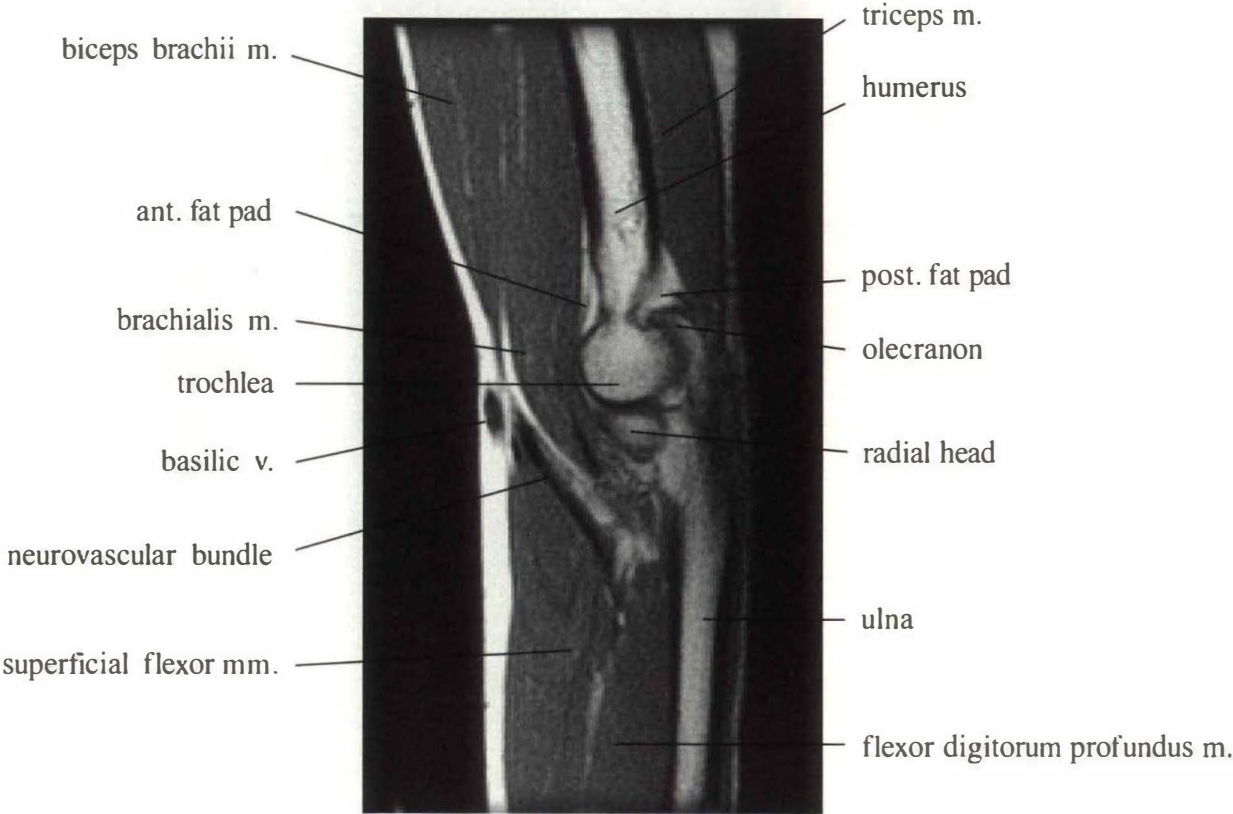
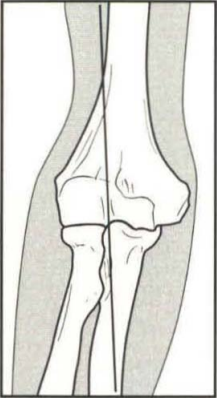
olecranon

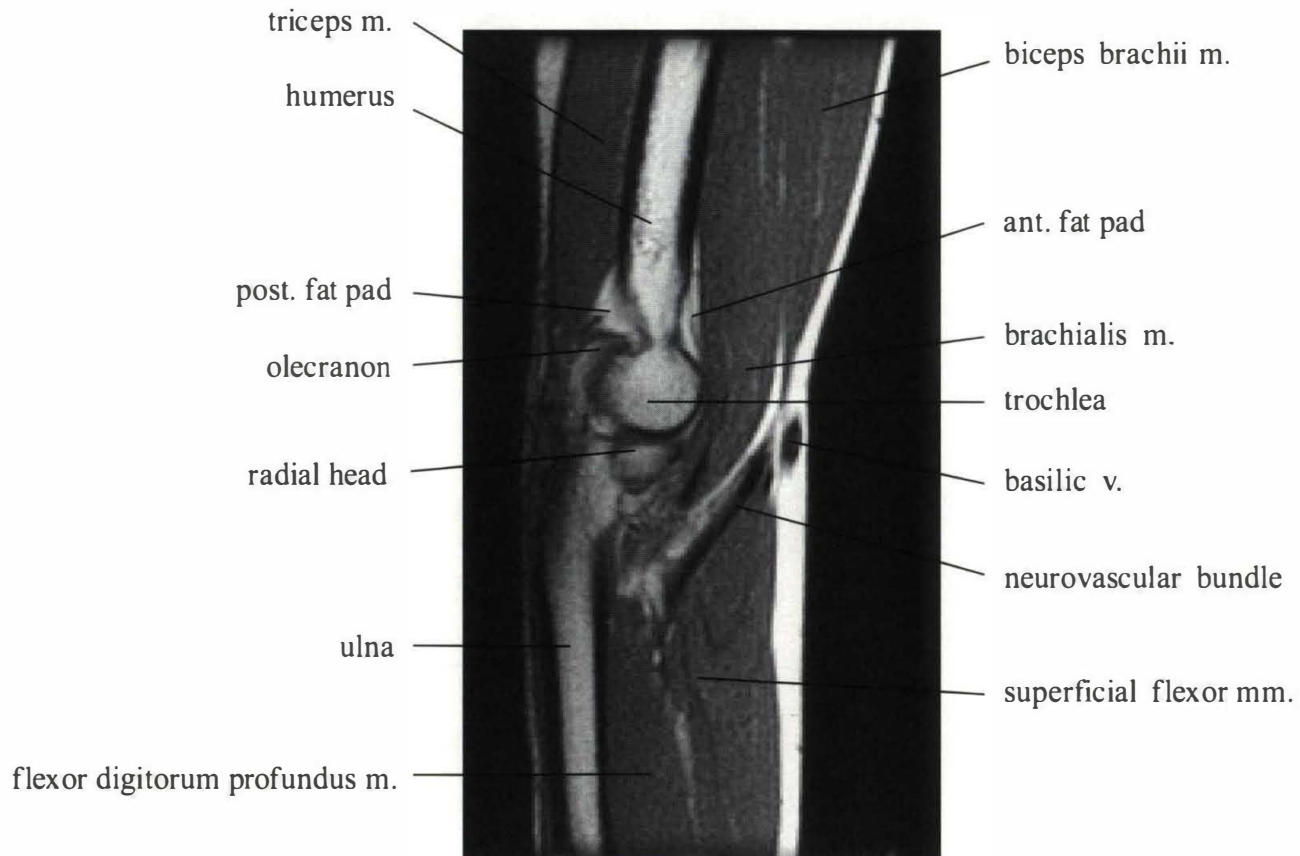
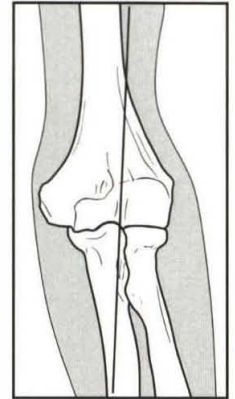
coronoid

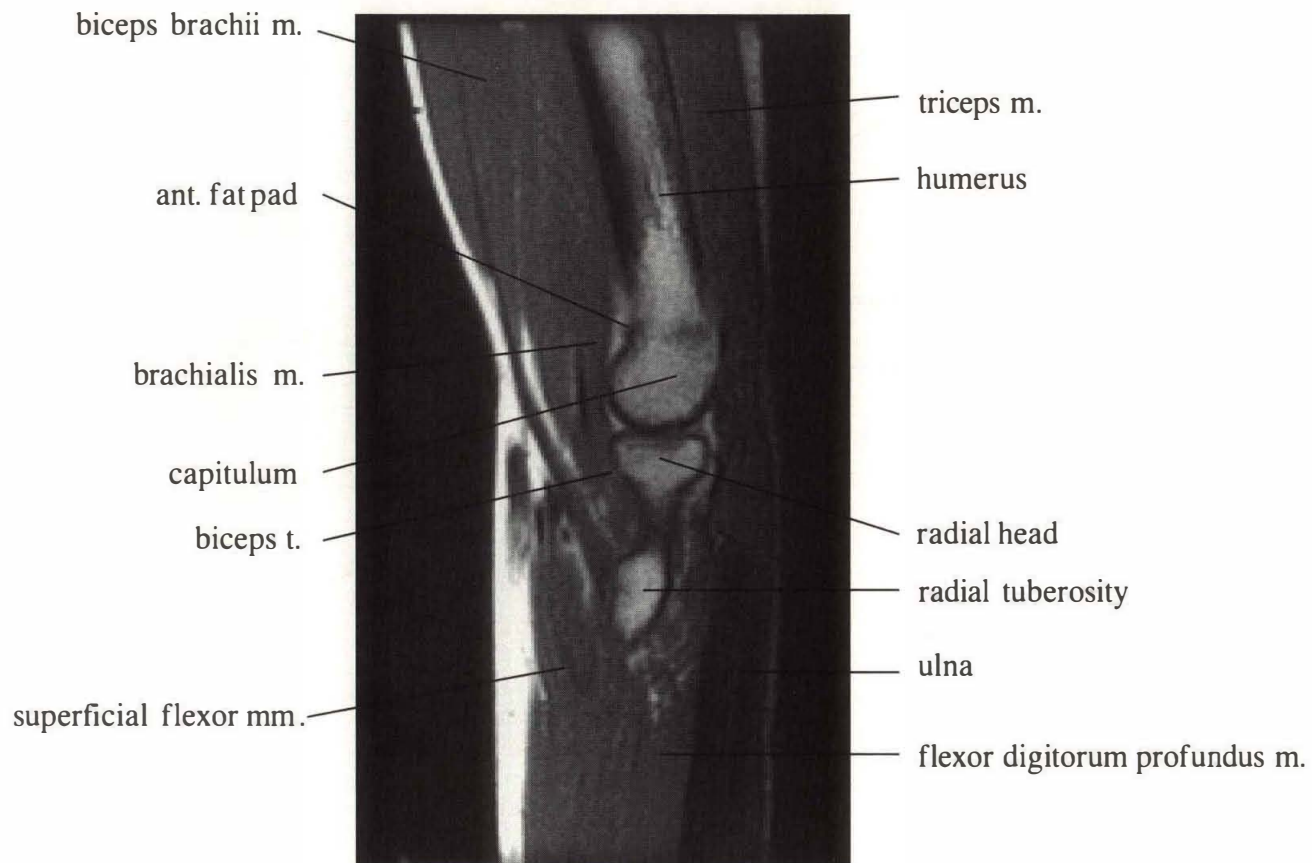
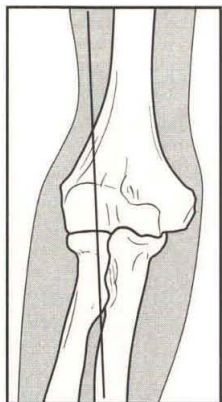
flexor digitorum profundus m.

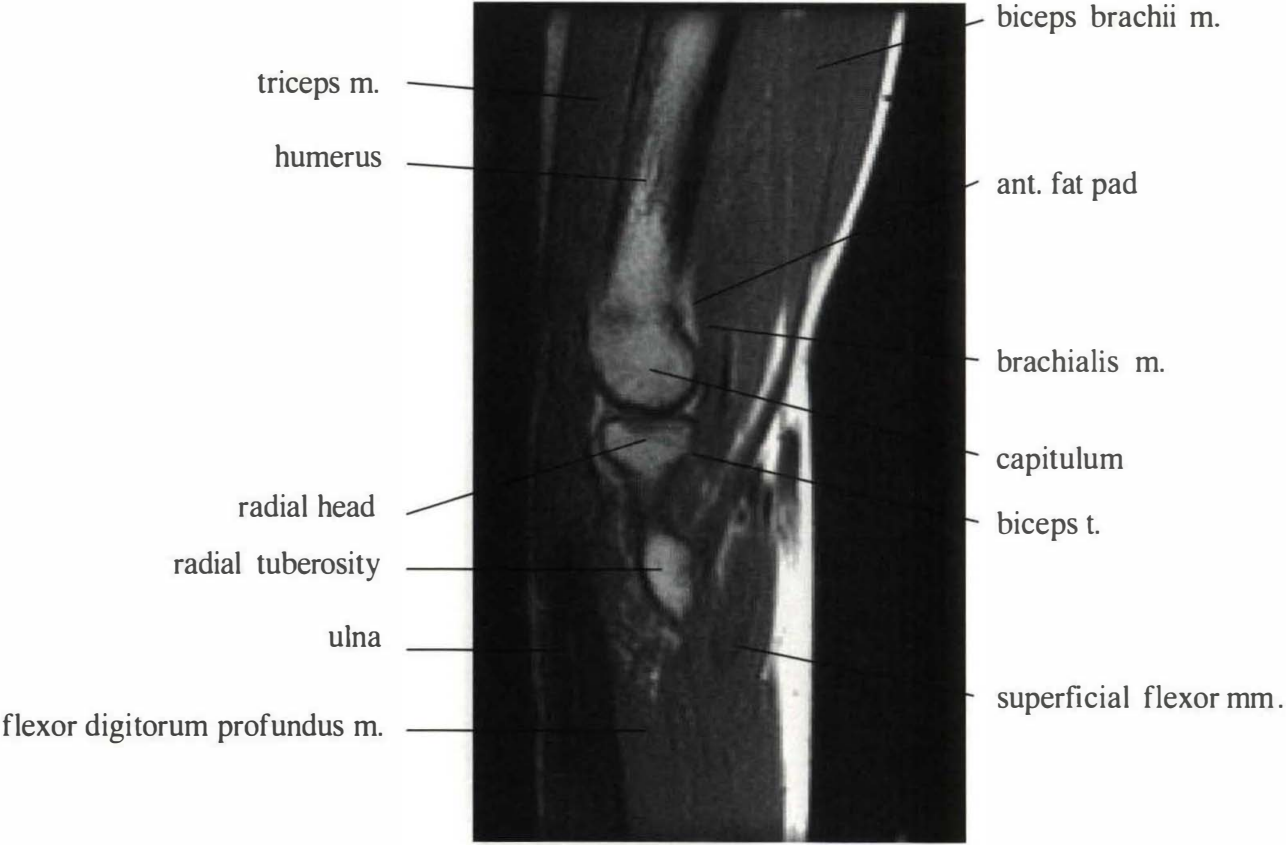
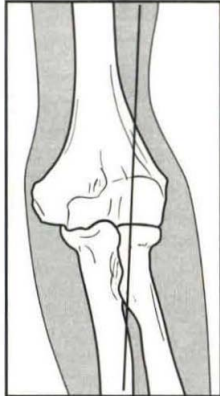


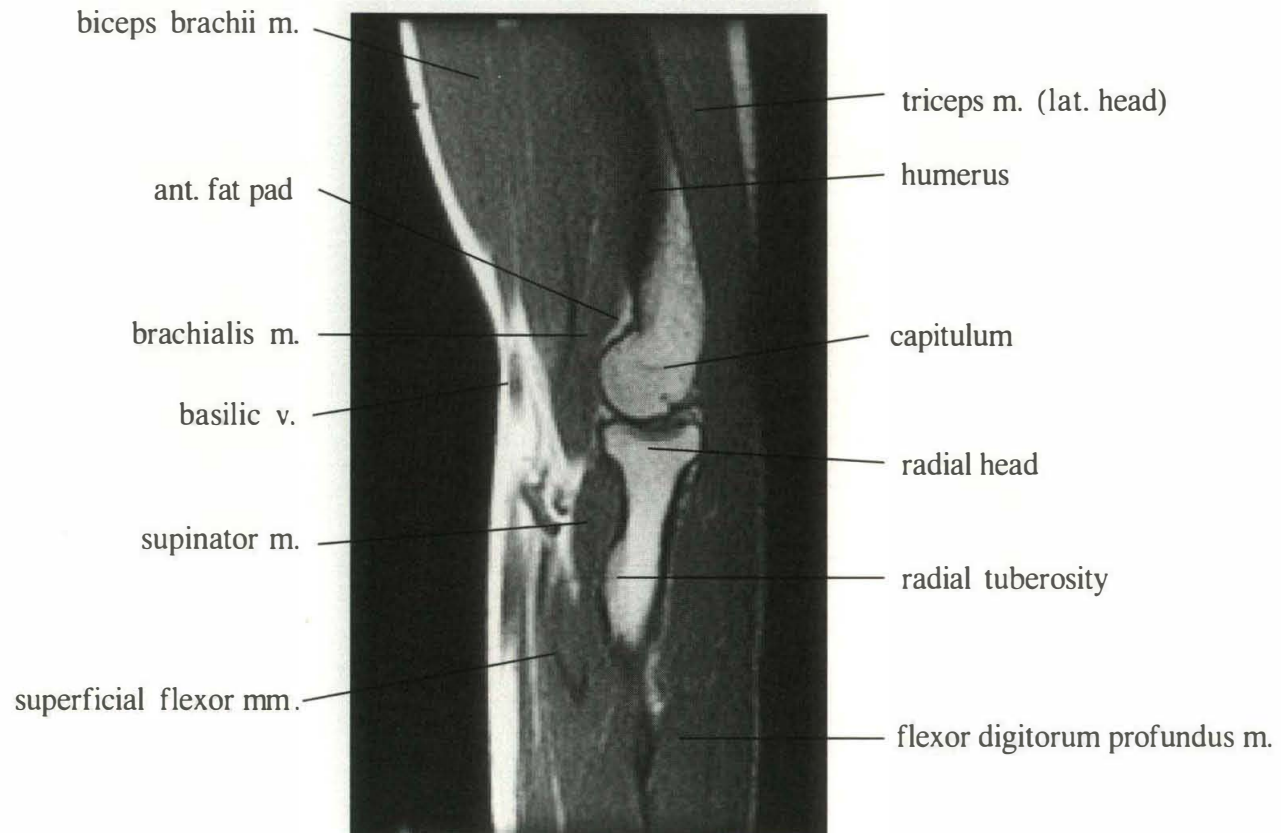
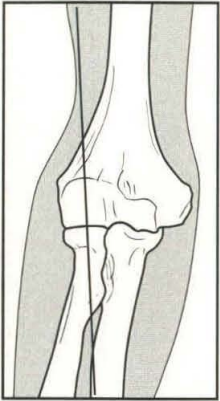


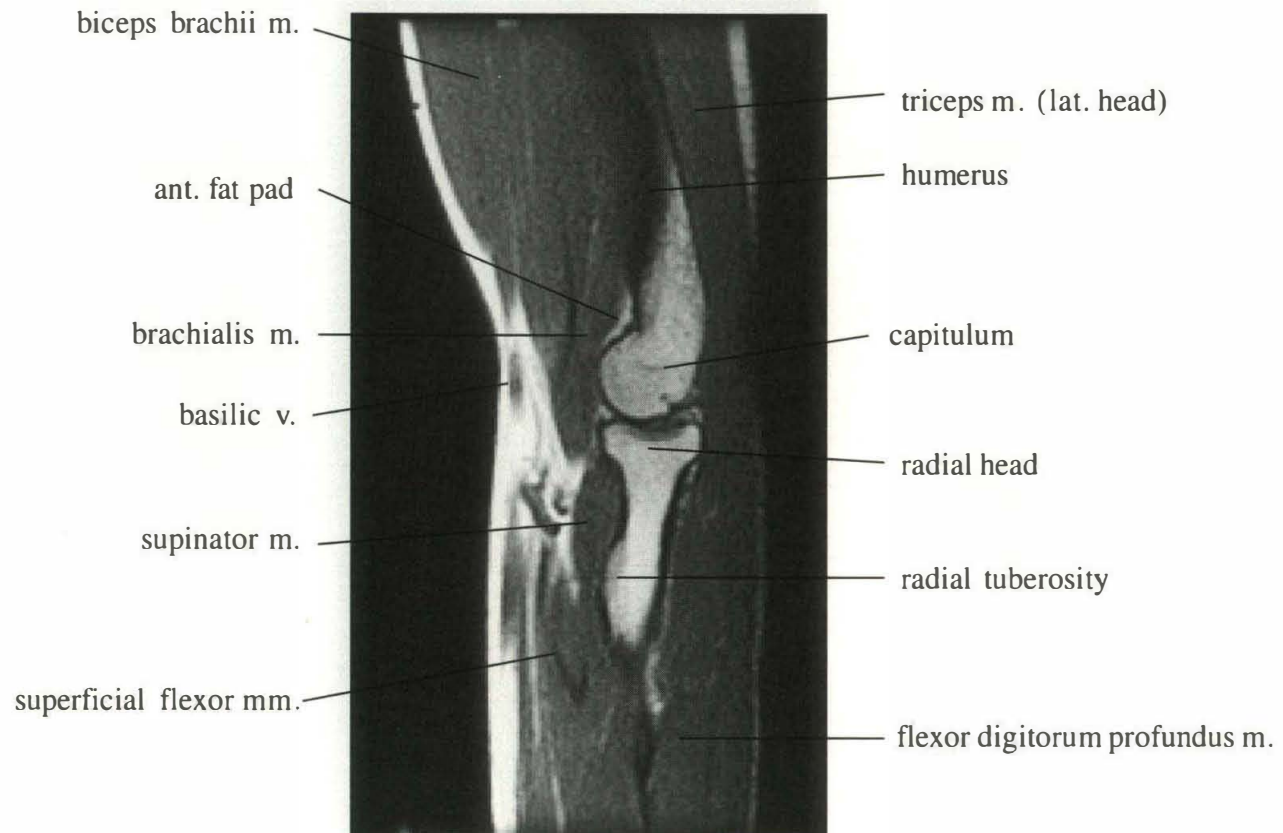
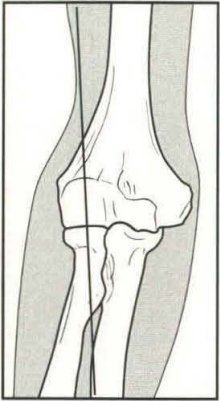


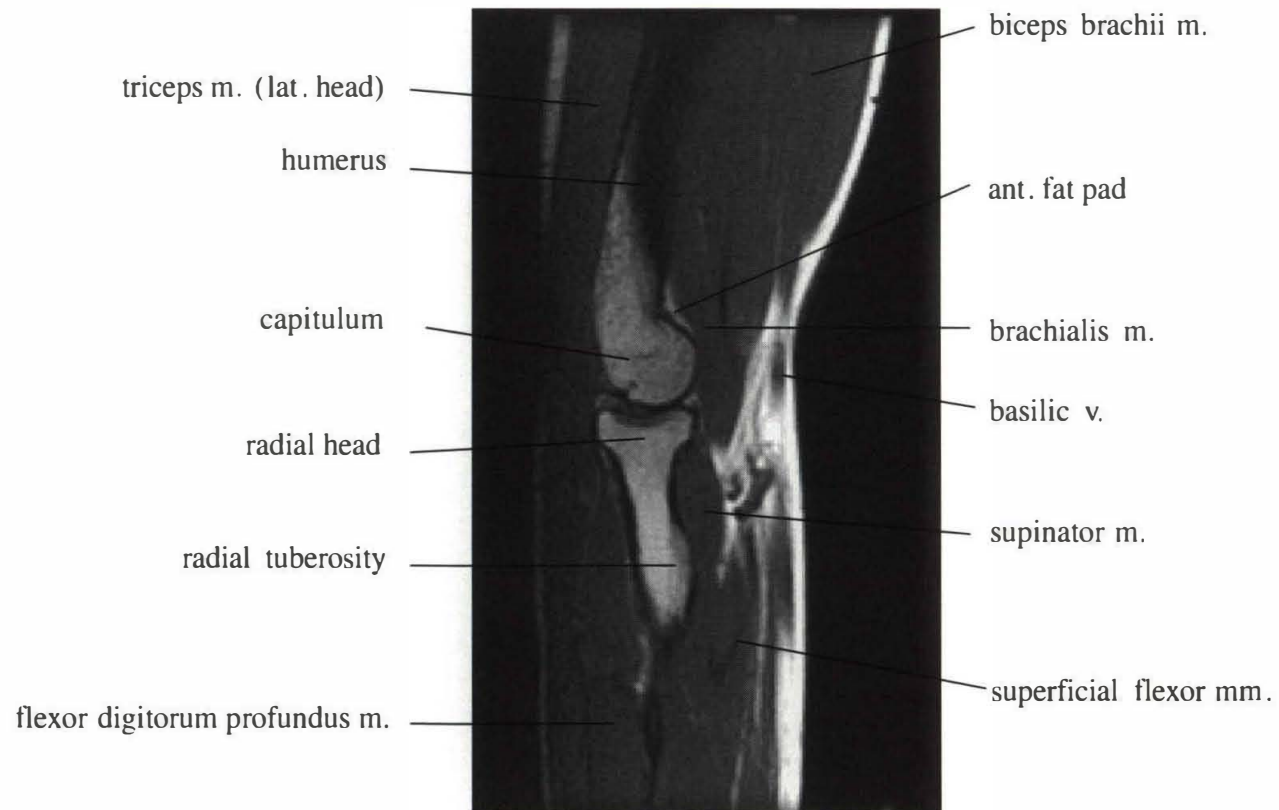
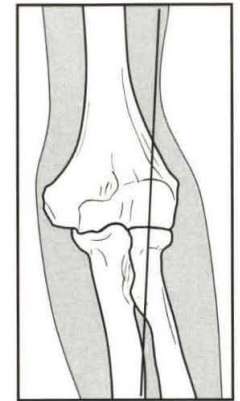


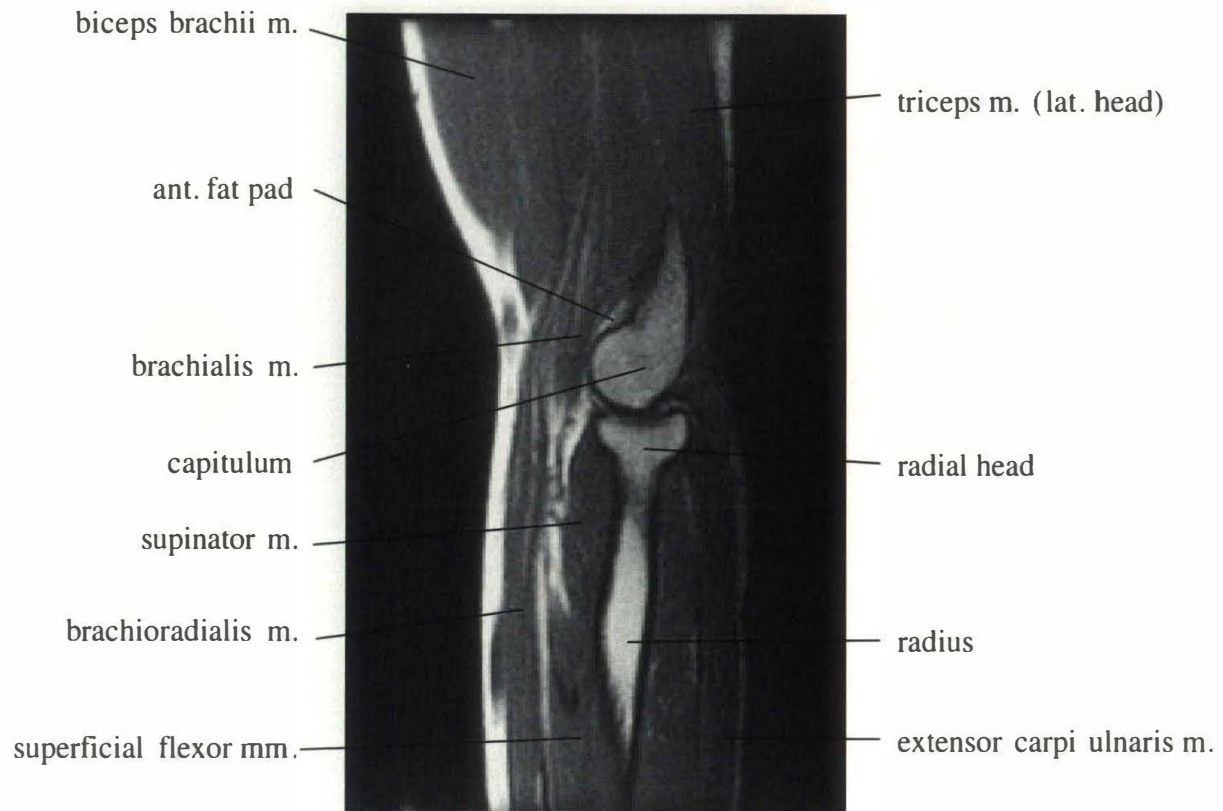
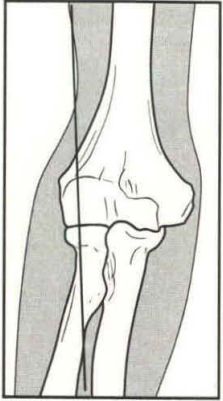


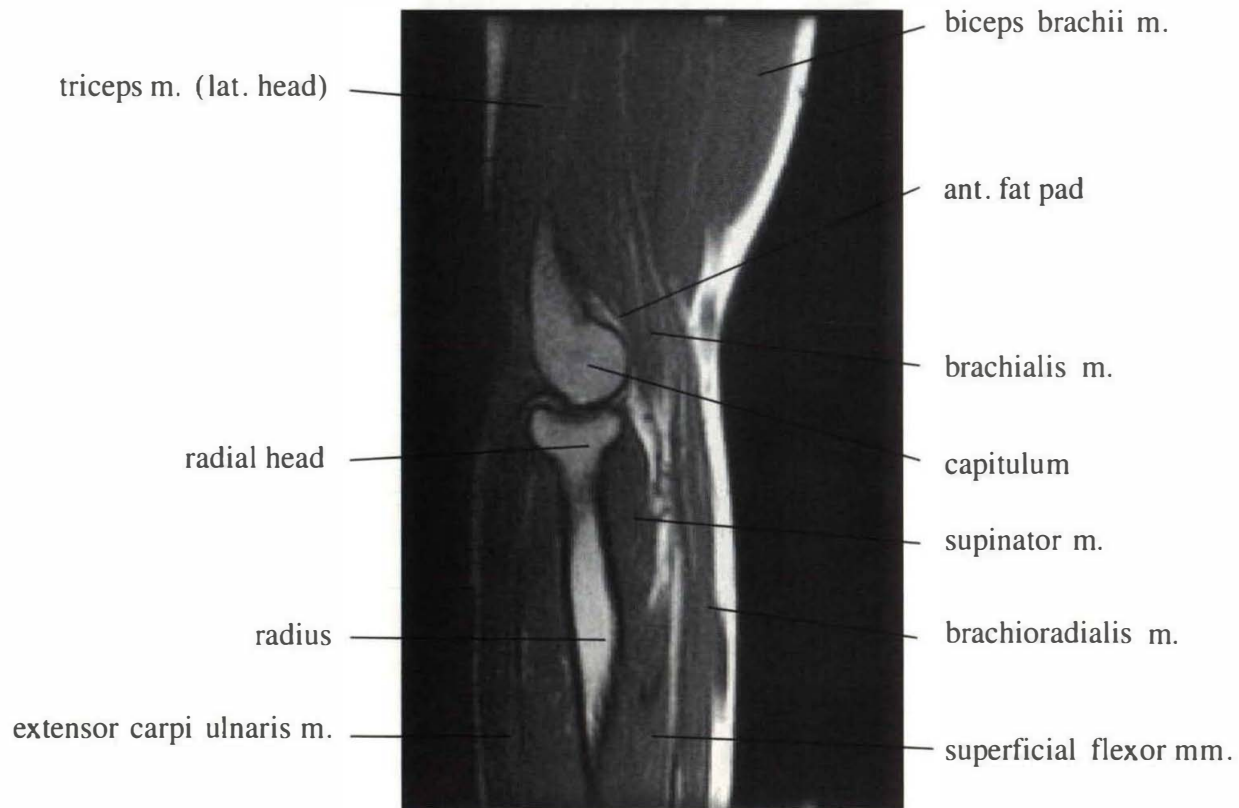
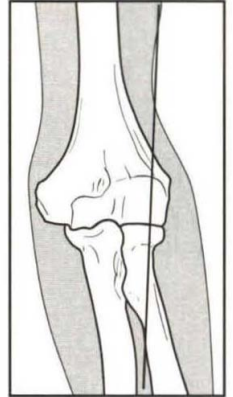


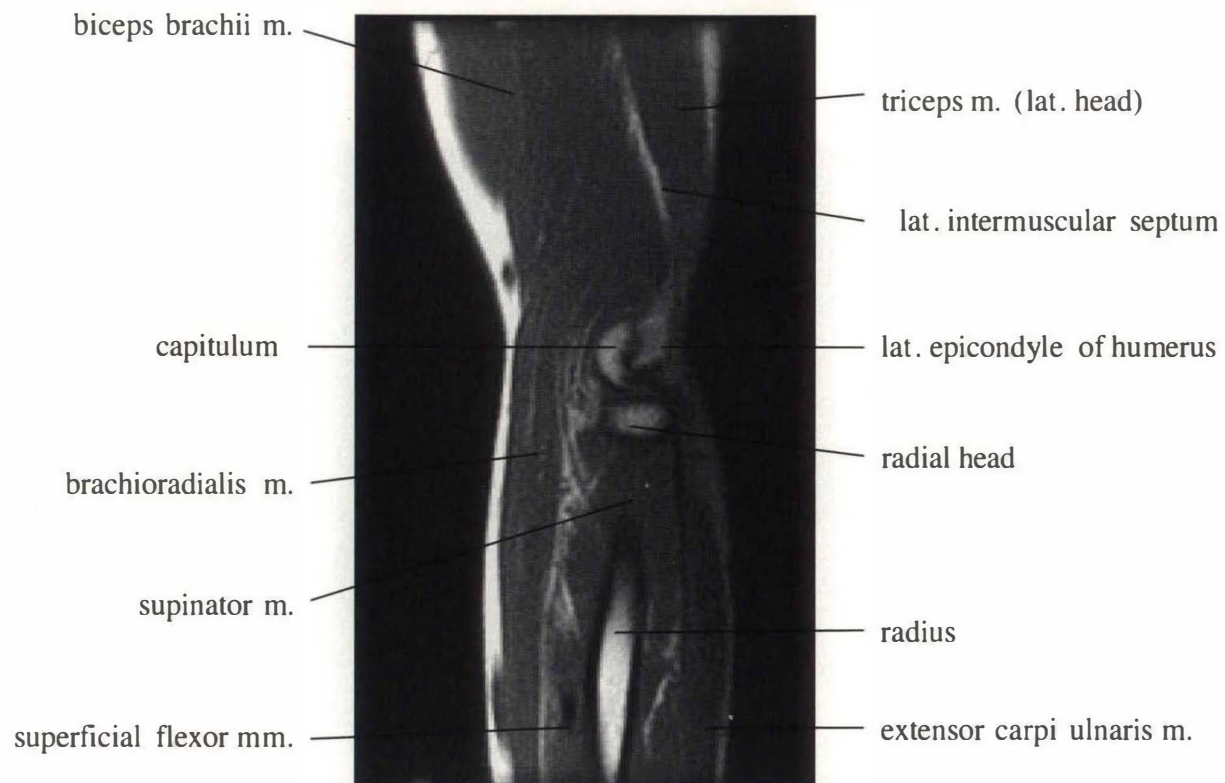
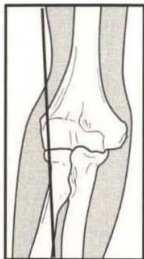


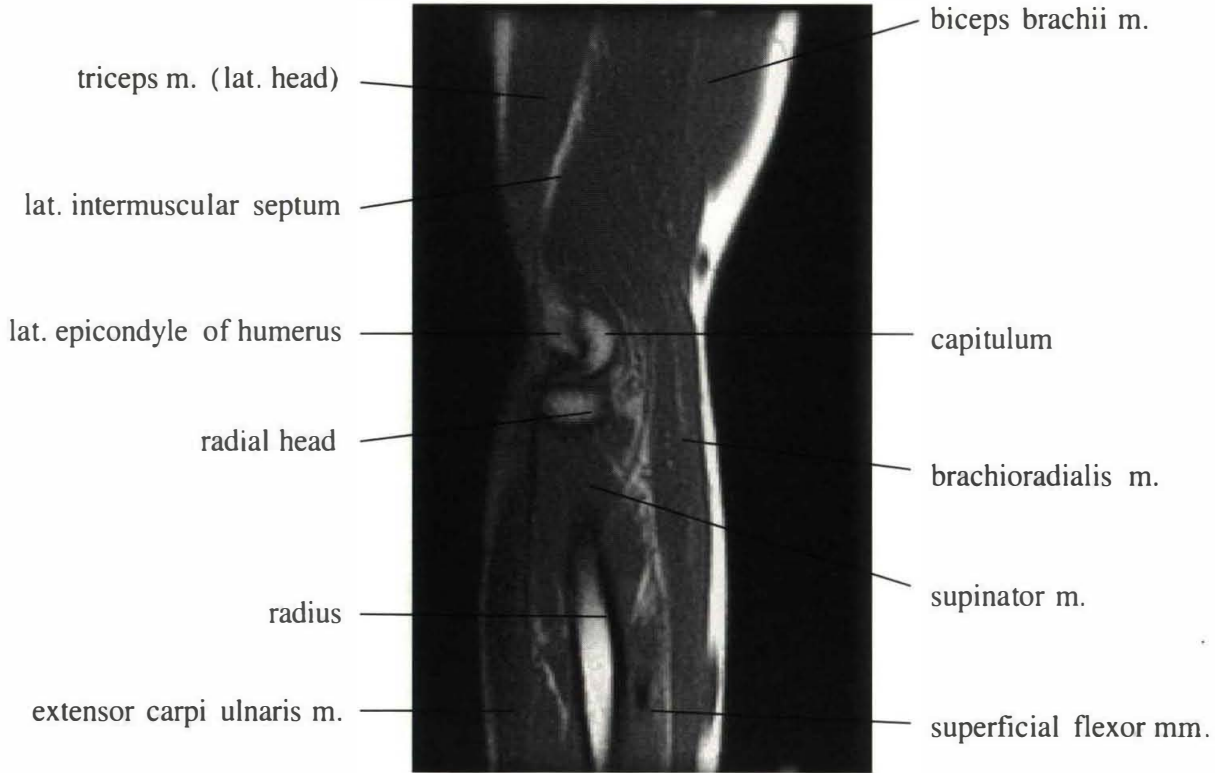
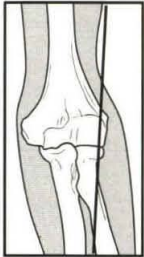




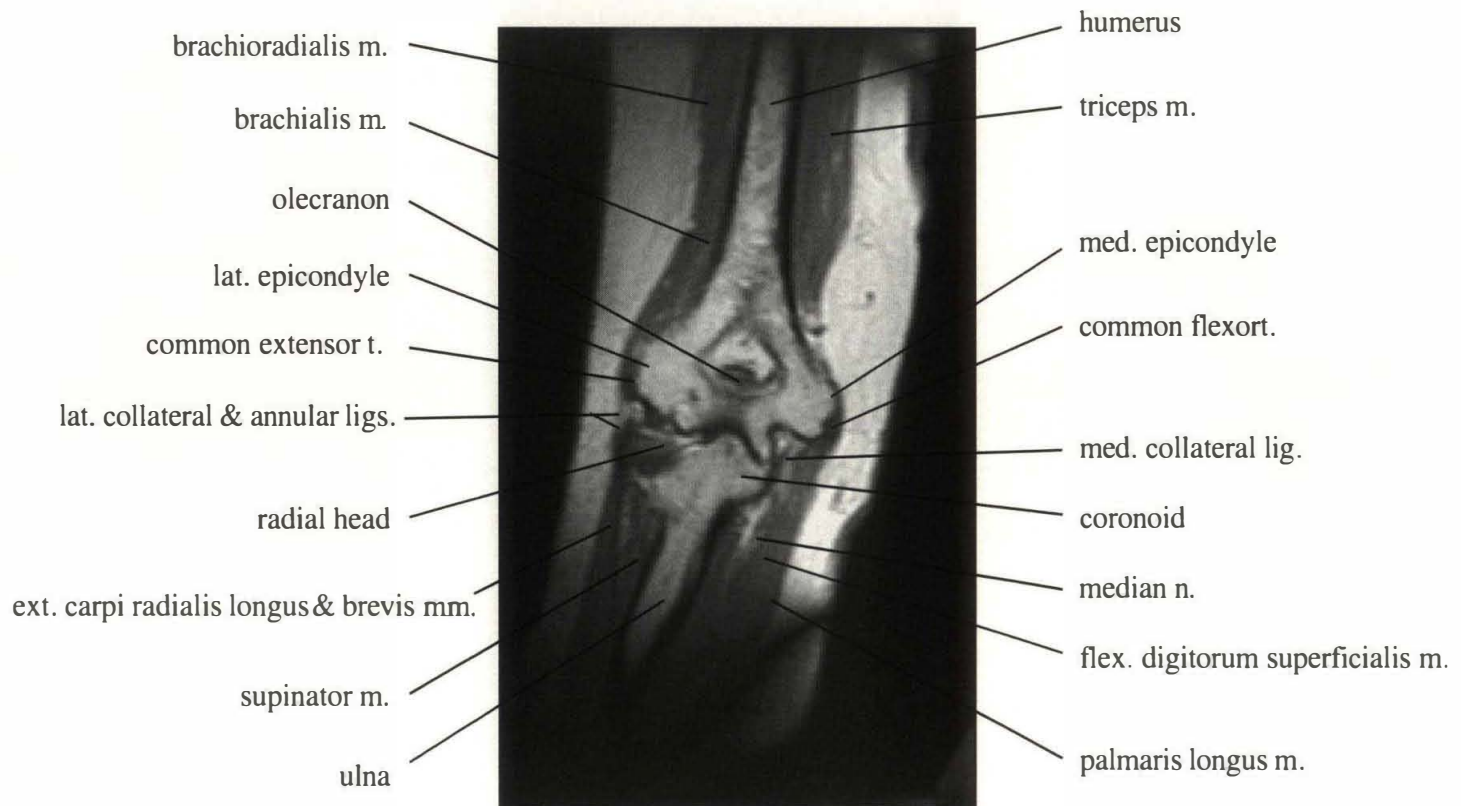


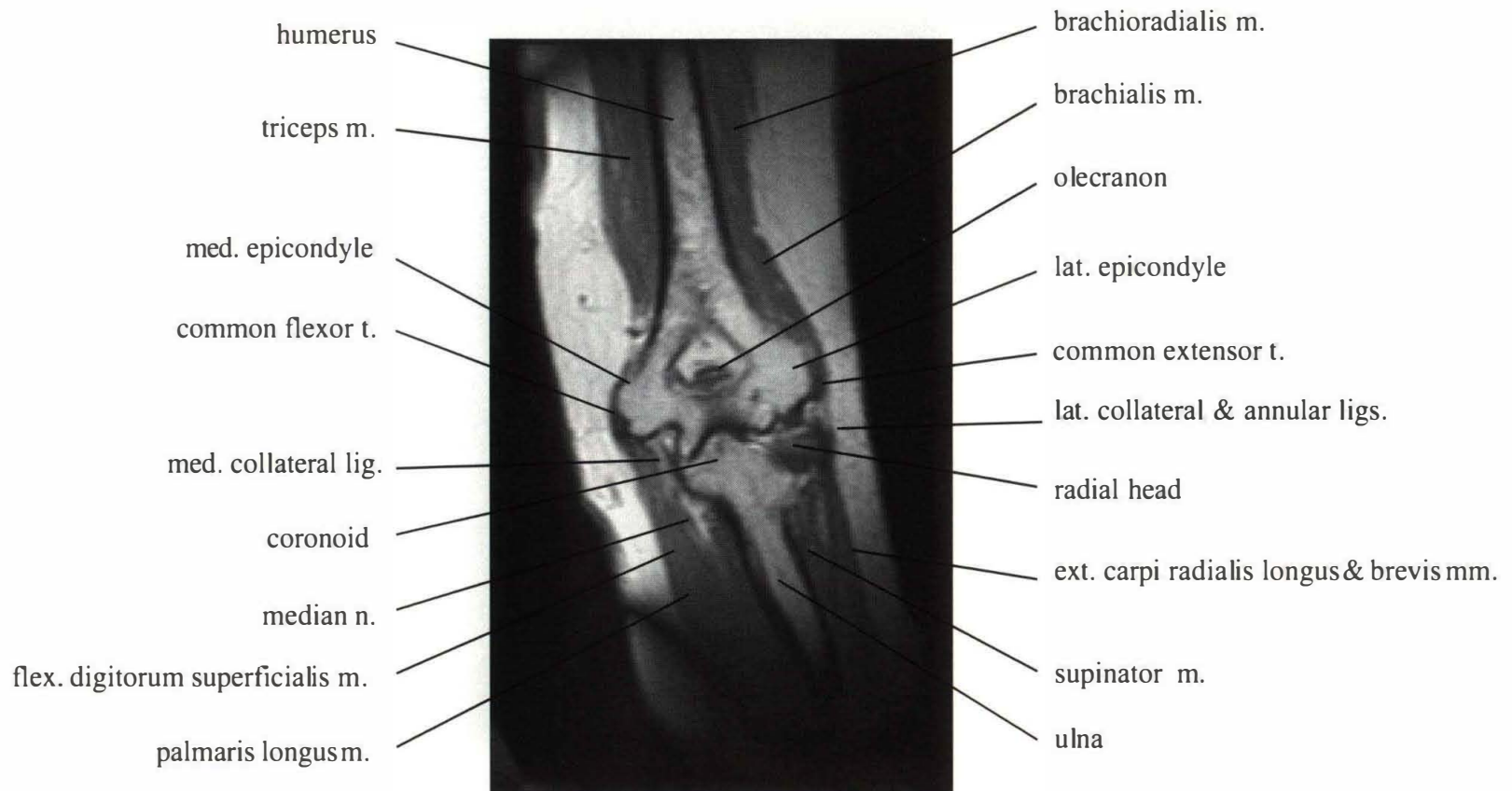
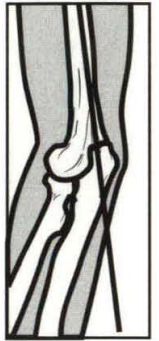


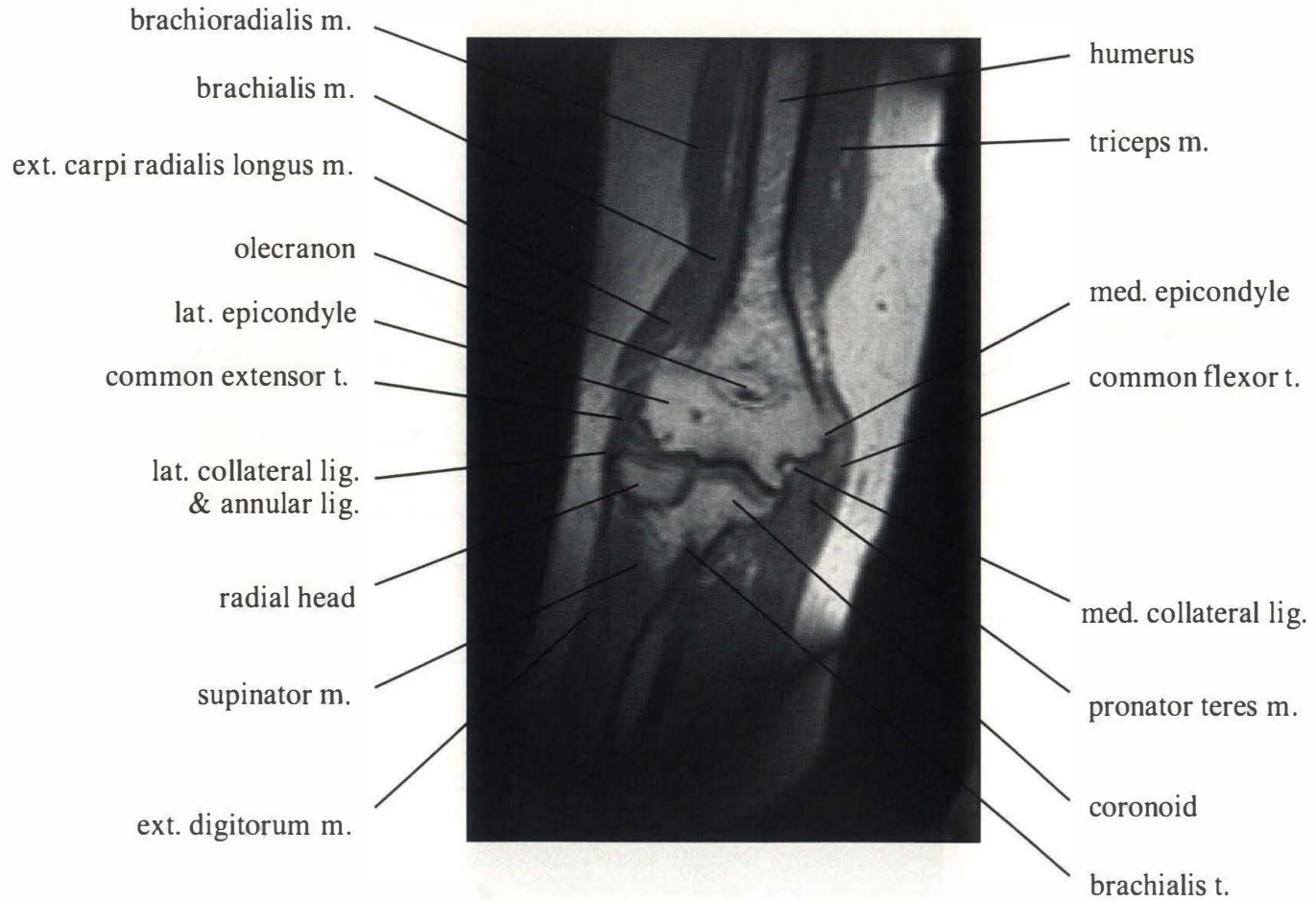


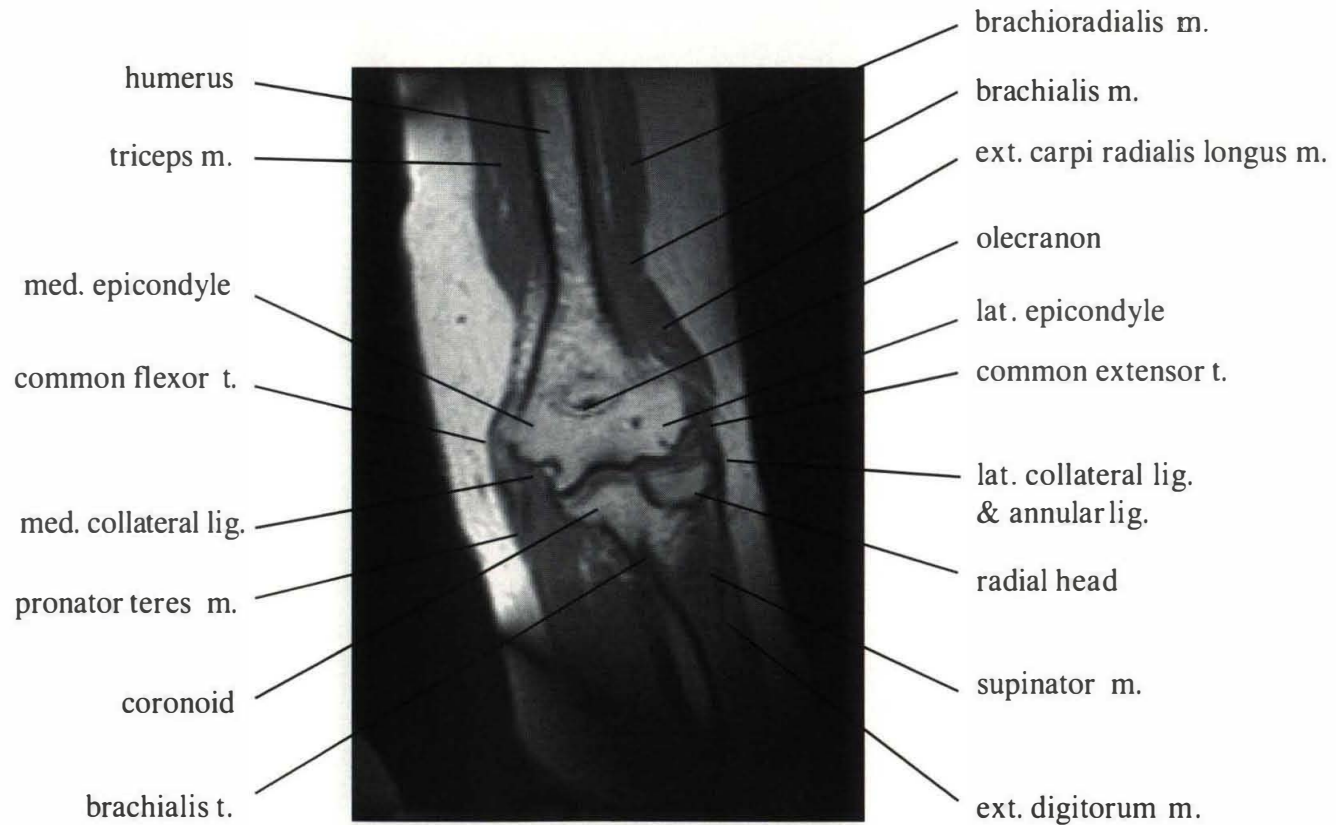
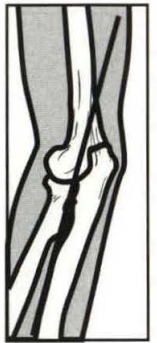


THE ELBOW: CORONAL ANATOMY









humerus

triceps m.

med. epicondyle

common flexor t.

med. collateral lig.

pronator teres m.

coronoid

brachialis t.

brachioradialis m.

brachialis m.

ext. carpi radialis longus m.

olecranon

lat. epicondyle

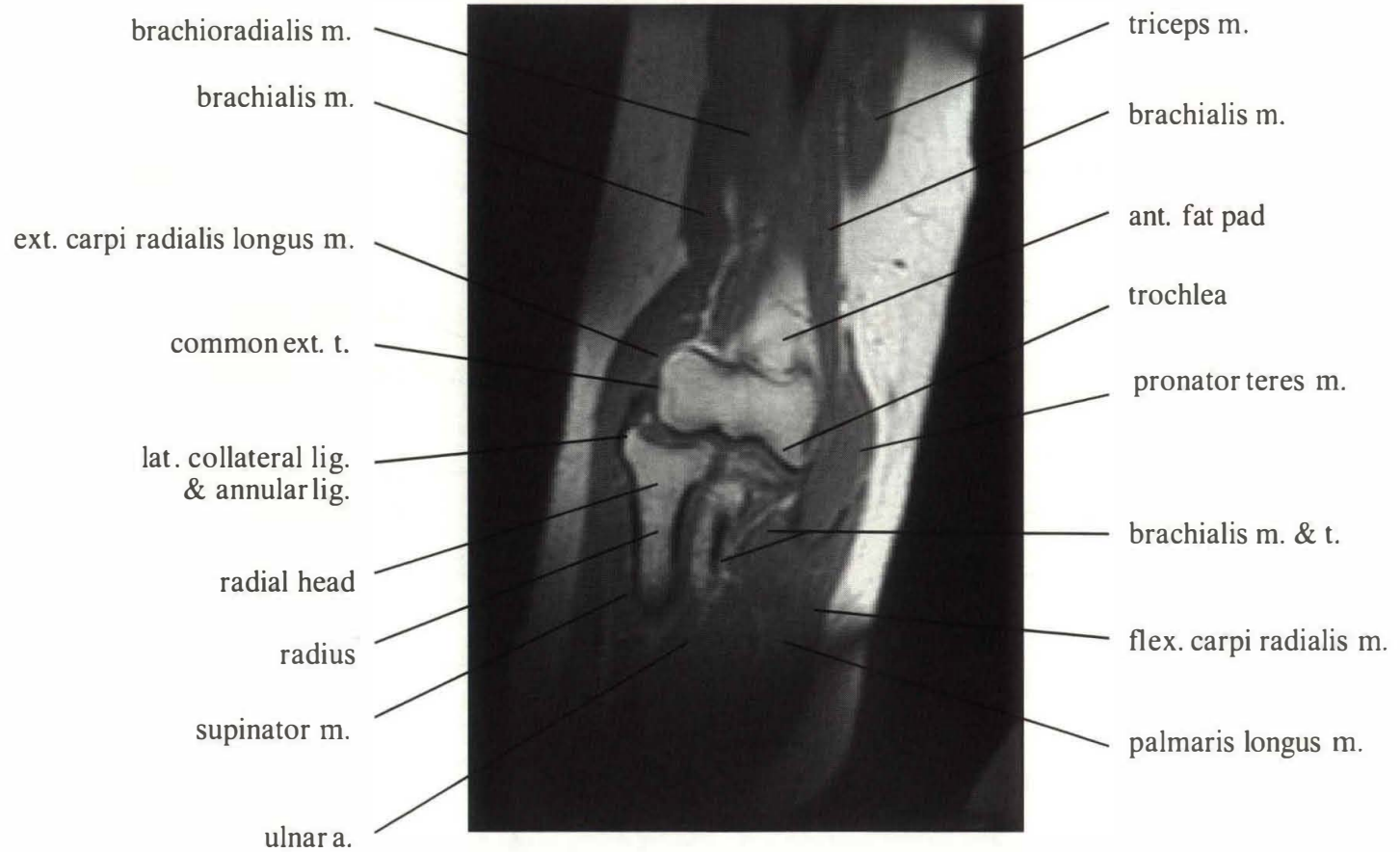
common extensor t.

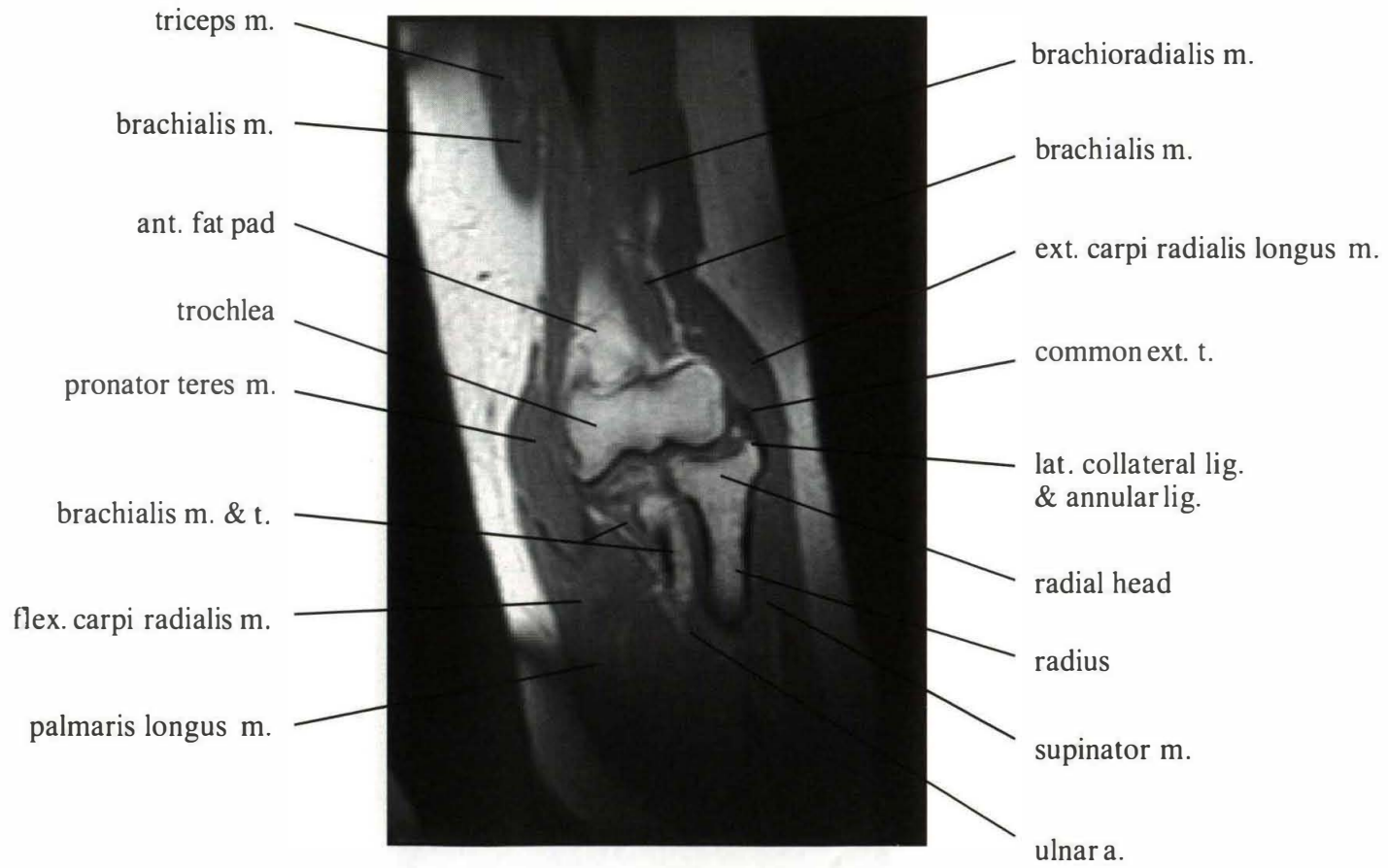
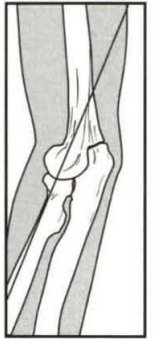
lat. collateral lig.
& annular lig.

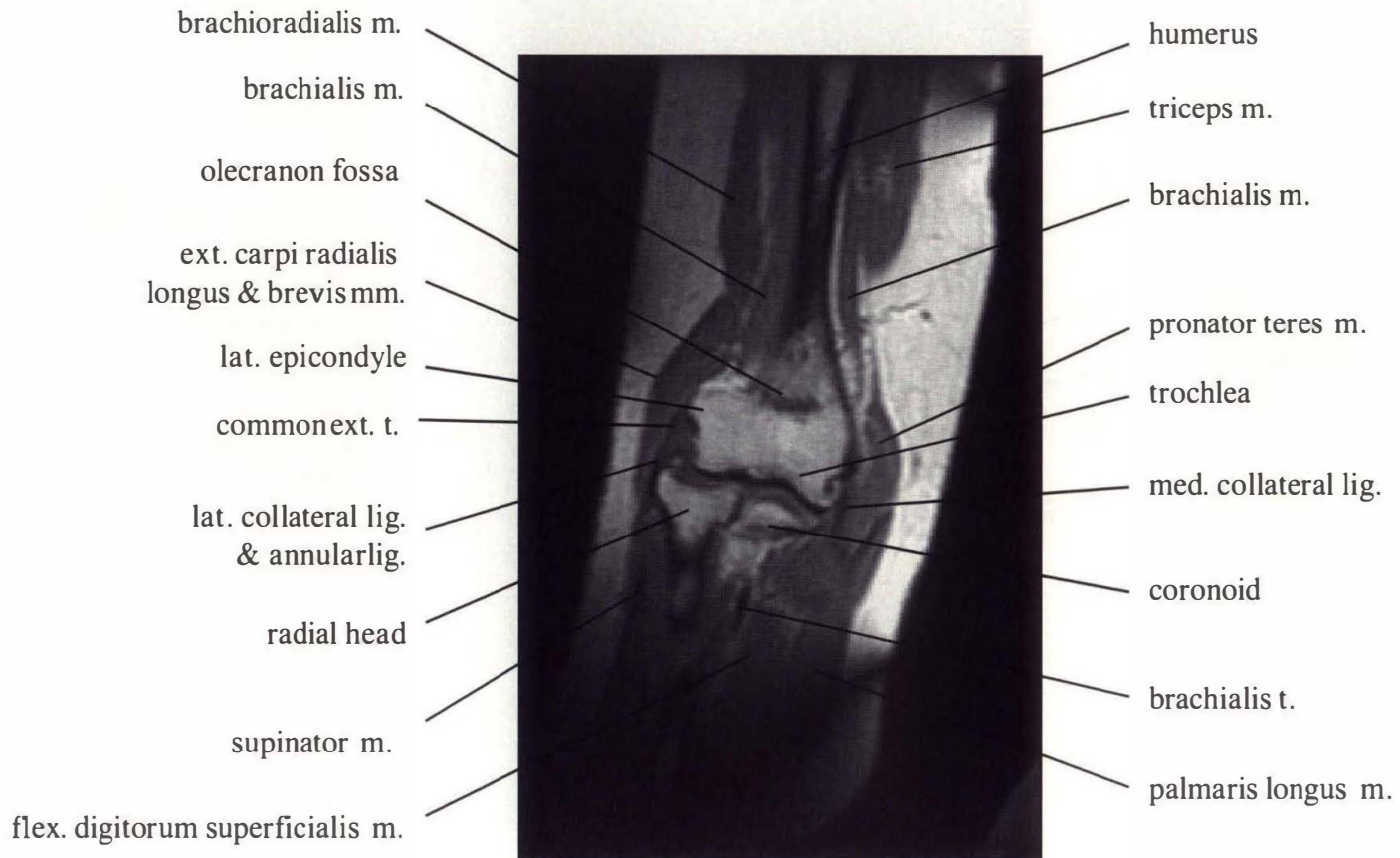
radial head

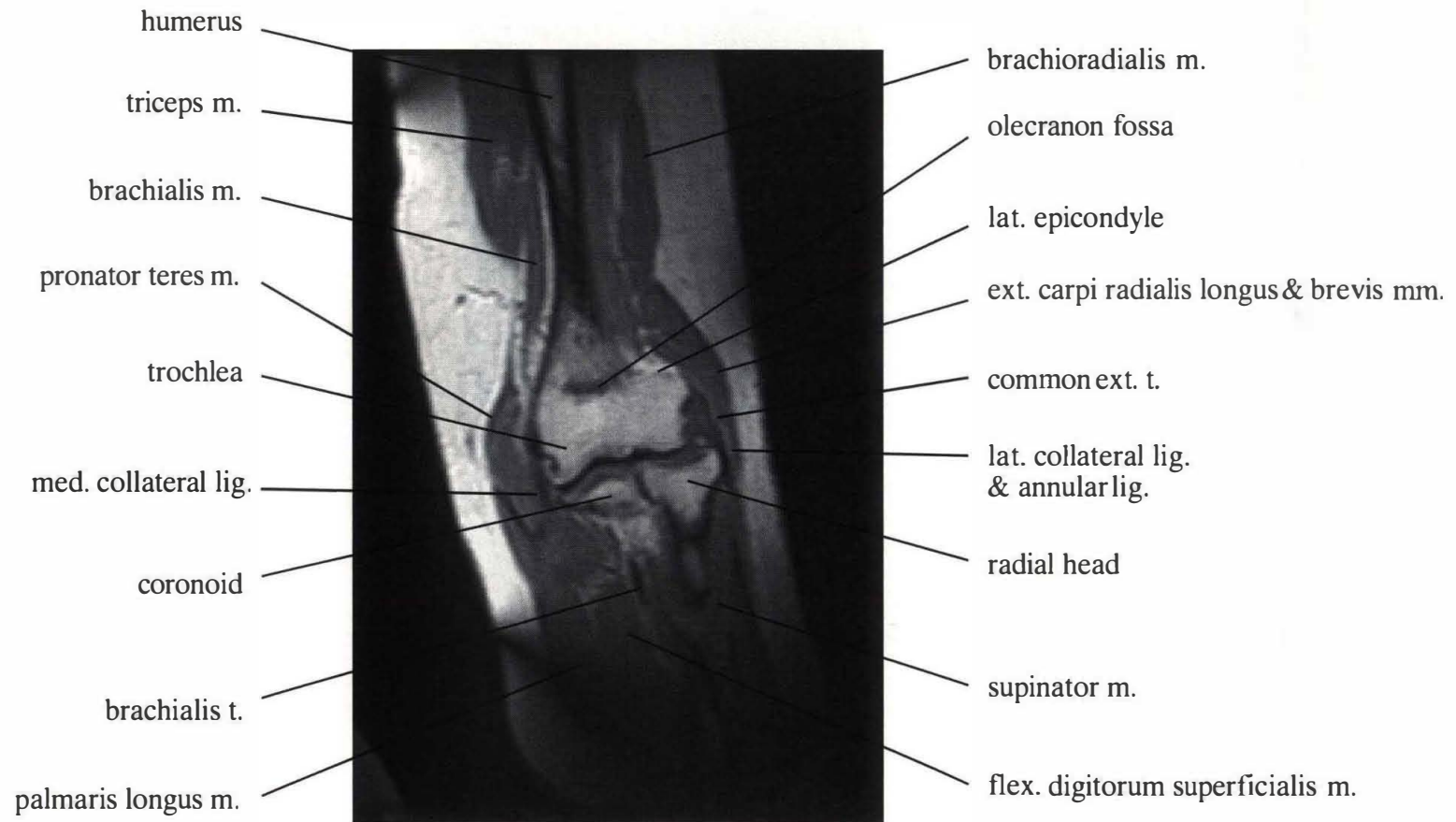
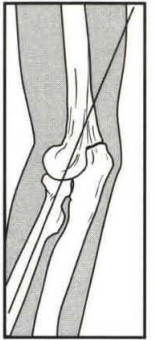
supinator m.

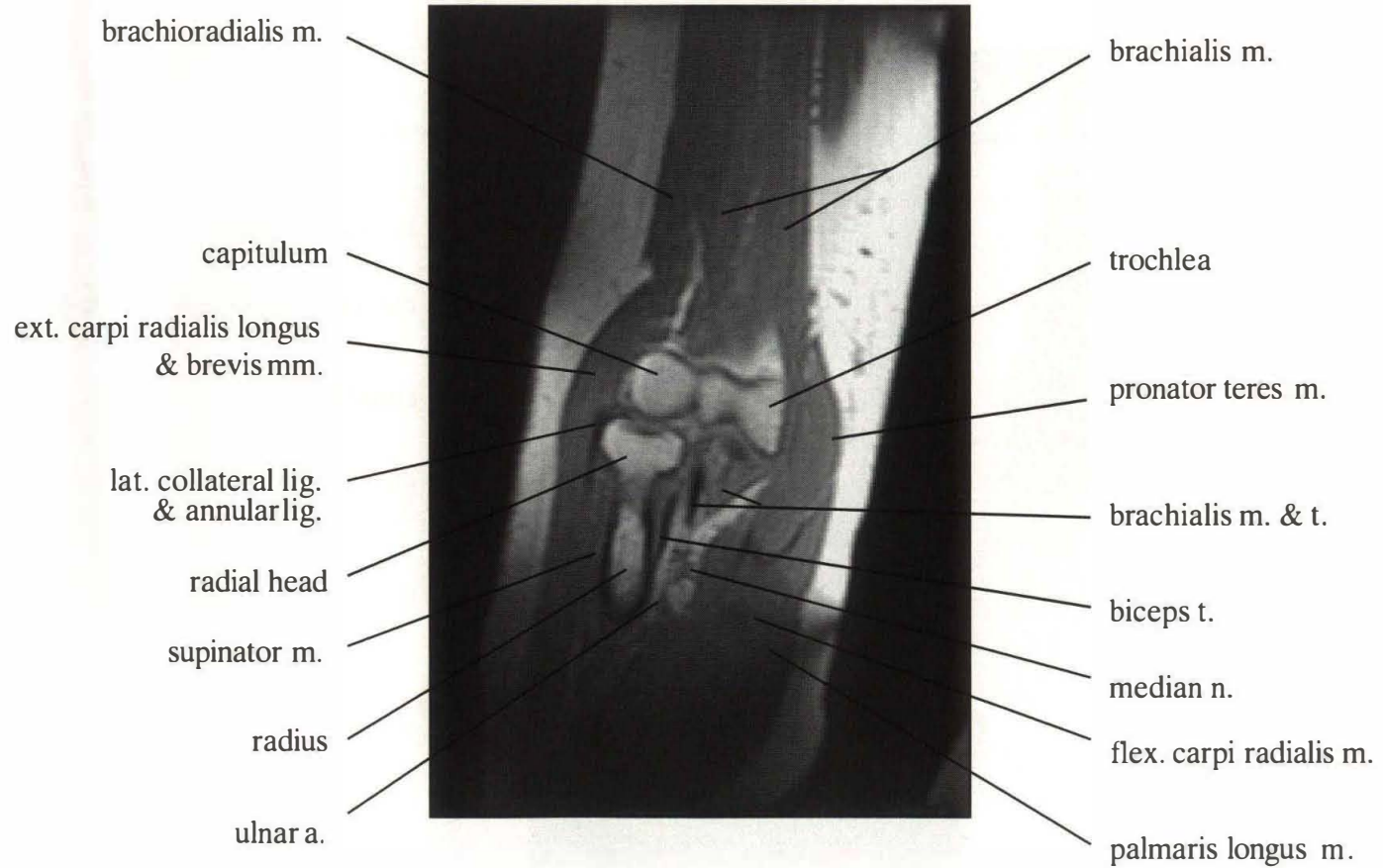
ext. digitorum m.

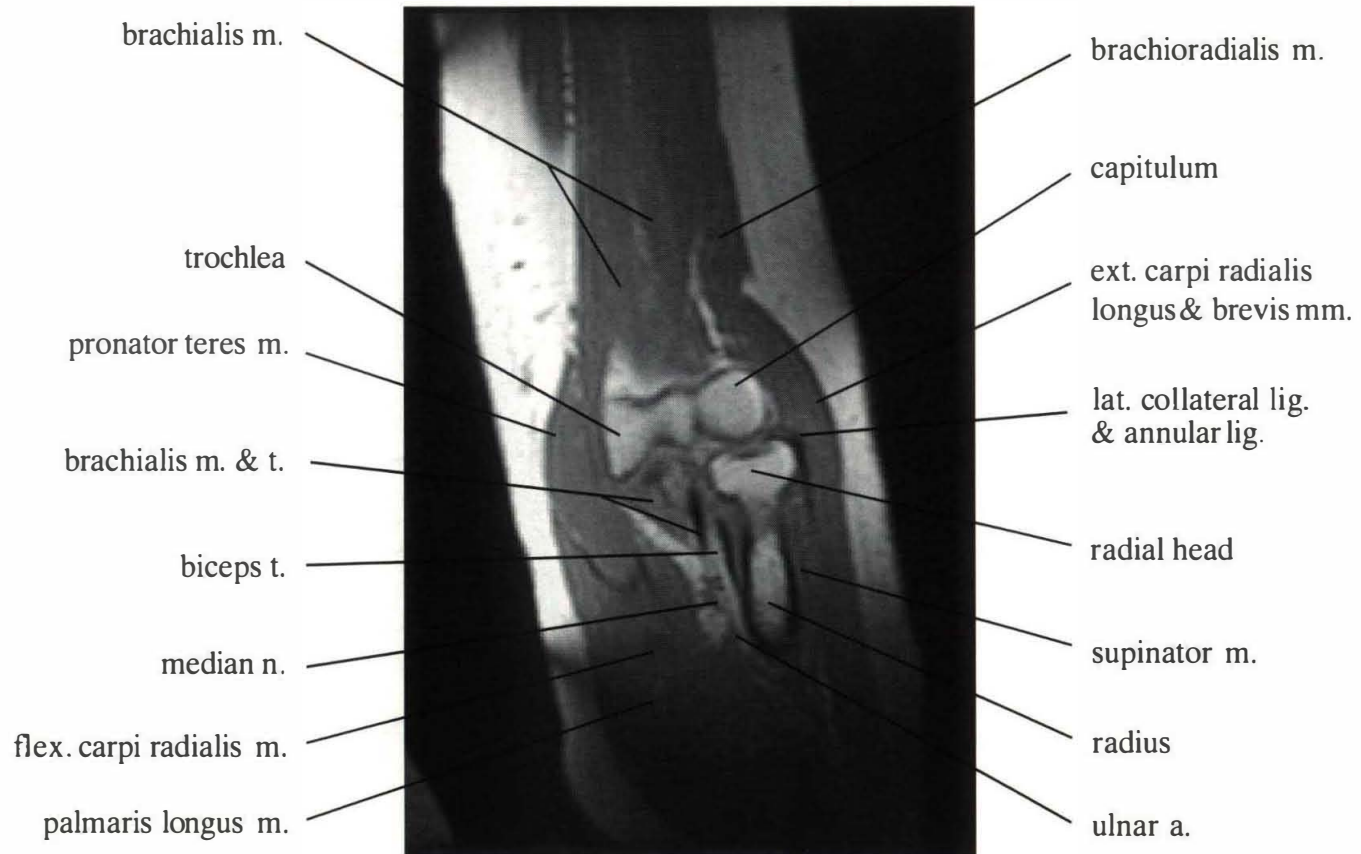
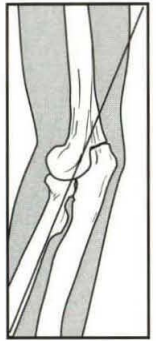


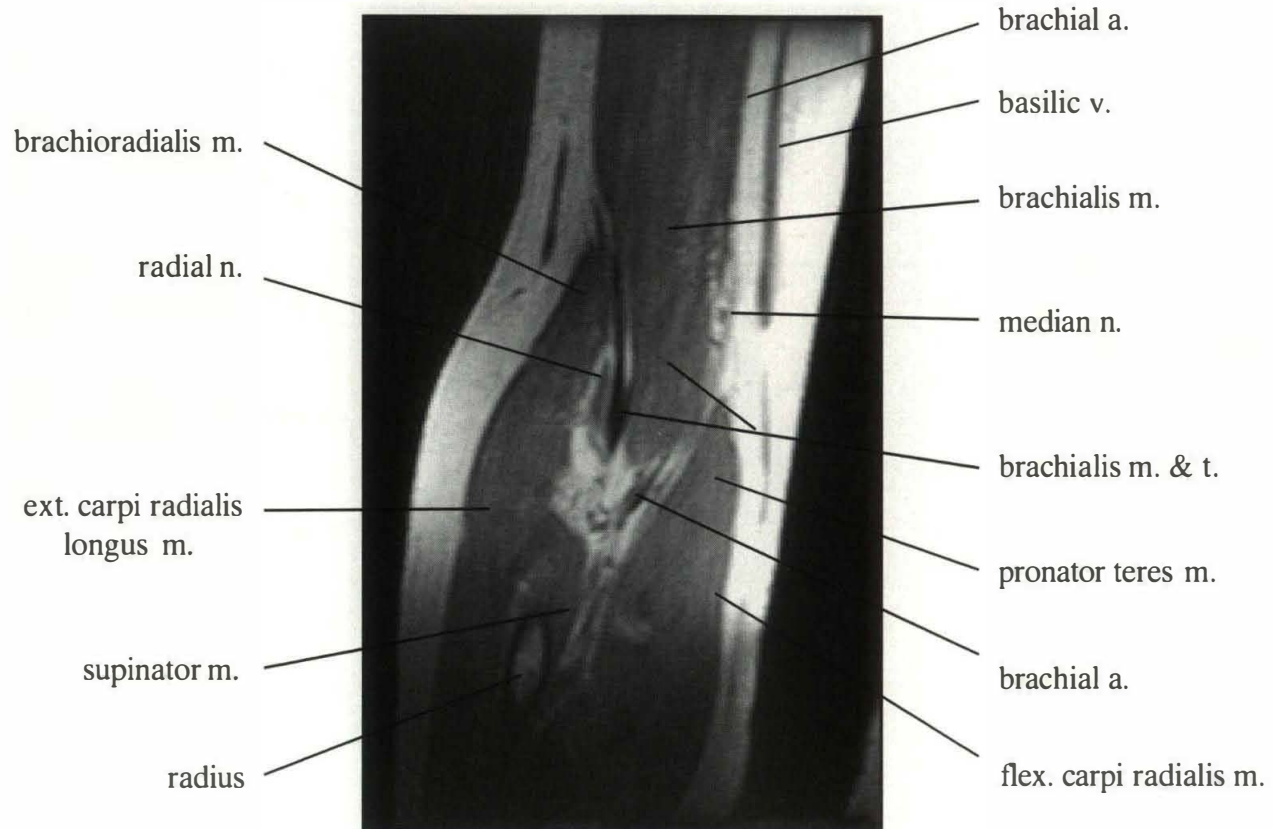


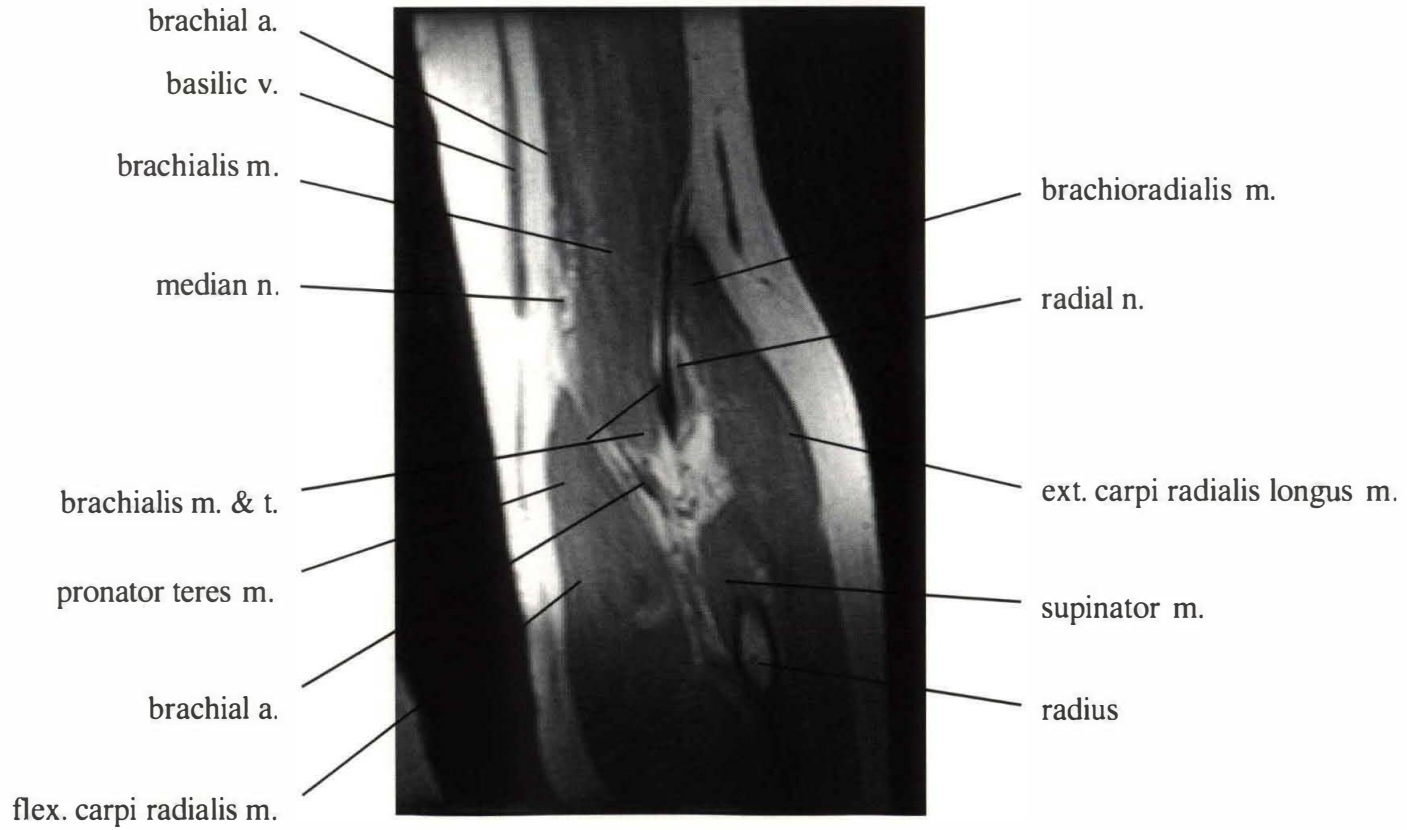




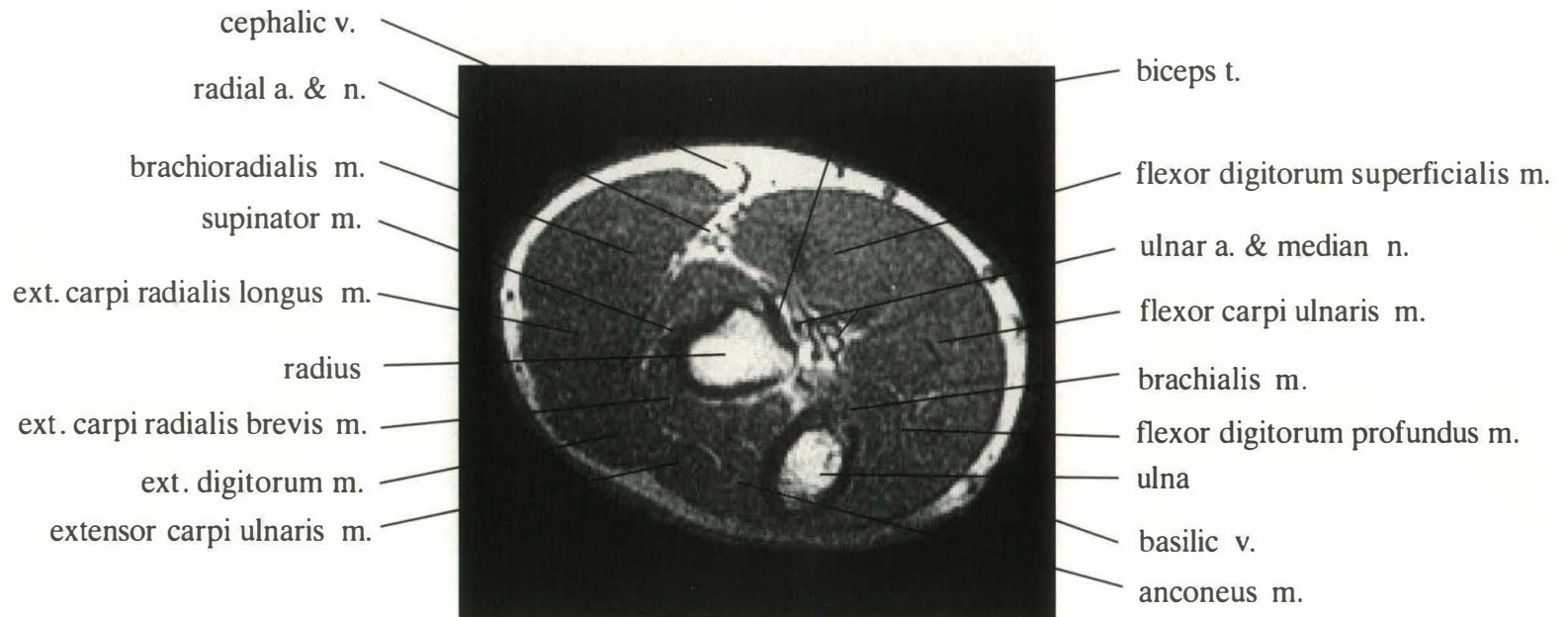
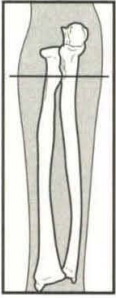


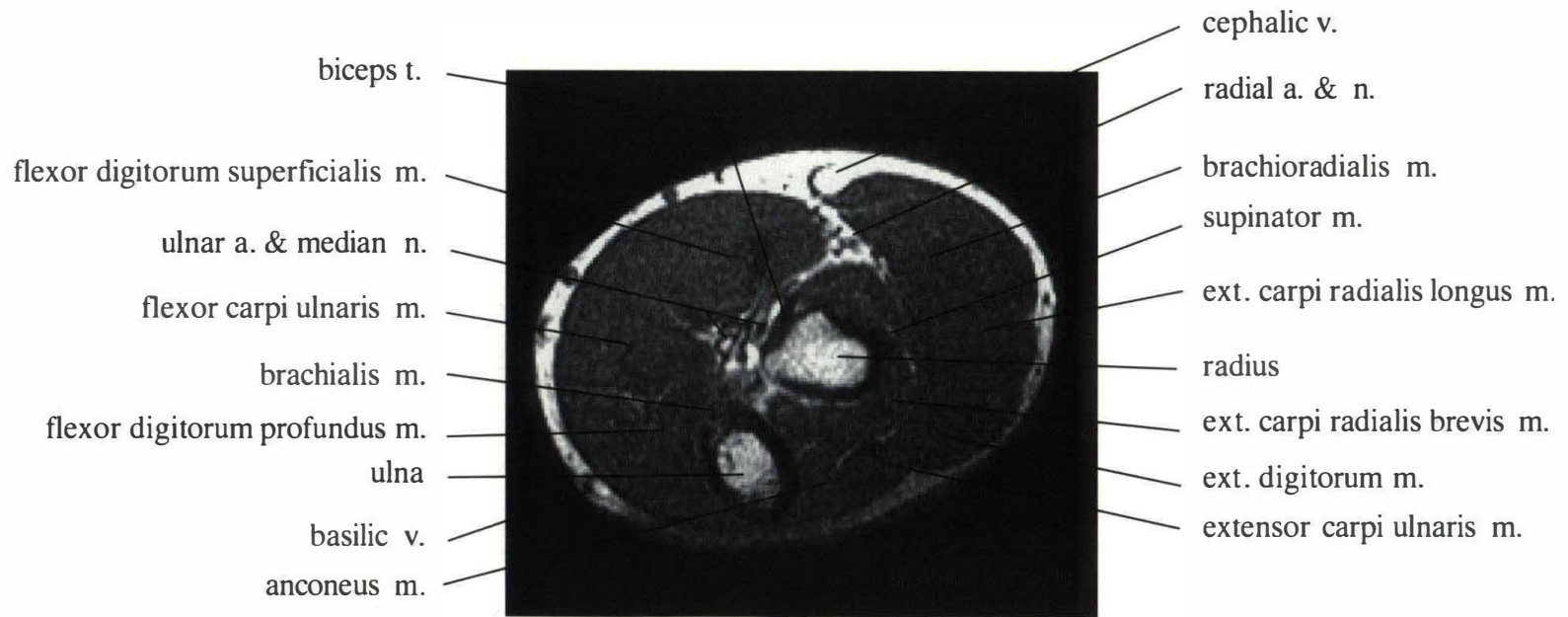
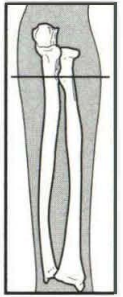


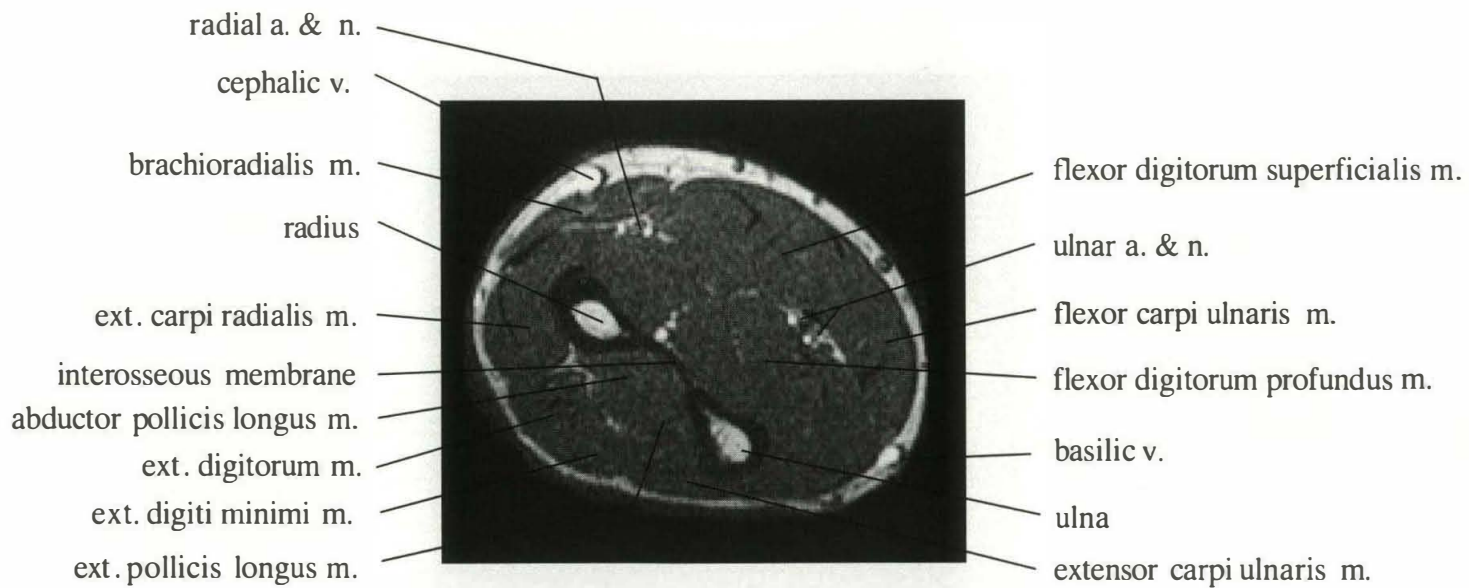
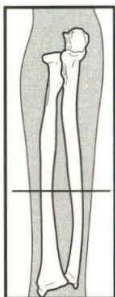


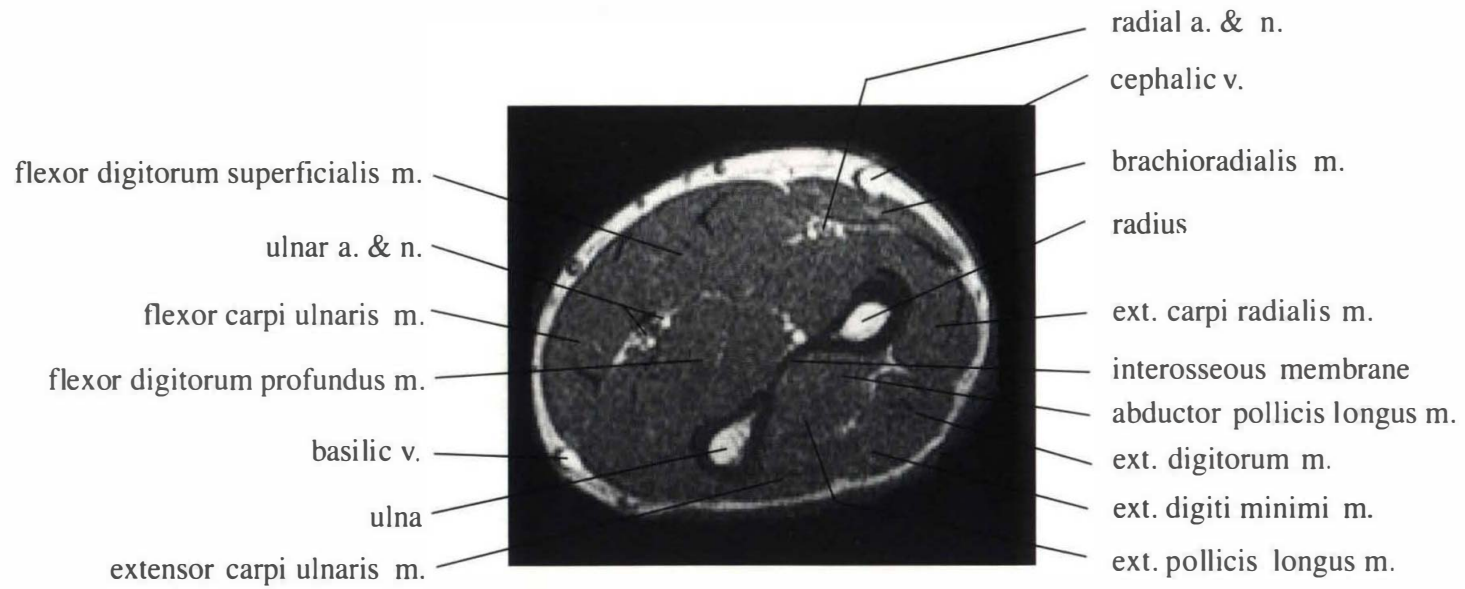
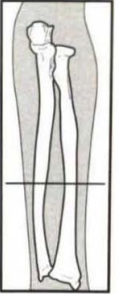


THE FOREARM: AXIAL ANATOMY



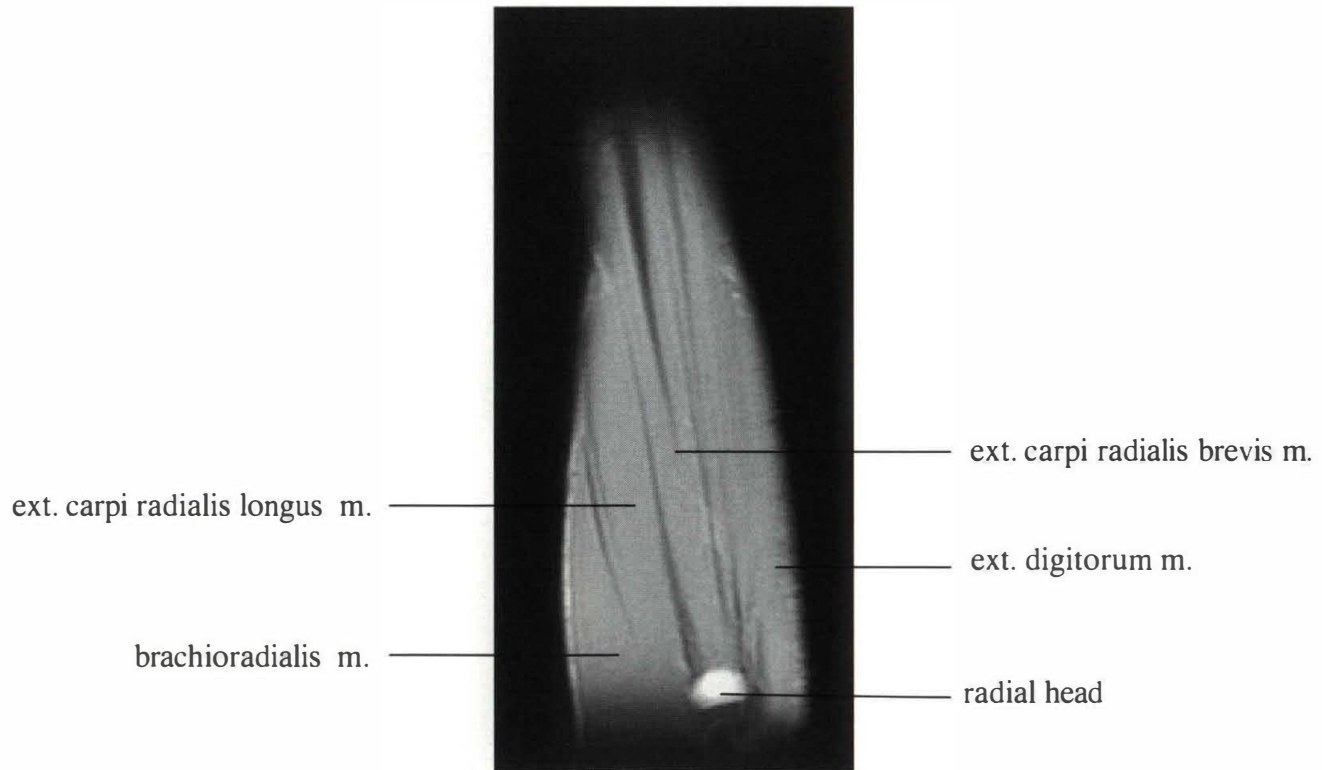


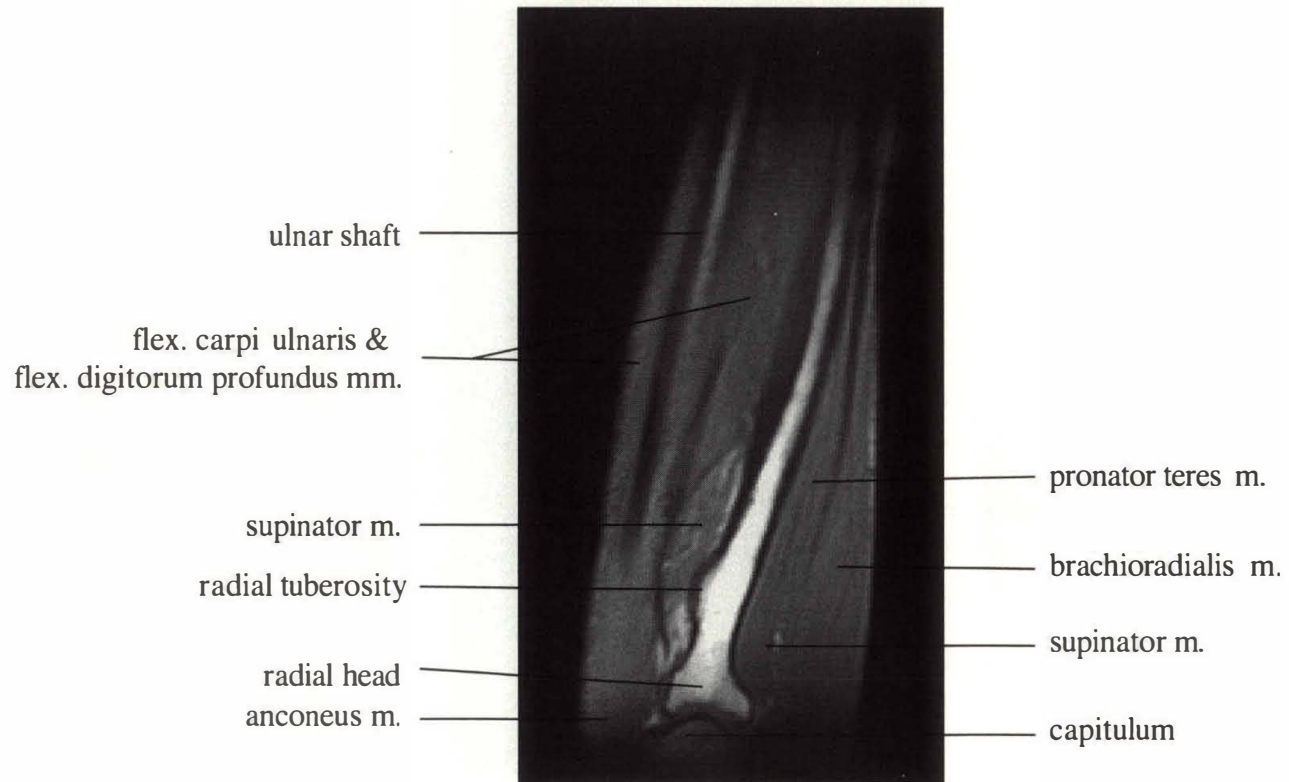


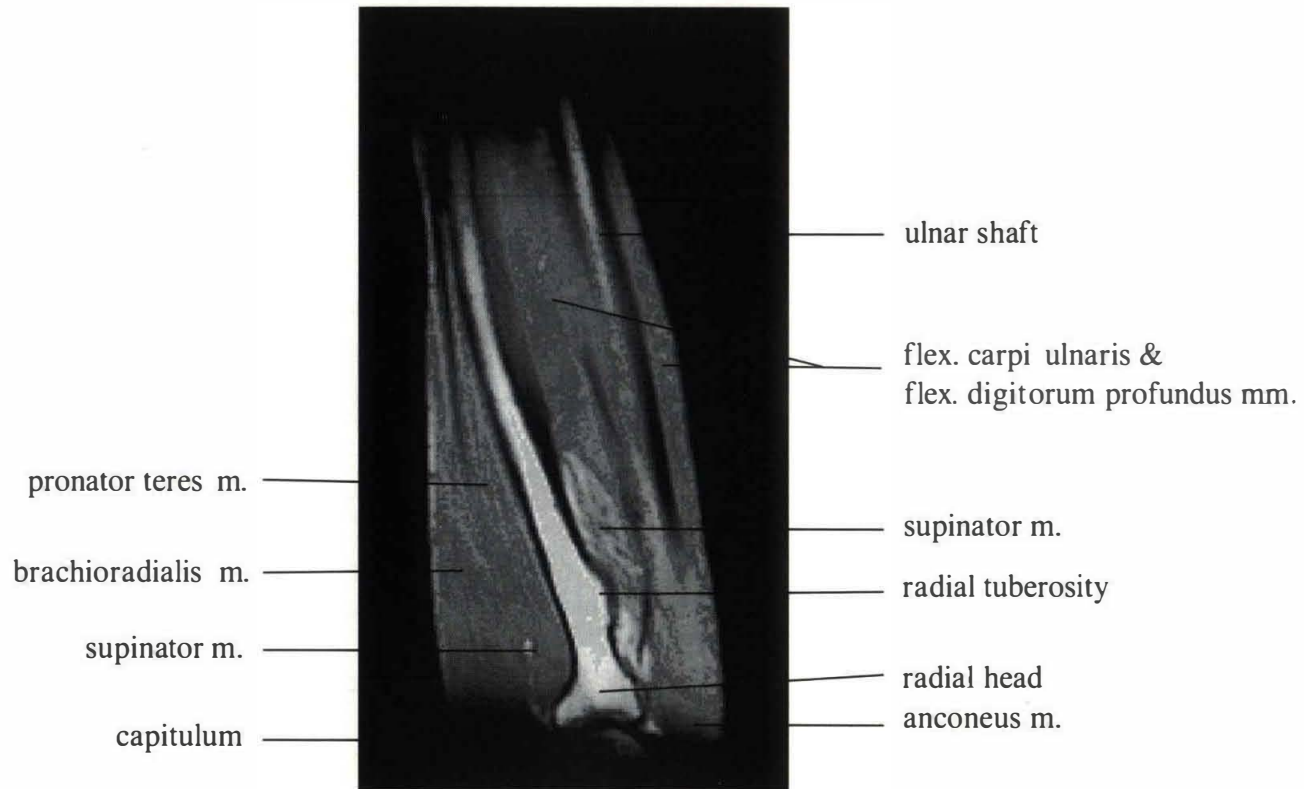


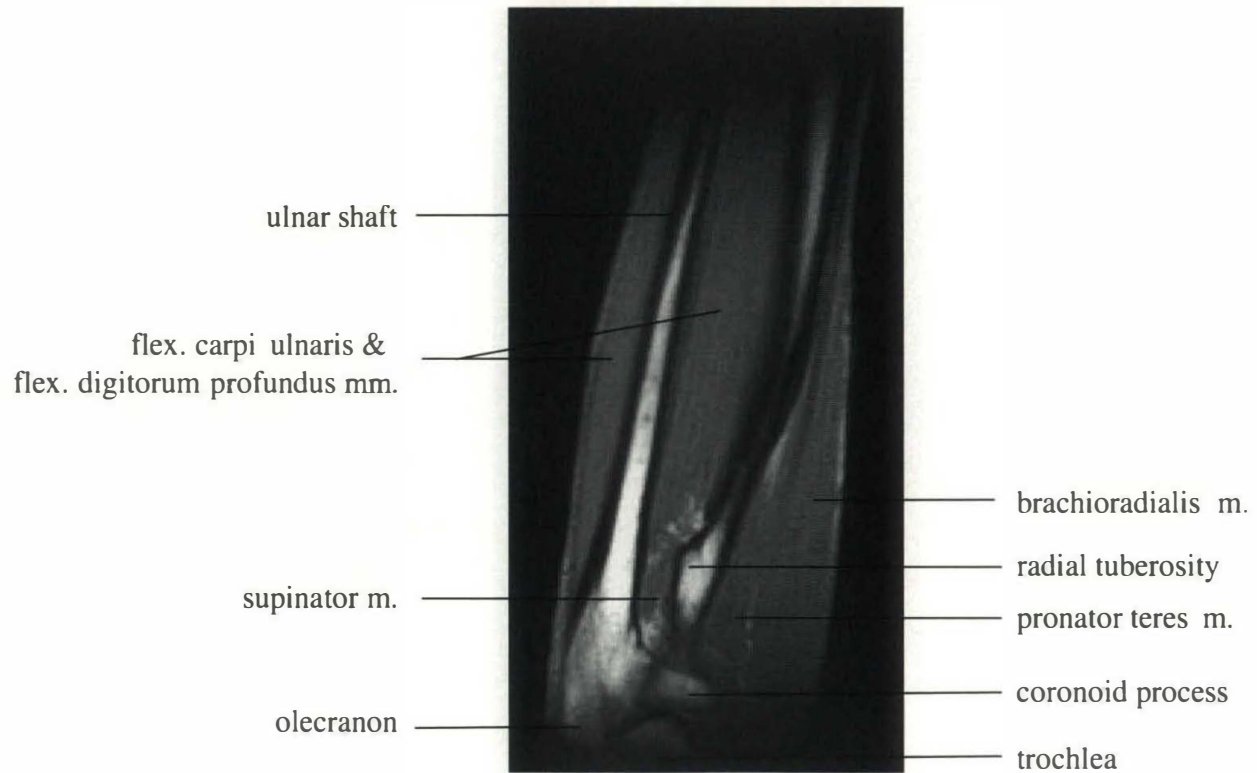
THE FOREARM: SAGITTAL ANATOMY

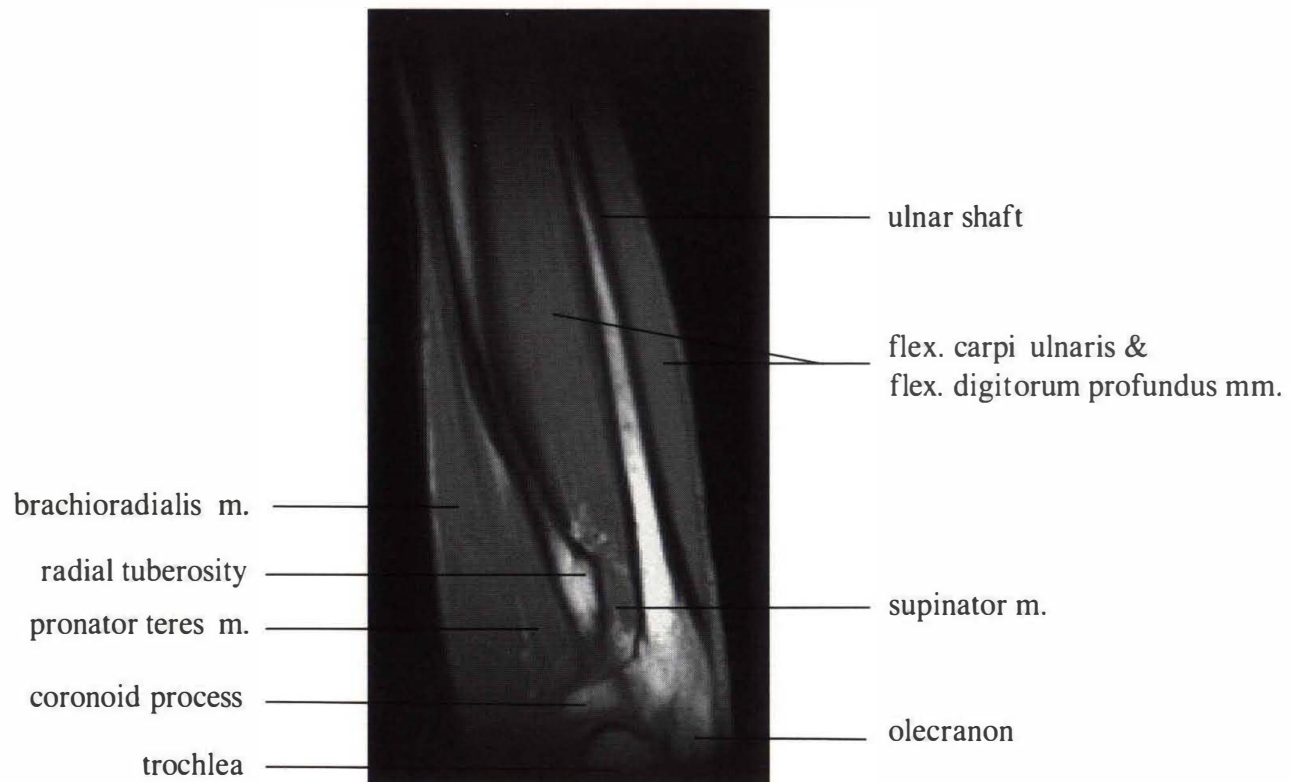
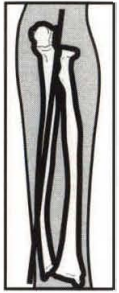


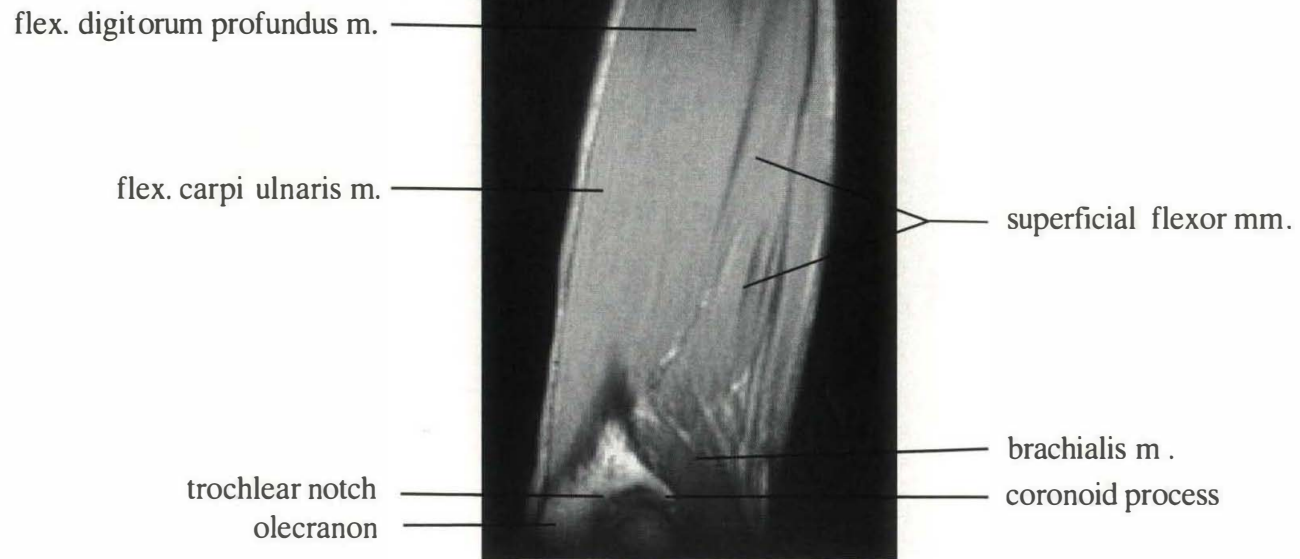


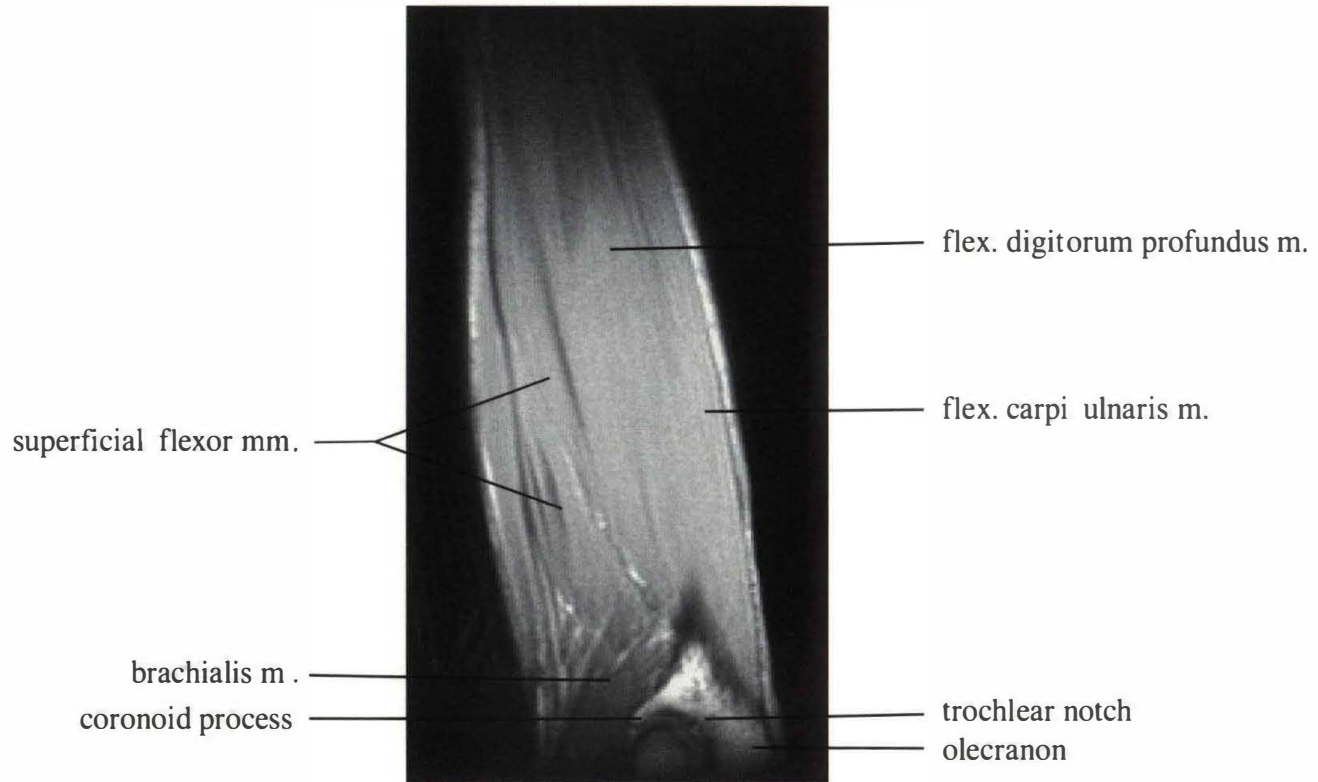














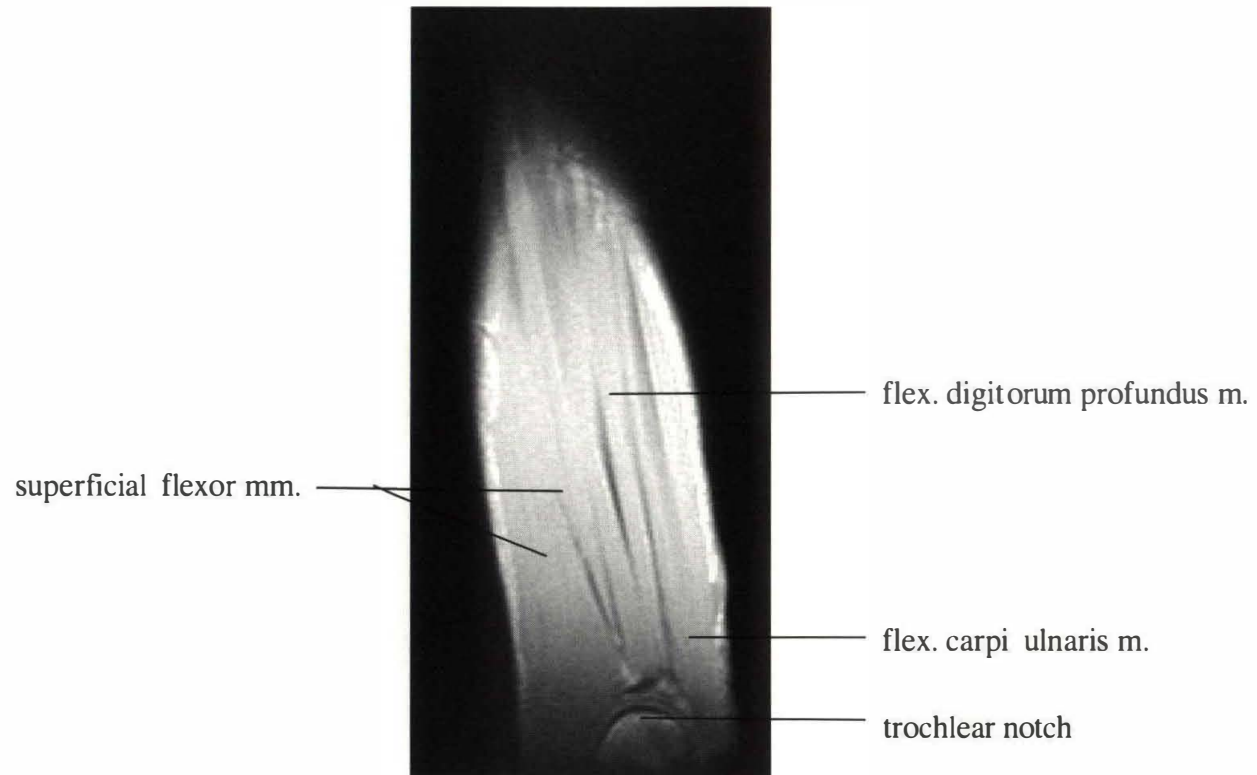
flex. digitorum profundus m.

flex. carpi ulnaris m.

trochlear notch



superficial flexor mm.



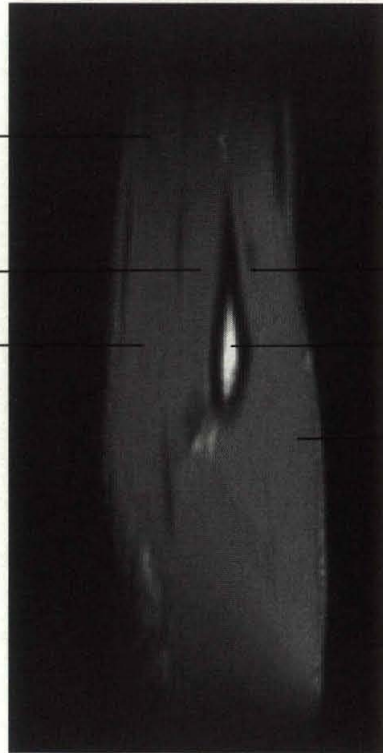
THE FOREARM: CORONAL ANATOMY



flex. carpi superficialis m.

pronator teres m.

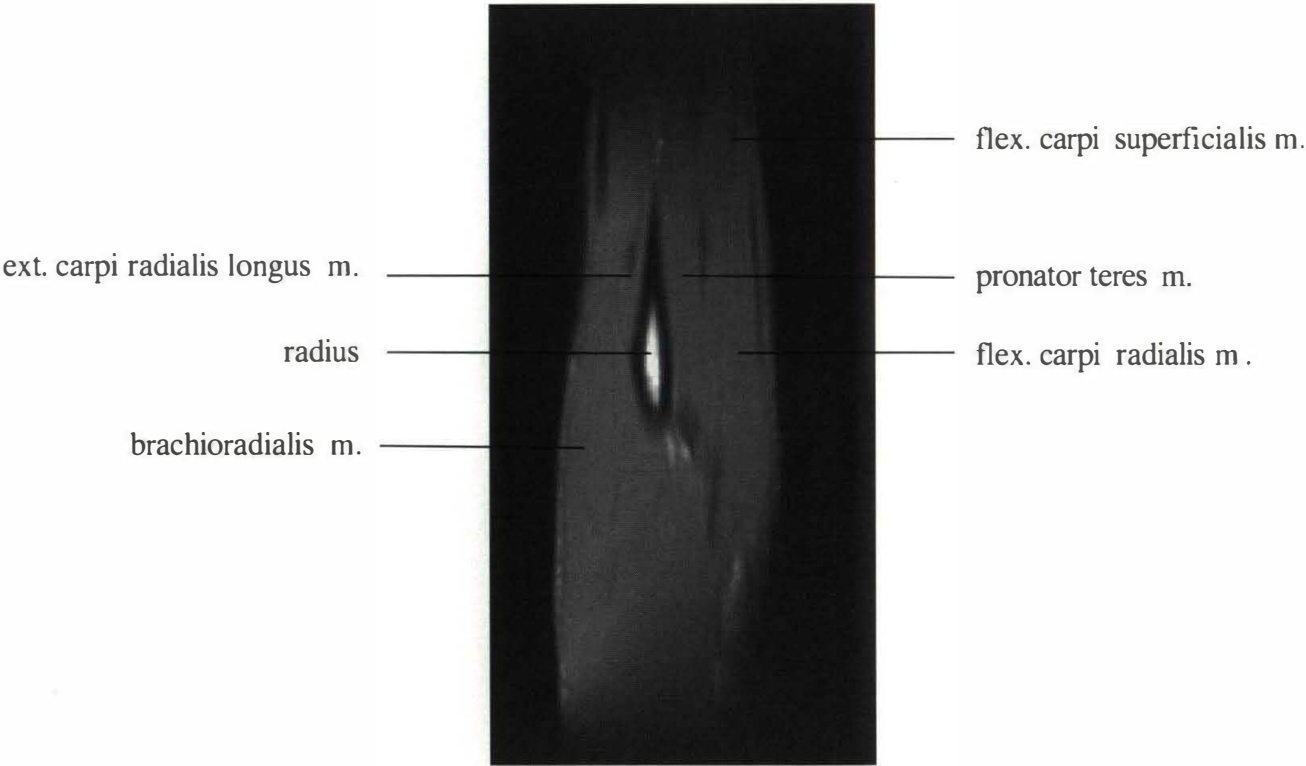
flex. carpi radialis m.



ext. carpi radialis longus m.

radius

brachioradialis m.

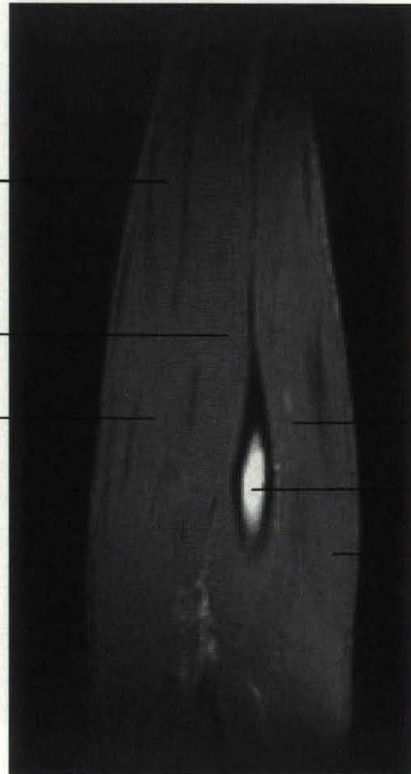




flex. digitorum superficialis m.

pronator teres m.

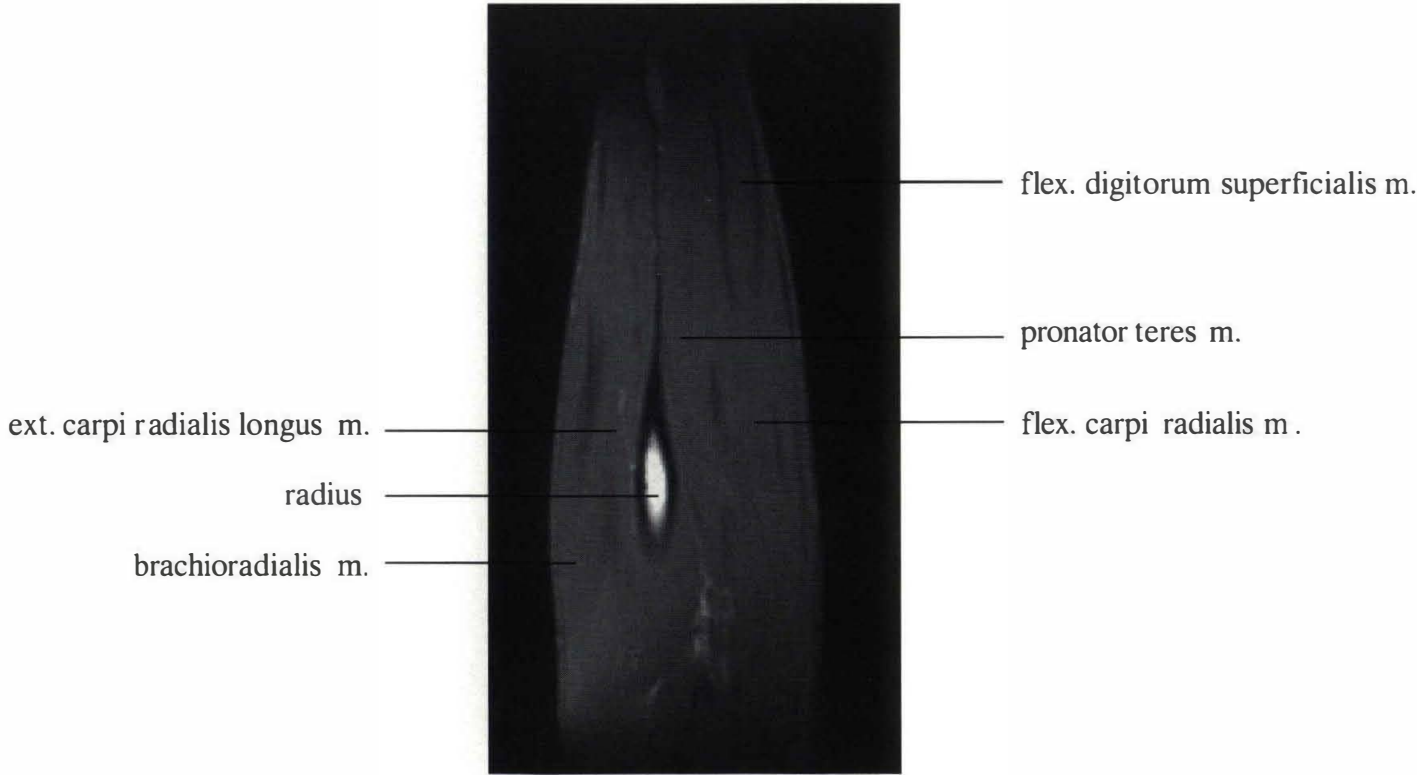
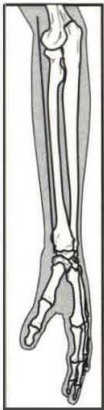
flex. carpi radialis m.



ext. carpi radialis longus m.

radius

brachioradialis m.



ext. carpi radialis longus m.

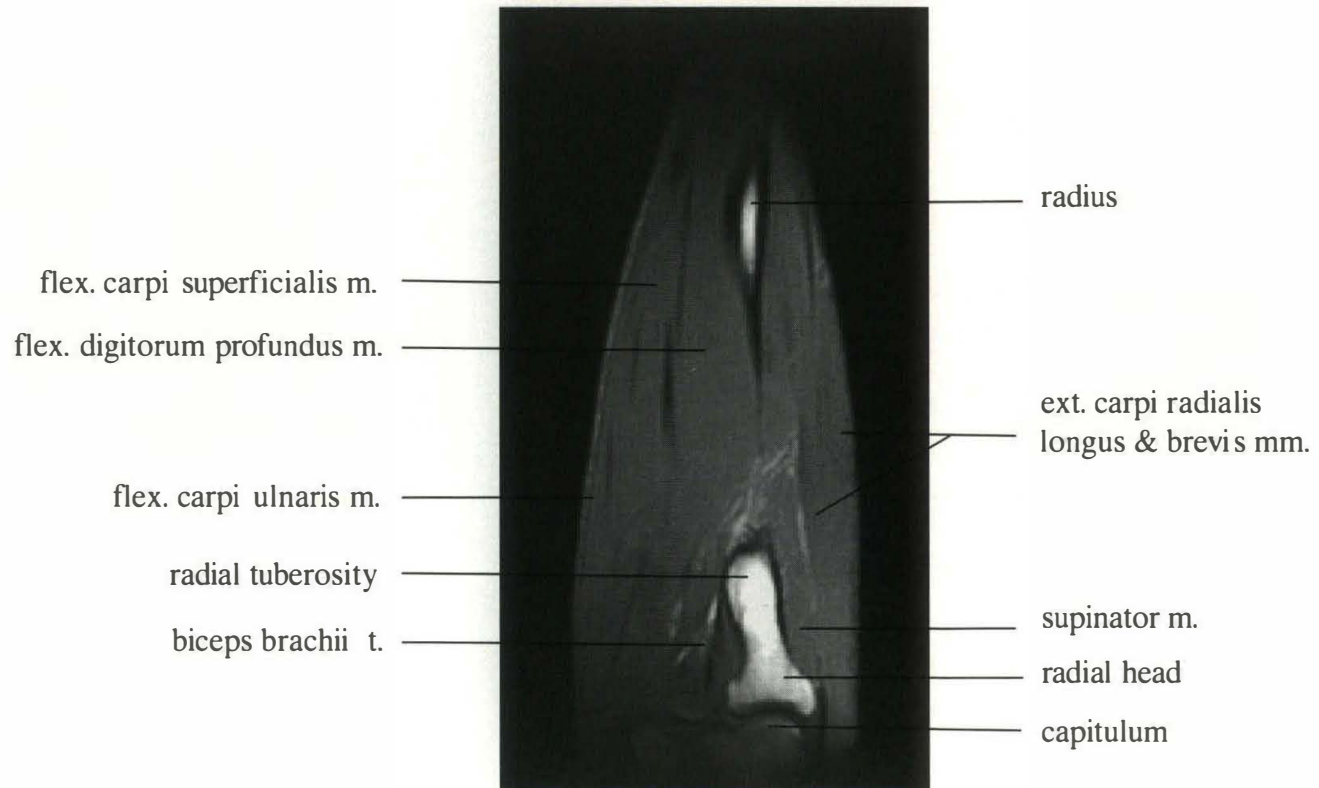
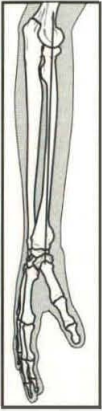
radius

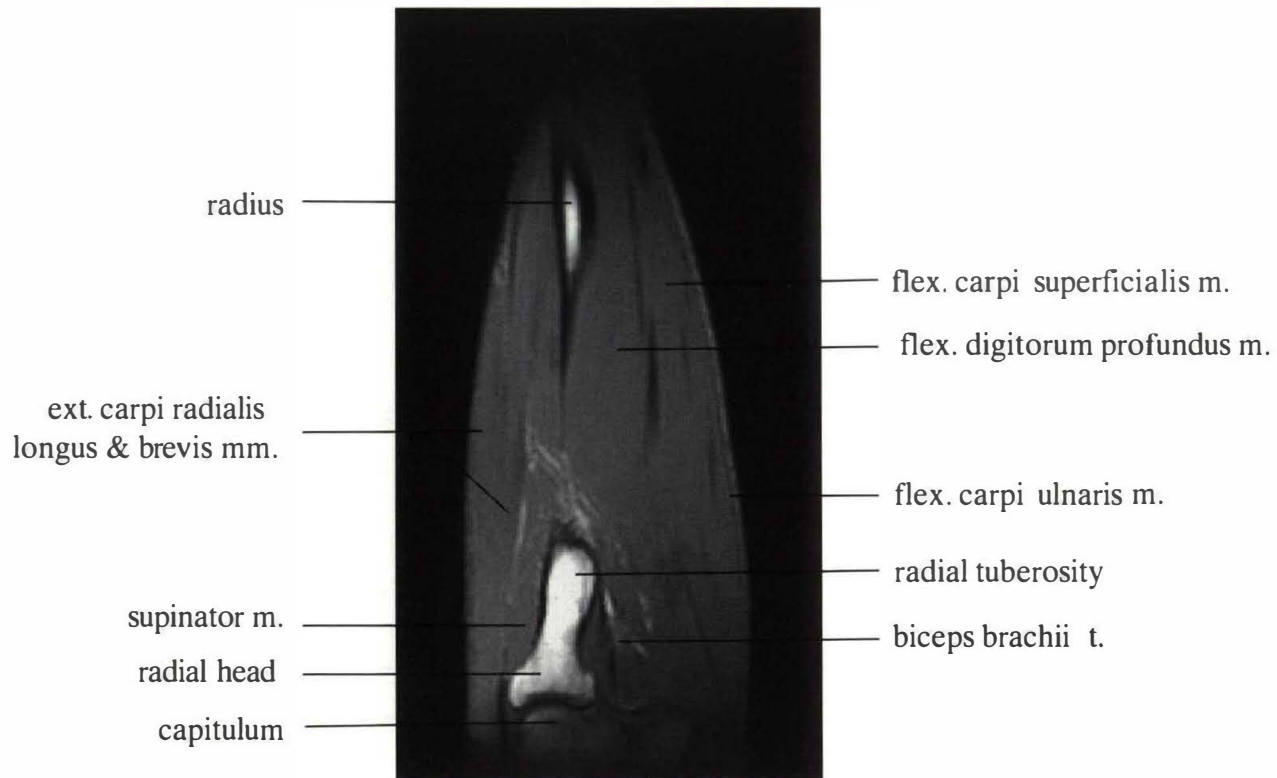
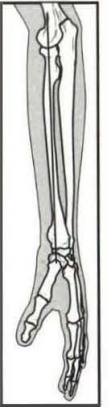
brachioradialis m.

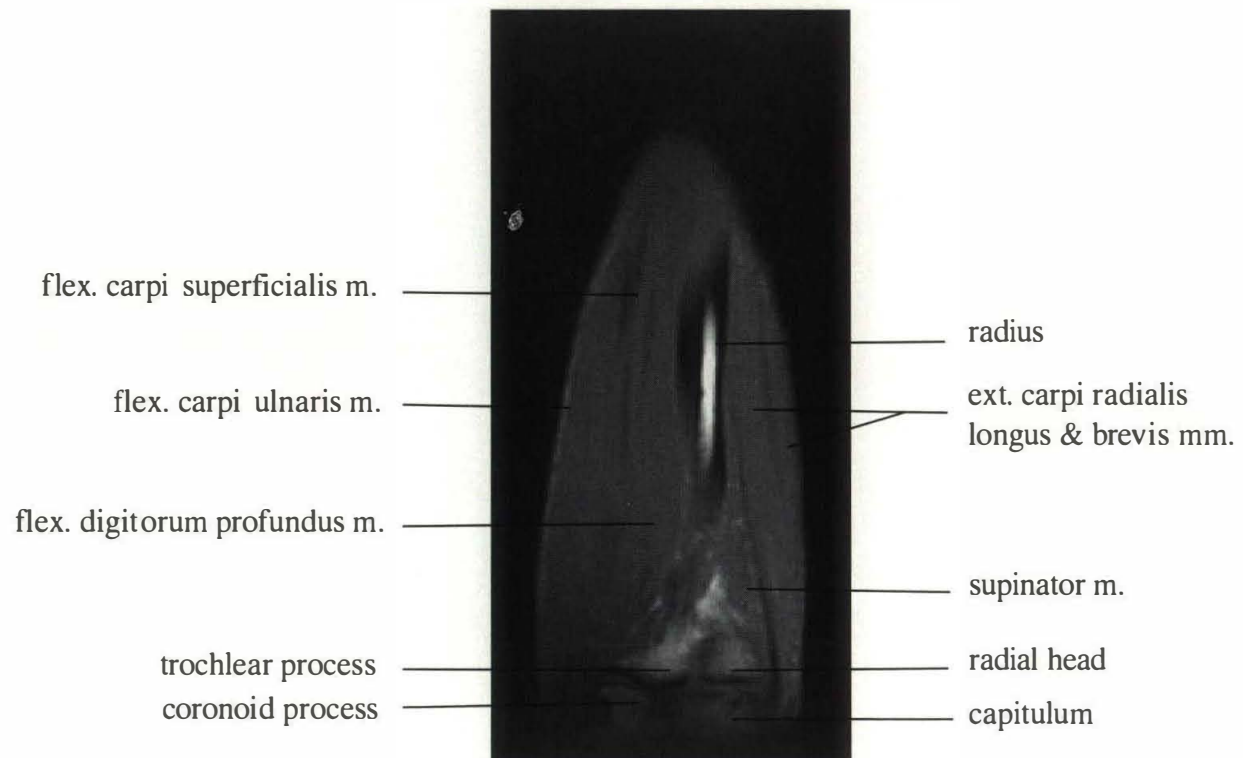
flex. digitorum superficialis m.

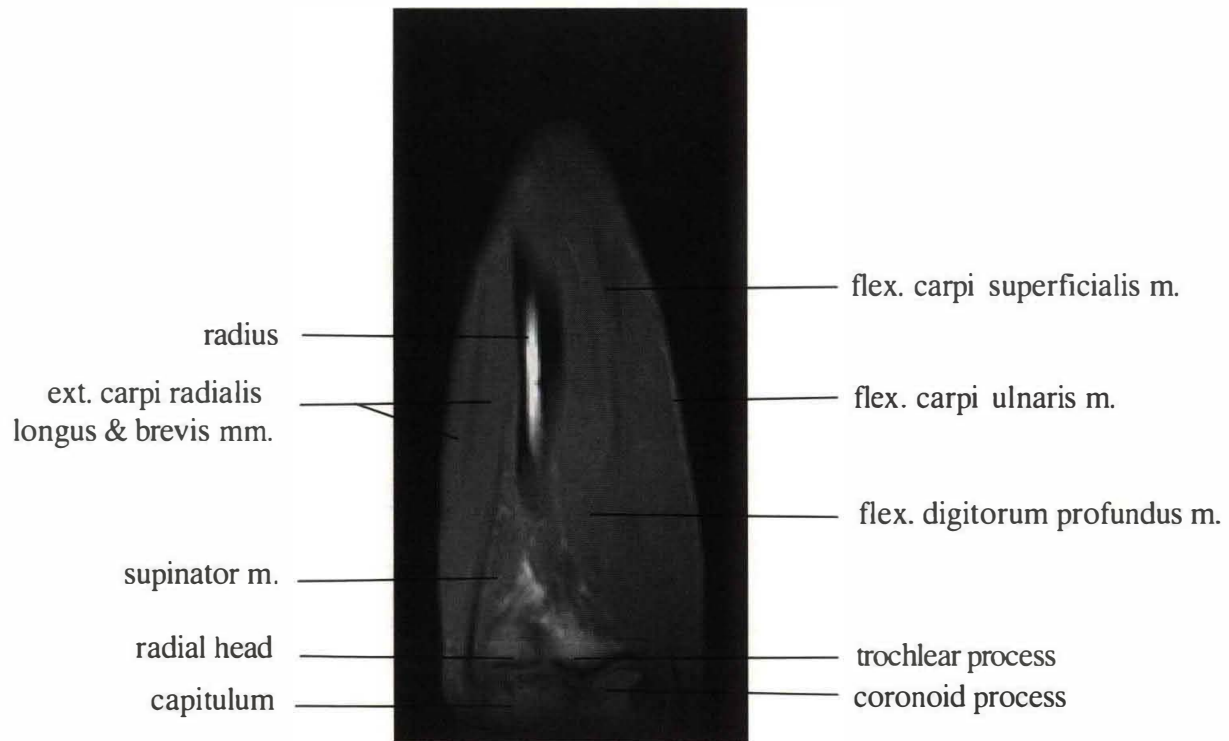
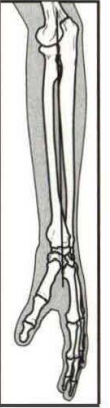
pronator teres m.

flex. carpi radialis m.









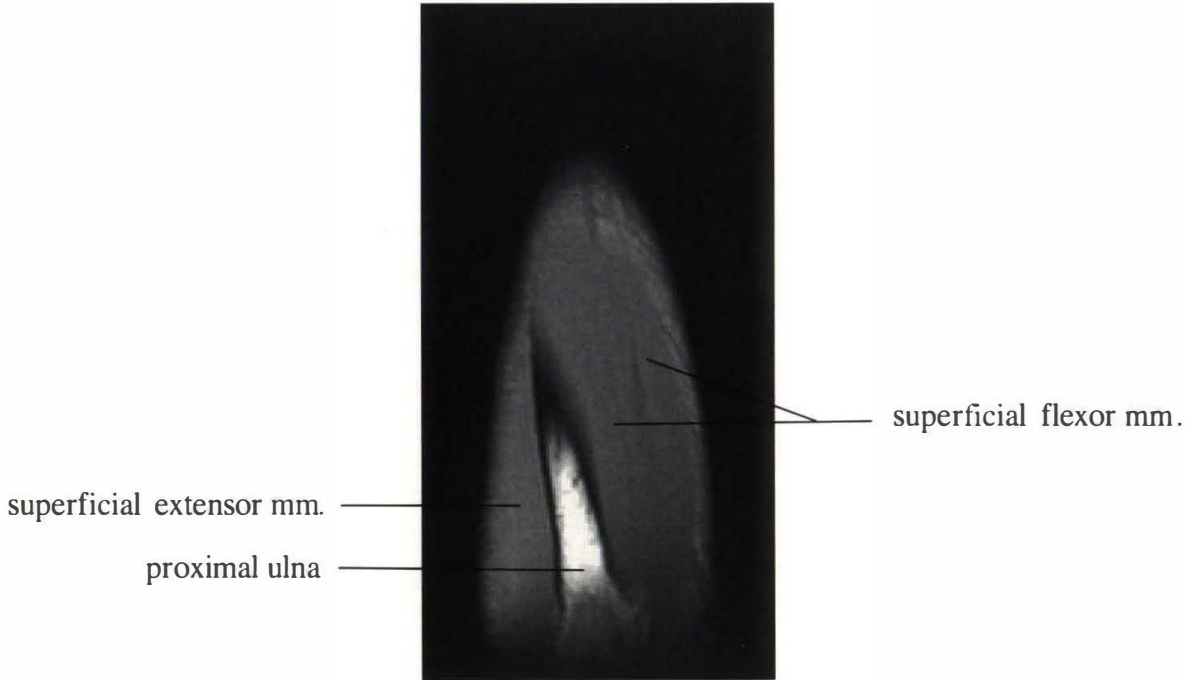
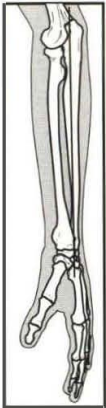


superficial flexor mm.



superficial extensor mm.

proximal ulna



THE WRIST AND HAND

The wrist and the hand are “small parts” of the body. MR imaging has not been used as often in these areas because of the technical challenges they present. However, newer developments in surface coils and gradient hardware have allowed more accurate imaging of the wrist, hand, ankle, and foot because of faster data acquisition, smaller fields of view, and thinner slices. The major indications for wrist examination are suspected abnormalities of tendons and ligaments (especially the lunatotriquetral and scapholunate), presumed compressive neuropathies (especially of the median nerve), suspected avascular necrosis (particularly of the lunate, as in Kienböck’s syndrome), and soft-tissue masses (especially ganglia) and soft-tissue or bony tumors. Rarely, MR imaging may be necessary to delineate the extent of infection in this region.

PRACTICAL PROTOCOL CONSIDERATIONS

The wrist and hand may be imaged by using the “head” or “knee” coils, but MR imaging with a dedicated circumferential quadrature or phased array coil is best. Use of the dedicated coils optimizes signal-to-noise ratio and allows the imager to produce high-resolution images with very small fields of view. The other advantage of the dedicated coils is that the patient may lie in the supine position with the arm at rest along the side. The hand and wrist should be placed in the neutral position without radial or ulnar deviation to maintain the alignment of the carpus and in pronation with the fingers held in extension. Although this is the ideal positioning, this technique may be modified according to the clinical indications for the study and the needs of the individual patient.

In general, it is best to use the smallest field of view that can be acquired (usually 6–8 cm) given the other parameters of the scan. Spin-echo images usually require a 256×256 matrix, and gradient-echo images may require alteration of the flip angle to optimize the T2-like contrast. Fat saturation may be used to increase the detection of fluid or edema. Some researchers have used the intravenous administration of gadolinium to study inflammatory arthritides or the intraarticular administration of MR contrast agents to study ligamentous disruptions. However, this is not standard technique at most institutions. In addition, kinematic studies of the wrist and hand are performed mainly for research purposes at this time.

Menu of Protocols: Wrist and Hand

Plane	Pulse Sequence	FA (degrees)	TR (msec)	TE (msec)	TI (msec)	FOV (cm)	Matrix (256×-)	ST/G (mm)	NEX	Comments
Localizer (coronal, transaxial, sagittal)	SE		600	20		8	128	3/1	2	Either is acceptable
Transaxial	SE, double echo		2250	20/80		8	128	3/1	2	Either is acceptable
Transaxial	FSE		2500	10		8–10	256	3/1	2	
Transaxial	FSE, FS		4000	108		8–10	192	3/1.5	2	
Transaxial	3D, GRE	30	45	10		6–8	192	1/0	1	
Sagittal	SE		450	20		8	128	3/1	2	Either is acceptable
Sagittal	SE, double echo		2500	30/90		8–10	128	3/1	2	
Sagittal	FSE, double echo		3000	20/100		8–10	192	3/1	1	
Sagittal	FSE, FS		4000	18		8–10	192	3/1.5	2	
Coronal	SE, double echo		2000	20/80		8	8128	3/1	2	Either is acceptable
Coronal	3D, GRE	30	45	9		8	192	VAR/0	2	
Coronal	3D, GRE	20	30	12		8–12	128	1.2/0	2	
Coronal	GRE	25	600	20		8–10	192	3/1.5	2	
Coronal	FMPIR		3000	51	150	12	128	4/1	1	
Pre-GAD (axial, coronal, sagittal)	SE (±FS)		600	20		8–10	192	3/1	2	Depends on site of abnormalities
Post-GAD (axial, coronal, sagittal)	SE (±FS)		600	20		8–10	192	3/1	2	Intraarticular GAD for ligaments, intravenous GAD for tumors, cysts, infection

MAJOR OSTEOCHONDRAL STRUCTURES/LANDMARKS

Wrist

- Distal radius
 - Articular cartilage
 - Styloid process
 - Ulnar (sigmoid) notch
 - Dorsal tubercle

- Distal ulna
 - Articular cartilage
 - Styloid process
 - Ulnar head
- Carpus
 - Scaphoid
 - Lunate
 - Triquetrum (and its tubercle)
 - Pisiform (sesamoid of flexor carpi ulnaris tendon)
 - Hamate (and its hamulus)
 - Capitate
 - Trapezoid (lesser multangular)
 - Trapezium (greater multangular)
 - Triangular fibrocartilage complex (TFCC)

Hand

- Metacarpals (I–V)
 - Metacarpal base
 - Metacarpal shaft
 - Metacarpal head
- Proximal phalanges
 - Base
 - Shaft
 - Head
- Distal phalanges
 - Base
 - Tuberosity (tuft)
- Sesamoids (variable)

MAJOR LIGAMENTS/TENDONS/BURSAE

Ligaments of the Wrist

The ligaments of the wrist provide for carpal and distal radioulnar stability. These ligaments are generally divided into two groups: extrinsic and intrinsic. The extrinsic ligaments extend from the radius, ulna, and metacarpals and bind the radius to the carpal bones. The intrinsic ligaments originate and insert within the carpus and bind the carpal bones together.

Radiocarpal Extrinsic Ligaments

- Volar (palmar) ligaments
 - Radioscaphocapitate
 - Long radiolunate (radiolunotriquetral)
 - Short radiolunate
 - Radioscapholunate
 - Radiolunate (ligament of Testut)
 - Radioscaphoid (ligament of Kuenz)
- Radial collateral ligament (from radial styloid tip to scaphoid waist on radial side)

Dorsal Extrinsic Ligaments

- Dorsal radioscapholunotriquetral
- Scaphotriquetral

Ulnocarpal Extrinsic Ligaments (Triangular Fibrocartilage (TFCC) Ligaments)

- Volar radioulnar
- Dorsal radioulnar
- Ulnotriquetral
- Ulnolunate
- Ulnar collateral
- Meniscal homologue

Intrinsic (Intercarpal) Ligaments

- Dorsal intercarpal
- Volar intercarpal
- Interosseous
 - Scapholunate
 - Lunatotriquetral
 - Deltoid (arcuate)—(stabilizes distal carpal row on proximal row)
 - Trapezoid—capitate
 - Trapezium—trapezoid
 - Capitate—hamate

Tendons of the Wrist

Palmar Group

- Carpal tunnel (volar boundary: the “flexor retinaculum,” which extends from the scaphoid tuberosity and inserts on the trapezium, the hook of the hamate, and the pisiform; dorsal boundary: the lunate and capitate bones)
 - Flexor pollicis longus
 - Flexor digitorum superficialis (four tendons)
 - Flexor digitorum profundus (four tendons)
- Other flexor tendons
 - Palmaris longus
 - Flexor carpi radialis
 - Flexor carpi ulnaris

Dorsal Group

- Extensors
 - Extensor carpi ulnaris
 - Extensor digiti minimi
 - Extensor digitorum
 - Extensor indicis
 - Extensor pollicis longus
 - Extensor carpi radialis brevis

- Extensor carpi radialis longus
- Extensor pollicis brevis
- Abductor
 - Abductor pollicis longus

Bursae of the Wrist

- Ulnar bursa (covers digital flexor tendons-variable)

Components of Guyon's Canal (Ulnopalmar aspect of wrist superficial to flexor retinaculum)

- Ulnar nerve
- Ulnar artery
- Anomalous muscles

Ligaments of the Hand

- Palmar metacarpal
- Palmar carpometacarpal
- Deep transverse metacarpal
- Palmar (palmar plates)
- Collateral

Tendons of the Hand

- Long extensor tendon
- Flexor digitorum profundus
- Flexor digitorum superficialis

MAJOR MUSCLES

Wrist

(See forearm)

Hand

(See forearm)

- Lumbricals (associated with flexor digitorum profundus tendons)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES

Wrist

(See forearm)

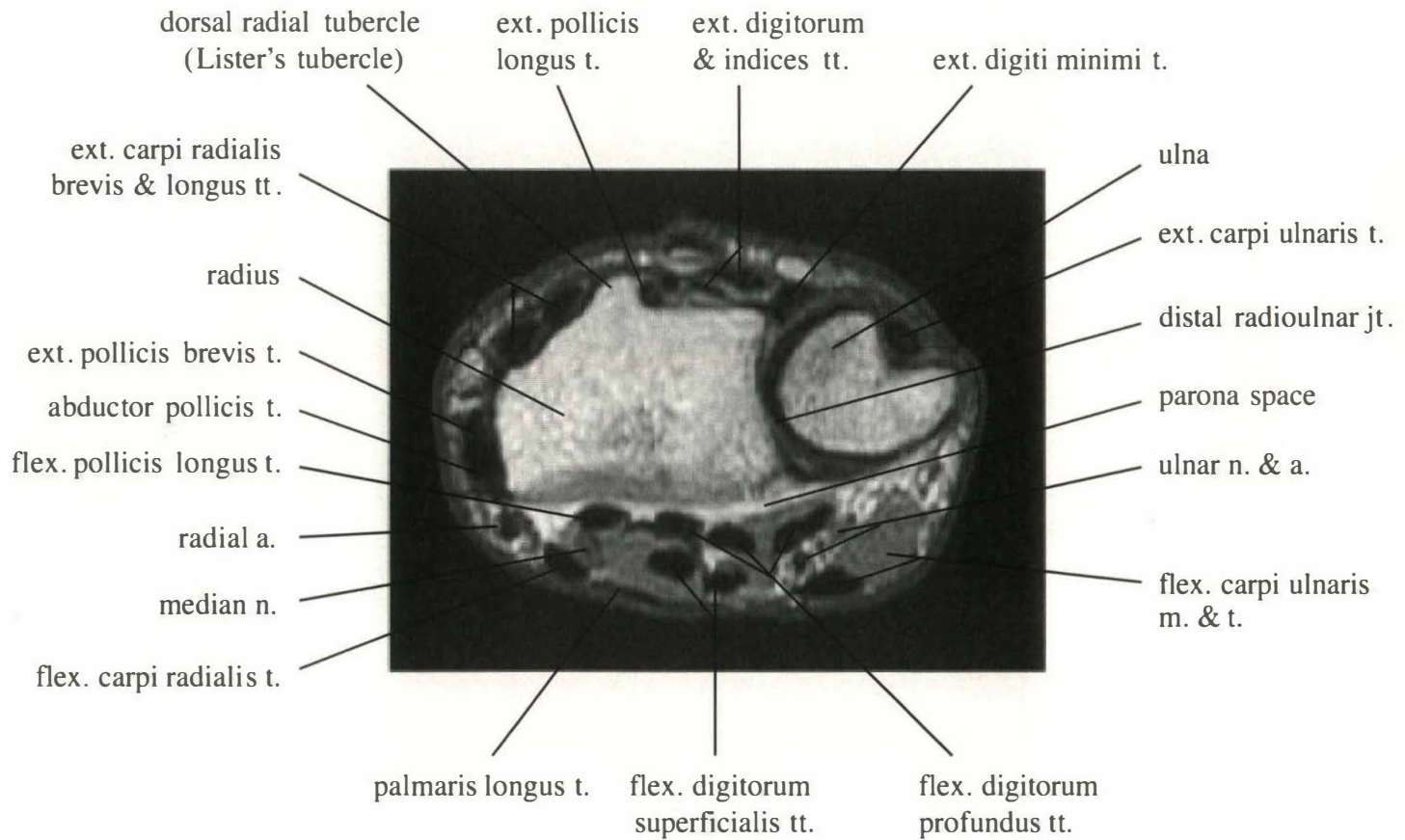
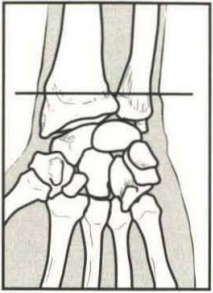
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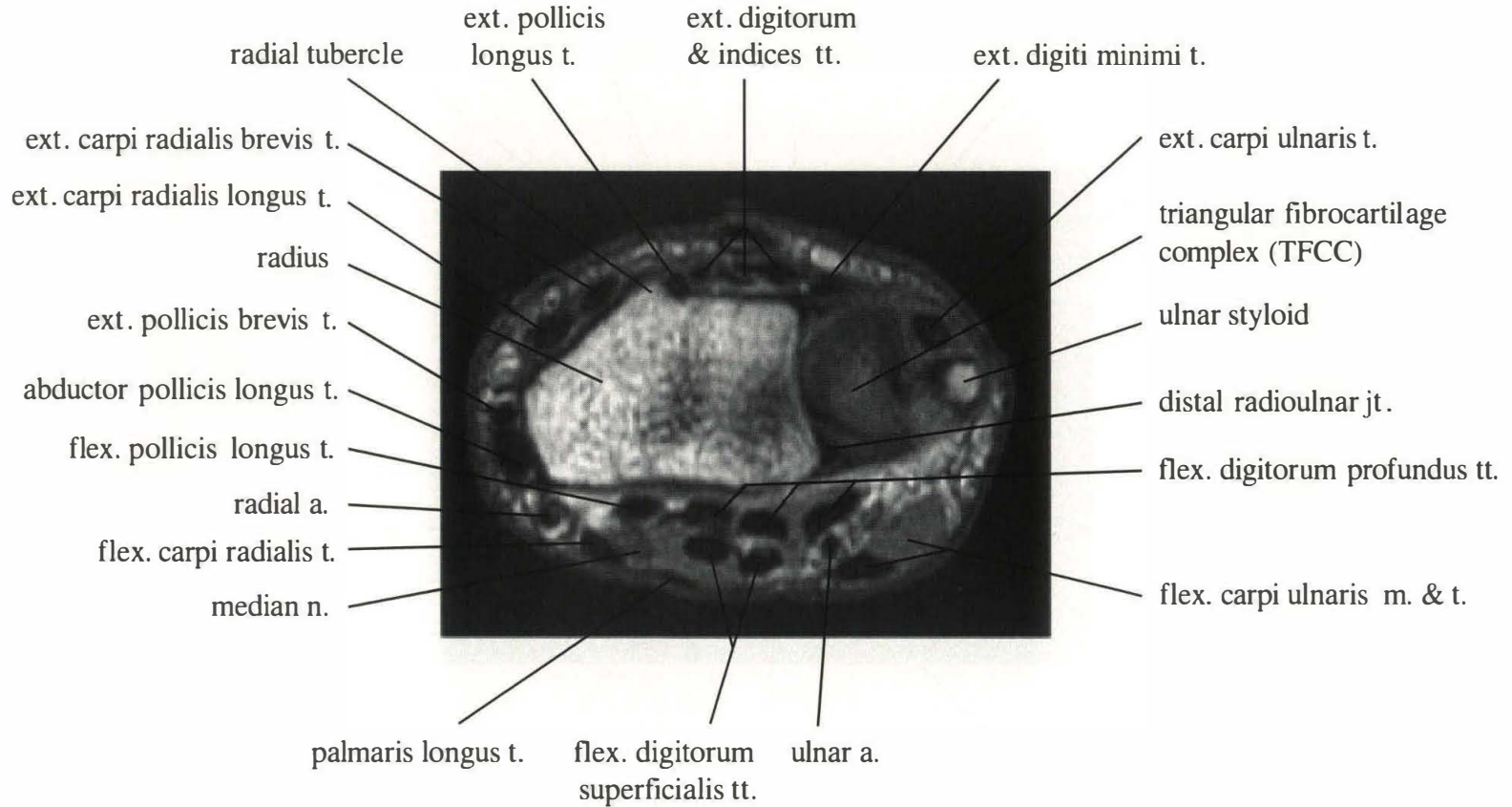
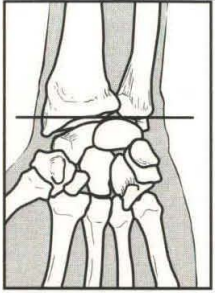
(See forearm)

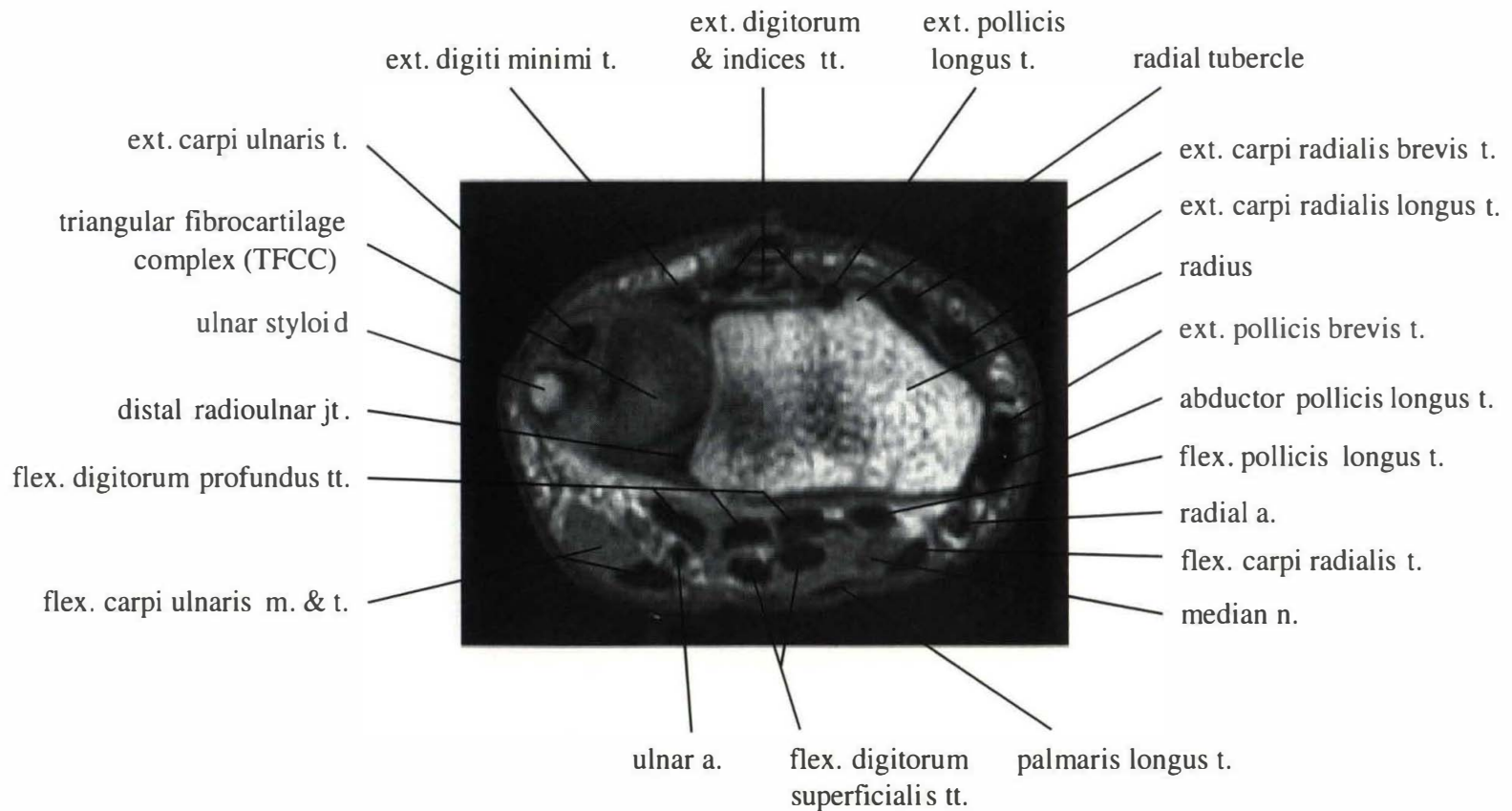
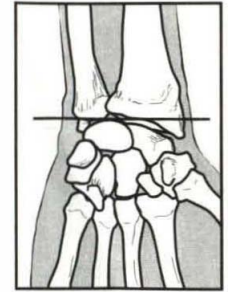
Lumbricals

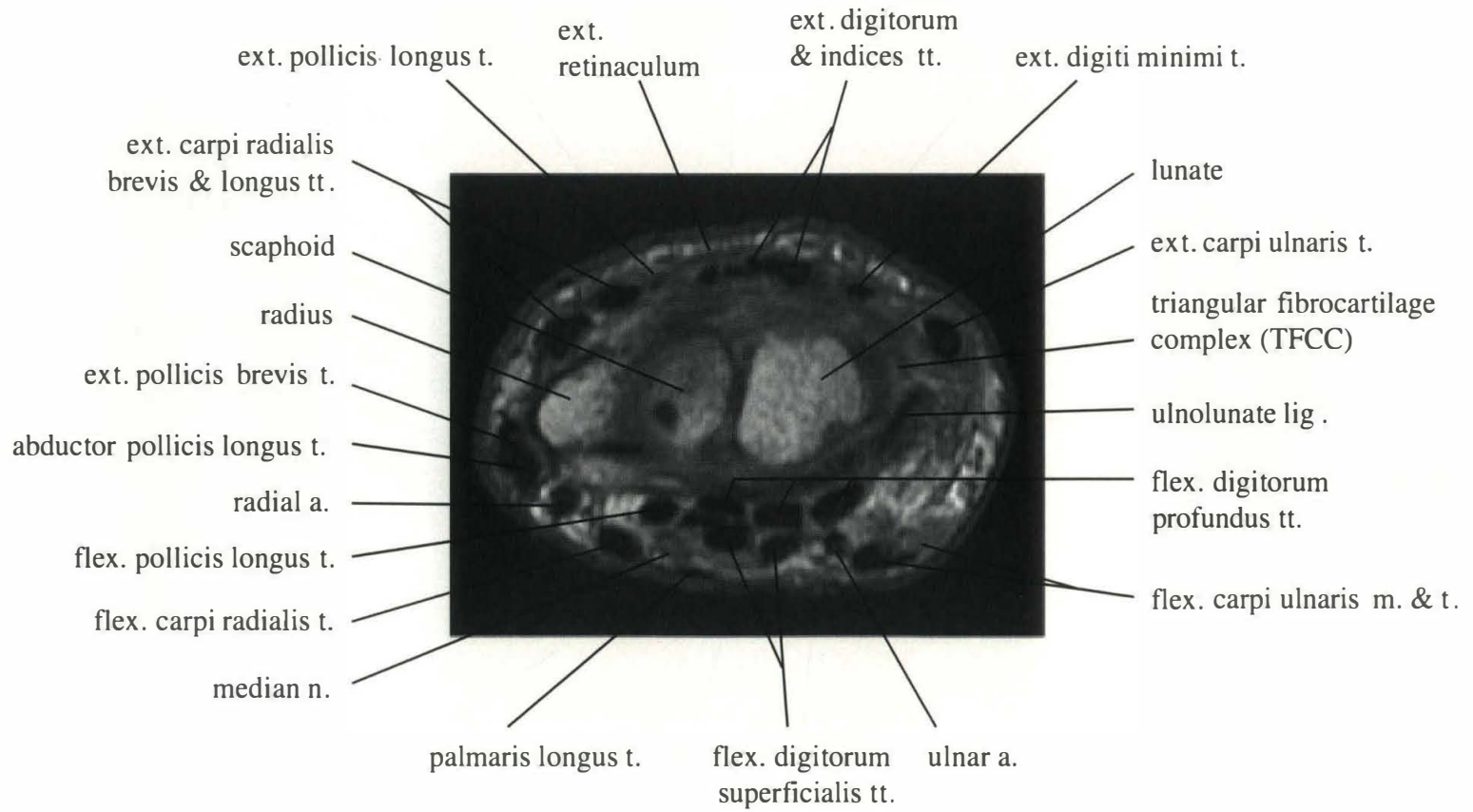
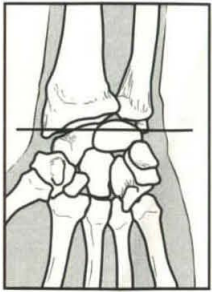
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
-Two lateral	Distal to flexor retinaculum from radial/palmar surfaces of flexor digitorum profundus muscle	Radial border of expansion of extensor digitorum muscle at level of proximal phalanx	Median N.
-Two medial	Contiguous sides of tendons for digits III/IV and IV/V	Radial border of expansion of extensor digitorum muscle at level of proximal phalanx	Deep branch of ulnar N.

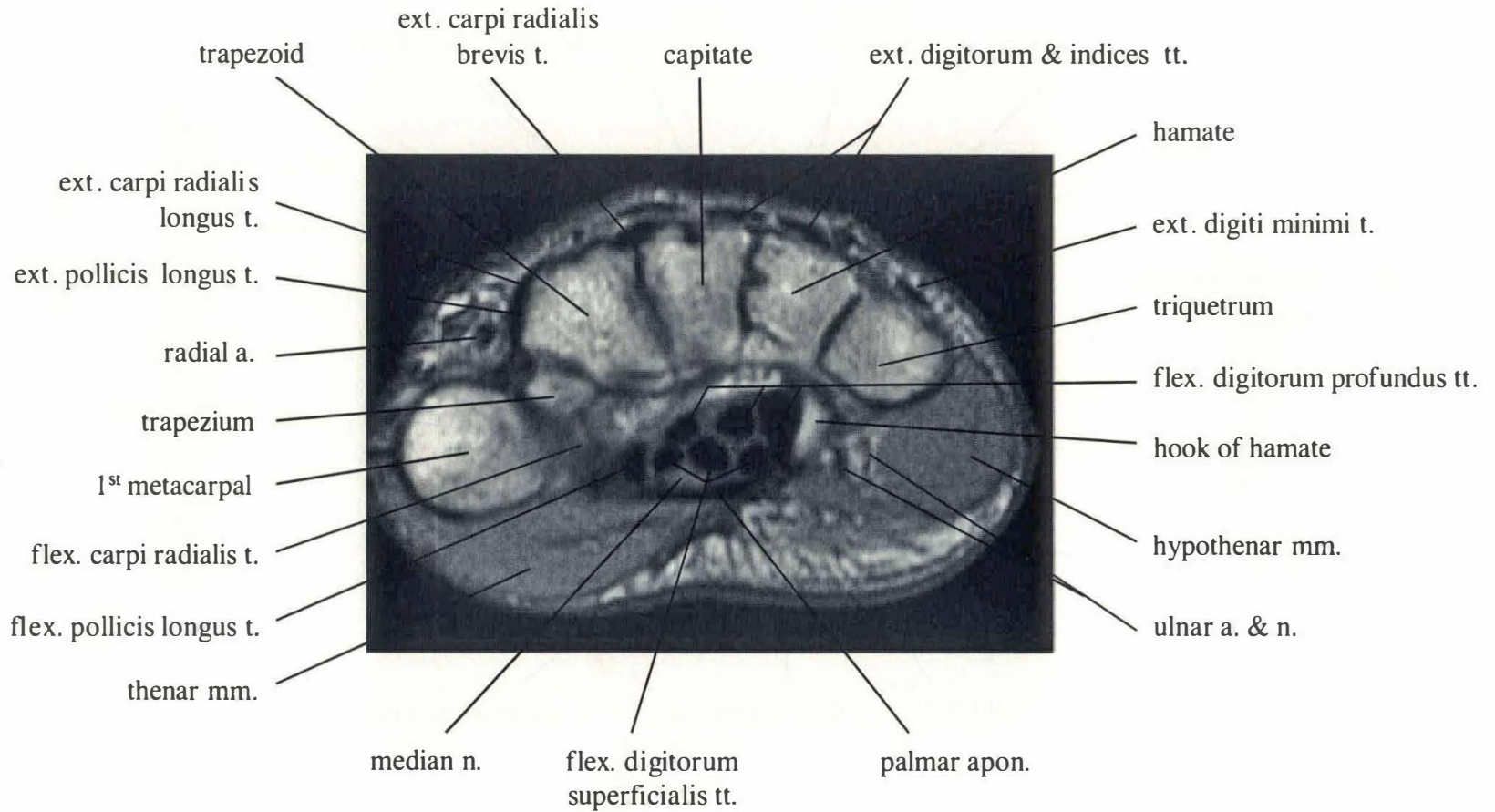
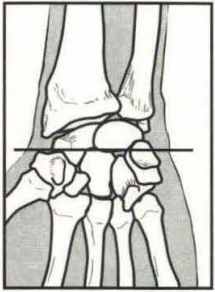
WRIST AND HAND: AXIAL ANATOMY

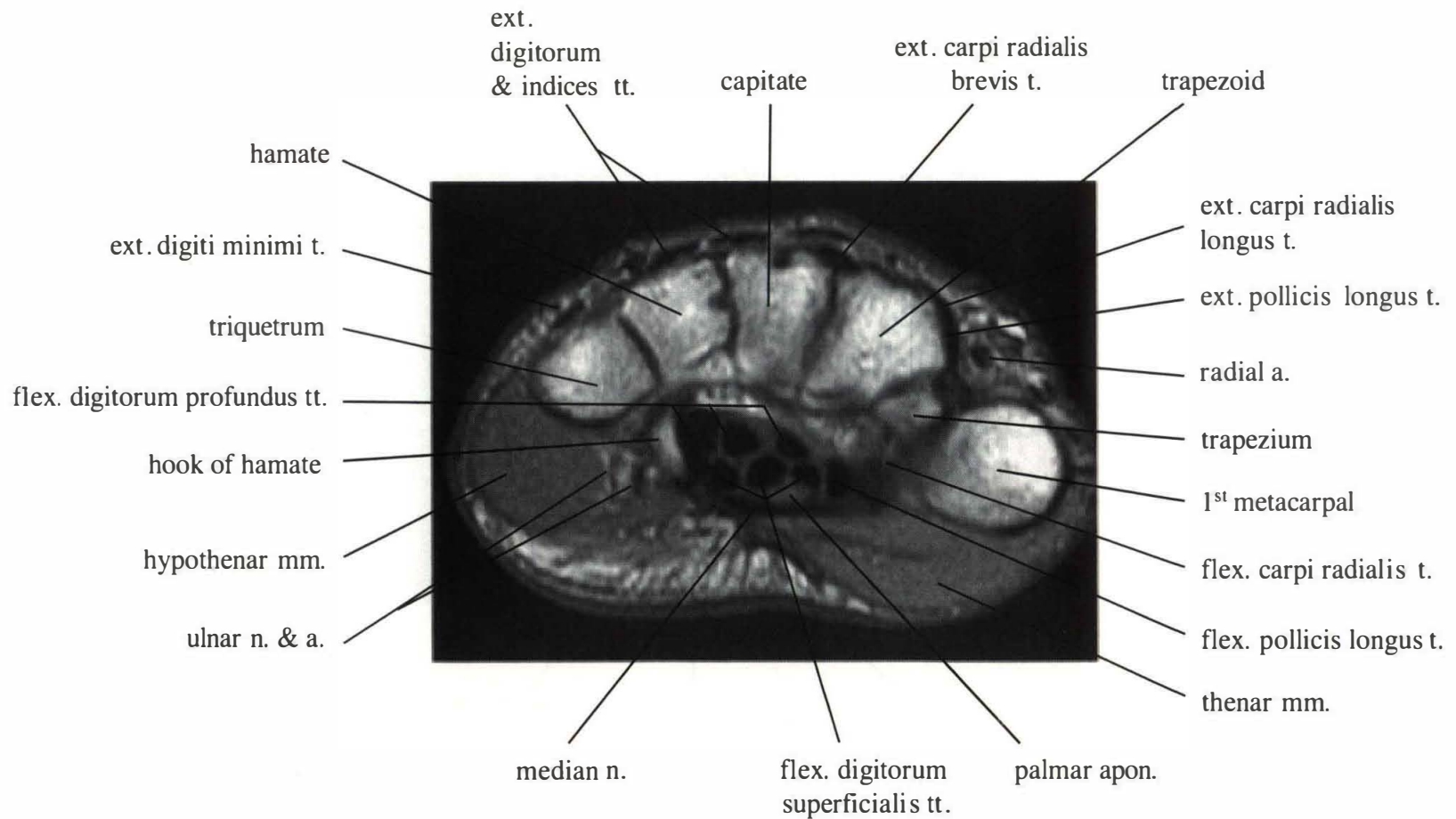
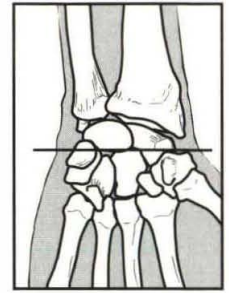


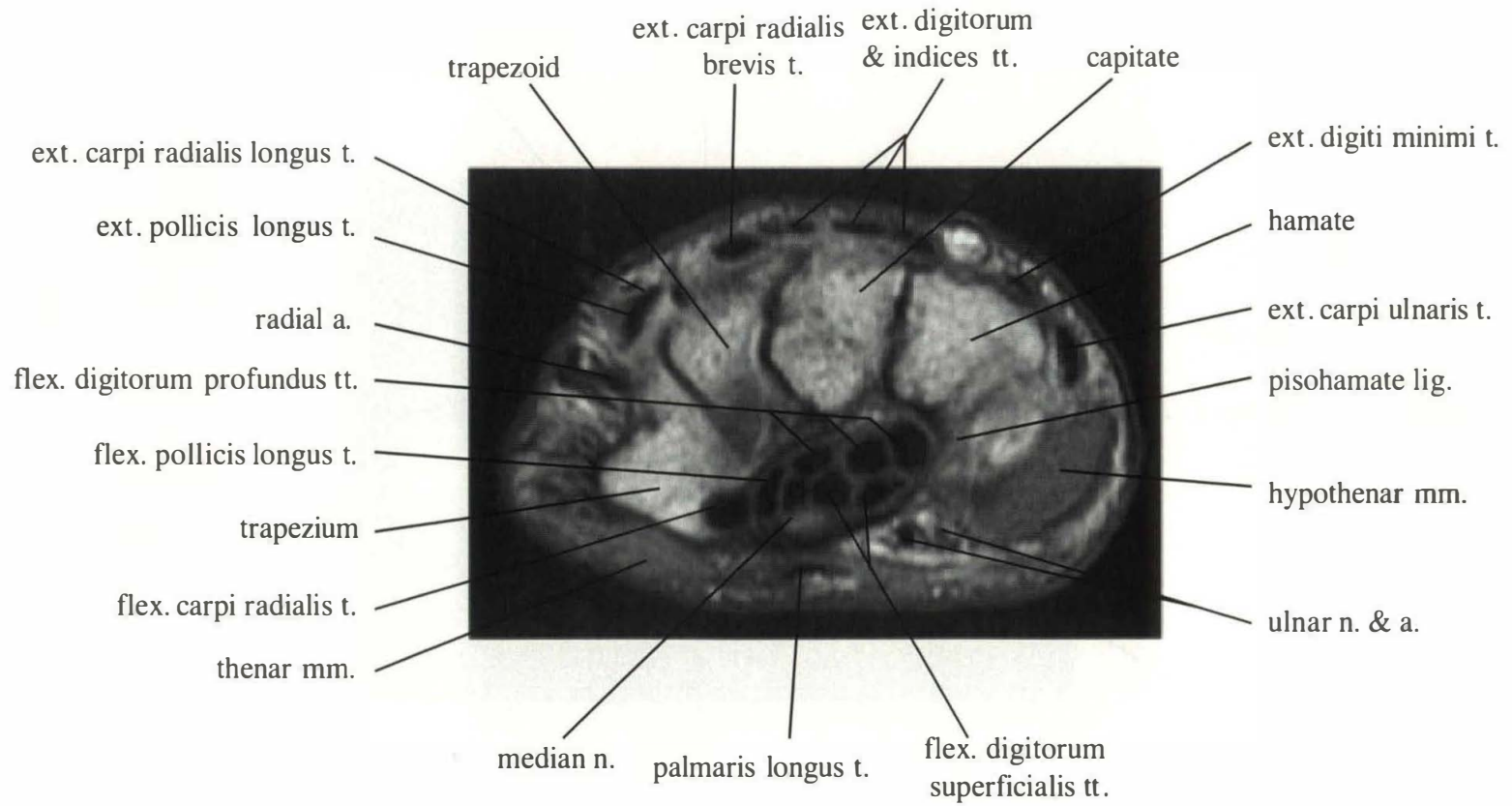
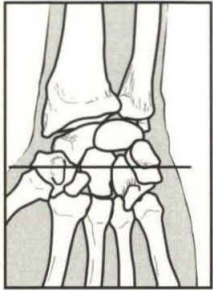


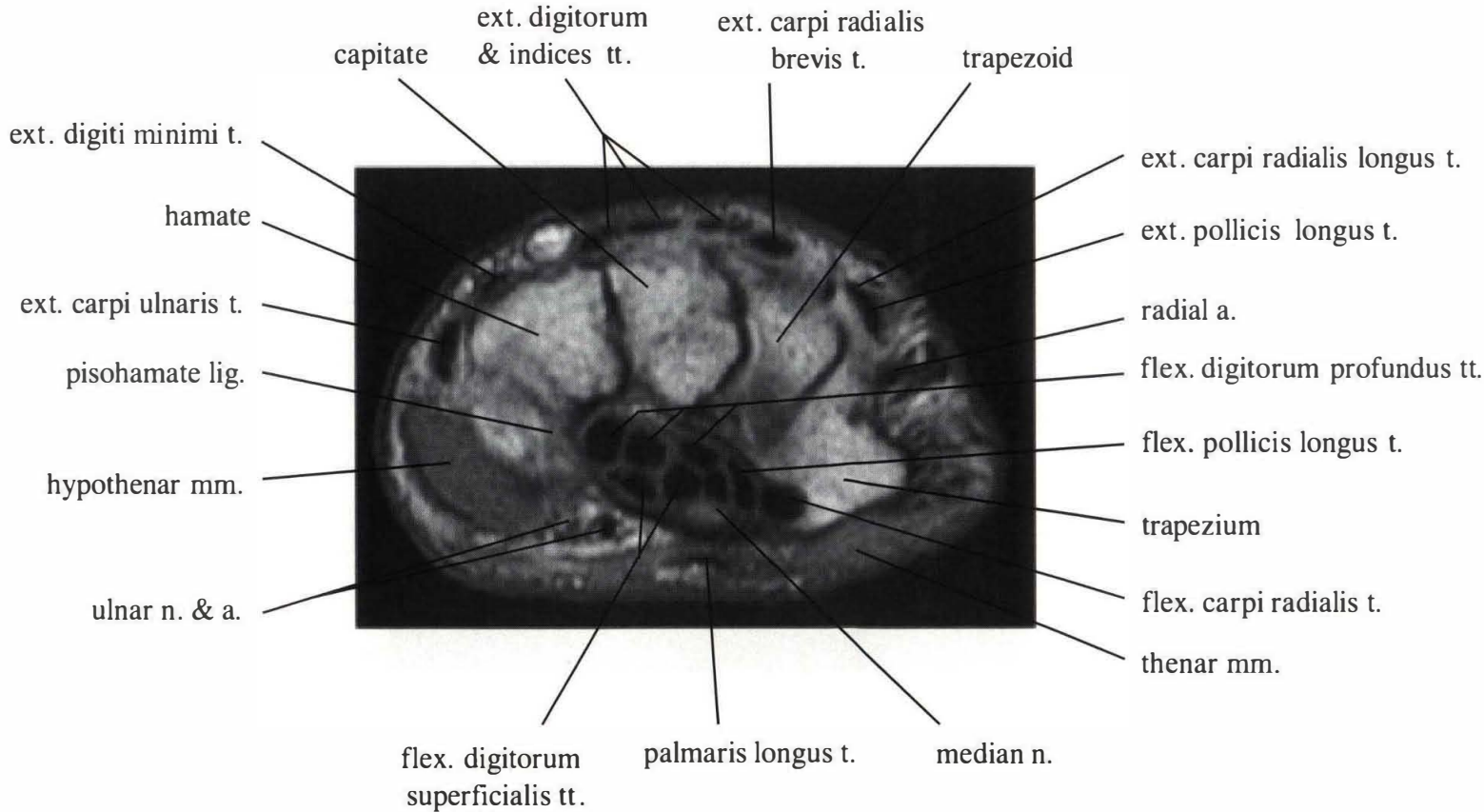
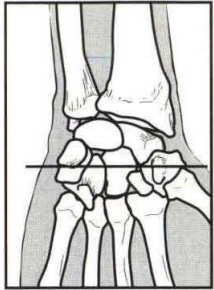


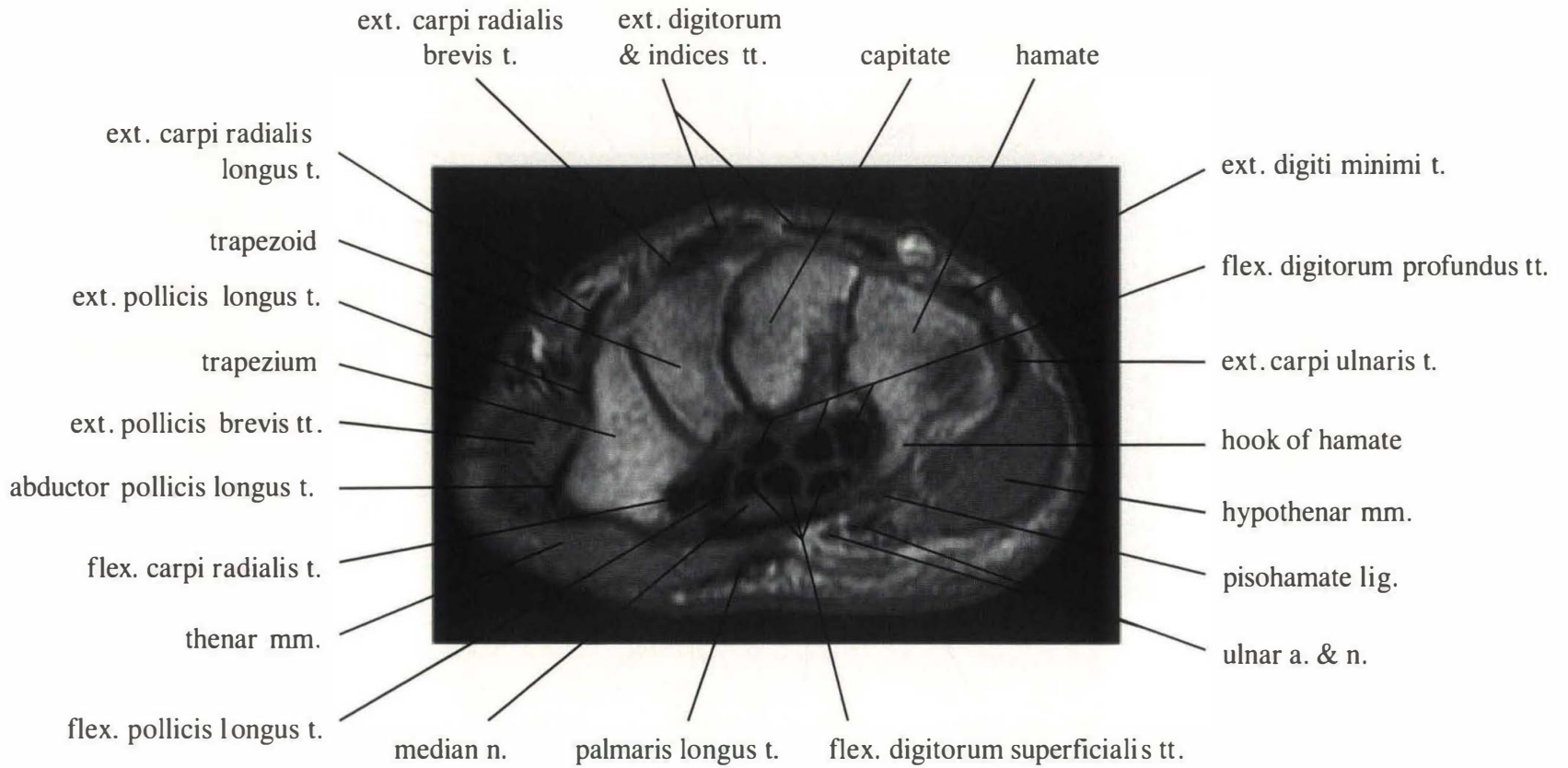
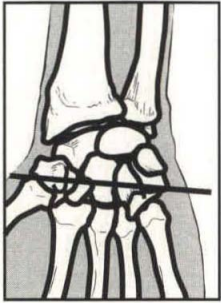


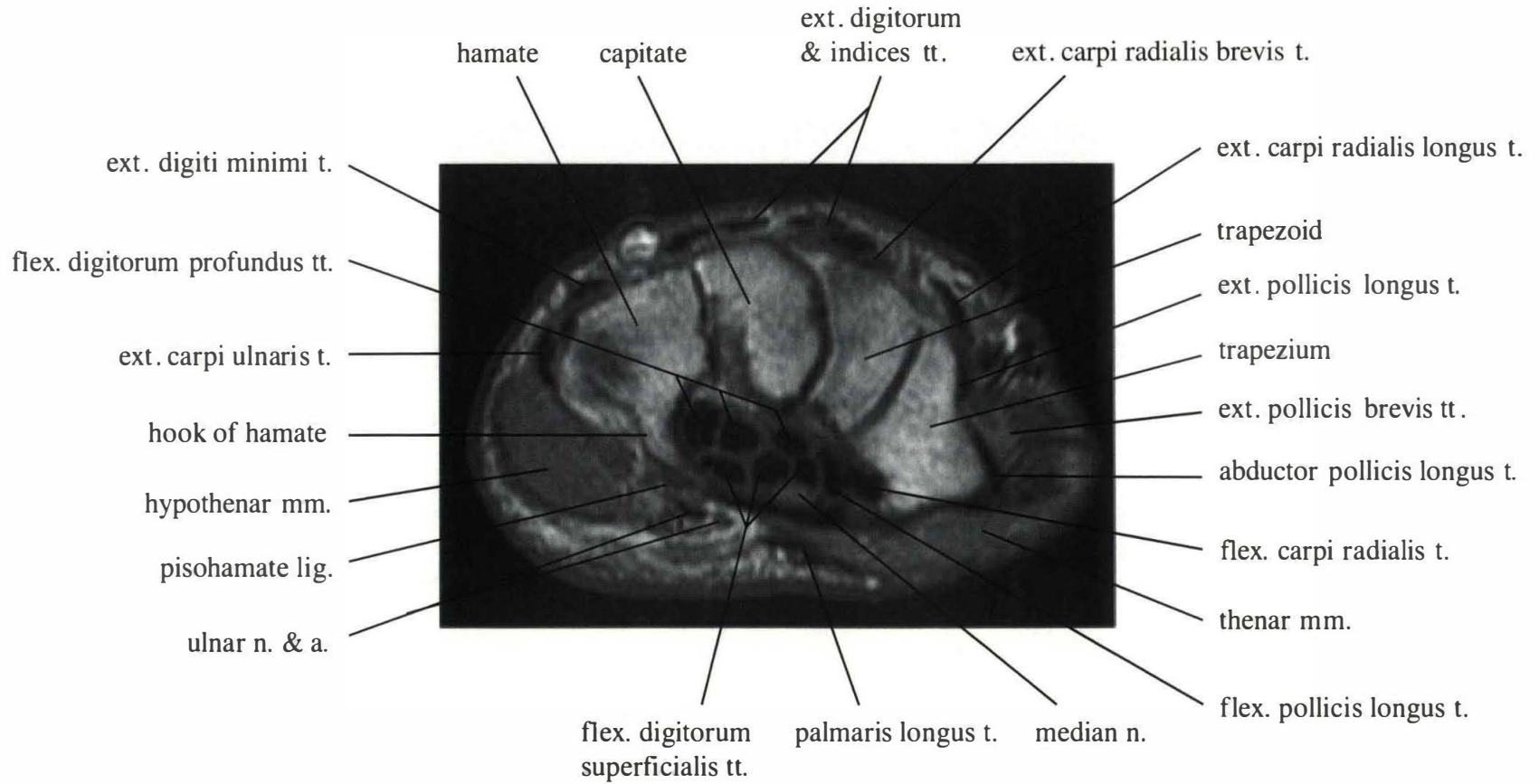
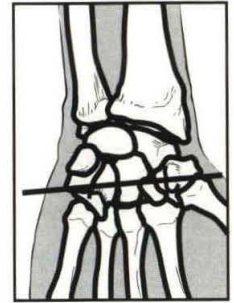


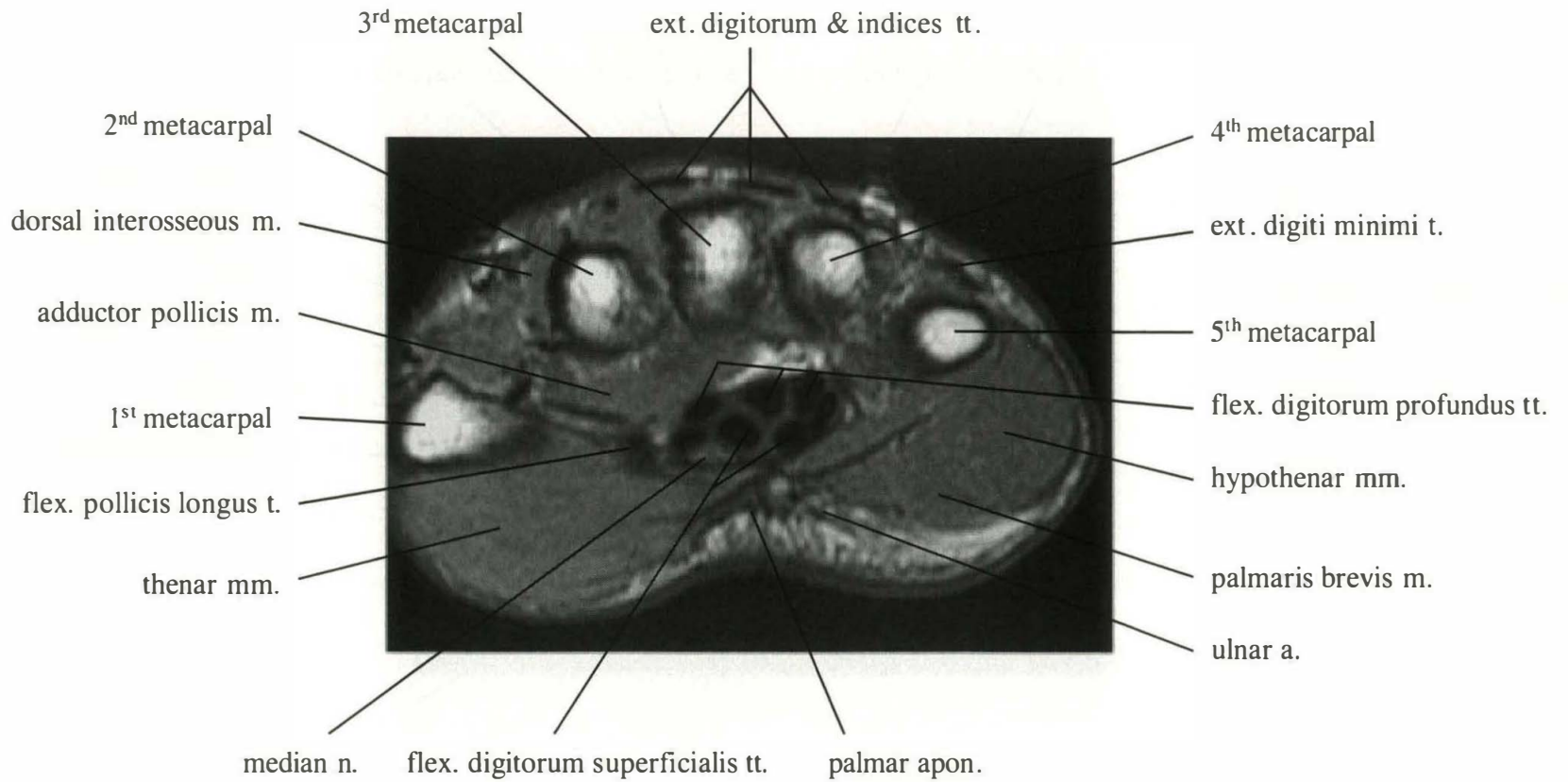
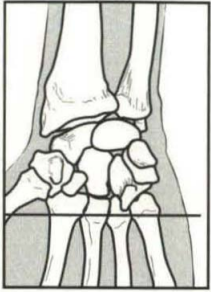


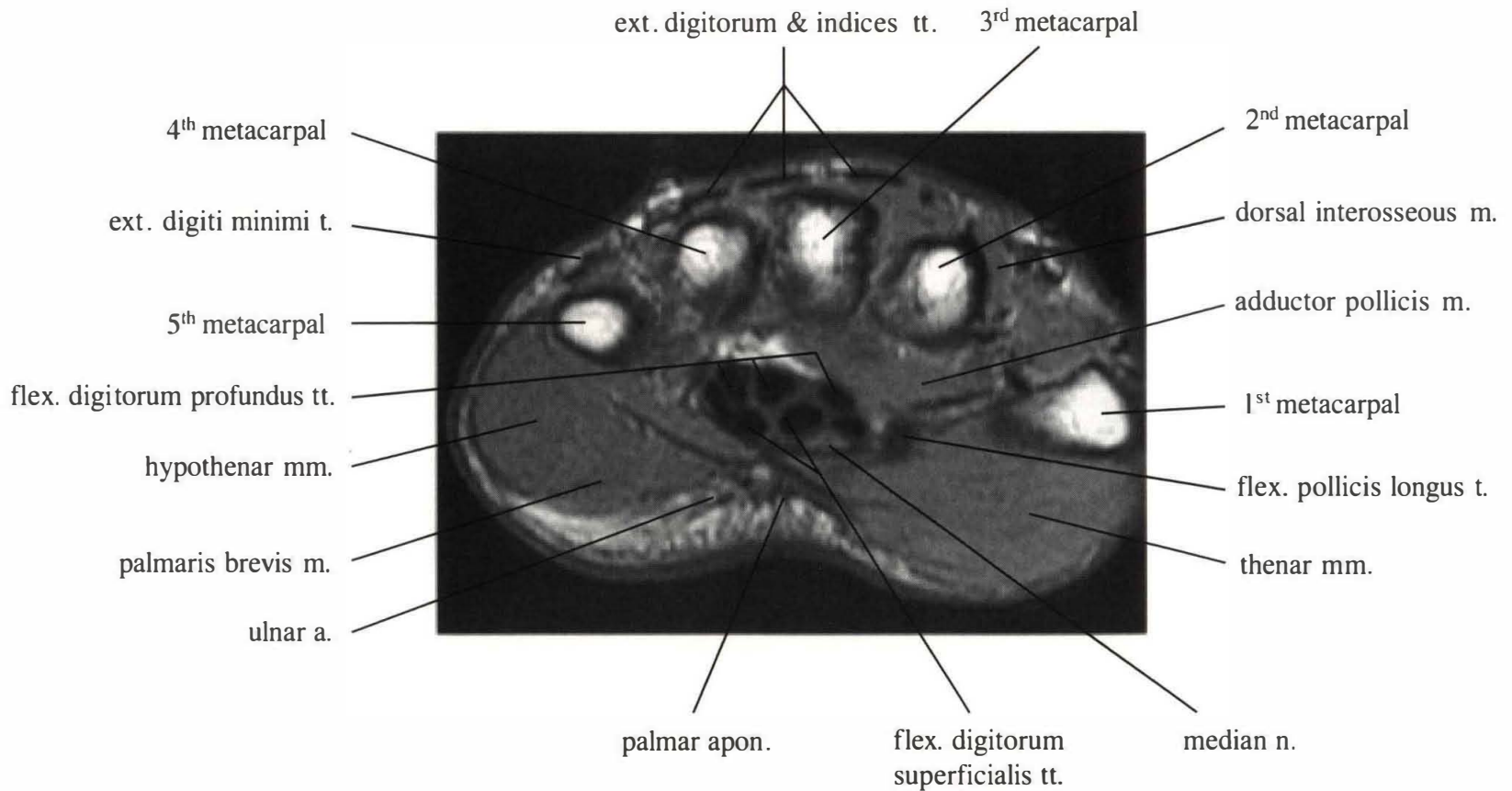
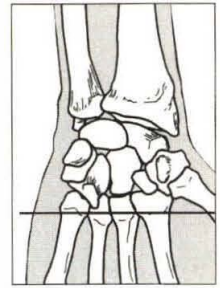




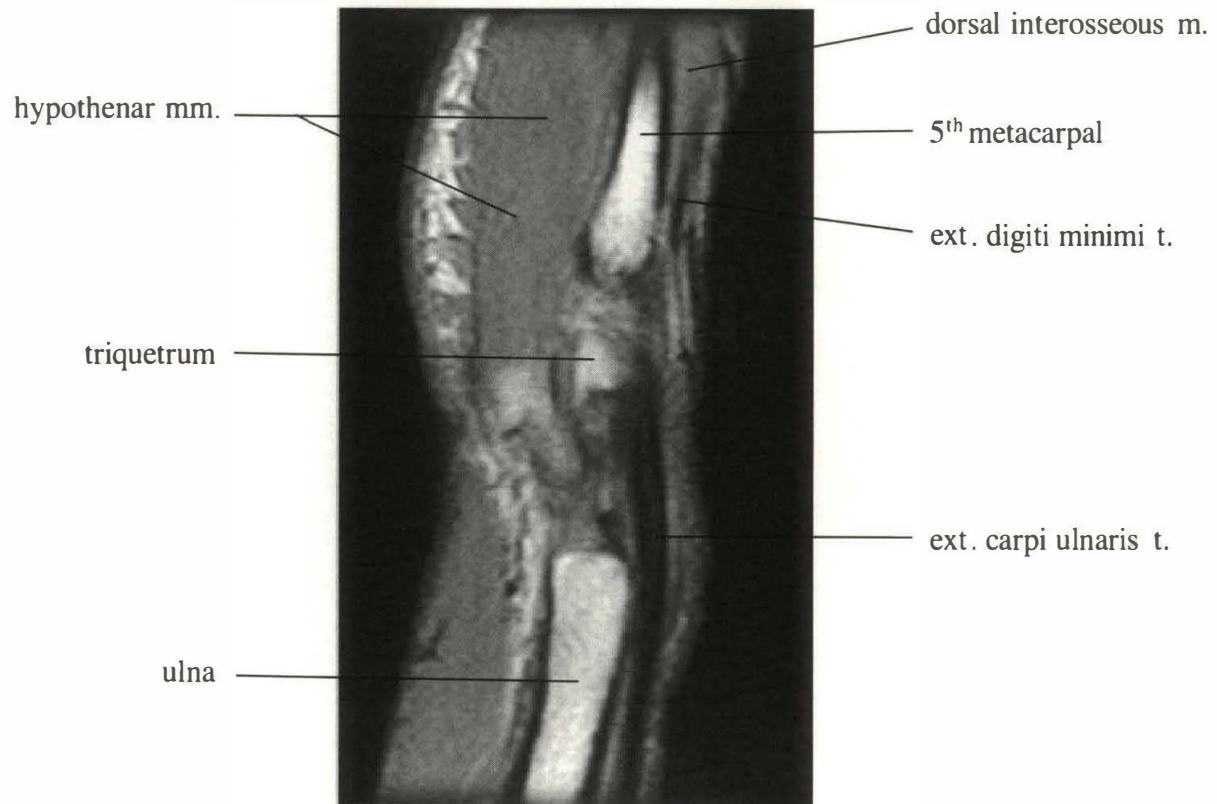
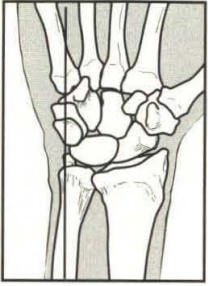


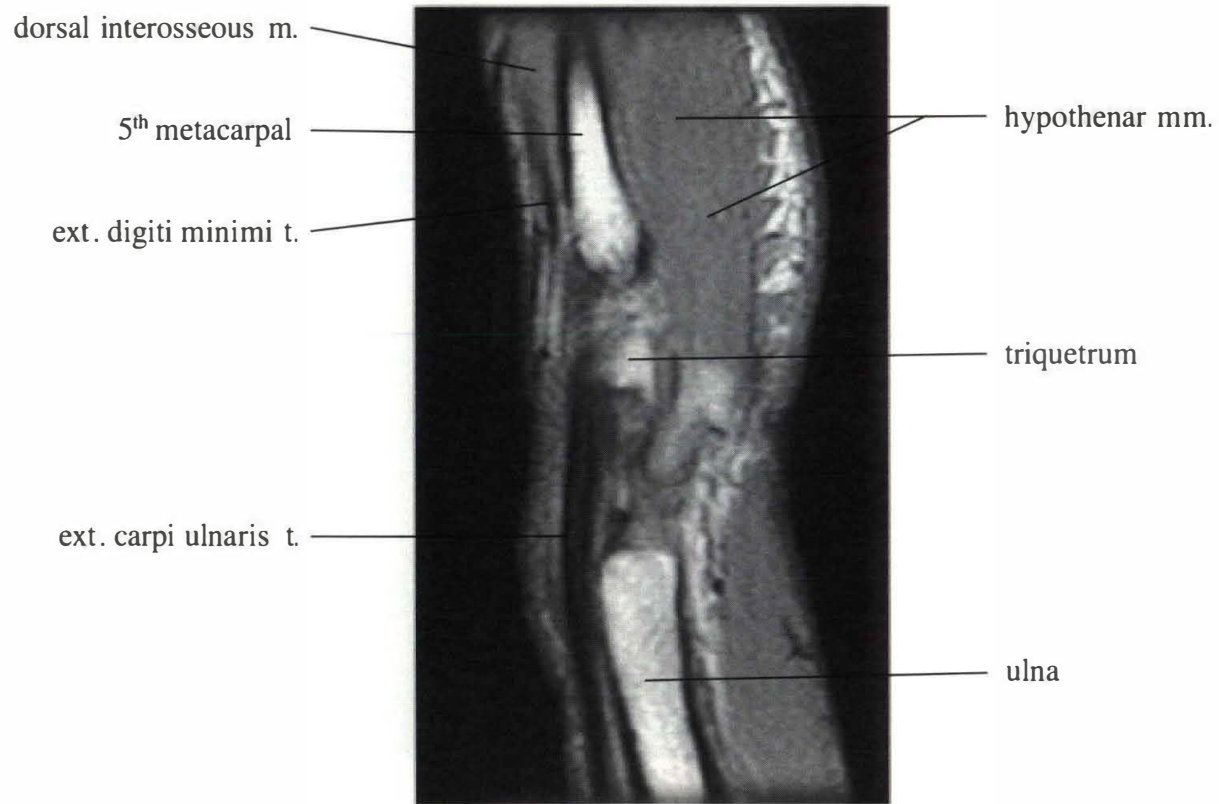
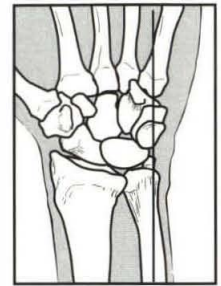


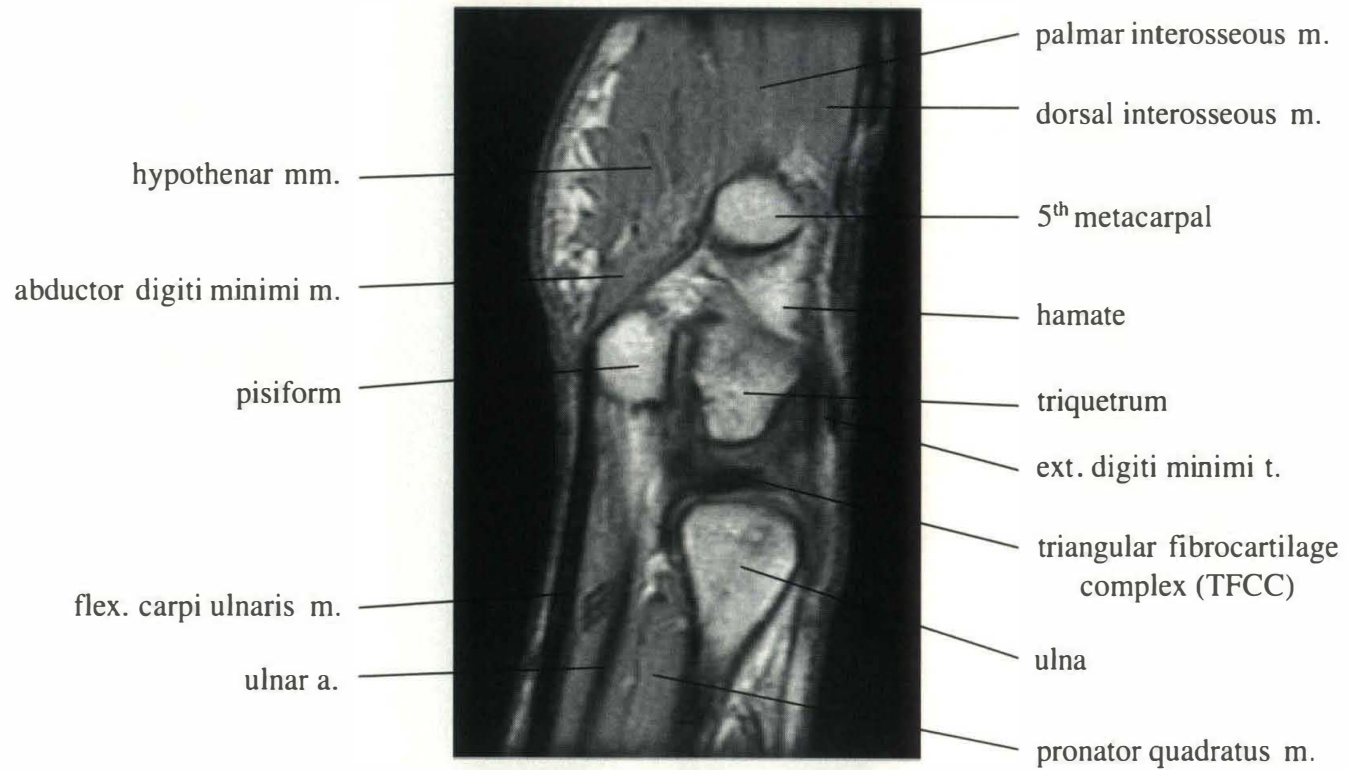
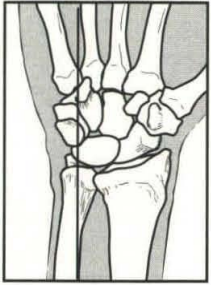


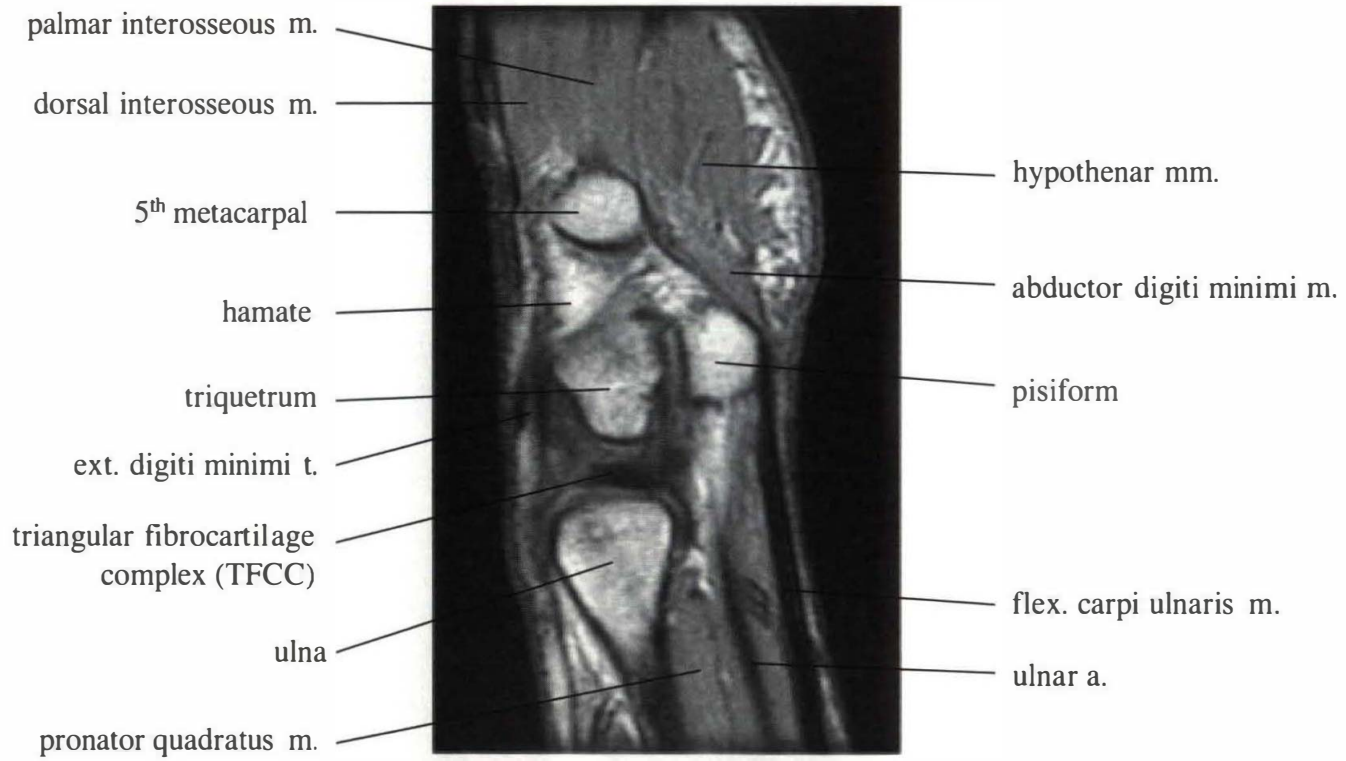
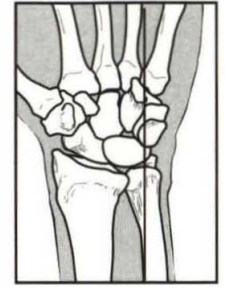


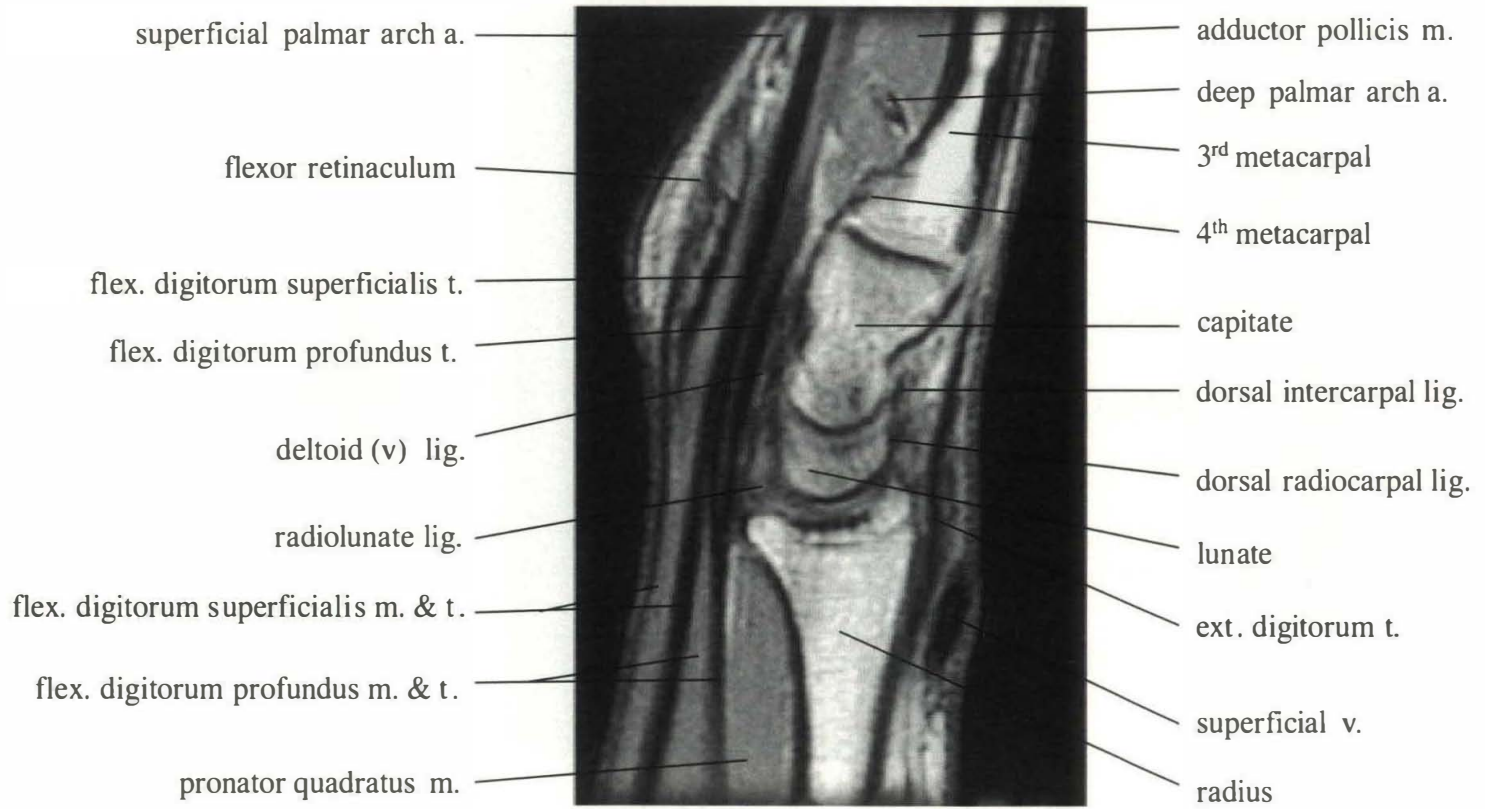
THE WRIST AND HAND: SAGITTAL ANATOMY

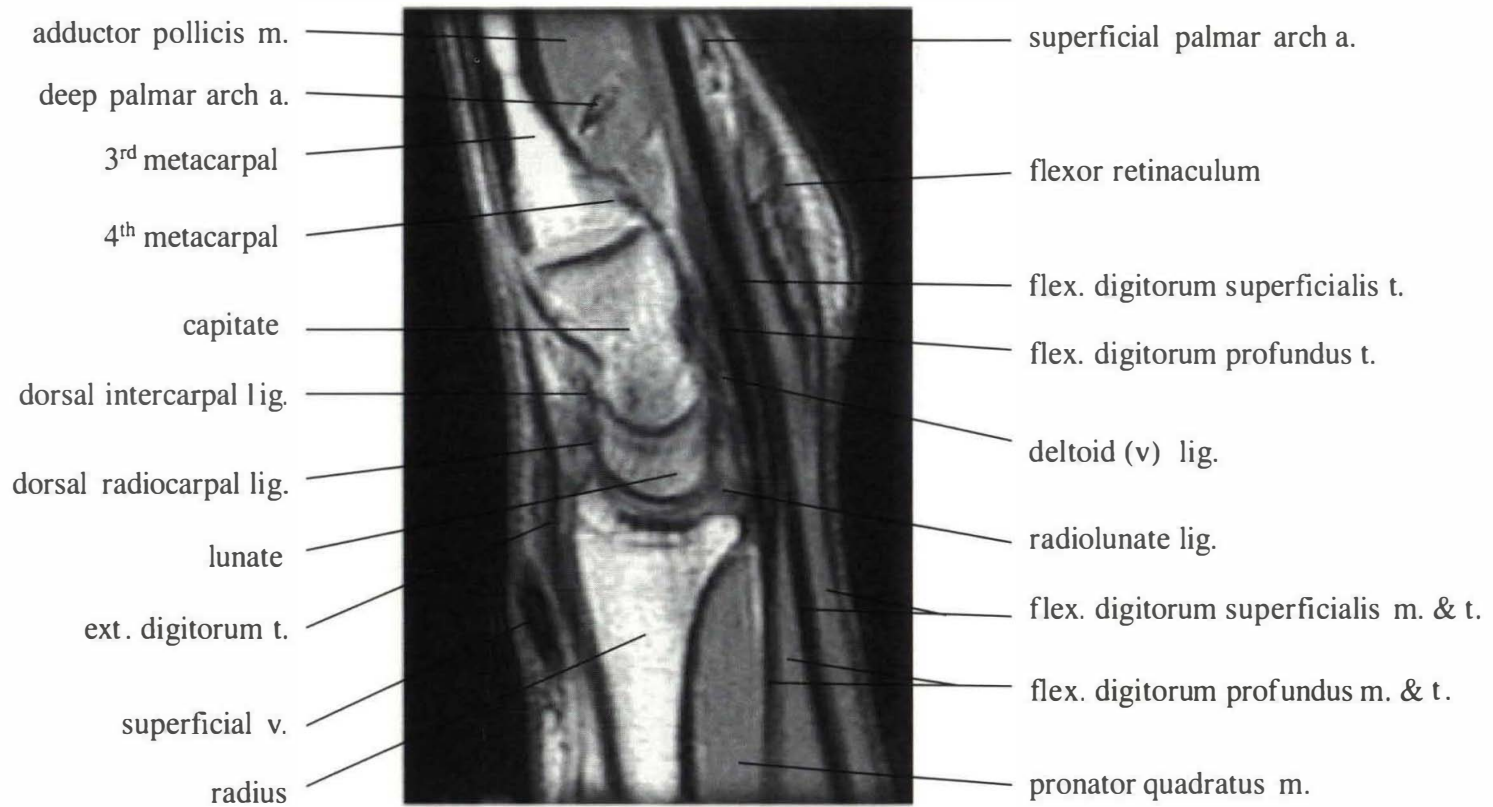
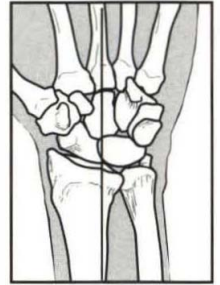


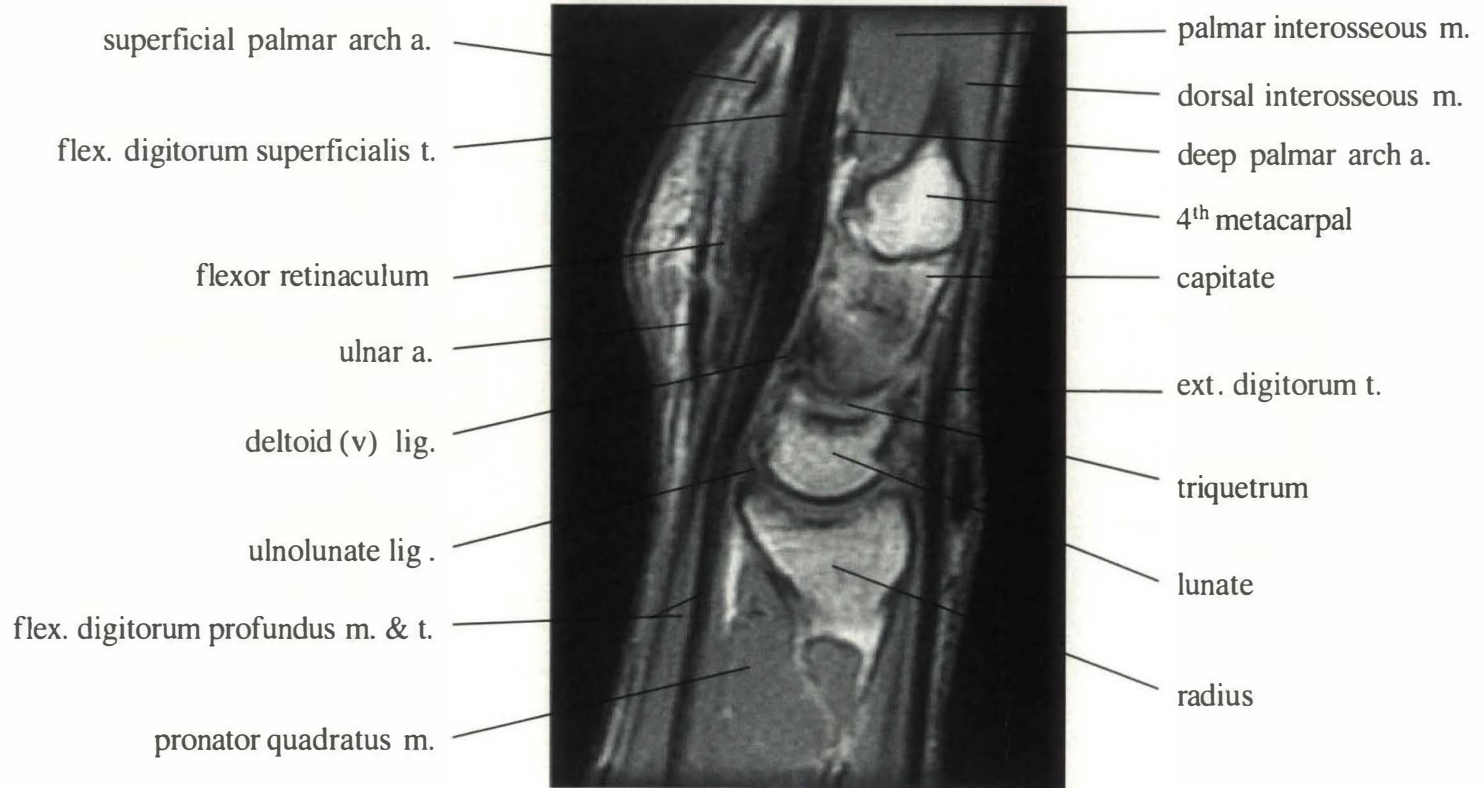
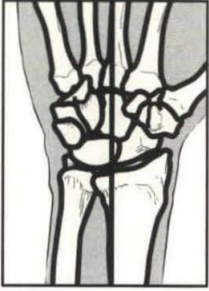


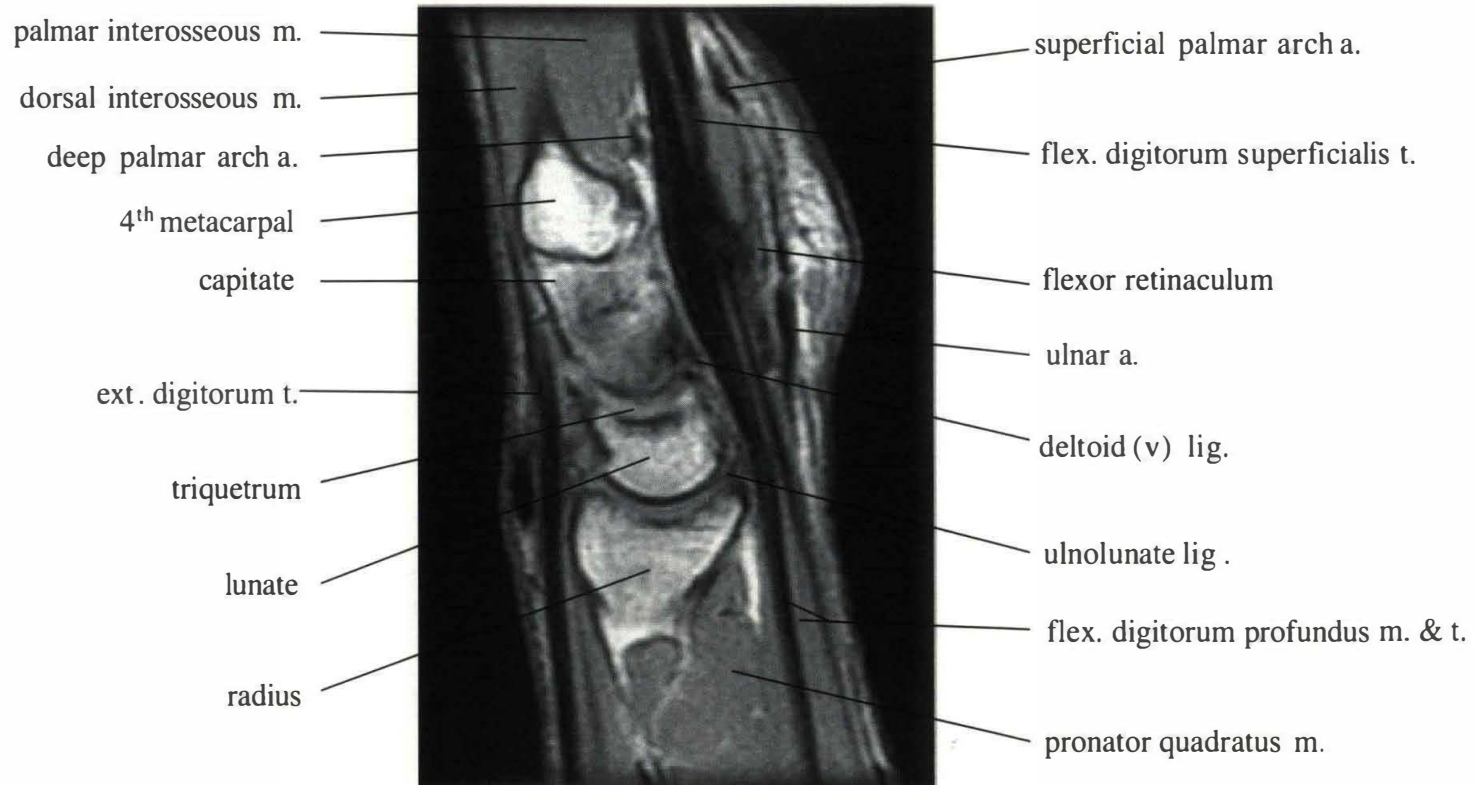
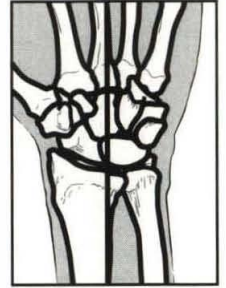


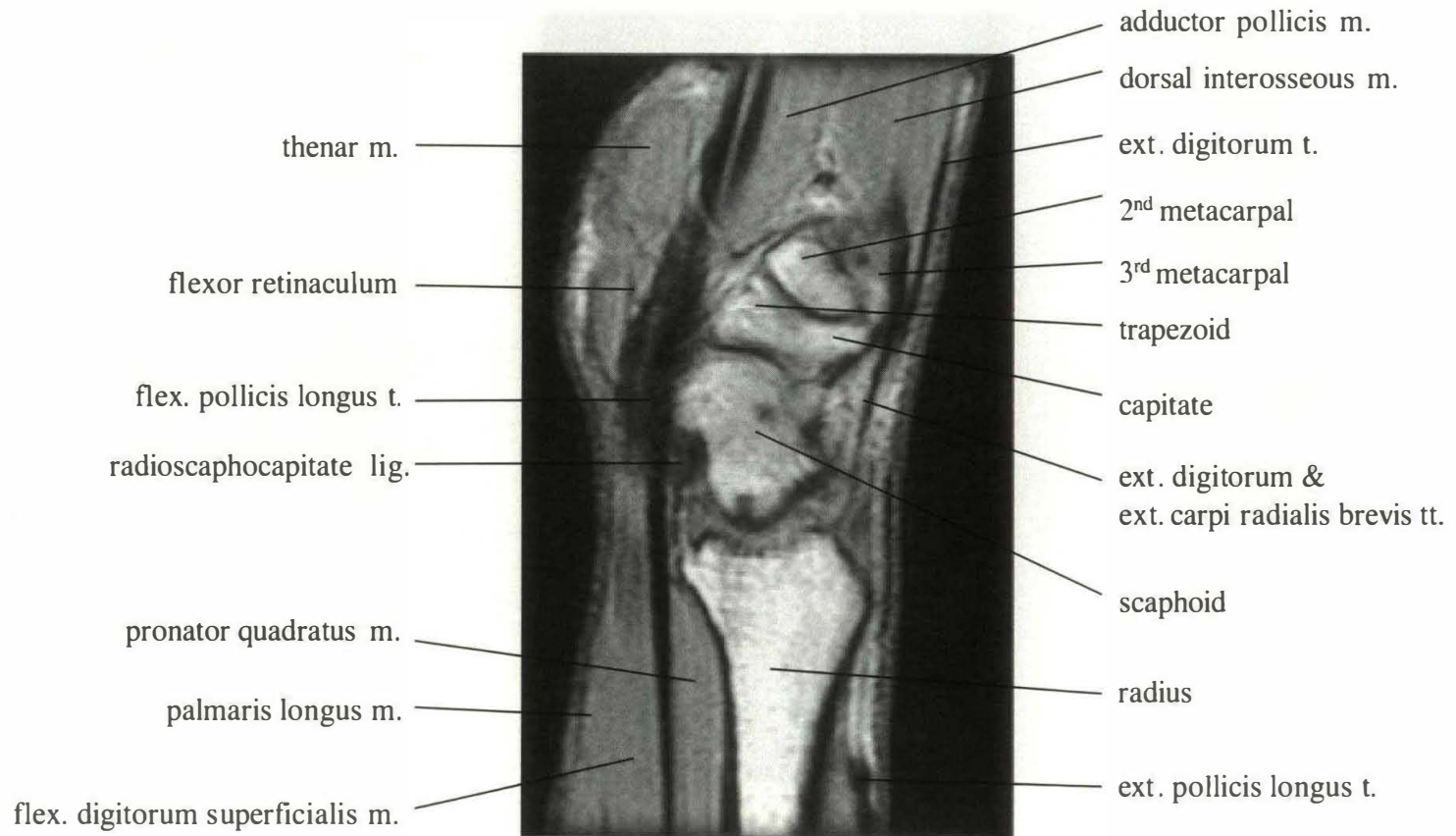


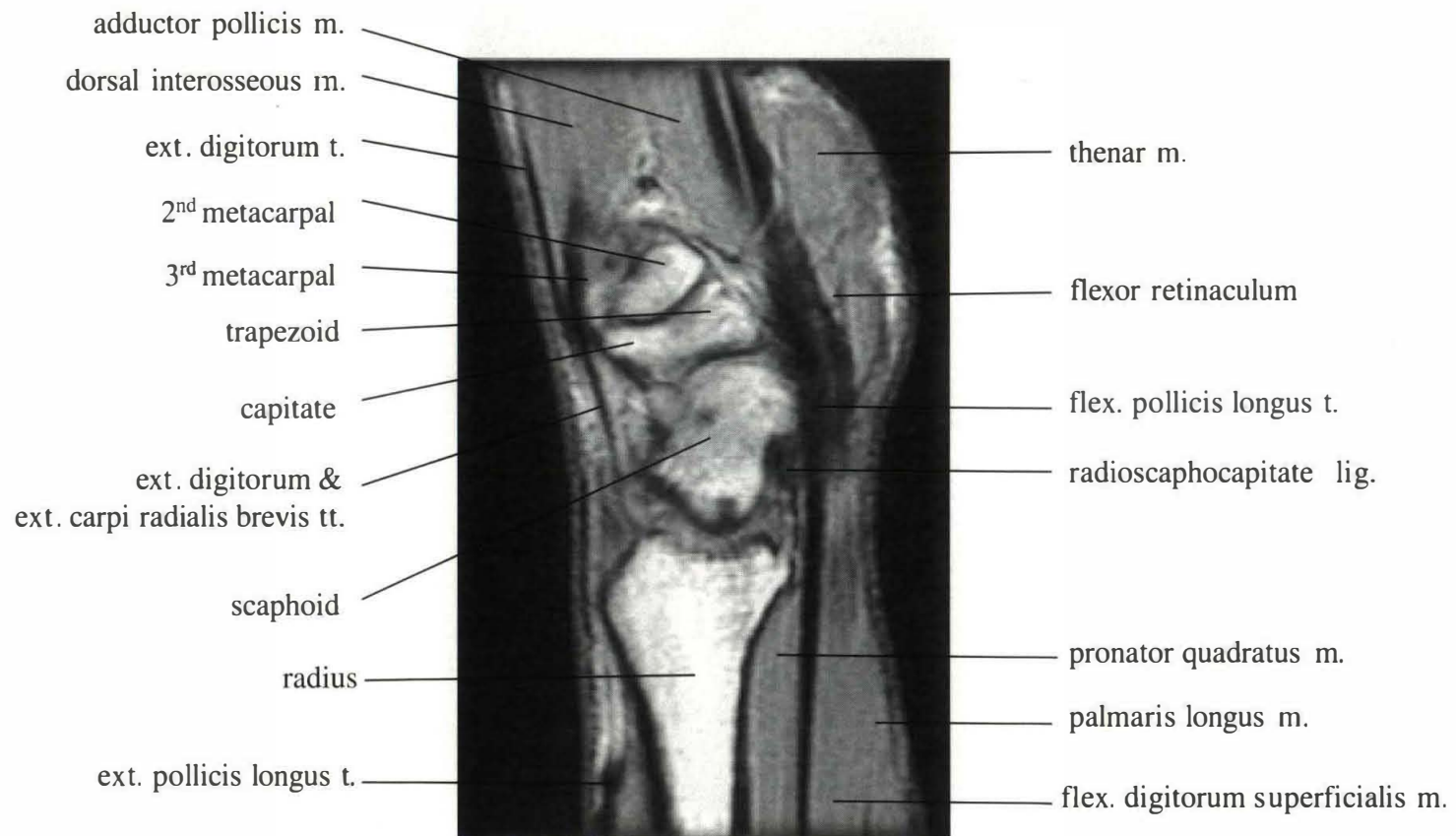
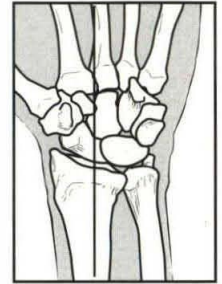


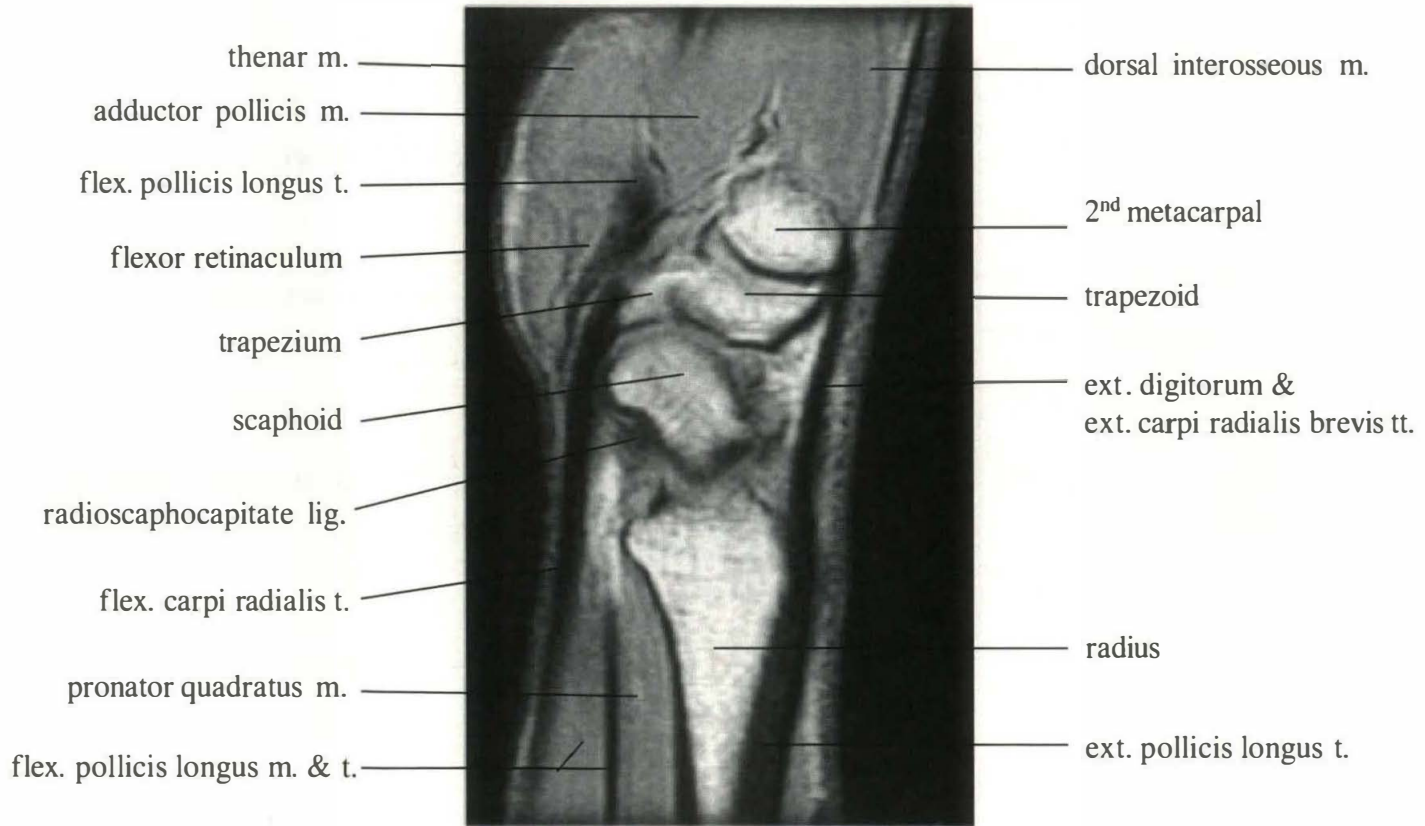
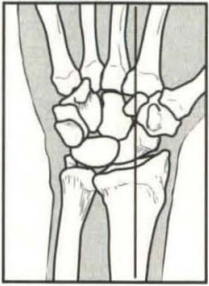


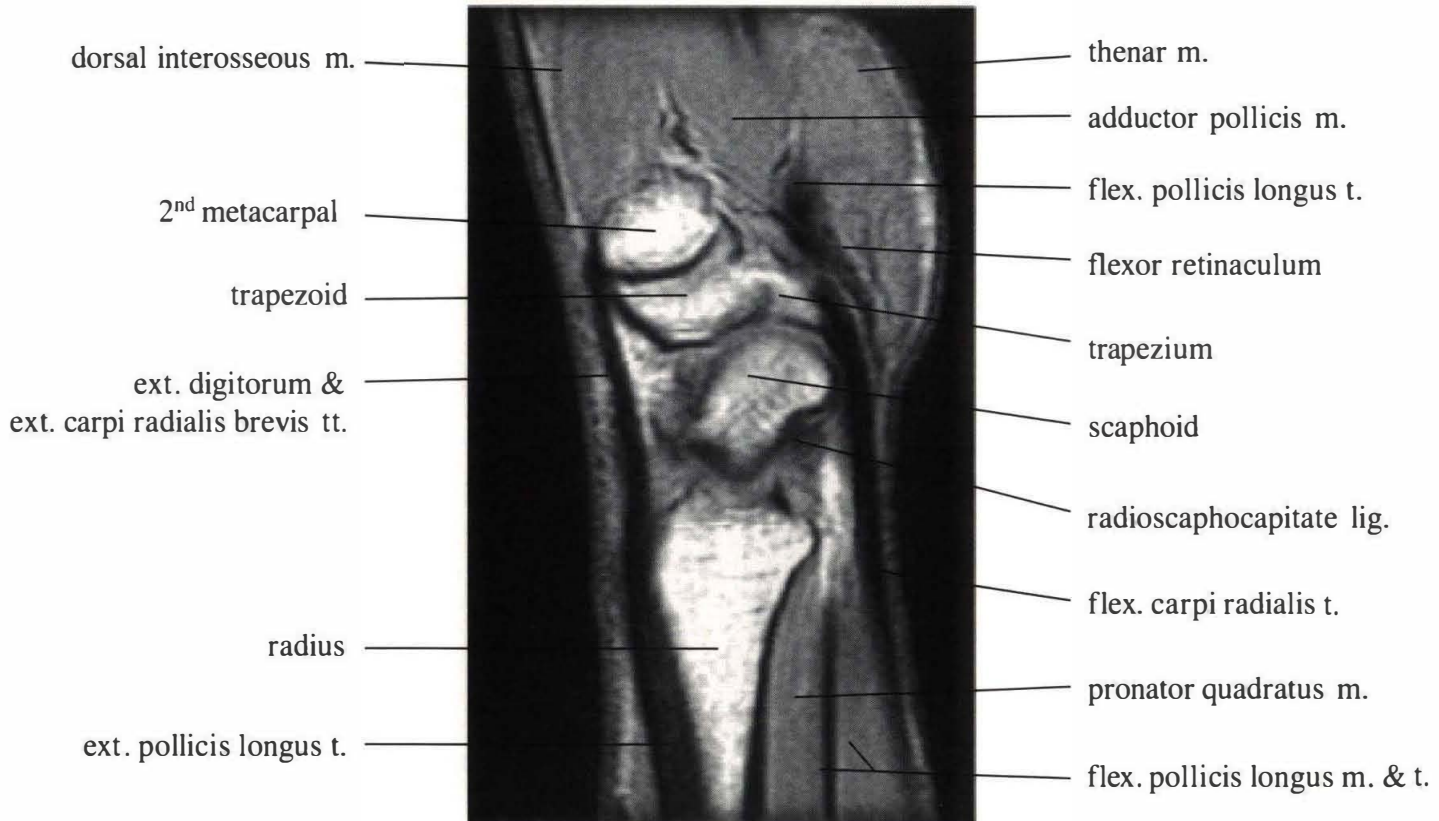
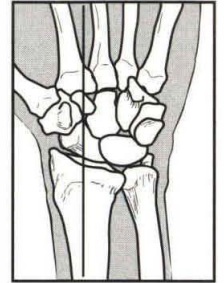




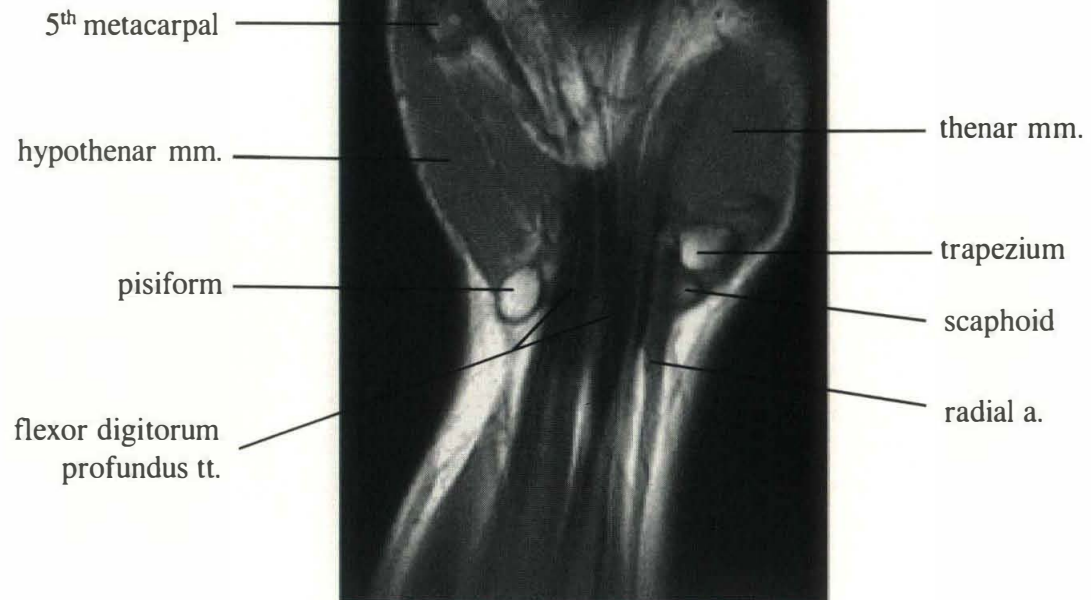
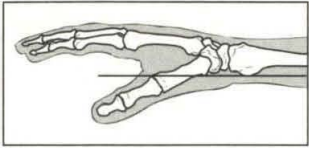


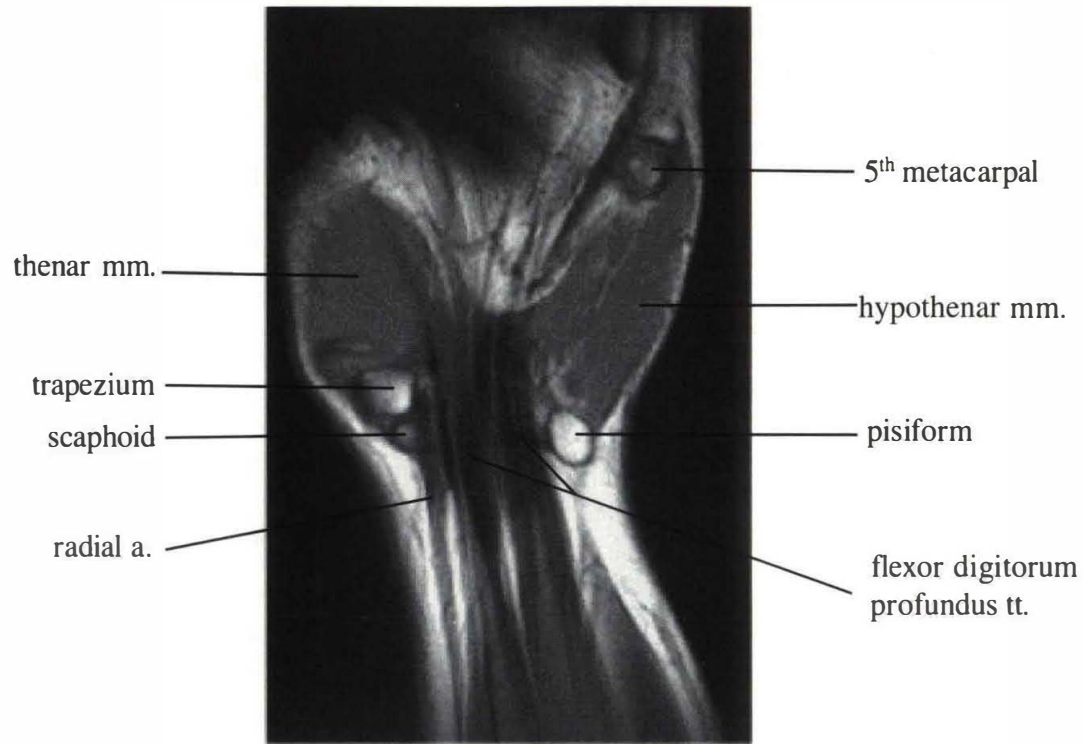
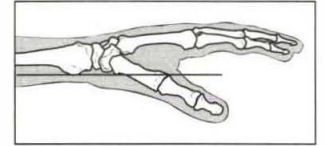


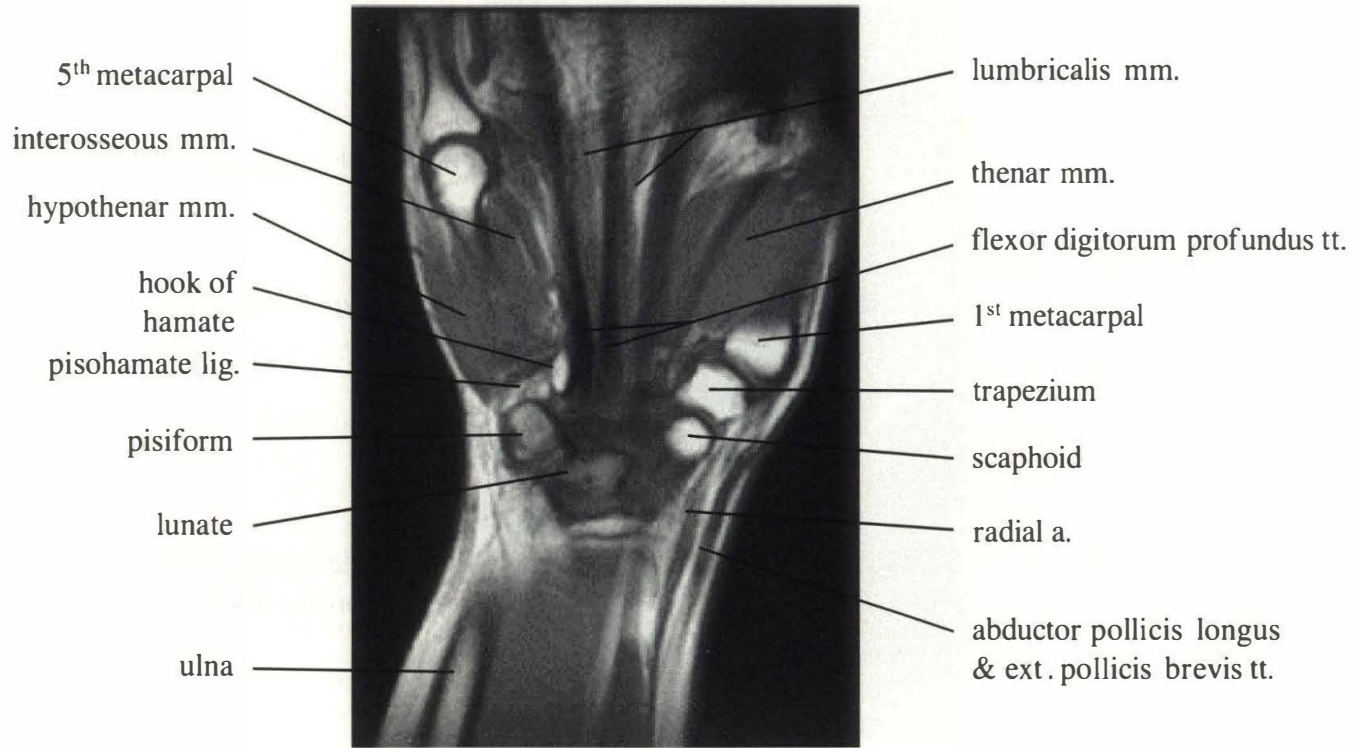
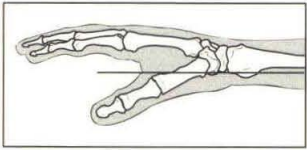




THE WRIST AND HAND: CORONAL ANATOMY







5th metacarpal

interosseous mm.

hypothenar mm.

hook of hamate

pisohamate lig.

pisiform

lunate

ulna

lumbricalis mm.

thenar mm.

flexor digitorum profundus tt.

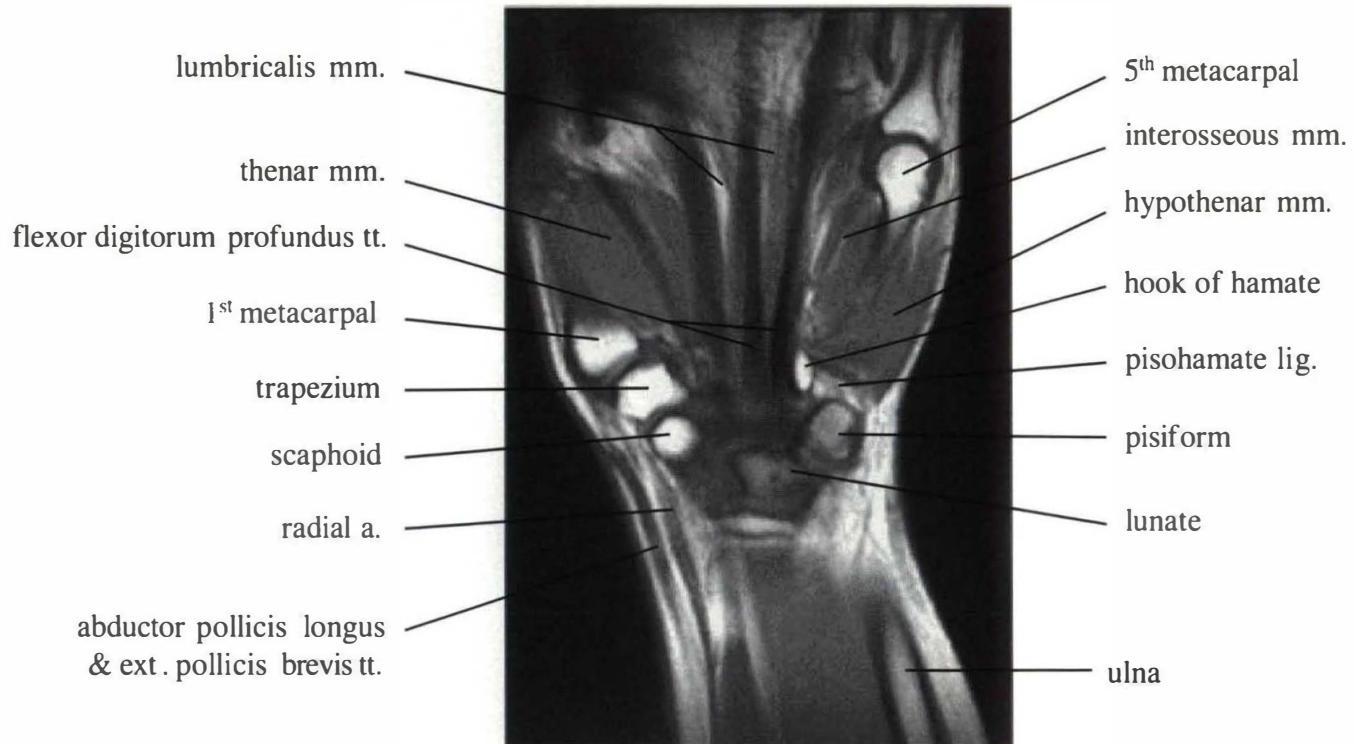
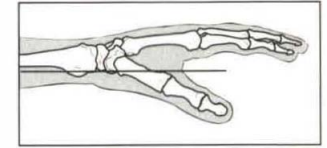
1st metacarpal

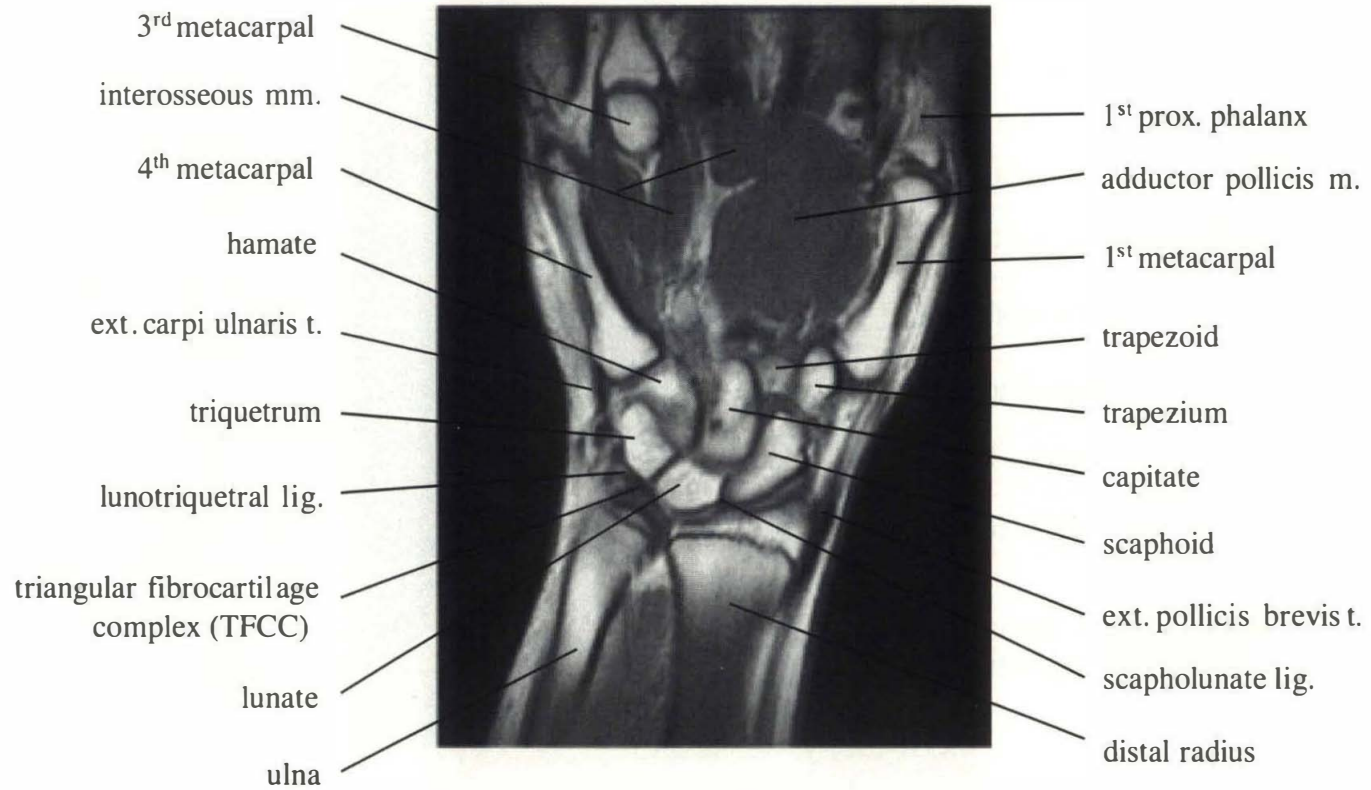
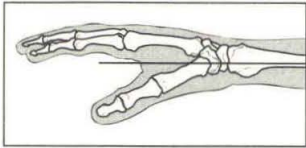
trapezium

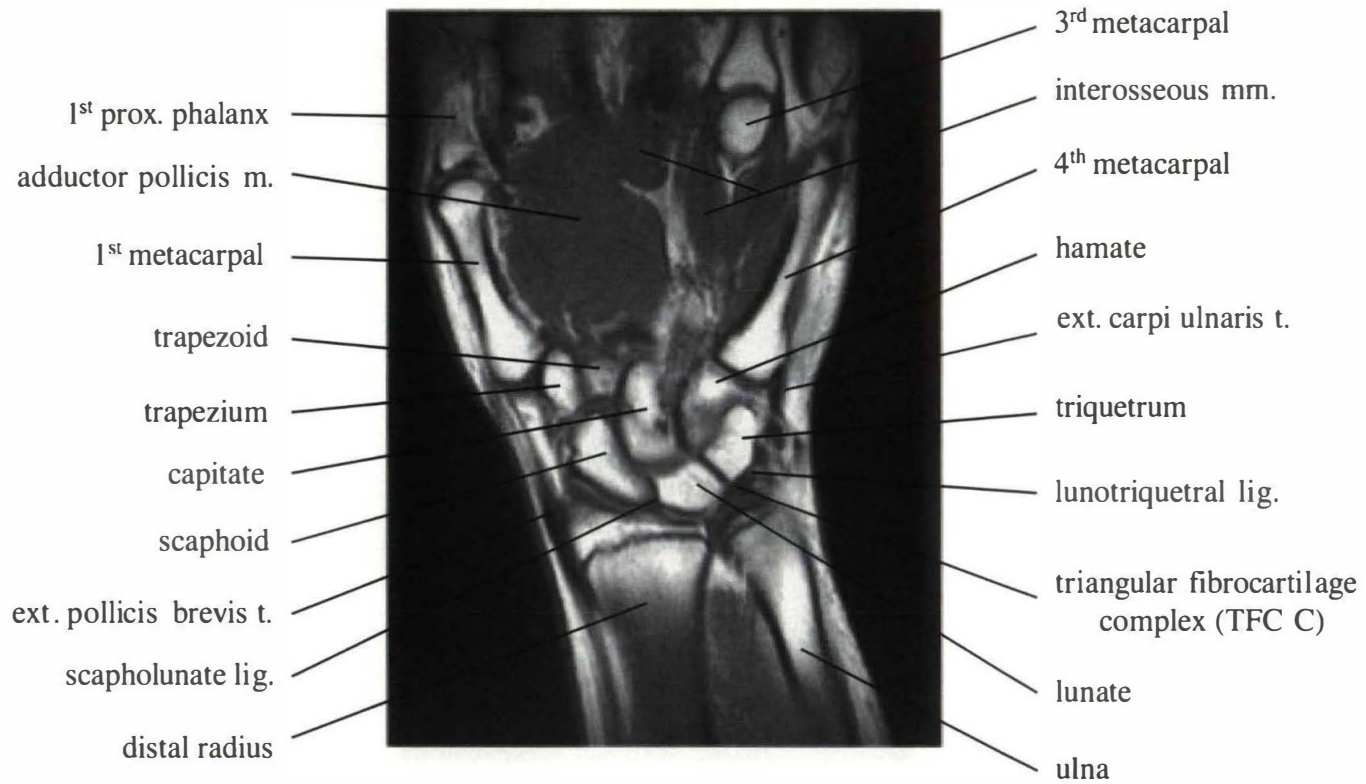
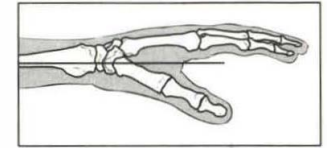
scaphoid

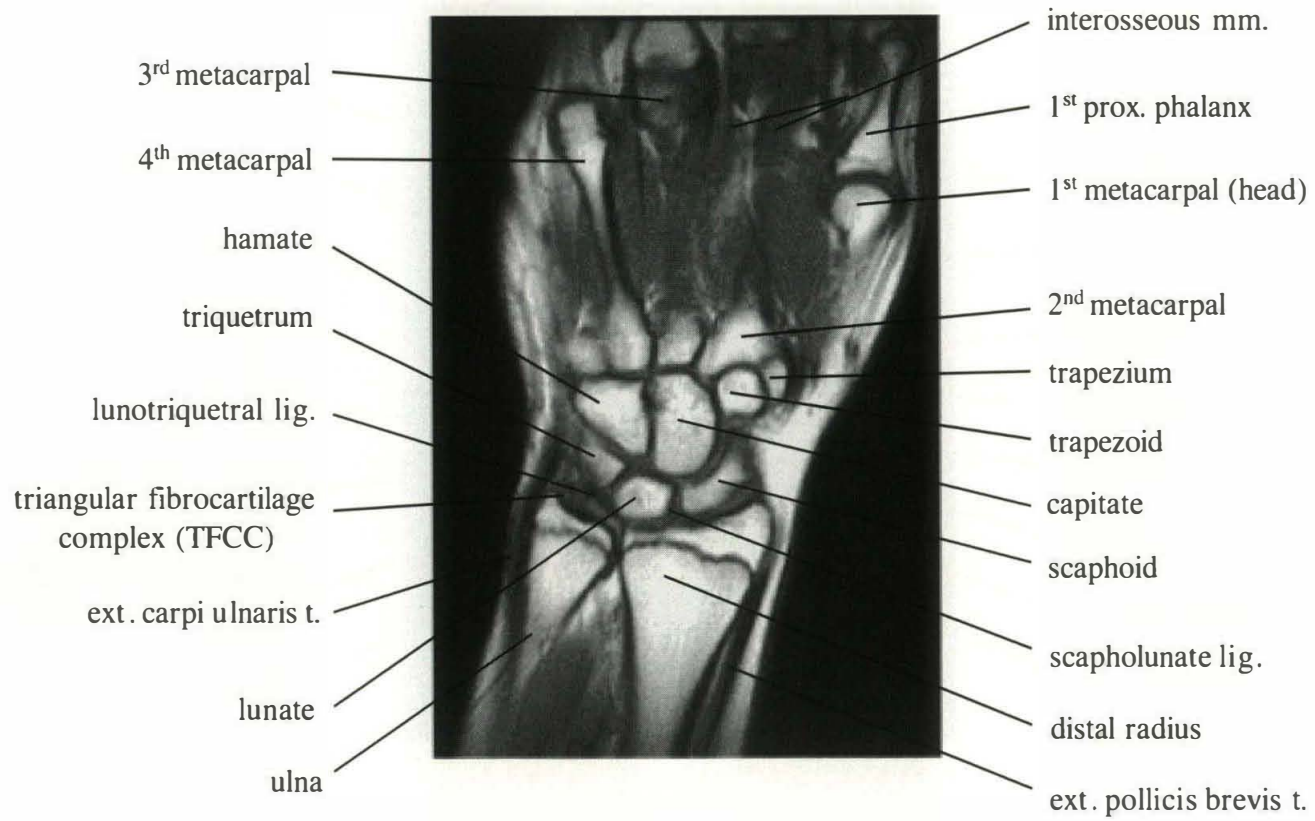
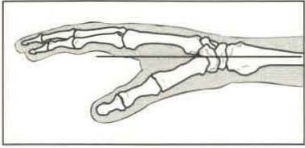
radial a.

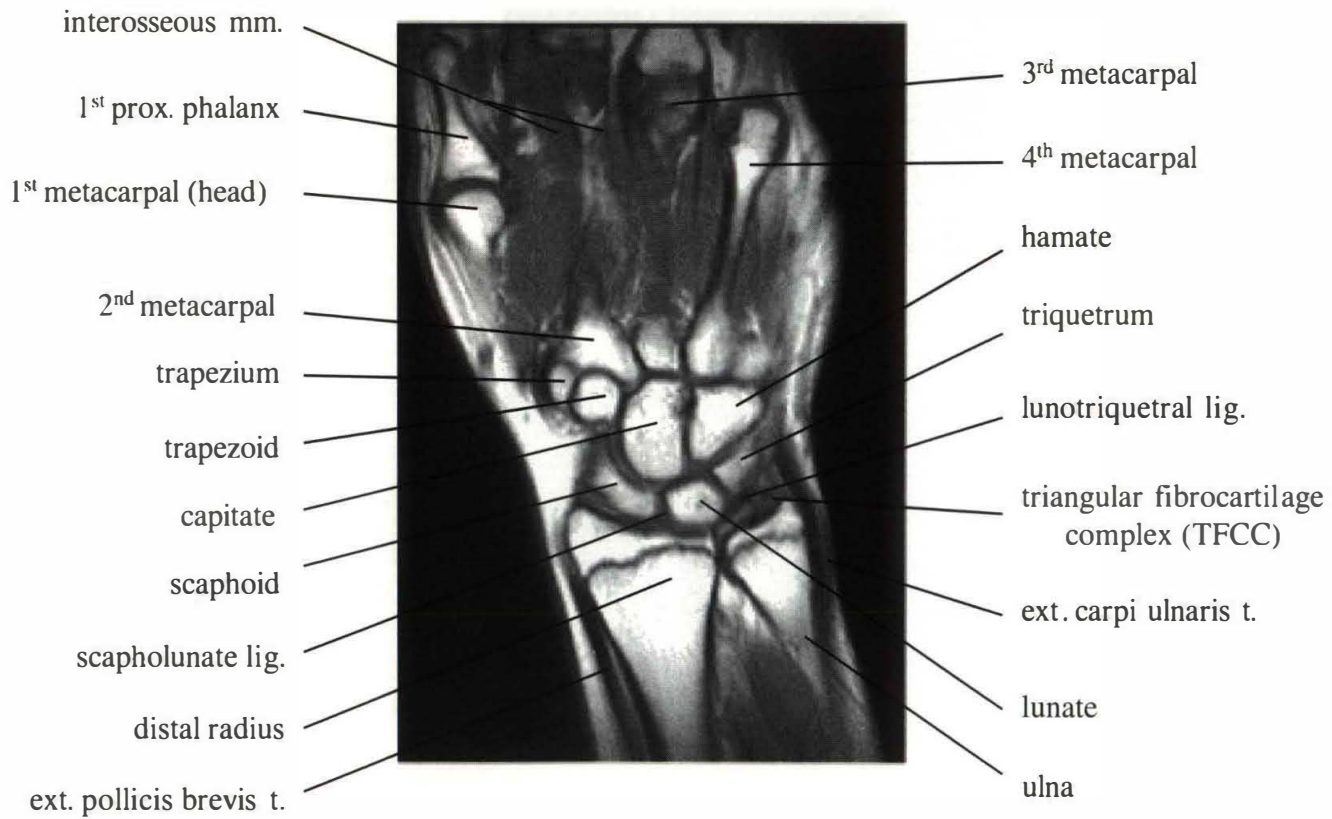
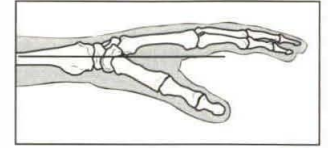
abductor pollicis longus
& ext. pollicis brevis tt.

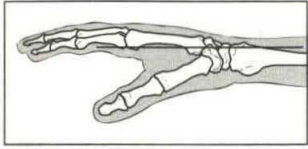




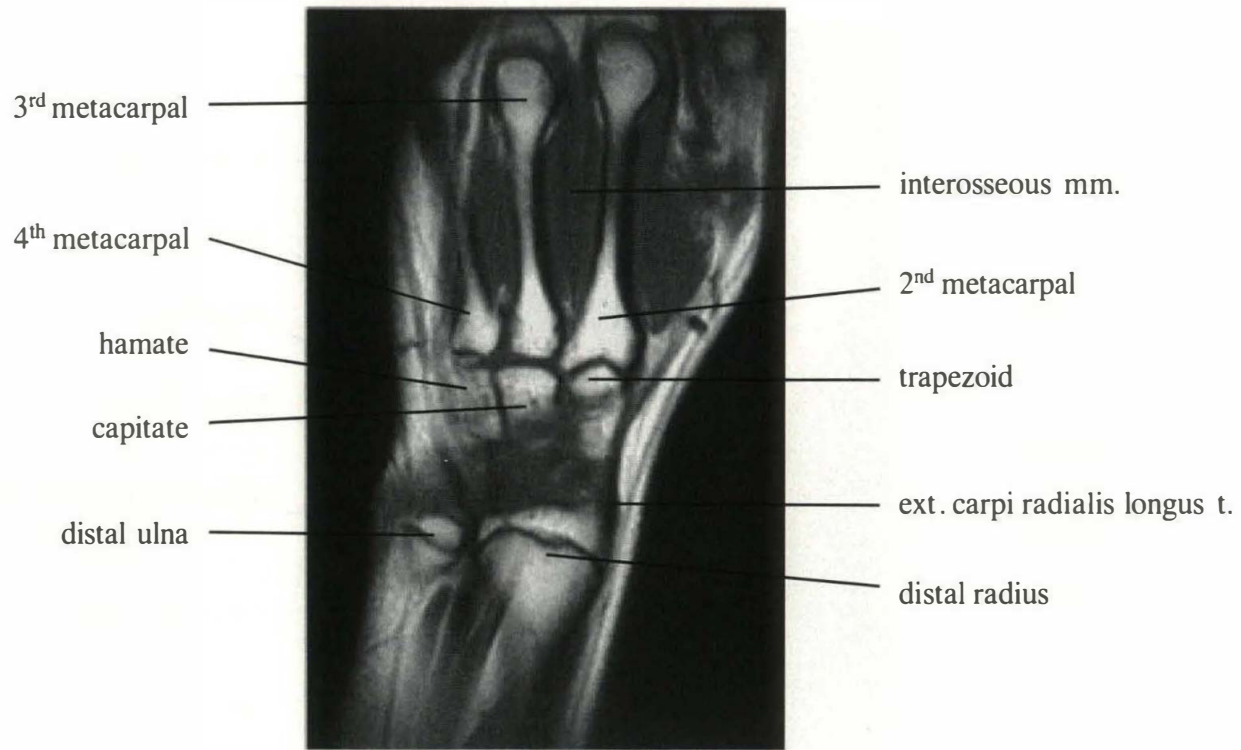


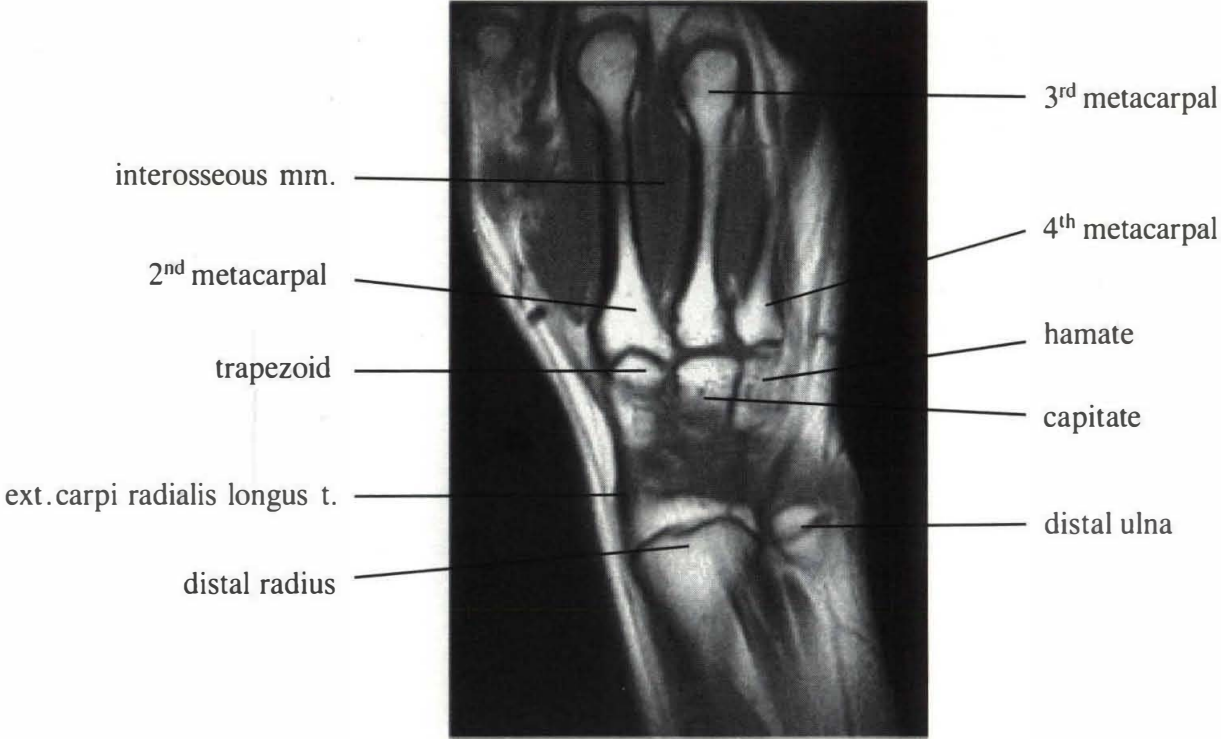
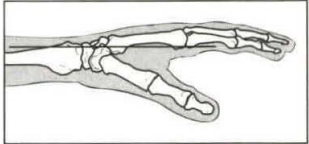


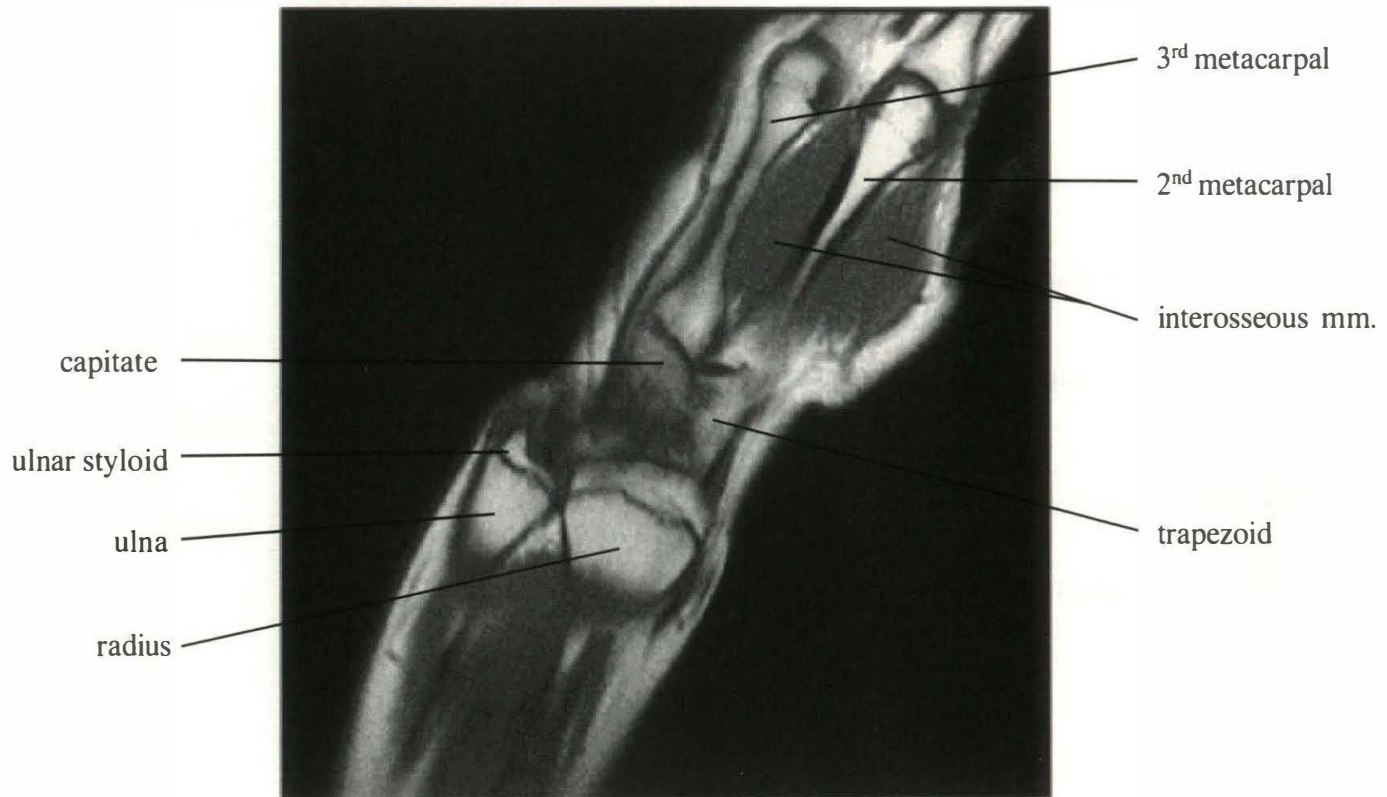
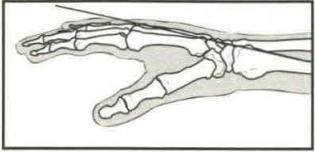


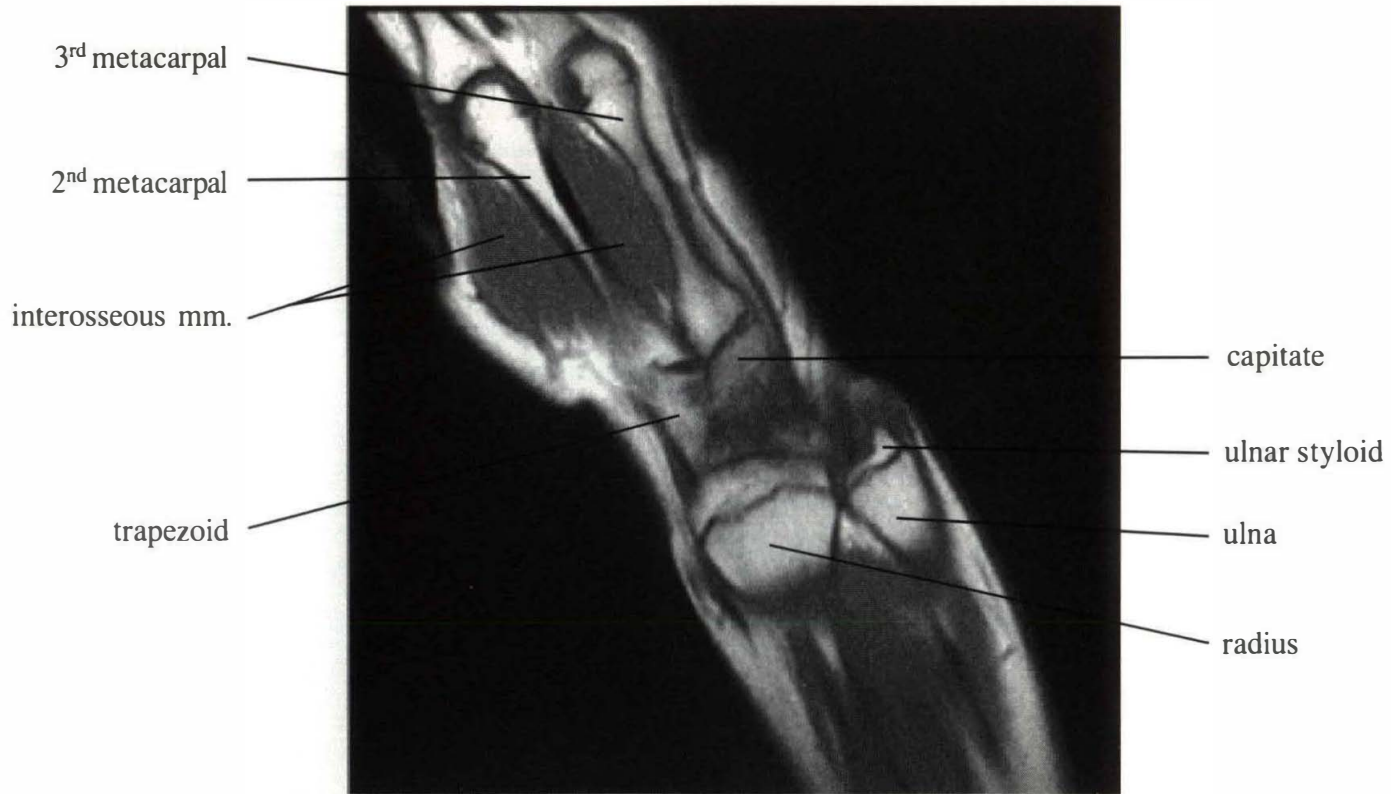
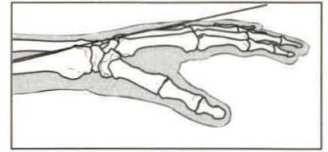


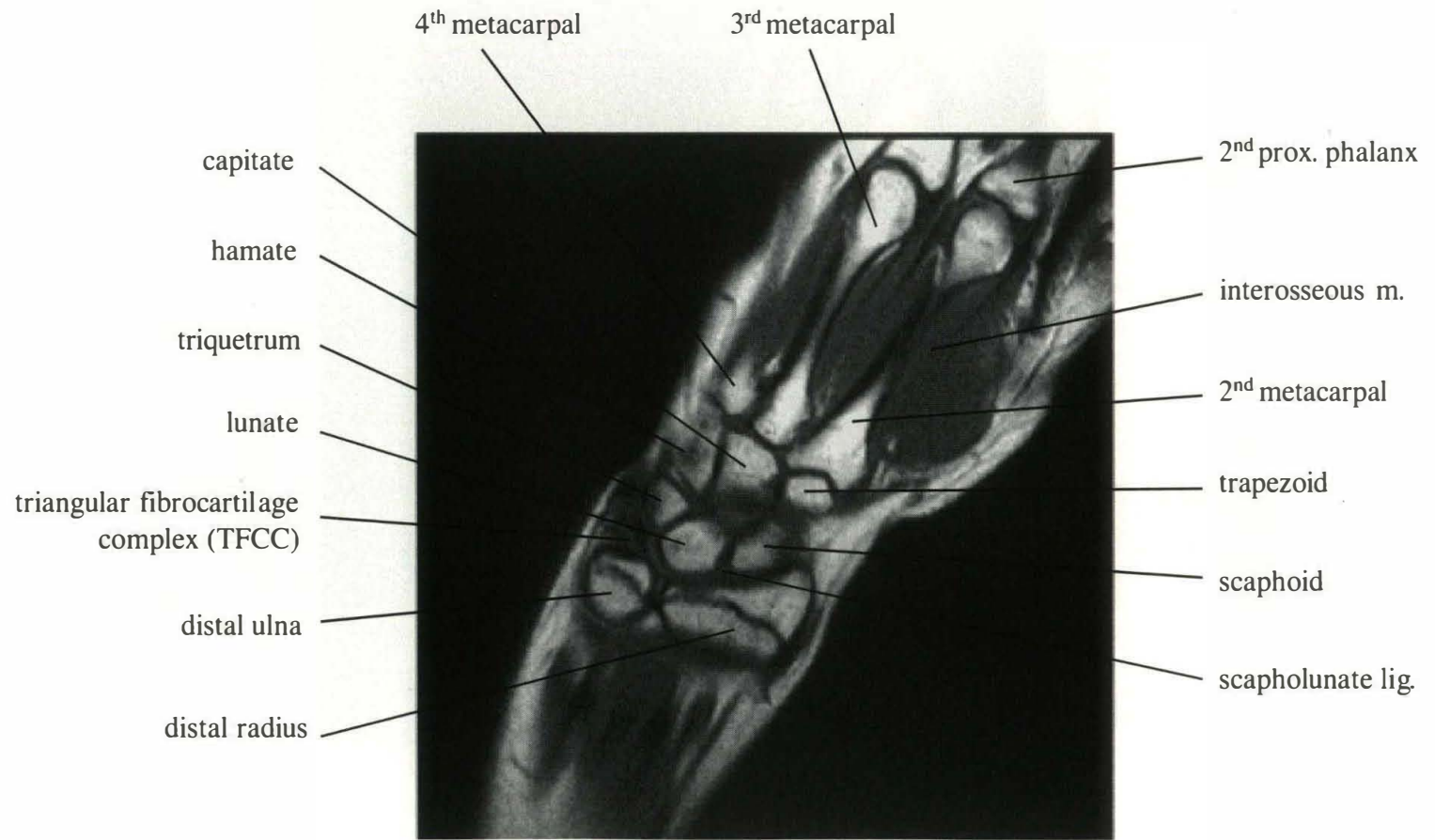
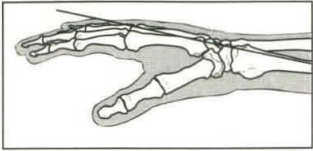
Wrist and Hand: Oblique Coronal

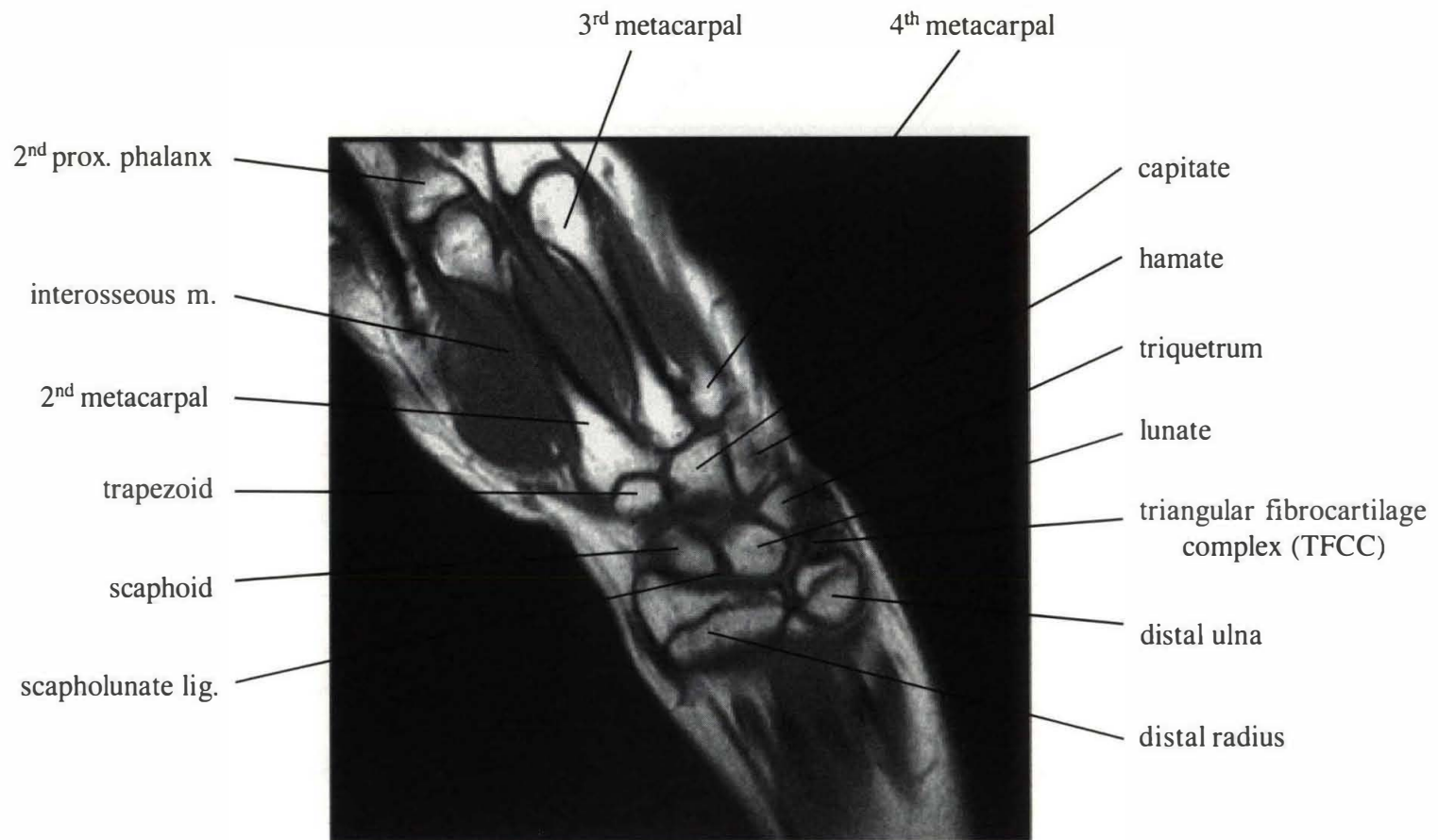
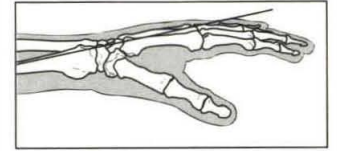


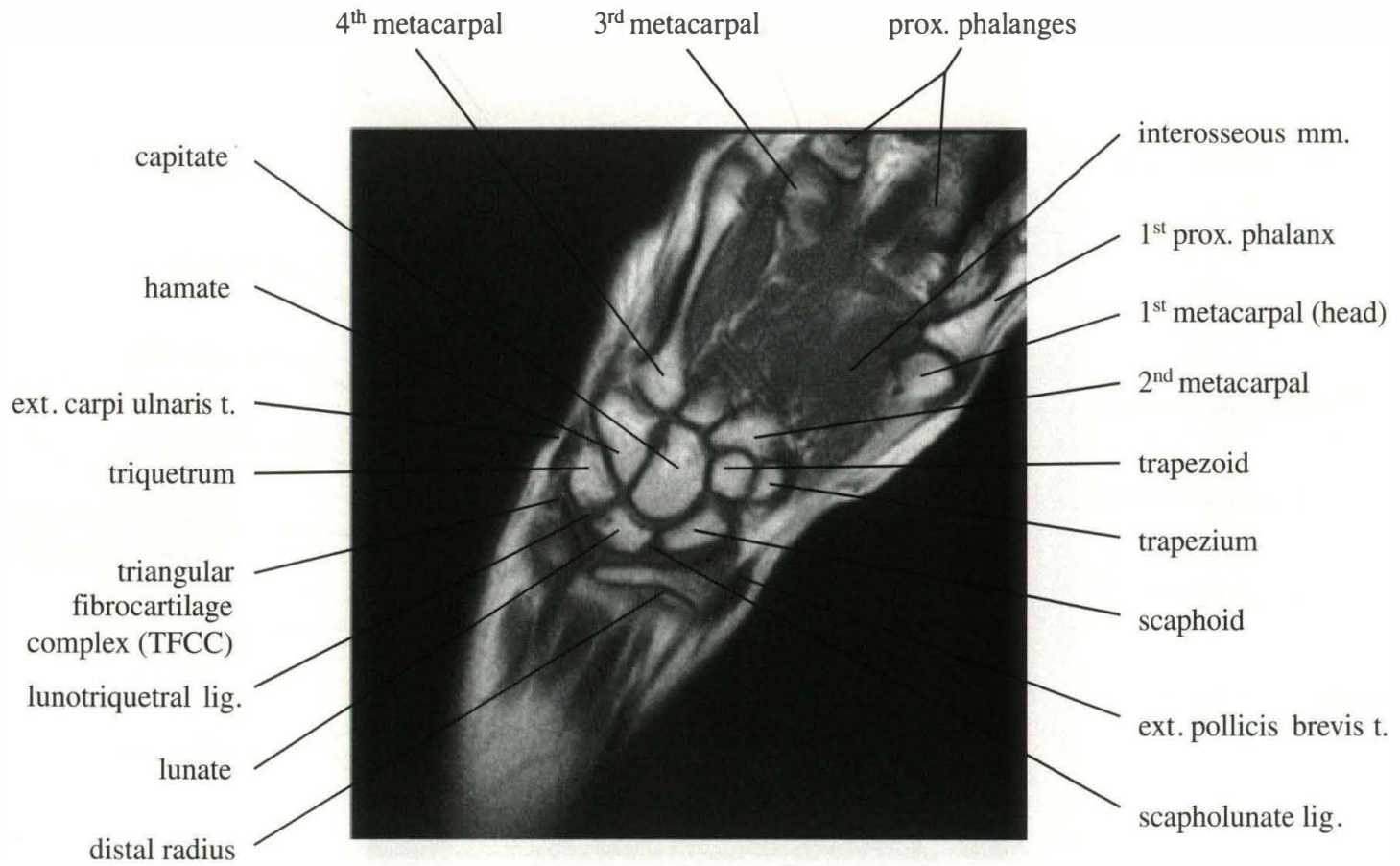
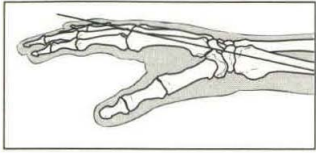












4th metacarpal

3rd metacarpal

prox. phalanges

capitate

hamate

ext. carpi ulnaris t.

triquetrum

triangular
fibrocartilage
complex (TFCC)

lunotriquetral lig.

lunate

distal radius

interosseous mm.

1st prox. phalanx

1st metacarpal (head)

2nd metacarpal

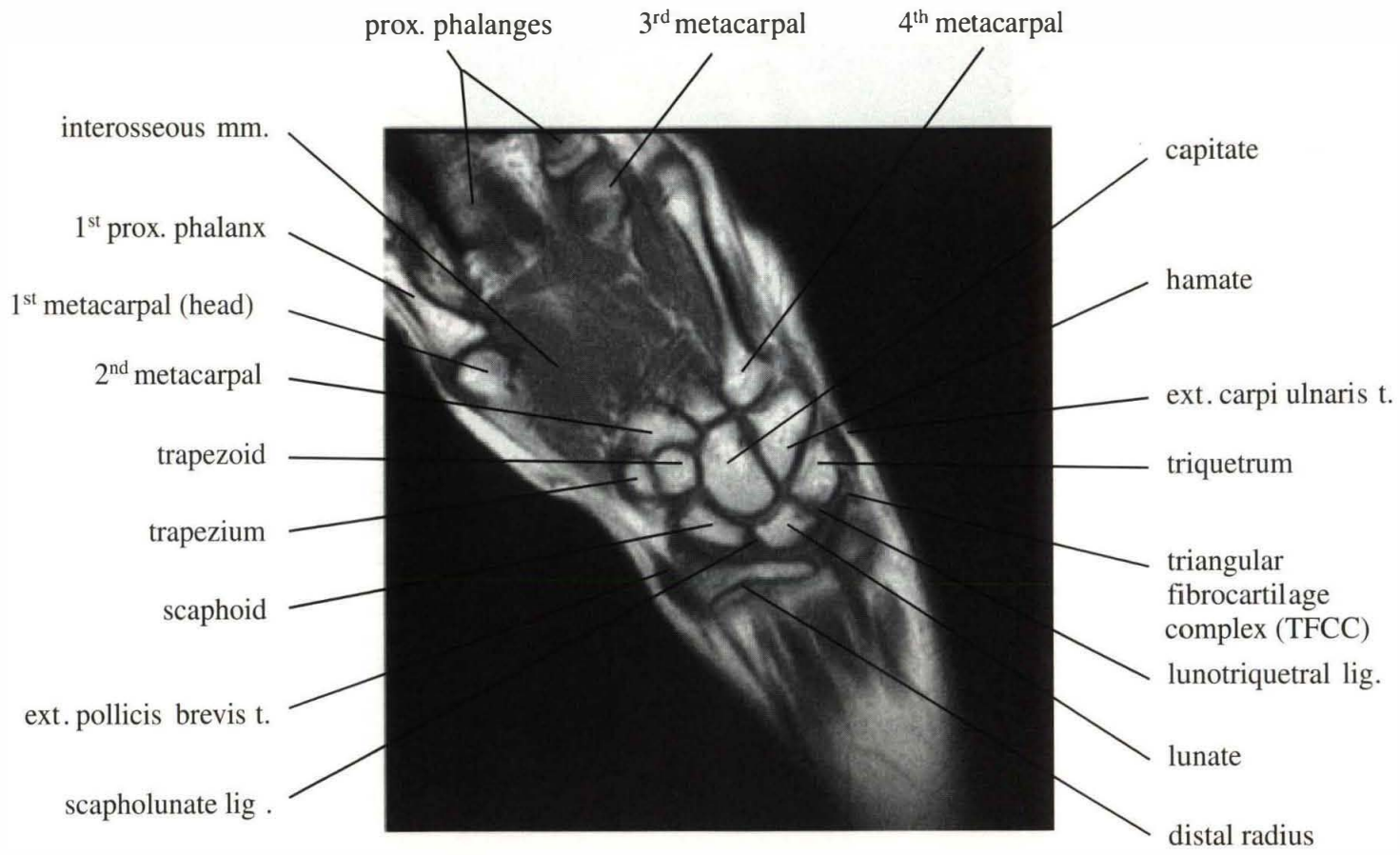
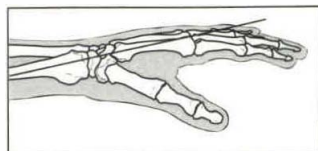
trapezoid

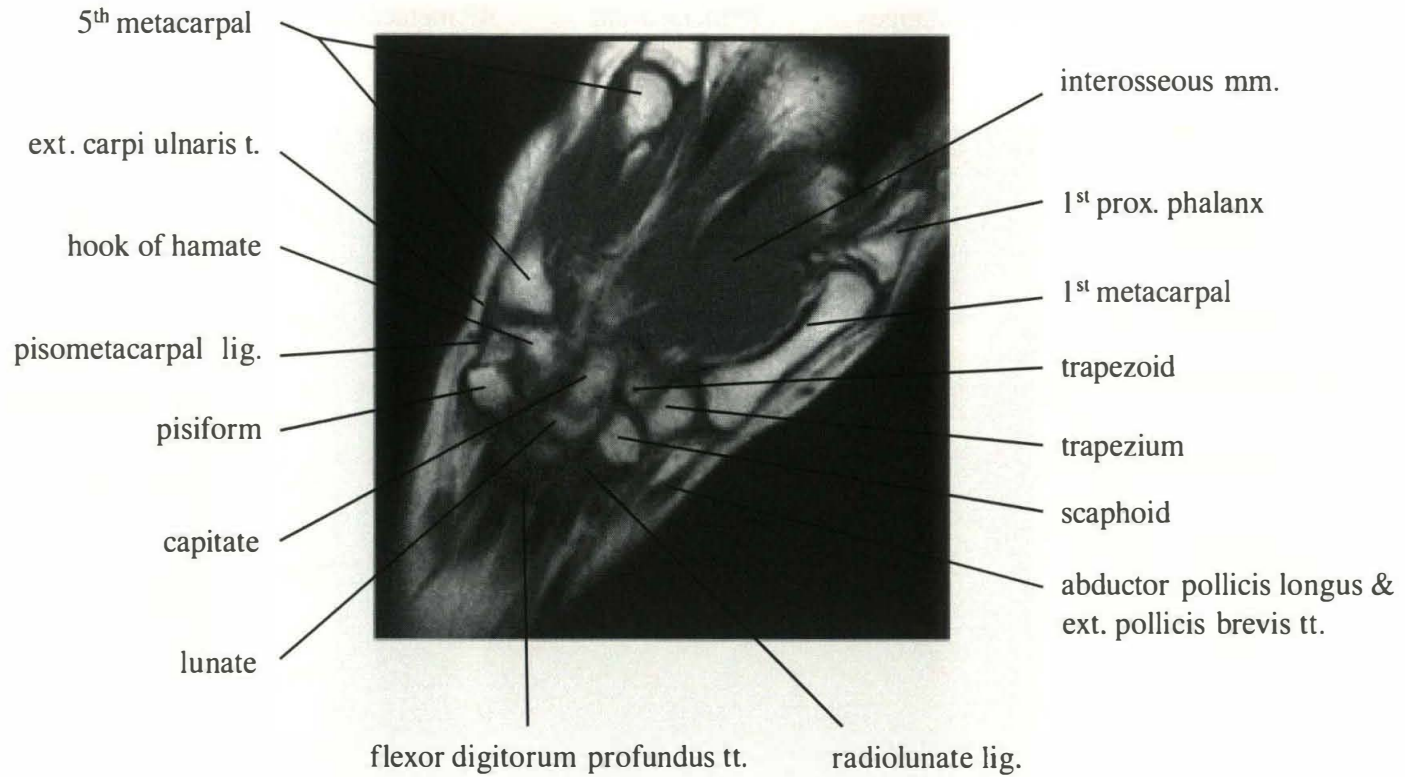
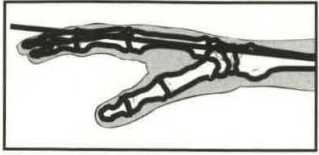
trapezium

scaphoid

ext. pollicis brevis t.

scapholunate lig.





5th metacarpal

ext. carpi ulnaris t.

hook of hamate

pisometacarpal lig.

pisiform

capitate

lunate

flexor digitorum profundus tt.

radiolunate lig.

interosseous mm.

1st prox. phalanx

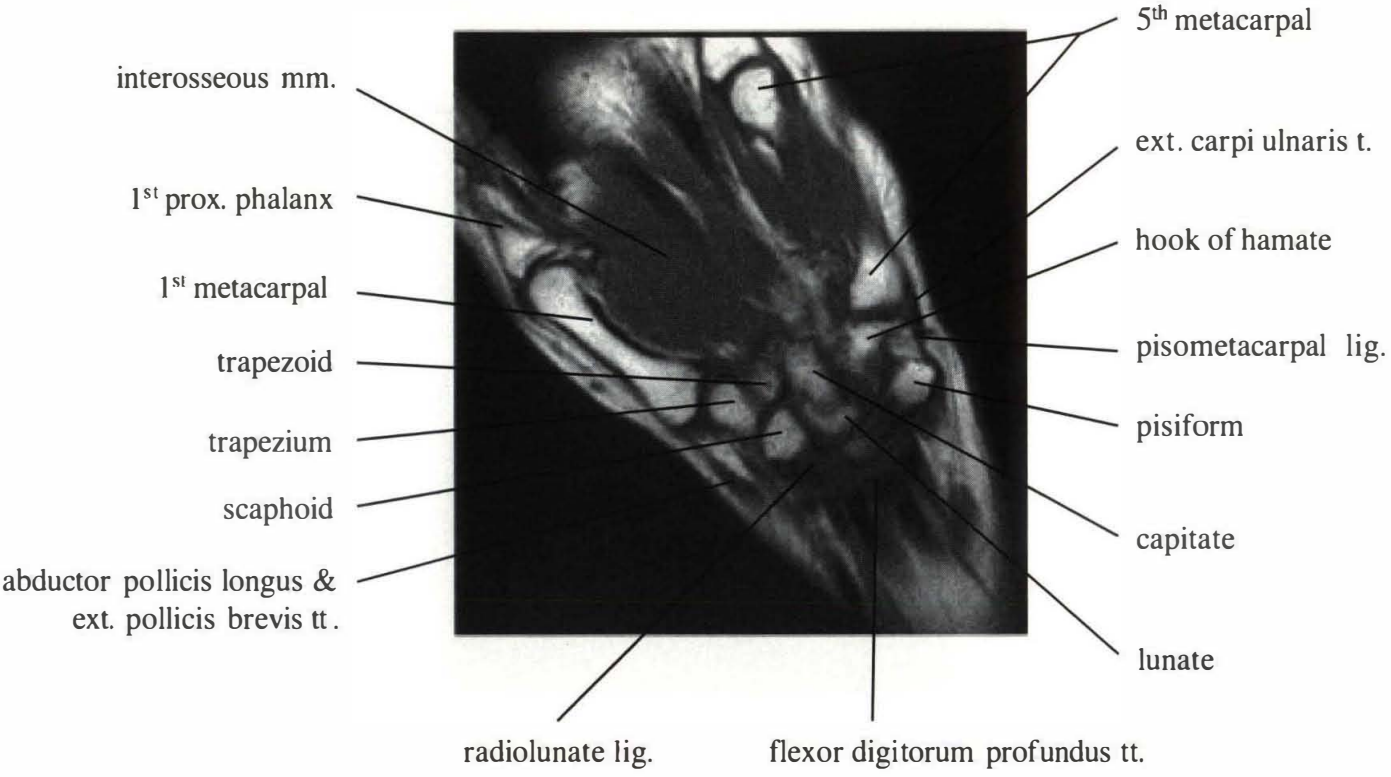
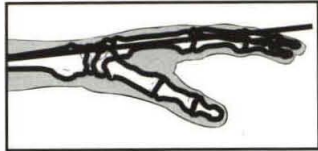
1st metacarpal

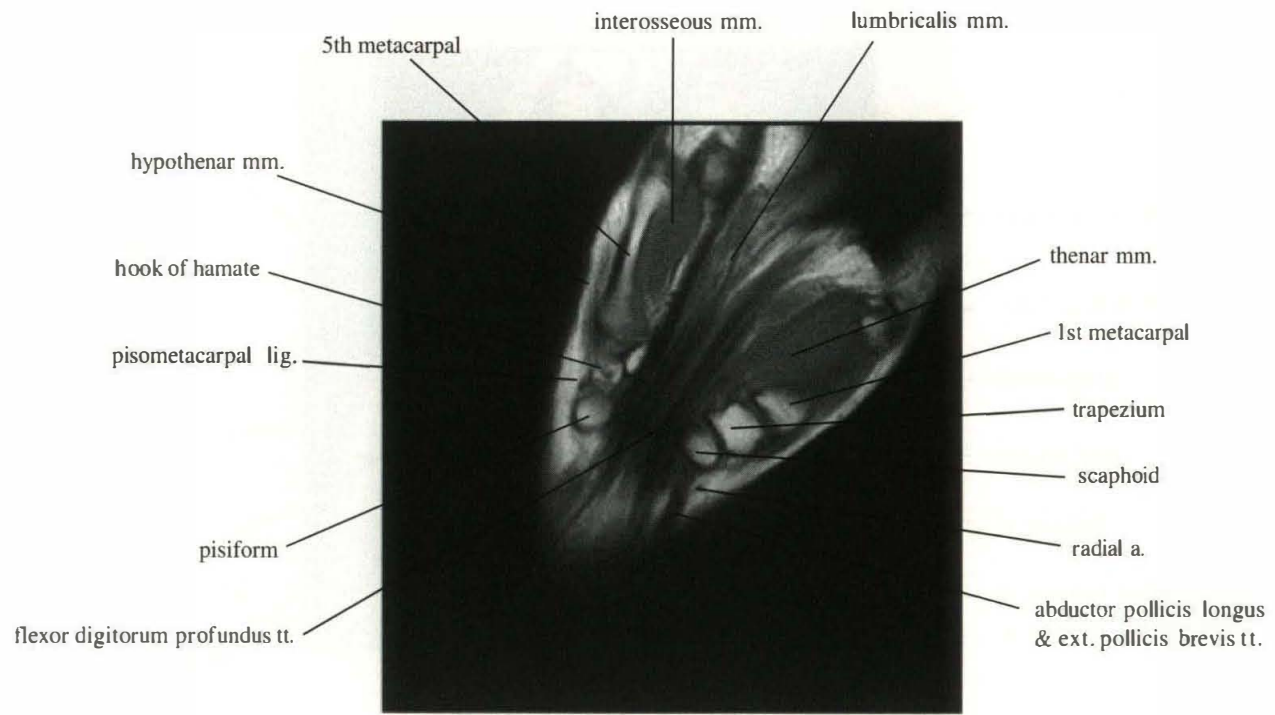
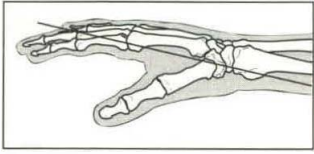
trapezoid

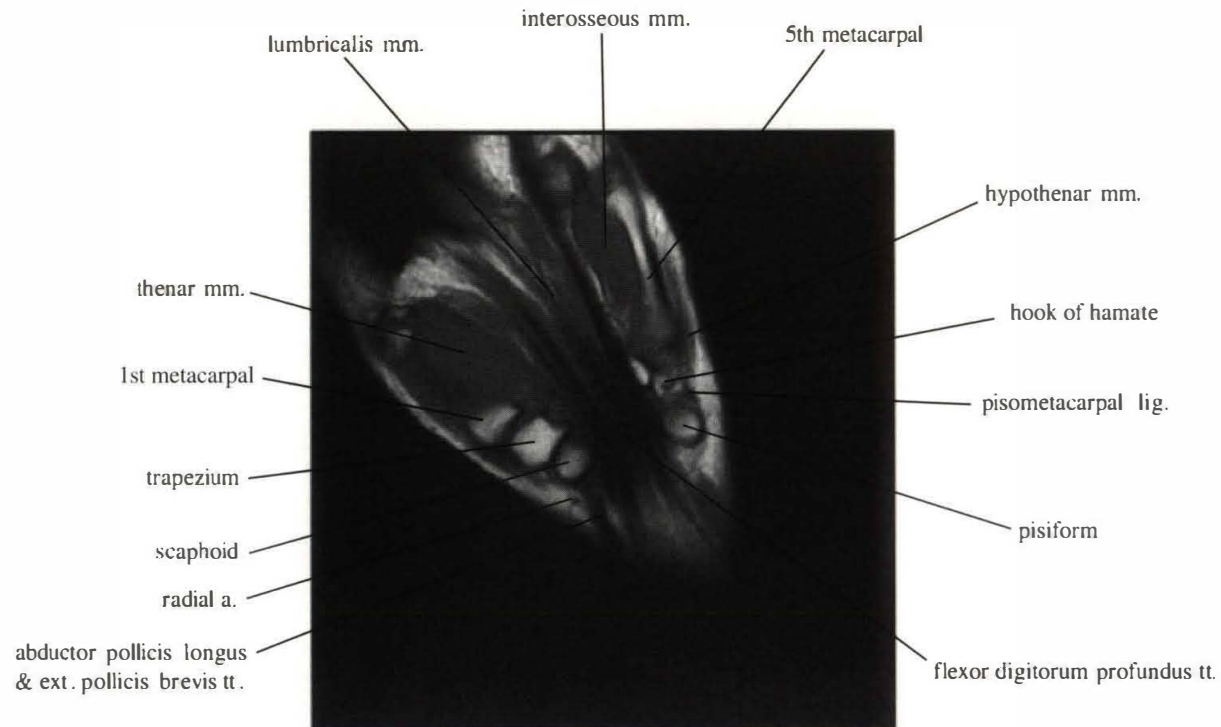
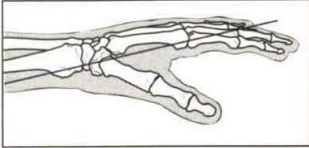
trapezium

scaphoid

abductor pollicis longus &
ext. pollicis brevis tt.







THE HIPS AND THIGH

The major indications for MR imaging of the hip and thigh include suspected infection, avascular necrosis, metastatic disease, transient osteoporosis (bone marrow edema) of the hip, and insufficiency fractures which may not be apparent on plain film examination. Bone and soft-tissue tumors or posttraumatic conditions (e.g., acute hemorrhage) are major indications for MR imaging of the thigh. Generally, MR studies of the hip may be performed with a standard protocol, and the studies do not usually require monitoring. Suspected soft-tissue or osseous tumors should be monitored while the patient is in the scanner, and the images should be approved before the patient leaves the MR suite, if possible.

PRACTICAL PROTOCOL CONSIDERATIONS

For MR examination of the hip and thigh, the patient is placed in the supine position with the legs resting comfortably. If a palpable abnormality, surgical scar, or other suspicious area is present at physical examination, a bath oil bead or vitamin E tablet should be placed at the proximal and distal or medial and lateral ends, or both, of the suspected abnormal site. Both hips are done routinely, but if there is a soft-tissue or osseous mass on one side, only the affected side is imaged.

In general, the body coil is used unless the surface coil is required for closer evaluation of a soft-tissue or intraosseous lesion. If there is a suspicion of a femoral neck fracture and the plain films are normal, a limited protocol consisting of a coronal T1-weighted sequence and/or a coronal inversion recovery sequence can be performed. Since this examination is “limited,” the charge should be reduced if possible. Both hips can be imaged together for symmetry, and then dedicated images can be acquired. The atlas demonstrates both imaging methods.

Menu of Protocols

Hips										
Plane	Pulse Sequence	FA (degrees)	TR (msec)	TE (msec)	TI (msec)	FOV (cm)	Matrix (256X-)	ST/G (mm)	NEX	Comments
Localizer (transaxial)	SPGR	30	8	2.2		VAR	128	10/0	1	Either is acceptable
Localizer (coronal)	FMPIR		3000	25	150	VAR	128	4/1	2	
Localizer (coronal)	SE		450	min		VAR	128	5/1	1	
Coronal	FSE		3000	102		VAR	192	4/1	2	Either is acceptable
Coronal	FMPIR		3000	51	150	VAR	128	4/1	2	
Coronal	FSE, double echo		4000	20/100		VAR	256	5/1	1	
Oblique coronal										Same choices as coronal Plane parallel to long axis of femoral neck
Transaxial	FSE, double echo, \pm FS		4000	20/100		VAR	256	5/1	1	Either is acceptable
Transaxial	SE		300	min		VAR	192	4/1	2	
Sagittal	SE		850	20		VAR	192	3/1	1	Either is acceptable
Sagittal	FSE, double echo, \pm FS		4000	20/100		VAR	192	5/1	2	
Sagittal	SPGR, FS	30	45	15		VAR	192	2/0	1	
Thigh										
Localizer (transaxial)	SE		500	min		VAR	192	5/1.5	1	
Coronal, sagittal	SE		500	min		VAR	192	5/1.5	1	
Coronal	SE		1000	min		VAR	192	5/1.5	2	
Coronal	FMPIR		2500	30	150	VAR	128	5/1.5	2	
Sagittal	SE		1000	min		VAR	192	5/1.5	2	
Sagittal	FMPIR		2500	30	150	VAR	128	5/1.5	2	
Axial	SE		600	20		VAR	192	4/1	2	
Axial, pre-GAD	SE		600	20		VAR	192	4/1	2	
Axial, pre-GAD	SE, FS		600	20		VAR	192	4/1	2	

MAJOR OSTEOCHONDRAL STRUCTURES/LANDMARKS

- Ilium/Acetabulum
 - Iliac crest
 - Anterior superior iliac spine
 - Anterior inferior iliac spine
 - Iliopectineal line
 - Hip joint
 - Triradiate cartilage
 - Anterior column
 - Posterior column
 - Acetabular labrum
- Ischium
 - Ischial ramus
 - Ischial tuberosity
- Pubis
 - Superior pubic ramus
 - Obturator crest
- Femur
 - Femoral articular cartilage
 - Femoral head
 - Fovea capitis of femoral head
 - Femoral neck
 - Greater trochanter
 - Lesser trochanter
 - Anterior intertrochanteric line
 - Posterior intertrochanteric line
 - Trochanteric fossa
 - Pectineal line
 - Linea aspera

MAJOR LIGAMENTS/TENDONS/BURSAE

Ligaments

(Hip ligaments are capsular thickenings)

- Iliofemoral (“Y” ligament of Bigelow)—strongest
- Ischiofemoral
- Pubofemoral
- Capitis femoris (intracapsular)
- Ligamentum teres (acetabular fossa to fovea capitis)
- Transverse acetabular ligament

Tendons

- Iliopsoas
- Rectus femoris
- Gluteal (maximus, intermedius, minimus)

Bursae

- Iliopsoas
- Iliopectineal
- Trochanteric

MAJOR MUSCLES

Compartments

The muscles of the hip and thigh are divided into four groups.

- Anterior compartment
 - Sartorius
 - Quadriceps femoris
 - Rectus femoris
 - Vastus lateralis
 - Vastus intermedius
 - Vastus medialis
 - Articularis genus
- Medial compartment
 - Gracilis
 - Pectineus
 - Adductor longus
 - Adductor brevis
 - Adductor magnus
 - Obturator externus
- Posterior compartment (the “hamstrings”)
 - Semitendinosus
 - Semimembranosus
 - Biceps femoris
- Lateral compartment
 - Gluteus maximus
 - Gluteus medius
 - Gluteus minimus
 - Tensor fasciae latae
 - Obturator internus
 - Superior gemellus
 - Inferior gemellus
 - Quadratus femoris
 - Piriformis

- Other hip/thigh muscles
 - Psoas major
 - Iliacus

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Sartorius	Anterior superior iliac spine (ASIS)	Tibial medial surface near tuberosity and neighboring fascia	Femoral N.
– Rectus femoris	Straight head— anterior inferior iliac spine Reflected head— groove above acetabulum	Across patellar ligament surface to tibial tuberosity	Femoral N.
– Articularis genu	Upper shaft of femur along margin of greater trochanter, above gluteal tuberosity, and upper portion of linea aspera	Proximal aspect of patella and anterior aspect of lateral condyle of tibia	Femoral N.
Medial Compartment			
– Gracilis	Pubic symphysis and inferior ramus of pubic bone	Upper shaft of tibial shaft between sartorius and semitendinosus tendons	Anterior division of obturator N.

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Pectineus	Pectin of pubis, pectineal fascia, anterior margin of obturator sulcus, and pubofemoral ligament	Upper half of pectineal line of femur behind lesser trochanter	Femoral N. Rarely from accessory obturator or obturator N.
– Adductor longus	Medial portion of superior pubic ramus	Middle third of medial tip of linea aspera	Anterior division of obturator N. and occasionally branch from femoral N.
– Adductor brevis	Inferior pubic ramus between origin of gracilis and obturator externus	Distal two-thirds of pectineal line of femur and upper one-third of linea aspera	Anterior (or posterior) branch of obturator N.
– Adductor magnus	Lower part of inferior pubic ramus	Medial gluteal ridge and superior aspect of linea aspera by a tendon from distal three-fourths of linea aspera. Adductor tubercle at distal end of medial supracondylar ridge	Posterior branch of obturator N. and a branch from tibial division of sciatic N. (L4, S1)
– Obturator externus	External aspect of superior and inferior pubic ramus and ischial ramus	Trochanteric fossa of femur	Branch of obturator N. (L3, L4)

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
Posterior Compartment (Hamstring Group)			
– Semi-tendinosus	Lower and medial aspect of ischial tuberosity in common with long head of biceps femoris muscle	Upper part of medial surface of tibia behind and distal to gracilis insertion	Two branches of tibial division of sciatic N. (L4, L5, S1, S2)
– Semi-membranosus	Upper and outer impression of ischial tuberosity	Horizontal groove on posteromedial aspect of medial tibial condyle—extension continues as oblique popliteal ligament of knee joint	Tibial division of sciatic N. (L4, L5, S1, S2)
– Biceps femoris, long head	Lower and medial impression of ischial tuberosity and sacrotuberous ligament	By a tendon that extends to lateral condyle of femur	Tibial division of sciatic N. (S1, S2, S2)
– Biceps femoris, short head	Lateral lip of linea aspera of femur, proximal two-thirds of supracondylar ridge, and lateral intermuscular septum	Lateral aspect of fibular head, lateral condyle of tibia, and into lateral fascia of leg	Branch of common peroneal division of sciatic N. (L5, S1, S2)

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
Lateral Compartment			
– Gluteus maximus	Outer aspect of iliac crest, posterior gluteal line of ilium, thoracolumbar fascia between posterior superior ilium and side of sacrum, lateral parts of S4, S5, and coccygeal vertebrae, and posterior aspect of sacrotuberous ligament	Iliotibial tract, gluteal tuberosity of femur, adjacent part of tendinous origin of vastus lateralis	Inferior gluteal N. branches from sacral plexus (L5, S1, S2)
– Gluteus medius	External surface of ilium between anterior and posterior gluteal lines, and from gluteal aponeurosis	Posterosuperior angle of greater trochanter of femur	Superior gluteal N. (L4, L5, S1)
– Gluteus minimus	Ilium between anterior and inferior gluteal lines	Anterior border of greater trochanter of femur	Superior gluteal N. (L4, L5, S1)
– Tensor fasciae latae	Iliac crest and gluteus medius	Joins iliotibial tract about one-third of way down the thigh	Superior gluteal N. Lateral femoral circumflex (L4, L5, S1)
– Obturator internus	Pubic ramus near obturator foramen, ischium, obturator internus fascia	Medial side of greater trochanter of femur	Superior gluteal N. (L4, L5, S1)

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

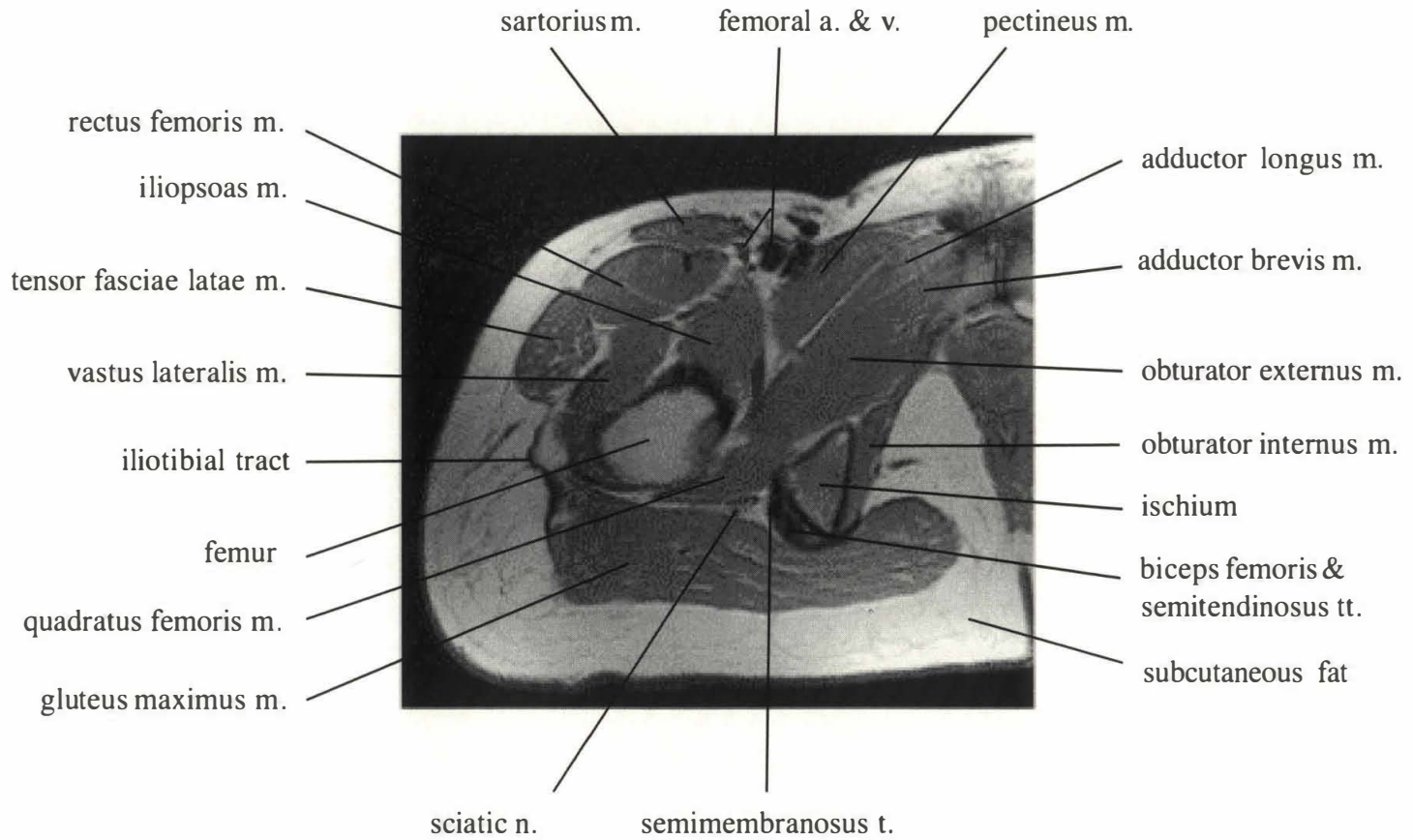
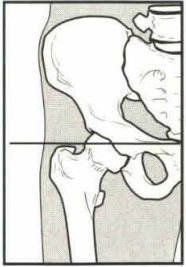
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
- Superior gamellus	Ischial spine and lesser sciatic notch	Unites with obturator internus tendon and inserts into medial side of greater trochanter	Superior gluteal N. (L4, L5, S1)
- Inferior gamellus	Ischial tuberosity	Greater trochanter of femur	Superior gluteal N. (L4, L5, S1)
- Quadratus femoris	Ischial tuberosity	Inferiorly and dorsally on greater trochanter	Medial femoral circumflex N.
- Piriformis	Front of sacrum between S1 and S4 foraminae, posterior border of greater sciatic notch, from sacrotuberous ligament near sacrum	Upper border of greater trochanter of femur	One or two branches of S1 or S2 N.
Outer Hip/Thigh Compartment			
- Psoas major	From T12 to L5 intervertebral disks and bodies, from L1 to L4 bodies and from ventral surfaces of lumbar transverse processes	Lesser trochanter of femur	Branches from L1, L2, L3, and L4 N.

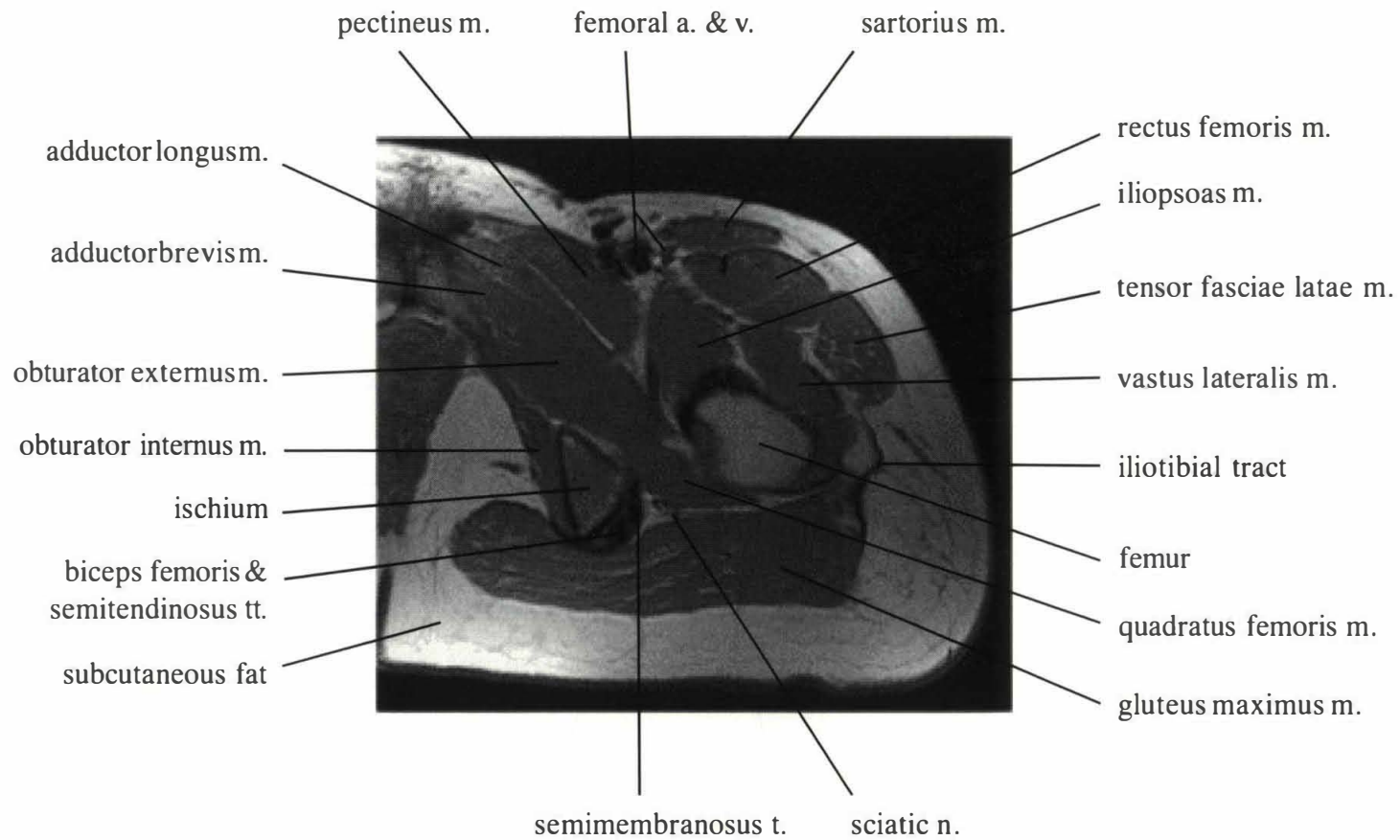
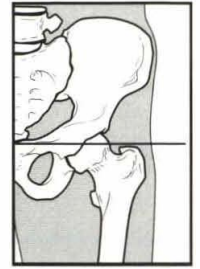
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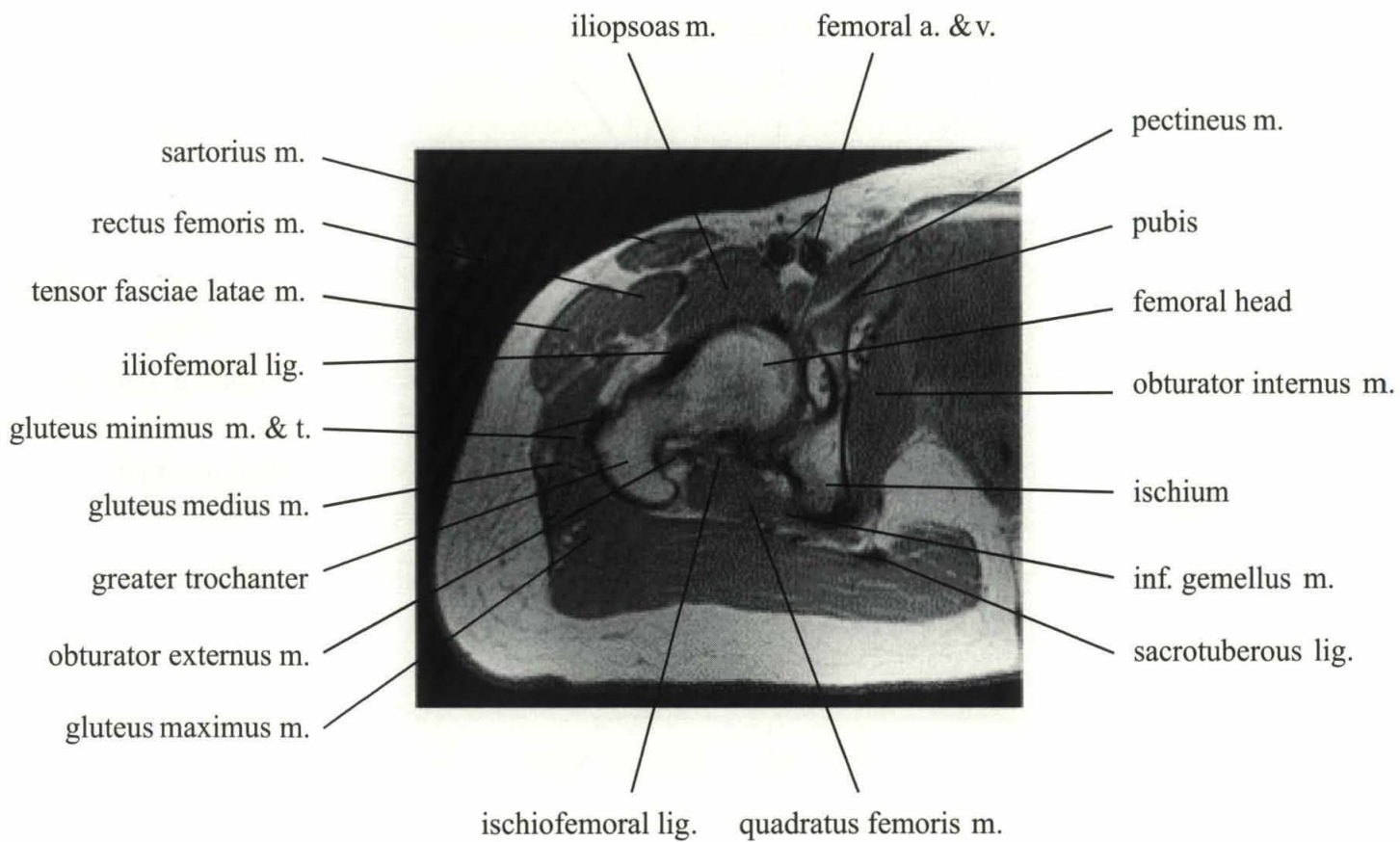
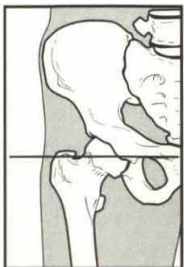
ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (*CONTINUED*)

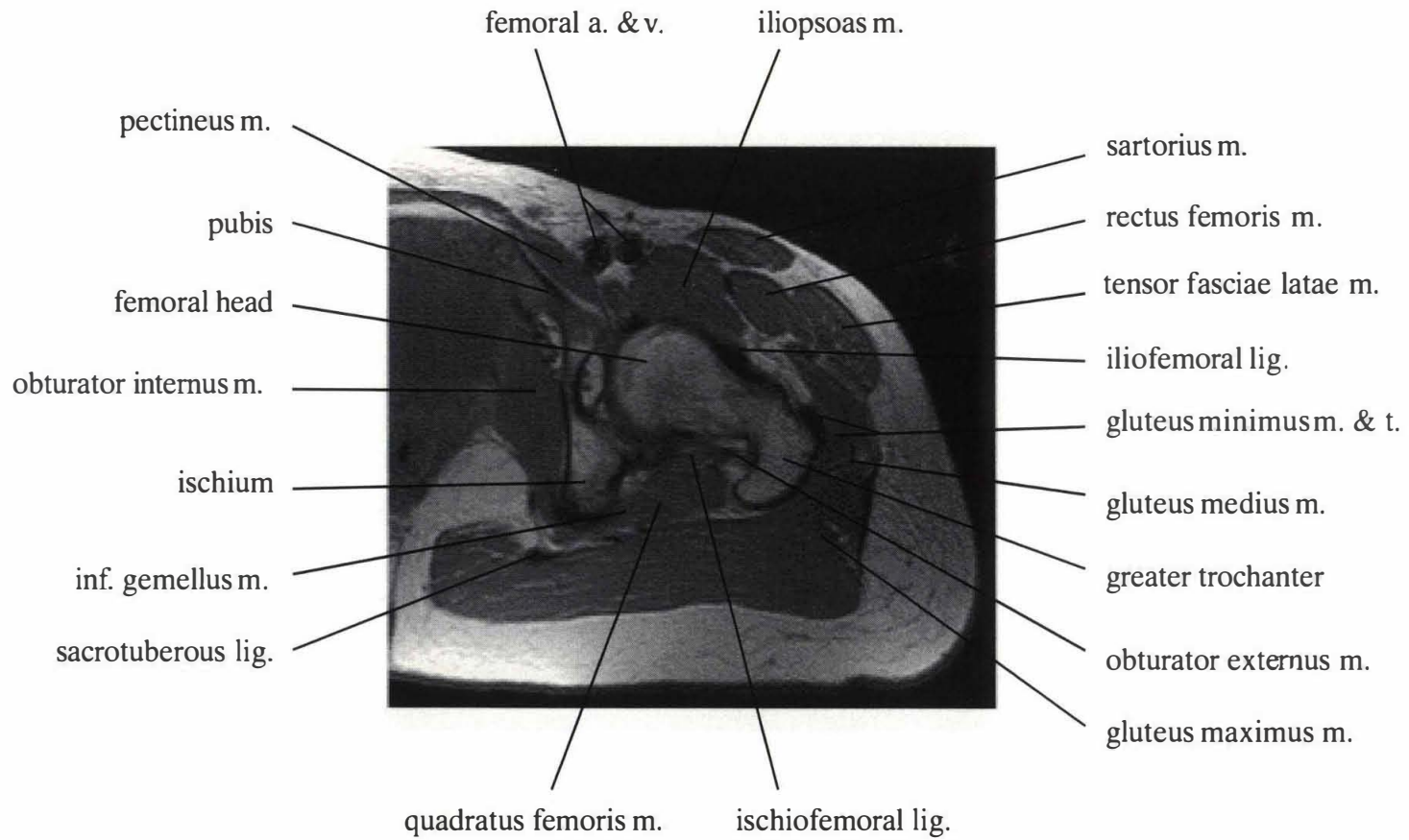
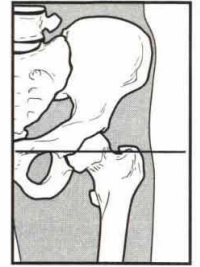
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Iliacus	Iliac crest, iliolumbar ligament, iliac fossa, anterior sacroiliac ligaments, sacral ala, and ventral border of ilium	Lateral aspect of the psoas tendon above inguinal ligament and onto femur distal to lesser trochanter; lateral portion is attached to tendon of rectus femoris and hip joint capsule	Femoral N. and L1 to L4 N.

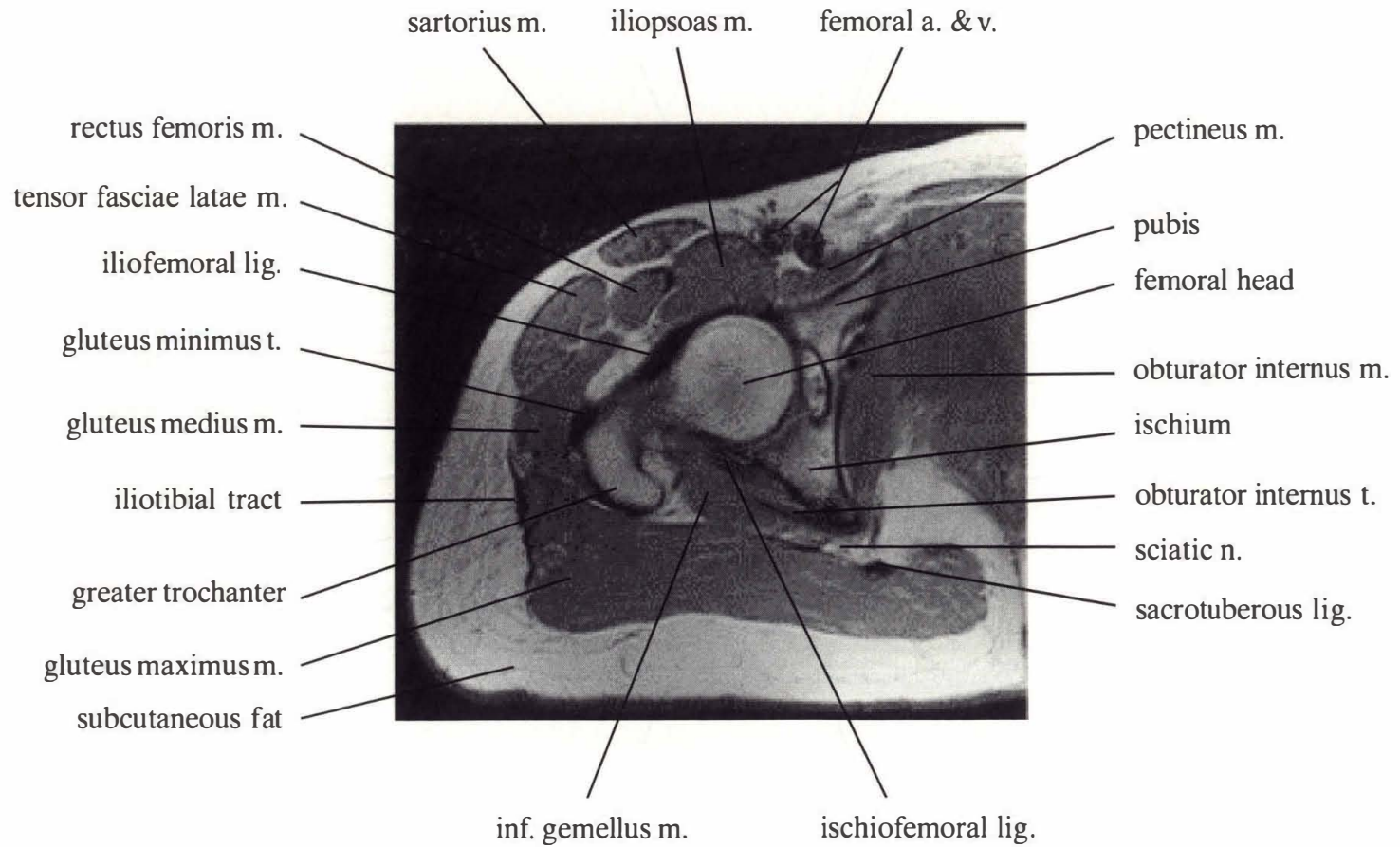
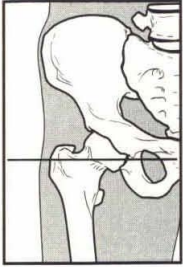
THE HIPS: AXIAL ANATOMY

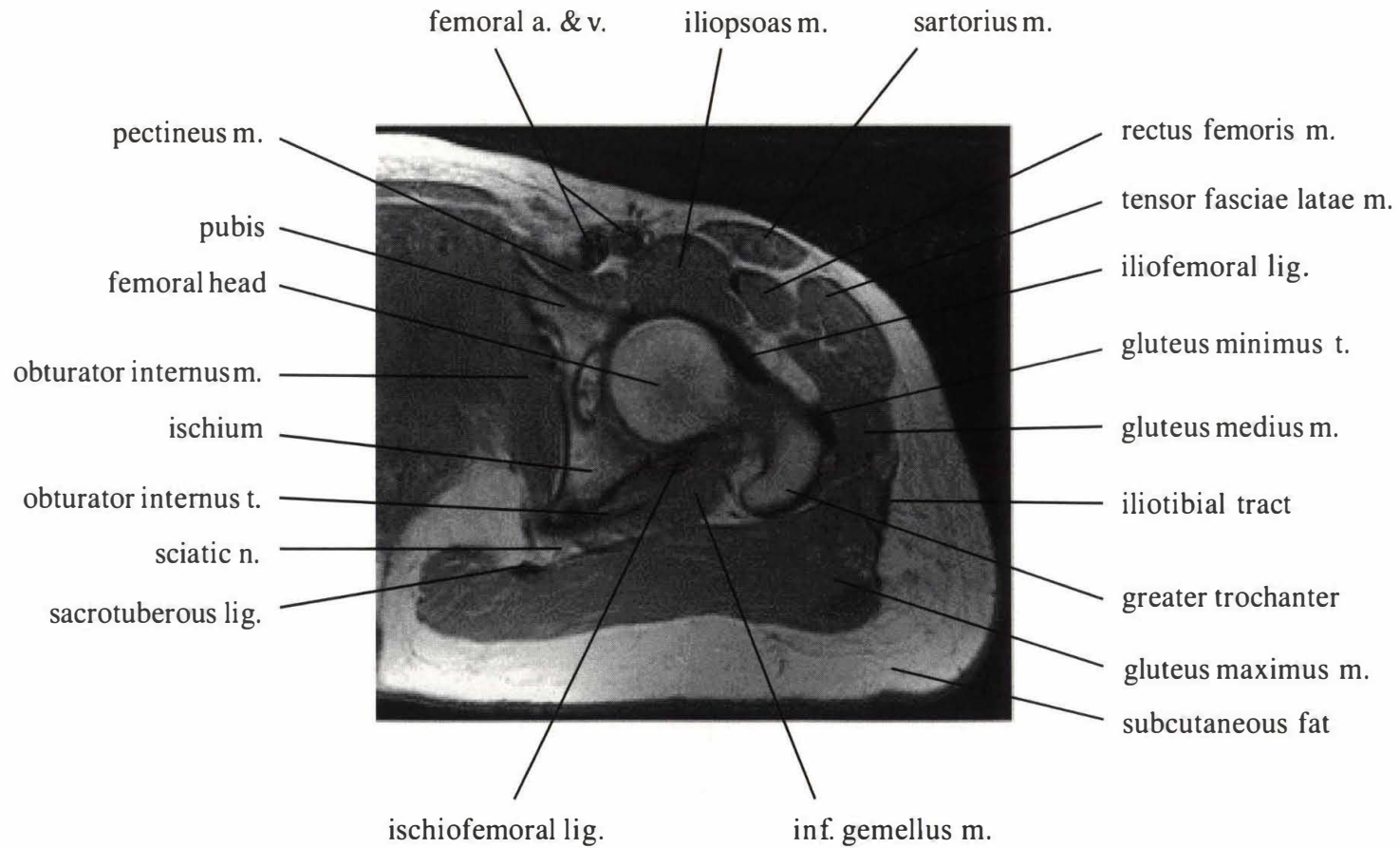
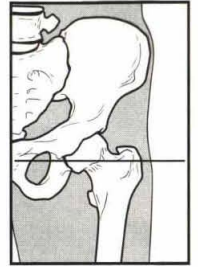


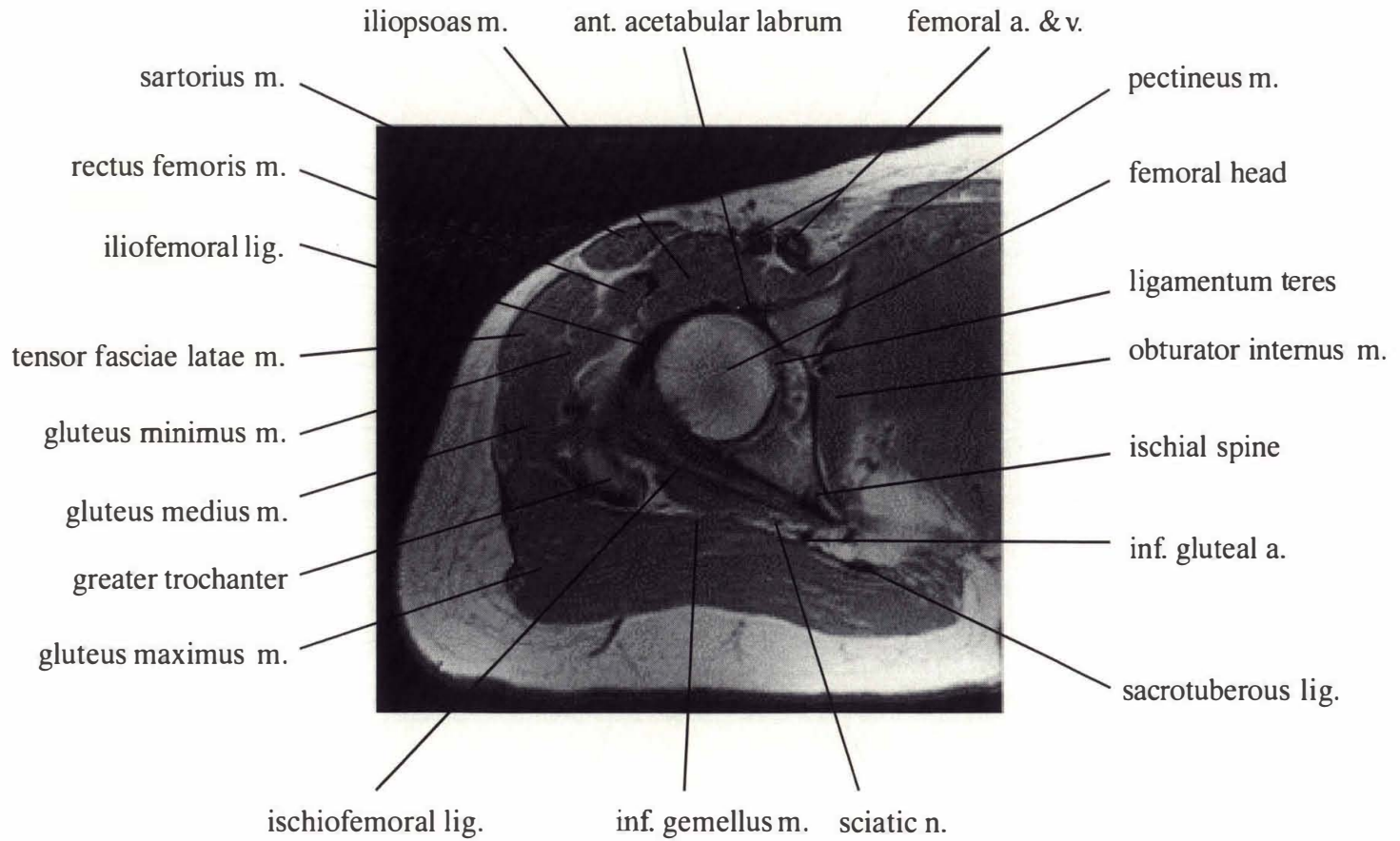
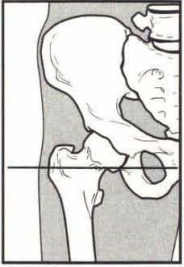


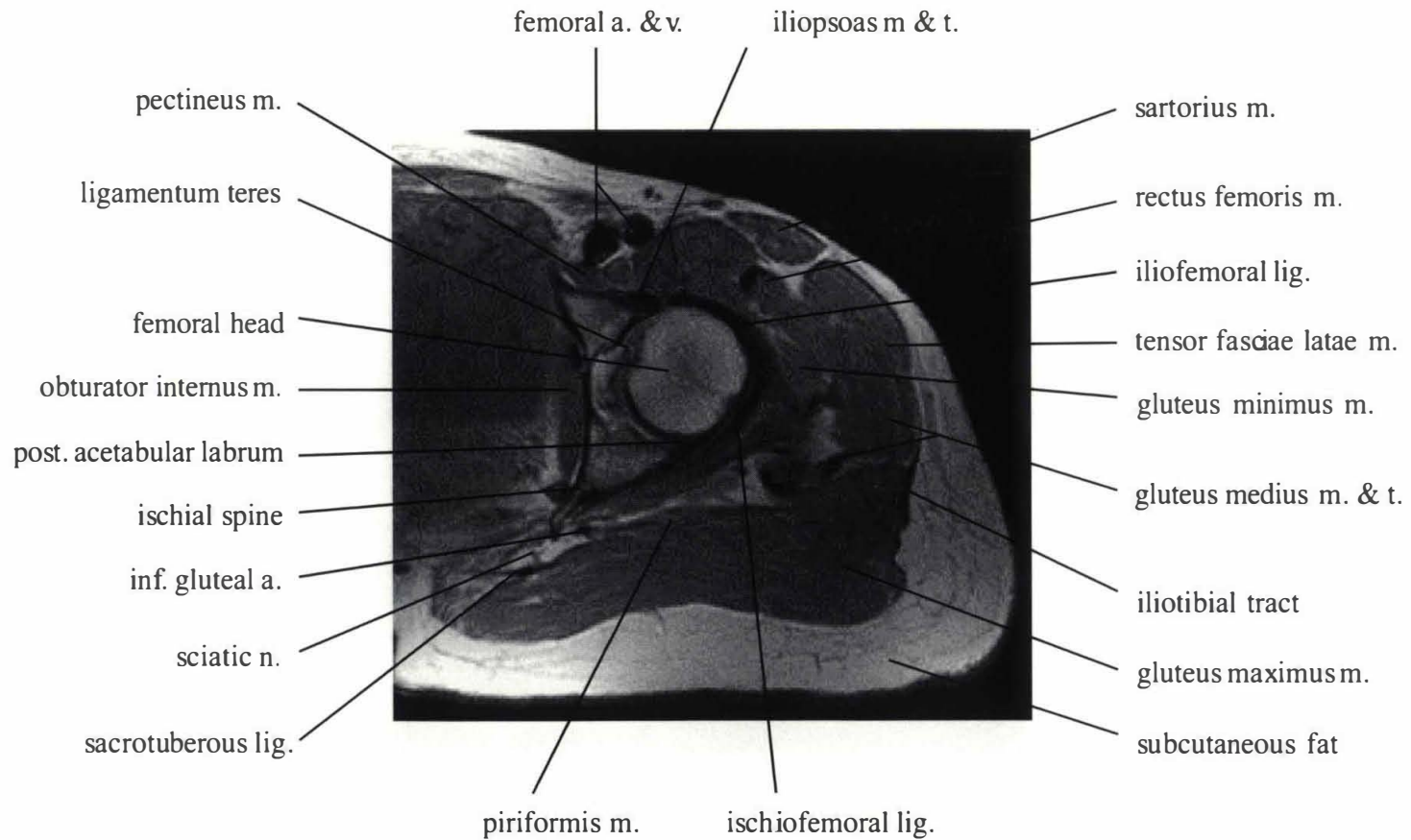
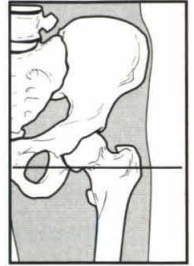


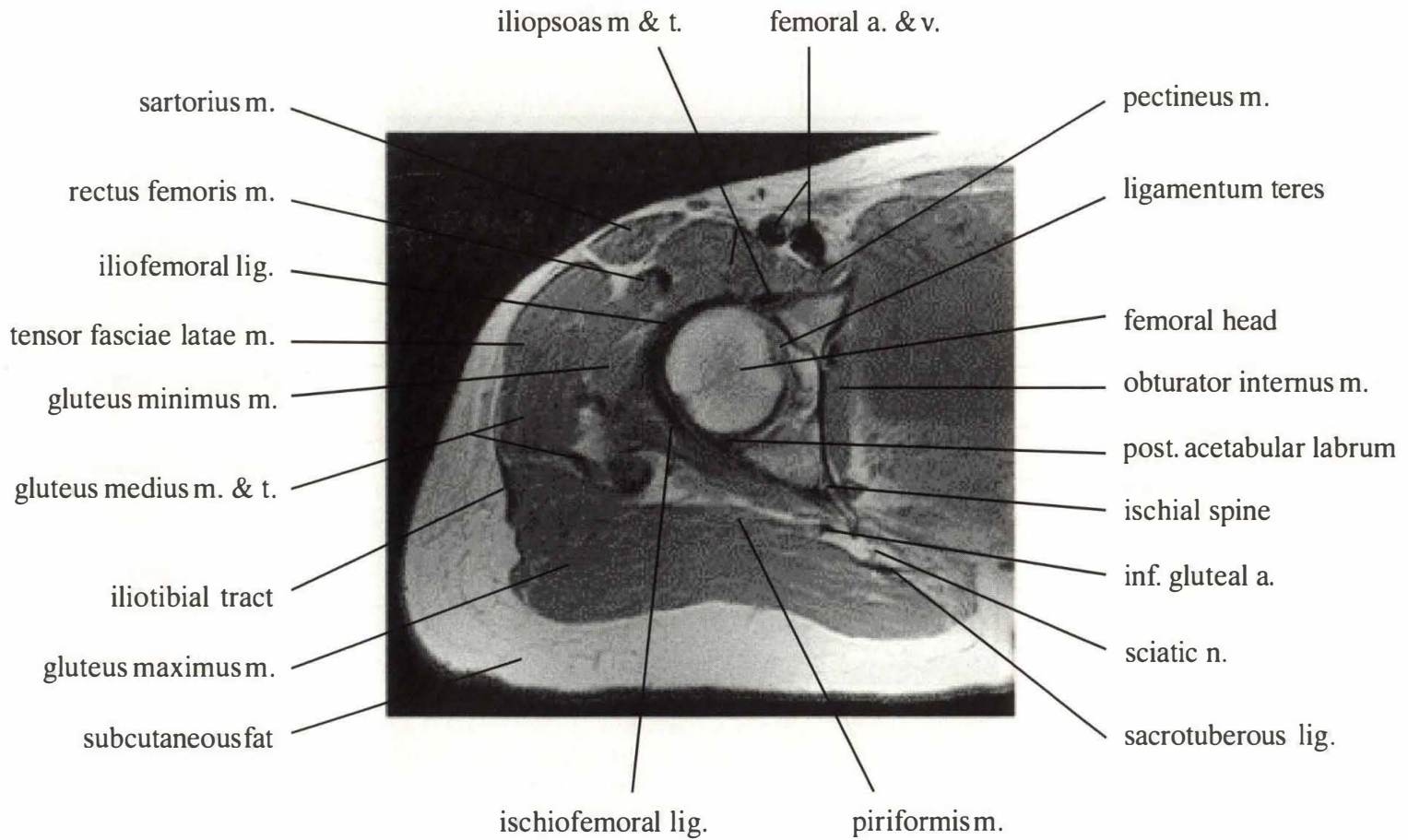
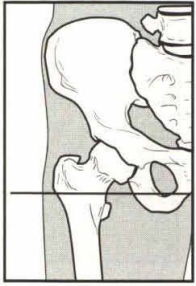


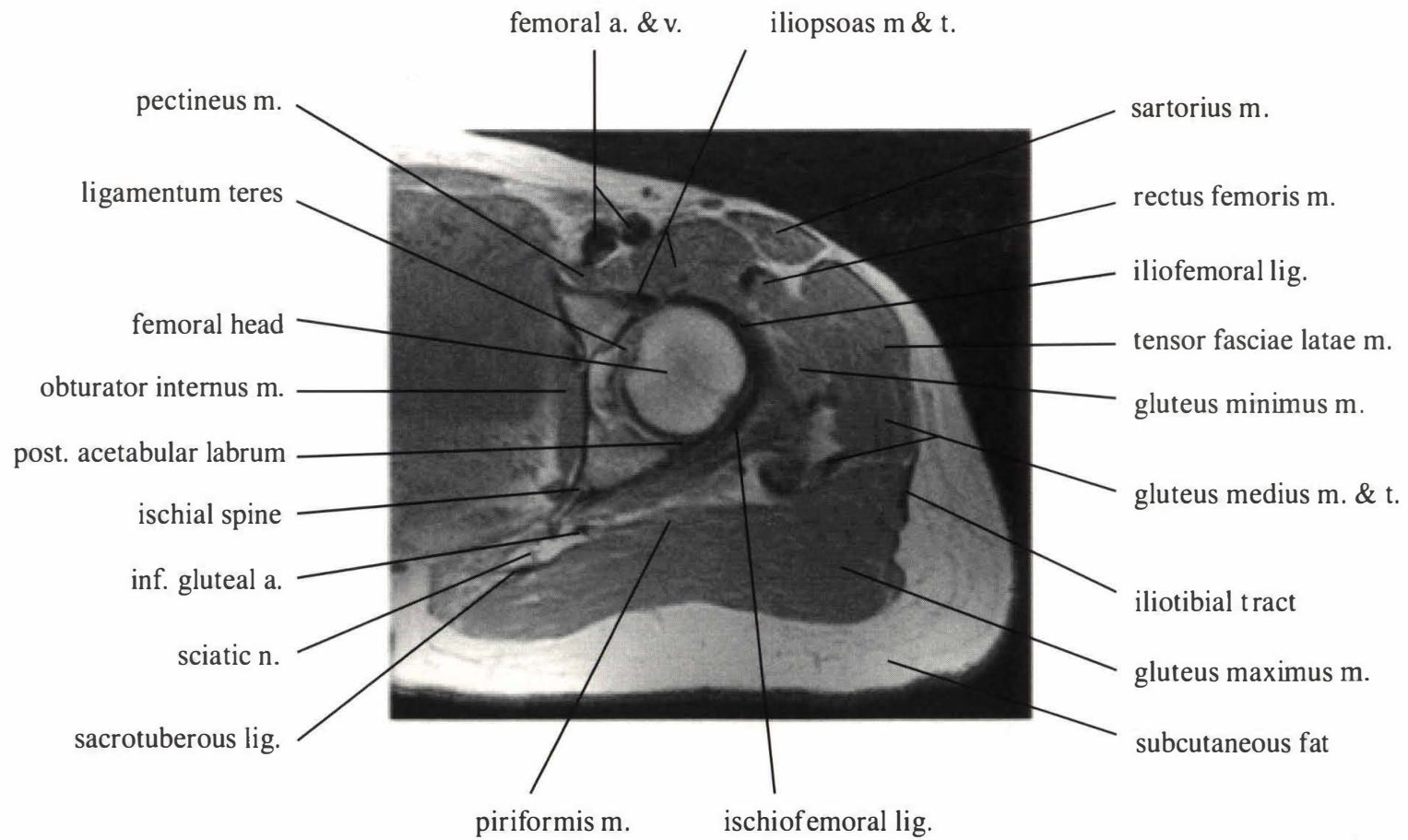
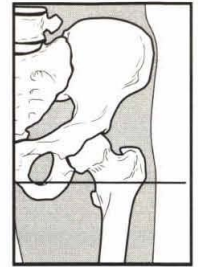




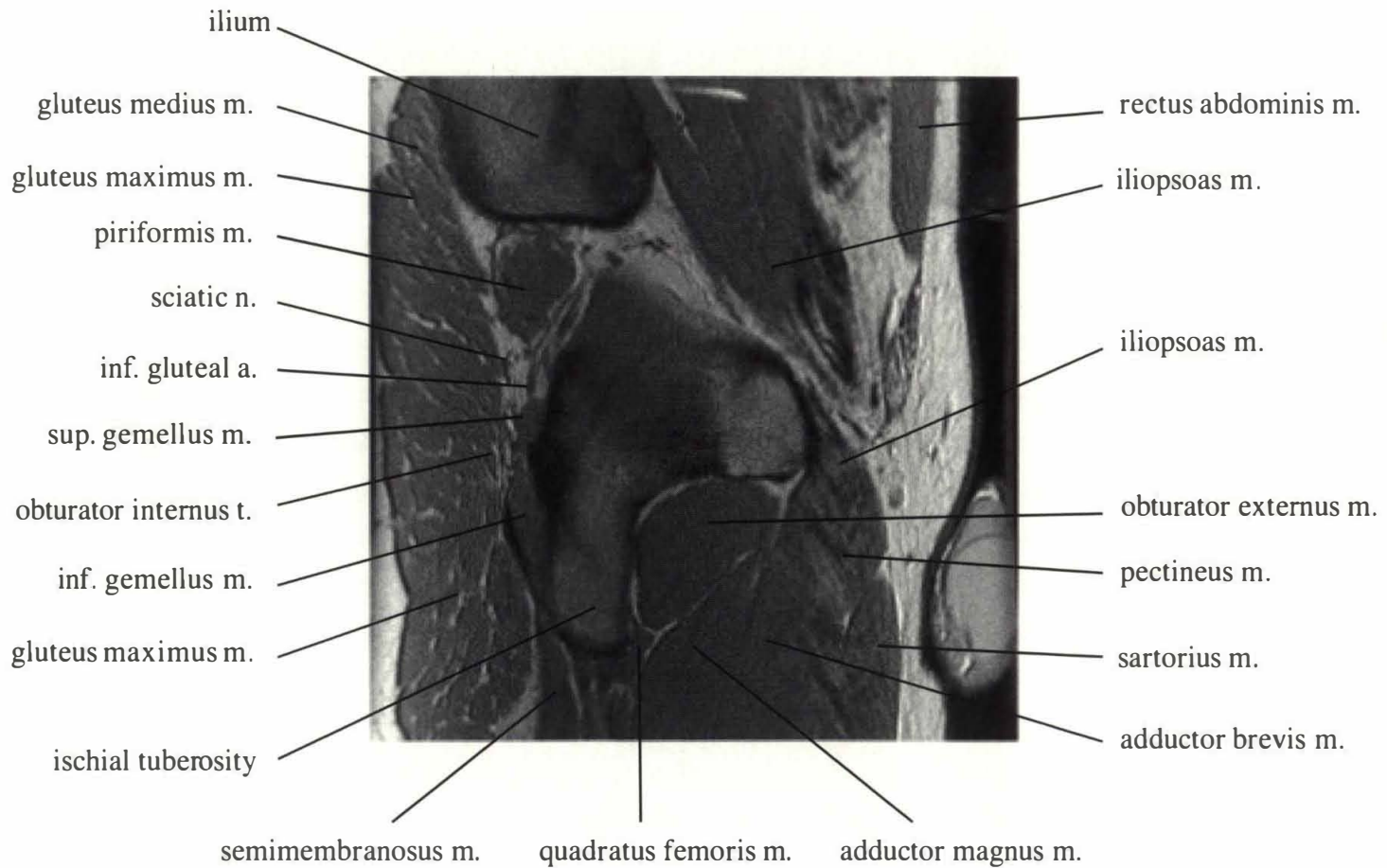
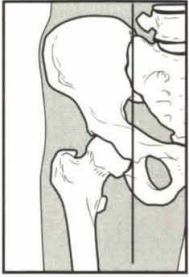


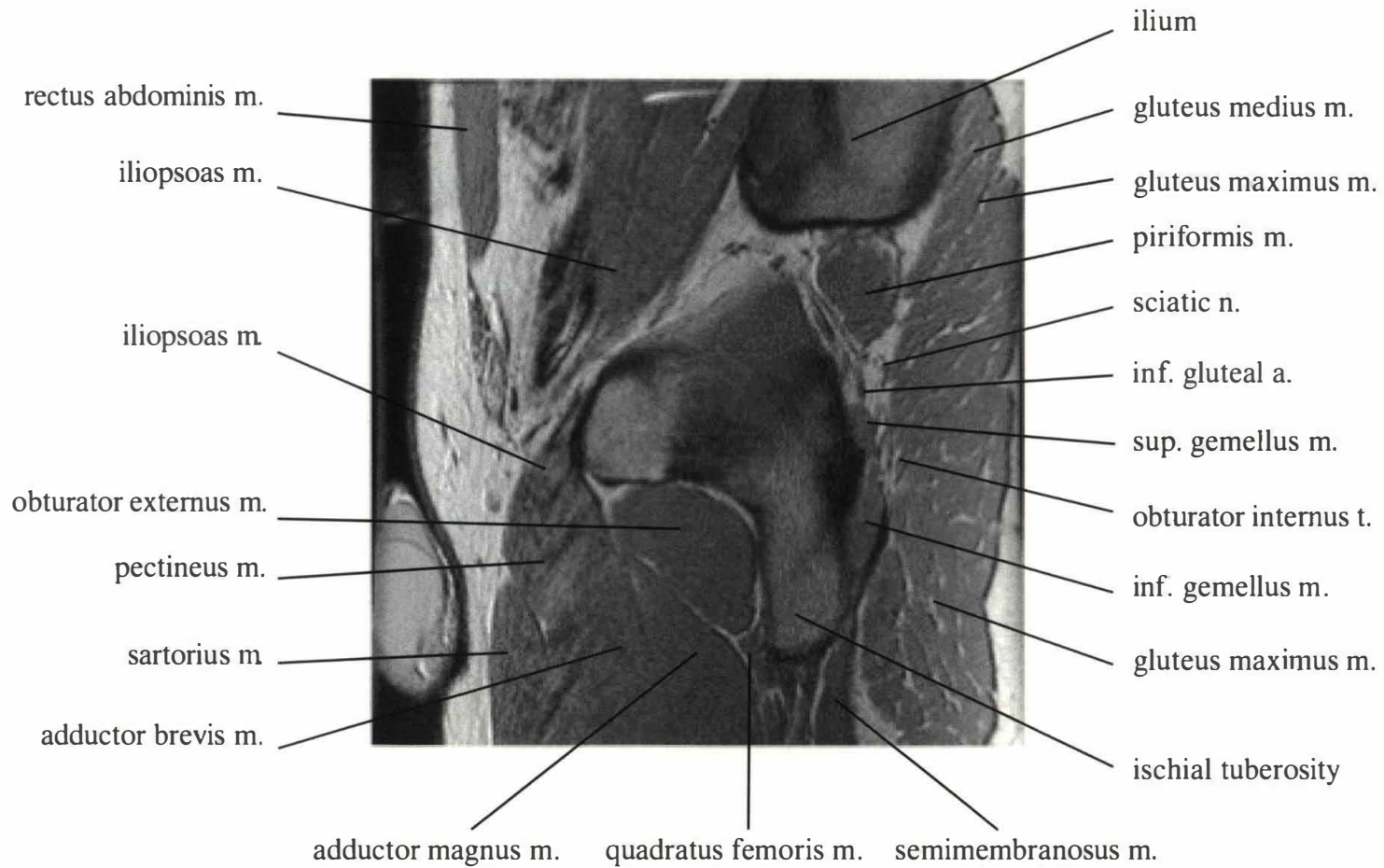
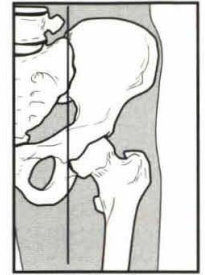


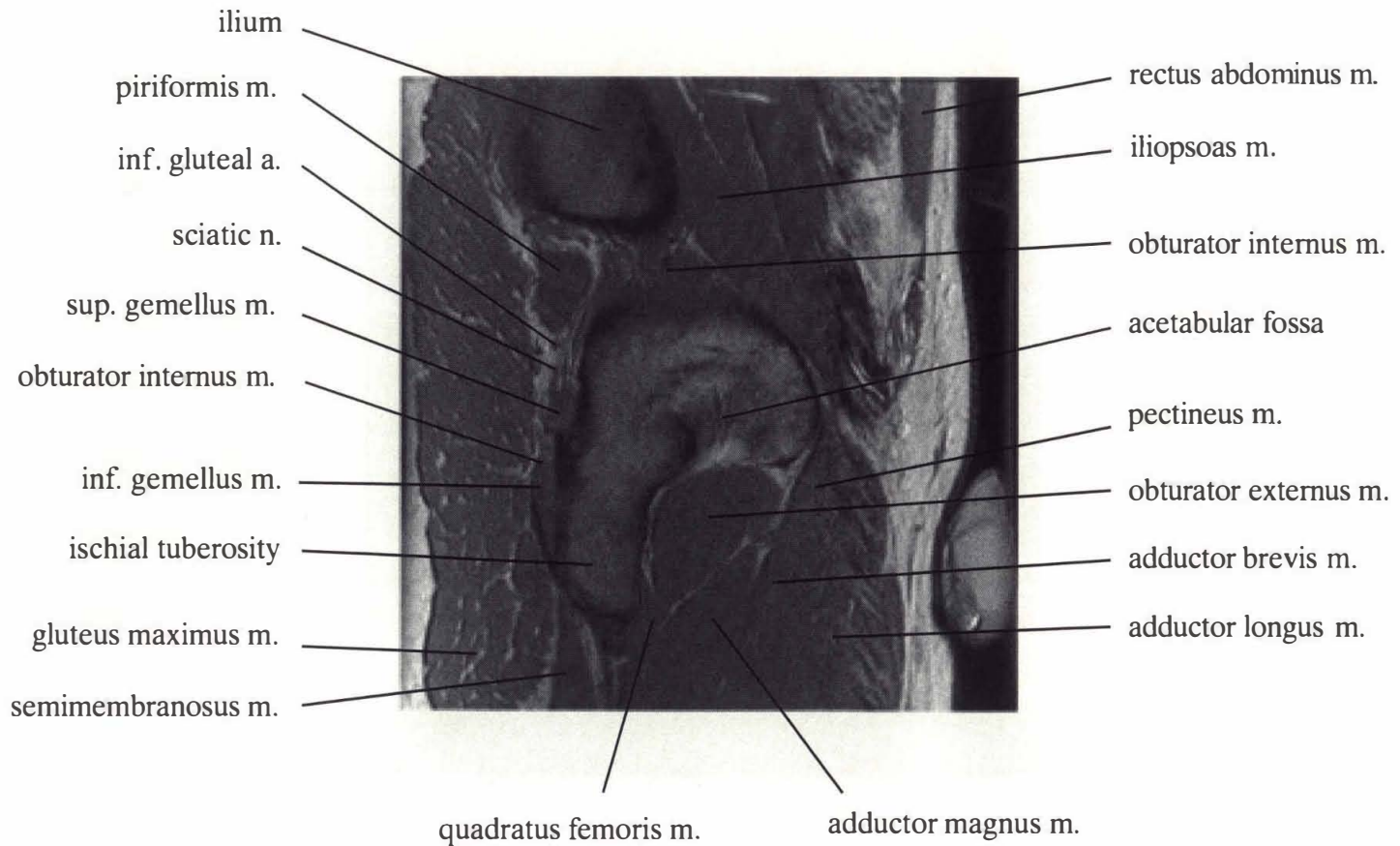
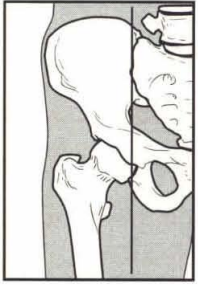




THE HIPS: SAGITTAL ANATOMY







ilium

piriformis m.

inf. gluteal a.

sciatic n.

sup. gemellus m.

obturator internus m.

inf. gemellus m.

ischial tuberosity

gluteus maximus m.

semimembranosus m.

rectus abdominus m.

iliopsoas m.

obturator internus m.

acetabular fossa

pectineus m.

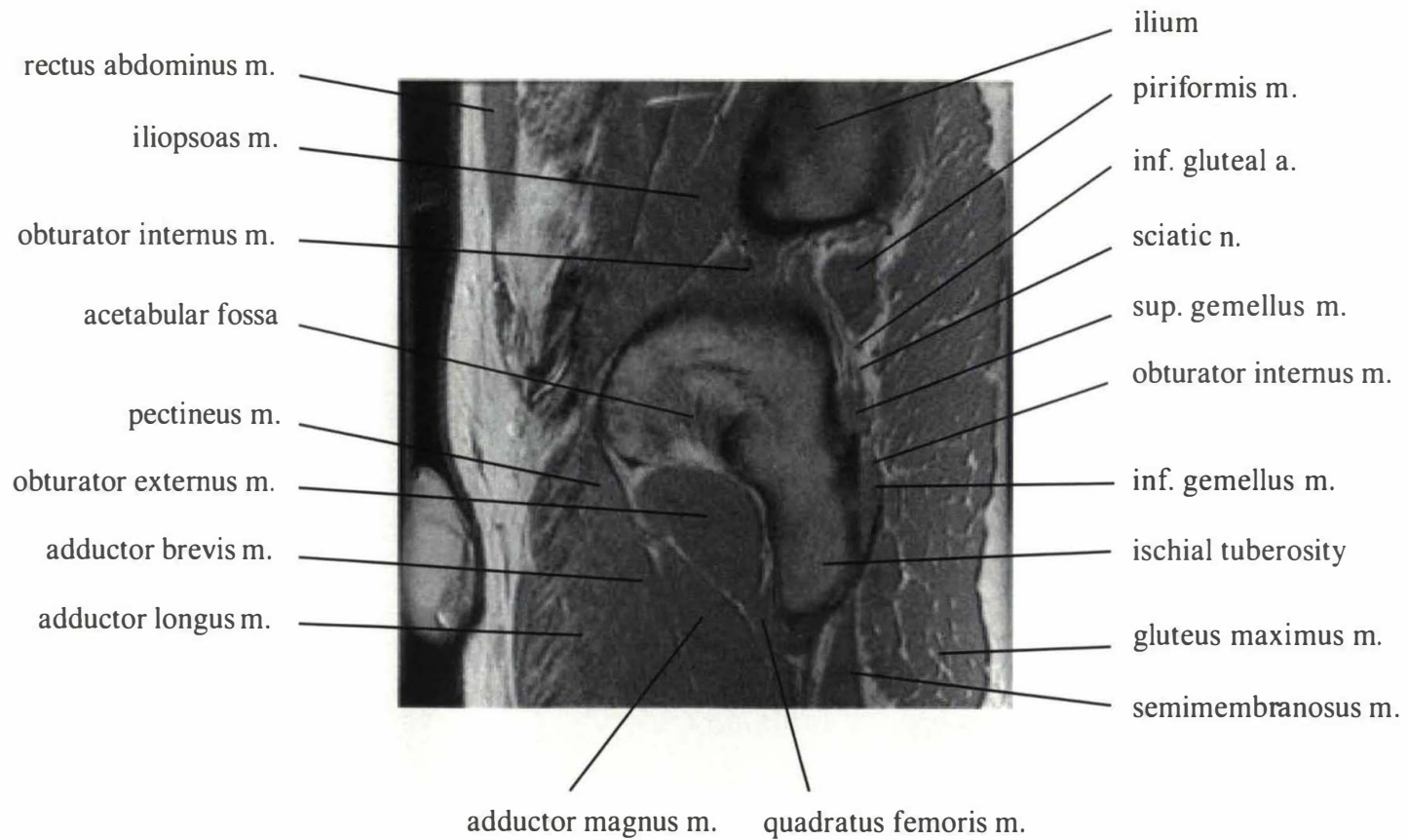
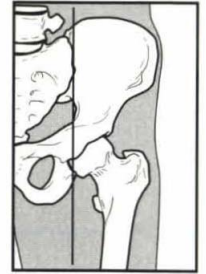
obturator externus m.

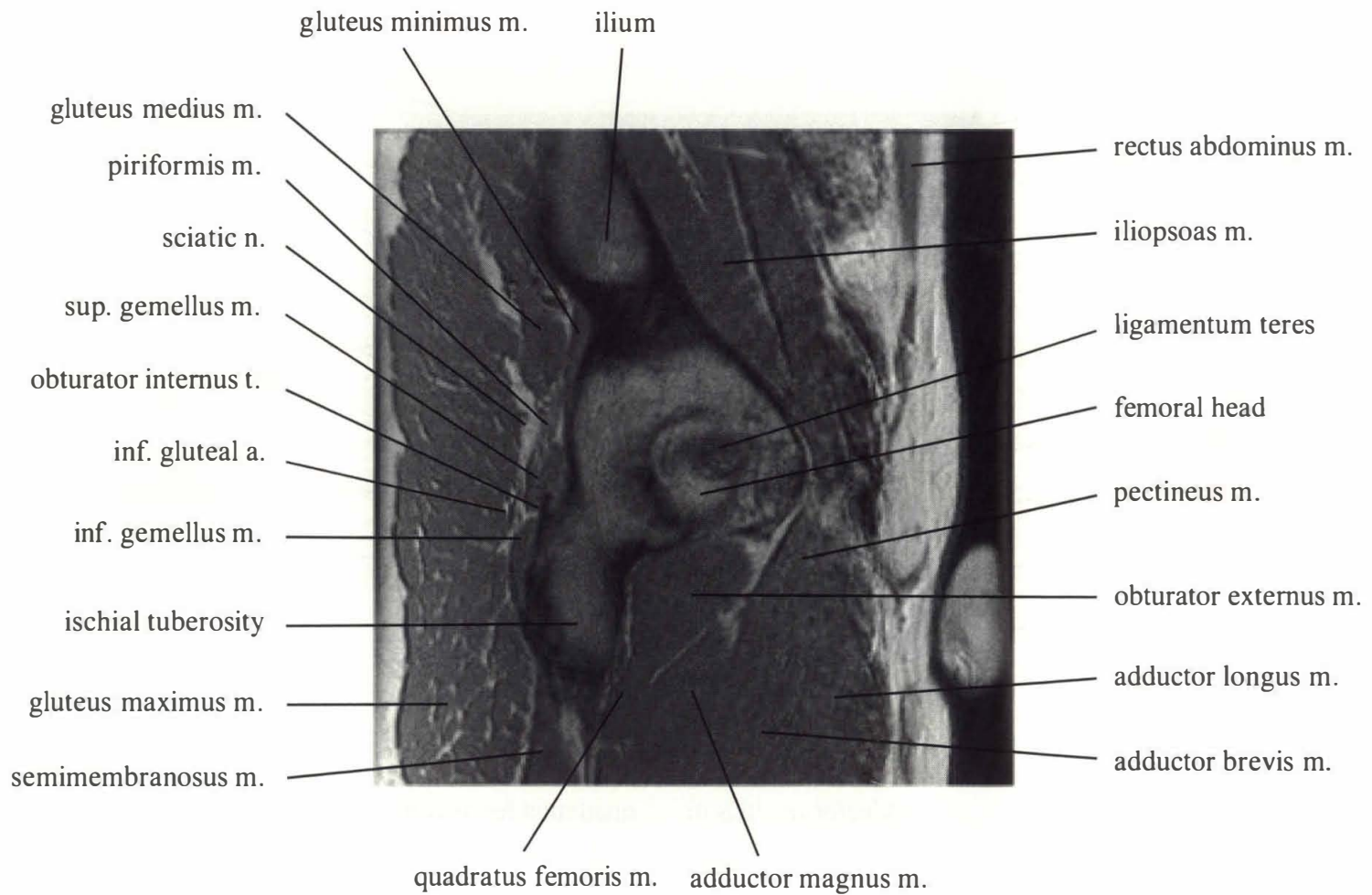
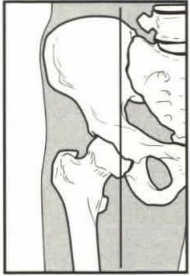
adductor brevis m.

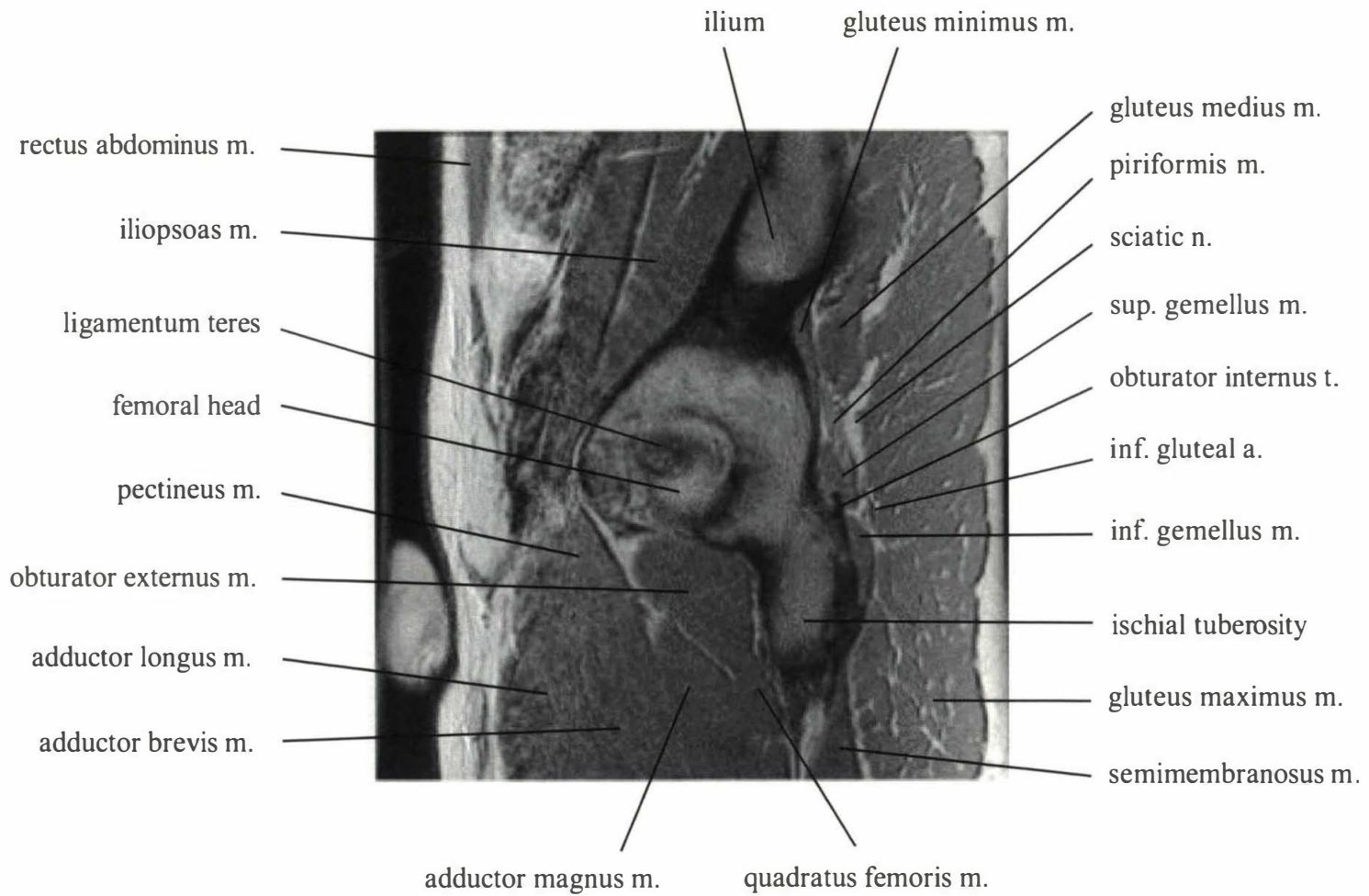
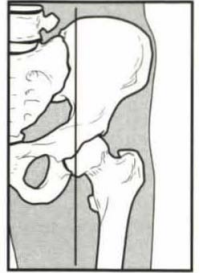
adductor longus m.

quadratus femoris m.

adductor magnus m.







rectus abdominus m.

iliopsoas m.

ligamentum teres

femoral head

pectineus m.

obturator externus m.

adductor longus m.

adductor brevis m.

adductor magnus m.

ilium

gluteus minimus m.

gluteus medius m.

piriformis m.

sciatic n.

sup. gemellus m.

obturator internus t.

inf. gluteal a.

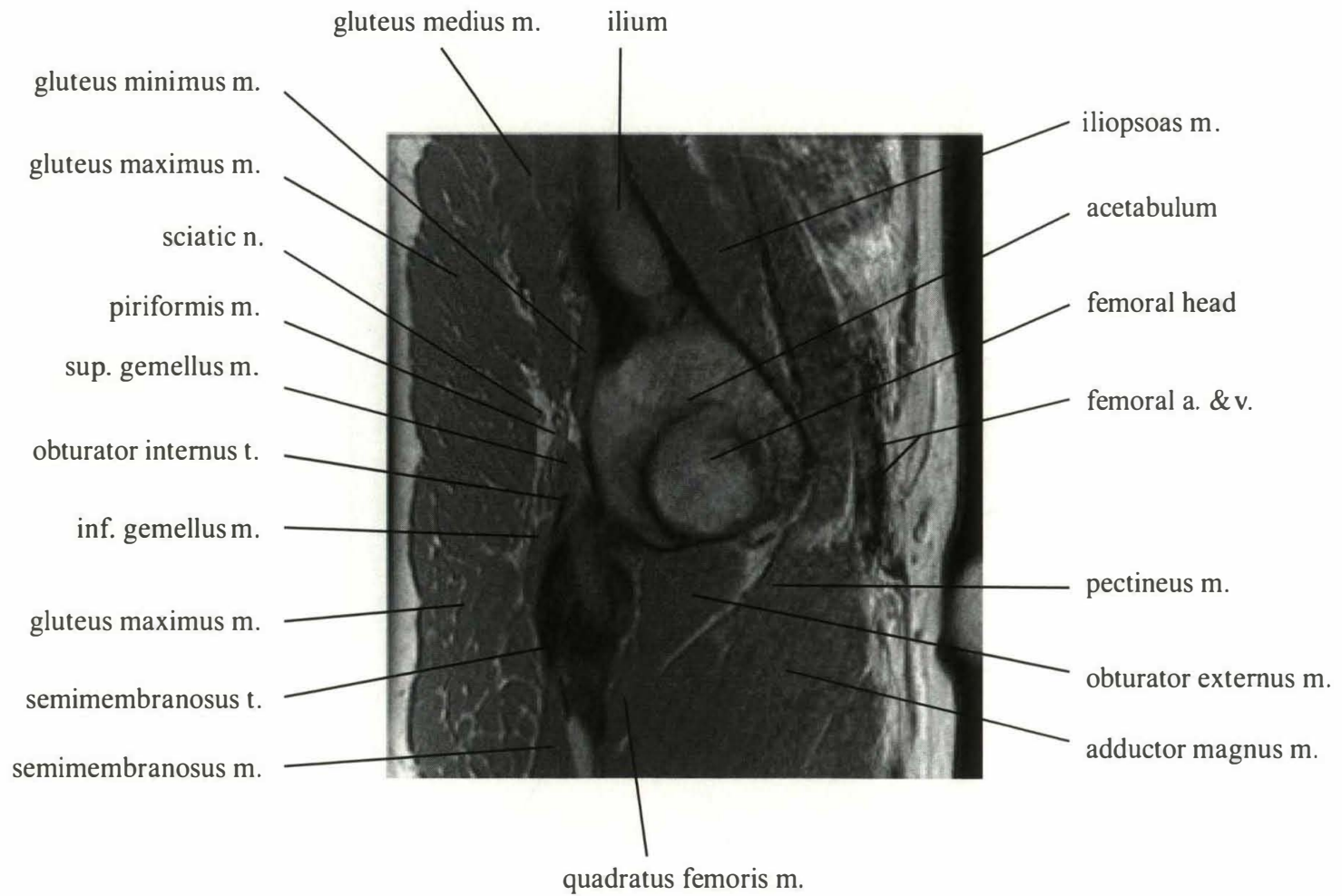
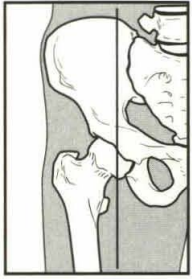
inf. gemellus m.

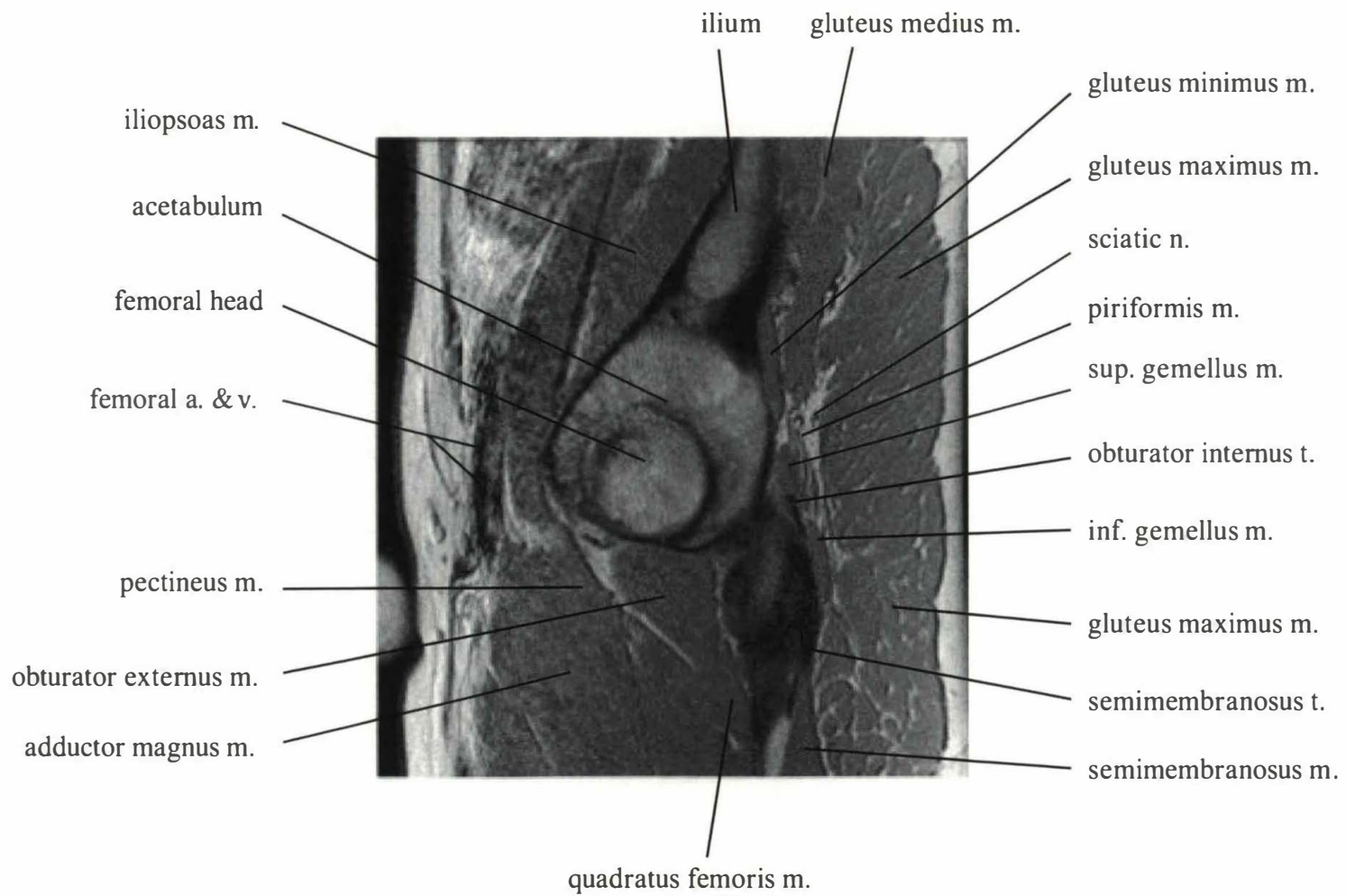
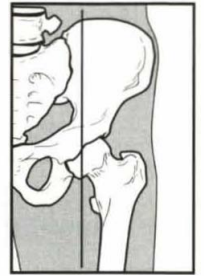
ischial tuberosity

gluteus maximus m.

semimembranosus m.

quadratus femoris m.





iliopsoas m.

acetabulum

femoral head

femoral a. & v.

pectineus m.

obturator externus m.

adductor magnus m.

ilium

gluteus medius m.

gluteus minimus m.

gluteus maximus m.

sciatic n.

piriformis m.

sup. gemellus m.

obturator internus t.

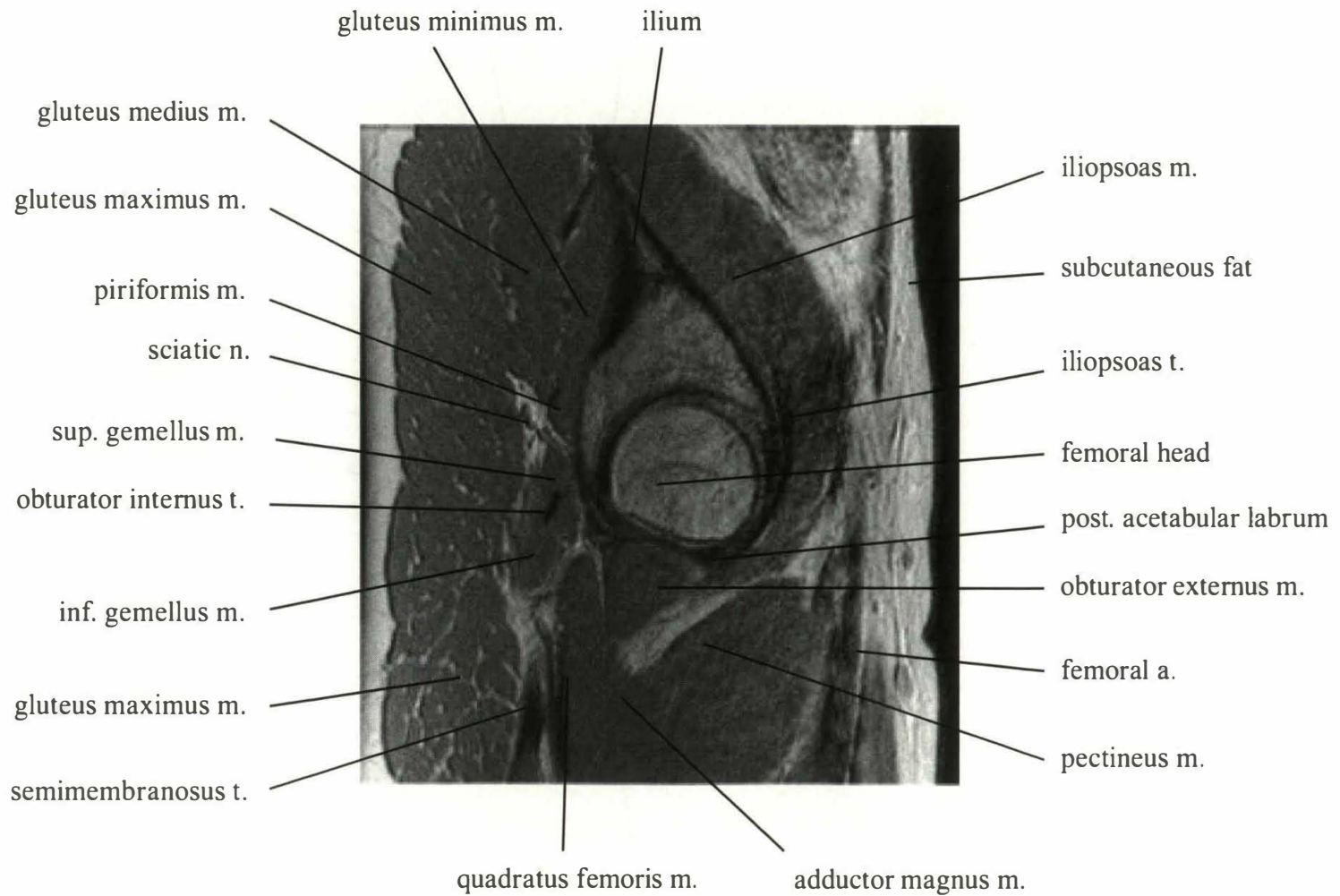
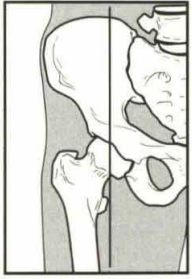
inf. gemellus m.

gluteus maximus m.

semimembranosus t.

semimembranosus m.

quadratus femoris m.



gluteus minimus m.

ilium

gluteus medius m.

gluteus maximus m.

piriformis m.

sciatic n.

sup. gemellus m.

obturator internus t.

inf. gemellus m.

gluteus maximus m.

semimembranosus t.

quadratus femoris m.

adductor magnus m.

iliopsoas m.

subcutaneous fat

iliopsoas t.

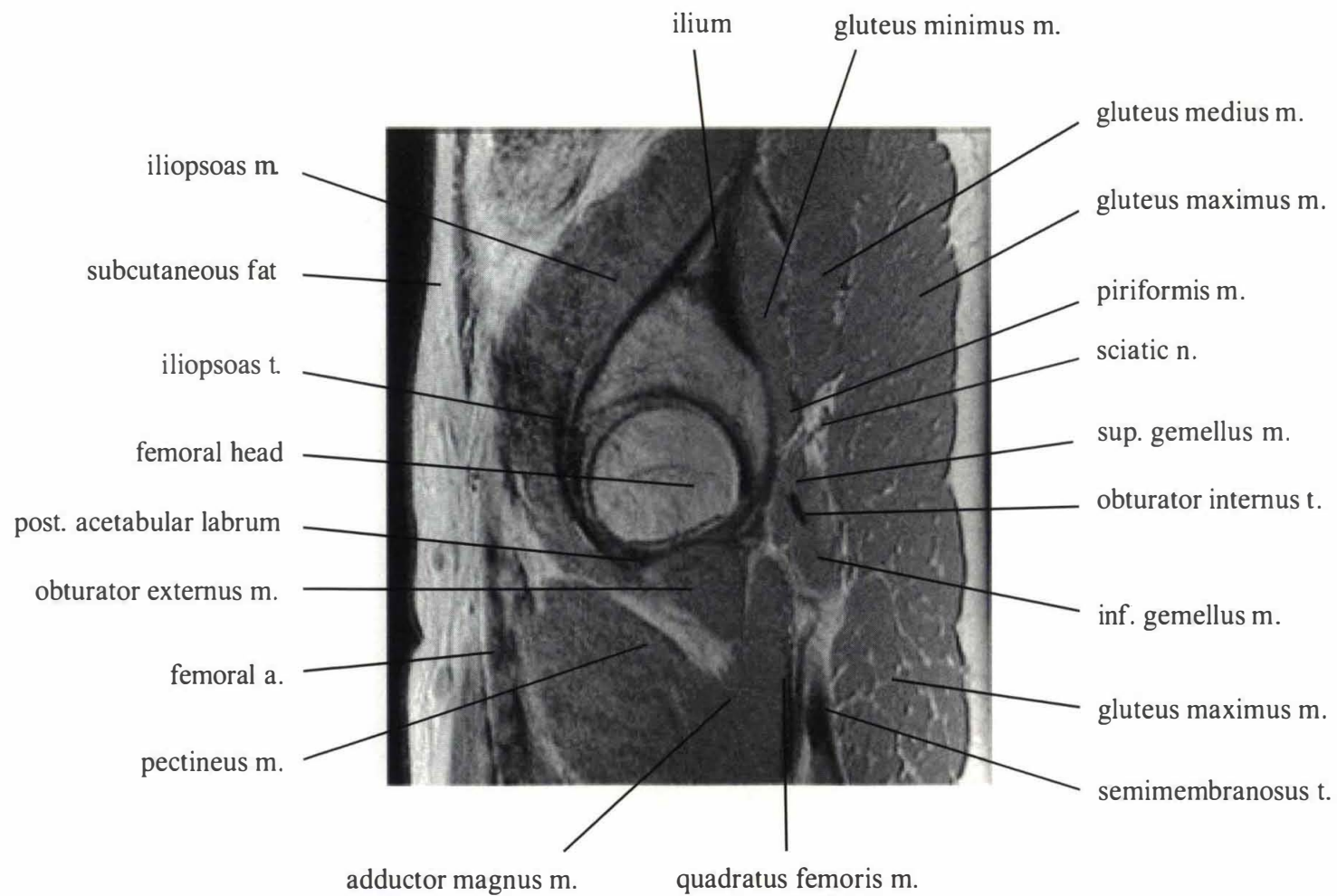
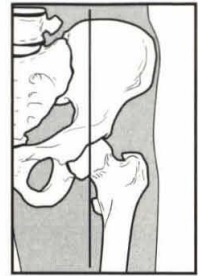
femoral head

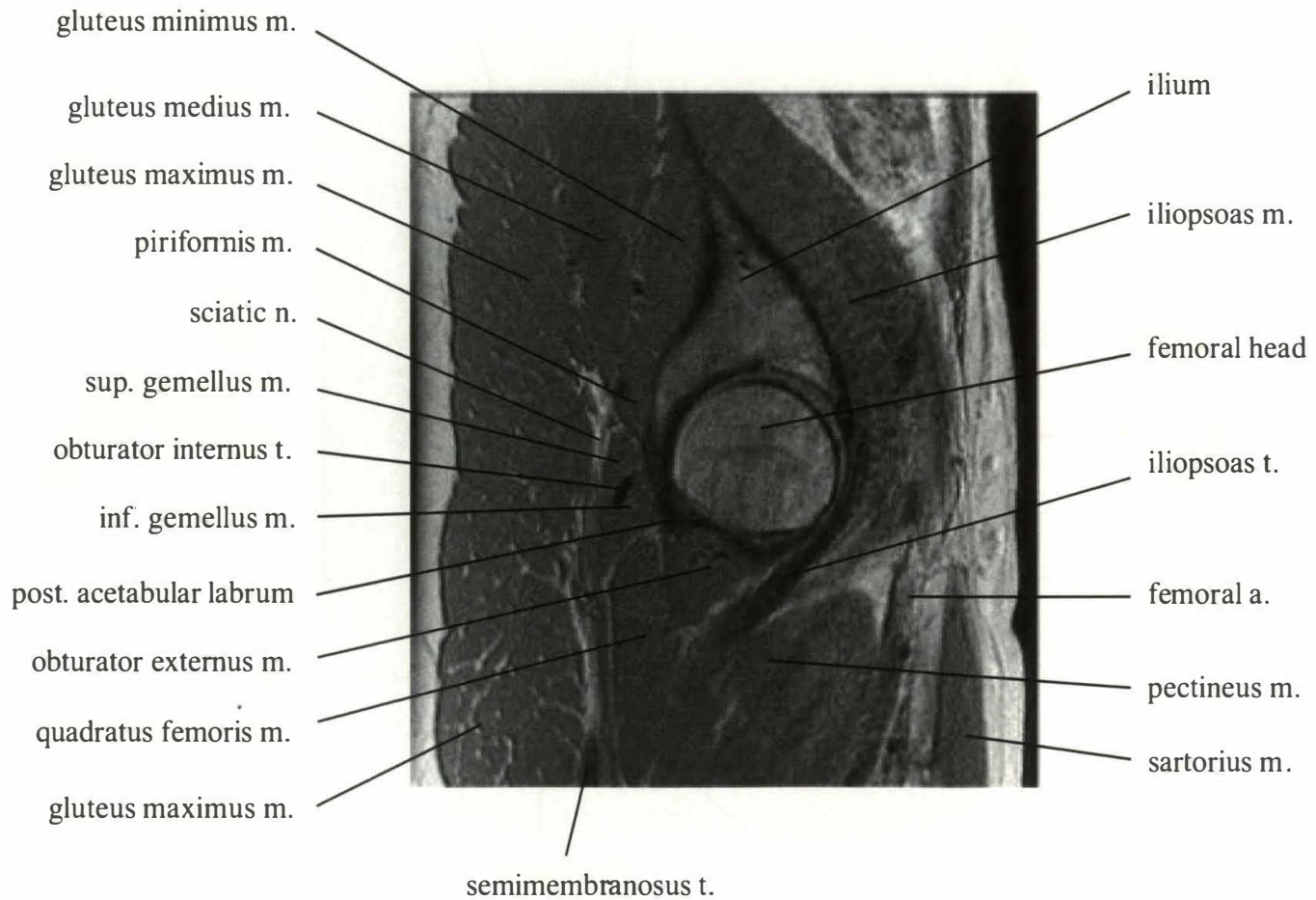
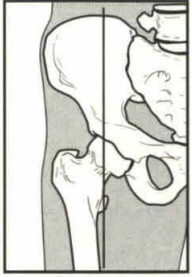
post. acetabular labrum

obturator externus m.

femoral a.

pectineus m.





gluteus minimus m.

gluteus medius m.

gluteus maximus m.

piriformis m.

sciatic n.

sup. gemellus m.

obturator internus t.

inf. gemellus m.

post. acetabular labrum

obturator externus m.

quadratus femoris m.

gluteus maximus m.

ilium

iliopsoas m.

femoral head

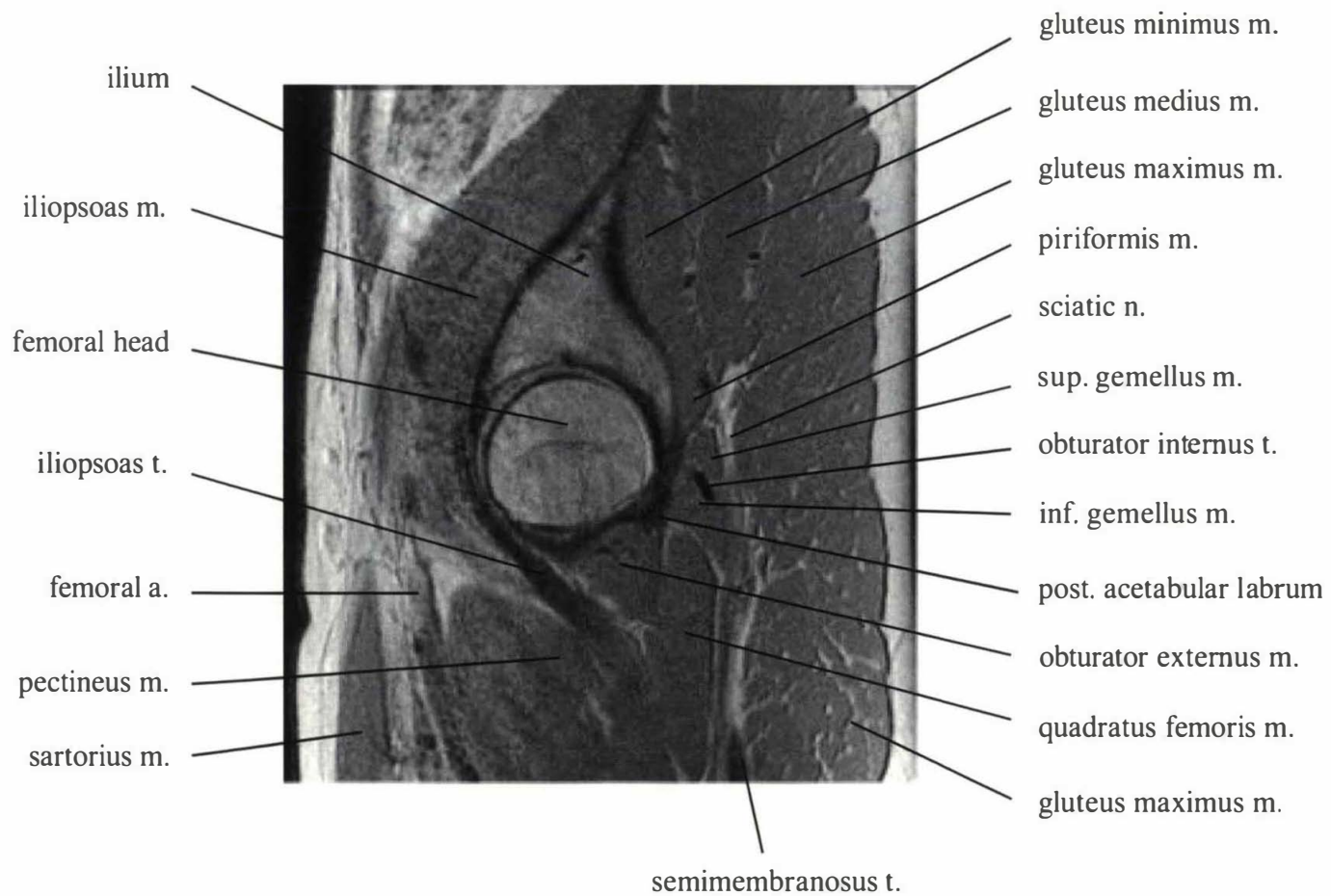
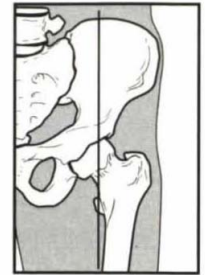
iliopsoas t.

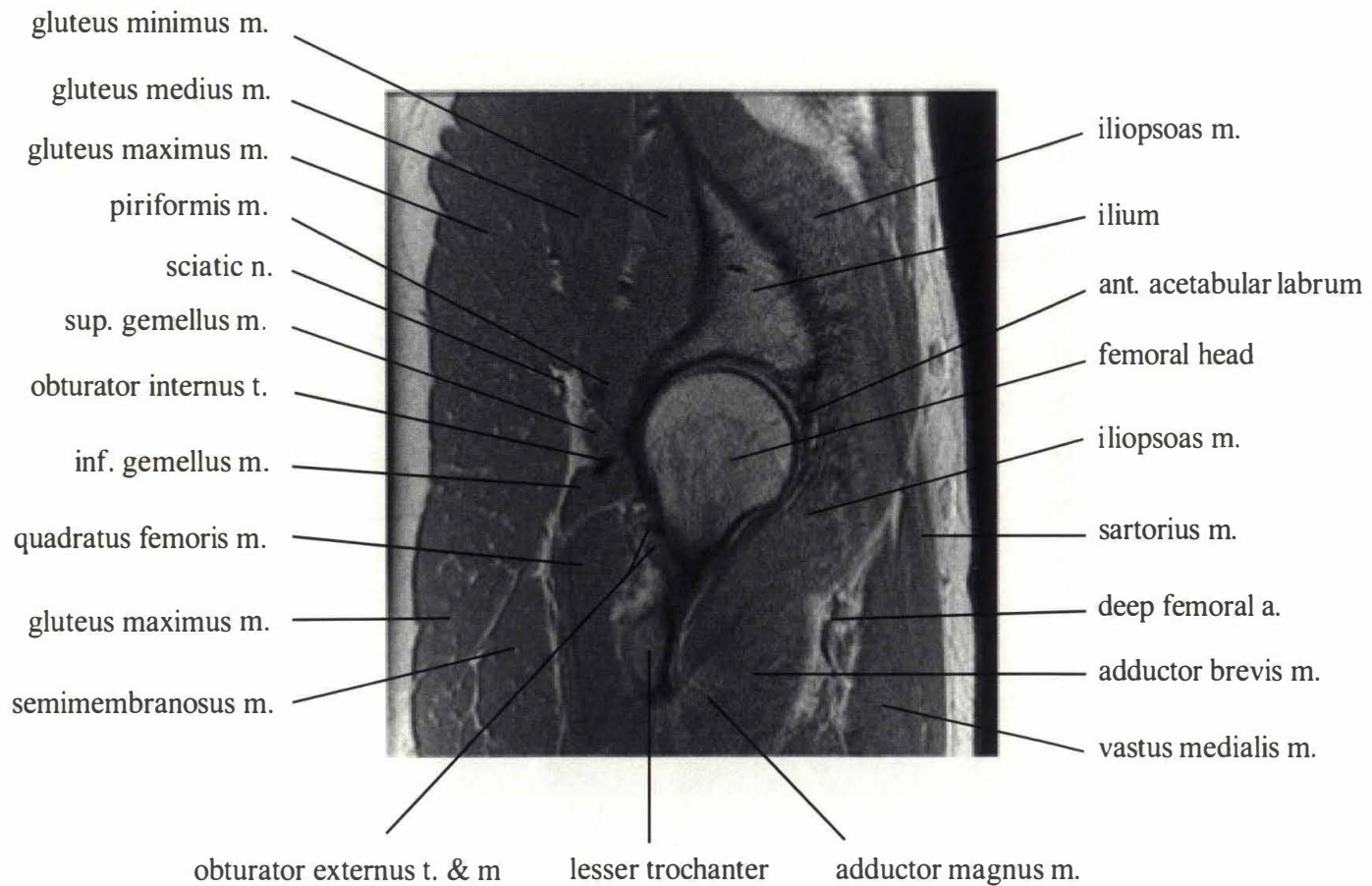
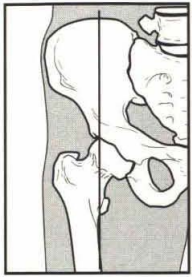
femoral a.

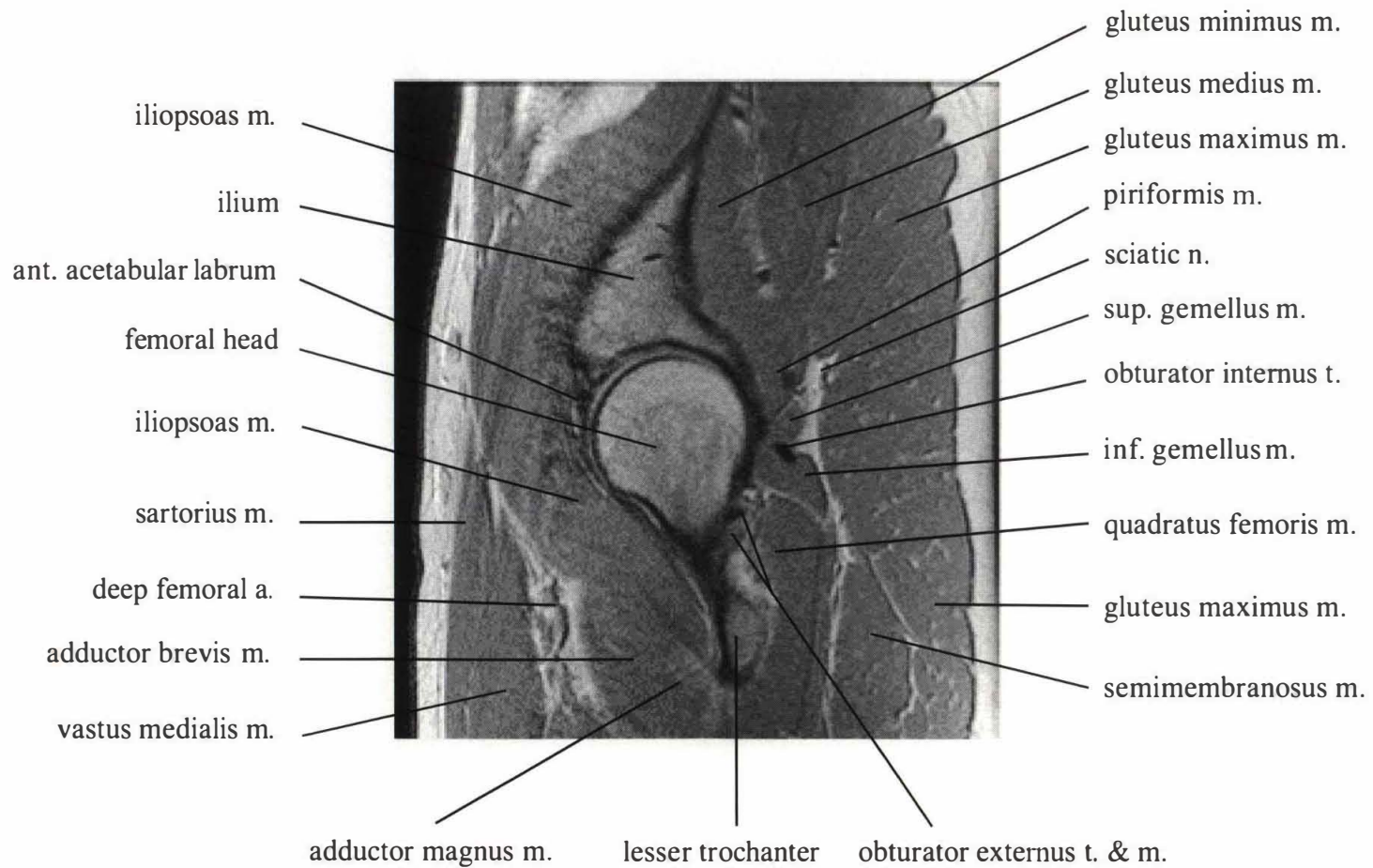
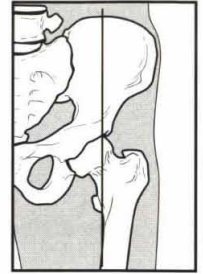
pectineus m.

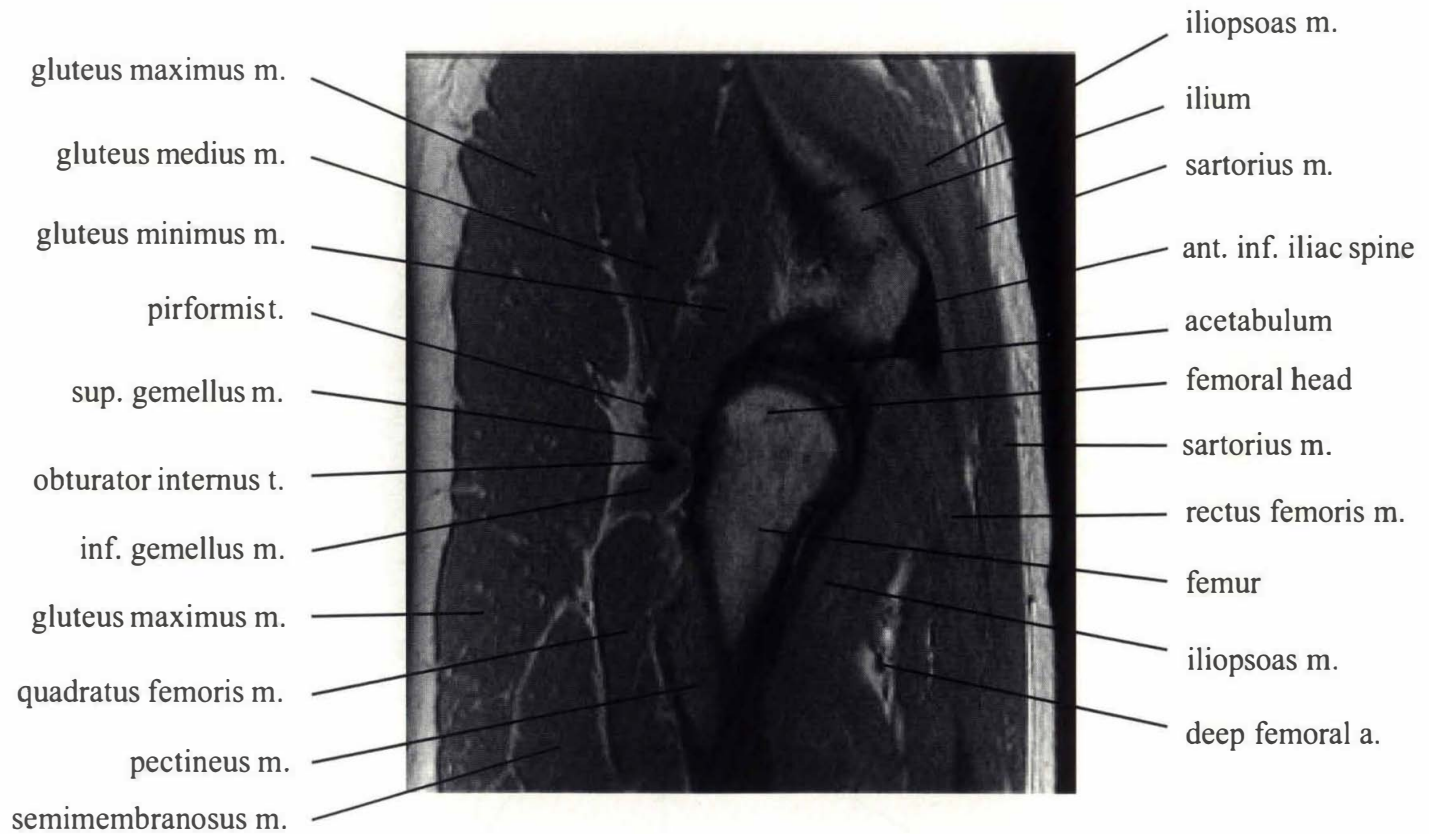
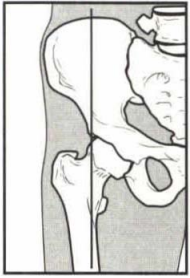
sartorius m.

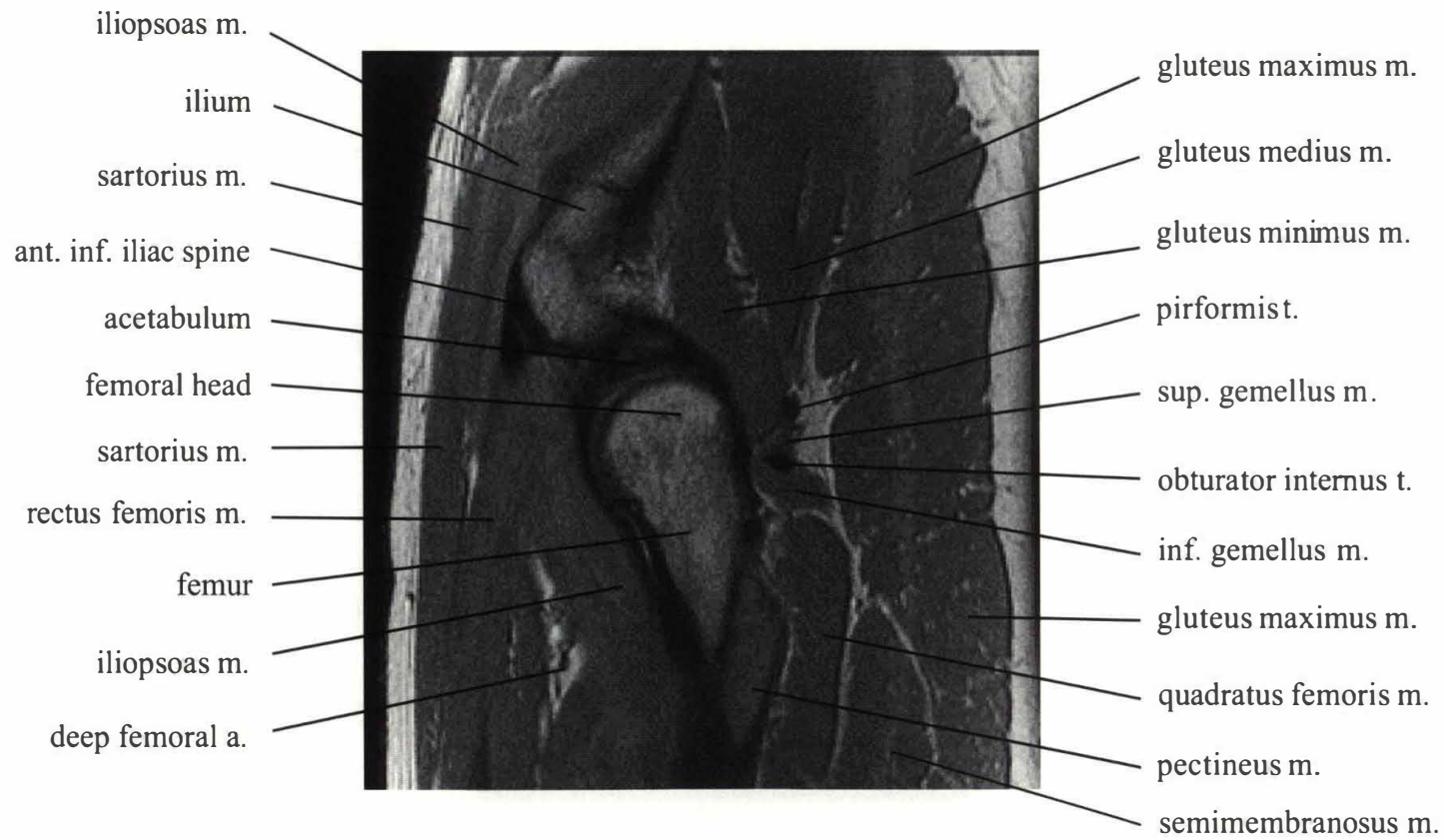
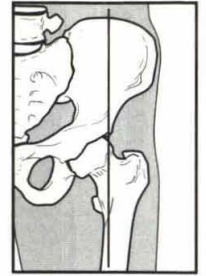
semimembranosus t.

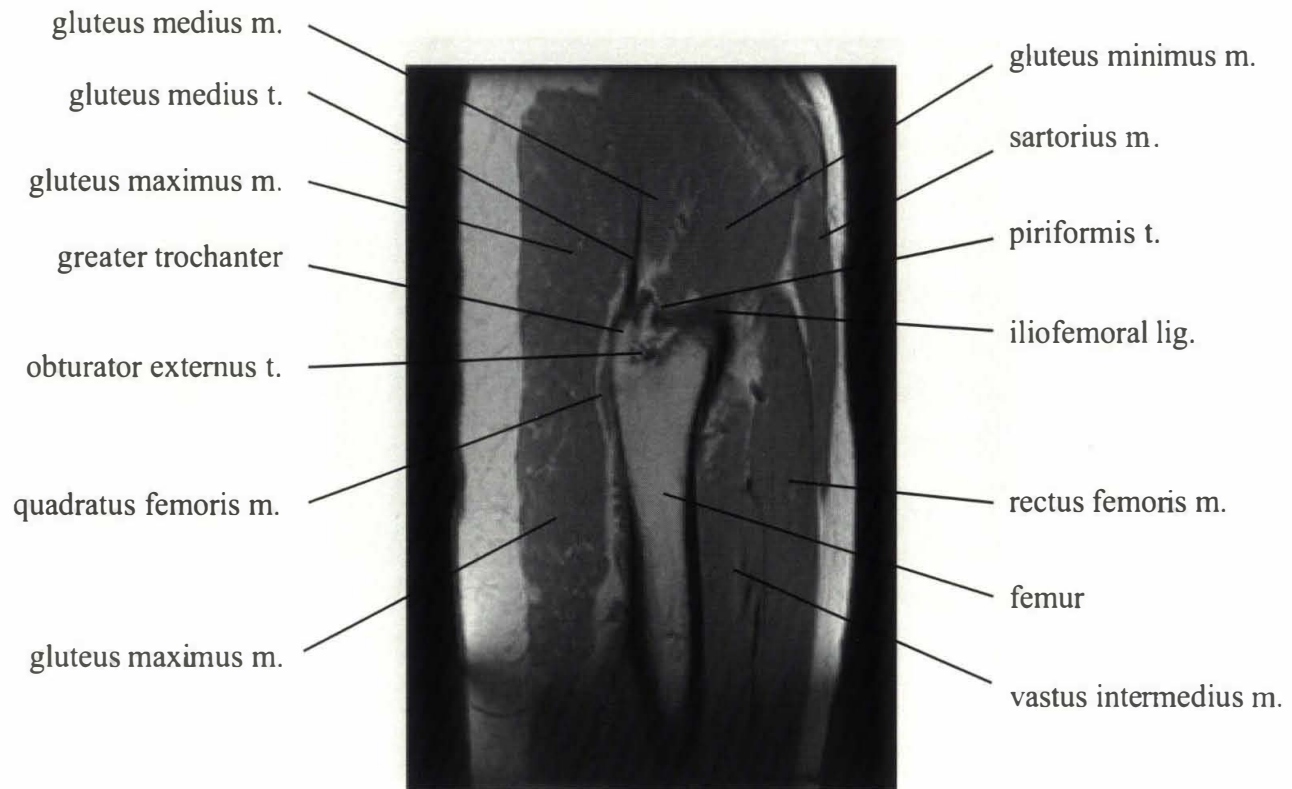


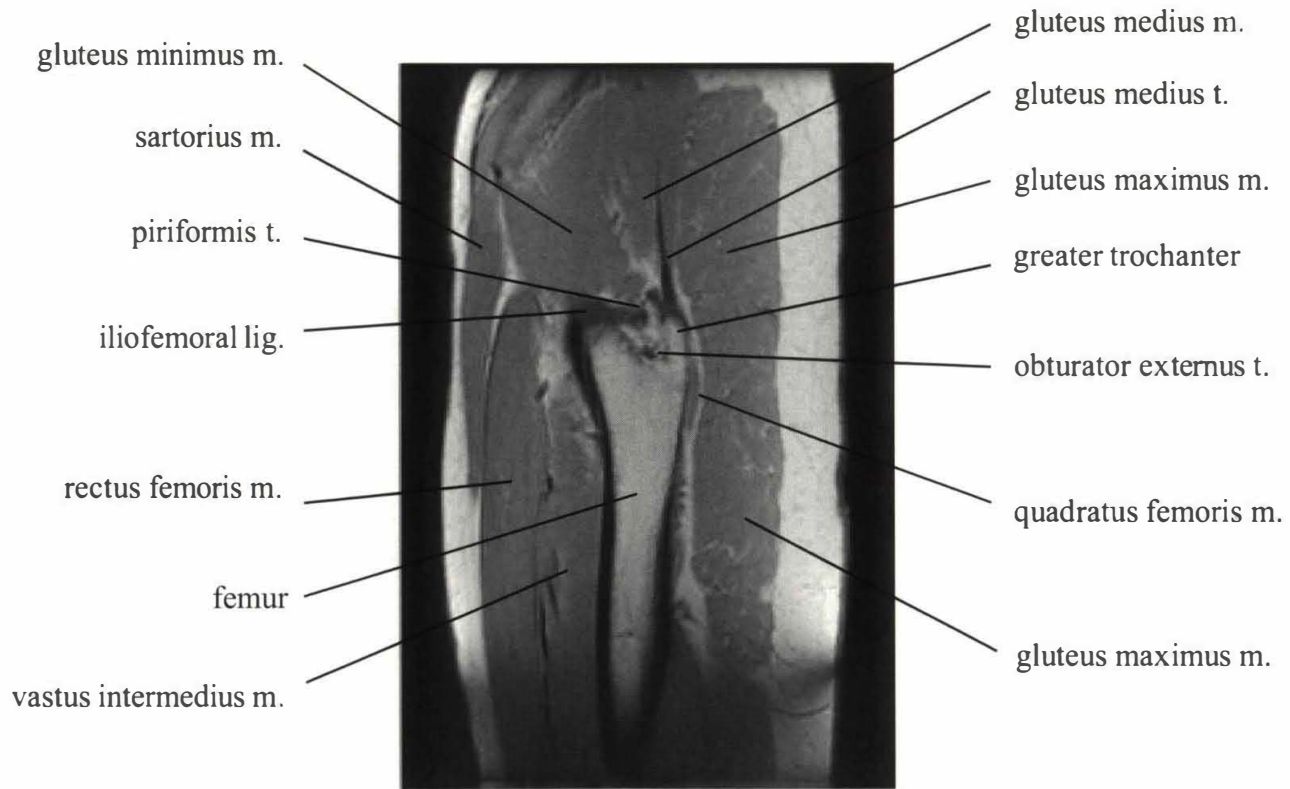
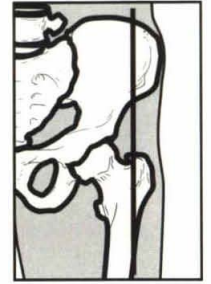




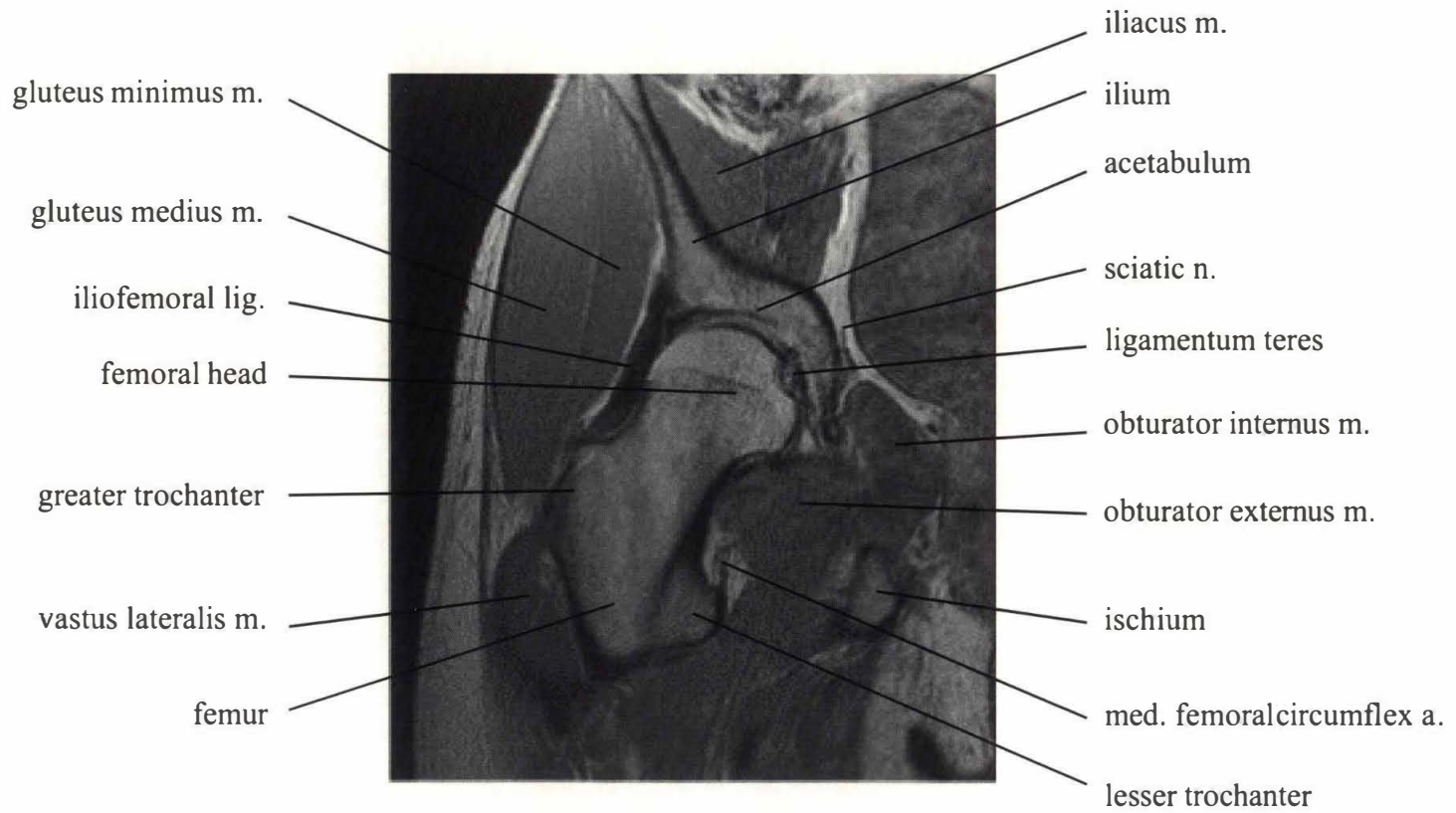
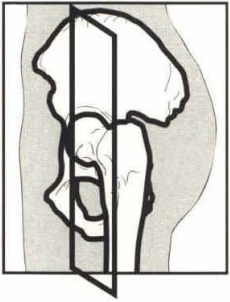


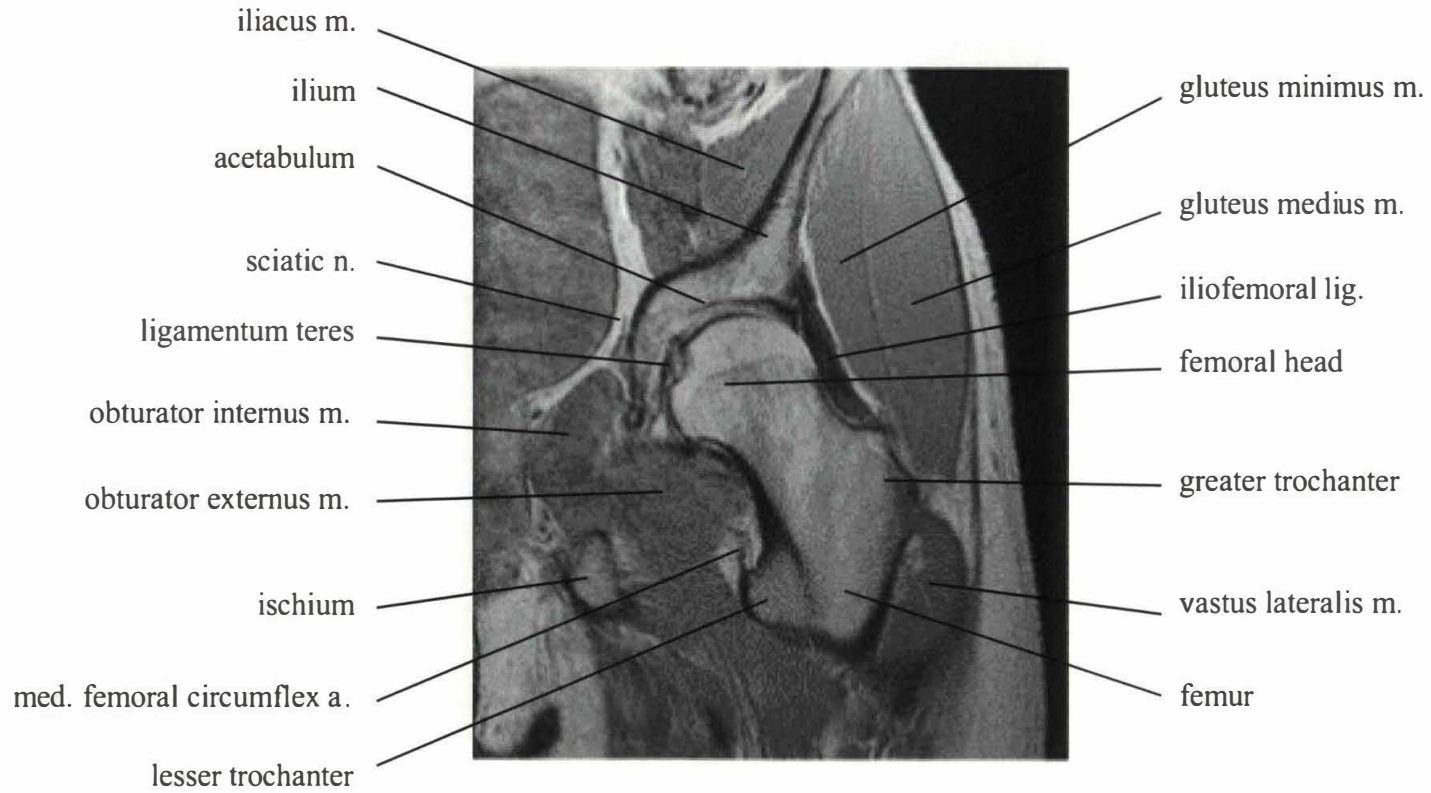
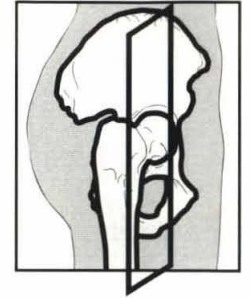


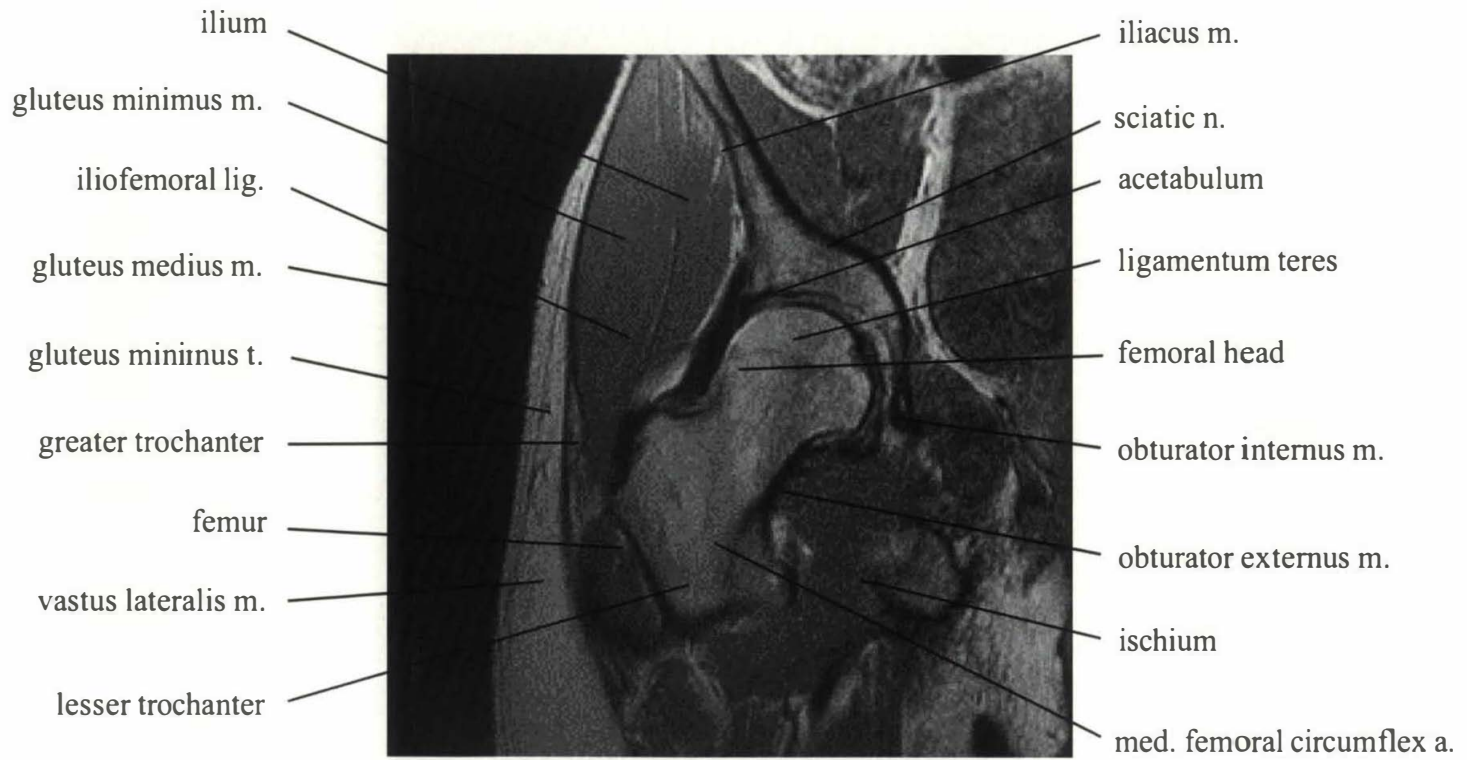
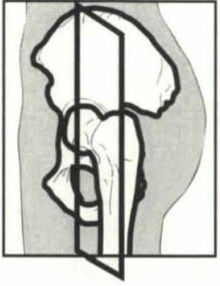




THE HIPS: CORONAL ANATOMY







ilium

gluteus minimus m.

iliofemoral lig.

gluteus medius m.

gluteus minimus t.

greater trochanter

femur

vastus lateralis m.

lesser trochanter

iliacus m.

sciatic n.

acetabulum

ligamentum teres

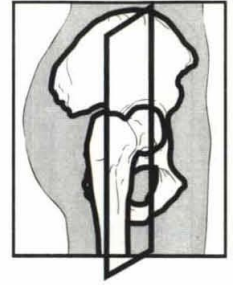
femoral head

obturator internus m.

obturator externus m.

ischium

med. femoral circumflex a.



iliacus m.

sciatic n.

acetabulum

ligamentum teres

femoral head

obturator internus m.

obturator externus m.

ischium

med. femoral circumflex a.

ilium

gluteus minimus m.

iliofemoral lig.

gluteus medius m.

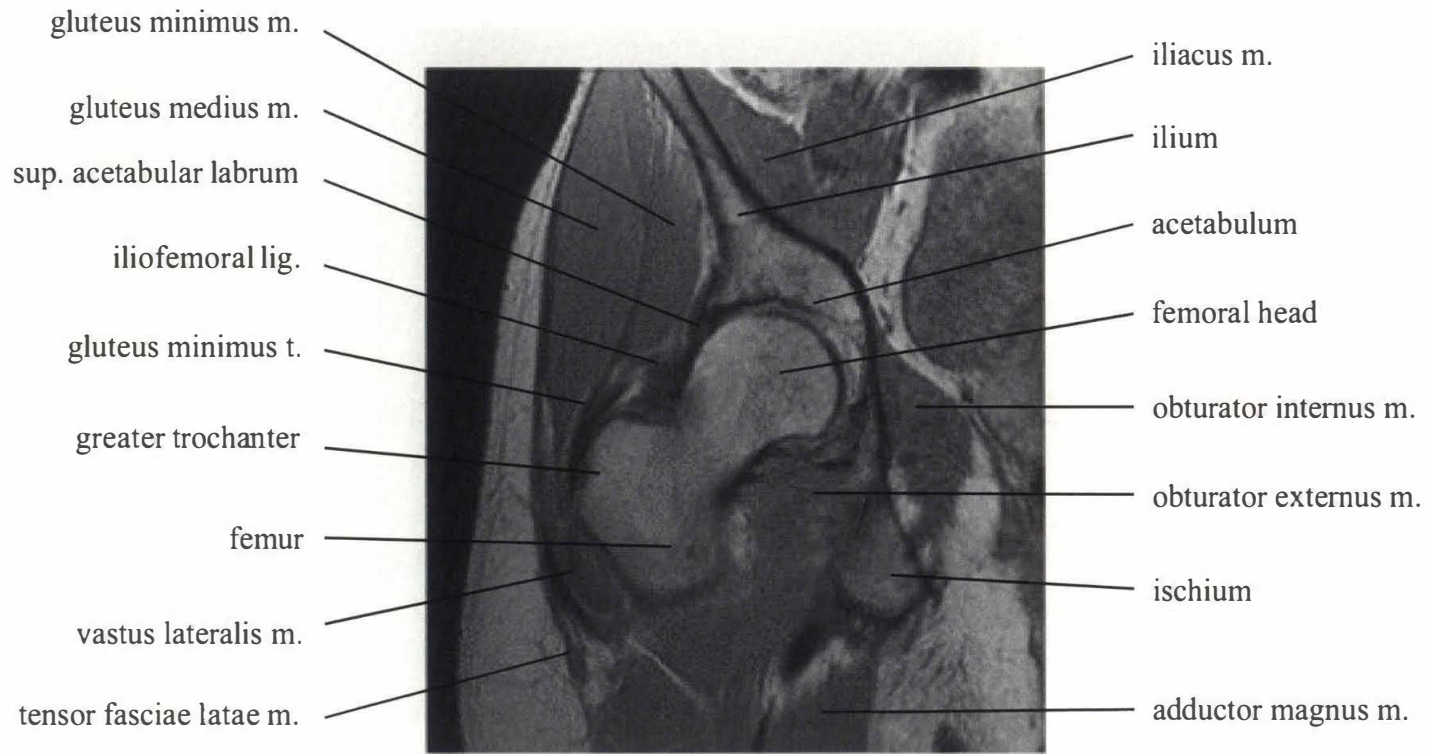
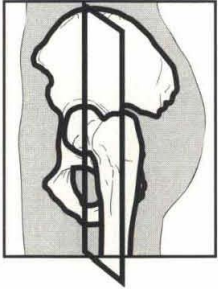
gluteus minimus t.

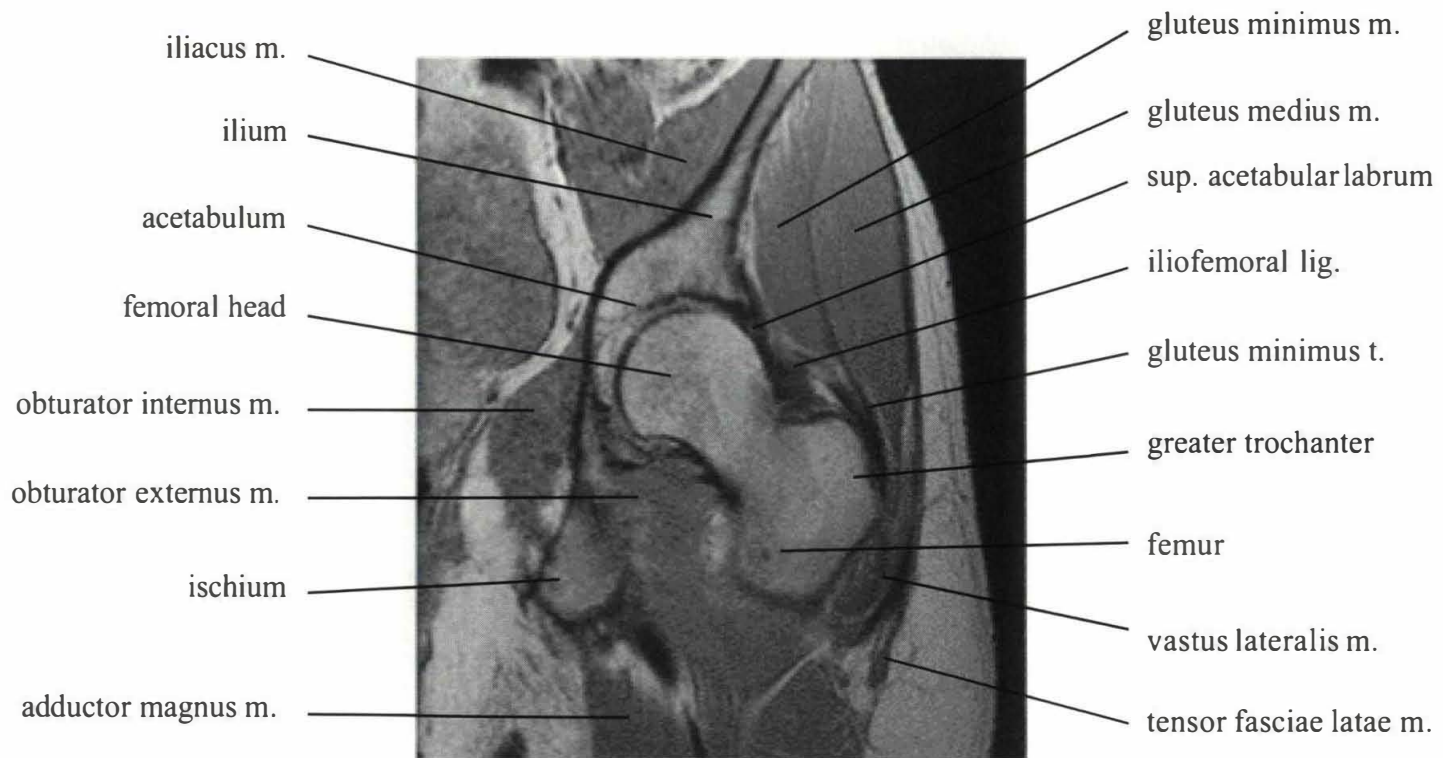
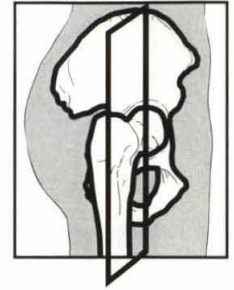
greater trochanter

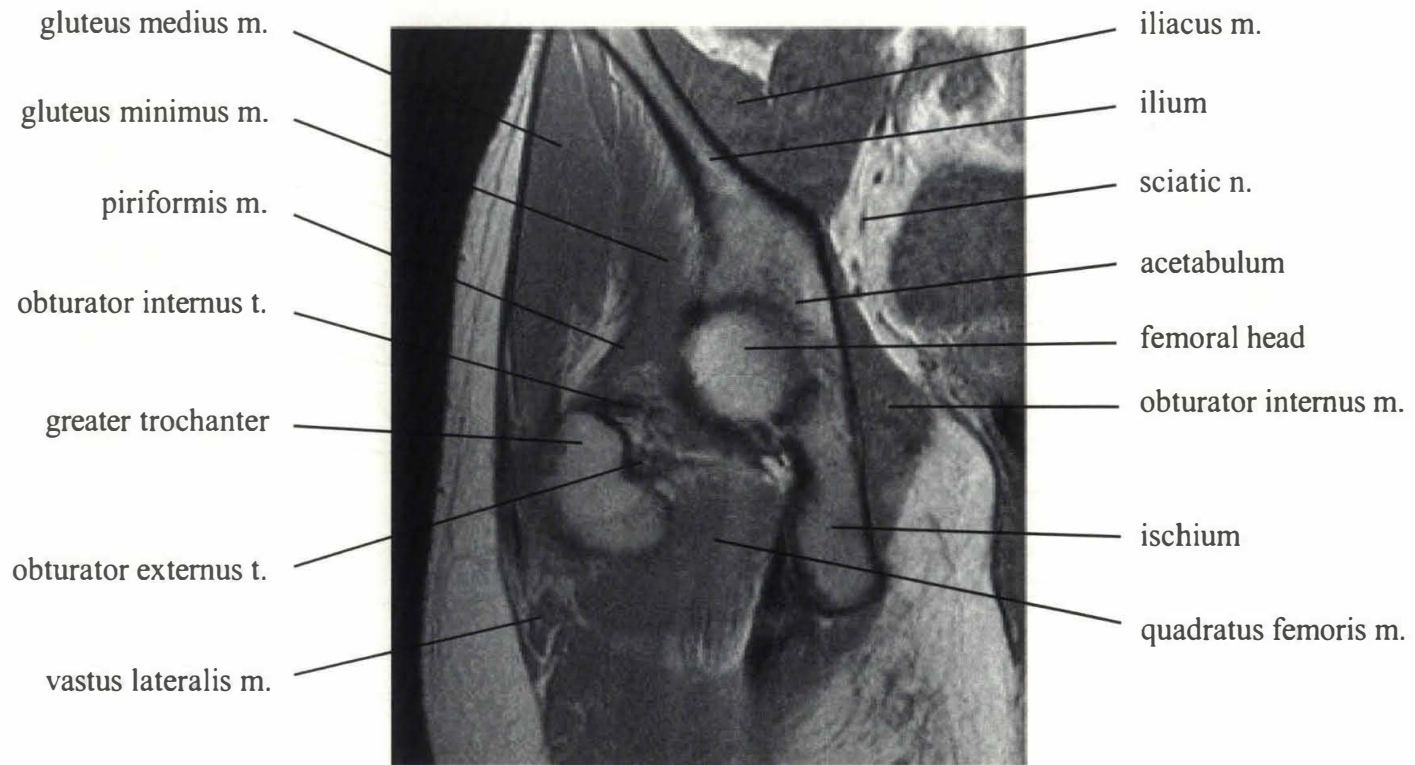
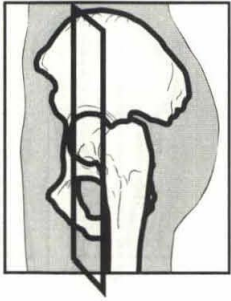
femur

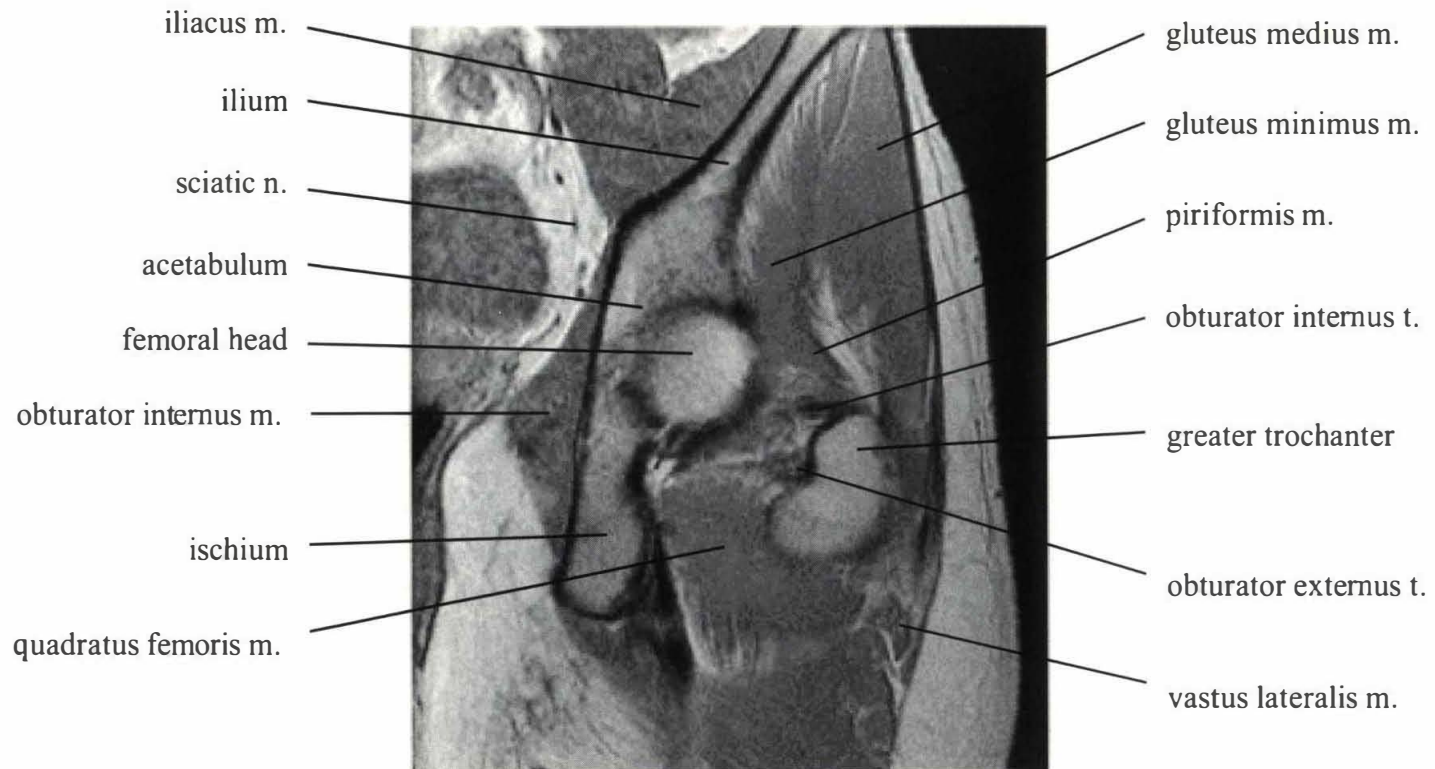
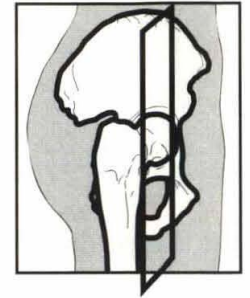
vastus lateralis m.

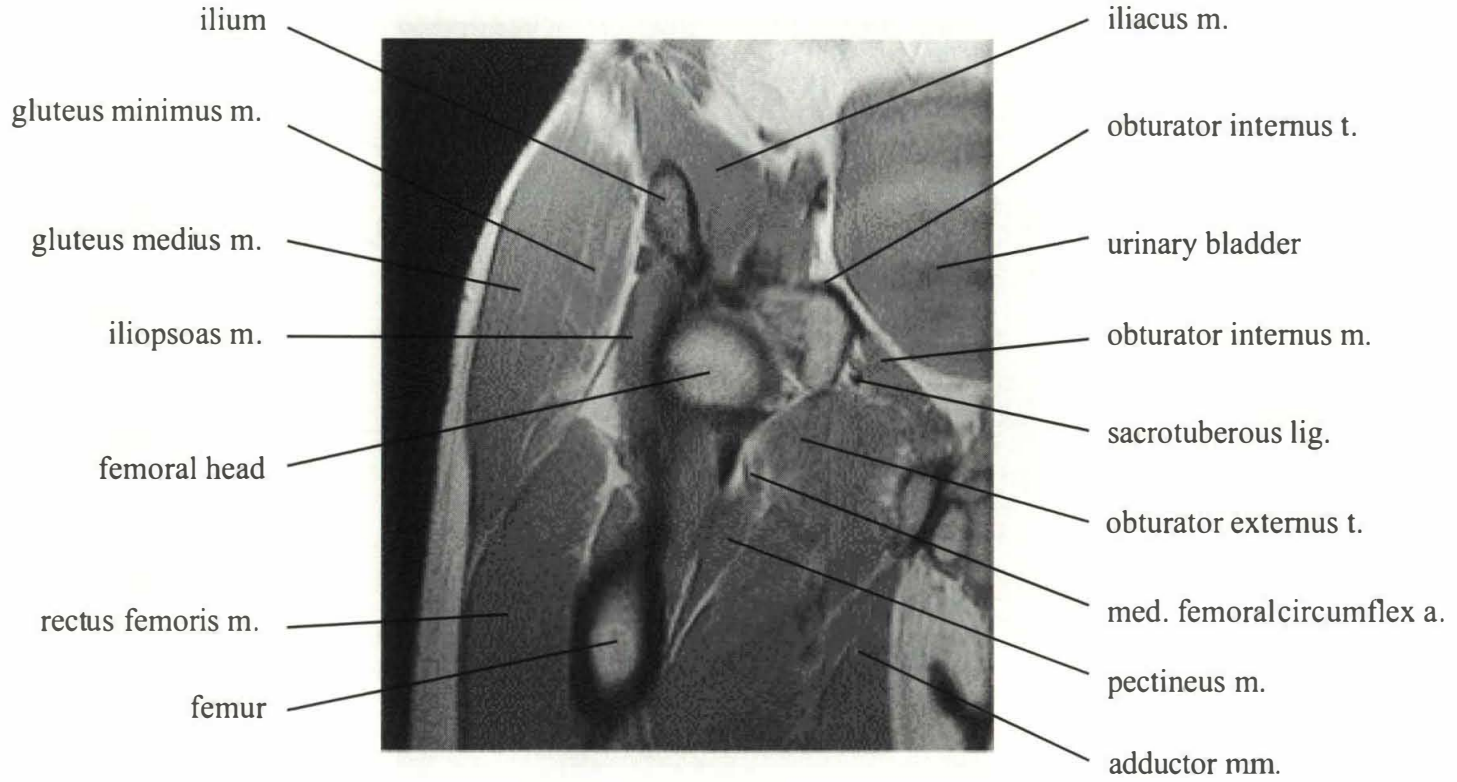
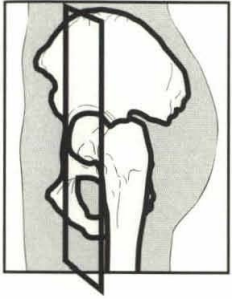
lesser trochanter

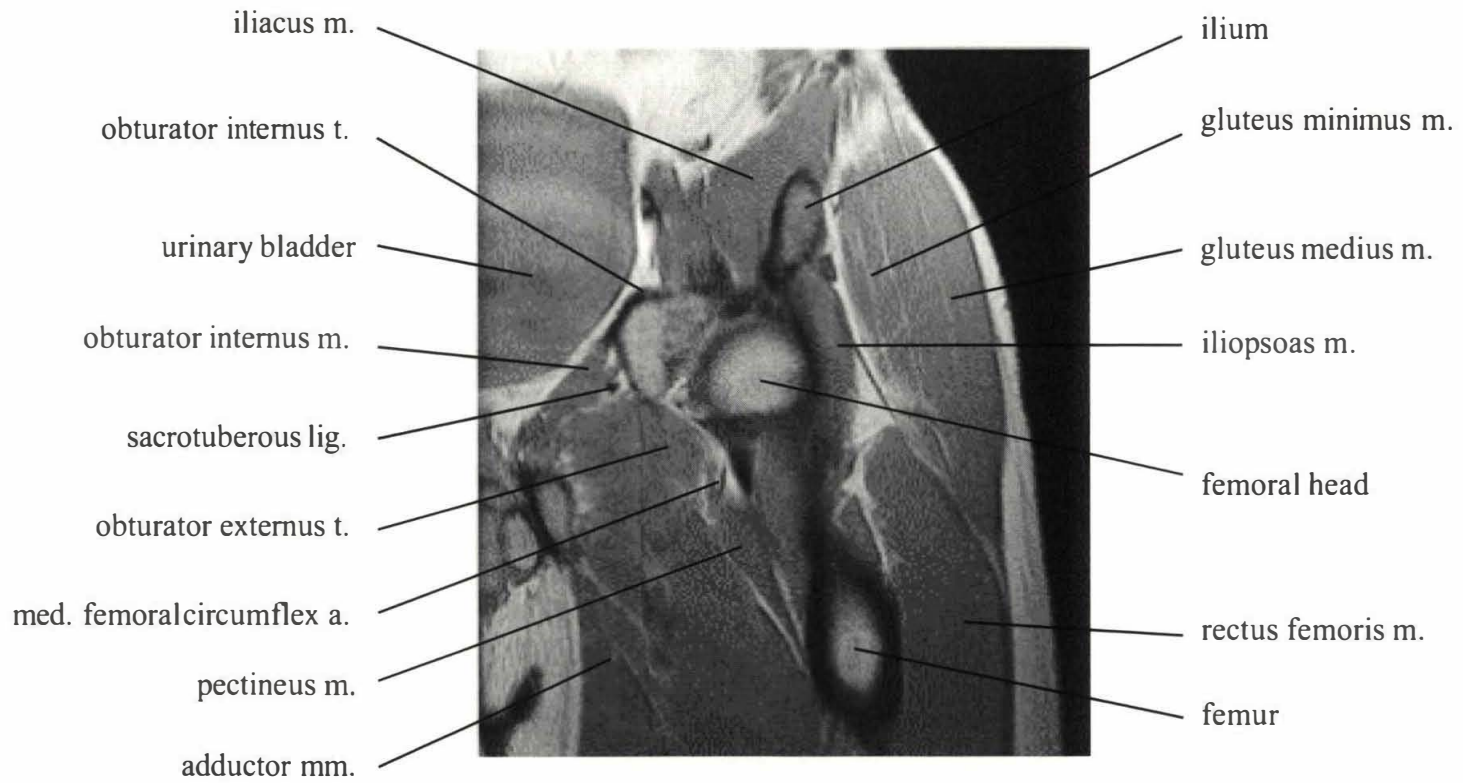
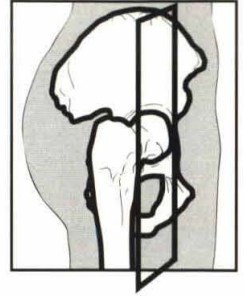












iliacus m.

obturator internus t.

urinary bladder

obturator internus m.

sacrotuberous lig.

obturator externus t.

med. femoral circumflex a.

pectineus m.

adductor mm.

ilium

gluteus minimus m.

gluteus medius m.

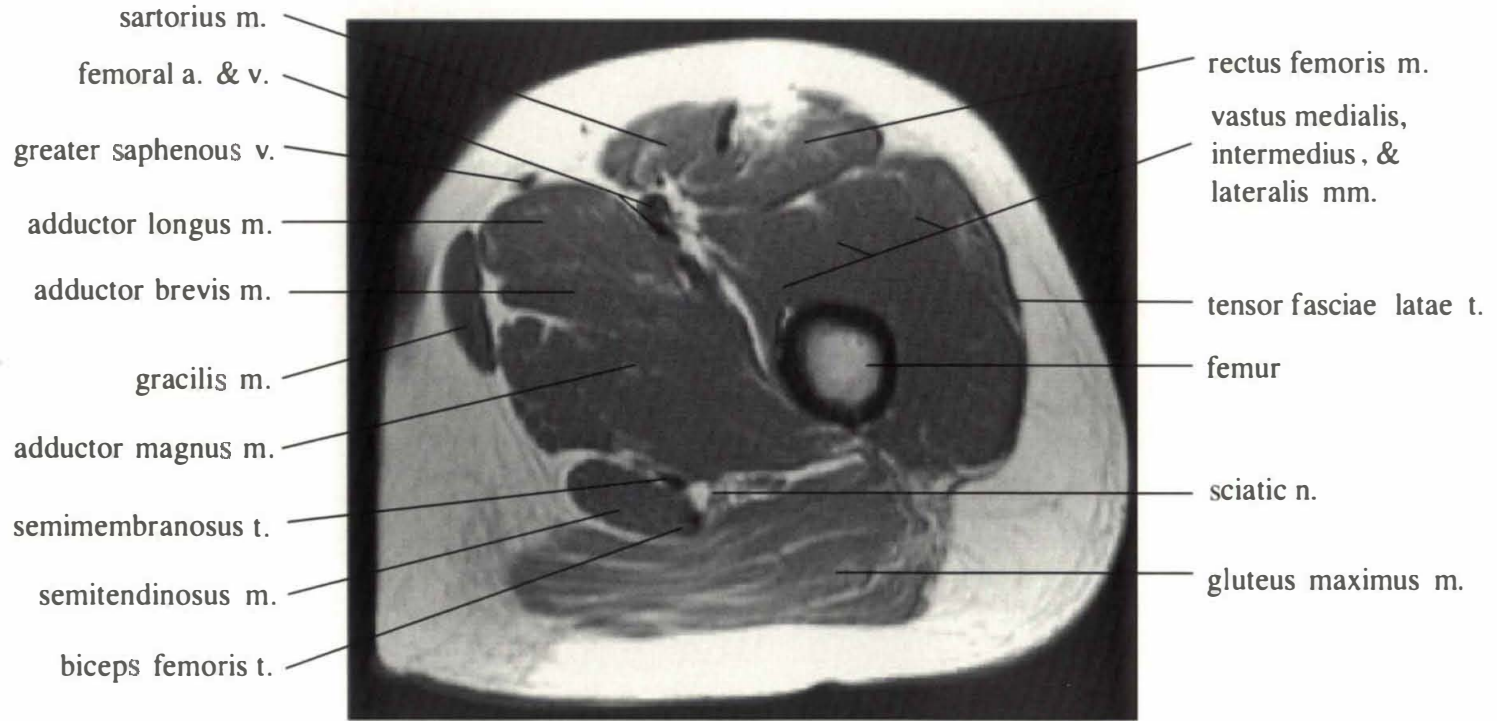
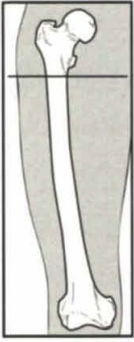
iliopsoas m.

femoral head

rectus femoris m.

femur

THE THIGH: AXIAL ANATOMY



sartorius m.

femoral a. & v.

greater saphenous v.

adductor longus m.

adductor brevis m.

gracilis m.

adductor magnus m.

semimembranosus t.

semitendinosus m.

biceps femoris t.

rectus femoris m.

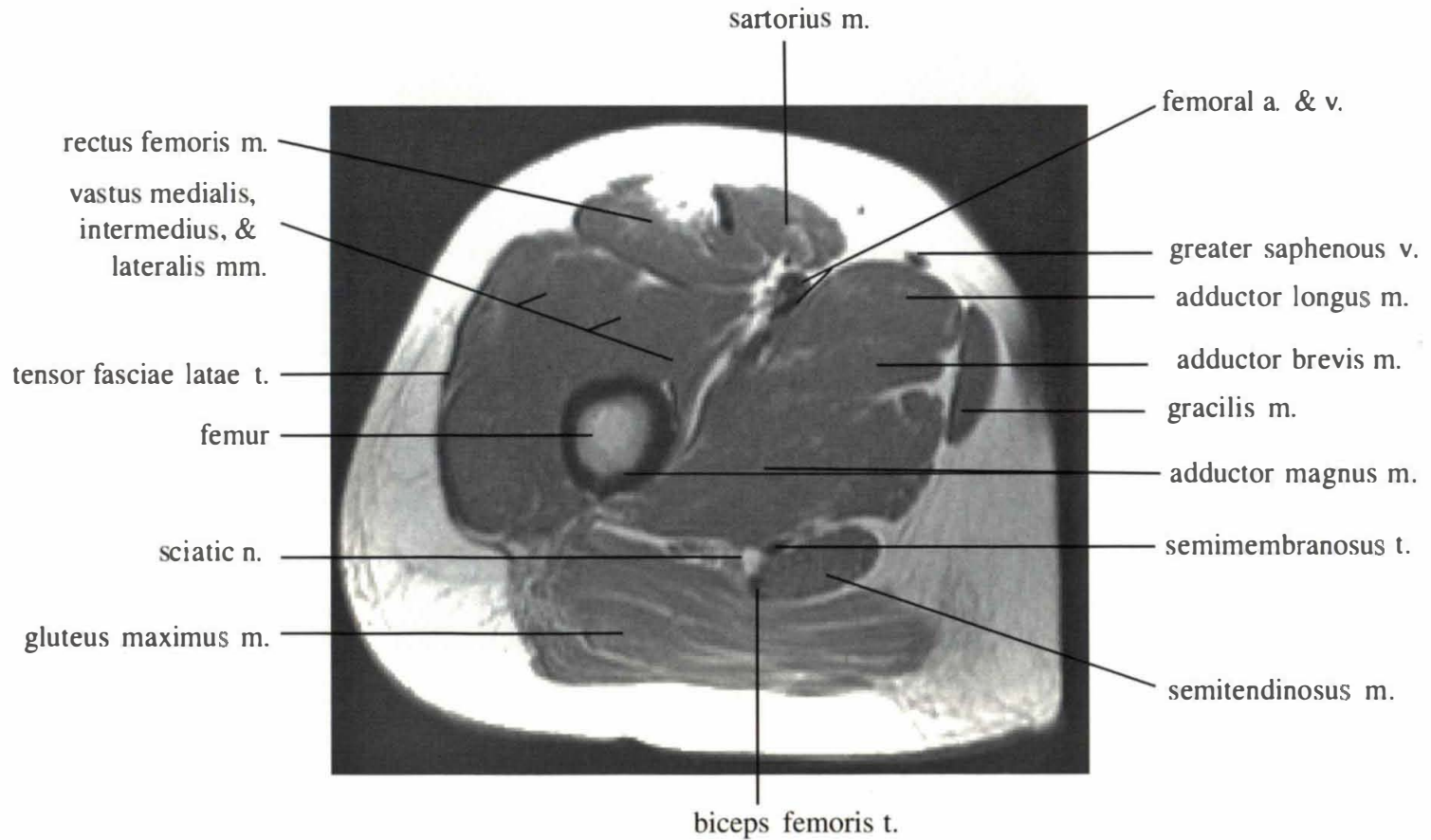
vastus medialis,
intermedius, &
lateralis mm.

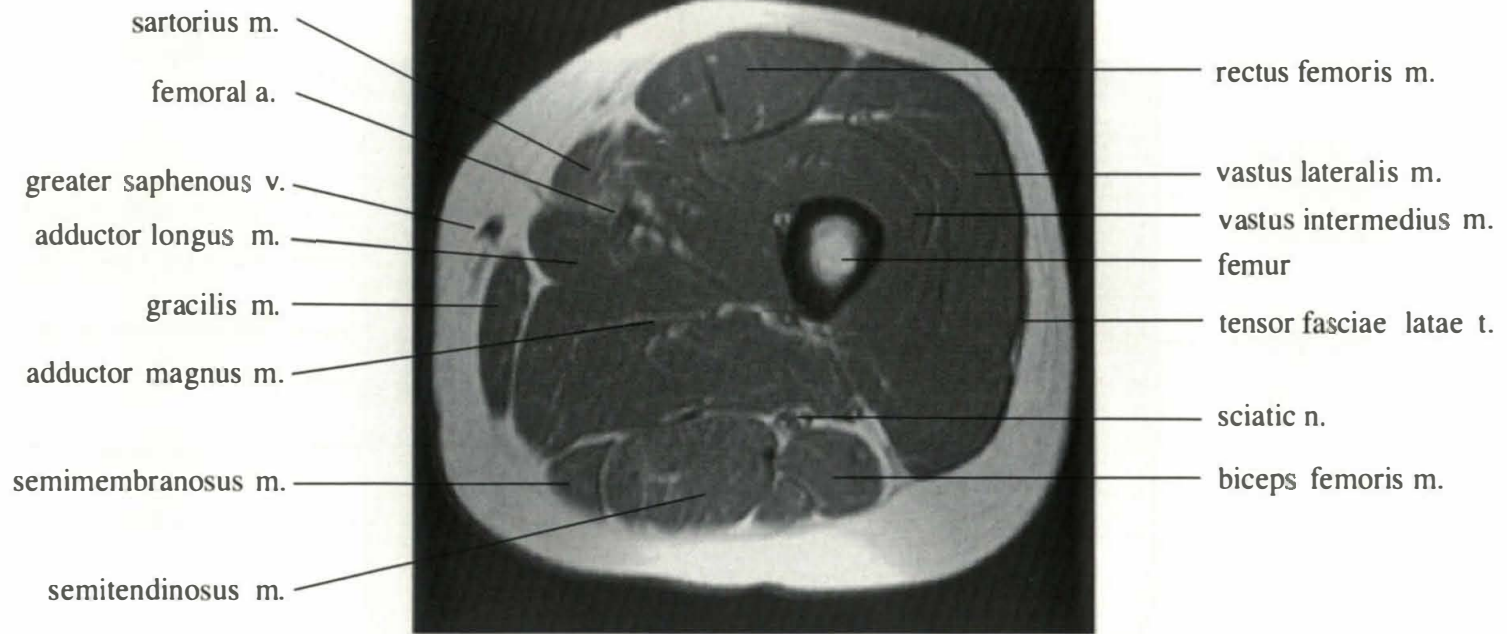
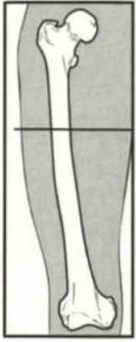
tensor fasciae latae t.

femur

sciatic n.

gluteus maximus m.





sartorius m.

femoral a.

greater saphenous v.

adductor longus m.

gracilis m.

adductor magnus m.

semimembranosus m.

semitendinosus m.

rectus femoris m.

vastus lateralis m.

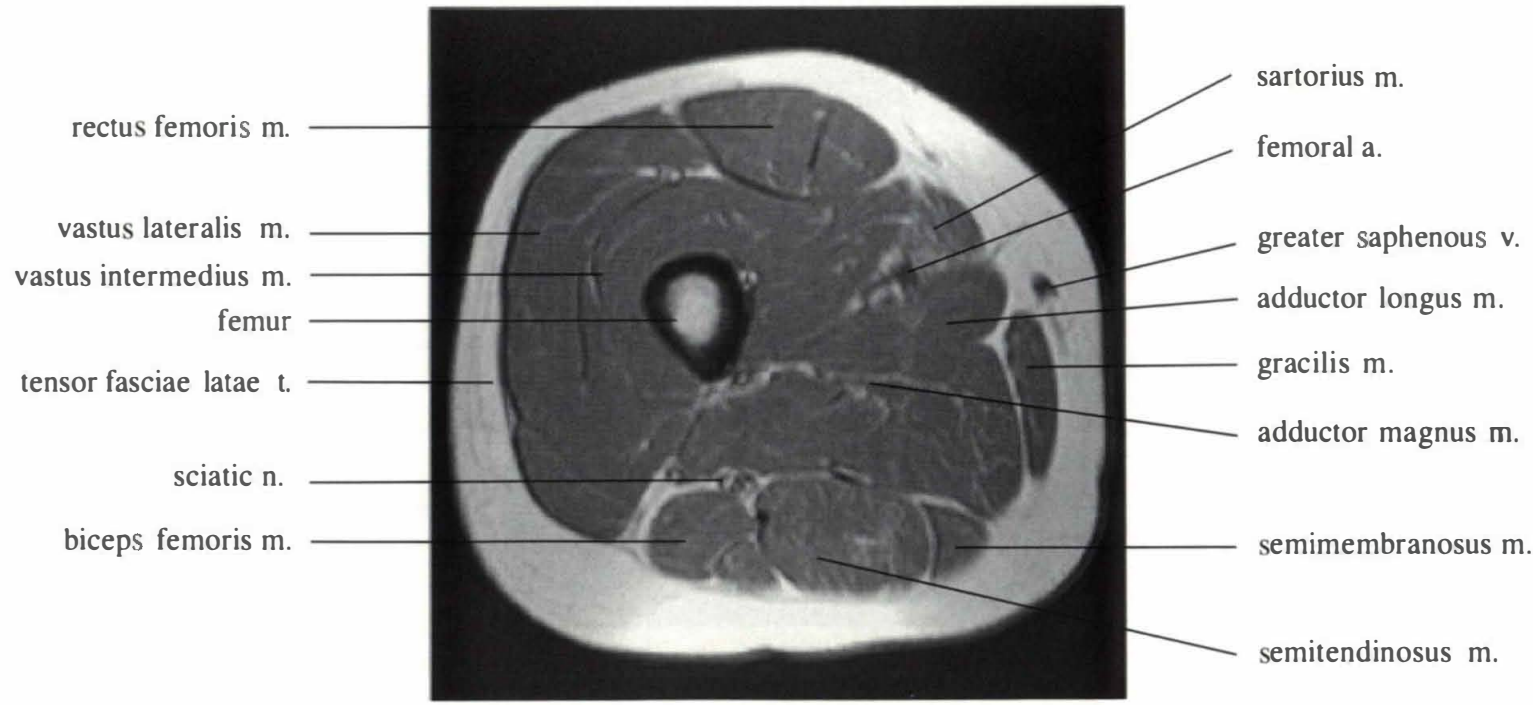
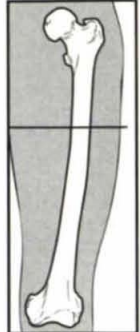
vastus intermedius m.

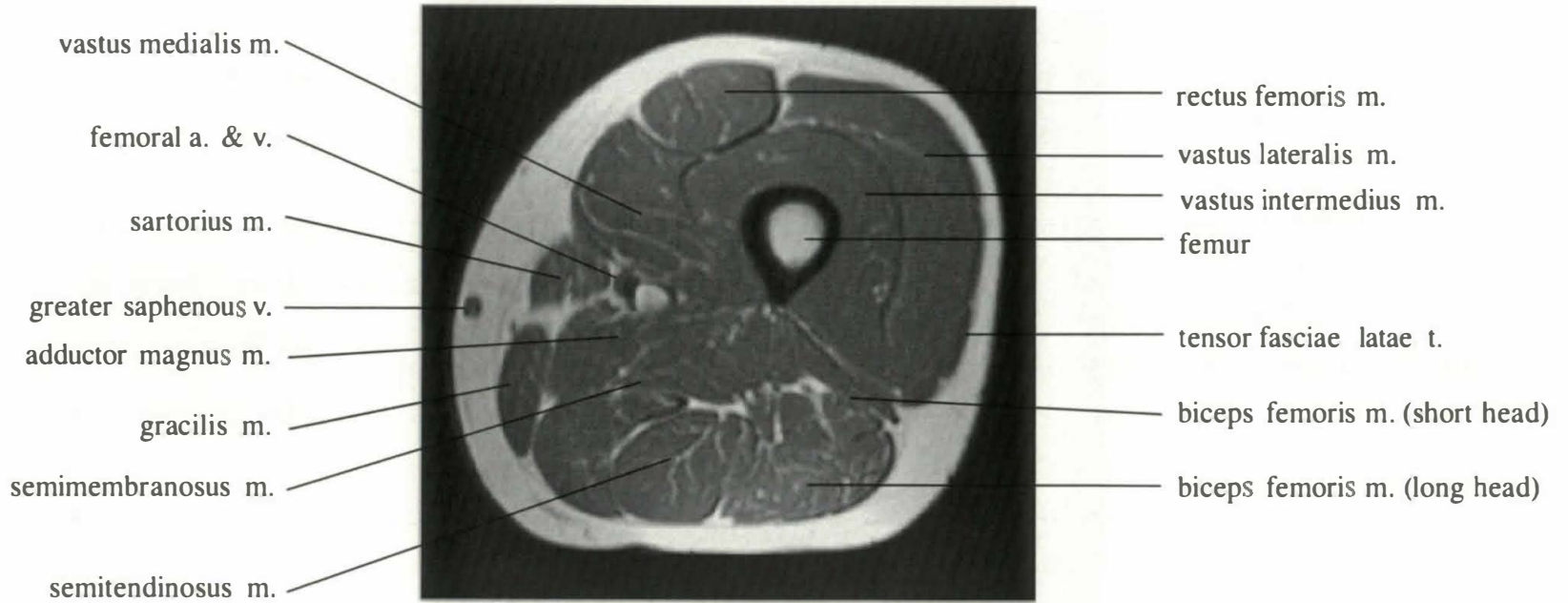
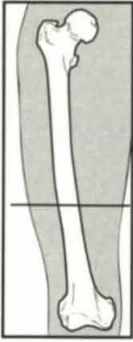
femur

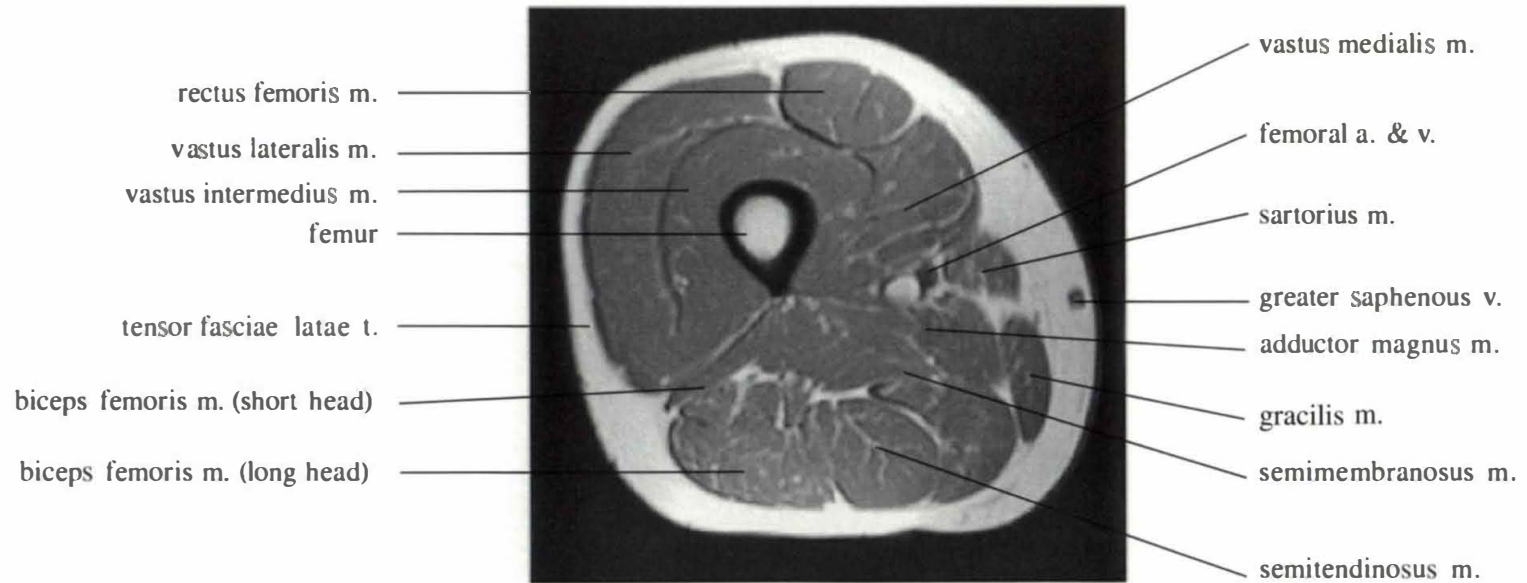
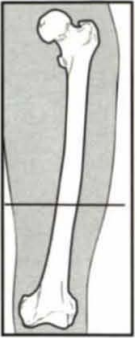
tensor fasciae latae t.

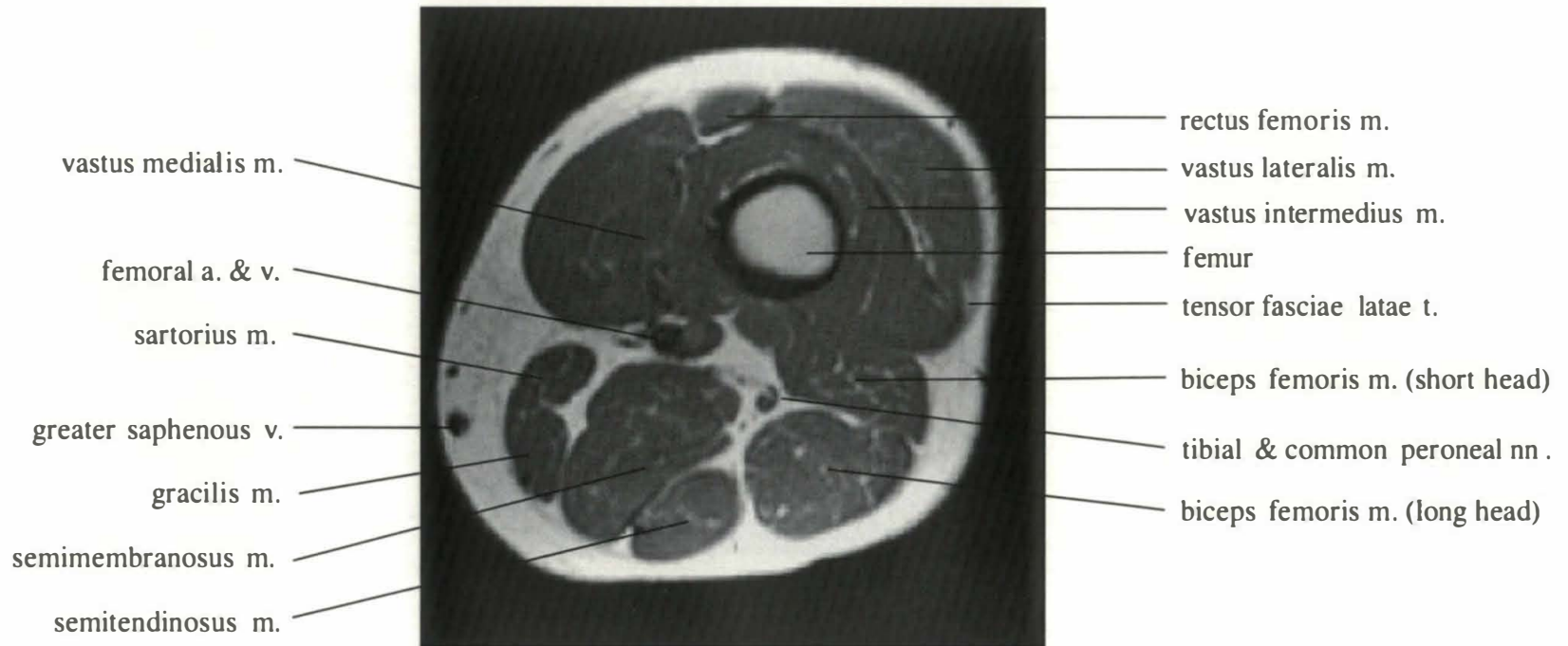
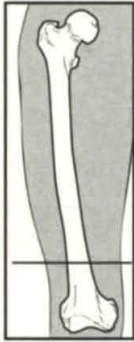
sciatic n.

biceps femoris m.









vastus medialis m.

femoral a. & v.

sartorius m.

greater saphenous v.

gracilis m.

semimembranosus m.

semitendinosus m.

rectus femoris m.

vastus lateralis m.

vastus intermedius m.

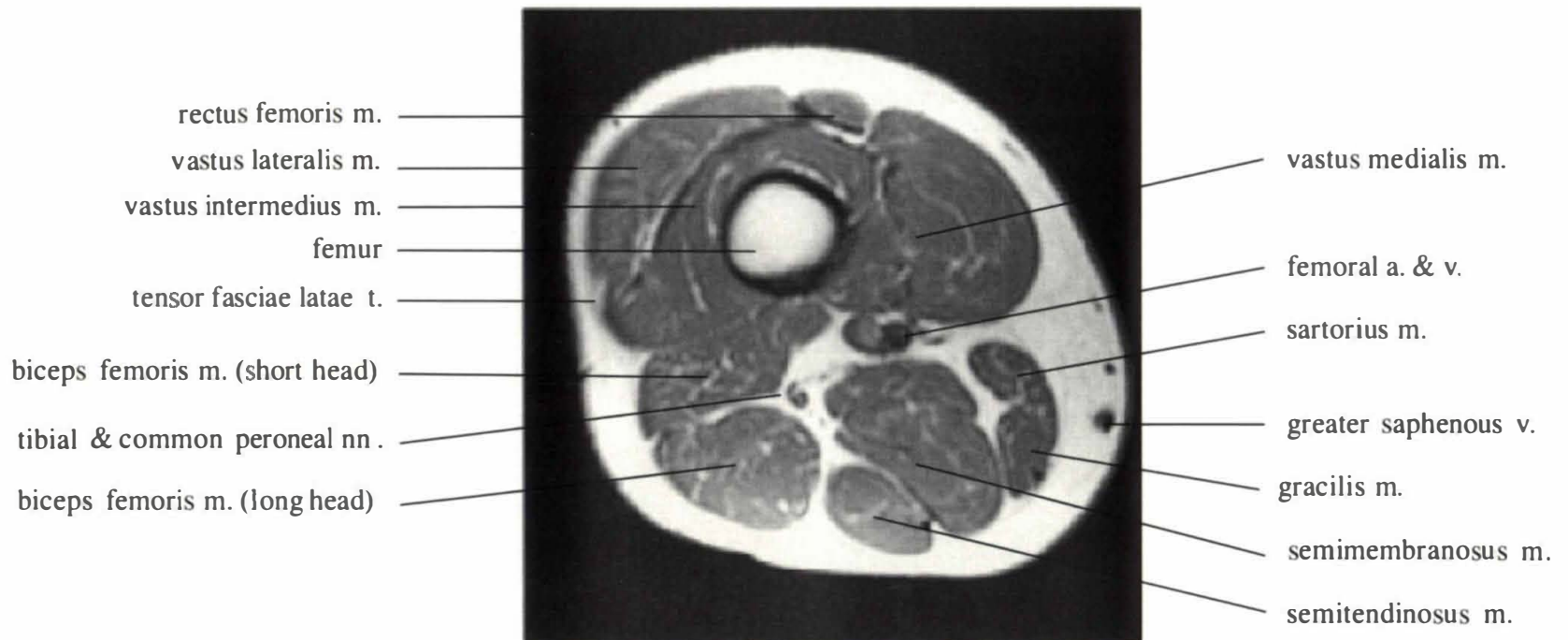
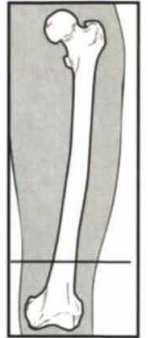
femur

tensor fasciae latae t.

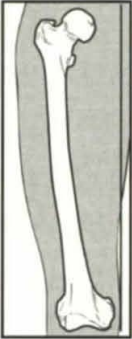
biceps femoris m. (short head)

tibial & common peroneal nn.

biceps femoris m. (long head)



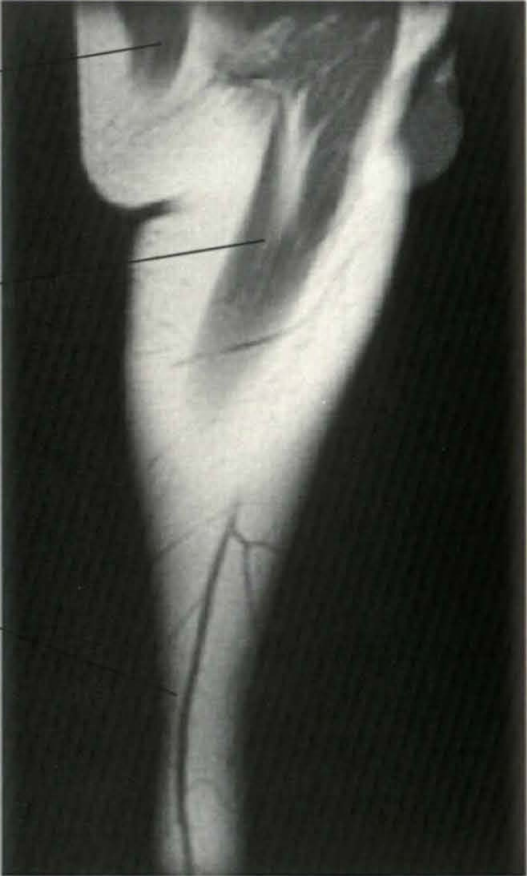
THE THIGH: SAGITTAL ANATOMY

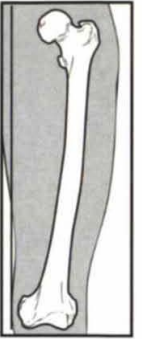


gluteus maximus m.

gracilis m.

greater saphenous v.

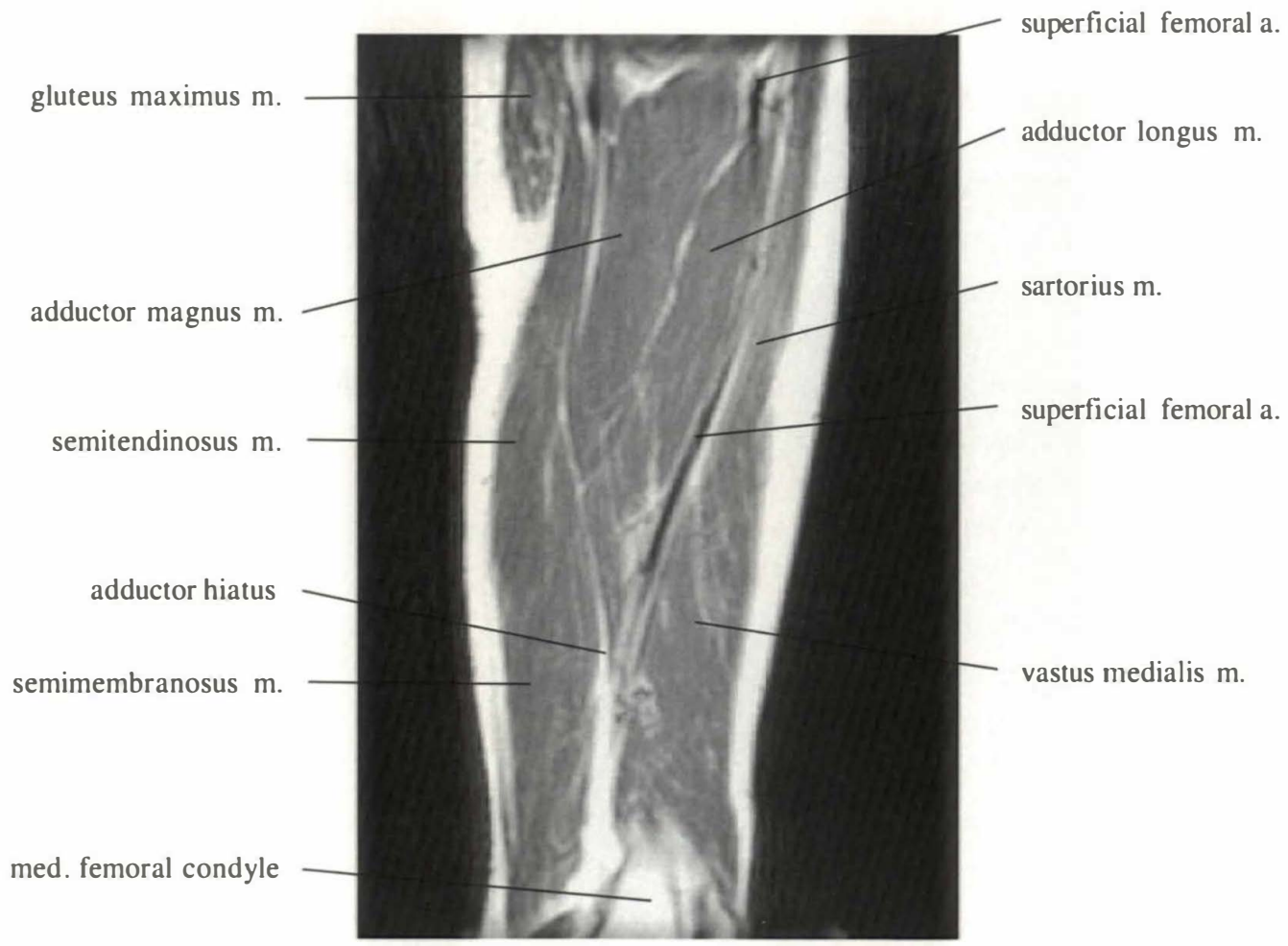
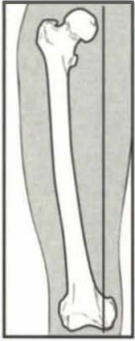


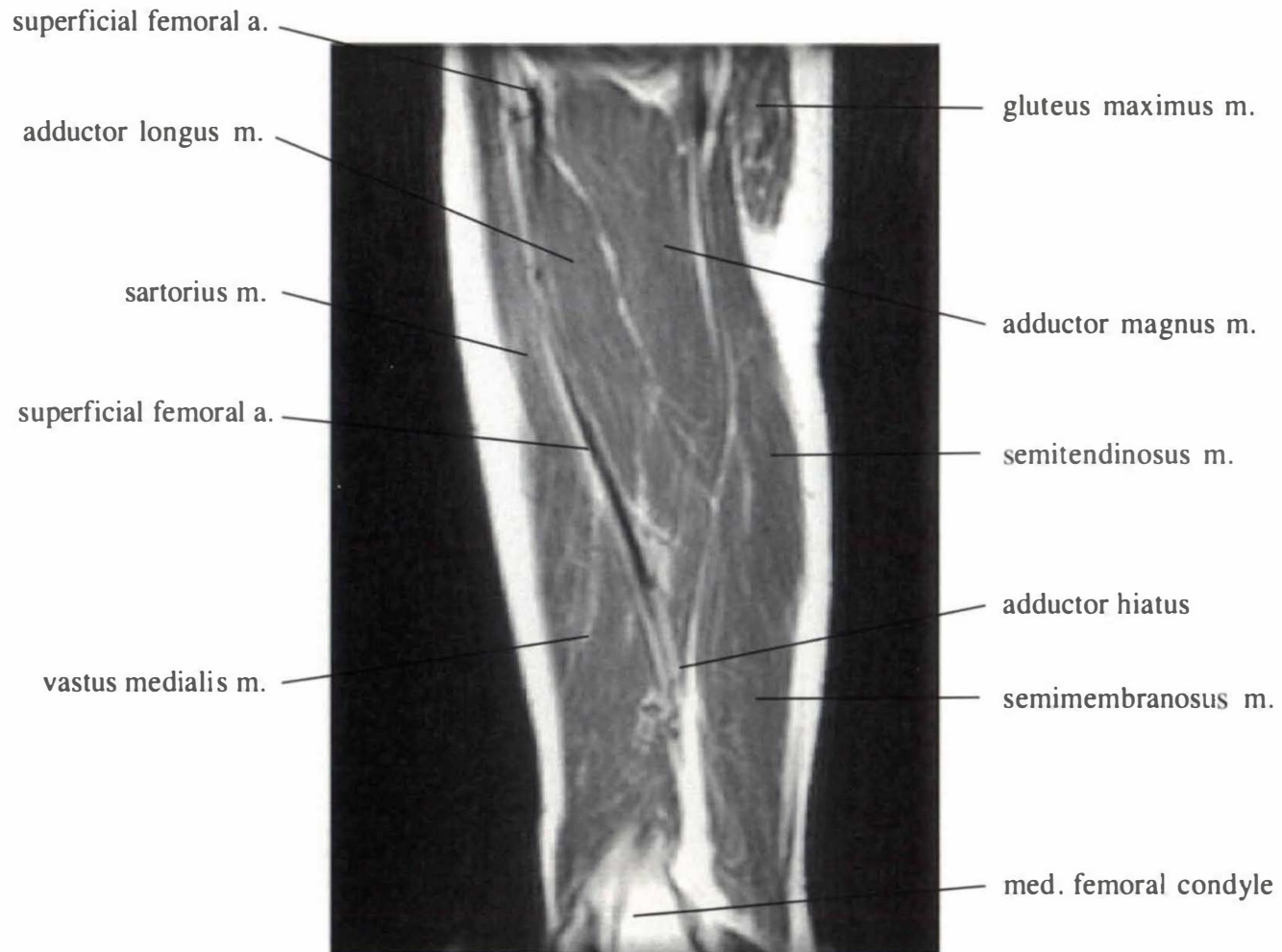


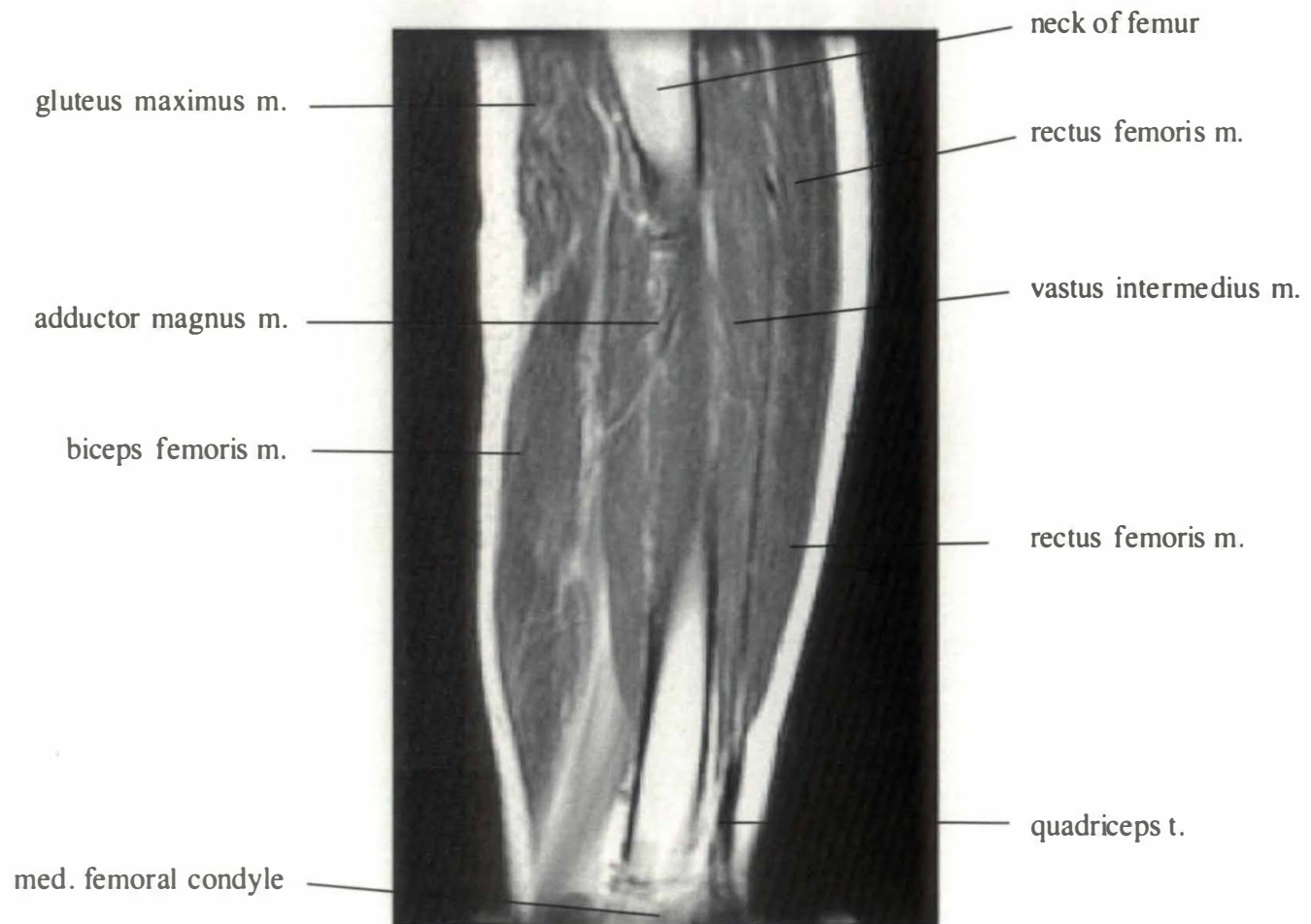
gluteus maximus m.

gracilis m.

greater saphenous v.







gluteus maximus m.

adductor magnus m.

biceps femoris m.

med. femoral condyle

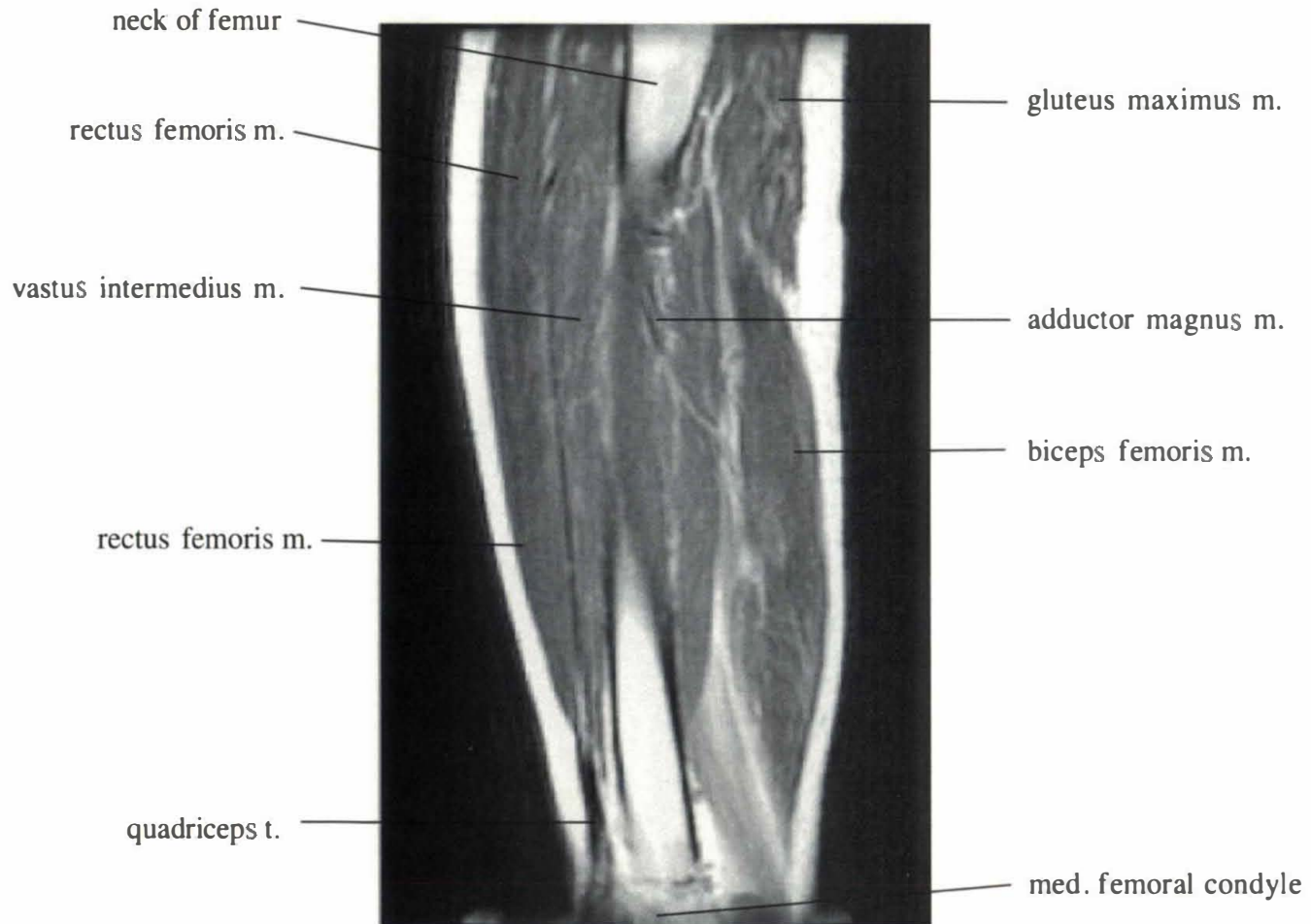
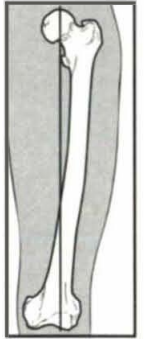
neck of femur

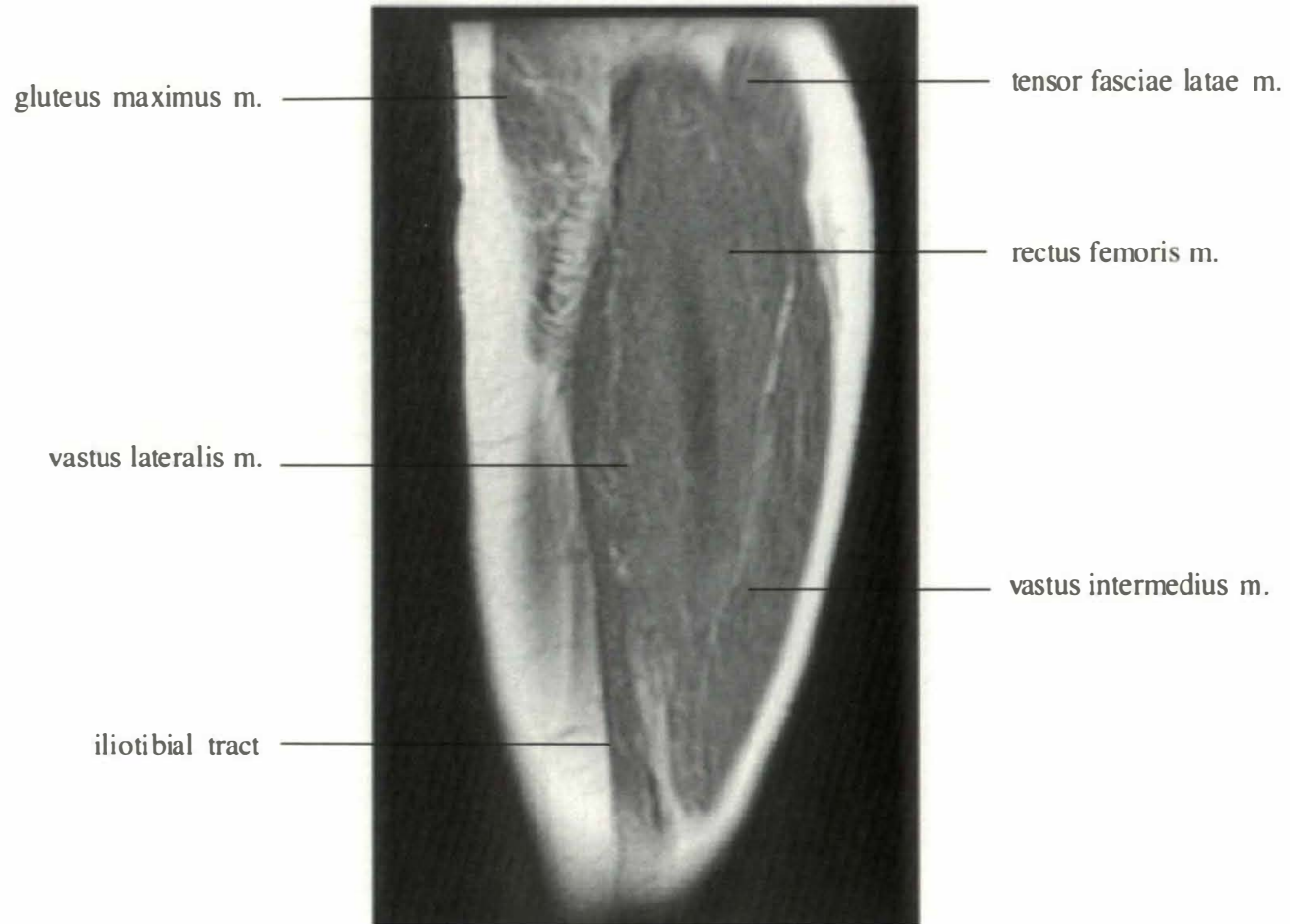
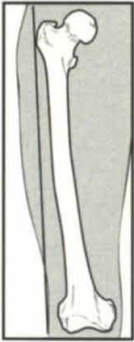
rectus femoris m.

vastus intermedius m.

rectus femoris m.

quadriceps t.





gluteus maximus m.

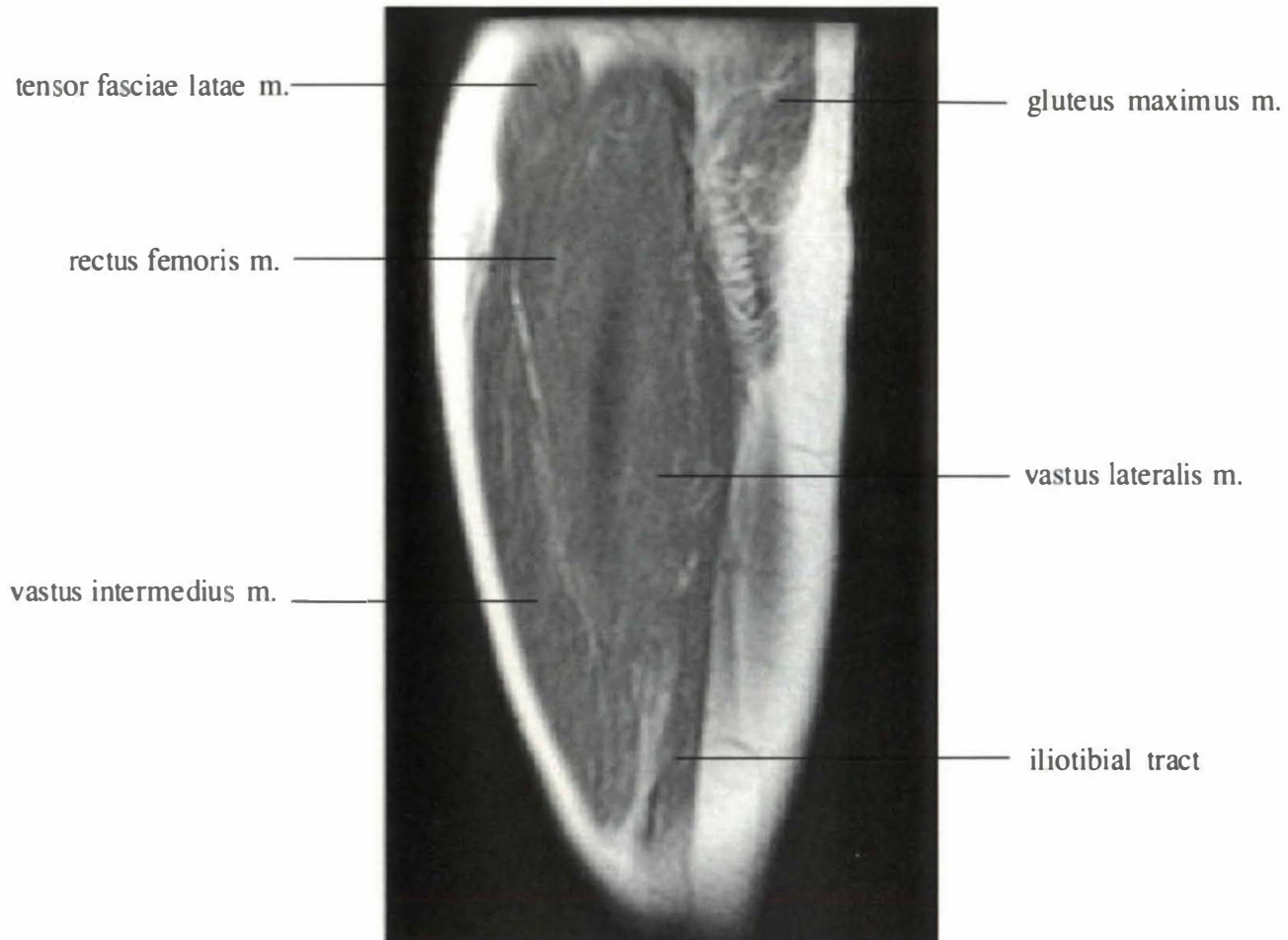
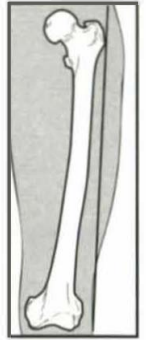
tensor fasciae latae m.

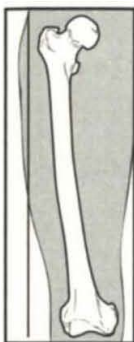
rectus femoris m.

vastus lateralis m.

vastus intermedius m.

iliotibial tract





vastus lateralis m.



vastus lateralis m. —————



THE THIGH: CORONAL ANATOMY



gluteus maximus m.

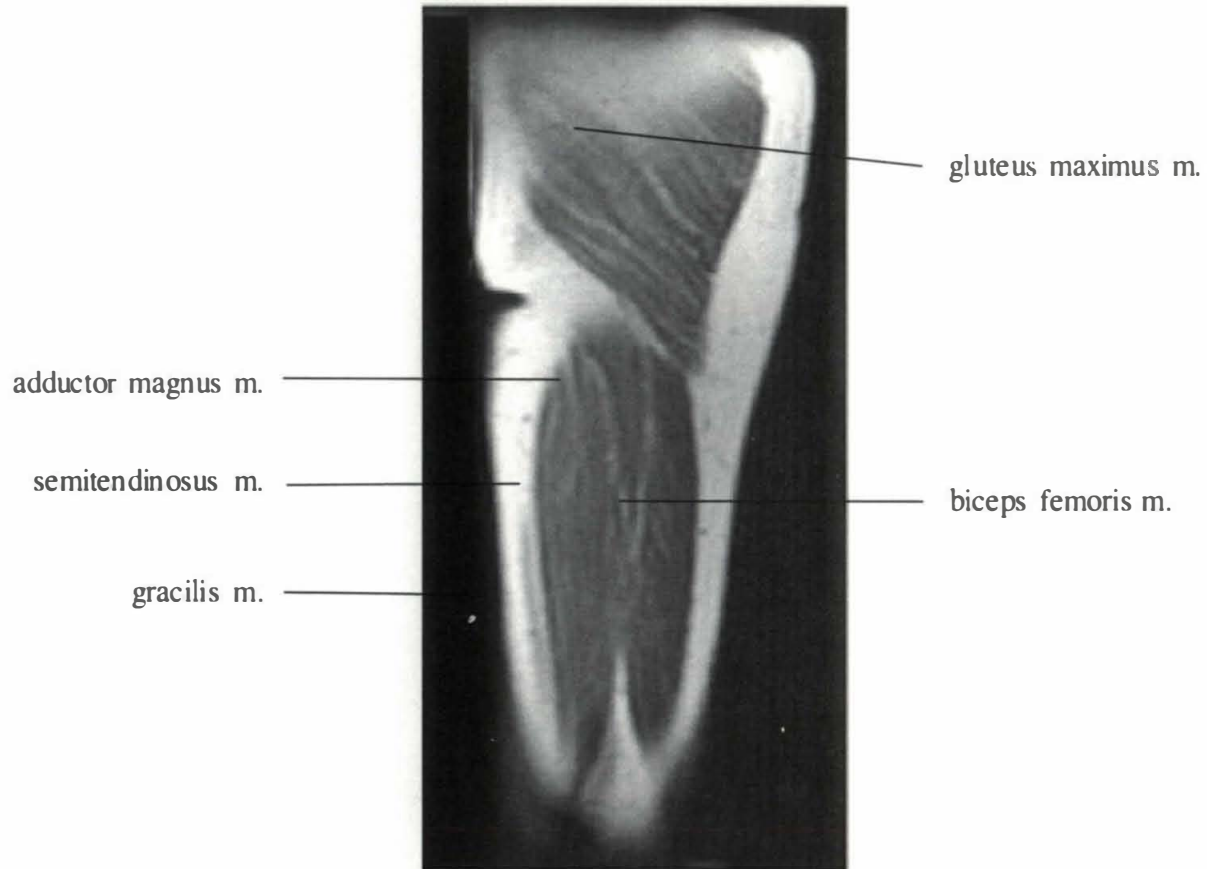
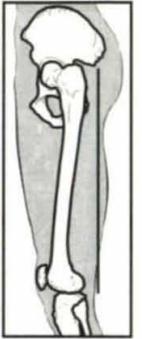
biceps femoris m.

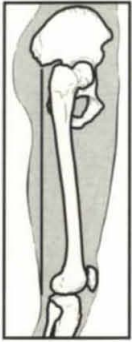


adductor magnus m.

semitendinosus m.

gracilis m.





gluteus maximus m.

biceps femoris m.

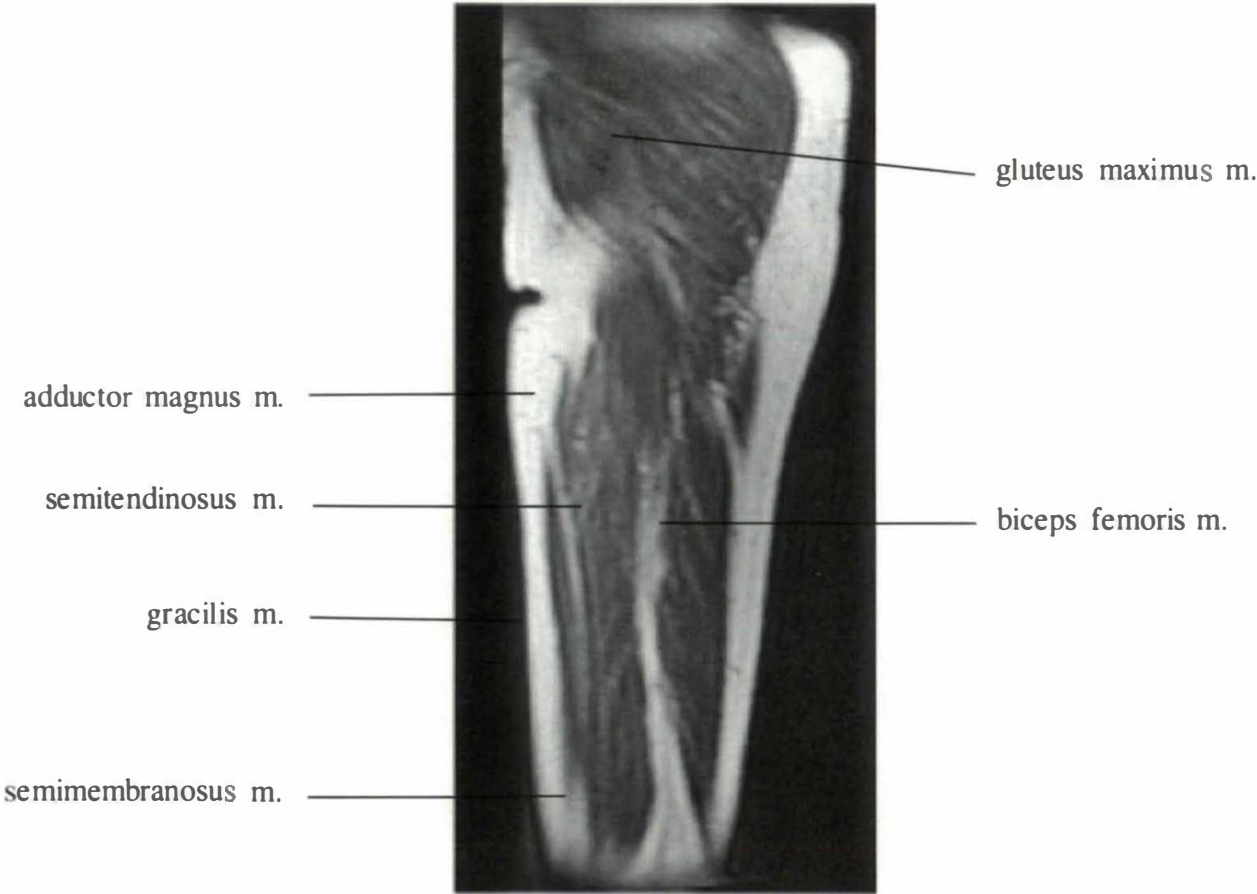
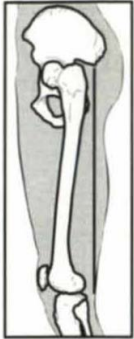


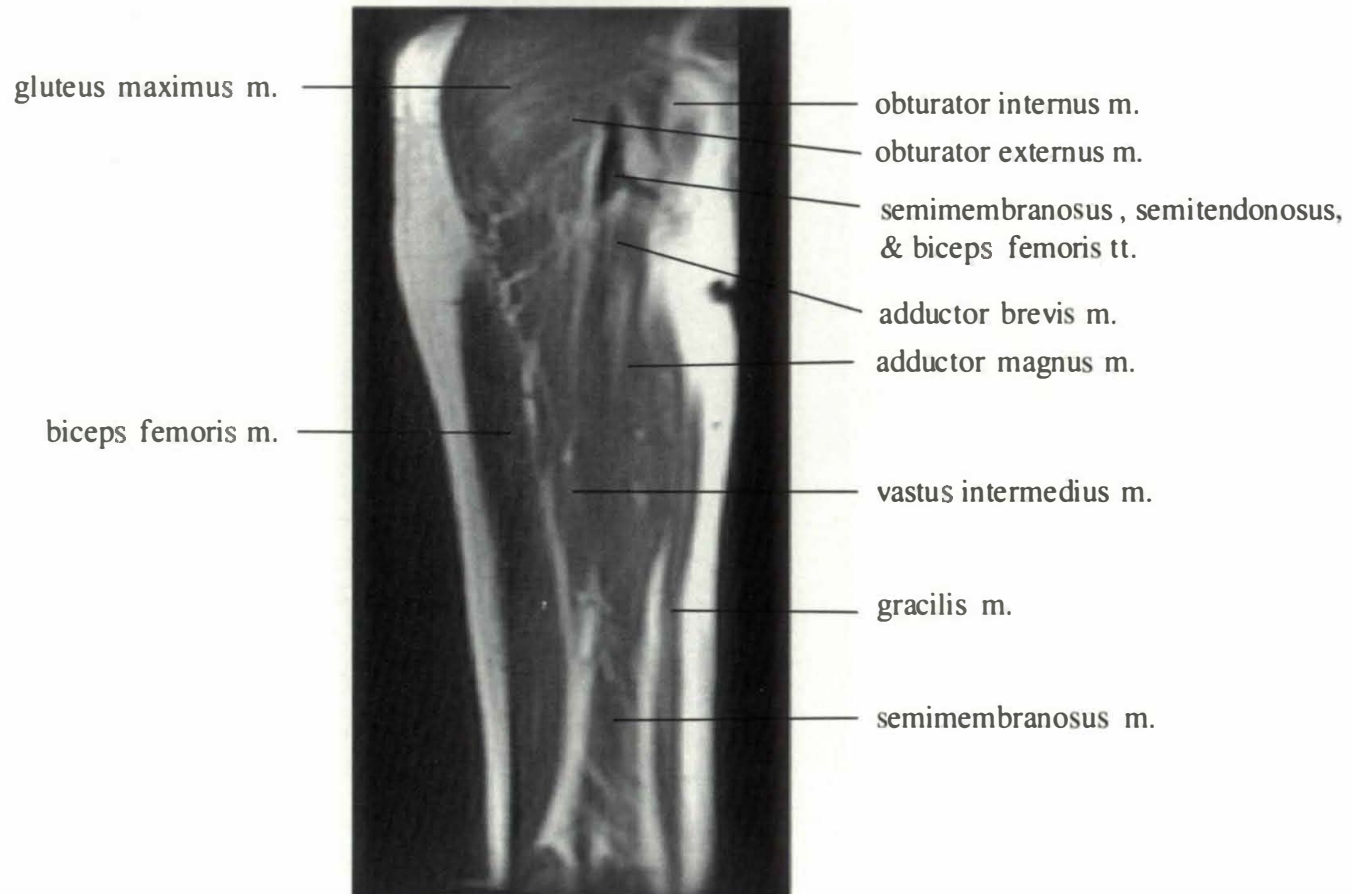
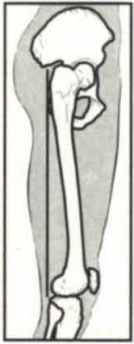
adductor magnus m.

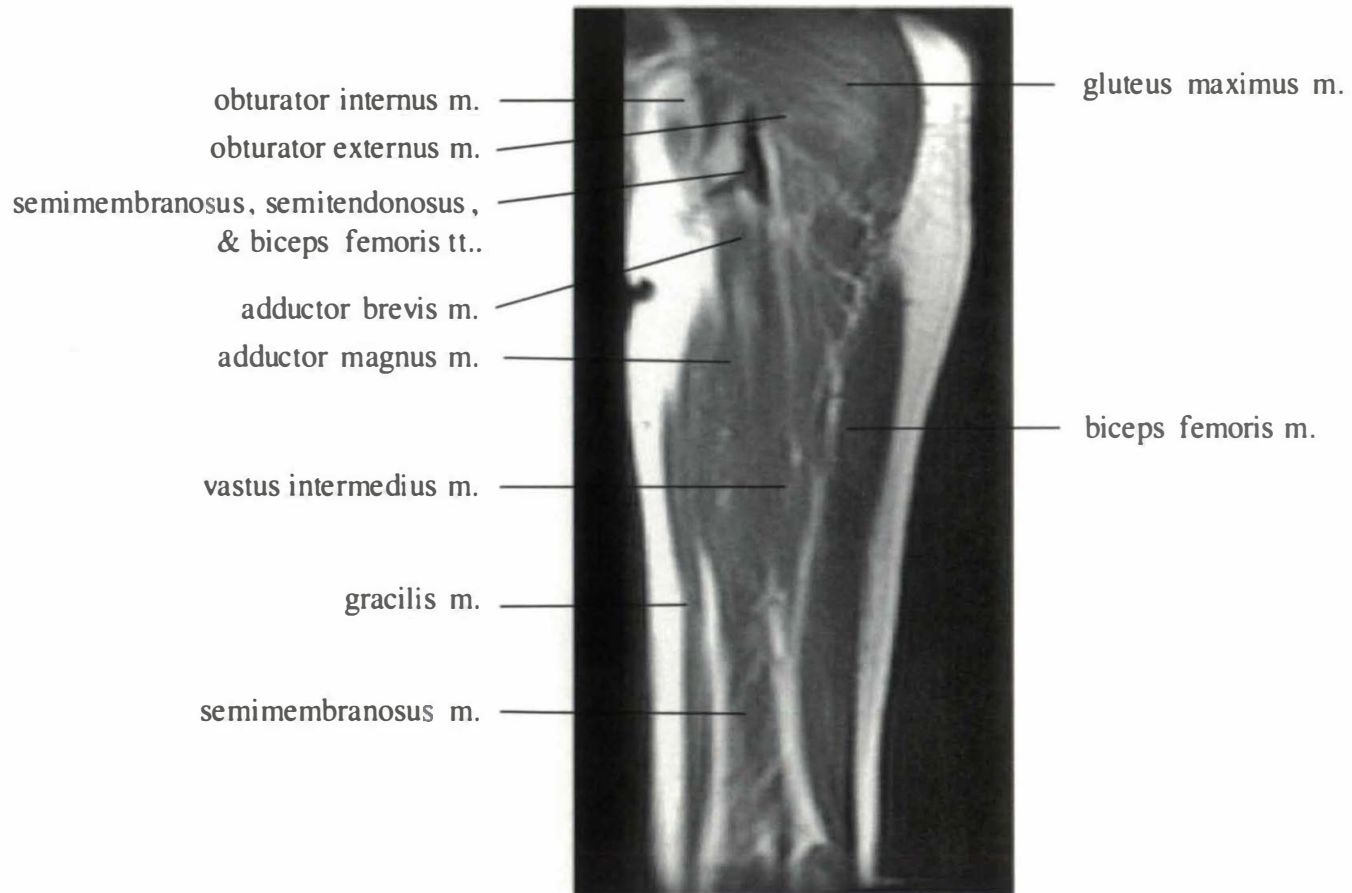
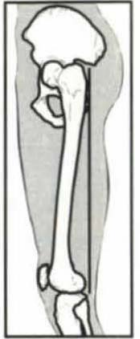
semitendinosus m.

gracilis m.

semimembranosus m.







obturator internus m.

obturator externus m.

semimembranosus, semitendinosus,
& biceps femoris tt..

adductor brevis m.

adductor magnus m.

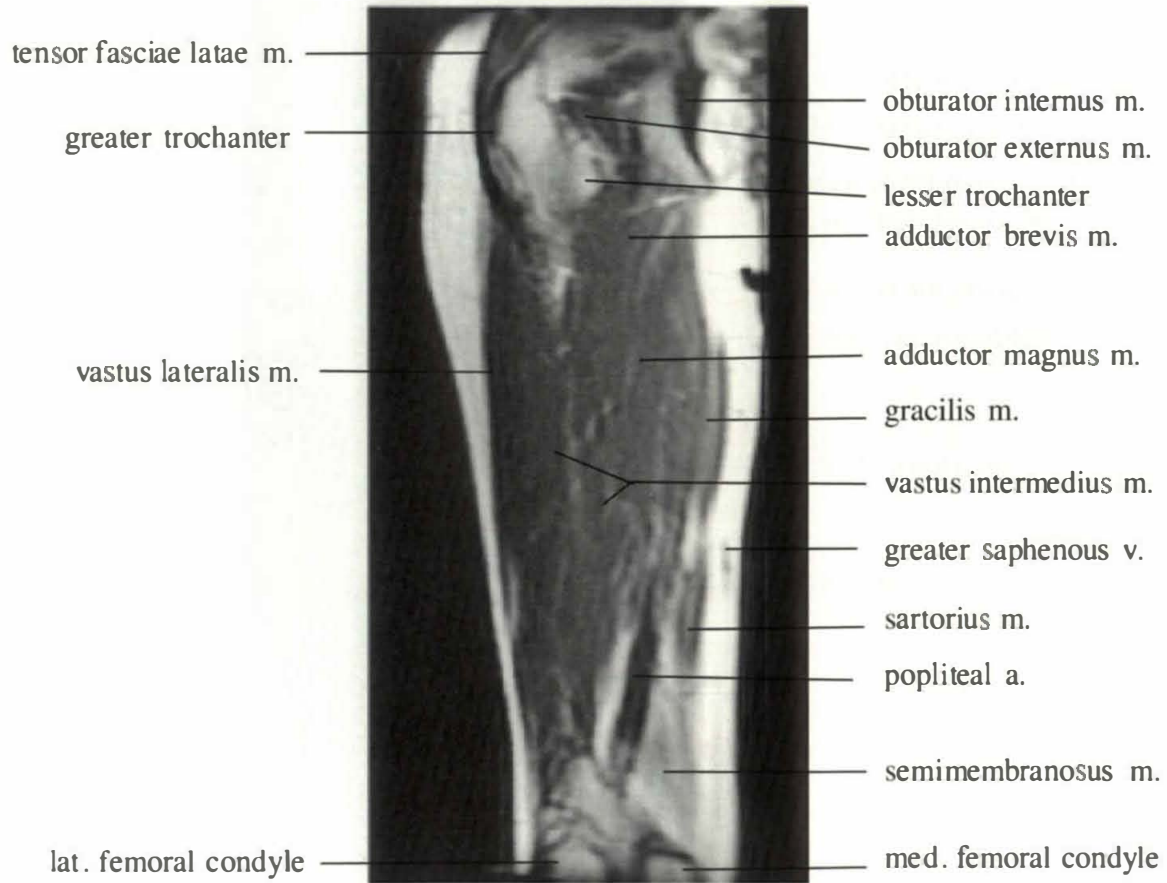
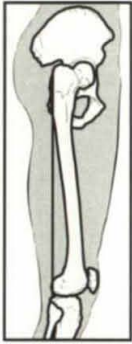
vastus intermedius m.

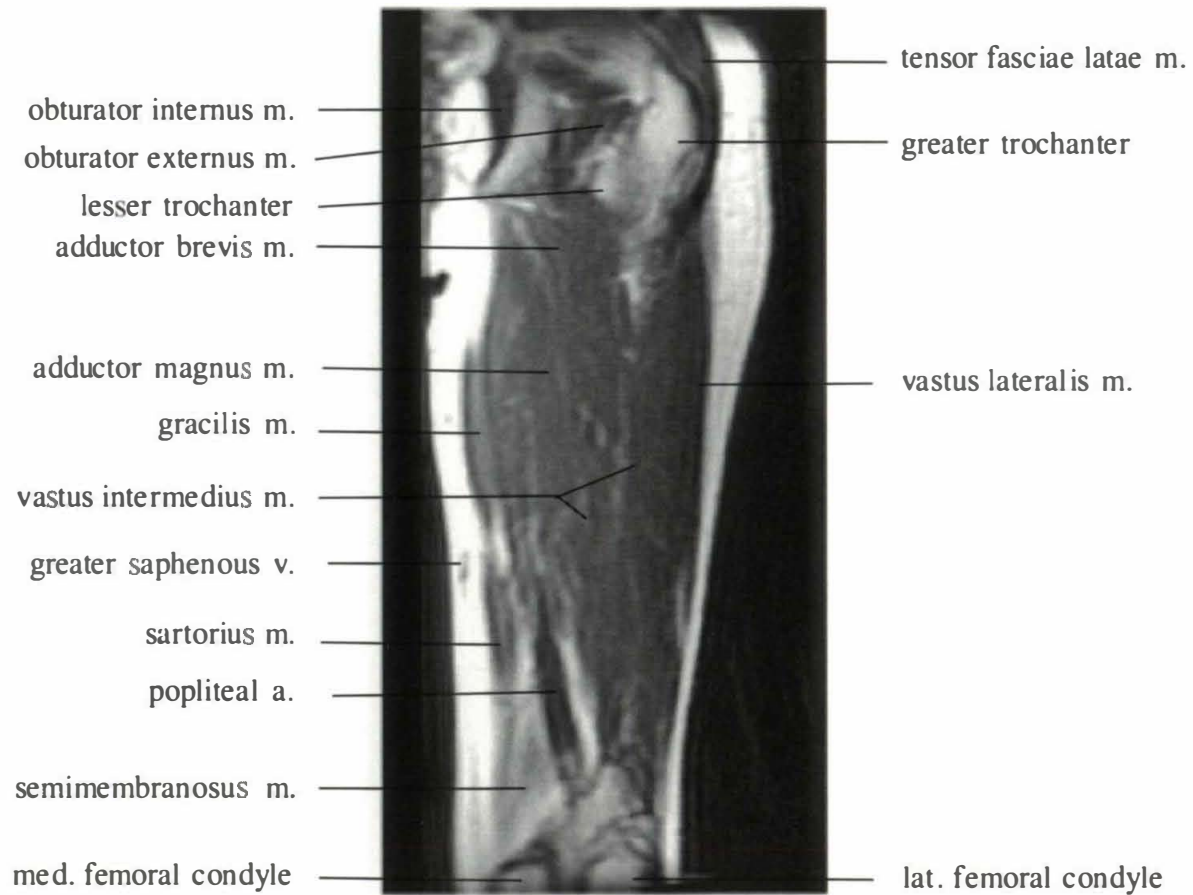
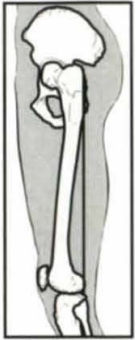
gracilis m.

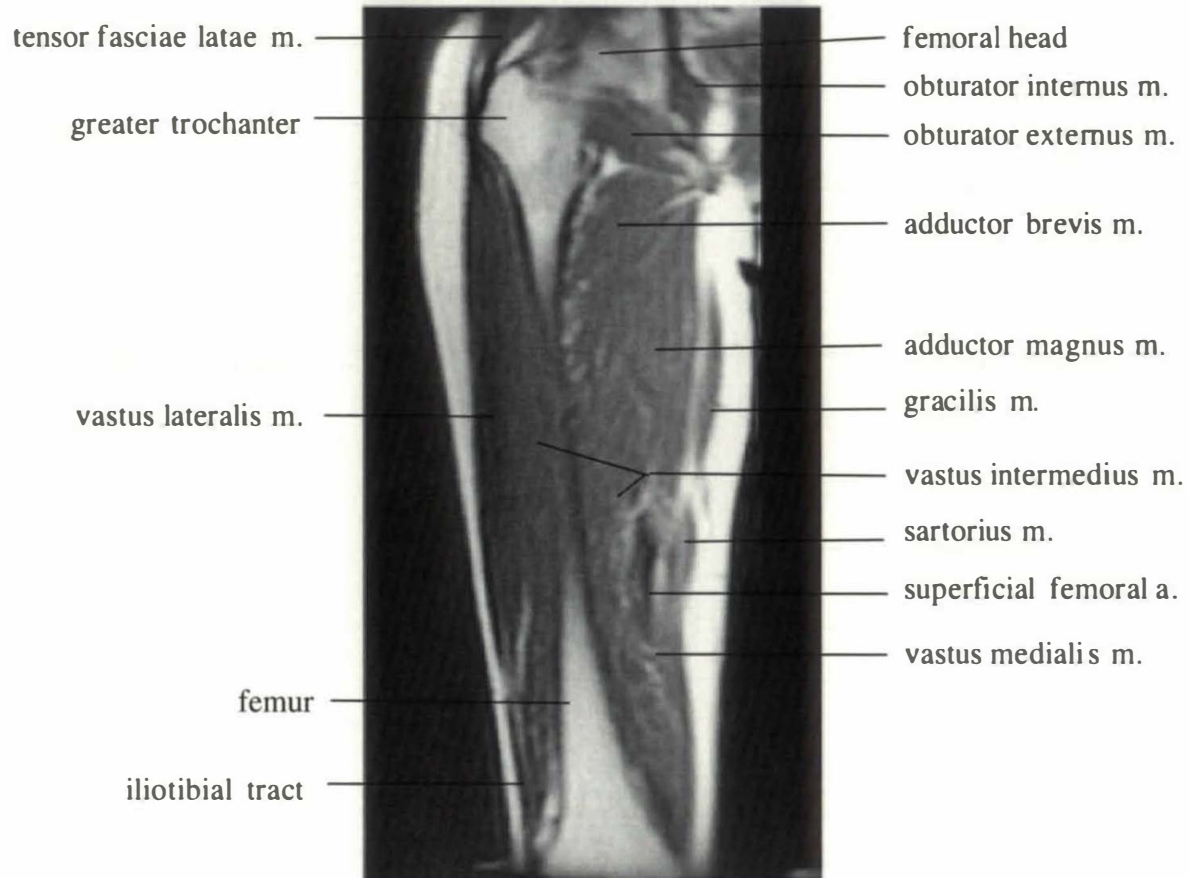
semimembranosus m.

gluteus maximus m.

biceps femoris m.







tensor fasciae latae m.

greater trochanter

vastus lateralis m.

femur

iliotibial tract

femoral head

obturator internus m.

obturator externus m.

adductor brevis m.

adductor magnus m.

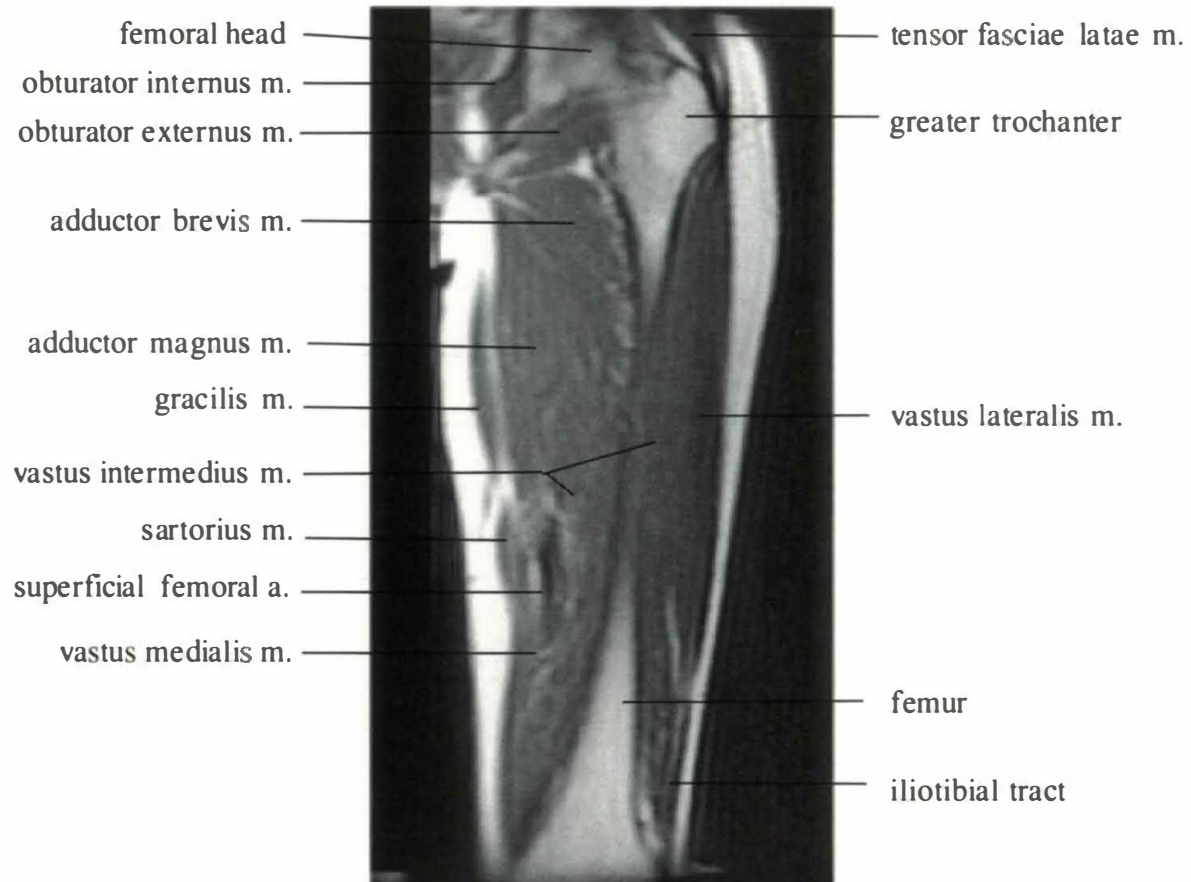
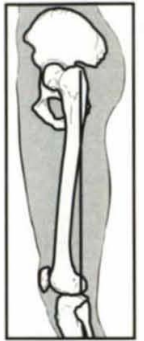
gracilis m.

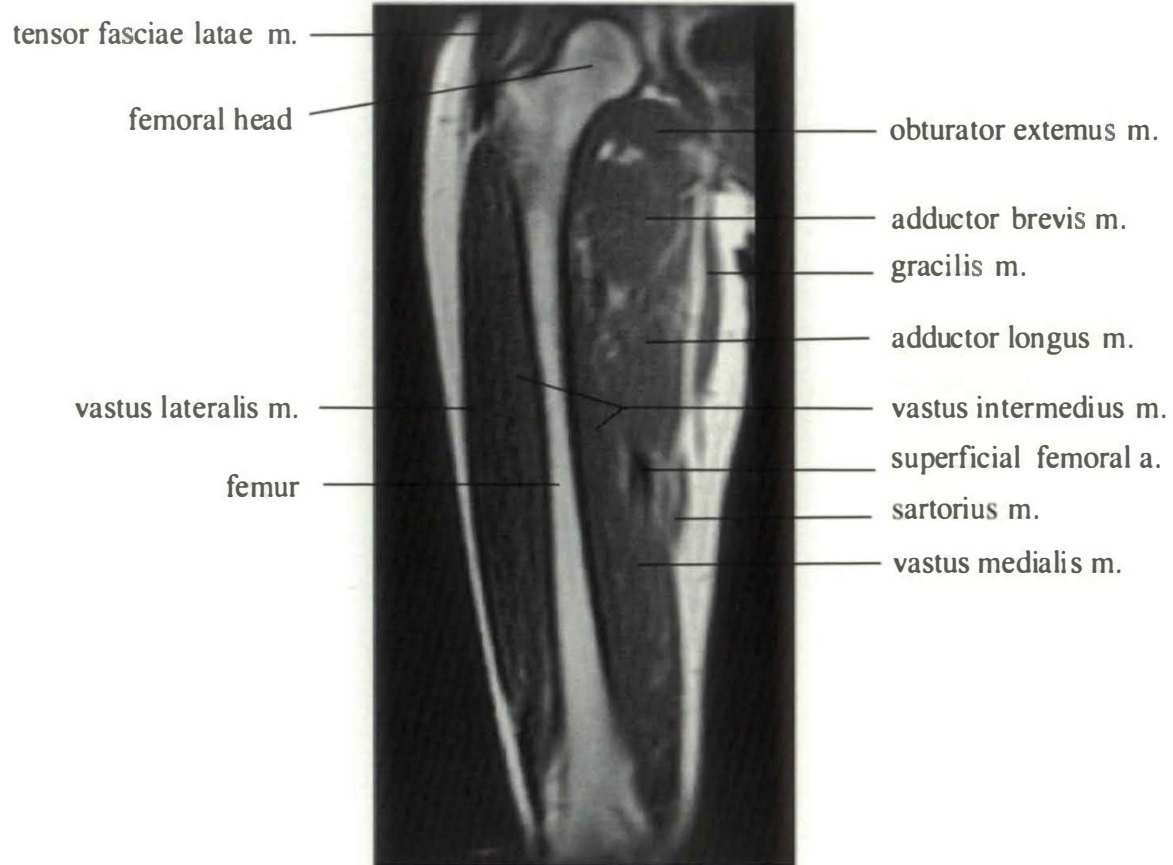
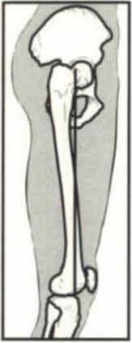
vastus intermedius m.

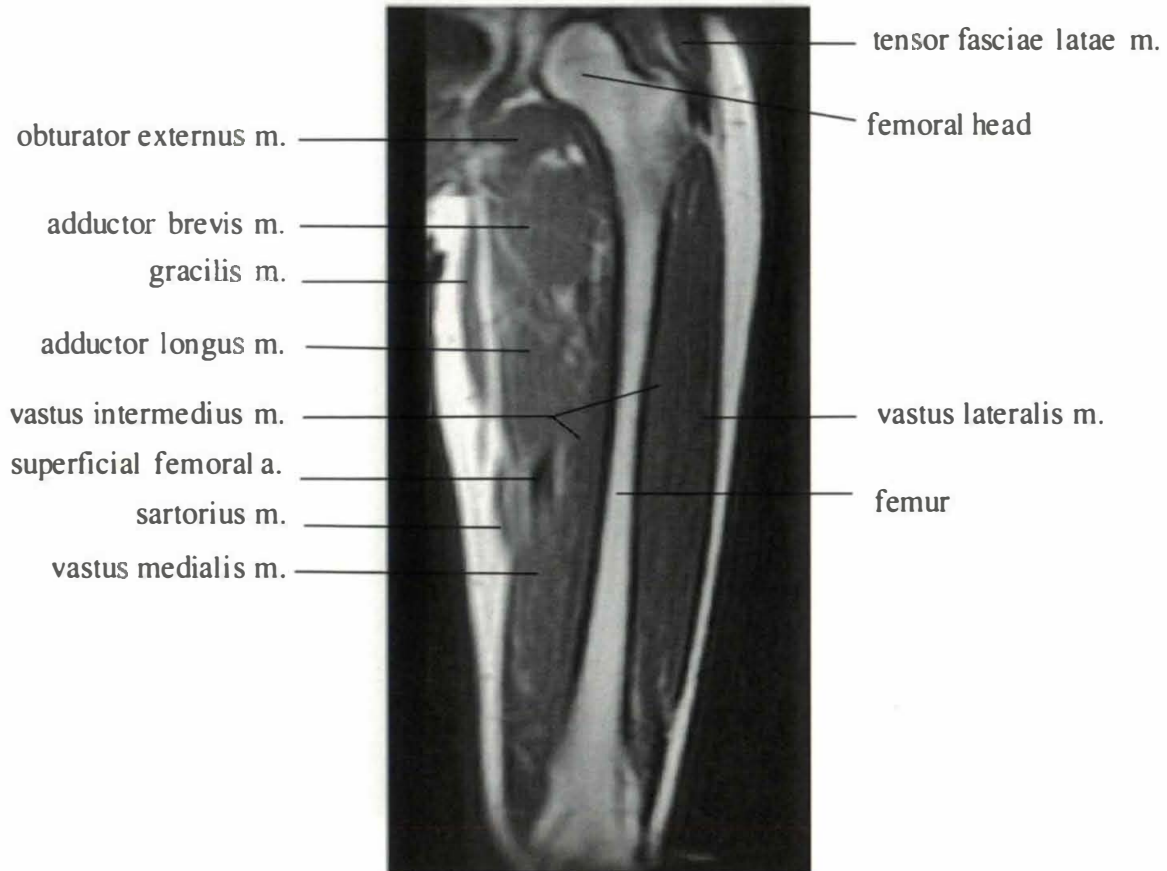
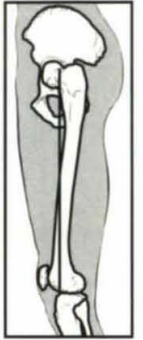
sartorius m.

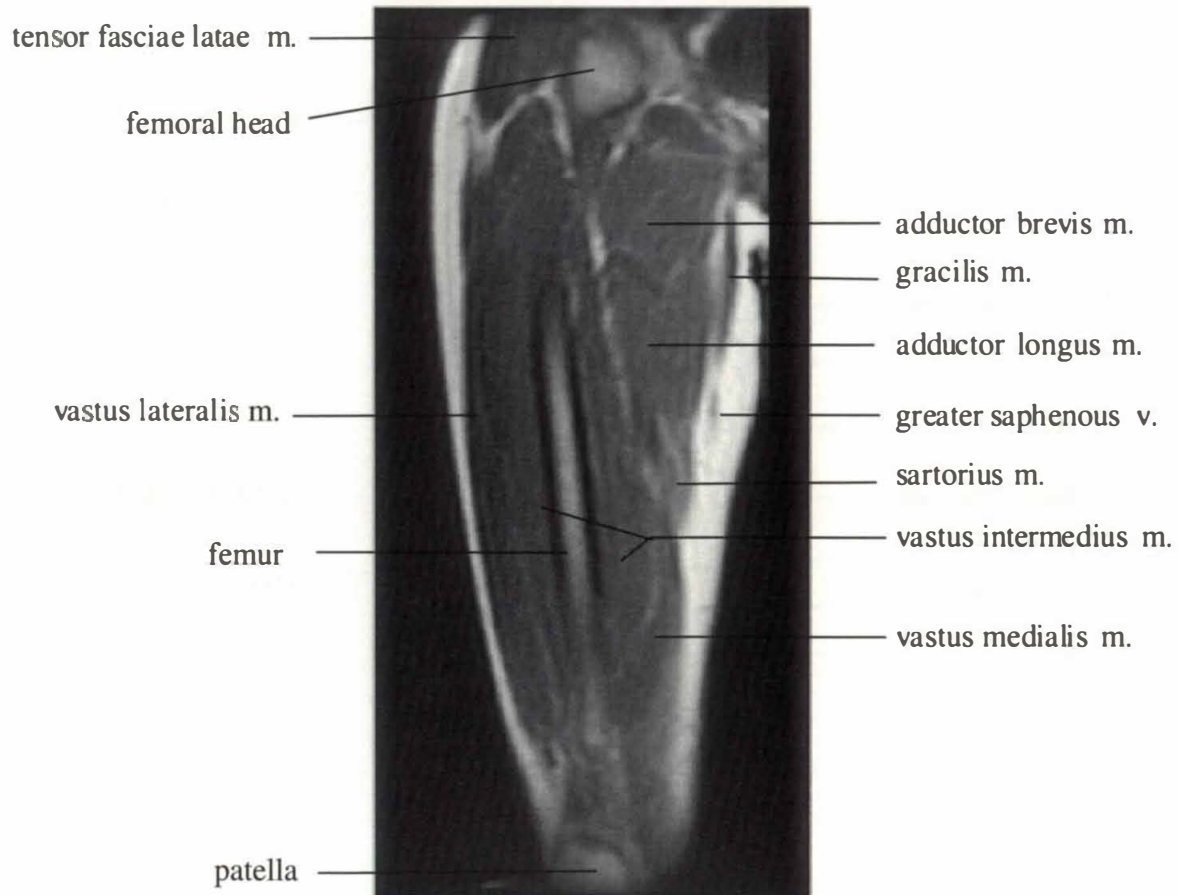
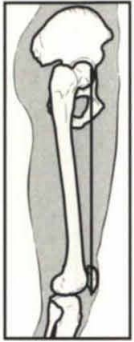
superficial femoral a.

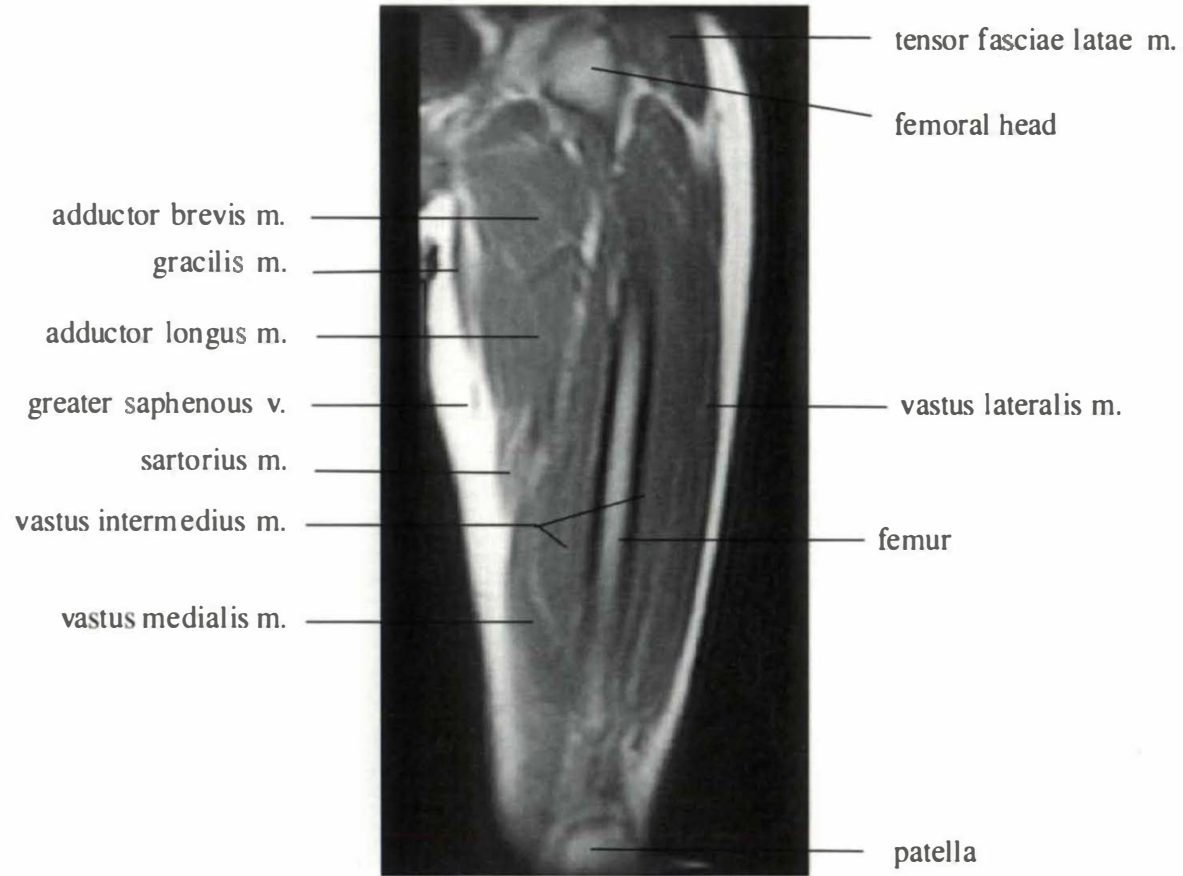
vastus medialis m.



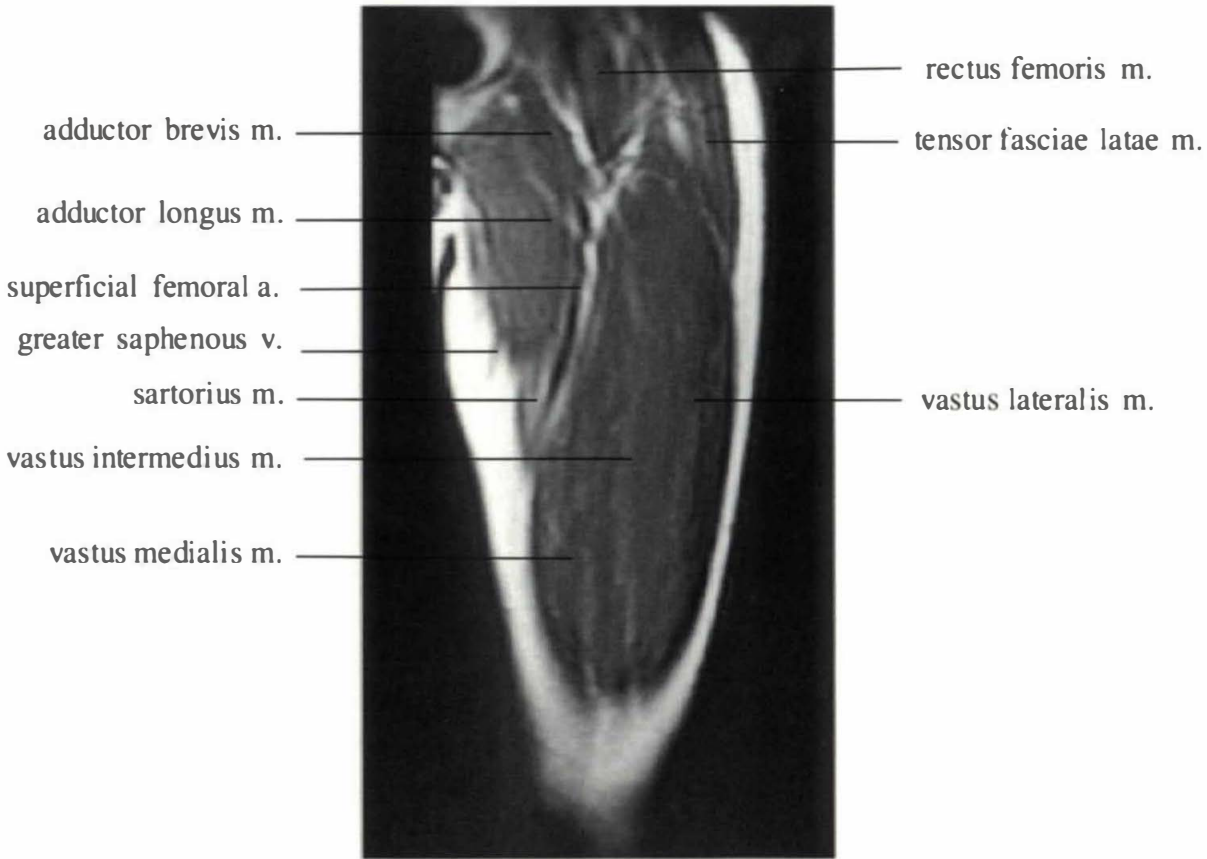
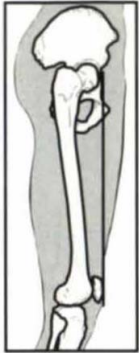


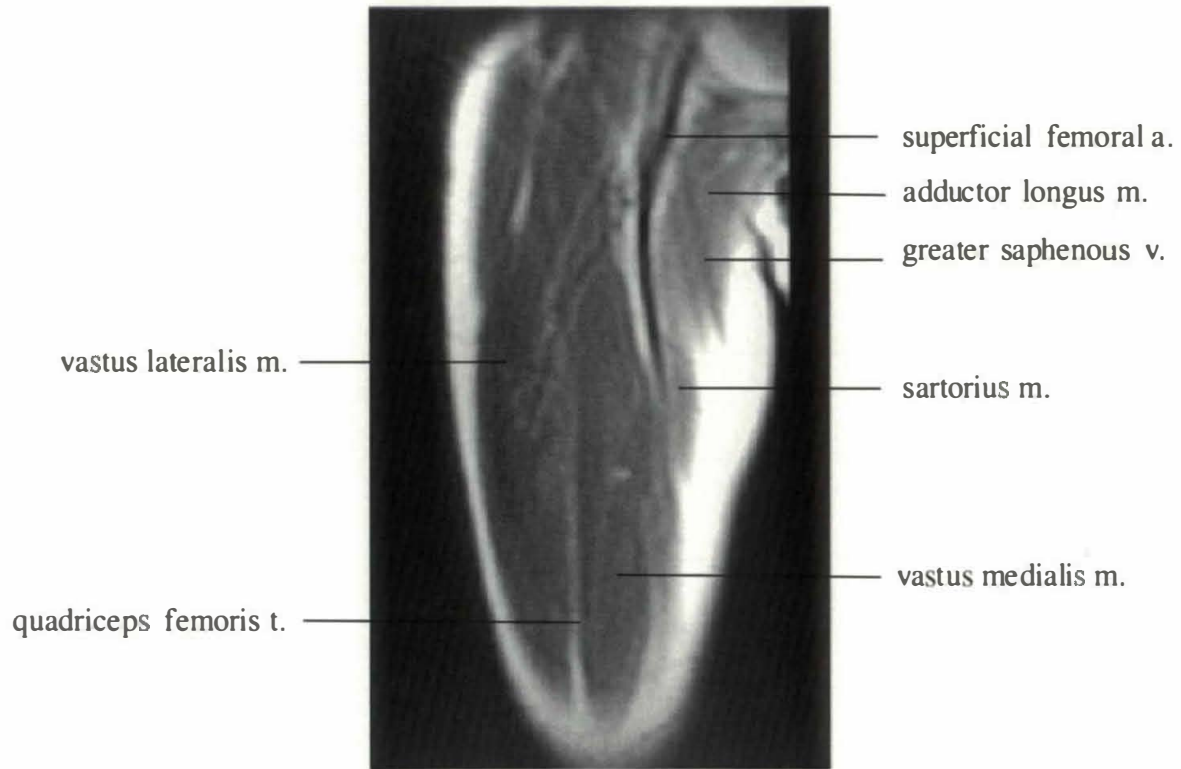
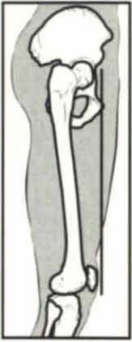


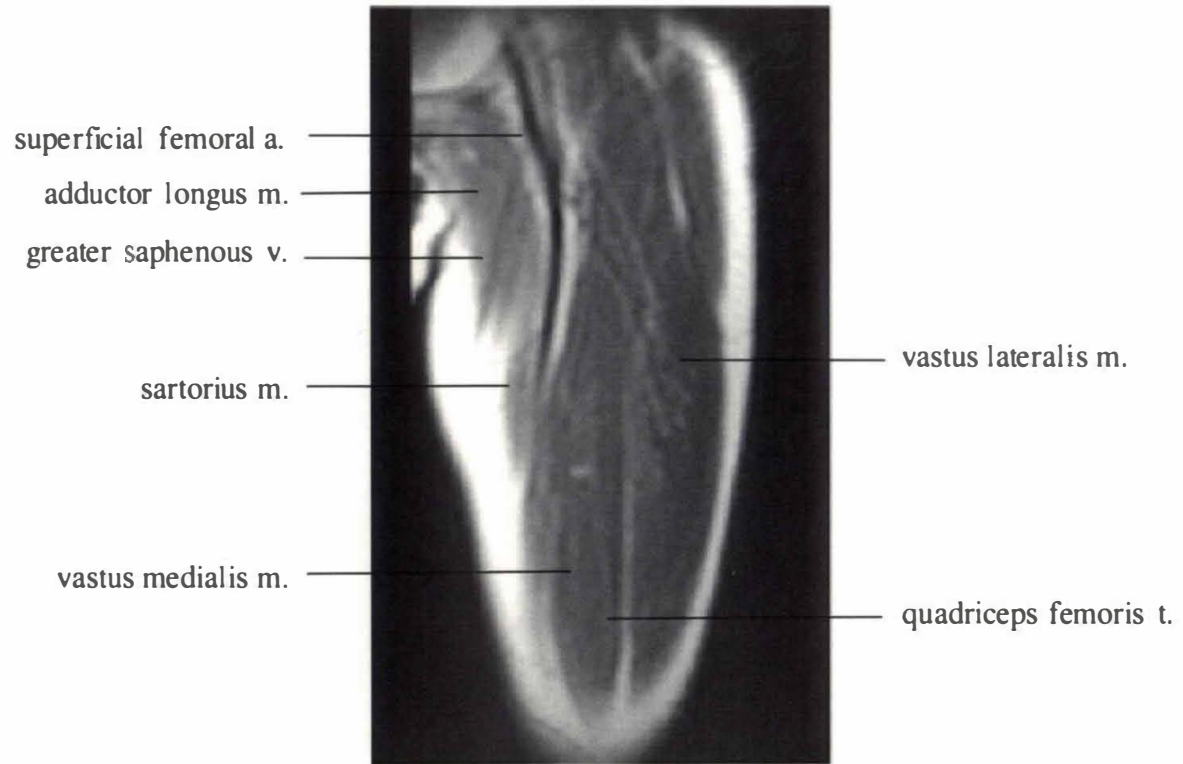
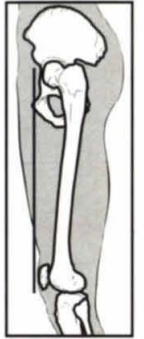












superficial femoral a.

adductor longus m.

greater saphenous v.

sartorius m.

vastus medialis m.

vastus lateralis m.

quadriceps femoris t.

THE KNEE AND THE LOWER EXTREMITY

A. THE KNEE

The knee is the joint most commonly examined with MR imaging. The primary indications for the MR study are to delineate the sequelae of trauma or define chronic and unexplained knee pain. The major abnormalities encountered are meniscal tears, ligament or tendon injury or disruption, bone “bruises” (intramedullary contusions), and cartilage damage (either acute or remote).

PRACTICAL PROTOCOL CONSIDERATIONS

For MR imaging of the knee, the patient is placed in the supine position with the knee centered in the dedicated extremity (or preferably “knee”) coil. The patient is asked to place the knee in a comfortable position, usually 15°–20° of external rotation with slight flexion (usually 5°–10°). This position is not only most comfortable for the patient but is convenient for visualization of the anterior cruciate ligament (ACL) on the sagittal images. The partial flexion also helps in the evaluation of the patellofemoral compartment and patellar alignment.

Below is a list of suggested protocol options accumulated from the literature. The choice of protocol may depend upon the type of equipment available and needs of the practice; therefore, this list is meant to be merely a practical outline. In many practices, standard spin-echo (SE) sequences, instead of fast spin-echo (FSE) sequences, are still used. This method is certainly acceptable, although slightly more time-consuming. Radial imaging and three-dimensional (3D) volumetric techniques are alternative protocols, but these are not routinely used today.

Menu of Protocols: Knee

Plane	Pulse Sequence	FA (degrees)	TR (msec)	TE (msec)	TI (msec)	FOV (cm)	Matrix (256X-)	ST/G (mm)	NEX	Comments
Localizer (sagittal)	FMPIR		2500	25	150	18	128	5/2.5	1	Sensitive to bone contusions
Localizer (transaxial)	2D SPGR	30	34	min		20	256	5/0	1	Either is acceptable
Localizer (transaxial)	SE		600	min		14	256	4/1	2	
Sagittal	SE, double echo		2000	20/80		14	192	4/1	1	Either is acceptable
Sagittal	FSE (\pm FS)		5500	85		16	192	4/0.5	1	
Sagittal	FSE, double echo		4000	20/100		12-14	256	3/1	1	
Coronal	FSE, FS		3000	20		14	192	4/0.5	2	Either is acceptable
Coronal	FSE, FS		5500	85		16	192	4/0.5	2	Sensitive to edema
Coronal	FSE (+1-FS)		4000	105		11	256	4/1	2	
Coronal	FMPIR		3000	51	150	16	128	4/1	2	Sensitive to edema
Transaxial	FSE, FS		3000	20		14	256	4/1	2	Excellent for patellar cartilage
Transaxial	3D GRE	20	40	13		16	128	1.2/0	2	
Transaxial	SPGR	30	34	3.3		20	128	5/2	1	

MAJOR OSTEOCARTILAGINOUS STRUCTURES/LANDMARKS

- Femur
 - Femoral condyles
 - Femoral condylar hyaline cartilage
 - Femoral trochlea
 - Femoral trochlear hyaline cartilage
- Lateral meniscus
- Medial meniscus
- Patella
- Patellar hyaline cartilage
- Tibia
 - Tibial plateaus (condyles)
 - Intercondylar eminence
 - Tibial condylar hyaline cartilage
 - Tibial condylar spines
 - Tibial tubercle (tuberosity)

MAJOR LIGAMENTS/TENDONS/BURSAE

<i>Ligament</i>	<i>Origin</i>	<i>Insertion</i>
• Anterior cruciate (ACL)	Inner aspect of lateral femoral condyle	Anterior tibia adjacent to anterior tibial spine
• Coronary (meniscomfemoral and meniscotibial components)	Medial and lateral menisci	Femur/tibia
• Fibular collateral (FCL)	Lateral condyle of femur	Head of fibula
• Meniscomfemoral (Humphrey's—crosses anterior to PCL) (Wrisberg—crosses posterior to PCL)	Posteromedial aspect of lateral meniscus	Inner aspect of medial femoral condyle
• Patellar	Inferior margin of patella	Anterior tibial spine
• Posterior cruciate (PCL)	Inner aspect of medial condyle	Posterior tibia femoral
• Tibial collateral (TCL)	Medial condyle of femur	Medial tibia (5–7 cm below joint line)
• Transverse meniscal	Anteromedial aspect of lateral meniscus	Anteromedial aspect of lateral meniscus

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
Extensor Group			
• Rectus femorus	Anterosuperior iliac spine	Patellar retinacula	Femoral N.
– Straight head			
– Reflected head	Upper margin of acetabulum and at joint capsule	Patellar retinaculum	Femoral N.
• Sartorius	Anterosuperior iliac spine	Medial tibia via pes anserinus	Femoral N.

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
• Vastus medialis	Medial lip of linea aspera and terminal tendons of adductor longus/magnus	Medial retinaculum	Femoral N.
• Vastus lateralis	Base of greater trochanter and lateral lip of the linea aspera aponeurosis	Patella retinaculum	Femoral N.
• Vastus intermedius	Anterolateral mid-to distal femur	Common terminal tendon	Femoral N.
Flexor Group			
• Biceps femoris			
– Long head	Posterior surface of ischial tuberosity	Head of fibula (portion to lateral condyle of tibia)	Tibialis component of sciatic N.
– Short head	Middle third of lateral lip of linea aspera		Peroneal division of sciatic N.
– Semi-membranosus	Ischial tuberosity of tibia	1. Medial condyle 2. Posterior wall of knee joint capsule 3. Fascia of popliteus tendon (via pes anserinus)	Tibialis component of sciatic N.
– Semi-tendinosus	Ischial tuberosity	Medial surface of proximal end of tibia and fascia of leg (via pes anserinus)	Tibialis component of sciatic N.

B. THE LOWER EXTREMITY

The major indications for MR imaging of the lower limb include suspected tumors, stress injuries, infection, or acute muscle and soft-tissue injuries such as acute hemorrhage and muscle tears. Before the patient arrives, study protocol should be determined according to the clinical indication, and, ideally, the examination should be monitored.

PRACTICAL PROTOCOL CONSIDERATIONS

For MR imaging of the lower limb, the patient is usually placed in the supine position with the extremity resting comfortably within the magnet. If the patient has a palpable abnormality or a surgical scar, a bath oil bead or vitamin E tablet should be placed at the upper and lower margins of the scar or the palpable mass. If the mass is large, these localizers should reflect the superior and inferior margins of the lesion.

The body coil can be used for the localizer, but torso or surface coils should be used if possible to provide better signal-to-noise ratio. Most of these examinations should be planned before the patient arrives, and the exact protocol will vary according to the indications for the study. The patient should be monitored during the examination to ensure that the areas of clinical concern are covered by the MR study. Spin echo, fast spin echo, and gradient echo techniques are used, and some of the more common ones will be outlined in the next section.

Menu of Protocols: Lower Extremity

Plane	Pulse Sequence	FA (degrees)	TR (msec)	TE (msec)	TI (msec)	FOV (cm)	Matrix (256X-)	ST/G (mm)	NEX	Comments
Localizer (transaxial)	SE		500	min		VAR	192	5/1.5	1	Mark area of concern
Coronal, sagittal	SE		500	min		VAR	192	5/1.5	1	
Coronal	SE		1000	min		VAR	192	5/1.5	2	Either is acceptable
Coronal	FMPPIR		2500	30	150	VAR	128	5/1.5	1	
Sagittal	SE		1000	min		VAR	192	5/1.5	2	Either is acceptable
Sagittal	FMPPIR		2500	30	150	VAR	128	5/1.5	2	
Transaxial	SE		600	20 VAR		VAR	192	4/1	2	
Transaxial, pre-GAD	SE		600	20		VAR	192	4/1	2	Repeat after GAD
Transaxial, pre-GAD	SE, FS		600	20		VAR	192	4/1	2	Repeat after GAD

MAJOR OSTEOCHONDRAL STRUCTURES/LANDMARKS

(See knee and ankle/foot)

MAJOR LIGAMENTS/TENDONS/BURSAE

(See knee and ankle/foot)

MAJOR MUSCLES

Compartments

The lower leg is divided into four main compartments by the interosseous membrane, the crural fascia, and the intermuscular septae.

- Anterior compartment muscles
 - Tibialis anterior
 - Extensor digitorum longus
 - Extensor hallucis longus
 - Peroneus tertius
- Lateral compartment muscles
 - Peroneus longus muscle
 - Peroneus brevis muscles
- Posterior compartment muscles
 - Superficial group
 - Plantaris
 - Soleus
 - Gastrocnemius
- Deep group
 - Popliteus
 - Flexor digitorum longus
 - Tibialis posterior
 - Flexor hallucis longus and popliteus

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
Anterior Compartment			
– Tibialis anterior	Lateral condyle of tibia, interosseous membrane, crural fascia and intramuscular septum	Medial surface of the medial cuneiform, base of first metatarsal	Branches from common peroneal N. and deep peroneal N.
– Extensor digitorum longus	Lateral condyle of tibia, anterior surface of fibula, intermuscular septum, and crural fascia near tibia	Tendon divides into two parts below superior ext. retinaculum. Four tendons then cross dorsal surface of each toe. Tendons divide into one central and two lateral slips; lateral slip inserts on base of distal phalanx, and central slip ends on dorsum of middle phalanx. Extensor expansions are formed over MTP joints, and lateral slips of tendon are jointed distally by interosseus tendons and lumbrical muscles.	Branches of deep peroneal N.

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Extensor hallucis longus	Middle two-thirds of anterior surface of fibula and interosseous membrane	Base of distal phalanx of great toe	Deep peroneal N.
– Peroneus tertius (in essence, a lateral slip of extensor digitorum longus muscle and often merges with it except at its insertion)	Distal one-third of anterior surface of fibula, interosseous membrane, and anterior intermuscular septum	Dorsal shaft of fifth metatarsal	Distal nerve to extensor digitorum muscle (a branch of deep peroneal)
Lateral Compartment			
– Peroneus longus	Fibula—head and upper two-thirds of lateral surface of body, anterior and posterior intermuscular septae, and crural fascia	Inferolateral lateral aspect of medial cuneiform, base and inferolateral surface of first metatarsal	Common peroneal N. primarily, partially by superficial peroneal

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Peroneus brevis	Fibula—lower two-thirds of lateral surface, anterior and posterior intramuscular septae	Tuberosity of base of fifth metatarsal	Superficial peroneal N., less commonly off branch supplying peroneus longus
Superficial Posterior Compartment			
– Gastrocnemius			
• Medial head	Popliteal surface of femur just above medial femoral condyle	After aponeurotic fusion with tendon of soleus muscle it forms calcaneal tendon and inserts onto posterior and superior surface of calcaneus	Tibial portion of sciatic N.
• Lateral head	Upper and posterior portion of lateral surface of lateral femoral condyle at end of supracondylar line		
– Soleus	Posterior surfaces of fibular head, upper one-third of fibular shaft, intermuscular septum, medial border of middle third and soleus line of tibia	Fuses with tendon of gastrocnemius to form calcaneal tendon inserting onto posterior and superior surface of calcaneus	Tibial portion of sciatic N.

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ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

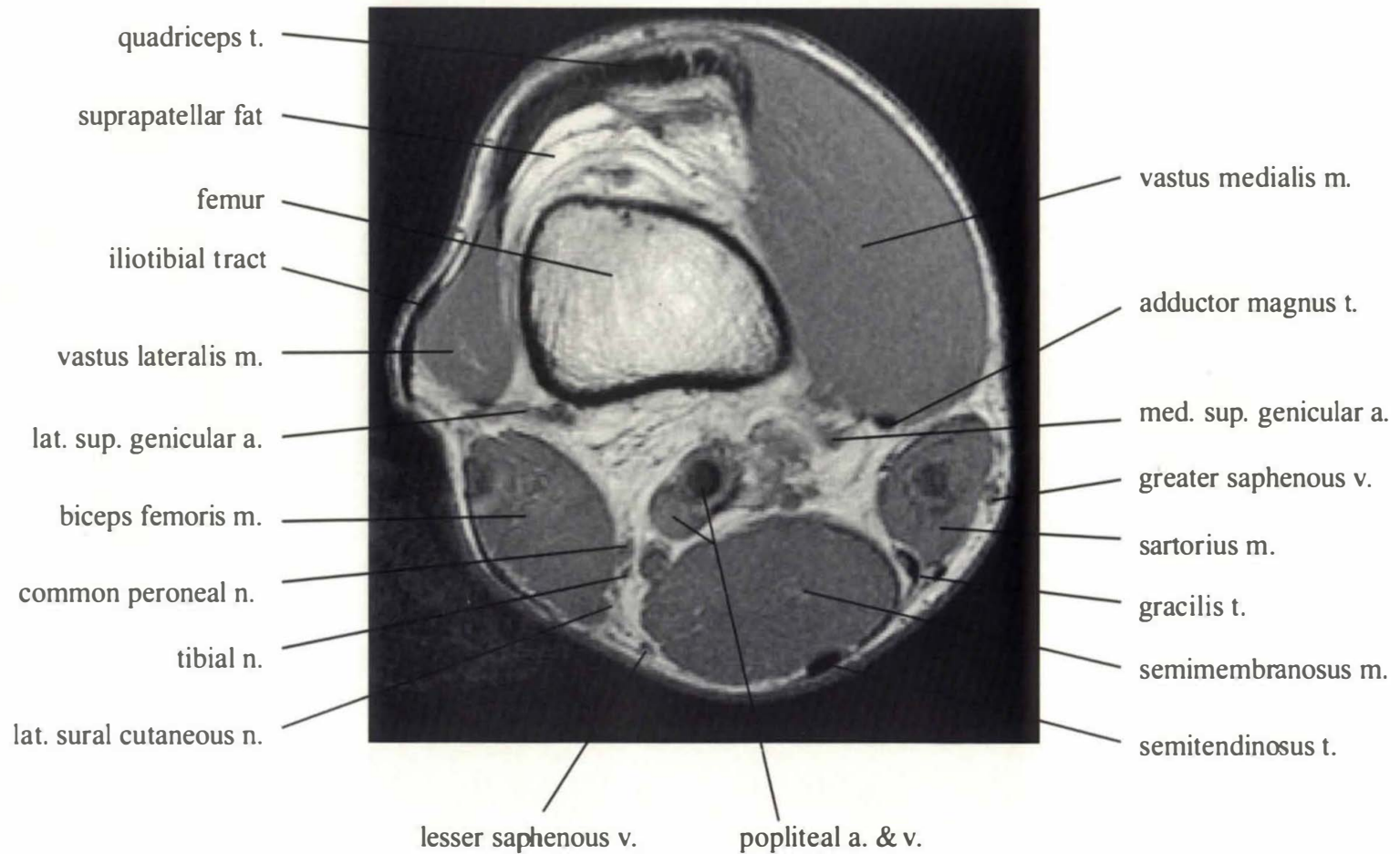
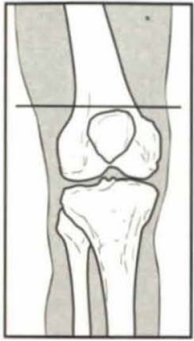
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Plantaris	Lower lateral supracondylar femur just above lateral head of gastrocnemius muscle, oblique popliteal ligament	Via medial border of calcaneal tendon it inserts onto posterior and superior aspect of calcaneus	Tibial portion of sciatic N.
Deep Posterior Compartment			
– Popliteus	Anterior end of groove on lateral aspect of lateral femoral condyle	Shaft of tibia proximal to popliteal line of tibia	Tibial N. (separate branch or with nerve to posterior tibial muscle)
– Flexor hallucis longus	Lower two-thirds of posterior surface of fibular shaft and intramuscular septum	Bases of distal phalanx of second to fourth toes	Tibial N.
– Flexor digitorum longus	Medial side and posterior surface of midtibia and intermuscular septum	Bases of terminal phalanges of second to fourth toes	Tibial N.

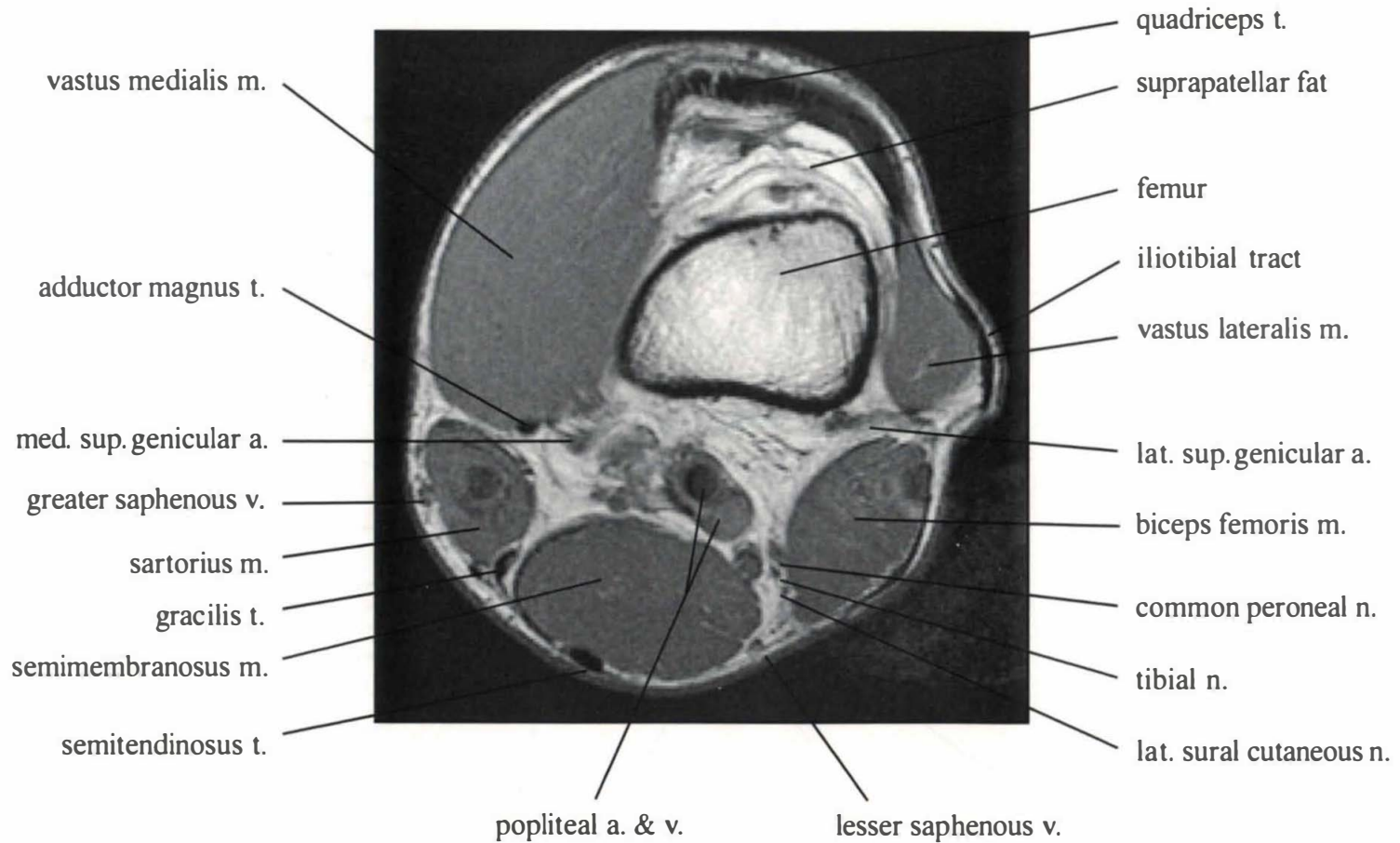
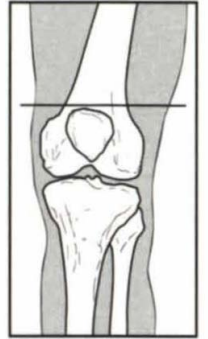
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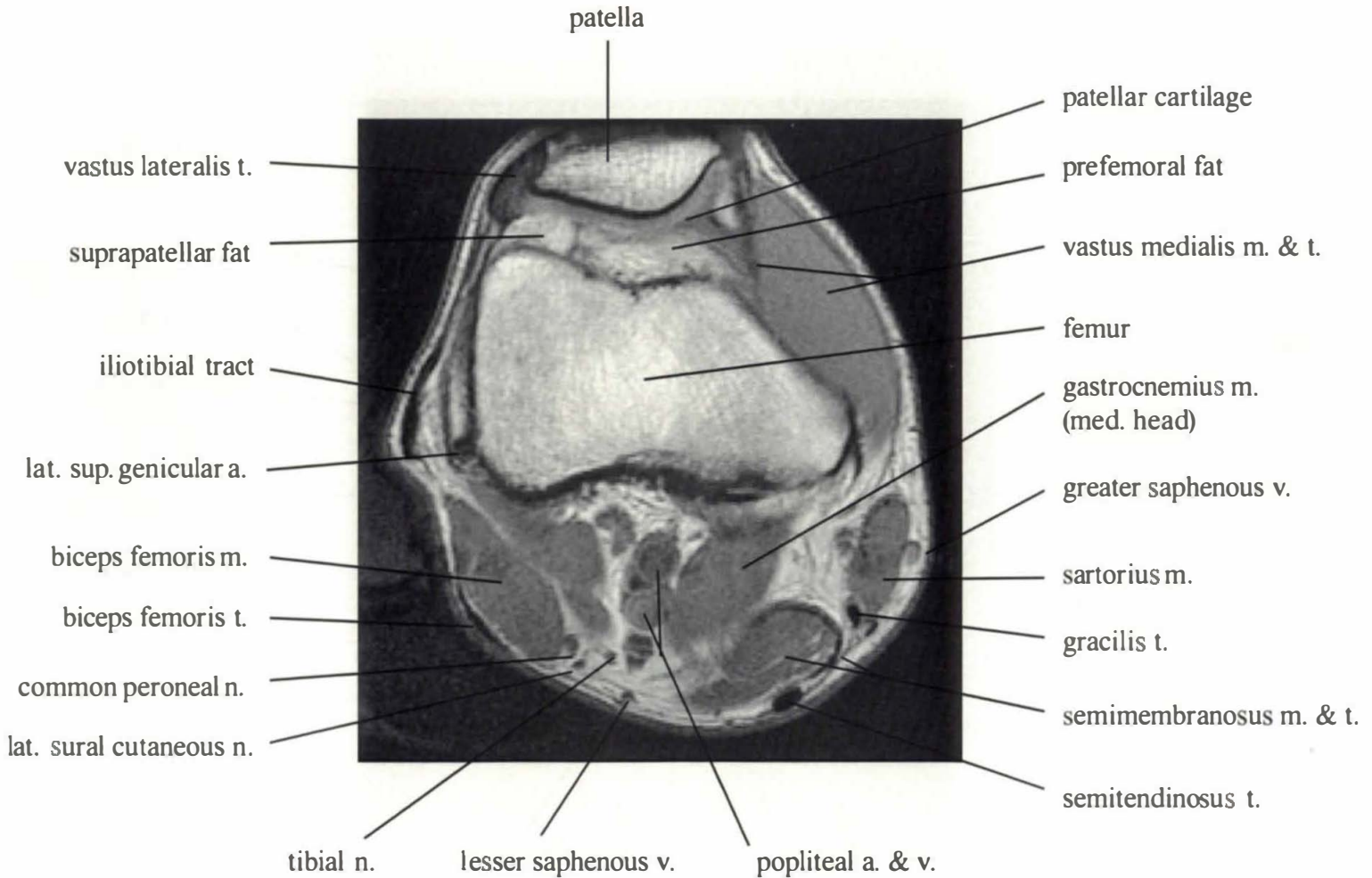
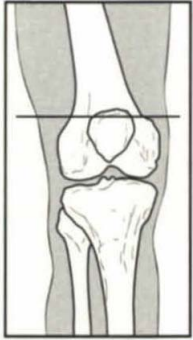
ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

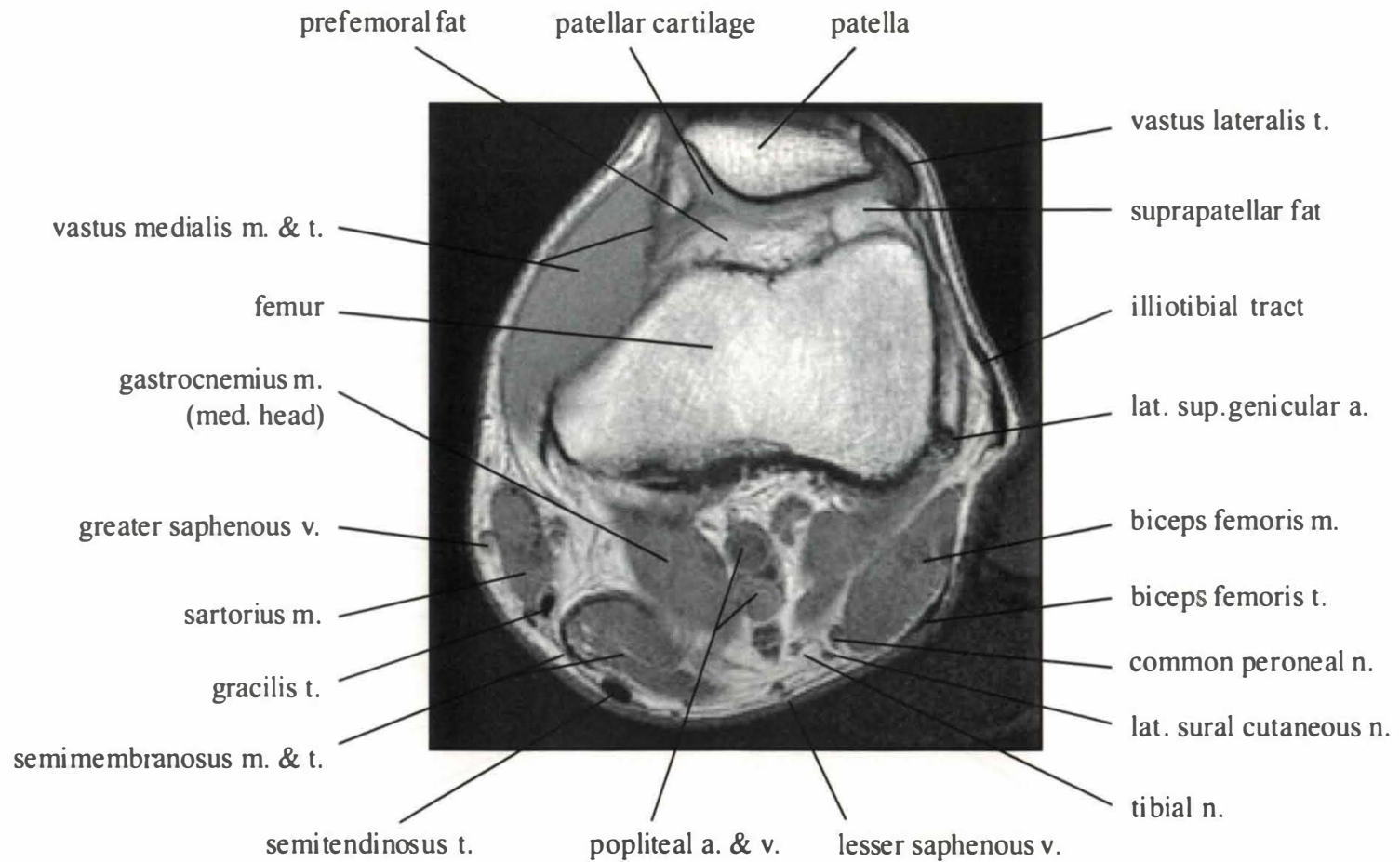
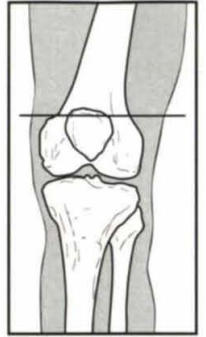
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
- Tibialis posterior	Lateral half of middle one-third of posterior surface of tibia, medial aspect of fibular head and proximal portion of body, interosseous membrane	Tuberosity of navicular and under surface of medial cuneiform, extension continues forward and lateral to intermediate and lateral cuneiforms and to plantar surfaces of bases of second to fourth metatarsals	Tibial N.

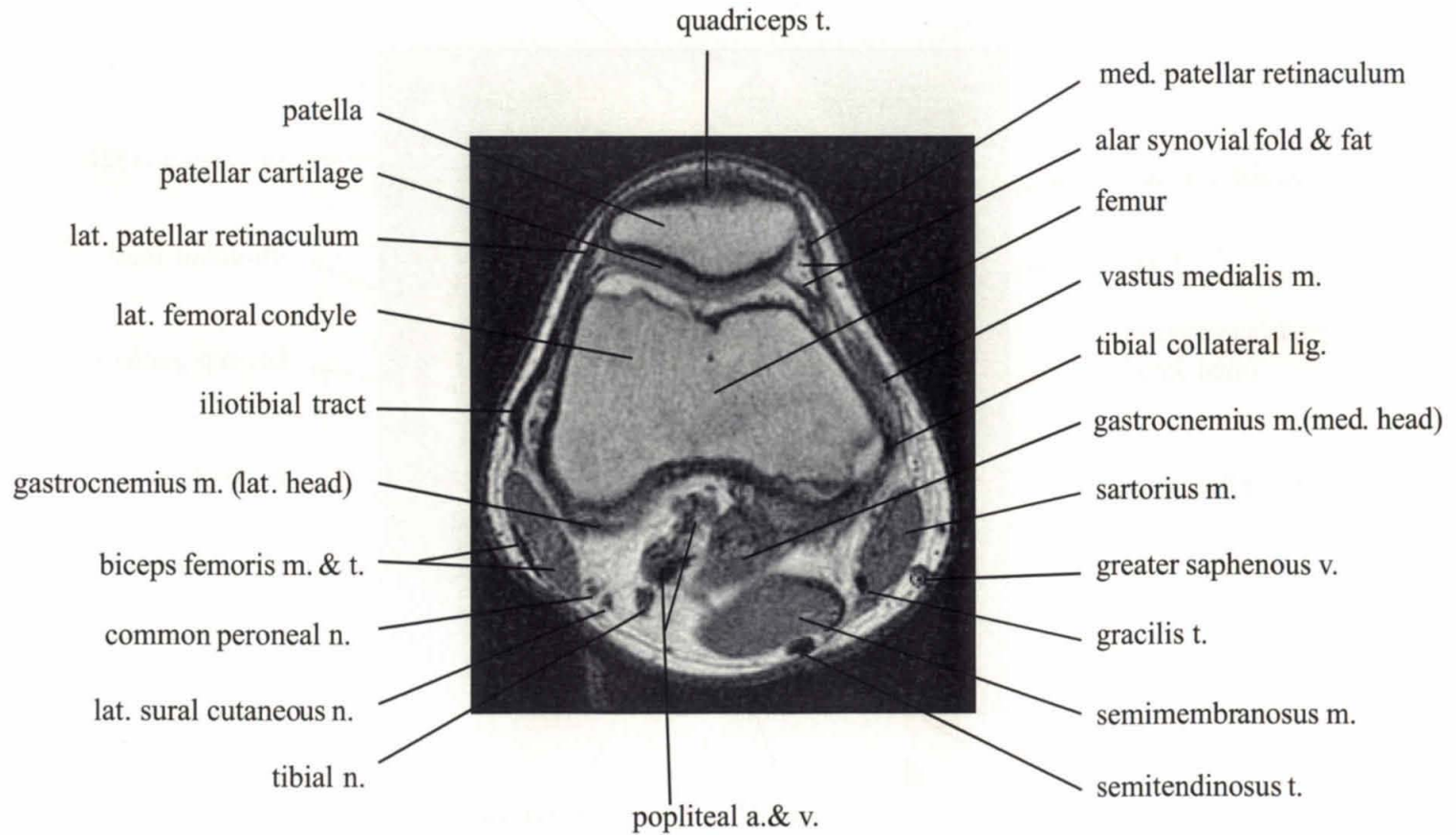
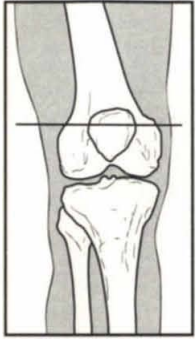
THE KNEE: AXIAL ANATOMY

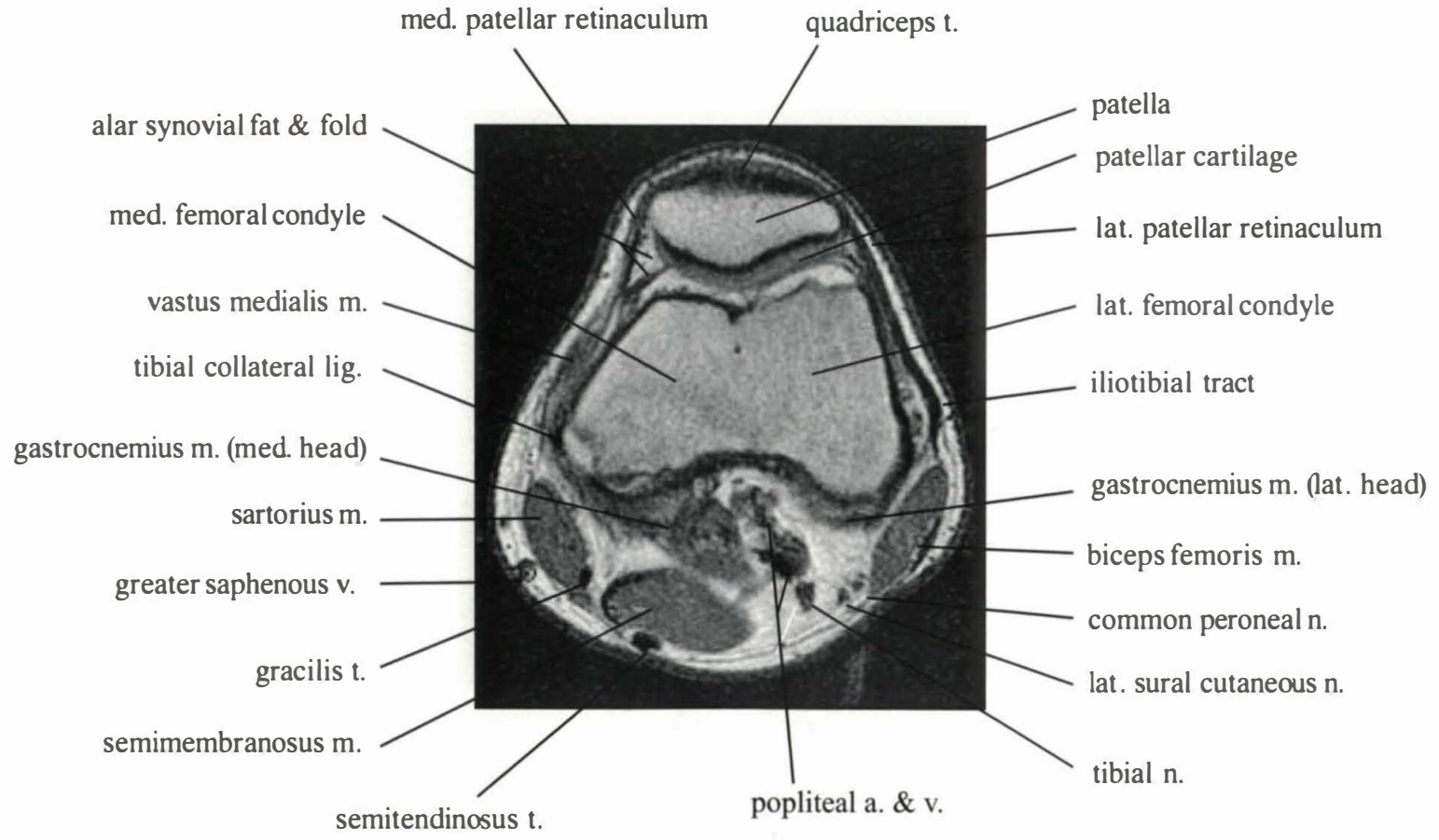
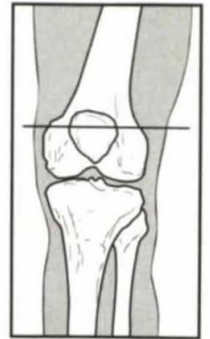


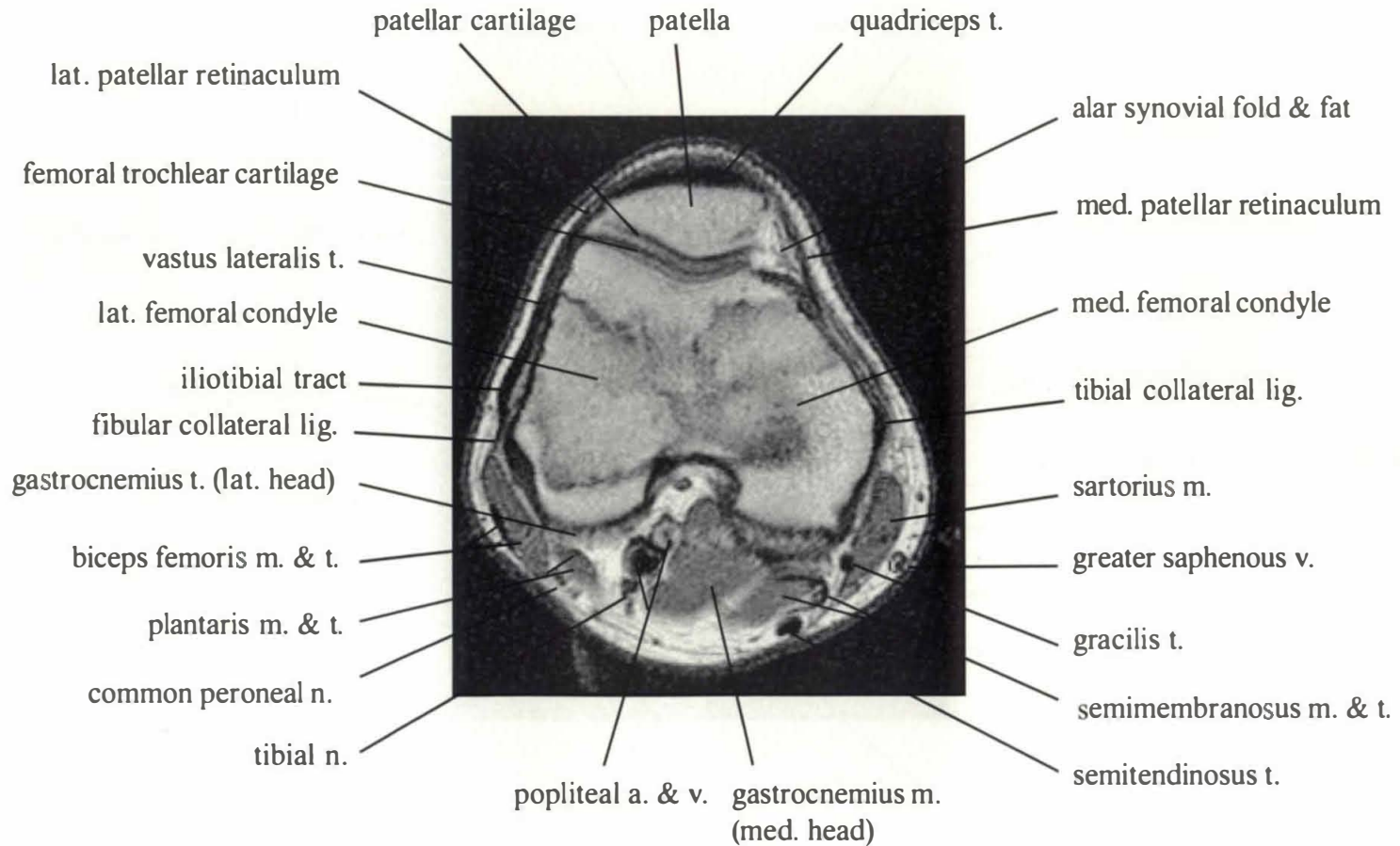
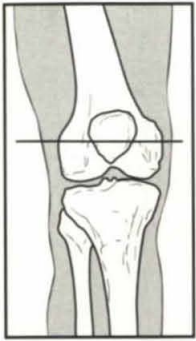


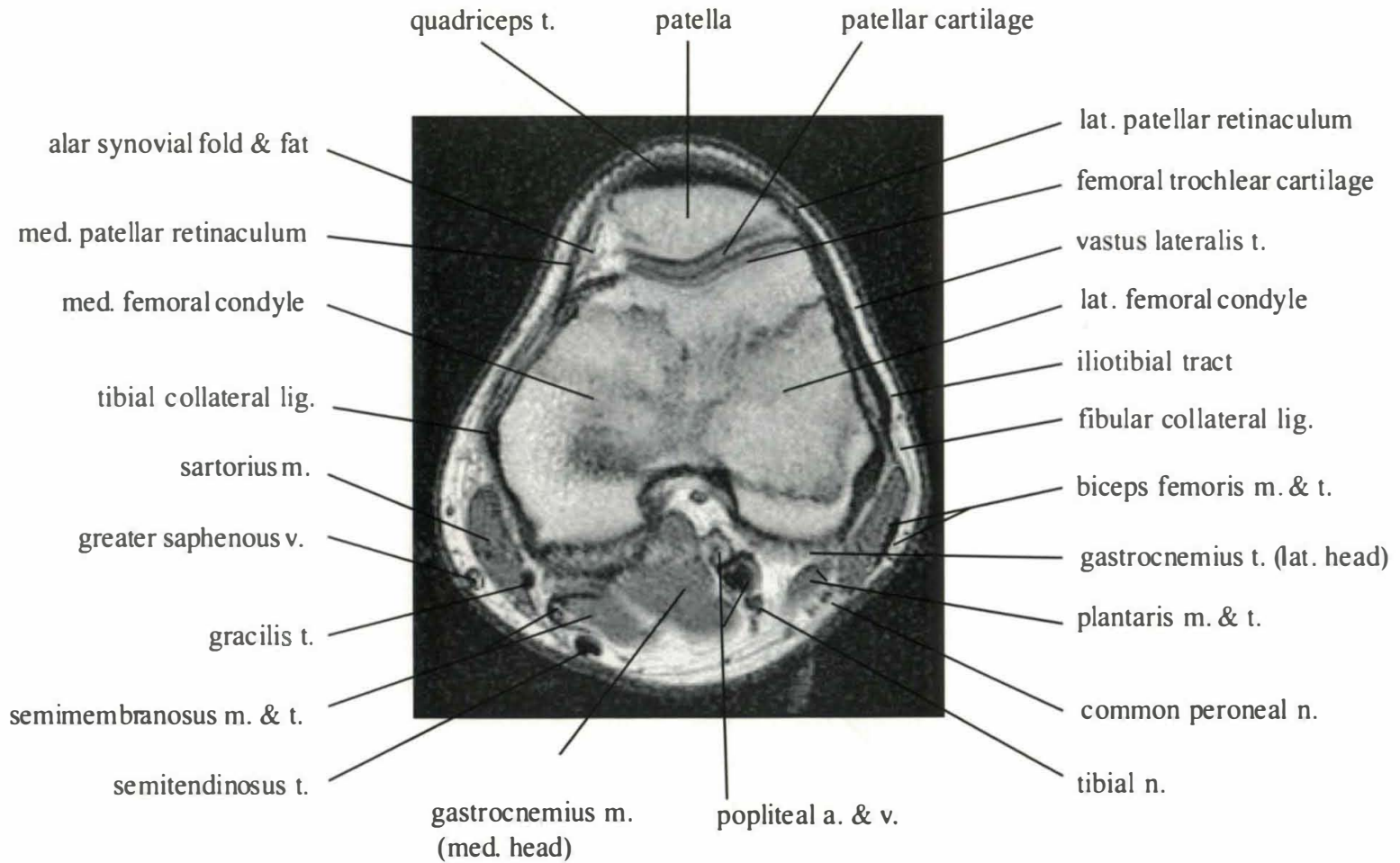
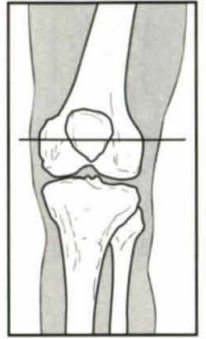


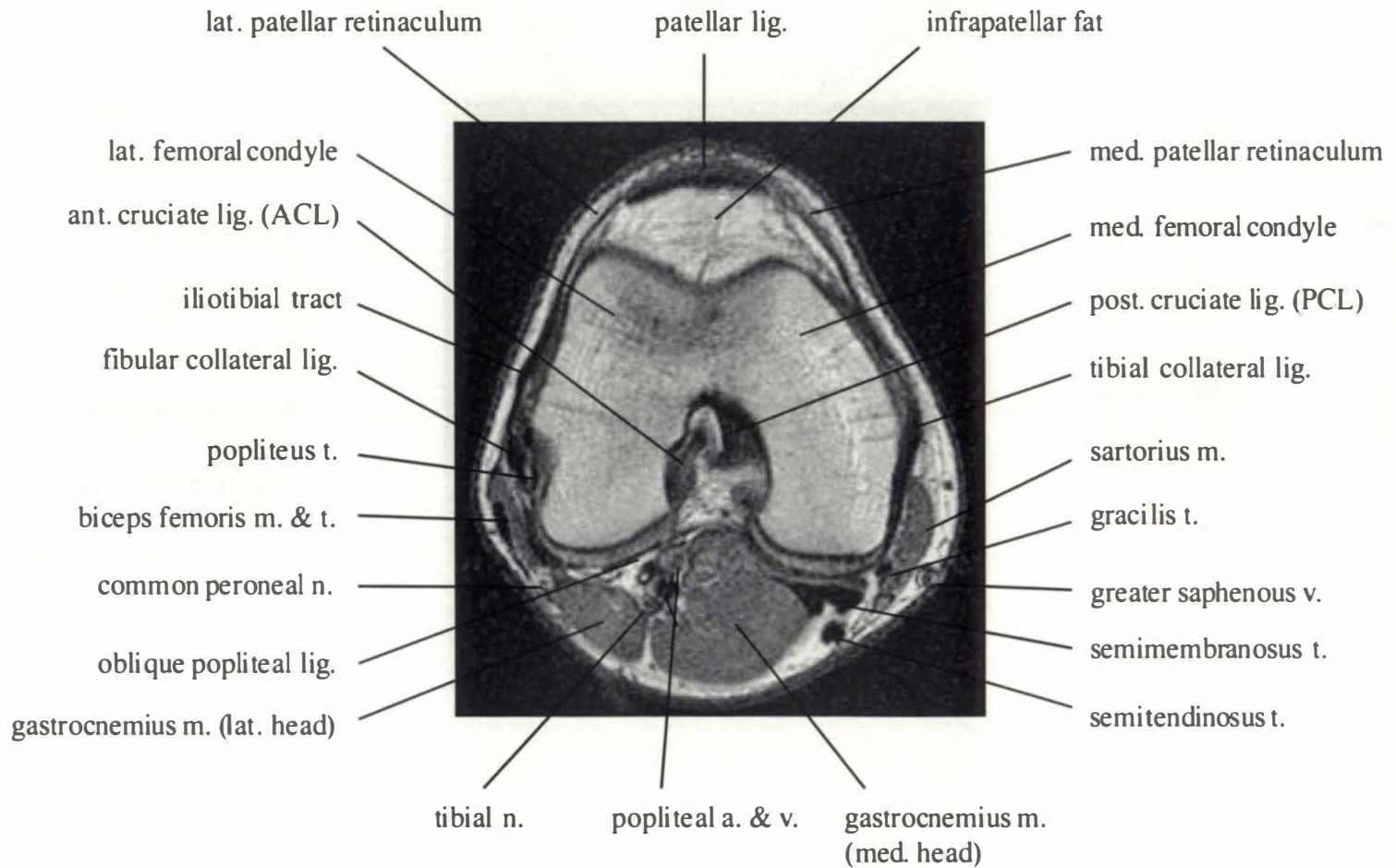


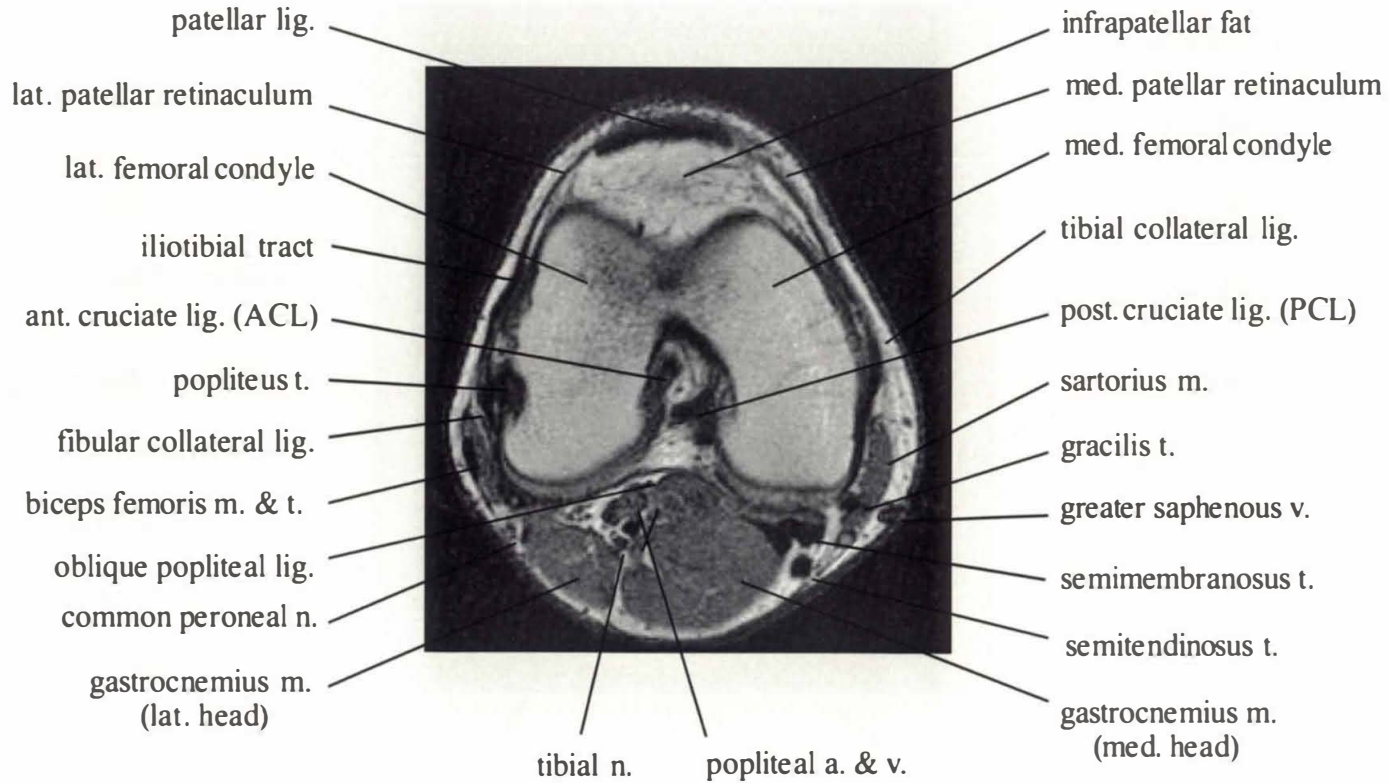
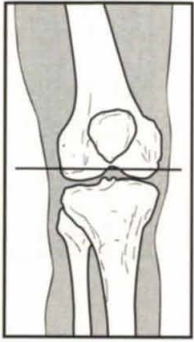


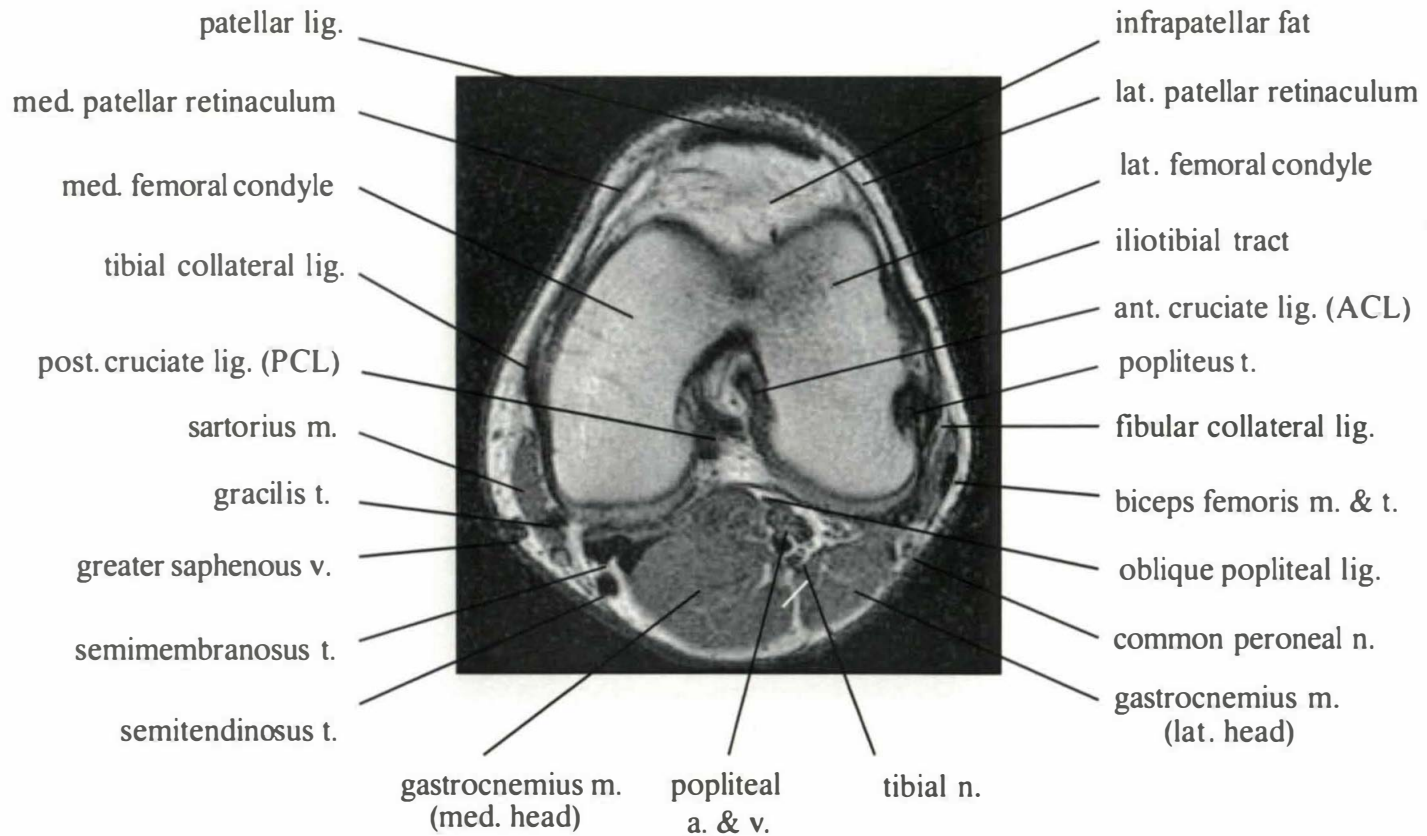
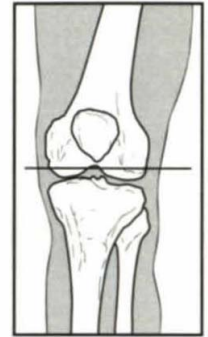


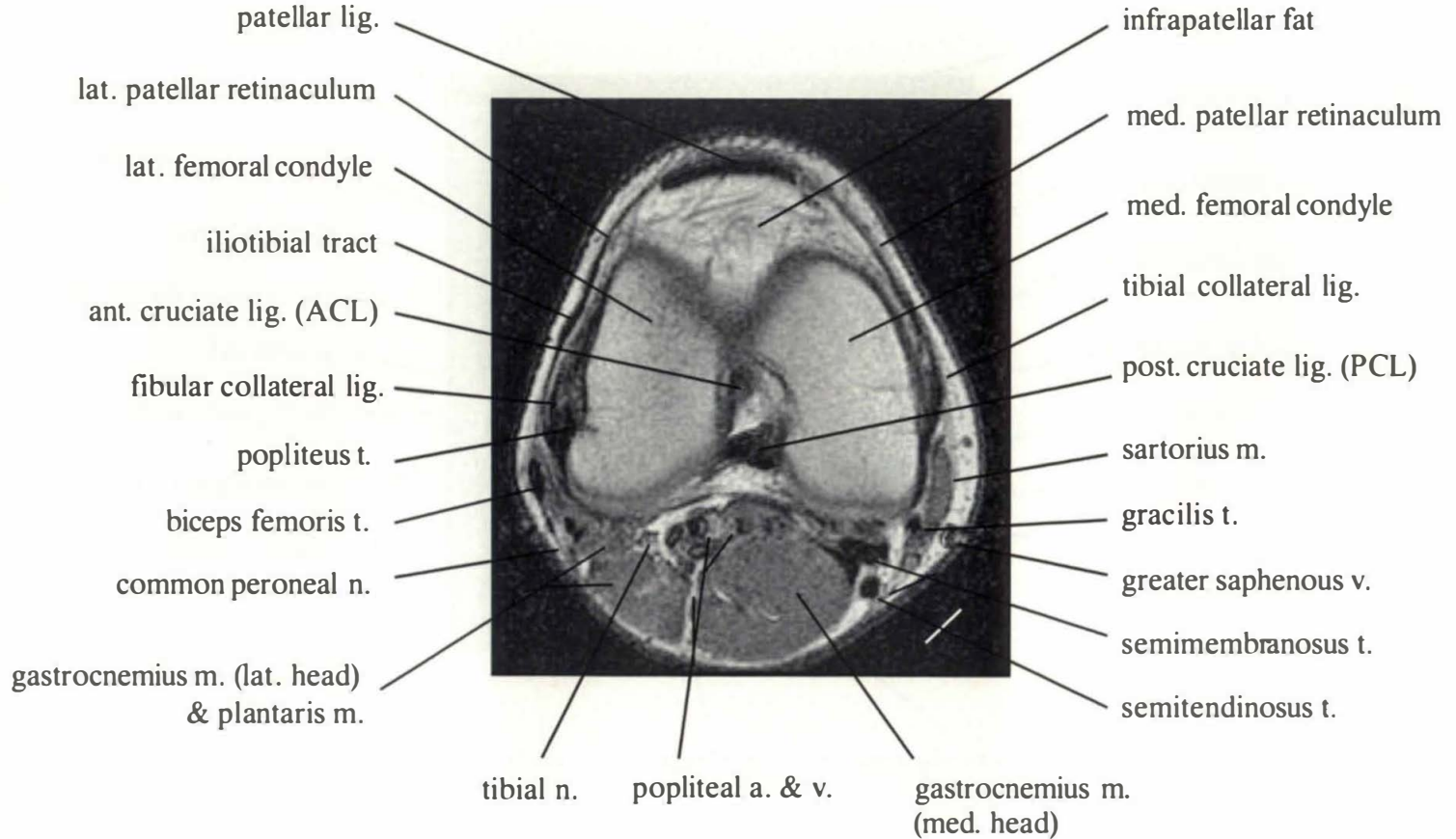
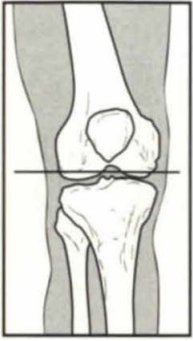


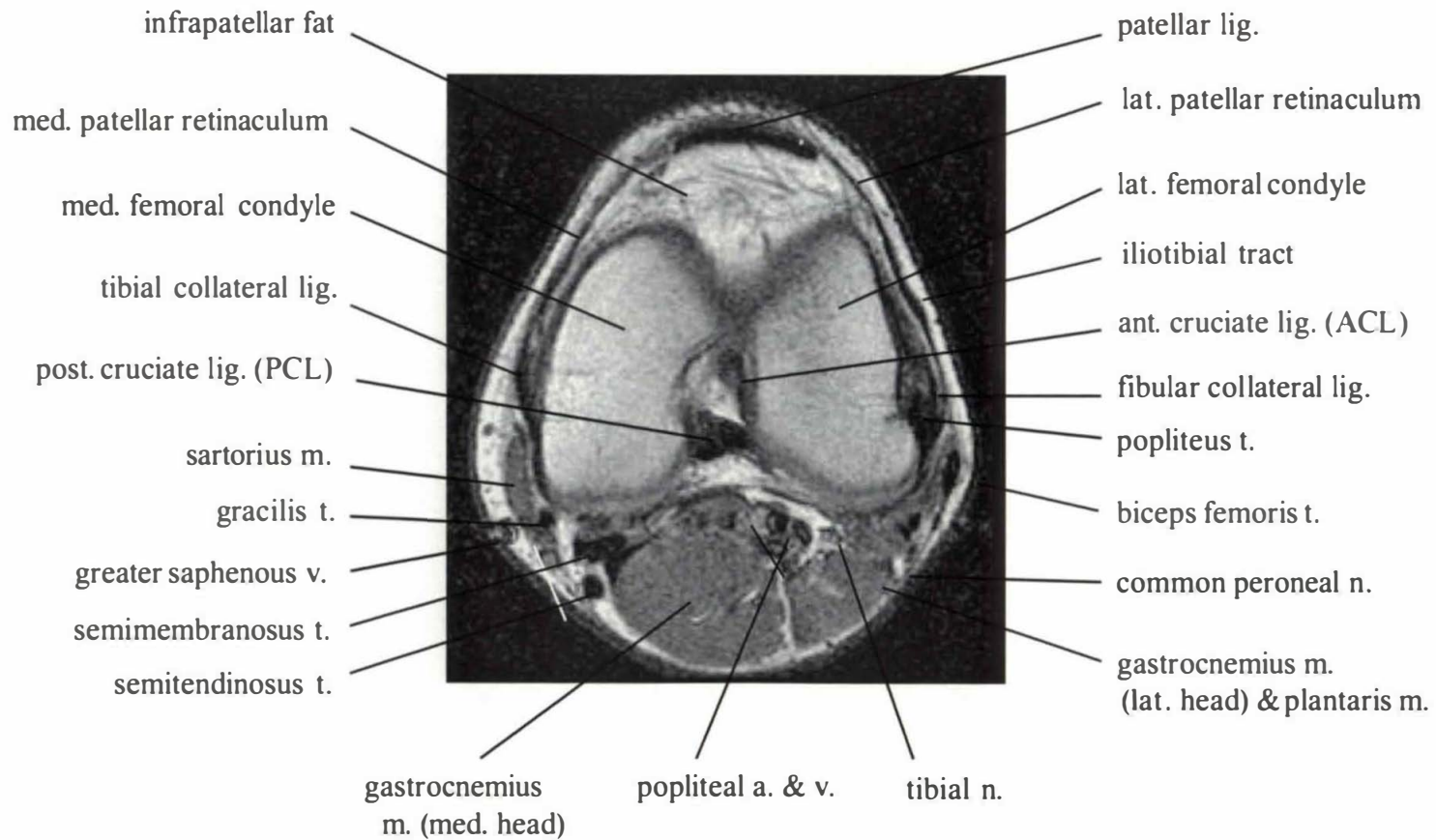
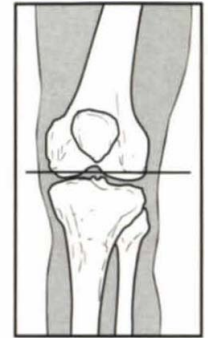


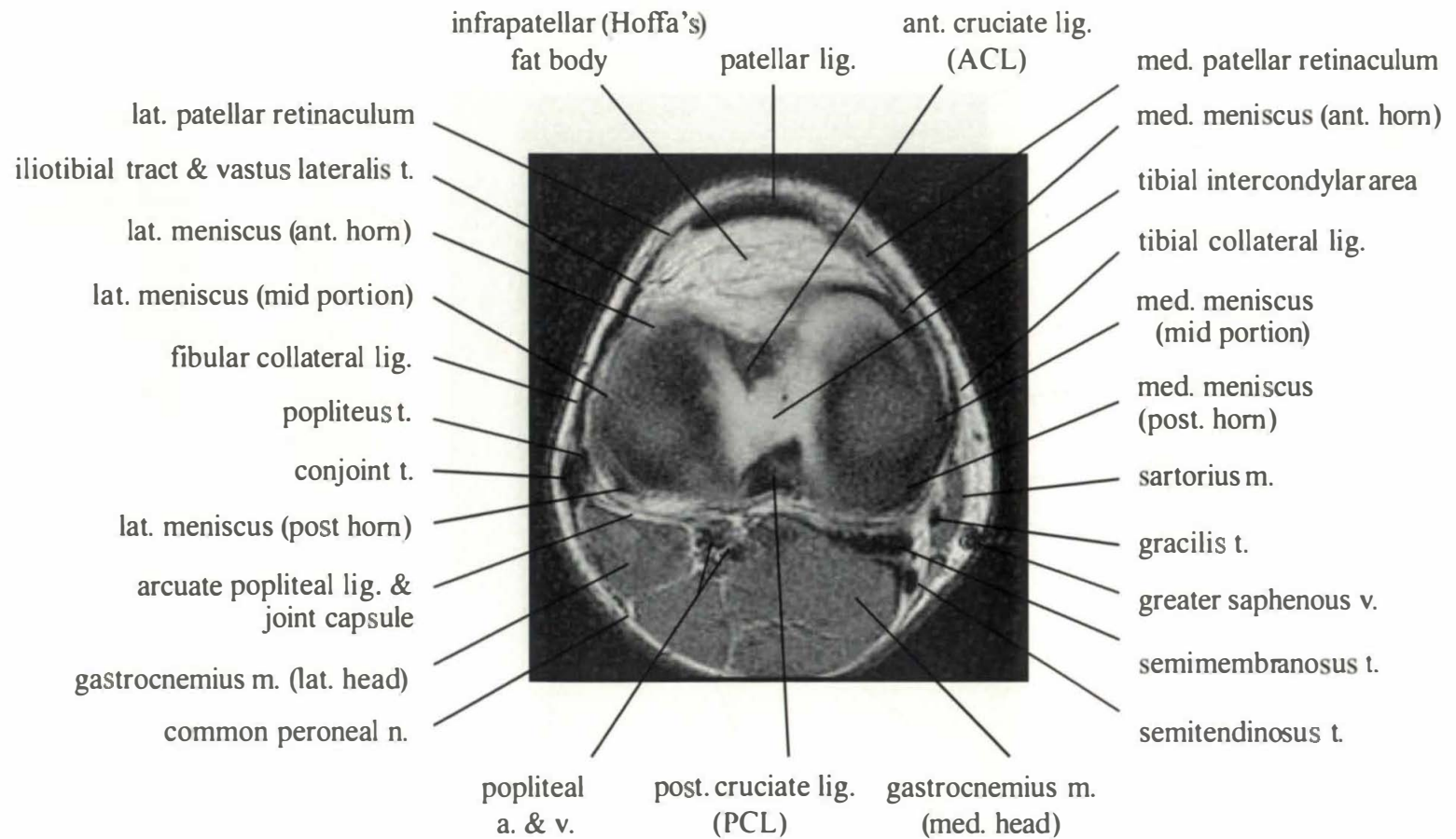


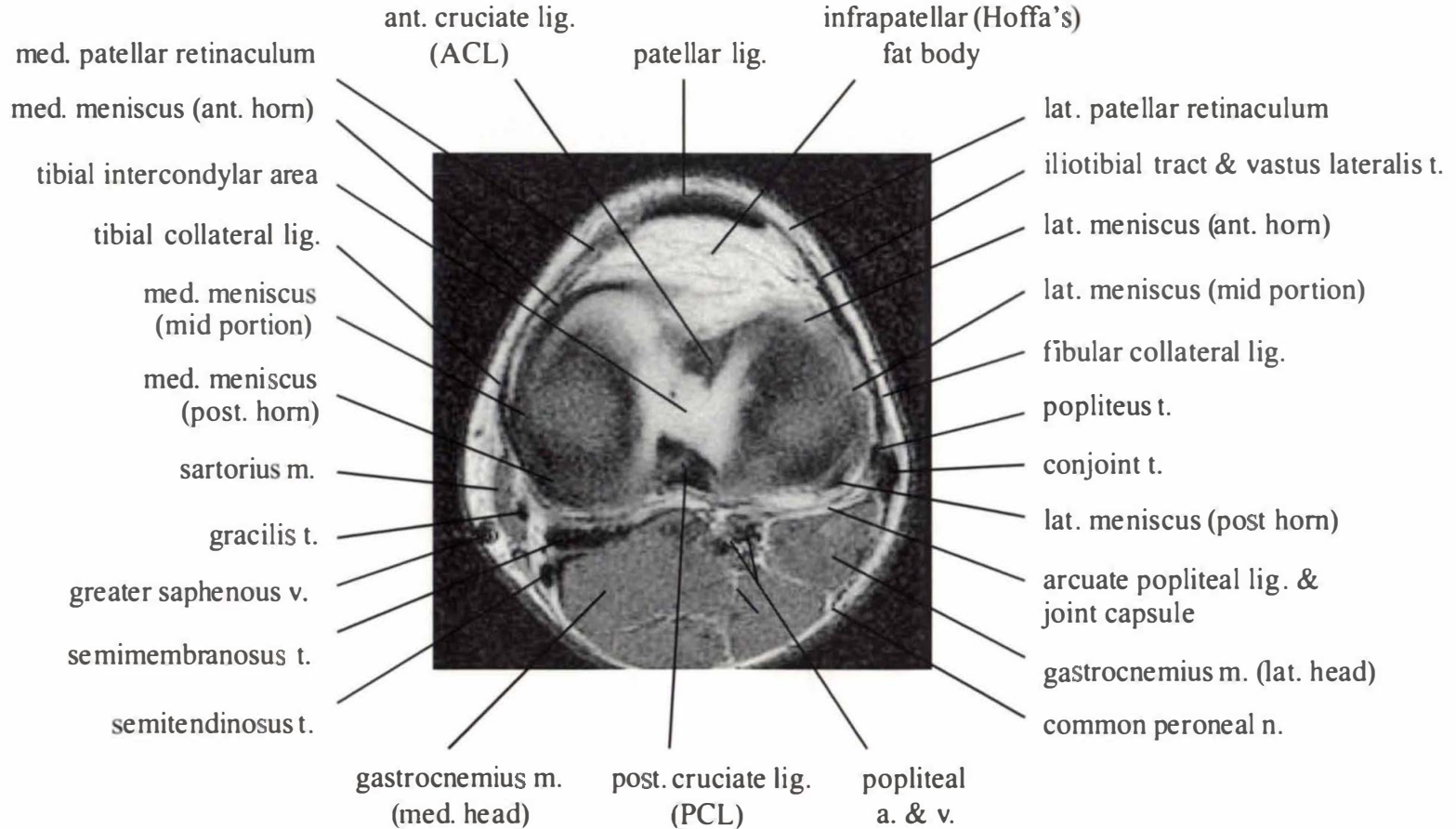
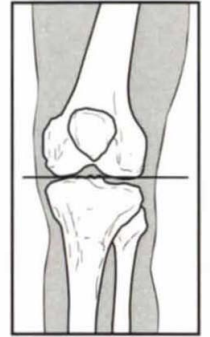


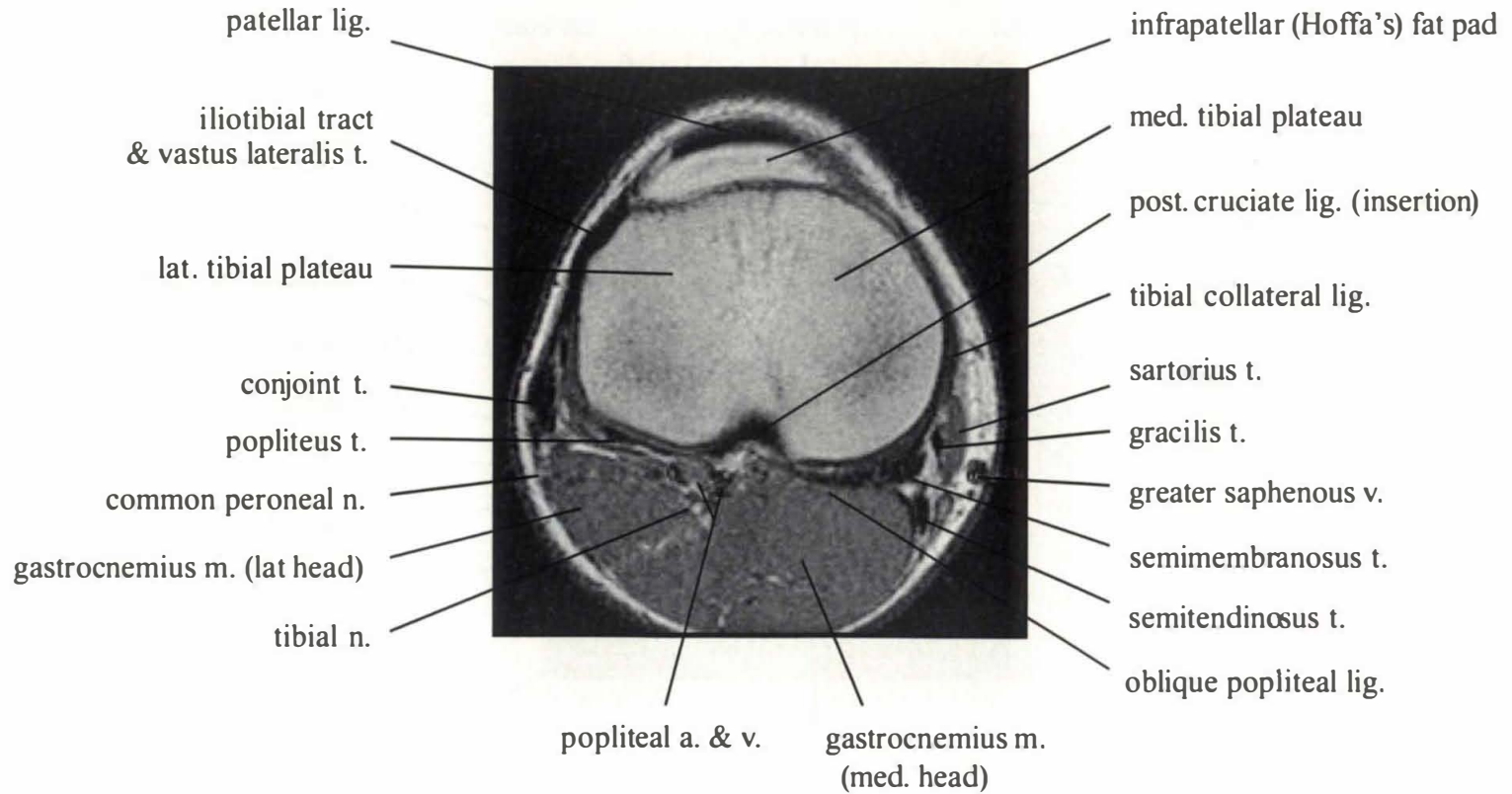
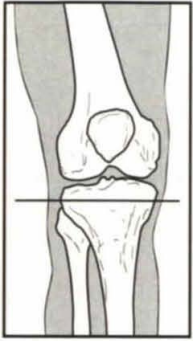


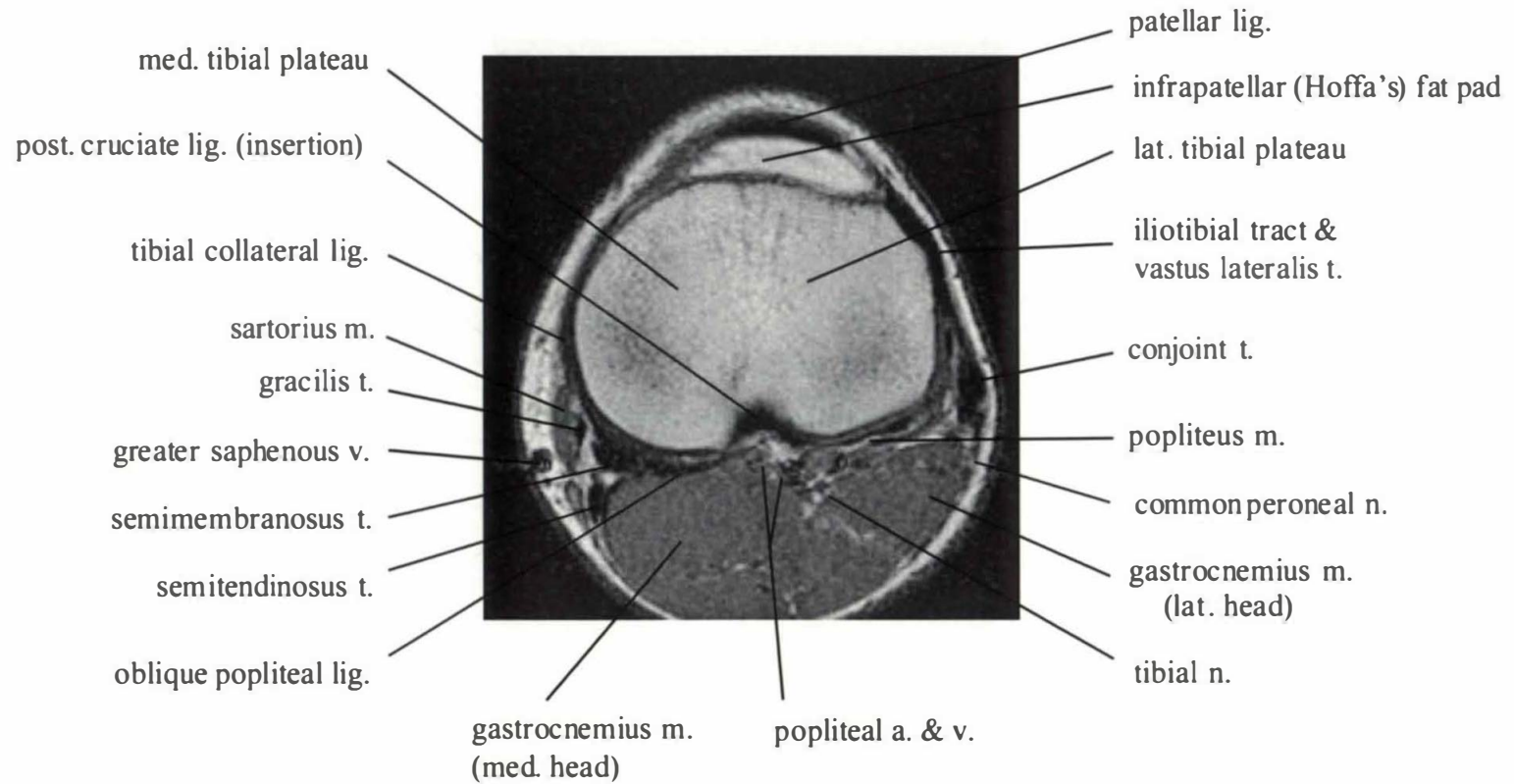
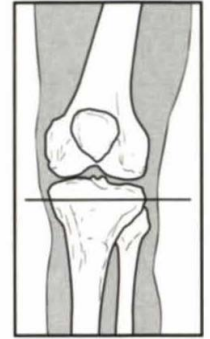


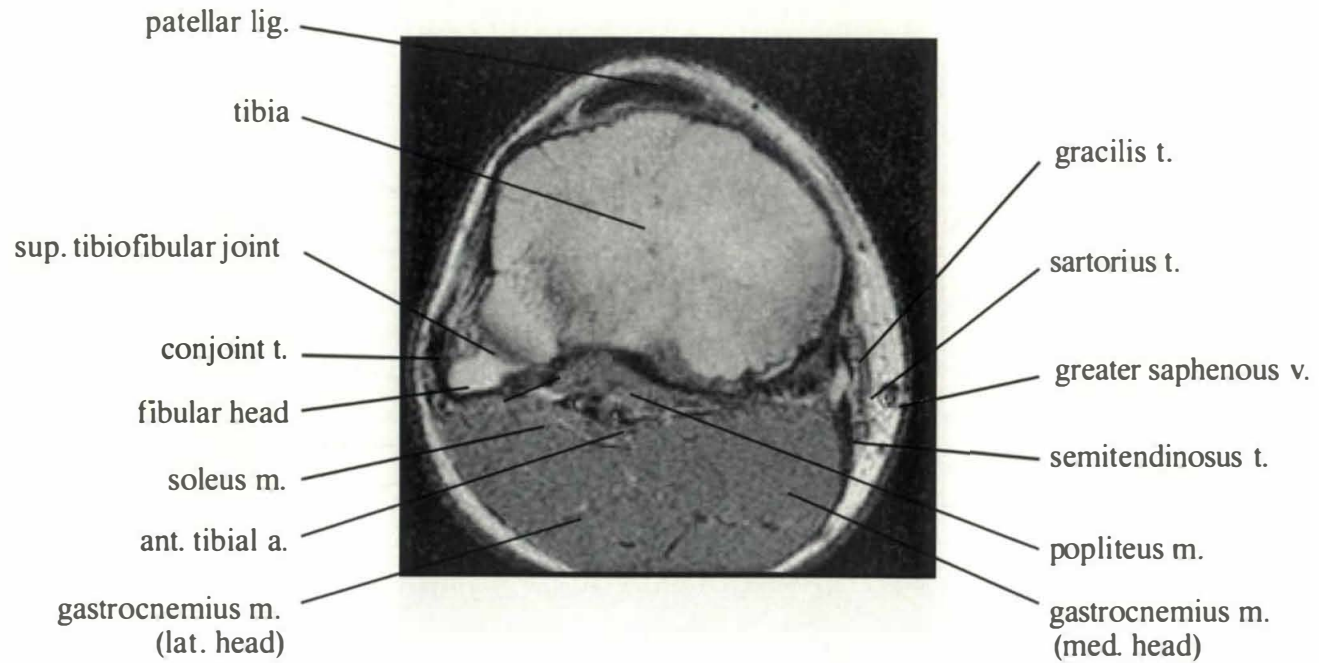
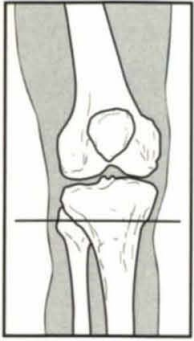


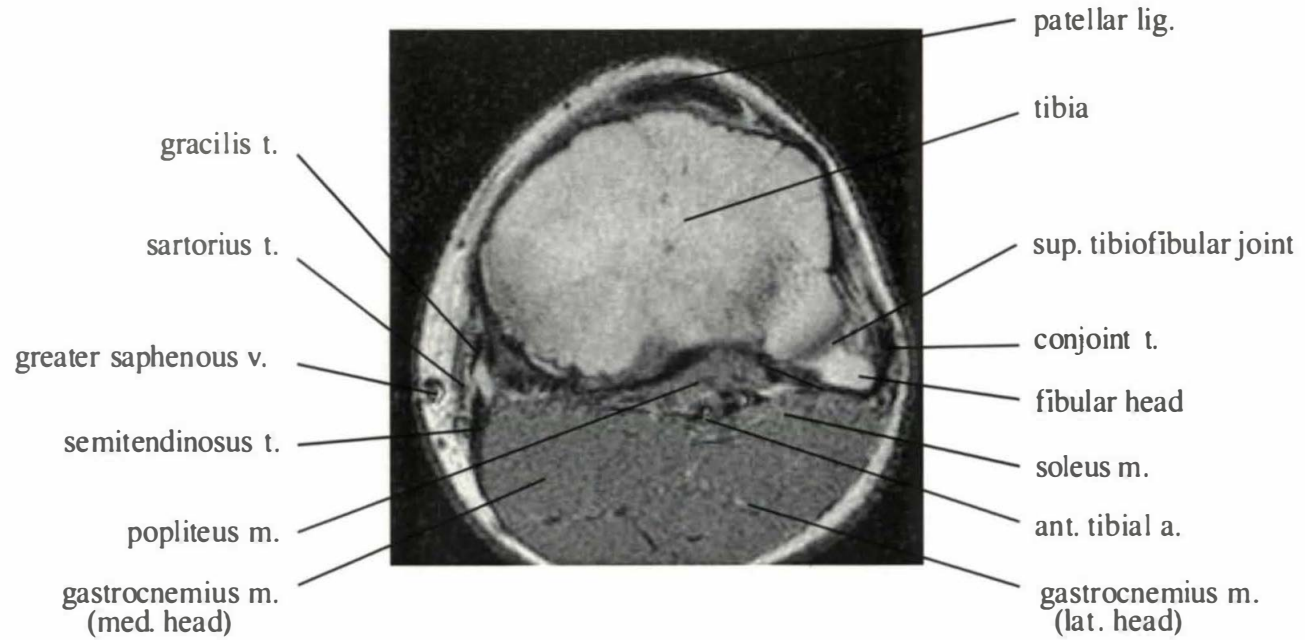
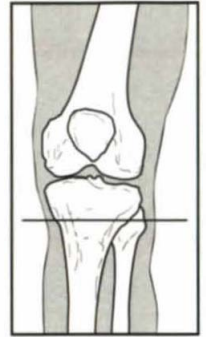




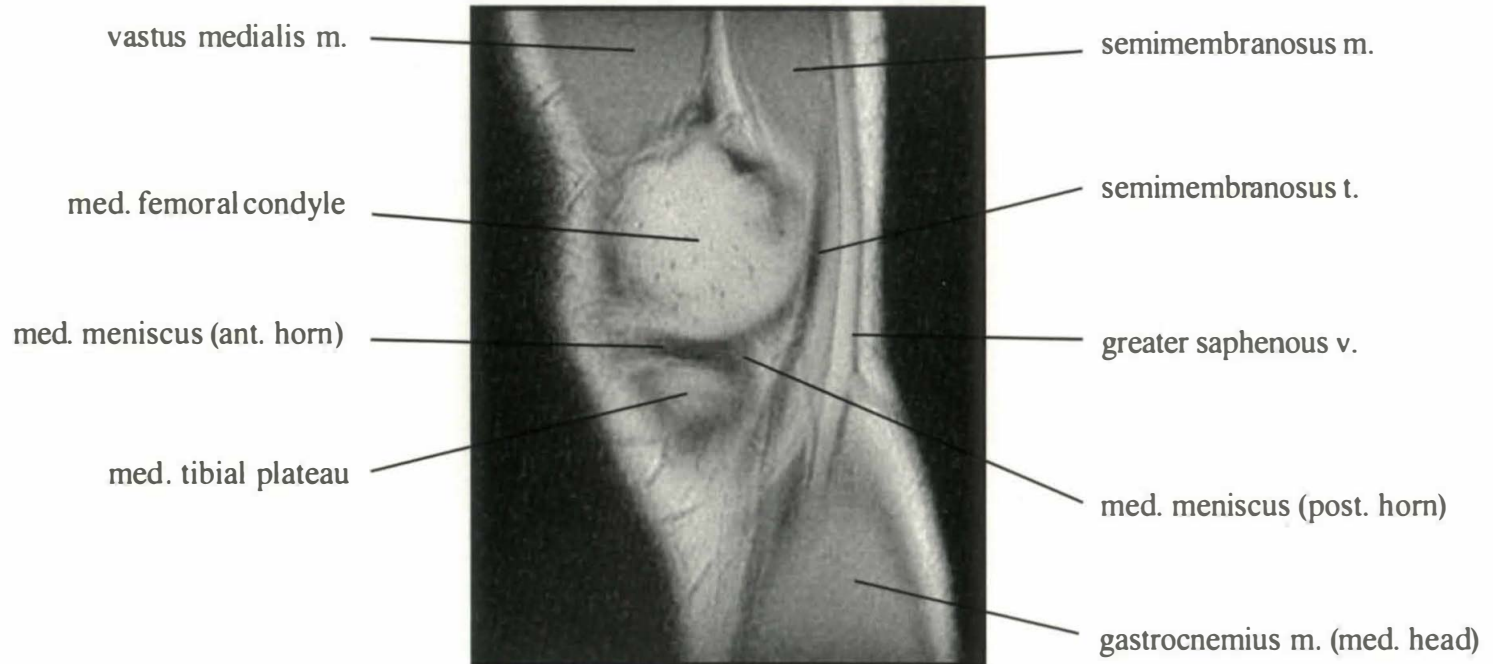
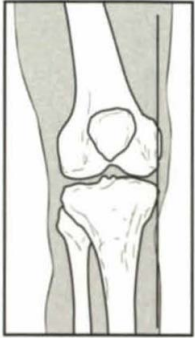


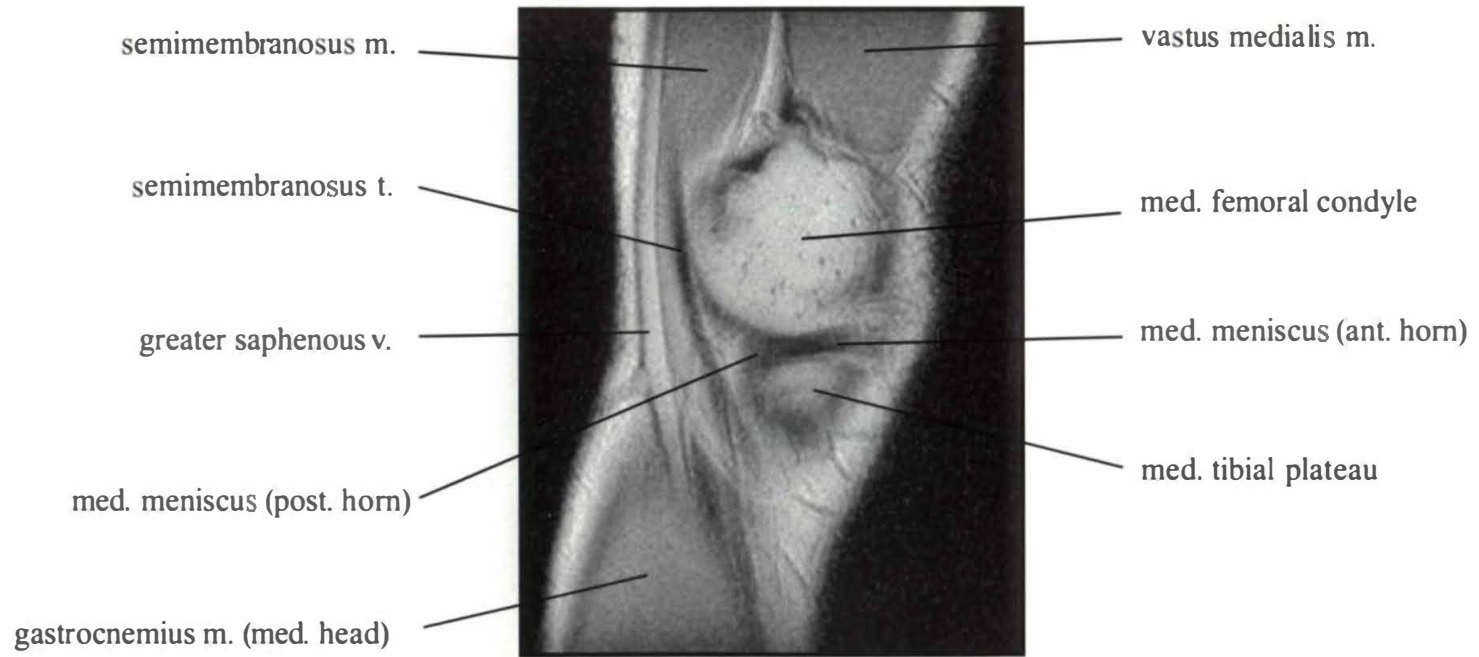
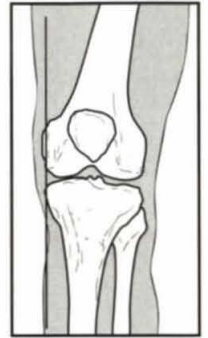


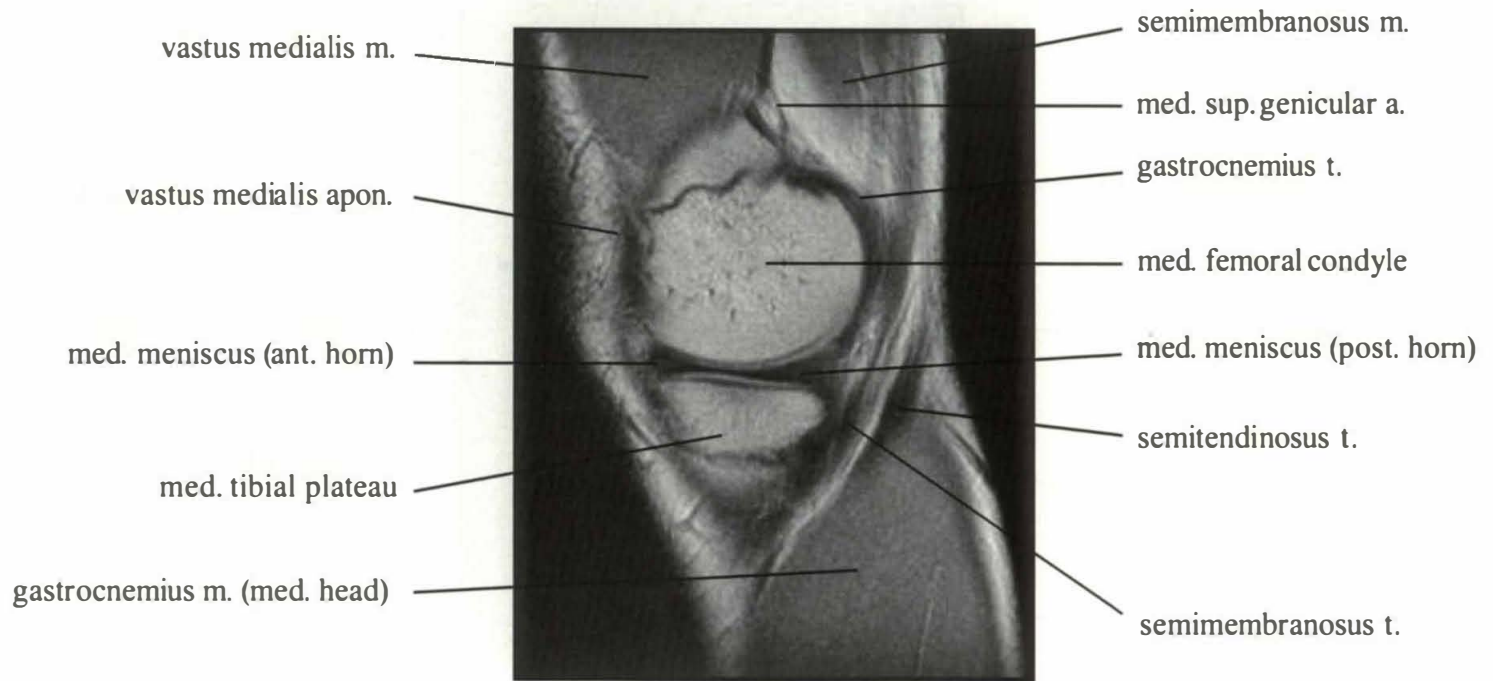


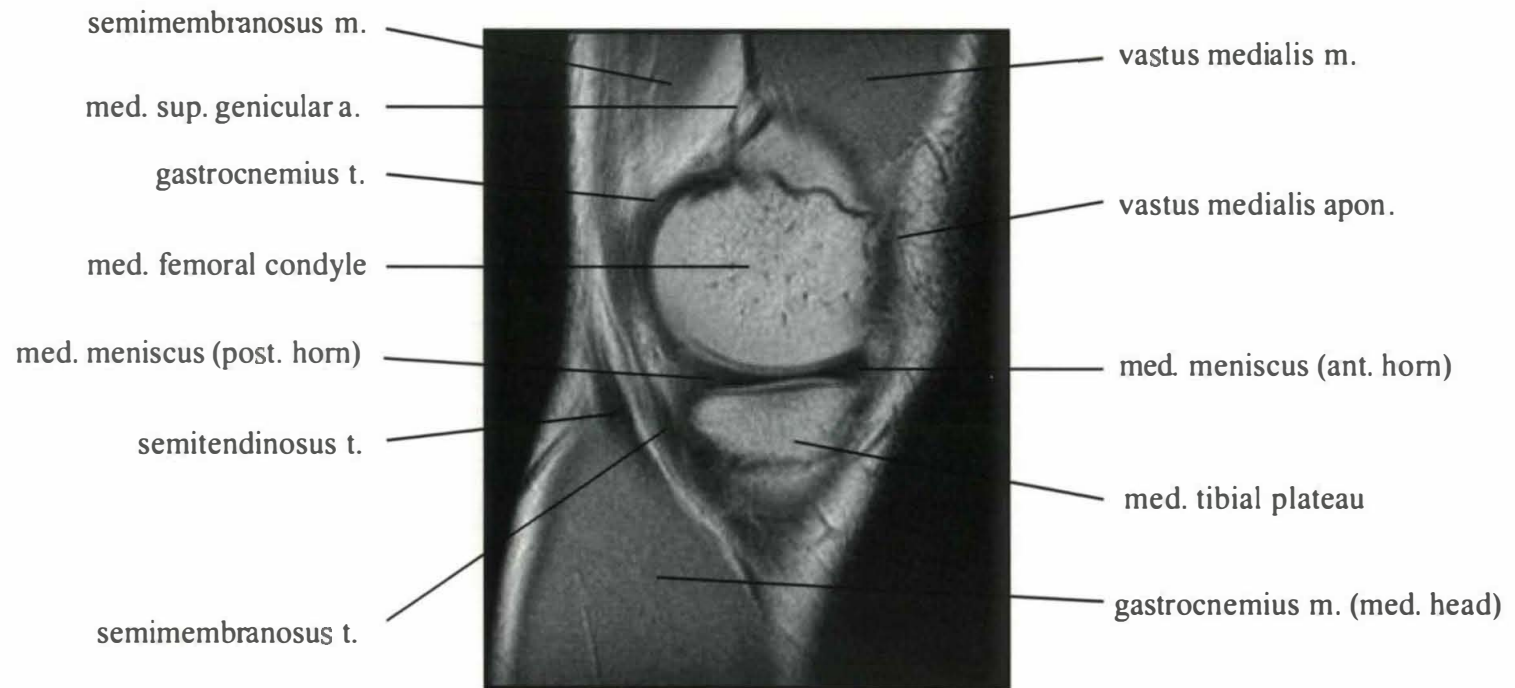


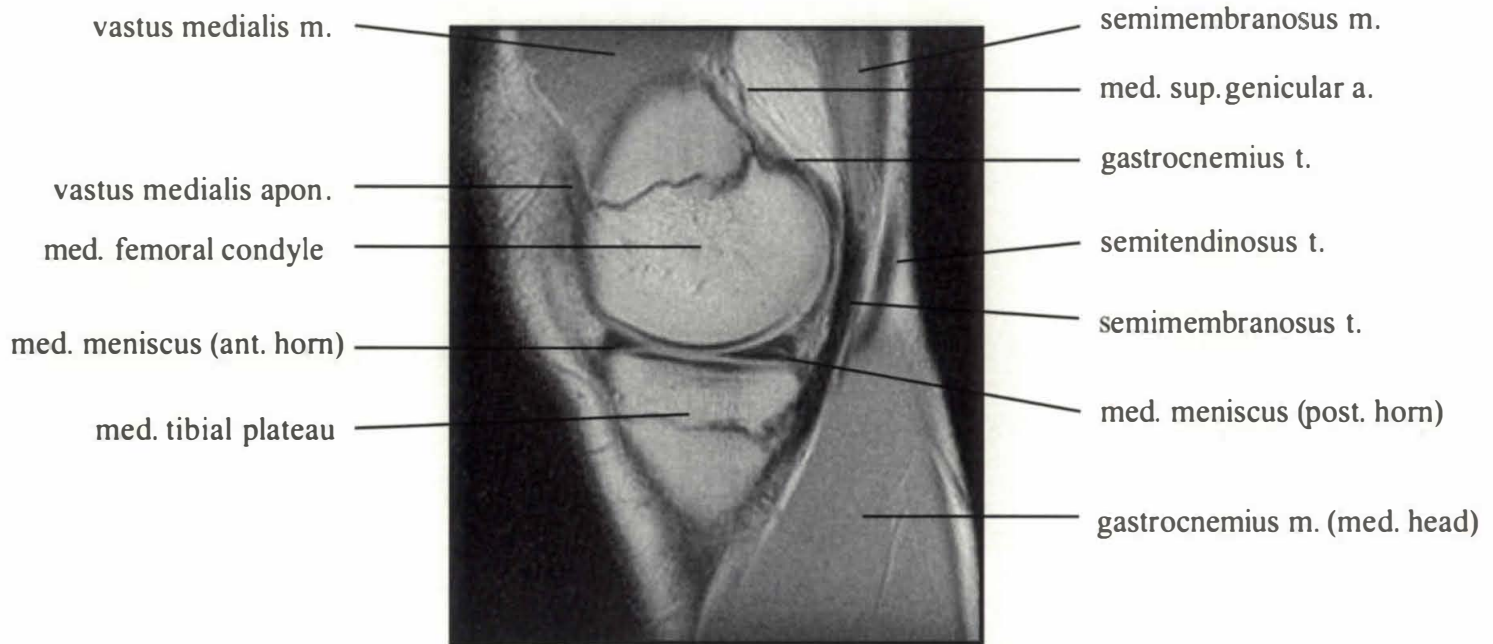
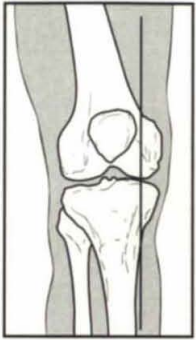
THE KNEE: SAGITTAL ANATOMY

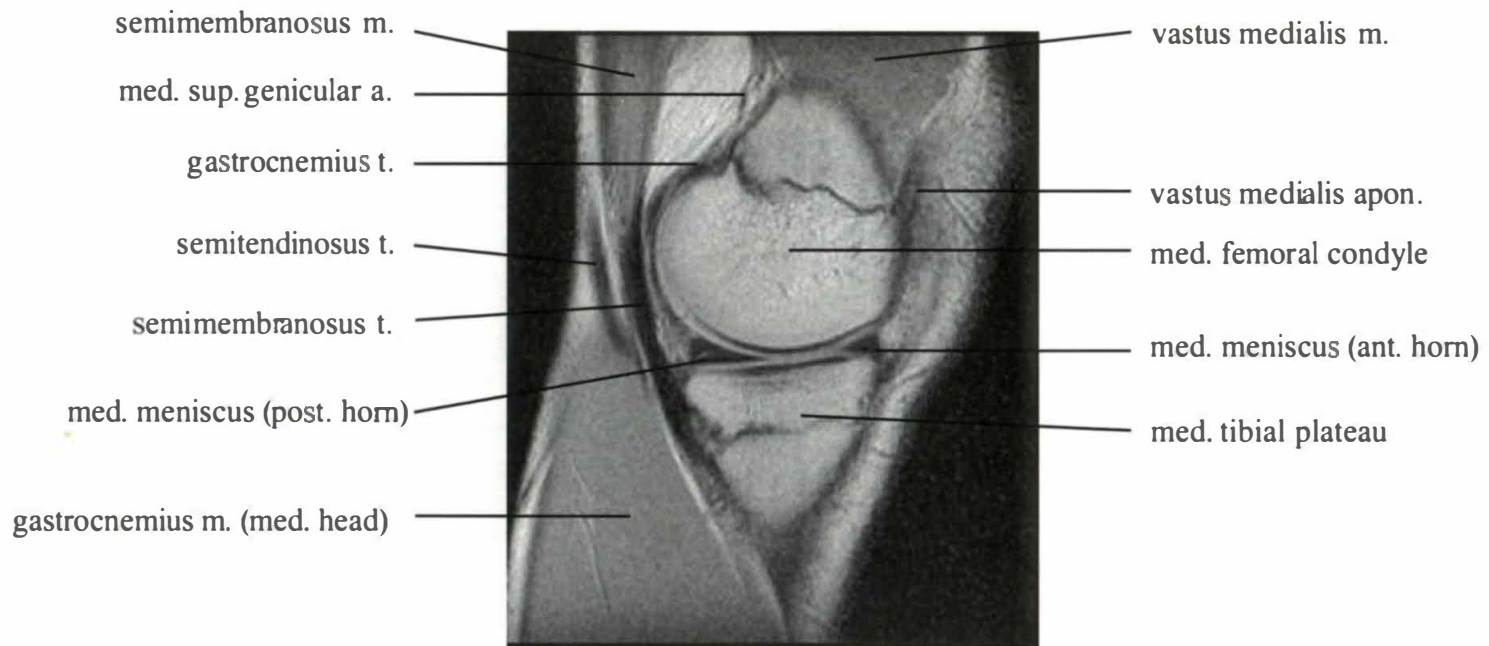
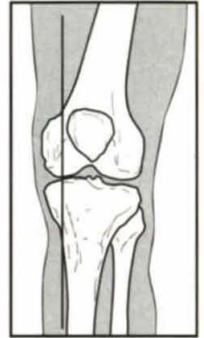


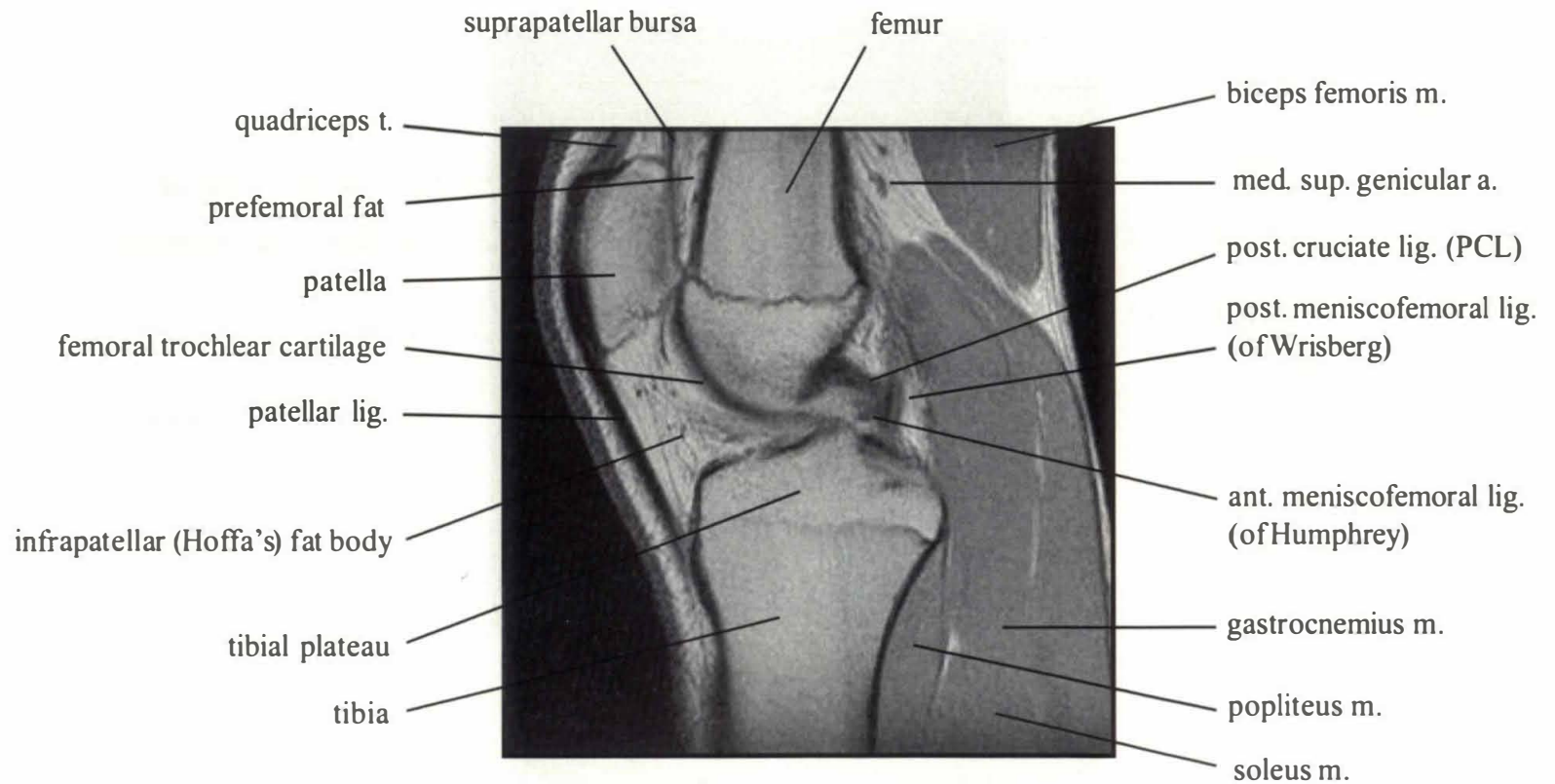
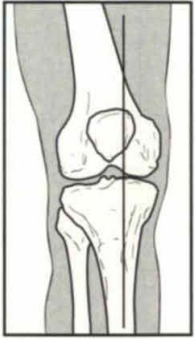


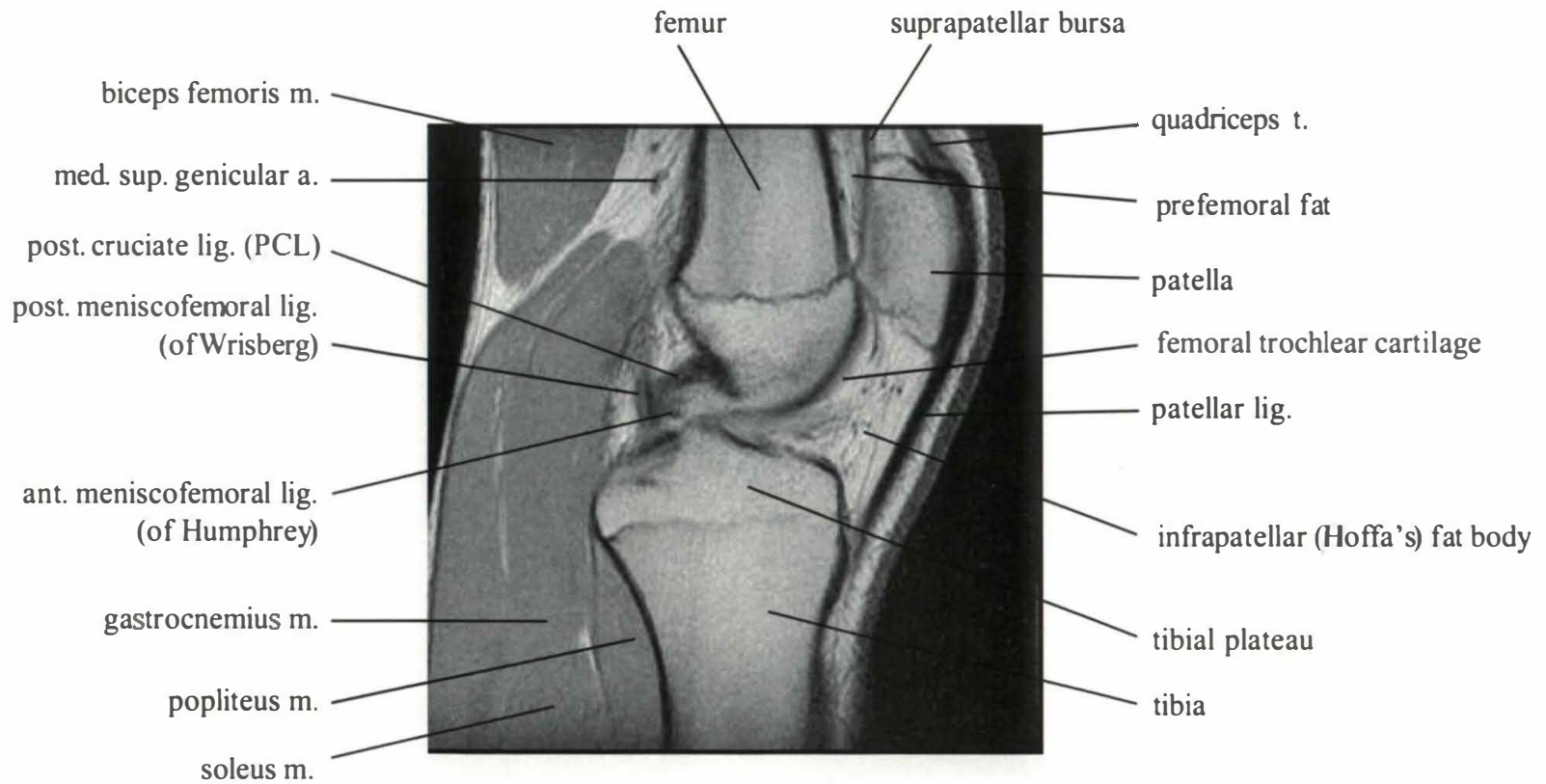


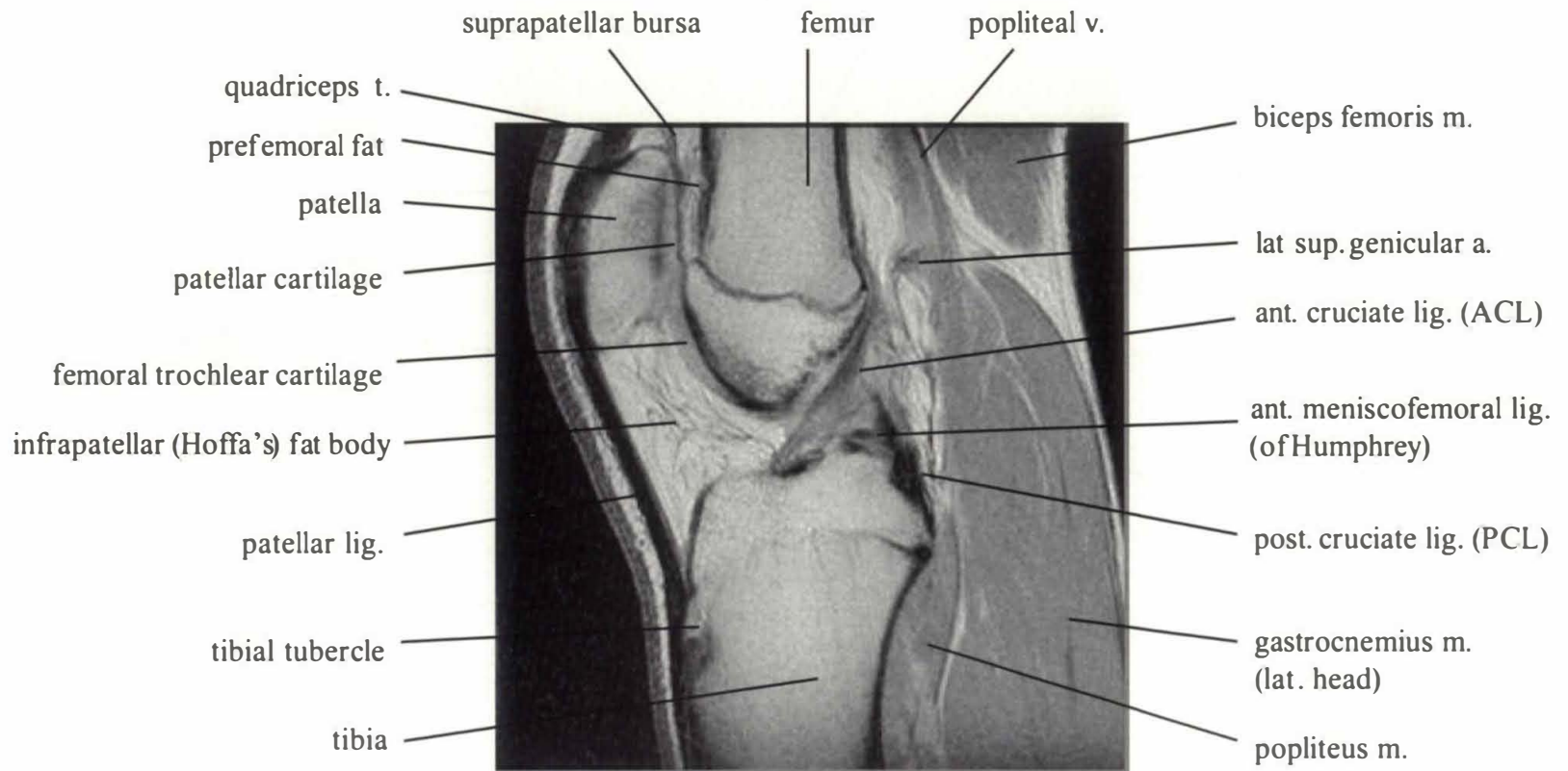
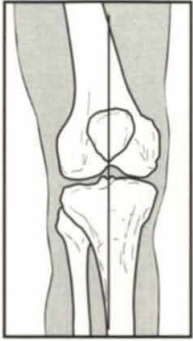


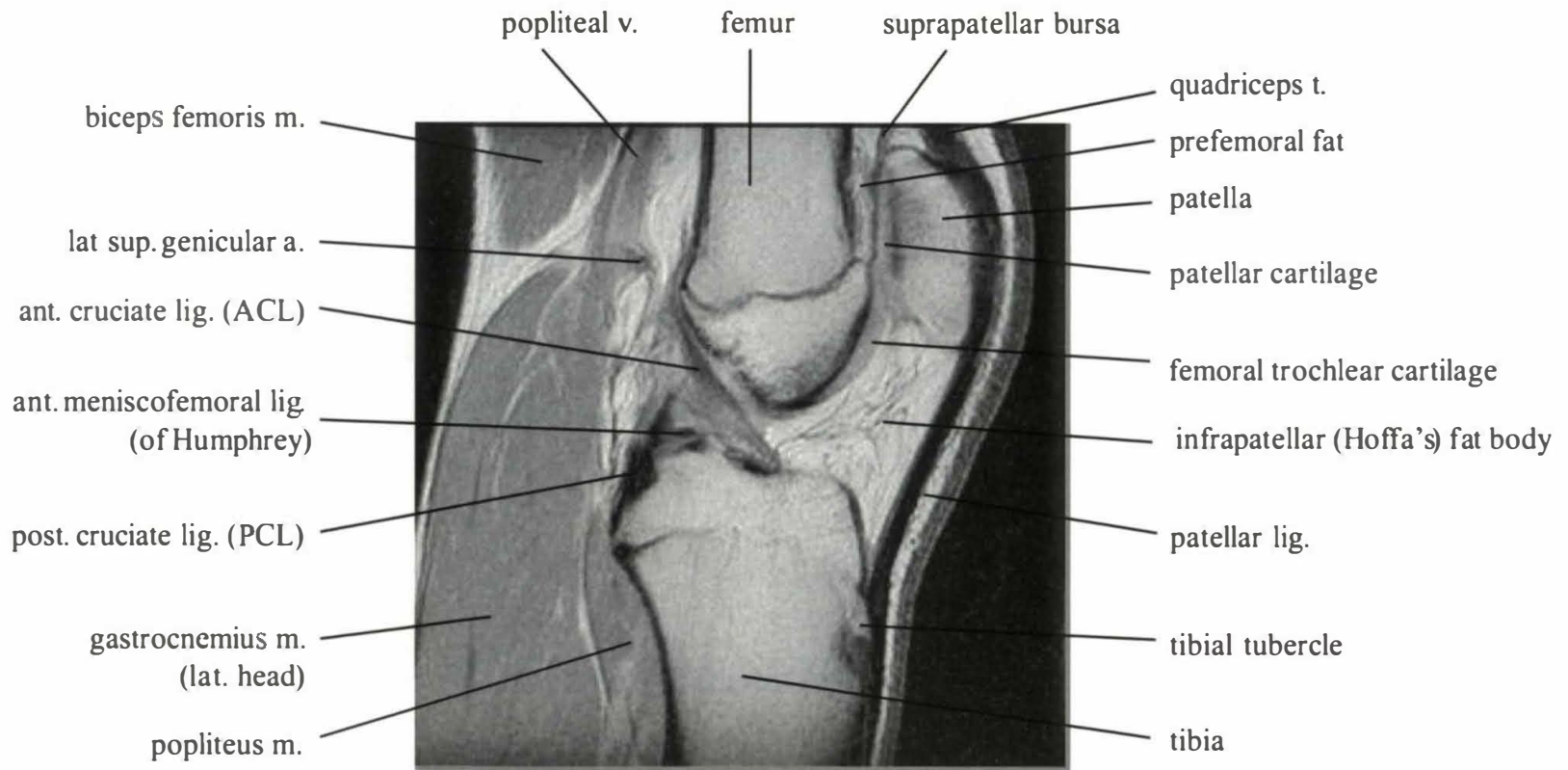
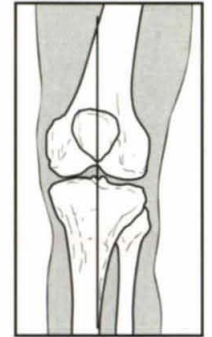


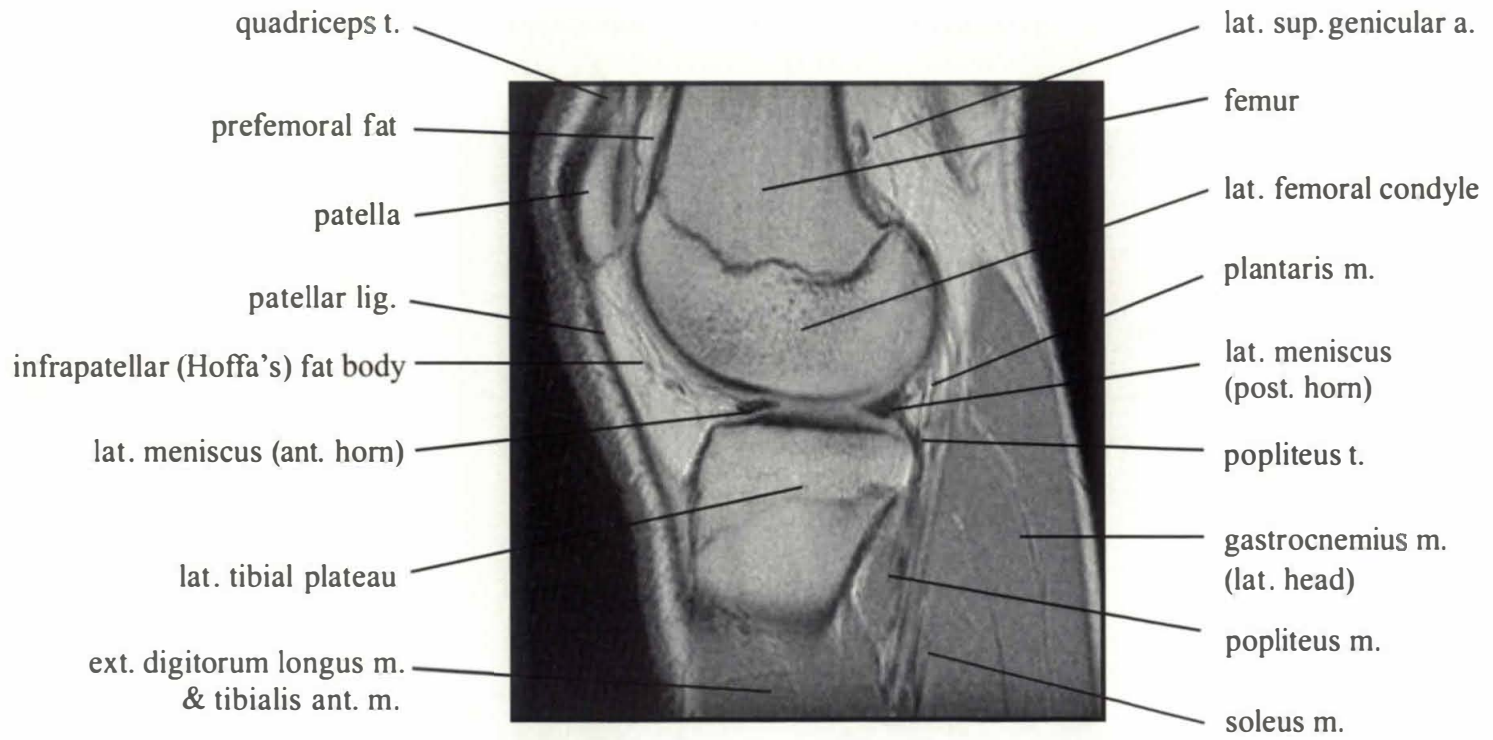
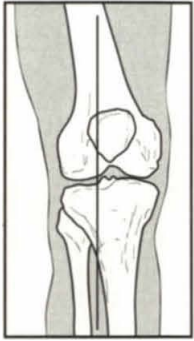


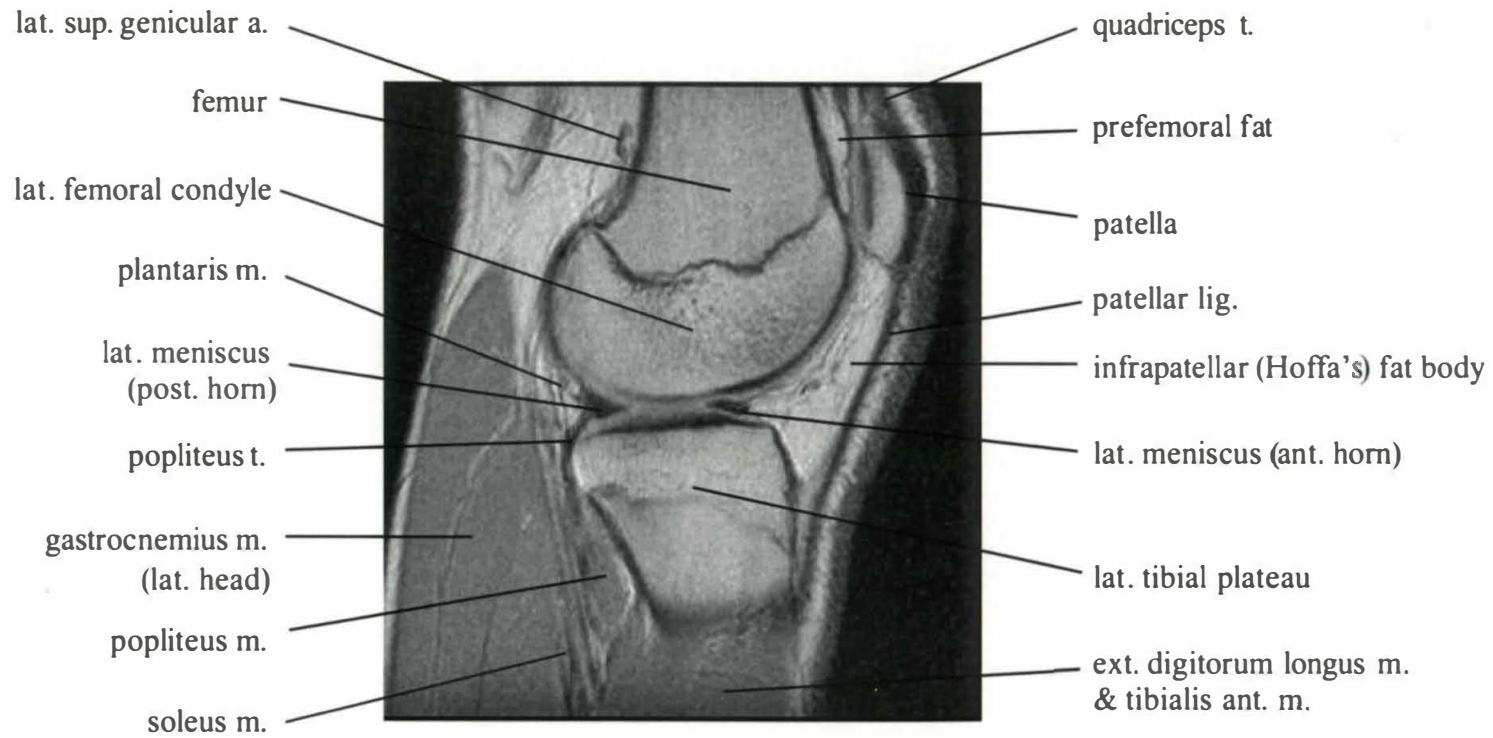
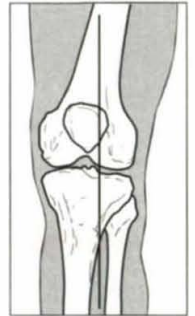


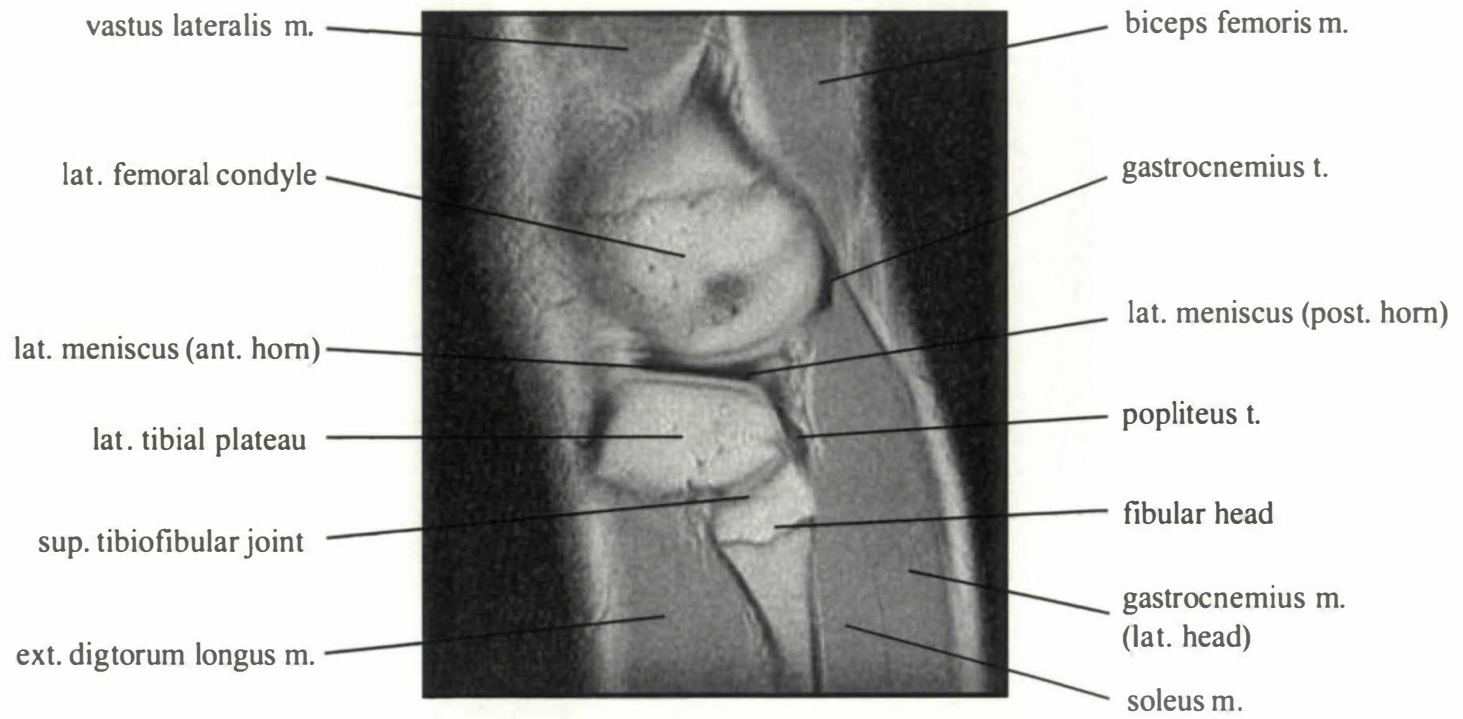
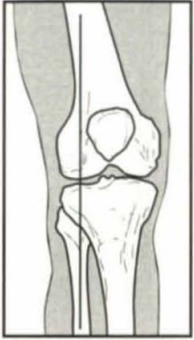


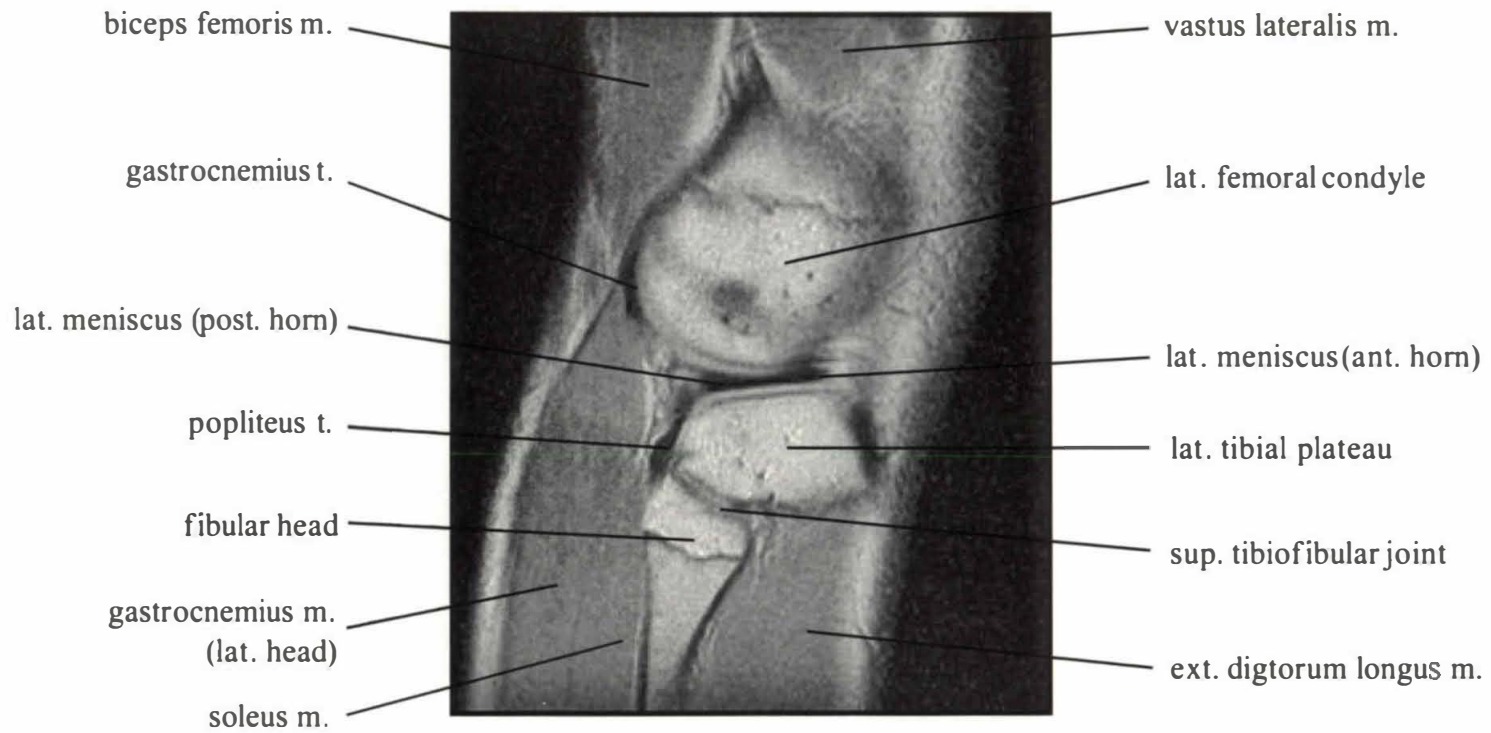
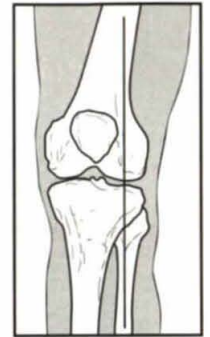












biceps femoris m.

gastrocnemius t.

lat. meniscus (post. horn)

popliteus t.

fibular head

gastrocnemius m.
(lat. head)

soleus m.

vastus lateralis m.

lat. femoral condyle

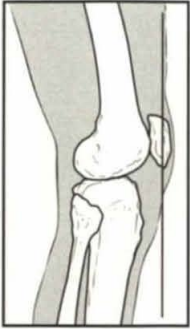
lat. meniscus (ant. horn)

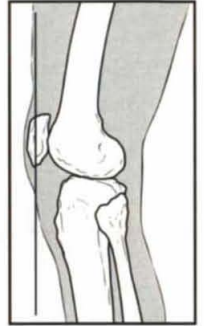
lat. tibial plateau

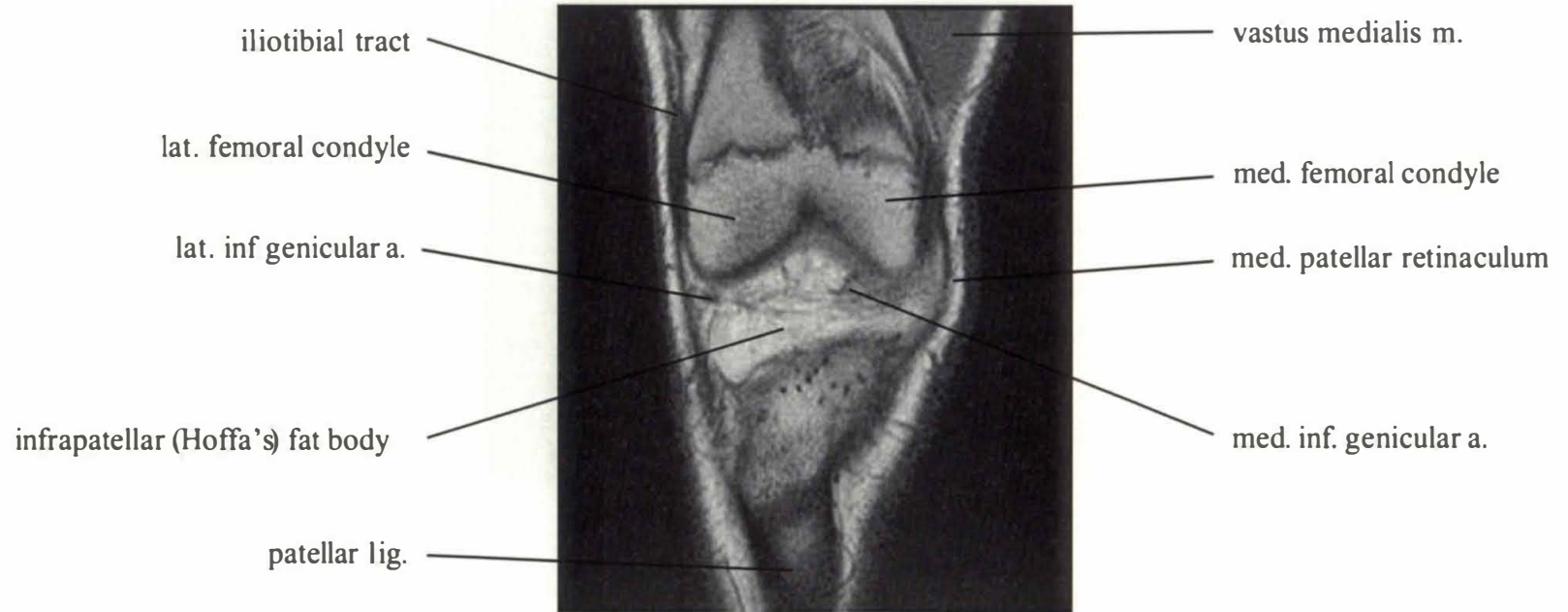
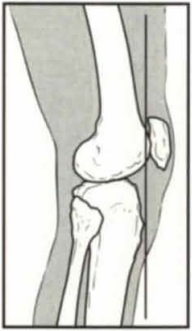
sup. tibiofibular joint

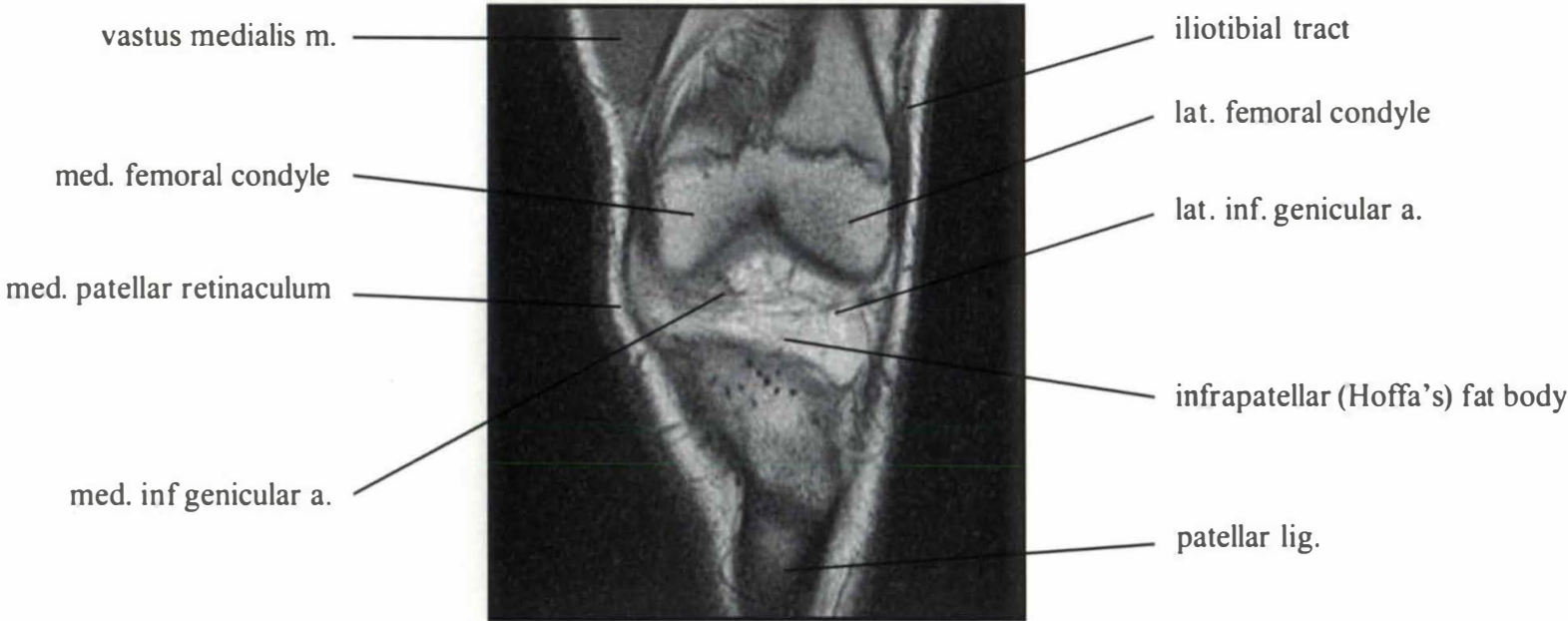
ext. digitorum longus m.

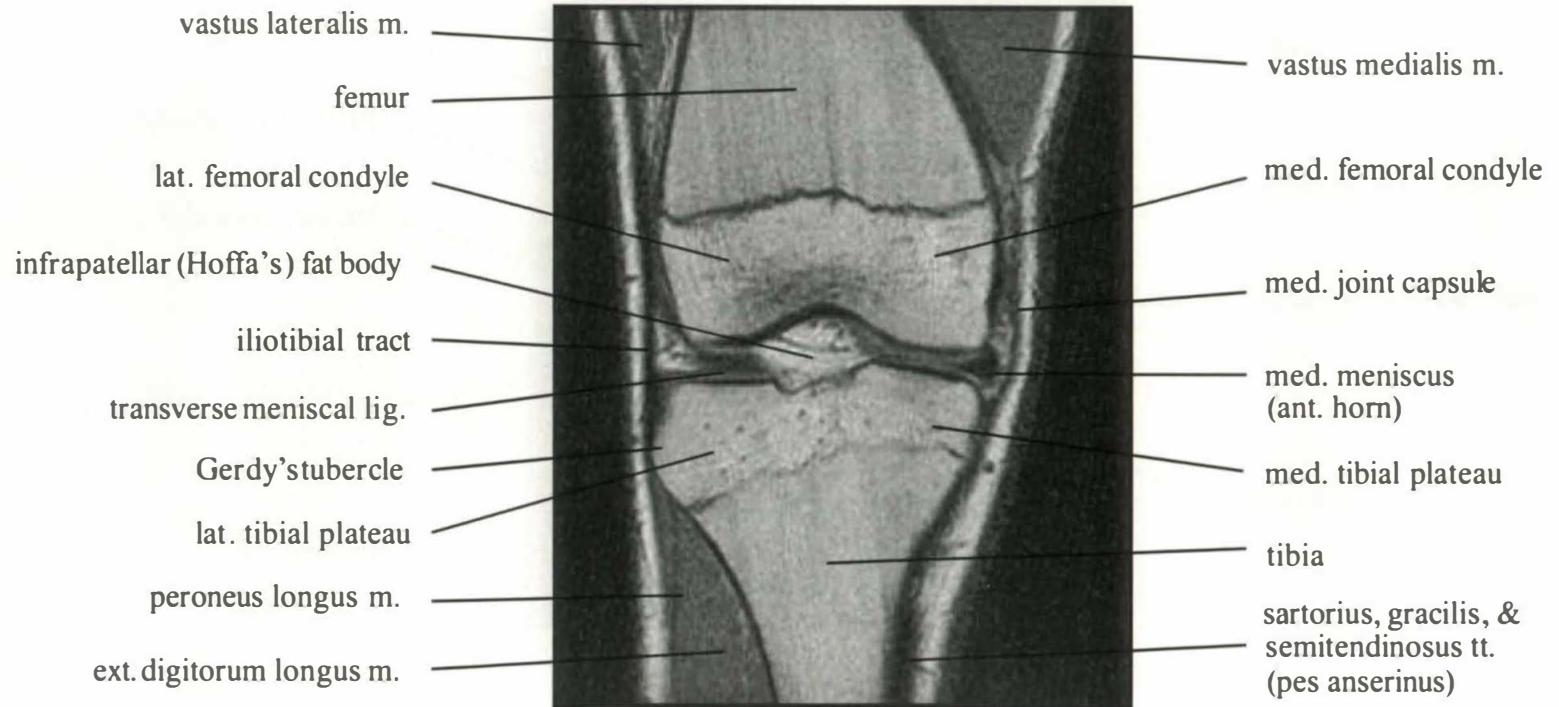
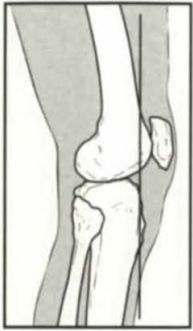
THE KNEE: CORONAL ANATOMY

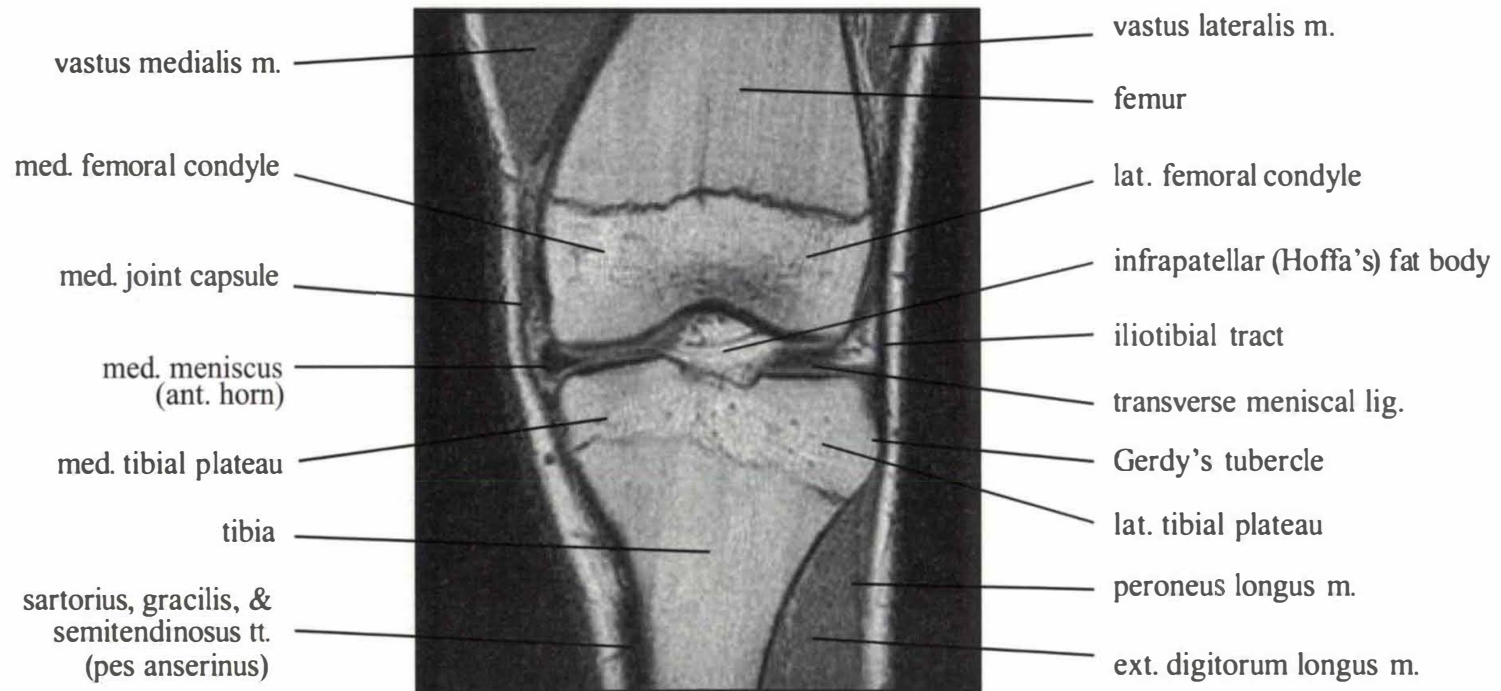
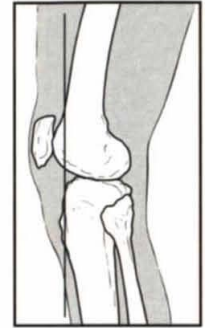


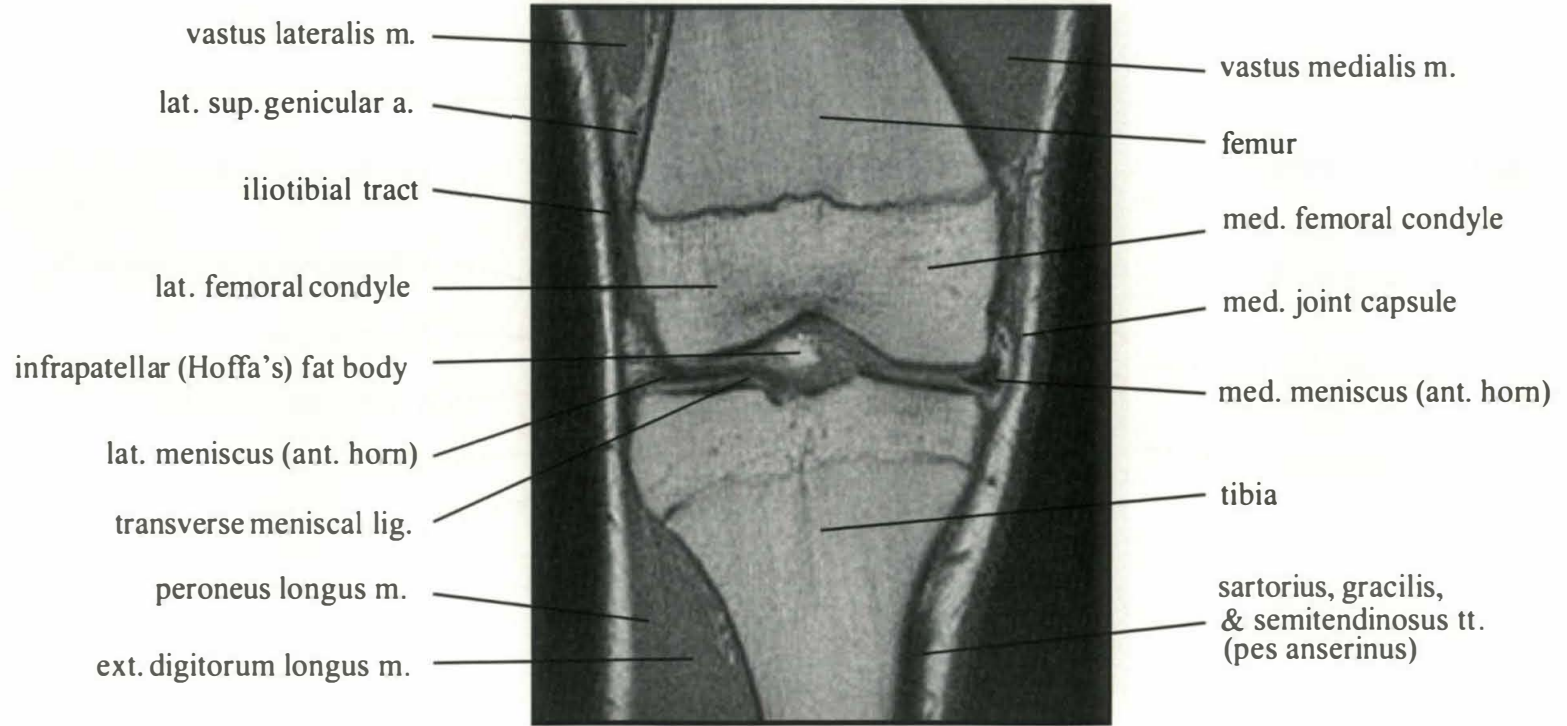
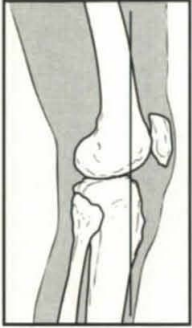


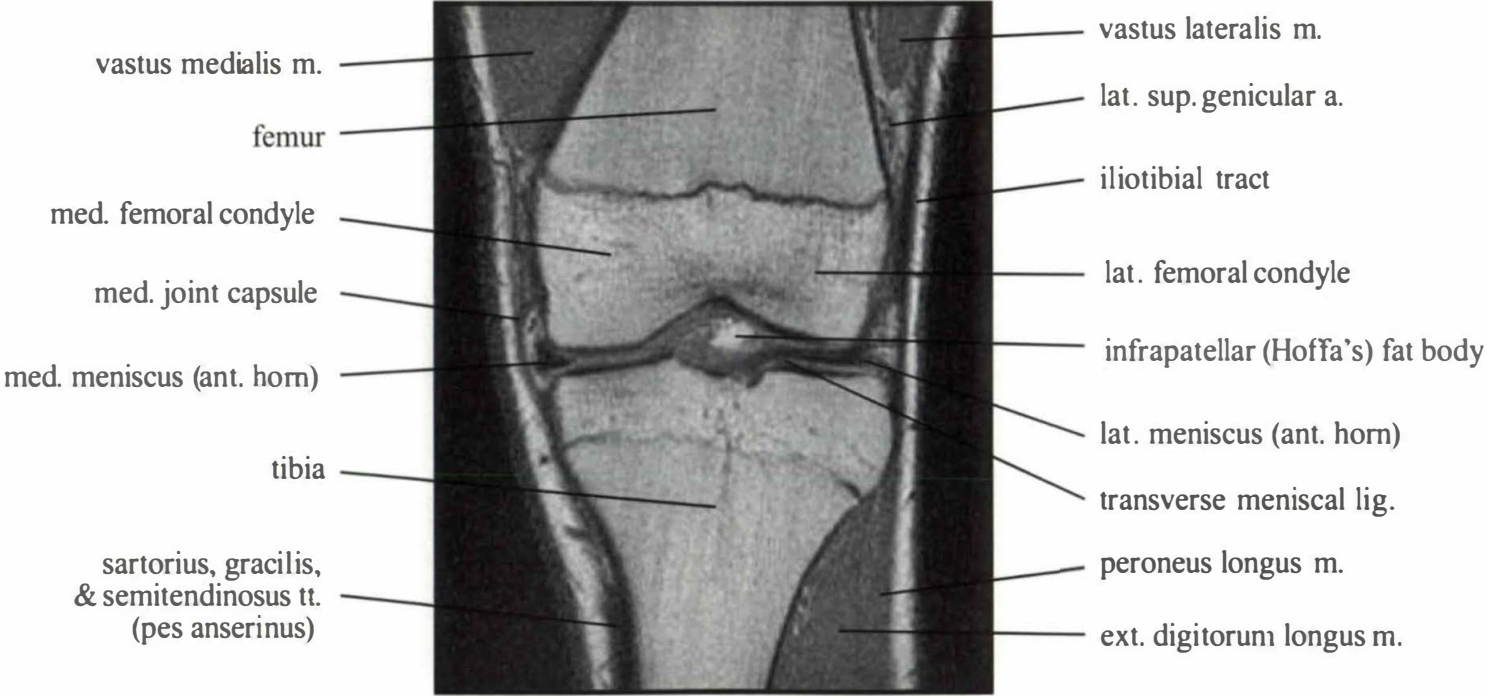
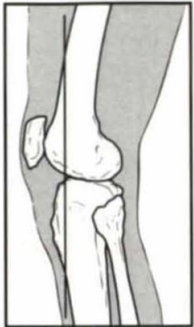


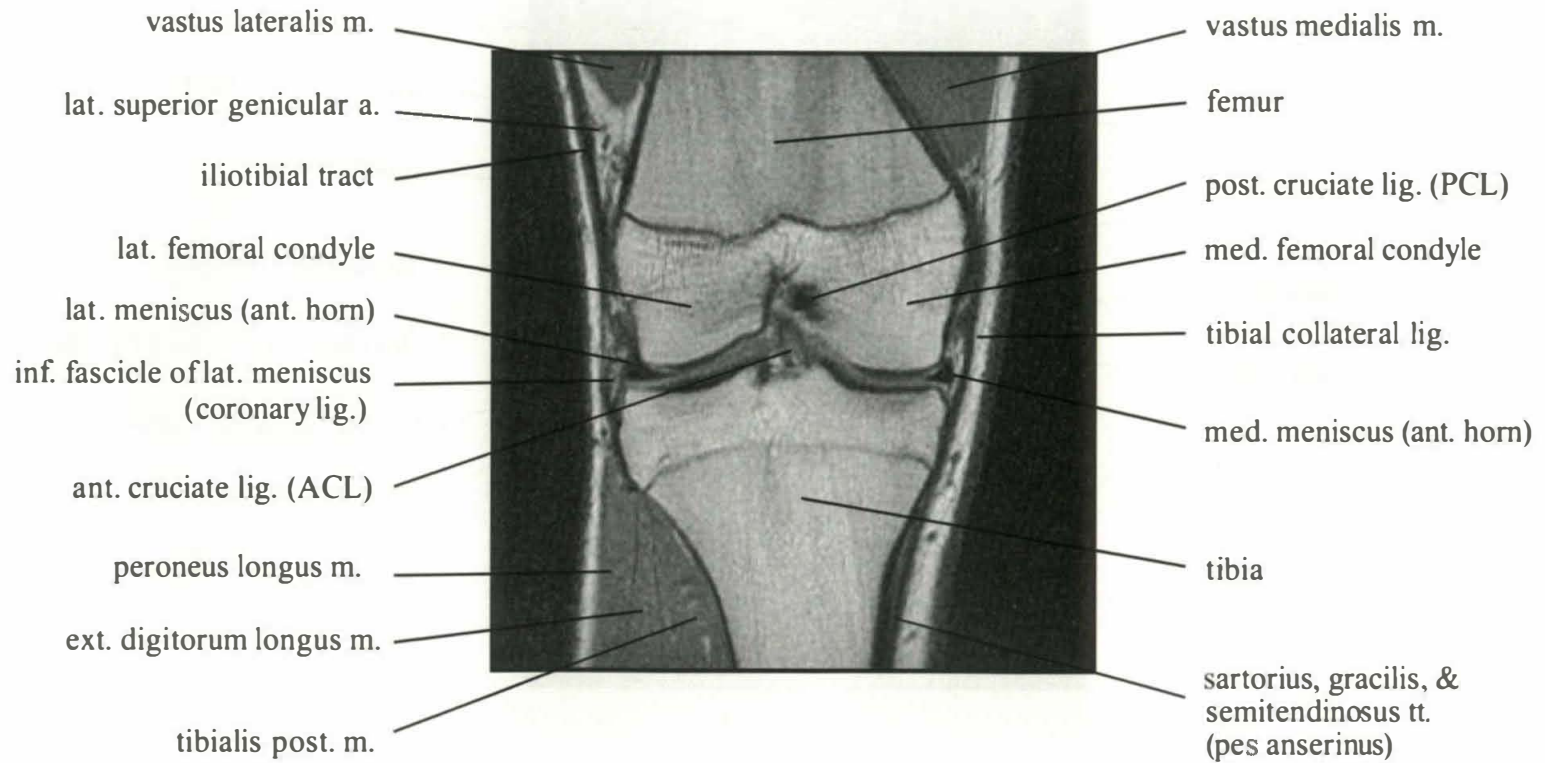


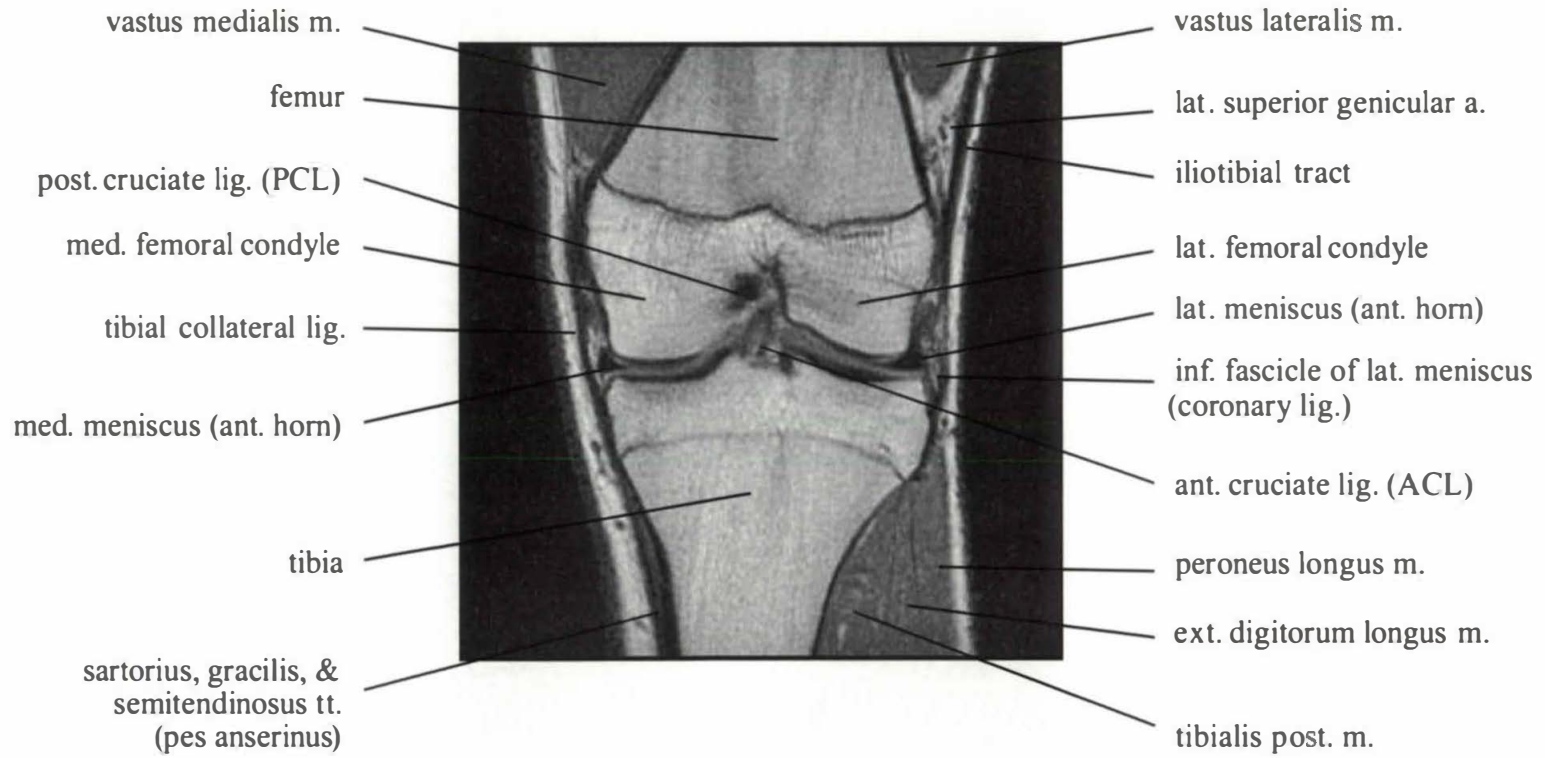
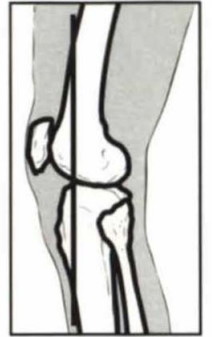


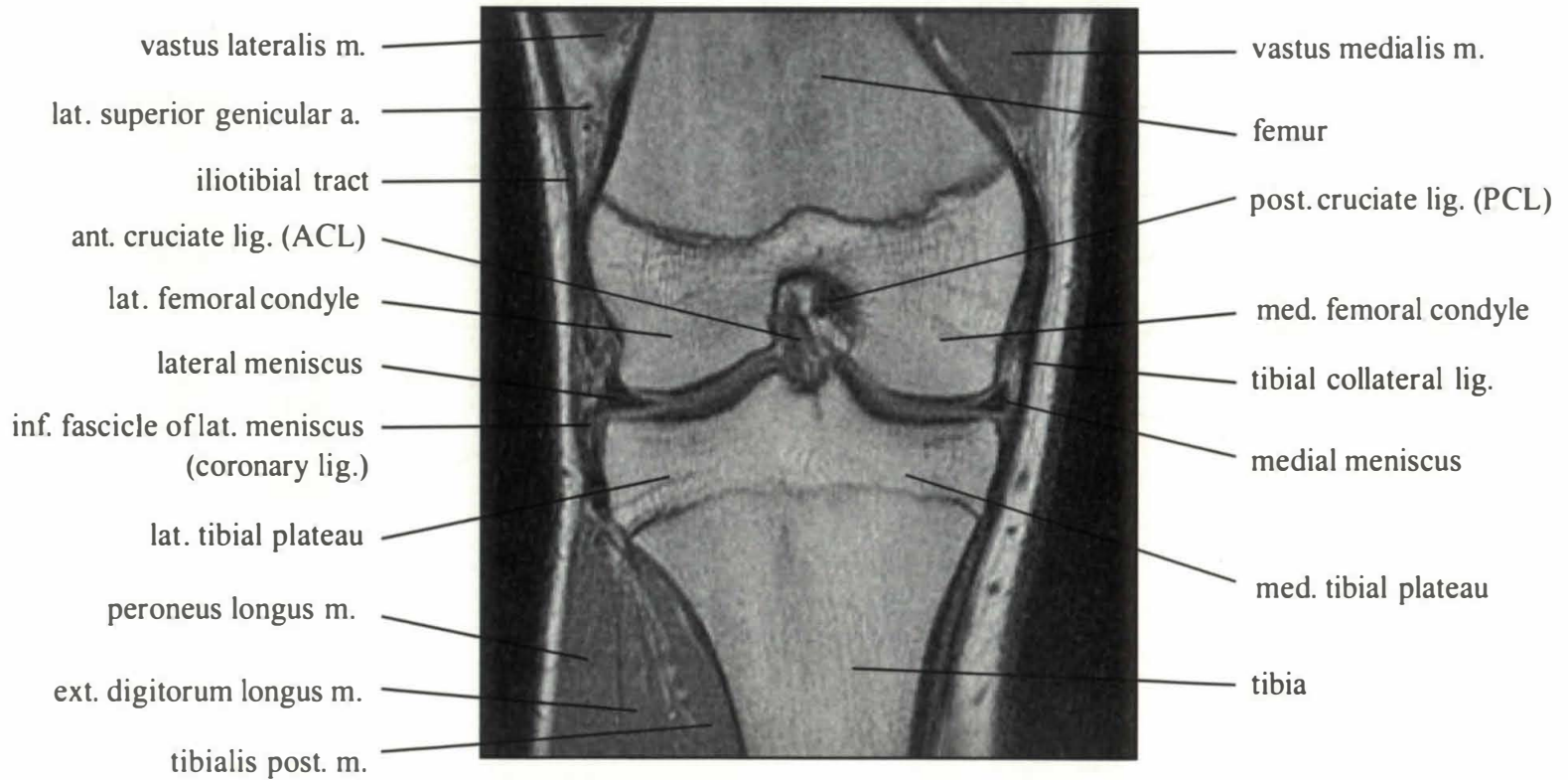
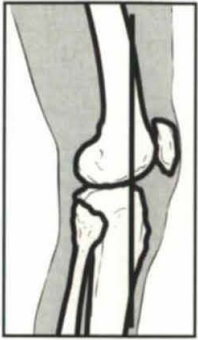


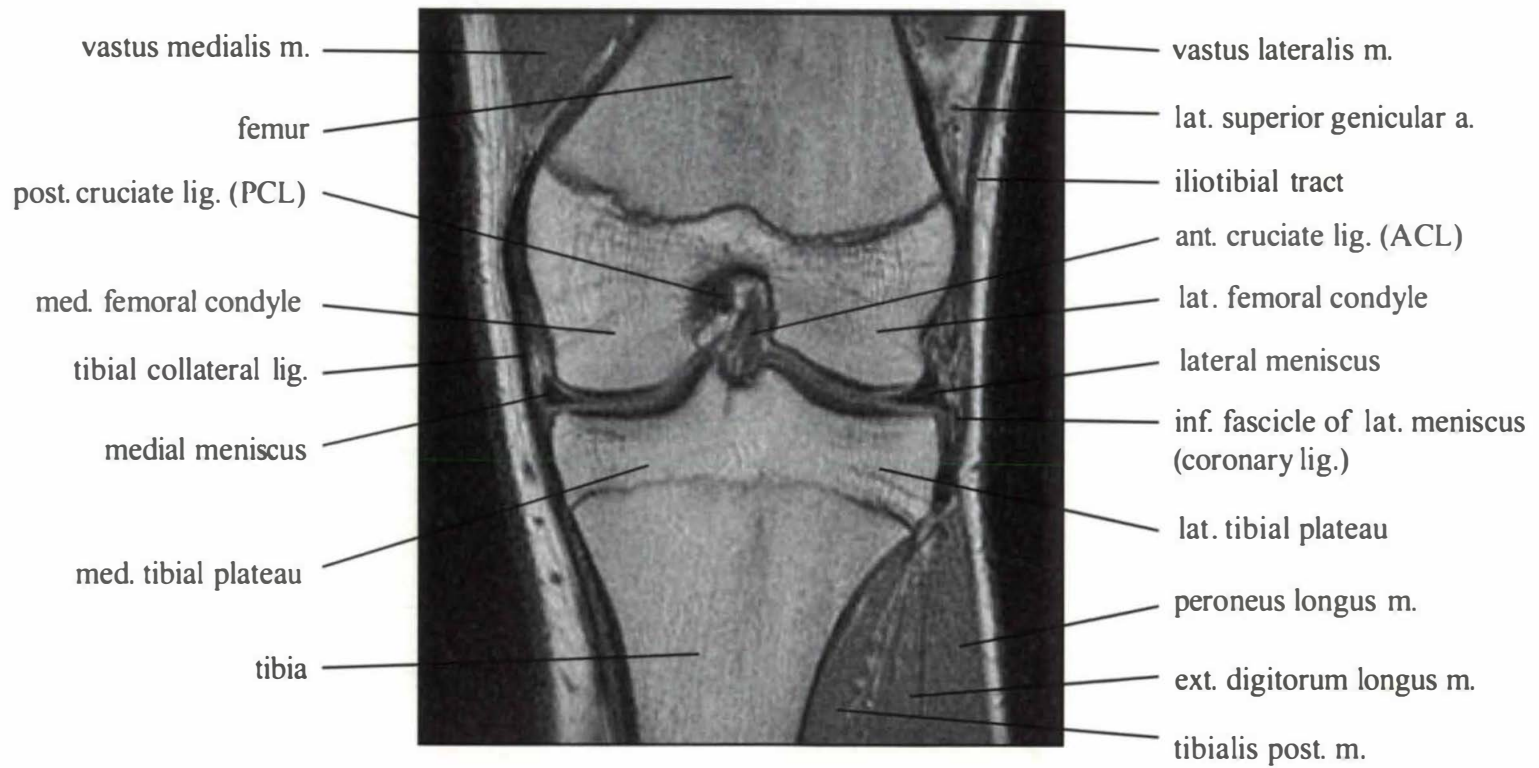
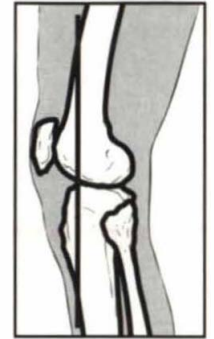


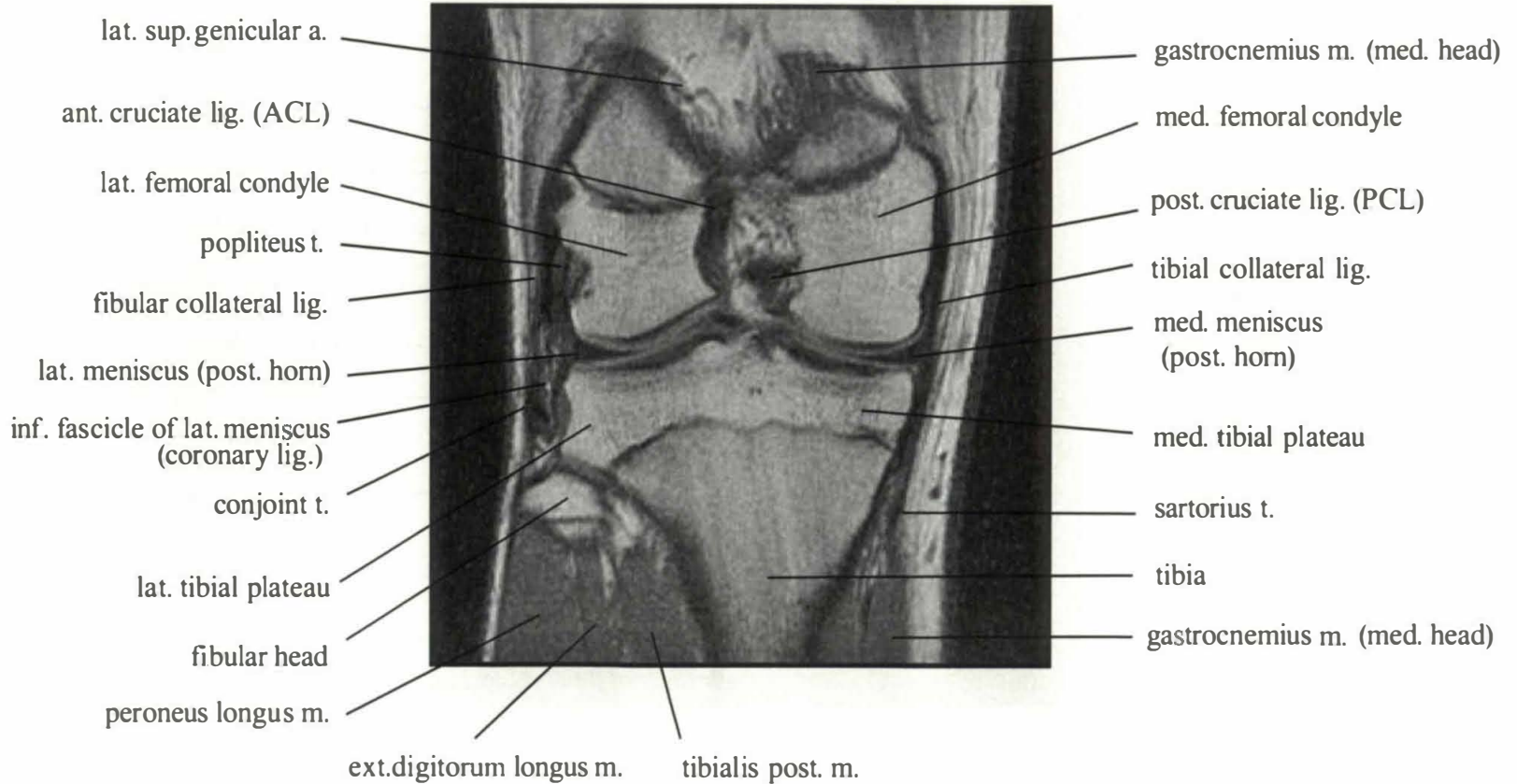
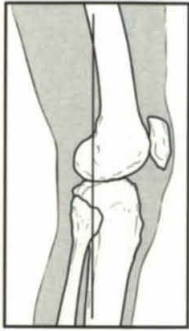


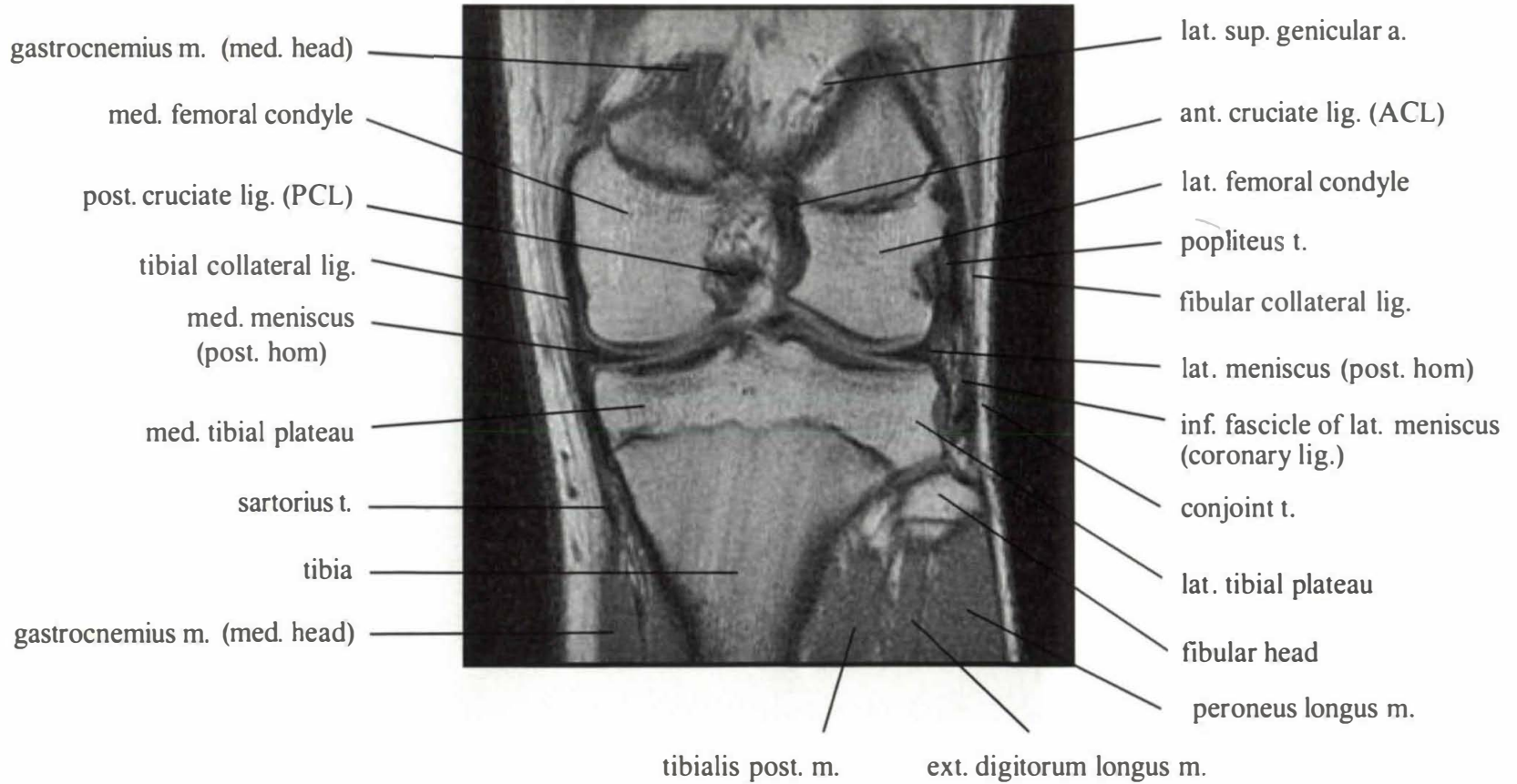
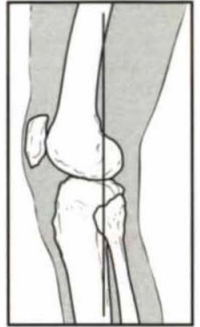


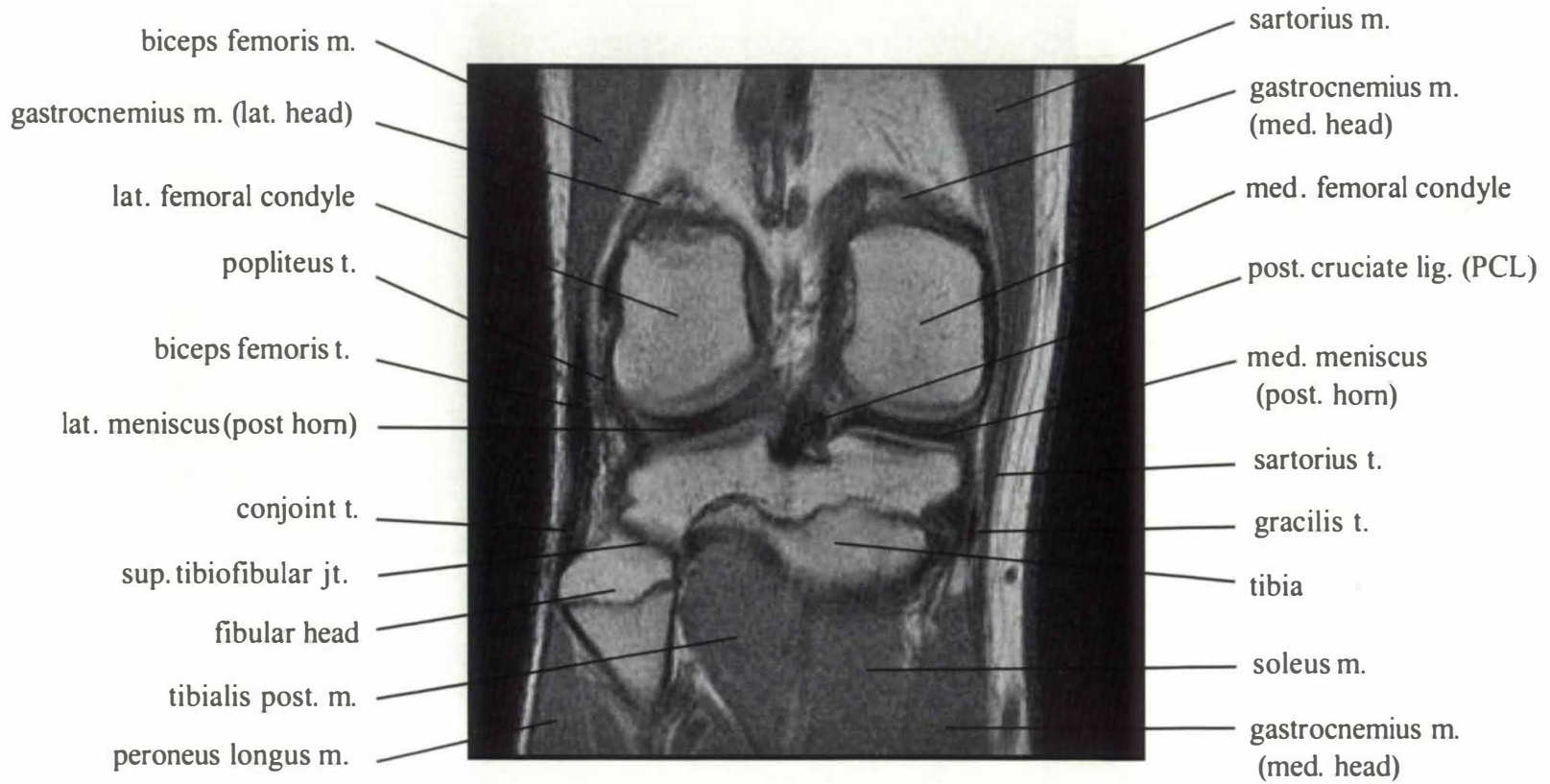


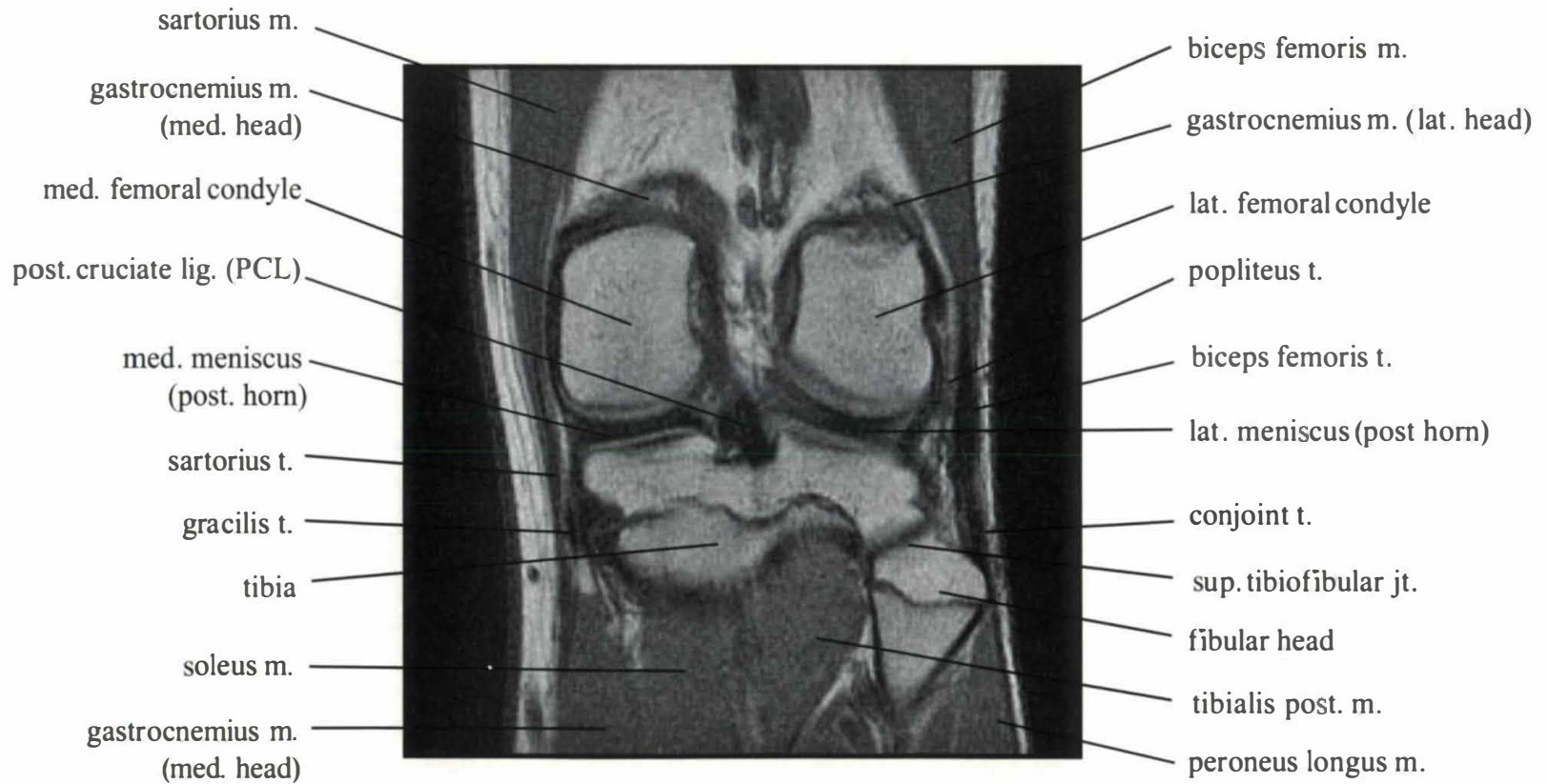
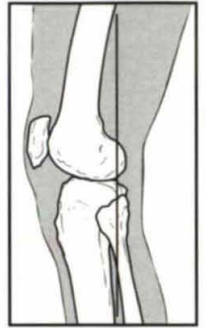


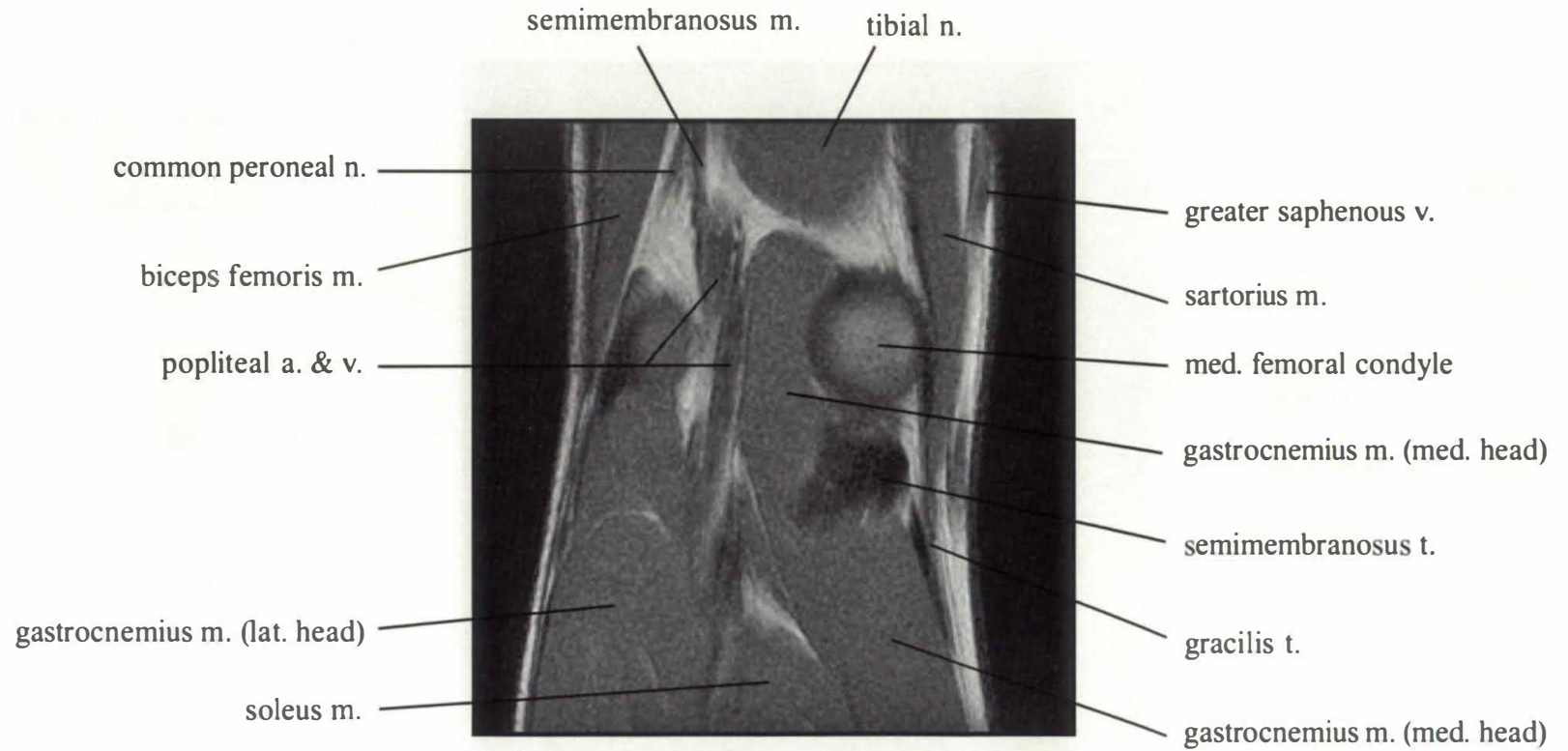
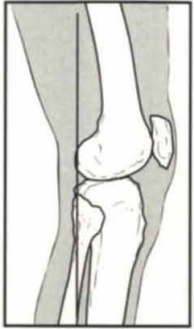


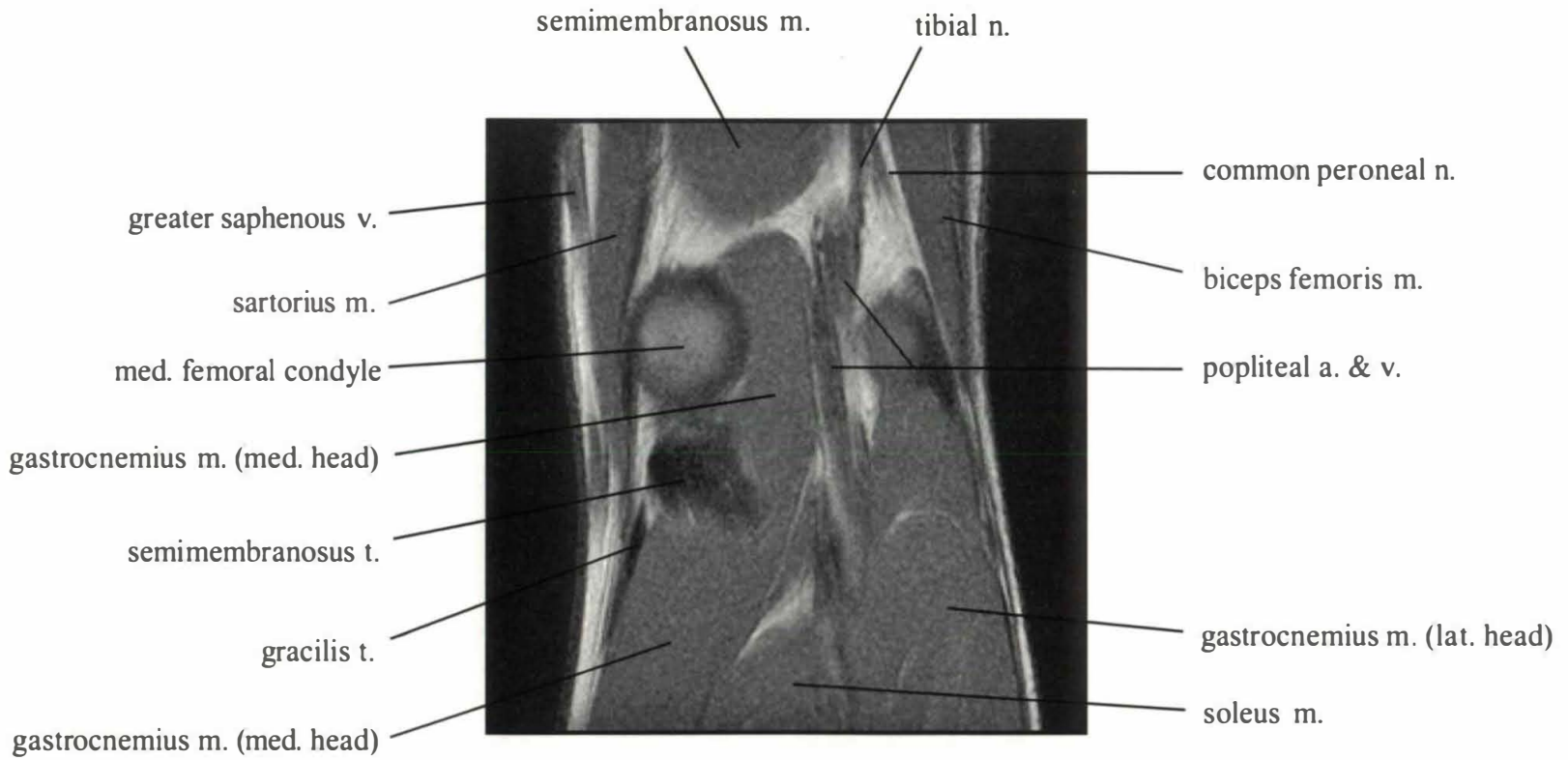
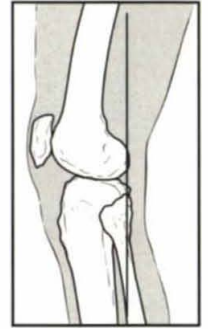




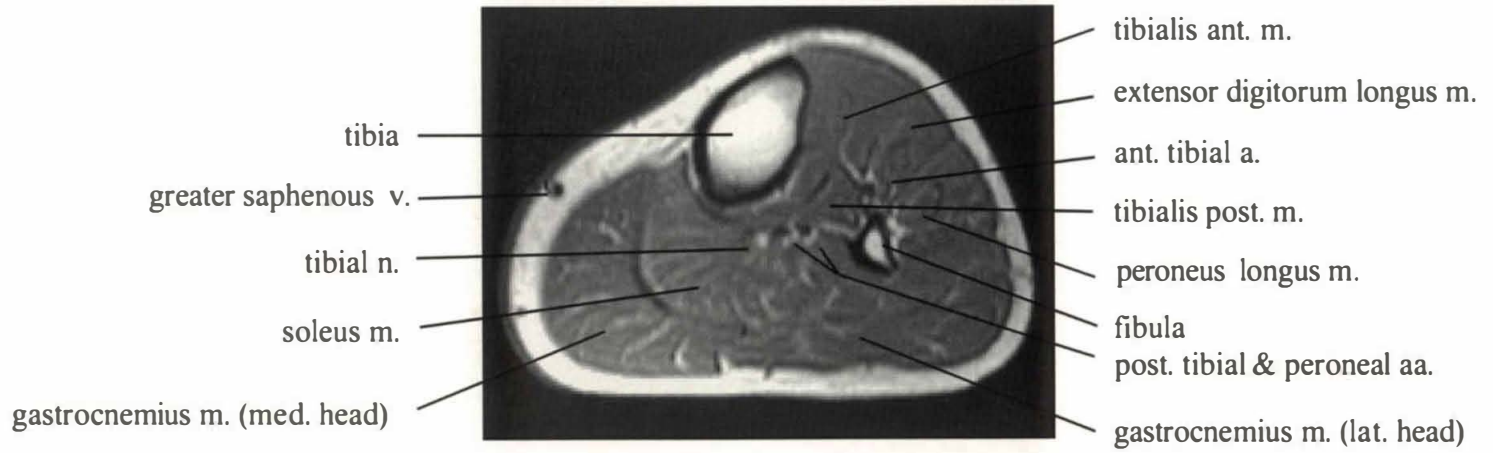


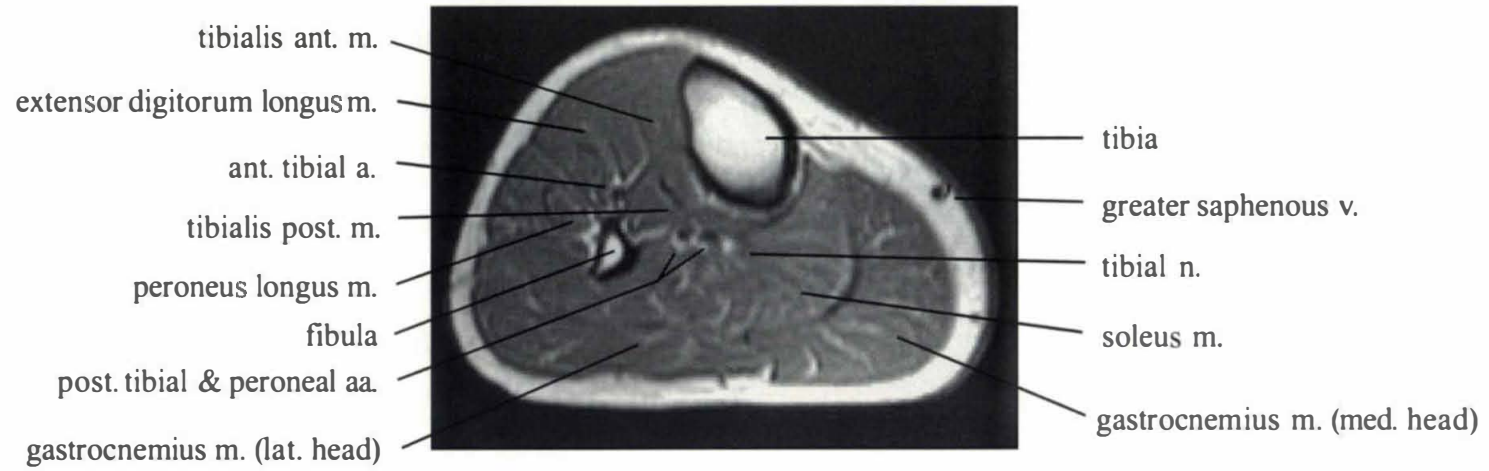


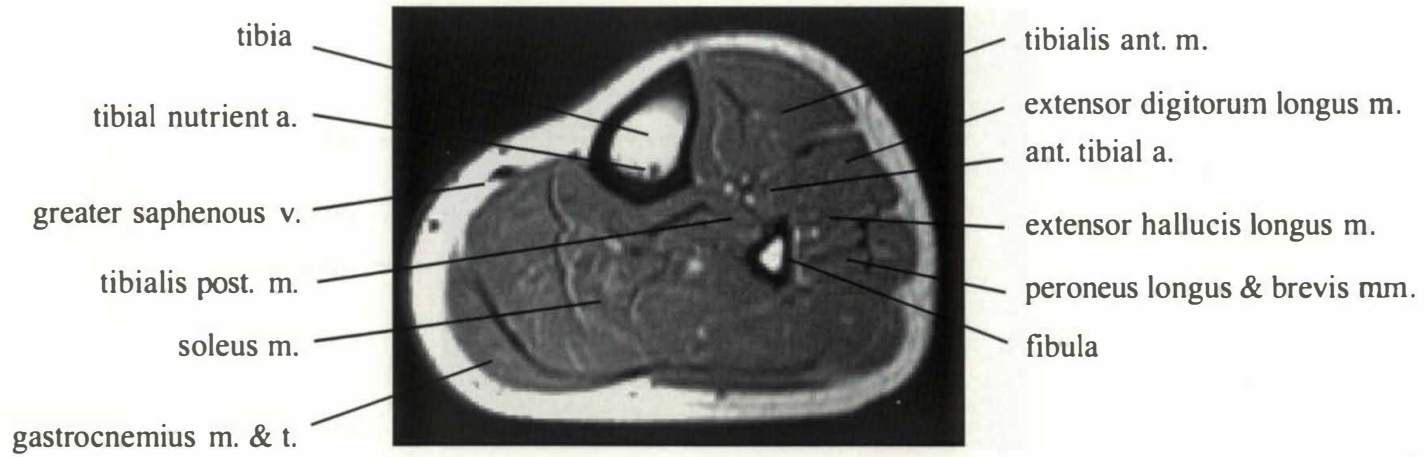
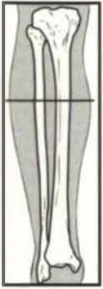


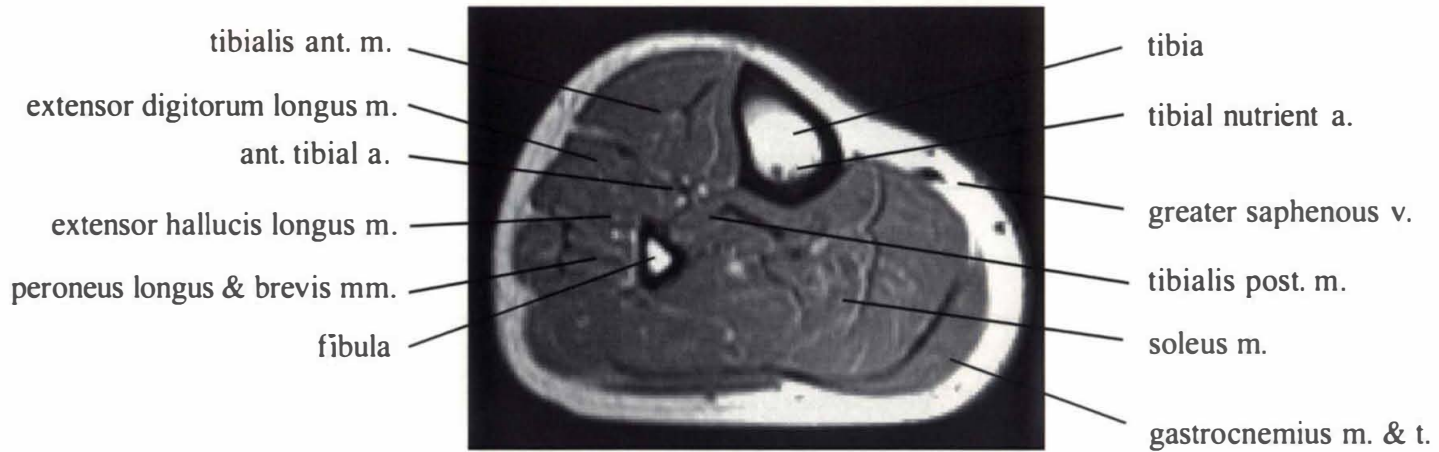
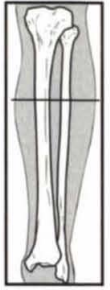


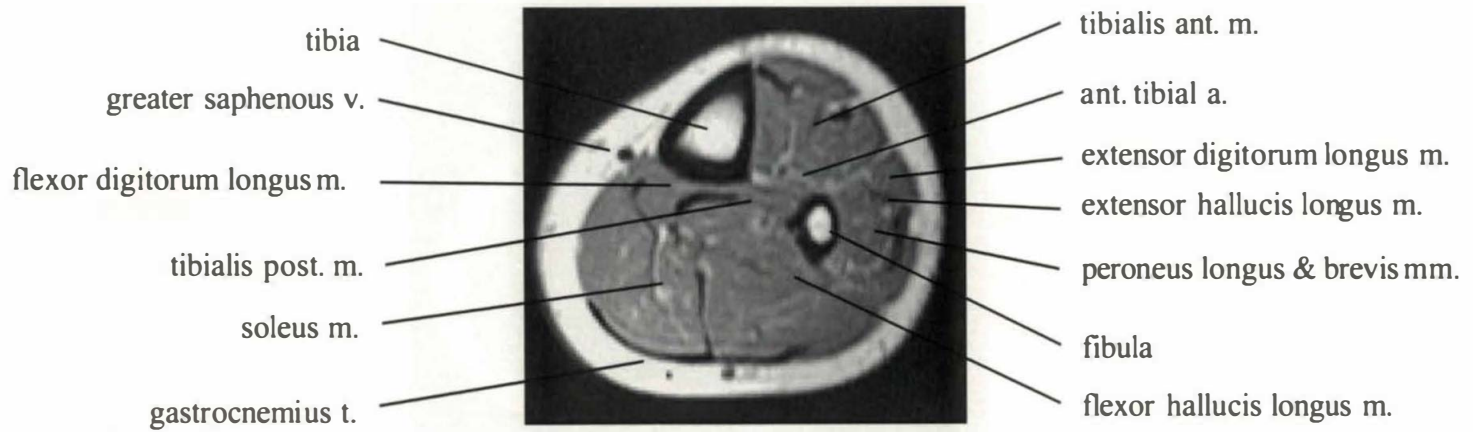
THE LOWER EXTREMITY: AXIAL ANATOMY











tibia

greater saphenous v.

flexor digitorum longus m.

tibialis post. m.

soleus m.

gastrocnemius t.

tibialis ant. m.

ant. tibial a.

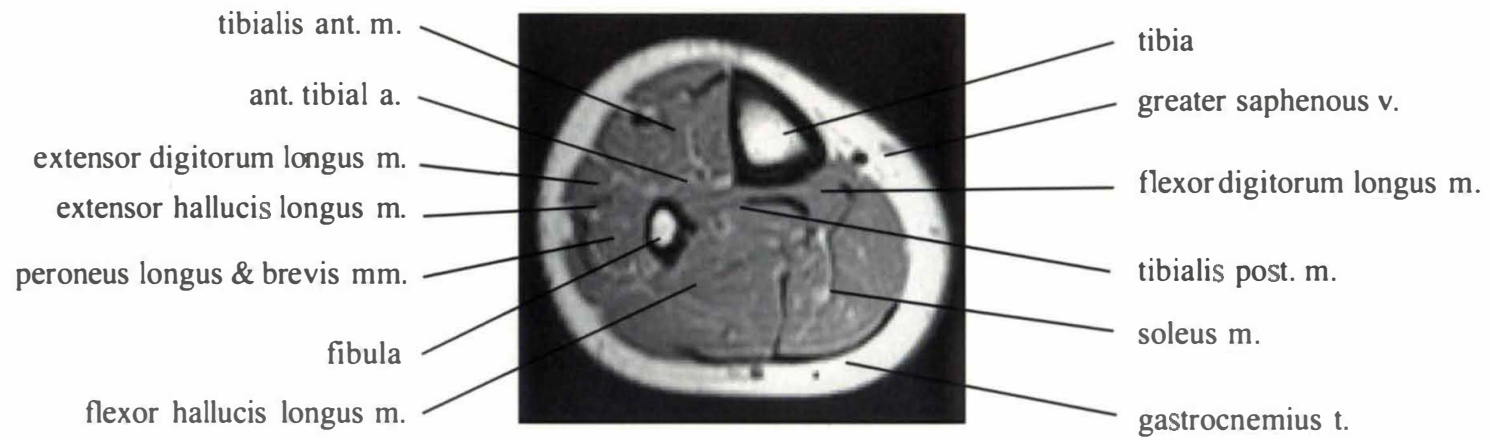
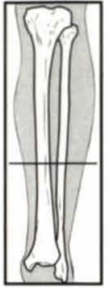
extensor digitorum longus m.

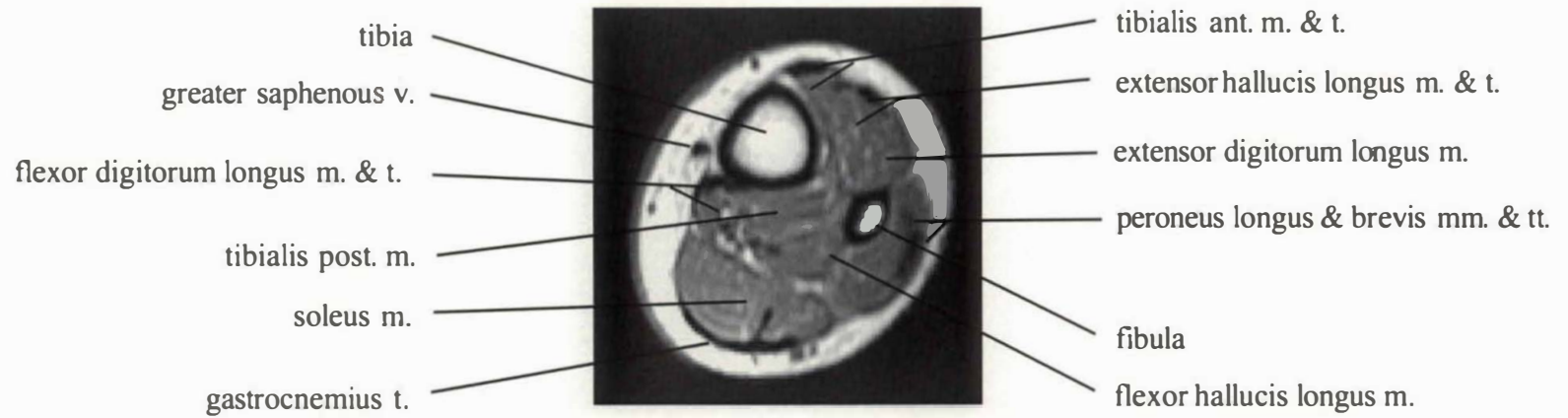
extensor hallucis longus m.

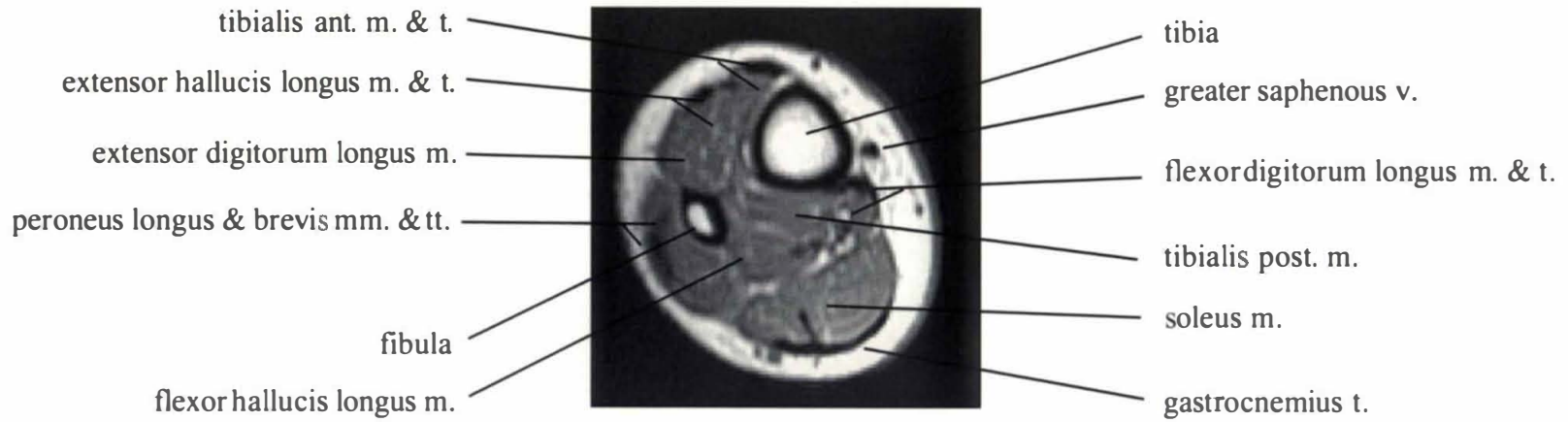
peroneus longus & brevis mm.

fibula

flexor hallucis longus m.







tibialis ant. m. & t.

extensor hallucis longus m. & t.

extensor digitorum longus m.

peroneus longus & brevis mm. & tt.

fibula

flexor hallucis longus m.

tibia

greater saphenous v.

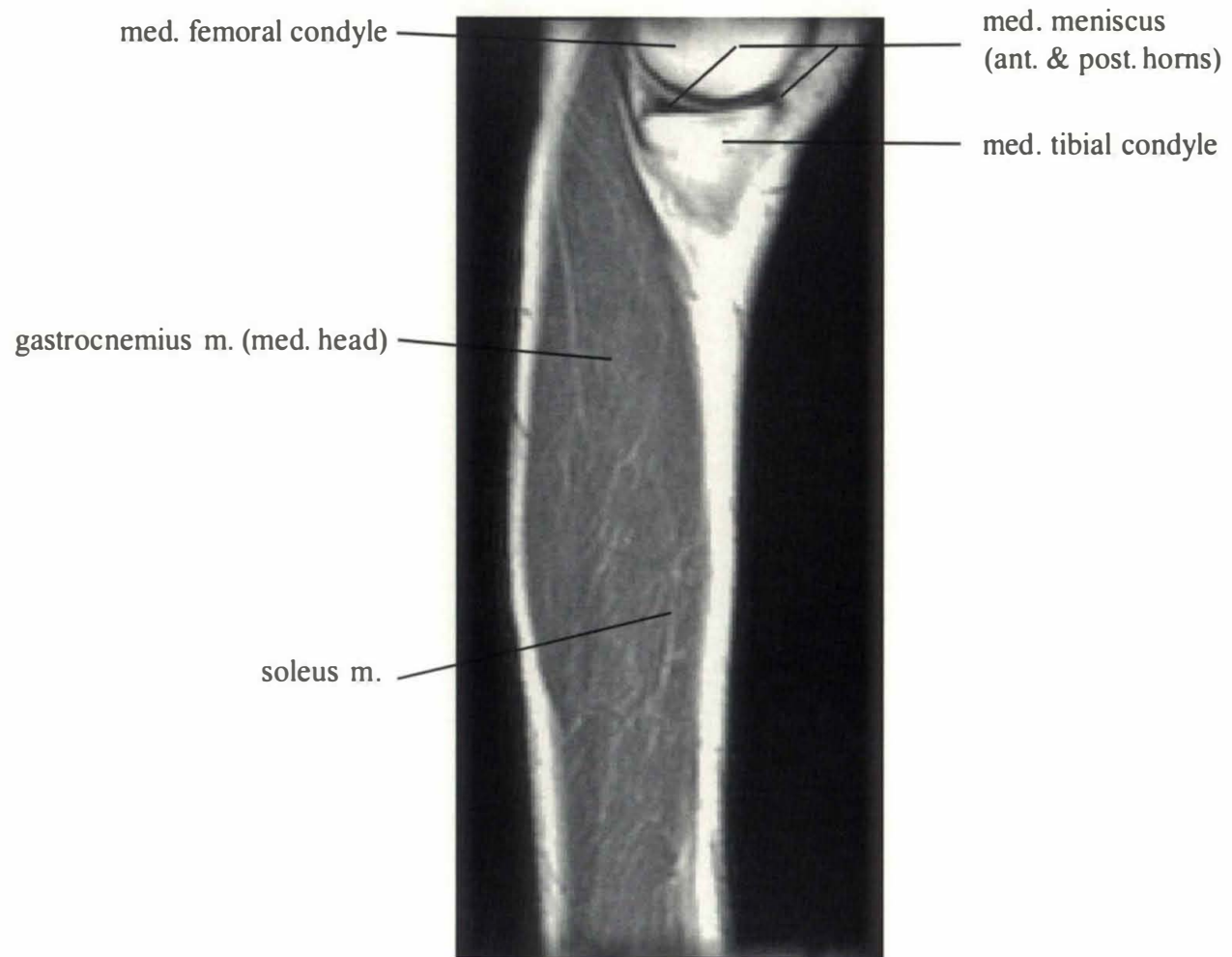
flexor digitorum longus m. & t.

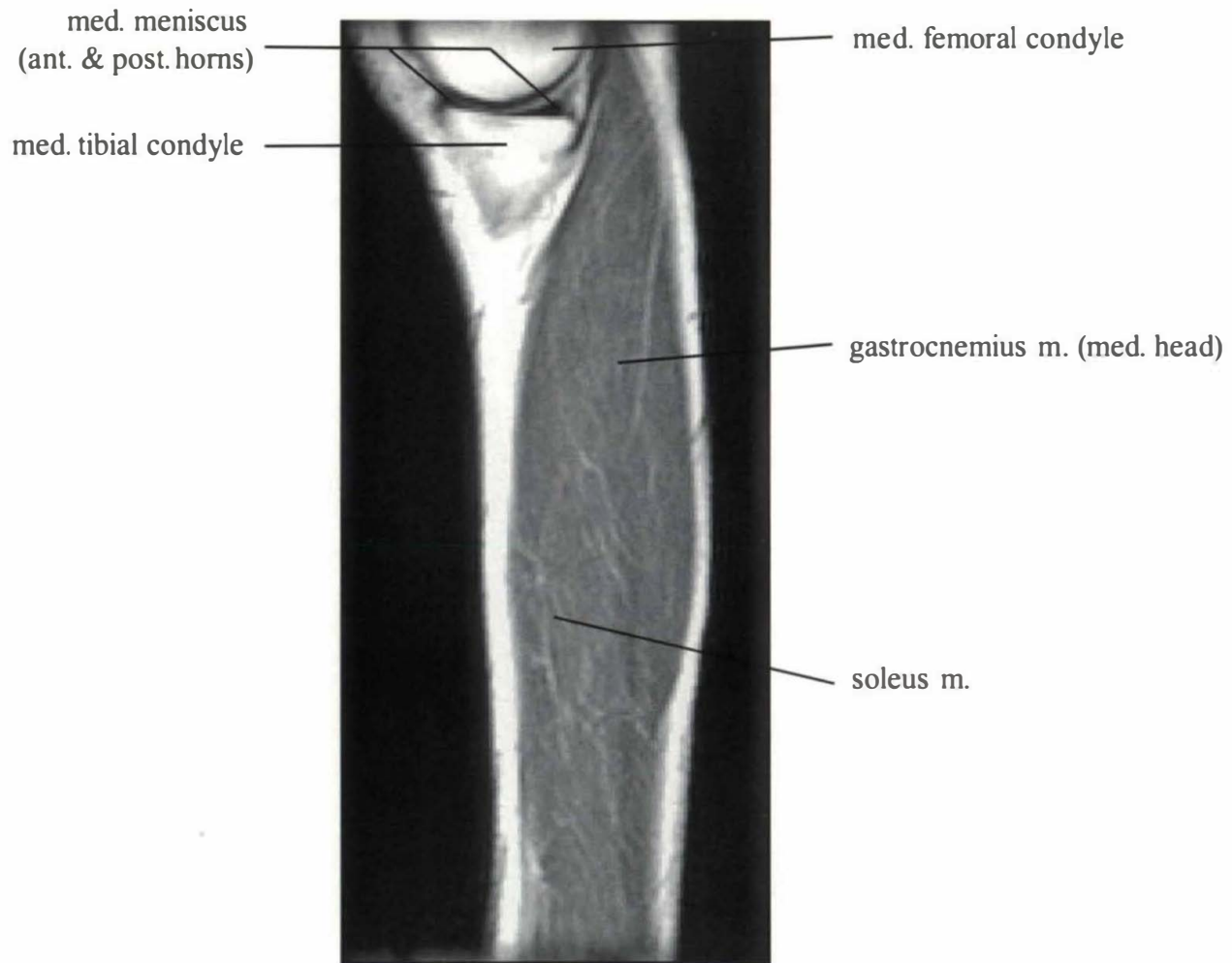
tibialis post. m.

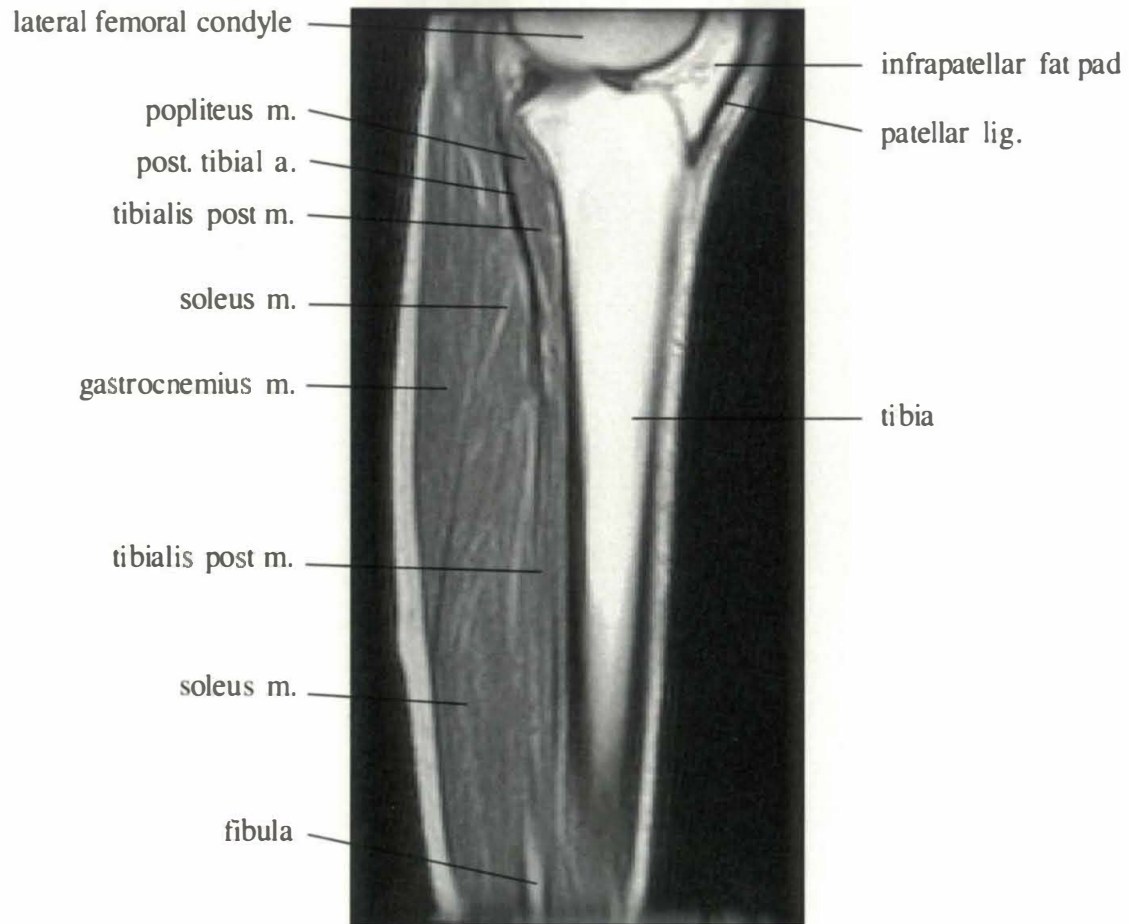
soleus m.

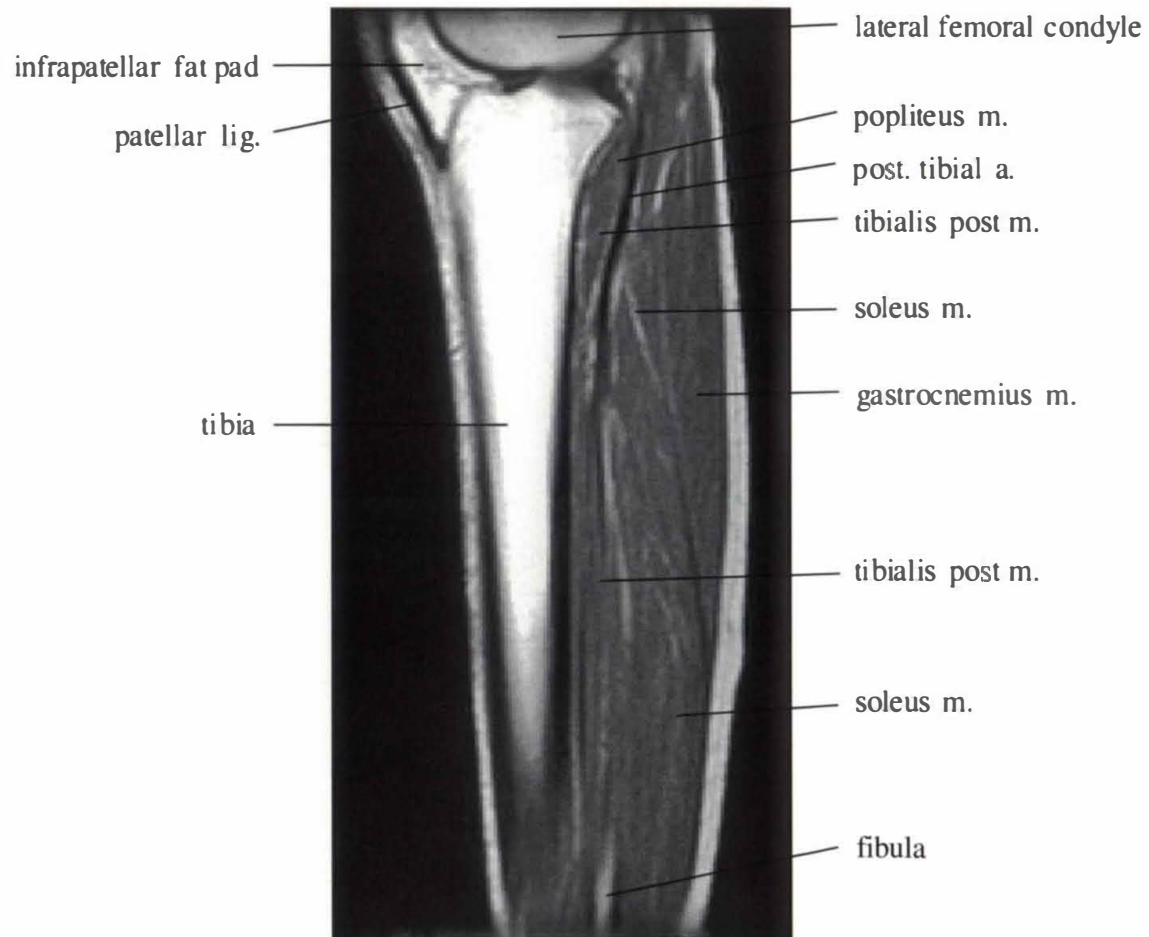
gastrocnemius t.

THE LOWER EXTREMITY: SAGITTAL ANATOMY









infrapatellar fat pad

patellar lig.

tibia

lateral femoral condyle

popliteus m.

post. tibial a.

tibialis post m.

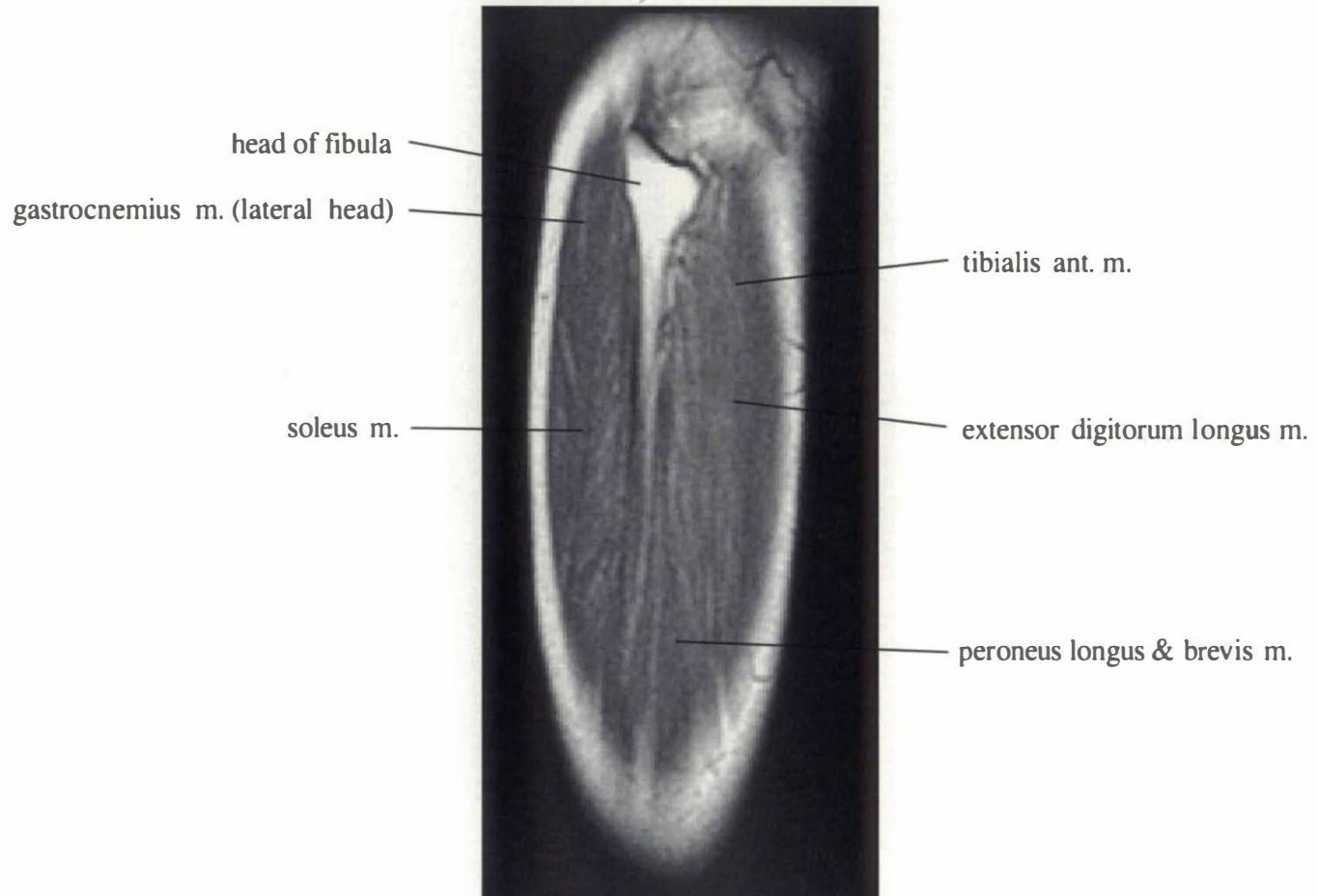
soleus m.

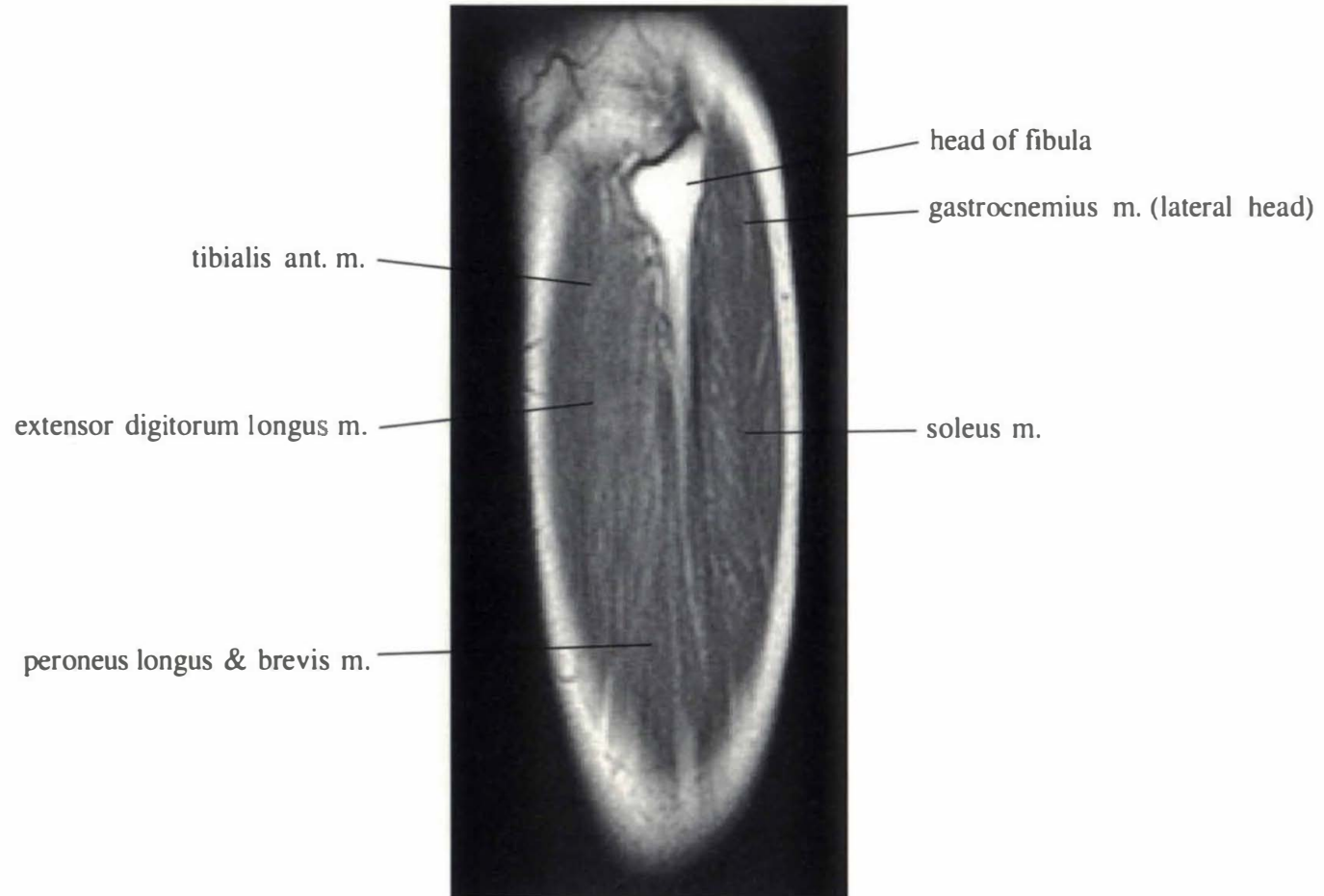
gastrocnemius m.

tibialis post m.

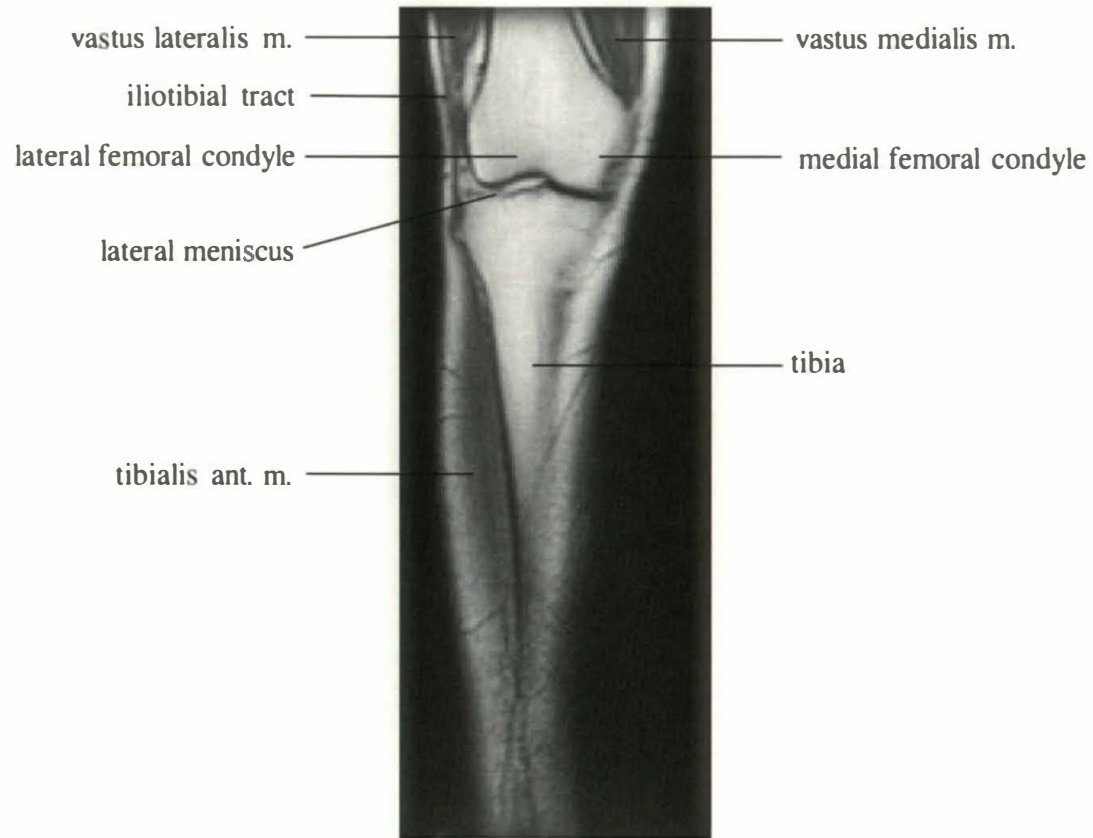
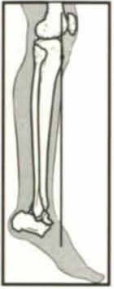
soleus m.

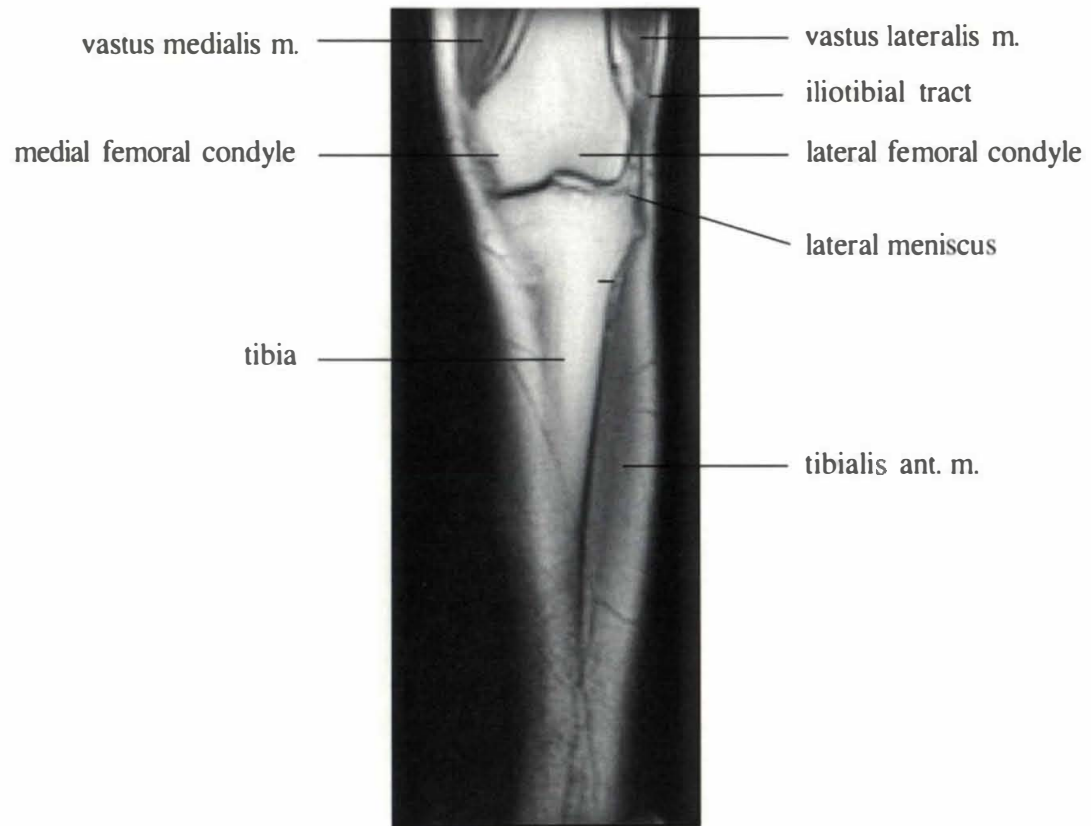
fibula

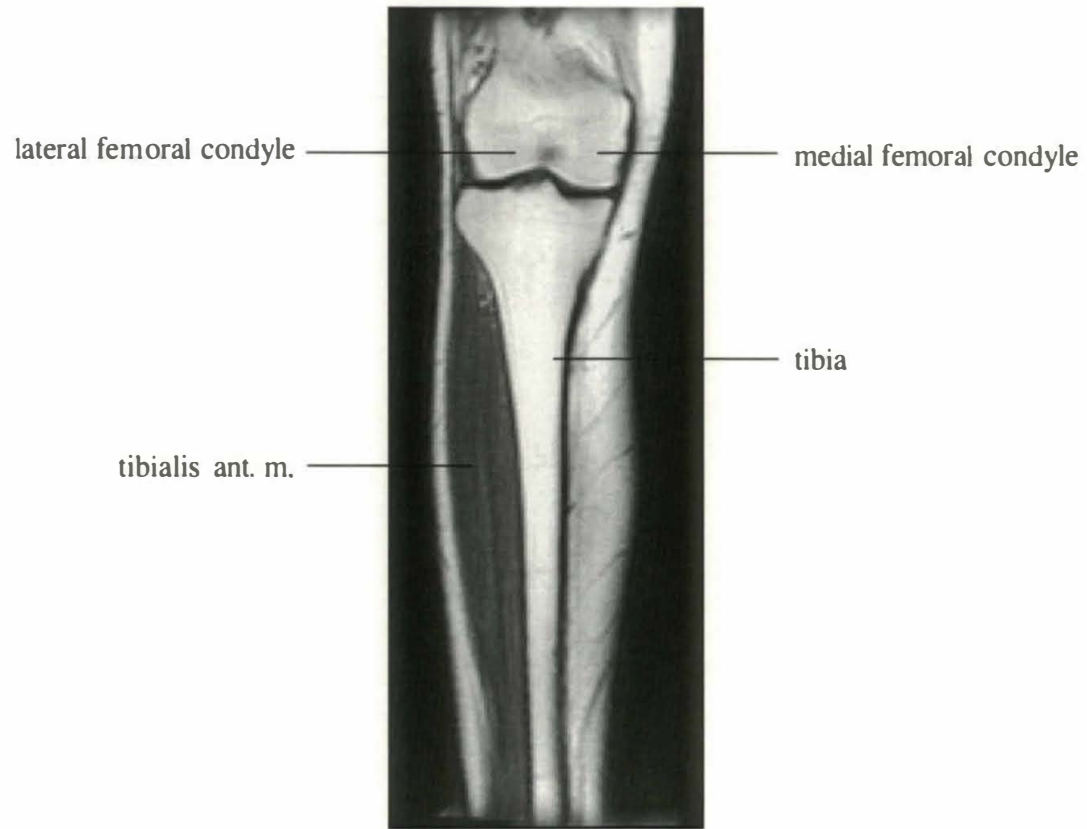


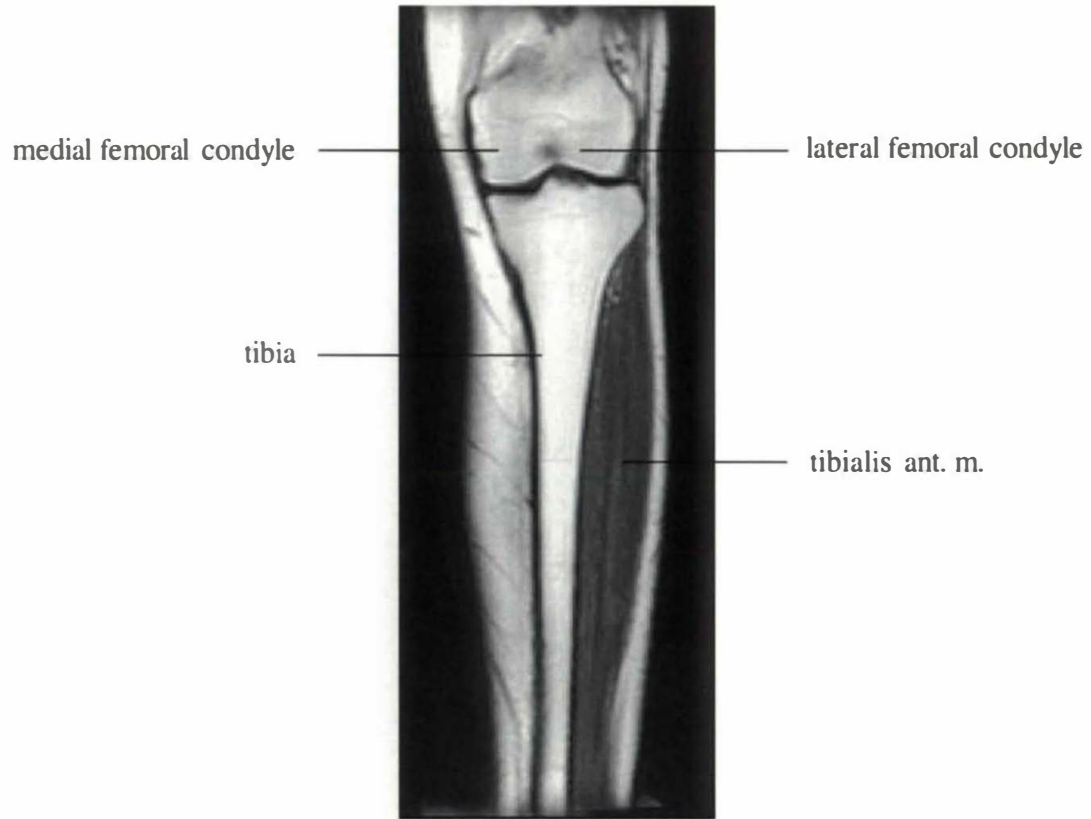


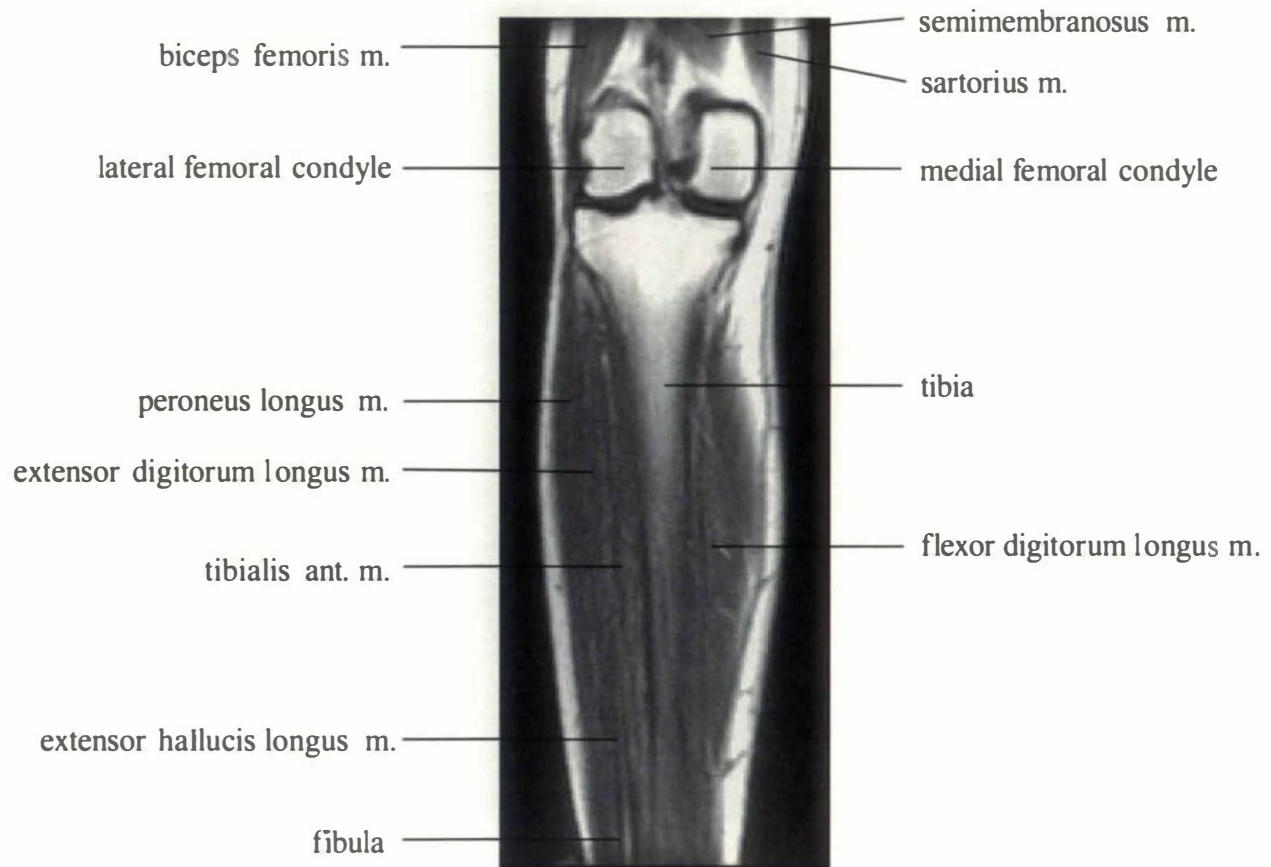
THE LOWER EXTREMITY: CORONAL ANATOMY

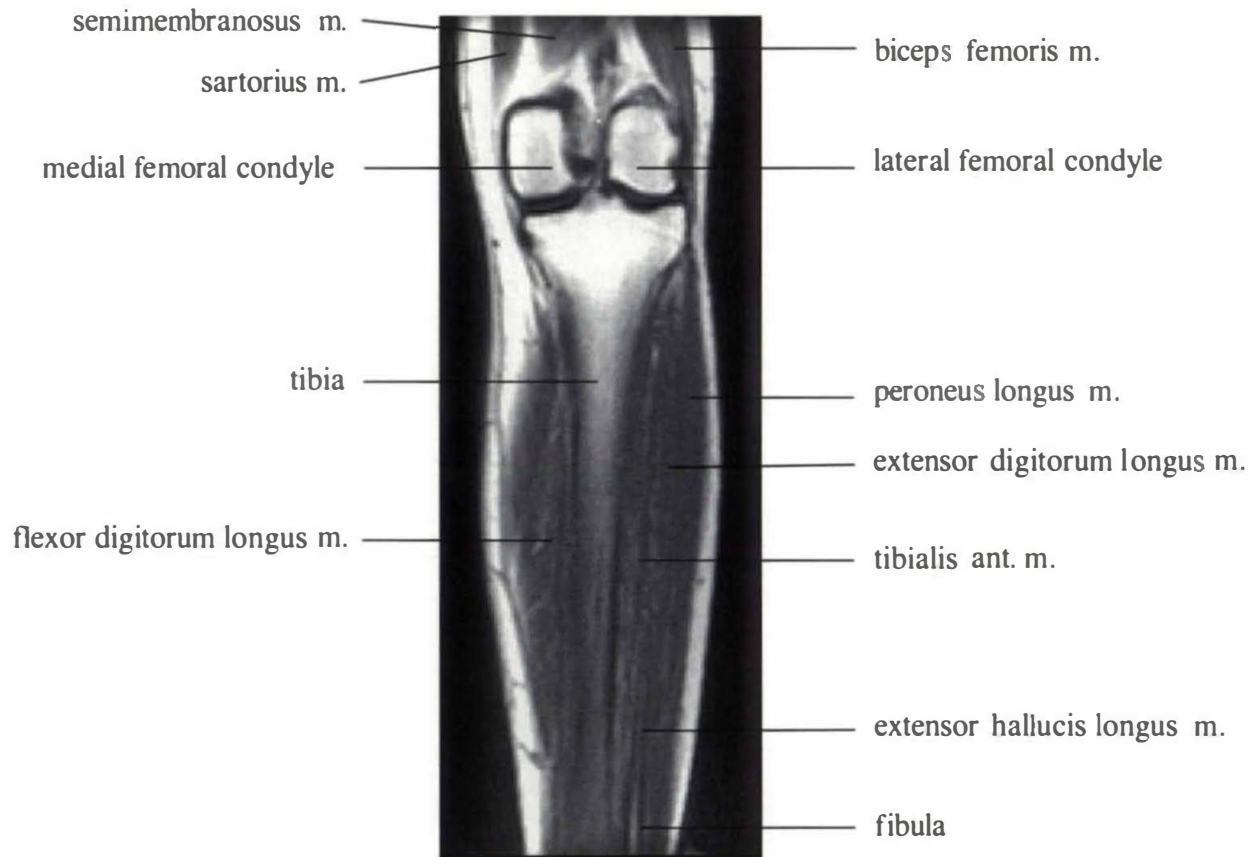


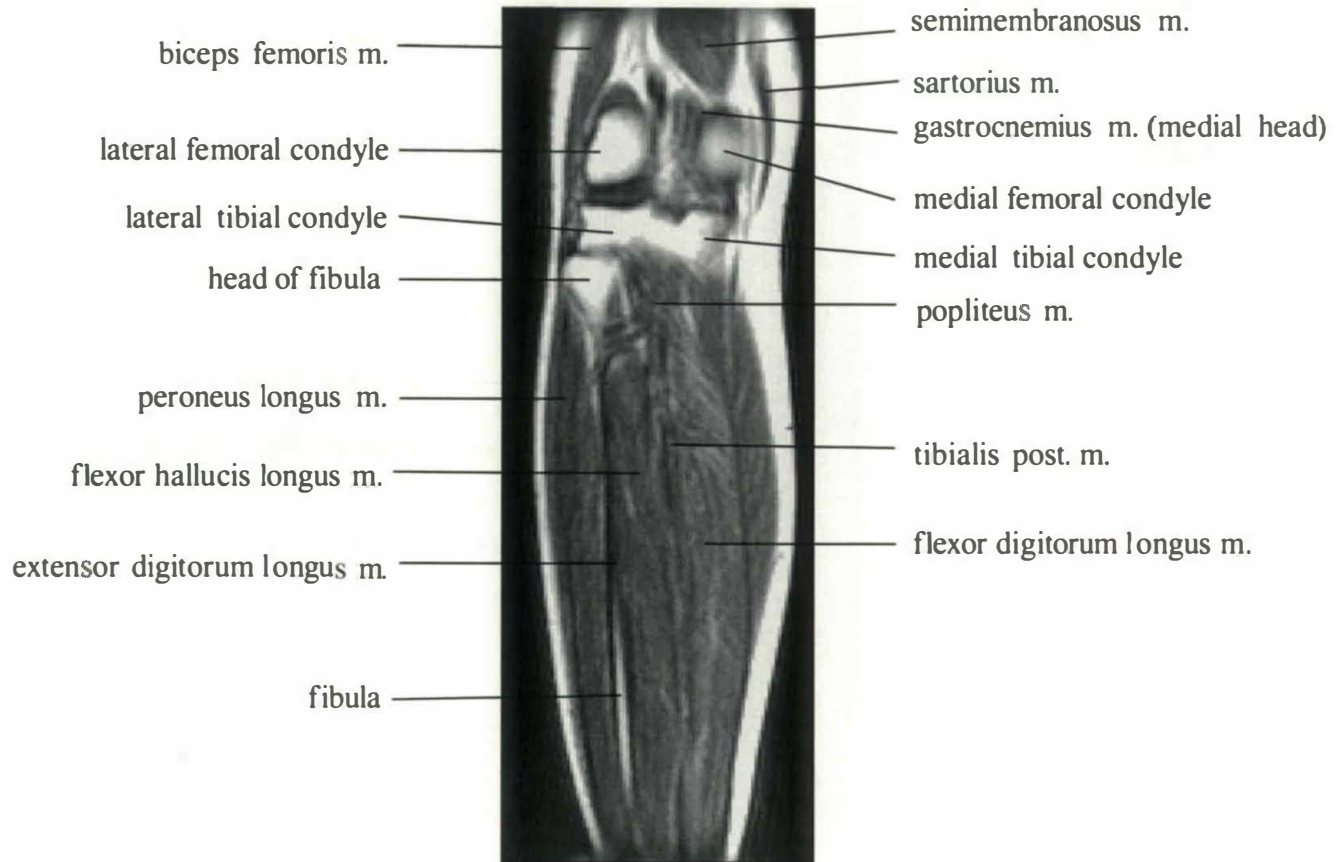


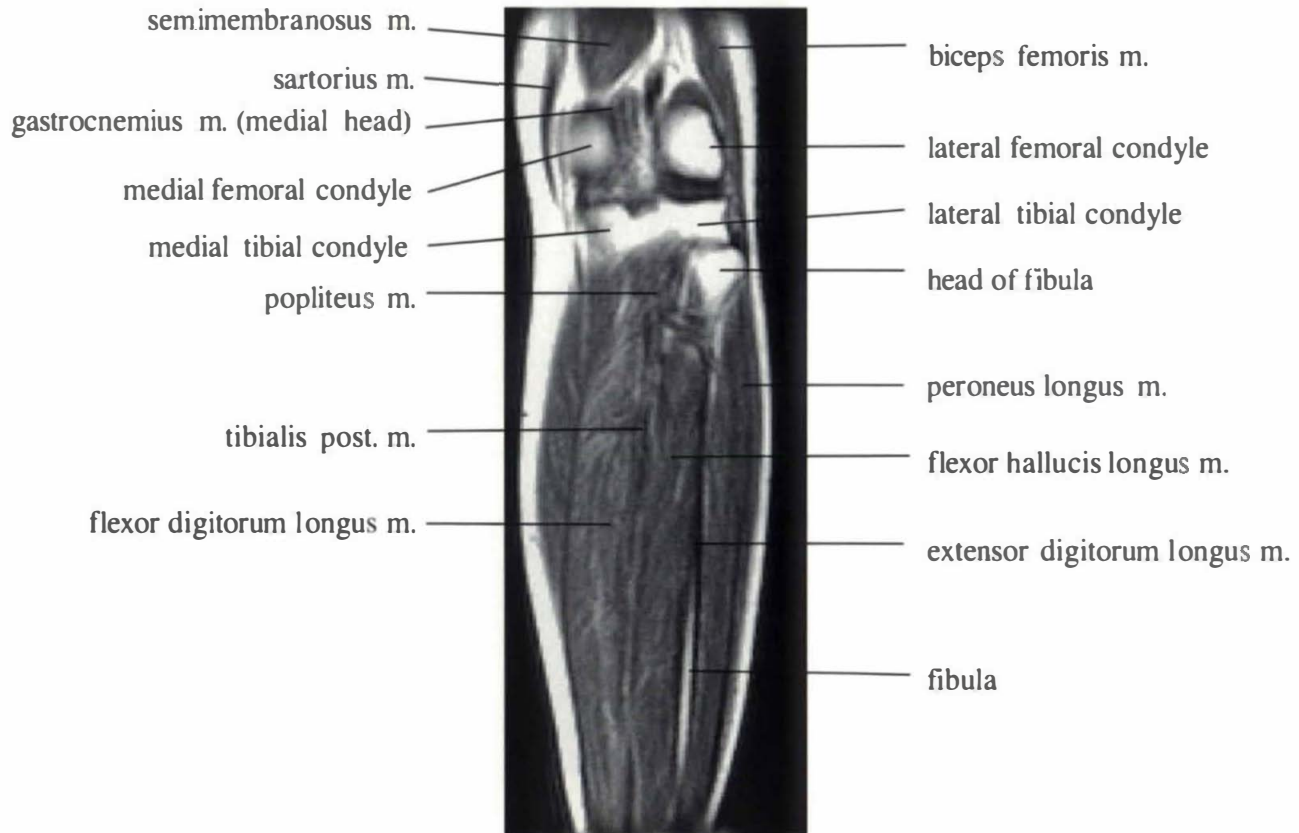


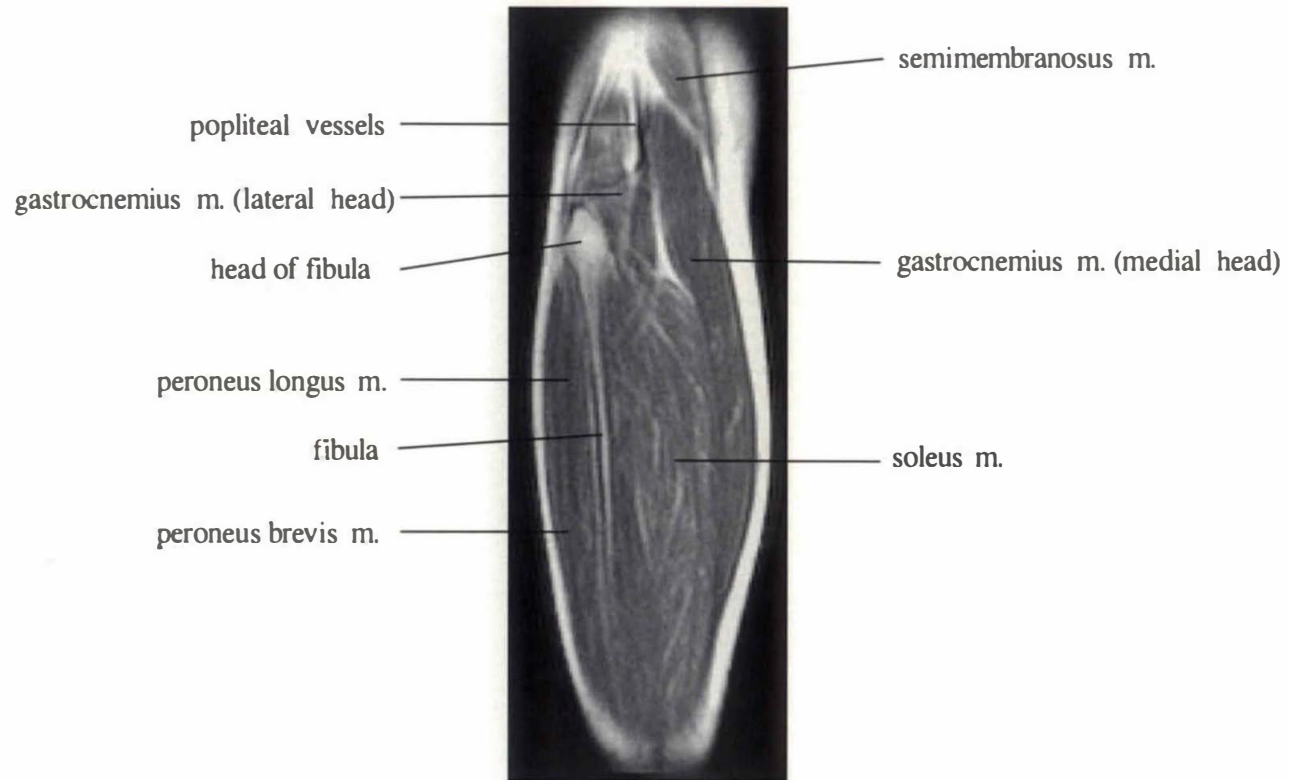


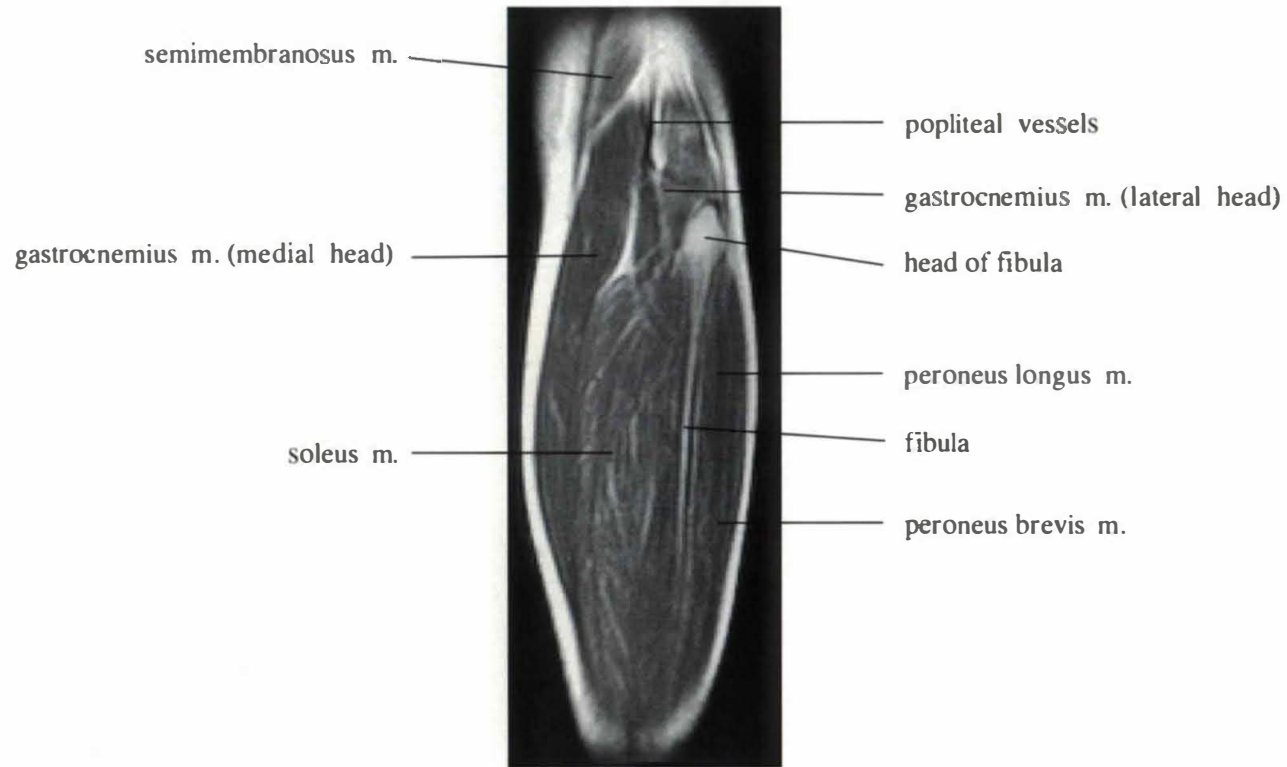










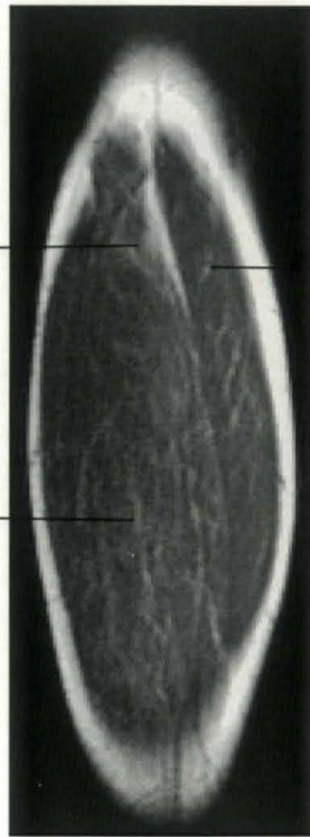


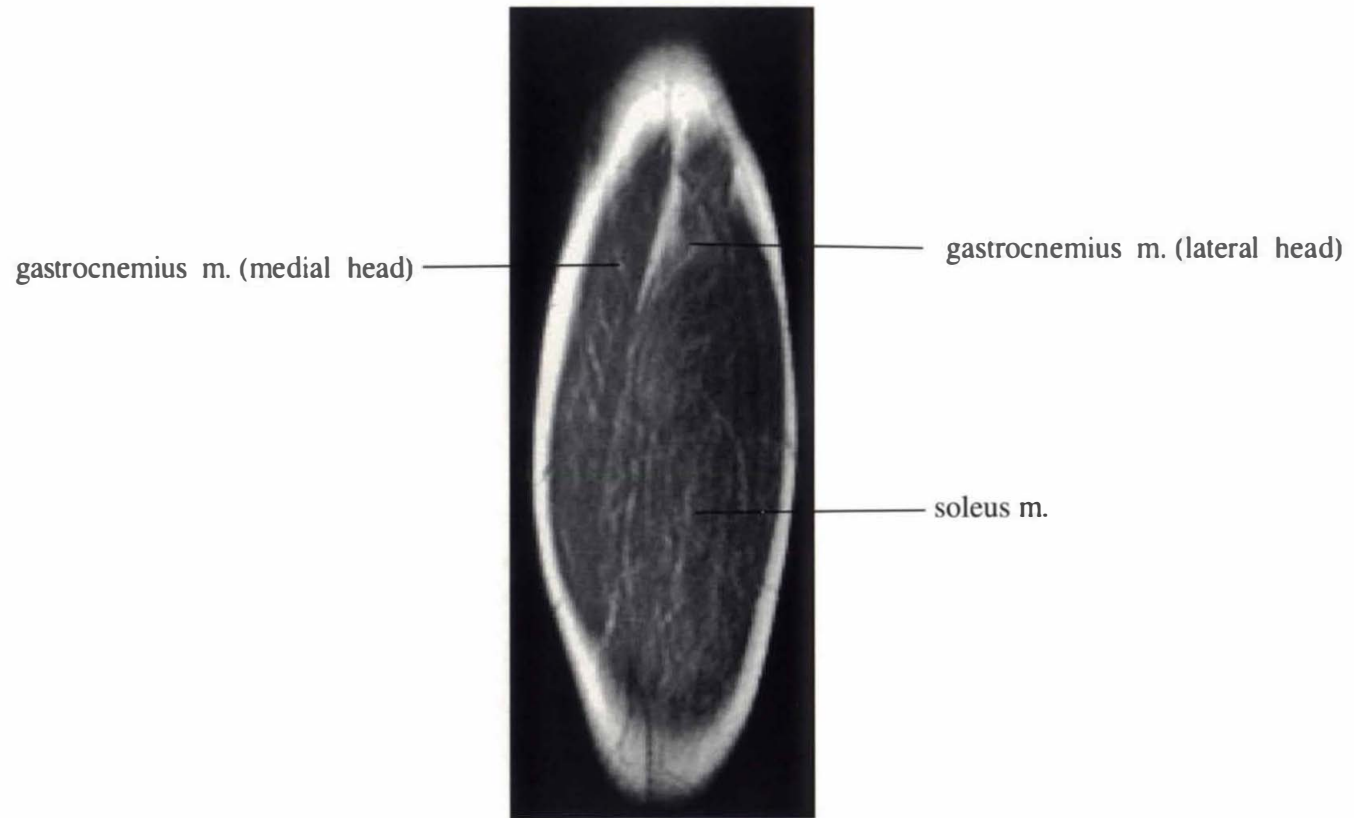


gastrocnemius m. (lateral head)

gastrocnemius m. (medial head)

soleus m.





THE ANKLE AND FOOT

Interest in MR imaging of the ankle and foot has been increasing in recent years. The most common reason for MR imaging of the foot and ankle is for evaluation of suspected injuries to the tendons, ligaments, or chondroosseous structures, particularly osteochondrosis dissecans of the talus. Other common indications for the study include suspected tarsal coalition, suspected stress fractures (fatigue fractures and insufficiency fractures), evaluation of the neuropathic foot in diabetes, evaluation of Morton's neuroma, and preoperative evaluation of suspected soft-tissue infection of osteomyelitis. Less common rationales for the MR imaging study include suspected plantar fasciitis, suspected soft-tissue ganglions, and evaluation of the patient with arthritis.

PRACTICAL PROTOCOL CONSIDERATIONS

MR imaging of the foot and ankle can be performed with the same extremity coils that are used for imaging of the knee or with dedicated extremity surface coils such as the quadrature or phased array coils. Either of these coils can give diagnostic images. The patient is placed in the supine position with the foot comfortably positioned in the coil and the toes up. In general, small fields of view (10–12 cm) are used. Ten 3–4 mm slices with 0.5- to 1-mm interslice gaps are used.

Occasionally, the patient may be imaged with the foot in plantar flexion to decrease the curvature of the peroneal tendons and minimize the “magic angle” effect. When necessary, oblique axial and coronal planes may also be employed to visualize the obliquely oriented ligaments of the ankle. Intravenous gadolinium is used mainly for the evaluation of solid masses or suspected infection.

Menu of Protocols: Ankle and Foot

Plane	Pulse Sequence	FA (degrees)	TR (msec)	TE (msec)	TI (msec)	FOV (cm)	Matrix (256X-)	ST/G (mm)	NEX	Comments
Localizer (transaxial)	SE		500	min		20	192	4/1	1	Either is acceptable
Localizer (coronal)	SE		300	20		24	192	5/1	0.5	
Localizer (sagittal)	SE		300	min		18	128	5/1	1	
Transaxial	SE, double echo		2000	20/80		12	128	3-4/1	2	Either is acceptable
Transaxial	FSE, double echo		6000	17/102		14-15	256	4/0.5	1	
Transaxial	FSE, FS		5200	70		14	256	5/1	2	
Coronal	FSE, FS		3000	20		12	128	3-4/1	2	Either is acceptable
Coronal	FSE, double echo		6000	17/102		15	128	4/0.5	2	
Coronal	SE		300	min		12-14	192	3/1.5	2	
Sagittal	SE		600	20		12	128	3/1	2	Either is acceptable
Sagittal	FMPIR		5500	18	150	15-16	256	4/0.5	2	
Sagittal	FSE, double echo		4000	20/100		12-14	192	3/1	2	
Sagittal	SE, double echo		2000	20/80		16	192	3/1	1-2	
Sagittal	3D FRE, SPGR, FS	30	45	15		12-14	192	1.5/0	1	
Pre-GAD (axial, coronal, sagittal)	SE (\pm FS)		600	20		12-14	192	3/1	2	Depends on site of abnormality— intravenous GAD for tumors, cysts, infection
Post-GAD (axial, coronal, sagittal)	SE (\pm FS)		600	20		12-14	192	3/1	2	Depends on site of abnormality— intravenous GAD for tumors, cysts, infection

MAJOR OSTEOCHONDRAL STRUCTURES/LANDMARKS

Ankle

- Distal tibia
 - Tibial articular cartilage
 - Medial malleolus
 - Posterior malleolus
 - Fibular notch

- Distal fibula
 - Lateral malleolus
 - Fossa of lateral malleolus

Foot

- Talus
 - Head
 - Neck
 - Trochlea
 - Posterior process
 - Medial tubercle
 - Lateral tubercle
- Calcaneus
 - Tuberosity
 - Medial process
 - Lateral process
 - Sustentaculum tali
- Navicular
 - Navicular tuberosity
- Cuboid
- Cuneiforms
 - Lateral
 - Intermediate
 - Medial
- Metatarsals
 - Base
 - Shaft
 - Head
- Proximal phalanges (I-V)
 - Base
 - Head
 - Tuberosity (V)

- Middle phalanges
- Distal phalanges
 - Base
 - Tuberosity (tuft)
- Sesamoid bones (variable)

MAJOR LIGAMENTS/TENDONS/BURSAE

Ligaments

- Tibiofibular joint
 - Anterior tibiofibular
 - Posterior tibiofibular
- Lateral collateral ligamentous complex
 - Anterior talofibular
 - Calcaneofibular
 - Posterior talofibular
- Deltoid (medial)
 - Superficial
 - Anterior tibiotalar
 - Tibionavicular
 - Tibiocalcaneal
 - Posterior tibiofalar
 - Deep
 - Anterior tibiotalar
 - Posterior tibiotalar
- Interosseous talocalcaneal
- Dorsal talonavicular
- Bifurcate
 - Calcaneonavicular portion
 - Calcaneocuboid portion
- Dorsal cuboideonavicular
- Dorsal cuneonavicular

- Dorsal intercuneiform
- Dorsal tarsometatarsal
- Dorsal metatarsal
- Dorsal cuneocuboid
- Dorsal calcaneocuboid
- Plantar calcaneonavicular
- Plantar cuboideonavicular
- Plantar cuneonavicular
- Plantar calcaneocuboid
- Plantar tarsometatarsal
- Deep transverse metatarsal
- Plantar ligaments (plates)

Tendons

- Anterior tendons (under superior and inferior extensor retinaculae)
 - Extensor digitorum longus
 - Extensor hallucis longus
 - Tibialis anterior
- Medial tendons (under flexor retinaculum)
 - Flexor hallucis longus
 - Flexor digitorum longus
 - Tibialis posterior
- Lateral tendons
 - Peroneus brevis
 - Peroneus longus
- Posterior tendons
 - Achilles tendon (largest tendon in body)
- Peroneus tertius

Bursae

- Retrocalcaneal (pre-Achilles)

MAJOR MUSCLES

(See lower limb)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES

(See lower limb)

FOOT

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
Interosseous			
– Dorsal interosseous (I, II)	From the sides of metatarsals (I, II)	Same sides of bases of proximal phalanges (I, II)	Deep branch of lateral plantar N.
– Dorsal interosseous (III, IV)	From the sides of metatarsals (III, IV)	Lateral sides of bases of proximal phalanges (III, IV)	Deep branch of lateral plantar N.
– Plantar interosseous	Bases of medial sides of metatarsals (III, IV, V)	Medial sides of proximal phalanges (III, IV, V)	Deep branch of lateral plantar N.
Great Toe Intrinsic Muscles			
– Abductor hallucis	Medial process of calcaneal tuberosity flexor retinaculum, intermuscular septum	Medial aspect of base of proximal phalanx of first toe	Lateral plantar N.

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Abductor hallucis brevis			
• Medial belly	Plantar aspect of cuboid and lateral cuneiform, tibialis anterior tendon, medial first metatarsal	Blends with abductor hallucis to insert on medial aspect of base of proximal phalanx of first toe	Lateral plantar N.
• Lateral belly	Plantar aspect of cuboid and lateral cuneiform, tibialis anterior tendon, medial first metatarsal	Lateral side of base of proximal phalanx of first toe	Lateral plantar N.
Fifth Toe Intrinsic Muscles			
– Abductor digiti minimi	Lateral and medial processes of calcaneus, intermuscular septum, lateral plantar fascia	Lateral side of proximal phalanx of fifth toe	Lateral plantar N.
– Flexor digiti minimi brevis	Tuberosity of cuboid, base of fifth metatarsal, peroneus longus tendon sheath	Base of proximal phalanx of fifth toe	Superficial branch of lateral plantar N.
– Opponeus digiti minimi (variably present)	Tuberosity of cuboid, peroneus longus tendon sheath	Lateral surface of fifth metatarsal	Superficial branch of lateral plantar N. or branch of nerve to flexor digiti minimi brevis

(continued)

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

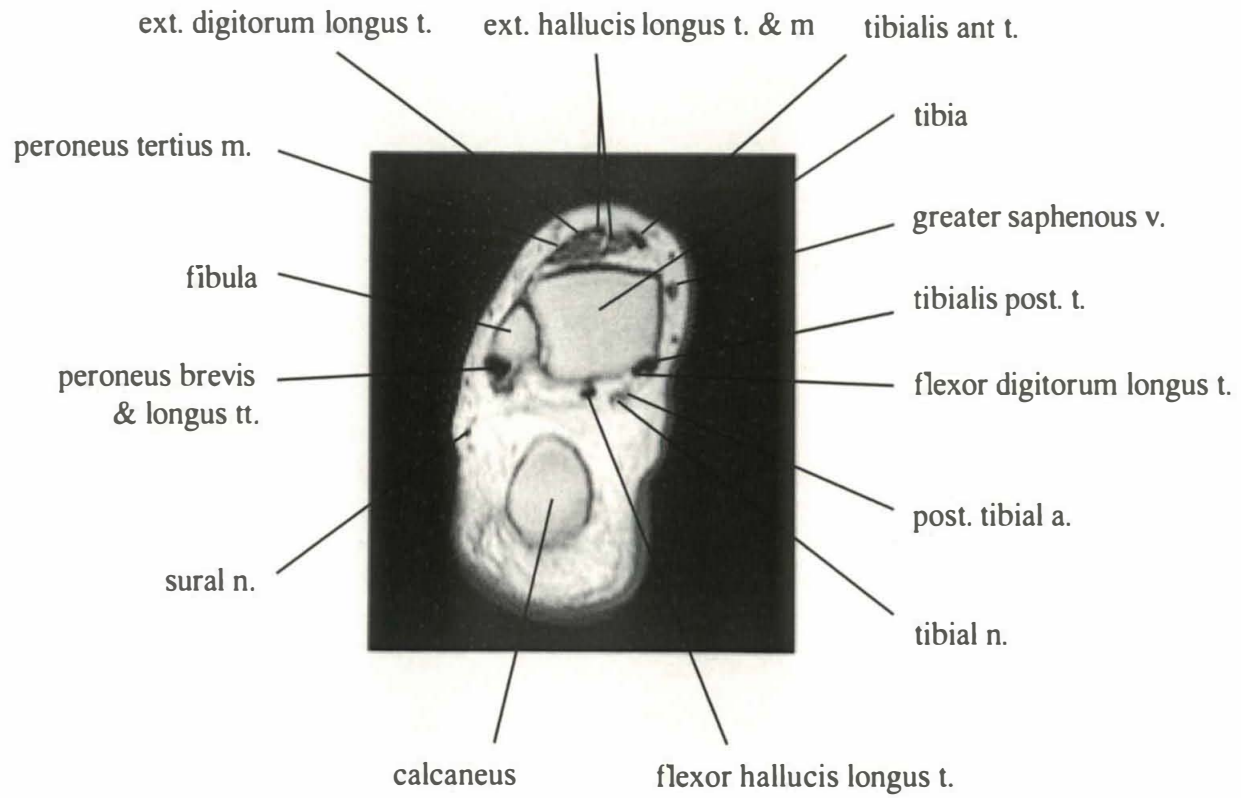
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
- Extensor digitorum brevis	Lateral and superior calcaneal surfaces and inferior extensor retinaculum	Base of first metatarsal (extensor hallucis brevis), base of second proximal phalanx, bases of remaining middle phalanges	Deep peroneal N.
- Flexor digitorum brevis	Medial process of calcaneus, plantar aponeurosis, intermuscular septum	Pass superficial to long flexor, divide to form opening on proximal phalanx of toes through which long flexor tendons pass, then insert onto base of middle phalanx	Lateral plantar N.
- Quadratus plantae (accessory to long digital flexor)			
• Lateral head	Lateral border of plantar surface of calcaneus and from long plantar ligament	Tendon of flexor digitorum longus muscle	Lateral plantar N.
• Medial head	Medial surface of calcaneus and medial border of long plantar ligament	Tendon of flexor digitorum longus muscle	Lateral plantar N.

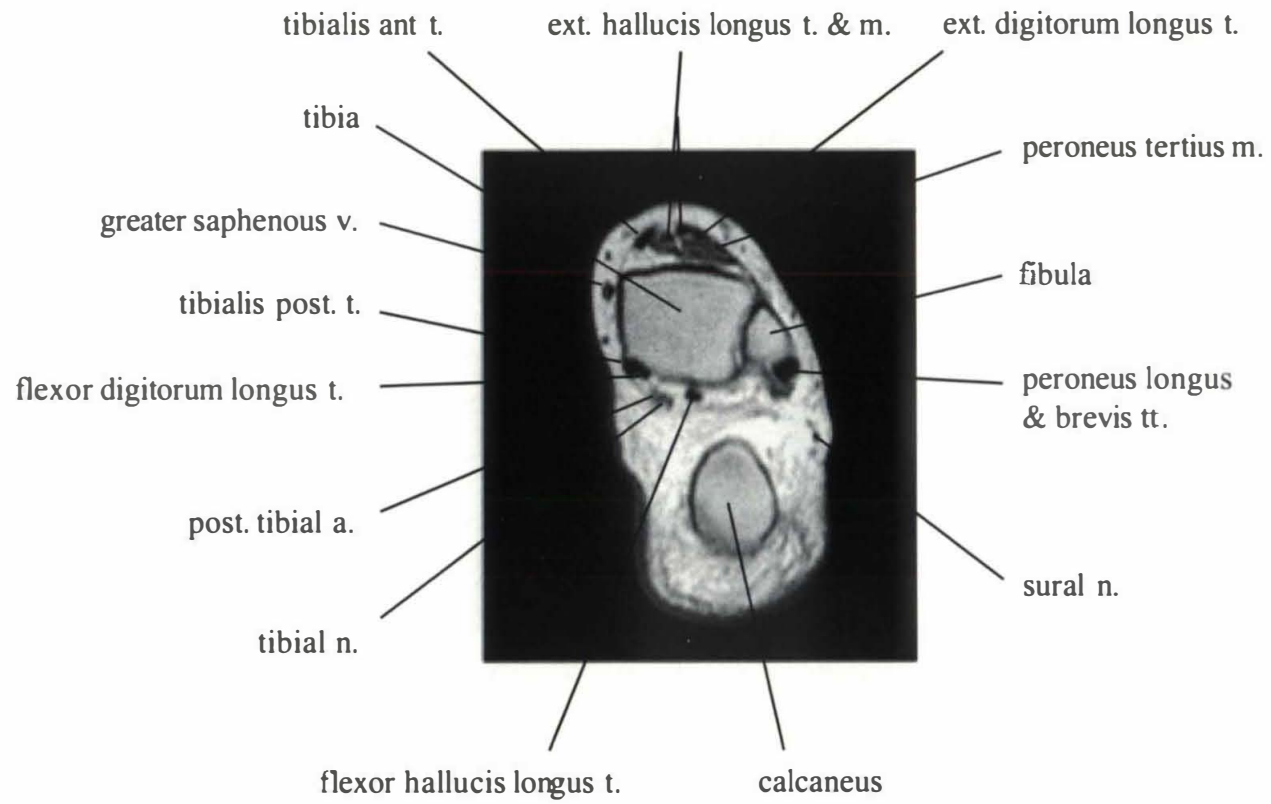
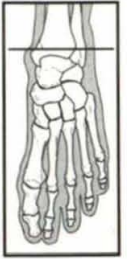
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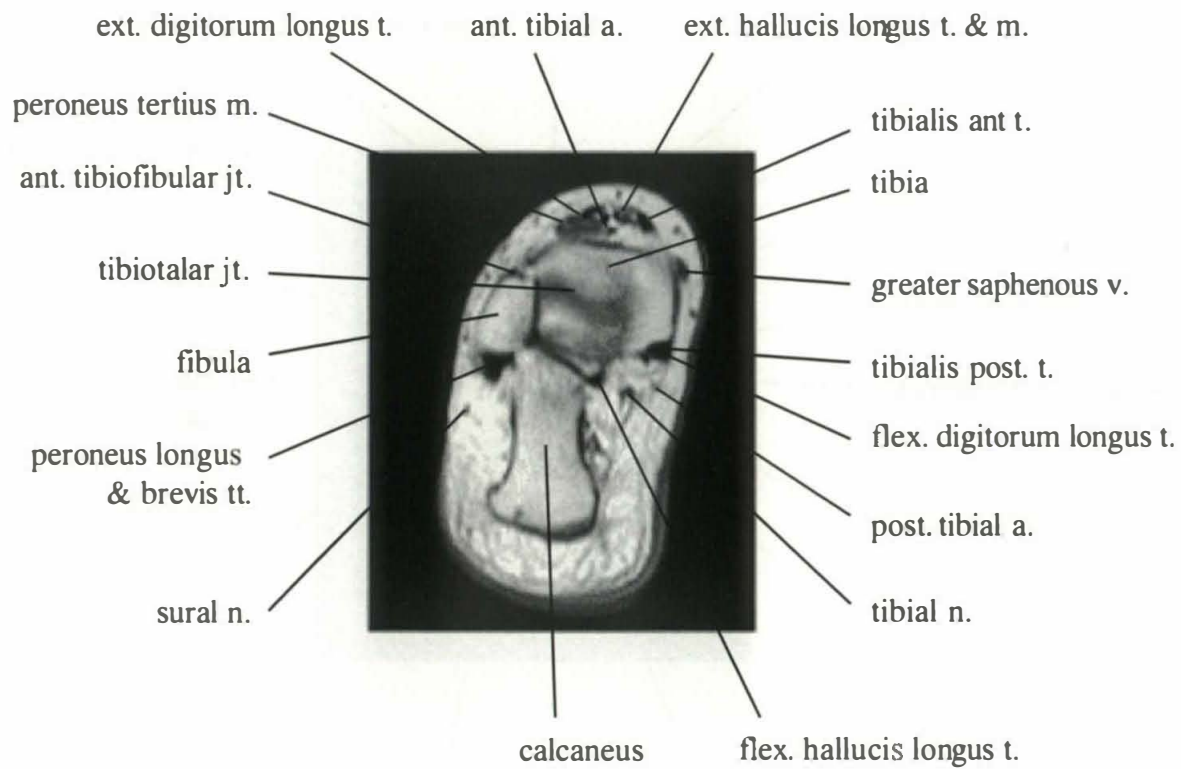
ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (*CONTINUED*)

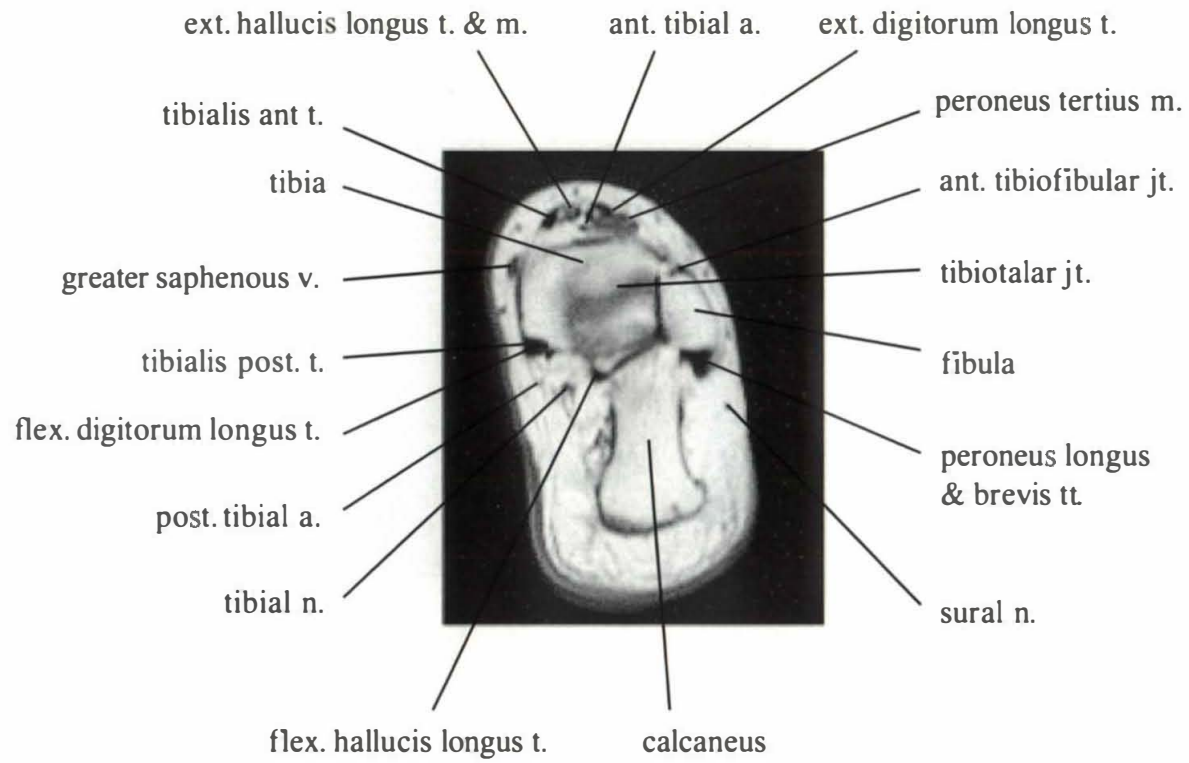
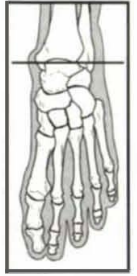
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
• Lumbricals	Four tendons of flexor digitorum longus muscle	Medial surface of extensor expansion over lateral four toes	Lateral plantar N.

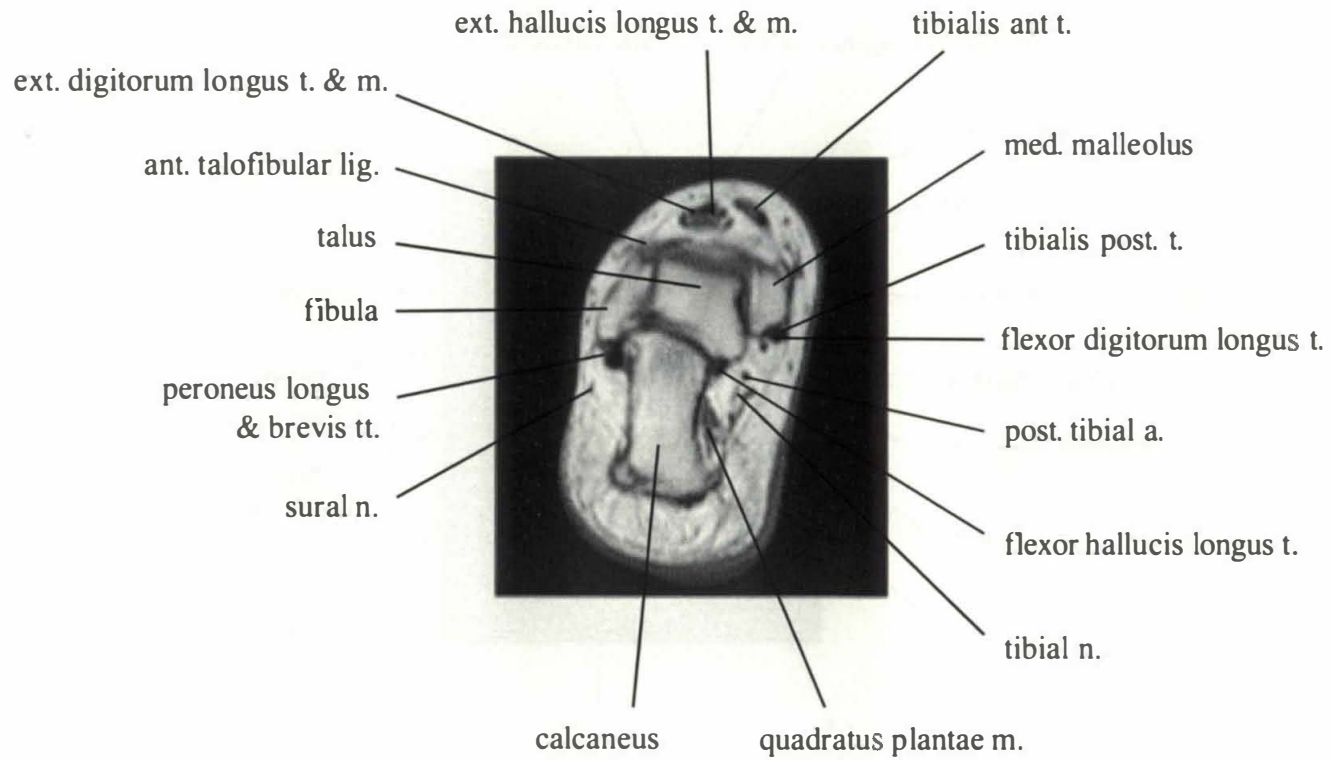
THE ANKLE: AXIAL ANATOMY

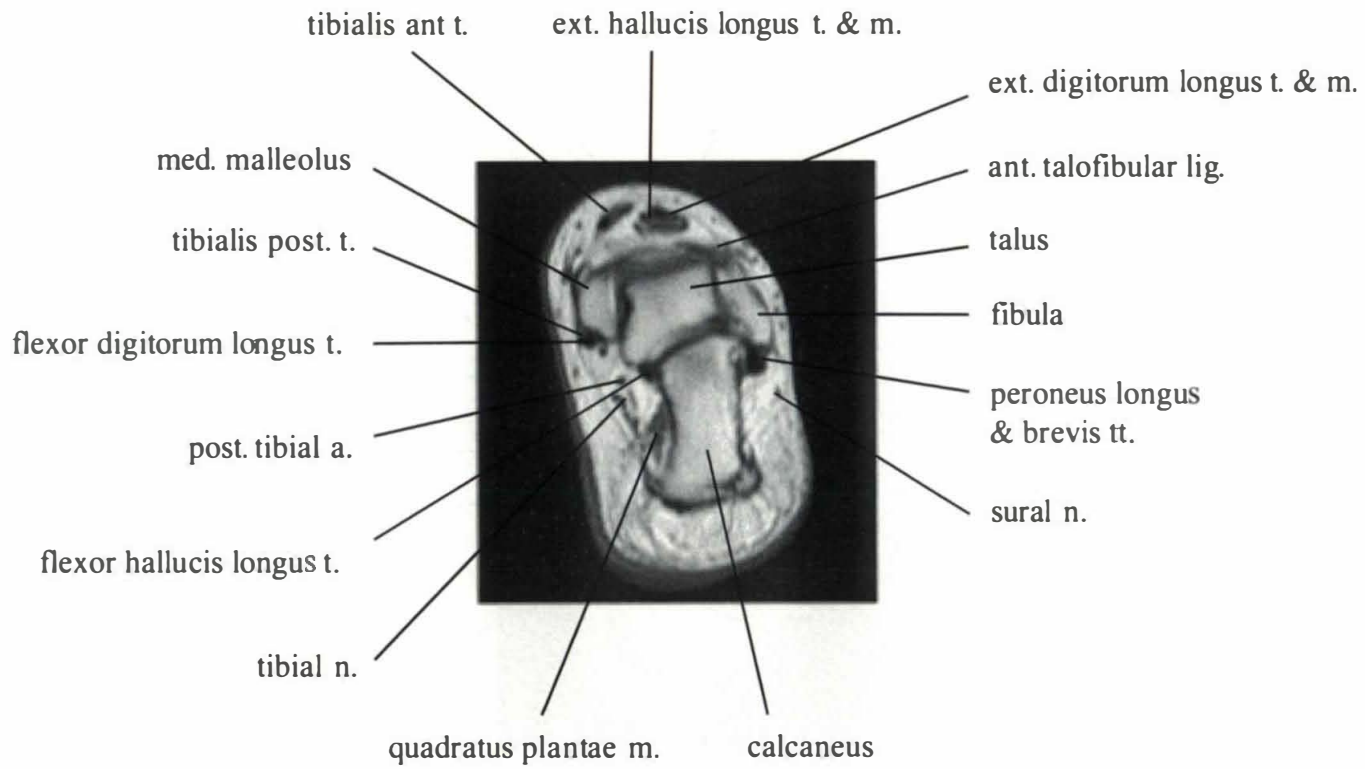


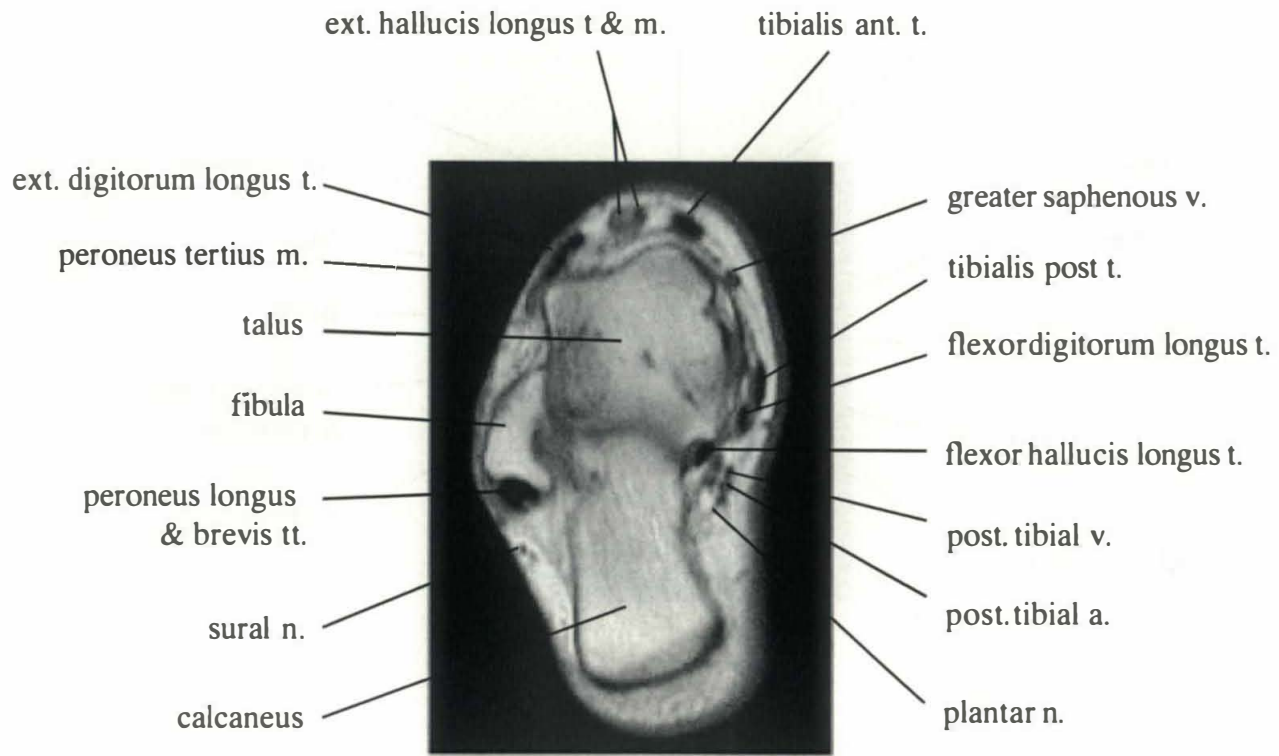


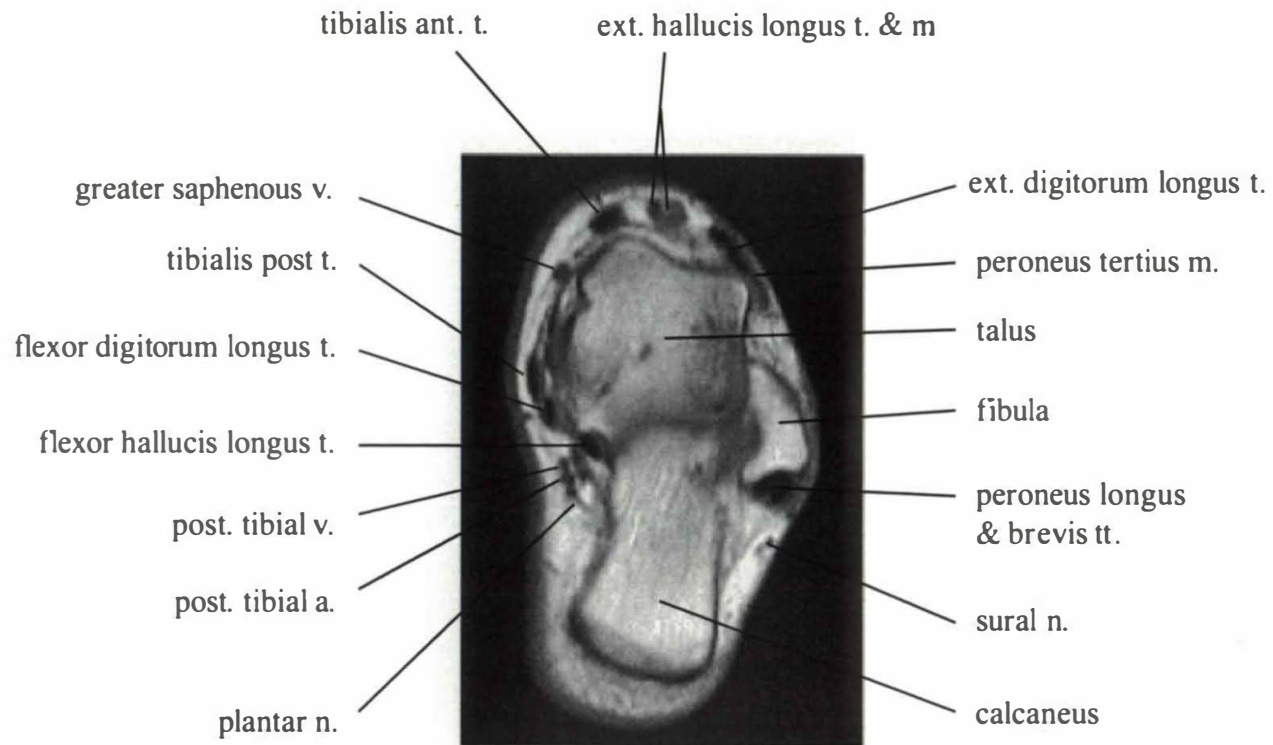
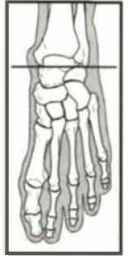


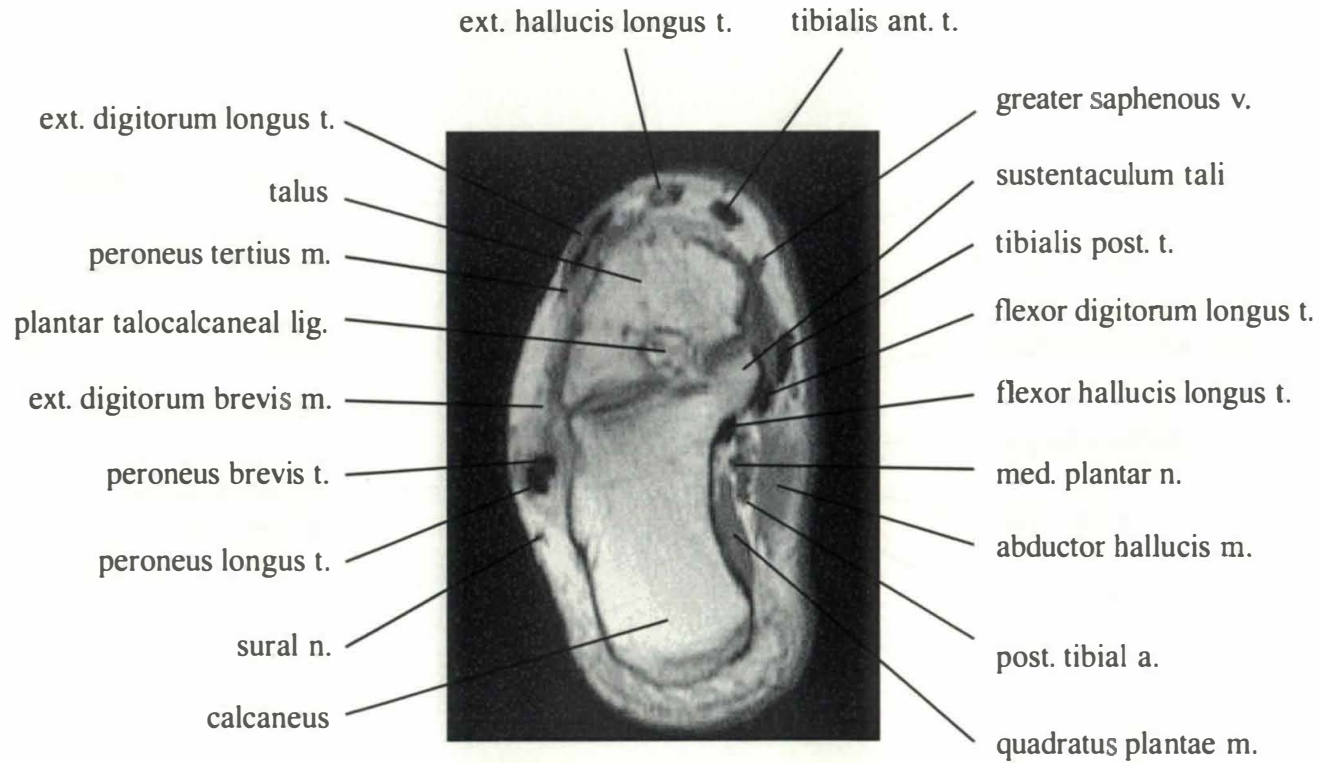
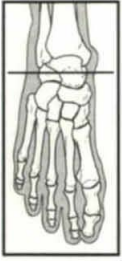


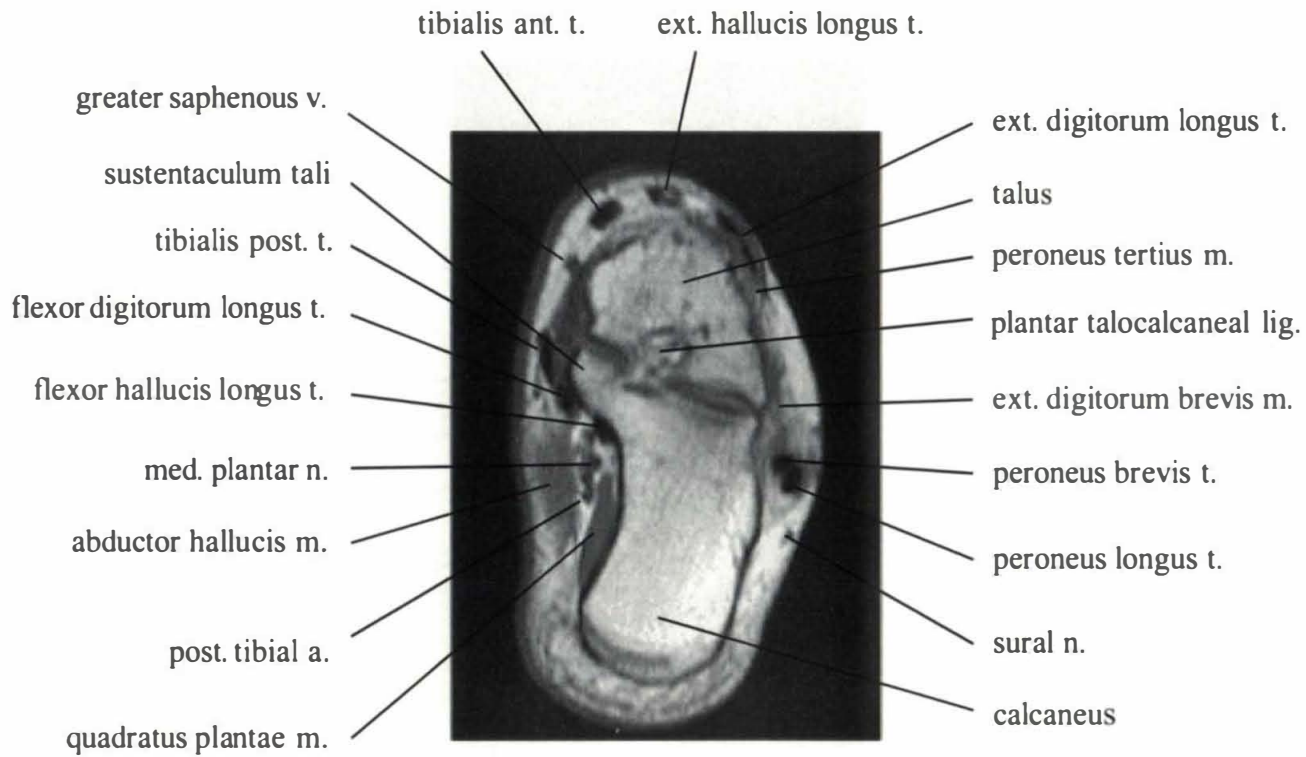
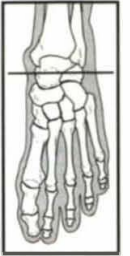












tibialis ant. t.

ext. hallucis longus t.

greater saphenous v.

sustentaculum tali

tibialis post. t.

flexor digitorum longus t.

flexor hallucis longus t.

med. plantar n.

abductor hallucis m.

post. tibial a.

quadratus plantae m.

ext. digitorum longus t.

talus

peroneus tertius m.

plantar talocalcaneal lig.

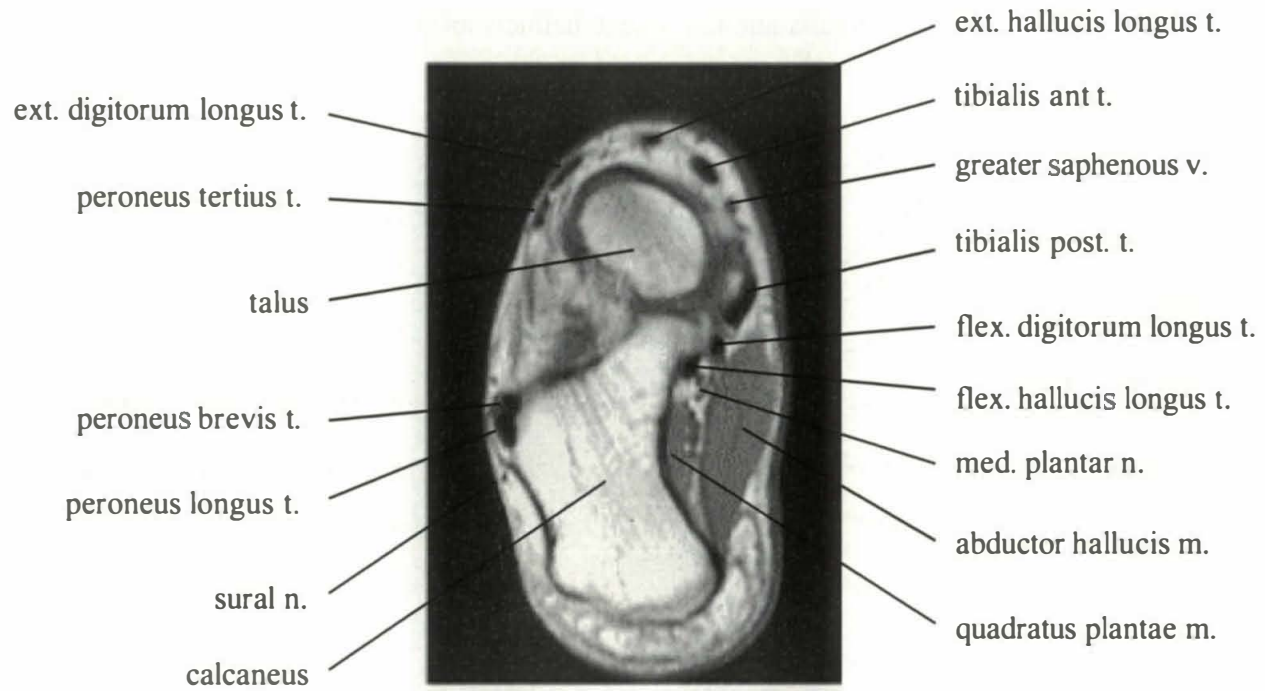
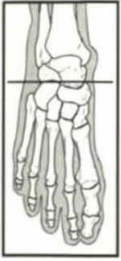
ext. digitorum brevis m.

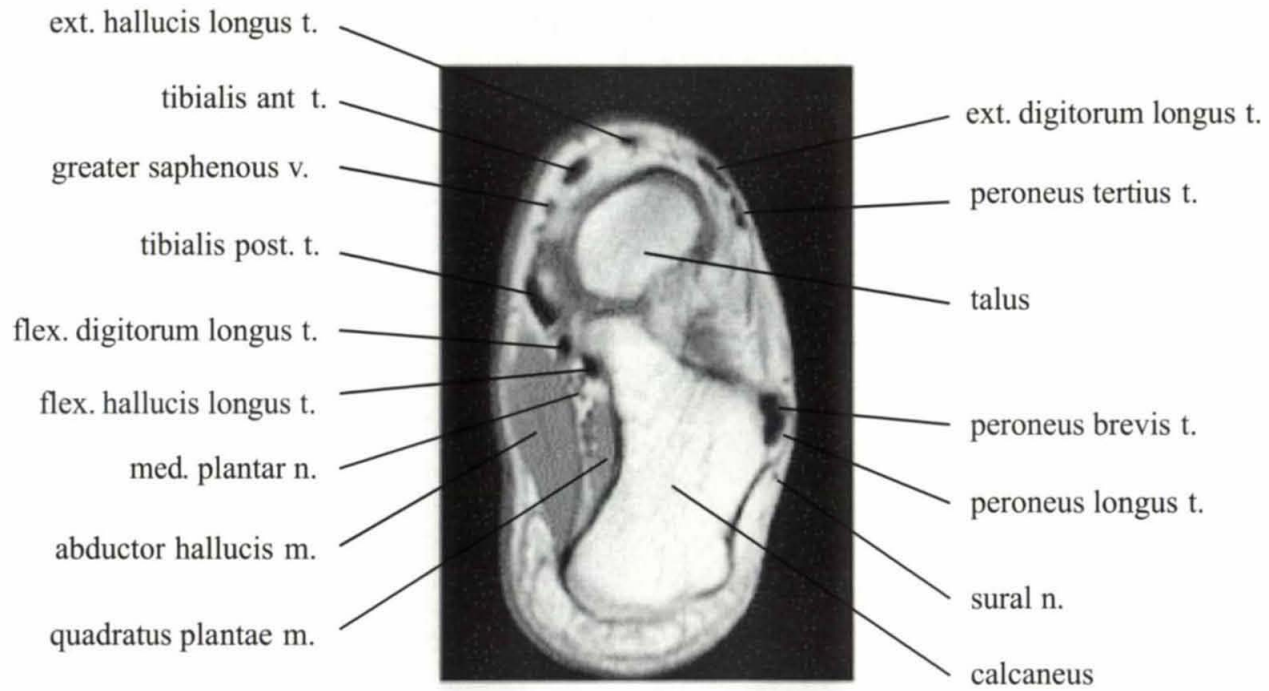
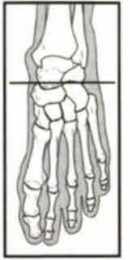
peroneus brevis t.

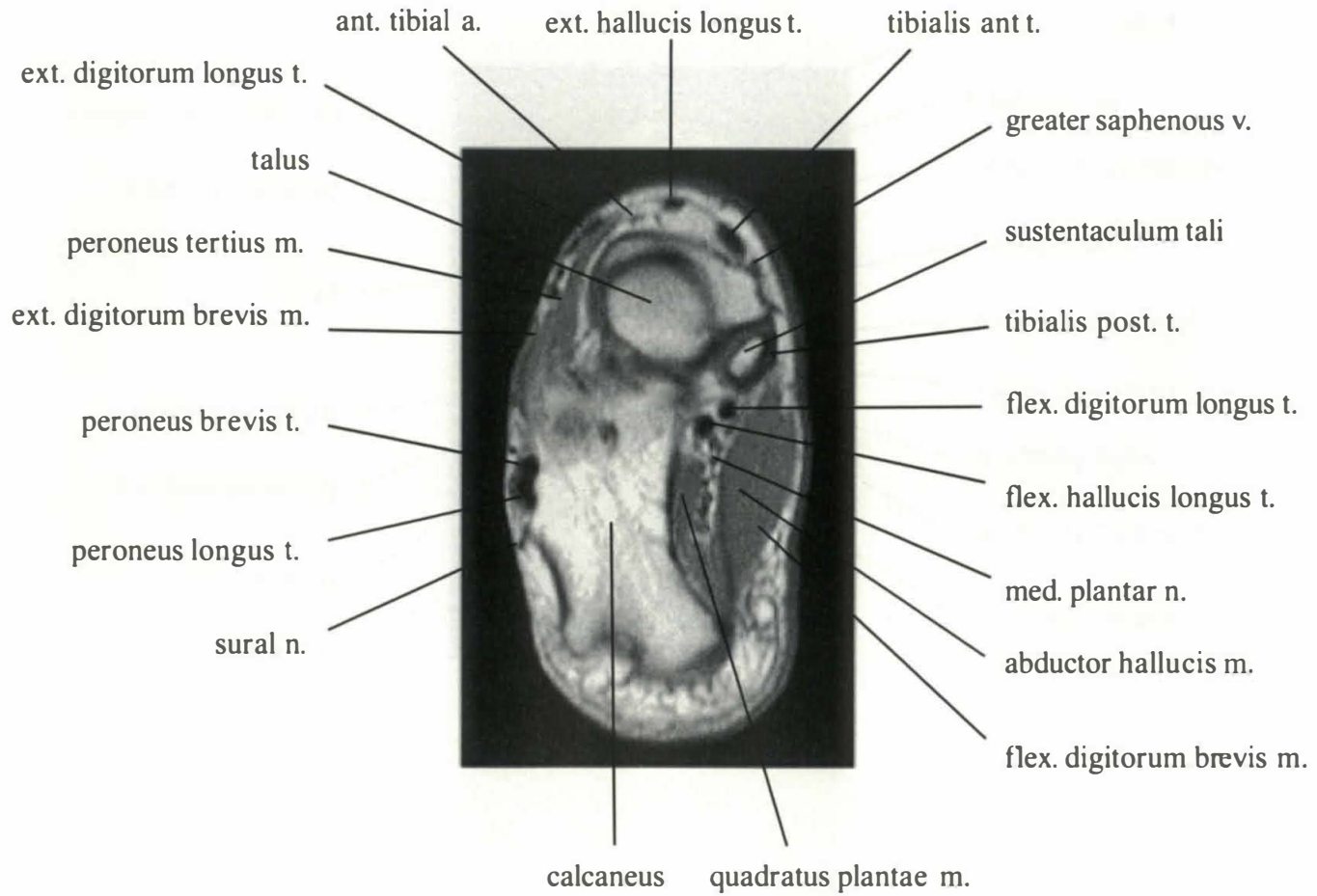
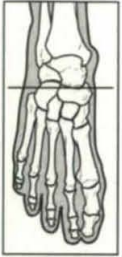
peroneus longus t.

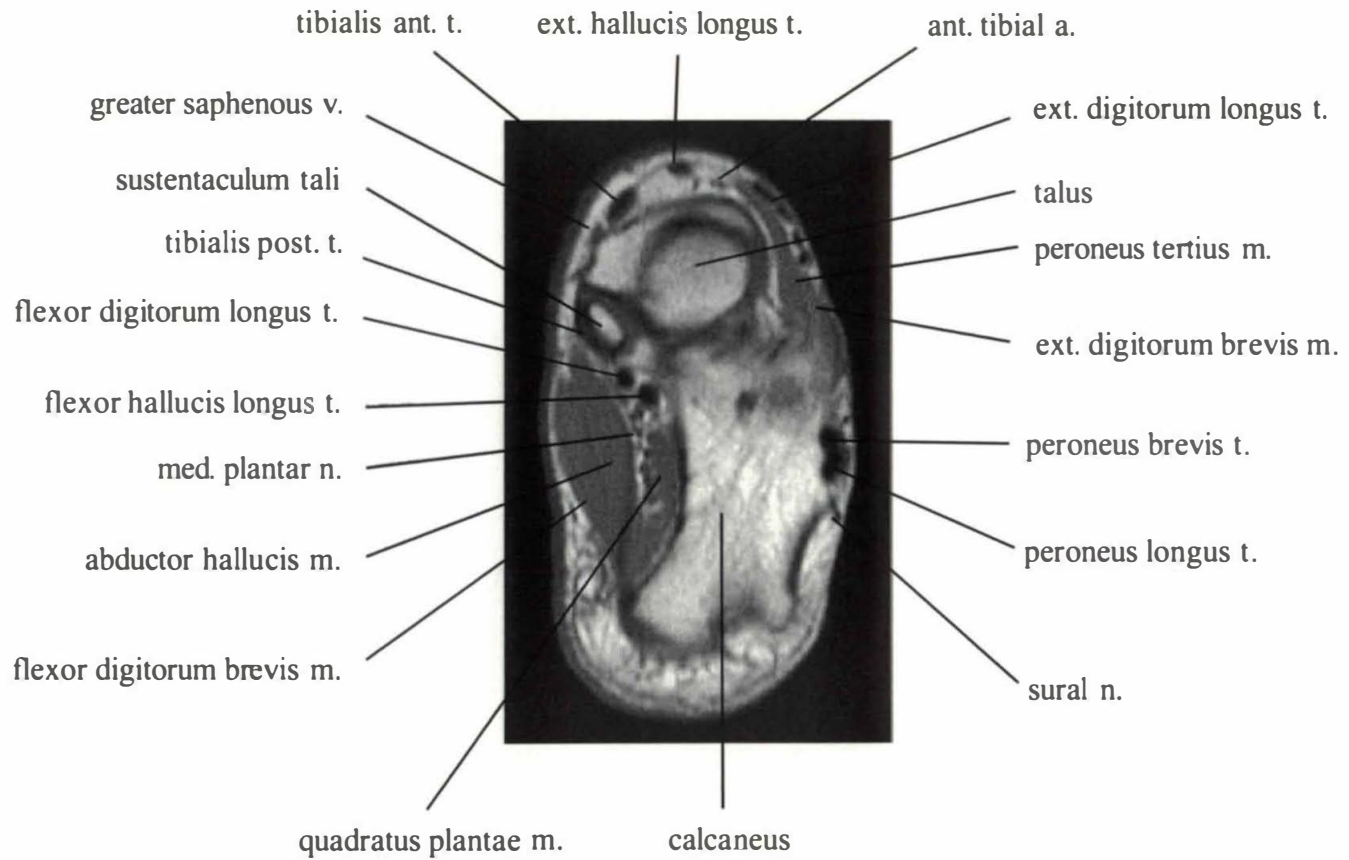
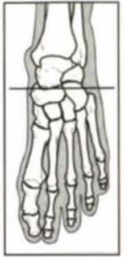
sural n.

calcaneus

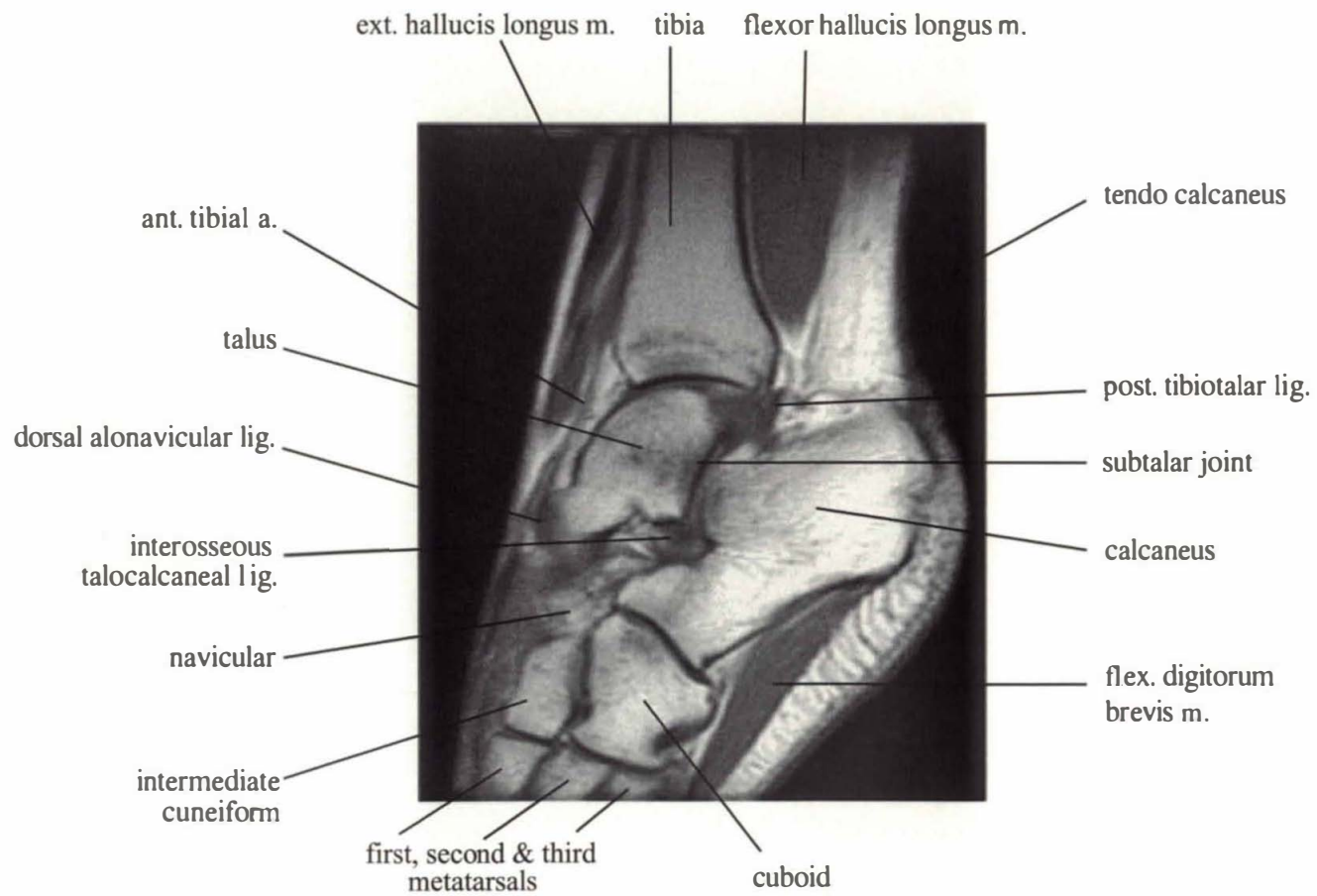


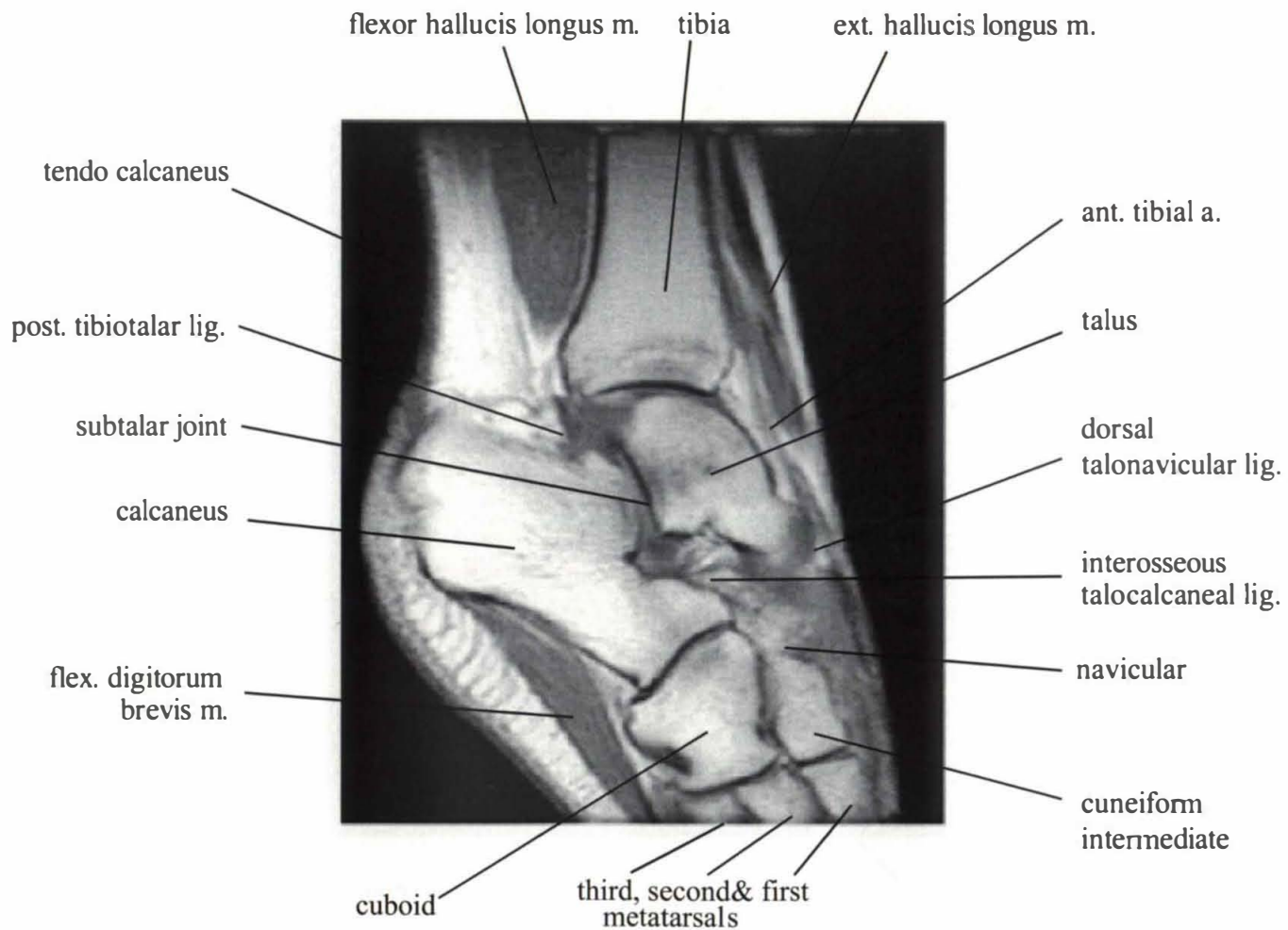


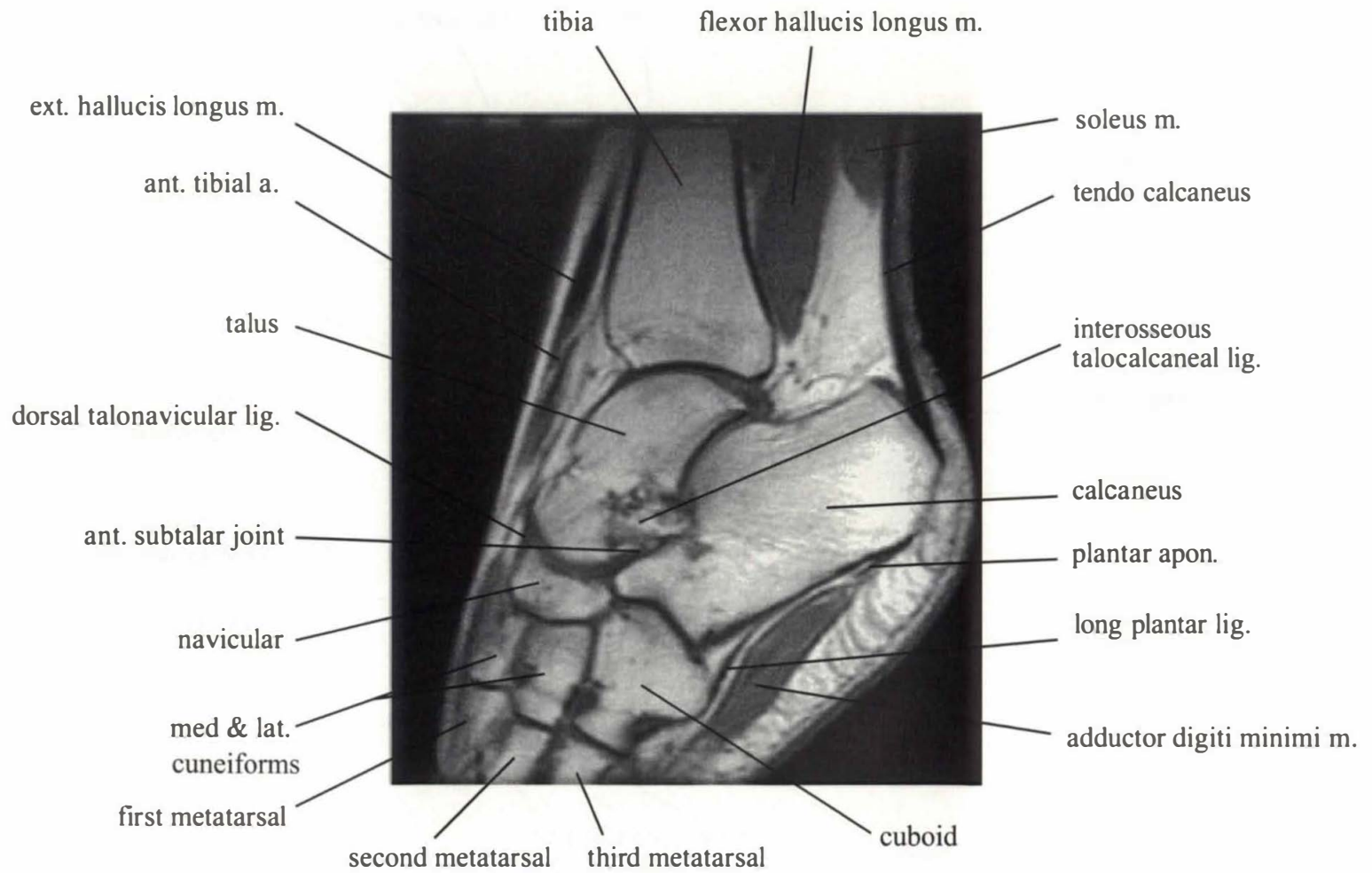


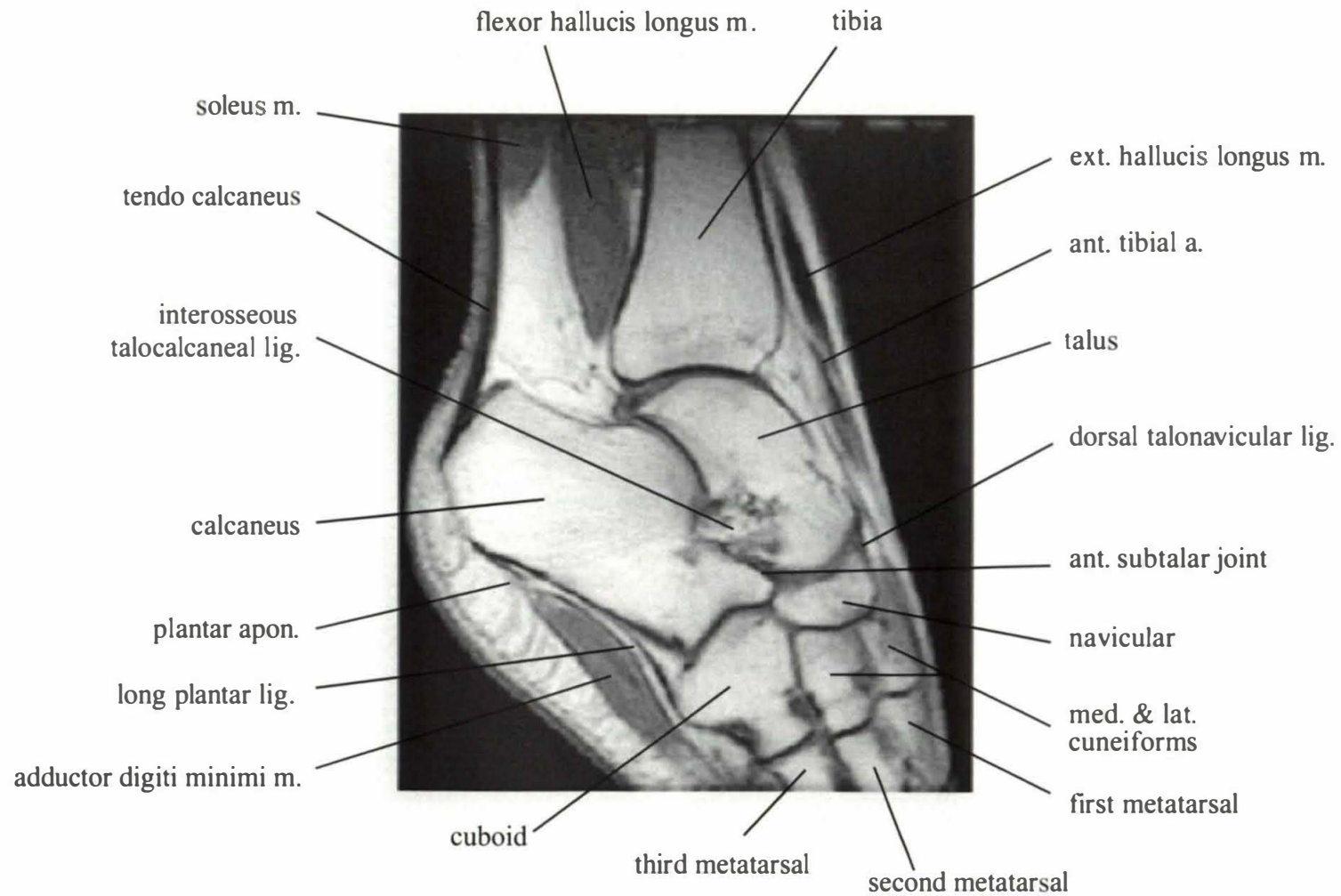


THE ANKLE: SAGITTAL ANATOMY









flexor hallucis longus m.

tibia

soleus m.

tendo calcaneus

interosseous talocalcaneal lig.

calcaneus

plantar apon.

long plantar lig.

adductor digiti minimi m.

cuboid

third metatarsal

second metatarsal

ext. hallucis longus m.

ant. tibial a.

talus

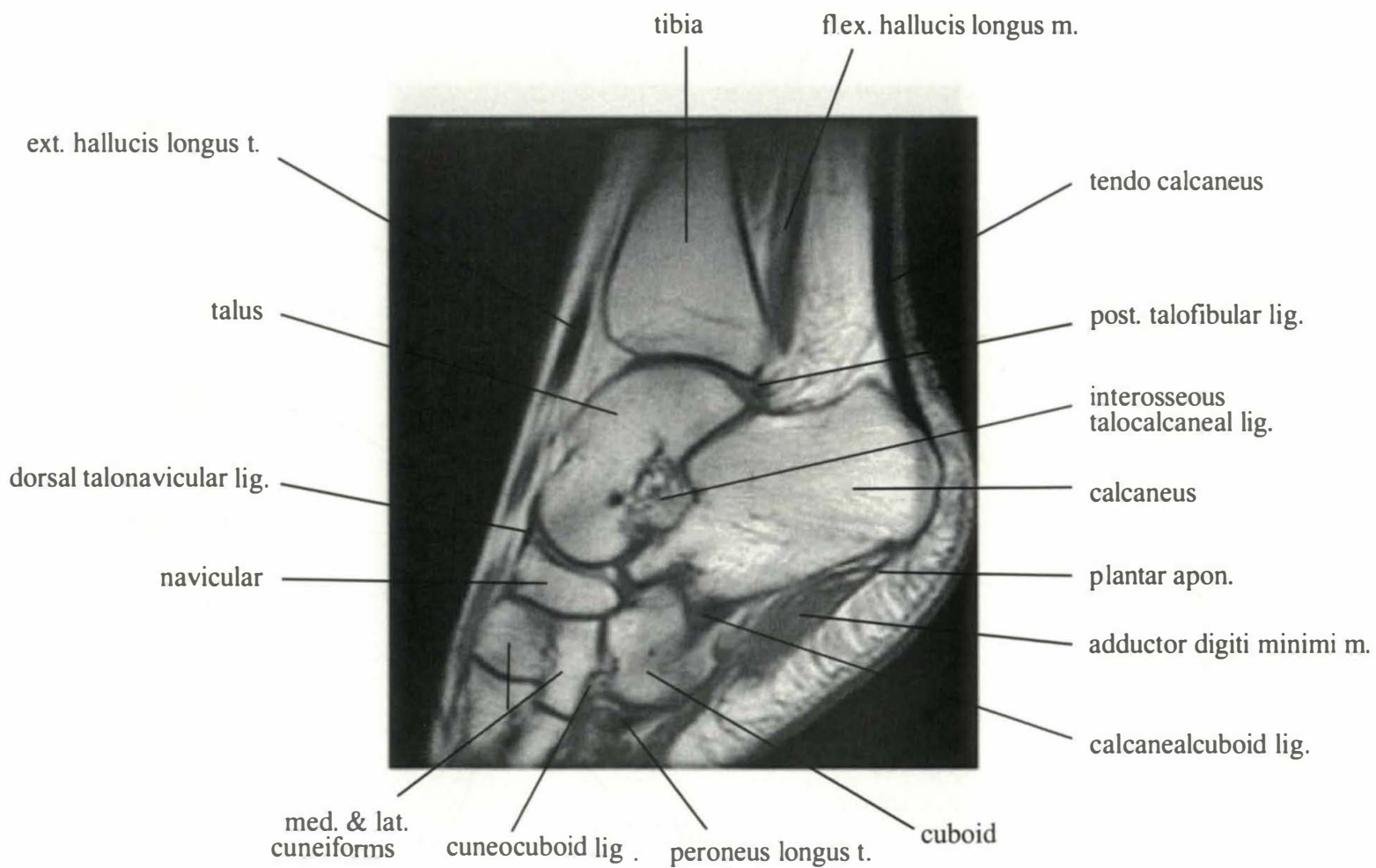
dorsal talonavicular lig.

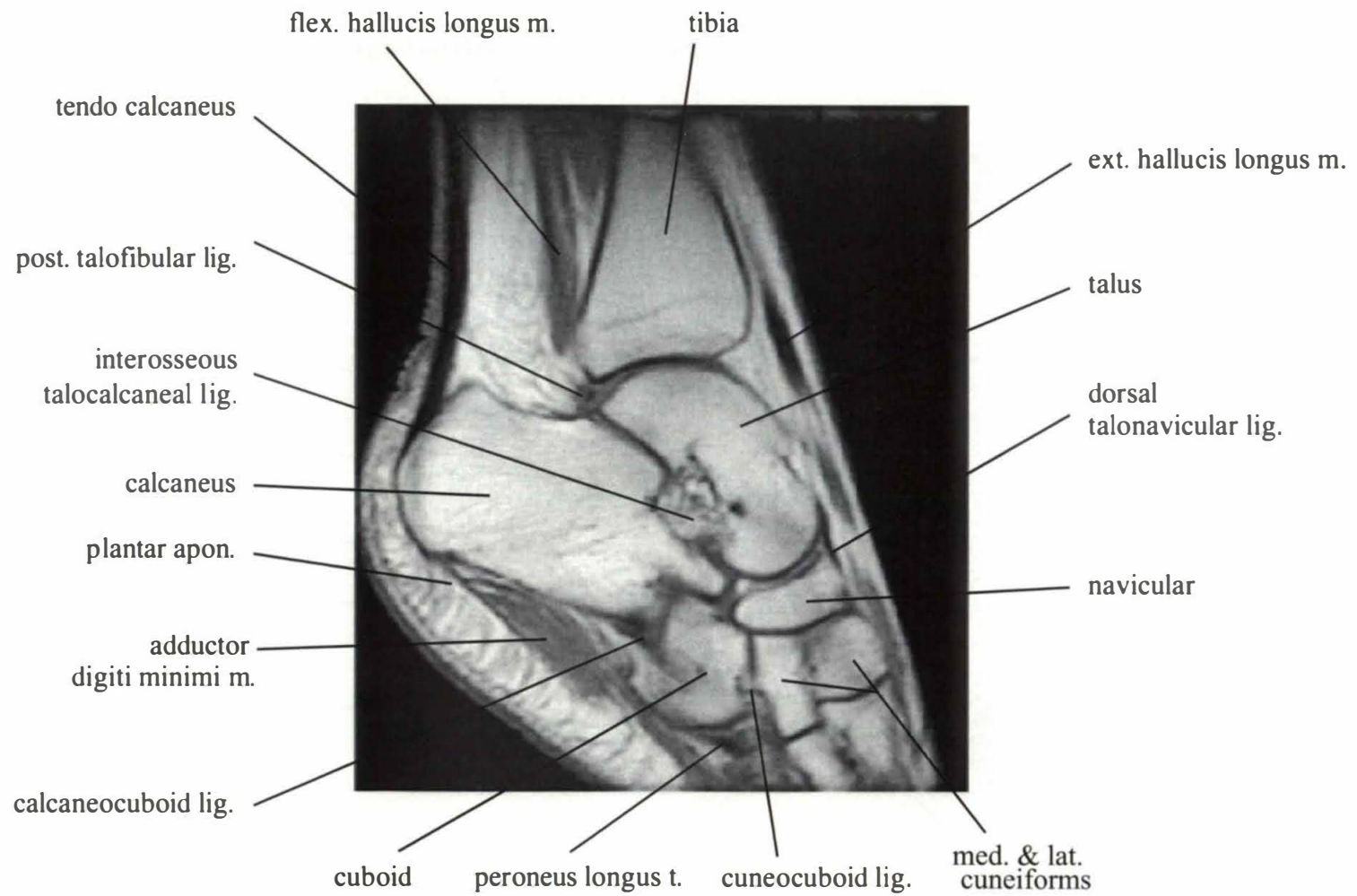
ant. subtalar joint

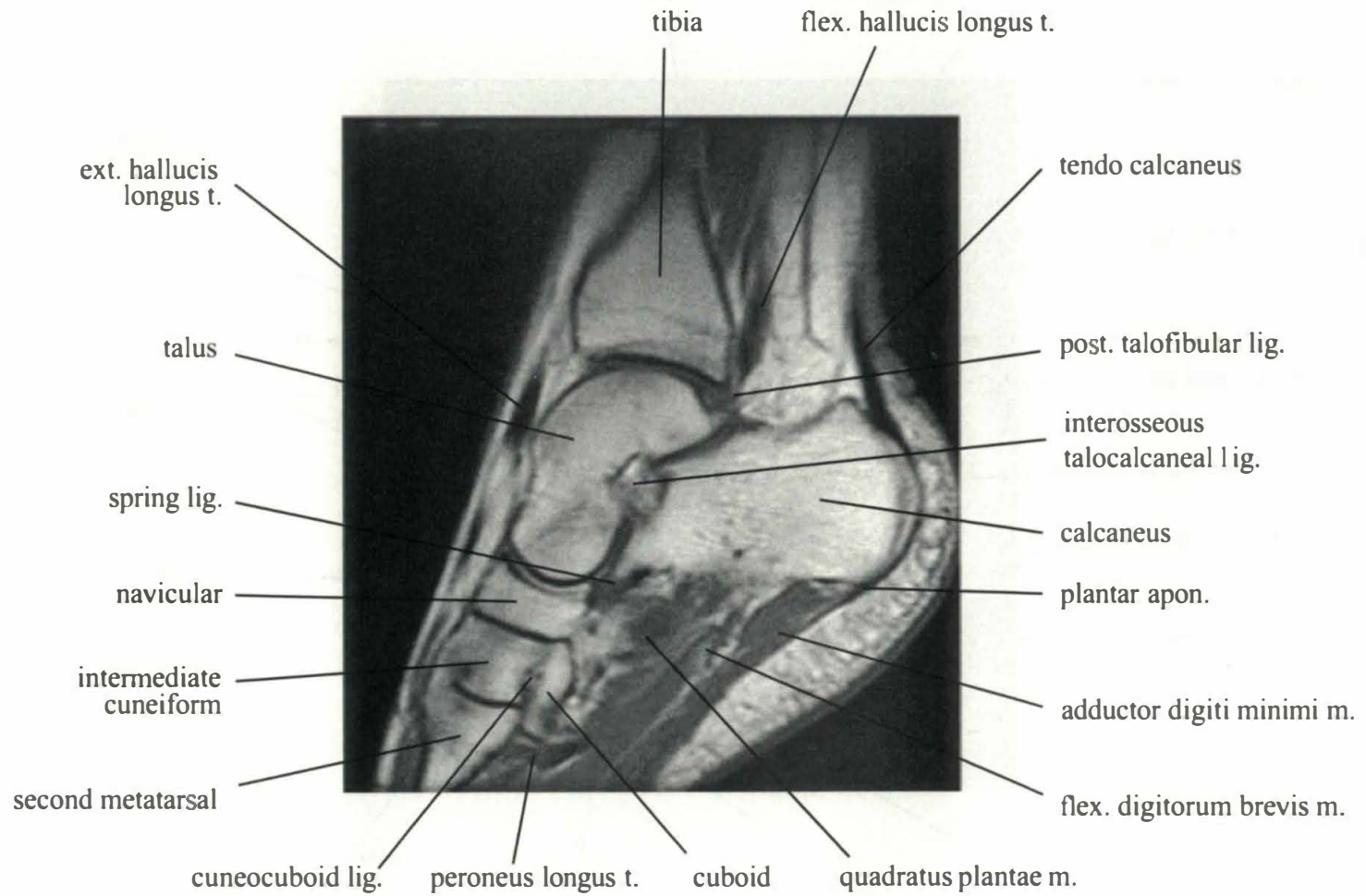
navicular

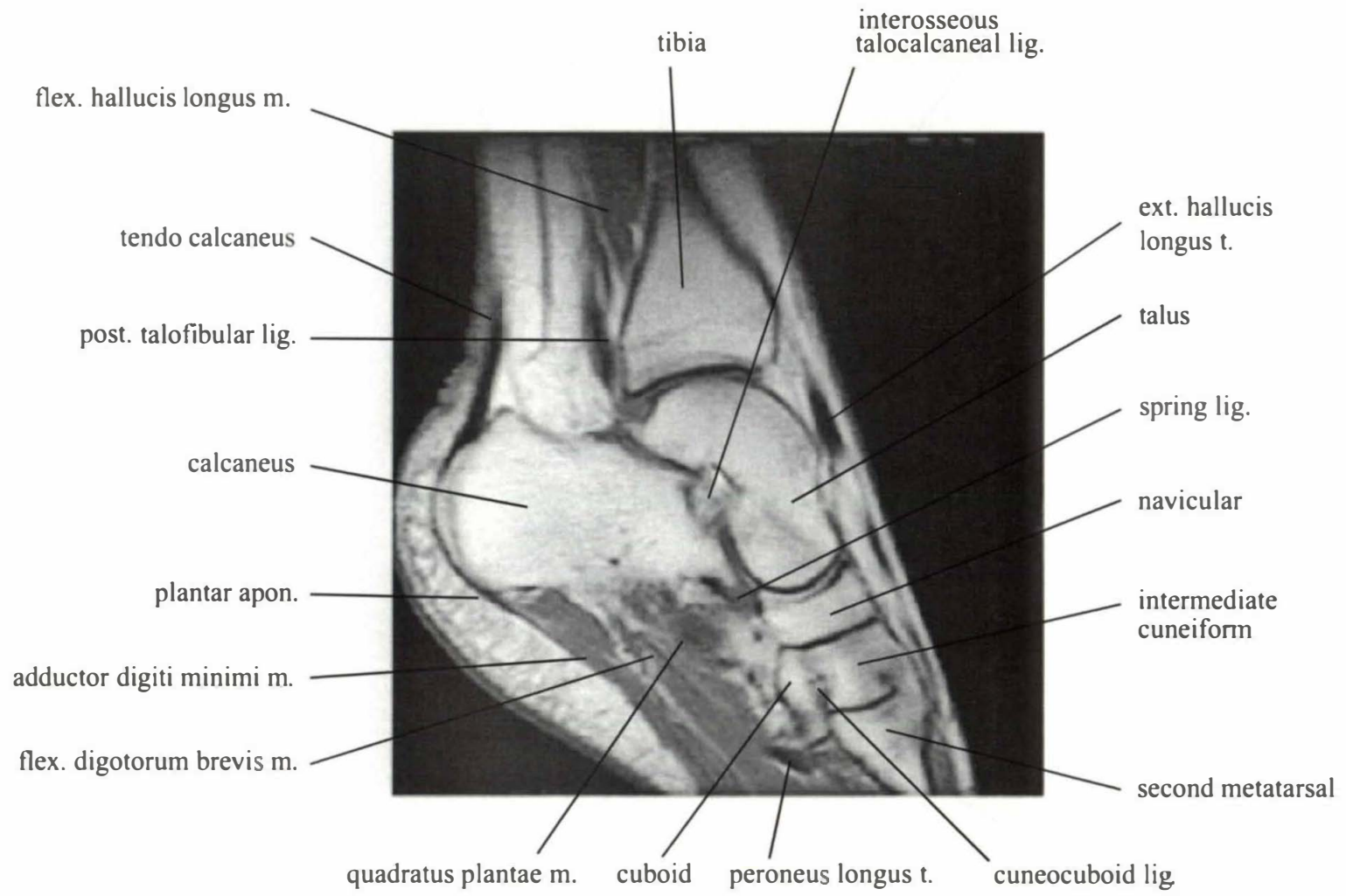
med. & lat. cuneiforms

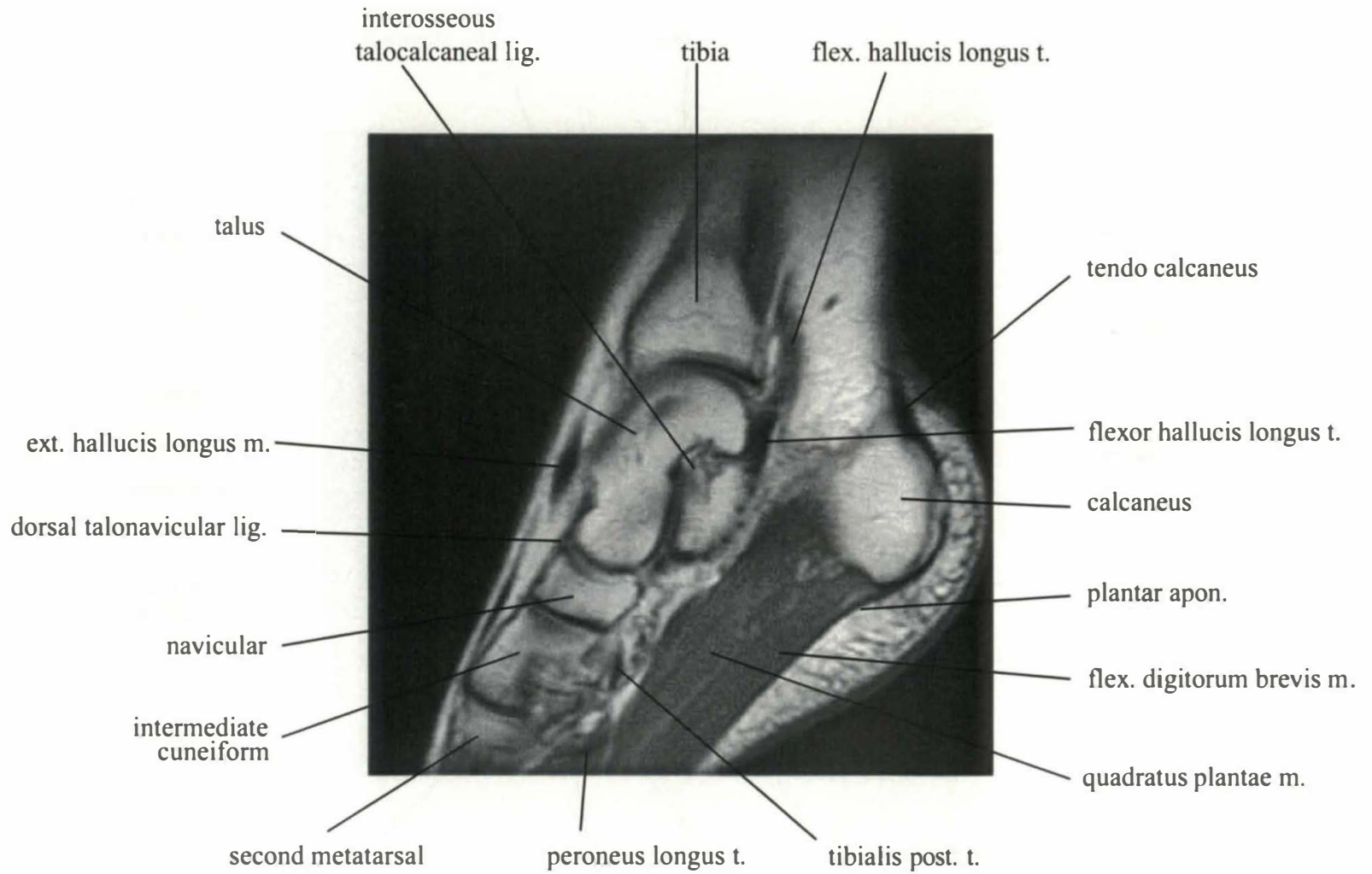
first metatarsal

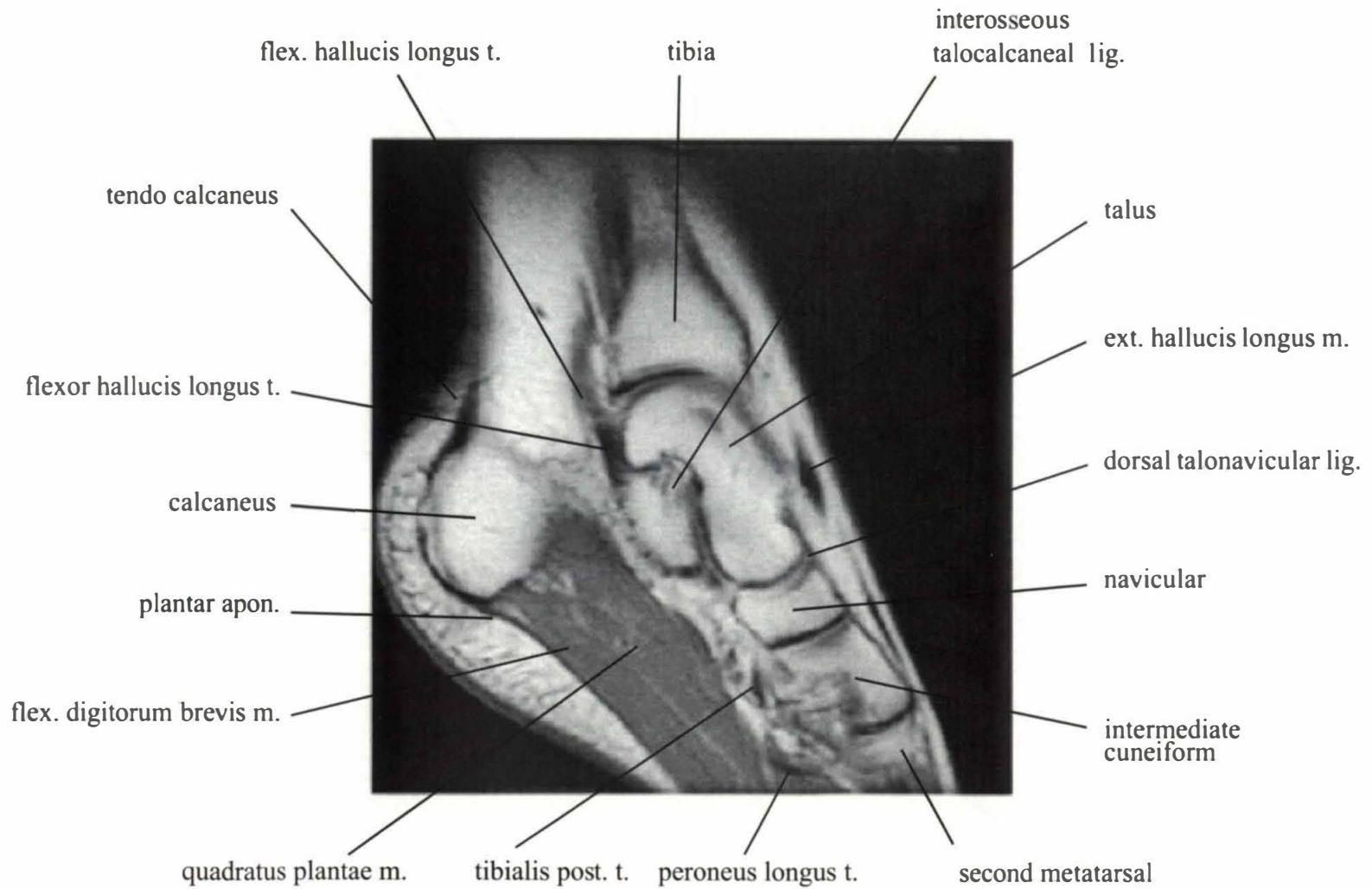


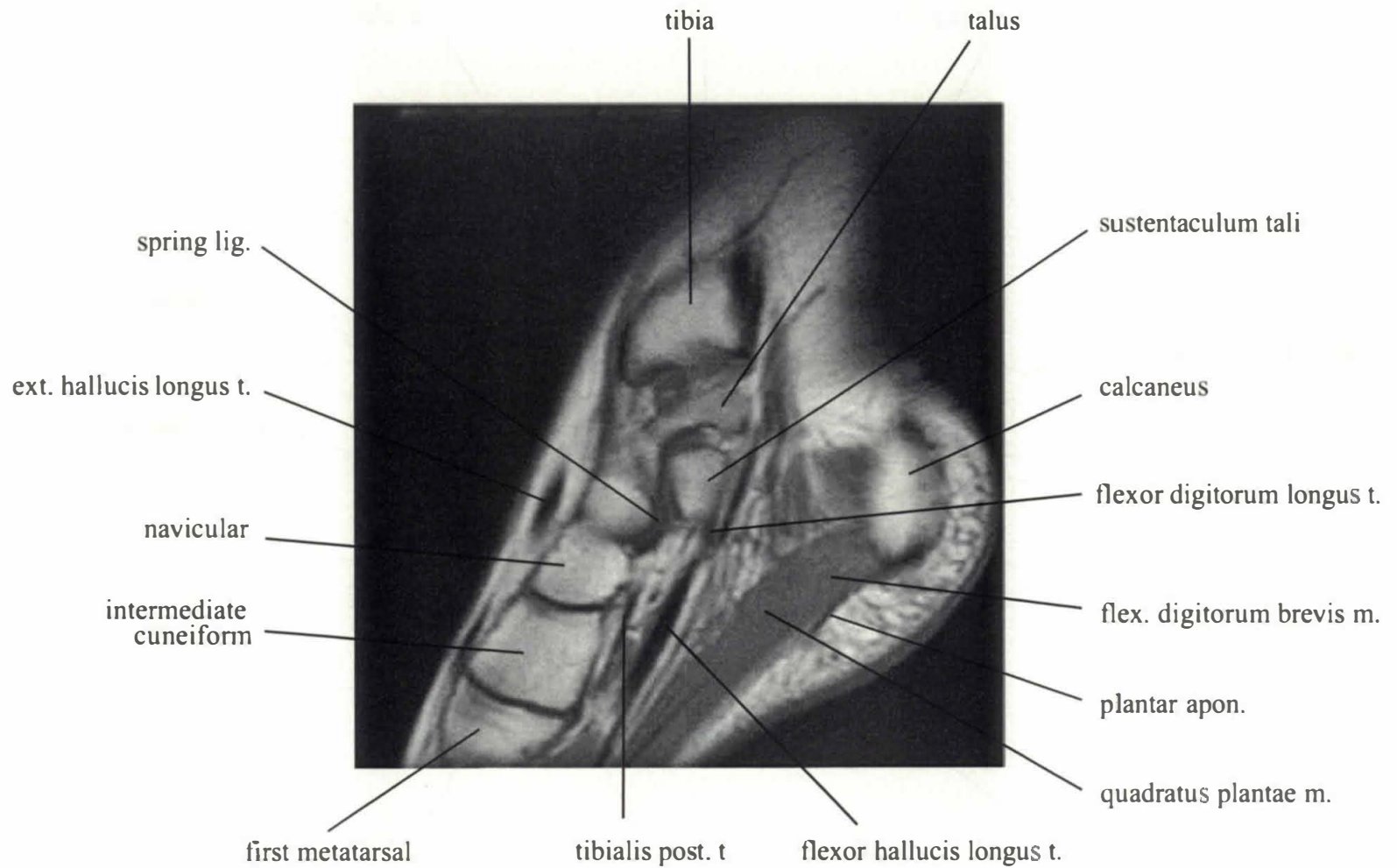
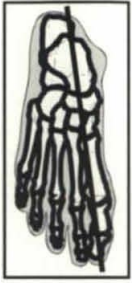


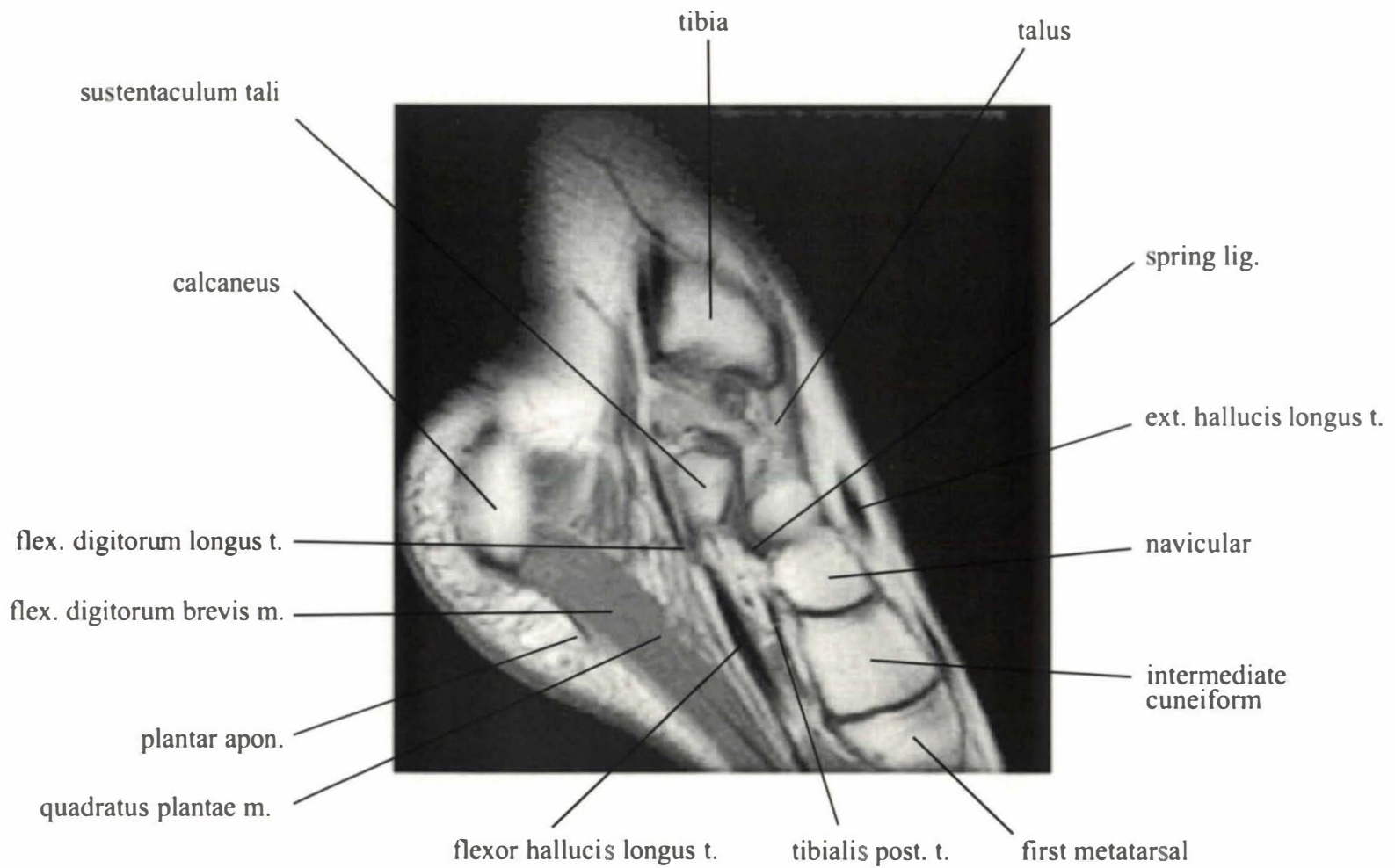












tibia

talus

sustentaculum tali

calcaneus

spring lig.

ext. hallucis longus t.

flex. digitorum longus t.

navicular

flex. digitorum brevis m.

intermediate cuneiform

plantar apon.

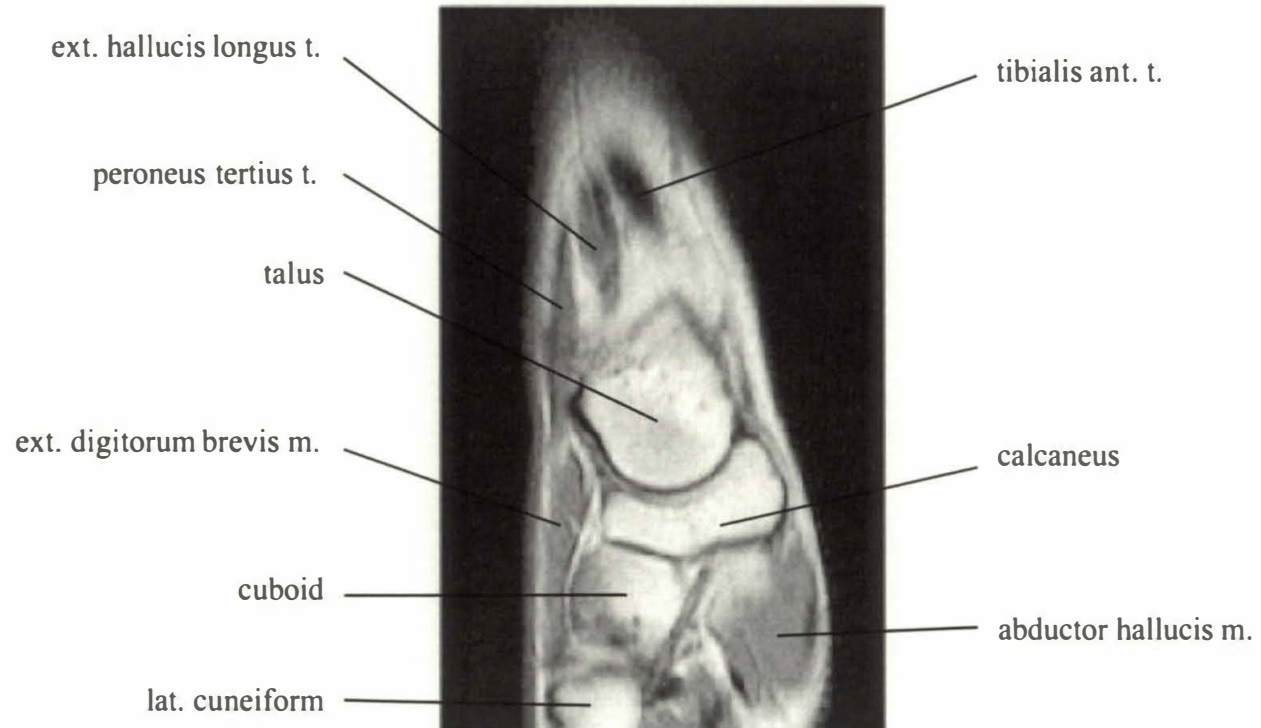
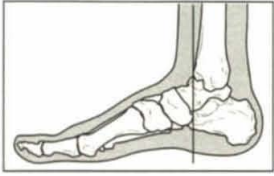
quadratus plantae m.

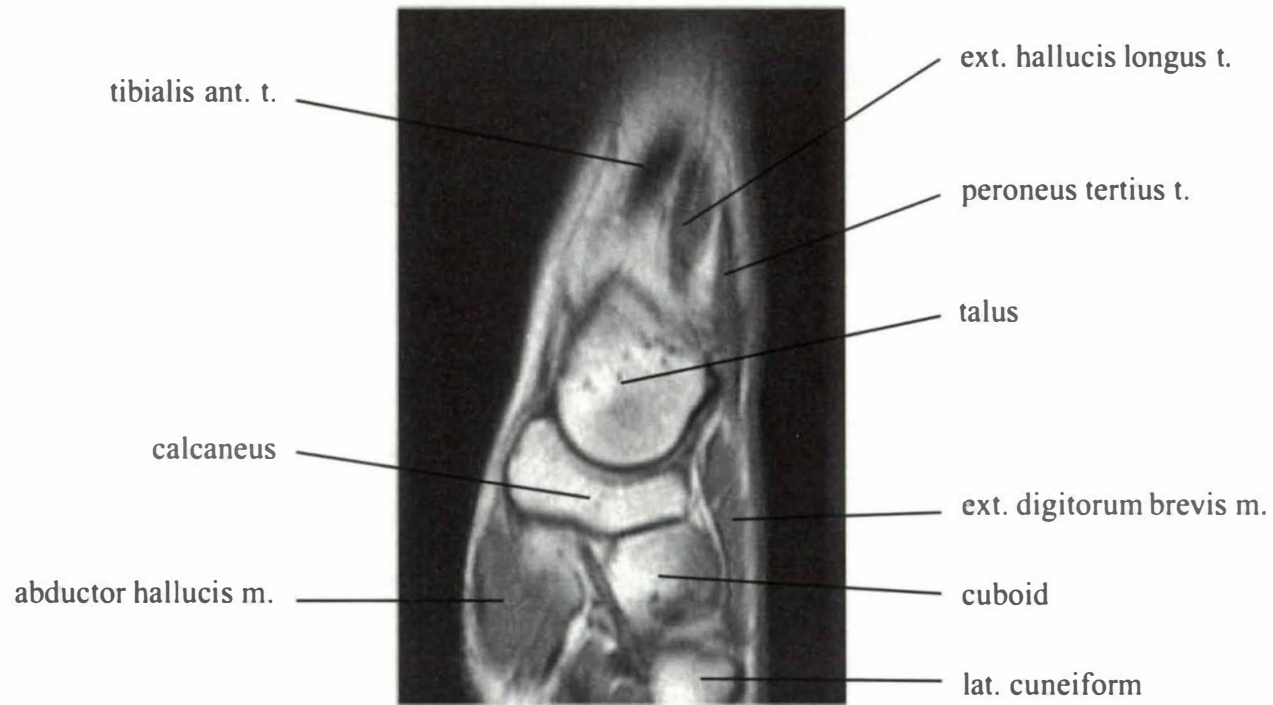
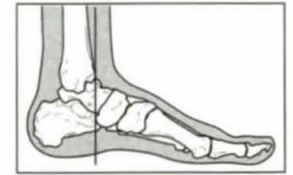
flexor hallucis longus t.

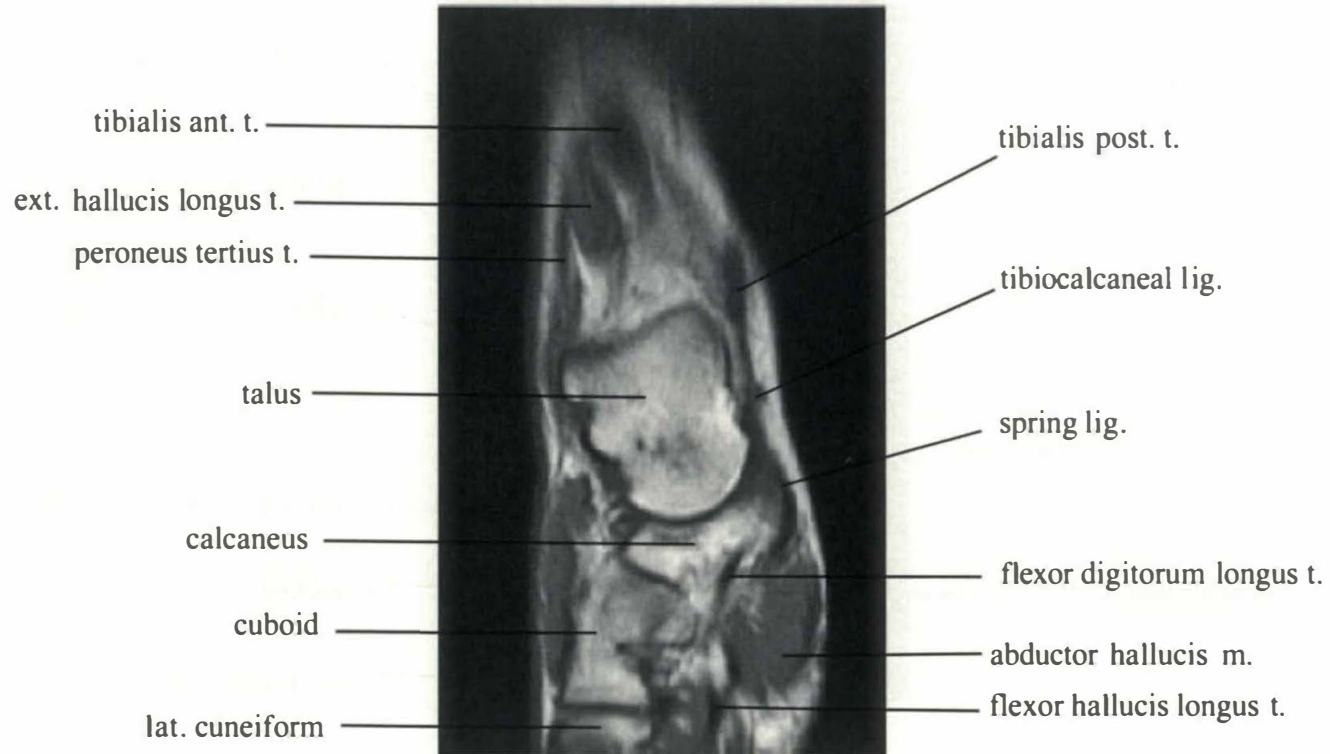
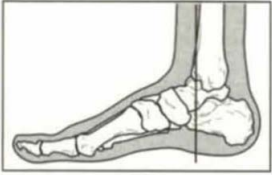
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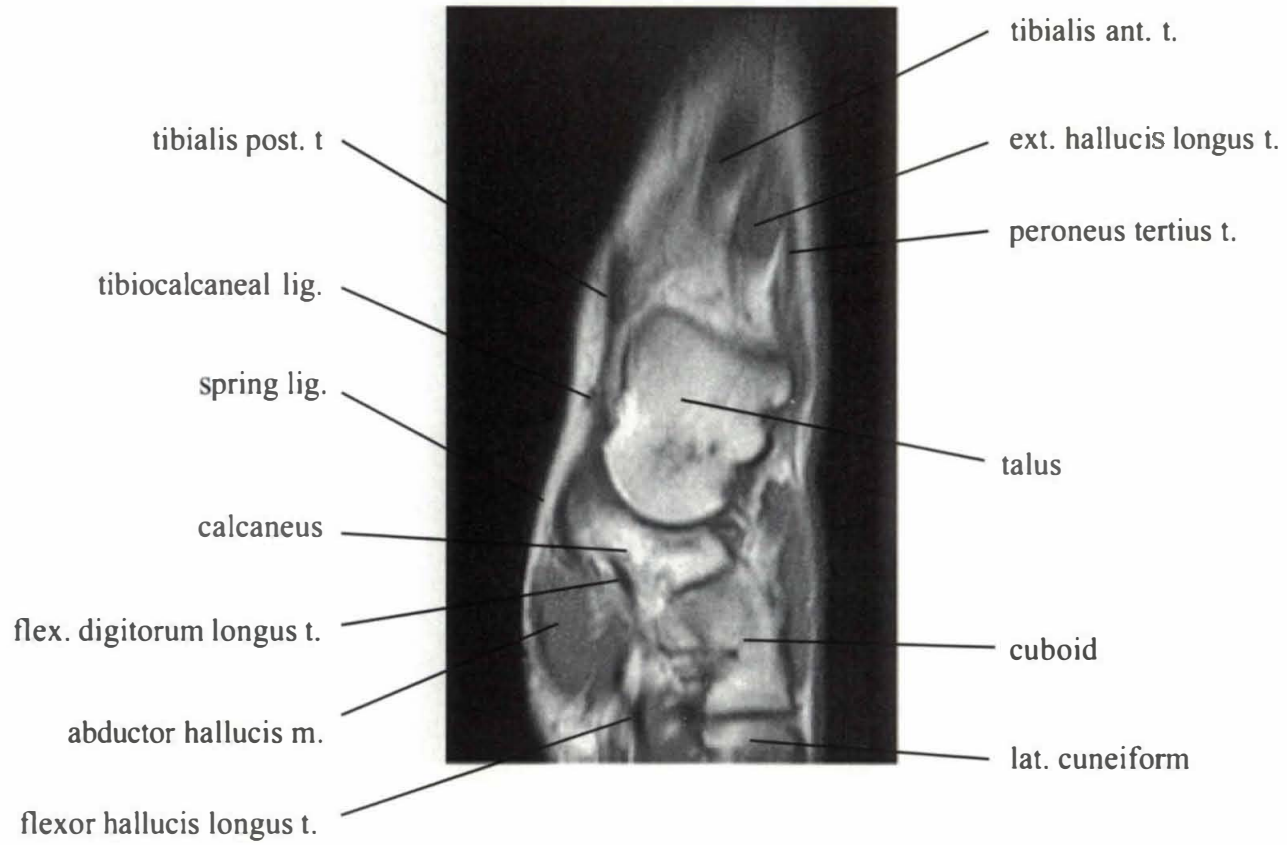
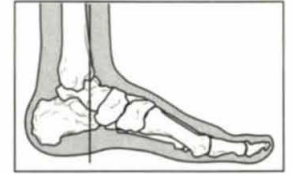
first metatarsal

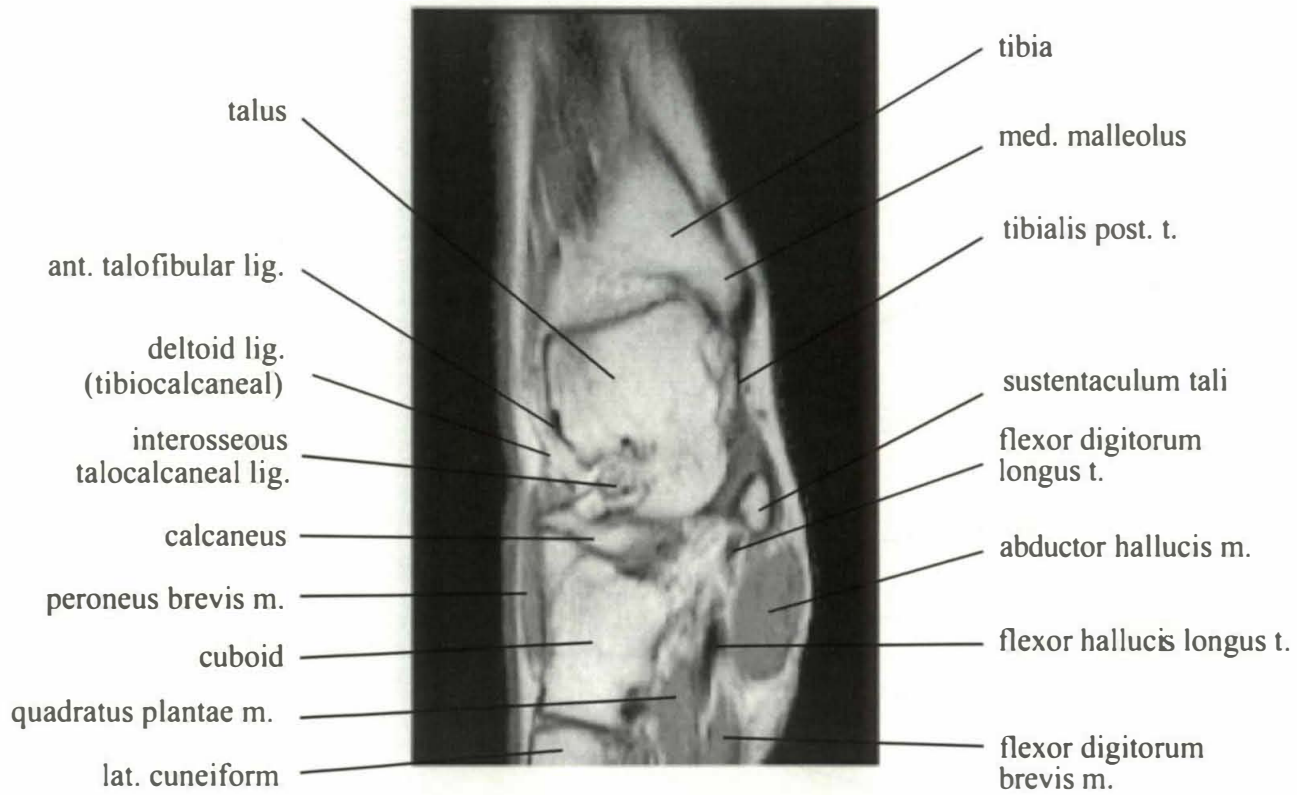
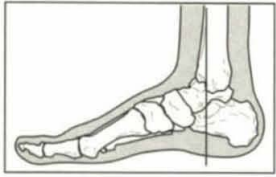
THE ANKLE: CORONAL ANATOMY

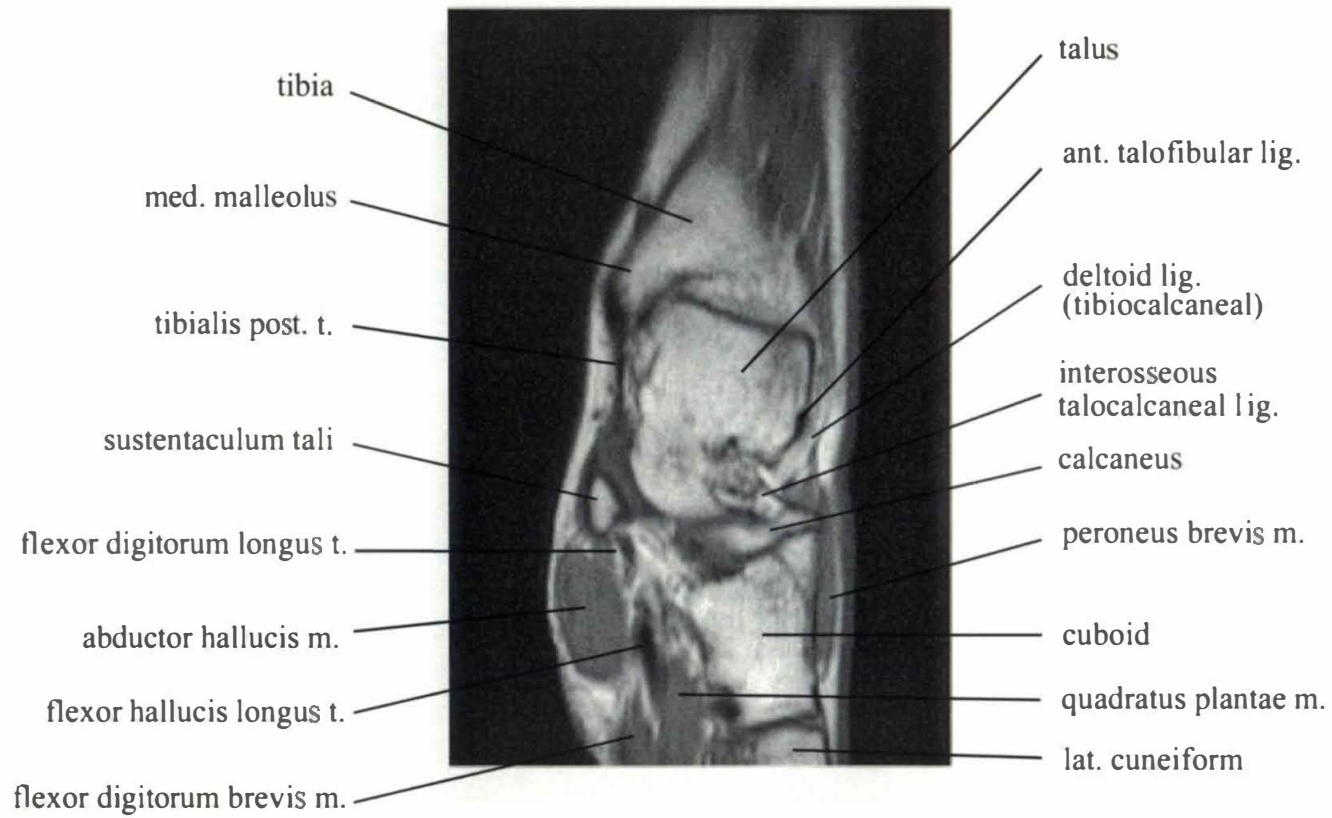
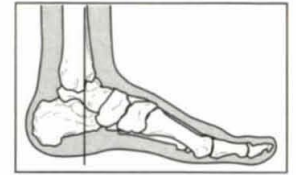


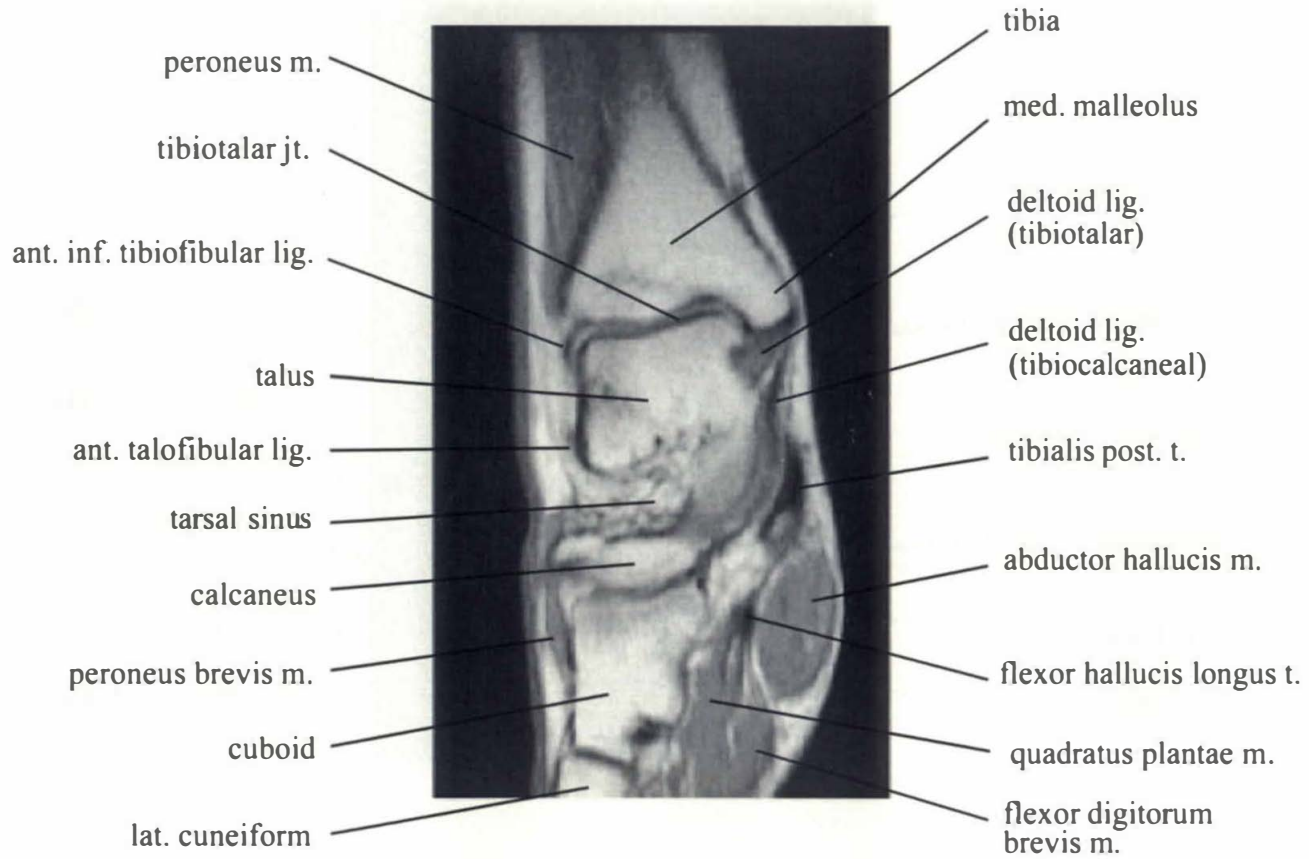
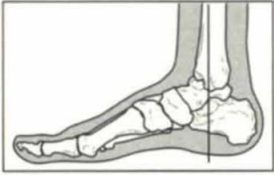


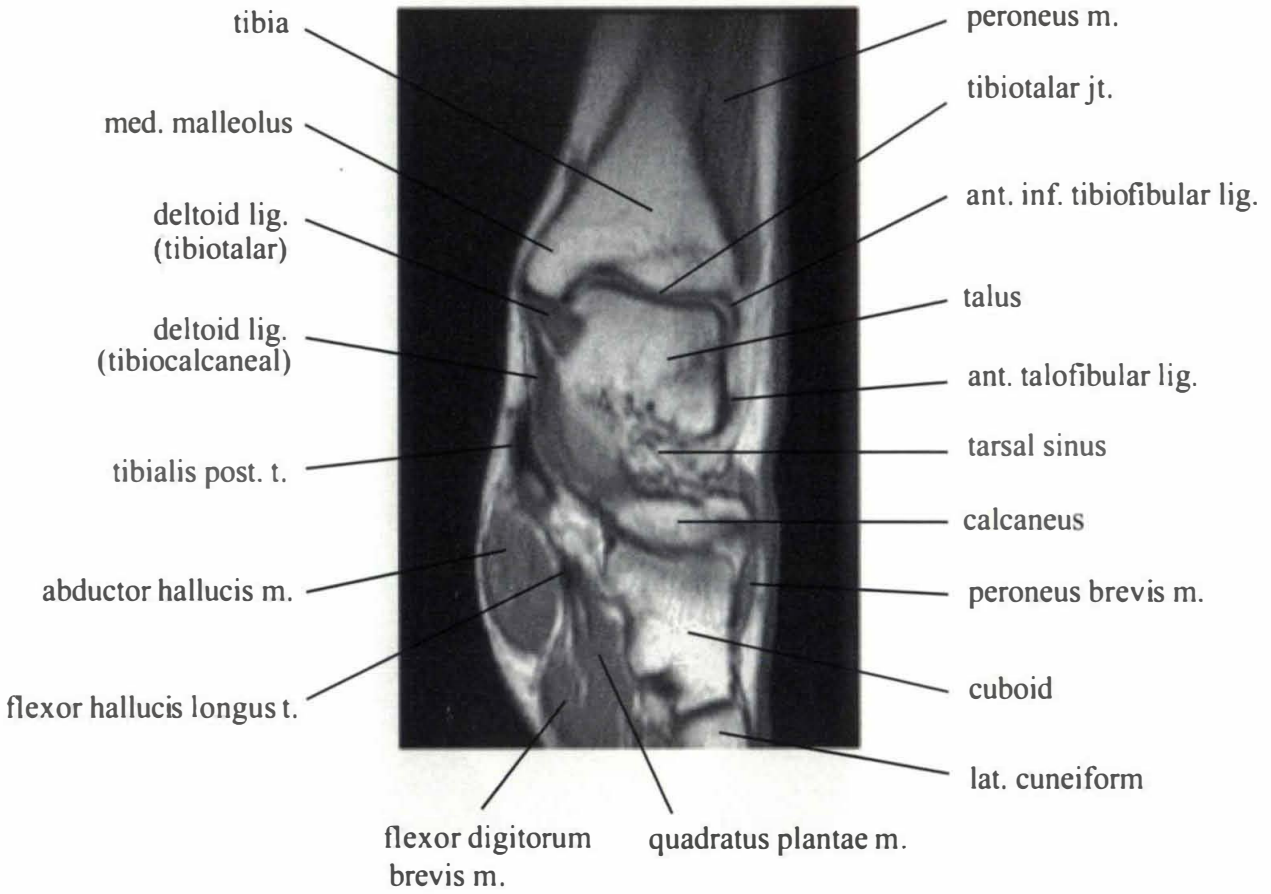
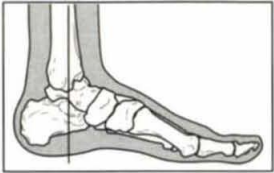


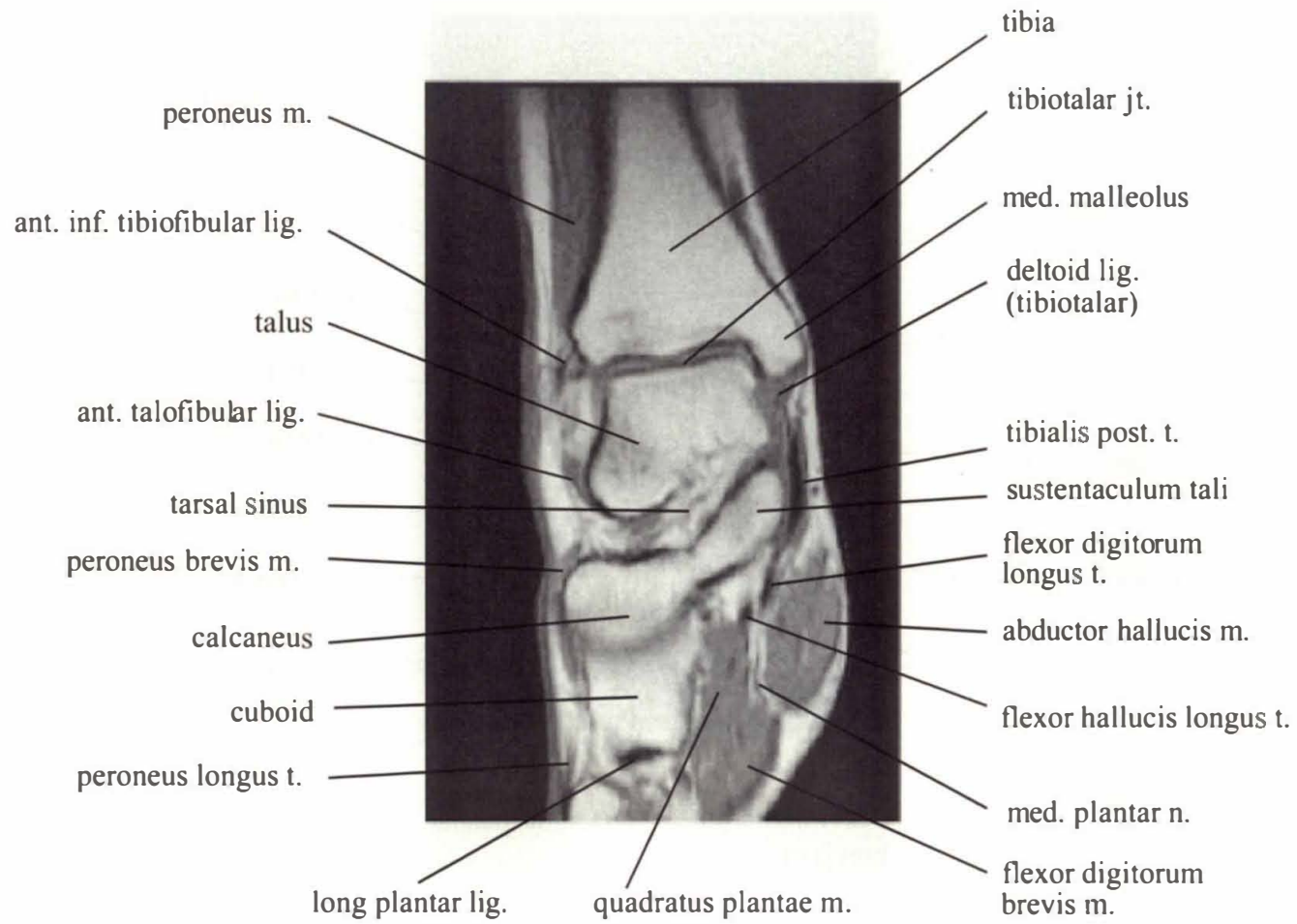
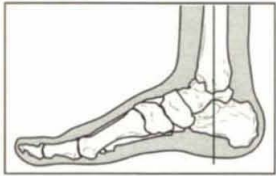


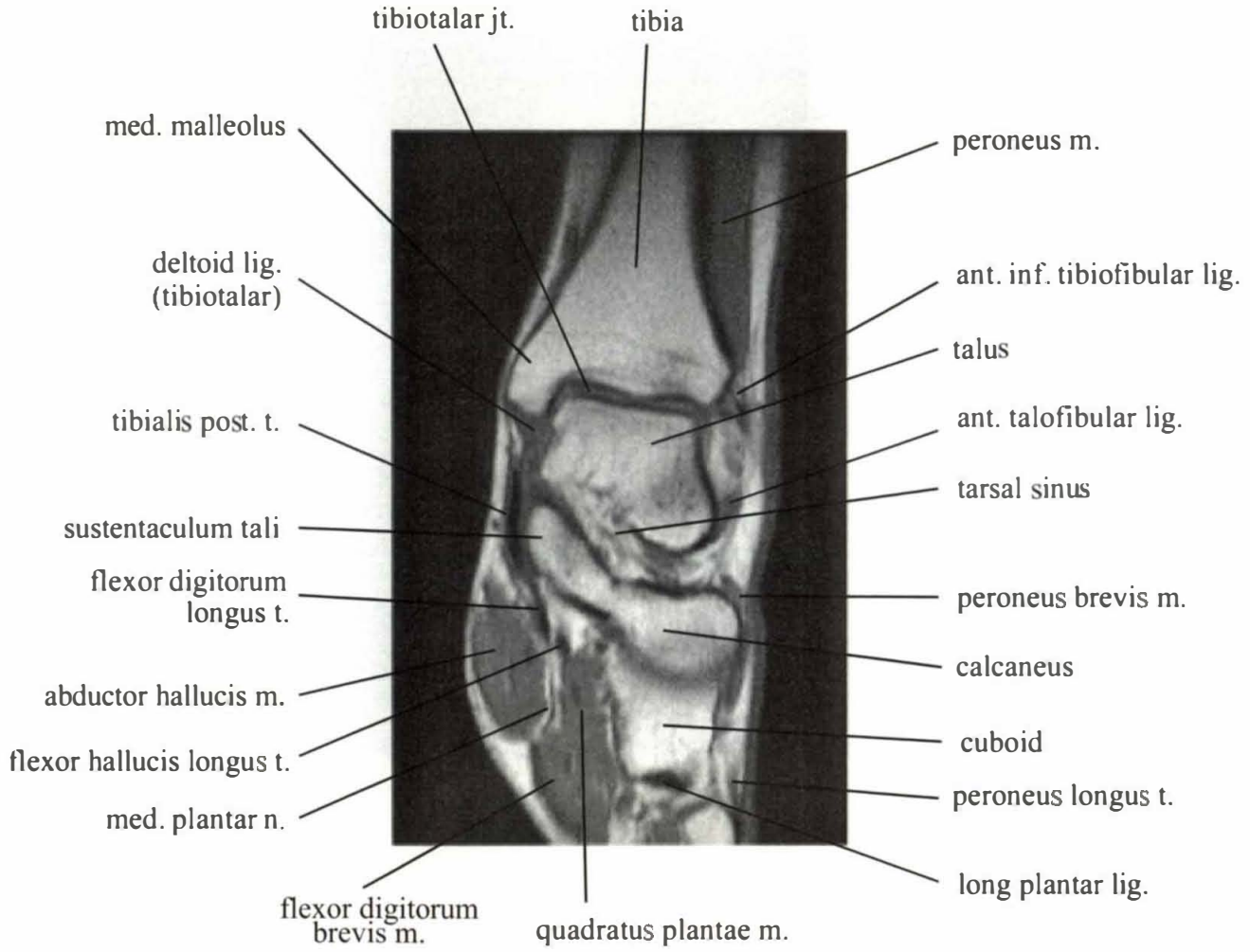
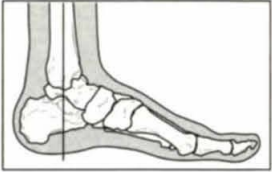


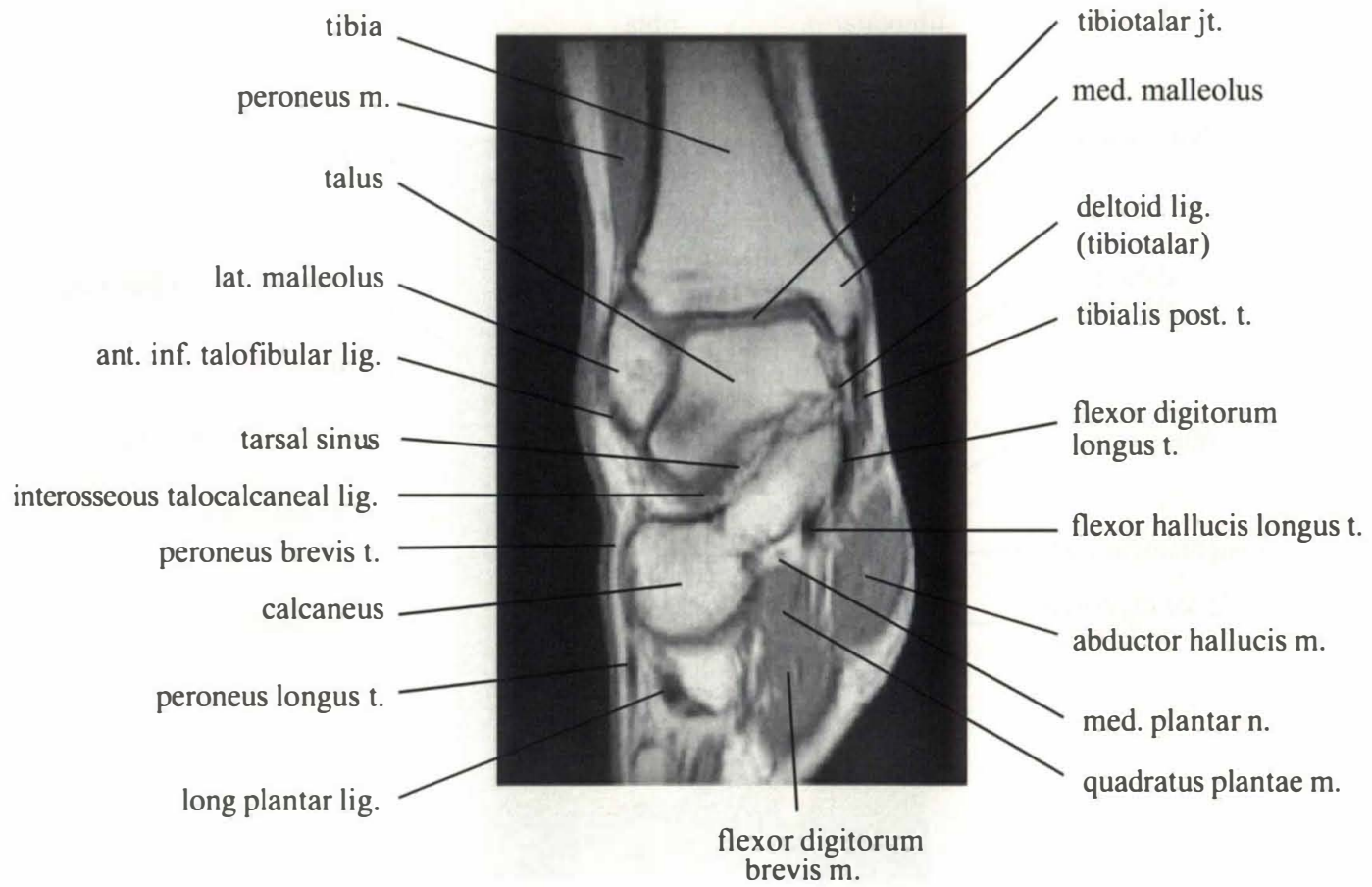
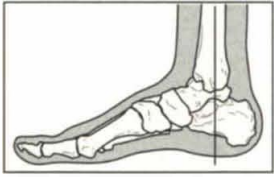


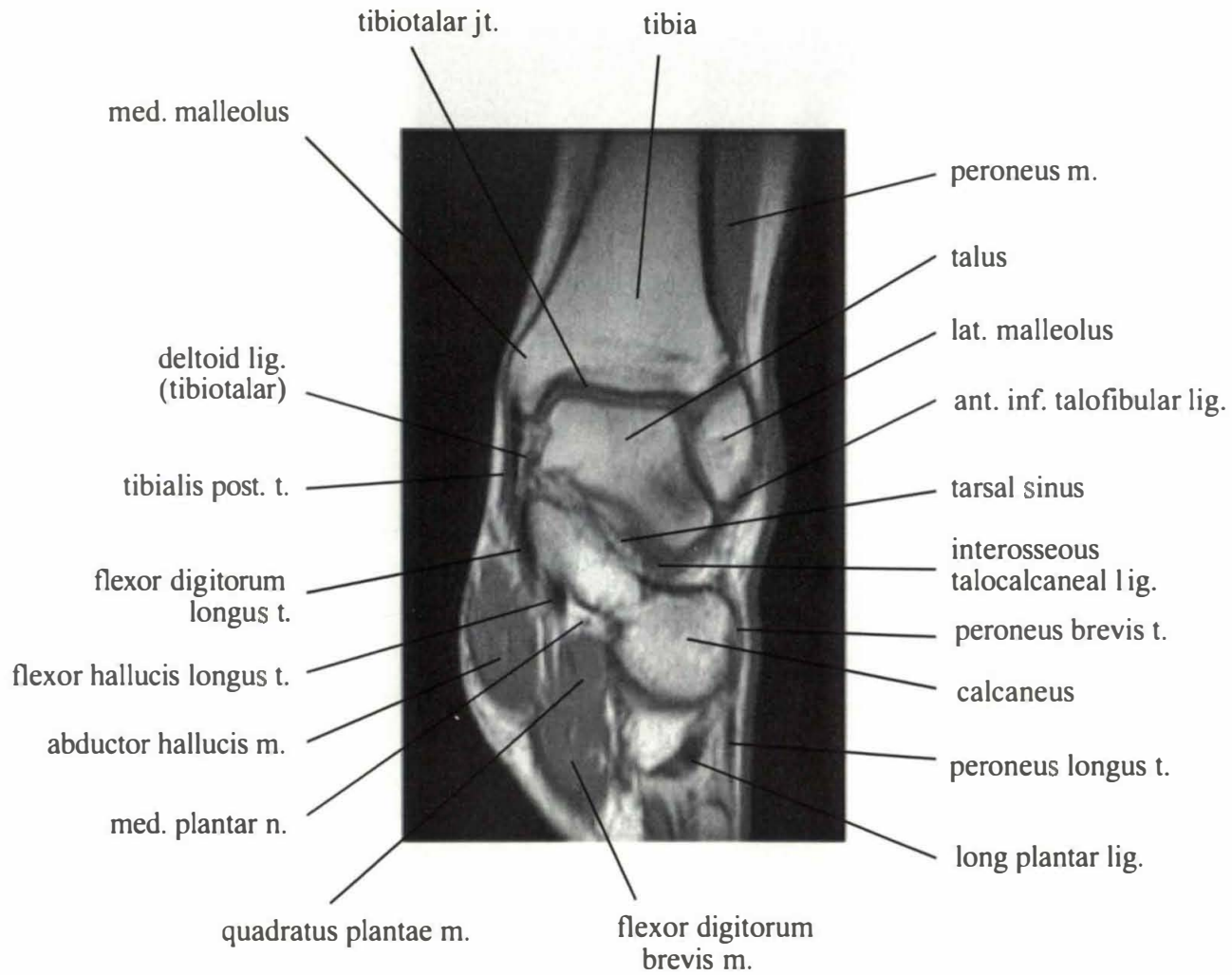
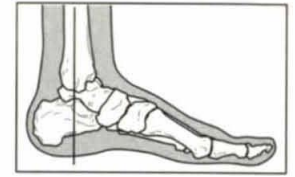


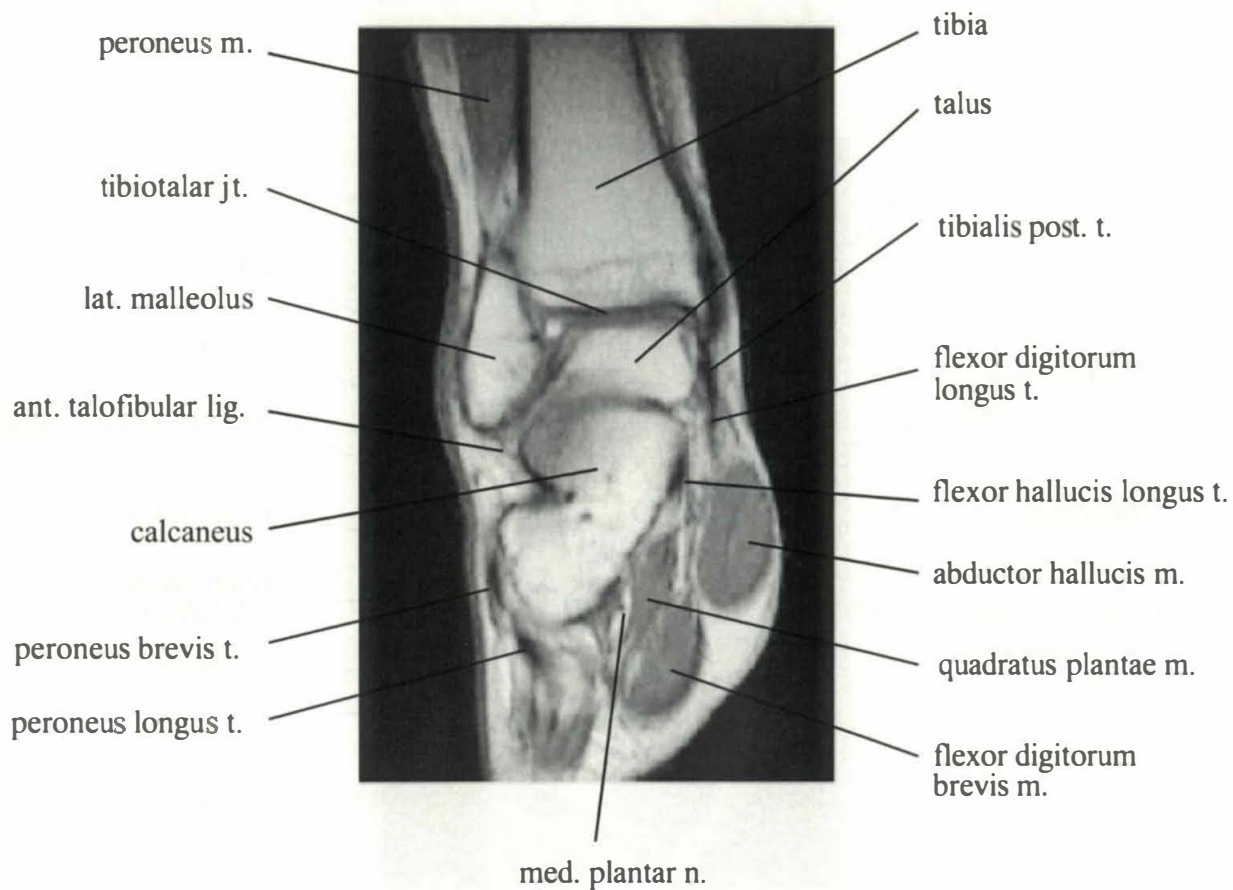
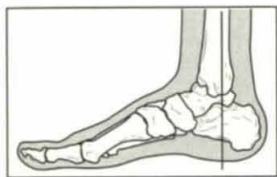


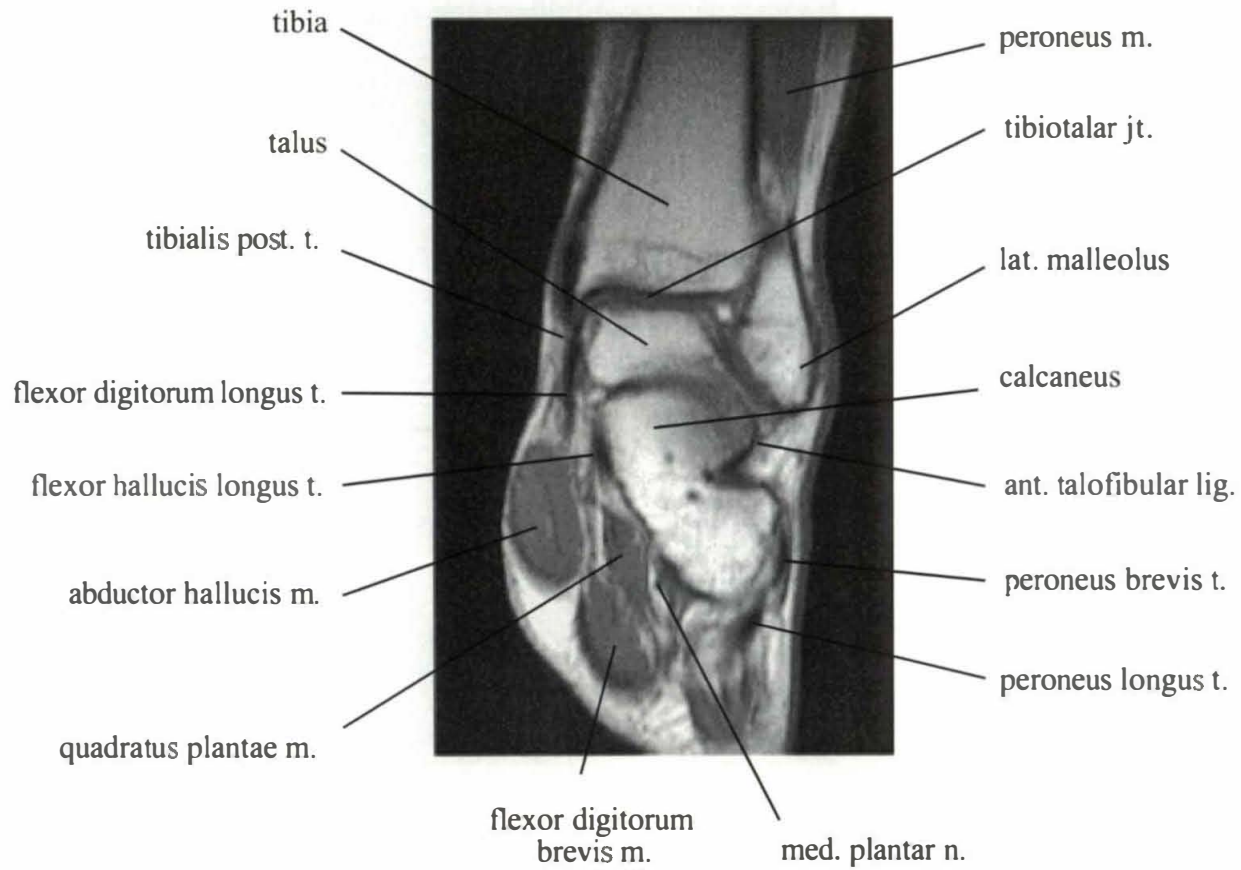
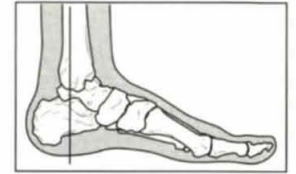


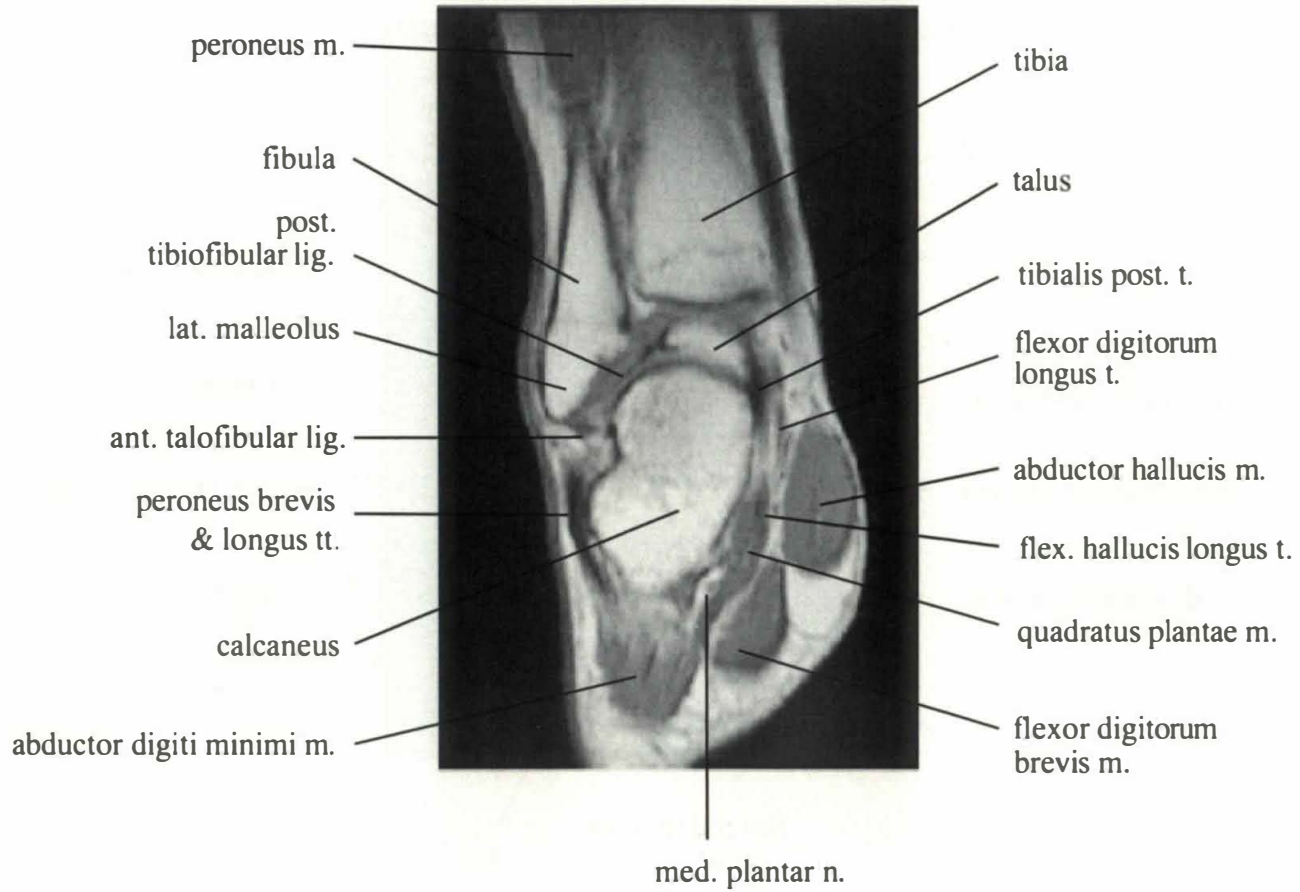
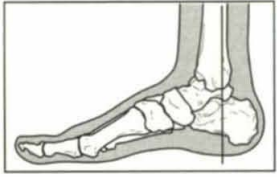


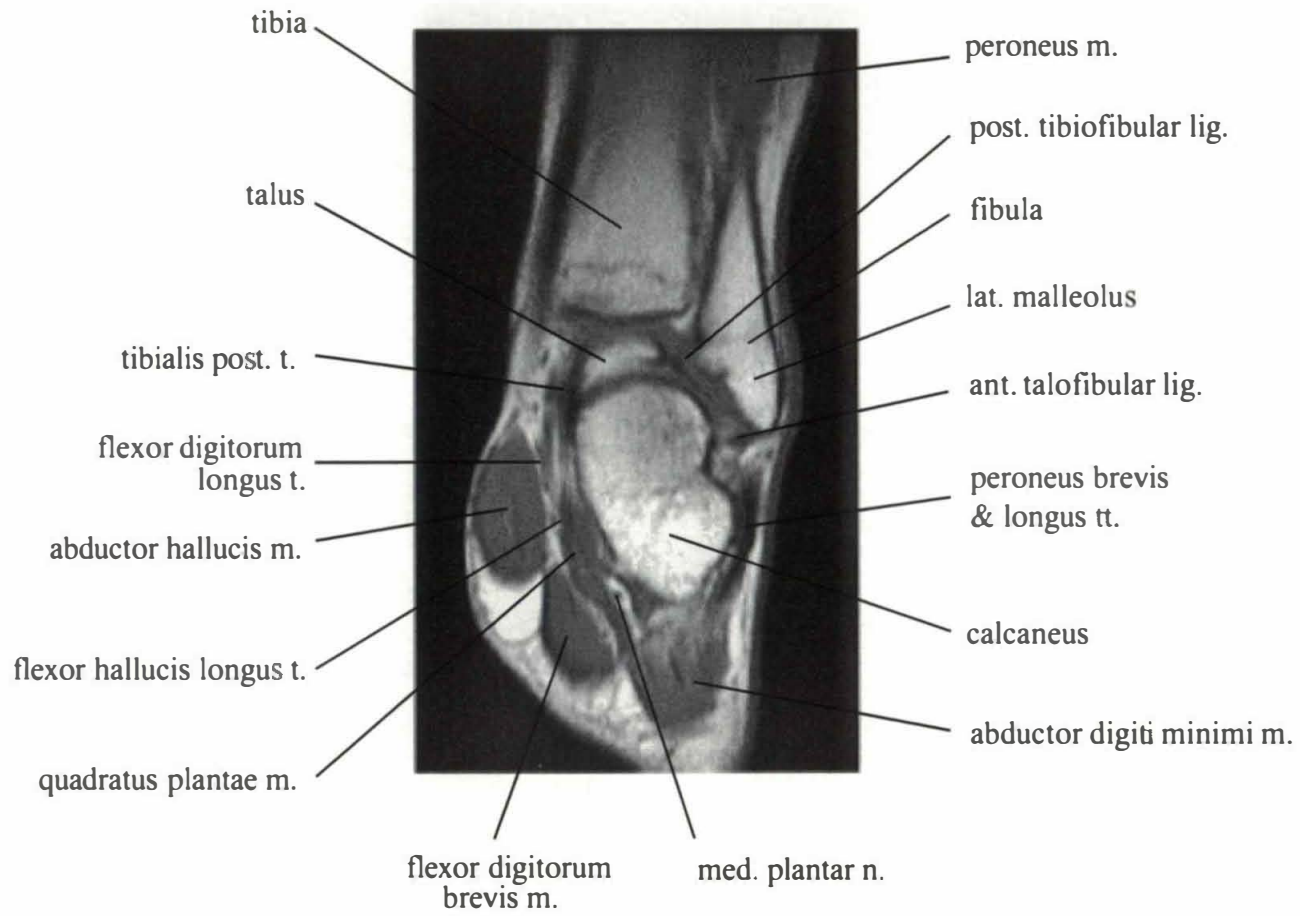
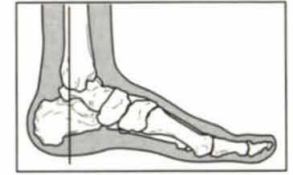


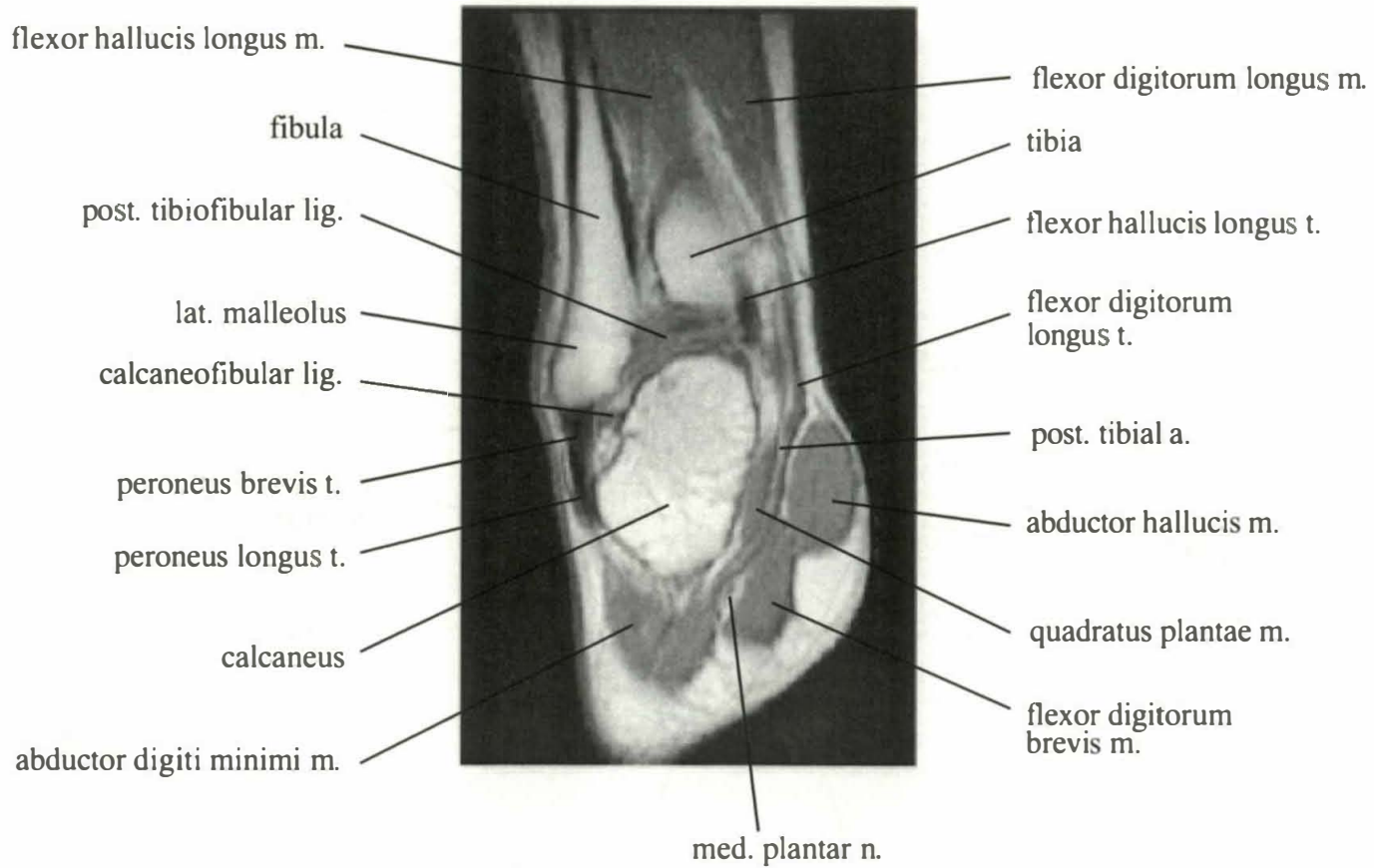
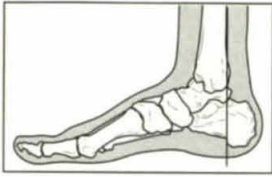












flexor hallucis longus m.

fibula

post. tibiofibular lig.

lat. malleolus

calcaneofibular lig.

peroneus brevis t.

peroneus longus t.

calcaneus

abductor digiti minimi m.

flexor digitorum longus m.

tibia

flexor hallucis longus t.

flexor digitorum longus t.

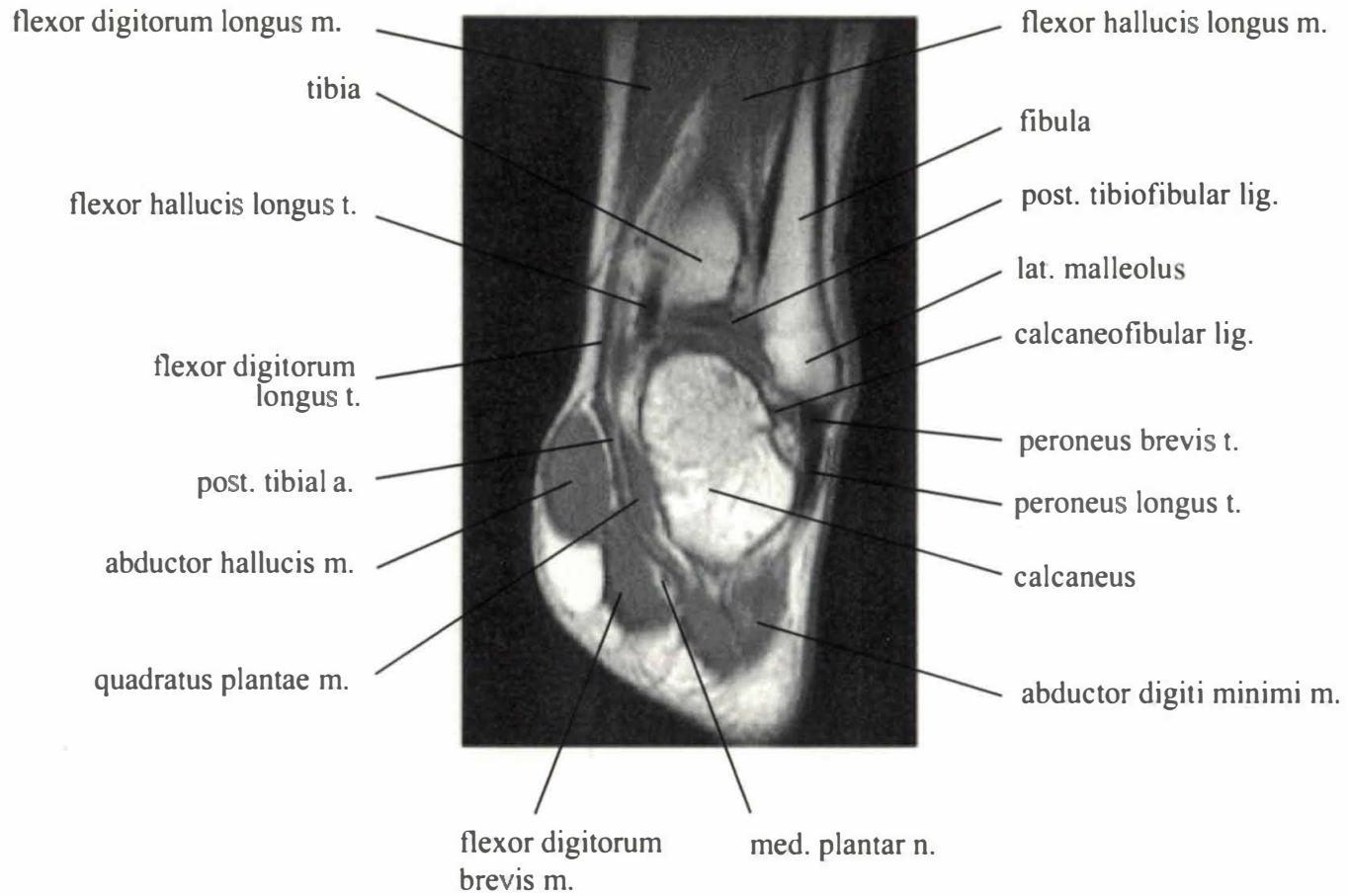
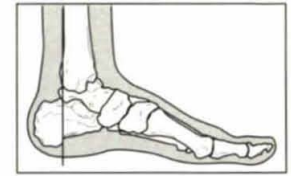
post. tibial a.

abductor hallucis m.

quadratus plantae m.

flexor digitorum brevis m.

med. plantar n.



THE LUMBAR SPINE

MR images of the lumbar spine are often interpreted by neuroradiologists at academic institutions. However, this anatomic region is becoming increasingly important for the imager interpreting musculoskeletal scans. A large number of orthopaedists specialize in spine abnormalities, and it is important for the musculoskeletal radiologist to be able to communicate with them. The lumbar spine is included in this atlas for the sake of completeness, since many other atlases do not cover this anatomic region.

By far, the major indication for MR imaging of the lumbar spine is suspected degenerative disk disease. Evaluation consists of a search for disk protrusions, disk herniations, extruded disks, or secondary features of degenerative disease such as spinal stenosis. The patient who has undergone back surgery is also a candidate for MR imaging when there is suspicion of a recurrent disk herniation or complications from the surgery such as fractures or infection.

MR imaging is often used in the setting of acute trauma to evaluate the sequelae of injury and is an alternative to CT myelography.

Finally, lumbar spine imaging is performed for suspected infection, bleeding, primary tumors of the spinal column, and congenital disease.

PRACTICAL PROTOCOL CONSIDERATIONS

The patient is imaged while lying in the supine position. A variety of coils may be used, but the most common ones are coils with planar surfaces, quadrature coils, or the multicoil phased array design. The advantage of the phased array coil is that the areas of interest can be changed without changing the patient's position.

Cardiac gating or respiratory gating may be useful in some patients.

Menu of Protocols: Lumbar Spine

Plane	Pulse Sequence	FA (degrees)	TR (msec)	TE (msec)	TI (msec)	FOV (cm)	Matrix (256X-)	ST/G (mm)	NEX	Comments
Localizer (coronal)	SE		200	min		30	128	20/0	1	
Sagittal	SE		600	16		30	256	4/1	4	Either is acceptable
Sagittal	SE		3000	17		30	256	4/1	2	
Sagittal	SE		4000	102		30	256	4/1	2	
Sagittal	FSE, FS, double echo		3000	14/98		30	256	4/1	2	
Oblique transaxial	SE		4000	VAR		22	192	4/1	2	
Oblique transaxial	SE		550	min		20	192	5/1	2	
Oblique transaxial	FSE		4500	102		16	192	5/2	2	

MAJOR OSTEOCHONDRAL STRUCTURES/LANDMARKS**Lumbar Spine**

- Vertebral bodies
- Intervertebral disk
- Posterior elements
 - Pedicle
 - Transverse process
 - Lamina
 - Spinous process
 - Superior articular facet (process)
 - Inferior articular facet (process)
- Sacrum
 - Promontory
 - Sacral foramen (anterior/posterior)
- Coccyx (with its fused segments)

MAJOR LIGAMENTS/TENDONS/BURSAE

Ligaments

- Anterior longitudinal
- Ligamentum flava
- Supraspinal (connect tips of spinous processes)
- Interspinal
- Sacroiliac (across sacroiliac joint)
 - Ventral
 - Interosseous
 - Short/long dorsal
- Sacrotuberous (sacrum to ischial tuberosity)
- Sacrospinal (sacrum to ischial spine)
- Iliolumbar (lumbar spine to superior ilium)

Tendons

Bursae

MAJOR MUSCLES

Deep Muscles

- Erector spinae
 - Longissimus
 - Iliocostalis lumborum
 - Spinalis
- Interspinal
- Intertransverse

Transversospinal Muscles

- Multifidus
- Rotares
- Quadratus lumborum
- Psoas

Other Muscles [Visibility on MR Images of the Lumbar Spine Depends on Field of View (FOV)]

- Serratus posterior inferior
- Latissimus dorsi
- Transverse abdominal
- Internal abdominal oblique
- External abdominal oblique

ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES

Psoas, iliacus, piriformis, gluteus maximus, gluteus medius (see Hips and Thigh)

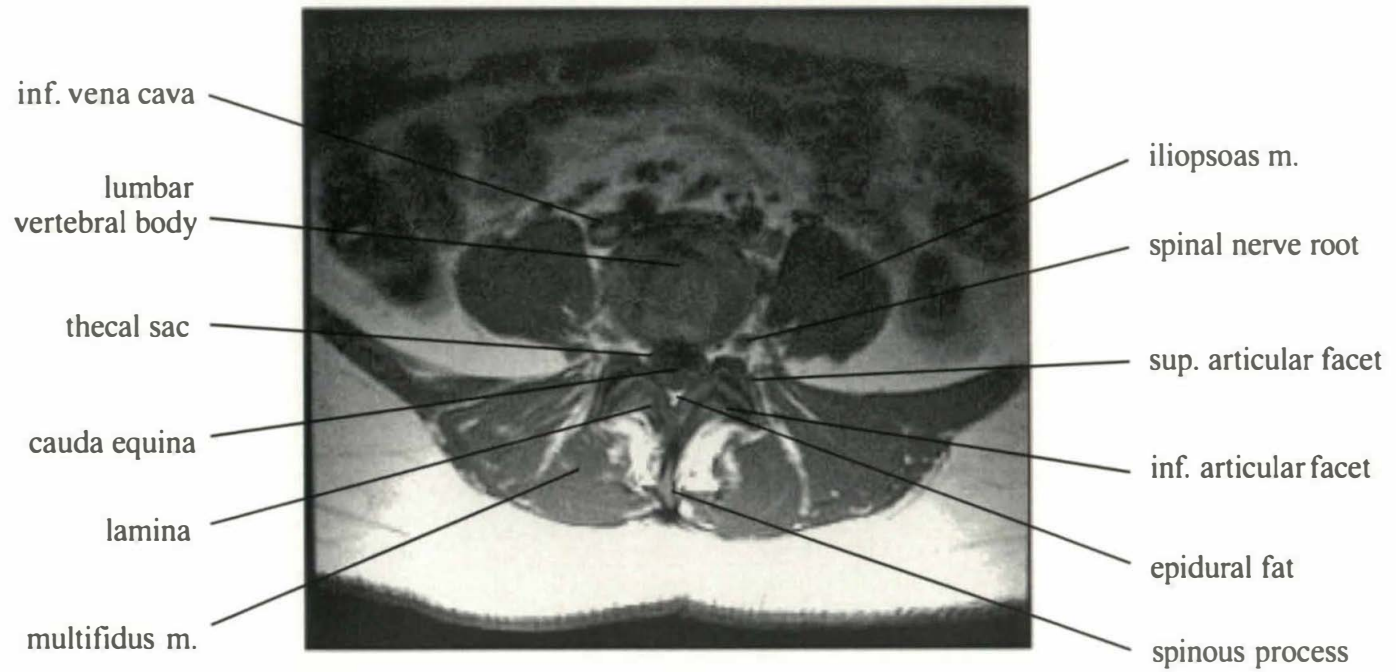
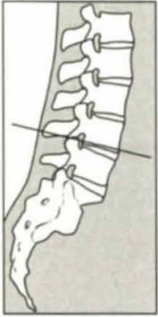
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
• Erector spinae	Common origin—posterior sacral surface, posterior iliac crest, lumbar spine spinous processes		
– Iliocostalis lumborum	Crest of ilium	Angles of lower six or seven ribs	Dorsal rami of spinal N.
– Longissimus		Lower nine or 10 ribs	Dorsal rami of spinal N.
– Spinalis	Last two thoracic and first two lumbar vertebrae	Spinous processes between fourth and eighth thoracic vertebrae	Dorsal rami of spinal N.
– Interspinal	Spinous process of vertebral body	Adjacent spinous process	Dorsal ramus of spinal N.

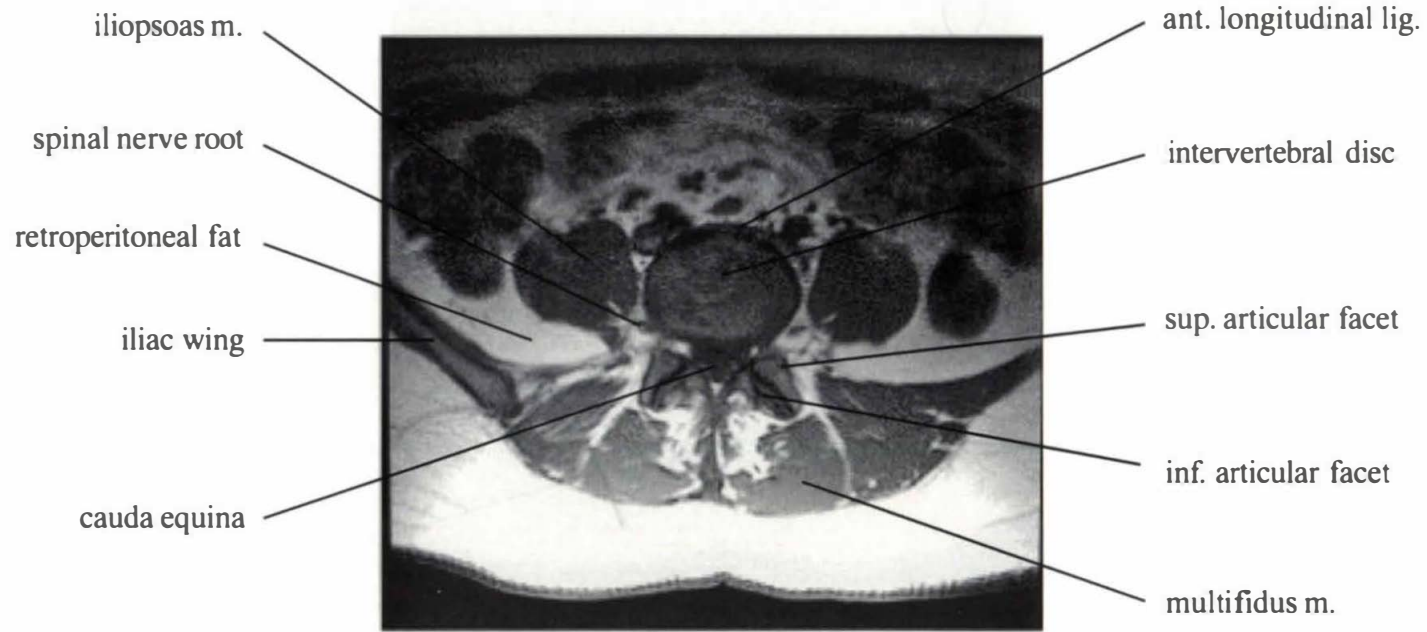
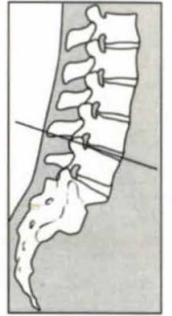
(continued)

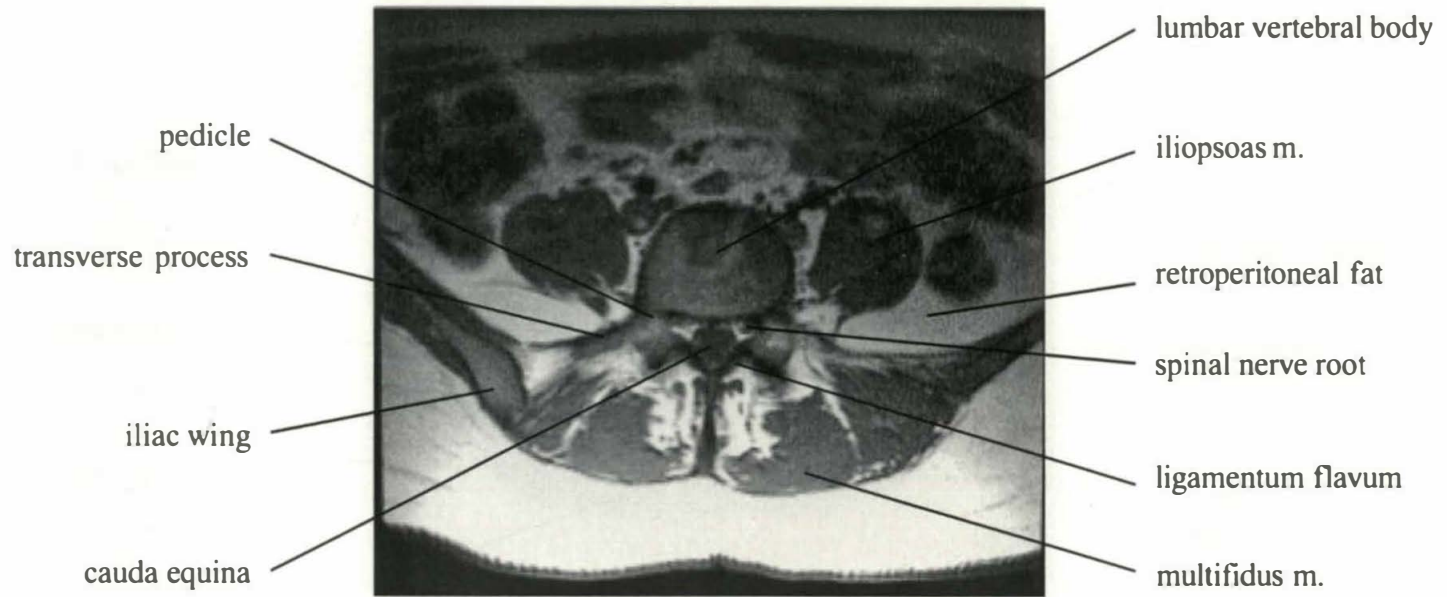
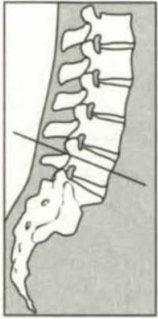
ORIGIN/INSERTION/INNERVATION OF MAJOR MUSCLES (CONTINUED)

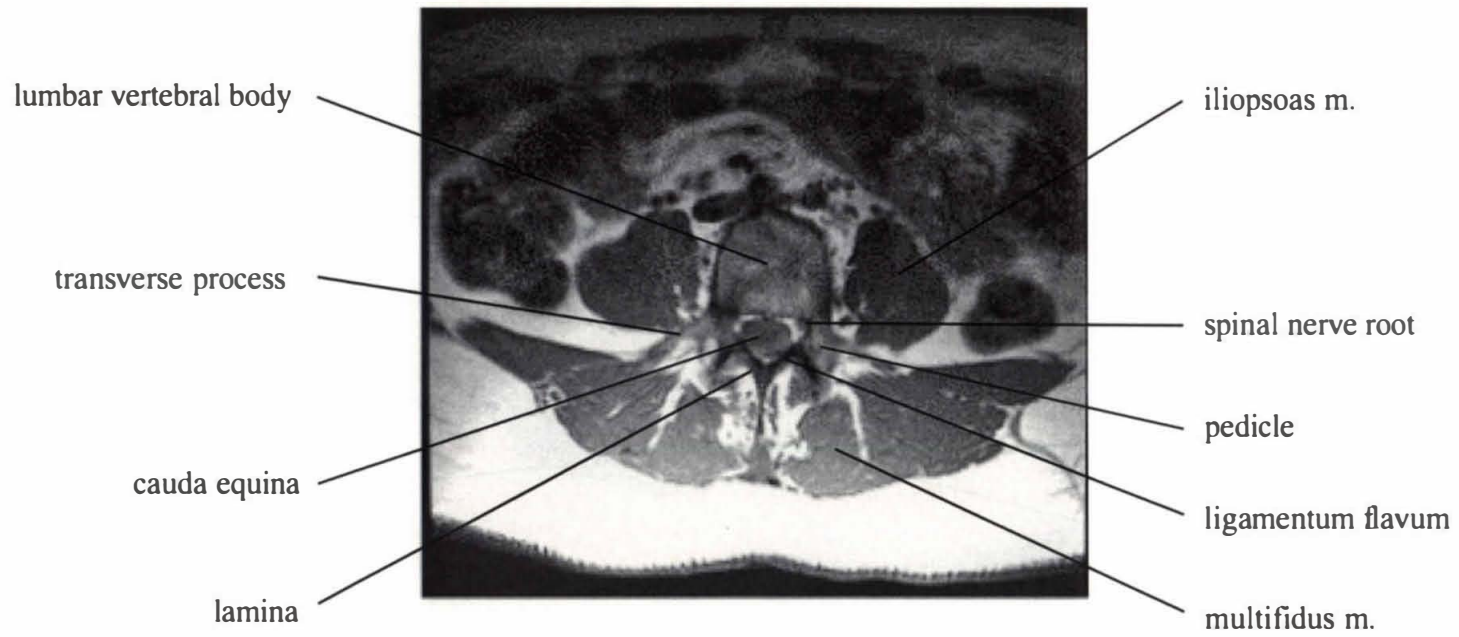
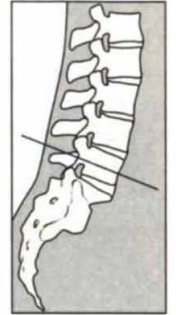
<i>Muscle</i>	<i>Origin</i>	<i>Insertion</i>	<i>Innervation</i>
– Intertransverse	Transverse process of vertebral body	Adjacent transverse process	Dorsal ramus of spinal N.
• Transversospinal muscle			
– Multifidus	Posterior surface of sacrum	Spinous processes of all vertebrae	Dorsal ramus of spinal N.
– Rotares	Posterior surface of sacrum	Adjacent or second spinous process	Dorsal ramus of spinal N.

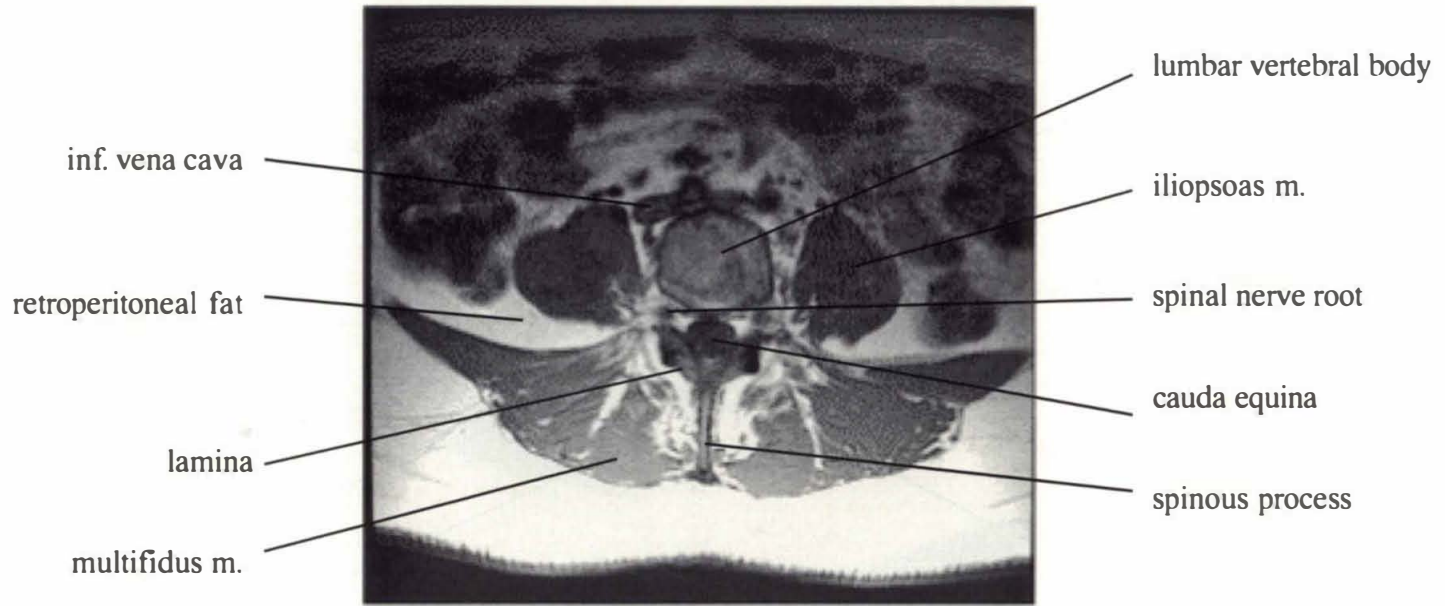
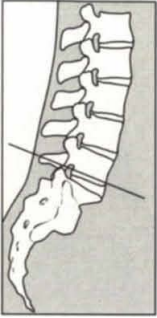
THE LUMBAR SPINE: AXIAL ANATOMY



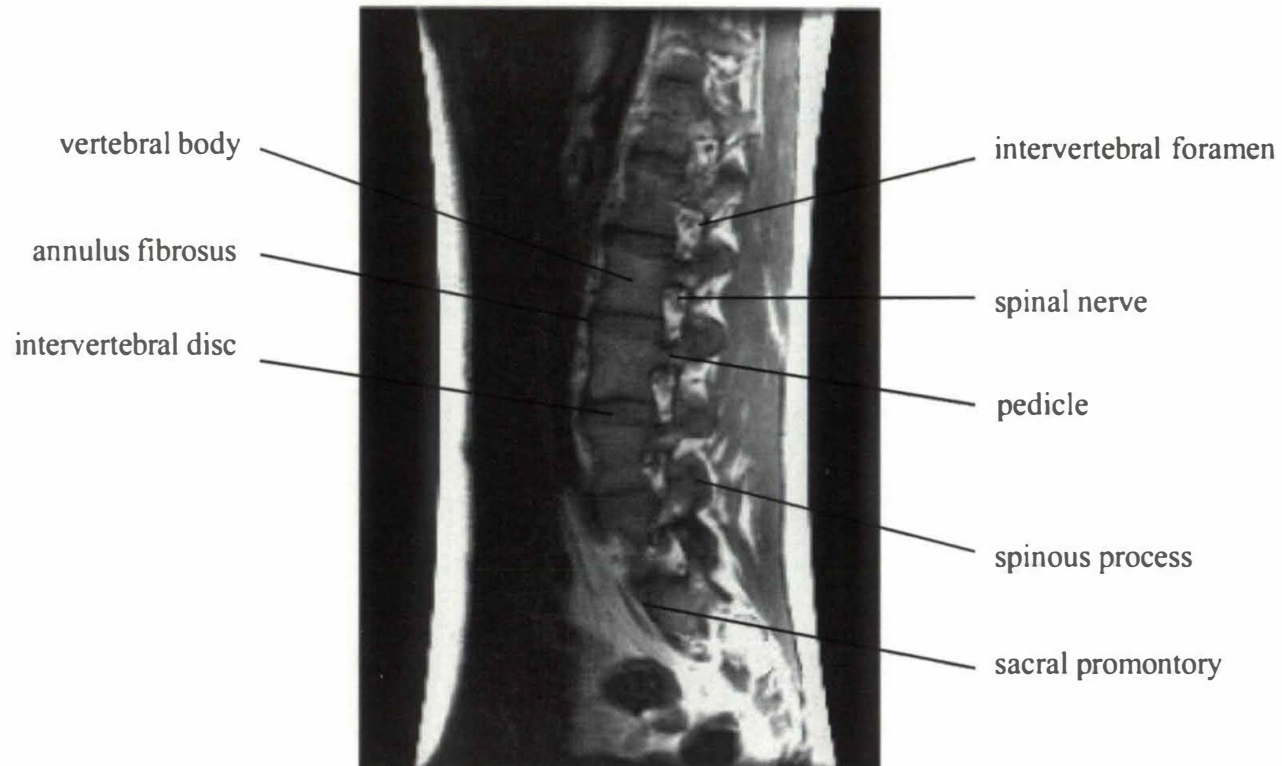
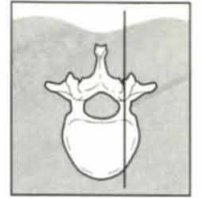


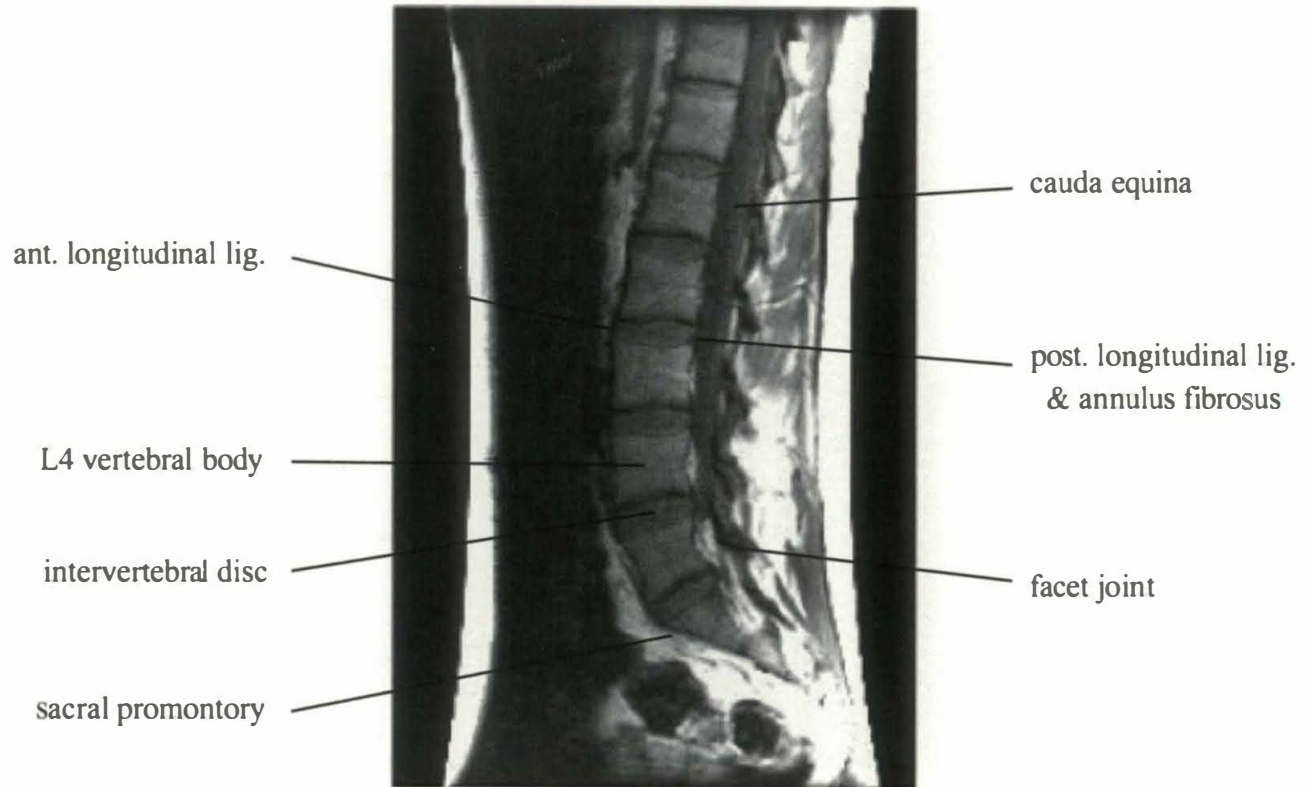
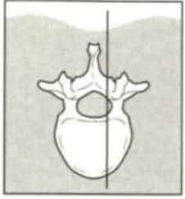


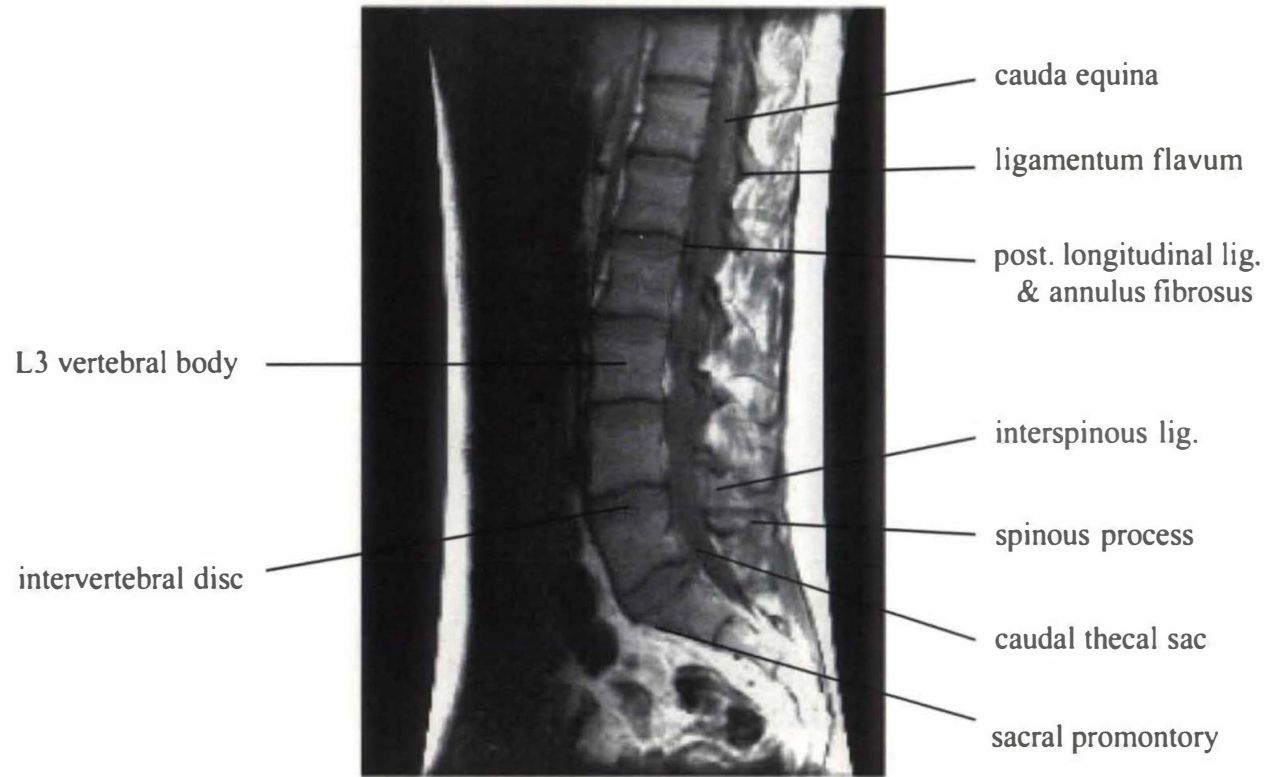
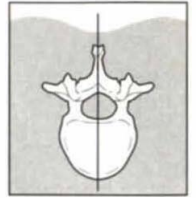


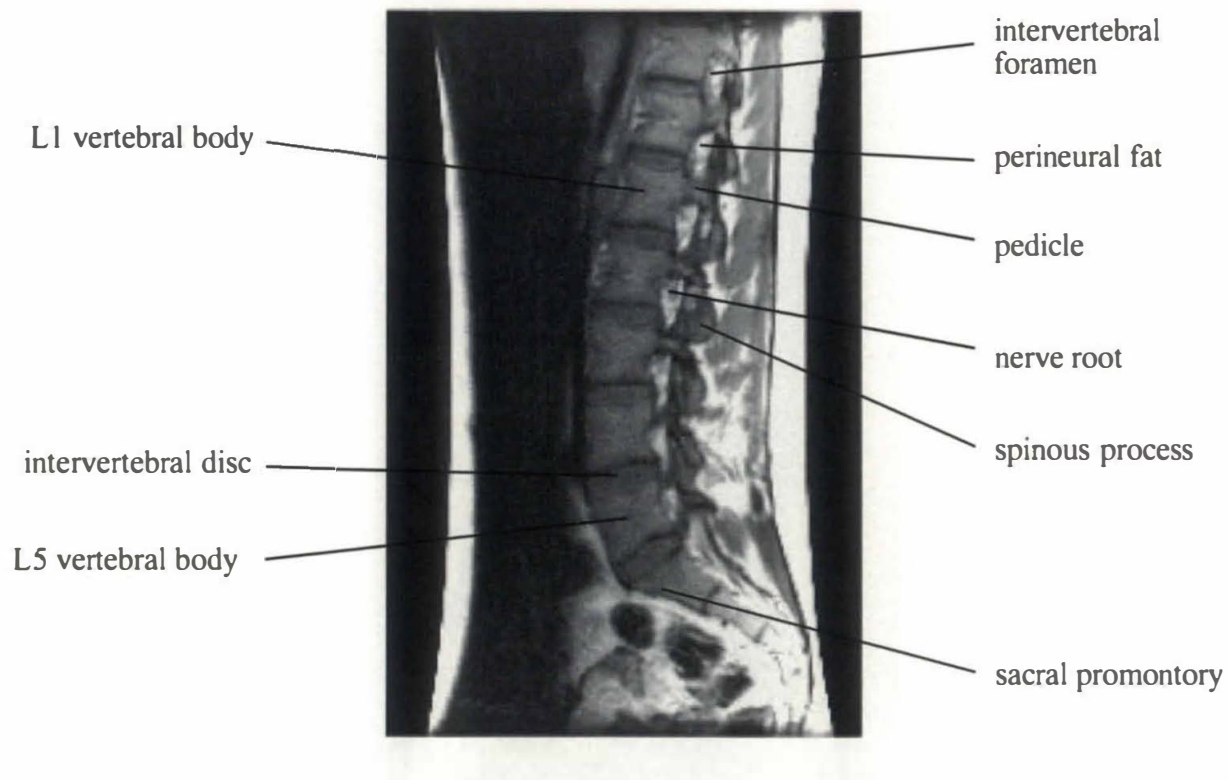
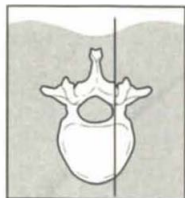


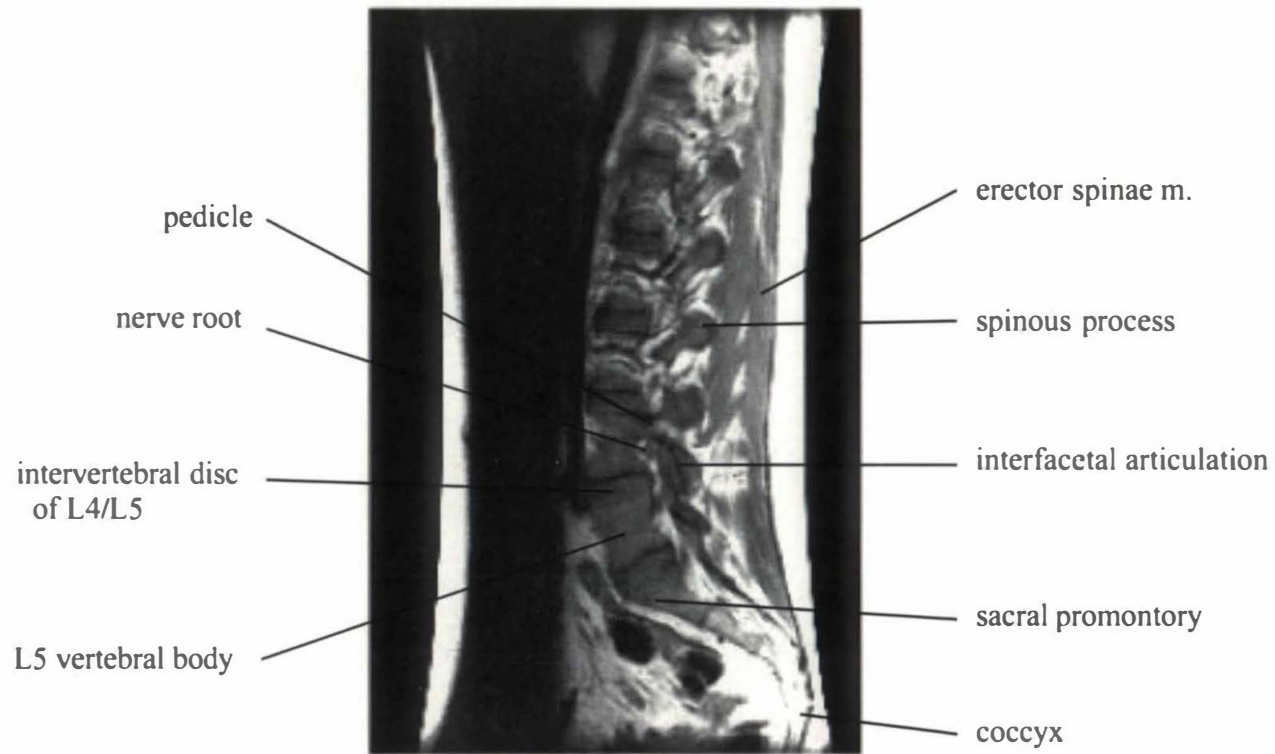
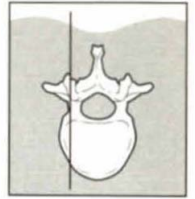
Lumbar Spine: Sagittal Anatomy











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