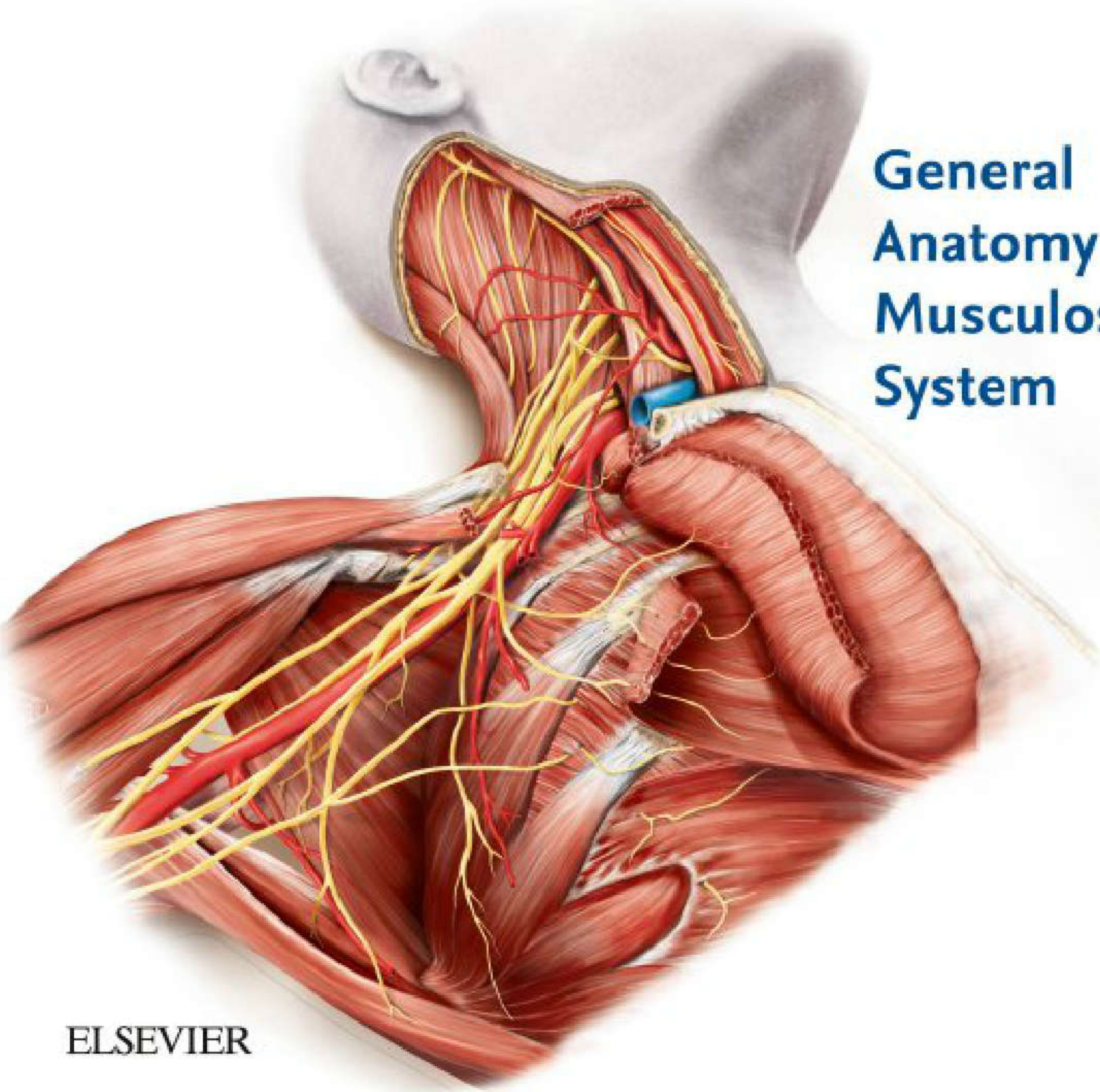
ATLAS OF ANATOMY

Sobotta

16th Edition

Edited by
Friedrich Paulsen and
Jens Waschke

English Version with
Latin Nomenclature



General Anatomy and Musculoskeletal System

ELSEVIER

F. Paulsen, J. Waschke

Sobotta

Atlas of Anatomy

Friedrich Paulsen, Jens Waschke (Eds.)

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This atlas was founded by Johannes Sobotta †, former Professor of Anatomy and Director of the Anatomical Institute of the University in Bonn, Germany.

German Editions:
1st Edition: 1904–1907 J. F. Lehmanns Verlag, Munich, Germany
2nd–11th Edition: 1913–1944 J. F. Lehmanns Verlag, Munich, Germany
12th Edition: 1948 and following editions
Urban & Schwarzenberg, Munich, Germany
13th Edition: 1953, ed. H. Becher
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18th Edition: 1982, eds. H. Ferner and J. Staubesand
19th Edition: 1988, ed. J. Staubesand
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Prof. Friedrich Paulsen

Dissection course for students

In his teaching, Friedrich Paulsen puts great emphasis on ensuring that the students in his dissection classes can actually work on body donation cadavers. *'Carrying out dissection yourself is not only extremely important for gaining a three-dimensional understanding of anatomy, forming the fundamental basis of virtually any field of medical science. In dissection classes you will also experience for the first time the touch and feeling of the human body, the organs and individual tissues, but in most cases it will also be your first intensive encounter with issues around death and dying, and the clinical causes of death. You will not only study anatomy, but also learn how to deal with a quite unique and challenging situation as part of a team. Never again will you be in such close contact with your fellow students and teaching staff.'*
Friedrich Paulsen was born in Kiel in 1965 and, after completing his 'Abitur' in Brunswick, he initially trained as a nurse. He then studied medicine at the Christian Albrecht University (CAU) in Kiel. After his house officer training at the Oromaxillofacial Surgery Clinic and a period as resident physician at the ENT Clinic of CAU, in 1998 he moved to the Anatomical Institute of CAU where he graduated as medical doctor in 1997 and further qualified by performing his State doctorate in anatomy in 2001. In 2003 he was offered full professorship at the Anatomy Departments of the Ludwig Maximilians University (LMU) in Munich and the Martin Luther University (MLU) in Halle/Wittenberg. In Halle, he founded a clinical anatomy training centre. After declining yet another professorship, this time at the University of Saarland, he accepted a post at the Friedrich Alexander University (FAU) in Nürnberg as Professor of Anatomy and Head of its Anatomical Institute, a post he has held since 2010. He has continued to decline professorships offered by a number of other renowned universities.
Friedrich Paulsen is an honorary member of the Anatomical Society of Great Britain and Ireland as well as Romania and has been granted numerous scientific awards including the Dr Gerhard Mann Sicca research prize, the Sicca research prize of the German Federation of Ophthalmologists, and the Commemorative Medal of the Comenius University in Bratislava. Additionally, he received several teaching awards.
The key focus of his research is on the innate immune response of the eye surface, and on investigating the causes of dry eyes. Visiting research fellowships have taken him to Spain and the United Kingdom. He is the editor of the journal *Annals of Anatomy* and, as vice-president of Learning and Teaching (until 3/2018), and now People (since 4/2018) also a member of the FAU university administration since 2016.

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Prof. Jens Waschke

Making courses more clinically relevant

For Jens Waschke, one of the most important challenges in the teaching of modern anatomy is how to optimally adapt the courses to meet the requirements of clinical training and subsequent professional practice.
'The clinical aspects of the Atlas give students in the first semesters of medical school a grounding in anatomy and at the same time show them the importance of having a thorough understanding of human anatomy for their subsequent clinical practice, instead of just learning anatomical structures by rote. On the other hand, we prefer to avoid covering highly specialised details that are only needed by a few specialists for occasional diagnostic procedures or surgery, as is the case in other contemporary anatomy books. Since students at the beginning of their training are unable to distinguish between the necessary basics and specialised details, this can cause a mental overload and prevent them from focusing on the essentials.'
Jens Waschke (born in 1974 in Bayreuth) studied medicine at the University of Würzburg, achieving a doctorate in anatomy under Prof. Detlev Drenckhahn in the year 2000. After his intership training in the Anatomy and Internal Medicine Departments, he qualified as a professor of anatomy and cell biology in 2007. Jens Waschke spent nine months as a visiting scholar at the Davis campus of the University of California under Prof. Fitz-Roy Curry in 2003–2004. From 2008 onward he chaired the newly established Department III of the University of Würzburg before being appointed professor at the Ludwig Maximilians University in Munich, where he has been the head of Department I (Vegetative Anatomy) of the Anatomical Institute since 2011. Jens Waschke is heavily involved in the German Anatomical Society as an examiner in specialist anatomy and a member of its Study Commission, and he heads their working group on reducing formaldehyde exposure. He is a representative of the IFAA (International Federation of Associations of Anatomists) and an honorary member of the Anatomical Society of Ethiopia (ASE).
In his research he primarily investigates the biological mechanisms regulating cell adhesion and the external and internal barrier functions of the human body. His research predominantly focuses on the regulation of the endothelial barrier during inflammation, and also the mechanisms behind the impaired cell adhesion seen in diseases such as the blistering skin disorder pemphigus, Crohn's disease and arrhythmogenic cardiomyopathy. The aim is to better understand cell adhesion and to discover new treatment approaches.

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Preface of the 24th German Edition

In the preface of the first edition of his atlas in May 1904, Johannes Sobotta writes: 'Long-standing experience in cadaver dissection classes has prompted the author to ensure that the illustrations of the peripheral nervous system and the blood vessels depict the relevant structures in the same way that the student is accustomed to seeing them on the cadaver, i.e. that they depict the vessels and nerves from the same region together. Furthermore, the atlas alternates between pages of text and full-page diagrams. The latter contain the key illustrations in the atlas, while the former – in addition to sketches and schematic drawings and legends – contain a brief, concise text to help the student find information quickly when using the book in the dissection hall.'

Just as fashions change on a regular basis, so do students' reading and studying habits. The ubiquitousness of multi-media and the ready availability of information and stimuli are surely the main reasons why these habits are changing at a much faster rate than ever before. Publishers and publishing houses must stay abreast of these developments and of students' changing expectations regarding atlases and textbooks they wish to use, as well as ensuring the digital availability of the contents. In addition to interviews with students and systematic surveys, a publisher can sometimes gauge students' expectations from the textbook market itself. Detailed textbooks claiming to be completely comprehensive are increasingly being abandoned in favour of textbooks that didactically meet students' educational needs and cover the contents of their courses and exams – whether they are studying medicine, dentistry or biomedical science. Likewise, although the images in atlases such as Sobotta have fascinated many generations of doctors and medical professionals around the world with their precise naturalistic representations of real dissections, they are sometimes perceived by students as being too complicated and too detailed. This realisation requires us to consider how we can build upon the obvious strengths of an atlas – which in the course of over 100 years of tradition and 23 German editions, has become a benchmark of accuracy and quality – to meet modern didactic concepts without the overall work losing its unique, exclusive characteristic and its originality.

For educational reasons, we have maintained the Sobotta's original concept and chosen to publish the atlas, as it has been since the first edition, in three volumes: General Anatomy and Musculoskeletal System (1); Internal Organs (2); and Head, Neck and Neuroanatomy (3). And while the concept mentioned in the preface of the first edition, i.e. linking the pictures in the Atlas with an explanatory text, may be old-fashioned, it has now come back into fashion – we have simply modernised the concept. Each picture is thus completed with a short explanatory text to introduce the students to the structure depicted and to explain why those particular dissection and depiction methods have been chosen for that particular region. The individual chapters have been systematically structured to follow today's methods of studying, while various illustrations have been updated or replaced. The majority of these new illustrations have been designed from the point of view of the learner, to make it easier to study the key pathways of blood supply and innervation. We have furthermore revised numerous existing illustrations and reduced the number of labels, using bold type to facilitate access to the anatomical content. The numerous clinical practice examples ('Clinical Remarks') show the somewhat 'dry' subject of anatomy at its most vibrant best, demonstrating to beginners how relevant anatomy is for their subsequent professional life and giving them a tantalising taste of their clinical training to come. Another revised feature is the introductory preface to the individual chapters, which sum up the content and the key issues, and include a real-life clinical case. In addition, each chapter ends with a summary of questions which would typically be asked in oral anatomy exams and exam tests. As in the 23rd edition, each chapter contains a brief introduction to the embryology of each body region.

Readers should please note two things:

1. The 24th edition of the Sobotta Atlas cannot replace an explanatory textbook.
2. No matter how good an educational concept is, students still have to put in many hours of intensive studying themselves – a good concept can but make that knowledge more accessible. Learning anatomy is not difficult, but it does take a lot of time; time that is well spent, since everybody – doctor and patient – will benefit from it in the long run. The aim of the 24th edition of the Sobotta Atlas is not only to facilitate your study, but also to make the time you spend studying engaging and interesting, so that the atlas is something you will repeatedly want to pick up and consult, both during your medical training and your subsequent professional career.

Erlangen and Munich, summer of 2017,
exactly 113 years after the first edition was published

Friedrich Paulsen and Jens Waschke

Acknowledgements of the 24th German Edition

The work on the 24th edition of the Sobotta Atlas has once again been a lot of fun, and this intensive involvement has continued to strengthen our sense of pride in the Sobotta.

Today, more than ever, an extensive anatomy atlas of the calibre of the Sobotta requires a lot of teamwork with the coordination of the publishing house. The cornerstone of the 24th edition has been laid by Dr Katja Weimann, who extensively coordinated the project. We are very grateful for her hard work. Also, without the long-standing experience of Dr Andrea Beilmann, who has worked on several previous editions of the Sobotta and has been a true pillar of strength for the Sobotta team, many things would not have been possible. We would like to thank her again most profusely for all her help and support. Benjamin Rempe, another member of the four-person team behind the 24th edition of the Sobotta, has contributed to Sobotta for the first time, approaching the task with real passion and enthusiasm. His unique way of motivating the team served as a continual source of encouragement and motivation for the editors. Benjamin: thank you very much. We fondly recall the monthly conference calls in which Benjamin Rempe and Dr Andrea Beilmann helped us carefully craft the Sobotta Atlas and, despite their different approaches, showing a remarkable gift for intuitively adopting a uniform working style. Sibylle Hartl coordinated the project in collaboration with Dr Andrea Beilmann and was responsible for the entire print production. We are truly grateful to her. Without the tenacity and the protective hand of Dr Dorothea Hennessen and Rainer Simader, who were both in charge of the overall management of the 'Sobotta 24th edition' project and who never lost faith in their Sobotta team or the tight schedule, this edition in its present form would not have been possible. Others whom we are similarly grateful to for their involvement in the project and their share of its success are: Dr Antje Kronenberg (editing), the abavo GmbH team (technical image processing and typesetting) and Nicola Kerber (layout design). We would very much like to thank Dr Ursula Osterkamp-Baust for exhaustively compiling the index.

Special thanks to our team of illustrators Dr Katja Dalkowski, Marie Davidis, Johannes Habla, Anne-Kathrin Hermanns, Martin Hoffmann, Sonja Klebe, Jörg Mair and Stephan Winkler, who in addition to updating the existing images also helped us develop a large number of new illustrations.

For their help in producing the clinical images, we would also like to thank Dr Frank Berger, Institute of Clinical Radiology of Ludwig Maximilians University, Munich; Prof. Christopher Bohr, Phoniatrics and Paediatric Audiology, ENT Clinic at Friedrich Alexander University, Erlangen/Nürnberg; Dr Eva Louise Bramann, Ophthalmology Clinic at Heinrich Heine University, Düsseldorf; Prof. Andreas Dietz, Director of the ENT Clinic and Outpatients' Clinic at the University of Leipzig; Prof. Gerd Geerling, Ophthalmology Clinic at Heinrich Heine University, Düsseldorf; Dr Berit Jordan, University Clinic and Outpatients' Clinic for Neurology, Martin Luther University, Halle/Wittenberg; Dr Axel Kleespies, Surgical Clinic, Ludwig Maximilians University, Munich; Prof. Norbert Kleinsasser, University Clinic for Illnesses of the Ear, Nose and Throat, Julius Maximilians University, Würzburg; Dr Hannes Kutta, ENT practice, Hamburg-Altona/Ottensen; Dr Christian Markus, Anaesthesiology Clinic, Julius Maximilians University, Würzburg; Jörg Pekarsky, Institute for Anatomy II, Friedrich Alexander University, Erlangen/Nürnberg; Dr Dietrich Stövesandt, Clinic for Diagnostic Radiology, Martin Luther University, Halle/Wittenberg; Prof. Jens Werner, Surgical Clinic, Ludwig Maximilians University, Munich; Dr Tobias Wicklein, Erlangen, and Prof. Stephan Zierz, Director of the University Clinic and Outpatients' Clinic for Neurology, Martin Luther University Halle/Wittenberg.

Last but not least, we would like to thank our families, who not only were very gracious and understanding of all the time we devoted to the 24th edition of the Sobotta, but who also gave us very helpful suggestions whenever we needed feedback. You have been a true support.

Erlangen and Munich, summer of 2017
Friedrich Paulsen and Jens Waschke

1. List of Abbreviations

Singular:			Plural:		
A.	=	Arteria	Aa.	=	Arteriae
Lig.	=	Ligamentum	Ligg.	=	Ligamenta
M.	=	Musculus	Mm.	=	Musculi
N.	=	Nervus	Nn.	=	Nervi
Proc.	=	Processus	Procc.	=	Processus
R.	=	Ramus	Rr.	=	Rami
V.	=	Vena	Vv.	=	Venae
Var.	=	Variation			

♀ = female
♂ = male

Percentages:
In the light of the large variation in individual body measurements, the percentages indicating size should only be taken as approximate values.

2. General Terms of Direction and Position

The following terms indicate the position of organs and parts of the body in relation to each other, irrespective of the position of the body (e.g. supine or upright) or direction and position of the limbs. These terms are relevant not only for human anatomy but also for clinical medicine and comparative anatomy.

General terms

anterior – posterior = in front – behind (e.g. Arteriae tibiales anterior et posterior)
ventralis – dorsalis = towards the belly – towards the back
superior – inferior = above – below (e.g. Conchae nasales superior et inferior)
cranialis – caudalis = towards the head – towards the tail
dexter – sinister = right – left (e.g. Arteriae iliacae communes dextra et sinistra)
internus – externus = internal – external
superficialis – profundus = superficial – deep (e.g. Musculi flexores digitorum superficialis et profundus)
medius, intermedius = located between two other structures (e.g. the Concha nasalis media is located between the Conchae nasales superior and inferior)
medianus = located in the midline (Fissura mediana anterior of the spinal cord). The median plane is a sagittal plane which divides the body into right and left halves.
medialis – lateralis = located near to the midline – located away from the midline of the body (e.g. Fossae inguinales medialis et lateralis)
frontalis = located in a frontal plane, but also towards the front (e.g. Processus frontalis of the maxilla)
longitudinalis = parallel to the longitudinal axis (e.g. Musculus longitudinalis superior of the tongue)
sagittalis = located in a sagittal plane
transversalis = located in a transverse plane
transversus = transverse direction (e.g. Processus transversus of a thoracic vertebra)

Terms of direction and position for the limbs

proximalis – distalis = located towards or away from the attached end of a limb or the origin of a structure (e.g. Articulationes radioulnares proximalis et distalis)

for the upper limb:
radialis – ulnaris = on the radial side – on the ulnar side (e.g. Arteriae radialis et ulnaris)

for the hand:
palmaris – dorsalis = towards the palm of the hand – towards the back of the hand (e.g. Aponeurosis palmaris, Musculus interosseus dorsalis)

for the lower limb:
tibialis – fibularis = on the tibial side – on the fibular side (e.g. Arteria tibialis anterior)

for the foot:
plantaris – dorsalis = towards the sole of the foot – towards the back of the foot (e.g. Arteriae plantares lateralis et medialis, Arteria dorsalis pedis)

3. Use of Brackets

[ ]: Latin terms in square brackets refer to alternative terms as given in the Terminologia Anatomica (1998), e.g. Ren [Nephros]. To keep the legends short, only those alternative terms have been added that differ in the root of the word and are necessary to understand clinical terms, e.g. nephrology. They are primarily used in figures in which the particular organ or structure plays a central role.

( ): Round brackets are used in different ways:
– for terms also listed in round brackets in the Terminologia Anatomica, e.g. (M. psoas minor)
– for terms not included in the official nomenclature but which the editors consider important and clinically relevant, e.g. (Crista zygomaticoalveolaris)
– to indicate the origin of a given structure, e.g. R. spinalis (A. vertebralis).

Colour Chart

Concha nasalis inferior
Mandibula
Maxilla
Os ethmoidale
Os frontale
Os lacrimale
Os nasale
Os occipitale
Os palatinum
Os parietale
Os sphenoidale
Os temporale
Os zygomaticum
Vomer

In the newborn the following cranial bones are indicated by only one colour:

Os nasale, Os temporale, Mandibula
Maxilla, Os incisivum
Os occipitale, Os palatinum

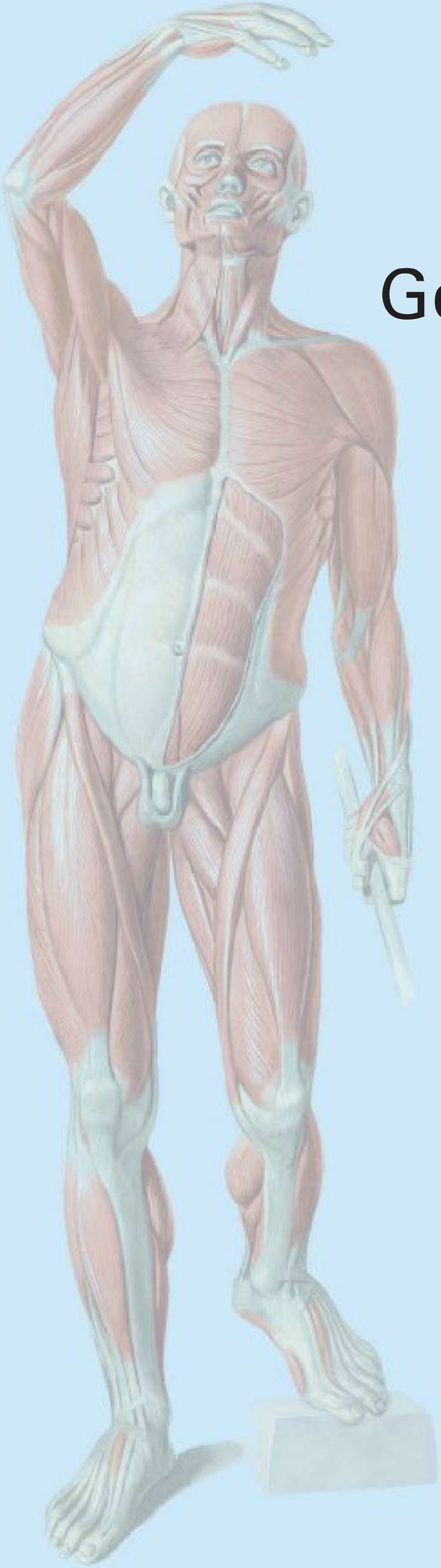
Table of Content

General Anatomy

Trunk

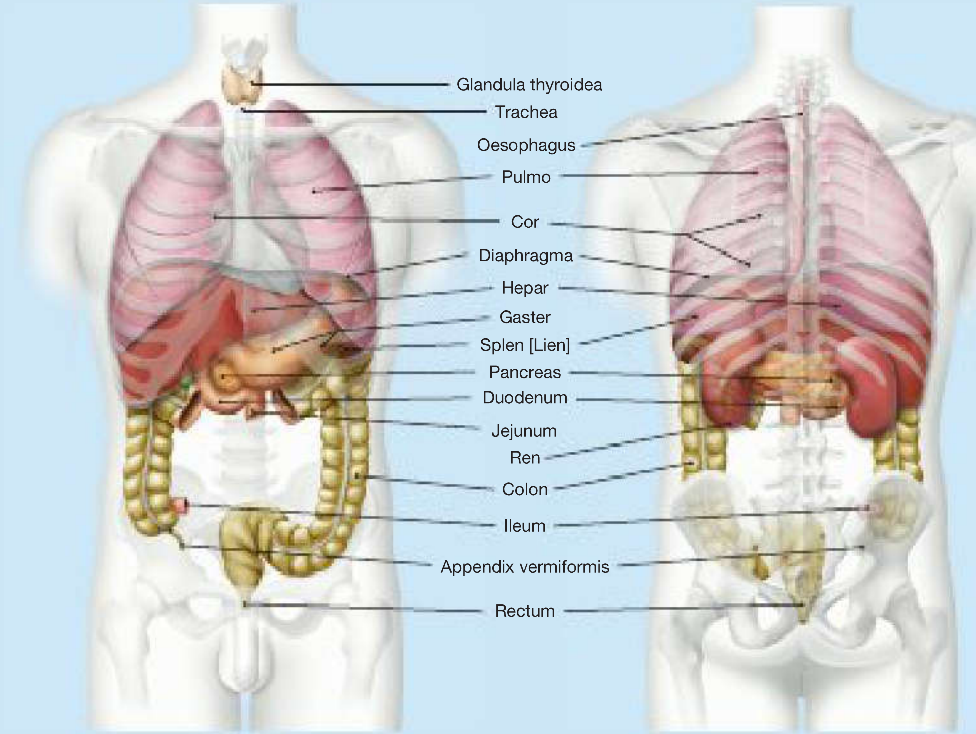
Upper Limb

Lower Limb



General Anatomy

1



Overview

The Greek word ‘ανατεμνειν’ **(anatemnein)** means ‘cut open’. It describes the oldest method in anatomy, which was already practised in ancient times. Anatomy is the study of the structure of the healthy body. Without the knowledge of anatomy, no functions can be derived and without the knowledge of structure and function, no pathological changes can be understood. In order to learn a new language, there needs to be a foundation of vocabulary and grammatical knowledge. The same is true of anatomy. In order to be able to learn the subject, you need principles and functional knowledge which will be of **central importance** throughout your medical studies. Not only do levels, axes and orientation lines on the body, descriptions and possibilities of movement play a role in clinical practice, but also knowledge of the musculoskeletal system, including biomechanical processes, the location of internal organs and their projection onto the body surface, the circulatory systems of the body and the structure of the nervous system. They form the **basis** for any diagnostic (especially imaging techniques such as X-ray, ultrasound, scintigraphy, computed tomography, magnetic resonance imaging) and therapeutic measures.

Main Topics

After studying this chapter, you should be able to:

- orientate yourself on the human body, divide the body into different sections and describe its blueprint, know the main axes and levels, describe movement directions and know directional terms, the position of the parts of the body and general terms of anatomy;
- divide the body surface into regions and describe the projection of inner organs onto the body surface;
- explain principles of embryonic development, starting with fertilisation;
- know principles of the musculoskeletal system, such as the classification of bones, construction of a tubular bone, names of bones of the skeleton, structure of a joint, joint types, terminology of joint motion and auxiliary structures of joints (intervertebral joints, labra, bursae, ligaments);
- explain basic concepts of general muscle theory, such as the structure of a skeletal muscle, muscle types, tendon attachment sites, auxiliary muscles and tendons, and describe principles of muscle mechanics;
- describe the various circulatory systems, such as systemic circulation, including the heart and major arteries and veins, pulmonary circulation, organisation of the prenatal cardiovascular system, portal vein circulation and lymphatic vessel system (lymph circulation) with lymph nodes;
- understand the nervous system (structure, somatic and autonomous nervous system) and know the dermatomes on the body surface;
- describe principles of diagnostic imaging techniques such as conventional X-ray, sonography (ultrasound), computed tomography, magnetic resonance imaging, scintigraphy;
- describe the structure of the skin and its appendages.

Clinical Relevance

In order not to lose reference to future everyday clinical life with so many anatomical details, the following describes a typical case that shows why the content of this chapter is so important.

An Open Ductus Arteriosus (BOTALLI) (PDA)

Case Study

A premature infant, born in the 34th week of pregnancy plus two days (34+2 NNW) develops shortly after birth (4th day of life) increased shortness of breath and poor feeding. The girl is very pale and her hands and feet are relatively cold.

Result of Examination

The on-duty pediatrician at the neonatal station notices on palpation of the abdomen an enlargement of the liver and spleen (hepatosplenomegaly) and auscultation of the heart reveals a loud machine-like murmur (systolic crescendo and diastolic decrescendo murmur) in the 2nd intercostal space on the left, which is accompanied by a tactile whirring across the chest. Palpation of the pulse shows a fast pulse with high blood pressure (Pulsus celer et altus). He immediately takes further diagnostic steps.

Diagnostic Procedure

The electrocardiogram (ECG) shows left-ventricular stress. The chest X-ray indicates an enlarged pulmonary vessel and a left-sided widening of the heart. The completed echocardiography (colour Doppler examination, → Fig. a) shows blood flow between the aorta and pulmonary vessels, enabling the direct imaging of a shunt.

A shunt is a short circulation connection between normally separate vessels or cavities.

The diagnosis of a patent Ductus arteriosus (BOTALLI) (PDA) (→ Fig. b) is thus confirmed.

Diagnosis

An open Ductus arteriosus (BOTALLI).

Treatment

A drug treatment with the prostaglandin synthesis inhibitor ibuprofen is initiated to close the haemodynamically effective open PDA.

Further Developments

Although the symptoms improve slightly under treatment, a pronounced systolic heart murmur can still be heard and the PDA is detectable in the colour Doppler examination. For this reason, an interventional closure by means of cardiac catheterisation is introduced the following day by inserting an umbrella system. Shortly after the procedure, the pulse of the girl is already within the normal range, breathing is calm and no heart murmur is detectable. The girl remains for some time on the neonatal ward and progresses well, and can therefore be discharged.

Dissection Lab

Consider the pressure and flow conditions in the large and small circulation with the heart as the central organ and reflect on how the blood flows in the baby girl with PDA (→ Fig. 1.39).

Consider which other shunts are obliterated after birth.

Back in the Clinic

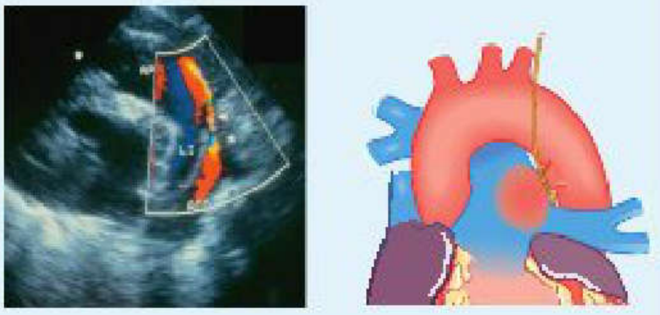
After birth, the increasing oxygen concentration arising from the lungs unfolding and the first breaths normally cause the ductus arteriosus to contract and close. In premature babies many organs are not yet fully developed. The cause of the persistence of a PDA is therefore attributed to the fact that the vessel muscles here contract less well, as they are less developed, and a relatively high prostaglandin concentration leaves Ductus arteriosus open.

From pregnancy week 28 women should not take prostaglandin synthesis inhibitors (e.g. ibuprofen) for pain medication, so that the Ductus arteriosus does not close too early.

After birth, the prostaglandin levels normally drop quickly and the ductus arteriosus closes up spontaneously. Therefore, therapeutic measures with prostaglandin synthesis inhibitors are often successful.

Right after birth, initial examination of the newborn is carried out in order to determine whether all vital functions, such as the respiratory and cardiovascular systems, are in order.

In the case of a haemodynamically effective PDA, a left-to-right shunt occurs due to high pressure in the systemic circulation and low pressure in the pulmonary circulation with volume overload on the left side of the heart, so that blood from the aorta flows into the lungs, which causes increased pulmonary blood flow and increased pressure in the pulmonary circulation. Thus a certain part of the blood from the lungs reaching the left ventricle and from there the aorta, circulates through the Patent ductus arteriosus again with the lungs (machine-like murmur). There is a lack of circulating blood in the systemic circulation (cold hands and feet); as a reaction, the heart rate increases (Pulsus celer et altus) in order to transport enough oxygen to the periphery of the body. If the PDA is not treated, the continual increased pressure leads to damage of the vessels in the lungs. These thus react to a remodelling (modification of the vessel structure), whereby the increased pressure is further 'fixed' and may increase so much that it exceeds the pressure of the systemic circulation with the result of a shunt reverse (right-to-left shunt), whereby blood reaches the systemic circulation directly from the pulmonary circulation, without being pre-saturated with oxygen. The result is cyanosis (bluish discolouration of the skin, lips and mucous membranes) and a rapid decrease in capacity. At some point the heart undergoes decompensation.



a b

Fig. a A colour Doppler examination. [O548]
Fig. b Patent Ductus arteriosus (BOTALLI). [L126]

Parts of the Body

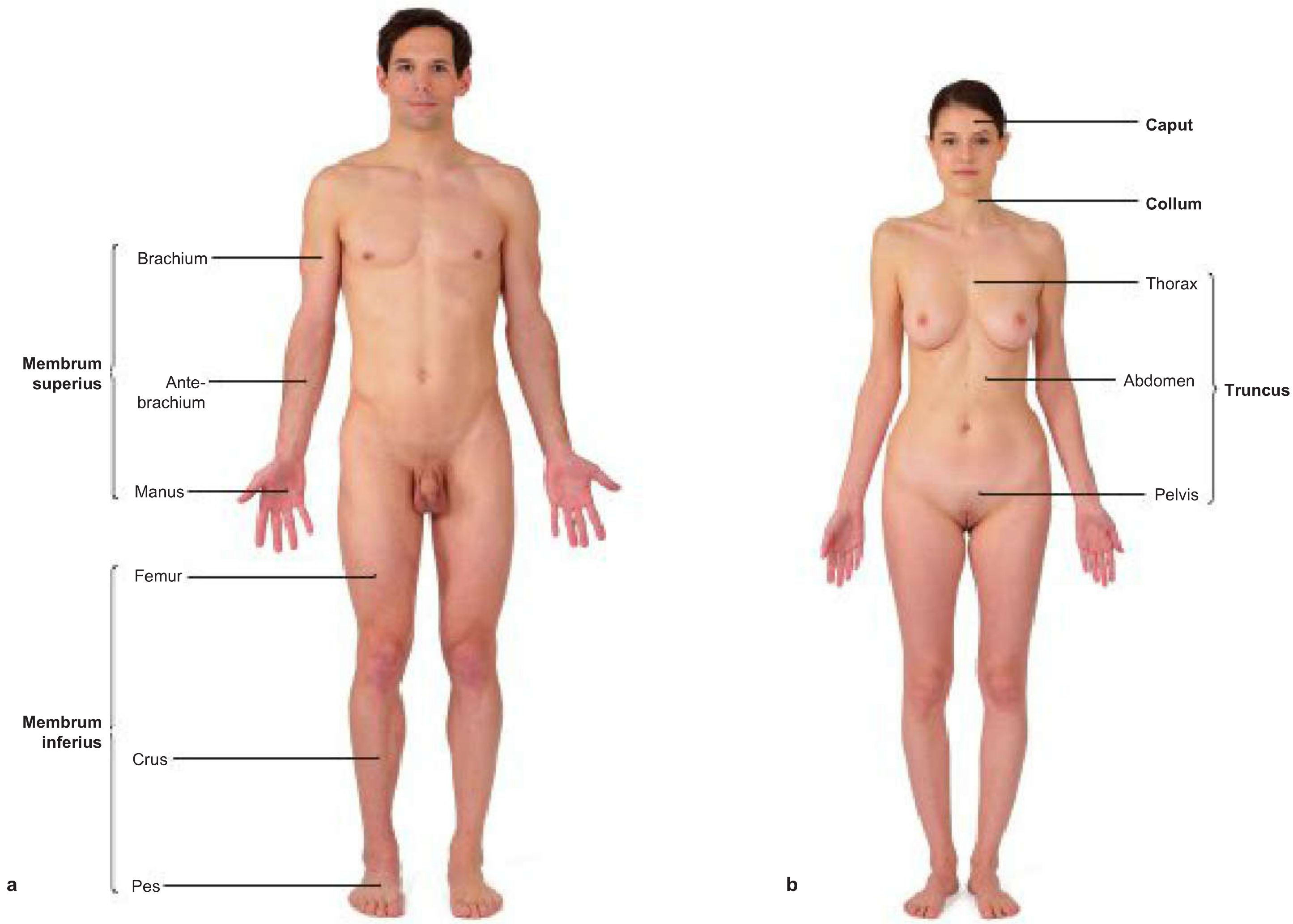


Fig. 1.1a and b Surface anatomy of the man (a) and the woman (b); ventral view. [J803]
Usually anatomical descriptions relate to an upright position; the face is facing the front, the arms are suspended sideways, palms are turned to the body or to the front, the legs are parallel and the feet face forward.
The body is divided up into the head (caput), neck (collum), trunk (truncus) including the chest (thorax), tummy (abdomen), hips (pelvis) and back (dorsum) and the upper limbs (membrum superius) and lower limbs (membrum inferius). The limbs are sub-divided into the upper arm (brachium), forearm (antebrachium) and hand (manus), and the thigh (femur), lower leg (crus) and foot (pes).

Secondary sexual characteristics: the external appearance of a human being is identified in the different stages of life by physical attributes. These occur in men and women as gender dimorphism (gender differences) (especially after sexual maturity). The development of sexual organs is genetically determined. Responsible for their development are the primary sex organs (ovaries and testes), which are referred to as the primary sexual characteristics. Responsible for the outer appearance are mainly the secondary sexual characteristics (table), which develop in puberty.

Outer Appearance	
Man	**Woman**
Beard growth	Mammary gland (Mamma)
Hair growth on the front thorax and abdomen (great individual variation) and also on the back and extremities	Distribution of subcutaneous fat (more consistent, smoother outlines)
Pubic hair growth up to the navel	Pubic hair growth up to the height of the mons pubis
Reduced hairline (receding hairline, pattern baldness)	Even hairline
Larger body size	Smaller body size and muscle mass
Narrower pelvis	Horizontally oval pelvis

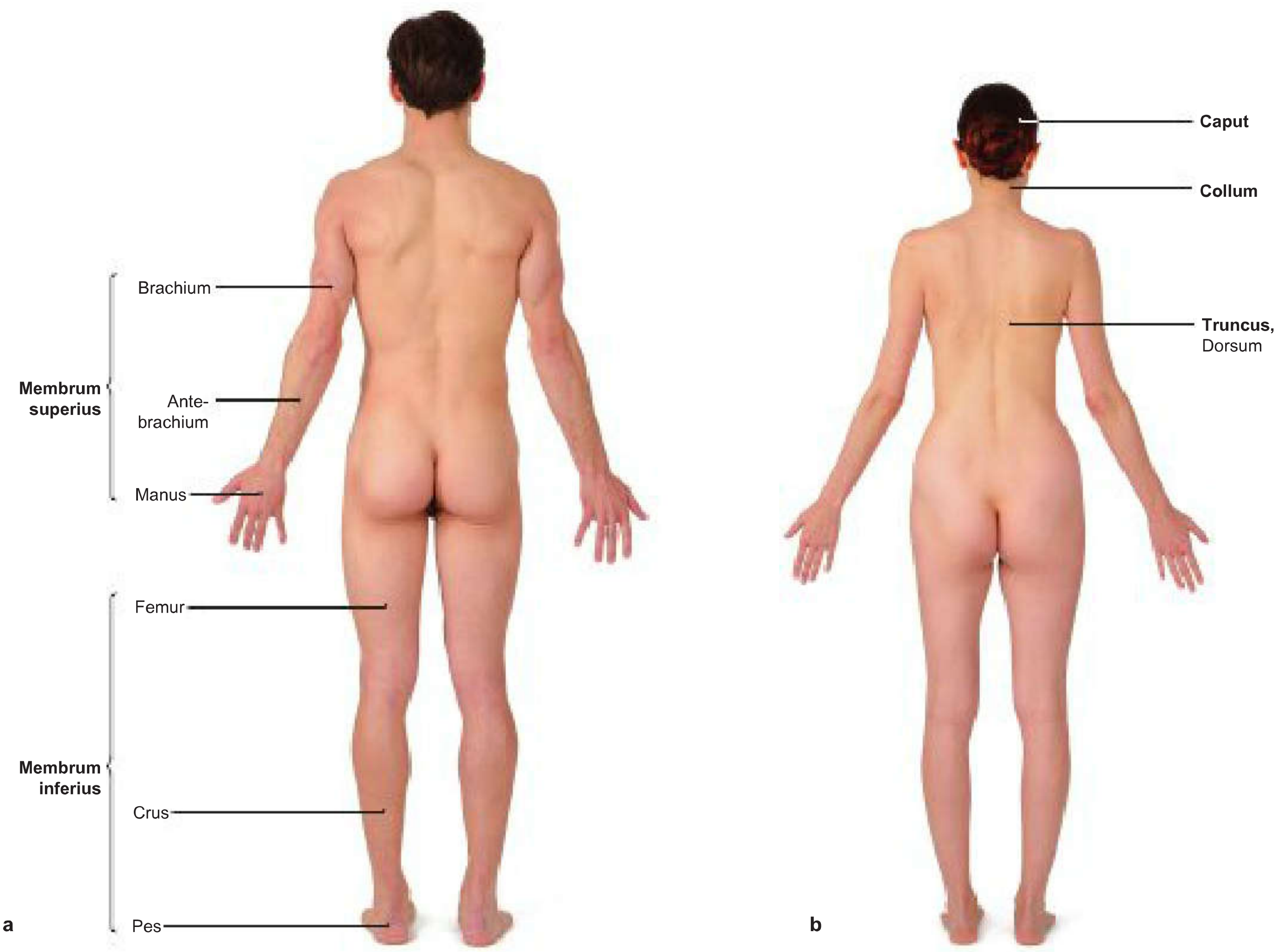
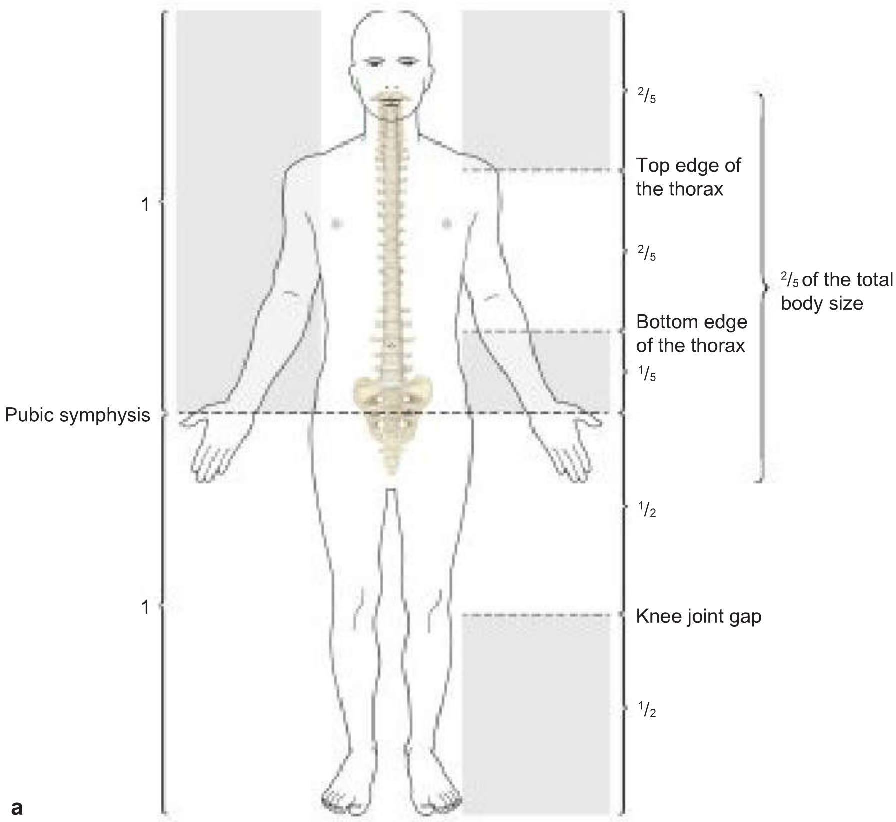


Fig. 1.2a and b Surface anatomy of the man (a) and the woman (b); dorsal view. [J803]

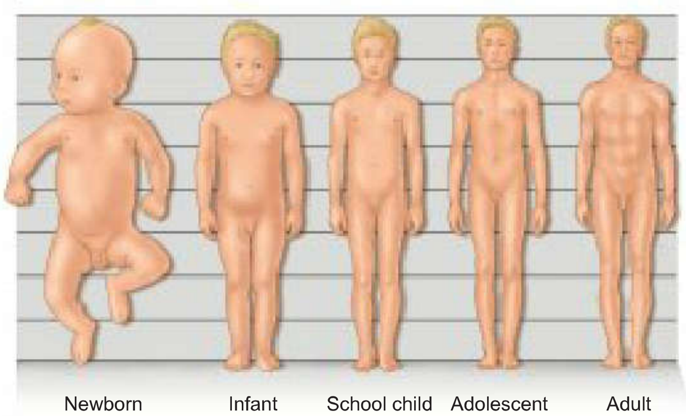
Clinical Remarks

As part of the **anamnesis** (from old Greek αναμνησις, *anámnesis* = reminder), the medical history of a patient in relation to his or her current complaints is taken. A detailed medical history includes biological, psychological and social aspects. The information gathered often enables conclusions regarding risk factors and causal relationships. The anamnesis does not have a direct link to treatment, although talking about the issues may have a beneficial and clarifying effect. The medical history is normally collected prior to medical examination, but in the case of an emergency requiring immediate treatment, it must be postponed until later. The aim of the medical history is to restrict to the greatest possible extent all possible diagnoses preferably by means of the main symptoms and exclusion criteria. In order to be able to make a definitive diagnosis, further examinations are usually necessary following the medical history.

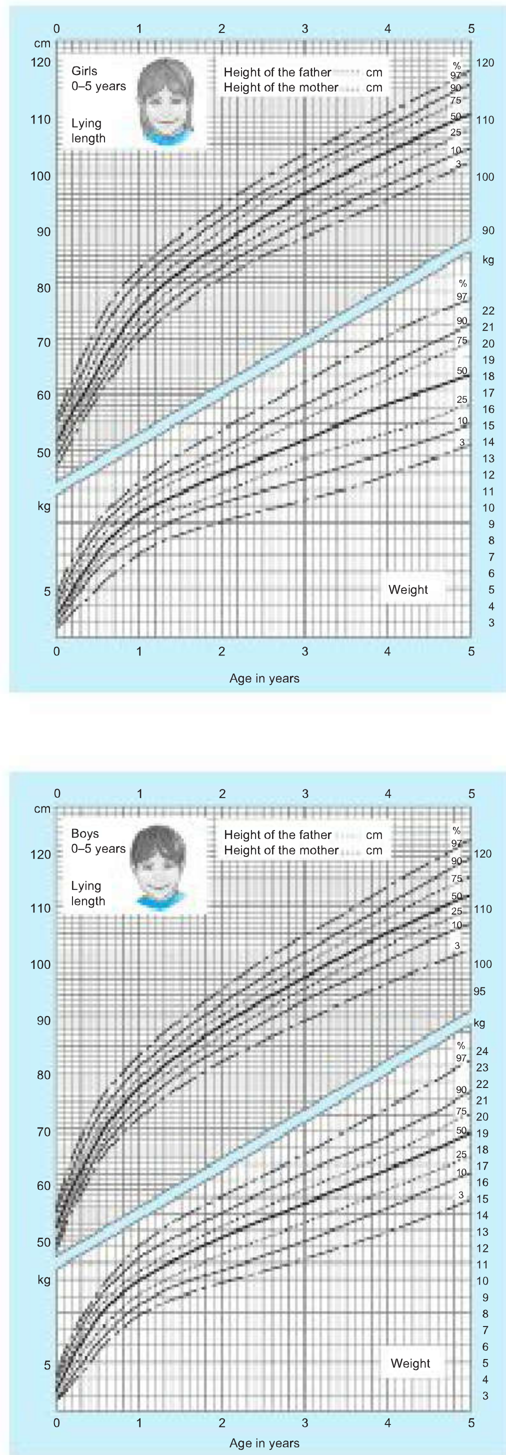
Body Proportions



a



b

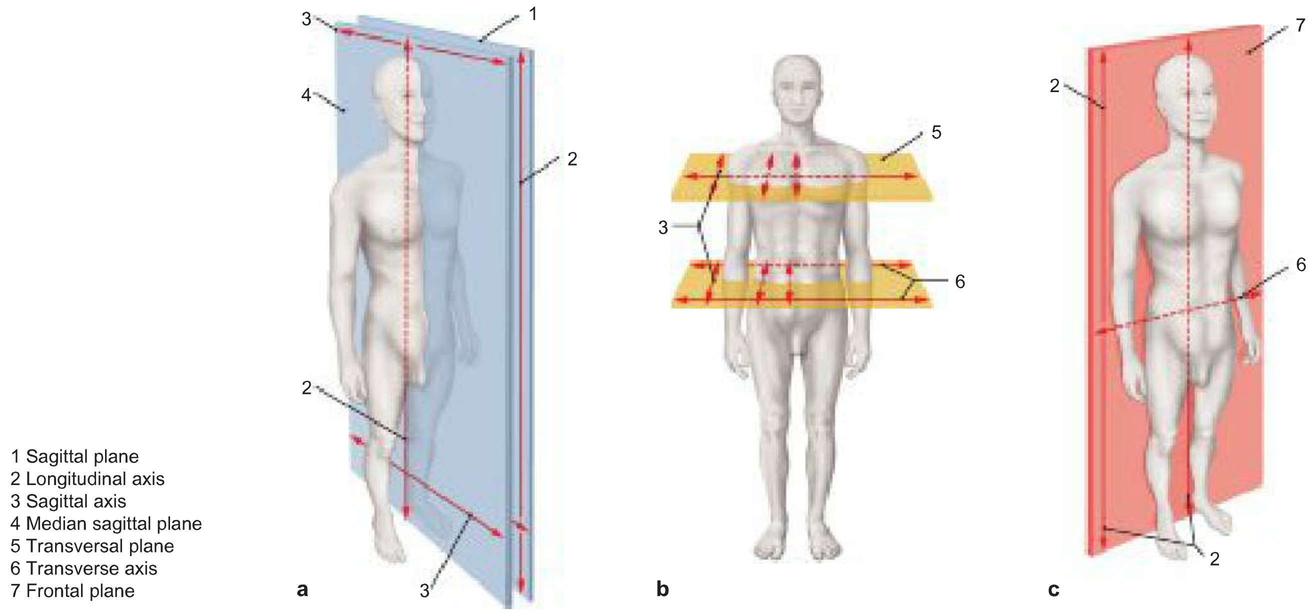


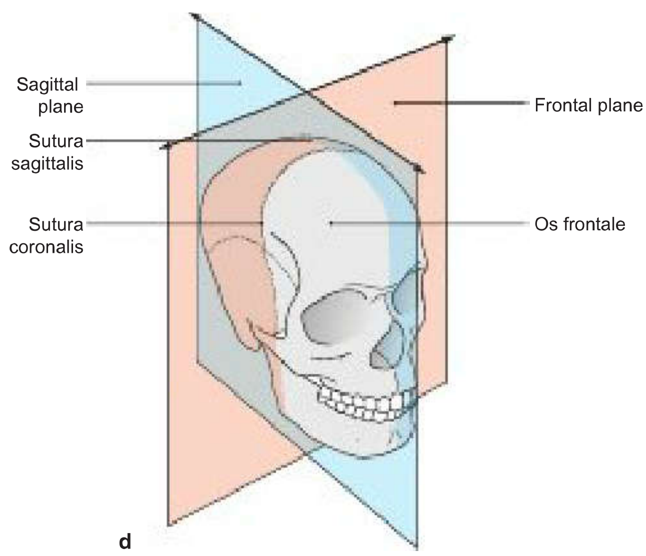
c

Fig. 1.3a to c
a Normal body proportions; frontal view. [L127]
If an adult is divided horizontally into two equal halves, the middle is approximately at the level of the upper edge of the pubic bone. The bottom half can be divided into another two equal halves at the level of the knee. The top half can be divided into five equal sections, of which the head and neck down to the top of the shoulders form ⅖, the thorax another ⅖ and the abdominal area ⅕. The spine occupies ⅖ of the total body size.
b Body proportions in different stages of development. [L238]
Body size refers to the measurement from the crown of the head to the soles of the feet (body length). In pediatrics, the postnatal period is divided into stages of development. In the different stages of development the body changes length continuously. **(1)** neonatal period (the first two weeks of life), **(2)** infancy (up to the end of the first year of life), **(3)** early childhood (up to the end of the fifth year of life), **(4)** school age (up to the onset of puberty), **(5)** puberty (maturation into adult, length varies), **(6)** adolescence (completion of the development and growth in length of the skeletal system up to **(7)** adults. Sometimes the term 'old age' is later used in medicine for elderly adults. At this point in time, the body length has decreased through age appropriate degenerative processes.
c Percentile curves. [L157]

Clinical Remarks

In order to assess correct body growth (standard) or divergent body growth (variability) in children, body height, weight and head circumference are analysed separately in relation to age and using percentile tables (→ Fig. 1.3c) for girls (left, 0–5 years) and boys (right, 0–5 years).





Major Axes	
Sagittal axis	runs perpendicular to the transversal and longitudinal axes
Transversal axis	runs perpendicular to the longitudinal and sagittal axes
Longitudinal or vertical axis	runs perpendicular to the sagittal and transversal axes

Major Planes	
Median (sagittal) plane	symmetry plane, divides the body into two equal halves
Sagittal plane	runs parallel to the median (sagittal) plane
Transversal plane	all cross-sectional planes of the body
Frontal plane	parallel to the forehead

Fig. 1.4a to d Planes and axes as well as radiological terms. [L127]
a The sagittal plane (Planum sagittale), between the sagittal and longitudinal axes.
b The transversal plane = horizontal plane (Planum transversale), between the transversal and sagittal axes.
c The frontal plane = coronal plane (Planum frontale), between the longitudinal and transversal axes.
d The coronal suture and sagittal suture (Sutura coronalis and Sutura sagittalis) are used especially in radiology as terms of motion: the sagittal layer corresponds to the sagittal plane, and the coronal layer corresponds to the frontal plane.

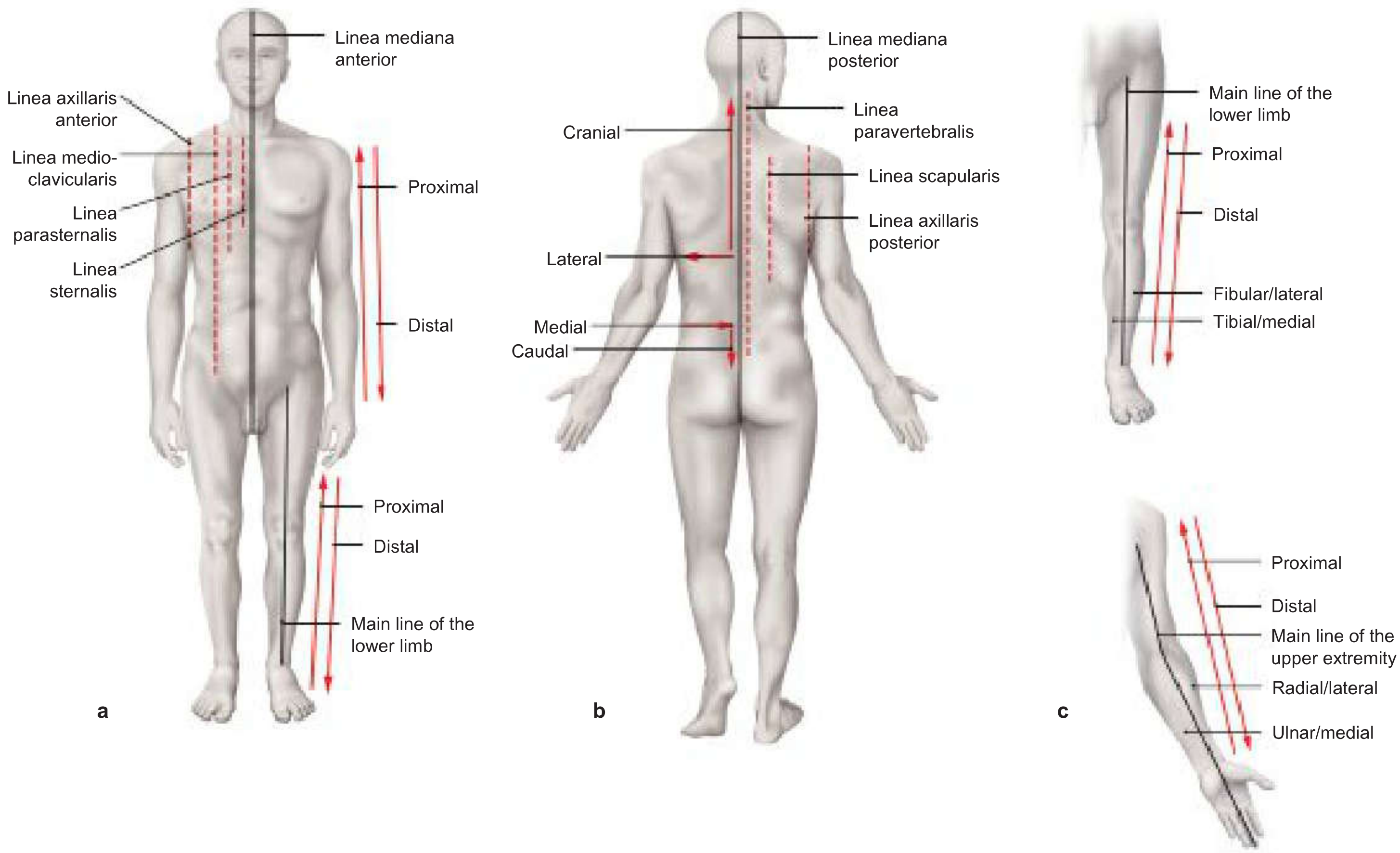
Directions of Movement	
Extension	Extension of the trunk or extremities
Flexion	Bending of the trunk or extremities
Abduction	Pulling the extremities away from the body
Adduction	Pulling the extremities towards the body
Elevation	Lifting the arm above the horizontal plane
Rotation	Internal and external rotation of the extremities about the longitudinal axis
Circumduction	Gyration, composite movement made up of, e.g. adduction, abduction, flexion and extension

Radiological Sectional Planes	
Radiological term	**Anatomical term**
Sagittal layer	Sagittal plane
Coronal layer	Frontal plane
Axial layer	Transversal plane
Radiology terminology in imaging procedures (computed tomography and magnetic resonance imaging) defines the three main anatomical planes as layers with their own nomenclature.	

Anatomical Planes and Positions

Terms of Direction and Position

Anatomical Terms of Movement		
Region	**Term**	**Movement**
Limbs	Extension	Elongation
	Flexion	Bending
	Abduction	Pulling away from the body
	Adduction	Pulling towards the body
	Elevation	Elevation of the arm/shoulder above the horizontal plane
	Depression	Lowering the arm/shoulder from above the horizontal plane
	Internal rotation	Inward rotation
	Outer rotation	Outward rotation
	Pronation	Rotation movement of hand/foot with hand turned inwards or sole of foot turned outwards
	Supination	Rotation movement of hand/foot with palm of hand turned outwards or sole of foot turned inwards
	Radial abduction	Swivelling hand/fingers towards the radius
	Ulnar abduction	Swivelling hand/fingers towards the ulna
	Palmar flexion/Volar flexion	Bending palm of hand towards back of arm
	Plantar flexion	Bending sole of the foot towards back of leg
	Dorsiflexion	Bending back of hand/foot towards front of arm/leg
	Opposition	Placing the thumb opposite the little finger
	Reposition	Returning the thumb to the index finger
	Inversion	Lifting the inner side of the foot using the talocalcaneonavicular joint
	Eversion	Lifting the outside of the foot using the talocalcaneonavicular joint
Spine	Rotation	Rotation in the longitudinal axis
	Lateral flexion	Lateral tilt
	Inclination (flexion)	Forward tilt
	Reclination (extension)	Backward tilt
Pelvis	Flexion (anterior/ventral rotation)	Pelvic tilt towards the front
	Extension (dorsal rotation)	Pelvic stretching towards the back
Temperoman-dibular joint	Abduction	Opening the jaw
	Adduction	Closing the jaw
	Protrusion/protraction	Pushing forward the lower jaw
	Retrusion/retraction	Pulling back the lower jaw
	Occlusion	Interlocking the upper and lower jaw teeth
	Mediotrusion	Lower jaw on one side facing ventromedial
	Laterotrusion	Lower jaw on one side facing dorsolateral



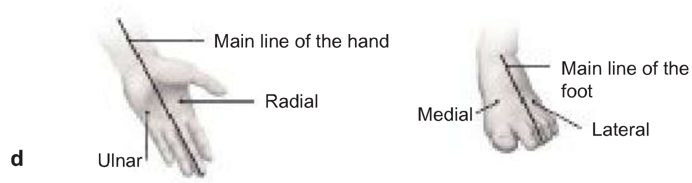


Fig. 1.5a to d Orientation lines and terms of motion and location. [L127]
a Ventral view
b Dorsal view
c Lower limb ventral, upper limb with supinated hand
d Hand palmar and view towards the back of the foot

Terms of Motion and Location for Parts of the Body			
cranial or superior	towards the head	apical	directed or belonging to the top
caudal or inferior	towards the tail bone	basal	towards the base
anterior or ventral	towards the front	dexter	right
posterior or dorsal	towards the back	sinister	left
lateral	towards the side, away from the midline	proximal	towards the torso
medial	in the middle, towards the midline	distal	towards the end of the limbs
median or medianus	within the median plane	ulnar	towards the ulna
intermedius	lying in between	radial	towards the radius
central	towards the interior of the body	tibial	towards the tibia
peripheral	towards the surface of the body	fibular	towards the fibula
profundus	low-lying	volar or palmar	towards the palm
superficial	lying on the surface	plantar	towards the sole
external or externus	external	dorsal	(extremities) towards the back (dorsum) of the hand or the foot
internal or internus	internal	frontal	towards the front
		rostral	towards the mouth or nose tip (only for terms relating to the head)

Terms of Movement

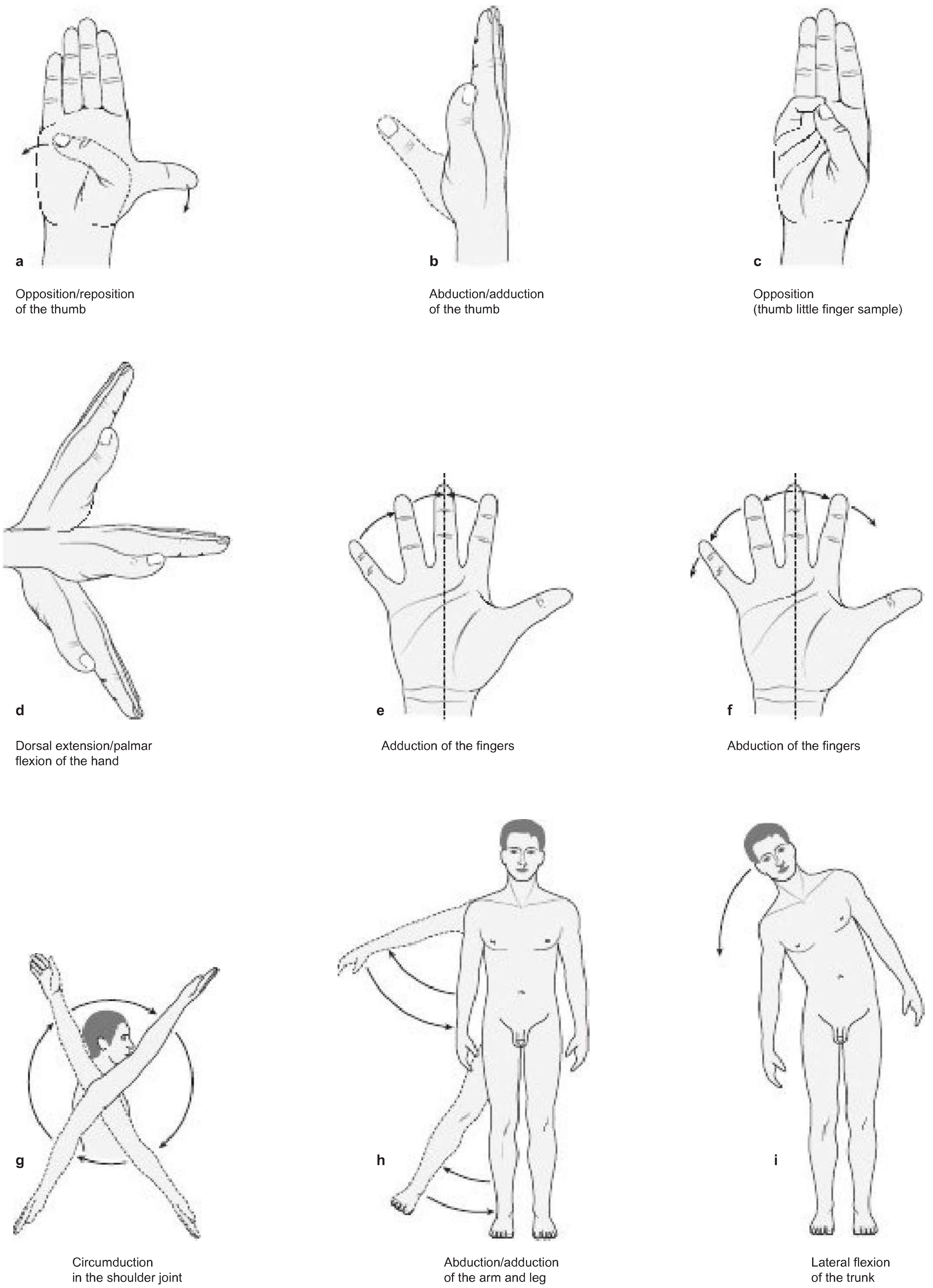


Fig. 1.6a to i Terms of movement. [L126]

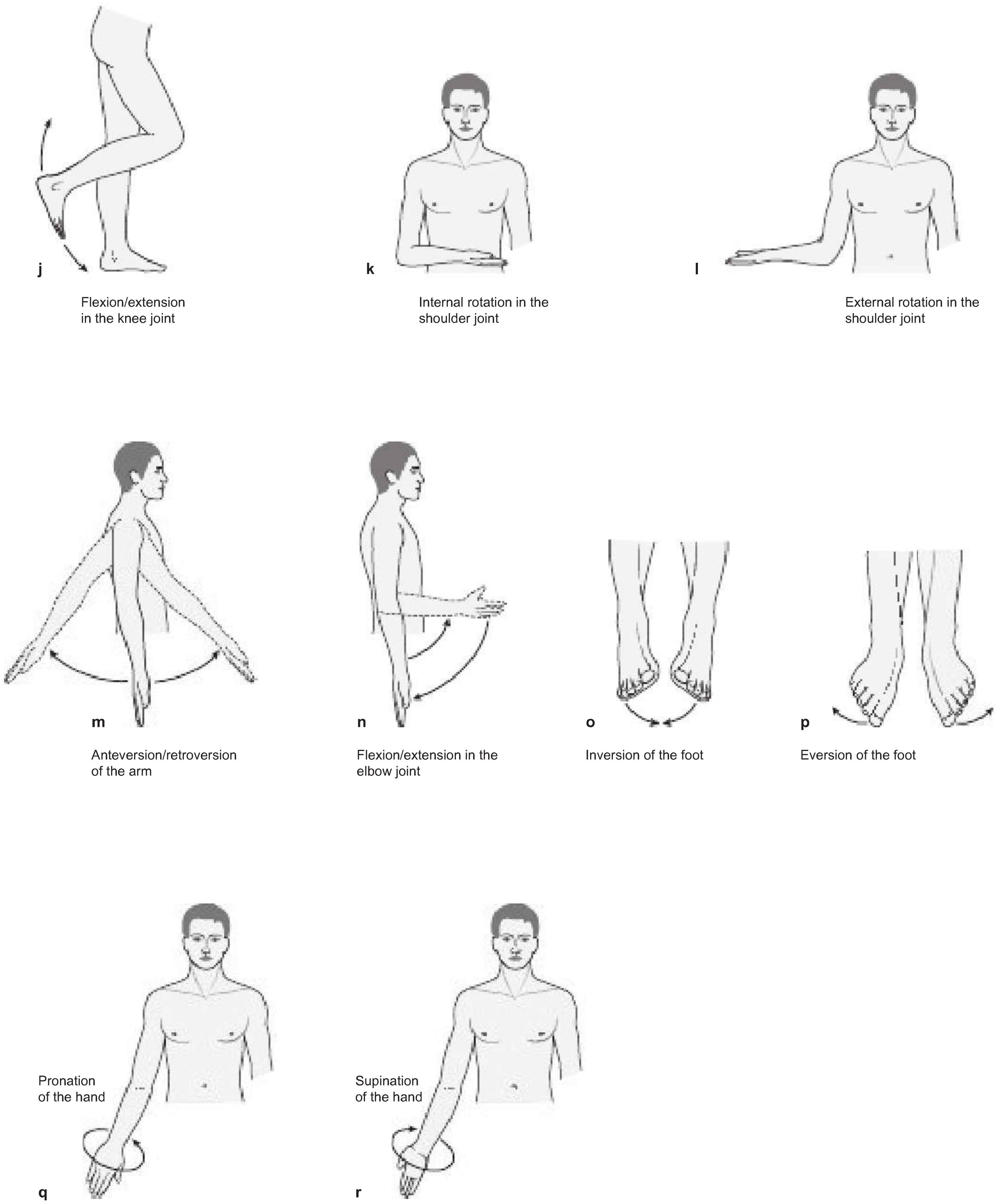


Fig. 1.6j to r Terms of movement. [L126]

Regions of the Body

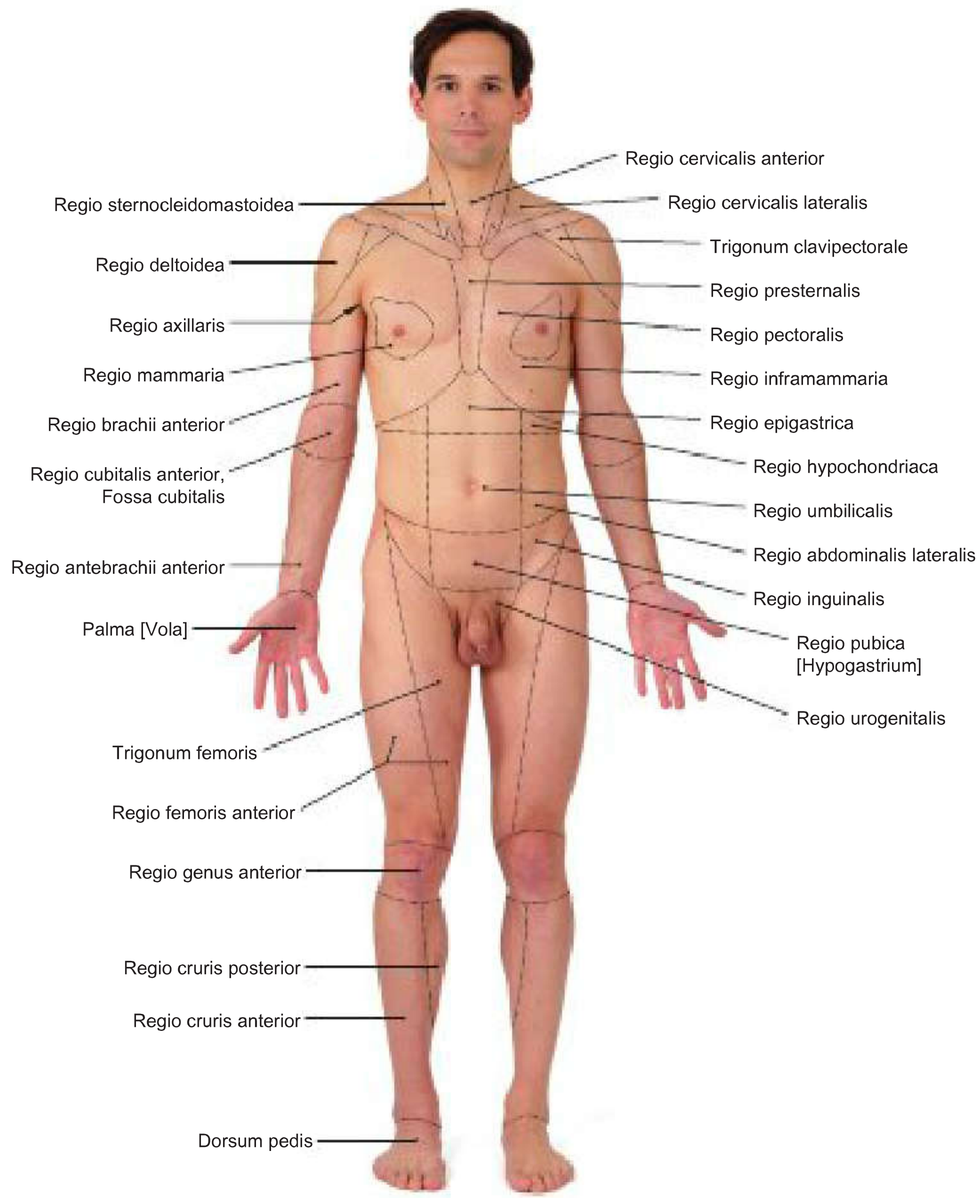


Fig. 1.7 Regions of the body; ventral view. [J803]
The body surface is divided into regions to allow description and facilitate orientation.
Regio: region; trigonum: triangle.

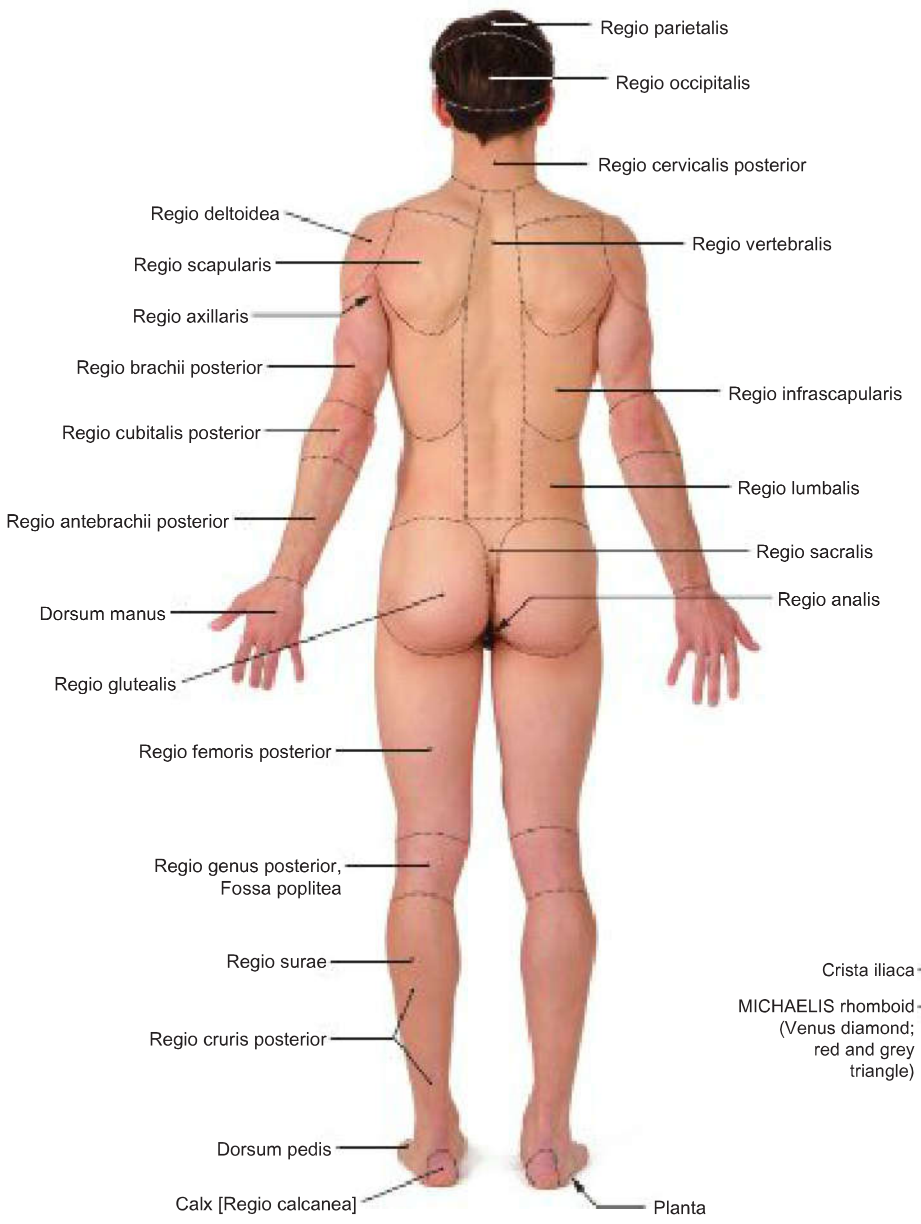


Fig. 1.8 Regions of the body; dorsal view. [J803]
The body surface is divided into regions to allow description and facilitate orientation.
Regio: region; trigonum: triangle.

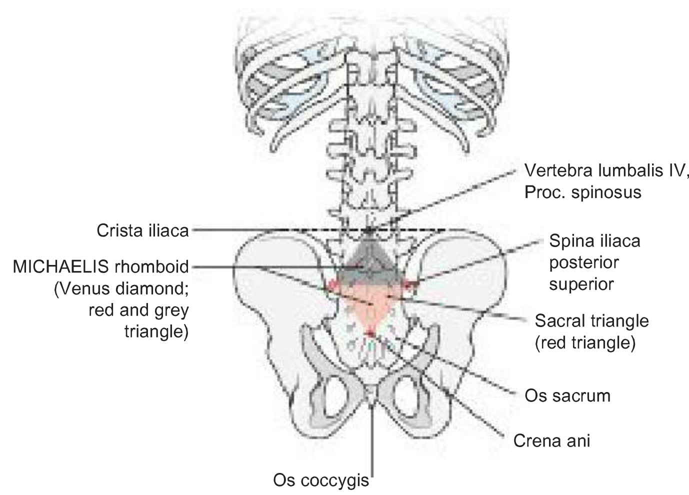


Fig. 1.9 Rhombus of MICHAELIS (Venus diamond) and sacral triangle; dorsal view. [L126]
Presentation of palpable and visible corners of the Rhombus of MICHAELIS (female) and sacral triangle (male).

Relaxed Skin Tension Lines

Fig. 1.10a and b Relaxed skin tension lines.
a Ventral view, **b** dorsal view. [J803]
Tension lines (syn. LANGER's lines) are caused by the alignment of collagen and elastic fibres in the reticular layer of the skin. Their development is dependent on age, nutritional status, general condition and anatomical peculiarities.

Clinical Remarks

Any injury to the skin leaves traces to varying degrees, e.g. a scar on the knee after a crash, or on the abdomen after removal of the appendix (appendectomy). A scar is the physiological end state of tissue repair. It consists of coarse collagenous connective tissue and differs from the surrounding skin by the lack of hair, sebaceous and/or sweat glands. If scars appear at an exposed location or become hyperplastic (keloid formation), they can be aesthetically intrusive. In order to make a scar in planned surgical procedures on the body as discrete as possible, the incision is made along tension lines of the skin. On the edges of wounds that run perpendicular or at an angle to the tension lines, there is significantly higher tension than on the edges of wounds that run parallel to the lines. Wherever possible, therefore, surgical incisions are made in the direction of the tension lines. This reduces the risk of the wound margins spreading (dehiscence) as well as the development of extensive scars.

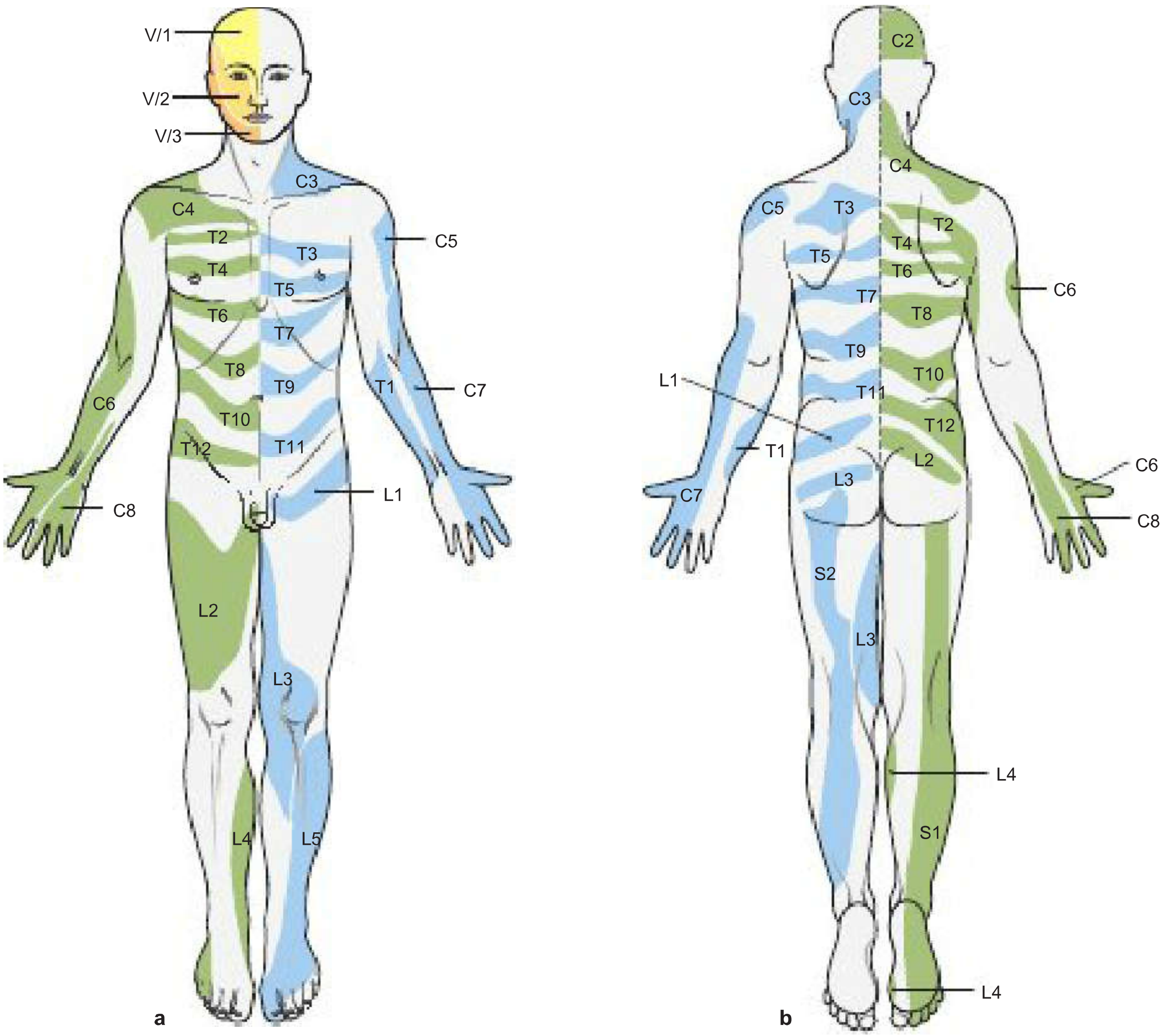


Fig. 1.11a and b Segmental innervation of the skin (dermatomes). **a** Ventral view, **b** dorsal view. [L126]

A **dermatome** is an area of skin innervated autonomously by the sensory fibres of a spinal cord nerve (spinal nerves, → Fig. 1.45). Each spinal nerve can thus be assigned to an area of skin. However, the innervation areas of adjacent spinal nerves overlap and, in addition, many cutaneous nerves are composed of the sensory fibres of several spinal nerves joined together (Rami ventrales of spinal nerves develop branches in the neck and lumbar sacral area [plexus] → Fig. 1.46), so that the dermatomes differ from the innervation fields of the cutaneous nerves. With the exception of the midline, where the overlap is very low, the **autonomous area** of each individual spinal nerve (skin area exclusively innervated by a particular sensory nerve) is much smaller than the total skin area innervated by it. For reasons of clarity, the dermatomes are represented alternately for the right (green) side of the body and the left (blue) side of the body. Thus, e.g. T7 is visible on the left side in blue, T8 on the right side in green and T9 again on the left side in green, etc. Regions where no colour is assigned (e.g. the area between C4, T2 and T3 around the midline), are areas in which an extraordinarily high variability and a very strong interindividual overlap occurs, so that no clear assignment is possible. Presentation of the dermatomes is based on an evidence-based dermatome card according to LEE and co-workers (2008). In order to keep the figure clear and understandable, the dermatomes S3, S4 and S5 are not shown (they cover the area of the perineum including the anus and the external genitalia). The skin of the face is not innervated by spinal nerves but by the cranial nerve (N. trigeminus [V]). Similar to the spinal nerves, its three branches also have autonomous sensory skin innervation areas (yellow).

– Clinical Remarks

Damage to a spinal nerve typically leads to loss of sensitivity in its autonomous area. **Herpes zoster** is a viral disease that is associated with an extremely painful skin rash with blisters. The virus affects a spinal nerve. The virus triggers inflammation which spreads from the nerve to the associated dermatome and triggers the skin symptoms (colloquially: **shingles**). The disease is caused by the **varicella zoster virus**, belonging to the herpes virus family, which is transmitted in 99 % of cases in childhood and triggers **chickenpox** after infection, if the child has not previously been vaccinated against it. The virus persists in the body (spinal ganglion) and can be reactivated in cases of immunodeficiency.

Internal Organs, Surface Projection

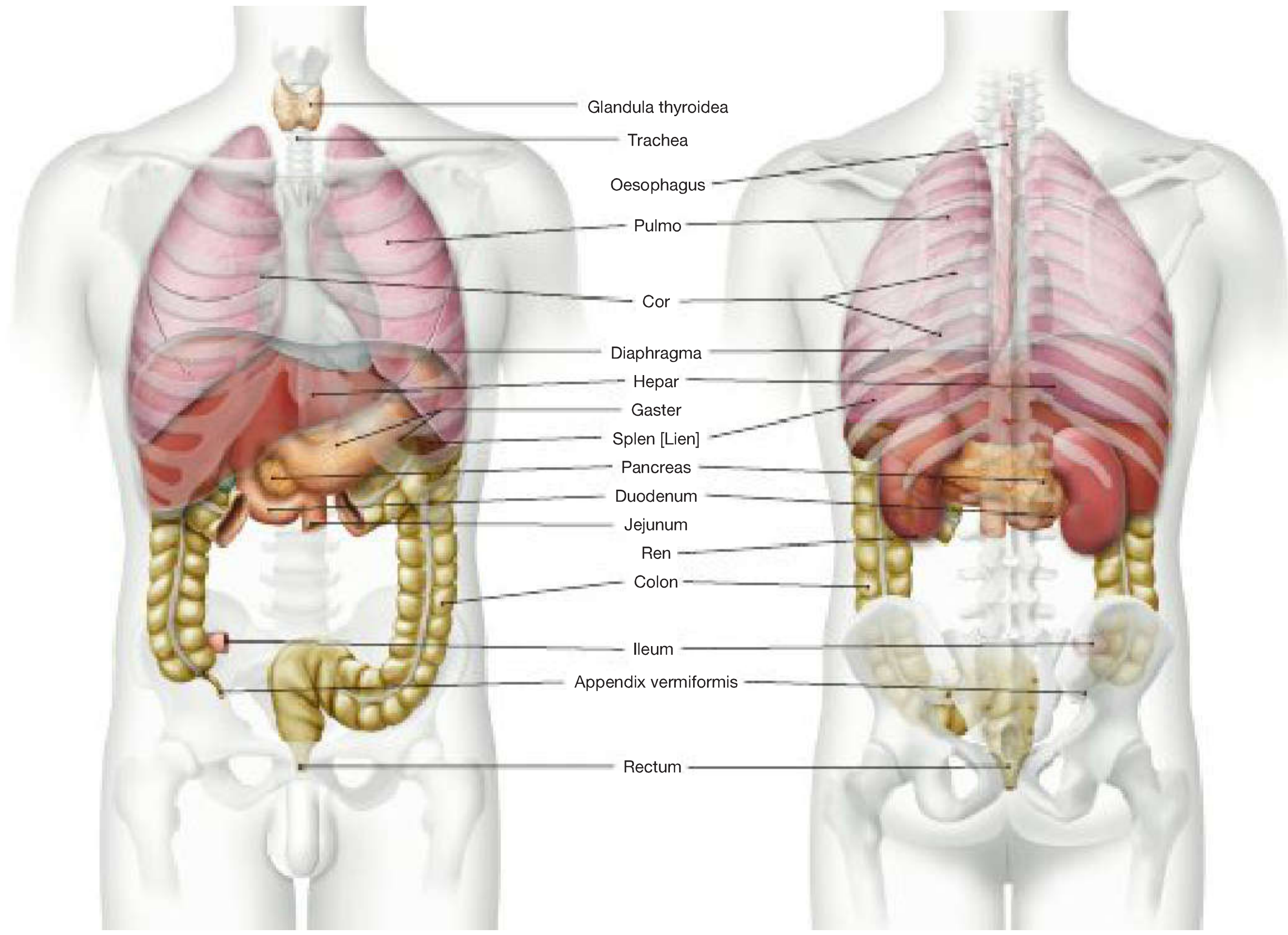


Fig. 1.12a and b Projection of the internal organs onto the body surface. [L275]
Projection of the internal organs onto the ventral trunk wall **(a)** and onto the dorsal trunk wall **(b)**: oesophagus, thyroid gland (Glandula thyroidea), trachea, lungs (Pulmo), heart (Cor), diaphragm, liver (Hepar), stomach (Gaster), spleen (Splen [Lien]), pancreas, duodenum, jejunum, kidney (Ren), colon, ileum, appendix (Appendix vermiformis) and rectum.

Clinical Remarks

Even without technical instruments, it is possible to gain an insight on individual organs and their projection onto the body surface through practice. The term **auscultation** (from Latin auscultare = listen) refers to the monitoring of the body, typically with a stethoscope. Auscultation is part of the physical examination of a patient.

Percussion (from Latin percutere = beat) refers to tapping the body surface for diagnostic purposes. Underlying tissue is hereby set in vibration. The resulting acoustic sounds provide information about the state of the tissue. Thus, the size and position of an organ (e.g. liver) or the air content of the tissue (e.g. lung) can be assessed.

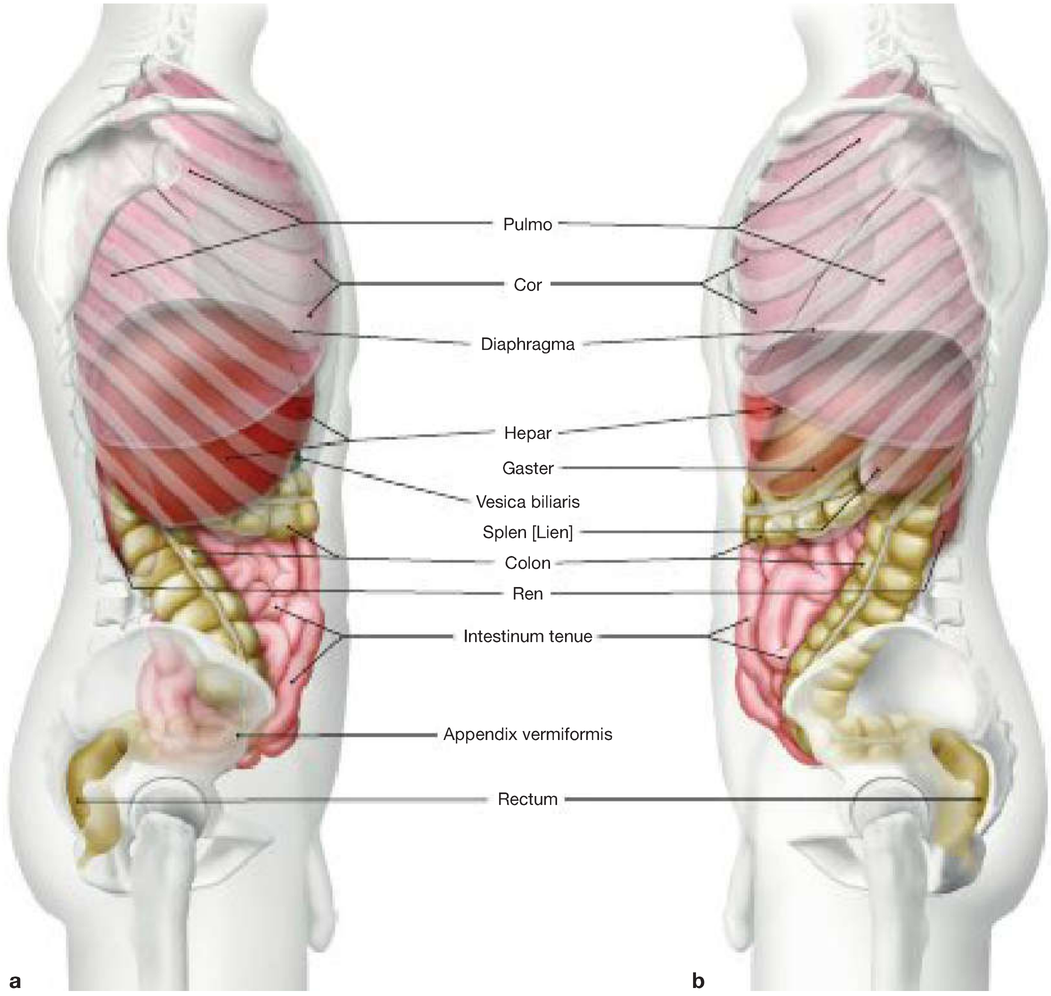


Fig. 1.13a and b Projection of internal organs onto the body surface. [L275]
Projection of the internal organs onto the right trunk wall **(a)** and onto the left trunk wall **(b):** lungs (Pulmo), heart (Cor), diaphragm (Diaphragma), liver (Hepar), stomach (Gaster), gallbladder (Vesica biliaris), spleen (Splen [Lien]), large intestine (Colon), kidney (Ren), small intestine (Intestinum tenue), appendix (Appendix vermiformis) and rectum (Rectum).

– Clinical Remarks

Through knowledge of the **projection** of the internal organs onto the body surface, disease symptoms can be linked to specific organs during an initial physical examination and without reference to the medical history. For example, appendicitis (inflammation of the appendix [Appendix vermiformis]) is usually associated with discomfort in the lower right abdomen.

Development

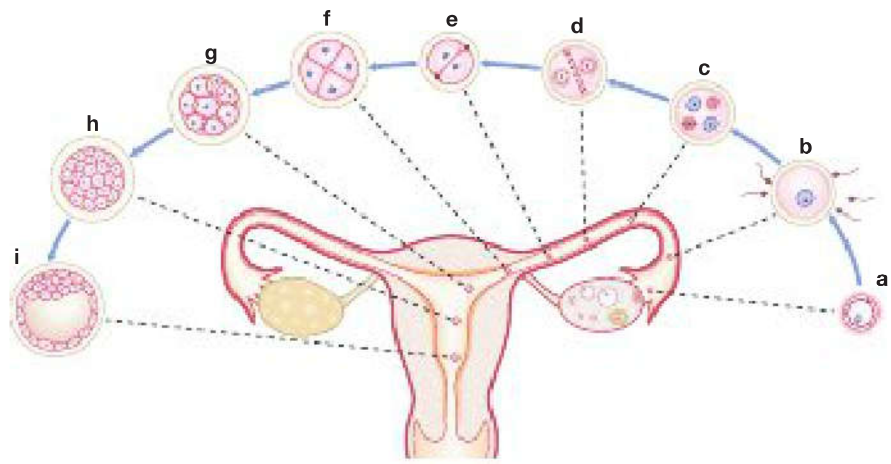


Fig. 1.14a to i First week of embryonic development: fertilisation and implantation. [E838]
Normally within 24 hours after **ovulation, a) fertilisation (b)** occurs in the ampulla of the oviduct. Fusion of the nuclei of the ovum and sperm creates a **zygote (c)**. Subsequent cell division **(2-, 4-, 8- and 16-cell stages; d–h)** generates a cell aggregate (morula) which is transported into the uterine cavity. Approximately on the 5th day after fertilisation, a fluid-filled cyst develops in the morula **(blastocyst, i),** which on the 5th–6th day implants in the prepared lining of the uterus.

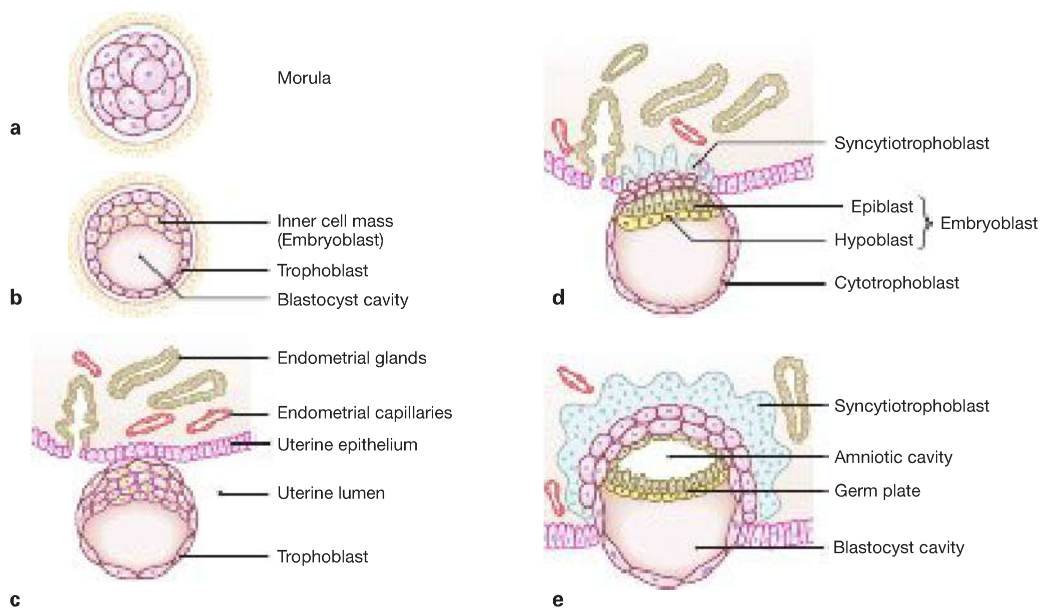


Fig. 1.15a to e First and second week of embryonic development: bilaminar germ (embryonic) disc. [E838]
Upon differentiation of the morula **(a)** into the blastocyst, the latter generates an inner cell mass **(embryoblast)** and a larger fluid filled (blastocyst cavity) outer cell layer **(trophoblast) (b)**. Interactions between the trophoblast and maternal tissues form the **uteroplacental circulation (c–e)**. The embryoblast develops into the bilaminar **embryonic disc** with ectoderm (columnar cells at the dorsal surface of the embryoblast) and endoderm (cuboidal cells at the ventral surface). The ectoderm forms a cavity dorsally, which becomes the **amniotic cavity**. The blastocyst cavity in front becomes the primary yolk sac, which is lined by the endoderm. On the 12th day the actual yolk sac forms out of the ectoderm; the original blastocyst cavity is lined by extra-embryonic mesoderm.

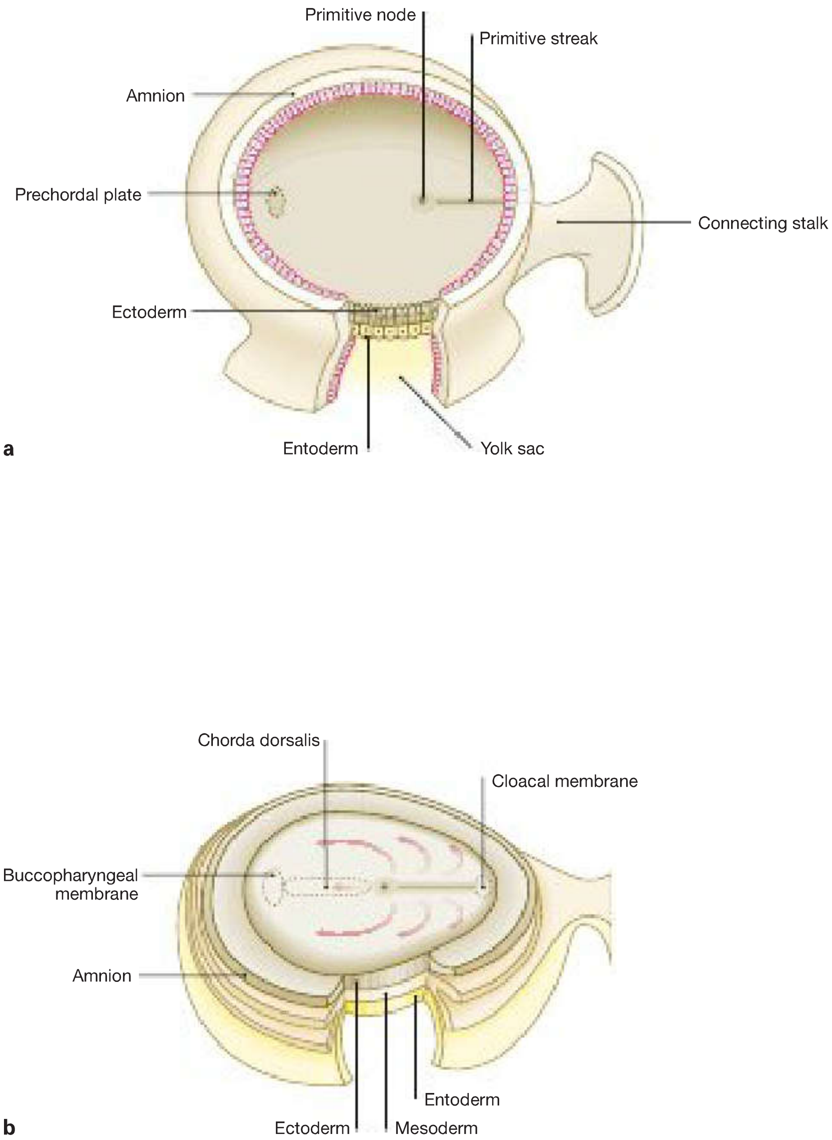


Fig. 1.16a and b Third week of embryonic development: gastrulation. [E838]
Development of the trilaminar germ disc begins with the appearance of the primitive streak at the dorsal surface of the ectoderm. The primitive streak is demarcated by the primitive node **(a)**. Cells migrate out of the primitive streak and form the **intraembryonic mesoderm** between the top of the yolk sac and the ectoderm of the amniotic cavity (gastrulation). Some of the cells protrude cranially as a **chordal projection** towards the cranial part of the embryo. Here, in the ectoderm, the **prechordal plate** (adhesion surface between ectoderm and endoderm – there is no mesoderm located between the two layers) evolves. The chordal projection develops a lumen and becomes a **Chorda dorsalis** (primitive stabilising structure of the embryo), which recedes later in development **(b)**. Only the Nuclei pulposi of the intervertebral discs remain as relics of the Chorda dorsalis. Some mesoderm cells migrate cranially past the prechordal plate and form the heart. The **three germ layers** (ectoderm, mesoderm, endoderm) are the building blocks for the **development of all organs.** For further information on which organs emerge from which germ layer, see textbooks on embryology.

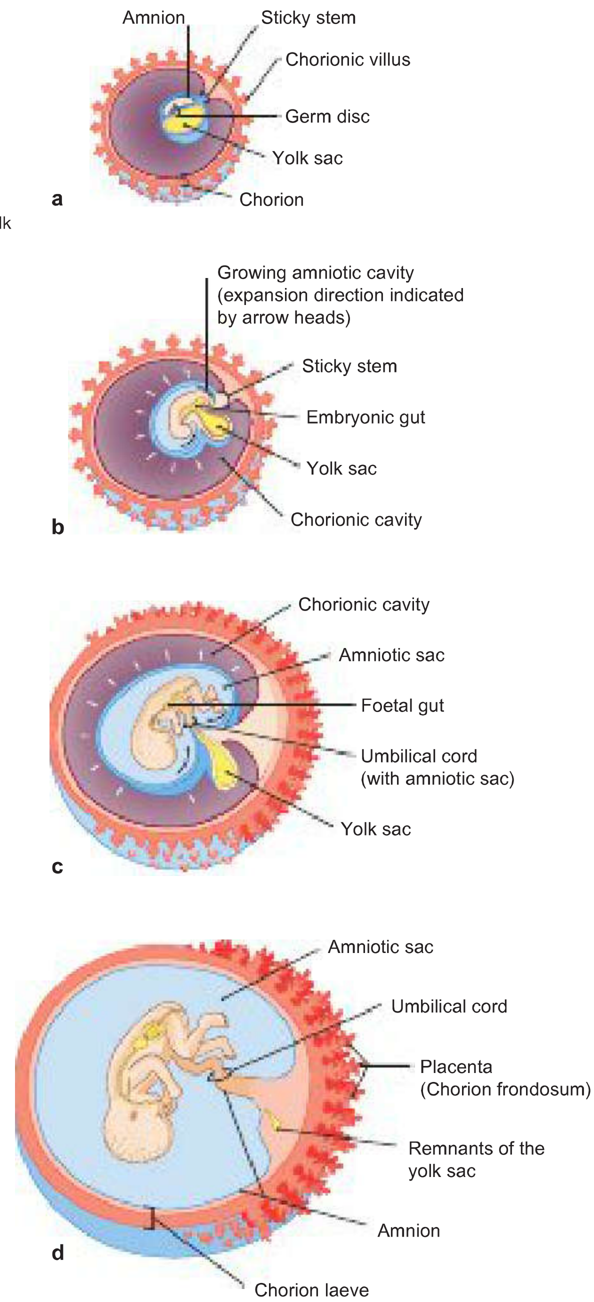


Fig. 1.17a to d Further development. [E347-09]
a condition as presented in → Fig. 1.16a. 3rd week: the amnion covers the dorsal surface of the embryo; the **chorionic cavity** is still very large at this early stage.
b In the 4th week the **amnion** envelops the entire embryo with the exception of the umbilical cord. **c** In the period that follows the amnion grows rapidly. The slower growth of the chorion cavity and yolk sac makes these smaller. **d** Finally the amnion displaces the chorionic cavity completely and forms the **amniotic sac.** The yolk sac has receded to remnants.

Skeleton

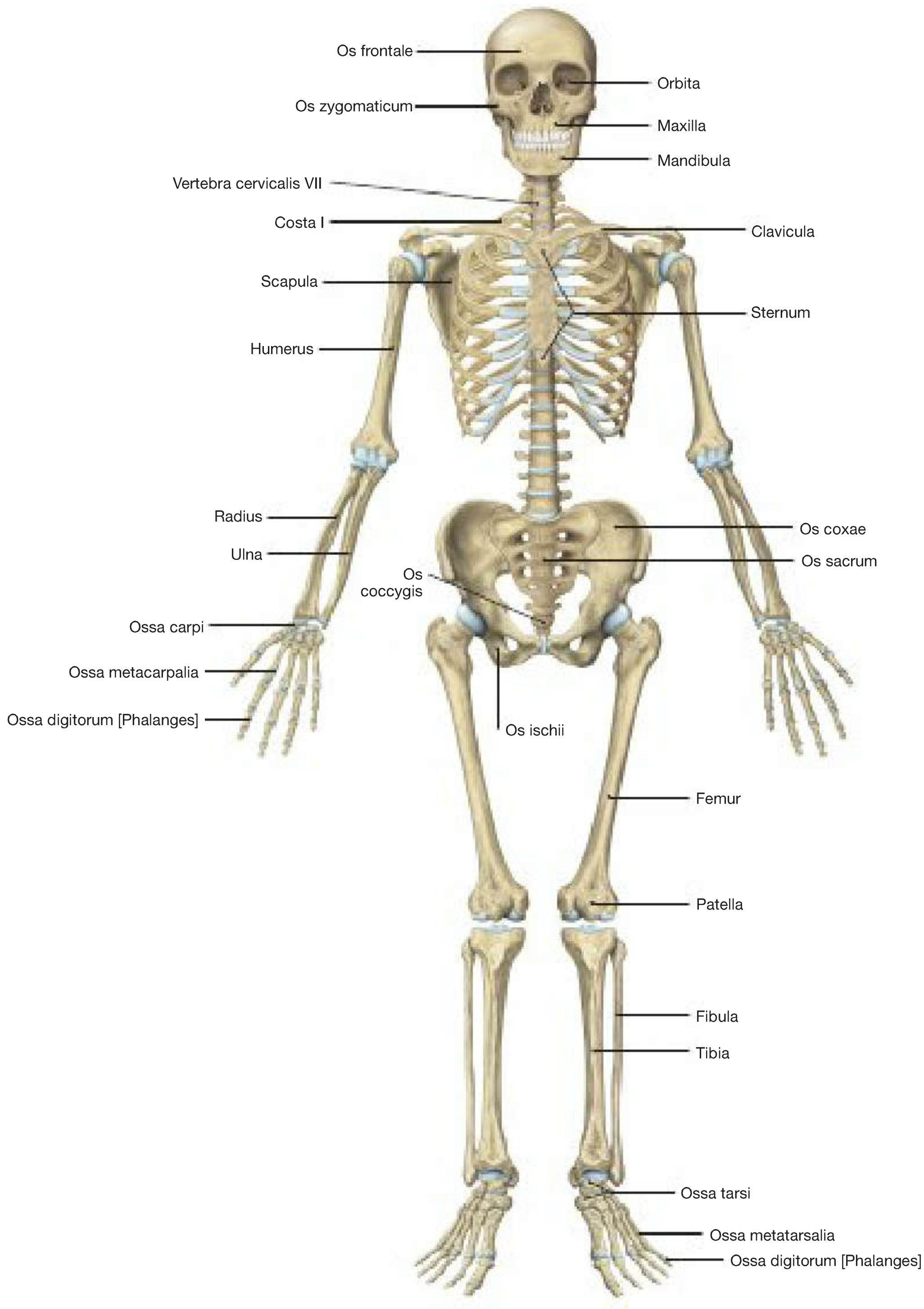


Fig. 1.18 Skeleton, skeletal system; ventral view. [L127]
The bones of the skeleton are grouped according to their shape and structure into:

- **long bones** (Ossa longa), e.g. hollow bones of the extremities, such as the femur and humerus
- **short bones** (Ossa brevia), e.g. carpal bone and tarsal bone
- **flat bones** (Ossa plana), e.g. ribs, sternum, scapula, ileum and bones of the skull
- **aerated bones** (Ossa pneumatica), e.g. frontal bone, ethmoid bone, sphenoid bone, maxilla and temporal bone
- **irregular bones** (Ossa irregularia, cannnot be assigned to other bones), e.g. vertebrae and mandible
- **sesamoid bones** (Ossa sesamoidea, bones embedded in tendons), e.g. patella and pisiform bone
- **accessory bones** (Ossa accessoria, not normally found in all human skeletons), e.g. sutural bone of the skull, cervical rib

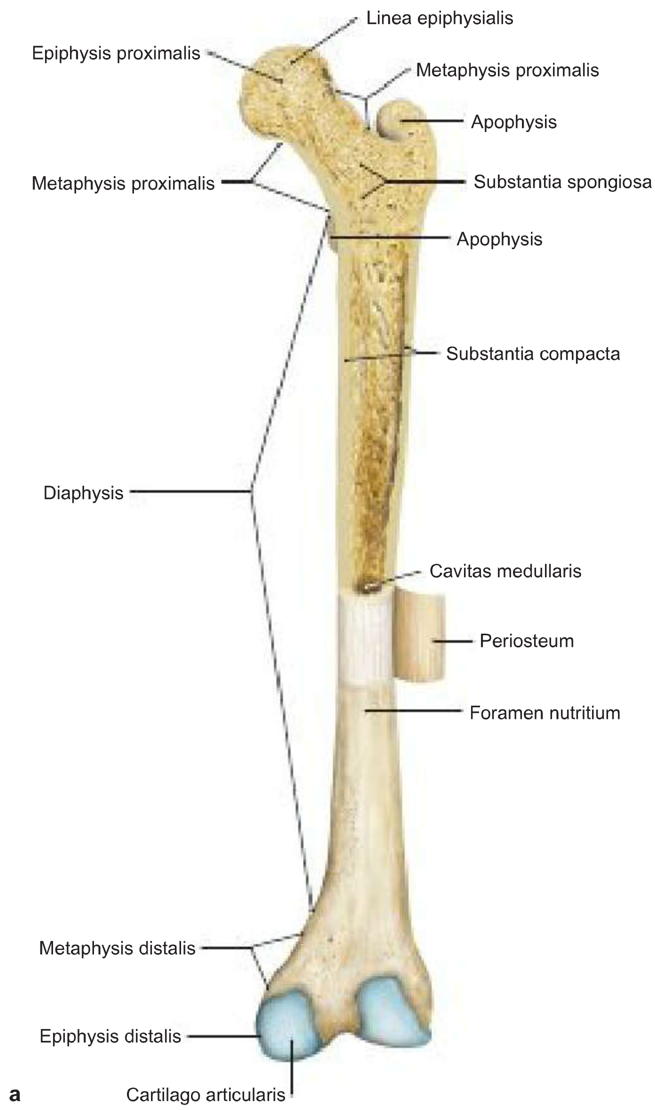
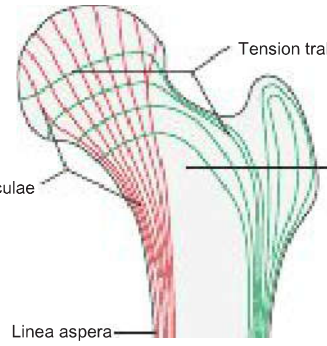


Fig. 1.19a Structure of a long tubular bone, os longum; section through the proximal part of the right thigh bone (femur) of an adult. In the area of the diaphysis (bone shaft) the periosteum (bone membrane) is raised and to the side; dorsal view.

a Macroscopically, two different types of bone tissue can be distinguished, merging together without sharp margins: Substantia compacta or corticalis (compacta or compact bone is very thin in the epiphysis [end piece of the bone] and solid in the diaphysis) and Substantia spongiosa, (spongiosa, spongy or cancellous bone is only well-developed in the epi- and metaphysis [bone portion between dia- and epiphysis]).

The **compact bone** in the diaphysis appears as a solid mass; the **cancellous bone** in the epi- and metaphysis forms a three-dimensional system of fine, branching rod-like bones **(trabeculae),** which are distinguished by the amount of stress into either a tension or compression trabecula. The special cancellous structure is only clearly visible in the epi- and metaphysis. The space in between the trabeculae is filled with blood-forming red marrow (young person) or yellow marrow (old person). The orientation of the individual trabeculae is parallel to the lines of tensile and compressive stress generated within the bone. (In the femur, these forces are proximal and eccentric, adding additional bending stress to the bone.) In a long evolutionary process, bones have developed the greatest possible mechanical robustness with the least possible amount of material and weight.

The Foramen nutritium to which the Canalis nutritius (pulling diagonally through the compact bone) is attached, is the entry point for the vessels into and out of the bone marrow (blood supply to the diaphysis). In the area of the meta- and epiphysis there are also numerous different sized holes in the thinner cortical bone, that in particular supply blood to the epiphyses.



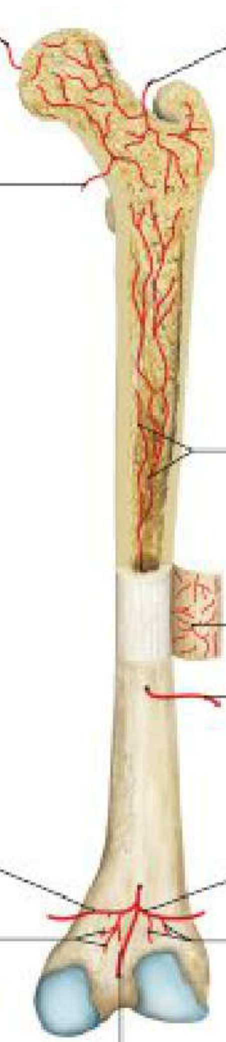


Fig. 1.19b and c
b Functional adjustment of bone. [L126]
Compact (cortical) bone and cancellous bone adapts to the amount of stress to the bone. In areas of higher force (pressure), the compact bone is thicker **(quantitative adjustment).** For example, on the femur, you can see this on the medial side (thicker cortical bone, Linea aspera) because the bone here in the frontal plane is exposed to a strong bending force. Compressive and traction forces applied to the bones are absorbed through the alignment of the trabeculae in the form of compression trabeculae (pressure trajectories) and traction trabeculae (traction trajectories) **(qualitative adjustment).** In the process, pressure trajectories are compressed (compression trajectories); tension trajectories are stretched (expansion trajectories). In areas of bone which are not subjected to any stress, no cancellous bone forms. This is referred to as **neutral fibre.** In the femur it does not appear as fibre but as WARD's triangle.
c Blood supply of a long tubular bone.
Only the arteries are illustrated. The blood supply to the diaphysis takes place via the **Vasa nutritia** (normally two with the femur illustrated). In the area of metaphyses and epiphyses, the cortical bone is thinner and pierced by many different-sized holes, through which the local blood vessels (supplying blood to the epiphyses in particular) enter. The entry points of these vessels are not referred to as Foramen nutritia. **Bone marrow arteries** are found in the centre of the diaphysis and the outer corticalis or compact bone is supplied by the **richly vascularised periosteum** (→ Fig. 1.20b). For the blood supply to the rest of the cortical bone → Fig. 1.20a.

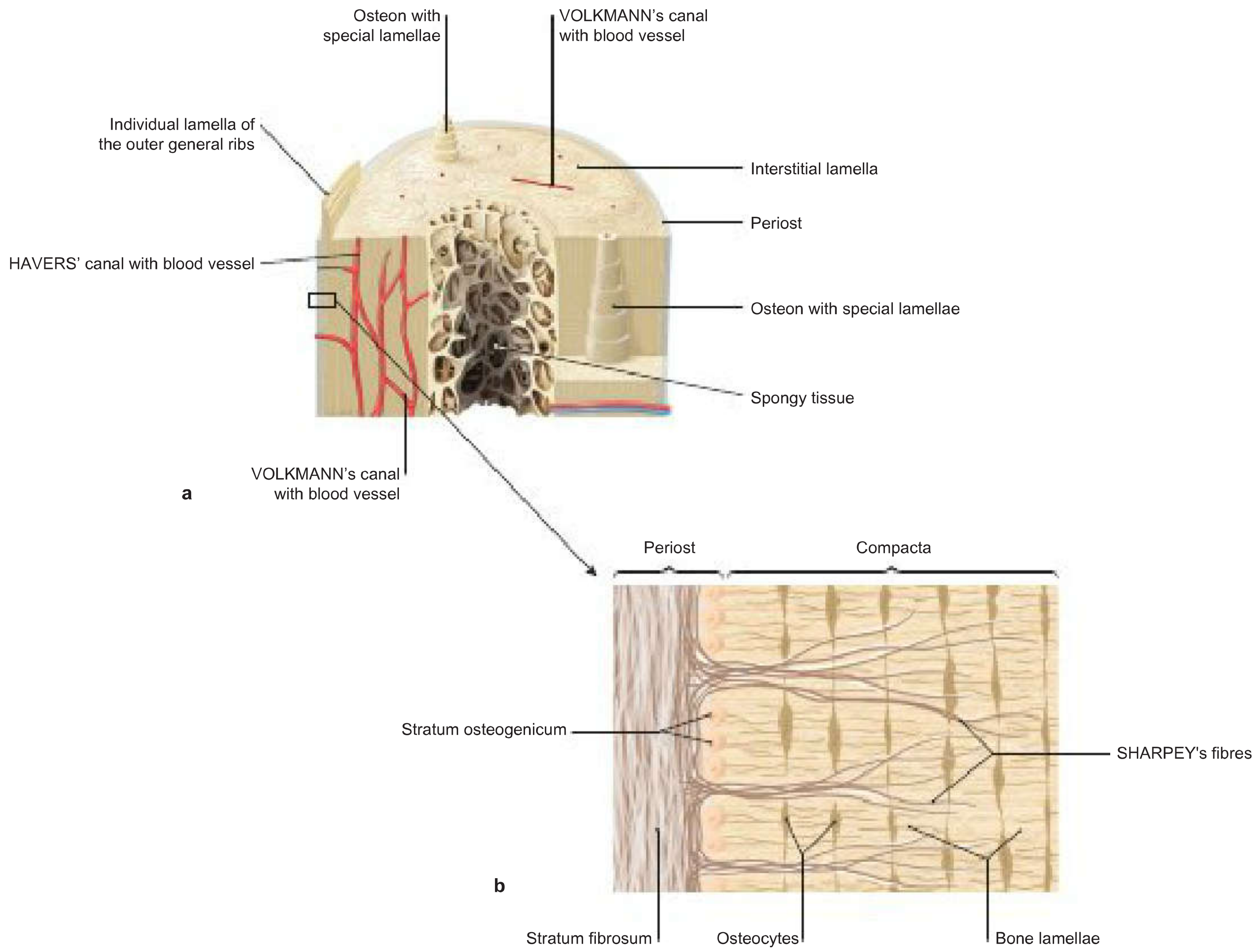


Fig. 1.20a and b Structure of a long tubular bone, os longum (a); structure of the bone membrane, periosteum (b), (section enlargement in Fig. 1.20a). a [L266], b [L127]

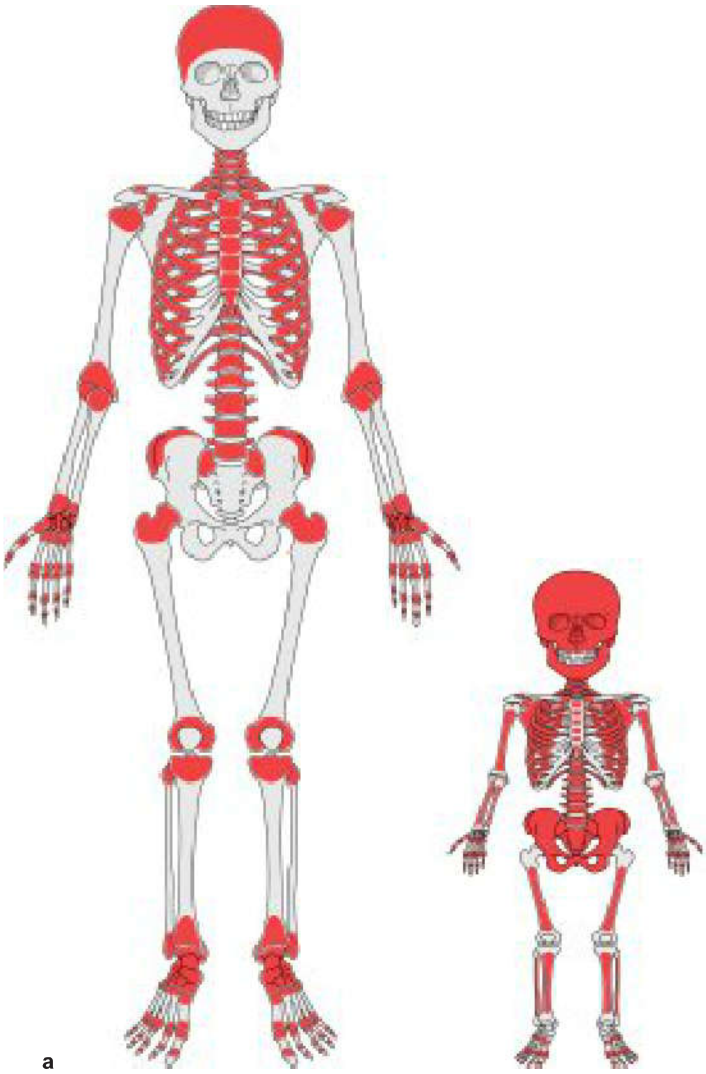
a The basic histological structure of the mature bone is the same with compact (cortical) and cancellous bone and is referred to as **lamellar bone**. Building units of the mature bone are bone lamellae that form fine tubular systems **(osteons)** particularly in the compact bone. In the cancellous bone the lamellae are predominantly parallel to the surface of the trabeculae. In the compact bone, the bony lamellae with vessels form osteons, a system (HAVERS system) made of approx. five to 20 bony lamellae **(special lamellae),** which are arranged concentrically around a HAVERS' canal and can be a few centimeters in length. The collagen fibrils in the **osteon lamellae** run in screw-like twists, in which the direction of rotation changes from lamella to lamella. Remains of old degraded osteons fill out the space between the intact osteons **(interstitial lamellae).** On the outer and inner surface, compact bone is marked by lamellae that surround the whole bone element (outer and inner **general lamellae**).

b The very well innervated bone membrane (periosteum) covers the outer surface of the bone. It consists of the external fibrous sheath made of collagen fibrils. From the fibrous sheath, collagen fibrils radiate as SHARPEY's fibres into the compact (cortical) bone and secure the periosteum to the bone. Inside it is the Stratum osteogenicum. It lies directly on the bone and is made from the same cells that coat all internal bone surfaces as en(d)osteum. From here, reconstruction and repair processes originate.

– Clinical Remarks

The **(fracture)** of a bone leads to the formation of two or more fragments with or without dislocation. Apart from pain, certain signs are abnormal mobility, grinding sounds upon movement (crepitation), axis misalignment, initial muscle stupor (lack of muscle activity) and corresponding X-ray findings. The **healing of a fracture** ideally occurs under complete refrainment from load-bearing and movement. Under these conditions, the broken pieces will be restored to full load-bearing capacity; correspondingly also in long bones with recovery of the medullary cavity. For the healing of a fracture, the blood supply to the bone has a central role (especially in fractures in the area of articular capsules and when osteosynthesis measures are involved). **Primary** fracture healing without callous formation is only possible in a small, irritation-free fracture (after operative osteosynthesis with optimum adaptation of the fracture ends using plates and screws). As part of primary fracture healing, the gap is bridged by capillaries from opened HAVERS' canals, around which osteons form and stretch across the gap. With **secondary** fracture healing, often a somewhat thicker **callus** forms, which is gradually converted into functional bone mass.

Bone Marrow



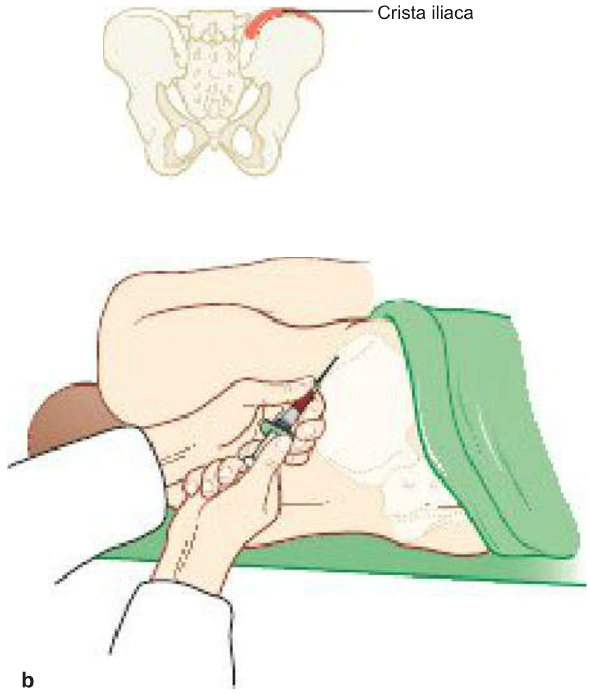


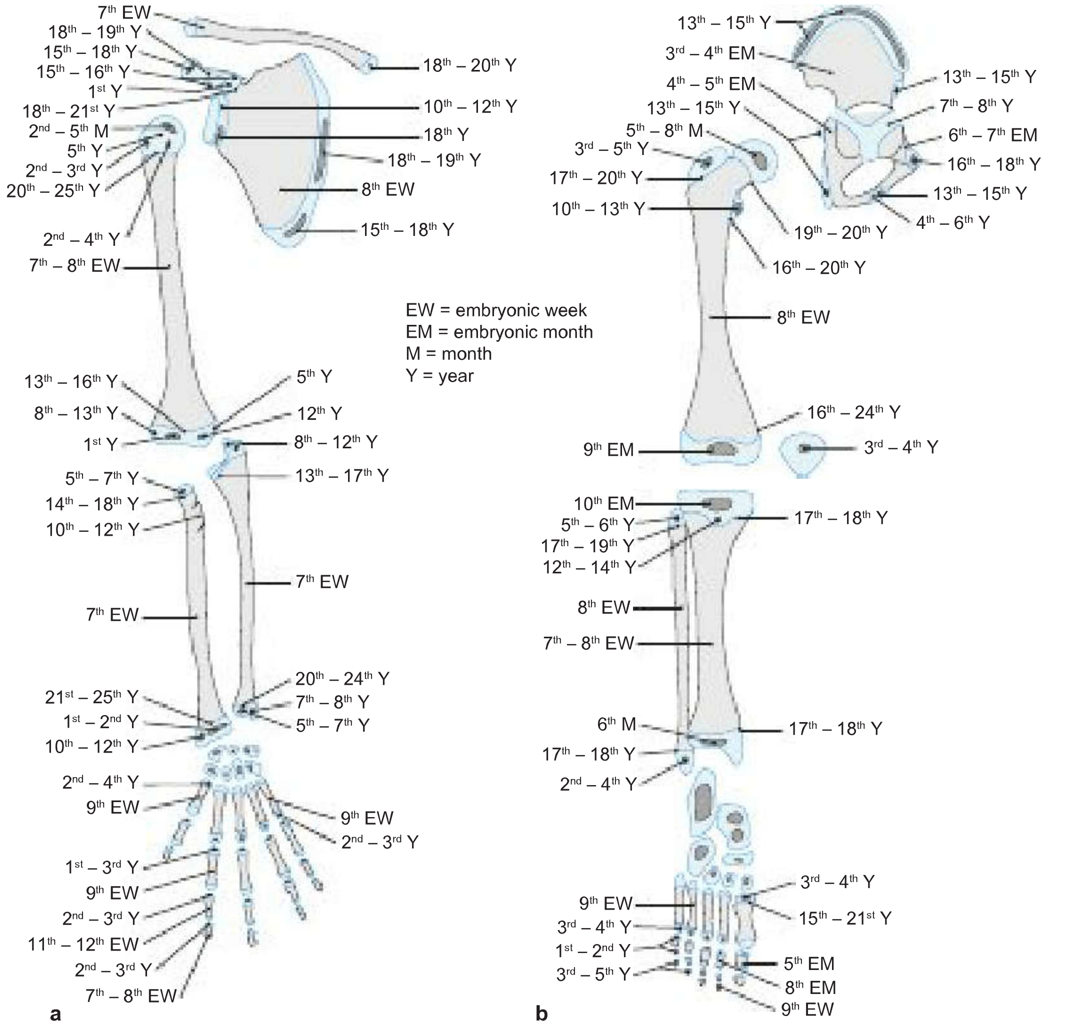
Fig. 1.21a and b Spatial distribution of red, blood-forming bone marrow and yellow bone marrow (a); bone marrow collection (b). a [L127], b [L126]

a In the fetal period, formation of the blood begins in the yolk sac and is gradually replaced by blood formation sites in the liver and spleen. From the 5th month of life, blood formation begins in the bone marrow and in a child virtually extends to the whole bone marrow. In adults, red marrow (Medulla ossium rubra) is found only in the epiphyses of tubular bones and in certain areas of the remaining bones. Otherwise, yellow bone marrow (Medulla ossium flava) is found (mainly diaphyses) which, if necessary, can be converted into red marrow in a short space of time. Red marrow fulfils the task of blood formation; yellow bone marrow consists mainly of fatty and connective tissue.

b For **bone marrow collection**, the Spina iliaca posterior superior and the Crista iliaca can easily be felt under the skin. The biopsy needle is introduced into the bone at this site. The schematic drawing above shows the area of the red bone marrow that is to be punctured.

Clinical Remarks

Under both physiological conditions (e.g. altitude training) and pathological conditions (e.g. significant blood loss) the yellow bone marrow in the diaphyses of adults can be converted back into red bone marrow in a short time to produce more blood for the body. If the stimulus (altitude training) disappears or the blood supply is balanced, yellow bone marrow forms again. **Bone marrow puncture** is carried out for diagnostic reasons (e.g. a bone marrow biopsy on suspicion of a disorder of the haematopoietic system – e.g. leukemia or for therapeutic reasons (e.g. collection of healthy bone marrow from a donor for subsequent treatment of leukemia in a recipient). The most common site for bone marrow puncture (→ Fig. 1.21b) is the iliac crest **(iliac crest lumbar puncture)** due to its accessibility. A puncture at the sternum (sternal puncture) is now only very rarely carried out.



Os scaphoideum 3rd – 6th M
Os lunatum 3rd – 6th Y
Os trapezium 3rd – 8th Y
Os trapezoideum 3rd – 7th Y

Os pisiforme 8th – 12th Y
Os triquetrum 1st – 4th Y
Os hamatum 2nd – 5th M
Os capitatum 2nd – 4th M

Talus 7th EM
Calcaneus 5th – 6th EM
Os naviculare 4th Y
Os cuboideum 10th EM

Os cuneiforme mediale 2nd – 3rd Y
Os cuneiforme intermedium 3rd – 4th Y
Os cuneiforme laterale 12th M

Fig. 1.22a and b Ossification of the skeleton of the upper (a) and lower limb (b); location of epi- and apophysis bone cores and chronological sequence for bone core formation. [L126]

Bone development **(osteogenesis)** begins with consolidation of embryonic connective tissue (mesenchymal consolidation). There are two types of bone development: in desmal osteogenesis the mesenchymal cells are directly differentiated from the bone-forming cells (osteoblasts) which produce bone tissue (ossification). The resulting bone is also called the **connective tissue bone** (desmal bone). An example of this is the clavicle. In **chondral osteogenesis** cartilage-forming cells (chondroblasts) arising from the mesenchymal cells initially create a cartilage model of the future bone (primordial skeleton out of hyaline cartilage). The cartilage model is then transformed into bone: in the area of diaphysis, **perichondrium ossification** occurs with development of a perichondrium bone sleeve (the processes that occur correspond to those in desmal osteogenesis). In the area of metaphysis, **enchondral ossification** occurs in the form of the development of a growth plate which is detectable until the completion of bone growth (see textbooks on histology). The resulting bone is also called **replacement bone** (cartilage bone).

The timing for the appearance of these **ossification centres** holds clues as to the stage reached in skeletal development and, thus, to the individual skeletal and bone age. A distinction is made between primary ossification centres, which during the foetal period emerge in the area of the diaphyses **(diaphyseal ossification),** and the endochondral ossification of the primordial cartilaginous epi- and apophyses as well as the marginal rims of the flat bones, which begins with the exception of the distal epiphysis of femur and the proximal epiphysis of tibia (maturity signs) only after birth **(secondary or epi- and apophyseal ossification).** With the closing of the epiphyseal plates (synostosis), length growth is complete. Thereafter, isolated ossification centres are no longer visible in X-ray images.

– Clinical Remarks

For the planning of treatment and prognosis of orthopaedic diseases and deformities in childhood, determining skeletal age and any existing growth reserves is of great importance. Epiphyseal plate injuries (e.g. from fractures near joints), are feared especially in the area of the lower extremity because growth disorders can lead to a difference in leg length or be associated with misaligned joints.

Bone Joints

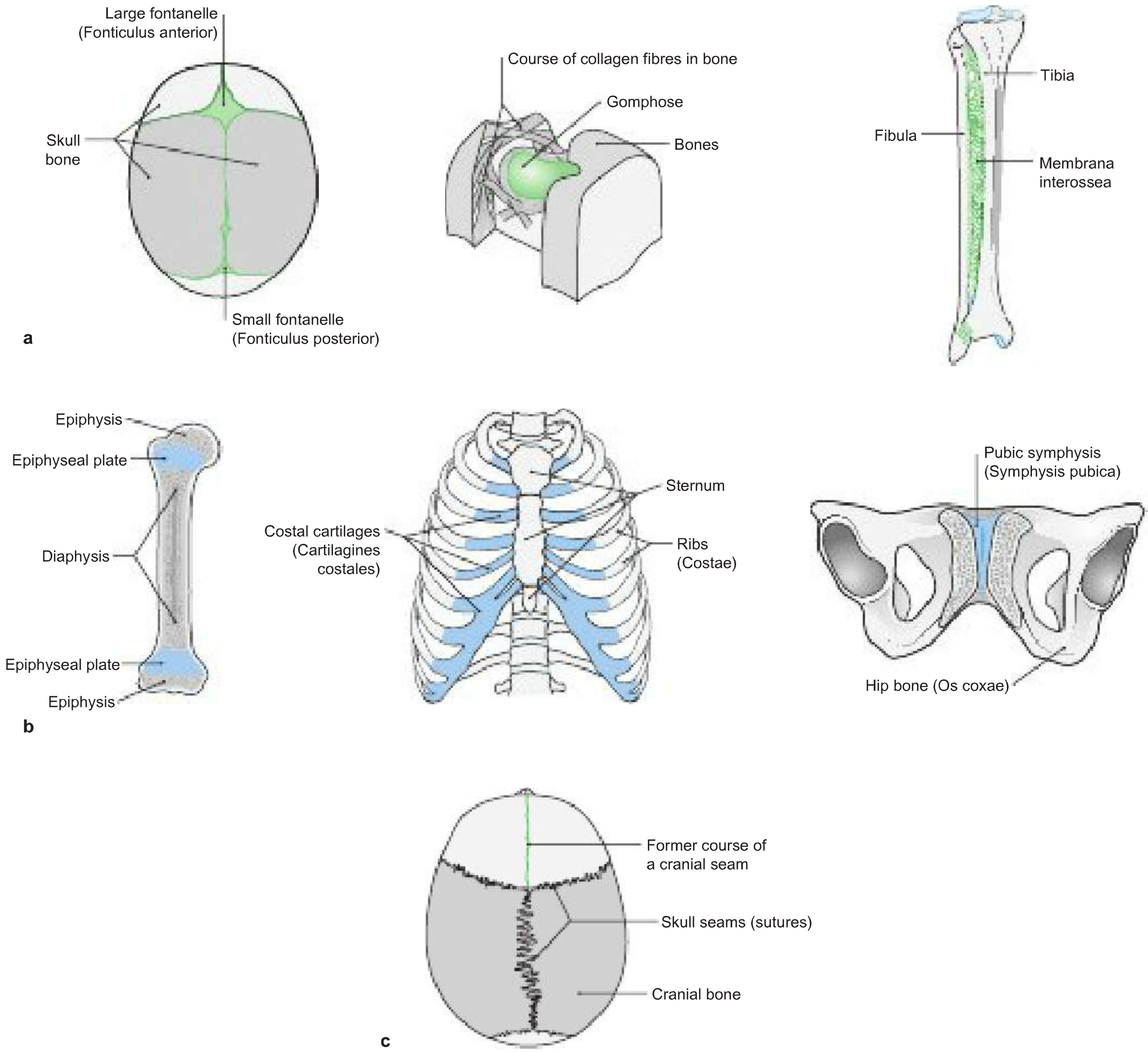


Fig. 1.23a to c Synarthrosis: Junctura fibrosa [syndesmosis]; b cartilaginous joint, Junctura cartilaginea [synchondrosis]; c bony joint, Junctura ossea [synostosis]. [L126]

a Fibrous joints Bone joints connected with connective tissue are referred to as fibrous joints. These include sutures (cranial sutures), syndesmoses (e.g. the connection between the tibia and fibula) and gomphoses (e.g. anchorage of the teeth in the dental alveoli of the maxilla and mandibula).

b Cartilaginous joints. In cartilaginous joints, the bones are connected by **hyaline** cartilage (synchondrosis, e.g. epiphyseal plates or the connection between the ribs and the sternum) or by **fibrous cartilage** (symphysis, e.g. Symphysis pubica).

c Bony joints. In bony joints, the bones are **fused** together, e.g. on the frontal bone of the skull. Synostoses originate from syndesmoses and synchondroses.

Clinical Remarks

Anchylosis may occur when two bones within an existing joint (e.g. after a joint infection or by immobilisation) become fused. Joint development disorders can lead to the fusing of skeletal elements with resulting synostosis **(coalition).** They are especially common in the skeleton of the hand and foot. The stiffening of a joint for therapeutic reasons is known as **arthrodesis.** If a 'false' joint develops after unsuccessful fracture healing, this is known as a **pseudarthrosis**.

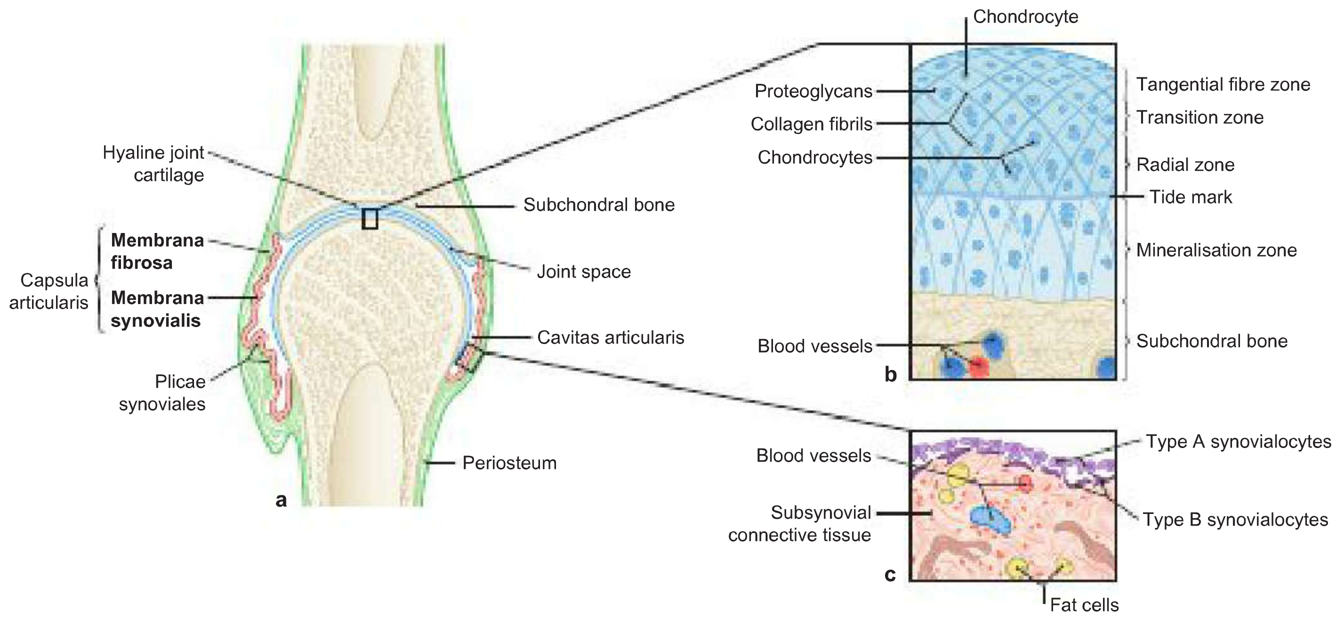


Fig. 1.24a to c Movable joint, Junctura synovialis [Articulatio, diarthrosis] (a) with development of joint cartilage (b) and joint capsule (c); schematic section. The joint-moving muscles and the joint capsule strengthening ligaments are not represented. [L126]

a Structure of the joint. The bone ends are covered by hyaline articular cartilage, under which lies the subchondral bone. The joint capsule encloses the joint cavity and consists of an outer **fibrous membrane** and an inner **synovial membrane.** The synovial membrane secretes the joint lubrication (synovia) into the joint cavity, which serves as nourishment for the joint cartilage and parts of the intra-articular structures and lubrication (friction-free gliding of the joint surfaces), and also as a shock absorber (even distribution of compressive forces). Joints of very limited mobility due to a particularly firm joint capsule are called amphiarthroses (e.g. small joints in the wrist and ankle; Junctura synovialis).

b Structure of hyaline cartilage. The joint surfaces are covered by a layer of hyaline cartilage (joint cartilage) of varying thickness. Fibrous cartilage is found only in the mandibular and sternoclavicular joints. Cartilage thickness depends on the stress (finger joints 1–2 mm, Os sacrum 4 mm, patella 6–7 mm). The cartilage cells (chondrocytes) form an extra cellular matrix from proteoglycans (water binding) and collagen fibrils. The latter are aligned in the joint cartilage and form arcades (BENNINGHOFF's arcade scheme), which can be divided into different zones (tangential fibre zone, transition zone and radial zone). The tide mark forms the border between non-mineralised and mineralised cartilage (mineralisation zone). The joint cartilage is fixed to the subchondral bone, forms a smooth surface and reduces friction between the joint bodies. It distributes the pressure on the subchondral bone.

c Structure of the joint capsule. The joint capsule consists of the fibrous membrane and the synovial membrane. The **Membrana fibrosa** is made of dense connective tissue. The **Membrana synovialis** is composed of the following layers: a superficial loose layer of A cells (type A synovialocytes or M cells, specialised macrophages which take up the compounds of the joint cartilage metabolism), B cells (type B synovialocytes or F cells, active fibroblasts which produce collagen and proteoglycans including the hyaluronic acid of the synovia) and the subsynovial connective tissue rich in capillaries, fibroblasts and lipocytes.

Joints		
Immobile Joints (Synarthroses, Continuous Joints)	**Mobile Joints (Diarthroses, Discontinuous Joints) (→ Fig. 1.25)**	
• Filling tissue consisting of connective tissue, cartilage or bone between the skeletal elements (plates, joints) • No joint space • Low to moderate mobility	• Articulating skeletal elements • Joint space • Joint surfaces capped with cartilage (Facies articularis) • Joint cavity (Cavitas articularis) • Surrounding joint capsule (Capsula articularis) • Joint capsule strengthening ligaments • Depending on the ligaments, good or restricted mobility • Muscles that move and stabilise the wrist	
Synarthroses (→ Fig. 1.23) • Syndesmoses (fibrous joints) • Synchondroses (cartilaginous joints with mainly fibrous cartilage = symphysis) • Synostoses (bony joints, no movement possible)	**Diarthroses** are divided into joint types according to: • shape and form of the joints (→ Fig. 1.25) • number of movement axes (one, two, several) • number of articulating skeletal elements (simple joints = Articulationes simplice, composite joints = Articulationes compositates)	**Amphiarthroses** (fixed joints) are rigid joints with severely limited range of motion since the joints are connected by tight ligaments.

Types of Joint

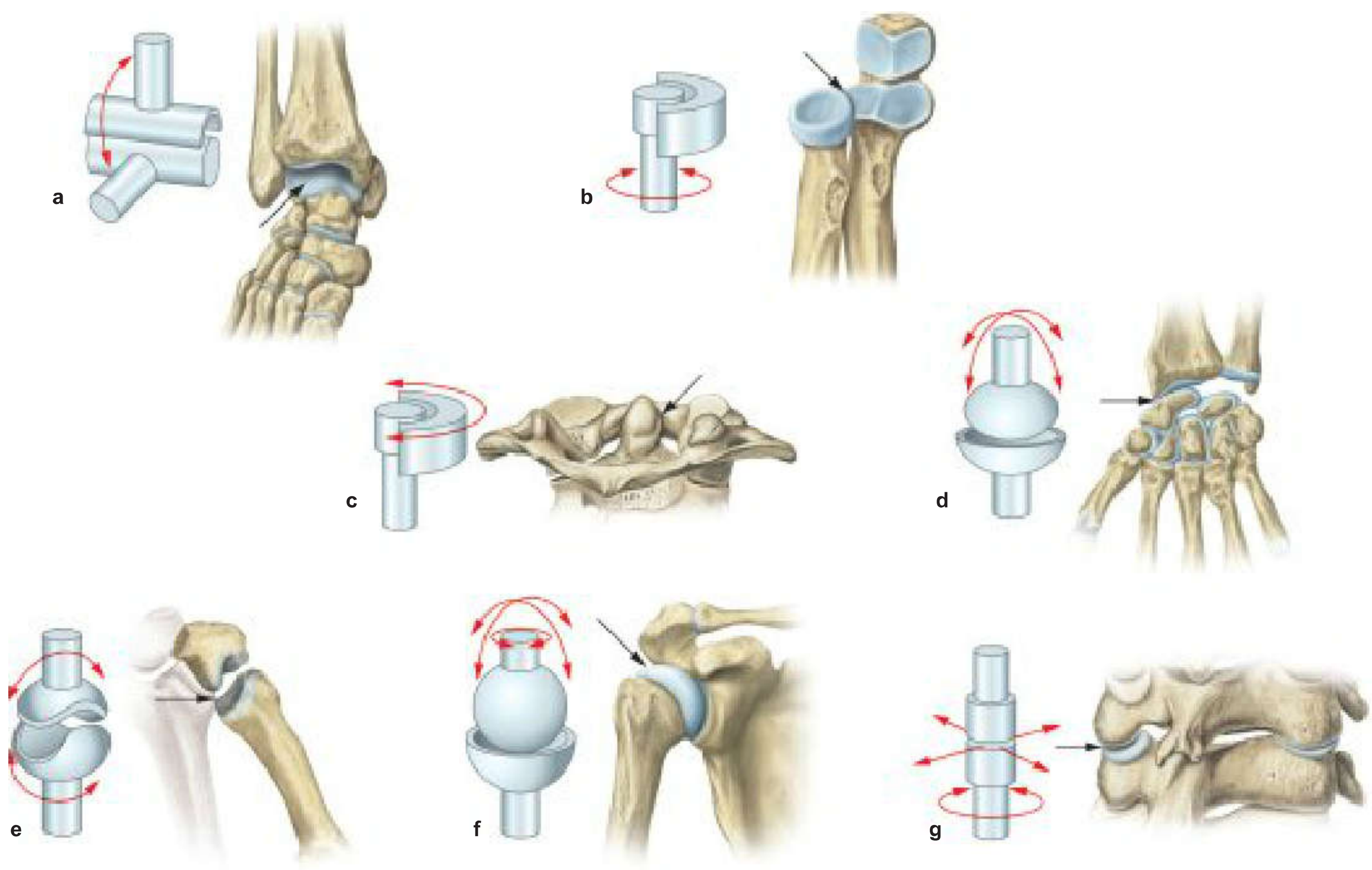


Fig. 1.25a to g Joints, synovial joints [articulationes, diarthroses]. [L127]

Joints usually have a significant range of motion. They are divided according to their shape and possible movements. A distinction is made according to the number of their main axes (corresponding to the body axes) uniaxial, biaxial and multiaxial joints.

- **a Hinge joint, Articulatio cylindrica (Ginglymus):** uniaxial joint, with which flexion and extension is possible (e.g. Articulatio talocruralis)
- **b Pivot joint, Articulatio conoidea:** uniaxial joint which allows rotational movements (e.g. Articulatio radioulnaris proximalis)
- **c Wheel joint, Articulatio trochoidea:** uniaxial joint which allows rotational movements (e.g. Articulatio atlantoaxialis mediana)
- **d Ovoid joint, Articulatio ovoidea, Articulatio ellipsoidea:** biaxial joint which allows flexion, extension, abduction, adduction and slight circumduction (e.g. proximal wrist joint)
- **e Saddle joint, Articulatio sellaris:** biaxial joint which allows flexion, extension, abduction, adduction and slight circumduction (e.g. carpometacarpal thumb joint)
- **f Ball joint, Articulatio spheroidea:** multiaxial joint which allows flexion, extension, abduction, adduction, medial rotation, lateral rotation and circumduction (e.g. shoulder joint)
- **g Plane joint, Articulatio plana:** joint which allows simple gliding movements in different directions (e.g. vertebral joint)

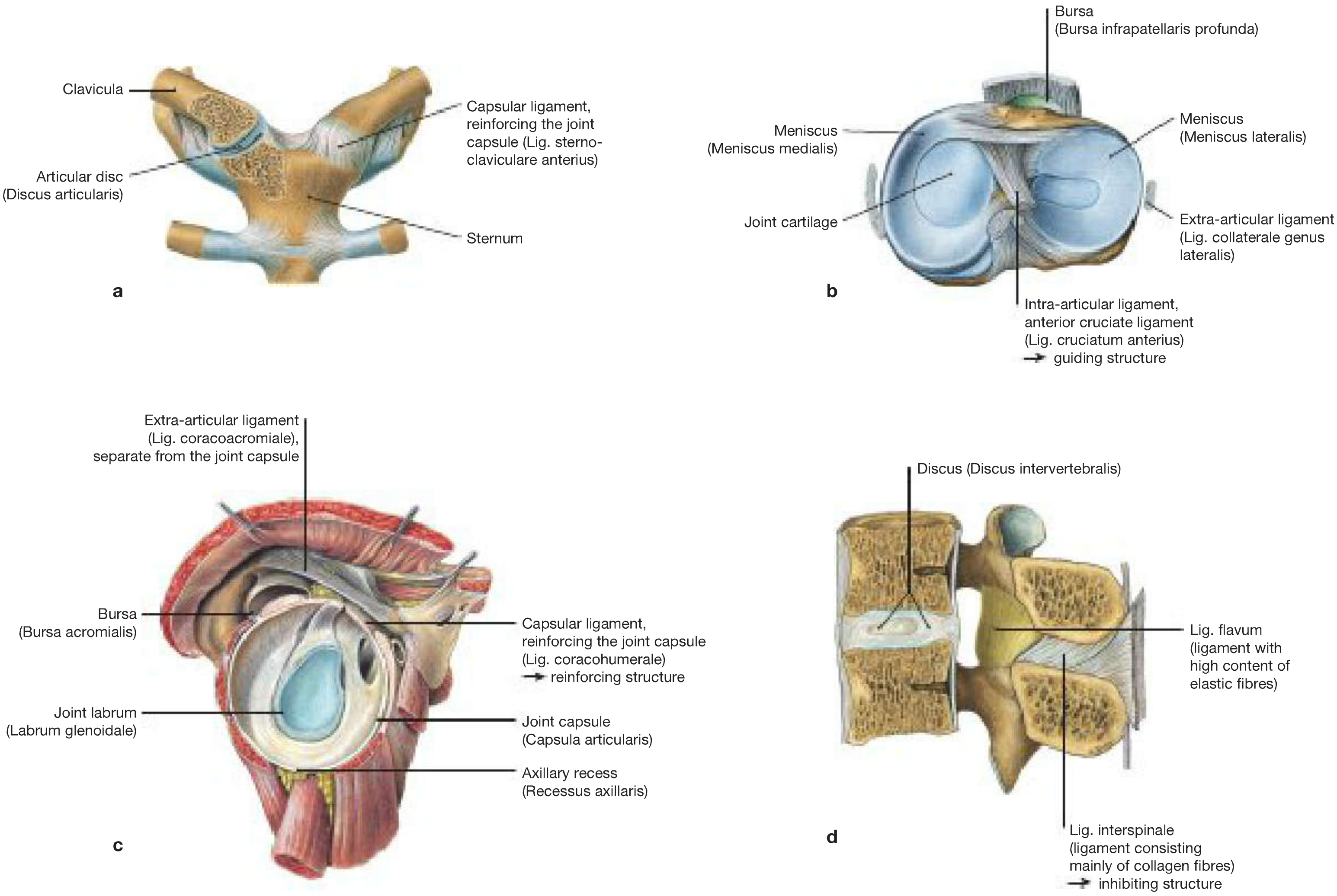


Fig. 1.26a to d Auxiliary structures of joints.
Many joints have intra-articular auxiliary structures which are necessary for biomechanical functioning and range of movement of the joints: **intra-articular discs** are used to compensate for incongruities (unevenness) between the articulating joint surfaces. They redistribute the compressive forces acting on them. Intra-articular discs occur as complete discs (**discus** = full moon, e.g. Discus articularis of the sternoclavicular joint **[a]** or Discus intervertebralis **[d]** in the spine) or as part of a disc (**meniscus** = crescent moon, e.g. Meniscus medialis and lateralis of the knee joint **[b]**). **Joint lips** (labra) are made of dense connective tissue and fibrous cartilage, are secured via a bony ring (limbus) and are used for the enlargement of the joint socket (e.g. joint **labrum** in the shoulder joint **[c]**). **Synovial bursae** (Bursae synoviales) are small fluid-filled sacs (like cushions) that occur in areas of joints with increased mechanical stress. They reduce the pressure or tension-based friction between tendons, muscles, bones or the skin. Like joint capsules, they have an outer fibrous sheath and an inner synovial sheath. The latter forms the liquid released into the inside of the little sac (Synovia). According to their location they are subdivided into skin bursae **(Bursa subcutanea),** tendon bursae (Bursa subtendinea, e.g. Bursa infrapatellaris profunda **[b]**) and ligament bursae (Bursa subligamentosa, e.g. Bursa subacromialis **[c]**). Ligaments (Ligamenta) are made of dense collagenous connective tissue and are used for connecting and fixing movable skeletal elements. They occur as **intra-articular ligaments** (e.g. **Ligamentum** cruciatum anterius **[b]**) within joints or as **extra-articular ligaments** (e.g. Lig. collaterale genus tibiale **[b]**). The extra-articular ligaments integrated in the joint capsule are called **capsular ligaments** (e.g. Lig. sternoclaviculare anterius **[a]** or Lig. coracohumerale **[c]**). They are opposed to **extra-capsular ligaments,** which have no association with the joint capsule. Functionally **reinforcing ligaments** (e.g. Lig. sternoclaviculare anterius **[a]** or Lig. coracohumerale **[c]**) can be distinguished from **guiding ligaments** (e.g. Lig. cruciatum anterius **[b]**) and **restraining ligaments** (e.g. Lig. interspinale **[d]**). Usually ligaments have several functions or additional features. The Ligamenta flava passing through the vertebral arch **[d]** has a high proportion of elastic fibres.

– Clinical Remarks

Degenerative changes are common in certain joints. They are known as **osteoarthritis** (joint wear). In Germany alone, approximately 5–6 million people suffer from arthrosis (degenerative arthropathy). Arthrosis is thus the most common disease to be seen by the family doctor. But also prevalent are immunological diseases such as **rheumatoid arthritis,** occurring primarily in the joint capsule and secondarily with joint cartilage destruction as well as injury or inflammation. The diseases often lead to an irritation of the Membrana synovialis, which causes more fluid to be secreted in the joint cavity. The result is an **articular effusion,** which may be so pronounced that the entire joint is under strain, painful and swollen. Trauma may lead to inflammation of a bursa **(bursitis).** This can then become much bigger and affect adjacent structures such as nerves through pressure or restrict movement in the neighbouring joint. The chronic irritation of certain bursae in the knee joint area is recognised as an occupational disease in professions carried out predominantly kneeling (e.g. floor layer).

Range of Movement in the Joints

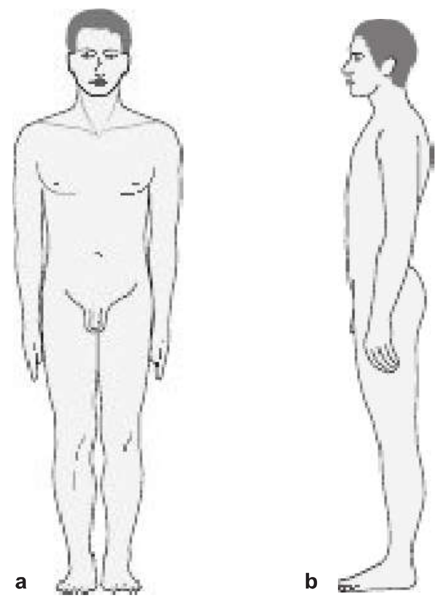


Fig. 1.27a and b Documentation for the range of movement in joints: neutral-zero method. [L126]
For a standardised documentation of the range of motion within the context of joint examination, the neutral-zero method is used. The joint positions are given using the positions of an upright person with arms hanging down as the zero degree starting position (**a** viewed from the front and **b** from the side). The extent of movement achieved from this zero position is measured in angle degrees. First the active range of movement away from the body is determined, followed by the active range of movement towards the body.

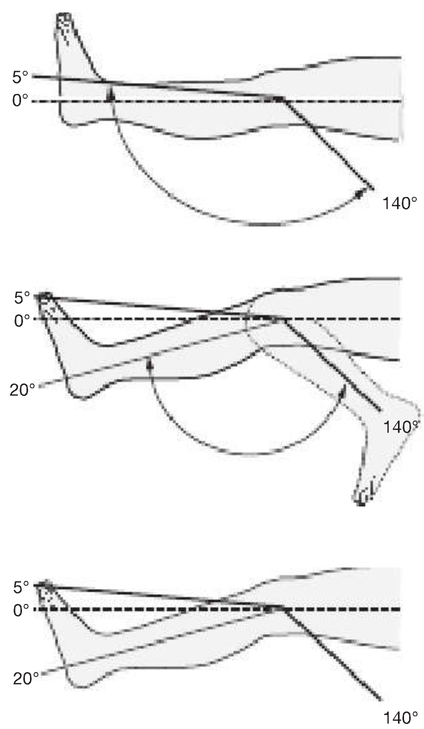


Fig. 1.28a to c Documentation for the range of movement in joints: examples. [L126]
- **a** The scope of movement of a normal healthy knee joint is 5° extension and 140° flexion. The ankle joint is considered to be in zero position at a right angle to the foot (90°). From this position, 20° extension and 40° flexion is possible (not shown). The normal scope of movement for the knee joint is given as 5°–0°–140° (knee stretched, passing through the zero position, knee bent). For the ankle joint it is 20°–0°–40° (dorsiflexion, passing through the zero position, plantarflexion).
- **b** Knee extension is not possible (text → clinical remarks)
- **c** Complete knee stiffening (text → clinical remarks)

Clinical Remarks

Limitations of joint movement are associated with a decreased range of movement. If joint movement is limited, or if the zero position of a joint is not achieved and there is contracture, this can be reproduced precisely with the neutral-zero method.
For **limited mobility after flexion contracture** the movement formula is e.g. 0°–20°–140° (→ Fig. 1.28b: knee extension not possible, zero position is not achieved, knee bent at 20° and can be bent further to 140°). A **complete stiffening of the knee** due to ossification (ankylosis) results in the knee being fixed in a 20° angle of flexion. The movement formula is 0°–20°–20° (→ Fig. 1.28c: knee extension not possible, zero position is not achieved, knee bent at 20° and cannot be bent further).

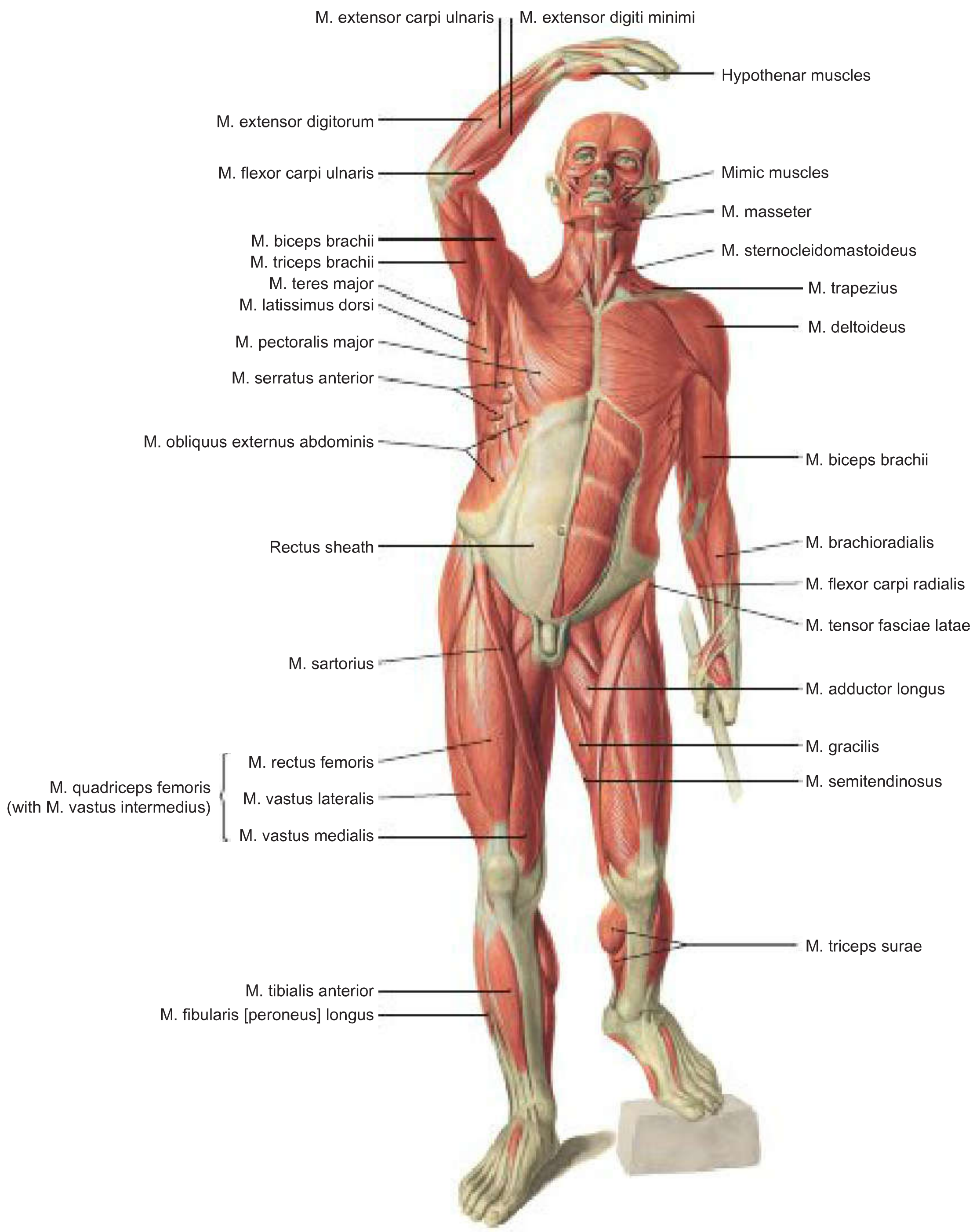
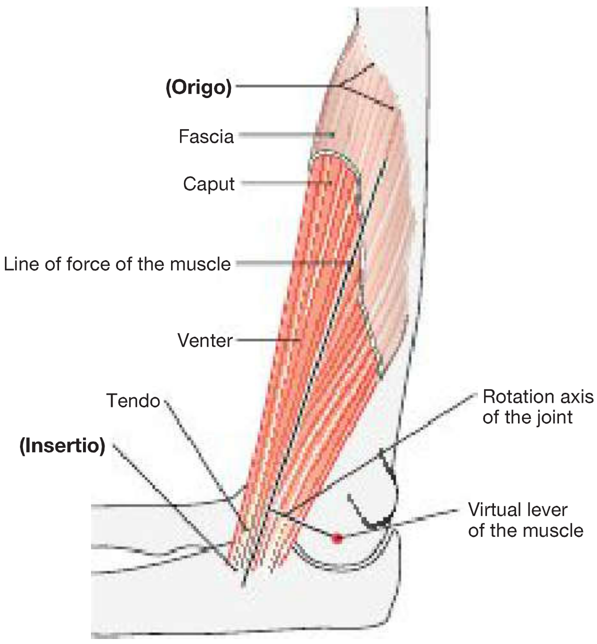


Fig. 1.29 Supporting and movement muscles. The 600+ muscles in the human body make up between 25 % (female) and 40 % (male) of the body weight and need 20 % of the body's energy at rest. This value can rise to 90 % during peak athletic performance. Functionally, within the working muscles, also known as extrafusal muscles, a distinction is made between **supporting muscles (tonic muscles)** and **movement muscles (phaseal muscles).** The supporting muscles **(red muscles)** are designed for continuous performance, tire slowly and have a very good blood vessel supply (e.g. M. adductor longus). The movement muscles **(white muscles)** are used for quick, short and powerful contractions, tire more quickly, are less well supplied with capillaries, and work primarily anaerobically (e.g. M. biceps brachii, Mm. vastus lateralis und medialis, M. tibialis anterior). People who do endurance sports (marathon runners) have more red muscles; people who do sports with short, sharp bursts of muscular activity (sprinters) have more white muscles.

A muscle (or muscle group) never moves alone, but is almost always dependent on one or more opponents (antagonists). Therefore, on the upper and lower extremities we have the extensors (agonists) and the flexors (antagonists). There are basically two types of muscular activity: **static and dynamic muscle.** With cycling, for example, the arm, neck and back muscles, in addition to the joint ligaments, perform static activity while keeping the torso and head steady, whereas the muscles involved in pedalling perform dynamic muscle activity.

Muscle Types



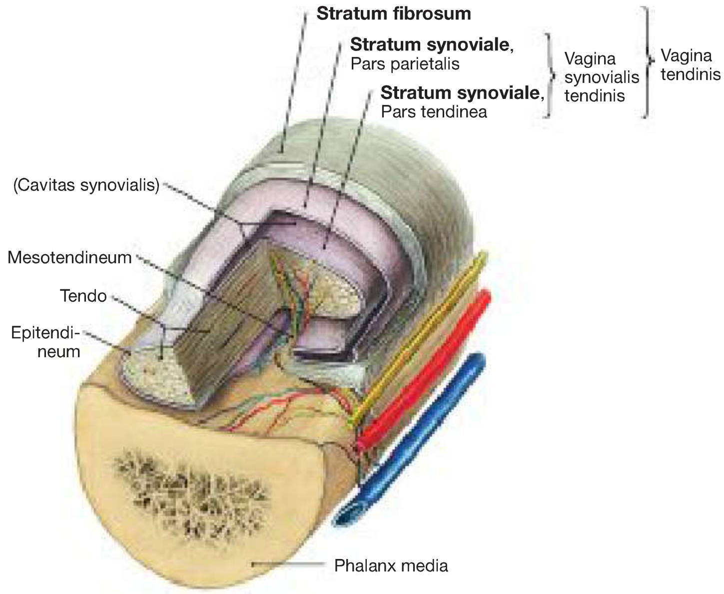


Fig. 1.30 Structure of the skeletal muscle using the example of the M. brachialis. [L126]

Skeletal muscles move bones in their joints and have a fixed point of origin (origo) and a flexible point of insertion (insertio). The origin is by definition sinewy or fleshy. It has a broader base and is less flexible than the muscle insertion. The origin of the extremity muscles is usually close to the body (proximal), and the insertion far from the body (distal). In the torso muscles, the origin is usually caudal and the insertion cranial. The attachment site on the stationary skeletal element is known as the fixed point and on the moving element the mobile point. The terms fixed point and mobile point are not absolute terms. They are reversed when the limb is not moved towards the body but the body is moved towards the limb. The muscle belly is inserted via a tendon (tendo, → Fig. 1.31) on the bone. The amount of force a muscle can transfer onto a joint depends on the length of the lever (vertical distance from the line of force of the muscle to the rotational axis of the joint = lever arm of force). The length of the lever varies depending on the joint position and is known as the virtual lever. Most muscles are enveloped on their free surface by a fascia. Fasciae are casings made of fibrous connective tissue which surround an individual muscle, several muscles (a muscle group) and tendons. The fasciae allow the muscle to contract almost invisibly without the surrounding tissue also contracting.

Fig. 1.31 Structure of the tendon sheath, vagina tendinis, vagina synovialis, using the example of a finger.

Tendon sheaths serve to provide better gliding and to protect tendons from deflection by bones or ligaments. In their structure they are similar to a joint capsule or a bursa set around the tendon. The inner tendon sheath sheet (Stratum synoviale, Pars tendinea) is fused with the tendon, the outer (Stratum synoviale, Pars parietalis) with the Stratum fibrosum of the tendon sheath. In the synovial cavity (Cavitas synovialis), joint lubrication (synovia) is delivered. Small blood vessels reach the tendon via the vincula brevia and longa (ligaments of the mesotendineum of varying length and breadth). The vincula can be found especially in the tendons of the finger flexors.

The muscle tendons transfer the traction of the muscles onto the bone. They consist mainly of parallel collagen fibres as well as a few elastic fibres and proteoglycans and glycoproteins stored in between. The living cells of the tendon are called tendinocytes. The tendon is enveloped in loose connective tissue (epitendineum). A distinction is made between pulling and gliding tendons. With pulling tendons the pull direction is identical to that of the muscle. In the case of gliding tendons, the tendon is deflected at a hypomochlion (point of deflection, e.g. bone edge, bone protrusion or sesamoid bone [bone stored in the tendon]). In the contact area the tendon glides on the hypomochlion and is subjected here to pressure and strain. This is the part of the tendon where fibrous cartilage occurs.

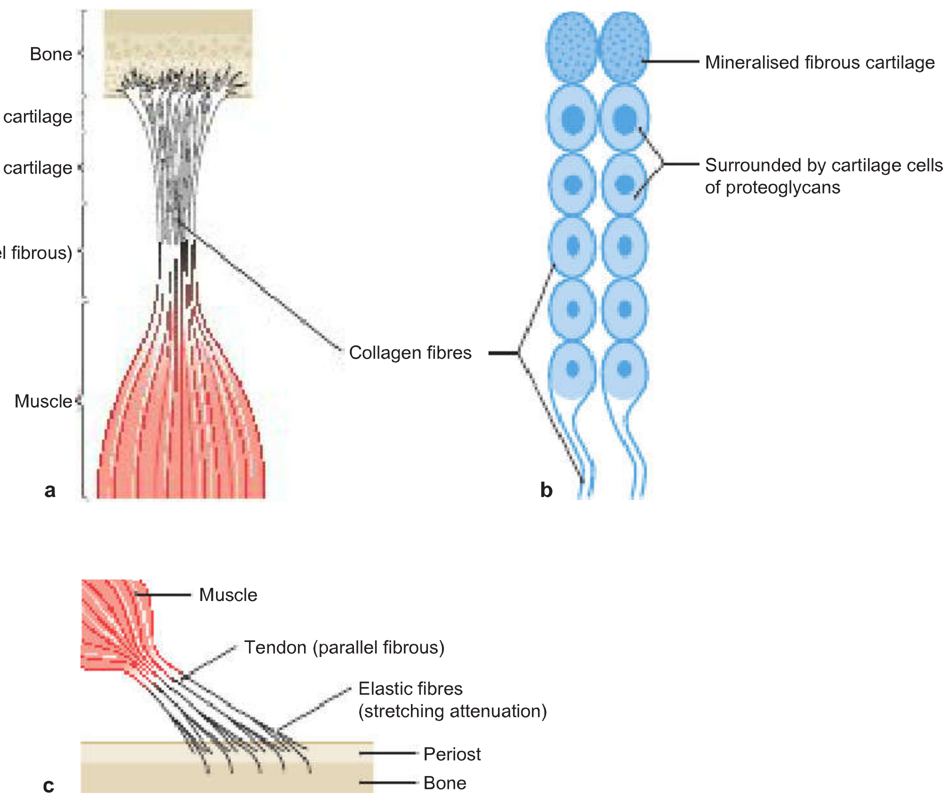


Fig. 1.32a to c Structure of tendon insertion zones. [L126]
To avoid avulsion or tearing of the tendons in the insertion area, tendon insertion zones are present to enable the different elasticity modules of connective tissue, cartilage and bone to adapt to each other. A distinction is made between chondral-apophyseal insertion zones and periostal-diaphyseal insertion zones.
a, b Chondral-apophyseal insertion zones are characteristic of muscles inserted in the area of formerly cartilaginous apophyses. However, these also occur with other muscles (e.g. masticatory muscles). At the insertion site, fibrous cartilage is present, of which the layer directly covering the bone is mineralised. In the insertion area there is no periosteum; the collagen fibres go directly into the bone and anchor the tendon here.
c Periostal-diaphyseal insertion zones are characteristic of the diaphyses of the long tubular bones. The collagen fibres of the planar tendons in the periosteum of the bone radiate inwards and thus anchor the tendon in the cortical bone. In this way, the force is transmitted over a very large area. The collagen fibres rarely go directly into the bone. At this site, therefore, there is no periosteum. On the bony skeleton the insertion areas show up as eminences (tubercles).

– Clinical Remarks

Especially in the hands and feet, painful **tendovaginitis (tendonitis)** is common and results from excessive use. **Tendovaginitis stenosans** (stenosing tenosynovitis) occurs when the muscles used for bending the hand are overused. People involved in occupations or activities with stereotypical movement (craftsmen, athletes, piano players – in some instances recognised as an occupational disease) are prone to this condition. In the course of the disease, minor injuries in the affected tendon occur, which the body attempts to repair with an inflammatory reaction. The inflammation is associated with swelling of the tendon, which in turn restricts the tendon sheath, leading to the formation of tendon nodules. In the case of the finger flexors, the tendons are fixed by means of annular (Ligg. anularia) ligaments. The thickened tendon area is wedged in individual annular ligaments and gives rise to the **phenomenon of 'trigger finger'**.

Types of Muscle

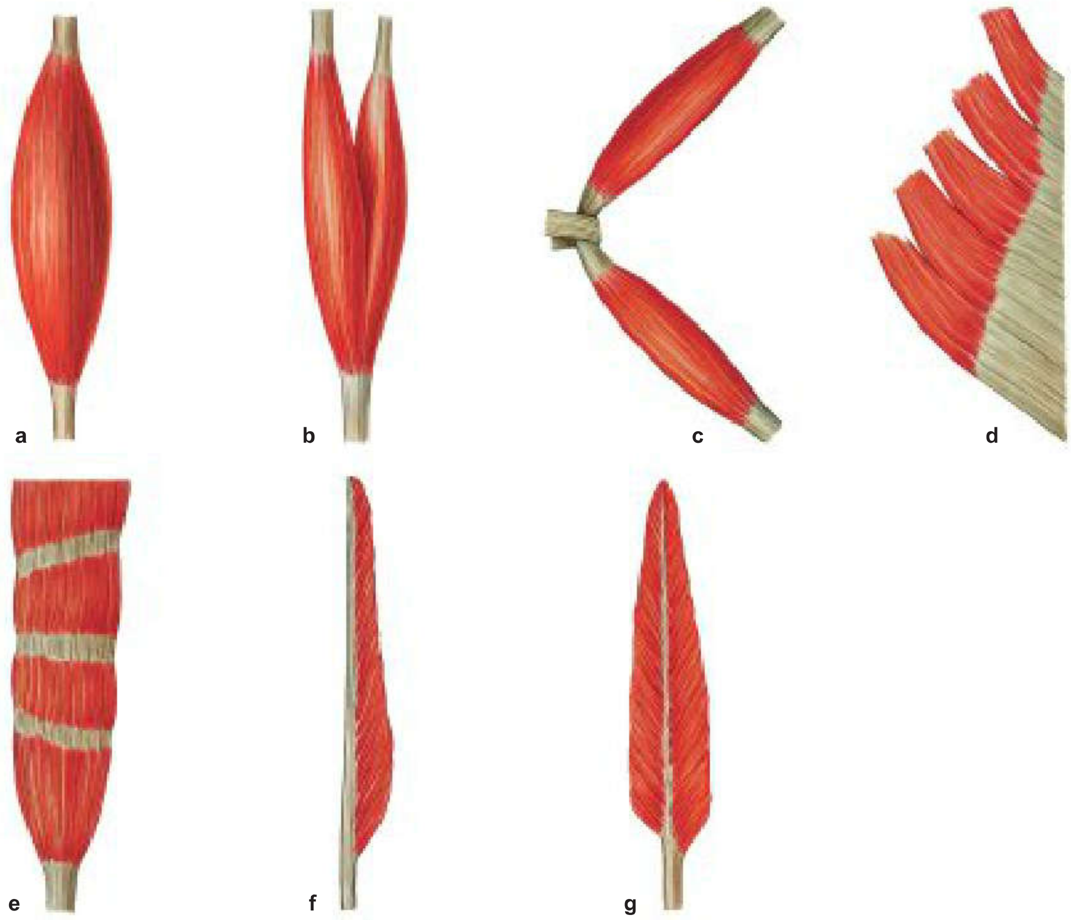


Fig. 1.33a to g Types of muscle.
Muscles can be divided up according to: (1) the arrangement of their muscle fibres (parallel course to the pull direction of the tendon with substantial movements using low force, or pennate = diagonal course of muscle fibres at a particular acute angle [pennation angle] with long, wide tendons using high muscle force); (2) the number of muscle heads (1, 2 or more); (3) differences in joint involvement (depending on whether a muscle is involved in movements in one or two joints or has no relationship to a joint: single-joint muscles, two-joint muscles, mimic muscles without joint involvement); (4) or form. Under the microscope skeletal muscles have a transverse stripe and can be divided according to their shape into:
a single-headed, parallel fibrous muscles (Musculus fusiformis)
b two-headed, parallel fibrous muscles (Musculus biceps)
c two-lobed, parallel fibrous muscles (Musculus biventer)
d multi-lobed, flat muscles (Musculus planus)
e multi-lobed muscles divided by intermediate tendons (Musculus intersectus)
f semipennate muscles (Musculus semipennatus)
g multipennate muscles (Musculus pennatus)

Definition

Functionally, a distinction is made between the passive and active musculoskeletal system:
- The **passive musculoskeletal system** includes bones, joints and ligaments. The skeleton gives the body its shape, serves as an insertion point for the muscles and forms the body cavities in which the bowels are protected. Joints connect the bones in a flexible manner.
- The **active musculoskeletal system** consists of the skeletal muscles which can move the bones in the joints and are controlled voluntarily.

Clinical Remarks

Stronger, unusual forms of stress (common in sports) may cause a tear in the muscle tissue (**torn muscle fibre** or **torn muscle** if damage is greater). The muscles of the upper and lower leg are most often affected. A **muscle strain**, in contrast, is not associated with macroscopic structural change with destruction of muscle cells and bleeding. Often, a few hours or days after strong physical exertion of certain muscles, **muscle soreness** (muscle pain) occurs. This is caused by small microtears in the muscle fibrils with a subsequent inflammatory reaction, which causes the subtle pain.

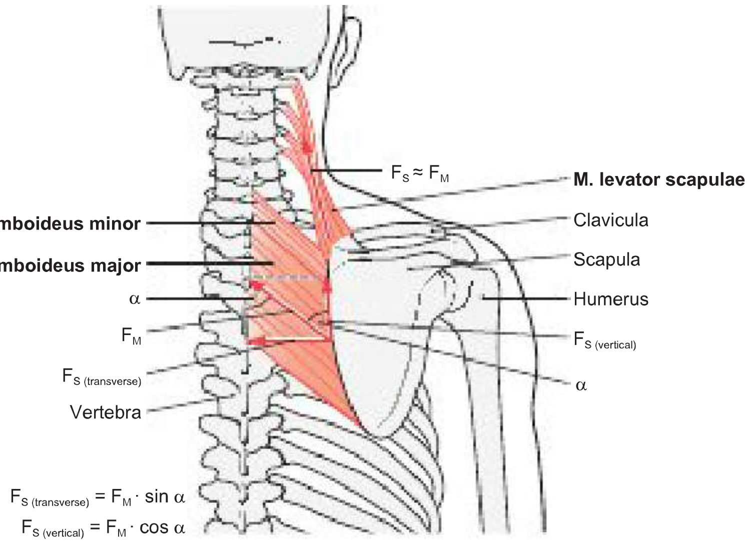


Fig. 1.34 Muscle and tendon force; vectors of muscle and tendon force using the example of the levator scapulae and rhomboid muscles. [L126]

There is a direct proportional relationship between muscle force and the physiological cross-section of the muscle (lifting force of a muscle relative to the cross-section of all muscle fibres positioned perpendicular to the direction of fibres). If the tendon of the muscle runs in the direction of pull (e.g. M. levator scapulae), the complete momentum generated is transferred to the tendon. In this case, muscle force (F_M) and tendon force (F_T) are almost equal.

If the muscle fibres are at an angle to the direction of the tendon pull (e.g. Mm. rhomboidei major and minor), only part of their contraction force is transferred to the tendon. Here the vertical tendon force (F_T [vertical]) relative to the muscle force (F_M) is reduced by the factor cos α and the transverse tendon force (F_T [transversal]) is reduced by the factor sin α.

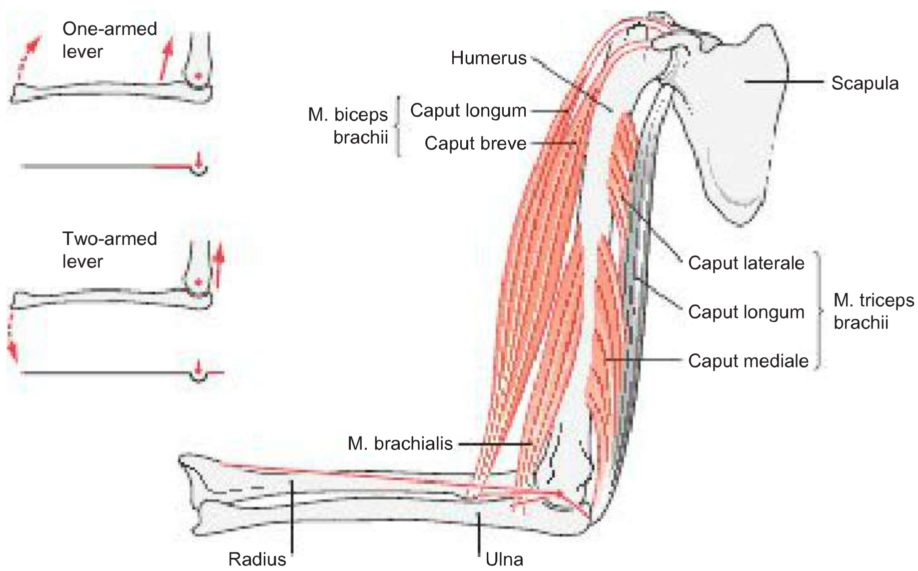


Fig. 1.35 Lever arm and muscle activity; main muscles of the elbow joint and their anatomical lever arms (red lines). [L126]

The lever arm is the part of a lever between the centre of rotation and the point where the force acts. For skeletal components to be moved around a rotational axis of a joint, a muscle must use an anatomical (existing) lever arm to generate torque. The length of the lever arm depends on the distance between the insertion of a muscle and the centre of rotation of the joint. For example, when the arm is moved towards the torso, the brachioradialis muscle has a long anatomical lever arm and the brachialis muscle a short anatomical lever arm. If a muscle engages a single-arm lever, the skeletal element is moved in the direction of the muscle pull (e.g. Mm. brachioradialis, biceps brachii, brachialis). In the case of two-arm levers, the muscular insertion point is moved in the direction of the muscle pull and the main part of the skeletal element is shifted in the opposite direction (e.g. M. triceps brachii; → Fig. 1.30).

Cardiovascular System

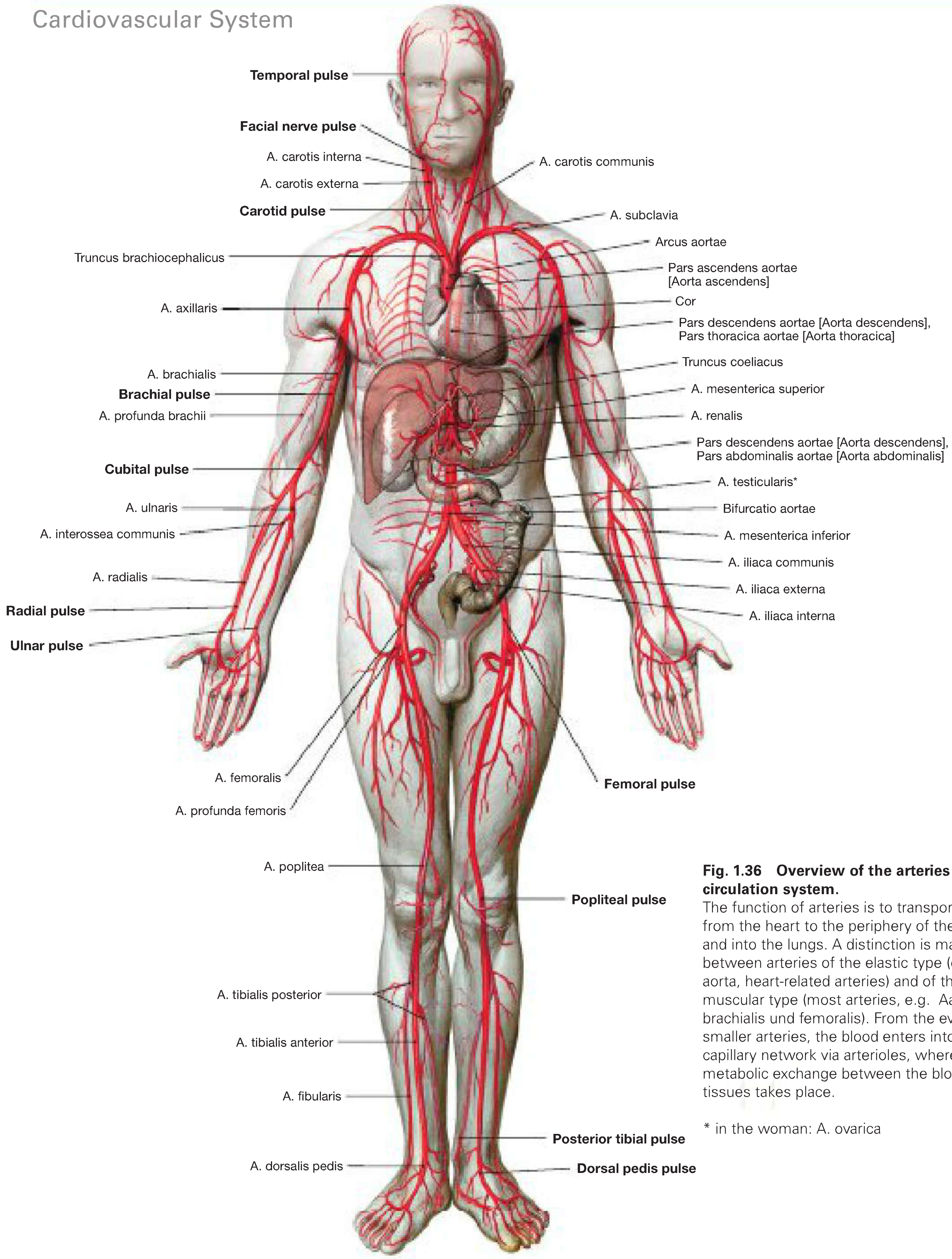


Fig. 1.36 Overview of the arteries of the circulation system.
The function of arteries is to transport blood from the heart to the periphery of the body and into the lungs. A distinction is made between arteries of the elastic type (e.g. aorta, heart-related arteries) and of the muscular type (most arteries, e.g. Aa. brachialis und femoralis). From the ever smaller arteries, the blood enters into the capillary network via arterioles, where metabolic exchange between the blood and tissues takes place.

* in the woman: A. ovarica

Clinical Remarks

In many parts of the body, large and medium-sized arteries run near the body surface. Their **pulse** can be felt by pressing the artery against a harder underlying structure. The most distal palpable pulse and thus farthest from the heart is the pulse of the dorsalis pedis artery on the arch of the foot. Examination of the arterial pulses give numerous indications on, e.g. the frequency of the heartbeat, circulation differences in the upper and lower extremities or, more generally, the blood flow in a body section. Pathological occlusion of end arteries (e.g. in the context of a hardening of the arteries) leads to the destruction of tissue supplied by the artery (e.g. occlusion of a coronary artery leads to a heart attack or myocardial infarction).

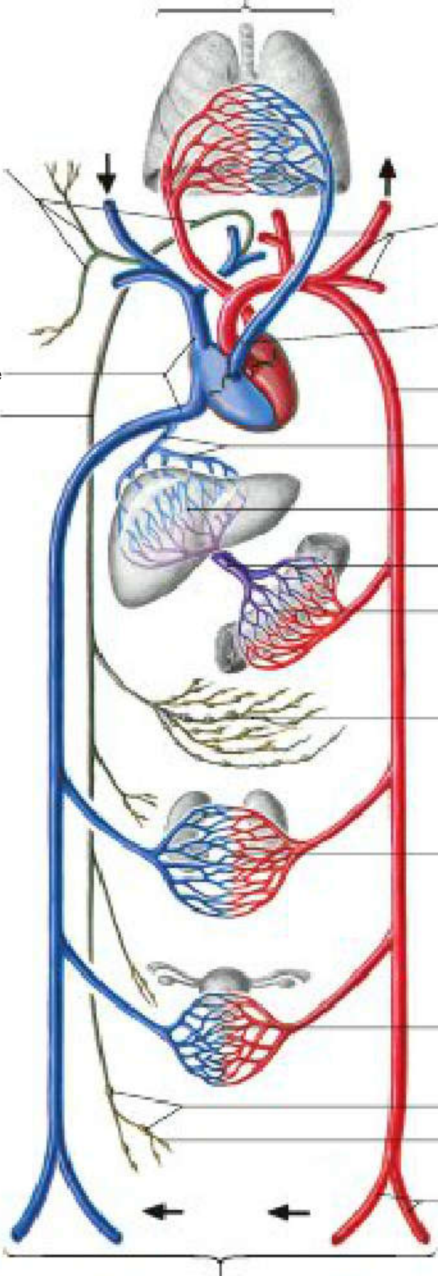
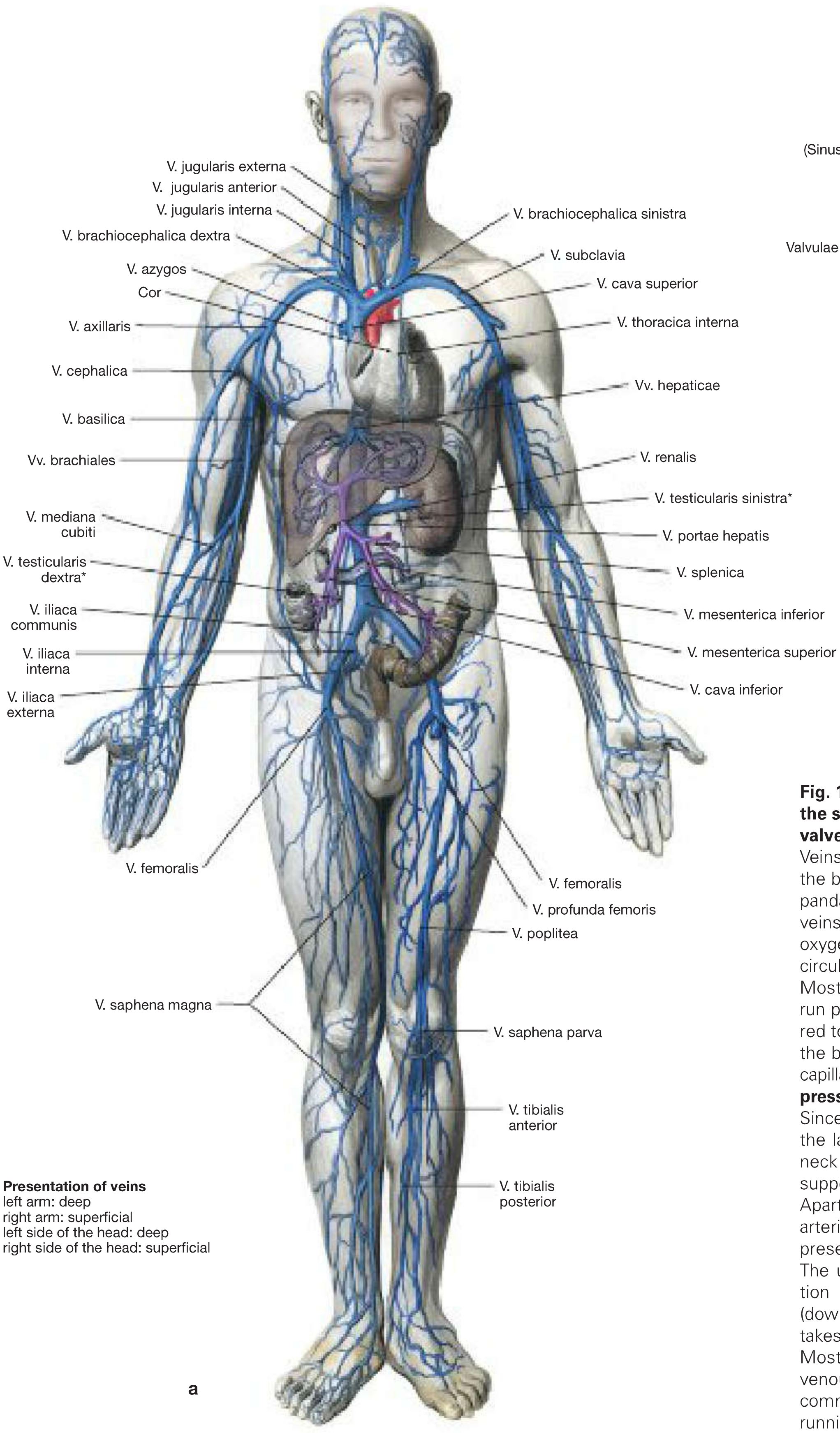


Fig. 1.37 Systemic and pulmonary circulation. [S010-2-16], [L238]
The systemic and pulmonary circulation together form the blood circulation, by which is understood the continuous transport of arterial and venous blood through the cardiovascular system consisting of blood vessels and the heart. The blood has to pass both circulations (systemic and pulmonary), which are connected in close succession. The motor for the transport of blood is the heart, lying between the two circulatory systems. The left side of the heart pumps oxygenated blood into the aorta and so into the arterial vascular system of the systemic circulation. Via connected arterial trunks (arteries, arterioles), the blood finally reaches the capillary bed, where the metabolic exchange takes place. Blood low in oxygen then reaches the right side of the heart through the venous system of the large (systemic) circulation (venules, veins). From here, the blood is pumped into the small (pulmonary) circulation, where it is resupplied with oxygen in the pulmonary capillaries, then back to the left side of the heart, where a new circulation process resumes through both circulation systems. A further classification is carried out according to the calibre of blood vessels through which the blood flows, into vessels of the macrocirculation (arteries, veins) and blood vessels of the microcirculation (vessel diameter < 100 µm; arterioles, capillaries, venules).



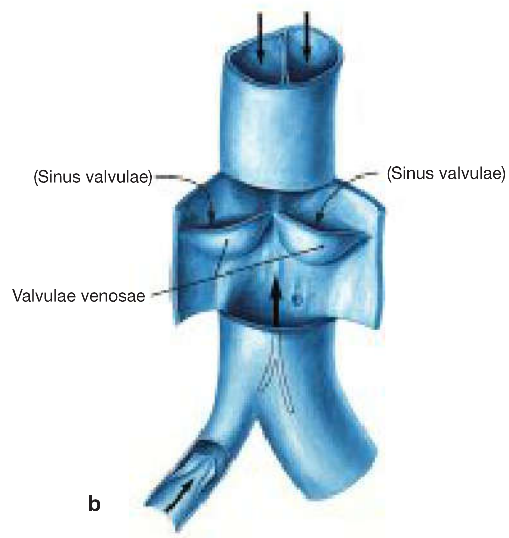


Fig. 1.38a and b Overview of the veins of the systemic circulation (a) and venous valves (b).
Veins transport blood from the periphery of the body back to the heart. They are easily expandable and have a reservoir function. The veins of the systemic circulation transport low-oxygenated blood and those of the pulmonary circulation transport high-oxygenated blood. Most veins are concomitant veins, i.e. they run parallel to corresponding arteries. Compared to the arteries, their course is variable and the blood pressure is significantly lower. With capillaries and venules, veins belong to the **low pressure system** of the blood circulation. Since veins mostly transport against gravity, the larger veins of the extremities and lower neck region possess valves (venous valves) to support venous blood flow back to the heart. Apart from the valves, the muscles and the arterial pulse (only when venous valves are present) also affect venous blood flow.
The upturned arrows indicate the flow direction of the blood. In the case of backflow (downturned arrows), closure of the valves takes place.
Most parts of the body contain a **superficial** venous system in the subcutaneous fat, which communicates with a **deeper** venous system running parallel to the arteries (both systems are separated by venous valves so that blood can only travel unidirectionally from the superficial to the deep veins). Particularly the veins of the extremities are subject to large individual variation.

* in the woman: ovarian vein

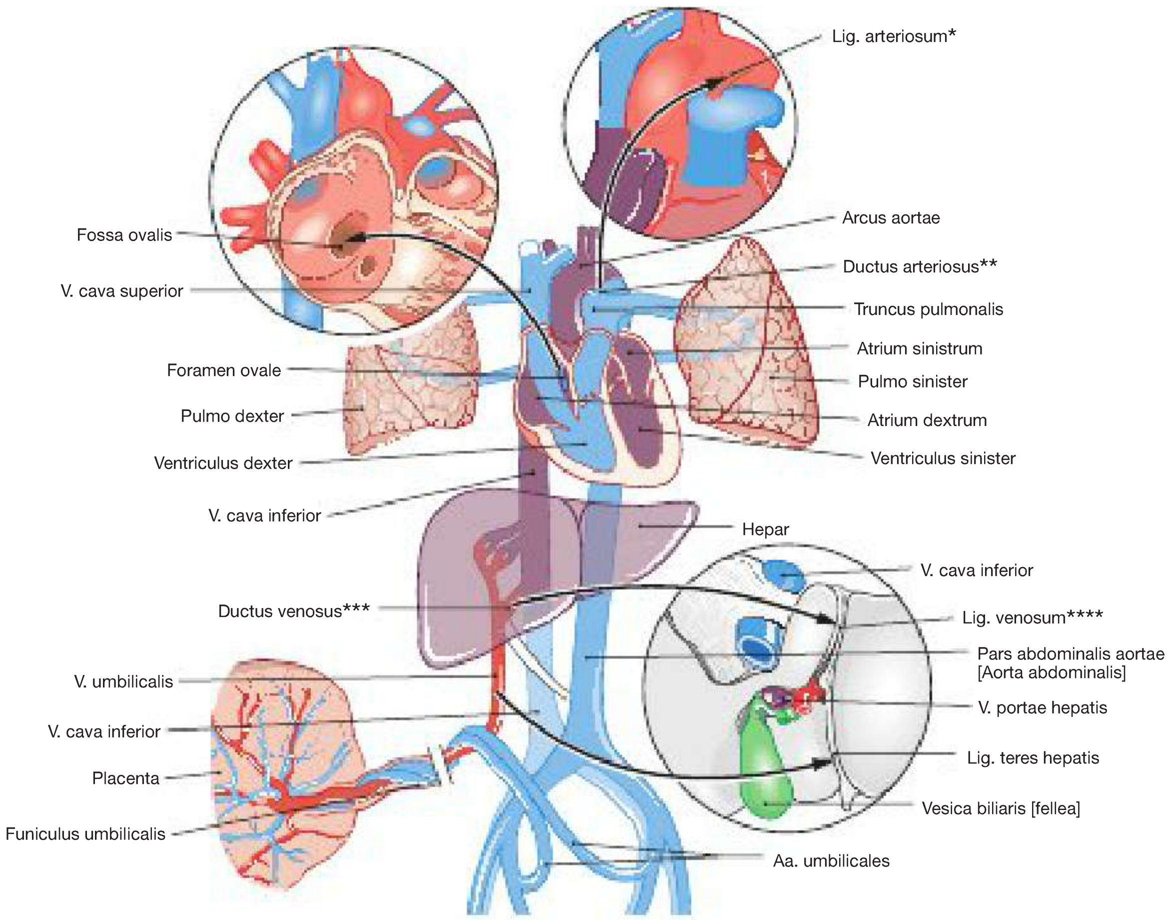


Fig. 1.39 Organisation of the prenatal cardiovascular system; schematic drawing. (according to [S010-17]) [L126]
Arrows indicate the direction of blood flow. The prenatal circulation is different from the circulation after birth.
Oxygenated blood is taken from the placenta via the umbilical vein to the liver, where it is mostly fed directly into the V. cava inferior via the venous duct (ARANTII). The main bloodstream flows from the V. cava inferior via the right atrium through the open Foramen ovale in the atrial septum directly into the left atrium. From here it flows into the left chamber, so it can be distributed via the aorta in the general circulation.
Venous blood from the upper half of the body enters the right atrium via the V. cava superior and is directed largely into the right ventricle. Upon contraction of the heart, the blood is led from here mostly via the ductus arteriosus (BOTALLI) directly to the aorta descendens. The two short heart circulations (open Foramen ovale and open Ductus arteriosus [BOTALLI]) are necessary because the lungs are not yet unfolded in the foetus. From the systemic circulation of the foetus, the blood reaches the two umbilical arteries (Aa. umbilicales) largely via the iliac vessels and from here the placenta via the umbilical cord.
Interruption of the placental circulation shortly after birth with the development of the lungs and the onset of breathing leads to **closure** of the:

- venous duct (ARANTII)
- Foramen ovale
- Ductus arteriosus (BOTALLI) between the pulmonary trunk and Arcus aortae
- Aa. umbilicales und V. umbilicalis

At this point, the cardiovascular system only consists of the heart as well as the large circulation (systemic circulation; supply of body tissues) and small circulation (pulmonary circulation; gas exchange) (→ Fig. 5.39). The cardiac output for an adult at rest is 70 ml.
Approximately 64% of blood resides in the venous system at any given moment and this can increase to approximately 80% (blood reservoir). The small arteries and arterioles of the muscles mainly determine the vascular resistance. In the arterial system (high pressure system) the average blood pressure is approx. 100 mmHg (= mm mercury column), whereas in the venous system it is approx. 20 mmHg. Between the two systems lies the capillary region in which metabolic-exchange takes place.

* BOTALLO's ligament
** BOTALLO's duct
*** ARANTIUS' duct
**** ARANTIUS' ligament

Portal Vein Circulation

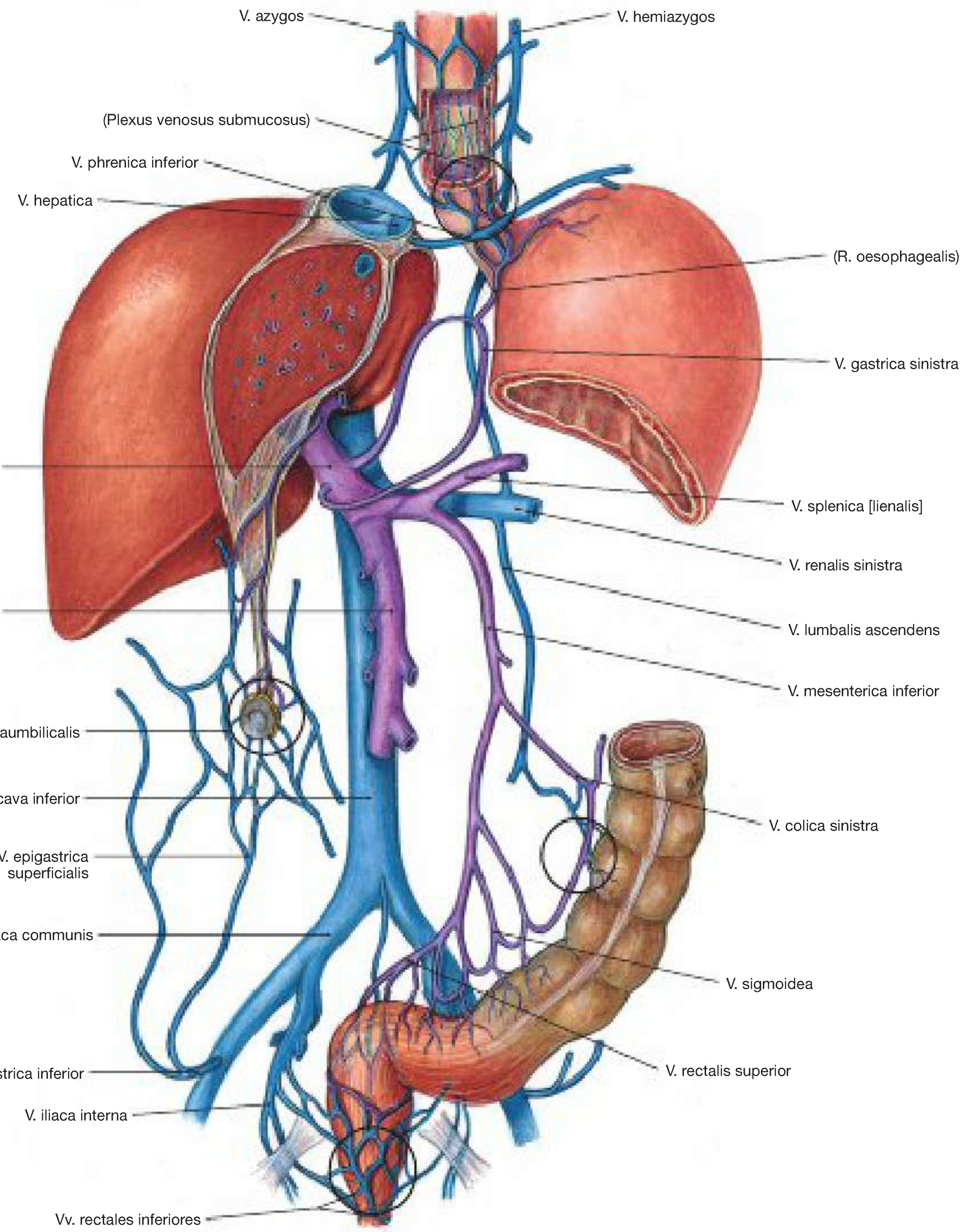


Fig. 1.40 Portal vein, V. portae hepatis and V. cava inferior; semi-schematic representation; inflows into the V. cava inferior in blue; tributaries into the V. portae hepatis in purple. Possible porto-caval anastomoses are highlighted by black circles.

The portal vein circulation has a special status within the systemic circulation (body circulation). Here two capillary areas (intestine, liver) are connected in succession. Prior to reaching the systemic circulation, venous blood from most unpaired abdominal organs (stomach, parts of the intestine, pancreas, spleen) is drained into the portal vein and from here into the liver. In this way, many nutritional substances absorbed in the abdominal digestive organs reach the liver and are metabolised here. Only after passing the liver does the blood reach the systemic circulation via the hepatic veins (Vv. hepaticae) into the cava inferior vein.

Clinical Remarks

In patients with e.g. liver cirrhosis, higher resistance of the liver and therefore increased **portal vein pressure** means significantly less blood flow through the liver. Bypassing the liver, the remainder of the blood flows through portocaval anastomoses directly into the systemic system. The veins occurring in the anastomosis area are not adapted to the increasing blood flow and can expand (development of **varicose veins**). This allows varices to form in the area of the gastroesophageal transition, a so-called Caput medusae in the area of the paraumbilical veins (rare) or varicose veins in the anal canal. Particularly **oesophageal varices** can be easily damaged during food intake and lead to life-threatening bleeding.

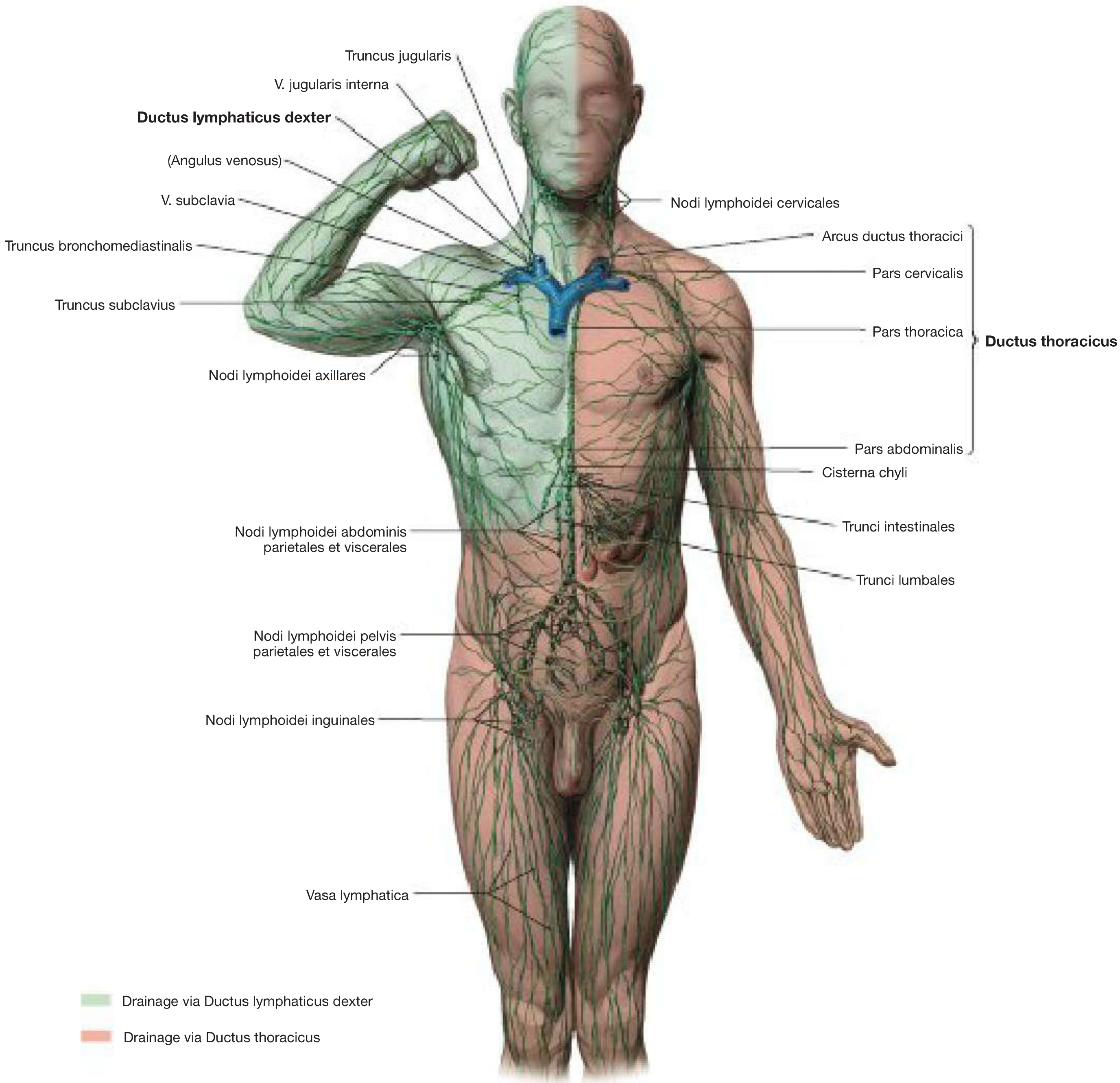


Fig. 1.41 Overview of the lymphatic vessel system.
The **lymph capillaries** incipient in the periphery absorb the fluid (lymph) from interstitium and lead it via lymph collectors to the **lymphatic vessels** and the intermediate **lymph nodes**. Lymph nodes responsible for the collection and filtration of a particular body region are called regional lymph nodes. Lymph nodes which receive lymph from various other lymph nodes are called collection lymph nodes.
Finally, the lymph reaches the major **lymphatic ducts** (Ductus thoracicus and Ductus lymphaticus dexter) and then passes to the venous blood vessel system of the systemic circulation. The largest share of lymph is drained through the **Ductus thoracicus** into the left venous angle (between the Vv. jugularis interna sinistra and subclavia sinistra); only the right upper quadrant of the body is drained through the **Ductus lymphaticus dexter** into the right venous angle (between the Vv. jugularis interna dextra and subclavia dextra.
In addition to the lymphatic vessels and lymph nodes, the lymphatic system also includes **lymphatic organs** (thymus, bone marrow, spleen, tonsils, mucosa-associated lymphatic tissue). It is functional in the immune system and fat absorption.

Lymph Nodes

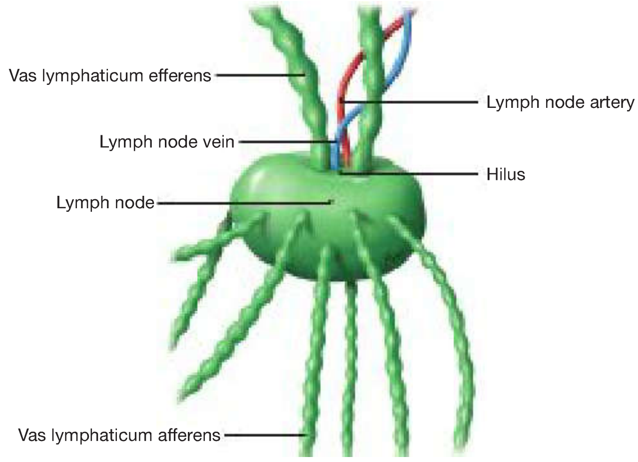


Fig. 1.42 Lymph nodes with inbound and outbound lymphatic vessels; semi-schematic representation. [L127]
Lymph nodes are part of the lymphatic system and are considered to be **secondary lymphatic organs**. They come in various shapes (mostly lens or bean-shaped with a diameter of 5–20 mm). The body contains approx. 1,000 lymph nodes and of those 200 to 300 are located in the neck alone. Functionally, lymph nodes are part of the immune system and play an important role in fighting infections.

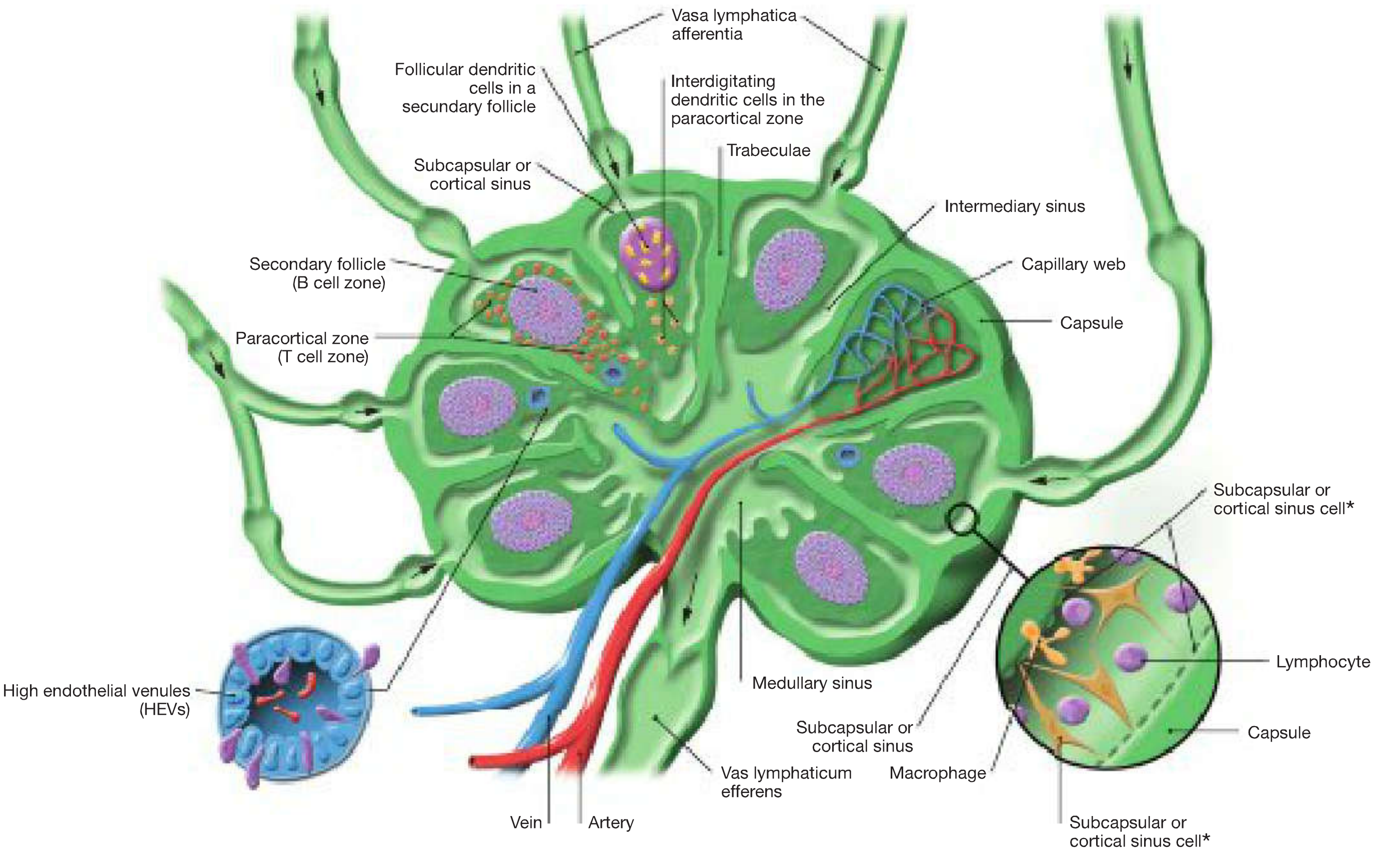


Fig. 1.43 Lymph nodes; schematic section. (according to [S010-2-16])
Besides the inbound and outbound lymphatic vessels (vasa afferentia and vasa efferentia), the blood vessel supply and the compartmentalisation of the lymph node into B-region (secondary follicle), T-region (paracortical zone), high endothelial venules, follicular and interdigitating dendritic cells, medullary sinus, intermediary sinus and subcapsular or cortical sinus (with cellular structure) are represented. [L127]

* sinus wall cells (reticular cells) not only line the sinus, but also traverse it

Clinical Remarks

Examination of the lymph nodes is an important aspect of the physical examination of a patient. Examination includes the palpable lymph nodes of the neck, axilla and groin. Lymph node enlargement can be a sign of inflammatory processes (lymphadenitis) or malignant disease (e.g. metastasis of a malignant tumour or a generalised disease of the lymphatic system, such as HODGKIN's disease).
A **sentinel lymph node** refers to those lymph nodes in the first drainage area of a malignancy (especially breast and prostate cancer and malignant melanoma). If this already contains tumour cells, it is highly likely to find further lymphogenic metastases in the surrounding area. If it is tumour-free, additional lymph node metastases are unlikely. The sentinel lymph node status is therefore crucial for further therapeutic procedures.

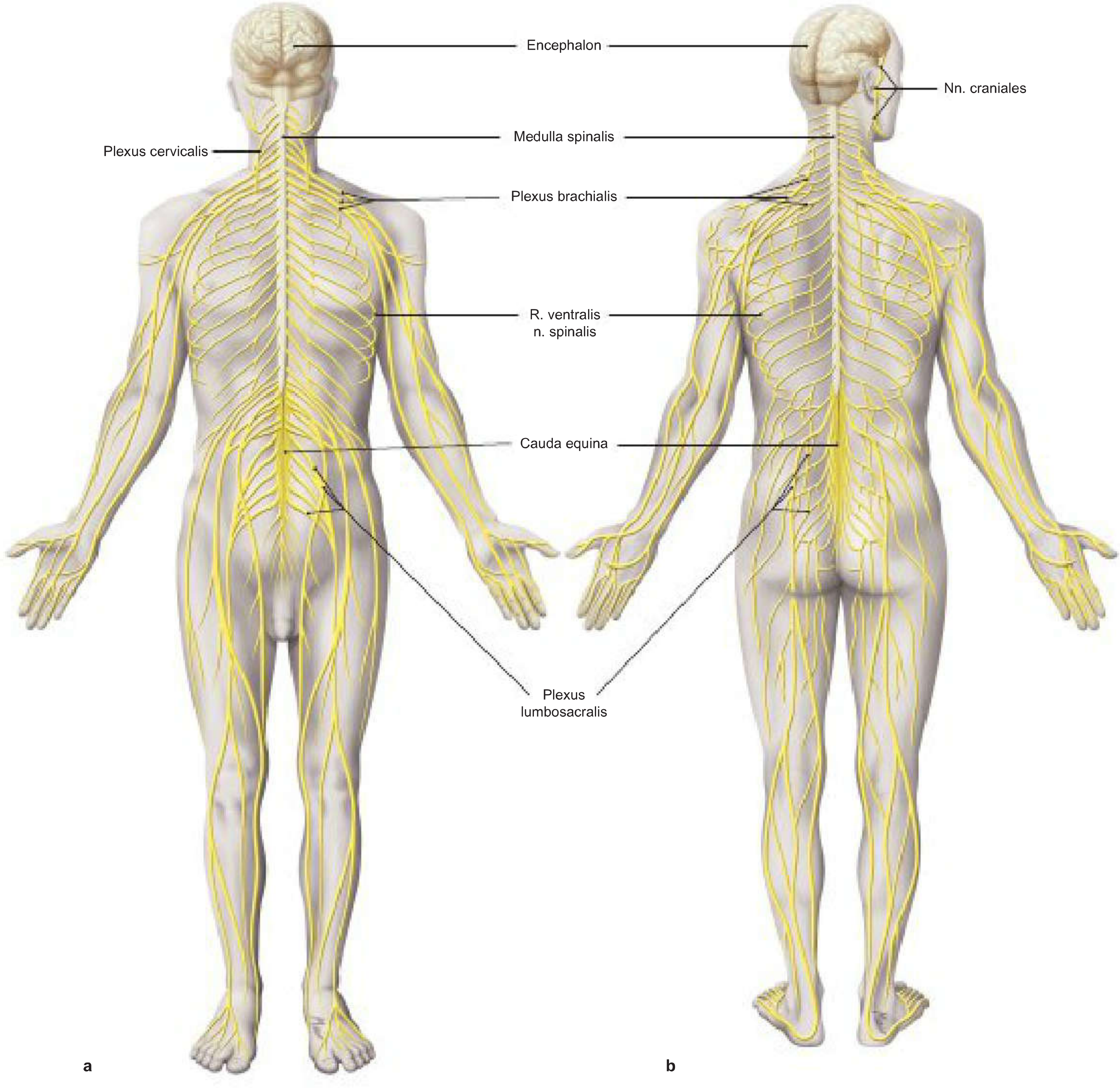


Fig. 1.44a and b Structure of the nervous system; ventral view **(a)** and dorsal view **(b)**. (according to [S010-2-16]) [L127]

The nervous system is composed of the central (**CNS;** brain, spinal cord) and peripheral nervous system **(PNS).** The PNS is mainly composed of spinal nerves (with connections to the spinal cord) and cranial nerves (with connections to the brain).

The nervous system controls the activity of muscles and intestines, is used to communicate with the environment and the inner self and meets complex functions, such as storage of experience (memory), development of ideas (thinking) as well as emotions. It is also used for rapid adjustment of the whole organism to changes in the outer world and the interior of the body. Functionally, the nervous system is divided into the **autonomic** (vegetative, visceral, for control of intestinal activity, mostly involuntary) and **somatic** (animalic, innervation of skeletal muscles, conscious sensory perception, communication with the environment) **nervous system.** Both systems are closely interlaced and interact with each other. Besides the nervous system, the endocrine system also participates in the regulation of body functions.

Spinal Nerve

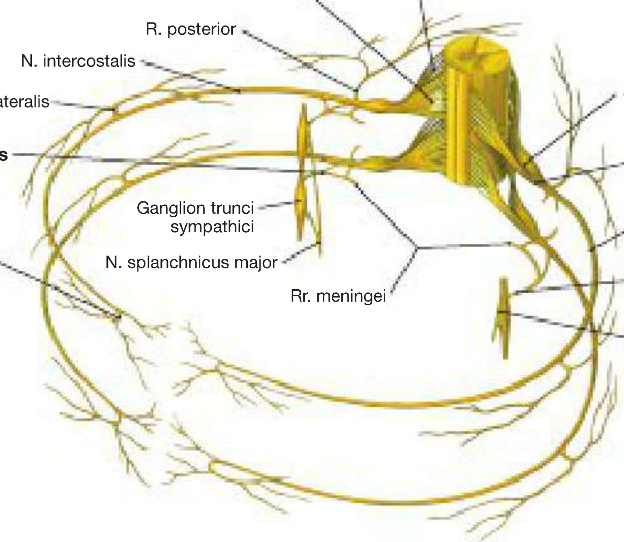


Fig. 1.45 Diagram of the spinal nerve (spinal cord segment) exemplified by two thoracic nerves; view from above at an oblique lateral angle.

The human body has 31 pairs of spinal nerves (eight cervical, twelve thoracic, five lumbar, five sacral and one coccygeal). Each spinal nerve consists of a front root (Radix anterior) and a rear root (Radix posterior). The cell bodies (perikarya) of motor neurons are located in the gray matter of the spinal cord and exit through the anterior root; the perikarya of sensory nerve cells are located in the dorsal root ganglion (Ganglion sensorium nervi spinalis). They continue through the posterior root into the spinal cord. Via communicating branches, connections are made from the spinal cord to the sympathetic trunk (ganglia trunci sympathici). All dorsal branches of the spinal nerves as well as the ventral branches of the thoracic spinal nerves T2 to T11 have a segmental arrangement. The remaining ventral branches usually come together to form the Plexus (Plexus cervicalis, brachialis, lumbosacralis).

Clinical Remarks

Excessive alcohol consumption, Diabetes mellitus, vitamin B deficiency, intoxication with heavy metals and drugs as well as impaired blood circulation can result in disorders of the peripheral nerves. This can lead to the malfunction or excessive excitation of the nerve cells (neurons). When many nerves are affected, this is referred to as **polyneuropathy.**

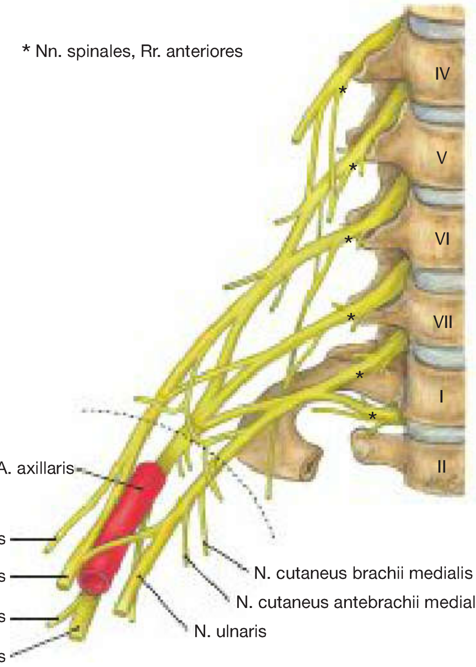


Fig. 1.46 Diagram of a plexus with the example of the brachial plexus; ventral view.

Plexus refers to a network of nerve fibres. In the human body we find the Plexus cervicobrachialis und lumbosacralis. Because the cervical plexus has no connection with the brachial plexus, the individual plexuses are mentioned, in contrast to the Plexus lumbosacralis where there is a connection between the Plexus lumbalis and Plexus sacralis. The brachial plexus is responsible for innervation of the muscles and sensitivity of the shoulder and arm. It forms the Rr. ventrales of the spinal nerve roots C5 to T1 and belongs to the somatic plexuses like the other plexuses mentioned. They contrast with the autonomic nervous plexuses. These include, for example, the Plexus coeliacus and the Plexus mesentericus superior in the upper abdomen, which are known collectively as the Plexus solaris. They contain sympathetic and parasympathetic fibres (→ Fig. 1.48a and → Fig. 1.48b).

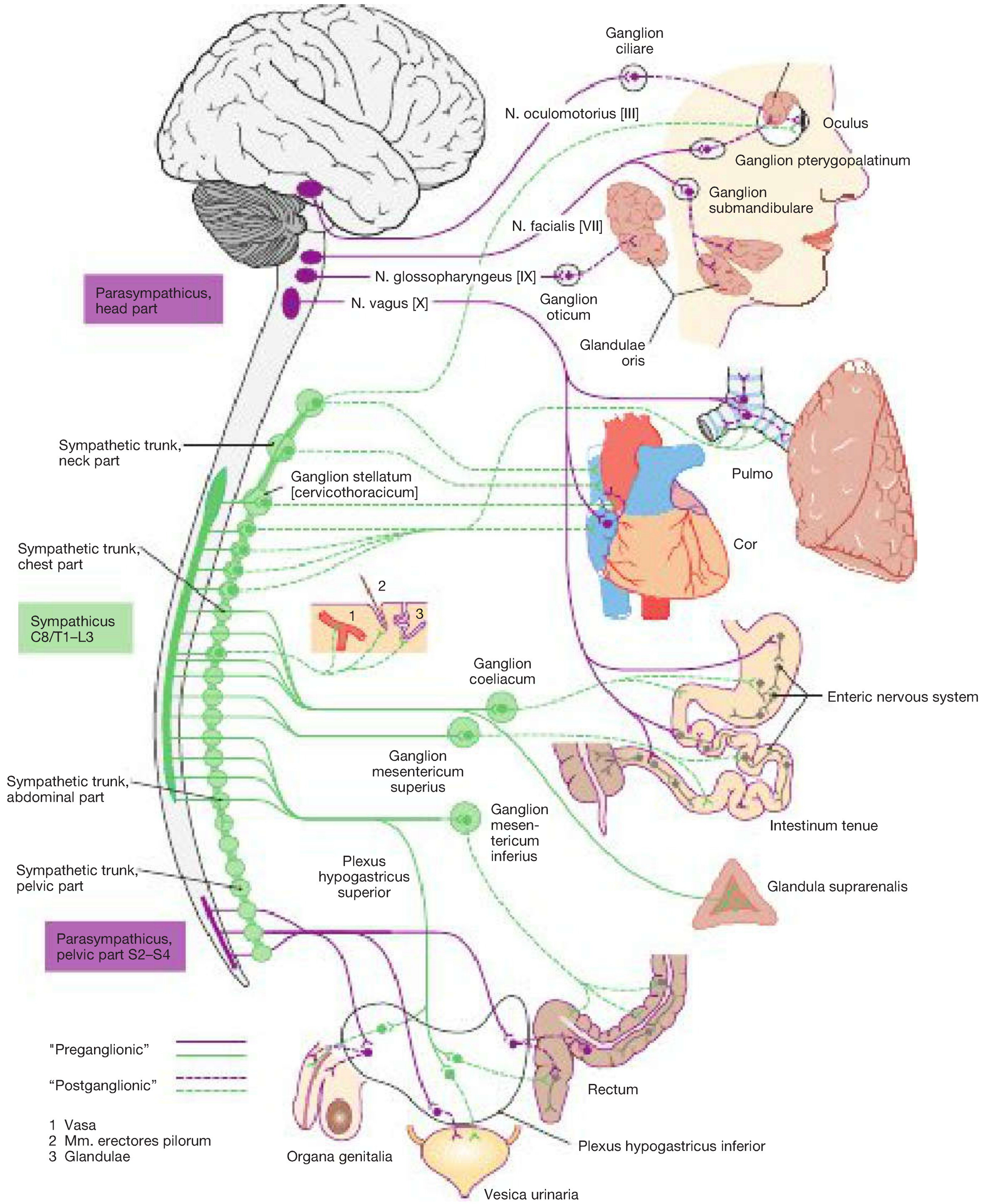


Fig. 1.47 Autonomic (vegetative) nervous system. [L106/L126]
The autonomic nervous system consists of the sympathetic, parasympathetic and enteric nervous system.
The nerve cells of the **sympathetic nervous system** are located in the lateral horn of the thoracolumbar segment of the spinal cord. Their axons project onto the sympathetic trunk ganglia and the ganglia of the digestive tract. Here the switch is made to post-ganglionic neurons that project to the effector organs. Sympathetic excitation takes place to mobilise the body during activity and also emergency situations. The trunk also consists of the adrenal medulla, which can release adrenaline and noradrenaline.
Core areas of the **parasympathetic nervous system** are found in the brain stem and the sacral spinal cord. Their axons reach ganglia near the effector organs in the head, thorax and abdominal cavity. Here the switch is made to post-ganglionic neurons, which reach the effector organs via short axons. The parasympathetic nervous system is used for food intake and processing as well as sexual arousal and is in opposition to the sympathetic nervous system.
The **enteric nervous system** regulates intestinal activity and is influenced by the sympathic and parasympathic nervous systems.

– Clinical Remarks

Disorders of the autonomic nervous system play a role in almost all medical disciplines. They can occur as independent diseases (e.g. inherited autonomic neuropathy), as a result of other diseases (e.g. autonomic neuropathy in diabetes mellitus or Parkinson's disease), or in response to external influences or other disorders (e.g. **vegetative dysregulation** accompanying stress, severe pain or psychiatric disorders). Depending on the affected region of the autonomic nervous system, disorders of the circulatory system, digestion, sexual function or other functions may prevail.

Autonomic Nervous System

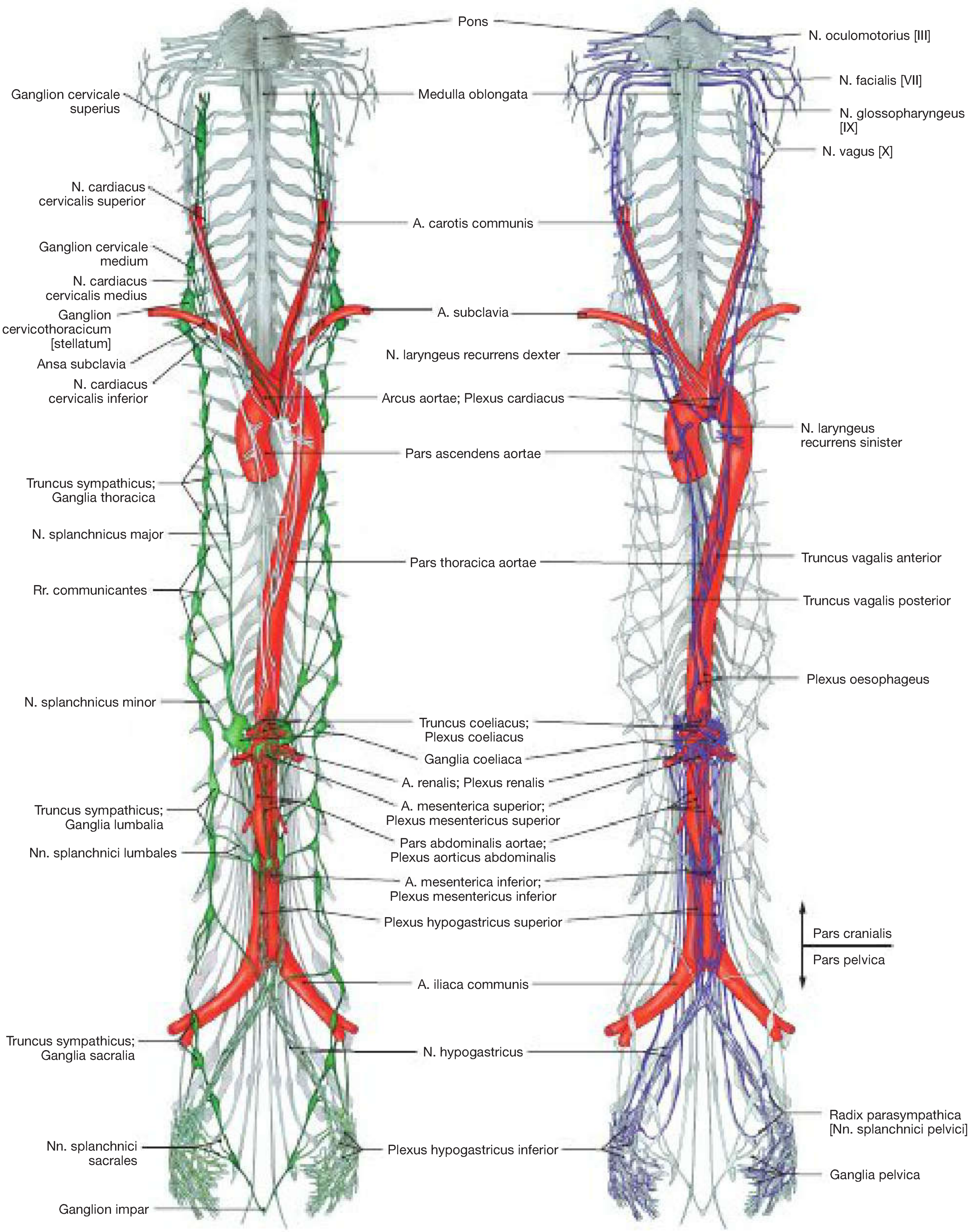


Fig. 1.48a and b Representation of the sympathetic nervous system, sympathetic part (a), and parasympathetic part (b).
The complete set of sympathetic ganglia lying near the spine and their connections with each other is referred to as the sympathetic trunk (Truncus sympathicus) (green). The parasympathetic fibres (purple) normally run together with other nerve fibers. The fibres of the autonomic nervous system form the vegetative plexus.

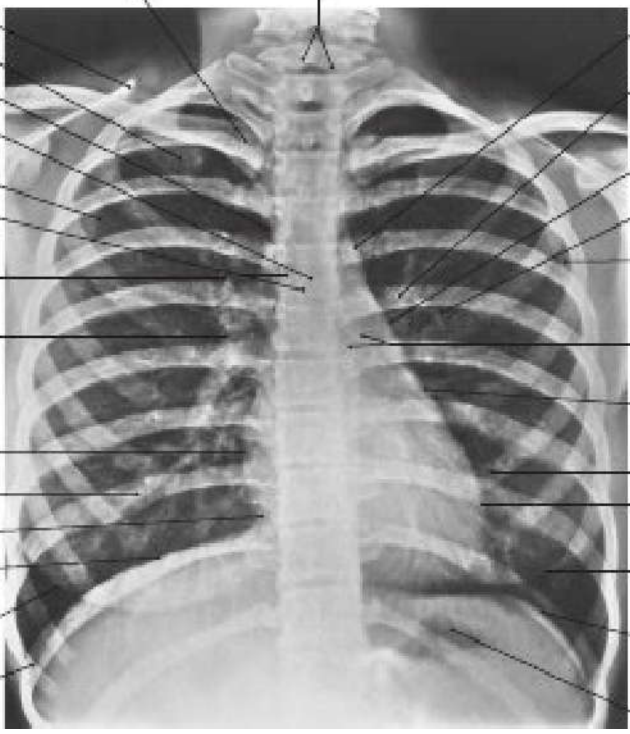


Fig. 1.49 Conventional X-ray, thorax overview image. [R316-007]
Normal X-rays are undoubtedly one of the most frequently produced images in hospitals and practices. Before evaluation takes place, one should establish clearly which technique has been used and whether it is a standard image. The chest X-ray is the most frequently requested X-ray image. The image is taken with the patient standing upright and the X-rays pass through the thorax in a posterior-anterior (pa) direction (patient faces radiographic film). With the patient lying down, the X-rays pass through the thorax in an anterior-posterior (ap) direction. A good radiographic image of the thorax displays the major bronchi and blood vessels of the lung, the cardiomediastinal contour, the diaphragm, ribs and peripheral soft tissue.

* Mammary shadow (contour)

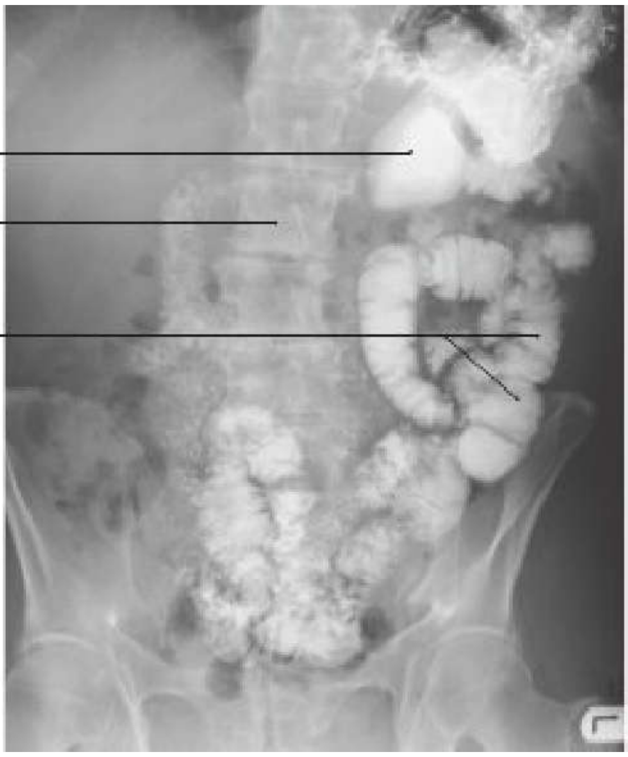


Fig. 1.50 Conventional X-ray, contrast agent imaging of the large intestine. [E402]
In order to display arteries, veins, intestinal loops or other hollow organs, these must be filled with substances that absorb the X-rays to a greater extent than under normal circumstances. The substance administered must not be toxic. A frequently used contrast agent is barium sulphate, an insoluble, non-toxic salt of high density. For vessels, iodinated molecules are normally used as a contrast agent. They are safe and well tolerated by most patients. Because they are excreted again via the urogenital tract, the kidneys, ureters and bladder (i. v. urography, i. v. urogram) can also be displayed.

Scintigraphy and Ultrasound

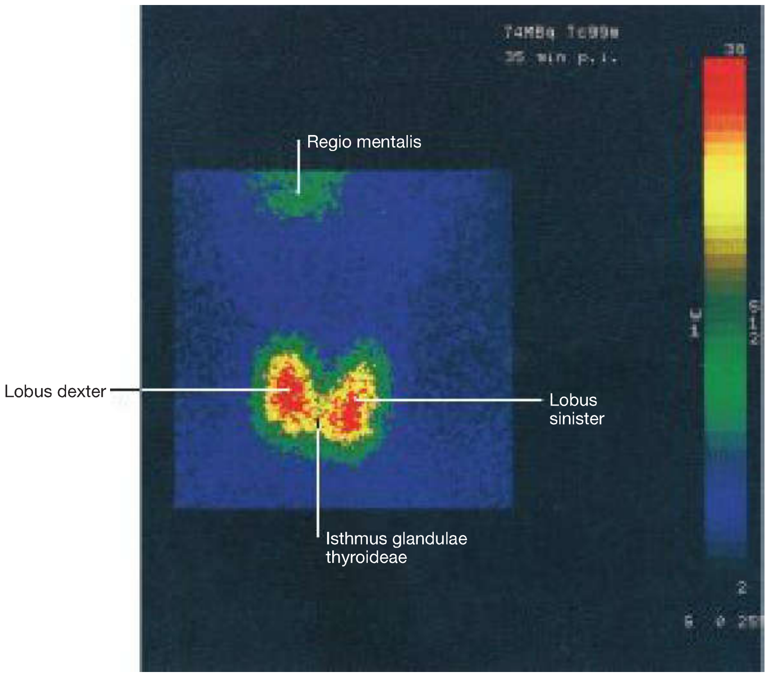


Fig. 1.51 Scintigraphy, scintogram of the thyroid gland. [R316-007]
In scintigraphy, gamma rays (a form of electromagnetic rays) are used to generate an image. Gamma rays are produced as a result of the decay of unstable atomic nuclei, whereas X-rays are excess energy released during the bombardment of atoms with electrons. The gamma ray emitter has to be administered to the patient. The radioisotope technetium-99m (^{99m}Tc) is most frequently used. It is usually injected in combination with other molecules. Following injection, and depending on how the radioactive pharmaceutical is absorbed, distributed, metabolised and excreted by the body, images are generated by a gamma camera.

Fig. 1.52 Sonography, ultrasound image of a foetus in the 28th week of pregnancy; lateral view. [T909]
Ultrasound examination of the body is used in all fields of medicine. Ultrasound is a very high frequency sound wave (no electromagnetic radiation), which is generated by piezoelectric materials, producing a series of sound waves. These sound waves are reflected from the inner organs and their contents (foetus in the uterus), registered by the same piezoelectric material, and evaluated in a computer. This creates a live image on the connected monitor so that with a foetus, for example, the movements of the extremities and the opening of the mouth can be tracked.

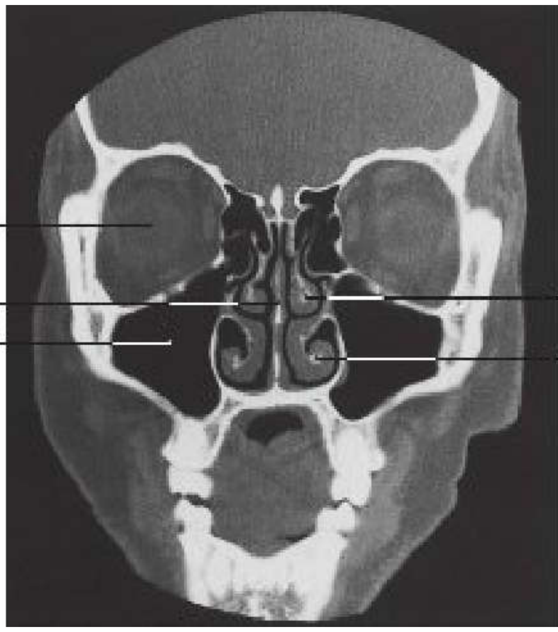


Fig. 1.53 Computed tomography, coronal computed tomogram (CT) of the sinuses. [R331]
Computed tomography (CT) was developed by Sir Godfrey Hounsfield in the 1970s. Since then, the use of constantly updated CT scanners has meant continual further development. The computed tomograph generates a series of cross-sectional images through the body in the transverse or, as shown here, coronal plane. The patient lies on a table and an X-ray tube takes one sectional image after the other while circulating around the body. Then a computer generates a sectional image using complex mathematical image analysis technology from the extensive data recorded.

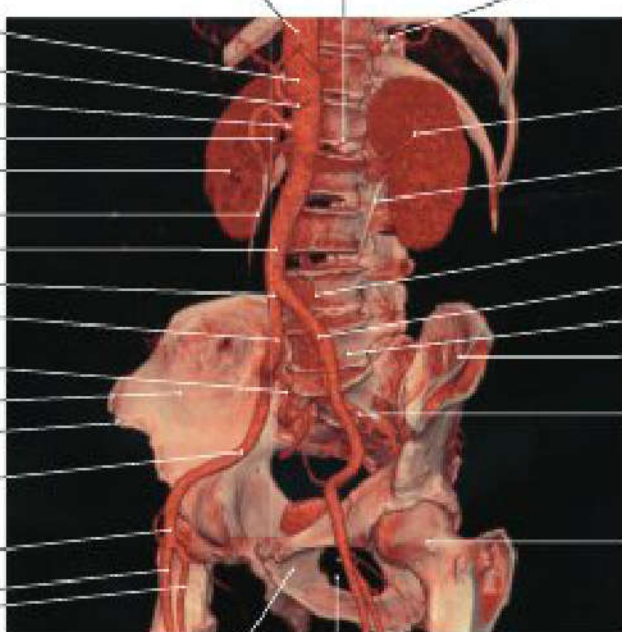


Fig. 1.54 3-D CT angiography, 3-D CT angiogram of different structures of the abdomen and pelvis (volume-rendering technique, VRT) derived from multidetector CT sections. [R316-007]
Modern computed tomography technology (e.g. 64-lines volume spiral multilayer CT) provides new dimensions and indications for CT diagnostics. State-of-the-art equipment technology guarantees an individual lowest-dose treatment for the patient. CT angiography is based on such a multi-layer CT. The relevant blood vessel regions are scanned during rapid intravenous injection of an iodinated contrast agent. The resulting sectional images of branching vessels are then processed by a computer to generate a 3-D image.

* clinical term: superficial femoral artery

Magnetic Resonance Imaging (MRI)

Fig. 1.55 Magnetic resonance tomography (MRT), axial (transverse) magnetic resonance image of the brain (T1-weighted). [R316-007]

In magnetic resonance imaging (MRI), the patient is exposed to a very strong magnetic field. All hydrogen protons in the body are aligned to the magnetic field. If the patient is exposed in the short term to a radio wave pulse, the magnets are deflected. When returning to the target position, the magnets emit small radio waves. Strength, frequency and the time needed by the protons to return to the original position influence the signal emitted. This signal is analysed and processed by a computer, which generates an image.

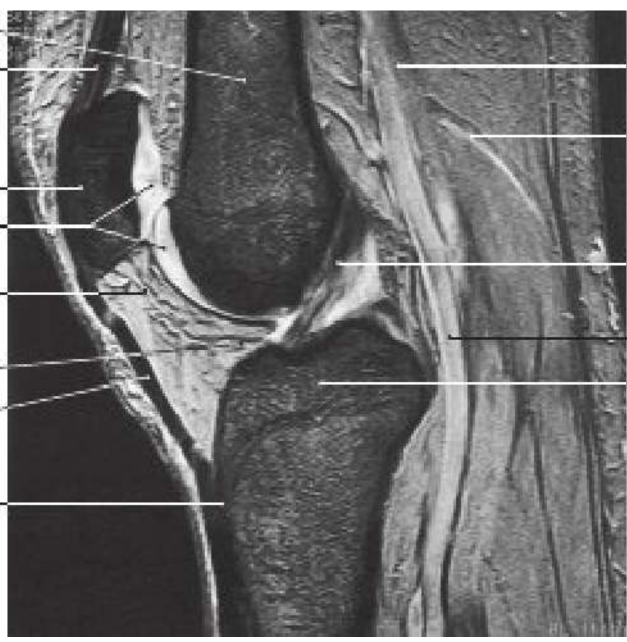


Fig. 1.56 Magnetic resonance tomography, sagittal magnetic resonance image (MRI) of a knee (T2-weighted). [R316-007]

By changing the sequence of pulses with which the protons are stimulated, different characteristics of the protons can be assessed. This is known as scan **weighting**. By changing the pulse sequence and the scanning parameters, T1-weighted images (liquids dark, fat bright, e.g. articular effusion dark) and T2-weighted images (liquids bright, fat medium bright, e.g. HOFFA's fat pad between patella and tibia clearly visible) are produced, emphasizing different tissue properties. MRI can also be used to generate angiograms of the peripheral and central circulation.

* HOFFA's fat pad

Fig. 1.57 Layers of the skin cover, integumentum commune; (hairy skin); C: Cutis, composed of epidermis (E) und dermis (D); SC: Subcutis; Fs: superficial fascia; Fm: muscle fascia; M: muscle; rc: retinaculum cutis; SG: eccrine sweat glands. HE staining, enlarged 22-fold [S010-2-16]

The skin (cutis) is composed of the **epidermis** (outer skin; epithelium) and underlying **dermis** (fibro-elastic connective tissue layer with capillary plexus, specialized receptors, nerves, immune cells, melatonin-producing cells, sweat glands, hair follicles, sebaceous glands, smooth muscle cells whose thickness varies depending on the body region). Below is the **subcutis** (subcutaneous adipose tissue). As the largest organ (approx. 2 m^2) it serves functionally as protection against mechanical damage, a thermal regulator, a sensory organ and protection against water loss.

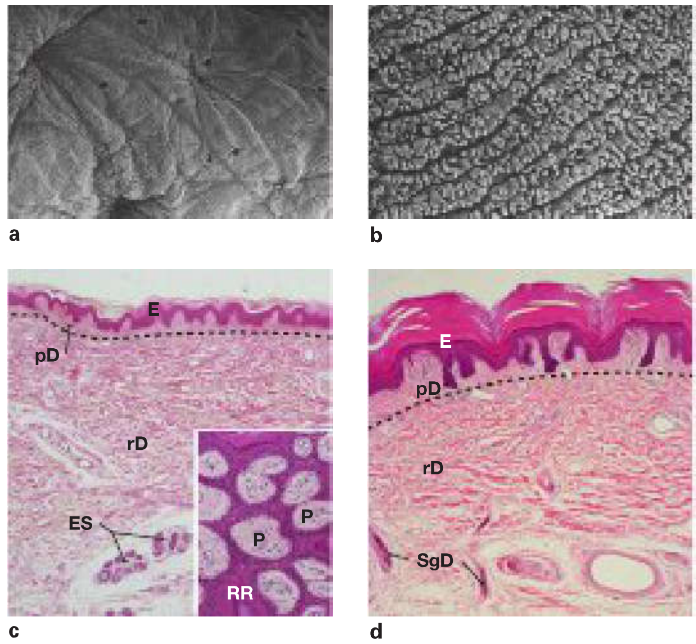


Fig. 1.58a to d Hairy skin (a and c, back of finger) and hairless skin (b and d, fingertips); E: epidermis; P: papillae; pD and rD: papillary dermis and reticular dermis; RR: rete ridges; SG: eccrine sweat glands; SGD: sweat gland duct. The dotted lines denote the boundaries between the above-mentioned dermal layers (papillary stratum and reticulare stratum). HE staining, enlarged 45-fold, insert 100-fold (**c, d** [S010-2-16])

The top panel shows scanning electron microscopy images of the surface of the dermal papillary layer after the epidermis has been removed. Below you can see vertical cross-sections through the epidermis and dermis, giving a histological overview. The insert on the left side displays a tangential cut through the epidermis (purple) and the papillary dermis (pink).

Clinical Remarks

The dermoepidermal connection is guaranteed by a number of different proteins and structures. If genetically any of these proteins or structures responsible for the adhesion mechanisms between the two zones are missing, shear forces lead to tears, associated with **blistering** (bullae) and in some cases with extensive detachment of the epidermis. Epidermis detachment can also occur through autoantibodies against components of the adhesion structures (bullous pemphigoid; pemphigus).

Hair

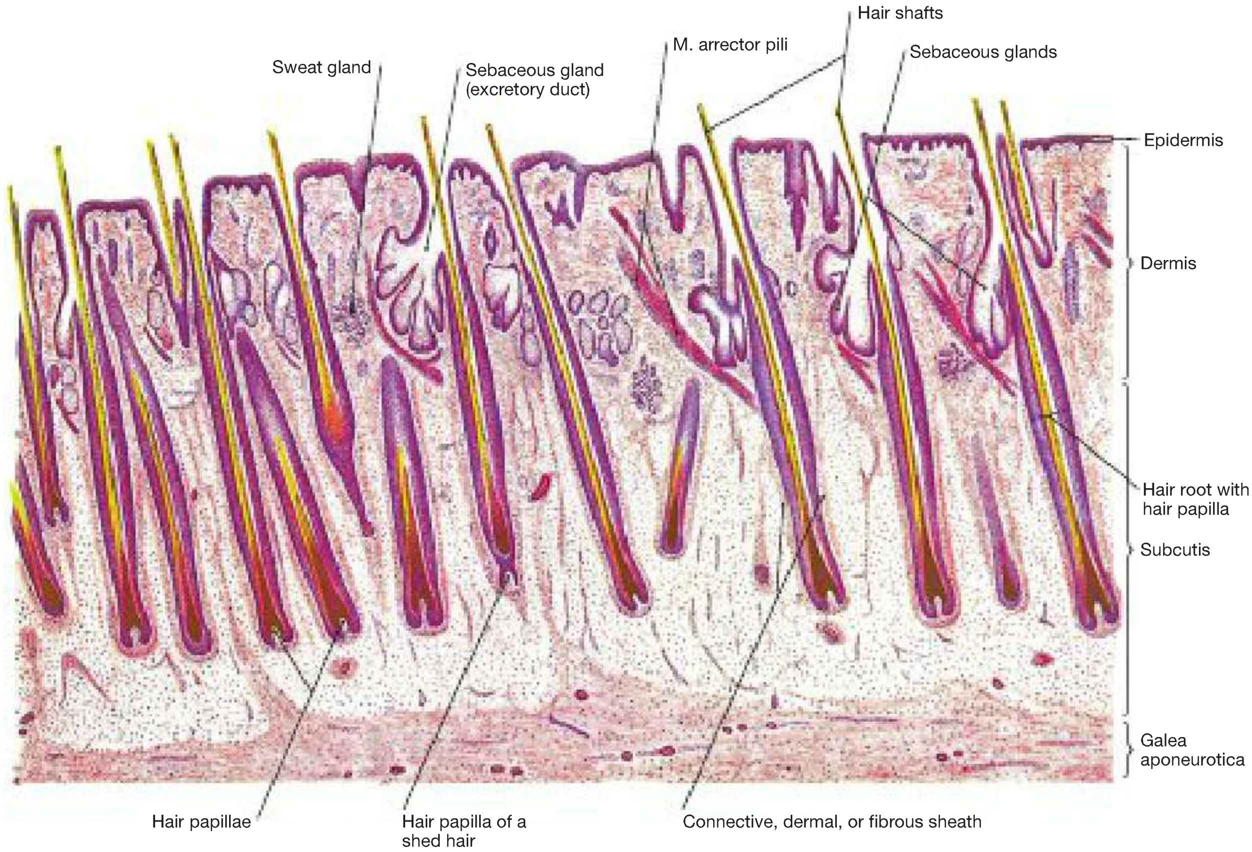


Fig. 1.59 Hair, Pili; longitudinal section through the scalp. [R170]
Hair is the product of keratinisation of the epidermis. It originates from invaginations of the epidermis which form follicles that contain mitotically active cells (matrix cells) at the base. The cells emerging from matrix cells diversify into horn cells, which form the hair shaft. Postnatally, a distinction is made between two basic types of hair:

- **vellus hair** (downy hair), which is soft, short (the follicles are in the dermis), thin and virtually unpigmented with no core; it corresponds to the fetal lanugo and covers most of the body in children and women
- **terminal hair** (long hair), which is strong, long (the follicles reach the subcutis), thick and pigmented with a core; it occurs as scalp hair, eyelashes, eyebrows, pubic hair, armpit hair and beard hair (in men) and usually differs considerably in different ethnic groups.

Hair serves to protect against UV light and heat as well as to provide tactile sensation.

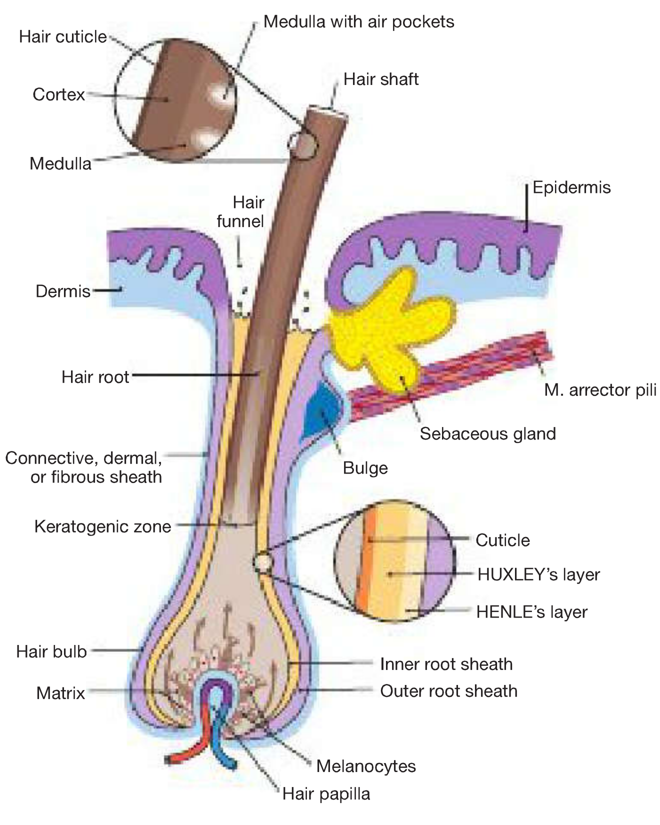


Fig. 1.60 Structure of a hair follicle; longitudinal section. [R170-3]
Hair arises in cylindrical epithelial depressions which reach down to the dermis or subcutis and are referred to as hair follicles. The **hair follicle** consists of the hair bulb and hair papilla. It is nourished by blood vessels and is the point of origin of hair growth. Each hair follicle has a sebaceous gland **(pilosebaceous gland unit)** and a smooth muscle **(musculus arrector pili)** associated with it. The latter is responsible for erection of the hair (sympathetic activation) whereby the epidermis is retracted, forming small pits (goose bumps).
A distinction is made between:

- the fully keratinised **hair shaft** with an epithelial hair root sheath
- the non-keratinised **hair root,** separated by the keratogenous zone (keratinisation of hair cells) from the keratinised hair shaft
- **the hair bulb** (bulbus pili), the distended epithelial initial part of the hair, which contains cell division – enabling **matrix cells**
- the **hair papilla,** a cell-rich connective tissue process of the dermis, which extends up into the hair bulb
- the **hair funnel;** represents the outlet of the follicle to the skin surface; it is accompanied by the sebaceous gland
- the **epithelial root sheath,** subdivided into the inner and outer root sheaths: the layers of the **inner** root sheath, from inside to outside, consist of: the cuticle, the HUXLEY's and HENLE's layers; the **outer** root sheath is composed of several layers of bright, non-keratinised cells, which only are keratinised in the area of the hair funnel and from there continue in the epidermis of the skin.

The hair colour depends not only on genetic predisposition but also on the pigment content (melanin) of the hair. Once production of melanin ceases, the hair turns to grey or white.

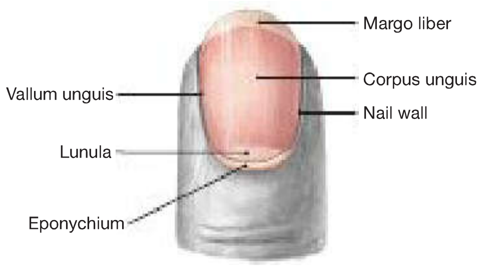


Fig. 1.61 Finger phalanx with nail.
The nail (unguis) is a convex-shaped, translucent keratin plate (nail plate) on the upper side of the distal phalanx of the fingers and toes. It provides protection for the toe and fingertips and supports the gripping function. It lies laterally in skin pockets (nail bed, Vallum unguis) which are surmounted by a skin fold (nail fold). The epithelium located beneath the nail plate at the dorsal end of the nail bed is known as the eponychium (cuticle, Cuticula). The nail plate is anchored here to the nail bed.

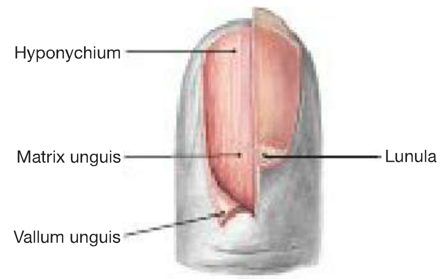


Fig. 1.62 Distal finger phalanx; nail partially removed.
The epithelium, on which the nail on the fingertip rests, is called the hyponychium. Beneath this lies the nail bed, composed of loose connective tissue, which is firmly fused with the periosteum of the distal phalanx. Proximally, the hyponychium turns into the nail matrix (matrix unguis), from which the nail plate emerges (visible from the outside as the lunula).

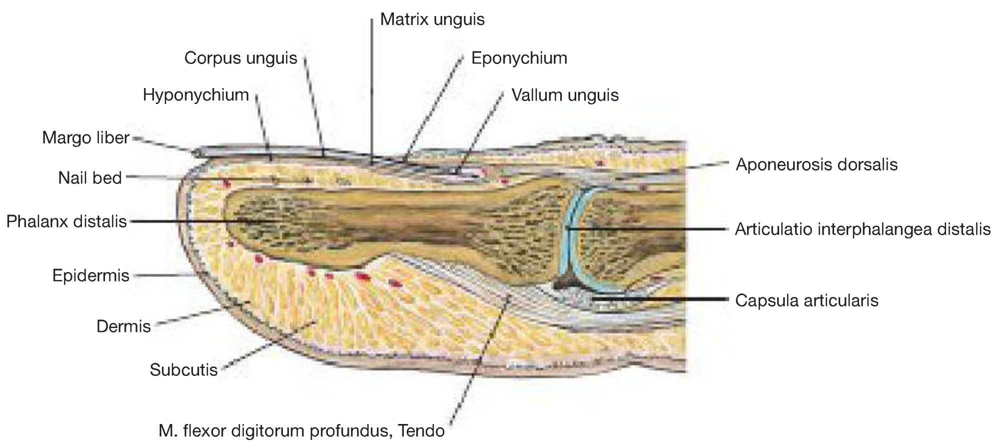


Fig. 1.63 Finger phalanx, Phalanx distalis; sagittal section.
The nail bed comprises the region between the nail and the distal phalanx. It consists of the epithelium (Hyponychium und Matrix unguis) and the underlying dermis.

Clinical Remarks

White spots under nails are due to defective fusion of the nail plate with the nail bed. Changes in light reflection at these points cause the nail plate to appear milky-white (similar to the lunula). Defective fusion can have different causes, e.g. it can be triggered by impact, drugs or various diseases. **Brittle nails** can be a sign of a lack of biotin (vitamin H). Biotin is required for the formation of keratin, the main component of the nail plate. Numerous systemic diseases are accompanied by nail changes. Psoriasis, for example, leads to the formation of **dents** (small pits), **oil stains** and sometimes **crumbling nails** or extreme **nail dystrophy.** Skin and nail injuries can be followed by colonisation by fungi **(nail mycosis),** for which the treatment, especially in toenails, can often be lengthy.

Practice Exam Questions

To check that you are completely familiar with the content of this chapter, practice questions from an oral anatomy exam are listed here.

Explain the structure of a bone:

- How do you distinguish bones according to their form and structure?
- How can you classify a long tubular bone?
- What happens in fracture healing?
- What types of bone connection do you know?
- How can bone adapt functionally to increased stress?

Describe the structure of a joint:

- What types of joint do you know?
- How is the joint capsule made up?
- What is meant by the neutral-zero method?
- What is an amphiarthrosis?
- What auxiliary structures do you know in joints?
- How is a bursa structured?

Explain the structure of a skeletal muscle:

- What types of muscle do you know and how can you classify muscles?
- How is a tendon sheath structured?
- What is meant by muscle activity?
- What is a lever arm?
- What is meant by dynamic muscle activity?

Explain different circulatory systems:

- Where can the pulse be detected on the upper and lower extremities?
- What is the low-pressure system within the circulatory system?
- What mechanisms are there for the return of venous blood to the heart?
- What short-circulation systems are there in foetal circulation?
- What is meant by the portal vein circulation?
- What course does the lymph take from the periphery of the body?
- Can you describe the general structure of a lymph node?

Explain the lymphatic drainage pathways in the neck:

- How many lymph nodes are there in the neck area?
- What lymph node groups exist in the neck area?
- Why is the throat area divided into lymphatic drainage regions (compartments)?
- What structures drain their lymph into the cervical lymph nodes?

Explain the structure of the nervous system:

- How is the nervous system divided up?
- What is a dermatome?
- What is meant by the autonomic (vegetative nervous system)?
- What is the enteric nervous system?

Explain imaging methods:

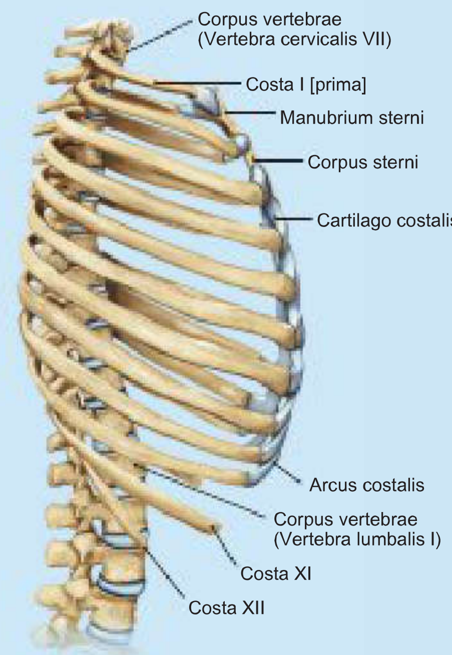
- Name some imaging methods used in routine clinical practice.
- How does computer tomography differ from magnetic resonance imaging?
- What is contrast agent imaging?
- What advantage does ultrasound offer compared to conventional X-ray imaging?

Explain the skin and its appendages:

- What layers of the skin do you know? How is a fingernail structured?
- How is a hair structured?
- Which basic types of hair do you know?

Trunk

2



Overview

The torso supports the head and upper extremities, which are secured in a flexible manner. The **spine** is the support structure of the torso, its vertebrae increase in size from top to bottom to support the weight of the body. To cushion any impact there are **intervertebral discs** (Disci intervertebrales) between the individual vertebrae which consist of a fibrous ring and a central gelatinous core. For protection against injuries, the spinal cord is enclosed by the vertebral arches in the vertebral canal. In the lower section, the vertebra is fused to the **sacrum** (Os sacrum) and together with the pelvic bone forms the stable pelvic ring. The characteristic curvature of the spine in humans is caused by the biped walk and the straightening of the torso. There is a variety of muscles mainly on the back and sides of the vertebrae (autochthonous muscles). This enables the individual vertebrae to move against each other. The viscera chambers of the torso lie in front of the spine, consisting of the thoracic cavity (Cavitas thoracis), **abdominal cavity** (Cavitas abdominalis) and **pelvic cavity** (Cavitas pelvis). The thoracic cavity is framed by the thorax, which includes the twelve pairs of ribs and the sternum as well as the vertebrae. The muscles are located between the ribs. In contrast, the wall of the abdomen consists solely of muscles and their tendons (aponeurosis). The thoracic and abdominal cavities are separated by the **midriff or diaphragm** (Diaphragma). The **mammary gland** (Mamma) is situated on the outer and front of the thoraric wall and can move freely on the M. pectoralis major. During pregnancy, it produces milk which is important for the nutrition of the baby. In males, there is a passageway **(inguinal canal)** in the lower section of the abdominal wall between the **scrotum** and the abdominal cavity which connects the spermatic cord and the structures contained in it to the corresponding organs and structures in the abdominal cavity, e.g. the urethra. Females also have an inguinal canal.

Main Topics

After studying this chapter, you should be able to:

- show and name palpable surface structures, allocate the regions of the torso and get your bearings topographically using anatomical guiding aides on the torso;
- explain the difference between dermatomes and the HEAD zone;
- know the principles of abdominal wall development, including the development of ribs, sternum and spine, and associated clinically relevant variations and malformations;
- describe the structure of the bony spine and thorax along with the corresponding joints, name the various pertaining ligaments, show them on the skeleton or slide and outline the scope of movement in the individual joints and in their entirety;
- describe the autochthonous muscles in the back and the corresponding fascia as well as the posture and movement functions of the head and torso;
- describe the layered structure of the abdominal wall, in particular muscles of the abdominal wall, thoracic and abdominal area, including the muscles in the thoracic and abdominal cavity and the muscles in the neck;
- name the base and origin of the straight and oblique abdominal muscles and explain the weak points of the abdominal wall as predilection sites for abdominal wall ruptures;
- describe the structure and the innervation of the diaphragm, explain the penetration points in addition to the penetrating structures and name possible weak points;
- name bypass circulation;
- describe the lymph catchment areas of the superficial axillary and inguinal lymph nodes;
- outline the morphological principles of lumbar puncture, epidural anaesthesia and pleurocentesis;
- describe the female breast from a topographical and onco-surgical perspective;
- explain the inguinal canal from a development history and clinical perspective;
- explain the structure of the Plexus lumbosacralis.

Clinical Relevance

In order not to lose reference to future everyday clinical life with so many anatomical details, the following describes a typical case that shows why the content of this chapter is so important.

Inguinal Hernia

Case Study

A 27-year-old man noticed a swelling in his right inguinal area which became larger when squeezed while doing sports or when coughing. Initially the swelling was very small, but over the last two months it has grown. Sometimes, he now also has a dull pain in the right lower abdomen and in the inguinal area. Otherwise, the young man feels well, has no other complaints or diseases and does not take medication.

Result of Examination

In a standing position and in comparison to the opposite side, one can already see a slight swelling of the skin in the inguinal area. The swelling can easily be pushed back manually (repositioning). There is no tenderness in the inguinal area, and the repositioning does not cause pain. If the examiner pushes an index finger from the caudal direction lightly in the direction of the inner inguinal ring and while pushing the inguinal skin in asks the young man to cough, he can feel a swelling at the fingertip, which leads to the right scrotum. This is a clear indication of an inguinal hernia. The neck of the hernia sack seems to lie lateral of the Vasa epigastrica inferiora and above the Tuberculum pubicum.

Diagnostic Procedure

No further resources are required for the diagnosis of the inguinal hernia. Only the clinical examination comes into question. It is, if possible, conducted on a standing patient as in the case of the young man. When probing with the index finger or with the little finger through the scrotal or inguinal skin through the outer hernia ring, the inner inguinal should lie at the tip of the finger (→ Fig. a). The patient is asked to cough and/or push down. In this way, even small hernias can be palpated. The young man is diagnosed as having an indirect inguinal hernia. In this case, the hernia sac has extended into the Fossa inguinalis lateralis over the inner inguinal ring through the inguinal canal up into the scrotum. The hernial orifice is the inner inguinal ring. The three finger rule can help to isolate direct inguinal hernias and femoral hernias in the inguinal area.

Femoral hernias (Herniae femorales) are more common in older women.

The palm of the right or left hand is placed on the Spina iliaca anterior superior from behind. The middle finger marks the course of the indirect hernia, the forefinger the direct hernia and the ring finger the femoral hernia (→ Fig. b).

Diagnosis

Hernia inguinalis.

Treatment

Inguinal hernias **always** have to be treated surgically. The patient is informed about a minimally invasive TEPP (total extraperitoneal patch plasty) and prepared for surgery. As part of the TEPP an endoscopy is conducted on the abdominal wall through two to three small cuts in the abdominal skin. In this procedure the hernial sac was exposed and dissected, the contents of the hernial sac (an intestinal loop, which caused the swelling and mild pain) were repositioned into the abdominal cavity and finally the hernial sac was removed. During the operation a thin plastic mesh is laid between the layers of the abdominal wall (behind the M. transversus and under the Peritoneum parietale).

Further Developments

The great advantage of this surgical procedure is the immediate ability to sustain pressure, which generally makes it possible to do even intense sport within one week. The young man was able to go home on the day after the operation and within a week he was able to actively devote himself to his hobby, volleyball, completely pain-free and with no swelling in the inguinal area.

Dissection Lab

Observe the limitations and the content of the inguinal canal (→ Fig. 2.151) in the dissection lab.

Regardless of gender, the R. genitalis of the N. genitofemoralis and the N. ilioinguinalis run through the inguinal canal.

Observe the N. ilioinguinalis in addition to the spermatic cord (consisting of A. testicularis, Plexus pampiniformis, Ductus deferens, A. ductus deferentis, R. genitalis of the N. genitofemoralis) in the male inguinal canal. In females, the Lig. teres uteri, the R. genitalis of the N. genitofemoralis, the N. ilioinguinalis and lymphatic vessels pass through this area from the uterus.

Back in the Clinic

The inguinal canal is a predilection site for hernias. A distinction is made between indirect and direct inguinal hernias depending on the hernial ring.

Direct inguinal hernias lie medial.

In the case in question, the patient had an indirect inguinal hernia, which was not hereditary but acquired. Such acquired indirect hernias are the most common abdominal wall ruptures in adults and are predominant in men. Direct inguinal hernias penetrate through the muscle-free Trigonum inguinale (HESSELBACH's triangle) into the Fossa inguinalis medialis. The triangle is a weak point, because in this area the abdominal wall only consists of Fascia transversalis und Peritoneum parietale. In this case, the hernial ring lies medial of the Vasa epigastrica inferiora.

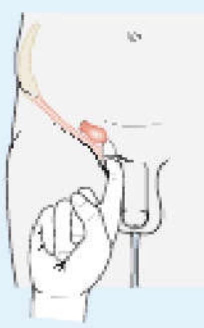


Fig. a Diagnosis of inguinal hernia using the finger. [L126]

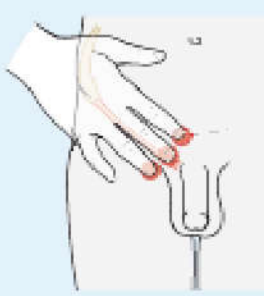


Fig. b Three-finger rule to define direct inguinal hernias and femoral hernias in the inguinal area. [L126]

Surface Anatomy

Back

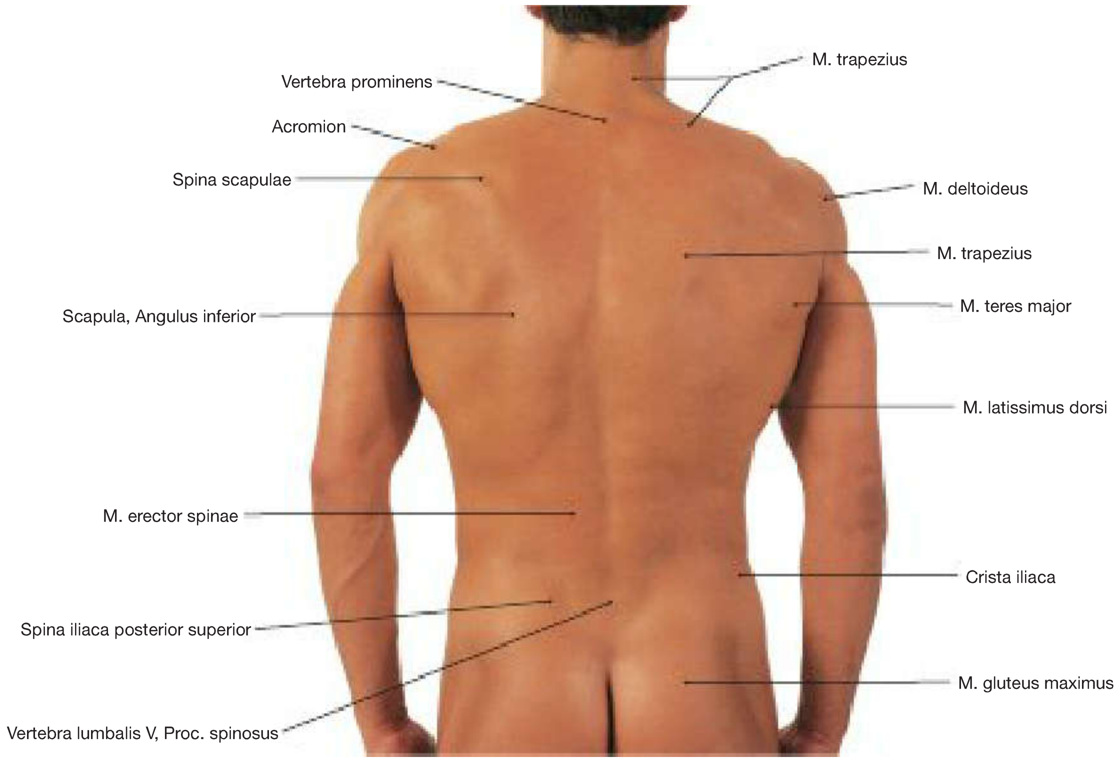


Fig. 2.1 Back, Dorsum, contours.
The contours of the back provide useful landmarks to determine different regions of the vertebral column, muscles, the approximate position of the end of the spinal cord or the position of organs (e.g. kidney). Particularly easily palpable bone points include the Proc. spinosus of the 7th cervical vertebra (Vertebra prominens), the acromion, the Spina scapulae, the Angulus inferior of the scapula and the Proc. spinosus of the 5th lumbar vertebra.

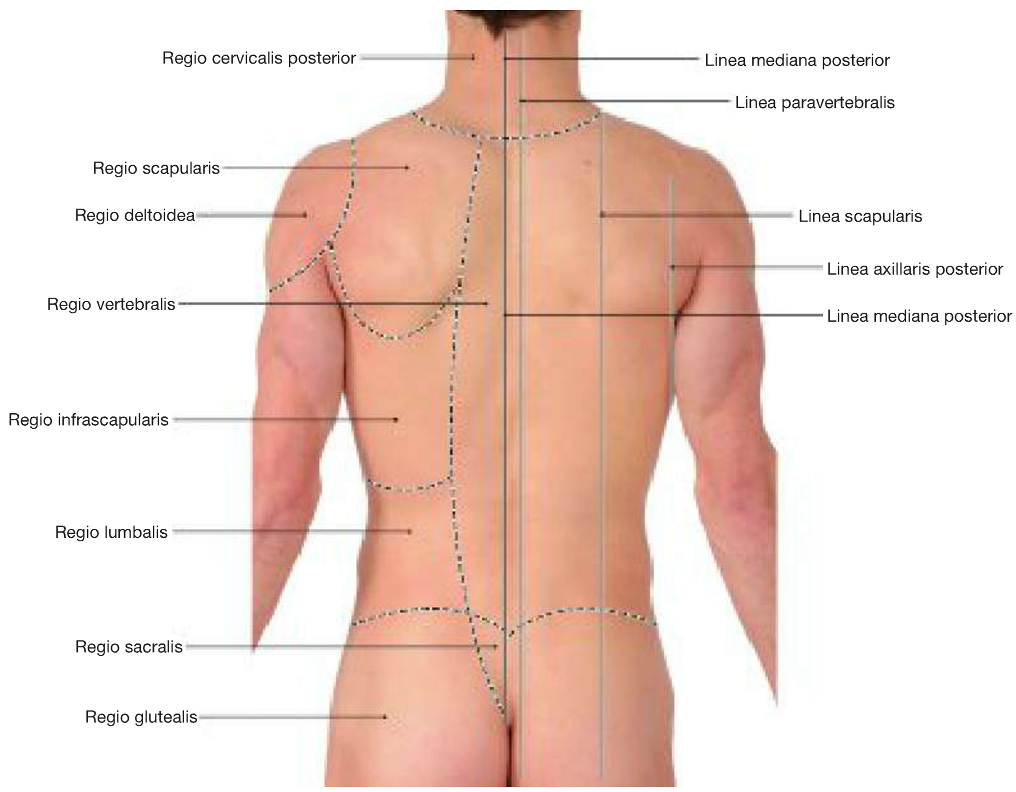


Fig. 2.2 Regions and orientation lines on the back. [J803]
A distinction is made between the following topographic regions on the back and in the neck region: Regio cervicalis posterior (Regio nuchalis), Regiones vertebralis, scapularis, infrascapularis, deltoidea, lumbalis, sacralis and glutealis. The Lineae mediana posterior, paravertebralis, scapularis and axillaris posterior serve as orientation lines.

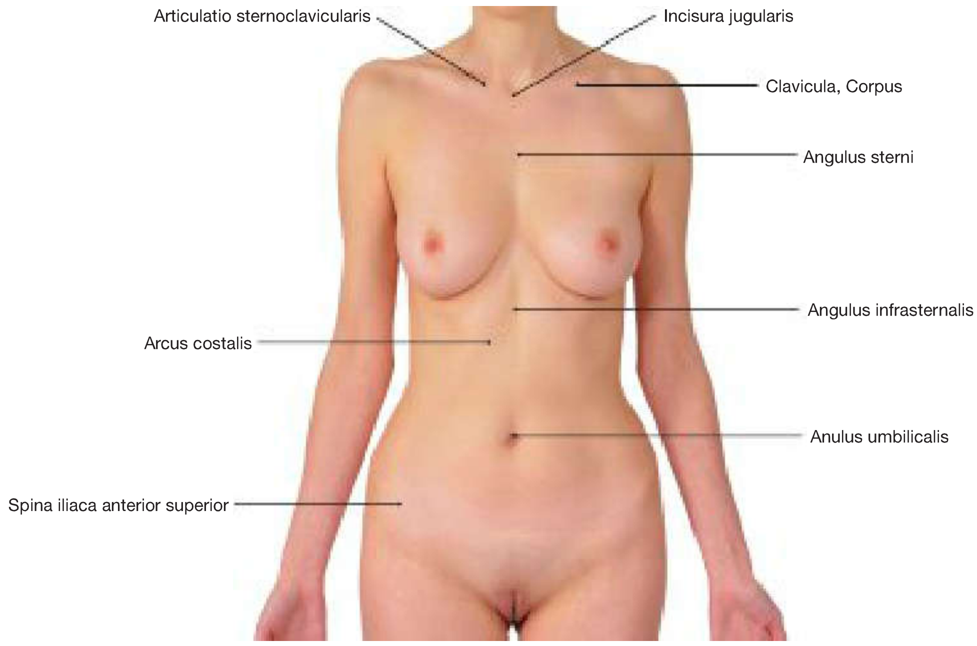


Fig. 2.3 Contours of the thoracic and the abdominal wall in a young woman. [J803]
Landmarks are useful to get one's bearings on the ventral wall, such as the costal arch (Arcus costalis), the navel (Anulus umbilicalis) and the Spina iliaca anterior superior. Other landmarks are depicted.

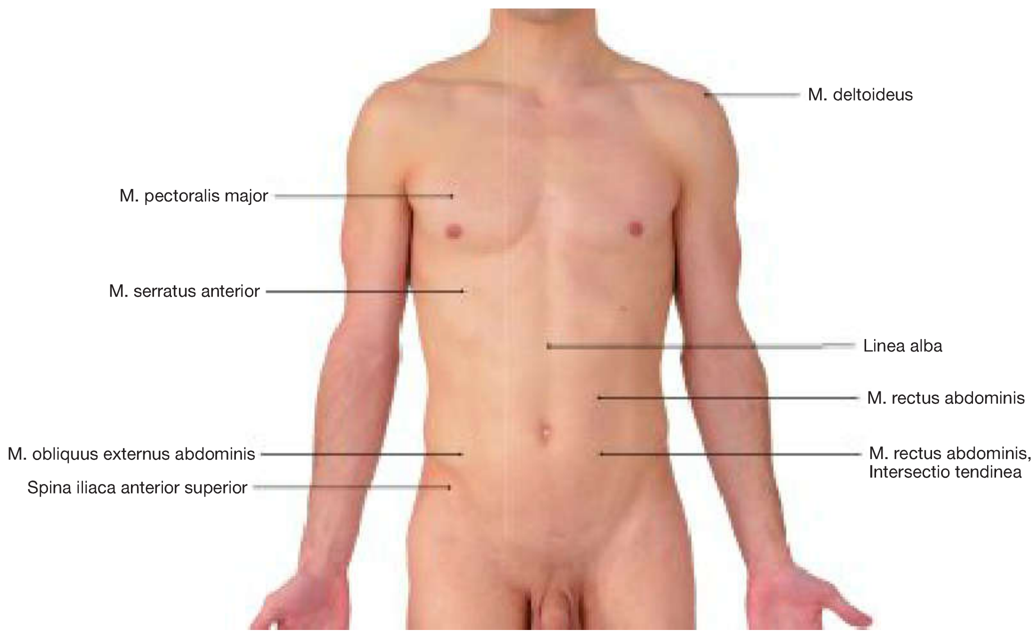


Fig. 2.4 Contours of the thoracic and the abdominal wall in a young man. [J803]
Landmarks on the ventral abdominal wall.

Thoracic and Abdominal Wall

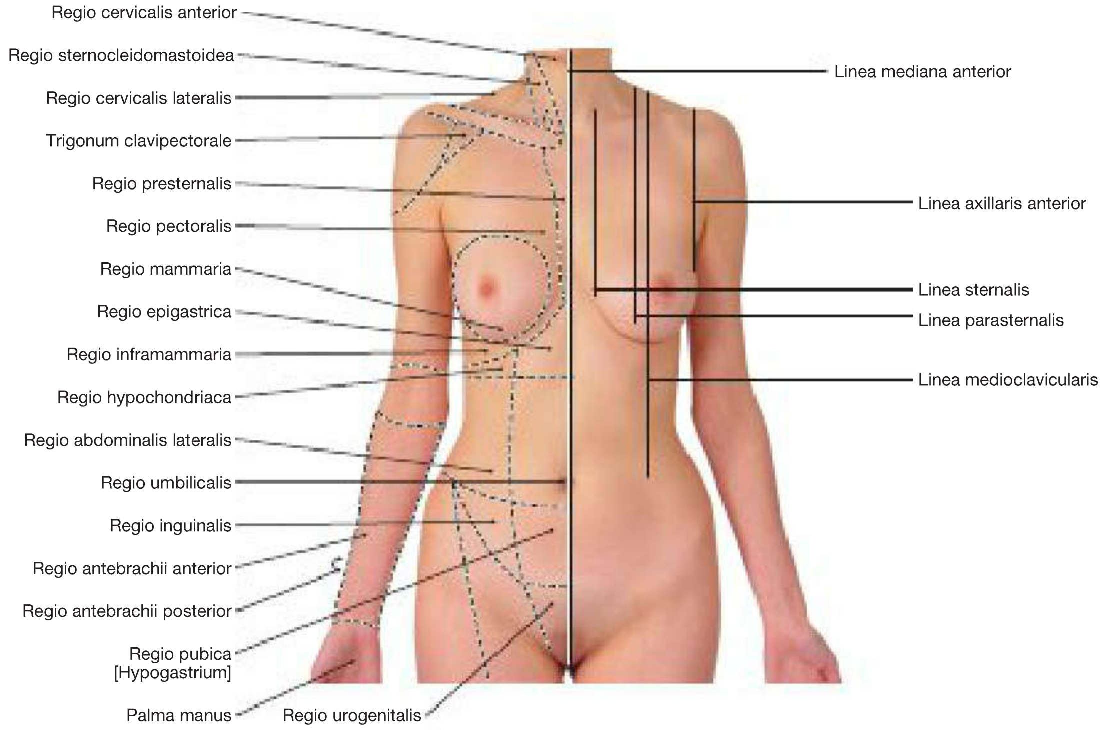


Fig. 2.5 Regions and orientation lines on the thoracic and abdominal wall in a young woman. [J803]
A distinction is made between the following topographic regions in the base of the neck and on the thoracic and abdominal wall: Regio cervicalis lateralis (Trigonum cervicale laterale), Regio sternocleidomastoidea, Regio cervicalis anterior (Trigonum cervicale anterius), Trigonum clavipectorale, Regiones presternalis, mammaria, inframammaria, deltoidea, epigastrica, hypochondriaca, umbilicalis, abdominalis lateralis, pubica and urogenitalis. The Lineae anterior, sternalis, parasternalis, medioclavicularis and axillaris anterior serve as orientation lines. The Regio pectoralis is overlapped in females by the Mamma and correspondingly by the Regiones mammaria und inframammaria. The Lineae mediana anterior, sternalis, parasternalis medioclavicularis and axillaris anterior serve as orientation lines.

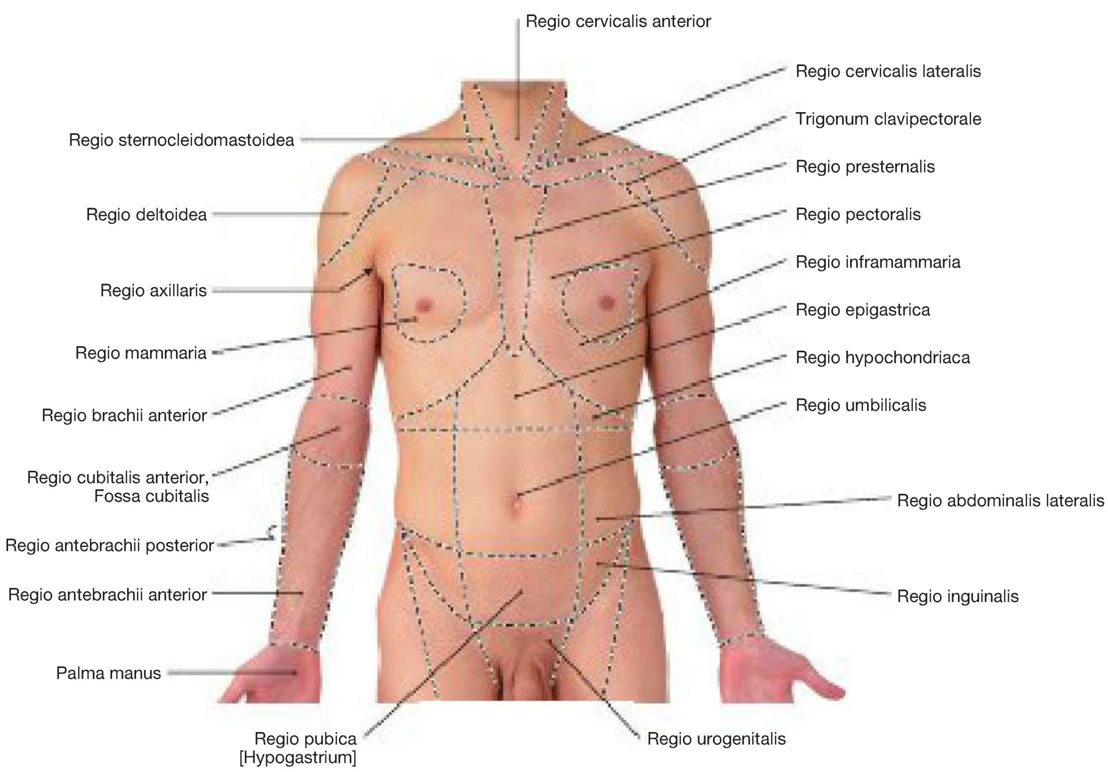


Fig. 2.6 Regions and orientation lines on the thoracic and abdominal wall in a young man. [J803]
A distinction is made between the following topographic regions in the base of the neck and on the thoracic and abdominal wall: Regio cervicalis lateralis (Trigonum cervicale laterale), Regio sternocleidomastoidea, Regio cervicalis anterior (Trigonum cervicale anterius), Trigonum clavipectorale, Regiones presternalis, mammaria, inframammaria, deltoidea, epigastrica, hypochondriaca, umbilicalis, abdominalis lateralis, pubica and urogenitalis. In the same way as in females (→ Fig. 2.5) the Lineae mediana anterior, sternalis, parasternalis, medioclavicularis and axillaris anterior serve as orientation lines.

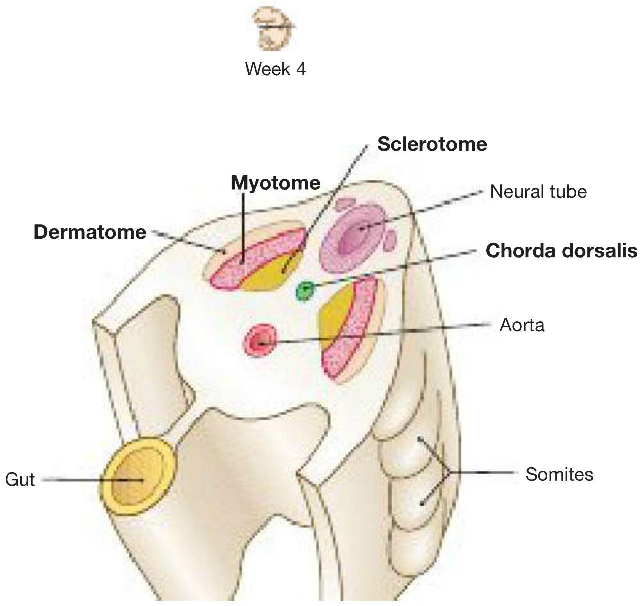


Fig. 2.7 Development of the trunk walls: division of the somites in the 4th week. [E838]
The elements of the supportive and movement uscular systems of the ventral and dorsal trunk wall originate exclusively from the middle cotyledon **(mesoderm).** The mesoderm condenses on both sides of the Chorda dorsalis and the neural tube to somites and unsegmented side plate mesoderms. Within the somites a ventromedial section, the **sclerotome,** can be differentiated in the 4th week. The cells of the sclerotome generally circulate around the neural tube and the Chorda dorsalis and differentiate into primitive vertebrae. The **myotome** and the **dermatome**, which supply the muscle and skin cells, emerge from the lateral section of the somites.

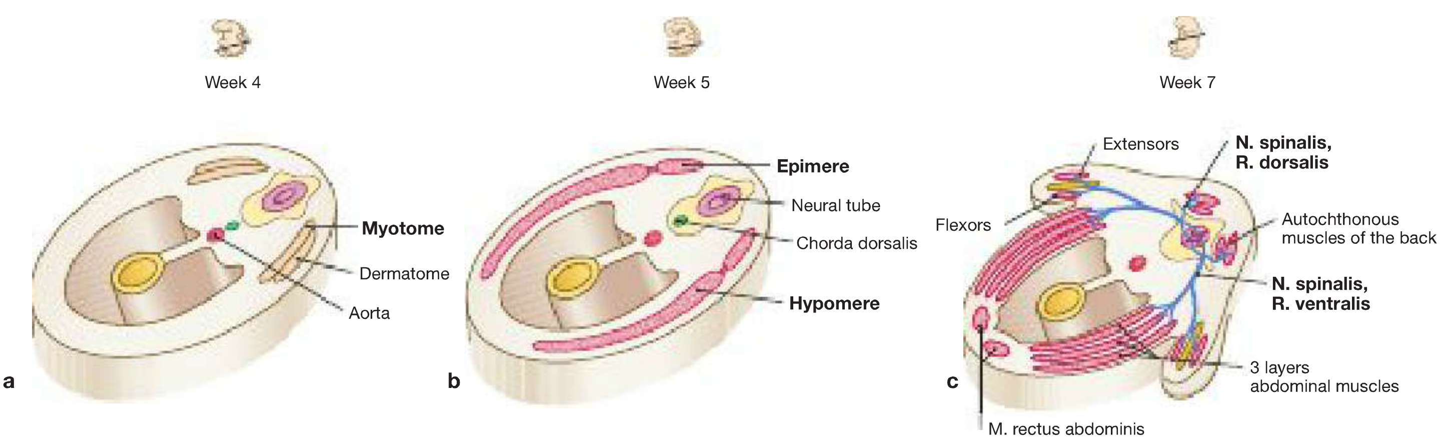


Fig. 2.8a to c Development of the trunk walls: formation of epimere and hypomere from the myotomes. [E838]
The striated muscles of the trunk develop from lateral sections of the somites the dermatomyotomes, which differentiated in the 4th week. In the 5th week a larger ventral group of mesenchymal cells, the **hypomere** (supplying the Mm. scaleni, the prevertebral neck muscles, the infrahyoid muscles, the Mm. intercostales, subcostales, transversus thoracis, the oblique abdominal muscles, the Mm. rectus abdominis, quadratus lumborum, the pelvic floor muscles and the sphincters of the anus and urethra), separates from a smaller dorsal group, the **epimere** (supplying the autochthonous muscles – M. erector spinae). In the 7th week the oblique and straight abdominal muscles differentiate from the hypomere in the area of the abdominal wall; the epimere forms parts of the autochthonous back muscles. The epimere and the hypomere get a separate nerve supply: the Rr. ventrales of the spinal nerves are responsible for the hypomere; the epimere is innervated by the Rr. dorsales of the spinal nerves.

Clinical Remarks

The **absence of individual muscles** does occur, but is often without clinical relevance. In contrast, varying degrees of severity of movement disorders are associated with uni- or bilateral absence of the M. pectoralis or the Mm. trapezius and serratus anterior, respectively. In the case of the very rare **prune-belly syndrome** the abdominal muscles are completely absent. The organs are palpable through the skin. Larger muscle defects can lead to hernias being pushed through the abdominal wall.

Development

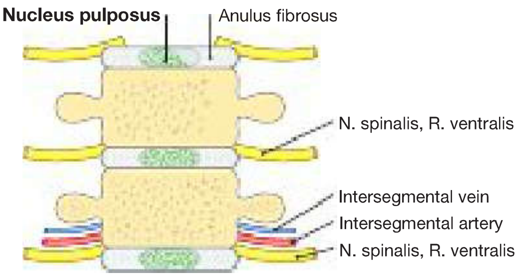


Fig. 2.9 Development of the trunk wall: Nuclei pulposi as remnants of the Chorda dorsalis in the adult vertebral column. [E838]

From the 4th development week cells migrate from the sclerotome and settle around the neural tube. A part of the cells wraps around the Chorda dorsalis and differentiates to vertebral bodies. The Chorda regresses to become the small base of the gelatinous Nucleus pulposus in the centre of the intervertebral discs.

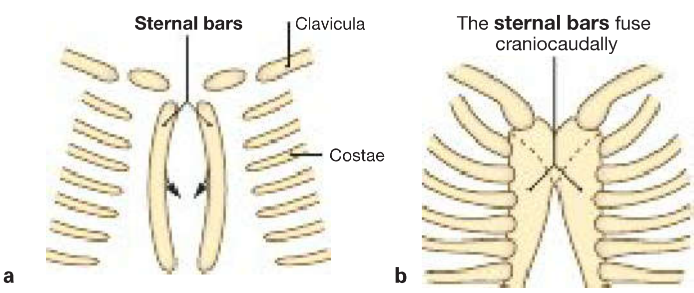


Fig. 2.10a and b Development of the ribs and the sternum. [21] [E347-09]

The sternum develops from two sternal bars which develop at a certain distance from each other as a vertial mesenchymal concentration in the thoracic wall (**a**) and fuse together (**b**). The Proc. xiphoideus only ossifies between the 20th and 25th year of life. The ribs in the thoracic region and the Procc. costales of the neck and lumbar vertebrae are created from sclerotome cells that have migrated ventrolaterally. They connect dorsally with the spine and ventrally in part with the sternum (ribs I–VII; **real ribs, Costae verae**). The VIIIth - Xth ribs fuse ventrally with each other and make indirect contact with the sternum via the cartilaginous costal arch **(false ribs, Costae spuriae).** Ribs XI and XII are exclusively connected with the vertebrae and end as freely floating ribs **(Costae fluctuantes)** in the ventral thoracic wall.

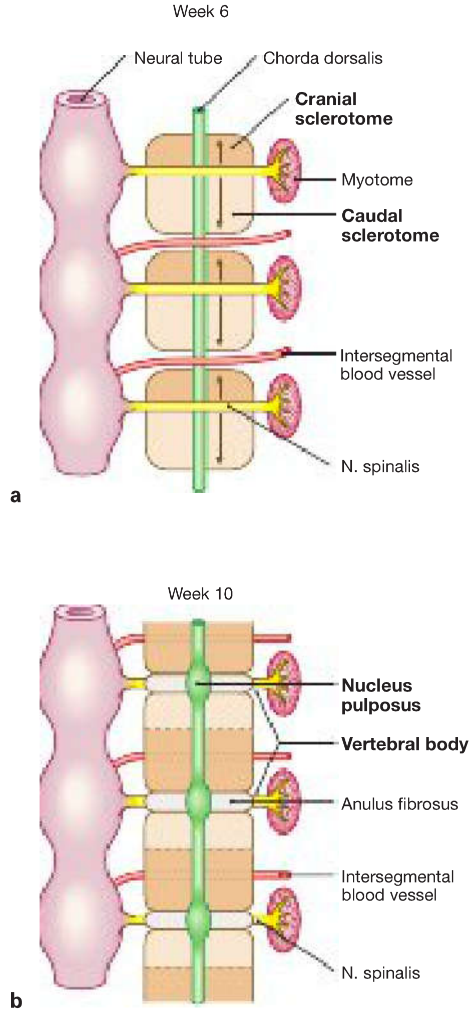


Fig. 2.11a and b Formation of the vertebral body by two adjacent sclerotomes. [E838]

The sclerotomes are divided into a cranial and caudal section. The myotome, which has been assigned to a sclerotome, is always innervated by a spinal nerve. Intersegmental vessels run between the sclerotomes and myotomes (6th week, **a**). Each of the individual vertebrae are created through a fusion of the caudal sclerotome section with a cranial sclerotome section of the adjacent (successive) sclerotomes. The spinal nerve belonging to the myotome is enclosed between the cranial and caudal sclerotome section as part of the fusion and exits from the Foramen intervertebrale. Intervertebral discs develop between the vertebrae system (**b**). Muscles that are created only from parts of a myotome (e.g. M. rotator brevis, → Fig. 2.74) can move two adjacent vertebrae against each other. The functional unit of all structures participating in the respective movement between two adjacent vertebrae is called a motion segment.

Clinical Remarks

A **spina bifida** is a split, dorsal open spine, in which single or multiple vertebral arches have not grown together. If not only the vertebral arches are open but also the neural folds, this is referred to as **rachischisis.** If the spinal cord is also affected, this can be associated with paralysis. If the cleft in the vertebral arches is covered with skin, it is called spina bifida occulta. If only one instead of two cartilage centres emerge in a vertebral body, the result is a **wedge vertebrae** (Hemivertebra). If two vertebrae fuse with each other, because the intervertebral discs have degenerated, the result is a **block vertebrae.**

Merger disorders of the sternum often occur as fissure formation of the Corpus sterni or the Proc. xiphoideus. Clinically these types of columns or holes are usually meaningless.

Accessory ribs are common in the cervical and lumbar region (cervical and lumbar ribs). In the lumbar region, accessory ribs are usually clinically insignificant. However, in the neck region they may lead to a compression of the brachial plexus or the subclavian artery (→ S. 65 and 73).

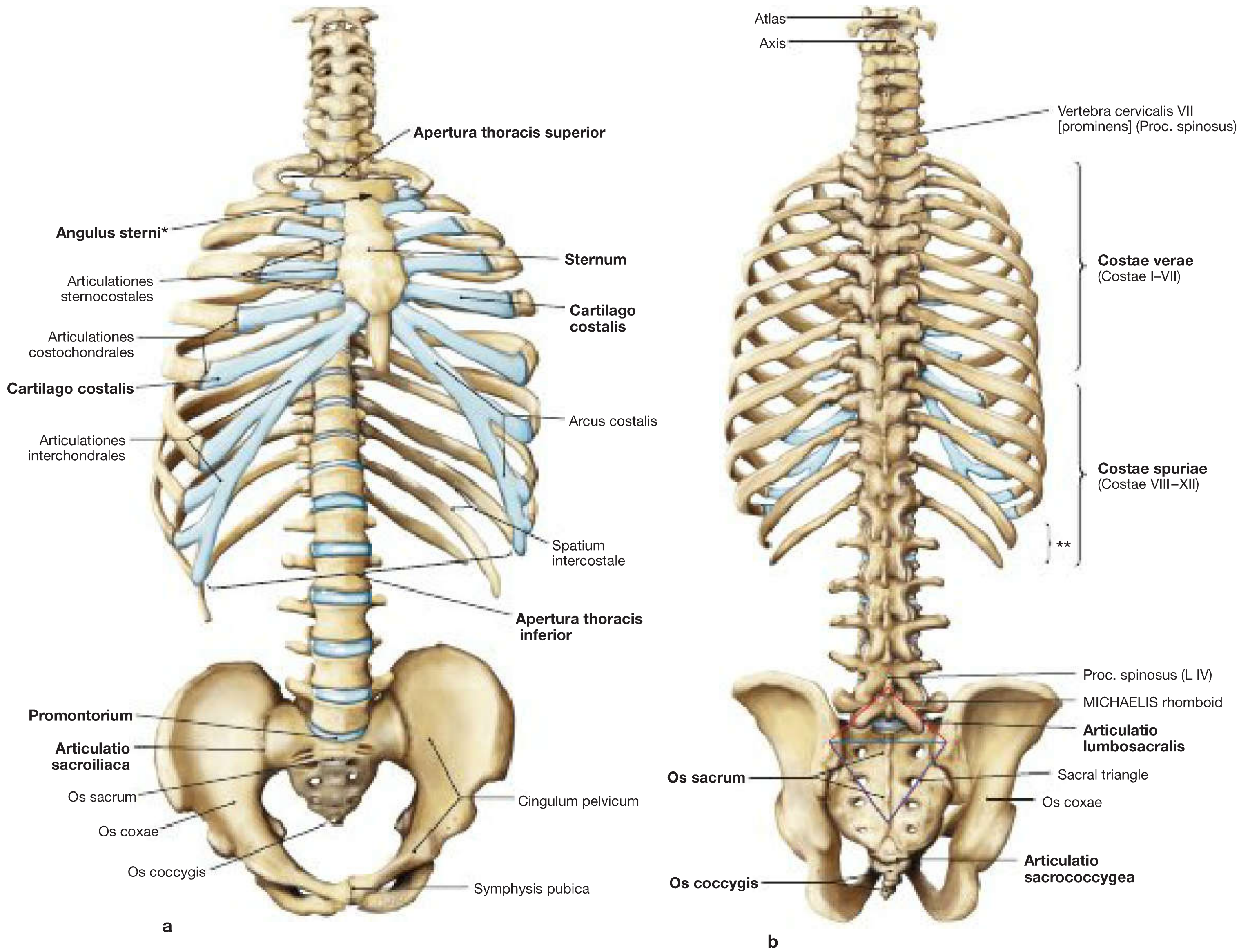


Fig. 2.12a and b Bone and cartilage of the trunk skeleton; ventral view (→ Fig. 2.12a) and dorsal view (→ Fig. 2.12b). [L266]
You can see the chest bones (Ossa thoracis) as well as the bones of the vertebral column (Columna vertebralis) and the pelvic girdle (Cingulum pelvicum).
Although all ribs articulate with the vertebral column, only the first seven ribs are directly connected to the sternum via their rib cartilage (Cartilago costalis). Therefore they are referred to as real ribs **(Costae verae)**. The remaining five rib pairs are considered false ribs **(Costae spuriae)**; ribs XI and XII). Ribs have no contact with the cartilaginous costal arch **(Costae fluctuantes).**

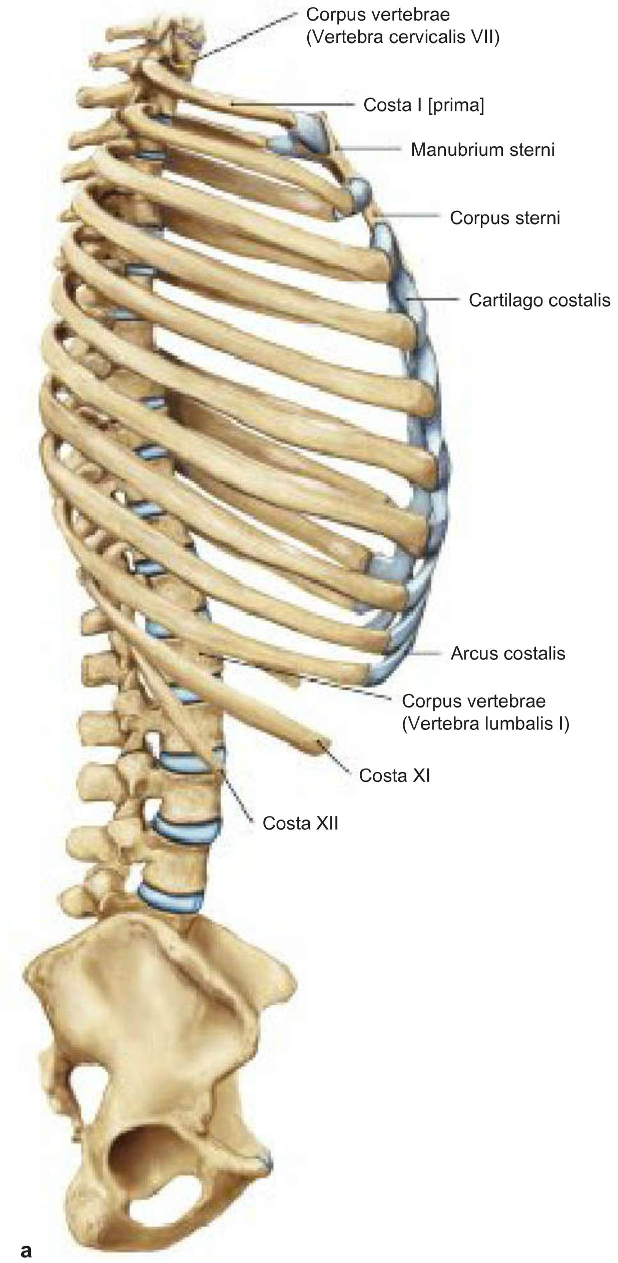
The diamond-shaped connection of the Proc. spinous of the 4th lumbar vertebra with the Spinae iliacae posteriores superiores and the start of the Crena ani on the back of the female is **called MICHAELIS rhomboid** (lumbar rhombus, venus diamond). In the case of the male the sacral triangle (connection between Spinae iliacae posteriores superiores and the start of the Crena ani) is visible.

* clinical term: Angulus LUDOVICI
** Costae fluctuantes (Costae XI–XII)

– Clinical Remarks

In the clinical examination the well palpable **Angulus sterni** (Angulus LUDOVICI) is an important landmark for orientation on the thorax. It is located at the level of the IInd rib. The shape of the sacral triangle (male) or the so-called MICHAELIS rhomboid (lumbar rhombus) in women provides information on the form of the pelvis. In the case of deformed pelvises, forexample due to rickets (vitamin D deficiency), the transverse axis is extended; in the case of scoliosis it becomes asymmetric.
The **Proc. spinous process of the 4th lumbar vertebra** lies at the same level as the iliac crest. It serves as a reference point for the lumbar puncture, as well as for the intrathecal or epidural (peridural) anaesthesia.

Skeleton of the Trunk



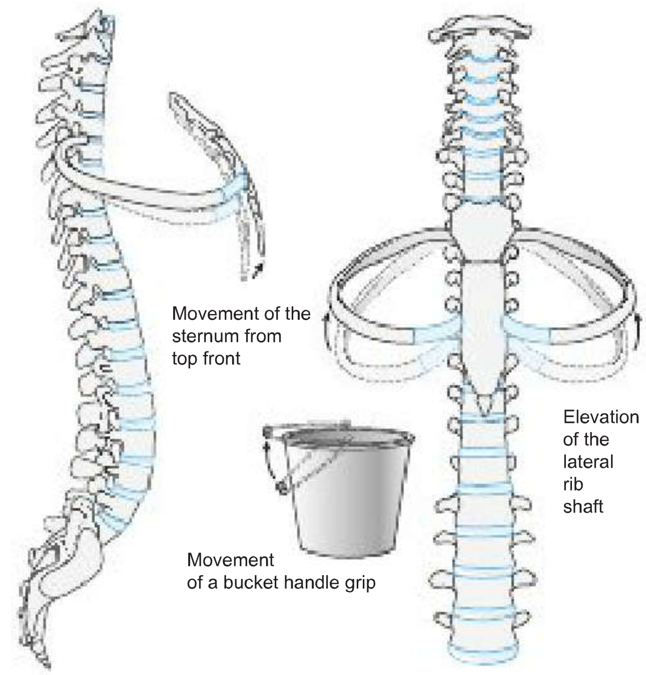


Fig. 2.13a and b Bone and cartilage of the skeleton of the trunk (a); lateral view right; movements of the thoracic wall (b). (a [L266]; b [L126])
The view is of the thorax (Cavea thoracis) with the twelve ribs on the right side. The XIth rib with its Corpus costae still extends far ventrally and is situated in a continued line with the costal arch. The XIIth rib is usually significantly shorter. Movements in the sternocostal joints and in the costovertebral joints when breathing in (inspiration) lead to an extension of the rib cage by raising the arch-shaped ribs, as illustrated in the bucket handle grip.

Clinical Remarks

With aging the rib cartilage ossifies, the ribs are lowered and the sternum comes closer to the spine. As a result the entire chest becomes flatter and the lower ribcage opening contracts. Therefore, rib fractures can often occur, e.g. in the course of resuscitation, even if a small amount of pressure is applied to the thorax of persons aged over 50. In contrast, young people's chests (especially in the case of children) can be forcefully compressed without the occurrance of rib fractures.

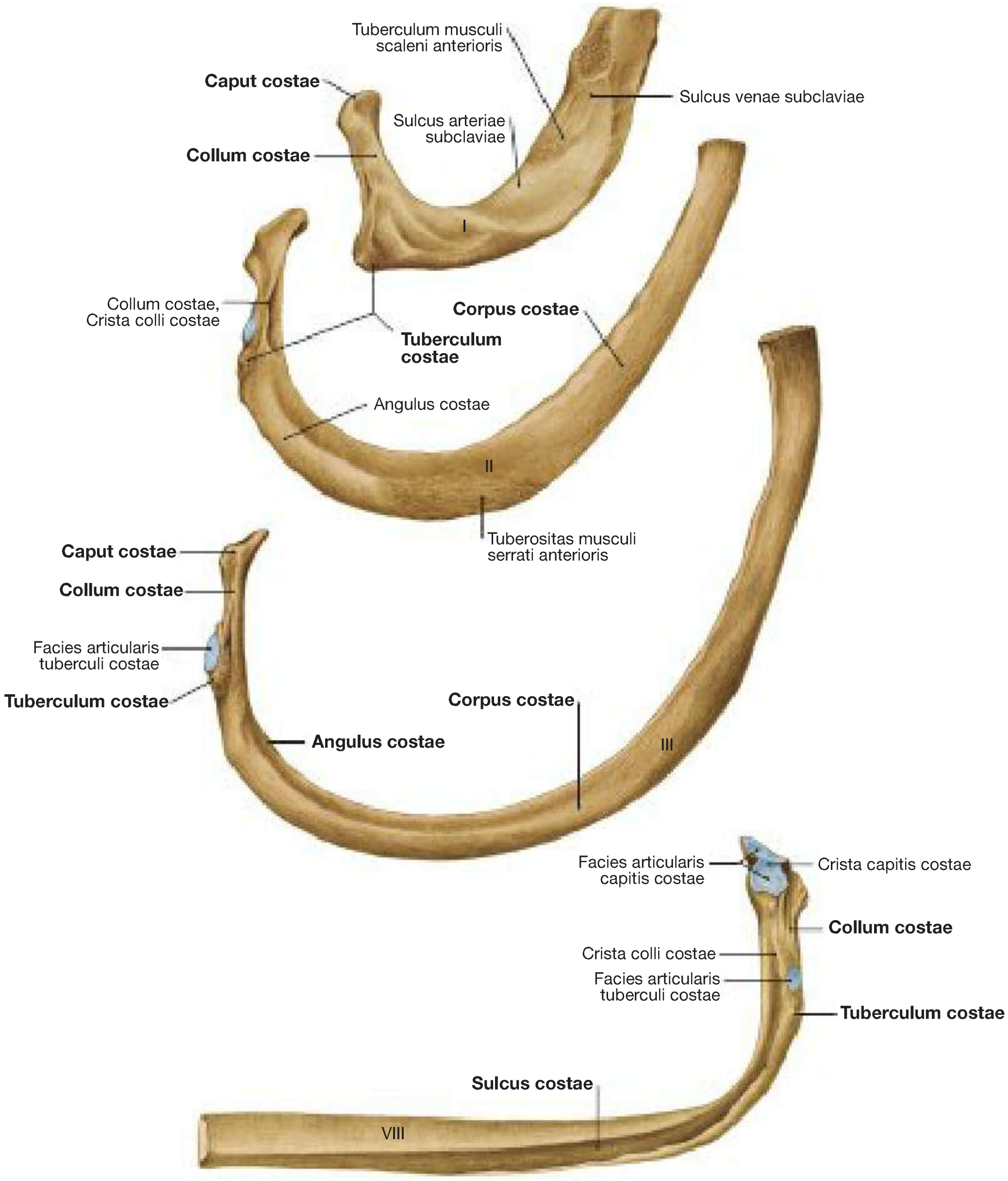


Fig. 2.14 Ribs, Costae; ribs I to III: view from cranial; rib VIII: caudal view.

The **ribs III to X** are typically shaped. The rib head (Caput costae) is wedge-shaped and bears two joint facets (Facies articulares capitis costae). The Tuberculum costae presents a joint surface (Facies articularis tuberculi costae). V., A. and N. intercostalis are deposited on the Sulcus costae. An invagination at the ventral end of the body of the rib (Corpus costae) facilitates contact with the rib cartilage.

Ribs I, II, XI, and XII deviate from the typical rib structure. Rib I is stumpy, broad and has the strongest curve; its head has only one joint facet. The IInd rib only has an implied Sulcus costae and a Tuberositas musculi serrati anterioris for the origin of the M. serratus anterior. The heads of the XIth and XIIth ribs have only one articular surface. They do not have contact with the costal arch and they have pointed ventral ends. They also have no Tuberculum costae.

– Clinical Remarks

Rib anomalies are common:

- A **cervical rib** can be found in approximately 1% of the population. As a result, the rib system on the 7th cervical vertebrae is enlarged. Apart from isolated enlargements of the Proc. transversus, uni or bilaterally, additional ribs which can be connected to the sternum may occur. The pressure of a cervical rib on the lower roots of the Plexus brachialis can cause sensory loss and motor deficits in the N. ulnaris.
- In the case of **two-headed ribs** two ribs are partially fused.
- A **bifid rib** is a variant, in which the rib forks in the front part into two ends.
- Extensions of the intercostal arteries which run in the Sulcus costae in the case of aortic isthmus stenosis cause pressure atrophy on the bone. This is referred to as **rib erosion**.

Ribs

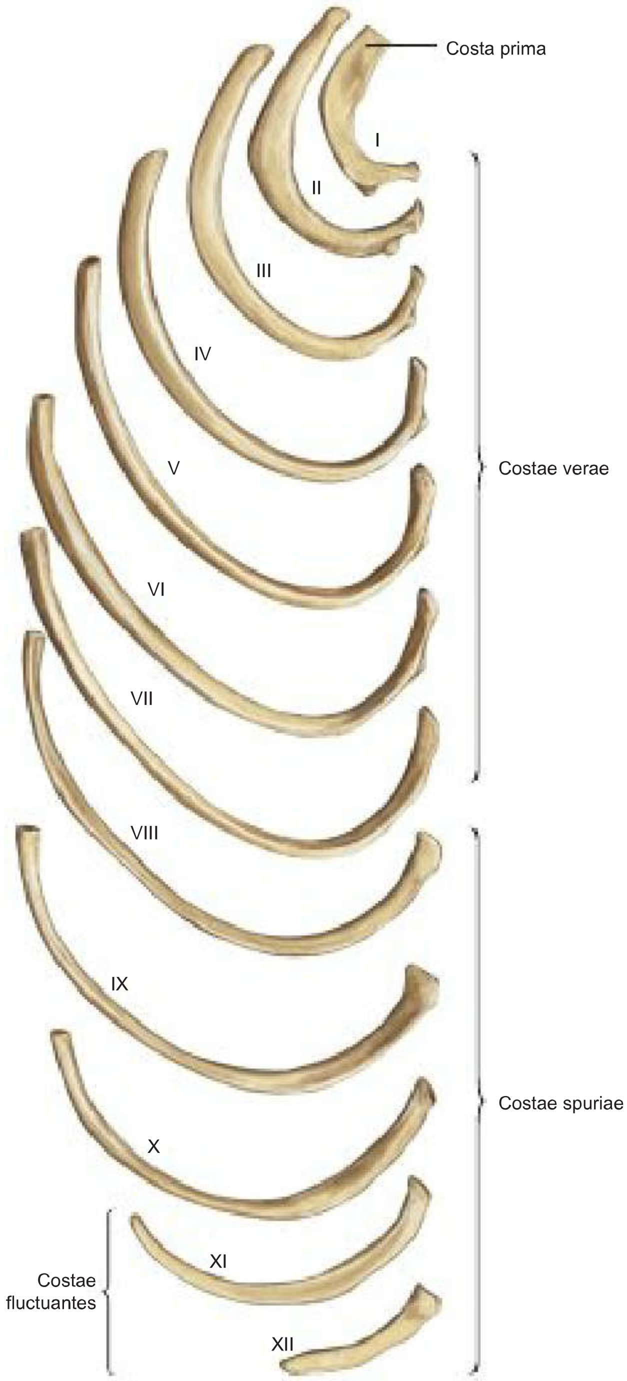


Fig. 2.15 Ribs, Costae; bony part of the ribs I–XII on the left side; superior view.

Usually, there are twelve rib pairs. Depending on whether the ribs (via rib cartilage) make contact with the sternum or (cartilaginous) costal arch or remain without contact to the sternum or costal arch, a distinction is made between **true ribs** (Costae verae, Ribs I-VII, which are connected directly and flexibly to the sternum), **false ribs** (Costae spuriae, Ribs VIII–XII, which are not directly connected to the sternum) and **free ribs** (Costae fluctuantes, Ribs XI, XII, which end freely between the thoraric wall muscles).

Clinical Remarks

Lumbar ribs are a common rib abnormality, affecting approximately 7–8% of the population. This involves additional ribs, which end freely between the thoracic wall muscles, as do the rib pairs XI and XII, but, in contrast to ribs XI and XII they do not come from the thoracic spine, but begin on the 1st or 2nd lumbar vertebrae. They can occur in close topographical proximity to the kidney and cause pain in this area.

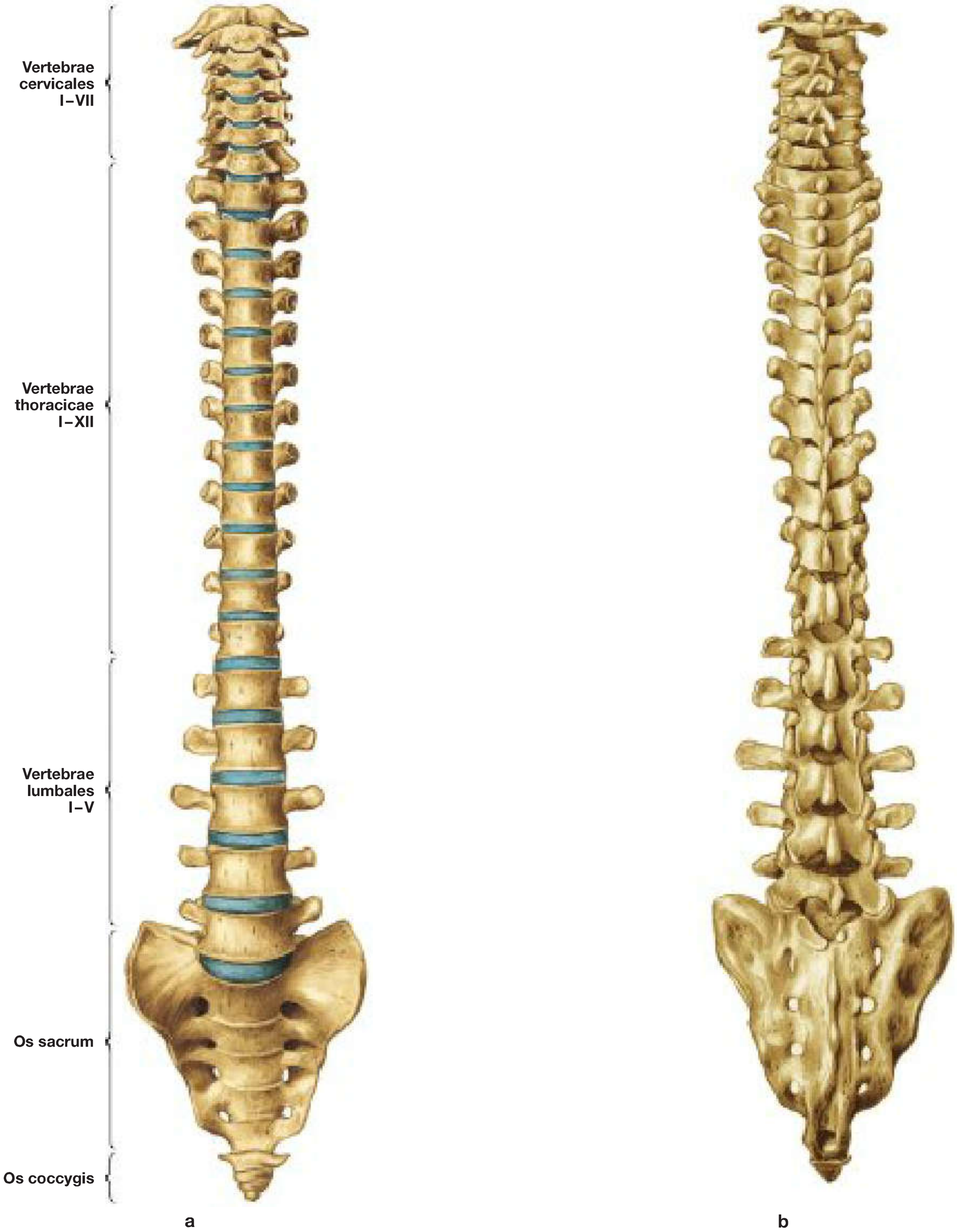


Fig. 2.16a and b Spine, Columna vertebralis; ventral (→ Fig. 2.16a) and dorsal view (→ Fig. 2.16b).
The spine is two-fifths of the size of a human. A quarter of this can be attributed to the intervertebral discs. The vertebral column consists of 24 presacral vertebrae (seven cervical vertebrae, twelve thoracic vertebrae, five lumbar vertebrae) as well as two synostotic sections, the sacrum (Os sacrum) and the coccyx (Os coccygis). The thoracic vertebrae are in contact with the twelve rib pairs; the sacrum articulates with the Ossa coxae. Within the spine, the stress in a standing position increases from cranial to caudal.

– Clinical Remarks

If the 5th lumbar vertebra merges with the Os sacrum (only 23 presacral vertebrae), this is referred to as **sacralisation.** If the top vertebra of the Os sacrum remains separated from the remainder of the sacrum and does not fuse with them (25 presacral vertebrae), the condition is called **lumbalisation.** In this case, an X-ray will show six lumbar vertebrae and four sacral vertebrae. If the Os sacrum exhibits five vertebrae, there is an additional sacralisation of the 1st Coccyx vortex. If the 1st cervical vertebra (Atlas) merges with the skull, it is referred to as **assimilation of the atlas.**

Spine

Fig. 2.17 Spine, Columna vertebralis; view from the left side.
In the sagittal plane, the spine shows characteristic curves:

- Cervical curve (bent forward convex)
- Thoracic kyphosis (bent backward convex)
- Lumbar curve (bent forward convex)
- Sacral kyphosis (bent backward convex)

Lordosis is the medical term for a ventrally-facing convex curvature of the spine, kyphosis for dorsally-facing.

In the first few months after birth, all sections of the vertebral column show a dorsal convex bend. The cervical curve forms when sitting, the lumbar curve when running.
The curves only form when the pelvis is tilted forward in relation to the biped walk in the 1st – 2nd years of life. Before this time the entire vertebral column is bent in all sections to the rear convex.

Clinical Remarks

Excessive curvature of the spine in the frontal plane **(scoliosis)** is always pathologic. This is a growth deformity of the spine with fixed lateral curvature, torsion of the spine and rotation of the axian organ, which cannot be straightened physiologically any more by using muscles. Scoliosis is one of the longest-known orthopaedic conditions. Despite intensive scientific and clinical efforts there are still many issues today that affect scoliosis and have not been satisfactorily resolved. However, almost everyone has minimal scoliosis as most people do not have legs that are the same length.

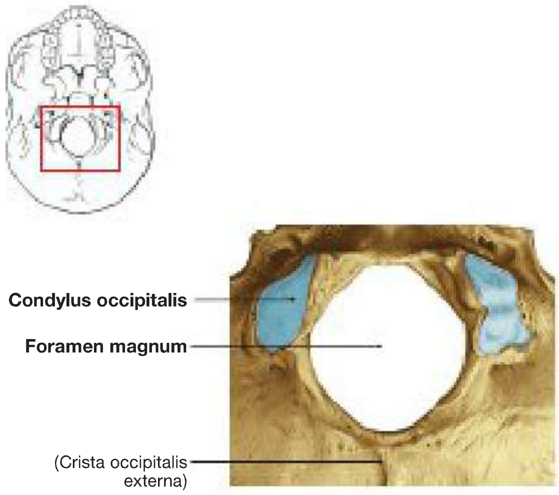


Fig. 2.18 Occipital bone, Os occipitale, section with the main hole and the joint bodies for the upper header joint; caudal view.
The condyles of the skull are located at the front lateral to the foramen magnum.

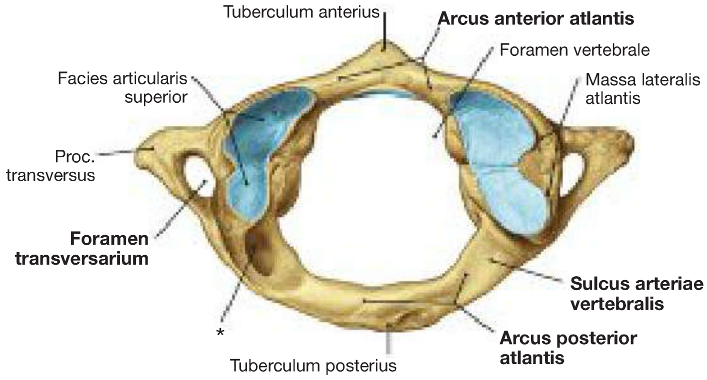


Fig. 2.19 1st Cervical vertebrae, atlas; cranial view.
The atlas has no vertebral body. During development, the latter fuses with the axis to form the dens. The front atlas arch (Arcus anterior atlantis) is located in front of the dens and articulates with it. The rear atlas form (Arcus posterior atlantis) does not have a Proc. spinosus. Instead it has a Tuberculum posterius. The upper articular surfaces of the atlas are often divided. Compared to other vertebrae, the atlas has a slightly longer transverse process.

* variant: Canalis arteriae vertebralis

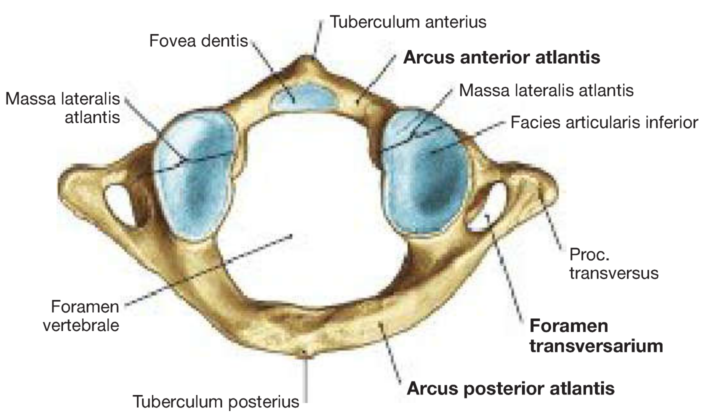


Fig. 2.20 1st Cervical vertebrae, atlas; caudal view.
The Fovea dentis for articulation with the dens axis is located on the inside of the Arcus anterior atlantis. The Facies articulares inferiores are shallow, concave and curved at an angle of approximately 30° to the transversal level. The Foramen transversarium, characteristic for the cervical vertebrae, serves the passage of the A. vertebralis.

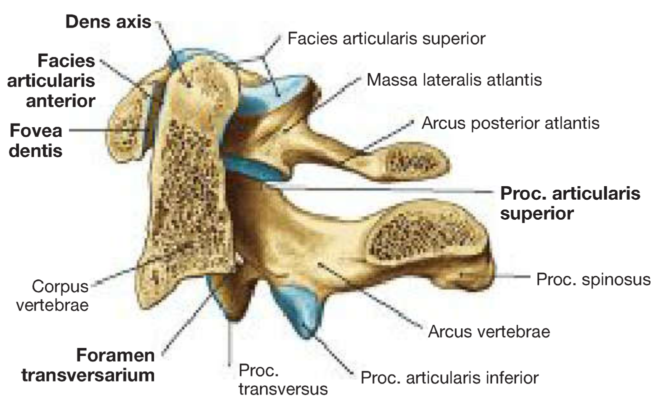


Fig. 2.21 1st and 2nd Cervical vertebrae, atlas and axis; median section; view from the left side.
The median section reveals the vertebral canal. The atlas and axis articulate with the Fovea dentis and the Facies articularis anterior in the Articulatio atlantoaxialis mediana. The Arcus posterior atlantis is significantly smaller in relation to the Arcus vertebrae of the axis.

Clinical Remarks

Degenerative changes of the cervical vertebrae becomes more frequent with age. They also manifest themselves as **osteochondrosis intervertebralis** with dorsal spondylophytes, which can lead to narrowing of the vertebral canal resulting in compression of the spinal cord. **Arthrosis** in the vertebral joints and the uncovertebral gaps (→ Fig. 2.24) with formation of osteophytes results in narrowing of the Foramen intervertebrale and/or the Foramen transversarium, with symptoms resembling spinal nerve compression as well as pressure on the A. vertebralis and the sympathetic nerve plexus.

Isolated fractures of the atlas arch are particularly common following car accidents, but have decreased in the past few years due to improved safety measures in vehicles (airbags). Fractures must be distinguished from atlas variants. In contrast to variations such as the occurrence of a Canalis arteriae vertebralis or abnormalities like the **assimilation of the atlas** (fusion with the internal surface of the cranial base), **cleft formations in the region of the vertebral arches** are common (→ page 73).

Cervical Vertebrae

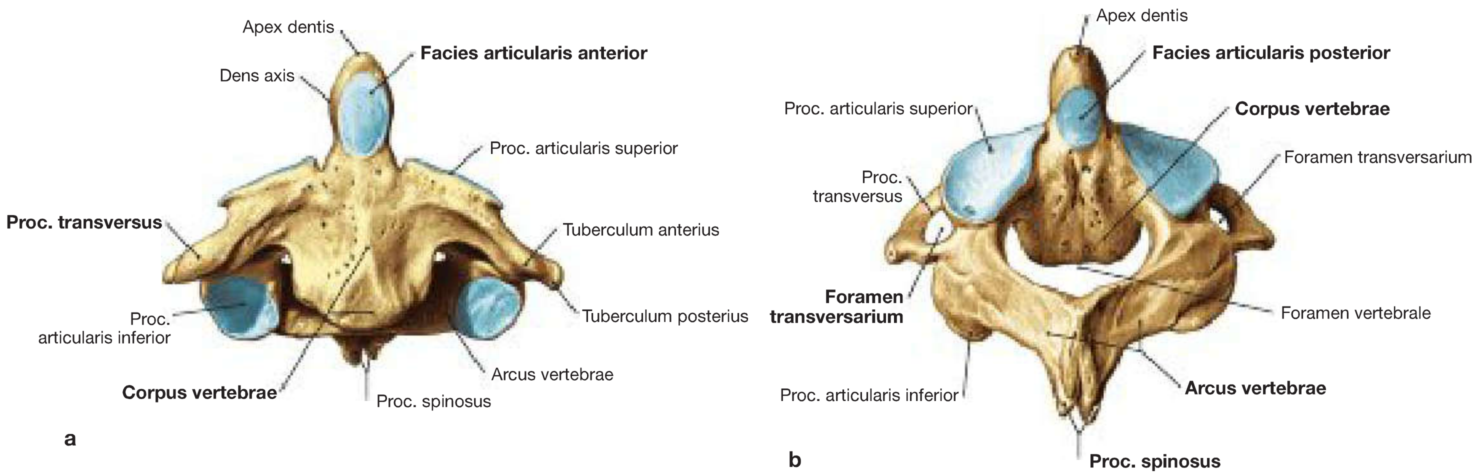


Fig. 2.22a and b 2nd Cervical vertebrae, axis; ventral view (→ Fig. 2.22a) and dorsal cranial (→ Fig. 2.22b).

A distinct feature that sets the axis apart from the other cervical vertebrae is the dens. On the front and on the back of the dens there is one joint surface (Facies articulares anterior and posterior) respectively. The joint surfaces of the Procc. articulares superiores drop off to the side and those of the Procc. articulares inferiores incline to the frontal plane. From the 3rd cervical vertebrae the joint surfaces of the Procc. articulares superiores incline to the frontal plane. The transverse process (Proc. transversus) is only weakly developed and the interspinous process (Proc. spinosus) is often split in two.

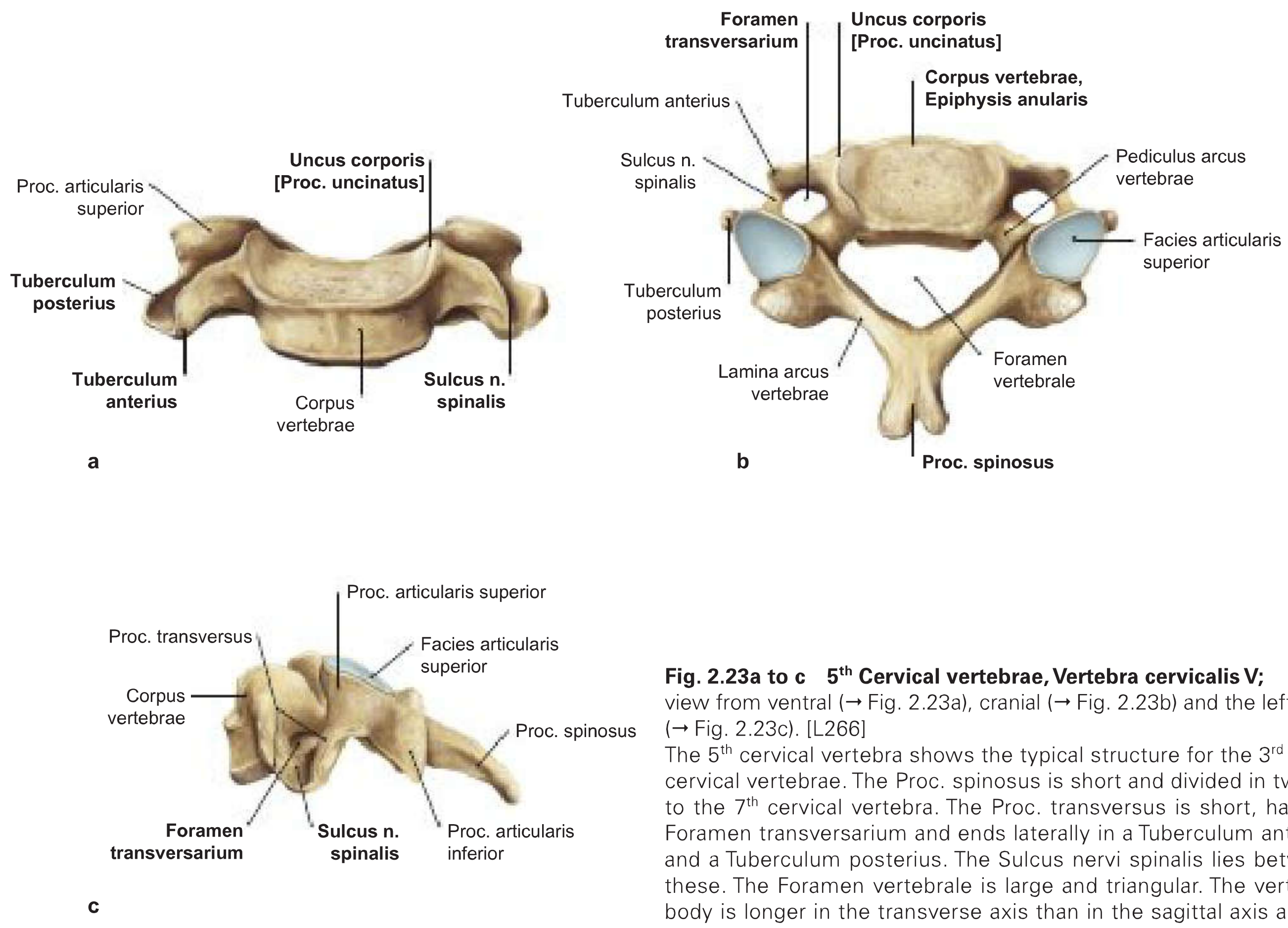


Fig. 2.23a to c 5th Cervical vertebrae, Vertebra cervicalis V; view from ventral (→ Fig. 2.23a), cranial (→ Fig. 2.23b) and the left (→ Fig. 2.23c). [L266]

The 5th cervical vertebra shows the typical structure for the 3rd to 6th cervical vertebrae. The Proc. spinosus is short and divided in two up to the 7th cervical vertebra. The Proc. transversus is short, has the Foramen transversarium and ends laterally in a Tuberculum anterius and a Tuberculum posterius. The Sulcus nervi spinalis lies between these. The Foramen vertebrale is large and triangular. The vertebral body is longer in the transverse axis than in the sagittal axis and as wide at the front as at the back.

Clinical Remarks

The **dens fracture** or the fracture of the vertebral body (the so-called Hangman's fracture) presents the risk of cervical cord compression and is mostly as a result of motor vehicle accidents. A dens fracture can also affect small children and is difficult to diagnose.

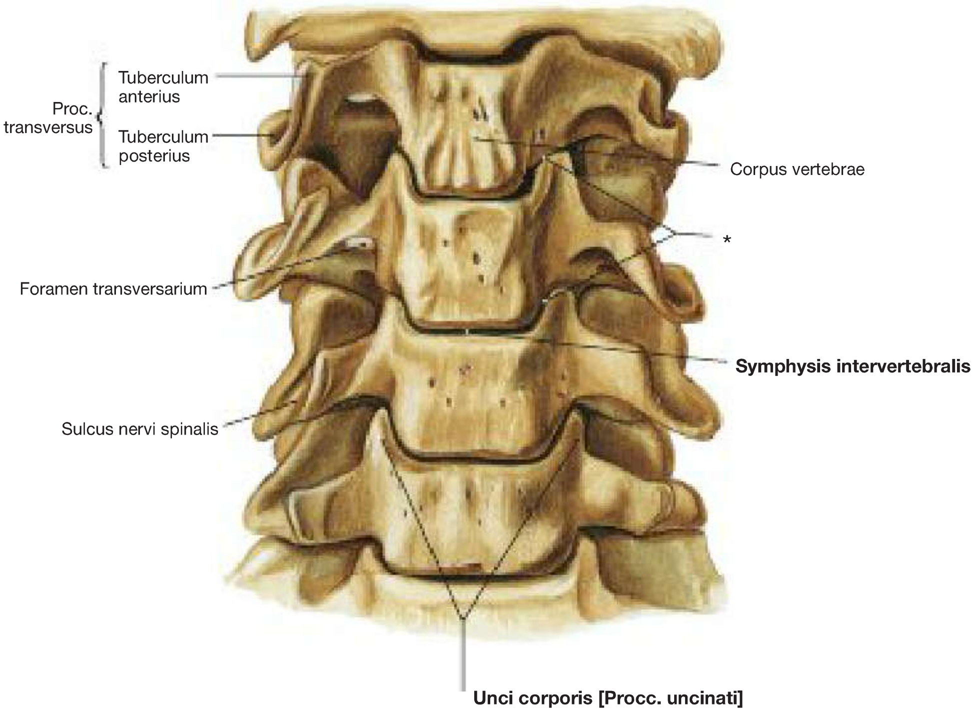


Fig. 2.24 2nd to 7th Cervical vertebrae, Vertebrae cervicales II–VII; ventral view.

The 3rd to 6th cervical vertebrae have a typical set-up, whereas the 1st, 2nd and 7th cervical vertebra deviate from this structure. On each side of their superior surface there is a raised lateral margin (Unci corporis). The Unci corporis, also referred to as Procc. uncinati, articulate together with the lateral and caudal parts of the Corpus vertebrae of the overlying vertebra in the Articulatio (Hemiarthrosis) uncovertebralis.

* so-called uncovertebral gaps

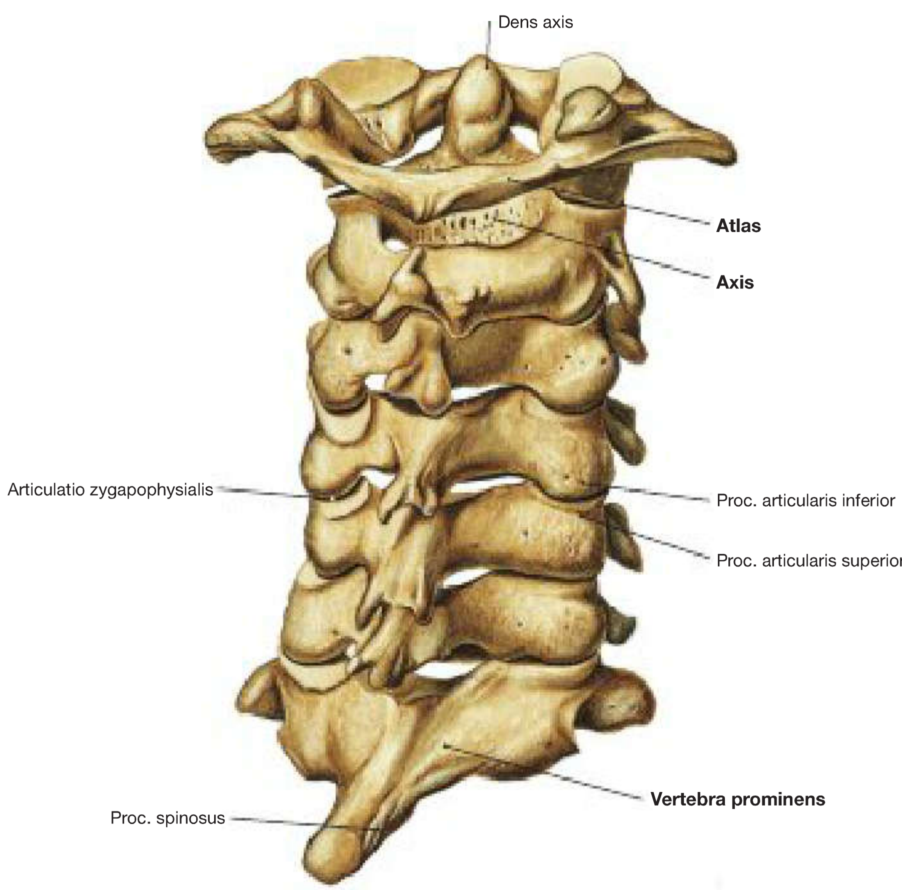
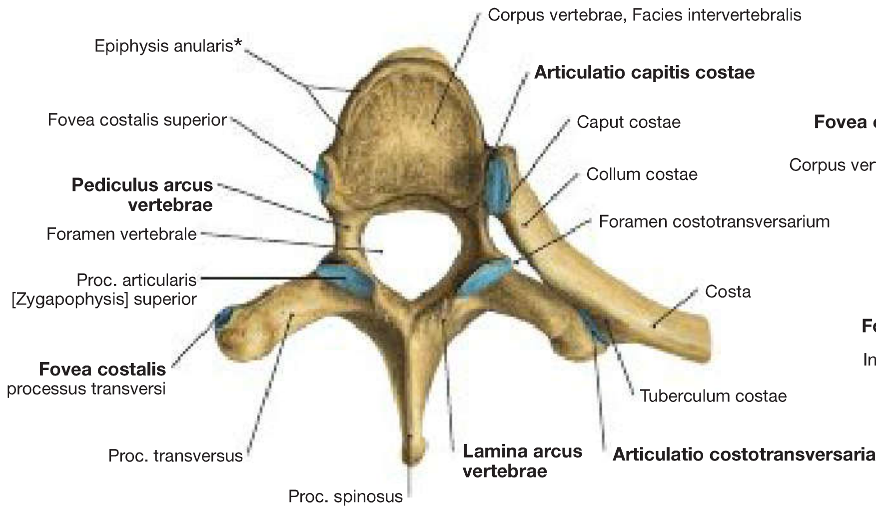


Fig. 2.25 1st to 7th Cervical vertebrae, Vertebrae cervicales I–VII; dorsal lateral view.

The long and non-divided spinosus process of the 7th cervical vertebra (which is also referred to as **Vertebra prominens**) can be easily felt at the back of the neck. However, it can be confused with the even more protruding spinous process of the 1st thoracic vertebra. The joint surface (Facies articularis superior or inferior) of a vertebral articular process (Proc. articularis superior or inferior) articulates with the respective partner in the Articulatio zygapophysialis.

Thoracic Vertebrae



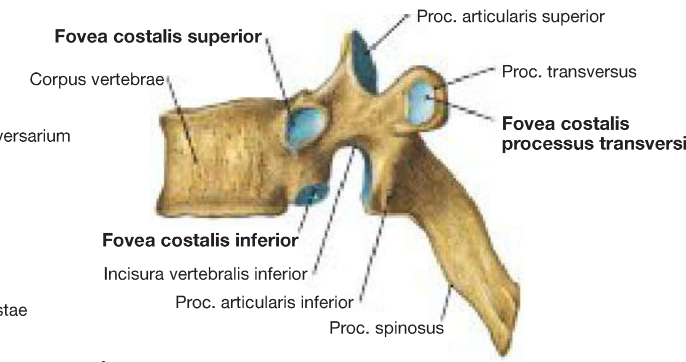
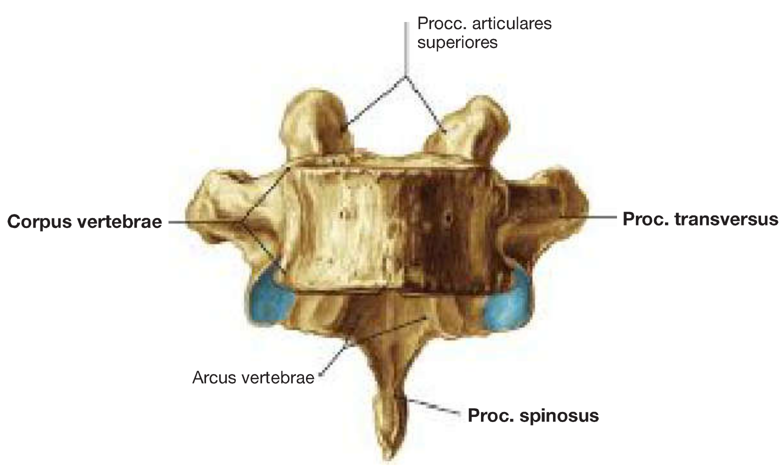


Fig. 2.26 Vertebrae: structural features using the example of a 5th thoracic vertebra; cranial view.
The vertebral arch (Arcus vertebrae) is divided into the Pediculus arcus vertebrae and into the Lamina arcus vertebrae. Procc. transversi originates laterally and Proc. spinosus dorsally from the arch. Joint surfaces (Procc. articulares) are located cranially and caudally for the vertebral joints (zygapophyseal joints). Laterally, the spine has a cranial and caudal joint surface for each of the rib heads (Foveae costales superior and inferior). At the Proc. transversus the Fovea costalis articulates into the Articulatio costotransversaria with the joint surface of the Tuberculum costae of the corresponding rib.

* also: annular rim

Fig. 2.27 6th Thoracic vertebrae, Vertebra thoracica VI; view from the left side.
The joint surfaces of the costal heads (Foveae costales superior and inferior) can be seen here, as well as the articular processes of the zygapophyseal joints (Procc. articulares superior and inferior) positioned almost in the frontal plane, the joint surfaces (Foveae costales) for the articulation with the Tuberculum costae of the ribs, the Incisura vertebralis inferior and the sharply sloping Proc. spinosus.



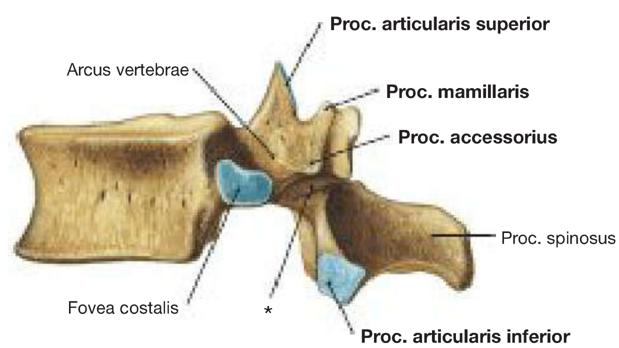


Fig. 2.28 10th Thoracic vertebrae, Vertebra thoracica X; ventral view on the vertebral body with cover and floor plate.
The joint surfaces of the Procc. articulares protrude over the vertebral body cranially and caudally.

Fig. 2.29 12th Thoracic vertebrae, Vertebra thoracica XII; view from the left side.
The 12th thoracic vertebrae has only one Fovea costalis on each side and already displays characteristics of the lumbar spine: the inferior joint processes point laterally. Also seen are Procc. mamillares and accessorii.

* region of the vertebral arch between the superior and inferior joint processes (so-called isthmus = interarticular portion)

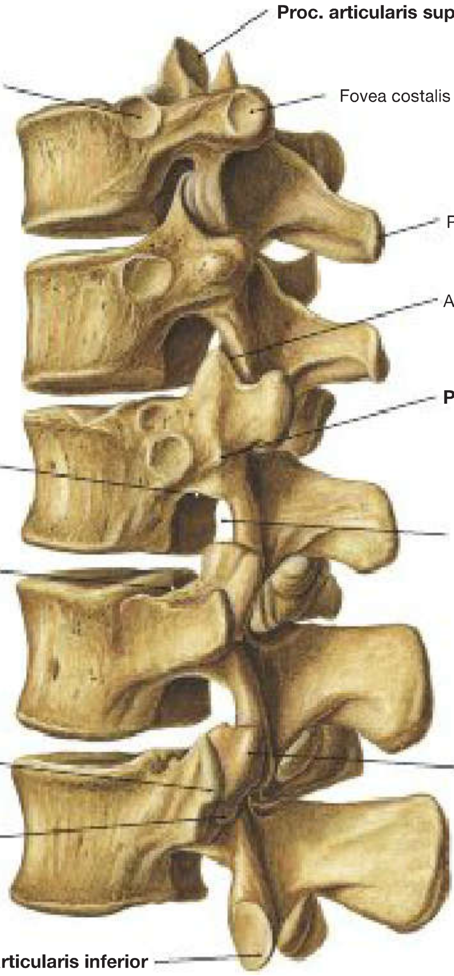


Fig. 2.30 10th–12th Thoracic vertebrae, Vertebrae thoracicae X–XII, and 1st to 2nd lumbar vertebra, Vertebrae lumbales I–II; dorsal view from the left side.
Due to the higher pressure, the bodies of the lumbar vertebrae are much more powerful than the remaining vertebrae. The Procc. spinosi are short and plump and aligned almost horizontally. The Procc. costales (originating from the rib system and fused with the vertebrae), the variable large Procc. accessorii, the Procc. articulares superiores (which support the upper joint surfaces, Facies articulares) and the Procc. mamillares (rest of the transverse process) as well as the Procc. articulares inferiores with the lower joint surfaces (Facies articulares) originate from the vertebral arches of the lumbar spine.

– Clinical Remarks

- Posterolateral disc problems or osteophytes of arthrotic modified vertebrae joints can lead to the **narrowing of the Foramen intervertebrale** and to compression of the spinal nerve roots with deficits.
- **Lumbar ribs** can cause kidney pain due to their close topographic link.
- **Lateral vertebral arch columns** can lead to the separation of the Procc. articulares inferiores from the rear part of the Arcus and of the Proc. spinosus from the rest of the vertebral section (so-called **spondylolysis**).
- The bony separation of the isthmus (→ Fig. 2.29) can primarily cause genuine slipping of the vertebrae **(spondylolisthesis)**.

Lumbar Vertebra

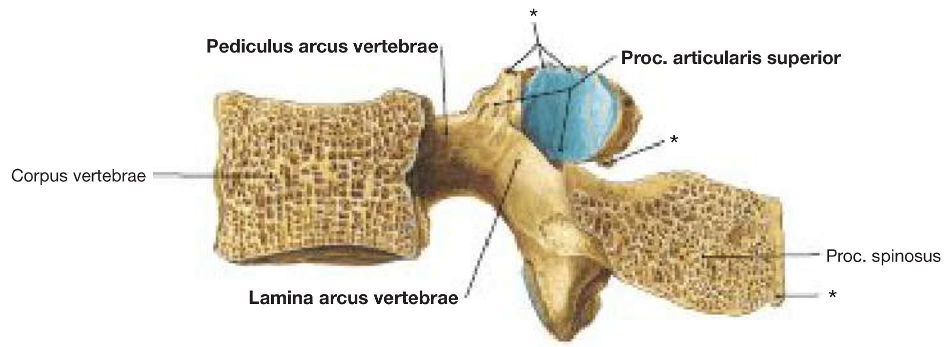
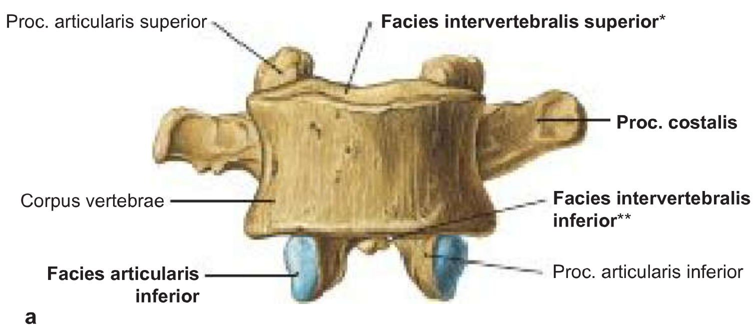
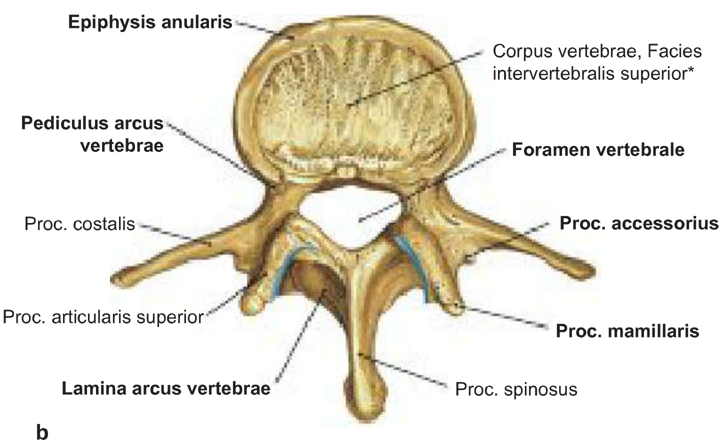


Fig. 2.31 3rd Lumbar vertebra, Vertebra lumbalis III, of an older person; median section; view from the left side.
The joint surfaces of the Procc. articulares superiores are facing each other (that is the reason they are not clearly visible from the side) and work with the inferior joint processes of the adjacent higher vertebra.

* ossification of ligament origins





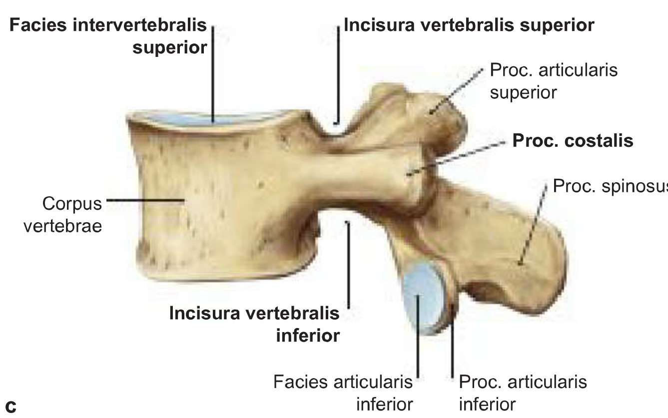
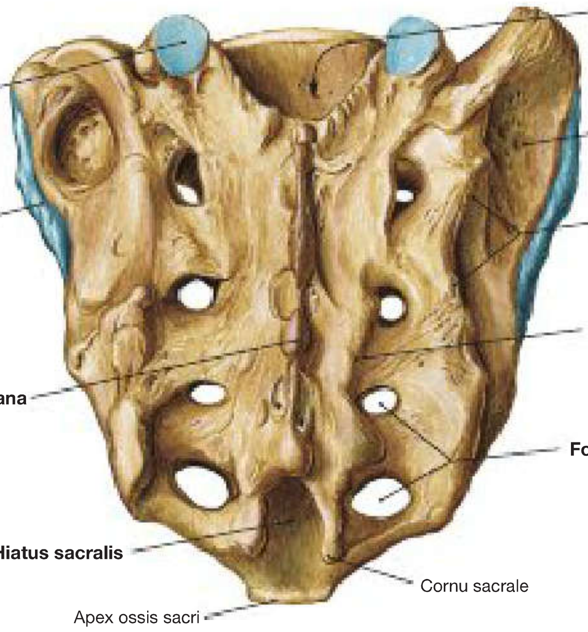


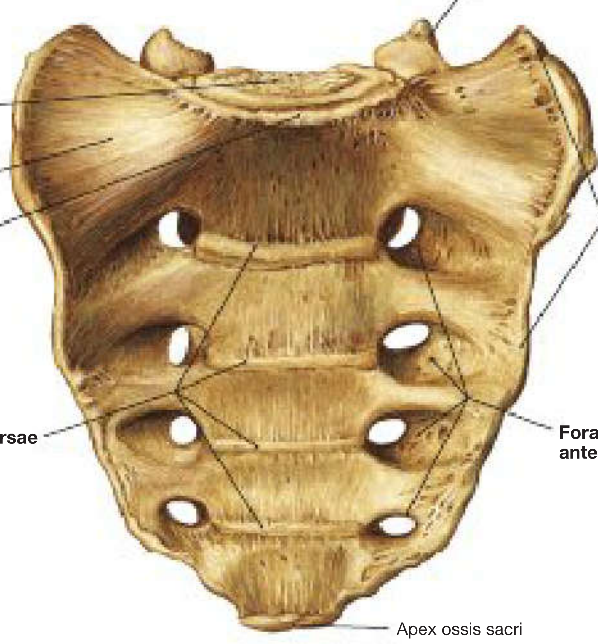
Fig. 2.32a to c 4th Lumbar vertebra, Vertebra lumbalis IV; view from ventral (→ Fig. 2.32a), cranial (→ Fig. 2.32b) and the left (→ Fig. 2.32c). [C L266]
The Pediculus arcus vertebrae is extremely powerful in relation to the size of a lumbar vertebra. On the side of the arch, you can see the different processes (Procc. costales, accessorii, mamillares and articulares superiores and inferiores), behind the strong Proc. spinosus.

In the ventral view the lumbar vertebra has a powerful body (Corpus vertebrae) with a distinct deck and base plate (Facies intervertebrales superior and inferior). The joint surfaces of the zygapophyseal joints protrude over the Corpus cranial and caudal.

* also: deck plate
** also: base plate



a



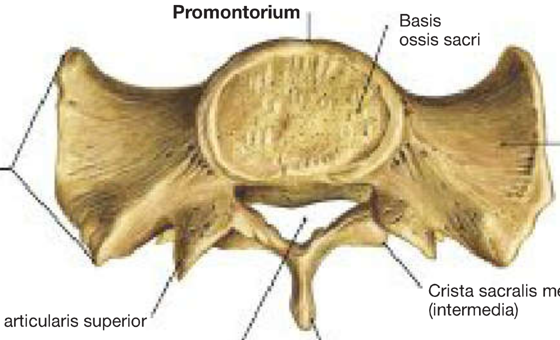
b

Fig. 2.33a to c Sacrum, Os sacrum; dorsal (→ Fig. 2.33a), ventral (→ Fig. 2.33b), and cranial views (→ Fig. 2.33c).

The **Facies dorsalis** has five lengthwise strips that are formed significantly differently by the fusion of the corresponding processes. The fusion of Procc. spinosi corresponds to the **Crista sacralis mediana,** its joint processes to the **Crista sacralis medialis** and its rudimentary lateral processes to the **Crista sacralis lateralis.** The Crista sacralis mediana terminates above the Hiatus sacralis, which represents the caudal opening of the vertebral canal. It is used as a gateway to sacral anaesthesia in children.

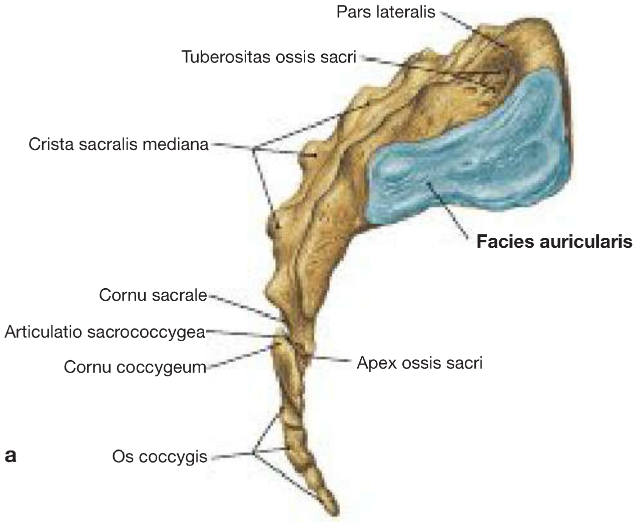
The **Facies pelvina** shows the fused borders of the sacral vertebrae body (Lineae transversae) and the paired Foramina sacralia anteriora, which represents the outlet opening for the ventral spinal nerve branches. The portion of the Os sacrum located laterally from the Foramina sacralia anteriora is referred to as Pars lateralis.

The **Basis ossis sacri**, which is visible from above, is the contact surface for the intervertebral disc with the 5th lumbar vertebra. This spinal disc bulges further into the pelvis and, together with the front edge of the Basis ossis sacri, is referred to as a **promontorium**. The Alae ossis sacri spreads laterally from the base as the cranial part of the Partes laterales. The triangular sacral channel lies behind the base and the Procc. articulares superiores to the side, making contact with the 5th lumbar vertebra.



c

Sacrum and Coccyx



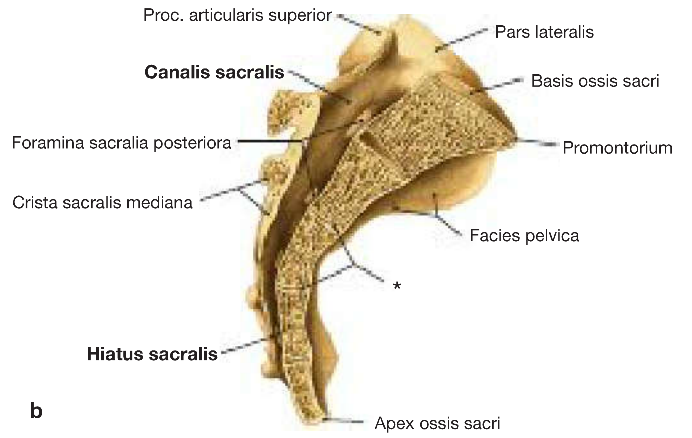
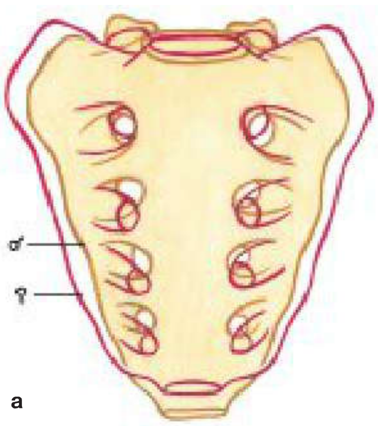


Fig. 2.34a and b Sacrum, Os sacrum; view from the right side (→ Fig. 2.34a) and median section; view from the right side (→ Fig. 2.34b).
The side view shows the Facies auricularis, which is used for the joint connection with the Os coxae (Articulatio sacroiliaca). The Tuberositas ossis sacri is located on the dorsal side, giving attachment to the ligaments.

The median section shows the entrance to the Hiatus sacralis and the transition to the Canalis sacralis.

* Remnants of intervertebral disc tissue can remain in adults. In addition, a partial fusion of the sacral vertebra is common.



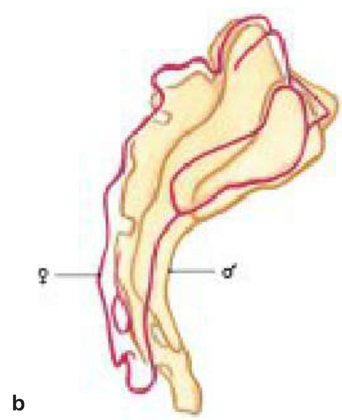
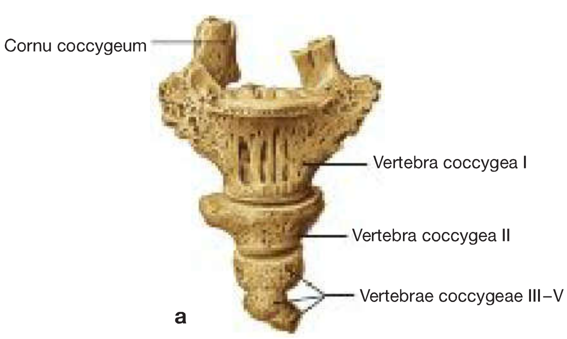


Fig. 2.35a and b Sacrum, Os sacrum; gender differences.
The sacrum of the male is a bit longer than that of the female, but not as wide. The shape of the female sacrum contributes to the wider shape of the female pelvis which is advantageous during birthing.



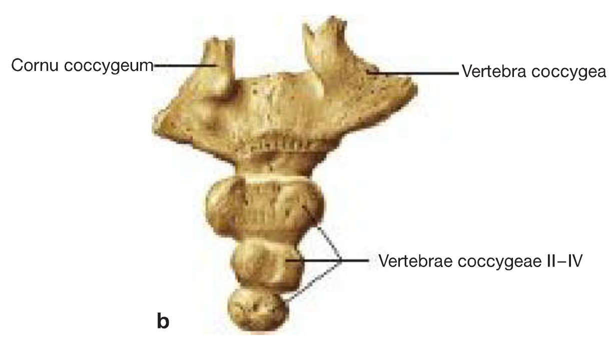


Fig. 2.36a and b Coccyx, Os coccygis; ventral cranial view (→ Fig. 2.36a), and dorsal caudal view (→ Fig. 2.36b).
The coccyx is formed from three to four vertebrae but can also be made up of five rudimentary vertebrae as shown here. The coccyx is connected to the Os sacrum via the coccygeal cornua and the rudimentary vertebral body.

The size of the coccygeal vertebrae decreases from cranial to caudal. Only the 1st coccygeal vertebrae is similar to the structure of a typical vertebra.

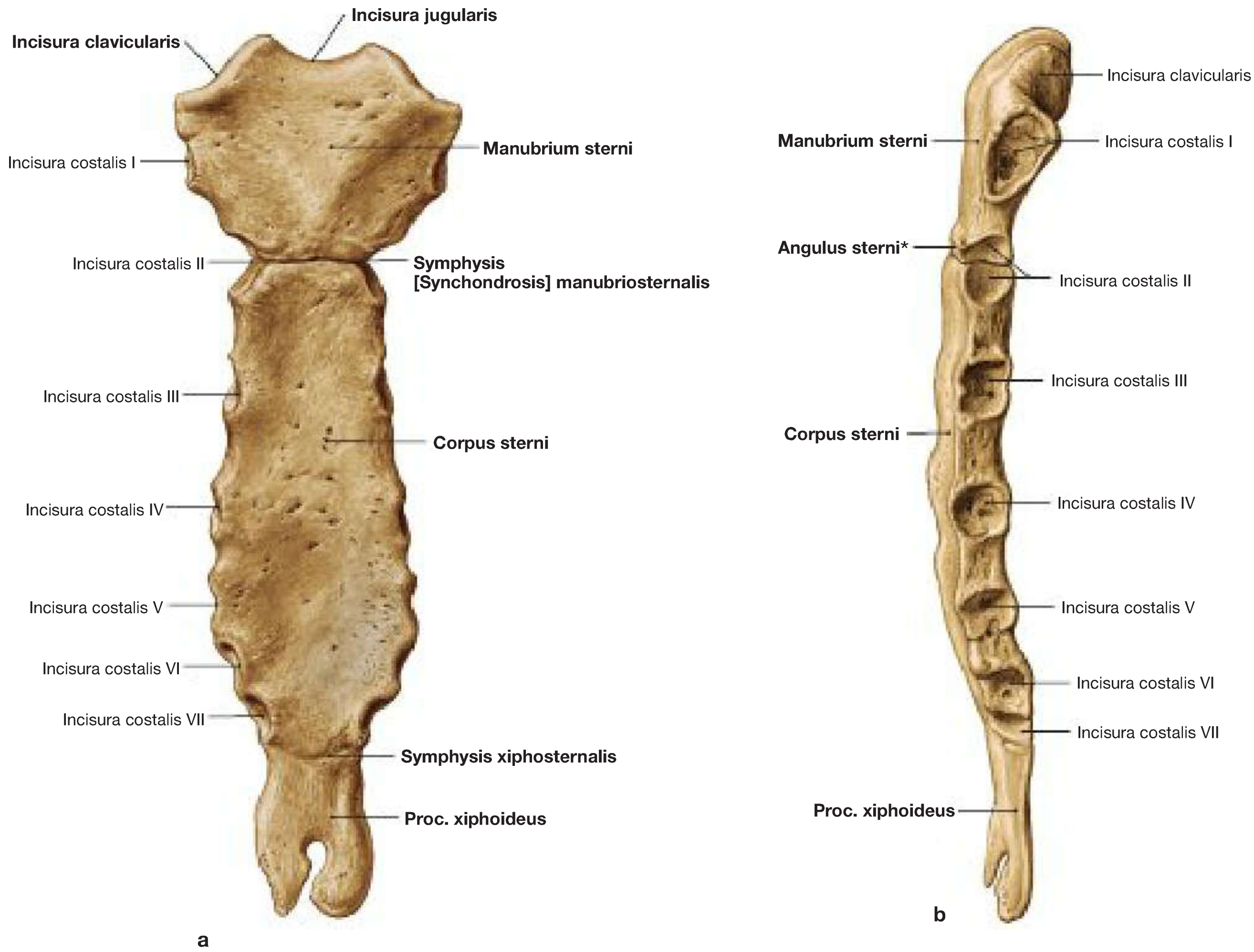


Fig. 2.37a and b Sternum; ventral (→ Fig. 2.37a) and lateral views (→ Fig. 2.37b).
The sternum has a handle (Manubrium), a body (Corpus) and a sword process (Proc. xiphoideus). It forms the Incisura jugularis which is the ventral upper margin of the upper thoracic aperture and articulates with the clavicles through the Incisurae claviculares and with the ribs I to VII via the Incisurae costales. Manubrium and Corpus are linked via the **Symphysis [Synchondrosis] manubriosternalis,** Corpus and Proc. xiphoideus via the **Symphysis xiphosternalis**. The Proc. xiphoideus can be divided.

* LUDOVICI

Clinical Remarks

Bone taps can be conducted on the sternum, pelvic and iliac crest. Rarely conducted today, the **sternal tap** is a diagnostic bone marrow tap to assess bone marrow cells for diseases of the blood. The puncture site is located in the median line in the Corpus sterni between the roots of the IInd and IIIrd rib. It is for example conducted on obese patients, since it is easier to puncture the sternum here than at the more commonly used iliac crest.

Areas that should not be tapped include the area of the rib-sternum connections, as there can be synchondrosis in this region, as well as the lower two thirds of the Corpus sterni, because, due to the paired bone system, there may be a **Fissura sterni congenita** (opening within the sternum) and the tap needle could penetrate into the heart (→ page 62).

Sternum

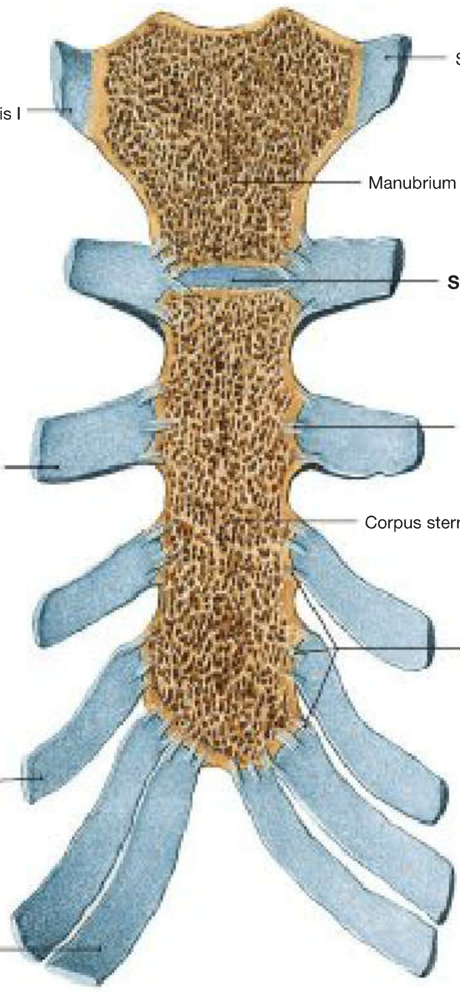


Fig. 2.38 Sternum and attachment of the rib cartilage, Cartilagines costales; flat cut.
Only a part of the costosternal insertions are true joints. Synchondrosis is also a regular occurrance (I^st, VI^th and VII^th rib).

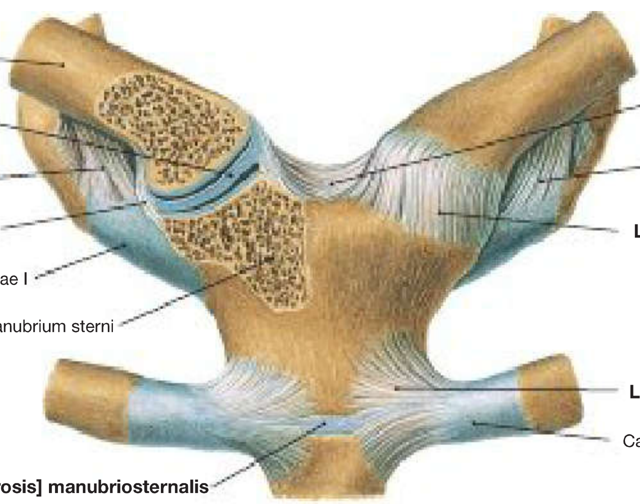
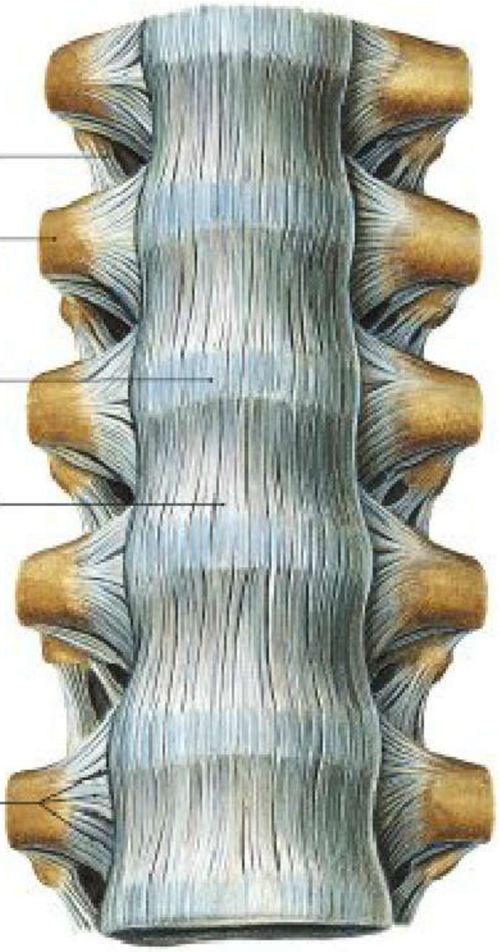


Fig. 2.39 Sternoclavicular joints, Articulationes sternoclaviculares; ventral view; right frontal section through the joint.
The sternoclavicular joint is a functional **ball and socket joint** with three degrees of freedom. It contains a fibrocartilaginous **Discus articularis,** dividing the joint into two chambers **(dithalamic joint).** The shape of this joint is a reflection of the demands of multiaxial mobility and very diverse mechanical stresses in different joint positions. Because the disc is able to absorb high shear forces, the joint surfaces can be kept small. The Ligg. sternoclavicularia anterius and posterius, and interclaviculare and costoclaviculare reinforce the joint capsule.



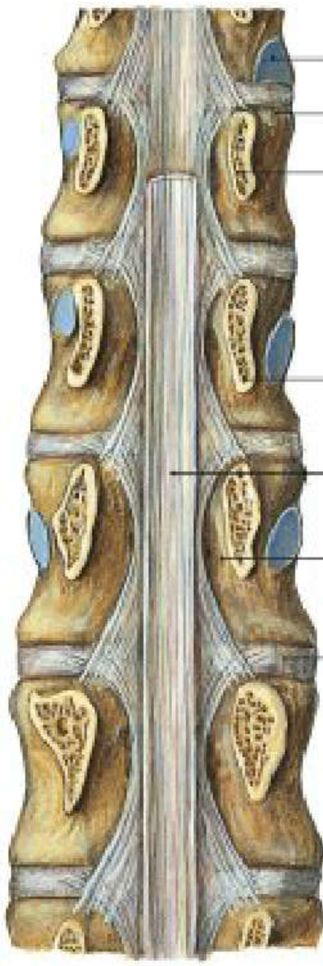


Fig. 2.40 Ligaments of the vertebral column using the example of the lower thoracic vertebral column; ventral view.
The anterior longitudinal band **(Lig. longitudinale anterius)** extends from the Tuberculum anterius of the atlas to the Os sacrum. It is firmly fused with the front surfaces of the vertebral body here and also affixed to the Disci intervertebrales. The ligament increases the strength of the spinal column when **extending.**

Fig. 2.41 Ligaments of the vertebral column using the example of the lower thoracic and upper lumbar vertebral column; dorsal view.
The posterior longitudinal band **(Lig. longitudinale posterius)** originates from the Membrana tectoria and extends into the Canalis sacralis. It is firmly connected with the intervertebral discs and the edges of the cover plates, securing the Disci intervertebrales. The ligament increases the strength of the spinal column when **flexed.**

Ligaments of the Vertebral Column

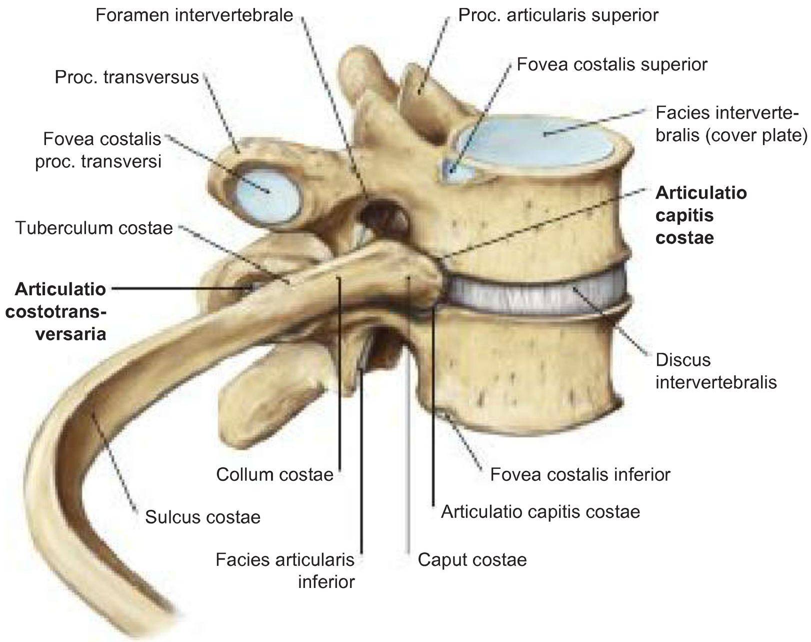


Fig. 2.42 Costovertebral joints, Articulationes costovertebrales; costovertebral joint at the height of the 7th and 8th thoracic vertebra; view from the right side. [L266]
The heads of the rib articulate via the **Articulatio capitis costae** with the thoracic vertebrae. With the exception of the Ist, XIth and XIIth rib it is a two chamber joint (dithalamic joint), as each head articulates with the top and bottom rim of two adjacent vertebrae.

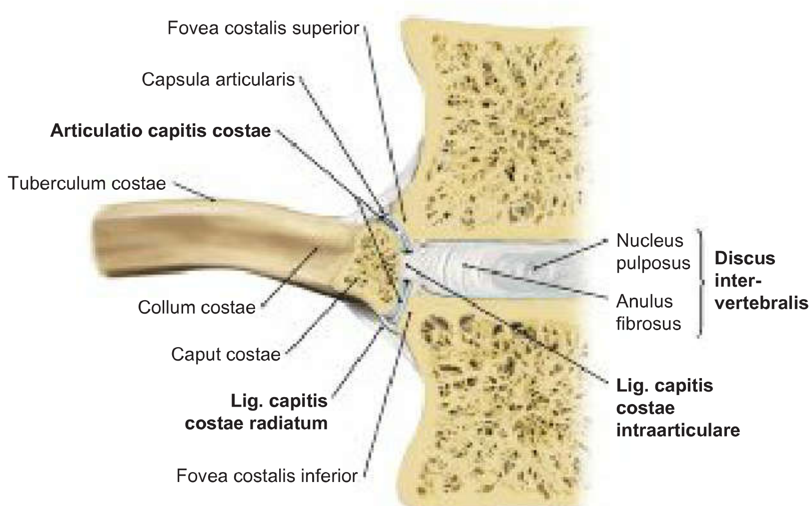


Fig. 2.43 Joint of head of rib, Articulatio capitis costae; lateral view from the right side. [L266]
Each head of the ribs II to X articulates with the upper and the lower edge of two adjacent vertebrae and with the intervertebral disc via a ligament (Lig. capitis costae intraarticulare), which is secured to the Crista capitis costae (not visible). The joint cavity is divided into two chambers (dithalamic joint).

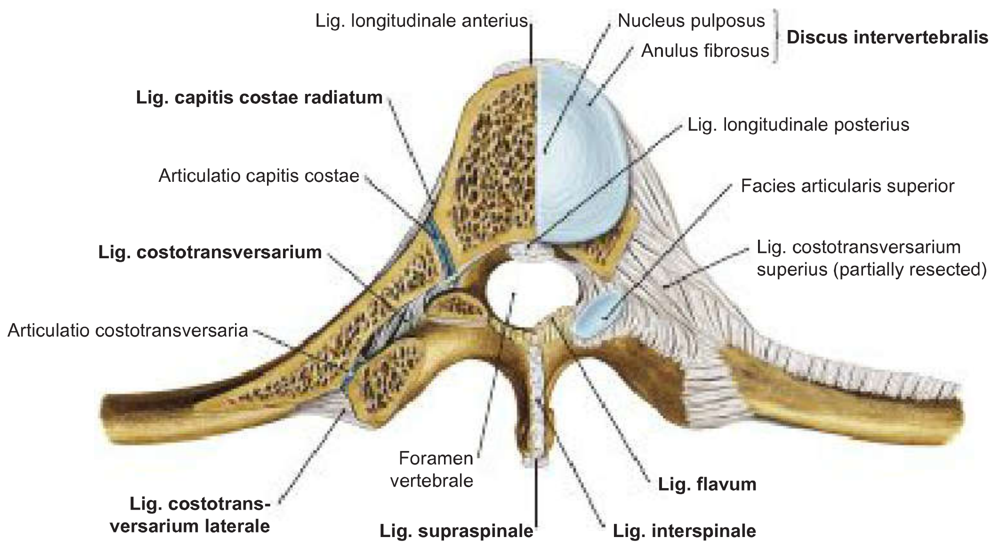


Fig. 2.44 Costovertebral joints, Articulationes costovertebrales; on the left transverse section at the level of the lower portion of a head of rib joint (Articulatio costovertebralis); right representation of the disc covering the vertebral body and the capsule ligament apparatus of the corresponding rib with the thoracic vertebrae; view from cranial.
The ribs articulate in the **Articulatio costotransversaria** with the Proc. transversus of the corresponding thoracic vertebra, for example rib I with the 1st thoracic vertebra or the Vth rib with T5 (exception XIth and XIIth rib). This causes the Facies articularis tuberculi costae and the Fovea costalis processus transversi to articulate. The joint capsules are weak and are strengthened by different ligaments (→ Fig. 2.45).

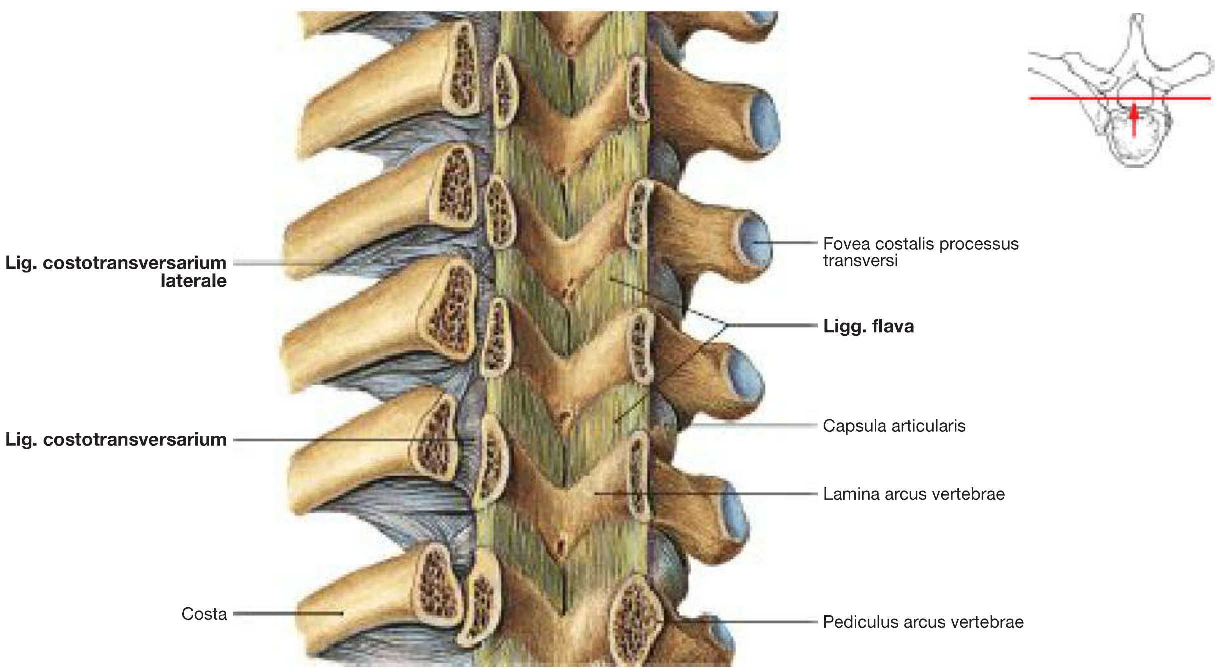


Fig. 2.45 Compounds of the vertebral arches; ventral view.
Between the vertebral arches the **Ligg. flava** stretches segmentally (yellowish colour, which is caused by an extremely high level of elastic fibres arranged like a scissor grid). They border the Foramina intervertebralia dorsally. The Ligg. flava which are stretched in every position support the muscles of the back when erecting the vertebral column from all flexed positions.

Ligaments of the Vertebral Column

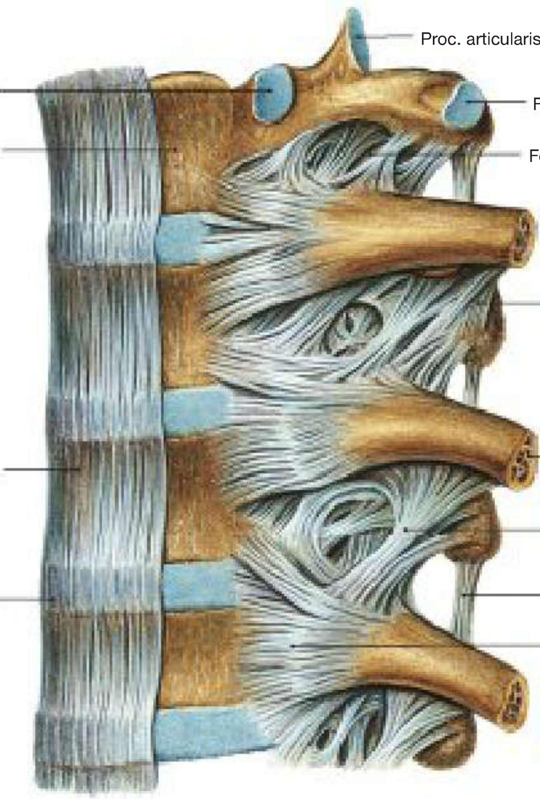


Fig. 2.46 Ligaments of the vertebral column and the costovertebral joints, Articulationes costovertebrales; view from the left side; lateral parts of the front longitudinal band removed.
The joint capsules of the Articulationes capitis costae are reinforced respectively by a Lig. capitis costae radiatum; the joint capsules of the Articulationes costotransversariae are secured by the Ligg. costotransversaria (Lig. costotransversarium laterale and Lig. costotransversarium superius).

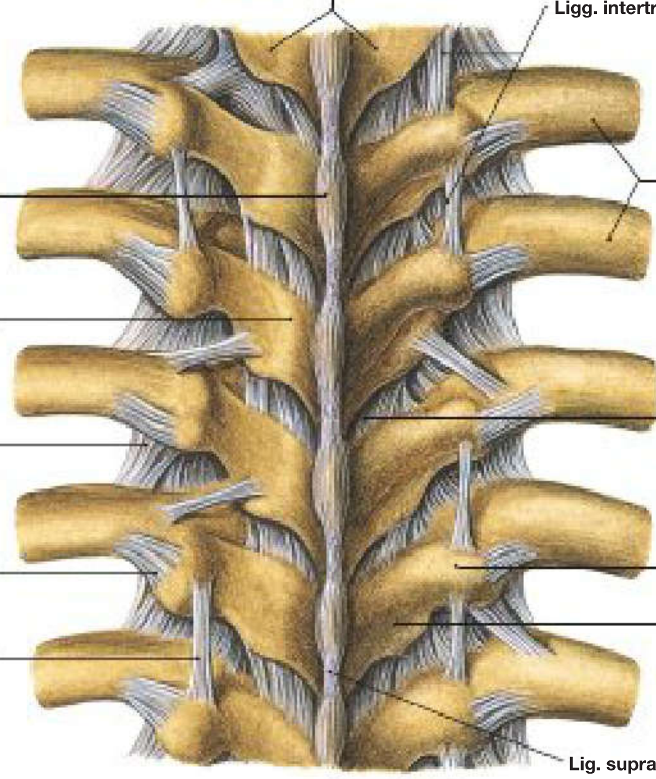


Fig. 2.47 Ligaments of the vertebral arches and the costovertebral joints, Articulationes costovertebrales; dorsal view.
The joint capsules of the Articulationes costotransversariae are dorsally reinforced by the Ligg. costotransversaria lateralia and superiora. The Ligg. intertransversaria guarantee additional stability.

* The median portion of the Fascia thoracolumbalis is referred to as the Lig. supraspinale.

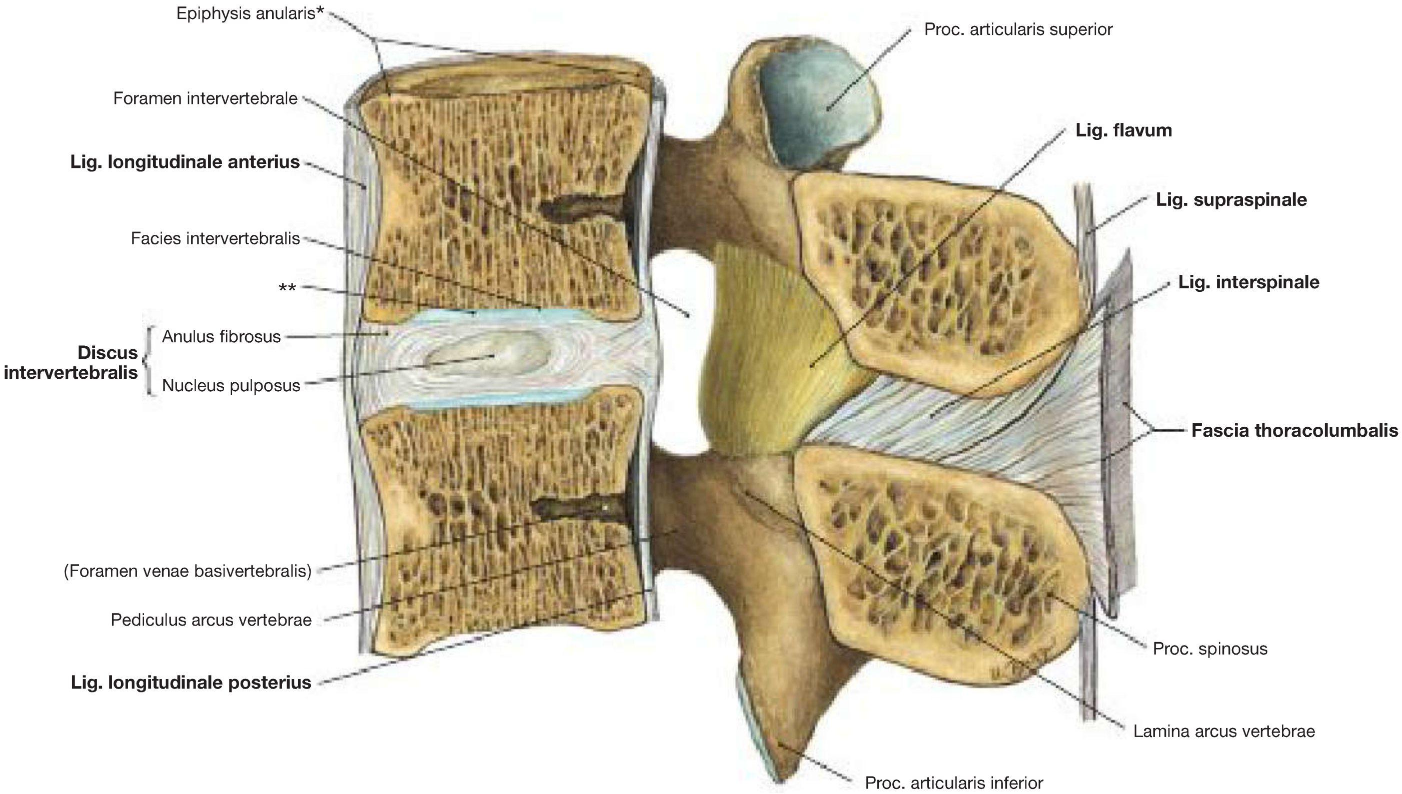
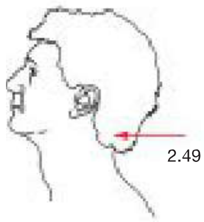


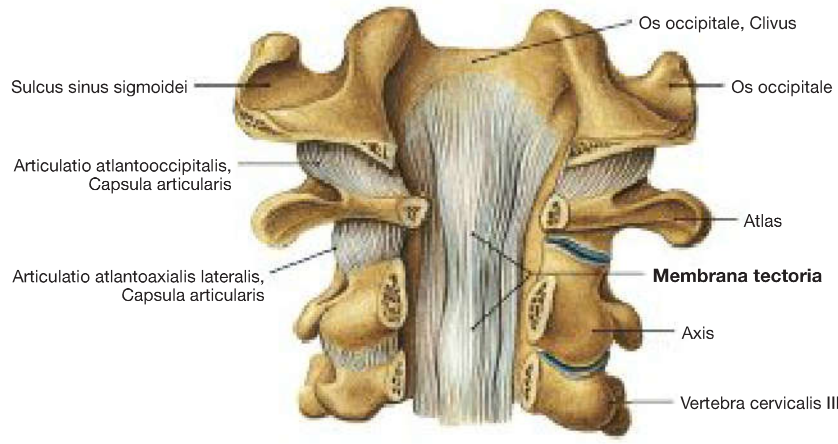
Fig. 2.48 Lumbar motion segment; median section; view from the left side.
The intervertebral disc (Discus intervertebralis) consists of a central gelatinous nucleus (Nucleus pulposus), originating from the Chorda dorsalis, and a connective tissue ring (Anulus fibrosus) surrounding the nucleus pulposus without sharp limitations. The Anulus fibrosus is largely affixed by a bony rim and hyaline cartilaginous coverage (**) of the end plate as non-ossified remains of the vertebral body epiphyses (*) on the Corpus vertebrae as well as via the Lig. longitudinale posterius, and to a lesser extent via the Lig. longitudinale anterius. A Discus intervertebralis connects two adjacent vertebrae as Symphysis intervertebralis. The tension over the Ligg. flava, interspinale and supraspinale is guaranteed in the area of the vertebral arches. The Lig. interspinale radiates into the Fascia thoracolumbalis in the thoracolumbar area.

* also: annular rim
** hyaline cartilagenous covering on the base plate

Clinical Remarks

The genetic (HLA-B27 positive) Spondylitis ankylosans **(Morbus BECHTEREW)** accompanies a progressive ossification of the Anulus fibrosus of the ligaments, the vertebral joints, the Ligg. capitum costarum radiata and costotransversaria and the Ligg. longitudinale anterius and interspinalia. In the early stages, it is mostly only the sacroiliac joints that are affected. In spite of a limited ability to flex, the contour of the back initially looks normal. When the disease progresses, the back appears flat as a board (as if ironed smooth). In addition, there is a significant restriction of thoracic wall excursions and lessening of the respiratory capacity.





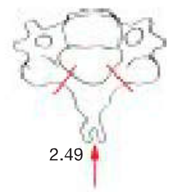


Fig. 2.49 Head joints with deep ligaments; dorsal view.
The **Membrana tectoria** is the extension of the **Lig. longitudinale posterius** to the cranial. It covers the ligaments and the joint capsule of the Articulatio atlantoaxialis mediana (not visible). The joint capsule of the Articulatio atlantooccipitalis can be recognised laterally between the occipital bone and atlas, and the joint capsule of the Articulatio atlantoaxialis lateralis is visible between atlas and axis.

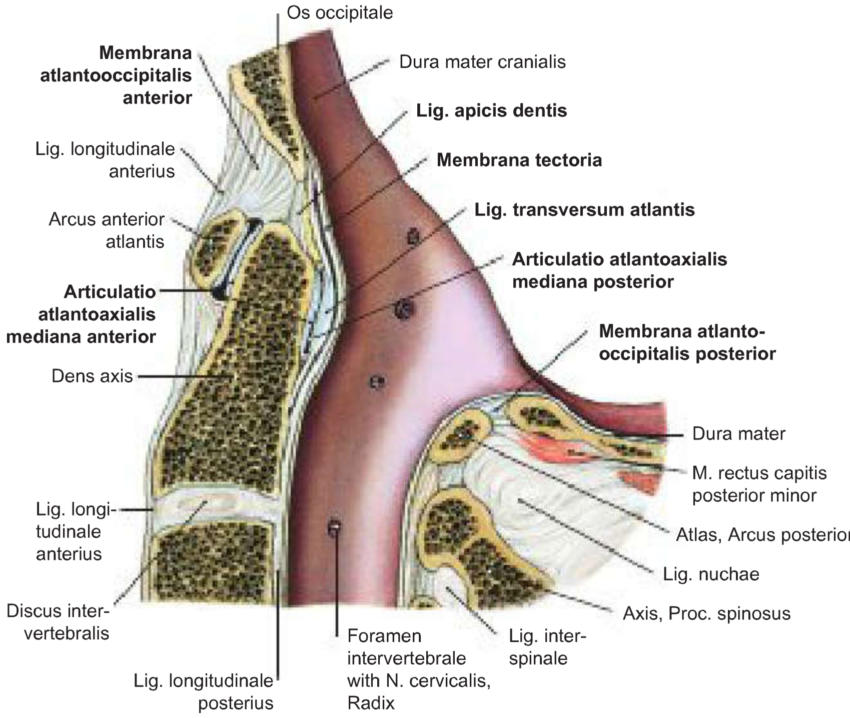


Fig. 2.50 Cervico-occipital transition region with intermediate atlantoaxial joint and ligaments; median-sagittal section; view from the left side.
As part of the so-called lower head joint (consisting of Articulationes atlantoaxiales laterales and Articulatio atlantoaxialis mediana, which is opposed to the upper head joint consisting of Articulationes atlantooccipitales) we see the flexible connection in the median section between dens axis and the front atlas arch (Articulatio atlantoaxialis mediana). The joint capsule is reinforced above the atlas of the **Membrana atlantooccipitalis anterior** and the **Lig. longitudinale anterius** (→ Fig. 2.53). On the rear side, the Fasciculi longitudinales and the Lig. transversum atlantis (collectively **Lig. cruciforme atlantis**) form a reinforcement of the joint capsule as well as the 'cruciate ligament' covering **Membrana tectoria,** which in turn is covered with hard meninges (dura mater spinalis). On the dorsal side of the vertebral canal the **Membrana atlantooccipitalis posterior** extends between Os occipitale and atlas and the **Ligamentum nuchae** on the back of the neck of the axis to the occiput.

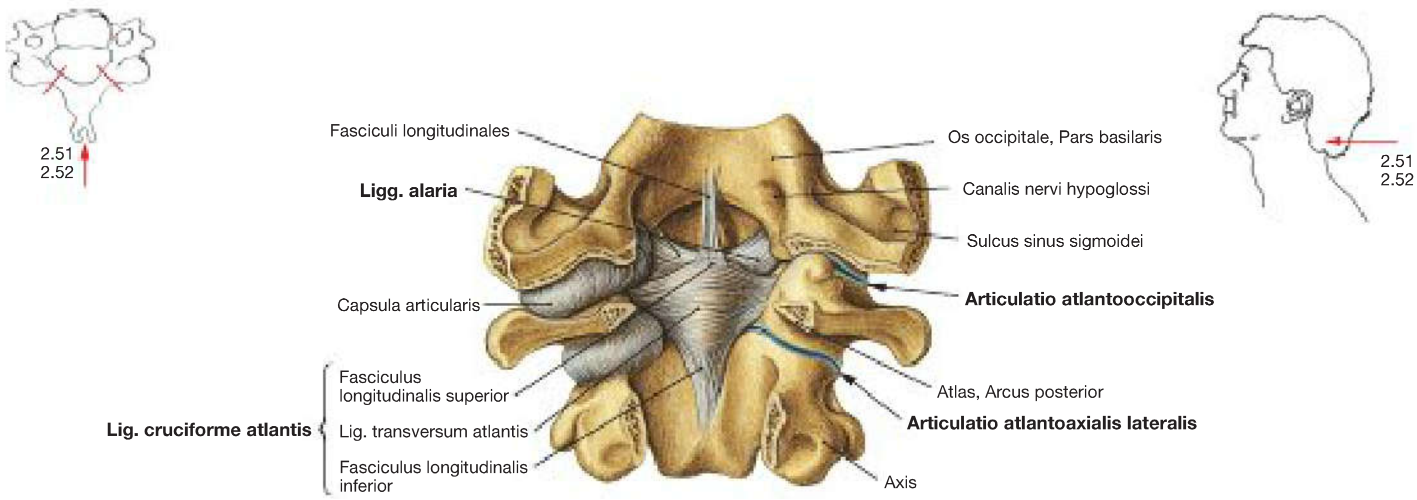


Fig. 2.51 Head joints with deep ligaments; dorsal view; after removal of the Membrana tectoria.
Centrally, one can recognise the **Lig. cruciforme atlantis,** which consists of the Lig. transversum atlantis and the two Fasciculi longitudinales. Behind it, you can see the winged ligaments **(Ligg. alaria),** which originate at the tip and the sides of the dens axis (→ Fig. 2.52) and pull upwards diagonally. On the one hand, the joint capsules of the Articulatio atlanto-occipitalis and the Articulatio atlantoaxialis can be identified; on the other hand, the joint capsules have been removed and you can see the joint opening.

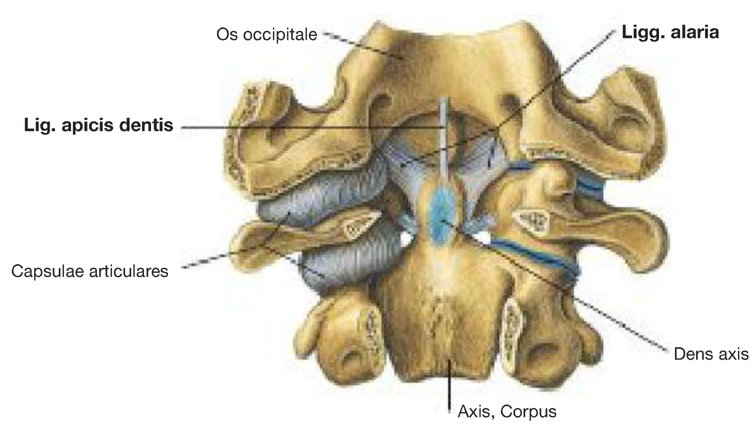


Fig. 2.52 Head joints with deep ligaments; dorsal view; after removal of Membrana tectoria und Lig. cruciatum atlantis. One can see the **Ligg. alaria** (→ Fig. 2.51) which frequently project to the Massae laterales of the atlas and the thin **Lig. apicis dentis.**

Clinical Remarks

In the case of a rupture of the Lig. transversum atlantis or the Lig. cruciforme atlantis, there may be dislocation of the dens axis in the vertebral canal and, therefore, in the medulla oblongata and spinal cord with contusion or separation of the structures **(neck fracture).** The nerve centres for respiration and blood circulation are subsequently destroyed. This results in immediate death.
Occasionally, a missing dens or incomplete formation of the dens axis may cause an **atlantoaxial subluxation**.

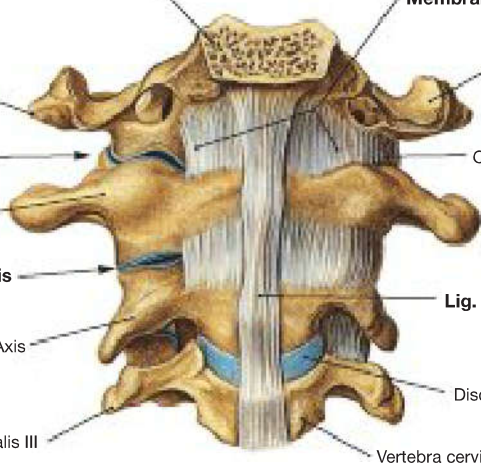


Fig. 2.53 Head joints with ligaments and upper cervical spine; ventral view.
In the midline, you can see the **Lig. longitudinale anterius.** The **Membrana atlantooccipitalis anterior** extends between occipital bone and atlas. Lateral thereof, you can see the joint capsule of Articulatio atlantooccipitalis, which has been removed on the opposite side.

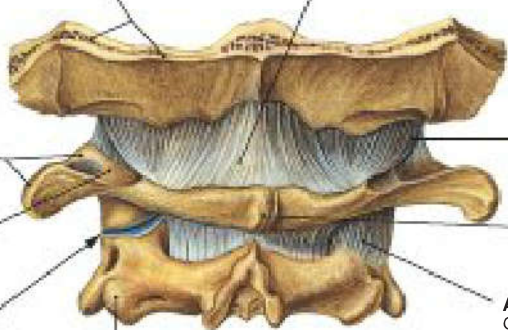
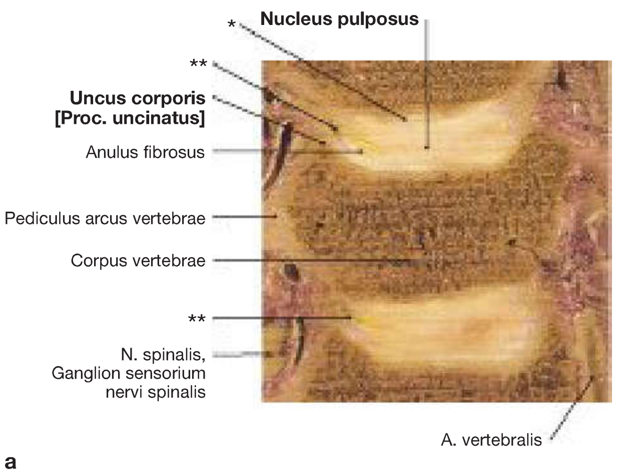


Fig. 2.54 Head joints; dorsal view.
Dorsally you can look between the Os occipitale and the Arcus posterior atlantis to the Membrana atlantooccipitalis posterior and see the Lig. atlantooccipitale laterale. Between the atlas and the axis you can see the joint capsule of the Articulatio atlantoaxialis lateralis, which has been removed on the left.



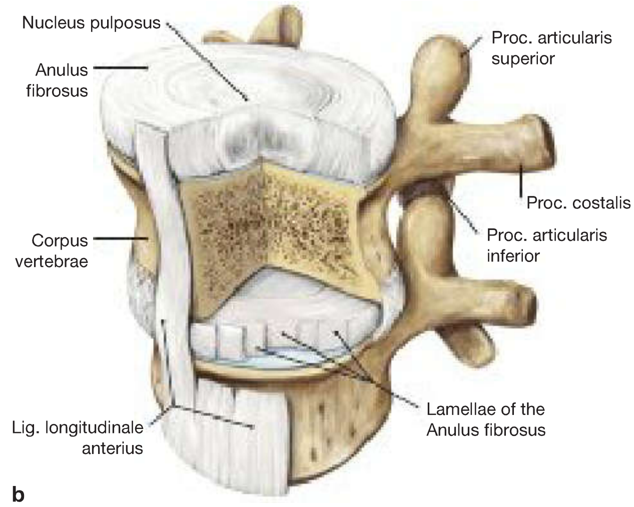


Fig. 2.55a and b Intervertebral discs, Disci intervertebrales.

a Cervical intervertebral discs, Disci intervertebrales cervicales; frontal section; ventral view.
As early as in the 1st decade of life, so-called uncovertebral gaps (**) start forming in the lateral areas of the cervical intervertebral discs. Approximately between the 5th and 10th year of life, there are cleft formations in the Disci intervertebrales of the cervical spine, which assume a joint-like character. They are called uncovertebral joints, which initially provide functional benefits in terms of the movement of the cervical spine, but can tear completely later in life and can have negative effects (→ clinical remarks).

b Structure of the Disci intervertebrales, lumbar intervertebral discs, Disci intervertebrales lumbales; view from the front diagonally. [L266]

An intervertebral disc consists of an outer fibrous ring (Anulus fibrosus), which is structured from opposing blades (herring bone pattern) made of collagen fibres. It is fused at the front and rear with Ligg. longitudinalia anterius and posterius respectively. It is further divided into an external zone, an internal zone and a transition zone. The latter establishes the connection to the gelatinous Nucleus pulposus. The Nucleus pulposus borders the cartilage of the deck and floor plates of the adjacent vertebrae and the sides of the Anulus fibrosus (transition zone), cranially and caudally. If the Anulus fibrosus tears, the disc prolapses (→ clinic, → Fig. 2.57).

* hyaline cartilaginous coverage of the end plates of the vertebral body as non-ossified portions of the vertebral body epiphyses
** so-called uncovertebral gap

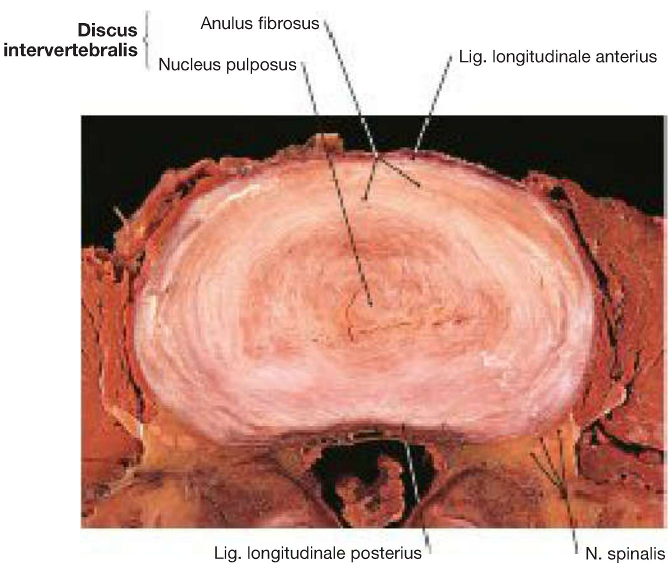


Fig. 2.56 Lumbar intervertebral disc, Discus intervertebralis lumbalis; cranial view.
The intervertebral disc (Discus intervertebralis) consists of a central gelatinous nucleus **(Nucleus pulposus),** originating from the Chorda dorsalis, and a connective tissue ring **(Anulus fibrosus)** surrounding the Nucleus pulposus.

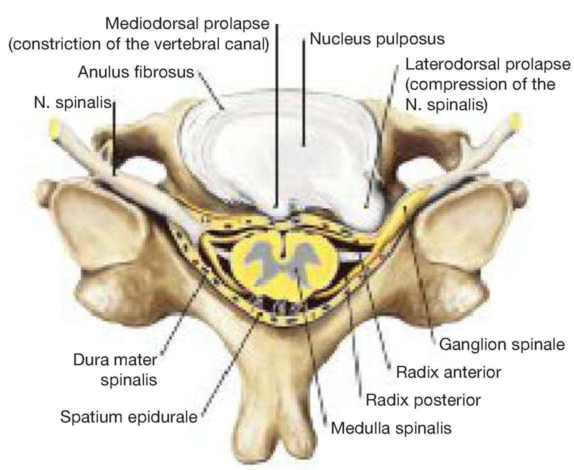


Fig. 2.57 Disc prolapse. [L266]
Representation of a laterodorsal prolapse with compression of the N. spinalis and a mediodorsal prolapse with constriction of the vertebral canal.

Clinical Remarks

Degeneratively caused intervertebral disc changes in the lumbar and cervical column are most common (→ Fig. 2.57). This can result in intervertebral disc protrusion or disc prolapse (**slipped disc,** herniated pulposus). This shifts intervertebral disk tissue either by laterodorsal (posterolateral, more frequent) or after mediodorsal (posteromedian, more seldom) in the vertebral canal (→ Fig. 2.57). This results in compression of the spinal nerve roots **(spinal radicular syndrome).** Most often, the segments S1, L5 and L4 are affected. In the cervical spine, ruptures of the intervertebral discs originating from the uncovertebral columns can cause a hernia.

Cervical Spine, X-ray

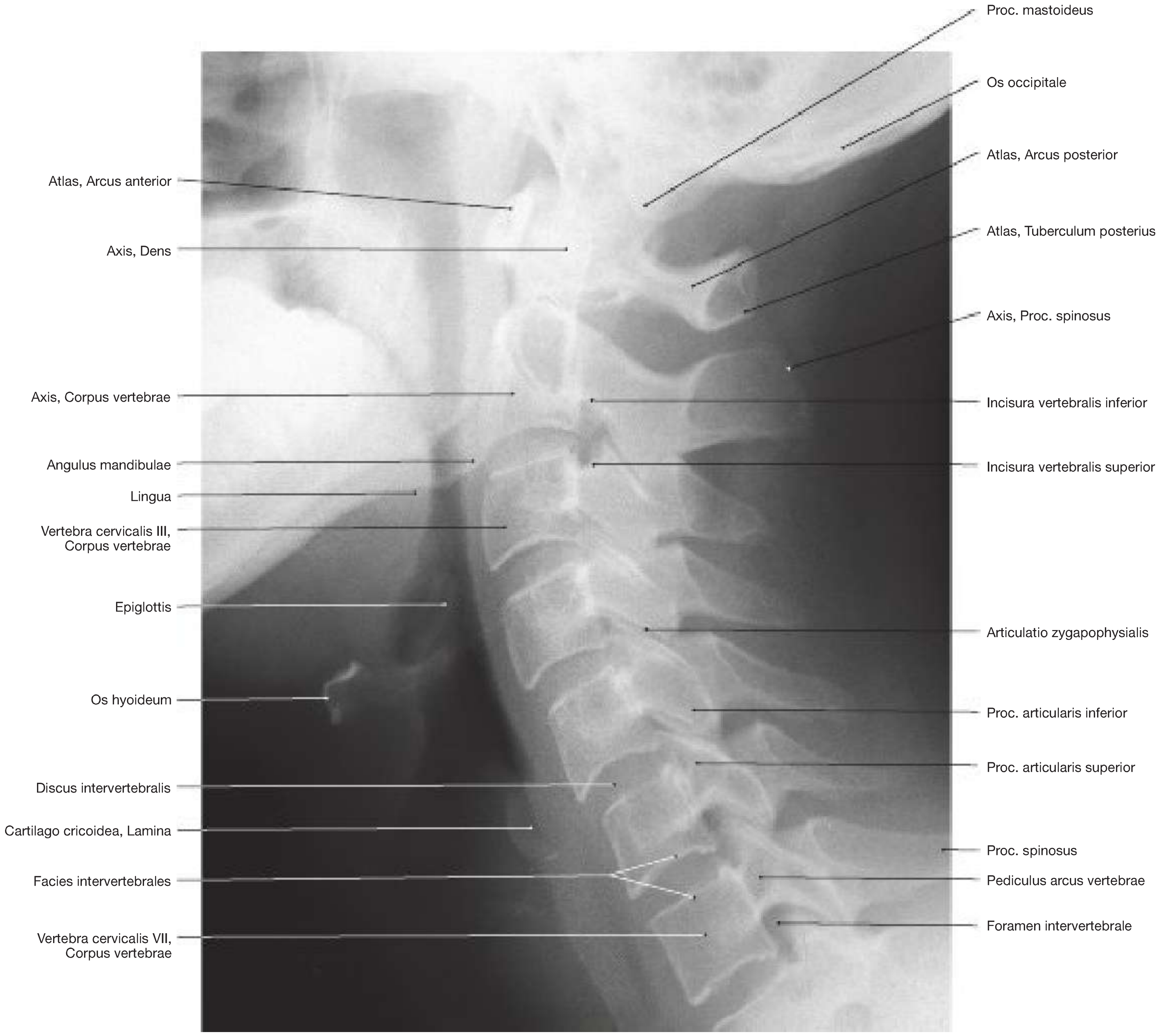


Fig. 2.58 Cervical vertebrae, Vertebrae cervicales; X-ray image in lateral beam projection; setting: upright position; central beam set at the 3rd cervical vertebrae; shoulders dragged down. [T904]

Clinical Remarks

A dorsally convex curved spine is referred to as a **kyphosis**. In the thoracic vertebral column, this slight curvature is physiological, but in the cervical and lumbar vertebral column it is always pathologic. A reinforcement of the kyphosis leads to the formation of a hunch (Gibbus) and appears in various forms (e.g. early childhood as **humpback,** in the younger years as juvenile or **adolescence kyphosis** [Morbus SCHEUERMANN], in more advanced years with loss of elasticity and disc degeneration as senile or **age kyphosis**). Congenital kyphosis is usually caused by hemi- or block vertebrae.
A strong non-physiological lordosis is called **hyperlordosis** and occurs particularly in the lumbar vertebral column.

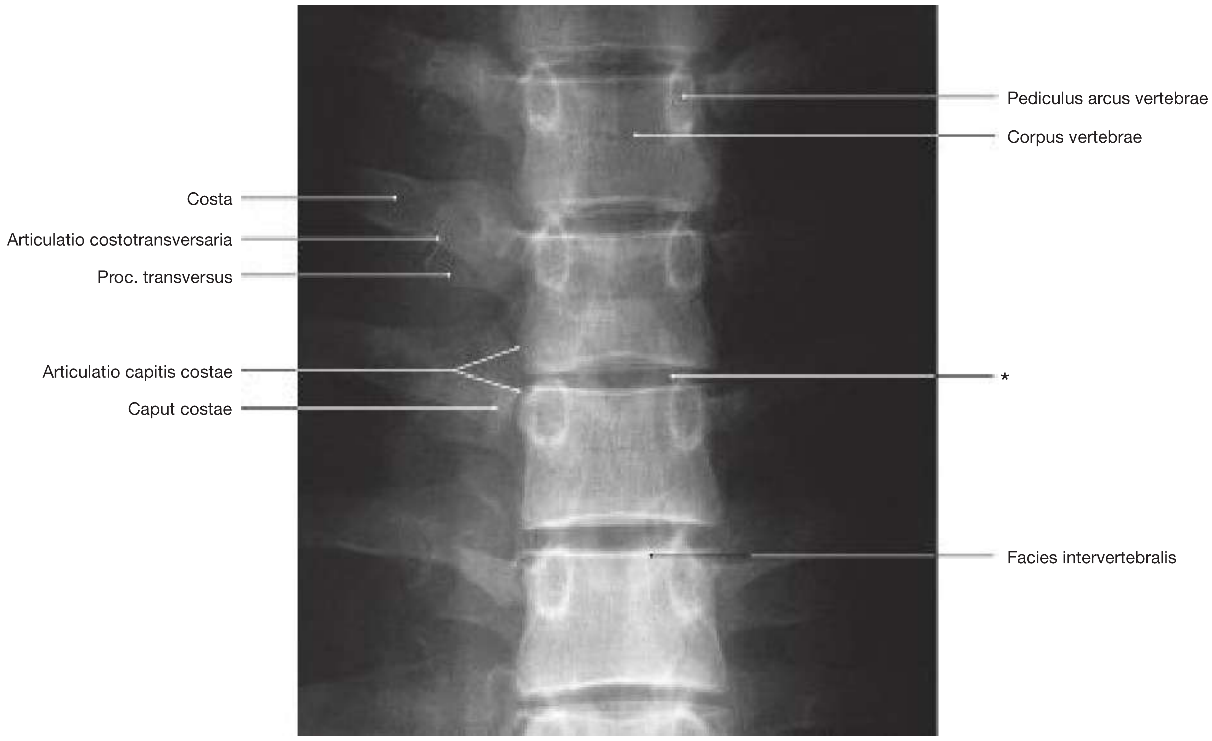


Fig. 2.59 Thoracic vertebrae, Vertebrae thoracicae; X-ray in antero-posterior (AP) beam projection; setting: upright position, thorax in inhalation position; central beam on the 6th thoracic vertebrae. [T902]

*intervertebral disc space

Clinical Remarks

The spine is more frequently a **metastases point** for malignant tumours because of the dense capillary net within the vertebrae. The normal bone matrix of affected vertebrae together with the mechanical bone properties are destroyed. This can lead to even smaller loads causing vertebral collapses. Often vertebral fragments enter the vertebral canal or the Foramen intervertebrale and result in injuries and compression of the spinal cord and the spinal nerves.

Lumbar Spine, X-ray

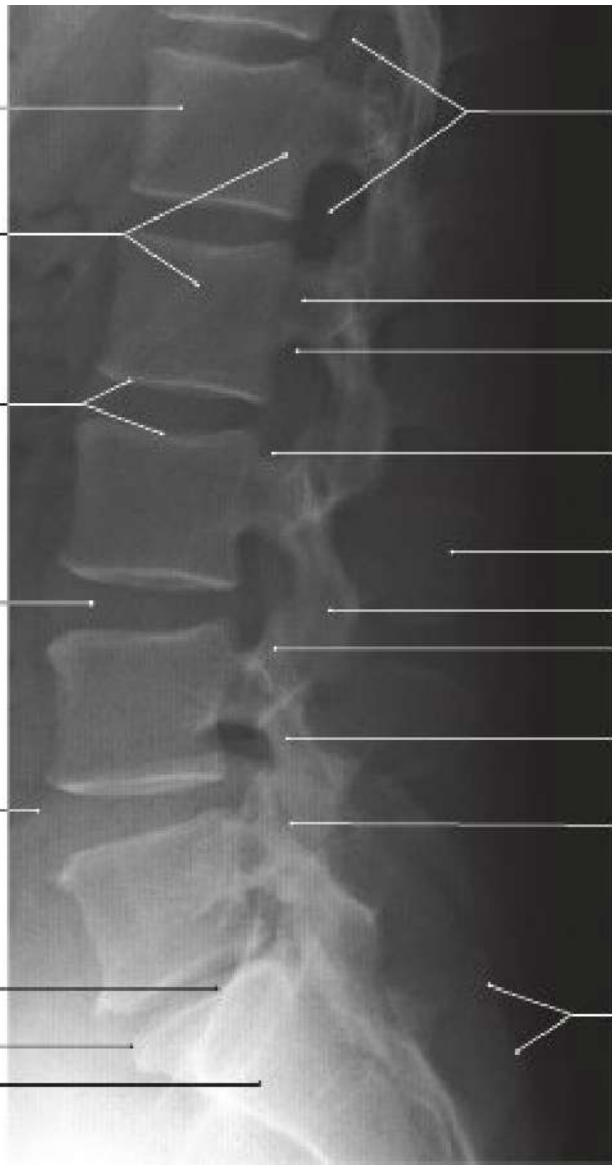


Fig. 2.60 Lumbar vertebra, Vertebrae lumbales; X-ray in lateral beam projection; setting: upright position; central beam on the 2nd lumbar spine. The taper at the front edge of the lower lumbar vertebrae is an initial sign of degenerative changes and thus of pathological changes. [T902]

* intervertebral disc space

** vertebral arch area between the superior and inferior joint process (so-called Isthmus = interarticular portion)

*** The terminal points indicate the course of rib XII, which is poorly visible in this copy of the X-ray.

Clinical Remarks

Osteoporosis is a metabolic bone disease with largely unknown aetiology which is characterised by a localised or general decrease of bony mass or density without changing the external shape of the bone. This condition primarily affects women over 55 and men over 70 years of age. Genetic predisposition, lack of physical activity, poor nutritional state and unfavourable oestrogen levels contribute to the development of osteoporosis. As a result of the weakened bone structure, fractures such as vertebral fractures, distal radius fractures, and femoral neck fractures occur frequently.

Fig. 2.61 Lumbar vertebrae, Vertebrae lumbales, and sacrum, Os sacrum; X-ray image in anteroposterior (AP) beam projection; setting: upright position; central beam on the 2nd lumbar spine. [T902]

*intervertebral disc space

Fig. 2.62 Lumbar vertebrae, Vertebrae lumbales; X-ray in oblique beam projection; setting: upright position. [E402]
The experienced radiologist will recognise a dog-like figure ('Scotty dog', dotted lines) in this oblique X-ray image. The central area is the interarticular part. The clinical term refers to the vertebrae section between the superior and inferior joint facets of the zygapophyseal joints (→ Fig. 2.29).

* interarticular portion

Clinical Remarks

Fractures in the area of the interarticular part (isthmus) lead to a change in the figure of the dog, e.g. dog with collar, produced by a lysis zone. This is mostly the result of sport injuries, which can lead to damage particularly to the interarticular part (Isthmus) at the level of L4 and L5. However, the cranial vertebra can shift ventrally, even without the presence of a fracture of the interarticular part, via the underlying vertebrae. The reason for this is usually a change in the setting of the joint facets that can be inherited or may arise in the context of degenerative changes. All the above-mentioned conditions (including a fracture of the interarticular part) are termed **spondylolisthesis** (vertebral slippage).

Spine, CT

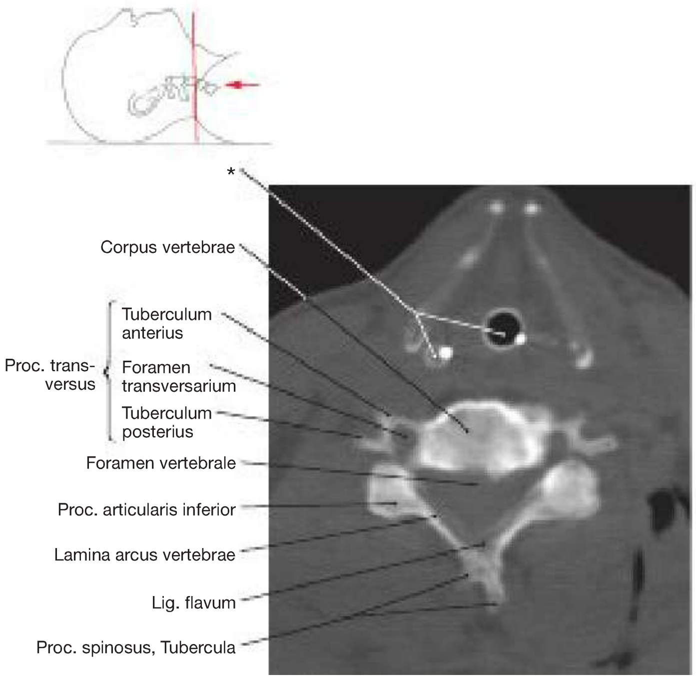


Fig. 2.63 Cervical spine; computed tomographic (CT) cross-section at the level of the intervertebral disc between the 4th and 5th cervical vertebrae. [T902]

* artificial respiration tube and endoscopic instrument

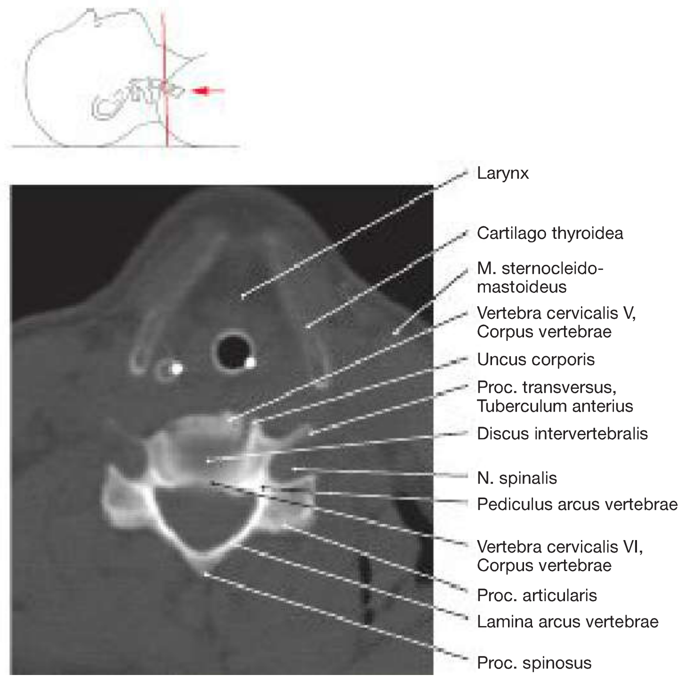


Fig. 2.64 Cervical spine; computed tomographic (CT) cross-section at the level of the 5th cervical vertebra. [T902]

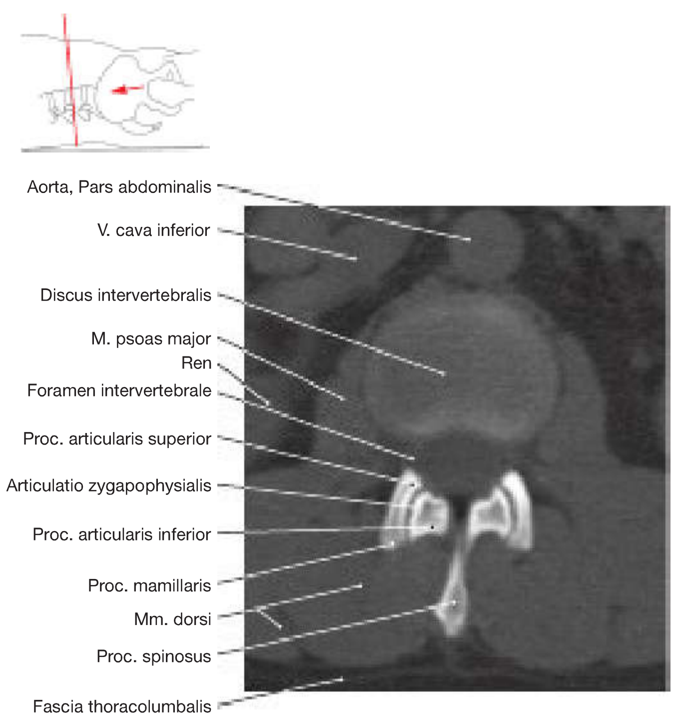


Fig. 2.65 Lumbar vertebral column; computed tomographic (CT) cross-section at the level of the intervertebral disc between the 2nd and 3rd lumbar vertebrae. [T902]

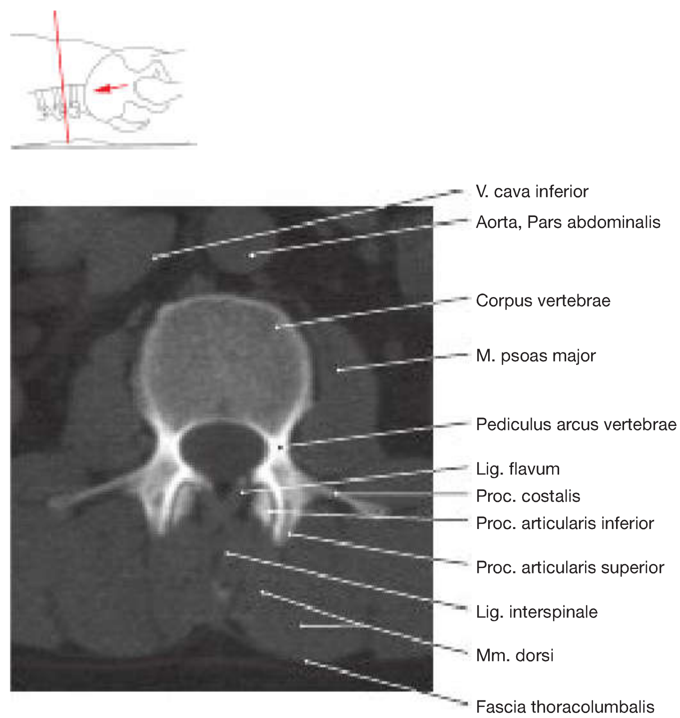


Fig. 2.66 Lumbar spine; computed tomographic (CT) cross-section at the level of the pediculi of the 3rd lumbar vertebra. [T902]

Clinical Remarks

Some genetic disorders are associated with variations of the vertebrae number. The **KLIPPEL-FEIL syndrome** for example is a hereditary development disorder of the cervical spine with spinal fusion during the early embryonic stage (generally of atlas and axis or of the 5th and 6th cervical vertebrae). The characteristics of this disorder, caused by the fusion, are a short neck and often shoulder elevation. Spina bifida, lower placement of ears, and abnormalities of heart and other organs can also accompany this disease.
When a vertebra only emerges on one side from the corresponding sclerotome, it is referred to as a semi-vertebra **(hemivertebra)**.

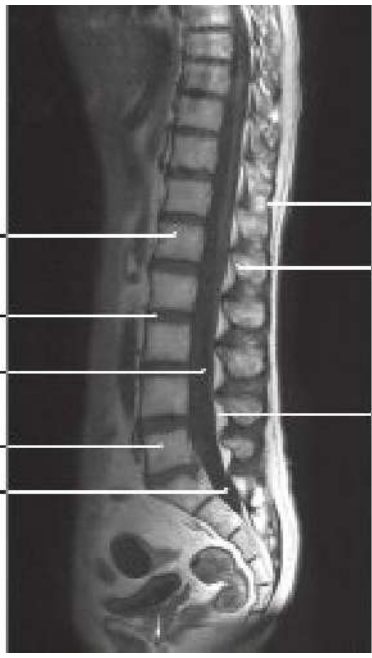


Fig. 2.67 Lumbar spine; magnetic resonance tomographic median section (MRI) of the thoracic and lumbar spine and the Os sacrum. [T906]
MRI is a suitable imaging technique to view intervertebral discs, the spinal cord, and the epidural space (Spatium epidurale).

Fig. 2.68 Medial disc prolapse; T2-weighted magnetic resonance tomographic sagittal section (MRI) in the lumbar part of the vertebral column. [E402]

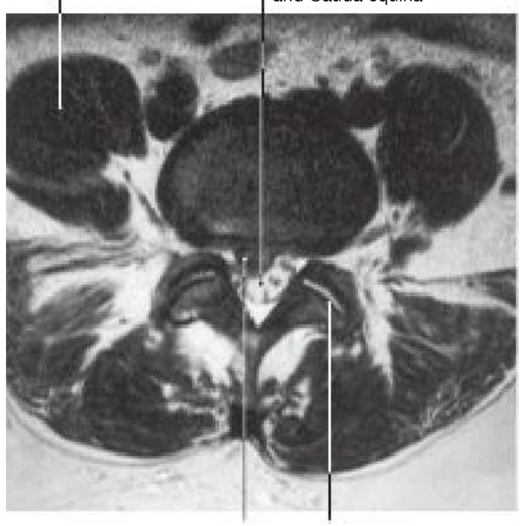


Fig. 2.69 Medial disc prolapse; T2-weighted magnetic resonance tomographic transverse section (MRI) in the lumbar part of the vertebral column. [E402]

Clinical Remarks

Aging decreases the ability of the Anulus fibrosus and Nucleus pulposus to retain water which, among other symptoms, leads to the formation of small cracks in the Anulus fibrosus **(Chondrose).** This can be detected radiologically by a reduction in height and pathologically by an instability with increased mobility in the motion segment. In due course, gradual height reduction of the disc and the resulting reduction in mechanical buffer function lead to increased strain on the superior and inferior intervertebral surfaces of the vertebral bodies. Radiologically, this manifests itself in a **sclerotisation** with increased radiation density **(osteochondrosis).** Furthermore, it causes the formation of **spondylophytes** (bony osteophytes) to the vertebral bodies, which are also radiologically visible. If the radial cracks in the Anulus fibrosus increase, intervertebral disc tissue can emerge from the intervertebral space (**disc prolapse;** → Fig. 2.68 and → Fig. 2.69).

Superficial Muscles of the Back

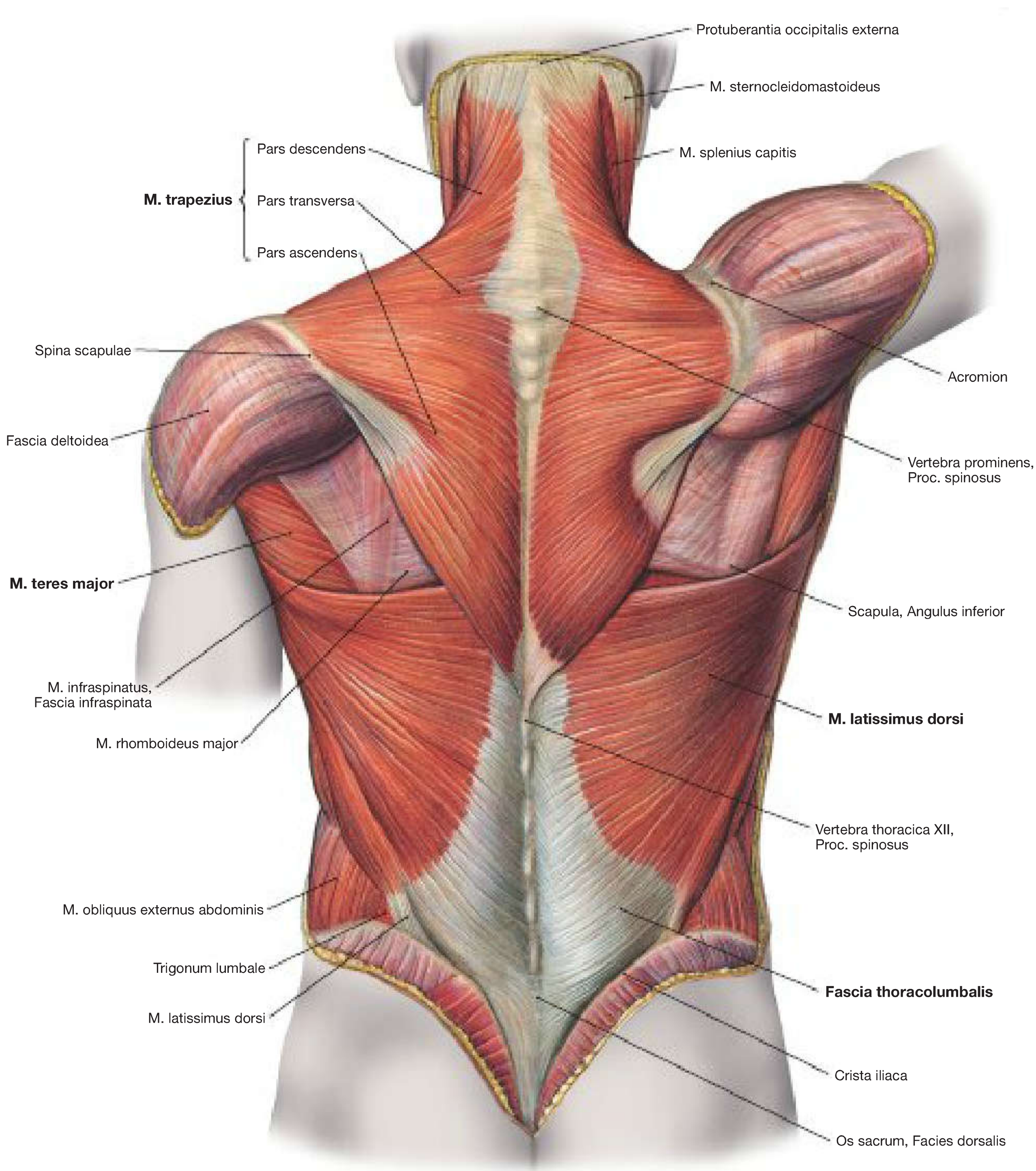


Fig. 2.70 Superficial layer of the trunk-arm and trunk-shoulder girdle muscles; dorsal view.

The Mm. trapezius and latissimus dorsi form the largest part of the superficial layer of muscles of the back. The **M. trapezius** secures the scapula and thus the shoulder girdle. It also allows the scapula and with it the clavicle to pull backwards medially to the spine. The Partes descendens and ascendens turn the Angulus inferior of the scapula medially. Furthermore, the Pars descendens adducts and supports the M. serratus anterior in shoulder elevation.

The **M. latissimus dorsi** is the largest muscle of the human body with respect to the surface area. It lowers the elevated arm, adducts it, can pull it backwards from the adduction position to the rear medially, rotates inwardly and can support the expiration. It is often referred to as a coat pocket muscle. On an evolutionary level, the M. latissimus dorsi coheres with the **M. teres major.** It pulls the arm to the rear medially, is involved in the adduction and rotates inwardly.

→ T 27, 28

Clinical Remarks

Units of the **M. latissimus dorsi** are used to **cover defects of the trunk wall**, as well as for the reconstruction of the breast after resection in breast cancer. To this end, a so-called pedicle flap is formed, on which the A. and V. thoracodorsalis are prepared and displaced. The **M. pectoralis major** (ventral trunk wall) is often used as a pedicle flap graft to cover **facial defects**.

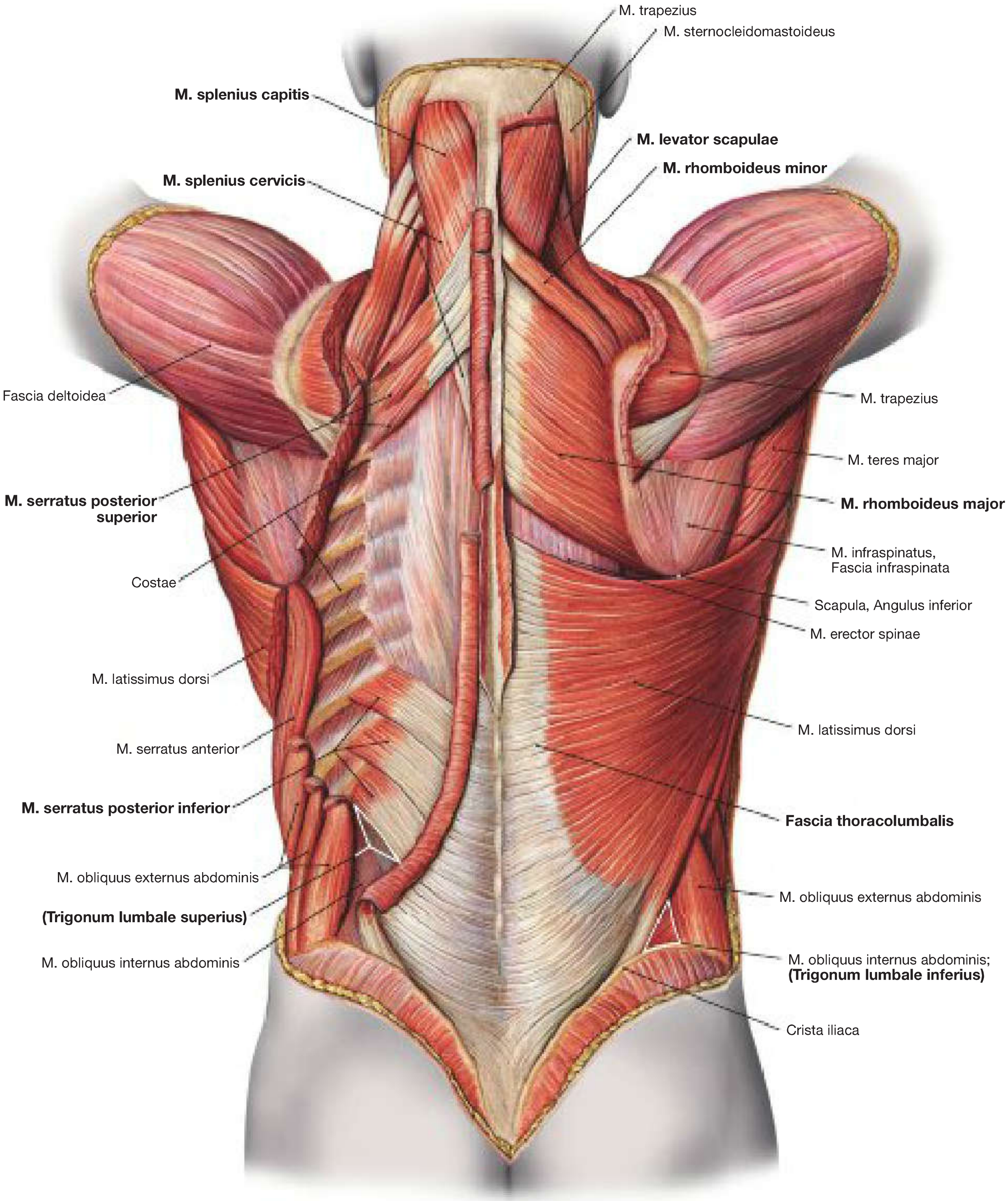


Fig. 2.71 Deep layer of the trunk-arm and trunk-shoulder girdle muscles; dorsal view.
After removal of the M. trapezius, the Mm. levator scapulae, rhomboideus minor and major are visible on the right side. The **M. levator scapulae** can lift the scapula and simultaneously turns its Angulus inferior medially.
M. rhomboideus minor and **M. rhomboideus major** fix the scapula to the thorax and pull it towards the spine.
After removal of the three muscles and the M. latissimus dorsi, the **Mm. serrati posteriores superior and inferior** become visible. The M. serratus posterior superior lifts the upper ribs and acts as a respiratory muscle in inspiration. The M. serratus posterior inferior broadens the lower thoracic aperture and stabilises the lower ribs during the contraction of the Pars costalis of the diaphragm. It is therefore also a respiratory muscle for inspiration.

The **Fascia thoracolumbalis** is designed as a rough aponeurosis. In a fibrous context it completes the osteofibrous channel formed by the spine and the dorsal surfaces of the ribs, and wraps around the autochthonous muscles in the back. Its superficial lamina serves as the origin for the M. latissimus dorsi and the M. serratus posterior inferior. The lamina is firmly fused with the tendon of the M. erector spinae. Cranially it separates the M. splenius cervicis from the M. trapezius and the Mm. rhomboidei and unites with the Fascia nuchae. The deep lamina is shown in → Figure 2.72.
In the area of the **Trigonum lumbale superius** (GRYNFELT-LESSHAFT-LUSCHKA triangle) and the **Trigonum lumbale inferius** (PETIT triangle) it may lead to the formation of GRYNFELT and PETIT **lumbal hernias**.

→ T 27, 28

Deep Muscles of the Back

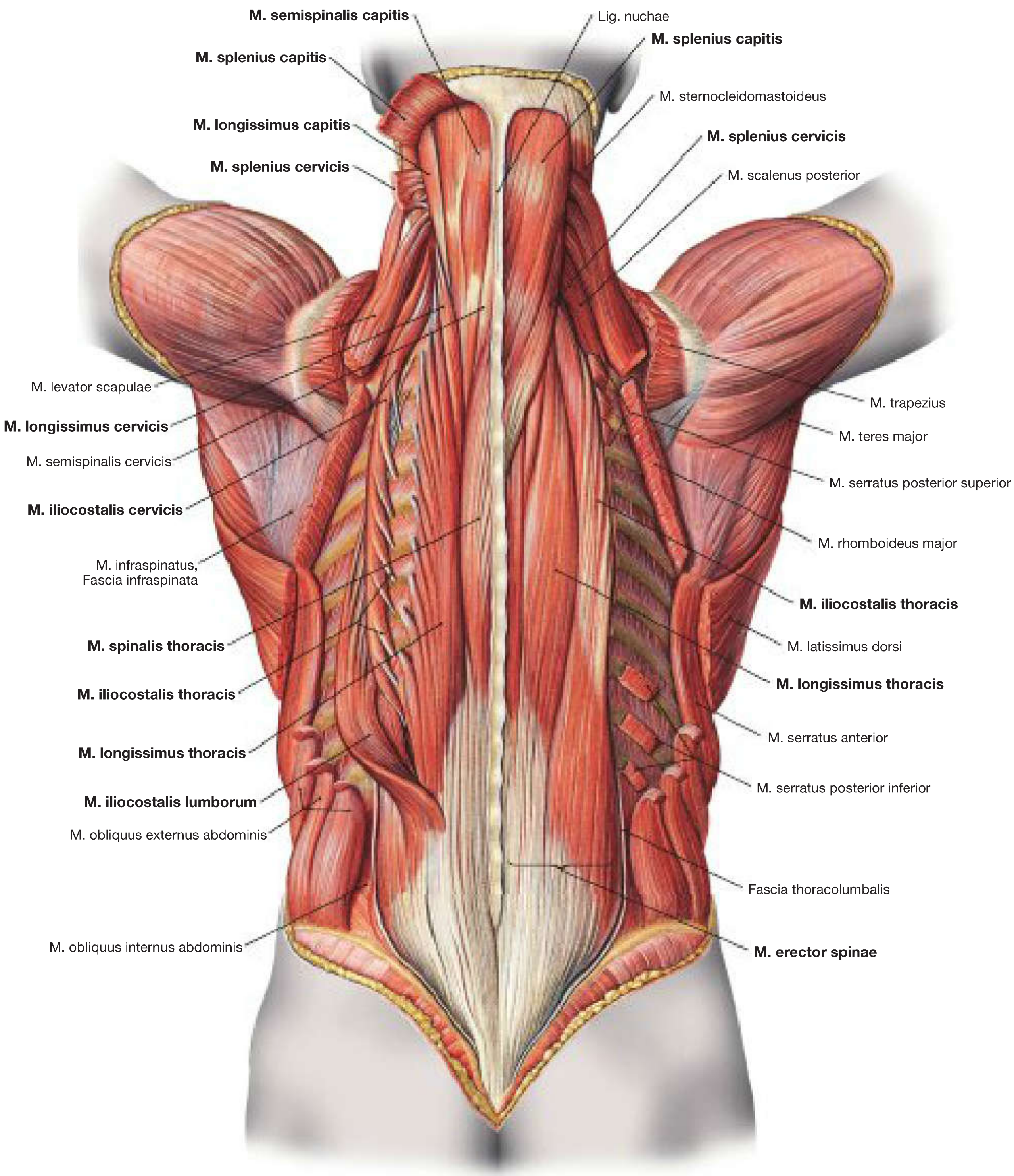


Fig. 2.72 Superficial layer of the deep (autochthonous) back muscles; dorsal view.
The autochthonous muscles of the back are collectively named **M. erector spinae**. It is divided into a medial and a lateral tract. Each tract is composed of different systems respectively (→ Fig. 2.73). The M. erector spinae extends from the sacrum to the occipital bone. The abdominal muscles and the M. erector spinae together act as a functional unit (bow-tendon principle).

→ T 18

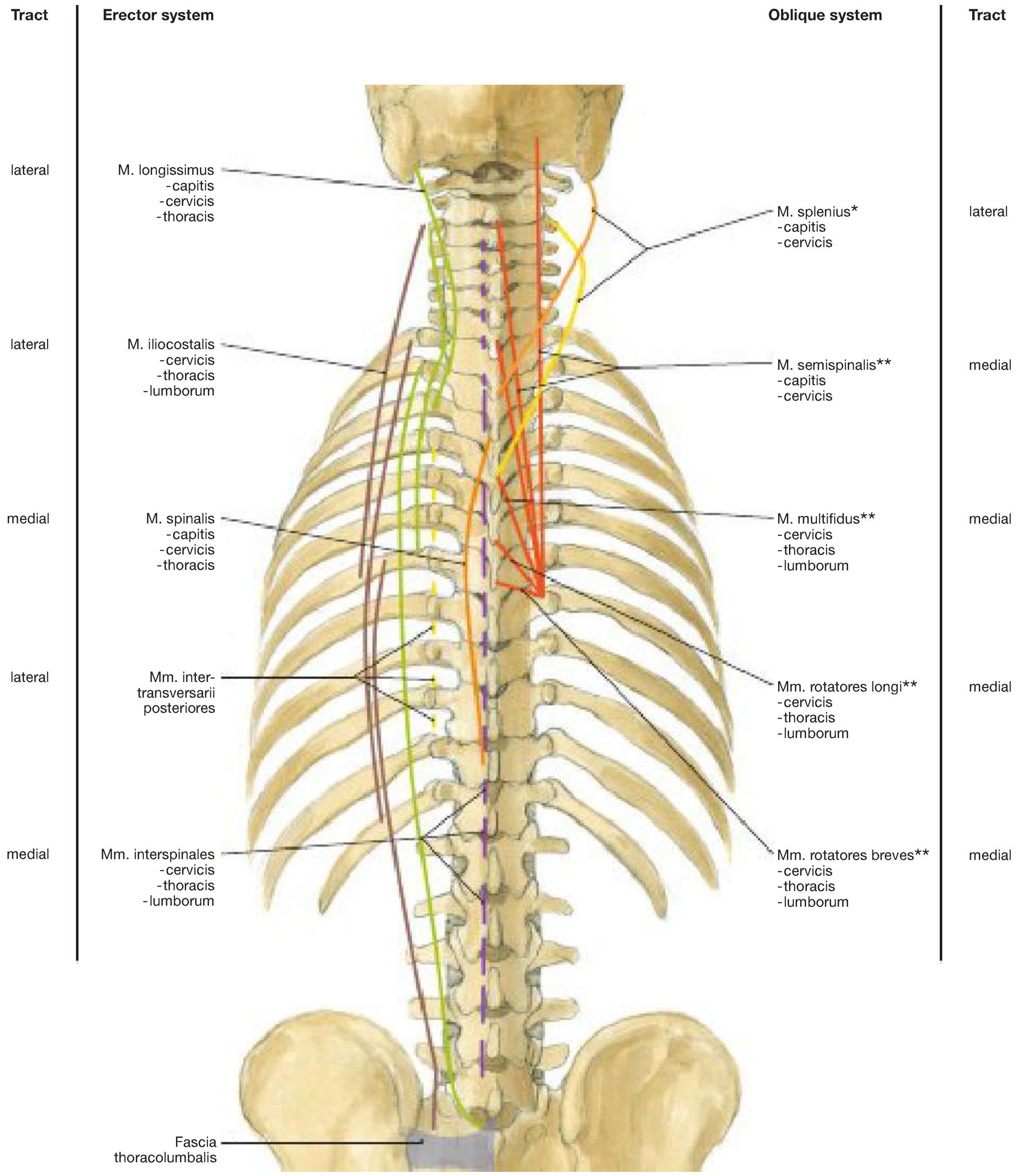


Fig. 2.73 Deep (autochthonous) back muscles; orientation scheme of the muscle groups.
The autochthonous muscles of the back, collectively named M. erector spinae, can be divided into a longitudinal erector system and an oblique system, as well as into a lateral and medial tract.
The **lateral tract** is divided into an intertransversal system (Mm. intertransversarii), a sacrospinal system (M. iliocostalis, M. longissimus) and a spinotransversal system (M. splenius cervicis, M. splenius capitis):

- The **intertransversal system** is used for the stabilisation as well as the lateral flexion and extension between the transverse processes.
- The **sacrospinal system** stretches the spine, leads to the extension of and is used for the lateral flexion and the rotation of the torso on the ipsilateral side.
- The **spinotransversal system** acts as a stabiliser according to the bow-tendon principle and, together with the short neck muscles, supports all movements of the cervical spine and the atlanto-occipital joints.

The **medial tract** is divided into a spinal system (Mm. interspinales, M. spinalis) and into a transversospinal system (Mm. rotatores breves, Mm. rotatores longi, M. multifidus, M. semispinalis). Functionally, the **spinal system** is important for extension and torsion; the **transversospinal system** stabilises and rotates to the contralateral side.

* spinotransversal system
** transversospinal system

Deep Muscles of the Back

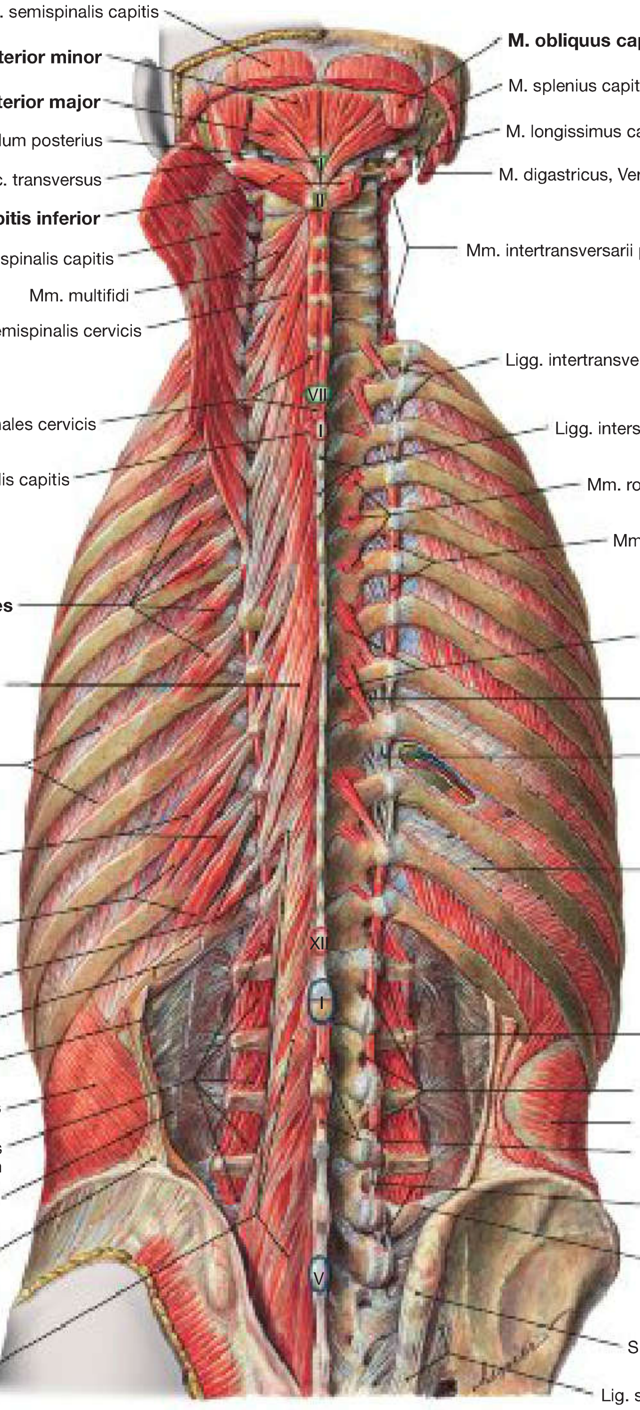


Fig. 2.74 Back muscles, Mm. dorsi and neck muscles, Mm. suboccipitales; dorsal view.
Upon removal of the Mm. splenius capitis and semispinalis capitis, the short neck muscles (Mm. rectus capitis posterior minor, rectus capitis posterior major, obliquus capitis superior, obliquus capitis inferior) become visible.
The Mm. levatores costarum, which are also depicted, are not assigned to the autochthonous back muscles, because they are innervated from the Rr. ventrales of the spinal nerve. Contraction of these muscles leads to a rotation on the contralateral side and to an inclination to the side on the ipsilateral side. Some authors also discuss the role this muscle group plays in inspiration. For the classification of the remaining depicted autochthoneous back muscles (→ Fig. 2.73).

→ T 18

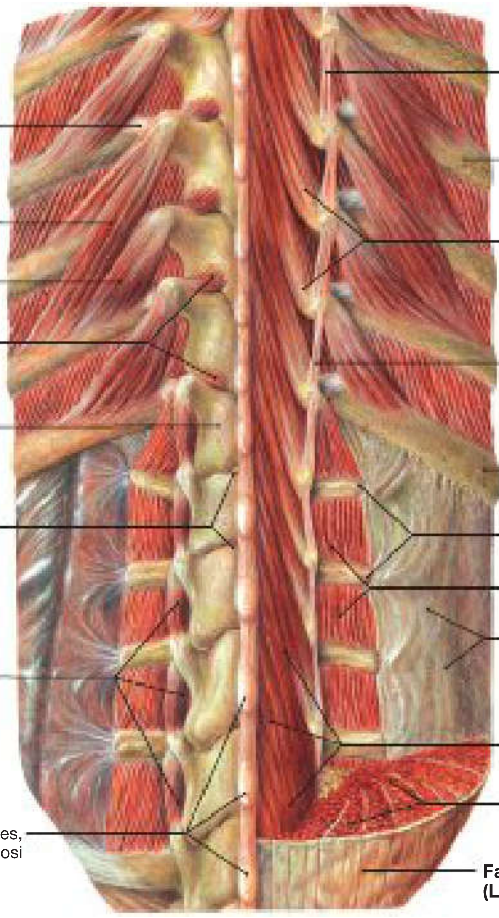
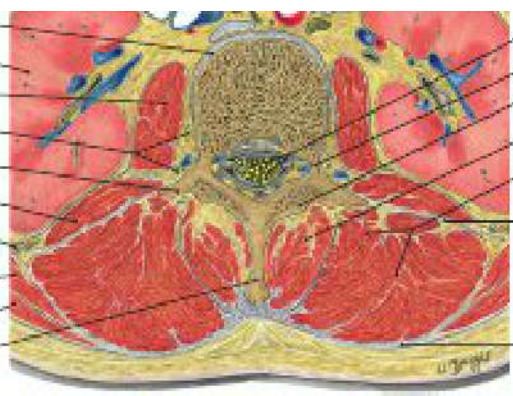


Fig. 2.75 Deep layer of the muscles of the back, Mm. dorsi, in the region of the lower thoracic and lumbar part of the vertebral column; dorsal view.
A cross-section through the M. erector spinae in the caudal region is shown on the right. On the medial side there is the Mm. multifidi, which belongs to the medial tract, and the superficial and deep layer of the Fascia thoracolumbalis. On the left side of the body the Mm. rotatores thoracis are visible.



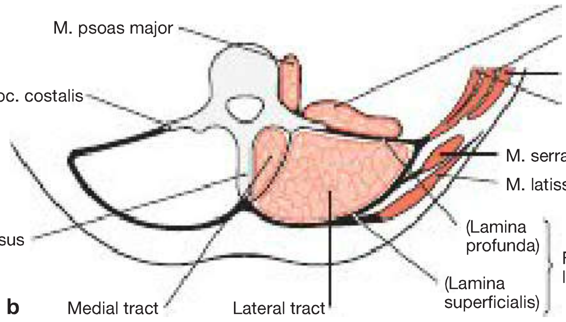


Fig. 2.76a and b Autochthonous back muscles (→ Fig. 2.76a) **and Fascia thoracolumbalis** (→ Fig. 2.76b); cross-section at the level of the 2nd lumbar vertebra; caudal view. (b [L126])
The autochthonous back muscles lie with their lateral (*) and medial tract (**) in an osteofibrous channel, which is enclosed from the inside by the dorsal vertebrae parts and from the outside by the Fascia thoracolumbalis. The latter is divided into a powerful superficial layer (Lamina superficialis) and a powerful deep fascia layer (Lamina profunda).

→ T 18

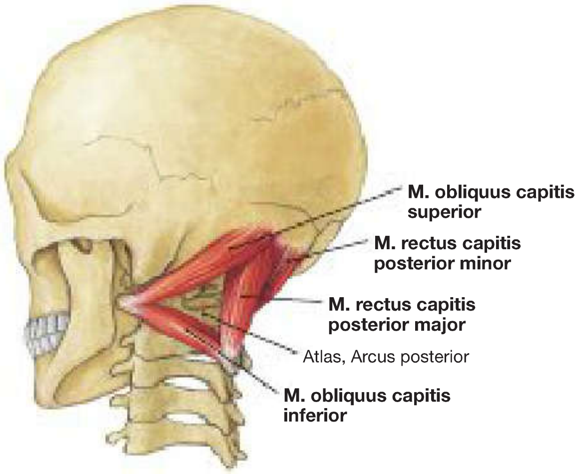


Fig. 2.77 Short neck muscles, Mm. suboccipitales; oblique dorsal view.
The Mm. rectus capitis posterior major, obliquus capitis superior, and obliquus capitis inferior together create a triangle **(vertebralis triangle).** The M. rectus capitis posterior minor is located medially to the M. rectus capitis posterior major. Functionally, the four muscles direct precise movements of the head joints (Articulationes atlantooccipitalis and atlantoaxialis) and perform minute adjustments of the head in the atlanto-occipital and atlantoaxial joint.

→ T 18

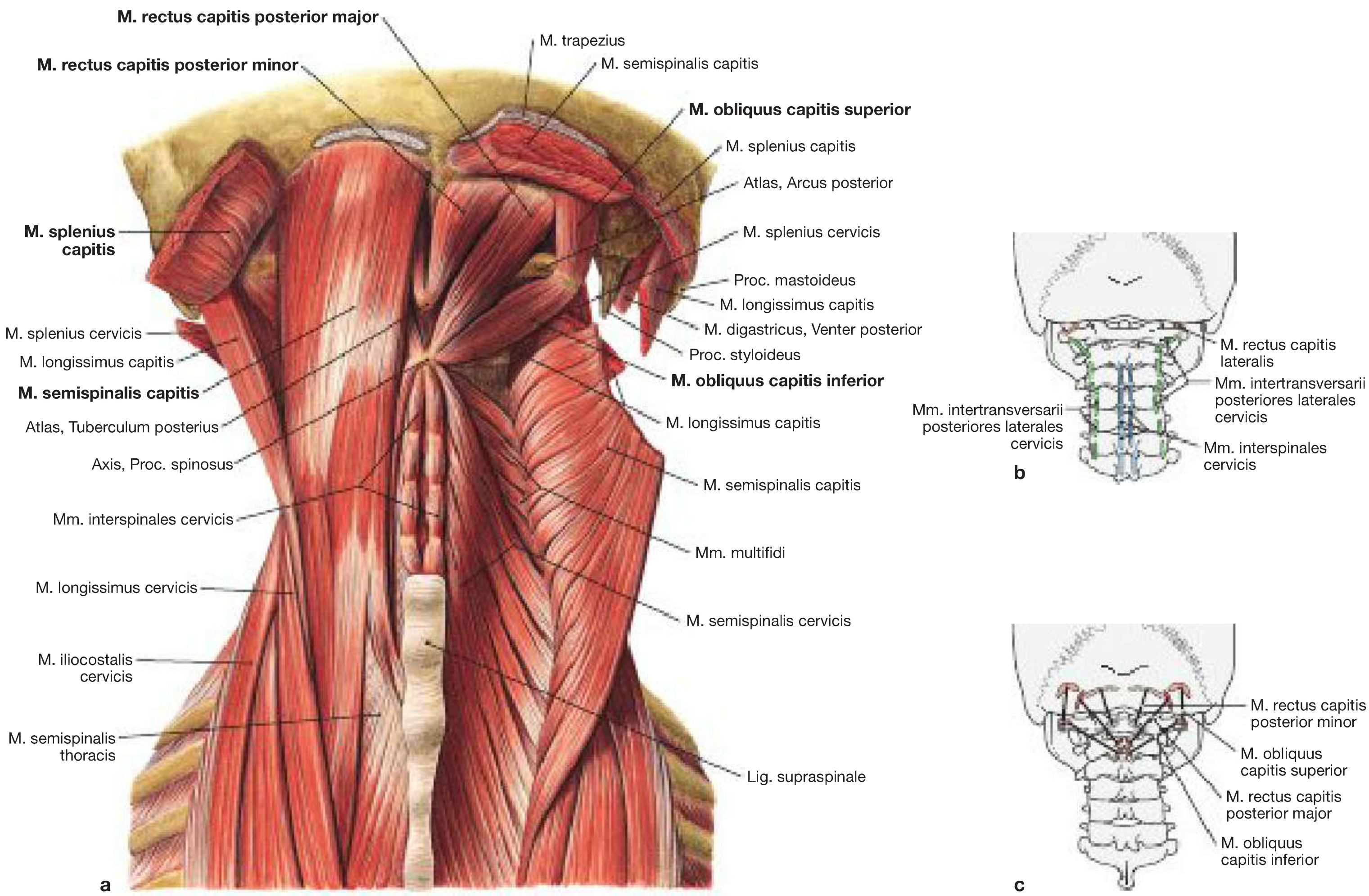


Fig. 2.78a to c Back muscles, Mm. dorsi, and neck muscles, Mm. suboccipitales; dorsal view. (b, c [L126])
a To view the short muscles of the neck, the Mm. splenius capitis and semispinalis capitis were removed on the right side. The M. rectus capitis posterior minor has its origin at the Tuberculum posterius of the atlas and starts medially at the Linea nuchalis inferior. The M. rectus capitis posterior major originates at the Proc. spinosus of the axis and starts laterally to the M. rectus capitis posterior minor at the inferior nuchal line. The M. obliquus capitis superior originates at the Proc. transversus of the atlas and starts above and laterally to the M. rectus capitis posterior major. The M. obliquus capitis inferior comes from the Proc. spinosus of the axis and starts at the Proc. transverse of the atlas.
b Position of the short neck muscles and **c** of the short head joint muscles (Mm. suboccipitales) with origin and insertion points.

→ T 18

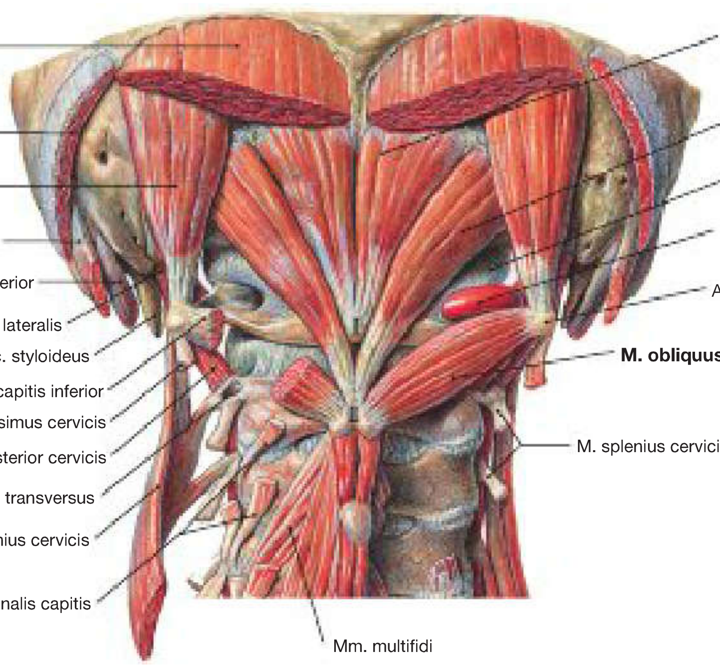


Fig. 2.79 Neck muscles, Mm. suboccipitales; dorsal view.
The Mm. rectus capitis posterior major, obliquus capitis superior, and M. obliquus capitis inferior all border the vertebralis triangle **(Trigonum arteriae vertebralis).** The A. vertebralis crosses the Arcus posterior atlantis at the base of this triangle.

I = Tuberculum posterius of the atlas
II = Proc. spinosus of the axis

→ T 18

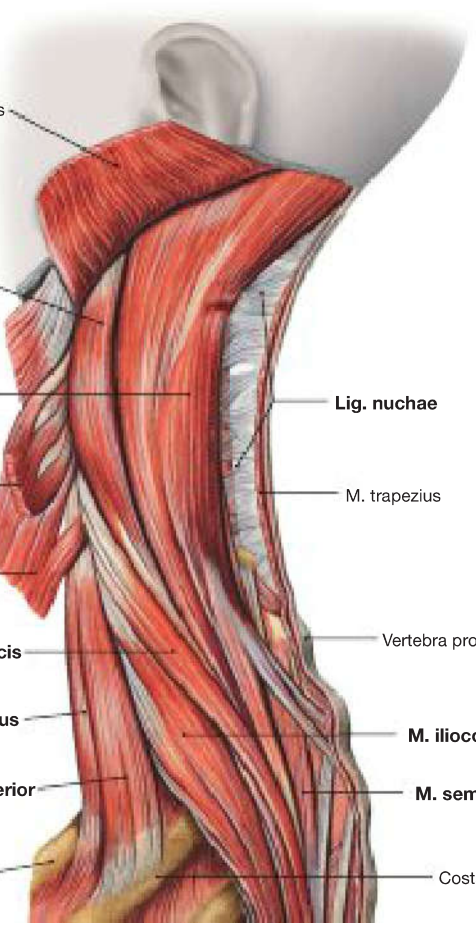


Fig. 2.80 Back muscles, Mm. dorsi, and neck muscles, Mm. colli; view from the left side.
Upon dissection of the M. splenius capitis (the rest displaced cranially), the lateral view of the neck reveals from anterior to posterior the Mm. scalenus medius and posterior as well as autochthonous muscles of the back with the lateral (Mm. iliocostalis cervicis, longissimus cervicis, splenius cervicis, longissimus capitis) and medial (Mm. semispinalis thoracis, semispinalis capitis) tract. After removal of the superficial back muscles in the neck area, the Lig. nuchae and remnants of the M. trapezius can be seen in the midline.

→ T 18

Thoracic and abdominal Wall Muscles

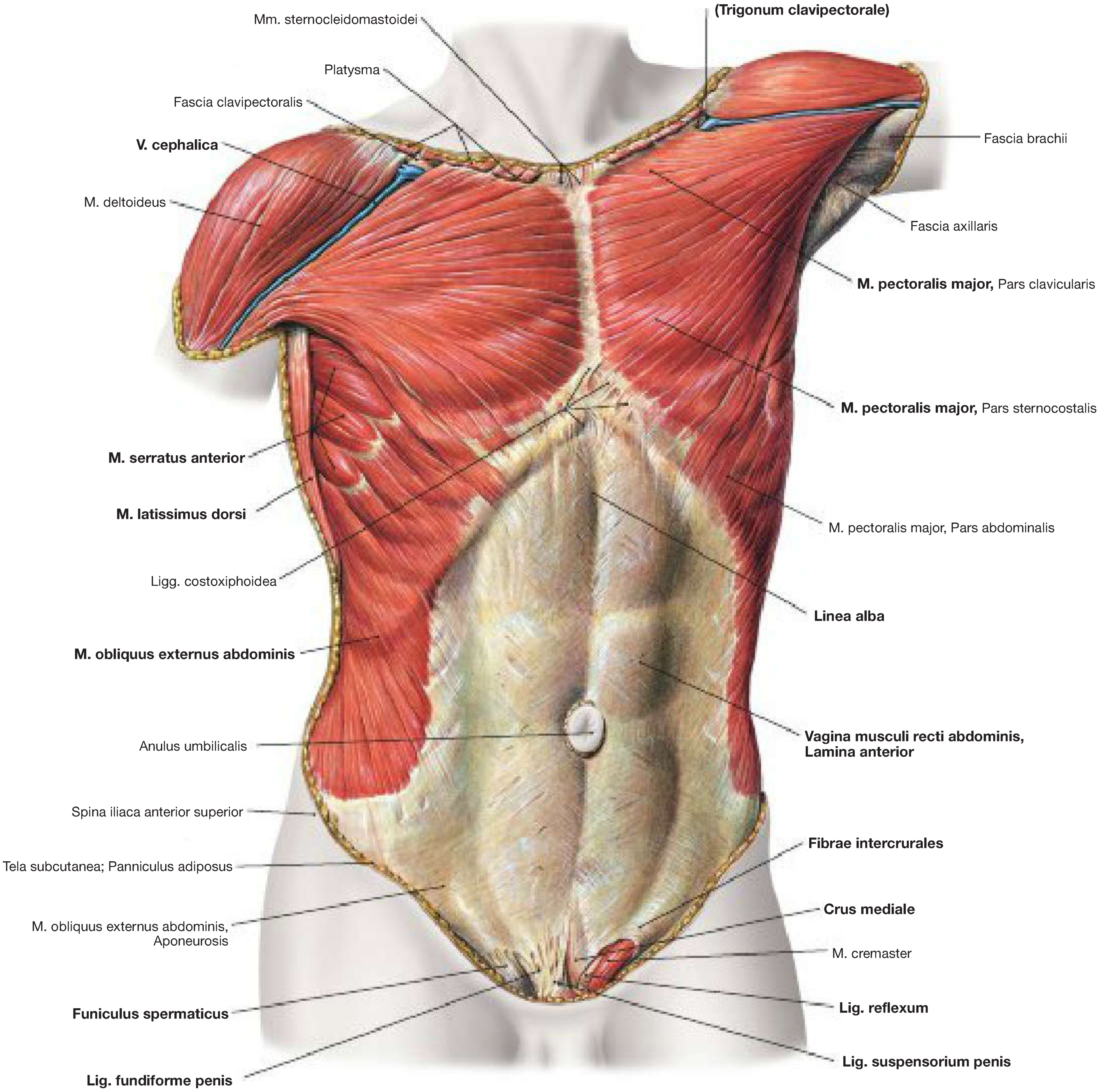


Fig. 2.81 Surperficial layer of the muscles of the thoracic and abdominal wall, Mm. thoracis and Mm. abdominis; ventral view.

The V. cephalica runs on the border between M. deltoideus and M. pectoralis major to the Trigonum clavipectorale (MOHRENHEIM fossa) where it leads deeply into the V. axillaris. The lower margin of the M. pectoralis major forms the anterior axillary fold and the anterior margin of the M. latissimus dorsi forms the posterior axillary fold; the M. serratus anterior forms the floor of the axilla.

The **M. pectoralis major** functionally participates in the anteversion (= flexion) of the arm in the shoulder joint and is also a strong adductor and rotates inwardly. It can also pull the shoulder forward and lower it when the arm is secured. In addition, it is an auxiliary muscle for inspiration.

In the abdominal region, the rectus sheath is formed by the aponeurosis of the oblique abdominal muscles. On the exterior we see the **M. obliquus externus abdominis,** which with its aponeurosis forms the outer surface of the rectus sheath.

In the midline, the aponeuroses merge in the linea alba. The caudal suspensory ligaments for the penis, Ligg. fundiforme and suspensorium penis, are shown. To the side, the Funiculus spermaticus is visible and on the opposite side the Anulus inguinalis superficialis with Crus mediale, Fibrae intercrurales and Lig. reflexum.

→T 15, 24, 25, 28

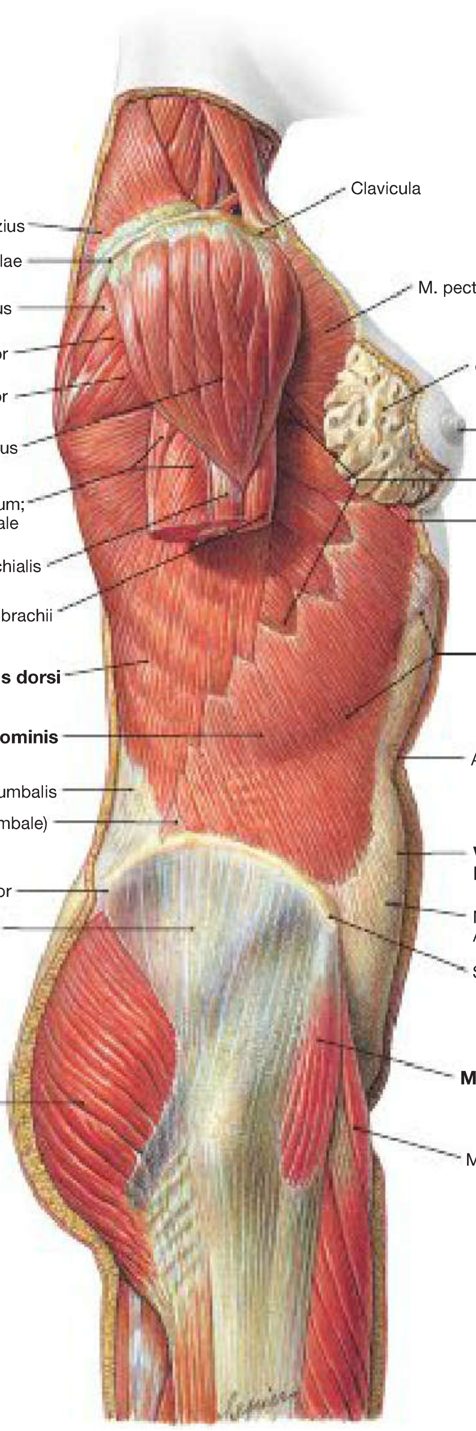


Fig. 2.82 Muscles of the thoracic and abdominal wall, Mm. thoracis und Mm. abdominis; view from the right side.
The lateral view shows the female breast (Mamma) which supports the M. pectoralis major. The lateral abdominal wall shows the muscular origins of the M. obliquus externus abdominis interlacing with those of the **M. serratus anterior.** Dorsally, the M. latissimus dorsi covers it.
The **M. obliquus externus abdominis** extends from lateral upper back to medial front lower. The fibres coming from the lower ribs run almost perpendicular to the Labium externum of the Crista iliaca. The remaining fibres pass to the ventral trunk wall into a sheet-like layer of aponeurosis, which is involved in the structuring of the rectus sheath (Vagina musculi recti abdominis). On the upper thigh, you can see the Fascia glutea, as well as the **Mm. gluteus maximus** and **tensor fasciae latae** radiating into the iliotibialis tract.

→ T 24, 25, 27, 28

Thoracic and Thoracic Wall Muscles

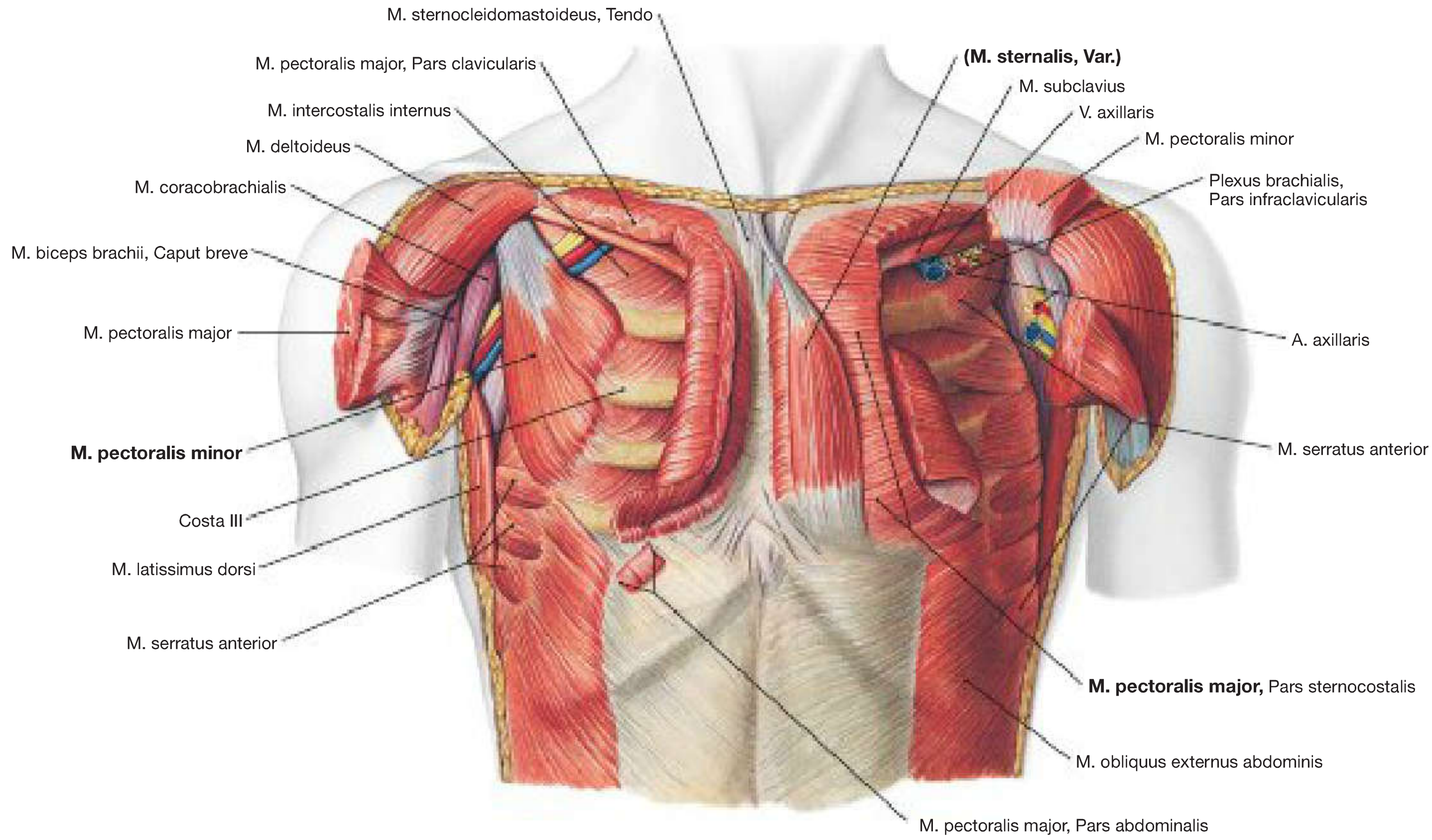


Fig. 2.83 Muscles of the thoracic wall, Mm. thoracis; ventral view. The M. pectoralis major was removed on both sides, as well as the M. pectoralis minor on the left side. On the right side of the body, the course of the neurovascular bundle to the upper extremity is visible below the M. pectoralis minor. Although the **M. pectoralis minor** is considered a muscle of the shoulder, it does not start at the upper extremity but at the Proc. coracoideus. The M. pectoralis minor originates from ribs III to V and participates in depression and rotation of the scapula. It is not at all uncommon for a very variable M. sternalis to appear on the M. pectoralis major.

→ T 13, 15, 24

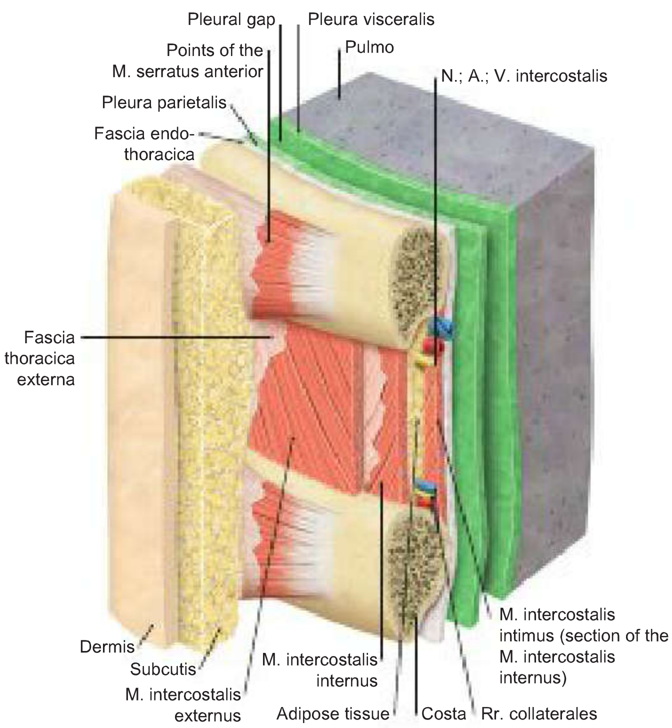


Fig. 2.84 Muscles and structure of the thoracic wall, Mm. thoracis; representation of an intercostal space. [L127]
The thoracic wall is formed from the outside to the inside: Cutis/Subcutis, Fascia musculi serrati, M. serratus anterior, Fascia thoracica externa, M. intercostalis externus, M. intercostalis internus, M. intercostalis intimus (as part of the M. intercostalis internus), Fascia intercostalis interna (not shown, → Fig. 2.85), Fascia endothoracica, Pleura parietalis. The pleural gap and the Pleura visceralis connect to the Pleura parietalis, which covers the lungs. The N., A. and V. intercostalis run below the ribs into the Sulcus costae from the outside to the inside, with the much smaller Rr. collaterales running above the ribs.

→ T 13

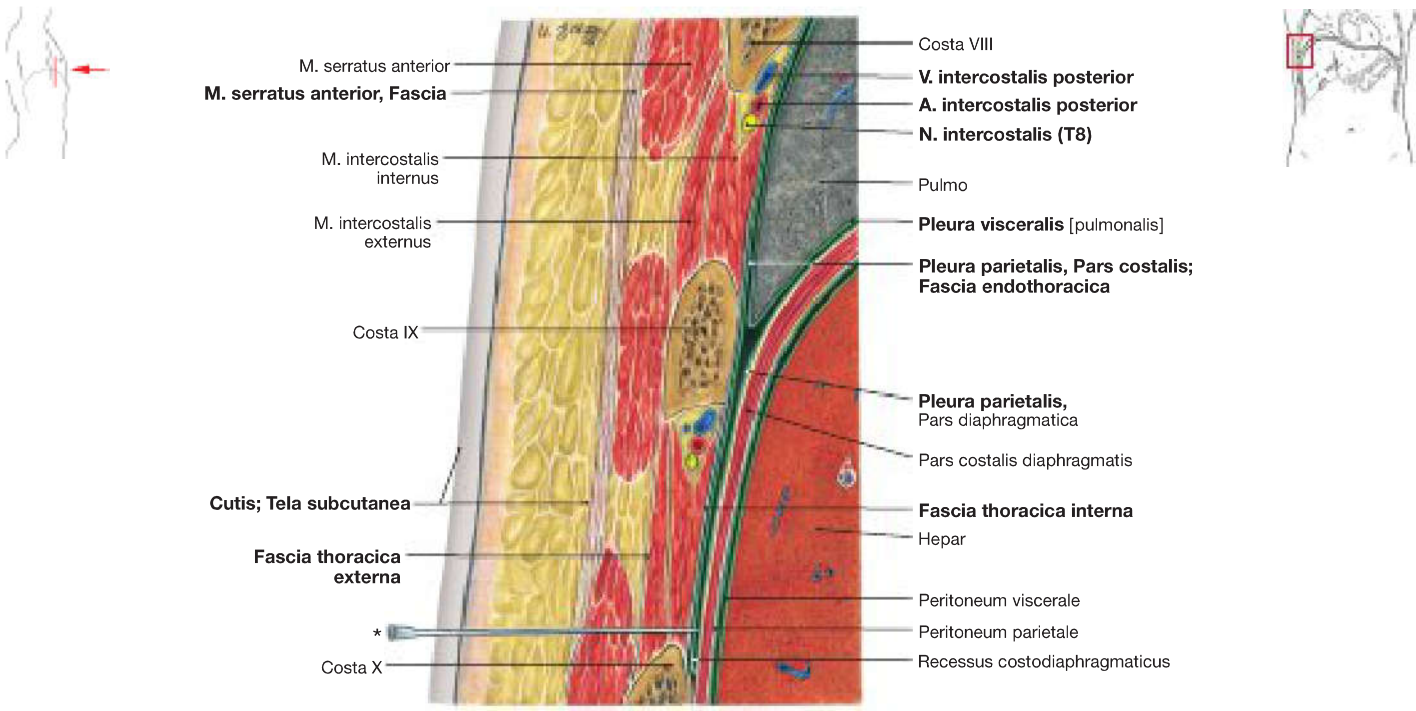


Fig. 2.85 Muscles of the thoracic wall, Mm. thoracis; frontal section through two intercostal spaces.
The M. intercostalis internus, with its innermost part (M. intercostalis intimus), is enveloped in a real muscle fascia, which is known as the Fascia thoracica interna. This borders on the Fascia endothoracica towards the thoracic cavity, with the Fascia endothoracica are lying between the Fascia thoracica interna and the Pleura parietalis.

* position of the needle during pleural puncture

– Clinical Remarks

In the case of a pleural effusion, a tap of the gap space **(pleural puncture) is conducted** between the pleura layers, which cover ribs (Pleura parietalis) and lungs (Pleura visceralis). There are a few variations for the diagnostic puncture (for obtaining material, e.g. in the case of inflammation) and therapeutic puncture (e.g. for relief and recovery of good ventilation). In the pleural puncture the following structures are pierced: Cutis/Subcutis, Fascia musculi serrati, M. serratus anterior, Fascia thoracica externa, M. intercostalis externus, M. intercostalis internus, Fascia thoracica interna, Fascia endothoracica, Pleura parietalis. The pleural puncture is always carried out on the top edge of the rib, because the neurovascular pathways run just below the rib (V., A. and N. intercostalis).

Thoracic Wall Muscles

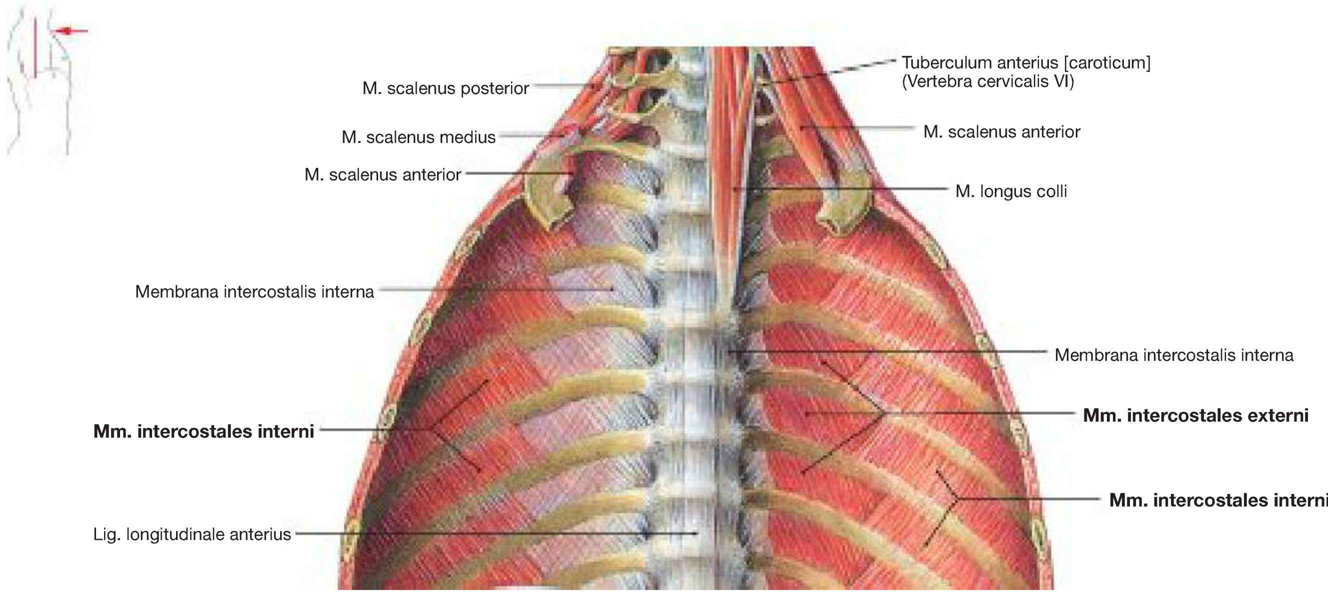


Fig. 2.86 Posterior wall of the thoracic cavity, Cavea thoracis; ventral view.
The **Mm. intercostales externi** run from behind and above to the front and below. They initiate at the Tubercula costarum and extend forwards to the parasternal cartilage transfer (not visible). These muscles act together with the Mm. intercartilaginei (not shown) by elevating the ribs during inspiration.
The **Mm. intercostales interni** pull from behind and below towards the top and the front. They initiate at the Angulus costae and run to the sternum (not visible). They act by **depressing the ribs** in expiration. One exception is the sections running between the cartilaginous portions of the ribs (Mm. intercartilaginei), which support inspiration. The muscular elements of the Mm. intercostales interni stretching across multiple segments, known as the Mm. subcostales and serving the same function as the Mm. intercostales interni, are not shown.

→ T 11–13

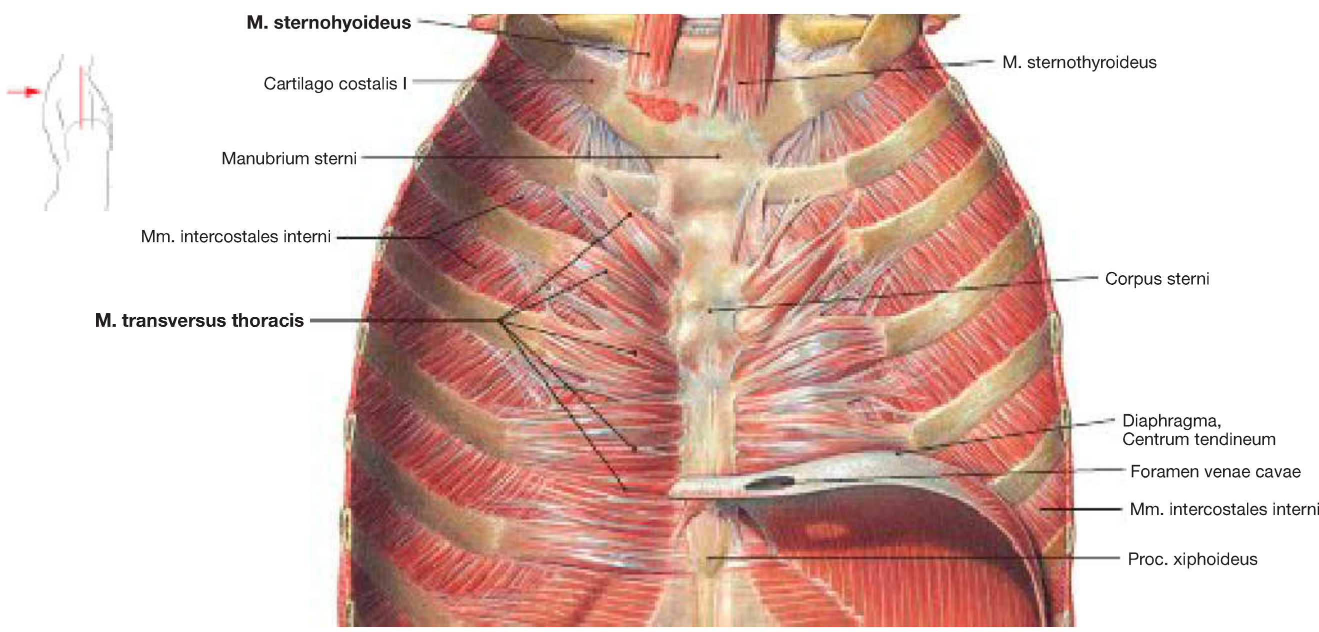


Fig. 2.87 Anterior wall of the thoracic cavity, Cavea thoracis; dorsal view.
The view of the inner wall of the front thoracic cavity next to the sternum shows the cluster of the **M. transversus thoracis.** They originate at the lateral side of the sternum and of the Proc. xiphoideus and start on the inside of the 2^{nd} to 6^{th} rib cartilage. They act as **expirators.** The M. sternothyroideus and the M. sternohyoideus originate on the back of the manubrium sterni.

→ T 13

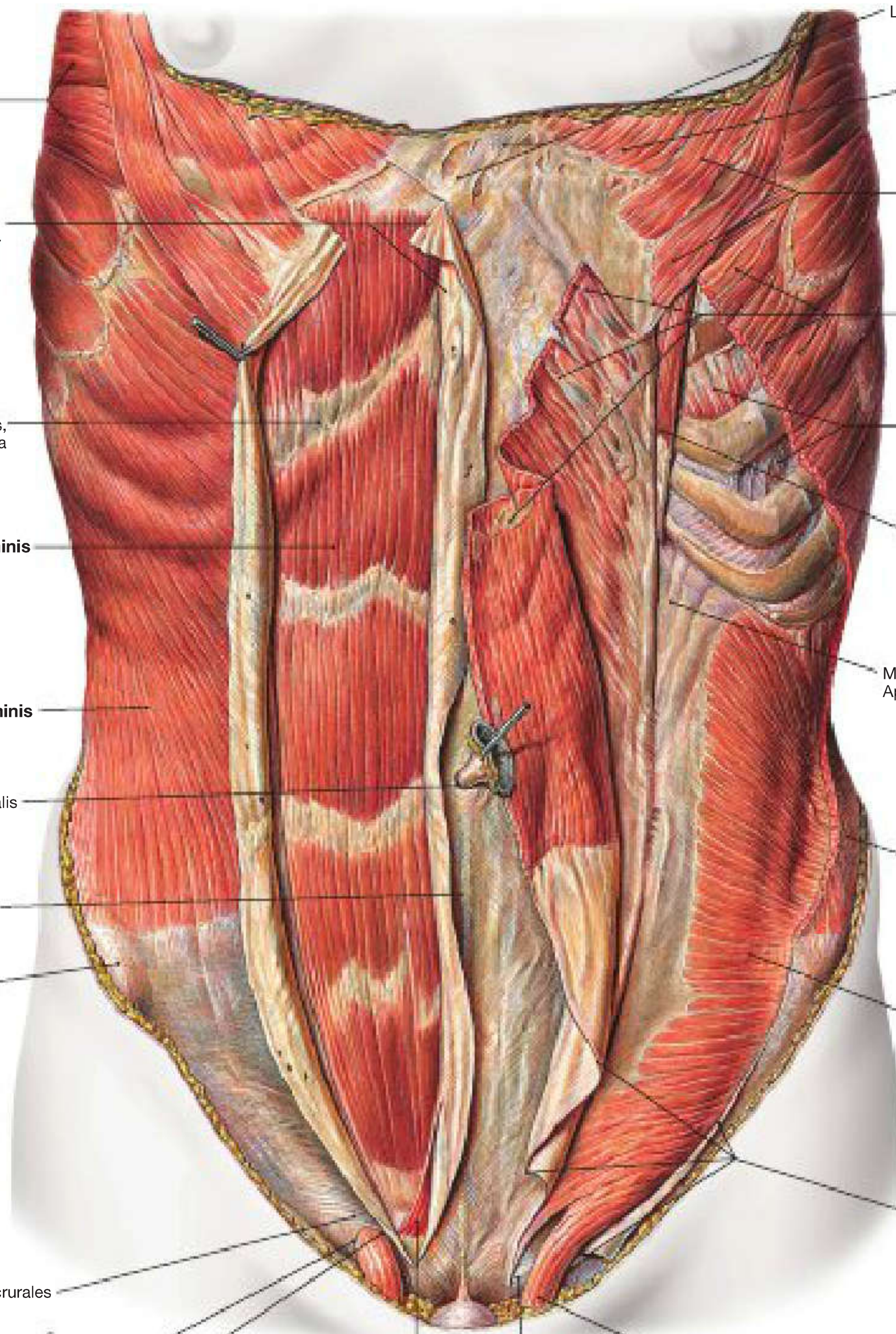


Fig. 2.88 Superficial and middle layer of the abdominal muscles, Mm. abdominis; ventral view.

On the right side, the superficial layer (Lamina anterior) of the rectus sheath (Vagina musculi recti abdominis) opens up. You can see the underlying **M. rectus abdominis**. It is interrupted by three to four Intersectiones tendinei, which as a result of extensive training can structure the so-called six-pack. The muscle located in the rectus sheath is used for trunk flexion and lateral flexion. In the caudal part of the rectus sheath we see the small triangular **M. pyramidalis,** which originates from the Os pubis and projects into the Linea alba. The M. pyramidalis resembles a rudimentary pouch (from a comparative anatomical standpoint, the kangaroo possesses a strongly developed M. pyramidalis).

On the left side, the **M. obliquus externus abdominis** is removed and medially folded above the rectus sheath. The largest part passes into an aponeurosis, which helps form the superficial layer (Lamina anterior) of the rectus sheath. It plays a functional part when bending forward, to the side and when twisting the upper body, and acts as an oblique brace and as abdominal wall tension. Together with the muscle on the opposite side, as well as the Mm. obliqui interni and transversi abdominis, it forms a functional collective.

→ T 13–15, 24

Abdominal Muscles

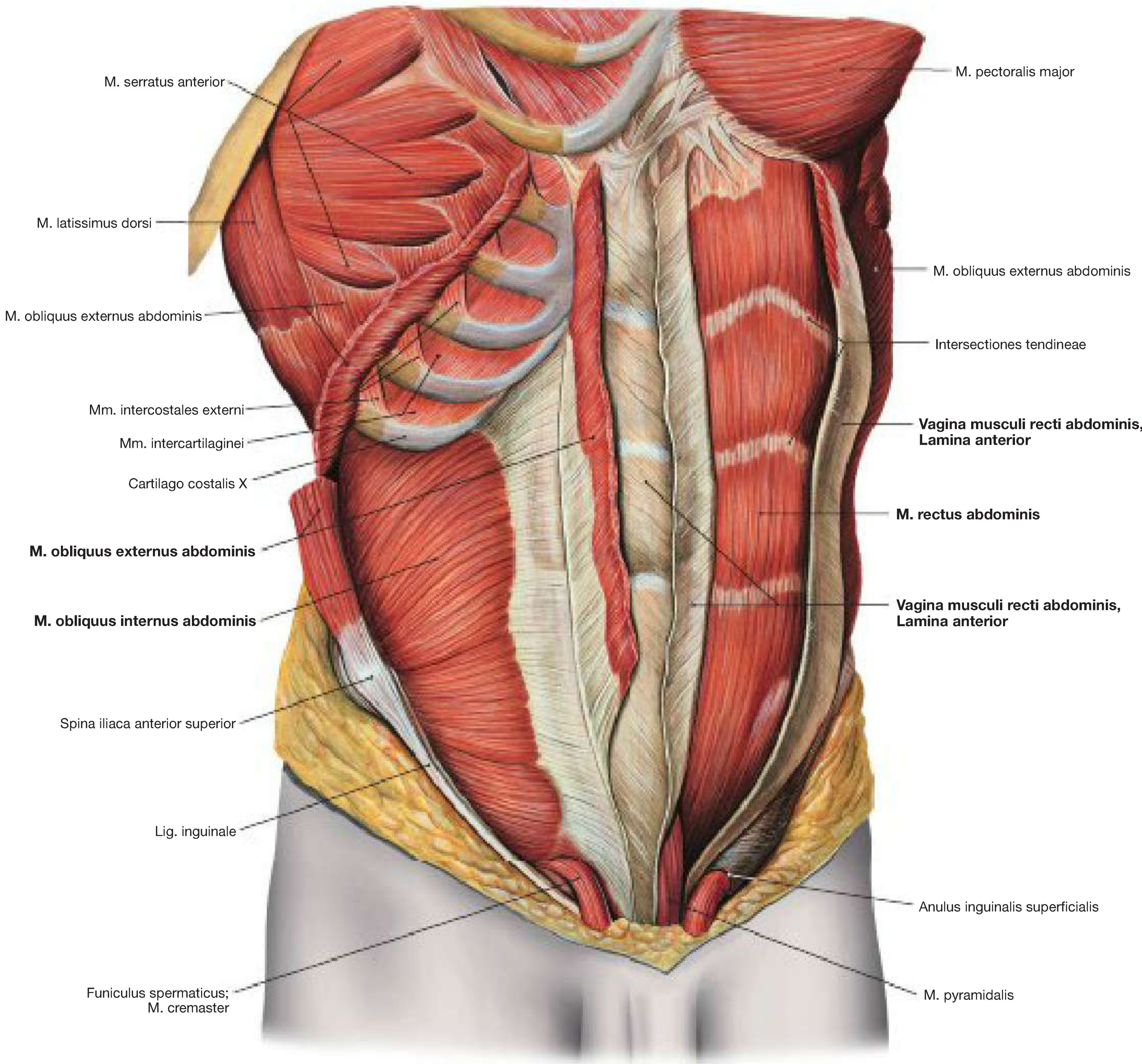


Fig. 2.89 Middle layer of the abdominal muscles, Mm. abdominis; ventral view.

On the right side, the M. obliquus externus abdominis has mostly been removed. Underneath you can see the **M. obliquus internus abdominis.** Its aponeurosis is involved in the construction of both the superficial (Lamina anterior) as well as the deep (Lamina posterior) layer of the rectus sheath. The M. obliquus internus abdominis extends from lateral caudal to cranial medial. As in the M. obliquus externus abdominis it acts as an oblique brace and as abdominal wall tension and plays a functional part when bending forward, to the side and when twisting the upper body.

→ T 13–15, 24

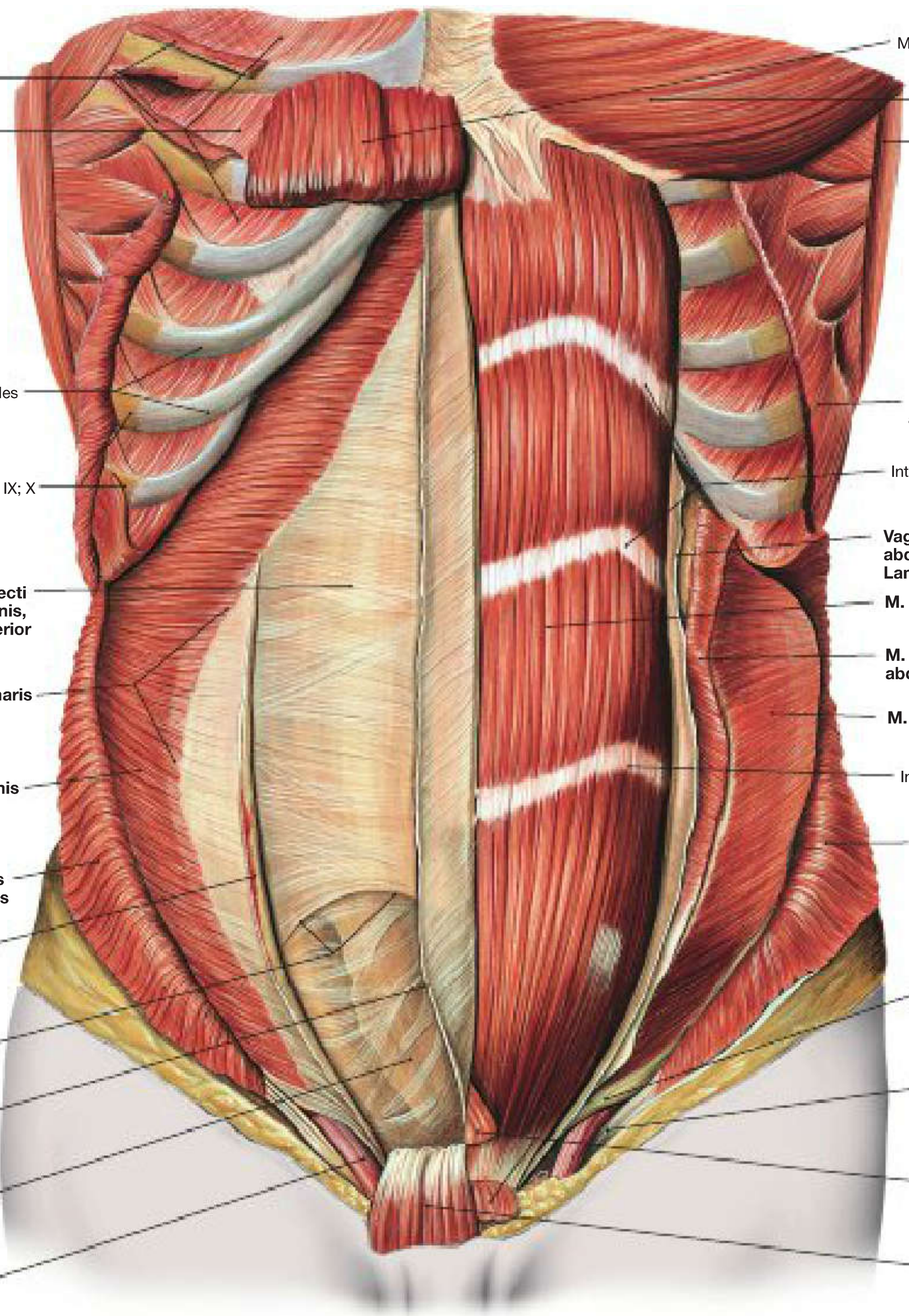


Fig. 2.90 Deep layer of the abdominal muscles, Mm. abdominis; ventral view.

On the right side of the abdomen, the M. transversus abdominis is visible. In addition, the front layer (Lamina anterior) of the rectus sheath (Vagina musculi recti abdominis) has been removed and the M. rectus abdominis has been separated from the rectus sheath.

In the area of a crescent-shaped line (Linea semilunaris), the muscle fibres of the **M. transversus abdominis** insert into the aponeurosis, which for the most part forms the posterior wall of the deep layer (Lamina posterior) of the rectus sheath. Caudally of the Linea (Zona) arcuata, the aponeurosis participates in the formation of the Lamina anterior of the rectus sheath (→Fig. 2.93). The aponeurosis radiates into the Linea alba. Functionally, the M. transversus abdominis is mainly involved in the so-called stomach crunch and supports forced expiration.

The deep layer (Lamina posterior) of the rectus sheath is formed in the upper section (from the sternum to the Linea [Zona] arcuata) from a part of the aponeurosis of the M. obliquus internus abdominis and the aponeurosis of the M. transversus abdominis. Underneath (from the Linea arcuata to the Os pubis), the Lamina posterior only consists of the Fascia transversalis and Peritoneum parietale.

→T 13–15

– Clinical Remarks

A rare **SPIEGHELIAN hernia** can occur at the lateral margin of the Linea arcuata which borders the Linea semilunaris.

Surgical scars in the abdominal wall can be the starting point for **incisional hernias**.

Muscle Functions

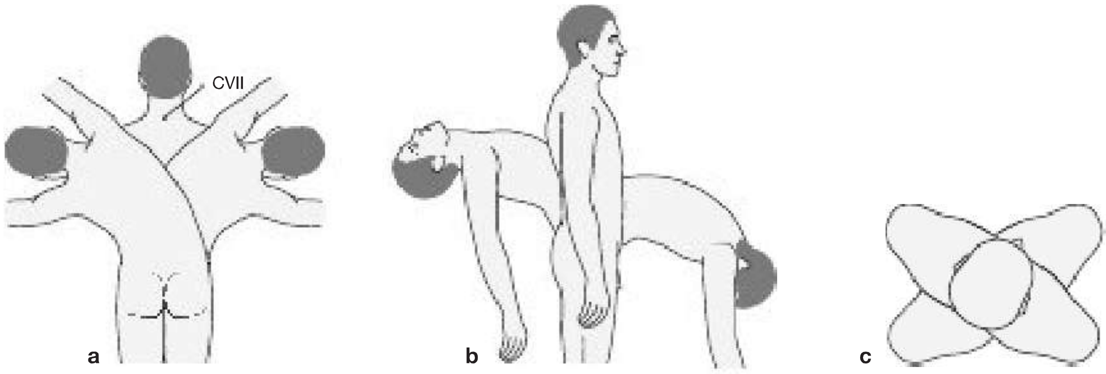


Fig. 2.91a to c Movement directions of the trunk. [L126]

a Side-bending (lateral flexion) of the trunk.

Bending to both sides up to 40° is usually normal (0°/40°). Vertebra prominens (CVII) and SI serve as reference points when determining the angle in the upright and maximal lateral flexion position. The lateral flexion of the trunk is supported by the Mm. obliquus externus abdominis, obliquus internus abdominis, quadratus lumborum, iliocostalis, psoas major, longissimus and splenius.

b Forward (flexion) and backward bending (extension) of the trunk in the vertebral joints.

The range of motion is between approximately 100° flexion und 50° extension. A straight line between the acromion of the scapula and the Crista iliaca of the femur is used to determine these angles. The forward flexion of the trunk is supported by the Mm. rectus abdominis, obliquus externus abdominis, obliquus internus abdominis and psoas major. The Mm. iliocostalis, psoas major, longissimus, splenius, spinalis, semispinalis, multifidus, trapezius, and levatores costarum bend the spine dorsally.

c Torsion of the trunk.

Bilateral anterior to posterior rotation of the trunk by approximately 40° is possible. A line connecting the acromion of the scapula on both sides serves as a reference axis. Ipsilateral rotation of the trunk is supported by Mm. obliquus internus abdominis, iliocostalis, longissimus and splenius. Rotation of the trunk to the contralateral side is achieved by the Mm. obliquus externus abdominis, semispinalis, multifidus, rotatores and levatores costarum.

The scope of movement of the individual sections of the spine is mainly limited by the vertebral joints. As for the entire vertebral column, bending forwards (flexion) and backwards (extension) at approximately 100°–0°–50°, side-bending (lateral flexion) of 0°/40°, and torsion (rotation) of 40°–0°–40° are possible; these serve as normal reference values to assess movement restrictions.

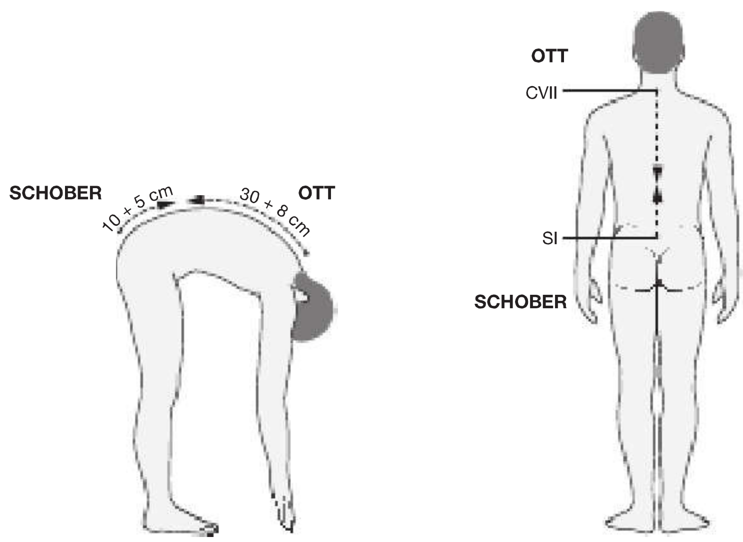


Fig. 2.92 Objective assessment of movement restrictions of the lumbar part of the vertebral column (method of SCHOBER) and the thoracic part of the vertebral column (the OTT sign). [L126]

Clinical Remarks

Method according to SCHOBER: To objectify movement restrictions of the lumbar spine, the patient is asked to stand upright and the examiner places his/her right thumb on the tip of the cranial part of the Crista sacralis mediana and the index finger of the same hand on the Proc. spinosus of a lumbar vertebra about a hand width (10 cm) above. With maximum flexion, the distance between the two points usually increases by 5 cm (4–6 cm).

OTT sign: The same applies to the OTT sign, which measuress the mobility in the area of the thoracic spine. The measuring section begins at the Proc. spinosus of the 7th cervical vertebra (Vertebra prominens) and leads 30 cm towards the tailbone. Again, the changes in the measurement distance (normally 8 cm) are retained after flexion.

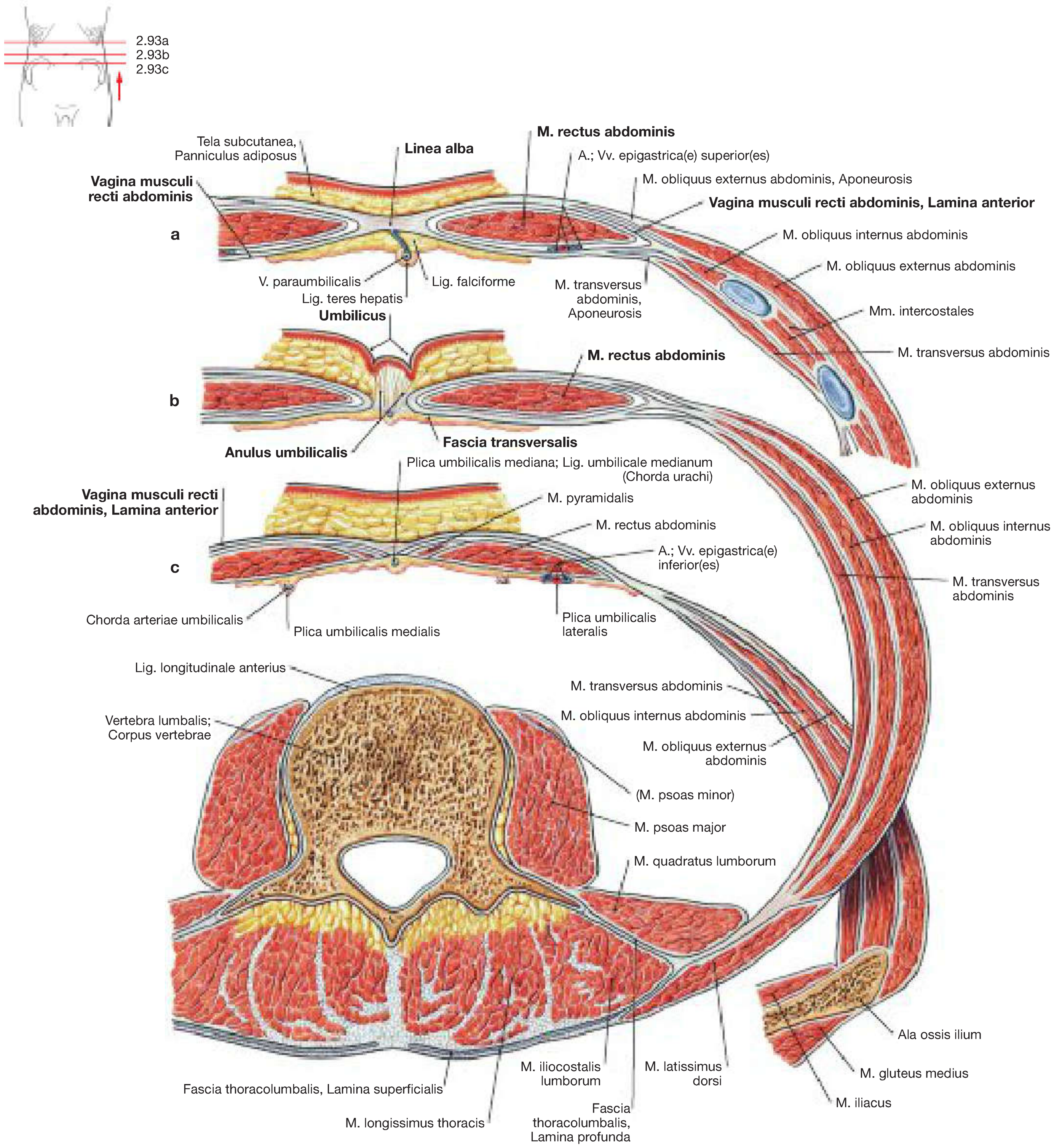


Fig. 2.93a to c Structure of the rectus sheath, Vagina musculi recti abdominis; horizontal sections; caudal view.

The Mm. rectus abdominis and pyramidalis are stored in a fixed connective tissue sheath (Vagina musculi recti abdominis), which is formed from the aponeurosis of the oblique abdominal muscles (Mm. obliquus externus abdominis, obliquus internus abdominis und transversus abdominis as well as the Fascia transversalis and the Peritoneum parietale on the inside of the abdominal wall). All aponeurosis radiate into the median-lying linea alba. The structure of the rectus sheath differs in the upper and lower section. The limit is the **Linea (Zona) arcuata.**

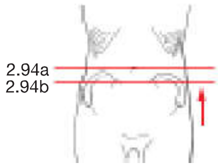
In the **upper section**, the anterior layer (Lamina anterior) of the rectus sheath is formed by the aponeurosis of the M. obliquus externus abdominis and the front portion of the aponeurosis of the M. obliquus internus abdominis; the posterior layer (Lamina posterior) consists of the posterior part of the aponeurosis of the M. obliquus internus abdominis, the aponeurosis of the M. transversus abdominis as well as the Fascia transversalis and the Peritoneum parietale (**a, b**).

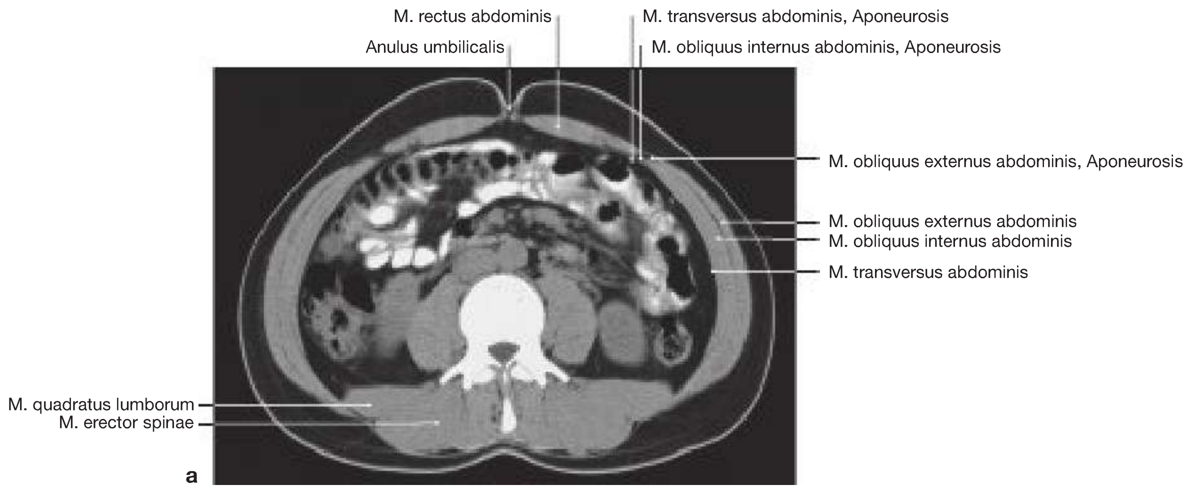
In the **lower section**, all three aponeuroses run in front of the M. rectus abdominis (**c**). The posterior side of the rectus sheath is very thin here and is formed exclusively by the Fascia transversalis and the Peritoneum parietale (→ Fig. 2.90).

The navel (umbilicus) is a potential weak spot on the anterior abdominal wall, which is thinner in the region of the umbilical pit and the Papilla umbilicalis than in other parts (**b**).

→ T 14–16, 18, 42

Abdominal Wall, CT





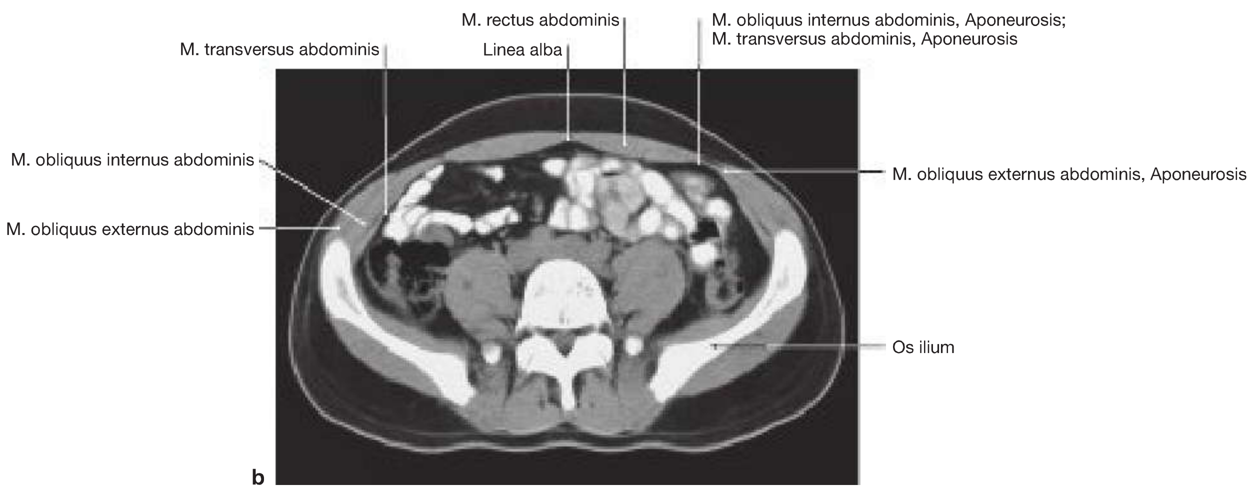


Fig. 2.94a and b Abdominal muscles, Mm. abdominis; ventral view; computed tomography (CT) cross-sections. [T893]
In the CT the oblique and the straight abdominal muscles can be separated from each other. The M. erector spinae and the M. quadratus lumborum are also clearly visible.

Clinical Remarks

Naval hernias occur in newborns and adults – in the case of newborns, the naval papilla is not yet developed; in adults it occurs through the spreading of the connective tissue of the naval papilla at extreme hyperextension of the abdominal wall (pregnancy, obesity). The hernial orifice is the umbilical ring (Anulus umbilicalis).

An **omphalocele** (congenital umbilical hernia) is a birth defect resulting in the persistence of the physiological umbilical hernia during the foetal period.

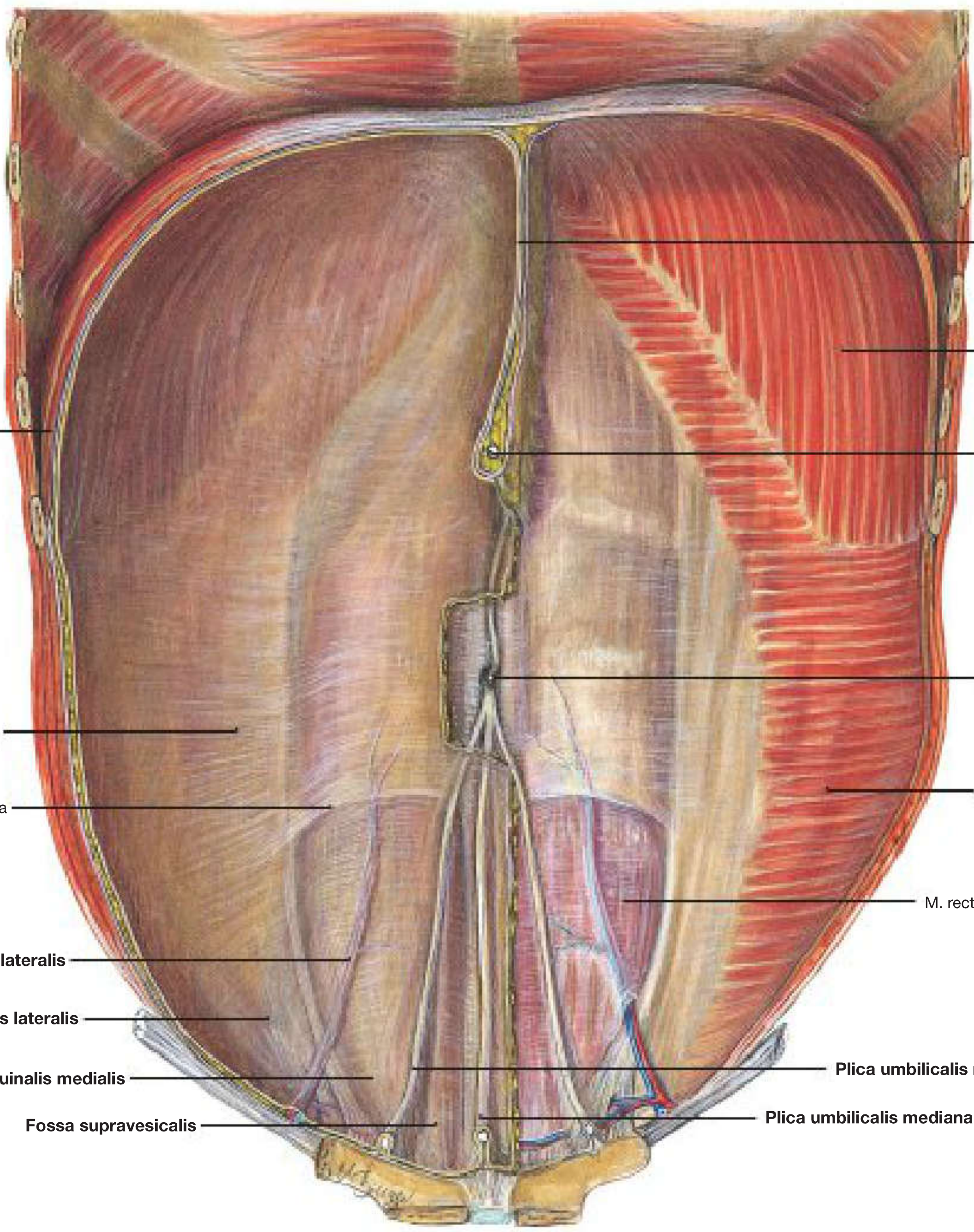


Fig. 2.95 Inside of the anterior abdominal wall; dorsal view. On the right side, the fascia and the peritoneum covering the diaphragm and the M. transversus abdominis have been removed.

On the inside of the abdominal wall, you can see different folds (Plicae), pits (fossae) and ligaments (Ligamenta). The **Lig. falciforme hepatis** (sickle-shaped band of liver) passes from the diaphragm and the liver at right angles to the side of the belly. It extends to the navel (Umbilicus), as it is a developmental remnant of the mesentery of the umbilical vein in the foetus. The umbilical vein itself closes up immediately after the birth and remains as a rounded connective tissue thread **(Lig. teres hepatis)** at the edge of the Lig. falciforme hepatis. Below the umbilicus, you can see the **Plica umbilicalis mediana** (containing the obliterated Urachus – original urinary tract, which extends from the crown of the bladder to the navel) and lateral thereof the **Plicae umbilicales mediales** (containing the obliterated Aa. umbilicales) and **laterales** (containing the Vasa epigastrica inferiora). Cavities (Fossae supravesicales, inguinal medial and lateral inguinal) form between the folds. The **Fossa inguinalis lateralis** corresponds to the inner inguinal ring located beneath; **Fossa inguinalis medialis** lies at the same level as the outer inguinal ring.

→ T 14, 15, 19

Diaphragm and Posterior Abdominal Wall

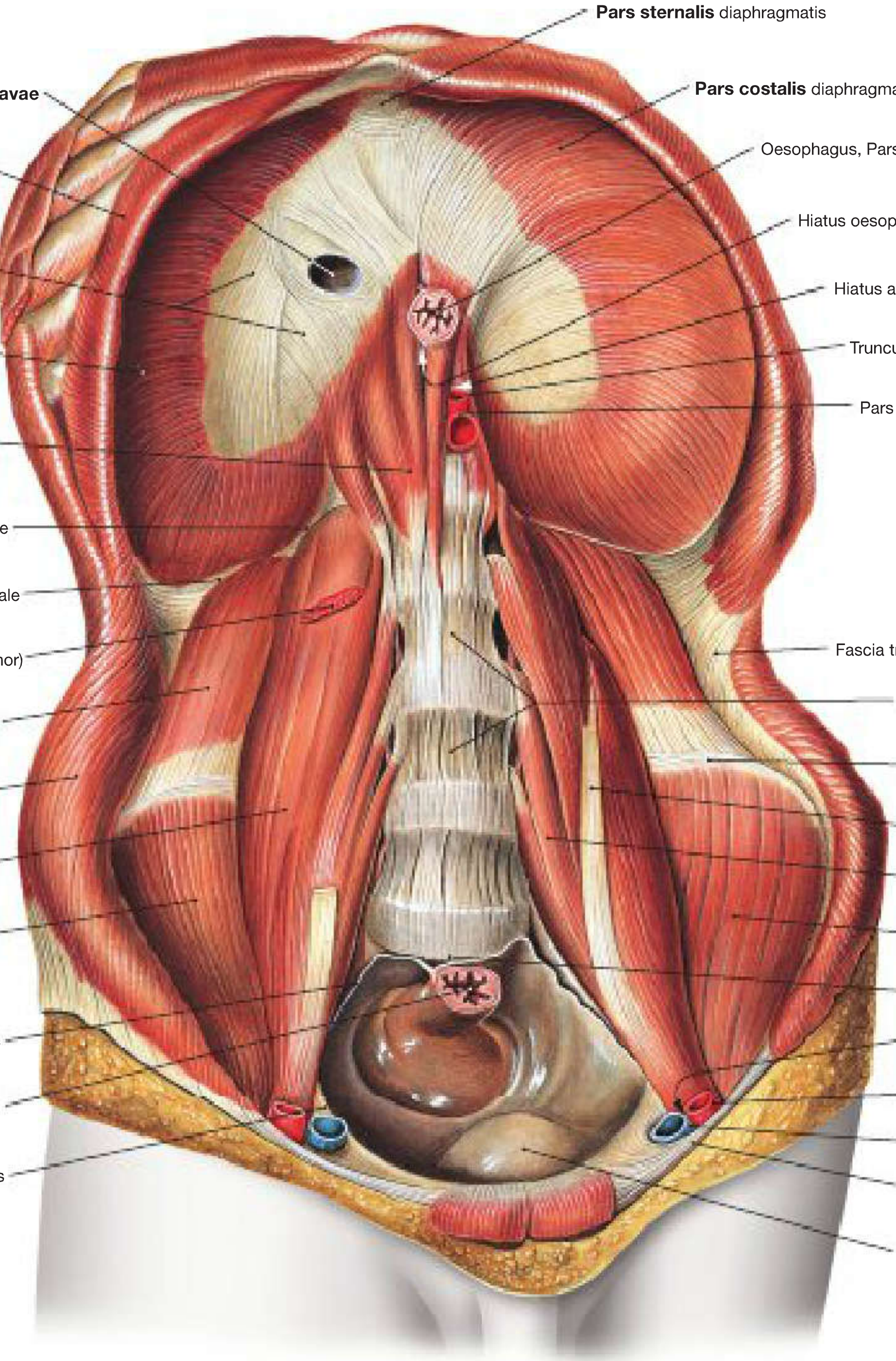


Fig. 2.96 Diaphragm, Diaphragma, and abdominal muscles, Mm. abdominis; ventral view.
The diaphragm is composed of a central tendon plate **(Centrum tendineum)** with attached muscles, which have their origin at the sternum (Pars sternalis), the ribs (Pars costalis), and the lumbar region of the vertebral column (Pars lumbalis).
After removal of the retroperitoneum, the paravertebral locations of the Mm. iliopsoas (composed of a M. psoas major und M. iliacus respectively), the M. quadratus lumborum, and, as a variant, the M. psoas minor are visible.
The **M. psoas major** originates together with the **M. iliacus**, which comes from the Fossa iliaca at the Trochanter minor of the femur and is the strongest flexor in the hip joint. It can guide the upper body from lying down into the sitting position and is involved in the lateral flexion of the trunk. The **M. quadratus lumborum** originates from the Labium internum of the Crista iliaca and starts at the XIIth rib as well as the Procc. costales of the 1st– 4th lumbar vertebra. It can lower the XIIth rib and is involved in the lateral flexion of the trunk.

* FALLOPIAN ligament or POUPART ligament

→ T 15, 16, 19, 42

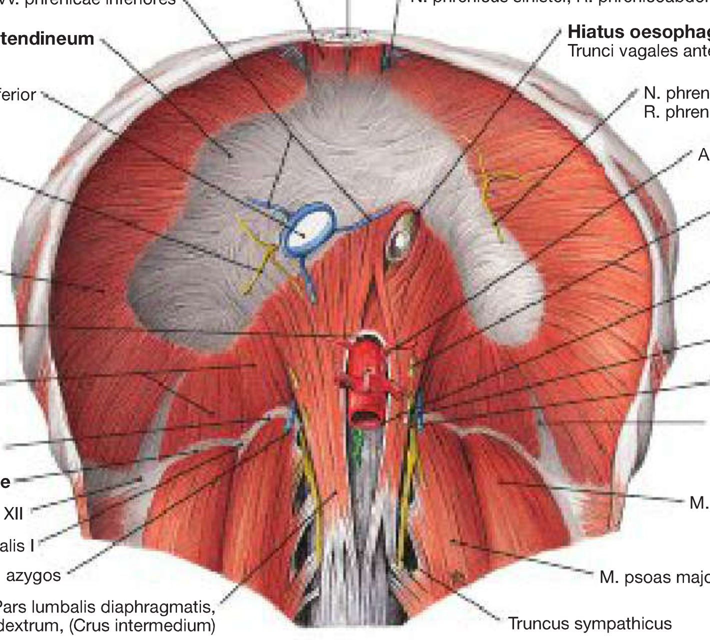


Fig. 2.97 Diaphragm, Diaphragma; caudal view. [L240]
The diaphragm is divided into the Centrum tendineum, as well as into the Partes sternales, costales and lumbales. The **Trigonum sternocostale** lies between the Pars sternalis und Pars costalis and the **Trigonum lumbocostale** (BOCHDALEK triangle) between the Pars costalis and Pars lumbalis. The usual guidance that the Vasa thoracica interna passes through the Trigonum sternocostale, is incorrect. The vessels run ventrally in front of the Trigonum sternocostale.

→ T 19

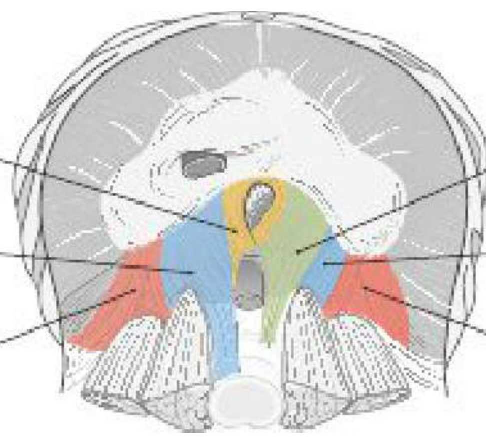


Fig. 2.98 Diaphragm, Diaphragma; caudal view. [L126]
Coloured presentation of the diaphragm leg on the right side (Crus dextrum) and left side (Crus sinistrum). Each diaphragm leg is divided into Crus mediale (right: yellow, left: green), crus intermedium (light blue) and crus lateral (red). The Crus dextrum is affixed to the lumbar vertebrae bodies L1–L3 and the intervening intervertebral discs, the Crus sinistrum to the lumbar vertebrae L1 and L2 and the intervening discs. The Crus mediale dextrum forms a loop around the esophagus (Hiatus oesophageus). Right and left diaphragm legs are connected via the spine through a tendon arch (Hiatus aorticus), which runs behind the aorta. Above the M. psoas major, the diaphragm forms the Lig. arcuatum mediale (psoas arcade), and above the M. quadratus lumborum it forms the Lig. arcuatum laterale (quadratus arcade).

Diaphragm

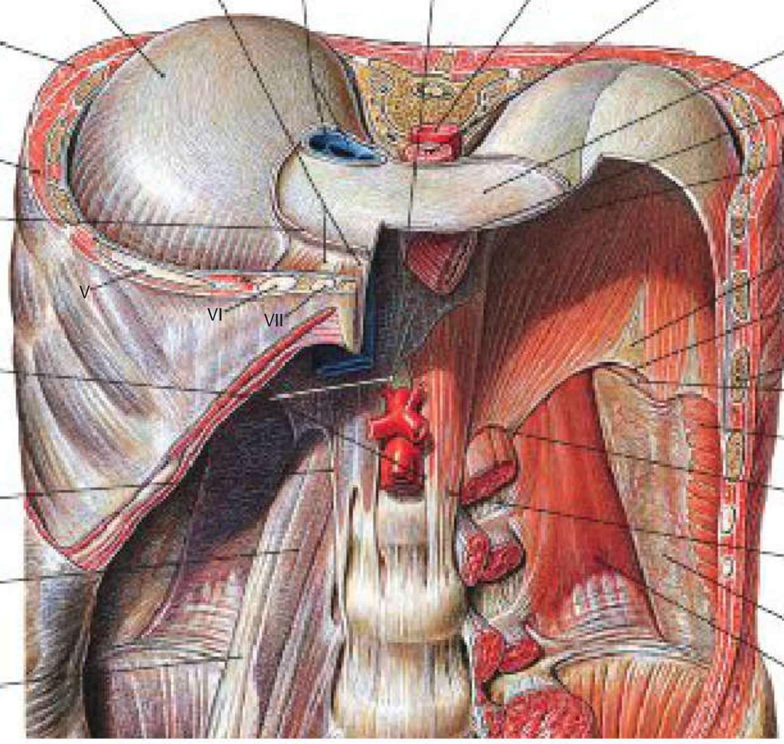


Fig. 2.99 Diaphragm, Diaphragma, passageways and posterior abdominal wall muscles; ventral view.
The diaphragm is a double dome-shaped expansion between the thoracic and abdominal cavity (→ Fig. 2.96 and → Fig. 2.100).

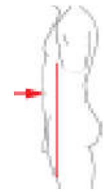
* clinical term: BOCHDALEK triangle
** quadratus arcade
*** psoas arcade (Lig. arcuatum mediale)

→ T 19

Clinical Remarks

Diaphragmatic hernias are classified as congenital (Hernia diaphragmatica spuria) and acquired (Hernia diaphragmatica vera). If the shifted organs are covered by a peritoneum (hernial sac), one speaks of real hernias.
The **congenital** form is usually presented as a gap in the diaphragm through which abdominal organs (stomach, intestine, liver, spleen) can pass into the thorax. Congenital hernias (usually the physiological weaknesses of the diaphragm in the Trigonum sterno or lumbocostale [MORGAGNI hernia] are affected) often have no hernial sac.

Acquired diaphragmatic hernias are usually sliding hernias or paraoesophageal hiatus hernias (→ Fig. 2.101). In a **hiatal hernia** the stomach partially passes through the slit-shaped opening of the diaphragm for the passage of the oesophagus (oesophageal hiatus). In the axial **sliding hernia** the cardia is pulled up through the diaphragm into the thoracic cavity.
In addition, there are **mixed forms**. An especially severe form is the **upside-down stomach** (thoracic stomach, where large parts of the stomach have slipped into the thoracic cavity).



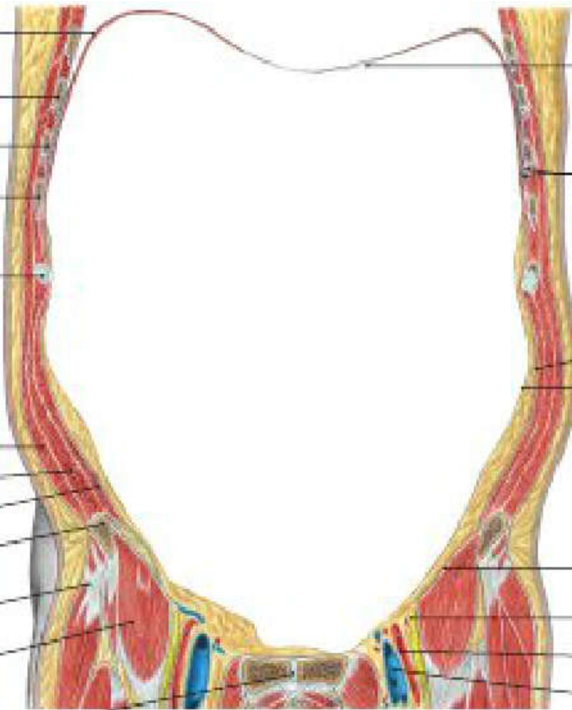


Fig. 2.100 Diaphragm, Diaphragma, and oblique muscles of the abdominal wall, Mm. abdominis; frontal section; ventral view. [L238]
The illustration shows the dome-shaped expansion of the thin diaphragm. The Partes costales originate from the side of the IXth rib and radiate into the Centrum tendineum. The diaphragmatic domes are positioned between the 5th and 6th intercostal spaces during normal breathing. The lateral abdominal wall is formed by the oblique abdominal muscles (Mm. obliquus externus abdominis, obliquus internus abdominis and transversus abdominis).

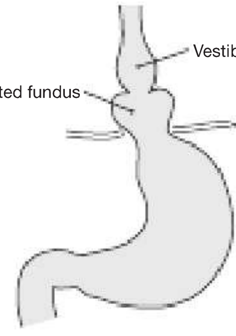


Fig. 2.101a and b Axial (sliding hernia) (a) and paraoesophageal hiatus hernia (b); schematic drawing. [S008-3]

Arteries of the Ventral Trunk Wall

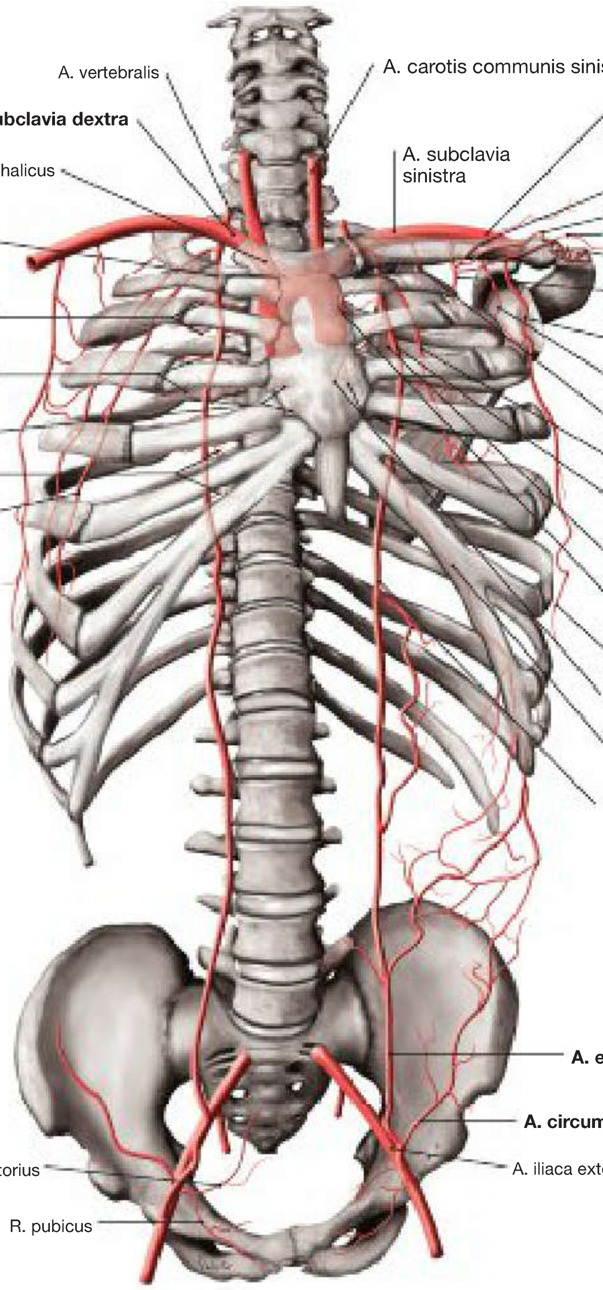


Fig. 2.102 Arteries of the ventral wall of trunk. [L266]
The ventral wall of the trunk is supplied with blood from branches of the Aa. subclavia, axillaris, iliaca externa and femoralis. The muscles of the abdominal wall receive blood through segmentally arranged Aa. lumbales derived from the Aorta abdominalis (not shown).

* clinical term: A. mammaria interna

Branches of the A. thoracica interna

- Rr. mediastinales
- Rr. thymici
- Rr. bronchiales
- Rr. tracheales
- A. pericardiacophrenica
- Rr. sternales
- Rr. perforantes
  - Rr. mammarii mediales
- Rr. intercostales anteriores
- A. musculophrenica
- A. epigastrica superior

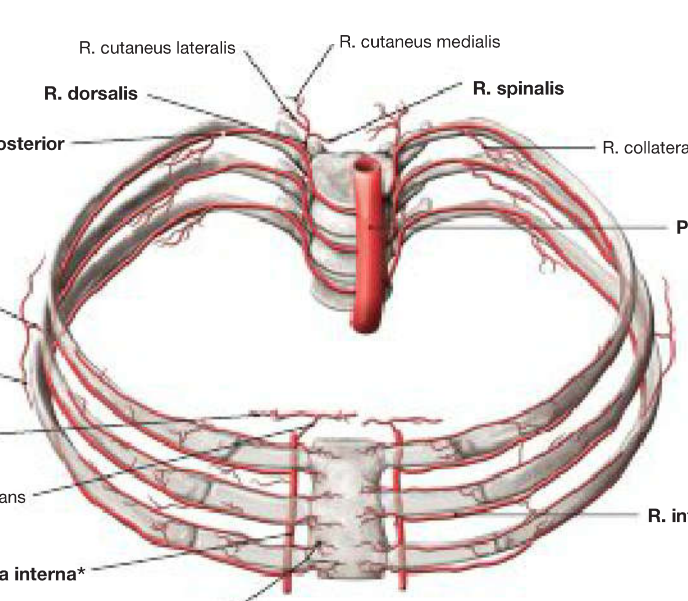


Fig. 2.103 Arteries of the thoracic wall. [L266]
The intercostal arteries form anastomoses between A. thoracica interna and Pars thoracica aortae.

* clinical term: A. mammaria interna

Branches of the Pars thoracica aortae [Aorta thoracica]	
• Aa. intercostales posteriores – R. dorsalis – R. cutaneus medialis – R. cutaneus lateralis – R. spinalis	– R. collateralis – R. cutaneus lateralis – Rr. mammarii laterales

Clinical Remarks

Stenosis of the aortic isthmus, a narrowing of the aorta in the aortic arch area, results in the formation of a vertical and a horizontal bypass circulation:

- **Vertical bypass circulation:** between Aa. subclaviae and iliacae externae via Aa. thoracicae internae, epigastricae superiores and epigastricae inferiores (within the rectus sheath) as well as in the area of the abdominal wall over Aa. musculophrenicae, epigastricae inferiores and circumflexae ilium profundae
- **horizontal bypass circulation:** between the Aa. thoracicae internae and Aorta thoracica via Rr. intercostales anteriores and Aa. intercostales posteriores to supply the thoracic and abdominal organs. The enlargement of the intercostal arteries leads to the formation of rib usures (→ clinical remarks on p. 65). The bypass circulation contribute to the maintenance of blood supply to parts of the body wall and lower extremities (a difference in blood pressure between upper and lower extremities is usually still measurable).

Veins of the Ventral Wall of the Trunk

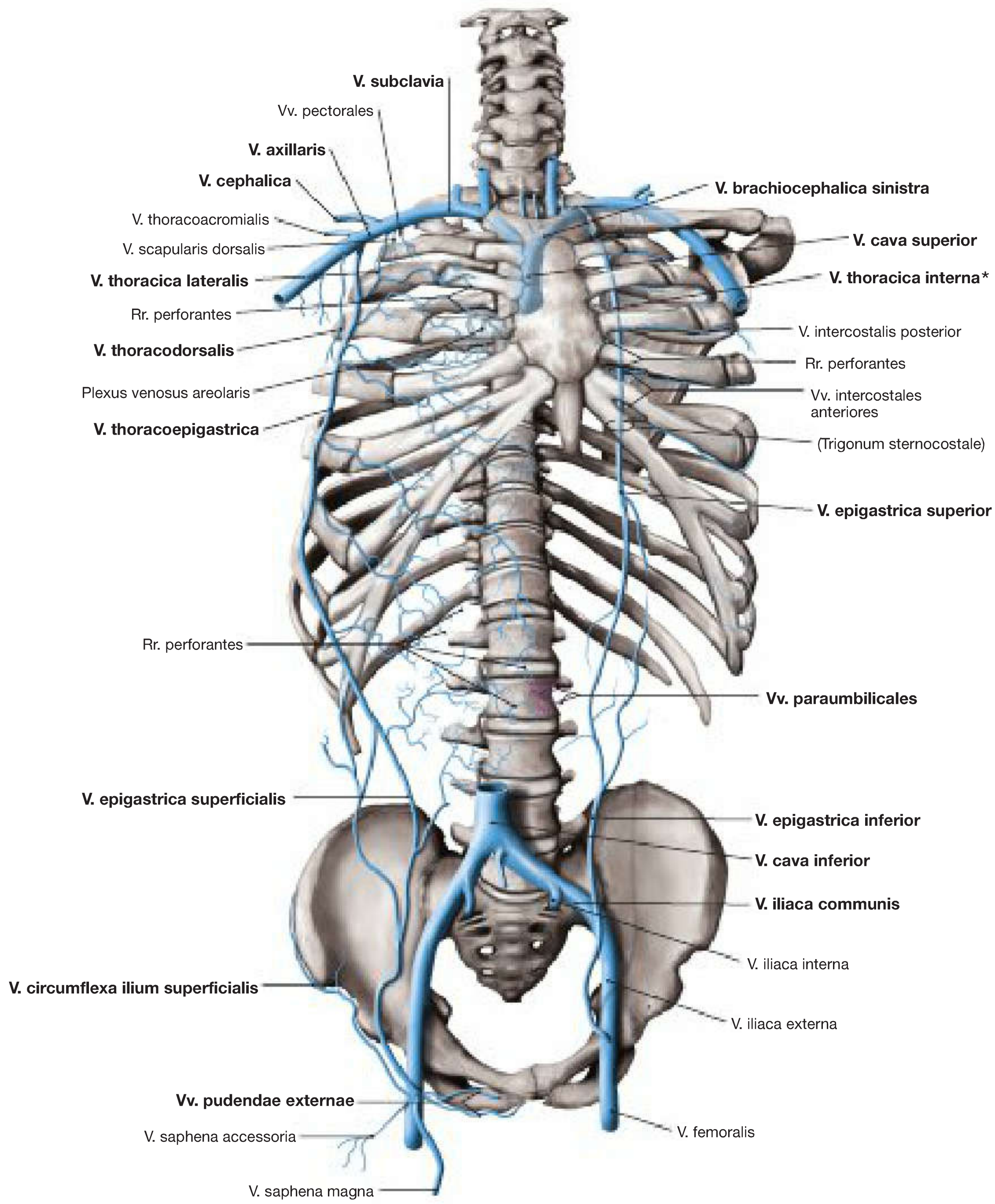


Fig. 2.104 Veins of the ventral wall of the trunk. [L266]
The veins of the ventral wall of the trunk, generate a superficial (shown on the right side of the body) and a deep (left side of the body) **system of anastomoses** between Vv. cavae superior and inferior.

* clinical term.: V. mammaria interna

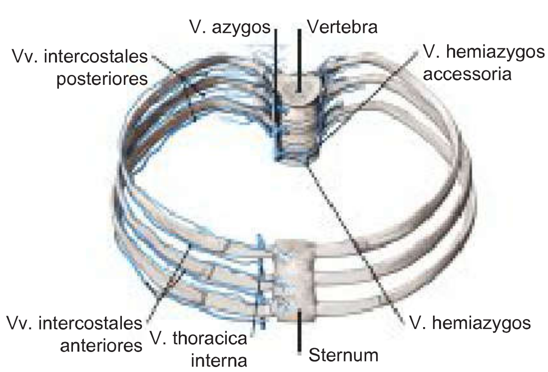


Fig. 2.105 Veins of the thoracic wall. [L266]
The veins run with the arteries in the area of the thoracic wall. Ventrally the Vv. intercostales anteriores drain into the V. thoracica interna and dorsally into the Vv. azygos and hemiazygos as well as hemiazygos accessoria. In doing so, they form venous anastomoses between both drains.

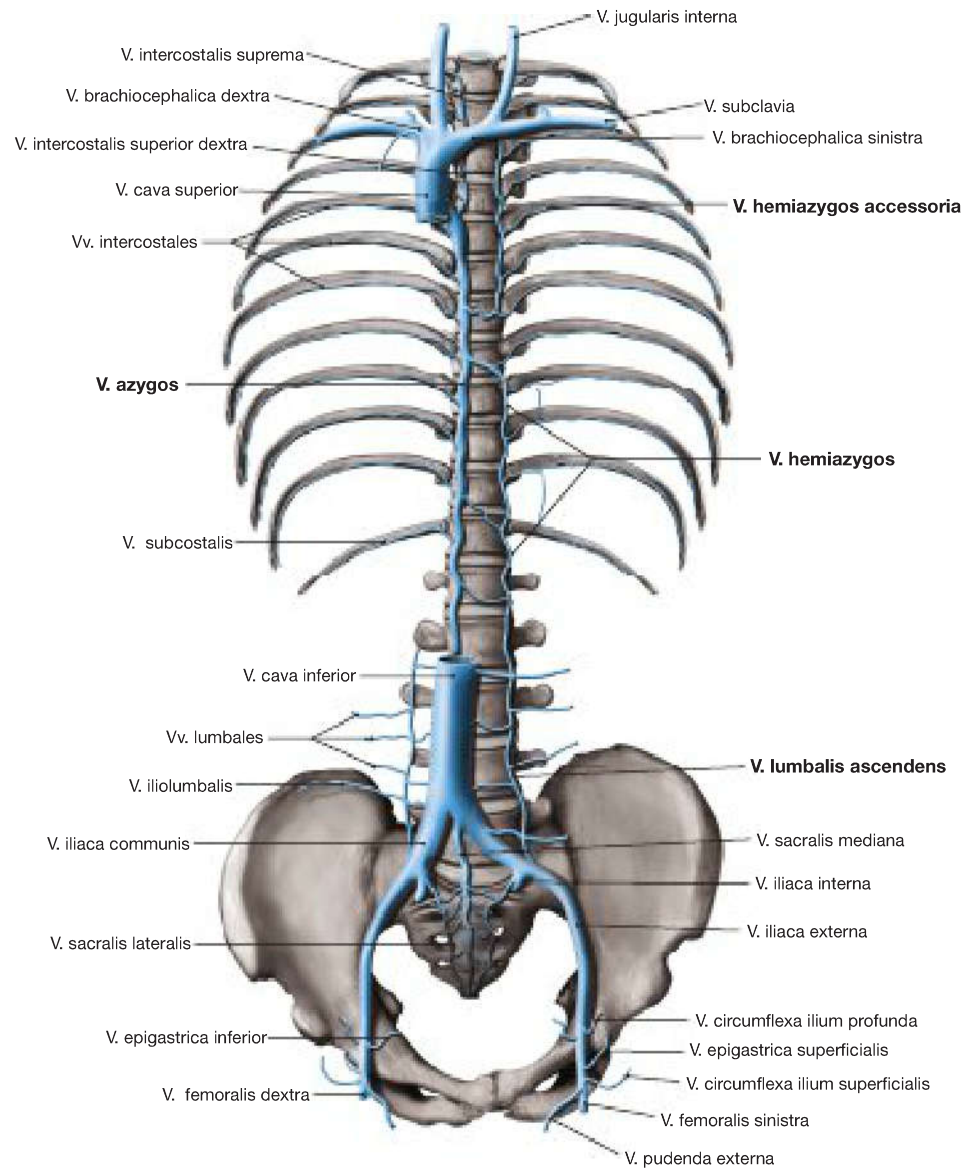


Fig. 2.106 Azygos system. [L266]
The azygos system drains blood between the V. iliaca interna and V. cava superior. The V. lumbalis ascendens on the right side, which connects the V. azygos with the V. iliaca communis dextra, is covered by the V. cava inferior. In addition, there are also direct connections from the Vv. lumbales ascendentes to the V. cava inferior. In the system, the Plexus venosus sacralis and the Plexus venosi vertebrales externi and interni as well as the Vv. lumbales are activated.

– Clinical Remarks

As a result of venous congestion of the V. cava superior, the V. cava inferior or the Vv. iliacae communes through thrombosis, a mass formation or the growth of tumours, bypass circulation between the V. cava superior and V. cava inferior **(cavocaval anastomoses)** can develop:

- between V. iliaca externa and V. cava superior via V. epigastrica inferior, V. epigastrica superior, V. thoracica interna and V. brachiocephalica
- between V. femoralis and V. cava superior via V. circumflexa ilium superficialis/epigastrica superficialis, V. thoracoepigastrica, V. axillaris and V. brachiocephalica
- between V. iliaca interna and V. cava superior via Plexus venosus sacralis, Plexus venosi vertebrales externi and interni, Vv. azygos and hemiazygos
- between Vv. lumbales and V. cava superior via Vv. lumbales ascendentes, Vv. azygos and hemiazygos

Portocaval anastomoses (→ Fig. 6.90, Vol. 2).

Arteries and Veins of the Thoracic Wall

Fig. 2.107 Arteries of the thoracic wall. [L266]
Aorta and A. thoracica interna are connected via the Aa. intercostales posteriores and the Rr. intercostales anteriores. Below the rib arch the A. musculophrenica runs as a branch of the A. thoracia interna. These vessels provide blood to the thoracic and abdominal wall.

* clinical term: A. mammaria interna

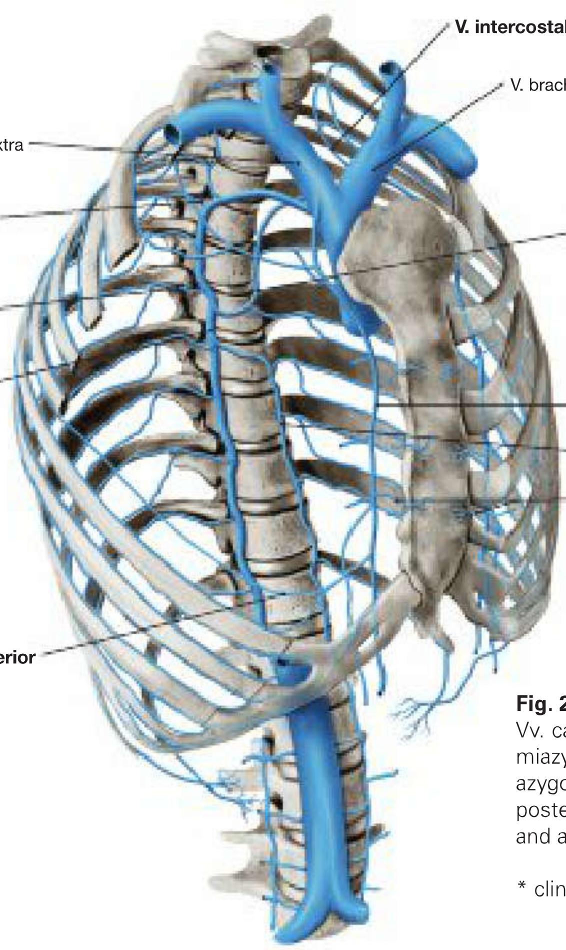


Fig. 2.108 Veins of the thoracic wall. [L266]
Vv. cavae superior and inferior are connected by the Vv. lumbares, hemiazygos, and azygos veins. Additional anastomoses exist between the azygos system and the Vv. thoracicae internae via the Vv. intercostales posteriores and anteriores. The veins drain the blood from the thoracic and abdominal wall.

* clinical term: V. mammaria interna

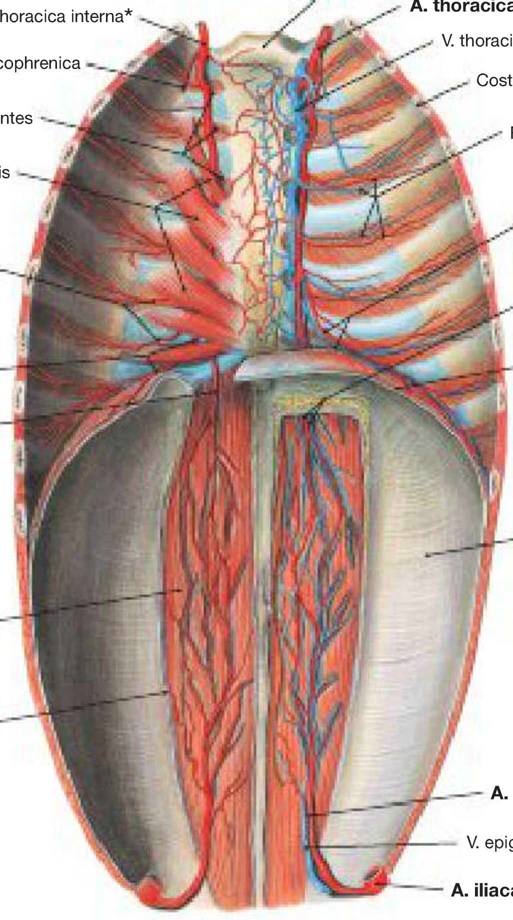


Fig. 2.109 Vessels at the posterior aspect of the ventral wall of the trunk; dorsal view.
The epigastric vessels (Vasa epigastrica superiora und inferiora) run on the back of the M. transversus abdominis and are visible in the upper two-thirds of the abdomen, after removal of the rectus sheath and after removal of the fascia transversalis. The A. thoracica interna is covered on the left side of the body by the M. transversus thoracis. Below this it passes through the Trigonum sternocostale of the diaphragm into the rectus sheath and is used for the A. epigastrica superior. The A. epigastrica inferior derives from the A. iliaca externa.

* clinical term: A. mammaria interna
** clinical term: V. mammaria interna

– Clinical Remarks

As well as the V. saphena magna, the A. thoracica (mammaria) interna is often used for operative revascularisation of the heart in high-grade **coronary stenosis** (narrowing of the coronary arteries) as a **bypass**. Bypass circulation in stenosis of the aortic isthmus → p. 119; cavocaval anastomoses → p. 121.

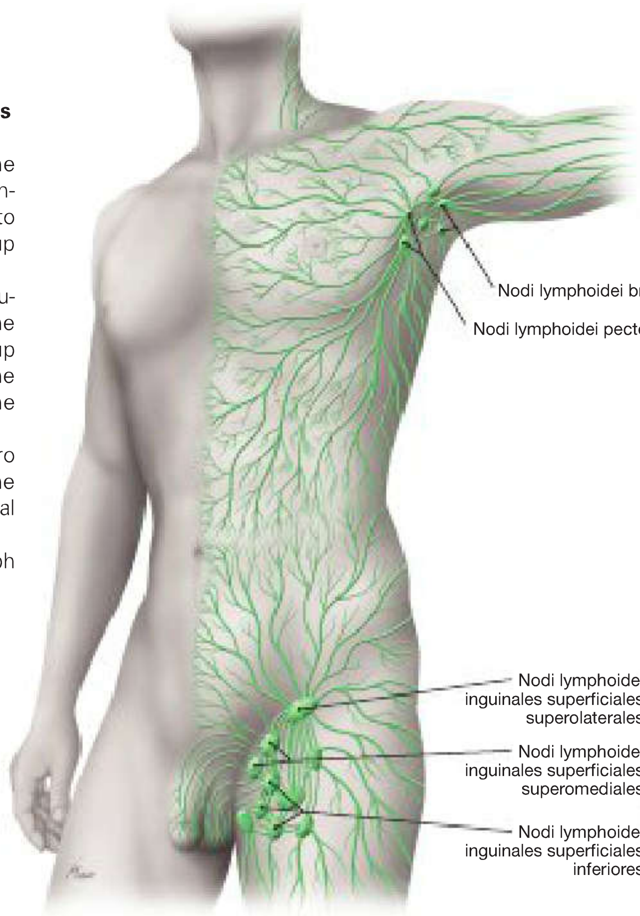


Fig. 2.110 Superficial lymphatic vessels and regional lymph nodes of the ventral wall of the trunk. [L127]
The **axillary lymph nodes** (Nodi lymphoidei axillares, including the Nodi lymphoidei brachiales and pectorales) collect the lymph of the entire upper extremity, of large parts of the ventral wall of the trunk, up to the watershed at the level of the umbilicus, as well as of the back, up to the corresponding watershed (→ Fig. 2.111).
The **superficial inguinal lymph nodes** (Nodi lymphoidei inguinales superficiales) consist of a vertical and horizontal group. They collect the lymph of the entire lower extremity, of the ventral wall of the trunk, up to the watershed at the level of the umbilicus, the posterior and the back up to the watershed, as well as the external genitalia (including the penis), and the perineal and anal region.
In **women** the lymphatic vessels, which come from the Corpus utero and the uterotubal junction that pass through the inguinal canal with the Lig. teres uteri (→ Fig. 2.113), drain their lymph into the superficial inguinal lymph nodes.
In **men**, the lymph of the testis is drained into the paraaortal lymph nodes (not shown).

Fig. 2.111 Superficial lymphatic vessels of the posterior trunk wall. [L127]
The lymph of the back region is drained above the umbilicus into the axillary lymph nodes and below thereof into the superficial inguinal lymph nodes.

Fig. 2.112 Superficial lymphatic vessels and regional lymph nodes of the female external genitalia as well as the perineal and anal region; caudal view. [L127]
The lymph from the external genital, perineal and anal region is drained into the superficial inguinal lymph nodes. The first lymph station is the **Nodi lymphoidei inguinales superficiales superomediales.**

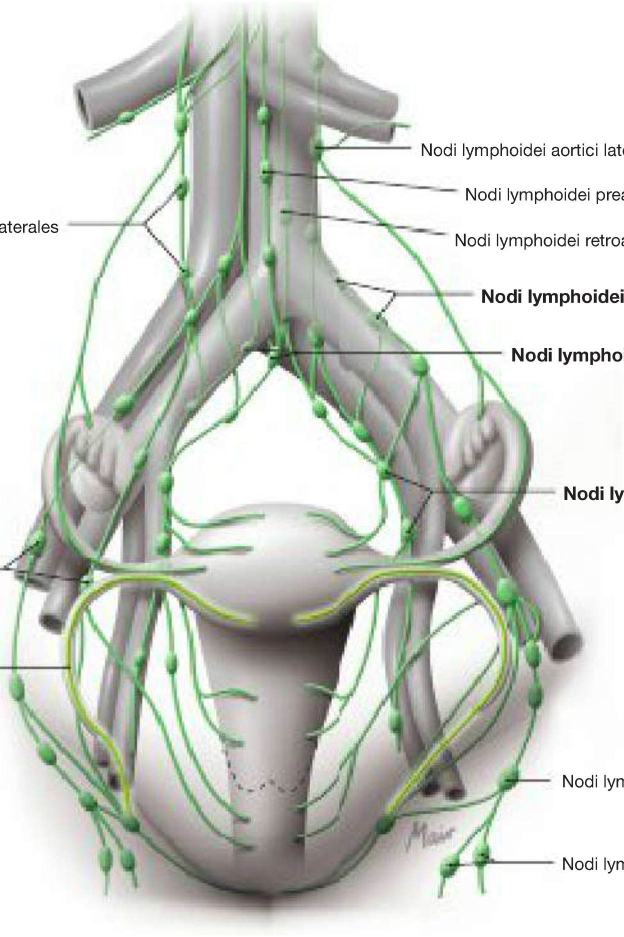


Fig. 2.113 Superficial and deep lymphatic vessels and regional lymph nodes of the Vagina, Uterus, uterine fallopian tube, Tuba uterina and ovary, Ovar; ventral view. [L127]

- The lymph of the upper two thirds of the vagina is drained into the pelvic lymph nodes, while the lower third drains into the inguinal lymph nodes.
- The lymph from the ovary, uterine FALLOPian tube and a part of the uterine fundus and corpus flows along the A. ovarica, which is located in the Lig. suspensorium ovarii, to the **Nodi lymphoidei lumbales.**
- A second part of the lymph from the fundus, corpus and cervix uterii is taken to the A. uterina in the **Nodi lymphoidei iliaci.**
- A third part of the lymph from the fundus and corpus uterii is drained along the Lig. teres uteri to the **Nodi lymphoidei inguinales superficiales** (highlighted in colour).

– Clinical Remarks

The inguinal lymph nodes are of clinical importance in the context of inflammation and malignancy, as an enlargement can be an initial indication of a pathological process in the catchment area. In this context, a **metastatic route** from the uterus via the lymphatic vessels at the Lig. teres uteri through the inguinal canal has to be considered for women.

Skin Innervation of the Back

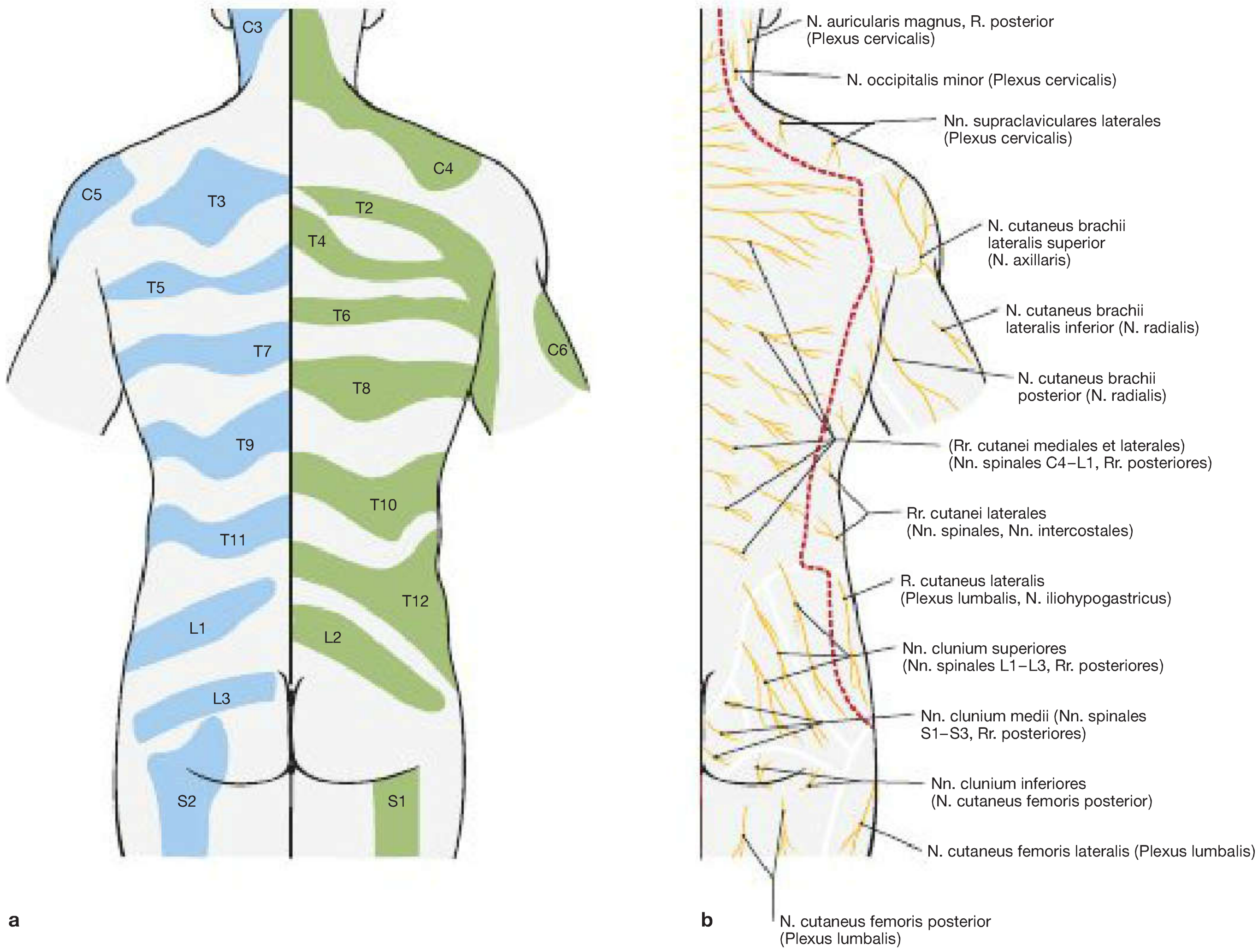


Fig. 2.114a and b Segmental skin innervation (dermatomes) [**a** whole body view] **and cutaneous nerves of the back** [**b** half body view]; dorsal view. [L126]

As numerous cutaneous nerves are made up fibres from multiple spinal nerves, the dermatome differs from the area of innervation of the cutaneous nerves. The dermatomes are alternately presented on the left (blue) and on the right (green). Thus, e.g. T7 is on the left-hand side in blue, T8 is on the right-hand side in green and then T9 again is visible on the left-hand side visible in green, etc. The reason for this type of presentation is the fact, that the dermatomes are not autonomous zones of the sensitive skin innervation but that they overlap to an exceptionally strong level and in varying degrees (the overlap only proves very low in the midline). Regions where no colour is assigned (e.g. the area between C4, T2 and T3 around the midline), are areas where an extraordinarily large variability and a very strong interindividual overlap might happen, so that no clear assignment is possible. Presentation of the dermatomes is based on an evidence-based dermatome card according to LEE and co-workers (2008). In order to keep the figure clear and understandable, the dermatomes S3, S4 and S5 are not shown (they cover the area of the perineum including the anus and the external genitalia). The cutaneous nerves are shown on the right. The broken red line (→ Fig. 2.114b) indicates the demarcation between the innervation area between the Rr. posteriores (dorsal) branches and Rr. anteriores (ventral) branches of the spinal nerves.

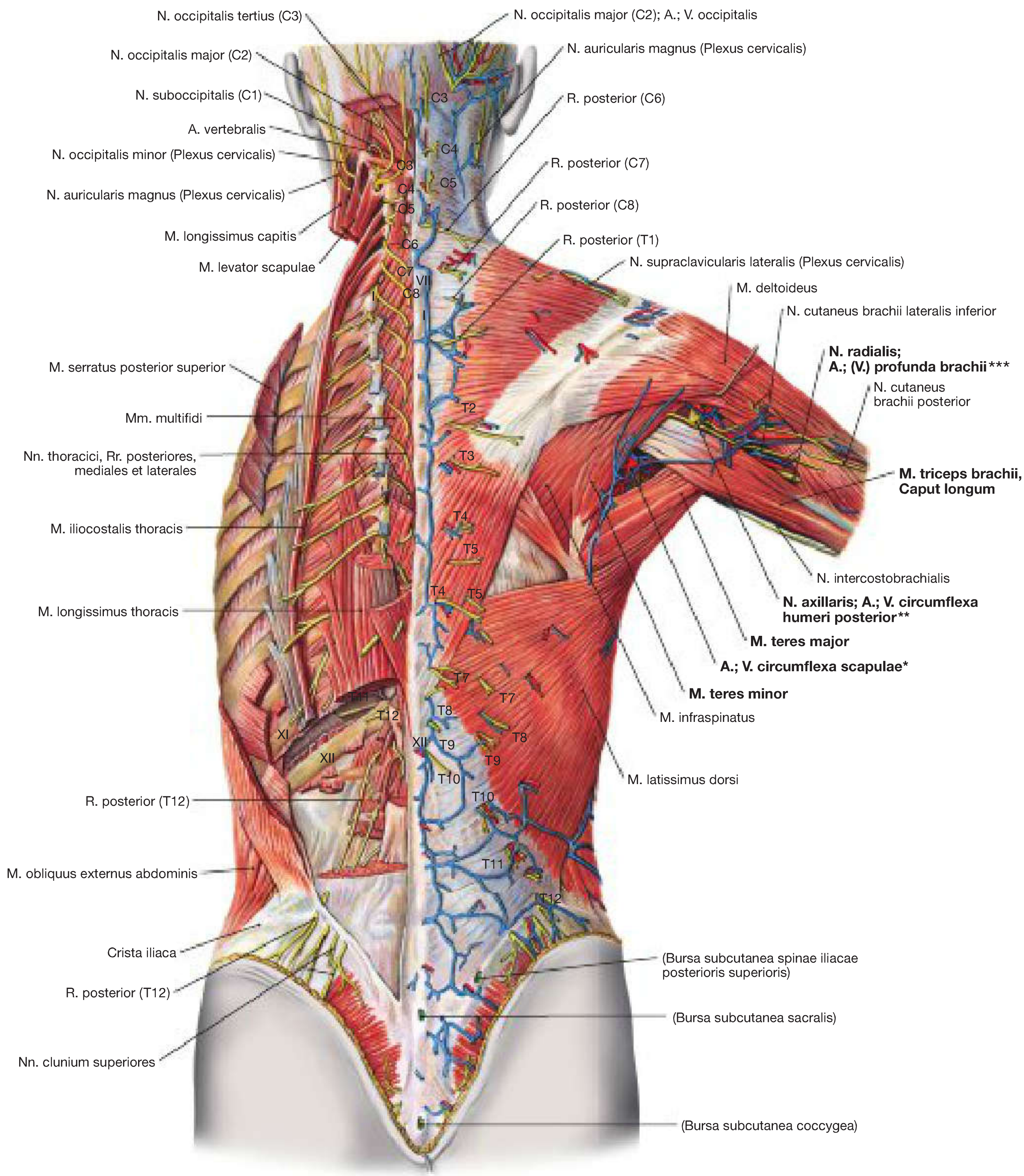


Fig. 2.115 Vessels and nerves of the back; dorsal view; after the superficial muscles and shoulder girdle were removed on the left side.
Vessels and nerves in the **medial axillary space:** A. and V. circumflexa scapulae (margins: cranial M. teres minor, caudal M. teres major, lateral Caput longum of the M. triceps brachii)
Vessels and nerves in the **lateral axillary space:** A. and V. circumflexa humeri posterior, N. axillaris (margins: cranial M. teres minor, caudal M. teres major, medial Caput longum of the M. triceps brachii, lateral humerus shaft)
Vessels and nerves in the **triceps slit:** A. and V. profunda brachii, N. radialis (margins: cranial M. teres major, medial Caput longum of M. triceps brachii, lateral humeral shaft)

* vessels and nerves in the medial axillary space
** vessels and nerves in the lateral axillary space
*** vessels and nerves in the triceps slit

Vessels and Nerves of the Neck

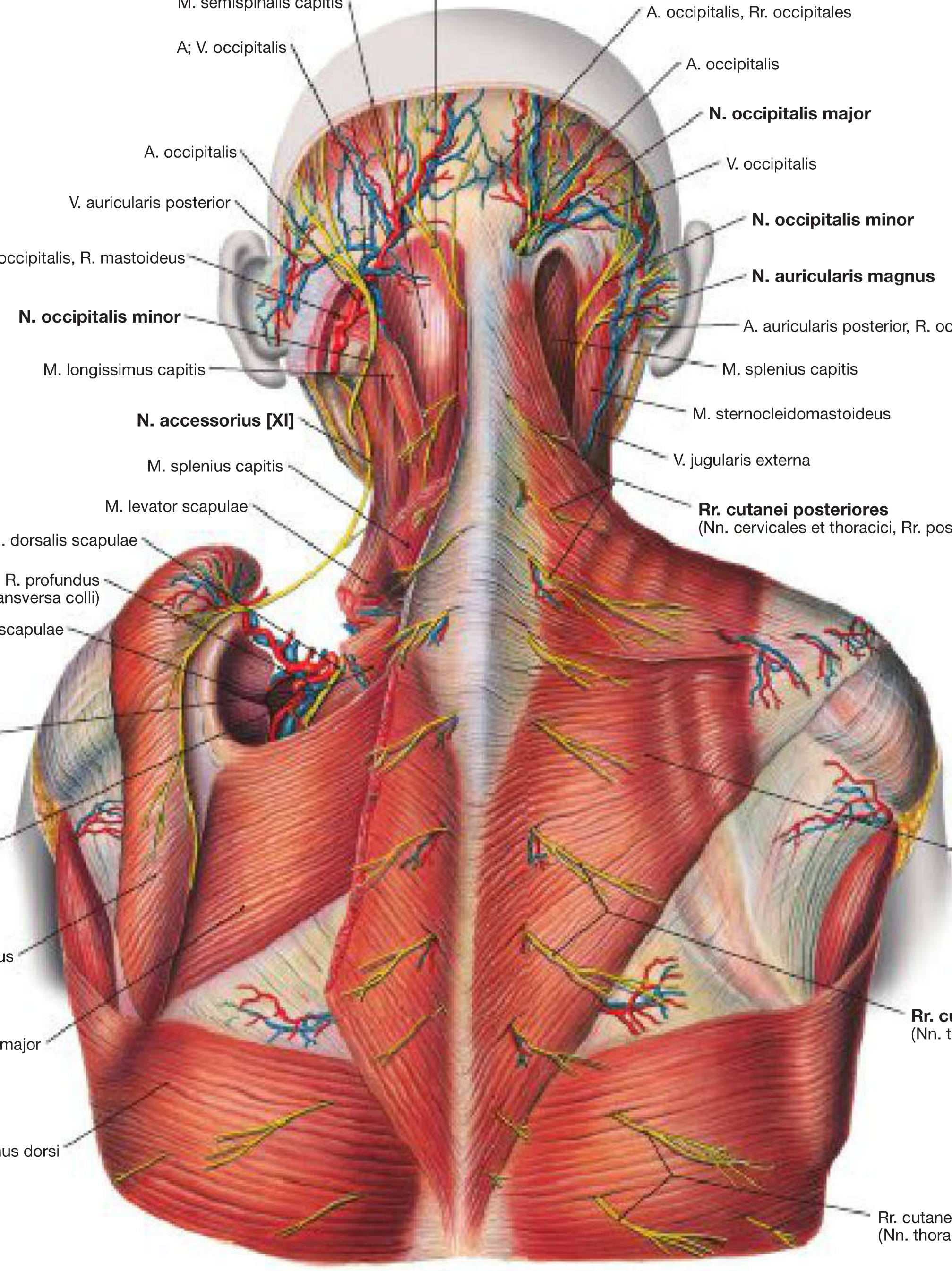


Fig. 2.116 Vessels and nerves of the occipital region, Regio occipitalis, neck, Regio cervicalis posterior [Regio nuchalis], and upper back area; dorsal view.

Up to the scapular line, the skin of the back receives segmental innervation from the Rr. posterior [dorsales] of the spinal nerves (Rr. cutanei posteriores). The N. occipitalis major from C2 and the N. occipitalis tertius from C3 (not shown) provide cutaneous innervation for the posterior neck and occipital region (Rr. mediales der Rr. posteriores [dorsales]). The N. occipitalis minor comes from the Plexus cervicalis (Rr. anteriores [ventrales]) via the Punctum nervosum (ERB's point). The course of the N. accessorius [XI] in the neck and shoulder region is also shown.

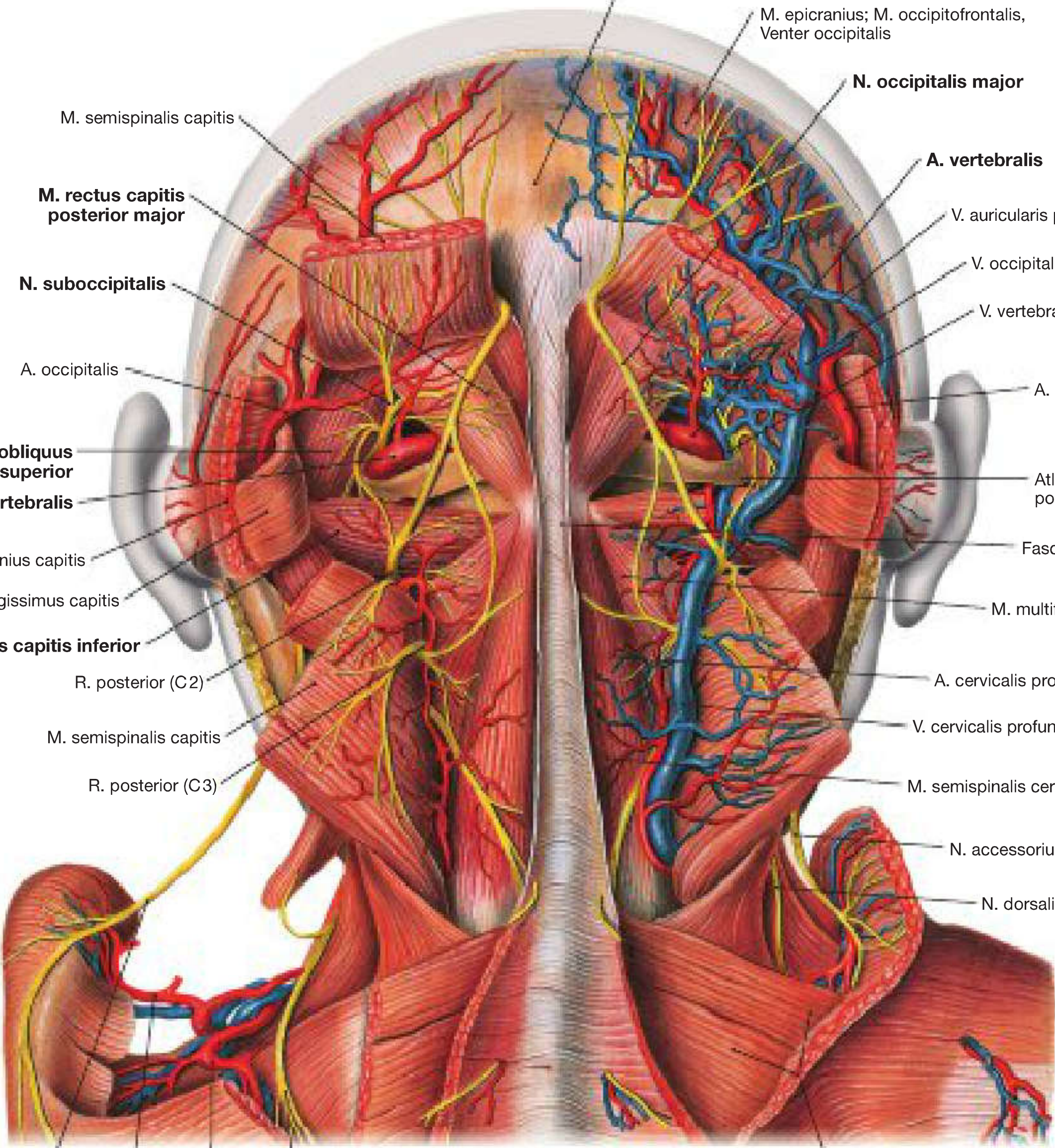


Fig. 2.117 Vessels and nerves of the occipital region, Regio occipitalis, and neck, Regio cervicalis posterior; dorsal view.
To demonstrate the deep neurovascular pathways on both sides, the Mm. trapezius, sternocleidomastoideus, splenius capitis, and semispinalis capitis were detached and partially removed. On both sides the short neck muscles (Mm. recti capitis posterior minor and major as well as Mm. obliqui capitis superior and inferior), which frame the **Vertebralis triangle** (Trigonum arteriae vertebralis) are visible. Besides arteries and veins, Nn. occipitalis major and suboccipitalis as well as the N. accessorius [XI] are shown.

Nerves of the Neck, and the Deep Posterior Neck Area

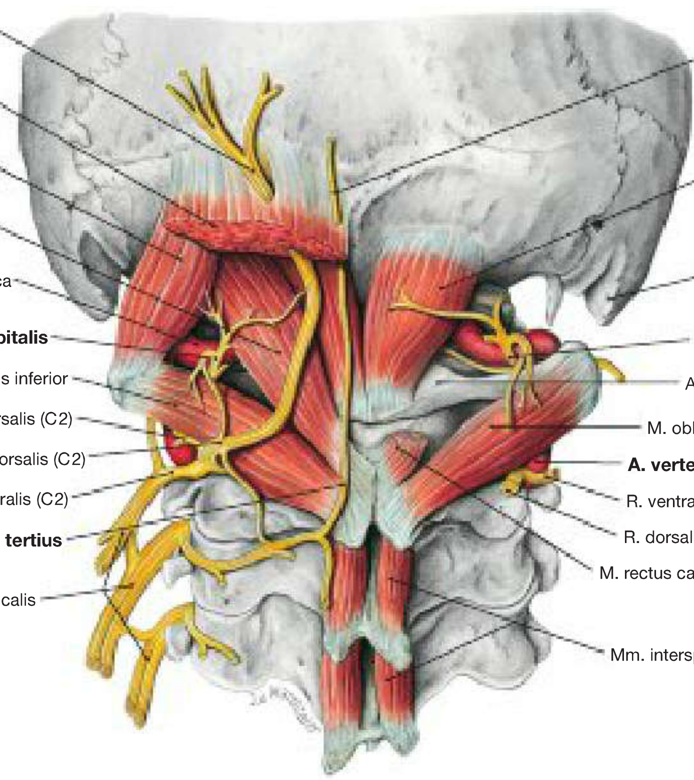


Fig. 2.118 Nerves of the neck, Regio cervicalis posterior; dorsal view.
The R. posterior from C2 continues as the **N. occipitalis major** on the occiput. The R. posterior from C3 continues as the **N. occipitalis tertius** in the area of the Lig. nuchae cranially. From the depth of the vertebralis triangle (Trigonum arteriae vertebralis), in which the A. vertebralis lies, the R. posterior comes from C1 and innervates the short neck muscles as **N. suboccipitalis**.

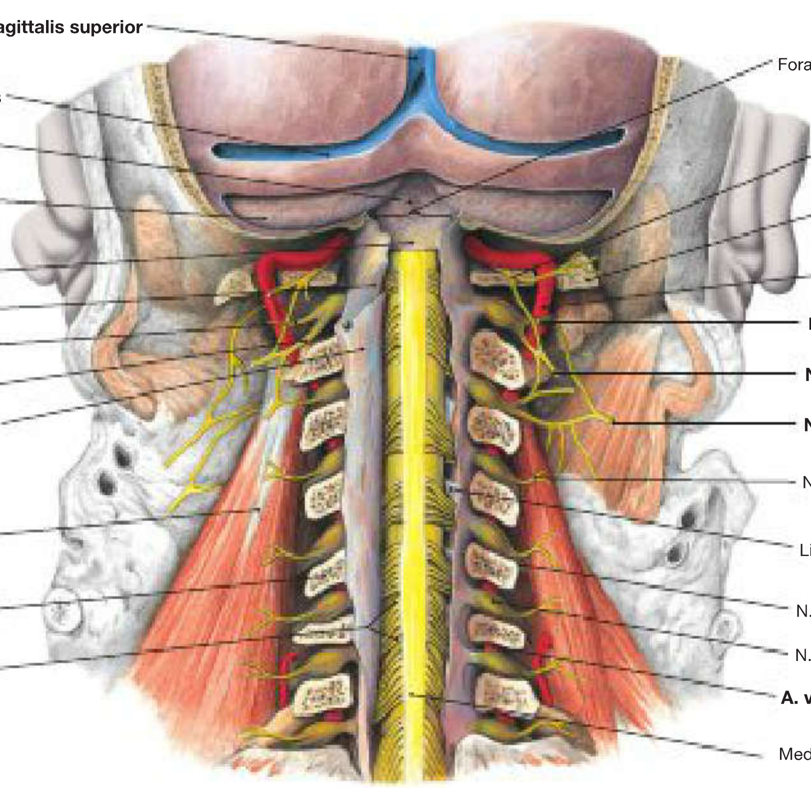


Fig. 2.119 Vessels and nerves of the deep posterior neck area, Regio cervicalis posterior, and content of the vertebral canal; dorsal view.
The vertebral canal is open from the dorsal side and the occipital bone is removed; this provides a view of the dura mater with opened Sinus sagittalis superior and Sinus transversus.
Between the cervical vertebrae you can see the **A. vertebralis** ascend.

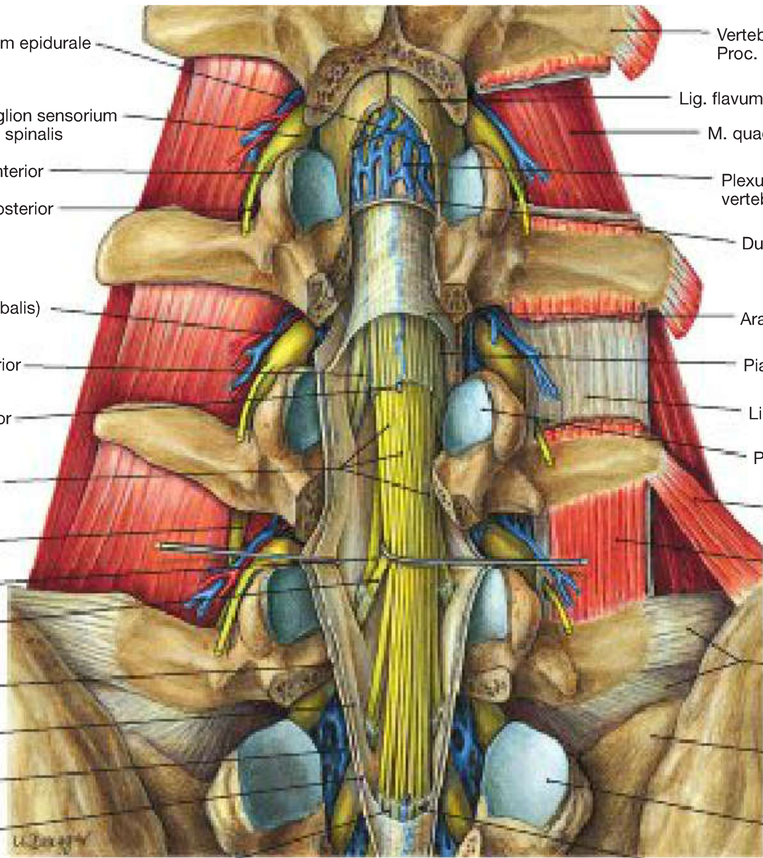


Fig. 2.120 Vessels and nerves of the open vertebral canal of the lumbar spine, Regio lumbalis; dorsal view.

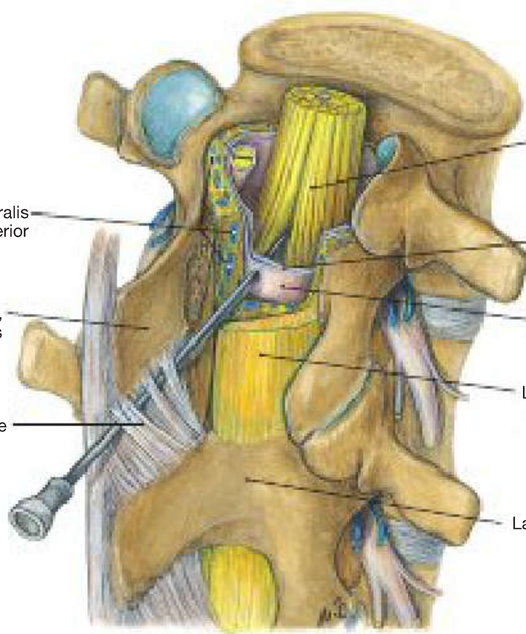


Fig. 2.121 Lumbal puncture, management of the needle.

– Clinical Remarks

In order to attain cerebrospinal fluid for diagnostic purposes or to apply drugs in the subarachnoid space, a **spinal puncture** is carried out. This is conducted below the 2nd lumbar vertebra, typically between the spinosus processes of L3/L4, and L4/L5, to ensure that the spinal cord is not injured. The Cauda equina can be found at this level; the subarachnoid space has its largest expansion here. The needle is inserted through the Ligg. supraspinale and interspinale, the epidural space, the Dura mater and the Arachnoidea until the needle enters the subarachnoid space (→ Fig. 2.121).

Spinal Nerve and Foramen Intervertebrale

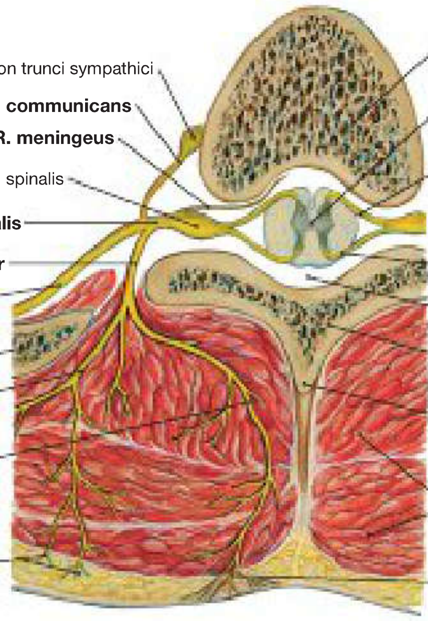


Fig. 2.122 Spinal nerve, N. spinalis, in the thoracic region; caudal view.
The root of the spinal nerve is only a few millimetres long (Truncus nervi spinalis). It is formed from the Radices anterior and posterior that merge with the Truncus nervi spinalis. The greater R. anterior (in the thoracic area as N. intercostalis) and the smaller R. posterior emerge from the Truncus. This is divided into a medial (R. medialis) and a lateral (R. lateralis) branch that innervate the autochthonous muscles (Mm. dorsi) as well as the skin of the back with their terminal ends (Rr. cutanei medialis and lateralis). The spinal nerve connects via the R. communicans with the boundary line (Truncus sympathicus). The R. meningeus of the spinal nerve follows the declining path into the vertebral canal and innervates the ligaments of the vertebral column and the spinal cord. The N. intercostalis runs below the rib (not shown) ventrally, innervates the Mm. intercostales externi and interni and pass on the Rr. cutanei lateralis and anterior for skin innervation.

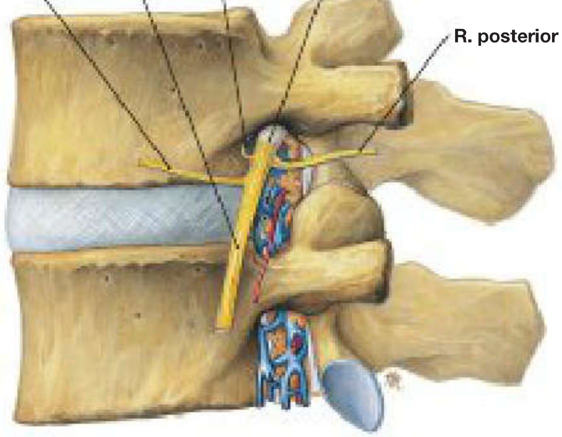


Fig. 2.123 Spinal nerve, N. spinalis, in the lumbar region; lateral view from the left side. [S010-17; L240]
After the spinal nerve has passed through the Foramen intervertebrale it divides into the Rr. anterior, posterior, meningeus and communicans.

Clinical Remarks

Posterolateral disc problems, spondylophytes or tumours can cause the **narrowing of the Foramen intervertebrale** with compression of the spinal nerve roots and resulting nerve function loss.

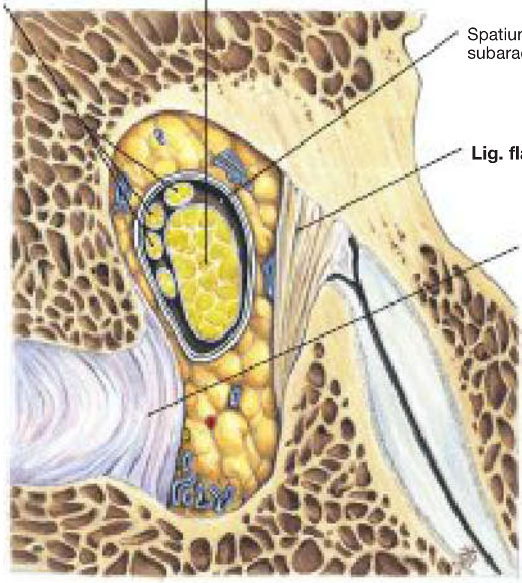


Fig. 2.124 Spinal nerve, N. spinalis, in the lumbar region. Sagittal section at the level of the Foramen intervertebrale; view from the left side. [S010-17; L240]
In the Foramen intervertebrale, the Radices anterior and posterior have not yet fused to the spinal nerve. They are still in the pocket of the dura and will immersed in cerebral spinal fluid. Ventrally you can see the intervertebral disc (Discus intervertebralis) and dorsally the Lig. flavum, as well as the adjacent zygapophyseal joint.

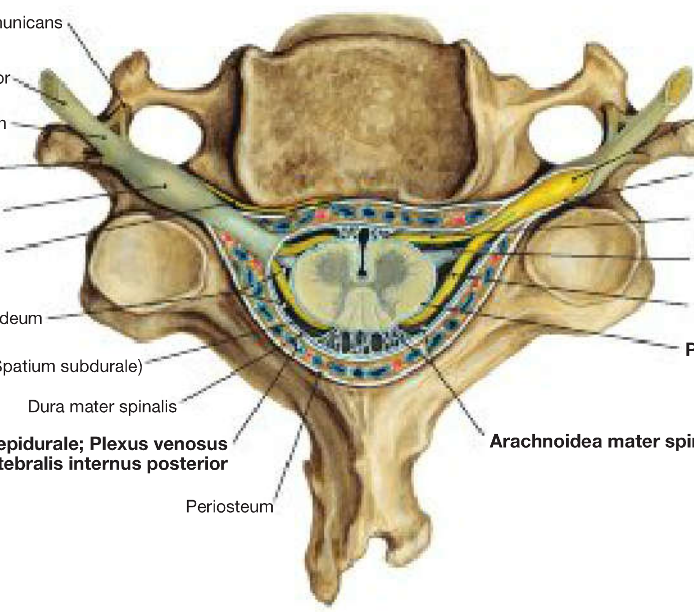


Fig. 2.125 Content of the vertebral canal, Canalis vertebralis; cross-section at the level of the 5th cervical vertebra; view from cranial.
The spinal cord is surrounded by the dura, arachnoidea and pia mater and immersed in cerebrospinal fluid in the subarachnoid space (Spatium subarachnoideum). In the vertebral canal, the dural sac and the exiting spinal nerve roots are surrounded and protected by adipose tissue with embedded venous plexus (Plexus venosi vertebrales interni anterior and posterior) and with nourishing blood vessels.

See epidural anaesthesia → page 403, Vol. 3.

Spinal Nerve

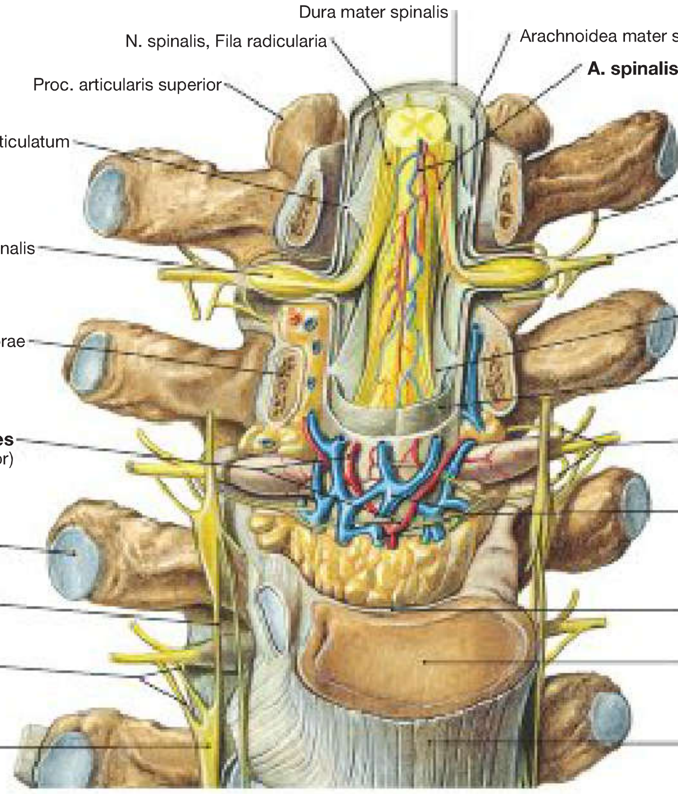


Fig. 2.126 Thoracic spine with spinal cord, Medulla spinalis, and sympathetic trunk, Truncus sympathicus; ventral view.
You can see the Spatium epidurale encapsulating the meninges in the vertebral canal, in which the Plexus venosus vertebralis internus anterior, as well as the Rr. spinales of the A. intercostalis posterior are visible in its adipose tissue. The A. spinalis anterior runs along the spinal cord.

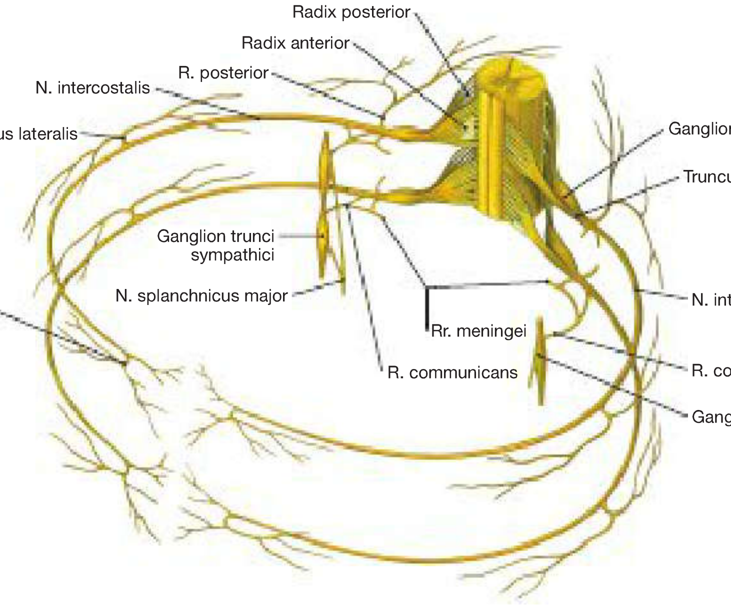


Fig. 2.127 Structure of a spinal nerve, N. spinalis, and spinal cord segment, exemplified by two thoracic nerves, Nn. thoracici; oblique superior view.
Each spinal nerve has an anterior root (Radix anterior) and a posterior root (Radix posterior). The cell bodies (perikarya) of motor nerve fibres are located in the grey matter of the spinal cord and exit through the anterior root; the perikarya of sensory nerve fibres are located in the dorsal root ganglion (Ganglion sensorium nervi spinalis) and enter the spinal cord via the dorsal root. Connections from the spinal cord to the Ganglion trunci sympathici (ganglion of the sympathetic trunk) are made via Rr. communicantes. The branches of the dorsal spinal nerves branches are arranged segmentally; apart from the intercostal nerves II–XI, the ventral branches merge in the plexus.

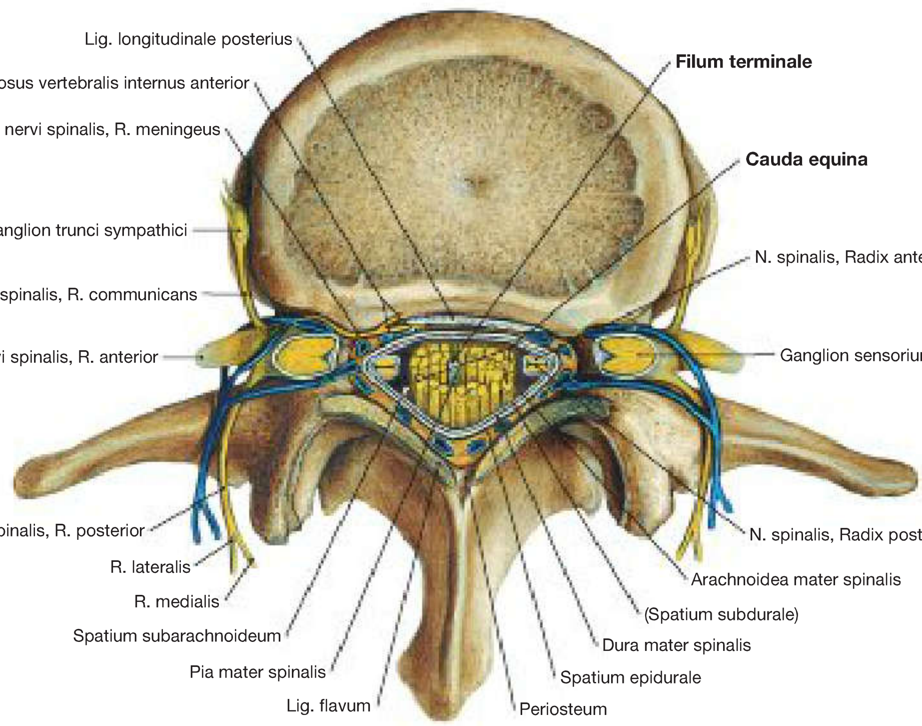


Fig. 2.128 Content of the vertebral canal, Canalis vertebralis; cross-section at the level of the 3rd lumbar vertebra; view from cranial.
Below the 1st/2nd lumbar vertebra, the nerve roots of L2 pull caudally up to and including the N. coccygeus in the dural sac as a loose bundle, to its exit points. This entire collection of nerve roots is named **cauda equina**.

Between the nerve fibre processes, you can see the extremely thin **Filum terminale,** which connects to the Conus medullaris of the spinal cord.

For lumbal puncture → page 403, Vol. 3.

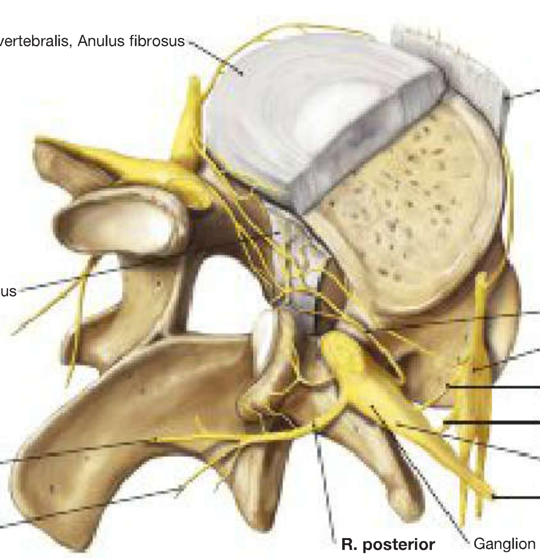


Fig. 2.129 Nerves of the spine, Columna vertebralis; oblique view from the right. [L266]
Branches of the spinal nerve are shown to adjacent structures. These include the **R. meningeus** which sensitively innervates membrane of the spinal cord, small branches projecting from the **R. posterior** to the Capsula articularis of the zygapophyseal joints, as well as the Rr. communicantes albus and griseus connecting to the Truncus sympathicus.
Preganglionic sympathetic fibres run via the **R. communicans albus** from the lateral horn of the spinal cord to the Truncus sympathicus. Postganglionic sympathetic fibres run via the **R. communicans griseus** from the sympathetic trunk to the spinal nerve. Autonomic fibers of the sympathetic trunk innervate the spinal discs and ligaments of the vertebral column.

Vessels and Nerves of the Vertebral Canal

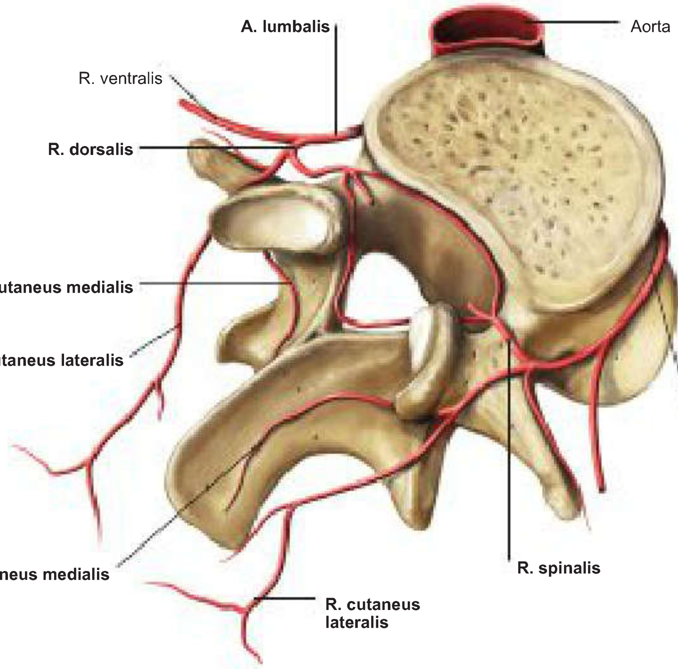


Fig. 2.130 Arteries of the vertebral canal, Canalis vertebralis; oblique view from the right side. [L266]

In the thoracic and lumbar spine there is a strictly segmental arterial supply. Paired **Aa. intercostales posteriores** emerge as segmental branches from the Aorta thoracica to supply the adjacent vertebrae with blood. Each artery leads into a **R. dorsalis**, from which a **R. spinalis** passes the Foramen intervertebrale of the corresponding motion segment and enters the vertebral canal. The segmental spinal arteries of anastomose various levels in the vertebral canal via ascending and descending branches. The arch plates (laminae) and the spinosus processes are reached from the inside of the posterior artery branches. Parallel to the dorsal spinal nerve branches of the same name, the terminal branches of the Rr. posteriores run as **Rr. cutanei mediales** and **Rr. cutanei laterales.** They supply the posterior bony structures from the outside with blood and the dorsal back muscles and the skin via their terminal ends.

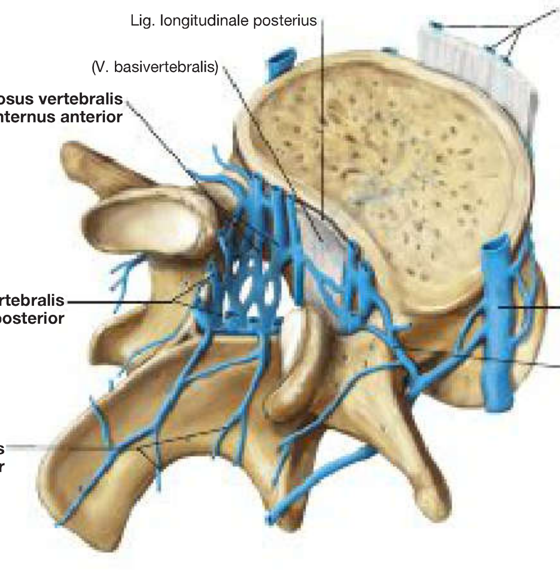


Fig. 2.131 Veins of the vertebral canal, Canalis vertebralis; oblique dorsal view from the right. [L266]

The vertebral canal is filled with a dense network of veins which form the **Plexus venosi vertebrales interni anterior** and **posterior.** Located in the Spatium epidurale, this venous plexus covers the meninges with the bone marrow contained here, as well as the cauda equina. The two plexus are connected with the **Plexus venosus vertebralis externus posterior** via Vv. intervertebrales. This vein drains the blood (in the area of the lumbar spine) into the paravertebral oriented Vv. lumbales ascendentes (the Vv. azygos, hemiazygos and hemiazygos accessoria run through the thoracic region). They also take blood from the disc located on the front of the vertebral body and the **Plexus venosus vertebralis externus anterior**.

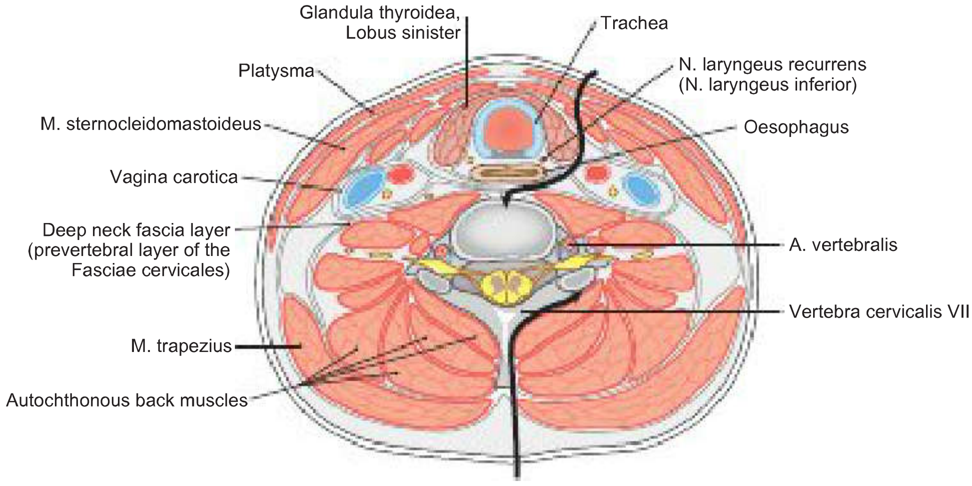


Fig. 2.132 Operational access pathway to the cervical spine, ventrally at the level of the first tracheal ring; horizontal section. [L126]
Operative access pathways to the spine are an integral part of spine surgery for a wide variety of reasons, such as for the treatment of herniated discs, spinal canal stenosis, and for procedures in the treatment of scoliosis, vertebral fractures, tumours and metastases, birth defects or degenerative instability (e.g. vertebral slippage). The surgeon has to penetrate the soft tissue shell of the spine from the exterior. In the case of anterior access at the level of the first tracheal ring, access is made at the anterior border of the M. sternocleidomastoideus. The neck viscera with the surrounding general organ fascia is brought forward, while the carotid sheath remains at the back with its content.

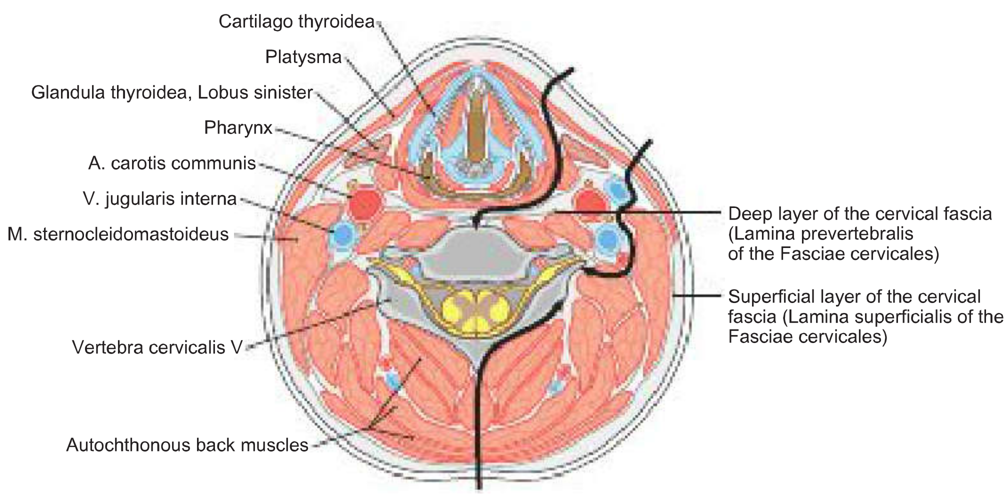


Fig. 2.133 Operational access pathways to the cervical spine at the level of the vocal folds; horizontal section. [L126]
Depending on the cause for operative intervention (→ Fig. 2.132), access to the cervical spine from the anterior, lateral or dorsal (e.g. according to FRYKHOLM) is necessary.

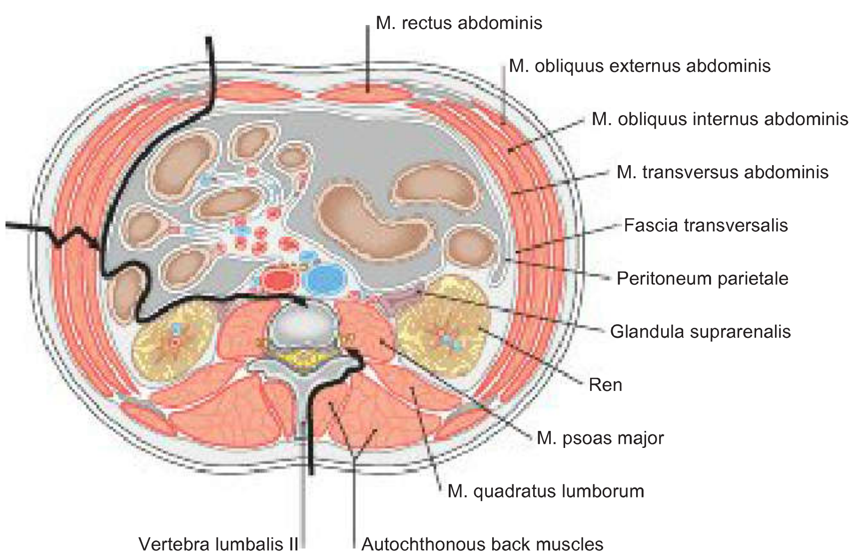


Fig. 2.134 Operational access pathways to the lumbar spine at the level of the 1st lumbar vortex; horizontal section. [L126]
Also in the lumbar spine, depending on the cause for surgical intervention (→ Fig. 2.132) access from the anterior, lateral or dorsal is necessary. In the case of access from anterior and lateral all efforts are made not to injure the peritoneum. Dorsal access is relatively simple in comparison because you can use the Processus spinosus to get your bearings on the respective lumbar vertebra.

Female Breast, Overview and Development

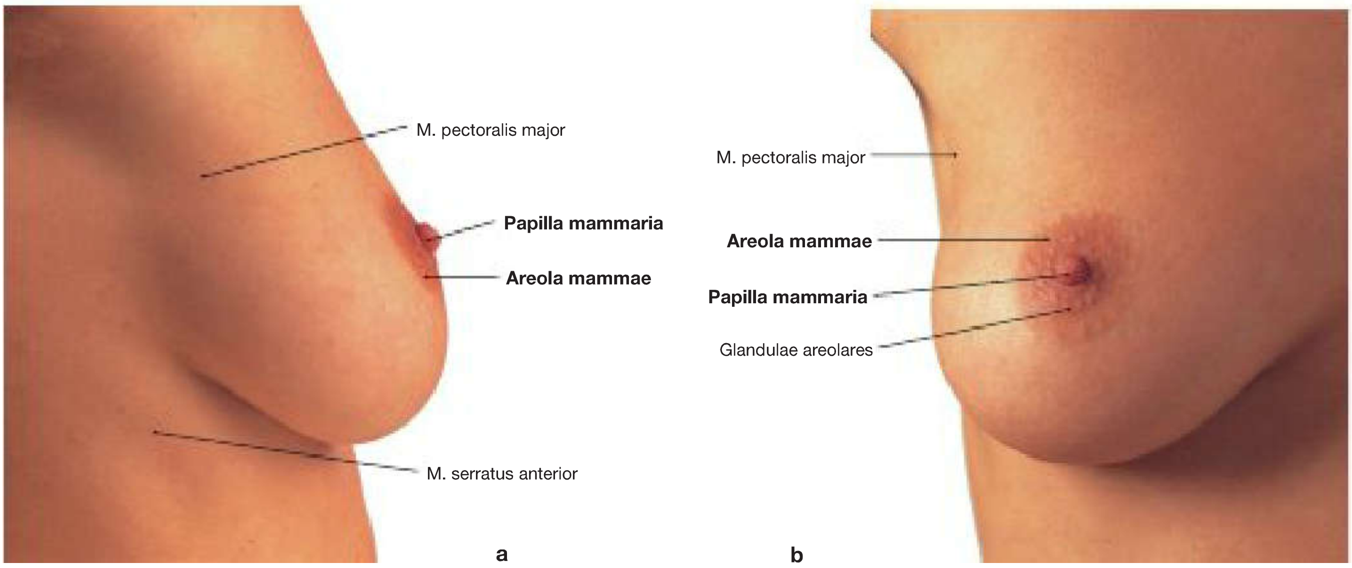


Fig. 2.135a and b Breast, Mamma; lateral view (→ Fig. 2.135a) and ventral view (→ Fig. 2.135b).

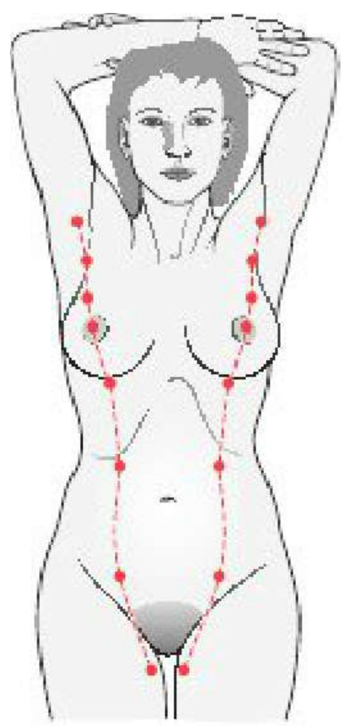


Fig. 2.136 Milk line. [L126]
The mammary gland development begins in the milk line, a strip of condensed epithelium, which forms in the 6th development week in the surface ectoderm and which extends from the armpit into the inguinal region. The milk line regresses to the area above the M. pectoralis major. The breast (Mamma) development takes place here.

Clinical Remarks

The absence of nipples **(athelie)** or breasts **(amastia, aplasia of mammary gland)** are rare congenital anomalies that can occur unilaterally or bilaterally. In the case of surplus nipples or breasts one speaks of **polythelie** or **polymastie.** This is usually hereditary and can also affect men.
The rudimentary mammary tissue usually does not develop further in men after birth. However, if breast growth does continue in men (often in the context of hormonal disorders), one speaks of **gynecomastia.**
Some female breasts are too large **(mammary hypertrophy),** causing shoulder and back pain. In such cases, breast reduction surgery is indicated.

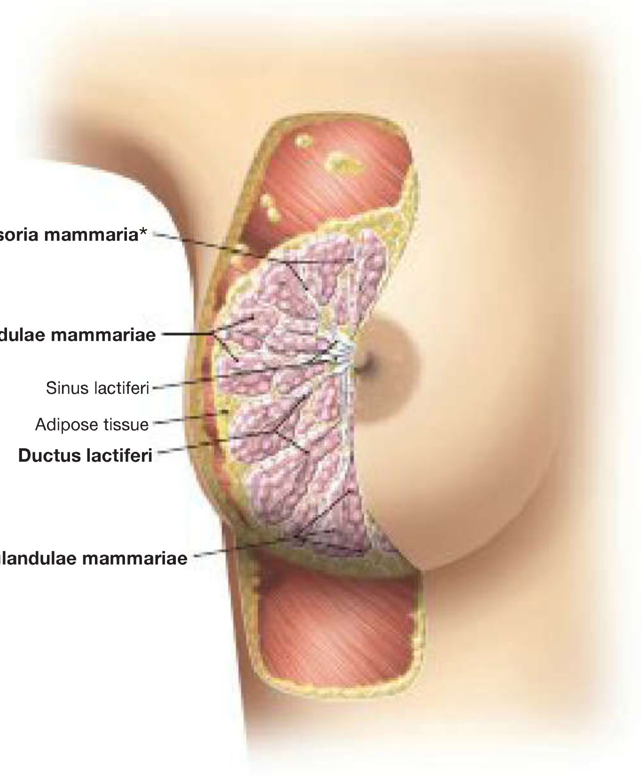


Fig. 2.137 Breast, Mamma; ventral view. [L127]
The breast consists of the mammary gland (Glandula mammaria) and a fibrous stroma, which contains adipose tissue. The breast has up to 20 individual lobes (Lobi), each possessing a separate efferent duct opening on the nipple (Papilla mammaria). Terminals parts that are arranged in groups (lobuli) are located at the ends of the branched efferent ducts. During pregnancy, the glandular tissue transforms into the lactating breast.

* clinical term: COOPER ligaments

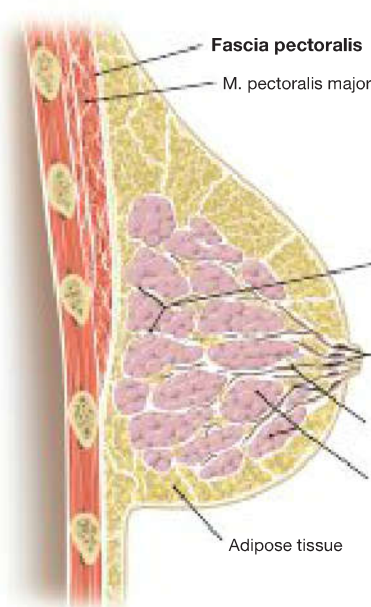


Fig. 2.138 Breast, Mamma; sagittal section. [L127]
The breast is flexibly secured with strong connective tissue threads (Ligg. suspensoria mammaria, COOPER ligaments) on the Fascia pectoralis of the M. pectoralis major.

* clinical term: COOPER ligaments

Female Breast, Blood supply and Lymph Drainage

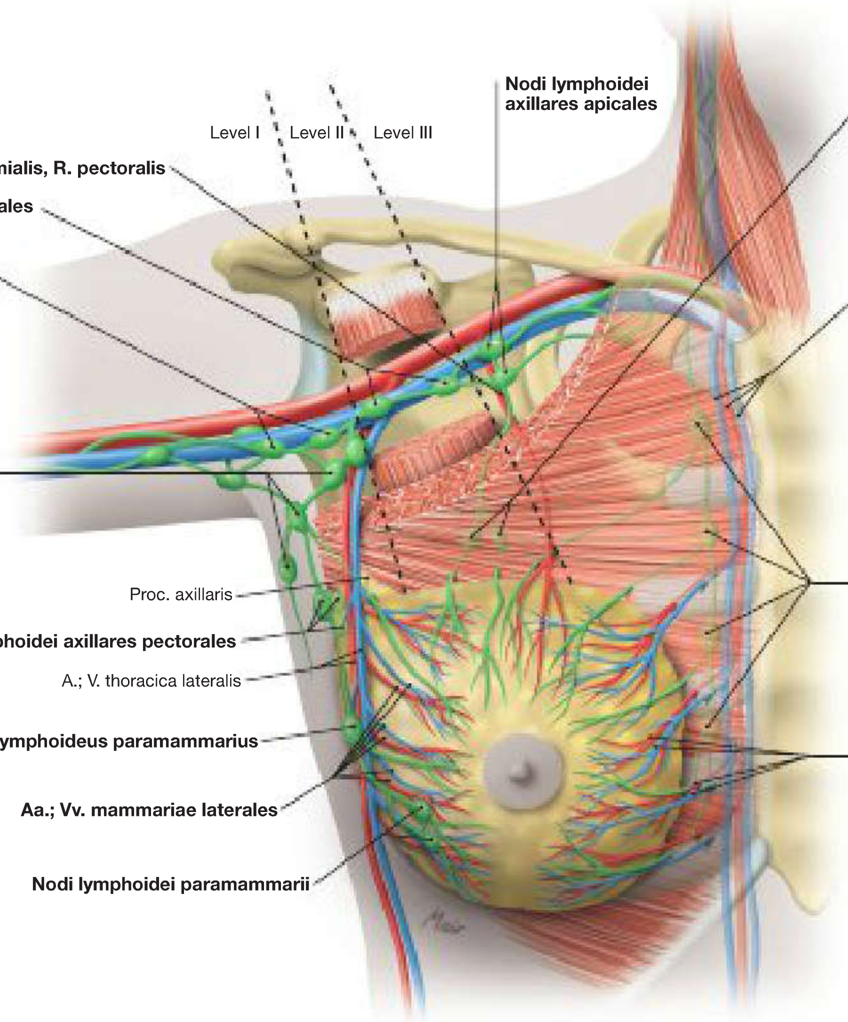


Fig. 2.139 Blood supply of the female breast, lymphatic drainage passages of the female breast lymphs, and location of regional lymph nodes.
The approximately 40 axillary lymph nodes do not just filter the lymph of almost the entire upper extremity but also collect two thirds of the lymph from the breast and most of the lymph from the thoracic and upper abdominal wall. The **Truncus subclavius** collects the lymph of the axillary lymph nodes and drains it on the right into the **Ductus lymphaticus dexter** and on the left into the **Ductus thoracicus** (not shown).

* clinical term: ROTTER lymph nodes

Clinical Remarks

From a clinical topographic and oncosurgical viewpoint, lymph nodes of the female breast are categorized into **three levels**. In doing so, the M. pectoralis minor acts as a boundary:
- Level I lies lateral of the M. pectoralis minor.
- Level II lies under the M. pectoralis minor.
- Level III lies medial to the M. pectoralis minor.

The parasternal lymph nodes of both sides are interconnected. The lymph is drained via level I into level II and from here into the Nodi lymphoidei axillares apicales in level III. From here, the lymph passes into the Truncus subclavius.

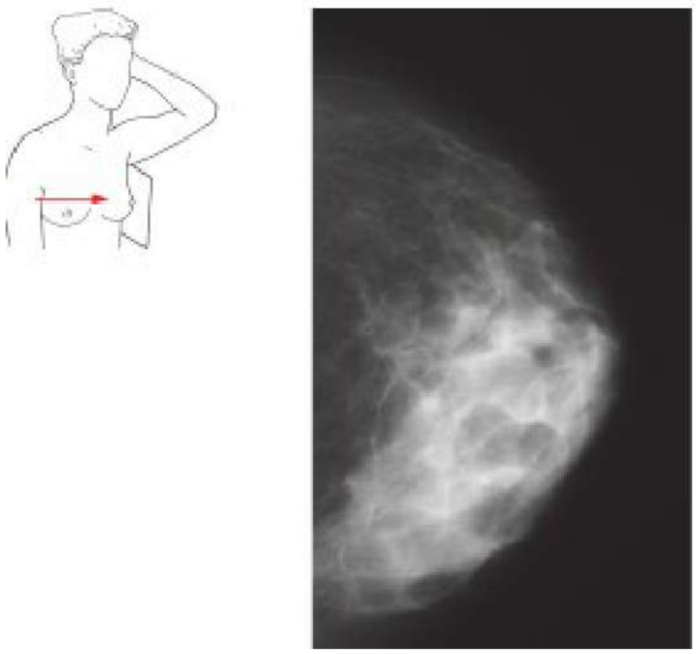


Fig. 2.140 X-ray of the breast (mammography) of a 47-year-old woman.
A mammography is an X-ray examination for the early detection of breast cancer (mammary carcinoma), the most common cancer in women.

Fig. 2.141 X-ray of the breast (mammography) of a 23-year-old woman. [G198]
You can see the normal breast tissue as unfocused white consolidations, primarily behind the nipple. In young women, the mammary tissue can be extremely tight and only contain small quantities of interspersed fat.

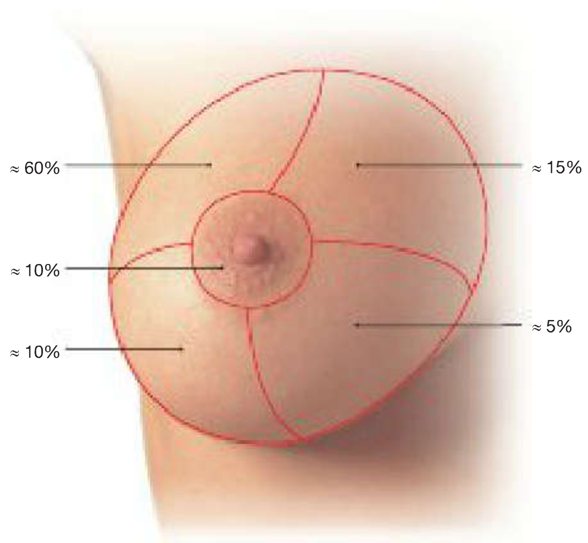


Fig. 2.142 Frequency of occurrence of breast cancer in relation to the location percentage.

Fig. 2.143 Mammography of malignant breast cancer. [T903]

Clinical Remarks

Breast cancer is responsible for 18% of all cancer deaths in women in Germany. This means that breast cancer is the first cause of cancer death, even before intestinal and lung cancer. In women, breast cancer is the leading cause of death between the age of 35 and 55 years. In about 60% of all cases the upper outer quadrant of the breast is affected (→ Fig. 2.142). Breast cancer originates mostly from the epithelium of the Ductus lactiferi (ductal carcinoma) and metastasises mainly into the axillary lymph nodes, less often into the retrosternal (parasternal) lymph nodes.

The first lymph node located in the drainage area is known as the sentinel (guard). It usually represents the first station for a metastatic lymph node settlement. The number of affected lymph nodes in the three hierarchical levels is directly related to the survival rate. Breast cancer of the medial quadrant can metastasise via the interconnected parasternal lymph nodes on the other side.

Skin Innervation of the Thoracic and Abdominal Wall

Fig. 2.144 Segmental sensory innervation of the ventral thoracic and abdominal wall (dermatomes).
Skin regions which are innerved by the sensitive fibres of a single spinal nerve are called dermatomes. The nipple lies in the dermatome T4 to T5; the navel in the dermatome T10.

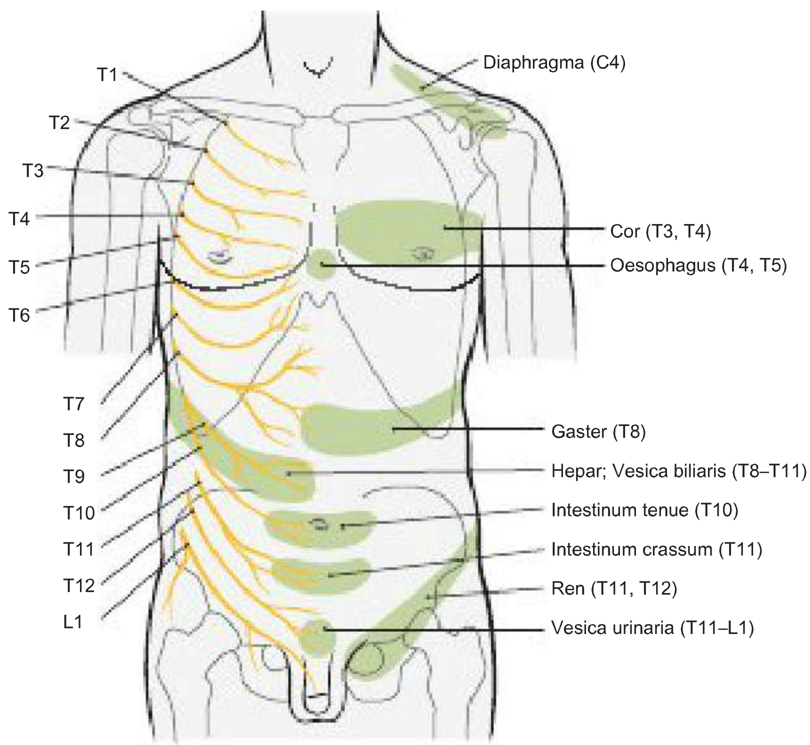


Fig. 2.145 Segmental sensory innervation of the thoracic and abdominal wall. [L126]
The spinal nerves which are responsible for the innervation of the dermatomes are shown on the right side (→ Fig. 2.144).
A HEAD's zone is the name for an area in which there is a link between the somatic (= animal) and the autonomic nervous system via the associated spinal cord segment, due to the structured body (Metamerie). Certain internal organs are assigned to this area. The HEAD's zone, which is assigned to a specific organ, can extend over several dermatomes, but has a maximum reflective significant point.

Clinical Remarks

Shingles **(herpes zoster)** is the most common infection of the peripheral nervous system. Herpes zoster leads to an acute neuralgia, which is limited to the dermatome of a specific sensory spinal or cranial nerve. The cause is an infection with varicella zoster virus, which causes chickenpox on first infection and is now re-activated. It leads to a vesicular rash (blistering), which is limited to the innervation area of a sensitive root ganglion or a sensitive cranial nerve. Initially, the patient suffers from intense burning and localised pain, followed three to five days later by blistering. An irritation of the corresponding internal organ of a **HEAD's zone** (→ Fig. 2.145) can initiate a viscerocutaneous reflex resulting in pain in a specific, mostly ipsilateral zone (zone of hyperalgesia). This phenomenon is called **referred pain**. The pain can sometimes spread to adjacent segments or to the whole of the affected body side (generalisation).

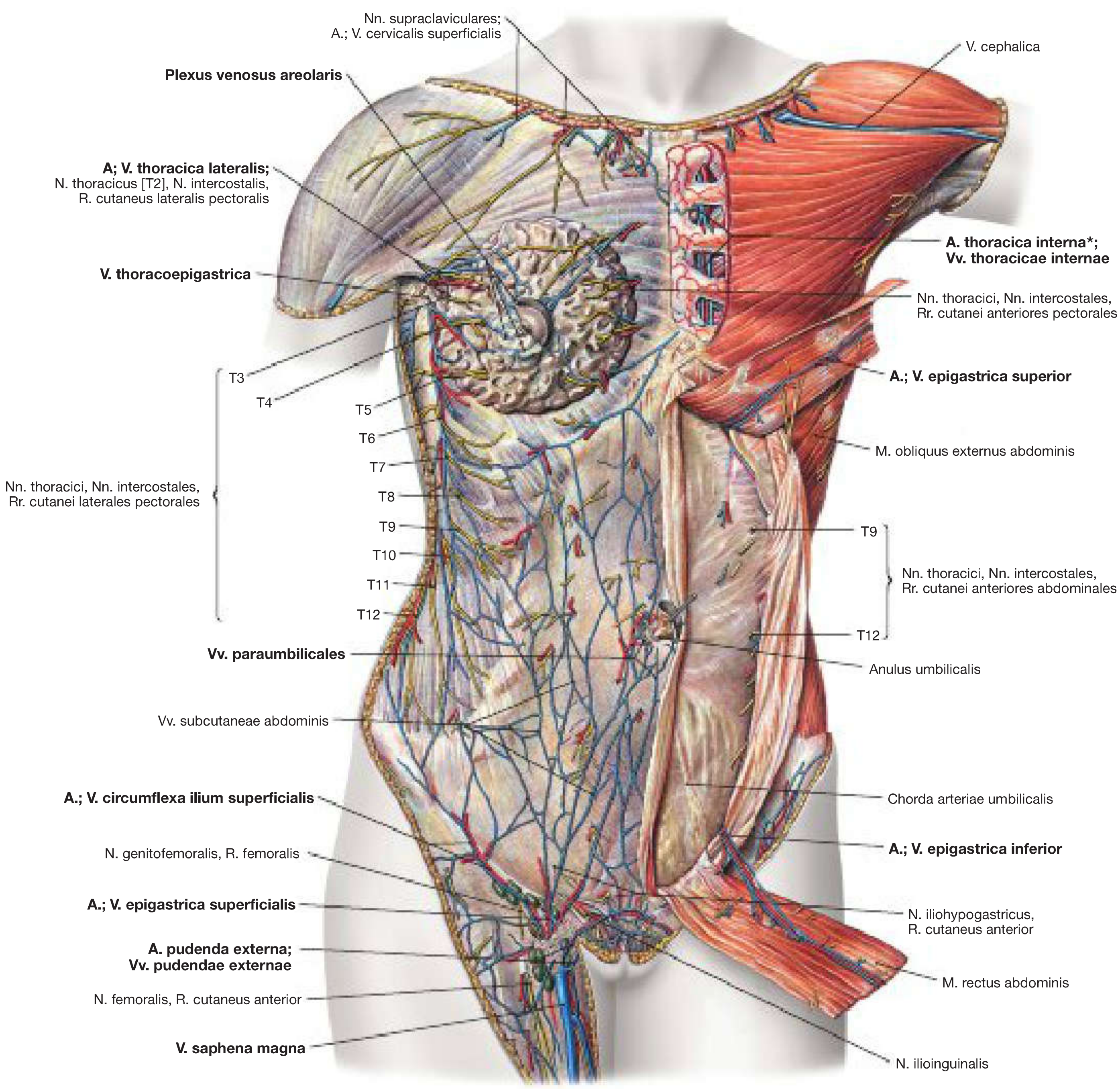


Fig. 2.146 Epifascial and deep vessels and nerves of the abdominal wall in the female; ventral view.
On the right side of the body, the Fasciae deltoidea, pectoralis, thoracica, abdominis and lata are presented with their epifascial neurovascular pathways and the mammary gland. The Mamma receives its blood supply from the Rr. mammarii mediales of the A. thoracic interna and from the Rr. mammarii laterales of the Aa. thoracica lateralis and thoracodorsalis.

On the left side of the body, the superficial fascia has been removed to provide a clear view of the muscles. The rectus sheath is opened, the M. rectus abdominis is cut along the middle; its parts are folded upward and downward. On the back, you can see the Vasa epigastrica superiora and inferiora.

* clinical term: A. mammaria interna

Inner Outline of the Anterior Abdominal Wall

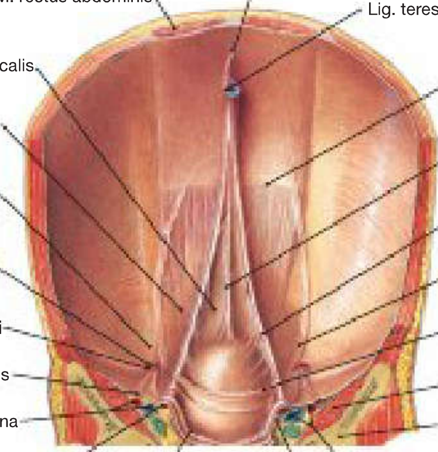


Fig. 2.147 Anterior abdominal wall of a newborn; view from the inside.
In the case of a mature newborn, the descent of the testes into the scrotum (Descensus testis) is complete. Above the Anulus inguinalis profundus the Peritoneum parietale descends as Proc. vaginalis peritonei slightly into the inguinal canal.

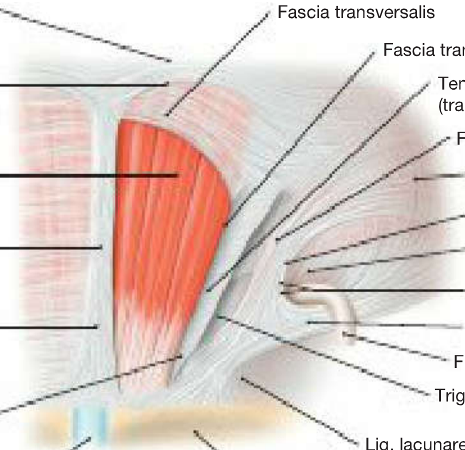


Fig. 2.148 Anterior abdominal wall; view from the inside; Peritoneum parietale and Fascia transversalis are partially removed. [L127]
Presentation of the Trigonum inguinale (HESSELBACH triangle), of the Lig. interfoveolare (HESSELBACH ligament) and the Fossa inguinalis lateralis with the extending Funiculus spermaticus.

* clinical term: HESSELBACH's ligament
** clinical term: HESSELBACH's triangle
Based on: Tillmann, B. N.: Atlas der Anatomie. 2. Aufl. Springer, 2010

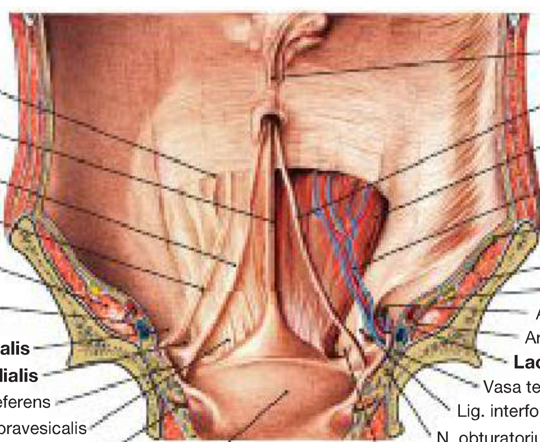


Fig. 2.149 Anterior abdominal wall; view from inside.
The Fossa inguinalis medialis, Fossa inguinalis lateralis, Lacuna vasorum and Lacuna musculorum are presented. To view the neurovascular pathways, the Peritoneum parietale and the Fascia transversalis were removed from the right side of the body.

* clinical term: HESSELBACH's ligament
** clinical term: HESSELBACH's triangle

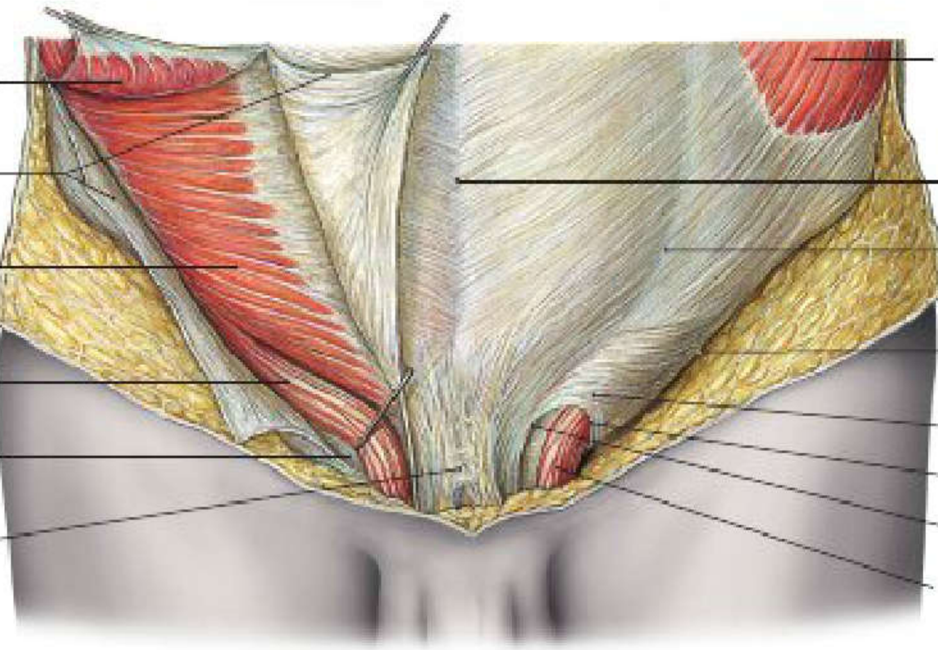


Fig. 2.150 Outer inguinal ring, Anulus inguinalis superficialis; ventral view.
Boundaries of the outer inguinal ring are the **Crus mediale** and **Crus laterale,** formed by the aponeurosis of the M. obliquus externus abdominis, between which the Fibrae intercrurales stretch. The caudal margin is formed by the **Lig. reflexum** as part of the Lig. inguinale.

On the right side of the body the aponeurosis of the M. obliquus externus abdominis is folded back and provides a view of the **M. obliquus internus abdominis**. Muscle fibres of the M. obliquus internus abdominis separate as **M. cremaster** and draw down into the scrotum along with the Funiculus spermaticus.

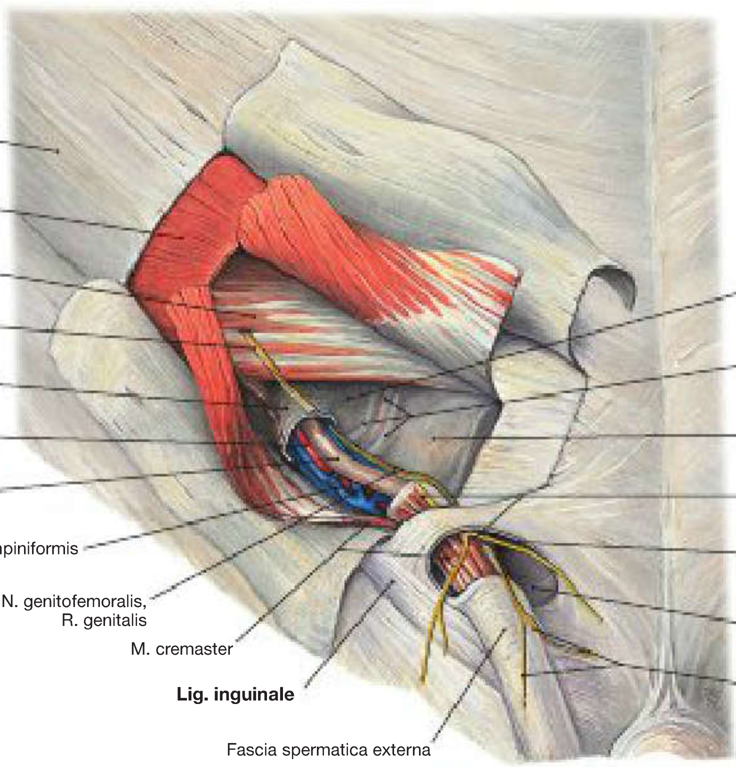


Fig. 2.151 Walls and contents of the inguinal canal, Canalis inguinalis, right side; ventral view. [L240]
The inguinal canal is confined at the front by the aponeurosis of the M. obliquus externus abdominis, from below by the Lig. inguinale, at the back by the fascia transversalis and from the top by the free edge of the M. transversus abdominis.

Clinical Remarks

The **cremasteric reflex** is defined as contraction of the M. cremaster when touching the inside of the thigh, resulting in an elevation of the testis on the same side. It is a physiological extrinsic reflex. Afferent fibres run in the R. femoralis of the N. genitofemoralis, and the efferent fibres in the R. genitalis of the N. genitofemoralis.

The Anulus inguinalis profundus is the **internal hernial canal** for indirect inguinal hernias, the Fossa inguinalis medialis (HESSELBACH's triangle, → Fig. 2.149) is the internal hernial canal for direct inguinal hernias and the Septum femorale in the Lacuna vasorum is the internal hernial canal for **femoral hernias**.

Inguinal Canal

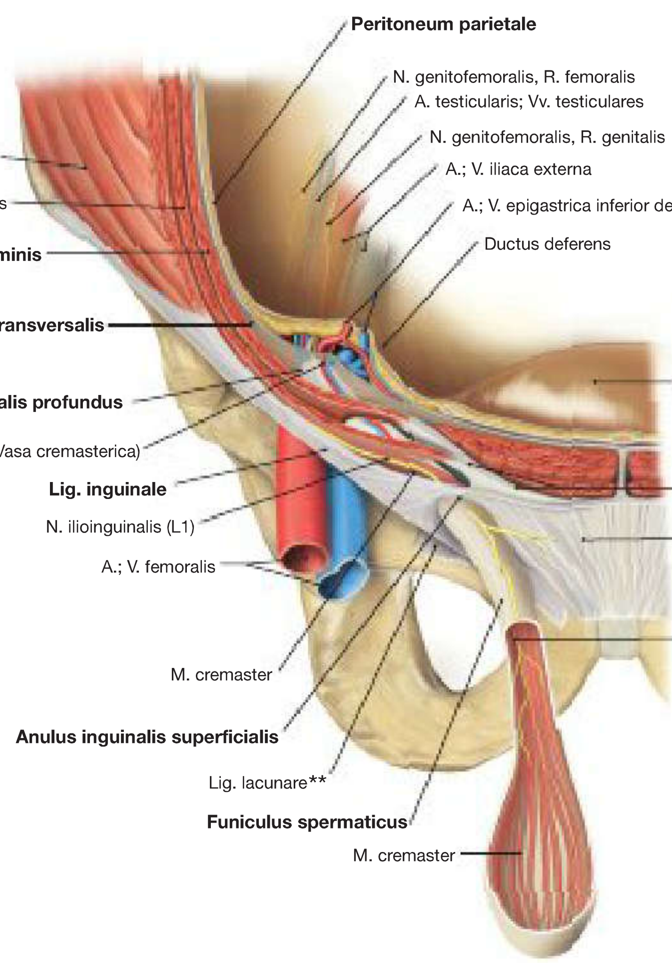


Fig. 2.152 Inguinal canal, Canalis inguinalis and spermatic cord, Funiculus spermaticus right side; ventral view. [L280]

The approximately 4–6 cm long inguinal canal penetrates the ventral abdominal wall above the inguinal ligament in an oblique angle from a posterior-lateral-cranial to anterior-medial-caudal direction. The inner opening is the **Anulus inguinalis profundus** of which is formed the posterior by the peritoneum and the Fascia transversalis, cranially by the M. transversus abdominis and caudally by the Lig. inguinale. The outer opening is the **Anulus inguinalis superficialis,** which is confined at the front by the aponeurosis of the M. obliquus externus abdominis and below by the Lig. inguinale (Lig. reflexum). The **Funiculus spermaticus appears from the inguinal canal.** On its Fascia spermatica externa, the N. scrotalis anterior of the N. ilioinguinalison gets to the front section of the scrotum. The **M. obliquus internus abdominis** runs like the M. transversus abdominis above the Funiculus spermaticus and provides fibres (M. cremaster) which run along the Funiculus spermaticus up to the testes, between the Fasciae spermaticae externa and interna. The Funiculus spermaticus is enclosed in a separate fascia (Fascia cremasterica). The M. cremaster plays a decisive role in the thermoregulation of the spermatogenesis.

* transversus conjoined tendon
** clinical term: GIMBERNAT's ligament

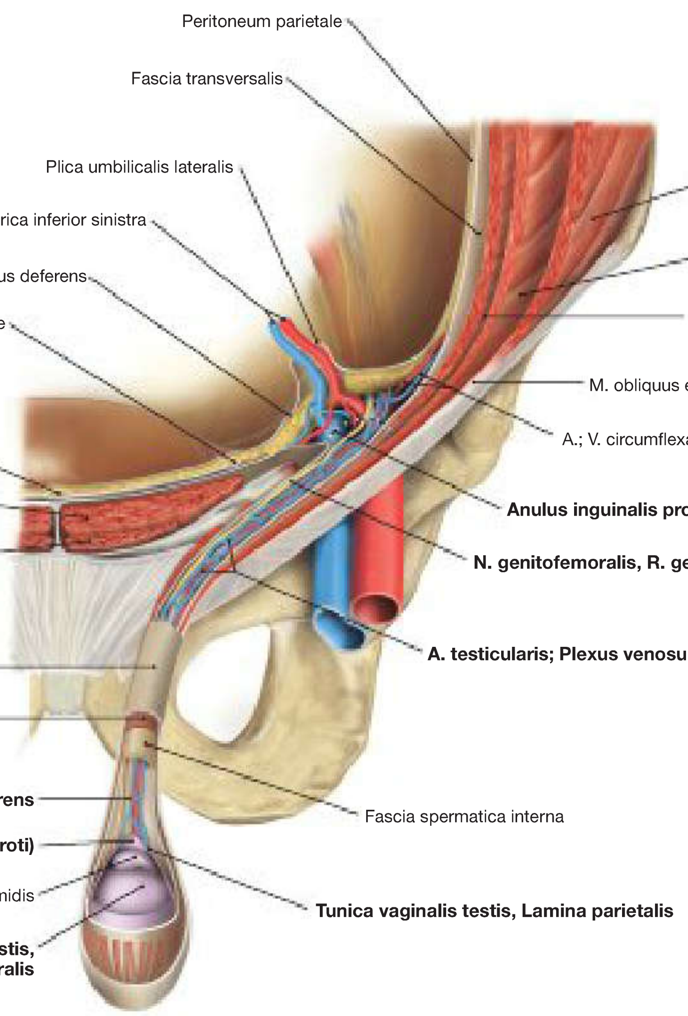


Fig. 2.153 Content of the spermatic cord, Funiculus spermaticus, and testicular sheaths, left side; ventral view. [L280]
Covered by the Fascia spermatica externa, M. cremaster and Fascia spermatica interna, the **spermatic cord** contains the spermatic duct (ductus deferens), the A. ductus deferentis, the A. testicularis (a direct branch of the aorta), the plexus pampiniformis (drains into the V. testicularis and from there on the right side into the V. cava inferior and on the left side into the V. renalis), the R. genitalis of the N. genitofemoralis and the Vestigium processus vaginalis (obliterated Proc. vaginalis testis which guided the testicular descent from the abdominal cavity into the scrotum, → Fig.2.154).

The **testis** is covered by the Laminia visceralis of the Serosa (Epiorchium) and is separated by the Cavum serosum scroti (a cavity) from the encasing Lamina parietalis (Periorchium). The epiorchium and periorchium are connected at the mesorchium. The Fascia spermatica interna is enveloped by the fibres of the M. cremaster which in turn is enveloped by the Fascia spermatica externa. The two testicles (testes) are embedded in the scrotum (not shown), which is padded by the membrane (Tunica dartos). The latter contains a number of myoepithelial cells, which can collectively cause the scrotum to contract and are thus involved in the thermoregulation of the spermatogenesis.

Clinical Remarks

Fluid accumulation in the Cavitas serosa scroti is referred to as **hydrocele**. Cysts within the Proc. vaginalis testis lead to swelling of the Funiculus spermaticus and are referred to as hydrocele funiculi spermatici.
Retention cysts of the epididymis are called **spermatoceles**. Malformation of the mesorchium (attachment zone of the testis and epididymis) can lead to **testicular torsion** (common in puberty) with strangling of the venous return via the Plexus pampiniformis and subsequent strangling of the A. testicularis with risk of aseptic necrosis of the testes.
A back-flow of blood in the Plexus pampiniformis is called **varicocele**, which occurs in 80% of all cases on the left side (because the V. testicularis on the left drains into the V. renalis on the left). Causes are often obstacles in drainage, e.g. such as a renal tumour. Varicoceles can lead to infertility.

Development of the Inguinal Canal

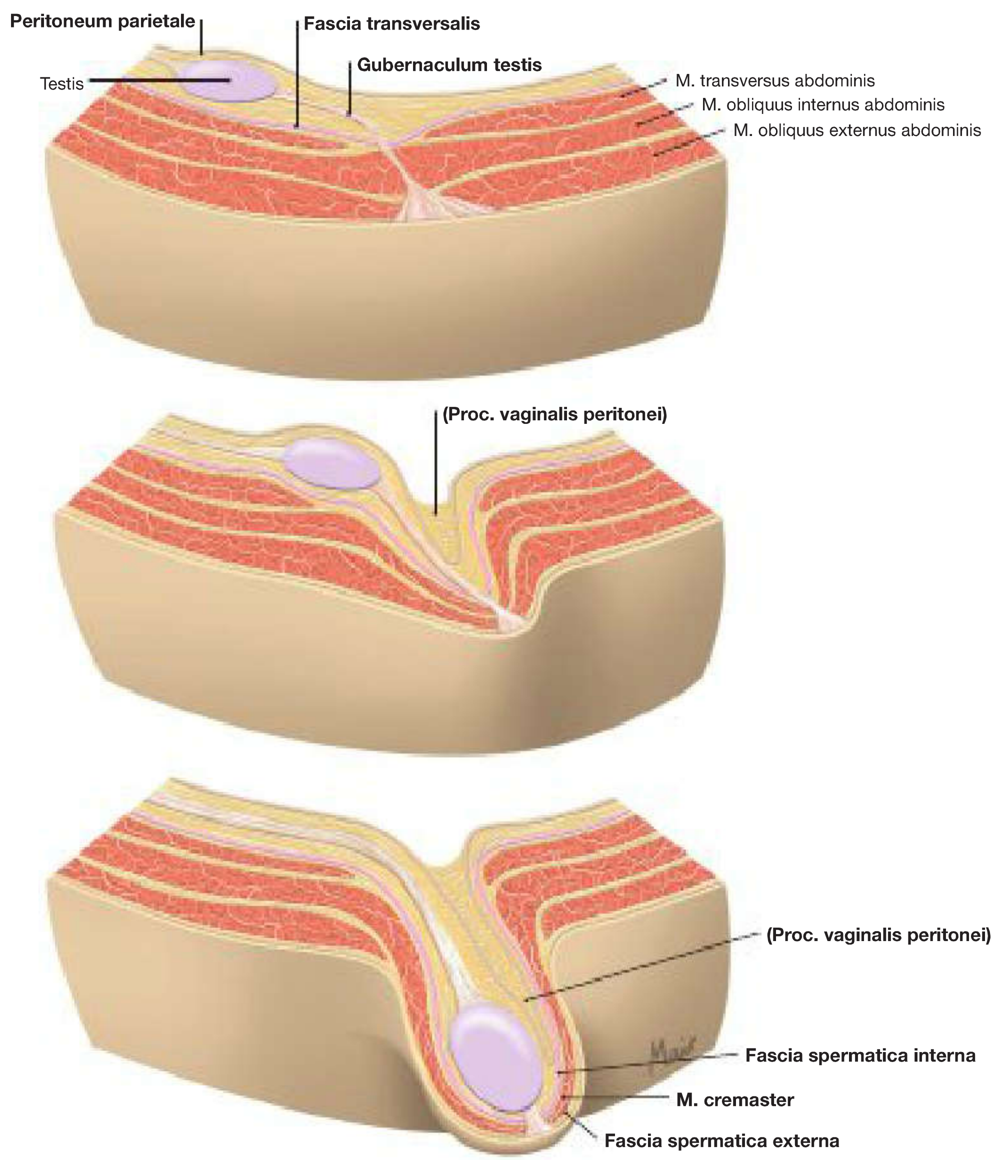


Fig. 2.154 Descensus testis from the 7th week (post conception) until birth. [L127]
In the male embryo, the testes move out of the abdominal cavity in the foetal period by descending along the lower Gubernaculum testis under the Peritoneum parietale at the dorsal abdominal wall into the scrotum.

The peritoneum parietale forms a pouch in the inguinal canal (Proc. vaginalis peritonei), which reaches down to the scrotum and ends up above the testes. The Proc. vaginalis peritonei obliterates shortly after birth, except for a remnant near the testis (Tunica vaginalis testis).

Clinical Remarks

The Descensus testis in the scrotum is a sign of foetal maturity at birth. **Disorders of the Descensus testis** occur in approx. 3% of all newborns. The testicle can remain in the abdominal cavity or in the inguinal canal (testicular retention, cryptorchidism, ectopic testis).

Due to the high ambient temperature (spermatogenesis usually runs at 35 °C), a **testicular ectopy** as fertility problems and an increased risk of malignant degeneration may occur.

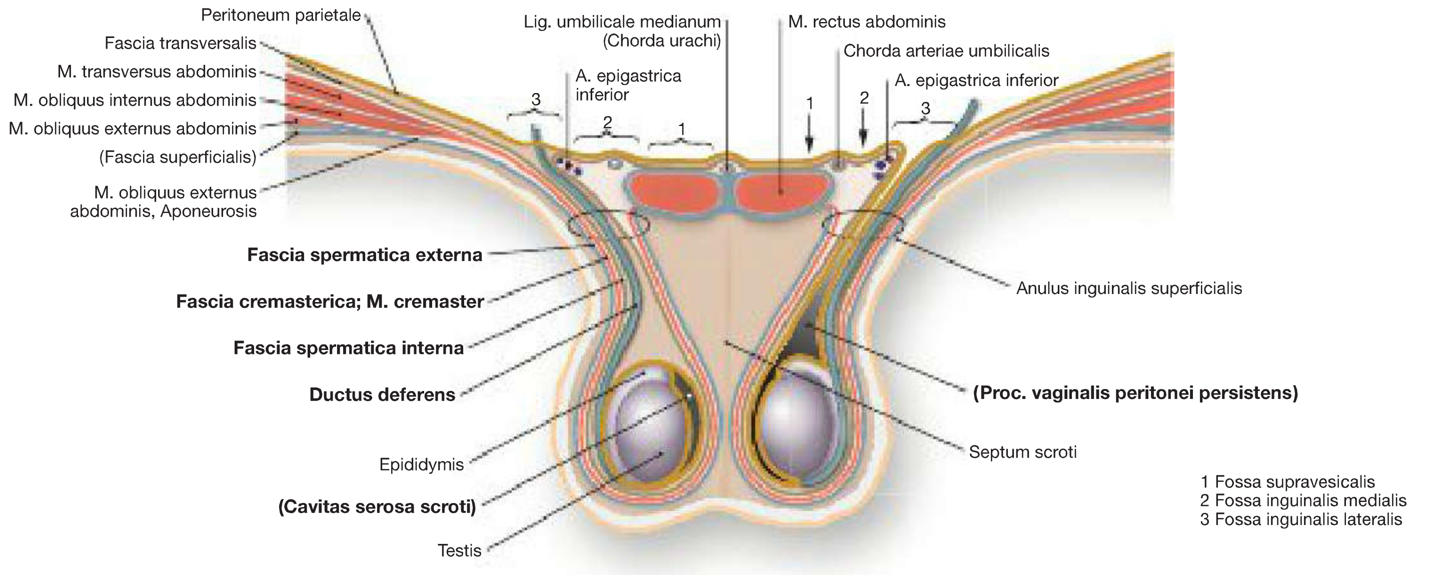


Fig. 2.155 Structure of the abdominal wall and the coverings of the spermatic cord, Funiculus spermaticus, and testes, Testis; schematic representation. For didactic reasons the inguinal canal, the spermatic cord and the scrotum are drawn on the same plane. [L275]
The Descensus testis causes the testis to lie in a pouch of the abdominal wall which extends into the scrotum. Therefore, scrotum and spermatic cord possess the same structure as the abdominal wall.
The fascia of the M. obliquus externus abdominis continues as **Fascia spermatica externa** on the Funiculus spermaticus. Underneath it lies the M. cremaster (enveloped by the Fascia crematerica) which has separated from M. obliquus internus abdominis. Under the M. cremaster lies the **Fascia spermatica interna**, which envelopes the contents of the Funiculus spermaticus. As the next layer, the Fascia Spermatica interna is a separation from the aponeurosis of the M. transversus abdominis. With the exception of a remnant in the testicular region (Tunica vaginalis testis with Lamina parietalis = Periorchium and Lamina visceralis = Epiorchium), the Proc. vaginalis is obliterated and has become the **Vestigium processus vaginalis** (a fibrous cord; left side of the image). On the right side of the image, the Pro vaginalis testis is not closed, but persists (Proc. vaginalis peritonei persistens). There is an open connection between the abdominal cavity and Cavitas serosa scroti.

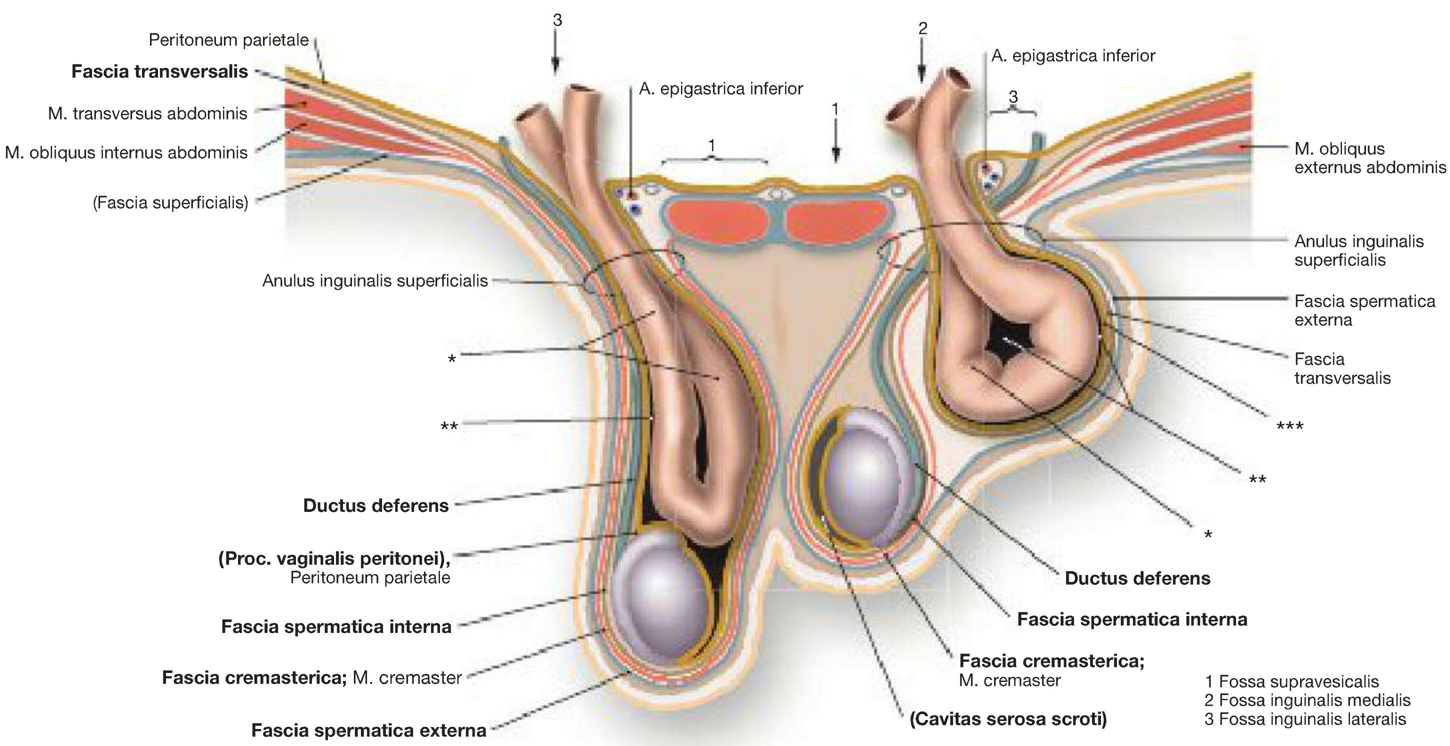


Fig. 2.156 Hernias; schematic drawing. Left side of the image: lateral, indirect hernia; right side of the image: medial, direct hernia. [L275]
Indirect hernias (canal hernias) enter into the inguinal canal in the Fossa inguinalis lateralis through the Anulus inguinalis profundus.
Direct inguinal hernias penetrate through the muscle-free Trigonum inguinale (HESSELBACH's triangle) into the Fossa inguinalis medialis, which is a weak spot in the abdominal wall. Here, the posterior abdominal wall consists only of the Fascia transversalis and Peritoneum parietale (Paries dorsalis tenuis canalis inguinalis).

- * intestinal loop in the hernial sac
- ** peritoneal space
- *** newly formed peritoneal hernial sac

Inguinal Canal of a Newborn

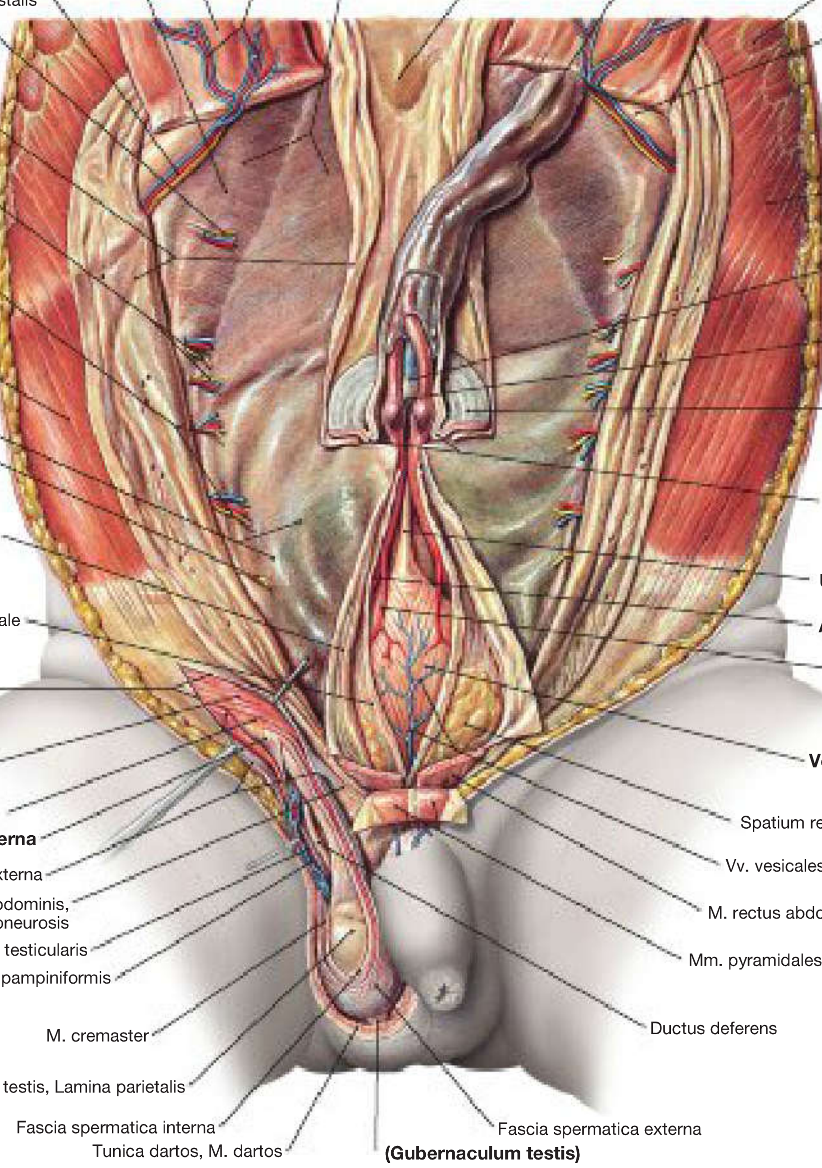


Fig. 2.157 Anterior abdominal wall of a newborn; the Mm. recti abdominis are folded upwards cranially; the abdominal cavity is opened in the median plane together with the umbilical cord; on the right side the inguinal canal is prepared.

The Fascia spermatica externa is secured via remnants of the Gubernaculum testis to the base of the scrotum sac. In the area of the opened abdominal cavity up to the navel you can see the bladder with the Urachus and the umbilical cord blood vessels.

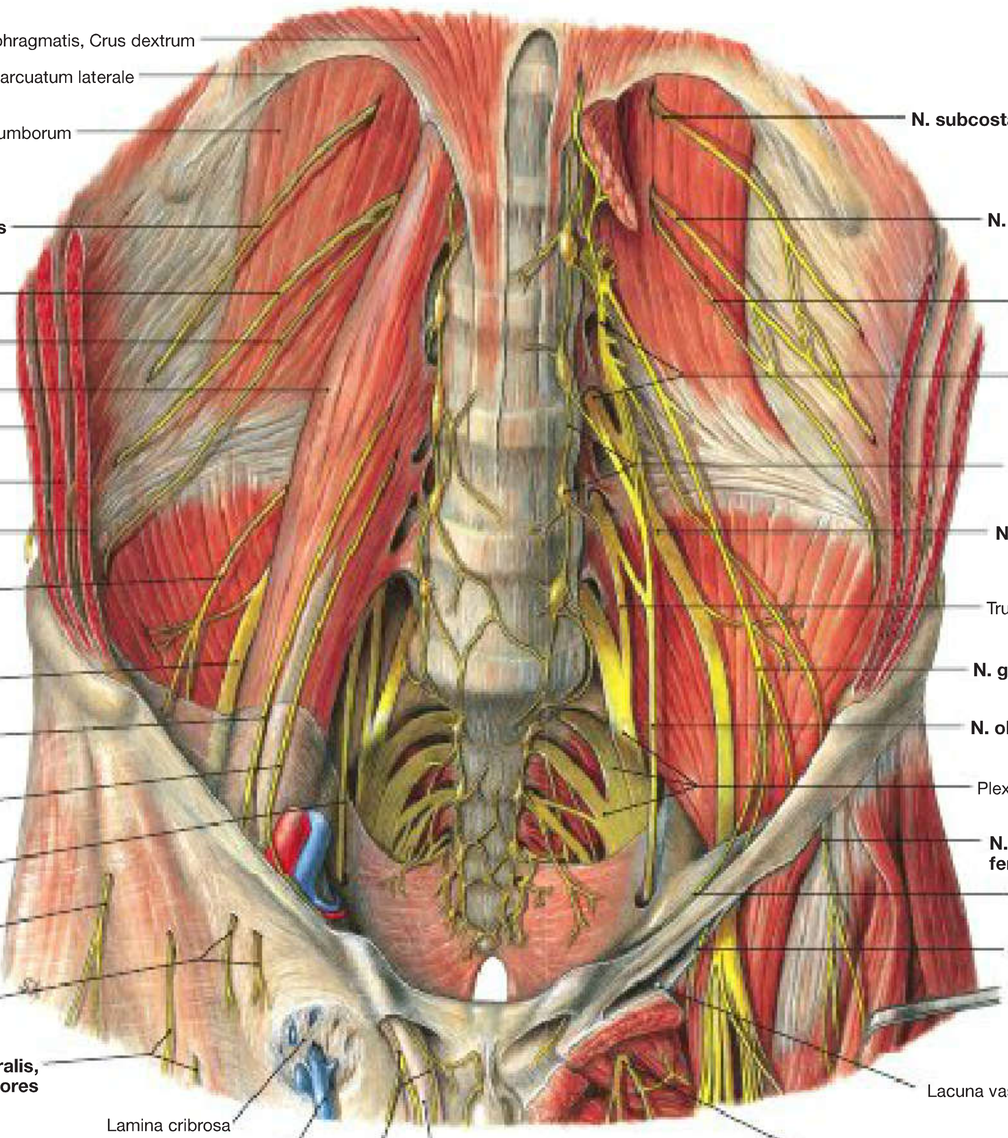


Fig. 2.158 Posterior abdominal wall with Plexus lumbosacralis; ventral view. [L238]

The Plexus lumbosacralis consists of the Plexus lumbalis (T12, L1–L3 [L4]) and the Plexus sacralis ([L4] L5, S1–S5). The Plexus lumbalis is important for the innervation of the wall of the trunk. The illustration shows the segmental organisation and the course of the **Rr. anteriores [ventrales] of the spinal nerves of the Plexus lumbalis**, which innervate the abdominal muscles, the inguinal region and the thigh. Cranially to caudally, these are the Nn. subcostalis (intercostalis XII), iliohypogastricus (T12, L1), ilioinguinalis (L1), genitofemoralis (L1, L2) with R. femoralis and R. genitalis and the N. cutaneus femoris lateralis (L2, L3). In addition, you can see the exit of the N. femoralis (L1–L4), which after crossing through the Lacuna musculorum, provides Rr. cutanei anteriores for skin innervation on the thigh, and also the N. obturatorius ([L1] L2–L4), which enters the Canalis obturatorius.

→ T 40

Practice Exam Questions

To check that you are completely familiar with the content of this chapter, practice questions from an oral anatomy exam review are listed here.

Explain the structure of a vertebra:

- How do the vertebrae of the different sections of the spine differ from each other?
- What are the characteristics of the 1st and 2nd cervical vertebrae?
- Which ligaments stabilise the spine and how are the cervical spine and skull connected to each other?
- Which movements can be carried out in the spine between two vertebrae and in general?
- What is meant by a motion segment?
- Which muscles are instrumental to the movements of the spine?

Explain the structure of the thoracic wall:

- What structures must be pierced consecutively during a pleural puncture?
- What must be taken into account during a pleural puncture from an anatomical point of view?
- What is the course of the intercostal muscles and what are their functions?

Explain the structure of the abdominal wall:

- How is the rectus sheath formed?
- Where are the weak points?
- What functions do the straight and oblique abdominal muscles have?
- What passes into the abdominal wall folds?

Explain the structure of the diaphragm:

- What points of penetration do you know and what passes through them?
- Which weak spots do you know?
- What is meant by the quadratus arcade?
- How is the diaphragm innervated and what is it covered with?

Explain the blood supply in the area of the thoracic and abdominal wall:

- What arterial connections exist between the upper and lower halves of the body?
- What is meant by vertical and horizontal bypass circuits?
- Can you name cavocaval anastomoses?
- Which blood vessels run on the inside of the thoracic and abdominal wall and communicate with each other?

Explain the structure of the neck muscles and their localised structures:

- What are the short neck muscles called?
- What is meant by the vertebral triangle?
- What are the nerves of the neck called?

Explain the structure of the epidural space:

- How is a spinal nerve structured?
- What structures are in the Foramen intervertebrale?
- To what structures do you have to pay attention in a lumbal puncture?

Specify location and structure of the Mamma:

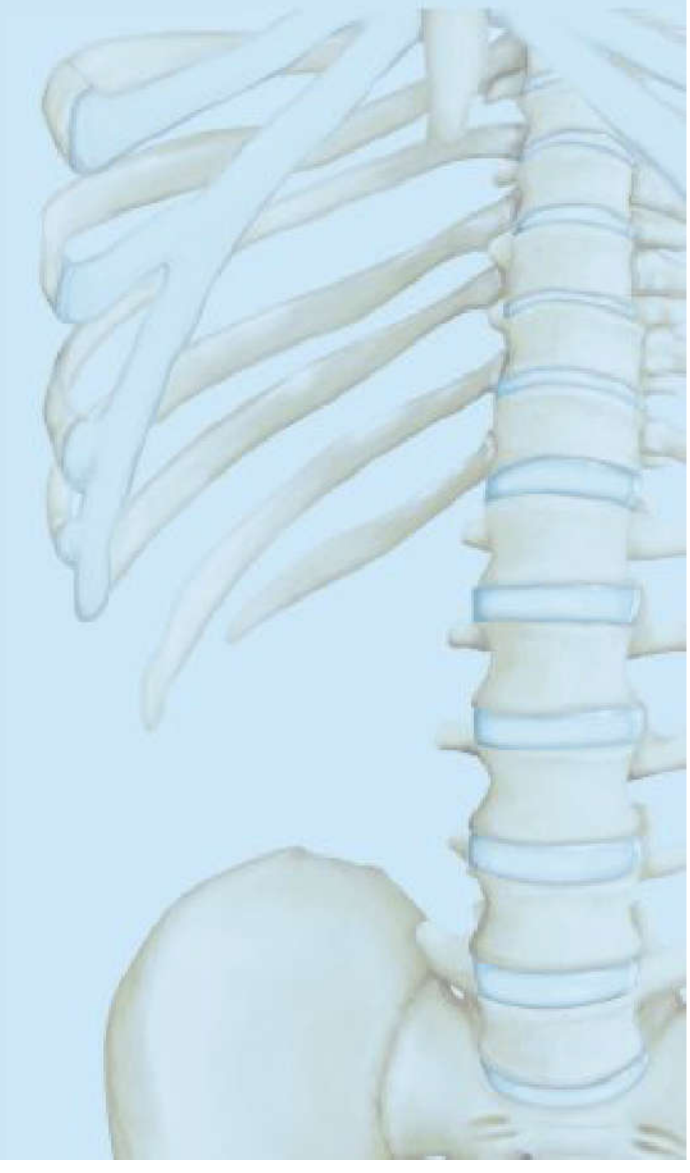
- What is the milk line and where does it run?
- Why is the female breast divided into quadrants?
- Name local lymph node groups in the area of the Mamma.
- From a clinical topographic and oncosurgical viewpoint, lymph nodes of the female breast are divided into levels. Which are these and what are their borders?

Explain the difference between dermatome and HEAD's zone:

- Can you name characteristic dermatomes on the ventral trunk wall?
- Show the HEAD's zone, which is assigned to the heart. What is meant by referred pain?

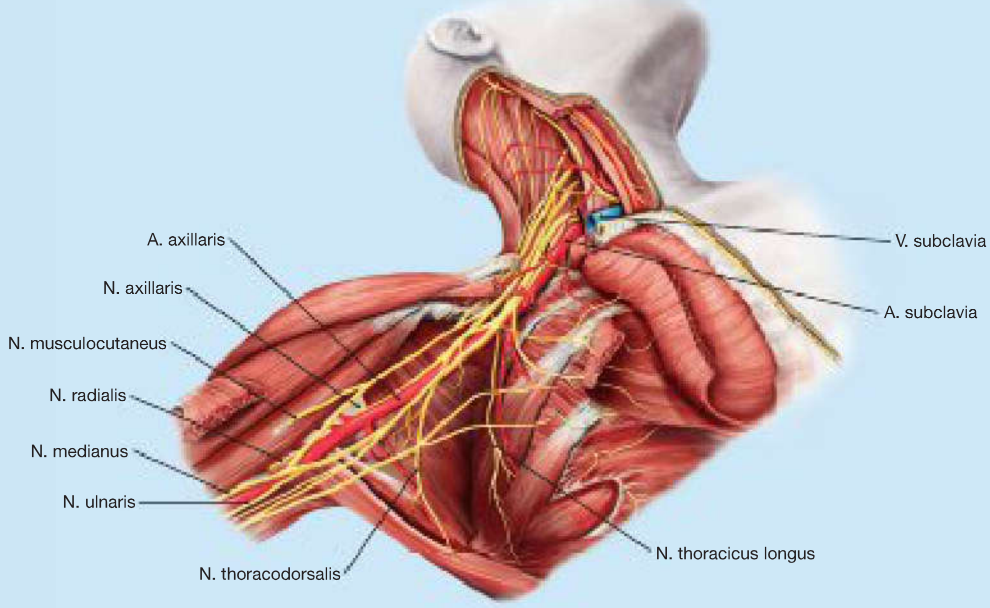
Explain the structure of the inguinal canal:

- What structures course through the inguinal canal?
- How is the inguinal canal confined?
- What is the Proc. vaginalis peritonei and what happens if it does not obliterate? Explain Descensus testis.
- What is meant by indirect inguinal hernia, and direct?



Upper Limb

3



Overview

The **upper limb** includes the **shoulder girdle and arm.** The shoulder girdle consists of the clavicle and the shoulder blade on each side. The arm is subdivided by joints into the upper arm, forearm and hand. The shoulder girdle and thus the whole upper limb are only anchored by the medial clavicular joint directly at the torso.
In contrast to the lower limb, which is a running and support organ, the upper limb is a **tactile and grasping organ.** In the evolutionary development its range of motion has significantly increased. As the turning movement is made by the forearm bones in conjunction with the wrists, the hand gained a considerably increased freedom of motion. Other features are the **differentiated mobility of the individual fingers** and the **opposition** of the thumb, which enables the grasping function and is unique in its efficiency.
The muscles of the upper limb are innervated by a **nerve plexus (Plexus brachialis)**, fed mainly via the spinal nerves from the spinal cord segments C5–T1. Various nerves for the shoulder and arm come from the Plexus brachialis. The blood vessels that supply the arm are the **A. and V. subclavia** and their downstream vascular branches. To a large extent the lymphatic vessels run in conjunction with the veins and are connected to the **axillary lymph nodes**, which also drain the thoracic wall including the mammary gland.

Main Topics

After studying this chapter, you should be able to:

- name the basic principles of limb development and the clinically relevant variations and malformations;
- describe the bony structures of the shoulder girdle and arm as well as their joints along with the range of motion on a skeleton;
- explain the course of the ligaments on the joints, as well as the origin, insertion (attachment) and function of all muscles of the shoulder girdle and arm, and to show these on a skeleton or dissected corpse. With regard to the hand muscles, it is often sufficient to describe the basic principles of their course and function as well as their innervation;
- describe the arrangement of the Plexus brachialis, to show its structures on the dissection and to explain the symptoms associated with plexus lesions;
- name the functions and dysfunctions of the shoulder nerves;
- describe the course, function and precise symptoms associated with a lesion of the major nerves in the arm and to show these on the corpse;
- identify all arteries of the upper limb on the dissection;
- explain the vascular anastomoses of the shoulder and upper arm region;
- understand the basic principle of the venous flow in the upper limb;
- name the large epifascial veins and show them on the corpse;
- explain the principles of the lymph flow in the upper limb;
- explain the axillary lymph node stations and their clinical relevance;
- specify the neurovascular pathways, which cross the MOHRENHEIM's fossa;
- name the borders of the axillary spaces, to describe the penetrating structures and locate them on the corpse;
- explain the course of the neurovascular pathways in the elbow joint;
- explain the architecture and penetrating structures of the carpal tunnel and of the GUYON's canal.

Clinical Reference

In order not to lose reference to future everyday clinical life with so many anatomical details, the following describes a typical case that shows why the content of this chapter is so important.

Brachial Plexus Lesion

Case Study

A 20-year-old man is found at a crash barrier at the side of the road following a motorcycle collision. He is dizzy, but conscious and responsive. As far as can be seen, he seems to have no obvious external injuries. The patient is stabilised on a vacuum stretcher with a cervical collar, to avoid the risk of shifting broken bones and damaging the spinal cord, and is brought to hospital.

Result of Examination

The patient is conscious and fully orientated. He has severe pain at different points. His heart rate (100/min), respiratory rate (25/min) and blood pressure (140/100 mmHg) are slightly increased.

Diagnostic Procedure

Apart from bruises (contusions) and skin abrasions found during the examination, the computerised tomography (CT) shows no additional evidence of broken bones (fractures) or internal injuries. The next day, after the injuries have been bandaged, an in-depth dynamic testing of the patient's mobility is conducted; this involves an examination of all joints as well as their range of motion being noted according to the neutral ('zero') method. The right arm can neither be raised (abducted) nor flexed in the elbow joint (→ Fig. a). It remains slack on the side of the body; the palm is turned outwards towards the back, i.e. the shoulder is rotated inwards. The movement of the hand and fingers is not affected. The touch sensation is lost in a strip-shaped area extending from the outside of the shoulder over the lateral forearm down to the thumb (dermatomes C5–C6). A magnetic resonance imaging (MRI) of the right shoulder is carried out. It shows that the spinal nerve roots of the spinal cord segments C5 and C6 have been torn off (avulsion) at their exiting point.

Diagnosis

Lesion of the Plexus brachialis type ERB (→ Fig. b).

Treatment

Initially the neurosurgeons secure the torn-off (avulsed) nerve roots by suturing the surrounding connective tissue. In the setting of a scientific study this surgical procedure is combined with the local application of growth factors that should accelerate the growth of nerve fibres. Physical therapy is begun in the postoperative days. After months of intense training ability to move is again possible to a limited extent.

Further Developments

The function of the elbow joint can be restored with restrictions, but the sensory disturbances persist in the forearm and thumb.
The complex symptoms (clinical signs) can only be explained by using detailed anatomical knowledge during physical examination – brachial plexus lesion.

Dissection Lab

The Plexus brachialis is one of the most complex structures which can be exposed in the dissection lab. It can only be displayed and explained after thoroughly studying it in an anatomy atlas (→ Fig. 3.91): The **Plexus brachialis** is formed by anterior branches (Rami) of the spinal nerves. The nerves of the lower cervical and the upper thoracic segments (C5–T1) supply the Plexus. The anterior branches of the spinal nerves combine initially to form **three trunks (Trunci)** that run between the deep cervical muscles (Mm. scaleni) through the **Hiatus scalenus** to reach the axilla. There they form **three fascicles** surrounding the A. axillaris.

It is advisable to focus extensively on the origin of the nerves in the dissection hall – otherwise it is easy to lose track of the overall picture!

The individual nerves then emerge from the trunks and fascicles. The cranial spinal cord segments (C5, C6) supply the proximal shoulder muscles and the corresponding skin regions via **short shoulder nerves**. The caudal segments (C8, T1) supply the forearm and hand via long nerves. The **N. musculocutaneus** activates the flexors of the elbow joint in the upper arm and forms the lateral cutaneous nerve of the forearm. The flexors in the forearm are innervated by the **N. medianus and N. ulnaris** (from the medial fascicle). The extensor muscles are controlled by the **N. radialis** (posterior fascicle).

The Plexus brachialis is a good reference point, because the nerves form an 'M'!

Back to the Clinic

The symptoms show that a mixed motor and sensory lesion causes the loss of function. Considering the dysfunctions of all affected muscles and skin areas, the losses can be attributed to the spinal cord segments C5–C6. Therefore, it is likely that the impact on the crash barrier caused the shoulder to be pulled downwards, leading to an avulsion of the upper nerve roots of the Plexus brachialis. Therefore the diagnosis is an upper plexus lesion type ERB.

This is often queried in conjunction with the anatomy of the Plexus brachialis!

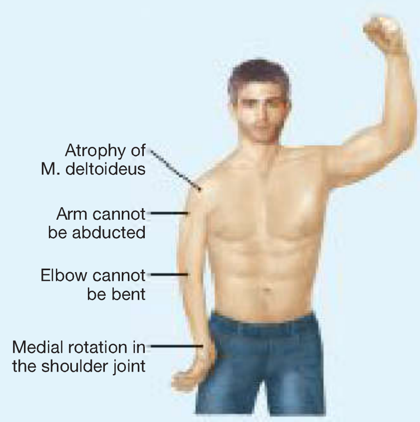


Fig. a Clinical picture of an upper brachial plexus lesion (ERB type). [L238]

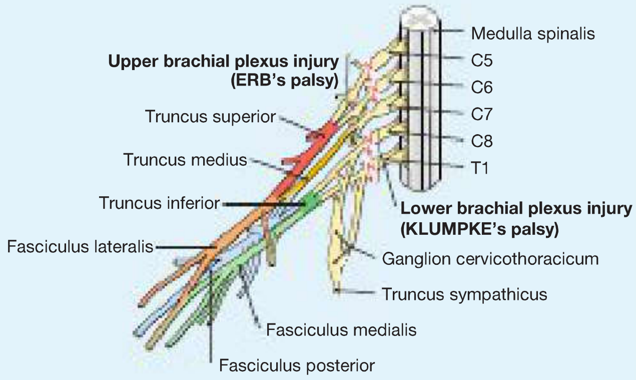
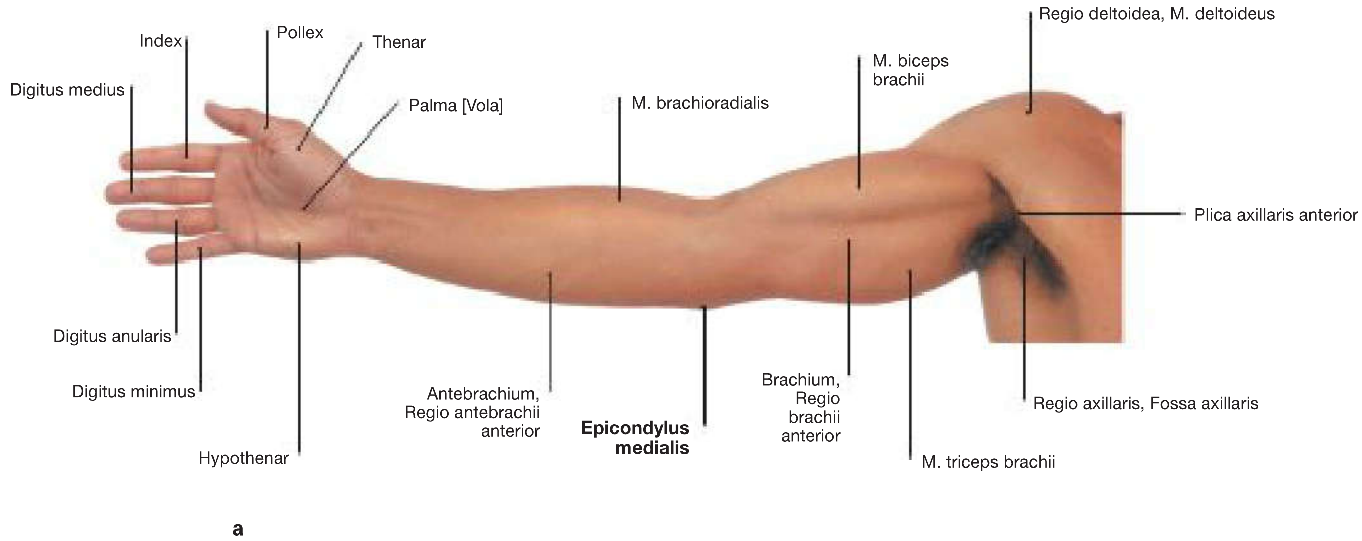


Fig. b Lesions of the Plexus brachialis, different types of spinal nerve lesions, right side; frontal view. [L126]

Surface Anatomy



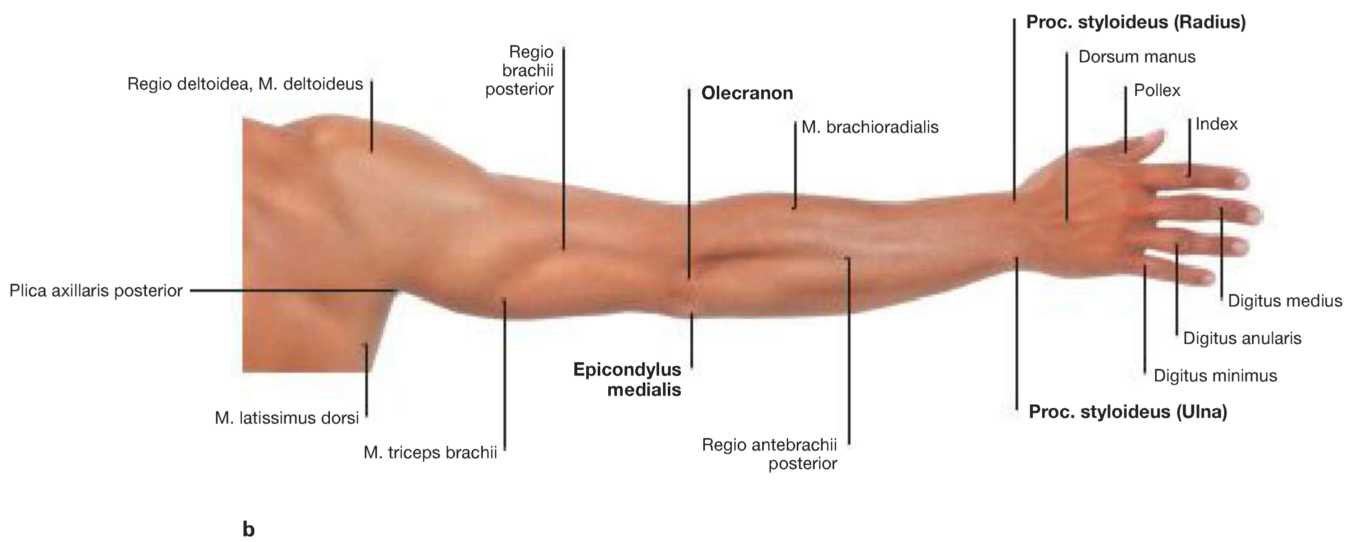


Fig. 3.1a and b Surface relief of the arm, right side; ventral view (→ Fig. 3.1a) and dorsal view (→ Fig. 3.1b).

Clinical Remarks

The surface relief of the arm is determined by the muscles and by some of the skeletal elements. The palpable bony landmarks facilitate orientation during the physical examination.

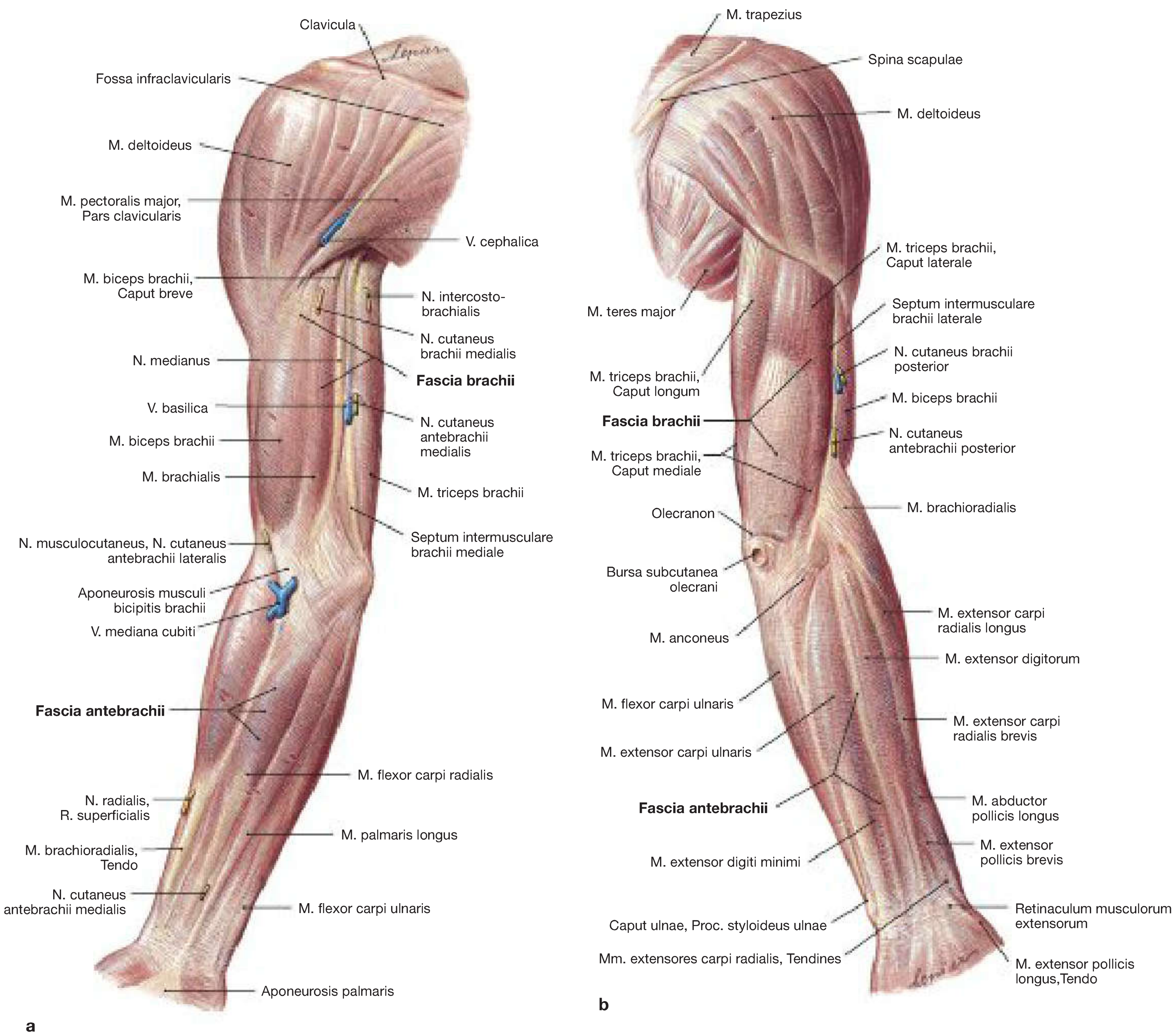


Fig. 3.2a and b Fascia of the upper arm, Fascia brachii, and of the forearm, Fascia antebrachii, right side; ventral view (→ Fig. 3.2a) and dorsal view (→ Fig. 3.2b).

As the illustration shows, the surface relief is determined primarily by the individual muscles. The muscles are covered with their own fascias and bundled to muscle groups. These group fascias are covered by a shared fascia, the fascia of the upper arm and the forearm, which lies underneath the subcutis of the skin. During dissection, after having displayed all important subcutaneous structures such as the cutaneous nerves and epifascial veins, the subcutaneous adipose tissue is removed completely to expose the outer layer of fascia.

Development

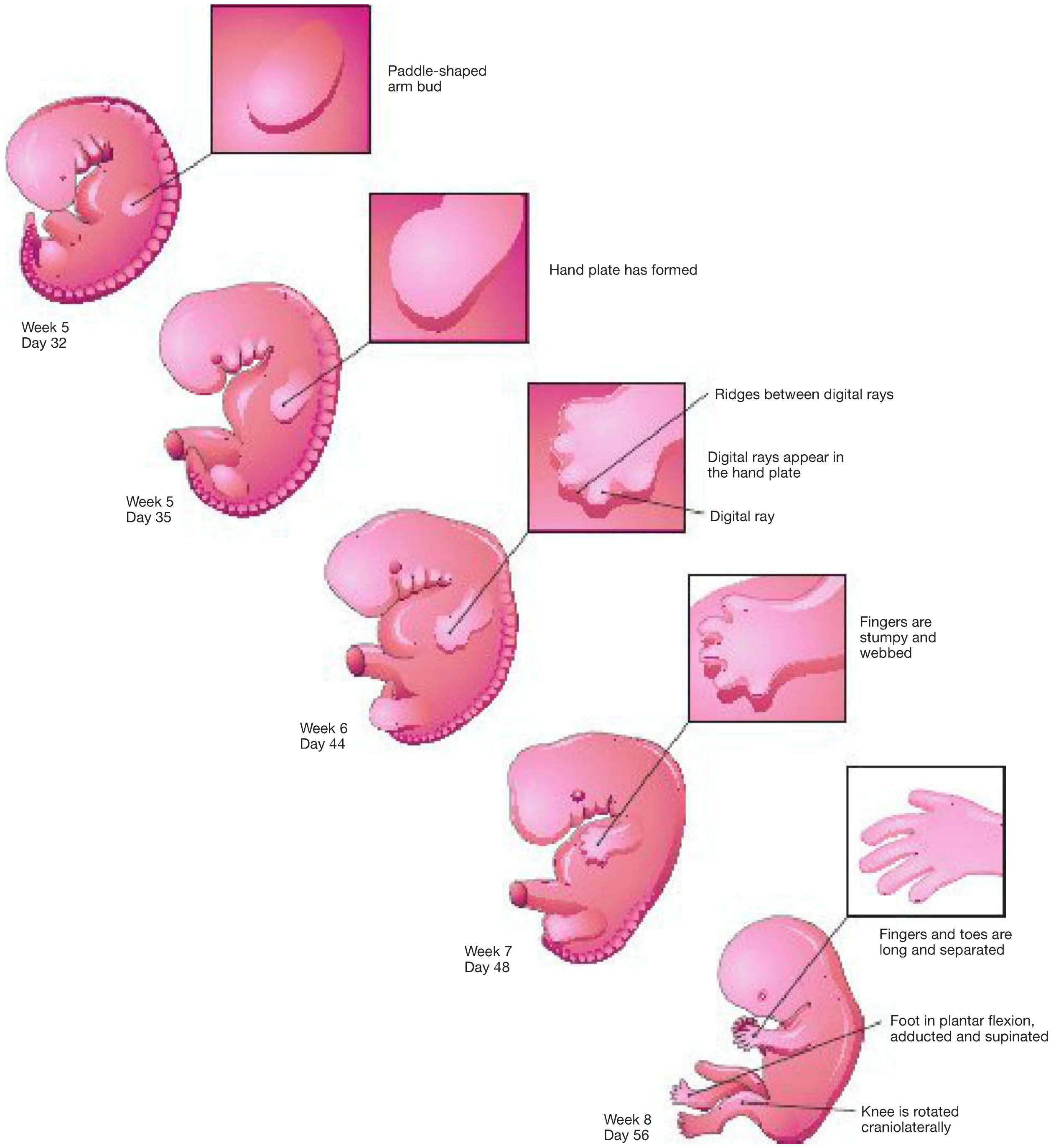


Fig. 3.3 Development of the limbs in week 5–8; schematic drawing. [E347-09]

The **limbs** begin to develop from week **4.** The flipper-like **arm buds** form on day **26–27** and therefore two days earlier than the leg buds. At this time, the primordial limbs consist of a mesenchymal core of connective tissue, originating from the mesodermal somatopleura as well as a superficial ectodermal layer which later forms the epidermis of the skin (→ Fig. 3.4). The ectoderm at the distal edge of the limb buds (ectodermal side bar) produces growth factors which attract precursors of muscle cells from the somites of the mesoderm in the torso region. The limb buds show in **week 5–6** signs of a **segmentation** in the primordial arms and legs. From week 6 the finger rays separate from each other as a result of the programmed cell death (apoptosis) in the interpositioned tissue. Up to the **end of week 8** the **fingers and toes** are completely **separated.**

In contrast to the primordial arms, the **primordial legs in week 8** undergo a rotation, leading to a **cranial-lateral orientation of the knee**. Therefore, the extensor muscles of the upper and lower leg lie ventrally, whereas they are on the dorsal side on the arm. Furthermore, **in week 8 the foot** initially becomes **plantarflected, adducted** and **supinated.** This foot position is generally reversed by week 11.

Clinical Remarks

A **congenital clubfoot** is the most common malformation (or deformity) of the extremities. In this case the foot is fixed in plantar flexion and supination. It is therefore assumed that this deformity is caused by the physiological foot position of the embryo in weeks 8 to 11 of gestation not reversing.

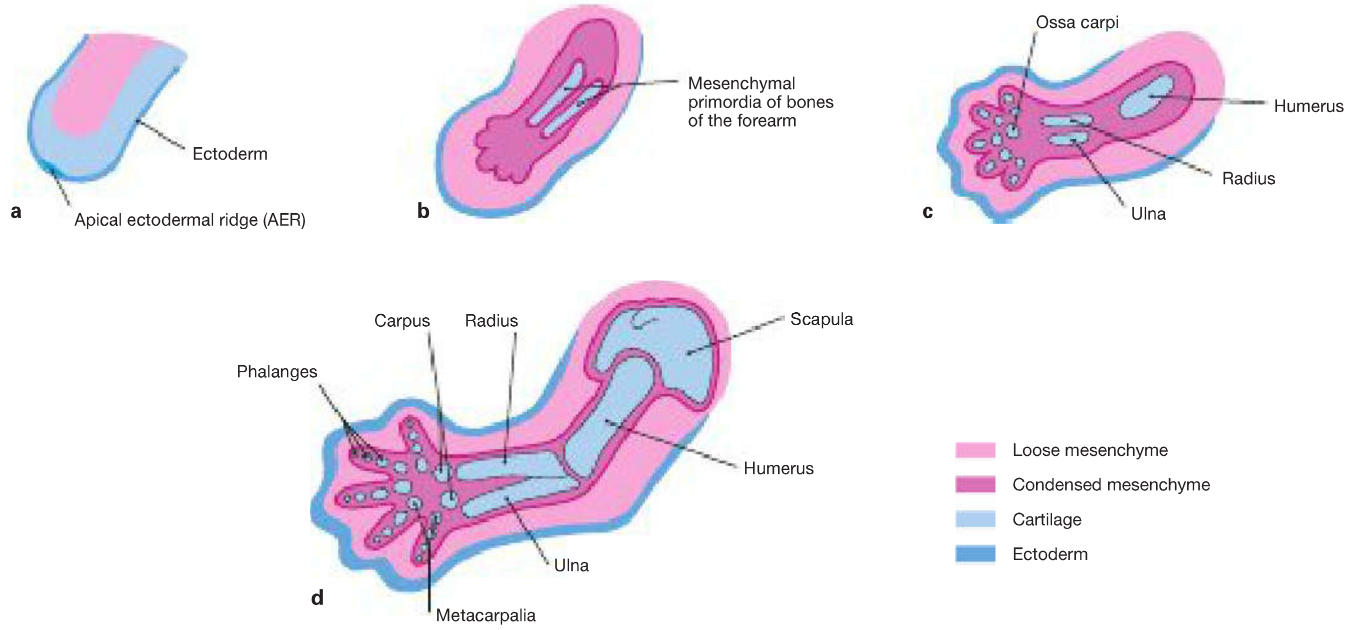


Fig. 3.4a to d Development of the cartilaginous precursors of the bones of the upper limbs in weeks 4–8; schematic longitudinal sections. [E347-09]

In **week 4** the primordial limbs consist of a mesenchymal core of connective tissue and a layer of superficial ectoderm that later forms the epidermis of the skin. The mesenchyme is consolidated so that – between **week 4 and week 6** on the arm and between **week 6 and week 8** on the leg – a **cartilaginous skeleton** develops as a precursor of future bone. This process advances from proximal to distal.

In this cartilaginous skeleton nuclei or ossification centres form, which **from week 7** initiate the ossification and thus the conversion of the cartilaginous skeleton into bony tissue **(endochondral ossification).** This ossification progresses in a specific pattern (→ p. 25).

- **Up to week 12 ossification centres (nuclei)** can be found in all bones of the upper limb, apart from the wrist. The ossification centres (nuclei) of the **wrist** emerge only after birth (postnatal) between the **1st and 8th year of life.** An exception is the clavicle, which emerges from **week 7** without a cartilaginous precursor and thus derives directly from the mesenchyme **(desmal ossification).**
- The ossification of the lower limb is a little bit delayed. While the first ossification centres (nuclei) in the femur and leg bones emerge as early as in **week 8**, the ossification centres in the phalanges do not follow before **week 9** and the **6th month.** The tarsal bones (1st–4th year of life) and the pelvic girdle (sometimes up to the 20th year) ossify postnatally.

The **closure of the epiphyseal gaps** which signifies the completion of the longitudinal growth of the limbs, takes place at the age of **14 to 25 years,** in most of the bones by **21 years.**

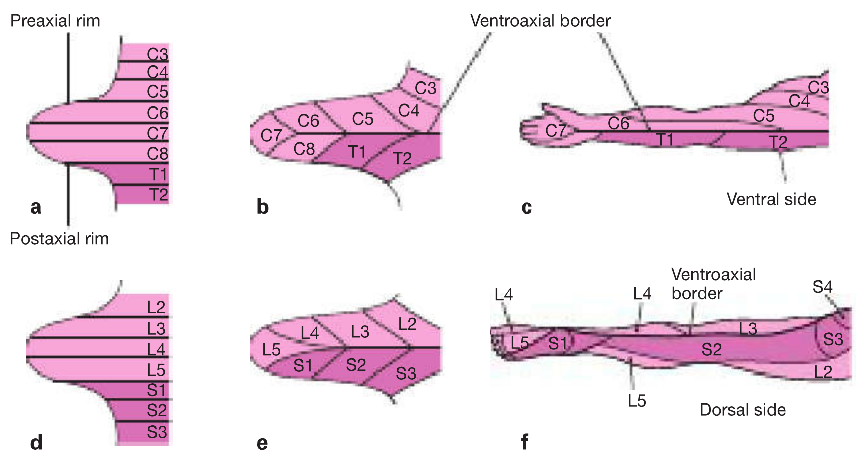


Fig. 3.5a to f Development of the dermatomes in the limb regions. [E347-09]

Sensory innervation of certain cutaneous areas is supplied by a single spinal cord segment (dermatome). In contrast to the belt-like orientation of the dermatomes on the torso, the dermatomes on the limbs initially have an almost longitudinal direction (**a, d**), following an increasingly oblique direction later in the development (→ Fig. 3.94 and → Fig. 4.126). Arms and legs show a ventral-axial border (**b, c, e, f**) with hardly any overlap of the individual areas with sensory innervation.

– Clinical Remarks

From the progression of the ossification **(bone age),** the future growth and adult height of children can be predicted by means of X-ray examinations. In X-ray examinations to exclude broken bones (fractures) it must be considered that the bones of children may in part still consist of ossification centres (nuclei) not yet ossified or fused. Therefore the bones are not fractured.

Skeleton of the Upper Limb

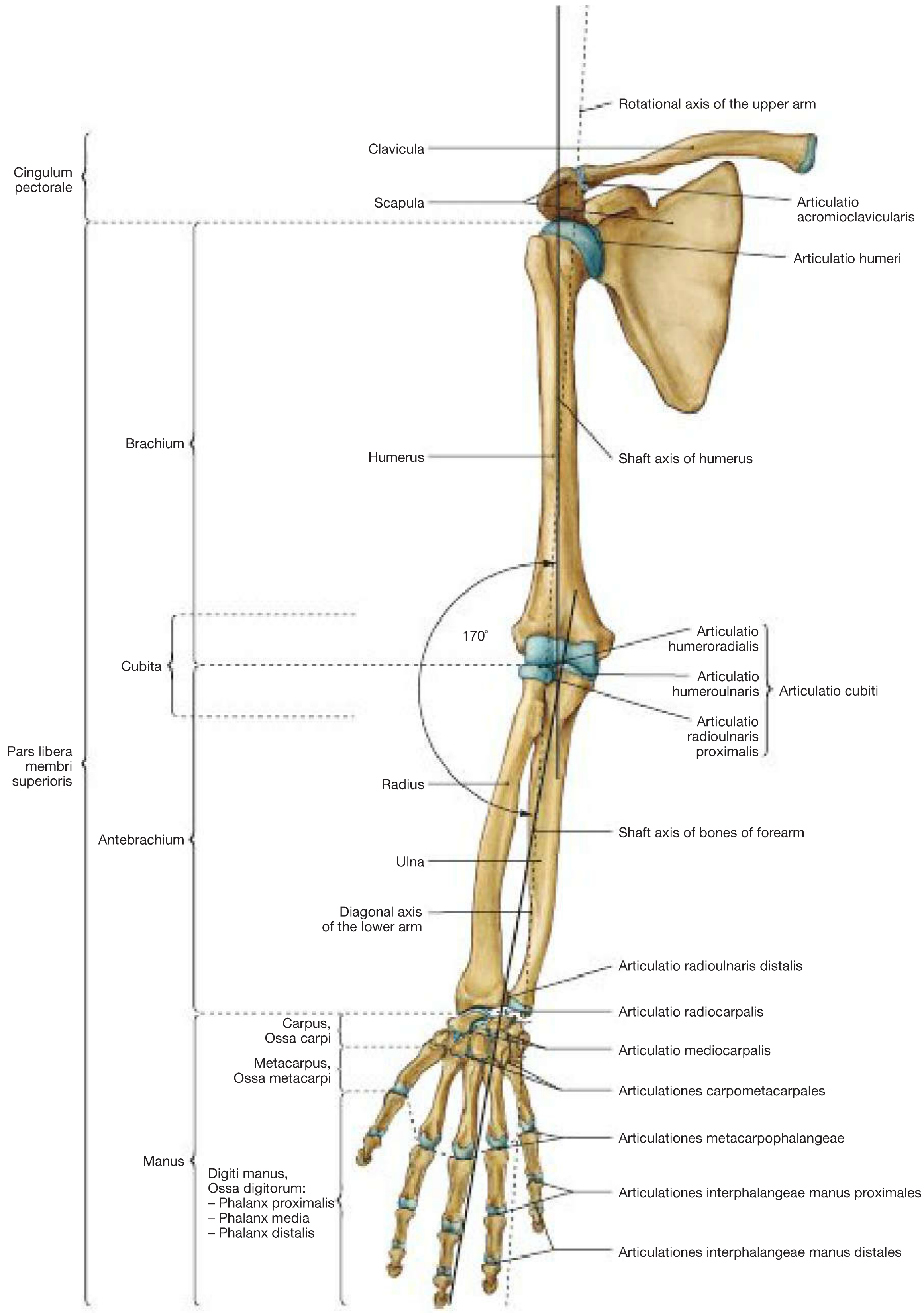


Fig. 3.6 Bones and joints of the upper limb, Membrum superius, right side; ventral view.
Similar to the leg, the bones of the upper arm and forearm form a carrying angle open to the lateral side of 170° which is divided in half by the transverse axis of the elbow joint. The **rotation axis** of the upper arm in the shoulder joint corresponds to the connecting line between the humeral head and elbow joint. It continues as a diagonal axis of the forearm extending from the proximal to the distal joint between the bones of the forearm (radioulnar joints). The **inversion/eversion or rotational movements (pronation/supination)** of the forearm take place around this axis.

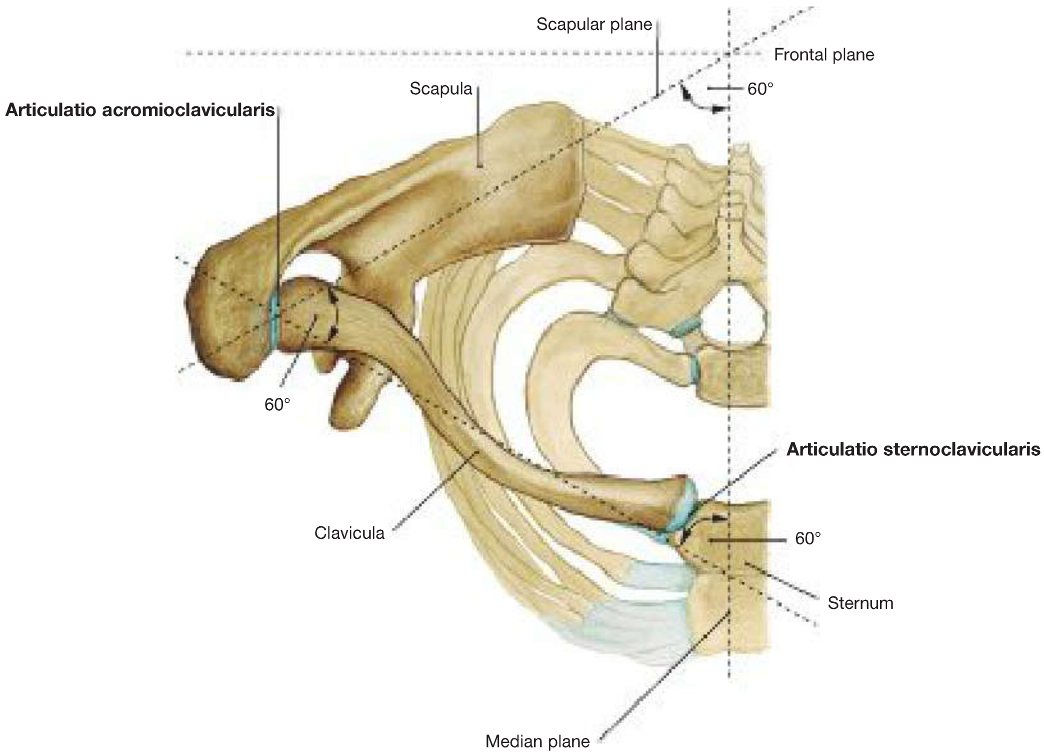


Fig. 3.7 Shoulder girdle, Cingulum pectorale, right side; cranial view.
The shoulder girdle consists of the **clavicle** (Clavicula) and the **shoulder blade** (Scapula). Both bones are connected in the lateral clavicular joint (Articulatio acromioclavicularis). The clavicle articulates via the medial clavicular joint (Articulatio sternoclavicularis) with the axial skeleton.

The clavicle forms an angle of approx. 60° with both the median plane and the shoulder blade (scapular plane), respectively. The shoulder blade is positioned in the scapular plane, which again has an angle of 60° to the median plane.

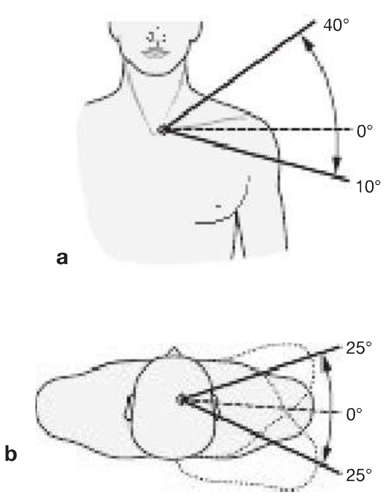
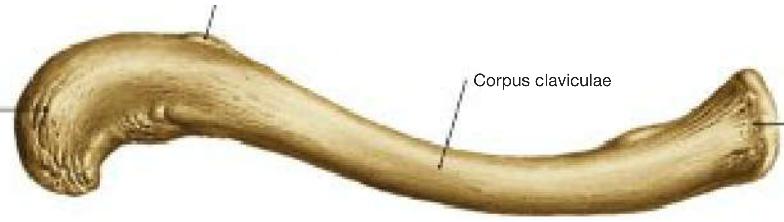


Fig. 3.8a and b Range of motion in the shoulder girdle starting from the medial clavicular joint. [L126]
Both clavicular joints form functional **ball-and-socket joints,** which generally behave like a functional unit since the shoulder girdle is only connected to the axial skeleton in the medial clavicular joint. In addition to forward and backward movements (protraction and retraction), a discrete lowering (depression) and a relatively substantial lifting (elevation) of the shoulder is possible. The fixed sternal end of the clavicle allows a rotation of about 45°. The range of motion of the upper limb is significantly increased by the mobility of the shoulder girdle.

Range of motion of the shoulder girdle:
- Elevation–depression: 40°–0°–10°
- Protraction–retraction: 25°–0°–25°

Clavicle



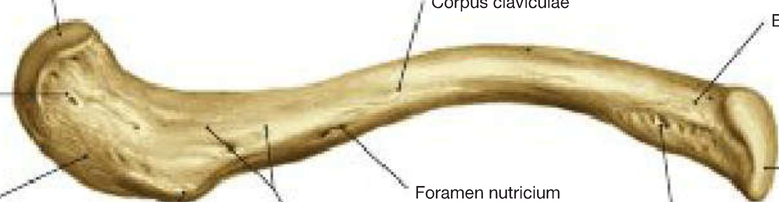


Fig. 3.9a and b Clavicle, Clavicula, right side; cranial view (→ Fig. 3.9a) and caudal view (→ Fig. 3.9b).

Matching an isolated clavicle to either side of the body is often not easy. It should be noted that the Extremitas sternalis is rather clumsily designed, while the Extremitas acromialis is flat and elongated. On the skeleton the convexity at the sternal end is directed ventrally. On the underside of the bone there are two distinctive apophyses, onto which both parts of the Lig. coracoclaviculare are attached (→ Fig. 3.18). The **Tuberculum conoideum lies medially,** the **Linea trapezoidea lies laterally.**

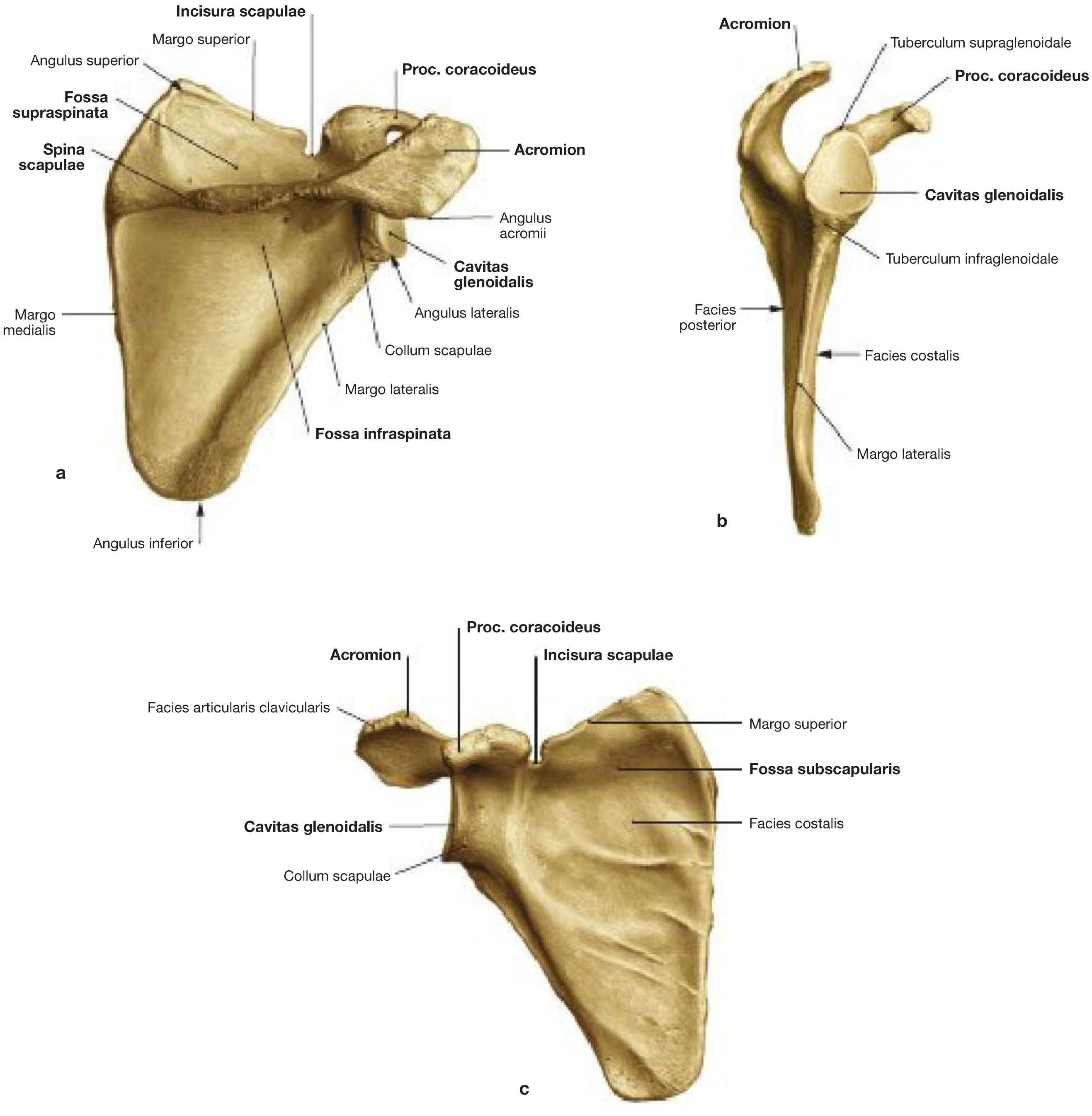


Fig. 3.10a to c Shoulder blade, Scapula, right side; dorsal view (→ Fig. 3.10a), lateral (→ Fig. 3.10b) and ventral views (→ Fig. 3.10c).

The shoulder blade is a flat bone with three edges and three angles. The dorsal T-shaped protrusion of the Spina scapulae serves as an important apophysis for the attachment (origin and insertion) of muscles.

Clinical Remarks

The **N. suprascapularis** passes through the **Incisura scapulae,** which is bridged by the Lig. transversum scapulae superius (→ Fig. 3.18). In the case of ossification of the ligament, a **compression** of the nerve may occur and result in a weakening of its target muscles (M. supraspinatus and M. infraspinatus), which are important for the abduction and lateral rotation of the arm.

Humerus

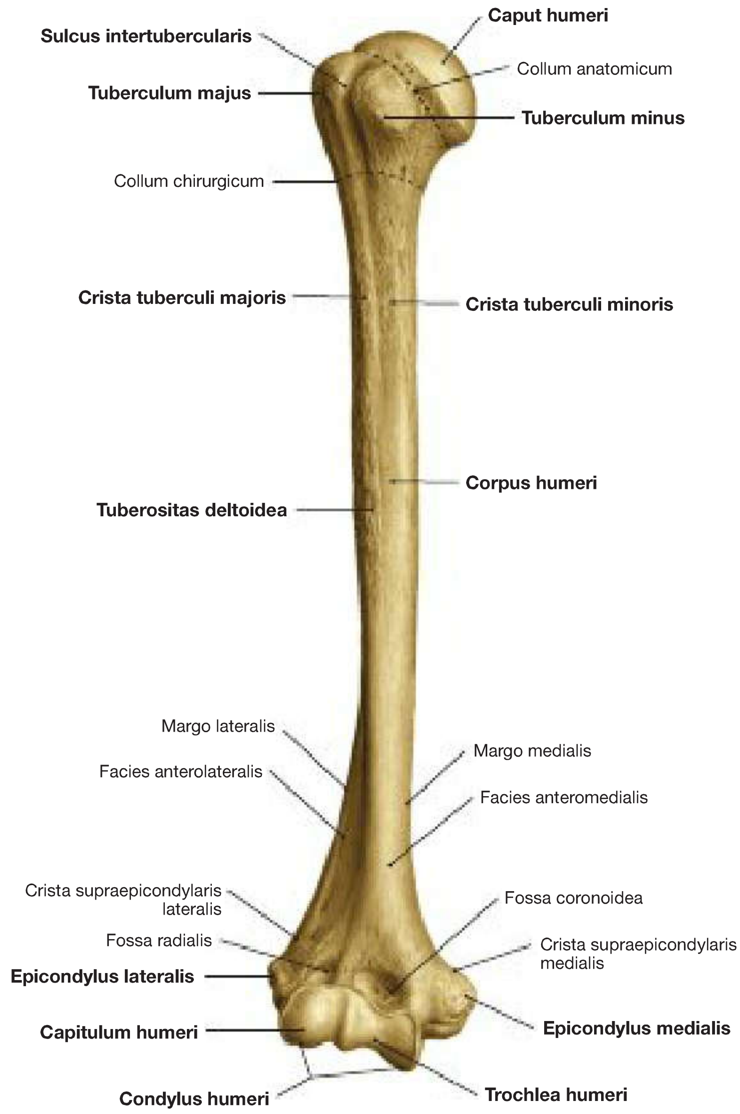
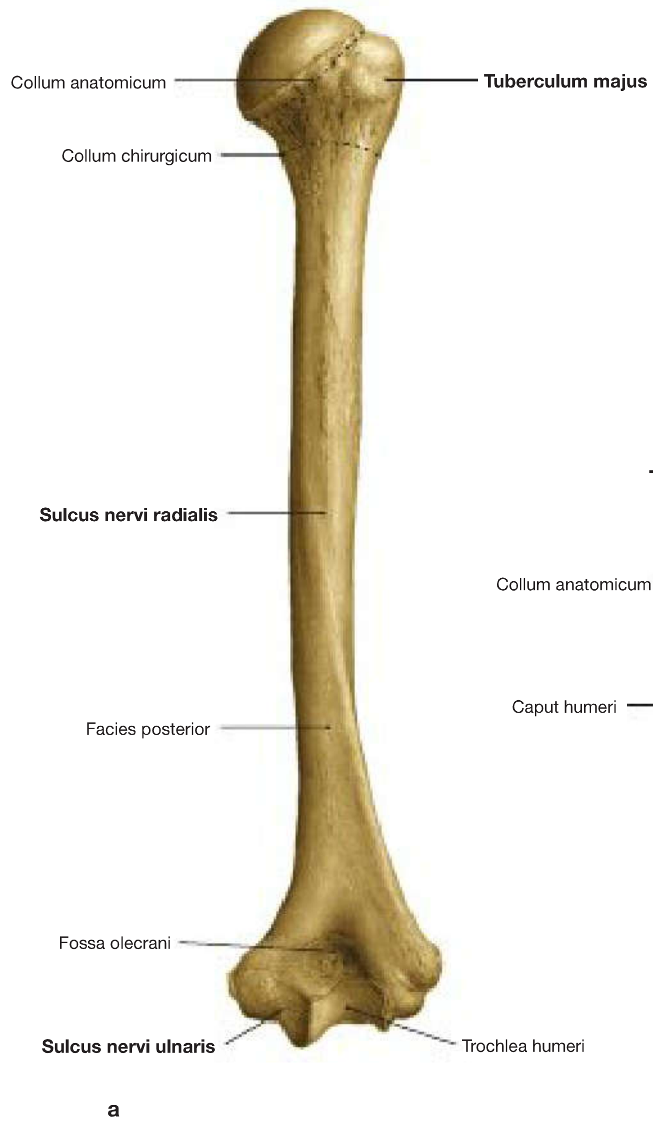


Fig. 3.11 Bone of the upper arm, Humerus, right side; ventral view. The head of the humerus forms an angle of 150°–180° with the axis of the shaft **(collodiaphyseal angle).** In addition, the head shows a **retrotorsion** of 15°–30°, i.e. the neck of the humerus is rotated backwards in relation to the transverse axis of the distal condyles. In the proximal part of the shaft the Tuberculum majus is located laterally and the Tuberculum minus medially.



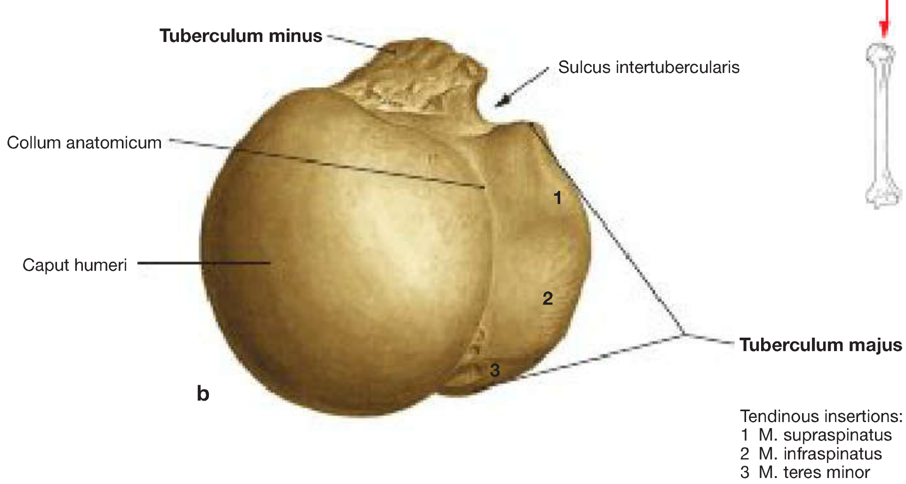


Fig. 3.12a and b Bone of the upper arm, Humerus, right side; dorsal view (→ Fig. 3.12a) and proximal view (→ Fig. 3.12b).
The **Sulcus nervi radialis** winds dorsally around the shaft of humerus and is the groove of the N. radialis. The N. ulnaris which runs on the posterior side of the Epicondylus medialis in the **Sulcus nervi ulnaris**, can be mechanically irritated on impact **('funny bone').**

Clinical Remarks

Fractures of the humerus due to a fall are relatively common. In the case of **proximal fractures,** the **supplying blood vessels** (Aa. circumflexae humeri anterior and posterior) and the N. axillaris (→ p. 233), which loop around the humerus, may become damaged. In the case of fractures or surgical treatment of fractures in the **shaft area**, the N. radialis can be damaged resulting in clinical signs of a **radial nerve lesion** (→ p. 236). In this location, it can also be compressed **('park bench lesion'). Distal fractures** may cause **damage to the ulnar nerve** in the Sulcus nervi ulnaris (→ p. 240). Since the nerve is extremely exposed (or vulnerable) in this area, lesions of the N. ulnaris represent one of the most common nerve lesions of the upper limb.

Ulna

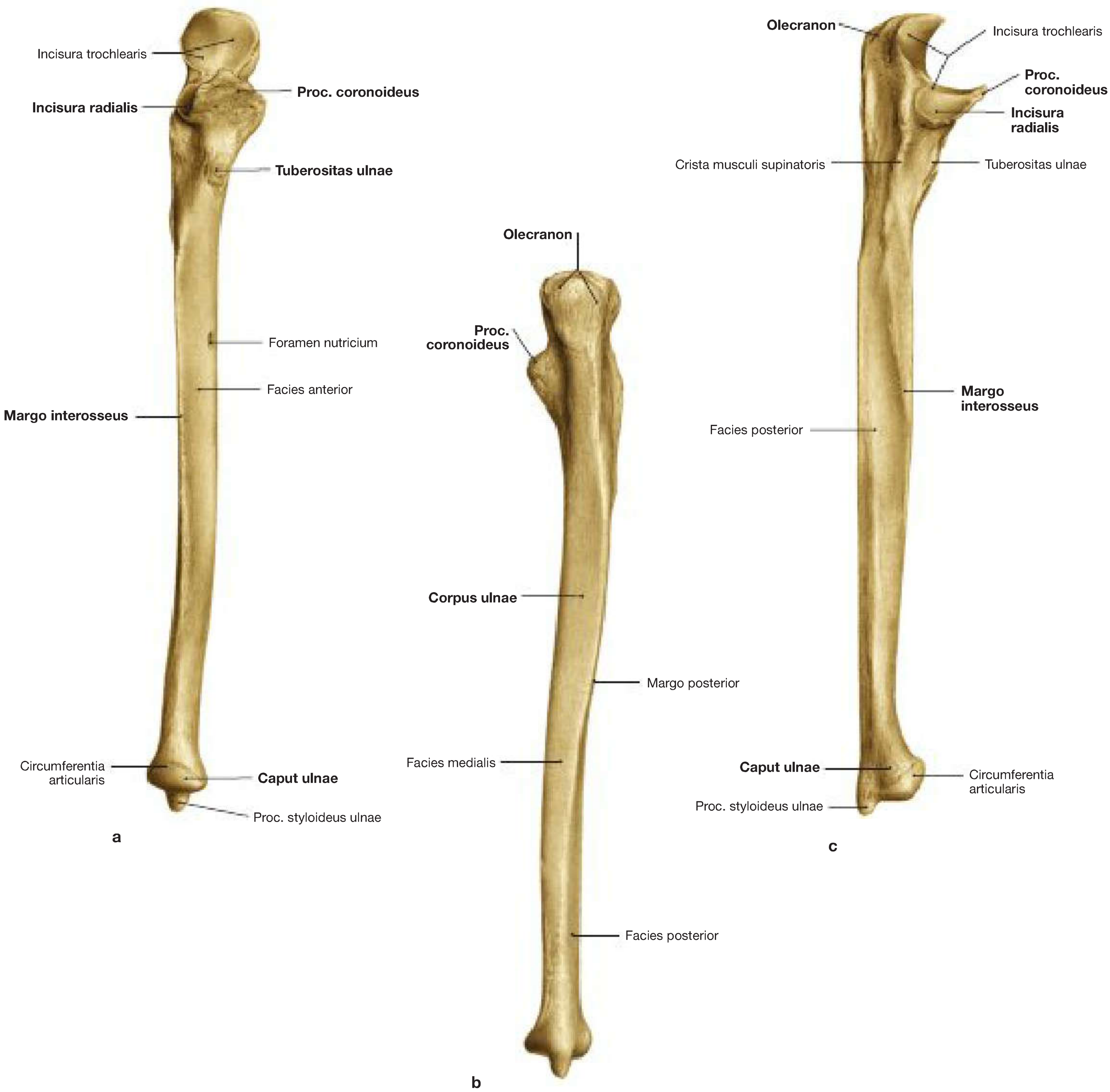


Fig. 3.13a to c Ulna, right side; ventral view (→ Fig. 3.13a), dorsal view (→ Fig. 3.13b), and radial view (→ Fig. 3.13c).

It is possible to match an isolated ulna to one side of the body, with reference to the position of the Incisura radialis, which points laterally.

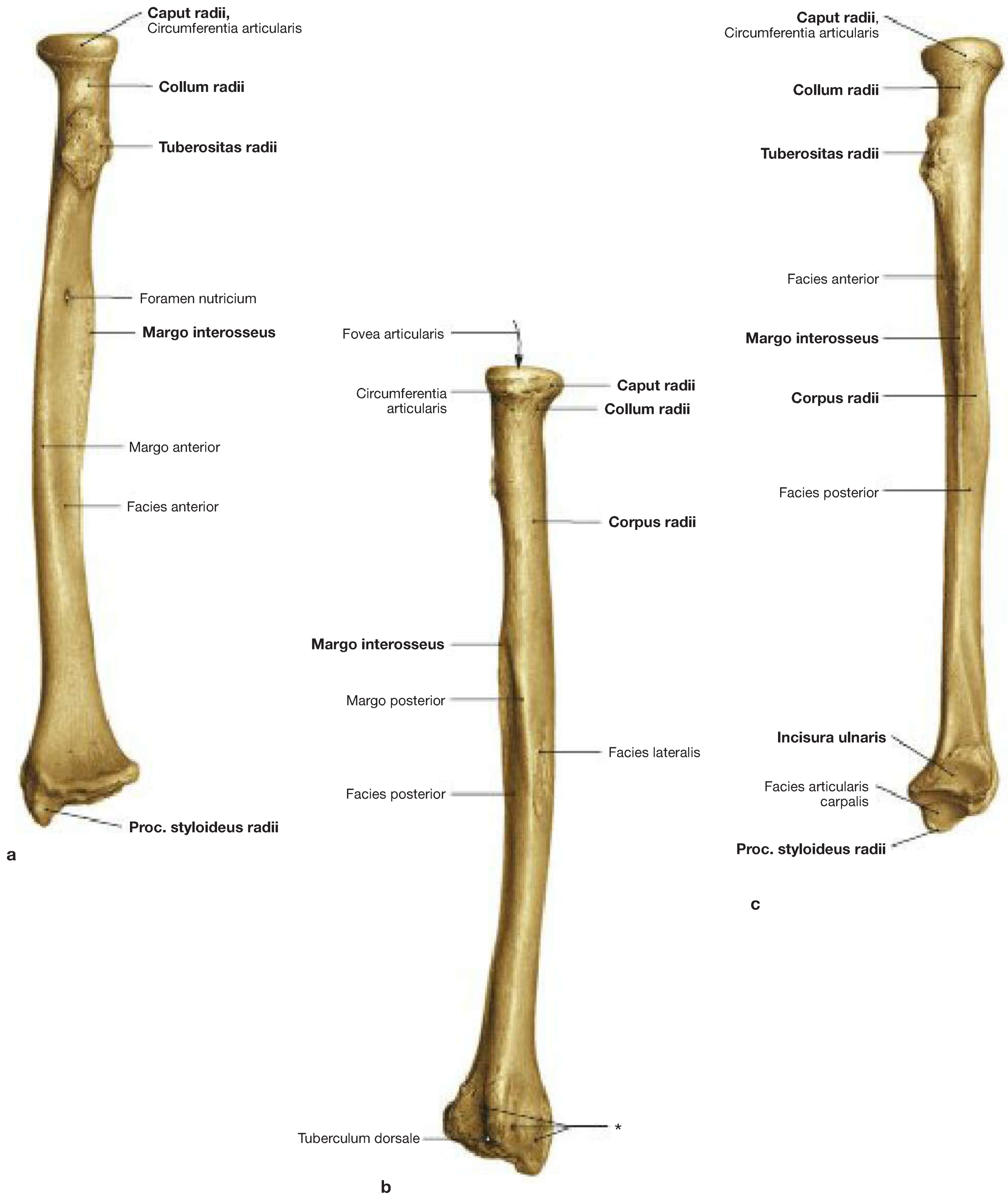


Fig. 3.14a to c Radius, right side; ventral view (→ Fig. 3.14a), dorsal view (→ Fig. 3.14b), and ulnar view (→ Fig. 3.14c).

It is possible to match an isolated radius to one side of the body, with reference to the position of the Proc. styloideus radii, which points laterally. In contrast, the Incisura ulnaris points in the direction of the ulna.

* grooves and bony ridges for the insertion of extensor tendons

Hand Skeleton

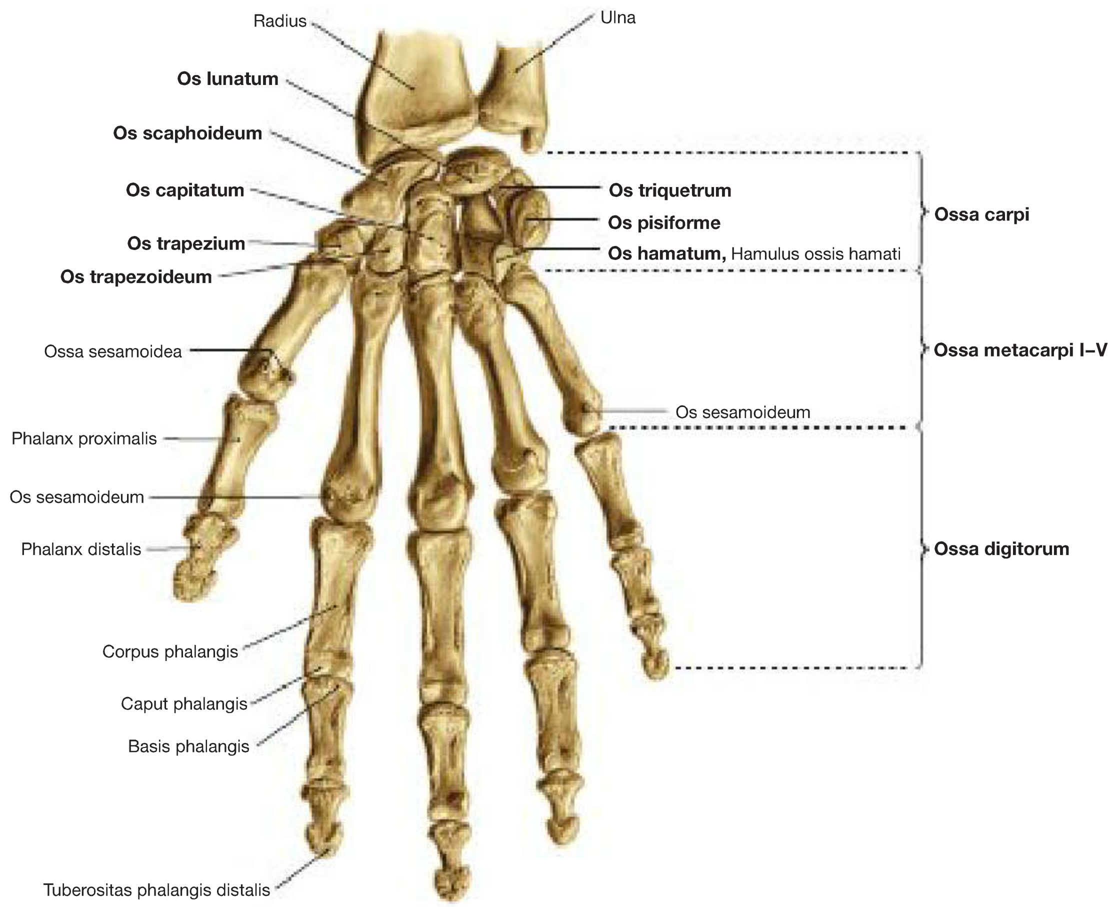


Fig. 3.15 Hand skeleton (or bones), Ossa manus, right side; palmar view.

The hand (Manus) can be divided into the wrist (Carpus, with Ossa carpi), the middle hand (Metacarpus, with Ossa metacarpi) and the fingers (Digiti, with Ossa digitorum). The digits consist of several phalanges. The bones of the wrist (or carpal bones) form the Sulcus carpi, which is the base of the carpal tunnel (→ Fig. 3.116). It is confined by the scaphoid and trapezium bones (Os scaphoideum and Os trapezium) on the radial side and by the pisiform and hamate bones (Os pisiforme and Os hamatum) on the ulnar side.

Fig. 3.16 Hand skeleton (or bones), Ossa manus, right side; dorsal view.
The wrist (Carpus) consists of a proximal and a distal row. In the proximal row the scaphoid (Os scaphoideum), lunate (Os lunatum) and triquetral bones (Os triquetrum) are aligned in the radial to ulnar direction. The triquetral bone docks palmar on the pisiform bone (Os pisiforme), which is actually not a carpal bone. As a sesamoid bone (Os sesamoideum), it is embedded in the tendon of the M. flexor carpi ulnaris. The distal row is composed of the large trapezium (Os trapezium), the small trapezoid (Os trapezoideum), the capitate (Os capitatum) and the hamate bones (Os hamatum).

For many decades, there has been a mnemonic for the carpal bones in anatomical literature, which has become a true classic:

Some **L**overs **T**ry **P**ositions **T**hat **T**hey **C**an't **H**andle.

Clavicular Joints

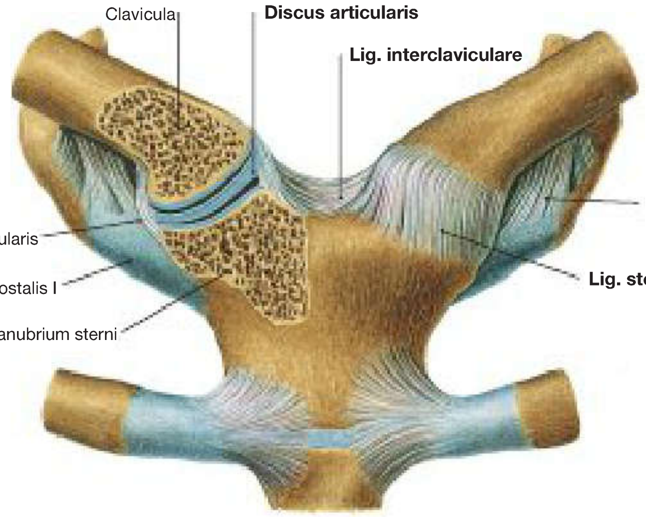


Fig. 3.17 Medial clavicular joint, Articulatio sternoclavicularis; ventral view of the joint on both sides.
The medial clavicular joint is the only articulated connection between the upper limb and the axial skeleton. The slightly saddle-shaped articular surfaces – the socket of the breastbone and the head of the clavicle – are separated by a Discus articularis of fibrous cartilage, which absorbs the traction forces of lateral displacement. The joint ligaments are very stable and consist of the **Ligg. sternoclavicularia anterius** and **posterius** connecting the two bony elements on the front and back of the joint and the **Lig. interclaviculare,** as a cranial connection between the two clavicles. From the cartilage of rib I, the **Lig. costoclaviculare** extends to the sternal end of the clavicle, and the M. subclavius to the acromial end.

Overview of Joints of the Upper Limb

- Medial clavicular joint **(sternoclavicular joint):** ball-and-socket joint
- Lateral clavicular joint **(Articulatio acromioclavicularis):** plane joint (acts with the medial joint as ball-and-socket joint)
- Shoulder joint **(Articulatio humeri):** ball-and-socket joint
- Elbow joint **(Articulatio cubiti):** composite joint, consists of:
  - Humeroulnar joint **(Articulatio humeroulnaris):** hinge joint
  - Humeroradial joint **(Articulatio humeroradialis):** ball-and-socket joint
  - Proximal radioulnar joint **(Articulatio radioulnaris proximalis):** pivot joint
- Distal radioulnar joint **(Articulatio radioulnaris distalis):** pivot joint
- Proximal wrist joint **(Articulatio radiocarpalis):** condyloid joint
- Distal wrist joint **(Articulatio mediocarpalis):** interlocked hinge joint (acts with the proximal joint as condyloid joint)
- Wrist (or carpal) and metacarpal joints **(Articulationes intercarpales, Articulationes carpometacarpales, Articulationes intermetacarpales):** amphiarthroses, except the carpometacarpal joint of the thumb **(Articulatio carpometacarpalis pollicis):** saddle joint
- Metacarpophalangeal joints **(Articulationes metacarpophalangeae):** ball-and-socket joints, except metacarpophalangeal joint of the thumb: hinge joint
- Middle and distal finger joints **(Articulationes interphalangeae manus):** hinge joints

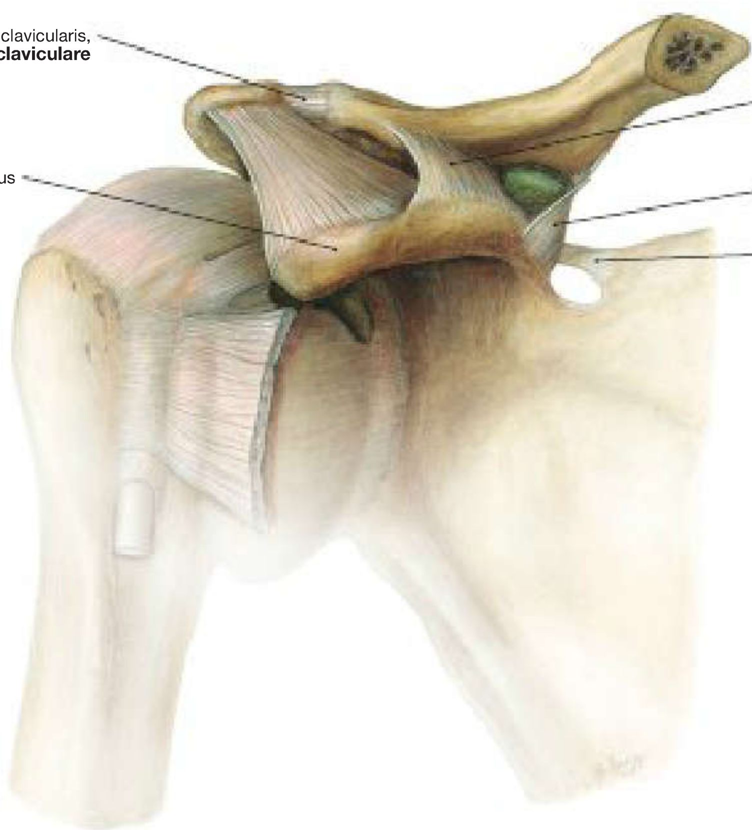
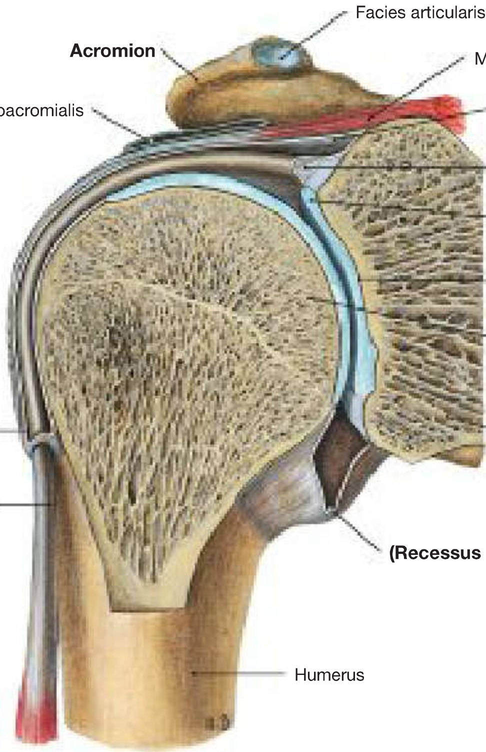


Fig. 3.18 Lateral clavicular joint, Articulatio acromioclavicularis, right side; ventral view.
The lateral clavicular joint is an articulated connection between the clavicle and the shoulder blade. There is usually a fibrocartilaginous Discus articularis between the plane joint surfaces, which only partly divides the joint cavity. The joint capsule is reinforced by the **Lig. acromioclaviculare**. The **Lig. coracoclaviculare** is also important for the stability of the acromioclavicular joint, with two distinct ligaments which connect the Proc. coracoideus of the shoulder blade with the clavicle. The **Lig. conoideum,** which passes to the Tuberculum conoideum, lies medially. Laterally the **Lig. trapezoideum** attaches to the Linea trapezoidea, which is located below the acromial end of the clavicle (→ Fig. 3.9b).

– Clinical Remarks

While the sternoclavicular joint is well protected by its stable ligaments (e.g. in the case of a fall), **lesions of the acromioclavicular or AC joint** (clinical term: joint at the shoulder corner), are relatively common (→ Fig. 3.42).

Shoulder Joint



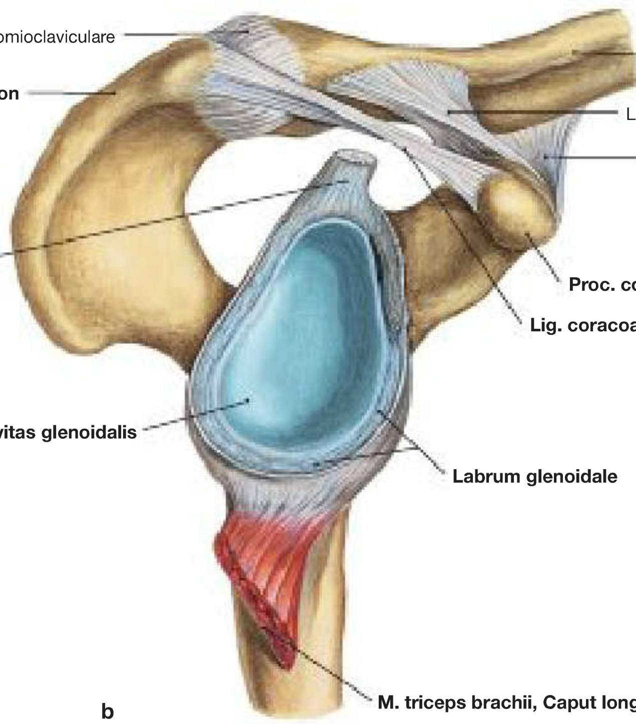


Fig. 3.19a and b Shoulder joint, Articulatio humeri, right side; section in the scapular plane, ventral view (→ Fig. 3.19a), and presentation of its socket, lateral view (→ Fig. 3.19b).

The Cavitas glenoidalis of the scapula, together with the fibrocartilaginous lip (Labrum glenoidale) forms the socket of the shoulder joint, articulating with the head of the humerus. It is a particularly impressive ball-and-socket joint. The joint capsule (Capsula articularis) originates from the Labrum glenoidale, and on the cranial rim of the socket it also encloses the tendinous origin of the Caput longum of the M. biceps brachii. The long head of the biceps originates at the Tuberculum supraglenoidale and passes through the joint capsule, while the long head of the triceps (Caput longum of the M. triceps brachii) originates at the Tuberculum infraglenoidale, outside the capsule. The joint capsule inserts at the Collum anatomicum of the humerus, so that the Tubercula majus and minus remain extra-articular. Caudally, the joint capsule has a reserve fold (Recessus axillaris). The joint capsule is reinforced on various sides by ligaments (→ Fig. 3.20) and by the radiating tendons of the rotator cuff muscles (→ Fig. 3.23 and → Fig. 3.50). The shoulder joint is covered by the **'shoulder roof',** which comprises the Proc. coracoideus, and the acromion as well as the **Lig. coracoacromiale**, which connects these two bony projections.

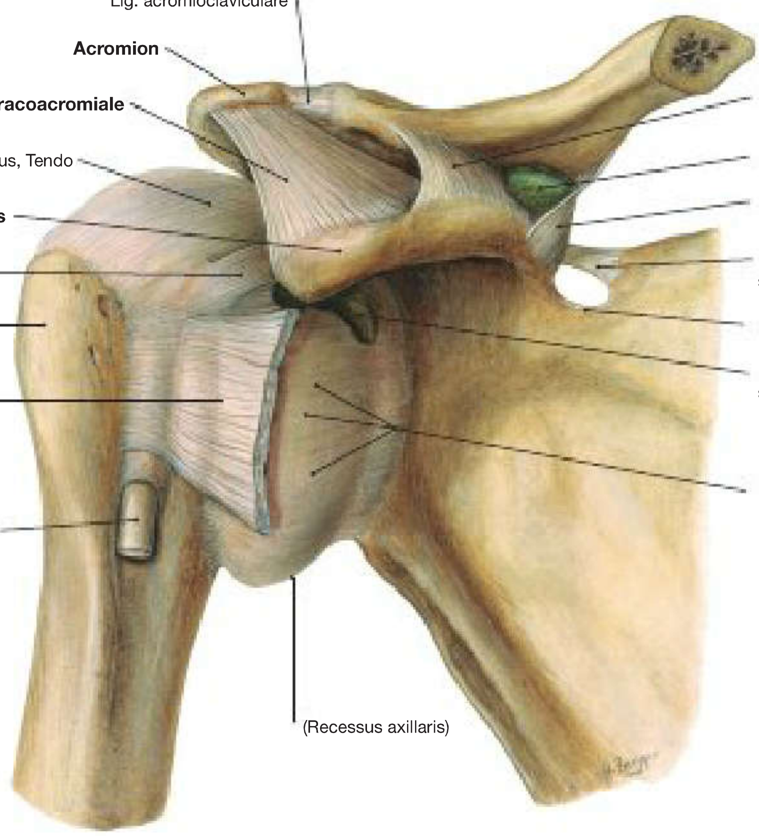


Fig. 3.20 Shoulder joint, Articulatio humeri, right side; ventral view.
The joint capsule (Capsula articularis) is supported by various ligaments and by tendons of the **rotator cuff** muscles (muscle guidance). The **Lig. coracohumerale** lies cranially and extends from the Proc. coracoideus backwards into the capsule. The **Ligg. glenohumeralia** consist of various fibrous tracts and stabilise the anterior part of the capsule. Since the muscles of the rotator cuff also radiate into the capsule at the top, front and back, the bottom of the joint capsule is particularly thin and vulnerable. The **Lig. coracoacromiale**, together with the Proc. coracoideus and the acromion, form the 'roof of the shoulder' and subsequently have no link to the joint capsule. The shoulder roof is an addition to the joint socket and stabilises the head of the humerus from above when pressure is exerted on the supported arm. As a canopy of the joint, the 'shoulder roof' also limits the abduction and anteversion of the shoulder joint, and thereby prevents the arm being raised above the horizontal plane (elevation), if the scapula is not rotated at the same time.

– Clinical Remarks

The socket of the shoulder joint is relatively small. Thus, this joint has a large range of motion but is also prone to injury. Therefore dislocations **(luxations)** of the shoulder joint are among the most common dislocations of the human body (→ p. 185).

Shoulder Joint

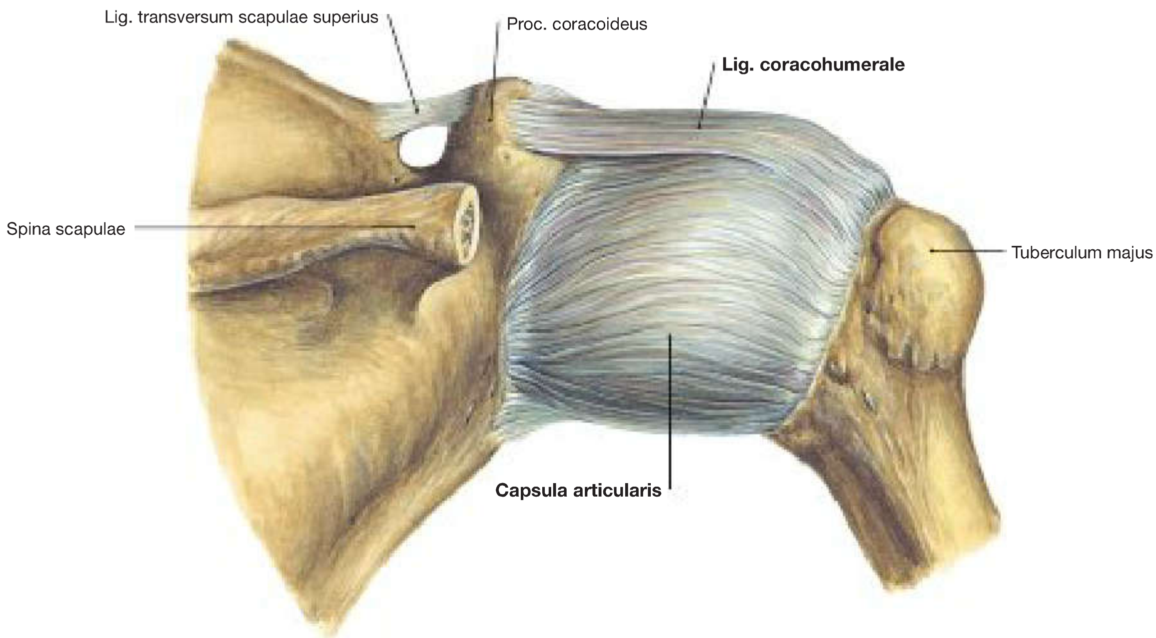


Fig. 3.21 Shoulder joint, Articulatio humeri, right side; dorsal view.

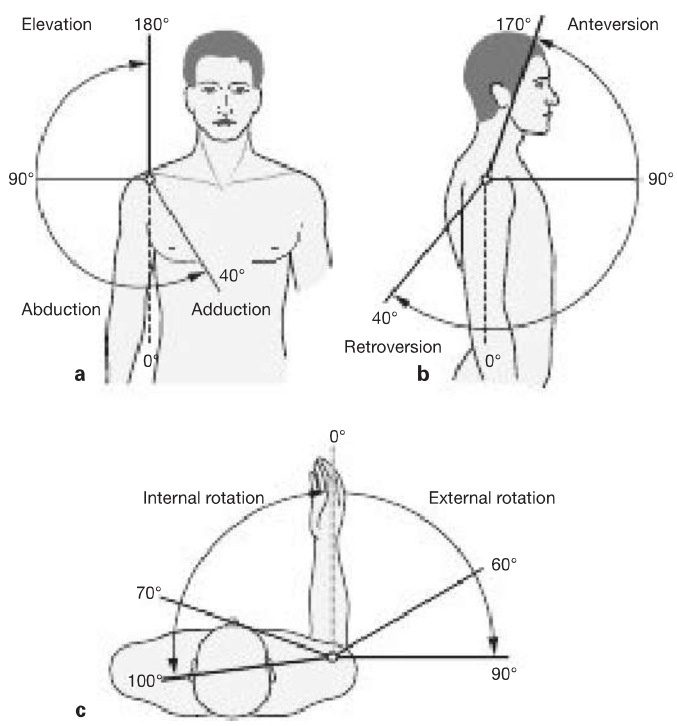


Fig. 3.22a to c Range of motion in the shoulder joint with and without the involvement of the clavicular joints. [L126]
a, b The shoulder joint is a **ball-and-socket joint** with three degrees of freedom of movement and has the maximum range of motion of all joints in the human body. When the movements of abduction and anteversion are exclusively performed in the shoulder joint (thin lines), the range of motion is restricted by the shoulder roof. In the case of combined movements of the shoulder and the clavicular joints (thick lines), when the shoulder blade is rotated, the range of motion is significantly increased. Then even the abduction of the arm above the horizontal plane **(elevation)** is possible. The rotation of the scapula, induced by the M. serratus anterior and the M. trapezius, already starts at the beginning of the abduction movement.
c In order to be able to examine the rotation of the shoulder joint, the position of the forearm has to be right-angled to the elbow joint like a pointer (below). If the arm is extended this is usually combined with an additional turning movement of the forearm.

Range of motion in the shoulder joint alone:
- Abduction–adduction: 90°–0°–40°
- Anteversion–retroversion: 90°–0°–40°
- External rotation–internal rotation: 60°–0°–70°

Range of motion in the shoulder joint with clavicular joints:
- Abduction–adduction: 180°–0°–40°
- Anteversion–retroversion: 170°–0°–40°
- External rotation–internal rotation: 90°–0°–100°

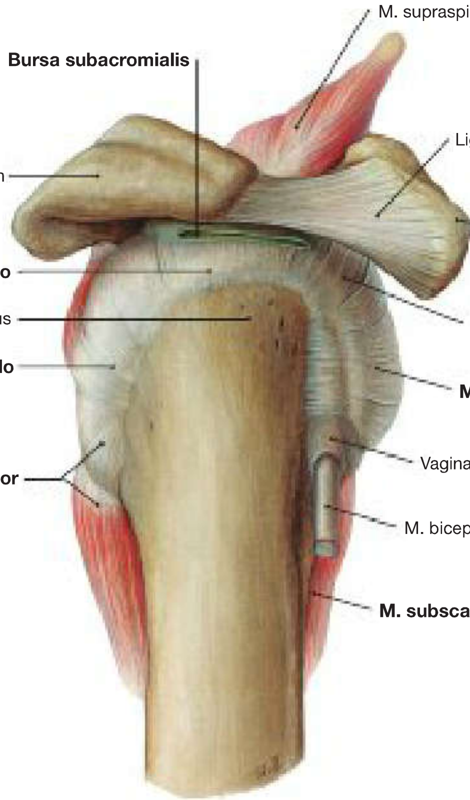


Fig. 3.23 Shoulder joint, Articulatio humeri, right side; lateral view.

The tendons of various muscles radiate into the joint capsule and stabilise it. These muscles are defined as **rotator cuff**: The **M. subscapularis lies at the front,** the **M. supraspinatus** at the top, and the **M. infraspinatus** and **M. teres minor** radiate from the posterior into the capsule. The capsule is only weak on the bottom.

In the area of the shoulder joint, there are various small serous bursae, some of which link partially with the joint capsule and form side extensions of the joint. The **Bursa subcoracoidea** below the Proc. coracoideus usually communicates with the **Bursa subtendinea musculi subscapularis,** located under the tendinous attachment point of the muscle (→ Fig. 3.20), which is often connected with the joint cavity (→ Fig. 3.49). The **Bursa subacromialis**, on the other hand, lies on the tendon of the M. supraspinatus and is mostly linked to the **Bursa subdeltoidea**. These two bursae together form the so-called **'subacromial side joint'** and allow a low-friction movement of the humeral head and of the tendons of the rotator cuff under the acromion.

Clinical Remarks

Degenerative changes of the supraspinatus tendon occur frequently. This may cause pain in arm abduction between 60° and 120° ('painful arc'), if the tendon is compressed below the shoulder roof **(impingement syndrome).** Also degenerative **calcareous deposits** in the 'subacromial side joint' can lead to painful movement restrictions.

Elbow Joint

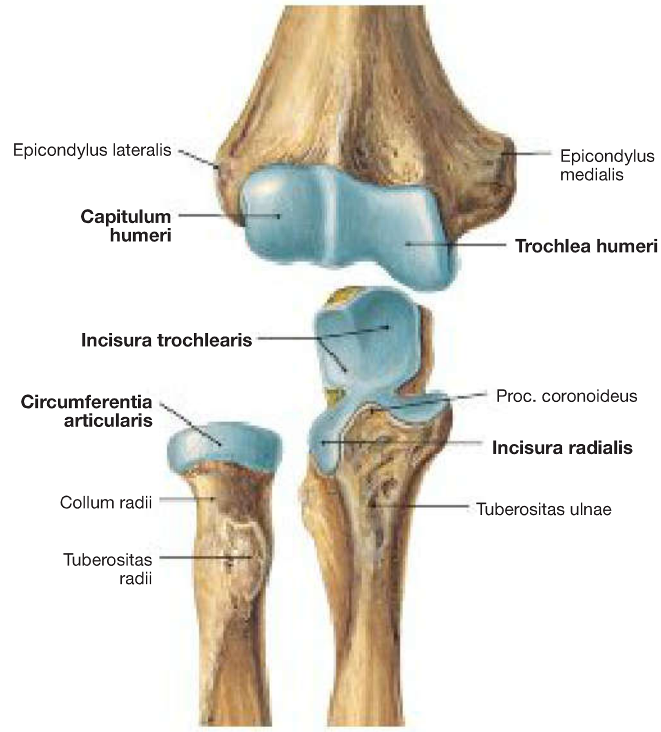
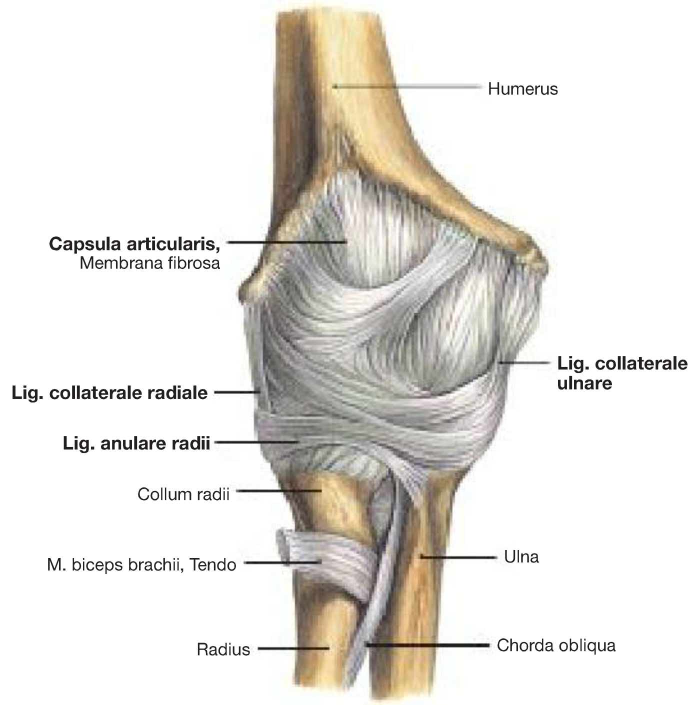
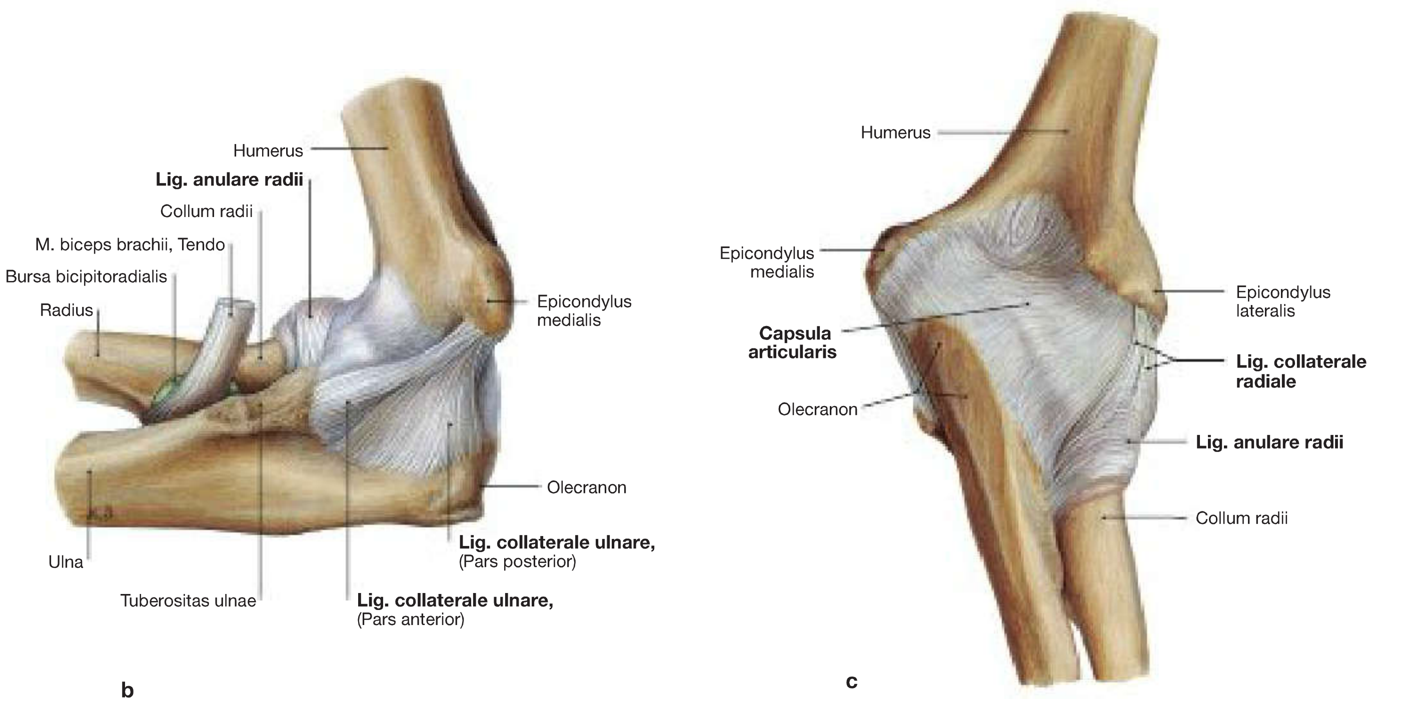


Fig. 3.24 Bony parts of the elbow joint, Articulatio cubiti; ventral view. The cartilage-covered joint surfaces are shown in blue.



a



b

c

Fig. 3.25a to c Elbow joint, Articulatio cubiti, right side; ventral (→ Fig. 3.25a), medial (→ Fig. 3.25b) and dorsal views (→ Fig. 3.25c).
The elbow joint is a composite joint (Articulatio composita), in which the humerus, the radius and the ulna articulate in three partial joints.

- **Articulatio humeroulnaris:** hinge joint with Trochlea humeri as a joint head and Incisura trochlearis of the ulna as joint socket
- **Articulatio humeroradialis:** ball-and-socket joint with the Capitulum humeri as the ball and the Fovea articularis of the radius as the socket
- **Articulatio radioulnaris proximalis:** pivot joint with the Circumferentia articularis of the Caput radii as the ball and the Incisura radialis of the ulna as the socket

The joint capsule (Capsula articularis) encloses the cartilaginous joint surfaces of all three bones. The capsule is reinforced by strong ligaments. Two **collateral ligaments** stabilise the elbow joint medially and laterally. Medially, the **Lig. collaterale ulnare** connects the Epicondylus medialis of the humerus to the Proc. coronoideus (Pars anterior) and Olecranon (Pars posterior) of the ulna. The **Lig. collaterale radiale** originates from the bottom of the Epicondylus lateralis and radiates into the **Lig. anulare radii**, which is attached at the anterior and posterior sides of the Incisura radialis of the ulna. Due to the course of this ligament, the head of the radius rotates in a sling-live movement.

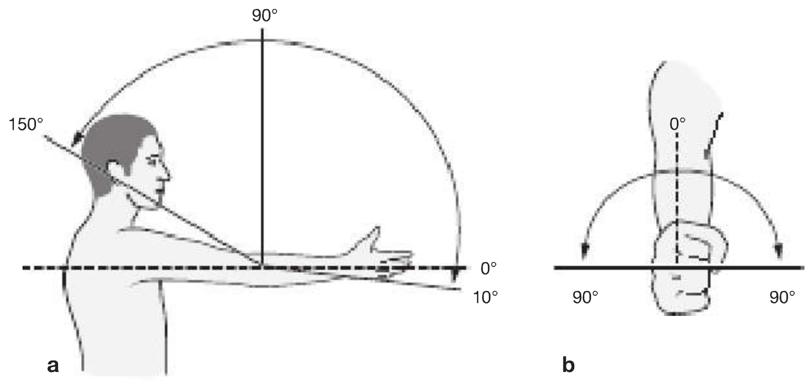


Fig. 3.26a and b Range of motion in the elbow joint. [L126]
The elbow joint enables hinge movements between the humerus and the ulna and between the humerus and the radius as well as rotational movements between the humerus and the radius and the radius and the ulna. Therefore, the partial joints together behave like a **pivot-hinge joint** (trochoginglymus). The humeroulnar joint is mostly guided by the bones. While the flexion is limited by the arm flexors (inhibited by soft tissue), the extension is limited by the olecranon (inhibited by the bones). The transverse axis of movement in the hinge joint is positioned in the centre of the Trochlea humeri (**a**).
The rotational movement is secured by the Lig. anulare radii **(ligament guidance, b).** In this turning movement, in which the distal radio ulnar joint is also involved (→ Fig. 3.30), the radius is rotating around the ulna. Starting in the neutral ('zero') position, in which the thumb points upwards, the forearm can be supinated (palm upward) and pronated (palm downward) in this turning movement. Although the humeroradial joint resembles a ball-and-socket joint according to the appearance of its articular surfaces, abduction and adduction is not possible, because the radius is tied to the ulna by the ring ligament and therefore can only follow the hinge movements of the humeroulnar joint.

Range of motion in the elbow joint:
- Extension–flexion: 10°–0°–150°
- Supination–pronation: 90°–0°–90°

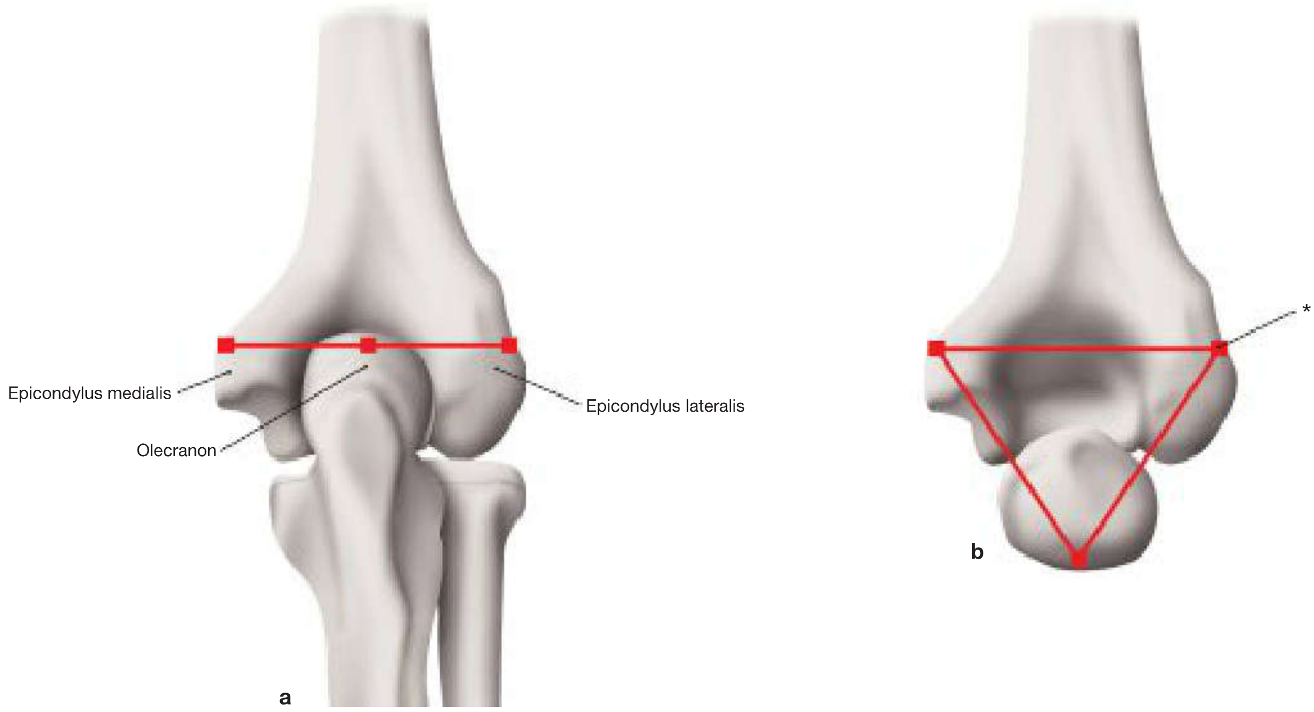


Fig. 3.27a and b HUETER's triangle. [L127]
In an extended position of the elbow joint, the tips of the epicondyles of the humerus and olecranon, seen from behind, lie on a line (**a**). In a flexed position they form an equal-sided triangle (HUETER's triangle, **b**). This triangle is important in the X-ray diagnostic, because bone fractures and dislocations lead to deviations of this triangle, which proves important in the x-ray diagnostic.

* clinical term: HUETER's triangle

Junctures of the Forearm Bones

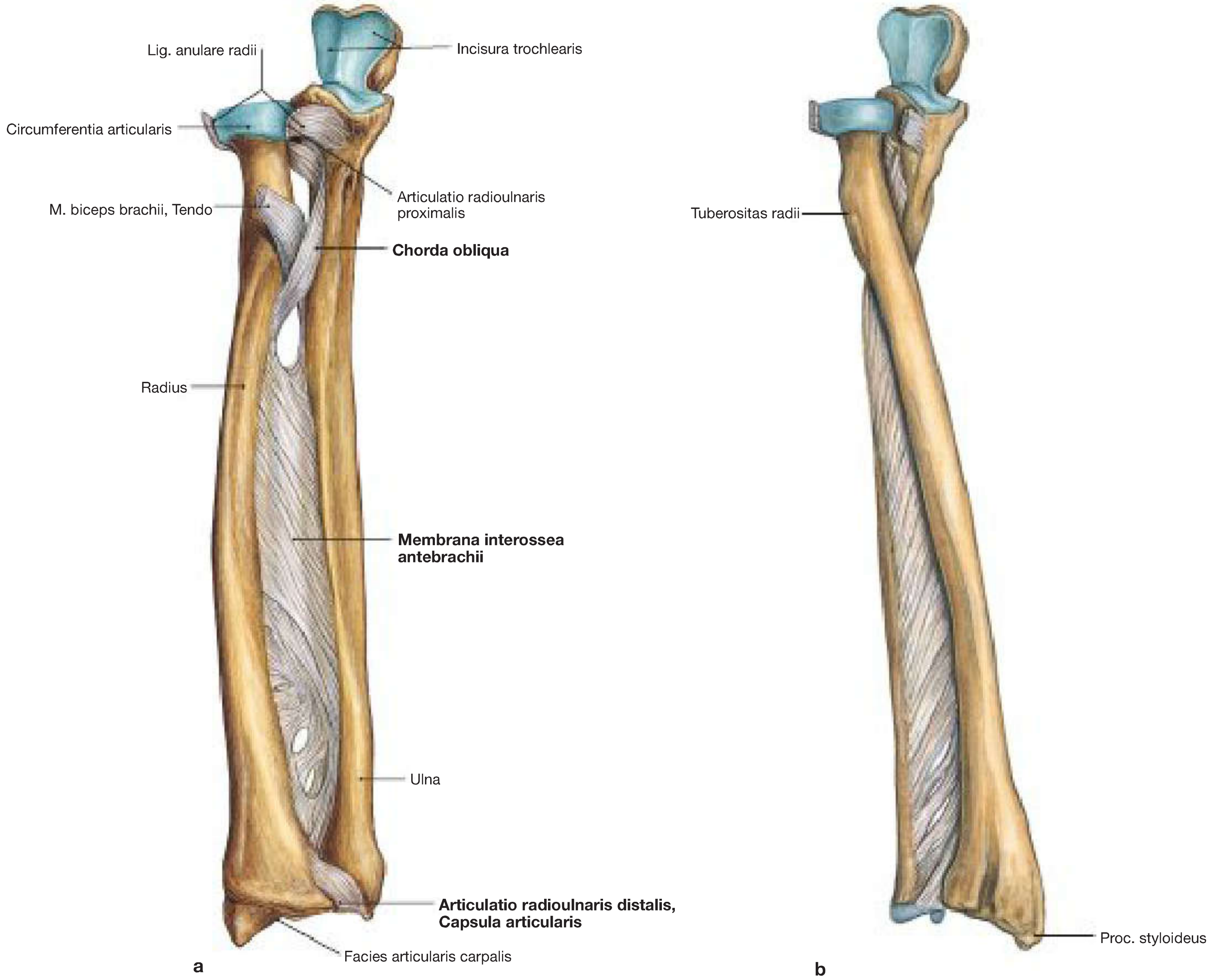


Fig. 3.28a and b Junctures of the forearm bones in the positions of supination (→ Fig. 3.28a) **and pronation** (→ Fig. 3.28b), **right side;** ventral view.

The bones of the forearm are connected by the tough Membrana interossea antebrachii, the fibres of which run predominantly in a proximal to distal direction from the radius to the ulna. Proximally it is supplemented by the Chorda obliqua that runs in the opposite direction. The figures illustrate how the radius rotates around the ulna. In the supinated position of the forearm both bones are parallel to each other, while they are crossed in the pronated position.

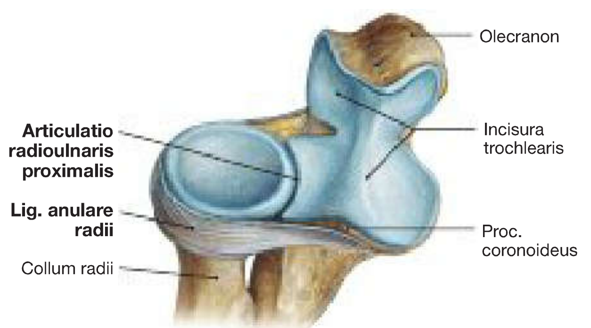


Fig. 3.29 Proximal radioulnar joint, Articulatio radioulnaris proximalis, right side; ventral view from proximally.

The proximal radioulnar joint is a **pivot joint** and part of the elbow joint. The common axis of movement for both the proximal and the distal radioulnar joints is the oblique (diagonal) axis of the forearm connecting the Caput radii and the Caput ulnae.

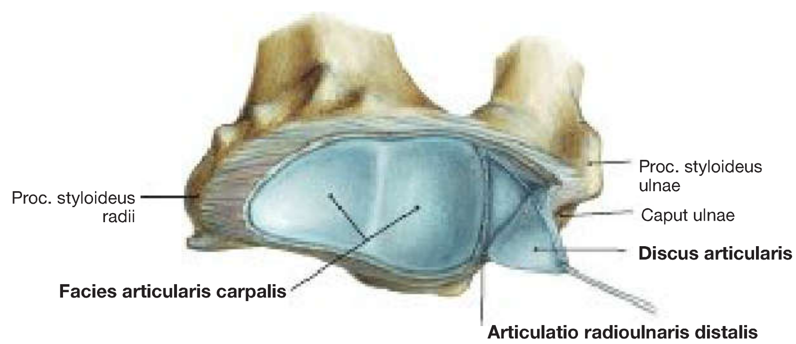


Fig. 3.30 Distal radioulnar joint, Articulatio radioulnaris distalis, right side; dorsal view from distally.

The distal radioulnar joint is also a pivot joint and adjacent to the proximal wrist. It is formed by the Caput ulnae and the Incisura ulnaris of the radius. The joint surface of the proximal wrist joint consists of the Facies articularis carpalis of the radius and the Discus articularis, which separates the Articulatio radioulnaris distalis from the proximal joint.

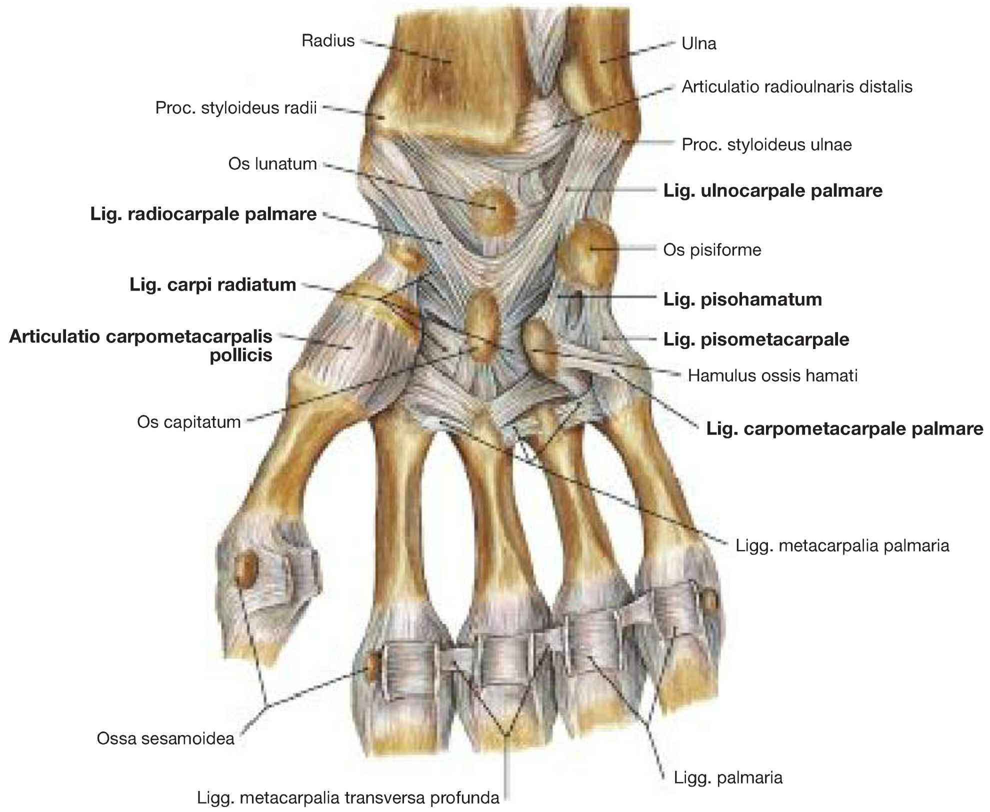


Fig. 3.31 Joints and ligaments of the hand, Articulationes and Ligamenta manus, right side; palmar view.

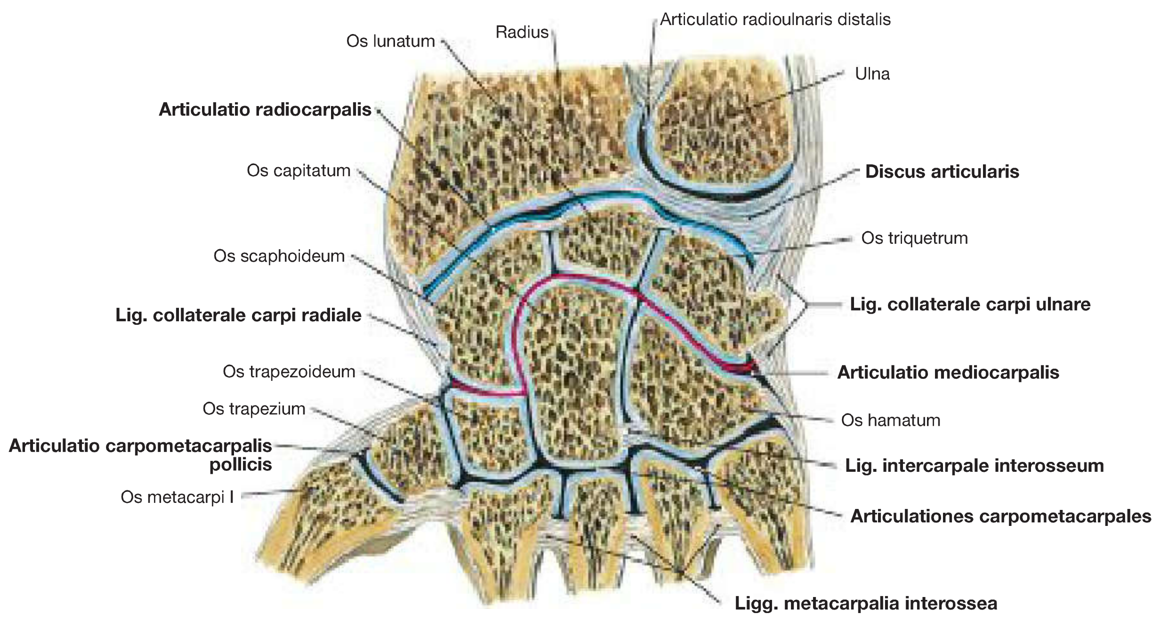


Fig. 3.32 Carpal and metacarpal joints, Articulationes carpi, right side; palmar view; surface section parallel to the back of the hand.

These include, in addition to the smaller articulated bones of the carpal and metacarpal bones, the two wrists joints.

- The **proximal joint (Articulatio radiocarpalis)** connects the forearm bones (socket) with the proximal row of the carpal bones (head) and is a condyloid (ellipsoid) joint. The ulna is separated from the Os triquetrum by the Discus articularis (→ Fig. 3.30).
- In the **distal joint (Articulatio mediocarpalis)** the proximal and distal rows of the carpal bones articulate in a wavy line with each other. According to the morphology of the joint surfaces it is an **interlocking hinge joint,** which along with the proximal joint functions in the sense of a **condyloid joint**.
- The **Articulationes carpometacarpales II to V** between the carpal and metacarpal bones and the **Articulationes intermetacarpales** between the bases of the metacarpal bones are usually tight amphiarthroses which allow relatively little movement. In contrast, the **carpometacarpal joint of the thumb** (Articulatio carpometacarpalis pollicis) is very flexible and enables flexion and extension as well as abduction and adduction.

Joints of the Hand

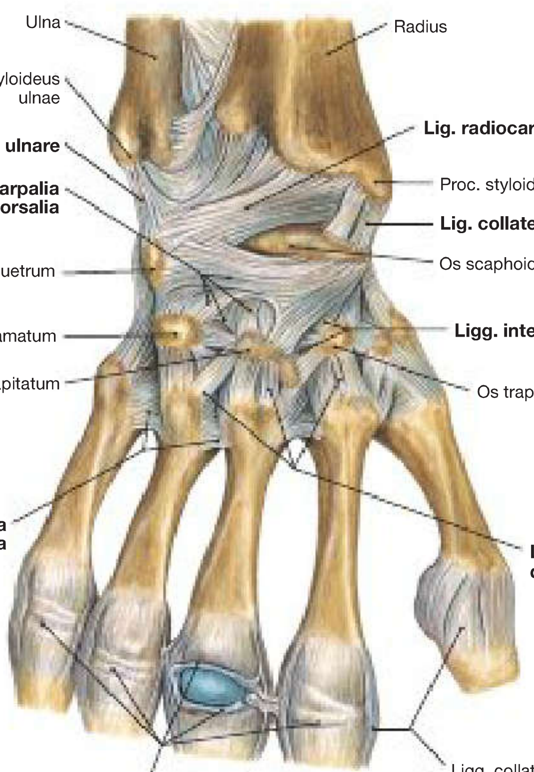


Fig. 3.33 Joints and ligaments of the hand, Articulationes and Ligamenta manus, right side; dorsal view.

Ligaments of the Carpal and Metacarpal Bones
• Ligg. radiocarpalia palmare and dorsale and Lig. ulnocarpale palmare
• Ligg. collateralia carpi radiale and ulnare: from the Procc. styloidei
• Ligg. intercarpalia palmaria, dorsalia, and interossea
• Lig. carpi radiatum: star-shaped (radiating) ligament with origin at the Os capitatum
• Lig. pisohamatum: continuation of the tendon of the M. flexor carpi ulnaris to the Os hamatum
• Lig. pisometacarpale: continuation of the tendon of the M. flexor carpi ulnaris to the Ossa metacarpi IV and V
• Ligg. carpometacarpalia palmaria and dorsalia
• Ligg. metacarpalia palmaria, dorsalia, and interossea

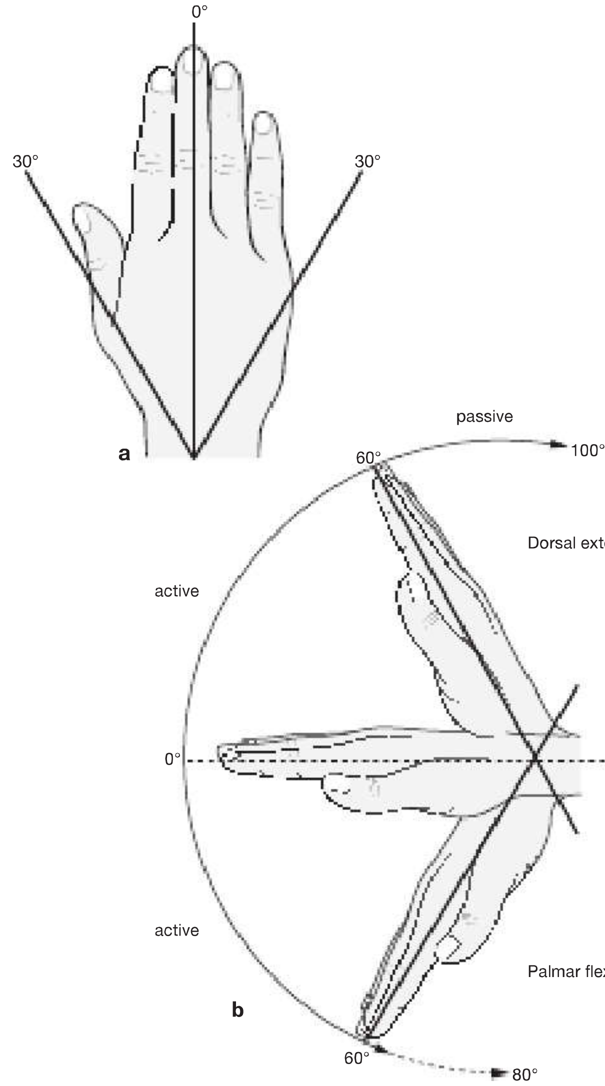


Fig. 3.34a and b Range of motion of the wrist joints. [L126]
The proximal and distal wrist joints function as **condyloid (ellipsoid) joints** and are both involved in the movements of the hand. Therefore combined movement axes can be specified, which for both joints run through the Os capitatum. The **ulnar and radial abduction movements** occur mainly in the **proximal wrist** with a combined dorsal-palmar axis running through the centre of the Os capitatum (**a**).
The **p**almar flexion is predominantly mediated by the **p**roximal wrist, while the **d**orsal extension predominantly takes place in the **d**istal wrist joint (mnemonic!) (**b**). The transverse axis of these movements also runs through the centre of the Os capitatum. As most of the other carpal and metacarpal joints are amphiarthroses, their ranges of motion are negligible. In contrast, the **carpometacarpal joint of the thumb** is very flexible and facilitates flexion and extension as well as abduction and adduction. These movements can be combined for a circumduction and opposition of the thumb, which is important for grasping objects.

Range of motion in the wrist joints:
- Ulnar abduction–radial abduction: 30°–0°–30°
- Dorsal extension–palmar flexion: 60°–0°–60°

Range of motion of the carpometacarpal joint of the thumb:
- Extension–flexion: 30°–0°–40°
- Abduction–adduction: 10°–0°–40°

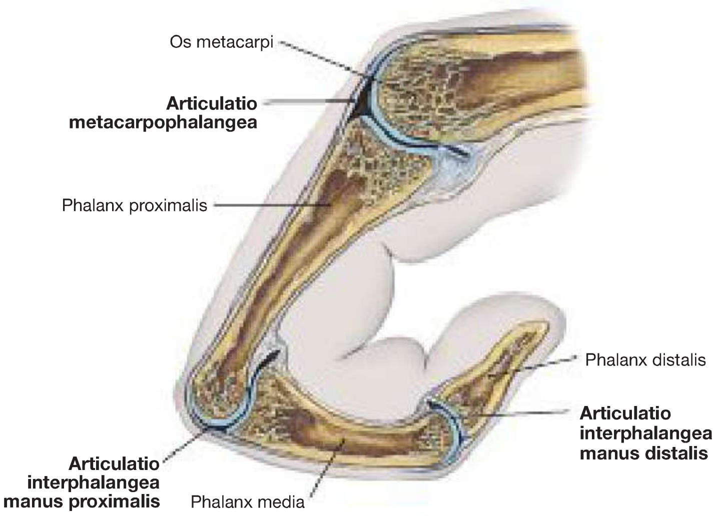


Fig. 3.35 Finger joints, Articulationes digiti, right side; lateral view, sagittal section.
This includes the metacarpophalangeal, proximal and distal interphalangeal joints of the hand.
The **metacarpophalangeal joints** (Articulationes metacarpophalangeae) are **ball-and-socket joints** between the heads of the metacarpal bones and the bases of the proximal phalanges. The metacarpophalangeal joint of the thumb, however, is a hinge joint.
The **proximal and distal interphalangeal joints** (Articulationes interphalangeae manus proximales and distales) between the heads and bases of the individual phalanges are hinge **joints.**

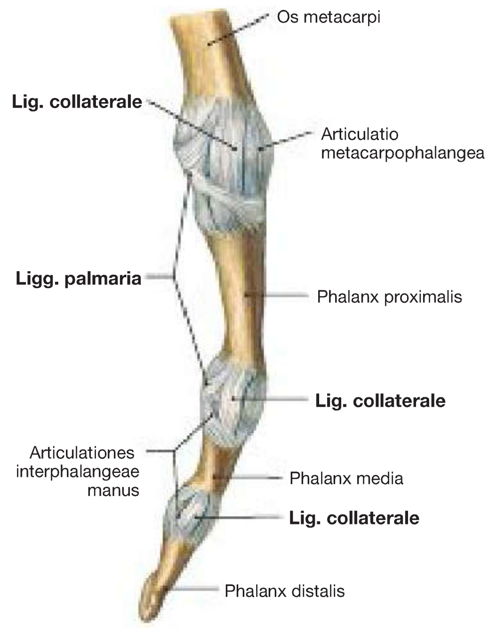


Fig. 3.36 Ligaments of the finger joints, Articulationes digiti, right side; lateral view.
- **Ligg. collateralia:** medial and lateral
- **Lig. palmare:** ventral
- **Lig. metacarpale transversum profundum:** connects the palmar ligaments to the distal interphalangeal joints (→ Fig. 3.45)

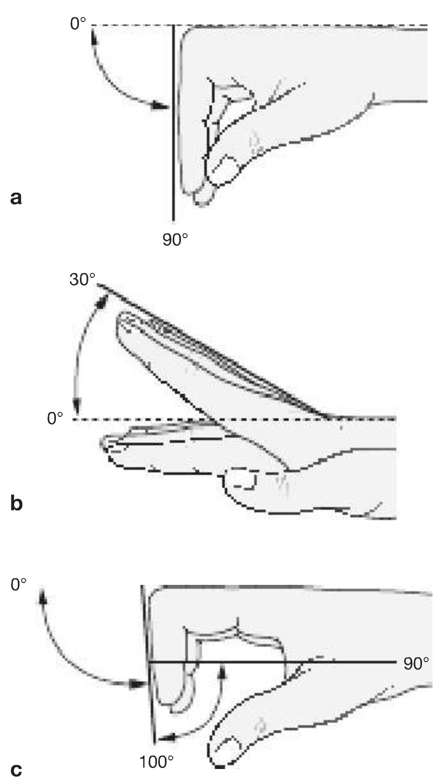


Fig. 3.37a to c Range of motion of the finger joints. [L126]
The metacarpophalangeal joints allow flexion and extension as well as radial and ulnar abduction movements. Passive rotation of the fingers is only possible if fingers are extended. The saddle joint of the thumb allows only hinge movements. This also applies to all proximal and distal interphalangeal joints, which can only be bent from the normal position.

Range of motion in the metacarpophalangeal joints:
- Dorsal extension–palmar flexion: 30°–0°–90°
- Ulnar abduction–radial abduction: (20–40)°–0°–(20–40)°

Range of motion in the proximal interphalangeal joints:
- Dorsal extension–palmar flexion: 0°–0°–100°

Range of motion in the distal interphalangeal joints:
- Dorsal extension–palmar flexion: 0°–0°–90°

Clinical Remarks

Clinically the following **terms and abbreviations** are often used for the finger joints:
- **MCP** (= **m**eta**c**arpo**p**halangeal joint)
- **PIP** (= **p**roximal **i**nter**p**halangeal joint)
- **DIP** (= **d**istal **i**nter**p**halangeal joint)

Shoulder Joint and Humerus

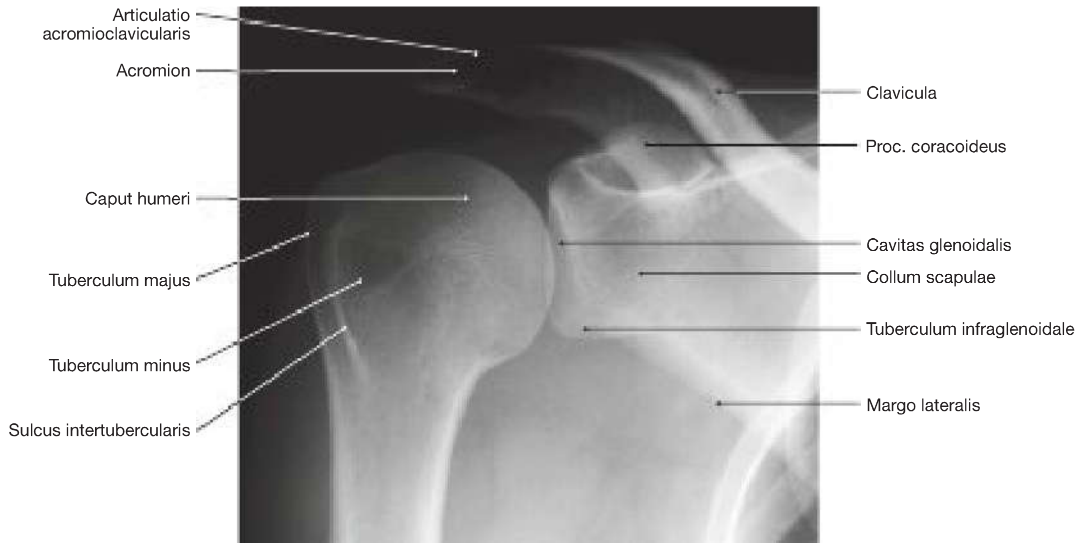


Fig. 3.38 Shoulder joint, Articulatio humeri, right side; X-ray image in anterior-posterior (AP) beam projection. [T902]

Fig. 3.39a and b X-ray images of humeral fractures.
a Humeral shaft fracture, which can lead to an injury of the N. radialis. [E402]
b Humeral head fracture, which can lead to an injury of the N. axillaris. [M502, M519]

Clinical Remarks

Broken bones (fractures) and **dislocations** (luxations), leading to malalignments of the skeletal elements, can be evidenced by X-ray diagnostic. Lesions of ligaments, however, are not visible and can only be detected with ultrasound or magnetic resonance imaging (MRI).

Fig. 3.40a and b Elbow joint, Articulatio cubiti, right side; X-ray in anterior-posterior (AP) beam projection (→ Fig. 3.40a) and in lateral beam projection (→ Fig. 3.40b). [T902]

Clinical Remarks

In the extended position of the elbow joint, both epicondyles of the humerus are in line with the olecranon. Fractures or dislocations may result in deviations from the normal position (→ Fig. 3.27).

Hand

Fig. 3.41 Hand, Manus, right side; X-ray in anterior-posterior (AP) beam projection.

Clinical Remarks

The fracture of the distal radius is the most common fracture of the human body. In order to diagnose it on an X-ray image, you have to be familiar with the X-ray anatomy of the wrists.
Regarding **fractures** of the carpal bones, the **scaphoid** is most frequently affected. In this case, an injury to the supplying blood vessels can lead to a necrosis that is visible in the X-ray image due to the decrease in bone density. After injuries, there may also be degenerative changes such as **osteoarthritis** of the hand and finger joints, which are associated with typical signs of arthritis such as bony appositions (osteophytes) and destruction of the joint surfaces.

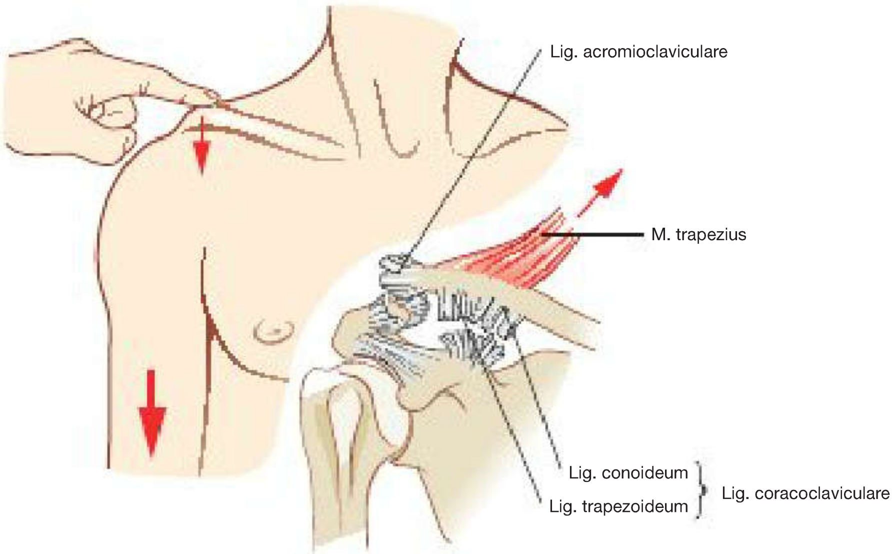


Fig. 3.42 Injury of the acromioclavicular joint ('shoulder separation'). [L126]
In the case of dislocation (luxation) of the acromioclavicular joint with rupture of the Ligg. coracoclaviculare and acromioclaviculare, the traction of the M. trapezius causes the lateral end of the clavicle to jump upwards (piano key sign). The **degree** of severity is determined by the ligaments involved, and classified according to **TOSSY:**

- **I Straining (overextension)** of the ligaments
- **II Partial rupture** of the ligaments
- **III Complete rupture** of the Lig. coracoclaviculare and the Lig. acromioclaviculare

In the case of a TOSSY III injury, a surgical stabilisation has to be performed. In clinical practise the adapted classification of ROCKWOOD (based on TOSSY's classification) is used more frequently, as it is more suitable for determining the indication of a surgical intervention.

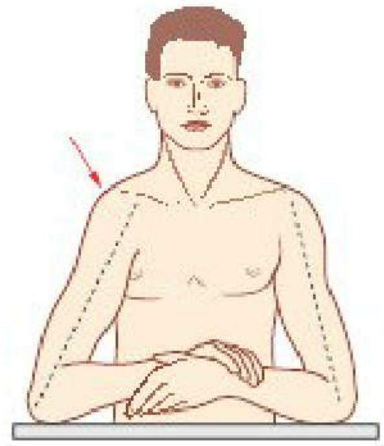


Fig. 3.43 Dislocation of the shoulder joint. [L126]
Dislocation of the shoulder is the most common type of dislocation in the body. The vulnerability of the joint is because it has fewer bones and ligaments. In most cases (90%), there is a Luxatio subcoracoidea (as shown here on the right side of the body), in which the head of the humerus pops under the Proc. coracoideus. The shoulder curvature is reduced, and the upper arm appears somewhat lengthened.

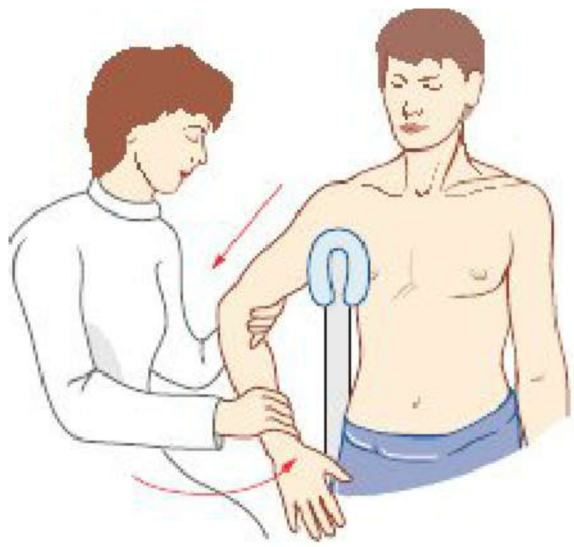


Fig. 3.44 Repositioning of the shoulder dislocation. [L126]
Using the ARLT method, the injured arm is laid over the back of a padded chair. The physician pulls the flexed arm towards the humerus until the head of the humerus pops back into the socket.

Fig. 3.45 Luxatio subcoracoidea. [M502, M519]
In this type of dislocation the head of the humerus pops under the Proc. coracoideus. The curvature of the shoulder is reduced, and the upper arm appears somewhat lengthened.

Shoulder and Arm Muscles

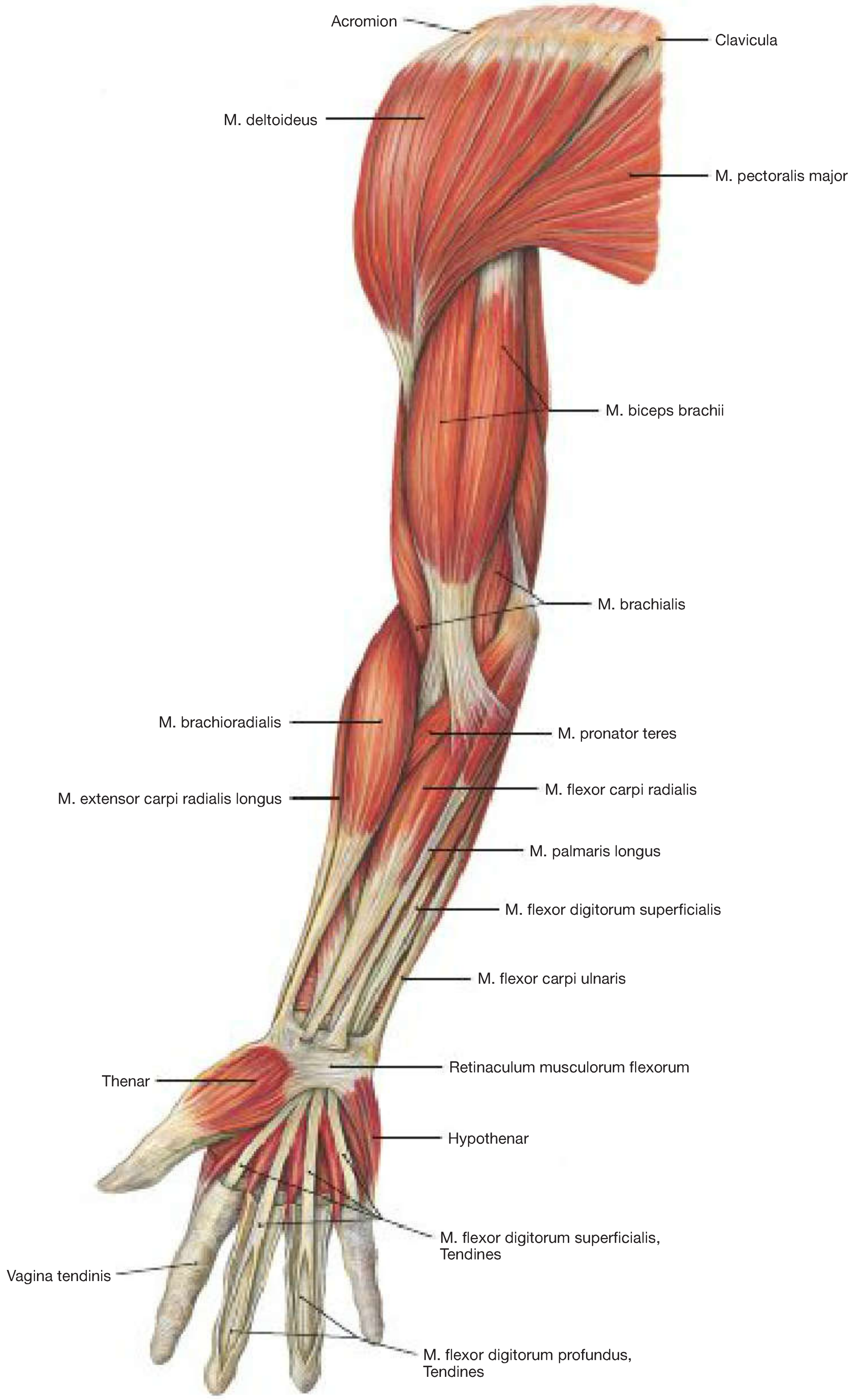


Fig. 3.46 Ventral muscles of the shoulder and arm, right side; ventral view.

→T 24–38

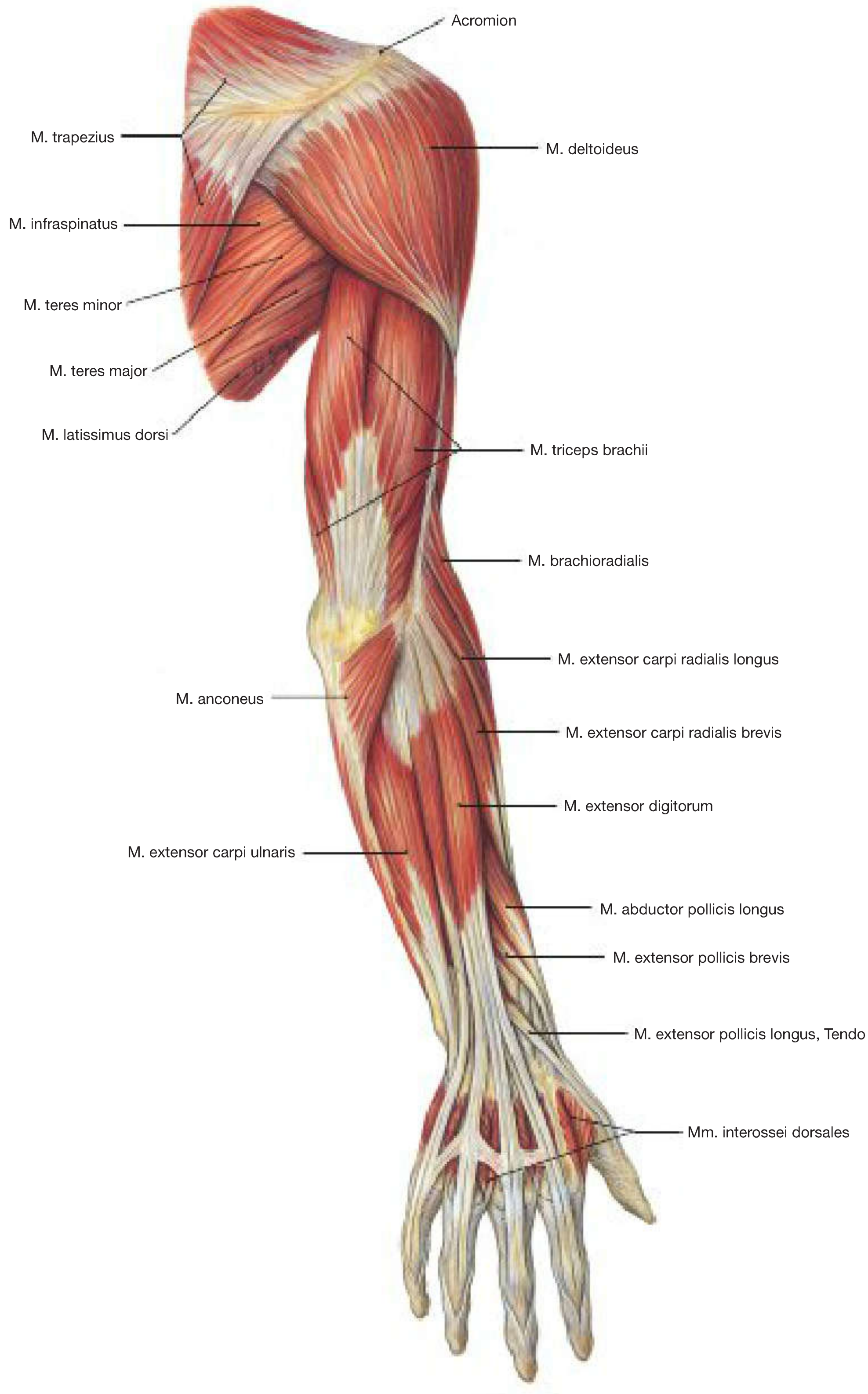


Fig. 3.47 Dorsal muscles of the shoulder and arm, right side; dorsal view.

→T 24–38

Muscles

Arm Muscles

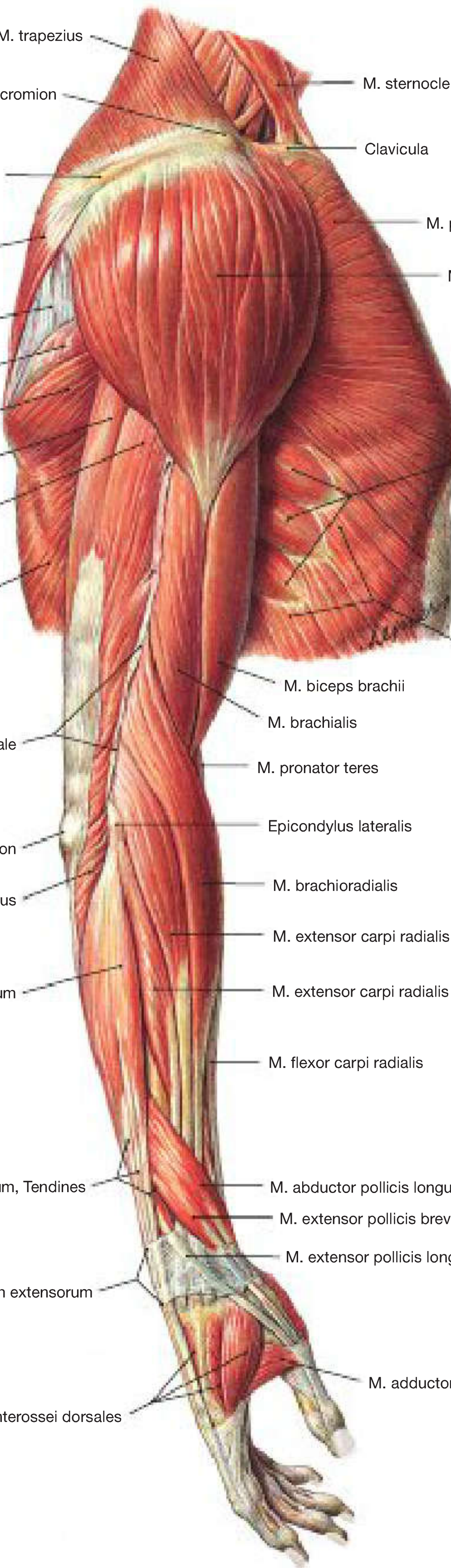


Fig. 3.48 Muscles of the arm and chest, right side; lateral view.

→T 24–38

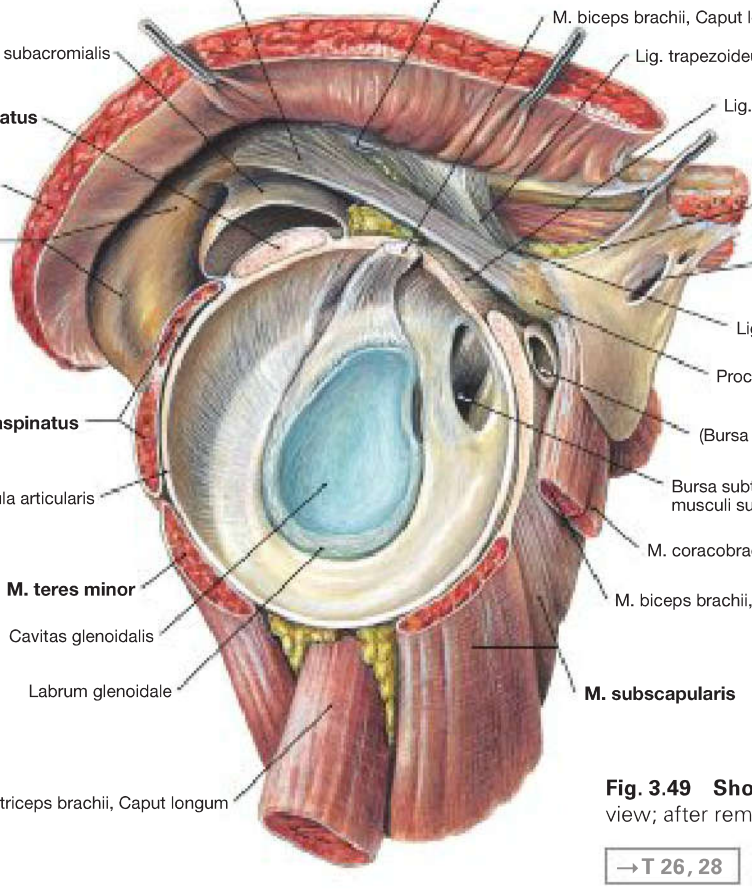
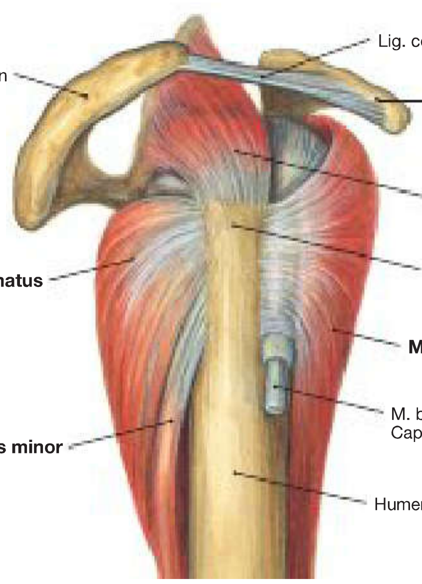


Fig. 3.49 Shoulder joint and shoulder muscles, right side; lateral view; after removal of the M. deltoideus and of the Caput humeri.

→T 26, 28

Fig. 3.50 Muscles of the rotator cuff; lateral view.
The extensive range of motion in the shoulder joint is an essential prerequisite for the tactile and grasping function of the upper limb. Based on the strong guidance of the muscles and the highly flexible positioning of the scapula, the shoulder joint only requires little support from bones and ligaments. However, if problems with the neuromuscular control arise, for example when the innervation of individual shoulder muscles is disrupted as a result of lesions or disorders of the supplying nerves, or if the balance of these muscles is disturbed, a stable articular position of the end points can no longer be guaranteed at the maximum range of motion. Dislocations occur when shearing forces act in tangential directions on the Cavitas glenoidalis, particular in the case of a fall.
The tendons of those muscles directly adjacent to the shoulder joint radiate into the joint capsule and form a tight rotator cuff around the head of the humerus. The **M. subscapularis** (anterior), the **M. supraspinatus** (superior), the **M. infraspinatus** (posterior superior) and the **M. teres minor** (posterior inferior) are included in the rotator cuff. Apart from the M. subscapularis, which inserts at the Tuberculum minus, all other muscles of the rotator cuff have their insertions at the Tuberculum majus and the Crista tuberculi majoris. The M. deltoideus is not part of this muscle group, as it does not radiate into the joint capsule, but passes over the joint.



→T 26, 28

Clinical Remarks

In addition to their role in various movements (kinematics), the muscles of the rotator cuff are very important in maintaining the correct position of the humeral head in the articular cavity (statics). In the case of impaired balance of the muscles, particularly regarding a relative weakness of the adducing (lower) portions of the muscles, there may be an **elevation of the humeral head**.

Muscles of the Shoulder Girdle

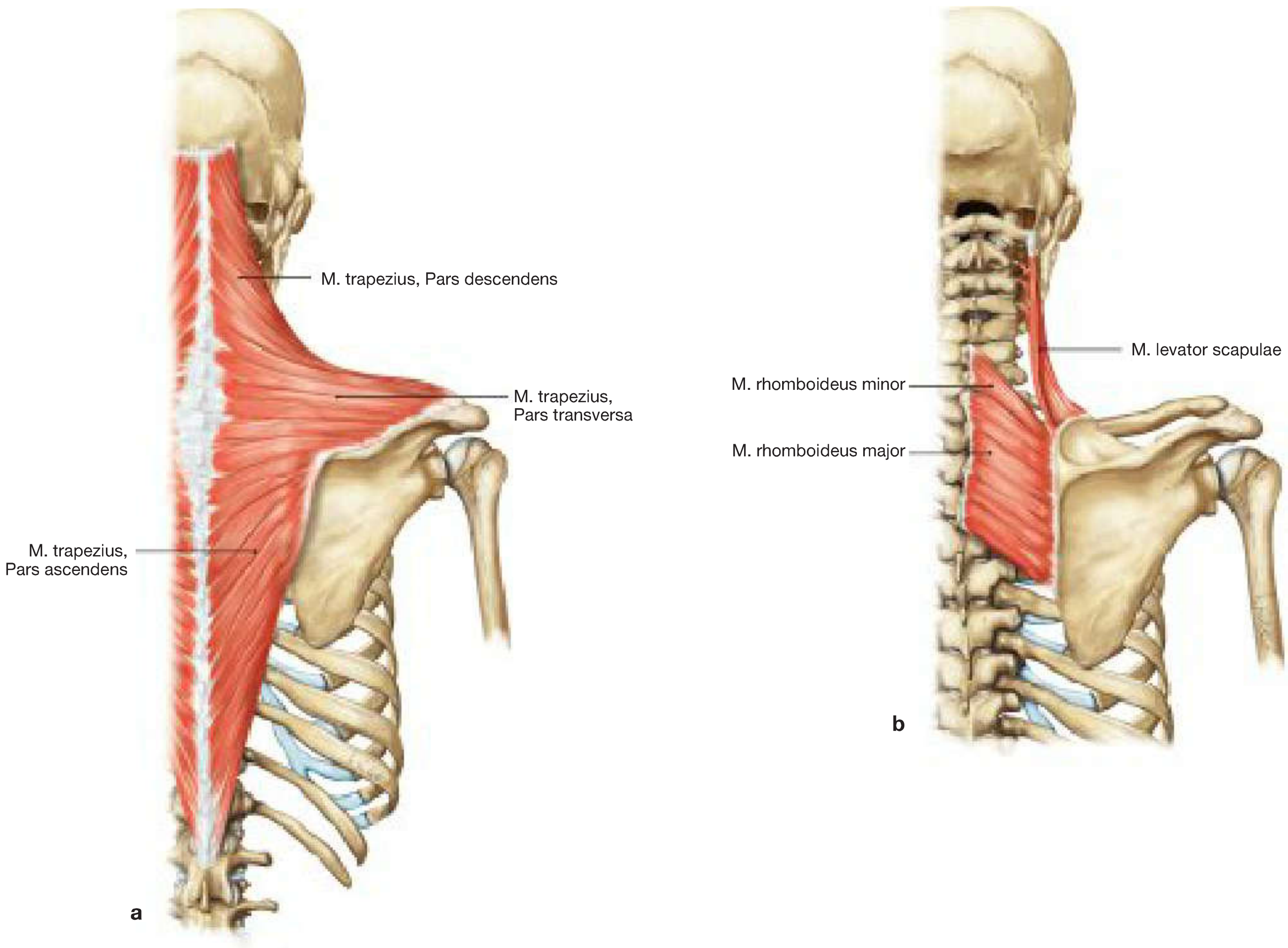


Fig. 3.51a and b Muscles of the shoulder girdle. [L266]
a M. trapezius
b M. levator scapulae and Mm. rhomboidei
In the shoulder area, there are two muscle groups. The muscles of the shoulder girdle insert at the scapula or clavicle, and primarily move the shoulder girdle and only indirectly move the arm. The shoulder muscles, on the other hand, insert at the humerus and move it directly. You can divide these muscles into subgroups according to their location. The **dorsal** muscles of the shoulder girdle include the M. trapezius, M. levator scapulae and Mm. rhomboidei. The M. levator scapulae and Mm. rhomboidei in particular, supported by the M. trapezius, attach the scapula to the torso.
Note: The dorsal muscles of the shoulder girdle are also presented as superficial muscles of the back when shown with the torso (→ p. 94 and 95).

→T 27

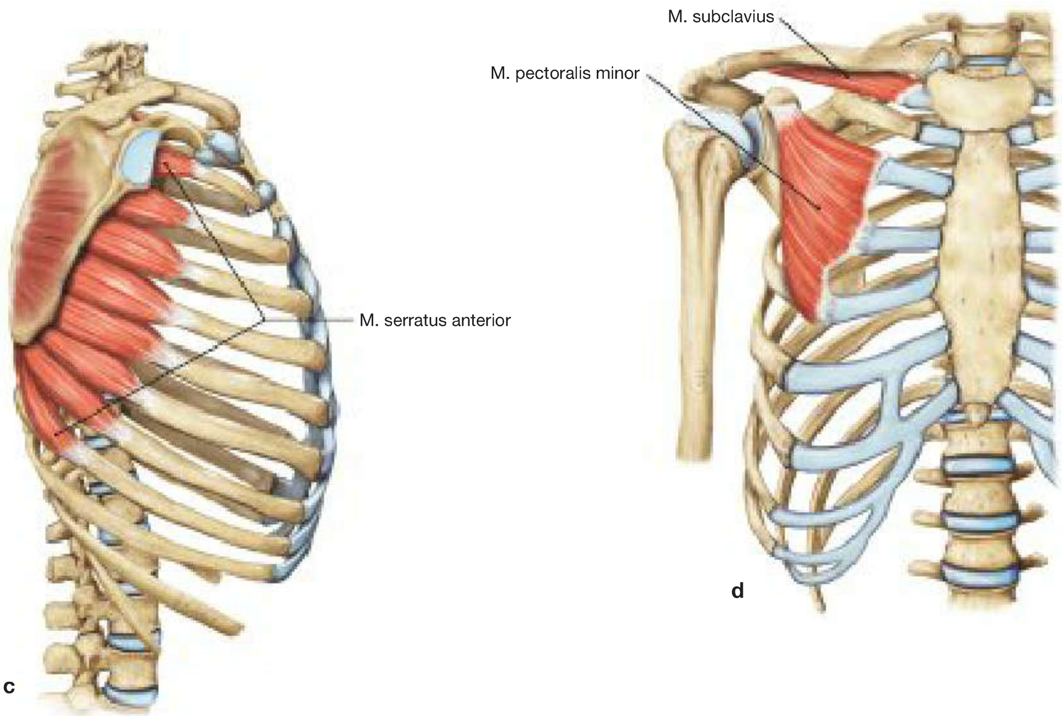


Fig. 3.51c and d Muscles of the shoulder girdle. [L266]
c M. serratus anterior
d M. pectoralis minor and M. subclavius
M. serratus anterior, M. pectoralis minor and M. subclavius belong to the **ventral** muscles of the shoulder girdle. The main function of the M. serratus anterior and also of the M. trapezius is the rotation of the scapula, which is necessary for raising the arm above the horizontal plane (elevation). The M. pectoralis minor can lower the scapula or, similar to the M. serratus anterior, raise the ribs when the arms are propped up, and thus act as an auxiliary respiratory muscle. The M. subclavius provides an active ligament fixation for the stabilisation of the sternoclavicular joint.
Note: The ventral muscles are also depicted in the context of the ventral abdominal wall (→ pp. 107–109).

→ T 24

Muscles

Shoulder Muscles

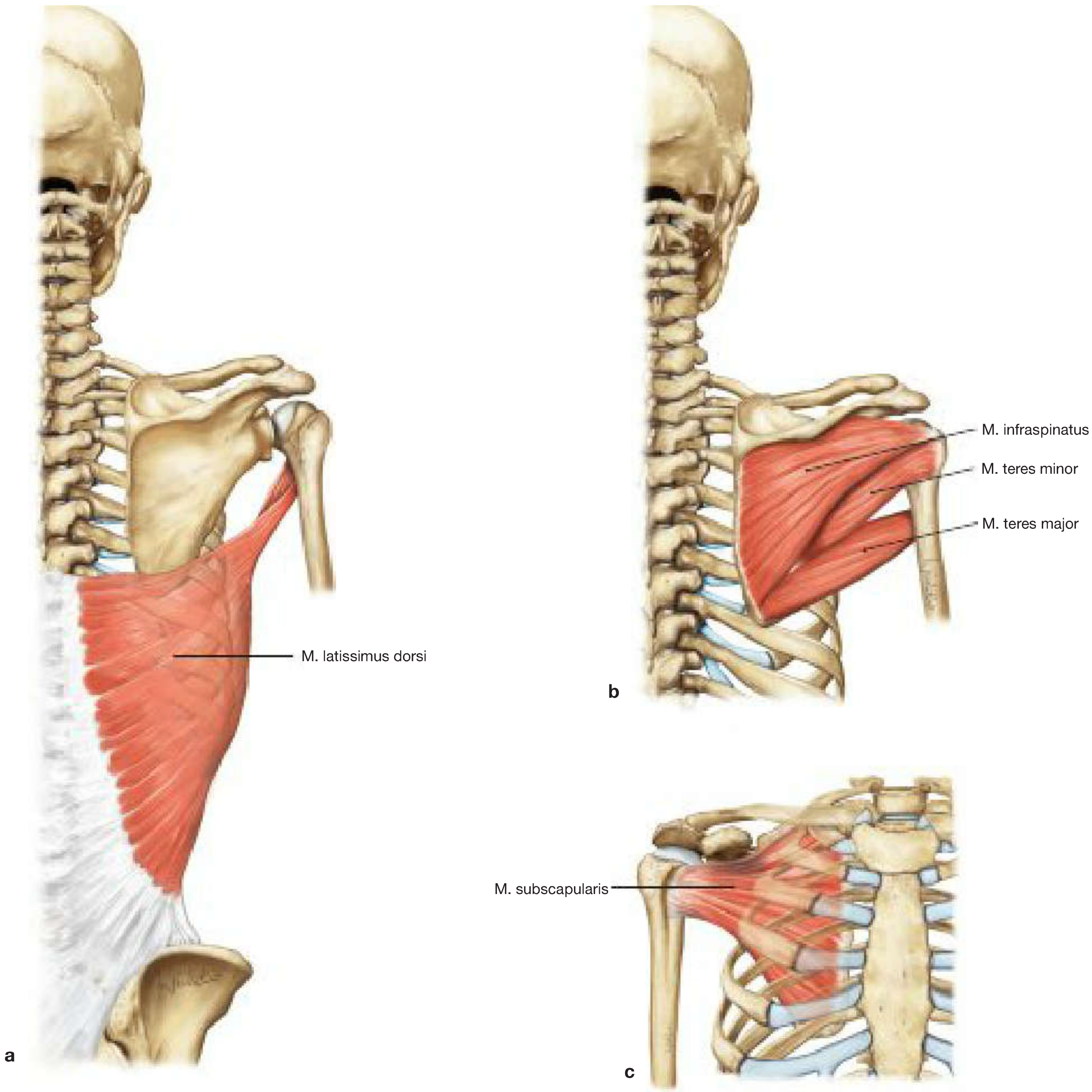
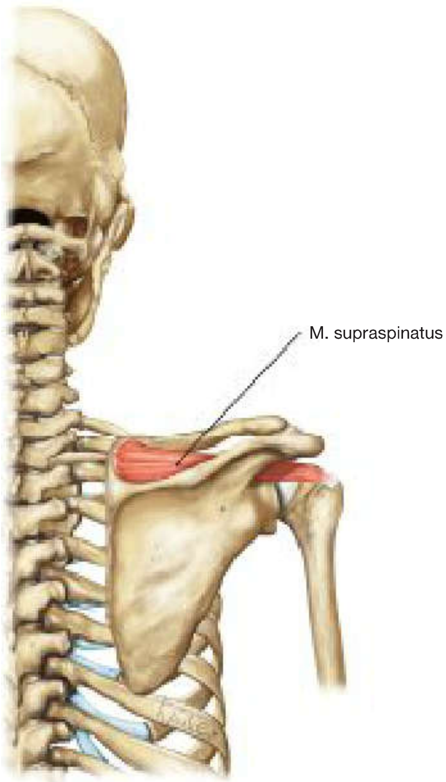


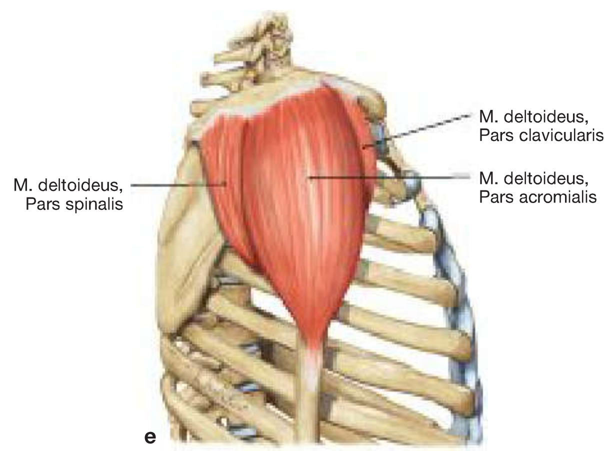
Fig. 3.52a to c Muscles of the shoulder. [L266]
a M. latissimus dorsi
b M. infraspinatus, M. teres minor, M. teres major
c M. subscapularis
In contrast to the muscles of the shoulder girdle, shoulder muscles act directly on the shoulder joint. The muscles can be divided into a dorsal and a ventral group. In addition, a lateral group can be defined which is described in most textbooks as part of the dorsal muscles. The **dorsal** shoulder muscles include the M. latissimus dorsi, M. infraspinatus, M. teres minor, M. teres major and M. subscapularis, which is the only muscle of this group on the ventral side of the scapula.

The **M. latissimus dorsi** can perform a powerful retroversion movement from an anteverted position (trajectory movement) and can induce a slight adduction and internal rotation in the shoulder joint. When moving against resistance, it is supported by the **M. teres major**. The M. latissimus dorsi can also support exhalation as an auxiliary respiratory muscle, by compressing the chest ('cough muscle').
The **M. subscapularis** is the most important internal rotator in the shoulder joint and is necessary for crossing the arms behind the back. Its antagonist is the **M. infraspinatus**, which enables a strong external rotation of the arm. The **M. teres minor** is part of the rotator cuff and stabilises the shoulder joint.

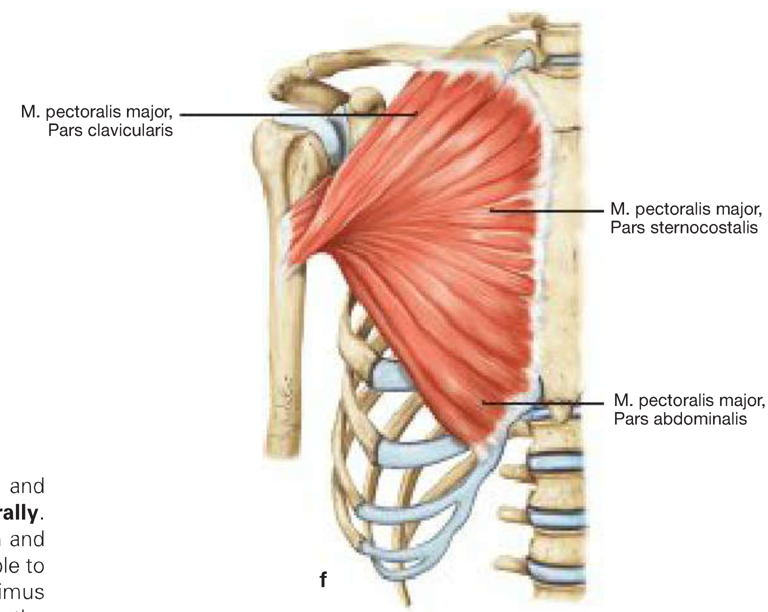
→T 28



d



e



f

Fig. 3.52d to f Muscles of the shoulder. [L266]
d M. supraspinatus
e M. deltoideus
f M. pectoralis major
The **lateral** shoulder muscles include the M. supraspinatus and M. deltoideus. **Only the M. pectoralis major is situated ventrally**. The **M. pectoralis major** is the strongest muscle for anteversion and adduction in the shoulder joint. Without this muscle, it is not possible to cross the arms in front of the torso. In addition to the M. latissimus dorsi, it can perform a strong retroversion movement out of the anteverted position (trajectory movement).
The **M. deltoideus** is the most important abductor but can support all other movements of the shoulder joint with its functionally distinct parts. The **M. supraspinatus** supports the M. deltoideus in the abduction.

→T 25, 26

Muscles of the Shoulder and Shoulder Girdle

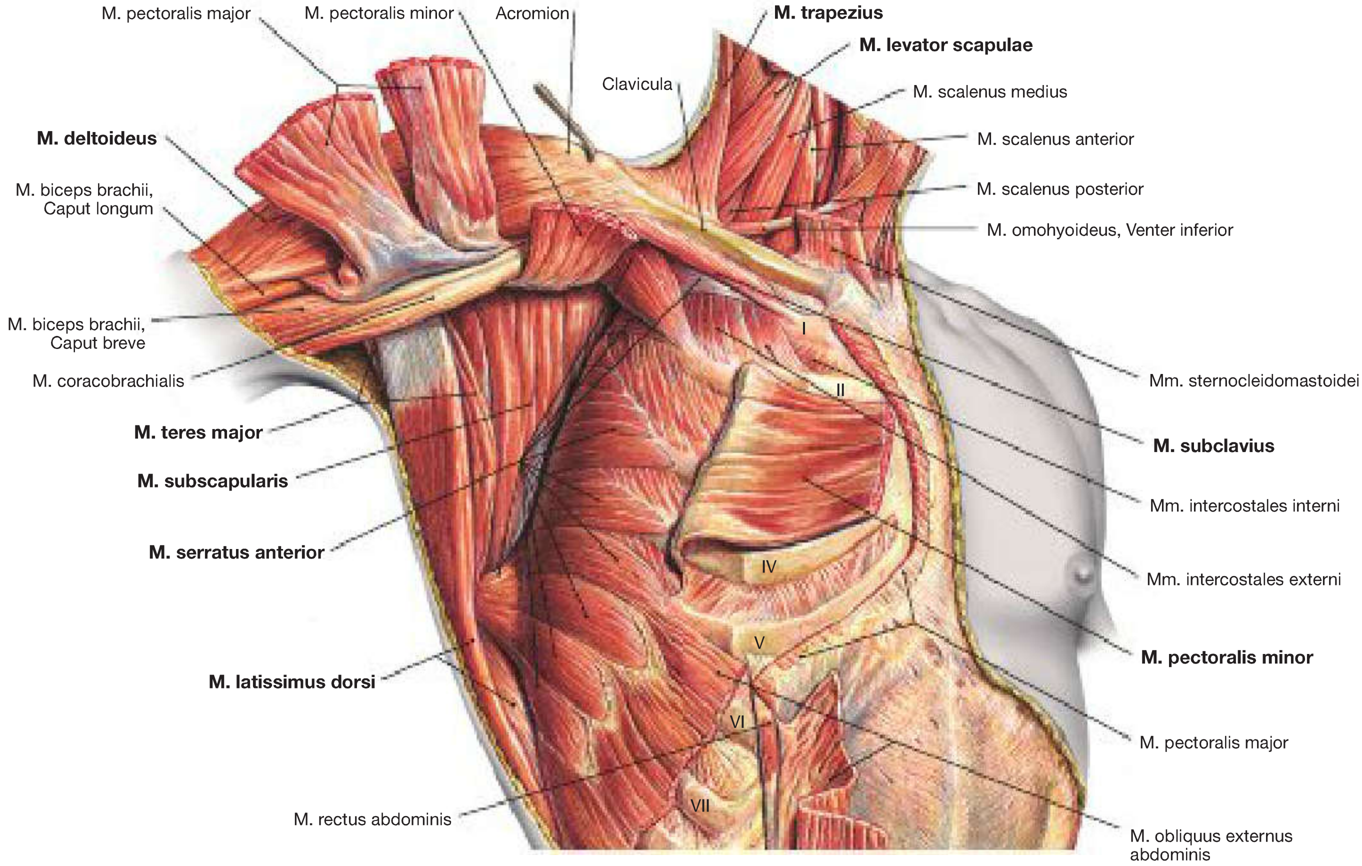


Fig. 3.53 Muscles of the shoulder girdle and the shoulder, right side; ventral view; Roman numerals denote the corresponding ribs. The anterior group (M. serratus anterior, M. pectoralis minor and M. subclavius) of muscles of the shoulder girdle are most visible here, whereas of the dorsal muscles, only the M. levator scapulae and a part of the M. trapezius are shown. The M. pectoralis minor has been unfolded so that the origins of the M. serratus anterior on ribs I to IX can be seen. The abduction position of the arm permits a clear view of the M. subscapularis which broadly covers the ventral area of the scapula.

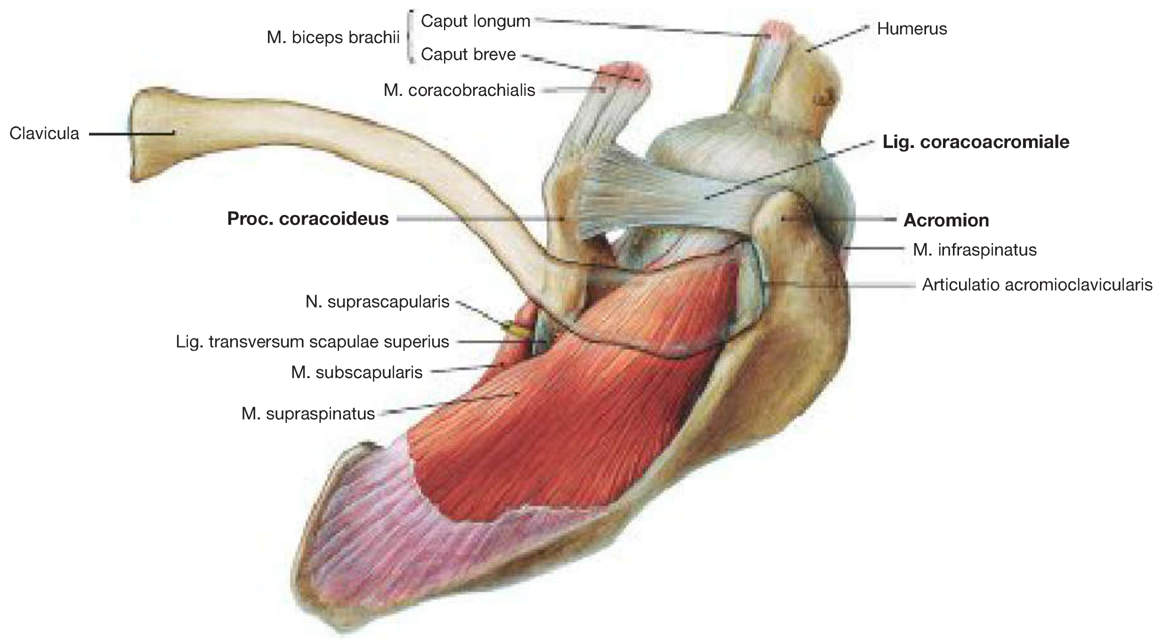
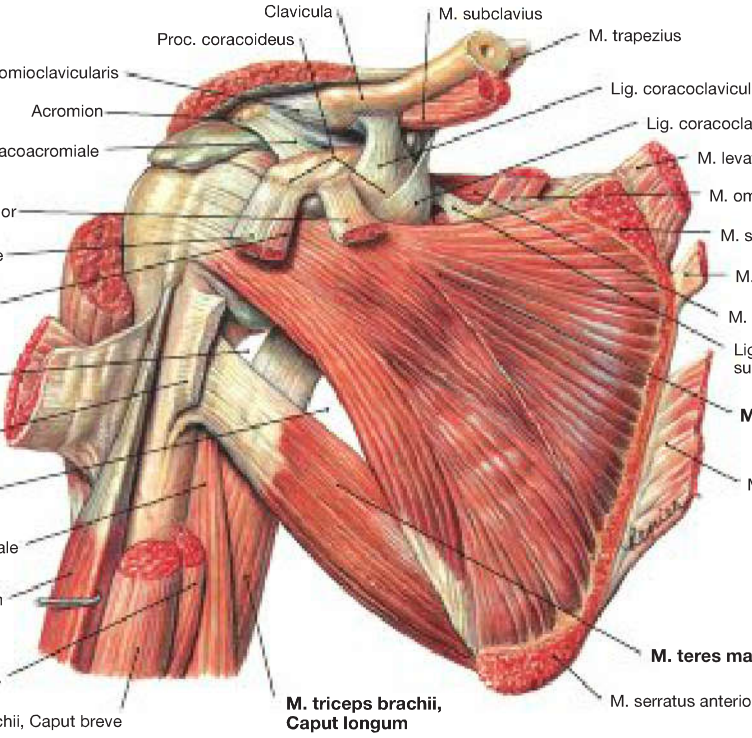


Fig. 3.54 Position of the M. supraspinatus in relation to the roof of the shoulder.
The 'roof of the shoulder' consists of the Acromion and the Proc. coracoideus which are connected by the Lig. coracoacromiale. The attaching tendon of the M. supraspinatus crosses underneath the roof of the shoulder before it radiates into the joint capsule. It is therefore understandable why this tendon can be compressed when the arm is abducted and therefore often exhibits painful degenerative changes.

→T 26, 28, 29



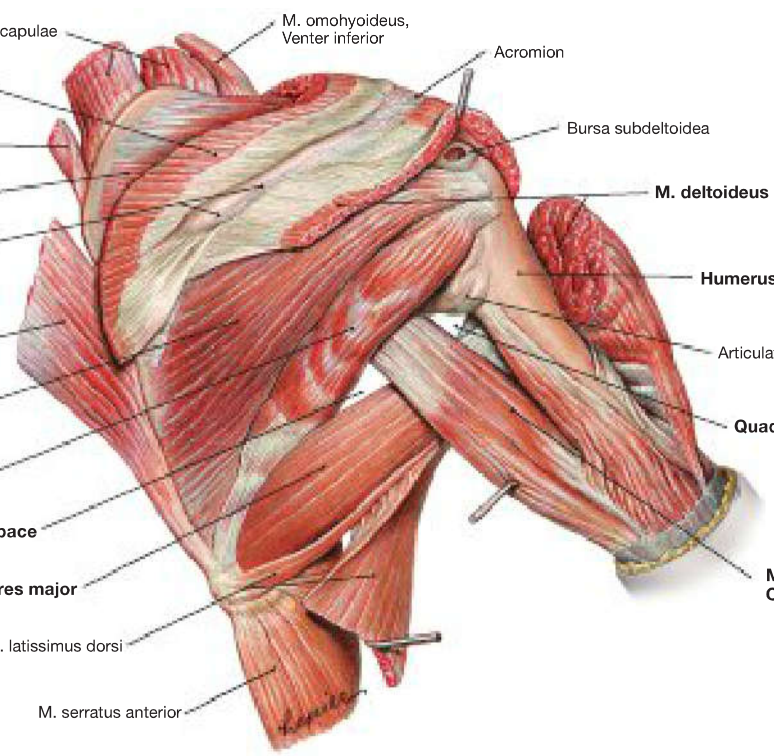
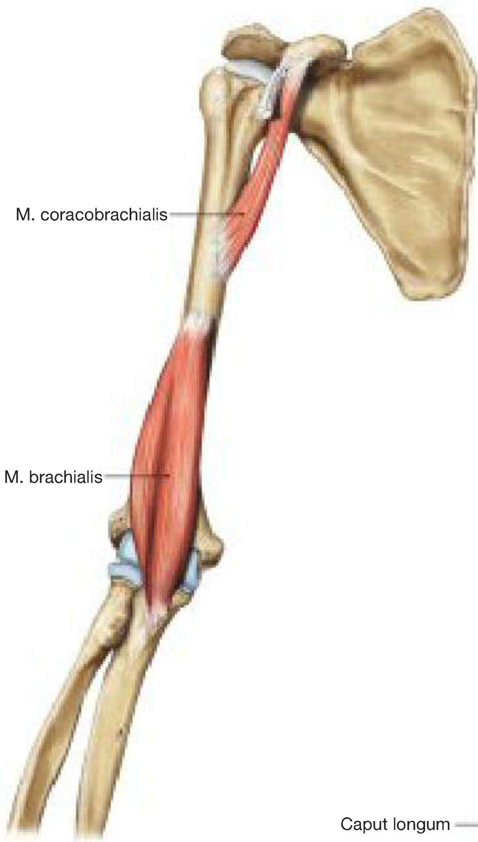


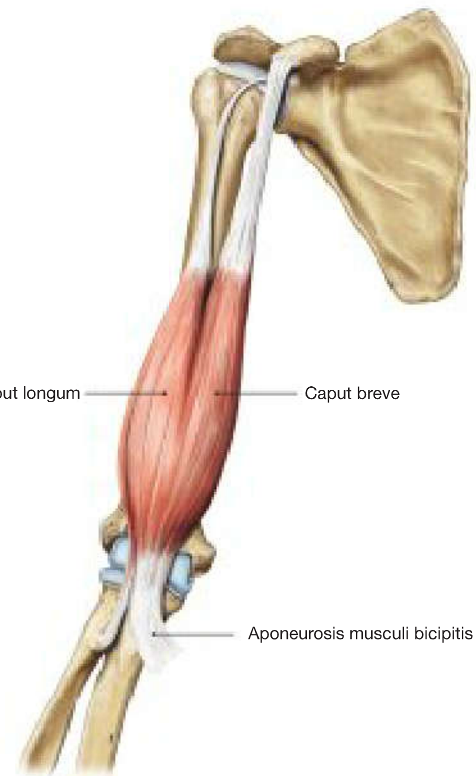
Fig. 3.55a and b Muscles of the shoulder girdle and shoulder, right side; ventral view (→ Fig. 3.55a) and dorsal view (→ Fig. 3.55b). Most of the muscles of the shoulder girdle have been removed to expose the shoulder muscles, so that only the muscle origins remain. In the ventral view it is particularly easy to recognise the M. subscapularis and its entire course. The course of the M. teres major is also easily recognisable. From its origin at the Angulus inferior of the scapula it crosses under the humerus before inserting on the Crista tuberculi minoris. The M. supraspinatus lies below the M. trapezius and runs (not shown here) under the roof of the shoulder to the upper part of the Tuberculum majus. The M. infraspinatus and M. teres minor insert below this point. The dissection specimens show both axillary gaps, which lie between the M. teres major and M. teres minor and are laterally bordered by the humerus: The two muscles diverge in a V-shape from their origins at the scapula and leave a gap between them, which is divided by the long head of the M. triceps brachii into the **triangular medial axillary space** (Spatium axillare mediale) and into the **square-shaped lateral axillary space** (Spatium axillare laterale). The A. and V. circumflexa scapulae pass through the medial axillary space on their way to the rear side of the shoulder blade. Together with the A. and V. circumflexa humeri posterior, the N. axillaris passes through the lateral axillary space (→ pp. 269 and 271) .

→ T 25, 26, 28, 30

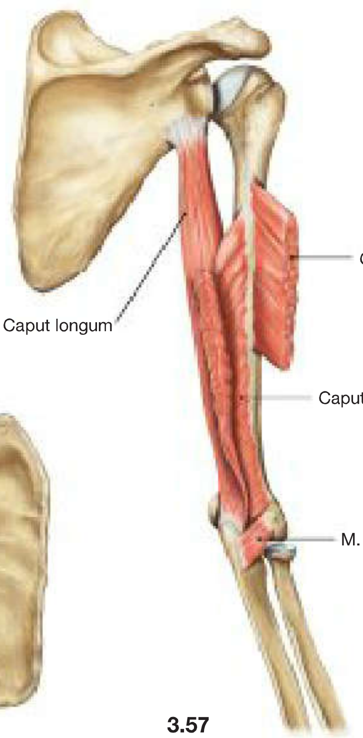
Muscles of the Upper Arm



3.56 a



3.56 b



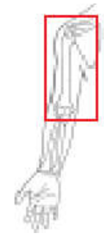
3.57

Fig. 3.56a and b Ventral muscles of the upper arm, right side; ventral view. [L266]
a M. coracobrachialis and M. brachialis
b M. biceps brachii
The M. coracobrachialis is situated on the anterior side of the upper arm, has its origin on the Proc. coracoideus and inserts medially on the humerus. In contrast to the other two ventral muscles, the muscle acts only on the shoulder joint and is involved in its adduction, internal rotation and anteversion. The M. coracobrachialis has however no decisive importance for any of these movements. Originating from the distal anterior surface of the humerus, the M. brachialis runs to the joint capsule and the Tuberositas ulnae. It acts as a strong flexor (in German: *'Brachialgewalt'*, brute force) only on the elbow joint.

In contrast to the M. coracobrachialis and M. brachialis, the M. biceps brachii and the M. triceps brachii (→ Fig. 3.57), which is the most important muscle on the rear side, are **double-jointed muscles** that are able to promote movements in the shoulder and elbow joints. The M. biceps brachii with its Caput breve originates from the Proc. coracoideus and therefore has the same functions as the M. coracobrachialis in the shoulder joint. The Caput longum originates at the Tuberculum supraglenoidale of the scapula and has an abducting function. However, its action on the elbow joint is significant. As it inserts at the Tuberositas radii, the M. biceps brachii is the **most important flexor in the elbow joint** and in particular the strongest **supinator of the forearm in a flexed position.**

Fig. 3.57 Dorsal muscles of the upper arm, M. triceps brachii and M. anconeus, right side; dorsal view. [L266]
The M. triceps brachii, which is situated on the back of the upper arm, originates with its Caput longum from the Tuberculum infraglenoidale, while its Caput laterale and Caput mediale broadly originate from the back of the humerus. In addition to its minor involvement in the adduction and retroversion of the shoulder joint, it is the **most import extensor of the elbow joint** because of its course with insertion on the olecranon and its great size. This function is supported by the M. anconeus, which runs from the Epicondylus lateralis of the humerus to the olecranon and to the rear side of the ulna.

→ T 29, 30



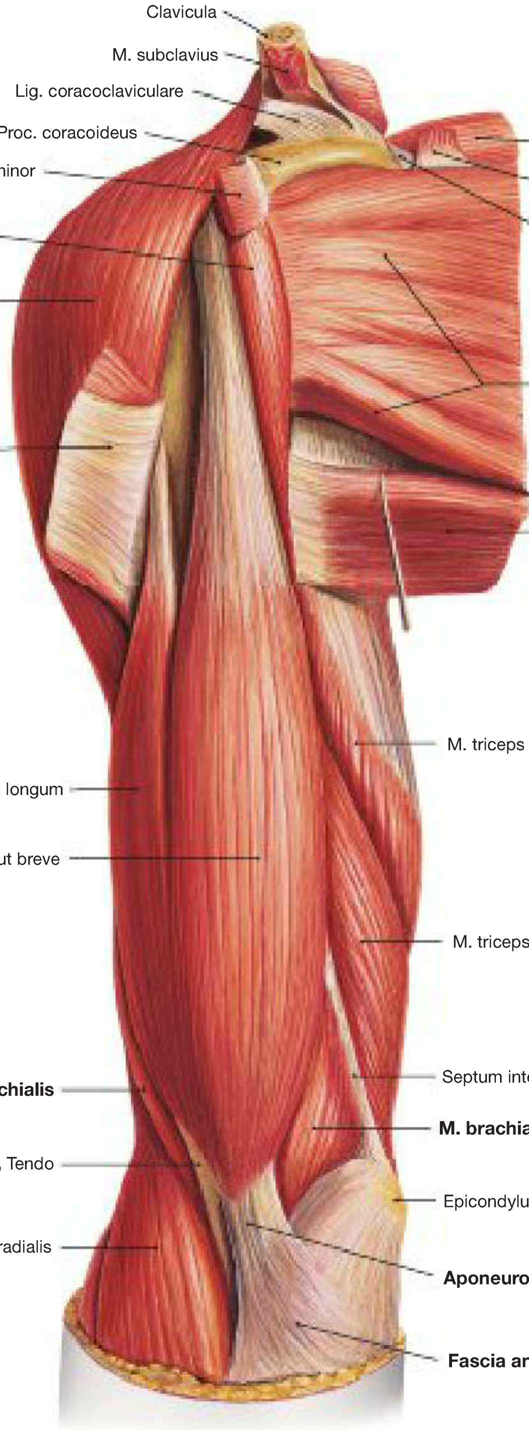
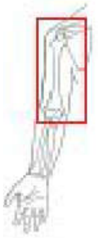


Fig. 3.58 Ventral muscles of the upper arm, right side; ventral view.

The M. coracobrachialis lies medial of the M. biceps brachii. The M. biceps brachii originates with its Caput breve at the Proc. coracoideus and with its Caput longum at the Tuberculum supraglenoidale. In addition to its main insertion on the Tuberositas radii, the M. biceps brachii also extends into the forearm fascia (Fascia antebrachii) with its Aponeurosis musculi bicipitis brachii. The M. brachialis is located deeper to the M. biceps brachii, so that only a part of its muscle belly can be recognised on both sides of the inserting tendon of the M. biceps brachii.

→ T 29, 30

Muscles of the Upper Arm



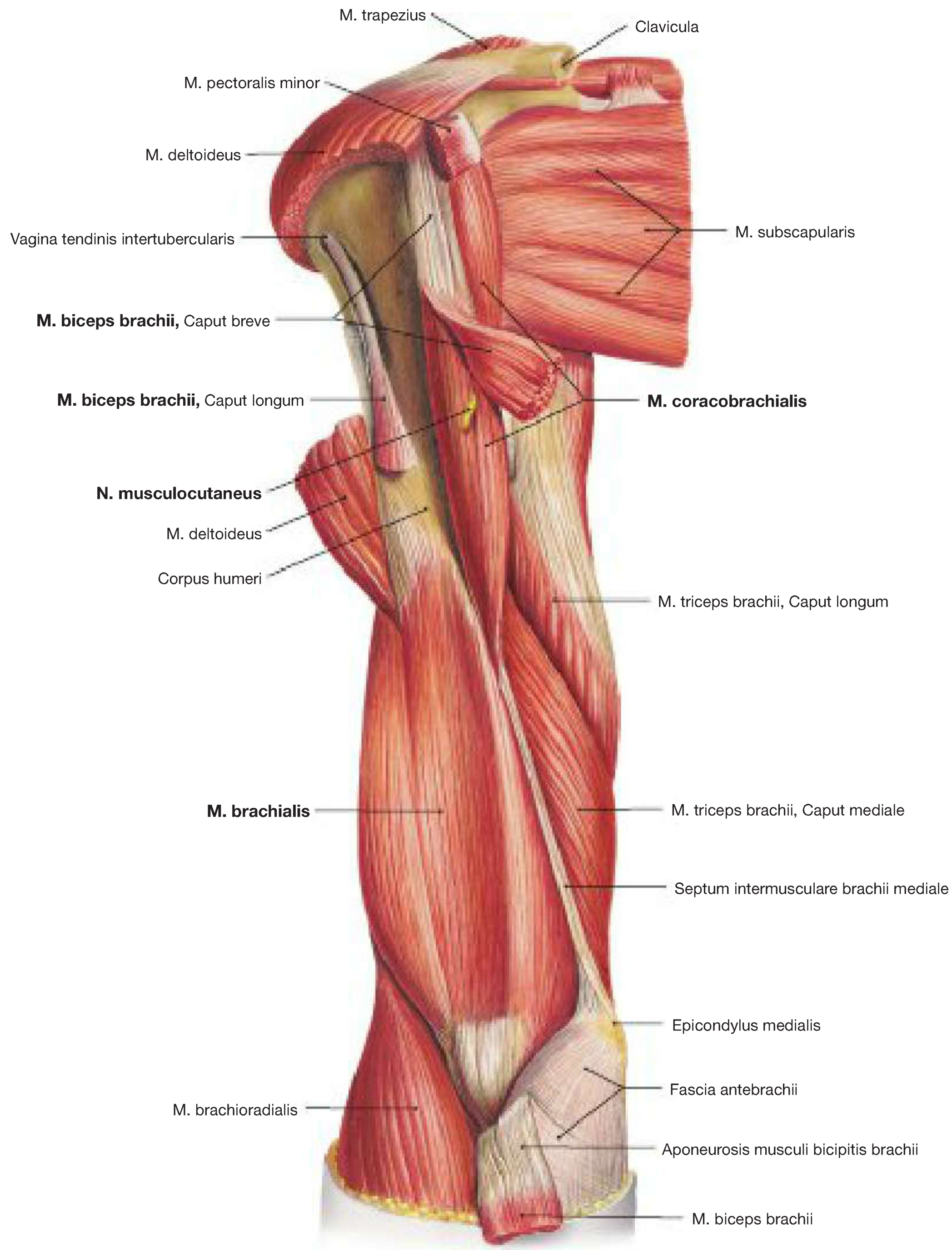


Fig. 3.59 Ventral muscles of the upper arm, right side; ventral view; after removal of the M. biceps brachii.
The M. biceps brachii was removed to reveal the underlying M. brachialis. The M. coracobrachialis can be easily identified, because it is usually pierced by the N. musculocutaneus which innervates the three muscles on the ventral side of the upper arm (M. coracobrachialis, M. biceps brachii, M. brachialis).

→ T 29, 30

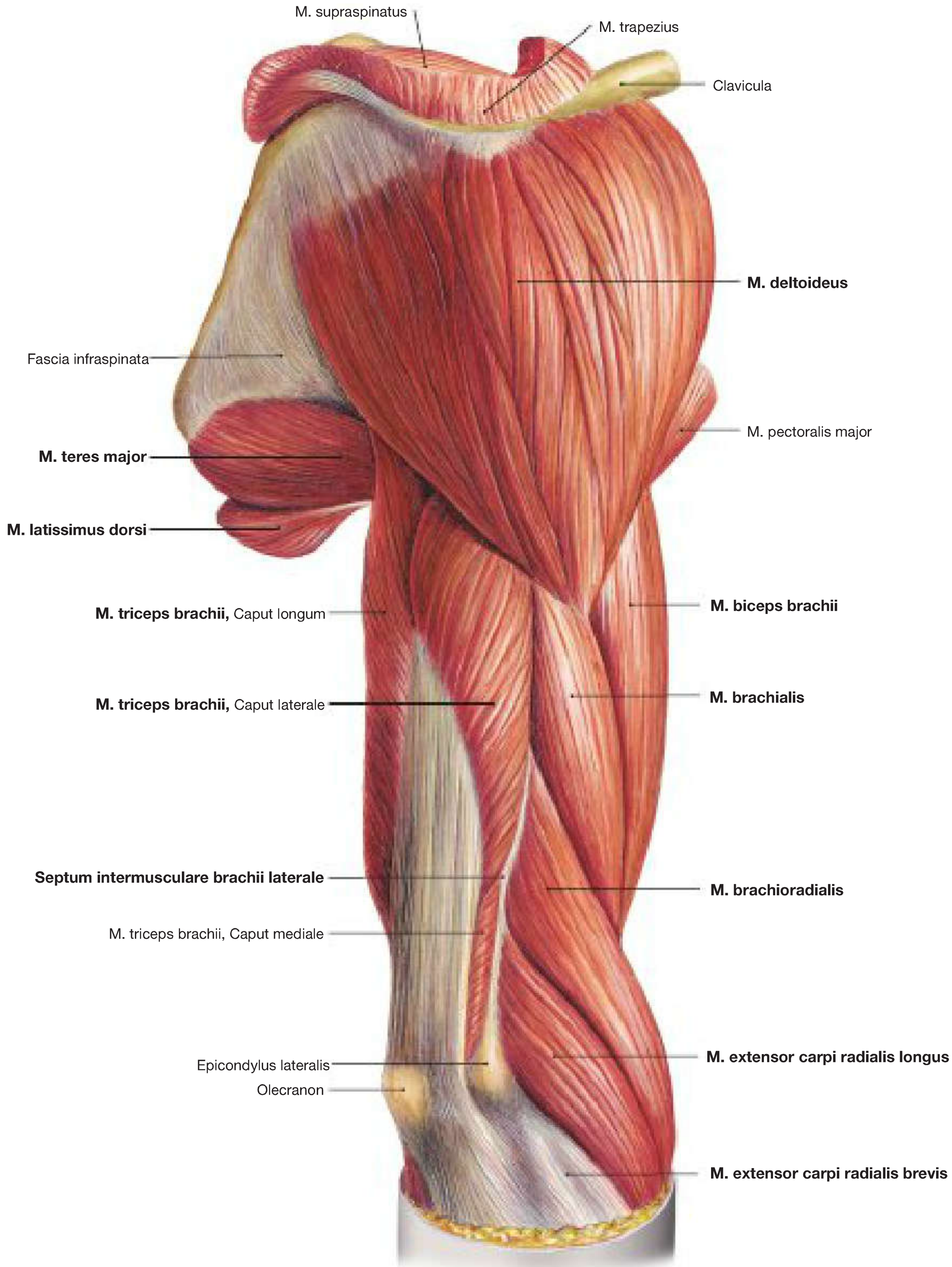
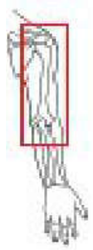


Fig. 3.60 Dorsal muscles of the shoulder and upper arm as well as ventral muscles of the upper arm, right side; dorsolateral view.
The M. triceps brachii almost completely covers the posterior aspect of the upper arm. Only the Caput longum and the Caput laterale, which both cover the Caput mediale, are visible here. All three muscle bellies insert on the olecranon. Separated by the Septum intermusculare brachii laterale, the flexor muscles (M. brachialis, M. biceps brachii) attach on the ventral side. The radial extensor muscles of the forearm also have their origins on the lateral aspect of the distal upper arm. From proximally to distally, these include the M. brachioradialis, M. extensor carpi radialis longus and M. extensor carpi radialis brevis. In addition to the M. deltoideus, other shoulder muscles, such as the M. teres major, the M. latissimus dorsi and the M. supraspinatus are visible here.

→T 26, 28, 29, 33

Muscles of the Upper Arm



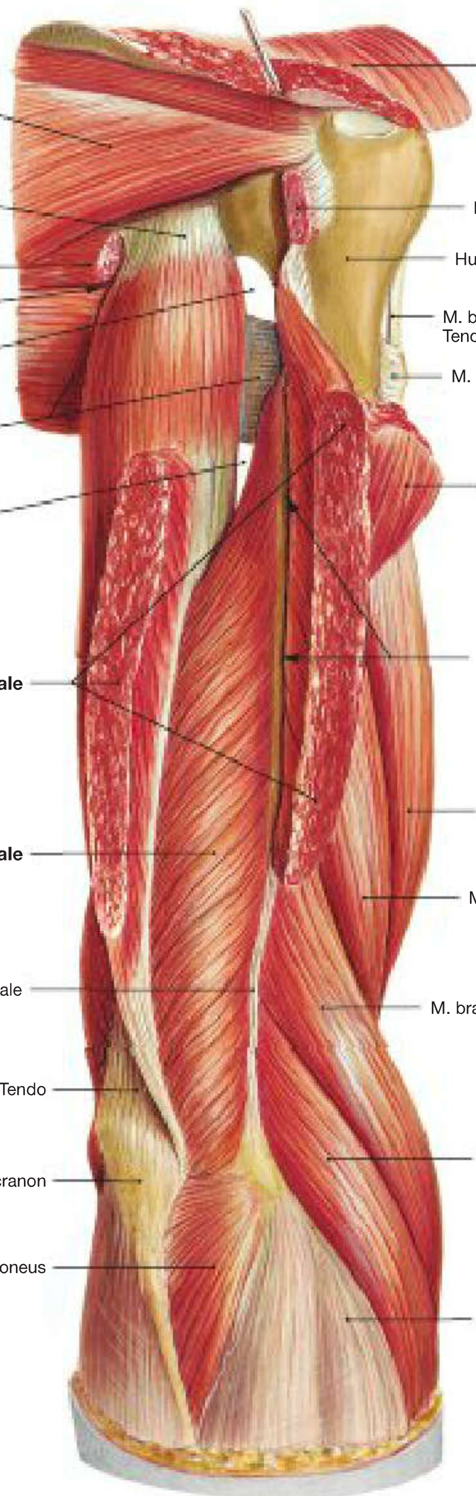


Fig. 3.61 Dorsal muscles of the shoulder and upper arm, right side; dorsal lateral view; after splitting the Caput laterale of the M. triceps brachii.

The Caput longum of the M. triceps brachii originates from the Tuberculum infraglenoidale of the scapula. The Caput laterale originates proximally and laterally of the Sulcus nervi radialis. Having split the Caput laterale, you can see the Caput mediale, which originates distally and medially of the Sulcus nervi radialis on the humerus. In addition, both **axillary spaces**, which are separated by the Caput longum, are visible between the M. teres minor and M. teres major (→ Fig. 3.55a and b). Passing through the so-called **triceps slit,** which lies distally of the M. teres major, the N. radialis reaches the dorsal side of the upper arm. The slit is bordered medially by the Caput longum and laterally by the Caput laterale of the M. triceps brachii.

→T 28, 30

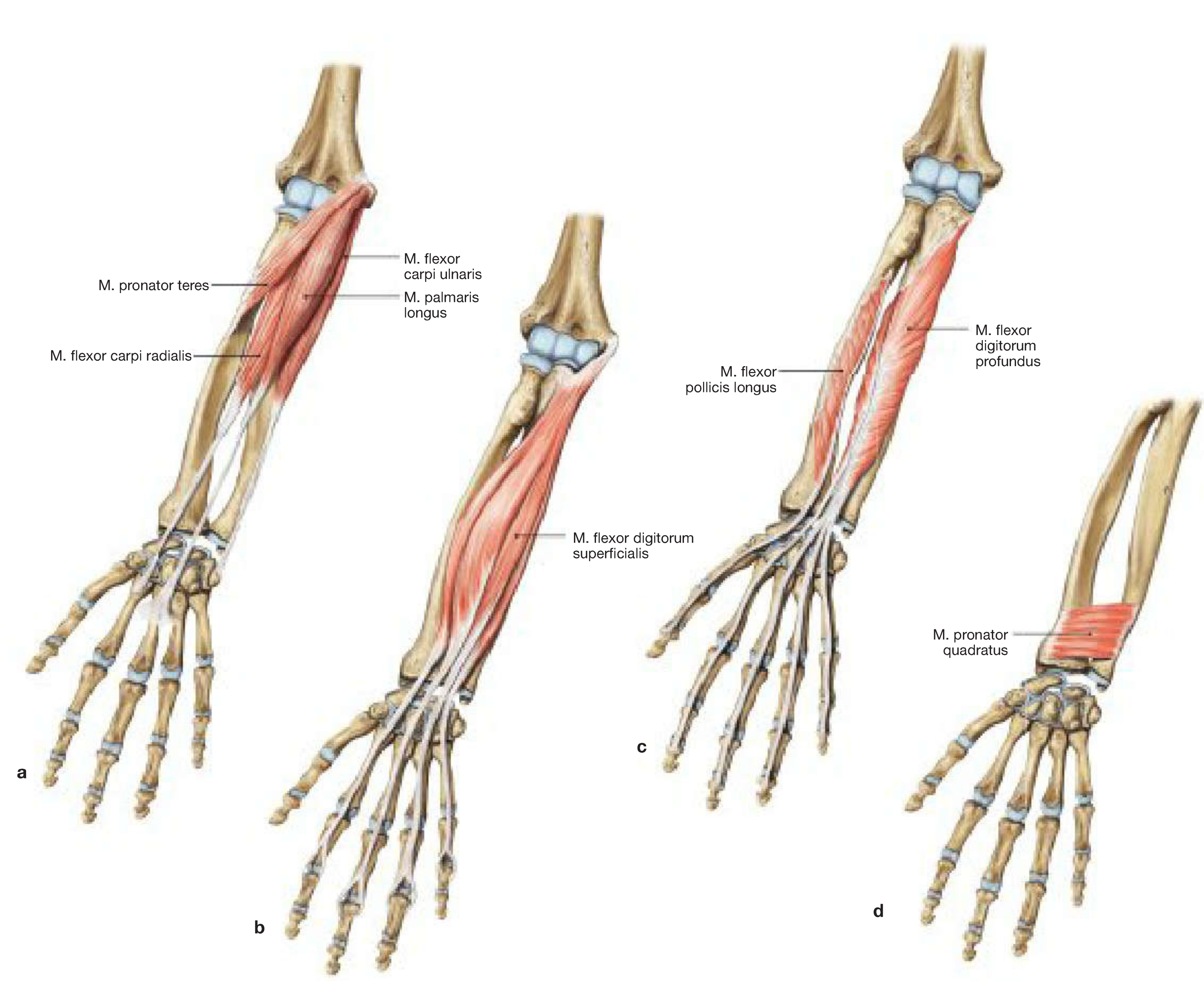


Fig. 3.62a to d Ventral muscles of the forearm, right side; ventral view. [L266]
The flexors of the forearm lie on the ventral side and are divided into a superficial and a deep group by the radial and ulnar neurovascular pathways. In these two groups the muscles lie in two layers on top of each other, so that **four different layers** can be distinguished:

- superficial layer
- middle layer
- deep layer
- deepest layer

a Superficial layer
From radial to ulnar, the superficial layer consists of the M. pronator teres, M. flexor carpi radialis, M. palmaris longus and M. flexor carpi ulnaris. These muscles have their common origin at the Epicondylus medialis of the humerus and are **flexors in the elbow joint** and, apart from the M. pronator teres, they are also flexors of the **hand joints (wrists).** The **M. pronator teres** crosses the diagonal axis of the forearm and is therefore the most important **pronator, together with the M. pronator quadratus in the deepest layer.** The M. palmaris longus, which may be lacking unilaterally or bilaterally in up to 20% of the cases, stretches the palmar aponeurosis in addition to flexing the wrist. When acting together with its antagonist on the extensor side, the M. flexor carpi ulnaris induces the ulnar abduction, whereas the M. flexor carpi radialis supports the radial abduction.

b Middle layer
The **M. flexor digitorum superficialis** constitutes the middle layer. It consists of four parts and its tendons extend to the palmar sides of the middle phalanges of the second to fifth fingers. Therefore, in addition to the elbow joints and wrists it also flexes the **proximal interphalangeal** and to a somewhat lesser extent the metacarpophalangeal **joints of the fingers.**

c Deep layer
The deep layer comprises the **M. flexor pollicis longus** on the radial side and the M. flexor digitorum profundus on the **ulnar side.** These two muscles originate from the anterior aspect of the forearm and therefore do not act on the elbow joint. As they continue up to the palmar sides of the distal phalanges, they flex the wrist and, in addition to the **distal interphalangeal joints of the fingers and the thumb,** they also flex the **metacarpophalangeal and the proximal interphalangeal joints to a lesser extent.**

d Deepest layer
Below the long flexor tendons, the **M. pronator quadratus connects** the front sides of the ulna and the radius.

→ T 31, 32

Muscles of the Forearm

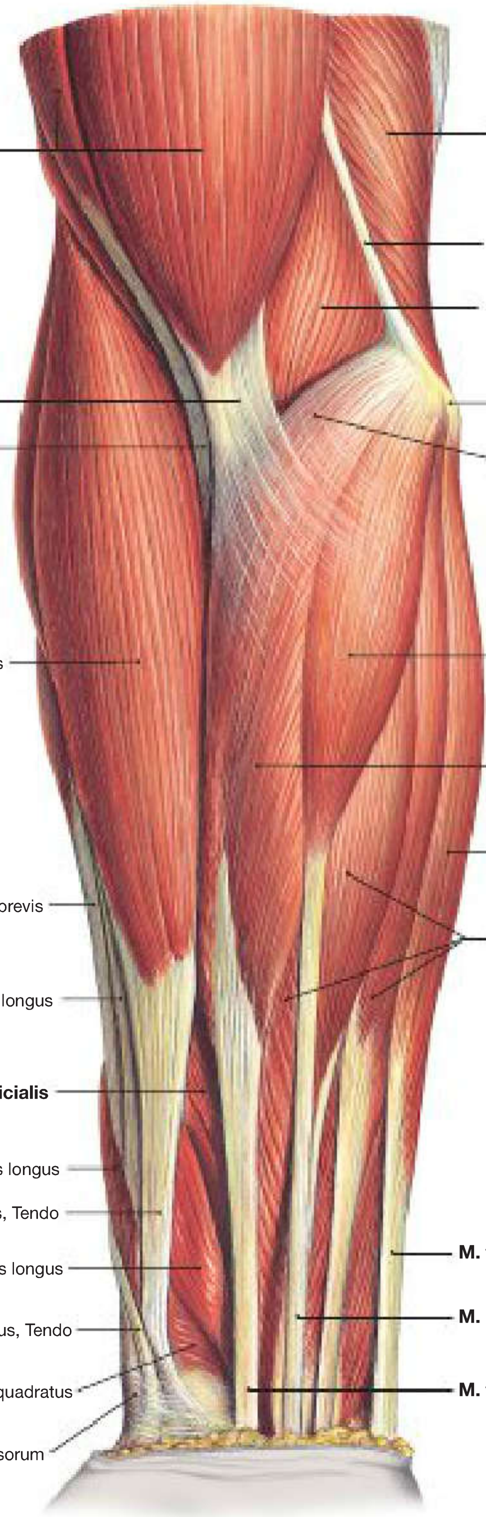


Fig. 3.63 Superficial layer of the ventral muscles of the forearm, right side; ventral view.
From radial to ulnar, the superficial flexor muscles of the forearm consist of the M. pronator teres, M. flexor carpi radialis, M. palmaris longus, and M. flexor carpi ulnaris. Parts of the M. flexor digitorum superficialis, which form the middle layer, are visible between the M. palmaris longus and M. flexor carpi ulnaris as well as between the tendons of these muscles. Radial to the superficial flexor muscles lies the radial muscle group of the forearm, which belongs to the extensor muscles because of their innervation and their action upon the wrists.

→ T 31

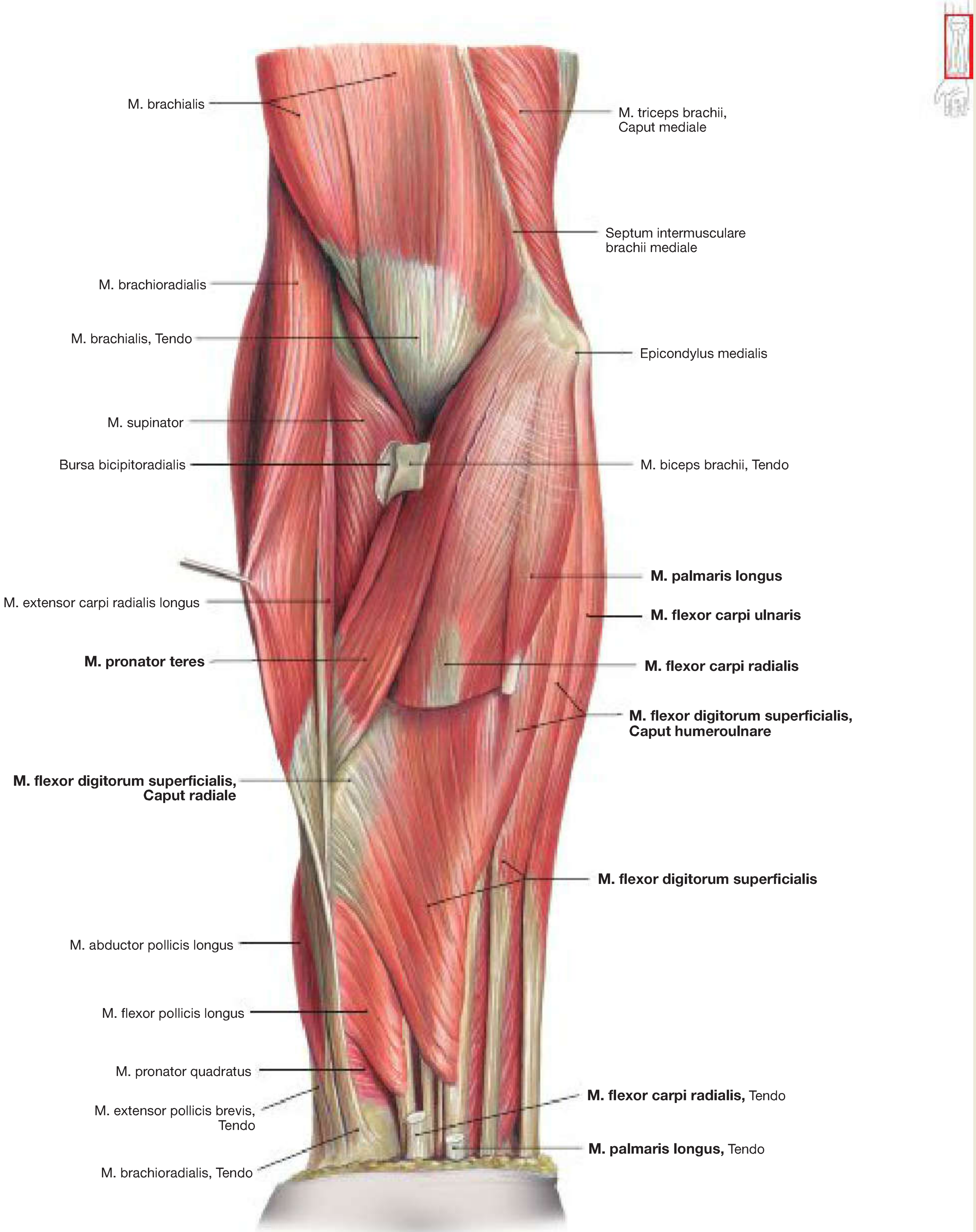


Fig. 3.64 Middle layer of the ventral muscles of the forearm, right side; ventral view; after partial cutting away of the M. flexor carpi radialis and M. palmaris longus.

The full extent of the M. pronator teres is visible after removal of the Aponeurosis musculi bicipitis brachii and folding back of the M. brachioradialis. Below the superficial layer of the flexor muscles lie the middle layer of the ventral muscles of the forearm, which consists of the four muscle bellies of the M. flexor digitorum superficialis. The entire width of this muscle only becomes visible when the M. flexor carpi radialis and the M. palmaris longus are pushed aside or have been cut away, as shown here. The Caput humeroulnare of the M. flexor digitorum superficialis originates from the Epicondylus medialis of the humerus and from the Proc. coronoideus of the ulna. Its Caput radiale originates at the anterior aspect of the radius.

On closer examination, it is clear that the bellies of the M. flexor digitorum are not on the same plane. Only the muscular parts for the third and fourth fingers are visible here, as they cover the muscle bellies relating to the second and fifth fingers.

→ T 31

Muscles of the Forearm

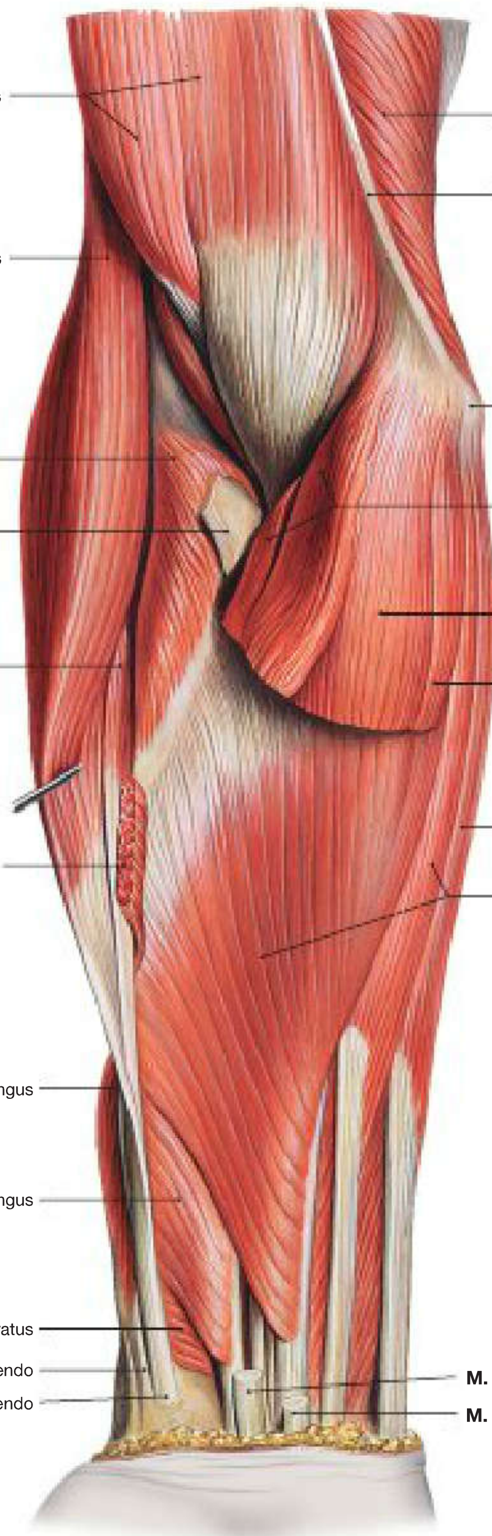


Fig. 3.65 Middle layer of the ventral muscles of the forearm, right side; ventral view; after extensive cutting away of the M. flexor carpi radialis, M. palmaris longus and M. pronator teres.
In contrast to → Fig. 3.64, the M. pronator teres was additionally split here to expose the origins of the M. flexor digitorum superficialis. The Caput humeroulnare originates from the Epicondylus medialis of the humerus and from the Proc. coronoideus of the ulna. The Caput radiale originates from the anterior aspect of the radius.

→ T 31

Clinical Remarks

After a stroke or lesions of the central nervous system an abnormal muscular hypertonicity can occur in the form of a **spasticity** or even without any major injury in the form of **dystonia**. Spasticity often affects entire muscle groups. Sometimes dystonia manifests selectively in individual flexor muscles, e.g. in the case of a writing spasm, or sometimes only in a single muscle belly, e.g. of the M. flexor digitorum superficialis. To enable a targeted treatment, e.g. the inhibition of signal transmission to the motor end plates by injection of botulinum toxin, a very precise understanding of the function and topography of the muscles is necessary.

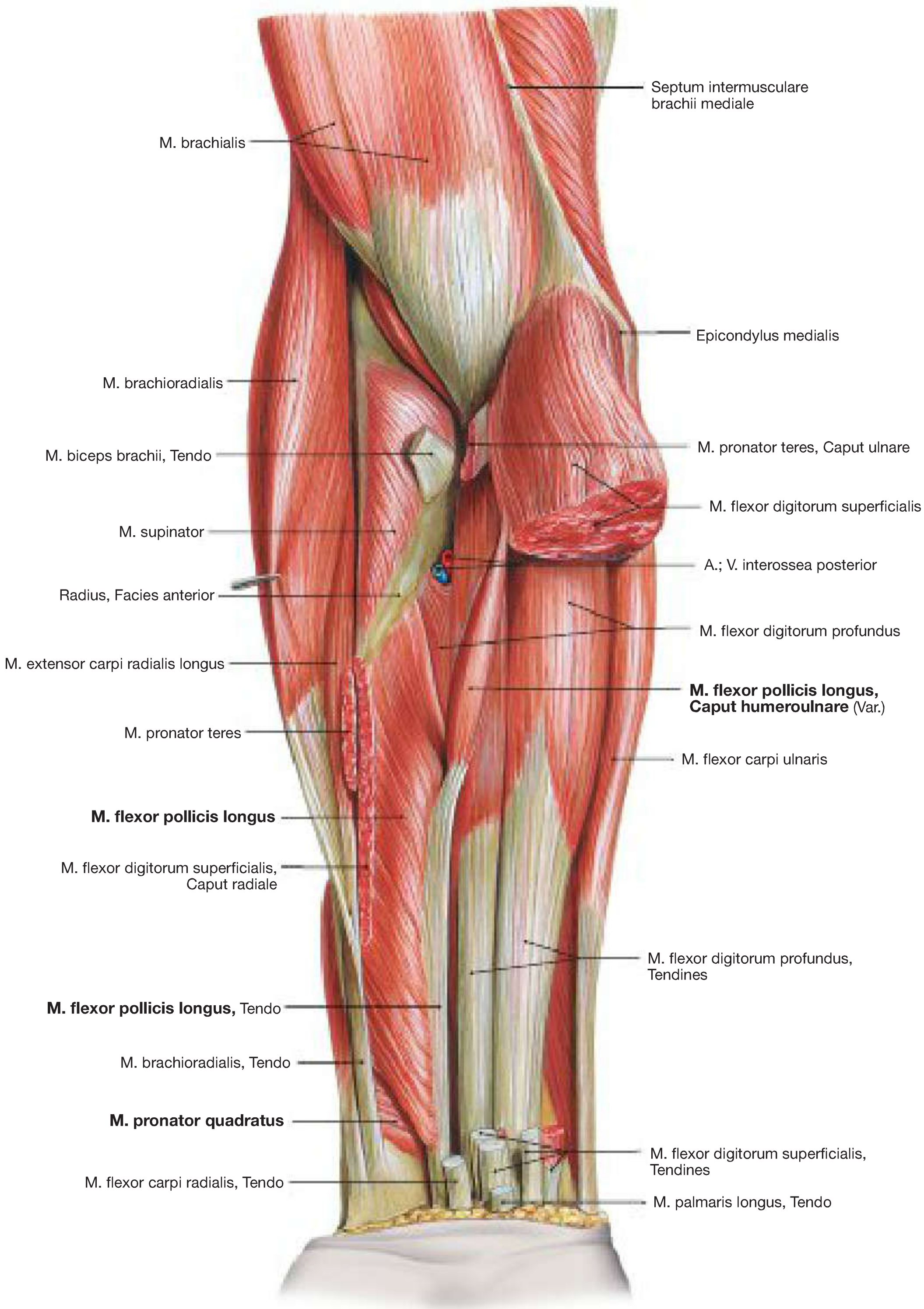


Fig. 3.66 Deep and deepest layer of the ventral muscles of the forearm, right side; ventral view; after removal of the superficial flexor muscles.

When all superficial muscles have been pushed a side or removed, the deep flexor muscles become visible as shown here. The M. flexor digitorum profundus originates from the anterior aspect of the ulna and from the Membrana interossea antebrachii. The M. flexor pollicis longus originates from the anterior aspect of the radius and in up to 40% of all cases with an additional Caput humeroulnare from the Epicondylus medialis and the Proc. coronoideus. The M. pronator quadratus is situated below the flexor tendons on the distal forearm where it passes along the anterior aspect of both two bones from the ulna to the radius.

→ T 32

Muscles of the Forearm

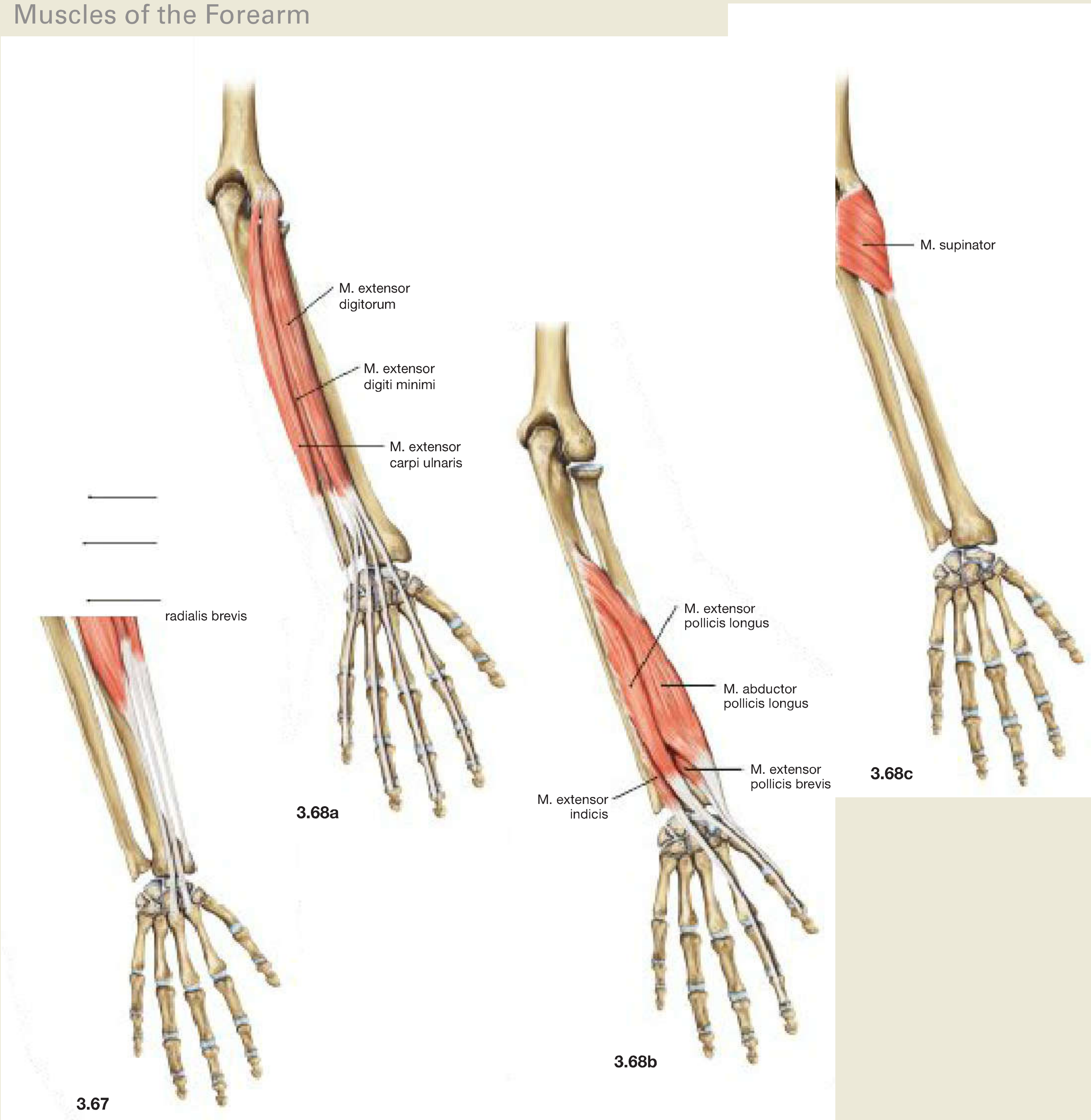


Fig. 3.67 Radial muscles of the forearm, right side; dorsal view. [L266]

From proximal to distal, the radial group of muscles includes the **M. brachioradialis,** and the **Mm. extensores carpi radialis longus and brevis.** These muscles originate from the lateral aspect of the humerus and, being located anterior to the transverse axis of the elbow joint, they are functionally involved in the flexion of this joint. The M. brachioradialis inserts on the distal radius and therefore acts only as a single joint. It can support the pronation and supination of the forearm from the respectively opposing positions. The Mm. extensores carpi radialis longus and brevis are extensors of the wrists and induce the radial abduction.

→ T 33

Fig. 3.68a to c Dorsal muscles of the forearm, right side; dorsal view. [L266]

a Superficial layer

The superficial extensors have their common origin at the **Epicondylus lateralis.** Excessive load of this tendinous origin can cause very unpleasant pain ('tennis elbow'). From radial to ulnar, this muscle group includes the **M. extensor digitorum,** the **M. extensor digiti minimi**, and the **M. extensor carpi ulnaris.** The M. extensor digitorum and M. extensor digiti minimi radiate into the dorsal aponeuroses of digits II to V. Therefore, these muscles extend the wrists as well as the metacarpophalangeal and proximal interphalangeal joints of the fingers. As the middle tract of the dorsal aponeurosis ends on the middle phalanges, the muscles are not involved in the extension of the distal interphalangeal joints.

b and c Deep layer

Distally from radial to ulnar, the deep layer consists of the **M. abductor pollicis longus, M. extensor pollicis brevis, M. extensor pollicis longus** and **M. extensor indicis** (→ Fig. 3.68b). The M. abductor pollicis longus abducts the thumb in the saddle joint, whereas the Mm. extensores pollicis brevis and longus extend the thumb in its carpometacarpal and distal interphalangeal joints. The M. extensor indicis extends the index finger in the carpometacarpal and proximal interphalangeal joints. Proximally, the deep layer of the wrist extensor muscles includes the **M. supinator** (→ Fig. 3.68c) which winds around the radius. It is the strongest supinator when the elbow joint is extended.

→ T 34, 35

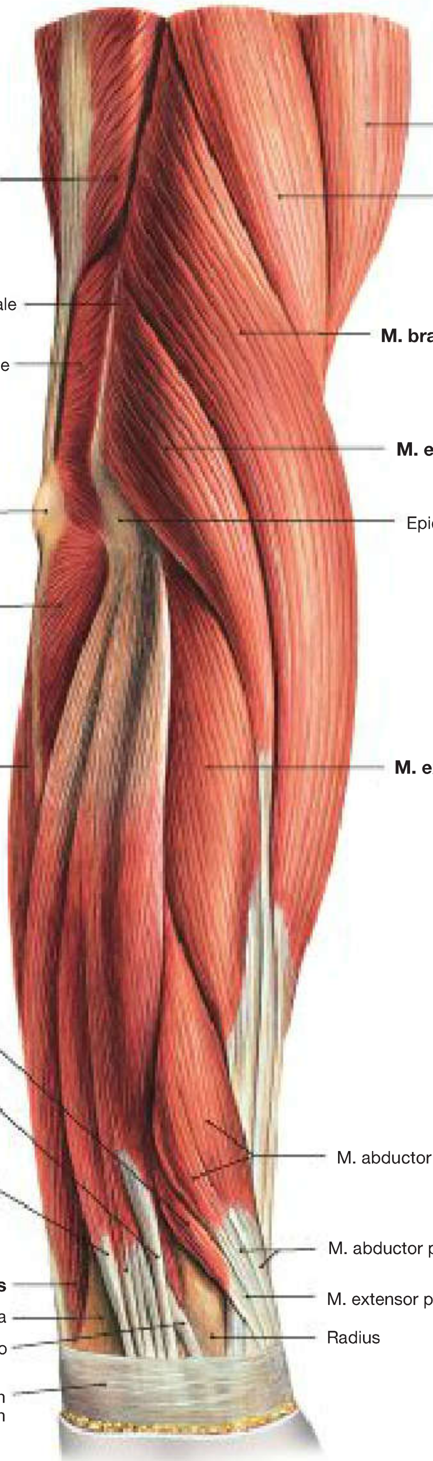


Fig. 3.69 Superficial layer of the dorsal muscles of the forearm and of the distal part of the upper arm, right side; lateral view.
The muscles of the radial muscle group are particularly visible in the lateral view. From proximal to distal there are the M. brachioradialis, and the Mm. extensores carpi radialis longus and brevis. The superficial extensor muscles (M. extensor digitorum, M. extensor digiti minimi, and M. extensor carpi ulnaris) follow in the ulnar direction. Between these muscle groups, the distal parts of the deep extensor muscles are visible distally (thus, they are not completely covered by the superficial extensors). The M. anconeus has been exposed without its fascia on the distal upper arm. This muscle belongs to the extensor muscles of the upper arm.

→ T 33–35

Muscles of the Forearm

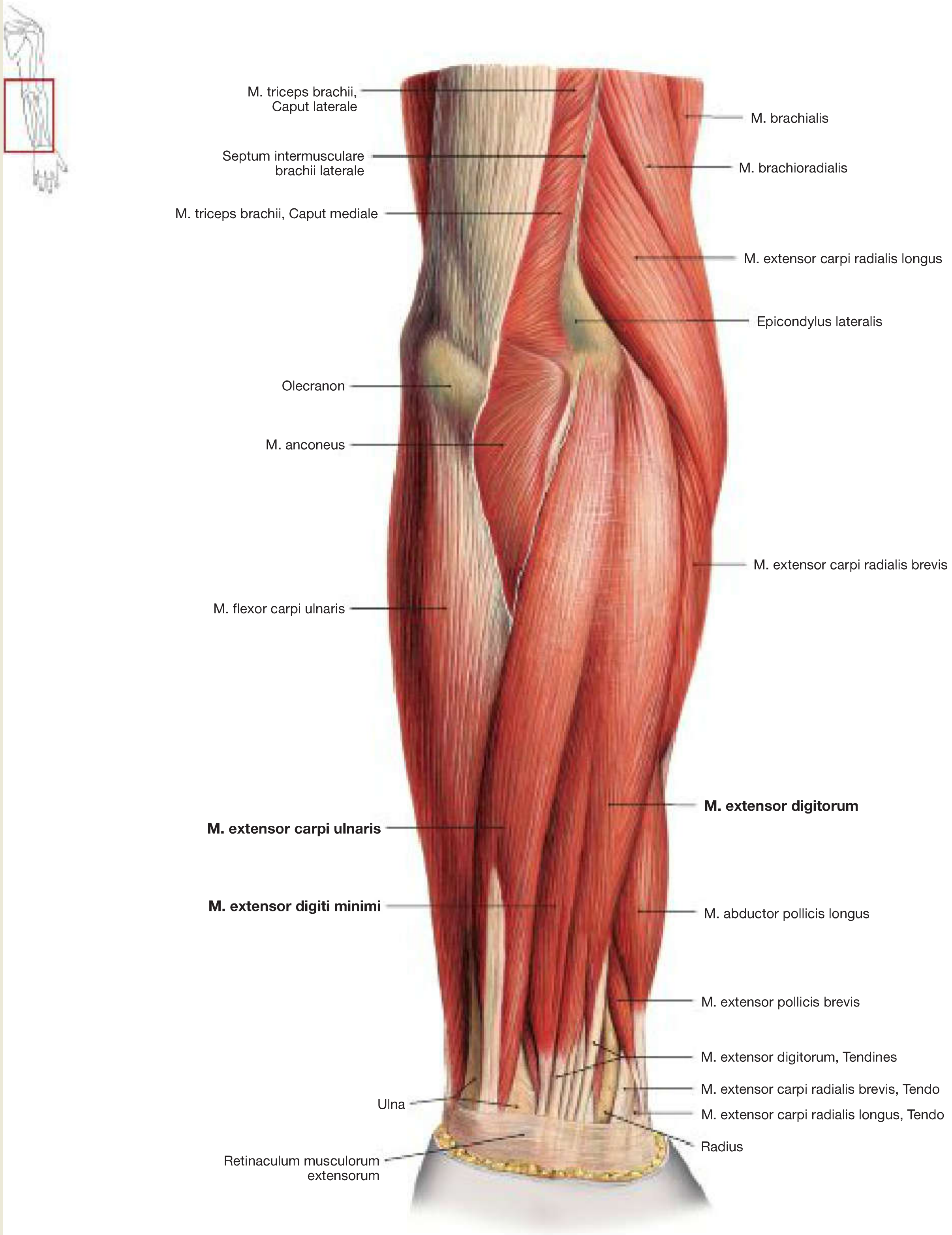


Fig. 3.70 Superficial layer of the dorsal muscles of the forearm and of the distal part of the upper arm, right side; dorsal view.
The superficial extensor muscles of the forearm are visible here. From radial to ulnar, this muscle group includes the M. extensor digitorum, M. extensor digiti minimi and M. extensor carpi ulnaris. The M. extensor carpi ulnaris follows the M. flexor carpi ulnaris of the superficial flexor group in the ulnar direction.

→ T 34

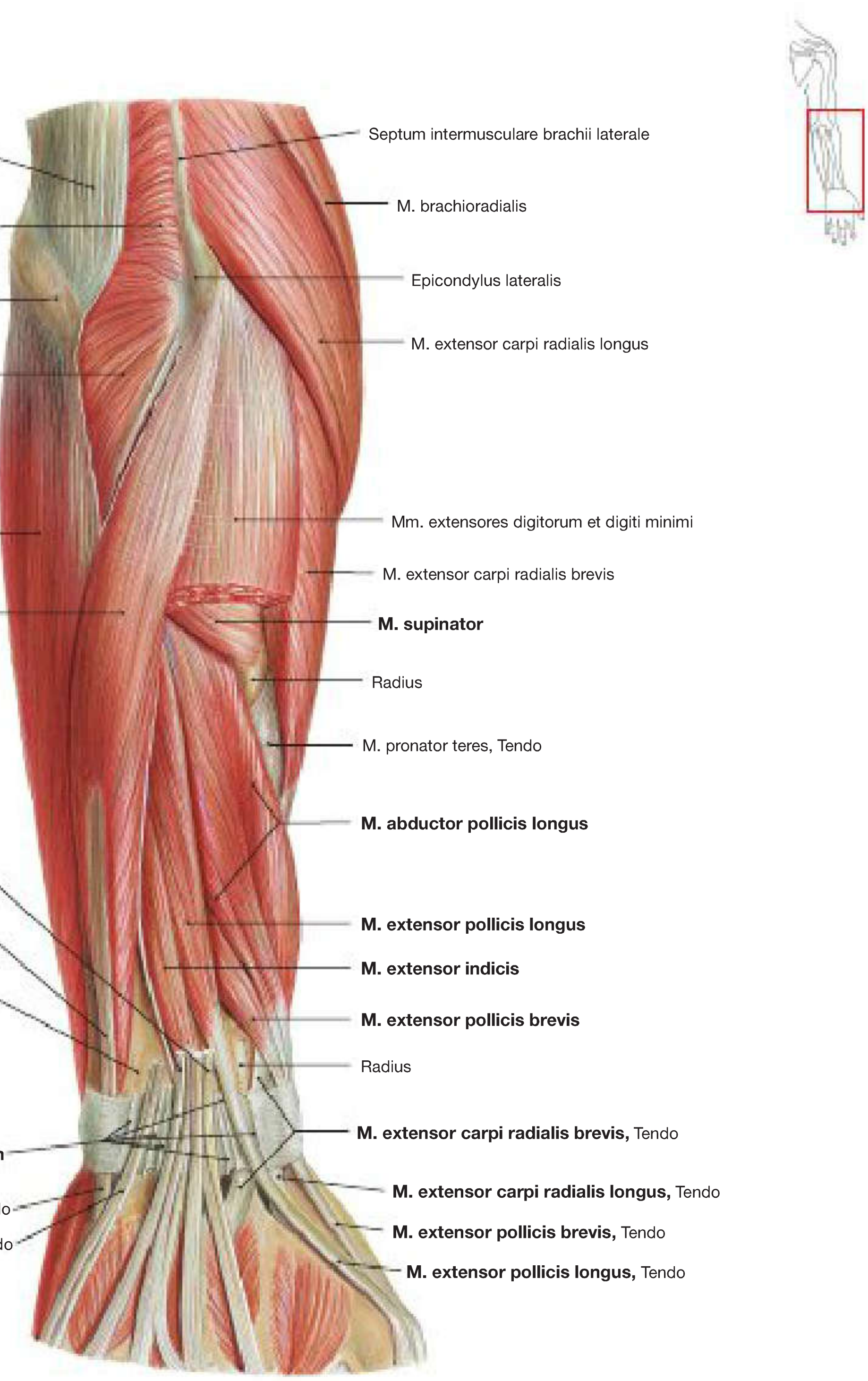


Fig. 3.71 Deep layer of the dorsal muscles of the forearm, right side; dorsal view; after partial removal of the Mm. extensores digitorum and digiti minimi.

After removal of the superficial extensor muscles of the forearm, the proximal parts of the deep extensor muscles beneath become visible. The deep layer consists proximally of the M. supinator; it is followed from radial to ulnar by the M. abductor pollicis longus, M. extensor pollicis brevis, M. extensor pollicis longus and M. extensor indicis.

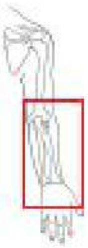
The Retinaculum musculorum extensorum forms **six osseofibrous tunnels,** through which the tendons of the extensor muscles pass to the dorsal side of the hand. In this dissection, the third, fourth and fifth osseofibrous tunnels have been opened.

Osseofibrous tunnels (or compartments) on the back of the hand are, from radial to ulnar:

- First tunnel: M. abductor pollicis longus and M. extensor pollicis brevis
- Second tunnel: M. extensor carpi radialis longus and M. extensor carpi radialis brevis
- Third tunnel: M. extensor pollicis longus
- Fourth tunnel: M. extensor digitorum and M. extensor indicis
- Fifth tunnel: M. extensor digiti minimi
- Sixth tunnel: M. extensor carpi ulnaris

→ T 35

Muscles of the Forearm



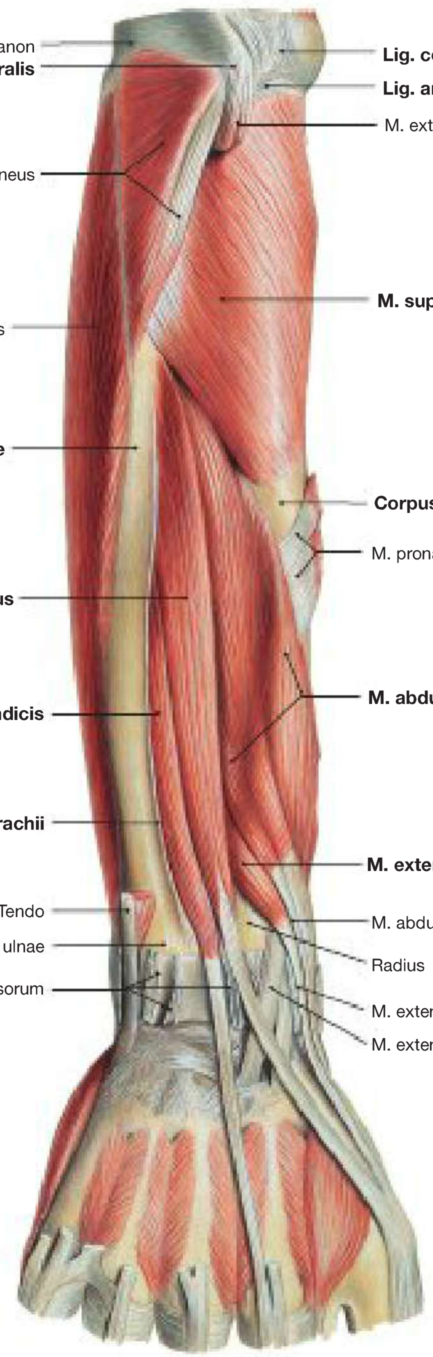
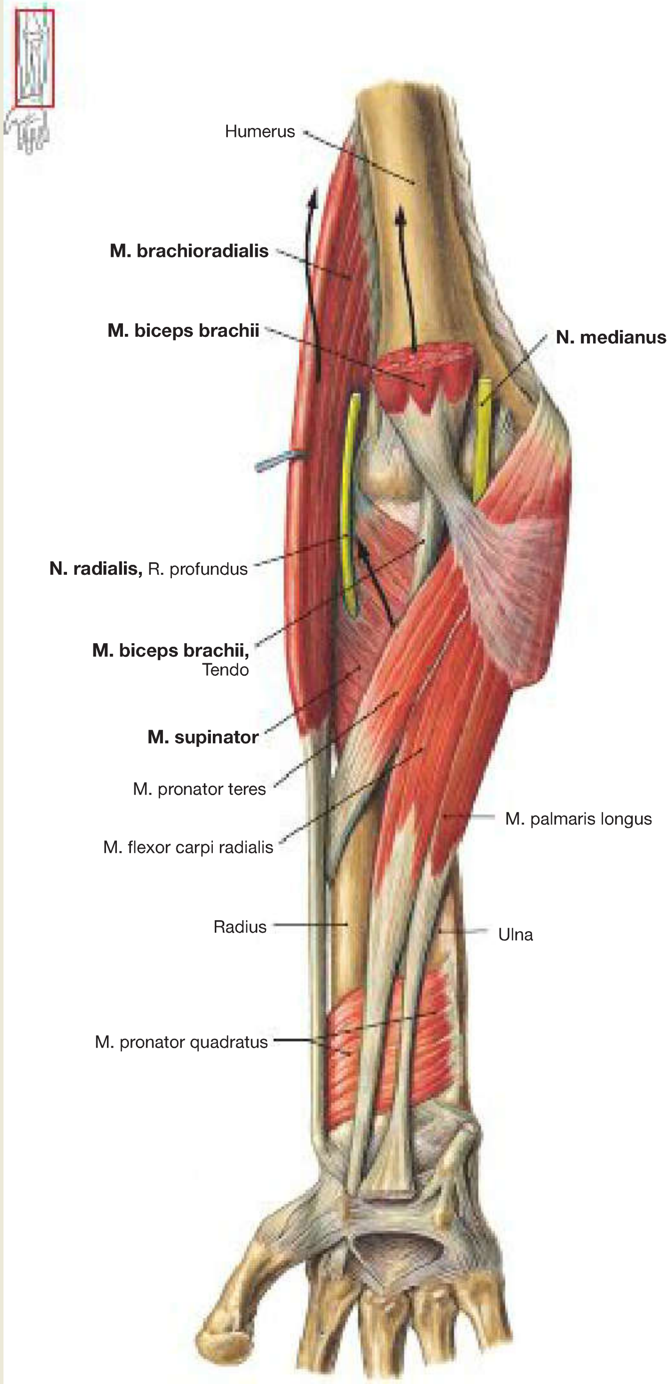


Fig. 3.72 Deep layer of the dorsal muscles of the forearm, right side; dorsal view; after complete removal of the superficial extensor muscles.

The superficial extensor muscles have been completely removed to visualise the origins of the deep extensor muscles. The M. supinator originates from the Epicondylus lateralis of the humerus, the radial ligaments (Lig. collaterale radiale and Lig. anulare radii) as well as the Crista m. supinatoris of the ulna. Its insertion encompasses the radius above and below the Tuberositas radii. The two muscles on the radial side (M. abductor pollicis longus, M. extensor pollicis brevis) have tendons passing through the first osseofibrous tunnel (or from compartment), and originate from the dorsal sides of the radius and the ulna and from the Membrana interossea antebrachii. In contrast, the two muscles on the ulnar side (M. extensor pollicis longus and M. extensor indicis) originate exclusively from the ulna and the Membrana interossea. Their tendons pass through the third and fourth tunnels. In this dissection, all six tunnels underneath the Retinaculum musculorum extensorum have been opened.

→ T 35



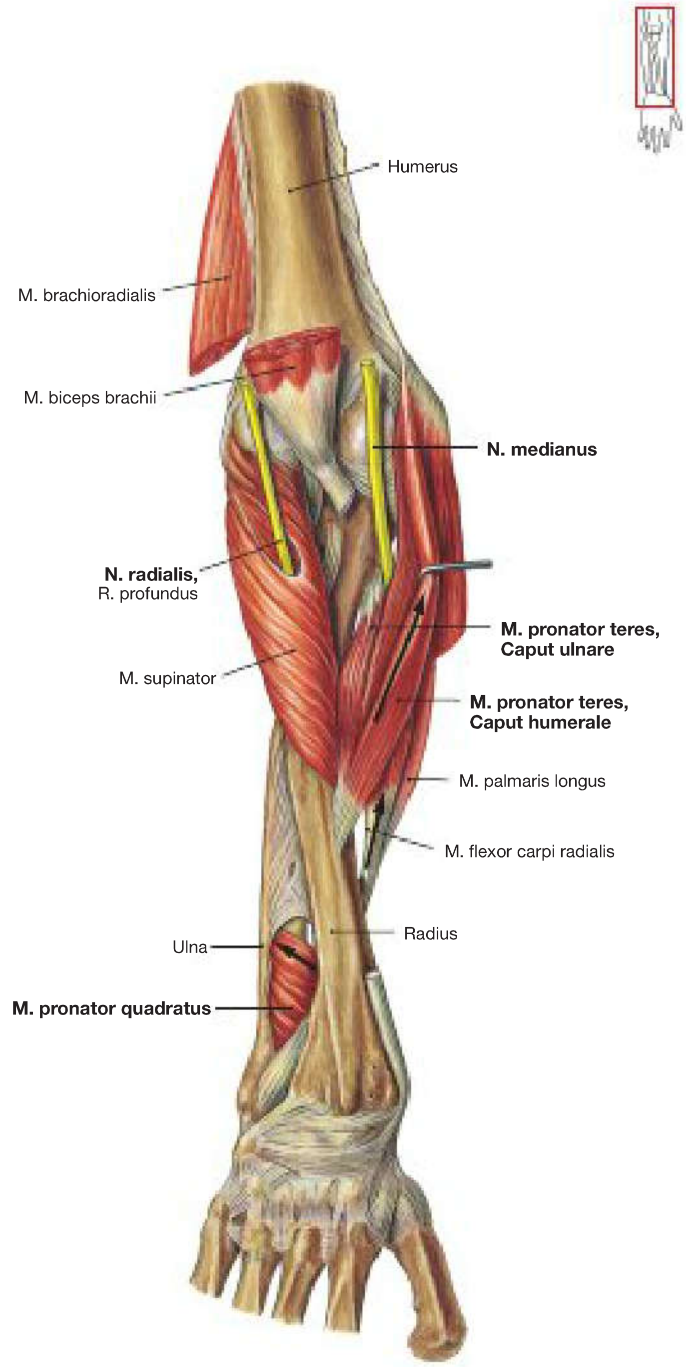


Fig. 3.73 Forearm, Antebrachium, in supination, right side; ventral and palmar view. The arrows indicate the traction vectors of the most important supinator muscles.
As a general rule, all muscles involved in pronation or supination cross the **diagonal axis of the forearm** (→ Fig. 3.6), which corresponds to the rotational axis of this movement. In addition, it can be noted that all relevant supinator and pronator muscles have **insertions on the radius**. The **most important supinator muscles** are the **M. biceps brachii** (in particular with flexed arm), **M. supinator** (with extended arm), and **M. brachioradialis** (from a pronated position). The M. supinator is pierced by the R. profundus of the N. radialis.
Compression or entrapment of the N. radialis can develop here, which among other things can cause a paralysis of the deep extensor muscles (→ p. 236).

Fig. 3.74 Forearm, Antebrachium, in pronation, right side; ventral view in the elbow region and dorsal view in the hand region, respectively. The arrows indicate the traction vectors of the **most important pronator muscles,** which are the **M. pronator teres, M. pronator quadratus** and **M. brachioradialis** (from a supinated position). The M. flexor carpi radialis and M. palmaris longus also promote pronation to a lesser degree.
The N. medianus passes between the two heads of the M. pronator teres, and rarely can also be compressed in this location (→ p. 238).

→ T 32, 33, 35

Tendons of the Back of the Hand

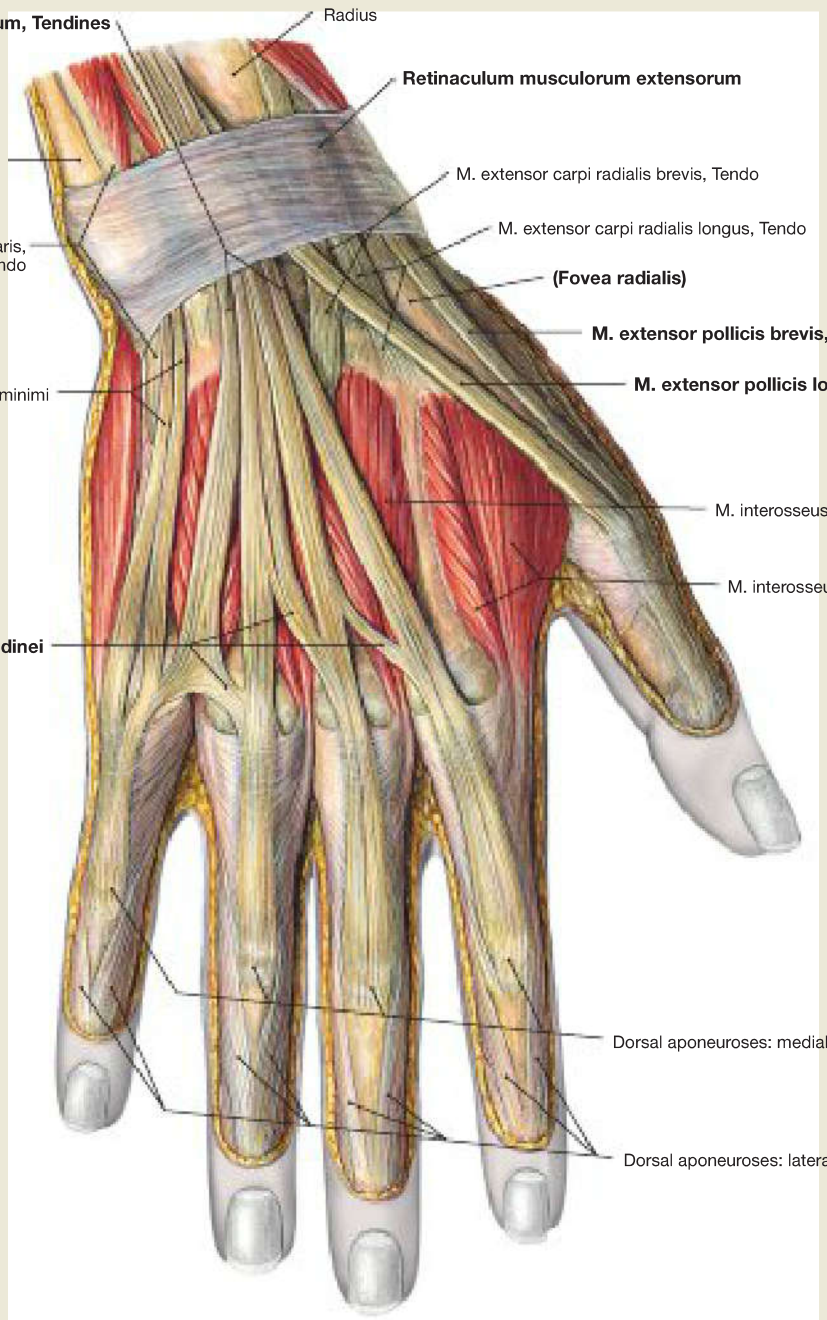


Fig. 3.75 Tendons of the back of the hand, Dorsum manus, right side; dorsal view.
The inserting tendons of the extensor muscles pass beneath the Retinaculum musculorum extensorum to the dorsal side of the thumb and to the dorsal aponeuroses of the fingers. The tendons of the M. extensor digitorum are connected by bridges (Connexus intertendinei), which slightly restrict a selective extension of individual fingers. The back of the hand does not have its own muscles. The Mm. interossei dorsales, which are visible under the extensor tendons, are included in the muscles of the palm. A shallow depression, bordered by the tendons of the M. extensor pollicis brevis and the M. extensor pollicis longus, is described as Fovea radialis **(Tabatière)**.

→ T 34, 35, 37

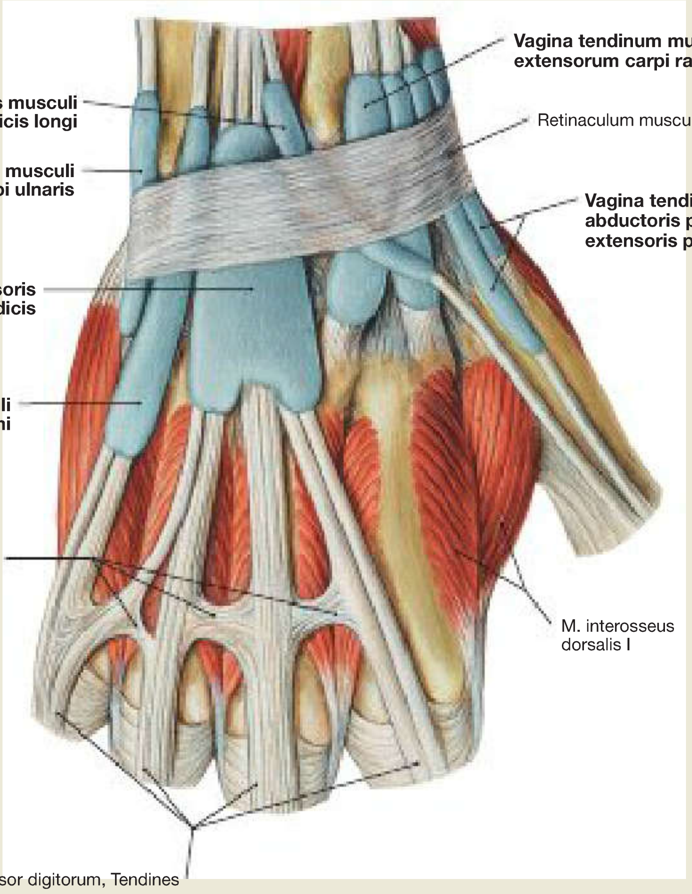


Fig. 3.76 Dorsal carpal tendon sheaths, Vaginae tendinum, of the hand, right side; dorsal view.
The tendons of the extensor muscles pass through six compartments or tunnels beneath the Retinaculum musculorum (→ Fig. 3.71). The individual muscles have for the most part their own **tendon sheaths,** which facilitate gliding of the tendons between retinaculum and hand bones. The tendons of the M. extensor digitorum and M. extensor indicis share a common tendon sheath.

Hand Muscles

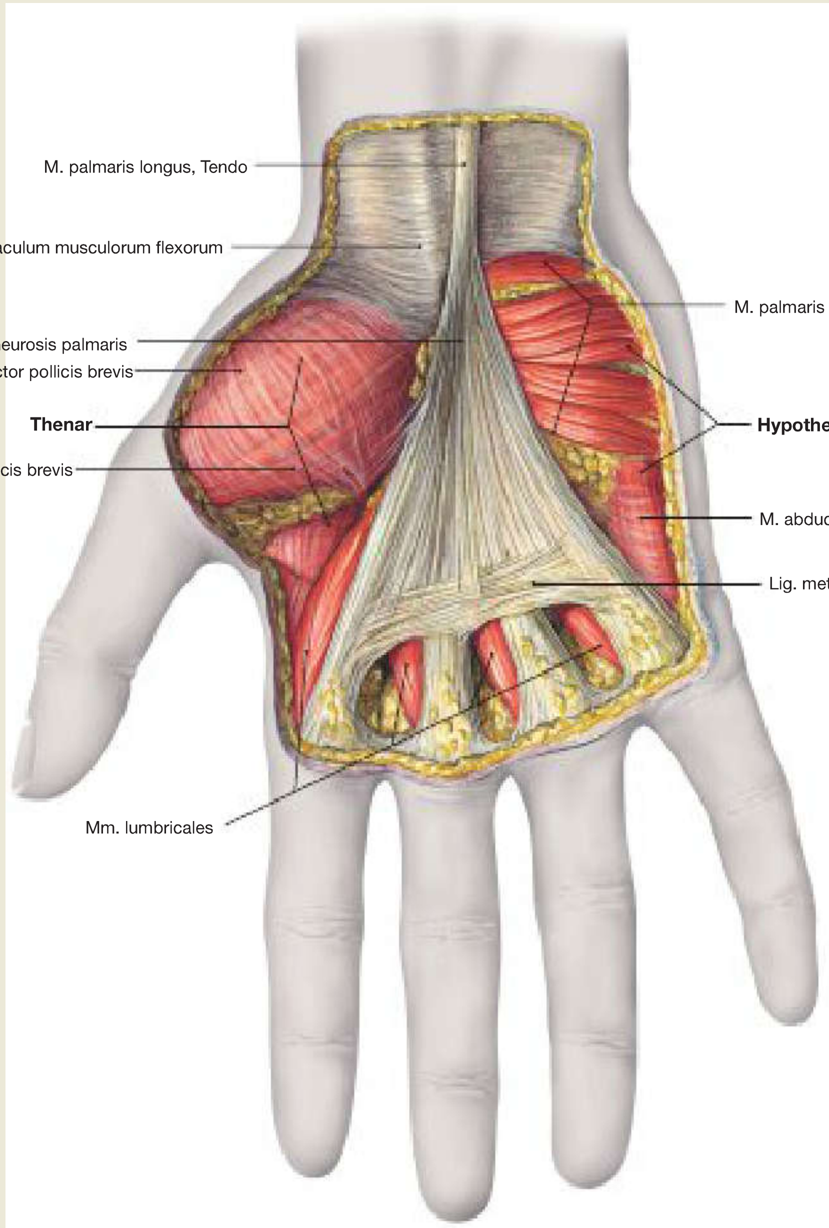


Fig. 3.77 Superficial muscle layer of the palm of the hand, Palma manus, right side; palmar view.

The muscles of the palm consist of **three groups.** The two marginal fingers (thumb and little finger) each have their own muscle group on both sides of the palm. The muscles of the thumb form the thenar eminence (Thenar) and the muscles of the little finger form the hypothenar eminence (Hypothenar). The muscles of the palm lie in-between. These three muscle groups form **three overlying layers.** During dissection you have to pay attention to the neurovascular structures running between the individual layers (→ pp. 280–282). The **palmar aponeurosis** (Aponeurosis palmaris) lies very close to the surface of the palm. It consists of longitudinal fibres and in particular proximally of strongly developed transverse fibres **(Lig. metacarpale transversum superficiale).** Proximally the palmar aponeurosis is attached to the Retinaculum musculorum flexorum and is extended by the M. palmaris longus. Distally it is attached to the tendon sheaths of the flexor muscles and the ligaments of the metacarpophalangeal joints of the fingers.

On the thenar eminence, the M. abductor pollicis brevis and the M. flexor pollicis brevis lie from radial to ulnar. The M. palmaris brevis and M. abductor digiti minimi lie superficially on the hypothenar eminence.

→ T 31, 36–38

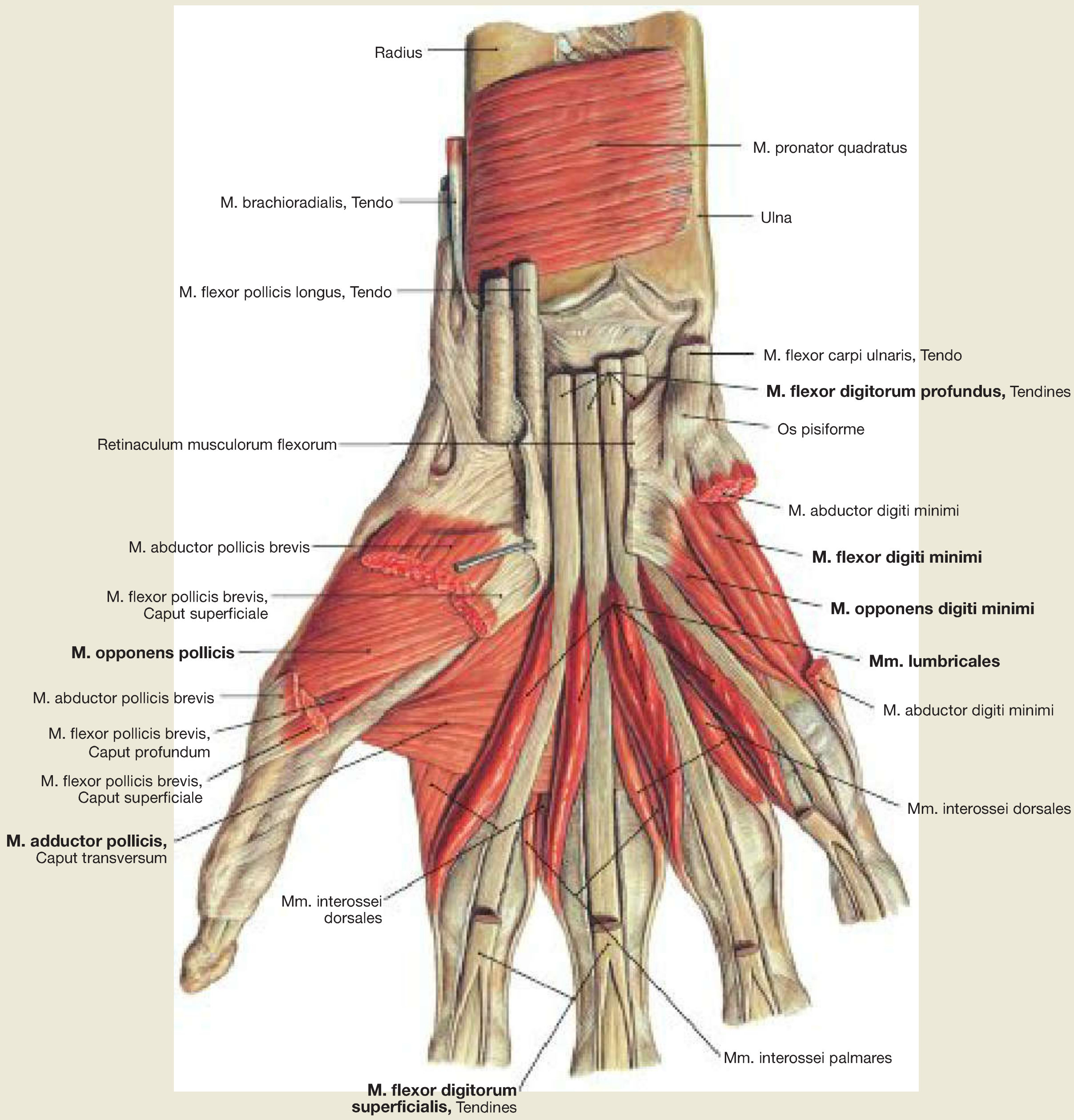


Fig. 3.78 Middle layer of muscles in the palm of hand, Palma manus, right side; palmar view; after removal of the palmar aponeurosis and the superficial muscles.

The three muscle groups in the palm of the hand (Palma manus) form three overlying layers. After removal of the superficial muscles, the muscles of the middle layer can be defined. These comprise the M. opponens pollicis and M. adductor pollicis on the thenar eminence, and the M. flexor digiti minimi and M. opponens digiti minimi on the hypothenar eminence, both of which are located radial to the superficial M. abductor digiti minimi. In the palm, the tendons of the M. flexor digitorum superficialis run to the middle phalanges and the tendons of the M. flexor digitorum profundus to the distal phalanges of the fingers. The tendons of the deep flexor muscle pierce the superficial flexor tendons (cut in this illustration). The tendons of the M. flexor digitorum profundus are the origin of the four Mm. lumbricales which also belong to the middle layer of muscles (for the function of the Mm. lumbricales → Fig. 3.85). The tendon of the M. flexor pollicis longus runs to the distal phalanx of the thumb.

→ T 32, 36–38

Tendon Sheaths of the Palm

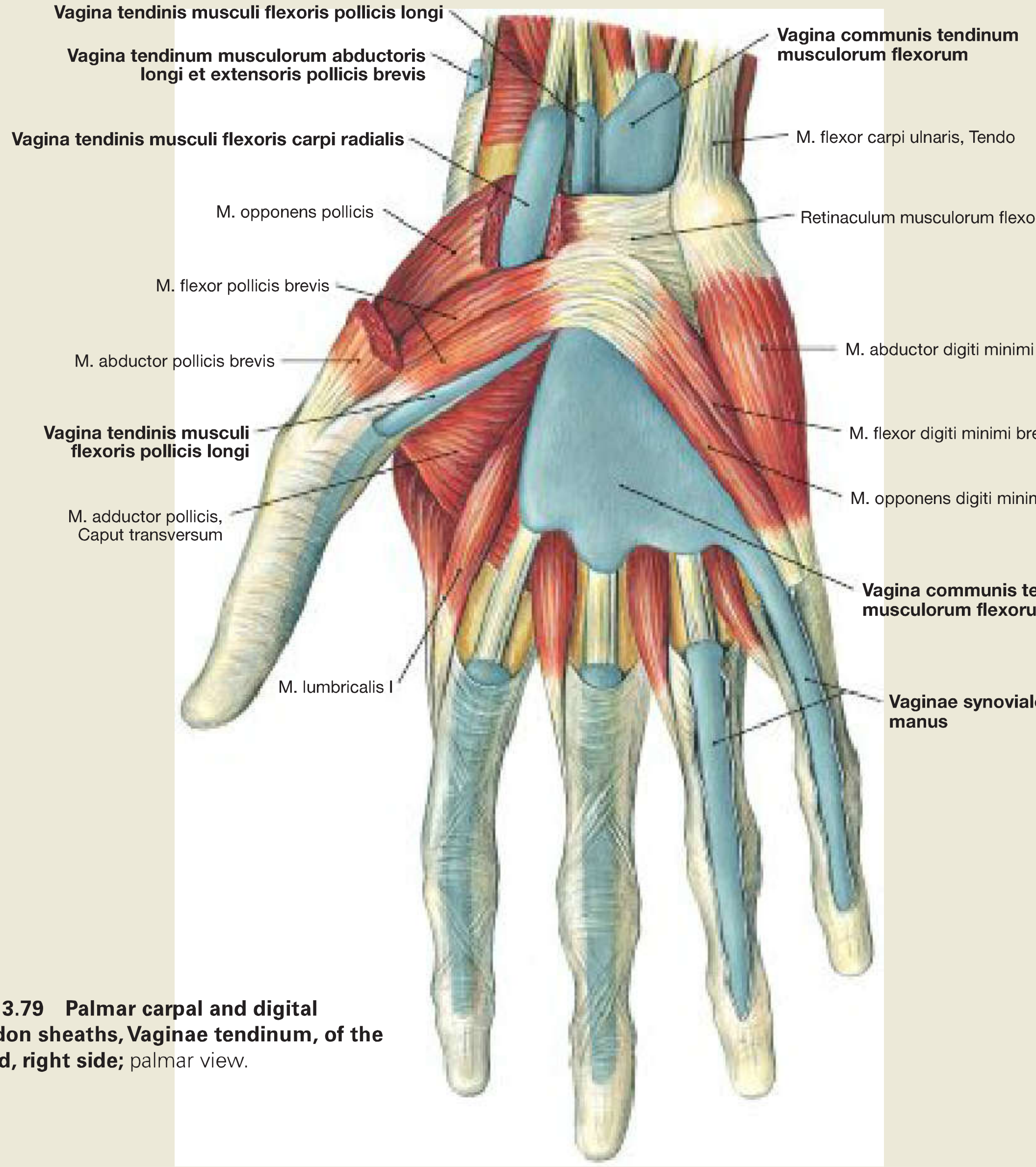


Fig. 3.79 Palmar carpal and digital tendon sheaths, Vaginae tendinum, of the hand, right side; palmar view.

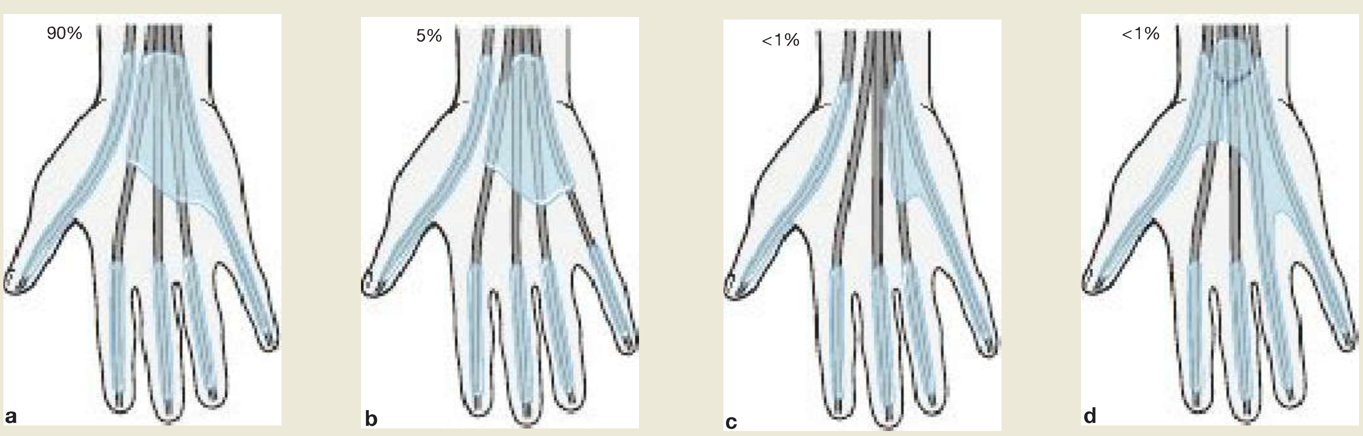


Fig. 3.80a to d Variants of the palmar tendon sheaths. [L126]
In contrast to the dorsal side there are usually only two tendon sheaths for the flexor tendons of the fingers. The **radial** tendon sheath surrounds the tendon of the M. flexor pollicis longus and extends to its distal phalanx. The **ulnar** tendon sheath encloses all tendons of the Mm. flexores digitorum superficialis and profundus at the wrists and extends only on the little finger up to the distal phalanx. The other fingers have their own tendon sheaths in the area of the phalanges.

Clinical Remarks

The arrangement of the tendon sheaths is of clinical importance as **bacterial infections** can quickly spread into the sheaths (phlegmon). Inflammation may spread to the ulnar tendon sheath and to the little finger (V-phlegmon) and, in the case of insufficient antibiotic therapy, may lead to stiffening of the entire hand.

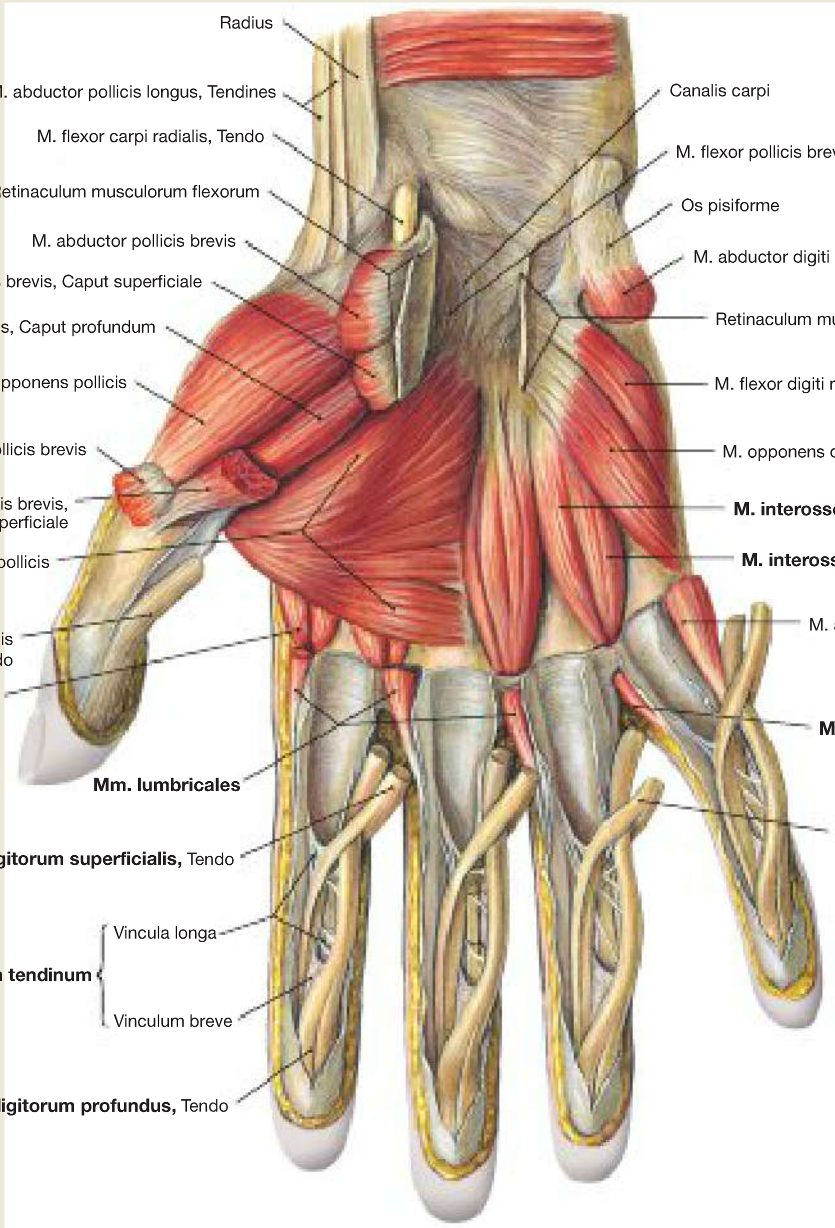


Fig. 3.81 Deep muscle layer of the palm of the hand, Palma manus, right side; palmar view; after removal of the tendons of the long flexor muscles of the fingers.

The three muscle groups of the palm form three overlying layers. After removal of the long flexor tendons the muscles of the deep layer become visible. The Mm. interossei comprise three **Mm. interossei palmares** and four **Mm. interossei dorsales,** all of which flex the metacarpophalangeal joints (for the course and function of the Mm. interossei → Fig. 3.82, → Fig. 3.83 and → Fig. 3.84). Since the palmar and dorsal muscles partly originate from different metacarpal bones, muscles of both groups are visible in the palmar view. However, the Mm. interossei dorsales lie in fact, as their name suggests, further dorsal between the Ossa metacarpi, so if you look on the back of your hand only the dorsal muscles are apparent (→ Fig. 3.75 and → Fig. 3,174).

The tendons of the Mm. interossei run palmar to the transverse axis of the metacarpophalangeal joints. Therefore, the **Mm. interossei are** the **main flexors of the metacarpophalangeal joints.**

The illustration shows how the tendons of the deep flexor muscles pierce through the superficial flexor tendons. The tendons are attached to the phalanges by small ligaments (Vincula tendinum).

→ T 31, 36, 37

Clinical Remarks

Knowledge of the function and course of the flexor muscles at the fingers is important when **examining** cuts. If it is not possible to bend the distal interphalangeal joints, the M. flexor digitorum profundus is affected. If, however, the flexion in the proximal interphalangeal joints is restricted while the distal joints can still be bent, this indicates an isolated injury of the M. flexor digitorum superficialis.

Hand Muscles

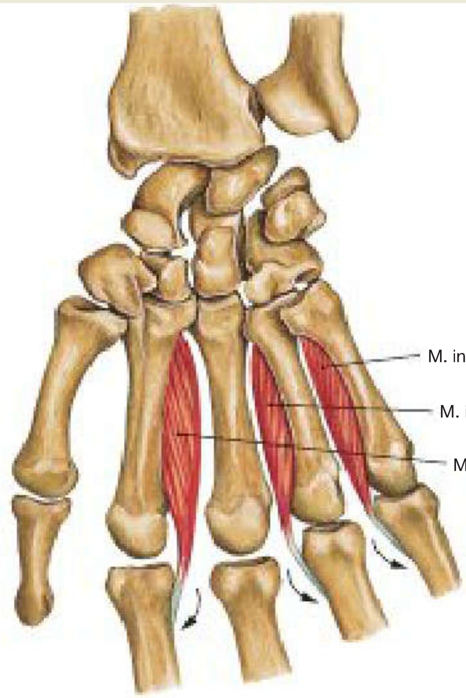


Fig. 3.82 Mm. interossei palmares, right side; palmar view.
The three Mm. interossei palmares originate from the ulnar aspect of Os metacarpi II and from the radial aspect of the Ossa metacarpi IV and V. They insert on the same side (ipsilateral) of the corresponding proximal phalanx of the fingers and their inserting tendons additionally radiate into the lateral tracts of the dorsal aponeuroses (arrows). Therefore, they **bend** the **metacarpophalangeal joints** of the fingers and somewhat **extend** the **proximal and distal interphalangeal joints.**

→T 37

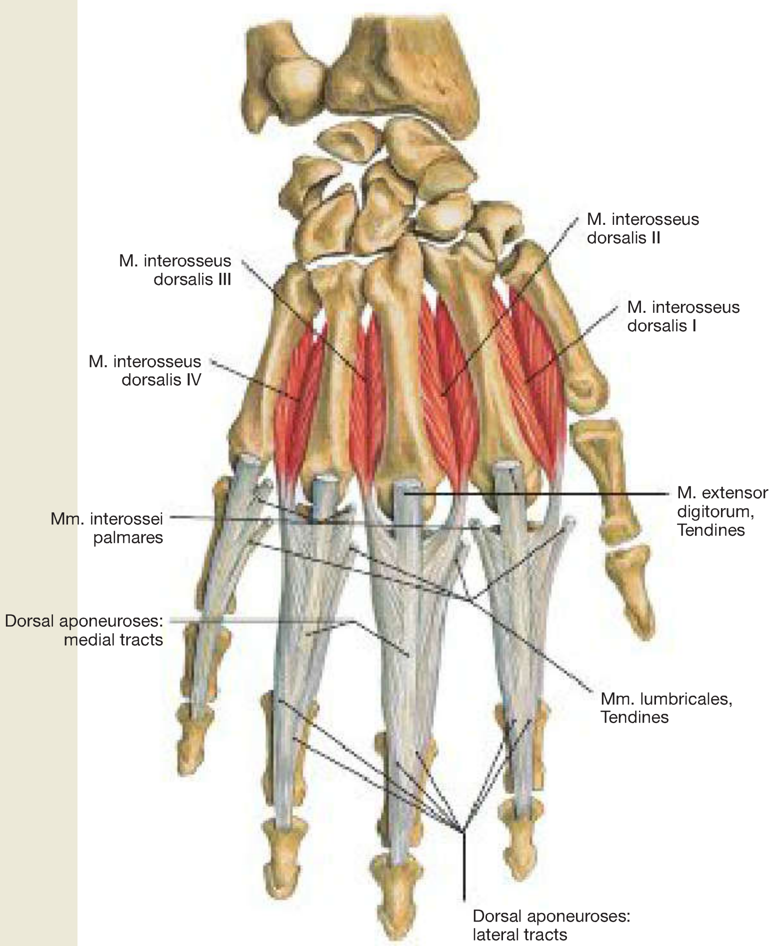


Fig. 3.83 Mm. interossei dorsales, right side; dorsal view.
The four Mm. interossei dorsales originate with two heads from opposing surfaces of the metacarpals I–V. They begin on both sides of the proximal phalanx of the middle finger, on the ulnar side of the ring finger, and on the radial side of the index finger. They also radiate into the lateral tracts of the dorsal aponeuroses of the fingers with a small portion of their inserting. Just like the palmar interosseous muscles they **bend** the **metacarpophalangeal joints** of the fingers and **extend** the **proximal and distal interphalangeal joints.**

→T 37

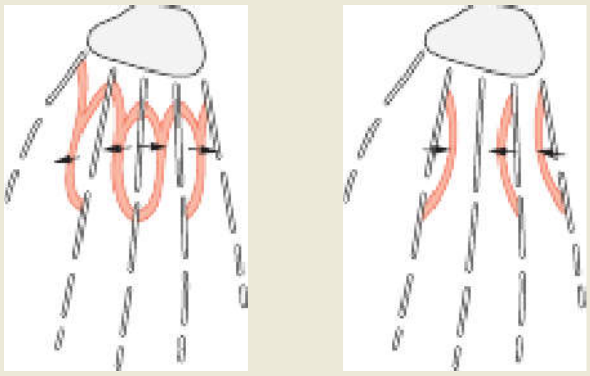


Fig. 3.84 Schematic drawing of the position of the Mm. interossei illustrating their effect on abduction and adduction of the fingers. [L126]

According to their course described on → p. 218, the **Mm. interossei dorsales** can spread the fingers **(abduction)** and can move the middle finger medially and laterally. **The Mm. interossei palmares** on the other hand can bring the fingers together **(adduction)**.

Their effects on the flexion and extension of the finger joints can be deduced from the course of their tendons in relation to the transverse axis of the finger joints and is explained on → pp. 220 and 221.

→ T 31, 36, 37

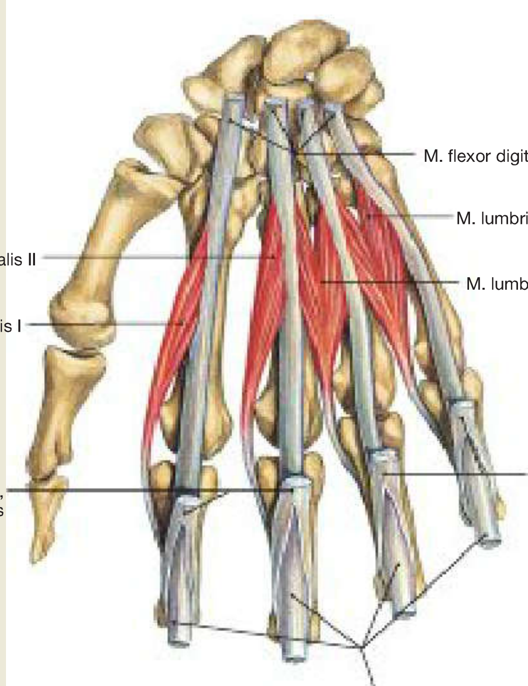


Fig. 3.85 Mm. lumbricales, right side; palmar view.

The two radial Mm. lumbricales originate with one head, but both the two ulnar lumbricales originate with two heads from the tendons of the M. flexor digitorum profundus. All muscles insert on the radial side of the proximal phalanges of fingers II–V and their tendons radiate into the lateral tracts of the dorsal aponeuroses of the fingers. Therefore, they **bend** the **metacarpophalangeal joints of the fingers** a little and **extend** the **proximal and distal interphalangeal joints.**

→ T 37

Hand Muscles

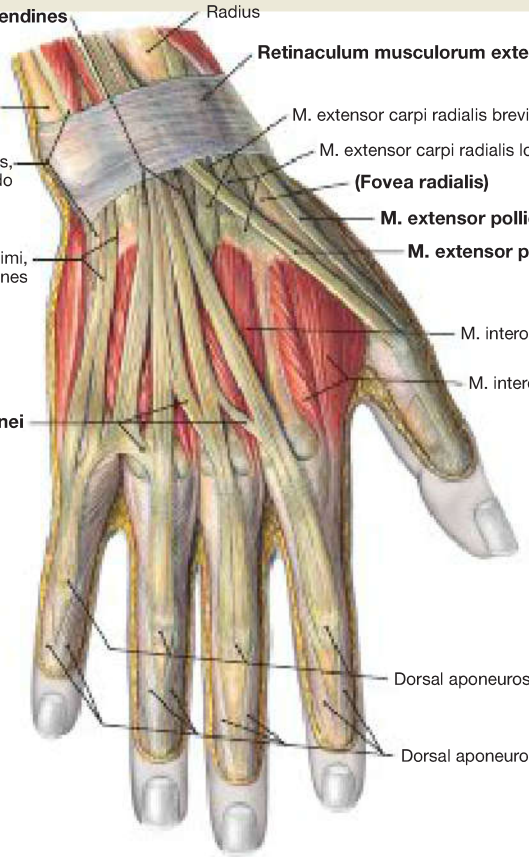


Fig. 3.86 Tendons of the long extensors and dorsal aponeuroses of the fingers, right side; dorsal view.
With the exception of the tendon of the M. extensor pollicis longus, which extends to the distal phalanx, the tendons of the Mm. extensores digitorum, extensor digiti minimi, and extensor indicis all end with the medial tracts of the dorsal aponeurosis at the middle phalanges.

→ T 37

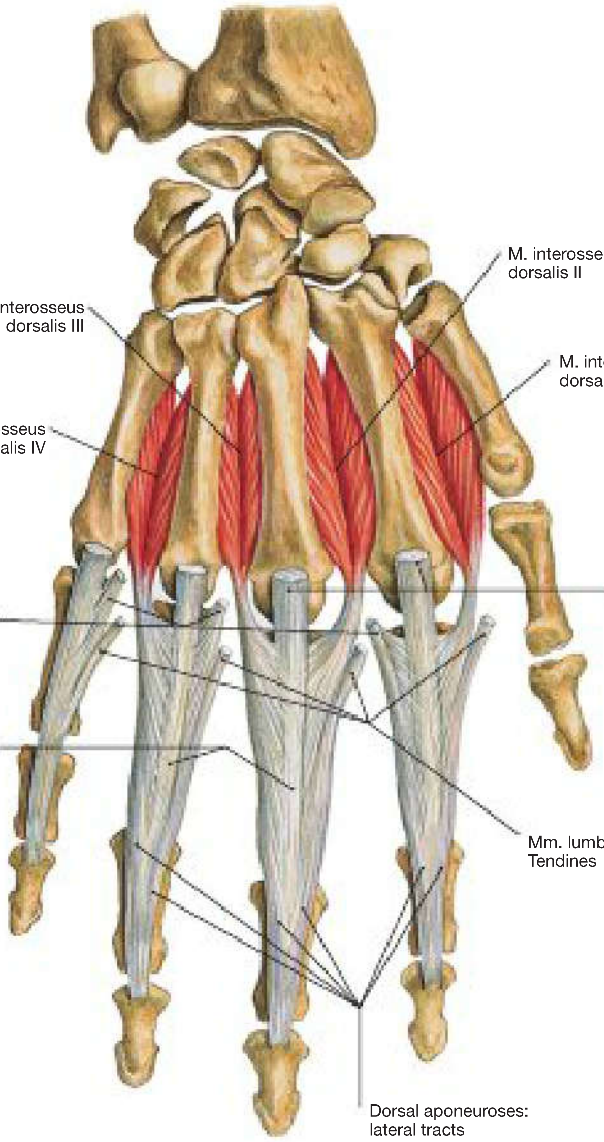


Fig. 3.87 Structure of the dorsal aponeurosis, right side; dorsal view.
The dorsal aponeurosis of the fingers consists of a **medial tract** as well as a **lateral tract on the medial and lateral aspect, respectively.** While the medial tract only extends to the middle phalanx, the lateral tracts extend up to the back of the distal phalanx.
The long extensor tendons end with the medial tract of the dorsal aponeurosis at the middle phalanx and can therefore not extend the distal interphalangeal joints of the fingers. In contrast, the **Mm. lumbricales** and to a lesser degree the **Mm. interossei palmares and dorsales** radiate into the lateral tracts of the dorsal aponeurosis. They therefore reach the transverse axis of the **distal interphalangeal joints** on the dorsal side and can extend **them.** It is clear that the Mm. lumbricales are the main extensors of the distal interphalangeal joints.

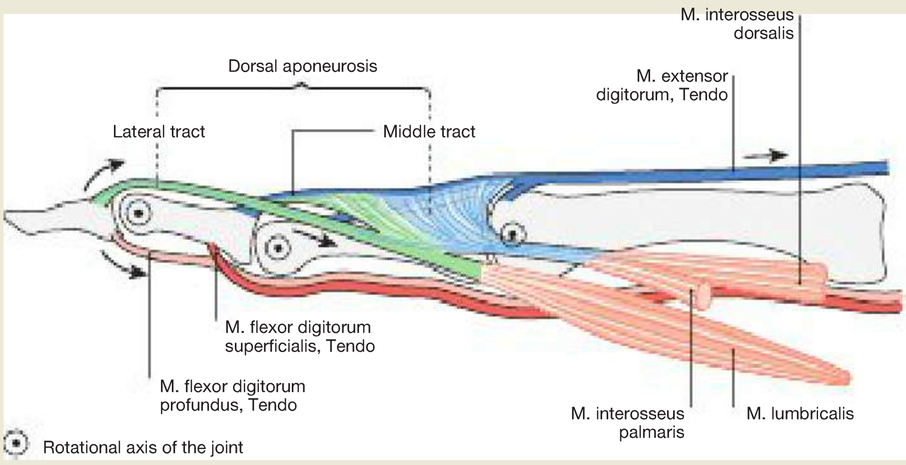


Fig. 3.88 Action of the flexor and extensor muscles of the fingers using the example of the middle finger; lateral view. [L126]

The function of the tendons of the forearm and hand muscles is determined by their course in relation to the axes of the finger joints and by their insertions at the proximal or distal interphalangeal joints of the fingers. The tendons of the **long flexor muscles of the fingers** (Mm. flexores digitorum superficialis and profundus) run palmar to the transverse axis of the finger joints, whereas the tendons of the **extensor muscles of the forearm** (M. extensor digitorum, M. extensor digiti minimi, M. extensor indicis) run dorsally. The M. flexor digitorum superficialis as well as the finger extensors have their insertions on the middle phalanges, so that these muscles cannot act on the distal interphalangeal joints. In contrast, the M. flexor digitorum profundus inserts on the palmar aspect of the distal phalanges so that it acts as the main flexor of the distal interphalangeal joints.

The course of the **Mm. interossei** and **Mm. lumbricales** is more complicated: both muscle groups run palmar to the transverse axis of the metacarpophalangeal joints and therefore acts as very effectively. On the middle phalanges they change however to the dorsal side, and radiate with different parts into the middle and lateral tracts of the dorsal aponeurosis. As the Mm. lumbricales contribute specifically to the lateral tracts of the dorsal aponeurosis, it is understandable why they are the main extensors of the distal phalanges.

Flexor muscles of the finger joints:

Each joint has its predominant flexor muscle. In the distal interphalangeal joint the M. flexor digitorum profundus is the only muscle that bends.

- **Metacarpophalangeal joints:** Mm. interossei palmares and dorsales, to a lesser extent also the Mm. lumbricales
- **Proximal interphalangeal joints:** M. flexor digitorum superficialis (also bends the metacarpophalangeal joint)
- **Distal interphalangeal joints:** M. flexor digitorum profundus (also bends the proximal interphalangeal and metacarpophalangeal joints)

Extensor muscles of the finger joints:

- **Metacarpophalangeal and proximal interphalangeal joints:** M. extensor digitorum, M. extensor digiti minimi, M. extensor indicis
- **Distal interphalangeal joints of the fingers:** Mm. lumbricales, to a lesser extent also Mm. interossei palmares and dorsales
- **Metacarpophalangeal joint of the thumb:** M. extensor pollicis brevis
- **Proximal and distal interphalangeal joints of the thumb:** M. extensor pollicis longus

Bending Mechanism of the Fingers

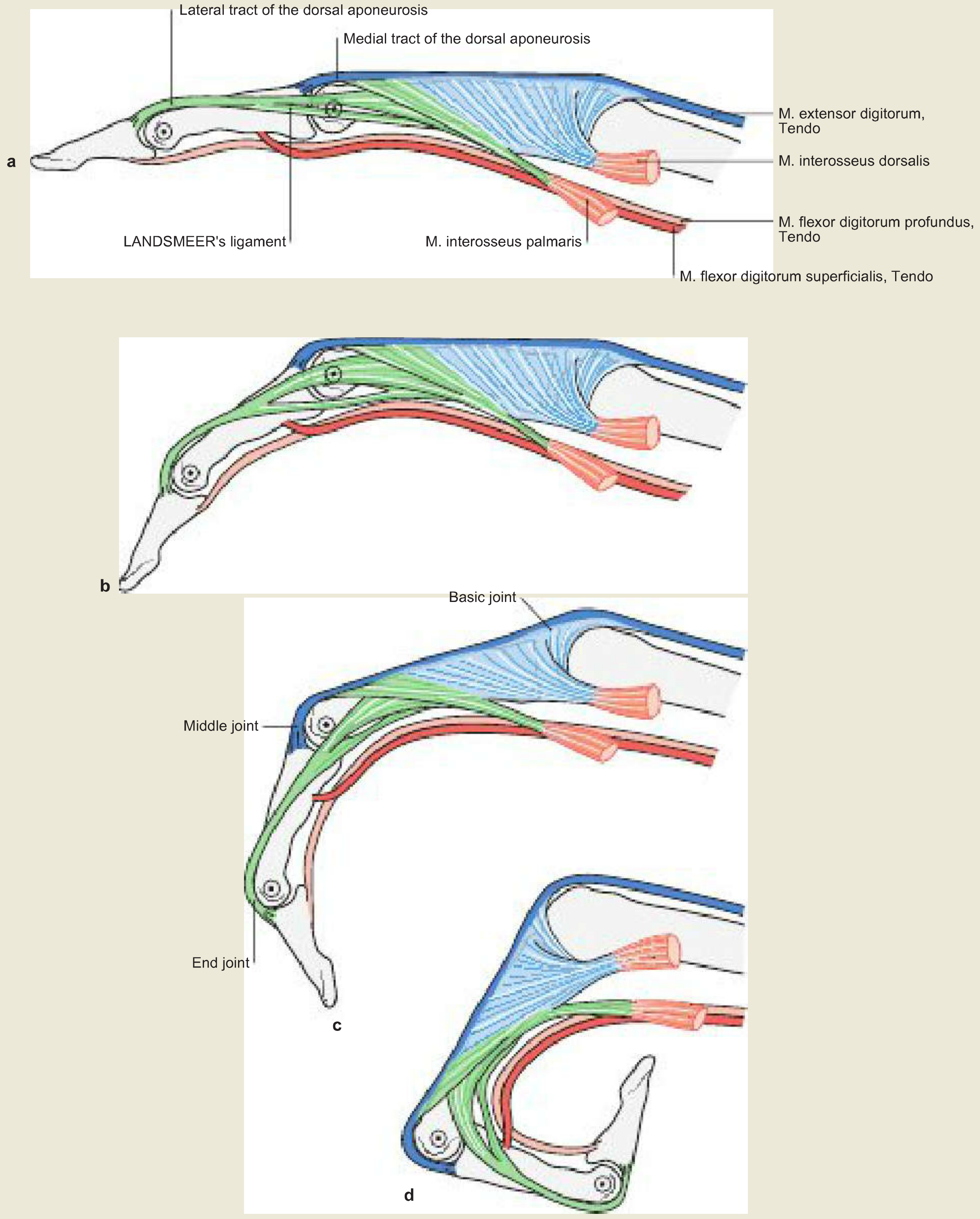
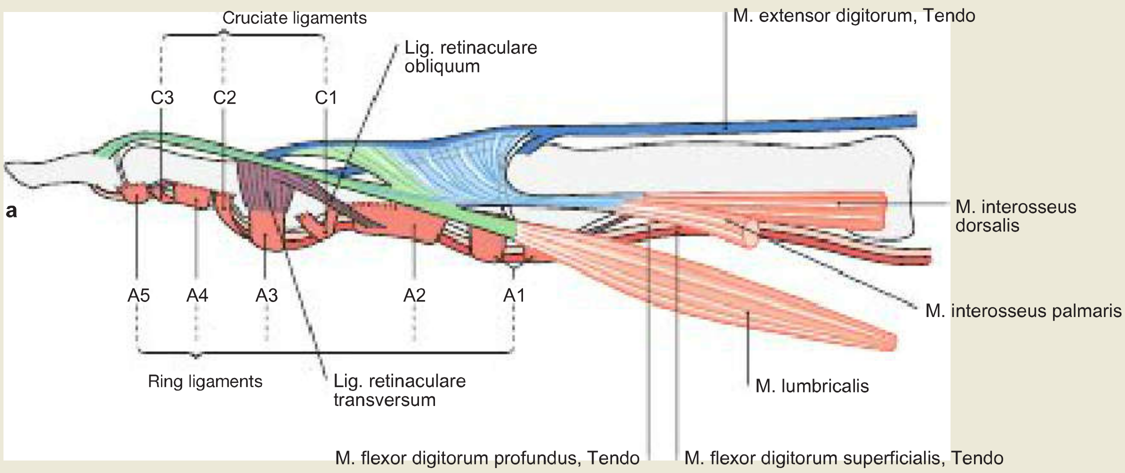


Fig. 3.89a to d Bending mechanism of the fingers; a flexion in the distal interphalangeal joint, b and c in the proximal interphalangeal joint, d in the metacarpophalangeal joint; lateral view. [L126]
During flexion of the fingers the long flexor muscles act together with the short palmar muscles. This results in the following sequence:
a Flexion is initiated by the **M. flexor digitorum profundus**.
b Flexion of the distal joint puts stress on the **fibre tracts** between the proximal phalanx and dorsal aponeurosis, thereby initiating the bending of the proximal interphalangeal joint.
c The flexion in the proximal interphalangeal joint is actively supported by the **M. flexor digitorum superficialis**. When flexing the tendons of the Mm. interossei and Mm. lumbricales, they are stretched because they run dorsally to the transverse axis of the proximal interphalangeal joint.
d The contraction of the **Mm. interossei and Mm. lumbricales** causes flexion in the metacarpophalangeal joint, as their tendons run palmar to the transverse axis in this area.
In this way flexion of the distal to the proximal joints continues!



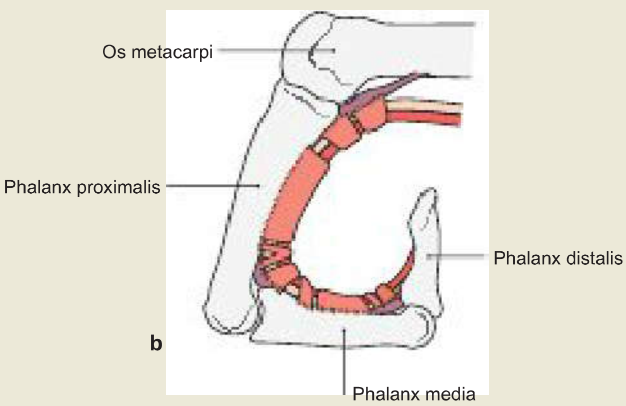


Fig. 3.90a and b Structure and function of the flexor and extensor tendons of the fingers; a finger extension, b finger flexion; lateral view. [L126]

The outer fibrous layer **(Vagina fibrosa)** of the tendon sheaths is attached to the phalanges and/or the joint capsules of the fingers by anular and cross-shaped tracts of fibres **(Pars anularis and Pars cruciformis),** which in clinical terms are also known as **ring and cruciate ligaments** and are abbreviated as A1–A5 and C1–C3. This ensures that the ends of the tendons are firmly attached to the bones and cannot lift by flexion.

Clinical Remarks

Ruptures of the so-called ring ligaments and the cruciate ligament of tendon sheaths are especially common in climbing because these structures are put under tremendous pressure.

Plexus brachialis

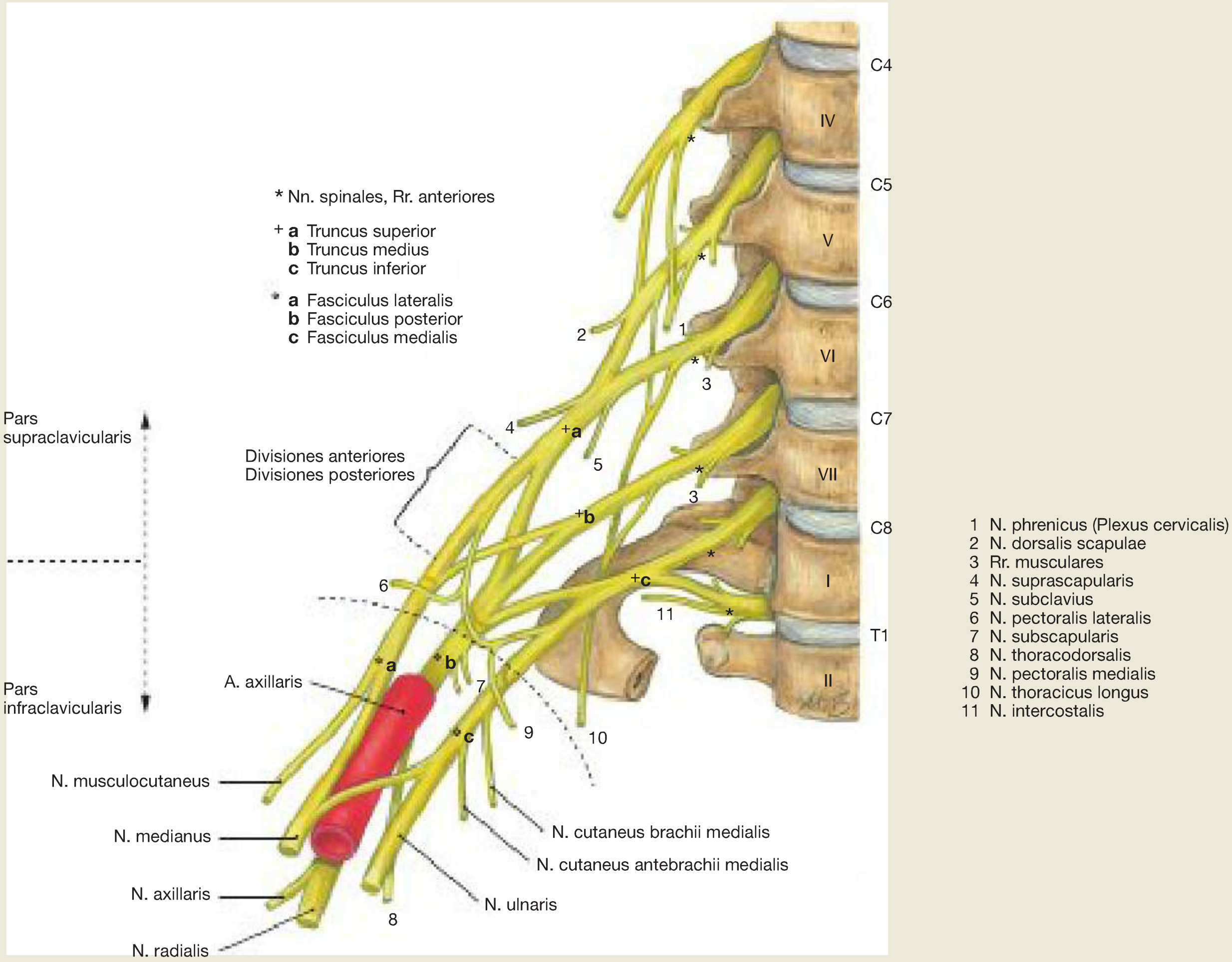


Fig. 3.91 Brachial plexus, Plexus brachialis (C5–T1): segmental arrangement of nerves, right side; ventral view.

The upper limb is innervated by the **Plexus brachialis**. The brachial plexus is formed by Rr. anteriores of the spinal nerves of the lower cervical and upper thoracic spinal cord segments **(C5–T1)**. First, the Rr. anteriores unite to form three **trunks** (Trunci) on different levels, then they rearrange at the level of the clavicle into **fascicles** (Fasciculi), which are named according to their location in relation to the A. axillaris. The **Truncus superior** contains nerve fibres from the spinal segments **C5 to C6,** the **Truncus medius** from **C7,** and the **Truncus inferior** from **C8 to T1.** The dorsal divisions (Divisiones posteriores) of all three trunks form the **Fasciculus posterior** (with nerve fibres from **C5–T1**). The ventral divisions (Divisiones anteriores) of the Truncus superior and the Truncus medius continue as **Fasciculus lateralis** (lateral of the A. axillaris, nerve fibres from **C5–C7**), and the anterior part of the Truncus inferior continues as **Fasciculus medialis** (medial of the A. axillaris, nerve fibres from **C8–T1**). Visualising this structure of the Plexus brachialis gives us a better understanding of the different peripheral nerves, with only a few exceptions. Topographically the Plexus brachialis can be divided into two parts. The **supraclavicular part** (Pars supraclavicularis) includes the Trunci and the nerves originating from these trunks or from the Rr. anteriores of the spinal nerves (C5–T1). The **infraclavicular part** (Pars infraclavicularis) consists of the Fasciculi. The nerves of the arm (→ Fig. 3.107) originate from the infraclavicular part, while the supraclavicular part is responsible for the innervation of the shoulder.

Pars supraclavicularis:
- Muscular branches of the brachial plexus to the Mm. scaleni and M. longus colli (C5–C8)
- N. dorsalis scapulae (C3–C5)
- N. thoracicus longus (C5–C7)
- N. suprascapularis (C4–C6)
- N. subclavius (C5–C6)

Pars infraclavicularis:
Fasciculus posterior (C5–T1):
- N. axillaris (C5–C6)
- N. radialis (C5–T1)
- Nn. subscapulares (C5–C7)
- N. thoracodorsalis (C6–C8)

Fasciculus lateralis (C5–C7):
- N. musculocutaneus (C5–C7)
- N. medianus, Radix lateralis (C6–C7)
- N. pectoralis lateralis (C5–C7)

Fasciculus medialis (C8–T1):
- N. medianus, Radix medialis (C8–T1)
- N. ulnaris (C8–T1)
- N. cutaneus brachii medialis (C8–T1)
- N. cutaneus antebrachii medialis (C8–T1)
- N. pectoralis medialis (C8–T1)

→ T 22, 23

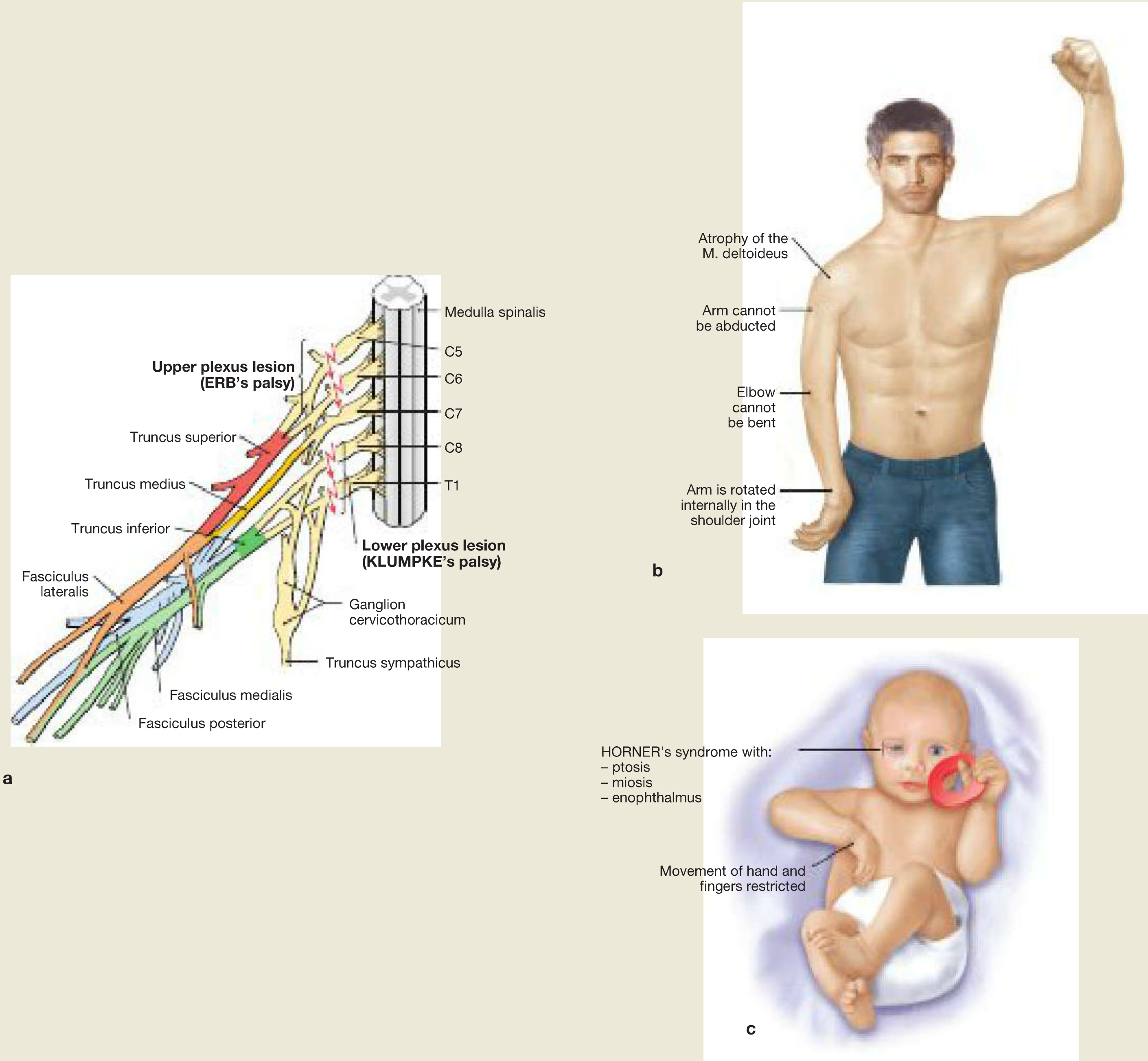


Fig. 3.92a to c Lesions of the Plexus brachialis (→ Fig. 3.92a). **Upper plexus lesion** (→ Fig. 3.92b). **Lower plexus lesion, right side** (→ Fig. 3.94c)**;** view from ventral. a [L126]; b and c [L238]

Lesions of the Plexus brachialis are caused by an avulsion of spinal nerve roots, which supply the Trunci of the Plexus brachialis.

Clinical Remarks

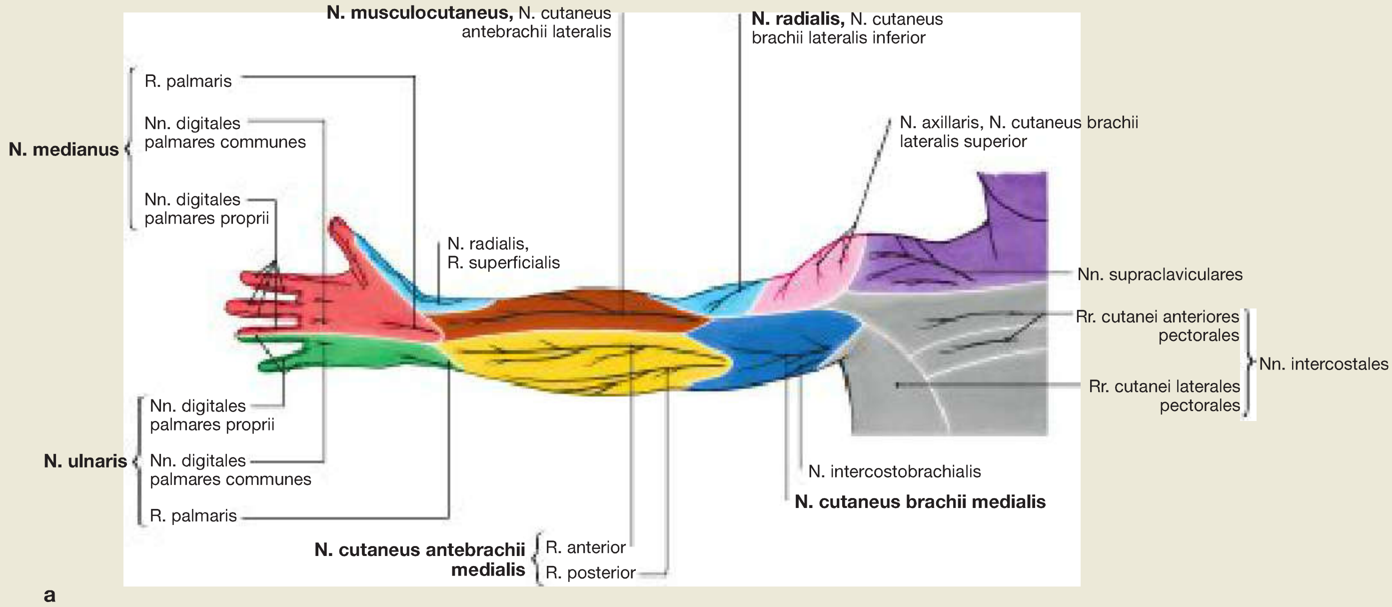
Severe injuries of the shoulder and arm (motorcycle accidents, abnormal position at birth, improper surgical positioning) can lead to lesions of the Plexus brachialis. Depending on the affected truncus, a distinction is made between:

- **Upper plexus paralysis (ERB, nerve roots of C5–C6 for the Truncus superior)**
  Pathomechanism: increased distance between neck and shoulder.
  Typical signs are a paresis (paralysis) of the abductors and lateral rotators of the shoulder and upper arm flexors, as well as the M. supinator. This results in adduction and internal rotation of the shoulder with an extended elbow joint and normal hand functions.
- **Lower plexus paralysis (KLUMPKE, nerve roots of C8–T1 for the Truncus inferior)**
  Pathomechanism: increased distance between torso and shoulder.
  In this case there is a paresis of the long flexor muscles of the fingers and the short muscles of the hand, with normal functions of the shoulder and elbow joints. This is frequently associated with **HORNER's syndrome** (miosis, ptosis, enophthalmus), since the preganglionic neurons of the cervical sympathetic chain also leave the spinal segments C8–T1 via the anterior roots.

The Truncus medius (C7) may be involved in both the upper and lower lesions, which is indicated by the paralysis of the M. triceps brachii and of the extensor muscles of the fingers.

In the case of a **complete lesion**, the mobility of the entire arm including the hand is impaired.

Innervation of the Skin



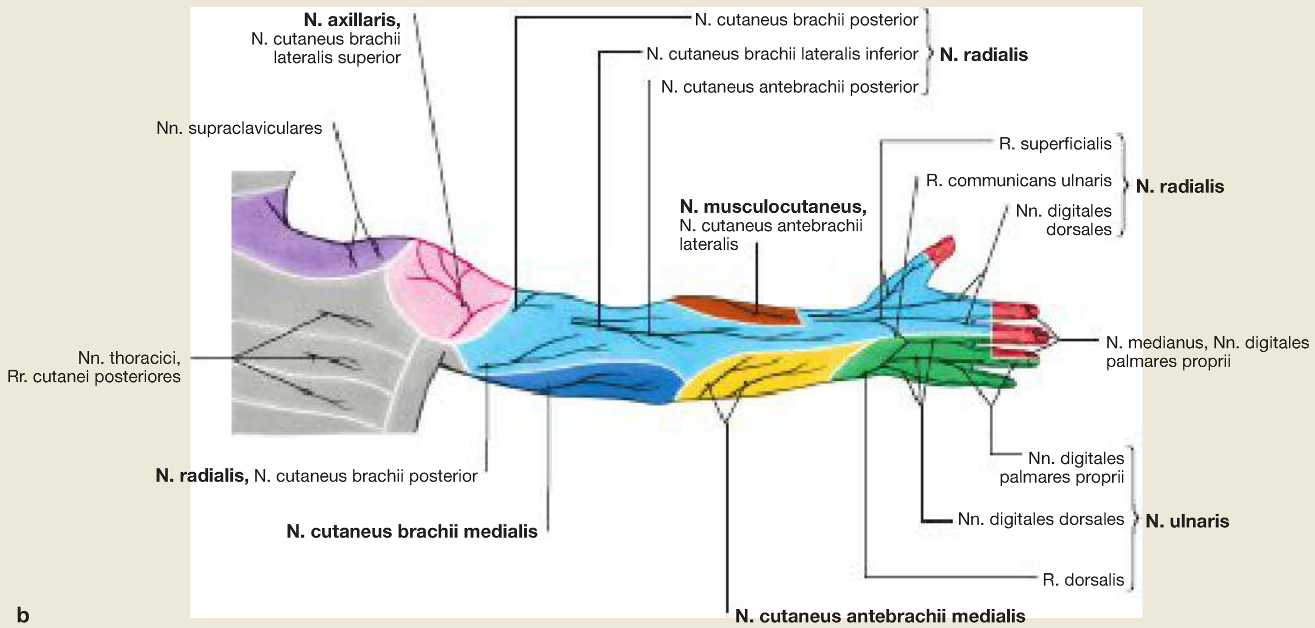


Fig. 3.93a and b Cutaneous nerves of the upper limb, right side; ventral view (→ Fig. 3.93a) and dorsal view (→ Fig. 3.93b). [L126]

All nerves of the infraclavicular part of the **Plexus brachialis participate** in the sensory innervation of the **shoulder** and **arm.** The lateral aspect of the shoulder is innervated by the N. axillaris. The lateral and dorsal sides of the upper arm, and the dorsal sides of the forearm and the radial 2½ fingers are innervated by the N. radialis. The N. musculocutanous supplies the lateral aspect of the forearm. The N. cutaneus brachii medialis and the N. cutaneus antebrachii medialis innervate the medial aspect of the arm. The N. medianus (palmar side of the radial 3½ fingers) and the N. ulnaris (palmar side of the ulnar 1½ fingers and dorsal side of the ulnar 2½ fingers) supply the hand.

→T 23

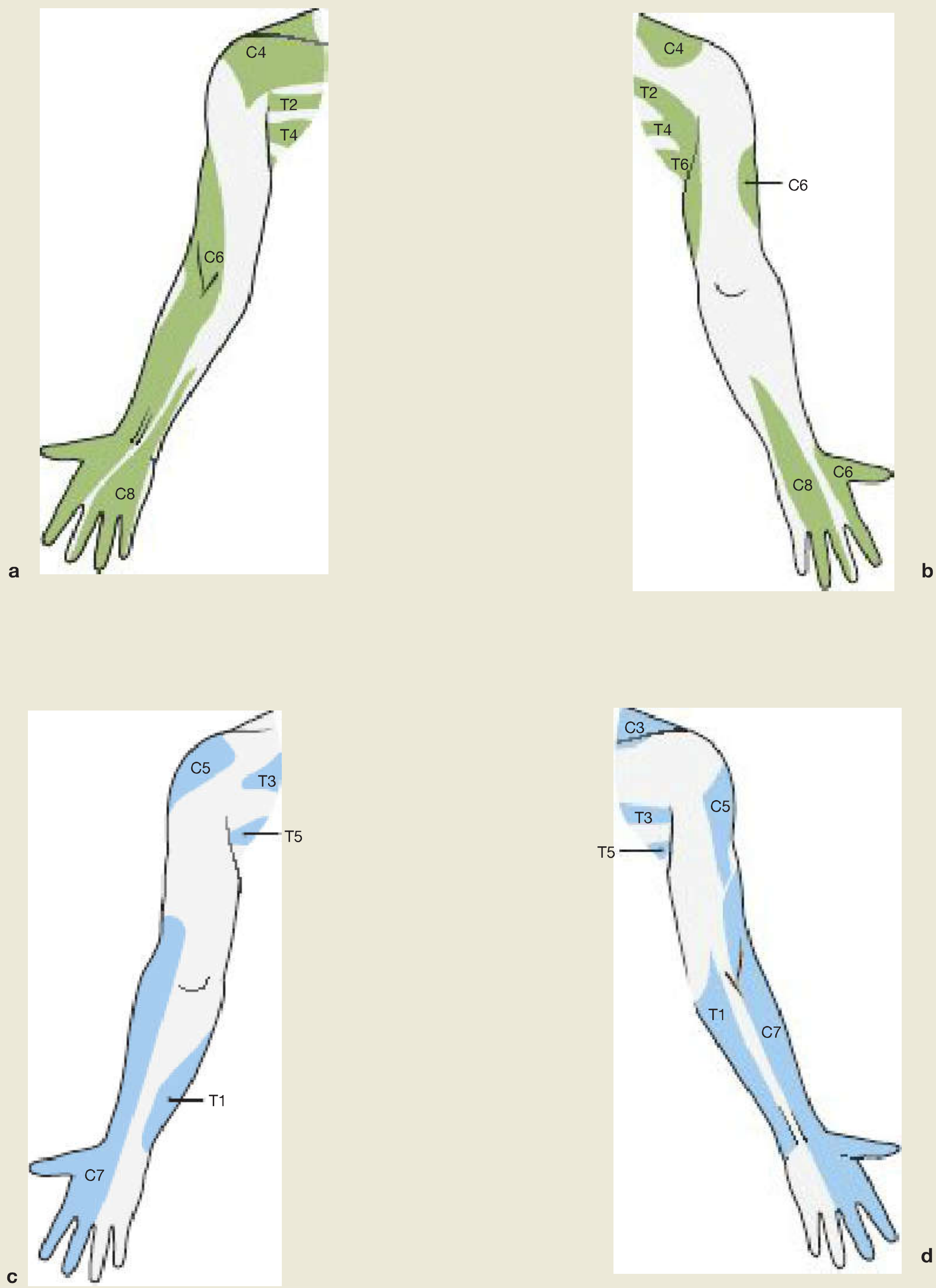


Fig. 3.94a to d Segmental innervation of the skin (dermatomes) of the upper limb, right side; ventral view (→ Fig. 3.94a and c) and dorsal view (→ Fig. 3.94b and d). [L126]
Certain areas of the skin are sensorily innervated by a single spinal cord segment. These cutaneous areas are referred to as **dermatomes**. As the cutaneous nerves of the arm contain sensory nerve fibres from several spinal cord segments, the dermatomes are not exactly congruent with the areas supplied by the cutaneous nerves (→ p. 226). In contrast to the torso, where the dermatomes are arranged in a belt-like pattern, their distribution on the arm is largely **along the longitudinal axis** (see development, → Fig. 3.5).

→ T 23

Clinical Remarks

The demarcations of the dermatomes are of great importance in the diagnosis of **herniated discs** and of narrowing **(stenosis) of the vertebral canal** or of the spinal nerve outlets (foramina): while the segment **C6** is responsible for the innervation of the radial forearm and the **thumb**, **C7** supplies the **third finger** and the adjacent halves of the fourth and second fingers. The **little finger** receives sensory innervation from the segment **C8,** and the ulnar side of the forearm from the segment T1.

Plexus brachialis

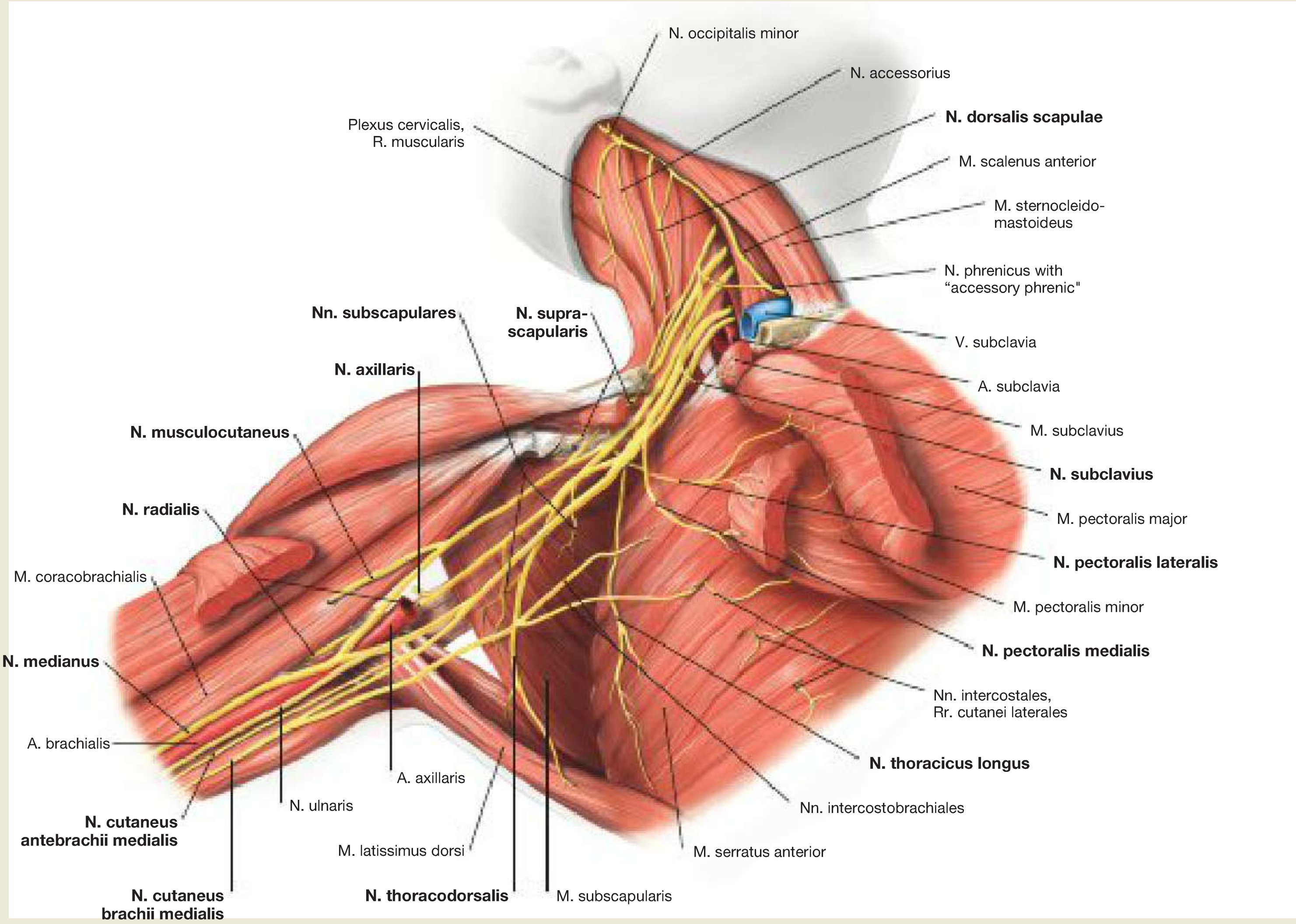


Fig. 3.95 Nerves of the Plexus brachialis, right side; ventral view after cutting through the Mm. pectorales major and minor near their insertion. [L266]

The nerves of the **supraclavicular part** (Pars supraclavicularis) of the Plexus brachialis originate from the Trunci or partly from the Rr. anteriores of the spinal nerves, and provide the innervation of the shoulder muscles. The **N. dorsalis scapulae** has the furthest cranial origin, and penetrates the M. scalenus medius. In a ventral view it is only visible if the head can be greatly extended backwards and sideways, as shown here. Further caudally, the **N. thoracicus longus** also passes through the M. scalenus medius. A specific feature of its course is that it runs under the Plexus brachialis to the chest wall, where it descends onto the M. serratus anterior, which it innervates. The **N. suprascapularis** emerges characteristically from the Truncus superior and turns dorsally, where it passes through the Incisura scapulae below the Lig. transversum scapulae superius to the dorsal side of the scapula. The **N. subclavius** is usually inconspicuous and difficult to expose. It innervates the M. subclavius and sometimes sends off a branch to the N. phrenicus ('accessory phrenic nerve').

The nerves of the **infraclavicular part** (Pars infraclavicularis) originate directly from the fascicles. The nerves of the arm as well as of the shoulder derive from the infraclavicular part.

The **Fasciculus posterior (C5–T1)** sends small nerves medially, including the two **Nn. subscapulares** and the **N. thoracodorsalis**. The **N. axillaris** branches off and courses through the lateral axillary space whereas the **N. radialis** continues its course through the triceps slit to the dorsal side of the upper arm. From the **Fasciculus lateralis (C5–C7)** the **N. pectoralis lateralis** initially branches off to the pectoral muscles, before the **N. musculocutaneus** passes laterally, where it usually penetrates the M. coracobrachialis. The remaining nerve fibres form the lateral root of the **N. medianus** (Radix lateralis). The medial root (Radix medialis) of the N. medianius comes from the **Fasciculus medialis (C8–T1),** after it has provided the **N. pectoralis medialis**, as well as the **N. ulnaris** and the sensory **Nn. cutanei brachii and antebrachii medialis**. Branches of the intercostal nerves often accompany the nerve to the upper arm as Nn. intercostobrachiales.

→T 22

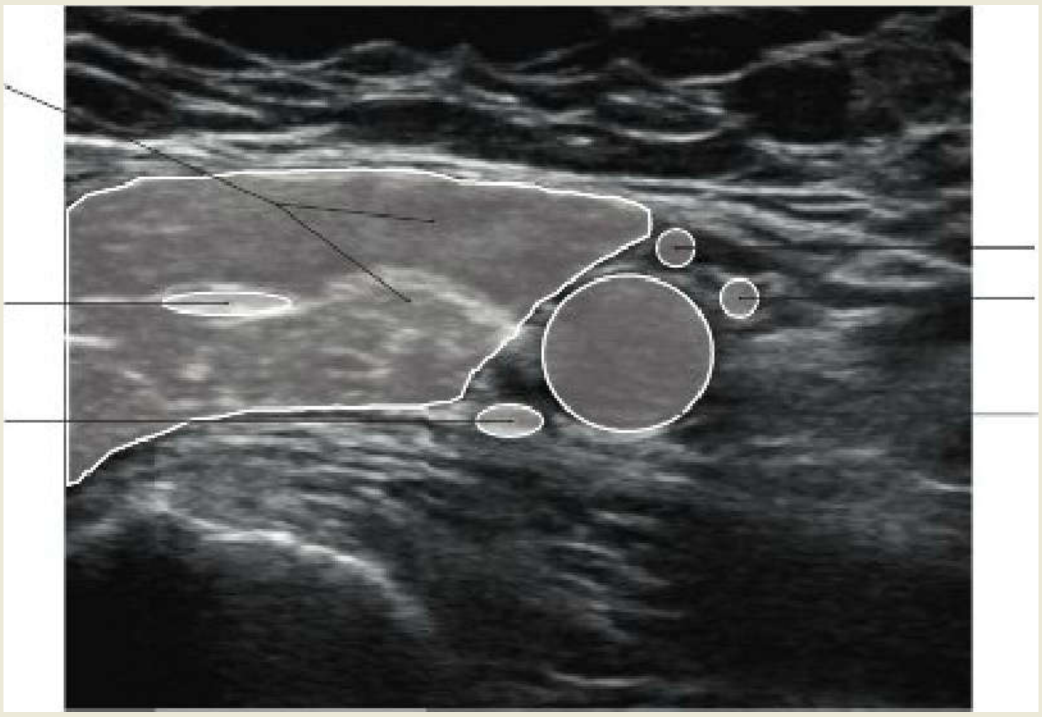


Fig. 3.96 Ultrasound image of the Plexus brachialis in the plexus anaesthesia, right side. [T863]
This image shows the nerves which emerge from the three fascicles of the Plexus brachialis in the arm region, by means of the ultrasound imaging technique. The **N. medianus** and the **N. ulnaris** originate from the medial fascicle and can be defined medial to the **A. axillaris.** The **N. radialis** which continues the course of the posterior fascicle, passes dorsally underneath the artery and is therefore visible in a longer section. Laterally, the **N. musculocutaneus** can be recognised as it enters in the M. coracobrachialis.

Clinical Remarks

As general anaesthesia is subjected to various risks, there is an increasing tendency to perform interventions in regional anaesthesia, in which local anaesthetics are applied to individual nerves or plexuses. When injecting these substances, it is important to show the target nerves and surrounding structures such as blood vessels using ultrasound. For this purpose, a detailed knowledge of topographical anatomy is needed, as shown here with the Plexus brachialis.

Shoulder Nerves of the Pars supraclavicularis of the Plexus brachialis

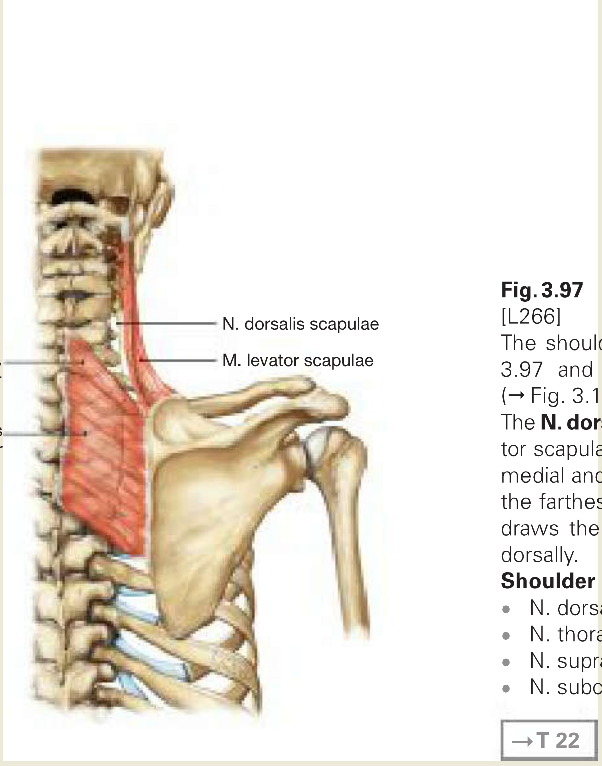


Fig. 3.97 N. dorsalis scapulae (C3–C5), right side; dorsal view. [L266]

The shoulder nerves originate from the Pars supraclavicularis (→ Fig. 3.97 and → Fig. 3.99) as well as from the Pars infraclavicularis (→ Fig. 3.101, → Fig. 3.102 and → Fig. 3.104) of the Plexus brachialis.

The **N. dorsalis scapulae** innervates the Mm. rhomboidei and the M. levator scapulae, both of which fix the scapula to the torso and pull it in a medial and superior direction. The nerve leaves the Plexus brachialis at the farthest cranial point, penetrates into the M. scalenus medius and draws the lower edge of the M. levator scapulae (indicator muscle!) dorsally.

Shoulder nerves of the Pars supraclavicularis:
- N. dorsalis scapulae (C3–C5)
- N. thoracicus longus (C5–C7)
- N. suprascapularis (C4–C6)
- N. subclavius (C5–C6)

→ T 22

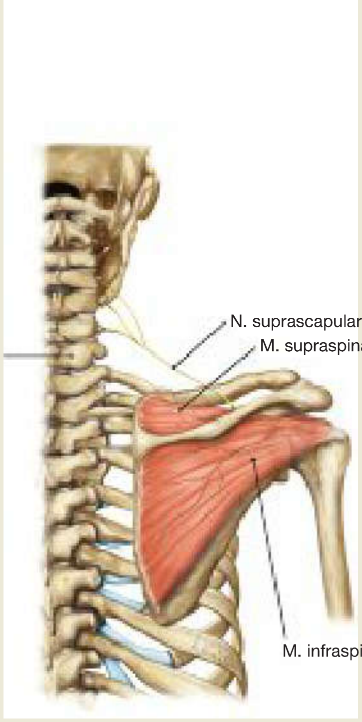


Fig. 3.98 N. suprascapularis (C4–C6), right side; dorsal view. [L266]

The **N. suprascapularis** innervates the **M. supraspinatus** (supports abduction) and the **M. infraspinatus** (most important external rotator of the shoulder!). The N. suprascapularis originates from the Truncus superior and runs dorsally above the clavicle. It passes under the **Lig. transversum scapulae superius** through the Incisura scapulae, and on the dorsal side of the scapula into the Fossa supraspinata, and then turns laterally around the Spina scapulae into the Fossa infraspinata. At the base of the Spina scapulae, it is sometimes covered by fibres of connective tissue which are referred to as **Lig. transversum scapulae inferius.**

Clinical Remarks

Lesions of the shoulder nerves of the Pars supraclavicularis:
- **N. dorsalis scapulae:** the scapula is displaced laterally and slightly lifts off the thorax. An isolated lesion is rare due to the protected location.
- **N. suprascapularis:** impaired external rotation (M. infraspinatus is the most important muscle) and, to a lesser degree, impaired abduction of the shoulder (M. supraspinatus). In addition to injuries in the lateral neck region, nerve entrapments in the Incisura scapulae are also possible.

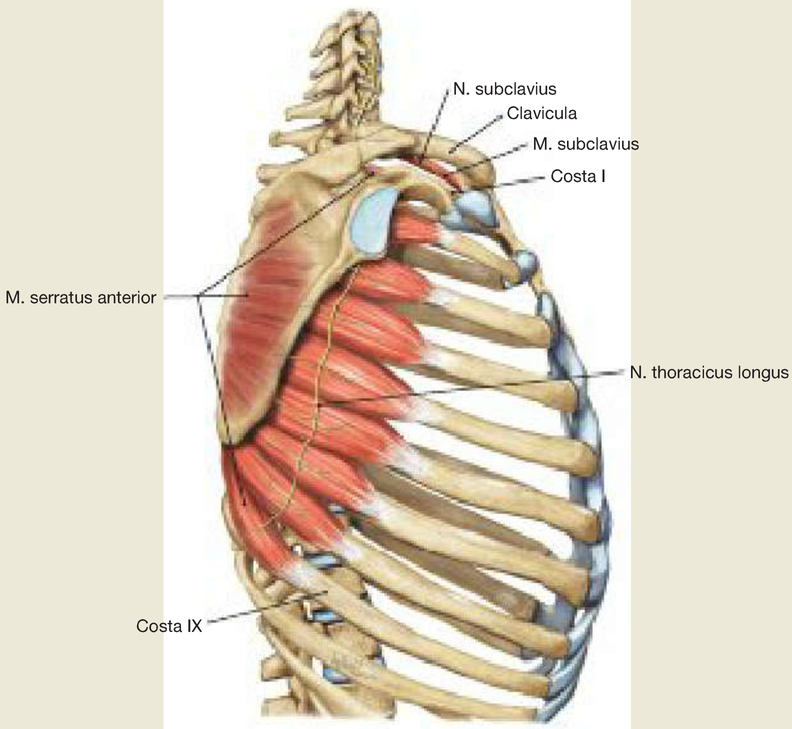


Fig. 3.99 N. thoracicus longus (C5–C7) and N. subclavius (C5–C6), right side; lateral view. [L266]
The **N. thoracicus longus** penetrates the M. scalenus medius, and then passes under the Plexus brachialis and the clavicule to the lateral side of the thorax, where it descends on the **M. serratus anterior** and innervates it. The M. serratus anterior contributes substantially to the rotation of the scapula. The muscle is required for the elevation of the arm in order to ensure that the abduction movement of the head of the humerus is not restricted by the shoulder roof.

The **N. subclavius** innervates the **M. subclavius,** which actively stabilises the sternoclavicular joint. The N. subclavius is closely adjacent to the M. subclavius and occasionally sends a branch to the N. phrenicus ('accessory phrenic nerve').

→T 22

Fig. 3.100 Scapula alata caused by lesions of the N. thoracicus longus, on both sides; dorsal view. [P320, P319]
The protruding medial margin of the scapula indicates a lesion of the N. thoracicus longus and is referred to as **Scapula alata**. In contrast to the impairment of the elevation, this symptom may not be perceived by the patient, but can be used diagnostically. The protrusion of the medial margin of the scapula is most noticeable when the patient leans against the floor or a wall, as shown here, and the M. serratus anterior cannot keep the shoulder blade fixed to the torso.

Clinical Remarks

Lesions of the shoulder nerves of the Pars supraclavicularis:
- **N. thoracicus longus:** elevation impossible! The medial margin of the scapula protrudes wing-like from the torso **(Scapula alata).** This lesion is frequently caused by carrying heavy loads on the back ('backpacker's palsy') whereby the nerve can be entrapped under the clavicle. Incisions into the chest wall can also lead to a lesion of the nerve.
- An isolated lesion of the N. subclavius is very rare and has no clear clinical symptoms.

Shoulder Nerves of the Pars infraclavicularis of the Plexus brachialis

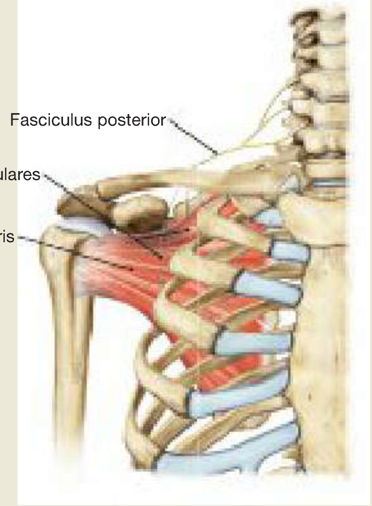


Fig. 3.101 Nn. subscapulares (C5–C7), right side; ventral view. [L266]

The shoulder nerves originate from the Pars supraclavicularis (→ Fig. 3.97, → Fig. 3.98, → Fig. 3.99) as well as the Pars infraclavicularis (→ Fig. 3.101, → Fig. 3.102, → Fig. 3.103) of the Plexus brachialis.

There are usually two **Nn. subscapulares** which innervate the **M. subscapularis** (the most important internal rotator of the shoulder joint!). Since the Nn. subscapulares descend directly from the posterior fascicle to the front of the scapula, they are very well protected.

Shoulder nerves of the Pars supraclavicularis:

- Nn. subscapulares (C5–C7) from the Fasciculus posterior
- N. thoracodorsalis (C6–C8) from the Fasciculus posterior
- N. pectoralis lateralis (C5–C7) from the Fasciculus lateralis
- N. pectoralis medialis (C8–T1) from the Fasciculus medialis
- N. axillaris (C5–C6) from the Fasciculus posterior

→T 22

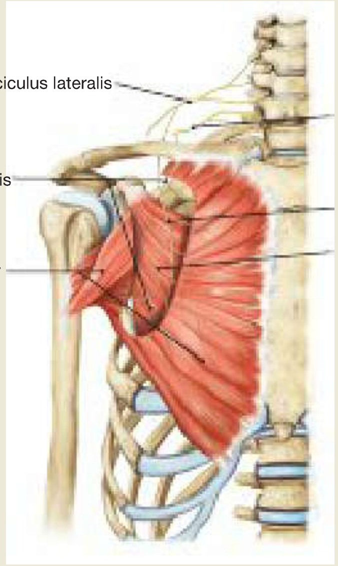


Fig. 3.102 Nn. pectorales lateralis (C5–C7) and medialis (C8–T1), right side; ventral view. [L266]

These derive their names because of their origin from the respective fascicle, not from the position (the **N. pectoralis medialis** is located laterally and the **N. pectoralis lateralis** medially, in general!). Both nerves innervate the **Mm. pectorales major and minor.** The M. pectoralis major is the most important muscle for the adduction and anteversion of the shoulder joint.

Fig. 3.103 N. thoracodorsalis (C6–C8), right side; dorsal view. [L266]

The **N. thoracodorsalis** accompanies the artery and vein of the same name to the medial side of the M. latissimus dorsi, and sends a branch to the M. teres major.

→T 22

Clinical Remarks

Lesions of shoulder nerves of the Pars infraclavicularis: in general, isolated injuries of individual infraclavicular shoulder nerves are rare due to their protected location.

- **Nn. subscapulares:** week medial rotation of the humerus; lesions may be caused by a proximal humeral fracture.
- **Nn. pectorales:** impairment of adduction and anteversion. As a clinical sign that can be used diagnostically, the arms cannot be crossed **in front of** the torso. The anterior axillary fold is sunken.
- **N. thoracodorsalis:** impaired adduction of the retroverted arm.

The arms cannot be crossed **behind** the back, as this would require retroversion, adduction and internal rotation ('apron grip'). The posterior axillary fold is sunken. Considering the size of the M. latissimus dorsi, there are mostly minor symptoms with movements out of the neutral position, because this muscle is, just like the M. teres major, not essential for movements of the shoulder joint! But the impairment may become significant in the case of gymnastics or other sports.

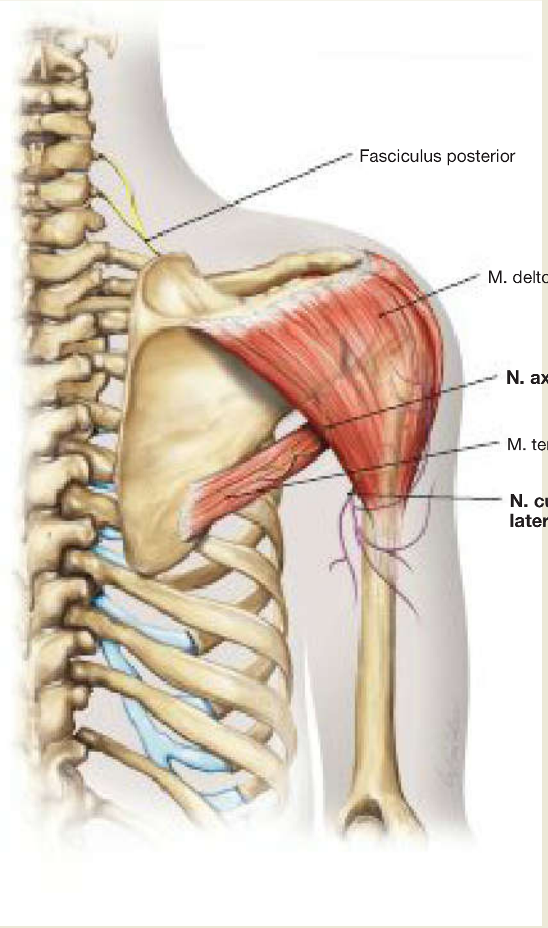


Fig. 3.104 Course and supply area of the N. axillaris (C5–C6), right side; dorsal view. [L266]
The **N. axillaris** originates from the Fasciculus posterior, traverses the **lateral axillary space** together with the A. circumflexa humeri posterior and courses around the surgical neck (Collum chirurgicum) of the humerus to reach the dorsal side of the arm. Here it innervates the **M. deltoideus** (the most important abductor in the shoulder joint!) and the **M. teres minor.** Its sensory terminal branch (N. cutaneus brachii lateralis superior [purple]) emerges posteriorly at the lower margin of the M. deltoideus and innervates the lateral aspect of the shoulder.

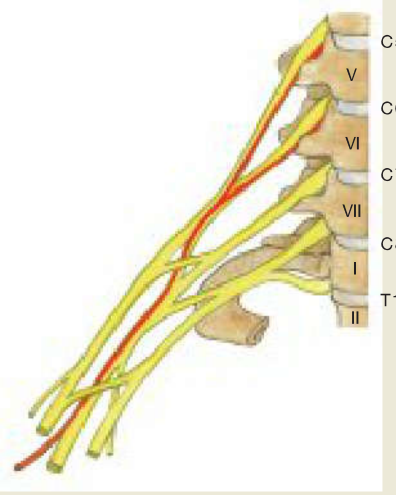


Fig. 3.105 Segmental arrangement of the N. axillaris, right side; ventral view.

Fig. 3.106 Lesion of the N. axillaris: paralysis and atrophy of the M. deltoideus. [T917]

→T 22

Clinical Remarks

Lesion of the N. axillaris: it can be injured in proximal humeral fractures and shoulder dislocations. The abduction of the arm is severely impaired and a complete sensory loss affects the lateral side of the shoulder. In the case of a long-lasting nerve lesion the roundness of the shoulder gets lost due to the muscle atrophy (→ Fig. 3.106).

Arm Nerves of the Plexus brachialis

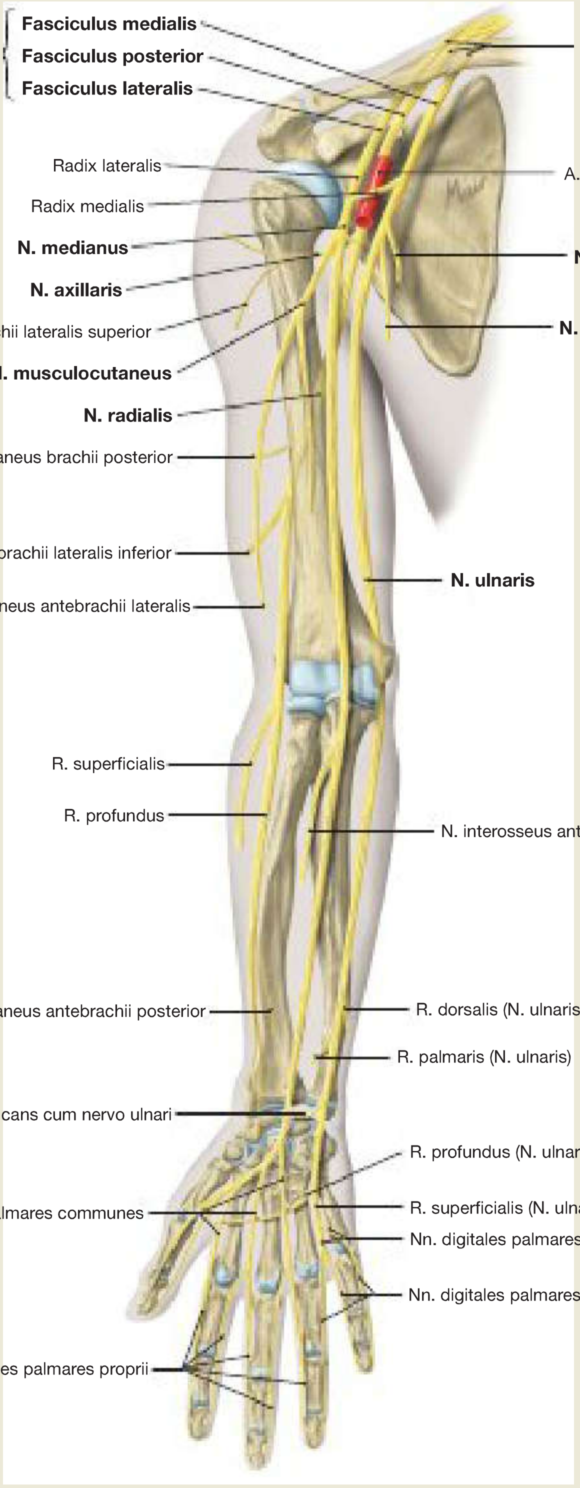


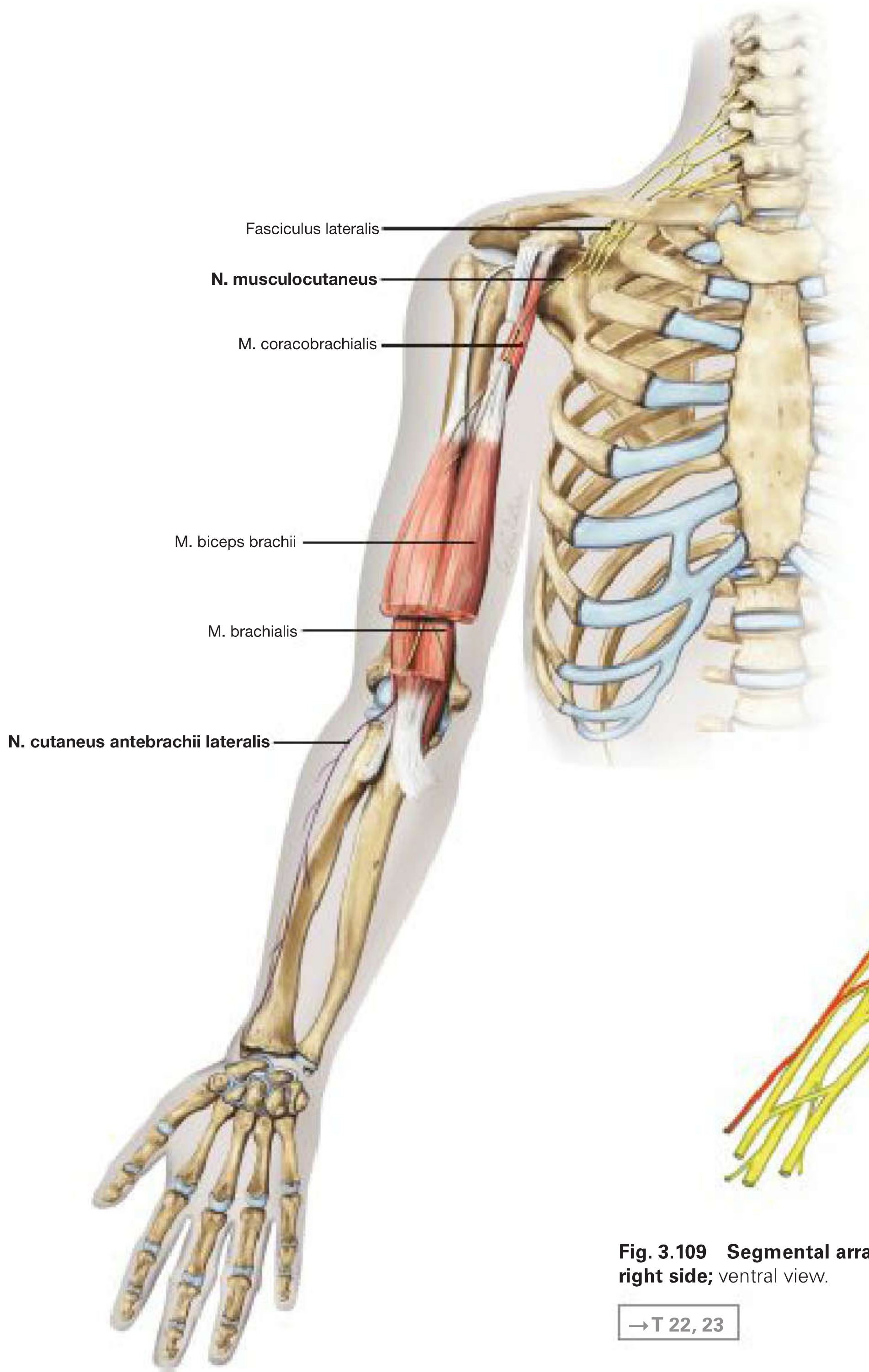
Fig. 3.107 Brachial plexus, Plexus brachialis (C5–T1): nerves of the arm, right side; ventral view. [L127]
The nerves of the arm, as well as some shoulder nerves (→ Fig. 3.101, → Fig. 3.102, → Fig. 3.103 and → Fig. 3.104) originate from the infraclavicular part of the Plexus brachialis. The N. radialis continues the course of the Fasciculus posterior. The N. musculocutaneus and the lateral root (Radix lateralis) of the N. medianus originate from the Fasciculus lateralis. The Fasciculus lateralis divides into the medial root (Radix medialis) of the N. medianus and into the N. ulnaris, as well as into the sensory nerves on the medial side of the upper arm (N. cutaneus brachii medialis) and of the forearm (N. cutaneus antebrachii medialis).

Arm nerves of the Pars infraclavicularis:
Fasciculus posterior (C5–T1):
- N. radialis (C5–T1)

Fasciculus lateralis (C5–C7):
- N. musculocutaneus (C5–C7)
- N. medianus, Radix lateralis (C6–C7)

Fasciculus medialis (C8–T1):
- N. medianus, Radix medialis (C8–T1)
- N. ulnaris (C8–T1)
- N. cutaneus brachii medialis (C8–T1)
- N. cutaneus antebrachii medialis (C8–T1)

→T 22



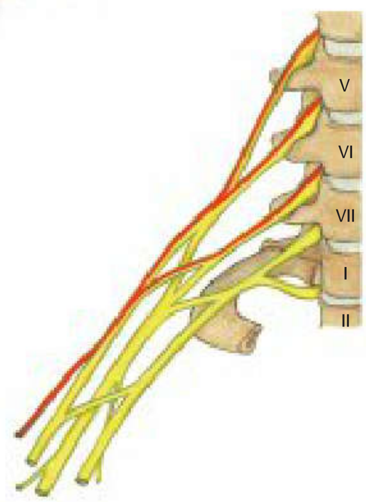


Fig. 3.109 Segmental arrangement of the N. musculocutaneus, right side; ventral view.

→ T 22, 23

Fig. 3.108 Course and supply area of the N. musculocutaneus (C5–C7), right side; ventral view. [L266]

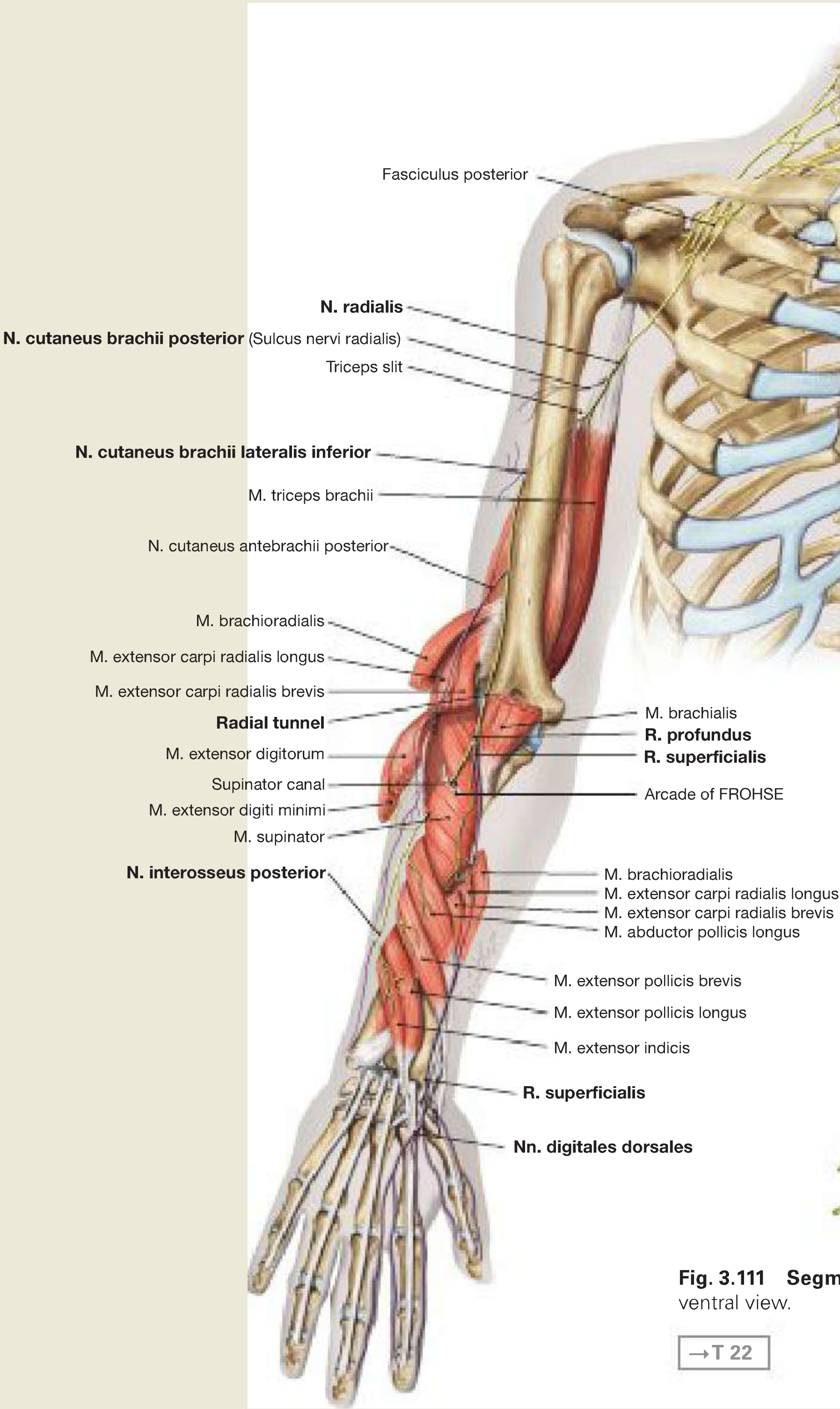
The **N. musculocutaneus** originates from the Fasciculus lateralis. It usually pierces the **M. coracobrachialis,** courses distally between the M. biceps brachii and M. brachialis, where its sensory terminal branch (N. cutaneus antebrachii lateralis [purple]) emerges between the two muscles and reaches the cubital fossa laterally. It supplies the three ventral muscles of the upper arm **(M. coracobrachialis, M. biceps brachii, M. brachialis)** with motor fibres and the radial forearm with sensory fibres.

Since the N. musculocutaneus penetrates the M. coracobrachialis, this nerve helps with orientation when dissecting the Plexus brachialis (indicator nerve!) (→ Fig. 3.149 and → Fig 3.150).

Clinical Remarks

Lesion of the N. musculocutaneus: this nerve is at risk in the case of shoulder dislocations. If it is damaged the flexion of the elbow joint is significantly reduced, but is maintained to a certain degree by the radial group of the extensors (innervated by the N. radialis) and the superficial flexor muscles of the forearm (innervated by the N. medianus) which also promote flexion in the elbow joint. The supination of the flexed arm and the biceps reflex are weakened due to the paralysis of the M. biceps brachii. The sensory deficit on the radial forearm can be mitigated, because the innervation areas of the medial and the dorsal sensory nerves often overlap.

N. radialis



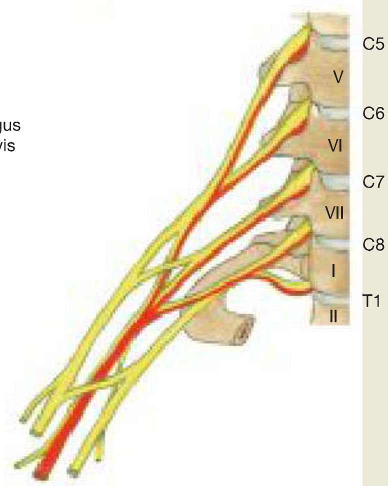


Fig. 3.111 Segmental arrangement of the N. radialis, right side; ventral view.

→T 22

Fig. 3.110 Course and innervation area of the N. radialis (C5–T1), right side; ventral view (the dorsal side is visible here due to the pronated position of the forearm). The sensory cutaneous branches are highlighted in purple. [L266]

The N. radialis originates from the Fasciculus posterior and passes through the **triceps slit** (→Fig. 3.61) between the Caput longum and Caput laterale of the M. triceps brachii to reach the dorsal side of the humerus, winding around it in the **Sulcus nervi radialis**. Before entering the sulcus, it provides motor branches to the **M. triceps brachii** and the sensory branch to the posterior side of the upper arm. The sensory branch to the posterior side of the forearm, however, departs from the Sulcus nervi radialis. Then the N. radialis enters between the M. brachioradialis and M. brachialis **from laterally (in the radial groove or tunnel)** into the cubital fossa, where it divides into a R. superficialis and a R. profundus. Prior to its division, it sends muscle branches to the **M. brachioradialis** and the **Mm. extensores carpi radialis longus and brevis.**

The **R. superficialis** initially runs with the A. radialis below the M. brachioradialis; then, however, it changes distally to the dorsal side of the hand, to supply the first interdigital space (Spatium interosseum) between the thumb and index finger (autonomic area!) and the dorsal side of the radial 2½ fingers with sensory nerve fibres.

In contrast, the **R. profundus** penetrates the **M. supinator (supinator canal)** below the cubital fossa, and also innervates the muscle, and then turns to the dorsal side of the forearm, where it provides muscle branches to **all extensors of the forearm**. At the entrance of the supinator canal, the muscle fascia forms a crescent-shaped reinforcement **(FROHSE-FRÄNKEL's arcade).** The terminal sensory branch is the N. interosseus antebrachii posterior, which supplies the wrists dorsally.

Autonomic region of sensory innervation: first interdigital space between thumb and index finger

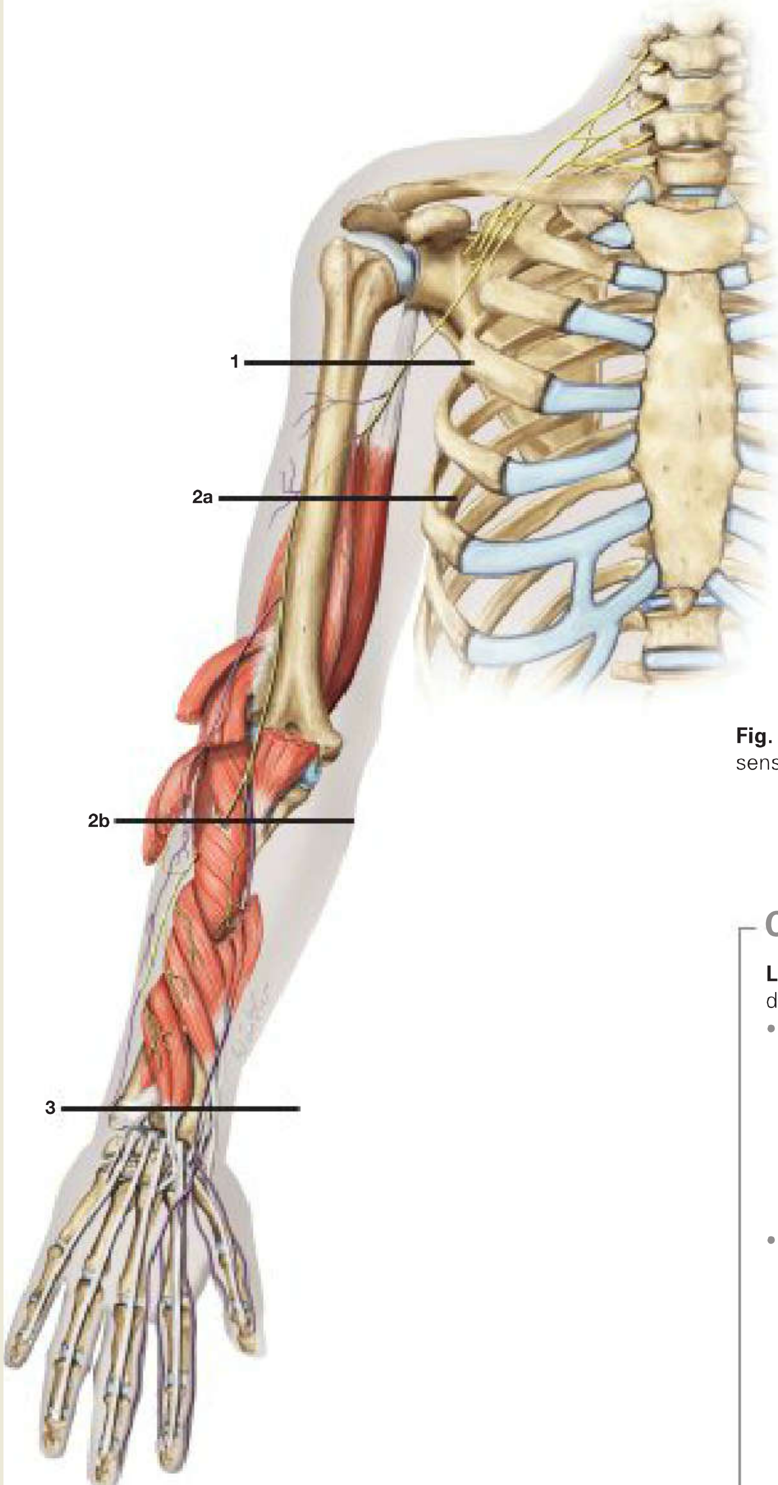


Fig. 3.112 **Lesion sites of the radial nerve (C5–T1); right side;** dorsal view (marked with bars). The sensory cutaneous branches are highlighted in purple. [L266]
Sensory autonomic region: first interdigital space
Common lesion sites (marked with bars):
1 **Proximal lesion** in the **axillary region**
2 **Intermediate lesion** near the **humeral shaft (a)** or **cubital region (b)**
3 **Distal lesion** in the **wrist region**

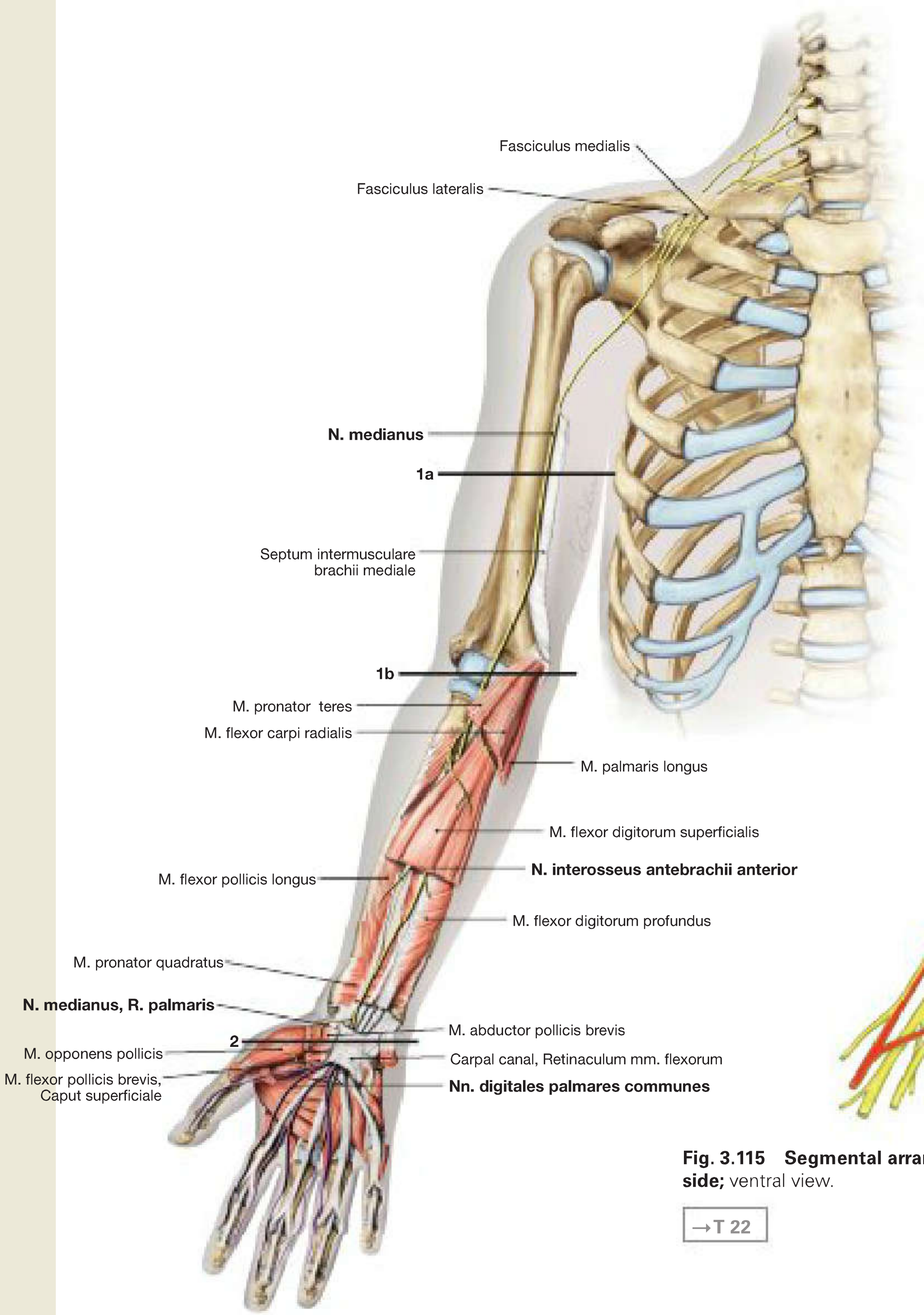
Fig. 3.113 Proximal lesion of the radial nerve: 'wrist drop' with sensory disturbances in the first interdigital space.

Clinical Remarks

Lesions of the radial nerve: a distinction is made between three different lesions:

- **Proximal lesion** in the area of the **armpit:** in the past caused by crutches, but is today more often due to incorrect positioning in the OP. A **dysfunction of the M. triceps** with reduced elbow extension and triceps reflex as well as a sensory loss on the back of the upper arm only occur in the case of proximal lesions (in addition to the symptoms caused by lesions in the region of the humeral shaft), because these nerve fibres already branch off before entering the Sulcus nervi radialis (→ Fig. 3.112, 1).
- **Intermediate lesion** near the **humeral shaft or the cubital fossa:** possible causes are a shaft fracture or nerve compression ('park bench lesion') or squeezing against the humerus. Nerve lesions in the cubital region can be caused by dislocations or high fractures of the radius, as well as by compression in the FROHSE-FRÄNKEL arcade. Lesions in the region of the **humeral shaft** (→ Fig. 3.112, 2a) result in a 'wrist drop' (→ Fig. 3.113) due to the dysfunction of all forearm extensors, including the radial group as well as an impairment of the finger and thumb extension and supination of the extended arm. In addition, a sensory deficit occurs on the dorsal side of the forearm, in the first interdigital space (autonomic region), and on the dorsal side of the radial 2½ fingers. If it is only the **R. profundus** that is entrapped while passing through the M. supinator (→ Fig. 3.112, 2b), there are no sensory deficits and the effect on the innervation of the wrist is negligible. A 'wrist drop' does **not** occur if only the finger extensors are impaired, whereas the Mm. extensores carpi radiales are sufficient for stabilisation of the wrist as part of the intact radial muscle group. Due to active insufficiency of the flexors, which cannot be compensated for by extension of the wrists, a **strong fist closure** is not achievable.
- **Distal lesion of the R. superficialis** in the **wrist region** (→ Fig. 3.112, 3), due to a distal radius fracture (the most common fracture in humans): the sensory deficit is confined to the first interdigital space and to the back of the radial 2½ fingers.

N. medianus



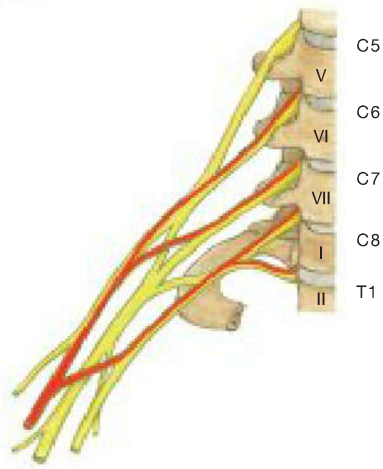


Fig. 3.115 Segmental arrangement of the N. medianus, right side; ventral view.

→T 22

Fig. 3.114 Course, supply area and lesion sites of the N. medianus (C6–T1), right side; ventral view. The sensory cutaneous branches are highlighted in purple. [L266]

The N. medianus consists of a lateral and a medial root that emerge from the respective fascicles. Firstly, it runs along the medial upper arm in the Sulcus bicipitalis medialis without providing any branches. The nerve then enters medially into the cubital fossa and passes **between the two heads of the M. pronator teres** into the intermuscular layer between the superficial and deep flexors of the forearm. Here it innervates **all flexor muscles of the forearm,** apart from the M. flexor carpi ulnaris and the ulnar head of the M. flexor digitorum profundus. The deep muscles, however, are supplied by the N. interosseus antebrachii anterior. In addition, this nerve provides sensory innervation to the palmar side of the wrist. The N. medianus passes between the tendons of the finger flexors through **the carpal tunnel** (Canalis carpi) and enters into the palm, where it divides into three Nn. digitales palmares communes. These nerves provide muscular branches to the **thumb muscles** (apart from the M. adductor pollicis and the Caput profundum of the M. flexor pollicis brevis) and to the two radial **Mm. lumbricales**. They then divide into the sensory terminal branches, which supply the palmar side of the radial 3½ fingers, and also the dorsal side of the distal phalanges.

Sensory autonomic region: distal phalanges of the index and middle fingers

Common lesion sites (marked with bars):

1 **Proximal lesion** in the **Sulcus bicipitalis medialis (a)** or in the **cubital fossa (b)**
2 **Distal lesion** in the **wrist region** and in the **carpal tunnel**

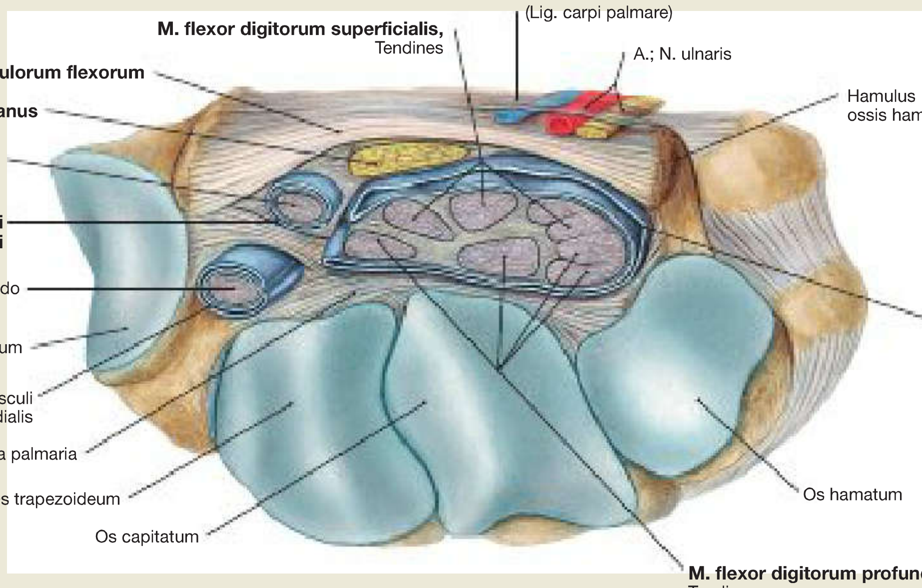


Fig. 3.116 Carpal tunnel, Canalis carpi, right side; distal view; transverse section at the level of the carpometacarpal joints.
Together with the carpal bones, the Retinaculum musculorum flexorum forms the carpal tunnel which is traversed by the N. medianus and the tendons of the long finger flexor muscles (→ Fig. 3.165). Inflammation (tendinitis) or swelling in the area of the carpal tunnel can lead to a compression of the N. medianus. Functional deficits caused by compression of the N. medianus in the carpal tunnel are referred to as **carpal tunnel syndrome**.

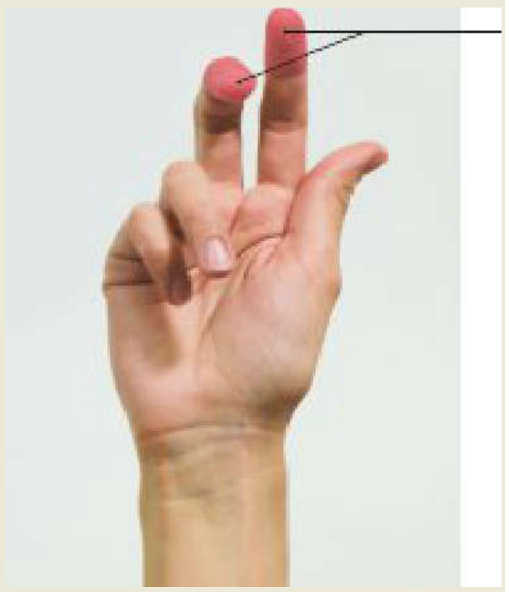


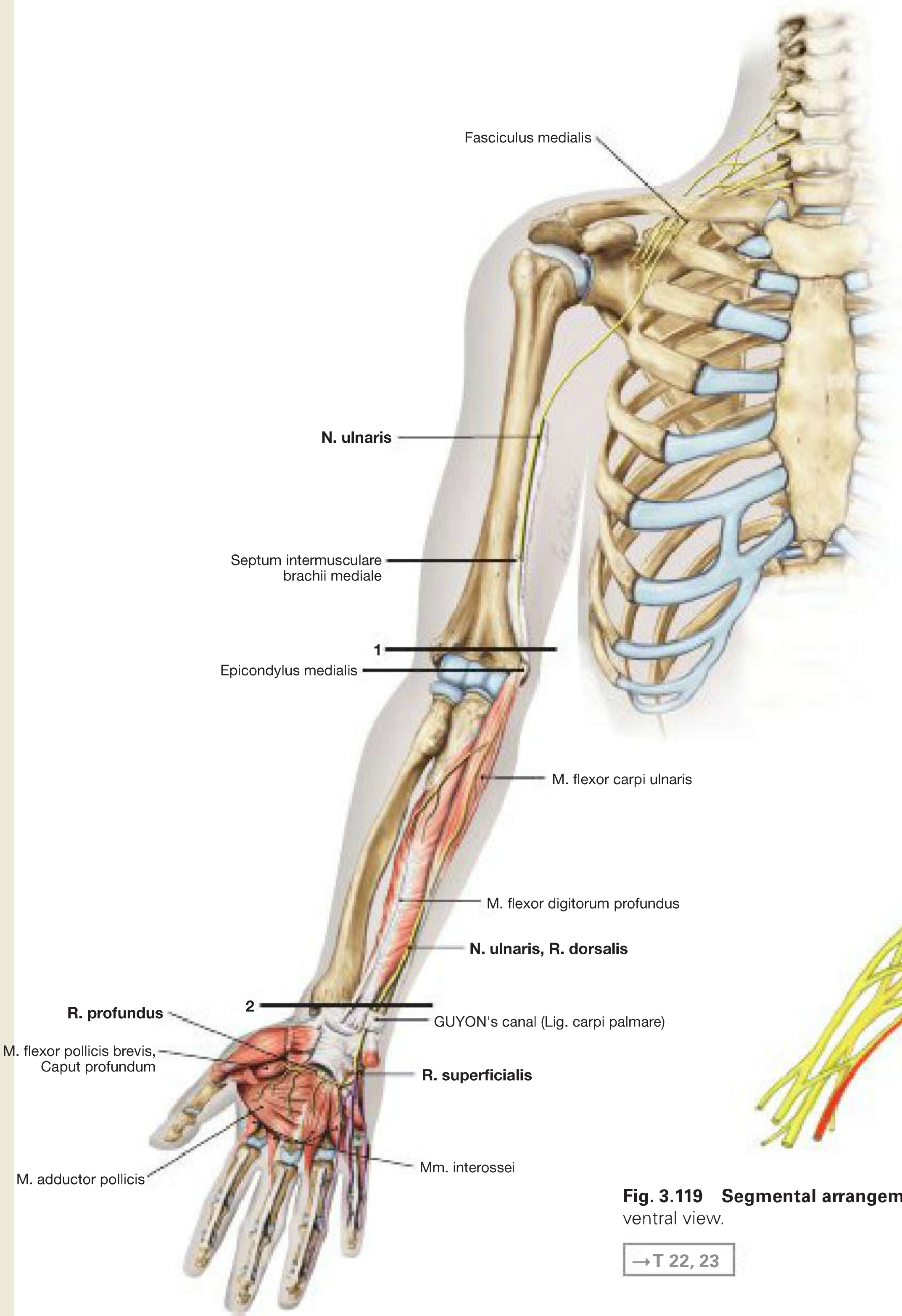
Fig. 3.117 Proximal lesion of the N. medianus: 'hand of benediction' with sensory deficits in the distal phalanges of the index and middle fingers.

Clinical Remarks

Lesions of the N. medianus:
A distinction is made between proximal and distal lesions:

- **Proximal lesion** in the Sulcus bicipitalis medialis (→ Fig. 3.114, 1a; e.g. in the case of incision wounds) or in the cubital region (→ Fig. 3.114, 1b): In the cubital fossa, the N. medianus can be entrapped or compressed due to distal humerus fractures, incorrect blood-taking or intravenous injection, or between the heads of the M. pronator teres (pronator teres syndrome). Only the proximal nerve lesion leads to the **'hand of benediction'**, a position in which the thumb, index and middle fingers can no longer be bent in the proximal and distal interphalangeal joints (→ Fig. 3.117). The reason is a lack of innervation to the superficial as well as the radial part of the deep finger flexor muscles. All other symptoms are similar to those of the distal lesion.
- **Distal lesions** in the **wrist region** (e.g. by 'cutting the arteries' with suicidal intention) or compression of the N. medianus in the carpal tunnel (**carpal tunnel syndrome,** the most common nerve injury of the upper limb; → Fig. 3.114, 2): these do not result in a 'hand of benediction', because the motor branches to the finger flexor muscles already branch off at the forearm! However, the result can be an **ape hand,** since the atrophy of the thenar eminence leads to a constant adduction position of the thumb due to the predominant activity of the M. adductor pollicis (innervated by the N. ulnaris). The **thumb-little finger test** is **negative,** because the thumb cannot be opposed due to dysfunction of the M. opponens pollicis, and as a result the distal phalanges of the thumb and little finger cannot touch each other. The **'bottle sign'** signifies that the abduction of the thumb is insufficient (dysfunction of the M. abductor pollicis brevis), and an object can therefore not be completely enclosed. **Sensory deficiencies** afflict the palmar side of the radial 3½ fingers. There is typically nighttime pain that radiates proximally.

N. ulnaris



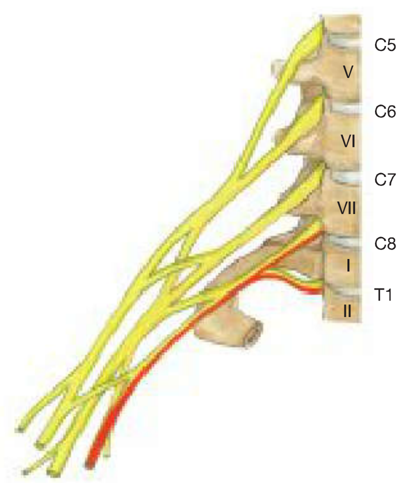


Fig. 3.119 Segmental arrangement of the N. ulnaris, right side; ventral view.

→T 22, 23

Fig. 3.118 Course, supply area and lesion sites of the N. ulnaris (C8–T1), right side; ventral view. The sensory cutaneous branches are highlighted in purple. [L266]

The N. ulnaris originates from the Fasciculus medialis and runs in the Sulcus bicipitalis medialis along the medial upper arm, then it penetrates the Septum intermusculare brachii mediale and passes onto the dorsal side of the Epicondylus medialis, where it is in direct contact to the bone in the **Sulcus nervi ulnaris ('funny bone')**. It provides no branches to the upper arm. In the forearm, the N. ulnaris passes with the A. ulnaris under the M. flexor carpi ulnaris to the wrist, where it enters through the **'GUYON's canal'** into the palm. Its R. dorsalis continues to the dorsal side of the hand and supplies the ulnar 2½ fingers with sensory innervation. In the forearm, the N. ulnaris provides motor innervation to the **M. flexor carpi ulnaris** and to the **ulnar head of the M. flexor digitorum profundus.** In the palm of the hand, the R. profundus branches off, which follows the deep palmar arterial arch to provide motor innervation to the **hypothenar muscles as well as** to all **Mm. interossei,** the two ulnar **Mm. lumbricales,** the **M. adductor pollicis** and the deep head of the **M. flexor pollicis brevis**. The R. superficialis provides motor innervation only to the **M. palmaris brevis** and continues in the sensory R. digitalis palmaris communis, which divides into terminal branches for the innervation of the palmar surfaces of the ulnar 1½ fingers (and dorsally of the distal phalanges).

Sensory autonomic region: distal phalanx of the little finger

Common lesion sites (marked with bars):

1 **Proximal lesion** in the area of the Epicondylus medialis (cubital tunnel syndrome)
2 **Distal lesion** in the **GUYON's canal**

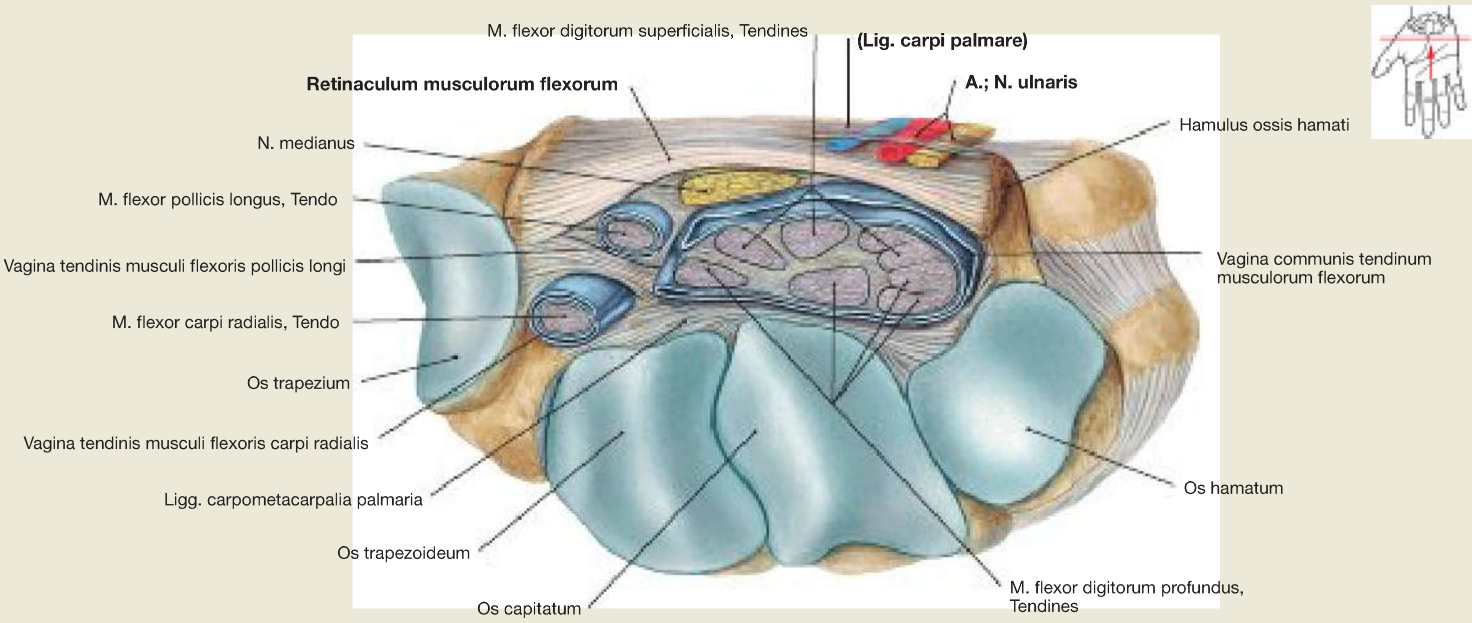


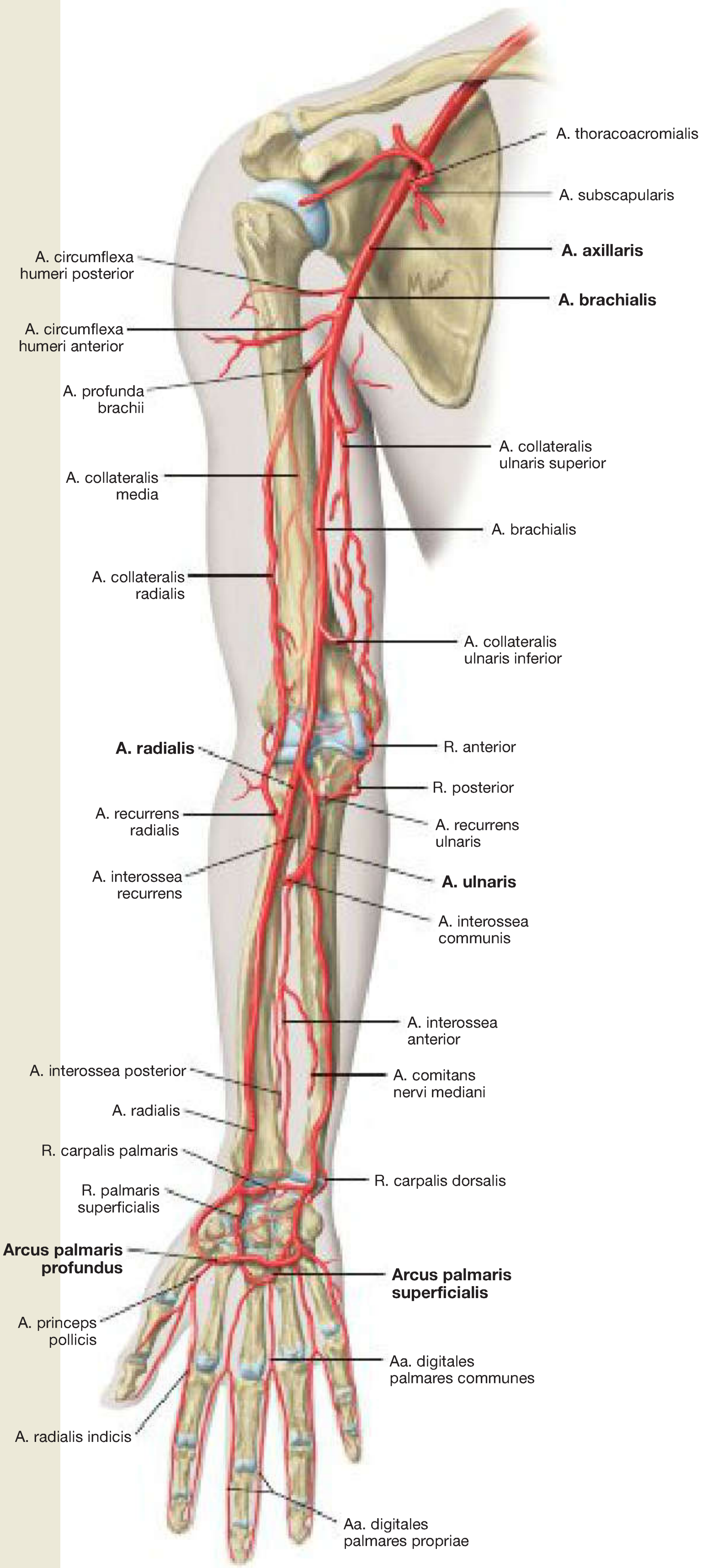
Fig. 3.120 GUYON's canal, right side; distal view; transverse section at the level of the carpometacarpal joints.
The GUYON's canal is formed by the Retinaculum musculorum flexorum and its superficial fibres (Lig. carpi palmare). The N. ulnaris, together with the A. and V. ulnaris, traverses the GUYON's canal (→ Fig. 3.165). Swelling or chronic pressure may cause a compression of the N. ulnaris **(GUYON's canal syndrome).**

Fig. 3.121 Proximal and distal lesions of the N. ulnaris: 'claw hand' with sensory deficit in the distal phalanx of the little finger.

Clinical Remarks

Lesions of the N. ulnaris: a distinction is made between proximal and distal lesions which cannot, however, be clearly separated:
- **Proximal lesion** in the Sulcus nervi ulnaris **(cubital tunnel syndrome),** usually due to chronic compression when leaning on the arm: this is the second most common nerve lesion of the upper limb.
- **Distal lesion** in the **GUYON's canal,** mostly due to chronic compression. In both cases, the result is a **'claw hand',** since the (obvious) atrophy of the Mm. interossei and of the two ulnar Mm. lumbricales impedes flexion of the fingers, especially in the metacarpopharyngeal joints and extension of the fingers in the distal interphalangeal joints. The **thumb-little finger test** is **negative,** because the little finger cannot be opposed due to dysfunction of the M. opponens digiti minimi, which means the distal phalanges of the thumb and little finger cannot touch each other. The **FROMENT's sign** (holding a sheet of paper between the thumb and index finger) indicates that insufficient adduction of the thumb is compensated for bending its distal phalanx (the M. flexor pollicis longus is innervated by the N. medianus). **Sensory deficits** occur in the palmar side of the ulnar 1½ fingers. If a compression injury into the palm of the hand (jackhammer) only affects the R. profundus, sensory symptoms can be missing.

Arteries of the Arm



Arteries of the Upper Limb
Branches of the A. subclavia: • A. vertebralis (→ chapter 8) • A. thoracica interna (→ chapter 2) • Truncus thyrocervicalis – A. thyroidea inferior – A. cervicalis ascendens – A. transversa cervicis/colli – A. suprascapularis • Truncus costocervicalis – A. intercostalis suprema – A. profunda cervicis
Branches of the A. axillaris: • A. thoracica superior (inconstant) • A. thoracoacromialis • A. thoracica lateralis • A. subscapularis – A. circumflexa scapulae – A. thoracodorsalis • A. circumflexa humeri anterior • A. circumflexa humeri posterior
Branches of the A. brachialis: • A. profunda brachii – A. collateralis media – A. collateralis radialis • A. collateralis ulnaris superior • A. collateralis ulnaris inferior
Branches of the A. radialis: • A. recurrens radialis • R. carpalis palmaris • R. carpalis dorsalis → Rete carpale dorsale → Aa. metacarpales dorsales → Aa. digitales dorsales • R. palmaris superficialis → Arcus palmaris superficialis • A. princeps pollicis • A. radialis indicis • Arcus palmaris profundus → Aa. metacarpales palmares
Branches of the A. ulnaris: • A. recurrens ulnaris • A. interossea communis – A. interossea anterior – A. comitans nervi mediani – A. interossea posterior with A. interossea recurrens • R. carpalis dorsalis • R. carpalis palmaris • R. palmaris profundus → Arcus palmaris profundus • Arcus palmaris superficialis → Aa. digitales palmares

Fig. 3.122 Arteries of the upper limb, right side; ventral view. [L127]
The **A. axillaris** is the continuation of the A. subclavia and extends from rib I to the lower margin of the M. pectoralis major. It is located between the three fascicles of the Plexus brachialis and the two roots of the N. medianus. In the upper arm it continues in the **A. brachialis**, which passes together with the N. medianus through the Sulcus bicipitalis medialis, and enters medially into the cubital fossa. There it divides into the A. radialis and the A. ulnaris. The **A. radialis** follows the radius between the superficial and deep flexor muscles up to the wrist, where it traverses the Fovea radialis (tabatière) in the dorsal direction, and then passes back into the palm between the heads of the M. interosseus dorsalis I. It is the main tributary of the deep palmar arch **(Arcus palmaris profundus).** The **A. ulnaris** gives off the A. interossea communis, passes along with the N. ulnaris beneath the M. flexor carpi ulnaris to the wrist and further through the GUYON's canal into the palm, where it contributes to the superficial palmar arch **(Arcus palmaris superficialis)**.

Clinical Remarks

In a complete physical examination, the **pulses** of the A. radialis and A. ulnaris are palpated on the radial and ulnar sides of the proximal wrist, respectively, to exclude any occlusion of the blood vessels by **arteriosclerosis** or blood clots **(emboli).**

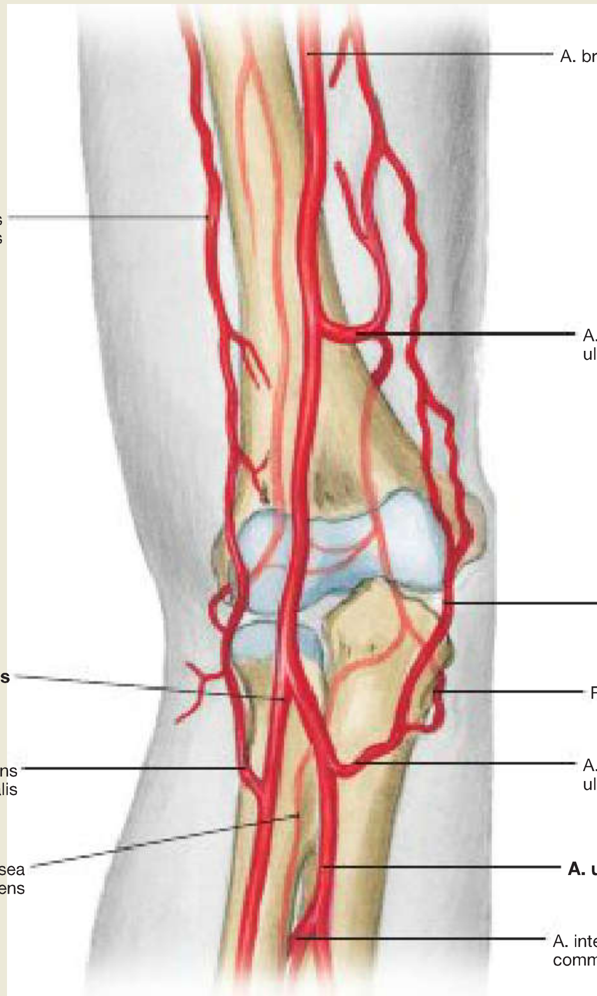


Fig. 3.123 Collateral circulation of the cubital region, Rete articulare cubiti, right side; ventral view, section of the cubital fossa.
In the elbow and cubital region, a collateral or bypass circulation for the main trunk of the A. brachialis is formed by anastomoses of the **four collateral arteries** (A. collateralis media and A. collateralis radialis from the A. profunda brachii, A. collateralis ulnaris superior and A. collateralis ulnaris inferior from the A. brachialis) with the **three recurrent arteries** (A. recurrens radialis, A. recurrens ulnaris and A. interossea recurrens from the blood vessels of the same name).

Rete articulare cubiti

The **collateral arteries** (A. collateralis media, A. collateralis radialis, A. collateralis ulnaris superior, A. collateralis ulnaris inferior) and the **recurrent arteries** (A. recurrens radialis, A. recurrens ulnaris, A. interossea recurrens) form a collateral circulation in the elbow region (Rete articulare cubiti).

Clinical Remarks

In the event of acute injuries, the collateral and recurrent arteries of the Rete articulare cubiti allow for a tourniquet applied to the **A. brachialis in the cubital fossa,** without endangering the blood supply of the forearm.

Arteries of the Shoulder

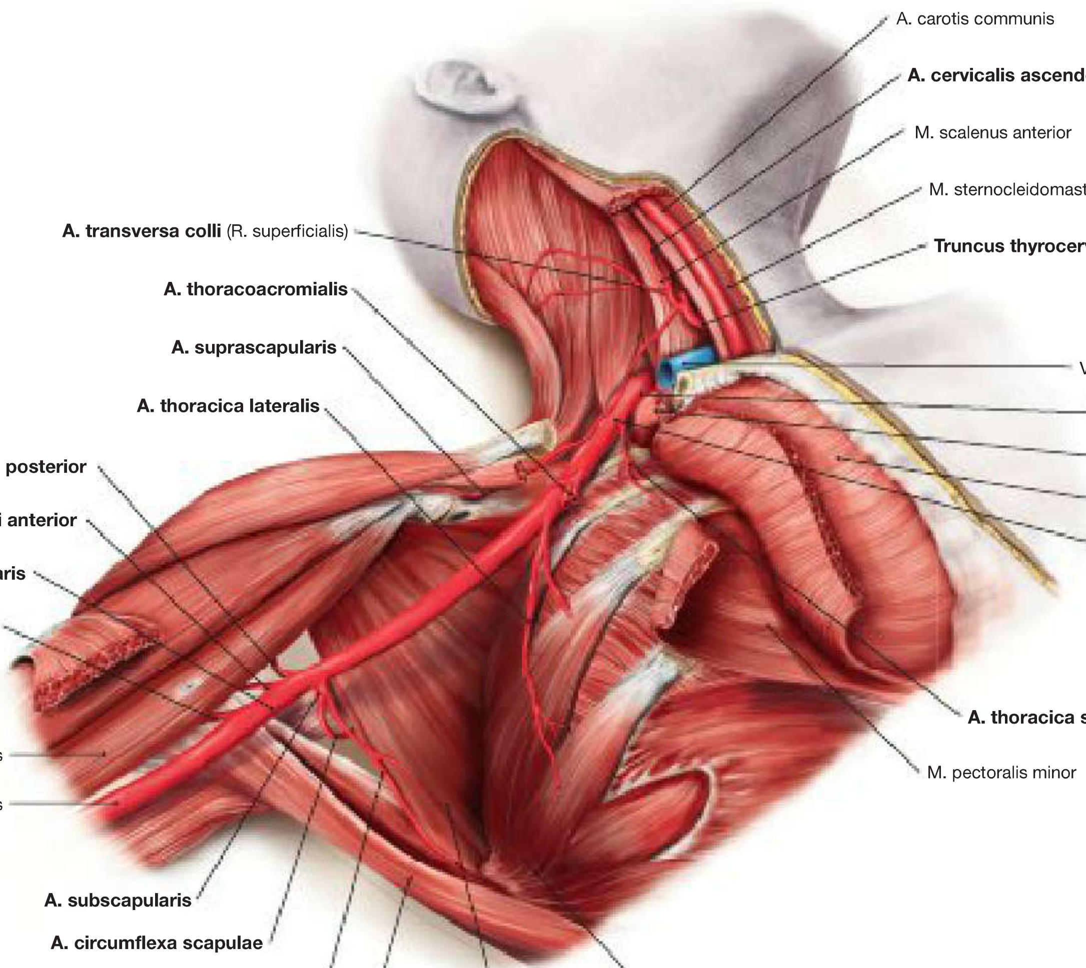


Fig. 3.124 Arteries of the shoulder, right side; ventral view after cutting the Mm. pectorales major and minor near their insertion. [L266]

This illustration shows the arteries of the shoulder which partly derive from the A. subclavia (→ Fig. 3.127) and mainly from the A. axillaris (→ Fig. 3.128). The A. suprascapularis and the A. transversa cervicis/colli originate from the Truncus thyrocervicalis of the A. subclavia. The **A. suprascapularis** runs dorsally behind the clavicle where it passes across the Lig. transversum scapulae superius to the dorsal side of the scapula. As shown here, it is often only the superficial branch of the **A. transversa cervicalis/colli** (R. superficialis) which originates from the Truncus thyrocervicalis and passes into the lateral cervical region to reach the inferior side of the M. trapezius. The deep branch (R. profundus) is in this case the last vessel branching directly off the A. subclavia and passing deep inside through the fascicles of the Plexus brachialis (not visible here).

The first branch of the A. axillaris is the **A. thoracica superior,** which runs off onto the upper chest wall. Then the **A. thoracoacromialis** branches off in a ventral-cranial direction, and immediately divides into its terminal branches (→ Fig. 3.126) before the **A. thoracica lateralis** descends along the lateral margin of the M. pectoralis minor. The next branch is the **A. subscapularis,** which as a strong, often short arterial trunk runs caudally and soon divides into the A. circumflexa scapulae and the A. thoracodorsalis. The A. circumflexa scapulae passes through the medial axillary space onto the dorsal side of the scapula. The **Aa. circumflexae humeri anterior and posterior** then originate and are slung around the neck of the humerus, whereby the artery to the dorsal side of the upper arm enters through the lateral axillary space.

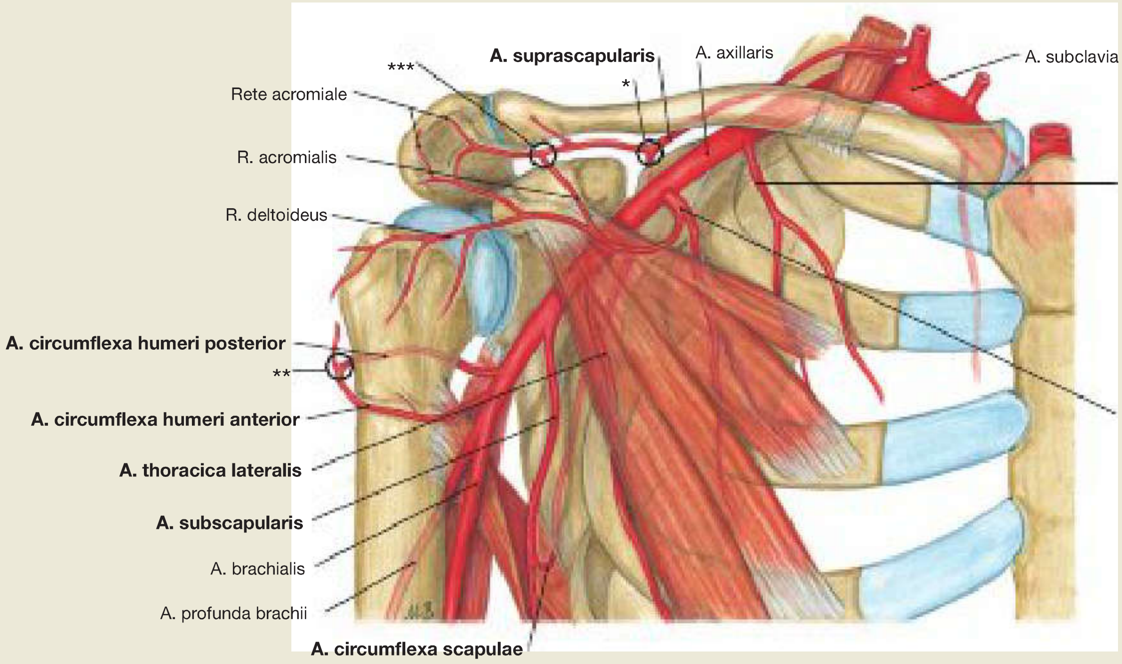


Fig. 3.125 Scapular anastomoses between the A. subclavia and A. axillaris, right side; ventral view.

Scapular anastomoses:

- The **A. circumflexa scapulae** originating from the A. subscapularis (from the A. axillaris) passes through the medial axillary space on the dorsal side, where it anastomoses in the Fossa infraspinata with the **A. suprascapularis** (from the current area of the A. subclavia) (*).
- The **A. circumflexa scapulae** can anastomose (not shown here) with the **A. dorsalis scapulae** (branch of the A. transversa cervicis/colli from the circulatory area of the A. subclavia) in the Fossa infraspinata via a branch at the medial margin of the scapula. This connection (if present) is often poorly developed.
- The **R. acromialis of the A. thoracoacromialis** (from the A. axillaris) can also anastomose with the **A. suprascapularis** (***).

Arm anastomoses:

- The **A. circumflexa humeri anterior** anastomoses (**) with the **A. circumflexa humeri posterior,** which passes through the lateral axillary space.

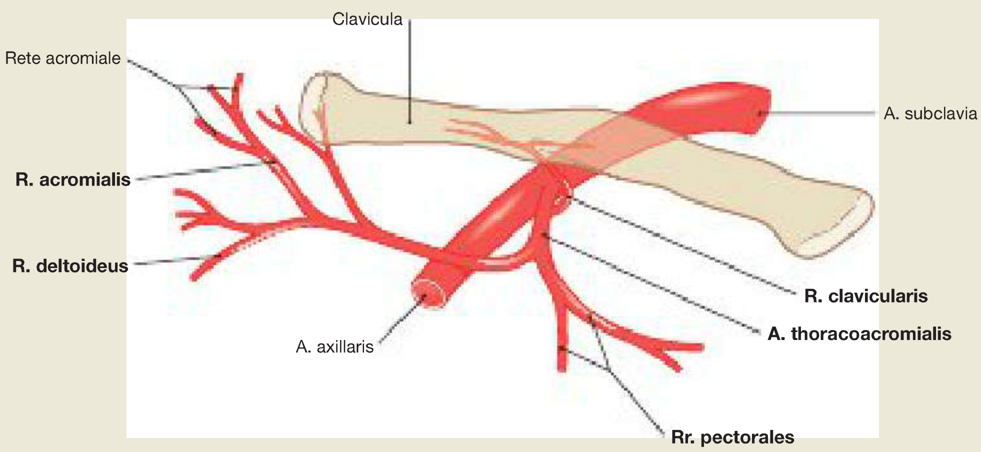


Fig. 3.126 Branches of the A. thoracoacromialis. [L126]

The **A. thoracoacromialis** divides into four terminal branches:

- Rr. pectorales to the Mm. pectorales
- R. clavicularis to the M. subclavius
- R. deltoideus to the M. deltoideus
- R. acromialis to the Rete acromiale

Clinical Remarks

The **scapular anastomoses** of the A. suprascapularis and A. dorsalis scapulae from the circulatory area of the A. subclavia with the A. circumflexa scapulae from the A. axillaris are important for collateral circulation of the blood supply to the arm, e. g. if the vessel is obstructed when the Truncus thyrocervicalis and the A. subscapularis branch off, or if a tourniquet must be applied in the case of a vascular injury.

A. subclavia

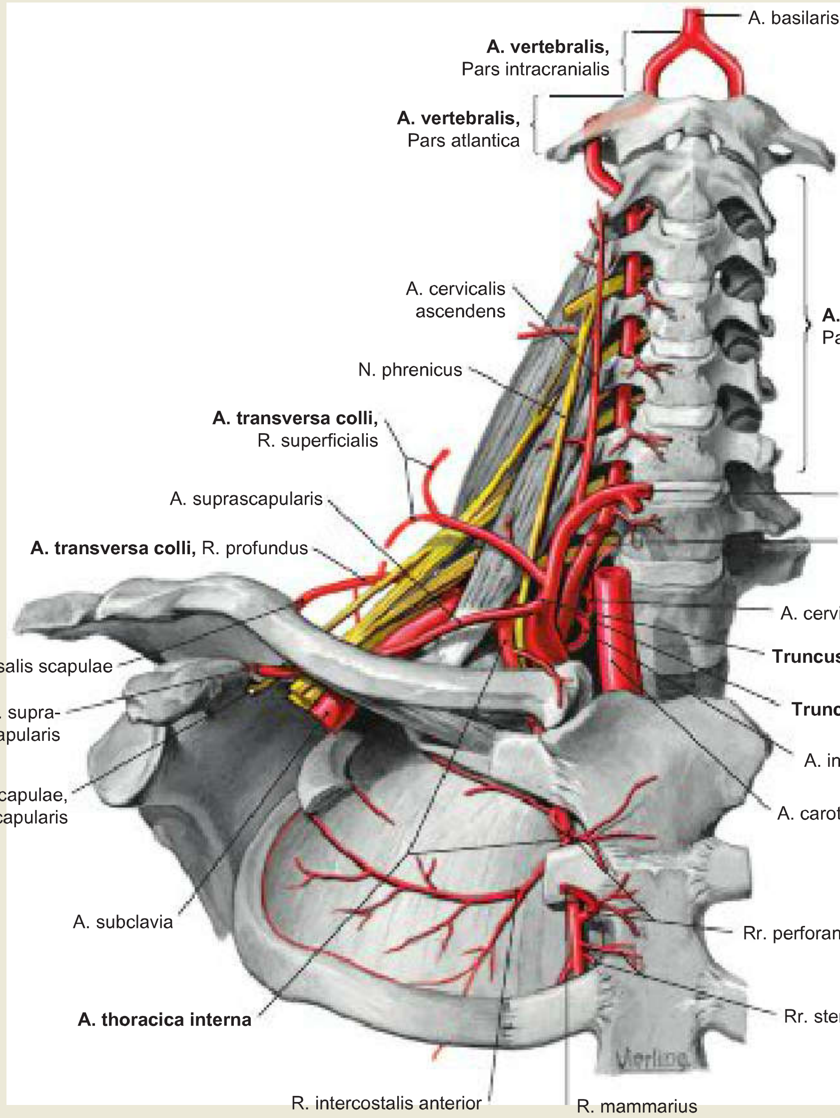


Fig. 3.127 Branches of the A. subclavia, right side; ventral view after removal of the superficial neck muscles, all shoulder/shoulder girdle and thoracic muscles. [S010-2-16]

In addition to the arm, the branches of the **A. subclavia** supply the neck region and its organs, as well as parts of the ventral thoracic wall and parts of the brain. Together with the Plexus brachialis, the artery passes through the scalene hiatus, and generally has four branches, of which the A. suprascapularis and the A. transversa cervicis/colli contribute to the blood supply of the upper extremity.

- **A. vertebralis:** ascending medially of the M. scalenus anterior in the cranial direction, it supplies neck muscles and cervical spine, the spinal cord, brain stem, inner ear, cerebellum and posterior parts of the cerebrum.
- **A. thoracica interna:** running caudally, it descends about 1 cm laterally to the sternal edge and supplies the mediastinum and diaphragm as well as the anterior thoracic wall.
- **Truncus thyrocervicalis:** this generally strong vascular trunk runs in a cranial direction and divides into four branches:
  - **A. thyoidea inferior:** the strongest branch of the Truncus thyrocervicalis supplies the thyroid gland, hypopharynx, oesophagus, larynx and trachea.
  - **A. cervicalis ascendens:** thin vessel on the M. scalenus anterior.
  - **A. transversa cervicis** (= A. transversa colli): runs in a lateral direction and splits into two branches:
    - R. superficialis: crosses the Plexus brachialis and continues to the bottom of the M. trapezius.
    - R. profundus: traverses the fascicles of the Plexus brachialis and continues as **A. dorsalis scapulae** along the Margo medialis of the scapula. It sometimes anastomoses on the dorsal side of the scapula with the A. suprascapularis, and the A. circumflexa scapulae (→ Fig. 3.125).
  - **A. suprascapularis:** passes behind the clavicle and accompanies the N. suprascapularis. In contrast to this nerve, it follows the Lig. transversum scapulae superius into the Fossa supraspinata and runs below the Lig. transversum scapulae inferius into the Fossa infraspinata to supply the muscles there. The A. suprascapularis usually anastomoses with the A. circumflexa scapulae and via thin branches with the A. dorsalis scapulae **(scapular anastomoses).**
- **Truncus costocervicalis:** this short vascular trunk runs caudally and divides into two branches:
  - A. intercostalis suprema: supplies the upper two intercostal spaces.
  - A. profunda cervicis: for prevertebral neck muscles

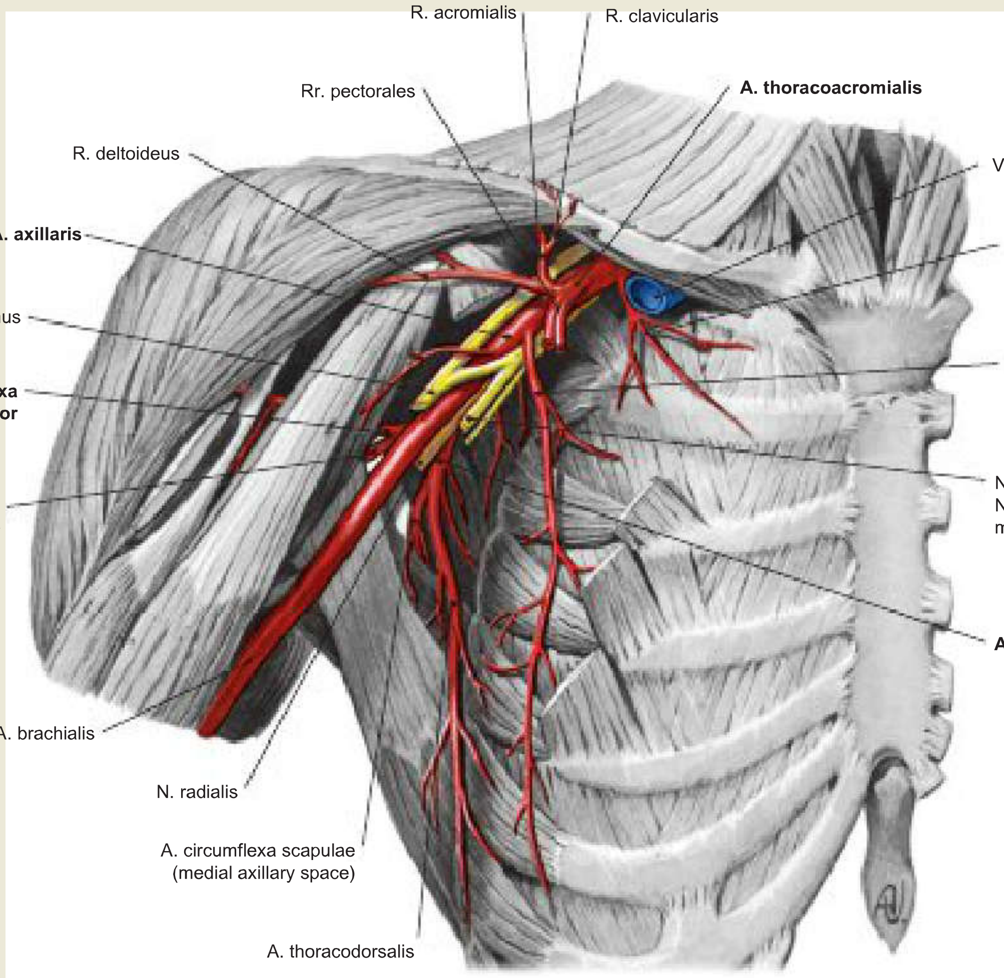


Fig. 3.128 Branches of the A. axillaris, right side; ventral view after removal of the Mm. pectorales major and minor. [S010-2-16]

The branches of the **A. axillaris** supply the shoulder and parts of the anterior thoracic wall. Usually there are six branches:

- **A. thoracica superior:** this inconstant thin vessel supplies the muscles of the upper thoracic wall.
- **A. thoracoacromialis:** the short vessel originates in the Trigonum clavipectorale, runs in a ventral-cranial direction and divides into four terminal branches (→ Fig. 3.126).
- **A. thoracica lateralis:** it descends laterally along the M. pectoralis minor in a caudal direction and provides Rr. mammarii laterales to supply the breast gland.
- **A. subscapularis:** the short, strong vessel descends caudally and divides into several branches:
  - The **A. circumflexa scapulae** passes through the **medial axillary space** on the back of the scapula into the Fossa infraspinata and anastomoses with branches of the A. suprascapularis and often via thin branches with the A. dorsalis scapulae **(scapular anastomoses).**
  - The **A. thoracodorsalis** continues the course of the A. subscapularis and accompanies the N. thoracodorsalis to the M. latissimus dorsi.
- **A. circumflexa humeri anterior:** it passes as a thin vessel around the front of the proximal humeral shaft.
- **A. circumflexa humeri posterior:** this artery can also branch off prior to the A. circumflexa scapulae, then passes through the **lateral axillary space** and anastomoses with the A. circumflexa humeri anterior **(upper arm anastomoses).**

A. brachialis

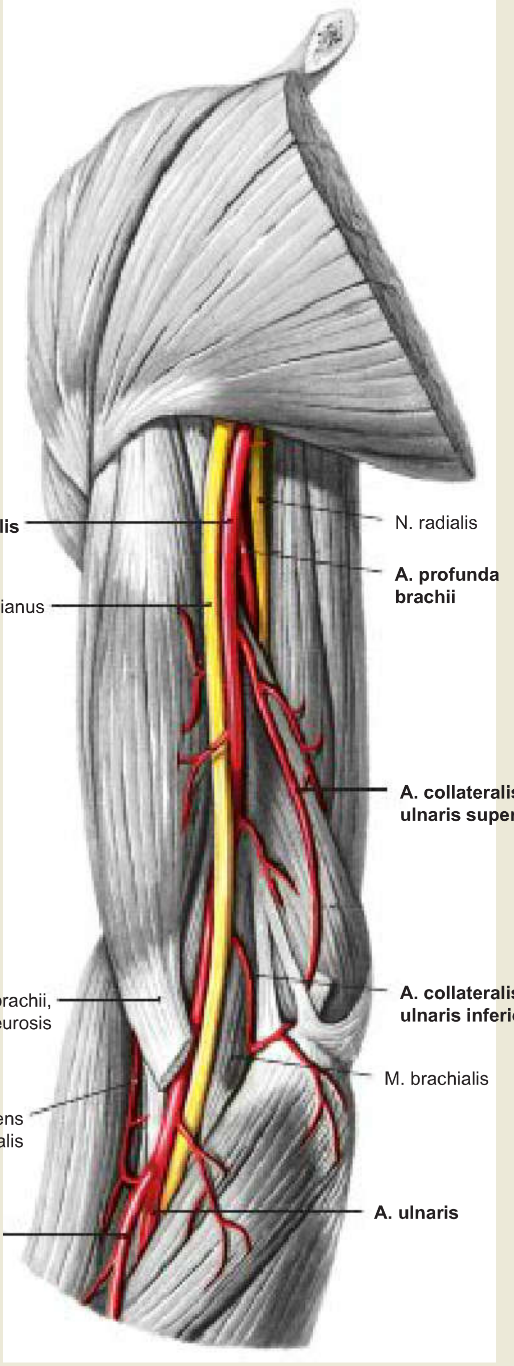


Fig. 3.129 Branches of the A. brachialis, right side; medial-ventral view. [S010-2-16]

The **A. brachialis** runs along the inside of the arm (Sulcus bicipitalis medialis) in the neurovascular bundle of the upper arm to the cubital fossa, where it divides into the **A. radialis** and **A. ulnaris**. The A. brachialis supplies the humerus, the elbow joint and the muscles of the upper arm. It provides three large vascular branches:

- **A. profunda brachii:** it passes with the N. radialis through the **triceps slit** and divides into:
  – **A. collateralis media:** passes to the dorsal vascular plexus on the elbow joint (Rete articulare cubiti → Fig. 3.123), and
  – **A. collateralis radialis:** continues the course along the Sulcus nervi radialis to the Rete articulare cubiti.
- **A. collateralis ulnaris superior:** it runs with the N. ulnaris to the Rete articulare cubiti.
- **A. collateralis ulnaris inferior:** it originates just above the cubital fossa and runs to the Rete articulare cubiti.

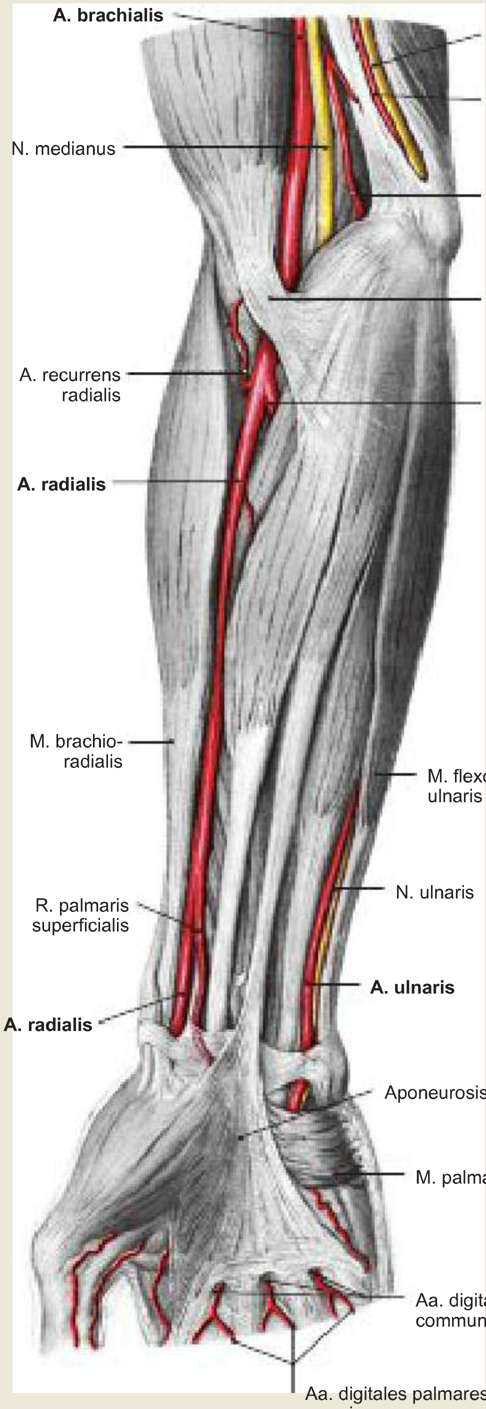


Fig. 3.130 A. radialis and A. ulnaris, right side; medial-ventral view. [S010-2-16]

On the radial side of the N. medianus, the **A. brachialis** enters the cubital fossa, where it provides the **A. ulnaris** dorsally of the M. pronator teres, while the **A. radialis** continues its course beneath the M. brachioradialis to the proximal wrist. It passes through the **Fovea radialis (tabatière)** dorsally, and then returns to the palm between the heads of the M. interosseus dorsalis I. There it is the main tributary of the deep palmar arch **(Arcus palmaris profundus,** → Fig. 3.132).

Branches of the A. radialis:
- **A. recurrens radialis:** it passes beneath the M. brachioradialis to the Rete articulare cubiti.
- **Rr. carpales palmaris and dorsalis:** these branches supply the carpus of the hand. The dorsal branch forms the Rete carpale dorsale, where the **Aa. metacarpales dorsales** originate, which together with the **Aa. digitales dorsales** supply the back of the hand and fingers (→ Fig. 3.167).
- **R. palmaris superficialis:** it forms the superficial palmar arch (Arcus palmaris superficialis) together with the A. ulnaris.
- **A. princeps pollicis:** it supplies the palmar surface of the thumb (→ Fig. 3.132).
- **A. radialis indicis:** it runs along the radial side of the index finger.
- **Arcus palmaris profundus:** (→ Fig. 3.132)

A. radialis and A. ulnaris

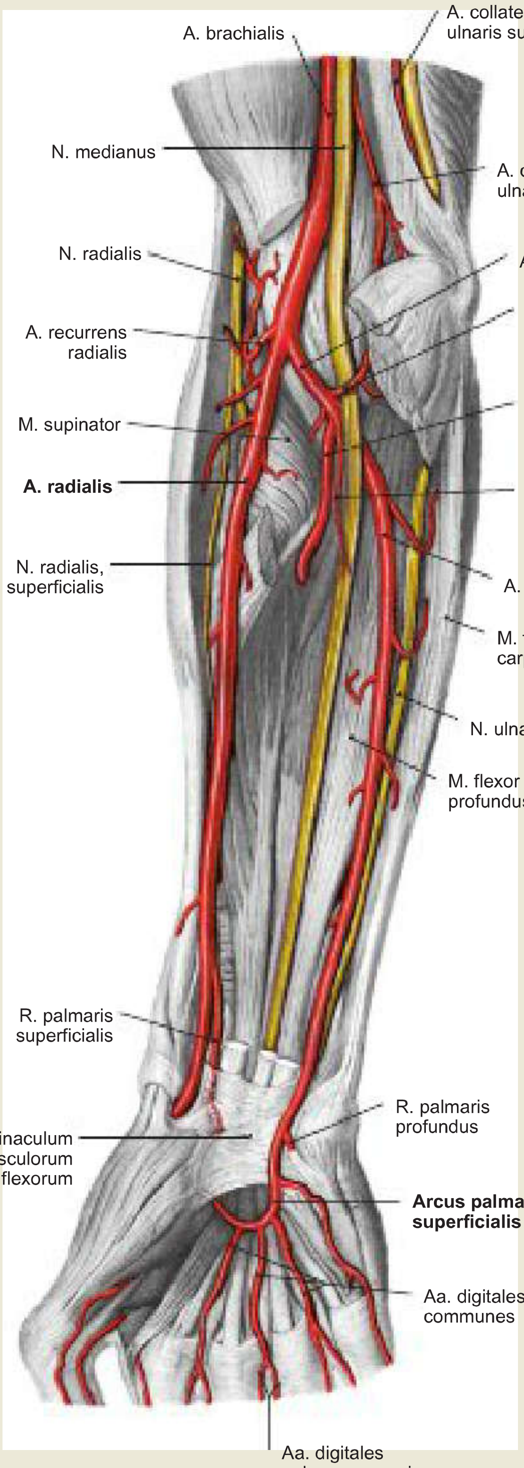


Fig. 3.131 A. radialis and A. ulnaris, right side; medial-ventral view after removal of the superficial flexor muscles of the forearm and of the palmar nerves. [S010-2-16]

The **A. ulnaris** branches off the A. brachialis dorsal to the M. pronator teres, provides the A. interossea communis and then runs together with the N. ulnaris beneath the M. flexor carpi ulnaris to the proximal wrist. It passes with the nerve through the **GUYON's canal** and is the main tributary of the superficial palmar arch **(Arcus palmaris superficialis).**

Branches of the A. ulnaris:

- **A. recurrens ulnaris:** it courses beneath the M. pronator teres to the Rete articulare cubiti.
- **A. interossea communis:** it is a short, strong blood vessel and divides into the
  - **A. interossea anterior:** it runs on the Membrana interossea antebrachii and penetrates it on the way to the Rete carpale dorsale.
  - **A. comitans nervi mediani:** this usually thin vessel accompanies the N. medianus.
  - **A. interossea posterior:** it passes through the Membrana interossea antebrachii to the Rete carpale dorsale. Below the M. anconeus it provides the **A. interossea recurrens** which leads to the Rete articulare cubiti.
- **R. carpalis dorsalis:** branch leading to the Rete carpale dorsale.
- **R. palmaris profundus:** it leads to the Arcus palmaris profundus.
- **Arcus palmaris superficialis:** The superficial palmar arch lies under the palmar aponeurosis on the tendons of the long flexor muscles, is supplied mainly by the A. ulnaris, and anastomoses with the R. palmaris superficialis of the A. radialis, which closes the arch. The **Aa. digitales palmares communes,** which divide into the **Aa. digitales palmares propriae** originate from the superficial palmar arch. These vessels represent the finger arteries.

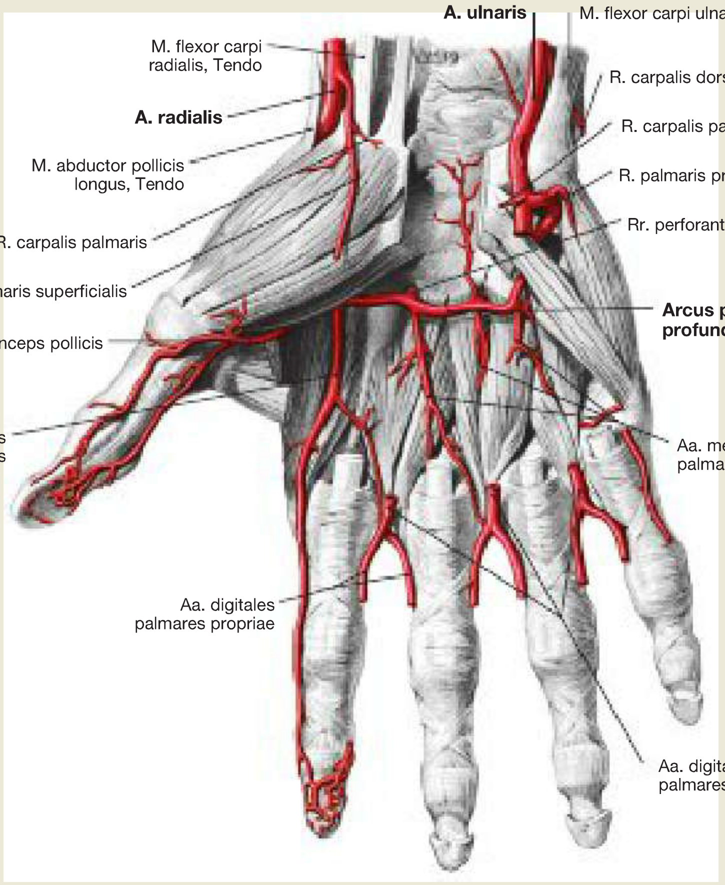


Fig. 3.132 Deep palmar arch, Arcus palmaris profundus, right side; palmar view after removal of the palmar aponeurosis, superficial palmar arch, palmar nerves and tendons of the long finger flexors. [S010-2-16]
The **A. radialis** forms the deep palmar arch **(Arcus palmaris profundus).** It lies below the M. adductor pollicis on the metacarpal bones and joins the R. palmaris profundus of the A. ulnaris. The three **Aa. metacarpales palmares** supply the Mm. interossei and connect distally with the finger arteries.

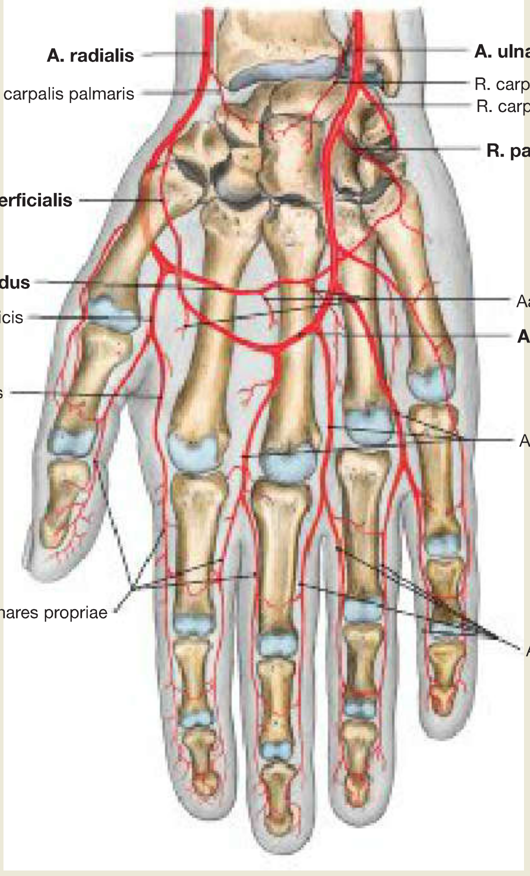


Fig. 3.133 Arteries of the hand, right side; palmar view.
The palm is supplied by the A. radialis and A. ulnaris, which are normally both involved in the formation of the two deep palmar arches. The **A. radialis** joins the **deep palmar arch** (Arcus palmaris profundus) and sends a connecting branch to the superficial palmar arch. Conversely the **A. ulnaris** forms the **superficial palmar arch** (Arcus palmaris superficialis) and sends a branch to the Arcus palmaris profundus.

Venous and Lymphatic Vessels of the Arm

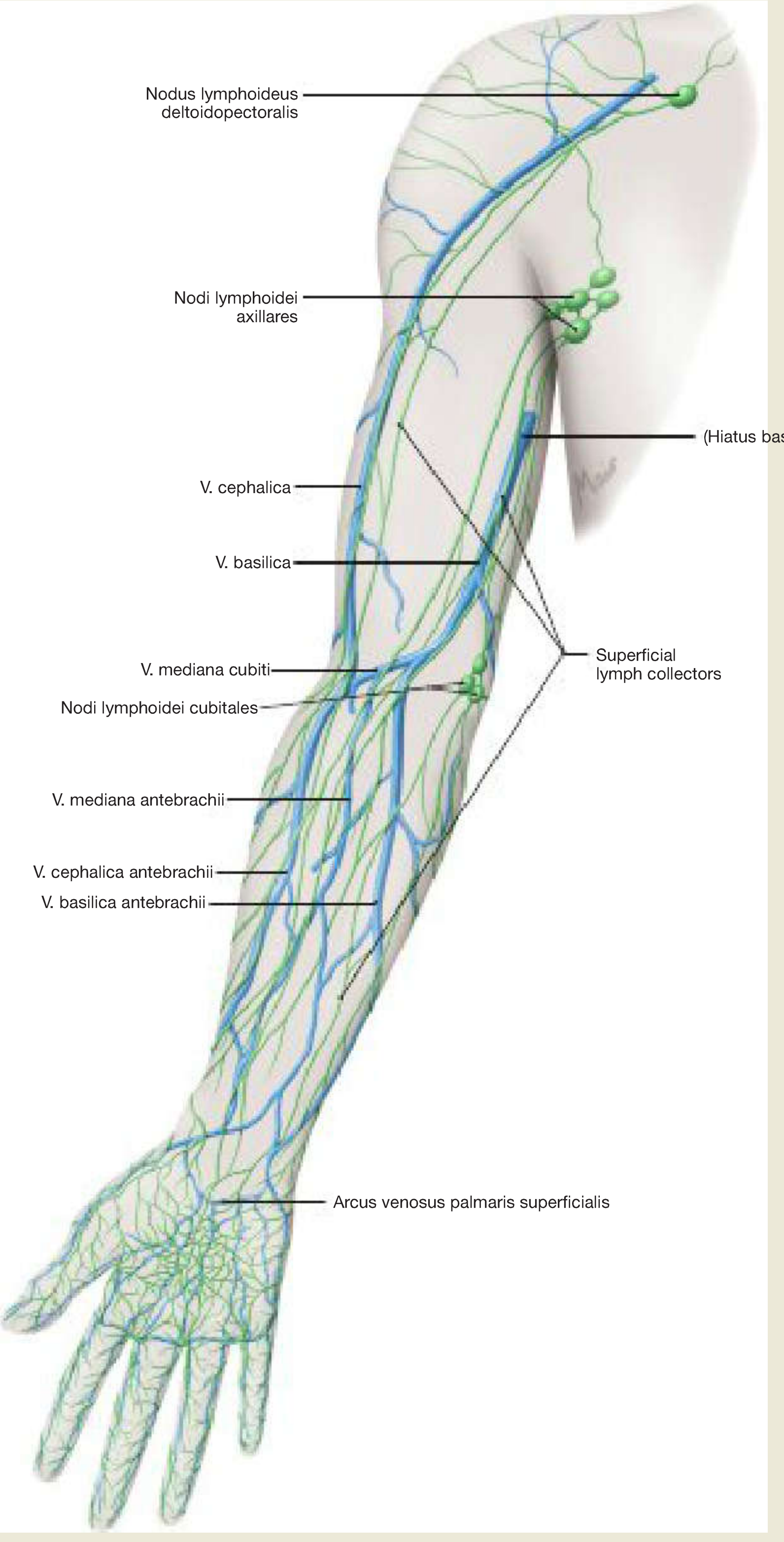


Fig. 3.134 Superficial veins and lymphatic vessels, right side; ventral view. [L127]

The **superficial venous system** of the arm consists of **two major trunks** which collect the venous blood from the hand:

On the dorsal side of the thumb, the **V. cephalica antebrachii** collects the blood from the venous plexus of the back of the hand, and then passes to the radial flexion side, where it connects in the cubital fossa via the V. mediana cubiti with the V. basilica antebrachii. In the upper arm, the V. cephalica runs in the Sulcus bicipitalis lateralis, and then flows into V. axillaris in the Trigonum clavipectorale (MOHRENHEIM's fossa). In the upper arm, this vessel may be poorly developed or absent.

The **V. basilica antebrachii** begins on the ulnar side of the back of hand, then changes to the ulnar flexion side and finally flows into the Vv. brachiales, located in the Hiatus basilicus in the lower half of the upper arm.

The **superficial epifascial lymph collectors** form a **radial,** an **ulnar** and a **medial** bundle in the forearm. In the upper arm the **medial brachial bundle** of the V. basilica follows, which drains into the axillary lymph nodes, while the **dorsolateral brachial bundle** which runs along the V. cephalica, is additionally linked to the supraclavicular lymph nodes.

The first regional lymph nodes of both lymphatic systems are located predominantly in the axilla (Nodi lymphoidei axillares); single lymph nodes are, however, also present in the cubital fossa (Nodi lymphoidei cubitales).

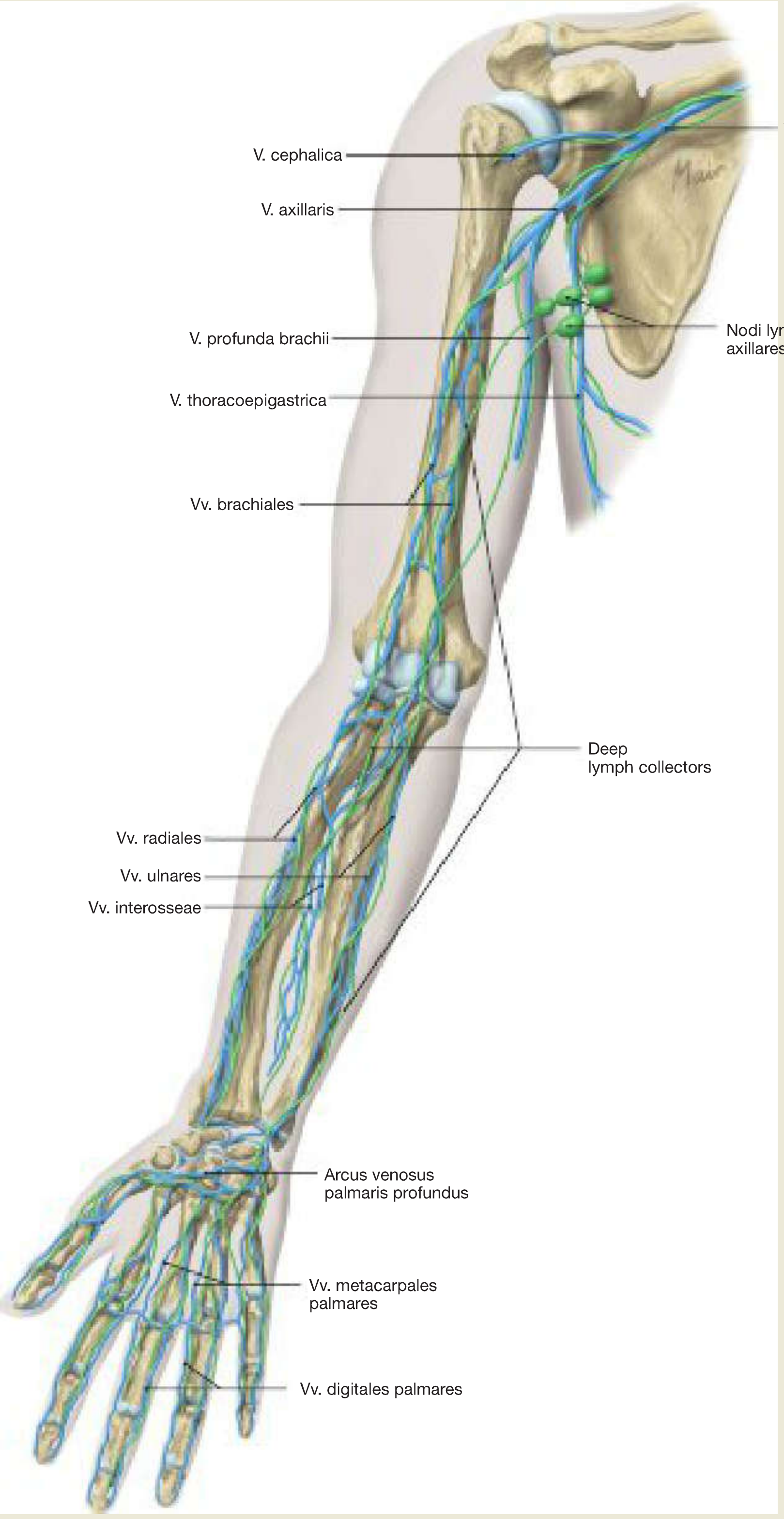


Fig. 3.135 Deep veins and lymphatic vessels, right side; ventral view. [L127]
The **deep venous system** and the **deep subfascial lymph collectors** accompany the respective arteries. The deep lymph collectors also drain mainly into the axillary lymph nodes (Nodi lymphoidei axillares), but are also linked to the lymph nodes of the cubital fossa (Nodi lymphoidei cubitales).

Lymph Nodes and Lymphatic Vessels of the Axilla

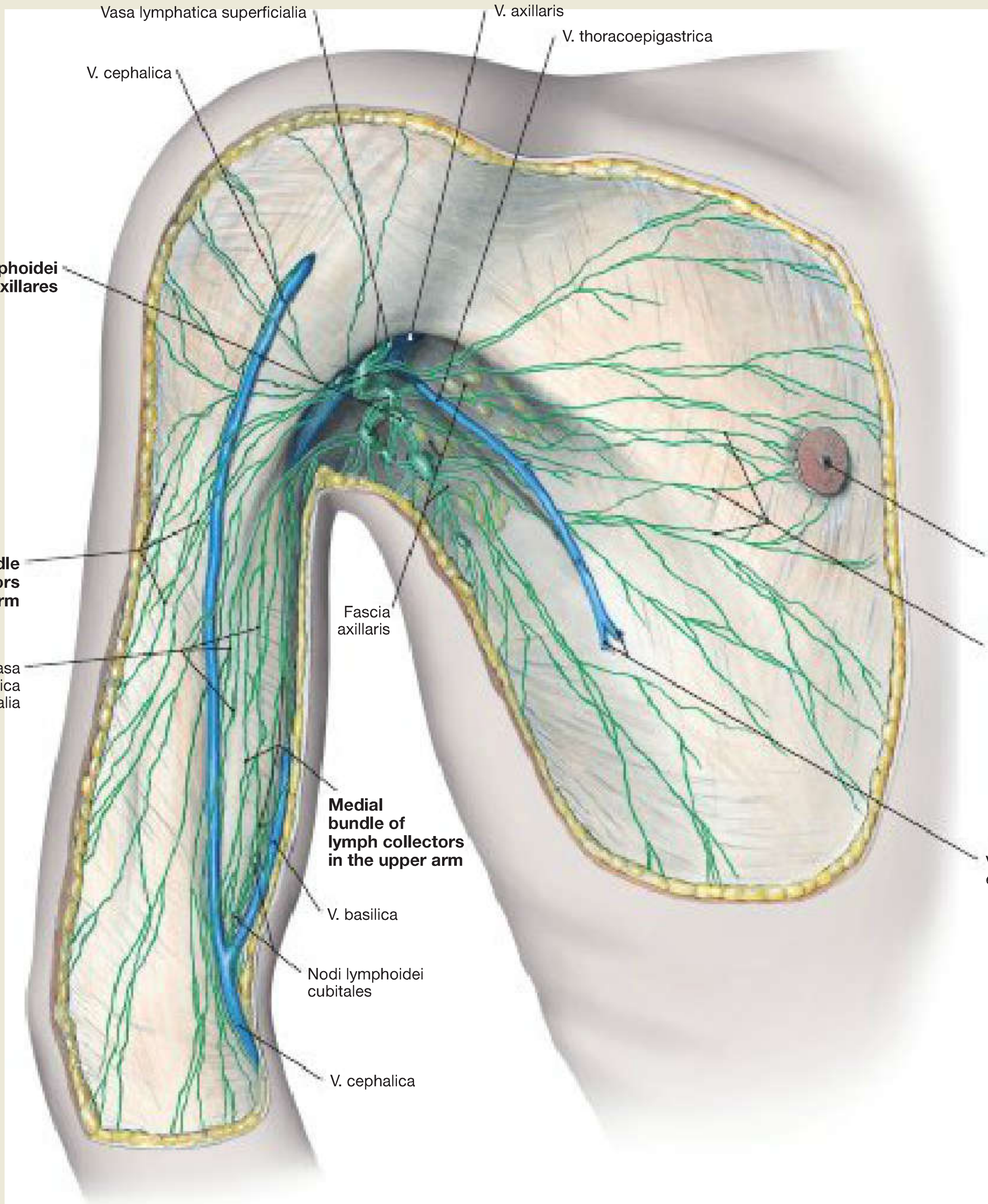


Fig. 3.136 Superficial lymphatic vessels and lymph nodes in the axilla, Fossa axillaris, and the lateral thoracic wall, Regio thoracica lateralis, right side; ventral view.

In the upper arm, the superficial epifascial lymph collectors form a medial bundle along the V. basilica and a dorsolateral bundle along the V. cephalica, both of which are mainly linked to the axillary lymph nodes. The axillary lymph nodes (Nodi lymphoidei axillares) are not only the regional lymph nodes of the arm, but also collect the lymph of the upper quadrants of the dorsal and ventral thoracic walls.

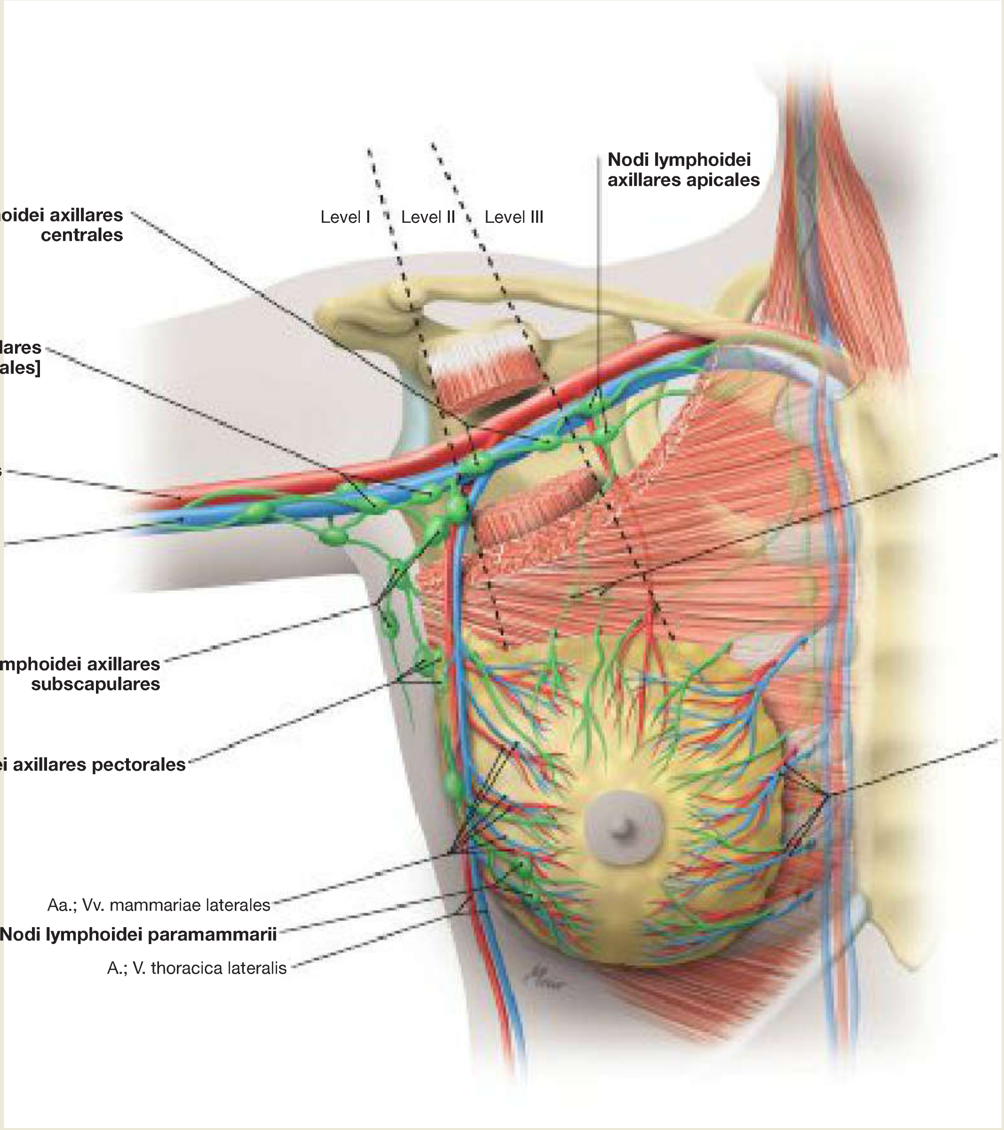


Fig. 3.137 Levels of lymph nodes in the axilla, Fossa axillaris, right side; ventral view. [L127]

In the adipose tissue of the axilla lie up to **50 lymph nodes** (Nodi lymphoidei axillares) which collect the lymph of the arm, the upper thoracic wall including the breast, and of the upper back. The lymph nodes are organised in **three levels** which are clinically important for the treatment of breast cancer. This division is based on the topographical relationship to the **M. pectoralis minor.** Superficial and deep lymph nodes are present in all three levels, but often cannot be attributed clearly to one of these two groups. However, the apical lymph nodes of level III collect the lymph of all other groups and serve as the last lymph node station prior to the Truncus subclavius which drains into the Ductus thoracicus (left side) or into the Ductus lymphaticus dexter (right side; topography of the axillary lymph nodes → Fig. 3.148).

Levels of axillary lymph nodes:
Level I, inferior group, lateral of the M. pectoralis minor:
- Nodi lymphoidei paramammarii (lateral of the mammary gland)
- Nodi lymphoidei axillares pectorales (along the A. and V. thoracica lateralis)
- Nodi lymphoidei axillares subscapulares (along the A. and V. subscapularis as well as the A. and V. thoracodorsalis)
- Nodi lymphoidei axillares laterales (along the A. and V. axillaris)

Level II, middle or median group, on and under the M. pectoralis minor:
- Nodi lymphoidei interpectorales (between M. pectoralis minor and M. pectoralis major)
- Nodi lymphoidei axillares centrales (under the M. pectoralis minor)

Level III, superior group, medial of the M. pectoralis minor:
- Nodi lymphoidei axillares apicales (subfascial in the Trigonum clavipectorale = MOHRENHEIM's fossa)

Clinical Remarks

Palpation of the lymph nodes is part of a complete physical examination. The physician should be aware that the axillary lymph nodes represent the regional lymph nodes for both the arm and the upper thoracic wall. Due to the frequency of breast cancer (approx. one in ten women will suffer from this once in her lifetime, but also men can be affected), each palpable enlarged axillary lymph node in women should be suspected as a sign of possible breast cancer.

Currently, the surgical removal of axillary lymph nodes **(lymphadenectomy)** as part of the surgical treatment in breast cancer patients is controversial, since it is not proven that this procedure, in addition to removal of the primary tumour, increases the survival rates. However, the diagnostic lymphadenectomy to determine the tumour growth and spreading (staging) is of great importance and requires knowledge of the topography of axillary lymph nodes.

Superficial Blood Vessels and Nerves of the Axilla

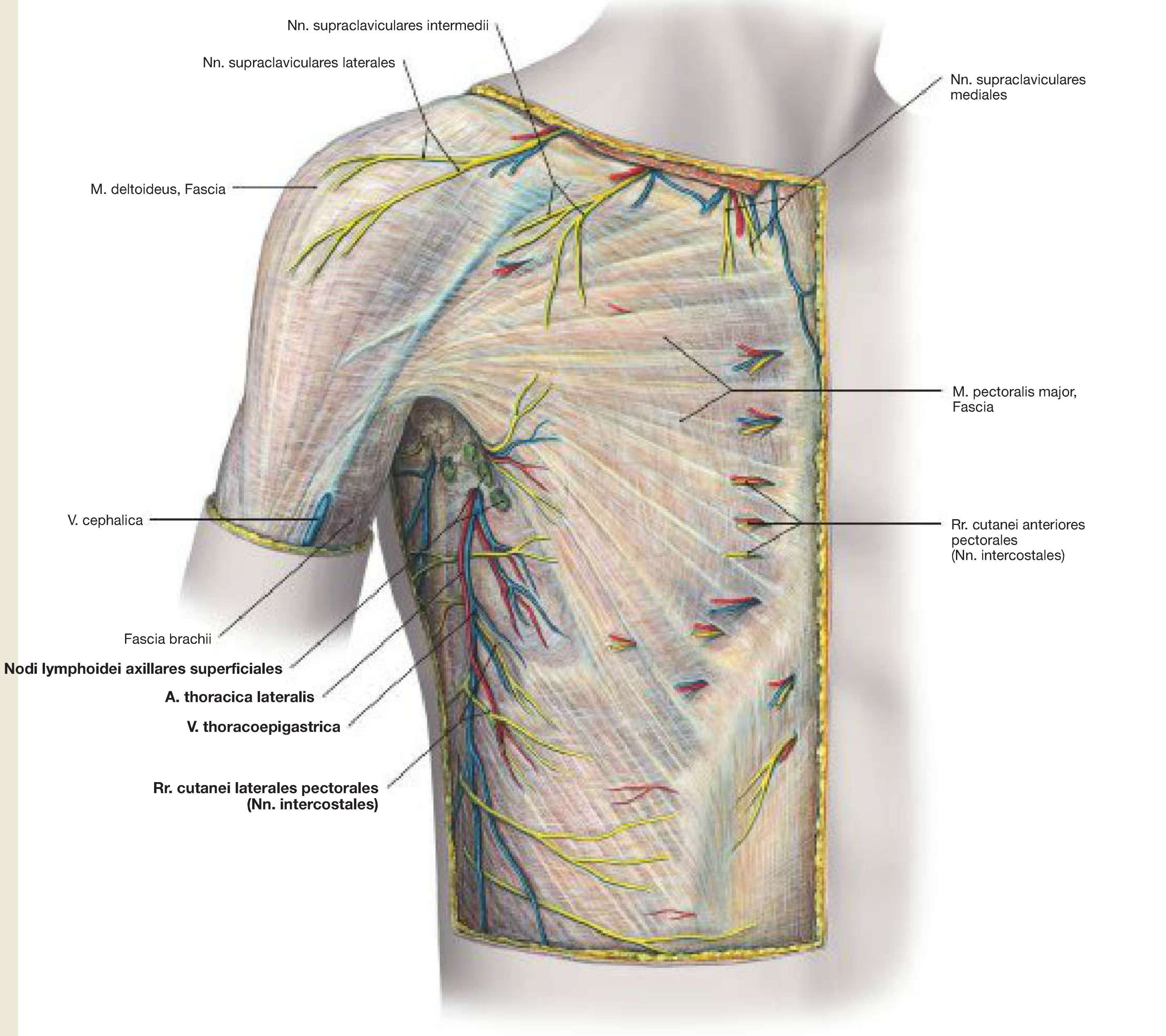


Fig. 3.138 Epifascial blood vessels and nerves in the axilla, Fossa axillaris, and the lateral thoracic wall, Regio thoracica lateralis, right side; ventral view.

Next to the superficial axillary lymph nodes (Nodi lymphoidei axillares superficiales), epifascial blood vessels and nerves are located in the axilla and the lateral thoracic wall. The V. thoracoepigastrica is very variably developed and lies approximately at the level of the anterior axillary fold, which is formed by the M. pectoralis major. It is sometimes accompanied by a branch of the A. thoracica lateralis. In the respective intercostal spaces, the lateral cutaneous branches of the Nn. intercostales leave the axilla (Rr. cutanei laterales pectorales).

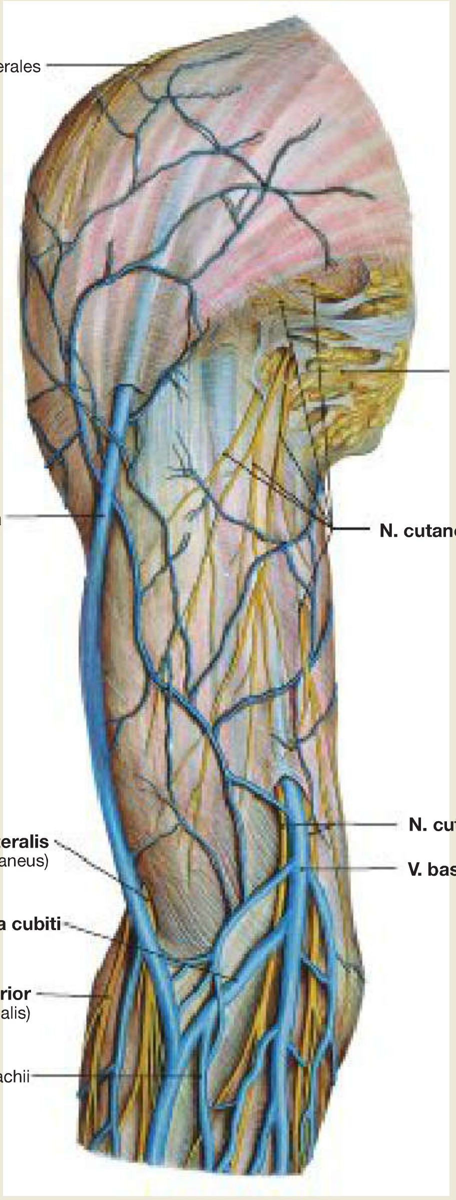


Fig. 3.139 Epifascial veins and nerves of the shoulder, Regio deltoidea, upper arm, Regio brachii anterior, and cubital region, Regio cubitalis anterior, right side; ventral view.

In the upper arm, the **V. cephalica** ascends in the Sulcus bicipitalis lateralis and lies in the shoulder region between the origins of the M. deltoideus and M. pectoralis major. In the cubital fossa it is usually connected via a **V. mediana cubiti** with the V. basilica. In the Sulcus bicipitalis medialis in the lower half of the upper arm, the **V. basilica** passes through the Fascia brachii and flows into one of the two Vv. brachiales. The **N. cutaneus brachii medialis** pierces the fascia in the axillary region with several thin cutaneous nerves, which radiate along the medial upper arm. These connect in parts with the **Nn. intercostobrachiales** from the Nn. intercostales. In the distal part of the upper arm, the cutaneous branches for the forearm pass through the fascia. The **N. cutaneus antebrachii medialis** accompanies the V. basilica the **N. cutaneus antebrachii lateralis** accompanies the V. cephalica. Since the N. cutaneus antebrachii lateralis is the sensory terminal branch of the N. musculocutaneus, it emerges between the M. biceps brachii and the underlying M. brachialis, between which the N. musculocutaneus runs. The **N. cutaneus antebrachii posterior** appears further laterally.

Clinical Remarks

Due to its good accessibility, the **V. cephalica** is frequently used for the implantation of **cardiac pacemakers** or **port systems** (for the application of chemotherapies or parenteral nutrition). There are also **central venous catheters (CVCs)** which can be introduced into the upper vena cava via the V. cephalica.

Superficial Blood Vessels and Nerves of the Upper Arm and Shoulder

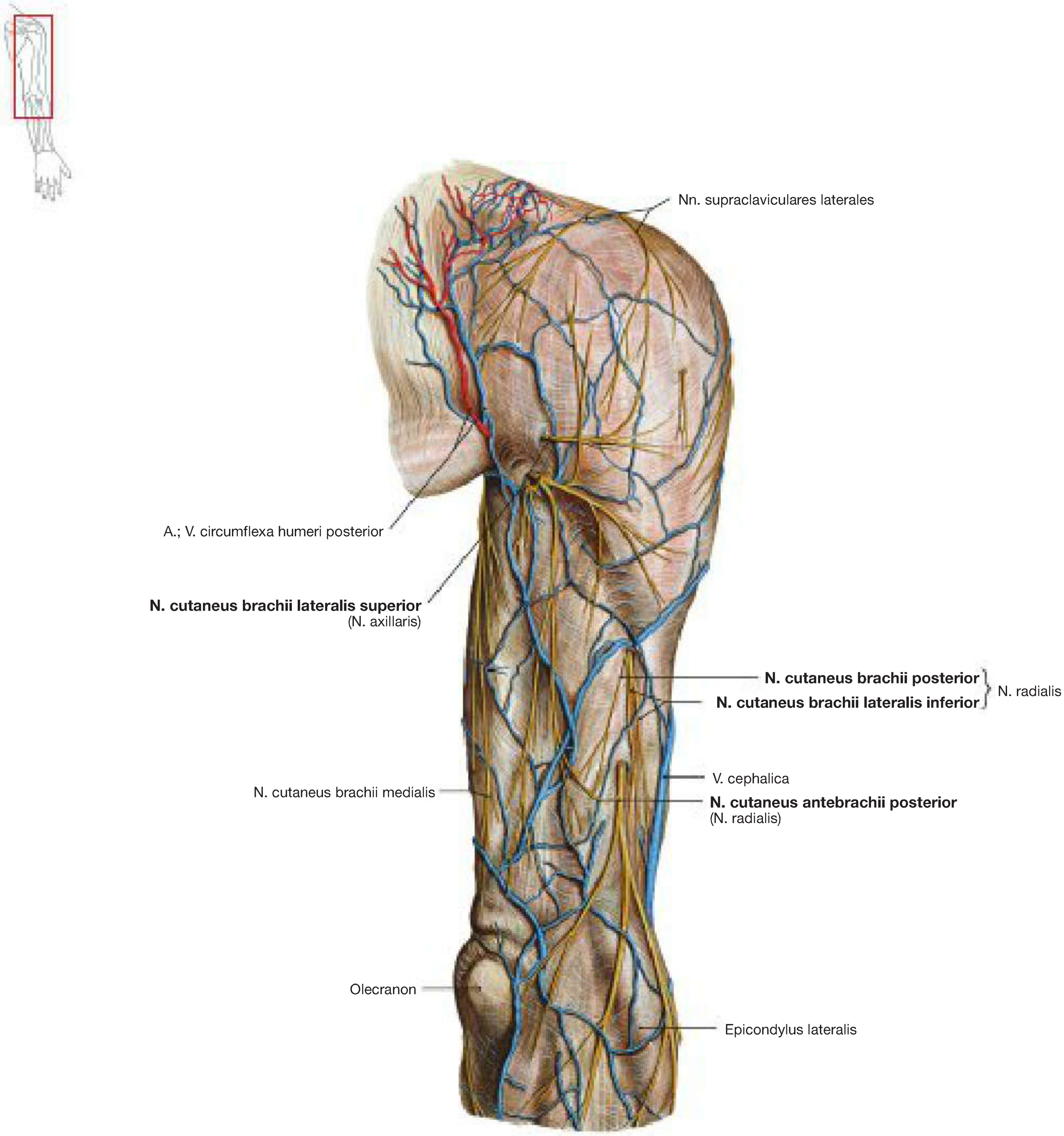


Fig. 3.140 Epifascial blood vessels and nerves of the shoulder, Regio deltoidea, upper arm, Regio brachii posterior, and cubital region, Regio cubitalis posterior, right side; dorsolateral view.
The **N. cutaneus brachii lateralis superior** is the sensory terminal branch of the N. axillaris. It passes through the fascia at the lower edge of the M. deltoideus, which is innervated by the N. axillaris. The **N. cutaneus brachii lateralis inferior, N. cutaneus brachii posterior** and **N. cutaneus antebrachii posterior**, however, are branches of the N. radialis and push through the fascia lateral of the M. triceps brachii. The exit of the N. cutaneus antebrachii posterior can usually be found between the M. triceps brachii and the ventrally located M. brachialis.

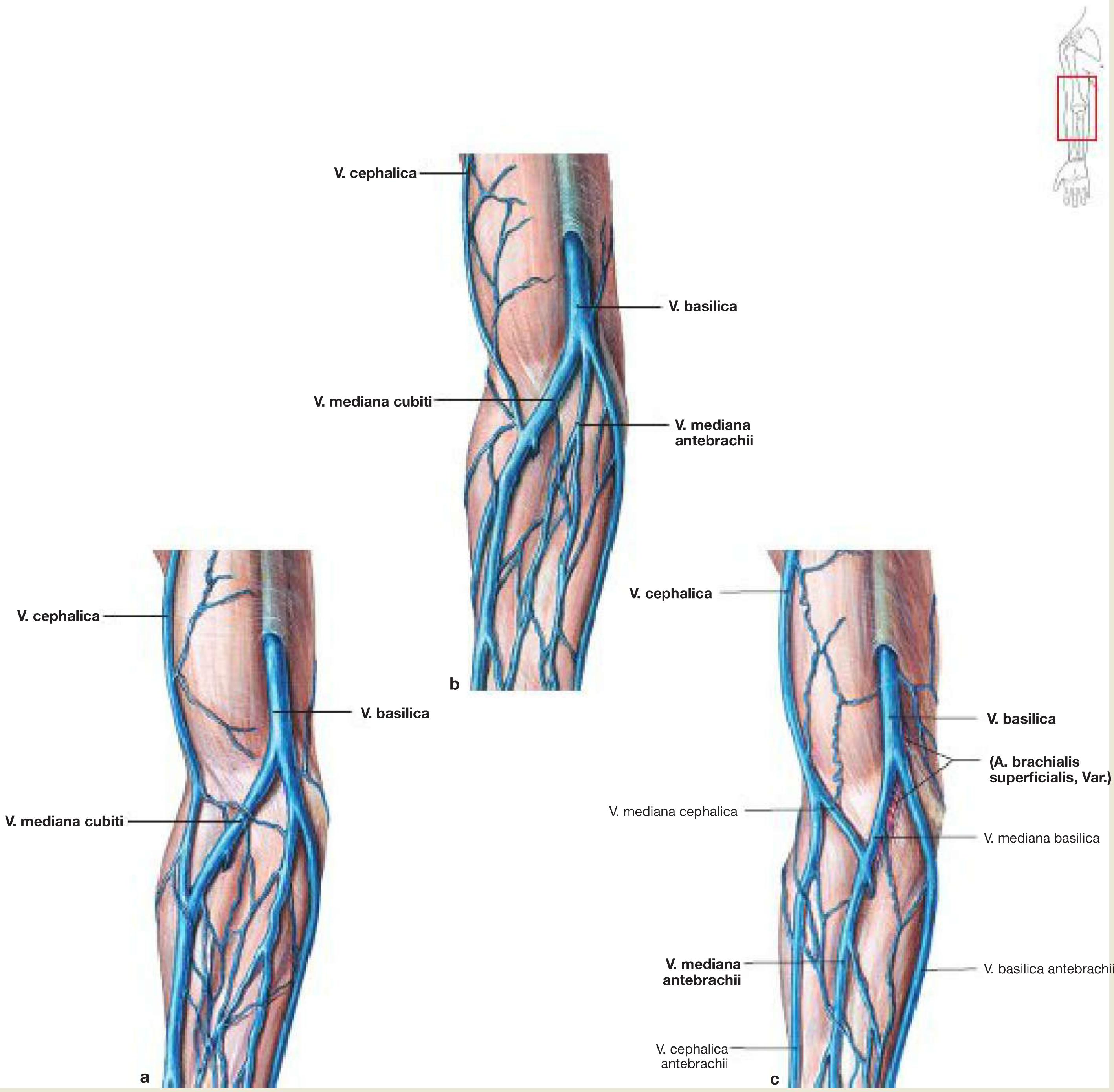


Fig. 3.141a to c Variations of epifascial veins in the cubital fossa, Regio cubitalis anterior, right side; ventral view.
As a general rule, a **V. mediana cubiti** connects the **V. cephalica** with the **V. basilica** (→ Fig. 3.141a and b). But the **V. cephalica** may vary substantially in the upper arm and can even be absent. Sometimes, the V. mediana cubiti is missing, but the V. cephalica antebrachii and the V. basilica antebrachii communicate indirectly via their connections to a V. mediana antebrachii on the front of the forearm (→ Fig. 3.141c). Special attention should be paid to the possibility of an additional A. brachialis superficialis, being present in the cubital fossa which may be situated right next to the veins.

Clinical Remarks

The veins in the cubital fossa are important for **taking blood** and for the **intravenous administration** of drugs. Because of their great variability, it is recommended to examine the exact course of the veins and to palpate them. If an arterial pulse can be felt, a superficial A. brachialis should be considered. Drugs should not be injected into the artery, because some substances may have toxic effects due to the insufficient dilution in the case of an intra-arterial injection.

Superficial Blood Vessels and Nerves of the Forearm

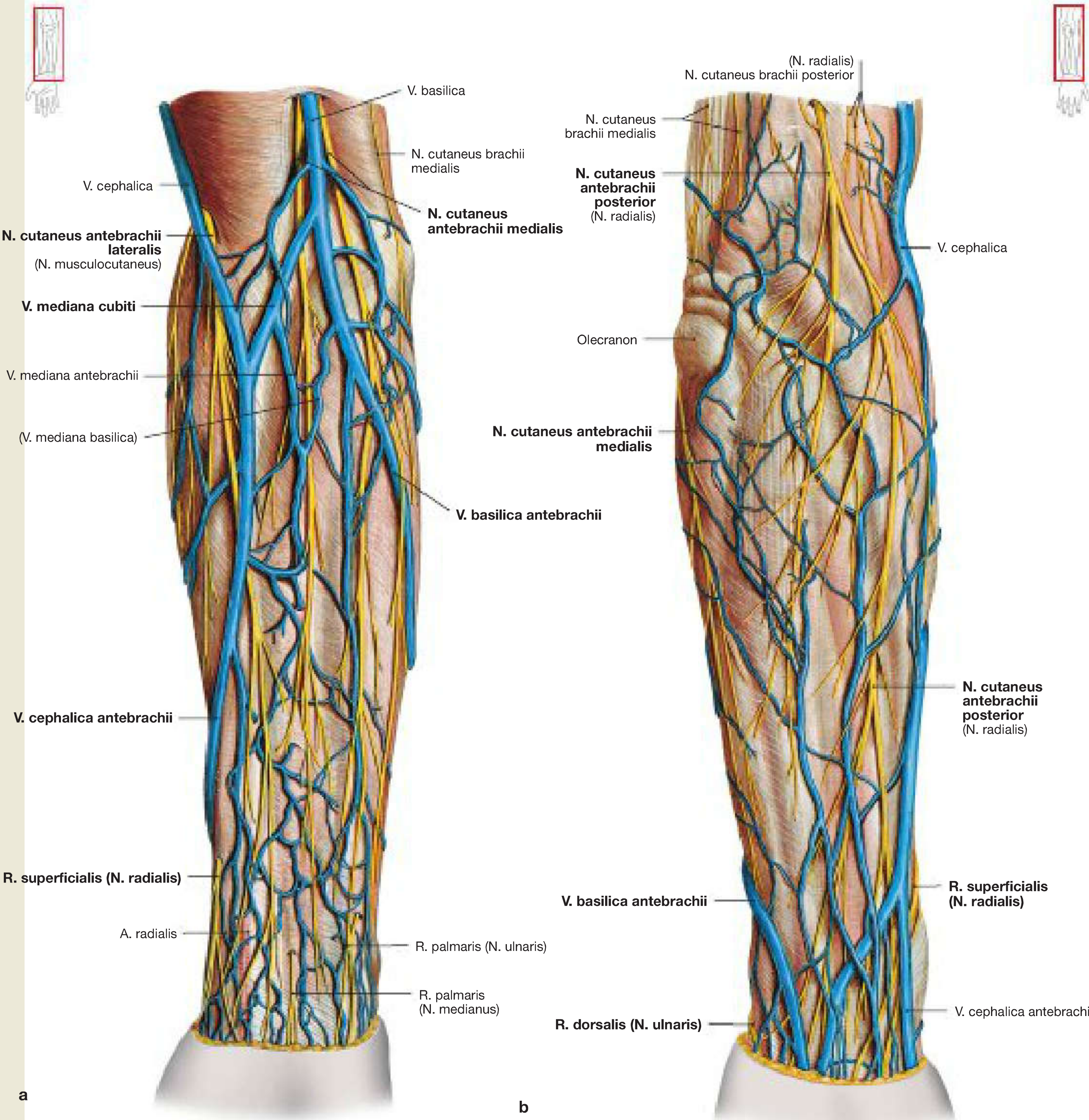


Fig. 3.142a and b Epifascial veins and nerves of the forearm regions, Regio antebrachii anterior and Regio antebrachii posterior, and of the cubital region, Regio cubitalis anterior, right side, ventral view (→ Fig. 3.142a) and dorsal view (→ Fig. 3.142b).

The **V. cephalica antebrachii** originates from the superficial venous plexus on the dorsal side of the thumb (Rete venosum dorsale manus), and then switches onto the radial ventral side of the forearm, while the **V. basilica antebrachii** passes from the ulnar back of the hand to the ulnar ventral side. In the cubital fossa, both veins usually communicate via the **V. mediana cubiti.** The cutaneous nerves and their branches fan out on the forearm. The **N. cutaneus antebrachii medialis** runs adjacent to the V. basilica, while the **N. cutaneus antebrachii lateralis** runs initially with the V. cephalica. The **N. cutaneus antebrachii posterior** exits between the M. triceps brachii and M. brachialis. On the distal forearm the **R. superficialis of the N. radialis** penetrates the fascia under the tendon of the M. brachioradialis and reaches the back of the hand. Similarly, the **R. dorsalis of the N. ulnaris** passes beneath the tendon of the M. flexor carpi ulnaris onto the dorsal side. The palmar branches of the N. medianus and N. ulnaris, which are located proximal to the wrists, can generally not be exposed well in dissections.

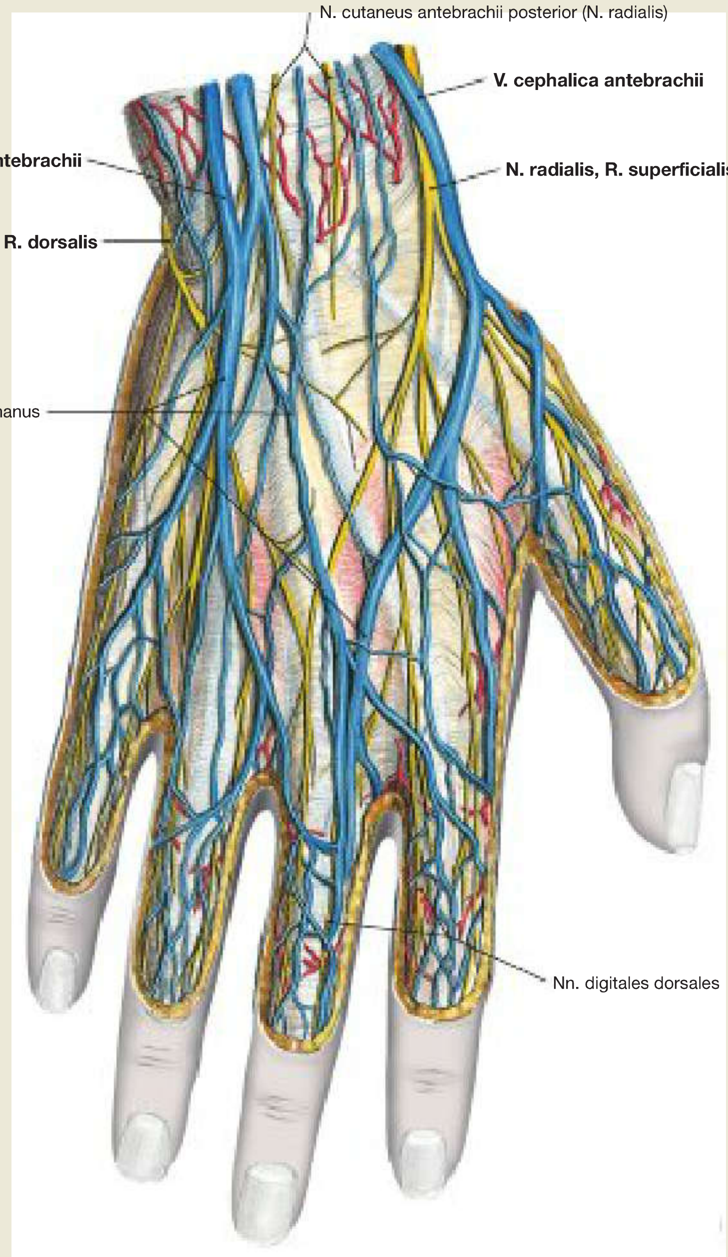


Fig. 3.143 Epifascial vessels and nerves of the back of the hand, Dorsum manus, right side; dorsal view.
The **V. cephalica antebrachii** originates from the superficial venous plexus on the dorsal side of the thumb, while the **V. basilica antebrachii** is supplied by ulnar veins on the back of the hand. Above the proximal wrist, the **R. superficialis of the N. radialis** passes beneath the tendon of the M. brachioradialis through the fascia onto the back of the hand. It divides into the Nn. digitales dorsales, which supply sensory innervation to the radial 2½ fingers dorsally. The ulnar 2½ fingers are innervated by the **R. dorsalis of the N. ulnaris,** which passes under the tendon of the M. flexor carpi ulnaris to the dorsal side.

Axilla

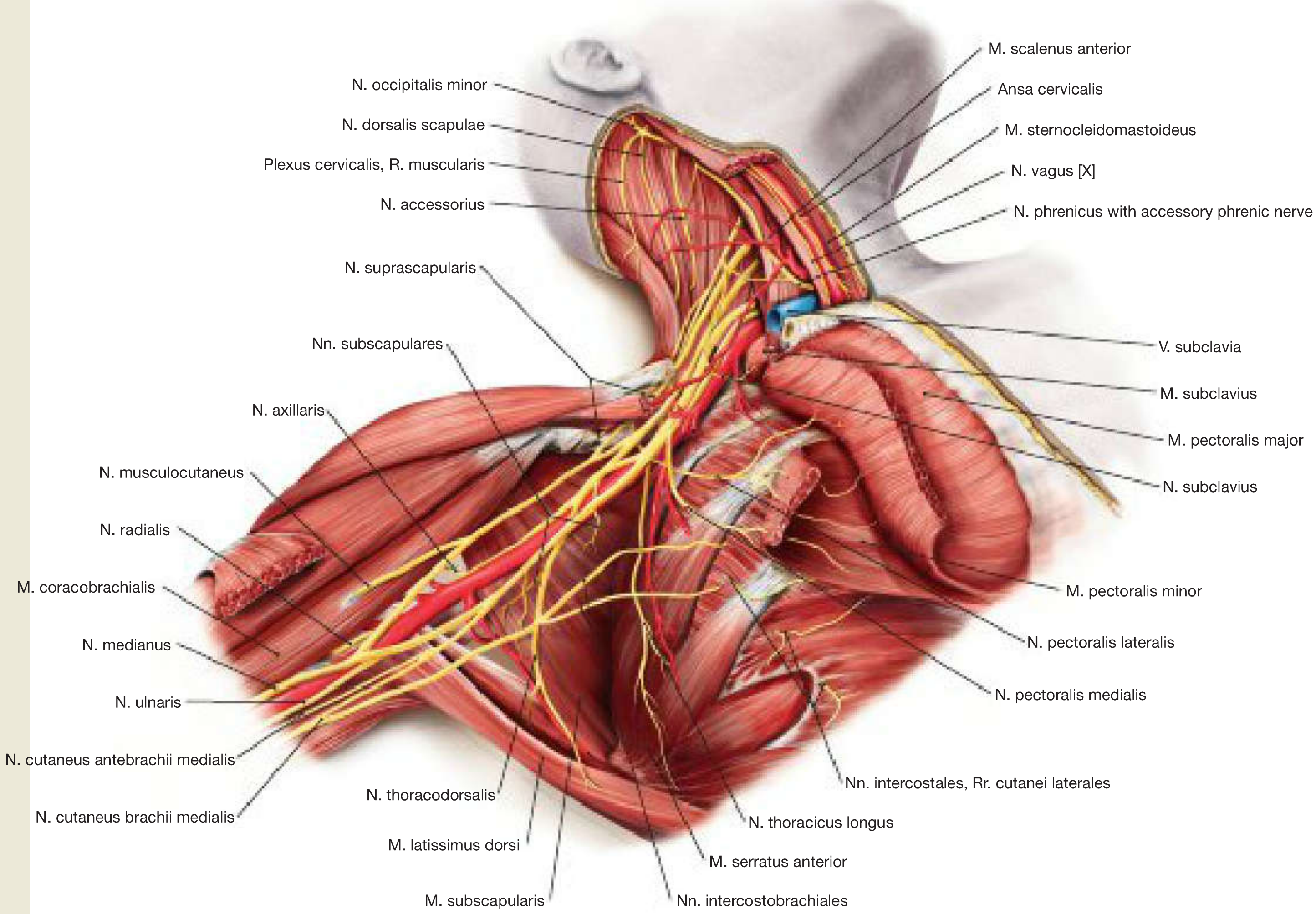


Fig. 3.144 Axilla, Fossa axillaris, with nerves from the Plexus brachialis and arterial branches of the A. axillaris, right side; ventral view after cutting through the Mm. pectorales major and minor near their insertions. [L266]

The **N. dorsalis scapulae** pierces the M. scalenus medius at a relatively high cranial level and is only visible ventrally as is shown here, if the head is greatly extended backwards and to the opposite side. It passes dorsally under the M. levator scapulae **(indicator muscle!).** The **A. transversa cervicis/colli** passes above the Plexus brachialis to the lower part of the M. trapezius. The **N. suprascapularis** turns laterally after leaving the Truncus superior and runs adjacent to the **A. suprascapularis**. While the nerve under the Lig. transversum scapulae superius passes through the Incisura scapulae, the artery crosses the ligament. The **N. subclavius** is usually inconspicuous and difficult to expose. It courses medially to reach the M. subclavius, and sometimes sends a branch to the N. phrenicus ('accessory phrenic nerve'). Underneath it the **A. thoracica superior** passes to the chest wall. The **N. thoracicus longus** originates from the supraclavicular part of the Plexus brachialis, but then crosses underneath the plexus on its way to the chest wall, where it terminates on the M. serratus anterior.

The **A. thoracoacromialis** originates in the Trigonum clavipectorale and the **Nn. pectorales medialis and lateralis** originate from the respective fascicles of the Plexus brachialis and innervate the pectoral muscles. The **A. thoracica lateralis** descends caudally at the lateral margin of the M. pectoralis minor. Then the **A. subscapularis** branches off the A. axillaris and divides into the **A. circumflexa scapulae,** which passes through the medial axillary space, and into the **A. thoracodorsalis, which** run adjacent to the **N. thoracodorsalis** and descends at the anterior margin of the M. latissimus dorsi.

The **Nn. subscapulares** leave the posterior fascicle of the Plexus brachialis and run medially to join the muscle of the same name, whereas the **N. axillaris** branches off in the lateral direction and turns dorsally with the **A. circumflexa humeri posterior** to pass through the lateral axillary space. This blood vessel connects with the A. circumflexa humeri anterior, which is the last branch of the A. axillaris.

The arm nerves of the infraclavicular part of the Plexus brachialis originate directly from the fascicles. The **N. radialis** continues the course of the posterior fascicle and passes through the triceps slit onto the back of the upper arm. The **N. musculocutaneus** originates from the lateral fascicle, passes laterally and usually penetrates the M. coracobrachialis. The remaining nerve fibres form the lateral portion of the **N. medianus,** of which the medial portion originates from the medial fascicle, which previously still provided the **N. ulnaris** and the sensory **Nn. cutanei brachii and antebrachii mediales** to the medial upper arm.

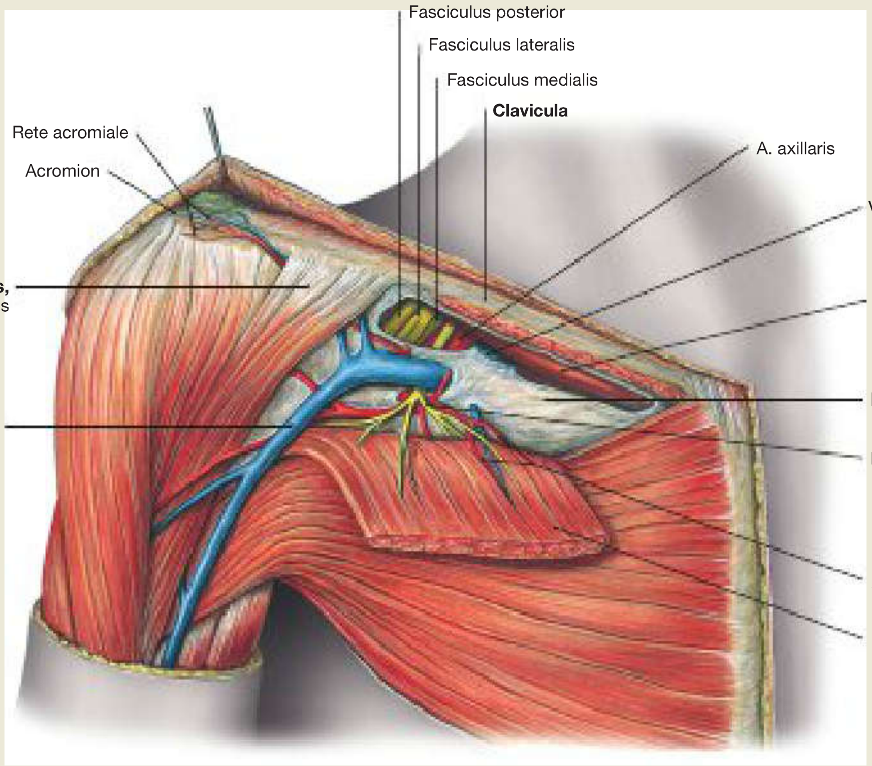
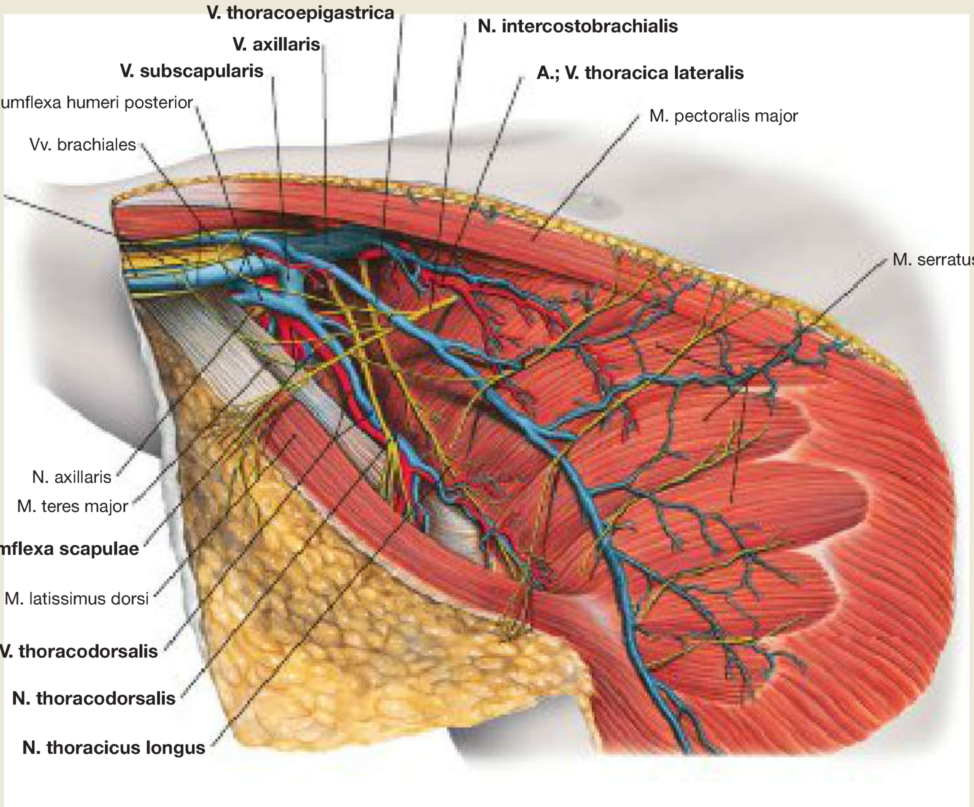


Fig. 3.145 Trigonum clavipectorale (MOHRENHEIM's fossa), right side.
The Trigonum clavipectorale is the narrow triangular space between the clavicle and and the origins of the M. pectoralis major and M. deltoideus. To expose the Trigonum clavipectorale in dissections, the origin point of the M. pectoralis major is detached from the clavicle and folded to the side, and the Fascia clavipectoralis is removed. In this triangle the **V. cephalica** flows into the V. axillaris, and the **Nodi lymphoidei axillares apicales** are also located there. Furthermore, the **A. thoracoacromialis** originates anteriorly from the A. axillaris and divides into its four terminal branches. The **Nn. pectorales medialis and lateralis** originate from the respective fascicles and pass together with the arterial branches to the pectoral muscles, which they supply.



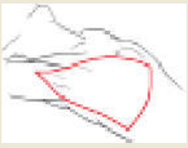


Fig. 3.146 Axilla, Fossa axillaris, right side; laterocaudal view.
The armpit is bordered by the M. pectoralis major in front and by the M. latissimus dorsi from behind, forming the two axillary folds. In the axilla, the three fascicles of the Pars infraclavicularis of the **Plexus brachialis** surround the **A. axillaris** and are covered ventrally by the **V. axillaris**. The **Nn. intercostobrachiales** from the **Nn. intercostales** cross the axilla and join the N. cutaneus brachii medialis. The **N. thoracodorsalis** passes with the blood vessels of the same name to the medial margin of the M. latissimus dorsi. Ventral thereof, the **N. thoracicus longus** descends on the M. serratus anterior and innervates it.

Axilla

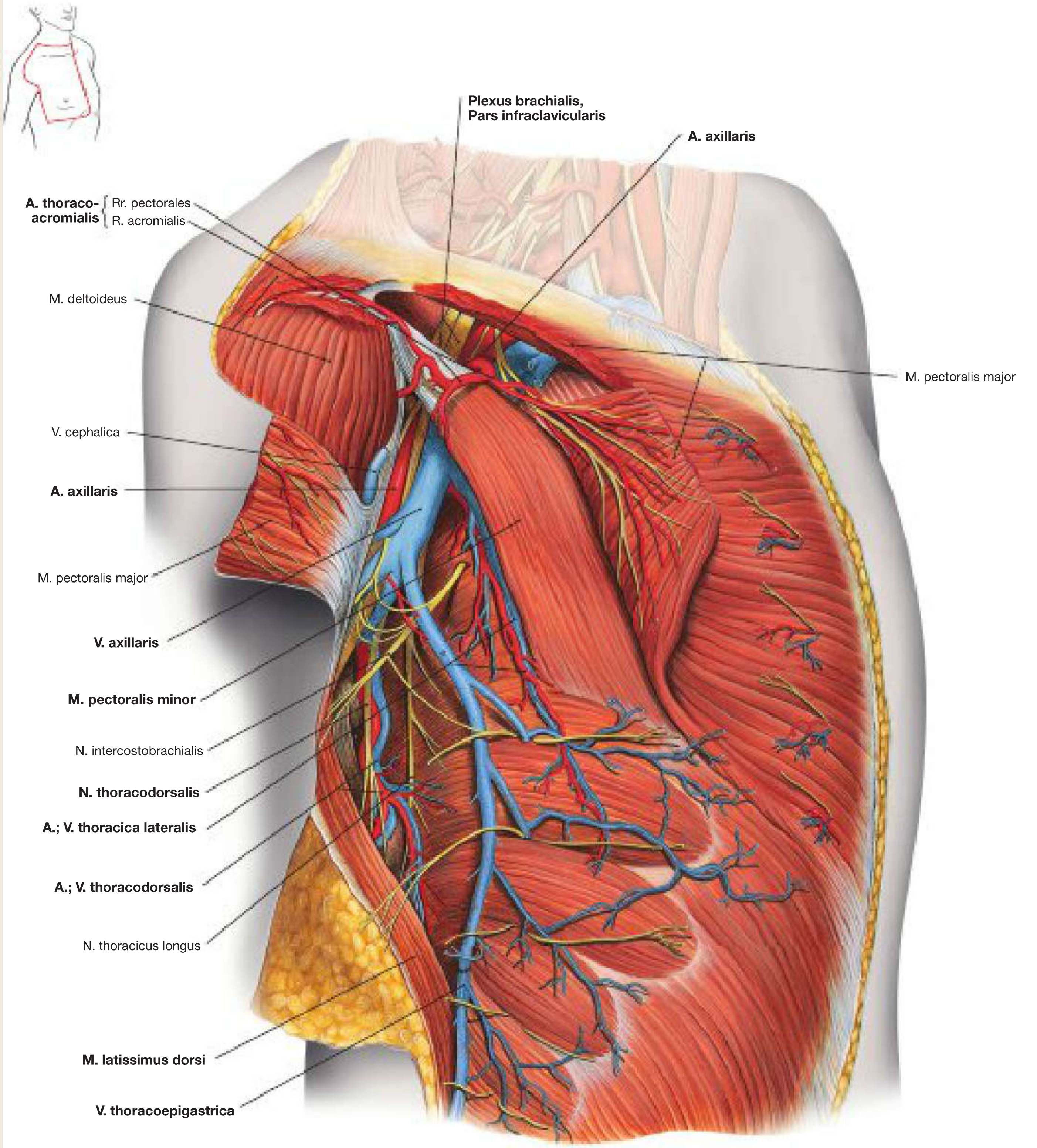
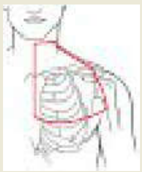


Fig. 3.147 Axilla, Fossa axillaris, and lateral chest wall, Regio thoracica lateralis, right side; lateral view.

Compared to → Fig. 3.146, the M. pectoralis major was split to expose the underlying **M. pectoralis minor** and the anatomical structures emerging from the Trigonum clavipectorale. On the superior margin of the M. pectoralis minor, the **A. thoracoacromialis** is shown with its branches. Together with the Nn. pectorales of the Plexus brachialis, the Rr. pectorales join up with the Mm. pectorales major and minor, which they supply. The M. pectoralis minor serves as an important landmark for the classification of axillary lymph nodes (→ Fig. 3.137). The **A. and V. thoracica lateralis run along its lateral margin.** Lateral thereof, the **A., V. and N. thoracodorsalis** descend to the inner surface of the M. latissimus dorsi, which they supply together. The V. thoracoepigastrica is not accompanied by an artery, and exhibits a very variable calibre and course (here it is well-developed) in the subcutaneous adipose tissue of the lateral thoracic wall.



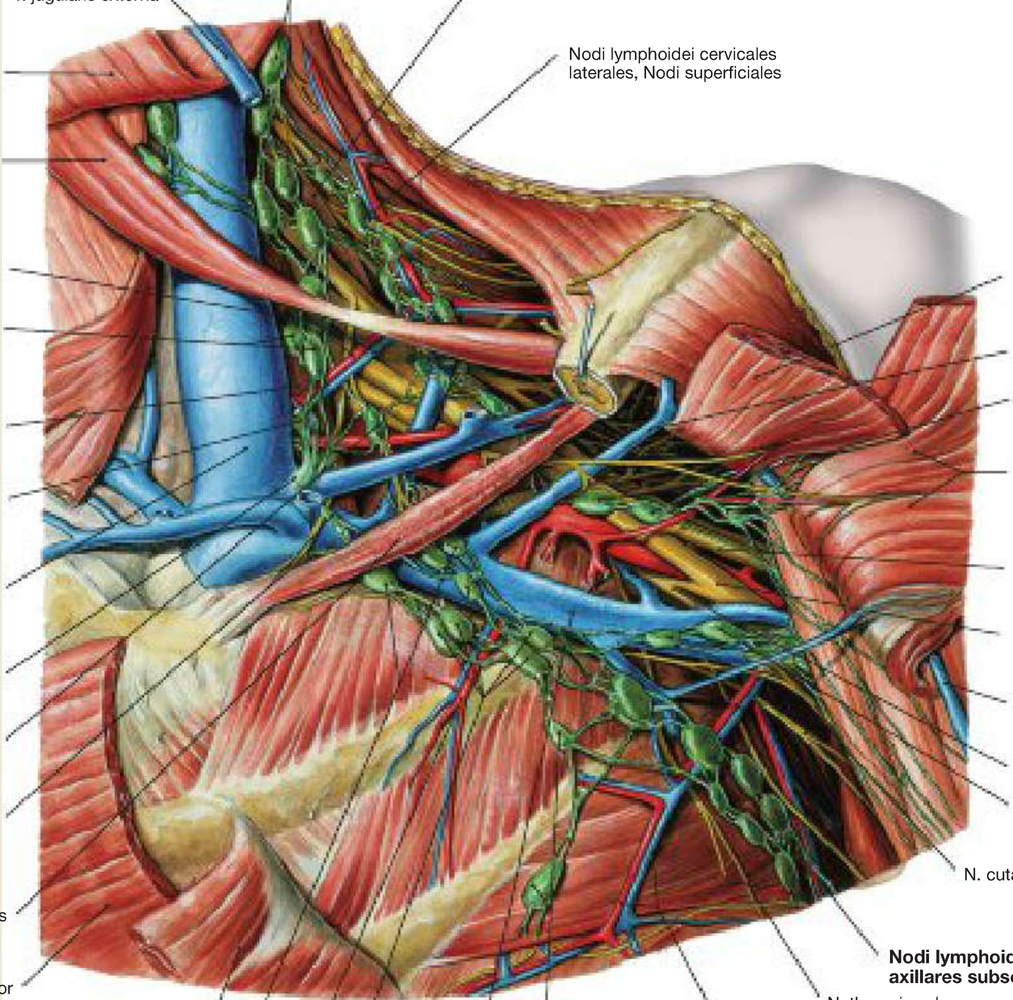


Fig. 3.148 Axilla, Fossa axillaris, and lateral chest wall, Regio thoracica lateralis, left side; ventral view.

In contrast to → Fig. 3.147, the left side of the body is shown here, to expose the **axillary lymphatic vessels** draining into the Ductus thoracicus, and its opening in the left venous angle, since this is often damaged in dissections. The M. pectoralis minor has been cut through, so that the axillary lymph nodes can be seen. According to their topographical relationship to the M. pectoralis minor, the axillary lymph nodes are grouped into **three levels** (→ Fig. 3.137). The first level (lateral of the M. pectoralis minor) includes the Nodi lymphoidei axillares pectorales along the A. and V. thoracica lateralis, as well as, further lateral, the Nodi lymphoidei axillares subscapulares and the Nodi lymphoidei axillares laterales along the V. axillaris. The second level (at the level of the M. pectoralis minor) includes the Nodi lymphoidei axillares centrales beneath the muscle. The third level (medial of the M. pectoralis minor) is the last station prior to the **Truncus subclavius,** which drains the lymph via the Ductus thoracicus on the left side into the left venous angle between the V. jugularis interna and V. subclavia.

Clinical Remarks

Before its opening into the left venous angle, the **Ductus thoracicus** collects the lymph of the entire inferior body half (including abdominal and pelvic organs), and additionally drains the lymph of the left thorax via the Truncus bronchomediastinalis sinister, as well as the lymph of the left arm via the Truncus subclavius sinister and the lymph of the left-sided head/neck region via the Truncus jugularis sinister.

Therefore, malignant tumours in the abdominal and pelvic region can spread with metastases in the left supraclavicular lymph nodes (so-called **VIRCHOW's glands**).

Vessels and Nerves of the Upper Arm

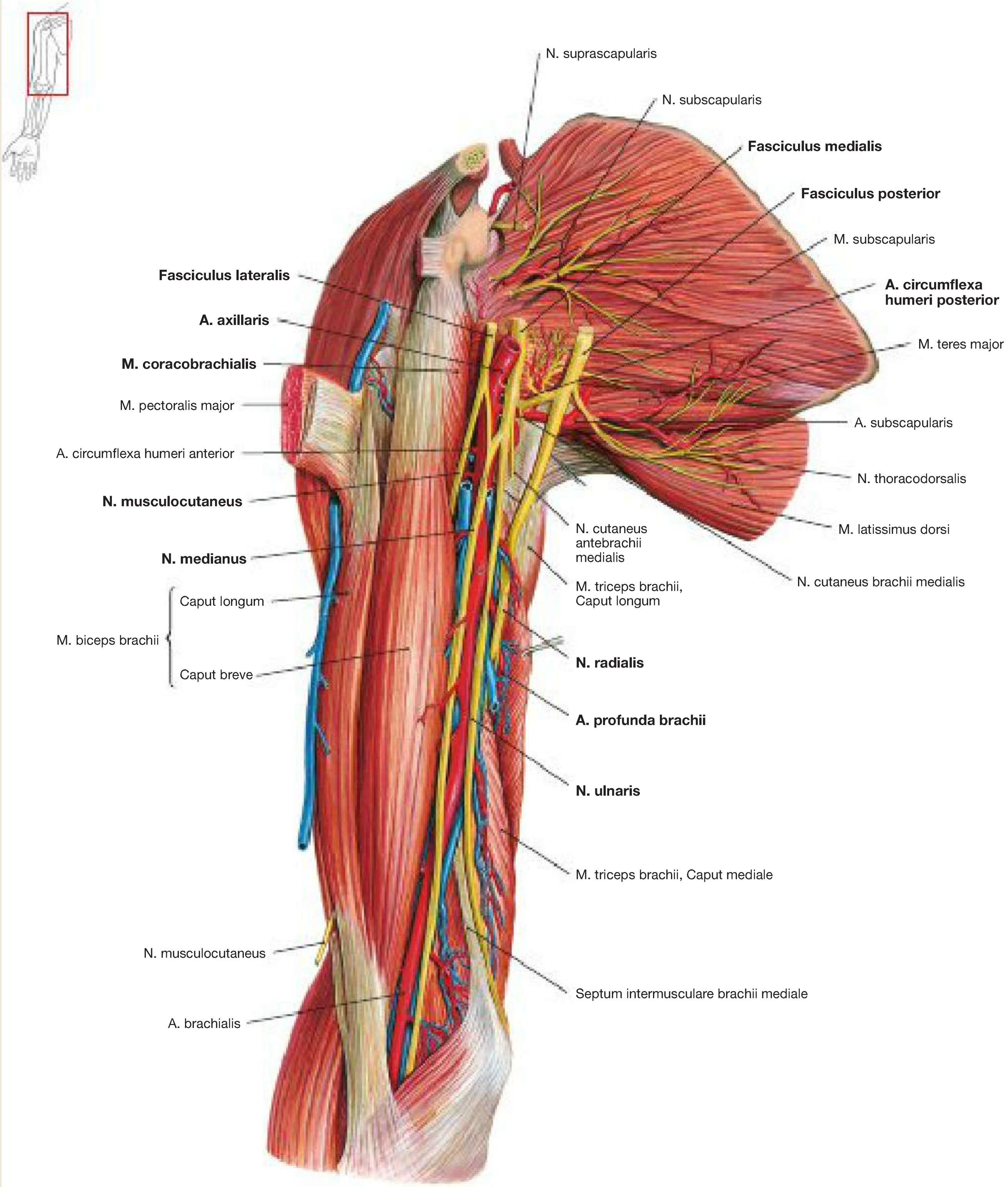
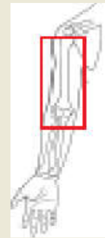


Fig. 3.149 Blood vessels and nerves of the axilla, Fossa axillaris, and of the medial side of the upper arm, Regio brachii anterior, right side; ventromedial view.

The M. pectoralis major was cut through near its insertion on the Crista tuberculi majoris, so that the Pars infraclavicularis of the **Plexus brachialis** can be seen. The three fascicles lie proximally. **The Fasciculus lateralis** and **Fasciculus medialis** lie on both sides of the A. axillaris, and with their nerves they form an M-shaped structure, which is helpful for orientation when dissecting the Plexus brachialis. The lateral arm of the 'M' is formed by the N. musculocutaneus, which can be easily identified as it penetrates the M. coracobrachialis. The middle part is formed by the medial and lateral roots of the N. medianus. The medial arm of the 'M' is formed by the N. ulnaris. In contrast to the N. medianus, which runs in the Sulcus bicipitalis medialis and reaches the cubital fossa medially, the N. ulnaris reaches the dorsal side of the Epicondylus medialis. The **Fasciculus posterior** was mobilised from its position behind the A. axillaris. It provides the N. axillaris proximally, which passes together with the A. circumflexa humeri posterior through the lateral axillary space, and then continues as N. radialis, which finally arrives at the back of the humerus, by traversing the triceps slit together with the A. profunda brachii.



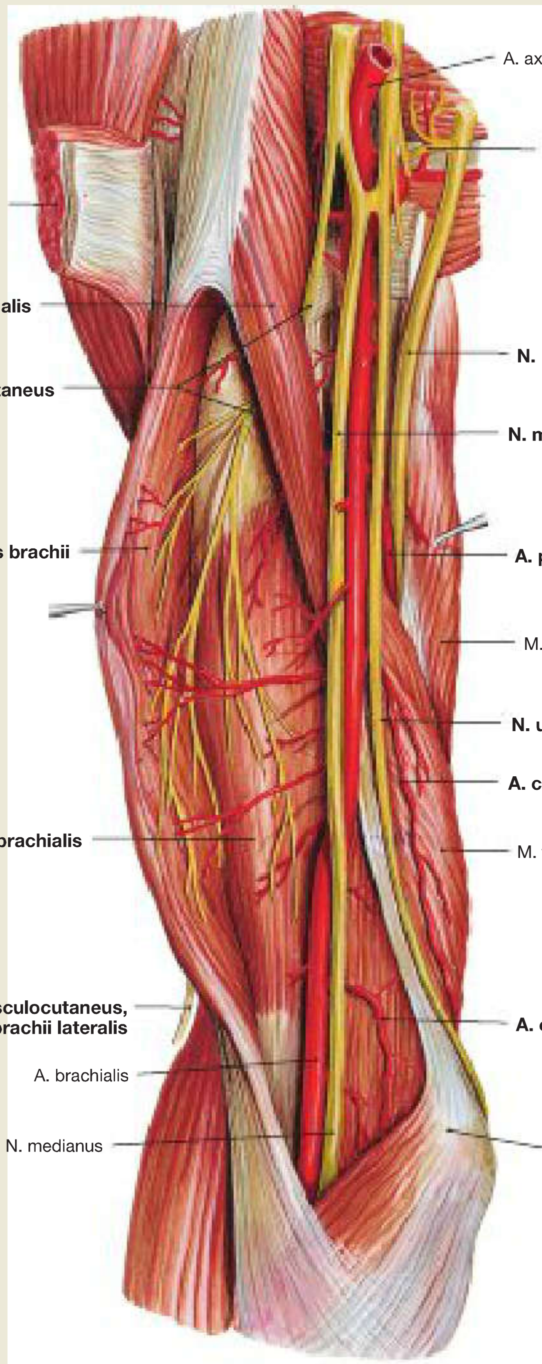


Fig. 3.150 Arteries and nerves of the axilla, Fossa axillaris, and of the medial side of the upper arm, Regio brachii anterior, right side; ventromedial view after removal of the M. biceps brachii.

The M. biceps brachii was lifted off laterally to expose the course of the N. musculocutaneus. The **N. musculocutaneus** penetrates and innervates the M. coracobrachialis, and then continues its course between the M. biceps brachii and the M. brachialis, which it also supplies with motor fibres. In the distal upper arm, the sensory terminal branch (N. cutaneus antebrachii lateralis) appears between the two muscles and turns to the radial side of the forearm. The **N. medianus** accompanies the A. brachialis inside the Sulcus bicipitalis medialis and further into the cubital fossa. The **N. ulnaris** arrives together with the A. collateralis ulnaris superior on the dorsal side of the Epicondylus medialis. In contrast, the A. collateralis ulnaris inferior is in most cases a thin blood vessel, originating proximal to the elbow from the A. brachialis. The **N. axillaris** leaves the Fasciculus posterior proximally and exits through the lateral axillary space, while the **N. radialis** passes with the A. profunda brachii through the triceps slit.

Axillary Spaces and Triceps Slit

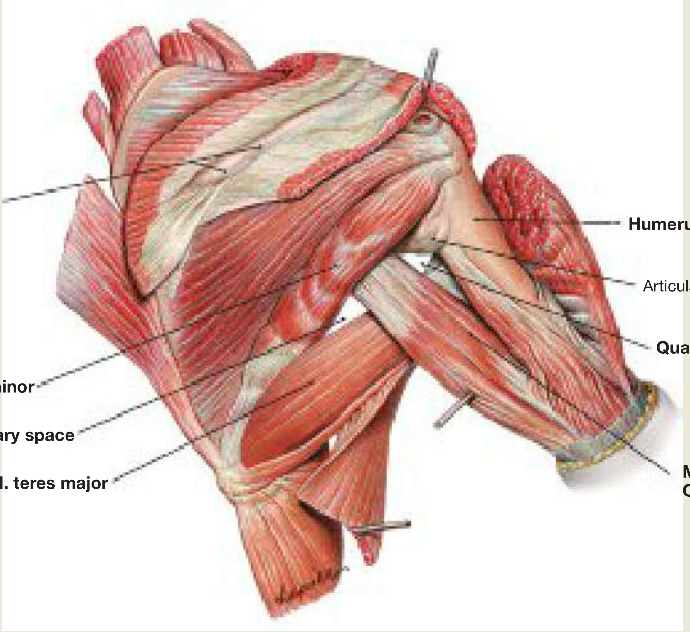
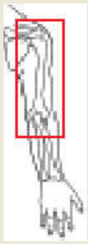


Fig. 3.151 Axillary spaces, right side; dorsal view.
The two axillary spaces between the M. teres major and M. teres minor are bordered laterally by the humerus: The two muscles diverge V-shaped from their origins at the scapula and leave a gap. The Caput longum of the M. triceps brachii subdivides this gap into the **triangular medial axillary space** (Spatium axillare mediale) and the **square or quadrangular lateral axillary space** (Spatium axillare laterale).
(For penetrating structures → Fig. 3.153)



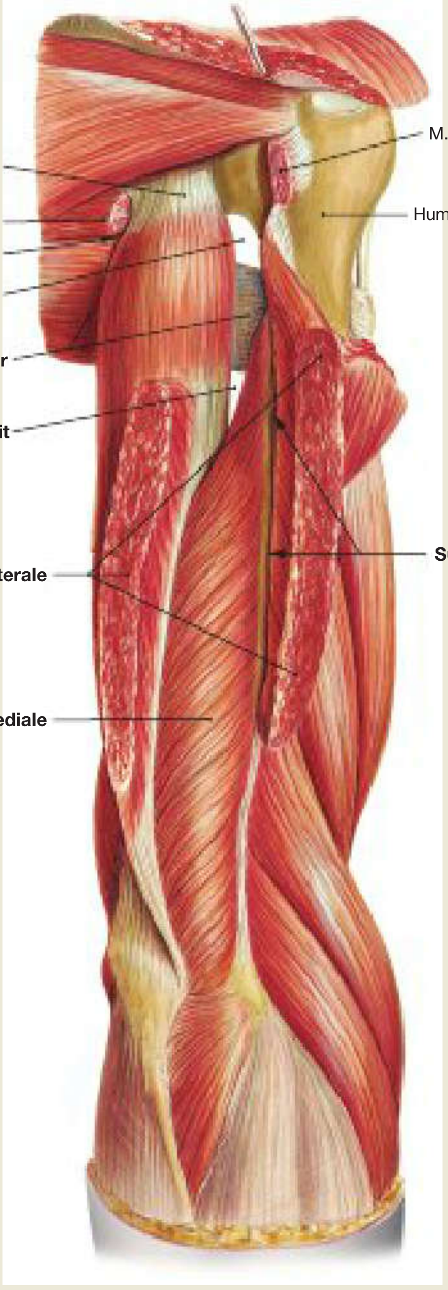


Fig. 3.152 Triceps slit, right side; dorsal lateral view; after splitting the Caput laterale of the M. triceps brachii.
The **triceps slit**, which is an important passageway from the axilla to the dorsal upper arm, is situated distally from the insertion of the M. teres major and thus caudally of the axillary spaces. The slit is bordered medially by the Caput longum and laterally by the Caput laterale of the M. triceps brachii.
(For penetrating structures → Fig. 3.153)

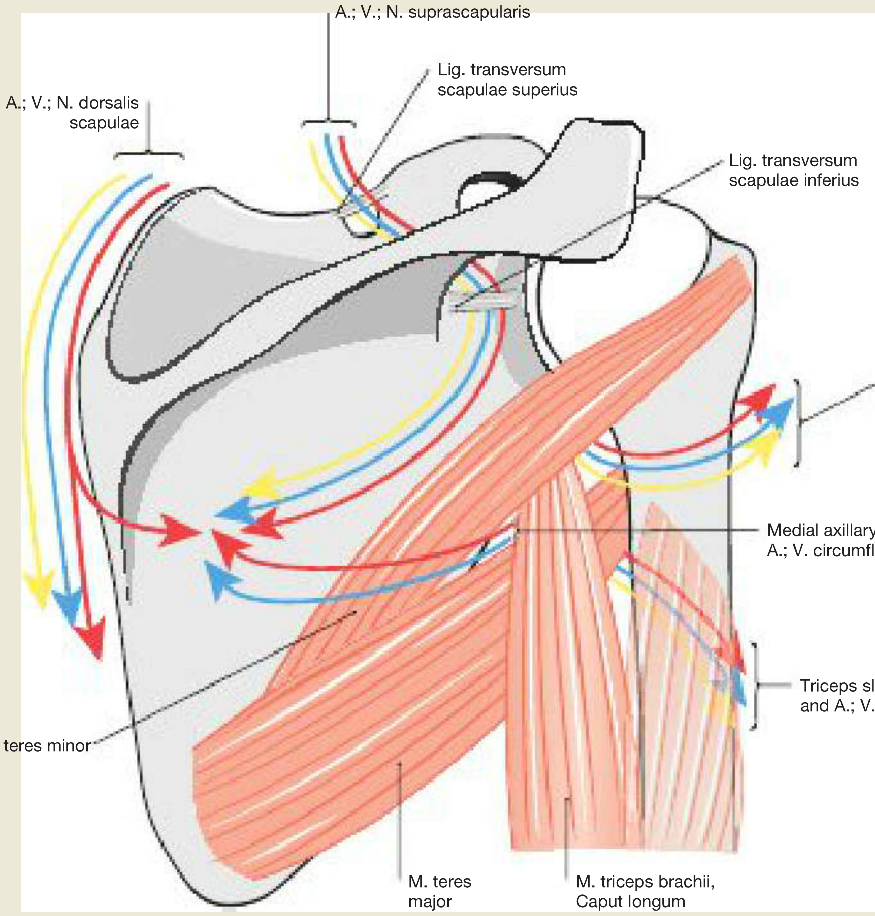


Fig. 3.153 Axillary spaces and triceps slit, right side; schematic representation in the dorsal view. [L126]

The two axillary spaces between the M. teres major and M. teres minor are bordered laterally by the humerus. The Caput longum of the M. triceps brachii separates the **triangular medial axillary space** from the **quadrangular lateral axillary space.** Traversing the axillary spaces are:

- the **medial axillary space:** A. and V. circumflexa scapulae
- the **lateral axillary space:** N. axillaris, A. and V. circumflexa humeri posterior.

The A. circumflexa scapulae anastomoses with the A. suprascapularis in the Fossa infraspinata, and via thin branches with the A. dorsalis scapulae **(scapular anastomoses).** The A. suprascapularis passes **above** the Lig. transversum scapulae superius into the Fossa supraspinata and **below** the Lig. transversum scapulae inferius into the Fossa infraspinata.

The A. circumflexa humeri posterior anastomoses with the A. circumflexa humeri anterior (**brachial anastomoses,** → Fig. 3.125).

The **triceps slit** is located caudally of the axillary spaces and is bordered by the Caput longum and the Caput laterale of the M. triceps brachii.

The following structures traverse the **triceps slit**: N. radialis, A. and V. profunda brachii.

Vessels and Nerves of the Upper Arm

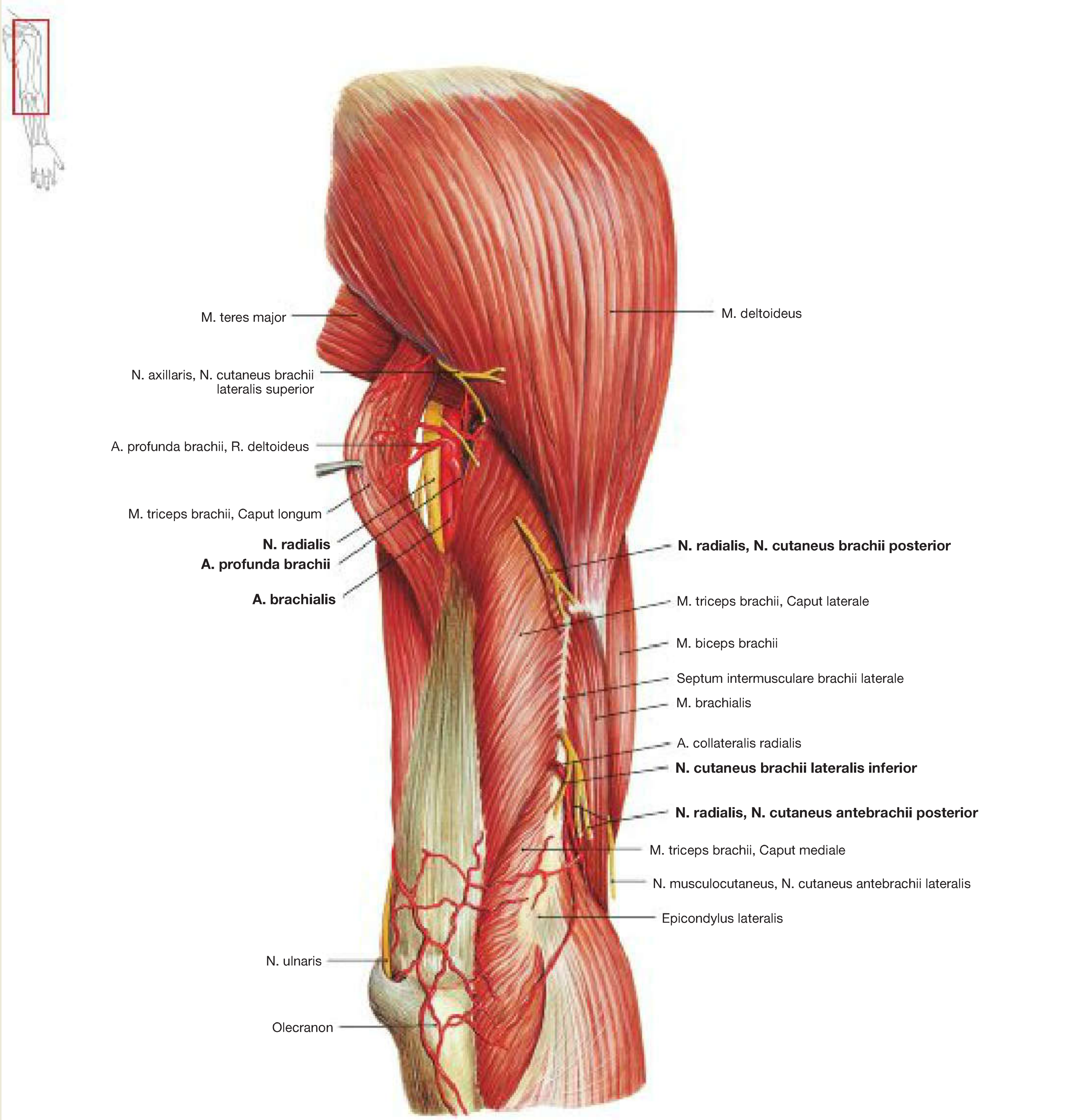


Fig. 3.154 Arteries and nerves on the lateral side of the upper arm, Regio brachii posterior, right side; dorsolateral view.
The Caput longum and Caput laterale of the M. triceps brachii have been pushed apart to better identify of the **triceps slit,** which is bordered by both muscle heads; the **N. radialis** and the **A. profunda brachii** cross the slit dorsally, and then run along the Sulcus nervi radialis of the humerus. As can be seen, prior to its passage through the triceps slit, the N. radialis innervates the M. triceps and also the N. cutaneus brachii posterior. However, along with the N. cutaneus ante brachii posterior, the N. cutaneus brachii lateralis inferior branches off the region of the Sulcus nervi radialis.

Clinical Remarks

In the case of a **humeral shaft fracture** with a radial nerve lesion, the M. triceps brachii remains generally intact, since the N. radialis already innervates the M. triceps and also the N. cutaneus brachii posterior when passing through the triceps slit. Since the N. cutaneus brachii lateralis inferior together with the N. cutaneus antebrachii posterior branch off in the region of the Sulcus nervi radialis, it is at risk of being damaged.

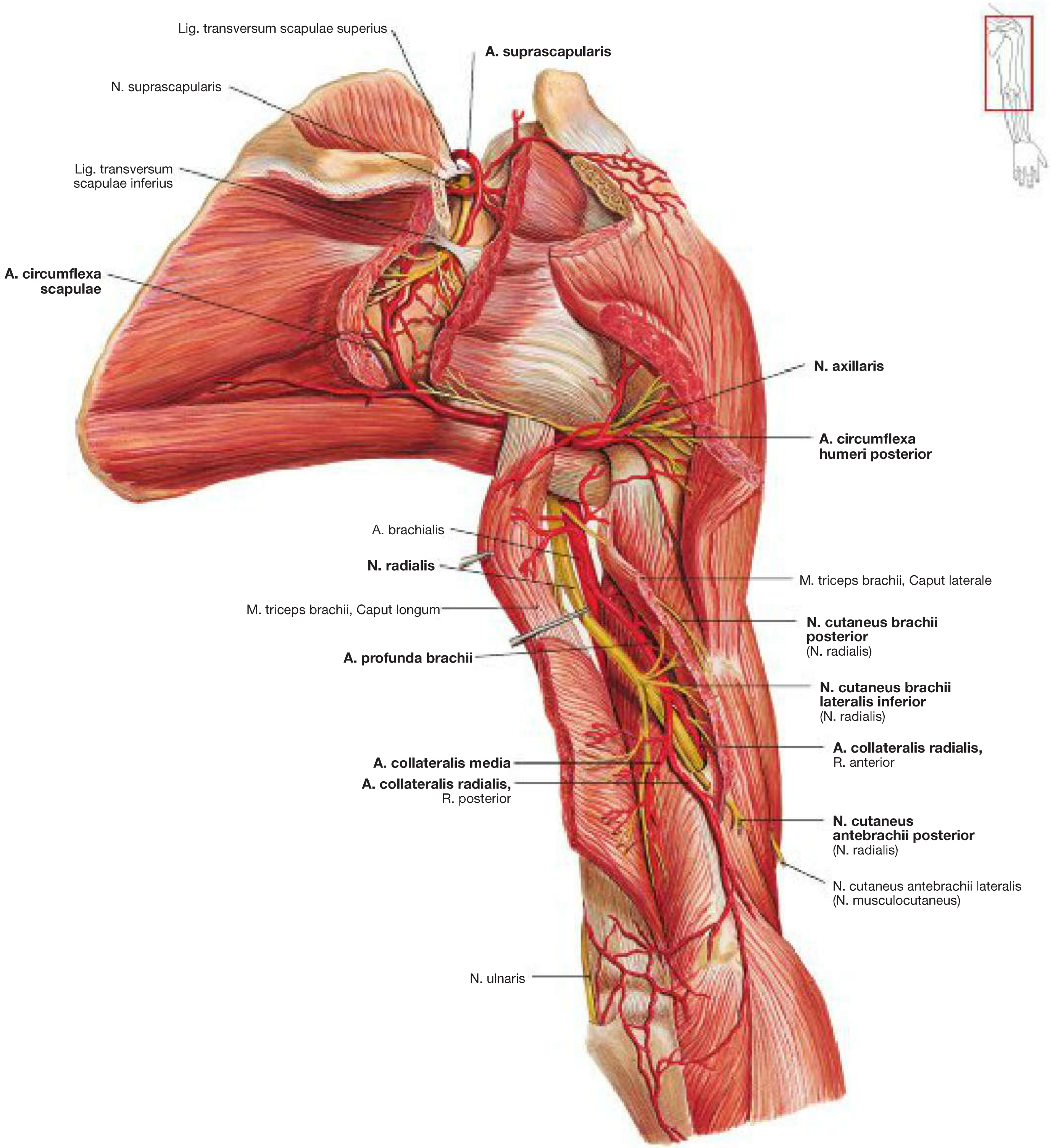


Fig. 3.155 Arteries and nerves of the shoulder, Regio deltoidea, and lateral side of the upper arm, Regio brachii dorsalis, right side; dorsolateral view.

Here we see the branching sequence again of the **N. radialis**. The **triceps slit** has been extended by sharply separating the Caput longum and Caput laterale of the M. triceps brachii from each other. The branches innervating the M. triceps brachii and the N. cutaneus brachii posterior already branch off when passing through the triceps slit. However, the N. cutaneus brachii lateralis inferior and the N. cutaneus antebrachii posterior are only provided once they are in the Sulcus nervi radialis. The N. radialis runs along with the A. profunda brachii, which divides into the A. collateralis media (to the Epicondylus medialis) and into the A. collateralis radialis (accompanying the nerve).

This illustration also shows the **axillary spaces** with the traversing structures. The N. axillaris passes with the A. circumflexa humeri posterior through the lateral axillary space. The A. circumflexa scapulae passes through the medial axillary space dorsally. In the Fossa infraspinata the A. circumflexa scapulae (circulatory area of the A. axillaris) forms an important anastomosis with the A. suprascapularis (circulatory area of the A. subclavia). With this arterial circle, which is often supplemented by anastomoses with the A. dorsalis scapulae (also in the circulatory area of the A. subclavia, not shown here), a bypass or collateral circulation for the blood supply of the arm can be maintained, if the A. axillaris is obstructed proximally.

The A. suprascapularis then passes above the Lig. transversum scapulae superius into the Fossa supraspinata of the scapula, while the N. suprascapularis passes below the ligament through the Incisura scapulae. On their way into the Fossa infraspinata, the nerve and artery are bridged by the Lig. transversum scapulae inferius.

Vessels and Nerves of the Forearm

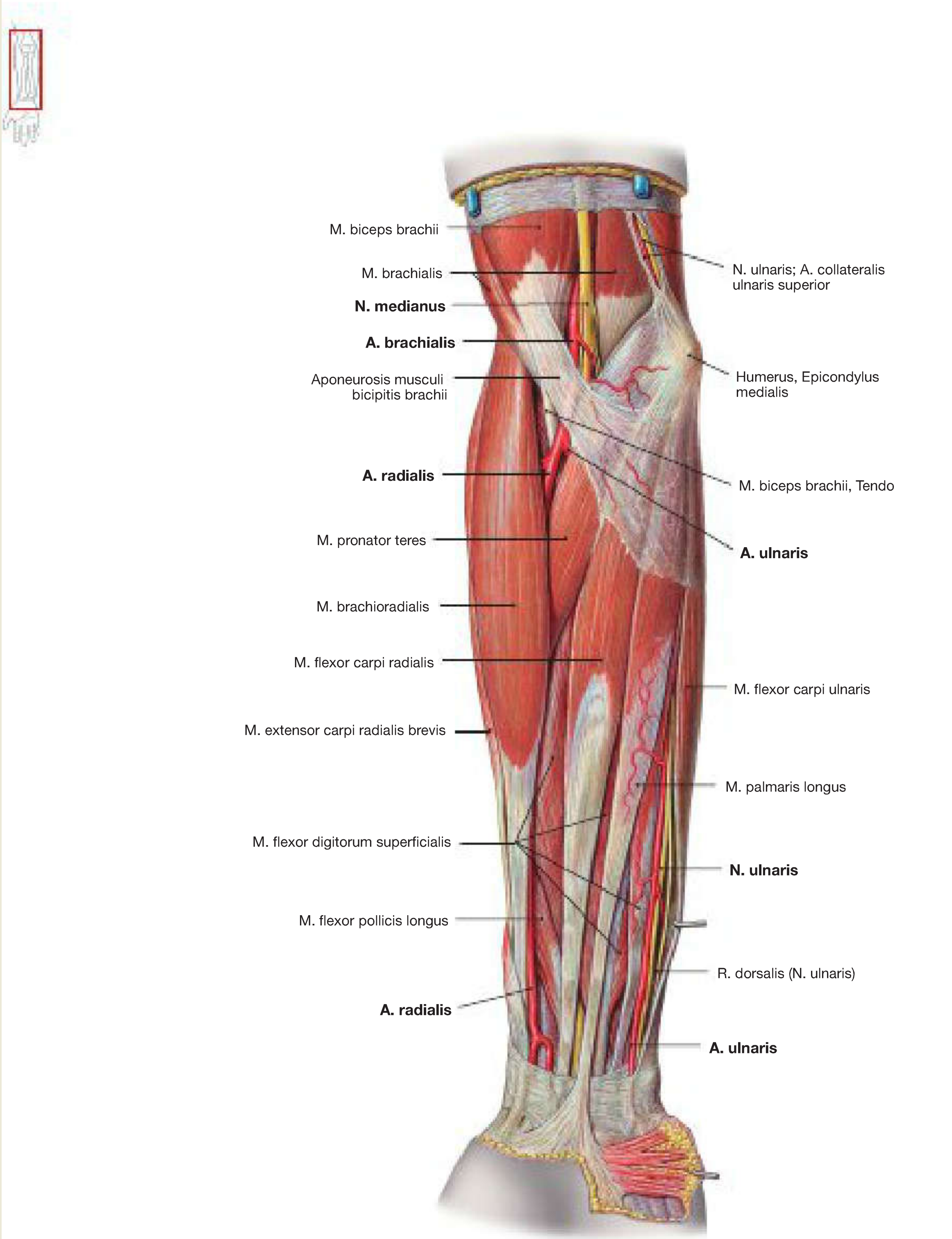


Fig. 3.156 Superficial arteries and nerves of the forearm, Regio antebrachii anterior, right side; ventral view.

Together with the A. brachialis, the **N. medianus** enters the cubital fossa medially. The A. brachialis divides into the A. radialis and the A. ulnaris, both of which descend to the respective sides of the wrists. The pulse of the A. radialis is preferably palpated just proximal to the wrist. The A. ulnaris is accompanied by the N. ulnaris, which is also covered by the M. flexor carpi ulnaris, as can be seen on the distal forearm.

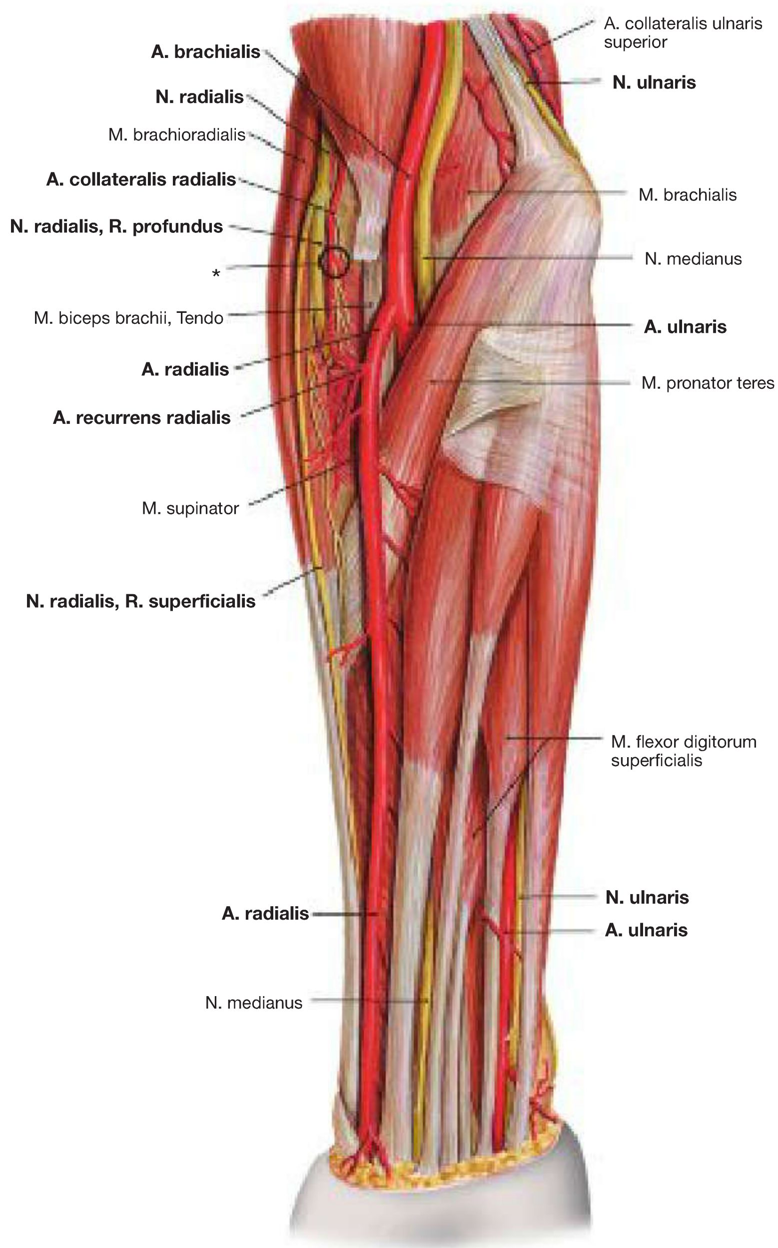


Fig. 3.157 Arteries and nerves of the superficial layer of the forearm, Regio antebrachii anterior, right side; ventral view; after removal of the M. brachioradialis and the Aponeurosis bicipitis antebrachii.

The M. brachioradialis and the insertion of the M. biceps brachii in the Fascia antebrachii (Aponeurosis musculi bicipitis antebrachii) have been removed to expose the bifurcation of the **A. brachialis** and the course of the A. and N. radialis. After the bifurcation of the A. brachialis, the **A. radialis** continues its course and passes beneath the M. brachioradialis onto the radial side of the wrist. Beneath the M. brachioradialis, the A. recurrens radialis also ascends to the vascular plexus of the elbow (Rete articulare cubiti), where it anastomoses with the A. collateralis radialis (*). The **A. ulnaris** branches off dorsally from the M. pronator teres, joins the N. ulnaris below the cubital fossa, and passes beneath the M. flexor carpi ulnaris onto the ulnar side of the wrist. Between the M. brachioradialis and M. brachialis **(radial tunnel)** the **N. radialis** passes from the lateral into the cubital fossa and divides up into R. superficialis and R. profundus. The **R. superficialis** accompanies the A. radialis up to the lower third of the forearm, before it changes to the dorsal side. The **R. profundus** innervates and penetrates the M. supinator **(supinator canal).** At the entrance to the muscle there is often a sharp-edged tendinous arch **(FROHSE-FRÄNKEL's arcade),** which can compress the nerve.

Vessels and Nerves of the Forearm

Fig. 3.158 Arteries and nerves of the deep layer of the forearm, Regio antebrachii anterior, right side; ventral view; after splitting the M. pronator teres and the M. flexor carpi radialis, and removal of the M. palmaris longus.

When the flexor muscles of the superficial layer of the forearm are split, the proximal branches of the **A. ulnaris** become visible: the A. interossea communis is a short strong descending vessel, whereas the A. recurrens ulnaris ascends below the M. pronator teres. The **N. medianus** passes between the two heads of the M. pronator teres into the layer between the middle and deep flexor muscles of the forearm.

On the distal forearm the tendon of the M. flexor carpi ulnaris has been cut through to expose the bifurcation of the **R. dorsalis of the N. ulnaris** and its course to the back of the hand.

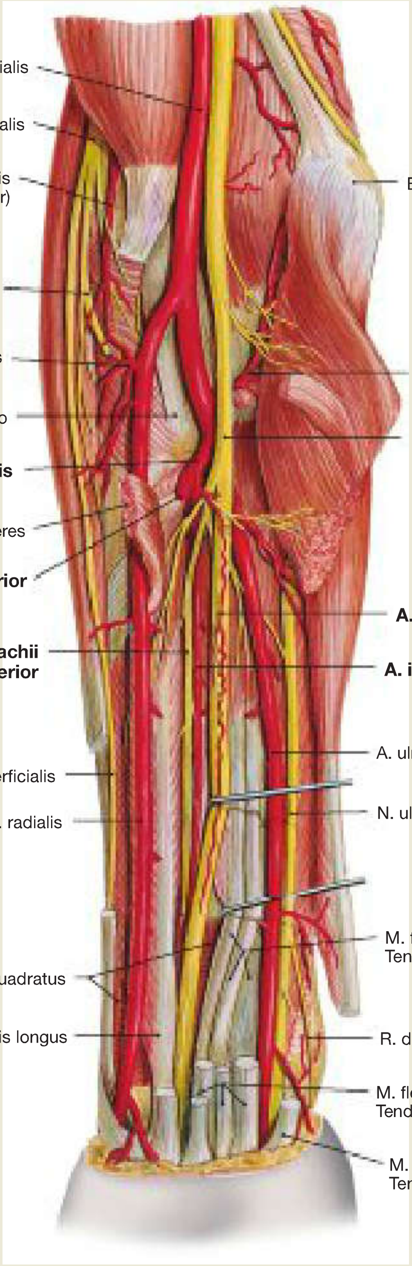
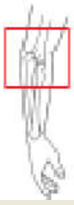


Fig. 3.159 Arteries and nerves of the deep layer of the forearm, Regio antebrachii anterior, right side; ventral view; after removal all superficial flexor muscles.

When all superficial flexor muscles, including the M. flexor digitorum superficialis, have been removed, the complete course of the **N. medianus** becomes visible. It passes distally between the superficial and deep flexor muscles in the midline of the forearm, and is often accompanied by its own thin blood vessel (A. comitans nervi mediani). On the proximal forearm, the N. interosseus antebrachii anterior branches off, providing motor fibres to the deep flexors and sensory fibres to the wrists. The nerve is accompanied by the A. interossea anterior, while the A. interossea posterior penetrates the Membrana interossea antebrachii and runs dorsally.

Vessels and Nerves of the Elbow and Cubital Fossa



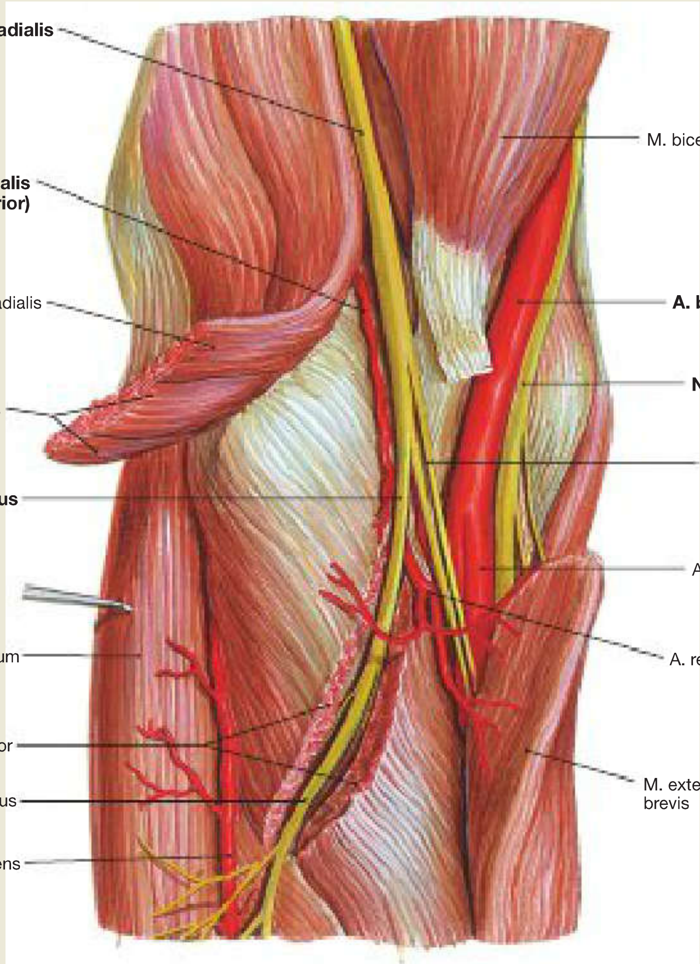


Fig. 3.160 Arteries and nerves of the cubital fossa, Regio cubitalis anterior, right side; lateral (radial) view.
The illustration shows the course of the arm nerves in the area of the cubital fossa and elbow after the splitting of various superficial flexor and extensor muscles. The **N. medianus** arrives from medially with the A. brachialis in the cubital fossa, while the **N. radialis** along with the A. collateralis radialis passes laterally between the M. brachioradialis and M. brachialis **(radial tunnel)** into the cubital fossa, where it divides into its two terminal branches. The R. superficialis continues the course below the M. brachioradialis. The R. profundus reaches the dorsal side by passing through the M. supinator **(supinator canal)**.

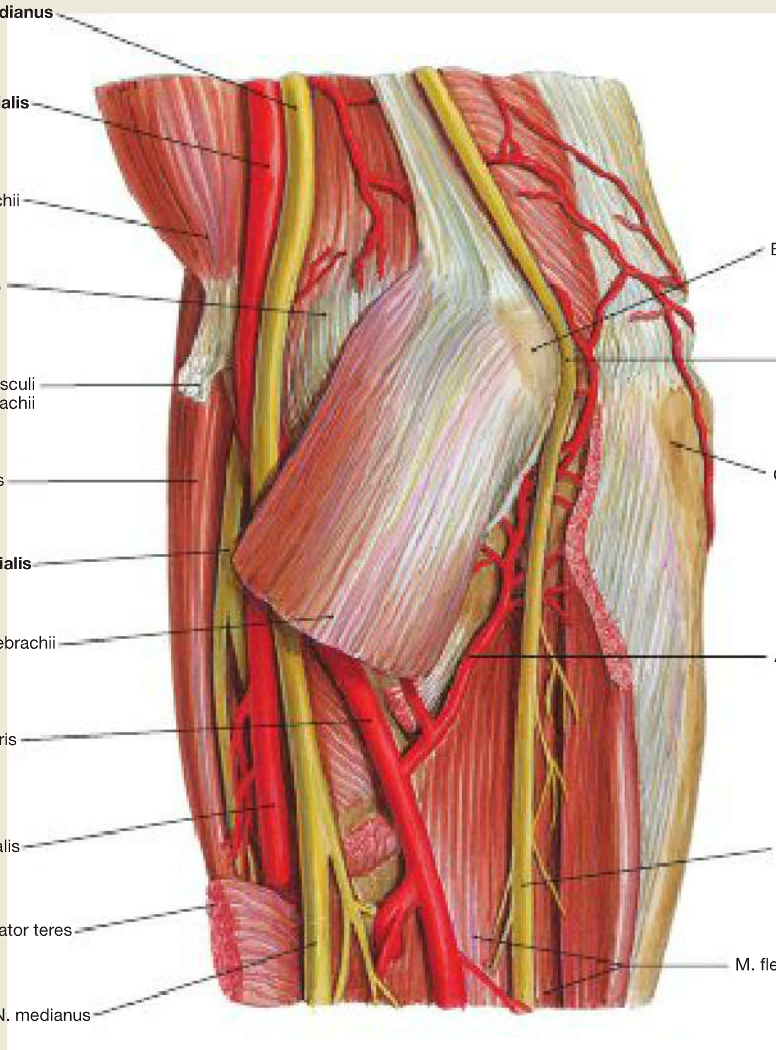


Fig. 3.161 Arteries and nerves of the elbow, Regio cubitalis posterior, right side; medial (ulnar) view.
On the elbow, the **N. ulnaris** is directly adjacent to the bone in the Sulcus nervi ulnaris **(cubital tunnel),** where it is easily irritated on compression **('funny bone').** Then the N. ulnaris passes under the M. flexor carpi ulnaris to the flexor side of the forearm, where it is joined by the A. ulnaris.

Vessels and Nerves of the Forearm

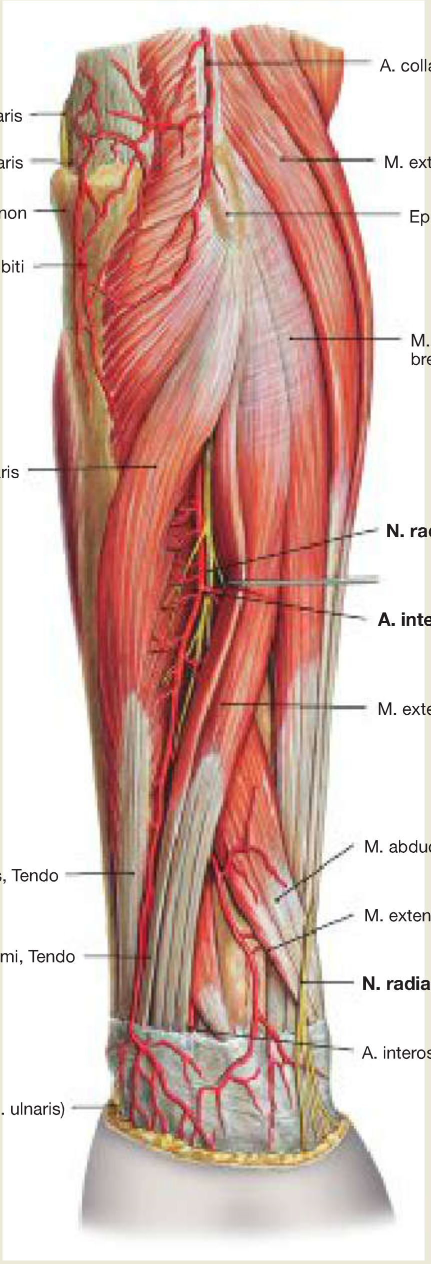


Fig. 3.162 Arteries and nerves of the deep layer of the forearm, Regio antebrachii posterior, right side; radial view.
The M. extensor digiti minimi is pushed to the side to show the course of the **R. profundus of the N. radialis**, which descends with the A. interossea posterior between the superficial and deep extensor muscles. At the radial side of the wrist, the **R. superficialis of the N. radialis** emerges from the M. brachioradialis and reaches the back of the hand.

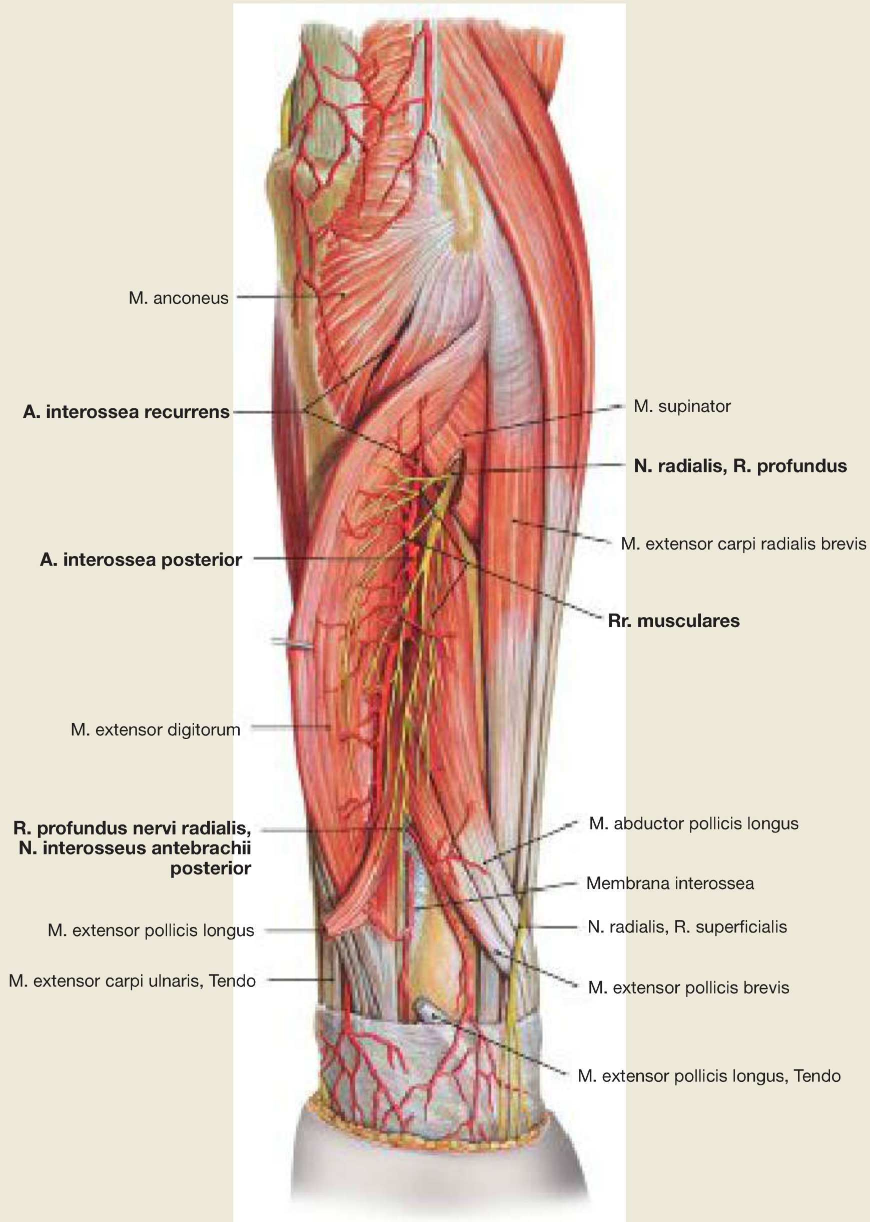


Fig. 3.163 Arteries and nerves of the deep layer of the forearm, Regio antebrachii posterior, right side; radial view.

The M. extensor digitorum was lifted sideways to expose the branches of the **R. profundus of the N. radialis** and of the **A. interossea posterior**. After its passage through the M. supinator, the R. profundus of the N. radialis innervates all superficial and deep extensor muscles on the forearm, before it runs into the sensory N. interosseus antebrachii posterior on the wrists. The A. interossea posterior, after its passage through the Membrana interossea antebrachii, provides the A. interossea recurrens which ascends below the M. anconeus to the vascular plexus of the elbow (Rete articulare cubiti).

Vessels and Nerves of the Palm

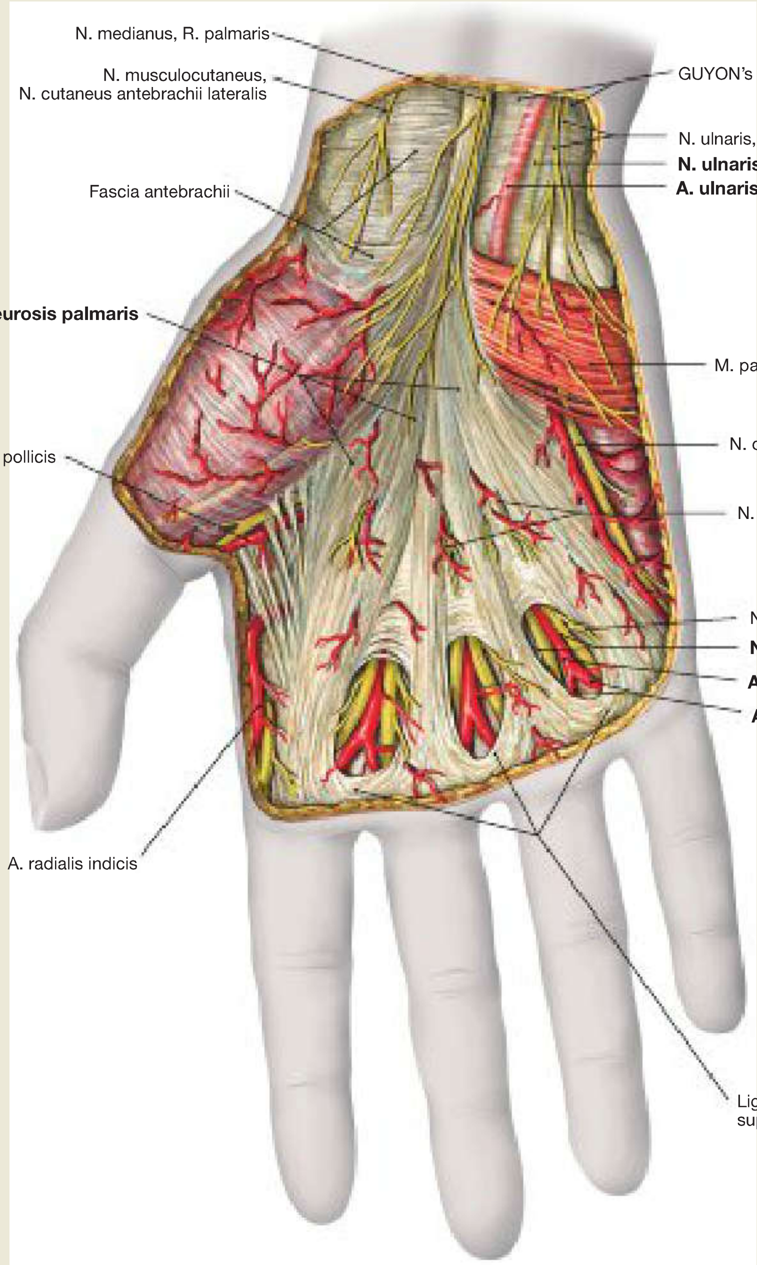


Fig. 3.164 Arteries and nerves of the superficial layer of the palm of the hand, Palma manus, right side; palmar view.

The blood vessels and nerves in the palm are covered by the **palmar aponeurosis** (Aponeurosis palmaris) and therefore are well protected. Proximal to the metacarpophalangeal joints and between the longitudinal tracts of the aponeurosis, the Nn. digitales palmares from the N. medianus and the N. ulnaris are visible as well as the bifurcations of the Aa. digitales palmares communes into the terminal branches for the individual fingers. As N. ulnaris and A. ulnaris lie superficially in the wrist region in the **GUYON's canal,** they are prone to injury and compression.

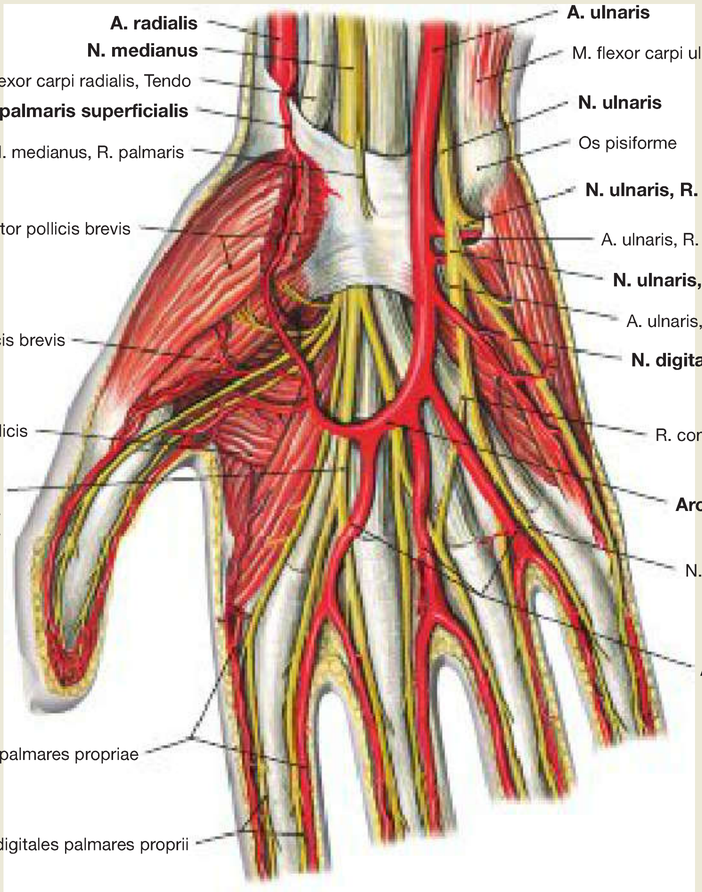


Fig. 3.165 Arteries and nerves of the middle layer of the palm of the hand, Palma manus, right side; palmar view; after removal of the palmar aponeurosis.

The **superficial palmar arch** (Arcus palmaris superficialis) is largely formed by the A. ulnaris, which anastomoses usually with a branch (R. palmaris superficialis) of the A. radialis. The Aa. digitales palmares for the ulnar 3½ fingers are provided by the superficial palmar arterial arch while it crosses the tendons of the long flexor muscles of the fingers.

The **N. ulnaris** accompanies the A. ulnaris through the **GUYON**'s **canal,** which has been opened here. Distally of the Os pisiforme, the N. ulnaris already divides into the R. profundus and the R. superficialis, which continues the course in the same direction. The **R. superficialis** splits into the Nn. digitales palmares for the sensory innervation of the ulnar 1½ fingers. The radial 3½ fingers are innervated by respective branches of the **N. medianus,** which enters the palm of the hand through the **carpal tunnel** (Canalis carpi) beneath the Retinaculum musculorum flexorum.

Vessels and Nerves of the Palm

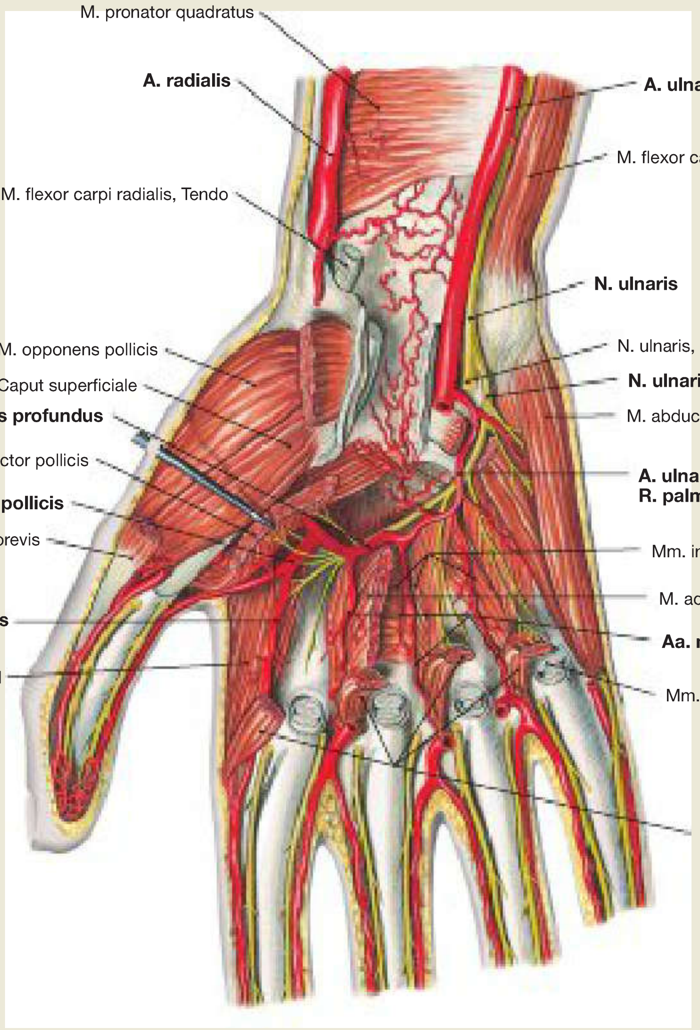


Fig. 3.166 Arteries and nerves of the deep layer of the palm of the hand, Palma manus, right side; palmar view; after removal of the long flexor tendons and the Mm. lumbricales, as well as splitting the M. adductor pollicis.

The **deep palmar arch** (Arcus palmaris profundus) originates from the A. radialis and anastomoses mainly with the R. palmaris profundus of the A. ulnaris. This arch is positioned **beneath** the M. adductor pollicis and on the bases of the Ossa metacarpi; thus, it lies further proximally than the superficial palmar arterial arch. The deep palmar arterial arch provides the usually rather thin Aa. metacarpales palmares. On its way over the Mm. interossei it is accompanied by the **R. profundus of the N. ulnaris**, which provides the motor innervation of muscles such as the little finger muscles, the Mm. interossei and the two ulnar Mm. lumbricales. The arteries supplying the thumb (A. princeps pollicis) and the radial side of the index finger (A. radialis indicis) are also branches of the A. radialis.

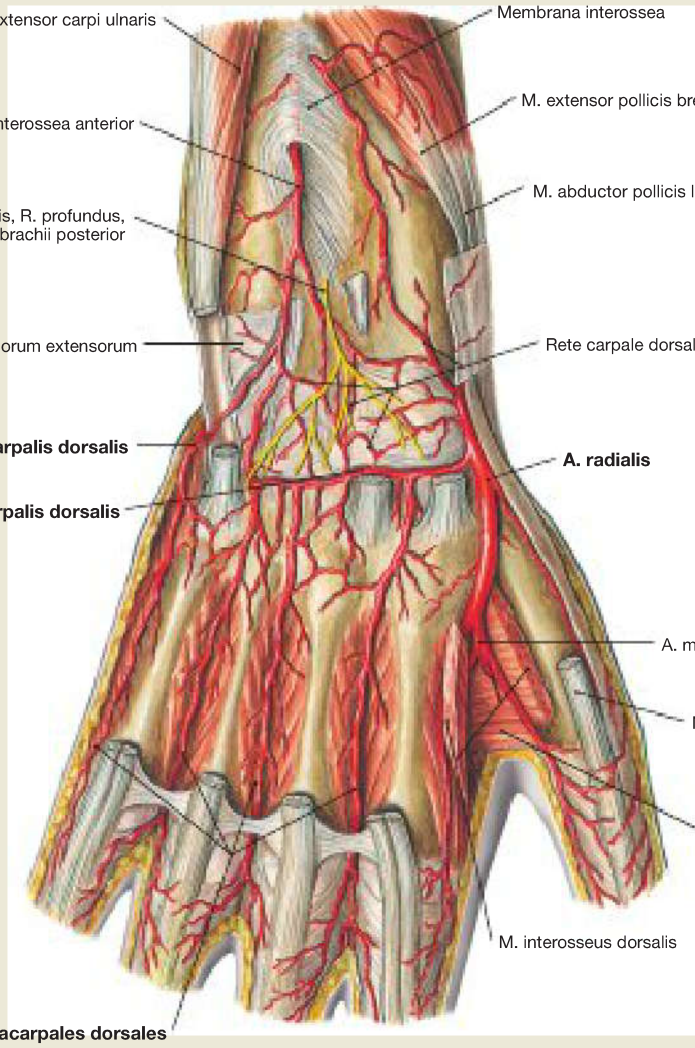


Fig. 3.167 Arteries and nerves of the back of the hand, Dorsum manus, right side; dorsal view; after removal of the long extensor tendons.

In the wrist region, both the **A. radialis** as well as the **A. ulnaris** provide one **R. carpalis dorsalis** each to the back of the hand, which anastomose with each other. The radial branch is usually stronger and contributes greatly to the Aa. metacarpales dorsales that supply the back of the hand, and as Aa. digitales dorsales the fingers up to the proximal interphalangeal joints. The middle and distal phalanges of the fingers are supplied by the palmar digital arteries. The A. metacarpalis dorsalis I is a direct branch of the A. radialis, which passes between the heads of the M. interosseus dorsalis I into the palm of the hand.

Vessels and Nerves of the Back of the Hand

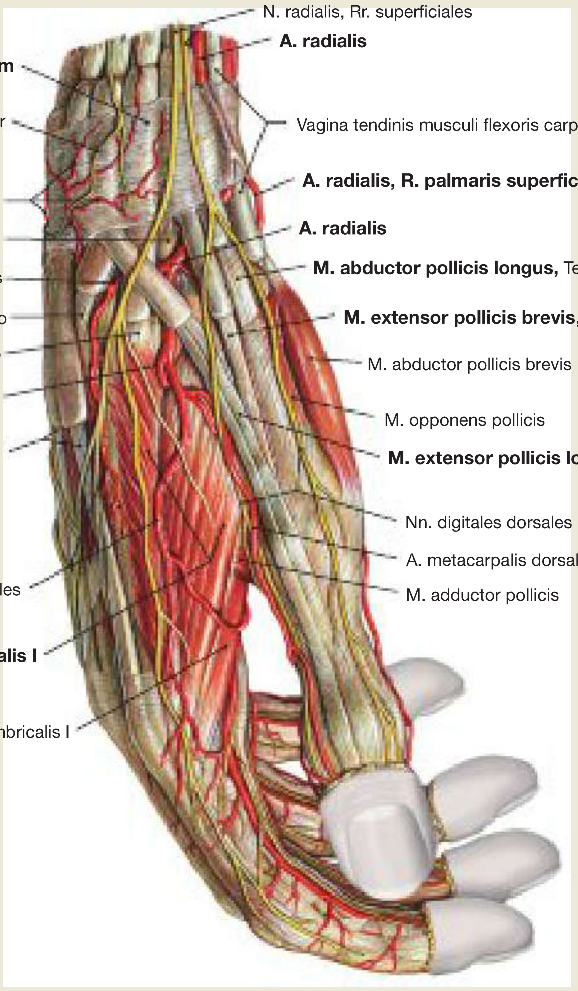
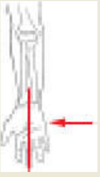


Fig. 3.168 Arteries and nerves of the back of the hand, Dorsum manus, right side; radial view.

This illustration shows the **course of the A. radialis** in the wrist region. At the proximal wrist, the A. radialis runs between the tendons of the M. brachioradialis and M. flexor carpi radialis. First, it crosses underneath the Retinaculum musculorum extensorum and provides the R. palmaris superficialis, which joins the superficial palmar arterial arch. The A. radialis then passes beneath the tendons of the two extensor muscles of the first osseofibrous tunnel (M. abductor pollicis longus and M. extensor pollicis brevis, → Fig. 3.71) to reach the **Fovea radialis (Tabatière;** between the tendons of the Mm. extensores pollicis brevis and longus), where it provides the R. carpalis dorsalis. After having crossed beneath the tendon of the M. extensor pollicis longus, the A. radialis releases the A. metacarpalis dorsalis to the thumb and passes between the two heads of the M. interosseus dorsalis I into the palm of the hand. Sometimes, however, there is also a variation with a superficial course of the artery passing over the extensor tendons.



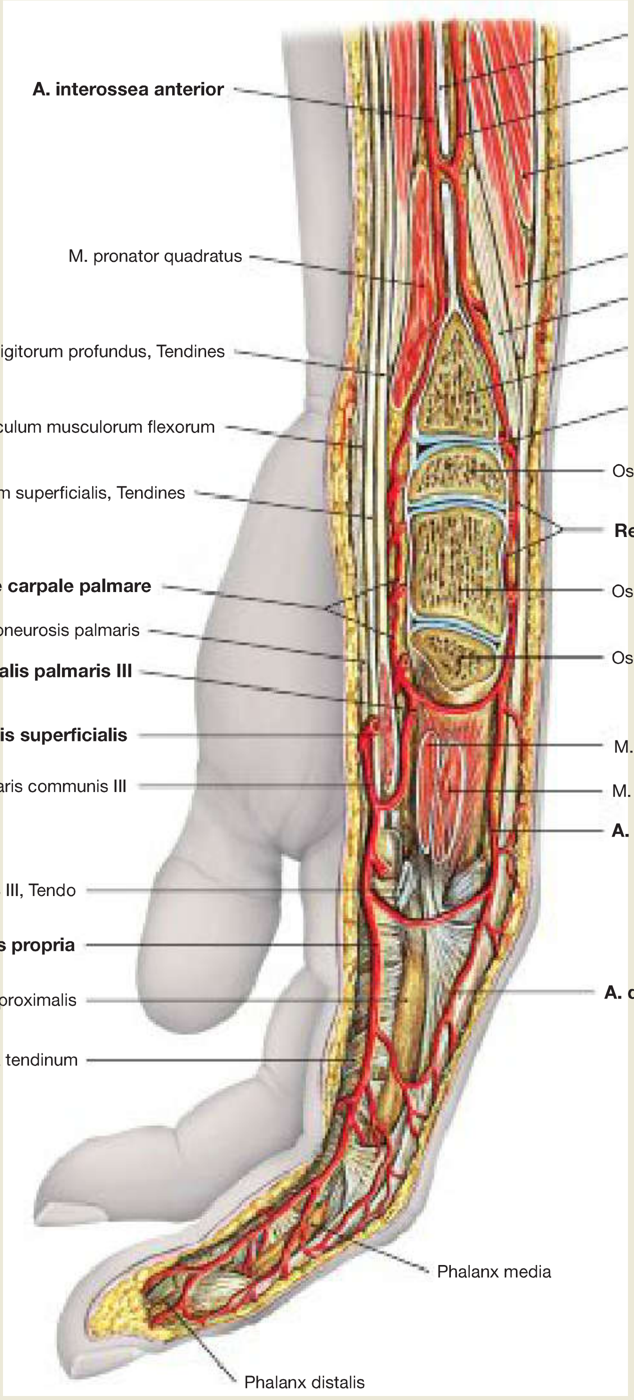


Fig. 3.169 Arteries of the hand, Manus, right side; ulnar view; sagittal section at the level of the ulnar plane of the middle finger. Along the distal forearm, the Aa. interosseae anterior and posterior run on both sides of the Membrana interossea antebrachii. The carpus of the hand is supplied by palmar and dorsal vascular plexuses (Rete carpale palmare and Rete carpale dorsale), which are fed by the A. radialis and A. ulnaris. The metacarpal and digital arteries on the back of the hand originate from the Rete carpale dorsale. The metacarpal arteries in the palm of the hand originate from the deep palmar arch and the digital arteries from the superficial palmar arch. Each finger is supplied by a total of four digital arteries (palmar and dorsal arteries at the radial and ulnar side, respectively). The dorsal digital arteries only extend up to the middle phalanx. The middle and distal phalanges are supplied by branches of the palmar digital arteries.

Upper Arm, Transverse Sections

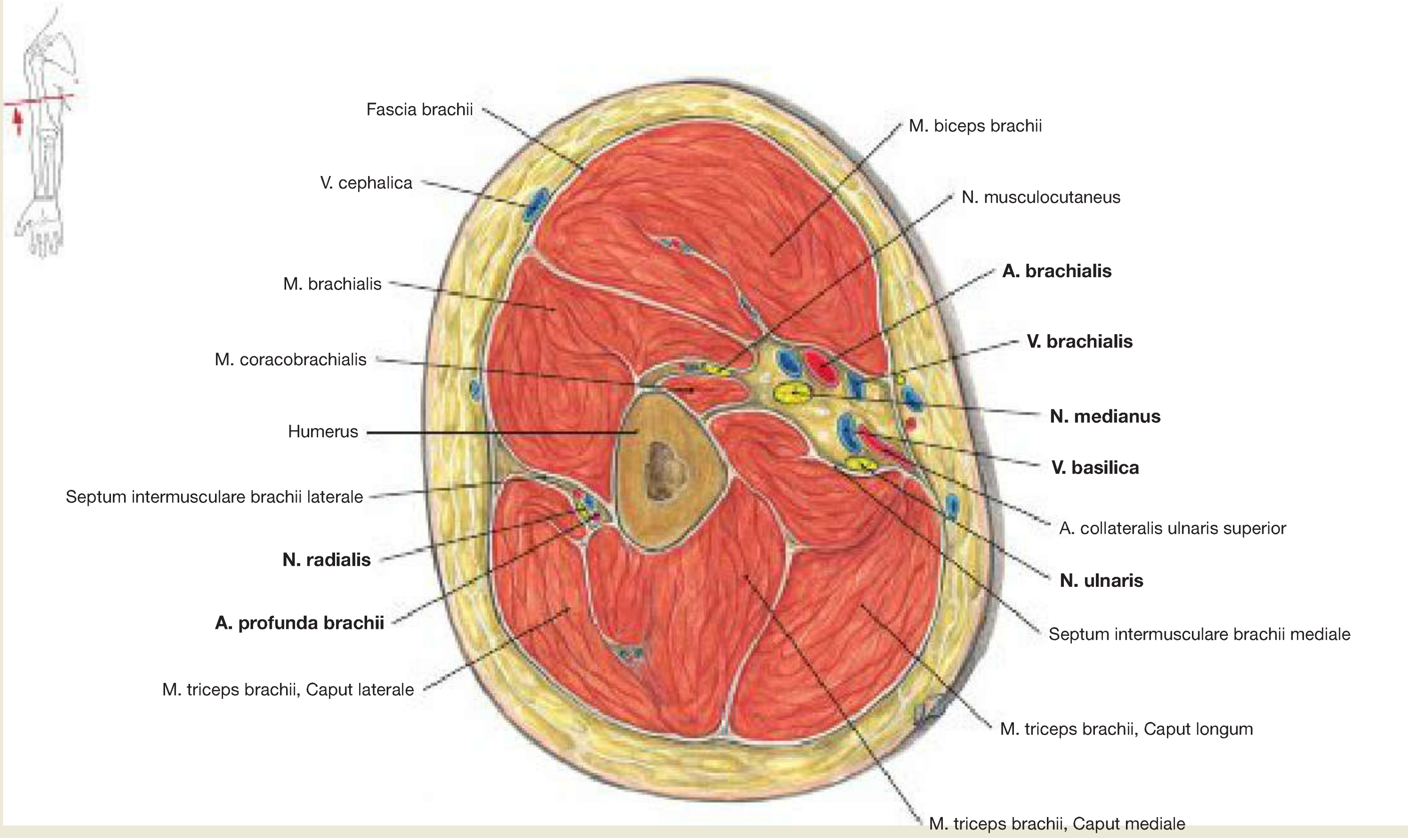


Fig. 3.170 Upper arm, Brachium, right side; distal view; transverse section in the middle of the upper arm.

In the cross-section it is particularly evident that there are **two muscle groups** in the upper arm. The flexor muscles of the elbow joint lie ventrally. The M. biceps brachii covers the M. brachialis, which originates a bit further laterally. The insertion of the M. coracobrachialis on the medial humeral shaft is also clearly delineated. The back of the upper arm is occupied by the heads of the M. triceps brachii. The **neurovascular pathways** run in **two bundles.** The N. medianus, accompanied by the A. brachialis and the Vv. brachiales, run medially in the Sulcus bicipitalis medialis in front of the Septum intermusculare brachii mediale (medial neurovascular pathway). The V. basilica has already pierced the fascia and has arrived here just before draining into the V. brachialis. The N. ulnaris penetrates the Septum intermusculare brachii mediale further distally and arrives on the dorsal side of the Epicondylus medialis. Laterally, the N. radialis, together with the A. profunda brachii in the Sulcus nervi radialis, loops around the humeral shaft (dorsal passageway) and descends between the M. brachialis and M. triceps brachii.

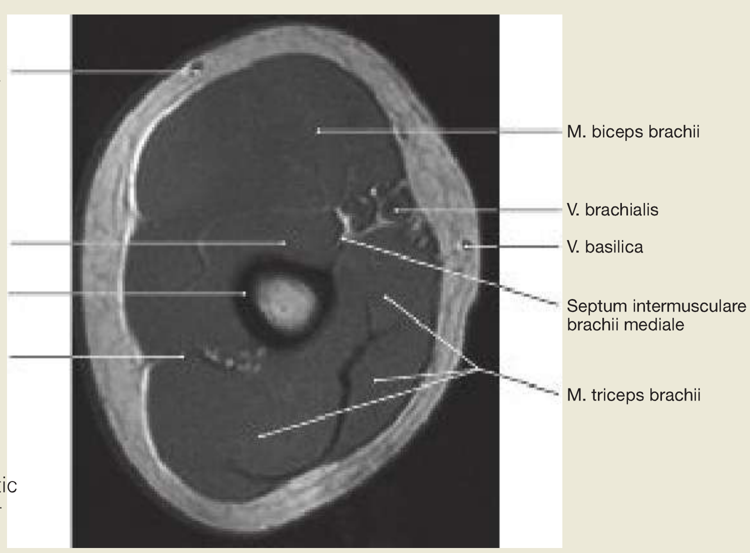


Fig. 3.171 Upper arm, Brachium, right side; distal view; magnetic resonance imaging (axial MRI scan) at the middle level of the upper arm.

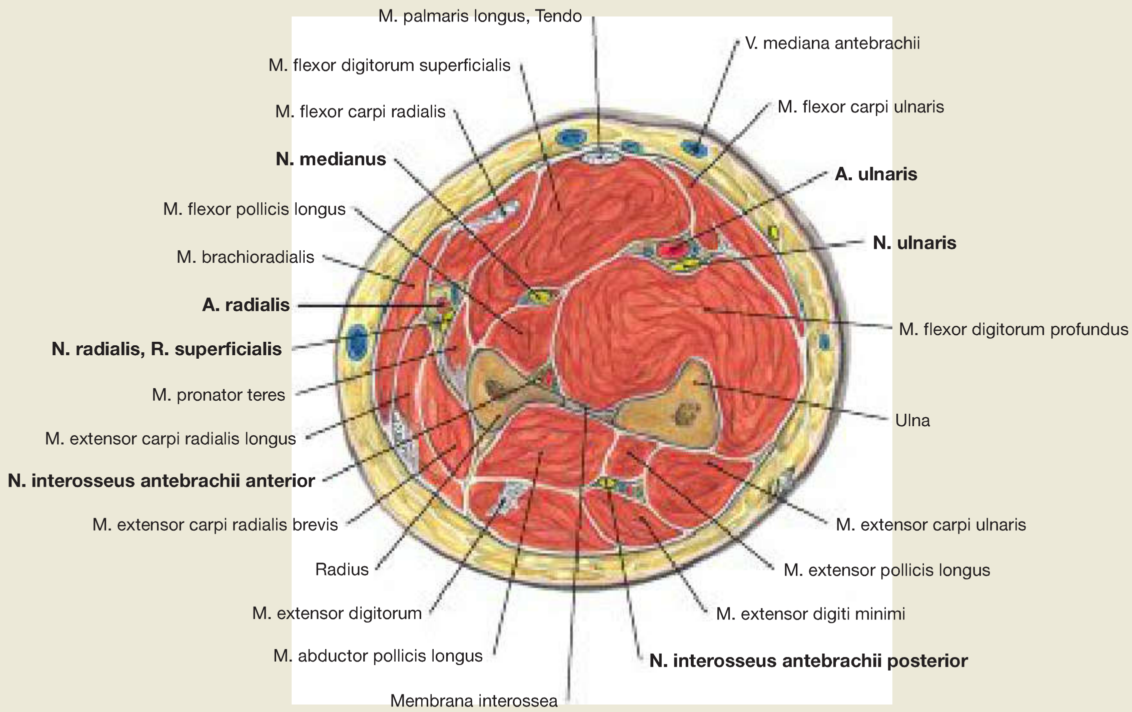


Fig. 3.172 Forearm, Antebrachium, right side; distal view; transverse section at the level of the distal third of the forearm.

On the forearm, there are **five neurovascular pathways** interposed between the groups of the superficial and deep flexor and extensor muscles. Underneath the M. brachioradialis, the A. and V. radialis run together with the R. superficialis of the N. radialis (radial neurovascular pathway). The N. medianus and its thin accompanying artery (A. comitans nervi mediani) are located between the superficial and middle layers of flexor muscles in the midline of the forearm (middle neurovascular pathway); under the M. flexor carpi ulnaris lie the A., V. and N. ulnaris (ulnar neurovascular pathway). The A. and V. interossea anterior and the N. interosseus anterior (interosseous neurovascular pathway) pass in front of the Membrana interossea antebrachii. The A. and V. interossea posterior and the N. interosseus posterior (dorsal neurovascular pathway) lie dorsally between the superficial and deep layers of the extensor muscles.

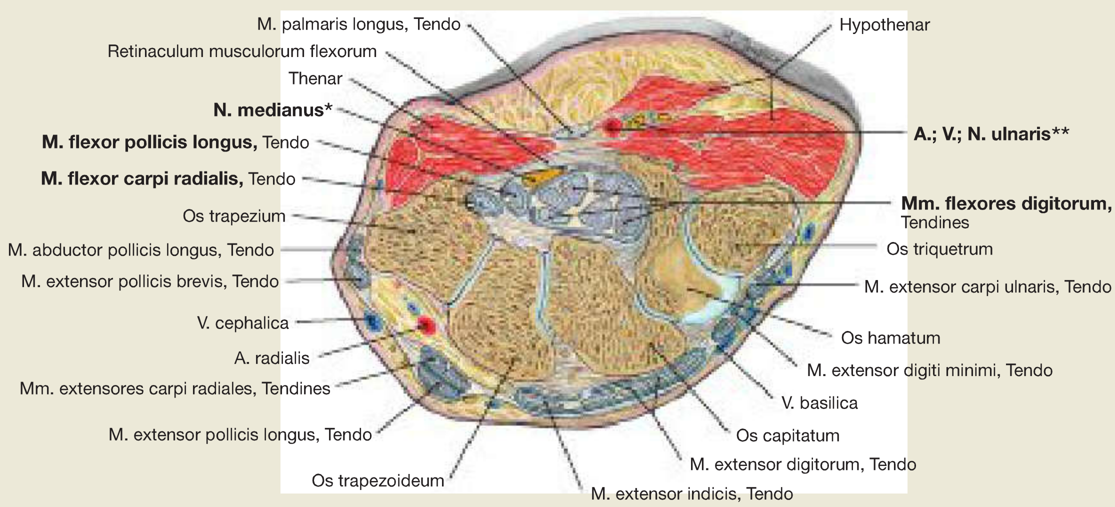


Fig. 3.173 Wrist, Carpus, right side; distal view; transverse section at the level of the distal row of the carpal bones.

On the palmar side of the wrist, there are **two neurovascular pathways** with great clinical significance. The carpal bones together with the Retinaculum musculorum flexorum form the **carpal tunnel** (Canalis carpi), through which the N. medianus together with the tendons of the long finger extensors pass. Any swelling of the tendon sheaths can therefore lead to compression of the N. medianus (carpal tunnel syndrome, → Fig. 3.116). The N., A. and V. ulnaris lie on the retinaculum in the **GUYON's canal,** due to this superficial position, they are at risk of external compression (distal lesion of the N. ulnaris → Fig. 3.120).

* carpal tunnel
** GUYON's canal

Metacarpus and Middle Finger, Transverse Sections

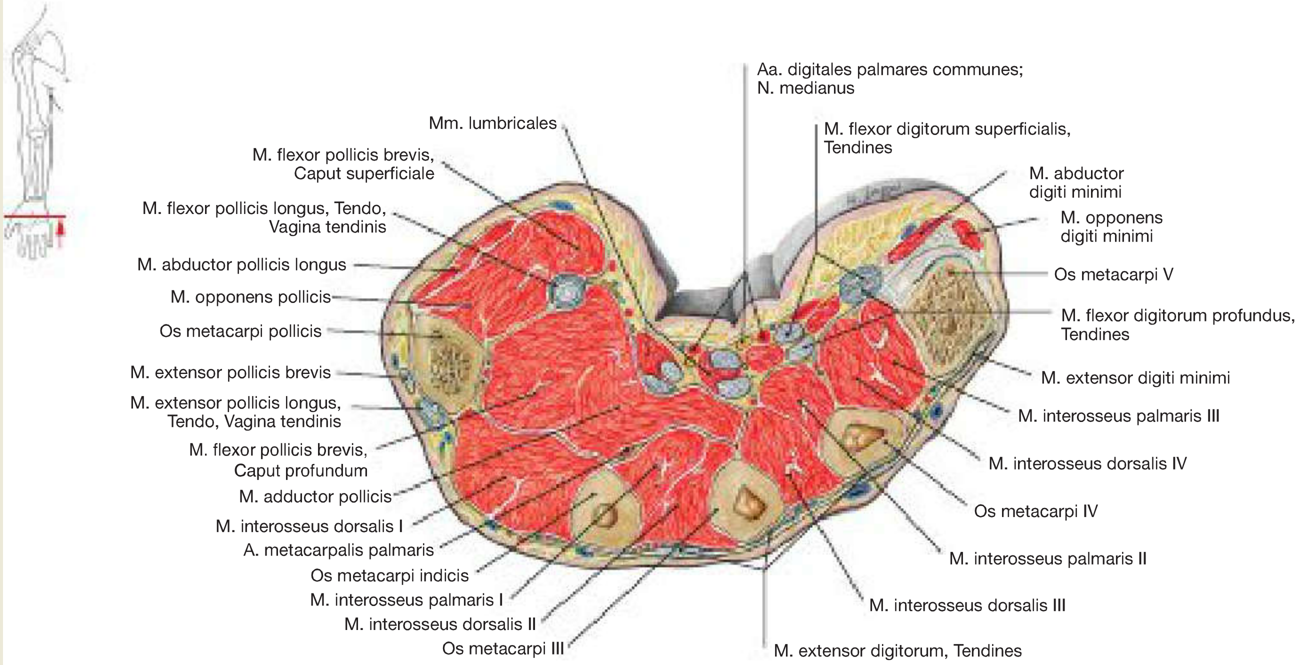


Fig. 3.174 Metacarpus; transverse section at the level of the middle of the third metacarpal bone.

The transverse section shows the position of the muscles in the palm of the hand, which are organised in three layers (→ pp. 212–215). **Superficially**, the M. abductor pollicis and M. flexor pollicis brevis, and the M. abductor digiti minimi cover the other muscles of the thenar eminence and the hypothenar eminence, respectively. The tendons of the long flexor muscles of the fingers run in the **middle layer.** The Mm. lumbricales originate from the tendons of the M. flexor digitorum profundus. The Mm. interossei palmares and dorsales form the **deep layer** of the palmar muscles. It can be seen in this muscle group that the bellies of the palmar muscles are actually facing the palm of hand to a greater extent than the dorsal muscles. In addition to the muscles, this illustration also clearly shows the positions of the digital arteries (Aa. digitales palmares communes) and the sensory terminal branches of the N. medianus, which cover the tendons of the finger flexor muscles (→ Fig. 3.165).

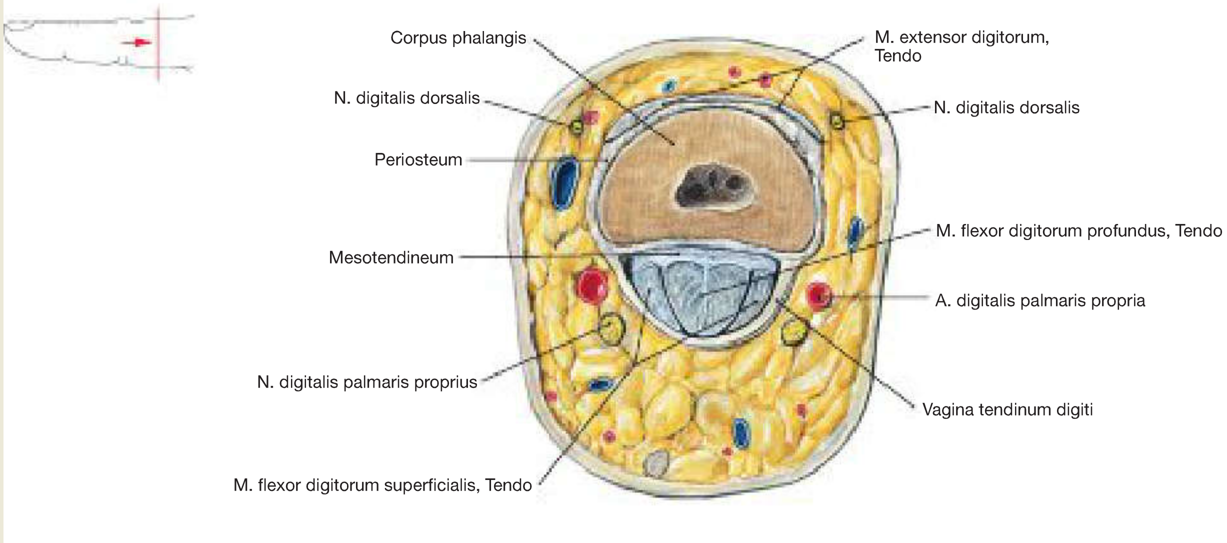


Fig. 3.175 Middle finger, Digitus medius [III] ; transverse section through the shaft of the middle phalanx.

The tendon of the M. flexor digitorum profundus has penetrated the inserting tendon of the M. flexor digitorum superficialis. Both tendons then share a common tendon sheath (Vagina tendinum digiti). The dorsal digital arteries and nerves are already much thinner at the middle phalanges than the corresponding palmar blood vessels and nerves. This explains why the middle phalanges are predominantly (and the distal phalanges exclusively) supplied by the **palmar branches** (A. digitalis palmaris propria and N. digitalis palmaris proprius) (→ Fig. 3.169).

Practice Exam Questions

To check that you are completely familiar with the content of this chapter, practice questions from an oral anatomy exam are listed here.

Show the sections and most important structures of the humerus on the skeleton:

- Where are the Sulcus nervi radialis and the Sulcus nervi ulnaris?
- What clinical importance do they have?

Explain the structure of the elbow joint in a joint model:

- Which skeletal elements articulate with each other? Which ligaments stabilise the wrist?
- Which types of joints can be found at the wrist?
- Which movements are possible, and with which ranges of motion?
- How are axes of movement performed?
- Which muscles are important for the individual movements?

Show the most important flexor muscles of the fingers:

- Which muscles act predominantly on the individual joints?
- Describe the course of the Mm. interossei with their origins and insertions.
- How do the individual muscles function in relation to their movement axes?
- How are these muscles innervated and which movements are affected when they fail?

Show the N. medianus and explain its course on the illustration:

- Explain its innervation area.
- Where is it damaged most often?
- What does the clinical picture look like in the case of a lesion in the wrist region, e. g. in carpal tunnel syndrome?

What arterial pulses can you palpate on the upper limb during a clinical examination?

- Show the blood vessel branching off the Truncus thyrocervicalis and explain their supply areas.
- Explain the course of the A. ulnaris and the A. radialis on an illustration.

How is the venous system of the arm organised?

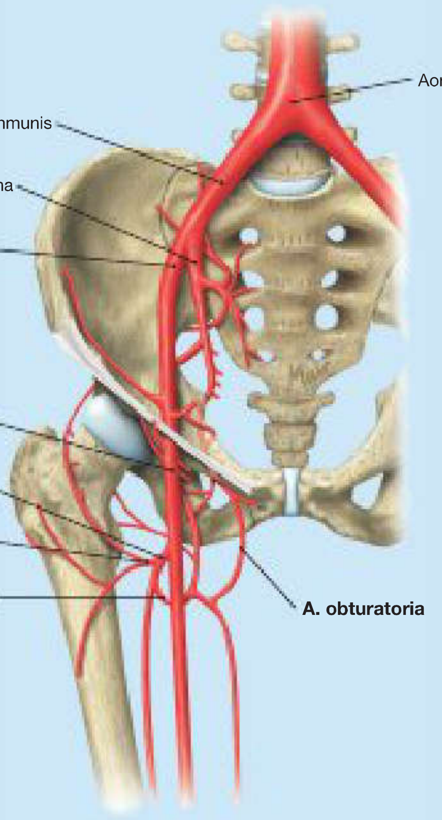
- Where can the physician take a blood sample most easily?

Explain the lymphatic drainage on the arm:

- How are the lymph nodes in the axilla organised?
- Which regions of the body do they drain?

Lower Limb

4



Overview

The **lower limb** can be divided into the **pelvic girdle and the leg.** The pelvic girdle consists of the sacrum and the two hip bones. The leg is divided by joints into the thigh, the lower leg and the foot.
The lower limb functions as a **locomotor and a supporting (or weight-bearing) organ.** The long bones of the legs enable a greater length of stride to accelerate locomotion. The individual joints of the lower limb are reinforced by stable ligaments to ensure a safe upright stance and to reduce the load of the muscle groups in the buttock, knee and calf region, which have an important support function.
The human foot acts to stabilise the upright stance. In contrast to the hand, the muscles of the foot are less involved in finely regulating distinct toe movements than in the active stabilisation of the foot and the tension of its arches.

The muscles of the lower limb are innervated by two nerve plexuses that are joined in the **Plexus lumbosacralis**. The plexuses are fed by the anterior branches of the spinal nerves from the spinal cord segments T12–S5, Co1. Different nerves to the pelvic girdle, the perineal and gluteal regions, as well as to the leg emerge from the Plexus lumbosacralis. The lower limb is primarily supplied by the **A. and V. iliaca externa** and their consecutive vascular segments. The lymphatic vessels largely run along the veins and are connected to the **lymph nodes of the groin**, which also drain the abdominal wall, including the external genitalia and certain pelvic organs.

Main Topics

After studying this chapter, you should be able to:

- name basic principles of limb development and the clinically relevant variations and malformations;
- describe the bony structures of the pelvic girdle and the leg as well as their joints, and motion range on a skeleton;
- explain the course of the ligaments on the joints, as well as the origin, insertion (attachment) and function of all muscles of the hip, thigh and lower leg, and to show these on a skeleton or dissection specimen; in the case of the foot muscles, basic information about their course, function and innervation are generally sufficient;
- describe the structure of the Plexus lumbosacralis and explain the symptoms associated with plexus lesions;
- describe the course, function and precise symptoms associated with nerve lesions in the lower limb and show these on a dissection;
- name all the arteries of the lower limb with their most important branches and identify them on the dissection specimen;
- specify the locations for pulse measurement;
- explain vascular anastomoses in the hip region;
- understand the basic principle of the venous flow in the lower limb;
- name the large epifascial veins and show them on the dissection specimen;
- explain the principles of the lymph flow in the lower limb;
- explain the regional lymph nodes of the leg and pelvis with their drainage areas;
- show the borders and contents of the Lacuna musculorum and Lacuna vasorum;
- explain the content and structure of the femoral triangle, the obturator canal and the adductor canal;
- explain the structure of the gluteal region, and identify the neurovascular structures passing through the Foramina suprapiriforme and infrapiriforme and/or the Foramen ischiadicum minus;
- explain the structure of the popliteal fossa (knee pit) and the arrangement of the neurovascular pathways crossing it.

Clinical Relevance

To ensure that the link to everyday life in the hospital does not get lost in the numerous anatomical details, the following outlines a typical case report that shows why the contents of this chapter are so important.

Femoral Neck Fracture

Case Study

A 74-year-old lady was taken to hospital by ambulance following a fall in her apartment. When her daughter found her, she was conscious and responsive. She could stand up if assisted. However, she could not put any weight on her right leg and her hip is so painful that standing for any length of time is impossible. She had fallen sideways when getting out of a chair. The mentally very alert lady insisted that she had not been knocked unconscious.

Result of Examination

The patient is conscious, awake and fully orientated. She has severe pain in the right hip region; a fresh haemorrhage is visible under the skin. The right leg appears shortened and is rotated outwards (→ Fig. a). Her cardiac (100/min) and respiratory rates (30/min) are increased, but her blood pressure (80/40 mmHg), on the other hand, is reduced. The patient is brought to the trauma ward of the nearby hospital by ambulance.

Diagnostic Procedure

The X-ray of the pelvis and the upper thigh that was taken in the ambulance shows a fracture in the neck area of the right femoral bone. Further fractures cannot be detected.

Diagnosis

Femoral neck fracture (→ Fig. b).

Treatment

Since it is likely that the blood vessels supplying the femoral neck were also damaged by the fracture (→ Fig. b), surgical treatment is carried out immediately in order to prevent shock due to severe haemorrhage. Since the healing of bone fragments is uncertain and lingering even after operative stabilisation, a hip prosthesis is inserted. In doing so, the head and neck of the femur as well as the socket on the hip bone are completely replaced by a titanium prosthesis (total hip endoprosthesis, TEP).

Further Development

As the prosthesis is stable, the weight-bearing mobilisation can be started the following day. Then follows a week of short-term care. After four weeks, discharge from hospital is possible and the patient can return home where she can continue to look after herself alone. This clinical picture is a common diagnosis. The physical examination already indicates a suspected diagnosis of femoral neck fracture. It is important to understand the blood supply to the hip joint in order to fully comprehend the therapeutic procedure – the preparations in the dissection lab help with this.

Dissection Lab

The **thigh bone (femur)** consists of a body or shaft (Corpus femoris), from which the neck (Collum femoris) and head of femur (Caput femoris) are angled medially. The head forms an articular surface embedded in the socket. The angle between the shaft and the neck is referred to as the Centrum-Collum-Diaphysis angle (CCD) and measures 126°. Because of this angle formation, the femur bears the weight of the upper half of the body asymmetrically. As a result, the bone is not uniformly exposed to compressive stress, but is also exposed to bending or tensile stress (increased risk of fracture!). In the area of the shaft, flexion is reduced by the traction force of the **Tractus iliotibialis** (iliotibial band) on the lateral side of the leg, into which the M. gluteus maximus and the M. tensor fasciae latae radiate. The external hip muscles are the most important extensors, rotators, and abductors of the hip joint.

This 3–5 cm broad fascial reinforcement must not be damaged during dissection!

The femoral head in a child is mainly nourished by a branch of the A. obturatoria (R. acetabularis) which courses from the hip socket to the head of the femur via the Lig. capitis femoris (→ Fig. 4.44). In adults, this branch supplies only a small proportion of the femur. The nutrition of the femur is now ensured by the Aa. circumflexae femoris medialis and lateralis, both of which commonly originate from the **A. profunda femoris**.

This artery and its branches is clearly visible deep inside the thigh from a frontal view!

It originates below the inguinal ligament from the A. femoralis and represents the main supplying vessel of the thigh (→ Fig. 4.136 and → Fig. 4.138).

Back in the Clinic

The femoral neck fracture of the patient has also caused a rupture of the branches of the Aa. circumflexae femoris medialis and lateralis. Due to the traction of the gluteal muscles at the Trochanter major, the femur is abducted and rotated outwards – recognisable as a shortening of the patient's leg. The risk of fracture in this area increases with age, as the CCD angle increasingly reduces in size (coxa vara). Due to a decrease in bone mass (osteoporosis) the bone stability is reduced in general. As a result of impaired blood supply, the chance of healing is reduced and secondary complications (vein thrombosis, pneumonia) may follow. Therefore, at this age, everything indicates the need for a TEP. In younger patients, partial prostheses are increasingly being used. It is important in these surgical interventions to take care of the Aa. circumflexae femoris medialis and lateralis as well as of the surrounding hip muscles. Of course, the anatomical conditions must also be considered in the various surgical approaches.

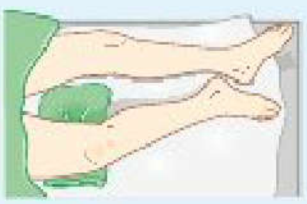


Fig. a Femoral neck fracture in a female patient after a fall. [L126]
Note the shortened appearance of the leg and its external rotation.

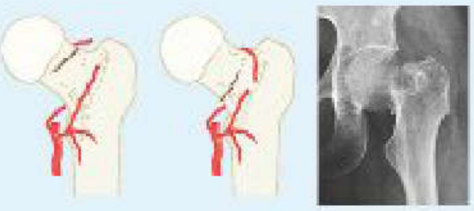


Fig. b Femoral neck fracture with vascular ruptures; left side: with ruptured vessels.
Ventral view [L126]; right side: X-ray image (AP). [M502, M519]

Surface Anatomy

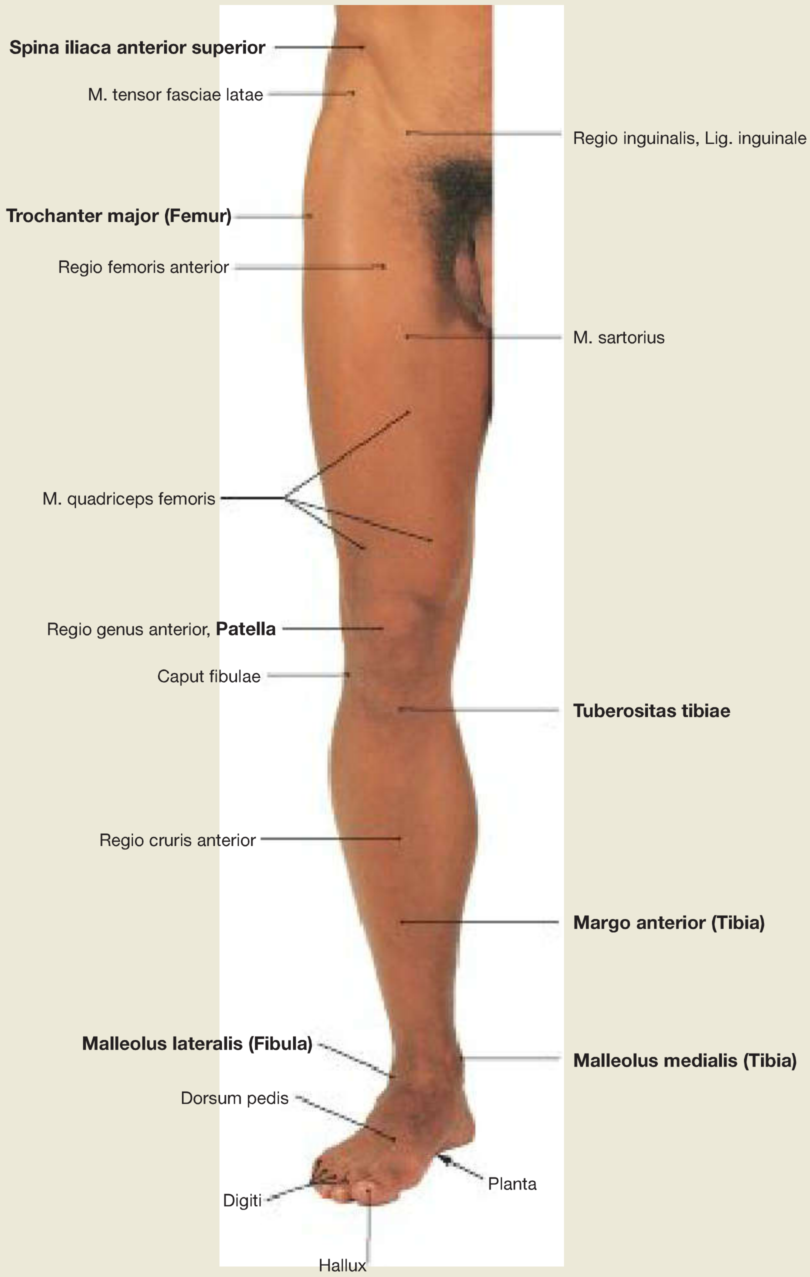


Fig. 4.1 Surface relief of the leg, right side; ventral view.
The surface relief of the leg is determined by the muscles and by some of the skeletal elements. The skeletal elements that are palpable through the skin are important landmarks for the physical examination.

Fig. 4.2 Surface relief of the leg, right side; dorsal view.

Skeleton of the Lower Limb

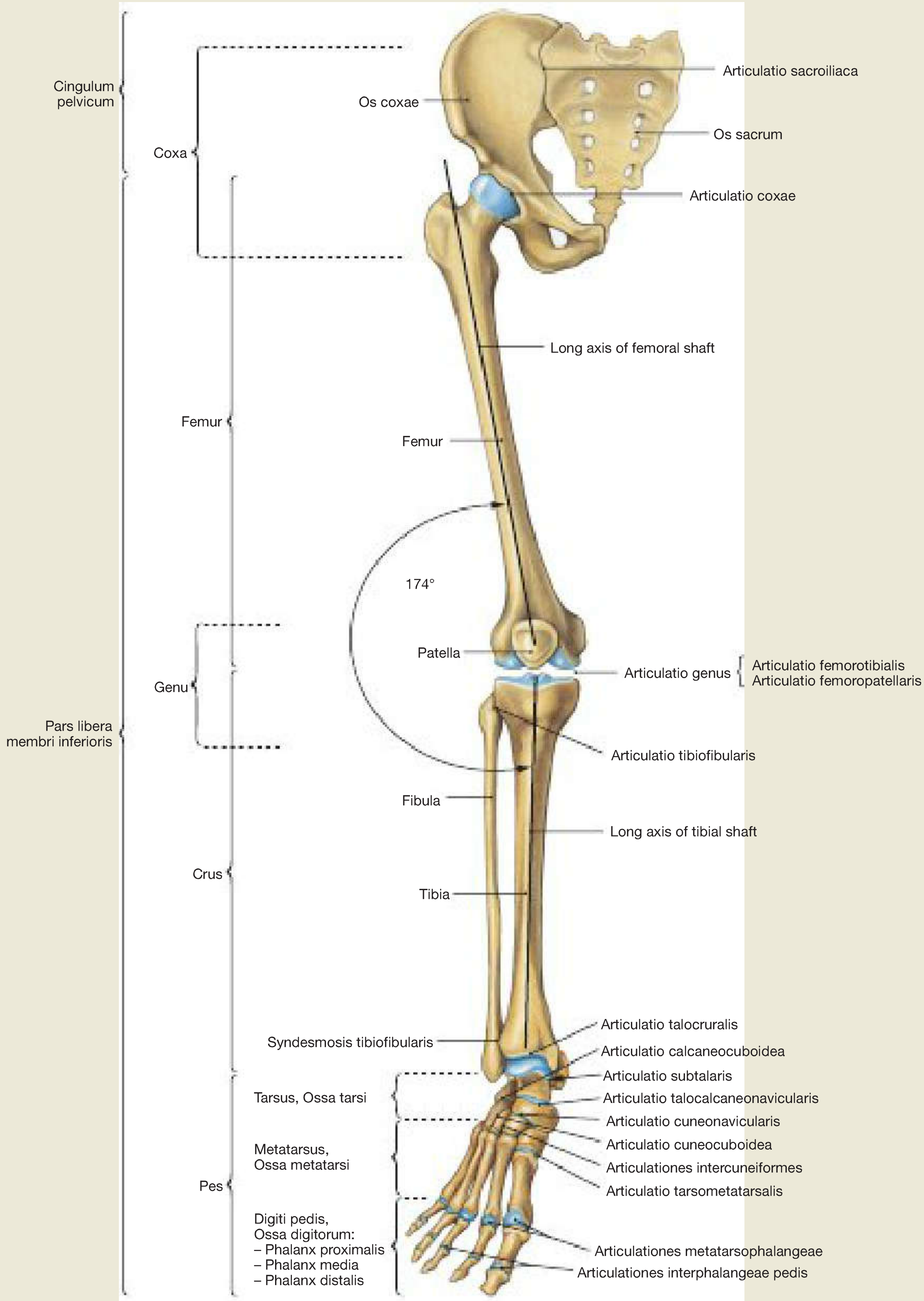
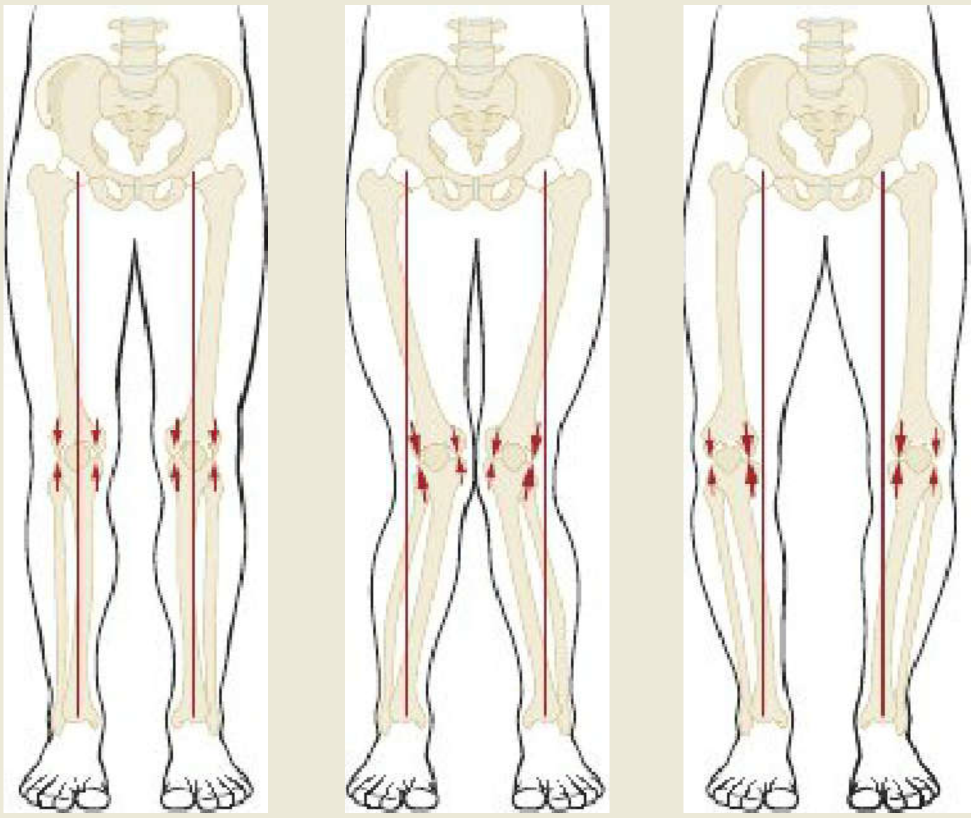


Fig. 4.3 Bones and joints of the lower limb, Membrum inferius, right side; ventral view.
Whereas the shoulder girdle consists of two bones (scapula and clavicle), the pelvic girdle (Cingulum pelvicum) is formed by two hip bones (Ossa coxae) and the sacrum (Os sacrum). The thigh and leg form a laterally open angle of 174°, referred to as the **Q-angle** (abduction angle).
In the **knock-knee deformity** (Genu valgum), the Q-angle is smaller and in the **bow-leg deformity** (Genu varum) it is larger. For the development of the lower limbs (→ pp. 158 and 159).



Normal Q-angle   Genu valgum knock-knee deformity   Genu varum bow-leg deformity

Fig. 4.4 Mechanical axis of the leg (MIKULICZ line). (According to [S010-1-16]) [L126]
Normally, the large joints of the lower limb lie on a virtual straight line, which is known as the mechanical axis. This is the connecting line between the centre of the femoral head in the hip joint and the middle of the malleolar fork in the ankle joint.
In the case of a **knock-knee** (genu valgum) deformity the knee is shifted **medially** from the **mechanical axis;** in the case of a **bow-leg** (genu varum) deformity the knee is shifted laterally**.**
The size of the arrows illustrates the ratio of stress on the medial and lateral joint compartments in relation to the mechanical axis.

Clinical Remarks

Since the whole body weight is transferred via the mechanical axis (MIKULICZ line) to the soles of the feet, the load on the joints is evenly distributed if the joints are aligned along this mechanical axis. Shifting of the knee joint in the case of a **knock-knee** (Genu valgum) or **bow-leg** (Genu varum) deformity results in an uneven load on both compartments of the knee joint (red arrows, → Fig. 4.4). This can lead to degenerative osteoarthritis in the knee joint **(gonarthrosis)** due to the wear and tear of menisci and joint cartilage. In the case of a **Genu valgum** this gonarthrosis affects the **lateral compartment** and in the case of a **Genu varum** it affects **the medial compartment.** For substantial deviations from the mechanical axis, surgical corrections by removal of a bony wedge (calcaneal osteotomy) may be performed.

Pelvis

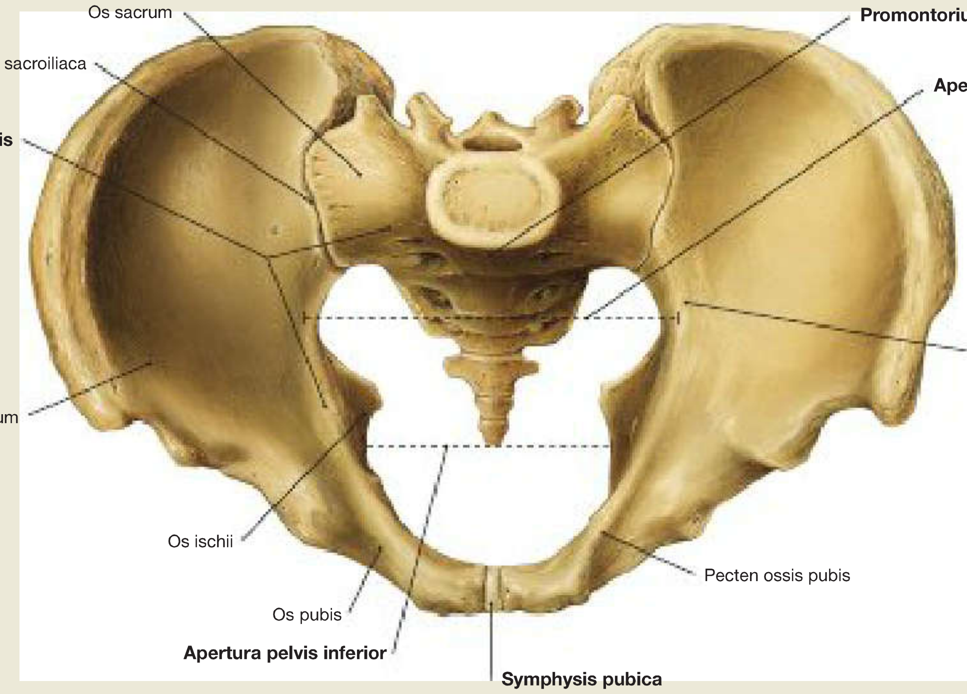
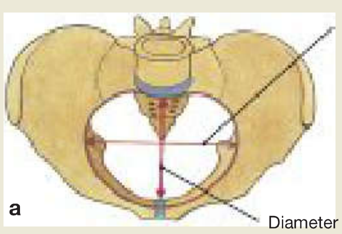


Fig. 4.5 Pelvis; ventrocranial view.
The sacroiliac joint (Articulatio sacroiliaca) and the pubic symphysis (Symphysis pubica) connect the two hip bones (Ossa coxae) and the sacrum (Os sacrum) to a stable ring construction, that surrounds the intestines together with the wings of the ilium and transfers the body weight to the legs.
The **Linea terminalis** is formed by the Pecten ossis pubis at the front, starting from the pubic symphysis, and by the Linea arcuata at the back, ending on the **promontory.** It includes the pelvic inlet **(Apertura pelvis superior)** and separates the **cranially** positioned **larger pelvis** (Pelvis major) from the **caudally** positioned **lesser pelvis** (Pelvis minor). The promontory is the furthest protruding part of the spine in the pelvic inlet. The pelvic outlet **(Apertura pelvis inferior)** is bordered at the front by the lower rim of the pubic symphysis and by the inferior pubic ramus, and on both sides by the ischial tuberosities and at the back by the tip of the coccyx.



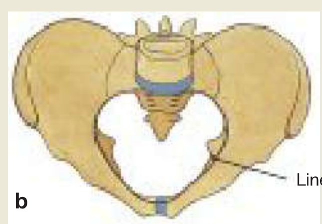


Fig. 4.6a and b Pelvis, female pelvis (→ Fig. 4.6a) and male pelvis (→ Fig. 4.6b).
The shape of the pelvis shows specific differences between the sexes: in **males** the pelvic inlet is **heart-shaped.** The somewhat smaller pubic angle is referred to as the Angulus subpubicus (→ Fig. 4.34a). In contrast, the pelvic inlet is usually **transverse oval** in **females.** In addition, the angle between the inferior pubic rami (Arcus pubicus, → Fig. 4.34b) and the distance between the ischial tuberosities, as well as the wings of the ilium, are larger than in men.

The **inner pelvic dimensions,** are used to determine the width of the pelvic inlet: the obstetric conjugate diameter **(Diameter vera)** between the posterior aspect of the pubic symphysis and the promontory, the **transverse diameter (Diameter transversa)** between the most laterally located points of the Linea terminalis on both sides, the diagonal diameter (**Diameter diagonalis,** → Fig. 4.7) between the lower rim of the pubic symphysis and the promontory, and the anatomic diameter (**Diameter anatomica,** → Fig. 4.7) between the upper rim of the pubic symphysis and the promontory.

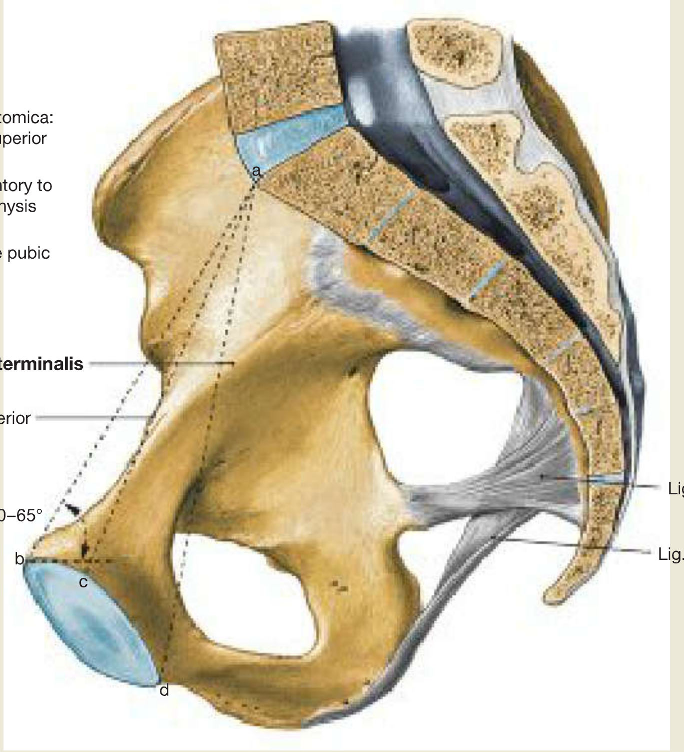


Fig. 4.7 Pelvis, female pelvis; medial view; median section with illustration of the internal pelvic diameters.
The inner pelvic dimensions vary greatly between individuals. The most important diameter is the **conjugate diameter** connecting the posterior aspect of the pubic symphysis and the promontory. **The anatomical diameter (Conjugata anatomica)** and the **Diameter diagonalis** indicate the distance from the promontory to the upper and lower rims of the pubic symphysis. The level of the pelvic inlet together with the horizontal level form the pelvic inclination angle of approx. 60–65°.

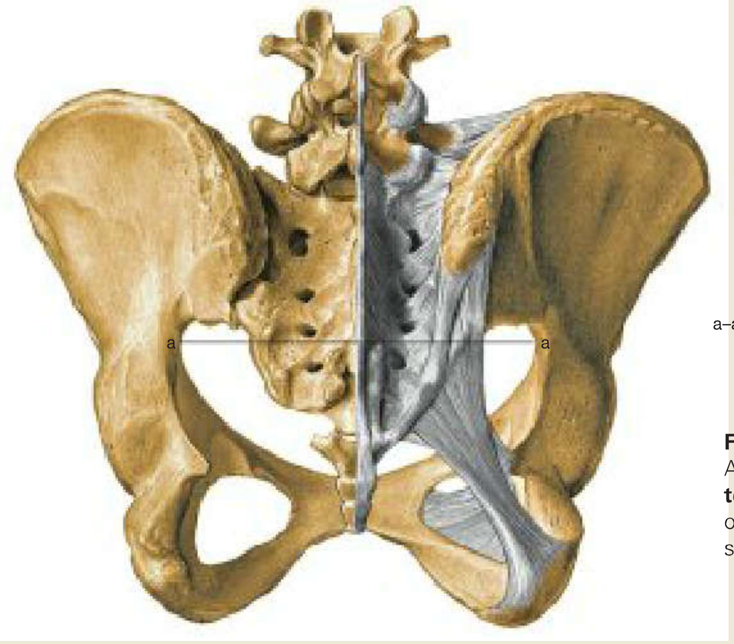


Fig. 4.8 Pelvis, female pelvis with pelvic dimensions; dorsal view.
A further internal diameter of some relevance is the **transverse diameter (Diameter transversa).** The different outer diameters (Distantiae), on the other hand, are of less practical importance and therefore not shown here.

Clinical Remarks

Because the pelvic inlet and the true pelvis encompass the birth canal, assessment of the pelvic diameter is of great importance during **pregnancy** to determine whether a vaginal birth is possible. The most important diameter for the passage of the foetal head is the **conjugate diameter** (clinical term Conjugata vera; at least 11 cm). It can be assessed by vaginal examination of the diagonal diameter, which spans the inferior side of the pubic symphysis to the promontory and is 1.5 cm longer than the Conjugata vera. This is determined in the case of a planned vaginal birth only if a disproportion between the size of the child and the maternal birth canal is suspected mostly by magnetic resonance imaging (MRI). In the case of a caesarean section, the conjugate diameter is directly measured routinely, in order to ascertain whether future vaginal births might also be possible. During pregnancy, the pubic symphysis and sacroiliac joints are loosened by the relaxin hormone which is released from the placenta and the ovary, so that the Conjugata vera expands by approx. 1 cm during childbirth.

Hip Bone

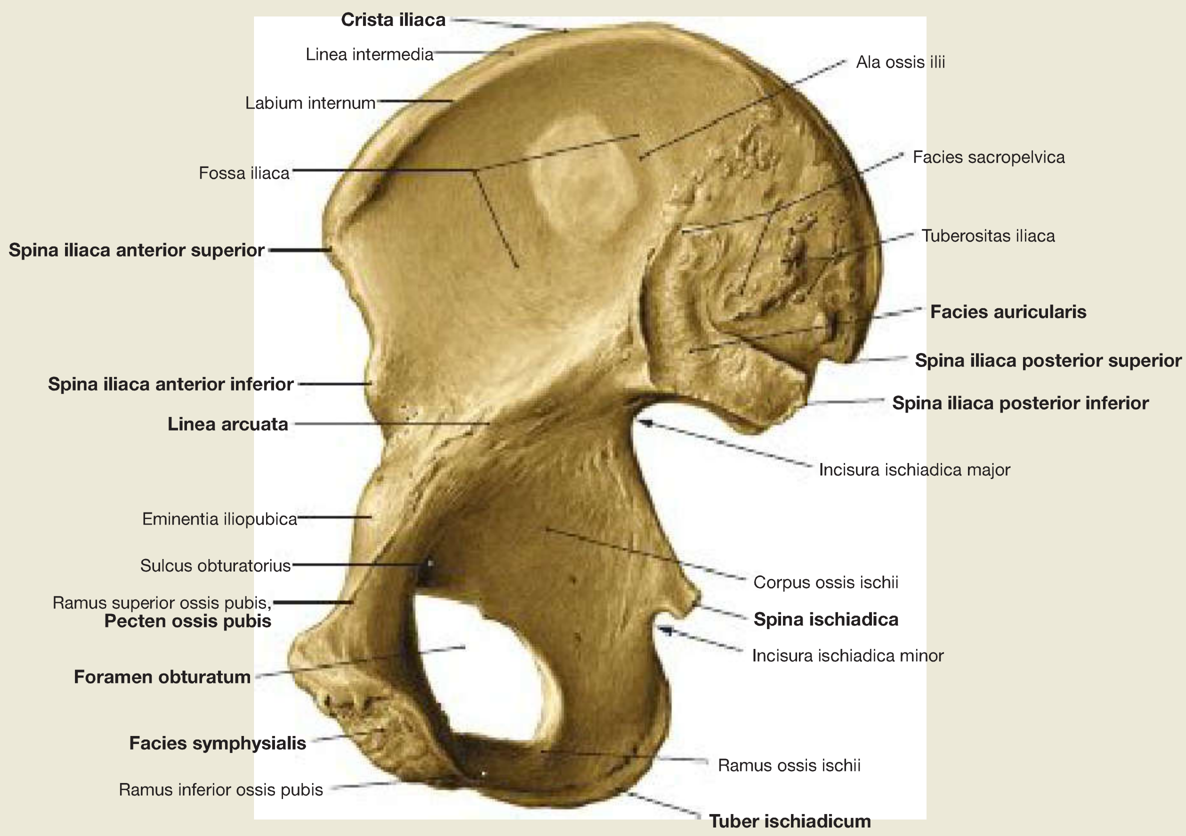


Fig. 4.9 Hip bone, Os coxae, right side; medial view.
The hip bone consists of three parts, the **ilium (Os ilium),** the **ischium (Os ischii)** and the **pubis (Os pubis).** The ilium (above) forms the iliac wing, the ischium (below, rear) and pubis (below, in front) form the bony ring around the Foramen obturatum. The **Facies auricularis** serves as the articular surface of the sacroiliac joint. The Discus interpubicus of the pubic symphysis is attached to the **Facies symphysialis**.

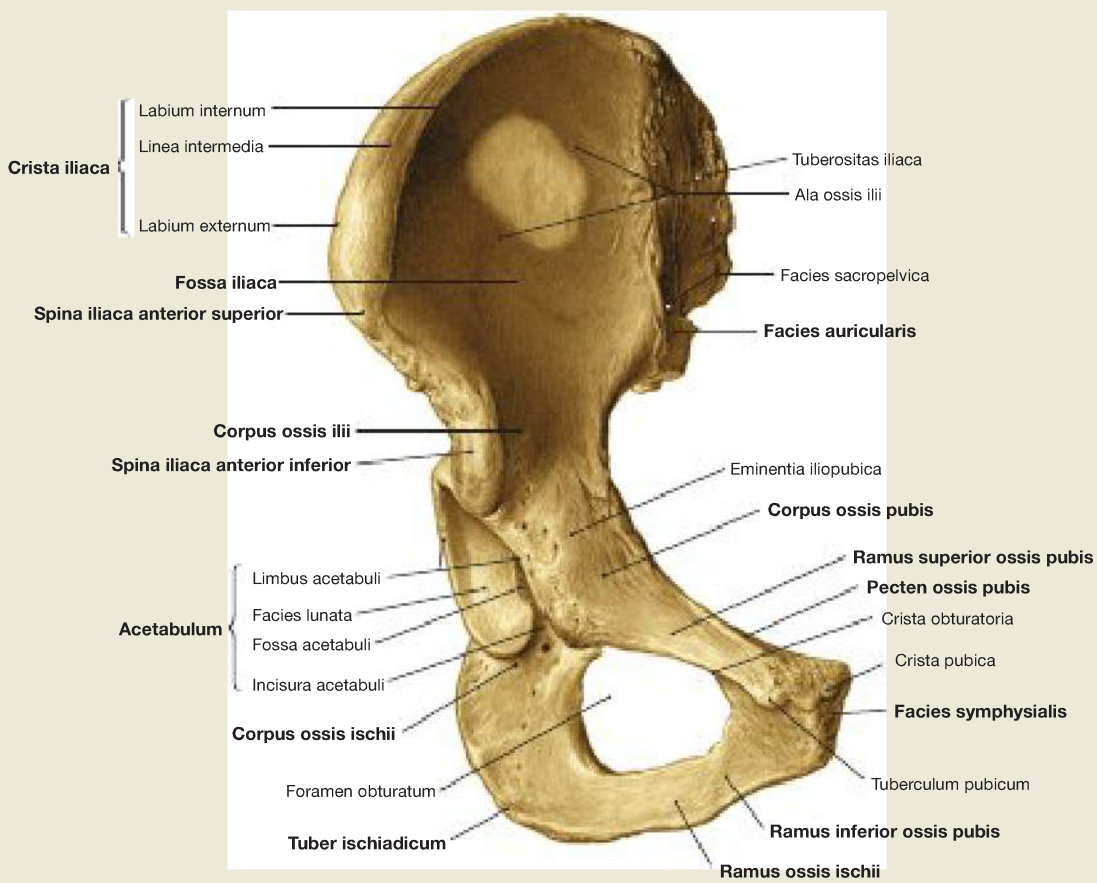


Fig. 4.10 Hip bone, Os coxae, right side; ventral view.

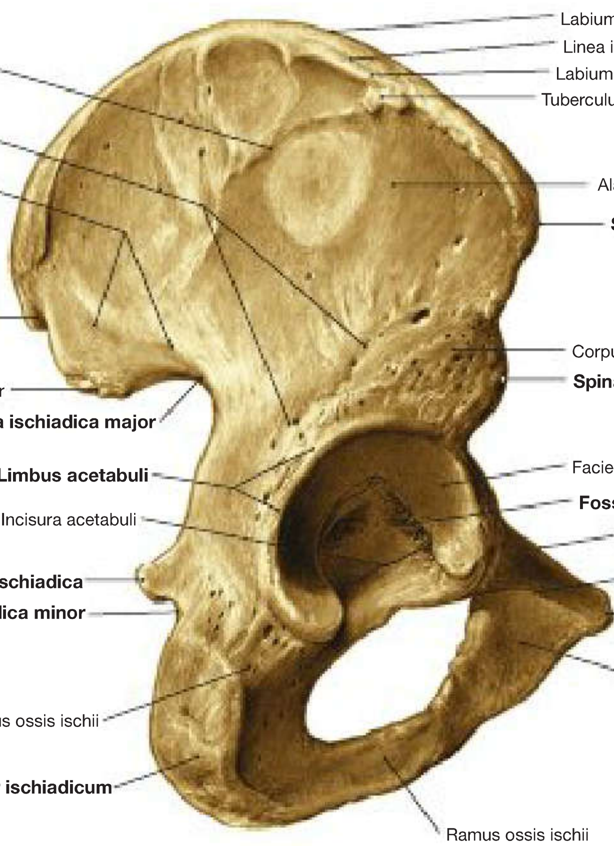


Fig. 4.11 Hip bone, Os coxae, right side; dorsolateral view.
The three parts of the hip bone, namely the ilium (Os ilium), the ischium (Os ischii), and the pubis (Os pubis), together form the hip socket (Acetabulum).

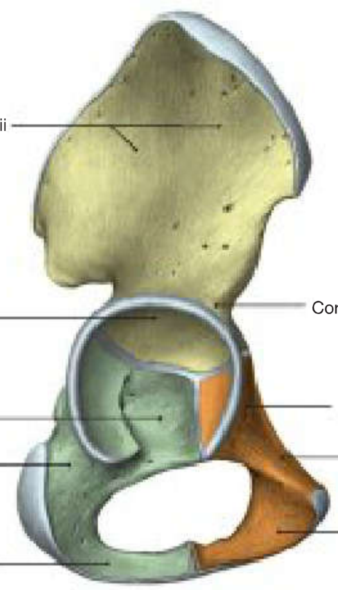


Fig. 4.12 Hip bone, Os coxae, of a six-year-old child, right side; lateral view.
The three parts of the hip bone (Os ilium, Os ischii, Os pubis) are linked by a Y-shaped cartilaginous junction (synchondrosis) of the acetabulum. The cartilaginous junction ossifies between the 13th and 18th year of life.

Clinical Remarks

In the case of severe trauma, such as the impaction of outstretched legs in a car accident, a fracture of the acetabulum with dislocation of the femoral head (central hip luxation) may occur.

The development of the pelvic bones in children with endochondral ossification in the area of the acetabulum must be considered in X-ray examinations during childhood and adolescence, in order to avoid the risk of confusing a cartilaginous junction with a fracture gap.

Femur

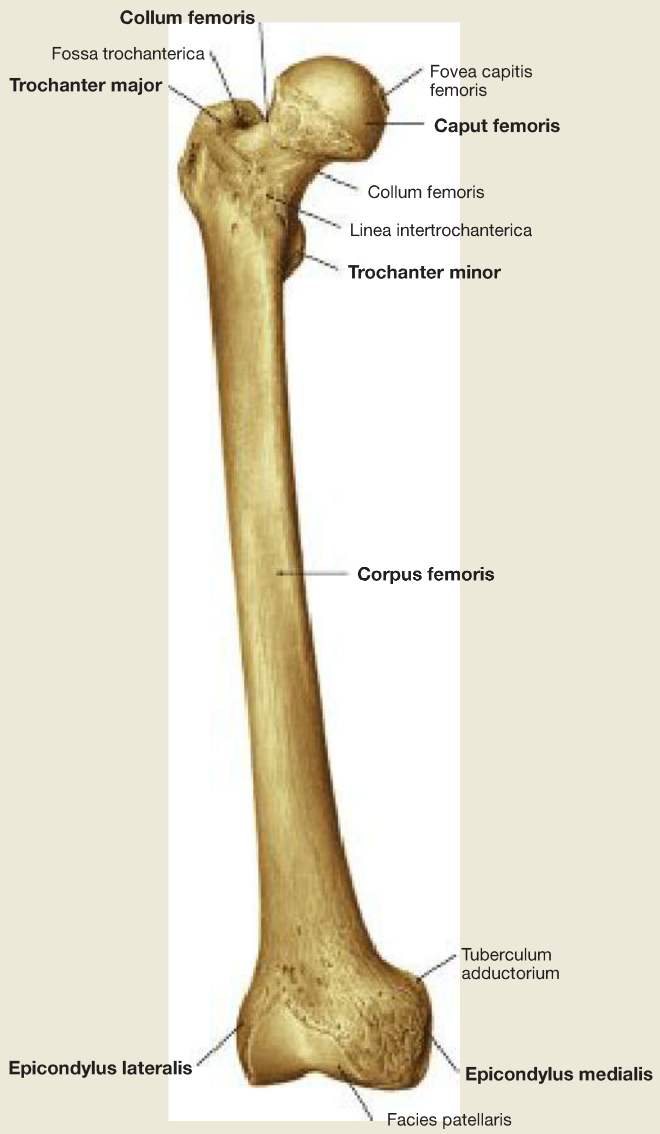


Fig. 4.13 Femur, right side; ventral view.
On the proximal shaft of the femur the Trochanter major is located laterally and the Trochanter minor dorsal-medially.

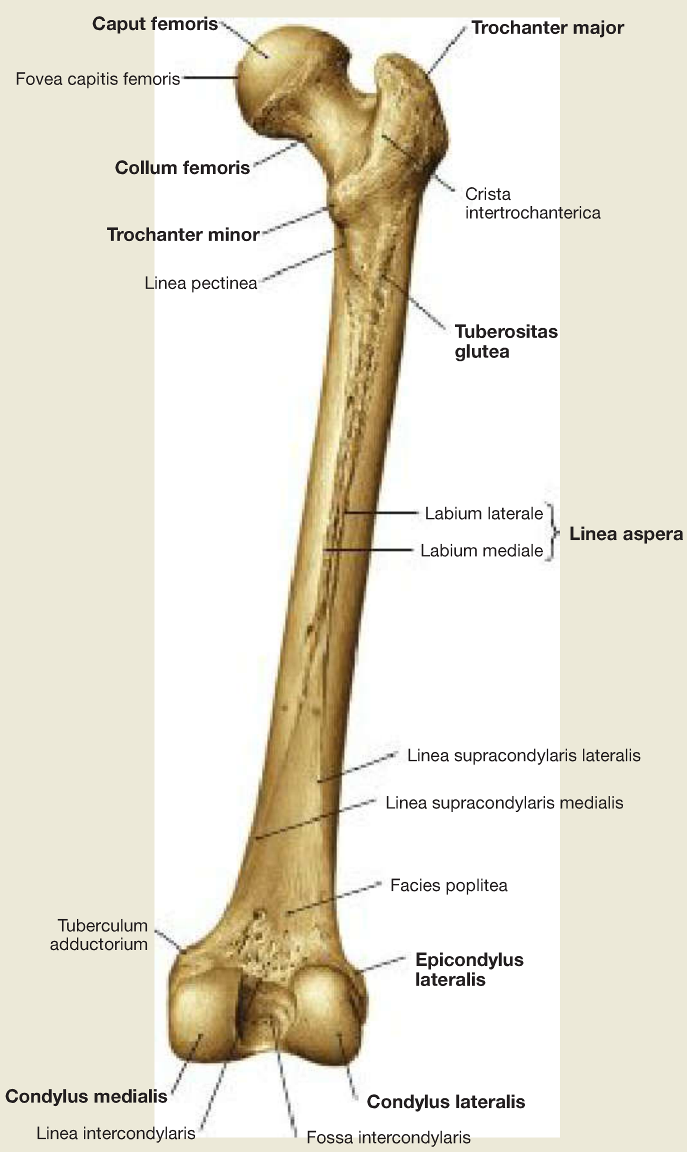


Fig. 4.14 Femur, right side; dorsal view.
The Linea aspera serves as apophysis for the origin of the M. quadriceps femoris and for the insertion of other muscles of the adductor group.

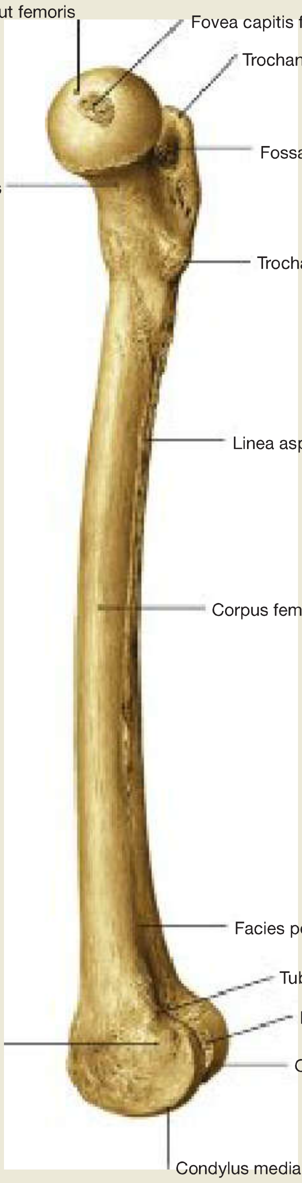


Fig. 4.15 Femur, right side; medial view.

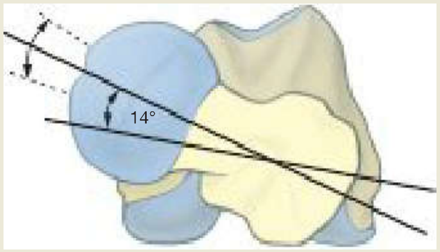


Fig. 4.16 Femur, right side; proximal view; the proximal and distal ends of the femur are projected on top of each other.
Against the axis connecting both femoral condyles (= transverse axis of the knee joint) the femoral neck is rotated by **12°–14°** anteriorly (**torsion angle of the femur**). In infants, this angle is approximately 30°. If the torsion angle of the femur is more pronounced, this results in an internal rotation of the toes (pointing inwards) when walking. If the angle of antetorsion is smaller than 12°, the toes point outwards.

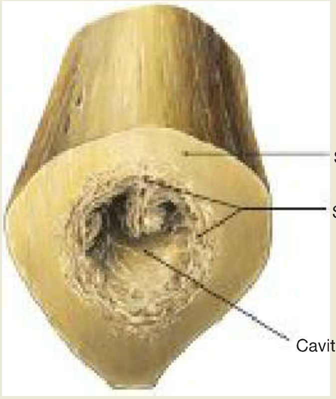


Fig. 4.17 Femur, right side; cross-section through the middle level of the femoral shaft; distal view.
The outer layer of solid Substantia spongiosa is followed by an inner layer of Substantia spongiosa and the central medullary cavity (Cavitas medullaris) which contains the bone marrow.

Femur

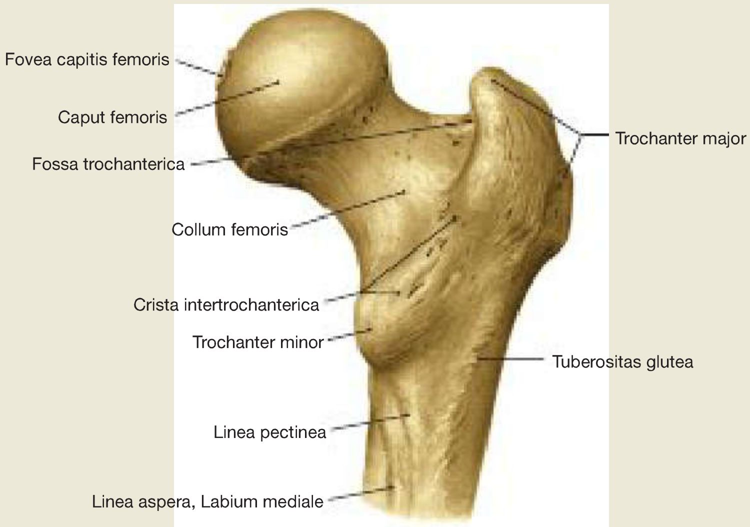


Fig. 4.18 Proximal end of the femur, right side; dorsal view.

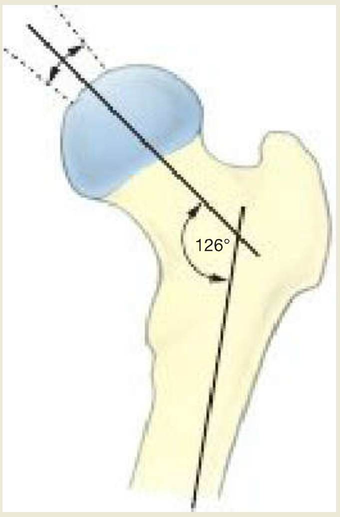


Fig. 4.19 Proximal end of the femur, right side, with illustration of the femoral neck-shaft angle.
The femoral neck forms an angle of **126° with the longitudinal axis of the femoral shaft.** This angle is referred to as the **Centrum-Collum-Diaphysis angle (CCD angle)**. In the newborn, the CCD angle measures 150°. An **increased CCD angle** is referred to as **Coxa valga,** a **decreased CCD angle** as **Coxa vara**.

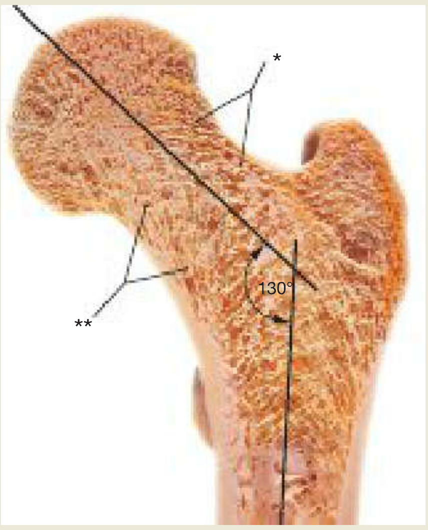


Fig. 4.20 Proximal end of the femur, right side, with illustration of the spongy bone structure in the case of an increased femoral neck-shaft angle (Coxa valga). Section at the level of the antetorsion angle.
The **spongy bone trabeculae** are arranged in **curved lines,** i.e. along the lines of maximum traction and compression forces (so-called trajectories). In coxa valga the **compressive** loads increase. Therefore, the medially located 'traction bundle' (**) of the spongy bone trabeculae is more developed, while the size of the laterally located 'compression bundle' (*) of the spongy bone is reduced.

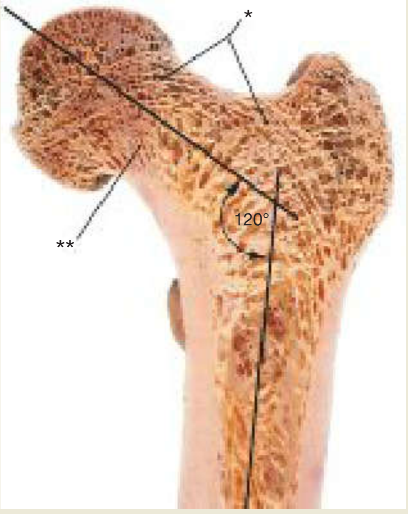


Fig. 4.21 Proximal end of the femur, right side, with illustration of the spongy bone structure in the case of a decreased angle of inclination (femoral neck-shaft angle) (Coxa vara). Section at the level of the antetorsion angle.
The **tensile** stresses increase in the Coxa vara. The lateral 'traction bundle' (*) of the spongy bone is strengthened and the medial 'pressure bundle' (**) is less pronounced. Because of the high **bending stress,** the cortical bone on the medial side of the femoral neck is particularly strong.

Clinical Remarks

Changes of the femoral neck-shaft angle can restrict the range of motion. In Coxa vara in particular, abduction is reduced. Changing the stress on the articular surfaces in the case of **Coxa vara** or **Coxa valga** may cause an increased attrition resulting in degenerative arthritis of the hip joint **(coxarthrosis)** or the knee joint **(gonarthrosis)**. In addition, **Coxa vara** predisposes to fractures of the femoral neck **due to increased bending stress.**

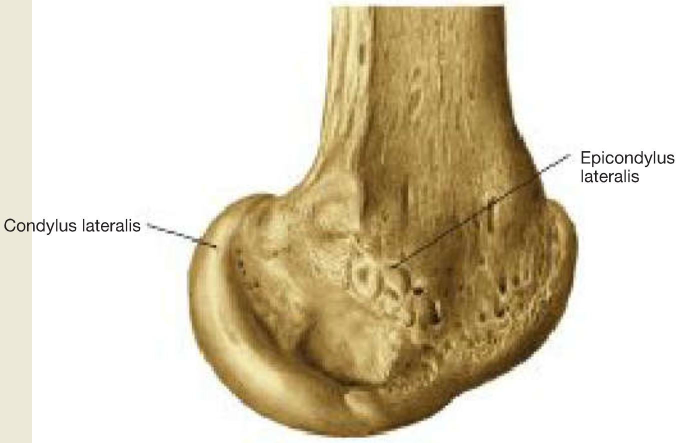


Fig. 4.22 Distal end of the femur, right side; lateral view.
To understand the flexion-extension movement in the knee joint (→ Fig. 4.61), the shape of the articular surfaces of the femoral condyles is important. The articular surfaces are shifted dorsally in relation to the median axis of the shaft **(retroposition).** In addition, the condyles have a **greater curvature at the back** (smaller radius of curvature) than at the front (larger radius of curvature). Thus their curvature is **spiral-shaped.** This phenomenon is more distinct at the medial than at the lateral condyle (→ Fig. 4.85b).

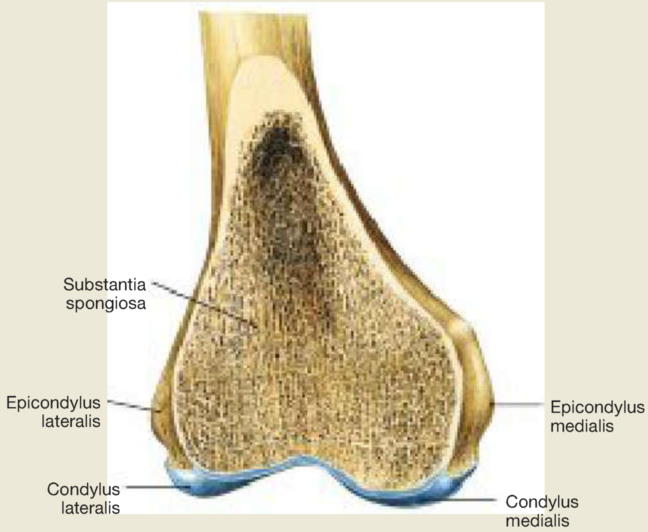


Fig. 4.23 Distal end of the femur, right side; frontal section through the joint bodies; ventral view.

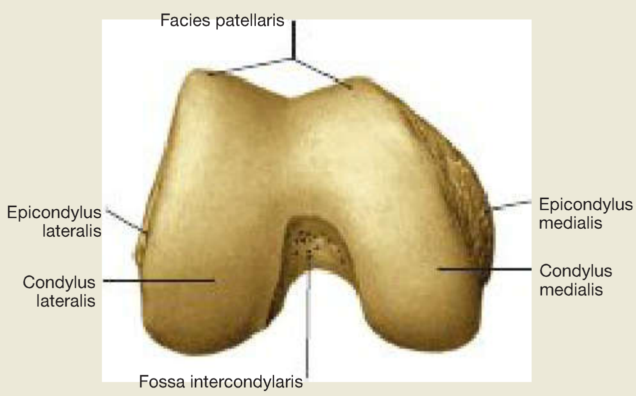


Fig. 4.24 Distal end of the femur, right side; distal view.

Clinical Remarks

Since attrition of the knee joints **(gonarthrosis)** are a common disease and frequently require prosthetic surgery of both articular surfaces (**total knee replacement,** TKR), anatomical knowledge of the articulating bones is of utmost importance. Recent studies have shown that the shape of the articular surfaces and the radius of curvature of both femoral condyles differ slightly on either side. In knee prosthetics therefore, every attempt is made to reproduce the shape of the articular surfaces as precisely as possible, so that the prostheses allow similar motion patterns as in a healthy knee.

Tibia

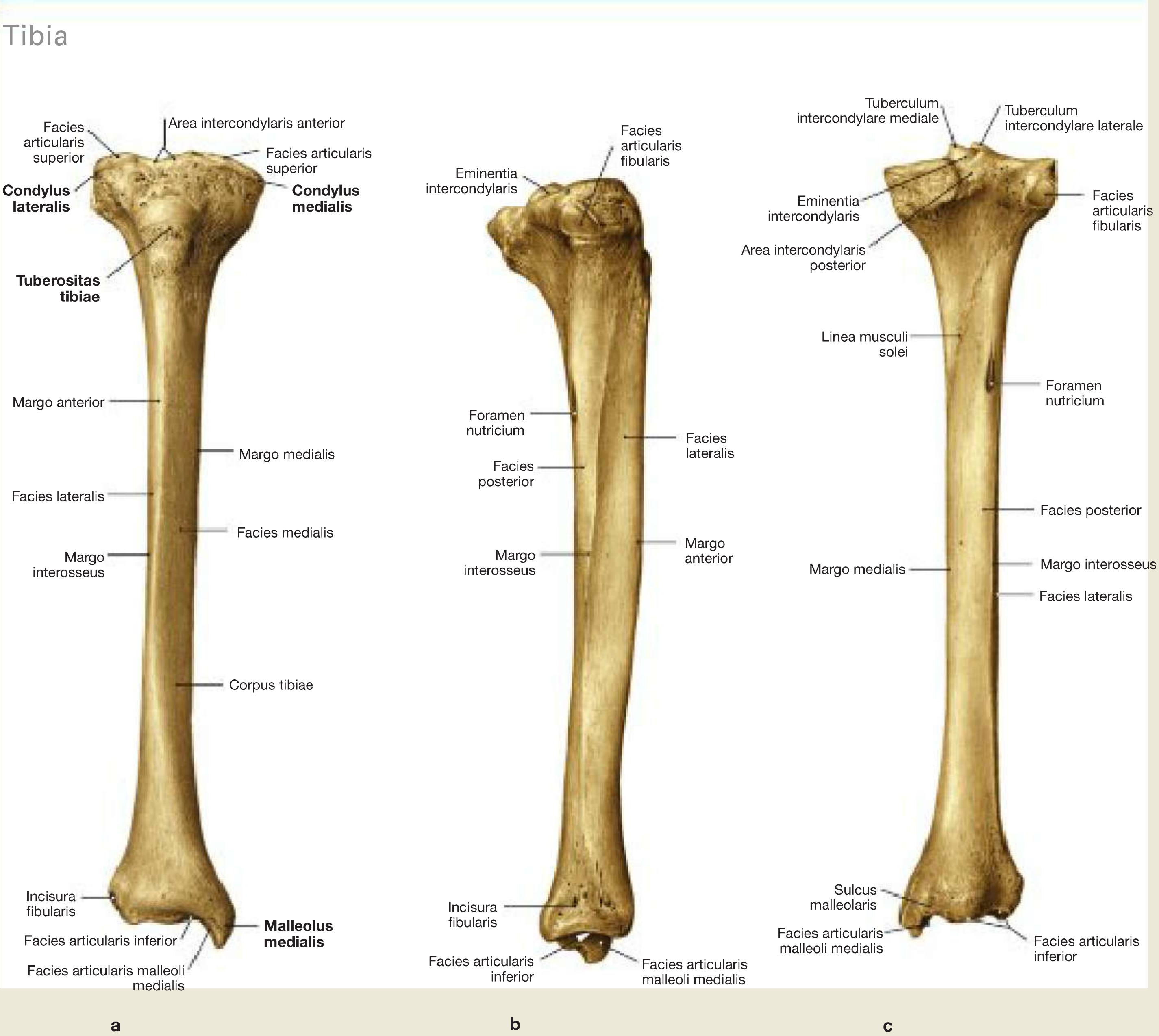


Fig. 4.25a to c Tibia, right side; ventral view (→ Fig. 4.25a), lateral view (→ Fig. 4.25b) and dorsal view (→ Fig.4.25c).
The proximal articular surface is shifted dorsally from the median axis of the shaft **(retroposition).** In addition, the articular surface is tilted slightly dorsally by 3°–7° **(retroversion).** The retroversion is more pronounced at the medial condyle than at the lateral condyle and especially affects the medial rim of the articular surface here.

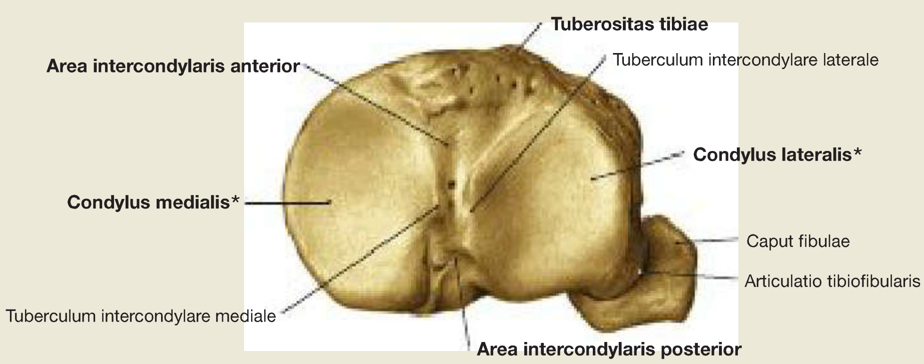


Fig. 4.26 Tibia and fibula, right side; proximal view.
The articular surfaces of the condyles (*) are collectively referred to as **Facies articularis superior**.

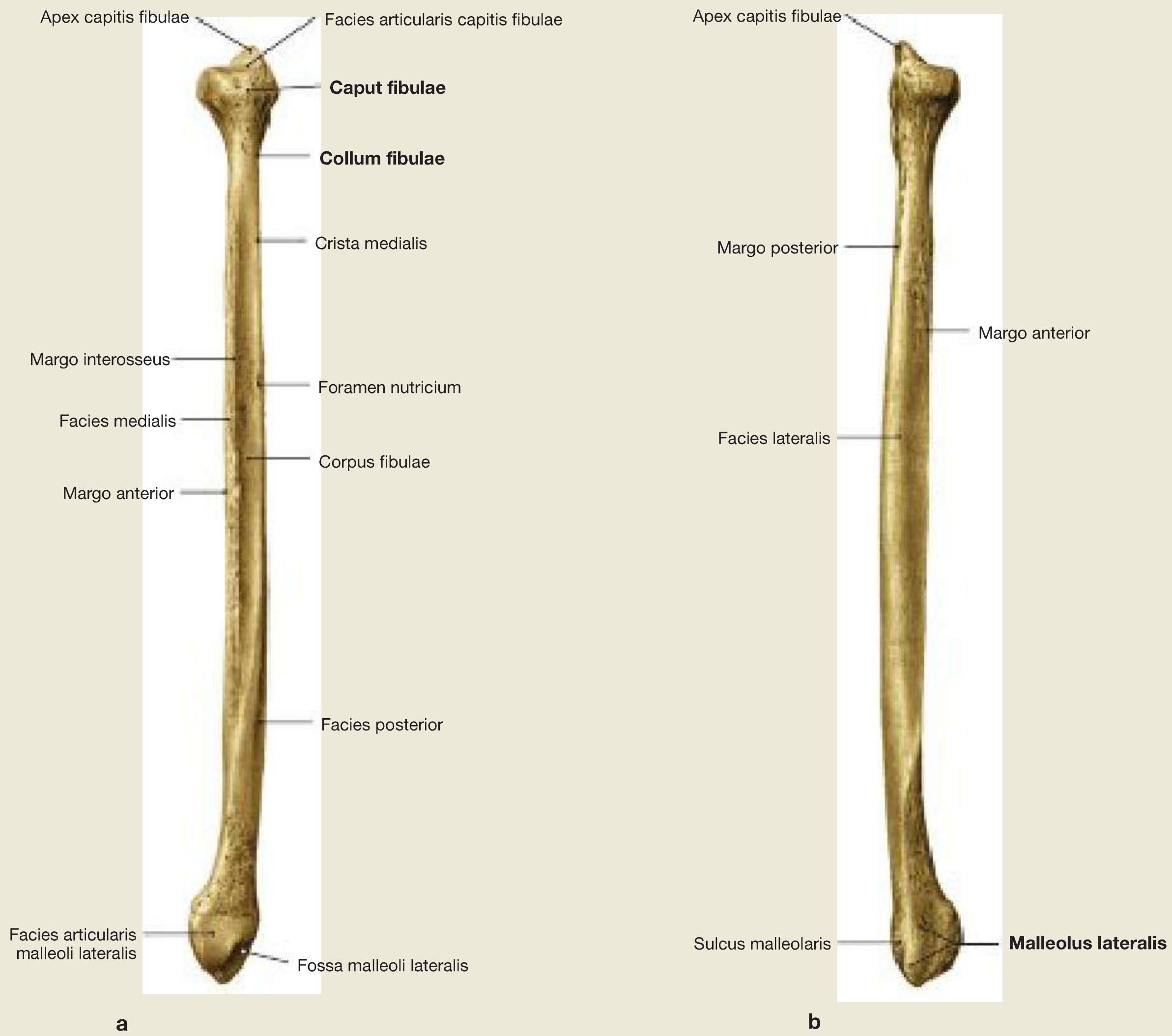


Fig. 4.27a and b Fibula, right side; medial view (→ Fig. 4.27a) and lateral view (→ Fig. 4.27b).

When positioning an isolated fibula, orientation is facilitated because both the articular surface of the fibula head and that of the ankle should be directed medially.

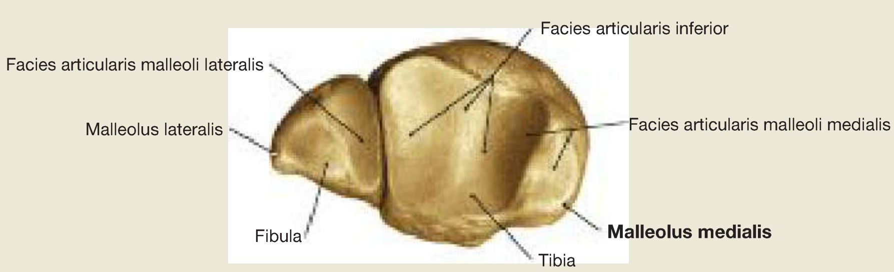


Fig. 4.28 Tibia and fibula, right side; distal view.

Bones of Foot

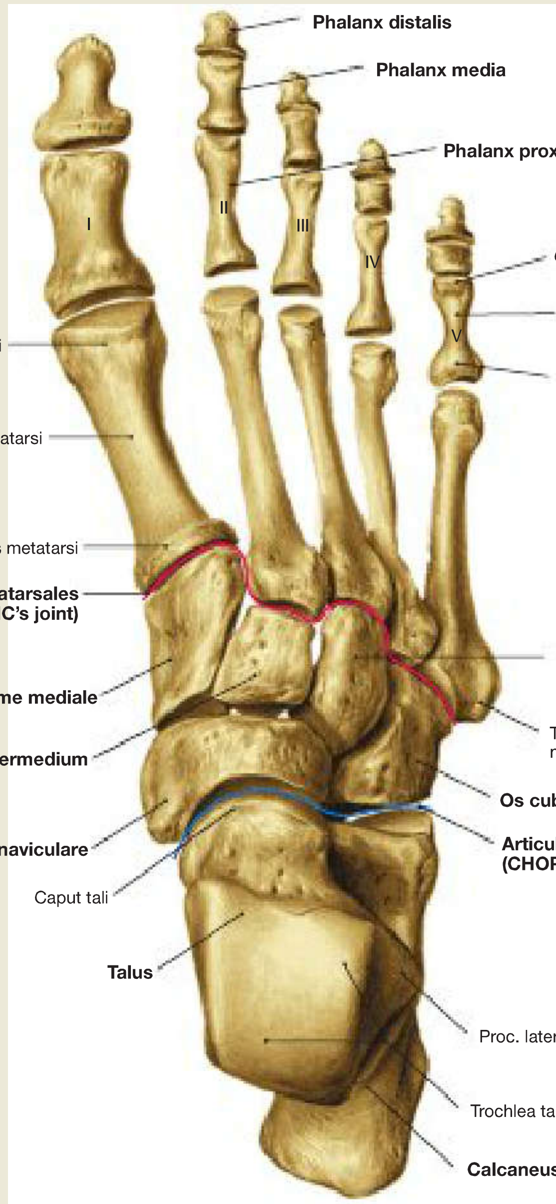
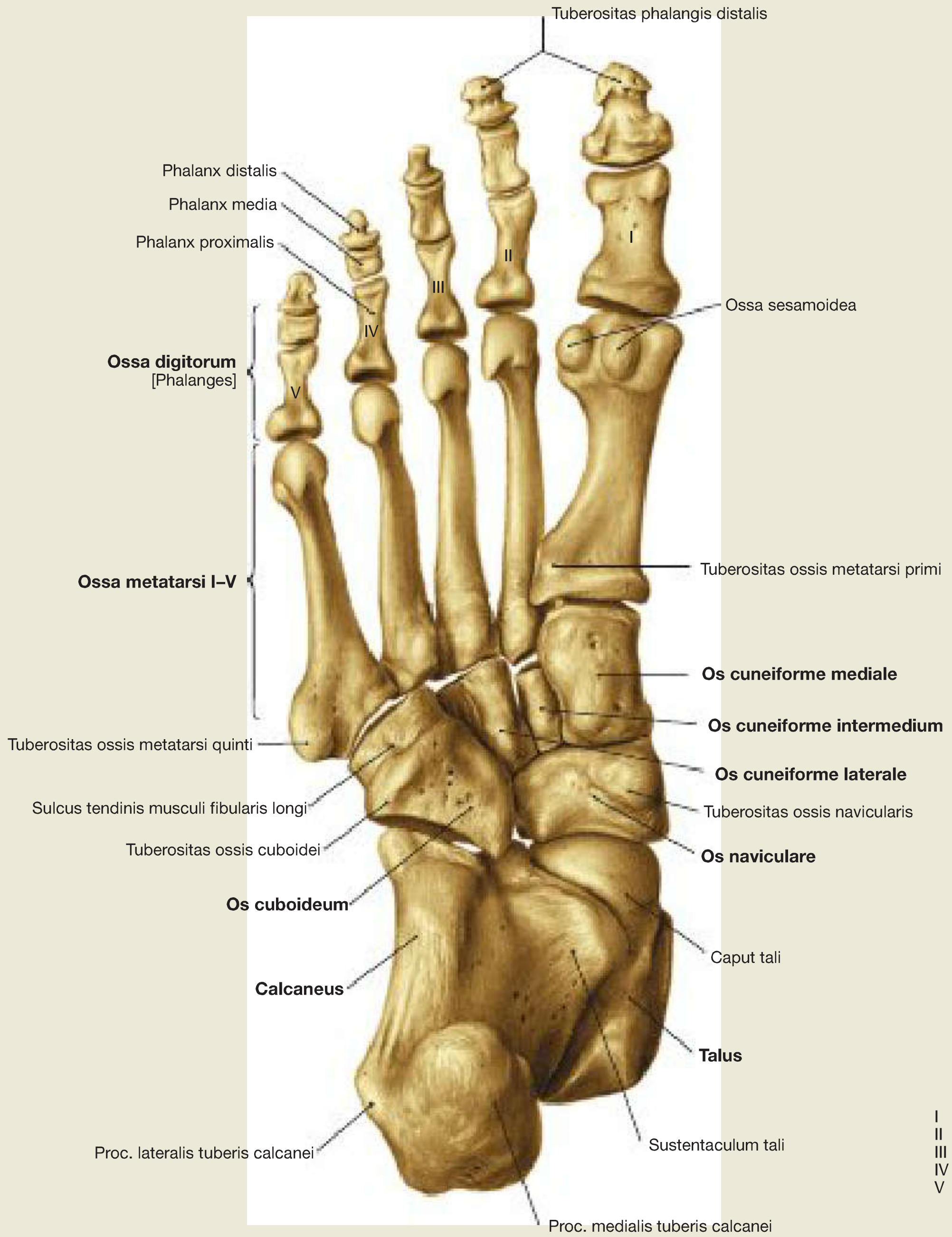


Fig. 4.29 Bones of foot, Ossa pedis, right side; dorsal view.
The foot **(Pes)** can be divided into the **tarsus** with tarsal bones, Ossa tarsi, the **metatarsus** with the metatarsal bones (Ossa metatarsi) and the toes (Digiti pedis)**,** which consist of several phalanges. The tarsus includes **the ankle or talus**, **the heel or calcaneus, the navicular bone (Os naviculare), the cuboid bone (Os cuboideum)** and the three **cuneiform bones (Ossa cuneiformia)**. Clinically, a distinction is made between the hindfoot and forefoot. The articular line in the tarsometatarsal joints is often seen as the border.

Clinical Remarks

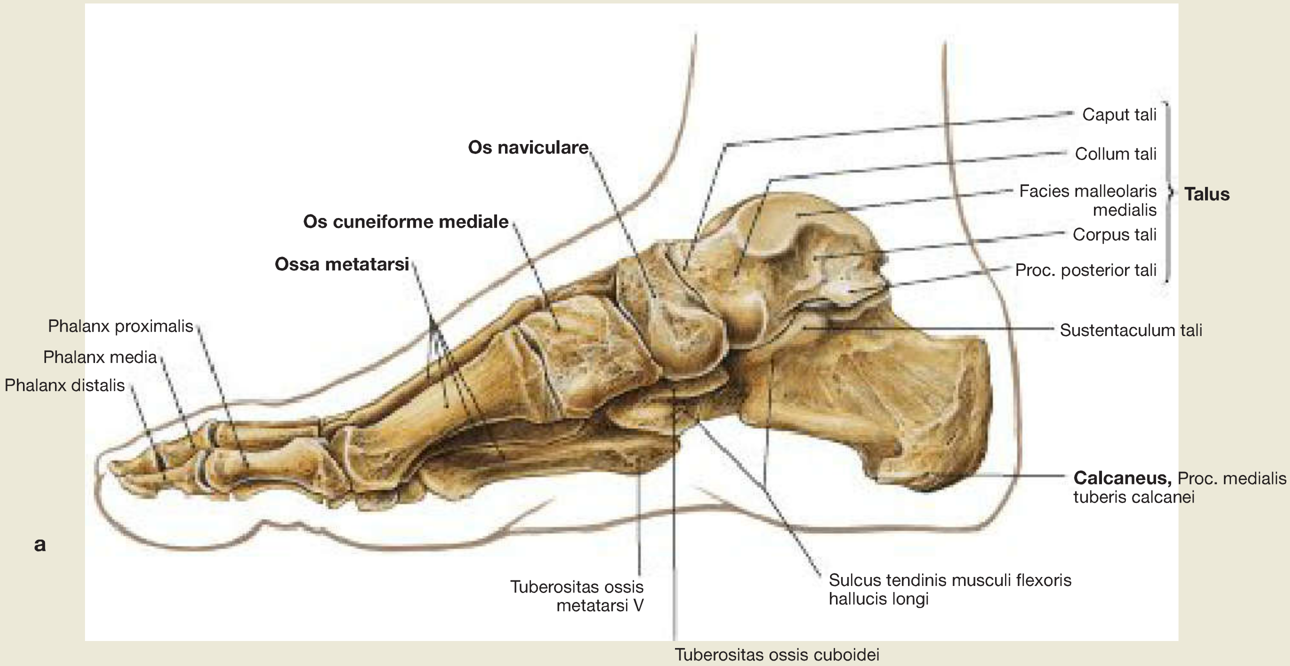
The Articulatio tarsi transversa (clinical term: **CHOPART's joint;** blue) and the Articulationes tarsometatarsales (clinical term: **LISFRANC's joint;** red) are preferred locations for surgical amputations in the case of injuries, frostbite, or circulatory disorders associated with necrosis. Very rarely dislocations **(luxations)** can occur in these joints.



I Hallux [Digitus primus]
II Digitus secundus
III Digitus tertius
IV Digitus quartus
V Digitus minimus [quintus]

Fig. 4.30 Bones of the foot, Ossa pedis, right side; plantar view.

Bones of Foot



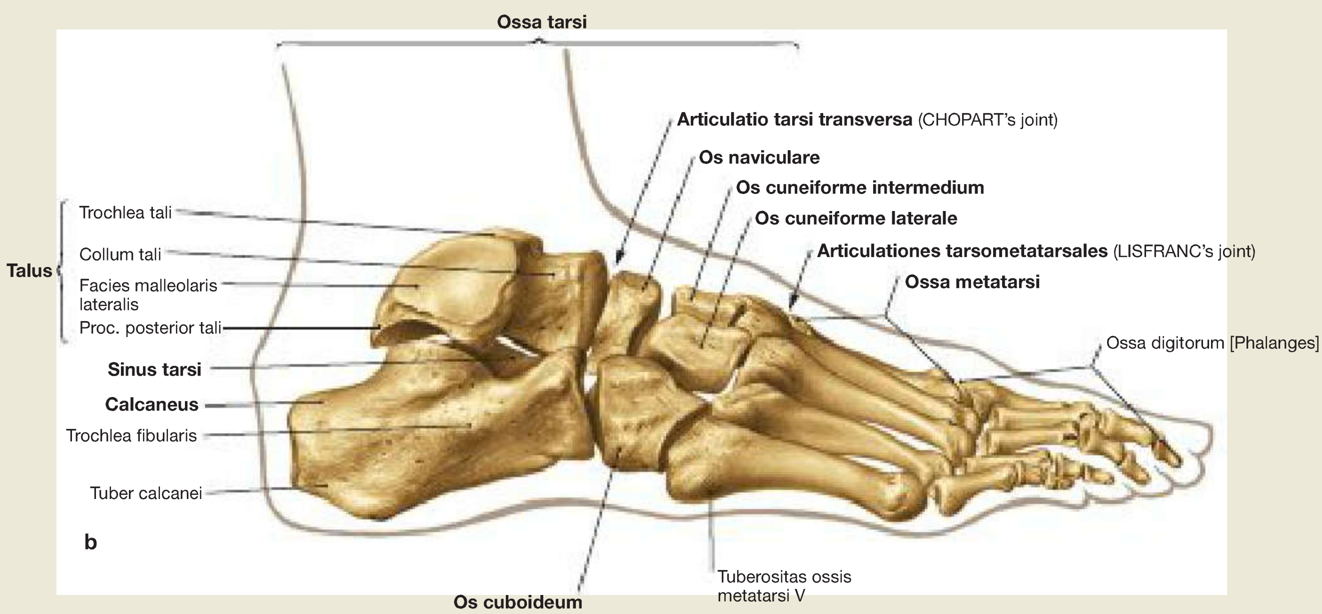
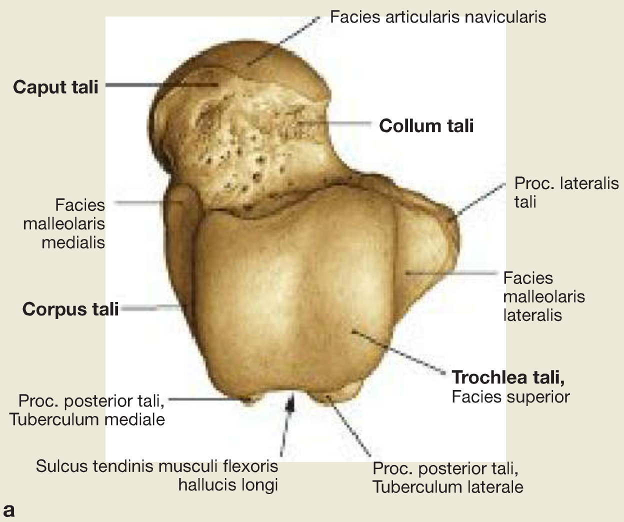


Fig. 4.31a and b Bones of the foot, Ossa pedis, right side; medial view (→ Fig. 4.31a) and lateral view (→ Fig. 4.31b).

The Sinus tarsi is a hollow space which is formed by the Sulcus tali and the Sulcus calcanei.



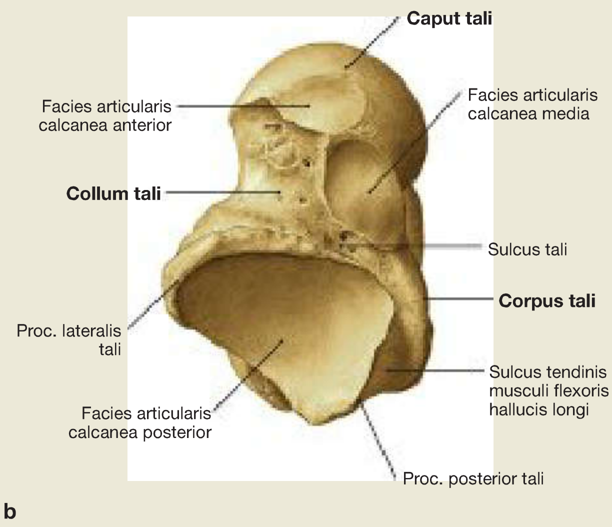
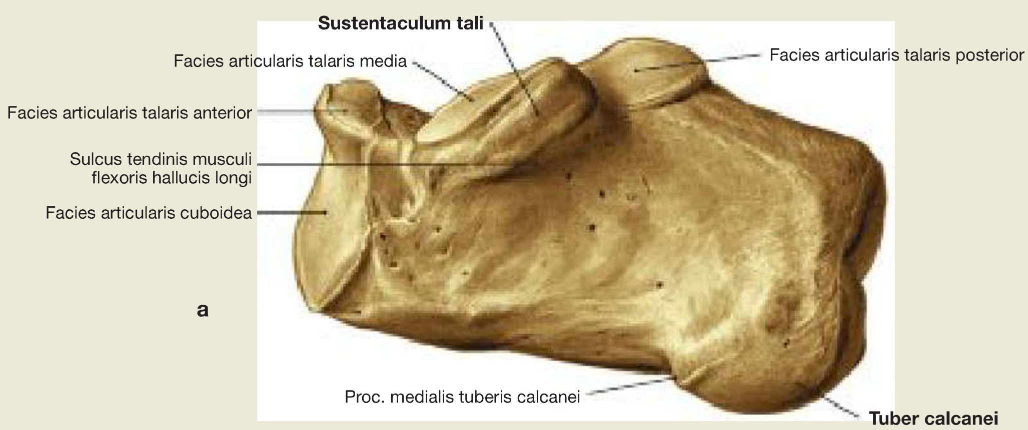


Fig. 4.32a and b Talus, right side; dorsal view (→ Fig. 4.32a) and plantar view (→ Fig. 4.32b).
The Trochlea tali is wider at the front than at the back.



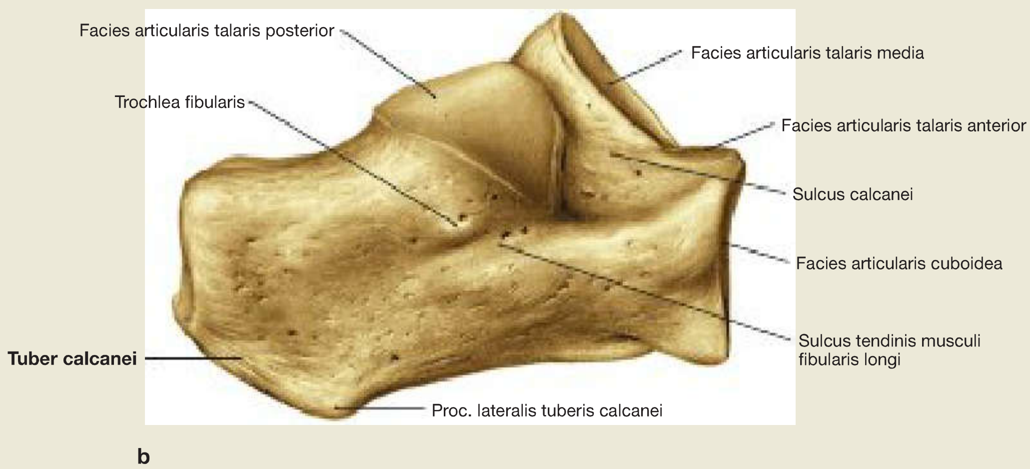
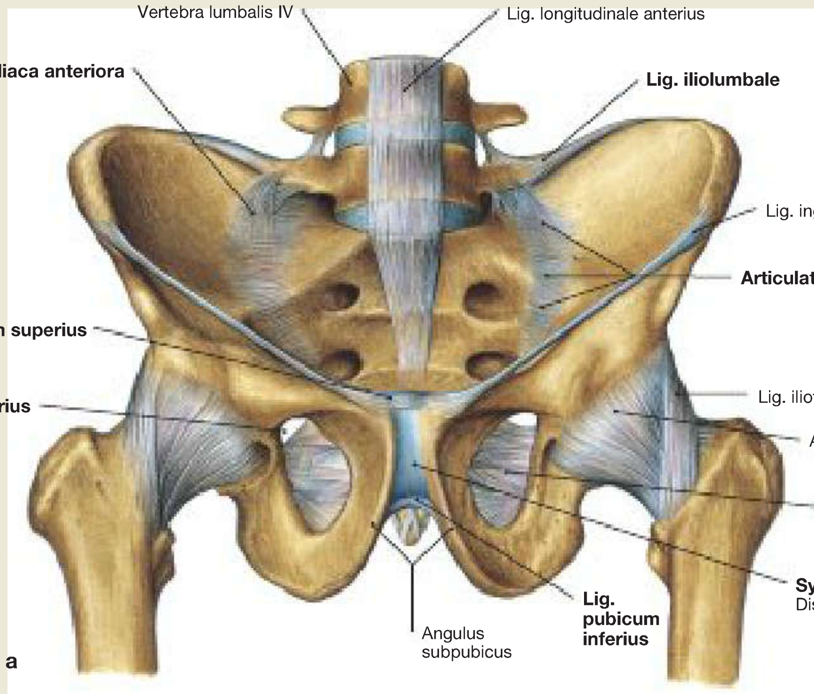


Fig. 4.33a and b Calcaneus, right side; medial view (→ Fig. 4.33a) and lateral view (→ Fig. 4.33b).

Joints and Ligaments of the Pelvis



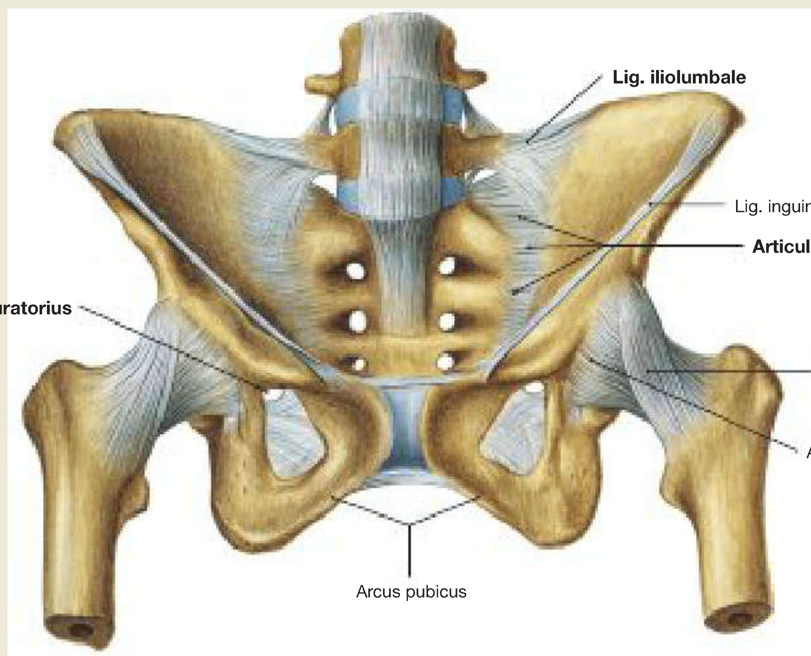
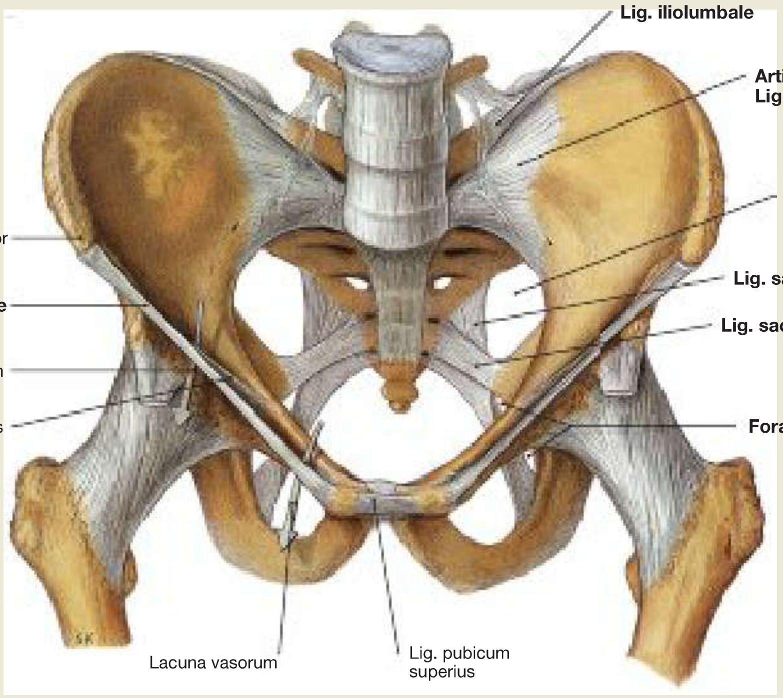


Fig. 4.34a and b Joints and ligaments of the pelvis in males (→ Fig. 4.34a) and females (→ Fig. 4.34b); ventral view.

The pelvic girdle (Cingulum pelvicum) is connected dorsally by the two amphiarthroses of the sacroiliac joints **(Articulationes sacroiliacae)** and ventrally by the pubic symphysis **(Symphysis pubica)** to form a ring structure. Each sacroiliac joint is stabilised ventrally by the **Ligg. sacroiliaca anteriora** and superiorly by the **Lig. iliolumbale** that runs from the Proc. costalis of the 4th and 5th lumbar vertebrae to the Crista iliaca (at the dorsal ligaments → Fig. 4.36a and → Fig. 4.36b). These strong ligaments only allow small tilting movements of the pelvis of about 10°.

The pubic symphysis is bridged by the **Lig. pubicum superius** above and the **Lig. pubicum inferius** below.

In both sexes, the Foramen obturatum is almost completely closed off by the **Membrana obturatoria** so that only the **Canalis obturatorius** remains open for the neurovascular pathways to pass through to the medial side of the thigh (A./V. obturatoria, N. obturatorius).



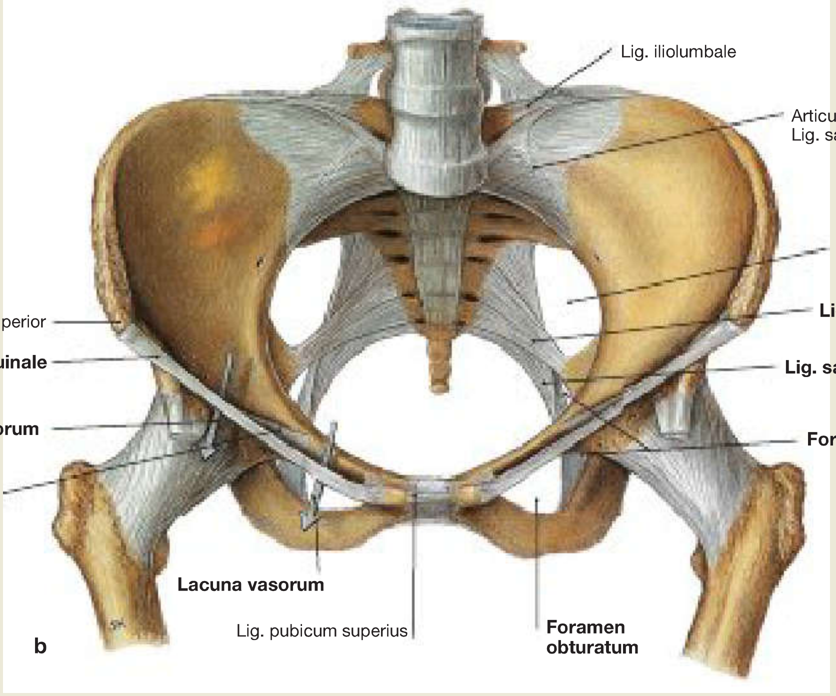
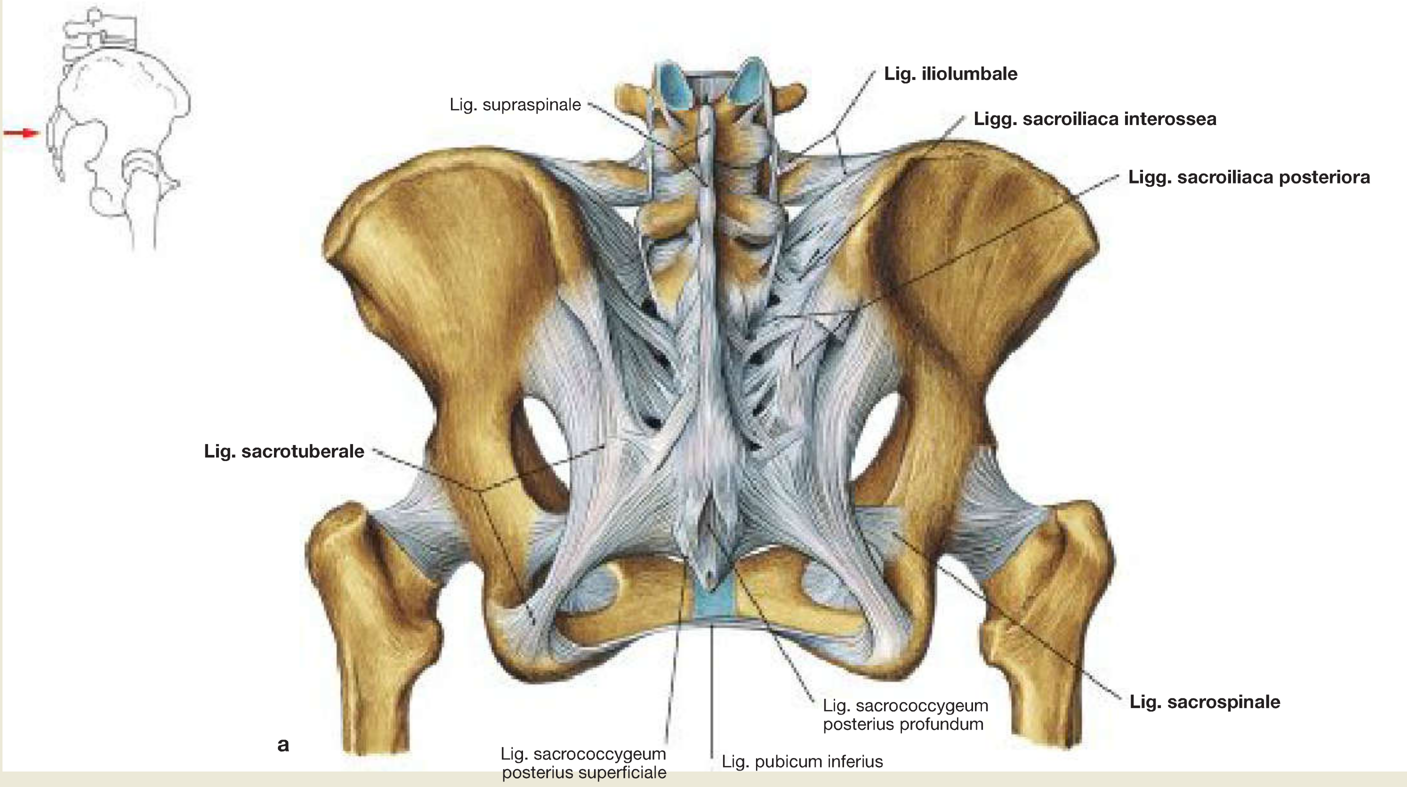


Fig. 4.35a and b Joints and ligaments of the pelvis in males (→ Fig. 4.35a) and females (→ Fig. 4.35b); ventrocranial view. [L238]
The almost horizontal **Lig. sacrospinale** connects the sacrum with the Spina ischiadica, and dorsally the oblique **Lig. sacrotuberale** runs to the Tuber ischiadicum. Both ligaments complete the Incisurae ischiadicae major and minor to the **Foramen ischiadicum majus** and the **Foramen ischiadicum minus.** These openings are significant passageways for the blood vessels and nerves of the Plexus sacralis to pass to the gluteal region (Regio glutealis). The space below the groin or inguinal ligament **(Lig. inguinale)** is divided by the Arcus iliopectineus into the lateral Lacuna musculorum and the medial Lacuna vasorum (→ Fig. 4.156) through which the neurovascular pathways pass to the anterior side of the thigh.

Joints and Ligaments of the Pelvis



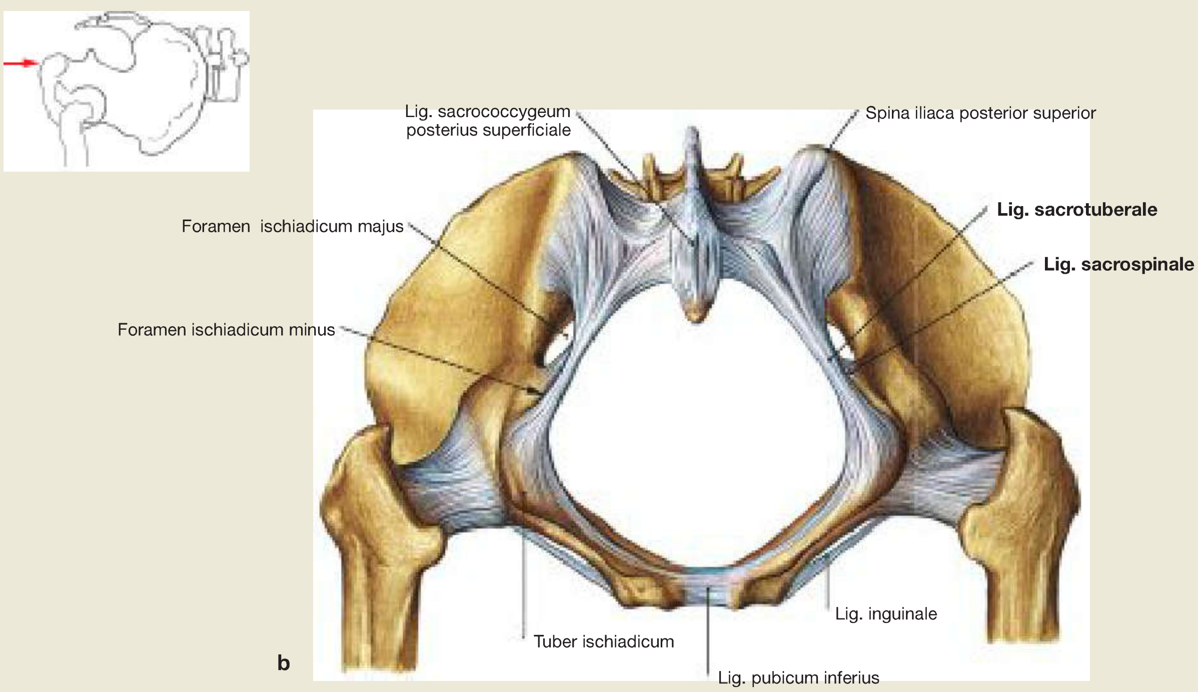
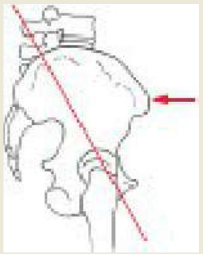
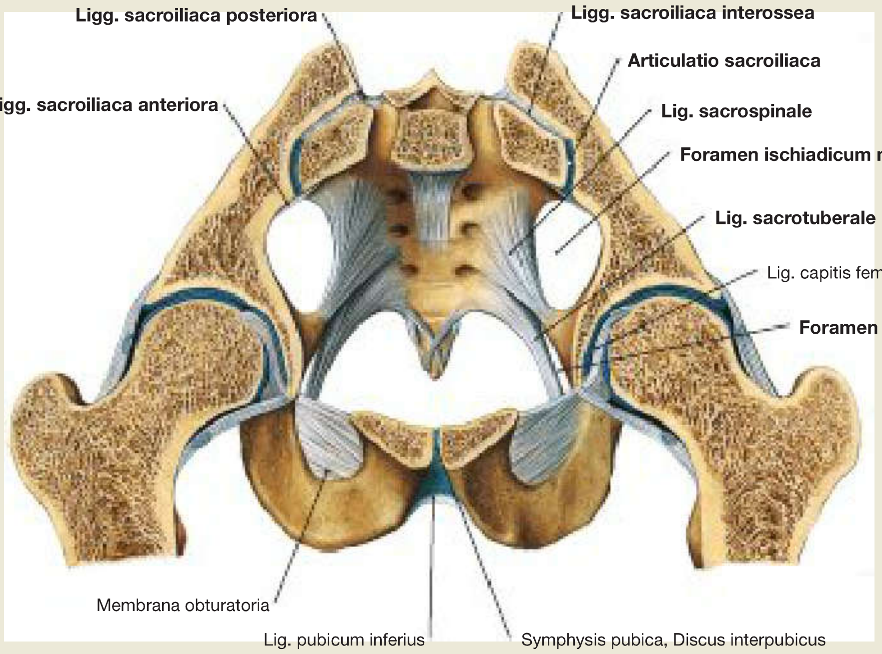


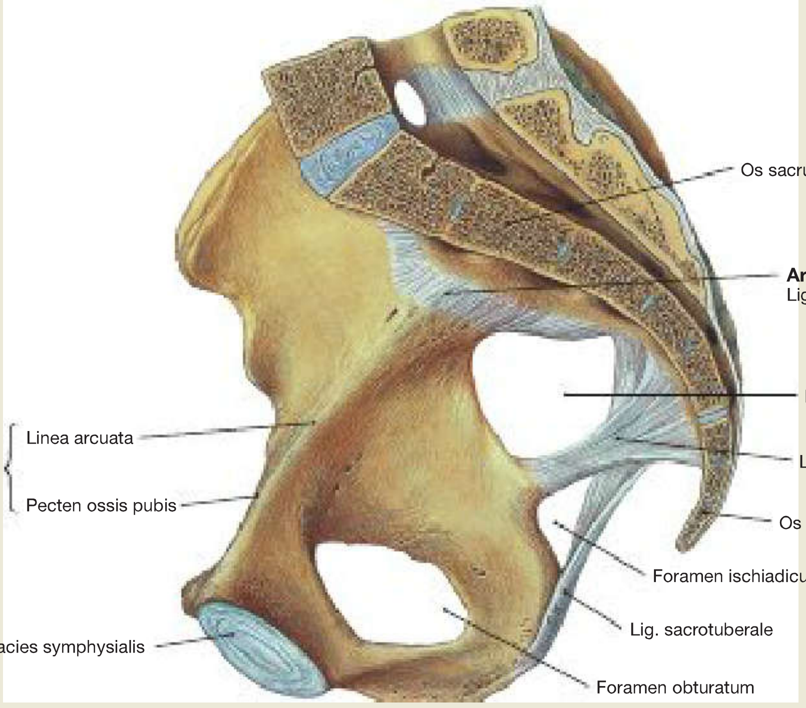
Fig. 4.36a and b Joints and ligaments of the pelvis in females; dorsal view (→ Fig. 4.36a) and caudal view (→ Fig. 4.36b).
On the dorsal side, the sacroiliac joint is stabilised by the **Ligg. sacroiliaca posteriora and interossea** (for the ligaments on the front → Fig. 4.34a and → Fig. 4.34b). Due to the strongly developed ligaments, particularly on the posterior side, only small tilting movements of the pelvis of up to 10° are possible.

The almost horizontal **Lig. sacrospinale** connects the sacrum with the Spina ischiadica, and dorsally the oblique **Lig. sacrotuberale** runs to the Tuber ischiadicum. Both ligaments confine the **Foramina ischiadica majus and minus** which are passageways for the blood vessels and nerves of the Plexus sacralis to the gluteal region.





a



b

Fig. 4.37a and b Joints and ligaments of the pelvis in females; oblique transverse section; ventrocaudal view (→ Fig. 4.37a) and median section; lateral view from the left side (→ Fig. 4.37b). b [L238]
The sacroiliac joint is illustrated here with its ligaments (**Ligg. sacroiliaca anteriora, posteriora** and **interossea** as well as the **Lig. sacrospinale** and the **Lig. sacrotuberale**). Only the **Lig. iliolumbale** is not visible. The Lig. sacrospinale and Lig. sacrotuberale confine the **Foramina ischiadica majus** and **minus** which are passageways for the blood vessels and nerves of the Plexus sacralis to the gluteal region.

Joints and Ligaments of the Pelvis

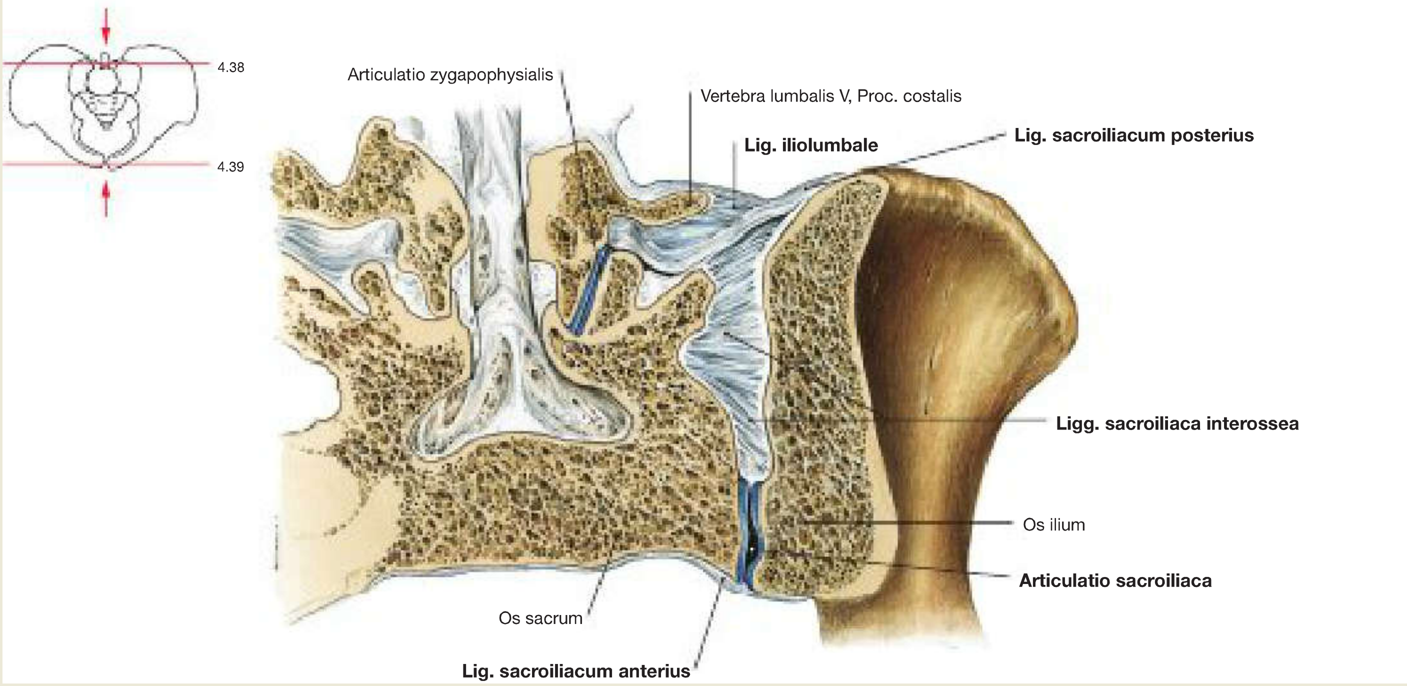


Fig. 4.38 Sacroiliac joint; Articulatio sacroiliaca; frontal section; dorsal view.
The strong ligaments, of which the **Ligg sacroiliaca anteriora** and **interossea**, as well as the **Lig. iliolumbale** can be seen here, stabilise the sacroiliac joint and enable a transfer of weight from the trunk to the pelvic girdle. In particular, the dorsal **Ligg. sacroiliaca interossea** and **posteriora** broadly connect the sacrum and ilium.

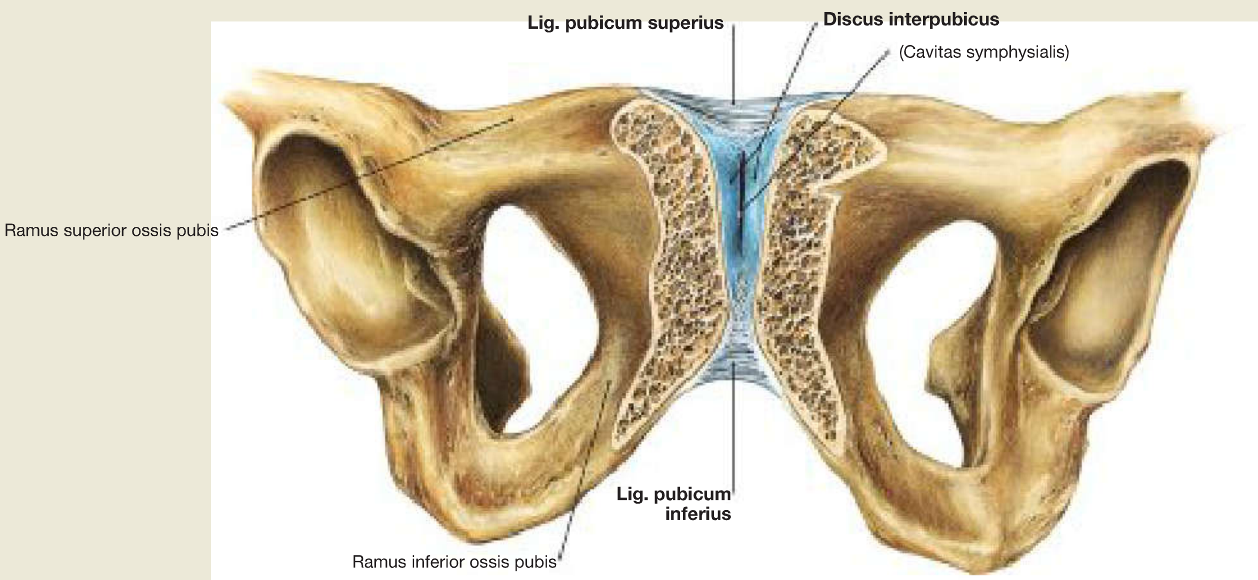
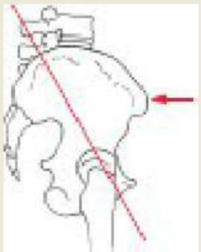


Fig. 4.39 Pubic symphysis, Symphysis pubica, oblique section; ventrocaudal view.
The pubic symphysis is a cartilaginous fixed joint (symphysis). The **Discus interpubicus** consists of fibrous cartilage; only the interfaces to the Facies symphysiales of the two pubic bones consist of hyaline cartilage. From the first decade of life, an elongated gap (Cavitas symphyialis) often begins to develop. This gap is bridged by the **Lig. pubicum superius** above and the **Lig. pubicum inferius** below.

Clinical Remarks

Pain in the sacroiliac joint can be caused by **injury** and **degenerative osteoarthritis** as well as rheumatic diseases, which in part tend to affect this joint (Morbus BECHTEREW) in the first instance. Since the sacroiliac joint is located directly below the nerve branches of the Plexus lumbosacralis, pain may radiate into the leg (→ p. 380).



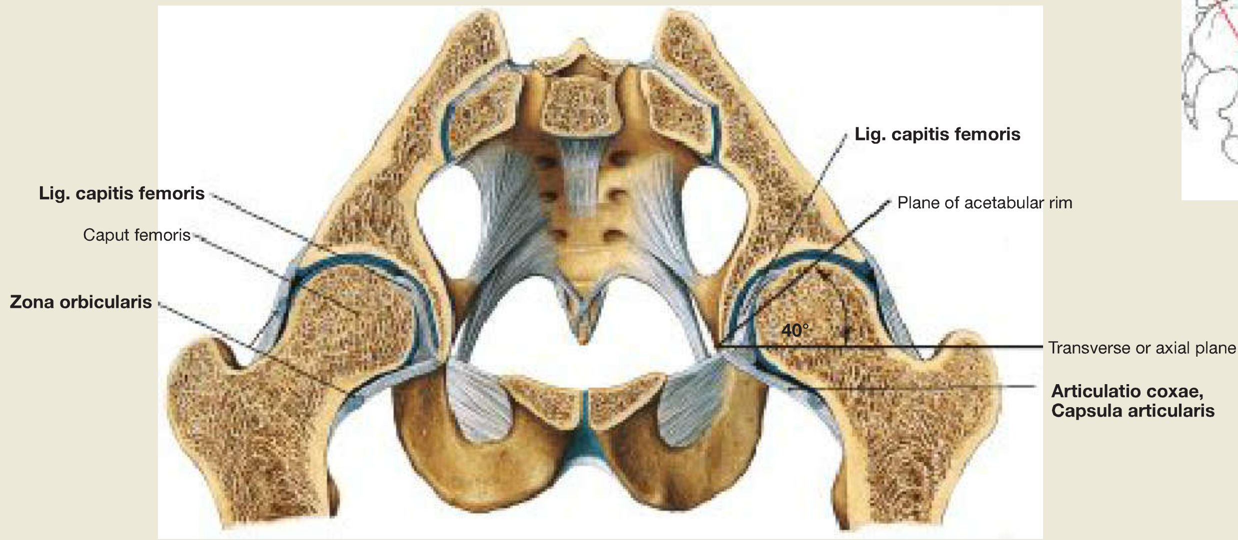


Fig. 4.40 Both hip joints, Articulationes coxae; oblique transverse section; ventrocranial view.

In the hip joint, the acetabulum forms the socket. Together with the Labrum acetabuli, the Acetabulum covers more than half of the femoral head (Caput femoris). Thus, the hip joint is a special form of a ball-and-socket joint, referred to as the **cotyloid joint** (Articulatio cotylica, enarthrosis). The **angle** between the **acetabular entrance plane** and the horizontal line is **40°.** The hip joint transfers the whole body weight onto the legs. Therefore, the joint capsule **(Capsula articularis)** is reinforced by strong ligaments. Circular fibres of the joint capsule surround the femoral neck, in particular on the dorsal side, and are referred to as **Zona orbicularis.** The ligaments of the capsule also radiate into this zone. The **Lig. capitis femoris** has no mechanical function.

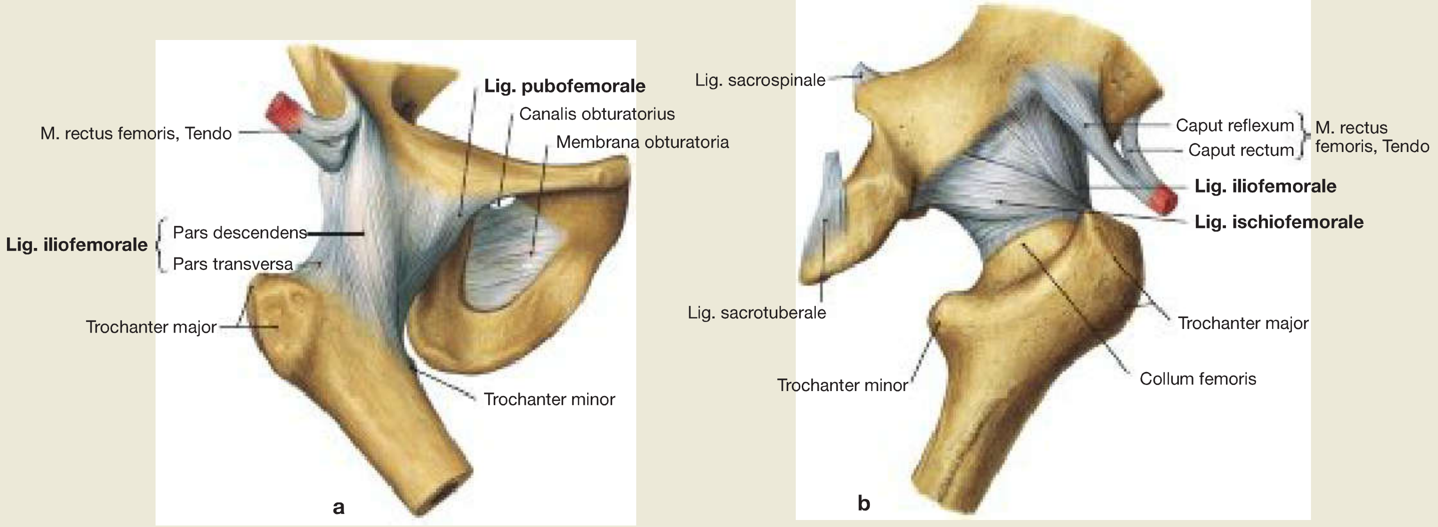


Fig. 4.41a and b Hip joint, Articulatio coxae, right side; ventral view (→ Fig. 4.41a) and dorsal view (→ Fig. 4.41b).

The hip joint essentially consists of three ligaments that spiral around the femoral head and neck. **Their main function** is to confine the **extension** and to **prevent the tilting** of the pelvis in a **dorsal direction,** since they become stretched by extension and thereby clamp the femoral head as if in a vice ('ligament vice'):

- **Lig. iliofemorale** (in front, above): inhibits not only extension, but also in particular the adduction, which lessens the load on the small gluteal muscles
- **Lig. pubofemorale** (in front, below): inhibits extension, abduction and external rotation
- **Lig. ischiofemorale** (rear): inhibits extension, and in particular internal rotation and adduction

Clinical Remarks

Orthopaedic studies show that the position and shape of the acetabulum and femoral head are important factors in the development of degenerative changes in the hip joint **(coxarthrosis)**. Premature degenerative changes may be induced by a flattened roof of the hip joint **(hip dysplasia),** which shows a smaller than usual **angle of the acetabular** rim plane as well as a larger than usual roof of the hip joint. The canopy can be too large if the acetabular rim with the hip socket tilted dorsally **(retroversion of the acetabulum)**, or if the articular surface is located deep inside the acetabulum **(Coxa profunda).**

Architecture and Movements of the Hip Joint

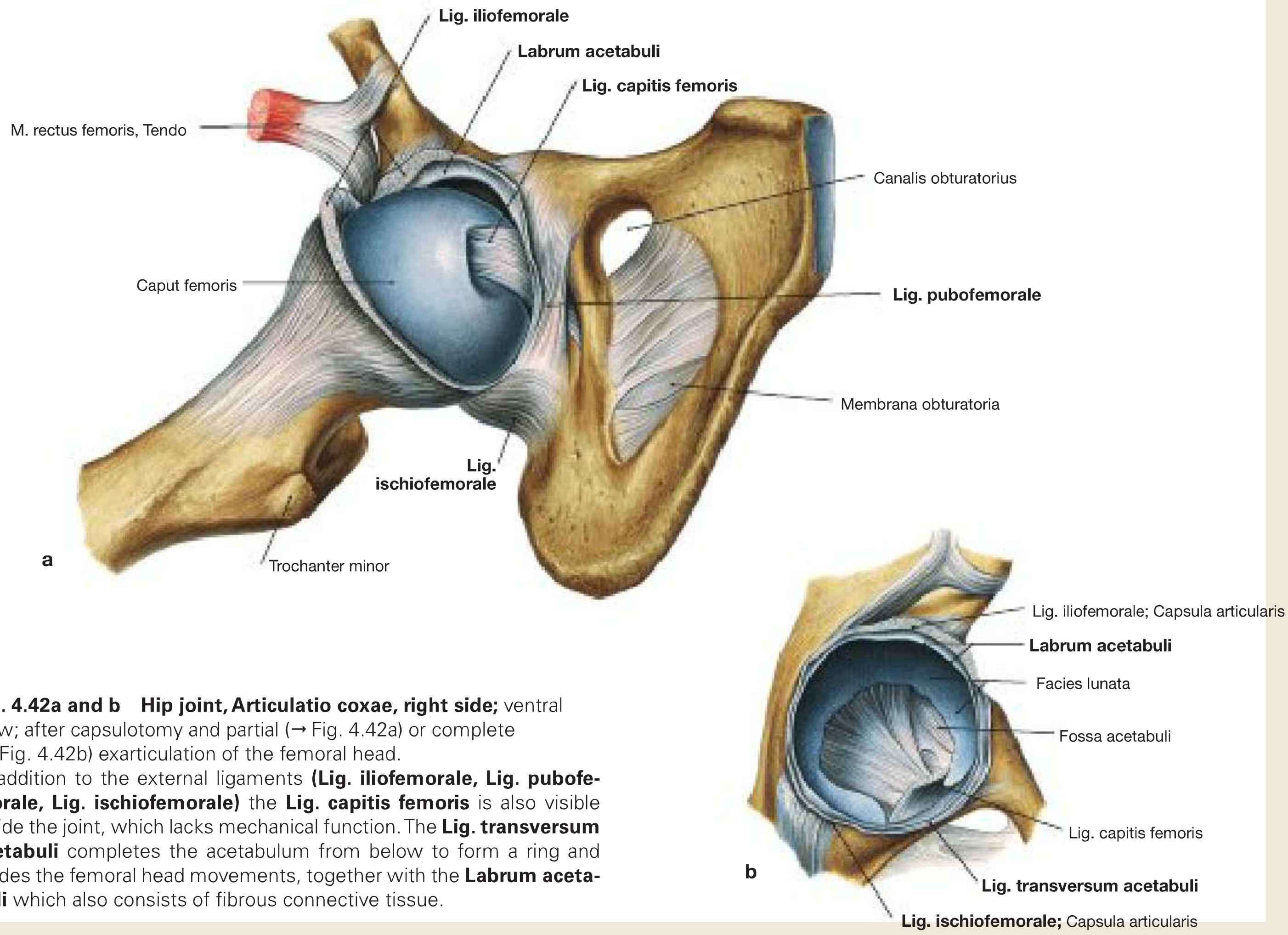


Fig. 4.42a and b Hip joint, Articulatio coxae, right side; ventral view; after capsulotomy and partial (→ Fig. 4.42a) or complete (→ Fig. 4.42b) exarticulation of the femoral head.
In addition to the external ligaments **(Lig. iliofemorale, Lig. pubofemorale, Lig. ischiofemorale)** the **Lig. capitis femoris** is also visible inside the joint, which lacks mechanical function. The **Lig. transversum acetabuli** completes the acetabulum from below to form a ring and guides the femoral head movements, together with the **Labrum acetabuli** which also consists of fibrous connective tissue.

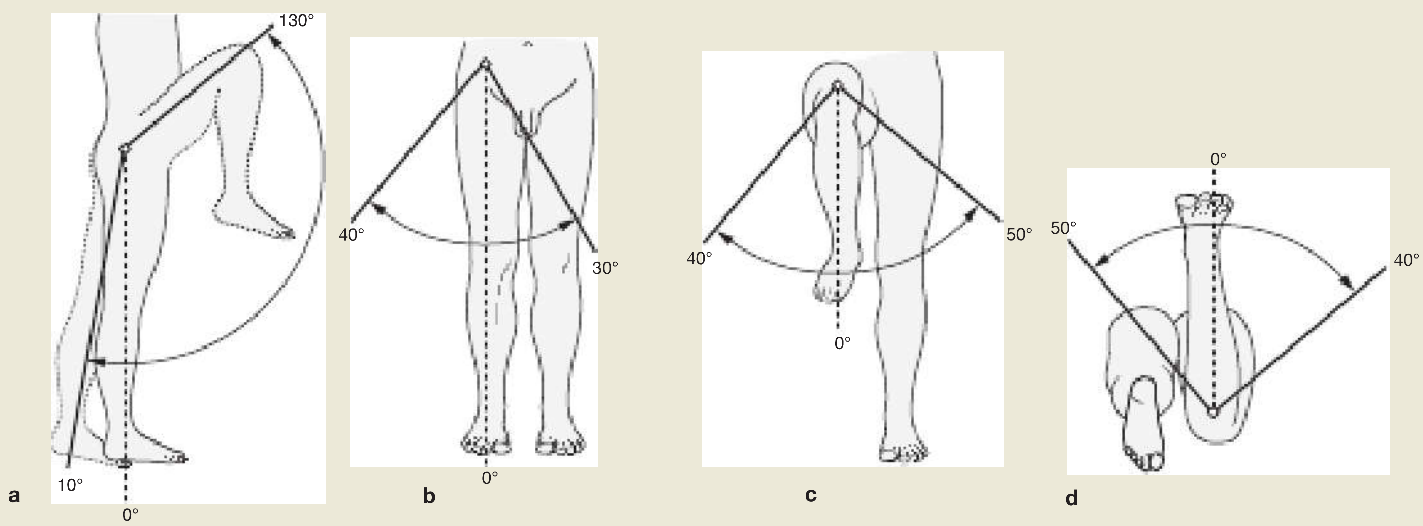


Fig. 4.43a to d Range of motion in the hip joint, Articulatio coxae. [L126]
The hip joint is a **cotyloid joint** (Articulatio cotylica, enarthrosis), which has three degrees of freedom. All its movement axes run through the centre of the femoral head. The range of motion is limited by the strict bony guidance in the acetabulum and by the strong ligaments. All the ligaments together limit the extension (retroversion) by surrounding the femoral head like a 'ligament vice' to ensure a stable stance. Flexion (anteversion), however, which is important when running, has a great degree of freedom and is inhibited only by soft tissues.
Also internal and external rotation, abduction and adduction are limited by the ligaments.

Range of motion:
a Extension–flexion: 10°–0°–130°
b Abduction–adduction: 40°–0°–30°
c and **d** Lateral rotation–medial rotation: 50°–0°–40°

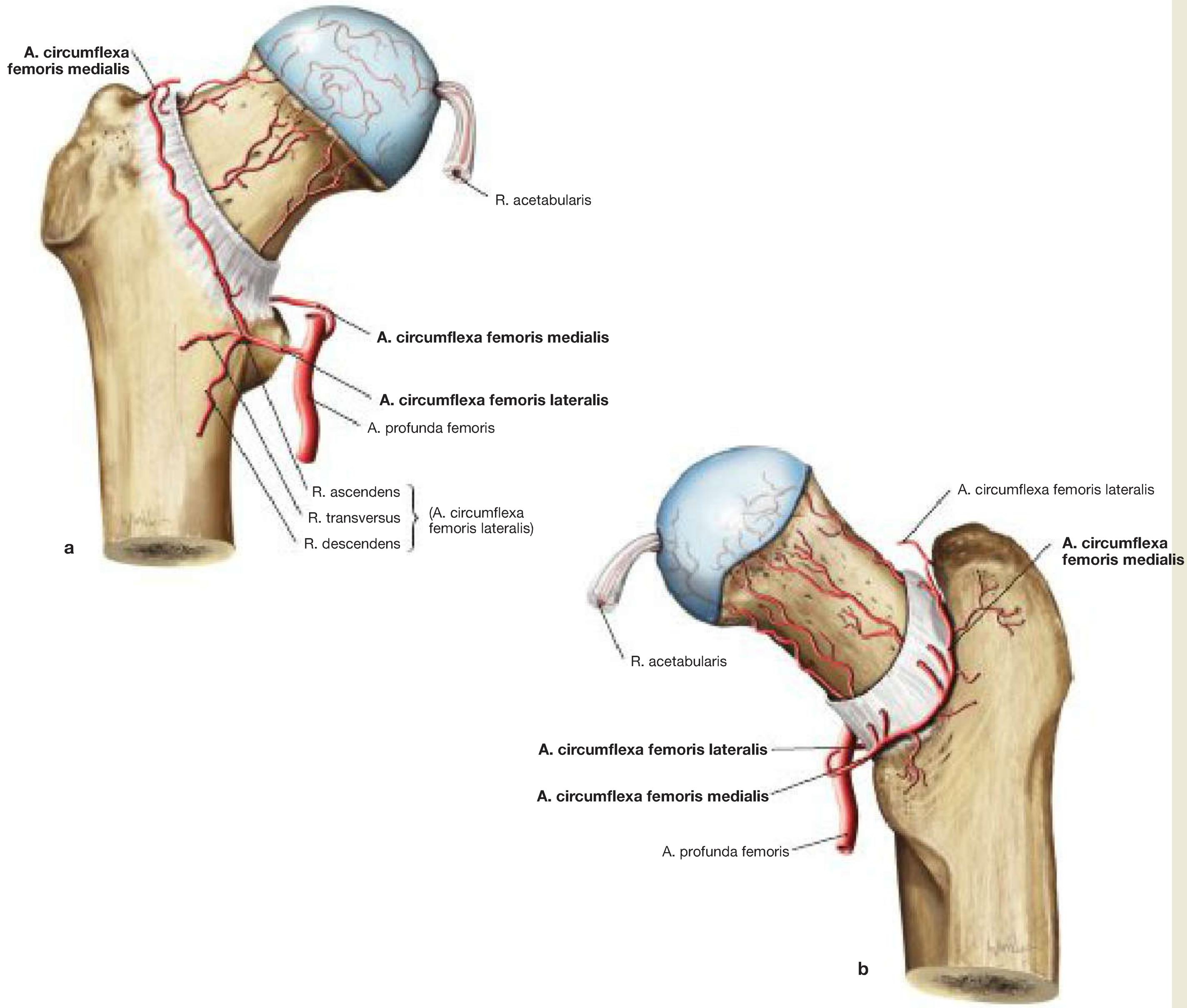


Fig. 4.44a and b Blood supply to the hip joint, right side; ventral view (→ Fig. 4.44a) and dorsal view (→ Fig. 4.44b). [L266]
In adults, the **A. circumflexa femoris medialis** is the main supplying vessel of the **femoral head.** While the **R. acetabularis** (of the A. obturatoria and A. circumflexa femoris medialis), passing through the Lig. capitis femoris, supplies a large proportion of the femoral head in infants, it supplies only one-fifth to one-third of the proximal epiphysis in adults. However, the A. circumflexa femoris medialis supplies the femoral head and neck via several smaller branches coursing on the posterior side of the neck within the joint capsule. The **A. circumflexa femoris lateralis** primarily supplies the **femoral neck** on the anterior side. The **acetabulum** is supplied ventrally and dorsally by the A. obturatoria, and cranially by the A. glutea superior.

Clinical Remarks

Arterial blood supply is crucial for the integrity of the femoral head. Oxygen deficiency (ischemia) results in **necrosis of the femoral head,** which, in the worst case scenario, requires the replacement of the femoral head by an **endoprosthesis**. Therefore, the supplying arteries must be treated with the utmost care in surgical interventions on the hip joint. This is particularly important, in cases of a degenerative arthritis, only the articular surface ('cap prosthesis') has to be replaced by a prosthesis, instead of the whole femoral head. Therefore, precise anatomical knowledge on the arterial supply of the hip joint has gained eminent importance during the last few years. It has to be noted that the A. circumflexa femoris medialis runs on the posterior side of the femoral neck, where it is covered and protected by the short hip muscles of the pelvitrochanteric group. These muscles should therefore be spared in order to avoid injury to the artery. Because the Aa. circumflexae femoris medialis and lateralis course between the layers of the joint capsule, the supplying arteries may be damaged in the case of intracapsular **femoral neck fractures**. Therefore, the immediate replacement of the femoral head by a prosthesis is the treatment which is increasingly being performed. Also the spontaneous necrosis of the femoral head during early puberty **(Morbus PERTHES)** appears to be mainly caused by an insufficient arterial blood supply to the femoral head.

Knee Joint

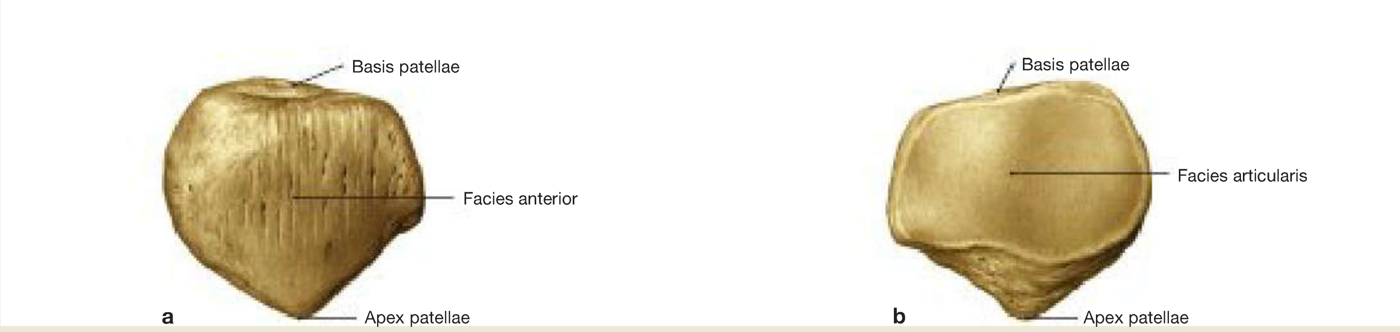


Fig. 4.45a and b Patella, right side; ventral view (→ Fig. 4.45a) and dorsal view (→ Fig. 4.45b).
The patella is a **sesamoid bone** (Os sesamoideum) within the tendon of the M. quadriceps femoris. It serves as a **hypomochlion** by guiding the tendon via the distal end of the femur to its insertion on the Tuberositas tibiae. This raises the virtual lever arm of the muscle and increases its torque.

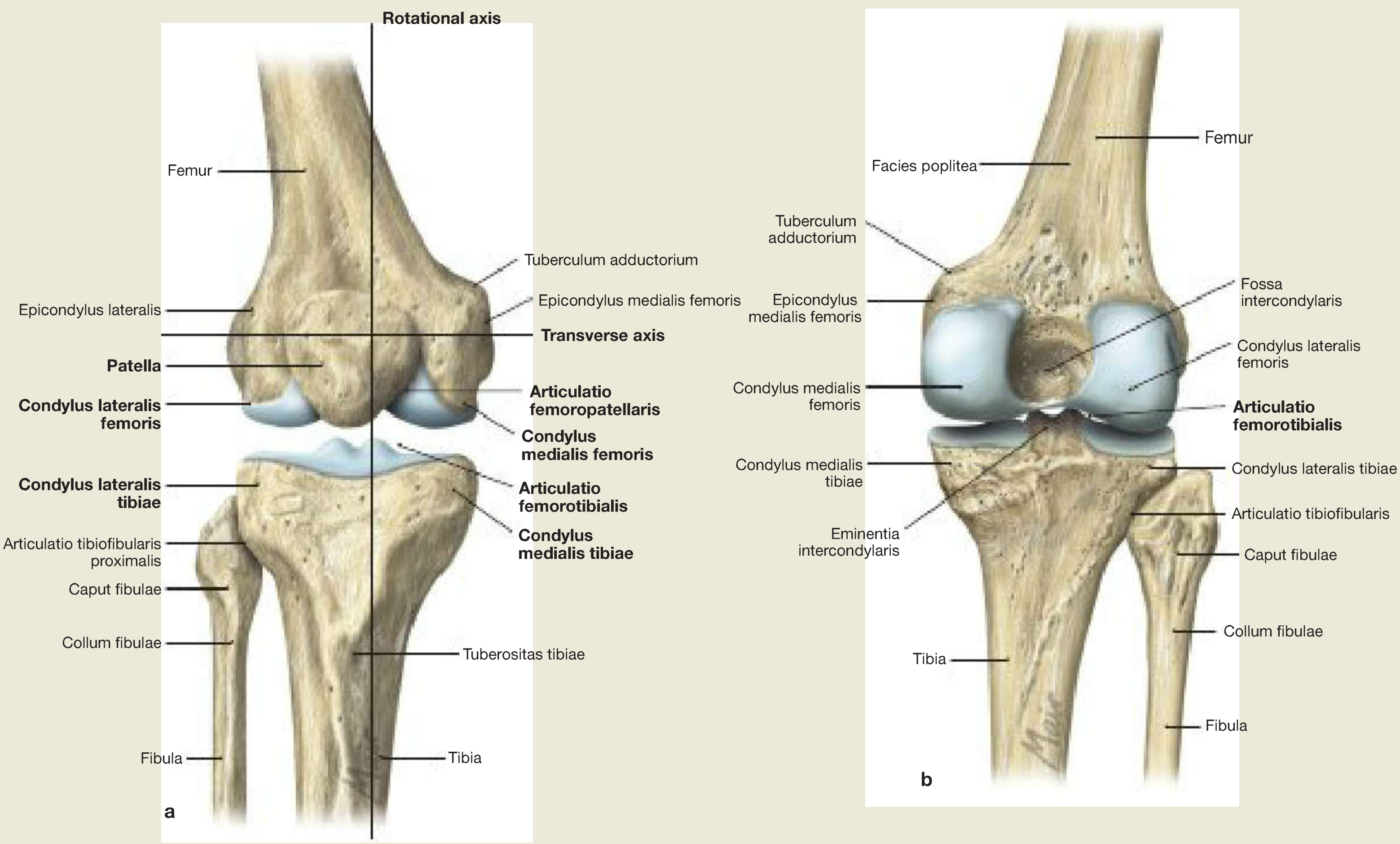


Fig. 4.46a and b Knee joint, Articulatio genus, right side; ventral view (→ Fig. 4.46a) and dorsal view (→ Fig. 4.46b). [L127]
In the knee joint the femur articulates with the tibia (**Articulatio femorotibialis)** and with the patella **(Articulatio femoropatellaris;** → Fig. 4.178). All the bones are ensheathed by a common joint capsule. In the Articulatio femorotibialis, the femoral condyles constitute the head, and the upper articular surface (Facies articularis superior) of both tibial condyles forms the socket of the joint. The knee joint is a **bicondylar joint** (Articulatio bicondylaris) which functions as a **pivot-hinge joint** (trochoginglymus) and possesses two degrees of freedom in movements. The instantaneous transverse axis for **extension** and **flexion movements** runs through the trochlea of the femoral condyles (c). The longitudinal axis of rotational movements runs eccentrically and perpendicularly through the Tuberculum intercondylare mediale. For the range of motion in the knee joint → p. 331.

Clinical Remarks

Besides the hip joint, the knee joint is especially stressed from bearing the weight of the body. Thus, degenerative changes **(gonarthrosis)** are a common disease of the knee joint, frequently requiring prosthetic replacement of the joint bodies. Since the knee joint is not well stabilised by muscles, **injuries to the ligaments** and the **menisci** do occur frequently. These can sometimes be treated with minimally invasive interventions **(arthroscopy)**, which requires good anatomical knowledge of the knee joint. Malformations of the patella or of the Facies patellaris of the femur may result in repeated **dislocation of the patella**. In addition to physical exercises or training of the respective M. vastus medialis or lateralis, surgical correction with tightening of the joint capsule (capsulorrhaphy) or transfer of the Lig. patellae is the treatment of choice.

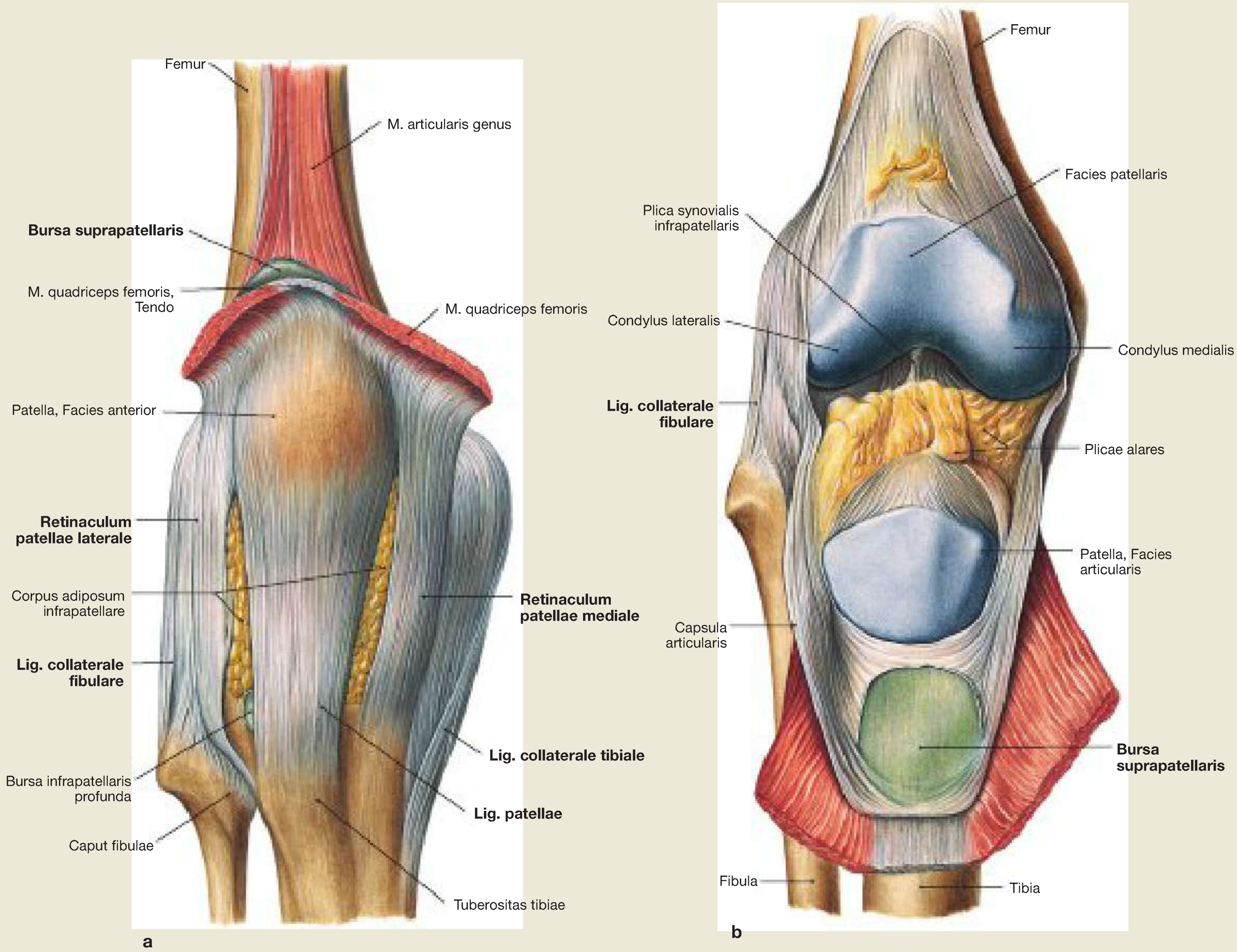


Fig. 4.47a and b Knee joint, Articulation genus, right side, with closed joint capsule (→ Fig. 4.47a) and after capsulotomy (→ Fig. 4.47b); ventral view.

The knee joint is surrounded by **extracapsular ligaments,** that stabilise the joint and reinforce the capsule from outside, and by **intracapsular ligaments** (→ Fig. 4.53), that lie within the Capsula fibrosa. This is an illustration of the extracapsular ligaments. Anteriorly, these include the **Lig. patellae,** which is a prolongation of the tendon of the M. quadriceps femoris, as well as the **Retinacula patellae mediale** and **laterale,** both of which have superficial longitudinal and deep transverse fibres. They are also considered to be parts of the inserting tendon of the M. quadriceps femoris (Mm. vasti medialis and lateralis). Medially and laterally, there are two collateral ligaments (**Ligg. collateralia tibiale** and **fibulare**) which insert on the respective bones of the lower leg. The joint capsule follows the joint surfaces at a short distance. The **HOFFA's fat pad (Corpus adiposum infrapatellare),** lying anteriorly between the Membrana fibrosa and Membrana synovialis, is connected to the anterior cruciate ligament via a fold, the Plica synovialis infrapatellaris, and has Plicae alares on both sides. The knee joint is associated with several **bursae,** some of which communicate with the joint capsule, as shown here for the Bursa suprapatellaris.

Capsular Ligaments of the Knee Joint

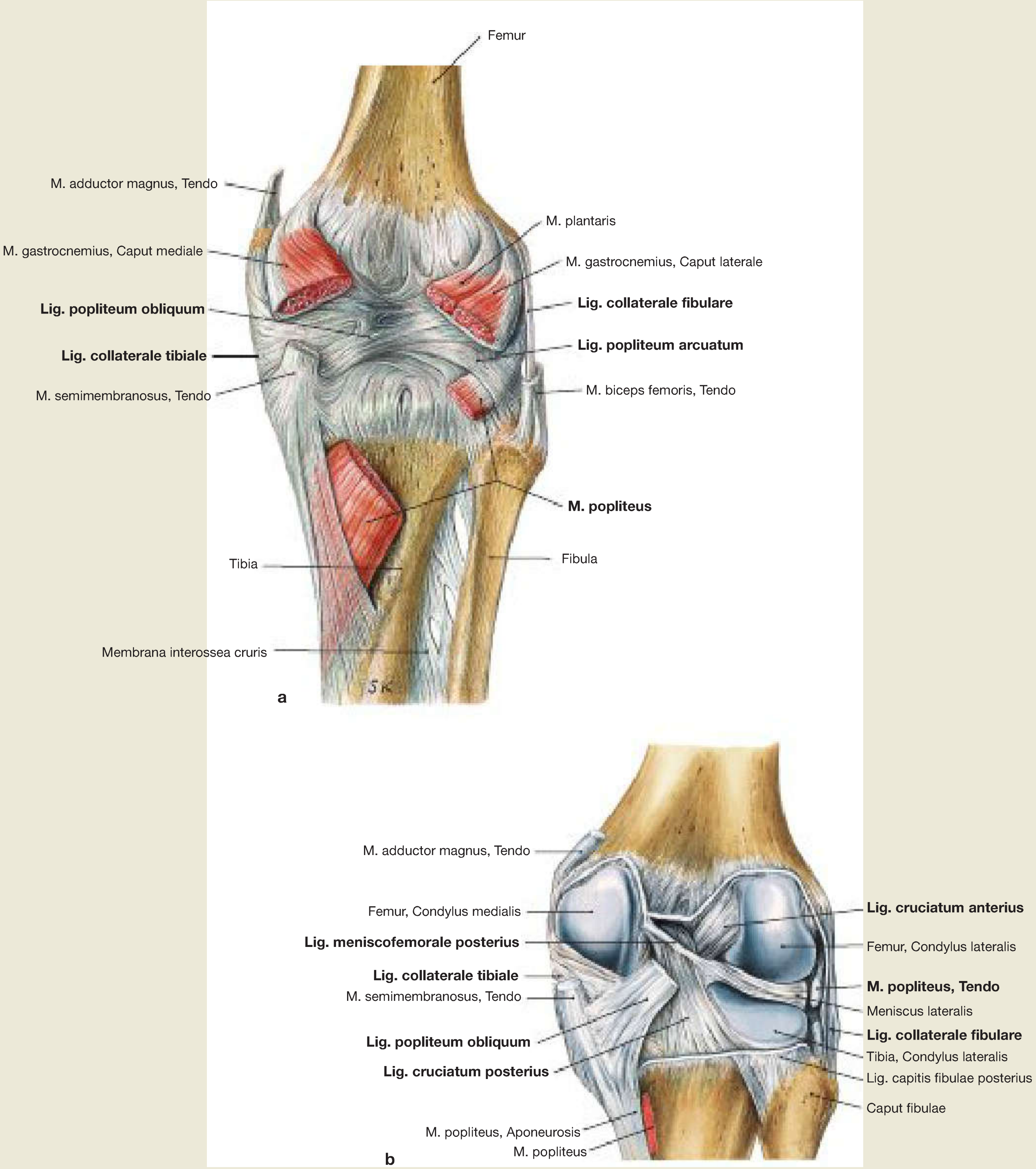


Fig. 4.48a and b Knee joint, Articulatio genus, right side, with closed joint capsule (→ Fig. 4.48a) and after capsulotomy (→ Fig. 4.48b); dorsal view. a [L238]

At the back of the knee joint, additional **extracapsular ligaments** reinforce the joint capsule. The **Lig. popliteum obliquum** passes from the lateral femoral condyle medially downwards, while the **Lig. popliteum arcuatum** runs in the opposite direction and thus bridges the M. popliteus. Of the two collateral ligaments, only the **Lig. collaterale tibiale** is attached to the joint capsule. The **Lig. collaterale fibulare**, however, is **not** fused with the capsule, but is separated by the originating tendon of the M. popliteus. After opening the joint capsule or capsulotomy (→ Fig. 4.48b), several **intracapsular ligaments** are visible. The anterior cruciate ligament **(Lig. cruciatum anterius)** runs from the inner surface of the lateral femoral condyle in an anterior direction to the Area intercondylaris anterior of the tibia. The posterior cruciate ligament **(Lig. cruciatum posterius)** runs in the opposite direction from the inner surface of the medial femoral condyle to the Area intercondylaris posterior of the tibia. The **Lig. meniscofemorale anterius** (not visible here) and the **Lig. meniscofemorale posterius** connect the posterior horn of the lateral meniscus (Meniscus lateralis) with the medial condyle in front and behind the posterior cruciate ligament and thus support the function of the posterior cruciate ligament.

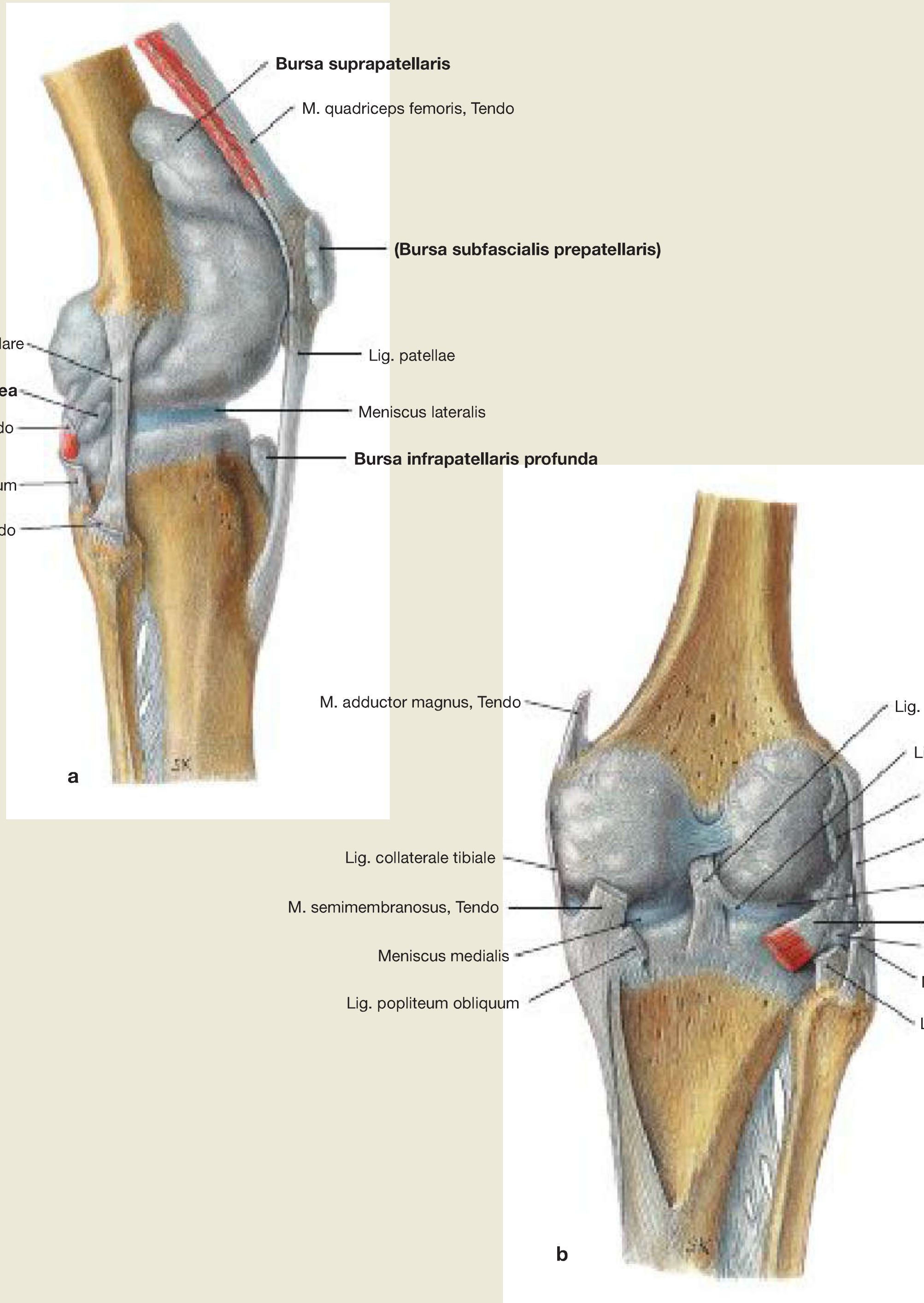


Fig. 4.49a and b Knee joint, Articulatio genus, right side, with synovial bursae; lateral view (→ Fig. 4.49a) and dorsal view (→ Fig. 4.49b); illustration of the articular cavity after injection of plastic moulding. [L238]

The knee joint is surrounded by up to 30 **synovial bursae (Bursae synoviales)**. Some bursae communicate with the joint capsule, such as the **Bursa suprapatellaris** (in front, above) below the tendon of the M. quadriceps femoris, or the **Bursa subpoplitea** (below) behind the tendon of the M. popliteus. Other bursae are located in places exposed to increased compression loading (e.g. when kneeling), such as the **Bursa prepatellaris** or the **Bursa infrapatellaris,** or serve as gliding surfaces below the tendons of muscle origins or insertions, such as the **Bursa musculi semimembranosi** or the **Bursae subtendineae musculorum gastrocnemii medialis and lateralis** (neither are shown).

Clinical Remarks

Intense mechanical loading of the knee (in bending activities) can cause an inflammation of the bursae **(bursitis).** Chronic inflammatory capsular effusions such as those occurring in rheumatic diseases (e.g. rheumatoid arthritis), can lead to enlargement and fusion of the bursae which appear as swelling in the popliteal fossa. Such a fusion of the Bursa musculi semimembranosi with the Bursa subtendinea musculi gastrocnemii medialis is termed **BAKER's cyst**.

Collateral Ligaments of the Knee Joint

Fig. 4.50a and b Medial ('inner') collateral ligament (Lig. collaterale tibiale), in an extended (→ Fig. 4.50a) and in a flexed position (→ Fig. 4.50b); medial view.
The medial collateral ligament **(Lig. collaterale tibiale)** is relatively broad and passes from the Epicondylus medialis of the femur to below the medial condyle of the tibia. Only its posterior fibres are attached firmly to the Meniscus medialis. With flexion of the knee, this ligament gets twisted, thereby fixing the position of the Meniscus medialis. In contrast, the lateral ('outer') collateral ligament **(Lig. collaterale fibulare)** is not merged with the Meniscus lateralis (→ Fig. 4.51). Because the anterior radius of curvature of the femoral condyles is larger, the collateral ligaments will be stretched with extension of the knee. Therefore, no rotation is possible in this position. In contrast, in a flexed position of the knee the ligaments are slack, because the posterior radius of curvature of the femoral condyles is smaller, so that rotational movements are possible.

Clinical Remarks

The collateral ligaments stabilise the knee joint medially and laterally. The medial collateral ligament (clinical term: **MCL**) in particular stabilises against **abduction,** the lateral collateral ligament (clinical term: **LCL**) against **adduction**. In the case of damaged ligaments (ligament rupture) the joint has a greater hinging capacity. This phenomenon is utilised during physical examination to assess potential lesions of the collateral ligaments.

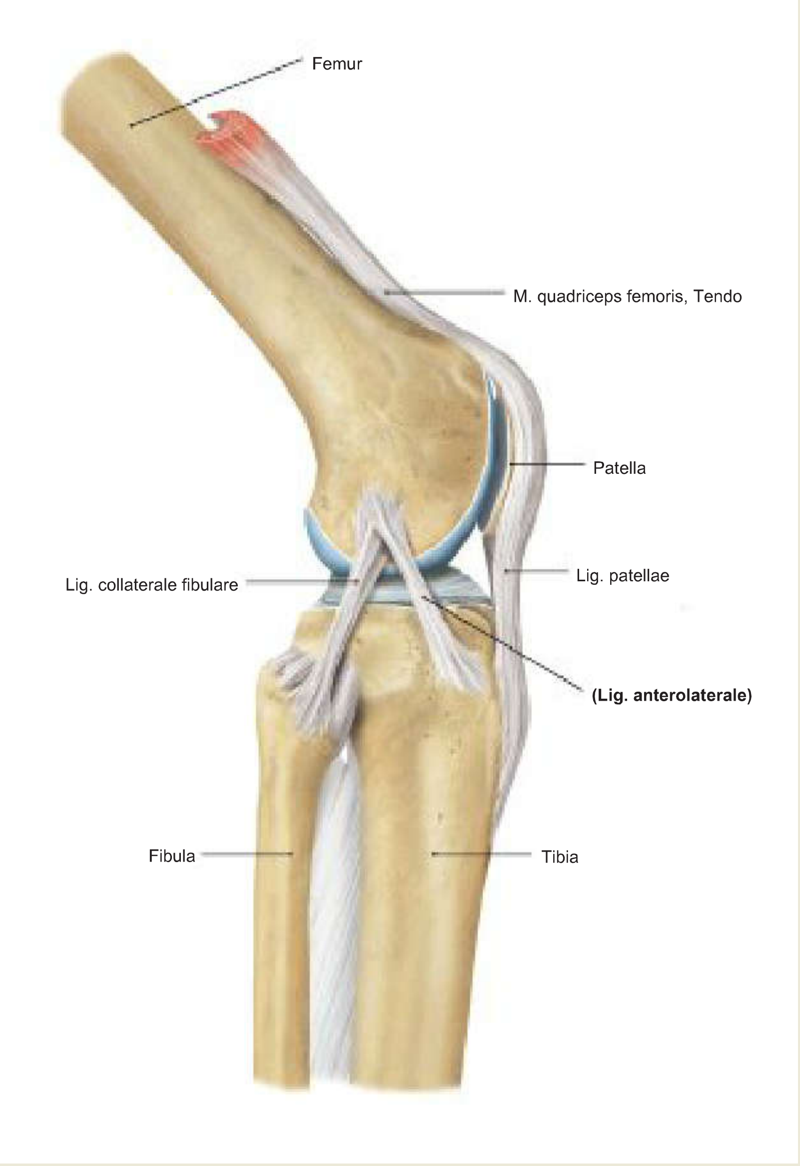


Fig. 4.51 Lateral collateral ligament (Lig. collaterale fibulare), and anterolateral ligament in extended position; lateral view. [L280]
The lateral collateral ligament **(Lig. collaterale fibulare)** runs from the Epicondylus lateralis of the femur to the head of the fibula and is thus not only significantly narrower than the medial collateral ligament, but also shorter. An additional ligament passing from the lateral Epicondylus of the femur to the Condylus lateralis of the tibia is the '**a**ntero**l**ateral **l**igament' (clinical term: ALL).

Capsule of the Knee Joint

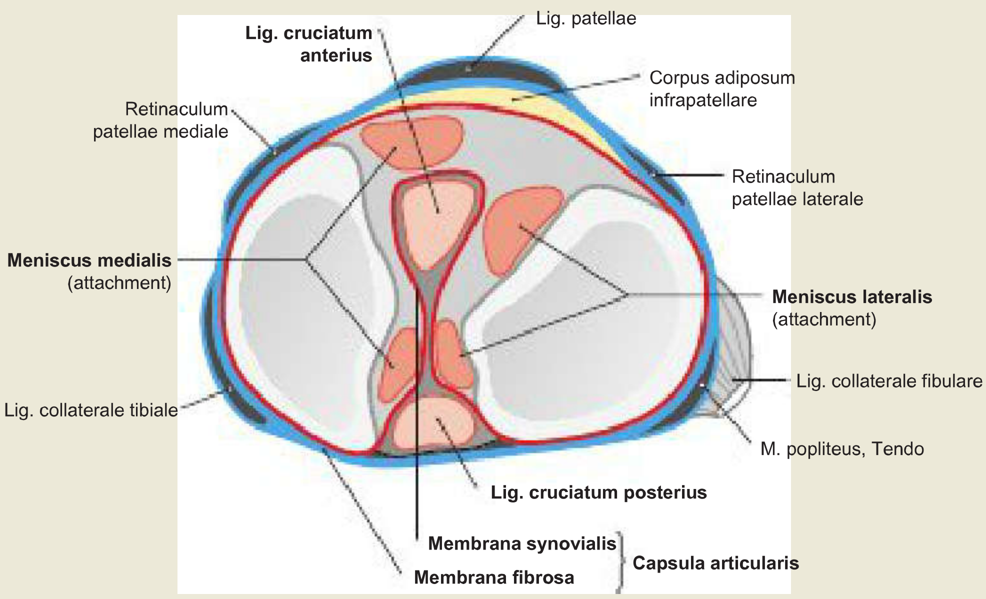


Fig. 4.52 Schematic representation of the capsule of the knee joint, right side; cranial view. [L126]

As with other joints, the capsule of the knee joint **(Capsula articularis)** consists of an external layer of dense fibrous tissue (Membrana fibrosa) and an internal lining, the Membrana synovialis. What is interesting is that the two layers are in direct contact only ventrally and laterally. In contrast, the Membrana synovialis diverges dorsally inwards and covers the **cruciate ligaments (Ligg. cruciata anterius et posterius)**. The cruciate ligaments are therefore not within the joint cavity. Their location is described as **extrasynovial** but **intracapsular.**

The illustration also shows the different **attachments of the collateral ligaments** to the joint capsule. While the medial collateral ligament is directly united with the joint capsule and the medial meniscus, the lateral collateral ligament is separated from the joint capsule by the tendon of origin of the M. popliteus.

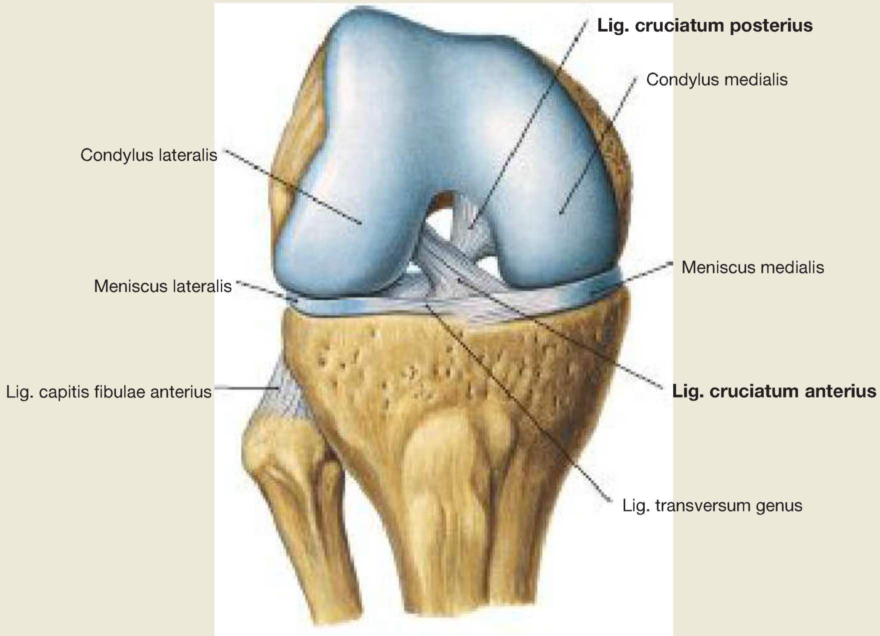


Fig. 4.53 Knee joint, Articulatio genus, right side, in 90° flexion; ventral view; after removal of the joint capsule and the collateral ligaments.
The most important inner ligaments are the two cruciate ligaments. The **anterior cruciate ligament (Lig. cruciatum anterius)** runs downwards from the inner surface of the lateral femoral condyle to the Area intercondylaris anterior of the tibia descending (from superior posterior lateral in an anterior direction). The **posterior cruciate ligament (Lig. cruciatum posterius)** runs downwards from the inner surface of the medial femoral condyle to the Area intercondylaris posterior of the tibia in the opposite direction (from superior anterior medial in a posterior direction). The cruciate ligaments are located inside the Capsula fibrosa **(intracapsular),** but outside the Capsula synovialis, and thus they are **extrasynovial.**

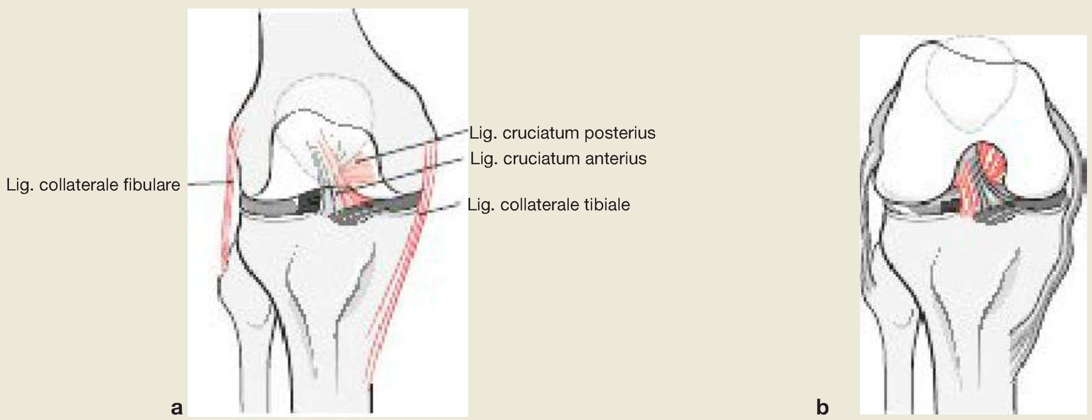


Fig. 4.54a and b Stabilisation of the knee joint, Articulatio genus, right side, with collateral and cruciate ligaments in an extended position (→ Fig. 4.54a) **and in a flexed position** (→ Fig. 4.54b); ventral view. [L216]
The cruciate ligaments together with the collateral ligaments form a functional unit. The **collateral ligaments** are **tense only during extension of the knee** and stabilise the knee joint in this position against rotational and abduction/adduction movements. In contrast, distinct parts of the **cruciate ligaments are tense in all positions of the knee joint:** the medial components during extension, and the lateral components during flexion.

Clinical Remarks

After **injury to the cruciate ligaments**, the lower leg can slide in a sagittal direction similar to a drawer: anteriorly with injury to the anterior cruciate ligament (clinical term: ACL, **'anterior drawer'** test), posteriorly with injury to the posterior cruciate ligament (clinical term: PCL, **'posterior drawer'** test). This is tested with the patient in a supine position: the examiner fixes the knee in a 90°-flexed position by sitting on the foot and pulls the lower leg forwards or pushes it backwards.

Menisci

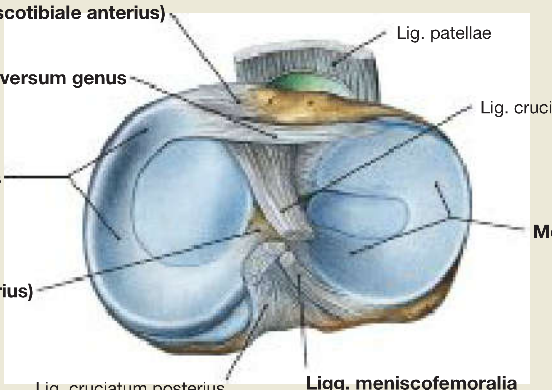


Fig. 4.55 Menisci of the knee joint, right side; cranial view.
Both menisci are roughly C-shaped and appear wedge-shaped in cross-sections. The **medial meniscus** is larger and anchored via the **Ligg. meniscotibialia anterius** and **posterius** to the respective Area intercondylaris of the tibia. In addition, the medial meniscus is fixed to the medial collateral ligament. In contrast, the **lateral meniscus** is fixed to the medial femoral condyle via the **Ligg. meniscofemoralia anterius** and **posterius**, but not attached to the lateral collateral ligament, from which it is separated by the tendon of the M. popliteus (→ Fig. 4.49b). The posterior horn of the lateral meniscus is only indirectly and flexibly connected to the tibia via the M. popliteus. Anteriorly, both menisci are interconnected through the **Lig. transversum genus**. This results in a significantly increased range of motion of the lateral condyle when bending the knee.
Both menisci are composed of fibrous cartilage inside and dense connective tissue outside.

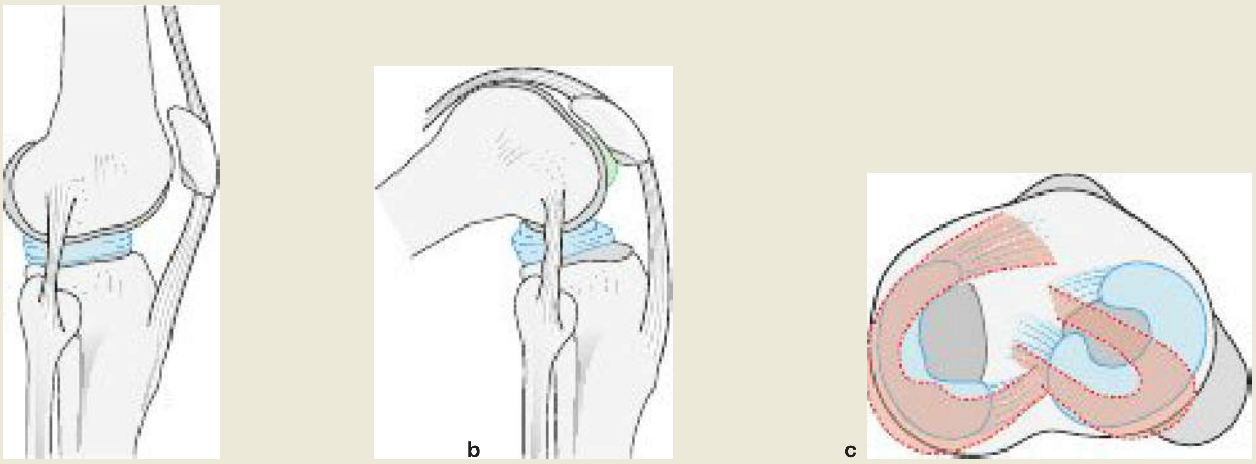


Fig. 4.56a to c Movability of the menisci during flexion. [L126]
a Extended position
b, c Flexed position

During flexion, both menisci are pushed posteriorly over the sides of the tibial condyles. The mobility of the lateral meniscus is considerably higher because it is less fixed.

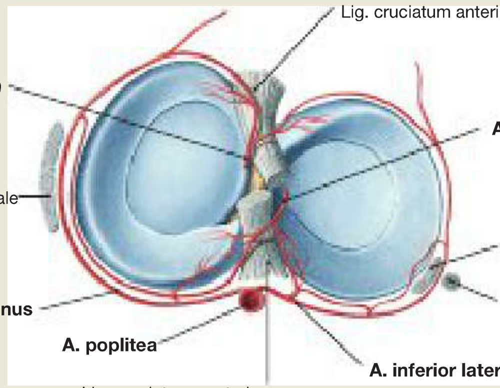


Fig. 4.57 Arterial blood supply to the menisci, right side; cranial view.
The **outer portions** are supplied with blood via a **perimeniscal capillary plexus**, that is fed by the Aa. inferiores medialis and lateralis genus and by the A. media genus (branches of the **A. poplitea**). In contrast, the **inner portions** are devoid of blood vessels and are supplied by diffusion from the **synovial fluid**.

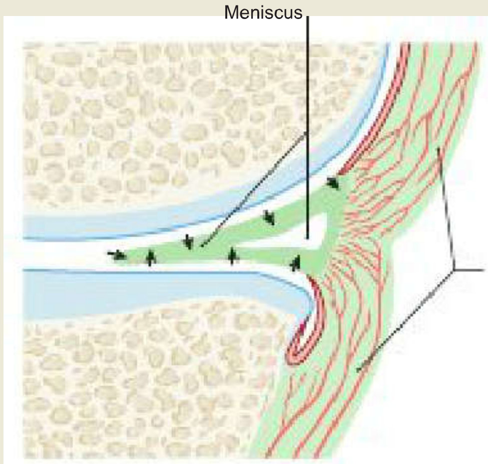


Fig. 4.58 Blood supply of the menisci. [L126]
Both menisci are composed of fibrous cartilage **inside** and dense connective tissue **outside.** The supply of the menisci has a major influence on their regenerative capacity. The **peripheral portion** of the menisci is supplied directly with **blood** from the perimeniscal capillary plexus of the A. poplitea and therefore it can regenerate relatively well after injury. In contrast, the **central portion** of the menisci is supplied indirectly by diffusion via the **synovial fluid**, and therefore its metabolism and regenerative capacities are restricted.

Damage of the Menisci

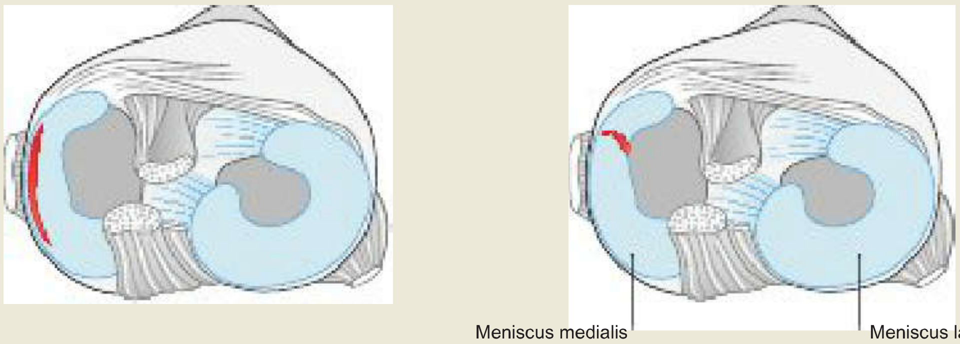


Fig. 4.59 Lesions of the medial meniscus, right side; cranial view. [L126]
As the medial meniscus is connected directly to the medial collateral ligament through the joint capsule, **lesions of the medial meniscus occur much more frequently** than lesions of the lateral meniscus. These might include partial ruptures or even avulsion of parts of the meniscus.

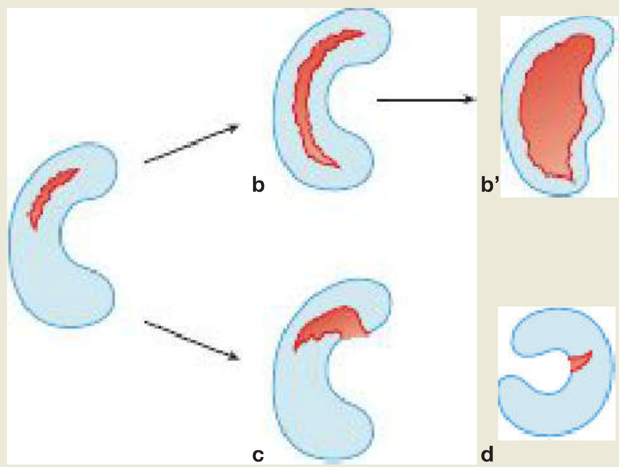


Fig. 4.60a to d Development (stages) of meniscal ruptures. [L126]
- **a** Occurrence of a longitudinal rupture or tear
- **b** Prolongation of the rupture (tear) from the posterior horn to the anterior horn and displacement into the joint (= bucket handle tears, b') or
- **c** Additional transverse rupture (mostly avulsion of the anterior or posterior horn)
- **d** Transverse rupture (tear), of the lateral C-shaped meniscus in most cases

Clinical Remarks

Meniscal injuries are common. Mostly the **medial meniscus is affected due to its stronger fixation to bone and capsule.** Acute injuries occur with sudden rotational movements of the flexed knee while bearing weight and cause a painful inhibition of active and passive extension movements. Chronic degenerative changes are often caused by a misalignment. If injuries affect the well-perfused peripheral areas of the menisci, spontaneous healing is possible. Rupture of the inner portions, on the other hand, typically require an arthroscopic partial removal (meniscectomy) in order to restore the freedom of movement. However, it can often result in degenerative osteoarthritis of the knee joint **(gonarthrosis)**.

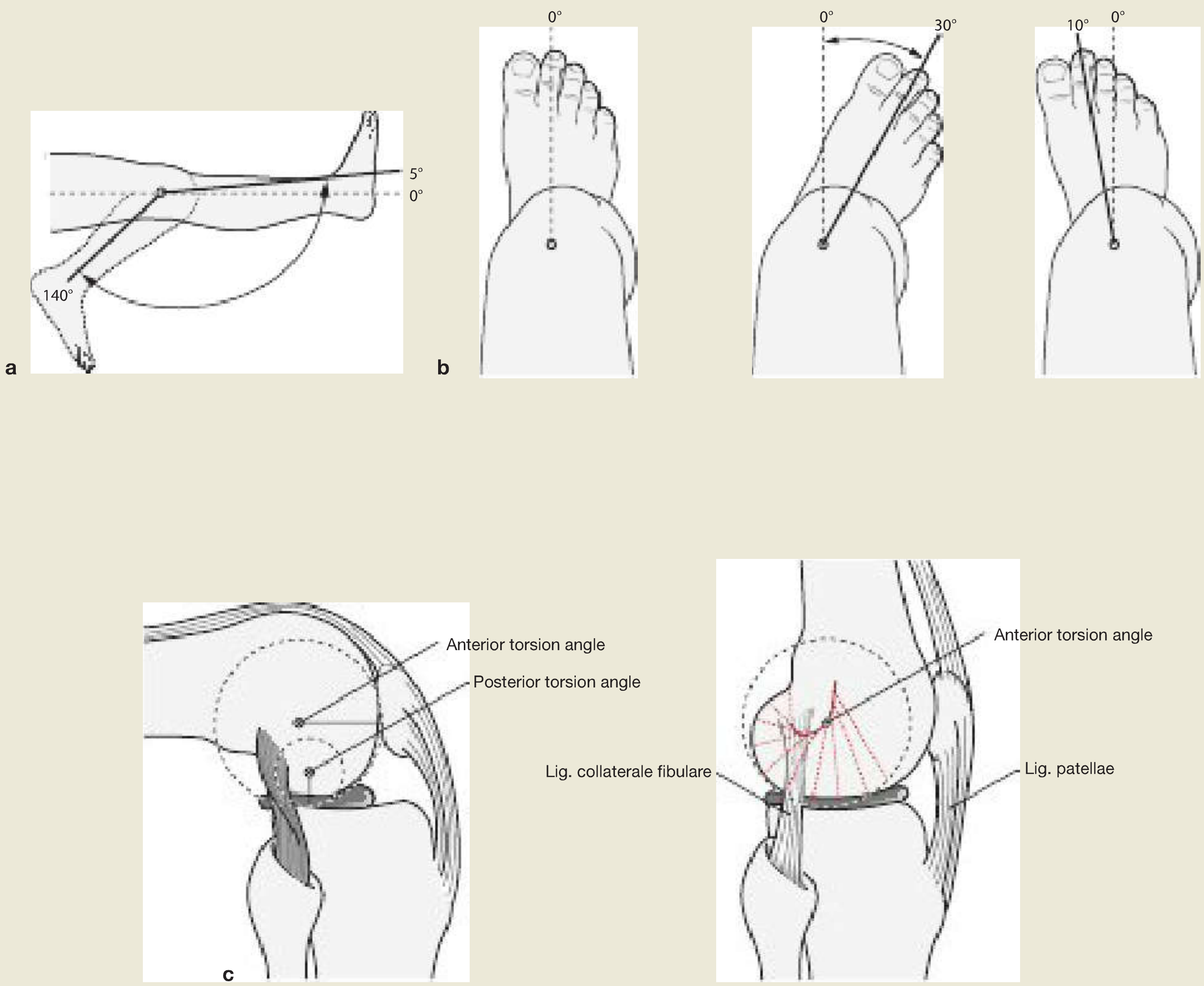


Fig. 4.61a to c Range of motion of the knee joint, Articulatio genus. [L126]

The knee joint is a **bicondylar joint** (Articulatio bicondylaris) which functions like a **pivot-hinge joint** (trochoginglymus) and possesses two degrees of freedom of movement. The transverse axis for **extension** and **flexion movements** runs through the trochlea of both femoral condyles (**c**). The **longitudinal axis** of **rotational movements** is slightly shifted medially and therefore it runs eccentrically and perpendicularly through the Tuberculum intercondylare mediale of the tibia. Due to the smaller posterior radius of curvature of the femoral condyles, the **transverse axis** does not remain in a constant position, but moves on a convex line posteriorly and superiorly during flexion (**c**). The flexion of the knee is therefore a **combined rolling and sliding movement,** in which the condyles roll up to 20° posteriorly and then turn in this position. Since the medial and lateral condyles of the femur and of the tibia are not identically shaped, it is predominantly the lateral femoral condyle that rolls (similar to a rocking chair), whereas the medial condyle rotates without changing place (similar to a ball-and-socket joint). At the same time, the femur turns slightly outwards. In the terminal phase of the extension movement, the tension of the anterior cruciate ligament also induces a forced lateral rotation of 5°–10°, during which the medial condyle of the femur even loses its contact with the medial meniscus. The active flexion of up to 120° can be increased up to 140° after pre-extension of the hamstring muscles (**a**). Passive flexion is possible up to 160°, and limited only by soft tissues. Extension is possible up to the neutral ('zero') position but can be increased passively by 5°–10°. Rotation is only possible with a flexed knee, because the collateral ligaments are tensed during extension and thus inhibit any rotation (**b**). External rotation is possible to a greater extent than internal rotation, as the cruciate ligaments are wrapped around each other during internal rotation. Abduction and adduction are almost completely inhibited by the strong collateral ligaments.

Range of motion:

a Extension–flexion: 5°–0°–140°.
b Lateral rotation–medial rotation: 30°–0°–10°

Knee Joint, Clinical Remarks

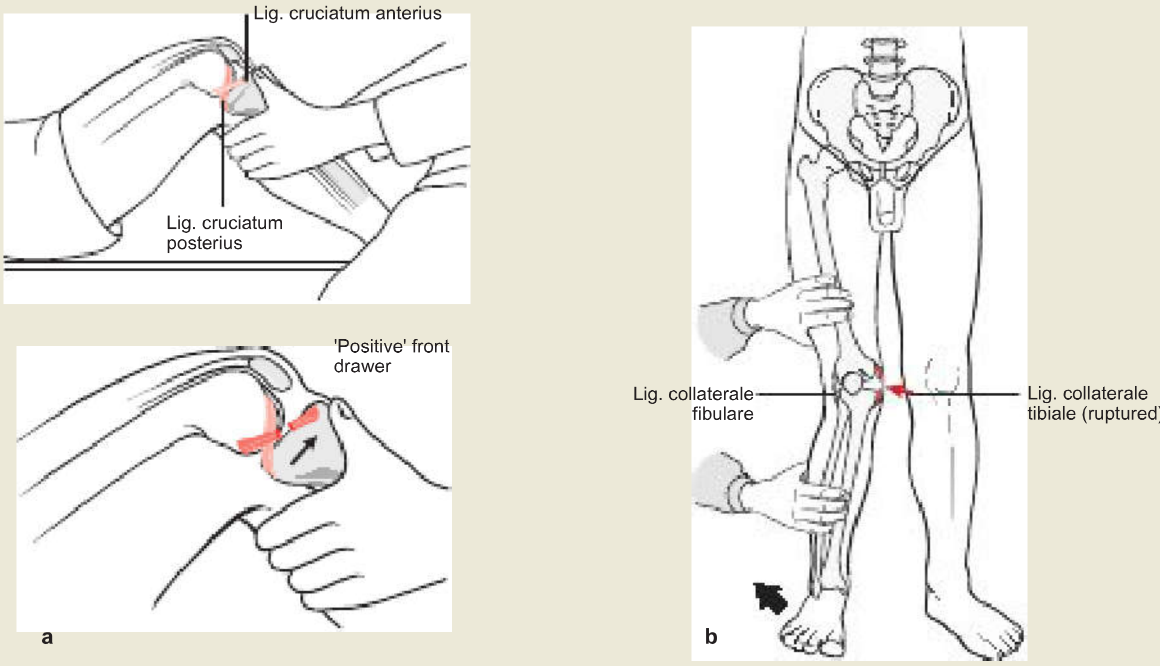


Fig. 4.62a and b Clinical examinations for assessing the ligament functions at the knee joint. [L126]
a Examination of the anterior cruciate ligament (drawer test)
b Examination of the medial collateral ligament

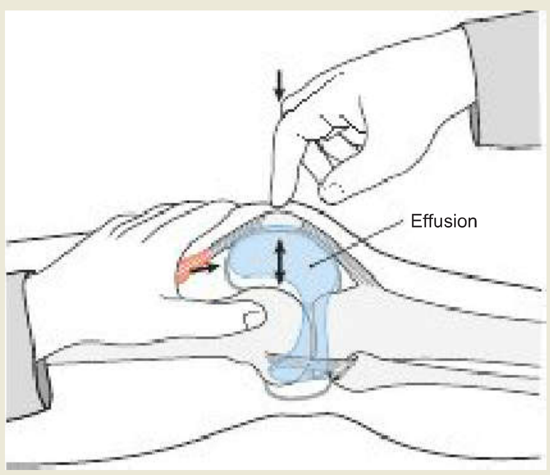


Fig. 4.63 Clinical examination of a knee joint effusion; lateral view, right side. [L126]
For an explanation → Clinical Remarks.

Clinical Remarks

Injuries to menisci and ligaments of the knee joint generally lead to an acute knee joint effusion. This is often obvious because of the swelling (increased volume). In order to confirm the findings, the phenomenon of the **dancing patella** is provoked. This is done by stroking the Recessus suprapatellaris with one hand from the thigh towards the knee joint. In the case of downwards pressure, the patella seems to move around as if on a water pillow.

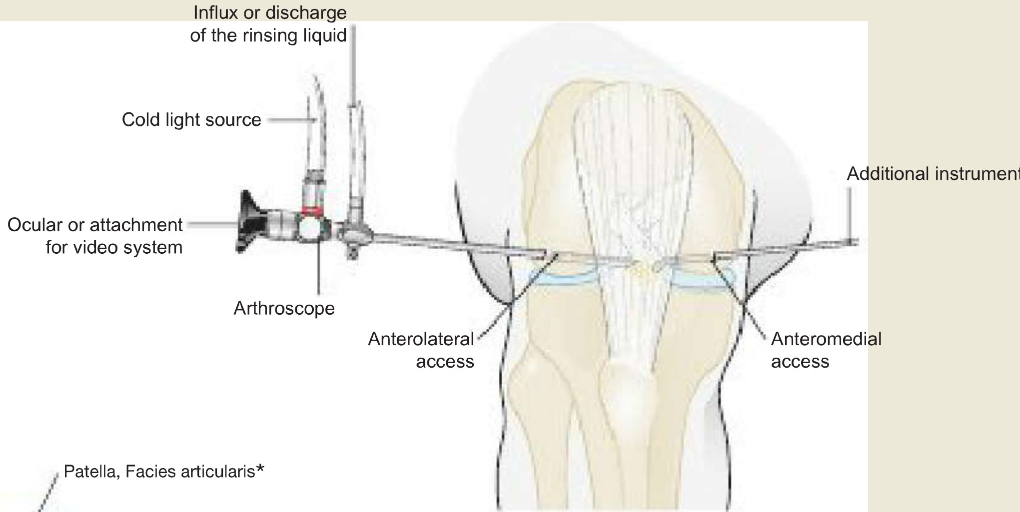
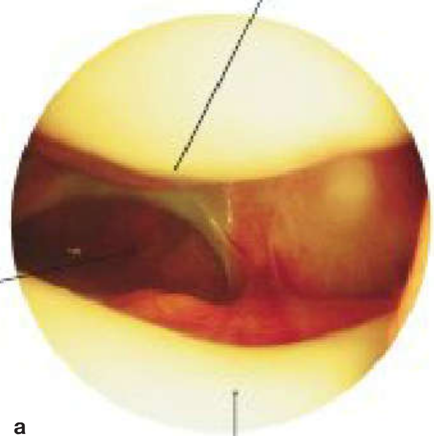
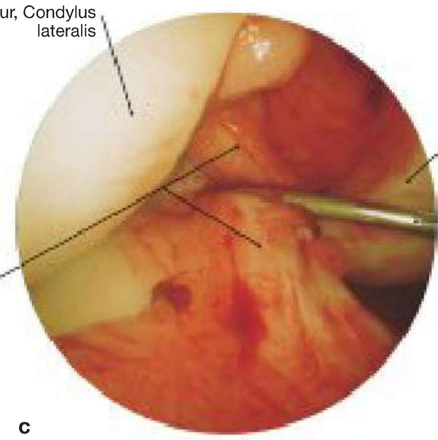


Fig. 4.64 Endoscopic examination (arthroscopy) of the knee joint. [L126]
Minimally invasive arthroscopy allows access to the joint cavity, in order to examine the structures of the knee joint and to perform minor surgical interventions.





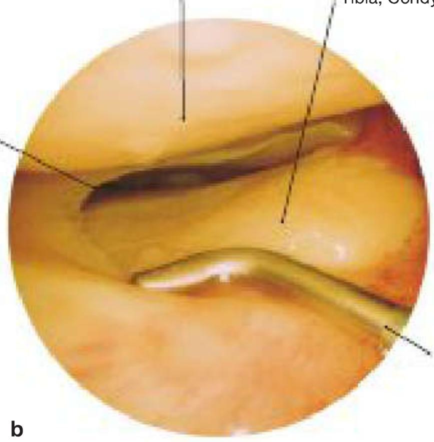


Fig. 4.65a to c Knee joint, Articulatio genus, right side; arthroscopic views. [T907]

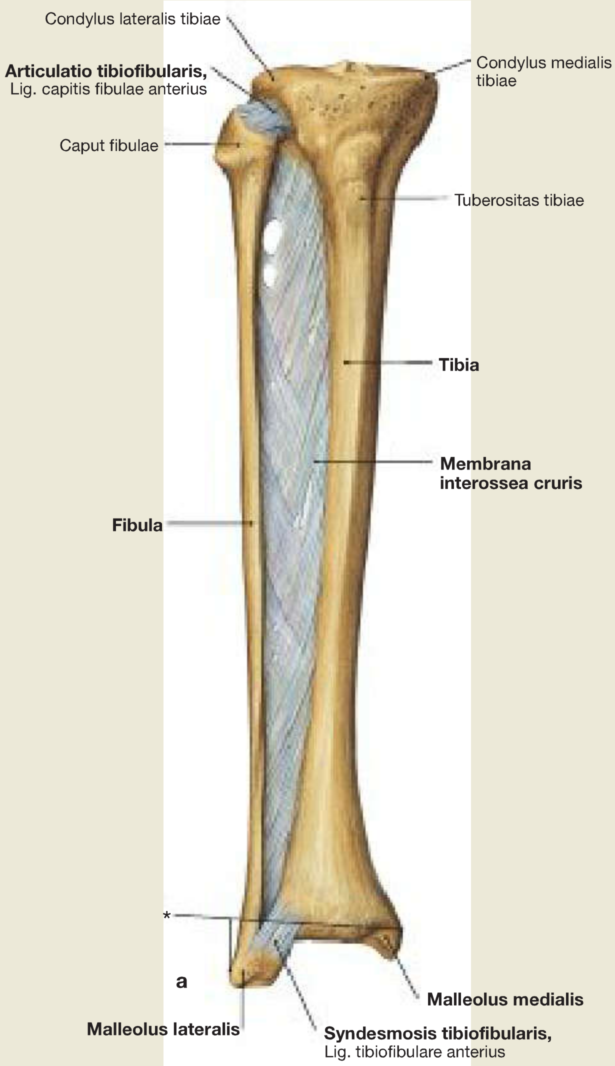
- **a** Distal view into the femoropatellar joint
- **b** Medial view onto the inner edge of the lateral meniscus
- **c** Anterior-lateral view onto the anterior cruciate ligament

* patellar ridge: ridge between the medial and lateral articular surfaces
** clinical term: Recessus suprapatellaris
*** palpating hook

Clinical Remarks

An **arthroscopy** is one of the procedures that is frequently carried out on the knee joint. On the one hand, they serve as a **diagnostic procedure,** if, for example, the rupture of a meniscus cannot be confirmed or excluded by MRI scans. On the other hand, they serve as **treatment**, such as the removal of torn meniscus parts, a repair of the cruciate ligaments (cruciate ligament reconstruction), or to remove floating bodies which painfully inhibit movements.

Connections of the Lower Thigh Bones



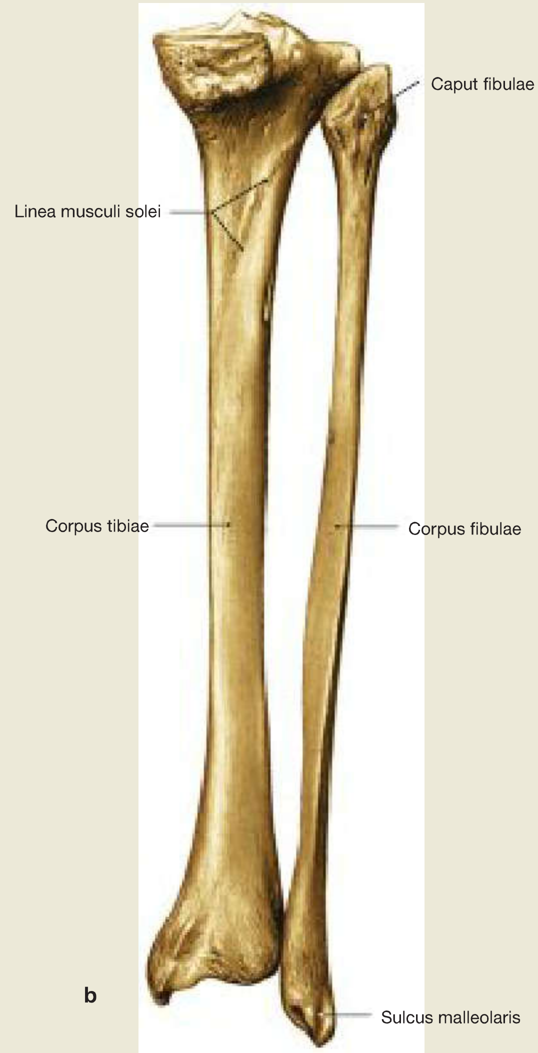


Fig. 4.66a and b Connections (junctions) of the tibia and fibula, right side; ventral view (→ Fig. 4.66a) and dorsal view (→ Fig. 4.66b). The proximal joint is an amphiarthrosis **(Articulatio tibiofibularis)** with the **Ligg. capitis fibulae anterius and posterius.** Distally both the bones are firmly connected by the **Ligg. tibiofibularia anterius and posterius**, and form the **tibiofibular syndesmosis (Syndesmosis tibiofibularis)**. The **Membrana interossea cruris** with its fibres of tight connective tissue, primarily running obliquely from the tibia downwards to the fibula, provides further stabilisation. Together with the inferior articular surface of the tibia, the medial and lateral ankles (Malleoli) form the **malleolar fork,** which provides the socket for the ankle joint.

* malleolar fork

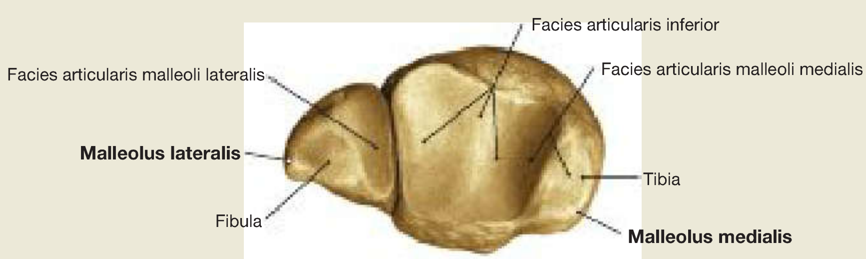


Fig. 4.67 Distal end of the tibia and of the fibula, right side; distal view.

Clinical Remarks

Proximal fractures in the head and neck regions of the fibula are referred to as **MAISONNEUVE fractures**.
Fractures of the distal end of the tibia are called **WEBER fractures**, which, depending on the involvement of the Syndesmosis tibiofibularis, are classified into three grades (→ Fig. 4.89 and → Fig. 4.90). Since minor deformities in the ankle joint already result in degenerative arthritis **(arthrosis, osteoarthritis)**, virtually all of these fractures are actually treated surgically with plates or screws.

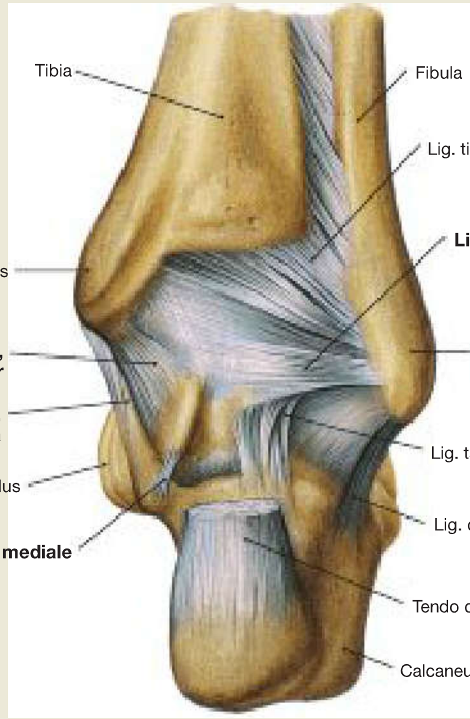


Fig. 4.68 Ankle joint (talocrural joint), Articulatio talocruralis, right side, with ligaments; dorsal view.

Parts of the Lig. collaterale mediale (Pars tibiotalaris posterior, Pars tibiocalcanea) and the lateral Lig. talofibulare posterius secure the joint at the back.

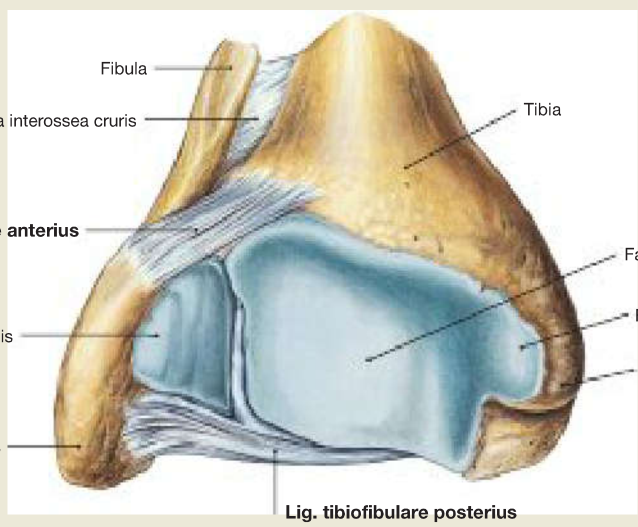


Fig. 4.69 Distal end of the tibia and of the fibula, right side; distal view.

The tibia and fibula are held together with the **Syndesmosis tibiofibularis** and form the malleolar fork, the socket of the ankle joint.

Ankle Joint

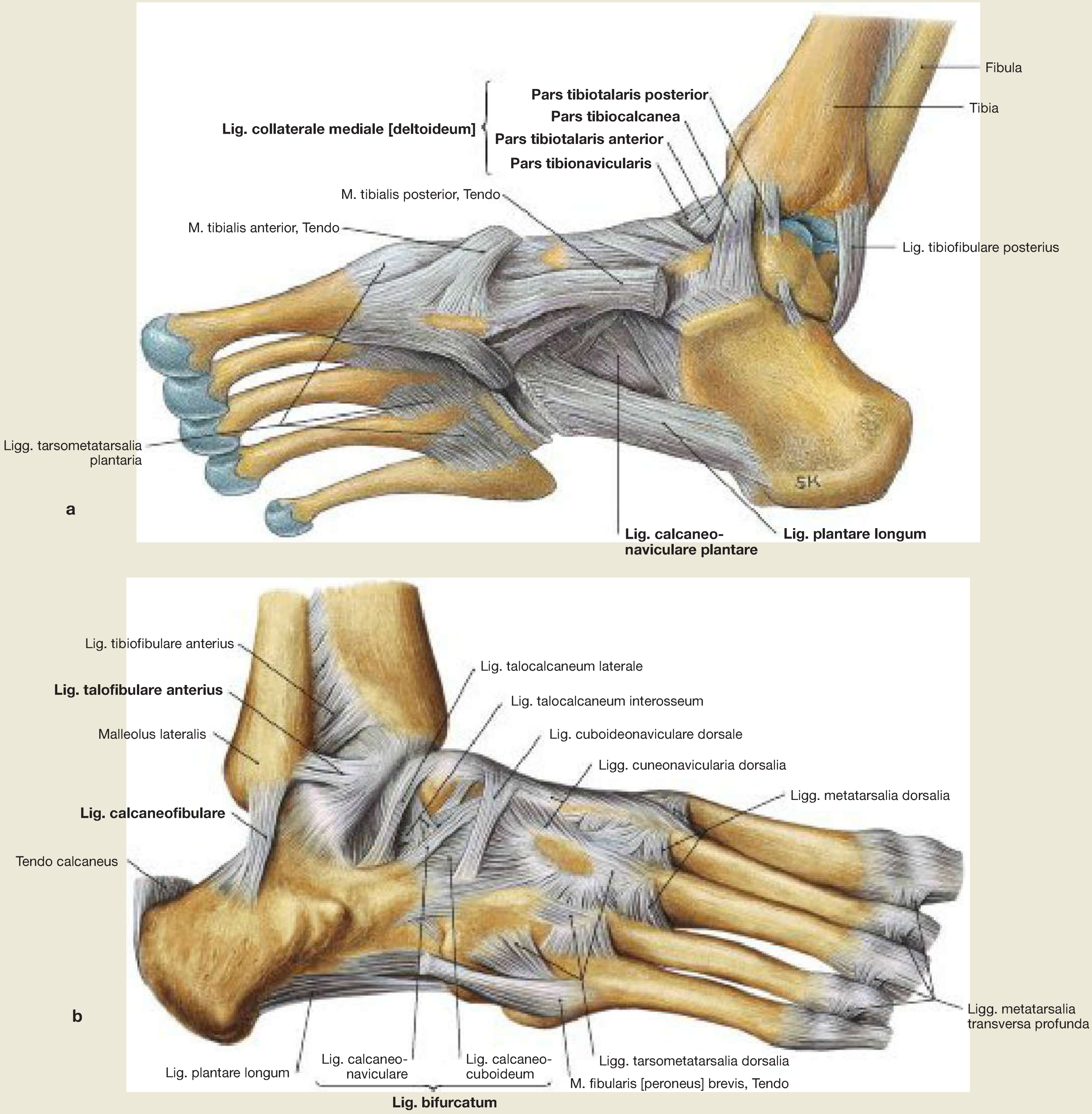
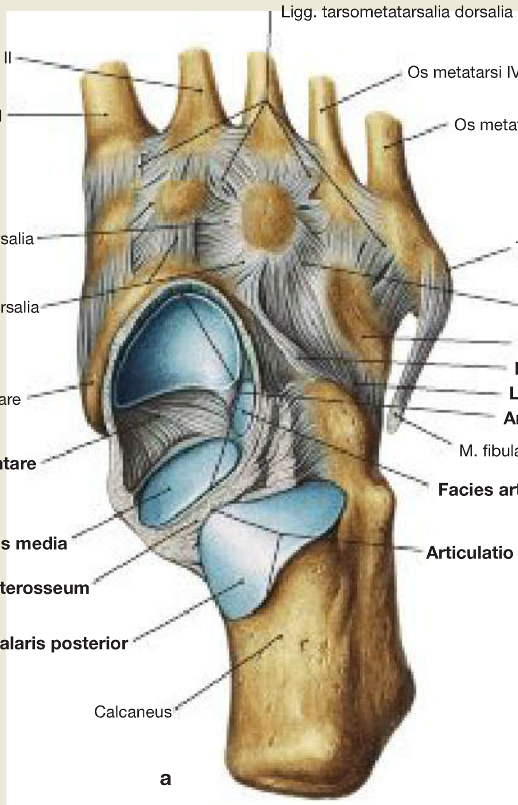


Fig. 4.70a and b Ankle joint, Articulatio talocruralis, right side, with ligaments; medial view (→ Fig. 4.70a) and lateral view (→ Fig. 4.70b). [L238]

Movements of the foot take place in the upper ankle joint and in the talocalcaneonavicular joint. The remaining tarsal and metatarsal joints are amphiarthroses, that can expand the range of motion in the talocalcaneonavicular joint, albeit only slightly. The malleolar fork forms the socket and the trochlea of the talus the joint head of the ankle joint. **Medially** both joints are stabilised by a fan-shaped ligament, known as the **Lig. collaterale mediale (deltoideum)** which is composed of four fibrous tracts (Pars tibiotalaris anterior, Pars tibiotalaris posterior, Pars tibiocalcanea, Pars tibionavicularis), that connect the corresponding bones. **Laterally**, there are **three separate ligaments (Lig. talofibulare anterius, Lig. talofibulare posterius, Lig. calcaneofibulare).** In addition, these ligaments also stabilise the talocalcaneonavicular joint.

Clinical Remarks

Injuries affect the **ankle joint** more **frequently** than the **talocalcaneonavicular joint,** since the ligaments in this region are not particularly strong. Since the trochlea of the talus is broader in the anterior than the posterior part (→ Fig. 4.32a), secure bony guidance is only guaranteed in dorsiflexion (extension) by widening of the malleolar fork. The most common ligament injury in humans is the rupture of the lateral ligaments (Lig. talofibulare anterius and Lig. calcaneofibulare) in **hypersupination trauma** ('twisting one's ankle').



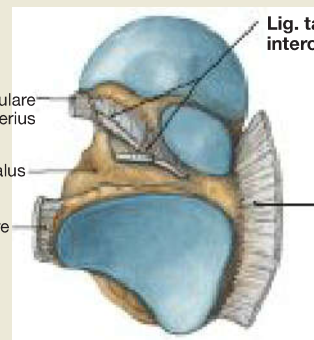


Fig. 4.72 Talocalcaneonavicular joint, Articulatio talocalcaneonavicularis, proximal joint bodies, right side; distal view.

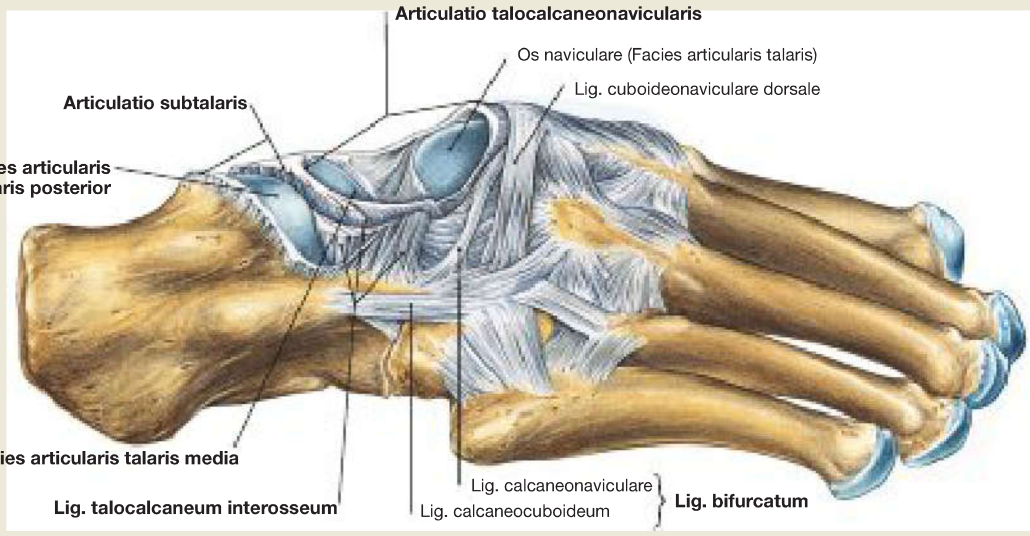


Fig. 4.71a and b Talocalcaneonavicular joint, Articulatio talocalcaneonavicularis, distal joint bodies, right side; proximal view (→ Fig. 4.71a) and lateral view (→ Fig. 4.71b) after the removal of the talus.

In the talocalcaneonavicular joint, the talus, calcaneus and Os naviculare articulate in two completely separated joints. The posterior joint **(Articulatio subtalaris)** is formed by the posterior corresponding articular surfaces of the talus and calcaneus. This partial joint is separated from the anterior partial joint **(Articulatio talocalcaneonavicularis)** by the **Lig. talocalcaneum interosseum**, which is positioned in the Sinus tarsi. In the anterior partial joint, the anterior articular surfaces of the talus and calcaneus articulate, whereas the head of the talus articulates anteriorly with the Os naviculare and inferiorly with the **Lig. calcaneonaviculare plantare (spring ligament).** At this point, the ligament usually has an articular surface of hyaline cartilage. It is involved in the bracing of the arches of the foot. Functionally, both partial joints form a single unit. This explains why the term **Articulatio talocalcaneonavicularis** is often used for the entire talocalcaneonavicular joint. Besides the ligaments of the ankle joint, there are additional ligaments that stabilise the skeletal elements of the talocalcaneonavicular joint. These include the Lig. talocalcaneum interosseum, the Lig. talocalcaneum mediale and the Lig. talocalcaneum laterale (→ Fig. 4.68 and → Fig. 4.70b). For the range of motion in the lower ankle joint → Fig. 4.79.

Joints of the Foot

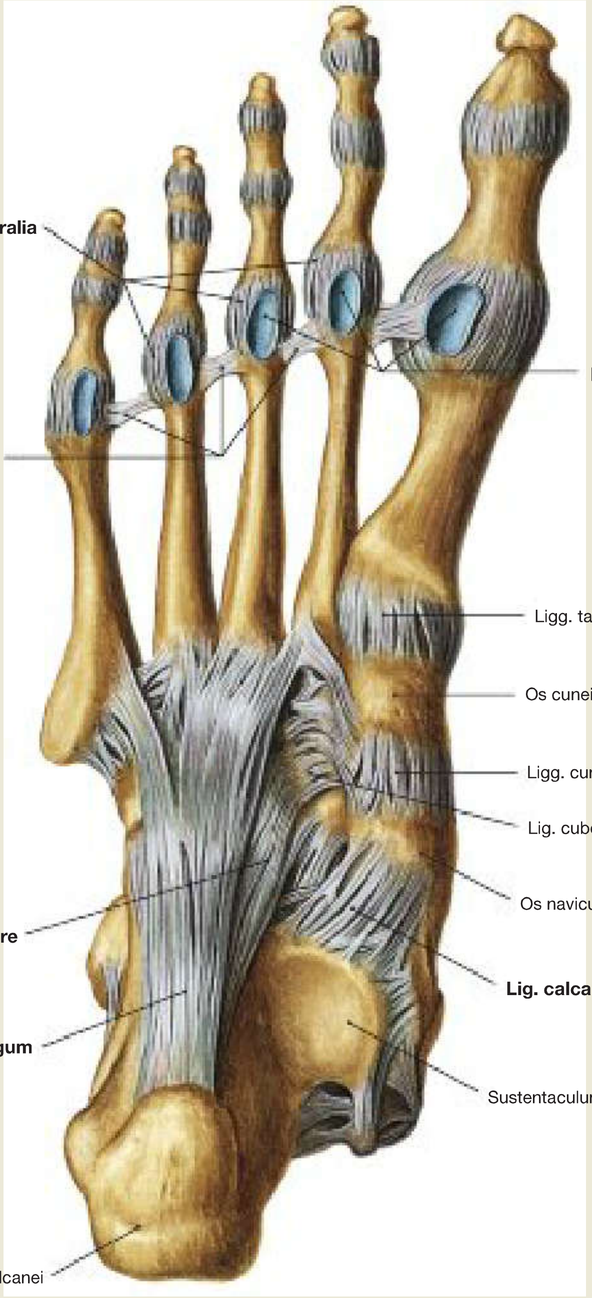


Fig. 4.73 Joints of the foot, Articulationes pedis, right side, with ligaments; plantar view.

The remaining tarsal and metatarsal joints are **amphiarthroses,** which are of minor significance for the mobility of the individual joints. Together, however, they enlarge the range of motion in the talocalcaneonavicular joint and connect the bones of the foot to an elastic (springy) base. In the tarsal region, two joints can be emphasised which contribute to the supination and pronation movements of the foot. The **CHOPART's joint** (Articulatio tarsi transversa) is composed of the Articulatio talonavicularis and the Articulatio calcaneocuboidea (→ Fig. 4.29). The **LISFRANC's joint** (Articulationes tarsometatarsales) serves as the connection to the metatarsus (→ Fig. 4.29). These two joints or articulation lines have clinical relevance as amputation lines. In addition, the tarsal bones articulate in several distinct joints. The metatarsal bones are connected proximally by the **Articulationes intermetatarsales and** distally by the **Lig. metatarsale** transversum profundum. The joints of the forefoot and midfoot are interlinked by strong plantar, dorsal and interosseous **ligaments**. The CHOPART's joint is stabilised in particular by the dorsal **Lig. bifurcatum**, which splits into two fibrous tracts (Lig. calcaneonaviculare and Lig. calcaneocuboideum) (→ Fig. 4.71a). The opposite ligament on the sole of foot is the **Lig. calcaneocuboideum plantare**. In addition to the spring ligament the **Lig. plantare longum** helps to maintain the arches of the foot. It is located more superficially than the other plantar ligaments and courses from the calcaneus to the Os cuboideum and to the Ossa metatarsi II to IV. The joints of the **toes** can be divided into **metatarsophalangeal joints** (Articulationes metatarsophalangeae) as well as **proximal and distal** (Articulationes interphalangeae proximales and distales) All joints of the toes are restricted in their mobility by strong ligaments on both sides **(Ligg. collateralia)** and by the **Ligg. plantaria** from below.

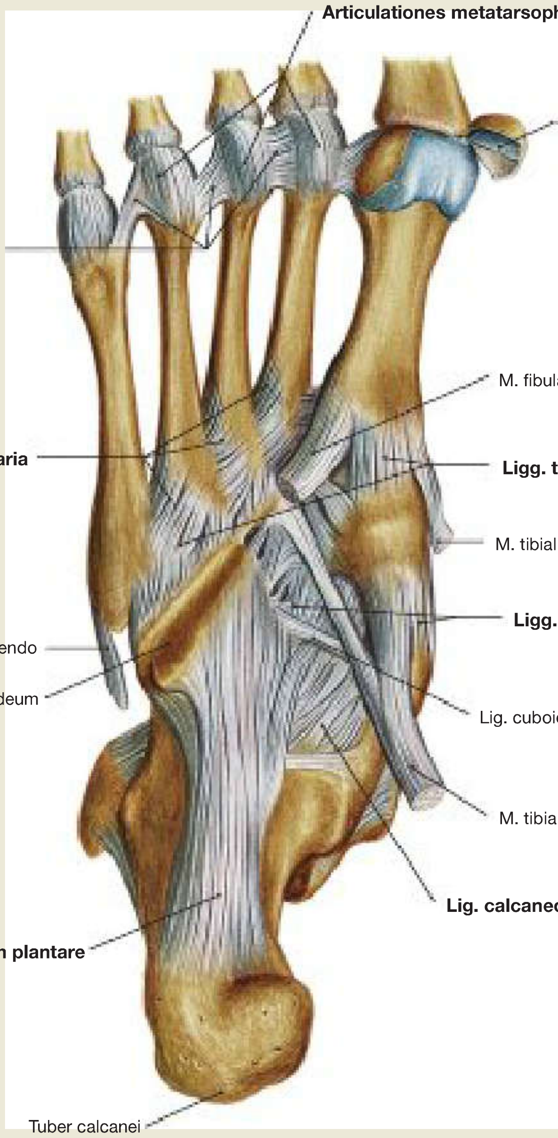


Fig. 4.74 Joints of the foot, Articulationes pedis, right side, with ligaments; plantar view; after removal of the Lig. plantare longum.

Clinical Remarks

One of the most common deformities in the first metatarsophalangeal joint is the **hallux valgus,** in which the head of the first metatarsal bone deviates medially and is markedly prominent, whereas the big toe (hallux) is adducted laterally. This may result in severe pain in the affected joint and may cause soft tissue swelling. The hallux valgus deformity often requires surgical revision. New therapeutic approaches attempt to paralyse the adductive muscles (M. adductor hallucis) by injections of botulinus toxin in order to resolve the deformity. In the **hammer toe** deformity, the proximal or distal interphalangeal joints are fixed in a flexed position. In the case of a **claw toe** deformity, the metacarpophalangeal joint is also overextended, whereby the proximal phalanx can be pushed over the metatarsal bone.

Arches of the Foot

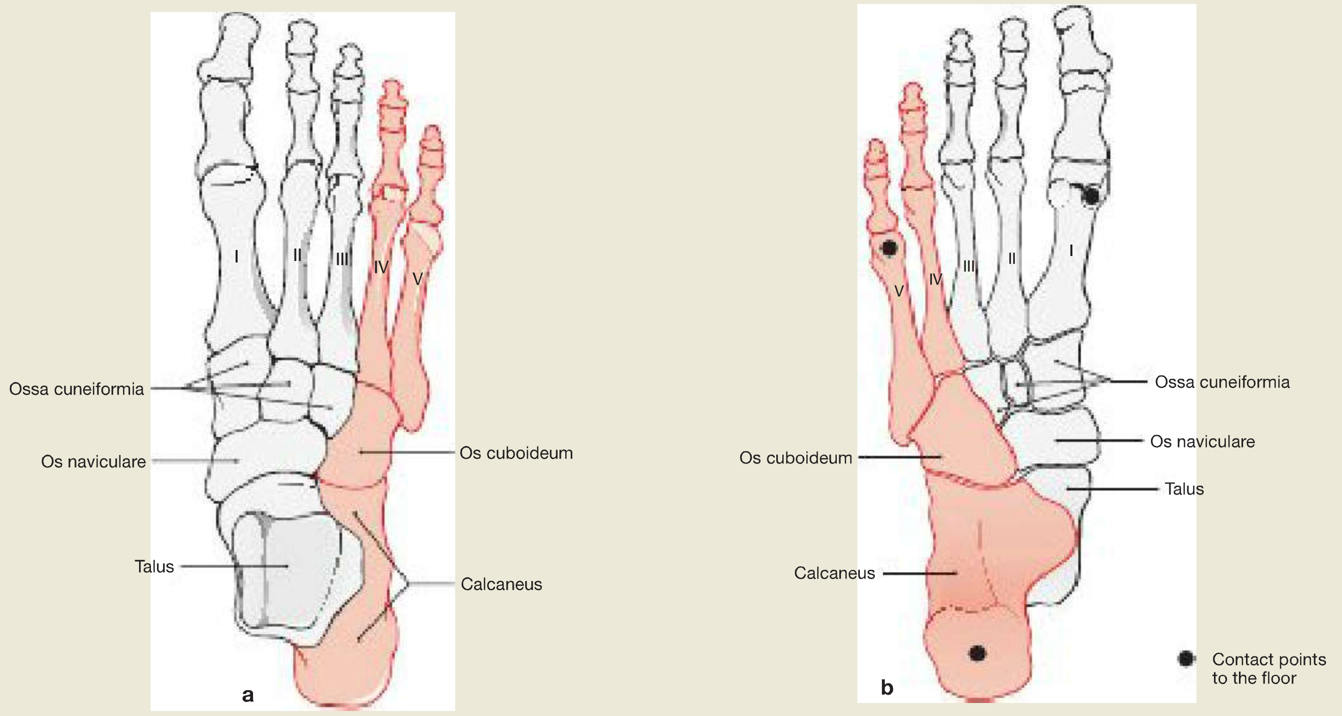


Fig. 4.75a and b Bones of the arches of the foot, right side; dorsal view (→ Fig. 4.75a) and plantar view (→ Fig. 4.75b). [L126]

When standing, the weight of the body is transmitted by **medial and lateral vectors**. The medial vector includes the first three metatarsal bones and continues via the Os naviculare, the Os cuneiformia and the Ossa metatarsi I–III up to the first three toes. The lateral vector is formed by the fourth and the fifth metatarsal bones and continues via the Calcaneus, Os cuboideum and Ossa metatarsi IV and V to the two lateral toes. The shape and support system of the tarsal and metatarsal bones form the **longitudinal arch** and the **transverse arch** of the foot. Due to these arches, the foot has only three contact points to the ground: the heads of the metatarsal bones I and V, and the Tuber calcanei.

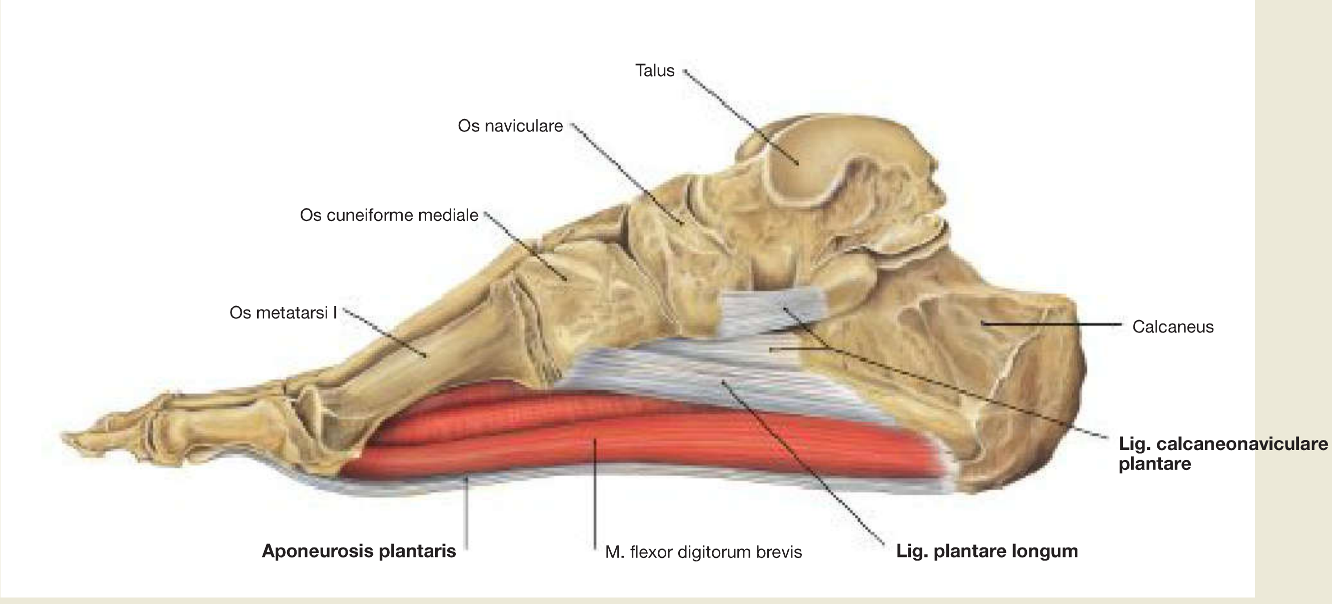


Fig. 4.76 Ligaments of the longitudinal plantar arch, right side; medial view. [L280]

The **ligaments** of the foot **passively** support the longitudinal arch of the foot. The ligamentous systems can be divided into three levels or layers:

- upper level: spring ligament (Lig. calcaneonaviculare plantare)
- middle level: Lig. plantare longum
- lower level: plantar aponeurosis (Aponeurosis plantaris)

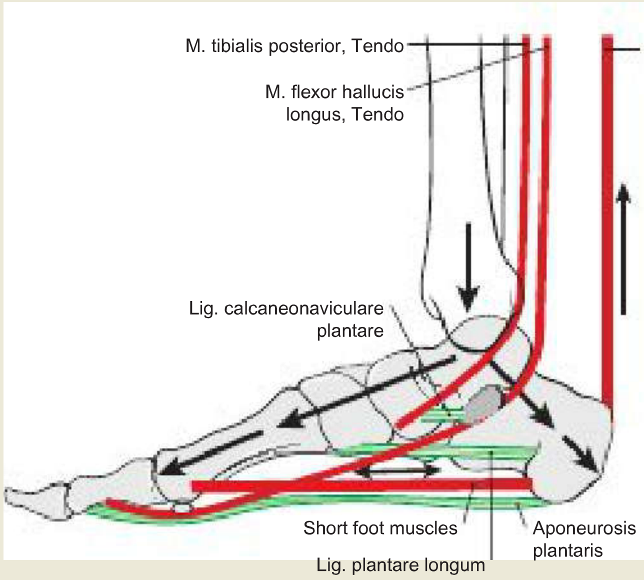


Fig. 4.77 Longitudinal arch of the foot, right side; schematic drawing, medial view. [L126]
The heads of all the metatarsal bones are located in the plantar plane, whereas in the posterior direction the Ossa cuneiformia, Os naviculare and talus increasingly overlay the lateral skeletal parts, so that the talus is on top of the calcaneus. Thereby the **longitudinal arch opens medially.** This is **actively** supported by the tendons of the **deep calf muscles** (M. flexor hallucis longus, M. flexor digitorum longus, M. tibialis posterior) and by the **short muscles** in the sole of the foot. This support structure provides a **tension banding** which counteracts the body weight.

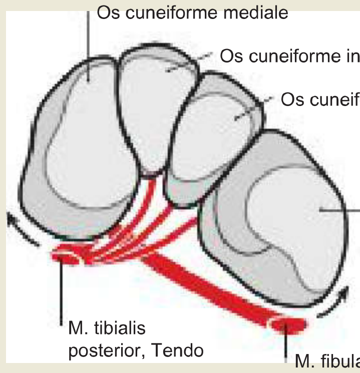


Fig. 4.78 Transverse arch of the foot, right side; schematic drawing, dorsal view. [L126]
The transverse arch of the foot is formed by the wedge-shaped **cuneiform bones** and the bases of the metatarsal bones, and is **passively** stabilised by the **ligaments** of the foot. It is **actively** supported in particular by the tendons of the **M. tibialis posterior** and **M. fibularis longus**, and by the **M. adductor hallucis**.

Clinical Remarks

Deformities of the feet are very common. The most common congenital deformity of the extremities is the **clubfoot** in which the foot is fixed in plantarflexion and supination. This is caused apparently by persistence (or insufficient regression) of the intrauterine physiological position of the feet (→ p. 158). However, deformities are more often secondary to the failure of the tension band system. In the **acquired flatfoot deformity (skewfoot, splayfoot and fallen ankes)** the foot is bent medially as the talus is lowered. Therefore, the metatarsal heads are spread out (splayed), so that the metatarsal bones II to IV come into contact with the ground, which can lead to painful pressure points.

Lower Limb

Movements of the Ankle and Other Joints of the Feet

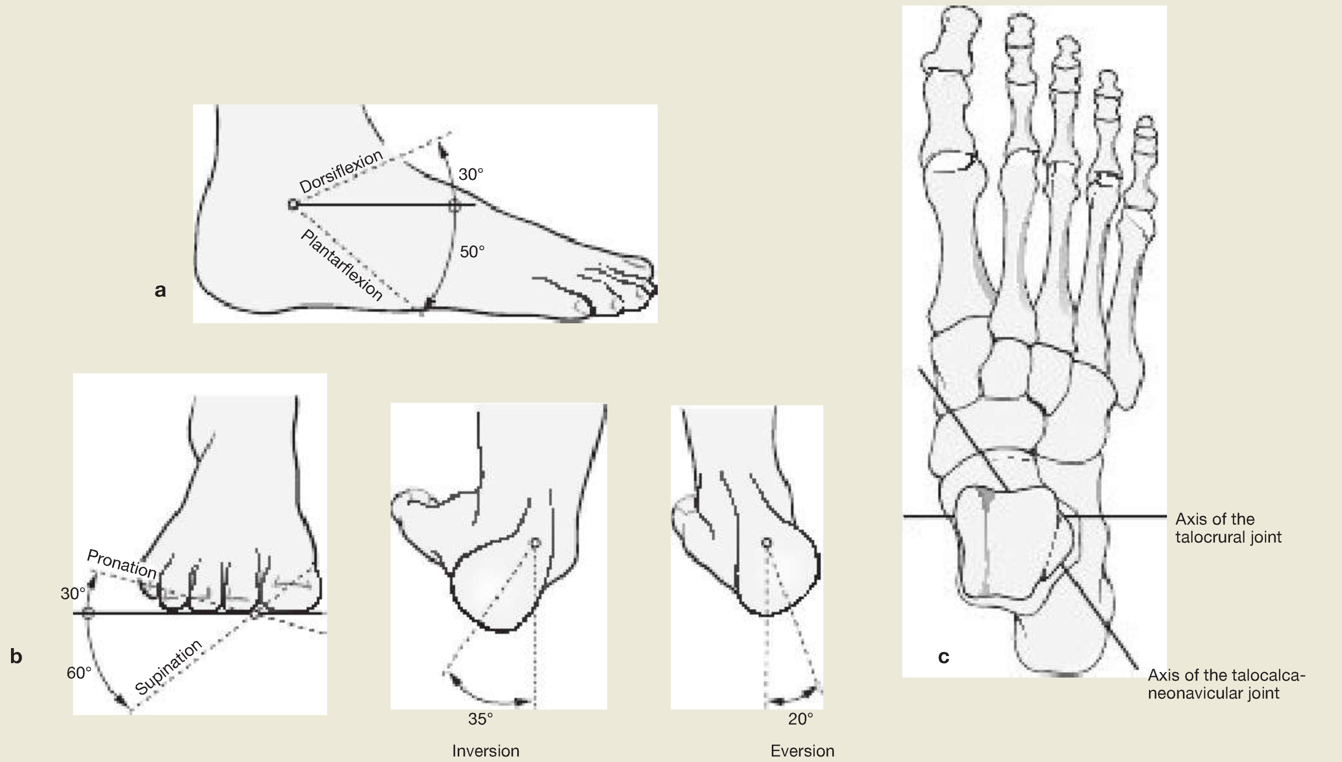


Fig. 4.79a to c Range of motion of the ankle joint and the talocalcaneonavicular joint. [L126]

The **ankle joint** is a classic **hinge joint** (ginglymus) allowing for **dorsiflexion (extension)** and **plantarflexion** of the foot (**a**). The transverse axis of the joint passes through both ankles or malleoli (**c**).

The **talocalcaneonavicular joint**, on the other hand, is an **atypical pivot joint** (Articulatio trochoide), for which a simplified axis has been defined. This axis runs from the neck of the talus to the calcaneus, and thus has a superior medial to lateral posterior orientation (**c**). This joint enables **inversion** (hind foot moving inwards or medially) and **eversion** (hind foot moving outwards or laterally) of the foot. These movements of the hind foot are complemented by the other foot joints (CHOPART's and LISFRANC's joints) to the movements of **supination** (lifting the medial side of the foot) and **pronation** (lifting the lateral side of the foot) (**b**).

Range of motion:
- Ankle joint: Dorsiflexion (extension) – plantarflexion: 30°–0°–50°
- Talocalcaneonavicular joint: Eversion – inversion: 20°–0°–35°
- Talocalcaneonavicular and other foot joints: Pronation – supination: 30°–0°–60°

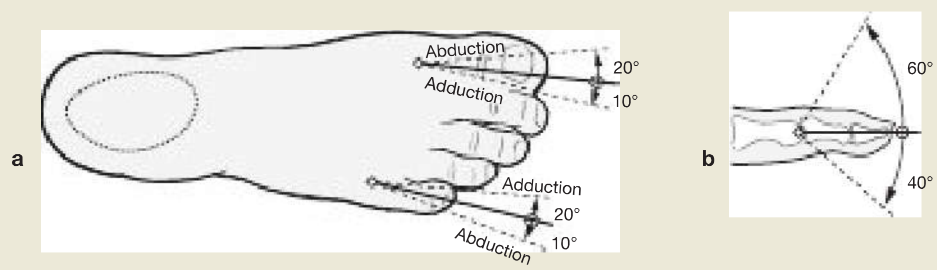


Fig. 4.80a and b Range of motion in the toe joints. [L126]

The metatarsophalangeal joints are condyloid joints, which are however restricted by tight ligaments to two degrees of freedom or two axes (rotational movements are not possible; **a**). The proximal and distal interphalangeal joints of the toes are hinge joints that allow only minor bending movements (**b**). More important than the active movement of the toes is their passive resistance in walking when rolling off the foot.

Range of motion in the metatarsophalangeal joints:
- Dorsiflexion (extension) – plantarflexion: 60°–0°–40°
- Adduction – abduction: 20°–0°–10° (adduction is defined as movement to the midline of the foot)!

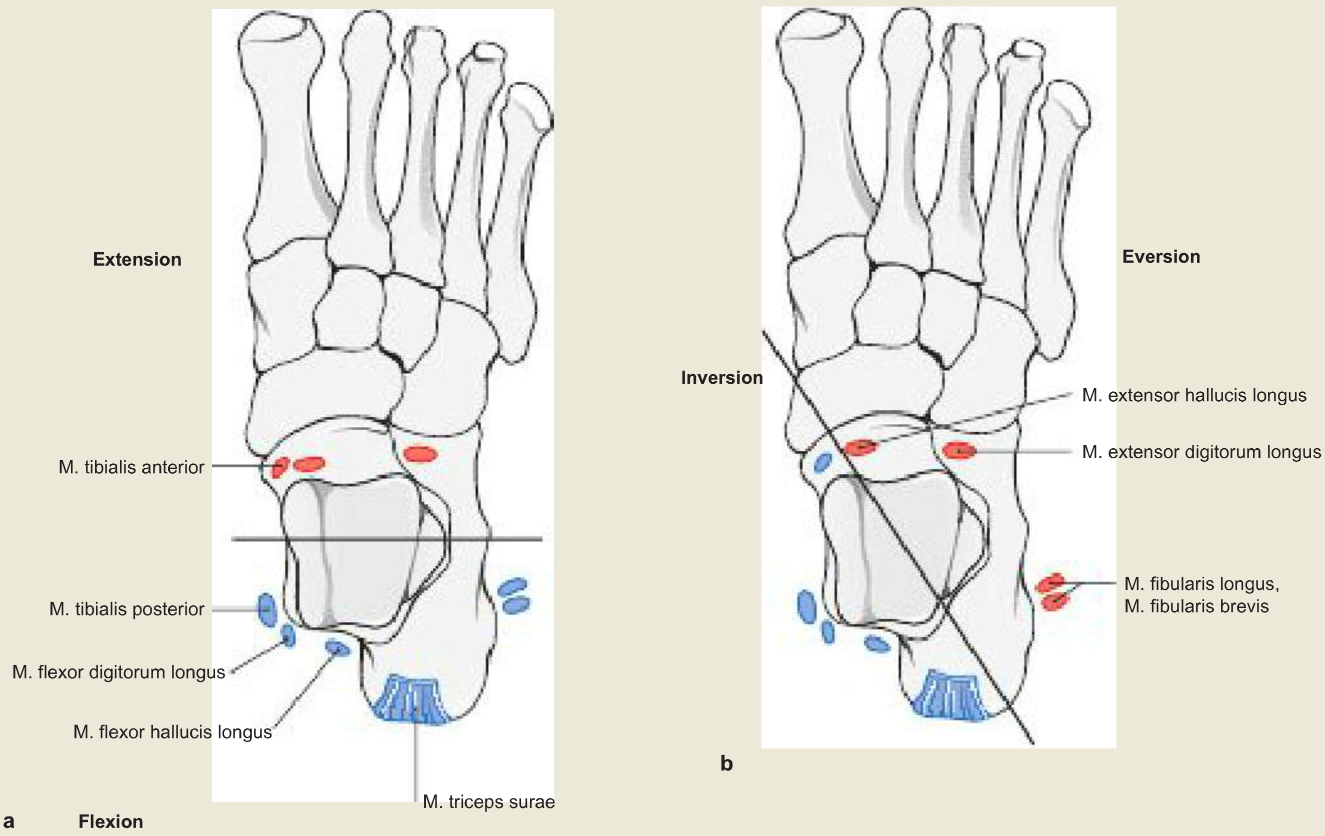


Fig. 4.81a and b Effect of the muscles of the leg on the ankle joints; schematic illustrations, dorsal view. [L126]
a Course of the inserting tendons in relation to the axis of the ankle joint, and **b** to the axis of the talocalcaneonavicular joint.
All muscles with inserting tendons that run ventrally to the flexion/extension axis of the ankle joint, are **dorsal extensors** (red). Muscles of which the tendons run dorsally to this axis are **plantar flexors** (blue). Muscles that run medially to the axis of the talocalcaneonavicular joint, are **supinators** (lift the medial side of the foot, blue). All muscles with inserting tendons that run laterally to the axis, act as **pronators** (lift the lateral side of the foot, red). Therefore, the muscles of the anterior group work as dorsal extensors and pronators with the exception of the M. tibialis anterior. The calf muscles are all plantar flexors and strong supinators. The primary function of the fibular muscle group is pronation, but it also supports the plantar flexion.

Pelvis

Fig. 4.82 Pelvis, male pelvis; X-ray with anterior-posterior (AP) beam projection; upright stance. [T895]

Clinical Remarks

X-ray images of the pelvis, or so-called plain pelvic X-rays, are a relatively common applied method. **Fractures** or **deformities** of the skeletal elements of the hip joint and of the pelvic girdle can be diagnosed with this method, as well as degenerative **arthritis** or local changes in the bone, e.g. caused by the spreading of malignant tumour cells **(metastases).**

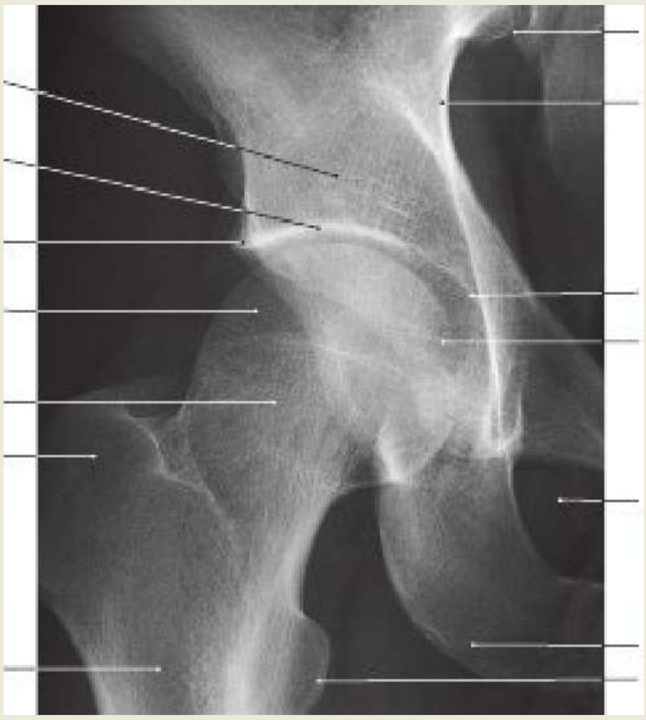


Fig. 4.83 Hip joint, Articulatio coxae, right side; X-ray in anterior-posterior (AP) beam projection; upright stance. [T902]

* Clinical term: roof of the acetabulum
** Clinical term: notch at the roof of the acetabulum

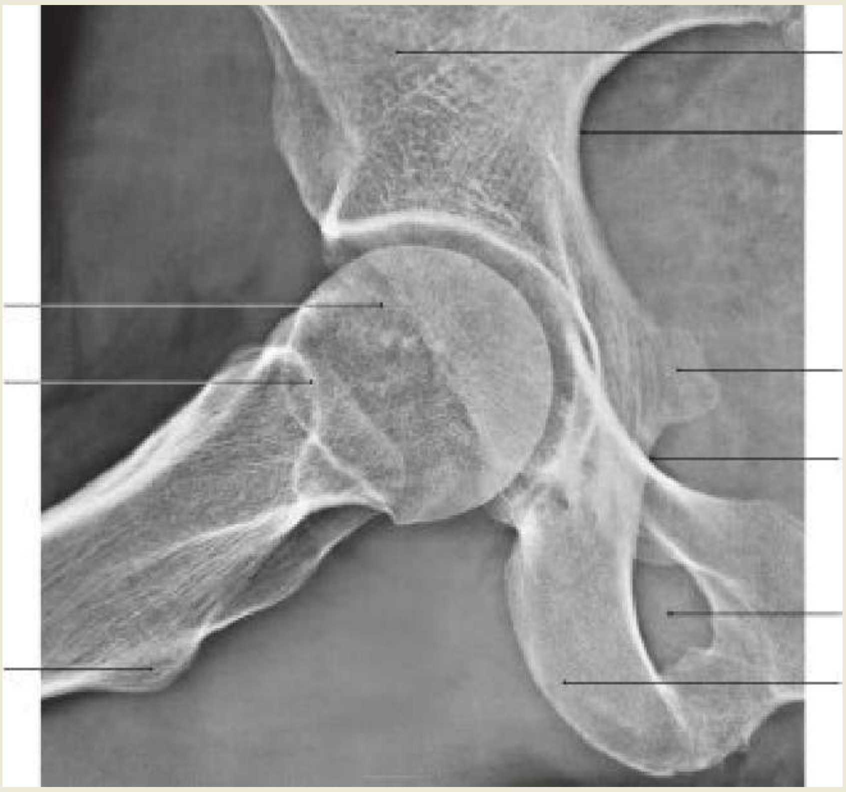


Fig. 4.84 Hip joint, Articulatio coxae, right side; X-ray in so-called LAUENSTEIN projection (abduction and flexion of the thigh; supine position).

Clinical Remarks

If a disease of the hip joint is suspected, special X-ray images are taken in various joint positions, such as the **LAUENSTEIN projection** in abduction and flexion of the thigh, for allowing a better assessment of the joint bodies.

Knee Joint

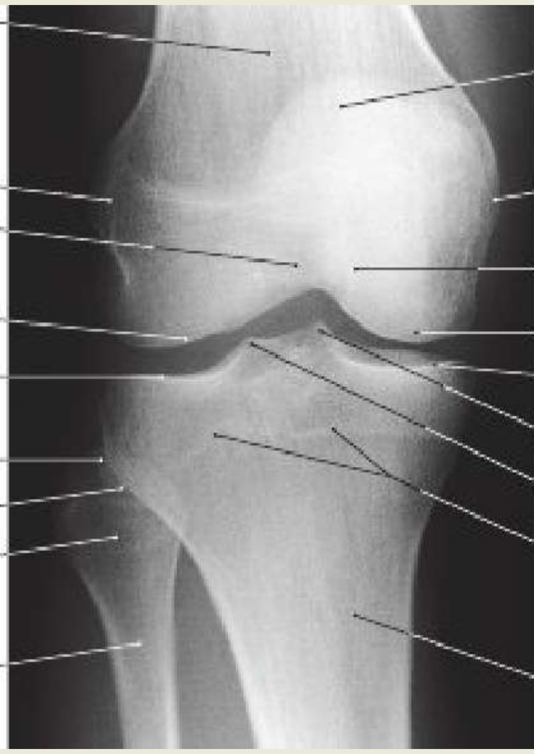


Fig. 4.85a and b Knee joint, Articulatio genus; X-rays with anterior-posterior (AP) beam projection (→ Fig. 4.85a) and with lateral beam projection (→ Fig. 4.85b); lying position. [T902]

It has to be considered that the contours of the medial and lateral femoral condyles are not congruent.

Clinical Remarks

With diseases of the knee joint, X-ray images are generally taken in two planes. The joint space and socket of the tibia can be better assessed in views with anterior-posterior (AP) beam projection, while the femoral condyles are better displayed in lateral views. In addition to fractures, misalignments and degenerative diseases such as osteoarthritis of the knee (gonarthrosis) can also be diagnosed easily.

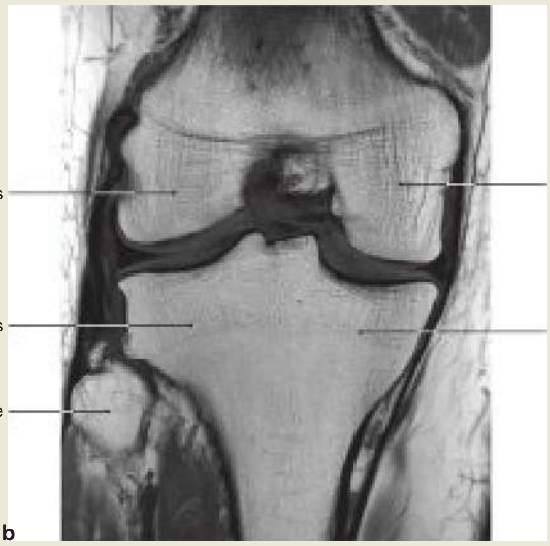


Fig. 4.86a and b Knee joint, Articulatio genus, right side; magnetic resonance imaging (MRI), coronary sagittal scan;
a fat-saturated T1w native method,
b T1w native. [T832]

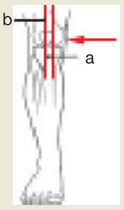


Fig. 4.87a and b Knee joint, Articulatio genus, right side; magnetic resonance imaging (MRI), sagittal scans; medial view. [T832]

Compact bone appears black in this MRI technique.

Clinical Remarks

Lesions of the ligaments and menisci of the knee joint cannot be assessed in a conventional X-ray image as only bony structures are shown. Therefore in cases of suspected soft tissue injury, **magnetic resonance imaging (MRI)** is performed increasingly. If MRI scans do not clearly exclude injuries, an endoscopic diagnostic procedure (**arthroscopy,** → p. 333) should be considered.

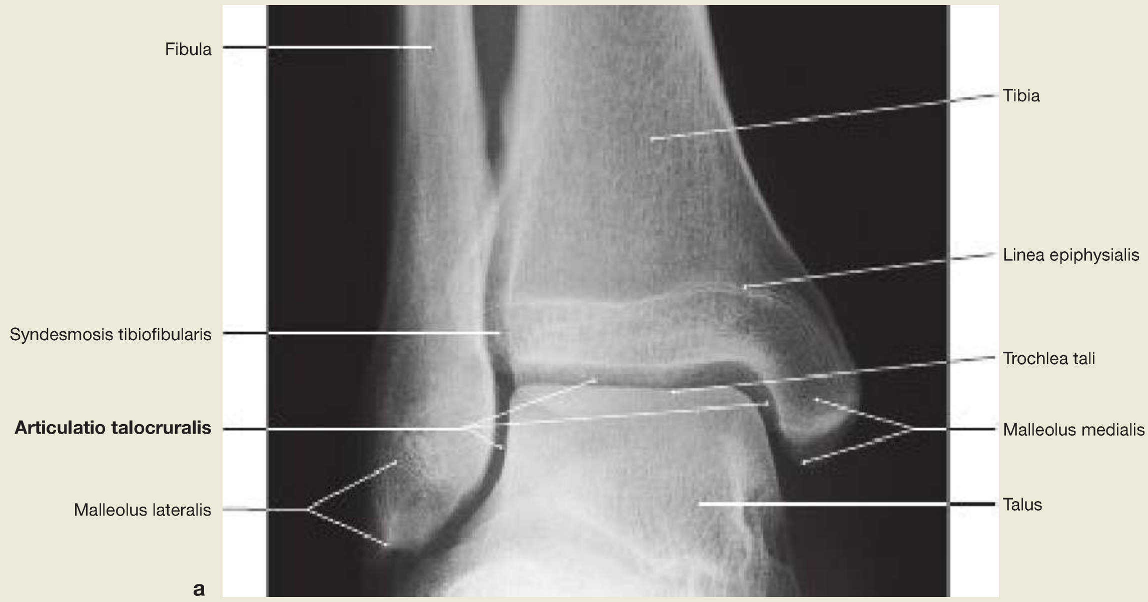


Fig. 4.88a and b Upper and lower ankle joints, Articulationes talocruralis and talocalcaneonavicularis, right side; X-ray images with anterior-posterior (AP) beam projection (→ Fig. 4.88a) and with lateral beam projection (→ Fig. 4.88b). [T902]

Fig. 4.89a and b Ankle joint, Articulatio talocruralis, right side, with fracture (WEBER B); X-ray images with anterior-posterior (AP) beam projection (→ Fig. 4.89a) and with lateral beam projection (→ Fig. 4.89b). [S008-3]
The fracture lines are marked with arrows.

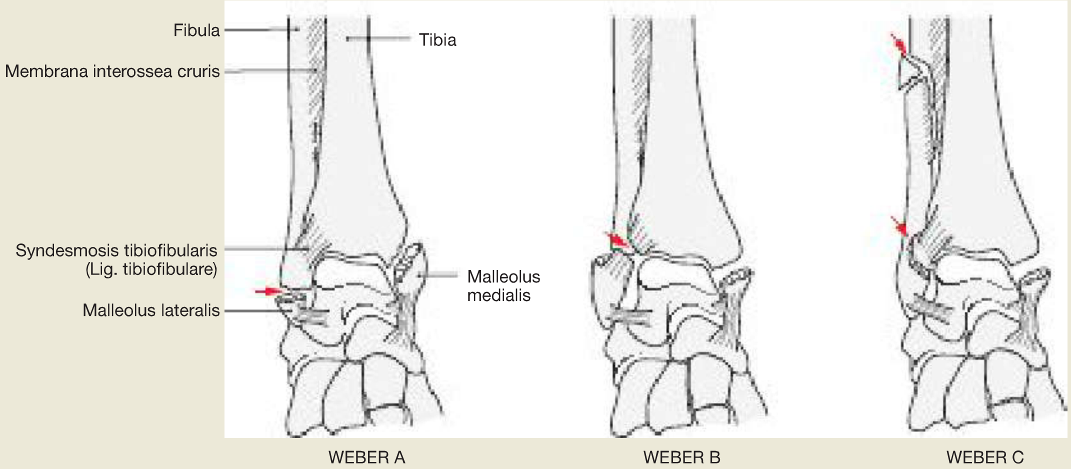


Fig. 4.90 Classification of ankle fractures according to WEBER grades A, B, C. [L126]

Clinical Remarks

Fractures of the distal end of the fibula are defined as **WEBER fractures** and classified in three grades of severity, according to the involvement of the Syndesmosis tibiofibularis.

- **WEBER A:** The Malleolus lateralis is broken **below** the syndesmosis, but this is intact.
- **WEBER B:** The fracture line goes **through** the syndesmosis which may be injured.
- **WEBER C:** The fracture is located **above** the ruptured syndesmosis. This WEBER C fracture is associated with a severe destabilisation of the ankle joint.

Fascia of the Leg

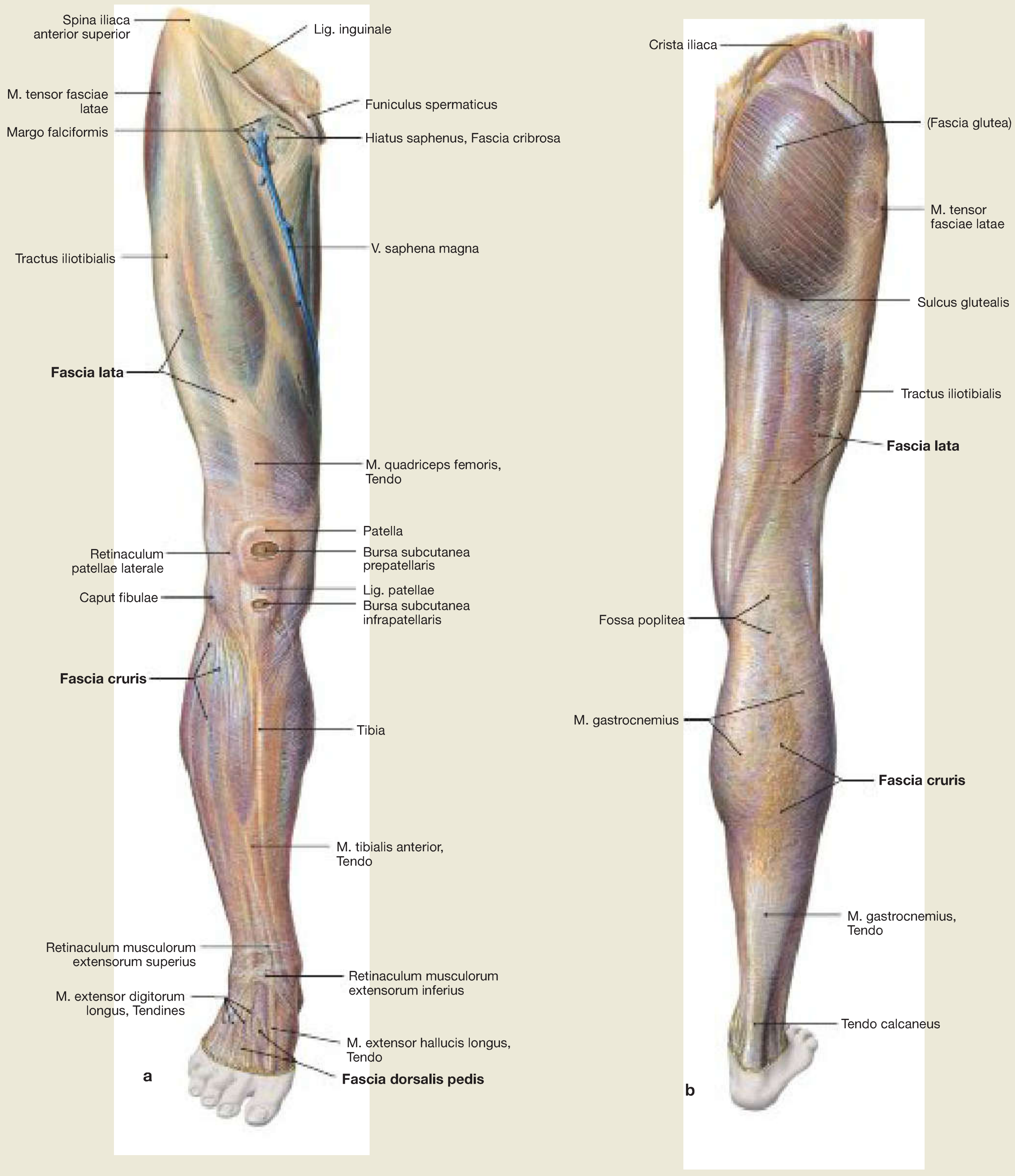


Fig. 4.91a and b Fascia of the thigh, Fascia lata, of the lower leg, Fascia cruris, and of the dorsum of foot, Fascia dorsalis pedis, right side; ventral view (→ Fig. 4.91a) and dorsal view (→ Fig. 4.91b).

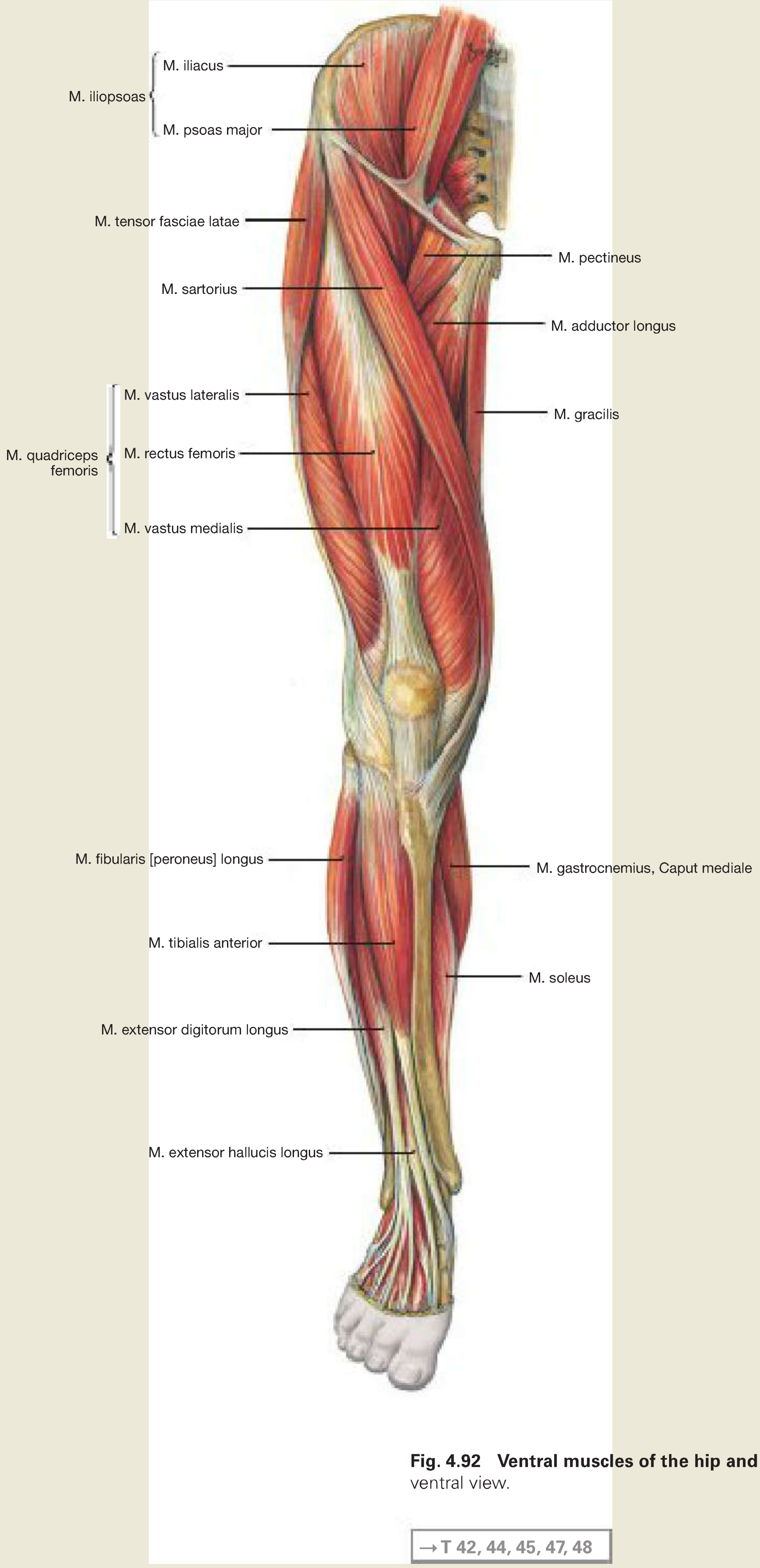


Fig. 4.92 Ventral muscles of the hip and leg, right side; ventral view.

→ T 42, 44, 45, 47, 48

Muscles of the Hip and Leg

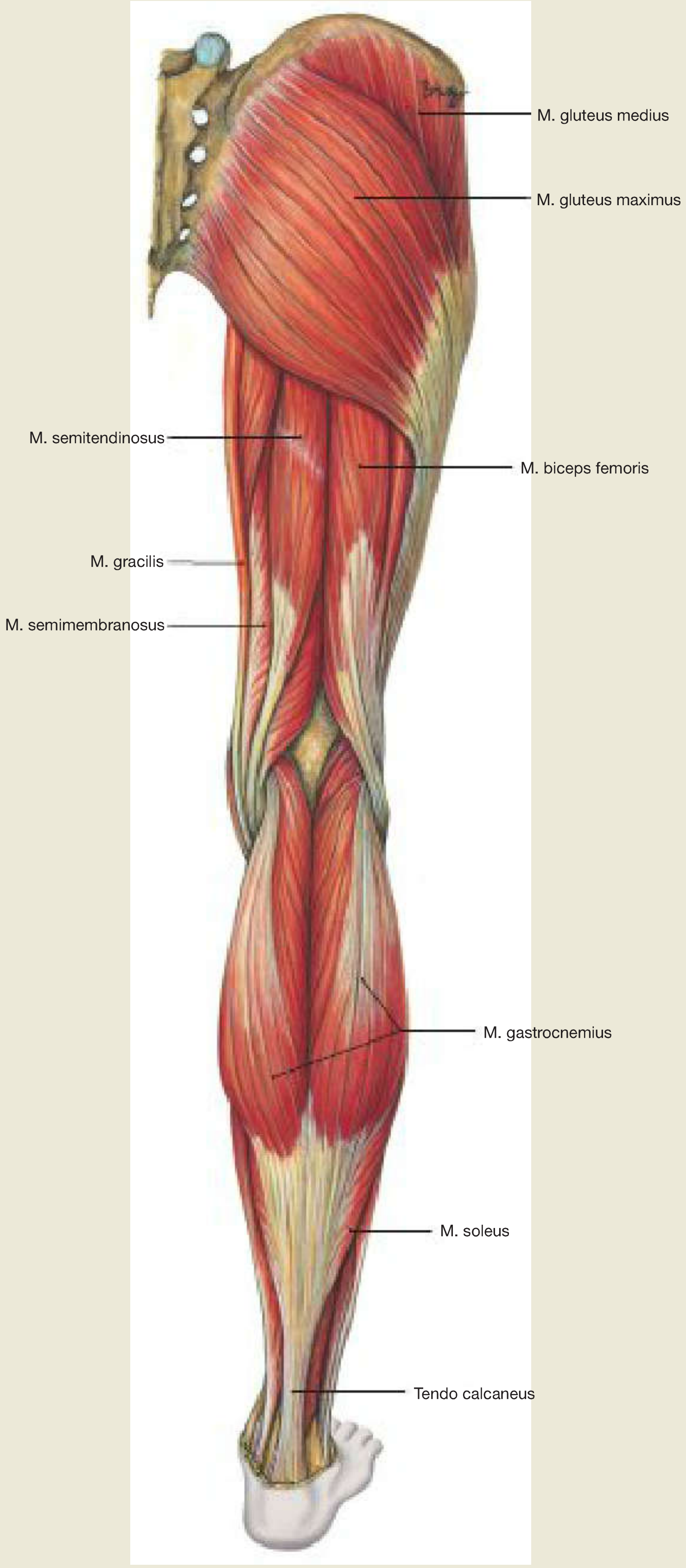


Fig. 4.93 Dorsal muscles of the hip and leg, right side; dorsal view.

→ T 43, 46, 49

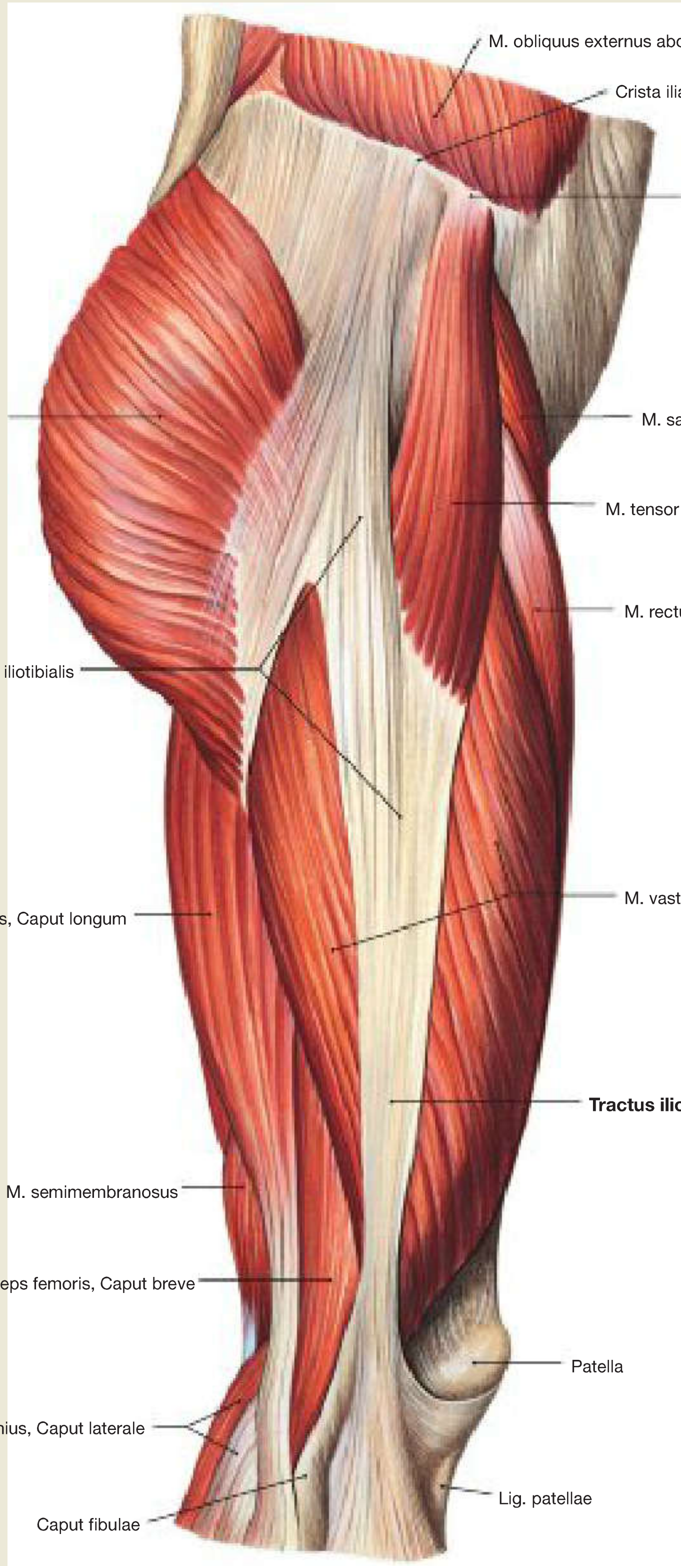


Fig. 4.94 Muscles of the hip and thigh, right side; lateral view.
The **Tractus iliotibialis** serves as reinforcement of the thigh fascia (Fascia lata), and connects the ilium with the tibia. It counterbalances the body weight-induced medial forces on the thigh bone. This principle is known as a **tension band effect**.

→ T 43, 44, 46

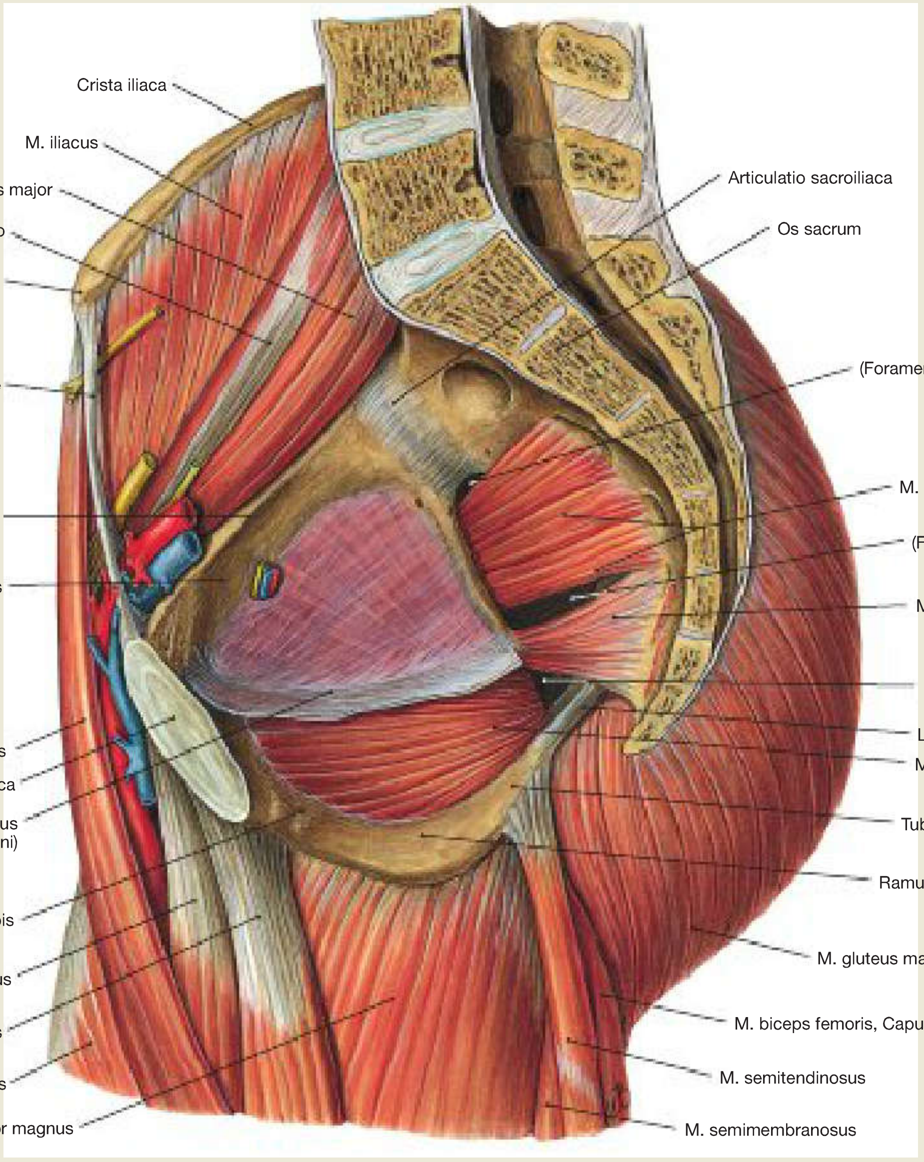


Fig. 4.95 Muscles of the hip and thigh, right side; medial view.

→ T 20a, 42–46

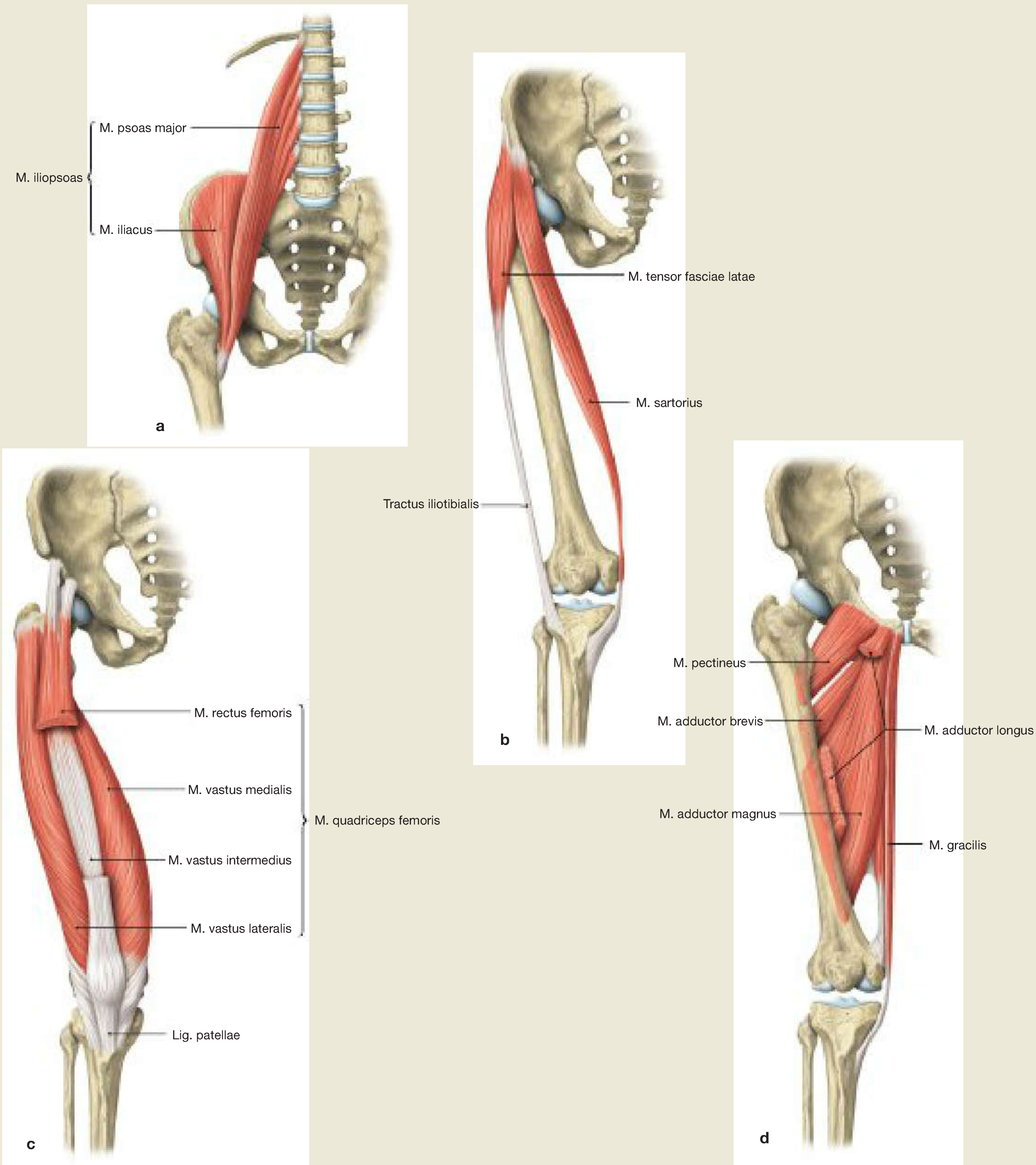


Fig. 4.96a to d Ventral muscles of the hip and thigh, and medial muscles of the thigh, right side; ventral view. [L127]

The muscles of the hip and thigh play a central role for getting up from a supine position and a stable upright stance as well as for walking.

The **ventral muscles** of the hip consist of the various parts of the **M. iliopsoas** (→ Fig. 4.96a). It is the **most important flexor** of the hip joint.

On the lateral thigh, the **M. tensor fasciae latae** (→ Fig. 4.96b) supports the tension band system of the **Tractus iliotibialis** via its insertion and thereby prevents fractures of the thigh bone. Together with the **M. sartorius** (→ Fig. 4.96b), it flexes the hip joint. Due to its innervation, the M. tensor fasciae latae also belongs to the dorsolateral group of hip muscles.

The four-headed **M. quadriceps femoris** (→ Fig. 4.96c) is the **only extensor of the knee joint** and is essential for the body to **stand up** from a squatting position. The M. rectus femoris spans two joints and additionally flexes the hip.

The medially located **adductor group** (Mm. adductores, → Fig. 4.96d) are the most important adductor muscles of the hip joint. They stabilise the hip when walking and standing.

→ T 42–45

Muscles of the Hip and Thigh

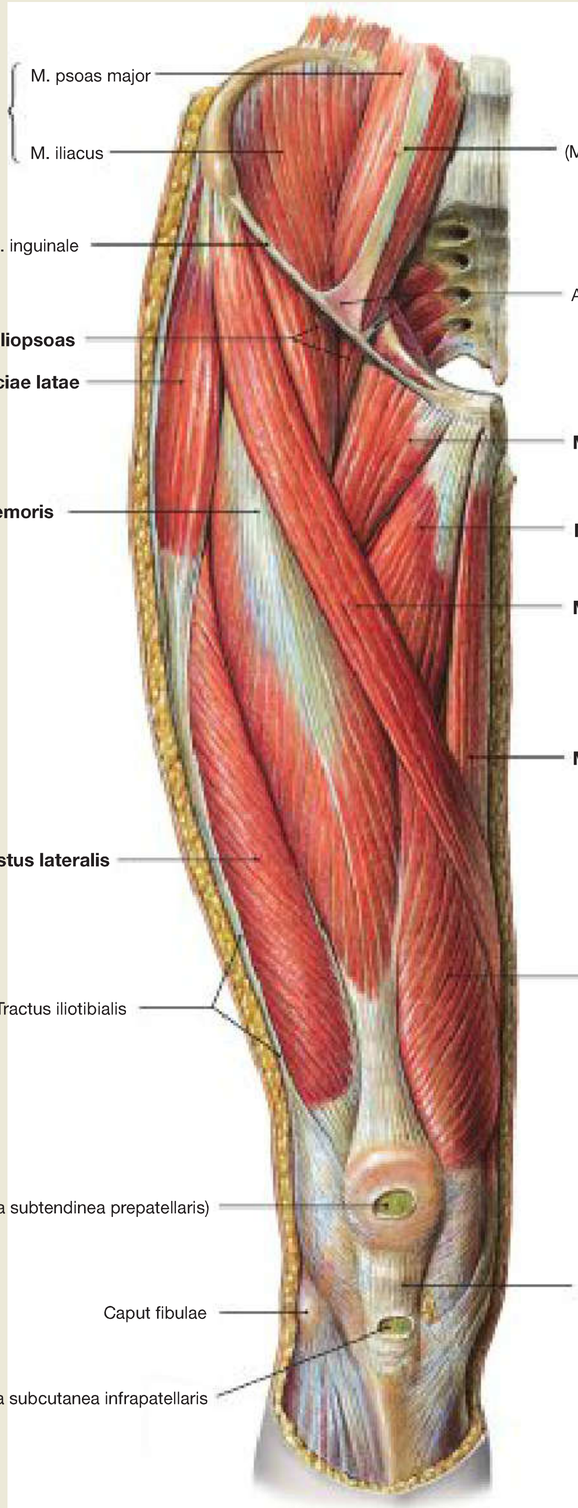


Fig. 4.97 Ventral muscles of the hip and thigh, and medial muscles of the thigh, right side; ventral view; after removal of the Fascia lata ventrally of the Tractus iliotibialis.

The **M. iliopsoas** is composed of two different muscles which originate from the inner surface of the lumbar spine (M. psoas major) and from the Fossa iliaca (M. iliacus). Below the inguinal ligament, these two muscles only run a short distance down the thigh to their common insertion at the Trochanter minor.

The **M. sartorius** is enveloped by a split portion of the Fascia lata and crosses the thigh medially before inserting on the medial aspect of the tibia posterior to the transverse (flexion) axis of the knee. Therefore, it can bend the hip joint as well as the knee joint.

Medially, the muscles of the **adductor group** lie in several layers on top of each other, therefore only the superficially located M. pectineus, M. adductor longus and M. gracilis are visible. The four heads of the **M. quadriceps femoris** (M. rectus femoris, M. vastus lateralis, M. vastus medialis, and M. vastus intermedius) lie distally and laterally of the M. sartorius. Their common inserting tendon incorporates the patella as a sesamoid bone before the fibres continue as Lig. patellae to the Tuberositas tibiae. The most lateral hip muscle is the **M. tensor fasciae latae,** which radiates into the Tractus iliotibialis. The common insertion of the Mm. sartorius, gracilis, and semitendinosus inferior to the medial tibial condyle is often referred to as the 'Pes anserinus superficialis'.

→ T 42, 45, 46

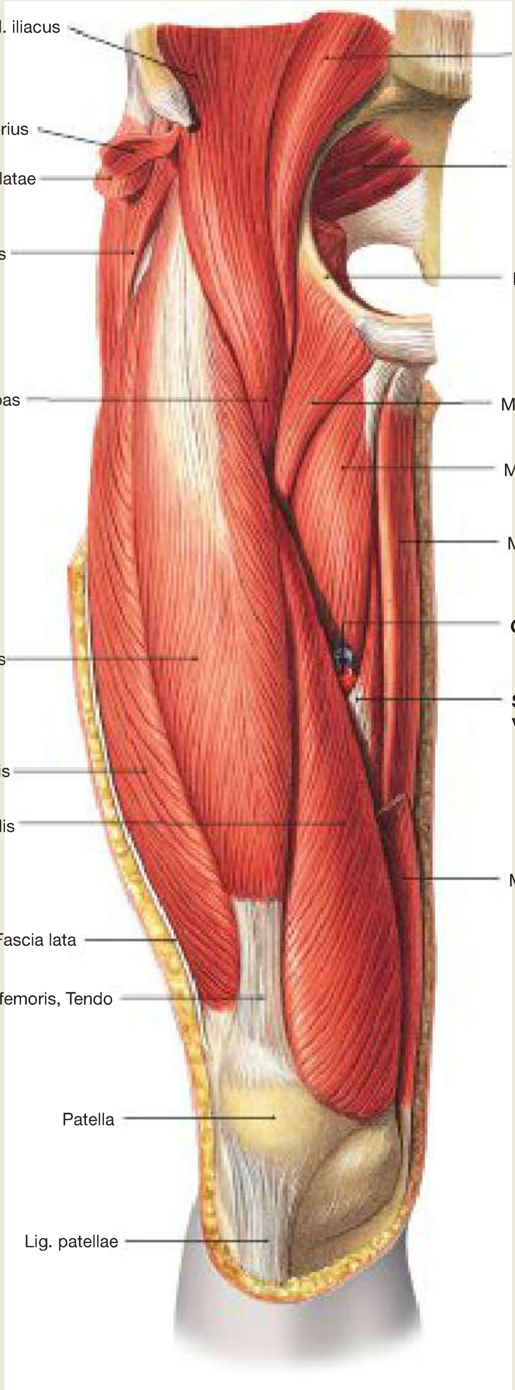


Fig. 4.98 Ventral muscles of the hip and thigh, and medial muscles of the thigh, right side; ventral view; after removal of the Fascia lata and of the Mm. sartorius and tensor fasciae latae.
After removal of the M. sartorius, the entrance to the **adductor canal** (Canalis adductorius) is visible where it is bordered dorsally by the M. adductor longus. The adductor canal is covered by the Septum intermusculare vastoadductorium, that connects the fascias of the M. vastus medialis, of the M. adductor longus and M. adductor magnus.

The four heads of the **M. quadriceps femoris** (M. rectus femoris, Mm. vasti lateralis, medialis, and intermedius) are located laterally to the adductor canal.

*The fourth head of the M. quadriceps femoris, the M. vastus intermedius, lies below the M. rectus femoris.

→ T 42, 45, 46

Clinical Remarks

If the hip joint is fixed in a flexed position due to **spasticity** or **dystonia** by permanent contraction of the M. iliopsoas, standing upright is impossible. Therapeutically, the motor innervation of the muscle is inhibited by the injection of botulinum toxin in order to relax the muscle via a synaptic blockade. The course of the muscle explains why only a small part of it is accessible by injections under the inguinal ligament, so that an additional injection into the lumbar section of the M. psoas major may be required if the effect was insufficient.

Muscles of the Hip and Thigh

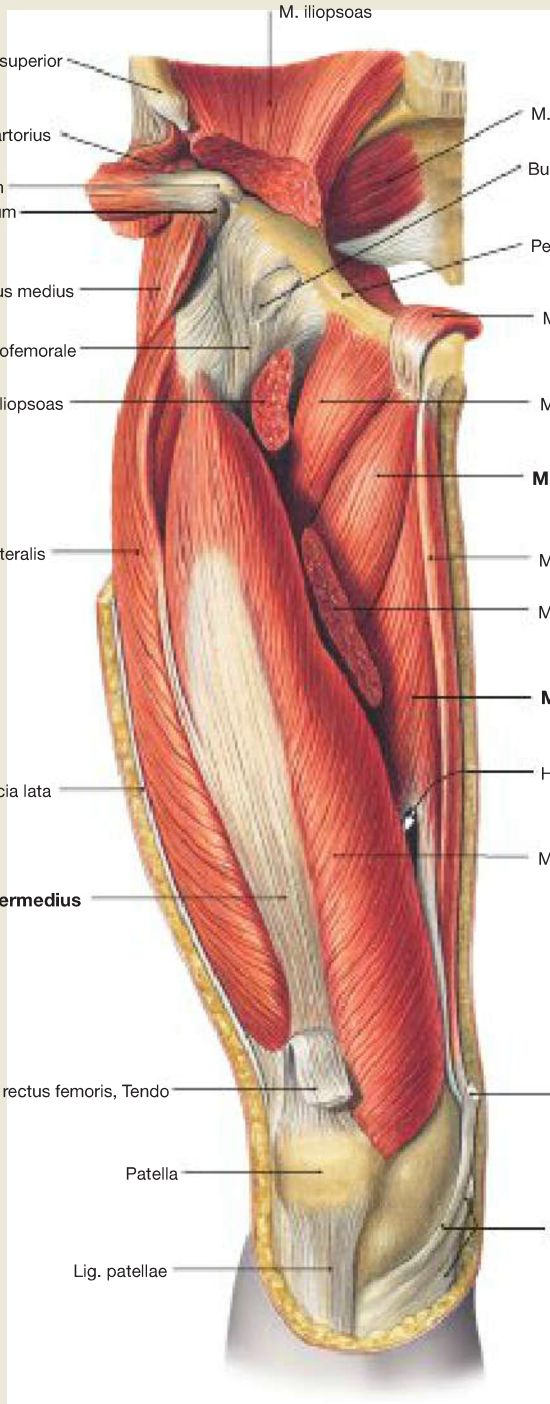


Fig. 4.99 Ventral muscles of the hip and thigh, and deep medial muscles of the thigh, right side; ventral view; after removal of the Fascia lata, of the Mm. sartorius, rectus femoris and adductor longus and partial removal of the M. iliopsoas in the joint area.
The M. rectus femoris and a part of the M. adductor longus are reflected superiorly. After removal of the M. rectus femoris, the **M. vastus intermedius** of the M. quadriceps femoris is visible. The resection of the M. sartorius and M. adductor longus reveals the deep adductor muscles, the **M. adductor brevis**, and parts of the **M. adductor magnus**.

* common insertion of the Mm. sartorius, gracilis and semitendinosus

→ T 42, 45, 46

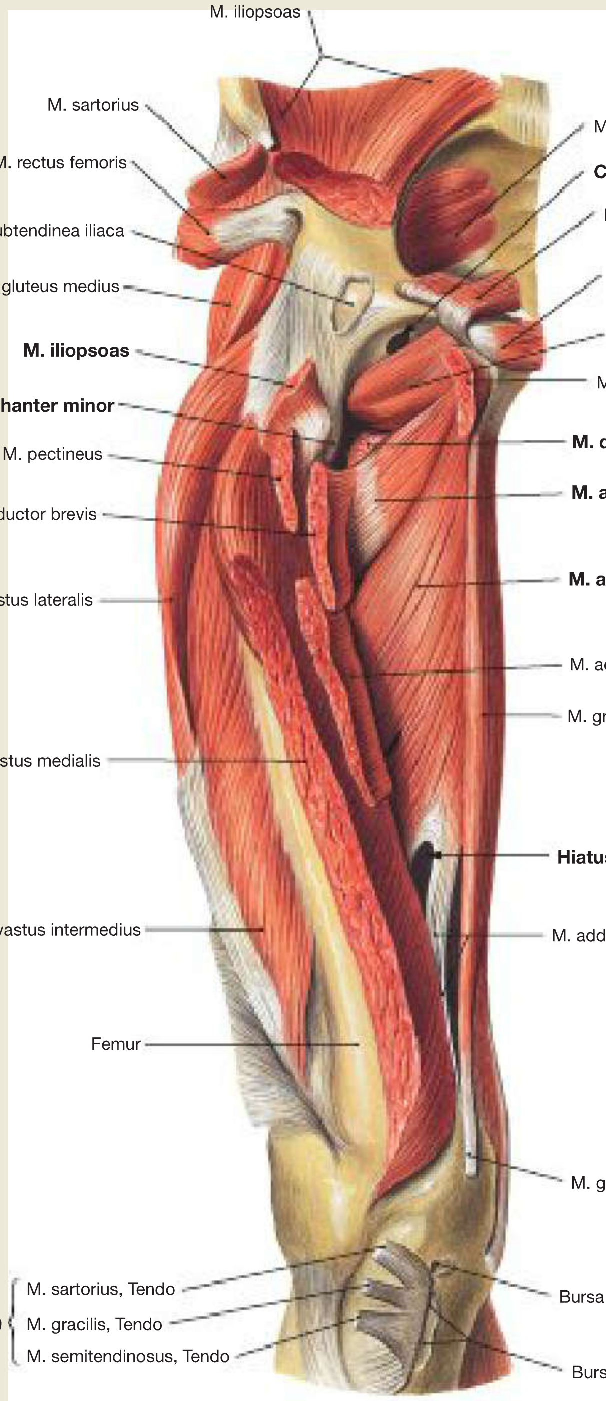


Fig. 4.100 Ventral muscles of the hip and thigh, and deep medial muscles of the thigh, right side; ventral view; after extensive removal of the superficial and some deeper muscles.

If, in addition to the superficial adductor muscles, the M. adductor brevis is also folded to the side, the **M. adductor magnus** becomes visible, the upper portion of which is also referred to as the M. adductor minimus. The M. adductor magnus and its inserting tendon form the **adductor hiatus** (Hiatus adductorius) through which the blood vessels of the thigh (A./V. femoralis) pass dorsally into the popliteal fossa. Proximally, the insertion of the M. iliopsoas on the Trochanter minor can be identified after resection of the M. pectineus and M. adductor brevis. The **Canalis obturatorius** is also exposed as an opening in the Membrana obturatoria, which forms a neurovascular passageway between the lesser pelvis and the thigh. Caudal of this opening, the almost horizontal fibres of the **M. obturatorius externus** and the deeper **M. quadratus femoris** are revealed, both of which belong to the pelvitrochanteric group of the dorsal hip muscles (→ p. 360). Since these two muscles are not displayed very often in dissection classes, it is hard to visualise their course.

→ T 42–45, 47

Muscles of the Hip and Thigh

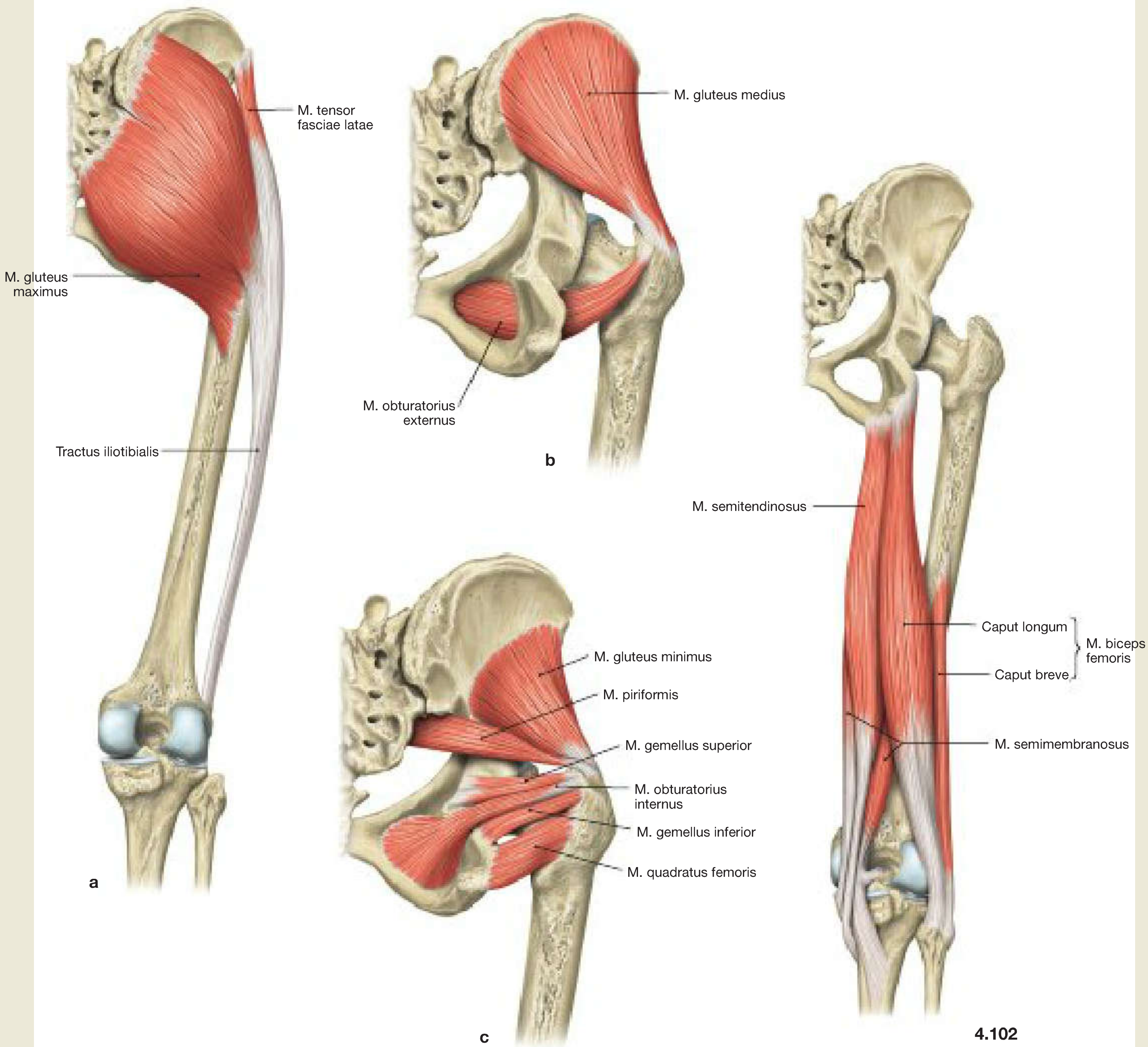


Fig. 4.101a to c Dorsal muscles of the hip, right side; dorsal view. [L127]

The dorsal muscles of the hip can be divided into a dorsolateral and a pelvitrochanteric group.

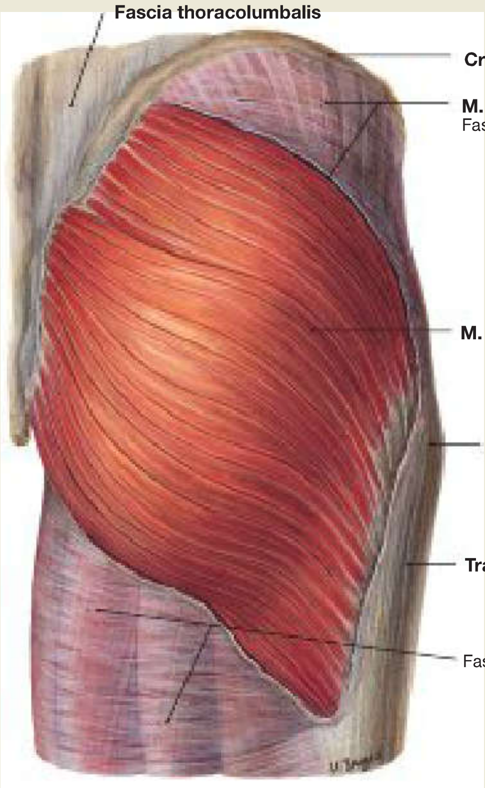
The **dorsolateral group** comprises the M. gluteus maximus, M. gluteus medius and M. gluteus minimus. According to its innervation, the **M. tensor fasciae latae** (→ Fig. 4.96b) may also be included in this group. The **M. gluteus maximus** (→ Fig. 4.101a) is the most important **extensor** and **lateral rotator** of the hip and is needed when climbing stairs, for example. In contrast, the **smaller gluteal muscles** (M. gluteus medius and M. gluteus minimus, → Fig. 4.101b and c) are the most important **abductors** and **medial rotators.** They stabilise the hip during standing and walking, and prevent the tilting of the pelvis to the opposite side when standing on one leg (for the function of the small gluteal muscles and their dysfunction leading to the **TRENDELENBURG's sign** → p. 389).

The medial or **pelvitrochanteric group** (M. piriformis, Mm. obturatorii internus and externus, Mm. gemelli superior and inferior, M. quadratus femoris, → Fig. 4.101c) consists only of **lateral rotators.**

Fig. 4.102 Dorsal (ischiocrural) muscles of the thigh, right side; dorsal view. [L127]

The name of the dorsal **(ischiocrural, hamstring) muscles** refers to their course on the posterior (dorsal) side of the thigh, where they originate from the Tuber ischiadicum and insert on both bones of the lower leg. Therefore these muscles span two joints and facilitate extension in the hip joint while serving as the **strongest flexors** in the knee joint. In addition, the lateral **M. biceps femoris** functions in **lateral rotation** of both joints, whereas the medial **M. semitendinosus** and **M. semimembranosus function in medial rotation.**

→ T 43, 44, 47



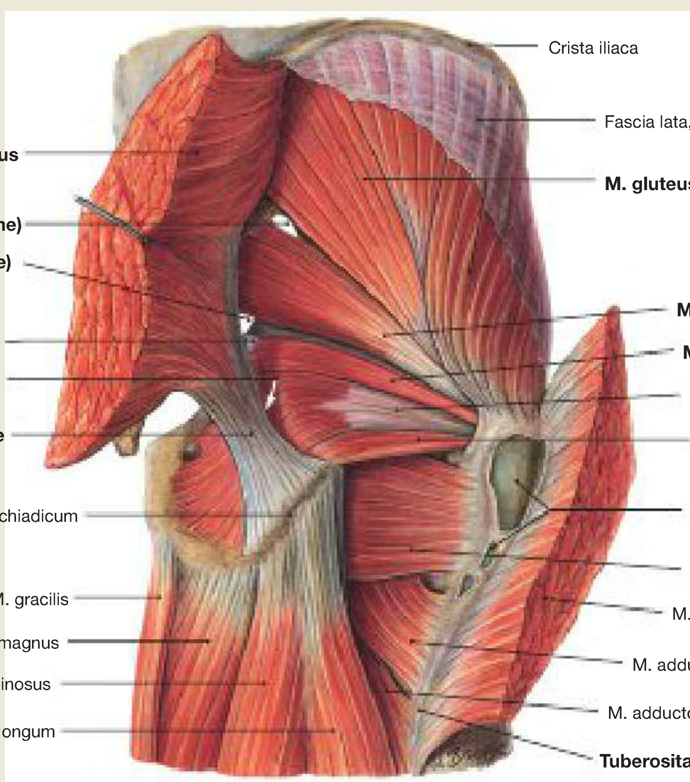
a

Fig. 4.103a and b Dorsal muscles of the hip and thigh, right side; dorsal view; after splitting of the Fascia lata (→ Fig. 4.103a) and separation of the M. gluteus maximus (→ Fig. 4.103b).

The illustration shows the superficial and the deep origins and insertions of the **M. gluteus maximus.** The muscle originates superficially from the posterior aspect of the sacrum, the iliac crest and the Fascia thoracolumbalis and deeply from the Lig. sacrotuberale. These muscle fibres run obliquely, while those of the M. gluteus medius, located deeply under the **M. gluteus maximus,** run almost vertically. The M. gluteus maximus has superficial insertions, in the Fascia lata and the Tractus iliotibialis, and deep insertions on the Tuberositas glutea of the femur. If the M. gluteus maximus is split or folded to the side, the remaining parts of the M. gluteus medius and the **pelvitrochanteric muscles** become visible.

The **M. piriformis** divides the Foramen ischiadicum majus into the **Foramina suprapiriforme** and **infrapiriforme,** which are important openings for neurovascular pathways from the pelvis. It should be noted that there can be a more tendinous portion of the **M. obturatorius internus** between its fulcrum ('hypomochlion') in the Incisura ischiadica minor and its insertion in the Fossa trochanterica.

→ T 43, 44, 47



b

Muscles of the Hip and Thigh

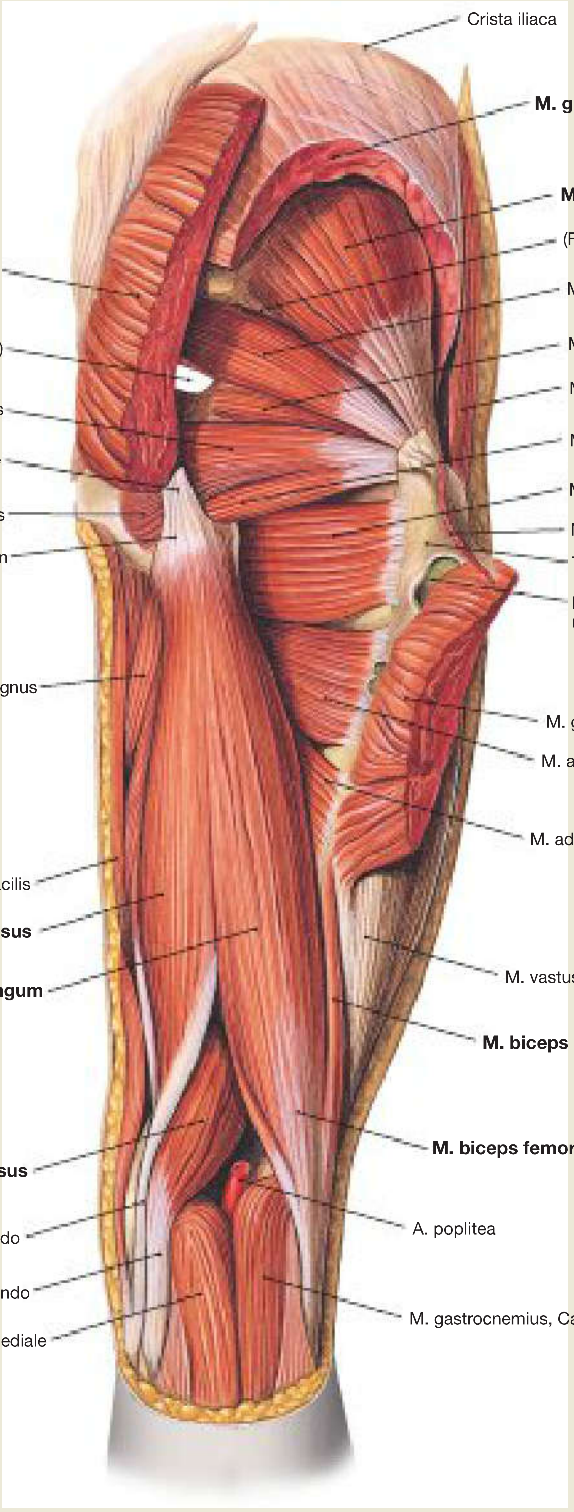


Fig. 4.104 Dorsal muscles of the hip and thigh, right side; dorsal view; after partial removal of the M. gluteus maximus and M. gluteus medius.

After cutting the M. gluteus medius in addition to the M. gluteus maximus, the **M. gluteus minimus** becomes visible. Together with the M. gluteus medius, it is referred to as the **small gluteal muscles**. Both muscles assist in the abduction of the hip and the stabilisation of the pelvis when standing on one leg.

On the dorsal side of the thigh, the **hamstring muscles** have been dissected, which run from the Tuber ischiadicum to the bones of the lower leg. Medially, the **M. semitendinosus** (named after its long tendon of insertion) is located superficially to the **M. semimembranosus** (named after its flat tendon of origin); the lateral **M. biceps femoris** has two heads, and its Caput longum originates from the Tuber ischiadicum, while its Caput breve has a distal origin on the femur (Labium laterale of the Linea aspera).

→ T 43, 47

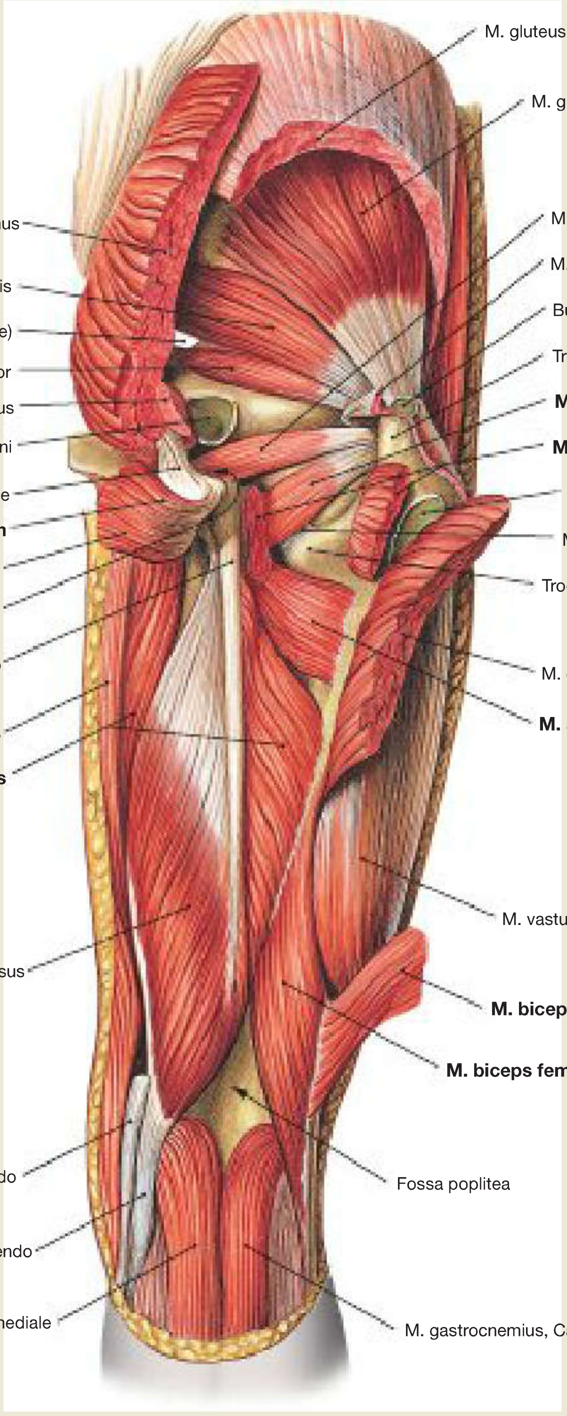
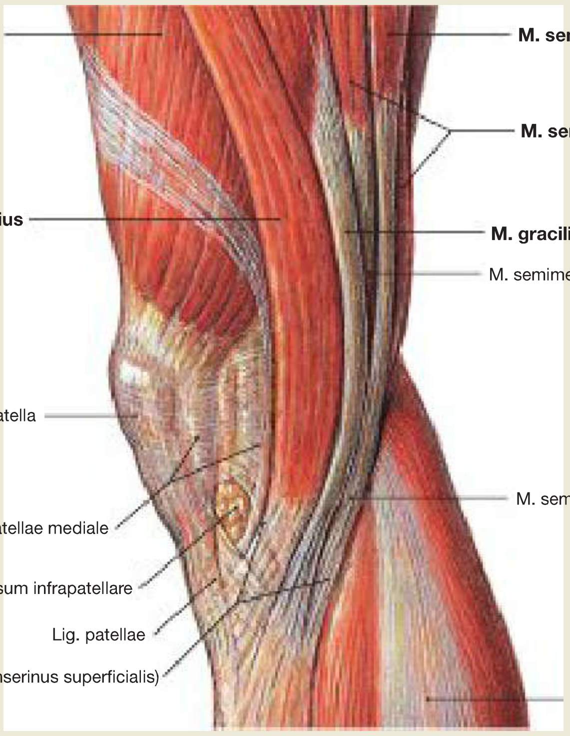


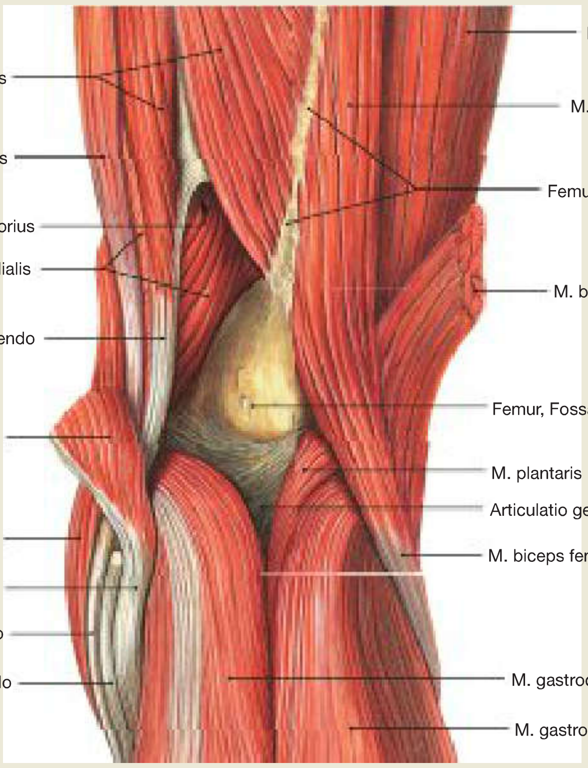
Fig. 4.105 Deep dorsal muscles of the hip and thigh, right side; dorsal view; after removal of the superficial gluteal and ischiocrural muscles.

Upon splitting the M. quadratus femoris, the deeper **M. obturatorius externus** is visible; its course is often difficult to visualise. Removal of the long head of the M. biceps femoris exposes the deep components of the adductor group. The **M. adductor magnus** consists of two functionally different muscle parts, which also have a different innervation. Its major component originates from the inferior pubic ramus (this part is sometimes referred to as the **M. adductor minimus**) and from the ischiopubic ramus. The posterior part, on the other hand, originates from the Tuber ischiadicum, and according to its function and innervation, it is ascribed to the ischiocrural muscles.

→ T 43, 44, 46, 47



a



b

Fig. 4.106a and b Muscles in the knee joint region, right side; medial view (→ Fig. 4.106a) and dorsal view (→ Fig. 4.106b).
The common insertion of the Mm. sartorius, gracilis and semitendinosus inferior to the medial tibial condyle is often referred to as the 'Pes anserinus superficialis'. The deep insertion of the M. semimembranosus is often referred to as 'Pes anserinus profundus'.

→ T 45–47

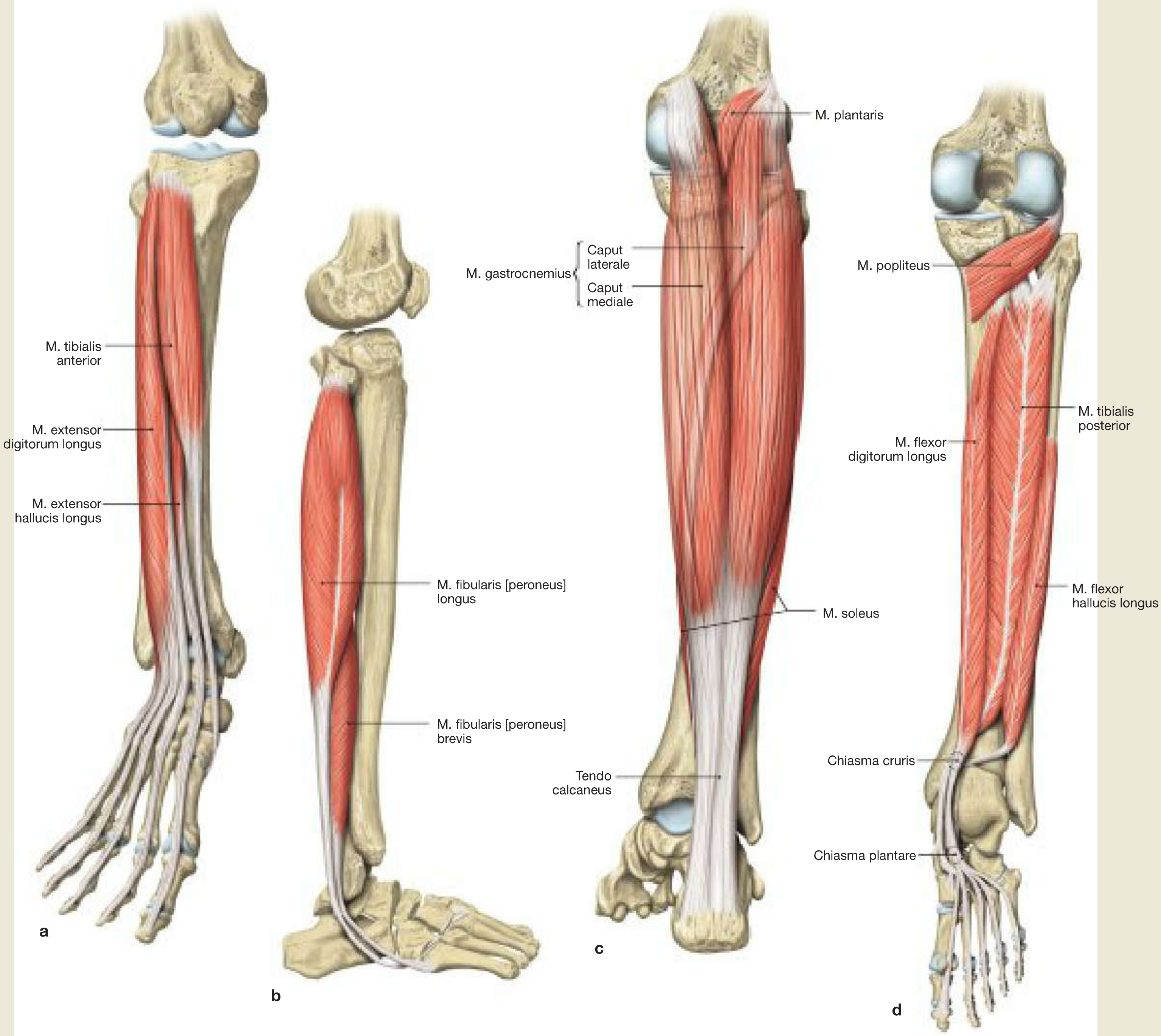


Fig. 4.107a to d Muscles of the lower leg, right side; ventral view (→ Fig. 4.107a), lateral view (→ Fig. 4.107b) and dorsal view (→ Fig. 4.107c and d). [L127]

In the lower leg region there are three muscle groups. In order to understand their function, it is important to know their positional relationship to the movement axes of the ankle joints (→ Fig. 4.81). All the muscles lying **in front** of the transverse axis of the talocalcaneonavicular joint are **extensors,** while the muscles **behind it** act as **flexors**. The muscles, the tendons of which lie **medially** to the oblique axis of the talocalcaneonavicular joint and have a medial superior to lateral inferior orientation, lift the medial side of the foot as **supinators.** In contrast, the **laterally** located muscles lift the lateral side of the foot and are referred to as **pronators**.

The ventral muscles of the lower leg are so-called extensors (→ Fig. 4.107a). They induce extension in the ankle joint, and have a predominantly pronating function in the talocalcaneonavicular joint, together with the other foot joints. The **M. tibialis anterior** is the most important extensor (→ Fig. 4.107a), whereas the **M. extensor digitorum longus** and **M. extensor hallucis longus** also extend the toes.

The lateral (fibular) muscles of the lower leg (→ Fig. 4.107b), consisting of the **Mm. fibulares longus and brevis,** represent the most important pronators, and act as plantar flexors in the ankle joint due to their position behind the flexion-extension axis. The true flexor muscles (plantar flexors), which can be divided into a superficial and a deep group, are located dorsally.

The **M. triceps surae** (→ Fig. 4.107c) belongs to the superficial dorsal muscles and comprises the **two-headed M. gastrocnemius** and the deeper located **M. soleus.** The M. triceps surae is the strongest flexor and plays an essential role in the supination of the foot. In contrast, the **M. plantaris** is of minor importance.

The deep dorsal muscles (flexors, → Fig. 4.107d) are largely equivalent to the extensors on the ventral side. The **M. tibialis posterior** is a strong supinator in addition to having a flexing function. The **M. flexor digitorum longus** and the **M. flexor hallucis longus** are flexors of the toes in the phalangeal joints. The **M. popliteus** has a special status as an important stabiliser of the knee joint. The tendon of the M. flexor digitorum longus crosses the tendon of the M. tibialis posterior above the medial malleolus **(Chiasma cruris)**, as well as the tendon of the M. flexor hallucis longus in the sole of the foot **(Chiasma plantare).**

→ T 48–51

Lower Leg Muscles

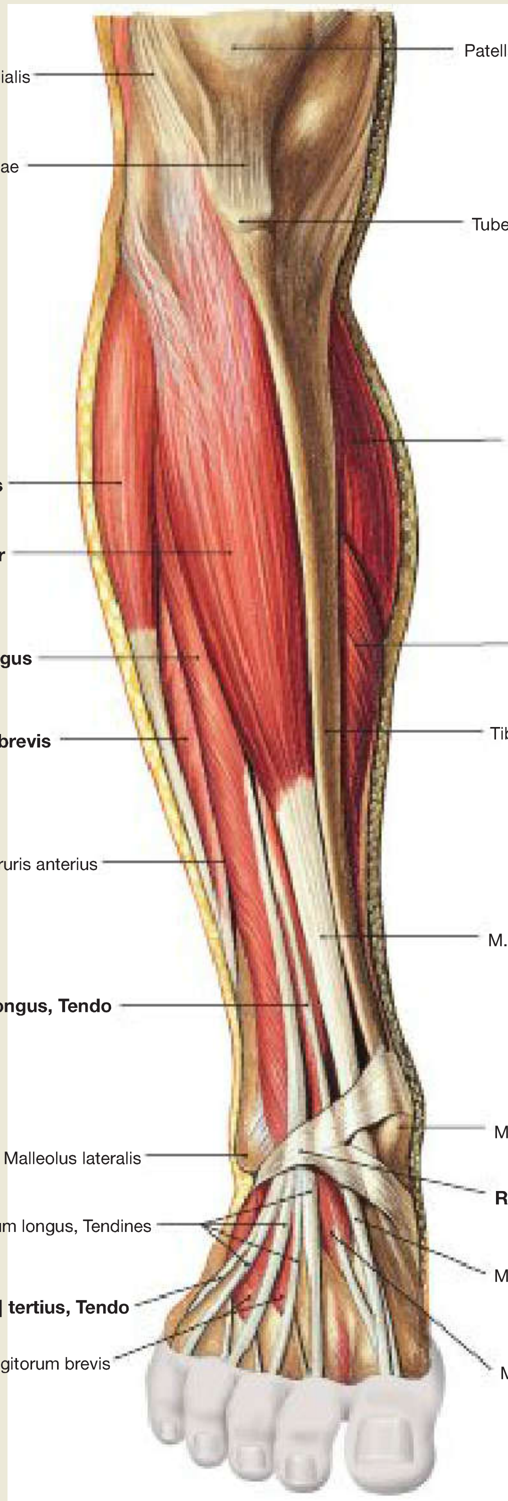


Fig. 4.108 Ventral and lateral muscles of the lower leg and foot, right side; ventral view.

The **M. tibialis anterior** of the extensor group can be palpated near the edge of the tibia. Since its inserting tendon courses medially to the axis of the talocalcaneonavicular joint, it functions as a (weak) supinator, in contrast to the other extensor muscles. The **M. extensor digitorum longus** originates proximally from the tibia and fibula, whereas the **M. extensor hallucis longus** is located between the other two extensors at the distal leg. Occasionally, the M. extensor digitorum longus splits off and inserts on the Os metatarsi V with distinct fibres, which are confusingly called **M. fibularis tertius**. In the distal part, the tendons are guided by a reinforcement of the fascia of the lower leg, the **Retinaculum musculorum extensorum**. The retinacula of the foot function as retaining ligaments and prevent the tendons from lifting off the bones during extension of the foot. Both fibular muscles (**Mm. fibulares longus** and **brevis**) constitute the lateral group and originate proximally and distally from the fibula. Clinically, they are often referred to by their former name as peroneal muscles (fibula, Greek term: perone).

→ T 48, 49

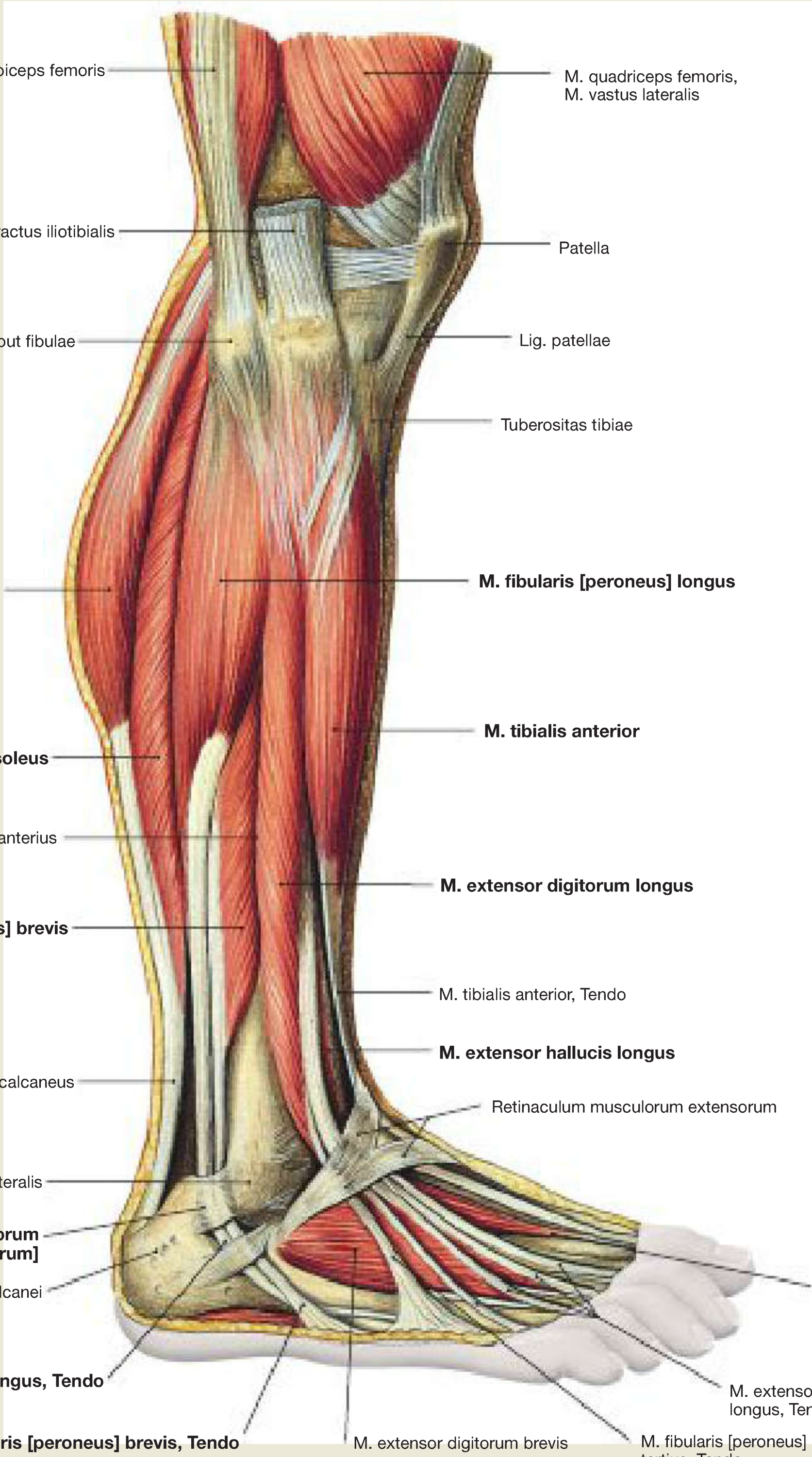


Fig. 4.109 Muscles of the lower leg and foot, right side; lateral view.

In the lateral view, all three muscle groups of the lower leg are visible. The fibular muscles are located laterally, just behind the anterior extensors, and the flexors are located dorsally. Since the deep flexors on the dorsal side are directly adjacent to the bones of the leg, only the superficial muscles (M. triceps surae), including the **M. gastrocnemius** and the deeper **M. soleus,** can be seen. The tendons of the fibular muscle group are guided by the **Retinacula musculorum fibularium**. The M. fibularis brevis inserts at the Os metatarsi V, whereas the tendon of the M. fibularis longus passes below the sole of the foot to the Os metatarsi I and the Os cuneiforme mediale, thus actively supporting the arches of the foot. It should be noted that the **M. extensor hallucis longus** is found distally between the M. tibialis anterior and the M. extensor digitorum longus.

→ T 48–50, 52

Lower Leg Muscles

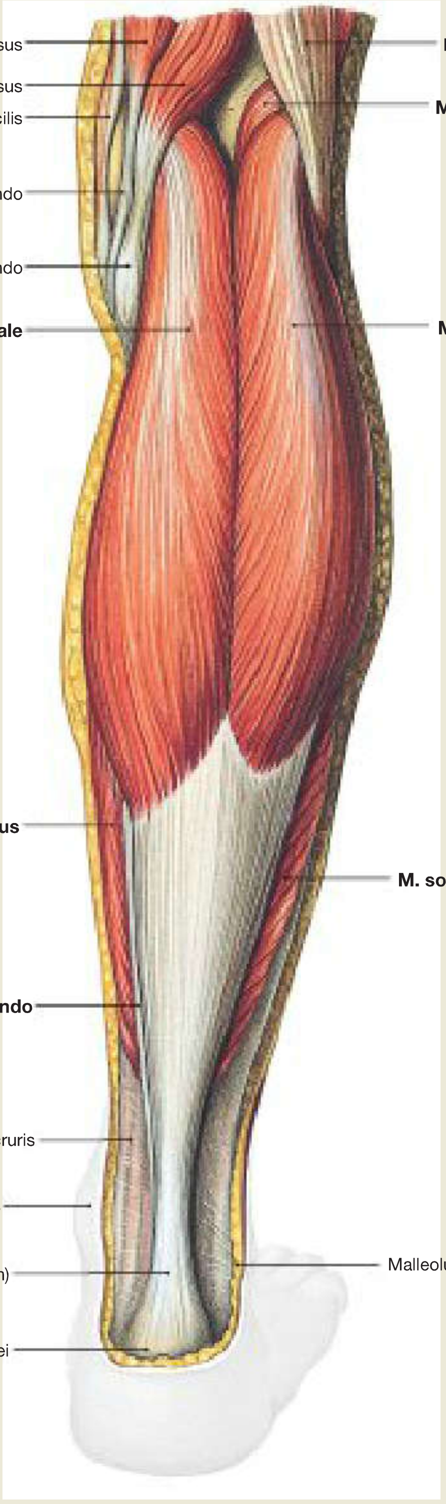


Fig. 4.110 Superficial layer of the dorsal muscles of the lower leg, right side; dorsal view.
The superficial flexor group consists of the **M. triceps surae** and the **M. plantaris.** The strong M. triceps surae is composed of the two-headed **M. gastrocnemius** and the deeper **M. soleus** lying under it. All superficial dorsal muscles insert at the heel bone via the **ACHILLES tendon** (Tendo calcaneus). The M. triceps surae is the strongest flexor of the ankle joint and the strongest supinator of the foot, even stronger than the M. tibialis posterior. If it fails (in the case of a herniated disc with lesion of the spinal cord segment S1 or lesion of the N. tibialis), standing on your toes is impossible!

→ T 50

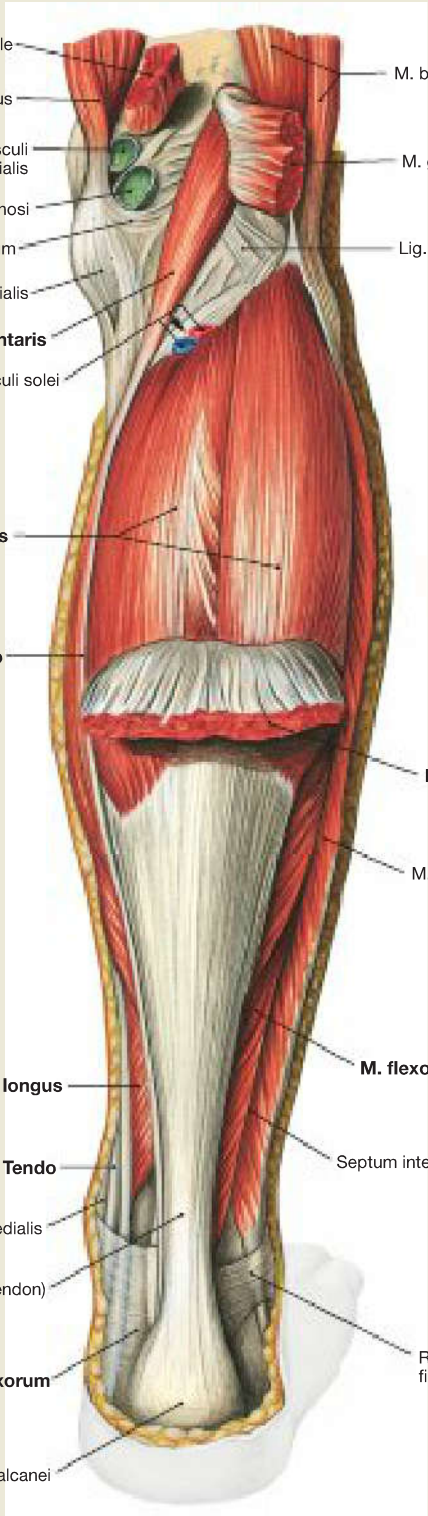


Fig. 4.111 Superficial layer of the dorsal muscles of the lower leg, right side; dorsal view; after cutting through the origins of the M. gastrocnemius.

When folding back the **M. gastrocnemius**, the **M. plantaris** becomes visible proximally, lying deep under the **M. soleus**. The muscle bellies of the deep flexors are located further distally and can be found on both sides of the ACHILLES tendon after removal of the Fascia cruris. Their tendons of insertion are guided through the **Retinaculum musculorum flexorum** at the medial malleolus.

→ T 51

Lower Leg Muscles

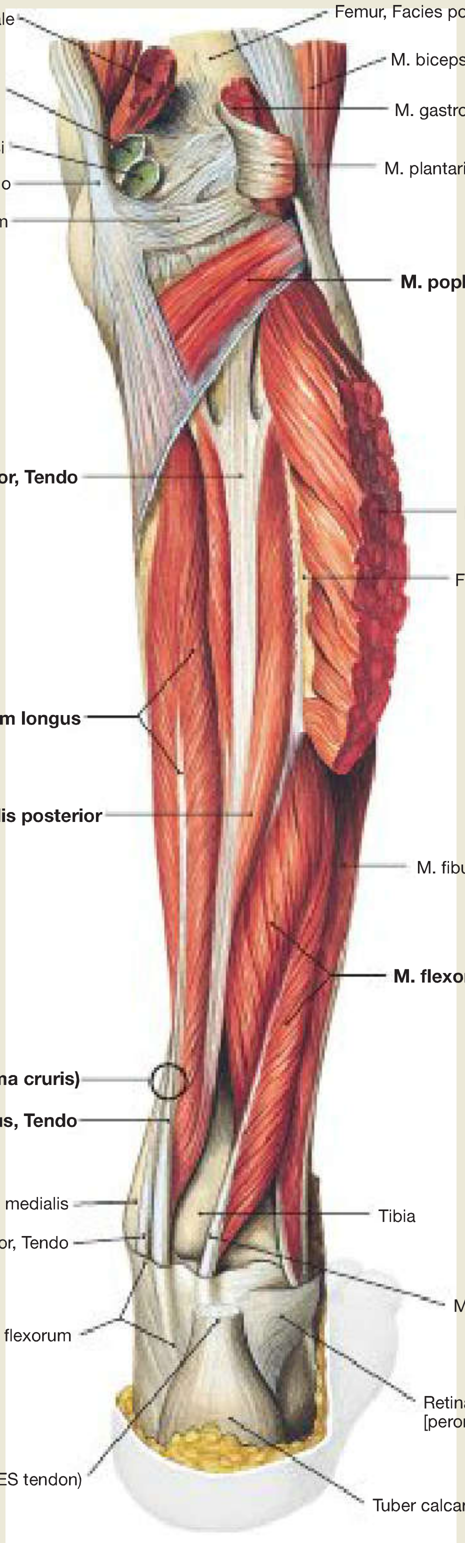


Fig. 4.112 Deep layer of the dorsal muscles of the lower leg, right side; dorsal view; after removing the superficial flexors.
After removal of the superficial flexors the deep muscles are visible. The **M. tibialis posterior** is located between the two flexor muscles of the toes. The **M. flexor digitorum longus** originates furthest medially, followed laterally by the **M. tibialis posterior** and then distally by the **M. flexor hallucis longus.** Their tendons converge at the medial malleolus where they are bridged by the **Retinaculum musculorum flexorum**. The tendon of the M. flexor digitorum longus crosses the tendon of the M. tibialis posterior in this course **(Chiasma cruris).**

The **M. popliteus,** which originates from the Condylus lateralis and the posterior horn of the Meniscus lateralis, lies proximally. The muscle inserts on the posterior aspect of the proximal tibia and thereby functions as a relatively strong **medial rotator.** Thus, the primary function of the M. popliteus is an **active stabilisation** of the knee against an extreme lateral rotation.

→ T 51

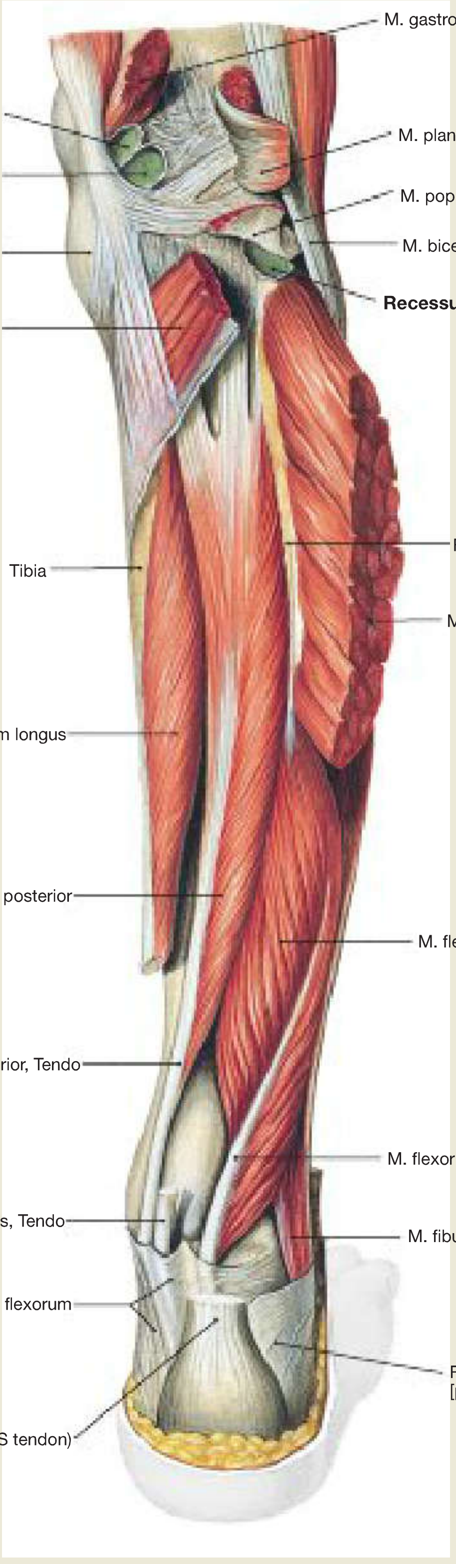


Fig. 4.113 Deep layer of the dorsal muscles of the lower leg, right side; dorsal view; after removal of the superficial flexors and splitting of the M. popliteus.
After severing the M. popliteus, the Bursa subpoplitea becomes visible, which usually communicates with the knee joint cavity and is therefore also referred to as **Recessus subpopliteus**. Further bursae are found below the tendons of origin and insertion of the dorsal muscles (**Bursa musculi semimembranosi** and **Bursae subtendineae musculorum gastronemii medialis and lateralis**). These can also communicate with the joint cavity (→ p. 323).

→ T 51

Tendinous Sheaths of the Foot

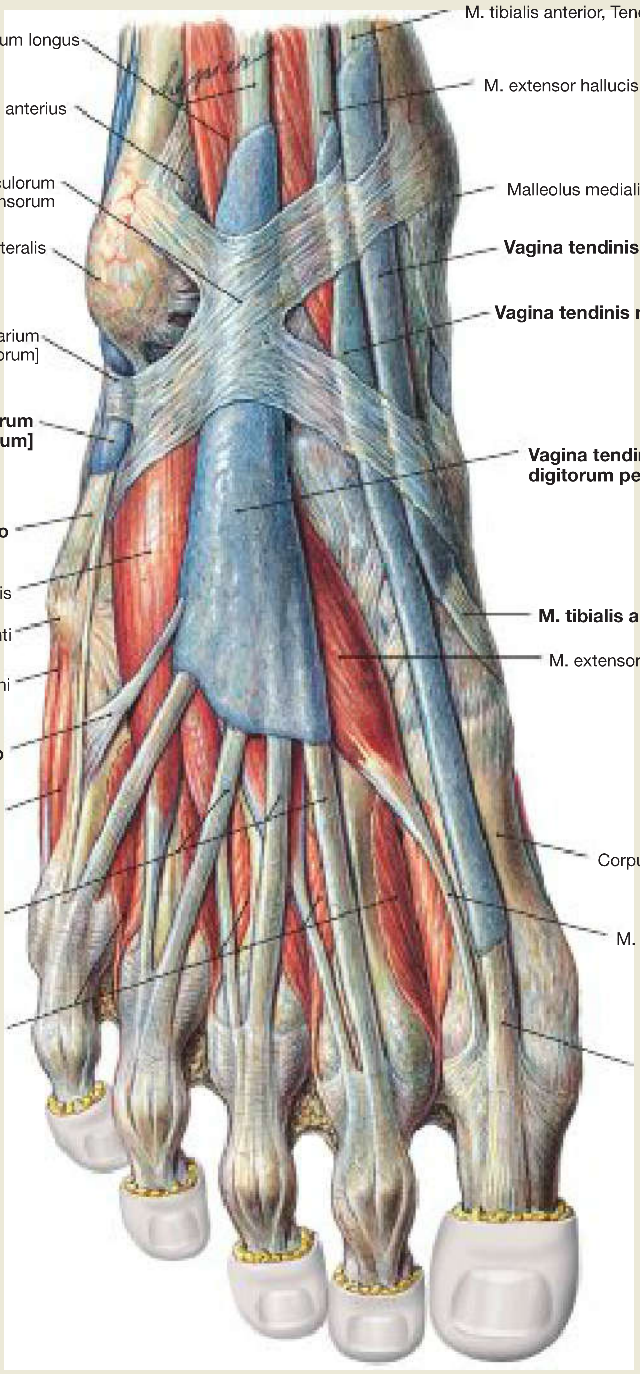
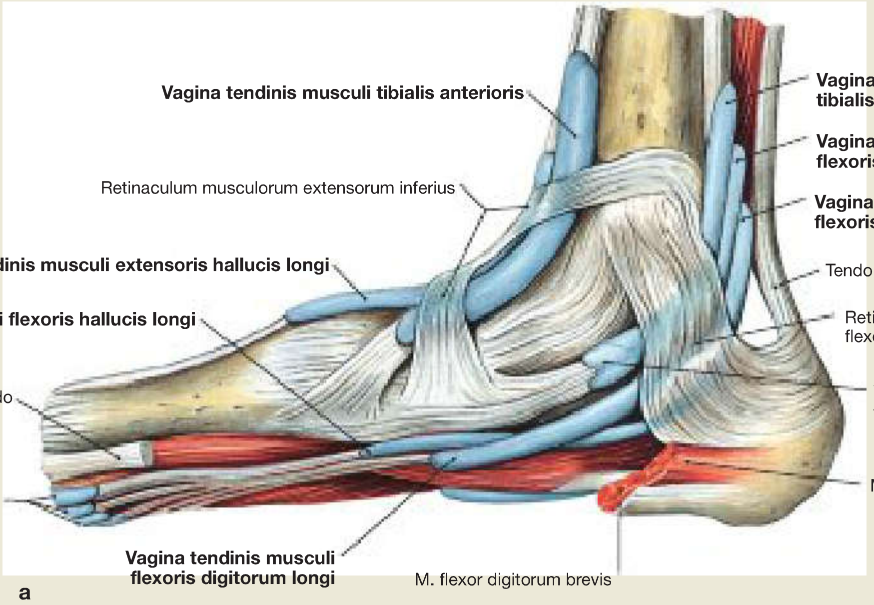
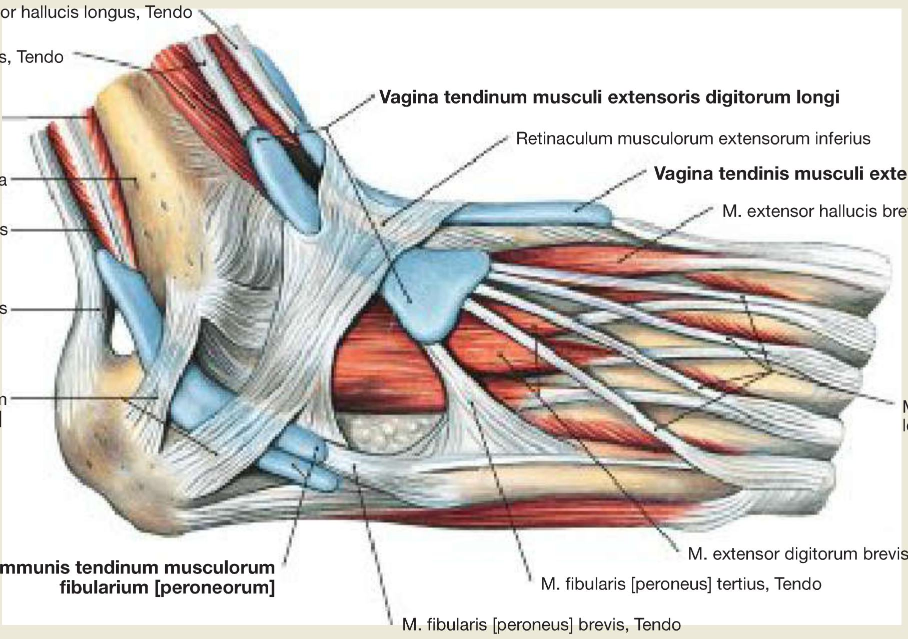


Fig. 4.114 Tendinous sheath, Vaginae tendinum of the foot, right side; dorsal view, in relation to the Dorsum pedis.
The Fascia cruris has been removed with the exception of the Retinaculum musculorum extensorum. The **retinacula** of the foot serve as retaining straps and prevent the tendons lifting off the bones during muscle contractions. Each extensor muscle has its own tendinous sheath (Vagina tendinis), which surround all its tendons of insertion in a 'guiding tube' and additionally serves as a gliding surface. In contrast, the tendons of the M. fibularis longus and M. fibularis brevis have a common synovial sheath.



a



b

Fig. 4.115a and b Tendinous sheaths, Vaginae tendinum, of the foot, right side; medial view (→ Fig. 4.115a) and lateral view (→ Fig. 4.115b).

The synovial sheaths surround the inserting tendons of all three muscle groups of the (lower) leg particularly, where the tendons are fixed to the bones by the retinacula. The Retinaculum musculorum flexorum forms the **malleolar canal** on the medial ankle, through which the neurovascular pathways (N. tibialis; A./V. tibialis posterior) also reach the sole of the foot.

Foot Muscles

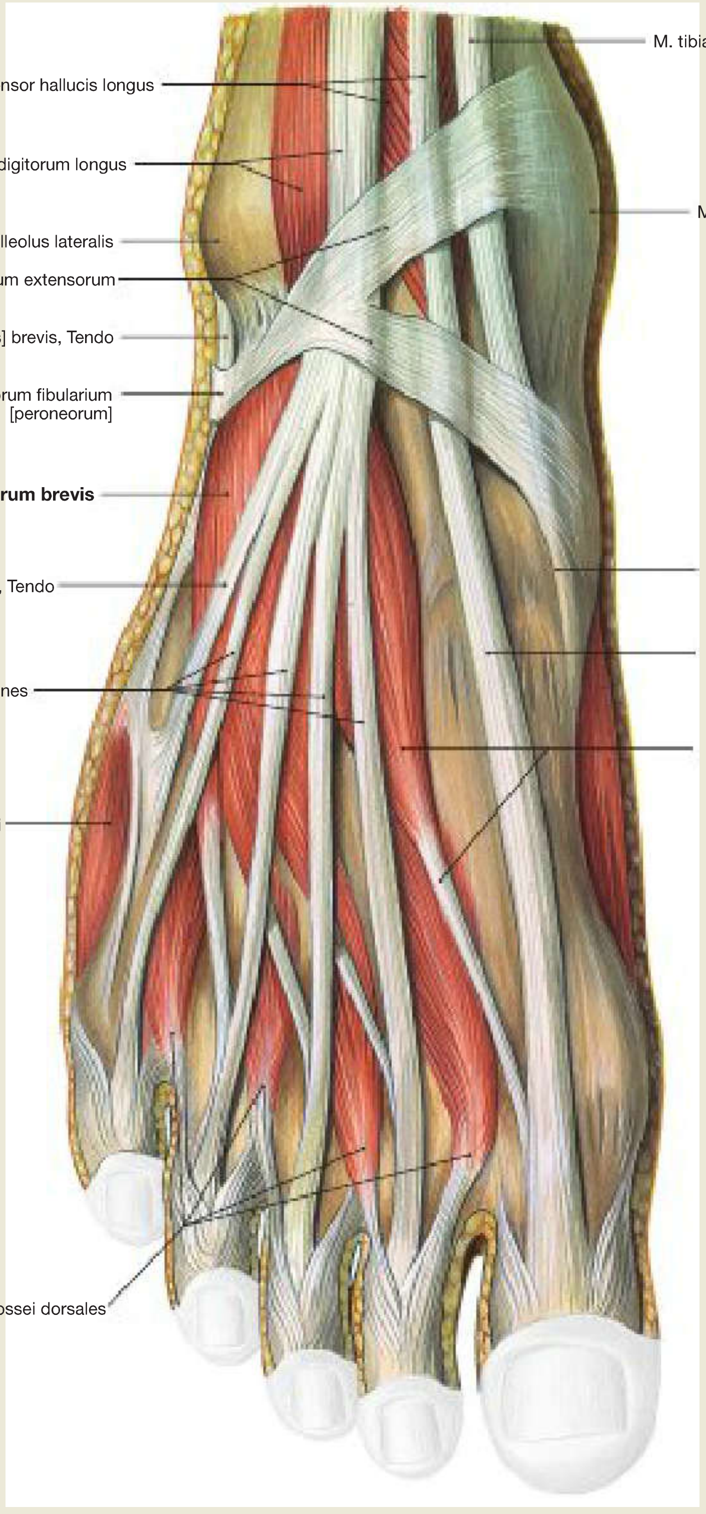


Fig. 4.116 Dorsal muscles of the foot, right side; dorsal view.
The long extensor tendons of the toes, having their muscle bellies on the ventral lower leg, also include two short extensors. The **M. extensor digitorum brevis** and the **M. extensor hallucis brevis** originate on the dorsal side of the calcaneus, and their tendons of insertion radiate laterally into the long extensor tendons and additionally into the dorsal aponeurosis. Thus they contribute to the extension of the toes and the first metatarsophalangeal joint. The Mm. interossei dorsales, which are also visible, are regarded as plantar muscles (→ p. 379).

→ T 48, 52, 54

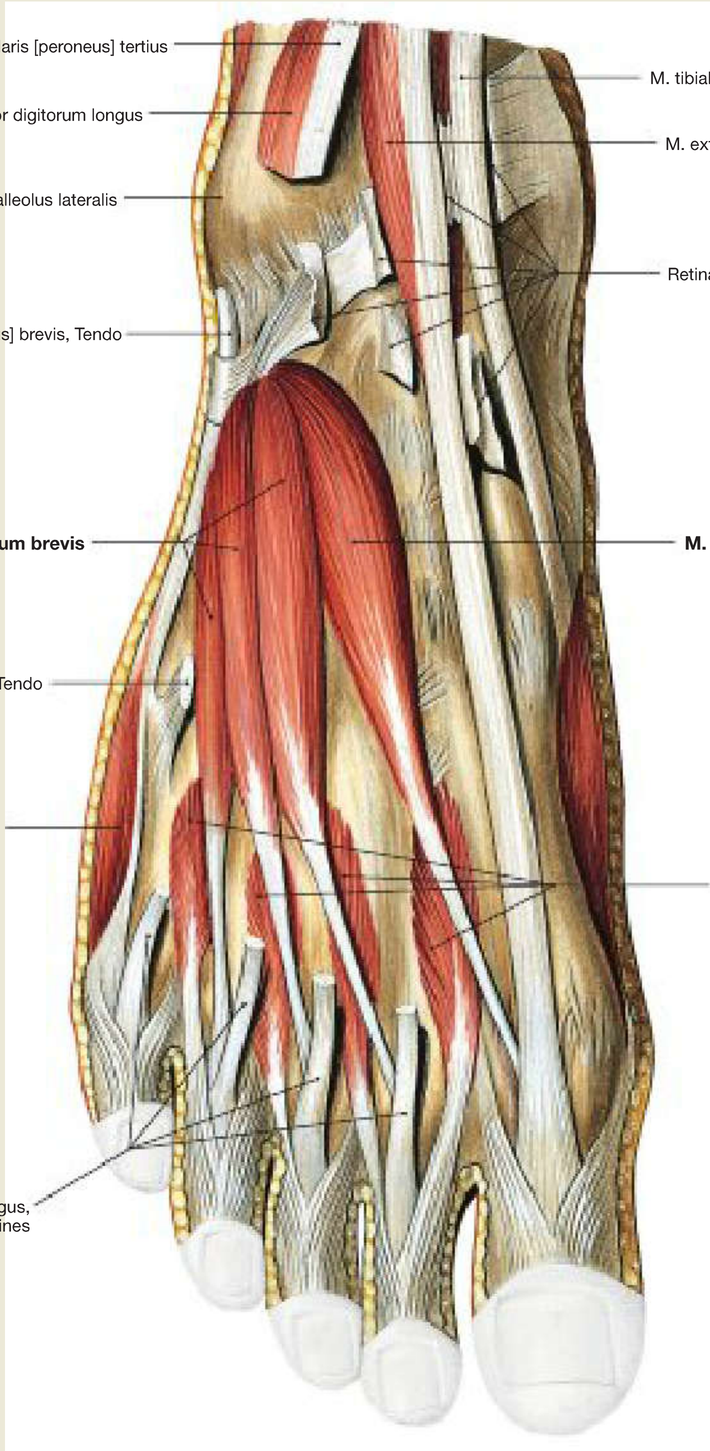


Fig. 4.117 Dorsal muscles of the foot, right side; dorsal view.
The Retinaculum musculorum extensorum was split and the tendon of the M. extensor digitorum longus has been partially removed. In this way, the muscles of the dorsum of the foot become visible. They comprise the short extensor muscles of the toes **(M. extensor digitorum brevis)** and of the big toe **(M. extensor hallucis brevis).** These muscles originate from the dorsal side of the calcaneus and insert into the dorsal aponeurosis of the second to fourth toes or at the dorsal side of the proximal phalanx of the big toe.

→ T 48, 52, 54

Foot Muscles

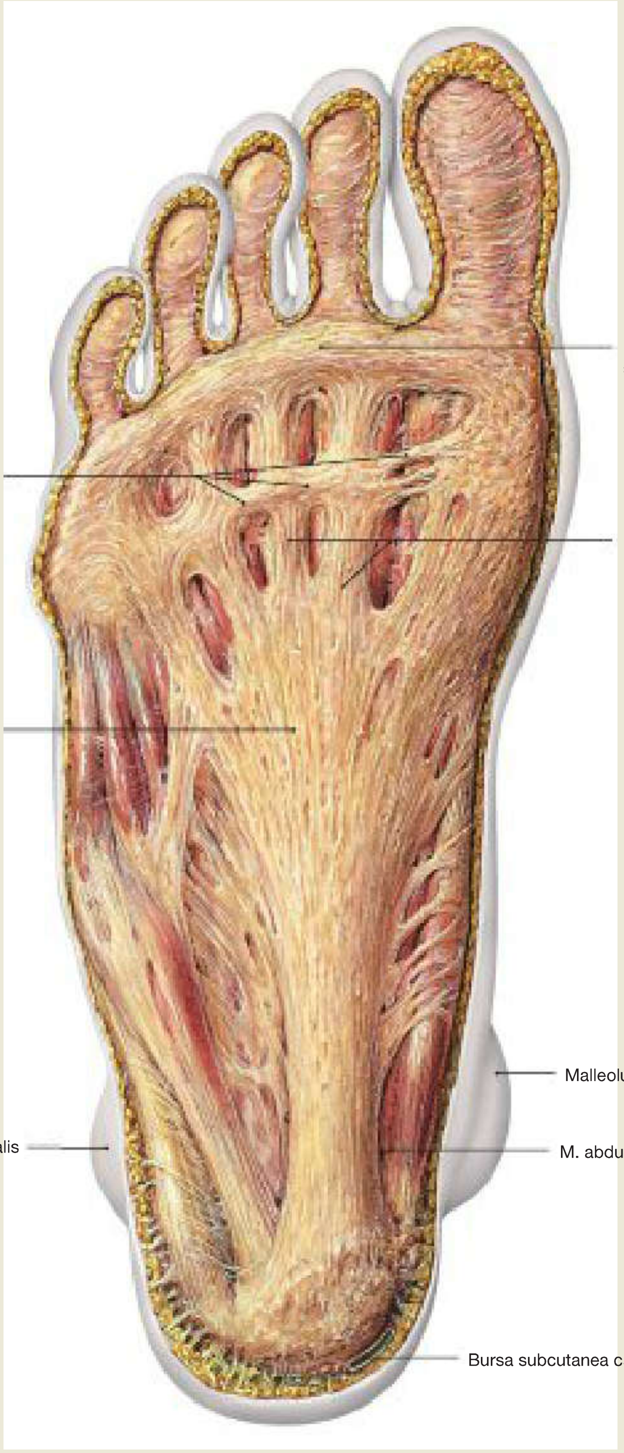


Fig. 4.118 Plantar aponeurosis, Aponeurosis plantaris, of the foot, right side; plantar view.
The **plantar aponeurosis** is a membranous plate of dense connective tissue with a strong central and two weaker lateral parts. Its **Fasciculi longitudinales** run from the Tuber calcanei to the ligaments of the metatarsophalangeal joints. Above the Ossa metatarsi they are connected via transverse fibre tracts **(Fasciculi transversi)**. The cross-links above the bases of the proximal phalanges of the toes are collectively referred to as **Lig. metatarsale transversum superficiale**. Two septa run from the plantar aponeurosis to the bones and thereby form three muscular compartments in the sole of the foot.

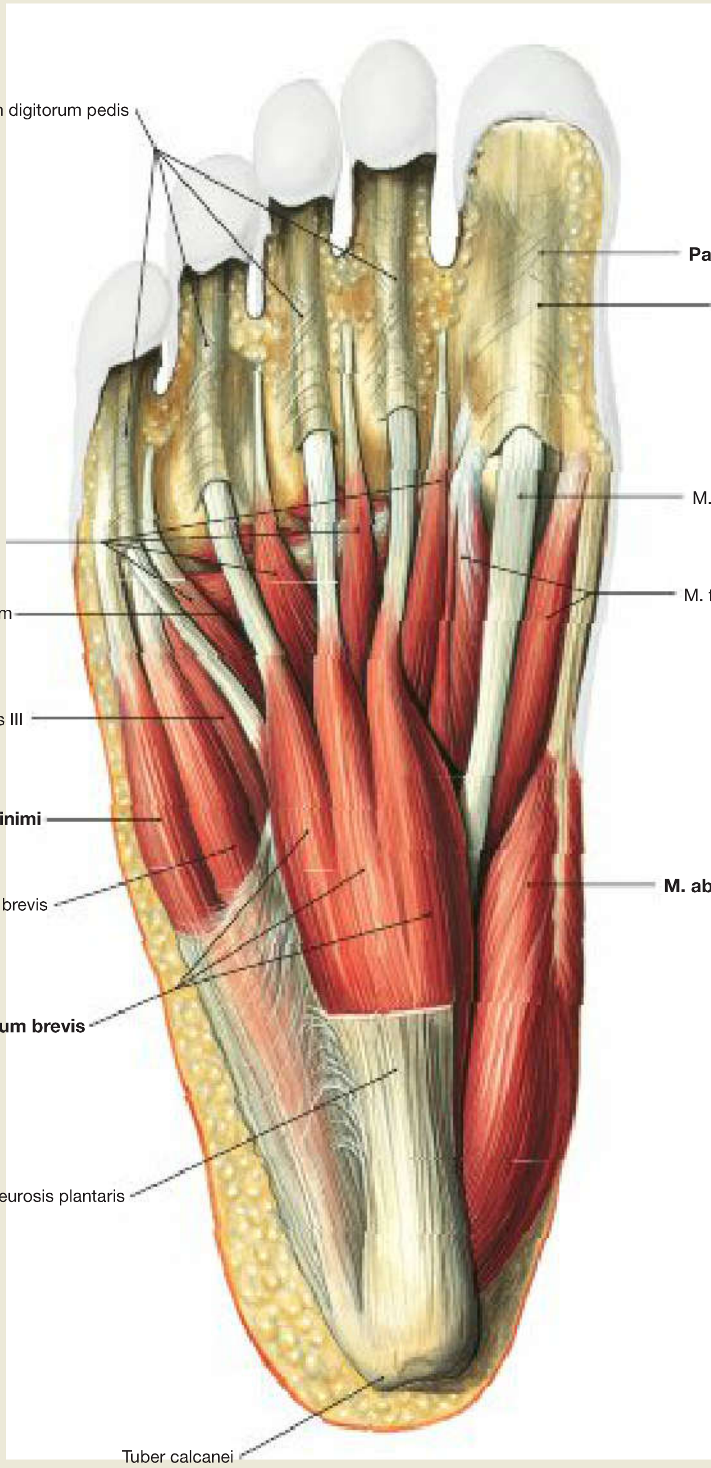


Fig. 4.119 Superficial muscle layer of the sole of the foot, right side; plantar view; after removal of the plantar aponeurosis.

Unlike the muscles of the hand, the plantar muscles are not so much involved in the differentiated movements of individual toes, but rather function as an **active tension system maintaining the arches of the foot** and should therefore be viewed as a functional unit. The plantar muscles support the ligaments, which act as a passive stabilisation system. Because of the septa, which run from the plantar aponeurosis to the bones of the foot, the muscles are divided into **three digital compartments** (of the big toe, the median toes, and the little toe). These compartments are not clearly separated from each other, so that it makes more sense when dissecting muscles to visualise them as **four layers**.

The muscles of the **superficial layer** comprise the **M. abductor hallucis,** the **M. flexor digitorum brevis**, and the **M. abductor digiti minimi.** The inserting tendons of the M. flexor digitorum brevis are pierced by the long flexor tendons. The tendons of the digital flexor muscles have their own tendinous sheaths (Vaginae tendinum) which are not connected with those in the tarsal region. These sheaths include reinforcing ligaments, which in part form 'tubes' around the tendons (Pars anularis) and have intersecting fibres in between (Pars cruciformis).

→ T 52–55

Foot Muscles

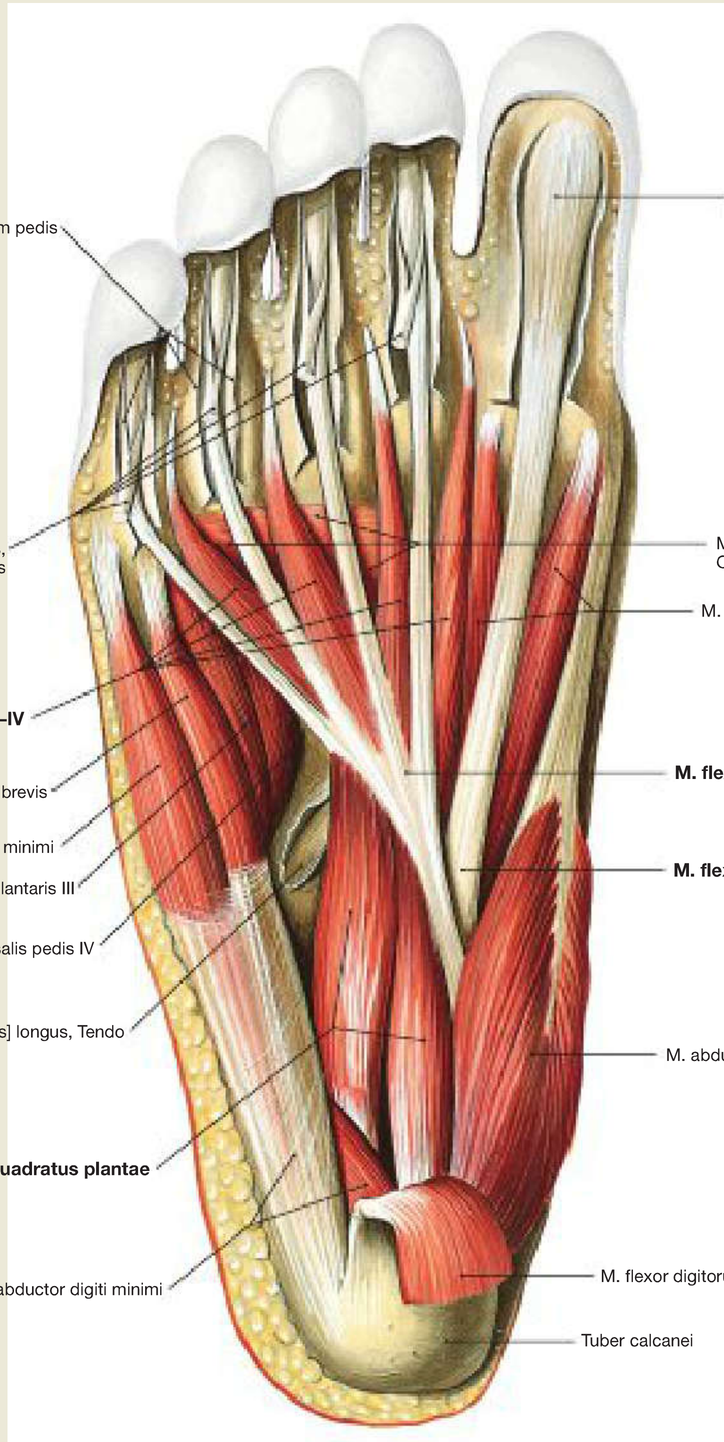


Fig. 4.120 Middle muscle layer of the sole of the foot, right side; plantar view; after cutting through the M. flexor digitorum brevis.
The muscles lie in **four layers** on top of each other. After removal of the M. flexor digitorum brevis, the muscles and their tendons of insertion in the **second layer** are visible. This layer is crossed by the **tendons** of the long flexor muscles (**M. flexor hallucis longus** and **M. flexor digitorum longus**) as well as by two muscles of the middle compartment. The tendon of the M. flexor digitorum longus is the insertion site of the **M. quadratus plantae**, which functionally supports the long flexor digitorum muscle and thus acts as an accessory flexor of the toes. The tendon also serves as the origin for the four **Mm. lumbricales** which insert medially on the proximal phalanges of the toes (II–V).

→ T 53–55

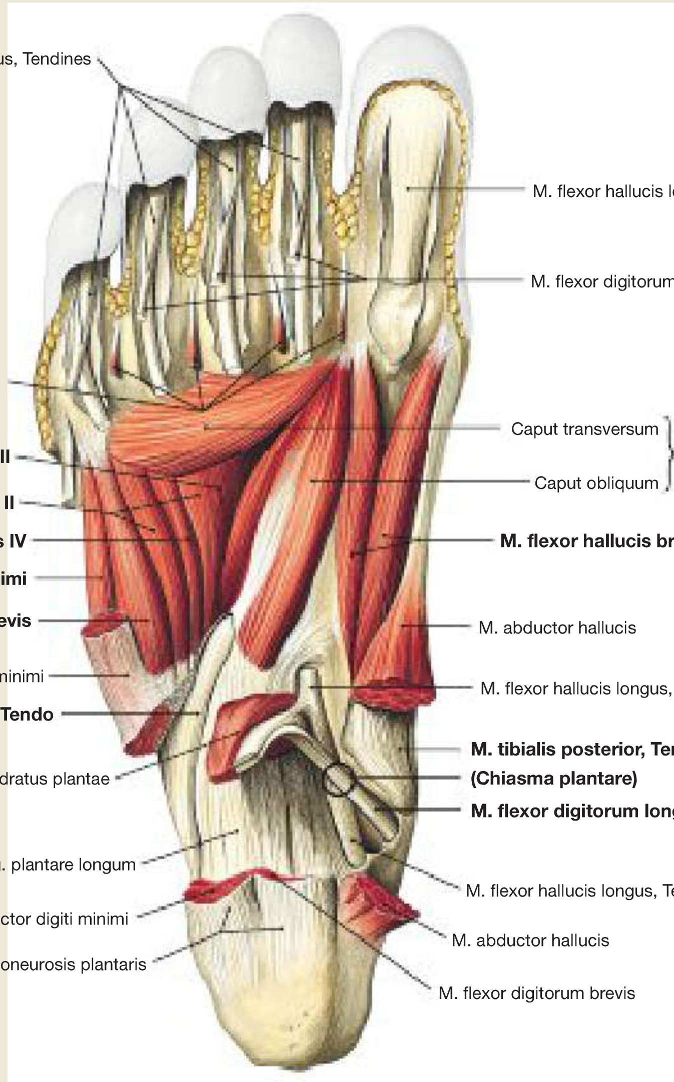


Fig. 4.121 Deep and deepest muscle layers of the sole of the foot, right side; plantar view; after removal of the two superficial layers and of the long flexor tendons.

The **M. flexor hallucis brevis** and the **M. adductor hallucis** are located within the **deep (third) layer** in the compartment of the big toe, whereas the **M. flexor digiti minimi brevis** and the inconstant **M. opponens digiti minimi** are located in the compartment of the little toe.

The **deepest (fourth) layer** comprises the three **Mm. interossei plantares** and the four **Mm. interossei dorsales,** as well as the **tendons of the M. tibialis posterior** and of the **M. fibularis longus**.

* The point where the tendon of the M. flexor digitorum longus crosses over the tendon of the M. flexor hallucis longus is also referred to as Chiasma plantare.

→ T 51, 53–55

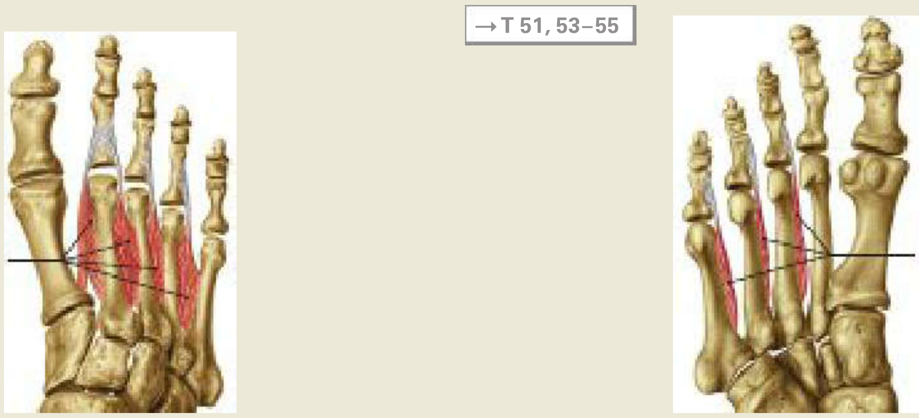


Fig. 4.122a and b Mm. interossei dorsales (→ Fig. 4.122a) and plantares (→ Fig. 4.122b) of the foot, right side; dorsal view (→ Fig. 4.122a) and plantar view (→ Fig. 4.122b).

The four **Mm. interossei dorsales** (I–IV) are two-headed muscles and originate from opposing sides of the bases of the Ossa metatarsi I to V. They insert on the proximal phalanges of the second to fourth toes in such a way that muscles I and II run along the medial and lateral sides of the second toe, whereas the muscles III and IV run laterally along the third and fourth toes. Therefore, these muscles do not only flex the metatarsophalangeal joints of the **toes II to IV**, but also guide their lateral **abduction** and the adduction of the **second toe** as well.

The three **Mm. interossei plantares** (I–III) only have one head and originate from the plantar side of Ossa metatarsi III–V. They insert on the medial side of the respective toes. As well as flexing the metatarsophalangeal joints, they also **adduct** the toes.

→ T 53–55

Plexus lumbosacralis

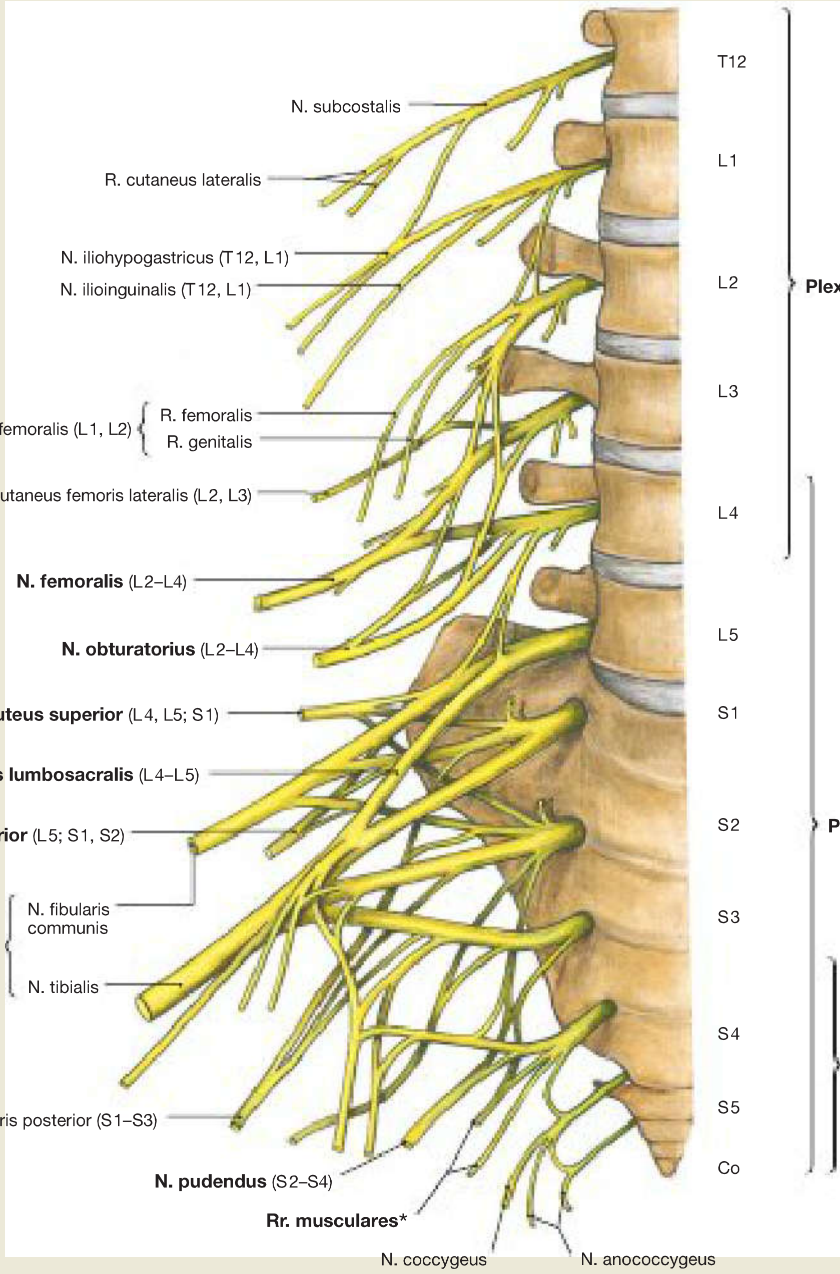


Fig. 4.123 Plexus lumbosacralis (T12–S5, Co1): segmental arrangement of the nerves, right side; ventral view.

The lower limb is innervated by the **Plexus lumbosacralis**. The plexus is composed of the Rr. anteriores of the spinal nerves which originate from the lumbar, sacral and coccygeal spinal cord segments and unite to form the **Plexus lumbalis** (T12–L4) and the **Plexus sacralis** (L4–S5, Co1). The segments S4–Co1 are also referred to as Plexus coccygeus. Both plexuses are connected by the **Truncus lumbosacralis** which conveys nerve fibres of the spinal cord segments L4, L5 from the Plexus lumbalis to the lesser pelvis. Functionally the most important nerves of the Plexus lumbalis are the N. femoralis and the N. obturatorius. The **N. femoralis** provides motor innervation to the ventral group of the hip and thigh muscles (flexing the hip joint and extending the knee), and sensory innervation to the ventral aspect of the thigh and the anterior-medial aspect of the leg. The **N. obturatorius** provides motor innervation to the adductor group and sensory innervation to the medial thigh. The strongest and longest nerve branch of the Plexus sacralis is the **N. ischiadicus.** With both its divisions (N. tibialis and N. fibularis communis) it provides motor innervation to the hamstring muscles (flexing the hip joint and extending the knee) and to all the muscles of the lower legs and feet. It also provides sensory innervation to the calf and foot. The **Nn. glutei superior and inferior** innervate the gluteal muscles which represent the major extensors, rotators and abductors of the hip. The **N. pudendus** innervates the muscles of the perineal region and provides sensory innervation to the external genitalia. The muscles of the pelvic floor are innervated by direct muscular branches (*).

→ T 40

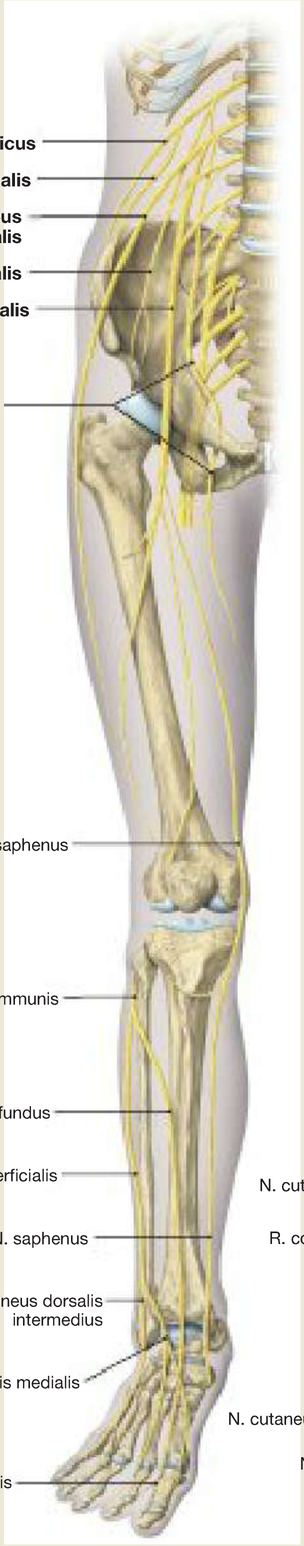


Fig. 4.124a and b Plexus lumbosacralis (T12–S5, Co1): nerves of the leg, right side; ventral view (→ Fig. 4.124a) and dorsal view (→ Fig. 4.124b). [L127]
The nerves of the **Plexus lumbalis** (T12–L4) run **ventrally** of the hip joint and supply the lower part of the lateral and anterior abdominal wall and the anterior side of the thigh. The branches of the **Plexus sacralis** lie on the **dorsal side** of the hip joint. They innervate the dorsal side of the thigh, as well as most of the leg and the entire foot.

Plexus lumbalis (T12–L4)

- Motor branches to the M. iliopsoas and M. quadratus lumborum (T12–L4)
- N. iliohypogastricus (T12, L1)
- N. ilioinguinalis (T12, L1)
- N. genitofemoralis (L1, L2)
- N. cutaneus femoris lateralis (L2, L3)
- N. femoralis (L2–L4)
- N. obturatorius (L2–L4)

Plexus sacralis (L4–S5, Co1)

- Motor branches to the pelvitrochanteric muscles of the hip (M. obturatorius internus, Mm. gemelli superior and inferior, M. quadratus femoris, M. piriformis; L4–S2)
- N. gluteus superior (L4–S1)
- N. gluteus inferior (L5–S2)
- N. ischiadicus (L4–S3)
- N. cutaneus femoris posterior (S1–S3)
- Cutaneous branches to the skin area of the ischial tuberosity (N. cutaneus perforans, S2, S3) and coccyx (N. anococcygeus, S5–Co1)
- N. pudendus (S2–S4)
- Nn. splanchnici pelvici (preganglionic parasympathetic fibres; S2–S4)
- Motor branches to the pelvic floor (M. levator ani and M. ischiococcygeus, S3, S4)

Innervation of the Skin

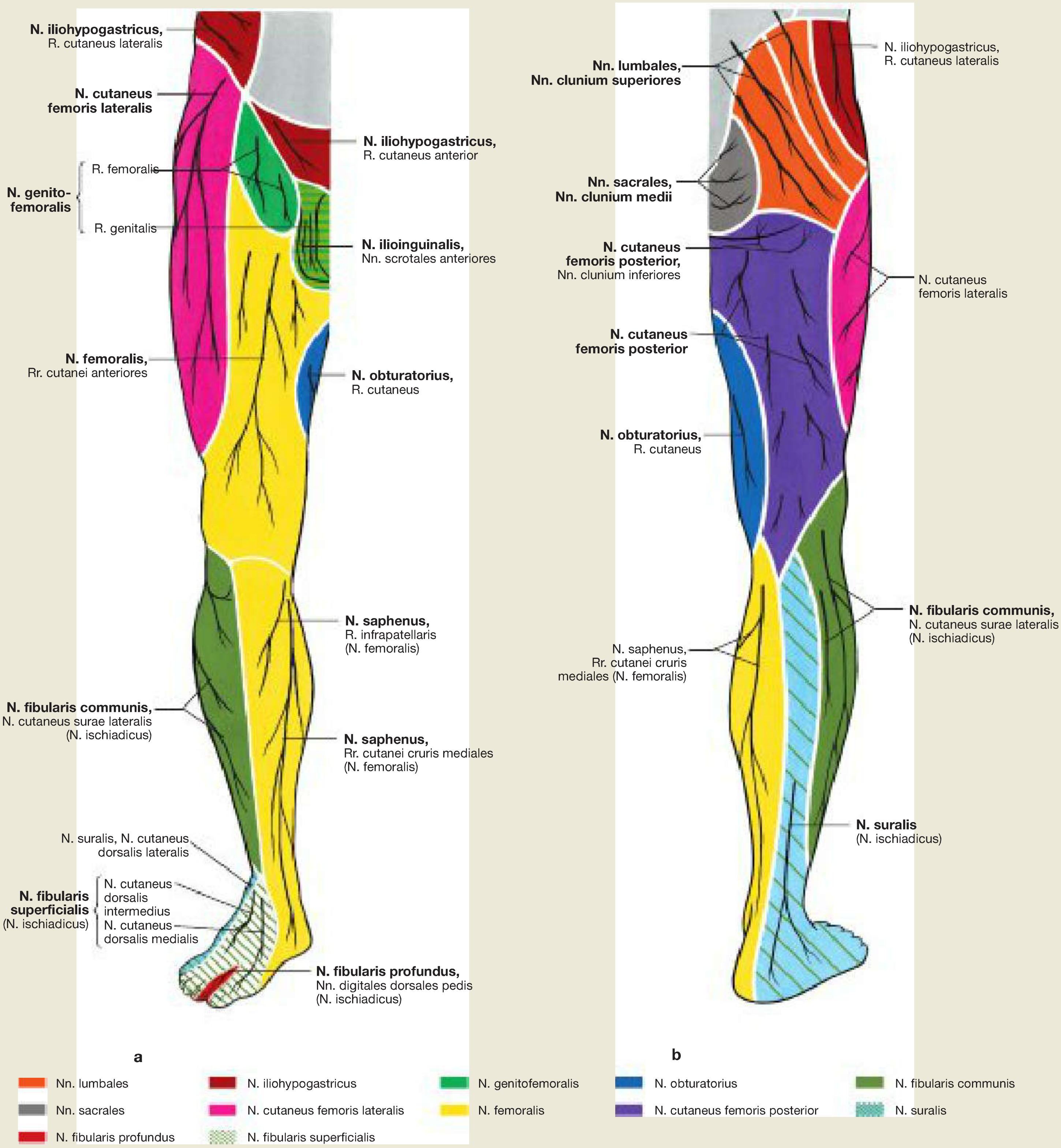


Fig. 4.125a and b Cutaneous nerves of the lower limb, right side; ventral view (→ Fig. 4.125a) and dorsal view (→ Fig. 4.125b).
The sensory innervation of the **inguinal region** and the **ventral side** of the leg is supplied by **all the nerves** of the **Plexus lumbalis.** The lateral aspect of the lower leg and the dorsum of the foot are innervated by branches of the Plexus sacralis. The **gluteal region** is innervated by the **Rr. posteriores** of the lumbar (Nn. clunium superiores) and sacral (Nn. clunium medii) spinal nerves, whereas the dorsal side of the entire leg and the sole of the foot are innervated by branches of the Plexus sacralis.

Clinical Remarks

The **pattern of referred pain** generated in the area of the plexus is influenced by the course of the nerves originating from the Plexus lumbalis and Plexus sacralis. If the **Plexus lumbalis** is compressed by a haematoma or a tumour, the pain typically radiates into the **anterior aspect** of the thigh. With compression of the **Plexus sacralis**, the pain radiates into the **dorsal side** of the thigh **(ischialgia)** and often down into the lower leg.

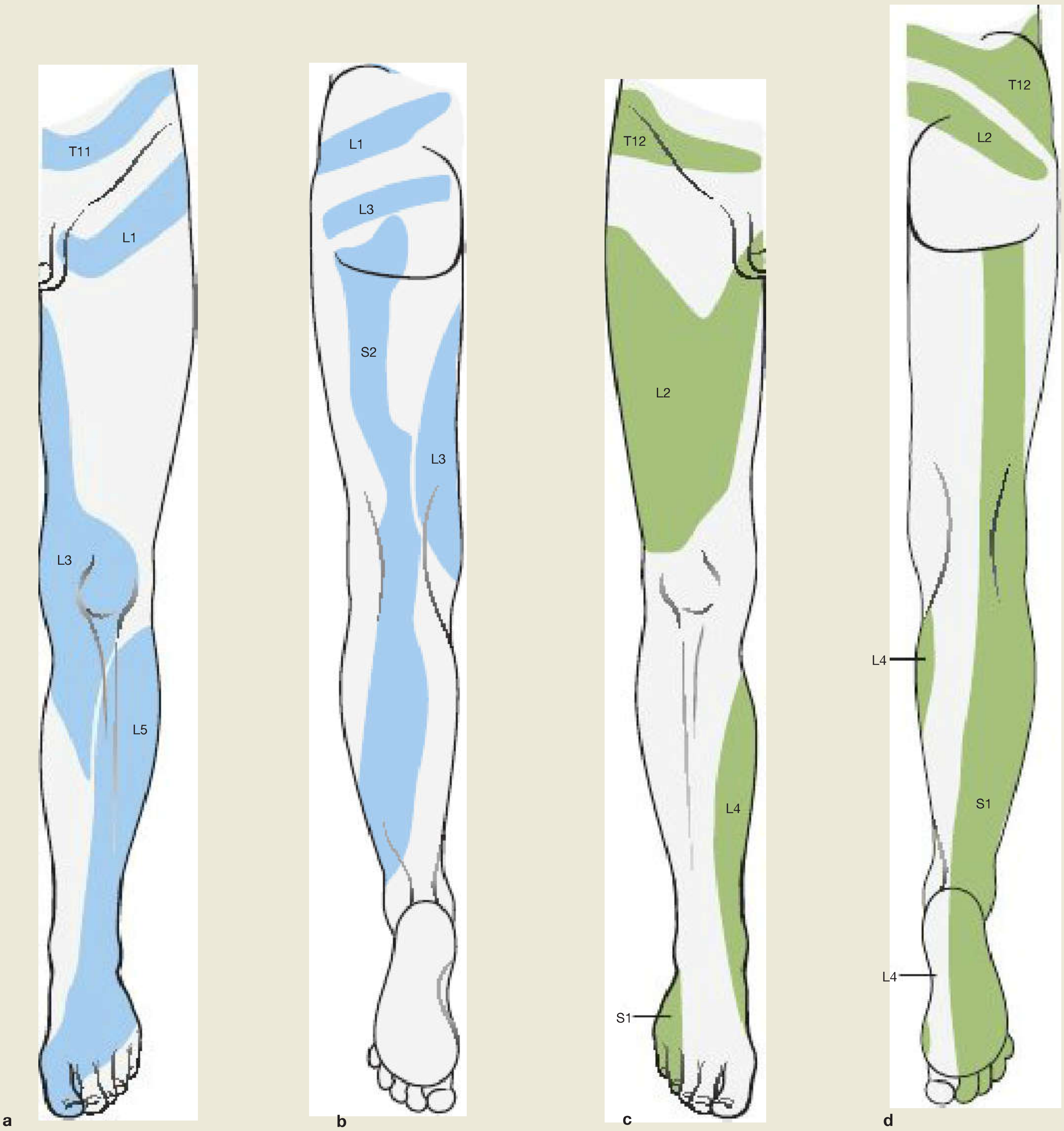


Fig. 4.126a to d Segmental cutaneous innervation (dermatomes) of the lower limb, right side; ventral view (→ Fig. 4.126a and → Fig. 4.126c) and dorsal view (→ Fig. 4.126b and → Fig. 4.126d). [L126]
Distinct areas of the skin are provided with sensory innervation by a single spinal cord segment. These cutaneous areas are referred to as dermatomes. Since the cutaneous nerves of the lower limb convey sensory fibres from several spinal cord segments, the borders of the dermatomes do not correspond with the areas supplied by the cutaneous nerves (→ Fig. 4.125). In contrast to the circular orientation of the dermatomes of the trunk, dermatomes on the anterior aspect of the lower extremity are obliquely oriented in a lateral superior to medial inferior direction, and longitudinally on the posterior side (Development, → p. 158).

Clinical Remarks

The localisation of the dermatomes are extremely important in the **diagnosis of the very common disc prolapses**. Disc prolapses mainly occur in the lower lumbar spine and can damage the nerve roots of L4–S1. While the nerve fibres from the segment **L4** innervate the **medial side of the foot**, the **big toe** and the **second toe are supplied by the L5** segment. The whole lateral side of the foot, including the **little toe,** is provided with sensory innervation by **S1**.

Plexus lumbalis

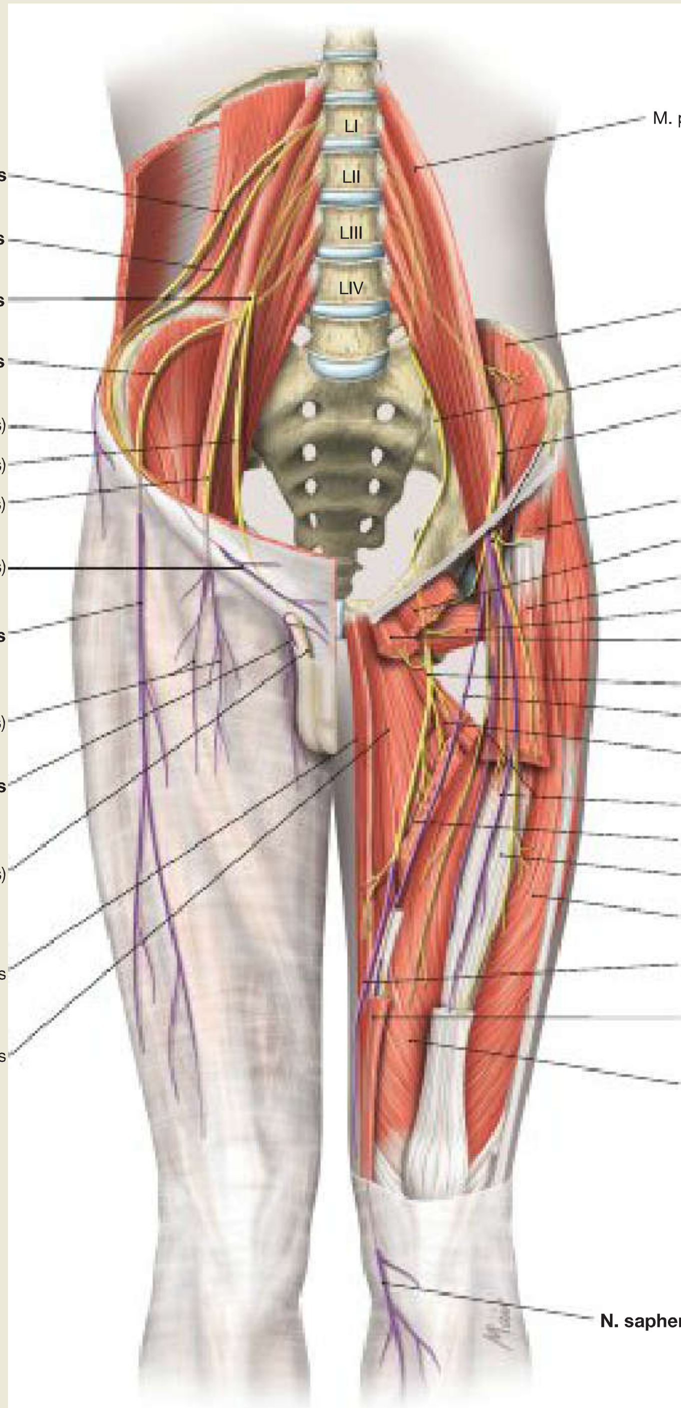


Fig. 4.127 Course and innervation areas of the nerves of the Plexus lumbalis (T12–L4); ventral view. The cutaneous branches are highlighted in purple. [L127]

The N. iliohypogastricus and **N. ilioinguinalis** (somewhat more caudally) run behind the kidney across the M. quadratus lumborum, and then pass anteriorly between the M. transversus abdominis and the M. obliquus internus. Both innervate the lower parts of these abdominal muscles. In addition, the N. iliohypogastricus provides sensory innervation to the skin above the inguinal ligament, while the N. ilioinguinalis supplies the anterior parts of the external genitalia. The **N. genitofemoralis** pierces the M. psoas major, crosses under the ureter and then divides into a lateral **R. femoralis,** that passes through the Lacuna vasorum and provides sensory innervation to the skin under the inguinal ligament, while the medial **R. genitalis** runs through the inguinal canal to the scrotum. The R. genitalis provides sensory innervation to the anterior parts of the external genitalia and to the M. cremaster in men. The **N. cutaneus femoris lateralis** passes laterally through the Lacuna musculorum and provides sensory innervation to the lateral side of the thigh. The **N. femoralis** passes medially through the Lacuna musculorum, where it subdivides in a fan-like manner. Its Rr. cutanei anteriores innervate the skin on the anterior side of the thigh. The Rr. musculares innervate the ventral group of the hip (M. iliopsoas) and thigh muscles (M. sartorius and M. quadriceps femoris), as well as the M. pectineus. Its terminal branch is the **N. saphenus**, which enters the adductor canal (→ p. 409) and leaves it through the Septum intermusculare vastoadductorium on the medial side of the knee joint to supply sensory innervation to the medial and anterior aspects of the lower leg. The **N. obturatorius** initially runs medially of the M. psoas major and then passes through the Canalis obturatorius (→ p. 409) to the medial aspect of the thigh. Here it sends a muscular branch to the M. obturatorius externus and divides into two branches, R. anterior and R. posterior (lying in front of and behind the M. adductor brevis), that innervate the muscles of the adductor group. The R. anterior ends with a cutaneous branch supplying the medial aspect of the thigh whereas the R. posterior also innervates the joint capsule of the knee.

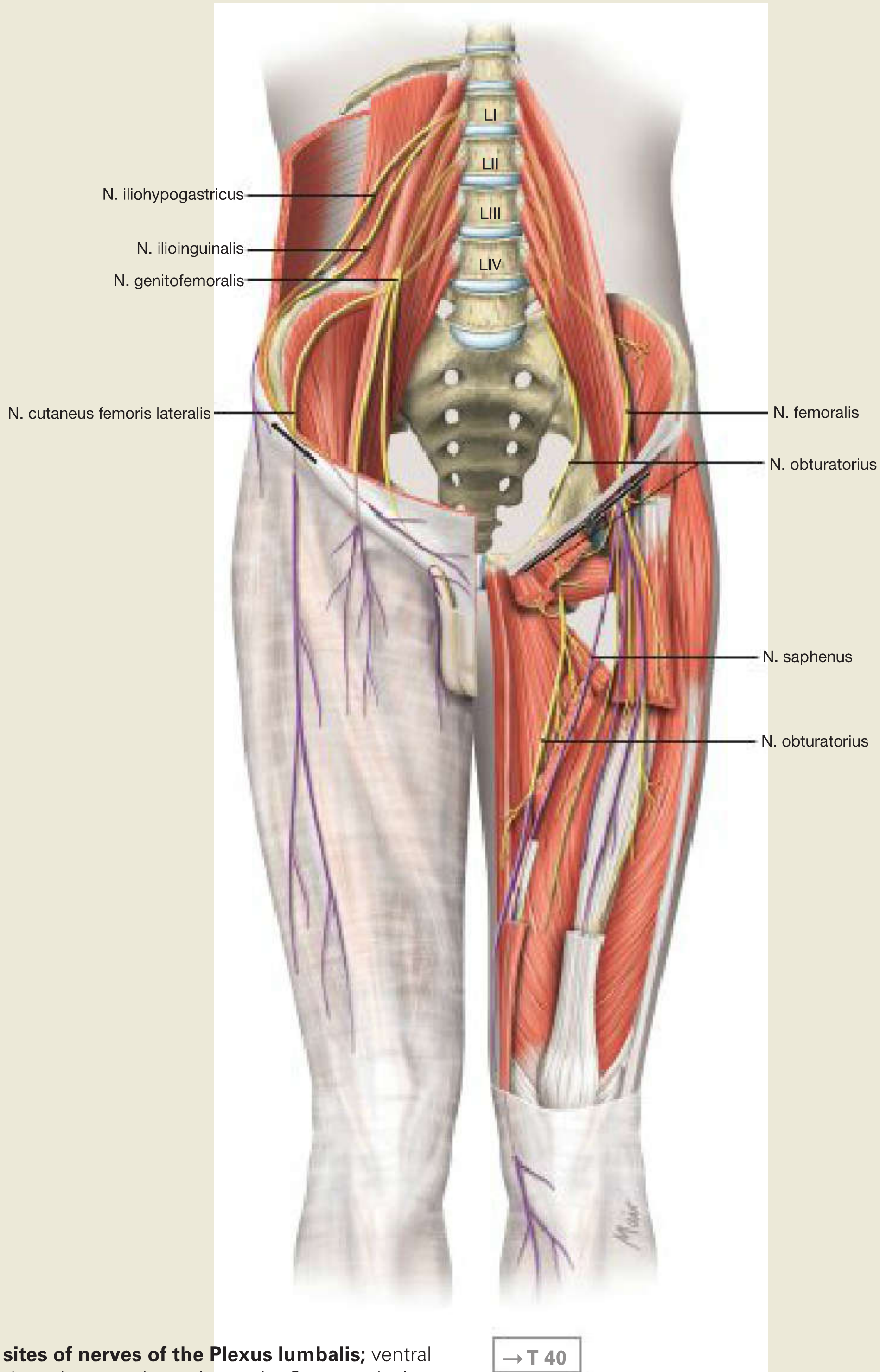


Fig. 4.128 Lesion sites of nerves of the Plexus lumbalis; ventral view. The cutaneous branches are shown in purple. Common lesion sites are marked with black bars. [L127]

→ T 40

Clinical Remarks

Lesions of the **N. iliohypogastricus, N. ilioinguinalis** and **N. genitofemoralis** are rare due to their protected location. Because of their close proximity to the kidney and the ureter, however, certain diseases of the kidney (inflammation of the renal pelvis, pyelonephritis, or kidney stones) may result in **pain radiating** into the inguinal region or the external genitalia.
In the case of an anterior surgical access to the hip joint or its incarceration under the inguinal ligament by tight trousers, the **N. cutaneus femoris lateralis** can be damaged. This may result in a sensory loss or pain along the lateral aspect of the thigh **(meralgia paraesthetica).**
The **N. femoralis** is most often damaged in the groin due to surgical interventions or diagnostic procedures (heart catheterisation). In addition to restricted hip flexion complete loss of knee extension makes it impossible to go up- or downstairs. The patellar tendon reflex (knee-jerk reflex) is lacking, and the sensory function of the anterior thigh and medial lower leg is absent.
The **N. obturatorius** is at risk when passing through the Canalis obturatorius. Besides a pelvic fracture, prolapses of the abdominal viscera (hernias) or advanced ovarian cancer can also be the cause of lesions. As a result of the failure of the adductor muscles, the upright stance becomes unbalanced, and closing and crossing the legs becomes impossible. Sensitivity or the sensory function of the medial thigh can be reduced. Painful dysaesthesias may also occur, which mimic diseases of the knee joint **(ROMBERG's knee phenomenon).**

Plexus sacralis

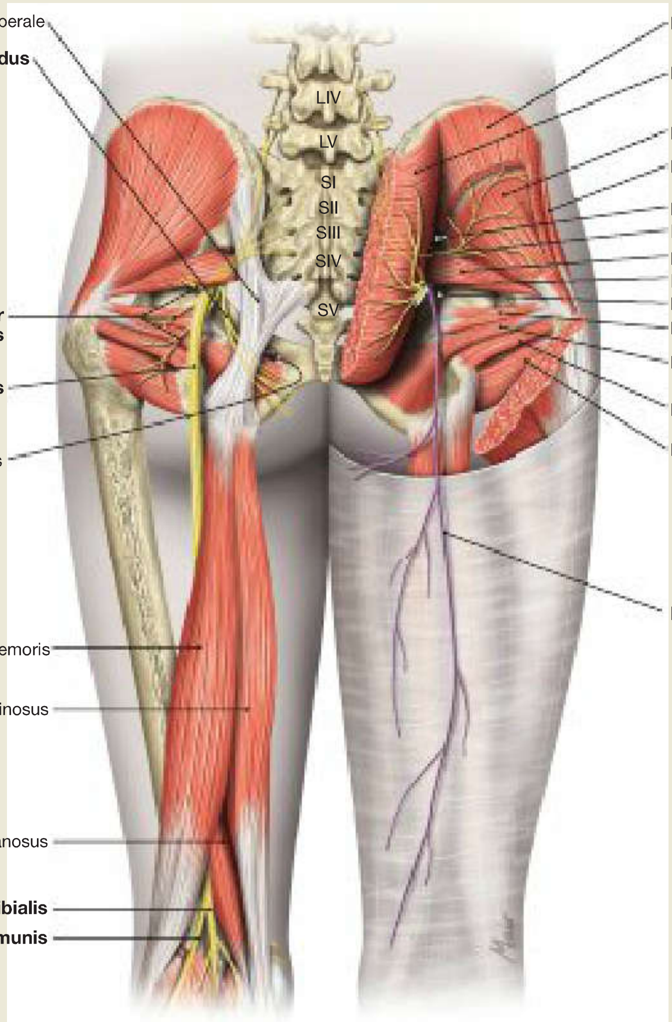


Fig. 4.129 Course and innervation areas of nerves of the Plexus sacralis (L4–S5, Co1); dorsal view. The cutaneous branches are shown in purple. [L127]

The **N. gluteus superior** exits the lesser pelvis through the Foramen suprapiriforme and provides motor innervation to the small gluteal muscles (the most important abductors and medial rotators of the hip joint) and the M. tensor fasciae latae. The **N. gluteus inferior** exits through the Foramen infrapiriforme and innervates the M. gluteus maximus, the strongest extensor and external rotator of the hip joint.

The **N. ischiadicus** is the strongest nerve of the human body. It consists of two divisions (N. tibialis and N. fibularis communis) which are joined only by their connective tissue sheath (epineurium) to form one trunk over a variable distance. The N. ischiadicus exits the pelvis through the Foramen infrapiriforme and runs under the M. biceps femoris to the popliteal fossa of the knee.

In most cases the **N. tibialis** and **N. fibularis communis** separate where they transfer to the distal third of the thigh. Occasionally (approx. 12%), both nerves already exit the pelvis separately (high division) in which case the N. fibularis communis often pierces the M. piriformis. In the thigh, the N. tibialis provides motor innervation to the hamstring muscles and to the posterior head of the M. adductor magnus. The N. fibularis only innervates the Caput breve of the M. biceps femoris in the thigh. With its two trunks, the N. ischiadicus provides motor innervation to all muscles of the lower leg and foot as well as sensory innervation to the whole lower leg (except medially, where it is supplied by the N. saphenus from the N. femoralis) and the foot (with the exception of the medial side).

After exiting the Foramen infrapiriforme, the **N. cutaneus femoris posterior** sends the sensory Nn. clunium inferiores to the skin of the lower buttocks. Then it continues its subfascial course to approximately the middle of the thigh and provides sensory innervation to the posterior thigh.

The course of the **N. pudendus** is relatively complicated. After exiting the Foramen infrapiriforme it winds around the Spina ischiadica with its eponymous blood vessels and passes medially through the Foramen ischiadicum minus into the Fossa ischioanalis. Here it runs laterally inside a fascial duplication of the M. obturatorius internus (ALCOCK's canal). The N. pudendus innervates the external sphincter of the anal canal (M. sphincter ani externus) as well as all the perineal muscles and provides sensory innervation to the posterior parts of the external genitalia (penis/clitoris).

The **muscular branches to the pelvitrochanteric muscles** also exit via the Foramen infrapiriforme, while the **muscular branches to the pelvic floor** and the parasympathetic **Nn. splanchnici pelvici** do not leave the lesser pelvis. The small **cutaneous branches** pierce the Lig. sacrotuberale (N. cutaneus perforans) or the M. ischiococcygeus (N. anococcygeus) and are of minor significance.

→ T 40

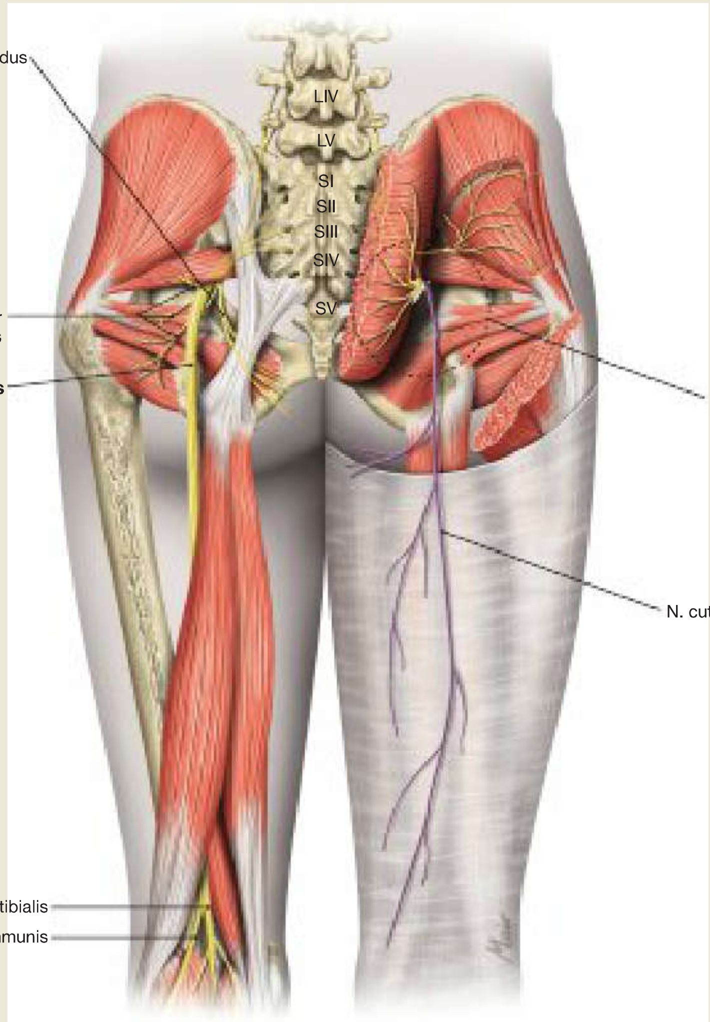


Fig. 4.130 Lesion sites of the most important nerves of the Plexus sacralis; dorsal view. The cutaneous branches are shown in purple. [L127]
Nerve lesions at the exit from the pelvis, e.g. due to incorrect intragluteal injection, are shown here on the right side of the body.

* damage due to incorrect intragluteal injection

Clinical Remarks

Lesions of the nerves of the Plexus sacralis – part 1 (part 2 → p. 389)
In the case of a **high division** of the N. ischiadicus, the **N. fibularis communis** can be compressed while passing through the M. piriformis. The resulting pain can mimic a disc hernia. Apart from intragluteal injections, the **N. ischiadicus** can also be damaged by compression during prolonged sitting or, in the case of pelvic fractures, dislocations and hip operations. The resulting paralysis of the hamstring muscles restricts the extension of the hip joint, but more importantly, the flexion and rotation in the knee joint. If both the N. tibialis and the N. fibularis are damaged completely, all the muscles of the leg and the foot are paralysed **and standing or walking is impossible.** When lifting the leg while walking, the foot is dragged **(steppage gait).** Standing on tiptoes is no longer possible. The sensory innervation of the lower leg (except ventral-medially) and foot is almost completely absent (for isolated lesions of the N. tibialis or N. fibularis → pp. 390 and 391). The damage of individual muscular branches to the pelvitrochanteric muscles, as well as lesions of the cutaneous branches, are functionally insignificant. The **muscular branches** to the pelvic floor and especially the parasympathetic **Nn. splanchnici pelvic** may, however, be injured during surgical procedures in the lesser pelvis, such as the excision of the rectum or the prostate gland. Insufficiency of the pelvic floor can result in **faecal** and **urinary incontinence**. Damage to the parasympathetic nerves can cause **erectile dysfunction** in men and problems with the **corpus cavernosum of the clitoris** in women.

Intragluteal Injection

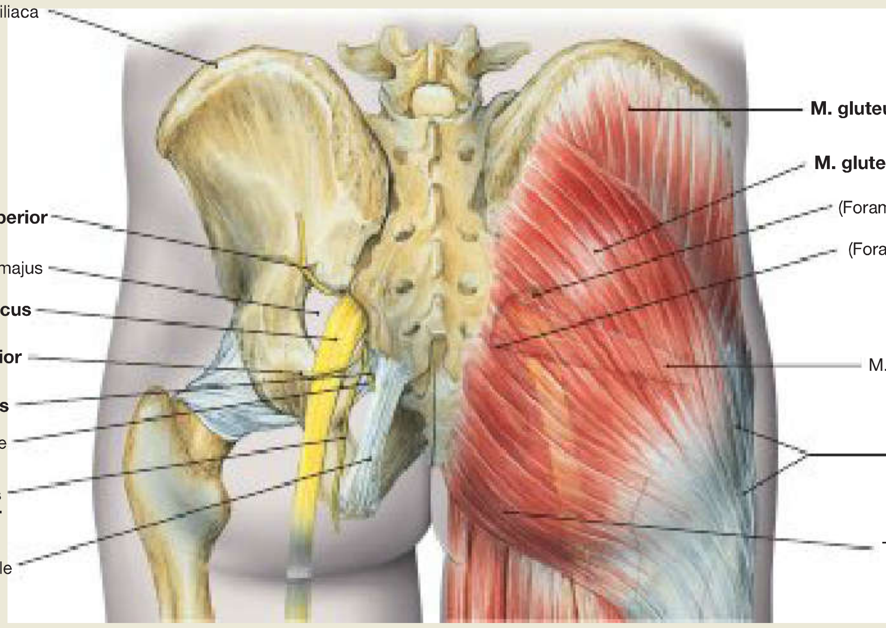


Fig. 4.131 Surface projection of the skeletal contour and the N. ischiadicus in the gluteal region.
In the case of an **incorrect intragluteal injection** into the M. gluteus maximus, all the neurovascular pathways that exit the Foramen ischiadicum majus are potentially at risk. Only the A. and V. pudenda interna and the N. pudendus, which pass through the Foramen ischiadicum minus into the Fossa ischioanalis, are relatively well-protected. Therefore, injections should always be given into the M. gluteus medius (→ Fig. 4.132).

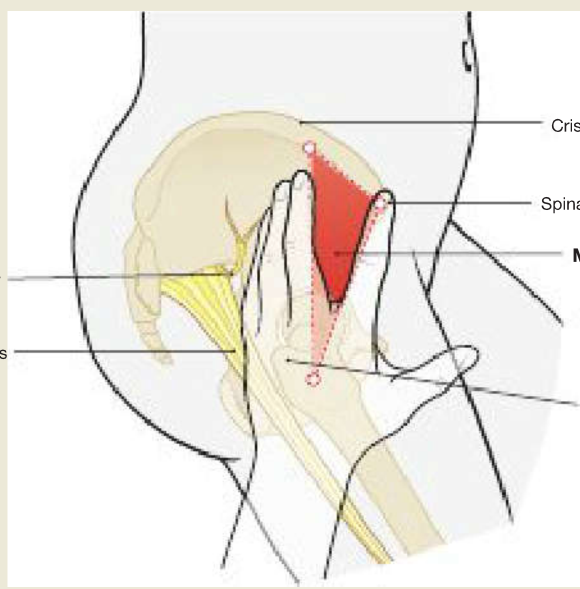


Fig. 4.132 Intragluteal injection (according to v. HOCHSTETTER). [L126]
To be absolutely sure of preventing any lesion of the neurovascular pathways in the gluteal region the **intragluteal injection** is given into the triangular field between the two spread-out fingers and the Crista iliaca, as shown here. The index finger is placed on the Spina iliaca anterior superior, and the palm of the hand lies on the Trochanter major. However, the muscular branch of the N. gluteus superior, running to the M. tensor fasciae latae, still remains at risk.

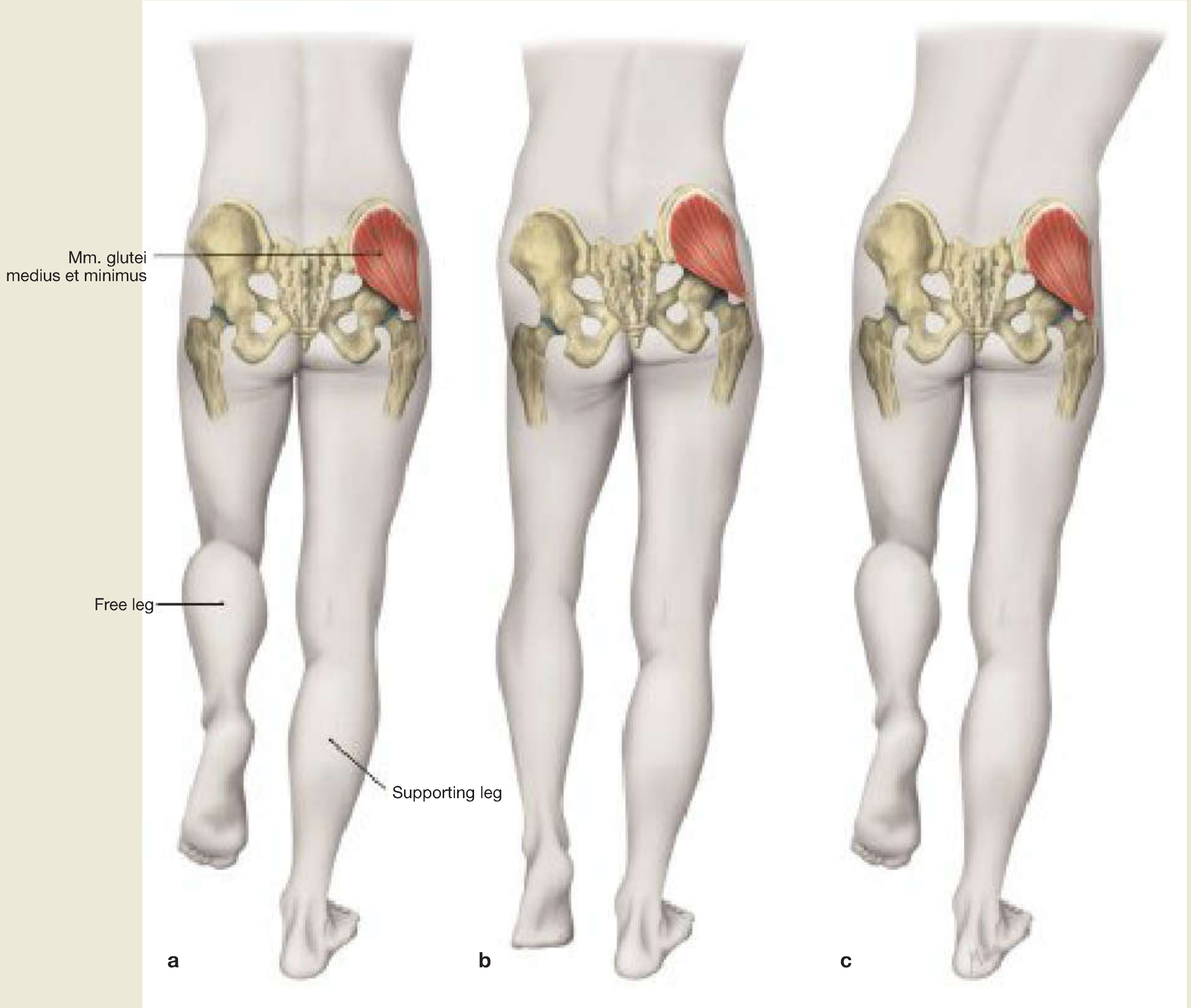


Fig. 4.133a to c TRENDELENBURG's sign and DUCHENNE's sign (limp) indicating a paralysis of the small gluteal muscles, on the right side. [L127]

a The gluteal muscles abduct the ipsilateral leg if the body weight is shifted to the other leg. In the one-leg stance, the muscles of the same side stabilise the pelvis and prevent it dropping to the opposite side (side of the free or non-supported leg).

b With functional insufficiency of the small gluteal muscles, such as in hip dysplasia or due to lesions of the N. gluteus superior, the pelvis drops to the healthy side when standing on the leg of the affected side **(TRENDELENBURG's sign).**

c While walking, the pelvis of the healthy side is elevated by shifting the trunk towards the affected side **(DUCHENNE's sign or limp).**

Clinical Remarks

Lesions of nerves of the Plexus sacralis – part 2 (part 1 → p. 387)
Due to the protected course of the **N. pudendus**, nerve lesions are rare, yet can lead to insufficiency of the perineal and sphincter muscles of the bladder and rectum, resulting in **incontinence,** and the sensory deficiency of the external genitalia can cause **disorders of sexual function**. When giving birth, the loss of sensation in the perineal region and the external genitalia may even be a desirable effect and therefore is induced by performing a **pudendal nerve block**. The Spina ischiadica is palpated through the vagina, and the N. pudendus is completely anaesthetised by injection of a local anaesthetic approximately 1 cm lateral and cranial of the Spina ischiadica before it enters the ALCOCK's canal. This procedure has become less important since the introduction of epidural anaesthesia, with the injection of local anaesthetics into the epidural space of the lower spinal cord.
In the case of an **incorrect intramuscular injection** in the gluteal region, the neurovascular pathways passing through the Foramina suprapiriforme and infrapirifome can be damaged. In addition to the blood vessels, the Nn. glutei superior and inferior, the N. cutaneus femoris posterior and the N. ischiadicus may be affected. The intragluteal injection according to v. HOCHSTETTER is applied into the M. gluteus medius (→ Fig. 4.132). Lesions of the **N. gluteus superior** can lead to paralysis of the small gluteal muscles (the most important abductors and medial rotators of the hip) and of the M. tensor fasciae latae. Dysfunctions of the small gluteal muscles make the one-leg stance on the affected side impossible, because the pelvis tilts to the healthy side **(TRENDELENBURG's sign).** If the **N. gluteus inferior** is damaged, the M. gluteus maximus, the strongest extensor of the hip joint, becomes paralysed. With normal gait, this can largely be compensated for by the hamstring muscles. However, going up- or downstairs, jumping and running are hardly possible any more. Lesions of the **N. cutaneus femoris posterior** compromise the sensory innervation on the dorsal aspect of the thigh.

N. tibialis

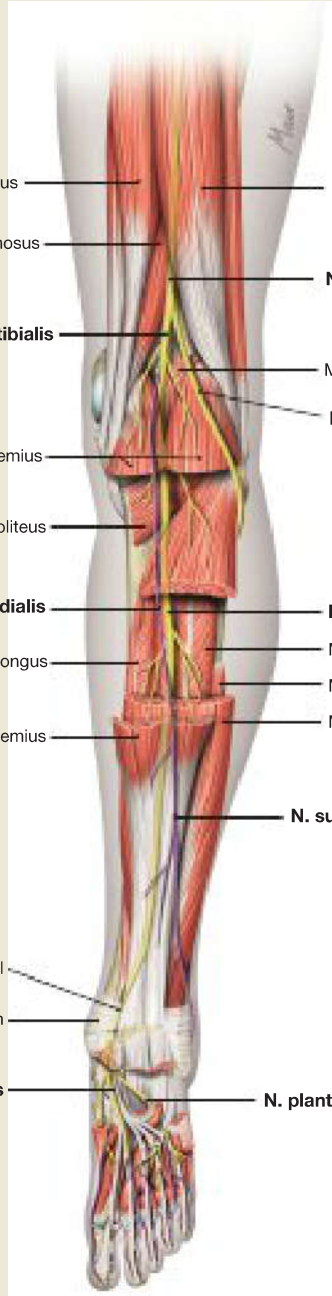


Fig. 4.134 N. tibialis: sensory innervation by cutaneous nerves (purple), and motor innervation by muscular branches, right side; dorsal view. [L127]

The **N. ischiadicus** often divides at the transition from the middle to the distal third of the thigh into the medial **N. tibialis** and the lateral **N. fibularis communis**. The N. tibialis innervates the dorsal muscles of the thigh (hamstring muscles and dorsal part of the M. adductor magnus). The N. tibialis continues the course of the N. ischiadicus in the direction of the popliteal fossa of the knee, passes between the heads of the M. gastrocnemius under the tendinous arch of the M. soleus **(Arcus tendineus musculi solei)**, and runs together the A. and V. tibialis posterior between the superficial and deep flexors to the medial ankle. In the popliteal fossa, the **N. cutaneus surae medialis** branches off to the medial calf, continues in the distal calf as **N. suralis** and along the lateral side of the foot as **N. cutaneus dorsalis lateralis**, whereby it most often receives a communicating branch of the N. fibularis communis. When passing underneath the Retinaculum musculorum flexorum **(malleolar canal or tarsal tunnel)**, the N. tibialis divides into its two terminal branches (**Nn. plantares medialis** and **lateralis** for the innervation of the sole of the foot. Thus, the N. tibialis provides motor innervation to all flexor muscles of the calf and all plantar muscles as well as sensory innervation to the middle calf and, after forming the N. suralis, to the lower calf and the lateral side of the foot.

Clinical Remarks

Lesions of the N. tibialis are rare, but may occur with injuries to the knee joint or due to nerve compression in the **malleolar canal/tarsal tunnel** associated with tibial fractures or ankle joint injury **(posterior tarsal tunnel syndrome)**. The tarsal tunnel syndrome is associated with burning pain in the sole of the foot and a loss of function of the plantar muscles. Flexion, adduction and spreading the toes apart are impossible. Paralysis of the Mm. interossei and Mm. lumbricales results in a **claw foot deformity.** In the case of nerve lesions in the knee region, all the flexor muscles of the lower leg are also paralysed (negative ankle jerk reflex). The plantar flexion is strongly restricted and only supported to a minor degree by the fibular muscle group. This results in a **fixed pronation** of the foot as well as a **pes calcaneus** in which the foot remains in a dorsiflexed position. It is not possible to stand on tiptoes.

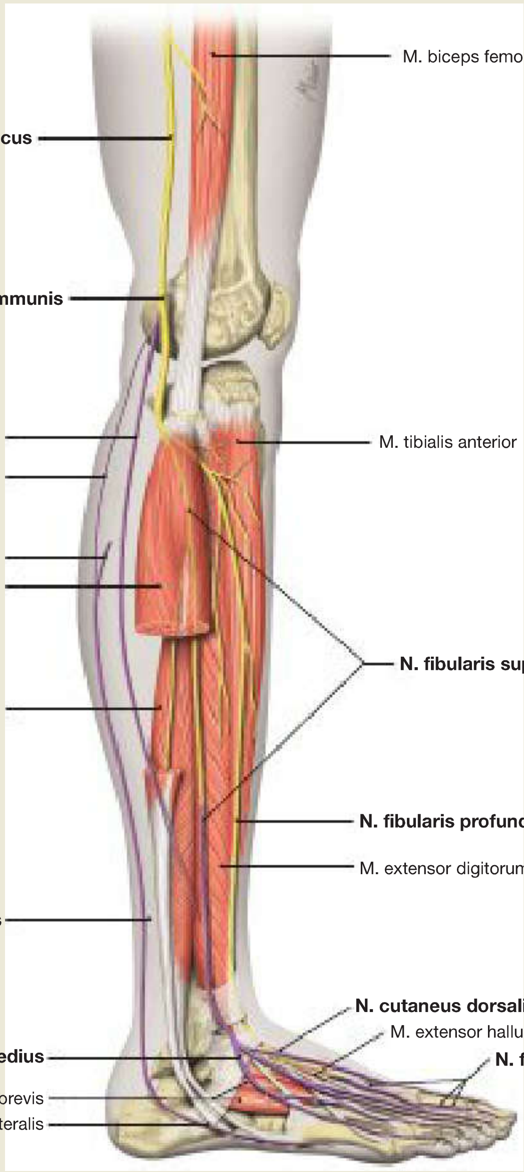


Fig. 4.135 N. fibularis communis: sensory innervation by cutaneous nerves (purple) and motor innervation by muscular branches, right side; lateral view. [L127]

After the division of the **N. ischiadicus** at the transition from the middle to the distal third of the thigh, the **N. fibularis communis** passes through the popliteal fossa and turns around the head of the fibula in the fibularis compartment, where it divides into its two terminal branches (Nn. fibulares superficialis and profundus). The N. fibularis only innervates the short head of the M. biceps femoris at the upper thigh. Prior to the division into its terminal branches, the N. fibularis communis sends the **N. cutaneus surae lateralis** to supply the skin of the lateral calf and a communicating branch to the N. cutaneus surae medialis.

The **N. fibularis superficialis** continues its course in the lateral compartment of the leg and innervates the fibular muscles, before piercing the fascia of the distal lower leg and dividing into the two sensory terminal branches (**Nn. cutanei dorsales medialis** and **intermedius**) for the dorsum of the foot.

The **N. fibularis profundus** passes into the extensor compartment and courses with the A. tibialis anterior to the dorsum of the foot. On its way, it innervates the extensors of the leg and of the dorsum of the foot, and sends a sensory terminal branch to the first interdigital space.

Clinical Remarks

Lesions of the N. fibularis communis are the most common nerve lesions of the lower limb. They can be caused by fractures of the proximal fibula, ski shoes that are too tight, or by crossing the legs. The resulting paralysis of the extensor muscles causes the toes to hang down (**pes equinus or footdrop deformity).** In compensation, patients raise the lower leg higher by flexing the knee **(steppage gait).** Due to the paralysis of the fibular muscles, the foot remains in a **supinated position.** The sensory perceptions in the lateral calf and the dorsum of the foot are lost.

The **N. fibularis profundus** can be damaged in the case of a compartment syndrome, in which a traumatic swelling of the extensor muscles **(tibialis anterior syndrome)** leads to compression of the nerve and its accompanying blood vessels. In this case, the fascia of the leg must be split. Lesions of the N. fibularis profundus are also associated with **pes equinus deformity and steppage gait**. However, the sensory function is only compromised in the first interdigital space! In the case of an **anterior tarsal tunnel syndrome**, compression of the sensory terminal branches under the Retinaculum musculorum extensorum results in dysaesthesia in the first interdigital space. Isolated lesions of the **N. fibularis superficialis** are less common (e.g. due to trauma to the fibular muscles), in which case the paralysis of the fibular muscles results in a **supinated position** of the foot. This leads to sensory losses on the dorsum of the foot, with only the sensitivity in the first interdigital space still intact.

Arteries of the Pelvis and Thigh

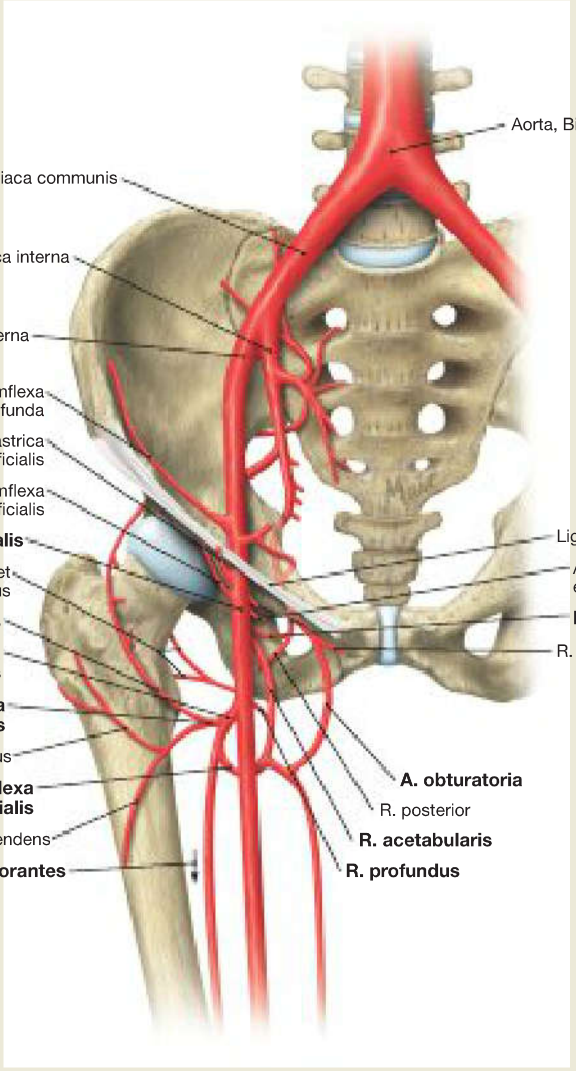


Fig. 4.136 Arteries of the pelvis and thigh, right side; ventral view. [L127]

The **A. iliaca communis** divides into the A. iliaca externa and A. iliaca interna in front of the sacroiliac joint. The **A. iliaca externa** provides the A. epigastrica inferior and the A. circumflexa ilium profunda to the ventral abdominal wall and then passes underneath the inguinal ligament. It then continues as **A. femoralis**, the artery supplying the entire leg, whereby the thigh, including the femoral head, is supplied by its strongest branch, the **A. profunda femoris,** of which the proximal branches (Aa. circumflexae femoris medialis and lateralis) wind around the femoral neck. The **A. iliaca interna** also participates in the supply of the thigh and buttock region (→ Fig. 4.139): the **Aa. gluteae superior and inferior** exit the Foramen ischiadicum majus dorsally and anastomose with the branches of the A. profunda femoris. In contrast, the **A. obturatoria** passes ventrally through the Canalis obturatorius onto the medial side of the anterior thigh. With great variability it anastomoses via a R. pubicus with a pubic branch from the A. epigastrica inferior. If this connection of blood vessels is well-developed, the term **corona mortis** is used, because interventions in the groin could lead to fatal bleeding in the past.

Arteries of the Lower Limb

Branches of the A. iliaca externa:
- A. epigastrica inferior
  - A. cremasterica/A. ligamenti teretis uteri
  - R. pubicus (anastomosis with A. obturatoria)
- A. circumflexa ilium profunda

Branches of the A. femoralis:
- A. epigastrica superficialis
- A. circumflexa ilium superficialis
- Aa. pudendae externae
- A. profunda femoris
  - A. circumflexa femoris medialis
  - A. circumflexa femoris lateralis
  - Aa. perforantes (usually three)
- A. descendens genus

Branches of the A. poplitea:
- A. superior medialis genus
- A. superior lateralis genus
- A. media genus
- Aa. surales
- A. inferior medialis genus
- A. inferior lateralis genus

Branches of the A. tibialis anterior:
- A. recurrens tibialis posterior
- A. recurrens tibialis anterior
- A. malleolaris anterior medialis
- A. malleolaris anterior lateralis
- A. dorsalis pedis
  - A. tarsalis lateralis
  - Aa. tarsales mediales
  - A. arcuata (Aa. metatarsales dorsales → Aa. digitales dorsales; A. plantaris profunda → Arcus plantaris profundus)

Branches of the A. tibialis posterior:
- A. fibularis
  - R. perforans
  - R. communicans
  - Rr. malleolares laterales
  - Rr. calcanei
  - A. nutricia fibulae and A. nutricia tibiae
- Rr. malleolares mediales
- Rr. calcanei
- A. plantaris medialis
  - R. superficialis
  - R. profundus (→ Arcus plantaris profundus)
- A. plantaris lateralis (→ Arcus plantaris profundus with Aa. metatarsales plantares → Aa. digitales plantares)

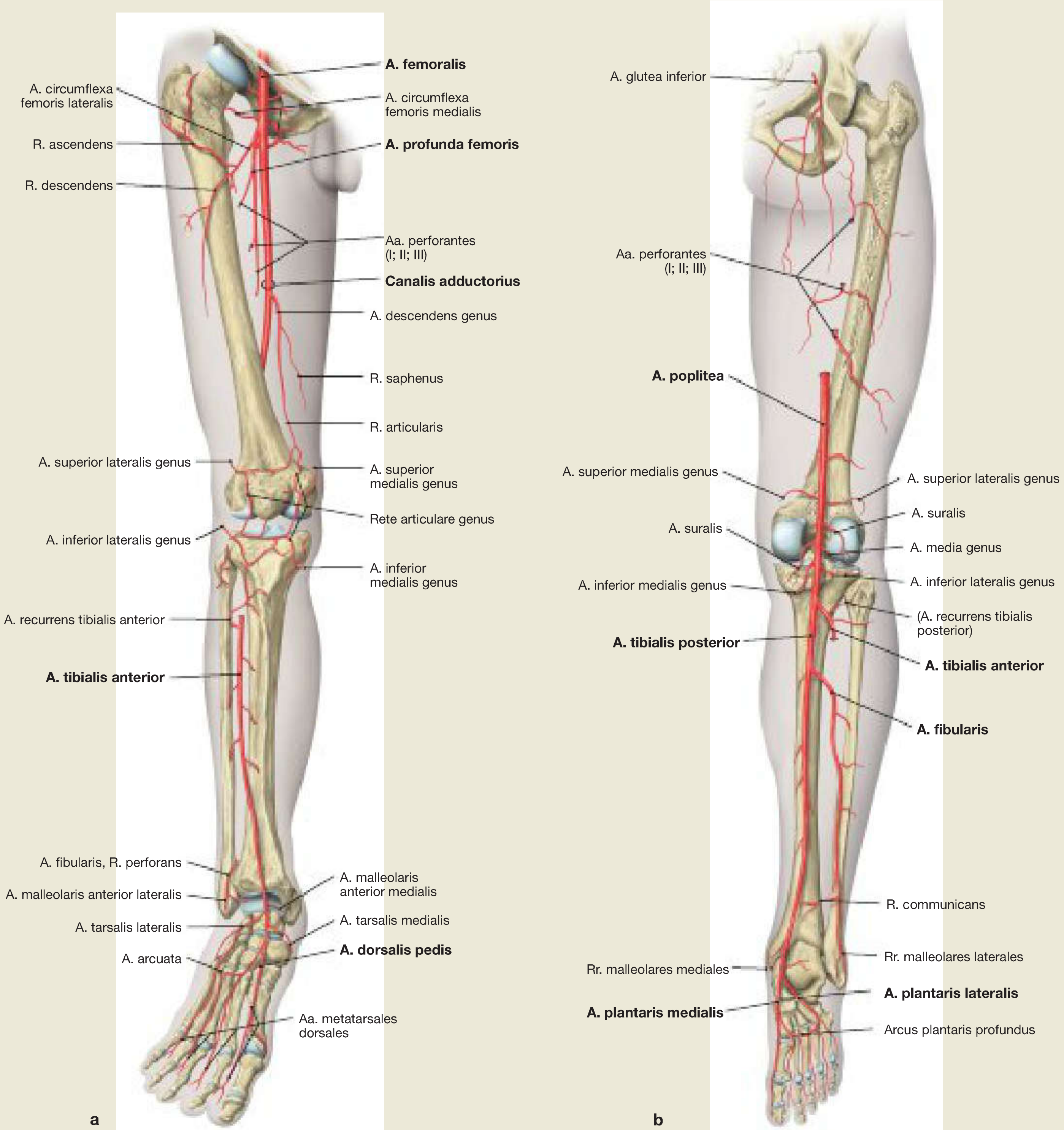


Fig. 4.137a and b Arteries of the leg, right side; ventral view (→ Fig. 4.137a) and dorsal view (→ Fig. 4.137b). [L127]

The **A. iliaca externa** runs from the A. iliaca communis in front of the sacroiliac joint. It continues underneath the inguinal ligament in the Lacuna vasorum as the **A. femoralis**, which after passing through the adductor canal is labelled as the **A. poplitea** (supplying vessel of the knee joint). This artery passes below the tendinous arch of the M. soleus, between the superficial and deep flexors of the lower leg and divides into the **A. tibialis posterior,** which continues its course, and into the **A. tibialis anterior,** which gets to the anterior extensor compartment through the Membrana interossea cruris. On the dorsum of the foot it continues as the **A. dorsalis pedis**. The A. tibialis posterior releases the **A. fibularis** as a large blood vessel supplying the lateral ankle, and continues its course towards the medial ankle and the malleolar canal/tarsal tunnel, through which it arrives in the sole of the foot, where it divides into its terminal branches (**Aa. plantares medialis** and **lateralis**).

Clinical Remarks

A complete physical examination includes palpation of the arterial **pulses** of the A. femoralis (in the groin), the A. poplitea (in the popliteal fossa), the A. dorsalis pedis (on the dorsum of the foot, lateral to the tendon of the M. extensor hallucis longus), and the A. tibialis posterior (behind the medial malleolus) to exclude any occlusion of the blood vessels due to **arteriosclerosis** or blood clots **emboli**.

Arteries of the Thigh

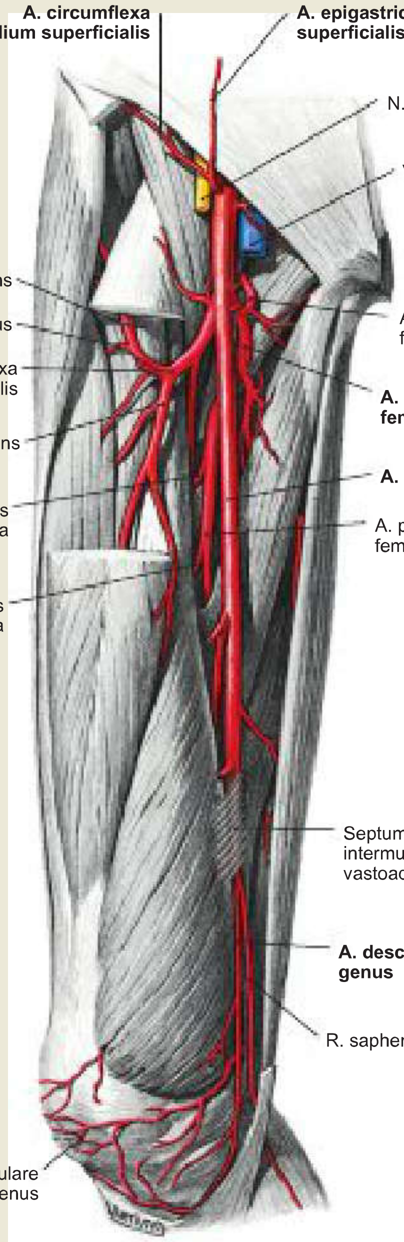


Fig. 4.138 Branches of the A. femoralis, right side; ventral view; after removal of the M. sartorius and splitting of the M. rectus femoris. [S010-2-16]

The **A. femoralis** runs between the N. femoralis (lateral) and the V. femoralis (medial) and has five branches:

- The **A. epigastrica superficialis** is a thin epifascial vessel and supplies the lower abdominal wall.
- The **A. circumflexa ilium superficialis** is an epifascial vessel, running laterally along the inguinal ligament.
- The **Aa. pudendae externae** supply the external genitalia (Rr. labiales/Rr. scrotales anteriores).
- The **A. profunda femoris** is the strongest branch and runs medially.
- The **A. descendens genus** originates in the adductor canal and supplies the knee joint and the skin in the knee region.

The **A. profunda femoris** is the main vessel supplying the hip joint and thigh. The other branches of the A. femoralis do not contribute to the arterial supply of the thigh. With its branches **(Aa. circumflexae femoris medialis and lateralis, Aa. perforantes)** the A. profunda femoris supplies the femur, the femoral neck and head as well as all the ventral and dorsal groups of the thigh muscles and parts of the gluteal region. The branches can also come directly from the A. femoralis.

Clinical Remarks

The femoral artery is tapped when performing a **left ventricular catheterisation**, in which the catheter is inserted into the left heart chamber in order to assess the ejection volume of the ventricle and the condition of the coronary arteries.

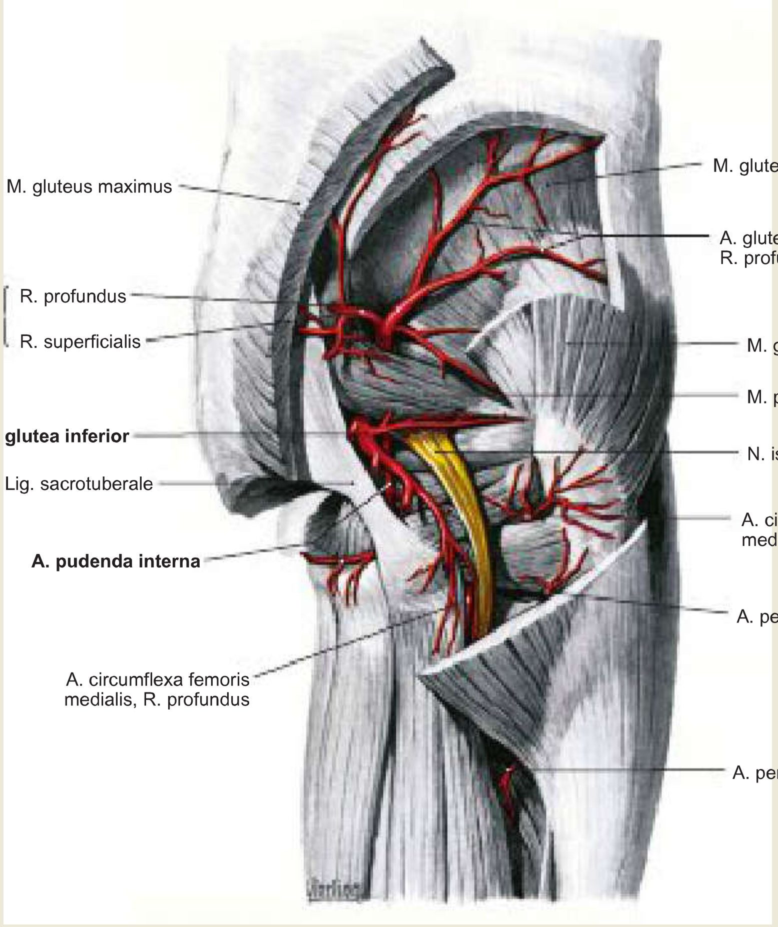


Fig. 4.139 Arteries of the gluteal region, right side; dorsal view; after removal of the Mm. glutei maximus and medius. [S010-2-16]

The gluteal region and the dorsal thigh are supplied by parietal branches of the **A. iliaca interna** (→ Fig. 7.10) and the **A. profunda femoris**.

Dorsal parietal branches of the **A. iliaca interna:**

- The **A. glutea superior** leaves the pelvis through the Foramen suprapiriforme and supplies the gluteal muscles. It passes laterally between the Mm. glutei medius et minimus.
- After passing through the Foramen infrapiriforme, the **A. glutea inferior** runs to the M. gluteus maximus.

Branches of the **A. profunda femoris:**

- **A. circumflexa femoris medialis:** its R. profundus supplies the posterior parts of the adductor and hamstring muscles, and the femoral head.
- **A. circumflexa femoris lateralis:** its R. ascendens runs to the gluteal muscles and to the femoral neck. It anastomoses with the A. circumflexa femoris medialis and the Aa. gluteae superior and inferior.
- **Aa. perforantes** (typically three): pierce the adductor and hamstring muscles.

The branches of the A. iliaca interna (including the A. obturatoria) anastomose with each other and with the A. profunda femoris, so that collateral circulations can be created.

Clinical Remarks

In different sections of the leg, **collateral circulations** are formed by arterial anastomosis. The connections of the A. profunda femoris with branches of the A. iliaca interna show a great variability, but in emergency situations they allow the A. femoralis to be tied off proximally to the A. profunda femoris.

Arteries of the Popliteal Fossa and of the Dorsal Leg

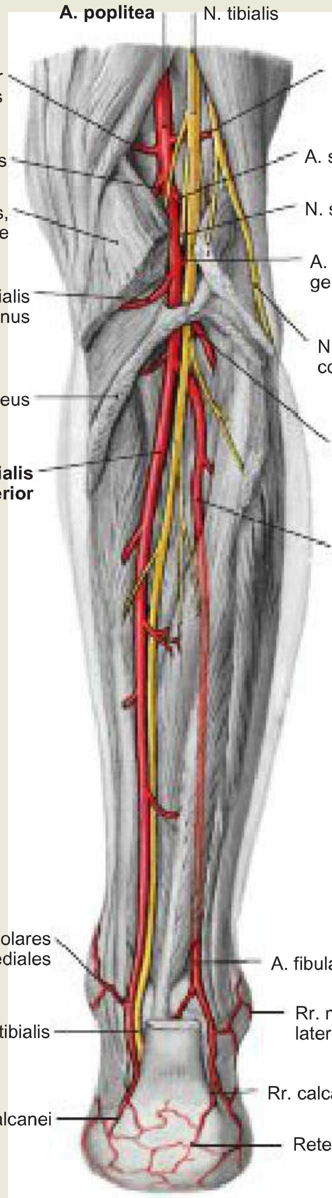


Fig. 4.140 Branches of the A. poplitea and A. tibialis posterior, right side; dorsal view; after removal of the superficial calf muscles. [S010-2-16]

After passing through the adductor hiatus, the A. femoralis continues its course in the popliteal fossa as the **A. poplitea**. It releases various branches, which form a vascular plexus in front of the knee joint (Rete articulare genus):

- **Aa. superiores medialis and lateralis genus** around the medial/lateral femoral condyle
- **A. media genus** to the knee joint
- **Aa. inferiores medialis and lateralis genus** to the proximal tibia/head of the fibula
- **Aa. surales** to the calf muscles

Terminal branches:

- **A. tibialis anterior:** passes through the Membrana interossea cruris (→ Fig. 4.141).
- **A. tibialis posterior:** continues the course of the A. poplitea and releases the following branches before passing through the malleolar canal/tarsal tunnel to the sole of foot:
  - **A. fibularis:** the strongest branch and descends along the dorsal side of the fibula; together with the **Rr. malleolares laterales** it supplies the lateral ankle and with the **Rr. calcanei** the lateral side of the heel.
  - **Rr. malleolares mediales** and **Rr. calcanei** supply the medial ankle and the medial side of the heel.

Clinical Remarks

In contrast to the **collateral circulations** in the gluteal region, the connections of the **Rete articulare genus** in the knee region (which is fed by the recurrent arteries of the leg and the third perforating artery of the A. profunda femoris), are not sufficient to supply the leg in the case of an occlusion of the A. poplitea. In contrast, the **arterial arch around the ankle** is generally well-developed, so that the supply to the foot is not acutely at risk, if either of the two Aa. tibiales or the A. fibularis is occluded.

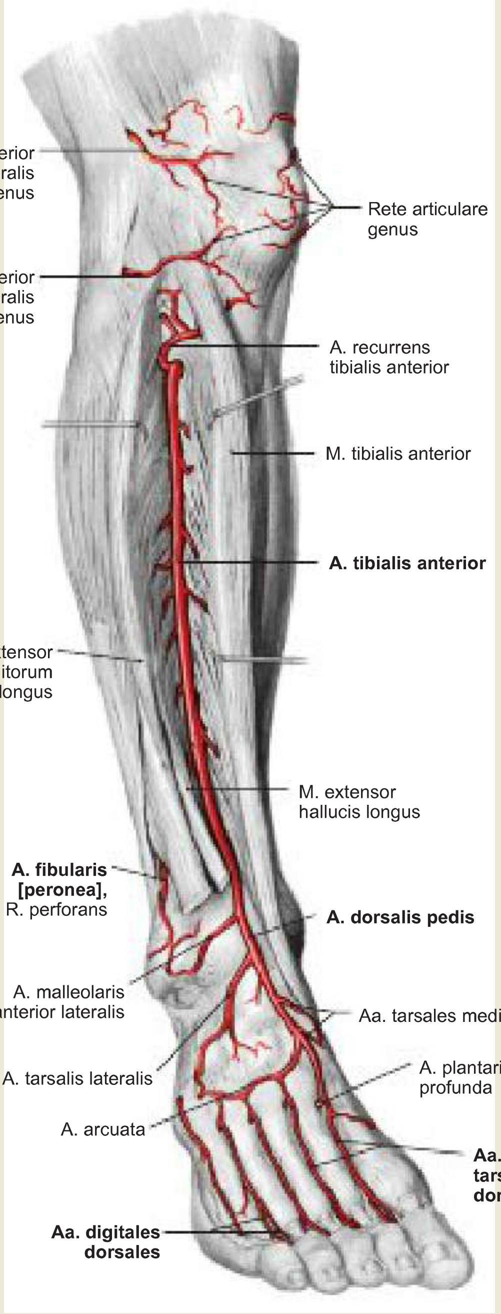


Fig. 4.141 Branches of the A. tibialis anterior and of the A. dorsalis pedis, right side; ventral view, after spreading of the extensor muscles of the leg and removal of the tendons apart the Mm. extensores digitorum longus and hallucis longus. [S010-2-16]

The **A. tibialis anterior** pierces the Membrana interossea cruris and descends in the extensor compartment before it continues on the dorsum of the foot as the A. dorsalis pedis. It has four branches:

- **A. recurrens tibialis anterior and A. recurrens tibialis posterior:** These vessels run before and after their passage through the Membrana interossea back to the knee joint.
- **A. malleolaris anterior medialis and A. malleolaris anterior lateralis:** With the branches of the A. tibialis posterior and of the A. fibularis, these arteries complete the vascular plexus of the medial and lateral ankles (malleoli).

The **A. dorsalis pedis** also has four branches:

- **A. tarsalis medialis and A. tarsalis lateralis** to the medial and lateral sides of the foot
- **A. arcuata:** forming an arch, it runs laterally and releases the Aa. metatarsales dorsales which continue as Aa. digitales dorsales to the toes.
- **A. plantaris profunda:** connects with the Arcus plantaris profundus of the sole of the foot.

Clinical Remarks

Due to the rich blood supply of the **tibia** (by the Vasa nutricia), it is possible to administer large volumes of fluid via an **intraosseous access** if in emergency situations no peripheral access can be found. The cannula is inserted medially to the Tuberositas tibiae into the Condylus medialis tibiae.

Arteries of the Sole of the Foot

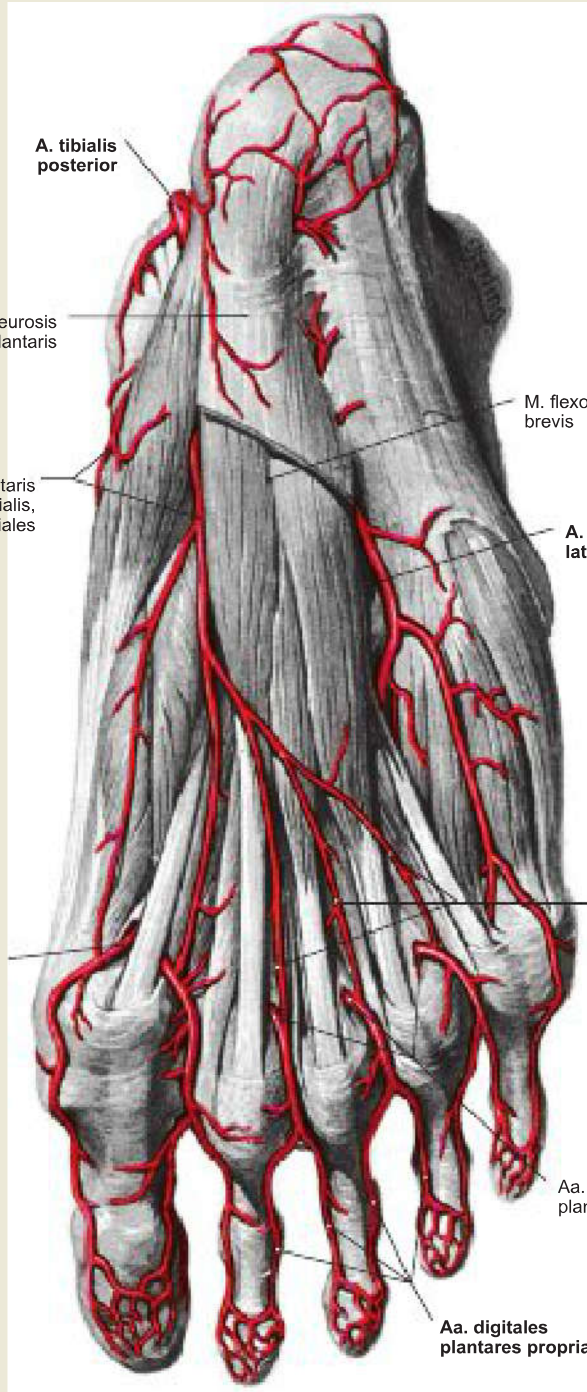


Fig. 4.142 Superficial arteries of the sole of the foot, right side; plantar view; after removal of the plantar aponeurosis. [S010-2-16]
After passing through the malleolar canal/tarsal tunnel the **A. tibialis posterior** divides into its two terminal branches in the sole of the foot:

- **A. plantaris medialis:** runs medially of the M. flexor digitorum brevis.
- **A. plantaris lateralis:** runs laterally under the M. flexor digitorum brevis. Both vessels together form the Arcus plantaris profundus (→ Fig. 4.143).

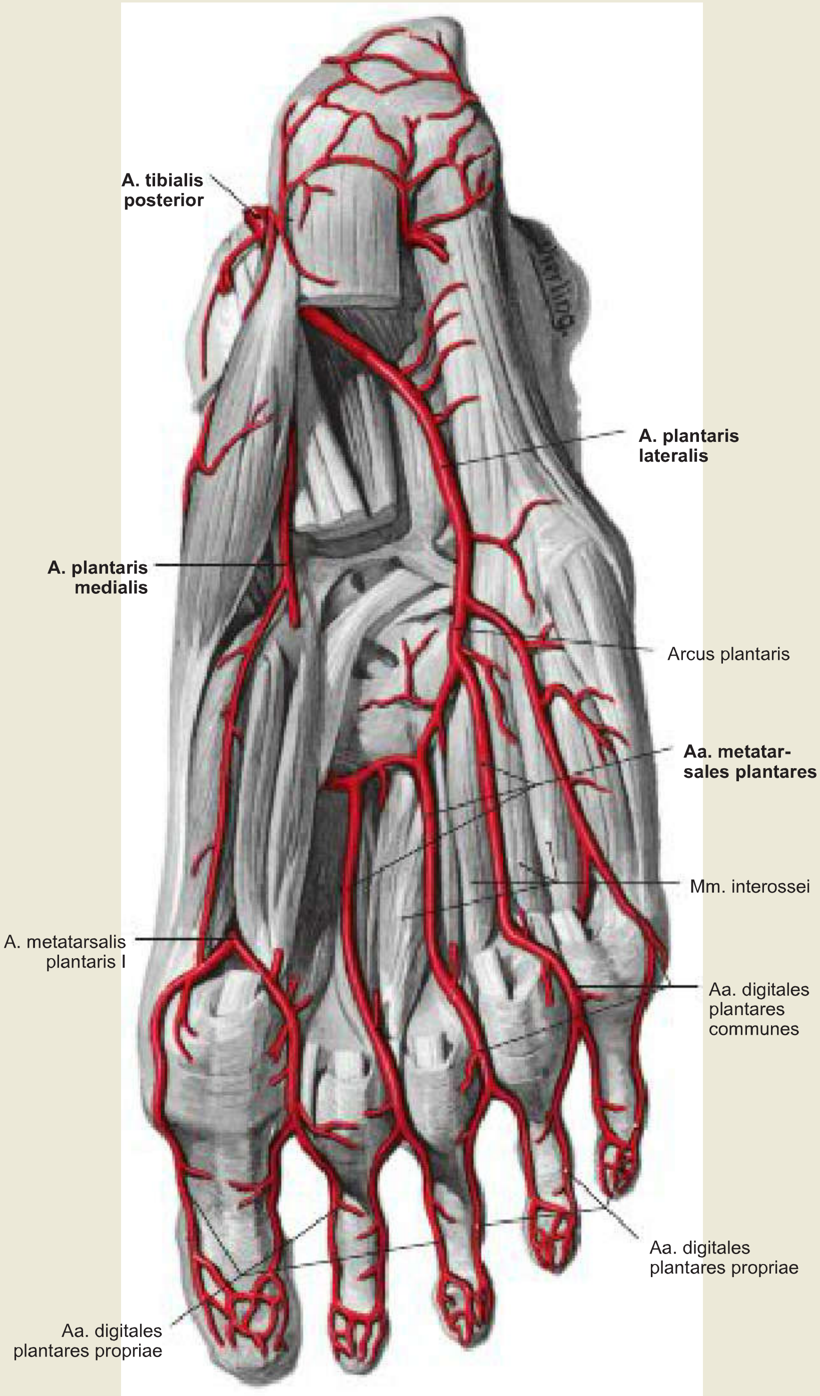


Fig. 4.143 Deep arteries of the sole of the foot, right side; plantar view; after removal of the plantar aponeurosis, the M. flexor digitorum brevis and the tendons of the Mm. flexores digitorum longus and hallucis longus. [S010-2-16]

The A. plantaris lateralis forms the arterial arch of the sole of the foot **(Arcus plantaris profundus),** which is completed by a deep branch of the A. plantaris medialis. The Aa. metatarsales plantares of the deep arterial arch supply the plantar side of the toes, together with the Aa. digitales plantares communes and the Aa. digitales plantares propriae.

Veins of the Leg

Fig. 4.144 Veins of the leg, right side; ventral view. [L127]
The veins of the **deep venous system** (dark blue) accompany the corresponding arteries. In the leg, two veins usually accompany the respective arteries, whereas in the thigh and the popliteal fossa only one concomitant vein is found. The **superficial venous system** of the lower limb (light blue) consists of two main vascular trunks which collect the blood from the dorsum and the sole at the sides of the foot.
The **V. saphena magna** originates at the medial sides of the foot, **anterior** to the medial ankle and ascends along the medial side of the lower leg and thigh to the Hiatus saphenus (→ Fig. 4.157). In the area of the so-called **venous star** it collects several tributaries from the inguinal region (see below) and drains deep inside into the V. femoralis.

On the dorsal aspect, the **V. saphena parva** starts at the lateral side of the foot **behind** the lateral ankle and runs over the middle of the calf into the popliteal fossa, where it drains into the V. poplitea. The V. saphena magna and the V. saphena parva are connected via variable branches.

Tributaries of the V. saphena magna in the area of the venous star:
- V. epigastrica superficialis
- V. circumflexa ilium superficialis
- V. saphena accessoria (inconstant and variable)
- Vv. pudendae externae

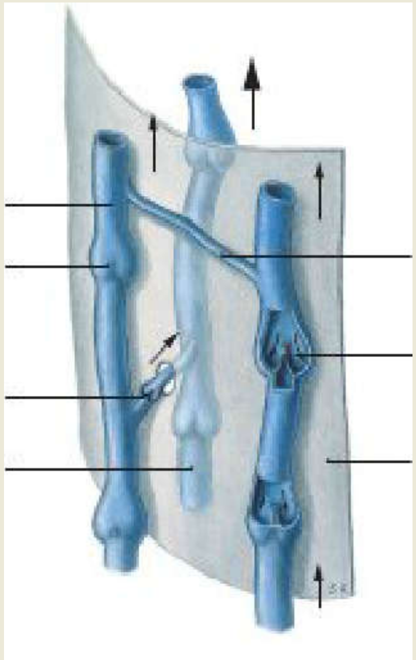


Fig. 4.145 Superficial and deep veins of the leg with venous valves: structural principle. [L238]

There is a **superficial** epifascial **venous system** in the limbs, as well as a **deep subfascial venous system** which accompanies the respective arteries. Both systems are connected by perforating veins **(Vv. perforantes)**. As **venous valves** direct the blood flow from the superficial towards the deep veins, the majority of the blood (85%) is transported back to the heart by the deep veins of the leg. Of the many perforating veins, three groups are of particular clinical relevance:

- DODD's perforating veins: medial aspect of the thigh, in the middle third
- BOYD's perforating veins: medial aspect of the proximal lower leg (below the knee)
- COCKETT's perforating veins: medial aspect of the distal lower leg

Fig. 4.146 Acute venous thrombosis in the leg with a large thrombus plug (arrows) in the V. femoralis. [R132]

Clinical Remarks

As the blood mainly flows via the deep veins of the legs to the heart, there is the risk that in the case of **deep vein thrombosis** blood clots can be transported to the lung, resulting in potentially fatal **pulmonary embolism**. An inflammation of the superficial veins **(thrombophlebitis),** e. g. due to prolonged immobilisation, is, however, in most cases a harmless condition.

In the clinic, the V. femoralis is often used as access route for a **right cardiac catheterisation** because the catheter can be inserted into this vein and pushed forward into the right ventricle. In contrast, the superficial veins can be used in **bypass surgery** to bridge occluded sections of the coronary arteries.

Dilation of the superficial veins **(varicosis)** with the formation of swollen varicose veins **(varices)** is a common condition. These are usually the result of a connective tissue weakness with insufficiency of the venous valves, but can also be secondary to a thrombosis with occlusion of the deep veins in the leg. This distinction is important, because the surgical removal of varicose veins **(vein stripping)** should only be carried out in deep veins that are open.

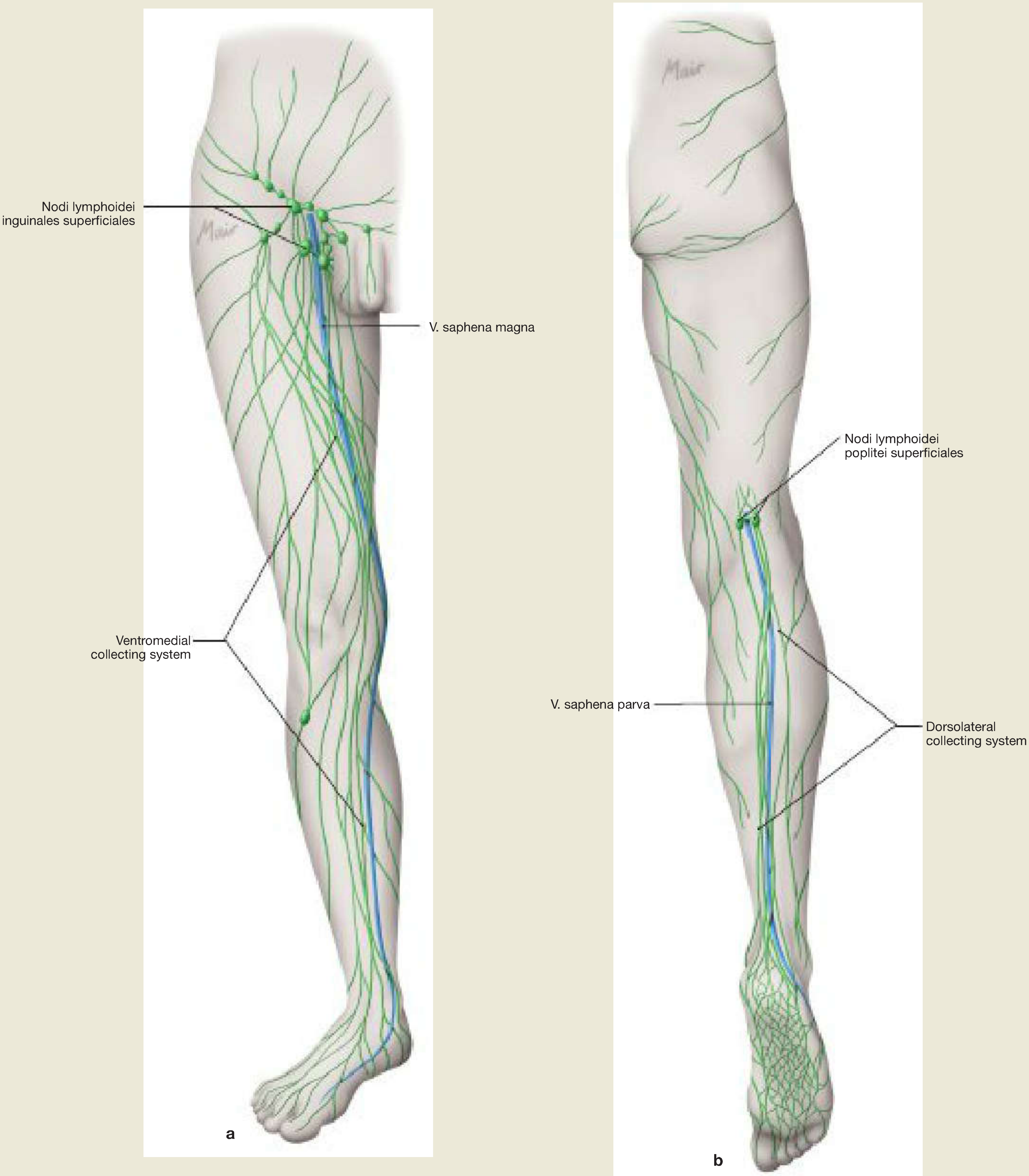


Fig. 4.147a and b Superficial lymphatic vessels of the leg, right side; ventral view (→ Fig. 4.147a) and dorsal view (→ Fig. 4.147b). [L127]
Along the veins of the leg there is a **superficial** and a **deep** system of lymphatic vessels or trunks **(bundles of collecting vessels),** and interposed lymph nodes in certain places. The superficial **ventromedial system** alongside the V. saphena magna is the main lymphatic drainage system of the lower limb and drains into the superficial inguinal lymph nodes **(Nodi lymphoidei inguinales superficiales)** (→ p. 403). The smaller **dorsolateral system** drains only the lateral side of the foot. It runs adjacent to the V. saphena parva and flows to the lymph nodes of the popliteal fossa (**Nodi lymphoidei poplitei superficiales** and **profundi**), and from there it drains into the deep inguinal lymph nodes **(Nodi lymphoidei inguinales profundi).** The deep collecting systems drain directly into the deep popliteal and inguinal lymph nodes.
While the venous drainage of the leg mainly occurs via the deep veins, the major part of the lymph is drained via the superficial collecting system.

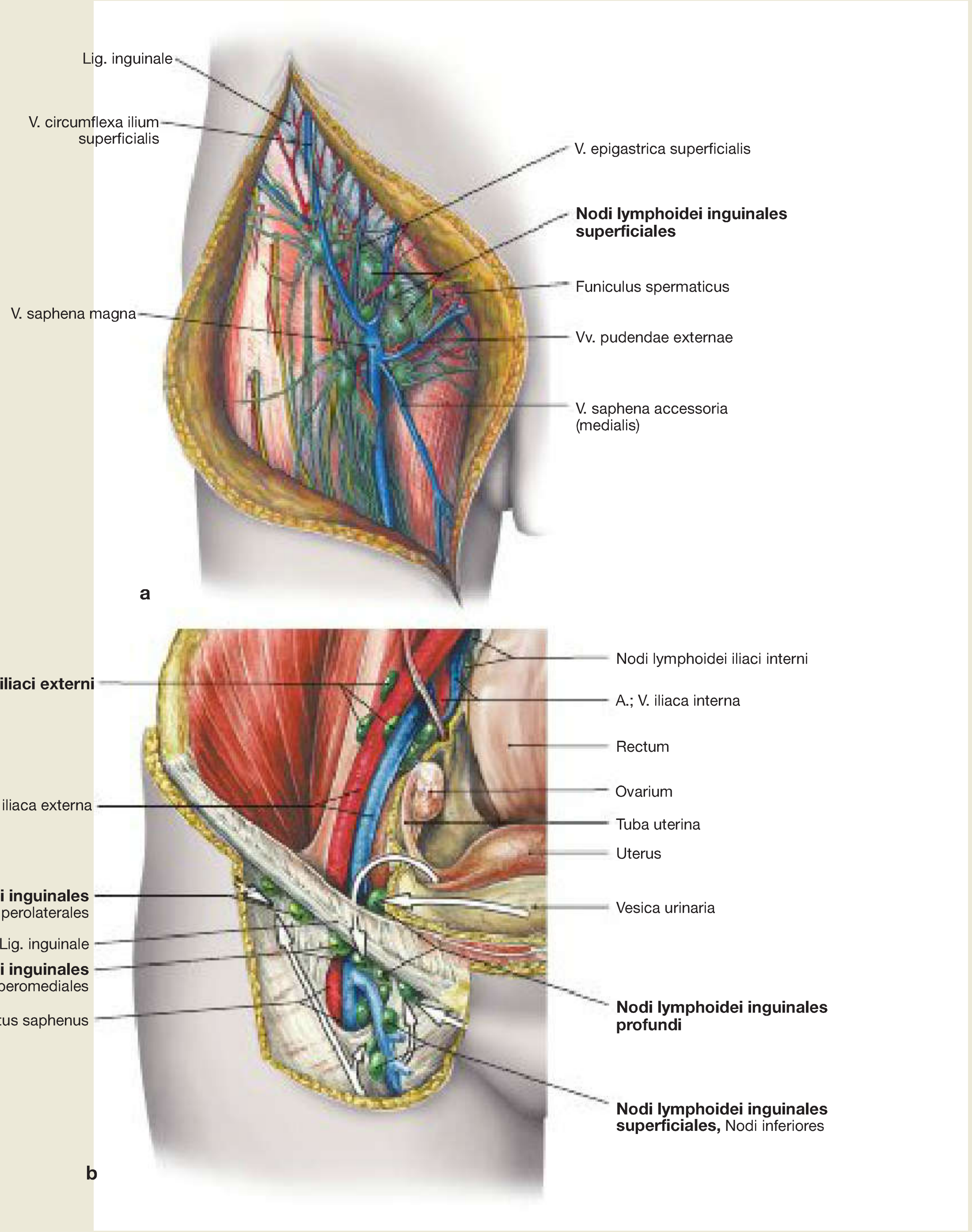


Fig. 4.148a and b Superficial lymph nodes of the inguinal region, Regio inguinalis (→ Fig. 4.148a) and their collection areas (→ Fig. 4.148b), right side; ventral view.

The groin harbours four to 25 superficial inguinal lymph nodes **(Nodi lymphoidei inguinales profundi),** from which the lymph is drained into one to three deep inguinal lymph nodes, located medially of the V. femoralis **(Nodi lymphoidei inguinales profundi)**, and then further into the Nodi lymphoidei iliaci externi in the pelvis. The superficial inguinal lymph nodes form a **vertical strand** along the V. saphena magna and a **horizontal strand** under the inguinal ligament.

The inguinal lymph nodes are not only the regional lymph nodes for most of the leg but also collect the lymph from the lower quadrants of the **abdominal wall** and the **back**, as well as the **perineal region** and the **external genitalia** (→ Fig. 2.110–2.113). The lymph from the **lower parts of the anal canal** and the **vagina**, as well as from the **uterus** and the adjacent uterine tubes (via lymphatic vessels along the Lig. teres uteri) also drains into the inguinal lymph nodes.

Clinical Remarks

Palpation of the lymph nodes is part of a complete physical examination. The inguinal lymph nodes represent the regional lymph nodes for nearly the entire leg. Only for the lateral side of the foot and the calf the generally non-palpable lymph nodes in the popliteal fossa are the first lymph node station. Therefore metastases can be transported into the inguinal region from all the above mentioned areas as well as from the anal canal and the internal female sex organs. In men, however, only the lymph flow from the external genitalia (penis, scrotum) is directed to the inguinal lymph nodes, while the lymph from the testes is drained into the lumbar lymph nodes via the spermatic cord.

Superficial Vessels and Nerves of the Inguinal Region and the Thigh

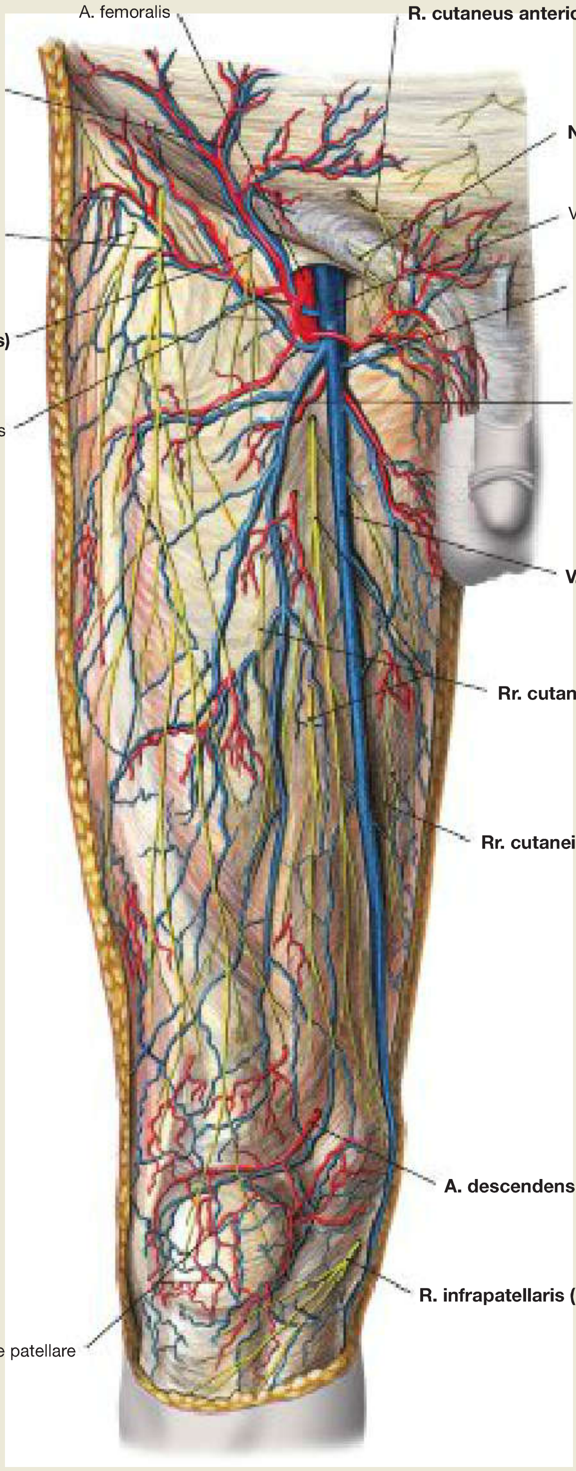


Fig. 4.149 Epifascial vessels and nerves of the inguinal region, Regio inguinalis, of the anterior thigh, Regio femoris anterior, and knee regions, Regio genus anterior, right side; ventral view.

With dissections in this region, the course of the cutaneous nerves and of the epifascial veins should especially be considered. The **N. ilioinguinalis** emerges from the inguinal canal above the inguinal ligament. The **R. cutaneus anterior** of the **N. iliohypogastricus** can be found just cranially. The **V. saphena magna** ascends along the medial side of the thigh and flows into the V. femoralis at the Hiatus saphenus. Here the vein collects several tributaries from the inguinal region, forming the so-called **venous star** (→ p. 400). These veins usually accompany thin arterial branches of the A. femoralis. Laterally of the A. femoralis, the **R. femoralis** of the **N. genitofemoralis** passes through the Lacuna vasorum. Medially of the Spina iliaca anterior superior, the **N. cutaneus femoris lateralis** passes through the Lacuna musculorum and innervates the lateral side of the thigh with its branches. The **Rr. cutanei anteriores** of the **N. femoralis** penetrate the fascia at different points and innervate the anterior side of the thigh. Medially of the V. saphena magna, several small **cutaneous branches of the N. obturatorius** supply a variable area on the medial aspect of the thigh. Medially below the knee, the fascia is pierced by the **R. infrapatellaris** of the **N. saphenus**. Just above the patella, the thin A. descendens genus runs to the Rete patellare.

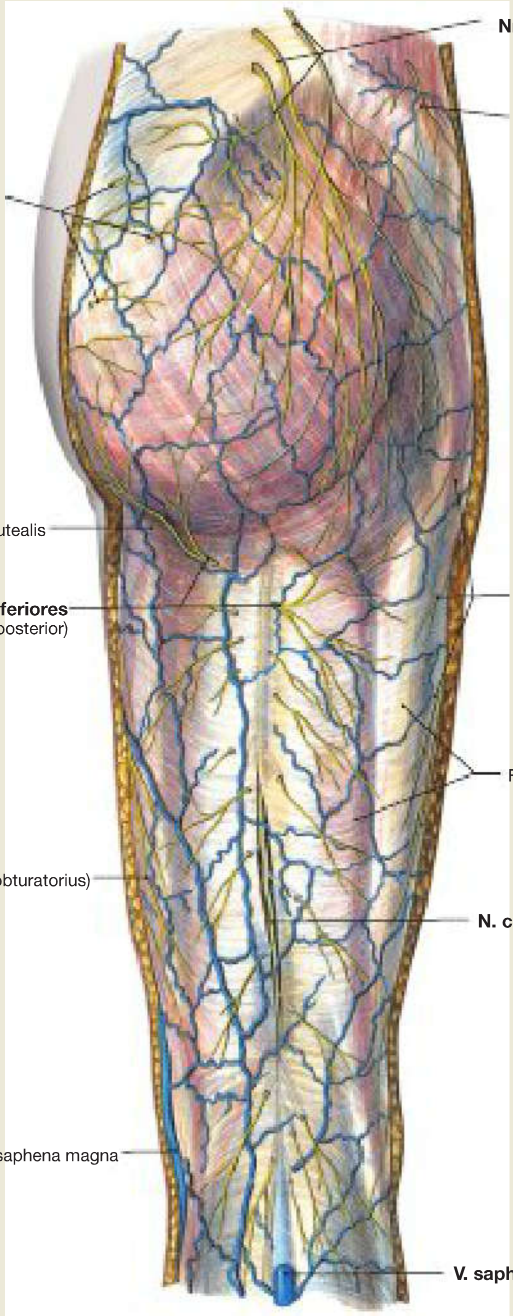


Fig. 4.150 Epifascial vessels and nerves of the gluteal region, Regio glutealis, thigh, Regio femoris posterior, popliteal fossa, Fossa poplitea, right side; dorsal view.

There are no significant epifascial veins on the posterior side of the thigh. The V. saphena parva of the leg flows into the subfascial V. poplitea in the popliteal fossa. The skin of the gluteal region is innervated by three groups of cutaneous nerves. The **Nn. clunium superiores** (Rr. posteriores from L1–L3) pass laterally of the autochthonous muscles of the back across the iliac crest. The **Nn. clunium medii** (Rr. posteriores from S1–S3) penetrate the M. gluteus maximus at its origin on the posterior side of the sacrum. In contrast, the **Nn. clunium inferiores** are branches of the N. cutaneus femoris posterior and ascend around the caudal side of the M. gluteus maximus. The **N. cutaneus femoris posterior** descends in the middle of the thigh, mostly piercing the fascia half way down, in order to provide sensory innervation to the posterior thigh.

Superficial Vessels and Nerves of the Leg

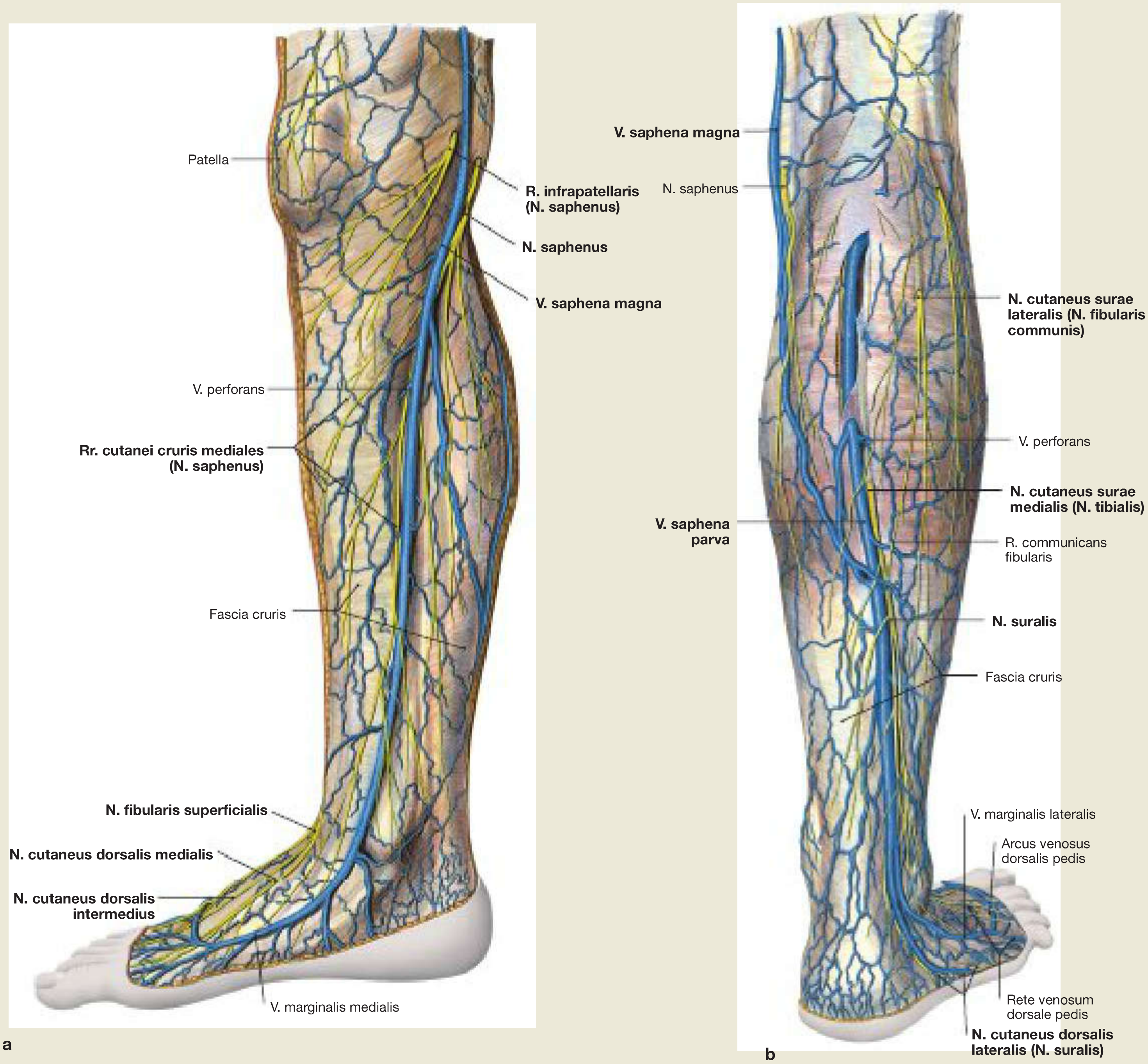


Fig. 4.151a and b Epifascial veins and nerves of the leg region, Regio cruris, and the foot region, Regio pedis, right side; medial view (→ Fig. 4.151a) and dorsolateral view (→ Fig. 4.151b).

The **V. saphena magna** originates from the medial side of the foot anterior to the medial ankle and ascends along the medial side of the leg and thigh. On the medial side of the knee, the **N. saphenus** pierces the fascia. Its nerve trunk joins the V. saphena magna dorsally and runs along the vein, where it divides into its sensory **Rr. cutanei cruris mediales**, which provide sensory innervation to the anterior and medial aspects of the leg and down to the medial side of the foot. The **R. infrapatellaris** of the N. saphenus passes ventrally of the V. saphena magna through the fascia and innervates the skin below the patella. In the distal third of the lateral aspect of the leg, the **N. fibularis superficialis** penetrates the fascia and divides into its two terminal branches (**Nn. cutanei dorsales medialis** and **intermedius**), that continue on the dorsum of foot. On the posterior side of the leg, the **V. saphena parva** emerges from the epifascial veins of the lateral side of the foot, and ascends behind the lateral ankle on the posterior side of the leg, penetrating the fascia in the popliteal fossa to flow into the V. poplitea. It runs alongside the **N. cutaneus surae medialis**, a branch of the N. tibialis, which in the distal third of the leg continues in a distal direction as **N. suralis.** This nerve usually receives a communicating branch from the **N. cutaneus surae lateralis** or directly from the N. fibularis communis. The terminal branch of the N. suralis is the **N. cutaneus dorsalis lateralis**, which innervates the lateral side of the dorsum of the foot.

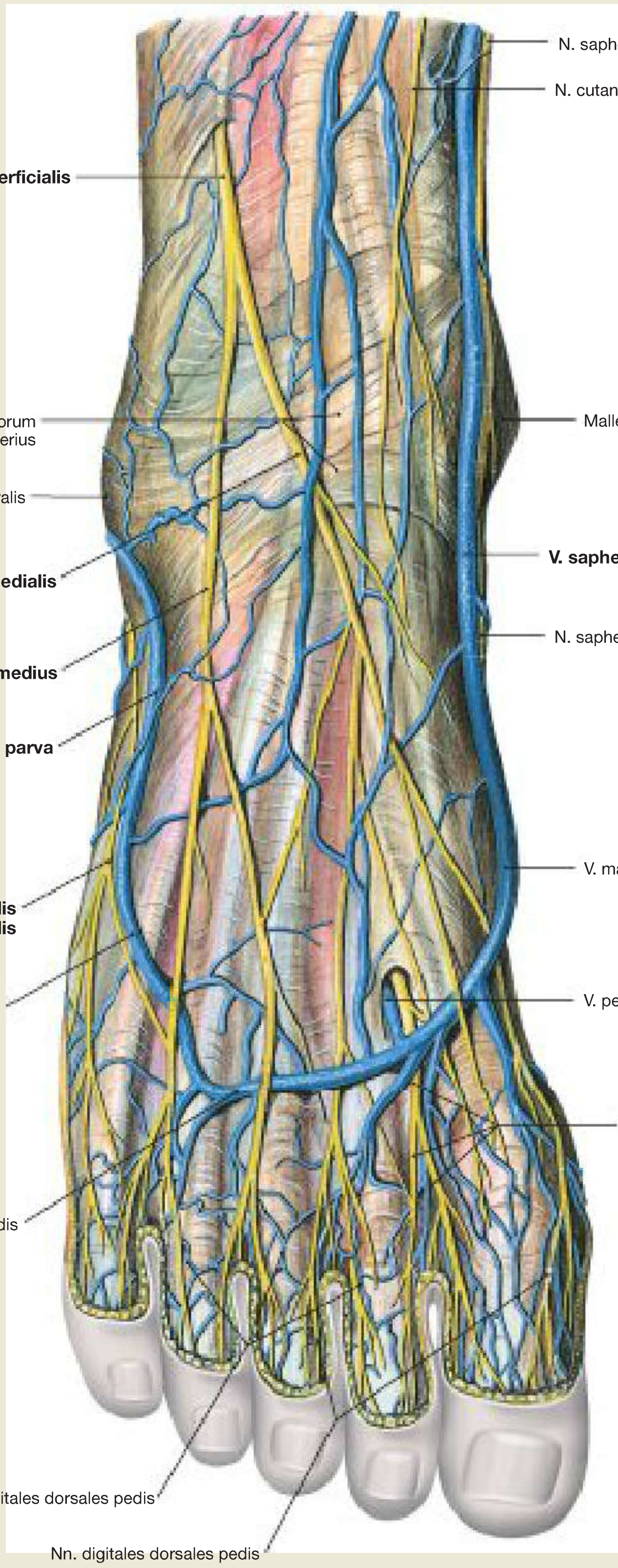


Fig. 4.152 Epifascial veins and nerves of the dorsum of the foot, Dorsum pedis, right side; dorsal view in relation to the Dorsum pedis.

The **V. saphena magna** originates from the epifascial veins of the dorsum of the foot at the medial side, and thus is a continuation of the Arcus venosus dorsalis. The smaller **V. saphena parva** emerges on the lateral side of the foot. At the distal end of the leg, the **N. fibularis superficialis** passes laterally through the fascia, and generally only thereafter divides into the **Nn. cutanei dorsales medialis** and **intermedius,** that provide sensory innervation to the dorsum of the foot and the toes. The lateral side of the foot is innervated by the **N. cutaneus dorsalis lateralis** from the N. suralis. Only the first interdigital space receives its sensory innervation from the terminal branches of the **N. fibularis profundus** that penetrate the fascia here.

Vessels and Nerves of the Thigh

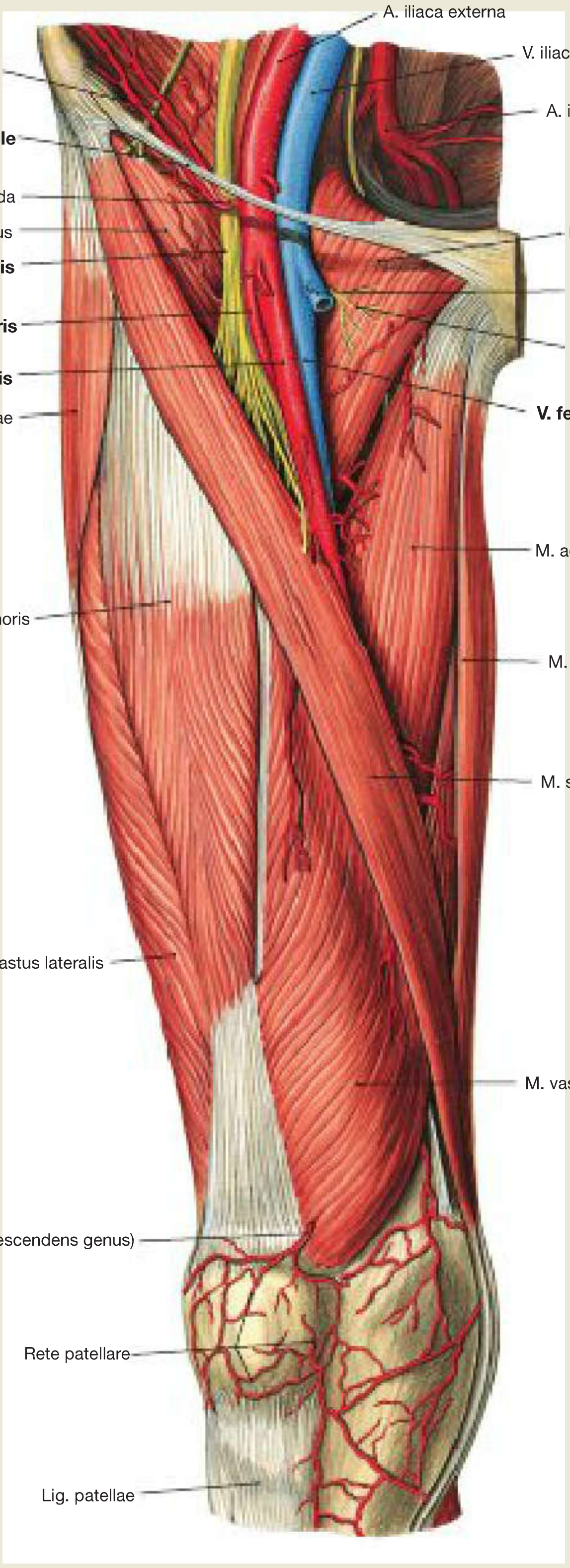


Fig. 4.153 Vessels and nerves of the thigh, Regio femoris anterior, right side; ventral view.

After removal of the Fascia lata, the individual muscles and the subfascial vessels and nerves are displayed in the femoral triangle **(Trigonum femorale).** The femoral triangle is limited proximally by the inguinal ligament **(Lig. inguinale),** medially by the M. gracilis and laterally by the M. sartorius.

From medially to laterally, the V. femoralis, the A. femoralis and the N. femoralis pass below the inguinal ligament. The **V. femoralis** flows into the **V. saphena magna.** The **A. femoralis** sends various small arteries into the inguinal region, and the **A. profunda femoris** also branches off 3–6 cm below the inguinal ligament. In the Fossa iliopectinea, the **N. femoralis** branches out in a fan-like pattern into the **N. saphenus**, which continues the course of the N. femoralis below the M. sartorius, into various **Rr. musculares** for the ventral muscle group of the thigh and the M. pectineus, as well as the sensory **Rr. cutanei anteriores**, supplying the skin on the anterior aspect of the thigh. Medially of the Spina iliaca anterior superior, the **N. cutaneus femoris lateralis** enters the Lacuna musculorum below the inguinal ligament.

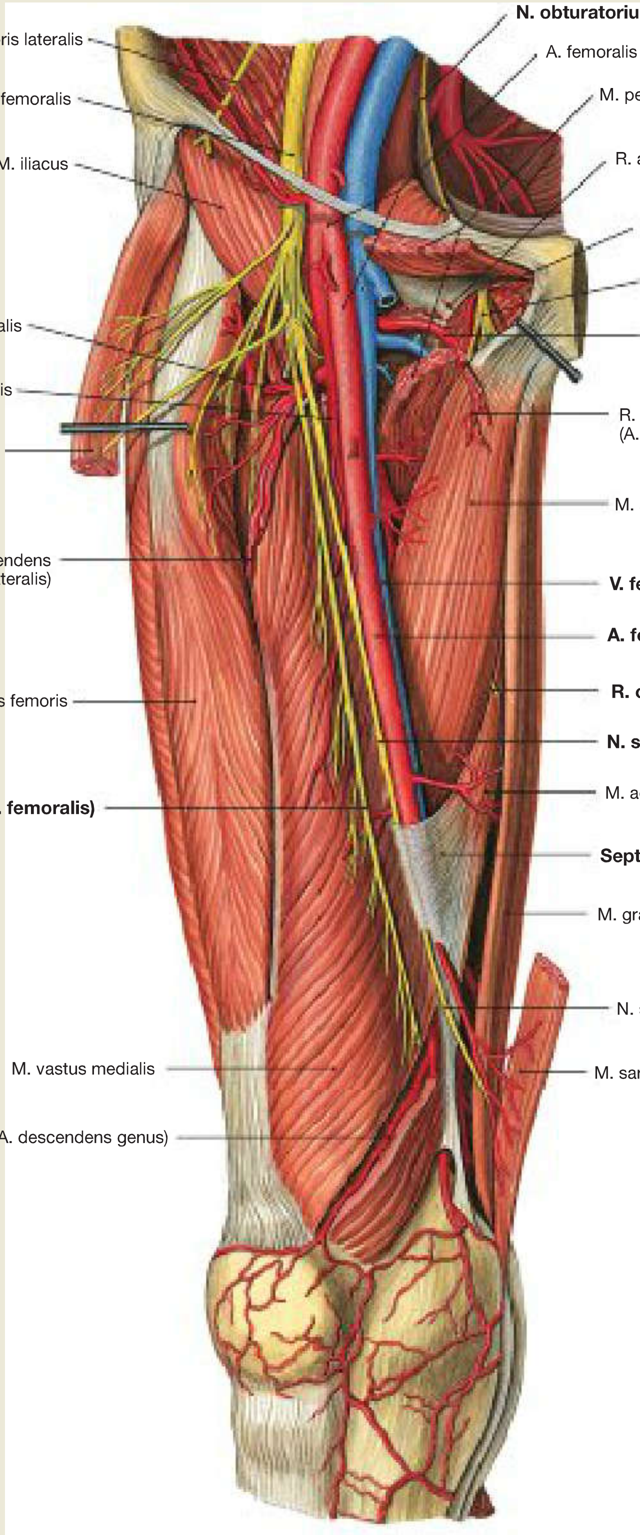


Fig. 4.154 Vessels and nerves of the anterior thigh, Regio femoris anterior, right side, ventral view; after partial removal of the M. sartorius and cutting through of the M. pectineus.
The **A. and V. femoralis** and the **N. saphenus** can be followed until they enter the adductor canal **(Canalis adductorius)**. The entrance of the adductor canal is formed by the M. vastus medialis, the M. adductor longus and the **Septum intermusculare vastoadductorium** which spans these muscles and the M. adductor magnus. By splitting the M. pectineus, the outlet of the **Canalis obturatorius** through which the **N. obturatorius** and the **A. and V. obturatoria** leave the pelvis, becomes visible.

Clinical Remarks

Lesions of the CNS or cerebral strokes may result in **spasticity**. The muscle tone of the adductors innervated by the N. obturatorius may be raised to such an extent that the legs cannot be spread and walking and standing become impossible. To relieve their spasms, several muscles can be relaxed by botulinus injections. These injections inhibit the signal transmission at the motor endplates. However, sometimes it is more effective to irreversibly damage the **N. obturatorius with phenol injections**. The needle is thereby inserted a few centimetres lateral to the pubic symphysis and under the inguinal ligament, to inject the N. obturatorius where it exits from the Canalis obturatorius.

Vessels and Nerves of the Thigh

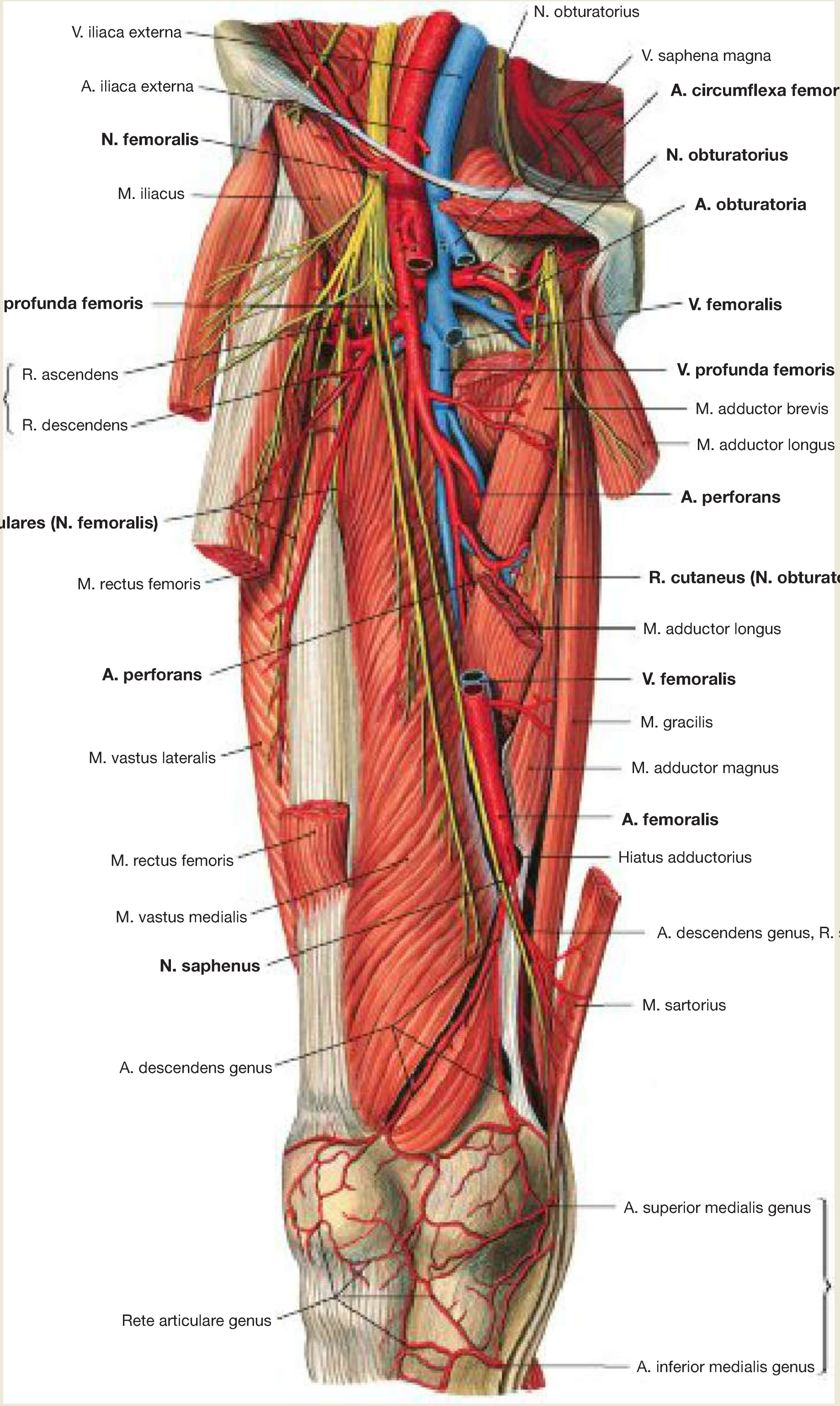


Fig. 4.155 Vessels and nerves of the anterior thigh, Regio femoris anterior, right side; ventral view; after partial removal of the M. sartorius and the M. rectus femoris as well as after cutting through the M. pectineus and M. adductor longus. The adductor canal is largely opened. The **A. profunda femoris** with its branches can be seen here. This artery originates 3–6 cm below the inguinal ligament and is the main supplying vessel of the thigh and femoral head (→ pp. 319 and 394). Its branches are the **Aa. circumflexae femoris medialis and lateralis,** which sometimes also originate independently from the A. femoralis. The A. circumflexa femoris medialis supplies the femoral neck and head with a deep branch, as well as the adductor muscles and the proximal parts of the hamstring muscles. It anastomoses with the **A. obturatoria,** which also contributes to the blood supply of the adductor muscles and the hip socket (acetabulum). The R. ascendens of the A. circumflexa femoris lateralis supplies the lateral muscles of the hip, and its R. descendens supplies the anterior muscles of the thigh. The main trunk of the A. profunda femoris is descending and releases usually three **Aa. perforantes** that pass onto the posterior side of the thigh to supply the deep adductor and hamstring muscles.

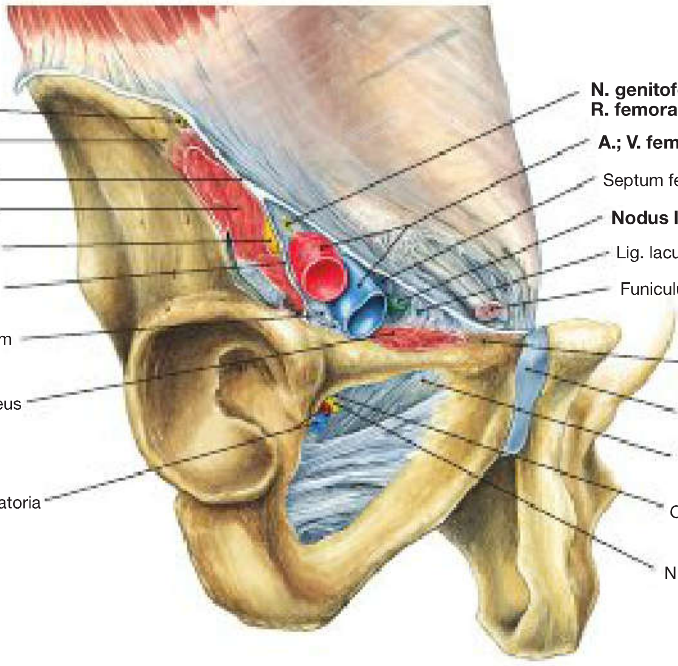


Fig. 4.156 Lacunae musculorum and vasorum, right side; oblique section at the level of the inguinal ligament; ventral view.
The space between the Os coxae and the **Lig. inguinale** (Fossa iliopectinea) is divided by the Arcus iliopectineus, which connects the inguinal ligament to the pelvic bones, into the lateral **Lacuna musculorum** and the **medial Lacuna vasorum**. The Lacuna musculorum is almost completely occupied by the **M. iliopsoas**. On this muscle lie two nerves, the **N. cutaneus femoris lateralis,** which is closely lateral to the Spina iliaca anterior superior, and medially, the **N. femoralis.** In the Lacuna vasorum lie (from lateral to medial) the **R. femoralis** of the **N. genitofemoralis,** the **A. femoralis,** the **V. femoralis**, and the deep inguinal lymph nodes **(Nodi lymphoidei inguinales profundi),** which are located most medially.

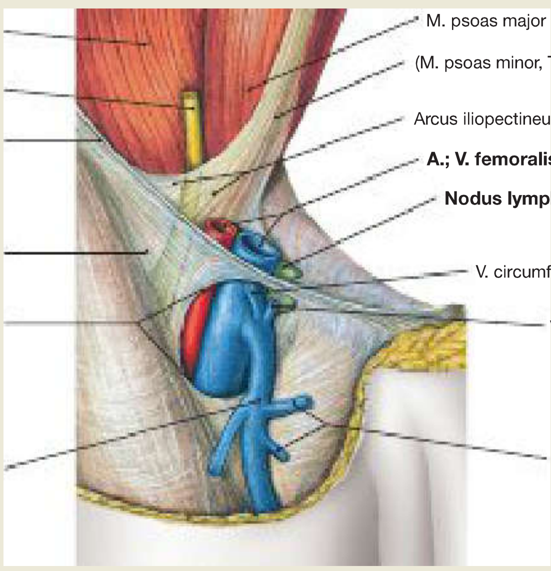


Fig. 4.157 Hiatus saphenus and Lacuna vasorum, right side; ventral view; after removal of the anterior abdominal wall, the Fascia iliaca and the abdominal viscera.
The Hiatus saphenus is an opening in the Fascia lata for the passage of the V. saphena magna before it flows into the V. femoralis. The deep inguinal lymph nodes **(Nodi lymphoidei inguinales profundi)** are located most medially in the Lacuna vasorum.

Clinical Remarks

The **topography of the Fossa iliopectinea** is of great importance for diagnostic and therapeutic interventions. From medially **(i**nner side) to laterally, the large vessels are arranged in the following sequence: **V.** femoralis, **A.** femoralis and **N.** femoralis **(iVAN).** Since the pulse of the A. femoralis is easily palpable, access to the V. femoralis is gained by piercing the skin about 1 cm medial of the artery, when a cardiac catheter is inserted into the right ventricle via the V. femoralis. The N. femoralis runs laterally to this artery, which is punctured, for example, to test the arterial blood gases as well as for a left cardiac catheterisation, and these procedures can damage the nerve.

Vessels and Nerves of the Gluteal Region and Thigh

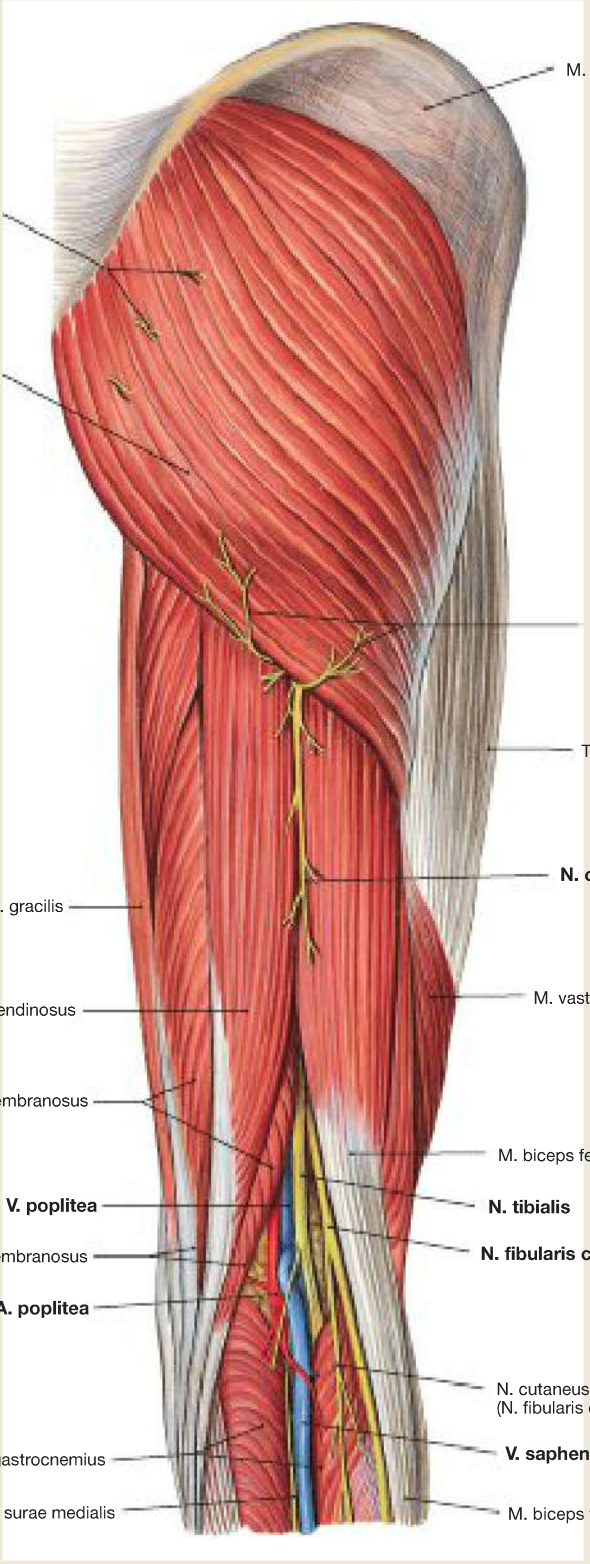


Fig. 4.158 Vessels and nerves of the gluteal region, Regio glutealis, posterior thigh, Regio femoris posterior, and popliteal fossa, Fossa poplitea, right side; dorsal view; after removal of the Fascia lata.

The **N. cutaneus femoris posterior** provides sensory innervation to the posterior aspect of the thigh. At the lower edge of the M. gluteus maximus, the nerve enters the groove between the M. biceps femoris and the M. semitendinosus, and runs below the fascia (subfascial) to the middle of the thigh; this has to be considered in dissections. On the distal thigh, the two muscles diverge and confine the **popliteal fossa (Fossa poplitea).** As a continuation of the A. and V. femoralis, the A. and V. poplitea enter the popliteal fossa after exiting the adductor canal, and they join the terminal branches of the N. ischiadicus (N. tibialis and N. fibularis communis). In the popliteal fossa, the **N. fibularis communis** runs most laterally and superficially, and the **N. tibialis,** the **V. poplitea** and the **A. poplitea (NVA)** follow medially in greater depth. The V. saphena parva ascends along the median line of the leg to the popliteal fossa and drains into the V. poplitea.

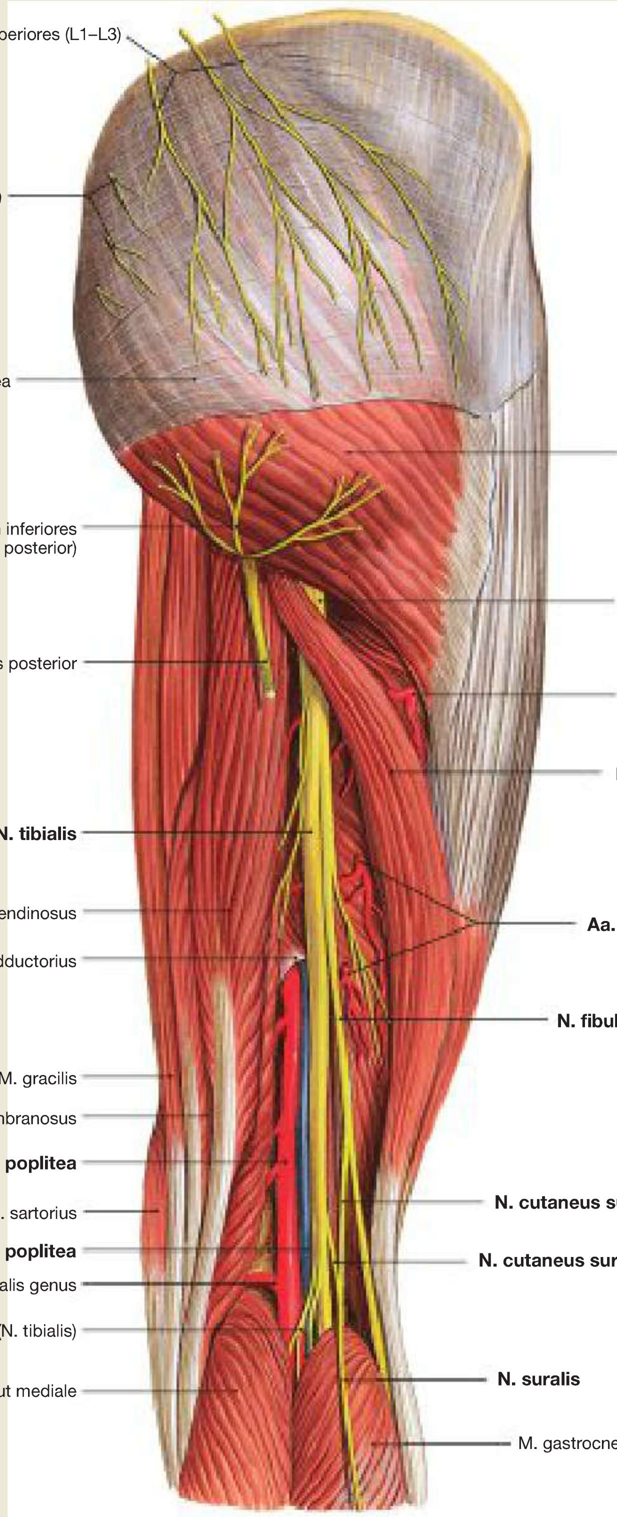


Fig. 4.159 Vessels and nerves of the gluteal region, Regio glutealis, posterior thigh, Regio femoris posterior, and popliteal fossa, Fossa poplitea, right side; dorsal view; after removal of the Fascia lata and lateral deflection of the Caput longum of the M. biceps femoris.

The **N. ischiadicus** descends under the guidance of the M. biceps femoris to the thigh. Usually at the level of the distal third (or significantly higher, as shown here), the N. ischiadicus divides into two terminal branches, of which the **N. tibialis** continues its course, while the **N. fibularis communis** turns laterally and winds around the fibular head below the popliteal fossa, before entering the fibular compartment. Mostly in the popliteal fossa, the cutaneous nerves branch off, providing sensory innervation to the calf, the N. tibialis releasing the **N. cutaneus surae medialis**, and the N. fibularis communis releasing the **N. cutaneus surae lateralis**. The **N. suralis** is formed by the N. cutaneus surae medialis, which often receives a communicating branch of the N. cutaneus surae lateralis. At the thigh, the **Aa. perforantes** of the A. profunda femoris penetrate the M. adductor magnus laterally of the N. ischiadicus, in order to supply the hamstring muscles.

Vessels and Nerves of the Gluteal Region and Thigh

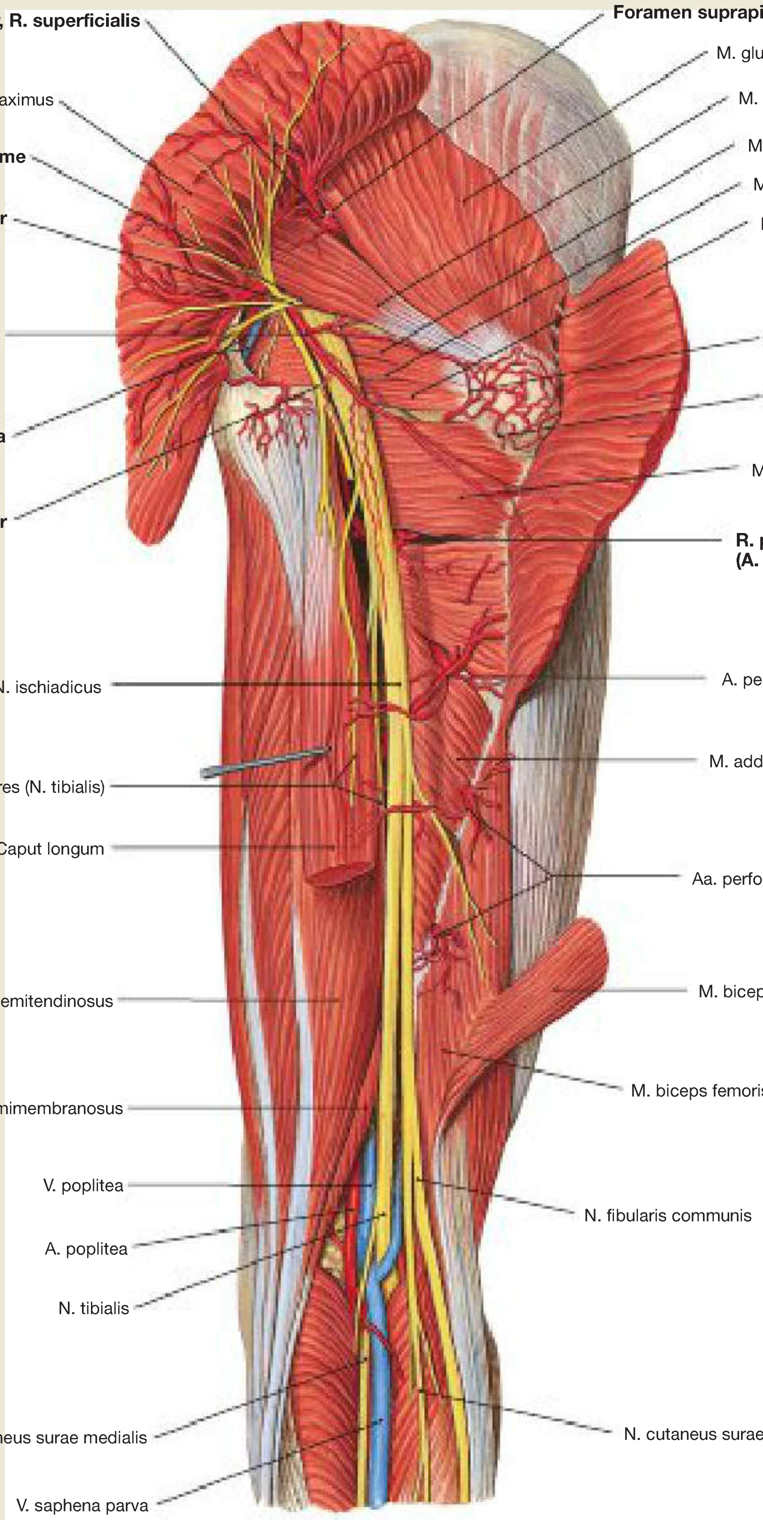


Fig. 4.160 Vessels and nerves of the gluteal region, Regio glutealis, posterior region of the thigh, Regio femoris posterior, and popliteal fossa, Fossa poplitea, right side; dorsal view; after cutting through the M. gluteus maximus and the Caput longum of the M. biceps femoris.

Together with the **N. cutaneus femoris posterior** and the **N. gluteus inferior,** as well as with the **A.** and **V. glutea inferior,** the **N. ischiadicus** passes through the Foramen infrapiriforme. They are accompanied by the **N. pudendus** and the **A.** and **V. pudenda interna,** but immediately wind around the Lig. sacrospinale, in order to pass below the Lig. sacrotuberale and enter the Fossa ischioanalis via the Foramen ischiadicum minus. The N. gluteus inferior innervates the M. gluteus maximus. The **N. gluteus superior** passes together with the **A.** and **V. glutea superior** through the Foramen suprapiriforme but remains in the layer below the M. gluteus medius, which it innervates, along with the deep vascular branches.

Clinical Remarks

The topography of the gluteal region explains why **intramuscular injections** should be applied into the **M. gluteus medius** and not into the M. gluteus maximus – the injection may otherwise cause bleeding or lesions of the nerves that are important for movements of the hip (Nn. glutei superior and inferior) and the leg (N. ischiadicus).

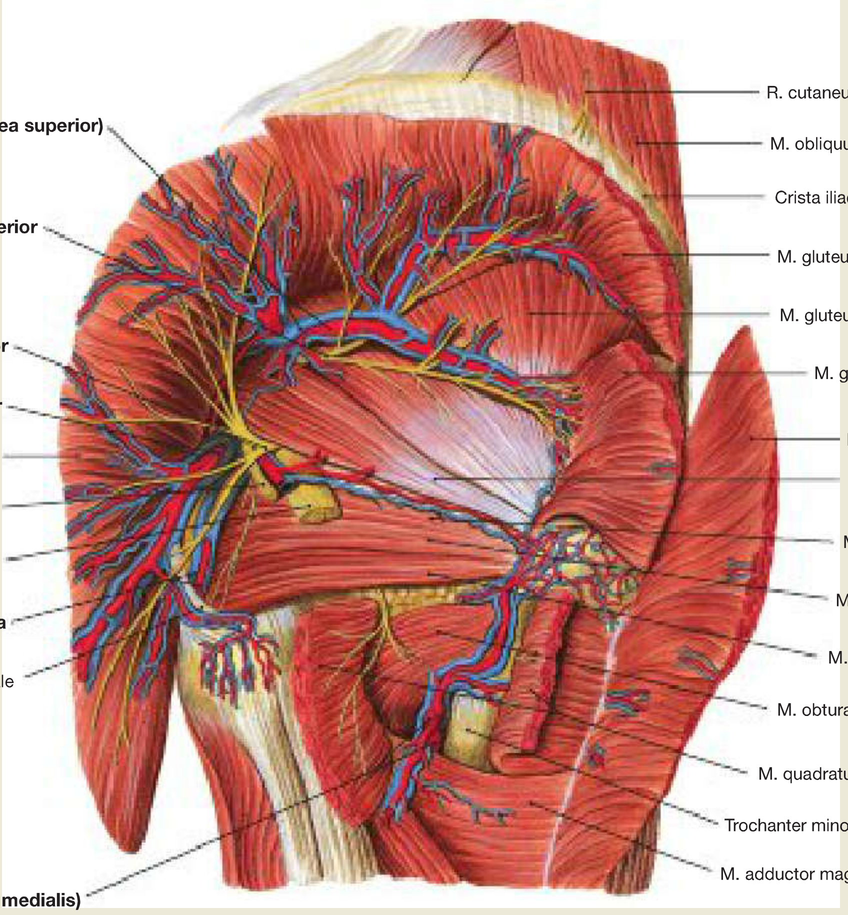
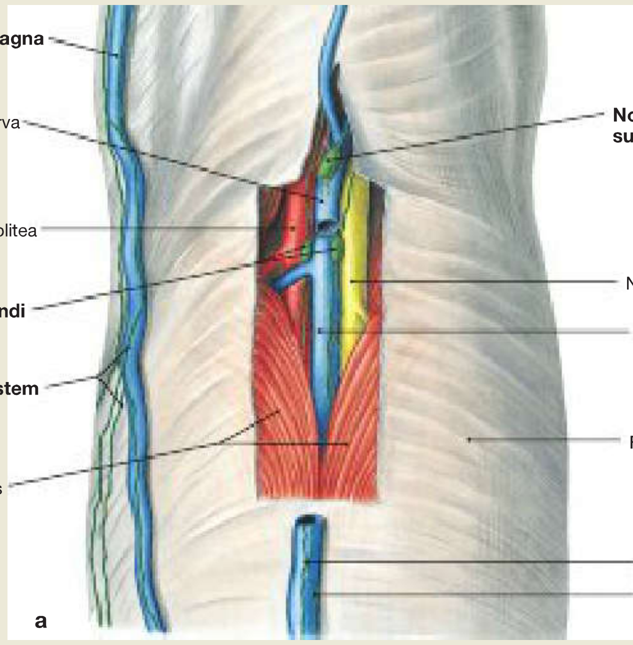


Fig. 4.161 Vessels and nerves of the gluteal region, Regio glutealis, and posterior region of the thigh, Regio femoris posterior, right side; dorsal view; after cutting through and partial removal of the Mm. glutei maximus and medius, and removal of the N. ischiadicus after its passage through the Foramen infrapiriforme. Cutting through the M. gluteus medius exposes the **N. gluteus superior** which passes through the Foramen suprapiriforme together with the **A.** and **V. glutea superior** and then runs laterally between the M. gluteus medius and the deeper M. gluteus minimus to the M. tensor fasciae latae, thereby innervating all these muscles. At different points, several branches of the **A. circumflexa femoris medialis** emerge between the pelvitrochanteric hip muscles. The deep branches of this artery cross the muscles and anastomose with the gluteal arteries.

Clinical Remarks

The topography of the gluteal region is particularly important for **hip joint surgery** needing dorsal access. If at all possible, the pelvitrochanteric muscles (in particular the M. quadratus femoris and M. obturatorius externus) should not be cut to prevent any damage to the A. circumflexa femoris medialis as the most important blood vessel supplying the femoral head.

Vessels and Nerves of the Popliteal Fossa



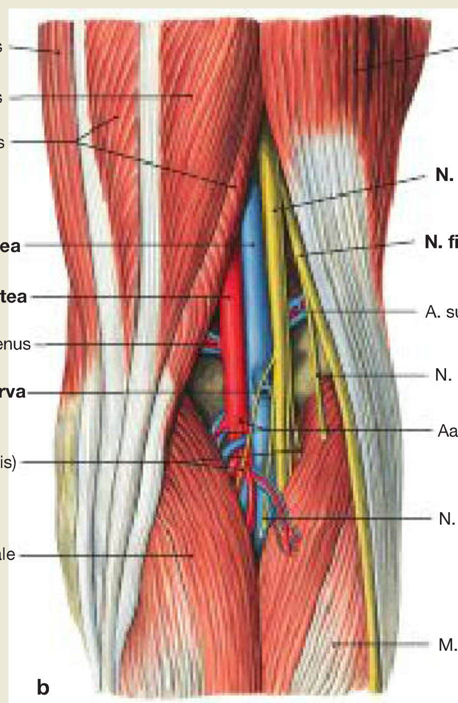


Fig. 4.162a and b Vessels and nerves of the popliteal fossa, Fossa poplitea, right side; dorsal view; after partial (→ Fig. 4.162a) and complete (→ Fig. 4.162b) removal of the fascia.

In the popliteal fossa the **N. fibularis communis** runs laterally and superficially, whereas the **N. tibialis,** the **V. poplitea** and the **A. poplitea (NVA)** run medially and in greater depth. The **V. saphena parva** ascends along the median line of the leg to the popliteal fossa and drains into the V. poplitea. The **dorsolateral lymphatic bundle** follows the course of the V. saphena parva, while the **V. saphena magna** ascends together with the stronger **ventromedial lymphatic bundle**. The first lymph node station for the dorsolateral lymphatic bundle consists of the **Nodi lymphoidei poplitei superficiales** and **profundi** (→ p. 402).

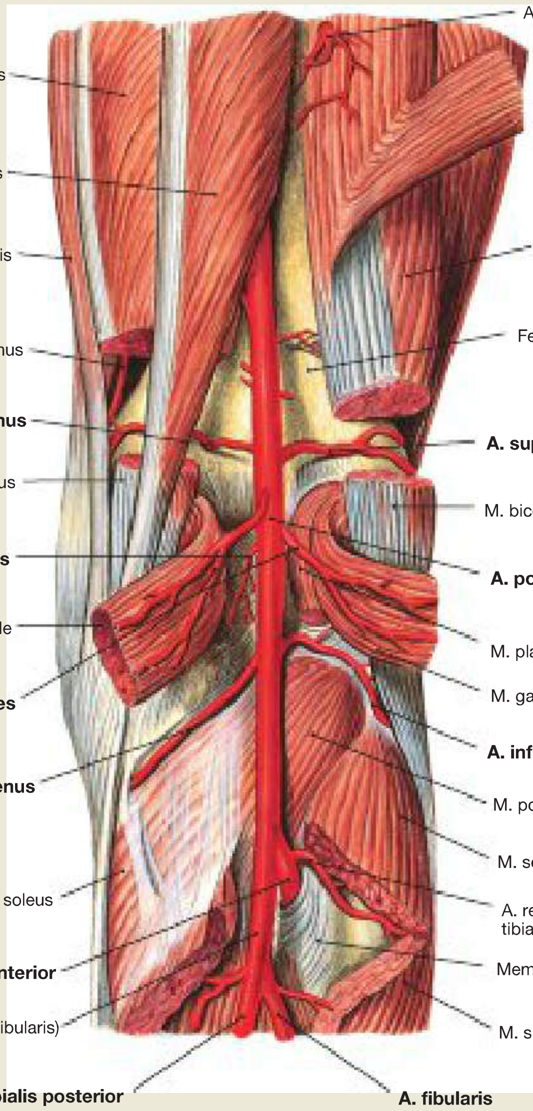


Fig. 4.163 Arteries of the popliteal fossa, Fossa poplitea, right side; dorsal view; after partial removal of the covering muscles.
The **A. poplitea** supplies the knee joint. Its branches above (Aa. superiores medialis and lateralis genus) and below (Aa. inferiores medialis and lateralis genus) the joint space form 'crown-like' vascular plexuses that supply the Rete articulare genus at the front of the knee. At the level of the knee joint, the A. media genus branches off to the knee joint. The Aa. surales supply the calf muscles. Below the popliteal fossa, the A. poplitea passes between the two heads of the M. gastrocnemius and divides into its terminal branches below the tendinous arch of the M. soleus. The **A. tibialis posterior** continues in this direction, while the **A. tibialis anterior** passes through the Membrana interossea cruris into the anterior extensor compartment.

Clinical Remarks

The section of the A. poplitea between the outlet of the A. tibialis anterior and the origin of the A. fibularis, running from the A. tibialis posterior, is also known by its clinical term as the **Truncus tibiofibularis**.

Vessels and Nerves of the Lower Leg

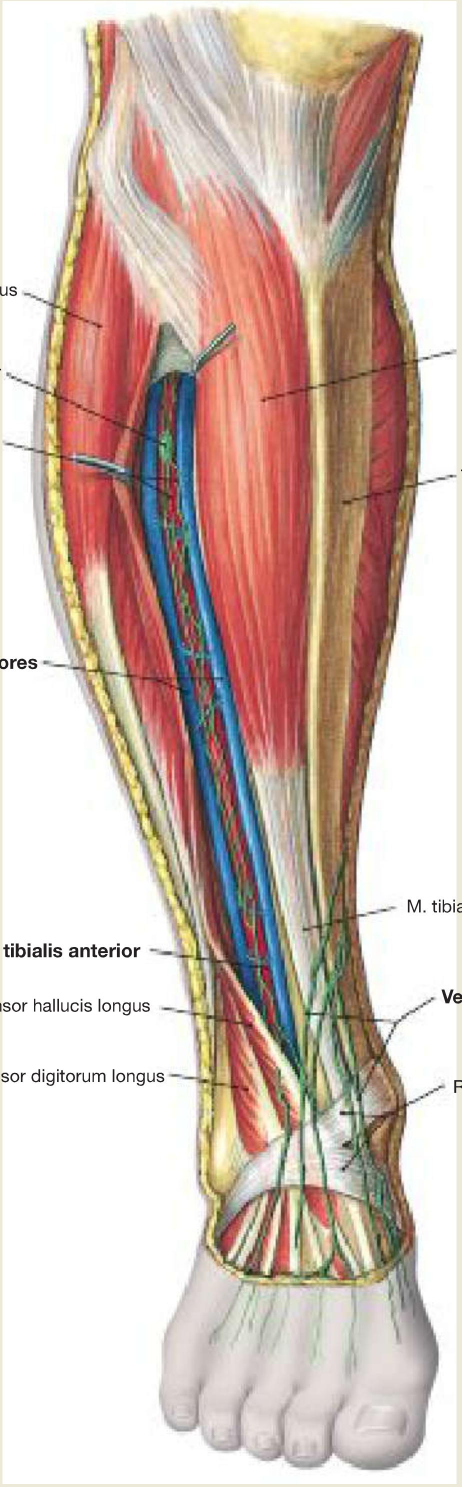


Fig. 4.164 Vessels and nerves of the lower leg, Regio cruris anterior, right side; ventral view; after spreading apart the extensor muscles.

This figure shows sections of the superficial and deep lymphatic systems: The **superficial lymphatic vessels** form the ventromedial lymphatic bundle and join the V. saphena magna at the medial side of the foot, while the dorsolateral lymphatic bundle runs with the V. saphena parva along the lateral side of the foot. The **deep lymphatic vessels** accompany the deep veins and arteries in the three muscular compartments as shown here for the extensor compartment.

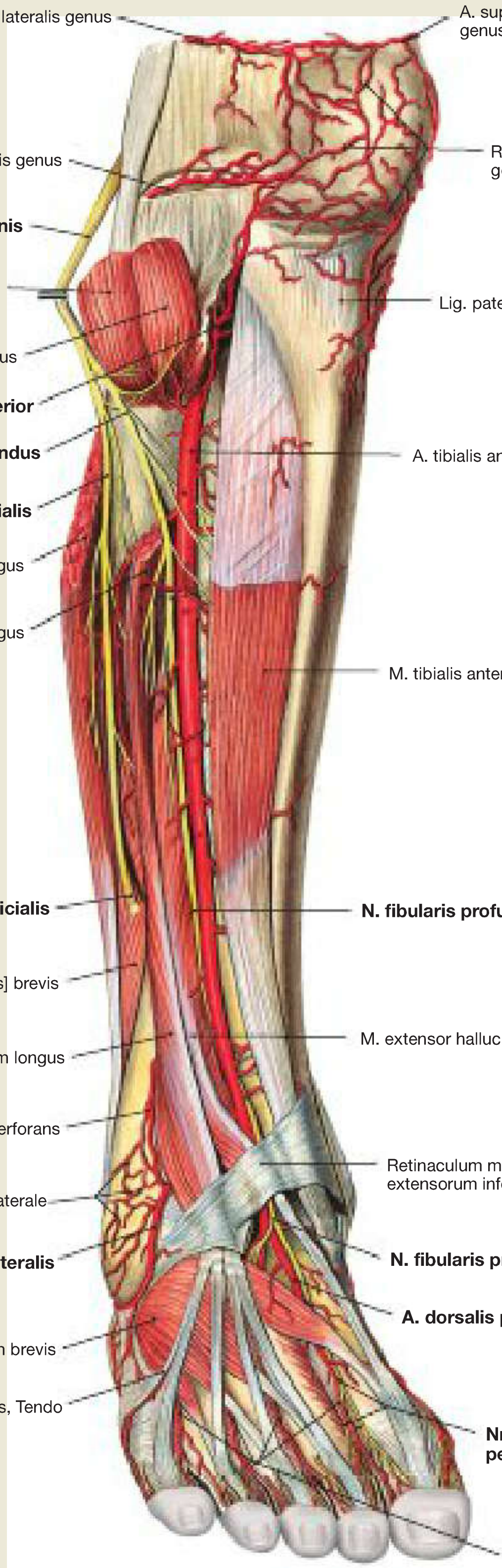


Fig. 4.165 Vessels and nerves of the lower leg, Regio cruris anterior, right side; ventral view; after removal of the Fascia cruris and cutting through the Mm. extensor digitorum longus and fibularis longus.

The **A. tibialis anterior** descends in the extensor compartment between the M. extensor digitorum longus and the M. tibialis anterior, and then continues as **A. dorsalis pedis** on the dorsum of the foot. The **A. recurrens tibialis posterior** is the first branch on the posterior aspect of the leg, then the artery passes through the Membrana interossea cruris, followed by the **A. recurrens tibialis anterior** branching off. At the level of the ankles it sends the **Aa. malleolares anteriores medialis and lateralis** to supply the malleolar vascular networks, that may provide sufficient collateral circulation if one of the arteries of the leg is occluded.

The **N. fibularis communis** winds laterally around the head of the fibula and enters the fibular muscle compartment. Here it divides into two branches, of which the **N. fibularis superficialis** descends into the fibular compartment, innervating the two fibular muscles and piercing the Fascia cruris in the distal third of the leg. In contrast, the **N. fibularis profundus** enters the extensor compartment where it accompanies the A. tibialis anterior. It provides motor innervation to all the extensors of the leg and the dorsum of the foot, and with its sensory terminal branches it innervates the first interdigital space.

Clinical Remarks

The **N. fibularis communis** can be damaged near the fibular head (by proximal fibular fractures, plaster casts or crossed legs). The resulting paralysis of the extensor muscles causes the tips of the toes to drop (**pes equinus or foot-drop deformity,** → p. 391). This is the most common nerve lesion of the lower limb!

Vessels and Nerves of the Popliteal Fossa and the Lower Leg

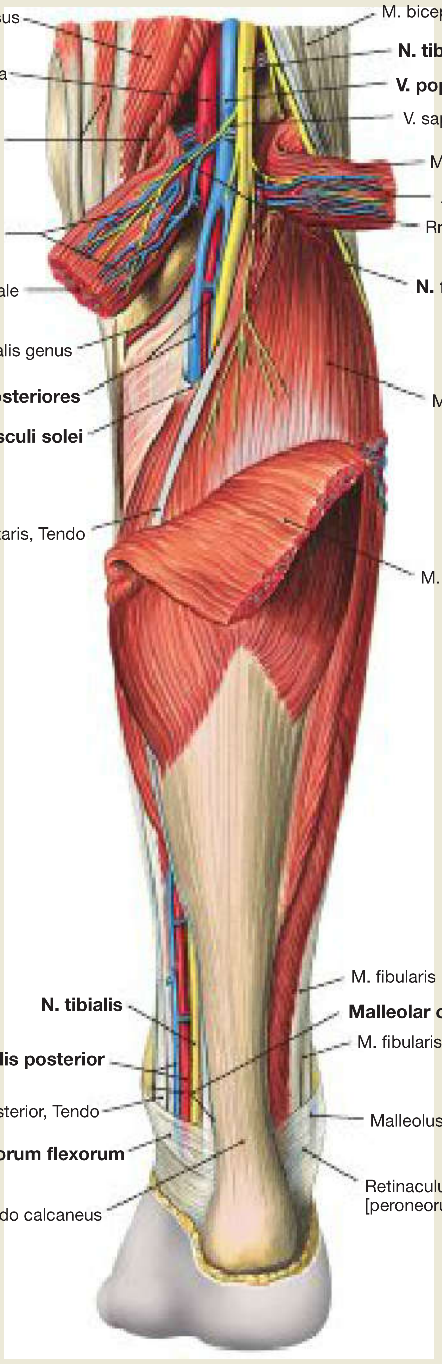


Fig. 4.166 Vessels and nerves of the popliteal fossa, Fossa poplitea, and posterior region of the leg, Regio cruris posterior, right side; dorsal view; after removal of the Fascia cruris and cutting through the M. gastrocnemius.

The **A. tibialis posterior** passes below the tendinous arch of the M. soleus (Arcus tendineus musculi solei) together with its two accompanying veins and the **N. tibialis** and descends into the layer between the superficial and deep flexors of the leg to the medial malleolus, and continues through the **malleolar canal/tarsal tunnel** below the Retinaculum musculorum flexorum to the sole of the foot.

Clinical Remarks

The **N. tibialis** can be compressed in the malleolar canal (**medial tarsal tunnel syndrome,** → p. 390). This causes burning pain in the sole of the foot and a loss of function of the plantar muscles of the foot. Flexion, adduction and spreading the toes apart are no longer possible. Paralysis of the Mm. interossei and Mm. lumbricales results in a **claw foot deformity.**

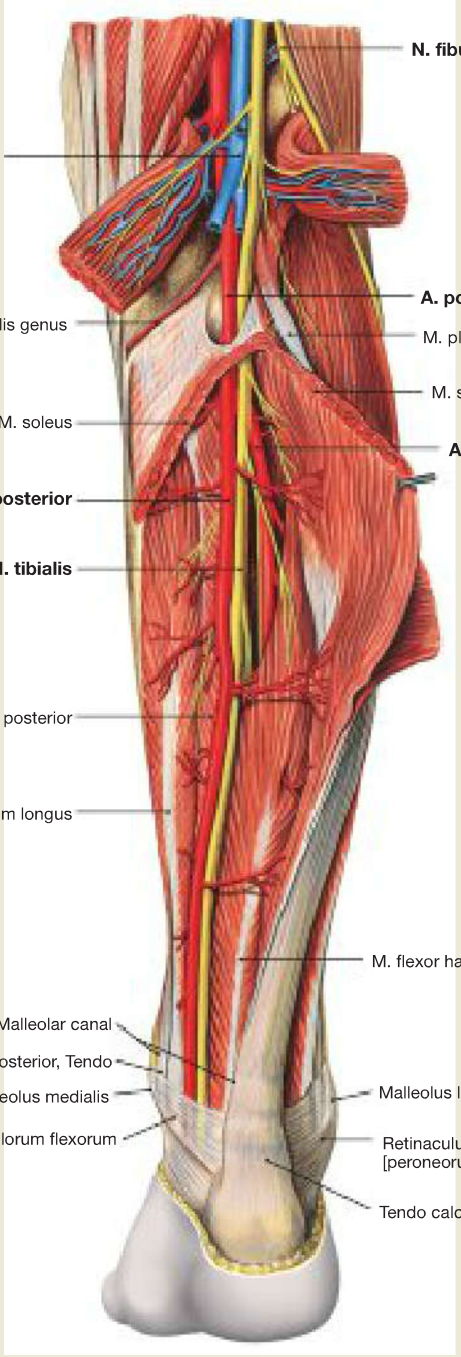


Fig. 4.167 Vessels and nerves of the popliteal fossa, Fossa poplitea, and posterior region of the leg, Regio cruris posterior, right side; dorsal view; after cutting through the Mm. gastrocnemius and soleus.

Shortly after passing underneath the tendinous arch of the M. soleus, the **A. tibialis posterior** releases the A. fibularis, its most important branch, directed to the lateral malleolus.

Vessels and Nerves of the the Lower Leg

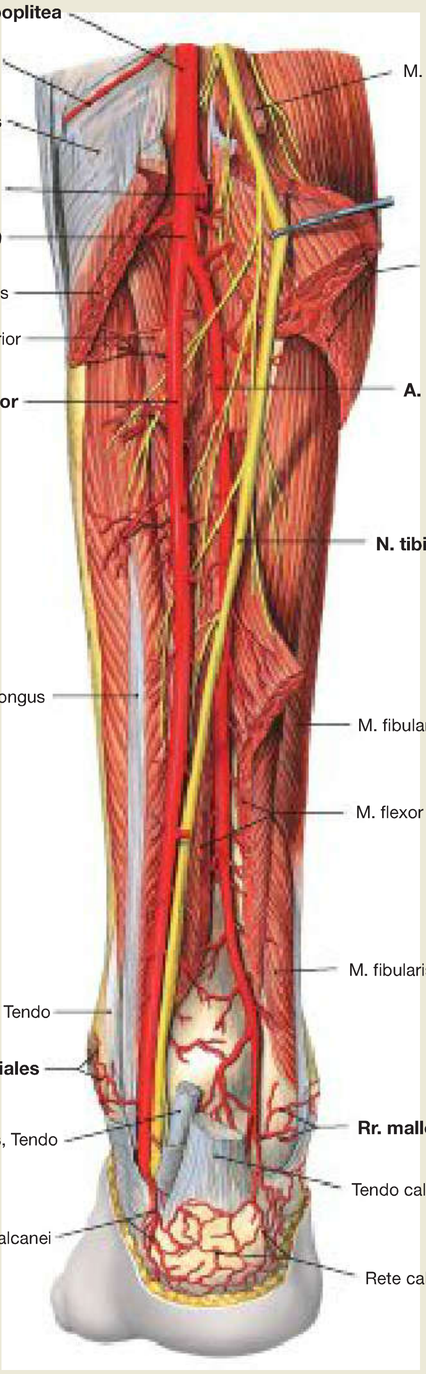


Fig. 4.168 Vessels and nerves of the posterior region of the leg, Regio cruris posterior, right side; dorsal view; after removal of the Fascia cruris and cutting through the Mm. gastrocnemius, soleus and flexor hallucis longus.

The **A. tibialis posterior** descends together with the **N. tibialis** between the superficial and deep flexors of the leg to the medial malleolus, and then continues by passing through the **malleolar canal/tarsal tunnel** underneath the Retinaculum musculorum flexorum to the sole of the foot. The **Rr. malleolares mediales** branch off to the medial malleolus.

On its way to the lateral malleolus, the **A. fibularis** pierces the M. flexor hallucis longus and runs in the deepest layer directly on the Membrana interossea cruris. Together with the branches of the Aa. tibiales anterior and posterior, the **Rr. malleolares laterales** complete the vascular circle around the ankle, which provides a sufficient collateral circulation in the case of a vascular occlusion.

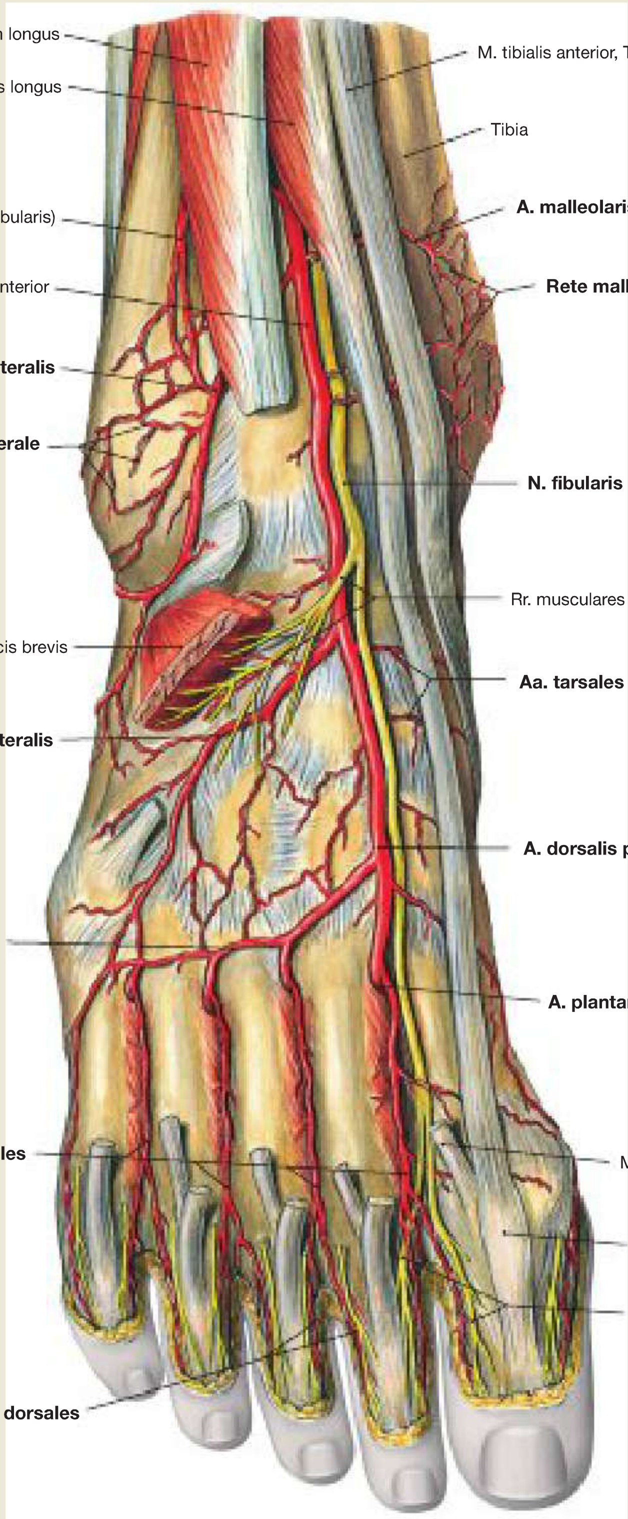


Fig. 4.169 Vessels and nerves of the dorsum of the foot, Dorsum pedis, right side; dorsal view in relation to the dorsum of the foot; after removal of the tendons of the M. extensor digitorum longus and of the short extensors of the toes.

The **A. tibialis anterior** continues on the dorsum of the foot as **A. dorsalis pedis**. It is accompanied by the **N. fibularis profundus**, which innervates the extensors of the leg and of the dorsum of the foot, and then divides into its sensory terminal branches to supply the first interdigital space. In the ankle region, the A. tibialis anterior supplies the vascular networks around the malleoli (Rete malleolare mediale and Rete malleolare laterale) with the **Aa. malleolares anteriores medialis** and **lateralis**. The **A. dorsalis pedis** sends several smaller Aa. tarsales mediales and a single A. tarsalis lateralis to the tarsal bones, and continues as A. arcuata which forms an arch on its way to the lateral side of the foot and releases to the Aa. metatarsales dorsales. These arteries give rise to the Aa. digitales dorsales which supply the toes. The A. plantaris profunda participates in the blood circulation of the sole of the foot by supplying the Arcus plantaris profundus.

Vessels and Nerves of the Sole of the Foot

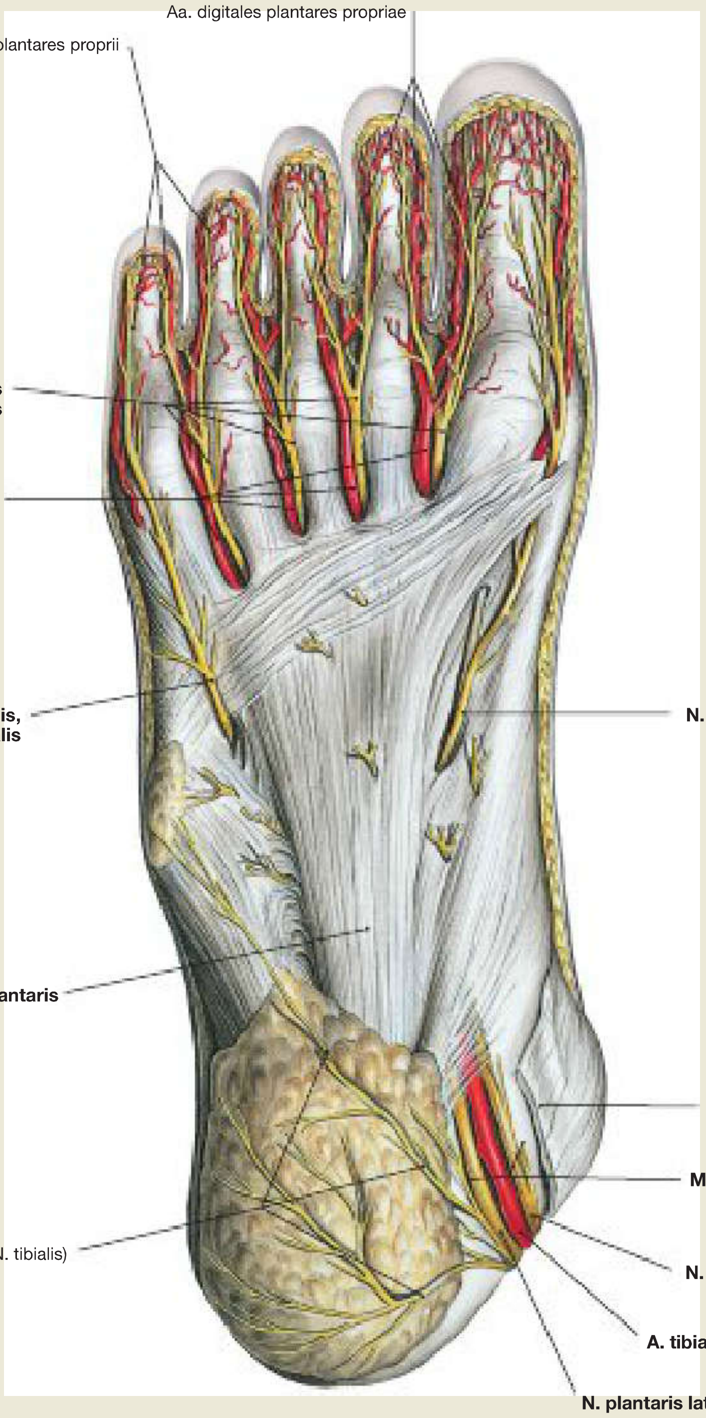


Fig. 4.170 Superficial layer of the arteries and nerves of the sole of the foot, Planta pedis, right side; plantar view.

The **N. tibialis** already divides at the medial malleolus into both its terminal branches (Nn. plantares medialis and lateralis) when passing through the malleolar canal/tarsal tunnel underneath the Retinaculum musculorum flexorum; its terminal branches provide various Nn. digitales plantares. The N. plantaris lateralis divides in a similar way to the N. ulnaris in the hand, into a R. superficialis and a R. profundus. The N. plantaris medialis has an additional branch, the N. digitalis plantaris proprius, at the medial side of the foot. These sensory branches pass between the longitudinal fibres of the plantar aponeurosis (Aponeurosis plantaris). The A. tibialis posterior only divides once it reaches the sole of foot.

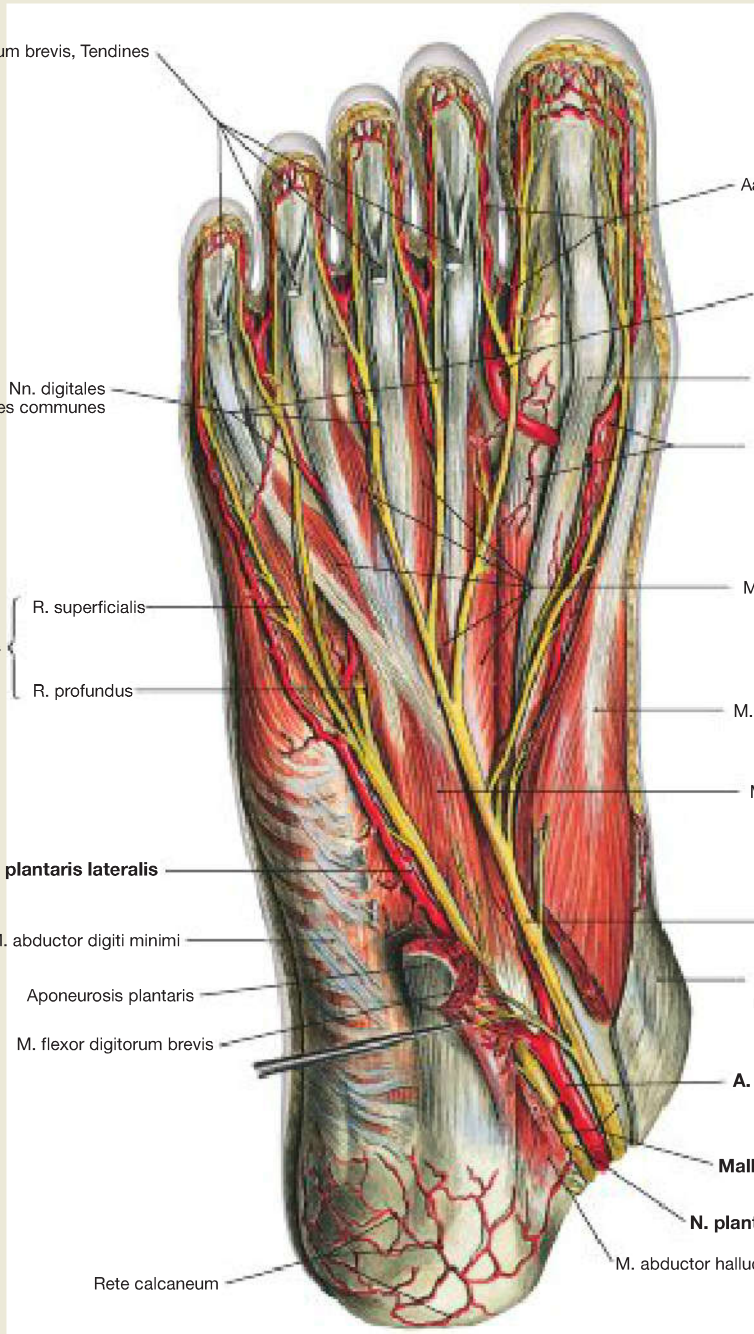


Fig. 4.171 Medial layer of the arteries and nerves of the sole of the foot, Planta pedis, right side; plantar view.

The M. flexor digitorum brevis and the M. abductor hallucis were split to expose the neurovascular structures of the malleolar canal/tarsal tunnel. The Nn. plantares medialis and lateralis are accompanied by the vessels of the same name from the A. tibialis posterior. The blood vessels run below the M. flexor digitorum brevis in the intermediate layer of the neurovascular pathways to the toes. Along the way, the nerves provide muscular branches to the short plantar muscles.

Vessels and Nerves of the Sole of the Foot

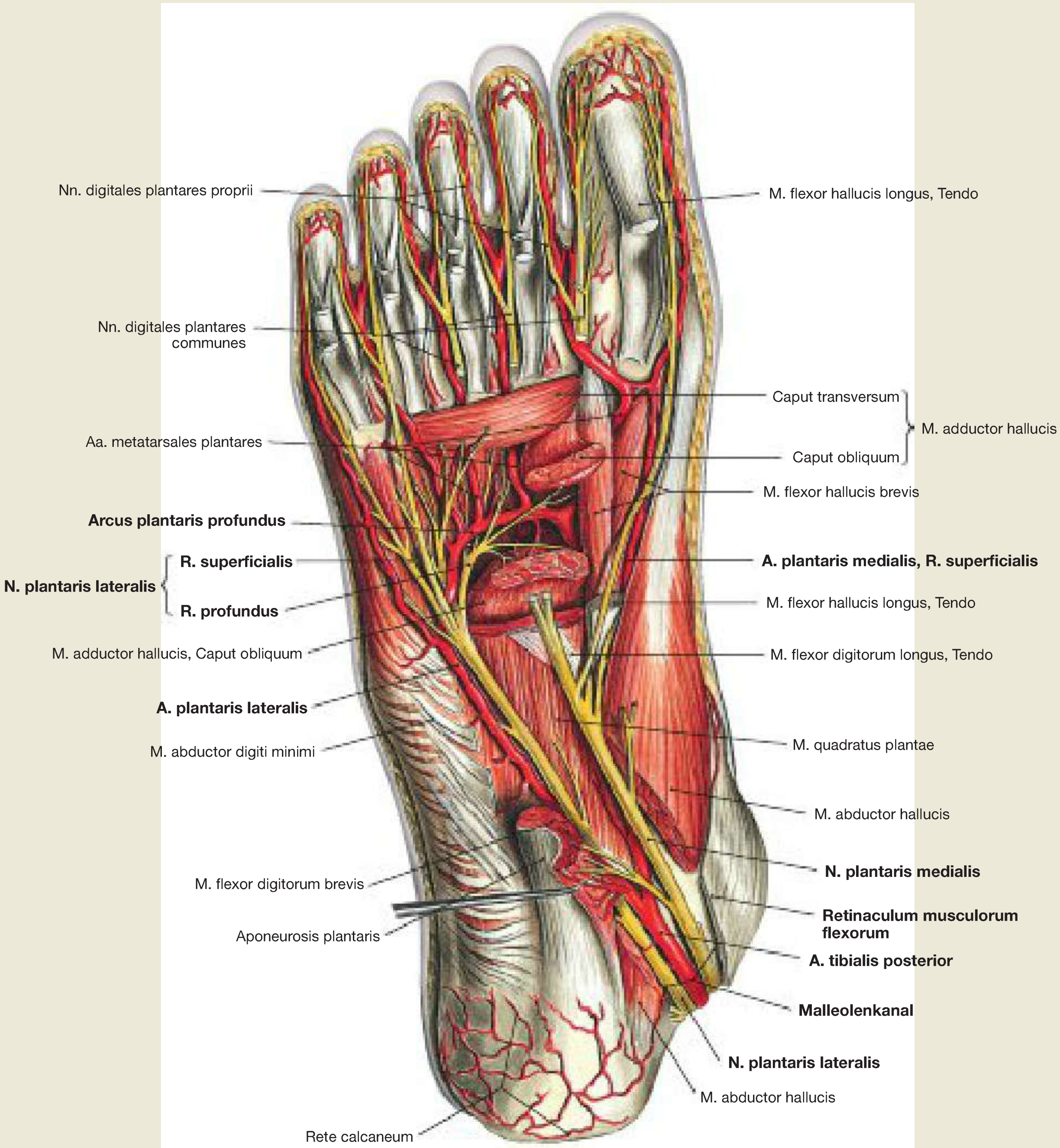


Fig. 4.172 Deep layer of the arteries and nerves of the sole of the foot, Planta pedis, right side; plantar view.
The M. flexor digitorum brevis and the M. abductor hallucis were split to expose the neurovascular structures in the malleolar canal/tarsal tunnel. In addition, the Caput obliquum of the M. adductor hallucis was cut, so that the deep plantar arch (Arcus plantaris profundus) and the R. profundus of the N. plantaris lateralis become visible.

The Arcus plantaris profundus is a continuation of the A. plantaris lateralis and receives further blood supply from the R. profundus of the A. plantaris medialis and of the A. plantaris profunda, which in turn originates from the A. dorsalis pedis. Together with the R. profundus of the N. plantaris lateralis, it forms an arch and runs on the Mm. interossei of the sole of the foot in the deep layer of the neurovascular pathways.

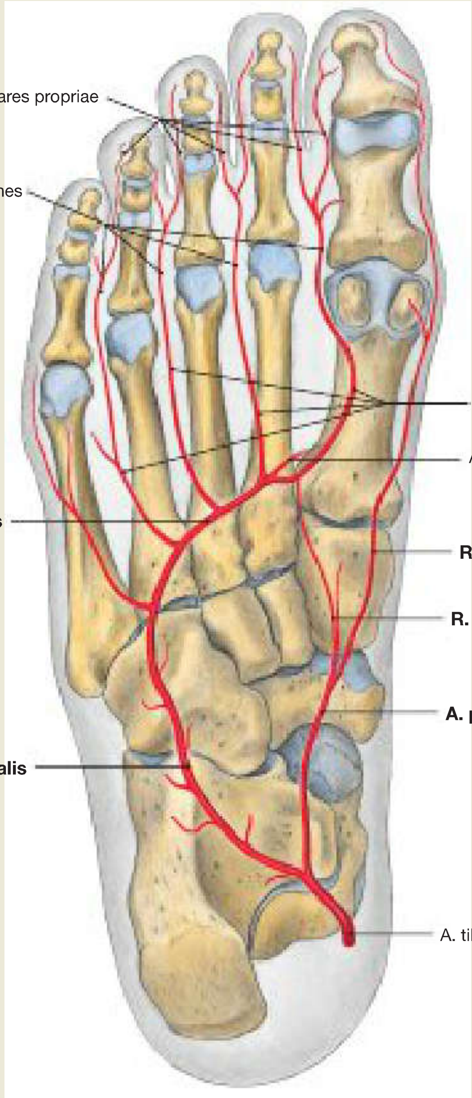


Fig. 4.173 Arteries of the sole of foot, Planta pedis, right side; plantar view.
The sole of the foot is supplied by the terminal branches of the A. tibialis posterior. The **A. plantaris medialis** provides a **R. superficialis** to the medial side of the foot and a **R. profundus** to connect with the **Arcus plantaris profundus**. This arterial arch is a direct continuation of the **A. plantaris lateralis.**

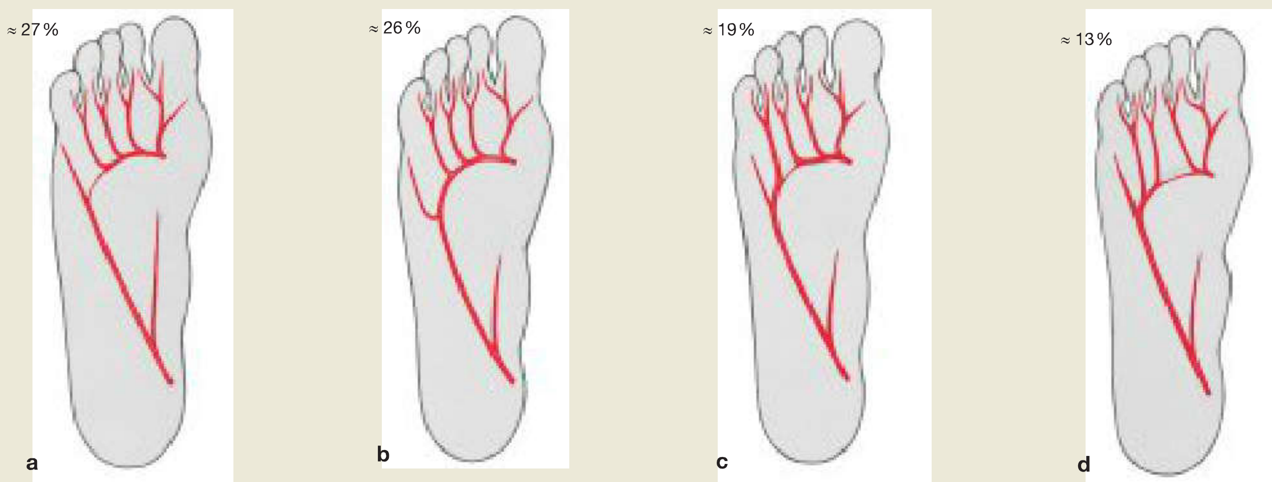


Fig. 4.174a to d Variations in the arterial supply of the toes, right side; plantar view.
The Arcus plantaris profundus receives its blood supply mainly from the A. dorsalis pedis and via the A. plantaris profunda (→ Fig. 4.174**a**) or from the A. tibialis posterior (→ Fig. 4.174**b**). Alternatively, both arterial systems can contribute to the blood supply of the toes (→ Fig. 4.174**c** and **d**).

Hip Joint, Oblique Section

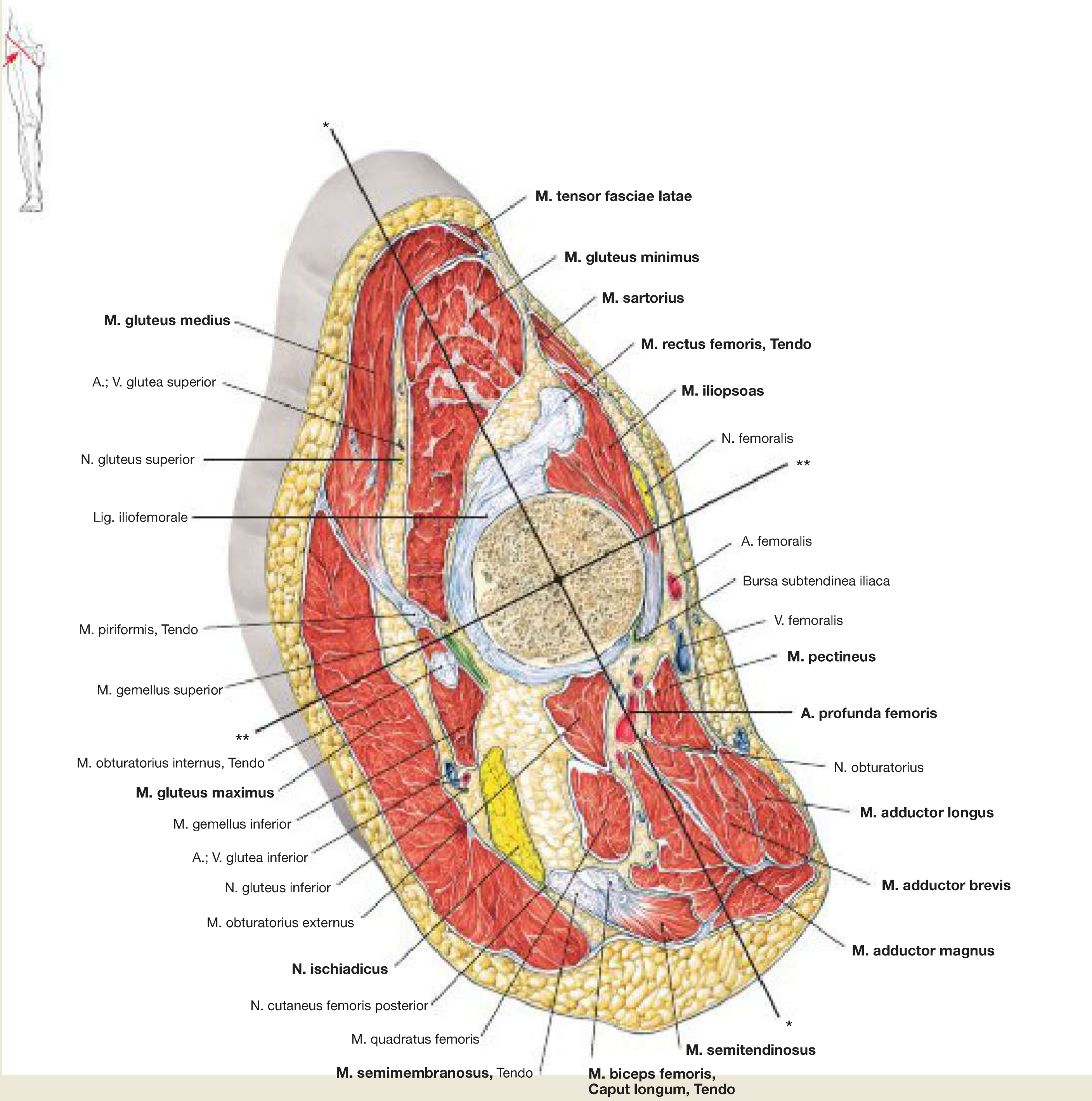
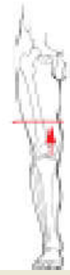


Fig. 4.175 Thigh, Femur, oblique section through the hip joint, right side; distal view with illustration of the movement axes of the hip joint.

The oblique section through the thigh at the level of the femoral head shows the position of the individual muscle groups in relation to the femoral head and the movement axes. The **M. gluteus maximus** is located dorsally of the hip joint, whereas the smaller gluteal muscles **(Mm. glutei medius and minimus)** may run in part ventrally of the longitudinal and transverse axes of the hip joint. This position explains why the M. gluteus maximus acts as an external rotator and extensor of the hip, while the smaller gluteal muscles can also flex the hip and are the strongest medial rotators. The **M. iliopsoas** is located anterior to the transverse axis and is the most important flexor of the hip joint. It is functionally supported by the anterior group of femoral muscles (M. sartorius, M. rectus femoris), the M. tensor fasciae latae and the superficial **adductor muscles** (Mm. adductores longus and brevis, M. pectineus, main part of the M. adductor magnus). As the dorsal part of the M. adductor magnus already lies behind the transverse axis, it acts an extensor together with the hamstring muscles, to which it belongs functionally and also according to its innervation.

Cross-sections of the limbs make it easy to visualise the positional relationships of the neurovascular structures in different compartments or layers. The **N. ischiadicus** initially lies under the M. gluteus maximus after leaving the lesser pelvis. Anteriorly, the **A. profunda femoris** is covered by the M. pectineus.

* transverse axis of movement in the hip joint
** sagittal axis of movement in the hip joint



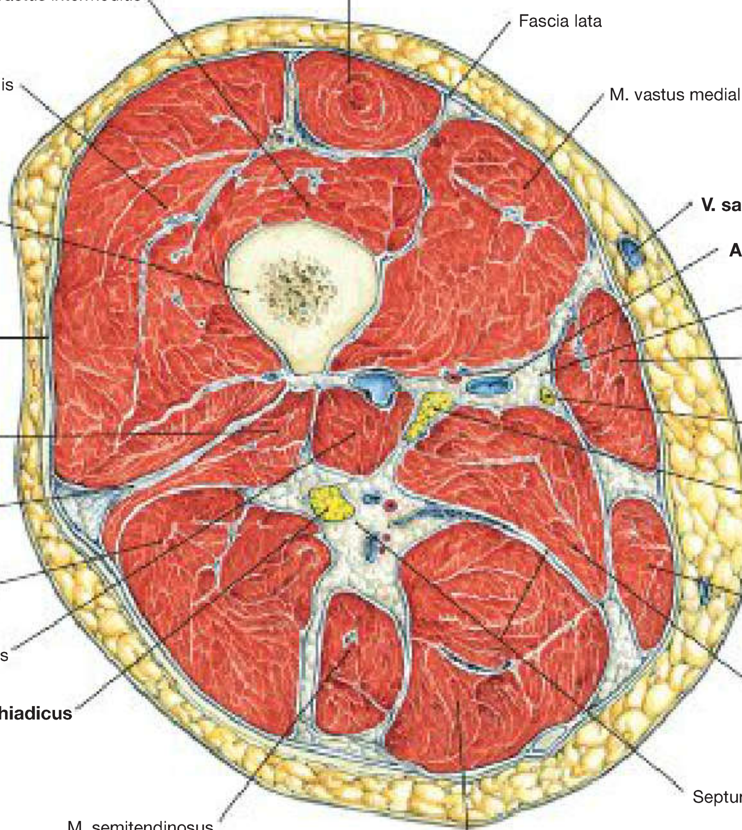


Fig. 4.176 Thigh, Femur, right side; transverse section in the middle of the thigh; distal view.
In this cross-section the **three muscle groups of the thigh** can be identified. The anterior group includes the M. quadriceps femoris and the M. sartorius. The adductor muscles are located medially and the hamstring muscles dorsally.

The **V. saphena magna** is found in the epifascial subcutaneous adipose tissue on the medial side of the thigh. The **A.** and **V. femoralis** pass together with the **N. saphenus** through the adductor canal (Canalis adductorius) of the M. quadriceps. The adductor canal is limited dorsally by the Mm. adductores longus and magnus, and covered medially by the M. vastus medialis, and ventrally by the M. sartorius. The **N. ischiadicus** is dorsally located under its guide muscle, the M. biceps femoris.

Knee, Transverse Section

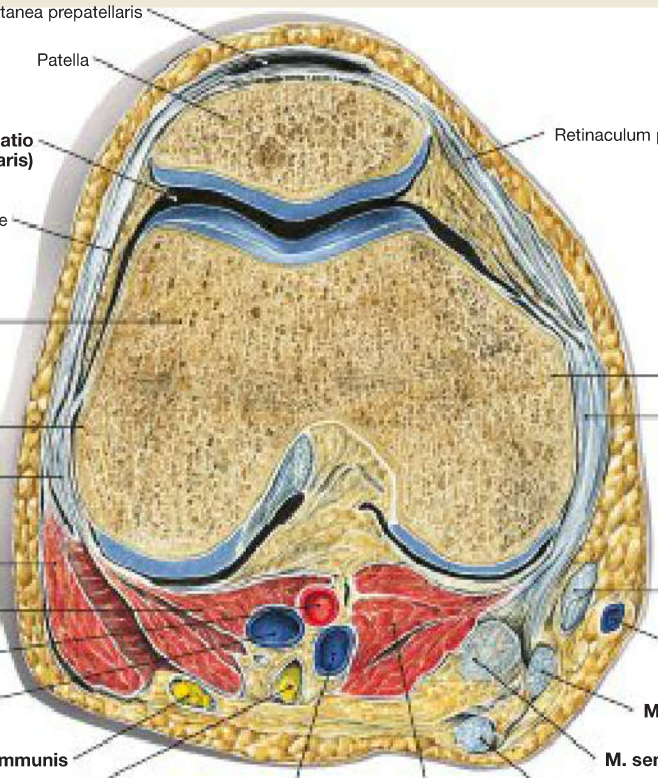
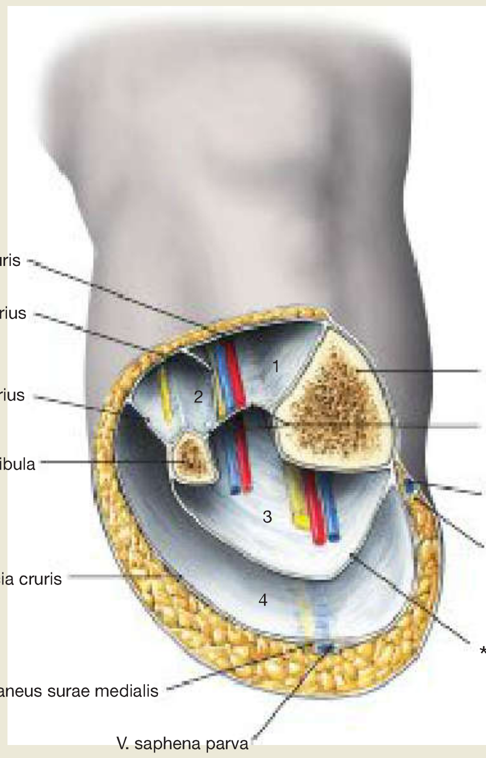


Fig. 4.177 Knee joint, Articulatio genus, right side; transverse section; distal view.

The transverse section through the knee joint shows the articular surfaces of the **Articulatio femoropatellaris.** The **M. biceps femoris** lies laterally on the posterior side, and is therefore the most important external rotator. On the medial side, however, several muscles are involved in the medial rotation: the inserting tendons of the **Mm. sartorius, gracilis, and semitendinosus** run superficially. They insert further distally in the common aponeurosis at the medial aspect of the tibia, commonly referred to as 'Pes anserinus superficialis'. The insertion of the tendon of the **M. semimembranosus** lies deeper and is referred to as 'Pes anserinus profundus'.

The **V. saphena magna** is found in the epifascial subcutaneous adipose tissue on the medial side of the knee. On the dorsal side the terminal branches of the N. ischiadicus (N. fibularis communis and N. tibialis) are located laterally and superficially, while the V. poplitea with the V. saphena parva lie more deeply, and the A. poplitea is the deepest structure (NVA).



1 Anterior (extensor) compartment:
A.; V. tibialis anterior
N. fibularis profundus
M. tibialis anterior
M. extensor digitorum longus
M. extensor hallucis longus
M. fibularis [peroneus] tertius

2 Lateral (fibular) compartment:
N. fibularis superficialis
M. fibularis [peroneus] longus
M. fibularis [peroneus] brevis

3 Posterior (deep or flexor) compartment:
A.; V. tibialis posterior
A.; V. fibularis
N. tibialis
M. flexor digitorum longus
M. tibialis posterior
M. flexor hallucis longus

4 Posterior (superficial) compartment:
M. triceps surae
M. plantaris

Fig. 4.178 Leg, Crus, right side; transverse section through the middle of the leg showing the osteofibrous tubes (compartments); distal view.

The Fascia cruris is attached to the bones of the leg by fibrous connective tissue septa. These septa confine and keep osteofibrous tubes, which are known as **compartments,** separated from each other. They contain the neurovascular pathways which run between the muscle bellies of the distinct muscle groups (→ Fig. 4.180). The Septum intermusculare anterius divides the anterior extensor compartment from the lateral fibular muscle compartment, which in turn is separated from the superficial flexors by the Septum intermusculare posterius. A deep layer of the Fascia cruris separates the superficial from the deep flexors, which are anteriorly adjacent to the Membrana interossea cruris. In the **anterior (extensor) compartment** the N. fibularis profundus is accompanied by the A. tibialis anterior and the Vv. tibiales anteriores. The N. fibularis superficialis is located in the **lateral (fibular)** compartment. In the **deep posterior (flexor) compartment** the N. tibialis together with the A. tibialis posterior and the Vv. tibiales posteriores can be found, as well as the A. and V. fibularis, which are covered by the M. flexor hallucis longus and which are embedded between the muscles. In the epifascial layer, the V. saphena magna runs on the medial side of the leg, and the V. saphena parva dorsally.

*deep part of the Fascia cruris

Leg, Transverse Section

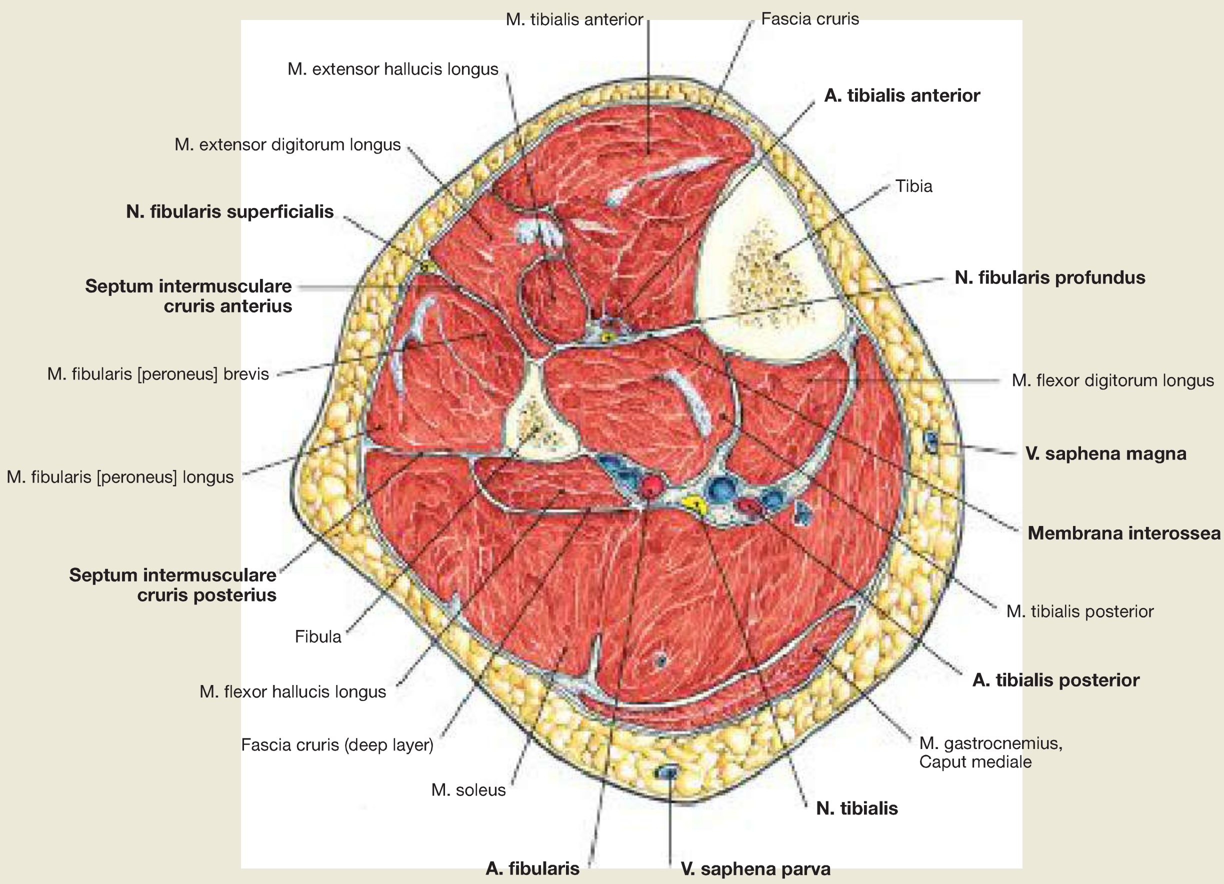
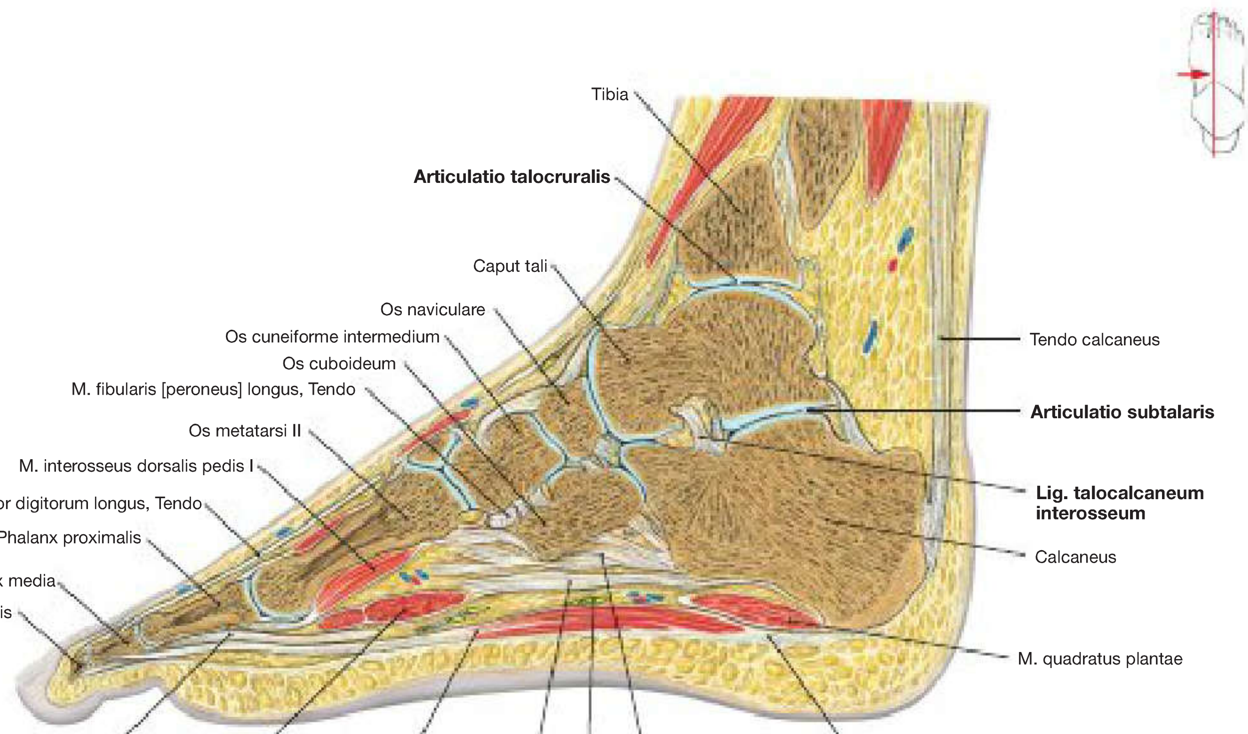


Fig. 4.179 Leg, Crus, right side; transverse section through the middle of the leg; distal view.
Together with the connective tissue septa attached to the bones of the leg, the Fascia cruris forms **osteofibrous tubes or compartments.** In these compartments run the neurovascular pathways between the muscle bellies of the individual muscle groups.

The anterior (extensor) compartment, which contains the N. fibularis profundus together with the A. tibialis anterior, has the highest clinical relevance.

Clinical Remarks

Compression syndrome (compartment syndrome) most often occurs in the anterior (extensor) compartment, less often in the lateral (fibular) compartment. In the case of post-traumatic swelling of the extensor muscles or after a long march on foot, the supplying vessels and nerves can be compressed and damaged by the muscles. In addition to pain, there may also be a pulse deficit of the A. dorsalis pedis, originating in the A. tibialis anterior. But most frequently, the compression causes a lesion of the N. fibularis profundis (→ p. 391) with resulting functional (extension) deficits in the ankle joint and loss of sensory perception in the first interdigital space. In an emergency, the treatment includes an immediate splitting of the fascia, which, however, requires long-term immobilisation of the open leg. To confirm the diagnosis, the pressure in the compartments should be measured with a pressure sensor.



a

b

Fig. 4.180a and b Foot, Pes, right side; sagittal section through the second metatarsal bone (→ Fig. 4.175a) and the corresponding magnetic resonance imaging sagittal section (MRI) scan (→ Fig. 4.175b); medial view. (b [T832])
In the surgical cut the joint space of the ankle joint **(Articulatio talocruralis)** and the posterior chamber of the lower ankle joint **(Articulatio subtalaris)** can be identified. The **longitudinal arch** is stabilised by three overlying ligaments (Aponeurosis plantaris, Lig. plantare longum, Lig. calcaneonaviculare plantare, → Fig. 4.76).

Practice Exam Questions

To check that you are completely familiar with the content of this chapter, practice questions from an oral anatomy exam are listed here.

Show the sections and most important structures of the femur on the skeleton:

- Which muscles insert at Trochanter major and Trochanter minor?
- How does the curvature of the femoral condyles influence the flexion movement in the knee joint and its stabilisation by the collateral ligaments?

Explain the structure of the knee joint on an articular model:

- Which skeletal elements articulate with each other?
- Which ligaments stabilise the knee joint and with which clinical tests can they be evaluated?
- Which types of joint are specifically involved?
- Which movements can be carried out and to what extent (range of motion)?
- Which orientation do the movement axes have?
- Which muscles are important for the individual movements?

Show the muscle groups of the leg:

- What is the position of the muscles in relation to the axes of the ankle joints and how does this influence their function?
- Explain the course of the M. triceps surae, including its origin and insertion.
- How is it innervated and which movements are restricted when it fails?

Show the N. fibularis communis and explain its course on the dissection.

- Explain its innervation area.
- Where is it damaged most often?
- Which clinical picture can be expected with a nerve lesion in the area of the fibular head, e. g. in the case of a high fracture of the fibula?

What arterial pulses can you palpate in a clinical examination of the lower limb ?

- Show the vessels branching off the A. femoralis and explain their supply areas.

How is the venous system of the leg (lower limb) organised?

- Where can you as a physician insert a cardiac catheter?

Explain the lymphatic drainage on the leg (lower limb):

- How are the lymph nodes in the groin organised?
- Which body regions do they drain?

Appendix

Picture Credits

Reference to the source for each figure in this work is given at the end of each caption in square brackets. All figures and graphics without a reference © Elsevier GmbH, Munich.
The editors sincerely thank all clinical colleagues that made ultrasound, computed tomographic and magnetic resonance images as well as endoscopic and intraoperative pictures available.

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E402 Drake, R.L./Vogl, A. W./Mitchell A.W.M./Tibbitts, R.M./ Richardson, P.E.: Gray's Anatomy for Students. 1st Ed., Elsevier/Churchill Livingstone, 2005
E460 Drake, R.L./Vogl, A. W./Mitchell A.W.M./Tibbitts, R.M./ Richardson, P.E.: Gray's Atlas of Anatomy. 1st Ed., Elsevier/ Churchill Livingstone, 2008
E838 Mitchell, B./Sharma, R.: Embryology. An Illustrated Colour Text. Elsevier/Churchill Livingstone, 1st Ed., 2005
E943 Kanski, J.: Clinical Ophthalmology: A Systemic Approach. 6th Ed., Butterworth-Heinemann, 2007
F885 Senger, M./Stoffels, HJ./Angelov DN: Topography, syntopy and morphology of the human otic ganglion: A cadaver study. Ann Anat 2014;196(5):327–35
G159 Forbes, A. et al.: Atlas of Clinical Gastroenterology. 3rd Ed., Mosby 2004
G198 Mettler, F.: Essentials of Radiology. 2nd Ed., Saunders 2005
G210 Standring, S.: Gray's Anatomy. 40th Ed., Elsevier/Churchill Livingstone, 2008
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R170 Welsch, U.: Sobotta Lehrbuch der Histologie. 2. A., Elsevier/Urban & Fischer, 2006
R235 Böcker, W./Denk, H./Heitz, P./Moch, H.: Pathologie. 4. A., Elsevier/Urban & Fischer, München 2008
R236 Classen, M./Diehl, V./Kochsiek, K.: Innere Medizin. 6. A., Elsevier/Urban & Fischer, 2009
R242 Franzen, A.: Kurzlehrbuch Hals-Nasen-Ohren-Heilkunde. 3. A., Elsevier/Urban & Fischer, 2007
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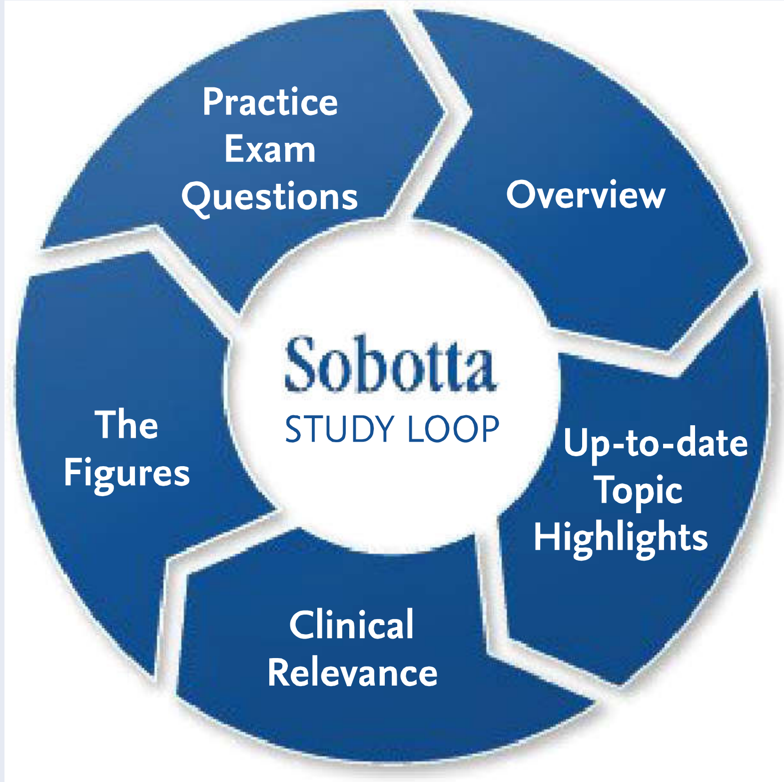
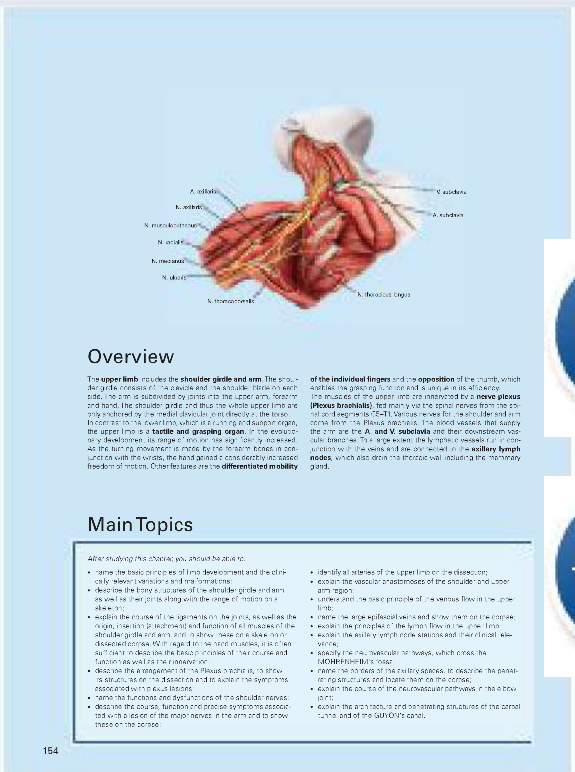




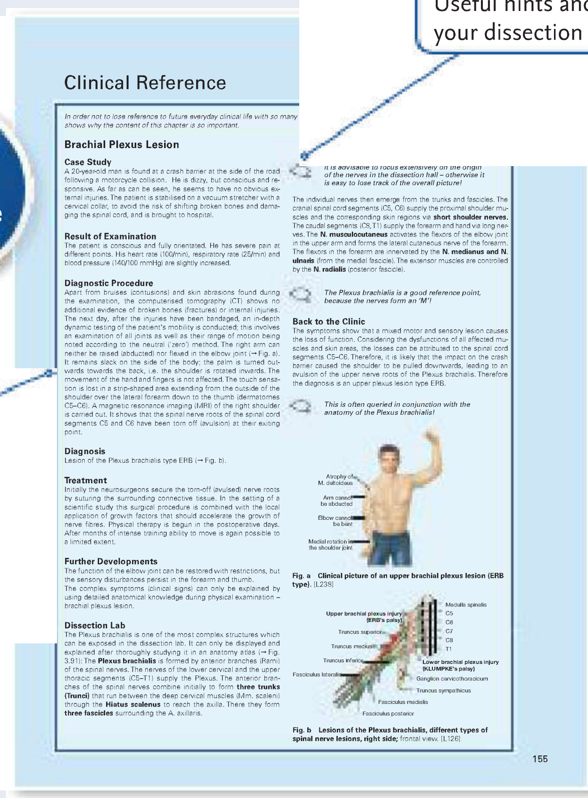
Overview

The chapter's core topics clearly presented – crucial anatomical information is highlighted.

Focused Topic Highlights

Enable interconnected competencies – via explaining anatomical content in context, thus indicating clear study objectives.

Useful hints and tips for your dissection course



Clinical Relevance

Actual clinical cases showcase practical application of the anatomical knowledge gained beyond the lecture hall.

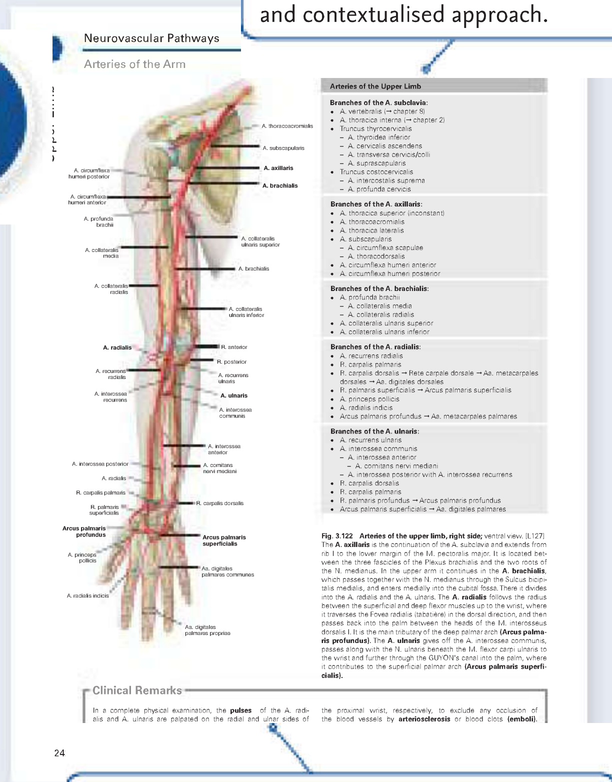
Each case report includes:

- A Case Study
- Examination Results
- Diagnostic Procedure
- Diagnosis
- Treatment
- Dissection Lab Tips
- In the Clinic

The Figures

A common theme runs through each chapter, from the surface to the detail. Clinical hints and teaching tables help you to understand and classify. Captions explain the relationships between the depicted anatomical structures. Individual structures that are relevant for tests and examinations are highlighted in bold.

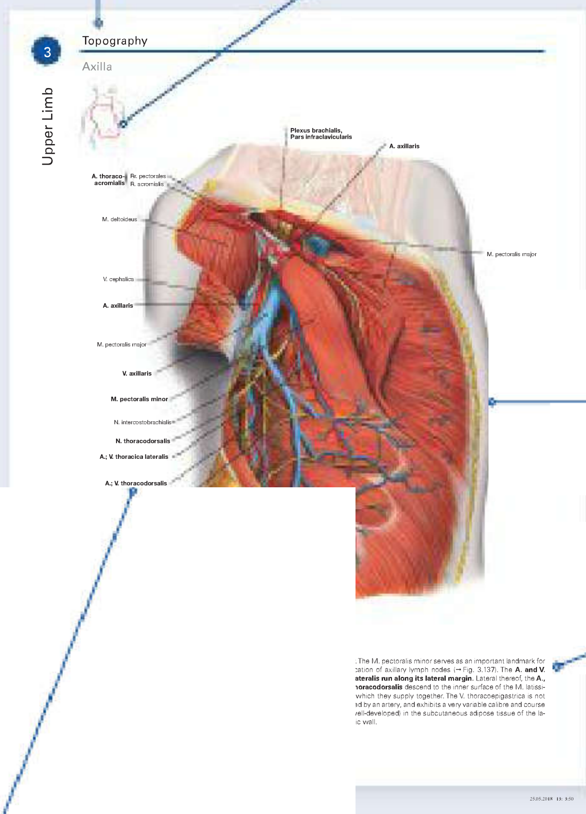
Clearly arranged tables enable you to memorise knowledge in a structured and contextualised approach.



Clinical Remarks present a typical clinical case and symptoms relevant to the depicted condition or illness. This acts as an aide-mémoire contextualising the displayed structure.

Sobotta's quick regional anatomical reference on every page aids quick orientation and helps you find your way around the chapters and their topics.

An orientation sketch points you to the current view or section depicted in the anatomical figure at a glance.



Various types of images are used in the atlas:

- realistic and detailed anatomical illustrations for a deeper insight
- schematic drawings highlighting functional relationships
- photos showcasing surface anatomy
- in-depth medical imaging scans

Each figure has a detailed caption which highlights the most important structures and the systematic and topographical relationships.

Important anatomical structures are highlighted to help you focus on the essential knowledge first.

Practice Exam Questions

Every chapter closes with a sampling of typical oral exam questions enabling you to test your knowledge gained within the chapter.

You will find these in the 16th edition

Volume 1 – General Anatomy and Musculoskeletal System

1 General Anatomy
Anatomical Planes and Positions → Surface Anatomy → Development → Musculoskeletal System → Neurovascular Pathways → Imaging Methods → Skin and its Appendages

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Surface Anatomy → Development → Skeleton → Imaging Methods → Muscles → Neurovascular Pathways → Topography, Dorsal Trunk Wall → Female Breast → Topography, Ventral Trunk Wall

3 Upper Limb
Surface Anatomy → Development → Skeleton → Imaging Methods → Muscles → Neurovascular Pathways → Topography → Cross-Sectional Images

4 Lower Limb
Surface Anatomy → Skeleton → Imaging Methods → Muscles → Neurovascular Pathways → Topography → Cross-Sectional Images

Volume 2 – Internal Organs

5 Organs of the Chest Cavity
Topography → Heart → Lung → Oesophagus → Cross-Sectional Images

6 Organs of the Abdominal Cavity
Development → Topography → Stomach → Intestines → Liver and Gallbladder → Pancreas → Spleen → Neurovascular Pathways → Cross-Sectional Images

7 Retroperitoneal Space and Pelvic Cavity
Topography → Kidney and Adrenal Gland → Urinary System → Rectum and Anal Canal → Genitalia → Cross-Sectional Images

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9 Eye
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10 Ear
Overview → Outer Ear → Middle Ear → Auditory Tube → Inner Ear → Hearing and Equilibrium

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12 Brain and Spinal Cord
Development → General Principles → Brain → Meninges and Blood Supply → Cerebral Areas → Cranial Nerves → Spinal Cord → Sections

Tables

Tables of Muscles, Joints and Nerves
Head → Neck → Trunk → Upper Limb → Lower Limb → Cranial Nerves