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Sobotta

Atlas of Human Anatomy

General Anatomy and Musculoskeletal System

15th Edition
Edited by F. Paulsen and J. Waschke
English Version with Latin Nomenclature

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Includes online access to www.e-sobotta.com

User's Guide to the Book

Introductory pages:
- The introductory pages provide all relevant anatomical informations concerning the subject of the chapter. Important details and connections are explained easily to understand.
- The Dissection Link for each chapter comprises brief and concise tips essential for the dissection of the respective body region.
- Exam Check Lists provide all keywords for possible exam questions.

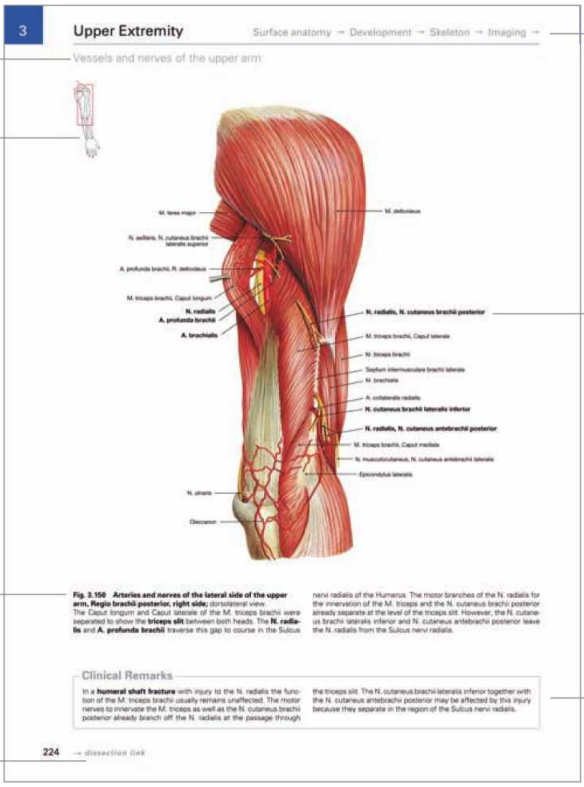
Atlas pages:
- The menu bar on top indicates the topics of each chapter, the bold print shows the subject of the respective pages.
- Important anatomical structures in the figures are highlighted in bold print.
- Small supplement sketches located next to complex views show visual angles and intersecting planes and, thus, facilitate orientation.
- Detailed figure captions explain the relationships of anatomical structures.
- Bulleted lists in figure captions as well as in tables help structuring complex facts and provide a better overview.
- Figures, tables, and text boxes are interconnected by cross-references.
- Cross-references link the figures to the separate Table Booklet with tables of muscles, joints, and nerves, thus providing a sufficient anatomical knowledge for the exam.
- Clinical Remarks boxes provide clinical background knowledge concerning the anatomical structures illustrated on the page.
- The dissection link on the page indicates if a tip for dissecting the illustrated anatomical region is available on www.e-sobotta.com.

Appendix:
- List of abbreviations, general terms of direction and position can be found at the end of the book.

Perfect Orientation – the New Navigation System

The subject of this page

Sketches facilitate orientation in complex figures by showing visual angles and intersecting planes.



The menu bar with the terms printed in bold indicates the subject of the current page.

Important anatomical structures are printed in bold.

Figure captions explain anatomical connections concerning the illustrated structures.

The Clinical Remarks boxes describe medical contexts to the anatomical structures illustrated on the page. Mostly, these clinical aspects are also of high relevance for the exam.

For pages with this dissection link detailed dissection tips can be found on www.e-sobotta.com.

The following contents can be found in the other two volumes:

Vol. 2 Internal Organs

5 Viscera of the Thorax

Heart → Lungs → Oesophagus → Thymus → Topography → Sections

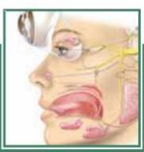
6 Viscera of the Abdomen

Development → Stomach → Intestines → Liver and Gallbladder → Pancreas → Spleen → Topography → Sections

7 Pelvis and Retroperitoneal Space

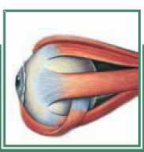
Kidney and Adrenal Gland → Efferent Urinary System → Genitalia → Rectum and Anal Canal → Topography → Sections

Vol. 3 Head, Neck, and Neuroanatomy



8 Head

Overview → Skeleton and Joints → Muscles → Topography → Vessels and Nerves → Nose → Mouth and Oral Cavity → Salivary Glands

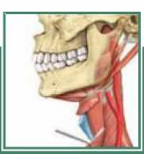


9 Eye

Development → Skeleton → Eyelids → Lacrimal Apparatus → Muscles of the Eye → Topography → Eyeball → Visual Pathway

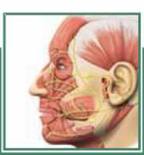
10 Ear

Overview → Outer Ear → Middle Ear → Auditory Tube → Inner Ear → Hearing and Equilibrium



11 Neck

Muscles → Pharynx → Larynx → Thyroid Gland → Topography



12 Brain and Spinal Cord

General → Meninges and Blood Supply → Brain → Sections → Cranial Nerves → Spinal Cord

Paulsen, Waschke

Sobotta

Atlas of Human Anatomy
Latin Nomenclature

General Anatomy and Musculoskeletal System

Translated by
T. Klonisch and S. Hombach-Klonisch

Sobotta

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General Anatomy and Musculoskeletal System

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Edited by F. Paulsen and J. Waschke

Translated by T. Klonisch and S. Hombach-Klonisch, Winnipeg, Canada

597 Coloured Plates with 700 Figures

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Editors

Prof. Dr. Friedrich Paulsen

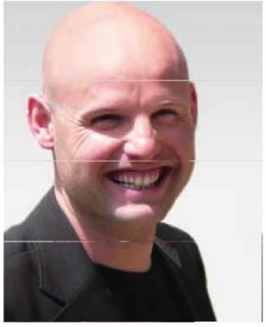
Dissecting Courses for Students

In his teaching, Friedrich Paulsen puts great emphasis on the fact that students can actually dissect on cadavers of body donors. "The hands-on experience in dissection is extremely important not only for the three-dimensional understanding of anatomy and as the basis for virtually every medical profession, but for many students also clearly addresses the issue of death and dying for the first time. The members of the dissection team not only study anatomy but also learn to deal with this special issue. At no other time medical students will have such a close contact to their classmates and teachers again."
"The dissection links in the atlas lead to online images that are relevant for the dissection. You can print them and take them along. The offered dissection tips are not instructions, but make sure that you are oriented exceptionally well and not 'cutting in the dark'."

Professor Friedrich Paulsen (born 1965 in Kiel) passed the 'Abitur' in Brunswick and trained successfully as a nurse. After studying human medicine in Kiel, he became scientific associate at the Institute of Anatomy, Department of Oral and Maxillofacial Surgery and the Department of Otolaryngology, Head and Neck Surgery of the Christian-Albrechts-Universität Kiel. In 2002, together with his colleagues, he was awarded the Teaching Award for outstanding teaching in the field of anatomy at the Medical Faculty of the University of Kiel. On several occasions he gained work experience abroad in the academic section of the Department of Ophthalmology, University of Bristol, UK, where he did research for several months.

From 2004 to 2010 as a University Professor, he was head of the Macroscopic Anatomy and Prosector Section at the Department of Anatomy and Cell Biology of the Martin-Luther-Universität Halle-Wittenberg. Starting in April 2010, Professor Paulsen became the Chairman at the Institute of Anatomy II of the Friedrich-Alexander-Universität Erlangen. Since 2006, Professor Paulsen is a board member of the Anatomical Society and 2009 he was elected the general secretary of the International Federation of Associations of Anatomy (IFAA).

His main research area concerns the innate immune system. Topics of special interest are antimicrobial peptides, trefoil factor peptides, surfactant proteins, mucins, corneal wound healing, as well as stem cells of the lacrimal gland and diseases such as eye infections, dry eye, or osteoarthritis.



Prof. Dr. Jens Waschke

More Clinical Relevance in Teaching

From March 2011 on, Professor Jens Waschke is Chairman of Department I at the Institute of Anatomy and Cell Biology at the Ludwig-Maximilians-Universität (LMU) Munich. "For me, teaching at the department of vegetative anatomy, which is responsible for the dissection courses of both Munich's large universities LMU and TU, emphasizes the importance of teaching anatomy with clear clinical relevance", says Jens Waschke.
"The clinical aspects in the Atlas introduce students to anatomy in the first semesters. At the same time, it indicates the importance of this subject for future clinical practice, as understanding human anatomy means more than just memorization of structures."

Professor Jens Waschke (born in 1974) habilitated in 2007 after graduation from Medical School and completing a doctoral thesis at the University of Wuerzburg. From 2003 to 2004 he joined Professor Fitz-Roy Curry at the University of California in Davis for a nine months research visit. Starting in June 2008, he became the Chairman at the Institute of Anatomy and Cell Biology III at the University of Wuerzburg. In 2005, together with his colleagues, Professor Waschke was awarded the Albert Koelliker Teaching Award of the Faculty of Medicine in Wuerzburg. In 2006, he was awarded the Wolfgang Bargmann Prize of the Anatomical Society.

His main research area concerns cellular mechanisms that control the adhesion between cells and the cellular junctions establishing the outer and inner barriers of the human body. The attention is focused on the regulations of the endothelial barrier in inflammation and the mechanisms, which lead to the formation of fatal dermal blisters in pemphigus, an autoimmune disease. The goal is to gain a better understanding of cell adhesion as a basis for the development of new therapeutic strategies.

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Translators

Prof. Dr. Thomas Klonisch

Professor Thomas Klonisch (born 1960) studied human medicine at the Ruhr-Universität Bochum and the Justus-Liebig-Universität (JLU) Giessen. He successfully completed his doctoral thesis at the Institute of Biochemistry at the Faculty of Medicine of the JLU Giessen and became a scientific associate at the Institute of Medical Microbiology, University of Mainz (1989–1991). As an Alexander von Humboldt Fellow he joined the University of Guelph, Ontario, Canada, from 1991–1992 and, in 1993–1994, continued his research at the Ontario Veterinary College, Guelph, Ontario. From 1994–1996, he joined the immunoprotein engineering group at the Department of Immunology, University College London, UK, as a senior research fellow. From 1996–2004 he was a scientific associate at the Department of Anatomy and Cell Biology, Martin-Luther-Universität Halle-Wittenberg, where he received his accreditation as anatomist (1999), completed his habilitation (2000), and held continuous national research funding by the German Research Council (DFG) and German Cancer Research Foundation (Deutsche Krebshilfe). In 2004, he was appointed Full Professor and Head at the Department of Human Anatomy and Cell Science at the Faculty of Medicine, University of Manitoba, Winnipeg, Canada, where he is currently serving his second term as department chairman.

His research areas concern the mechanisms employed by cancer cells and their cancer stem/progenitor cells to enhance tissue invasiveness and survival strategies in response to anticancer treatments. One particular focus is on the role of endocrine factors, such as the relaxin-like ligand-receptor system, in promoting carcinogenesis.

Prof. Dr. Sabine Hombach-Klonisch

Teaching clinically relevant anatomy and clinical case-based anatomy learning are the main teaching focus of Sabine Hombach-Klonisch at the Medical Faculty of the University of Manitoba. Since her appointment in 2004, Professor Hombach has been nominated annually for teaching awards by the Manitoba Medical Student Association.

Sabine Hombach (born 1963) graduated from Medical School at the Justus-Liebig-Universität Giessen in 1991 and successfully completed her doctoral thesis in 1994. Following a career break to attend to her two children she re-engaged as a sessional lecturer at the Department of Anatomy and Cell Biology of the Martin-Luther-Universität Halle-Wittenberg in 1997 and received a post-doctoral fellowship by the province of Saxony-Anhalt from 1998–2000. Thereafter, she joined the Department of Anatomy and Cell Biology as a scientific associate. Professor Hombach received her accreditation as anatomist in 2003 by the German Society of Anatomists and by the Medical Association of Saxony-Anhalt and completed her habilitation at the Medical Faculty of the Martin-Luther-Universität Halle-Wittenberg in 2004. In 2004, Professor Hombach was appointed Assistant Professor at the Department of Human Anatomy and Cell Science, Faculty of Medicine of the University of Manitoba. She has been the recipient of the Merck European Thyroid von Basedow Research Prize by the German Endocrine Society in 2002 and received the Murray L. Barr Young Investigator Award by the Canadian Association for Anatomy, Neurobiology and Cell Biology in 2009.

Her main research interests are in the field of cancer research and environmental toxicants. Her focus in cancer research is to identify the molecular mechanisms that regulate cancer cell migration and metastasis. She employs unique cell and animal models and human primary cells to study epigenetic and transgenerational effects facilitated by environmental chemicals.

Preface

In the preface to the first edition of his Atlas, Johannes Sobotta wrote in May 1904: "Many years of experience in anatomical dissection led the author to proceed with the presentation of the peripheral nervous system and the blood vessels such that the illustrations of the book are presented to the student exactly in the same manner as body parts are presented to them in the dissection laboratories, i.e. simultaneous presentation of blood vessels and nerves of the same region. Alternating descriptive and image materials are distinctive features of this atlas. The images are the core piece of the atlas. Apart from table legends, auxiliary and schematic drawings, the descriptive material includes short and concise text parts suitable for use of this book in the gross anatomy laboratory."

As with fashions, reading and study habits of students change periodically. The multimedia presence and availability of information as well as stimuli are certainly the main reasons of ever changing study habits. These developments and changing demands of students to textbooks and atlases, which they utilise, as well as the availability of digital media of textbook contents, is accounted for by editors and publishers. Apart from interviews and systematic surveys of students, the textbook sector is occasionally an indicator enabling the evaluation of expectations of students. Detailed textbooks with the absolute claim of completeness are exchanged in favour of educational books that are tailored to the didactic needs of students and the contents of the study of human medicine, dentistry, and biomedical sciences, as well as the corresponding examinations. Similarly, illustrations in atlases such as the Sobotta, which contain exact naturalistic depiction of real anatomical specimens, fascinate doctors and associated medical professions for many generations throughout the world. However, students sometimes perceive them as too complicated and detailed. This awareness requires the consideration of how the strength of the atlas, which is known for its standards of accuracy and quality during its centennial existence featuring 22 editions, can be adapted to modern educational concepts without compromising the oeuvre's unique characteristics and authenticity. After careful consideration, Elsevier and the editors Professor Reinhard Putz and Professor Reinhard Pabst, who were in charge of the atlas up to its 22nd edition, came to the conclusion that a new editorial team with the same great enthusiasm for anatomy and teaching would meet the new requirements best. Together with the Elsevier publishing house, we are extremely pleased to be charged with the new composition of the 23rd edition of Sobotta. In redesigning, a very clear outline of contents and a didactic introduction to the pictures was taken into account. Not every fashion is accompanied with something entirely new. Under didactical aspects we have revisited the old concept of a three-volume atlas, as used in Sobotta's first edition, with: General Anatomy and Musculoskeletal System (vol. 1), Internal Organs (vol. 2), and Head, Neck, and Neuroanatomy (vol. 3). We have also adopted, although slightly modified, the approach mentioned already in the preface of the first edition, i.e. combining the figures in the atlas with explanatory text which is an old trend being currently back into fashion once more. Each image is accompanied by a short explanatory text, which serves to introduce students to the image, explaining why the particular preparation and presentation of a region was selected. The individual chapters were systematically organised in terms of current subject matter and prevailing study habits; omitted and incomplete illustrations – particularly the systematics of the neurovascular pathways – were supplemented or replaced. The majority of these new figures are conceptualised to facilitate studying the relevant pathways of blood supply and innervation by didactical aspects. We have also reviewed many existing figures, reduced figure legends, and highlighted keywords by bold print to simplify access to the anatomical contents. Numerous clinical examples are used to enhance the "lifeless anatomy", present the relevance of anatomy for the future career to the student, and provide a taste of what's to come. Introductions to the individual chapters received a new conceptual design, covering in brief a summary of the content, the associated clinical aspects, and relevant dissection steps for the covered topic. It serves as a checklist for the requirements of the Institute of Medical and Pharmaceutical Examination Questions (IMPP) and is based on the German oral part of the preclinical medical examination (Physikum). Also new are brief introductions to each topic in embryology and the online connections of the atlas with the ability to download all images for reports, lectures, and presentations.

We want to emphasise two points:

1. The "new" Sobotta in the 23rd edition is not a study atlas, claiming completeness of a comprehensive knowledge and, thus, does not try to convey the intention to replace an accompanying textbook.
2. No matter how good the didactic approach, it cannot relieve the students of studying, but aid in visualisation. Anatomy is not difficult to study, but very time-consuming. Sacrificing this time is worthwhile, since physicians and patients will benefit from it.

The goal of the 23rd edition of Sobotta is not only to facilitate learning, but also to make learning exciting and attracting, so that the atlas is consulted during the study period as well as in the course of professional practice.

Erlangen and Wuerzburg, summer 2010, exactly 106 years after the first edition.

Friedrich Paulsen and Jens Waschke

Acknowledgements

First, we would like to express that the work on the Sobotta was exciting and challenging. During stages, at which one could see the progress of development of individual chapters and newly developed pictures with a slight detachment, one obtained satisfaction, was elated with pride and identified oneself evermore with the Sobotta.

The redesign of Sobotta is obviously not the sole work of two inexperienced editors, but rather requires more than ever a well-attuned team under the coordination of the publisher. Without the long experience of Dr. Andrea Beilmann, who supervised several editions of the Sobotta and exerted the calming influence of the Sobotta team, many things would have been impossible. We thank her for all the help and support.

Ms. Alexandra Frntic, who is also part of the four-member Sobotta team, pursued the first major project of her career and tackled it with passion and enthusiasm. Her liveliness and management by motivation have enlivened and cheered the editors. We express our gratitude to Ms. Frntic. We like to reflect back on the Sobotta initialisation week in Parsberg and weekly conference calls, in which Dr. Beilmann and Ms. Frntic supported us in the composition of the Sobotta and presented an admirable way to merge the variety of two personalities to achieve a single layout. Without the assertiveness, the calls for perseverance and the protective hand of Dr. Dorothea Hennessen, who directed the project of the "23rd edition of Sobotta" and always believed in her Sobotta team and the tight schedule, this edition would have not been published. Like a number of previous productions, the routinier Renate Hausdorf led the successful reproduction of the atlas. Other people involved in the editing process and the success of the 23rd edition of the Sobotta and whom we sincerely thank are Ms. Susanne Szczepanek (manuscript editing), Ms. Julia Baier, Mr. Martin Kortenhaus and Ms. Ulrike Kriegel (editing), Ms. Amelie Gutsmiedl (formal text editing), Ms. Sibylle Hartl (internal production), Ms. Claudia Adam and Mr. Michael Wiedorn (formal figure editing and typesetting), Ms. Nicola Neubauer (layout development and refining the typesetting data) and the students Doris Bindl, Derkje Hockertz, Lisa Link, Sophia Poppe, Cornelia Rippl and Katherina and Florian Stumpfe. For the compilation of the index, we express our gratitude to Dr. Ursula Osterkamp-Baust. Special thanks are expressed to the illustrators Dr. Katja Dalkowski, Ms. Sonja Klebe, Mr. Jörg Mair and Mr. Stephan Winkler, who in addition to revising existing illustrations have developed a variety of excellent figures. Priv.-Doz. Dr. rer. nat. Helmut Wicht, Senkenberg Anatomy, Goethe-Universität Frankfurt/Main, has revived the lifelessness of the introductions to the chapters indited by the two editors through his unique style of writing. We express our gratitude to Priv.-Doz. Dr. rer. nat. Wicht.

A big help to us was the advisory council, which in addition to the former editors Prof. Dr. med. Dr. h. c. Reinhard Putz, Ludwig-Maximilians-Universität Munich, and Prof. Dr. med. Reinhard Pabst, Hannover Medical School, and colleagues Prof. Dr. med. Peter Kugler, Julius-Maximilians-Universität Wuerzburg, and Prof. Dr. rer. nat. Gottfried Bogusch, Charité Berlin, supported us strongly with advice and critical comments. We would like to specifically emphasise the effort of Ms. Renate Putz, who corrected the manuscript very carefully; her comments were of crucial importance for the consistency of the work in itself and with the earlier editions.

For support with corrections and revisions, we express our sincere thanks to Ms. Stephanie Beilicke, Dr. rer. nat. Lars Bräuer, Ms. Anett Diker, Mr. Fabian Garreis, Ms. Elisabeth George, Ms. Patricia Maake, Ms. Susann Möschter, Mr. Jörg Pekarsky and Mr. Martin Schicht.

For assistance in creating clinical figures, we express our gratitude to Priv.-Doz. Dr. med. Hannes Kutta, Clinic and Polyclinic for Oto-Rhino-Laryngology at the University Hospital Hamburg-Eppendorf, Prof. Dr. med. Norbert Kleinsasser, University Clinic for Oto-Rhino-Laryngo-Pathology, Julius-Maximilians-Universität Wuerzburg, Prof. Dr. med. Andreas Dietz, Head of Clinic and Polyclinic for Oto-Rhino-Laryngology at the University Leipzig, Dr. med. Dietrich Stoevesandt, Clinic for Diagnostic Radiology at the Martin-Luther-Universität Halle-Wittenberg, Prof. Dr. med. Stephan Zierz, Director of the University Hospital and Polyclinic for Neurology at the Martin-Luther-Universität Halle-Wittenberg, Dr. med. Berit Jordan, Hospital and Polyclinic for Neurology at the Martin-Luther-Universität Halle-Wittenberg, Dr. med. Saadettin Sel, University Hospital for Ophthalmology at the Martin-Luther-Universität Halle-Wittenberg, Mr. cand. med. Christian Schroeder, Eckernförde, and Mr. Denis Hiller, Bad Lauchstädt.

We also would like to express our thanks to our anatomical mentors Prof. Dr. med. Bernhard Tillmann, Christian-Albrechts-Universität Kiel, and Prof. Dr. med. Detlev Drenckhahn, Julius-Maximilians-Universität Wuerzburg, whom we not only owe our anatomical training, the motivation for subject matter, and the sense of mission, but also have been great role models in their design of textbooks and atlases, as well as in their teaching excellence.

Our deepest gratitude to our parents, Dr. med. Ursula Paulsen and Prof. Dr. med. Karsten Paulsen, and also Annelies Waschke and Dr. med. Dieter Waschke, who intensely supported and sustained the Sobotta project. Karsten Paulsen, who passed away in May 2010, studied anatomy as a medical student from the 4th edition of Sobotta. Dieter Waschke used the 16th edition of Sobotta and continues to attain knowledge with medical literature even during retirement. The 23rd edition is dedicated to our fathers.

Last but not least, we thank our wives Dr. med. Dana Paulsen and Susanne Waschke, who not only had to share us with the Sobotta in the last year, but also were on hand with help and advice on many issues and have been strongly supportive.

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1

Anatomy – Reveal the Concealed

What Anatomy Is

"ανατομη" (anatome) means cut-up, "ανατεμνειν" (anatemnein) denotes to cut open. Consequently, anatomy is dissection and the anatomists are dissectors. The dissection reveals the otherwise non-visible constituents, and is the method which named the science: reveal, represent, divide, cut, sort, and name. Recognition of the parts is the key to understanding the subject.

"Anatomy […] dissects organisms into their […] constituents […], examining their external, sensorial perceptible properties and their internal structure. It is the study of death to make conclusions about life. Anatomy manually destroys an ideal creation in order to rebuild it mentally and to virtually recreate a human being. There is not a more glamorous task for the human mind."
Joseph Hyrtl (Anatomist, 1811–1894).

Although anatomy deals with death, it is devoted to life. It is not about death but rather about the comprehension of the human body which functions as a unit. The body donors are models only.

There are two other medical fields which deal with dead bodies: forensic medicine and pathology. Pathologists are interested in causes of diseases. Forensic medicine deals in particular with doubtful causes of death. Whereas the sole purpose of anatomists is to understand the living human body on a continuum from the embryonic stage to old age.

Eyes and hands are most important **tools of the anatomist.**The findings revealed by hands, tweezers, scissors, scalpels, and the visualization of these structures by eye is called gross or macroscopic anatomy. Structures in gross anatomy not discernible by the naked eye can be visualized by microtomes or light and electron microscopes. This field is called microscopic anatomy.

Organization and classification are basic aspects of **systematic anatomy.** The body is precisely classified according to systems. The bone system for example includes not only bones, but also bony parts and associated terminology. On the other hand, tissue systems are organized according to types and subtypes. **Topographic anatomy** is the study of regions or divisions of the body and emphasizes the relations between various structures in that region. The relationship of form and function is termed **functional anatomy.** Topographic anatomy and functional anatomy are the supreme disciplines of the physician and lead the path to **clinical anatomy.** This serves as practical application for diagnosis and therapy. Lastly, **comparative anatomy** serves in evolutionary phylogeny. It is of interest to biologists and compares bodies and body parts of different creatures.

Histology is a subdivision of microscopic anatomy and is dealing with the composition of organ tissues which are multicellular in structure. **Cytology,** the study of cells, focuses on structure and function of the single cell. **Embryology,** which mainly uses the microscope for examination of tiny embryos, describes the development of an organism (individual development, ontogenesis).

Dissection and analysis is the trade of the anatomy, but its real goal is to mentally assemble all parts into a functioning whole. This goal of understanding the structural design and shape of biological structures and conceptualizing it as a unified structure-function relationship can also be called **morphology.**

Linguae Anatomiae

The language of this classical discipline "Anatomy" (Linguae anatomiae) is predominantly Latin and (latinized) Greek. In the past 50 years, some English terms were added. The anatomic Termini technici (terminology) are usually marvellously graphic, concrete, and vivid. Even a word monster like "Cartilago arytenoidea" means simply (nothing more than) "the cartilage which looks like a gravy boat". This cartilage is located above the larynx and really looks like a boat-shaped pitcher to serve gravy. At times one needs visual imagination which anatomists do not lack. One does not need to be afraid of terminology, but rather enjoy its diversity. This is done most successfully when this terminology is translated into one's own language and imagination.

Body Donations – The Legacy

Dead human bodies are essential for carrying out lessons in dissection. These bodies are made available by body donations. The body donor bequeathed his/her body to an anatomical institute. This has to be done in person as a last will declaration during the lifetime of the donor. Next of kin are not authorized representatives in this legal matter. Every body donor has personally contacted an anatomy institute during his/her lifetime and, in the last will, donated his/her body to the institution for teaching and research after death.

The body donor usually receives a donor card which always needs to be at hand. When death occurs the body is brought to the anatomy institute and is used for lessons in dissection, for clinical preparations, for demonstration, or for surgery courses as well as for scientific studies. Following the courses and examinations, the mortal remains are usually cremated and buried in the cemetery of honour of the university. The memorial or funeral service is attended by family members, students, and instructors of the faculty.

Depending on institution and/or state/province, there are different regulations for the exhibition of bodies and organs. For example, body donors or organs of body donors can be exhibited in an anatomical collection for presentation and teaching purposes, if this is expressed in the body donor's will.

Reasons for body donations are diverse, and body donors represent all parts of society. The widely held assumption that body donors donate to be granted an inexpensive funeral is proven to be wrong. Many universities charge a fee for body donations and this has not resulted in a reduction of body donations.

Clinical Remarks

Human anatomy is the basis for the education of physicians, dentists, and other health professionals. The anatomical knowledge is constantly applied in daily patient care and must always be refreshed. The curricula of biomedical studies and education continue to encompass more scientific knowledge. The existing subjects have to be covered in fewer lectures, since competing subjects and new technologies require a greater amount of the limited curriculum hours. Training competent clinicians and specialists in health-related medical professions can be achieved effectively by supplementing anatomical facts with clinical examples. This also leads to an application-oriented learning and increases the motivation of the student. However, the extensive and time-consuming study of anatomy should not be neglected. Intrinsic and firm anatomy knowledge can then be applied to the benefit of the patient.

→ ***Dissection Link***

Dissection is done by hand using a scalpel (non-disposable scalpels!) and anatomical tweezers. Structures and organs as well as their topographic relationships are examined in this fashion.

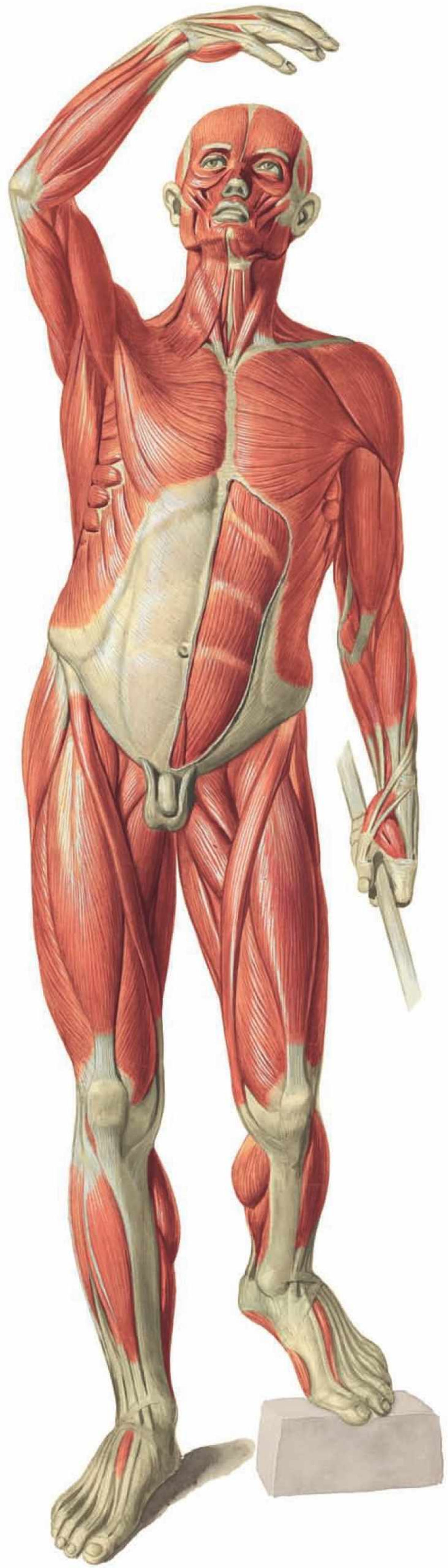
The nature of the tissue differs regionally. Areas with a lot of adipose tissues that can be removed bluntly by hand alternate with connective tissue which can be stripped off with the aid of scalpel only. As part of the preparation, different cavities are exposed which are filled with air, liquid, or solid constituents. The tissue of the organs (parenchyma) may – depending on the fixation – be hard, soft, spongy, tender, or elastic. Protected nerves and blood vessels are located in different layers of the body, and their dissection can be of varying difficulty. In some locations these are easily removable, in other regions they may adhere to adjacent tissues. To illustrate the muscles, mobilization by loosening the tight surrounding connective tissue sheaths (muscle fascia) is required.

To prevent damage, special attention needs to be paid to nerves and blood vessels entering and exiting the muscle. Partial severance of surrounding ligaments is needed to open joints. In contrast some structures such as the inner ear can be exposed with a hammer and chisel or saws and milling machines.

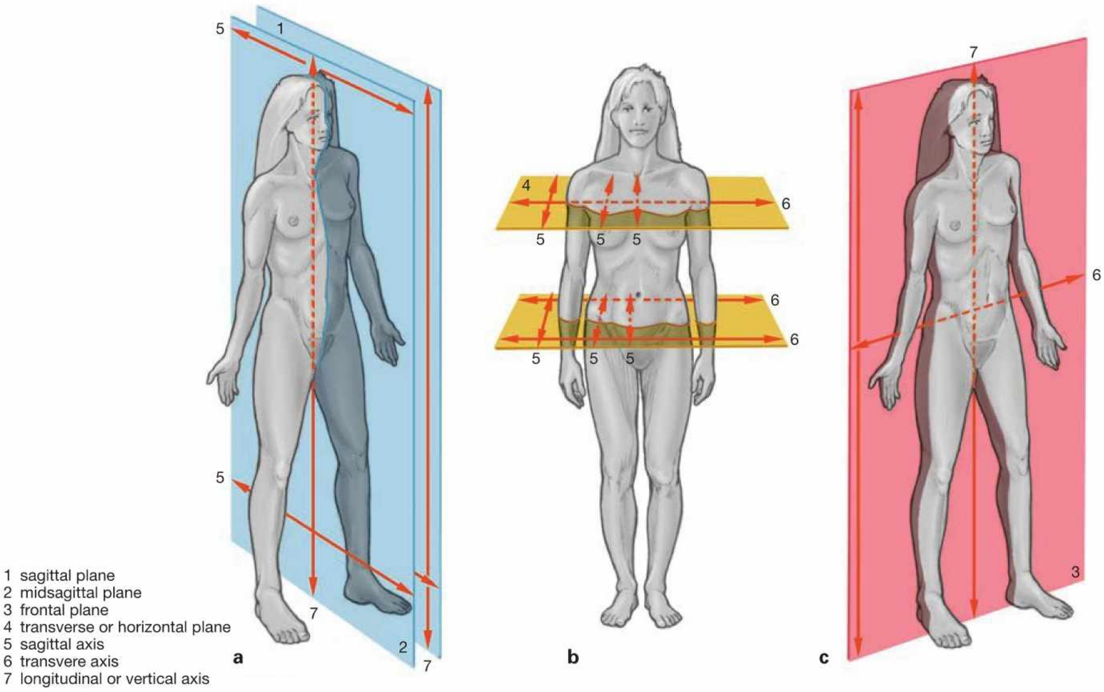
The preparation requires a lot of patience, manual dexterity, and spatial imagination. One gains great experiences and valuable insights which are not offered by any anatomy textbook or atlas. These include the three-dimensional understanding of the structures of the human body, the confrontation with death, but also teamwork.

EXAM CHECK LIST

• Main axes • main planes • directions and positioning of body parts • directions of movement • radiological terms of sectional planes • general embryology • general surface projection of inner organs • skeletal overview • bone structure • bone development • bony connections • type of joints • examination of joints • muscle types • muscle mechanics • cardiovascular system • greater and lesser blood circulatory system • portal system • overview: lymph system • spinal nerve • overview: central, peripheral, and autonomic nervous system • skin and finger nails • imaging techniques: radiograph, ultrasound, MRI, CT, and scintigraphy



Axes and planes



Figs. 1.1a to c Planes and axes.
a sagittal plane (Planum sagittale), encompasses sagittal and longitudinal axes
b transverse plane = horizontal plane (Planum transversale), encompasses transverse and sagittal axes
c frontal plane = coronal plane (Planum frontale); encompasses longitudinal and transverse axes

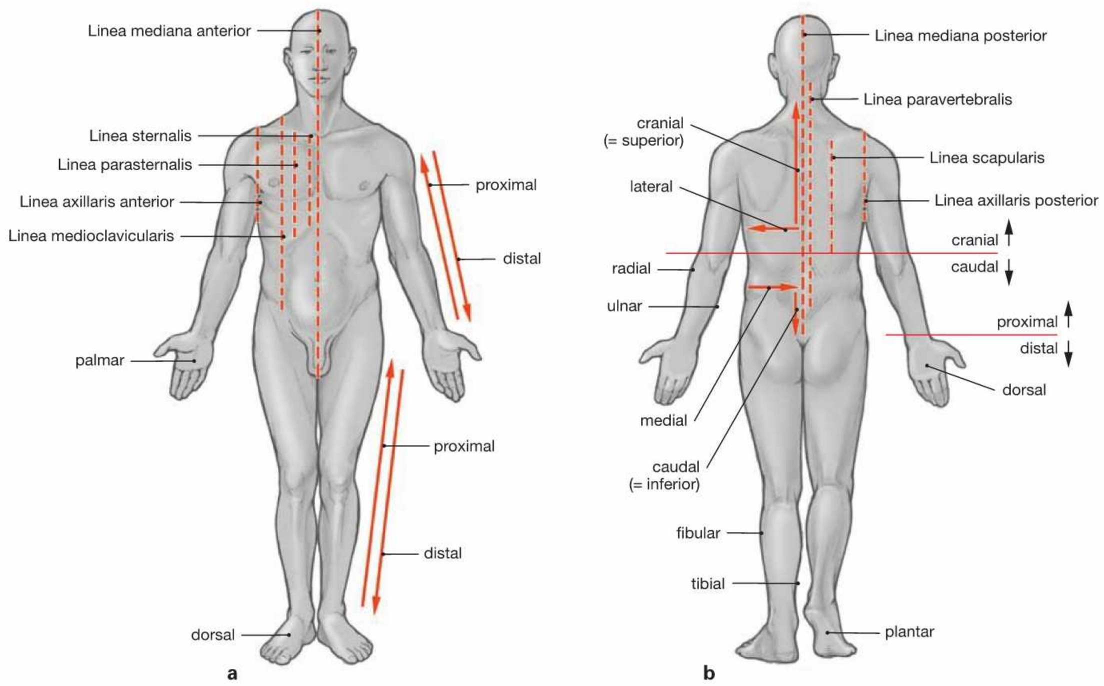
Main Axes	
sagittal axis	is positioned perpendicular to transverse and longitudinal axis
transverse axis	is positioned perpendicular to longitudinal and sagittal axis
longitudinal or vertical axis	is positioned perpendicular to sagittal and transverse axis

Main Planes	
median (sagittal) plane	symmetry plane, divides the body into two equal halves
sagittal plane	runs parallel to the median (sagittal) plane
transverse plane	any cross-sectional plane of the body
frontal plane	parallel to the forehead

Direction of Movement	
extension	stretching of the torso or the extremities
flexion	bending of the torso or the extremities
abduction	moving extremities away from the torso
adduction	moving extremities towards the torso
elevation	lifting of arms above the horizontal plane
rotation	turning extremities inwards and outwards around a longitudinal axis
circumduction	spinning motion

Radiological Section Planes	
Radiological Terms	**Anatomical Terms**
sagittal section	sagittal plane
coronal section	frontal plane
axial section	transverse plane

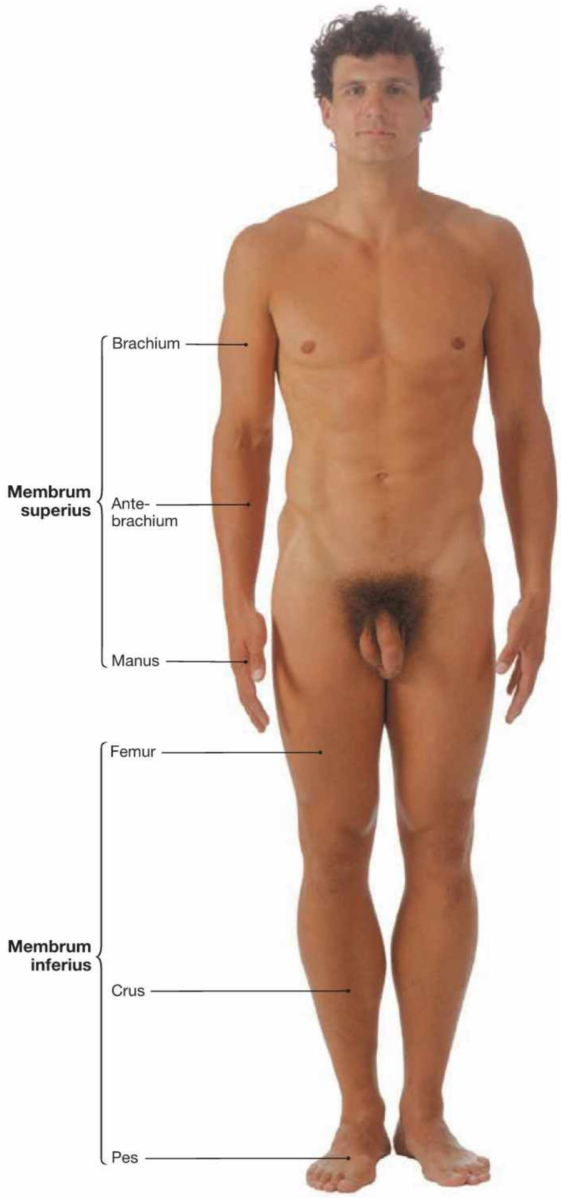
Radiology terminology in imaging procedures (computed tomography and magnetic resonance imaging) defines the three main anatomical planes as sections with their own nomenclature.



Figs. 1.2a and b Lines for orientation, directional information and relationships.
a ventral view
b dorsal view

Terms of Direction and Positioning of Body Parts			
cranial or superior	towards the head	apical	pointed or belonging to the tip
caudal or inferior	towards the sacrum	basal	pointed towards the base
anterior or ventral	towards the front or abdomen	dexter	right
posterior or dorsal	towards the back	sinister	left
lateral	sideways, away from the midline	proximal	towards the torso
medial	centered, towards the midline	distal	towards the end of the limbs
median or medianus	within the median plane	ulnar	towards the ulna
intermedial	positioned in between	radial	towards the radius
central	towards the interior of the body	tibial	towards the tibia
peripheral	towards the body surface	fibular	towards the fibula
profundus	located deeply	volar or palmar	towards the palm of the hand
superficial or superficialis	located superficially	plantar	towards the sole of the foot
external or externus	located externally	dorsal	(extremities) towards the back (dorsum) of the hand or the foot
internal or internus	located internally	frontal	towards the forehead
		rostral	(literally translated: „towards the beak") towards the mouth or tip of the nose (exclusively used for directional and positional information related to the head)

Parts of the body



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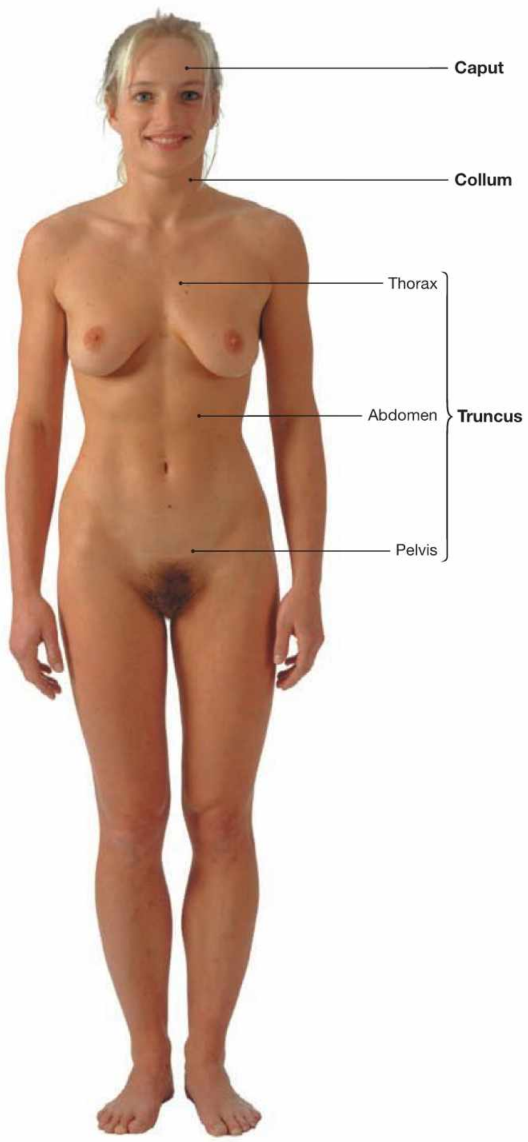
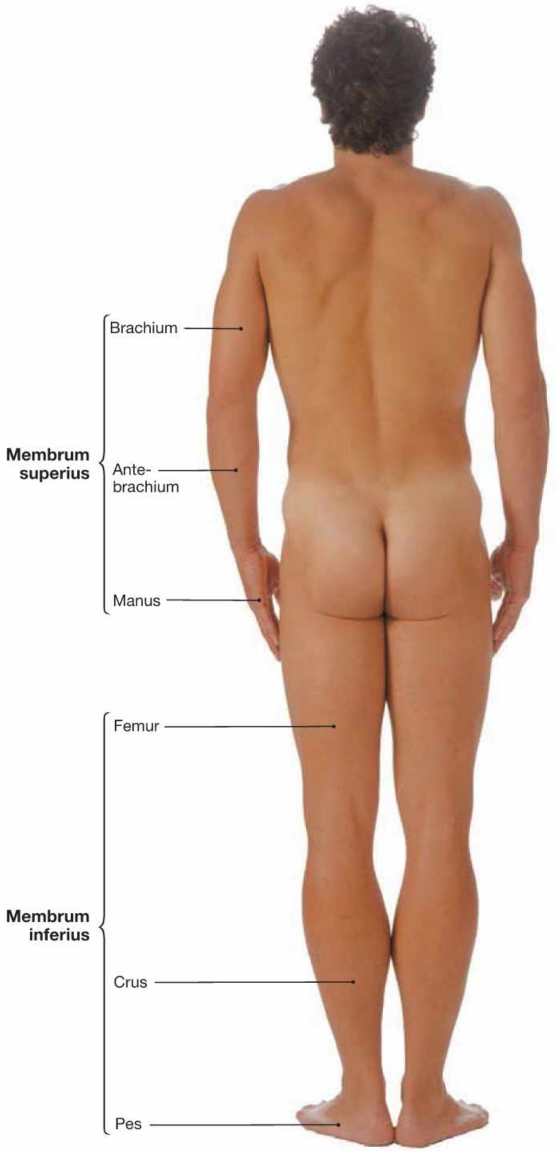


1.4

Fig. 1.3 and Fig. 1.4 Surface anatomy of the male (→ Fig. 1.3) and the female (→ Fig. 1.4); ventral view.
Anatomical terminology generally refers to the upright position with the face directed forwarzd, arms positioned sideways, palms pointing towards the body or forward, legs positioned beside each other with feet pointing forward.

The body is divided into head (Caput), neck (Collum), torso (Truncus) with chest (Thorax), abdomen (Abdomen), pelvis (Pelvis), back (Dorsum), and upper (Membrum superius) and lower (Membrum inferius) extremities. The extremities divide into the upper arm (Brachium), forearm (Antebrachium), hand (Manus) and upper leg (Femur), lower leg (Crus), foot (Pes).



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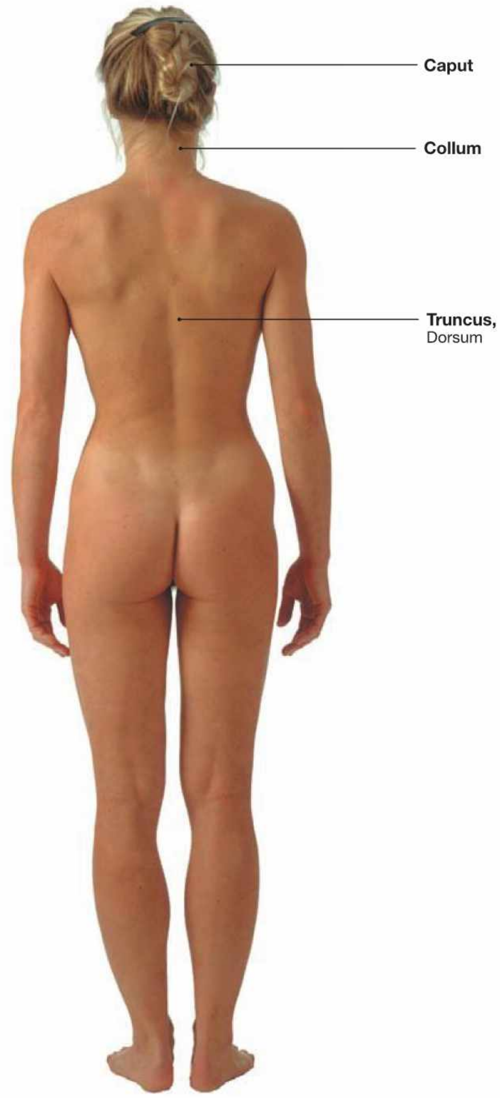


1.6

Fig. 1.5 and Fig. 1.6 Surface anatomy of the male (→ Fig. 1.5) and female (→ Fig. 1.6); dorsal view.

Clinical Remarks

During **anamnesis** (from ancient Greek. αναμνησις, *anámnesis* = memory) – taking a medical history – the history of a patient is carefully examined with reference to current symptoms. A detailed medical history includes biological, psychological, and social aspects. This gathered information often permits conclusions regarding risk factors and causal relationships. The anamnesis does not have a direct therapeutic goal, although talking about and clarifying the issues may have a salutary effect.

The history is usually taken before physical examination takes place, but in an emergency immediate treatment is required and taking the medical history is postponed. The goal of the accurate medical history is to narrow down the possible differential diagnoses. This process of elimination is based on key symptoms and exclusion criteria. Following the medical history, further investigations are often necessary to effectively diagnose a medical condition.

Regions of the body

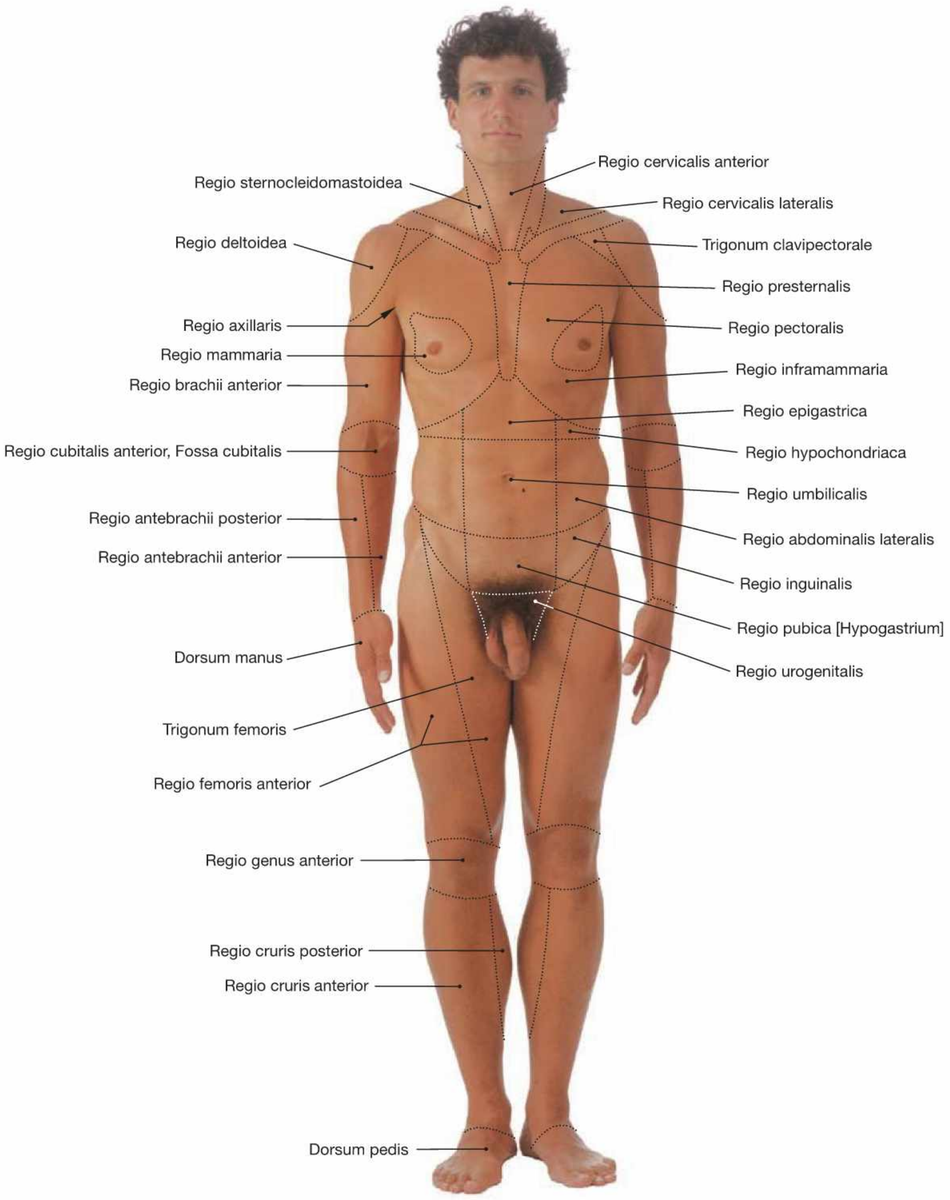


Fig. 1.7 Body regions; ventral view.
The body surface is divided into regions for better description and orientation. Regio: region; Trigonum: triangle.

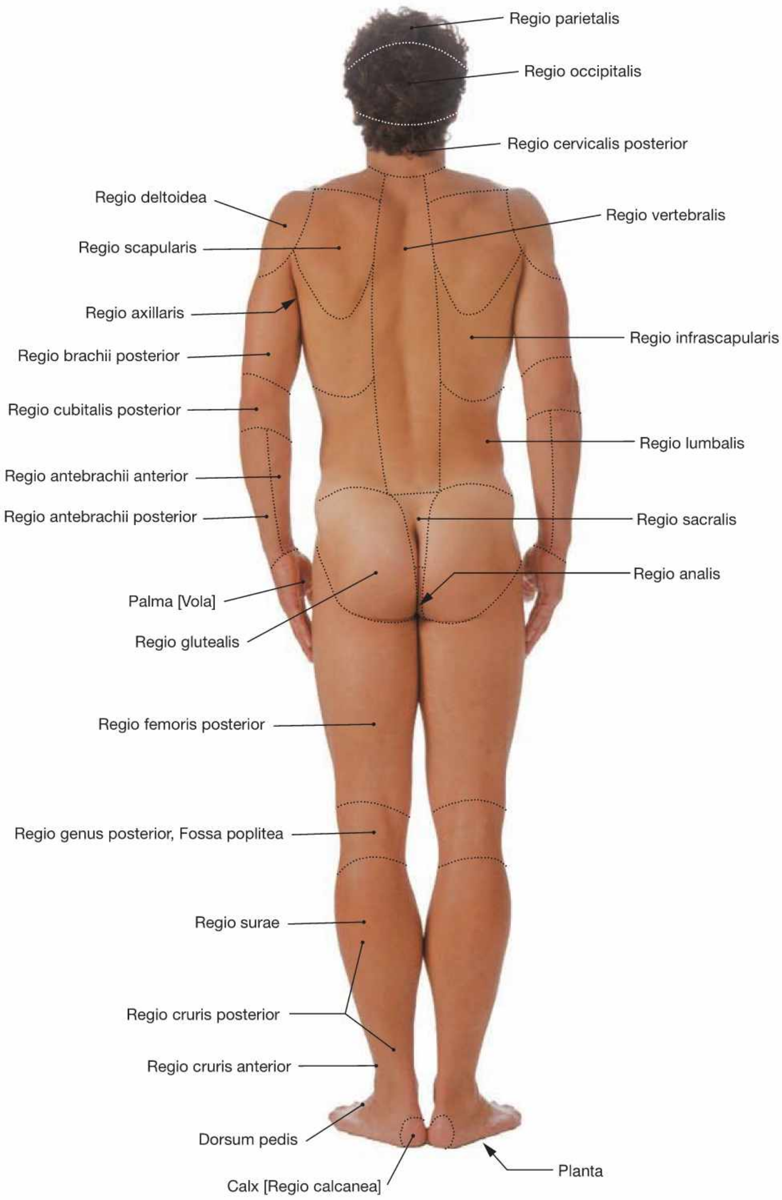
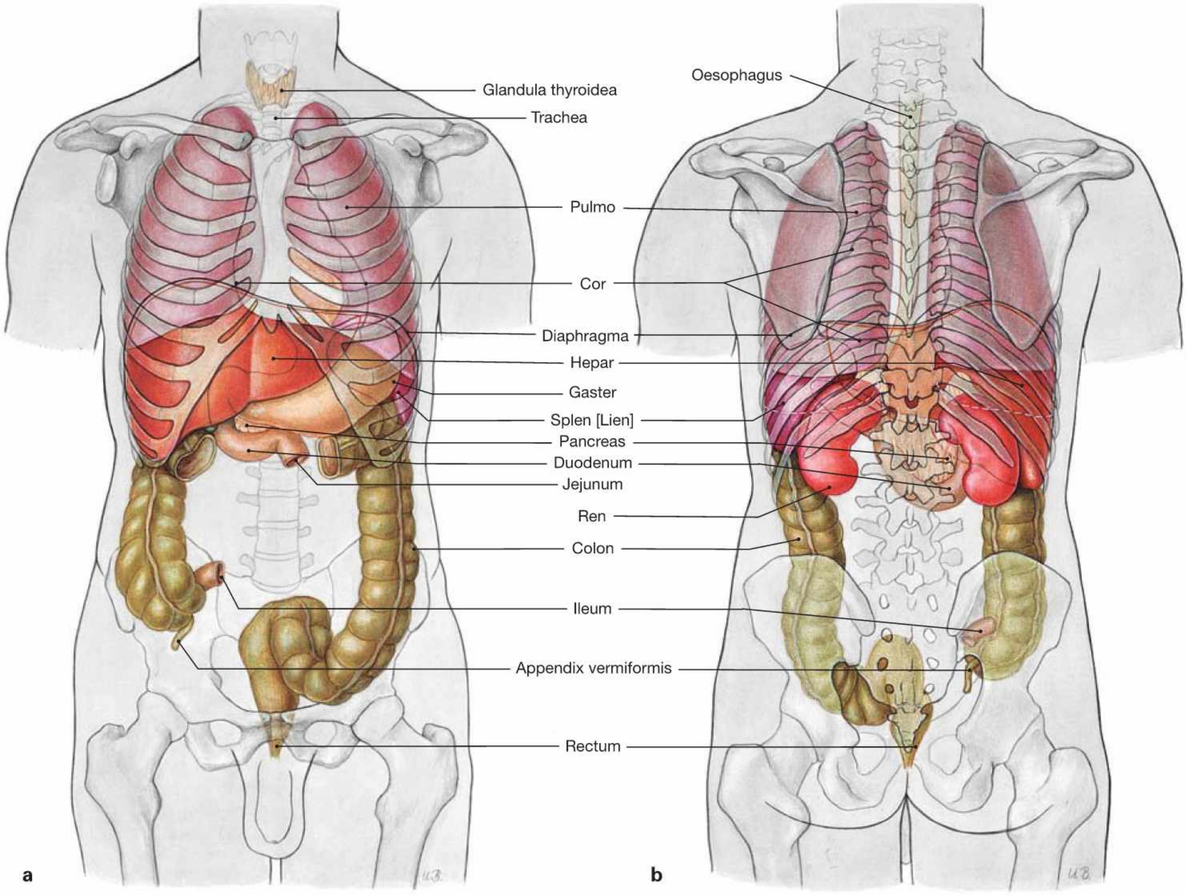


Fig. 1.8 Body regions; dorsal view.
The body surface is divided into regions for better description and orientation. Regio: region; Trigonum: triangle.

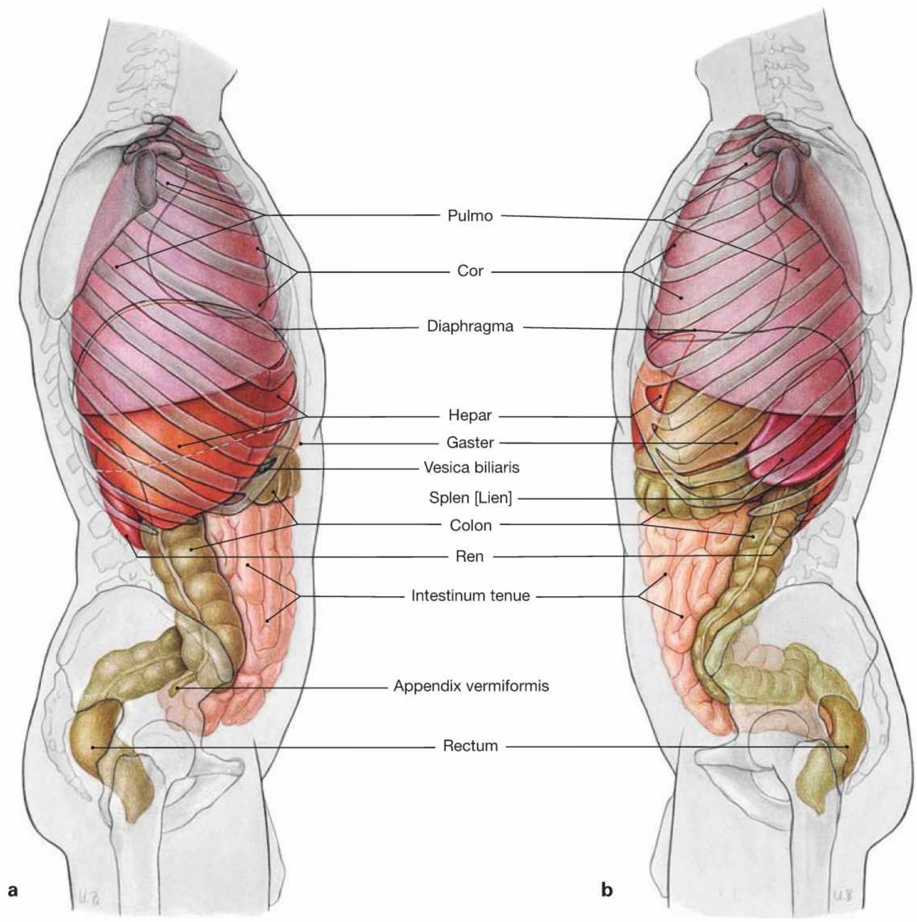
Inner organs, surface projection



Figs. 1.9a and b Projection of inner organs onto the body surface. Projection of inner organs onto the ventral abdominal wall (**a**) and onto the dorsal wall of the trunk (**b**): esophagus, thyroid gland (Glandula thyroidea), wind pipe (Trachea), lung (Pulmo), heart (Cor), diaphragm, liver (Hepar), stomach (Gaster), spleen (Splen [Lien]), pancreas, duodenum, jejunum, kidney (Ren), colon, ileum, appendix (Appendix vermiformis), and rectum (Rectum).

Clinical Remarks

Even without technical instruments, an examiner is able to obtain orientation on individual organs and their projection onto the body surface of the patient through practice. **Auscultation** (to auscultate originates from the Latin word "auscultare" and means listening) is part of the physical examination and includes the listening to the sounds of the organs typically done with a stethoscope. **Percussion** (to percuss originates from the Latin word "percutare" and means to beat or shake) is performed for diagnostic purposes and involves tapping the body surface of the patient. Percussion induces vibrations of the tissue beneath the surface of the body. The resulting 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.

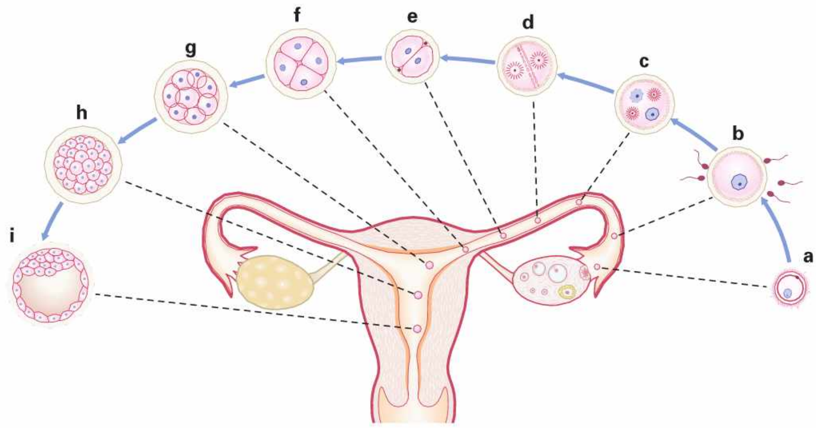


Figs. 1.10a and b Projection of inner organs onto the body surface. Projection of inner organs onto the right wall of the torso (**a**) and onto the left wall of the torso (**b**): lung (Pulmo), heart (Cor), diaphragm, liver (Hepar), stomach (Gaster), gall bladder (Vesica biliaris), spleen (Splen [Lien]), colon, kidney (Ren), small intestine (Intestinum tenue), appendix (Appendix vermiformis), and rectum.

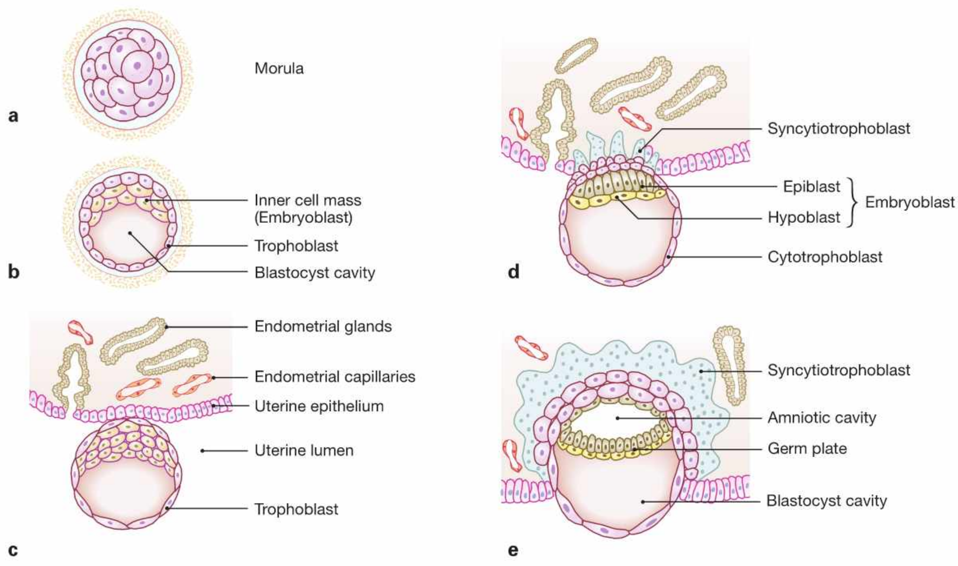
Clinical Remarks

Through knowledge of the **projection** of the internal organs onto the body surface, disease specific symptoms can already be linked to organs during physical examination. In addition to the patient's history, first clues of the diseased organ(s) involved can be deduced. For example, appendicitis (inflammation of the appendix [Appendix vermiformis]) is usually accompanied by discomfort in the right lower abdomen.

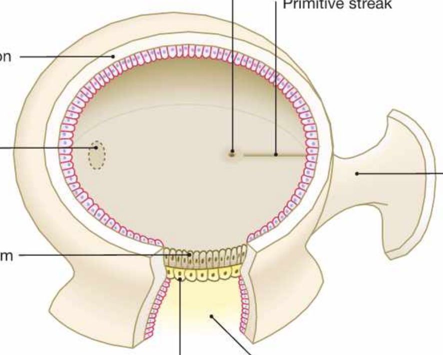
Development

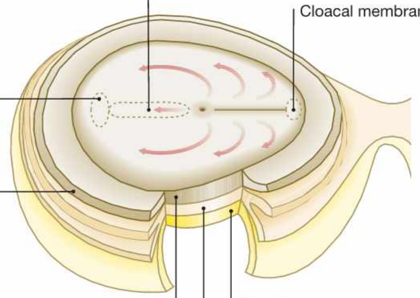


Figs. 1.11a to i First week of embryogenesis: fertilization and implantation. [21]
Within 24 hours after ovulation **(a), fertilization** (**b**) normally occurs in the ampulla of the oviduct. The fusion of the pronuclei of the ovum and sperm into a single diploid nucleus creates the **zygote** (**c**). Subsequent cell divisions **(2-, 4-, 8- and 16-cell stages; d–h)** generate a cell aggregate (Morula) which is transported into the uterine cavity. At approximately day 5 after fertilization, the morula develops into a fluid-filled cyst **(blastocyst; i)** which implants into the uterine mucosa at days 5–6.



Figs. 1.12a to e First and second week of embryogenesis: bilaminar embryonic disc. [21]
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)**. Through interactions between maternal tissues and the trophoblast cells the **utero-placental circulation** is formed (**c–e**). The embryoblast develops into the bilaminar **embryonic disc** with ectoderm (columnar cells at the dorsal surface of the embryoblast) and entoderm (cuboidal cells at the ventral surface). The ectoderm forms a dorsally located cavity which becomes the **amniotic cavity**. The ventrally located blastocyst cavity becomes the primary yolk sac which is lined by entoderm. At day 12, the secondary yolk sac (yolk sac proper) forms. The original blastocyst cavity is lined by extra-embryonic mesoderm.





Figs. 1.13a and b Third week of embryogenesis: gastrulation. [21]
Development of the trilaminate embryonic disc initiates with the appearance of the primitive streak at the dorsal surface of the ectoderm. At its cranial section, the primitive streak is demarcated by the primitive node (**a**). Cells migrating out of the primitive streak form the **intraembryonic mesoderm** located between the top of the yolk sac and the ectoderm of the amniotic cavity (gastrulation). Some of these cells form the **notochordal process** which extends towards the cranial part of the embryo where the **prechordal plate** has formed (adhesion between ectoderm and entoderm without an intervening mesoderm layer). The notochordal process develops a lumen (notochordal canal) and becomes the notochord (**Chorda dorsalis;** primitive stabilizing structure of the embryo) which regresses later in development (**b**). Relics of the notochord can be found in the Nuclei pulposi located within the vetrebral discs. Some mesoderm cells migrate cranially past the prechordal plate to create the primordial heart. **The three germ layers** (ectoderm, mesoderm, entoderm) are the building blocks for **the development of all organs.** Further information on the germ layers participating in specific organ formation can be found in embryology textbooks.

Skeleton

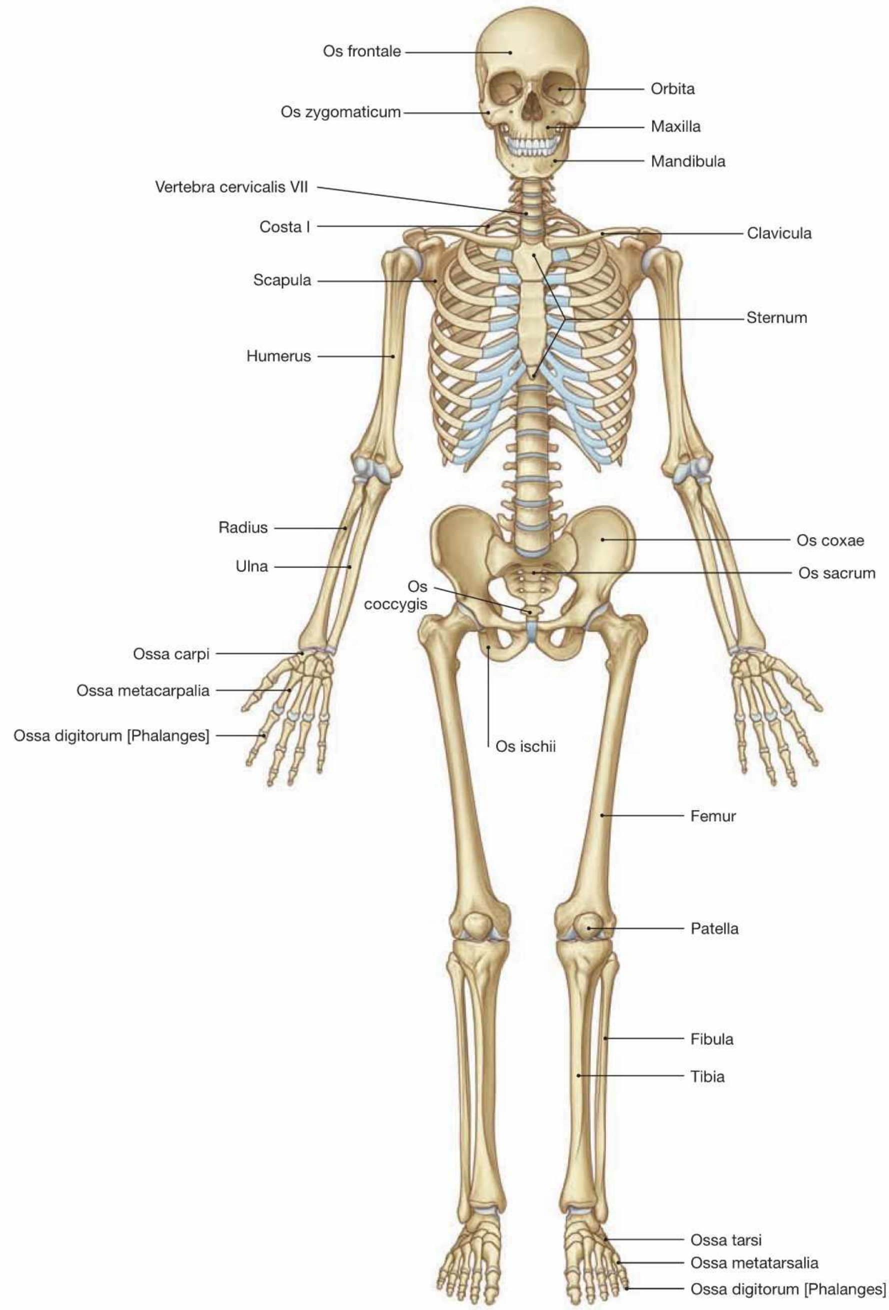


Fig. 1.14 Skeleton, Systema skeletale; ventral view. [10]
The bones of the skeleton are grouped according to their shape and structure:

- **long bones** (Ossa longa), e.g. hollow bones of the extremities, like femur and humerus
- **short bones** (Ossa brevia), e.g. carpal and tarsal bones
- **flat bones** (Ossa plana), e.g. ribs, sternum, scapula, pelvis, bones of the skull
- **air-filled bones** (Ossa pneumatica), e.g. frontal bone, ethmoid bone, maxilla, sphenoid bone
- **irregular bones** (Ossa irregularia, cannot be grouped with the other bones), e.g. vertebrae, mandible
- **sesamoid bones** (Ossa sesamoidea, bones embedded in tendons), e.g. patella, Os piriformis
- **accessory bones** (Ossa accessoria, accessory bones not commonly found in all human skeletons), e.g. sutural bones of the skull, cervical rib

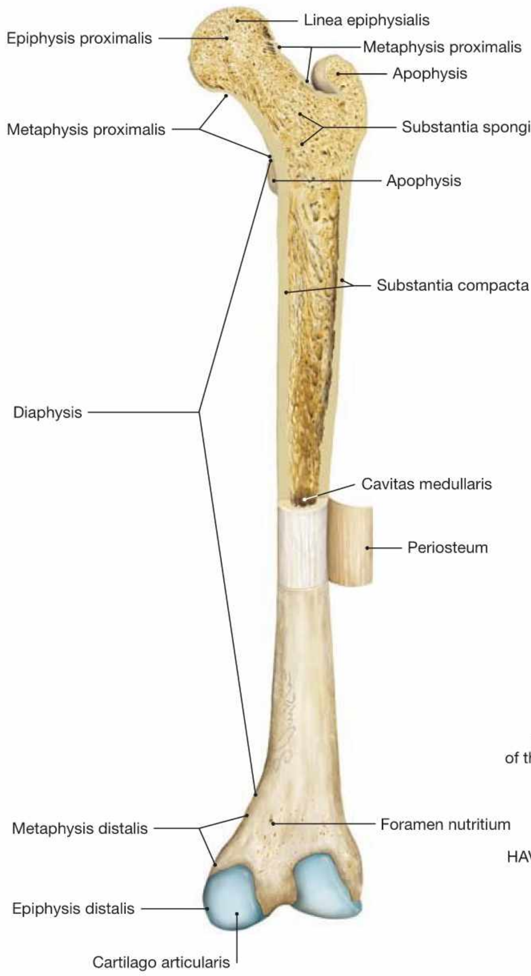


Fig. 1.15 Long bones (hollow bones), Os longum.
Section through the proximal part of the femoral bone of an adult. Periosteum of the diaphysis has been removed and folded sideways. Dorsal view. Sectioned femoral bone displays two distinct types of bones with no clear separation between them:

- Substantia compacta or corticalis (compacta, compact bone, very thin in the epiphysis, substantial in the diaphysis) and
- Substantia spongiosa (spongiosa, spongy or cancellous bone, substantial presence exclusively in the epiphysis and metaphysis).

In the diaphysis, the **compacta** appears as a solid mass; the **spongiosa** in epi- and metaphysis creates a three-dimensional network of delicate branched bones **(trabeculae).** Depending on the physical forces applying, they are divided into traction or compression trabeculae. The space in between the trabeculae is filled with blood-forming bone marrow (young person) or fatty lipids (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.) A long evolutionary process resulted in a light bone, combining maximal mechanical robustness with minimal bone deposit.

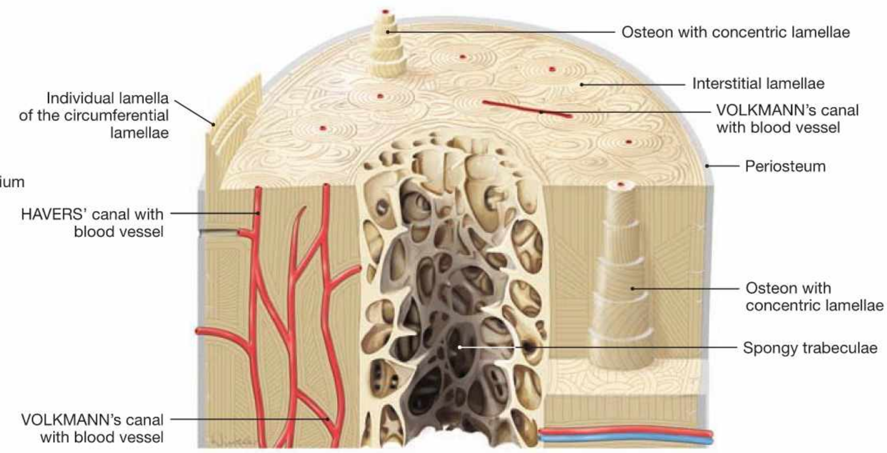
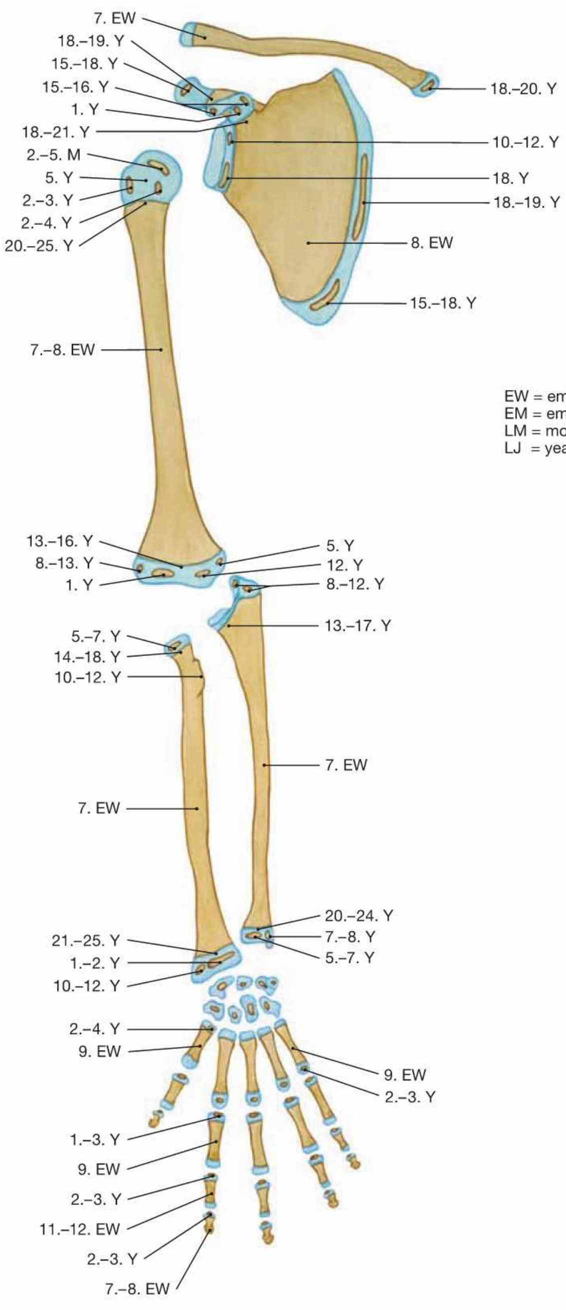


Fig. 1.16 Structure of a long hollow bone, Os longum.
The basic histological structure of both a mature compact bone and a mature spongy bone is similar and represents a **lamellar bone**. The mature bone is composed of lamellar concentric units, named **osteons**, most frequently found in the compacta of long bones. In spongy bones, the lamellae are primarily oriented parallel to the trabecular surface. In the compact bone, lamellae of bone matrix with central blood vessels create osteons, a system (HAVERS' system) of five to 20 bony lamellae **(special lamellae)** which are grouped concentrically around a HAVERS' canal and can be a few centimeters in length. Collagen fibres show perpendicular orientation in adjacent **lamellae of an osteon**. Remnants of previous osteons, called **interstitial lamellae**, are located between osteons. The outer and inner surface of the compacta is composed of lamellae surrounding the complete bone. These are called outer and inner **circumferential lamellae**.

Clinical Remarks

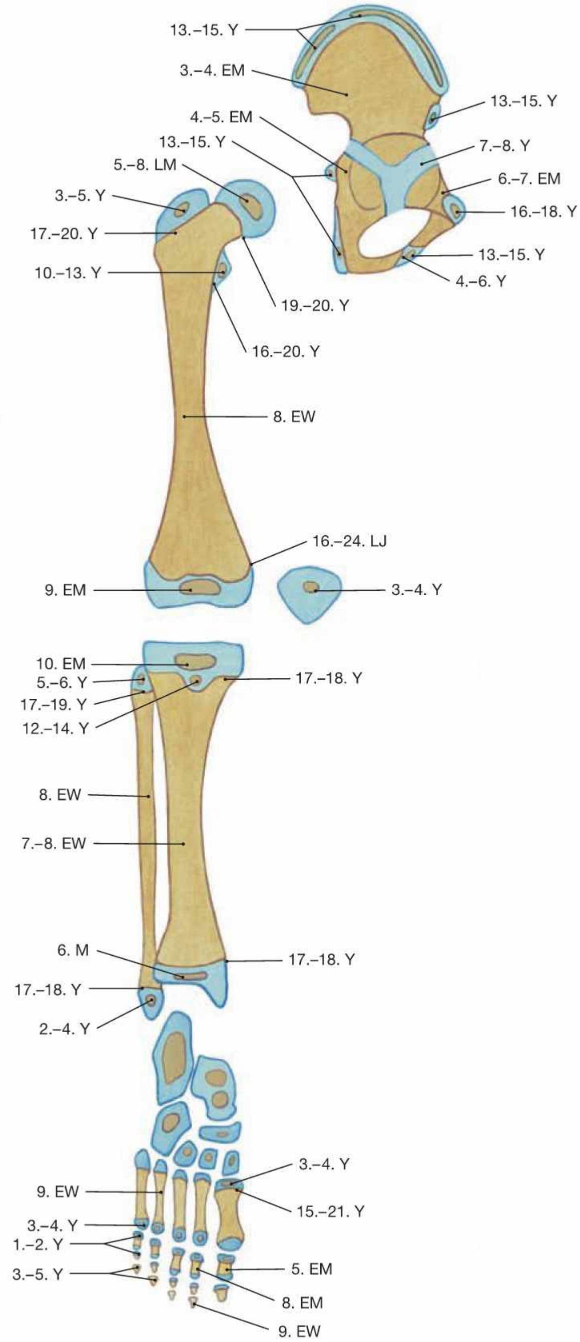
The **fracture** of a bone leads to the formation of two or more fragments with or without dislocation. Apart from pain, true signs are abnormal mobility, grinding sounds with movement (crepitation), axis misalignment, an initial muscle stupor (lack of muscle activity), and corresponding radiograph findings. Ideally, healing of a fracture involves complete immobilization and weight-bearing restrictions. Successful **healing of a fracture** is achieved when the formerly injured bone regains its full weight-bearing capacity and long bones have reformed the medullary cavity. The **primary** fracture healing exclusively occurs with narrow, irritation-free fracture gaps and does not involve callus formation, as is achieved surgically by osteosynthesis with plates and screws for optimal alignment of fractured ends. As part of the primary fracture healing, the fracture gap is bridged by capillaries from opened HAVERS' canals which are surrounded by osteons spanning the gap. The **secondary** fracture healing often forms a slightly thicker **callus** which is gradually converted into functional bone mass.

Bone development



1.17

EW = embryonic week
EM = embryonic mouth
LM = mouth of life
LJ = year of life



1.18

Os scaphoideum 3.–6. M
Os lunatum 3.–6. Y
Os trapezium 3.–8. Y
Os trapezoideum 3.–7. Y
Os pisiforme 8.–12. Y
Os triquetrum 1.–4. Y
Os hamatum 2.–5. M
Os capitatum 2.–4. M

Talus 7. EM
Calcaneus 5.–6. EM
Os naviculare 4. Y
Os cuboideum 10. EM
Os cuneiforme mediale 2.–3. Y
Os cuneiforme intermedium 3.–4. Y
Os cuneiforme laterale 12. M

Fig. 1.17 and Fig. 1.18 Ossification of the skeleton of the upper (→ Fig. 1.17) and lower extremities (→ Fig. 1.18); position of the epi- and apophysial ossification centres and chronological sequence of the formation of these ossification centres.
The timing for these bone nucleation sites to appear holds clues as to the stage reached in skeletal development and, thus, to the individual skeletal and bone age. We distinguish ossification centres formed around the shaft (diaphysis) of the cartilage model during the fetal period, resulting in the diaphyses **(diaphyseal ossification)** from ossification centres which in part form during the second half of the fetal period and in the first years of life within the cartilaginous epi- and apophyses **(epi- and apophyseal ossification)**. No further increase in body height occurs once the cartilaginous epiphyseal gaps ossify and disappear (synostosis). Thereafter, isolated bone nucleation sites are no more visible in the X-ray image.

Clinical Remarks

For treatment plans and the prognosis of orthopaedic diseases and deformities during childhood, the determination of skeletal age and any existing growth reserves are of great importance.

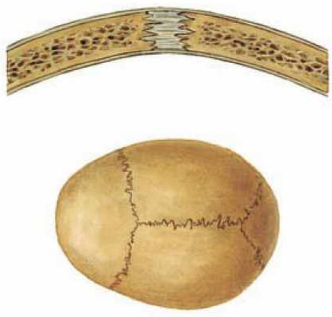


Fig. 1.19 Fibrous joint, Junctura fibrosa [Syndesmosis].
Fibrous joints between bones are found in sutures of the skull, syndesmoses (e.g. fibrous connections between the tibia and fibula or the radius and ulna), and gomphoses (e.g. fibrous anchoring of the teeth in their alveolar sockets of the maxilla and mandibula).

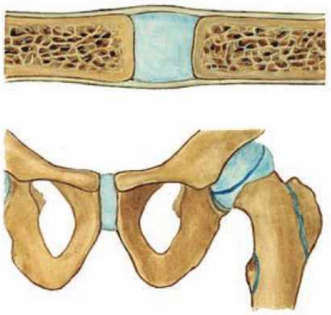


Fig. 1.20 Cartilaginous joint, Junctura cartilaginea [Synchondrosis].
Cartilaginous joints connect bones through **hyaline cartilage** (synchondrosis, e.g. connection between 1. rib and clavicle) or **fibrocartilage** (symphysis, e.g. Symphysis pubica).

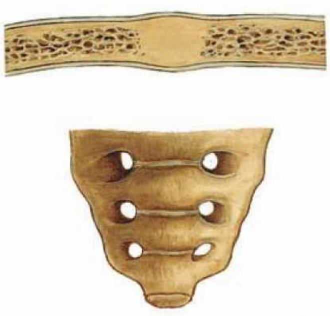


Fig. 1.21 Osseous joint, Junctura ossea [Synostosis].
At the osseous joints bones are **fused** as exemplified by the sacrum.

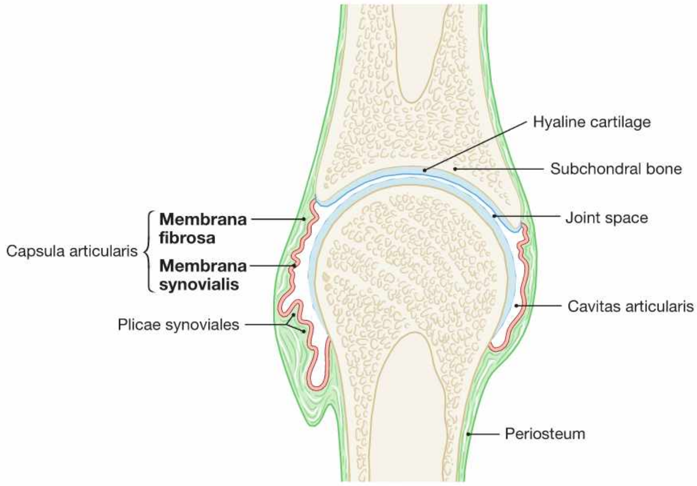


Fig. 1.22 Synovial (true) joint, Junctura synovialis [Articulatio synovialis, Diarthrosis]; schematic sectional view. (according to [1])
Hyaline cartilage at the bony ends covers the subchondral bone. The joint capsule encloses the joint cavity and consists of an outer fibrous membrane (Membrana fibrosa) and an innner synovial membrane (Membrana synovialis). The synovial membrane secretes the synovia into the joint cavity which acts as the grease of the joint. When the freedom of motion of a joint is restricted by an exceptionally strong joint capsule, this joint is called amphiarthrosis (e.g. small carpal joints of the hand and foot; Articulatio sacroiliaca).

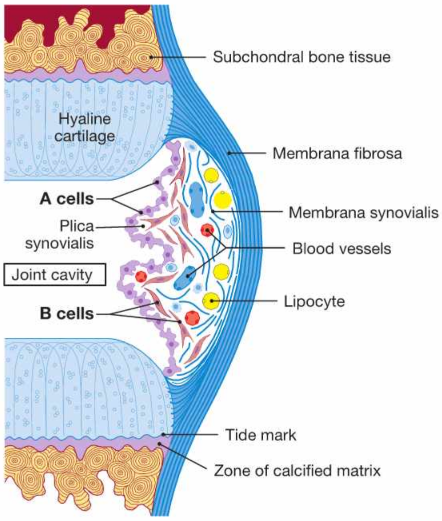
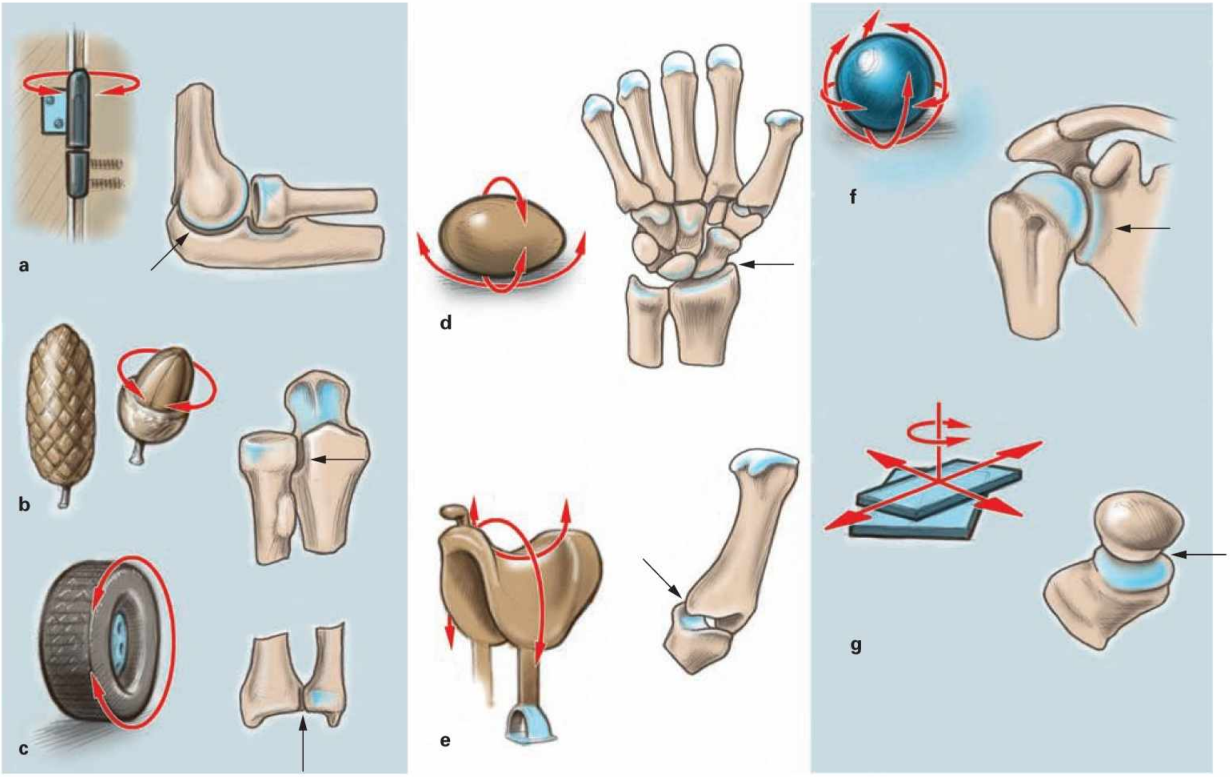
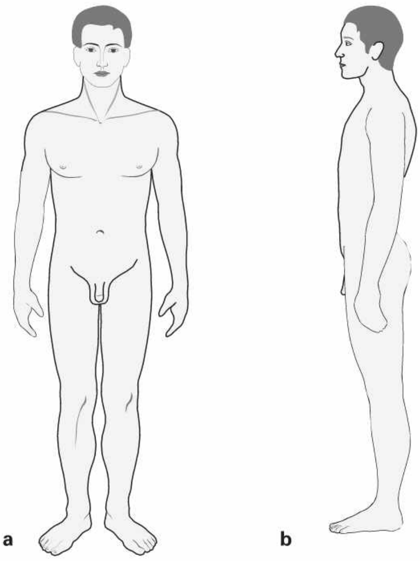


Fig. 1.23 Structure of the joint capsule. [24]
The joint capsule is composed of the Membrana fibrosa and the Membrana synovialis. The **Membrana fibrosa** consists of tough fibrous tissue. The **Membrana synovialis** is composed of the following layers: a superficial loose layer of A cells (type A synovialocytes or M cells, specialized macrophages which metabolize the metabolic compounds produced by the cells in the joint cartilage), B cells (type B synovialocytes or F cells, active fibroblasts which produce and secrete the outer collagen and proteoglycan aggregates, i.e. hyaluronic acid of the synovia) and the subsynovial connective tissue rich in capillaries, fibroblasts, and lipocytes. Collagen fibres within the articular cartilage are arranged in arcades (BENNINGHOFF's arcades).

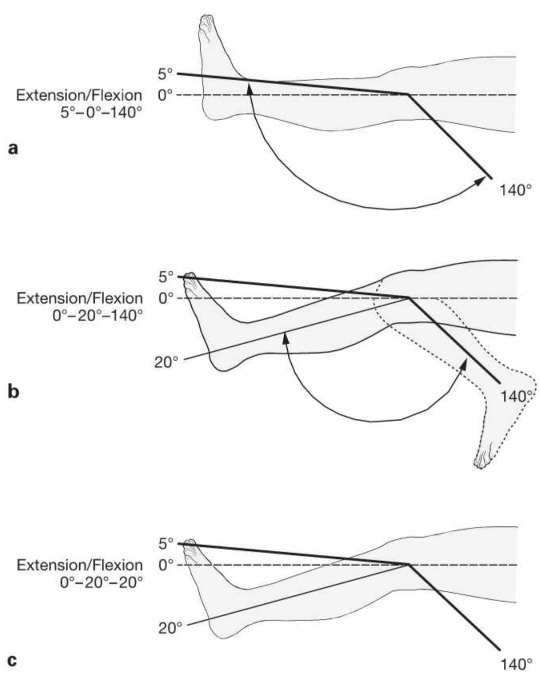
Types of joints



Figs. 1.24a to g Joints, Juncturae synoviales [Articulationes, Diarthroses].
Joints usually increase the range of motion significantly. They are classified according to the shape of their articulating surfaces and/or the freedom of movement they allow. Based on the main axes of motion, we distinguish uniaxial, biaxial, and multiaxial joints.
a hinge joint, Articulatio cylindrica (Ginglymus): uniaxial joint, permits flexion and extension
b conoid joint, Articulatio conoidea: uniaxial joint, permits rotational movement
c pivot joint, Articulatio trochoidea: uniaxial joint, permits rotational movement
d condylar joint, Articulatio ovoidea, Articulatio ellipsoidea: biaxial joint, permits flexion, extension, abduction, adduction, and restricted rotational movement
e saddle joint, Articulatio sellaris: biaxial joint, permits flexion, extension, abduction, adduction, and restricted rotational movement
f spheroidal or ball and socket joint, Articulatio spheroidea: multiaxial joint, permits flexion, extension, abduction, adduction, and rotational movement
g plane joint, Articulatio plana: joint permits simple gliding movements in different directions



Figs. 1.25a and b Documentation of the range of joint movement: neutral-null method.
The neutral-null method is a standardized goniometric method to determine the active range of movement in a joint. An upright position with arms hanging down to each side is considered the zero degree starting position when examining the joints (**a** view from the front and **b** from the side). The extent of achievable movement from this null position is expressed in degrees of angle measured. First the active range of movement away from the body is determined, followed by the active range of movement towards the body.



Figs. 1.26a to c Documentation of the range of joint movement: Examples.

- **a** The normal healthy knee joint has the following range of movement: 5° extension and 140° flexion (not shown). The 90° angle of the ankle joint in relation to the foot is considered the null position. This allows for a 20° extension and 40° flexion under normal conditions (not shown). The normal range of movement in the knee joint is 5°–0°–140° (knee stretched, null position, knee bent), that of the ankle joint is 20°–0°–40° (dorsal extension, null position, plantar flexion).
- **b** stretching of the knee impossible (see Clinical Remarks box)
- **c** complete stiffness of the knee (see Clinical Remarks box)

Clinical Remarks

Limitations of joint movement are associated with a decreased range of movement. A contraction is indicated if the joint mobility is restricted or the neutral position of a joint is not reached. The neutral-null method is used to document exactly the mobility of the impaired joint. For a **limited mobility of flexion contracture** the motion formula reads for example, 0°–20°–140° (→ Fig. 1.26b: extension of the knee is not possible, null position is not achieved, the knee is in 20° flexion, but can be further bent 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. 1.26c: knee extension is not possible, null position is not achieved, the knee is bent at 20° and cannot be bent further).

Types of muscles

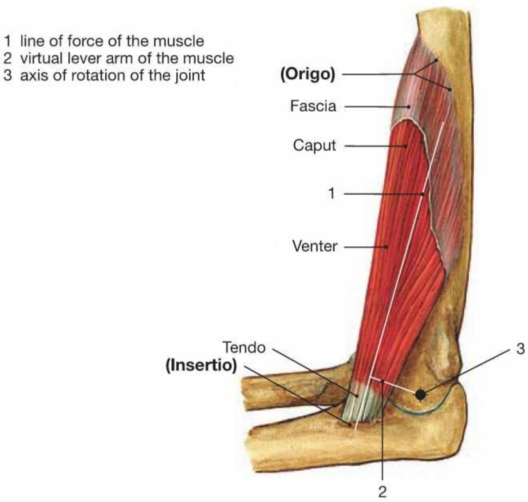


Fig. 1.27 Organization principle of skeletal muscles, exemplified by the brachial muscle, M. brachialis.
Skeletal muscles move bones in their joints and have a fixed point of origin (Origo) and a flexible point of insertion (Insertio). They are surrounded by a fascia. The belly of the muscle (Venter, Gaster) connects with the bone through a tendon. The amount of force a muscle can transfer onto a joint depends on the length of the lever (vertical distance of the vector force of the muscle and 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 virtual lever.

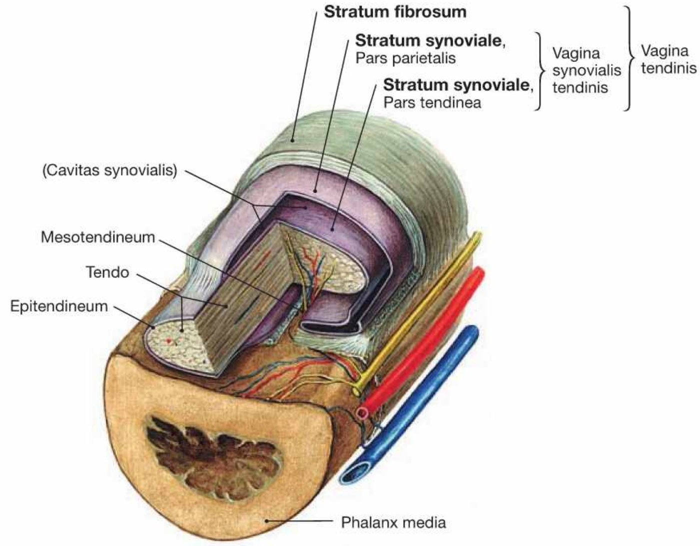
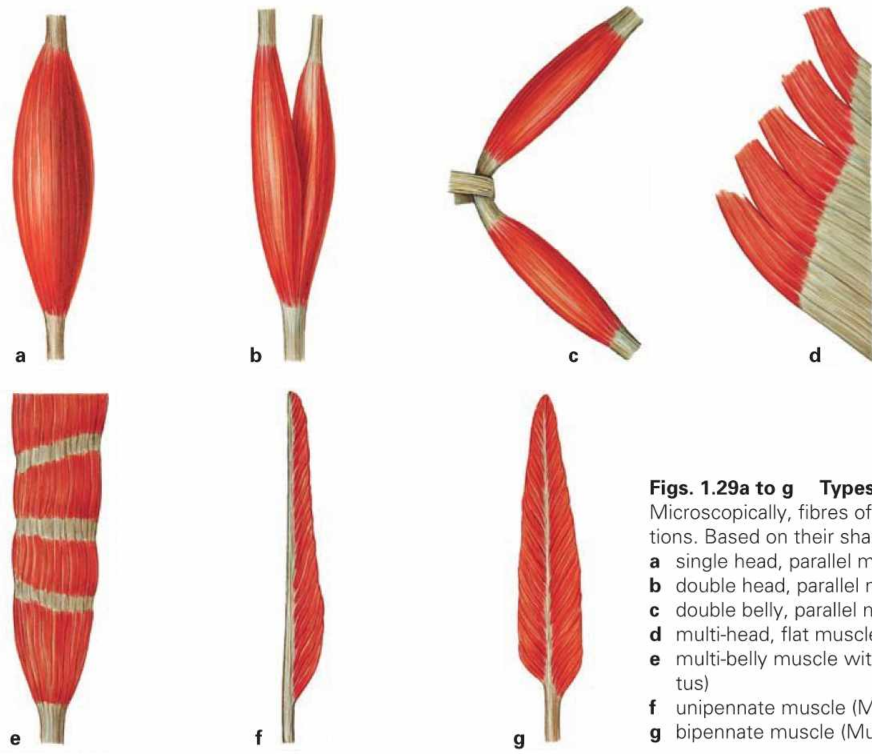


Fig. 1.28 Structure of a tendon sheath, Vagina tendinis, Vagina synovialis, exemplified by a finger.
Tendon sheaths reduce friction during movement and protect tendons which are deflected by muscles and bones. The composition of a tendon is similar to that of a joint capsule. The inner layer of the tendon sheath (Stratum synoviale, Pars tendinea) is part of the tendon, whereas the outer layer (Stratum synoviale, Pars parietalis) is part of the Stratum fibrosum of the tendon sheath. The gap between both layers (Cavitas synovialis) contains synovial fluid (Synovia).
Small blood vessels reach the tendon via Vincula brevia and longa (small ligaments from the mesotendineum).



Figs. 1.29a to g Types of muscles.
Microscopically, fibres of skeletal muscles exhibit typical cross-striations. Based on their shape skeletal muscles can be divided into:
a single head, parallel muscle fibres (Musculus fusiformis)
b double head, parallel muscle fibres (Musculus biceps)
c double belly, parallel muscle fibres (Musculus biventer)
d multi-head, flat muscle (Musculus planus)
e multi-belly muscle with tendinous intersections (Musculus intersectus)
f unipennate muscle (Musculus semipennatus)
g bipennate muscle (Musculus pennatus)

Definition

From a functional viewpoint, passive and active musculoskeletal systems can be distinguished:
- The **passive musculoskeletal** system includes bones, joints, and ligaments. The skeleton creates the shape of the body, is an attachment point for muscles, and forms body cavities that contain and protect inner organs. Joints provide flexible connections between bones.
- The **active musculoskeletal** system consists of the skeletal muscles which move the bones in the joints and can be controlled voluntarily.

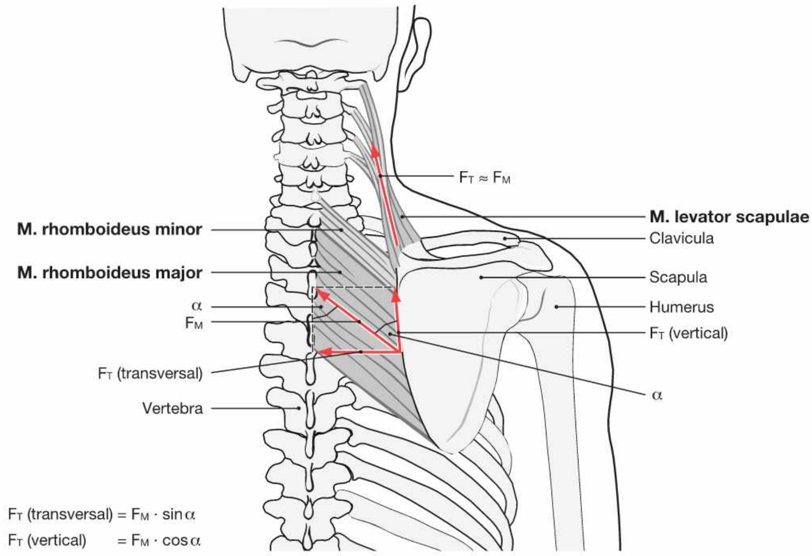


Fig. 1.30 Forces of muscles and tendons; vector forces of the muscles and tendons exemplified by the Mm. levator scapulae and rhomboidei. (according to [1])
There is a direct proportional relationship between the muscle force and the physiological cross-section of this muscle (lifting force of a muscle relative to the cross-section of all muscle fibres positioned perpendicular to the direction of these fibres). When the direction of a tendon and the vector force of the muscle align, the full force of the muscle is transferred to the tendon. In this case, muscle force (F_M) and tendon force (F_T) are almost equal. However, when the muscle fibres are oriented in an angle to the pull by the tendon (e.g. Mm. rhomboidei major and minor), only part of the contractile force is transferred to the tendon. Here the vertical tendon force (F_T [vertical]) is reduced by the factor cos α and the transverse tendon force (F_T [transverse]) is reduced by the factor sin α relative to the muscle force (F_M).

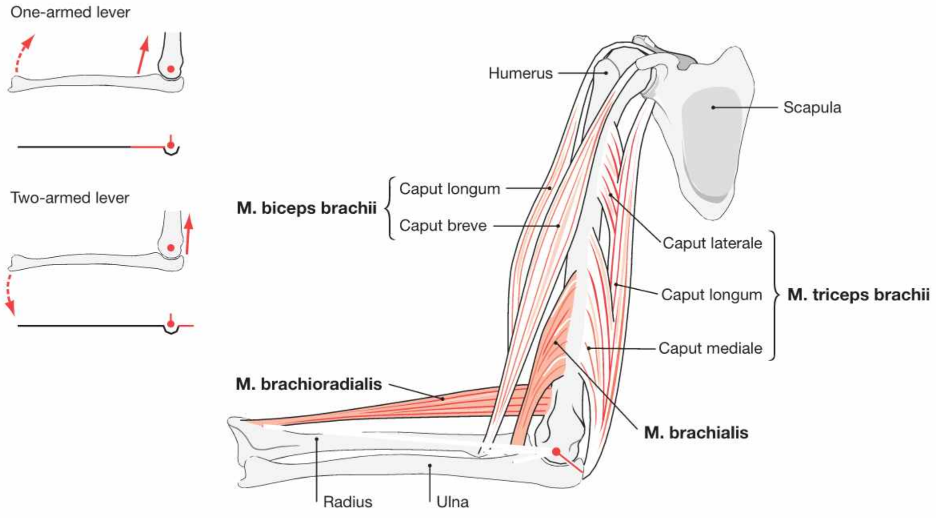


Fig. 1.31 Lever and muscle action; major muscles of the elbow joint and their anatomical levers (red lines). (according to [1])
The lever arm is the part of a lever which acts between the centre of rotation and the point where the force acts. For skeletal components to be moved around a rotational axis of a joint, a muscle must use an anatomical (existing) lever arm to create a torque. The length of the lever arm depends on the distance between the origin of a muscle and the centre of rotation of the joint. For example, when the arm is moved towards the torso the M. brachioradialis and the M. brachialis have a long and short anatomical lever arm, respectively. When muscle force is applied via an one-armed lever, the skeletal component will move in the direction of a traction force of this muscle (e.g. Mm. brachioradialis, biceps brachii, brachialis). With a two-armed lever, the point of muscle origin is moved in the direction of the muscular traction, but the main part of the skeletal component is moved in the opposite direction (e.g. M. triceps brachii; compare → Fig. 1.27).

The cardiovascular system

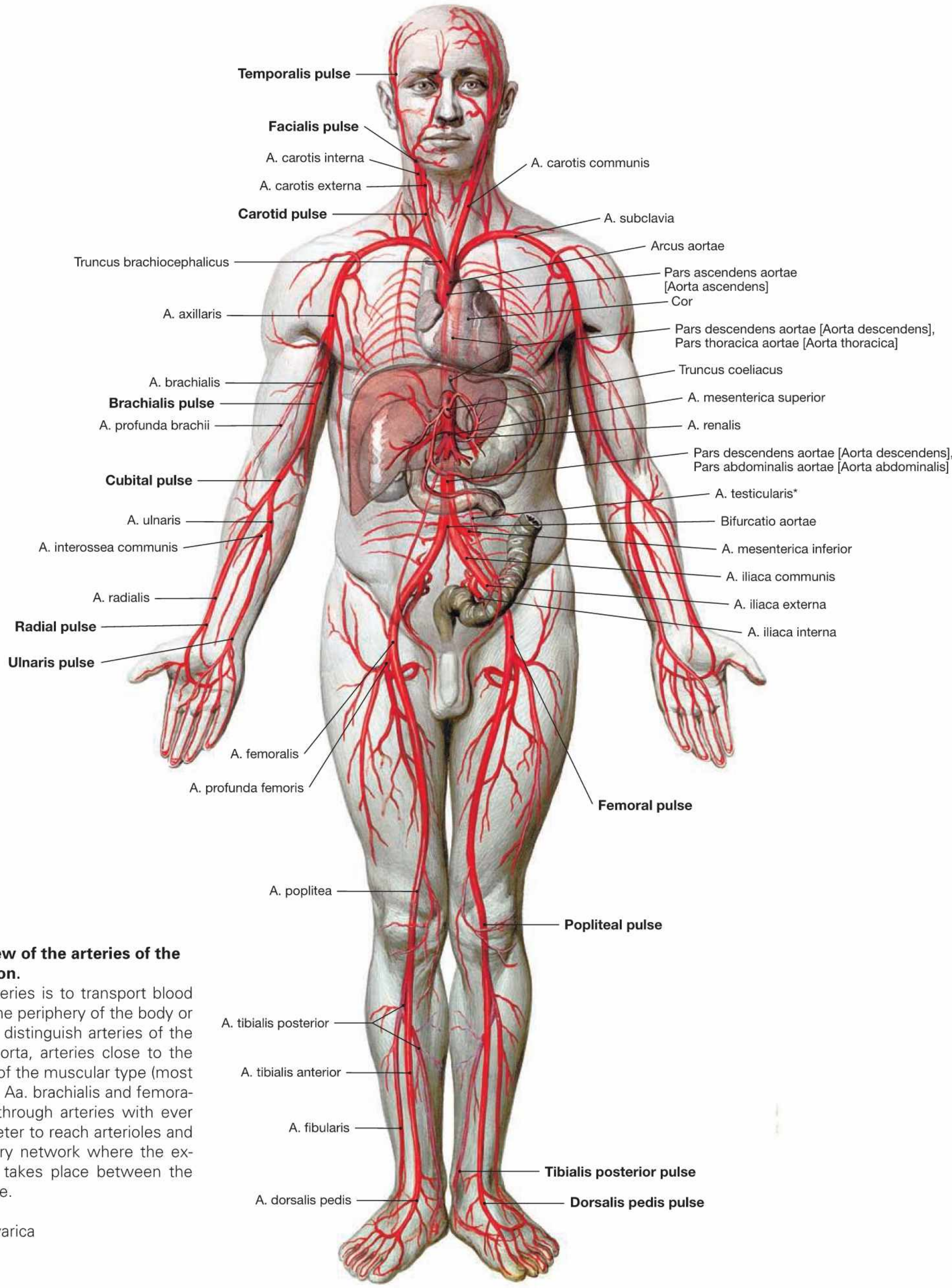
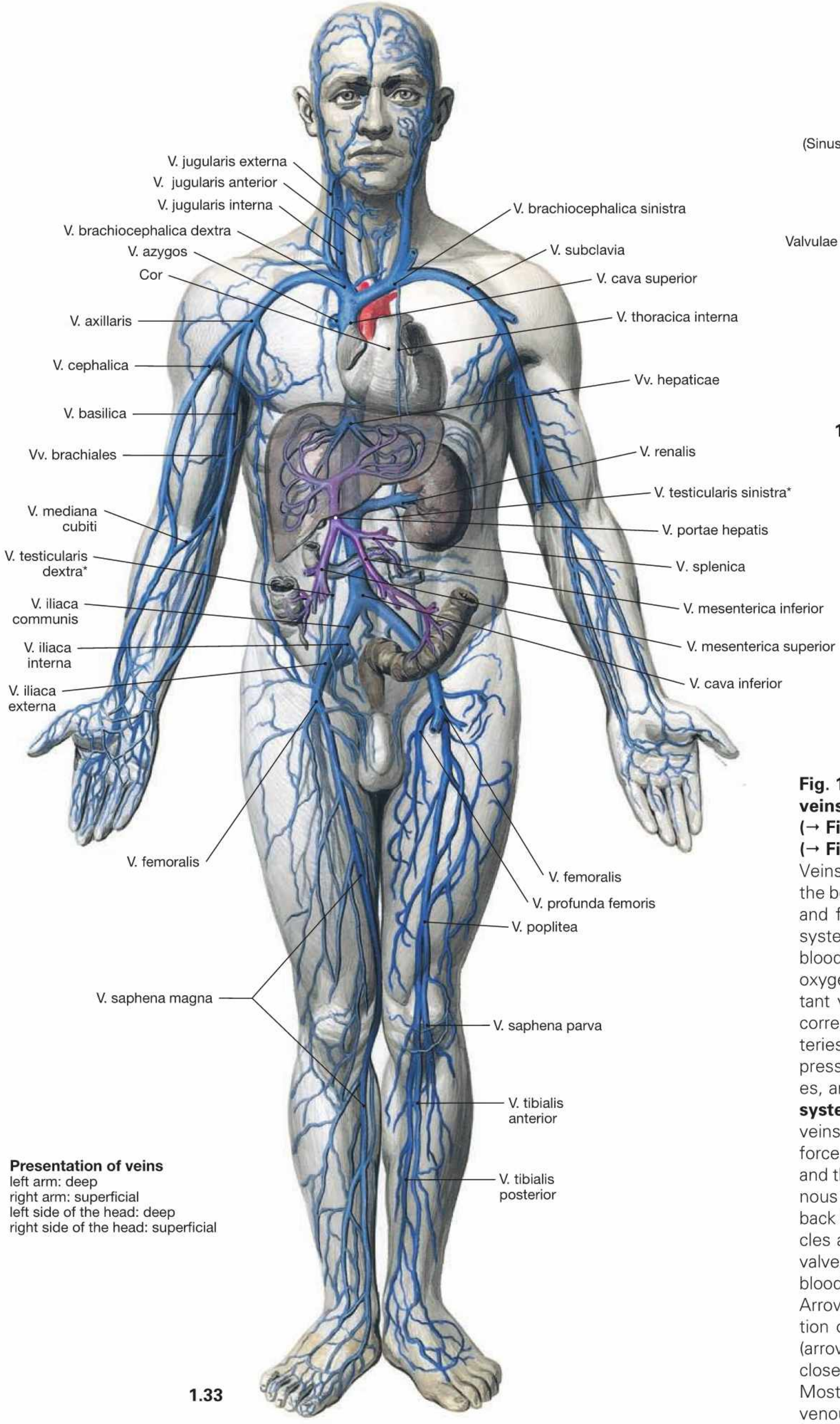


Fig. 1.32 Overview of the arteries of the systemic circulation.
The function of arteries is to transport blood from the heart to the periphery of the body or into the lungs. We distinguish arteries of the elastic type (e.g. aorta, arteries close to the heart) and arteries of the muscular type (most of the arteries, e.g. Aa. brachialis and femoralis). Blood travels through arteries with ever more narrow diameter to reach arterioles and enter into a capillary network where the exchange of oxygen takes place between the blood and the tissue.

* in women: A. ovarica

Clinical Remarks

In many parts of the body, large and medium-sized arteries run near the body surface. The **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 A. dorsalis pedis on the dorsum of the foot. The examination of the arterial pulse reveals many clues about the frequency of the heartbeat, differences of blood flow in the upper and lower extremity, and holds general clues about the circulation of the blood in a particular body section.



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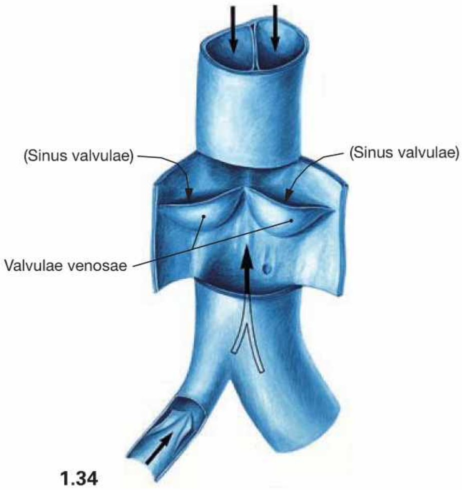


1.34

Fig. 1.33 and Fig. 1.34 Overview of the veins of the systemic circulation (→ Fig. 1.33) and venous valves (→ Fig. 1.34).

Veins transport blood from the periphery of the body back to the heart. They expand easily and function as reservoirs. The veins of the systemic circulation transport deoxygenated blood, those of the lung circulation transport oxygenated blood. Most veins are concomitant veins, meaning they run in parallel with corresponding arteries. Compared to the arteries, their course is variable and the blood pressure is significantly lower. Veins, capillaries, and venoles are part of the **low pressure system** of blood circulation. Most of the time, veins transport blood against gravitational force. Thus, larger veins of the extremities and the lower neck region possess valves (venous valves) to support the venous blood flow back to the heart. Apart from the valves, muscles and the arterial pulse (only when venous valves are present) also affect the venous blood flow.

Arrows pointing upwards indicate the direction of blood flow. When blood accumulates (arrows pointing downwards) the valves close.

Most parts of the body contain a **superficial** venous system in the subcutaneous fat pad 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).

* in women: V. ovarica

Systemic, pulmonary, and fetal blood circulation

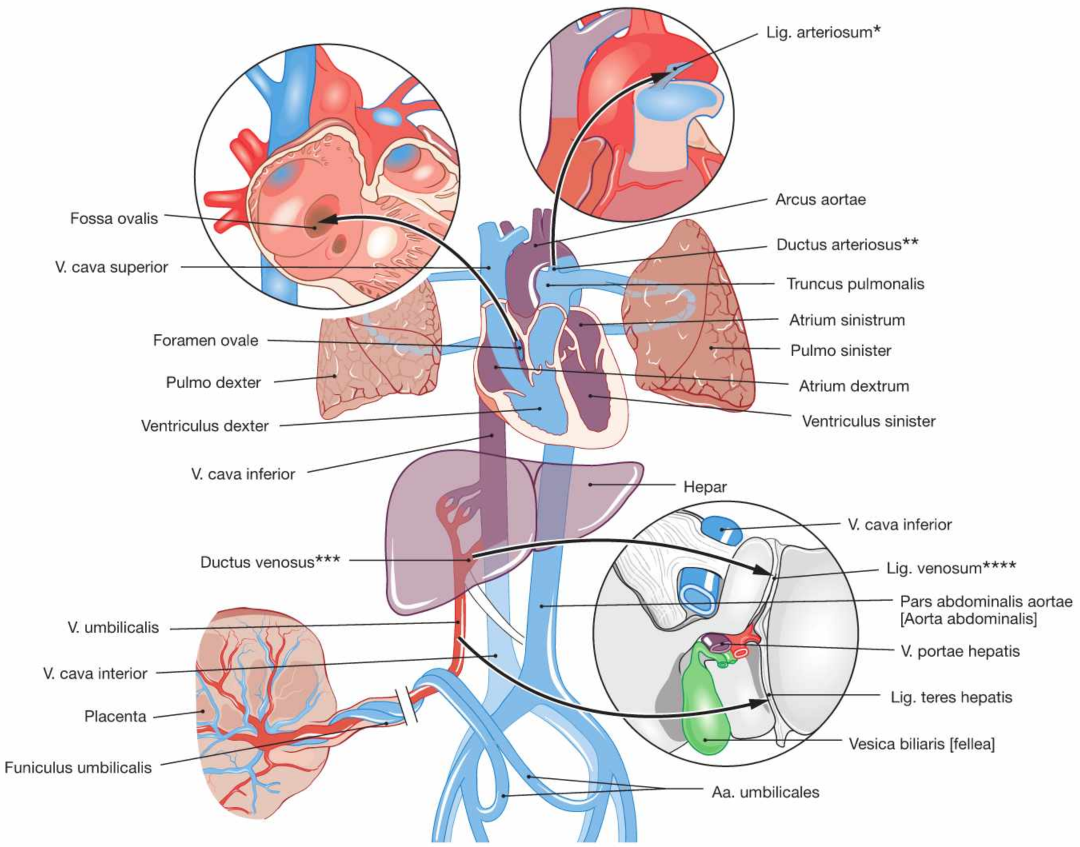


Fig. 1.35 The prenatal circulation; schematic representation. (according to [1])

Arrows indicate the direction of blood flow. The prenatal circulation is different from the circulation after birth.

Oxygenated blood is transported from the placenta and through the umbilical vein to the liver where most of the blood is drained by the Ductus venosus (ARANTII) directly into the V. cava inferior. From here, the major part of the blood reaches the right atrium of the heart, crosses over to the left atrium via the open Foramen ovale in the atrial septum, enters the left ventricle, and is ejected into the aorta and systemic circulation. **Venous blood** of the upper half of the body enters the right atrium through the V. cava superior and is directed mostly into the right ventricle. When the heart contracts, most of the ejection fraction is transported via the Ductus arteriosus (BOTALLI) directly into the Aorta descendens. Both shortcuts in the heart (open Foramen ovale and open Ductus arteriosus [BOTALLI]) are required since in the fetus the fluid-filled lungs are not yet inflated and constitute a barrier. Blood from the fetal systemic circulation is routed mainly via the internal iliac arteries (Aa. iliaca internae) into the paired umbilical arteries (Aa. umbilicales) located within the umbilical cord to reach the placenta. A sequence of events shortly after birth which involves the termination of the placental circulation, the inflation of the lungs, and the onset of breathing in the newborn results in the occlusion of:

- Ductus venosus (ARANTII)
- Foramen ovale
- Ductus arteriosus (BOTALLI) between Truncus pulmonalis and Arcus aortae
- Aa. umbilicales and V. umbilicalis

At this point, the cardiovascular system only consists of the heart, the systemic circulation (body circulation; supply of body tissues, and the smaller pulmonary circulation (gas exchange) (→ Fig. 5.10). The ejection fraction of the heart of a resting adult 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 approximately 100 mmHg (= mm mercury column), whereas in the venous system it is approximately 20 mmHg. Both systems are separated by the capillary bed where the exchanges of gas and nutrients take place.

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

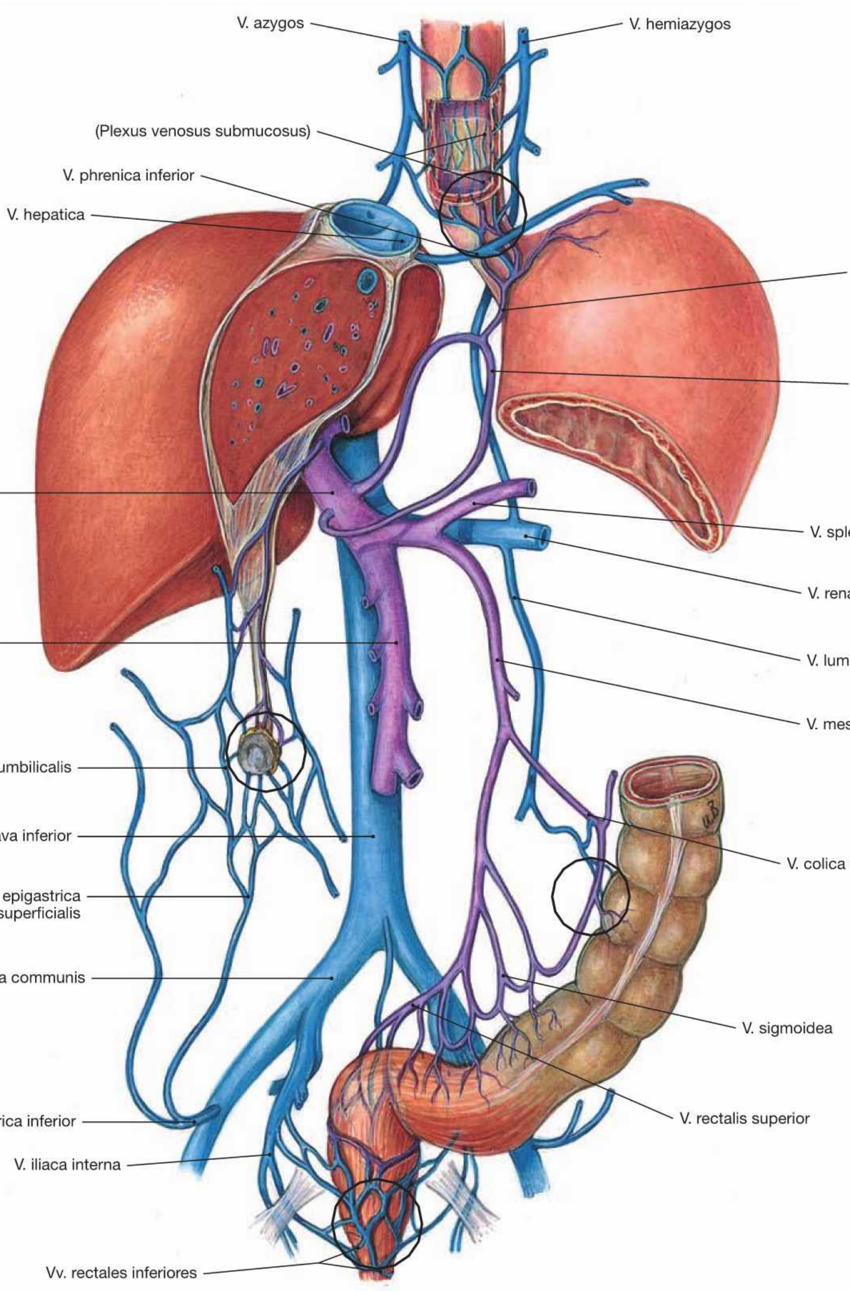


Fig. 1.36 Portal vein, V. portae hepatis, and inferior vena cava, V. cava inferior; semi-schematic representation; tributaries to inferior vena cava in blue; tributaries to the portal vein in purple. Potential portal-systemic anastomoses are encircled in black.
The portal-venous circulation constitutes a special part of the systemic circulation. Here, two separate capillary beds (intestine, liver) are connected in sequence. 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. This way, most of the nutrients absorbed through the intestinal tract first reach the liver and are metabolized there. Not until the blood has passed the liver, is it drained via the liver veins (Vv. hepaticae) into the inferior vena cava and the systemic circulation.

Clinical Remarks

In patients with liver cirrhosis significantly less blood flows through the liver due to higher resistance of the liver and therefore **increased portal vein pressure**. Bypassing the liver, the remainder of the blood flows through portocaval anastomoses directly into the systemic circulation. However, the veins in the anastomosis region are structurally not well suited to accommodate the increased blood flow and will form **varicose veins**. This can lead to oesophageal varices in the region of the gastro-oesophageal junction, to the rare formation of a Caput medusae (Medusa head) in the region of paraumbilical veins, or it can result in the occurrence of varicose veins in the anal canal. Especially **oesophageal varices** can easily be injured during food uptake and cause life-threatening haemorrhages.

Lymphatic system

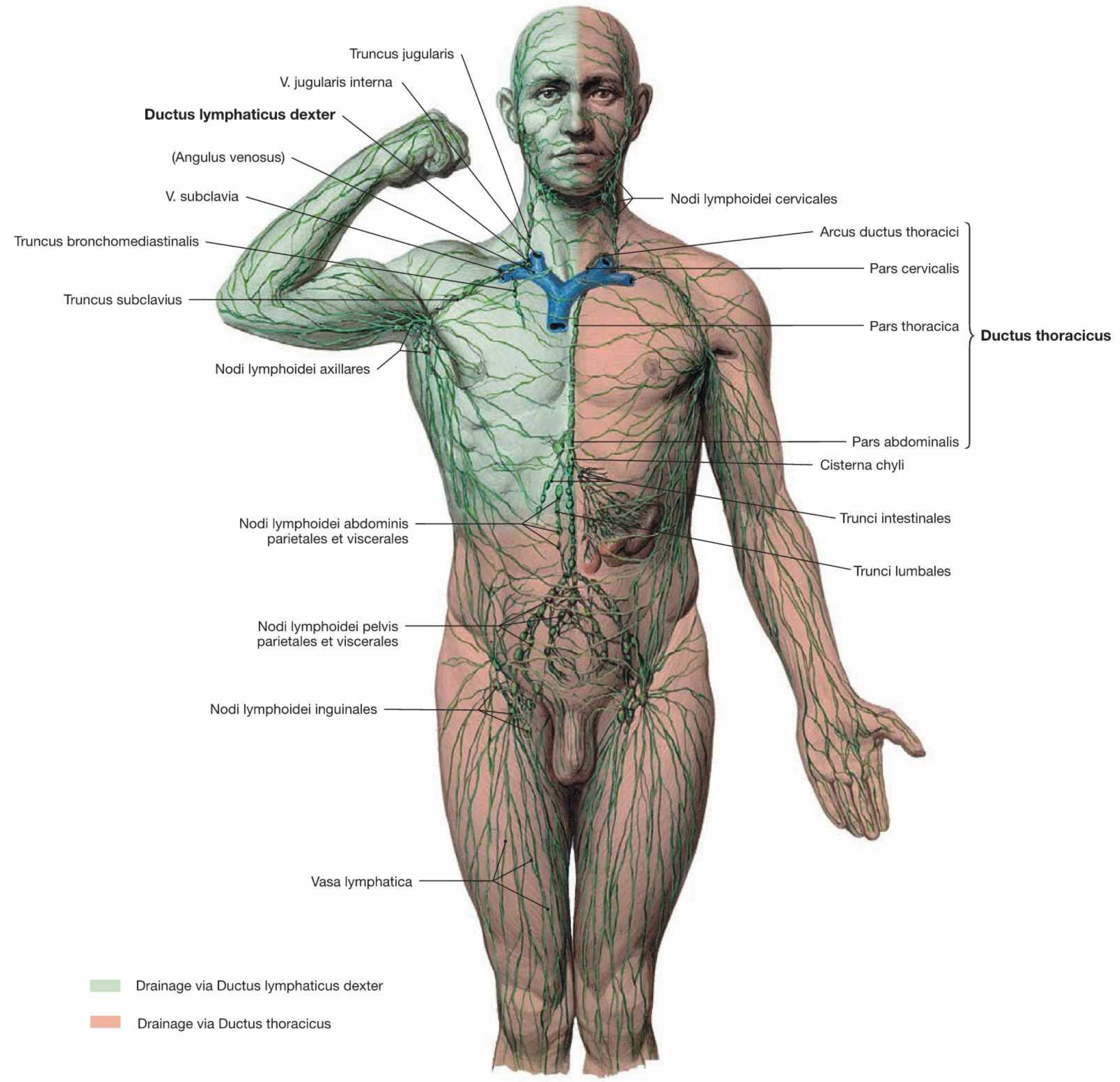


Fig. 1.37 Overview of the lymphatic system.
Starting in the body periphery, lymph capillaries collect interstitial fluid (lymph) and transport it via collecting ducts into **lymph vessels** and lymph nodes. **Lymph nodes** responsible for the collection and filtration of a particular body region are called regional lymph nodes. Those lymph nodes accepting lymph fluid from different lymph nodes are called collector lymph nodes.
Finally, the lymph reaches two major **lymphatic ducts**, the Ductus thoracicus and Ductus lymphaticus dexter, which drain the lymph into the venous blood of the systemic circulation. The major part of the lymph drains into the left venous angle (Angulus venosus, located between V. jugularis interna sinistra and V. subclavia sinistra) via the **Ductus thoracicus**. The **Ductus lymphaticus dexter** drains the lymph collected from the right upper quadrant into the right venous angle (located between V. jugularis interna dextra and V. subclavia dextra).
In addition to the lymph vessels and lymph nodes the lymphoid tissue also includes **lymphatic organs** (thymus, bone marrow, spleen, tonsils, mucosa-associated lymphoid tissue [MALT]). The lymphatic system has important functions in immune responses and resorption of lipids.

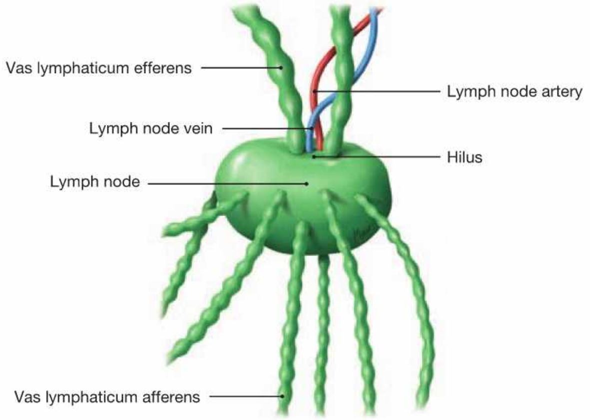


Fig. 1.38 Lymph nodes with in- and outgoing lymph vessels; semi-schematic representation.
Lymph nodes are part of the lymphatic system and considered secundary lymphatic organs. They come in various shapes (mostly lens- or bean-shaped with a diameter of 5–20 mm). The body contains about 1,000 lymph nodes 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 the defence against infections.

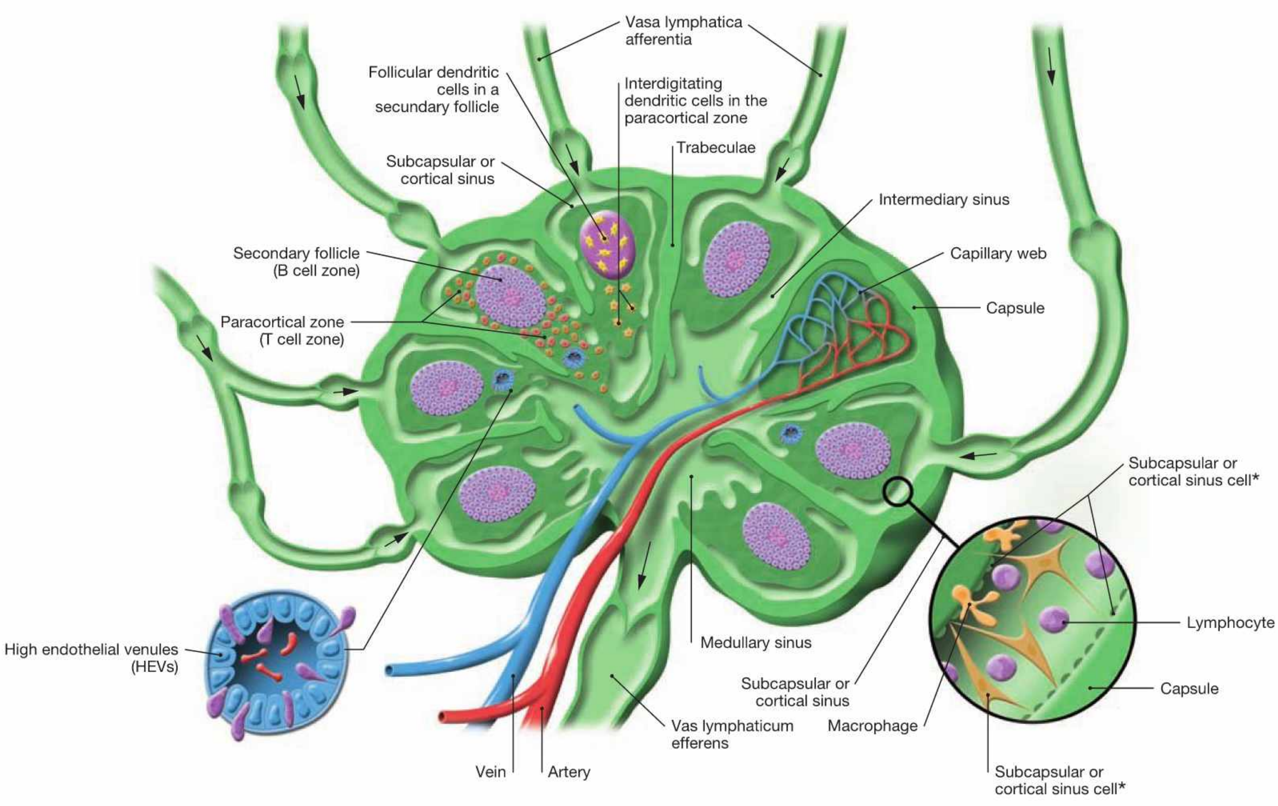


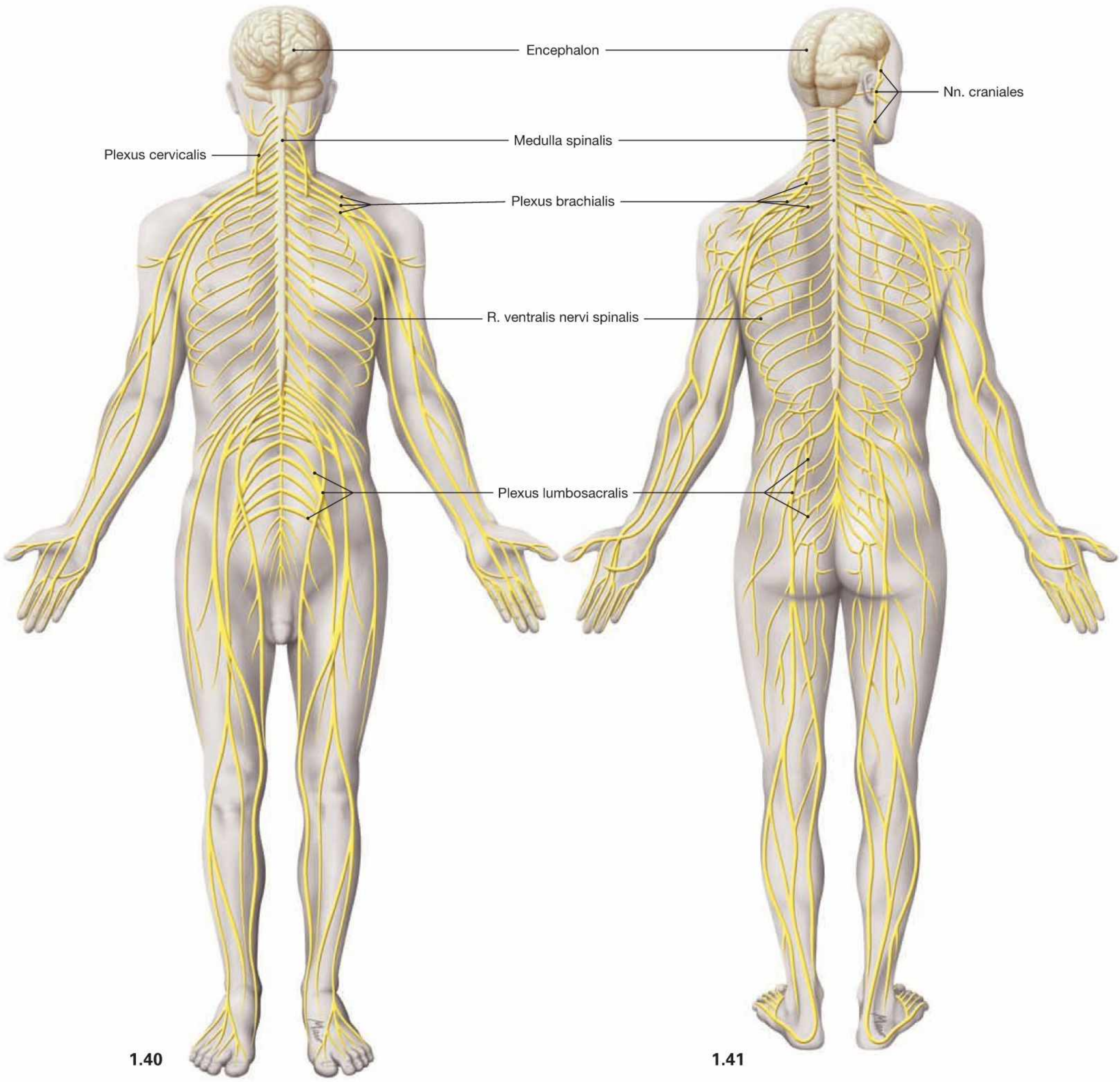
Fig. 1.39 Lymph nodes; schematic cross-section. (according to [2])
This cross-section of a representative lymph node shows in- and outgoing lymph vessels (Vasa afferentia and Vasa efferentia), blood supply, and compartmentalization of the lymph node into B region (secondary follicle), T region (paracortical zone) with postcapillary or high endothelial venules, follicular and interdigitating dendritic cells, medullary sinus, intermediate sinus, and subcapsular or cortical sinus (with cellular composition shown).

* Reticular cells lining the sinus wall also reside within the sinus.

Clinical Remarks

The **examination of lymph nodes** is an important aspect of the physical examination of a patient. The examination includes the palpable lymph nodes of the neck, the axilla, and the groin. The enlargement of lymph nodes can be a sign of inflammation (lymphadenitis) or malignant disease (e.g. metastasis of a malignant tumour or a generalized disorder of the lymphatic system such as HODGKIN's disease).

Nervous system



1.40 1.41

Fig. 1.40 and Fig. 1.41 Organization of the nervous system; ventral (→ Fig. 1.40) and dorsal view (→ Fig. 1.41). (according to [2])
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 is involved in complex functions that include the regulation of the activities of the muscles and the intestines, the communication with the environment and the inner self, and memorizing past experiences (memory). The nervous system is also essential for conceptualizing imaginations (thinking), generating emotions, and adapting quickly to changes in the surrounding world and the body interior. We distinguish the **autonomic** (visceral, regulating the activities of the intestines, predominantly involuntary) and the **somatic** (innervation of skeletal muscles, cognitive perception of sensory input) **nervous system.** Both systems interact with and affect each other. Apart from the nervous system, overall body functions are also regulated by the endocrine system.

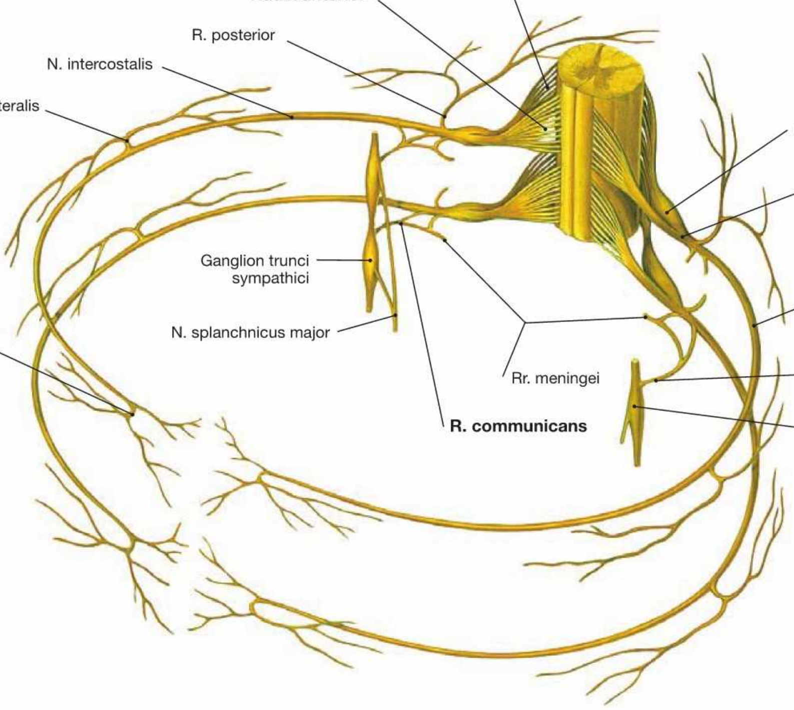


Fig. 1.42 Schematic representation of a spinal nerve (spinal cord segment) exemplified by two thoracic nerves; view from above in an oblique lateral angle.

The human body has 31 pairs of spinal nerves (eight cervical, twelve thoracic, five lumbar, five sacral pairs, and one coccygeal pair). Each spinal nerve is composed of an anterior root (Radix anterior) and a dorsal root (Radix posterior). The cell bodies (Perikarya) of motor nerves are located in the grey matter within the spinal cord. Their axons leave the spinal cord forming the anterior root. The perikarya of sensory nerves are located in the dorsal root ganglia (Ganglia sensoria nervi spinalis). Their processes enter the spinal cord via the dorsal roots. Rami communicantes connect the spinal cord with the sympathetic chain of ganglia (Ganglia trunci sympathici) of the sympathetic trunk (Truncus sympathicus). All branches of the dorsal spinal nerves as well as the ventral branches of the thoracic spinal nerves T2 to T11 have a segmental arrangement. The other ventral branches converge to form 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 perfusion can result in disturbances of peripheral nerves. This can lead to palsy or excessive excitation of nerve cells (neurons). **Polyneuropathy** resembles a clinical scenario in which many nerves are affected.

Autonomic nervous system

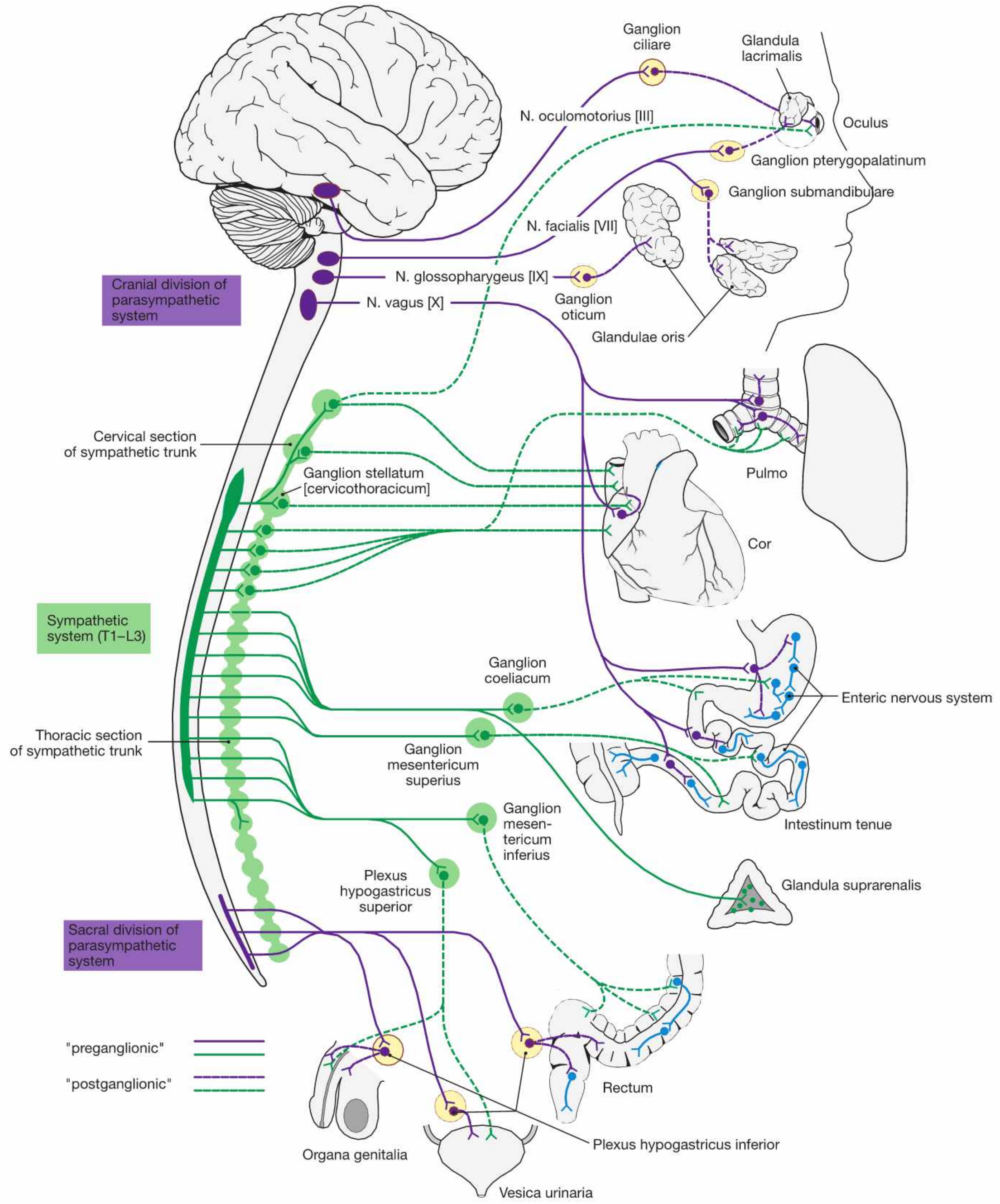


Fig. 1.43 Autonomic nervous system. [22]
The autonomic nervous system consists of the sympathicus, parasympathetic (Parasympathicus and enteric nervous system.
The nerve cells of the **Sympathicus** are located in the lateral horn of the thoracolumbar segment of the spinal cord. Their axons project into the ganglia of the sympathetic chain and the ganglia of the gastro-intestinal tract. Here, the preganglionic fibres synapse on postganglionic neurons which send their processes to the target organ. Activation of the symphatetic system occurs during mobilization of the body and in emergency situations (the three Fs: fright, flight, fight). The medulla of the adrenal gland is part of the sympathetic system and secretes adrenaline (epinephrine) and noradrenaline (norepinephrine) into the circulation.
The nuclei of the **Parasympathicus** are located in the brain stem and the sacral spinal cord. Preganglionic parasympathetic axons reach ganglia close to their target organs. Here, they synapse with postganglionic neurons which send short axons to their target organs. The parasympathetic system regulates food intake and digestion as well as sexual arousal. The Parasympathicus is the antagonist of the Sympathicus.
The **enteric nervous system** regulates the activity of the intestinal tract and is controlled by Sympathicus and Parasympathicus.

Clinical Remarks

Disorders of the autonomic nervous system play a role in almost all medical disciplines. These disorders can present as separate diseases (e.g. hereditary autonomic neuropathy), as a consequence of other diseases (e.g. autonomic neuropathy in diabetes mellitus or PARKINSON's disease), or in response to external conditions and other disorders (e.g. **autonomic dysregulation** due to 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.

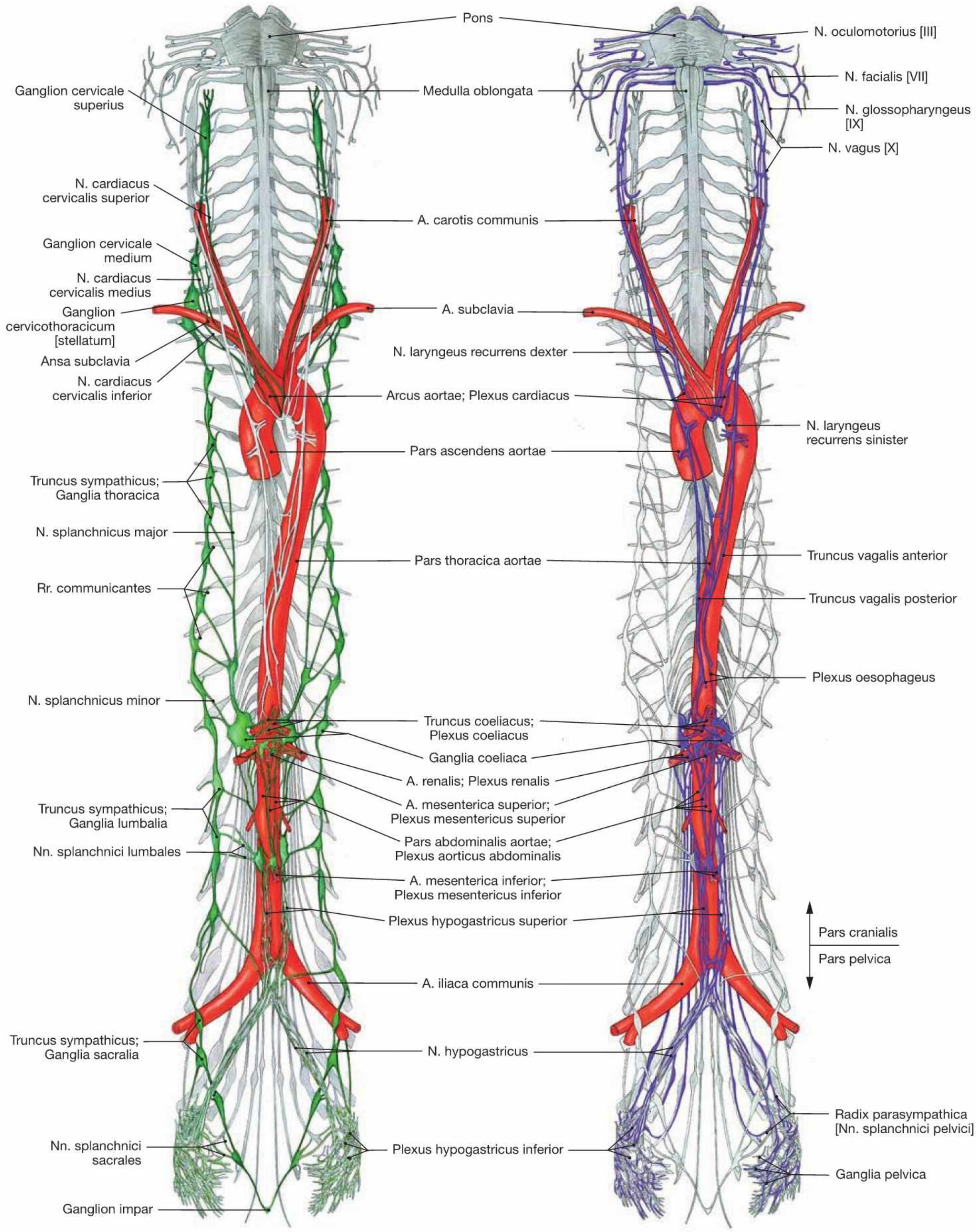


Fig. 1.44 Representation of the Sympathicus, Pars sympathica. The entire sympathetic chain of ganglia and their interganglionic connections located to both sides of the vertebral column are called the Truncus sympathicus (green).

Fig. 1.45 Representation of the Parasympathicus, Pars parasympathica. The parasympathetic fibres (purple) normally run together with other nerves fibres.

Radiography, fluoroscopy

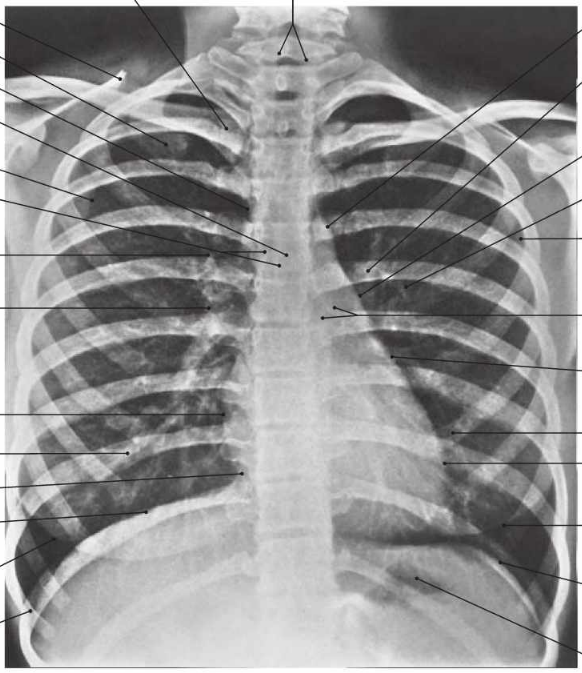


Fig. 1.46 Conventional radiograph (X-ray), overview of the thorax. [27]
Radiography is one of the most frequently used imaging techniques in hospitals and local clinical practice. Familiarity with the imaging technique is essential in understanding how such images are being generated and what type of radiographic image is viewed. Simple radiographic images of the thorax are among those most frequently generated. With a patient standing upright, the X-rays pass through the thorax in a posterior-anterior (PA) direction (patient faces radiographic film). In the lying position, the X-rays pass through the patient 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 conture, the diaphragm, the ribs, and the peripheral soft tissue.

* conture of the breast (mamma)

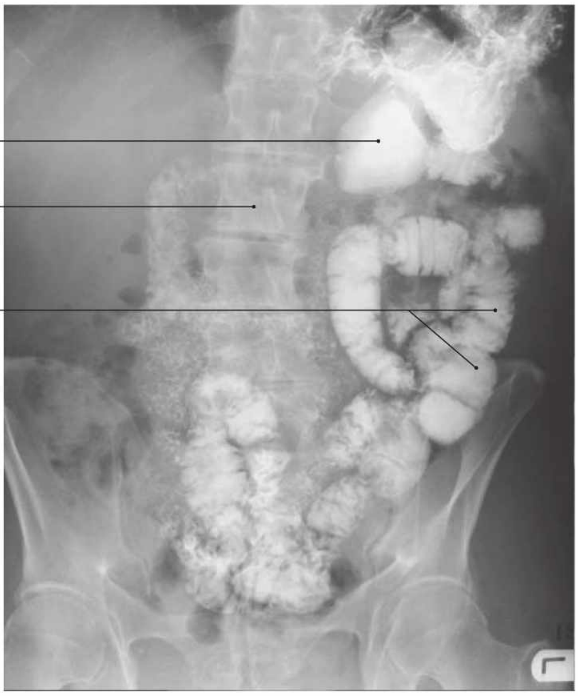


Fig. 1.47 Conventional radiograph (X-ray), colon fluoroscopy after barium swallow test. [8]
In a radiograph, hollow organs, such as arteries, veins, and intestinal loops, are poor in contrast and need to be filled with a substance that absorbs X-rays to increase contrast. These substances must not be toxic to the patient. A frequently used substance to increase contrast of the gastro-intestinal tract is the insoluble, non-toxic, high density salt barium sulfate. For applications in vessels iodine-containing molecules are usually employed. These substances are safe and well tolerated by most patients and can also be used to image the kidneys, ureters, and bladder (intravenous urogram [IVU], intravenous pyelogram [IVP]) as they are excreted by the kidneys.

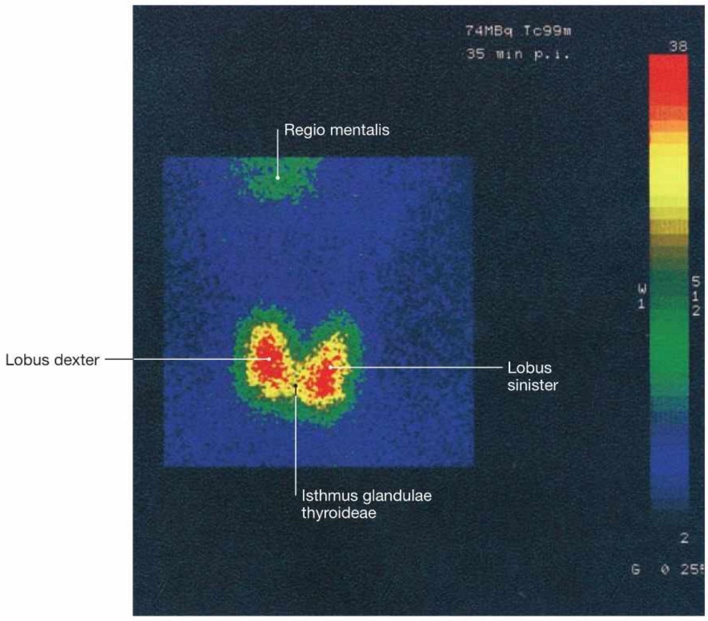


Fig. 1.48 Scintigraphy, scintigram of the thyroid gland. [27]
In scintigraphy, gamma rays (a form of electromagnetic rays) are used to generate an image. Gamma rays are produced as a result of the decay of unstable atomic nuclei, whereas X-rays are excess energy released during the bombardment of atoms with electrons. The gamma ray emitter has to be administered to the patient. The radio-isotope technetium-99m ($99m_{Tc}$) is most frequently used and injected as a cocktail together with other molecules. Upon injection, images are generated by a gamma camera, depending on how the radiopharmacon is absorbed, distributed, metabolized, or excreted by the body.

Fig. 1.49 Sonography, ultrasound image of a fetus at week 28 of pregnancy; lateral view.
Examinations of the body employing ultrasound are common in all medical specialties. Ultrasound represents a series of high-frequency sound waves (not an electromagnetic beam) generated by electric impulses in piezo-electric crystals. These sound waves are reflected from inner organs and their content (fetus in the uterus), registered by the same piezo-electric element, and transformed back into electrical impulses by the crystal. This information is then analysed by a computer and presented on a screen. This way, the movements of the extremities of the fetus and the opening of the mouth can be viewed as a live image.

Computed tomography (CT) and 3-D CT angiography

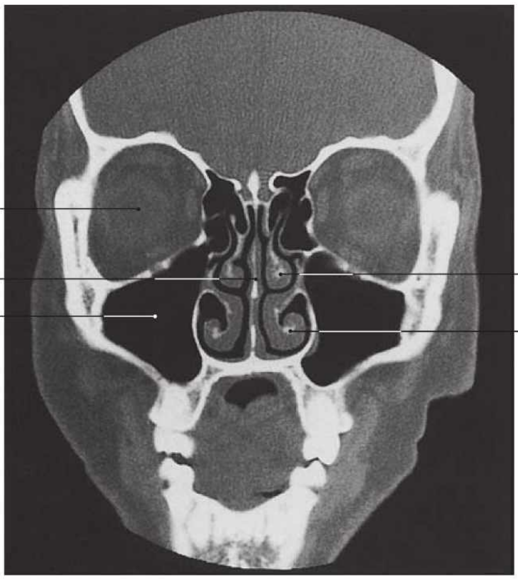


Fig. 1.50 Computed tomography, coronal computed tomogram (CT) of the sinuses. [11]
Computed tomography (CT) was developed by Sir Godfrey Hounsfield in the 1970es and has undergone constant refinement. The computed tomograph generates a series of sectional images through the body in the transverse or, as shown here, the coronal plane. The patient rests on a table and, while circulating the body, an X-ray tube takes one sectional image after the other. Once all images have been acquired, the individual sectional images are calculated by a computer applying complex mathematical algorithms.

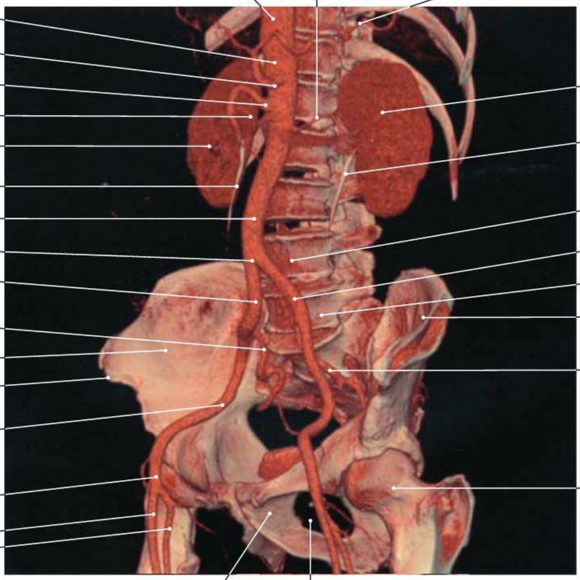


Fig. 1.51 3-D CT angiography, 3-D CT angiogram of different structures of the abdomen and pelvis (volume-rendering technique, VRT) derived from multidetector CT sections. [27]
Modern computed tomography technology (e.g. 64-lines volume spiral multilayer CT) provides new dimensions and indications for CT diagnostics and guarantees minimal dosage exposure for patients.
CT angiography is based on the same multilayer CT technology. In a blood vessel, the region of interest is scanned during fast intravenous injection of a iodine-containing substance to increase contrast of the structure. The resulting sectional images of branching vessels are then assembled by a computer to generate a 3-D image.

* clinical term: A. femoralis superficialis

Fig. 1.52 Magnetic resonance tomography (MRT) or imaging (MRI), axial (transverse) magnetic resonance image of the brain (T2-weighted). [27]

In magnetic resonance imaging patients are exposed to a powerful magnetic field. This causes all protons of hydrogen atoms in the body to align with the magnetic field which effectively transforms these hydrogen protons to become miniature magnets. Then patients are briefly exposed to radiofrequency pulses to systematically change the alignment of these protons.

When returning to their original position, the protons emit a weak radio wave that is detected by the instrument. The strength, frequency, and time it takes for the protons to return to their original position is an important information contained within the emitted signal and analysed by a computer to generate an image.

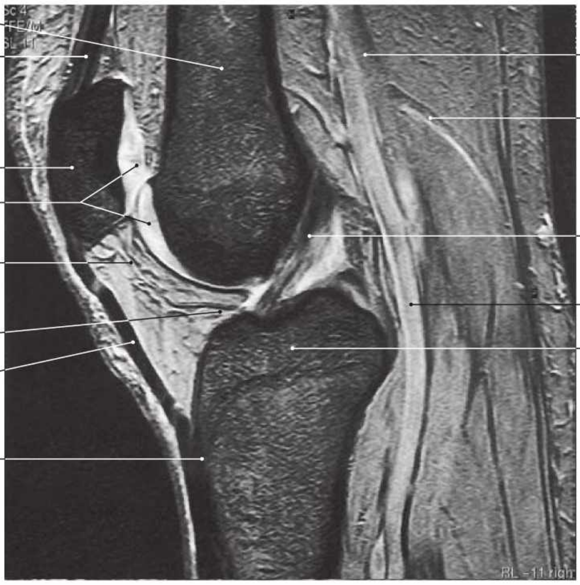
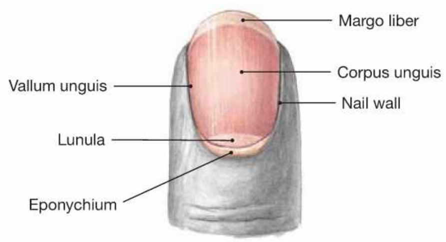


Fig. 1.53 Magnetic resonance tomography, sagittal magnetic resonance image (MRI) of a knee (T2-weighted). [27]

Altering the sequence of impulses used to excite protons allows for different characteristic features of these protons to be analysed. These characteristics are called **"weighting"** of an MRI scan. Alterations in pulse frequency and scanning parameters result in T1-weighted (fluids: dark, fat: bright; e.g. joint effusion dark) and T2-weighted (fluids: bright, fat: grey; e.g. the conspicuous HOFFA's fat pad between the patella and tibia) images. Thus, specifically T-weighted images emphasise particular tissue compartments. MRI can also be used to generate angiograms of the peripheral and central circulation.

* HOFFA's fat pad

Nails



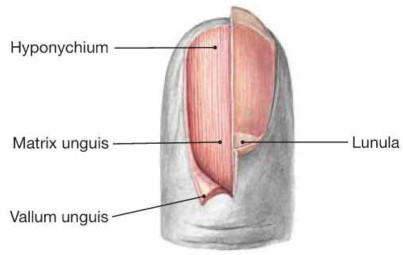


Fig. 1.54 Distal finger phalanx with nail.
The nail (Unguis) is a convex-shaped, translucent keratin plate on the upper side of the distal phalanx of the finger and toe. It serves to protect the tips of the fingers and toes and supports the grasping function of the fingers. The nail embeds into cutaneous slits (nail grooves, Vallum unguis) and its lateral margin is covered by the cutaneous nail wall or fold on both sides of the nail. The epithelial layer extending from the nail wall at the base of the nail onto the dorsal nail plate is called eponychium. The nail plate is anchored here to the nail bed, the skin beneath the nail plate.

Fig. 1.55 Distal finger phalanx; nail partially removed.
The epithelium located beneath the free margin of the nail at the tips of the phalanges is called hyponychium (also known as "quick"). Beneath the epithelial hyponychium lies the fibrous base of the nail bed which is tightly connected with the periost of the distal phalanx. The proximal hyponychium forms the nail matrix (Matrix unguis) which generates the nail plate. The Lunula is the visible part of the nail matrix.

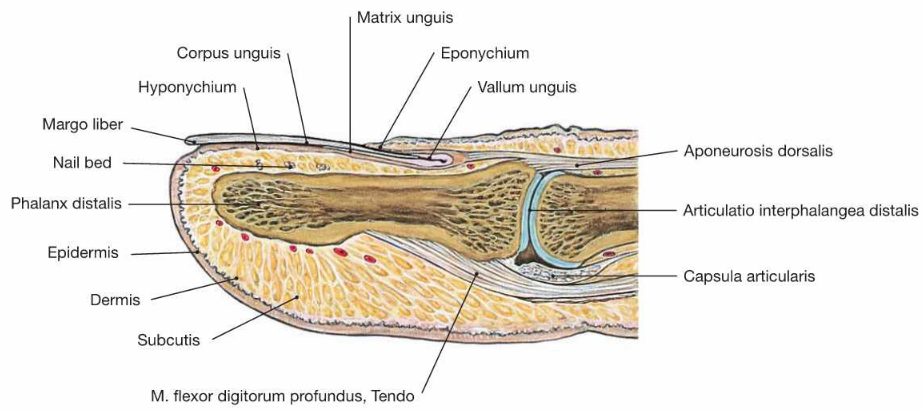
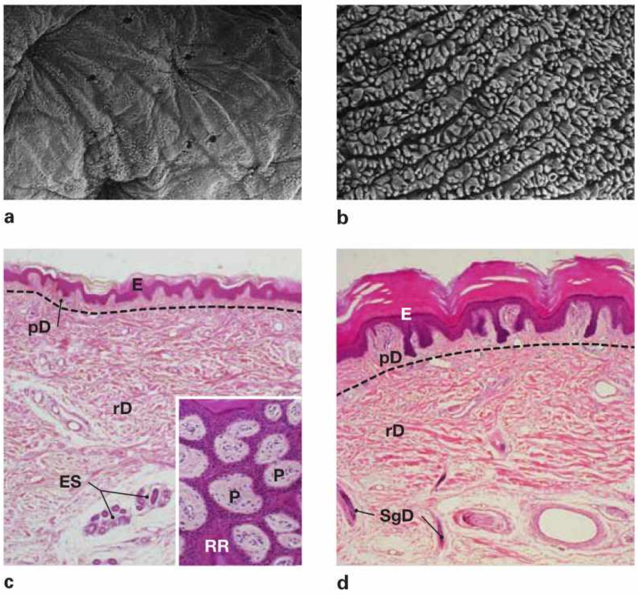


Fig. 1.56 Distal finger phalanx; Phalanx distalis; sagittal section.
The nail bed comprises the region between the nail and the distal phalanx. It consists of epithelium (Hyponychium and Matrix unguis) and the underlying dermis.

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). The lack of fusion may have different reasons, for example it occurs through physical trauma, it may result from certain medication, or it is linked to various diseases. **Brittle nails** signal lack of biotin (vitamin H). Biotin is required for the formation of keratin, the main component of the nail plate. Numerous systemic diseases are associated with nail changes. For example, psoriasis leads to the formation of **small pits, oily spots** and sometimes **crumbly nails** up to a complete **nail dystrophy**. Following skin and nail injuries, the nail can be colonized by fungi **(onychomycosis)**. Treatment of fungal infections of the toenails is often lengthy.

Fig. 1.57 Skin layers, Integumentum commune; (hairy skin);
C: cutis, composed of epidermis (E) and dermis (D); SC: subcutis; Fs: superficial fascia; Fm: muscle fascia; M: muscle; rc: Retinaculum cutis; ES: eccrine sweat glands. HE-staining, magnification: 22-fold. [2]
The skin (cutis) is composed of the **epidermis** and underlying **dermis** (fibro-elastic connective tissue with capillary plexus, specialized receptors, nerves, immune cells, melatonin-producing cells, sweat glands, hair follicles, sebaceous glands, smooth muscle cells; thickness varies depending on the body region). Beneath the dermis lies the **subcutis** (subcutaneous fat tissue).The skin is the largest organ of the body (approx. 2 m2) and serves many functions: it protects against mechanical injury, is a thermoregulator and a sensory organ, and prevents excessive fluid loss.



Figs. 1.58a to d Hairy skin (a and c, back of finger) and hairless skin (b and d, finger tip);
E: epidermis; P: papillae; pD and rD: papillary and reticular dermis; RR: rete ridges; ES: eccrine sweat glands; SgD: sweat gland efferent duct. The dotted lines indicate the margins between the dermal layers (Stratum papillare and Stratum reticulare). HE-staining. Magnification: 45-fold, inset 100-fold. (c, d [2])
The top panel shows scanning electron microscopy images of the surface of the dermal Stratum papillare after the epidermis has been digested and removed. The bottom panel shows the corresponding histological schematic overview images of sagittal sections through epidermis and dermis. The insert on the left image displays a tangential cut through the epidermis (purple) and the papillary dermis (pink).

Clinical Remarks

The dermo-epidermal connection is ensured by a number of different proteins and structures which are responsible for the adhesion mechanisms between these two zones. Genetic defects of some of these proteins and structures lead to injuries inflicted by shear forces resulting in cracks which may be associated with the **formation of blisters** (Bullae) and, in some cases, involve large detachment of the epidermis. Detachment of epidermis can also be caused by auto-antibodies against components of adhesive structures (bullous pemphigoid, pemphigus).

Hair

Fig. 1.59 Hairs, Pili; longitudinal section through the human scalp [24]
Hairs are the products of keratinization of the epidermis. They originate from invaginations of the epidermis which form follicles that contain mitotically active cells (matrix cells) at the base.
Matrix cells differentiate to become keratinized cells which form the shaft of the hair. Postnatally, we distinguish two types of hair:

- **Vellus hair** (fluffy hair) is soft, short, thin, largely without pigmentation, and does not contain a medulla (follicles are located in the dermis); similar to fetal lanugo hair, vellus hair covers most of the body in children and women.
- **Terminal hair** (long hair) is firm, long, thick, pigmented, and contains a medulla (follicles reach into the subcutis); it constitutes the hair of the head, eye brows, pubic region, arm pits, and beard (in men). The body distribution of terminal hair differs among ethnic groups.

Hair protects from UV-light and cold and serves to convey sensations of touch.

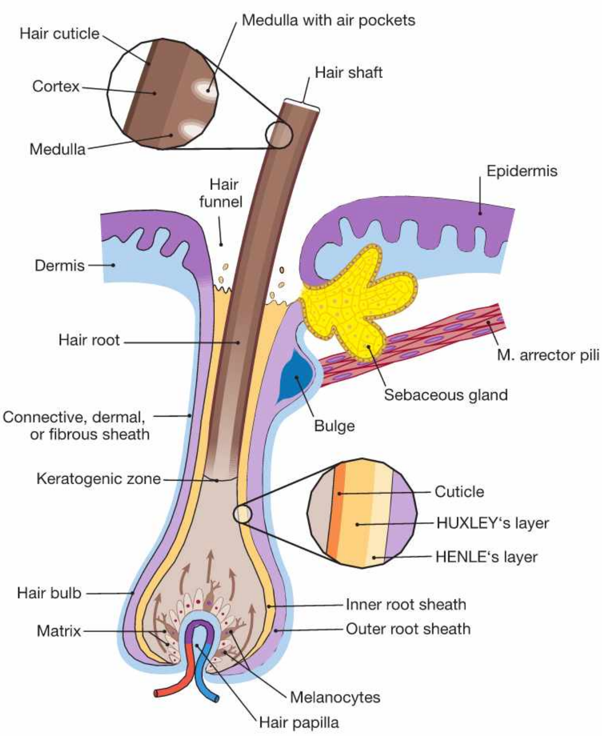


Fig. 1.60 Structure of a hair follicle; longitudinal section. [25]
Hair originates from hair follicles which are cylindrical invaginations of the epidermis into the dermis or subcutis. The **hair follicular body** consists of a hair bulb and the hair papilla. Each hair follicle receives a tuft of blood vessels to sustain its growth and is associated with a sebaceous gland **(hair-sebaceous gland unit)** and a smooth muscle **(M. arrector pili).** The latter is responsible for the erection of the hair (sympathetic activation) by indenting the epidermis to form small pits (goose bumps).
The following structures can be identified in a hair:

- a fully keratinized **hair shaft** with the epithelial inner and outer root sheaths
- non-keratinized **hair root** separated by the keratogenous zone (hair cells keratinizing) from the keratinized hair shaft
- **hair bulb** with its expanded base contains mitotically active matrix cells (regenerative part of the hair)
- dermal **hair papilla**, the cell- and blood vessel-rich dermal part which invaginates into the hair bulb from beneath
- **hair infundibulum** represents the surface opening of the follicle and contains the pilosebaceous canal of the hair-sebaceous gland unit
- **epithelial root sheath** of the hair which is divided into an inner and outer root sheath: cellular layers of the **inner** root sheath are (from hair medulla outward): cuticle, HUXLEY's and HENLE's layers; the **outer** root sheath is composed of multiple layers of bright, non-keratinized cells which begin to keratinize in the infundibular region of the hair and integrate into the epidermis.

Genetic predisposition and pigmentation (melanin content) determine the hair colour. Once the production of melanin ceases, the hair turns from grey to white.

Trunk

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2

Ventral and Dorsal Body Wall

It has become common practise and is also logic, to study the walls (Paries) of the trunk (Truncus) separately from the content of the cavity, the internal organs, since both parts follow different structural principles.
If one takes the view that the body wall is a structure composed of bones and muscles which surround the internal organs, then it consists of chest (Thorax), Abdomen, and Pelvis. According to this definition, the shoulder girdle (→ p. 135) is not part of the Thorax, since it is only resting on the thoracic walls. whereas the pelvic girdle (→ p. 264) is an integral and definite part of the trunk, as it holds and protects the organs of the lower abdomen.

Skeleton

The trunk (and the neck) is supported by the **vertebral column** (Columna vertebralis). The vertebral column is composed of single vertebrae and continues throughout the entire length of the trunk. Its most caudal section, the coccyx (Os coccygis), consists of a variable number (4–7) of rudimentary vertebrae. The tip of the tail piece of the coccyx points towards the posterior wall of the Rectum. In the pelvic region, five large single vertebrae are fused by synostosis, resulting in a very rigid vertebral column segment. In contrast, the five lumbar vertebrae (Vertebrae lumbales) enable flexion, extension, and lateral rotation of the vertebral column. The twelve thoracic vertebrae (Vertebrae thoracicae), which articulate with the twelve rib pairs, are notably less mobile.
The superior ten **rib pairs** (Costae verae et spuriae) are connected to the Sternum, the two inferior pairs (Costae fluctuantes) do not extend to the Sternum. Ribs, thoracic vertebrae, and sternum form the bony thorax or rib cage (Thorax). The ribs are easily palpable on both sides of the Sternum. Starting from the top of the rib cage, the first rib (Costa prima) is not palpable because it is hidden under the clavicle (Clavicula). The second rib (Costa secunda), however, is palpable. Counting the ribs, alongside with the use of auxiliary reference lines, helps identify specific locations on the Thorax. For instance, in an imaginary sagittal line passing through the middle of the clavicle and the fifth intercostal space that is below the fifth rib, the beat of the cardiac apex is palpable. This is where the apex of the heart is "knocking" on the chest wall from the inside.
The cartilaginous costal arch (Arcus costalis), which connects the seventh to tenth rib with the Sternum in an arch-shaped fashion, is also well palpable. It is the landmark for the inferior thoracic aperture, which constitutes a wide opening of the Thorax towards the Abdomen. The thoracic cavity is partitioned by the dome-shaped, steep and upward projecting diaphragm (see below). Abdominal organs, such as stomach, liver, spleen, and others, are located below to the diaphragm and "beneath the cartilage" (Regiones hypochondriacae). The pulsation of the Aorta abdominalis is palpable in the Regio epigastrica between the cartilaginous rib arches and immediately inferior to the xiphoid process (Proc. xiphoideus sterni).

Muscles

The muscles of the abdominal wall are voluntary, like those of the extremities. Muscles are classified into two major groups: muscles acting exclusively on the abdominal wall and muscles of the extremities (arising from the abdominal wall and acting on the shoulder girdle and the extremities). According to their location and function, the muscles of the wall of the trunk form four major groups: the autochthonous muscles of the back, muscles of the lateral and ventral wall of the trunk, muscles of the diaphragm, and muscles of the pelvic floor.
The **autochthonous muscles of the back,** which consists of numerous single muscles, are located to both sides of the vertebral column. Arranged in two powerful muscle strands, these muscles are oriented in a predominantly craniocaudal direction from the occiput to the pelvic girdle via the neck, thorax and loins. With the back extended, these muscles are particularly visible in the lumbar region. Overall, these muscles are effective in facilitating an erected spine posture, hence they are called M. erector spinae. The adjective "autochthonous" means "rooted or native" – during ontogenesis, all voluntary muscles of the body emerge bilaterally to the vertebral column, precisely the region of the autochthonous muscles of the back in adults. The muscular progenitor (precursor) cells (myogenic progenitor cells) of all other muscles migrate from this region across the ventral side of the trunk towards the extremities. Thus, one should name these "allochthonous" muscles, since they arise from cells "coming from outside".
The **muscles of the lateral and ventral wall of the trunk** exist as multilayered intercostal muscles (Mm. intercostales) of the thorax. They assist in respiration. The flanks of the Abdomen (Regiones laterales) contain flat, likewise multilayered muscles, which are also known as lateral abdominal muscles (Mm. obliqui and M. transversus). The anterior abdominal wall is formed by tough tendons (aponeuroses) of these lateral muscles. The straight abdominal muscle (M. rectus abdominis) extending longitudinally from the symphysis to the chest is ensheathed in these aponeuroses ("six-pack belly"). Together, these muscles rotate and flex the trunk. Beyond this, these muscles also control the tension of the abdominal wall, assist in expiration as well as in vocalization for speech and singing, and increase abdominal pressure.
The **diaphragm** (Diaphragma), the most important muscle of respiration, is voluntary, even though one is not aware of its actions. The diaphragm is located in the interior of the trunk, arises from the margins of the inferior thoracic aperture (see above) and forms a large thin-walled dome with the apex pointing towards the thoracic cavity. During contraction, the dome flattens and this leads to an increased volume of the thoracic cavity facilitating inhalation.
The **muscles of the pelvic foor** (Diaphragma pelvis and urogenitale) are also voluntary (pelvic floor exercise). They bear the weight of the visceral organs (caudally the bony pelvis is open). These muscles originate from the inner lower margins of the bony pelvis to form a funnel that tapers down towards the caudal end (→ p. 196 and 214).

Breast (Mamma)

The breasts (Mammae) are located on the female thorax – more precisely: they ride on top of the M. pectoralis major, a muscle of the shoulder girdle. Their major component is subcutaneous adipose tissue and only a small part consists of glandular tissue (Glandulae mammariae). Each mammary gland comprises 10 to 20 single glands (Lobi) and each gland sends its own efferent duct to the mammilla (Papilla mammaria). Only during breastfeeding (lactation period) – or in the presence of a malignant breast tumour – the glandular tissue proliferates, which should only serve the production of milk. Men also have tiny rudimentary mammary glands. They can also accumulate abundant adipose tissue in the breast region on top of the M. pectoralis (gynecomastia).

Clinical Remarks

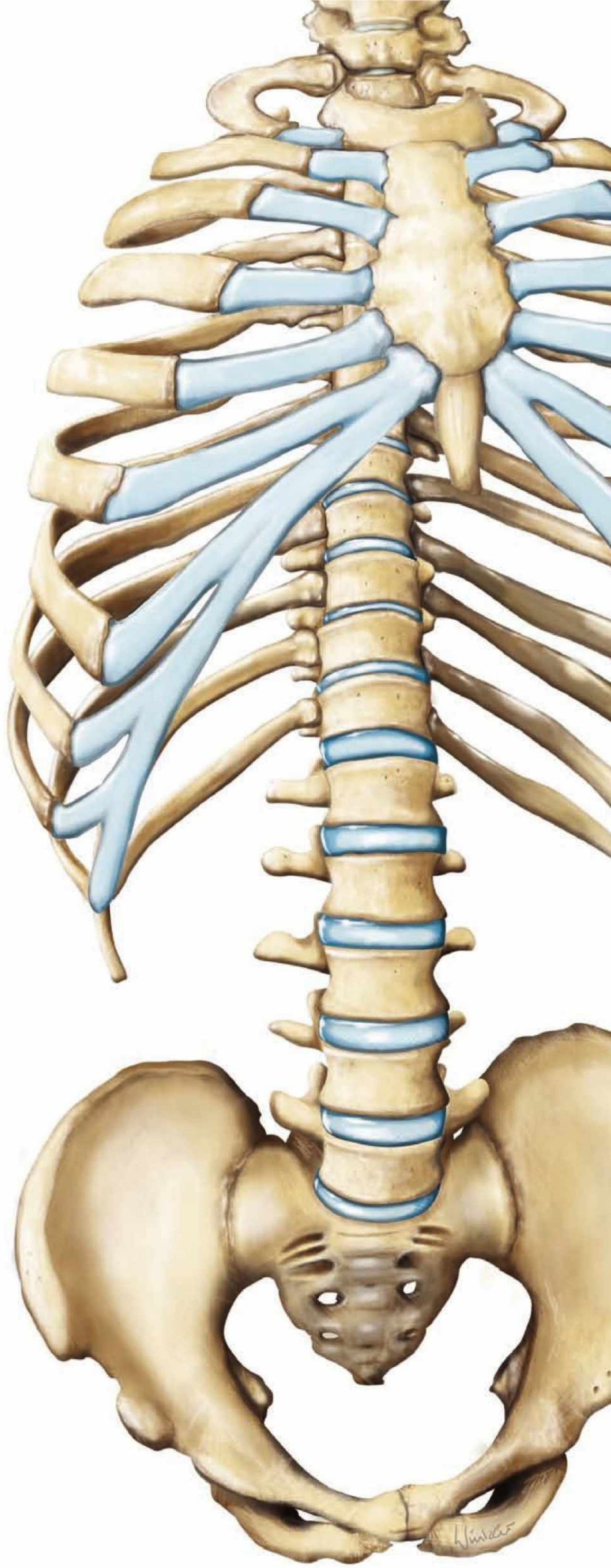
Anomalies in the region of the thoracic wall (e.g. Pectus excavatum [funnel chest], Pectus carinatum [pigeon chest or carinate chest]) as well as congenital anomalies and deformities of the mamma (e.g. amastia, aplasia, athelia, polythelia, polymastia, mammary hypertrophy) may occur.
The feminization of the male chest **(gynecomastia)** can have different underlying causes.
Stenosis of the aortic isthmus causes the formation of arterial circulatory bypasses which involve arteries of the ventral wall of the trunk (Aa. thoracica interna, epigastricae superior and inferior). This leads to an increased arterial diameter and pulsatile force resulting in the formation of erosions at the caudal aspect of the ribs in the vicinity of the dilated intercostal arteries.
Hernias are a common disease in the region of the ventral abdominal wall. At a breach point in the ventral abdominal wall (hernial canal), a hernial sac can form in which abdominal viscera can protrude and be trapped (hernial content). Men usually have congenital or acquired inguinal hernias.
The constriction or blockage of the upper or lower Vena cava leads to the formation of **cavocaval anastomoses** via superficial and deep veins of the abdominal wall with visible enlargement of the epifascial veins.
Deviations from the scrotal position of the testis can occur in cases of **maldescensus testis.**

→ Dissection Link

After preparation of the skin, the Mm. trapezius and latissimus dorsi as well as the Fascia thoracolumbalis are exposed. The M. trapezius is separated at its origin; the M. latissimus dorsi is separated in an arch-shaped manner near its origin. After dissection of blood and nerve vessels of the muscles, the Mm. levator scapulae and rhomboidei are exposed and the Trigonum lumbale fibrosum is defined. Following the removal of the origin of the M. latissimus dorsi, the structures passing through the axillary gaps are exposed. The Mm. serrati posteriores are exposed after removal of the Mm. rhomboidei at their origin. Subsequently, dissection of the M. erector spinae and the deep (internal) neck region occurs. Upon completion, the Mammae on the ventral side of the body are dissected and removed, the epifascial pathways are traced to thigh and upper arm, and the dissection of the axilla and MOHRENHEIM's fossa is completed. After removal of the M. pectoralis major, the Claviculae are exarticulated, the abdominal muscles are opened, the inguinal canal and the structure of the spermatic cord are exposed, the rectus sheath and the scrotum are opened and the testicular fasciae are displayed. In women, the inguinal canal is located along with the Lig. teres uteri.

EXAM CHECK LIST

• Columna vertebralis: development and skeletal components • Vertebra prominens • structure of a vertebra • Os sacrum • Os coccygis • vertebral connections • autochthonous muscles of the back • nerves and blood vessels: location of spinal ganglia and spinal nerves, innervation region of Rr. dorsales, N. occipitalis major, A. vertebralis, and Plexus venosi vertebrales • surface anatomy • palpable skeletal prominences • MICHAELIS' rhomboid • organization of the layers of the neck • Trigonum suboccipitale • morphological basis of lumbar puncture and epidural anaesthesia • basic development of the thorax • Angulus sterni • medioclavicular line • anterior and posterior axillary lines • scapular line •veins of the skin and lymphatic drainage • skeletal components and connections • thorax • Mm. intercostales • diaphragm • intercostal nerves and blood vessels • A. thoracica interna • collateral circulatory routes as a result of aortic stenosis • Vv. thoracicae internae • Vv. thoracoepigastricae • cavocaval anastomoses • mamma • basic development of the umbilicus • abdominal muscles • segmental nerves and blood vessels • N. subcostalis • Plexus lumbalis • Nn. iliohypogastricus, ilioinguinalis, and genitofemoralis • Vasa epigastrica • Canalis inguinalis • external genital organs



Back

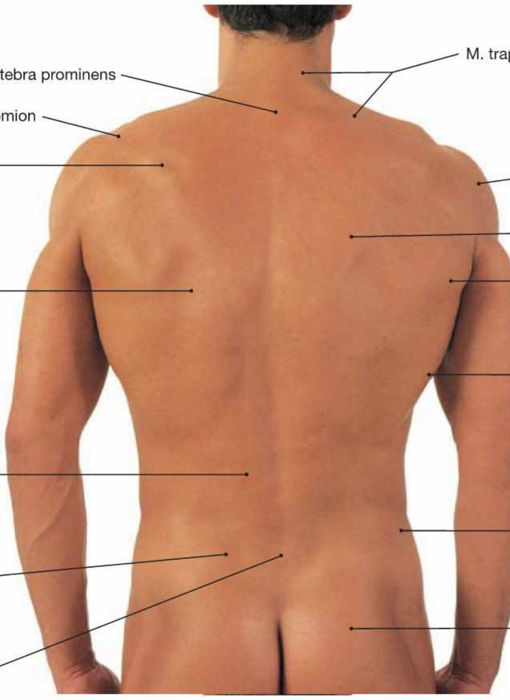


Fig. 2.1 Back, Dorsum, surface relief of the back.
The contours of the back provide useful landmarks to determine different regions of the vertebral column, muscles, the approximate position of the end of the spinal cord, and the position of organs (e.g. kidney). Bony landmarks are the Proc. spinosus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

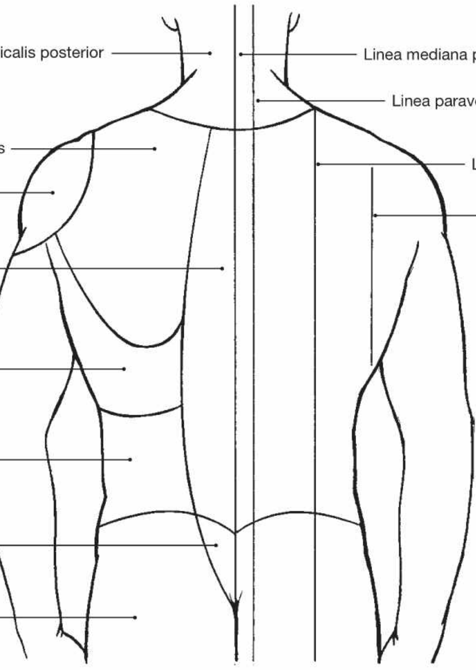


Fig. 2.2 Regions and orientation lines of the back.
The back and neck region have the following distinct topographic regions: Regio cervicalis posterior (Regio nuchalis), Regiones vertebralis, scapularis, infrascapularis, deltoidea, lumbalis, sacralis, and glutealis. Useful orientation lines of the back include the Linea mediana posterior, paravertebralis, scapularis, and axillaris posterior.

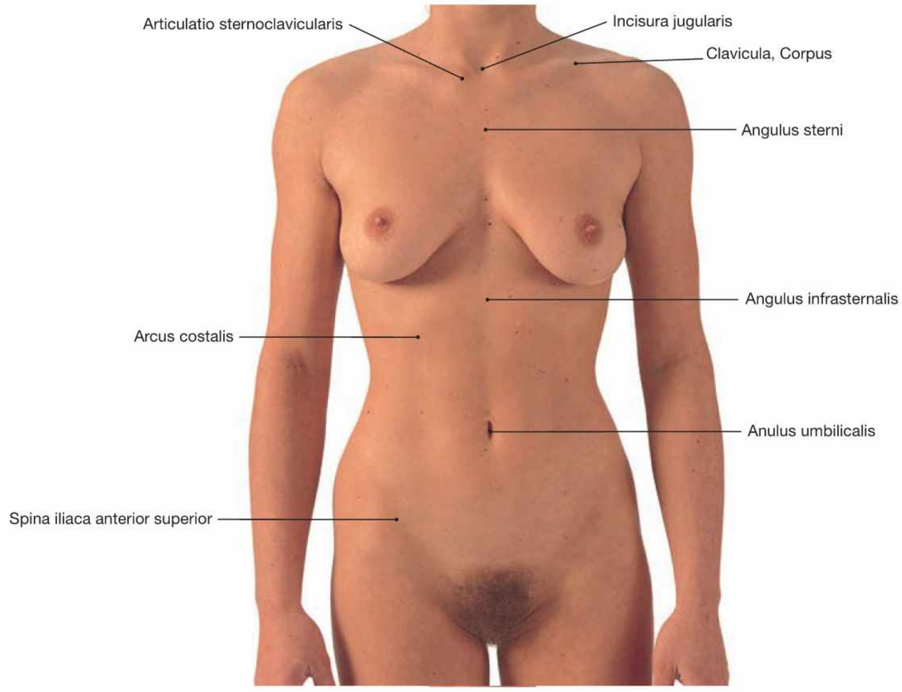


Fig. 2.3 Surface relief of the chest and the abdominal wall of a young woman.
Landmarks assist in the orientation at the ventral side of the trunk, like e.g. the costal arch (Arcus costalis), the umbilicus (Anulus umbilicalis), and the Spina iliaca anterior superior.
Additional landmarks are shown.

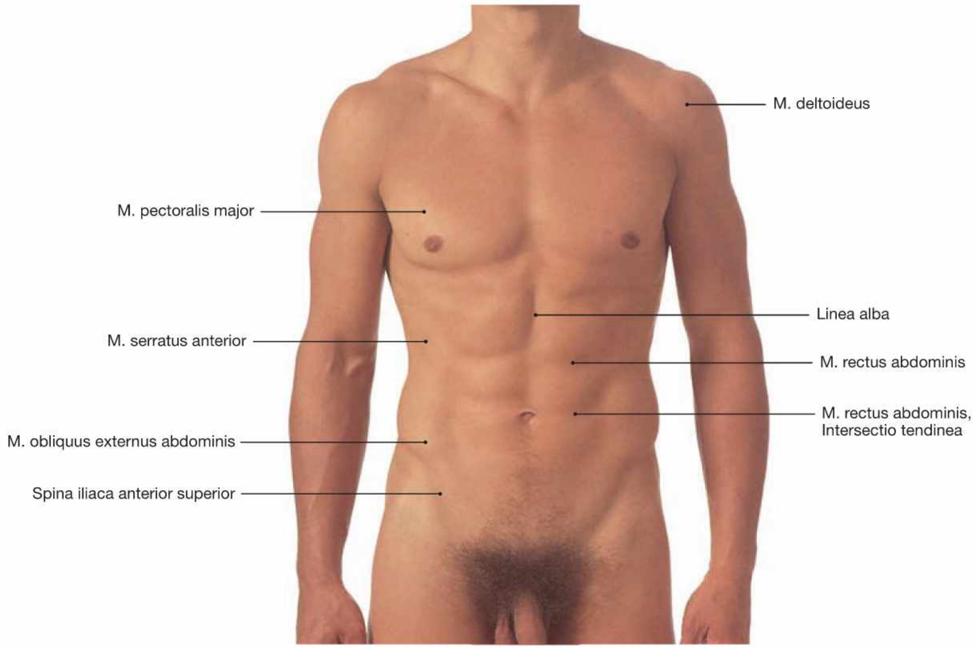


Fig. 2.4 Surface relief of the chest and the abdominal wall of a young man.
Landmarks on the ventral side of the trunk.

Development

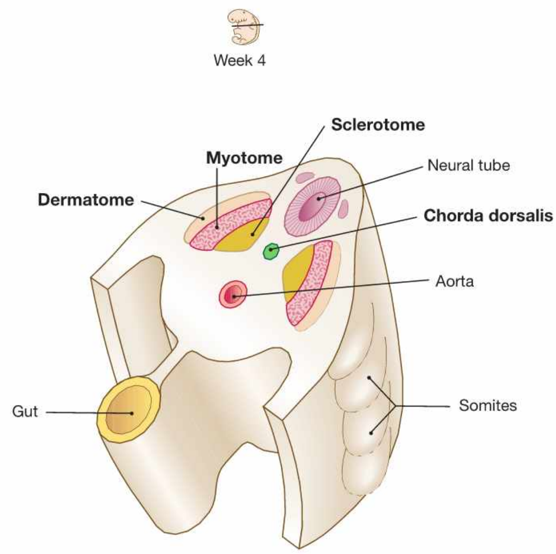
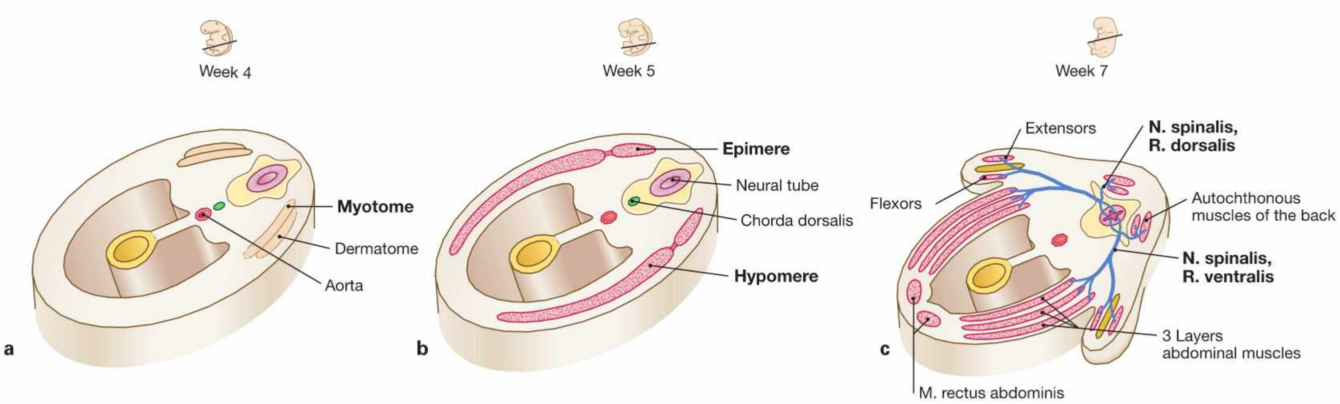


Fig. 2.5 Development of the walls of the trunk: organization of the somites at week 4. [21]
All elements of the supportive and muscular systems of the ventral and dorsal trunk originate exclusively from the middle germ layer **(Mesoderm)**. The mesoderm condenses on both sides of the Chorda dorsalis and the neural tube to form somites and unsegmented lateral mesoderm. At week 4, a ventromedial section of each somite differentiates to become a **sclerotome**. Migrating cells of the sclerotomes on both sides of the neural tube and the notocord (Chorda dorsalis) meet to form primitive vertebrae. Derivatives of the lateral section of each somite are the **myotome** and the **dermatome** which contribute cells for the development of the muscles and skin, respectively.



Figs. 2.6a to c Development of the walls of the trunk: differentiation of epimere and hypomere from myotomes. [21]
The striated skeletal muscles of the trunk originate from dermatomyotomes in the lateral section of the somites and starts differentiating at week 4. During week 5, a larger ventral group of mesenchymal cells, the **hypomere,** separates from a smaller dorsal cell population, the epimere. The hypomere is the origin of the Mm. scaleni, prevertebral neck muscles, infrahyoid muscles, Mm. intercostales, subcostales, transversus thoracis, oblique abdominal muscles, Mm. rectus abdominis, quadratus lumborum, pelvic floor muscles, and sphincter muscles of the anus and urethra. The autochthonous muscles of the back (M. erector spinae) derive from the **epimere.** In the region of the abdominal wall, the hypomere differentiates into the oblique and rectus abdominal muscles at week 7; the epimere forms part of the autochthonous back muscles. Epimere and hypomere receive separate nerve innervation: these are the Rr. ventrales and Rr. dorsales of the spinal nerves for the hypomere and epimere, respectively.

Clinical Remarks

The absence of individual muscles is often without clinical relevance. 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.

The **prune-belly syndrome**, which is very rare, presents a complete lack of abdominal muscles and the organs are palpable through the entire skin. Larger muscle defects in the abdominal wall are associated with the formation of hernias.

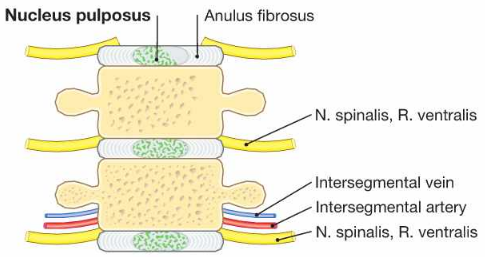
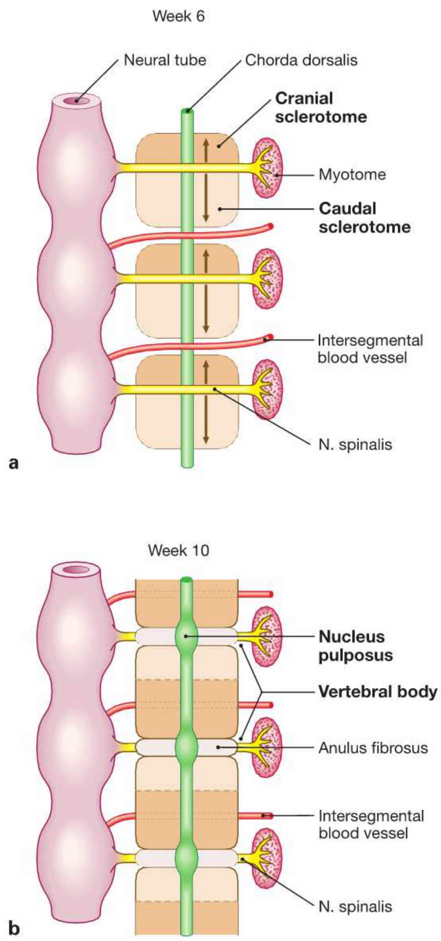
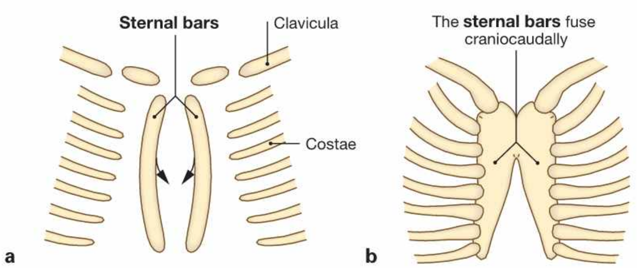


Fig. 2.7 Development of the wall of the trunk: Nuclei pulposi as remnants of the Chorda dorsalis in the adult vertebral column. [21]
From the beginning of week 4 of development, migrating cells from the scerotome assemble around the neural tube. A fraction of cells encircles the Chorda dorsalis and differentiates to become the vertebral body. The Chorda regresses to become the small jelly-like Nucleus pulposus in the centre of the intervertebral discs.





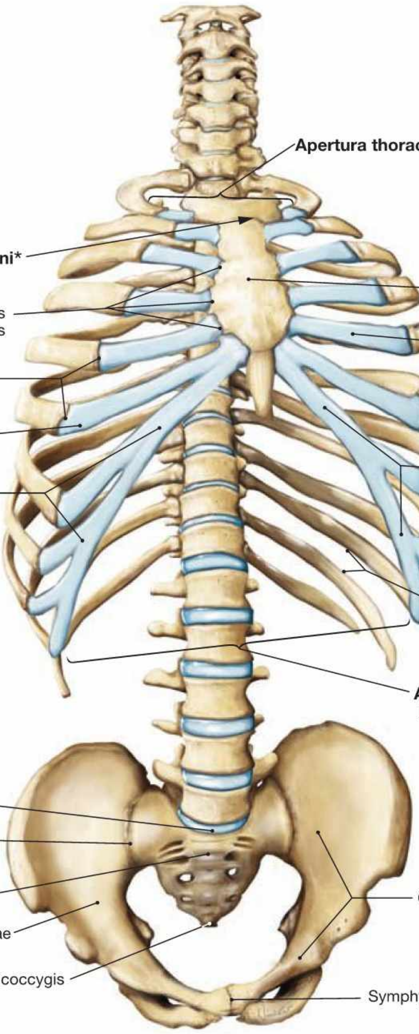
Figs. 2.8a and b Development of the ribs and the sternum. [21]
The sternum develops from two sternal bars which derive from parallel condensations of mesenchymal cells in the ventrolateral body wall (**a**) and fuse cranio-caudally in the median plane (**b**). Ossification of the Proc. xiphoideus occurs late at 20–25 years of age. The ribs in the region of the thoracic vertebral column and the Procc. costales of the neck and lumbar vertebrae derive from sclerotome cells that have migrated ventrolaterally. Dorsally they are connected with the vertebrae and ventrally they connect in part with the Sternum (ribs I to VII; **true ribs, Costae verae**). The ribs VIII. to X fuse ventrally and connect to the sternum in an arch via their own cartilage **(false ribs, Costae spuriae)**. Ribs XI and XII are exclusively connected with the vertebrae and end freely **(Costae fluctuantes)** in the ventral chest wall.

Fig. 2.9a and b Development of vertebral bodies from two adjacent sclerotomes. [21]
Sclerotomes divide into a cranial and caudal section. A myotome is associated with a sclerotome and receives innervation by a spinal nerve. In between the sclerotomes and the myotomes course the intersegmental blood vessels (week 6, **a**). The individual vertebrae are formed by the fusion of a caudal with a neighbouring cranial sclerotome section. Each spinal nerve associated with a myotome becomes sandwiched during the fusion of the cranial and caudal sclerotome sections and exits through a Foramen intervertebrale. Intervertebral discs develop between the primordial vertebrae (**b**). Muscles derived from a single myotome (e.g. M. rotator brevis, → Fig. 2.78) can move two neighbouring vertebrae into opposite directions. The functional unit of all structures participating in the motion of two neighbouring vertebrae is called a motion segment.

Clinical Remarks

A **spina bifida** represents a cleft dorsal vertebral column as a result of failed fusion of a single or multiple vertebral arches. A combination of incomplete closure of vertebral arches and exposure of underlying neural folds is called **rachischisis**. Paralysis occurs if the spinal cord is also affected. If the cleft in the vertebral arches is covered with skin, it is called spina bifida occulta. A **wedge-shaped vertebra** (hemivertebra) results if a vertebra lacks one of the two ossification centres. Fusion of two vertebrae and degeneration of the intervertebral disc creates a **block vertebra. Failure of fusion of the lateral sternal bands** often results in a gap formation in the Corpus sterni or the Proc. xiphoideus. Clinically, such gaps or holes are insignificant. **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 Plexus brachialis or the A. subclavia (→ p. 47 and p. 54).

Skeleton of the trunk



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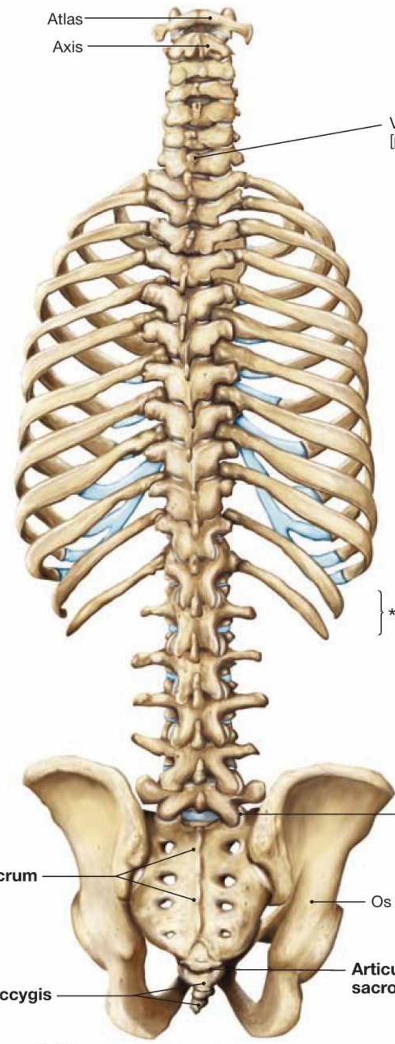

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Fig. 2.10 and Fig. 2.11 Bones and cartilages of the skeletal trunk; ventral views (→ Fig. 2.10) and dorsal view (→ Fig. 2.11).The bones of the thorax (Ossa thoracis) as well as the bones of the vertebral column (Columna vertebralis) and the pelvic girdle (Cingulum pelvicum) are shown.
Although all ribs articulate with the vertebral column, only the first seven ribs are directly connected to the sternum via their cartilage processes (Cartilago costalis). They are named true ribs (Costae verae). The remaining five pairs of ribs are false ribs (Costae spuriae); ribs XI and XII fail to connect with the cartilaginous arch (Costae fluctuantes). The rhomboid-shaped connection formed by the Proc. spinosus of the fourth lumbar vertebra with the Spinae iliacae posteriores superiores and the superior part of the Crena ani at the backside of a woman is named the **MICHAELIS' rhomboid**. In men, the sacral triangle (connection between Spinae iliacae posteriores superiores and the superior part of the Crena ani) is visible.

* clinical term: angle of LUDWIG (LUDOVICUS)
** Costae fluctuantes (Costae XI–XII)

Clinical Remarks

During physical examination the well palpable **Angulus sterni** (Angle of LUDWIG) is an important landmark for orientation on the thorax. It is located at the level of the second rib. The sacral triangle in men and the MICHAELIS' rhomboid (lumbo-rhomboid) in women provide information about the shape of the pelvis. Rickets (vitamin D deficiency) for example can cause a pelvis deformation with elongated transverse axis, whereas with scoliosis the pelvis becomes asymmetrical. The **Proc. spinosus of the 4th lumbar vertebra** lies at the same level as the iliac crests. It serves as a reference point for lumbar puncture and for intrathecal or epidural (peridural) anaesthesia.

Ribs

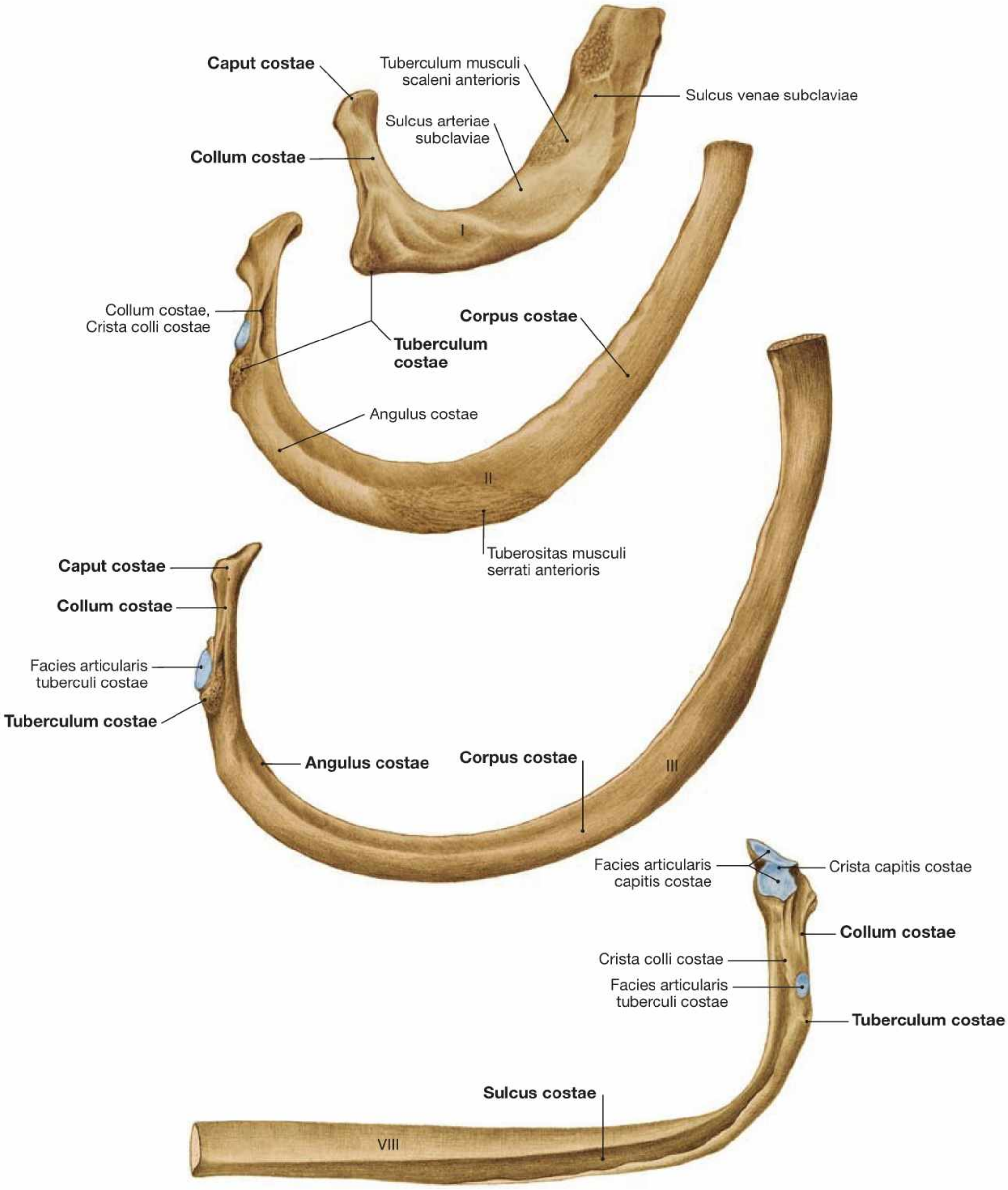


Fig. 2.12 Ribs, Costae; ribs I to III: cranial view; **rib VIII:** caudal view.

Ribs III to X are typically shaped. The head of the rib (Caput costae) is wedge-shaped and possesses two articular surfaces (Facies articulares capitis costae). The Tuberculum costae has one surface (Facies articularis tuberculi costae). The V., A., and N. intercostalis run in close proximity to the Sulcus costae. An invagination at the ventral end of the body of the rib (Corpus costae) facilitates contact with the rib cartilage.

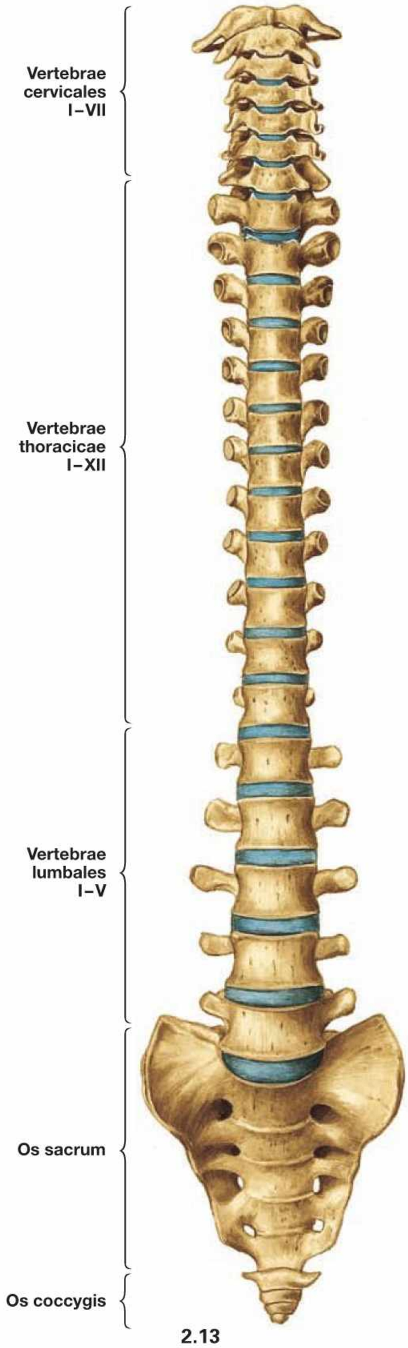
Ribs I, II, XI, and XII deviate from the typical rib structure.Rib I is stumpy, broad, and shows the strongest curving; the head has only one articular surface. Rib II displays only an outline of a Sulcus costae and a Tuberositas musculi serrati anterioris marks the origin of the M. serratus anterior. The heads of ribs XI and XII contain only one articular surface. These two ribs fail to contact with the costal arch, show pointed ventral ends, and have no Tuberculum costae.

Clinical Remarks

Rib anomalies are common:

- A **cervical rib** is observed in approximately 1% of the population. The rib primordial at the 7th cervical vertebra (C7) is enlarged. Apart from isolated enlargement of the Proc. transversus, uni- or bilaterally, additional ribs may be present which can be connected to the sternum. The pressure of a cervical rib on the lower roots of the Plexus brachialis can cause sensory loss and motor deficits in the innervation region of the N. ulnaris.
- **Two-headed ribs** arise from two partially fused ribs.
- In **bifid ribs** the anterior part of the rib divides into two parts.
- Widening of the intercostal arteries in the Sulcus costae during stenosis of the aortic isthmus results in pressure atrophy of the rib bone which is called **erosions (usures) of the rib.**

Vertebral column



2.13

2.14

Fig. 2.13 and Fig. 2.14 Vertebral column, Columna vertebralis; ventral (→ Fig. 2.13) and dorsal (→ Fig. 2.14) views.
The vertebral column accounts for 40% of the height of a human, a quarter thereof being due to the intervertebral discs. The vertebral column is composed of 24 presacral vertebrae (seven cervical vertebrae, twelve thoracic vertebrae, five lumbar vertebrae) as well as two synostotic parts, the sacral (Os sacrum) and the coccygeal bone (Os coccygis). The thoracic vertebrae connect with the twelve rib pairs, the sacrum articulates with the Ossa coxae. In the upright position, the physical force increases from cranial to caudal along the vertebral column.

Clinical Remarks

Sacralization refers to the fusion of the 5th lumbar vertebra with the Os sacrum (only 23 presacral vertebrae remaining). When the top sacral vertebra remains separated from the remainder of the Os sacrum (25 presacral vertebrae), the condition is called **lumbalization.** Radiograph examination reveals six lumbar vertebrae and four sacral vertebrae. When the sacrum has five vertebrae, there is an additional sacralization of the first coccygeal vertebra. Fusion of the first cervical vertebra (Atlas) with the skull is called **assimilation of the atlas.**

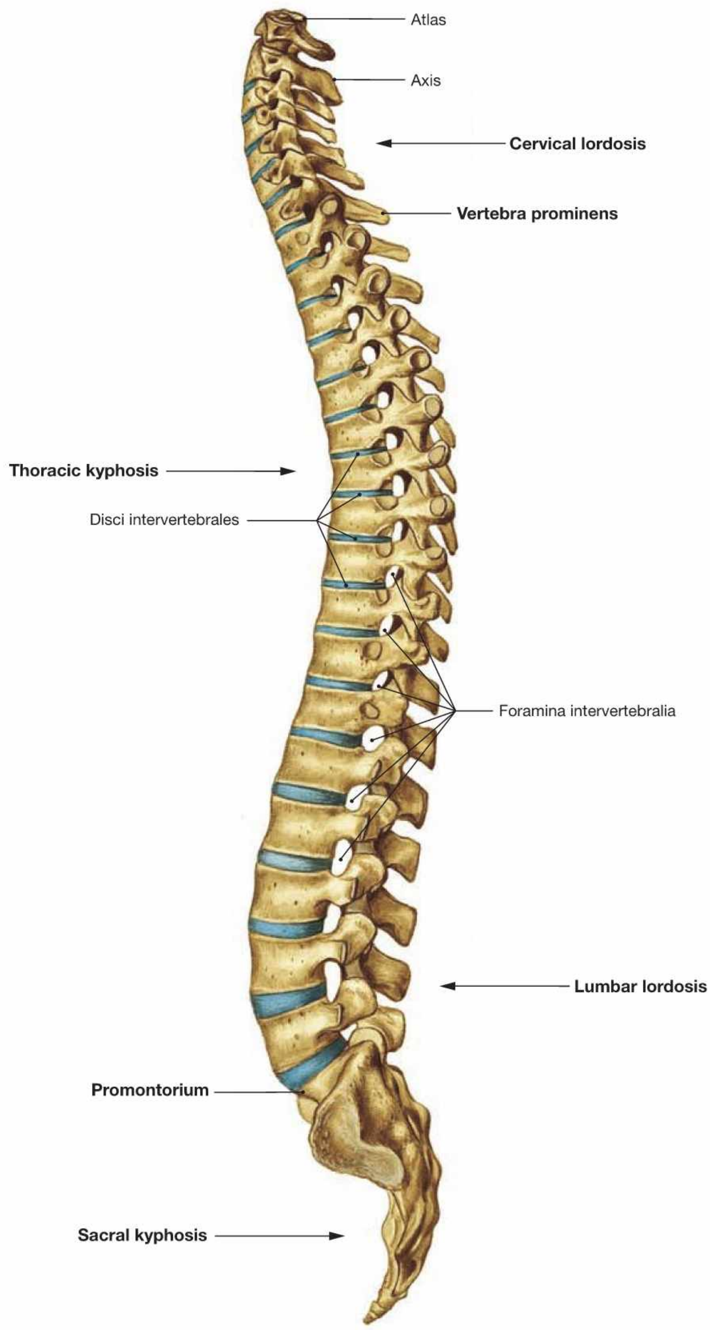


Fig. 2.15 Vertebral column, Columna vertebralis; view from the left side. When viewed in the sagittal plane the vertebral column has a characteristic curvature:

- cervical lordosis (ventral convex curvature)
- thoracic kyphosis (dorsal convex curvature)
- lumbar lordosis (ventral convex curvature)
- sacral kyphosis (dorsal convex curvature)

Lordosis and kyphosis are the medical terms for ventrally and dorsally directed convex curvatures of the vertebral column, respectively. In the first few months after birth, all sections of the vertebral column show a dorsal convex bend. The cervical lordosis develops with the ability to sit upright and the lumbar lordosis forms when learning to walk.
The vertebral curvatures form only after the pelvis has tilted forward as a result of the bipedal walk learned at the age of 1–2 years. Prior to this ability to walk upright, all sections of the vertebral column show a dorsal convex curvature.

Clinical Remarks

Excessive curvature of the spine in the frontal plane **(scoliosis)** is always pathologic. This growth deformity of the spine results in fixed lateral curvature, torsion, and rotation of the vertebral column which cannot be straightened physiologically by the use of muscles. Scoliosis is one of the oldest known orthopedic conditions. Despite intense scientific and clinical efforts, to this day many of the problems associated with scoliosis are not resolved satisfactorily. Due to unequal leg length, the majority of the population has a mild scoliosis.

Atlas and axis

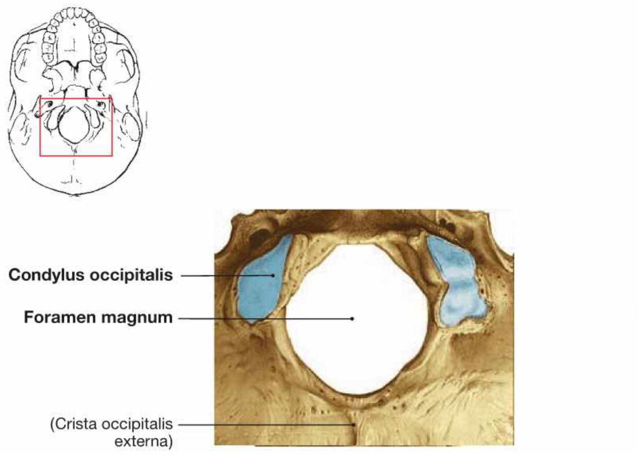


Fig. 2.16 Base of occipital bone, Os occipitale, region of the Foramen magnum and the occipital condyles for the upper head joint; caudal view**.**
The occipital condyles are located bilaterally to the Foramen magnum.
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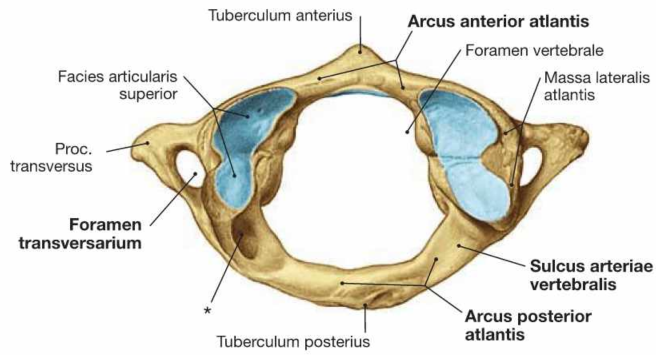


Fig. 2.17 1st Cervical vertebra, Atlas; cranial view.
The atlas does not possess a vertebral body. During development, the latter fused with the axis to form the Dens. The anterior vertebral arch (Arcus anterior atlantis) is positioned anterior to and articulates with the dens. At the posterior vertebral arch (Arcus posterior atlantis), the Proc. spinosus is replaced by a small Tuberculum posterius. The upper articular facets of the atlas are frequently separated into two sections. Compared to other vertebrae, the atlas has a slightly longer transverse process.

* variant: Canalis arteriae vertebralis

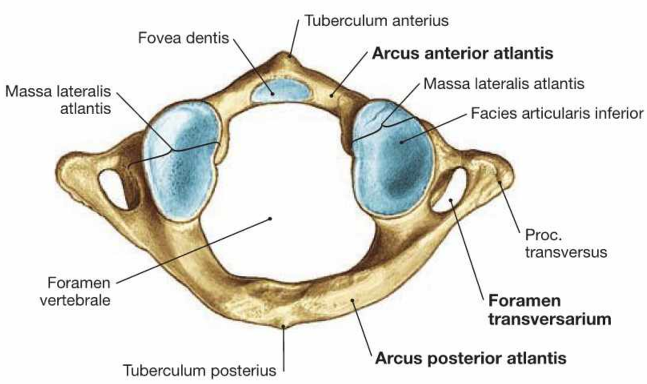


Fig. 2.18 1st Cervical vertebra, Atlas; caudal view**.**
The Fovea dentis articulates with the Dens axis and is located on the inside of the Arcus anterior atlantis. The Facies articulares inferiores are shallow, concave, and tilted in a 30° angle to the transverse plane. The Foramen transversarium is typical for cervical vertebrae and facilitates the passage of the A. vertebralis.

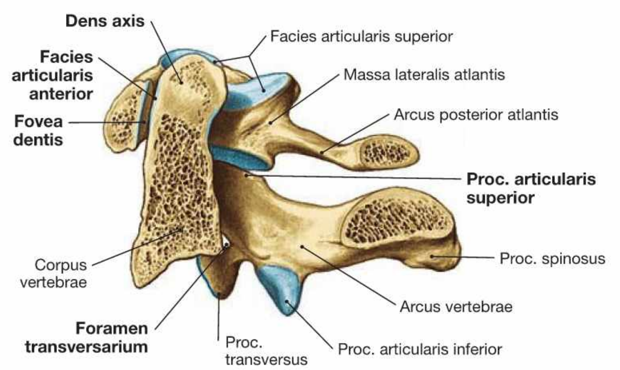


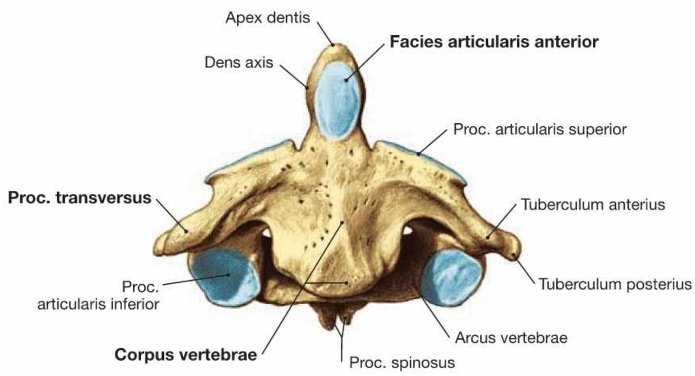
Fig. 2.19 1st and 2nd cervical vertebrae, Atlas and Axis; median section; view from the left side.
The median section permits the inspection of the vertebral canal. Atlas and axis articulate via the Fovea dentis and the Facies articularis anterior in the Articulatio atlanto-axialis mediana. The Arcus posterior atlantis is considerably smaller in relation to the Arcus vertebrae of the axis.

Clinical Remarks

Degenerative changes of the cervical vertebrae are common with advanced age and present as **Osteochondrosis intervertebralis** with dorsal spondylophytes which can lead to narrowing of the vertebral canal with resulting compression of the spinal cord. **Arthrosis** in the zygapophyseal 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 in pressure on the A. vertebralis and the sympathetic nerve plexus.

Isolated fractures of the atlantal arches occur especially as a result of motor vehicle accidents. The incidence declined in recent years due to improved safety measures in vehicles (air bag). 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 cranial base), **cleft formations in the region of the vertebral arches** are common (→ p. 54).

Cervical vertebrae



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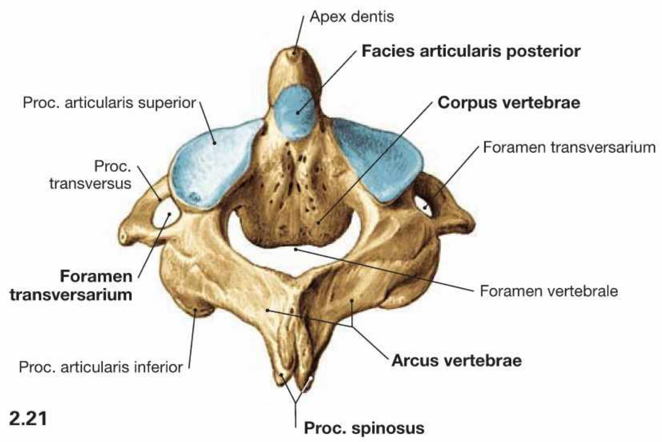


2.21

Fig. 2.20 and Fig. 2.21 2nd cervical vertebra, Axis; ventral (→ Fig. 2.20) and dorsocranial (→ Fig. 2.21) views.
A distinct feature that sets the axis apart from the other cervical vertebrae is the dens. The front and rear side of the dens are covered with articular facets (Facies articulares anterior et posterior). The articular facets of the Procc. articulares superiores are sloped to the outside and the Procc. articulares inferiores are positioned in an oblique angle to the frontal plane. Starting with the 3rd cervical vertebra, the articular facets of the Procc. articulares superiores also assume an oblique position in relation to the frontal plane. The transverse process of the axis (Proc. transversus) is short and the spinous process (Proc. spinosus) is frequently split in two.

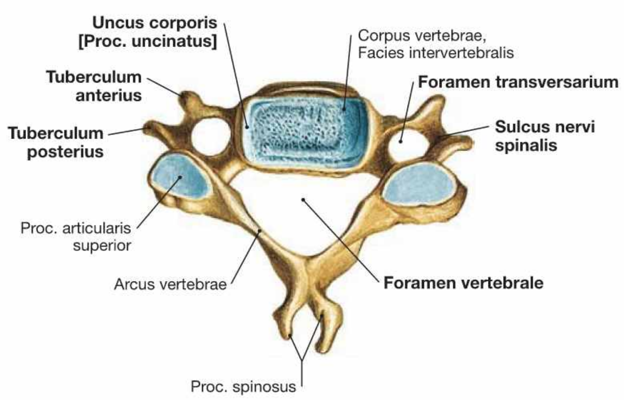


Fig. 2.22 5th cervical vertebrae, Vertebra cervicalis V; cranial view.
The 5th cervical vertebra exemplifies the typical structure of the 3rd to 6th cervical vertebrae. With the exception of the 7th cervical vertebra, the Proc. spinosus has two pointed ends. The Proc. transversus is short, has a Foramen transversarium and ends laterally in a Tuberculum anterius and in a Tuberculum posterius, with the Sulcus nervi spinalis located between them. The Foramen vertebrale is large and triangular. The vertebral body is longer in the transverse axis than in the sagittal axis and similarly wide at the front and back.

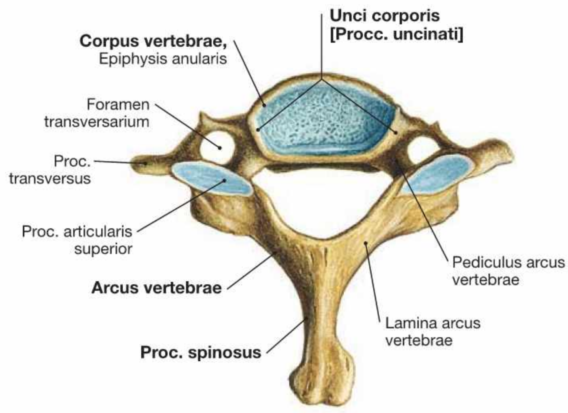


Fig. 2.23 7th cervical vertebra, Vertebra cervicalis VII; cranial view.
The 7th cervical vertebra has a long transverse process with a Tuberculum posterius only and a long and undivided spinous process.

Clinical Remarks

The **odontoid fracture** or the fracture of the Pars interarticularis (the so-called hanged man's fracture) presents the risk of cervical cord compression and is mostly seen as a result of motor vehicle accidents. An odontoid fracture can also affect small children and is difficult to diagnose.

Cervical vertebrae

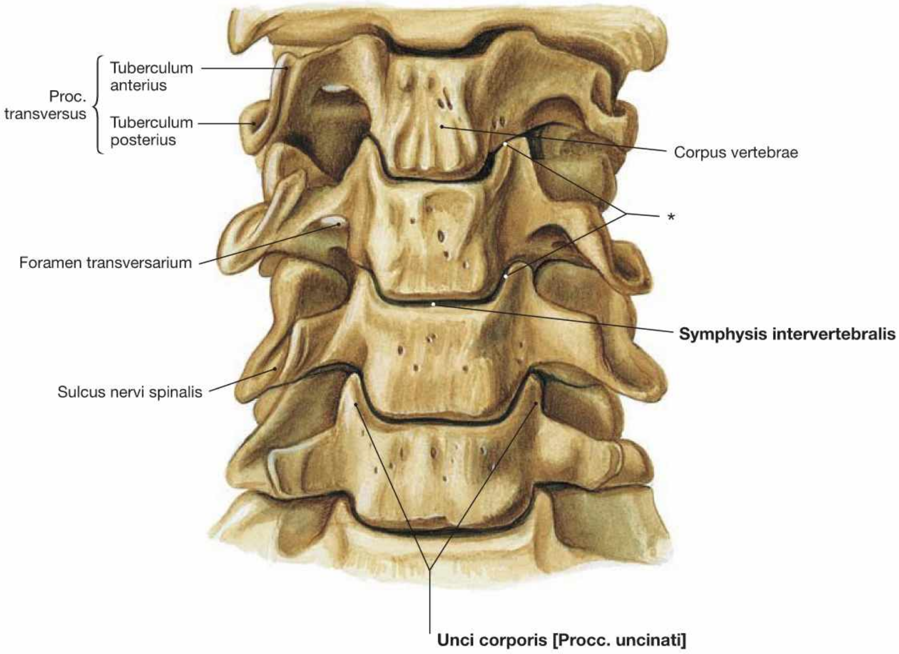


Fig. 2.24 2nd to 7th cervical vertebrae, Vertebrae cervicales II–VII; ventral view.
The 3rd to 6th cervical vertebrae have a typical structure, whereas the 1st, 2nd, and 7th cervical vertebrae deviate from this structure. The upper surfaces display a lip projecting upward at either side (Unci corporis). The Unci corporis are also named Procc. uncinati and articulate in the Articulatio (Hemiarthrosis) uncovertebralis with the lateral and caudal parts of the Corpus vertebrae of the above vertebra.

* so-called uncovertebral gaps

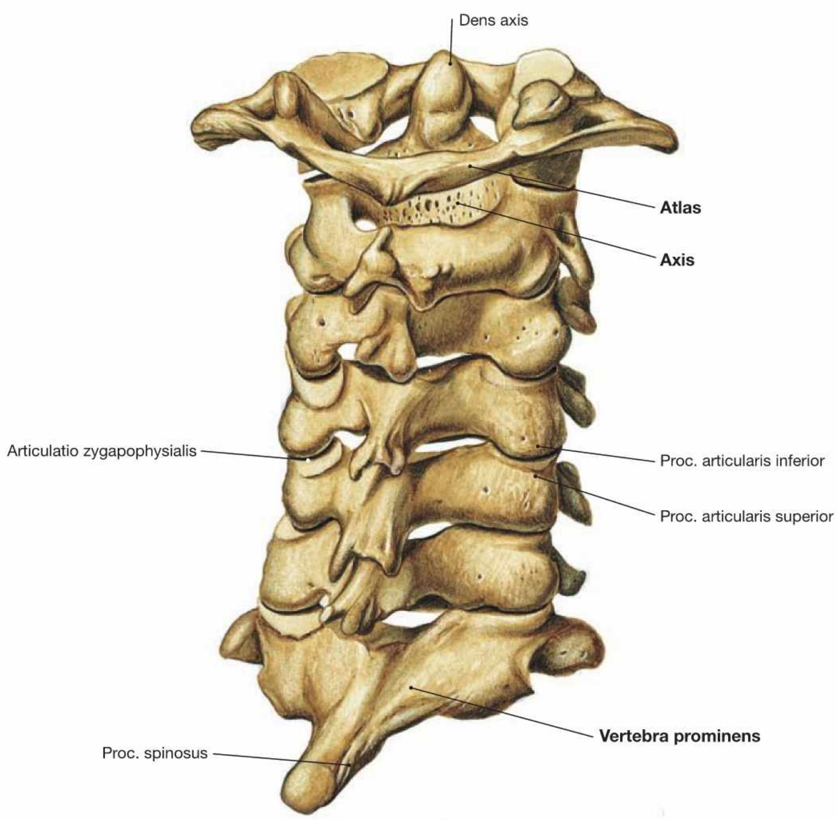
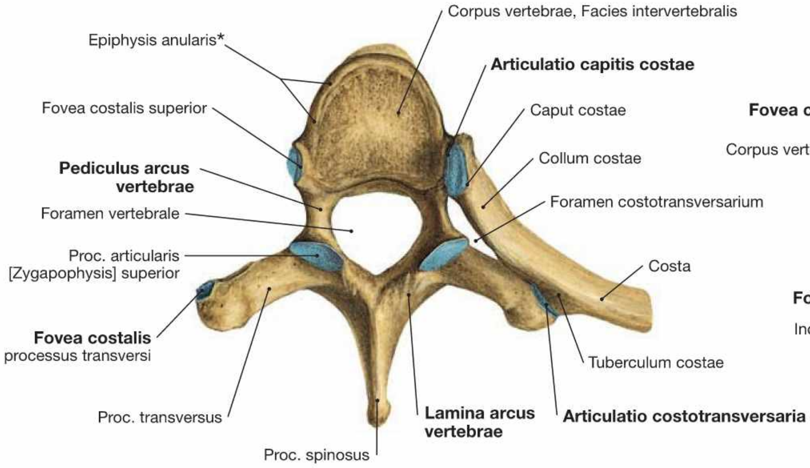


Fig. 2.25 1st to 7th cervical vertebrae, Vertebrae cervicales I–VII; lateral dorsal view.
The long and undivided spinous process of the 7th cervical vertebra can be easily palpated in the neck and is therefore also named Vertebra prominens. However, this cervical vertebra can be confused with the 1st thoracic vertebra which has an even more pronounced spinous process. The articular facets (Facies articularis superior or inferior) of a vertebral process (Proc. articularis superior or inferior) articulate with the corresponding partner in the Articulatio zygapophysialis.

Thoracic vertebrae



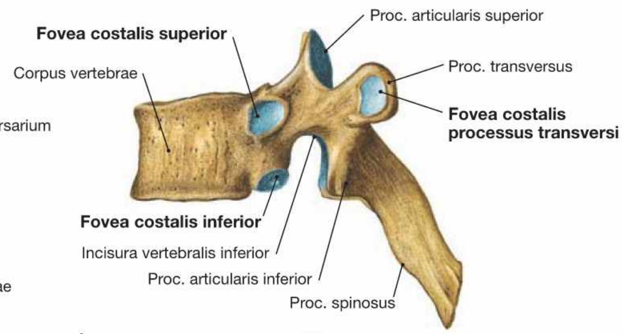
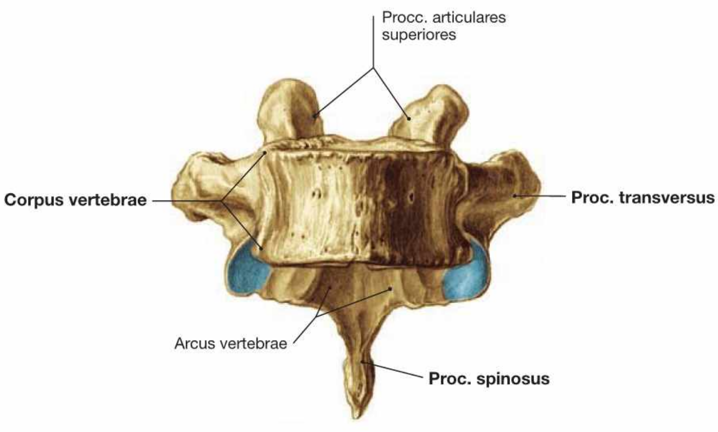


Fig. 2.26 Vertebra: example detailing the structure of the 5th thoracic vertebra; cranial view**.**
The vertebral arch (Arcus vertebrae) is divided in the Pediculus arcus vertebrae and the Lamina arcus vertebrae. Coming off the arch are bilaterally the Procc. transversi and dorsally the Proc. spinosus. Articular facets are located cranially and caudally and participate in the formation of the vertebral joints (zygapophyseal joints). The lateral cranial and caudal aspects of the vertebral body each possess a fovea for the articulation of the costal head (Fovae costales superior and inferior). In the Articulatio costotransversaria at the Proc. transversus, the Fovea costalis articulates with the facet of the Tuberculum costae of the corresponding rib.

* also: annular rim

Fig. 2.27 6th thoracic vertebra, Vertebra thoracica VI; view from the left side.
View of the articular facets for the costal heads (Foveae costales superior and inferior), the articular facets of the zygapophyseal joints positioned almost in the frontal plane (Procc. articulares superior and inferior), the facets (Foveae costales) for the articulation with the Tuberculum costae of the ribs, the Incisura vertebralis inferior and the Proc. spinosus pointing sharply downwards.



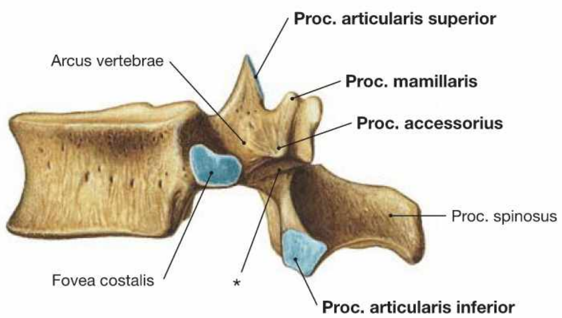


Fig. 2.28 10th thoracic vertebra, Vertebra thoracica X; ventral view onto the vertebral body with superior and inferior intervertebral surface.
The articular facets of the Procc. articulares extend beyond the vertebral body cranially and caudally.

Fig. 2.29 12th thoracic vertebra, Vertebra thoracica XII; view from the left side.
The 12th thoracic vertebra has a singular bilateral Fovea costalis and displays structural similarities to a lumbar vertebra: the inferior articular processes point laterally. In addition, this vertebra possesses Procc. mamillares and accessorii.

* area of the vertebral arch between the upper and lower articular process (so-called isthmus = interarticular portion)

Thoracic and lumbar vertebrae

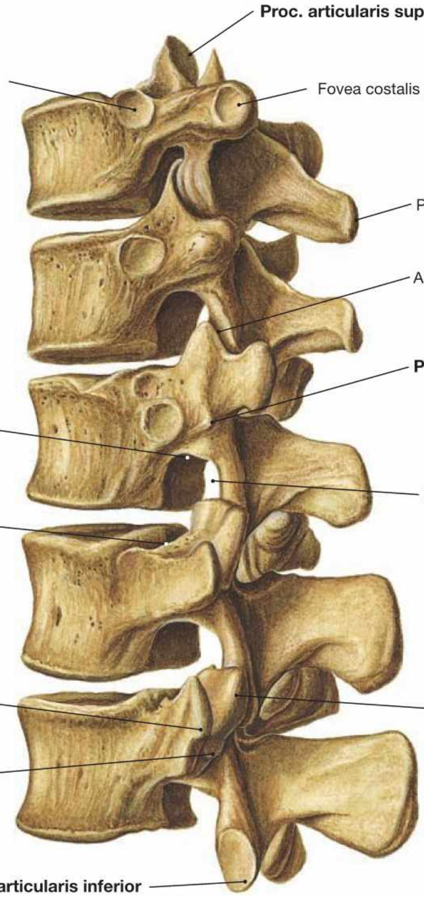


Fig. 2.30 10th to 12th thoracic vertebrae, Vertebrae thoracicae X–XII, and 1st to 2nd lumbar vertebrae, Vertebrae lumbales I–II; left dorsal view.

The lumbar vertebrae are larger and structurally more compact to withstand the increased compression forces imposed by the body weight. The Procc. spinosi are short, podgy, and point almost straight backward. The arches of the lumbar vertebrae are the origin of the Procc. costales (derived from the primordial ribs fused with the vertebrae), the variably large Procc. accessorii, the Procc. articulares superiores (supporting the upper articular facets, Facies articulares), the Procc. mamillares (remnants of the Proc. transversus), and the Procc. articulares inferiores with the lower articular facets (Facies articulares).

Clinical Remarks

- Posterolateral disc herniations or osteophytes caused by osteoarthritic-mediated degeneration of vertebral joints can lead to the **narrowing of the Foramen intervertebrale** and to compression of the spinal nerve roots with resulting deficits.
- **Lumbar ribs** can cause pain due to their close topographic relationship to the kidneys.
- **Cleavage of the lateral vertebral arch** causes separation of the Procc. articulares inferiores with the posterior part of the arch and the Proc. spinosus from the remainder of the vertebra (known as **spondylolysis**).
- The bony separation of the isthmus (→ Fig. 2.29) can cause vertebral slippage **(spondylolisthesis).**

Lumbar vertebrae

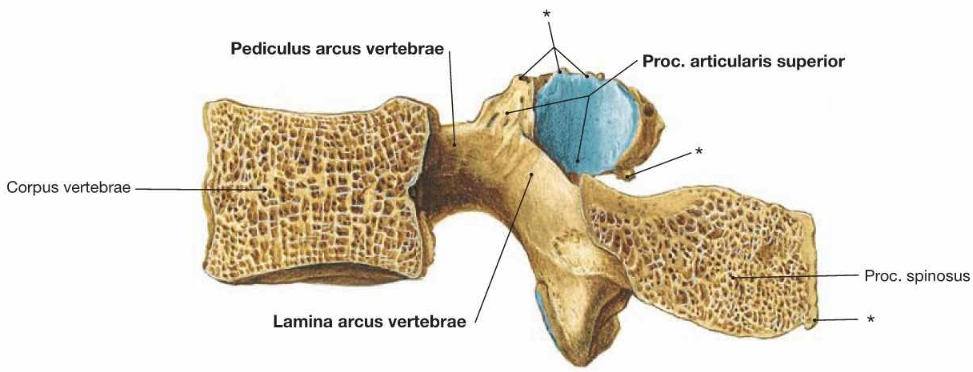
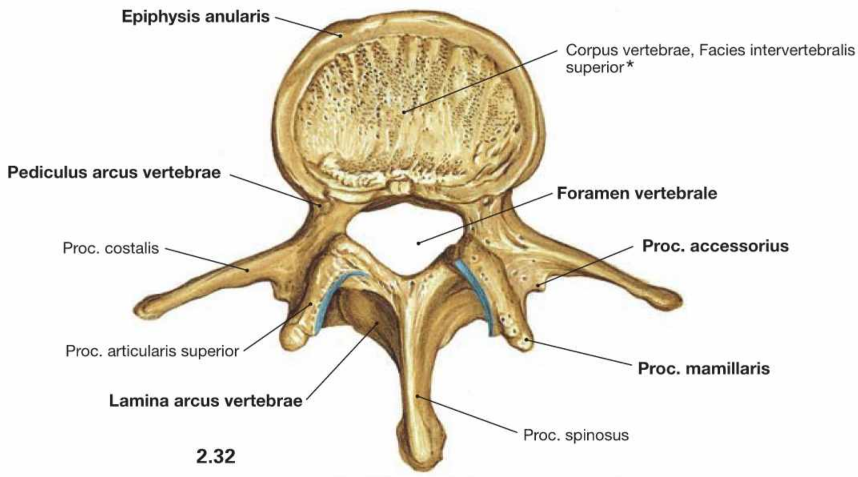


Fig. 2.31 3rd lumbar vertebra, Vertebra lumbalis III, of an elderly person; median section; view from the left side.
The articular facets of the Procc. articulares superiores are facing each other (that is the reason why they are not clearly visible from the side) and articulate with the inferior articular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

* ossification of ligamentous attachments



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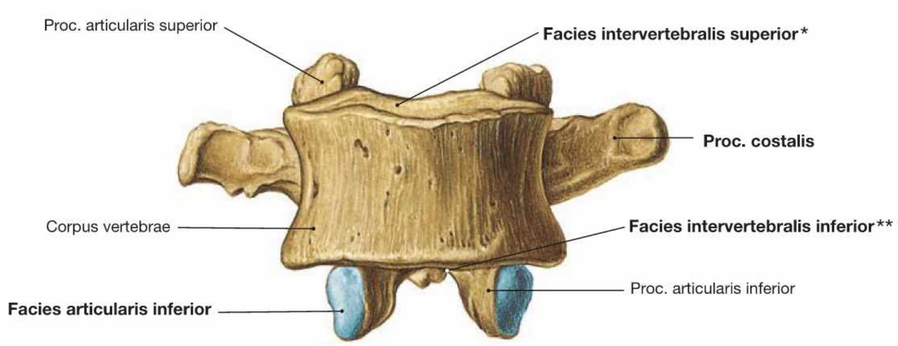
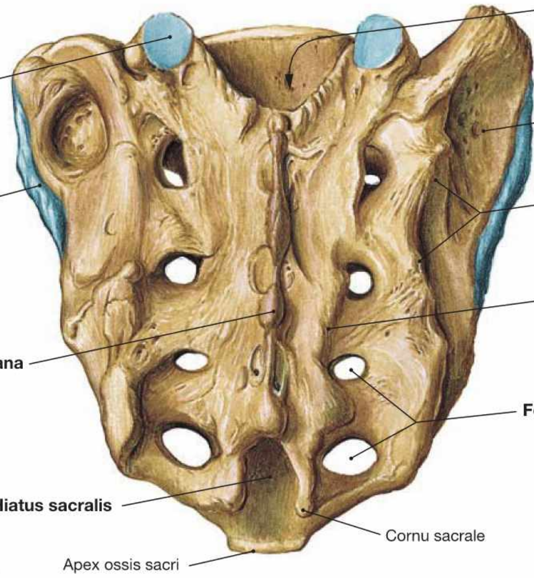


2.33

Fig. 2.32 and Fig. 2.33 4th lumbar vertebra, Vertebra lumbalis IV; cranial (→ Fig. 2.32) and ventral (→ Fig. 2.33) views**.**
The Pediculus arcus vertebrae is proportionally very large in comparison to the size of the lumbar vertebra. At the lateral aspect of the arch, the different processus are visible (Procc. costales, accessorii, mamillares, and articulares superiores and inferiores) and posterior the strong Proc. spinosus. When viewed from the ventral side, the lumbar vertebra has a massive body (Corpus vertebrae) with pronounced upper and lower intervertebral surfaces (Facies intervertebrales superior and inferior). The articular facets of the zygapophyseal joint extend beyond the cranial and caudal part of the vertebral body.

* also: superior vertebral end plate
** also: inferior vertebral end plate

Sacrum



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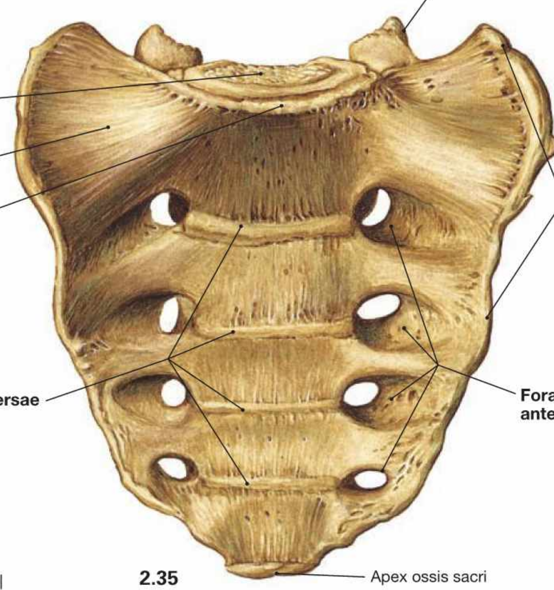
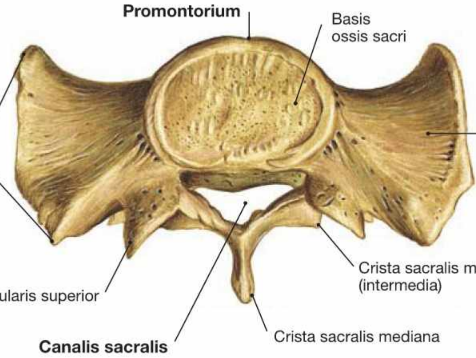


2.35

Figs. 2.34 to 2.36 Sacrum, Os sacrum; dorsal (→ Fig. 2.34), ventral (→ Fig. 2.35), and cranial (→ Fig. 2.36) views.

The dorsal surface **(Facies dorsalis)** displays five longitudinal crests of different intensity formed by the fusion of the corresponding vertebral processes. The **Crista sacralis mediana** results from the fusion of the Procc. spinosi, the **Crista sacralis medialis** corresponds to the fusion of the Procc. articulares, and the **Crista sacralis lateralis** represents the fusion of the rudimentary lateral processes. The Crista sacralis mediana terminates above the Hiatus sacralis which represents the caudal opening of the vertebral canal. In children, this opening is utilized for sacral anaesthesia.

The pelvic surface (**Facies pelvina**) displays the fused margins of the sacral vertebrae (Linae transversae) and the paired Foramina sacralia anteriora, where the branches of the spinal nerves exit. The Pars lateralis of the Os sacrum is located lateral to the Foramina sacralia anteriora. Visible from the top, the **Basis ossis sacri** is the contact surface for the intervertebral disc with the 5th lumbar vertebra. This intervertebral disc extends farthest into the pelvis and, together with the anterior rim of the Basis ossis sacri, is named the **Promontorium.** Lateral to the Basis ossi sacri, the Alae ossis sacri extend as cranial portion of the Partes laterales. Located posterior to the base is the triangular sacral canal and laterally thereof are the Procc. articulares superiores for articulation with the 5th lumbar vertebra.



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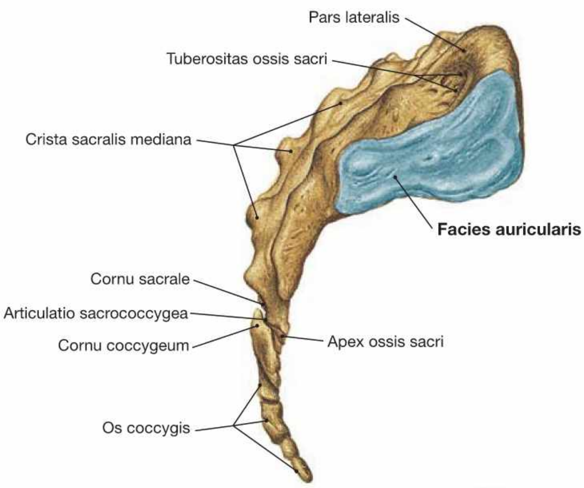


Fig. 2.37 Sacrum, Os sacrum; view from the right side.
The lateral view shows the Facies articularis, which is part of the joint with the Os coxae (Articulatio sacroiliaca). The Tuberositas ossis sacri is located at its dorsal aspect and serves as an insertion region for ligaments.

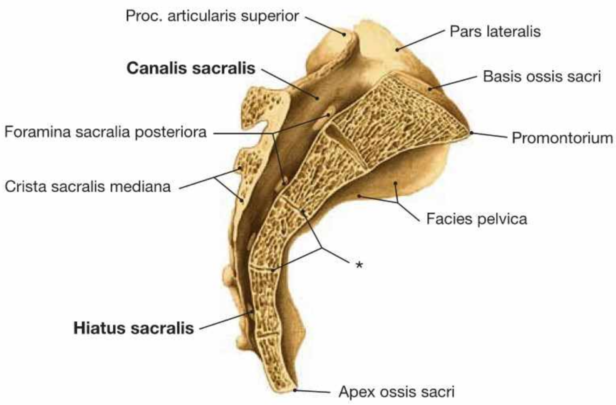


Fig. 2.38 Sacrum, Os sacrum; median section; view from the right side.
* In adults, remnants of the intervertebral discs can remain. In addition, incomplete fusions of sacral vertebrae are frequently found.

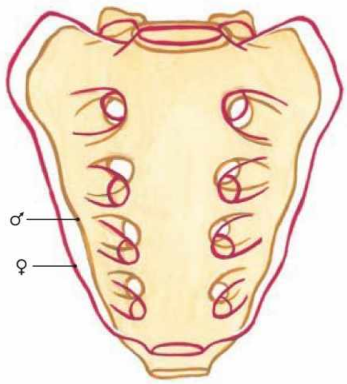


Fig. 2.39 Sacrum, Os sacrum; differences in sex.
Men have a slightly longer and narrower sacrum than women. The shape of the sacrum female contributes to the wider shape of the female pelvis which is advantageous during parturition.

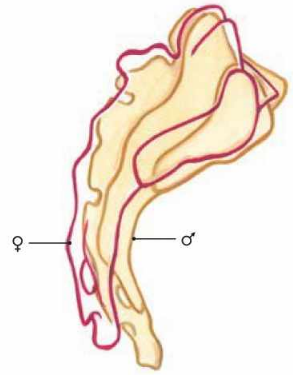


Fig. 2.40 Sacrum, Os sacrum; differences in sex.
The male sacrum is bent more than the female sacrum.

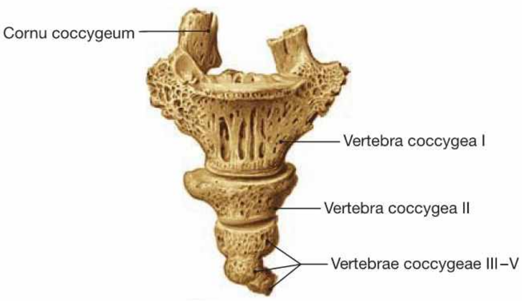


Fig. 2.41 Coccyx, Os coccygis; ventral cranial view.
The coccyx is formed from three to four vertebrae but can also be made up of five rudimentary vertebrae as is shown here. The coccyx is connected to the Os sacrum via the Cornua coccygea and the rudimentary vertebral body.

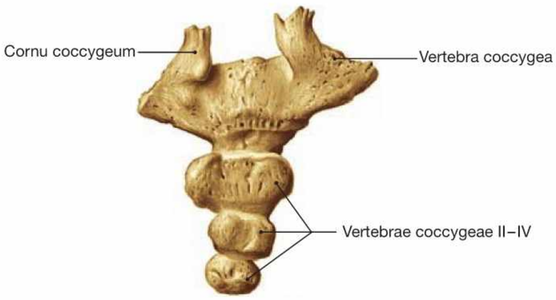
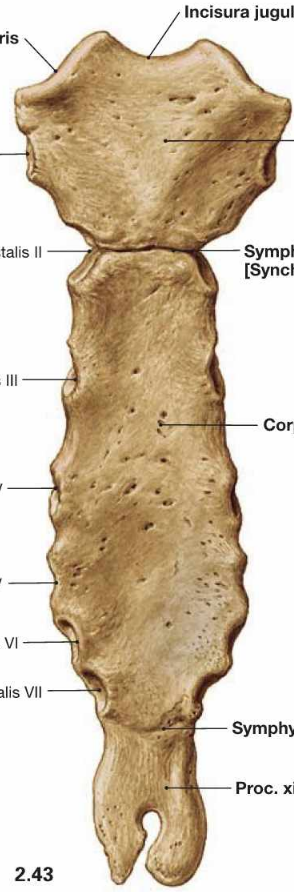


Fig. 2.42 Coccyx, Os coccygis; dorsal caudal view.
The size of the coccygeal vertebrae decreases from cranial to caudal. Of all coccygeal vertebrae, only the 1st coccygeal vertebra resembles a typical vertebral structure.

Sternum



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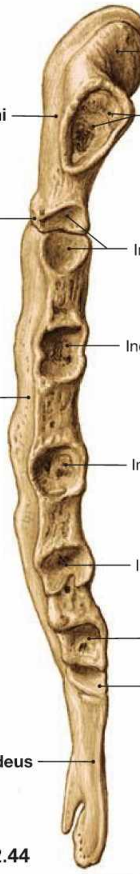


2.44

Fig. 2.43 and Fig. 2.44 Sternum; ventral (→ Fig. 2.43) and lateral (→ Fig. 2.44) views.
The Sternum is composed of the Manubrium and the Corpus sterni, and of the Proc. xiphoideus. Its upper end 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 sterni are connected by the **Symphysis [Synchondrosis] manubriosternalis,** whereas the Corpus sterni and Proc. xiphoideus articulate through the **Symphysis xiphosternalis.** The Proc. xiphoideus can be divided.

* angle of LUDWIG (LUDOVICUS)

Clinical Remarks

Bone marrow biopsies can be obtained from the sternum, the pelvis, and the iliac crest. The application of **sternal puncture** for diagnostic biopsy of bone marrow has become rare and has been replaced by iliac crest puncture. Sternal puncture serves to evaluate bone marrow cells in haematopoietic diseases. The puncture site is located in the median line of the Corpus sterni between the attachments of the ribs II and III. The region of the costosternal connections and the lower two-thirds of the Corpus sterni are **excluded from sternal puncture** due to possible presence of synchondroses and potential **Fissura sterni congenita** (opening in the sternum) as a result of incomplete fusion of the paired sternal bands. Needle puncture in these areas could lead to injury of the heart (⟶ p. 45).

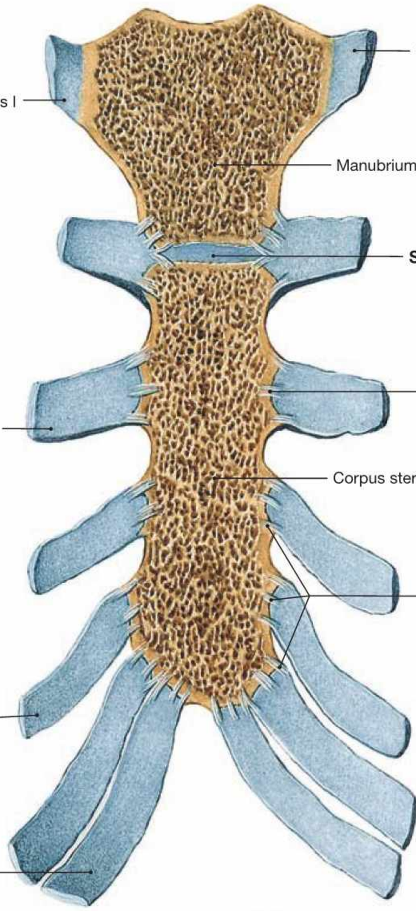


Fig. 2.45 Sternum and origin of cartilaginous parts of the ribs, Cartilagines costales; frontal section**.**
Only part of the costosternal insertions are true joints. Synchondroses are common (ribs I, VI and VII).

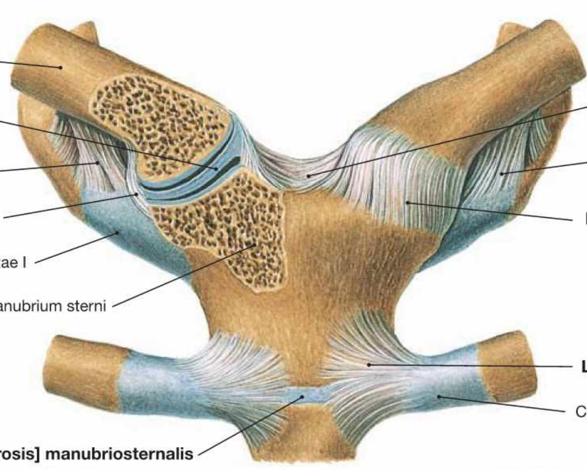
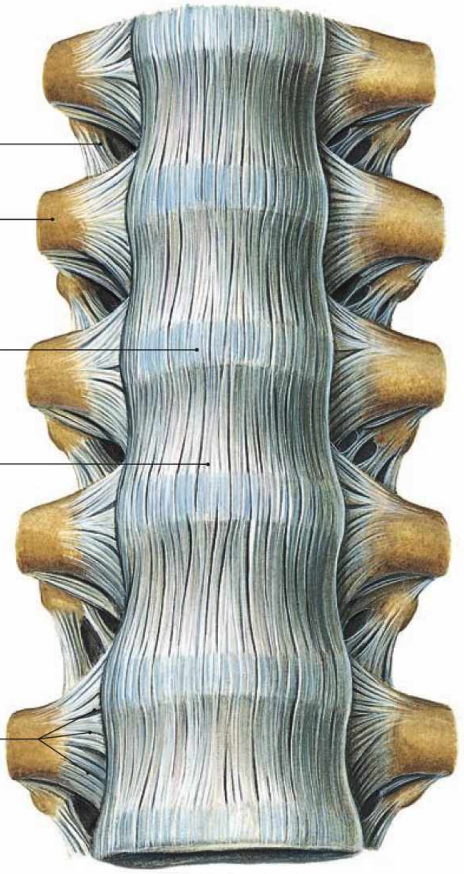


Fig. 2.46 Sternoclavicular joints, Articulationes sternoclaviculares; ventral view; right frontal section through the joint**.**
The sternoclavicular joint is a functional **ball and socket joint** with three degrees of freedom in movement. It contains a **Discus articularis** of fibrous cartilage, dividing 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 during different joint positions. Because the discus is able to absorb high shear forces, the articular facets can be kept small. The Ligg. sternoclavicularia anterius and posterius, interclaviculare and costoclaviculare strengthen the joint capsule.

Ligaments of the vertebral column



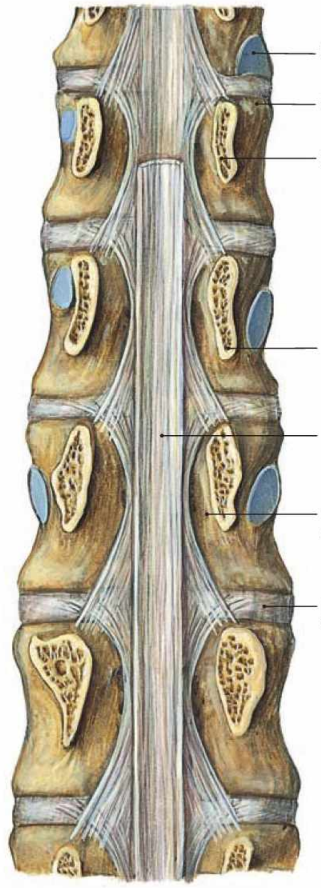


Fig. 2.47 Ligaments of the vertebral column using the example of the lower thoracic vertebral column; ventral view.
The anterior longitudinal ligament **(Lig. longitudinale anterius)** ranges from the Tuberculum anterius of the Atlas to the Os sacrum. It is fixed to the anterior surface of the vertebral bodies and to the intervertebral discs (Disci intervertebrales). This ligament increases the stability of the vertebral column during **extension.**

Fig. 2.48 Ligaments of the vertebral column using the example of the lower thoracic and upper lumbar vertebral column; dorsal view.
The posterior longitudinal ligament **(Lig. longitudinale posterius)** is a continuation of the Membrana tectoria and extends to the Canalis sacralis. It is fixed to the intervertebral discs and the rims of the intervertebral surfaces and secures the intervertebral discs (Disci intervertebrales). This ligament increases the stability of the vertebral column during **flexion.**

Ligaments of the vertebral column

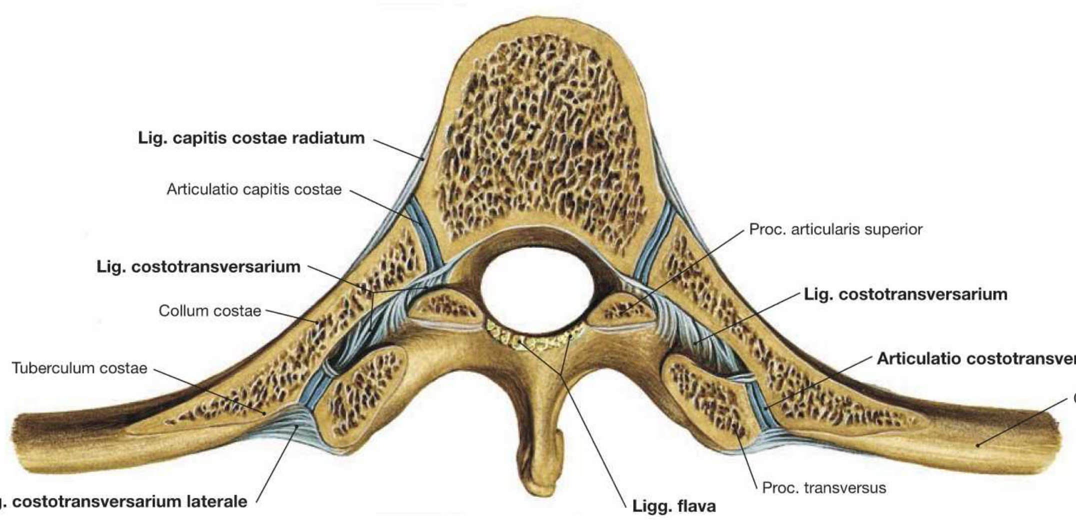


Fig. 2.49 Costovertebral joints, Articulationes costovertebrales; transverse section through the lower part of the costovertebral joint; cranial view.
The costal heads articulate with the thoracic vertebra/vertebrae in the **Articulatio capitis costae**. With the exception of the ribs I, XI and XII, this is a two-chambered joint (dithalamic joint). Each costal head articulates with the upper and lower rim of two adjacent vertebrae and, through a ligament (Lig. capitis costae intraarticulare; not visible), the intervertebral disc is fixed to the Crista capitis costae. In addition, the rib articulates with the Proc. transversus of the cranial vertebra in the **Articulatio costotransversaria** (exception are ribs XI and XII). This involves the Facies articularis tuberculi costae of the rib and the Fovea costalis processus transversi of the vertebral transverse process. The weak joint capsules are strengthened by different ligaments (→ Fig. 2.50).

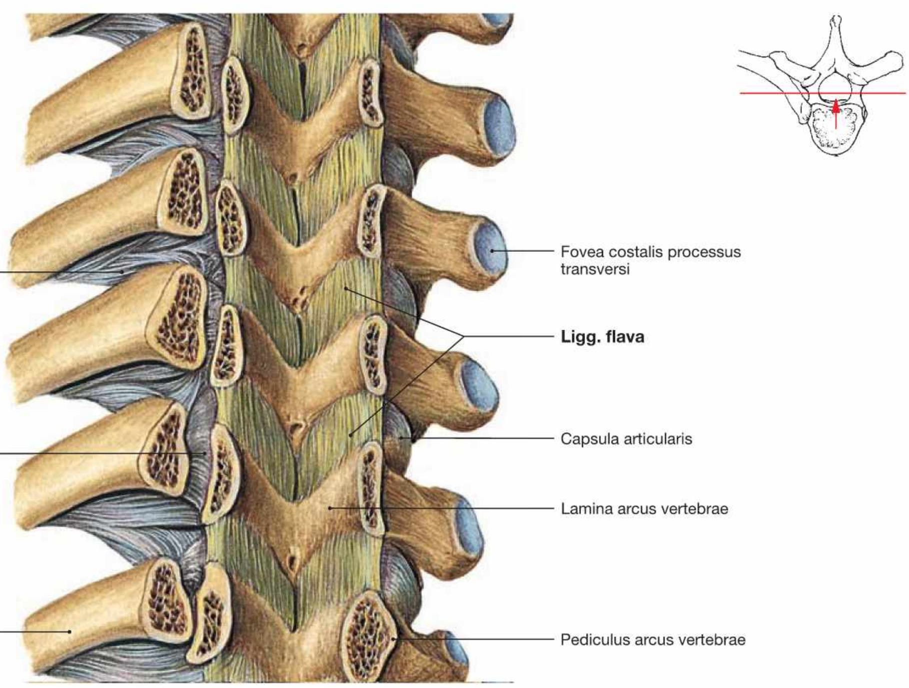


Fig. 2.50 Connections of the vertebral arches; ventral view.
In between the vertebral arches stretch the segmental **Ligg. flava** (yellow colour results from the high content of elastic fibres oriented perpendicular to each other). They form the dorsal demarcation of the Foramina intervertebralia. The Ligg. flava are always under tension and support the muscles of the back when erecting the vertebral column from all flexed positions.

Ligaments of the vertebral column

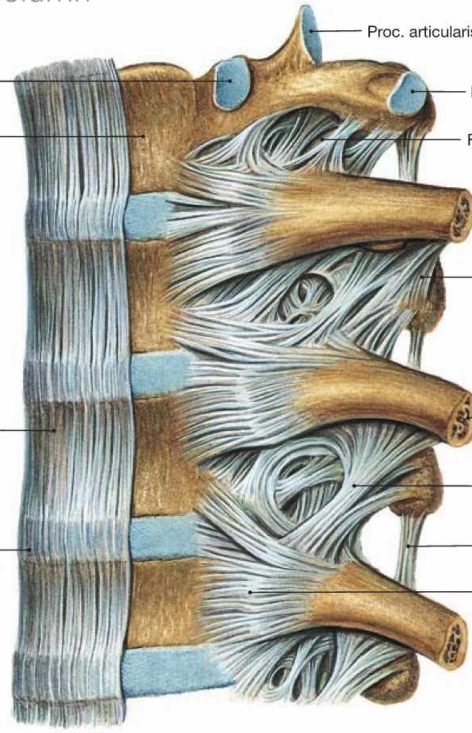


Fig. 2.51 Ligaments of the vertebral column and the costovertebral joints, Articulationes costovertebrales; view from the left side; lateral parts of the anterior longitudinal ligament removed.
The joint capsules of the Articulationes capitis costae are strengthened by the Ligg. capitis costae radiata; the joint capsules of the Articulationes costotransversariae are supported by the Ligg. costotransversaria (Lig. costotransversarium laterale and Lig. costotransversarium superius).

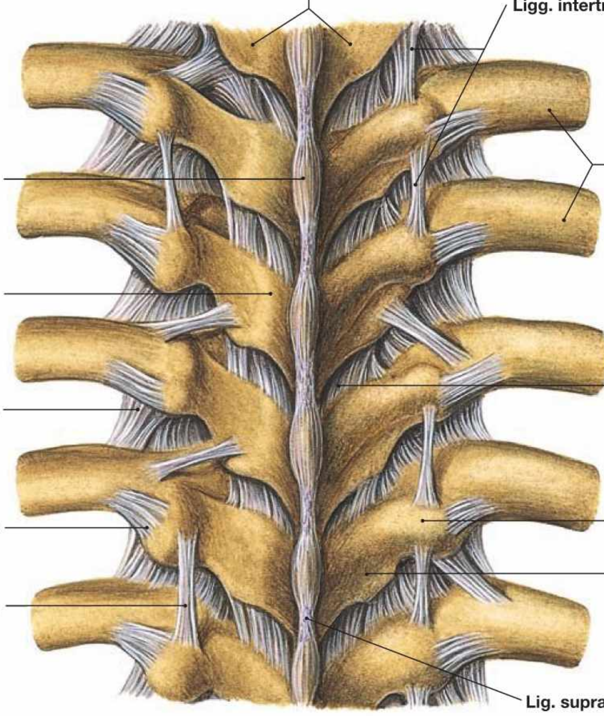


Fig. 2.52 Ligaments of the vertebral column and the costovertebral joints, Articulationes costovertebrales; dorsal view.
The dorsal part of the joint capsules of the Articulationes transversariae is strengthened by the Ligg. costotransversaria laterales and superiora. The Ligg. intertransversaria guarantee additional stability.

* The Lig. supraspinale is the median part of the Fascia thoracolumbalis.

Motion segment

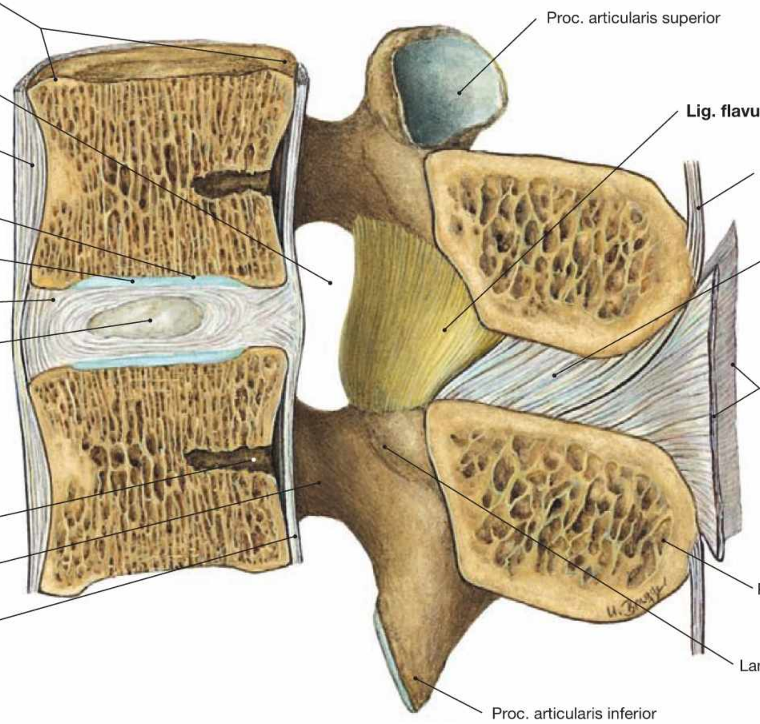


Fig. 2.53 Lumbar motion element; median section; view from the left side.
The intervertebral disc (Discus intervertebralis) is composed of a central gelatinous nucleus (Nucleus pulposus), a remnant of the Chorda dorsalis, and a ligamentous ring (Anulus fibrosus), which surrounds the Nucleus pulposus. The Anulus fibrosus is the non-ossified remnant of the epiphysis of the vertebral body (*). Its main attachment is to the Corpus vertebrae at the bony rim and the hyaline cartilaginous lining (**) of the intervertebral surface and the Lig. longitudinale posterius. Additional, although weaker, fixation is provided by the Lig. longitudinale anterius. A Discus intervertebralis acting as Symphysis intervertebralis connects two neighbouring vertebrae. The Ligg. flava interspinale and supraspinale provide the connection between the vertebral arches. In the thoracolumbar region, the Lig. interspinale projects into the Fascia thoracolumbalis.

* annular rim
** hyaline cartilaginous lining of the intervertebral surface

Clinical Remarks

The inherited (HLA-B27 positive) ankylosing spondylitis **(BEKHTEREV's disease)** involves a progressive ossification of the Anulus fibrosus of the intervertebral discs, the vertebral joints, the Ligg. capitum costarum radiata and costotransversaria and Ligg. longitudinale anterius and interspinalia. In the early stages, in most cases only the sacro-iliac joints are affected. Despite the limitation in flexing motions, the outline of the back seems normal initially. However, progression of the disease coincides with the back becoming flattened like a board. In addition, there is a significant restriction of chest wall excursions along with restrictions in respiratory capacity.

Cervico-occipital joints

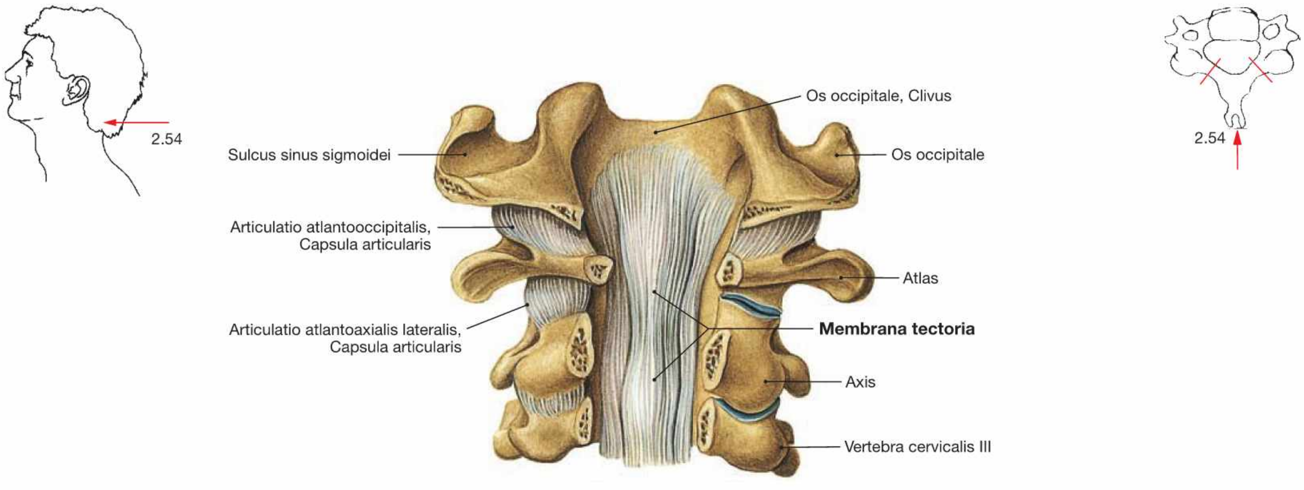


Fig. 2.54 Cervico-occipital joints with deep ligaments; dorsal view.
The **Membrana tectoria** is the cranial extension of the **Lig. longitudinale posterius** and covers the ligaments and the joint capsule of the Articulatio atlanto-axialis mediana (not visible). Lateral between Os occipitale and Atlas the joint capsule of the Articulatio atlantooccipitalis and between Atlas and Axis the joint capsule of the Articulatio atlanto-axialis lateralis are visible.

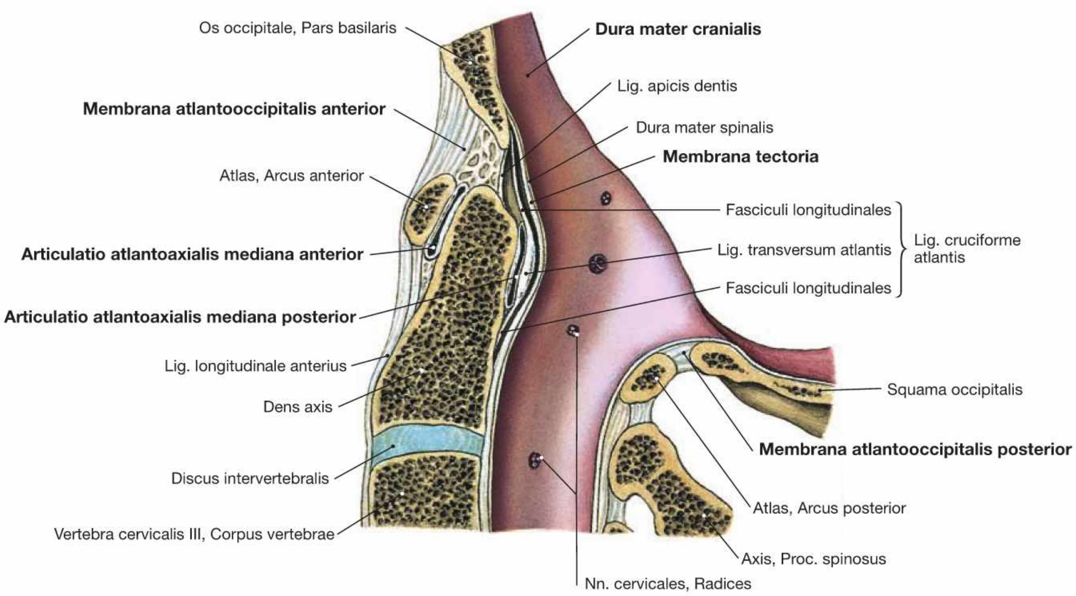


Fig. 2.55 Cervico-occipital transitional region with intermediate atlanto-axial joint and corresponding ligaments; sagittal section through the median plane; view from the left side.
A section through the articular connection between Dens axis and anterior arch of the Atlas is shown. This is part of the so-called lower head joint composed of the Articulationes atlantoaxiales laterales and the Articulatio atlantoaxialis mediana as opposed to the upper head joint which consists of the Articulationes atlantooccipitales. Above and below the Atlas, the joint capsule receives support through the **Membrana atlantooccipitalis anterior** and the upper part of the Lig. longitudinale superius, respectively. On the posterior side of the dens, the joint capsule is strengthened by the Fasciculi longitudinales and the Lig. transversum atlantis (jointly named **Lig. cruciforme atlantis**) as well as the **Membrana tectoria** which covers the Lig. cruciforme atlantis. The Membrana tectoria is covered by the Dura mater spinalis. The **Membrana atlantooccipitalis posterior** extends between the Os occipitale and Atlas at the dorsal aspect of the vertebral canal.

Cervico-occipital joints

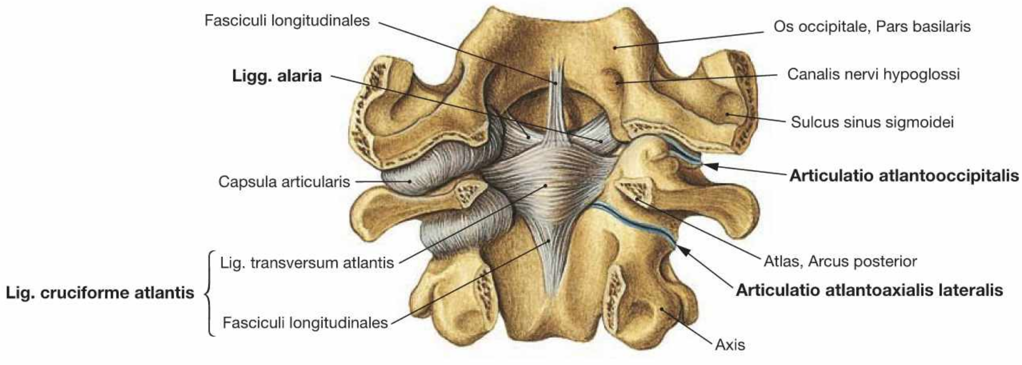
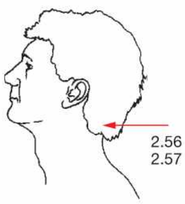
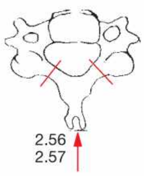


Fig. 2.56 Cervico-ocipital joints with deep ligaments; dorsal view; after removal of the Membrana tectoria.

Centrally located is the **Lig. cruciforme atlantis** composed of the Lig. transversum atlantis and the two Fasciculi longitudinales. Behind this ligament the **Ligg. alaria** (winged ligaments) are located which originate from the tip and the lateral surface of the Dens axis (→ Fig. 2.57); they project upwards in an oblique angle. On the left side, the joint capsule of the Articulatio atlantooccipitalis and the Articulatio atlantoaxialis are shown. On the right side, the joint capsules have been removed and the joint cavity is visible.





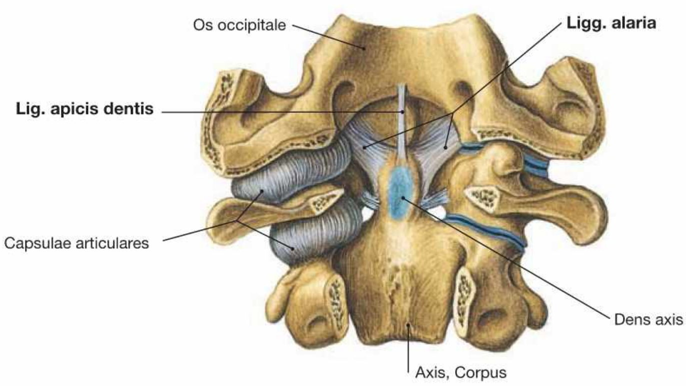


Fig. 2.57 Cervico-occipital joints with deep ligaments; dorsal view; after removal of the Membrana tectoria and Lig. cruciatum atlantis.

One can see the Ligg. alaria (→ Fig. 2.56) which frequently project to the Massae laterales of the Atlas and the thin **Lig. apicis dentis.**

Clinical Remarks

Rupture of the Lig. transversum atlantis and/or the Lig. cruciforme atlantis can lead to the dislocation of the Dens axis into the vertebral canal and, thus, into the Medulla oblongata. This will result in spinal cord contusion or transsection of the structures **(broken neck).** The nerve centres for respiration and blood circulation are destroyed, which will result in immediate death. Occasionally, a missing Dens axis or incomplete formation of the odontoid may cause an **atlanto-axial subluxation.**

Cervico-occipital joints

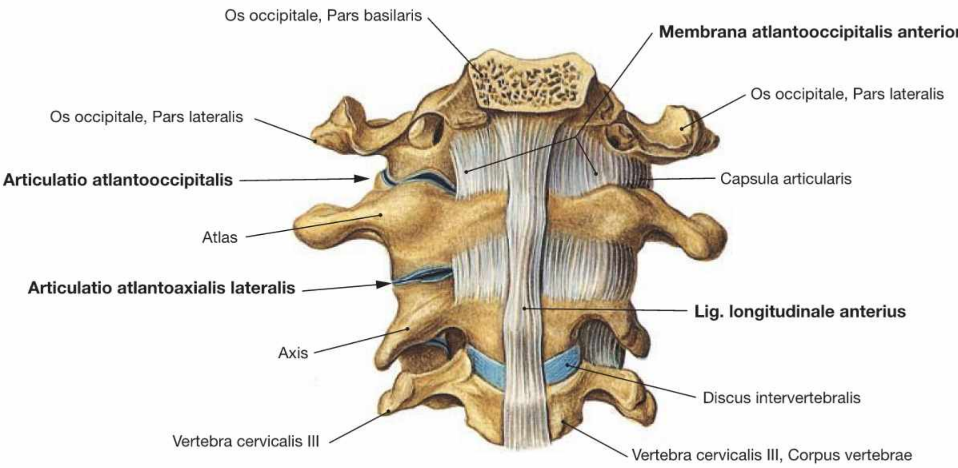


Fig. 2.58 Cervico-occipital joints with ligaments and upper cervical vertebral column; ventral view.
The **Lig. longitudinale anterius** is located in the midline. The **Membrana atlantooccipitalis anterior** extends from the occipital bone to the Atlas. The joint capsule of the Articulatio atlantooccipitalis is shown on the ride side and removed on the contralateral side.

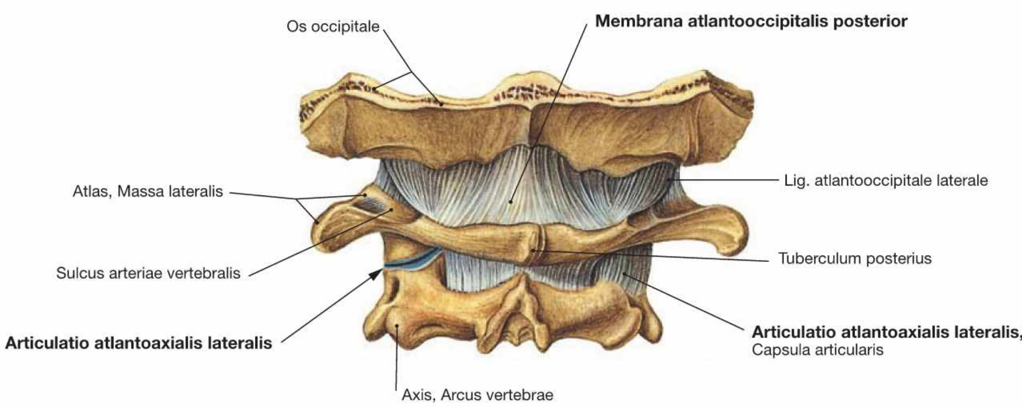
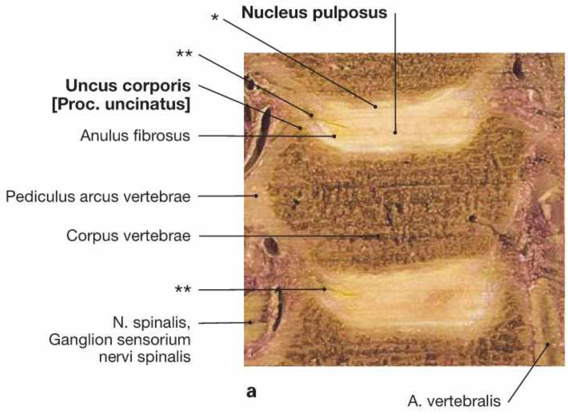
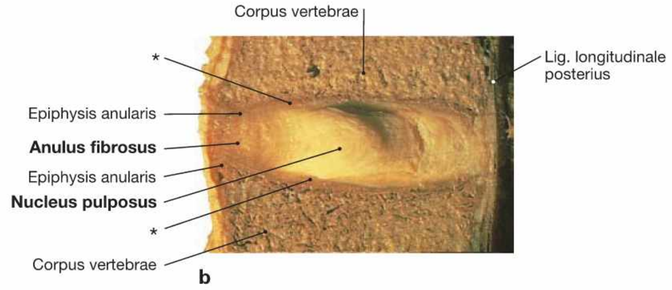


Fig. 2.59 Cervico-occipital joints; dorsal view.
Dorsal view onto the Membrana atlantooccipitalis posterior and the Lig. atlantooccipitale laterale between the Os occipitale and the Arcus posterior atlantis. The joint capsule of the Articulatio atlantoaxialis lateralis between Atlas and Axis is shown on the ride side and removed on the contralateral side.





Figs. 2.60a and b Intervertebral discs, Disci intervertebrales.

a Cervical intervertebral discs, Disci intervertebrales cervicales; frontal section; ventral view.

In the lateral areas of the cervical intervertebral discs so-called uncovertebral gaps (**) start forming already during the first decade of life. Between 5 to 10 years of age, the gaps become manifest and assume a joint-like character, hence their name uncovertebral joints. While providing increased flexibility of the cervical vertebral column at a younger age, later on these uncovertebral joints may rupture completely and, thus, can impact negatively on neck mobility (→ Clinical Remarks).

b Lumbar intervertebral disc, Discus intervertebralis lumbalis; median section (→ Fig. 2.53); view from the left.

* hyaline cartilaginous lining of the intervertebral surface as part of the non-ossified portion of the vertebral epiphyses

** so-called uncovertebral gap

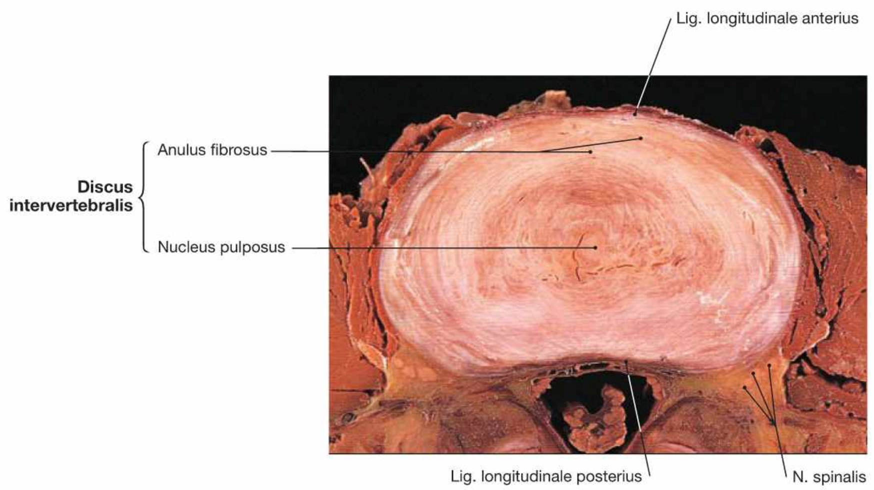


Fig. 2.61 Lumbar intervertebral disc, Discus intervertebralis lumbalis; cranial view.

The intervertebral disc (Discus intervertebralis) is composed of a central jelly-like nucleus (Nucleus pulposus), a remnant of the Chorda dorsalis, and a fibrous ring (Anulus fibrosus) surrounding the Nucleus pulposus.

Clinical Remarks

Degenerative alterations of the intervertebral disc occur most frequently in the lumbar and the cervical regions of the vertebral column. This can result in disc protrusion or disc prolapse (**slipped disc,** herniated Nucleus pulposus). The disc tissue shifts usually to the posterior and lateral side, rarely posteromedially, into the vertebral canal resulting in compression of the spinal nerve roots **(spinal radicular syndrome).** Most often, the segments S1, L5 and L4 are affected. In the cervical vertebral column, a slipped disc may occur upon rupture of the Discus intervertebralis, emanating from the uncovertebral gaps.

Cervical region of the vertebral column, radiography

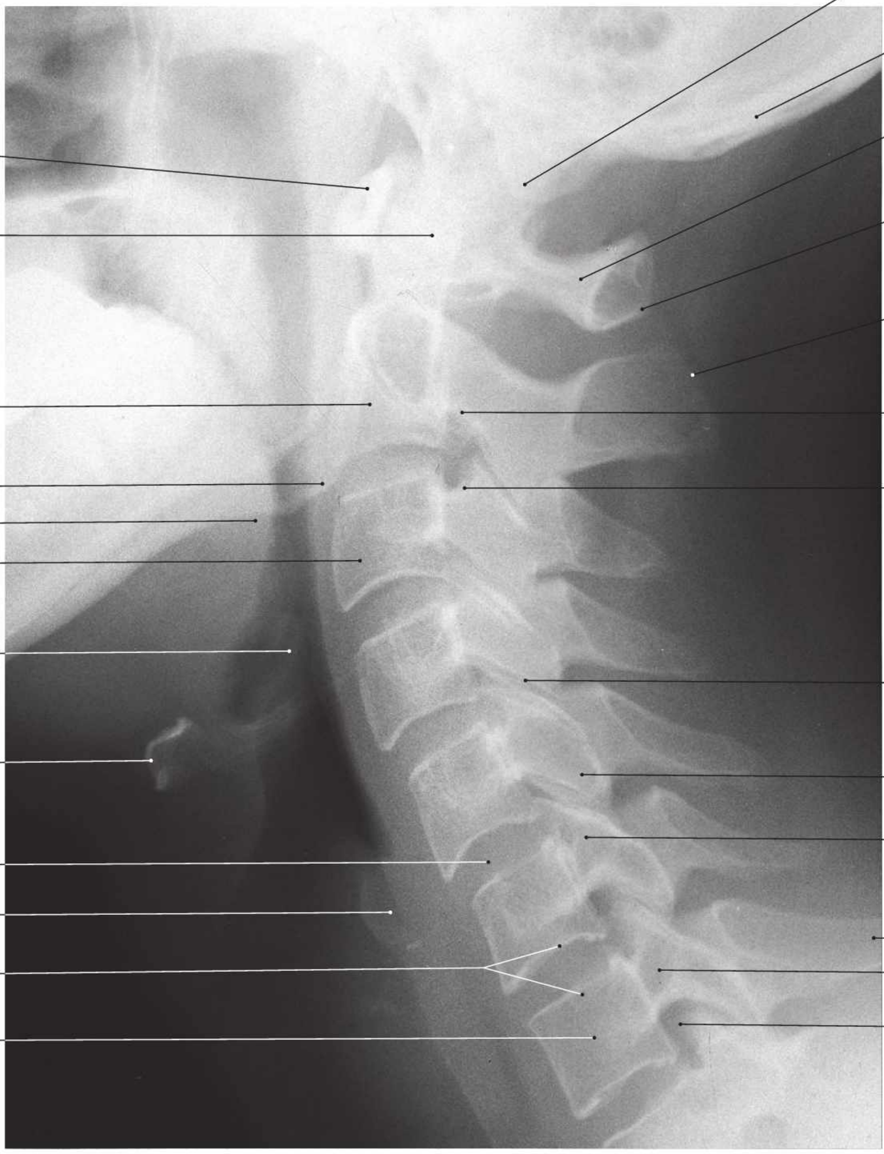


Fig. 2.62 Cervical vertebrae, Vertebrae cervicales; lateral radiograph of the cervical part of the vertebral column; upright position; the central beam is directed onto the 3rd cervical vertebra; shoulders are pulled downwards.

Clinical Remarks

Kyphosis is defined as a vertebral column curved dorsally convex. In the thoracic vertebral column, this slight curvature is physiological, however, in the cervical and lumbar vertebral column it is always pathologic. A pronounced kyphosis leads to hump formation (gibbus) and is present in various forms (e.g. in early childhood as **humpback;** in adolescence as juvenile or **adolescent kyphosis** [SCHEUERMANN's disease]; in adults through loss of elasticity and disc degeneration as **senile kyphosis**). Congenital kyphosis usually results from hemi- or fused vertebrae. A strong non-physiological lordosis is called **hyperlordosis** and occurs particularly in the lumbar vertebral column.

Thoracic region of the vertebral column, radiography

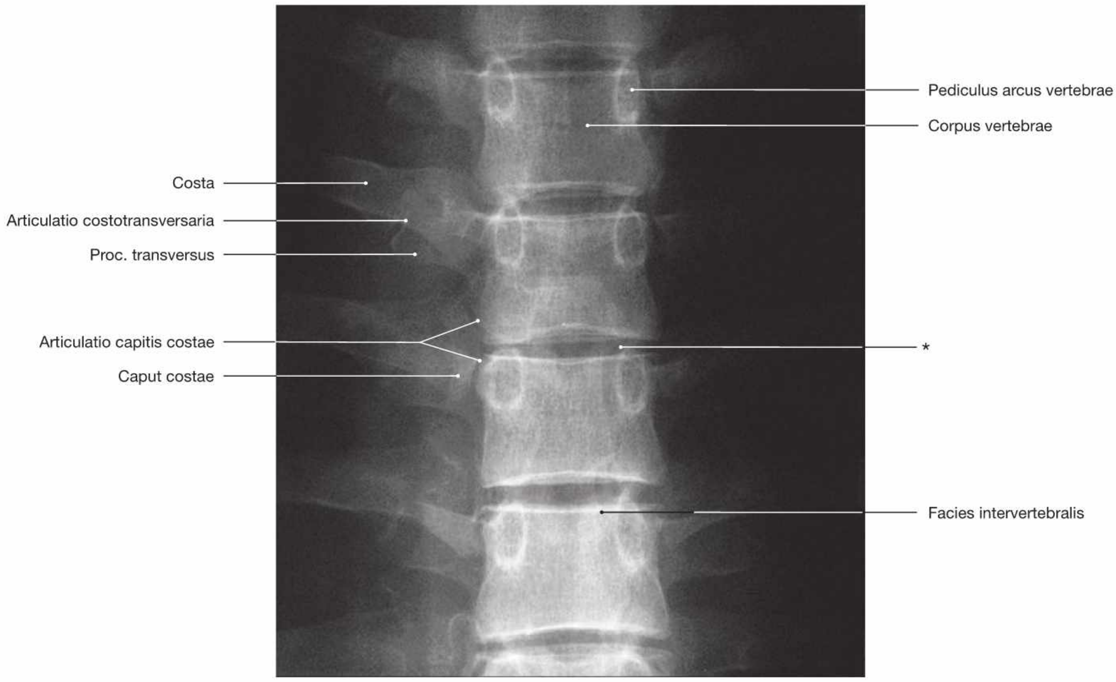


Fig. 2.63 Thoracic vertebrae, Vertebrae thoracicae; anterior-posterior (AP) radiograph of the thoracic part of the vertebral column; upright position with Thorax in inspiration; central beam is directed onto the 6th thoracic vertebra.

* intervertebral disc space

Clinical Remarks

Due to the dense capillary network within a vertebra, the vertebral column is frequently a **location for metastases** of malignant tumours. The normal bone matrix of affected vertebrae is destroyed and the mechanical bone properties have vanished. Therefore, even minor strain leads to collapse of vertebrae. Often vertebral fragments enter the vertebral canal or the intervertebral foramina and result in injuries and compression of the spinal cord and the spinal nerves.

Lumbar region of the vertebral column, radiography

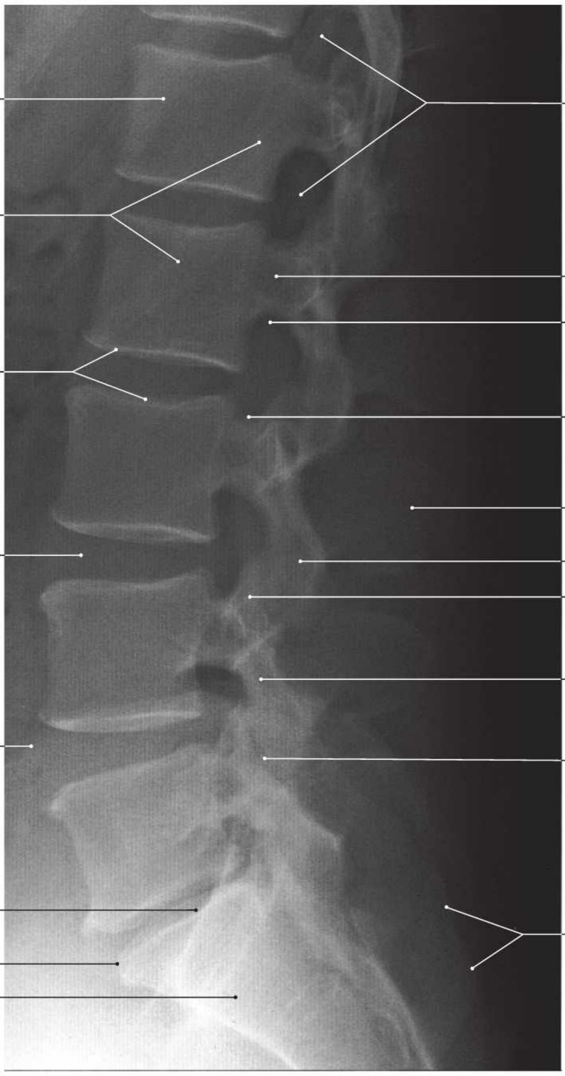


Fig. 2.64 Lumbar vertebrae, Vertebrae lumbales; lateral radiograph of the lumbar part of the vertebral column; upright position; central beam is directed onto the 2nd lumbar vertebra. The anterior edges of the lower lumbar vertebrae are oblique as an initial sign of degenerative changes and pathological alterations.

* intervertebral disc space
** region of the vertebral arch between the superior and inferior articular processes (isthmus = interarticular portion)
*** The terminal points indicate the position of the XII. rib, which is poorly visible in this copy of the radiograph.

Clinical Remarks

Osteoporosis is a metabolic bone disease (osteopathy) which is characterized by localized or universal reduction of bone tissue without changing the external shape of the bone. The etiology is mostly unknown. This condition mostly affects women over 55 and men over 70 years of age. Genetic predisposition, low physical activity, malnutrition, and unfavourable estrogen 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.

Lumbar region of the vertebral column, radiography

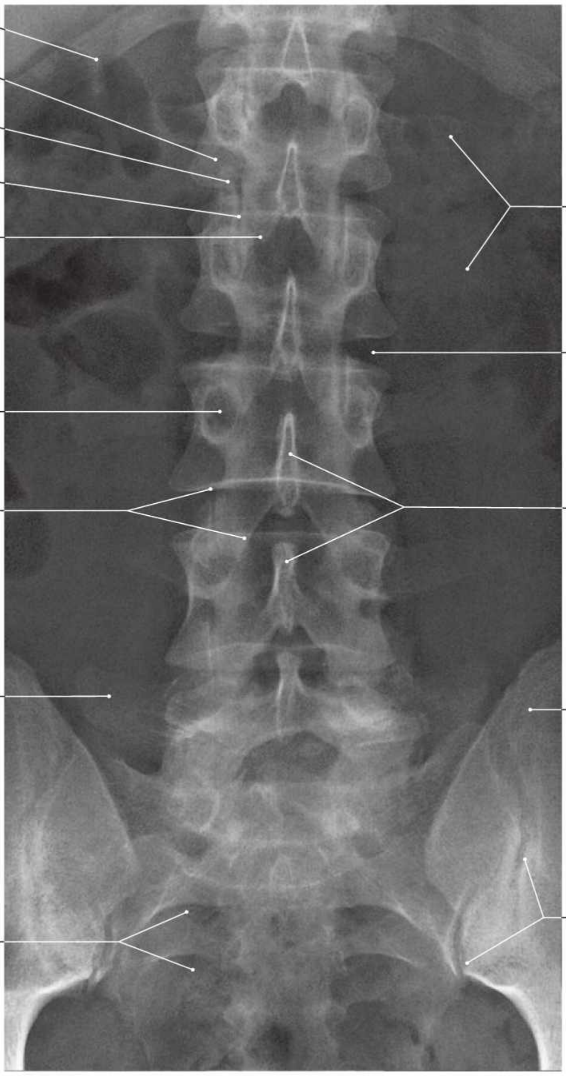


Fig. 2.65 Lumbar vertebrae, Vertebrae lumbales, and sacrum, **Os sacrum;** AP-radiograph of the lumbar part of the vertebral column and sacrum; upright position; central beam is directed onto the 2nd lumbar vertebra.

* intervertebral disc space

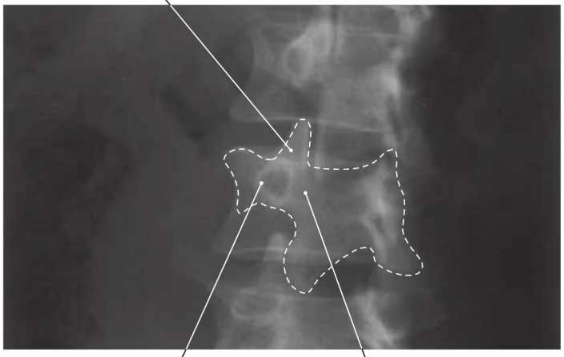


Fig. 2.66 Lumbar vertebrae, Vertebrae lumbales; radiograph with beam in an oblique angle; upright position. [8]
The experienced radiologist can recognize a dog-like figure ("Scotty dog", dotted lines) in this oblique radiograph image. The central part represents the interarticular portion. The clinical term refers to the superior and inferior articular facets of the zygapophyseal joints (→ Fig. 2.29).

* interarticular portion

Clinical Remarks

Fractures in the region of the interarticular portion (isthmus) lead to a change in the Scotty dog figure, such as dog collar, caused by a zone of lysis. Mostly as a result of sport injuries, damage occurs particularly to the Pars interarticularis at the level of L4 and L5 (isthmus). In the absence of a fracture of the ventral Pars interarticularis, the cranial vertebra shifts over the caudal vertebra as a result of congenital or degenerative changes of the position of the articular facet. All the above-mentioned conditions (including a fracture of the Pars interarticularis) are termed **spondylolisthesis** (vertebral slippage).

Vertebral column, CT

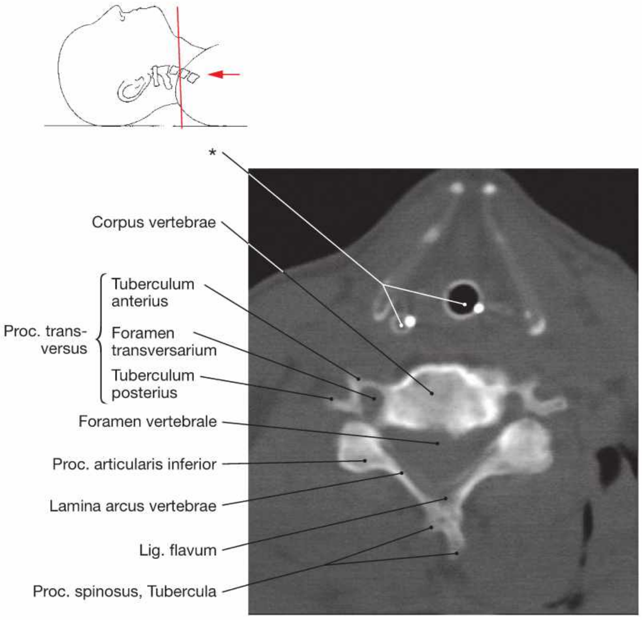


Fig. 2.67 Cervical part of the vertebral column; computed tomographic (CT) cross-section at the level of the intervertebral disc between the 4th and 5th cervical vertebrae.

* endotracheal tube and endoscopic instrument

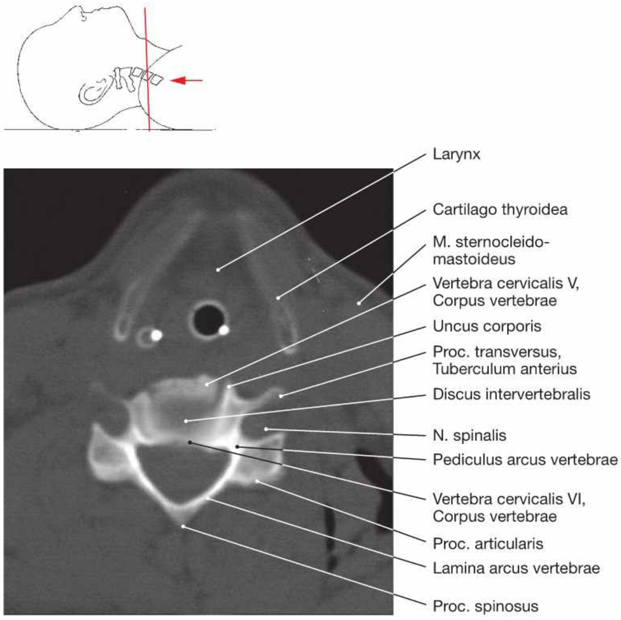


Fig. 2.68 Cervical part of the vertebral column; computed tomographic (CT) cross-section at the level of the 5th cervical vertebra.

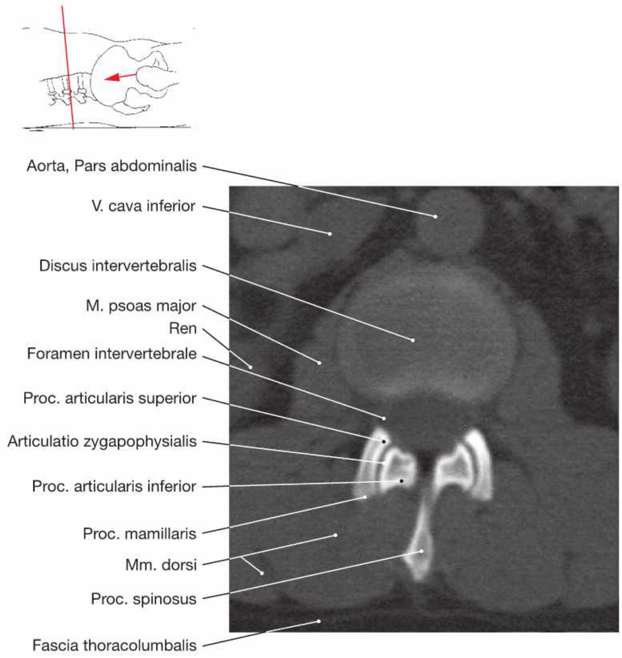


Fig. 2.69 Lumbar part of the vertebral column; computed tomographic (CT) cross-section at the level of the 2nd and 3rd lumbar vertebrae.

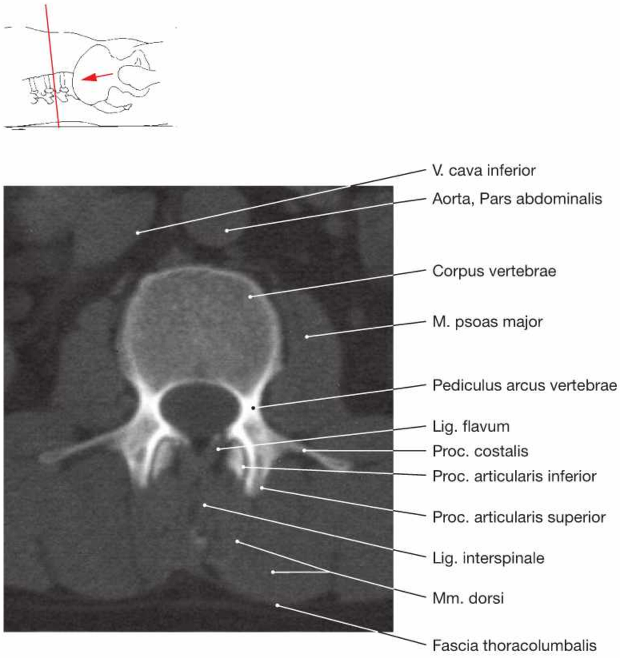


Fig. 2.70 Lumbar part of the vertebral column; computed tomographic (CT) cross-section at the level of the pediculi of the 3rd lumbar vertebra.

Clinical Remarks

Some genetic diseases are associated with differences in vertebrae count. The **KLIPPEL-FEIL syndrome** is a hereditary disorder of the cervical spine with spinal fusion (generally of atlas and axis or of the 5th and 6th cervical vertebrae) during the early embryonic stage. Characteristic features are a decreased neck length and often a congenital elevation of scapula due to spinal fusion. Spina bifida, lower placement of ears, and abnormalities of heart and other organs accompany this disease.
A vertebra that emerges from only one side of the associated sclerotome is termed a **hemivertebra.**

Vertebral column, MRI

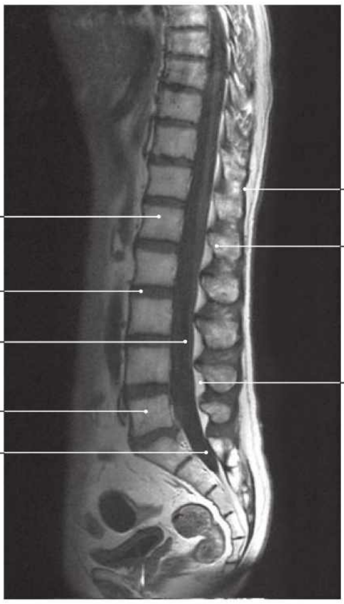


Fig. 2.71 Lumbar part of the vertebral column; magnetic resonance tomographic image (MRI) of the thoracic and lumbar part of the vertebral column and the sacrum.
MRI is a suitable imaging technique to view intervertebral discs, the spinal cord, and the epidural space (Spatium epidurale).

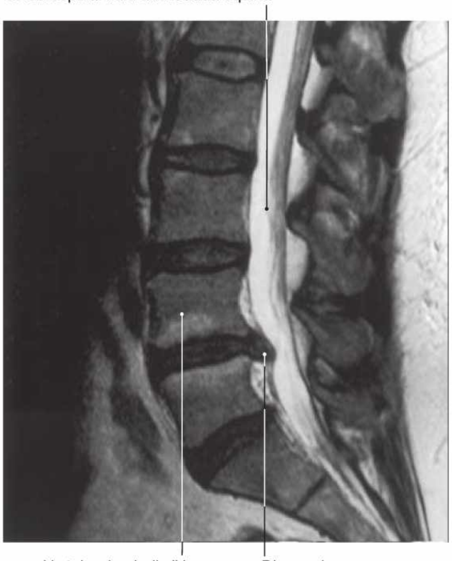


Fig. 2.72 Medial disc prolapse; T2-weighted magnetic resonance tomographic sagittal image (MRI) in the lumbar part of the vertebral column. [8]

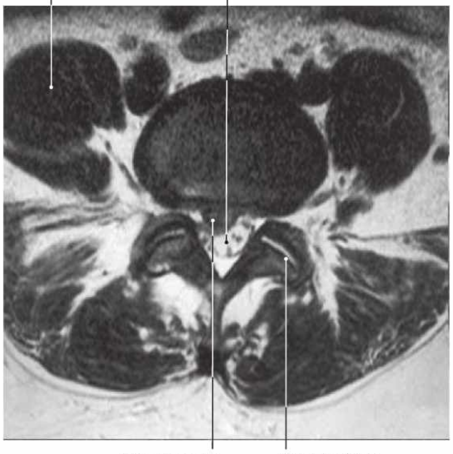


Fig. 2.73 Medial disc prolapse; T2-weighted magnetic resonance tomographic axial image (MRI) in the lumbar part of the vertebral column. [8]

Clinical Remarks

Aging decreases the ability of the Anulus fibrosus and Nucleus pulposus to retain water which leads to formation of small cracks in the Anulus fibrosus **(chondrosis)**. Notable are radiographic reduction in height and pathologic instability with increased mobility in the motion segment. Gradual height reduction of the disc and the resulting reduction in mechanical buffer function lead to increased strain on adjacent superior and inferior intervertebral surfaces of the vertebral bodies. On radiographic images, the **sclerotic process** is reflected by an increase in radiation density **(osteochondrosis)**. Further, it results in the formation of osteophytes (bony spurs) at the vertebral bodies, which are also visible in radiographs. With the radial cracks in the Anulus fibrosus increasing, intervertebral disc tissue can leave the intervertebral space (**disc prolapse**; → Figs. 2.72 and 2.73).

Superficial layer of muscles of the back

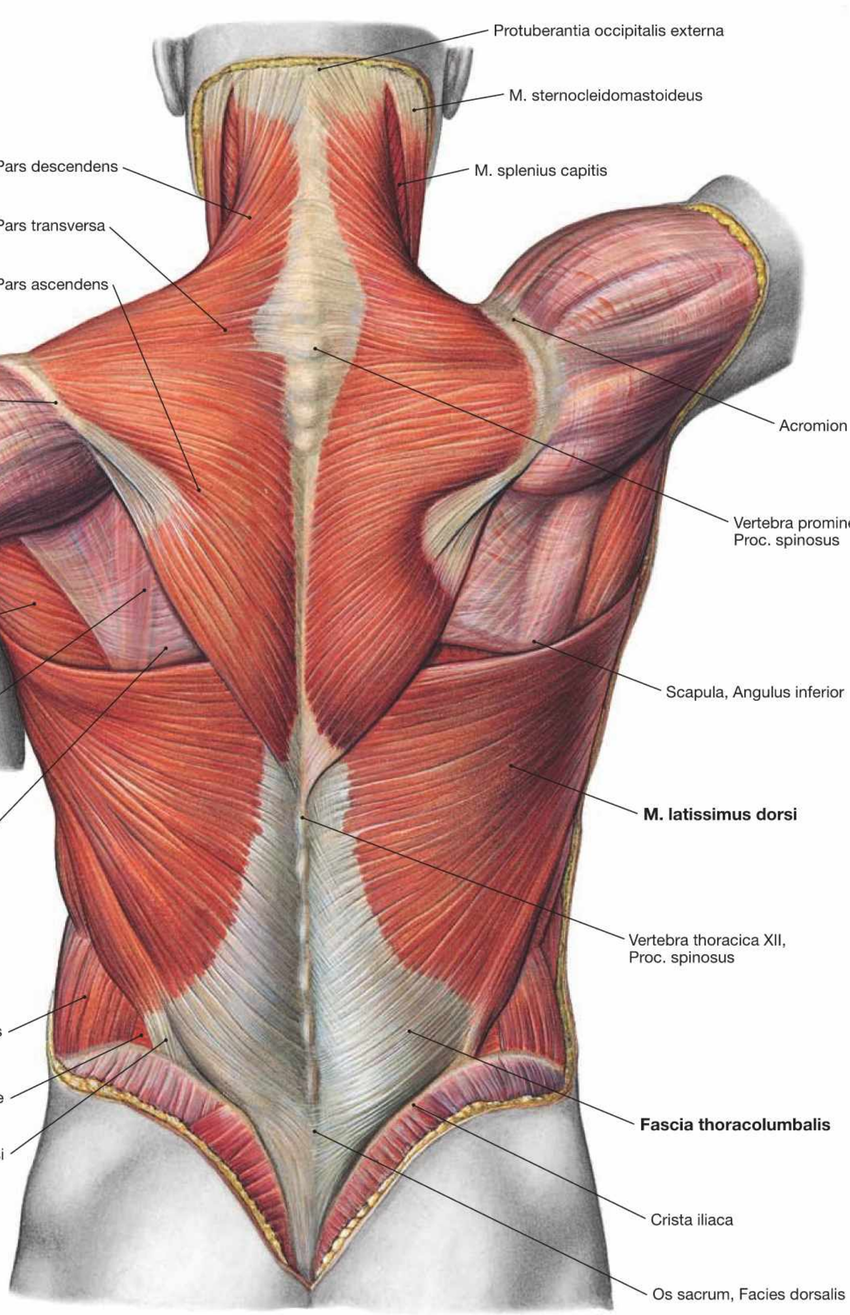


Fig. 2.74 Superficial layer of the trunk-arm and trunk-shoulder girdle muscles; dorsal view.
The Mm. trapezius and latissimus dorsi represent the largest part of the superficial layer of muscles of the back. The **M. trapezius** secures the scapula and thus the shoulder girdle and can move the scapula and clavicle backwards medially towards the vertebral column. The Partes descendens and ascendens turn the Angulus inferior of the scapula medially. The Pars descendens acts as an adductor and supports the M. serratus anterior in the elevation of the shoulder.

The **M. latissimus dorsi** is the largest muscle of the human body with respect to the surface area. It lowers the elevated arm, adducts the arm, can move the arm from an adducted position medially and backwards, rotates the arm inward, and assists in expiration. M. latissimus dorsi and **M. teres major** develop at the same time. The latter pulls the arm medially and backwards, supports adduction, and inward rotation of the arm.

→ T 27, 28

Clinical Remarks

A portion of the **M. latissimus dorsi** can be used to **cover defects of the wall of the trunk** as well as to reconstruct the mammary after resection of mammary carcinoma. For this purpose a suitable pedicle flap, on which the A. and V. thoracodorsalis are segmented and transferred, is prepared. The **M. pectoralis major** (ventral trunk wall) is often used as pedicle flap graft to cover **facial defects.**

Superficial layer of muscles of the back

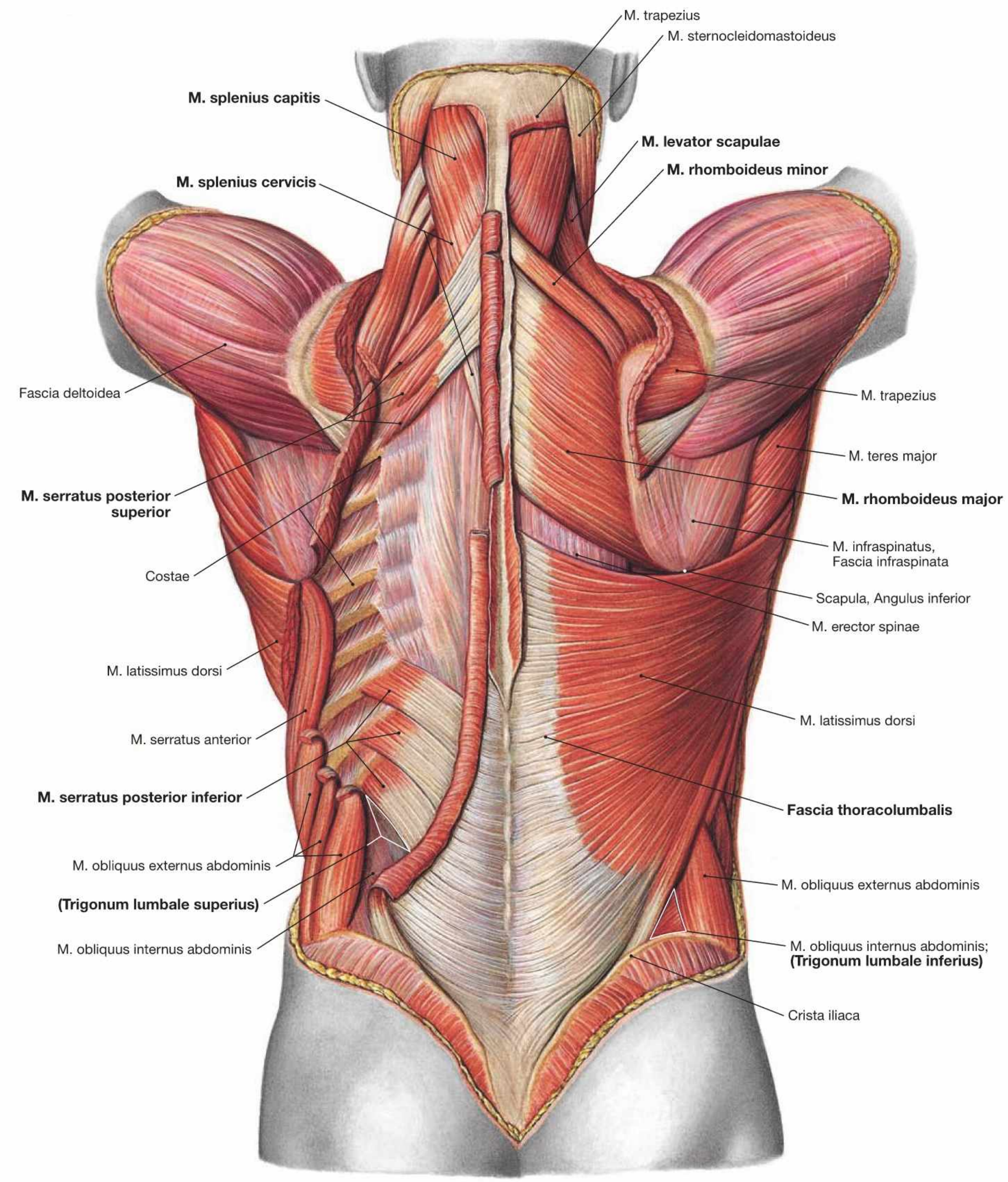


Fig. 2.75 Deep layer of the trunk-arm and trunk-shoulder girdle muscles; dorsal view.
After removal of the M. trapezius, the Mm. levator scapulae, rhomboideus minor and rhomboideus major are visible on the right side. The **M. levator scapulae** can lift the scapula and simultaneously turns the Angulus inferior of the scapula medially.
M. rhomboideus minor and **M. rhomboideus major** fix the scapula to the thorax and pull it towards the spine.
After the 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 upwards and supports inspiration. The M. serratus posterior inferior broadens the lower thoracic aperture and stabilizes the lower ribs during the contraction of the Pars costalis of the diaphragm. Thus, this muscle also supports inspiration.

The **Fascia thoracolumbalis** constitutes a dense aponeurosis. This tough fibrous structure surrounds the autochthonous (intrinsic) erector spinae muscles of the back and forms an osteofibrous tube together with the vertebral column and the dorsal side of the ribs. Its superficial lamina serves as origin for the M. latissimus dorsi and the M. serratus posterior. This lamina is firmly attached to the tendon of the M. erector spinae. It separates the M. splenius cervicis from the M. trapezius and the Mm. rhomboidei in its cranial section and merges with the Fascia nuchae. The deep lamina is shown in → Fig. 2.76.
The areas of the **Trigonum lumbale superius** (GRYNFELT's triangle in TA) and the **Trigonum lumbale inferius** (PETIT's triangle) are the sites for GRYNFELT's and PETIT's **lumbar hernias.**

→ T 27, 28

Deep layer of muscles of the back

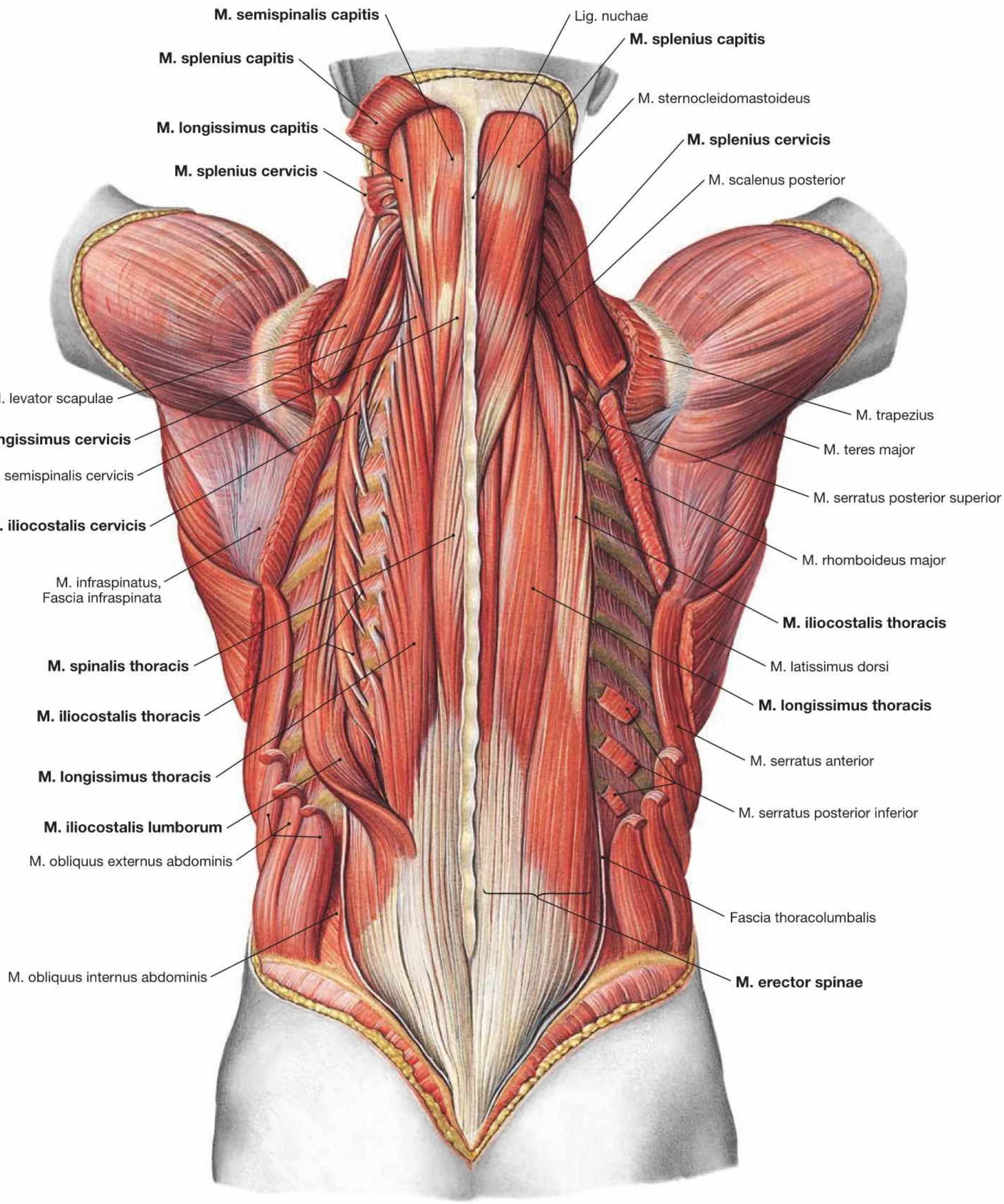


Fig. 2.76 Superficial layer of the deep (autochthonous) muscles of the back; dorsal view.
The autochthonous muscles of the back are collectively named **M. erector spinae.** It is divided into a medial and a lateral tract. Each tract is composed of different systems (→ Fig. 2.77). The M. erector spinae 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

Deep layer of muscles of the back, schematic diagram

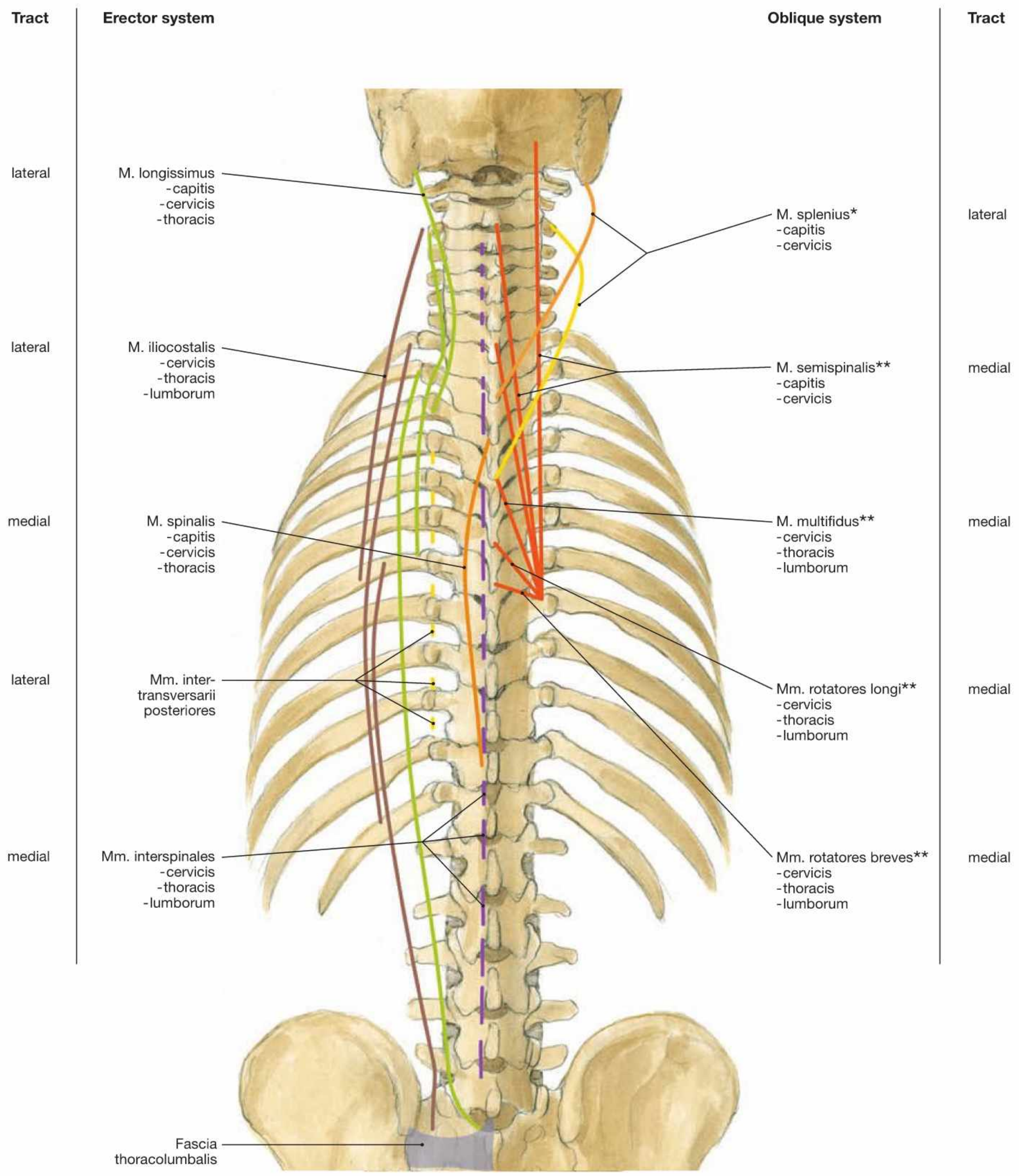


Fig. 2.77 Deep (autochthonous) muscles of the back; diagram of the different muscle groups.
The autochthonous muscles of the back, collectively named M. erector spinae, can be divided into a longitudinal erector system and an oblique system, as well as in a lateral and medial tract.
The lateral tract divides into an intertransversal system (Mm. intertransversarii), a sacrospinal system (M. iliocostalis, M. longissimus), and a spinotransverse system (M. splenius cervicis, M. splenius capitis):

- The **intertransversal** system serves as stabilizer, facilitates bending sideways and extension among transverse processes of the vertebrae.
- The **sacrospinal system** erects the spine, causes extension, and facilitates side-bending and rotational movements of the trunk on the ipsilateral side.
- The **spinotransverse system** acts as a stabilizer according to the bow-tendon principle and, together with the short neck muscles, supports all movements generated in the joints of the cervical spine and head.

The **medial tract** divides into a spinal system (Mm. interspinales, M. spinalis) and 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** stabilizes and rotates to the contralateral side.

* spinotransverse
** transversospinal

Deep layer of muscles of the back

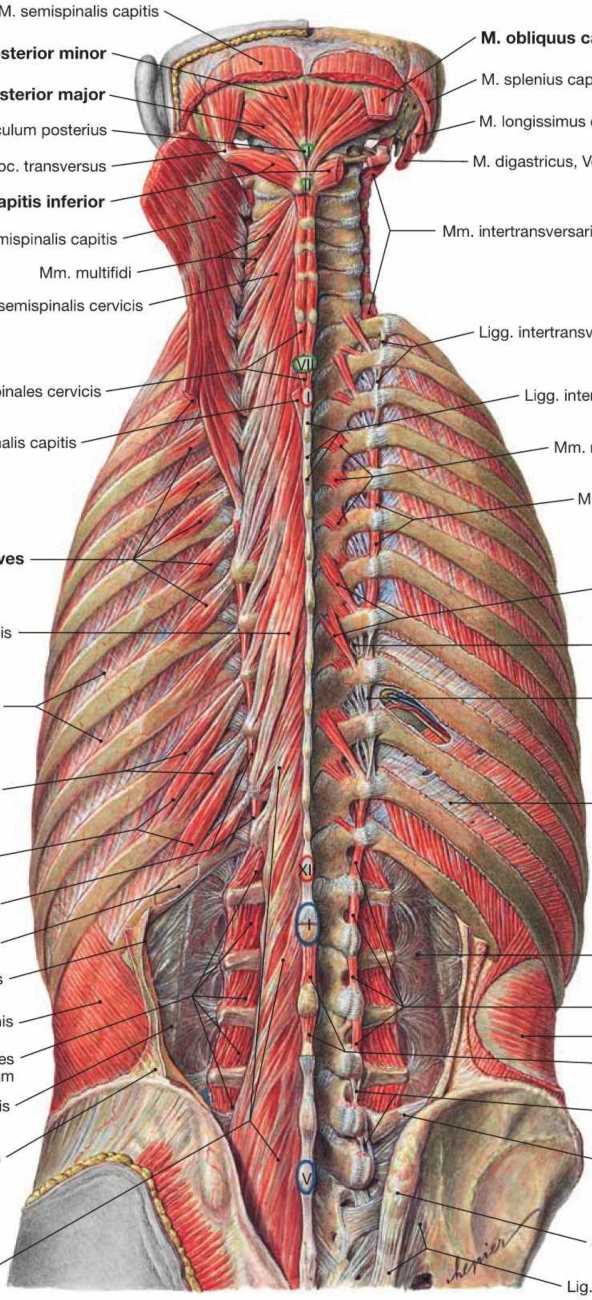


Fig. 2.78 Muscles of the back, Mm. dorsi, and muscles of the neck, Mm. suboccipitales; dorsal view.
Upon removal of the Mm. splenius capitis and semispinalis capitis, the short neck muscles (Mm. rectus capitis posterior minor, rectus capitis posterior major, obliquus capitis superior, obliquus capitis inferior) become visible.
Also depicted here are the Mm. levatores costarum which are not part of the autochthonous muscles of the back because they are innervated by Rr. ventrales of the spinal nerves. Contraction of these muscles results in rotation of the contralateral side and side-bending movements on the ipsilateral side. Some authors also discuss a role of this muscle group in inspiration. For the organization of the other shown autochthonous muscles of the back see → Fig. 2.77.

→ T 18

Deep layer of muscles of the back

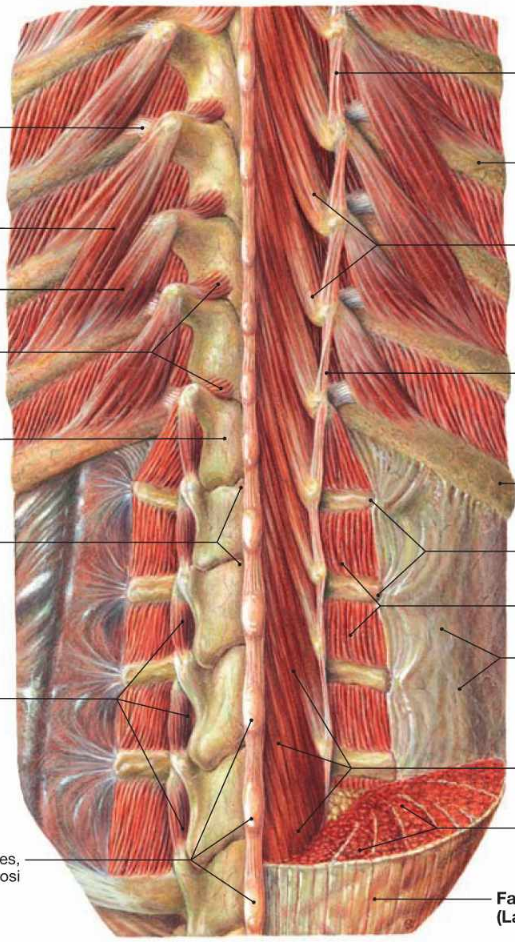


Fig. 2.79 Deep layer of the muscles of the back, Mm. dorsi, in the region of the thoracic and lumbar part of the vertebral column; dorsal view.
On the right side, a cross-section through the caudal region of the M. erector spinae is shown. The Mm. multifidi belong to the medial tract and are located medially, together with the superficial and deep leaf of the Fascia thoracolumbalis. On the left side of the body, the Mm. rotatores thoracis are visible.

→ T 18

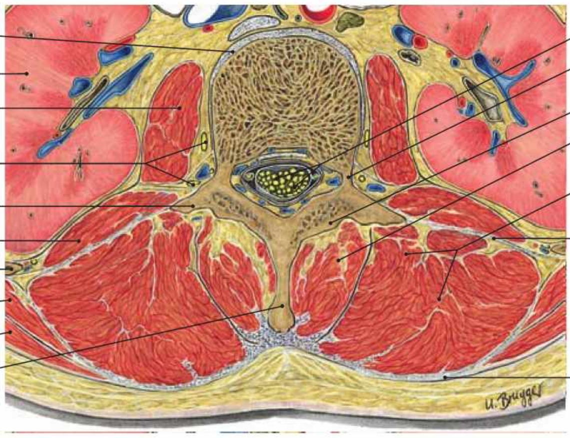


Fig. 2.80 Autochthonous muscles of the back; transverse section at the level of the 2nd lumbar vertebra; caudal view.
The autochthonous muscles of the back are located in an osteofibrous tube which is formed by the dorsal parts of the vertebrae at the inside and the Fascia thoracolumbalis on the outside. The autochthonous muscles of the back are divided into a lateral tract (*) and a medial tract (**).

→ T 18

Neck muscles

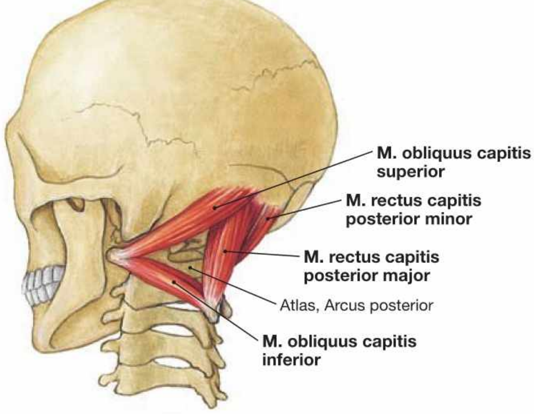


Fig. 2.81 Short muscles of the neck, Mm. suboccipitales; view from an oblique dorsal angle**.**
The Mm. rectus capitis posterior major, obliquus capitis superior, and obliquus capitis inferior create a triangle **(vertebralis triangle)**. The M. rectus capitis posterior minor is located medially to the 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 atlanto-axial joints.

→ T 18

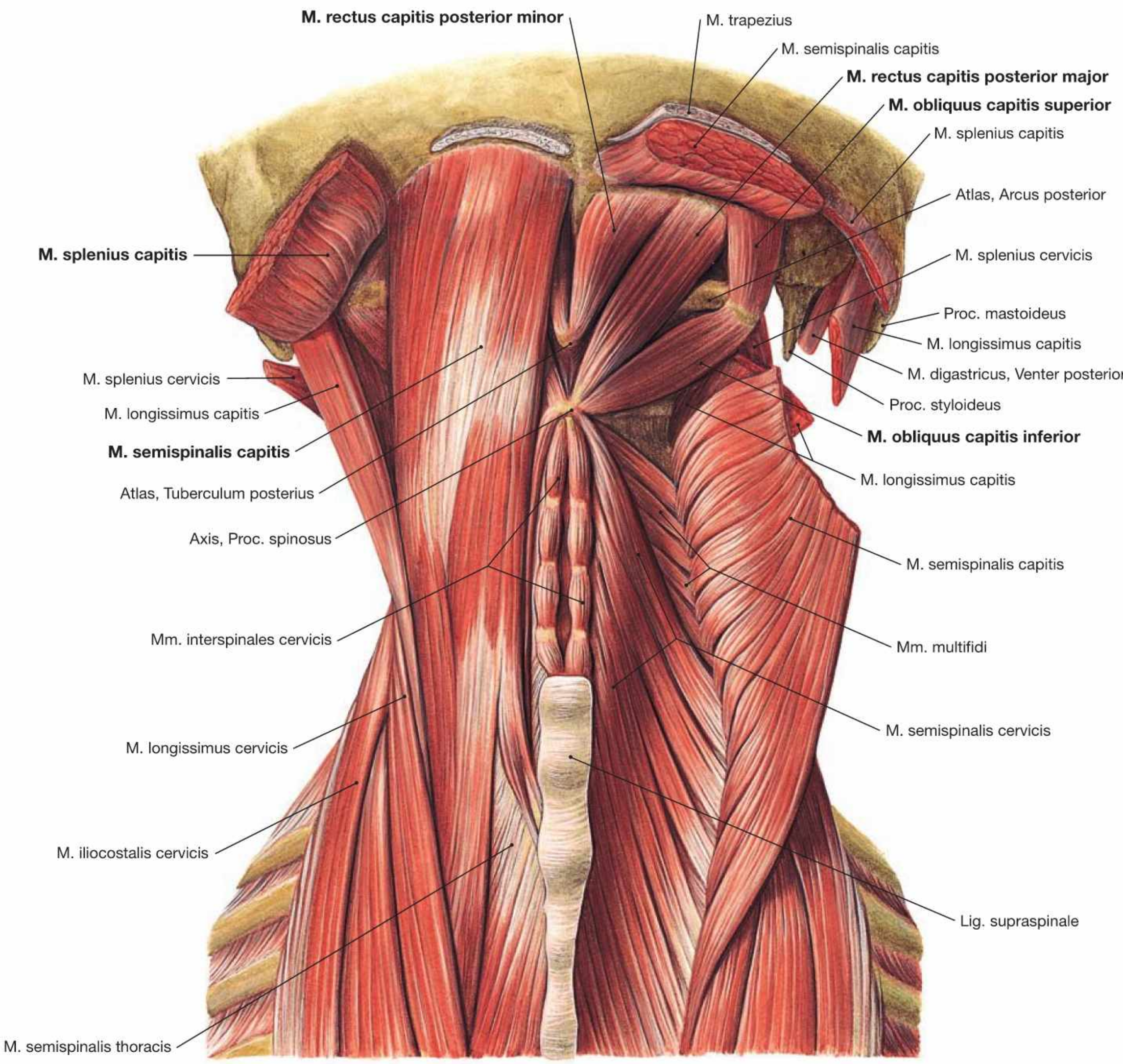


Fig. 2.82 Muscles of the back, Mm. dorsi, and muscles of the neck, Mm. suboccipitales; dorsal view.
To view the short muscles of the neck, the Mm. splenius capitis and semispinalis capitis on the right side were removed. The M. rectus capitis posterior minor has its origin at the Tuberculum posterius of the Atlas and inserts medially at the Linea nuchalis inferior. The M. rectus capitis posterior major originates at the Proc. spinosus of the Axis and inserts laterally to the M. rectus capitis posterior minor at the Linea nuchalis inferior. The M. obliquus capitis superior originates at the Proc. transversus of the Atlas and inserts above and laterally to the M. rectus capitis posterior major. The M. obliquus capitis inferior has its origin at the Proc. spinosus of the Axis and inserts at the Proc. transversus of the Atlas.

→ T 18

Neck muscles

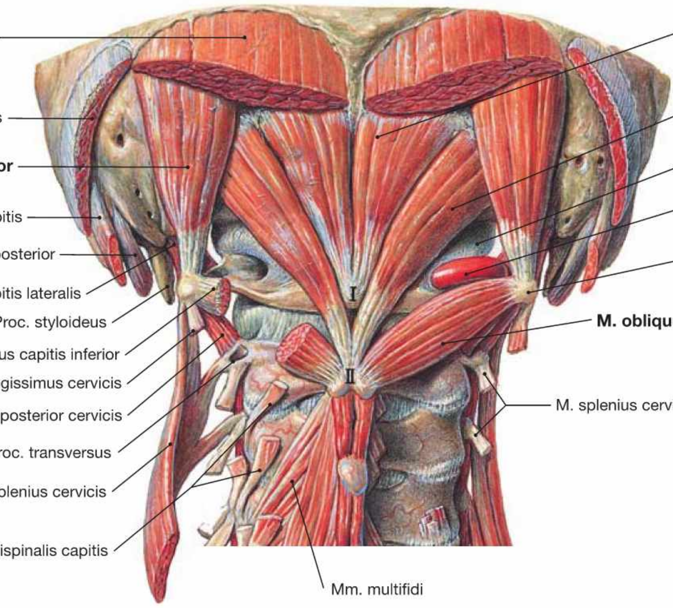


Fig. 2.83 Muscles of the neck, Mm. suboccipitales; dorsal view. The Mm. rectus capitis posterior major, obliquus capitis superior, and obliquus capitis inferior create the margins of the vertebralis triangle **(Trigonum arteriae vertebralis).** At the base of this triangle the A. vertebralis crosses the Arcus posterior atlantis.

I = Tuberculum posterius of the Atlas
II = Proc. spinosus of the Axis

→ T 18

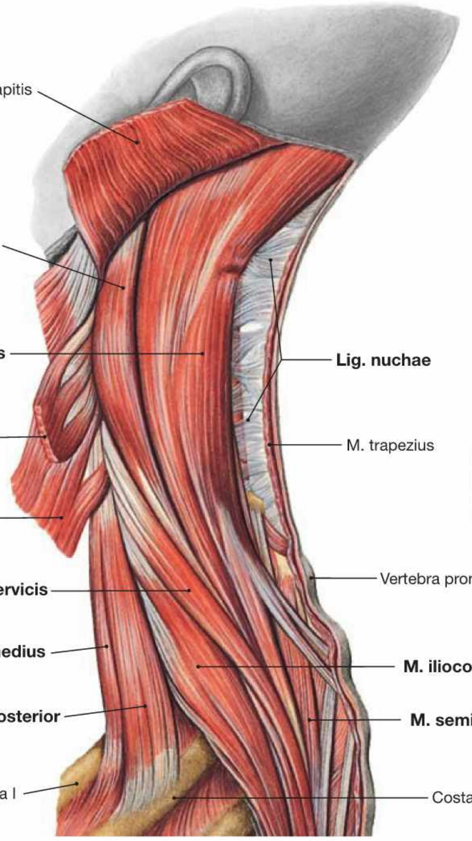


Fig. 2.84 Muscles of the back, Mm. dorsi, and muscles of the neck, Mm. colli; view from the left side.
Upon dissection of the M. splenius capitis (rest displaced cranially), the lateral view of the neck reveals from anterior to posterior the Mm. scaleni medius and posterior as well as autochthonous muscles of the back with the lateral (Mm. iliocostalis cervicis, longissimus cervicis, splenius cervicis, longissimus capitis) and medial (Mm. semispinalis thoracis, semispinalis capitis) tracts. With the removal of the superficial muscles of the back in the neck region the Lig. nuchae and parts of the M. trapezius become visible at the midline.

→ T 18

Muscles of the thoracic and abdominal wall

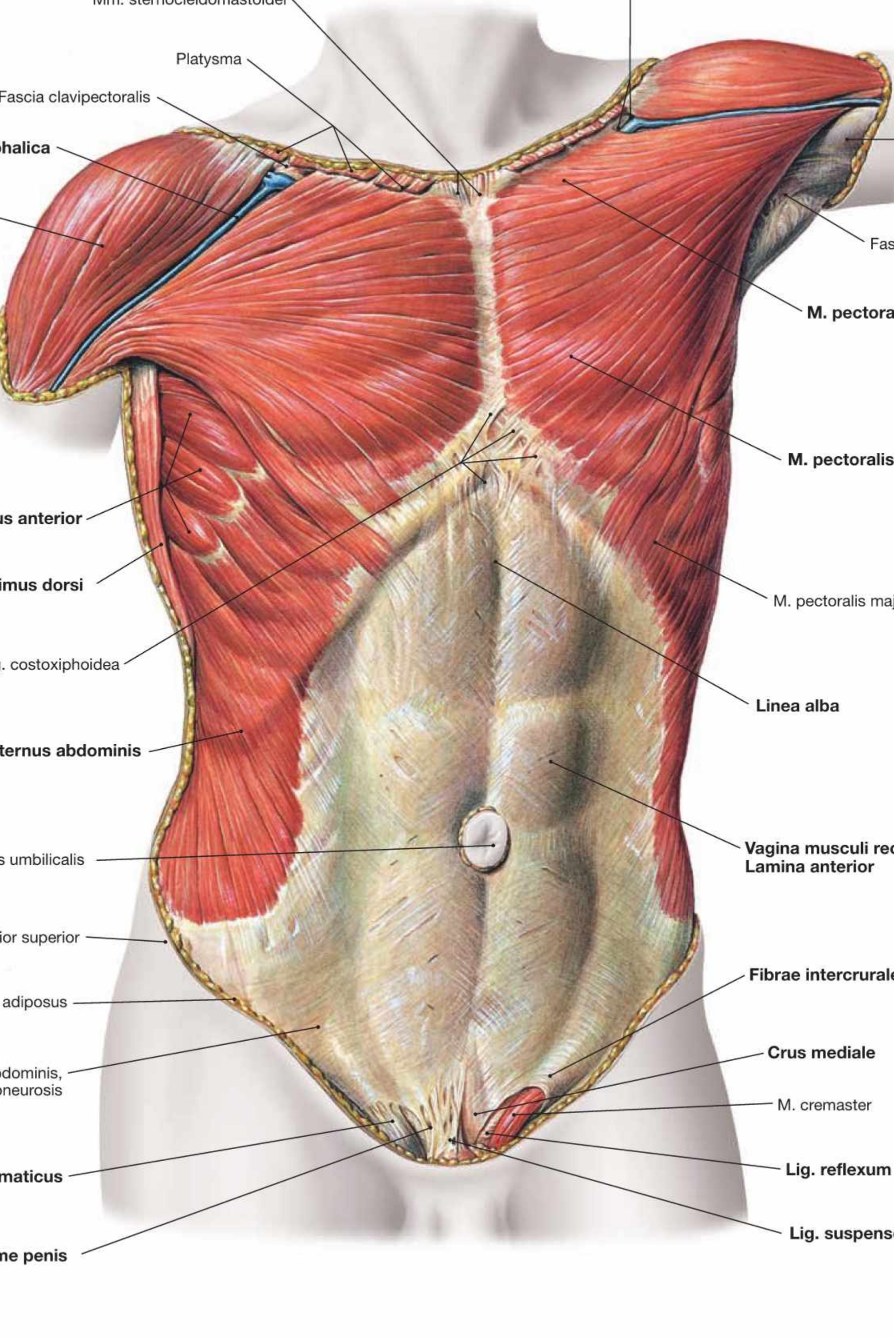


Fig. 2.85 Muscles of the thoracic and abdominal wall, Mm. thoracis and Mm. abdominis, superficial layer; ventral view**.**

The V. cephalica runs between the margins of the M. deltoideus and M. pectoralis major to the Trigonum clavipectorale (MOHRENHEIM's fossa) where it goes deep to join the V. axillaris. The lower margin of the M. pectoralis major constitutes the anterior axillary fold, the anterior margin of the M. latissimus dorsi creates 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 a strong adductor and medial rotator. In addition, this muscle can pull the shoulder forward and downward with the arm in a fixed position and assists in inspiration.

In the abdominal region, the rectus sheath is formed by the aponeuroses of the oblique abdominal muscles. The outmost oblique abdominal muscle, **M. obliquus externus abdominis,** sends its aponeurosis into the outer layer of the rectus sheath.

In the midline, the aponeuroses join in the Linea alba. The caudal suspensory ligaments for the penis, Ligg. fundiforme and suspensorium penis, are shown. Lateral thereof the Funiculus spermaticus and contralaterally the Anulus inguinalis superficialis with Crus mediale, Fibrae intercrurales, and Lig. reflexum are visible.

→ T 15, 24, 25, 28

Muscles of the thoracic and abdominal wall

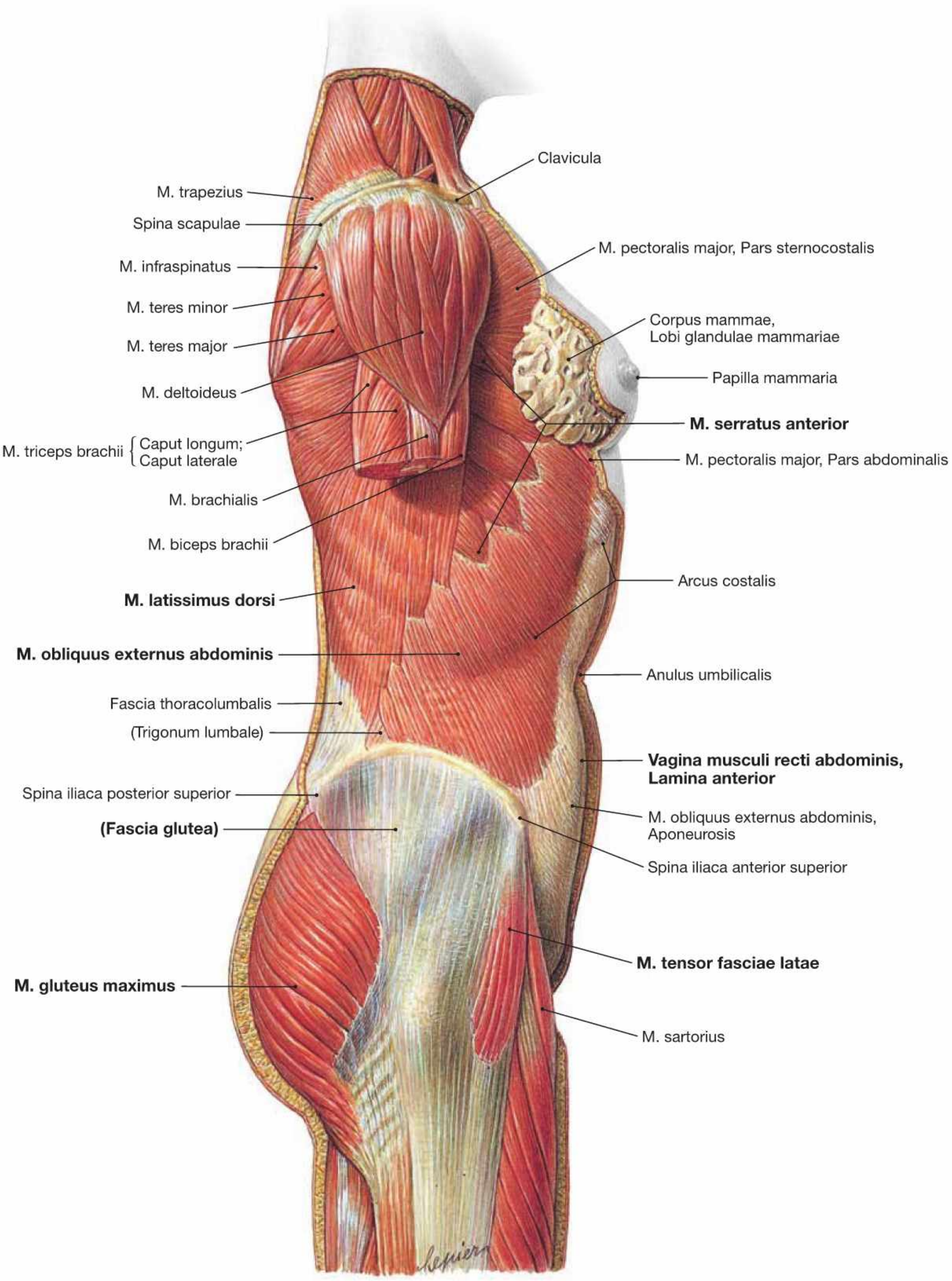


Fig. 2.86 Muscles of the thoracic and abdominal wall, Mm. thoracis and Mm. abdominis; view from the right side.

The lateral view demonstrates the female breast (Mamma) riding on the M. pectoralis major. The lateral abdominal wall displays the serrated interposition of the muscular origins of the M. obliquus externus abdominis with those of the **M. serratus anterior.** The M. latissimus dorsi covers these muscular serrations from dorsal.

The **M. obliquus externus abdominis** extends from lateral posterior cranial to medial anterior caudal. The muscle fibres coming from the lower ribs run almost vertical to the Labium externum of the Crista iliaca. The remaining muscle fibres enter into a sheet-like aponeurosis which participates in the formation of the rectus sheath (Vagina musculi recti abdominis). At the thigh, the Fascia glutea and the **Mm. gluteus maximus** and **tensor fasciae latae** radiating into the Tractus iliotibialis are visible.

→ T 24, 25, 27, 28

Muscles of the thoracic and abdominal wall

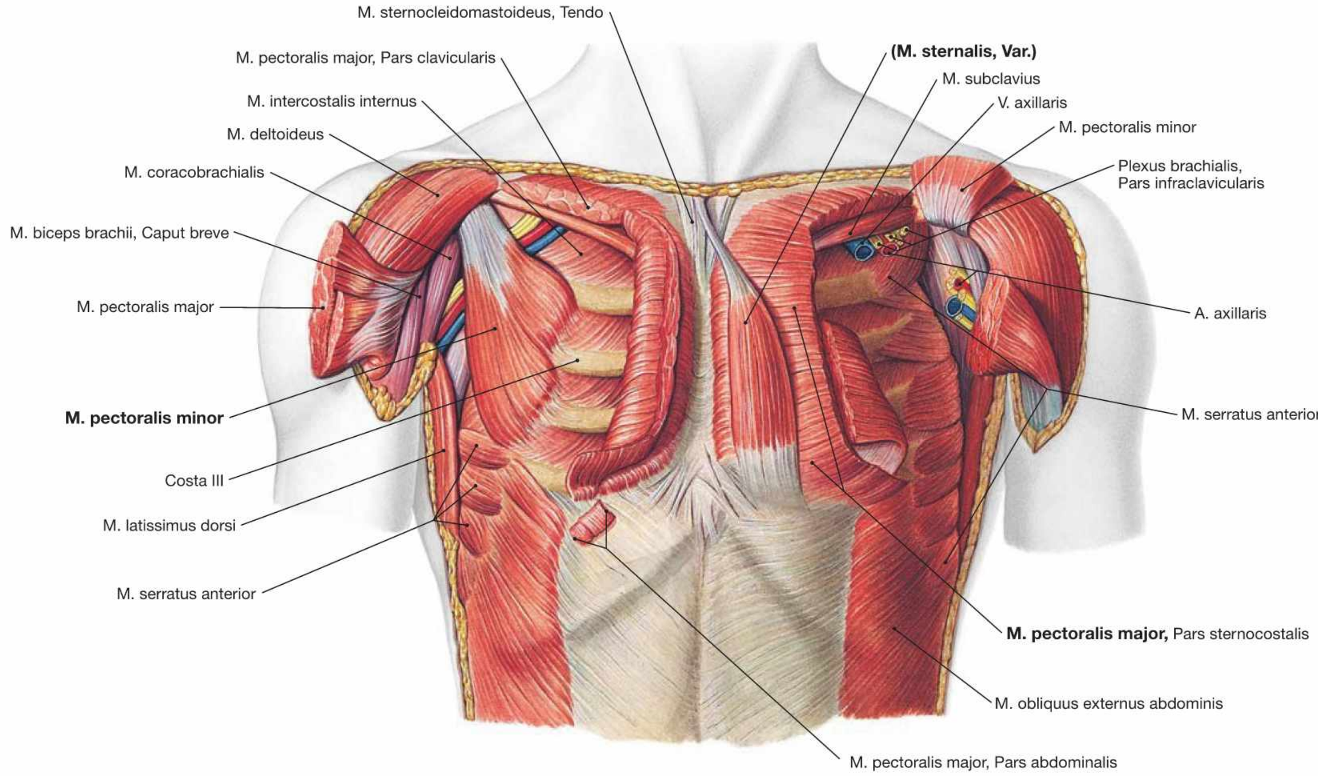


Fig. 2.87 Muscles of the thoracic wall; Mm. thoracis; ventral view. The M. pectorals major was removed on both sides, and the M. pectoralis minor was also removed on the left side. On the right side of the body, the course of the neurovascular bundle is visible below the M. pectoralis minor. Although the **M. pectoralis minor** is considered a muscle of the shoulder it does not insert 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. The very variable M. sternalis is a not infrequent variant located on top of the M. pectoralis major.

→ T 13, 15, 24

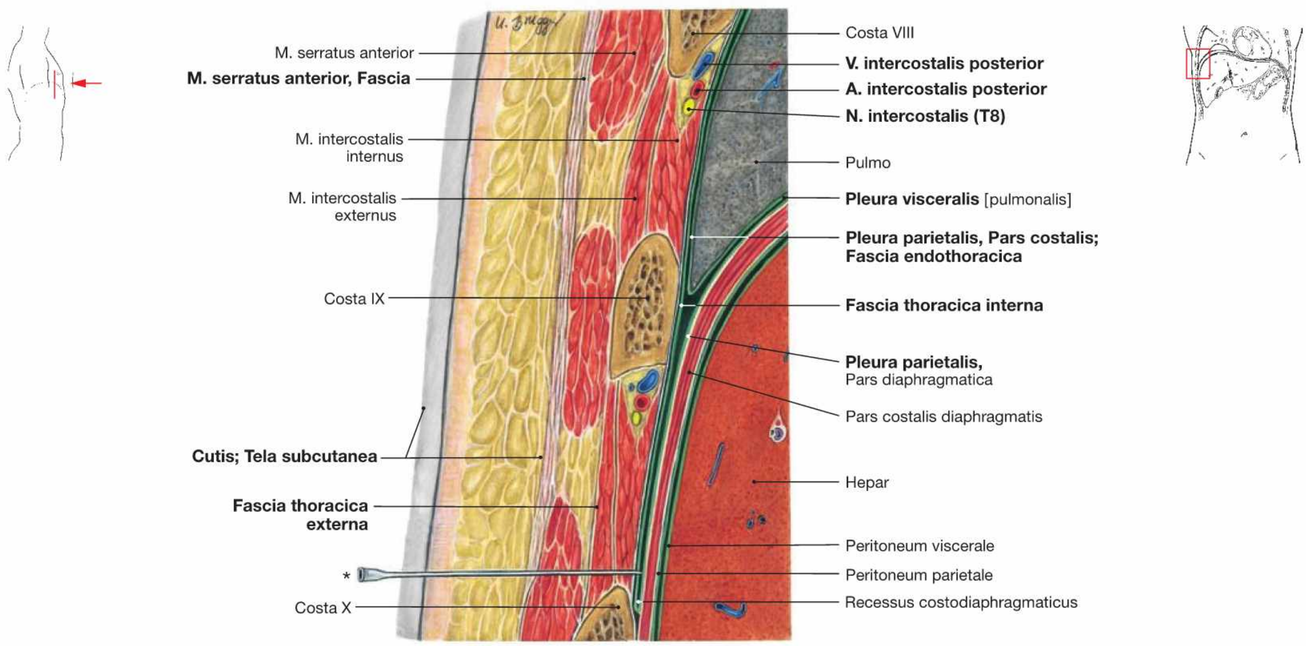


Fig. 2.88 Muscles of the thoracic wall; Mm. thoracis; frontal section through two intercostal spaces.
The following structures are penetrated during pleural puncture: Cutis/Subcutis, Fascia musculi serrati, M. serratus anterior, Fascia thoracica externa, M. intercostalis externus, M. intercostalis internus, Fascia intercostalis interna, Fascia endothoracica, Pleura parietalis. Pleural punctures always are conducted at the upper margin of the rib because the neurovascular structures (V., A., N. intercostalis) run below the rib.

* position of the needle during pleural puncture

→ T 13

Muscles of the thoracic and abdominal wall

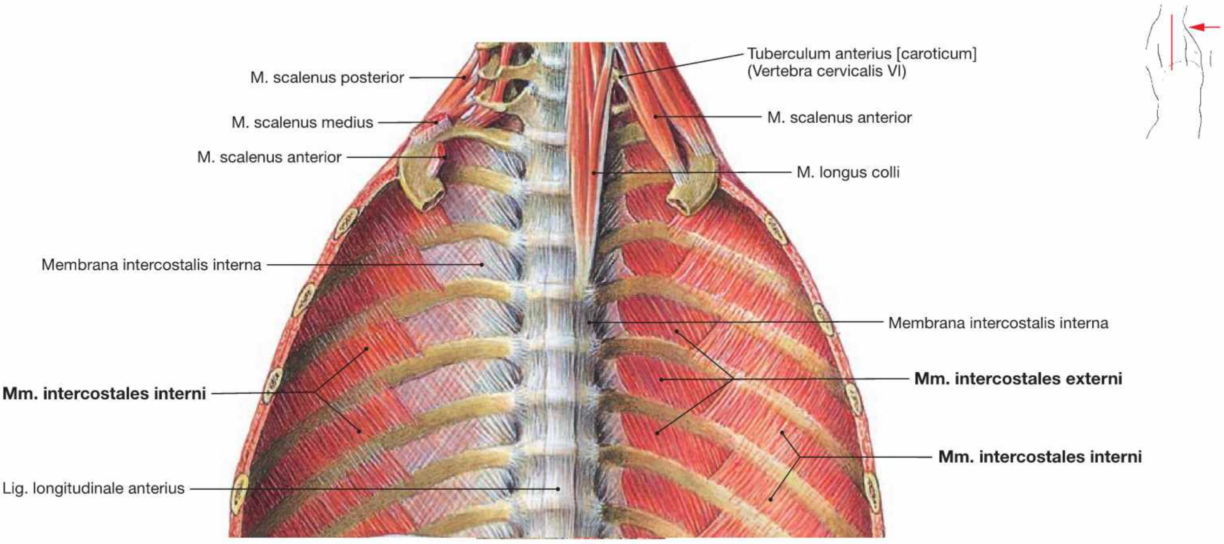


Fig. 2.89 Posterior wall of the thoracic cavity, Cavea thoracis; ventral view.
The **Mm. intercostales externi** project from posterior cranial to anterior caudal. They initiate at the Tubercula costarum and reach forward to the parasternal cartilage (not visible). These muscles act in concert with the Mm. intercartilaginei (not shown) by **elevating the ribs** during inspiration.
The **Mm. intercostales interni** project from posterior caudal to anterior cranial. They initiate at the Angulus costae and reach the sternum (not visible). They act during expiration by **depressing the ribs.** An exception are the muscular parts located between the cartilaginous parts of the ribs (Mm. intercartilaginei) which support inspiration. Not shown are the muscular elements of the Mm. intercostales interni stretching across multiple segments, known as Mm. subcostales, which serve the same function as the Mm. intercostales interni.

→ T 11–13

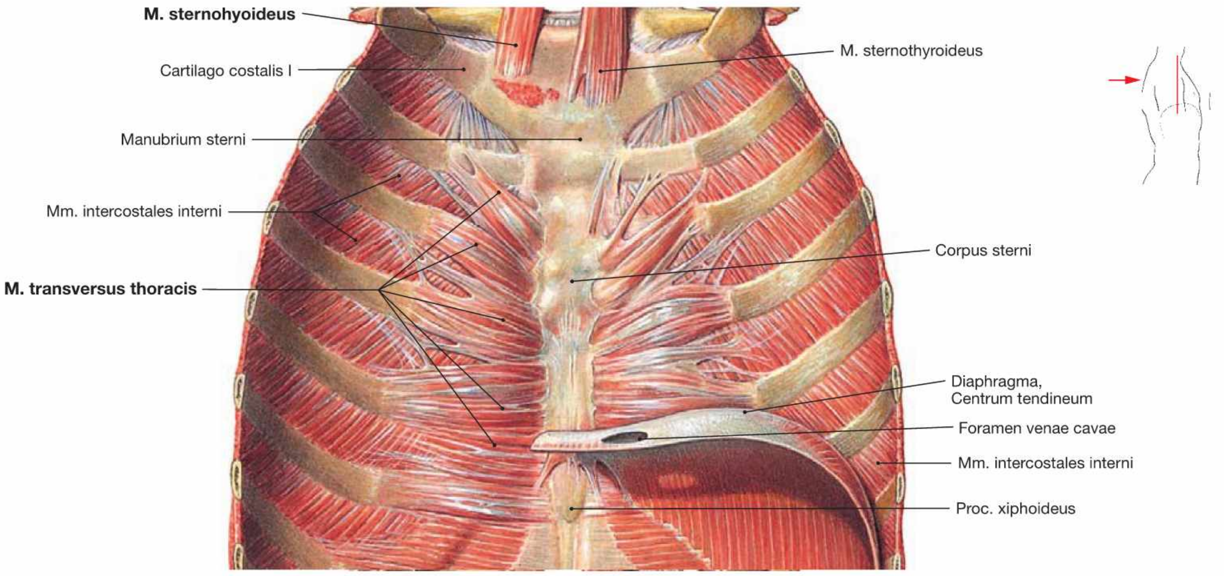


Fig. 2.90 Anterior wall of the thoracic cavity, Cavea thoracis; dorsal view.
The view onto the inner side of the anterior thoracic wall displays the sternum and the muscular bundles of the **M. transversus thoracis.** They originate at the lateral side of the sternum and of the Proc. xiphoideus and insert on the inside of the costal cartilages 2 to 6. The M. transversus thoracis supports expiration.
The posterior side of the Manubrium sterni serves as origin for the M. sternothyroideus and M. sternohyoideus.

→ T 13

Abdominal muscles

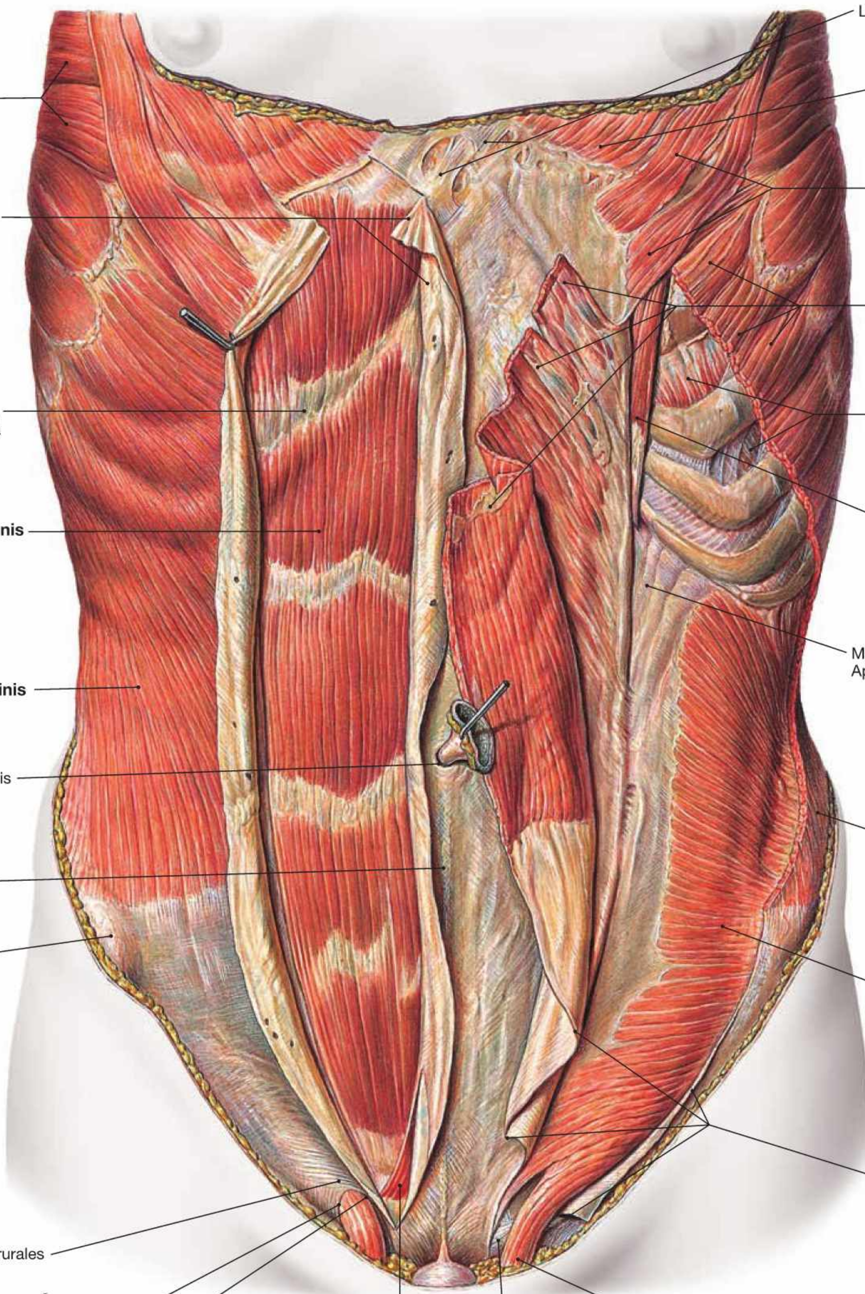


Fig. 2.91 Superficial and middle layer of the abdominal muscles, Mm. abdominis; ventral view.
On the right side, the superficial leaf (Lamina anterior) of the rectus sheath (Vagina musculi recti abdominis) has been opened and the **M. rectus abdominis** becomes visible. This muscle is separated into three to four Intersectiones tendineae which create the so-called six pack contour when exercised properly. The M. rectus abdominis serves to bend the trunk forward and sideways.
The caudal part of the rectus sheath contains the small triangular **M. pyramidalis** which originates from the Os pubis and projects into the Linea alba. The M. pyramidalis is a rudimentary pouch muscle (from a comparative anatomical standpoint, the kangaroo possesses a strongly developped M. pyramidalis).
On the left side, the **M. obliquus externus abdominis** has been detached and folded medially across the rectus sheath. The larger part of this muscle ends in an aponeurosis which contributes to the superficial leaf (Lamina anterior) of the rectus sheath. Functionally, this muscle participates in the forward and side-bending movements it lateral rotation of the upper torso. It is an element of the oblique and transverse muscular abdominal girdle, and creates a functional unit with the muscles of the opposite side as well as the Mm. obliqui interni and transversi abdominis.

→ T 13–15, 24

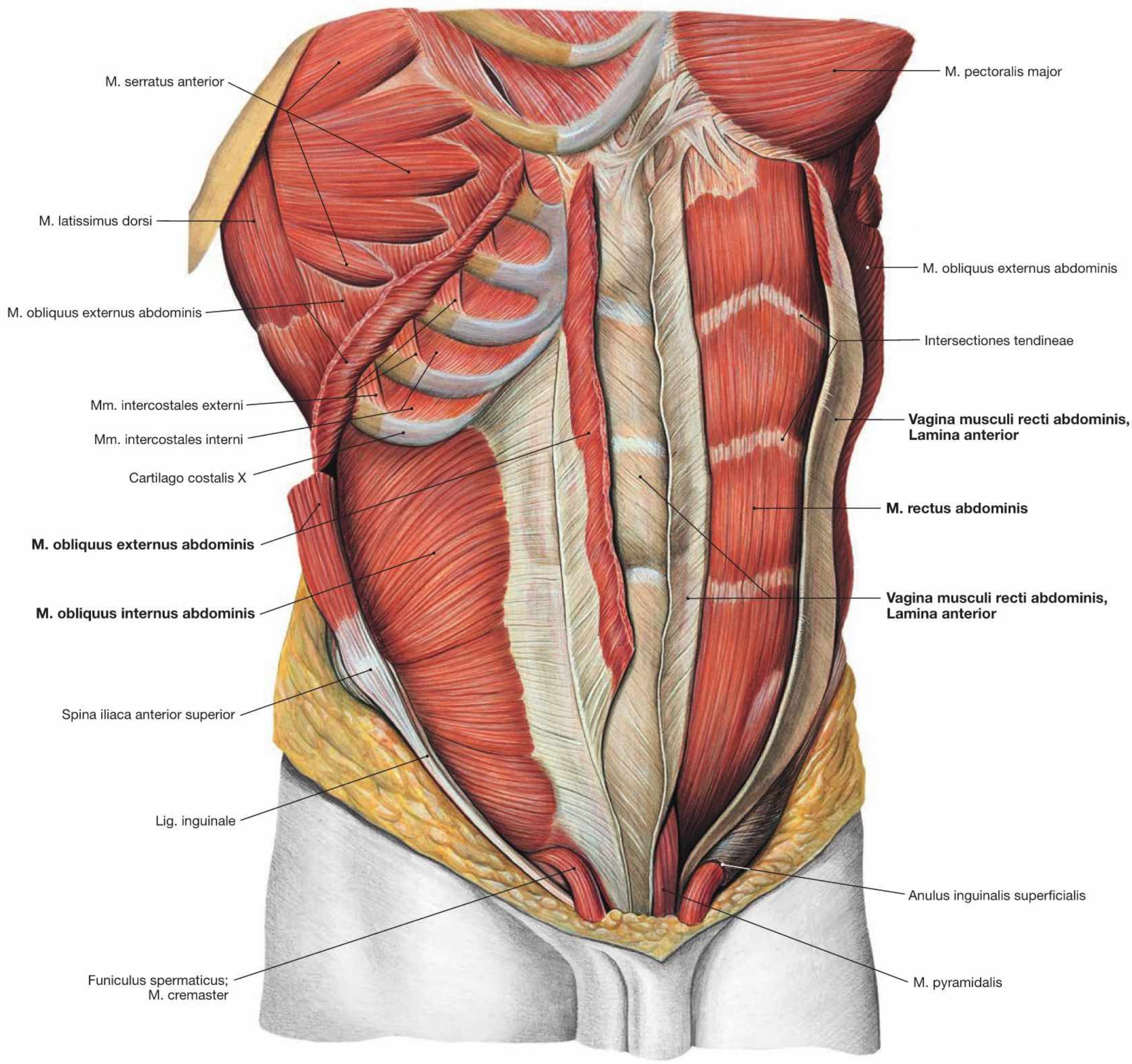


Fig. 2.92 Middle layer of the abdominal muscles, Mm. abdominis; ventral view.

On the right side, the M. obliquus externus abdominis is largely removed. Beneath lies the **M. obliquus internus abdominis.** Its aponeurosis contributes to formation of both the superficial (Lamina anterior) and the deep (Lamina posterior) lamina of the rectus sheath. The M. obliquus internus abdominis projects from lateral caudal to medial cranial and, like the M. obliquus externus abdominis, it participates in the oblique and transverse muscular abdominal girdle and supports forward and side-bending movements and lateral rotation of the upper torso.

→ T 13–15, 24

Abdominal muscles

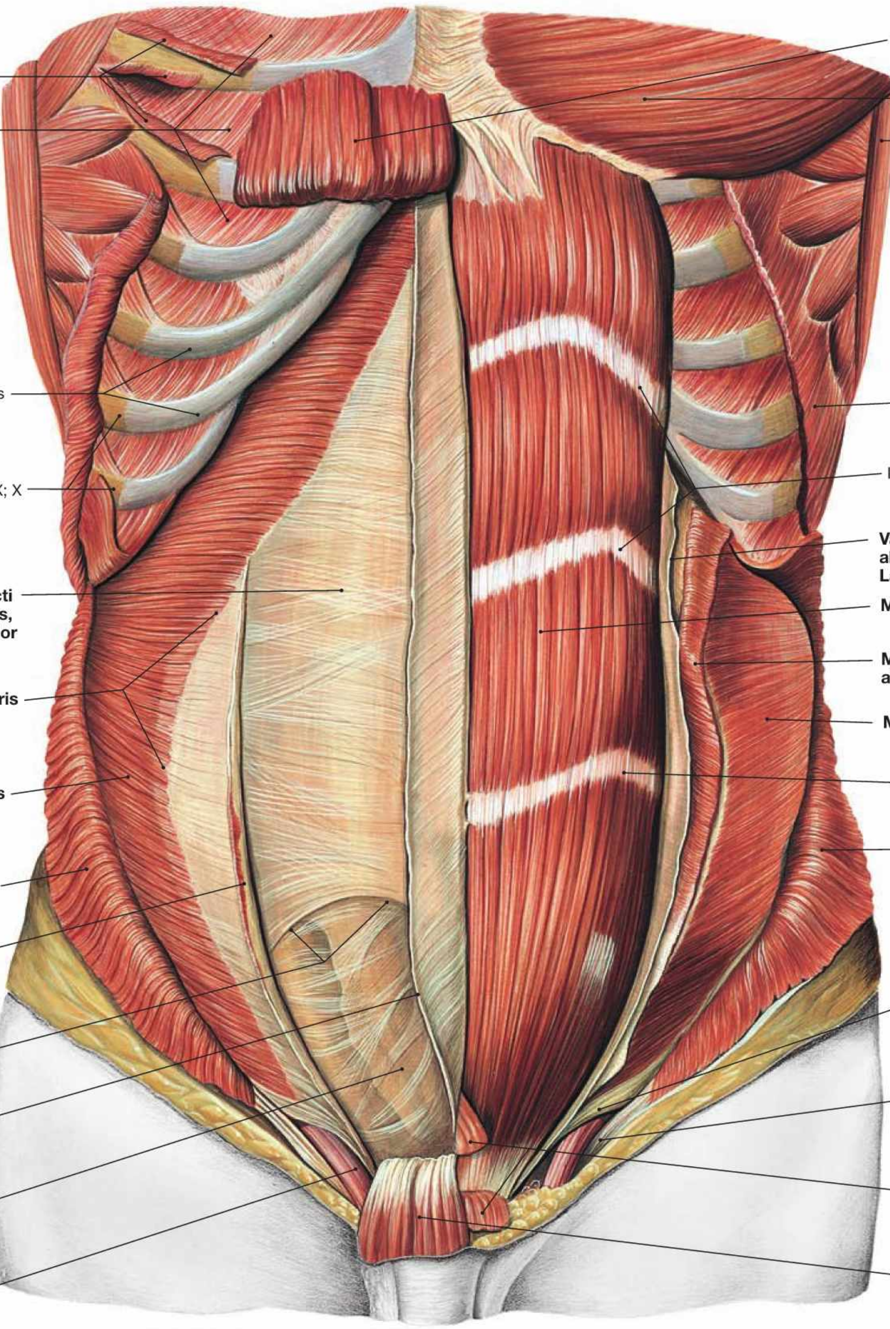


Fig. 2.93 Deep layer of the abdominal muscles, Mm. abdominis; ventral view.

On the right abdominal side the M. transversus abdominis is shown. In addition, the anterior lamina (Lamina anterior) of the rectus sheath (Vagina musculi recti abdominis) and the M. rectus abdominis have been removed.

The transition from muscle fibres to the aponeurosis of the **M. transversus abdominis** forms a semilunar line (Linea semilunaris). This aponeurosis contributes to the major part of the posterior lamina (Lamina posterior) of the rectus sheath. Caudally of the Linea (Zona) arcuata, the aponeurosis of the M. transversus abdominis participates in the formation of the Lamina anterior of the rectus sheath (→ Fig. 2.96). The aponeurosis radiates into the Linea alba. The M. transversus abdominis is mainly exerting a constrictive force which results in increased intra-abdominal pressure and supports forced expiration.

In its upper section (from sternum to Linea [Zona] arcuata), the deep lamina (Lamina posterior) of the rectus sheath is formed by the aponeuroses of both the M. obliquus internus abdominis and the M. transversus abdominis. Below (from Linea [Zona] arcuata to Os pubis), the Lamina posterior only consists of Fascia transversalis and Peritoneum parietale.

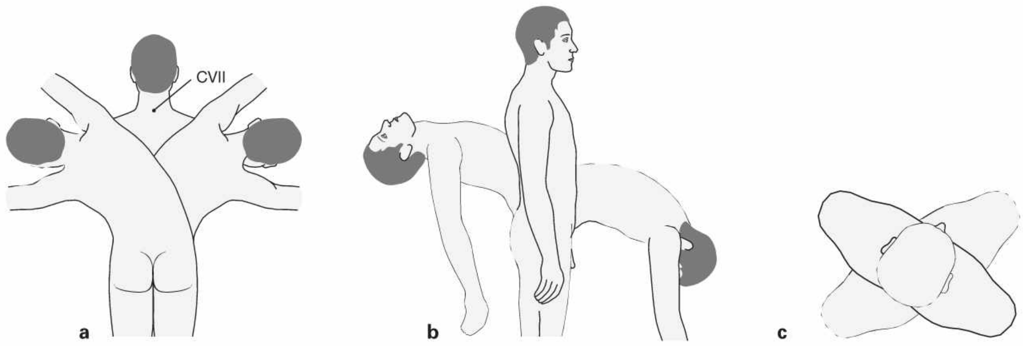
→ T 13–15

Clinical Remarks

A rare **SPIGELIAN hernia** can occur at the lateral margin of the Linea arcuata bordering on the Linea semilunaris.

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

Muscle function



Figs. 2.94a to c Directions of motion of the trunk.
a side-bending movements (lateral flexion) of the trunk
Bending to both sides up to 40° is 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 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 of the trunk (extension) 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. 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 participate in the dorsal flexion of the spine.
c rotation 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 vertebral joints in individual sections of the vertebral column restrict the range of movement. As for the entire vertebral column, bending forward (flexion) and backward (extension) of approximately 100°/0°/50°, a side-bending (lateral flexion) of 0°/40°, and a torsion (rotational movement) of 40°/0°/40° are possible; these serve as normal reference values to assess movement restrictions.

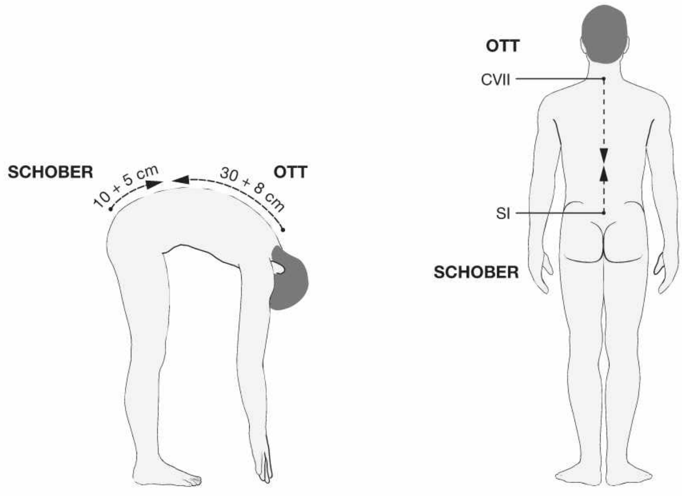


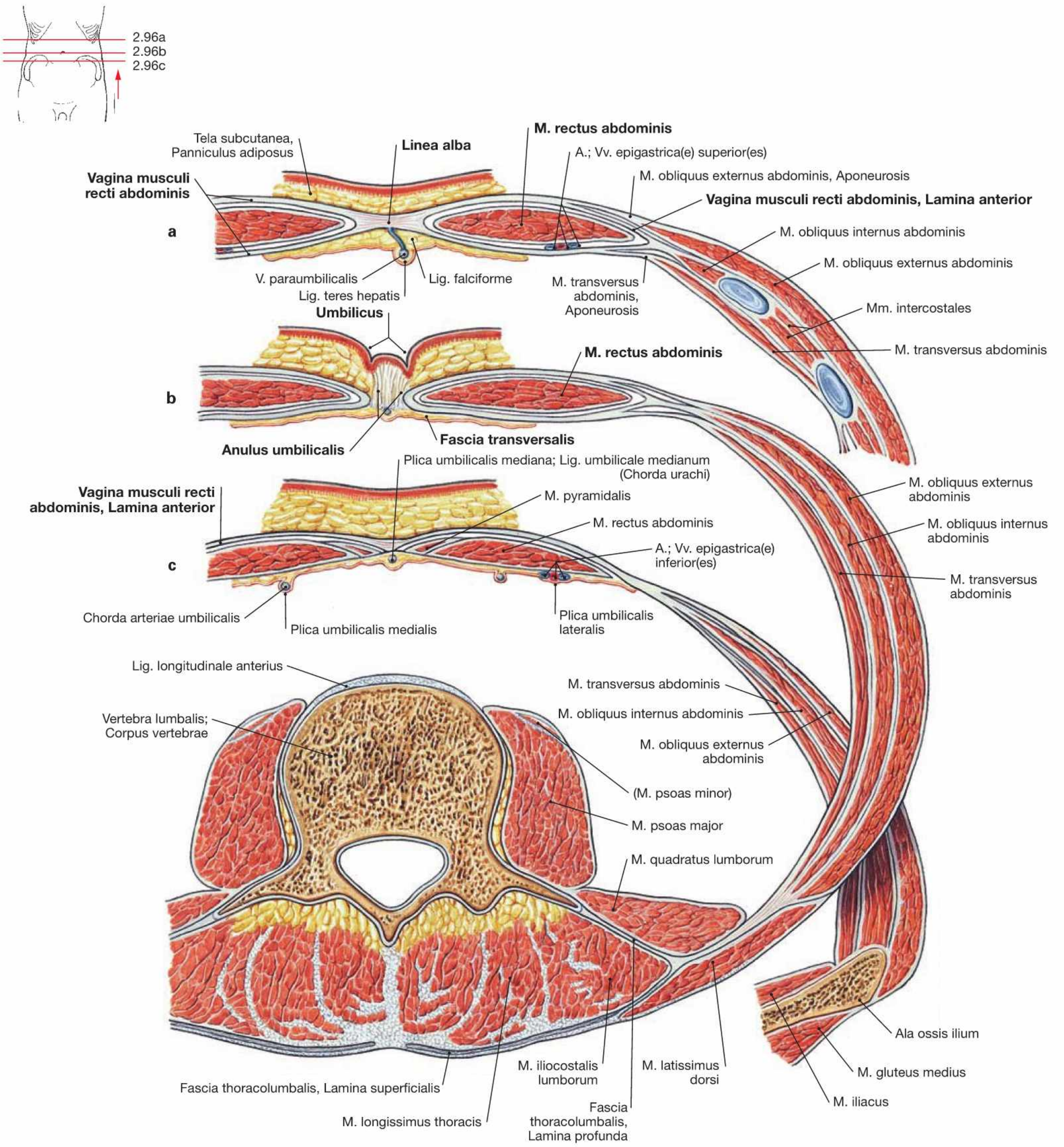
Fig. 2.95 Objective assessment of movement restrictions in the lumbar section of the vertebral column (method by SCHOBER) and the thoracic part of the vertebral column (OTT's sign).

Clinical Remarks

Method by 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 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 maximal flexion, the distance between the two points usually increases by 5 cm (4–6 cm).

OTT's sign: Mobility of the thoracic spine is determined in the same manner. The origin of measure is the Proc. spinosus of the 7th cervical vertebra (Vertebra prominens) and is traced 30 cm caudally. With maximal flexion, the distance between these two points usually increases by 8 cm.

Abdominal muscles, rectus sheath



Figs. 2.96a to c Structure of the rectus sheath, Vagina musculi recti abdominis; cross-section; caudal view.

The Mm. rectus abdominis and pyramidalis are embedded in a tough fibrous tube (Vagina musculi recti abdominis) which is formed by the aponeuroses of the oblique abdominal muscles (Mm. obliquus externus abdominis, obliquus internus abdominis, and transversus abdominis) as well as the Fascia transversalis and the Peritoneum parietale at the inside of the ventral abdominal wall. All aponeuroses radiate into the Linea alba. The upper section of the rectus sheath is different from the lower section.The border between both sections is the **Linea (Zona) arcuata.**

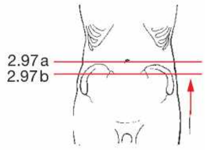
In the **upper section,** the anterior lamina (Lamina anterior) of the rectus sheath is formed by the aponeurosis of the M. obliquus externus abdominis and the anterior part of the aponeurosis of the M. obliquus internus abdominis; the posterior lamina (Lamina posterior) is composed of the posterior 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**).

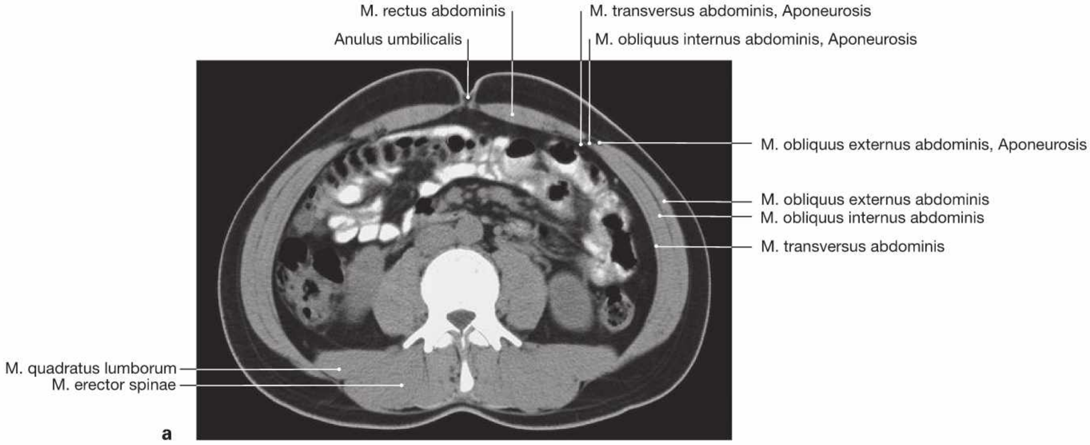
In the **lower section,** all three aponeuroses locate in front of the M. rectus abdominis (c). Here, the posterior side of the rectus sheath is very thin and composed exclusively by the Fascia transversalis and the Peritoneum parietale (→ Fig. 2.93).

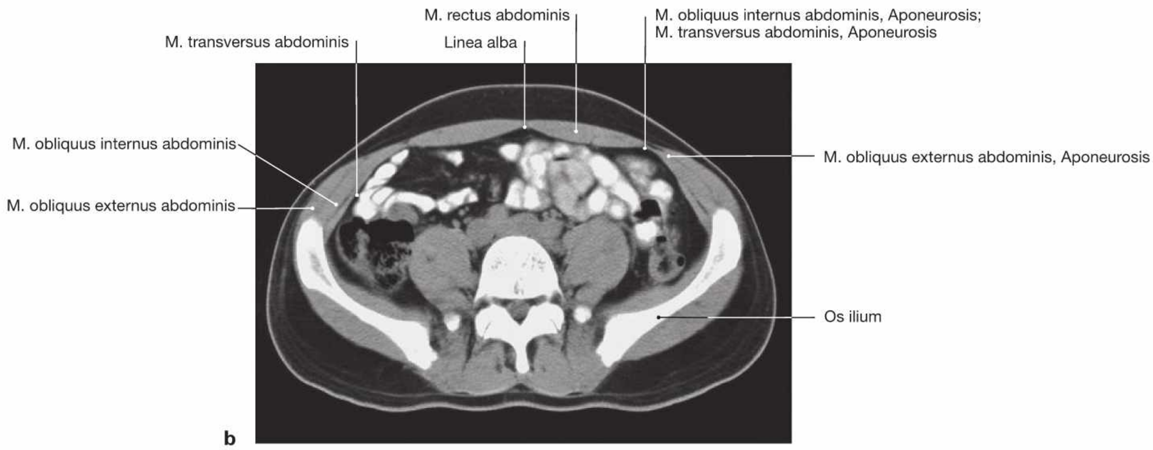
The umbilicus is a potential weak spot in the anterior abdominal wall which is thinner in the region of the umbilical pit and the Papilla umbilicalis as compared to other parts (**b**).

→ T 14–16, 18, 42

Abdominal wall, CT







Figs. 2.97a and b Muscles of the abdominal wall, Mm. abdominis; computed tomographic (CT) cross-sections.

The oblique and rectus abdominal muscles can be distinguished in CT scans. The M. erector spinae and the M. quadratus lumborum are also clearly visible.

Clinical Remarks

Umbilical hernias occur in newborns and adults. In newborns the umbilical papilla has not yet formed, whereas in adults the connective tissue of the umbilical papilla separates due to an excessive expansion of the abdominal wall during pregnancy or adiposity. The hernial canal is the umbilical ring (Anulus umbilicus). An **omphalocele** (congenital umbilical hernia) is a birth defect resulting in the persistence of the physiological umbilical hernia during the fetal period.

Inside of the ventral abdominal wall

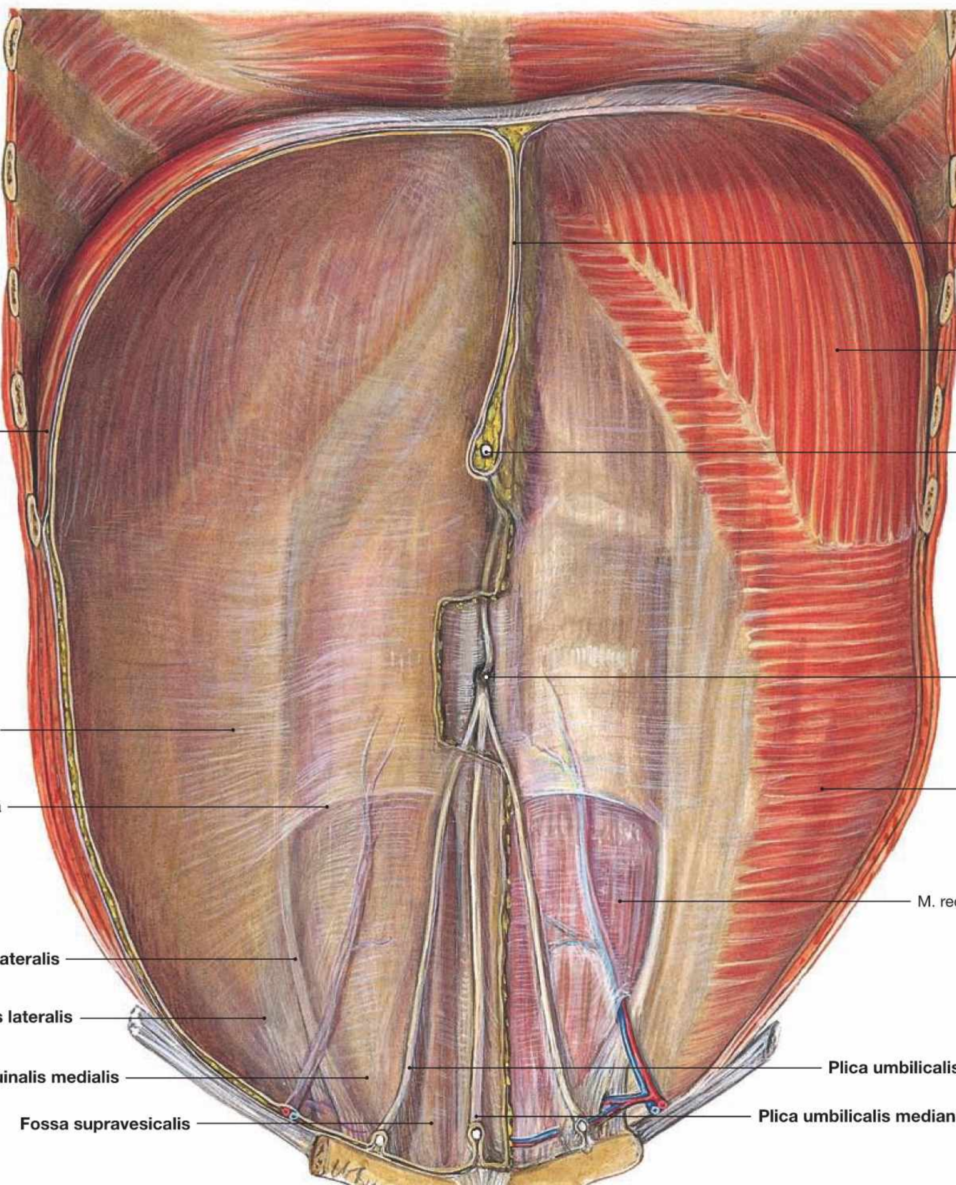


Fig. 2.98 Posterior aspect of the anterior abdominal wall; dorsal view. On the right side, the fascia and the peritoneum covering the diaphragm and the M. transversus abdominis have been removed. On the posterior aspect of the ventral abdominal wall different folds (Plicae), pits (Fossae), and ligaments (Ligamenta) are noticeable. The **Lig. falciforme hepatis** (sickle-shaped liver band) extends between the diaphragm and the liver and inserts in a right angle at the posterior aspect of the ventral abdominal wall. It extends to the umbilicus and represents the developmental remnant of the mesentery of the umbilical vein. The umbilical vein occludes immediately after birth and remains visible as a round ligamentous cord **(Lig. teres hepatis)** at the free border of the Lig. falciforme hepatis. Below the umbilicus are visible the **Plica umbilicalis mediana** (median umbilical fold; contains the remnants of the Urachus – the fibrous remnant of the allantois that stretches from the top of the urinary bladder to the umbilicus), lateral thereof the **Plicae umbilicales mediales** (medial umbilical folds; contain the remnants of the Aa. umbilicales), and farthest lateral the **Plicae umbilicales laterales** (lateral umbilical folds; contain the Vasa epigastrica inferior). The Fossae supravesicales, inguinales mediales, and inguinales laterales are located between the folds. The **Fossa inguinalis lateralis** corresponds to the inner inguinal ring located beneath; the **Fossa inguinalis medialis** locates at the same level as the outer inguinal ring.

→ T 14, 15, 19

Diaphragm and posterior abdominal wall

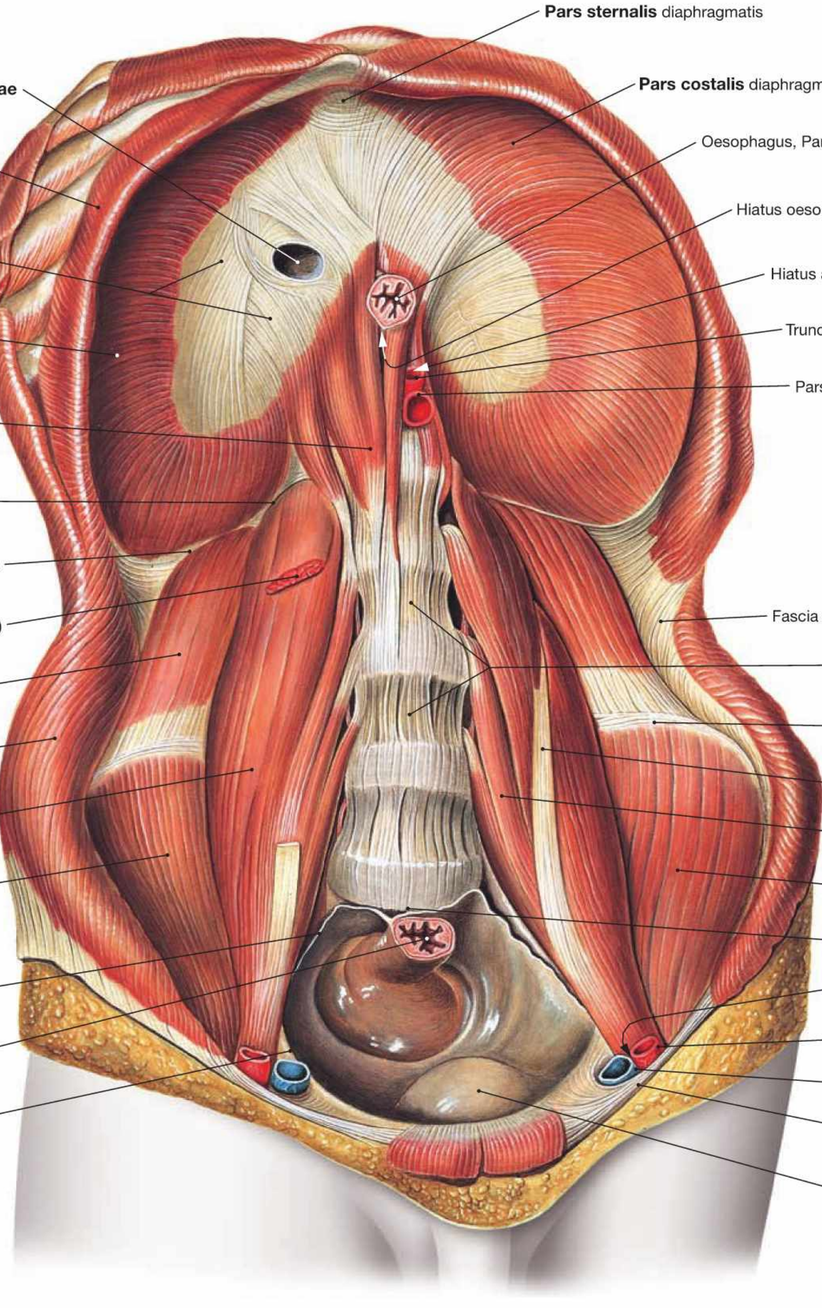


Fig. 2.99 Diaphragm, Diaphragma, and muscles of the abdominal wall, Mm. abdominis; ventral view.

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).

Upon removal of the retroperitoneum, the paravertebral location of the Mm. iliopsoas (composed of a M. psoas major and M. iliacus each), the M. quadratus lumborum, and, as a variant, the M. psoas minor are shown.

Both the **M. psoas major,** originating from the Fossa iliaca, and the **M. iliacus** insert at the Trochanter minor of the femur. The M. psoas major represents the strongest flexor of the hip. The M. psoas major can move the upper torso from a lying position into an upright sitting position and participates in the rotation of the trunk. The **M. quadratus lumborum** originates from the Labium internum of the Crista iliaca and inserts at the XII. rib and at the Procc. costales of the 1st to 4th lumbar vertebrae. This muscle is able to depress the XII. rib and participates in the forward flexion of the trunk.

* FALLOPIAN ligament or POUPART's ligament

→ T 15, 16, 19, 42

Diaphragm

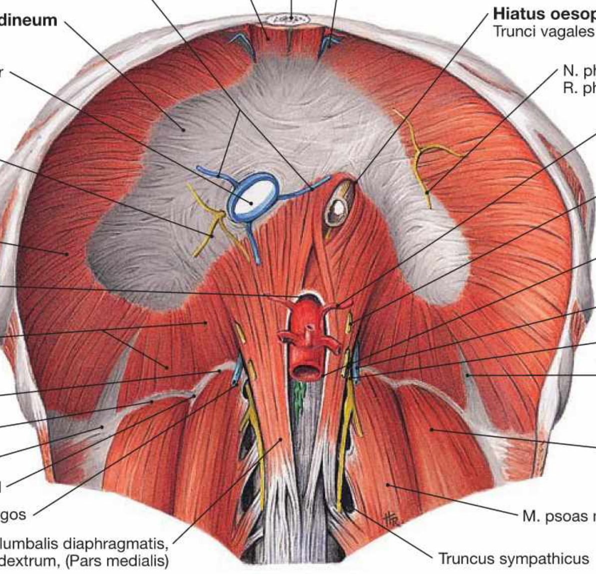


Fig. 2.100 Diaphragm, Diaphragma; caudal view**.**
The diaphragm comprises the Centrum tendineum and the Partes sternales, costales, and lumbales. The **Trigonum sternocostale** (LARREY's cleft) is located between the Pars sternalis and the Pars costalis, and the **Trigonum lumbocostale** (BOCHDALEK's triangle) between the Pars costalis and the Pars lumbalis.
The **Pars lumbalis** is divided into a Crus dextrum and Crus sinistrum, each of which is separated further into Crura mediale, intermedium, and laterale. The Crus dextrum is attached to the lumbar vertebral bodies of L1 to L3 and the intercalating Disci intervertebrales; the Crus sinistrum is attached to the lumbar vertebrae L1 and L2 and the intercalating Discus intervertebrale. The Crus mediale dextrum forms a loop around the oesophagus (Hiatus oesophageus). The right and left diaphragmatic crura are connected by a tendinous arch (Hiatus aorticus) at the level of the vertebral column. At the Hiatus aorticus the aorta enters the abdominal cavity. The Lig. arcuatum mediale (psoas arcade) demarcates the diaphragm from the M. psoas major, whereas the Lig. arcuatum laterale (quadratus arcade) separates the diaphragm from the M. quadratus lumborum.

→ T 19

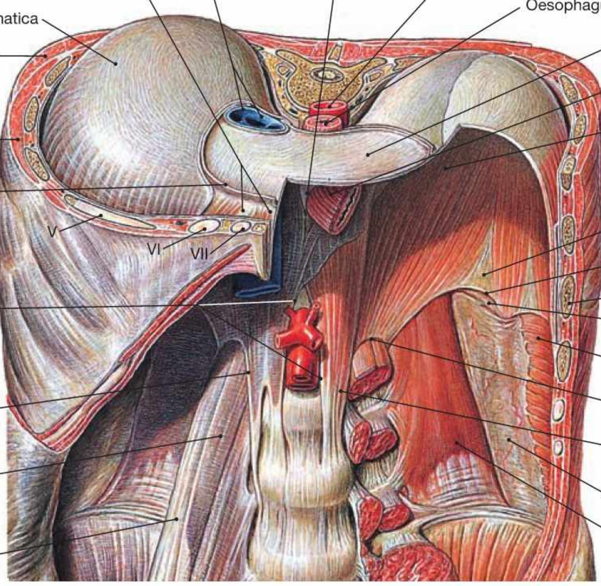


Fig. 2.101 Diaphragm, Diaphragma, with diaphragmatic apertures and muscles of the posterior abdominal wall; ventral view.
The diaphragm is a double dome-shaped incomplete separation between the thoracic and abdominal cavity (→ Figs. 2.99 und 2.102).

* clinical term: BOCHDALEK's triangle
** quadratus arcade
*** psoas arcade

→ T 19

Diaphragm

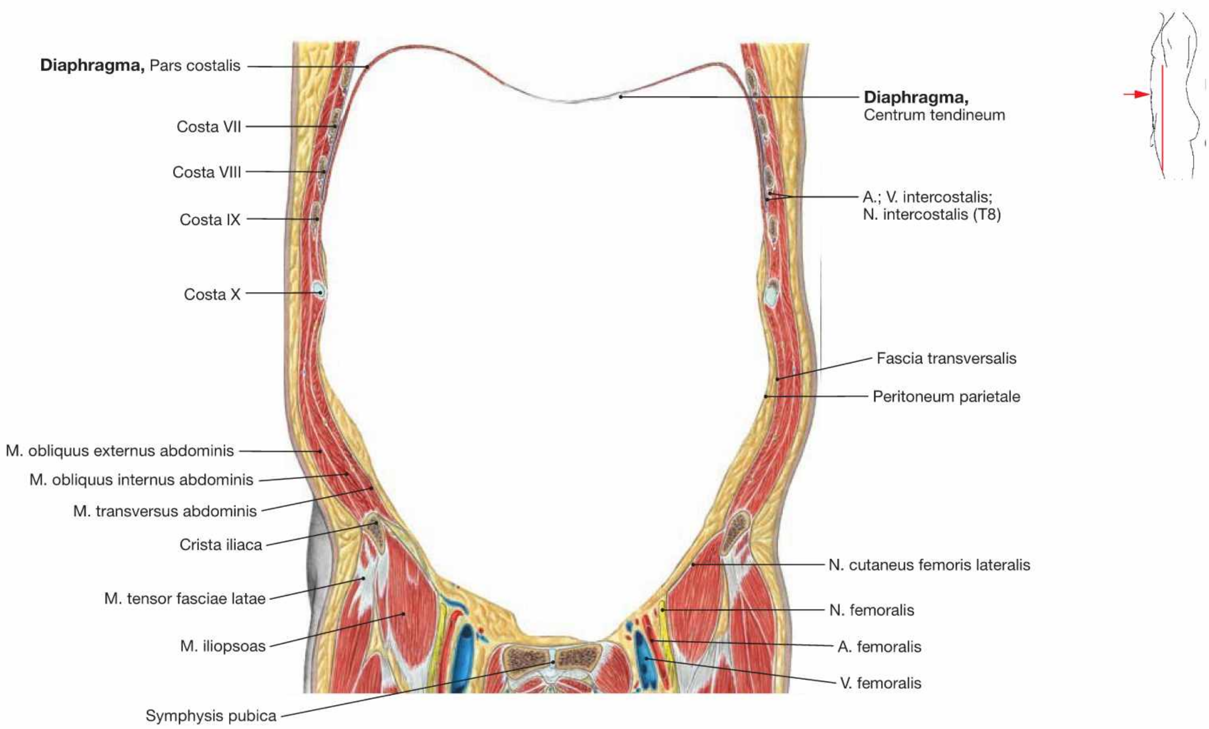
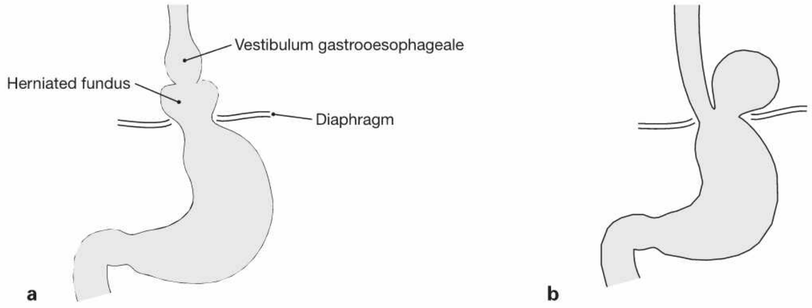


Fig. 2.102 Diaphragm, Diaphragma, and oblique muscles of the abdominal wall, Mm. abdominis; frontal section; ventral view.
The thin and dome-shaped diaphragm is shown. The Partes costales originate laterally from the XI. rib and project into the Centrum tendineum. The diaphragmatic dome positions between the 5th and 6th intercostal spaces during normal breathing. The lateral abdominal wall is composed of the oblique muscles of the abdominal wall (Mm. obliquus externus abdominis, obliquus internus abdominis, and transversus abdominis).



Figs. 2.103a and b Axial (sliding hernia) (a) and para-oesophageal hiatal hernia (b); schematic drawing. [17]

Clinical Remarks

Diaphragmatic hernias are classified as congenital (Hernia diaphragmatica spuria) and acquired (Hernia diaphragmatica vera). If the herniated organs are covered by peritoneum (hernial sac), it is called a true hernia.
The **congenital** form usually presents as a gap in the diaphragm through which abdominal organs (stomach, intestine, liver, spleen) pass into the thorax. Commonly, congenital hernias (usually occurring at the physiological weak points of the diaphragm in the Trigonum sterno- or lumbocostale [MORGAGNI's hernia]) have no hernial sac.

Acquired diaphragmatic hernias are usually sliding hernias or para-oesophageal hiatal hernias (→ Fig. 2.103). In a **hiatal hernia** the stomach partially passes through the physiologic slit-shaped opening of the diaphragm for the passage of the oesophagus (oesophageal hiatus). With an axial **sliding hernia,** the cardia is pulled through the diaphragm into the thorax.
There are also mixed forms. An especially severe form is the **upside-down stomach** (thoracic stomach, large parts of the stomach have slipped into the thoracic cavity assuming an upside-down position).

Arteries of the ventral wall of the trunk

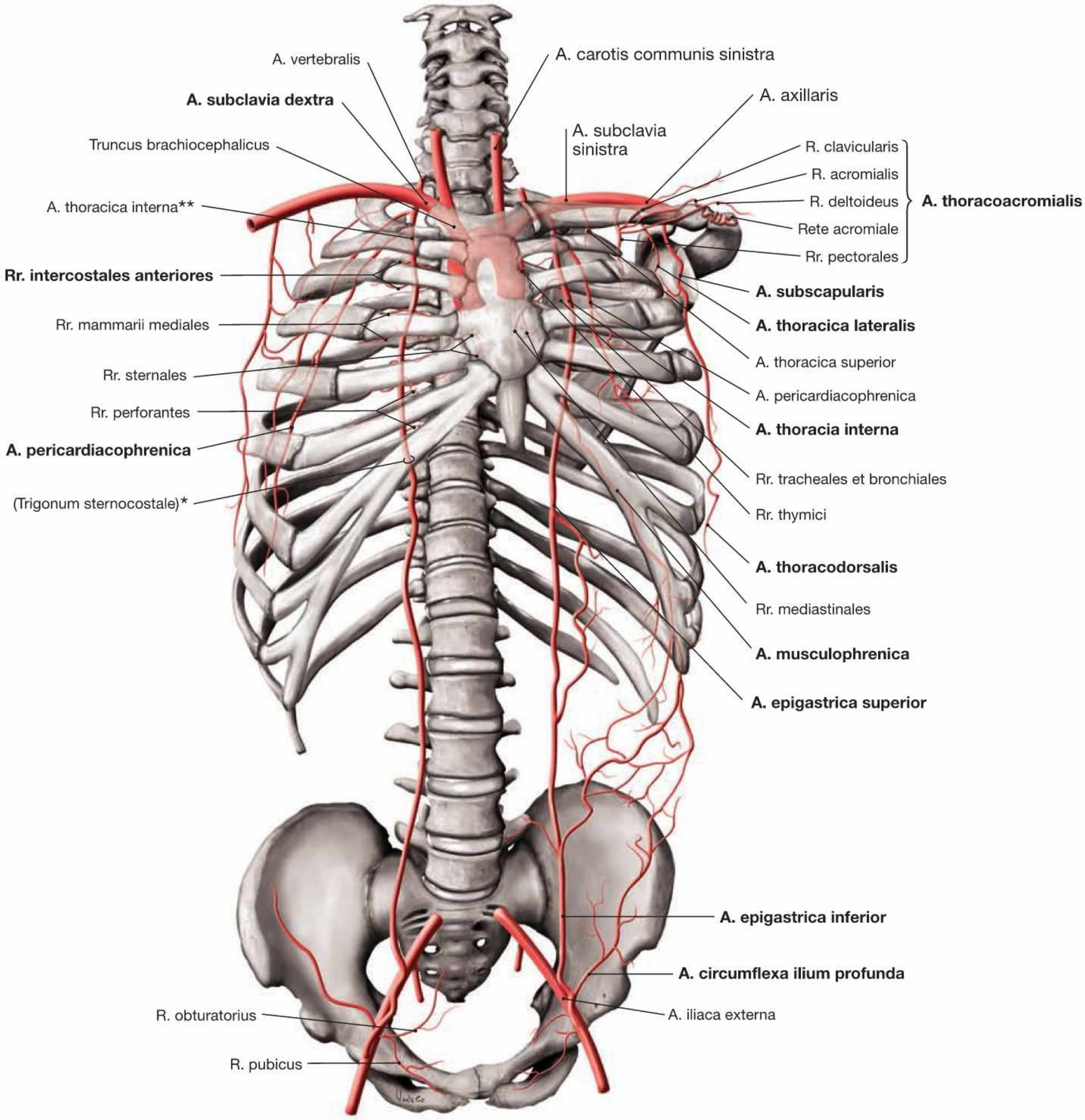


Fig. 2.104 Arteries of the ventral wall of the trunk.
The ventral wall of the trunk receives arterial blood through branches of the Aa. subclavia, axillaris, iliaca externa, and femoralis. The muscles of the abdominal wall receive blood through segmentally arranged Aa. lumbales derived from the aorta abdominalis (not shown).

* clinical term: LARREY's cleft
** 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

Arteries of the thoracic wall

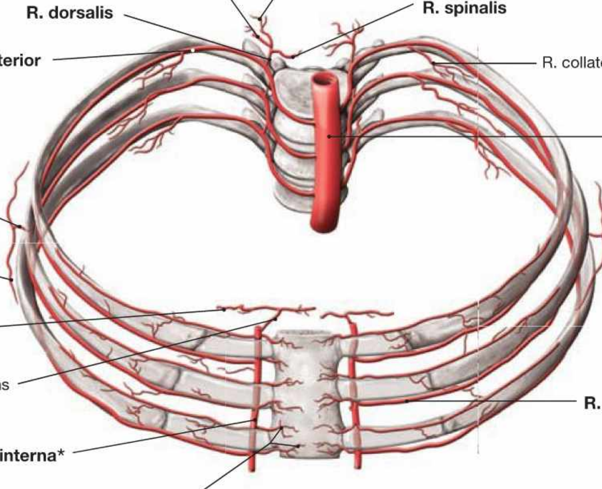


Fig. 2.105 Arteries of the thoracic wall.
The intercostal arteries create anastomoses between the A. thoracica interna and the Pars thoracica aortae.

* clinical term: A. mammaria interna

Branches of the Pars thoracicae 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, results in the formation of a vertical and a horizontal bypass circuit:

- **vertical bypass circuit:** between the Aa. subclaviae and iliacae externae via the Aa. thoracicae internae, epigastricae superiores and epigastricae inferiores (within the rectus sheath) and in the abdominal wall via the Aa. musculophrenicae, epigastricae inferiores, and circumflexae ilium profundae
- **horizontal bypass circuit:** 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 (erosions) (→ Clinical Remarks p. 47). The bypass circuits 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

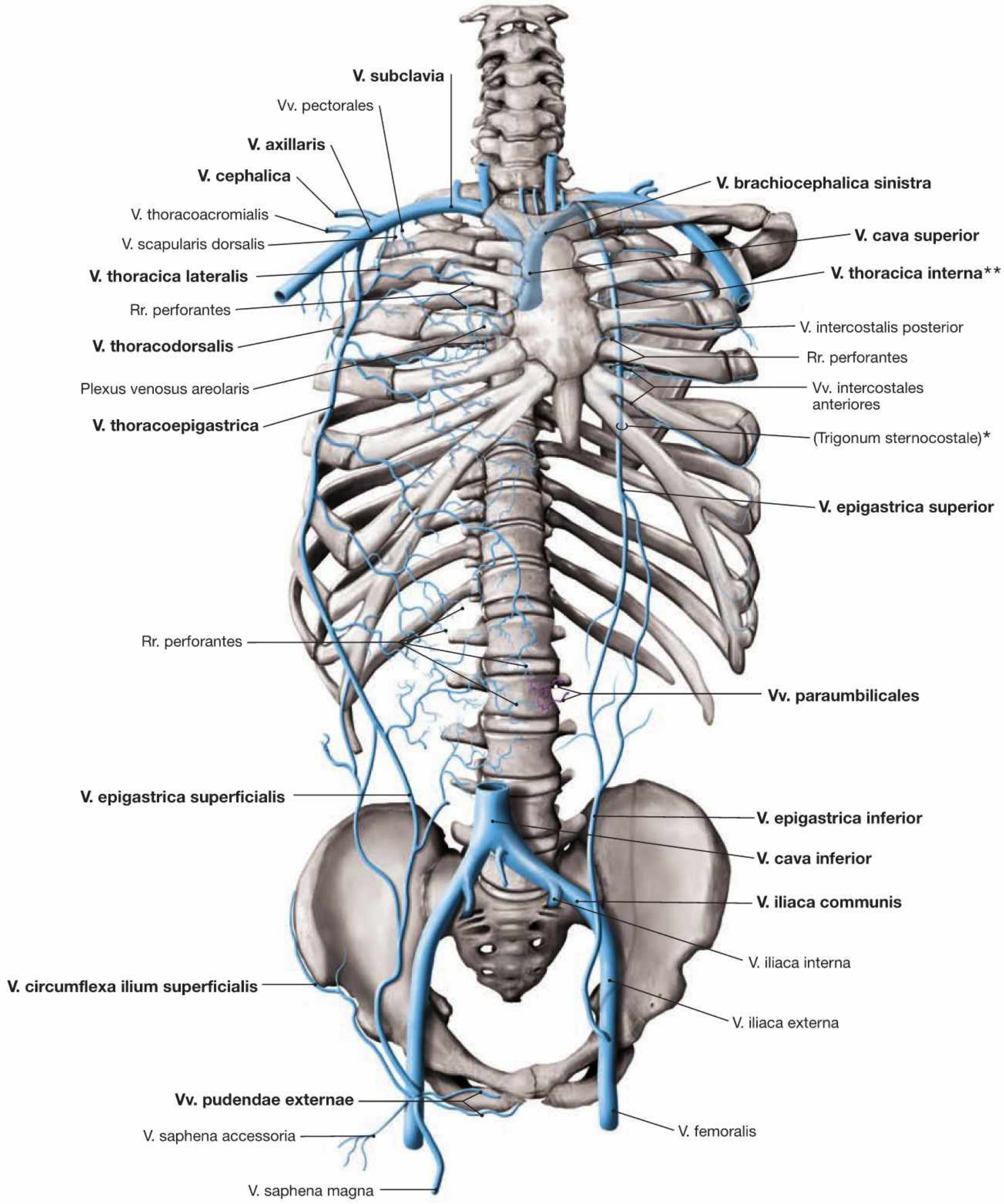


Fig. 2.106 Veins of the ventral wall of the trunk.
The veins of the ventral wall of the trunk, generate a superficial (shown on the right side of the body) and a deep (left side of the body) system of anastomoses between Vv. cavae superior and inferior.

* clinical term: LARREY's cleft
** clinical term: V. mammaria interna

Azygos system

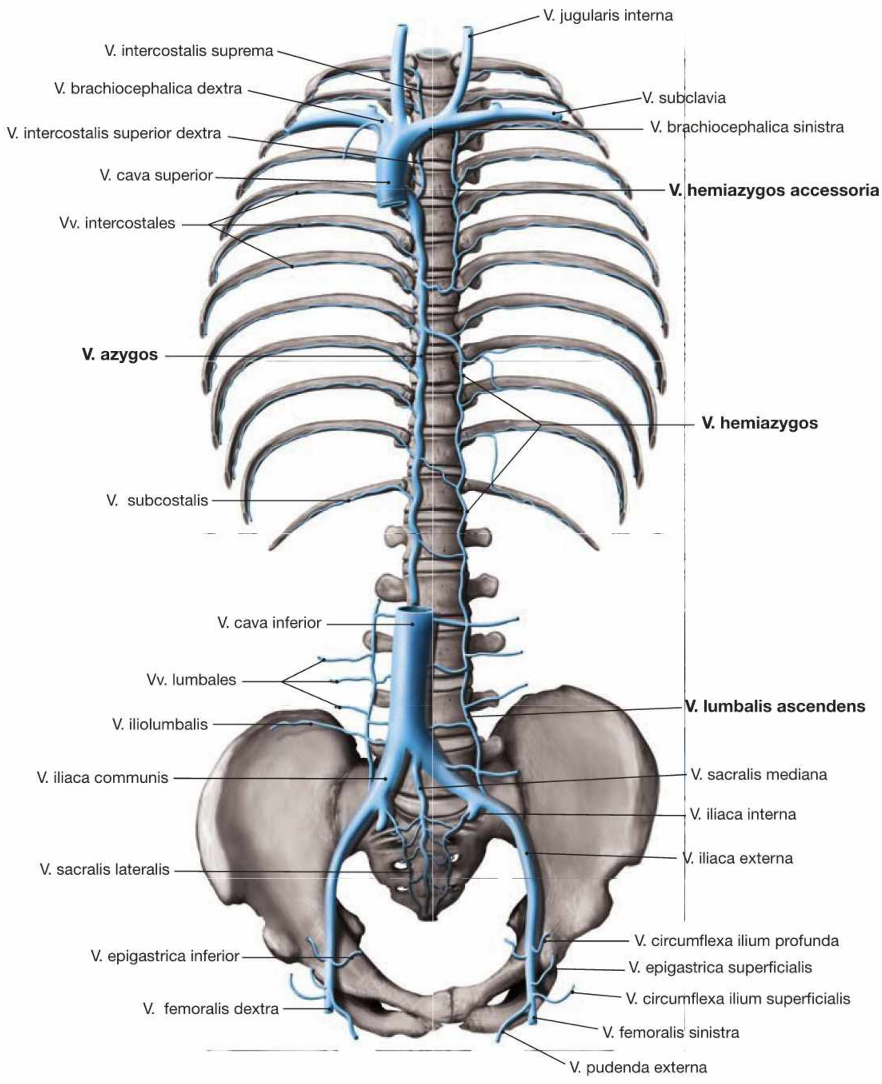


Fig. 2.107 Azygos system.
The azygos system drains blood between the V. iliaca interna and the V. cava superior. Hidden from view by the V. cava inferior, the V. lumbalis ascendens on the right side connects the V. azygos with the V. iliaca communis dextra. There are also direct connections of the Vv. lumbales ascendentes with the V. cava inferior. Integrated into this venous system are the Plexus venosus sacralis and the Plexus venosi vertebrales externi and interni as well as the Vv. lumbales.

Clinical Remarks

Venous congestion of the V. cava superior, the V. cava inferior, or Vv. iliacae communes results from a thrombosis, a mass formation and/or an invasion of tumours and can lead to the development of bypass circulation between the V. cava superior and V. cava inferior **(cavocaval anastomoses):**

- 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, V. azygos and V. hemiazygos
- between Vv. lumbales and V. cava superior via Vv. lumbales ascendentes, V. azygos and V. hemiazygos

Portocaval anastomoses (→ Fig. 6.70, Vol. 2).

Arteries and veins of the thoracic wall

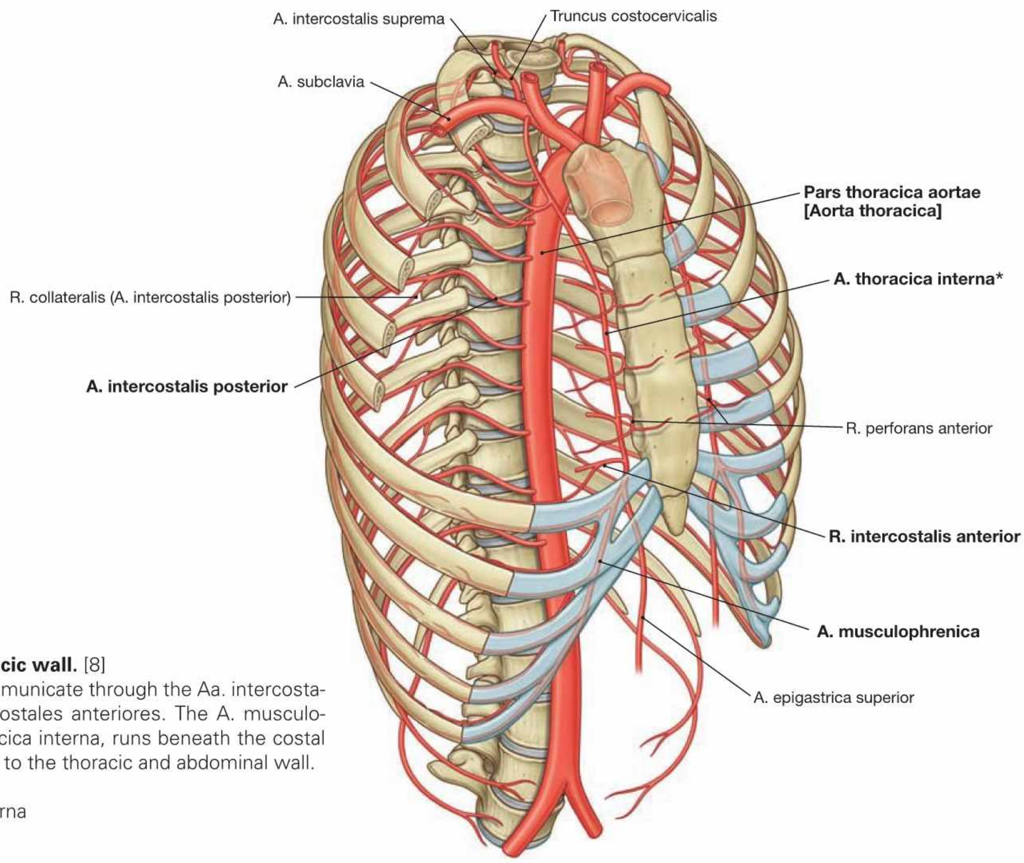


Fig. 2.108 Arteries of the thoracic wall. [8]
Aorta and A. thoracica interna communicate through the Aa. intercostales posteriores and the Rr. intercostales anteriores. The A. musculophrenica, a branch of the A. thoracica interna, runs beneath the costal arch. These vessels provide blood to the thoracic and abdominal wall.

* clinical term: A. mammaria interna

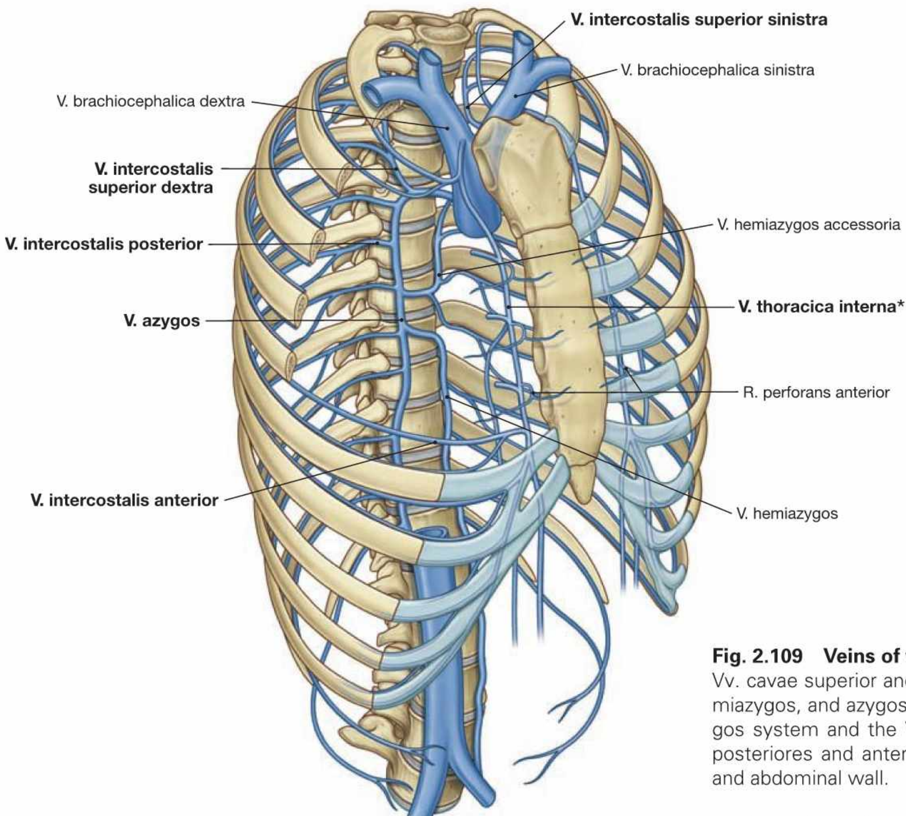


Fig. 2.109 Veins of the thoracic wall. [8]
Vv. cavae superior and inferior are connected by the Vv. lumbales, hemiazygos, and azygos. Additional anastomoses exist between the azygos system and the Vv. thoracicae internae via the Vv. intercostales posteriores and anteriores. The veins drain the blood of the thoracic and abdominal wall.

* clinical term: V. mammaria interna

Arteries and veins of the ventral wall of the trunk

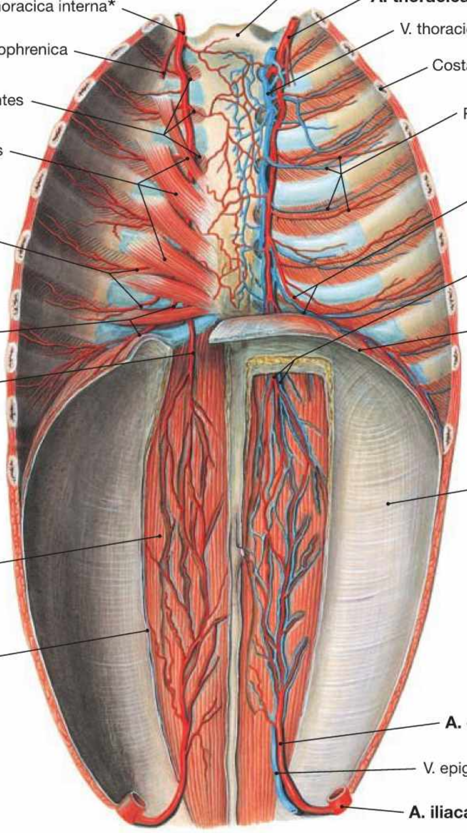


Fig. 2.110 Vessels at the posterior aspect of the ventral wall of the trunk; dorsal view.
The epigastric vessels (Vasa epigastrica superior and inferior) run at the posterior side of the M. transversus abdominis and become visible upon removal of the rectus sheath in the upper two thirds of the abdominal cavity and upon removal of the Fascia transversalis in the lower third of the abdominal cavity. The A. thoracica interna on the left side of the body is covered by the M. transversus abdominis. Upon entering the rectus sheath through the Trigonum sternocostale of the diaphragm, the A. thoracica interna becomes 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

The A. thoracica (mammaria) interna and the V. saphena magna are commonly used as grafts in coronary **bypass** surgery for revascularization of a heart with severe **coronary stenosis** (narrowing of the coronary arteries). Bypass circulation in stenosis of the aortic isthmus → page 97, cavocaval anastomoses → page 99.

Lymph vessels

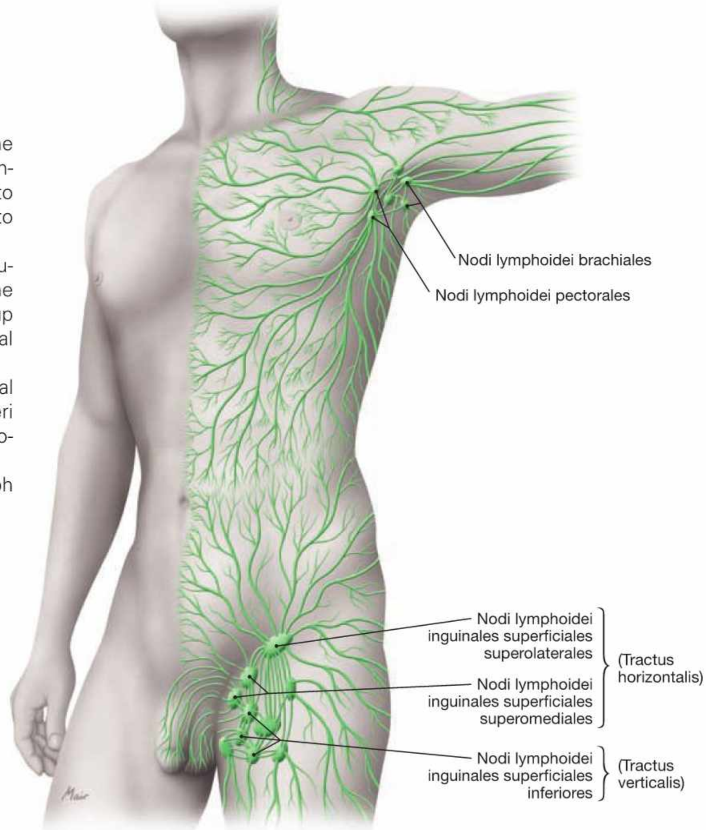


Fig. 2.111 Superficial lymph vessels and regional lymph nodes of the ventral wall of the trunk.
The **axillary lymph nodes** (Nodi lymphoidei axillares, including the Nodi lymphoidei brachiales and pectorales) collect the lymph of the entire upper extremity, of large parts of the ventral wall of the trunk up to the watershed at the level of the umbilicus, as well as of the back up to the respective watershed (→ Fig. 2.112).
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, as well as of the external genitalia (including the penis), the perineal and anal region.
In **women**, the lymph vessels of the Corpus uteri and the uterotubal junction that pass through the inguinal canal with the Lig. teres uteri (→ Fig. 2.114) drain their lymph into the superficial inguinal lymph nodes.
In **men**, the lymph of the testis is drained to the para-aortal lymph nodes (not shown).

Fig. 2.112 Superficial lymph vessels of the posterior wall of the trunk.
Above the umbilicus, the lymph is drained into the axillary lymph nodes, whereas below the umbilicus the lymph is drained into the superficial inguinal lymph nodes.

Lymph vessels

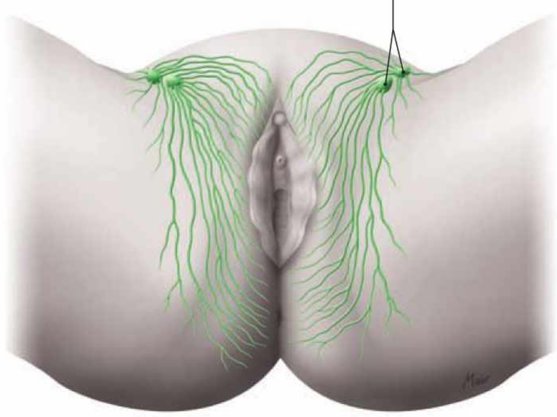


Fig. 2.113 Superficial lymph vessels and regional lymph nodes of the female external genitalia as well as the perineal and anal region; caudal view.
The lymph of external genitalia, perineum, and anal regions drains into the superficial inguinal lymph nodes. Initial lymphatic stations are the **Nodi lymphoidei inguinales superficiales superomediales.**

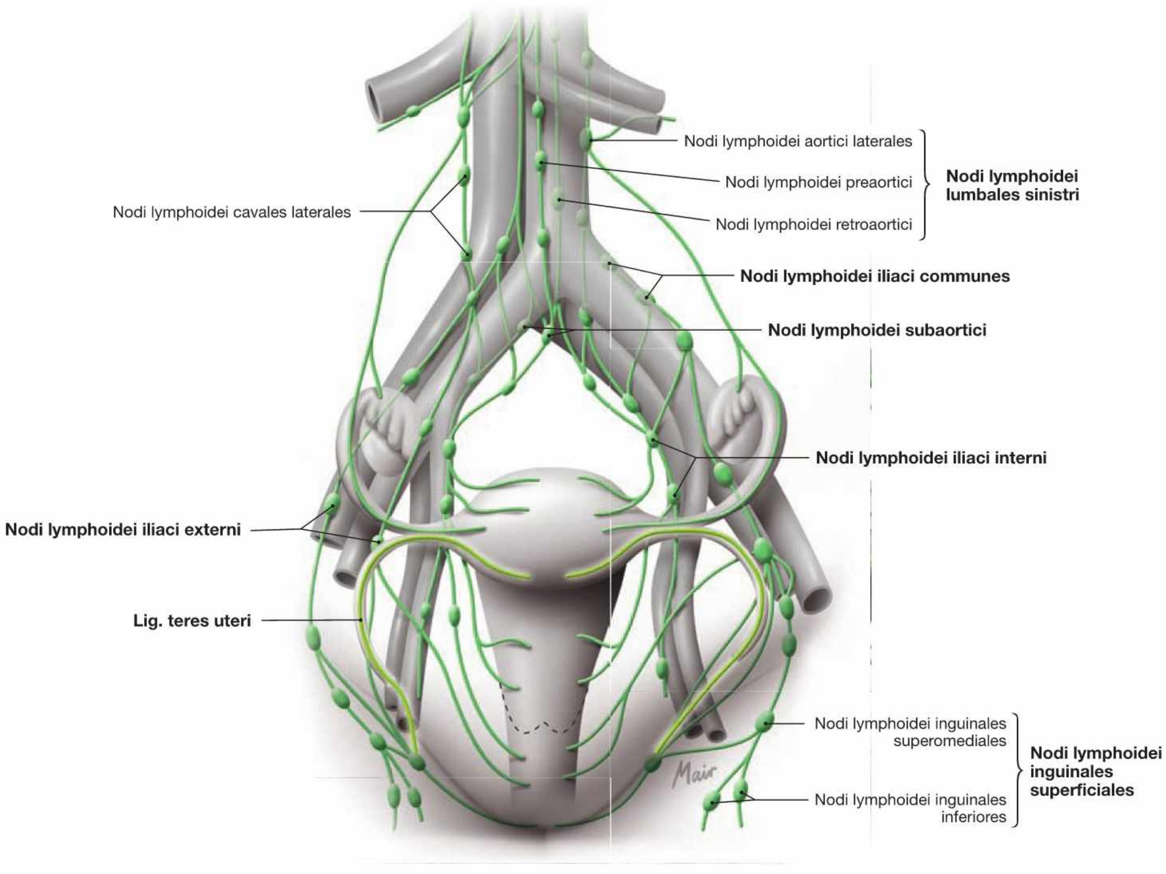


Fig. 2.114 Superficial and deep lymph vessels and regional lymph nodes of vagina, Vagina, uterus, Uterus, uterine (FALLOPIAN) tube, Tuba uterina, and ovary, Ovarium; ventral view.

- The lymph of the upper two thirds of the vagina is drained into the pelvic lymph nodes, the lower third drains into the inguinal lymph nodes.
- The lymph from the ovary, the FALLOPIAN tube, and part of the uterine fundus and corpus is drained alongside the A. ovarica, located in the Lig. suspensorium ovarii, into the Nodi lymphoidei lumbales.
- The second part of lymph from the uterine fundus, corpus, and cervix reaches the Nodi lymphoidei iliaci alongside the A. uterina.
- A third fraction of the uterine lymph from the fundus and corpus drains alongside the Lig. teres uteri into the Nodi lymphoidei inguinales superficiales (highlighted in yellow).

Clinical Remarks

Inguinal lymph nodes are of clinical significance in inflammation and malignant tumours. Their enlargement is a first indication of a pathological process located in their lymph draining tributary. In women, it is important to remember that one possible **metastatic route** from the uterus is via the lymphatic ducts along the Lig. teres uteri through the inguinal canal to the inguinal lymph nodes.

Innervation of the skin of the back

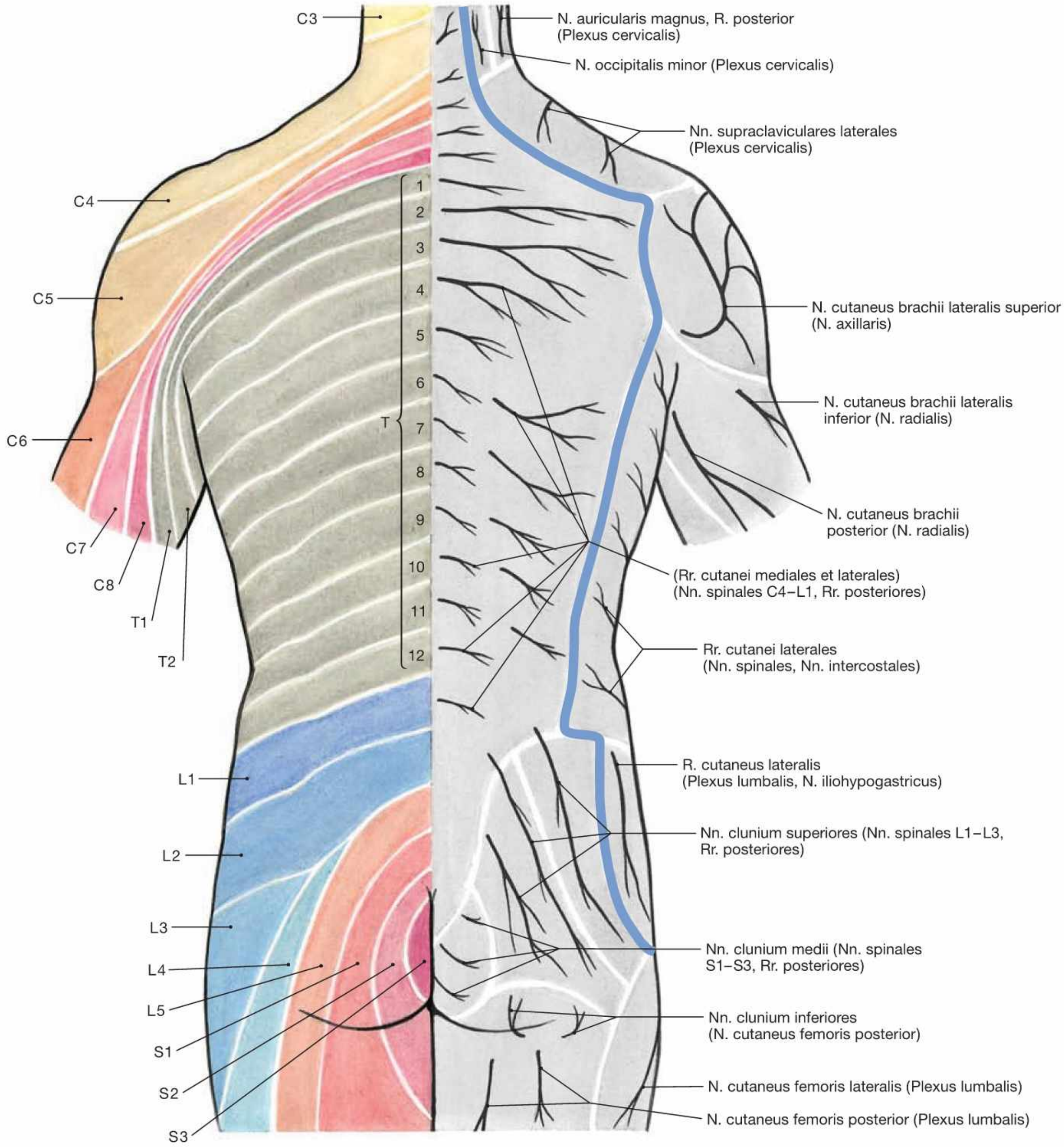


Fig. 2.115 Segmental innervation of the skin (dermatomes) and cutaneous nerves of the back; dorsal view.
Cutaneous nerves frequently receive nerve fibres from multiple spinal nerves, thus, the dermatome and the region of innervation of the cutaneous nerves differ. The dark blue line on the right indicates the demarcation between the innervation area of the Rr. posteriores (dorsales) and Rr. anteriores (ventrales) of the spinal nerves.

Vessels and nerves of the back

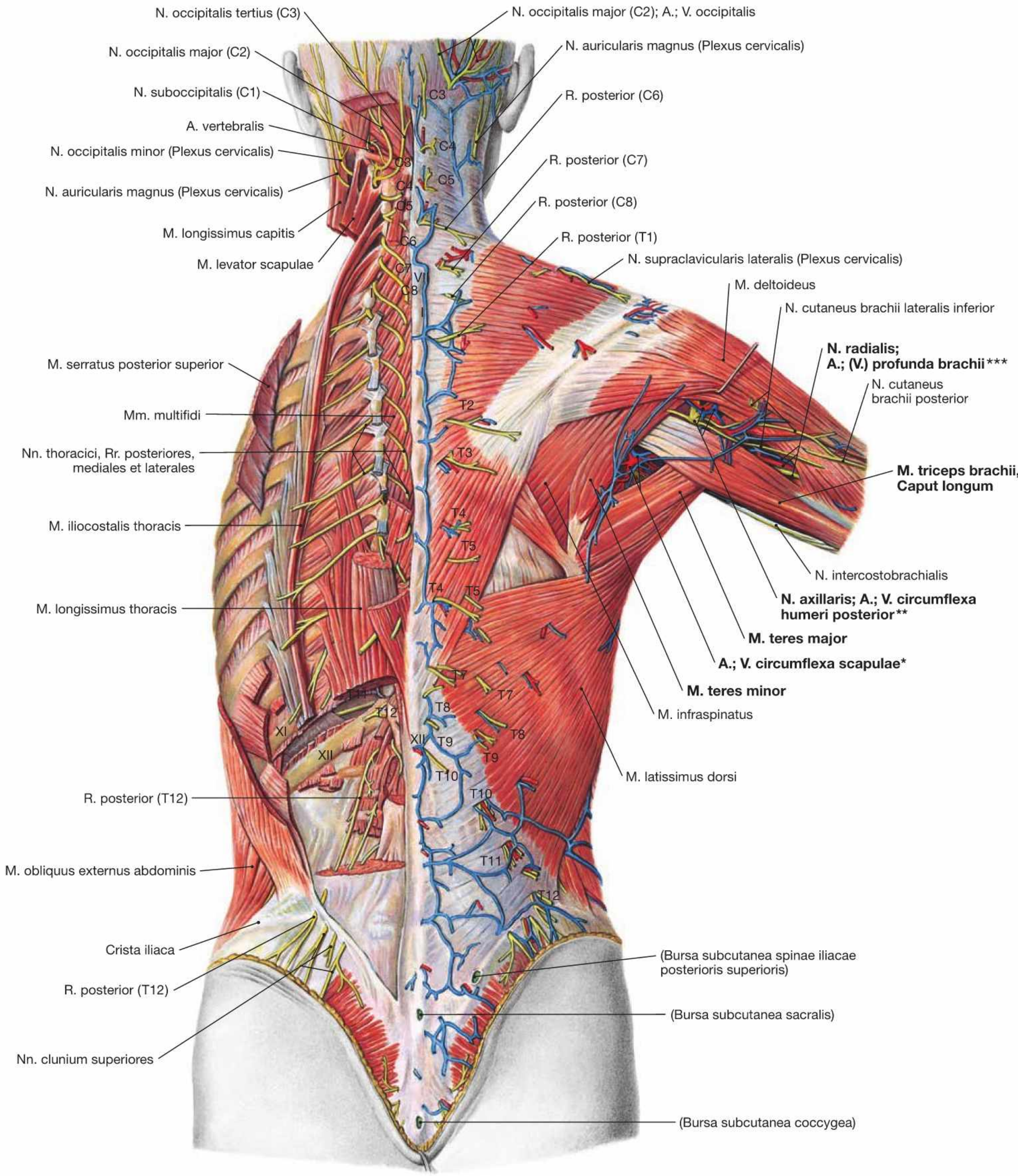


Fig. 2.116 Vessels and nerves of the back; dorsal view; superficial muscles and shoulder girdle were removed on the left side.

- vessels and nerves in the **medial axillary space** (triangular 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** (quadrangular 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 humeral shaft)
- vessels and nerves in the **triceps slit:** A. and V. profunda brachii, N. radialis (margins: cranial M. teres major, medial Caput longum of the M. triceps brachii, lateral humeral shaft)

* vessels and nerves in the triangular axillary space
** vessels and nerves in the quadrangular axillary space
*** vessels and nerves in the triceps slit

Vessels and nerves of the neck

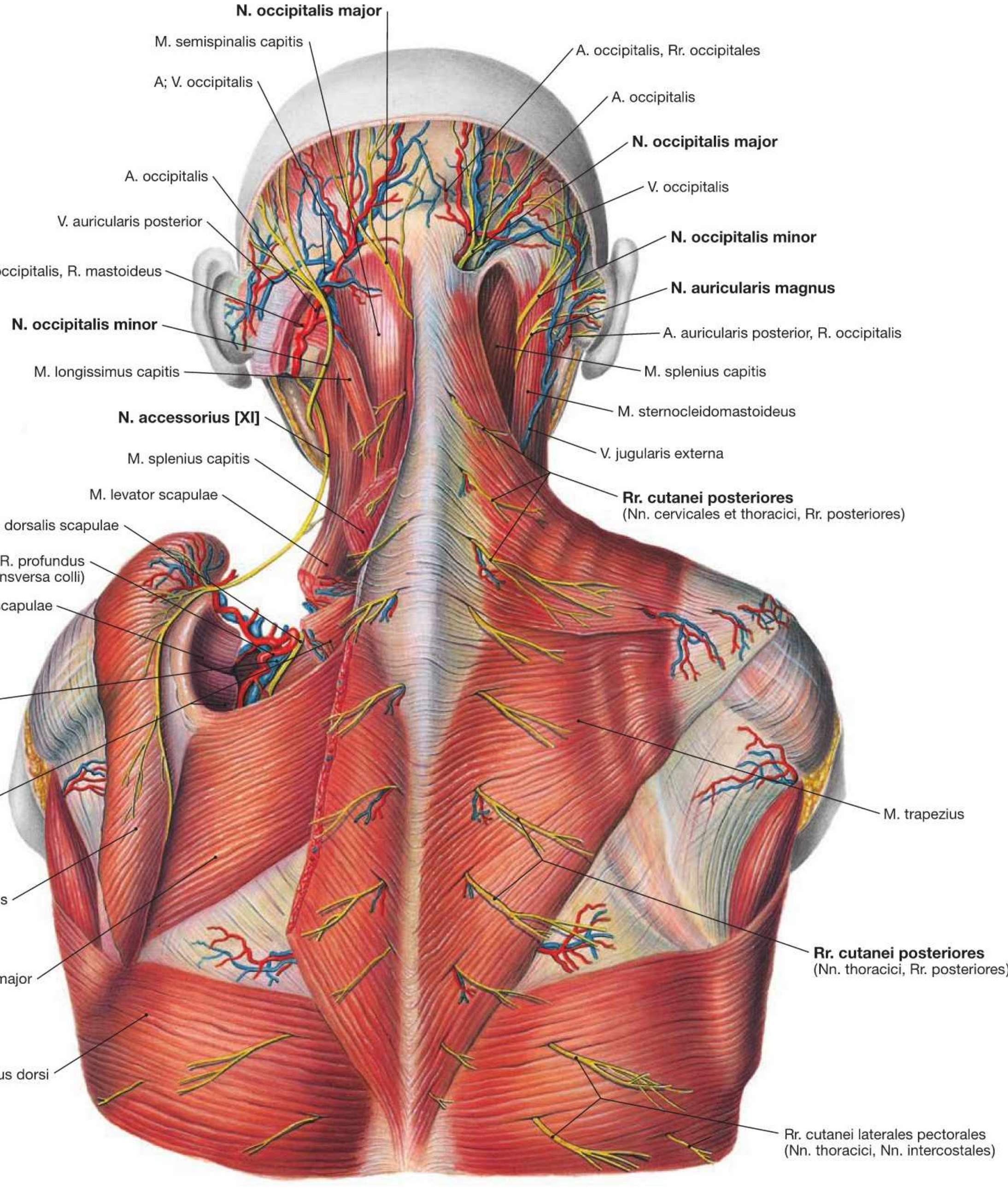


Fig. 2.117 Vessels and nerves of the occipital region, Regio occipitalis, posterior neck, Regio cervicalis posterior [(Regio nuchalis)], and upper region of the back; dorsal view.
Up to the scapular line, the skin of the back receives segmental innervation by the Rr. posteriores [dorsales] of the spinal 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 of the Rr. posteriores [dorsales]). The N. occipitalis minor derives from the Plexus cervicalis (Rr. anteriores [ventrales]) and is part of the Punctum nervosum (ERB's nerve point). The course of the N. accessorius [XI] in the neck and shoulder region is also shown.

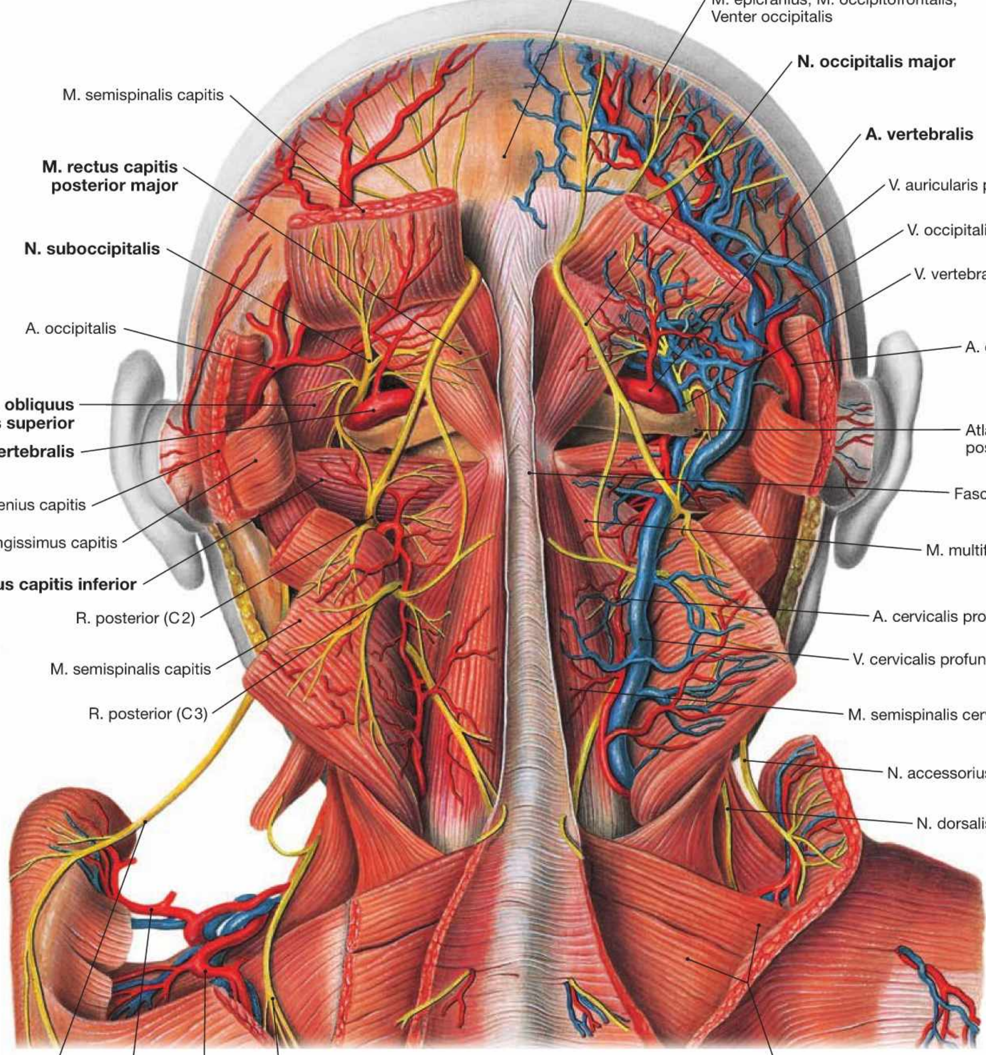


Fig. 2.118 Vessels and nerves of the occipital region, Regio occipitalis, and posterior neck, Regio cervicalis posterior; dorsal view.

To demonstrate the deep neurovascular tracts, the Mm. trapezius, sternocleidomastoideus, splenius capitis, and semispinalis capitis were detached and partially removed. On both sides of the posterior aspect of the neck the short neck muscles (Mm. recti capitis posterior minor and major as well as the Mm. obliqui capitis superior and inferior) are shown. These muscles create the margins of the **vertebralis triangle** (Trigonum arteriae vertebralis). Besides arteries and veins, the Nn. occipitalis major and suboccipitalis as well as the Nn. accessorii [XI] are shown.

Nerves of the neck and the deep posterior cervical region

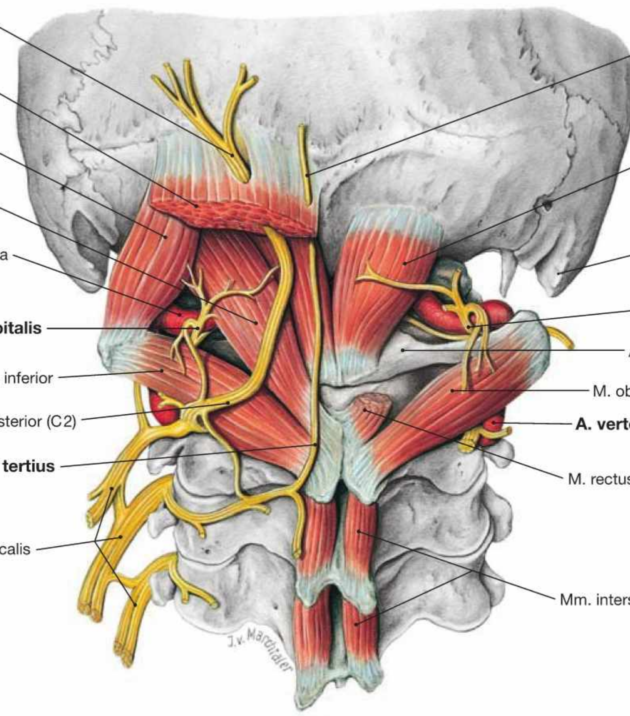


Fig. 2.119 Nerves of the posterior neck, Regio cervicalis posterior; dorsal view.
The **N. occipitalis major** represents the R. posterior from C2 and projects into the occipital region. The R. posterior from C3 projects cranially as **N. occipitalis tertius** into the Lig. nuchae. Ascending from the vertebralis triangle, which harbours the A. vertebralis, the R. posterior from C1 innervates the short neck muscles as **N. suboccipitalis**.

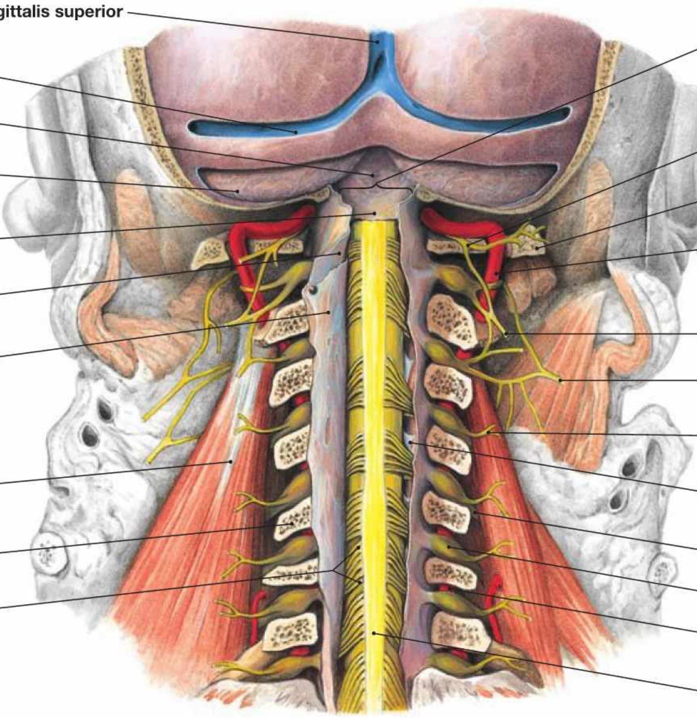


Fig. 2.120 Vessels and nerves of the deep posterior neck, Regio cervicalis posterior, and content of the vertebral canal; dorsal view.
The vertebral canal was accessed from dorsal and the occipital bone is removed to view the Dura mater with opened Sinus sagittalis superior and Sinus transversus.
The ascending part of the **A. vertebralis** between the cervical vertebrae can be seen.

Cauda equina and lumbar puncture

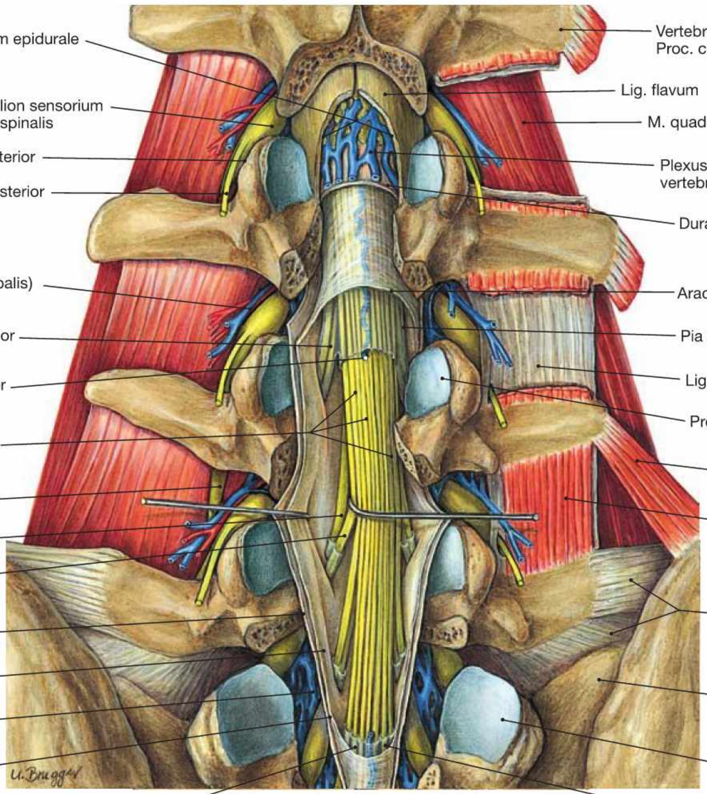


Fig. 2.121 Vessels and nerves of the opened vertebral canal of the lumbar section of the vertebral column, Regio lumbalis; dorsal view.

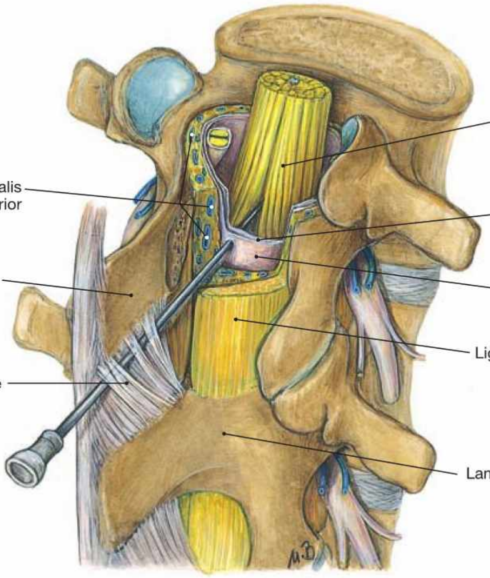


Fig. 2.122 Lumbar puncture, direction of the puncturing needle.

Clinical Remarks

To obtain cerebrospinal fluid for diagnostic purposes or to administer drugs into the subarachnoid space, a **lumbar puncture** is performed below the 2nd lumbar vertebra, usually between the Proc. spinosus of L3/L4 or L4/L5, to prevent spinal cord injuries. At the same level lies the Cauda equina; here, the subarachnoid space is the widest (lumbar cistern). The puncture needle is inserted through the Ligg. supraspinale and interspinale, the epidural space, the Dura mater, and the arachnoid until the needle enters the subarachnoid space (→ Fig. 2.122).

Spinal nerve and Foramen intervertebrale

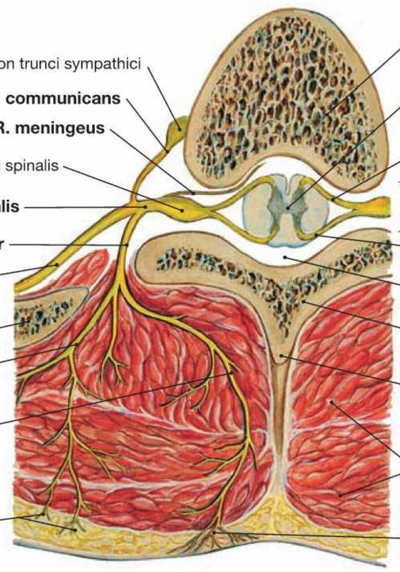


Fig. 2.123 Spinal nerve, N. spinalis, in the thoracic region; caudal view.
The stem of the spinal nerve is only a few millimeters long (Truncus nervi spinalis) and is created by the merger of the Radices anterior and posterior. The Truncus divides into the larger R. anterior (in the thoracic region as N. intercostalis) and the smaller R. posterior. The latter divides into a medial (R. medialis) and lateral (R. lateralis) branch which innervate the autochthonous muscles of the back (Mm. dorsi) and, with their terminal ends, provide cutaneous innervation of the back (Rr. cutanei medialis and lateralis). The R. communicans is the connection between the spinal nerve and the sympathetic trunk (Truncus sympathicus). The R. meningeus of the spinal nerve projects back into the vertebral canal and innervates the ligaments of the vertebral column and the meningeal membranes covering the spinal cord. The N. intercostalis runs along the underside of the rib (not shown) in a ventral direction, innervates the Mm. intercostales externi and interni, and provides Rr. cutanei lateralis and anterior for the innervation of the skin.

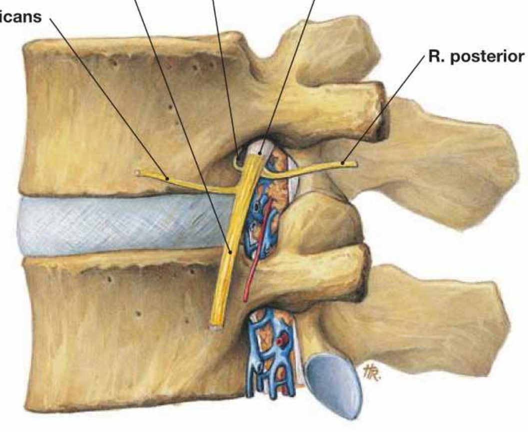


Fig. 2.124 Spinal nerve, N. spinalis, in the lumbar region of the vertebral column; view from the left side. [1]
Upon its passage through the Foramen intervertebrale, the spinal nerve divides into the Rr. anterior, posterior, meningeus, and communicans.

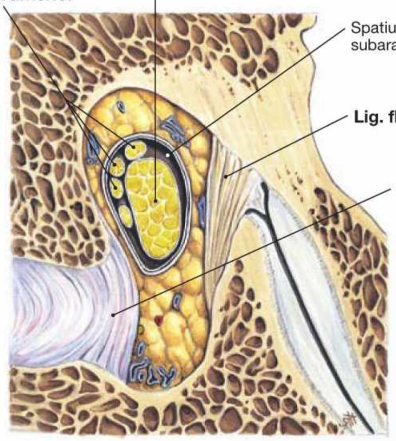


Fig. 2.125 Spinal nerve, N. spinalis, in the lumbar region of the vertebral column; sagittal section at the level of the Foramen intervertebrale; view from the left side. [1]
At the level of the Foramen intervertebrale the Radices anterior and posterior have not yet merged to form the spinal nerve. They are still surrounded by the Dura and immersed in cerebrospinal fluid. Shown are the ventrally located Discus intervertebralis and the dorsally located Lig. flavum with the adjacent zygapophyseal joint.

Clinical Remarks

Posterolateral disc herniations, spondylophytes, or tumours can lead to a **narrowing of the intervertebral foramina** with compression of the spinal nerve roots which results in deficits of nerve functions.

Spinal nerve

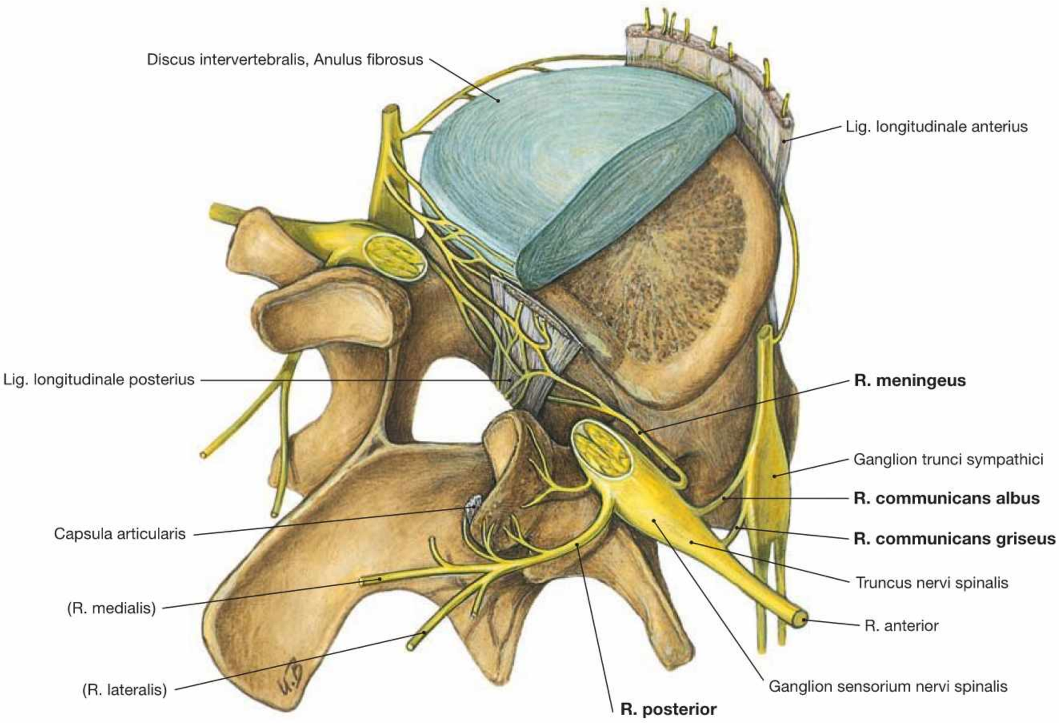


Fig. 2.126 Nerves of the vertebral column, Columna vertebralis; view from the right side in an oblique angle.

Branches of the spinal nerve are shown which project to adjacent structures. These include the **R. meningeus** for the sensory innervation of the meningeal membranes of the spinal cord, smaller branches derived from the **R. posterior** for the Capsula articularis of the zygapophyseal joints, and the Rr. communicantes albus and griseus connecting with the Truncus sympathicus.

The **R. communicans albus** contains preganglionic sympathetic fibres from the lateral column of the spinal cord for the Truncus sympathicus. The **R. communicans griseus** contains postganglionic sympathetic fibres of the sympathetic trunk which project back to the spinal nerve. Autonomic nerve fibres from the sympathetic trunk innervate the Disci intervertebrales and ligaments of the vertebral column.

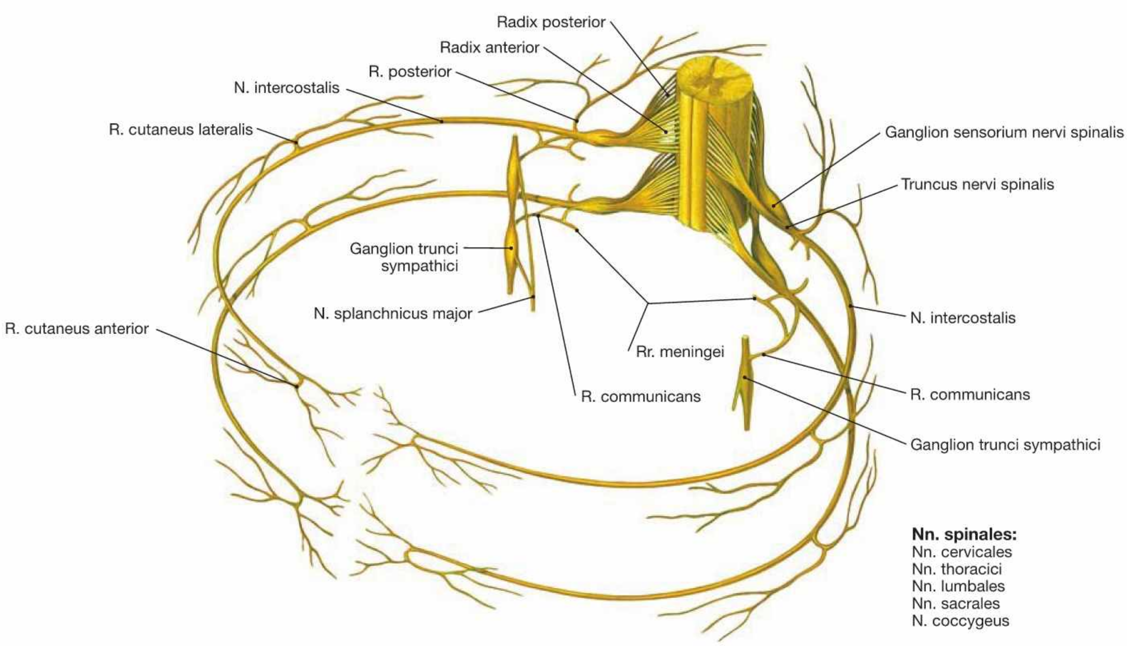


Fig. 2.127 Structure of a spinal nerve, N. spinalis, and spinal cord segment, exemplified by two thoracic nerves, Nn. thoracici; oblique superior view.

Each spinal nerve is composed of 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 the fibres enter the spinal cord via the dorsal root. Rr. communicantes connect the spinal cord with the chain of ganglia of the Truncus sympathicus (Ganglion trunci sympathici). The dorsal branches of the spinal nerves are arranged in a segmental order; with the exception of the intercostal nerves 2 to 11, the other ventral branches create plexus.

Blood vessels and nerves of the vertebral canal

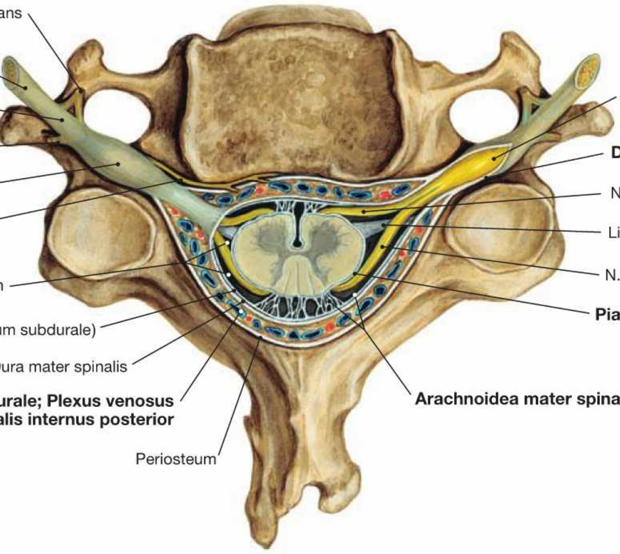


Fig. 2.128 Content of the vertebral canal, Canalis vertebralis; cross-section at the level of the 5th cervical vertebra; cranial view.
The spinal cord is surrounded by the Dura, the Arachnoidea and the Pia mater spinalis and immersed in cerebrospinal fluid in the subarachnoid space (Spatium subarachnoideum). In the vertebral canal, this dural tube and the exiting roots of the spinal nerves are surrounded and protected by adipose tissue with embedded venous plexus (Plexus venosus vertebralis internus anterior and posterior) and nourishing blood vessels.
See epidural anaesthesia ⟶ page 331, Vol. 3.

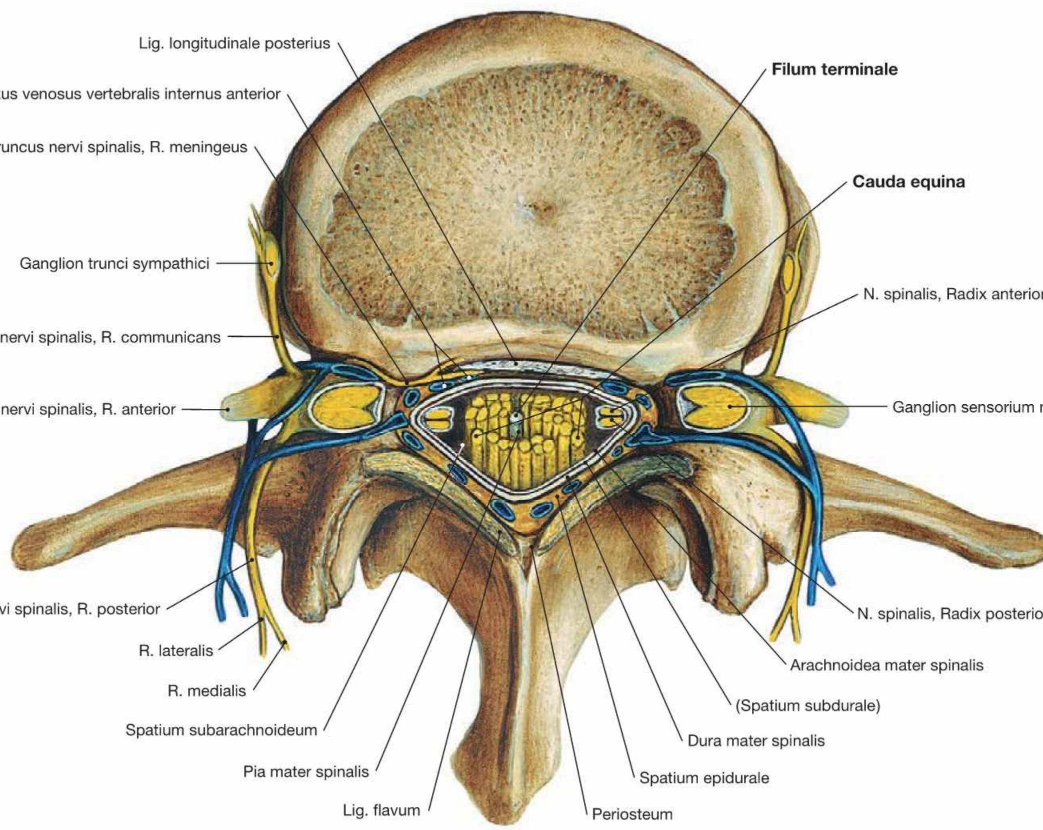


Fig. 2.129 Content of the vertebral canal, Canalis vertebralis; cross-section at the level of the 3rd lumbar vertebra; cranial view.
Below the 1st/2nd lumbar vertebra and before exiting the vertebral canal, nerve roots from L2 onwards, including the N. coccygeus, run caudally as a loose bundle of fibres surrounded by the dural sac. This entire collection of nerve roots is named Cauda equina. Located in between the nerve fibres and originating from the Conus medullaris of the spinal cord is the thin and thread-like Filum terminale.
See lumbar puncture ⟶ pages 109 and 331, Vol. 3.

Vessels and nerves of the vertebral canal

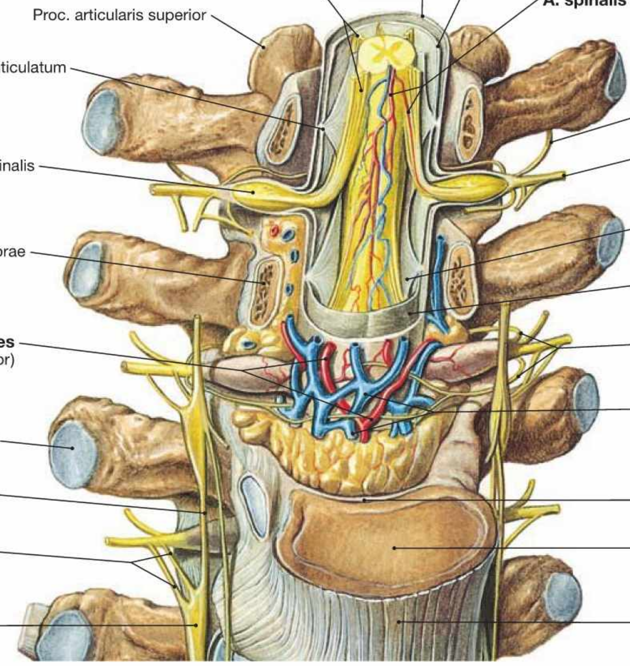


Fig. 2.130 Thoracic region of the vertebral column with spinal cord, Medulla spinalis, and sympathetic trunk, Truncus sympathicus; ventral view.
The Spatium epidurale is shown which surrounds the vertebral canal with its meninges. It contains the Plexus venosus vertebralis internus anterior and the Rr. spinales of the A. intercostalis posterior embedded in adipose tissue. The A. spinalis anterior runs on top of the spinal cord.

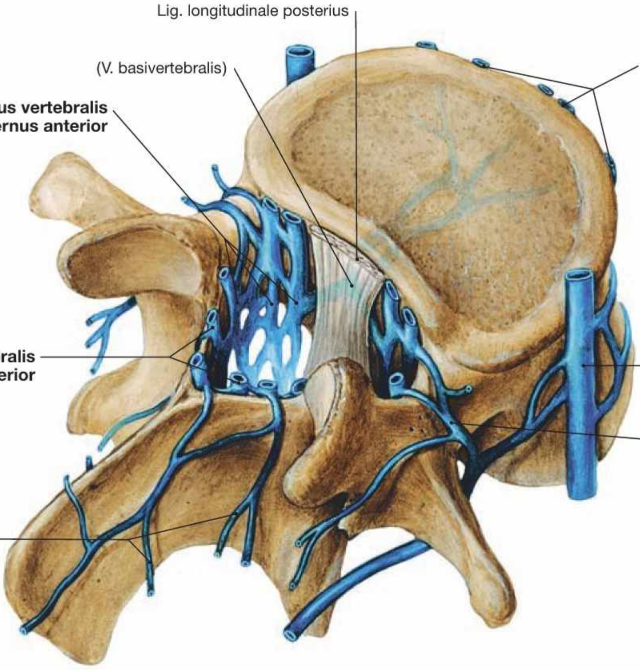
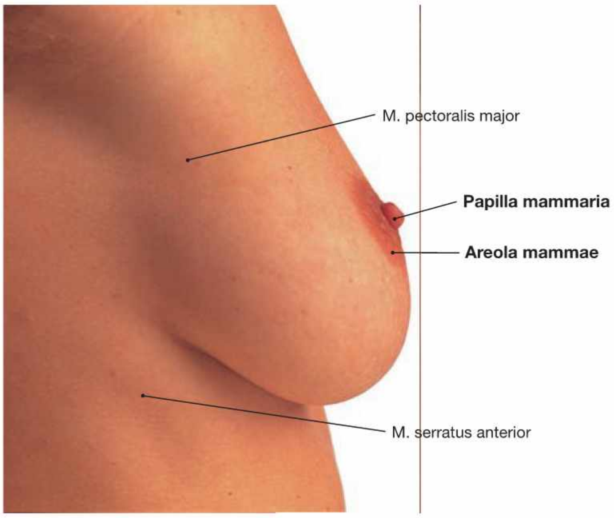


Fig. 2.131 Veins of the vertebral canal, Canalis vertebralis; view from the right side in an oblique dorsal angle.
The vertebral canal is filled with a dense network of veins which form the **Plexus venosi vertebrales interni anterior and posterior.** Located in the Spatium epidurale, this venous plexus covers the meninges which surround the spinal cord and the Cauda equina. The two plexus are connected with the **Plexus venosus vertebralis externus posterior** via Vv. intervertebrales. The latter plexus drains the blood (in the lumbar region of the vertebral column) into the paravertebral Vv. lumbales ascendentes (in the thoracic region of the vertebral column run the Vv. azygos, hemiazygos, and hemiazygos accessoria). These veins also collect blood from the **Plexus venosus vertebralis externus anterior** which drains the anterior side of the vertebral bodies and the intervertebral discs.

Overview and development



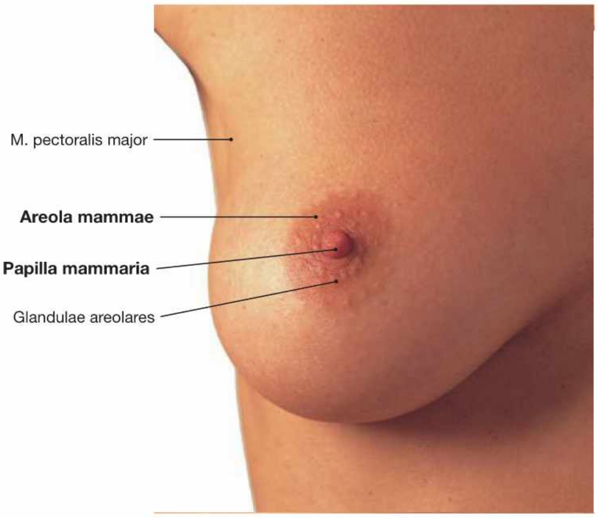


Fig. 2.132 Breast, Mamma; lateral view.

Fig. 2.133 Breast, Mamma; ventral view.

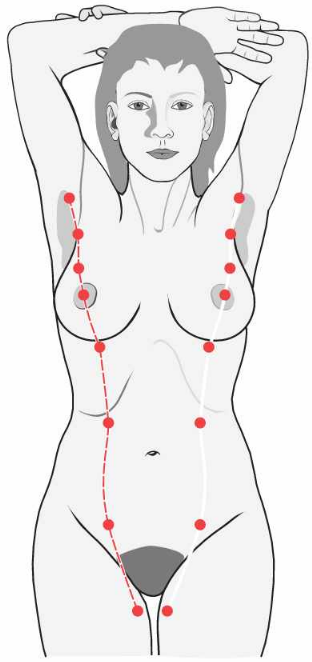


Fig. 2.134 Milk line.
The development of the mammary gland initiates in the milk line (mammary ridge), a strip of thickened surface ectoderm formed in embryonic week 6 that extends from the axillary pit to the inguinal region. With the exception of the area above the M. pectoralis major, the location for the development of the future breast (Mamma), the rest of the milk line normally regresses.

Clinical Remarks

The absence of the nipples **(athelia)** or breasts **(amastia, mammary aplasia)** are rare congenital anomalies that can occur uni- or bilaterally. Supernumerary nipples or breasts are called **polythelia** or **polymastia,** respectively. This is usually hereditary and can also affect men.
Typically, the rudimentary glandular tissue in male breasts does not develop further after birth. When breast growth occurs in men (possibly due to hormonal disorders), this condition is called **gynecomastia**.
Some female breasts are too large **(mammary hypertrophy),** which can be associated with shoulder and back pain. In such cases, a breast reduction surgery is indicated. Too small breasts or the absence of breasts can necessitate breast augmentation with surgical insertion of silicone prostheses.

Female breast

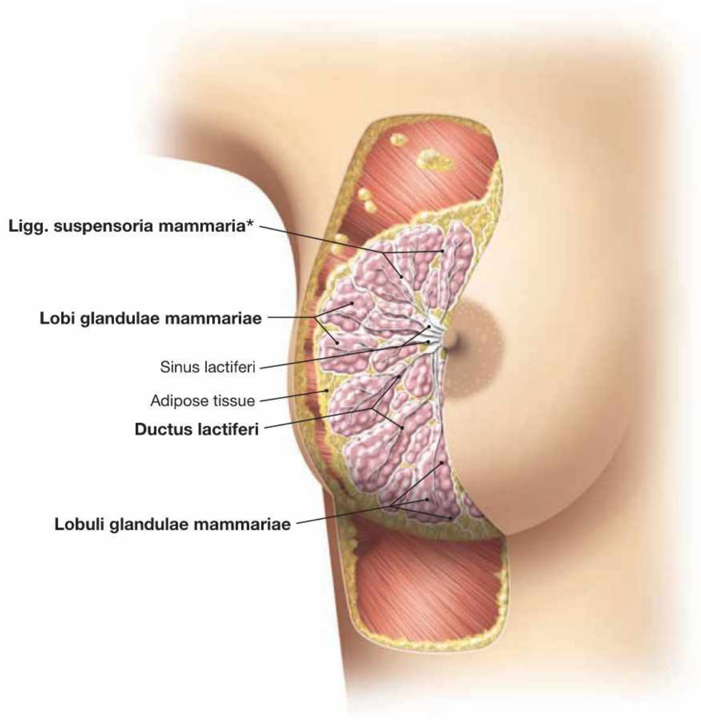


Fig. 2.135 Breast, Mamma; ventral view.
The breast is composed of the mammary gland (Glandula mammaria) and a fibrous stroma filled with adipose tissue. The breast has up to 20 individual glands (Lobi), each possessing a separate efferent lactiferous duct opening onto the mammary nipple (Papilla mammaria). The branched lactiferous ducts terminate in groups of alveoli (Lobuli). During pregnancy, the glandular tissue transforms into the lactating breast.

* clinical term: COOPER's ligaments

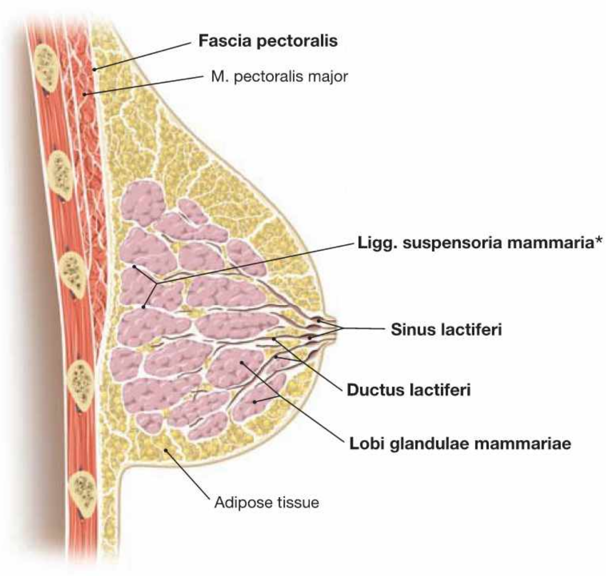


Fig. 2.136 Breast, Mamma; sagittal section.
Strong ligaments (Ligg. suspensoria mammaria, COOPER's ligaments) derived from the Fascia pectoralis of the M. pectoralis major support the breast in its normal position.

* clinical term: COOPER's ligaments

Blood supply and lymphatic drainage

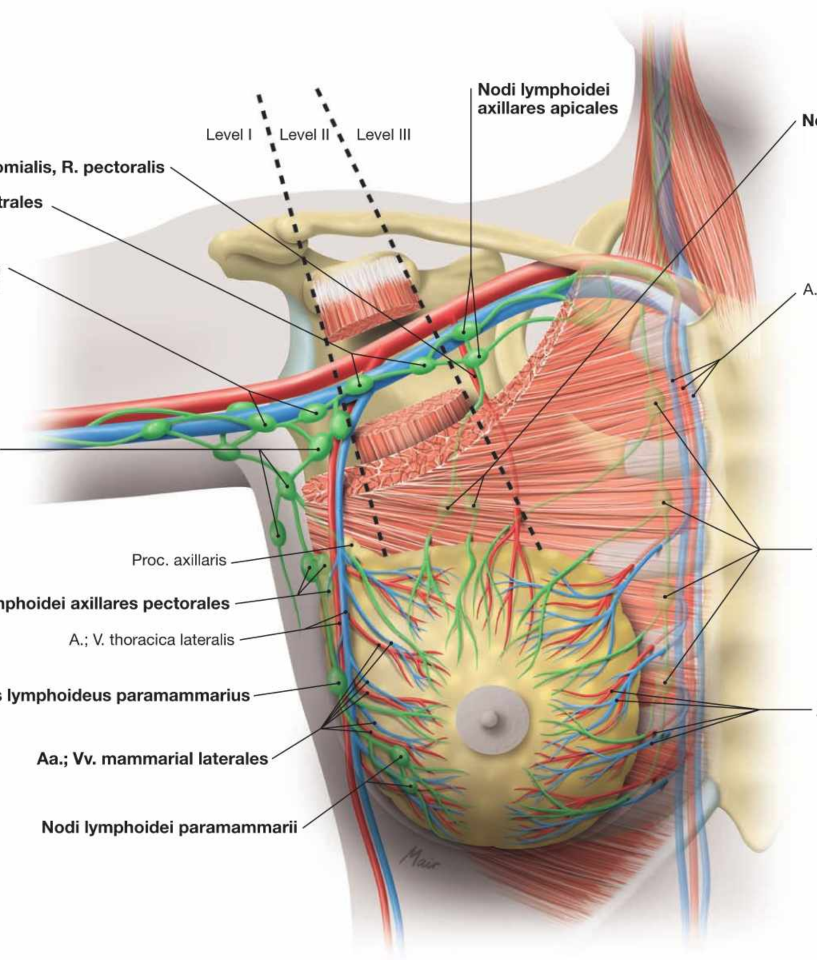


Fig. 2.137 Blood supply of the female breast, lymphatic drainage passages of the female breast, and location of regional lymph nodes.
The approximately 40 axillary lymph nodes do not just filter the lymph of almost the entire upper extremity but also collect two thirds of the lymph from the Mamma and the major part of the lymph fluids derived from the thoracic and upper abdominal wall. The **Truncus subclavius** collects the lymph of the axillary lymph nodes and drains it into the **Ductus lymphaticus dexter** and the **Ductus thoracicus** (not shown) on the right and left side, respectively.

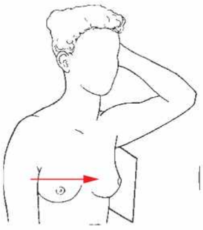
* clinical term: ROTTER's lymph nodes

Clinical Remarks

From a clinical topographic and oncosurgical viewpoint, lymph nodes of the female breast are categorized into three levels. The M. pectoralis minor acts as a boundary:

- Level I lies lateral to the M. pectoralis minor.
- Level II lies caudal to the M. pectoralis minor.
- Level III lies medial to the M. pectoralis minor.

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



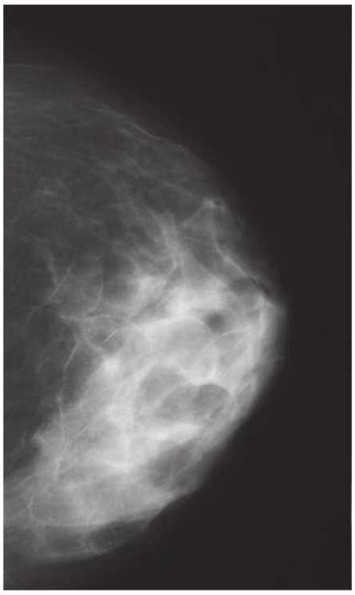


Fig. 2.138 Radiograph of the Mamma (mammography) of a 47-year-old woman.
Mammography is a radiological examination used for the early diagnosis of mammary carcinoma, the most frequent tumour in women.

Fig. 2.139 Radiograph of a Mamma (mammography) of a 23-year-old woman. [19]
Normal mammary parenchyma shows poorly demarcated white condensations primarily located beneath the region of the nipple (Mammilla). In young women, breast tissue can be extremely dense due to scarcely distributed adipose tissue.

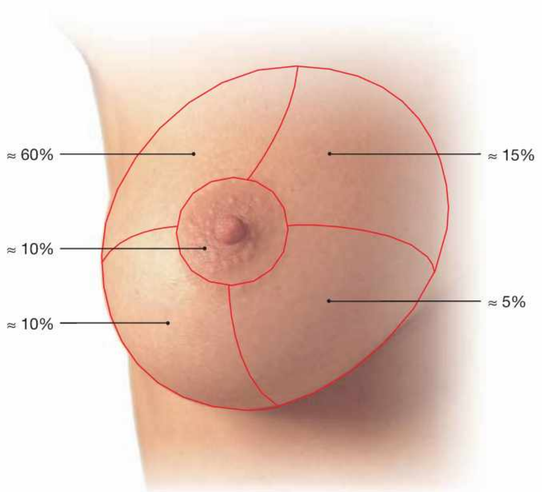


Fig. 2.140 Frequency of mammary carcinoma in relation to the location in percentage.

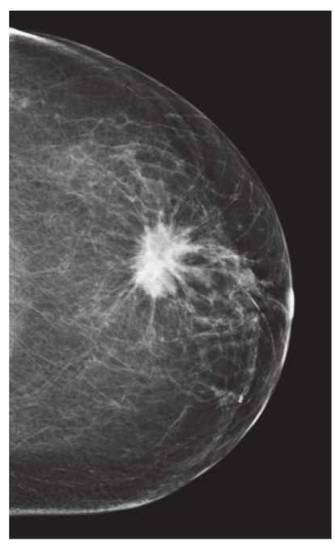


Fig. 2.141 Mammography of a malignant breast cancer.

Clinical Remarks

In Europe, **breast cancer** mortality ranges from 12–19% of all female cancer deaths. Thus, breast cancer is the leading cause of cancer deaths in most countries of the European Union, followed by lung and colorectal 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. 2.140). Breast carcinoma originating mostly from the epithelium of the Ductus lactiferi (ductal carcinoma) metastasizes mainly into the axillary lymph nodes, less often into retrosternal (parasternal) lymph nodes.

The first lymph node located in the lymph drainage tributary and to receive lymph is referred to as **sentinel (= the one that keeps guard) lymph node** which is usually also the first lymph node of metastatic colonization. The number of affected lymph nodes in the three hierarchical levels is directly related to the survival rate. Breast cancer of the medial quadrants can metastasize via the interconnected parasternal lymph nodes to the contralateral side.

Innervation of the skin of the thoracic and abdominal wall

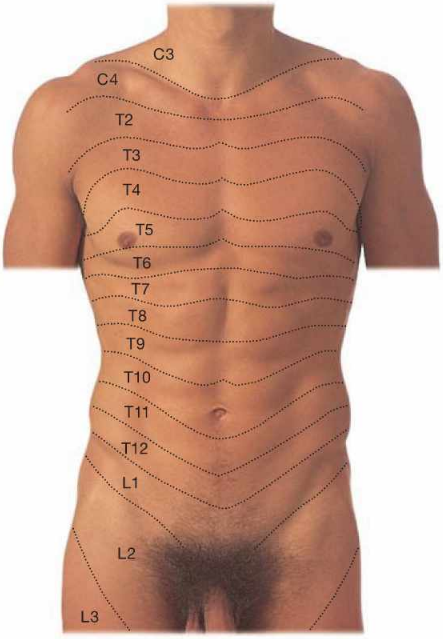


Fig. 2.142 Segmental sensory innervation of the ventral thoracic and abdominal wall (dermatomes).
Skin regions receiving sensory fibres from a single spinal nerve are named dermatomes. The mammilla is located within dermatomes T4 to T5; the umbilicus is located in dermatome T10.

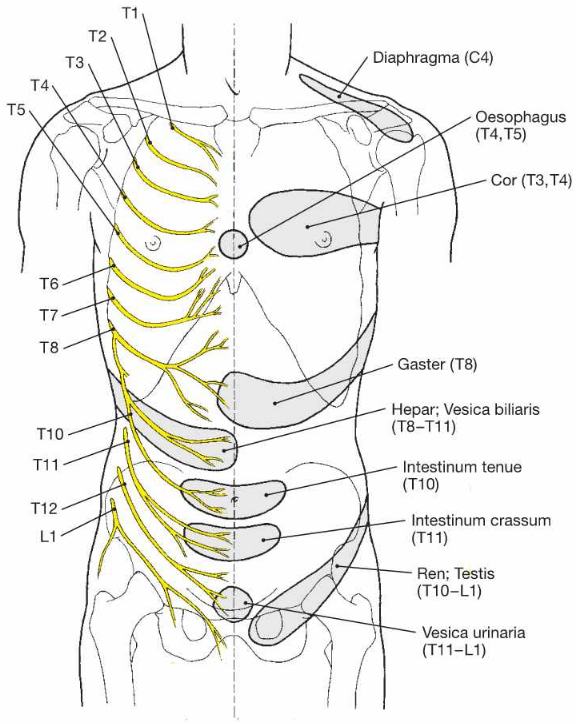


Fig. 2.143 Segmental sensory innervation of the thoracic and abdominal wall.
On the right side, the spinal nerves responsible for the innervation of the dermatomes are shown (→ Fig. 2.142).
HEAD's zones represent skin areas which refer to distinct viscera as a result of cross-connections between the somatic and autonomic nervous system in a corresponding spinal cord segment. These cross-connections of the somatic and autonomic nervous system are due to the segmented (metameric) body structure. HEAD's zones for referred pain relate to specific inner organs. The HEAD's zone of a specific organ can stretch across multiple dermatomes but has a specific point of maximal reflex.

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 dorsal root of a sensory spinal or cranial nerve. An initial infection with the varicella zoster virus caused chickenpox. Shingles are the result of a reactivation of the dormant virus. There is a vesicular exanthema (formation of blisters), which is restricted to the innervation of a sensory root ganglion or cranial sensory nerve. Initially, the patient suffers from intense burning and localized pain, followed three to five days later by exanthema. An irritation of the corresponding internal organ of a **HEAD's zone** (→ Fig. 2.143) 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 neighbouring segments or the affected body side (generalization).

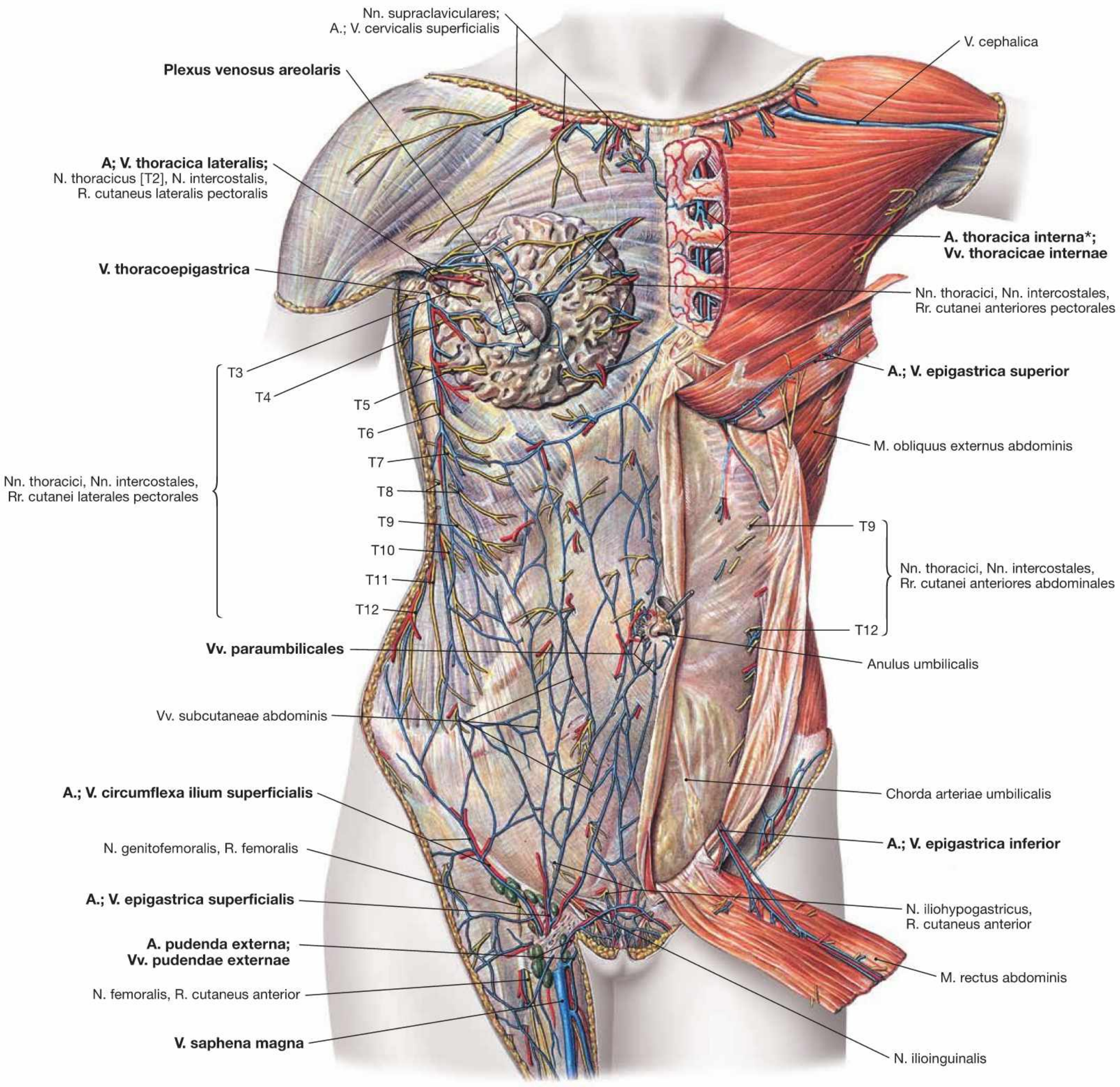


Fig. 2.144 Epifascial and deep vessels as well as nerves of the ventral wall of the trunk of a woman; ventral view.
On the right side of the body, the Fasciae deltoidea, pectoralis, thoracica, abdominis, and lata with their epifascial neurovascular structures and the mammary gland are shown. The Mamma receives its blood supply from the Rr. mammarii mediales of the A. thoracica interna and from the Rr. mammarii laterales of the Aa. thoracica lateralis and thoracodorsalis.

On the left side of the body, the superficial fascia was removed to provide a clear view of the muscles. The rectus sheath is opened, the M. rectus abdominis is cut in the middle; its parts are folded up- and downward. On the posterior aspect of the M. rectus abdominis the Vasa epigastrica superior and inferior are seen.

* clinical term: A. mammaria interna

Relief of the inside of the ventral abdominal wall

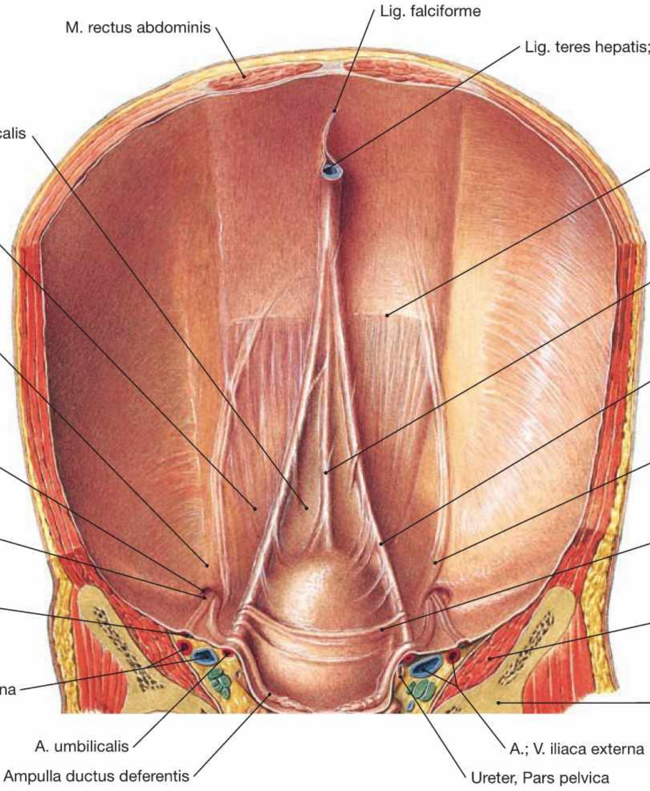


Fig. 2.145 Ventral abdominal wall of a newborn; inside view. The descensus of the testis into the scrotum is completed in a mature newborn.

Extending across the Anulus inguinalis profundus, the Proc. vaginalis peritonei of the Peritoneum parietale descends slightly into the inguinal canal.

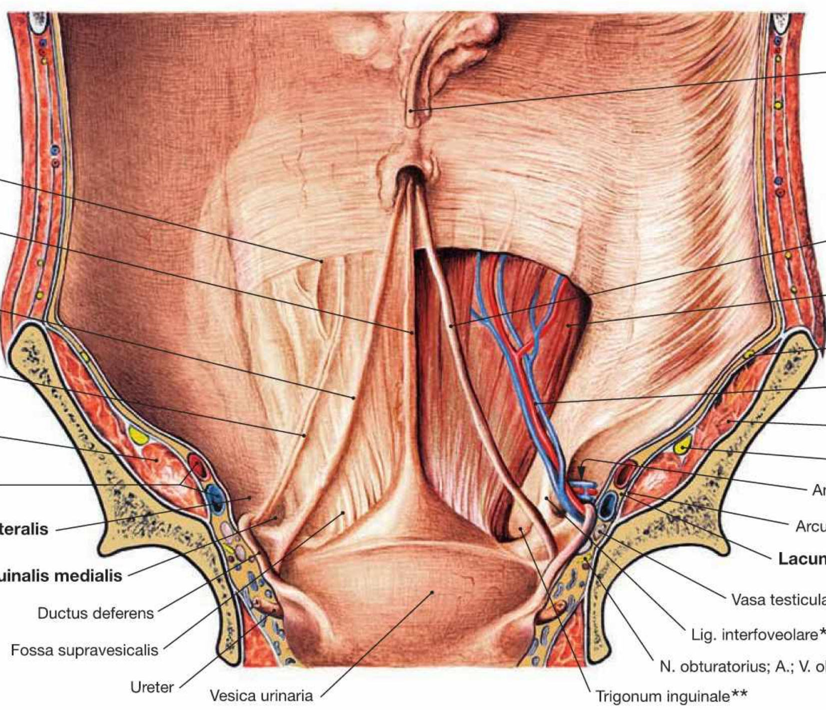


Fig. 2.146 Ventral abdominal wall; inside view. The Fossa inguinalis medialis, Fossa inguinalis lateralis, Lacuna vasorum, and Lacuna musculorum are shown. To demonstrate the neurovascular passage ways, the Peritoneum parietale and the Fascia transversalis were removed on the right side of the body.

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

Inguinal canal

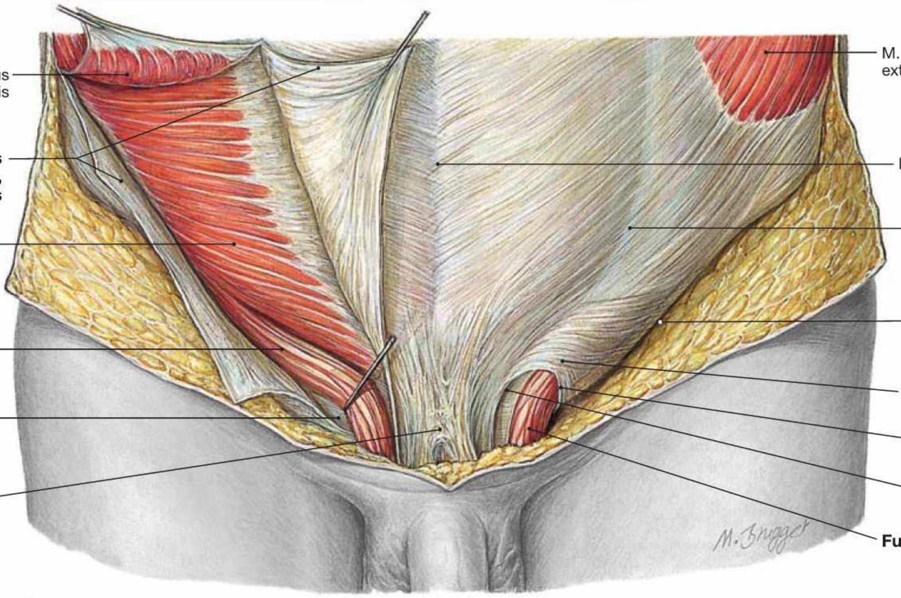


Fig. 2.147 Superficial inguinal ring, Anulus inguinalis superficialis; ventral view.
The **Crus mediale** and **Crus laterale** as part of the aponeurosis of the M. obliquus externus abdominis and interconnecting Fibrae intercrurales constitute the margins of the superficial inguinal ring. The caudal margin is the **Lig. reflexum** as part of the Lig. inguinale.

On the right side of the body, the aponeurosis of the M. obliquus externus abdominis was reflected and provides a clear view on the **M. obliquus internus abdominis**. Muscle fibres of the M. obliquus internus abdominis split off as **M. cremaster** and, as a superficial muscle layer, accompany the Funiculus spermaticus into the scrotum.

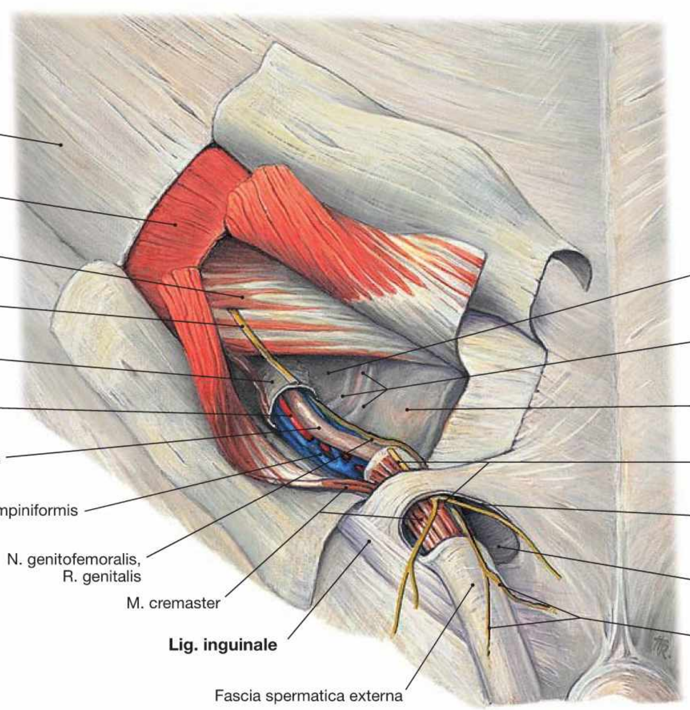


Fig. 2.148 Walls and content of the inguinal canal, Canalis inguinalis, right side; ventral view. [1]
The inguinal canal is confined by the aponeurosis of the M. obliquus externus abdominis in the front, caudally by the Lig. inguinale, posteriorly by the Fascia transversalis, and cranially by the free margin of the M. transversus abdominis.

Clinical Remarks

The **cremasteric reflex** is the contraction of the M. cremaster and resulting elevation of the testicle on the same side when touching the inside of the thigh. It is a physiological extrinsic reflex. The afferent fibres course in the R. femoralis of the N. genitofemoralis, the efferent fibres project in the R. genitalis of the N. genitofemoralis. The Anulus inguinalis profundus is the **hernial canal** of indirect inguinal hernias. The Fossa inguinalis medialis (HESSELBACH's triangle, → Fig. 2.146) is the hernial canal for direct inguinal hernias, whereas the Septum femorale in the Lacuna vasorum is the hernial canal for **femoral (thigh) hernias.**

Inguinal canal

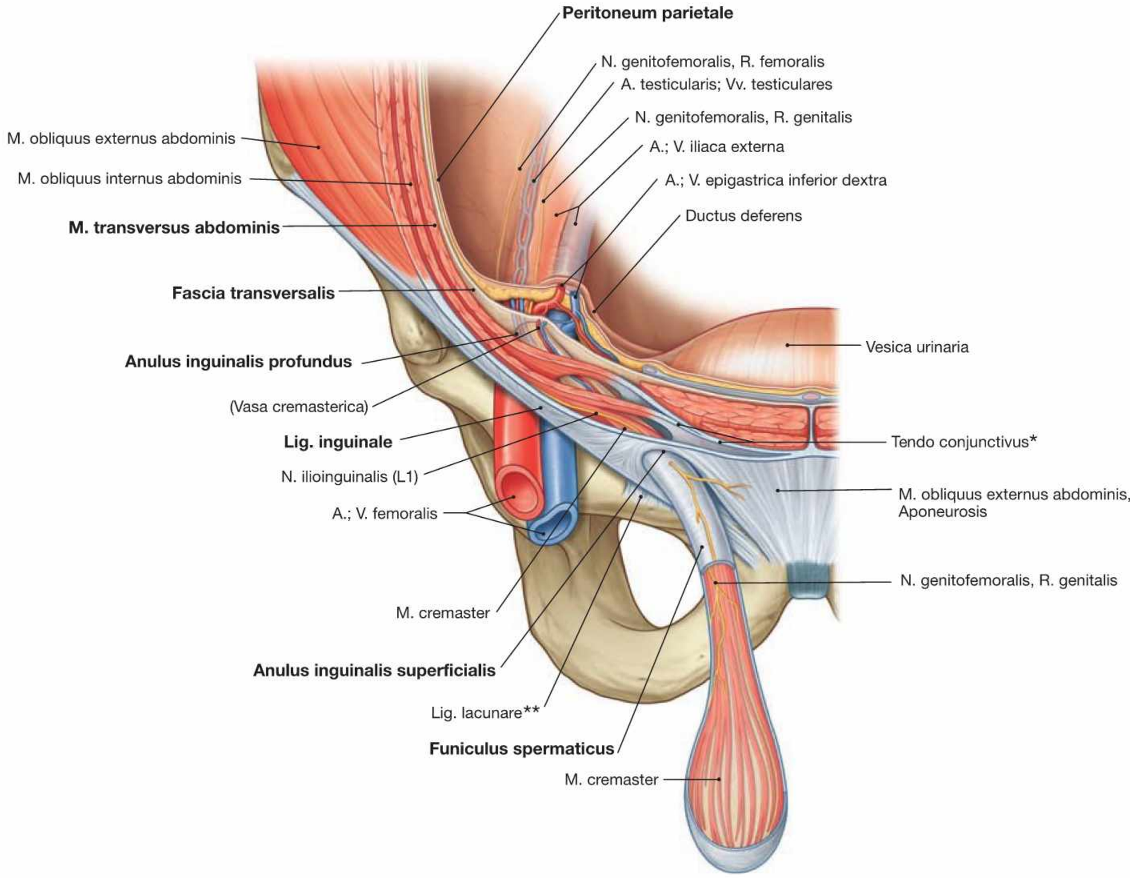


Fig. 2.149 Inguinal canal, Canalis inguinalis, and spermatic cord, Funiculus spermaticus, right side; ventral view. [10]

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 an anterior-medial-caudal direction. The inner opening is the **Anulus inguinalis profundus** which is formed by the Peritoneum and Fascia transversalis as the posterior demarcation and by the M. transversus abdominis and Lig. inguinale as cranial and caudal margins, respectively. The outer opening is the **Anulus inguinalis superficialis** with the aponeurosis of the M. obliquus externus abdominis and the Lig. inguinale (Lig. reflexum) being the anterior and caudal margins, respectively. Located in the inguinal canal is the **Funiculus spermaticus**. On its Fascia spermatica externa, the N. scrotalis anterior of the N. ilioinguinalis reaches the anterior part of the scrotum. Like the M. transversus abdominis, the **M. obliquus internus abdominis** is positioned superior to the Funiculus spermaticus and contributes muscle fibres (M. cremaster) that cover the Funiculus spermaticus. The M. cremaster has its own fascia (Fascia cremasterica), reaches onto the testis between Fasciae spermaticae externa and interna, and plays an important role in regulating the temperature for spermatogenesis to occur.

* transversus tendinous arch
** clinical term: GIMBERNAT's ligament

Inguinal canal

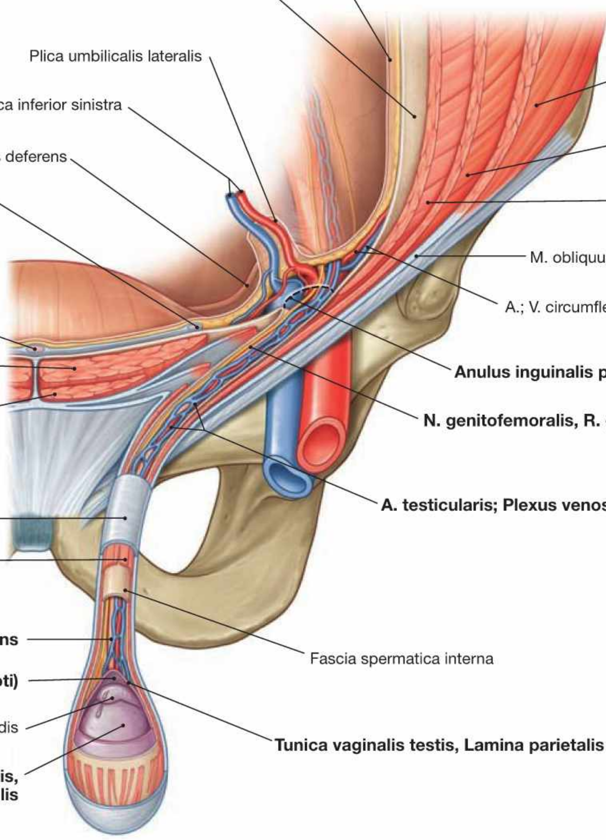


Fig. 2.150 Content of the spermatic cord, Funiculus spermaticus, and coverings of testis, left side; ventral view. [10]

Covered by the Fascia spermatica externa, the M. cremaster, and the Fascia spermatica interna, the **spermatic cord** contains the 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. 2.151).

The **testis** is covered by the serous Lamina visceralis (epiorchium) and the Lamina parietalis (periorchium) which are separated from each other by a gap, the Cavum serosum scroti. Epiorchium and periorchium are connected at the mesorchium. The other coverings listed from the inside to the outside are the Fascia spermatica interna, muscle fibres of the M. cremaster with Fascia cremasterica, and the Fascia spermatica externa. Both testes reside in the scrotum (not shown) which contains the protective dartos fascia (Tunica dartos). Myoepithelial cells in the Tunica dartos cause the scrotum to contract, a process involved in testicular thermoregulation and important for normal spermatogenesis to occur.

Clinical Remarks

Accumulation of fluid in the Cavitas serosa scroti is called **hydrocele.** Cysts in the Proc. vaginalis testis lead to dilation of the Funiculus spermaticus and are called funicular hydrocele (Hydrocele funiculi spermatici).
Retention cysts of the epididymis are called **spermatoceles.**
Malformation of the mesorchium (attachment zone of testis and epididymis) can lead to **testicular torsion** (common in puberty) with strangling of the venous return to the Plexus pampiniformis and followed by strangling of the A. testicularis with risk of aseptic necrosis of the testis.
Backflow of blood in the Plexus pampiniformis is called **varicocele,** which occurs in 80% of all cases on the left side (because the left V. testicularis drains into the left V. renalis). Frequent causes are the obstruction of drainage, as in kidney tumours. Varicoceles can lead to infertility.

Development of the inguinal canal

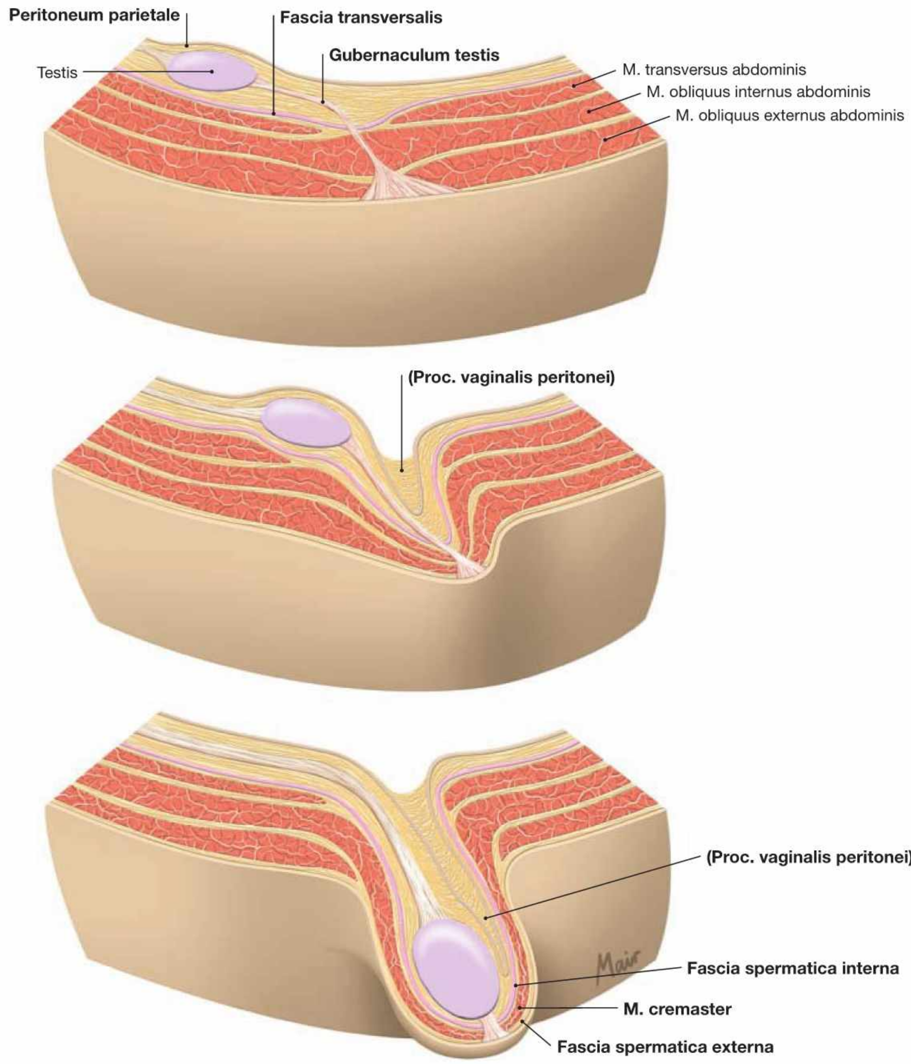


Fig. 2.151 Descensus testis from week 7 (post conception) until birth.
In the male fetus, the testes are relocated during the fetal period from the abdominal cavity along the Gubernaculum testis and beneath the Peritoneum parietale of the dorsal abdominal wall into the scrotum. The Peritoneum parietale creates an invagination (Proc. vaginalis peritonei) that stretches from the inguinal canal into the scrotum and becomes positioned superior to the testis. With the exception of a remnant on the testis (Tunica vaginalis testis), the Proc. vaginalis peritonei obliterates shortly after birth.

Clinical Remarks

The descenut of the testes into the scrotum is a sign of foetal maturity at birth. **Maldescensus testis** occurs in about 3% of all newborns. The testicle can lie in the abdominal cavity or in the inguinal canal (testicular retention, cryptorchidism, ectopic testis). Due to elevated temperature (spermatogenesis occurs at 35 °C), an **ectopic testis** location can result in infertility and an increased risk of malignant transformation.

Inguinal hernias

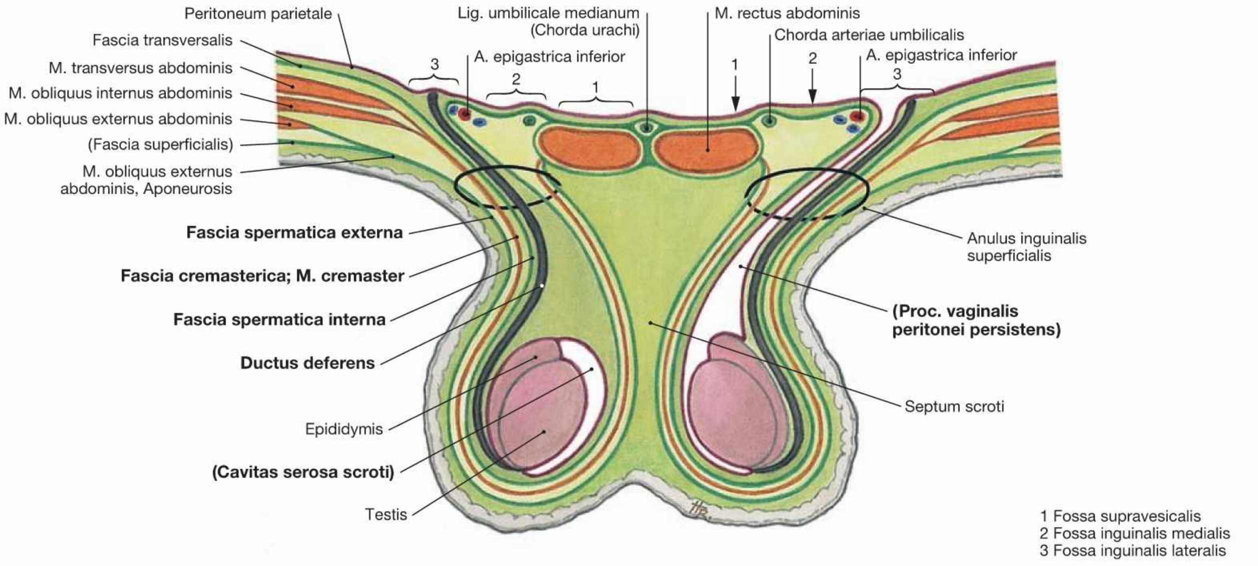


Fig. 2.152 Structure of the ventral abdominal wall and the coverings of the spermatic cord, Funiculus spermaticus, and testis, Testis; schematic diagram. For didactic reasons, the inguinal canal, the spermatic cord, and the scrotum are drawn in the same plane. (according to [1])

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** onto the Funiculus spermaticus. Beneath lies the M. cremaster which splits from the M. obliquus internus abdominis and is covered by the **Fascia cremasterica**. The next deeper layer contains the **Fascia spermatica interna** as part of the aponeurosis of the M. transversus abdominis which covers the content of the Funiculus spermaticus. With the exception of a remnant in the testicular region (Tunica vaginalis testis with Lamina parietalis = periorchium and Lamina visceralis = epiorchium), the Proc. vaginalis peritonei 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 Proc. vaginalis testis failed to close but persists (Proc. vaginalis peritonei persistens) and, thus, causes an open connection between the abdominal cavity and the Cavitas serosa scroti.

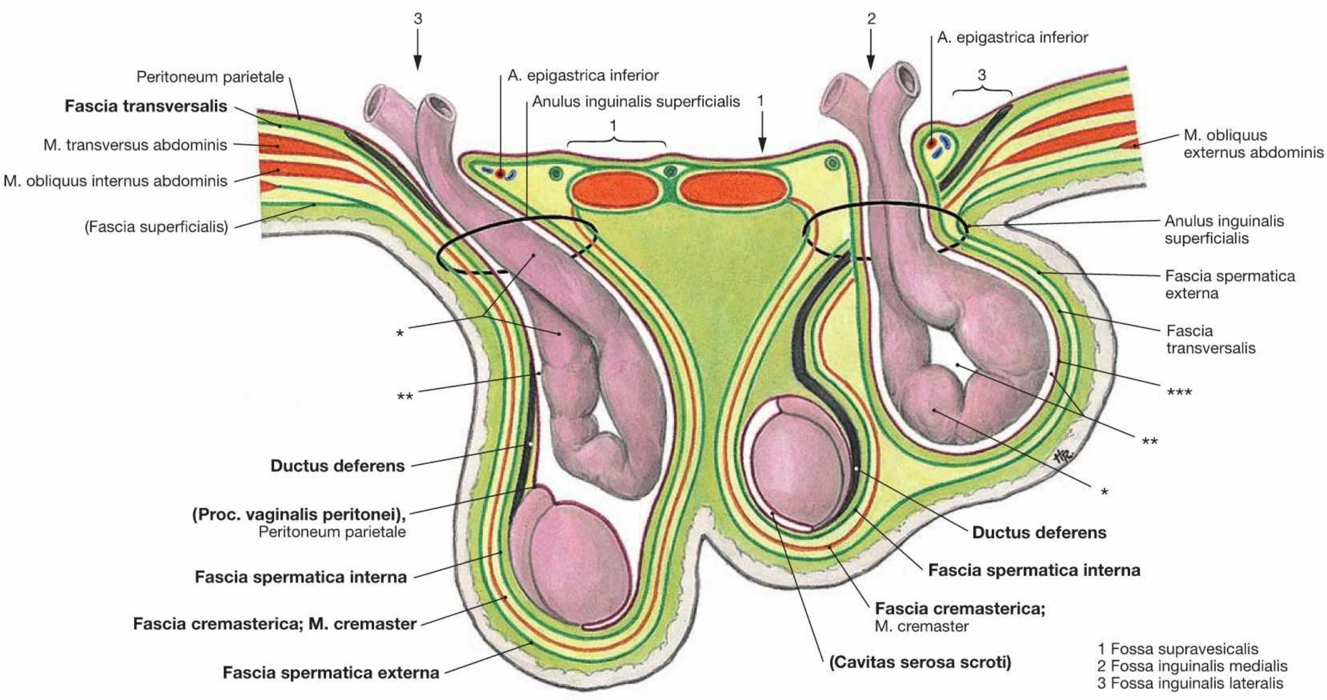


Fig. 2.153 Inguinal hernias; schematic drawing. Left side of the image: lateral, indirect hernia; right side of the image: medial, direct hernia. (according to [1])

Indirect inguinal hernias enter 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) in the Fossa inguinalis medialis which is a weak spot in the ventral abdominal wall. Here, the posterior abdominal wall consists only of the Fascia transversalis and the Peritoneum parietale (Paries dorsalis tenuis canalis inguinalis).

- * intestinal loop in hernial sac
- ** peritoneal cavity
- *** newly formed peritoneal hernial sac

Plexus lumbosacralis

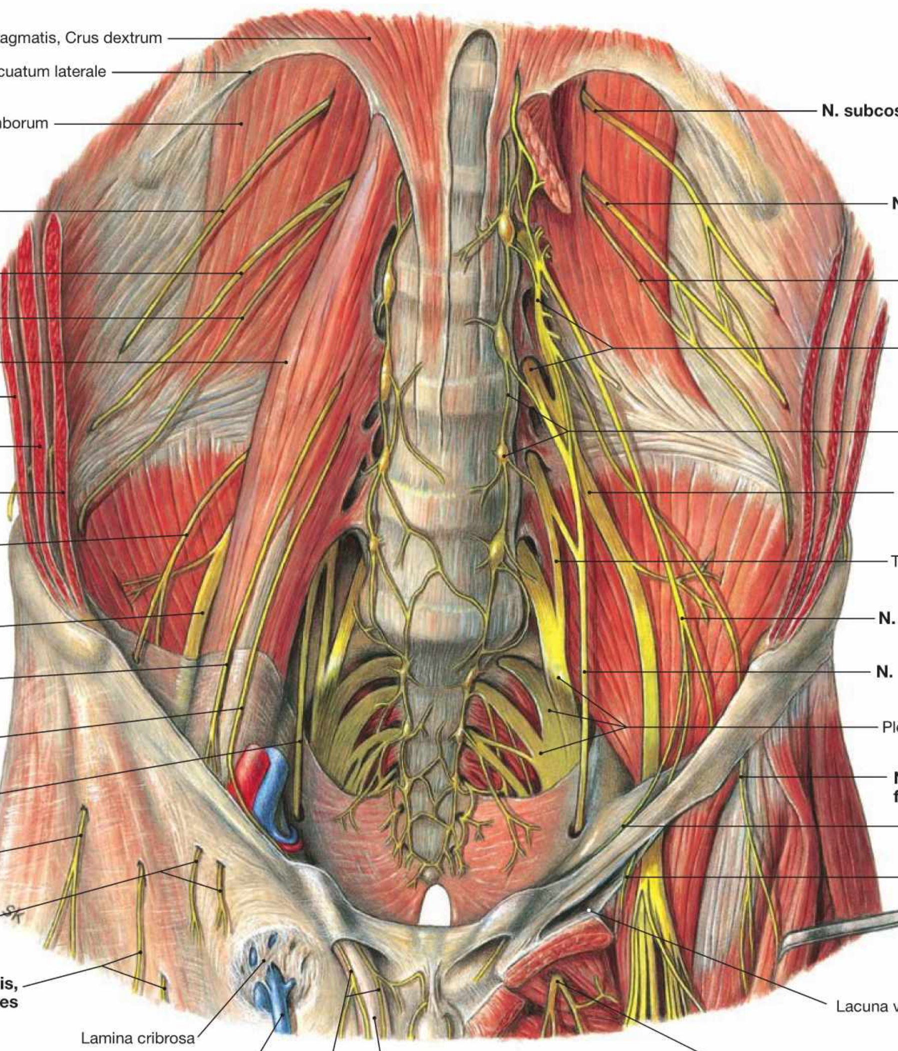


Fig. 2.154 Posterior abdominal wall with Plexus lumbosacralis; ventral view.

The Plexus lumbosacralis is composed 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. Shown are the segmental organization 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. These are from cranial to caudal 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). The N. femoralis (L1–L4) exits the vertebral column and, when completing its passage through the Lacuna musculorum, provides Rr. cutanei anteriores for the innervation of the skin of the thigh. Also shown is the N. obturatorius ([L1] L2–L4) entering the Canalis obturatorius.

→ T 40

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3

The Upper Limb – Grasp the Concept

The upper limb (Membrum superius) consists of the pectoral girdle (Cingulum membri superioris or pectorale) and the arm (Pars libera membri superioris). Both parts merge in the shoulder area (Greek: "omos", Regio deltoidea) and the axilla (Fossa axillaris).

Shoulder Pectoral Girdle

In contrast to the pelvic girdle, the pectoral girdle is not a rigid ring-shaped bony structure but is rather very mobile in itself and with respect to the trunk. Its structure consists ventrally of the collarbone (Clavicula) and dorsally of the shoulder blade (Scapula). The proximal end of the **Clavicula** articulates with the sternum (Articulatio sternoclavicularis). This medial part of the clavicle, which confines the Fossa jugularis laterally, is easily visualised and palpated. Tracing the clavicle laterally one reaches the acromioclavicular joint (Articulatio acromioclavicularis), in which the clavicle articulates with the acromion, a forward-positioned process of the **Scapula.** During circulating and swinging motions of the arm, one can feel the movements of the pectoral girdle with respect to the trunk. The Scapula, which is attached dorsally to the thorax, has no further articulations with the trunk. Various muscles of the thorax, neck, and head (M. trapezius) guide the movement of the Scapula.

The Scapula contains the glenoid cavity of the actual **shoulder joint** (Articulatio humeri). The shoulder joint – a ball and socket joint – is very mobile due to its limp capsule, but also vulnerable to dislocations (luxations). Normally numerous muscles, including those of the rotator cuff, support the shoulder joint. The "**shoulder**", as it is commonly referred to in everyday language, is a transition area of the Pars libera and the Cingulum and is referred to as the Regio deltoidea. The Regio deltoidea is named after the M. deltoideus, which covers the shoulder region. Below the shoulder joint, the **axilla** (Fossa axillaris) is located as a deep pit, which opens caudally. The muscular anterior border of the axilla is created by the M. pectoralis, and the likewise posterior border of the axilla is formed by the M. latissimus dorsi and the M. teres minor. The hairy axillary skin forms the roof of the pit and protects the large axillary neurovascular structures which, embedded in adipose tissue, emerge from the upper thoracic aperture and the neck to supply the limb.

Arm

The Pars libera membri superioris consists of the upper arm (Brachium), the region of the elbow (Regio cubitalis), the forearm (Antebrachium), the wrist region (Regio carpalis), and the hand (Manus).

On the medial side of the **upper arm,** contraction of the M. biceps reveals a longitudinal groove, the Sulcus bicipitalis medialis. The pulse of the A. brachialis is palpable in the sulcus and, when certain pressure is applied, one can feel the shaft of the bone of the upper arm, the Humerus. However, forceful palpations may induce unpleasant sensations as the N. ulnaris and N. medianus run parallel alongside the A. brachialis.

The term of the **elbow region,** Regio cubitalis, originates from the Latin verb "cubitare" (to lie). During antiquity when lying down at the table one leaned on one's elbows. More accurately: one leaned on the Olecranon of the Ulna, a bony process, which is noticeable on the dorsal side of the elbow joint (Articulatio cubiti). Both bony humps (Epicondylus medialis and lateralis), palpated medially and laterally of the Regio cubitalis are part of the Humerus. These epicondyles serve as the origin of extensor muscles to the wrist, which are positioned laterally, as opposed to the medially positioned flexor muscles to the wrist. The N. ulnaris runs in a groove behind the medial epicondyle. Dorsal impact on this nerve can cause painful sensations. In the elbow joint, the humerus articulates with both bones of the forearm and the latter two articulate with each other.

On the **forearm,** Antebrachium, the Ulna is palpable along the side of the fifth digit. Bulky muscles hide the Radius in its proximal aspect; distally however, towards the thumb, its shaft is palpable. During turning movements of the forearm and the hand (pronation and supination), which also involve the elbow joint, the Radius rotates around the stationary Ulna. Radius and Ulna are joined syndesmotically by the Membrana interossea, but proximally and distally they are connected by the formation of joints.

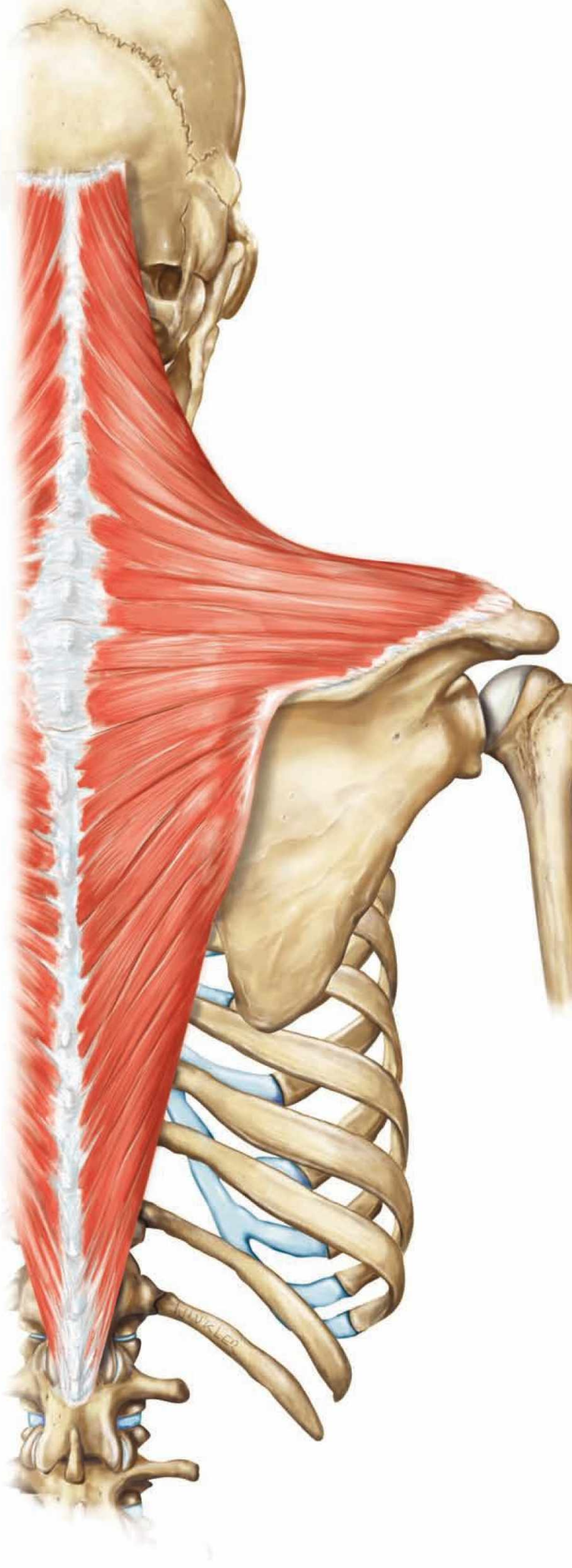
The **wrist area**, Regio carpalis, receives its name from the carpal bones, the Ossa carpi, which align in two rows at the base of the hand: a proximal and a distal row. These bones interlock in a complicated and three-dimensional puzzle resembling cypress cones ("carpus"). The two joints of the wrist are identified as articulating joint surfaces of the Ossa carpi with respect to each other, and the proximal row of Ossa carpi and the Radius of the forearm forming the second joint. The range of motion is largest at the Articulatio radiocarpalis and the joint space is located at the "midriff" of the Regio carpalis. The Ossa carpi are positioned mainly in the palm of the hand. The interlocking joint of the proximal and distal row of carpals is called the Articulatio metacarpalis and assists in flexion and extension of the hand.

The **hand** (Manus) consists of the palm and the digits, which protrude from the metacarpophalangeal joints (Articulationes metacarpophalangeales). On the inside of the hand (Palma or Vola manus) two larger muscle humps rise below the thumb and the fifth digit. These muscle humps are the thenar and hypothenar, respectively, and function correspondingly. The Ossa carpi are located in the proximal area of the palm below the base of thenar and hypothenar. The remaining larger part of the hand is supported by five long bones, the metacarpals (Ossa metacarpi). There are no muscles at the back of the hand (Dorsum manus). The Ossa metacarpi are easily palpable below the tendons of finger extensors and the characteristic network of veins (Rete venosum dorsale manus).

The **fingers** or digits (Digiti) are classified as long bones, which are also called phalanges. The thumb (Pollex) consists of only two phalanges in contrast to the other digits (Index, Medius, Anularius and Minimus) which all consist of three phalanges. The exceptional flexibility of the thumb, especially the ability to pose the thumb opposite to all the other digits (opposition of the thumb) is a special feature of the human hand. The flexibility of the thumb originates in the Os metacarpi pollicis which is more mobile than the other Ossa metacarpi with respect to the carpals.

Clinical Remarks

The **dislocation** (luxation) of the shoulder joint is more common than in any other joint of the body. Also, the **wear** of the tendons of the **rotator cuff muscles** due to lifting the arm and the entrapment of attached tendons under the acromion is a common disease. Depending on lifestyle, sooner or later this disease leads to impairments. Many **hand injuries** require surgical reconstitution to restore the function. Evidence of the significance of the hand is the fact that there is a separate specialisation for hand surgeons, which accounts for the highly complex anatomy of the hand. Quite often greatly detailed anatomical topics on this subject are found in the literature written by and for hand surgeons. Given the outstanding importance of the grasping function of the hand, it is conceivable why particularly the nerve lesions of the Nn. medianus, ulnaris, and radialis are important to know for the physician. The most common injury affects the N. ulnaris at the elbow ("funny bone"), which leads to a typical "clawed hand" position of the fingers. The distal lesion of the wrist (carpal tunnel syndrome) involves the N. medianus and is characterised by radiating pain and numbness in the radial fingers. However, in the first half of the last century the injury to the medial proximal Humerus (bayonet injury) was more frequent. This injury is associated with a characteristic "hand of benediction" position. The close proximity to the bone in the upper arm region makes the N. radialis particularly prone to injury resulting from fractures in this region. In this case, failure of the extensor muscles of the forearm results in the so-called wrist drop. However, the extension of the elbow is unaffected.



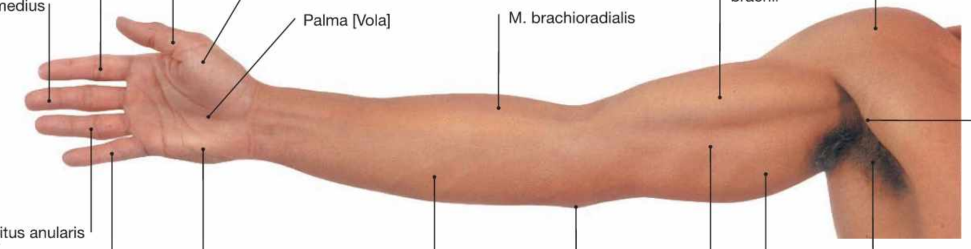
→ Dissection Link

Musculoskeletal systems are **dissected in layers** (stratigraphically) from superficial to deeper structures. In contrast to the leg, the arm can usually be dissected from both sides (ventral and dorsal) without turing over the body. First, the epifascial veins and cutaneous nerves within the subcutaneous adipose tissue are exposed. The V. cephalica and V. basilica are traced from the wrists to the upper arm. In the elbow region, these run alongside of the cutaneous nerves of the forearm. The cutaneous nerves of the upper arm and forearm are to be exposed before opening the fascia and displaying individual muscles. The dissection of the axillary fossa with the nerves of the Plexus brachialis and the branches of the A. axillaris requires special skills and is labour-intensive. In this region only some of the lymph nodes are displayed. The coures of individual nerves and blood vessels and their branches are systematically exposed and traced to achieve a complete dissection which facilitates understanding of the topography and function of neurovascular pathways. Dissection of the hand should be considered early in the dissection process. Exposure of the numerous small hand muscles and the branches of arteries and nerves in this region is time consuming.

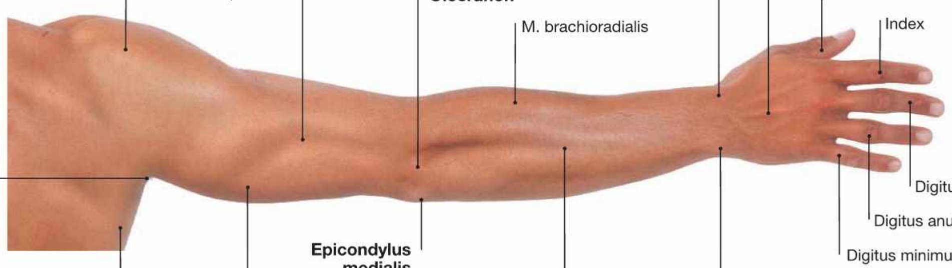
EXAM CHECK LIST

• Bones: apophyses and origins, insertions of muscles (also the small muscles of the hand) • rotator cuff • joints with ligaments (in particular shoulder and elbow) • muscles and their course, function, innervation • Plexus brachialis and its peripheral nerves including their innervation and course • nerve lesions and clinical symptoms • arteries and their branches, course and pulses • course of veins • lymphatic drainage including Nodi lymphoidei of the axilla and levels • topography: axilla and hand • carpal tunnel • transverse sections: Brachium and Antebrachium • surface anatomy

Surface anatomy



3.1



3.2

Fig. 3.1 and Fig. 3.2 Surface relief of the arm, right side; ventral (→ Fig. 3.1) and dorsal (→ Fig. 3.2) view.

Clinical Remarks

The surface relief of the arm is determined by the muscles and by some of the skeletal elements. The palpable parts of bones help with orientation during the physical exam.

Fascias of the arm

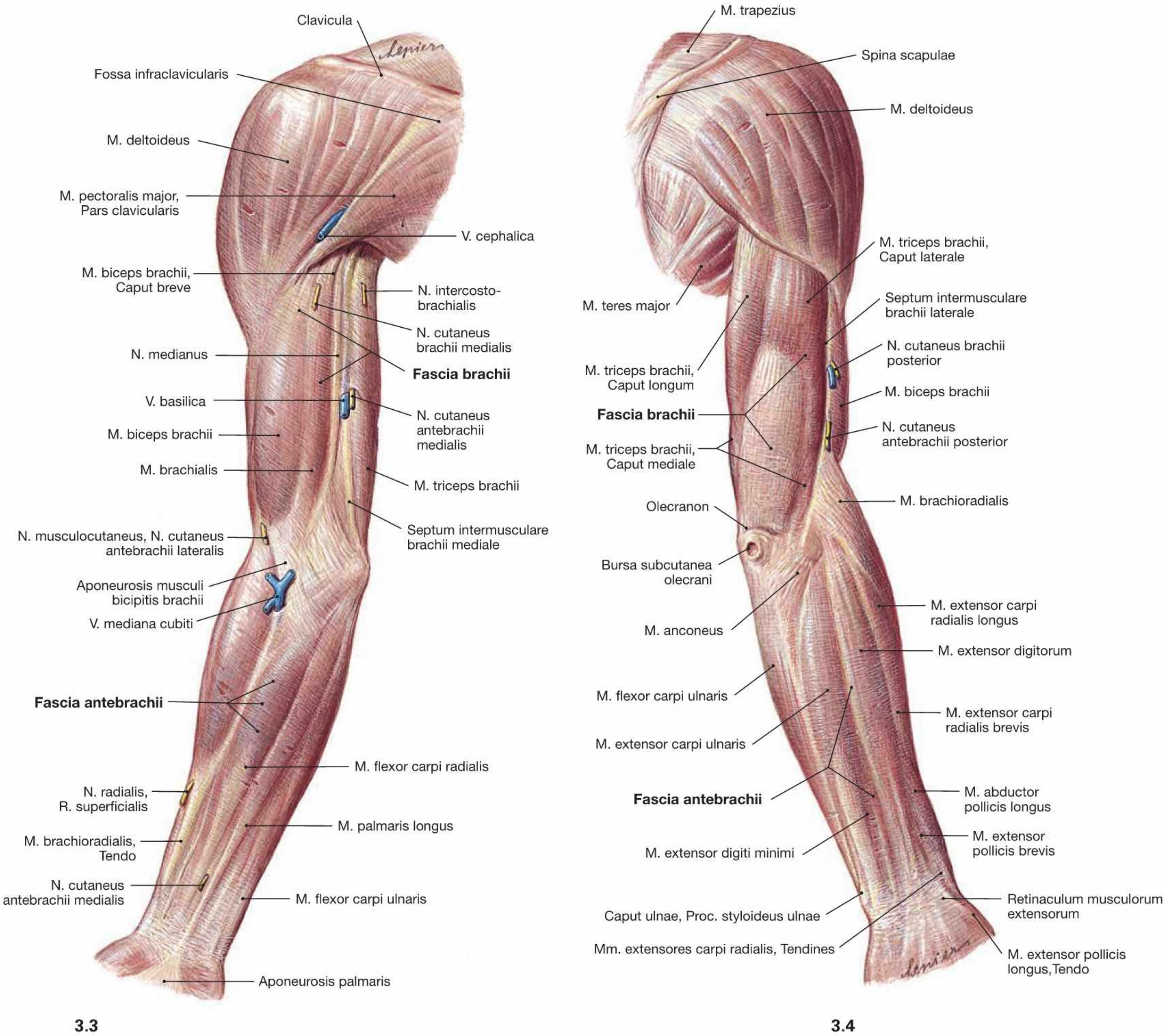


Fig. 3.3 and Fig. 3.4 Fascia of the upper arm, Fascia brachii, and fascia of the forearm, Fascia antebrachii, right side; ventral (→ Fig. 3.3) and dorsal (→ Fig. 3.4) view.

As shown in the illustration, the surface relief is determined predominantly by the various muscles. The muscles are covered with their own fascias and bundled to muscle groups. These group fascias are covered by a common fascia, the fascia of the upper arm and the forearm, which resides underneath the skin. After dissecting all important subcutaneous structures such as the cutaneous nerves and the epifascial veins, the subcutaneous adipose tissue is removed to display the fascias.

Development

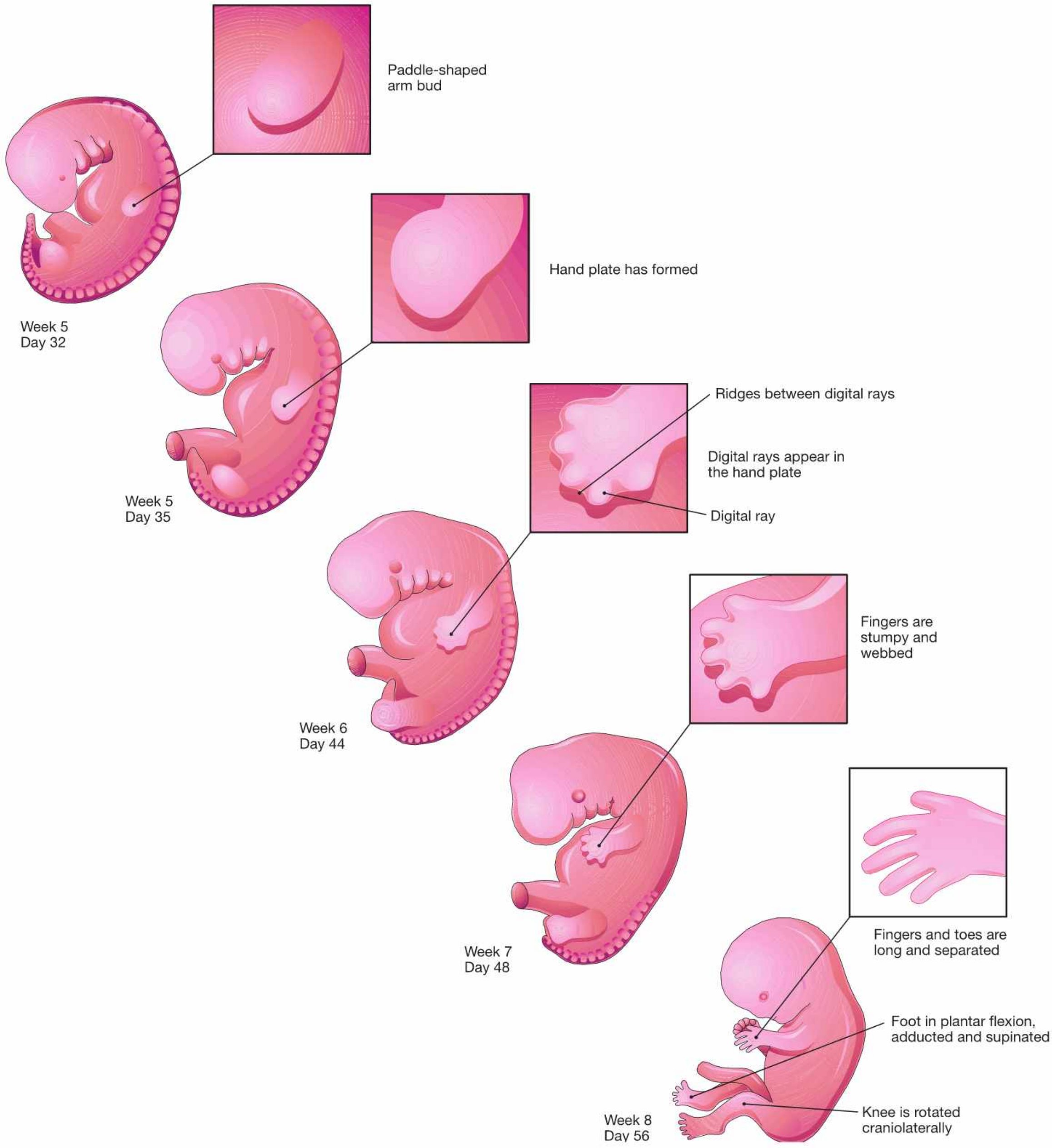


Fig. 3.5 Development of the extremities in week 5–8; schematic illustration. [20]

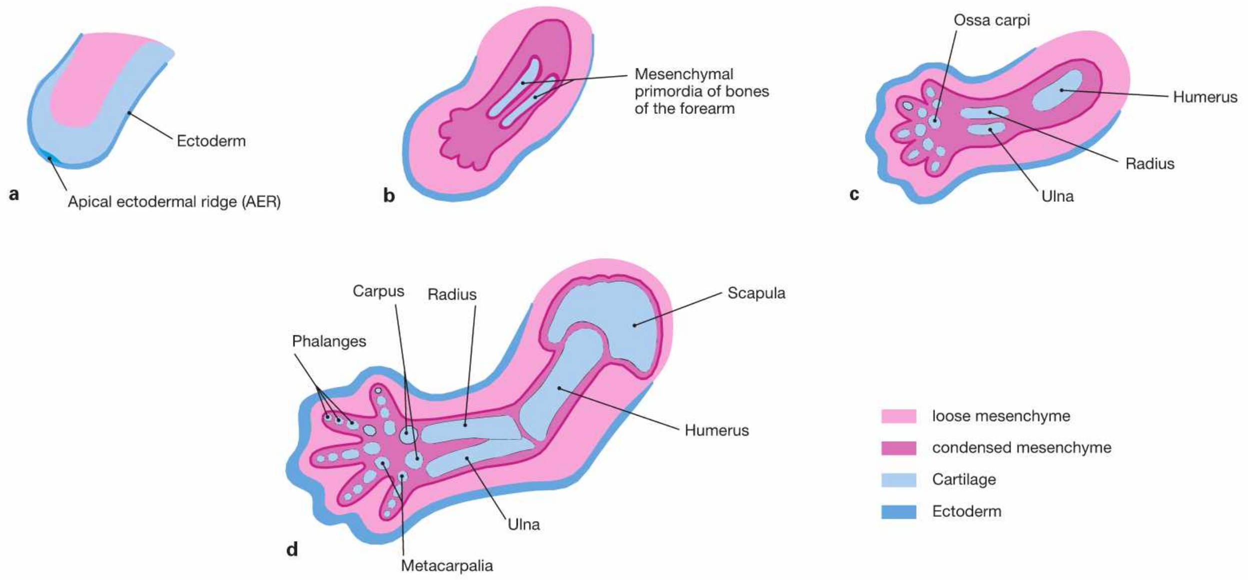
The extremities begin to develop in **week 4.** The fin-like **arm bud** develops on **day 26 – 27,** thus two days prior to the development of the leg bud. At this point in time, the primordial extremities consist of a mesenchymal core of connective tissue deriving from the mesodermal somatopleura and of an encasing surface ectoderm which later forms the epidermal layer of the skin (→ Fig. 3.6). Ectoderm of the distal edge of the limb bud (ectodermal ridge) expresses growth factors which attract muscle cell precursors from somites of the mesoderm of the trunk area. In **week 5 – 6,** the limb buds display a **spatial pattern formation** in the primordial arms and legs. Beginning in week 6, digital rays are forming through programmed cell death (apoptosis) in the interpositioned tissue. The **fingers and toes** are completely separated by the end of **week 8.**

In contrast to the arm anlage, the primordial **legs** rotate laterally during **week 8** resulting in the **knee** to be oriented in a **craniolateral** position. As a consequence of this rotation, the extensor muscles of the leg are in a ventral position, in contrast to the dorsal position of the extensor muscles in the arm. Furthermore, at **week 8** the **foot** is positioned in **plantar flexion, adduction,** and **supination.** This position is reversed until week 11.

Clinical Remarks

A **congenital clubfoot** is the most common malformation of the extremities. The foot is fixed in plantar flexion and supination. Therefore, it is assumed that this deformity is caused by the lack of reversion from a foot position that is physiological between weeks 8 and 11 of gestation.

Development



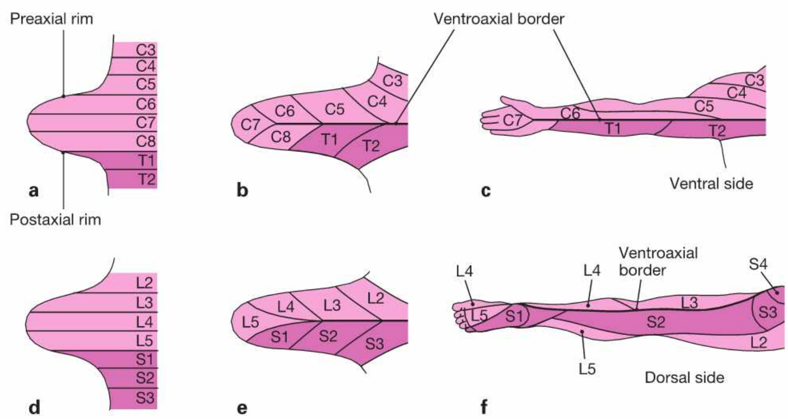
Figs. 3.6a to d Development of the cartilaginous precursors of the bones of the upper extremities in weeks 4–8; schematic longitudinal sections. [20]

In **week 4** the primordial limbs consist of a connective tissue (mesenchymal) core and a sheath of surface ectoderm which later forms the epidermis of the skin. Condensation of the mesenchyme results in formation of a cartilaginous skeleton during **weeks 4–6** in the arm and **weeks 6–8** in the leg. The **cartilaginous skeleton** serves as precursor for the formation of bones at a later point in time. This process advances from proximal to distal.

Within this cartilaginous skeleton primary ossification centres begin to establish in **week 7** which initiates the restructuring of the cartilage into bones **(endochondral ossification).** Ossification progresses according to a specific pattern (→ p. 16). At **week 12, ossification centres** are present in all bones of the upper limb except for the carpus. Ossification centres of the **carpus** only form postnatally between **1 and 8 years of age.** As an exception, ossification of the clavicle proceeds directly from the mesenchyme **(desmal ossification).**

Ossification in the lower extremity occurs with delay. Ossification centres in the femur are present already at the 6th month, but ossification of the phalanges occurs only between the 5th and 9th month. Ossification of the tarsus and the pelvic girdle occurs during the first to fourth year of age and up to the 20th year of age, respectively.

Closure of the epiphyseal plates with resulting cessation of the longitudinal growth of the extremities takes place between **years 14 and 25,** for most of the bones before **year 21.**



Figs. 3.7a to f Development of dermatomes in the extremities. [20]

Sensory innervation of certain areas of skin derives from one single spinal cord segment (dermatome). In contrast to the segmental orientation of the dermatomes in the trunk, dermatomes in the limbs are initially oriented almost longitudinally (**a, d**) and later during development in an increasingly oblique direction (→ pp. 197 and 329). Arms and legs show a ventroaxial border (**b, c, e, f**) with hardly any overlap by neighbouring dermatomes.

Clinical Remarks

From the progression of the ossification **(bone age)**, future growth and adult height can be predicted in children by radiological examinations. When examining X-rays of children, one must consider that their bones consist partly of individual ossification centres not yet connected by bone. Hence, these are not considered fractures.

Skeleton of the upper extremity

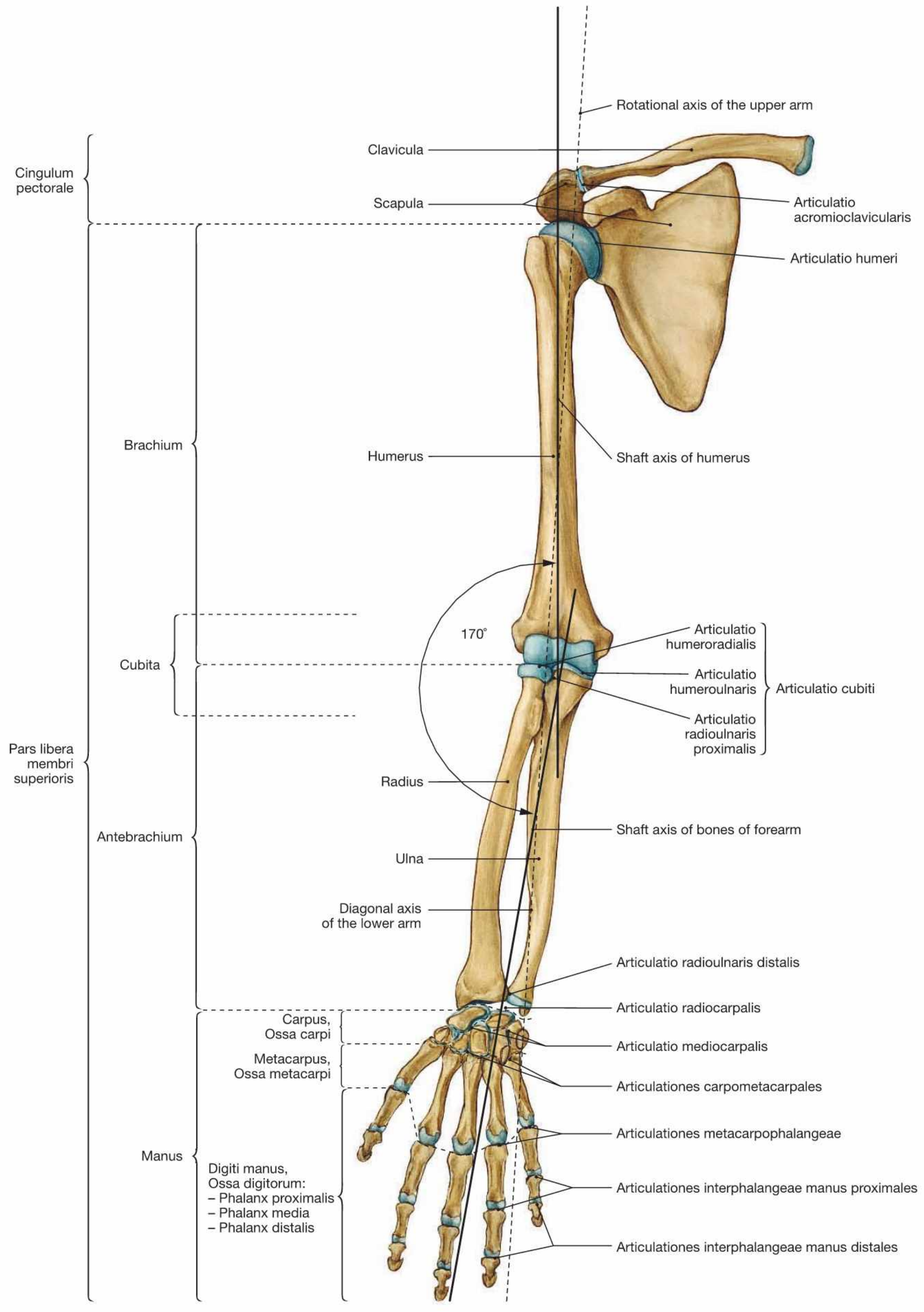


Fig. 3.8 Bones and joints of the upper extremity, Membrum superius; right side; ventral view.
Similar to the leg, upper arm and forearm form a **lateral open angle** of 170° which is divided in half by the transverse axis of the elbow joint. The connecting line between the head of Humerus and the head of Ulna depicts the rotation axis for the upper arm. The diagonal axis of the forearm is the axis for turning movements of the radius around the Ulna (pronation/supination).

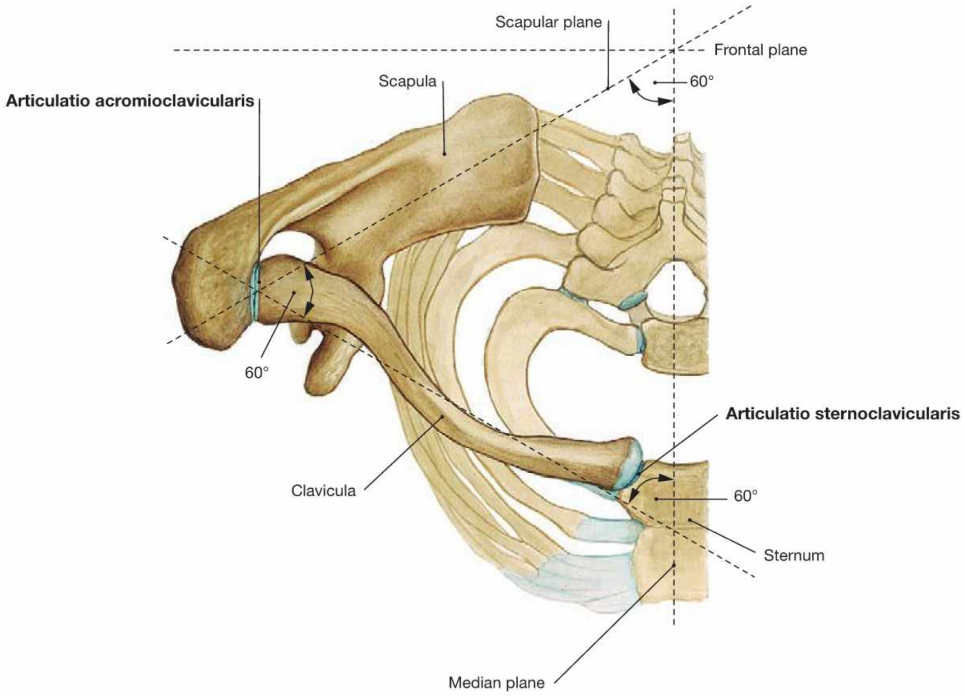
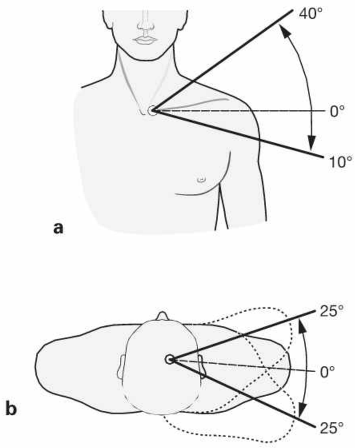


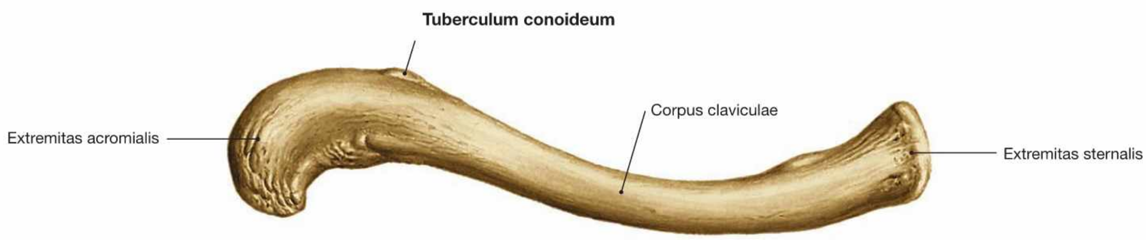
Fig. 3.9 Shoulder girdle, Cingulum pectorale, right side; cranial view.
The shoulder girdle consists of the **clavicle** (Clavicula) and the **shoulder blade** (Scapula). Both bones are connected in the lateral clavicular joint (Articulatio acromioclavicularis); the clavicle is also connected to the skeleton of the trunk through the medial clavicular joint (Articulatio sternoclavicularis).
The clavicle holds an angle of 60° with the median plane and with the scapular plane. The shoulder blade is positioned in the scapular plane which again has an angle of 60° to the median plane.



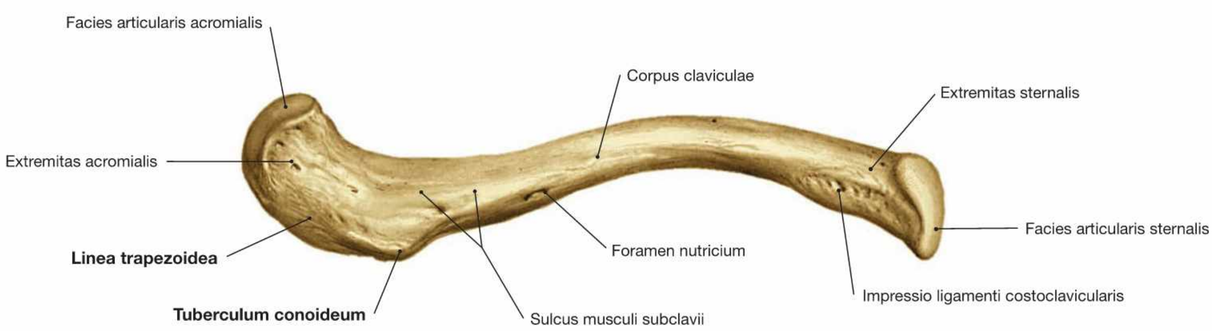
Figs. 3.10a and b Range of motion of the shoulder girdle with reference to the medial clavicular joint. (according to [1])
Both clavicular joints are **ball and socket joints** and both act as a functional unit since the connection of the shoulder girdle to the skeleton of the trunk is exclusively based on the medial clavicular joint. In addition to forward and backward movements (protraction and retraction), a discrete lowering (depression) and a substantial lifting (elevation) of the shoulder is possible. The clavicle is capable of a 45° rotation around its fixed sternal end. The motions in the shoulder girdle enable a substantially increased range of movement in the upper extremity.

Range of movement in the shoulder girdle:
- elevation–depression: 40°–0°–10°
- protraction–retraction: 25°–0°–25°

Clavicle



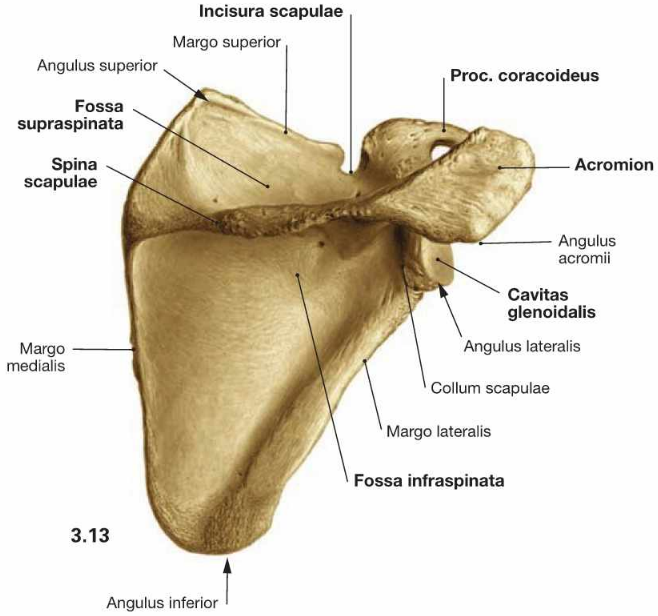
3.11



3.12

Fig. 3.11 and Fig. 3.12 Clavicle, Clavicula, right side; cranial (→ Fig. 3.11) and caudal (→ Fig. 3.12) view.
Matching an isolated clavicle to either side of the body is often not easy. It helps to know that the Extremitas sternalis is rather plump and the Extremitas acromialis is more pointed. When positioned in the skeleton, the sternal convexity is oriented ventrally. The inferior side of this bone shows two characteristic apophyses for the attachment of both parts of the Lig. coracoclaviculare (→ Fig. 3.28). Medially positioned is the **Tuberculum conoideum,** lateral thereof the **Linea trapezoidea** is located.

Shoulder blade



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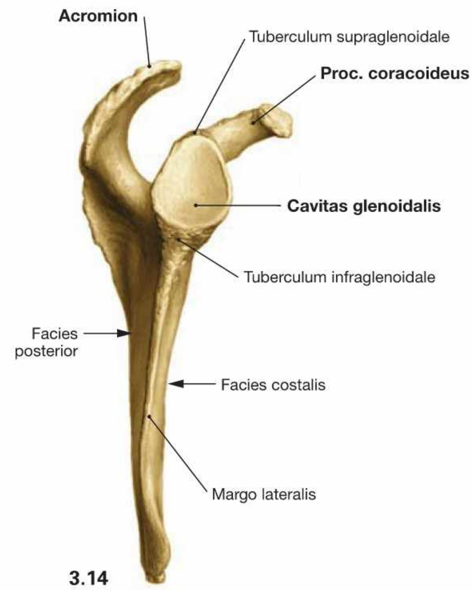

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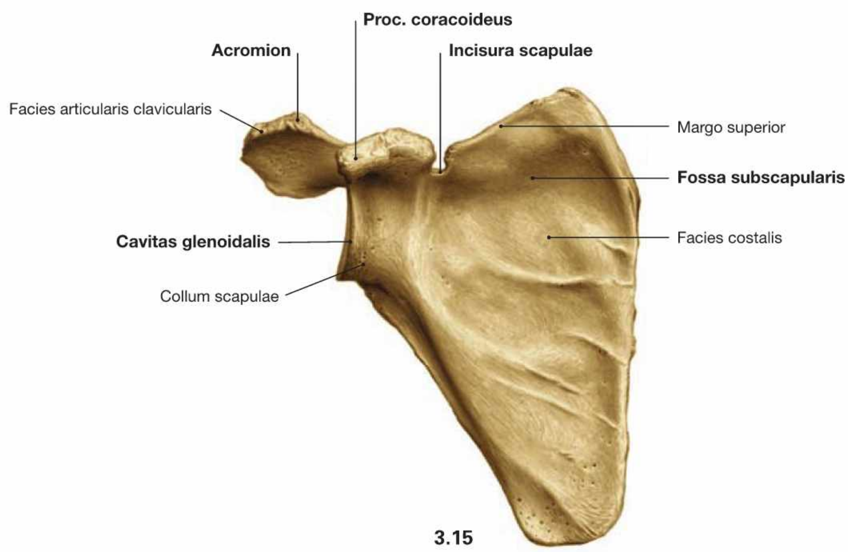


3.15

Figs. 3.13 to 3.15 Shoulder blade, Scapula, right side; dorsal (→ Fig. 3.13), lateral (→ Fig. 3.14), and ventral (→ Fig. 3.15) view.
The shoulder blade is a flat bone with three margins and three angles. The dorsal T-shaped protrusion, the Spina scapulae, serves as an important apophysis for the attachment of muscles.

Clinical Remarks

The **N. suprascapularis** passes through the **Incisura scapulae,** which is bridged by the Lig. transversum scapulae superius (→ Fig. 3.28). Ossification of the ligament can result in **compression** of the nerve with weakening of the dependent muscles (M. supraspinatus and M. infraspinatus). These muscles are important for abduction and external rotation of the arm.

Humerus

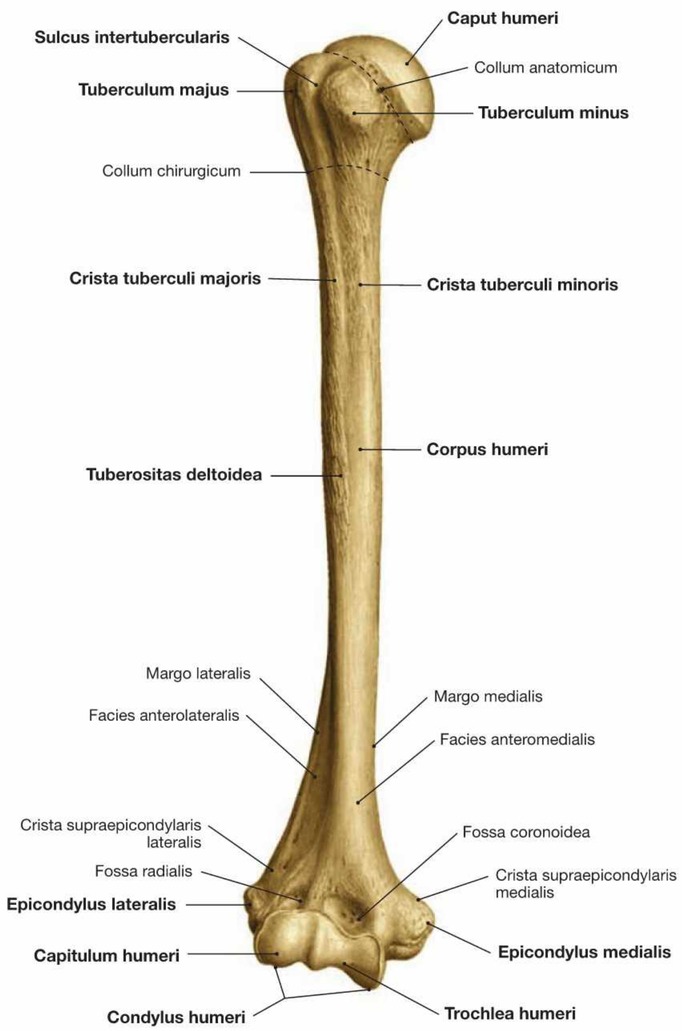
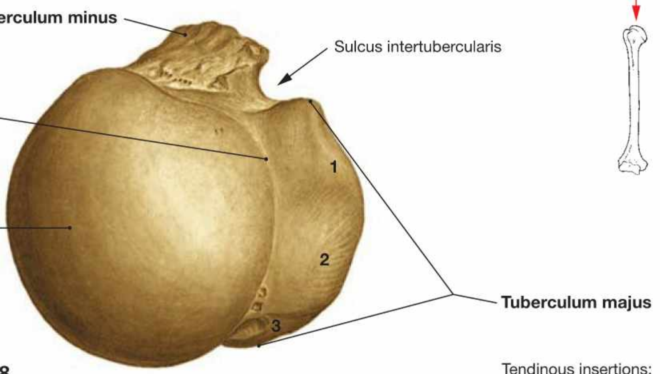


Fig. 3.16 Bone of the upper arm, Humerus, right side; ventral view.
The humeral head forms an angle of 150°–180° with the axis of the humeral shaft **(collodiaphyseal angle).** In addition, the head shows a **retrotorsion** of 15°–30° and a posterior rotation relative to the axis through the distal condyles. The Tuberculum majus and the Tuberculum minus are located laterally and medially on the proximal shaft, respectively.

3.17



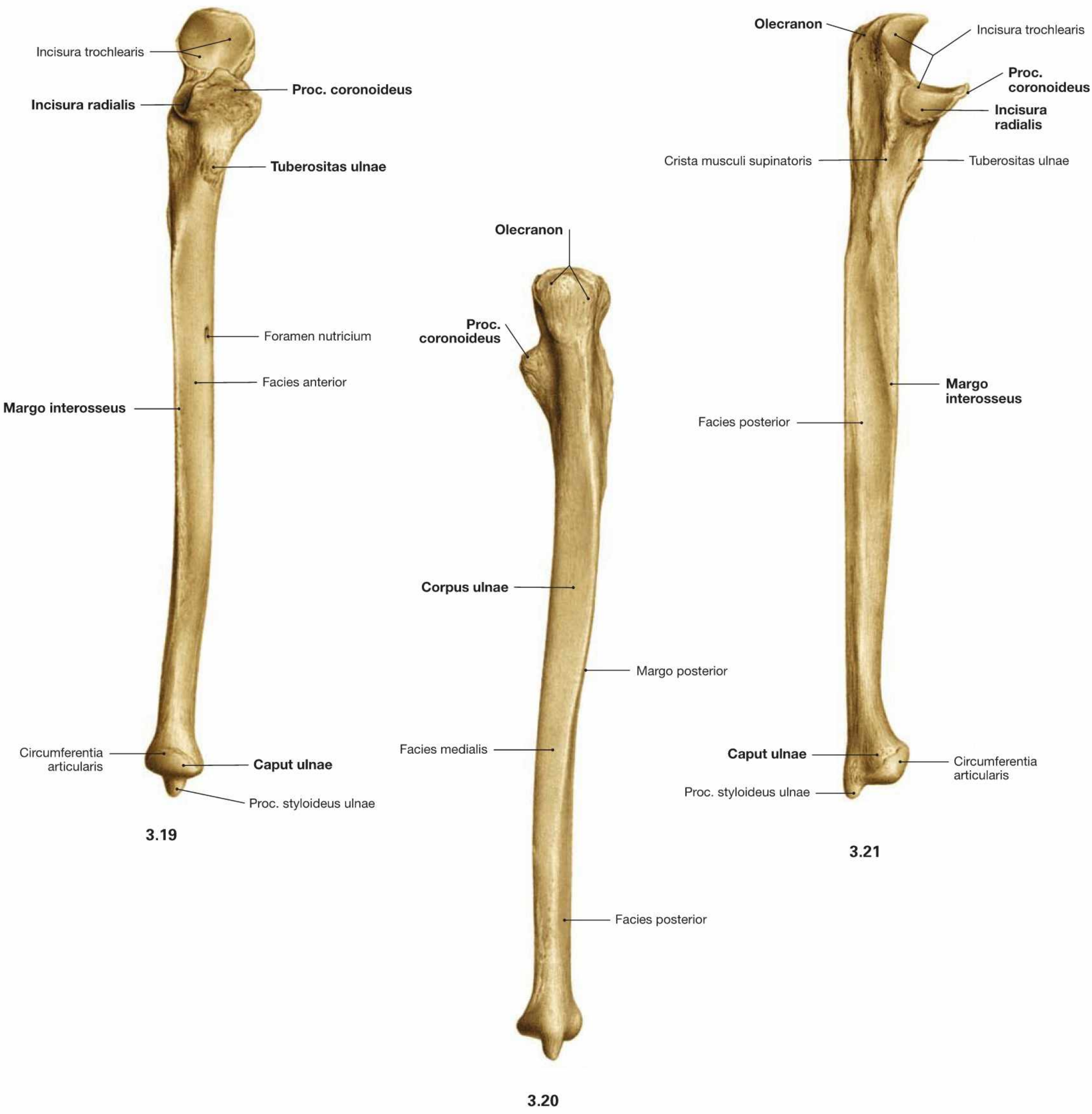
3.18

Fig. 3.17 and Fig. 3.18 Bone of the upper arm, Humerus, right side; dorsal (→ Fig. 3.17) and proximal (→ Fig. 3.18) view.
The **Sulcus nervi radialis** spirals around the dorsal shaft of the Humerus guiding the N. radialis. The posterior side of the Epicondylus medialis shows the **Sulcus nervi ulnaris** where the N. ulnaris may be irritated mechanically ("funny bone").

Clinical Remarks

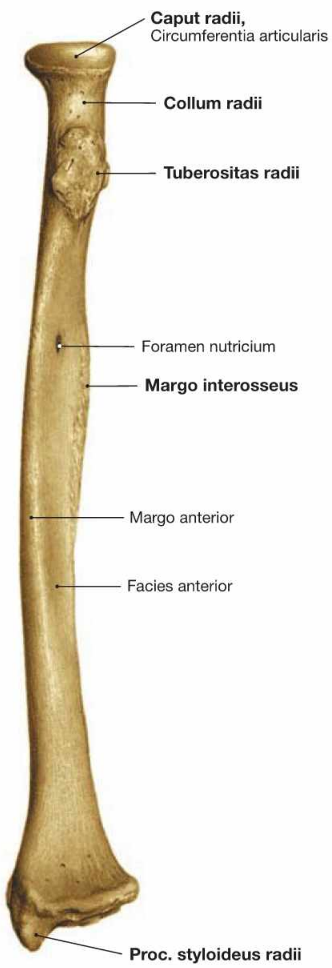
As a result of falls, fractures of the Humerus are relatively common. **Supplying blood vessels** (Aa. circumflexae humeri anterior and posterior) and the N. axillaris which loop around the Humerus may be damaged in **proximal fractures** (→ p. 200). The N. radialis may be injured during **fractures in the shaft area** or surgical treatment of such fractures (→ p. 203), resulting in a clinically obvious **N. radialis lesion** (radial nerve paralysis). In this region, the nerve may also be damaged by compression **("park bench paralysis"** or **"Saturday night palsy"). Distal fractures** may cause **damage to the N. ulnaris** in the Sulcus ulnaris (→ p. 207). Since the nerve is extremely exposed at this location, lesions of the N. ulnaris in this area represent the most common nerve lesions of the upper extremity.

Ulna



Figs. 3.19 to 3.21 Ulna, Ulna right side; ventral (→ Fig. 3.19), dorsal (→ Fig. 3.20), and radial (→ Fig. 3.21) view.

Matching an isolated Ulna to one side of the body is aided by the position of the Incisura radialis which points laterally.



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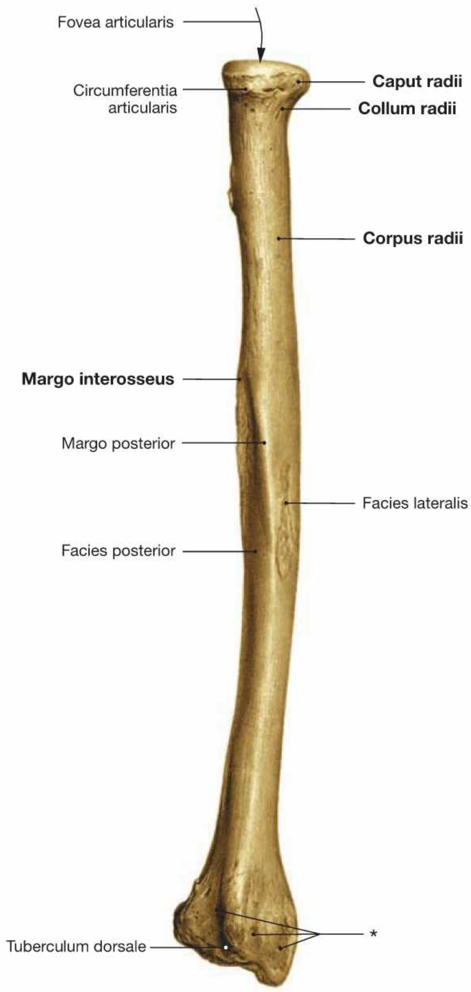

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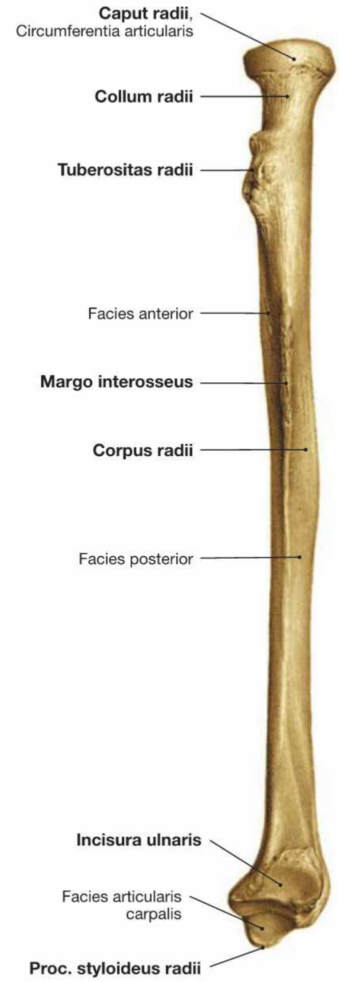


3.24

Figs. 3.22 to 3.24 Radius, Radius right side; ventral (→ Fig. 3.22), dorsal (→ Fig. 3.23), and ulnar (→ Fig. 3.24) view.
Matching an isolated Radius to one side of the body is aided by the position of the Proc. styloideus radii which points laterally. The Incisura radialis, however, points in an ulnar direction.
* grooves and bony crests for the extensor tendons

Skeleton of the hand

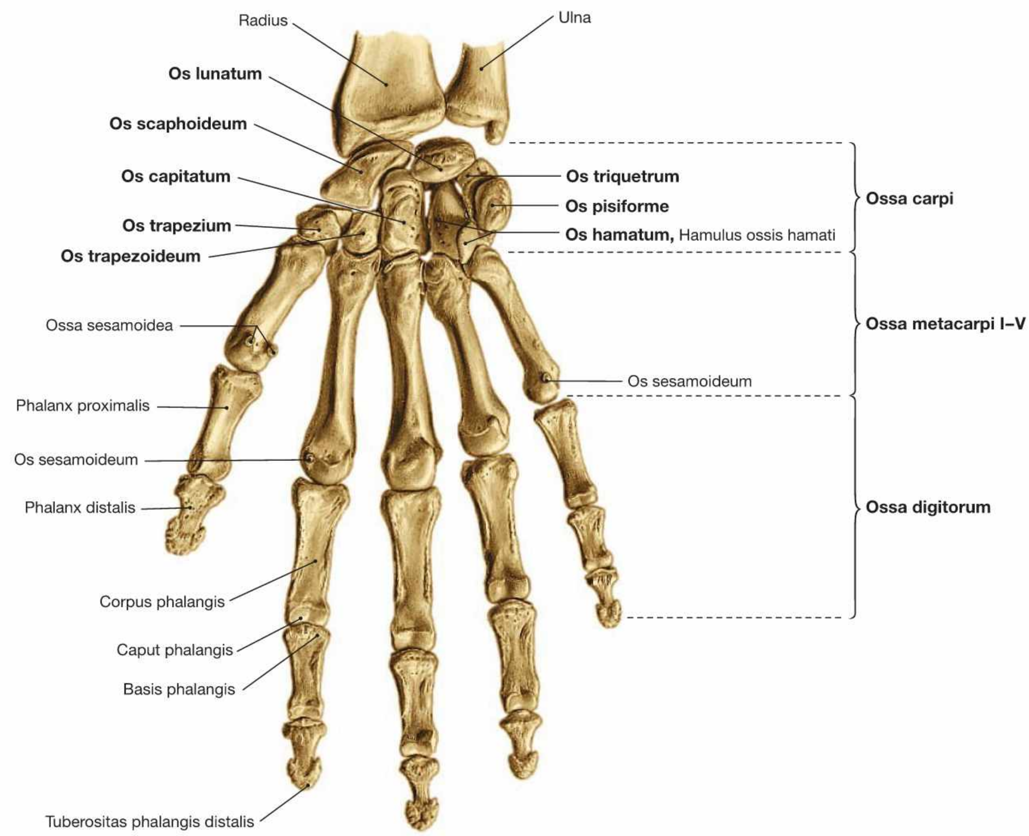


Fig. 3.25 Skeleton of the hand, Ossa manus, right side; palmar view.
The hand (Manus) consists of the wrist (Carpus with Ossa carpi), the metacarpus (Metacarpus with Ossa metacarpi) and the digits (Digiti with Ossa digitorum). Digits consist of several phalanges. The bones of the wrist form the Sulcus carpi which builds the base of the carpal tunnel (→ Fig. 3.125). The carpal tunnel is bordered by the scaphoid (Os scaphoideum) and the trapezium (Os trapezium) on the radial side and by the pisiform (Os pisiforme) and the hamate (Os hamatum) on the ulnar side.

Skeleton of the hand

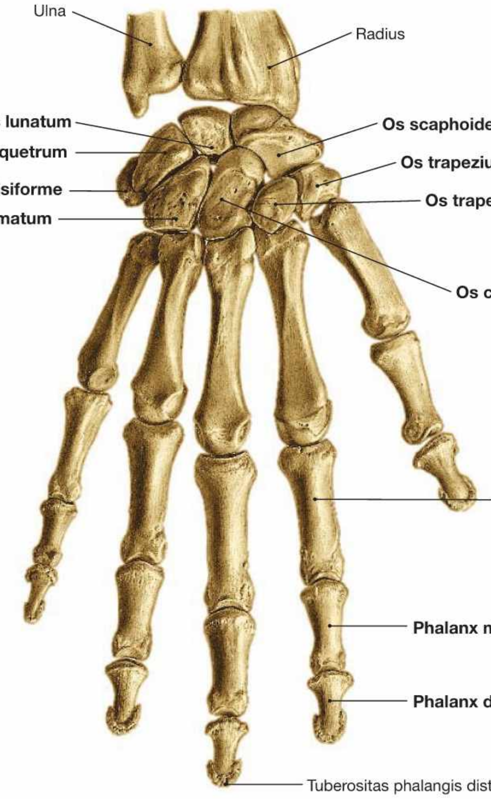


Fig. 3.26 Skeleton of the hand, Ossa manus, right side; dorsal view.

The wrist (Carpus) comprises a proximal and a distal row. From radial to ulnar the proximal row contains scaphoid (Os scaphoideum), lunate (Os lunatum) and triquetrum (Os triquetrum). The pisiform (Os pisiforme) is adjacent to the triquetrum on the palmar side. Strictly speaking, the Os pisiforme is not part of the Ossa carpi but serves as a sesamoid bone (Os sesamoideum) for the tendon of the M. flexor carpi ulnaris. The distal row comprises of the trapezium (Os trapezium), the trapezoid (Os trapezoideum), the capitate (Os capitatum), and the hamate (Os hamatum).

For many years, students have used mnemonics to help them memorising the sequence of the carpal bones:

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

Clavicular joints

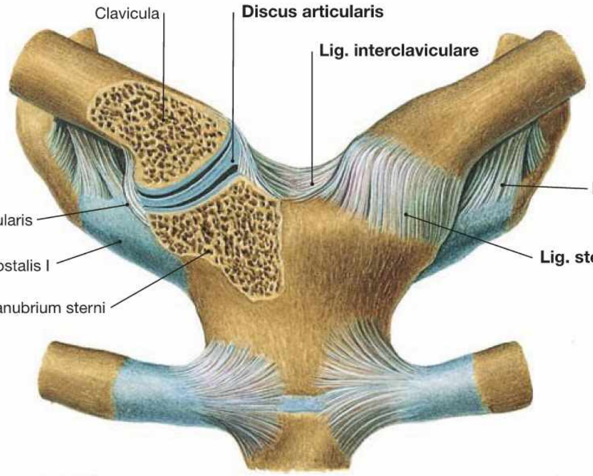


Fig. 3.27 Medial clavicular joint, Articulatio sternoclavicularis; ventral view of both joints.
The medial clavicular joint is the only articulating connection of the upper extremity with the skeleton of the trunk. The socket of the sternum and the ball of the clavicle are separated by a Discus articularis of fibrous cartilage which functions in balancing the traction force of lateral movements. The strong ligaments comprise the Ligg. sternoclavicularia anterius and posterius spanning both bony components on the ventral and dorsal side, and the Lig. interclaviculare connecting both clavicles cranially. The Lig. costoclaviculare spans between the cartilage of rib I and the sternal end of the clavicle; the M. subclavius extends to the acromial end of the clavicle.

Clavicular joints

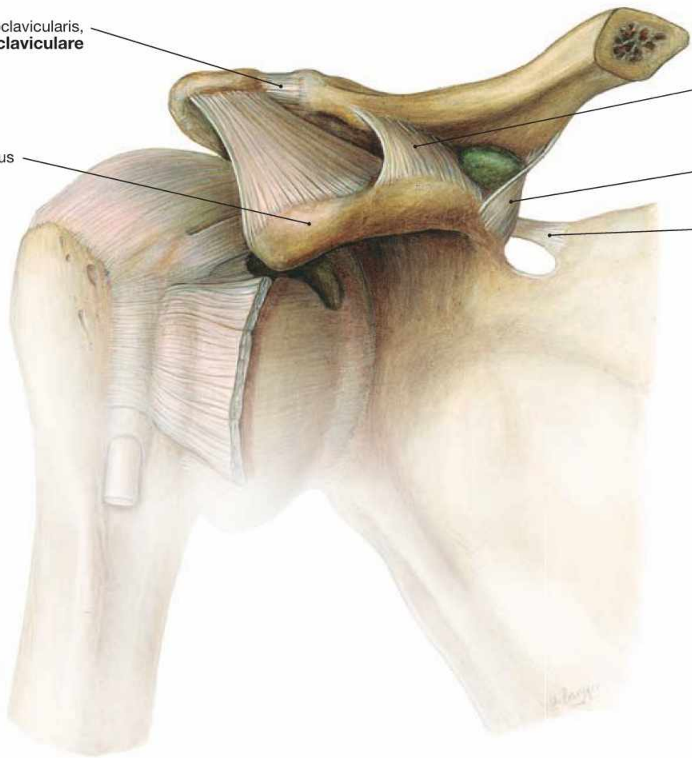


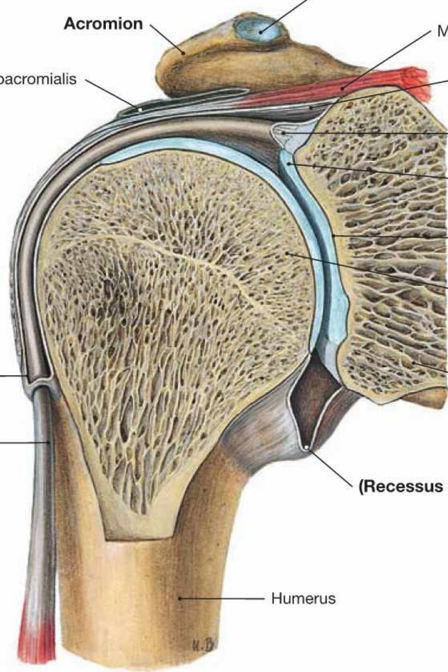
Fig. 3.28 Lateral clavicular joint, Art. acromioclavicularis, right side; ventral view.

The lateral clavicular joint connects the clavicle and the Scapula. The frequently present Discus articularis of fibrous cartilage incompletely separates the cavity of the joint. The joint capsule is supported by the Lig. acromioclaviculare. In addition, the Lig. coracoclaviculare helps to stabilise the acromioclavicular joint. This ligament consists of two separate ligaments, which independently connect the coracoid process with the Scapula. The Lig. conoideum reaches the Tuberculum conoideum medially. The Lig. trapezoideum inserts laterally on the inferior and acromial aspect of the clavicle along the Linea trapezoidea (→ Fig. 3.12).

Clinical Remarks

The sternoclavicular joint is well protected from injuries by its strong ligamentous support. However, **injuries to the acromioclavicular joint,** also called AC joint, occur frequently (e.g. as a result of a fall; → Fig. 3.57).

Shoulder joint



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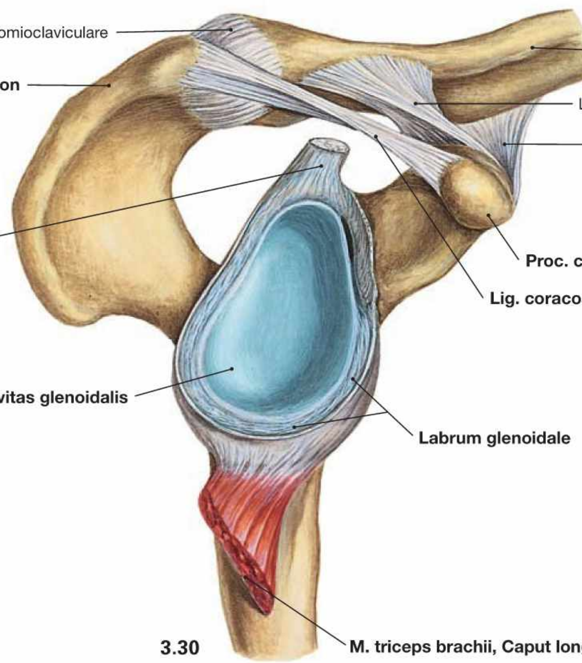


3.30

Fig. 3.29 and Fig. 3.30 Shoulder joint, Articulatio humeri, right side; section in the scapular plane, ventral (→ Fig. 3.29) and lateral view onto the joint socket (→ Fig. 3.30).

The Cavitas glenoidalis of the Scapula together with the glenoid labrum (Labrum glenoidale) of fibrous cartilage form the socket of the glenohumeral joint. It is a classical ball and socket joint where the humeral head articulates with the glenoid fossa of the Scapula. The joint capsule (Capsula articularis) originates from the Labrum glenoidale and includes at the superior aspect of the Labrum glenoidale the tendon of Caput longum of the M. biceps brachii. Originating from the Tuberculum supraglenoidale, the long head of the biceps projects through the shoulder joint, while the long head of the triceps (Caput longum of M. triceps brachii) has its origin at the Tuberculum infraglenoidale outside of the shoulder joint capsule. The capsule inserts at the Collum anatomicum of the Humerus, leaving Tuberculum majus and Tuberculum minus extra-articular. Inferiorly, the joint capsule extends to form a fold (Recessus axillaris). Various ligaments (→ Fig. 3.31) and inserting tendons of the rotator cuff muscles (→ Figs. 3.34 und 3.65) support the joint capsule on the posterior, superior, and anterior side. The **roof of the shoulder** comprises the Proc. coracoideus, the Acromion, and the connecting Lig. coracoacromiale.

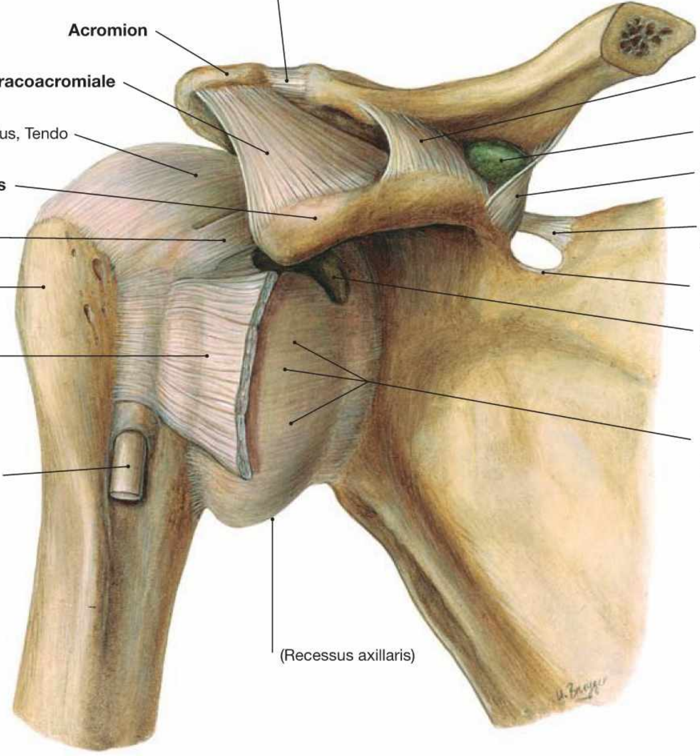


Fig. 3.31 Shoulder joint, Articulatio humeri, right side; ventral view.

The joint capsule (Capsula articularis) is supported by various ligaments and by tendons of the rotator cuff muscles. The **Lig. coracohumerale** is positioned cranially, originates from the Proc. coracoideus, and radiates into the posterior aspect of the capsule. The **Ligg. glenohumeralia** consist of different collagen fibre systems and stabilise the anterior part of the capsule. Since the tendons of the rotator cuff muscles also radiate into the capsule from anterior, superior, and posterior directions, the weakness of the inferior joint capsule is evident. The **Lig. coracoacromiale**, together with the Proc. coracoideus and the Acromion, form the **roof of the shoulder** outside of the joint capsule. The roof of the shoulder functions as an additional support for the glenoid fossa by stabilizing the humeral head superiorly against pressure from the arm. The structural elements of the shoulder roof also limit elevation of the arm above the horizontal plane (Elevation), unless the Scapula is rotated, too.

Clinical Remarks

The glenoid fossa of the shoulder joint is relatively small. Thus, this joint has a large range of motion but is also prone to injury. Dislocations **(luxations)** of the shoulder joint are among the most common dislocations of the body (→ p. 159).

Shoulder joint

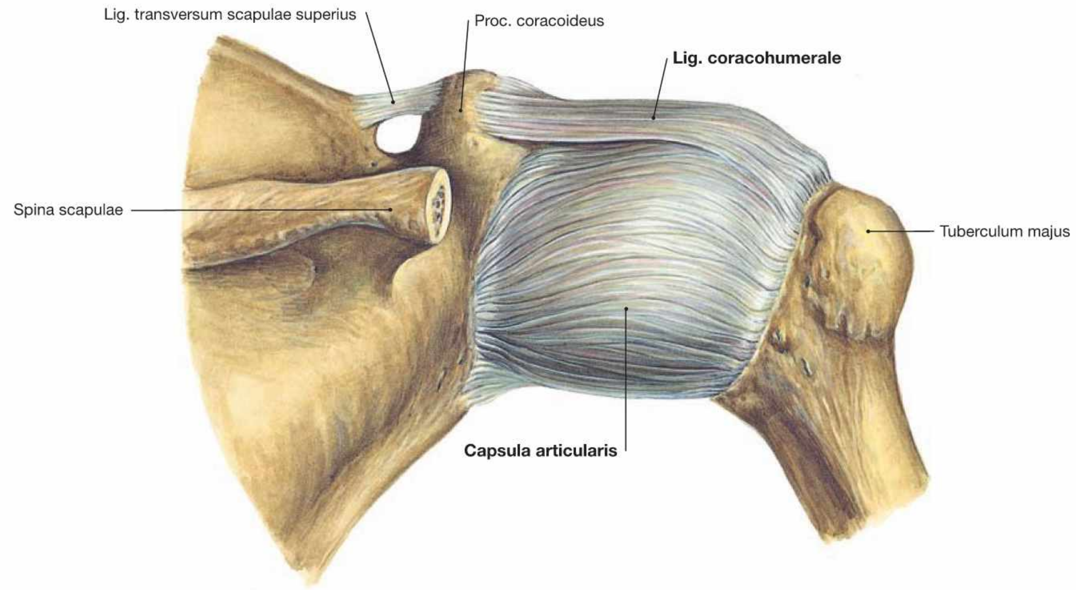
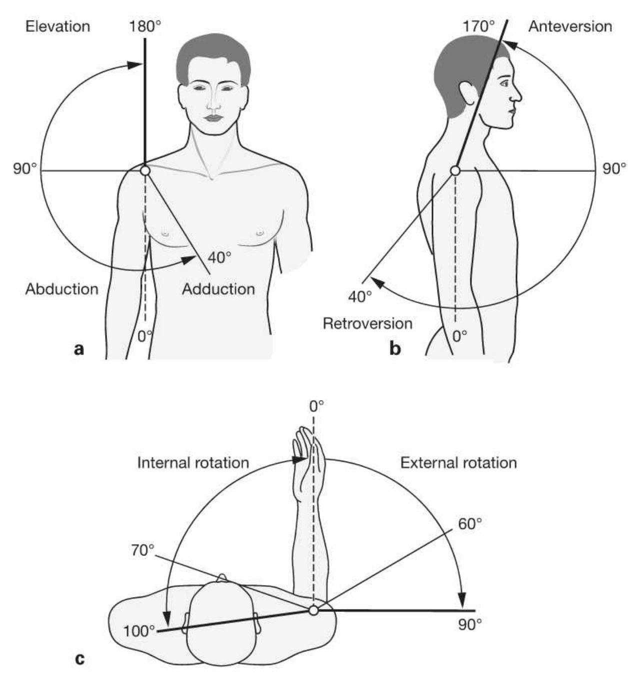


Fig. 3.32 Shoulder joint, Articulatio humeri, right side; dorsal view.



Figs. 3.33a to c Range of movement in the shoulder joint with and without contributions of the clavicular joints. (according to [1]).

a, b The shoulder joint is a **ball and socket joint** with three degrees of freedom of movement and the highest range of movement of all joints of the human body. When motions are exclusively performed in the glenohumeral joint, the extent of abduction and anteversion is restricted by the shoulder roof (thin lines). But if considering combined movements of shoulder and clavicular joints, allowing the Scapula to rotate, then a much higher range of movement is possible (thick lines). This also allows for the **elevation** of the arm above the horizontal plane. Rotation of the Scapula is mediated by the M. serratus anterior and M. trapezius and already becomes effective at the beginning of abduction of the arm.

c To determine rotational movements of the shoulder joint (see below) the forearm, which can be viewed like an indicator, has to be positioned in a 90° flexion of the elbow. With the arm extended, one mostly detects a combined rotation of the shoulder joint and the forearm.

Range of movement in the shoulder joint alone:
- abduction–adduction: 90°– 0°– 40°
- anteversion–retroversion: 90°– 0°– 40°
- external rotation–internal rotation: 60°– 0°– 70°

Range of movement in the shoulder and clavicular joints combined:
- abduction–adduction: 180°– 0°– 40°
- anteversion–retroversion: 170°– 0°– 40°
- external rotation–internal rotation: 90°– 0°– 100°

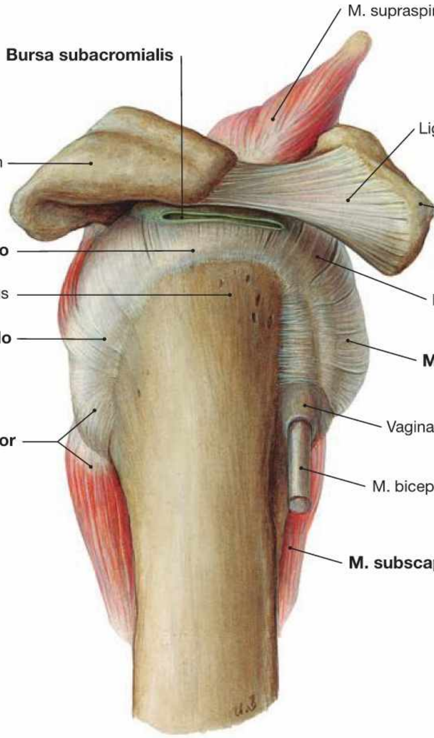


Fig. 3.34 Shoulder joint, Articulatio humeri, right side; lateral view.

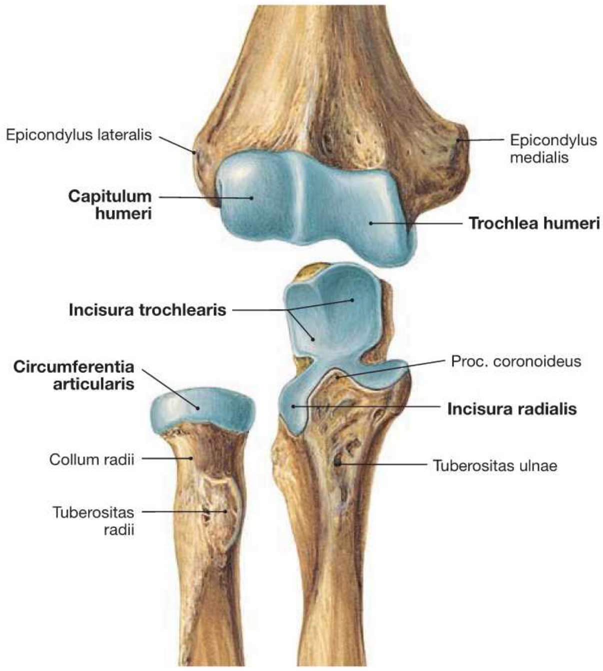
Several muscles contribute to the stabilisation of the shoulder joint through insertion of their tendons into the joint capsule. These muscles are collectively called the rotator cuff: **M. subscapularis** supports the joint capsule from the ventral, **M. supraspinatus** from the superior, and **M. infraspinatus** and **M. teres minor** from the dorsal aspect. Thus, the inferior aspect is the weakest part of the joint capsule.

Several synovial cushions (Bursae) are associated with the shoulder joint. Some of them communicate with the joint capsule and form extensions of the joint. The Bursa subcoracoidea which is positioned underneath the Proc. coracoideus frequently communicates with the Bursa subtendinea musculi subscapularis. The latter cushions the tendon of the M. subscapularis (→ Fig. 3.31) and often also communicates with the articular cavity (→ Fig. 3.64). The Bursa subacromialis is positioned on top of the supraspinatus tendon and is connected with the Bursa subdeltoidea. Thus, these two bursae together form the accessory subacromial joint. These bursae enable a friction-free movement of the head of the Humerus and of the tendons of the rotator cuff muscles beneath the Acromion.

Clinical Remarks

Degenerative alterations affecting the tendon of M. supraspinatus are common. Patients present with pain when lifting the arm. Abduction between 60–120° causes compression of the tendon underneath the roof of the shoulder **(impingement syndrome).** In addition, degenerativ charges due to calcifications in the accessory subacromial joint can be the cause of painful restrictions of shoulder movements.

Elbow joint



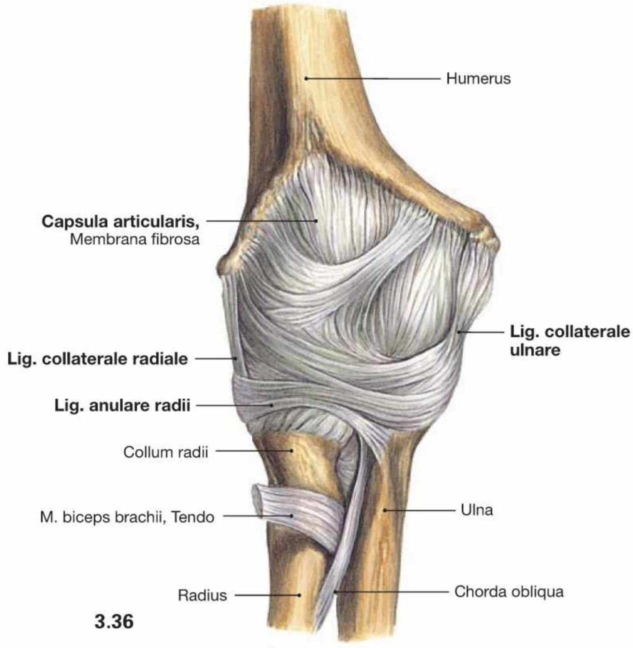
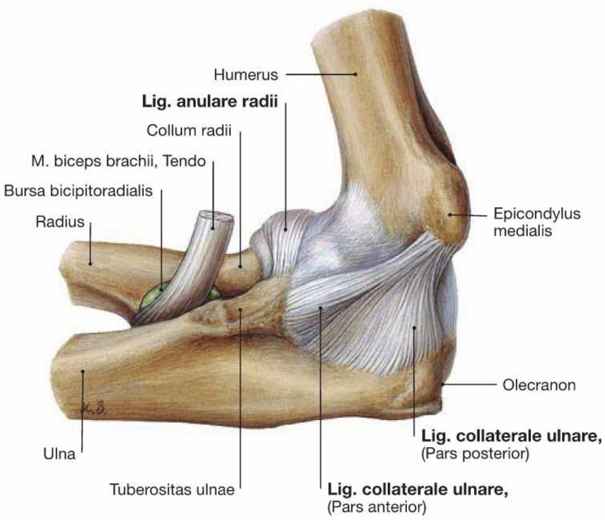
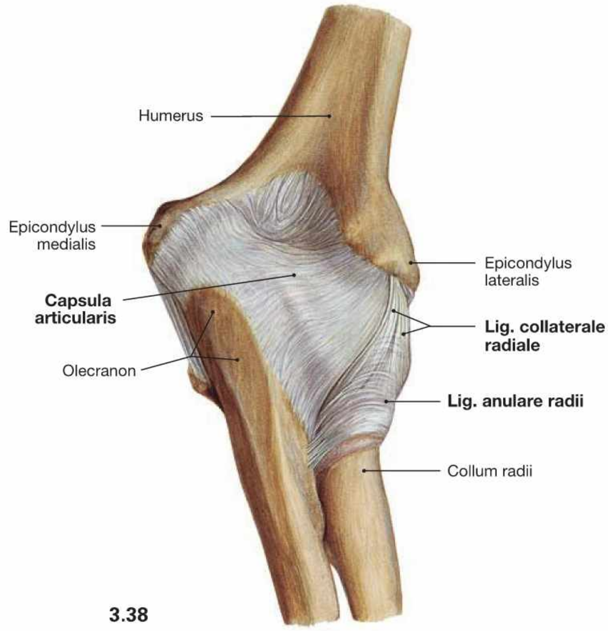


Fig. 3.35 Articulating bones of the elbow joint, Articulatio cubiti; ventral view. Articulating areas covered by hyaline cartilage are illustrated in blue.



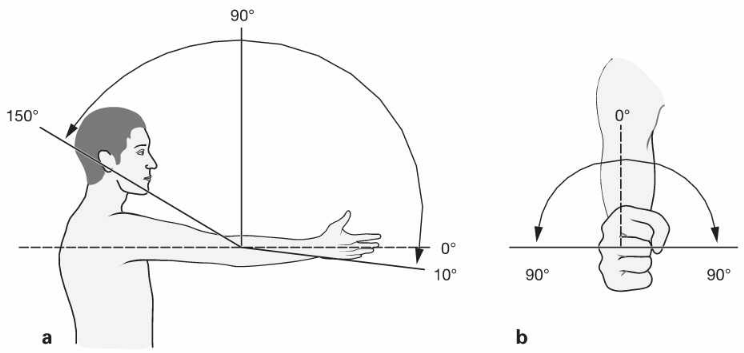


Figs. 3.36 to 3.38 Elbow joint, Articulatio cubiti, right side; ventral (→ Fig. 3.36), medial (→ Fig. 3.37), and dorsal (→ Fig. 3.38) view.

The elbow joint is a composite joint (Articulatio composita), with the Humerus, the Radius and the Ulna articulating in three partial joints.

- **Articulatio humeroulnaris:** hinge joint with the Trochlea humeri forming the ball and the Incisura trochlearis of the Ulna forming the socket
- **Articulatio humeroradialis:** multiaxial ball and socket joint involving the Capitulum humeri (ball) und the Fovea articularis of the Radius (socket)
- **Articulatio radioulnaris proximalis:** pivot joint involving the Circumferentia articularis of the Caput radii (ball) and the Incisura radialis of the Ulna (socket).

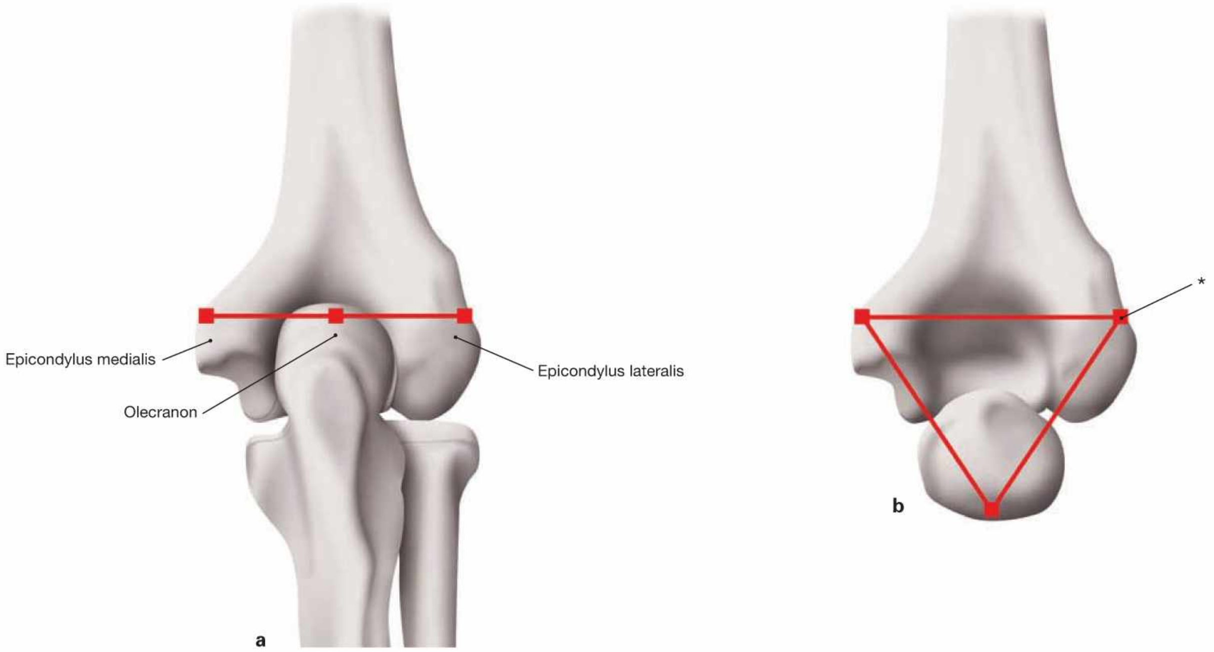
The joint capsule (Capsula articularis) encloses the cartilaginous articulating surfaces of all three bones. The capsule is reinforced by accessory ligaments. Two **collateral ligaments** are responsible for lateral stabilisation of the elbow joint. Medially, the Lig. collaterale ulnare connects the Epicondylus medialis of the Humerus with the Proc. coronoideus (Pars anterior) and the Olecranon (Pars posterior) of the Ulna. The Lig. collaterale radiale originates from the lateral aspect of the Epicondylus lateralis and radiates out to join the **anular ligament** (Lig. anulare radii) which is attached to the anterior and posterior side of the Ulna to loop the Caput of the Radius. The anular ligament allows for guided rotational movements in the proximal radio-ulnar joint.



Figs. 3.39a and b Range of movement in the elbow joint.
(according to [1])
The elbow joint enables two distinct movements: hinge movements between Humerus and Ulna and between Humerus and Radius and rotational movements between Humerus and Radius and between Radius and Ulna. Thus, the partitions of the elbow joint function as **hinge rotation joint** (trochoginglymus) when acting together. The joint between Humerus and Ulna is largely guided by bones. In contrast to the inhibition of arm flexion by soft tissues of the flexor muscles, extension of the arm is limited by the bony structure of the Olecranon. The transverse axis of movement in the elbow joint is positioned within the Trochlea humeri (**a**).

The rotational movements are guided by the Lig. anulare radii (**b**). Rotation of the Radius around the Ulna not only requires movements in the proximal but also in the distal radio-ulnar joint (→ Fig. 3.44). Starting from the neutral-null position and with the thumb pointing upwards the rotational movement in the radio-ulnar joint can result in supination (palm facing upwards) or pronation (palm facing downwards) of the forearm. Despite the fact that the articular surfaces of the humero-ulnar joint have the shape of a multi-axial ball and socket joint, the humero-ulnar joint is functionally confined to hinge movements. The circular anular ligament firmly ties the Radius to the Ulna and prevents abduction and adduction movements.

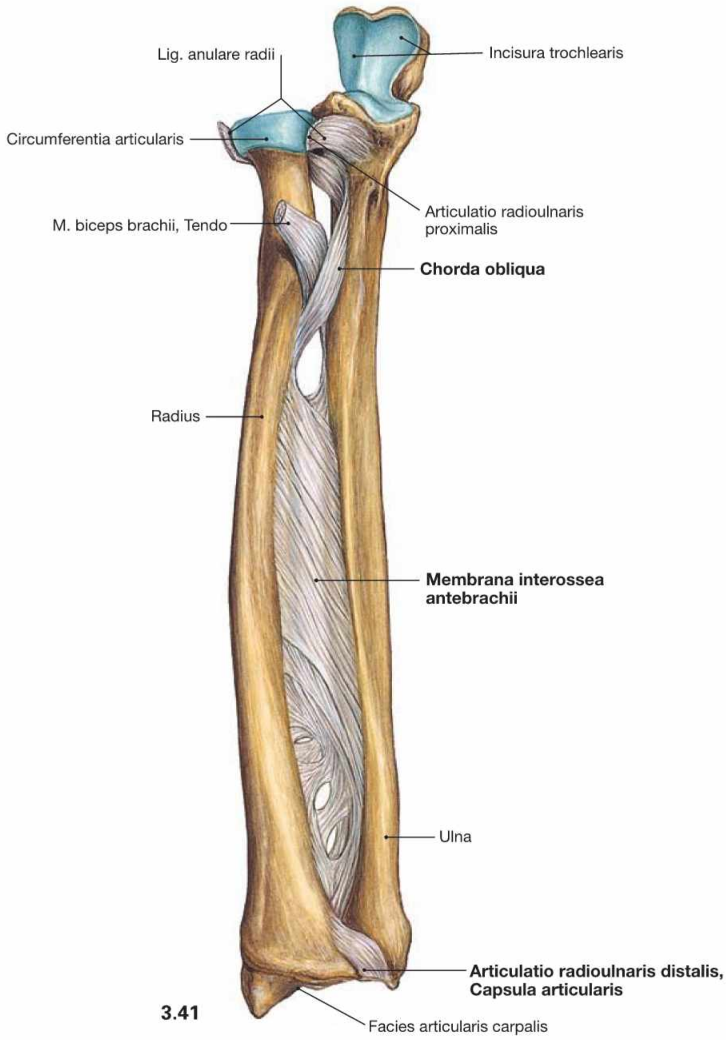
Range of movement in the elbow joint:
- extension–flexion: 10°– 0°–150°
- supination–pronation: 90°– 0°– 90°



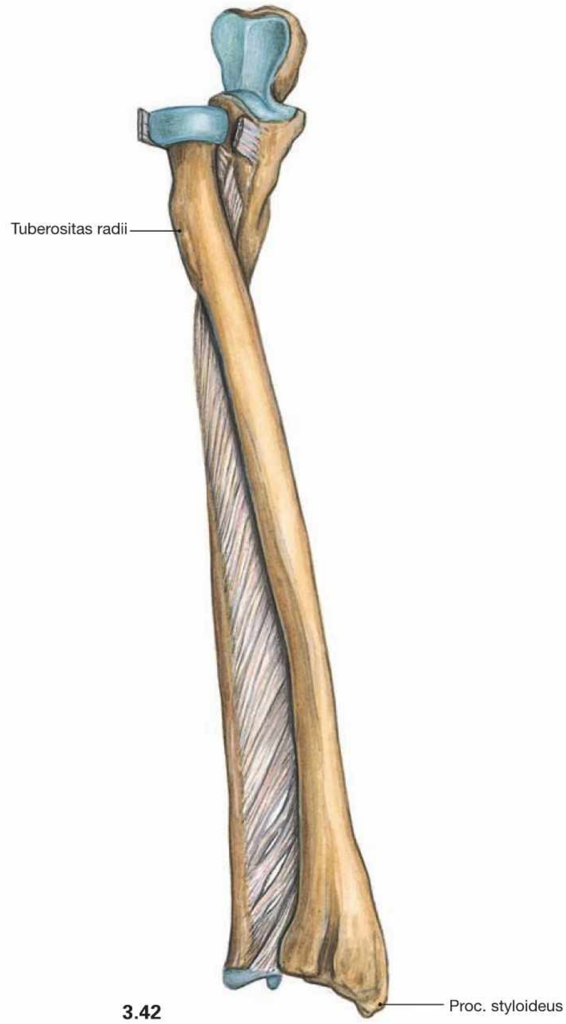
Figs. 3.40a and b HUETER's triangle.
In the extended position of the elbow joint, the epicondyles of the Humerus are in line with the Olecranon (**a**). In flexed position, however, the epicondyles form an equilateral triangle (HUETER's triangle, **b**). The Hueter's triangle has radiological relevance since fractures and dislocations may result in deviations from this triangular orientation of the epicondyles.

* clinical term: HUETER's triangle

Conjunctions between the bones of the forearm



3.41



3.42

Fig. 3.41 and Fig. 3.42 Conjunctions of the bones of the right forearm in supination (→ Fig. 3.41) and pronation position (→ Fig. 3.42); ventral view.
The bones of the forearm are connected by the tough Membrana interossea antebrachii whose collagen fibres are predominantly oriented from the Radius proximally to the Ulna distally. Proximally, the Chorda obliqua courses with an opposite orientation. The figures demonstrate the rotation of the Radius around the Ulna. Radius and Ulna are positioned in parallel during supination of the forearm but they cross during pronation of the forearm.

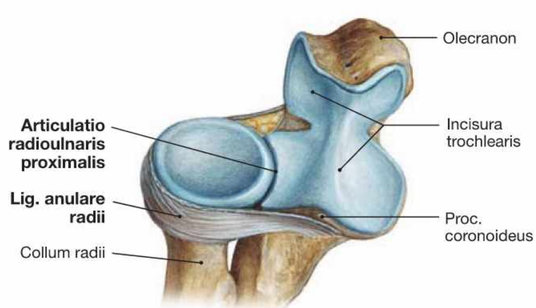


Fig. 3.43 Proximal radio-ulnar joint, Articulatio radioulnaris proximalis, right side; proximal and ventral view.
The proximal radio-ulnar joint is a pivot joint and part of the elbow joint. The common axis for both the proximal and the distal radio-ulnar joints is the diagonal axis of the forearm connecting the Caput radii with the Caput ulnae.

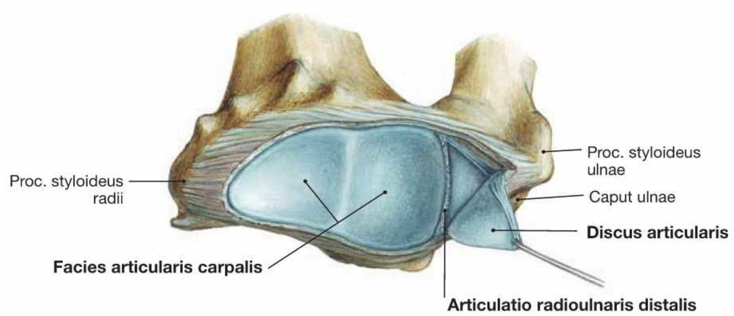


Fig. 3.44 Distal radio-ulnar joint, Articulatio radioulnaris distalis; distal and dorsal view.
The distal radio-ulnar joint is a pivot joint as well and is located adjacent to the proximal wrist joint. This joint comprises the Caput ulnae and the Incisura ulnaris of the Radius. In the proximal wrist joint the Facies articularis carpalis of the distal Radius and the articular disc of the distal radio-ulnar joint articulate with the proximal carpal bones.

Joints of Carpus and metacarpus

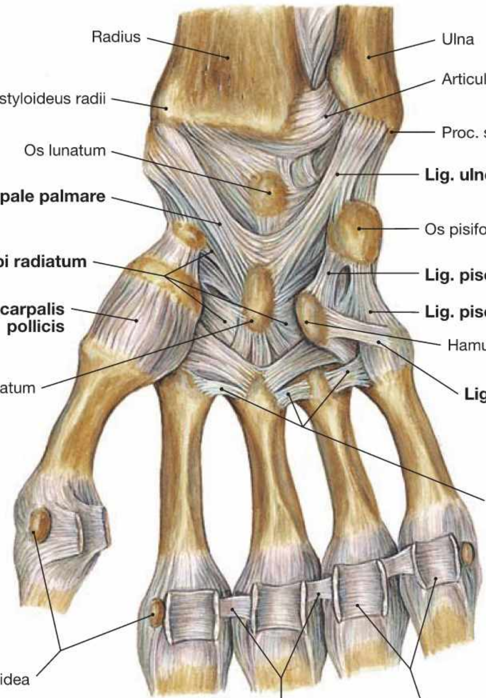


Fig. 3.45 Joints and ligaments of the right hand, Articulationes and Ligamenta manus, right side; palmar view.

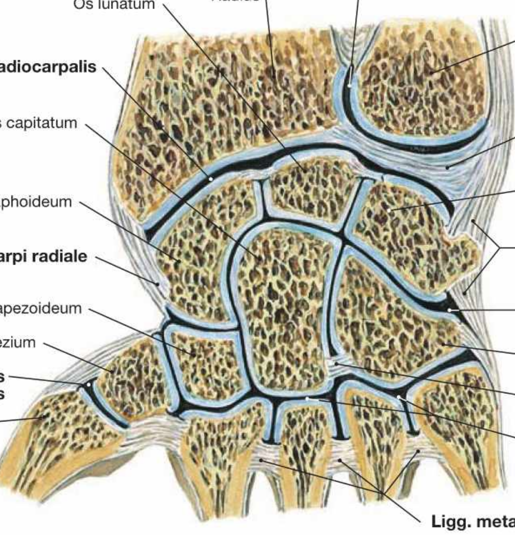


Fig. 3.46 Joints of the right carpus and metacarpus, Articulationes carpi, right side; view from palmar, section parallel to the dorsum of the hand.

In addition to smaller joints between the different bones of the carpus and metacarpus these consit of two wrist joints.

- The **proximal wrist joint** (Articulatio radiocarpalis) is a condyloid joint and connects the bones of the forearm (socket) with the carpus (joint head). Between Ulna and Os triquetrum resides a Discus articularis (→ Fig. 3.44).
- The **distal wrist joint** (Articulatio mediocarpalis) also functions as a condyloid joint. Carpal bones of the proximal row articulate with carpal bones of the distal row.
- The **Articulationes carpometacarpales II–V** between carpal and metacarpal bones and the **Articulationes intermetacarpales** between the bases of the metacarpal bones are tight amphi-arthroses allowing only very limited movements. In contrast, the **saddle joint of the thumb** (Articulatio carpometacarpalis pollicis) is highly mobile and allows flexion and extension as well as abduction and adduction movements.

Joints of carpus and metacarpus

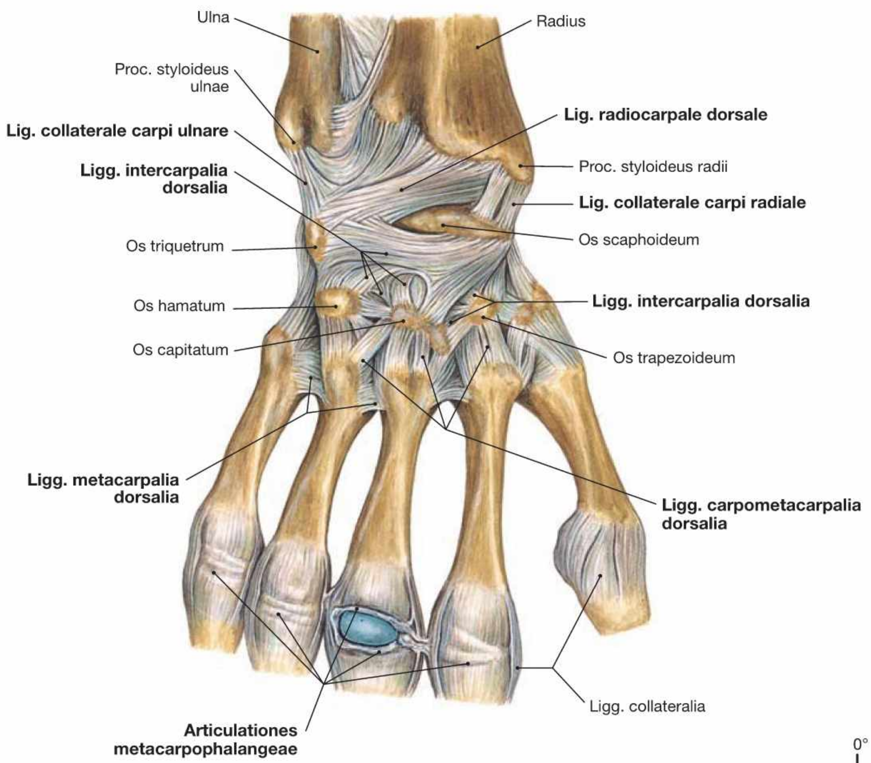
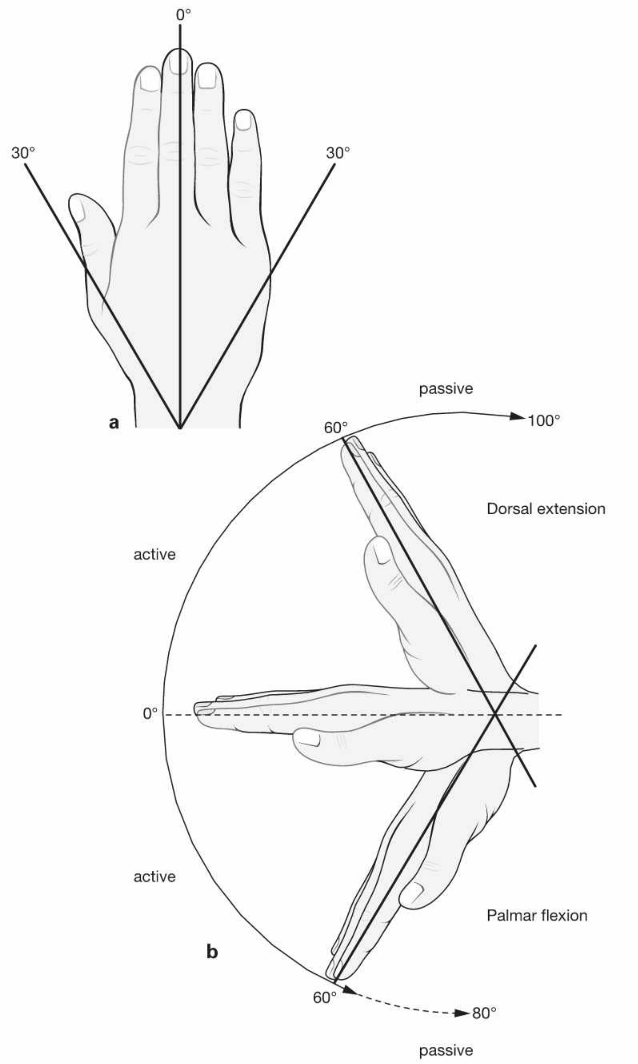


Fig. 3.47 Joints and ligaments of the hand, Articulationes and Ligamenta manus, right side; dorsal view.

Ligaments of Carpus and Metacarpus
• 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: ligaments radiating from the Os capitatum
• Lig. pisohamatum: continuation of the flexor carpi ulnaris tendon to the Os hamatum
• Lig. pisometacarpale: continuation of the flexor carpi ulnaris tendon to the Ossa metacarpi IV and V
• Ligg. carpometacarpalia palmaria and dorsalia
• Ligg. metacarpalia palmaria, dorsalia, and interossea



Figs. 3.48a and b Range of movement in the wrist joints. (according to [1])
Proximal and distal wrist joints function as **condyloid (ellipsoid) joints** and contribute both to the movements of the hand. Thus, the axes of movements for both joints are described as combined axes through the Os capitatum. Abduction of Radius and Ulna occurs mainly in the proximal wrist joint with a combined dorsopalmar axis of movements running through the centre of the Os capitatum **(a)**.
The **p**almar flexion is predominantly mediated by the **p**roximal wrist joint, and the **d**orsal extension by the **d**istal wrist joint (mnemonic, **b**). The transverse axis of these movements also runs through the centre of the Os capitatum. Most other joints of the carpus and metacarpus are amphi-arthroses and their range of motion is negligible. In contrast, the **saddle joint of the thumb** shows a great freedom of movements allowing not only flexion and extension but also adduction and abduction. These movements can be combined for circumduction and opposition of the thumb, both of which are important to grasp objects.

Range of movement in the carpal joints:
- ulnar abduction – radial abduction: 30°– 0°– 30°
- dorsal extension – palmar flexion: 60°– 0°– 60°

Range of movement in the saddle joint of the thumb:
- extension–flexion: 30°– 0°– 40°
- abduction–adduction: 10°– 0°– 40°

Finger joints

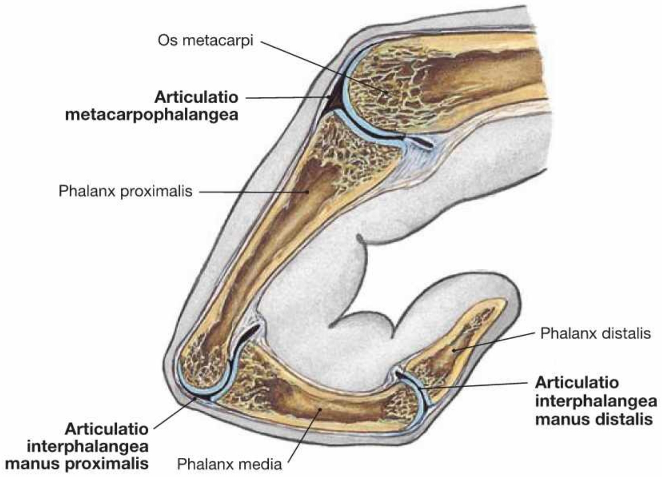


Fig. 3.49 Finger joints, Articulationes digitorum, right side; lateral view, sagittal section.
They comprise the metacarpophalangeal and interphalangeal joints. The **metacarpophalangeal joints** (Articulationes metacarpophalangeales) are condyloid joints in which the distal parts of the metacarpal bones articulate with 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 the bases of the respective digital bones are hinge joints.

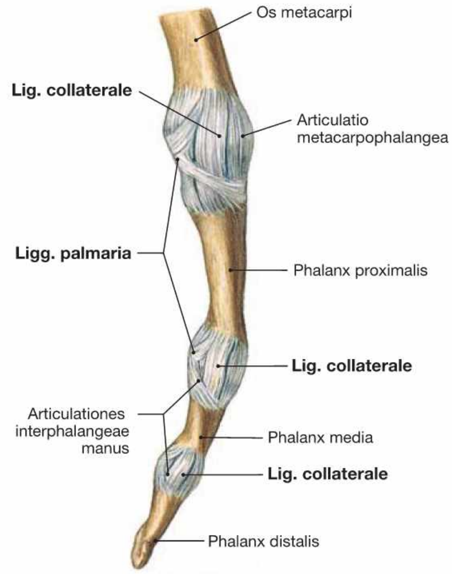
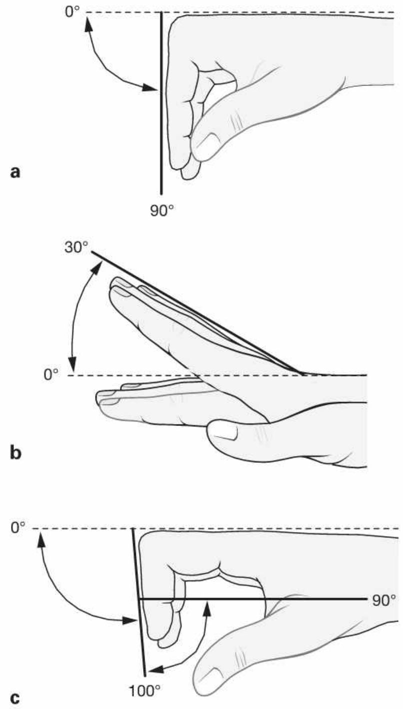


Fig. 3.50 Ligaments of the finger joints, Articulationes digiti, right side; lateral view.
- Ligg. collateralia: medial and lateral
- Lig. palmare: ventral
- Lig. metacarpale transversum profundum: connects palmar ligaments at the metacarpophalangeal joints (→ Fig. 3.45).



Figs. 3.51a to c Range of movement in the finger joints. (according to [1])
The metacarpophalangeal joints allow flexion and extension as well as radial and ulnar abduction. Rotational movements are only possible passively if fingers are in extension. The saddle joint of the thumb exclusively enables hinge movements. The same applies for the proximal and distal interphalangeal joints which exclusively enable flexion.

Range of movement in the metacarpophalangeal joints:
- dorsal extension–palmar flexion: 30°– 0°– 90°
- ulnar abduction–radial abduction: (20 – 40)°– 0°– (20 – 40)°

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

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

Clinical Remarks

Abbreviations and terms commonly used in the clinical setting:
- MCP joint = **m**eta**c**arpo**p**halangeal joint
- PIP joint = **p**roximal **i**nter**p**halangeal joint
- DIP joint = **d**istal **i**nter**p**halangeal joint

Shoulder joint and humerus

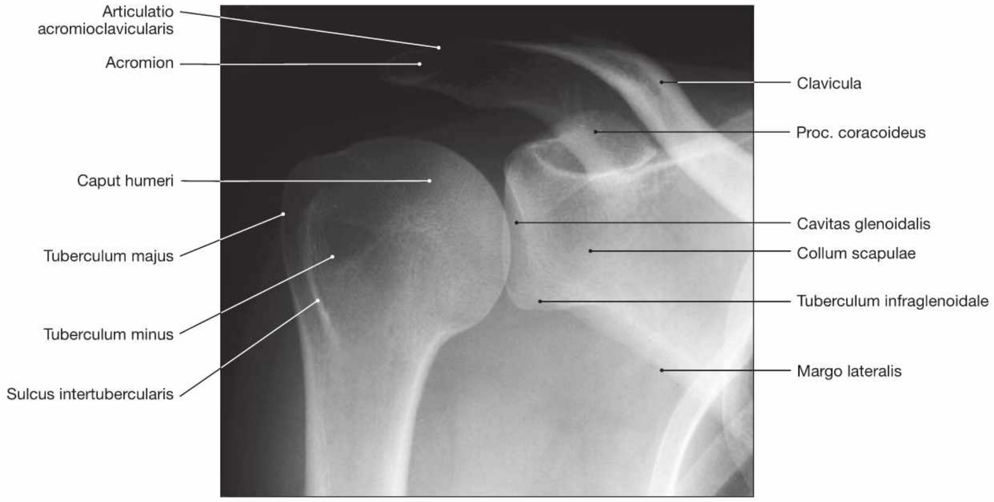
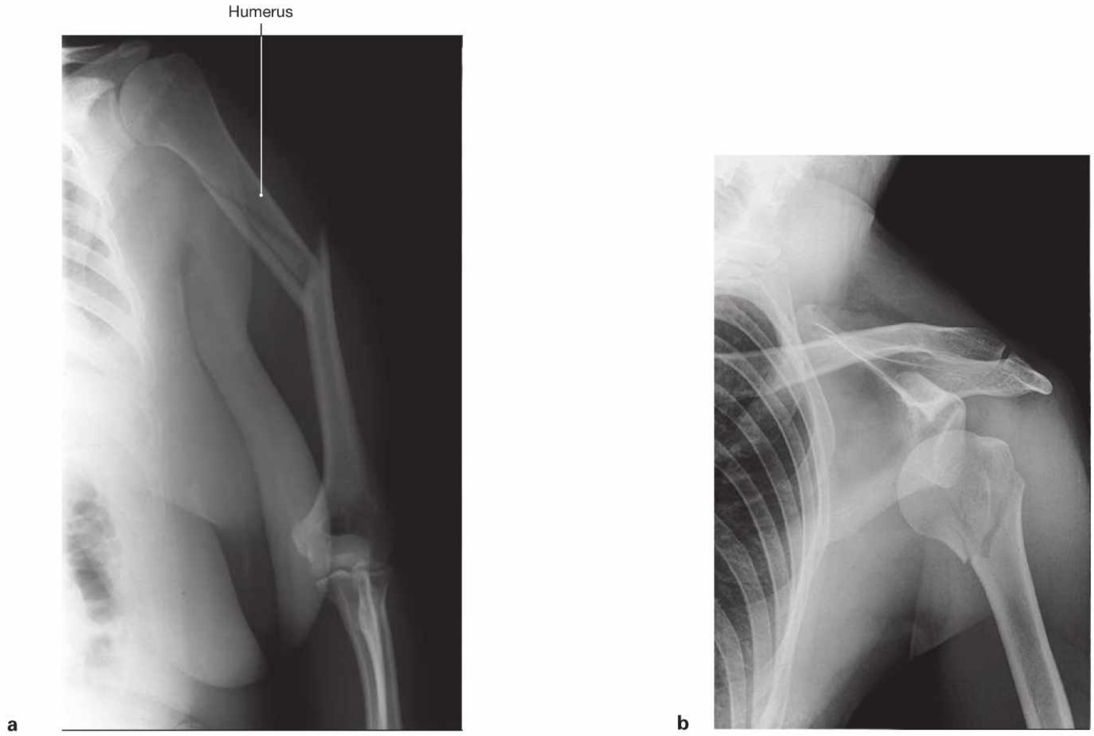


Fig. 3.52 Shoulder joint, Articulatio humeri, right side; radiograph in anterioposterior (AP) beam projection.

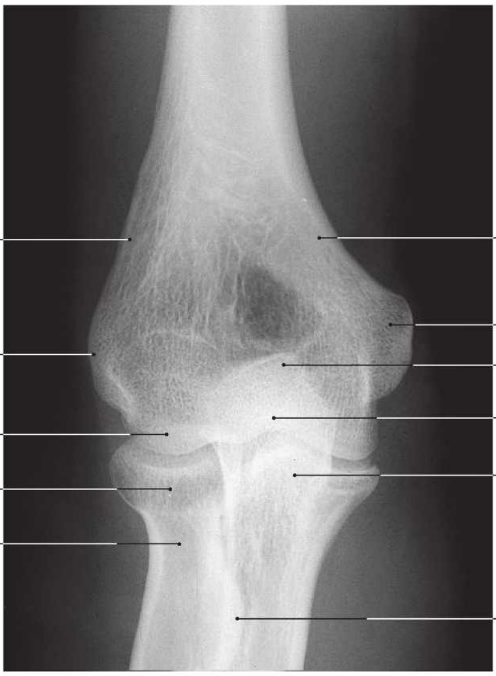


Figs. 3.53a and b Radiographs showing fractures of the Humerus.
a Fracture of the shaft of the Humerus, which may result in injury to the radial nerve. [8]
b Fracture of the head of the Humerus, which may result in injury to the axillary nerve. [4]

Clinical Remarks

Conventional radiographs are suitable for the identification of **fractures** and **dislocations** (luxations) leading to alterations in the position of skeletal elements. Injuries to the ligaments, however, cannot be detected by radiographic imaging but instead require the use of ultrasound or magnetic resonance imaging (MRI) as diagnostic tools.

Elbow joint



3.54

3.55

Fig. 3.54 and Fig. 3.55 Elbow joint, Articulatio cubiti, right side; radiographs in anterioposterior (AP; → Fig. 3.54) and lateral (→ Fig. 3.55) beam projections.

Clinical Remarks

In the extended position of the elbow joint, both epicondyles of the Humerus are in line with the Olecranon of the Ulna. Fractures or dislocations may result in deviations from the normal position (→ Fig. 3.40).

Hand

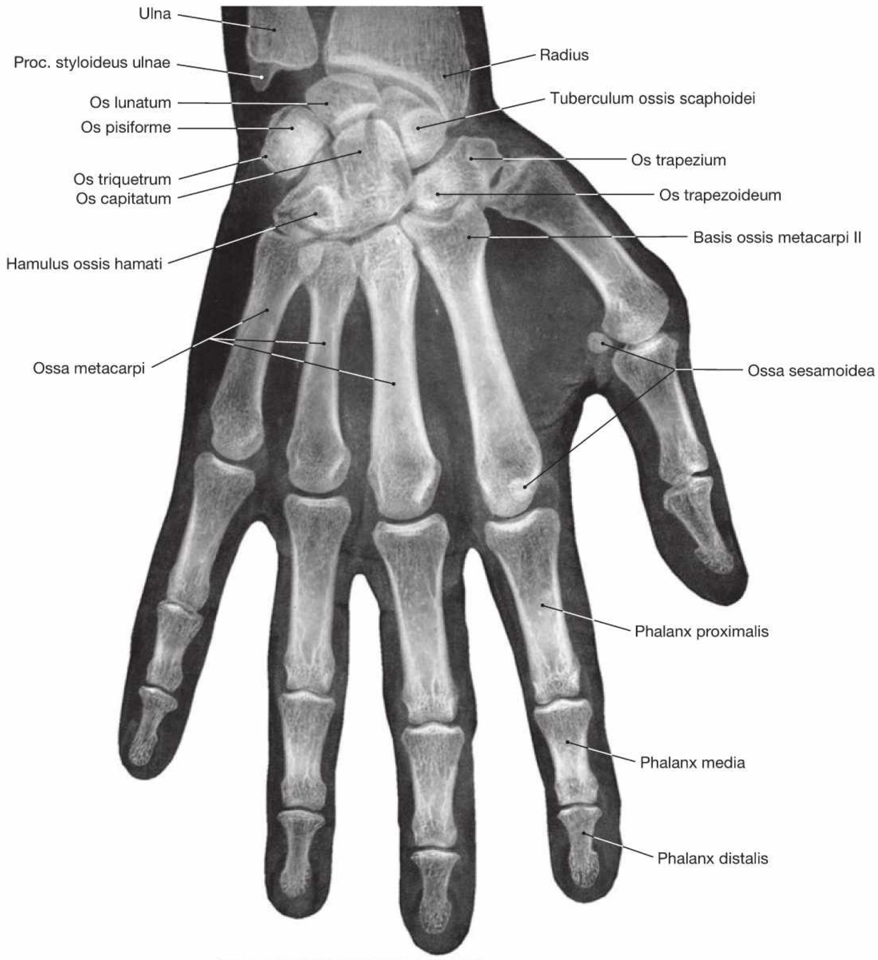


Fig. 3.56 Hand, Manus, right side; radiograph in anterioposterior (AP) beam projection.

Clinical Remarks

The fracture of the distal Radius is the most common fracture occurring in humans. The diagnosis of a distal Radius fracture based on the radiographic image requires profound knowledge of the radiological anatomy of the wrist joint.
Fractures of the carpus frequently involve the **scaphoid bone.** Concomitant injuries of the supplying blood vessels may result in necrosis of the scaphoid bone and show a reduced bone density in radiographic images. In addition, injuries may cause degenerative alterations such as arthrosis of the hand and finger joints. Typical radiological signs of **arthrosis** are the development of bony outgrowths (osteophytes) and destruction of the articular surfaces.

Dislocations of the shoulder

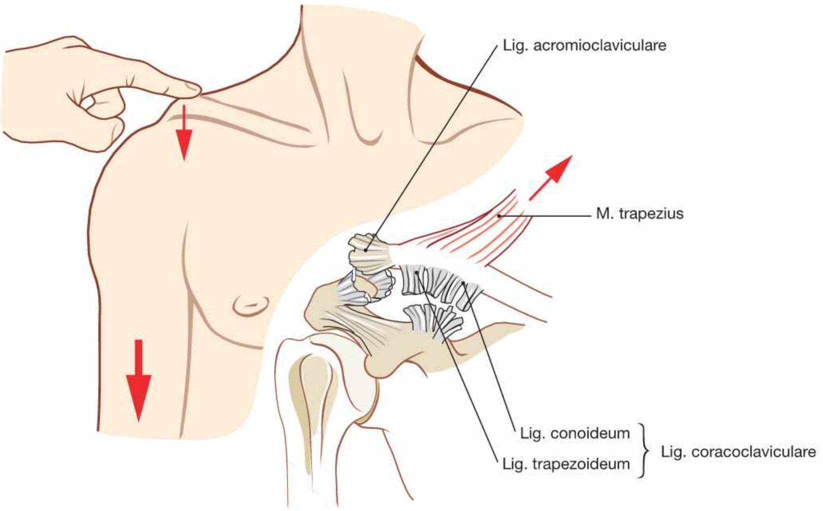


Fig. 3.57 Injury of the acromioclavicular joint ("shoulder separation"). (according to [1])
After dislocation (luxation) of the acromioclavicular joint and associated rupture of the Ligg. coracoclaviculare and acromioclaviculare, the lateral part of the clavicle is pulled up by the M. trapezius and the shoulder "drops" (weight of the arm). The **classification** of the severity is done according to **TOSSY:**
- **I overextension** of the ligaments
- **II partial rupture** of the ligaments
- **III complete rupture** of both components, the Lig. coracoclaviculare and the Lig. acromioclaviculare. This TOSSY-III injury requires surgical stabilisation.

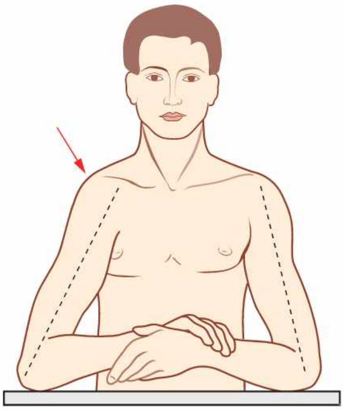


Fig. 3.58 Dislocation (luxation) of the shoulder joint. (according to [1])
Dislocation of the shoulder is the most common luxation in the body. The shoulder joint is prone to luxation because of the weak bony and ligamentous guidance for the movements of the head of Humerus. The most common (90%) form is the Luxatio subcoracoidea (as shown on the right side) with positioning of the Humeral head beneath the Proc. coracoideus. The contour of the shoulder (dome) is reduced and the upper arm appears longer.

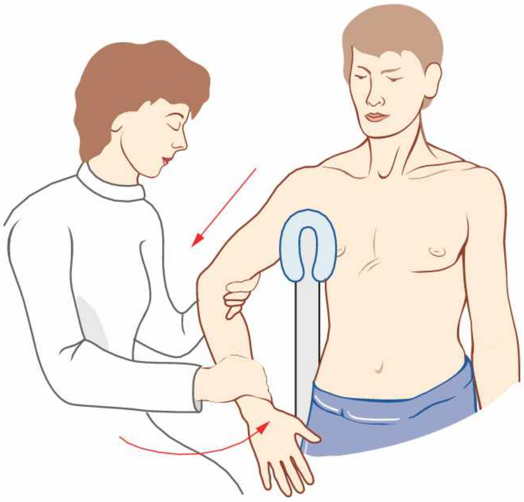


Fig. 3.59 Reposition of a dislocated shoulder. (according to [1])
The procedure according to ARLT requires the injured arm to be positioned over a cushioned back of a chair. The physician pulls the flexed arm in the direction of the Humerus until the head of the Humerus pops back into the glenoid fossa.

Fig. 3.60 Luxatio subcoracoidea. [4]
This type of luxation means that the head of the Humerus snaps to a position beneath the Proc. coracoideus. The dome of the shoulder is reduced and the arm appears longer.

Muscles of shoulder and arm

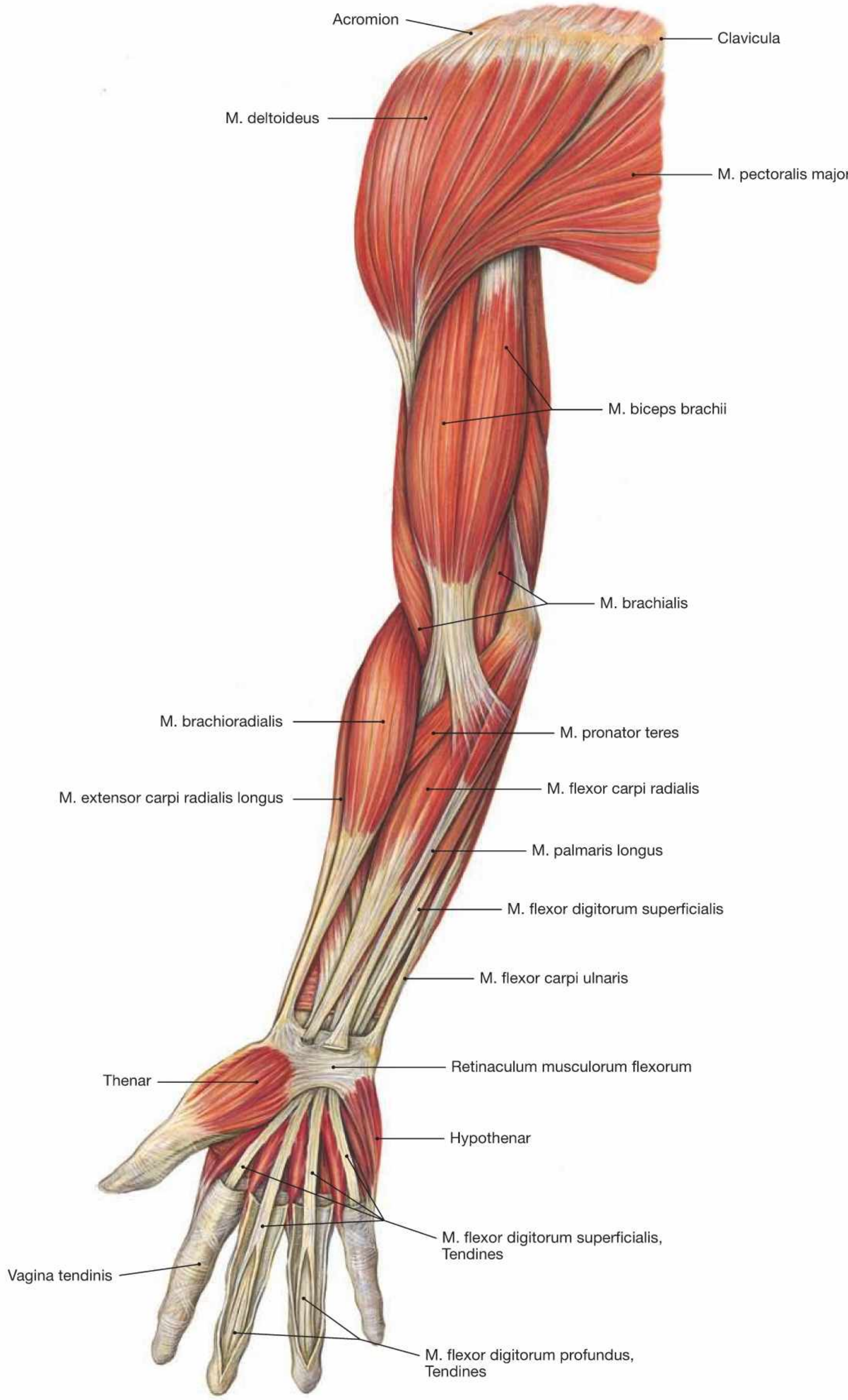


Fig. 3.61 Ventral muscles of the shoulder and arm, right side; ventral view.

→ T 24–38

Muscles of shoulder and arm

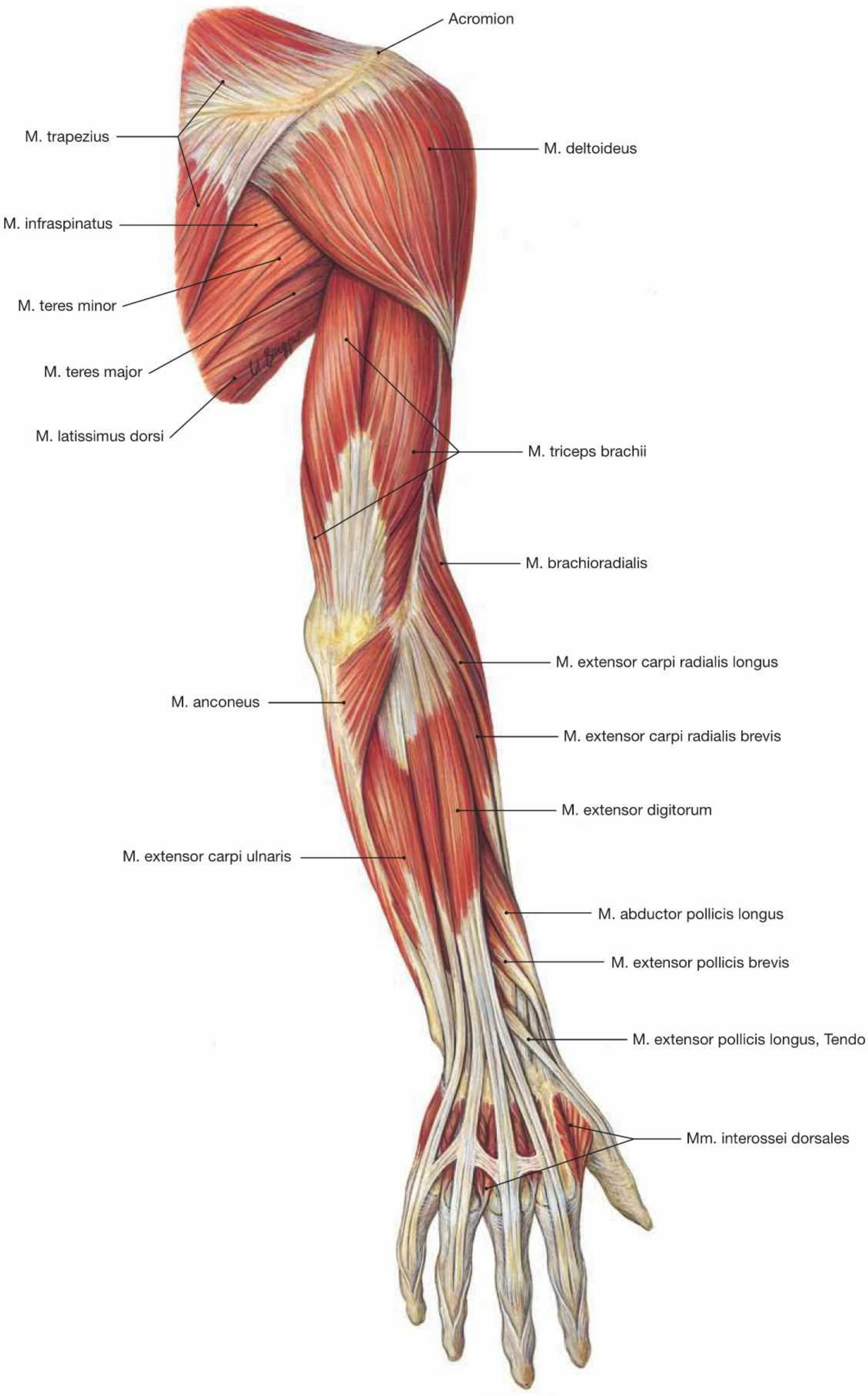


Fig. 3.62 Dorsal muscles of the shoulder and arm, right side; dorsal view.

→ T 24–38

Muscles of the arm

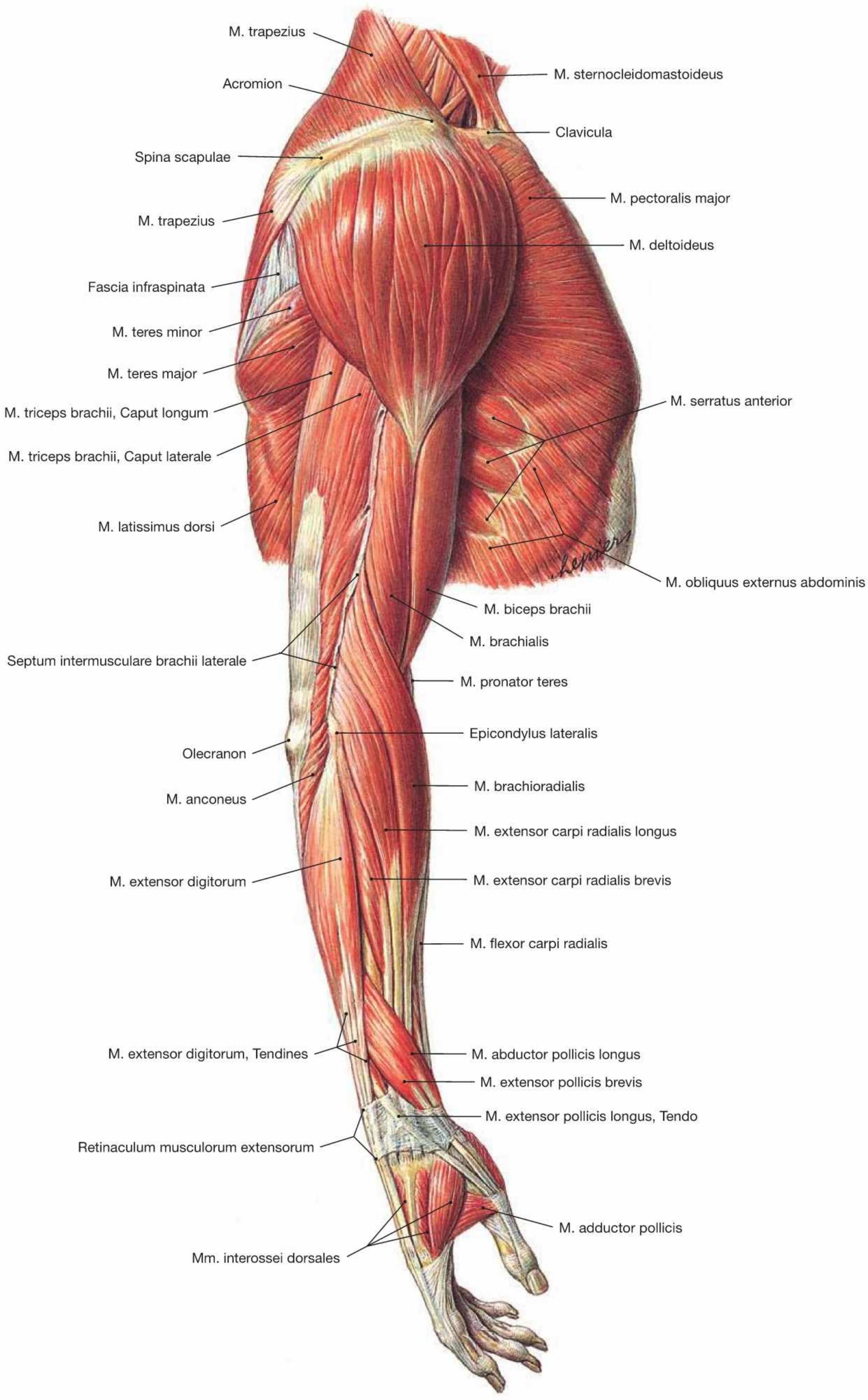


Fig. 3.63 Muscles of the arm and thorax, right side; lateral view.

→ T 24–38

Rotator cuff

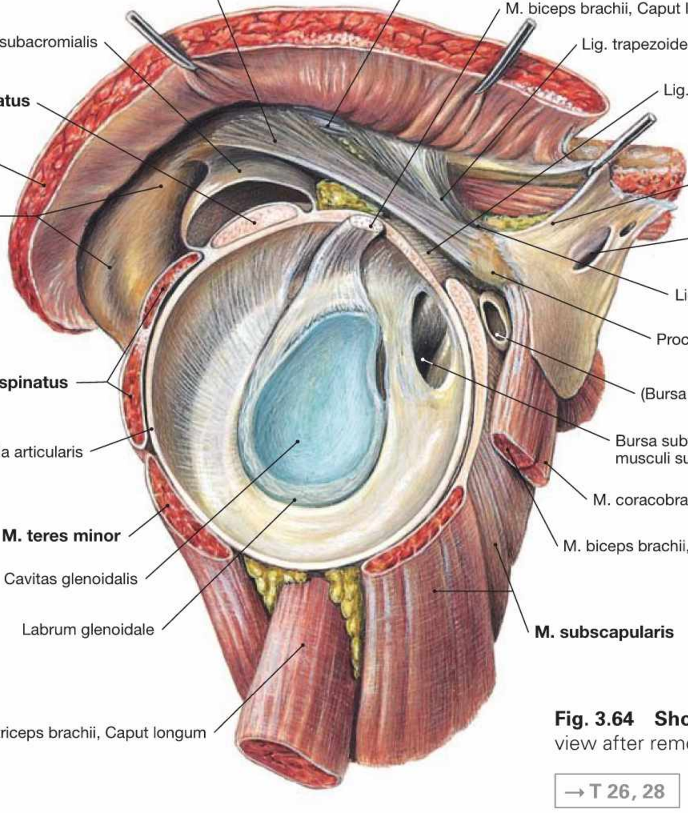


Fig. 3.64 Shoulder joint and shoulder muscles, right side; lateral view after removal of the M. deltoideus and the Caput humeri.

→ T 26, 28

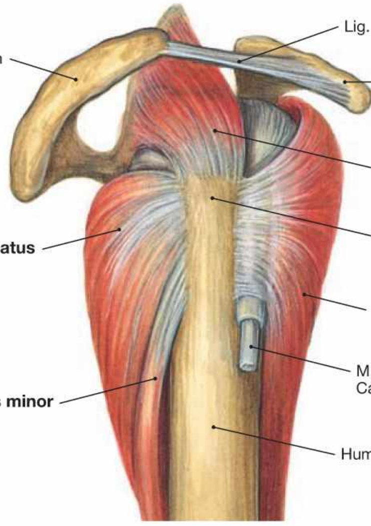


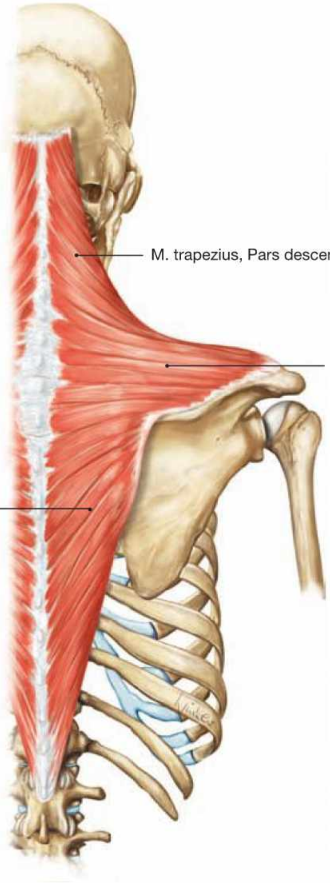
Fig. 3.65 Muscles of the rotator cuff; lateral view.
The extensive range of movement in the shoulder joint is an essential prerequisite for the touch and grip function of the upper extremity. Based on the strong guidance by muscles and the highly flexible positioning of the Scapula, the shoulder joint only requires little support by bones and ligaments. However, when neuromuscular problems arise, such as in nerve injuries or with a dysbalance between the rotator cuff muscles, the contact of the articular surfaces cannot be guaranteed anymore. Dislocations occur when shear forces act tangentially to the Cavitas glenoidalis, in particular during a fall.
The tendons of those muscles directly adjacent to the shoulder joint radiate into the joint capsule and form a tough rotator cuff around the head of the Humerus. Among these muscles are the **M. subscapularis** (ventral), the **M. supraspinatus** (superior), **M. infraspinatus** (dorsal superior), and the **M. teres minor** (dorsal inferior). With the exception of the M. subscapularis, which inserts on the Tuberculum minus, and in addition to their connection to the joint capsule, all muscles of the rotator cuff insert at the Tuberculum majus. The M. deltoideus is not part of the rotator cuff because there is no connection to the joint capsule.

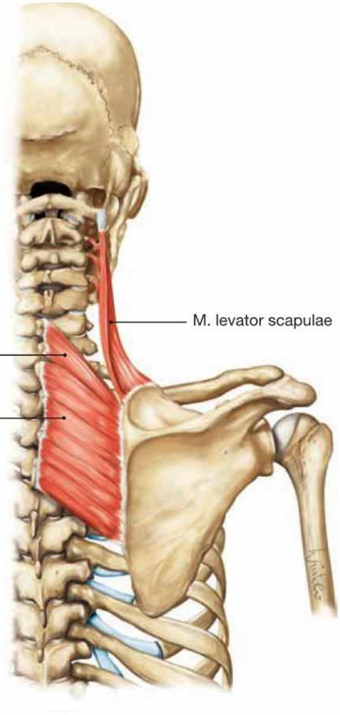
→ T 26, 28

Clinical Remarks

In addition to their role in the various movements (kinematics), the relevance of the rotator cuff muscles is to ensure the correct position of the humeral head in the glenoid fossa (statics). **Elevation of the humeral head** occurs as a result of muscular imbalance, especially a relative weakness of the adductory (inferior) parts of the muscles.

Muscles of the shoulder girdle

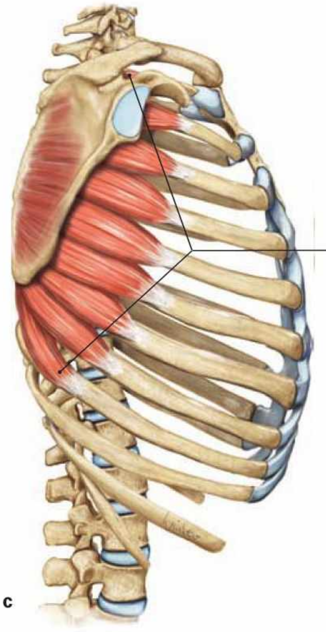


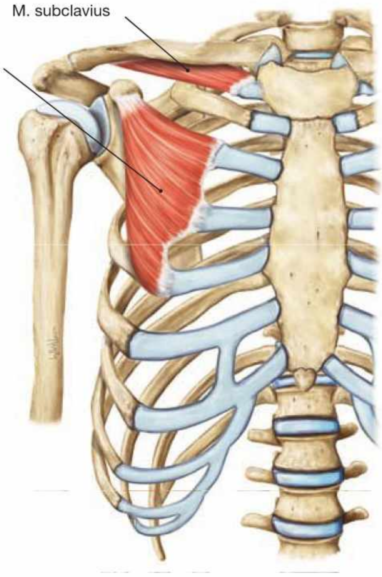


Figs. 3.66a and b Muscles of the shoulder girdle.
a M. trapezius
b M. levator scapulae and Mm. rhomboidei
The shoulder has two functional muscle groups. The muscles of the shoulder girdle originating from the Scapula or clavicle primarily move the shoulder girdle and only indirectly move the arm. In contrast, the muscles of the shoulder originating from the Humerus directly move the arm. These muscle groups can be subdivided according to their position. The **dorsal** muscles of the shoulder girdle comprise the M. trapezius, the M. levator scapulae, and the Mm. rhomboidei. **Ventral** muscles are the M. serratus anterior, the M. pectoralis minor, and the M. subclavius (→ Fig. 3.68). Fixation of the Scapula to the trunk is predominantly accomplished by the M. levator scapulae and the Mm. rhomboidei, with additional support from the M. serratus anterior and the M. trapezius.
The dorsal muscles of the shoulder girdle are also illustrated as superficial muscles of the back (→ pp. 74 and 75). The ventral muscles are also shown with the ventral wall of the trunk (→ pp. 86–88).

→ T 27

Muscles of the shoulder girdle





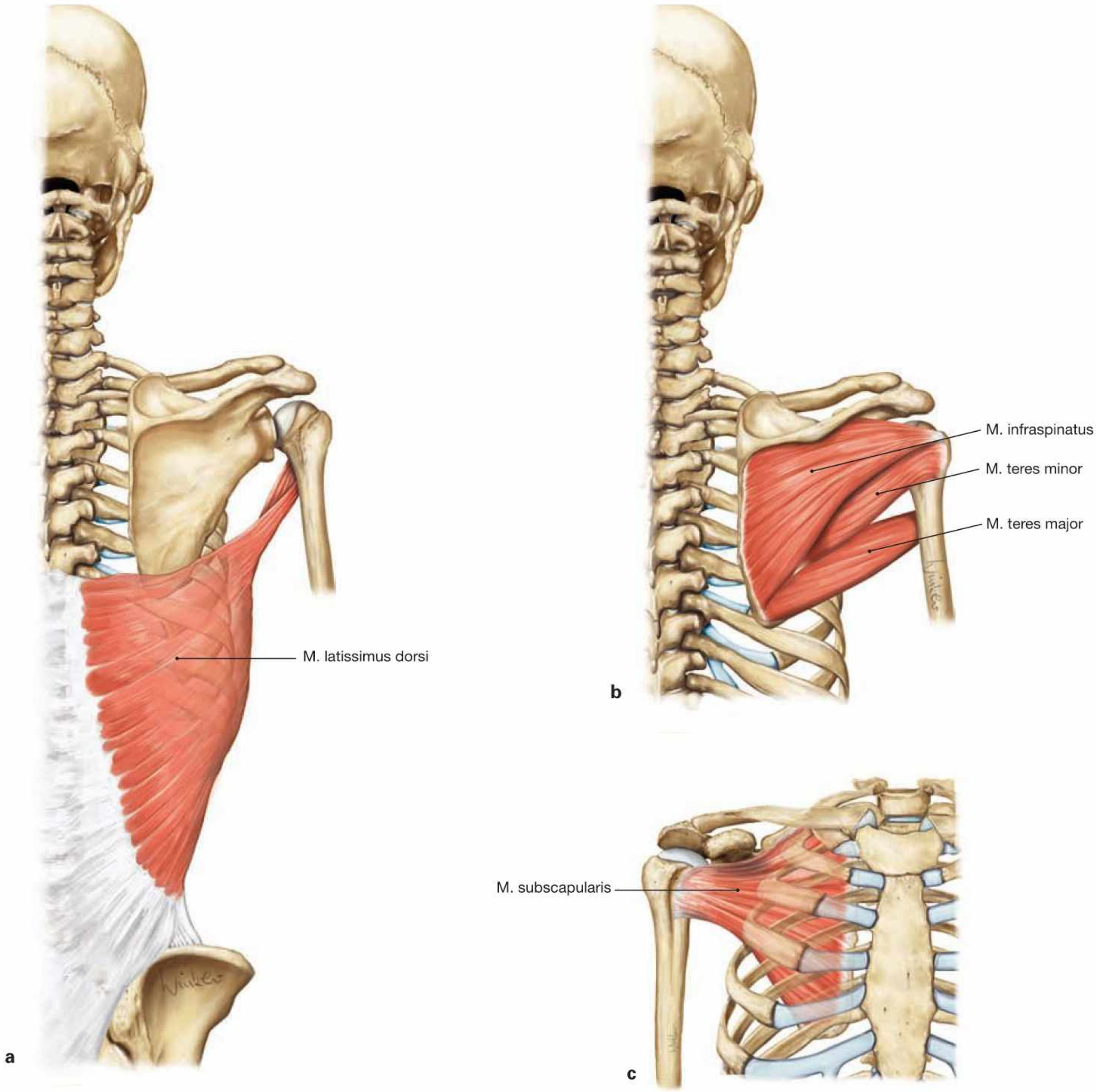
Figs. 3.66c and d Muscles of the shoulder girdle.
c M. serratus anterior
d M. pectoralis minor and M. subclavius

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 the M. trapezius is the rotation of the Scapula, a requirement for the elevation of the arm above the horizontal plane. In addition to its function in lowering the Scapula, the M. pectoralis minor supports the elevation of the ribs when the arm is fixed, thus, functioning as auxiliary muscle of inspiration similar to the M. serratus anterior. The M. subclavius acts as an active strap in the stabilisation of the sternoclavicular joint.

The dorsal muscles are also illustrated as superficial muscles of the back (→ pp. 74 and 75). The ventral muscles are shown with the ventral wall of the trunk (→ pp. 86 – 88).

→ T 24

Muscles of the shoulder



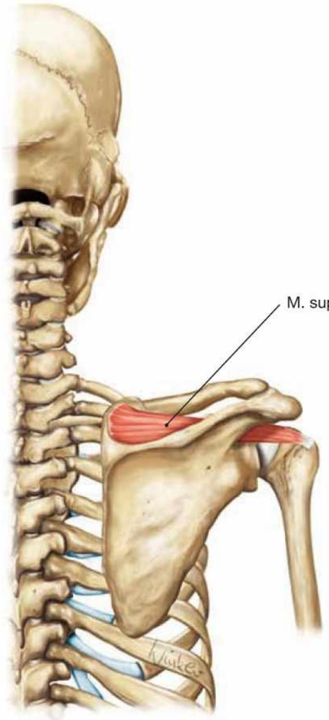
Figs. 3.67a to c Muscles of the shoulder.
a M. latissimus dorsi
b M. infraspinatus, M. teres minor, M. teres major
c M. subscapularis

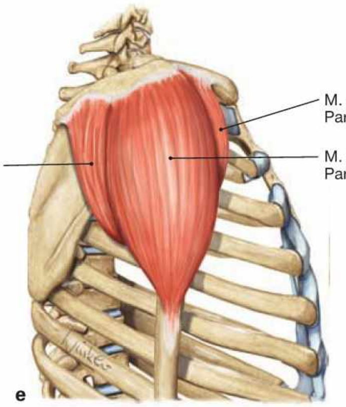
In contrast to muscles of the shoulder girdle, shoulder muscles directly act on the arm. They can be subdivided into a dorsal and a ventral group of muscles and an additional lateral group of muscles which is defined as a part of the dorsal group in some textbooks. The group of **dorsal** shoulder muscles comprises the M. latissimus dorsi, M. infraspinatus, M. teres minor, M. teres major, and M. subscapularis, the only muscle of this group positioned on the ventral side of the Scapula.

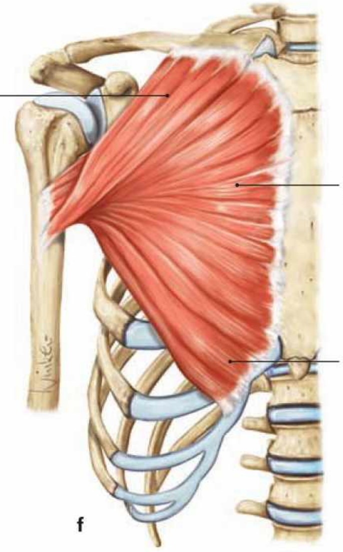
The **M. latissimus dorsi** enables a strong retroversion movement of the anteverted arm (such as raising the trunk to the arm when climbing or performing chin-ups). However, with the arms fixed its action aids in the compression of the thorax (e.g. when coughing; patients with COPD develop a strong M. latissimus dorsi).

The **M. subscapularis** is the most important medial rotator of the arm and its action is necessary in order to cross when crossing the arms behind the back. Its functional antagonist is the **M. infraspinatus** enabling a strong lateral rotation of the arm. M. teres major and M. teres minor are functionally less important on their own but support the action of the other shoulder muscles.

→ T 28







Figs. 3.67d to f Muscles of the shoulder.
d M. supraspinatus
e M. deltoideus
f M. pectoralis major

The group of **lateral** shoulder muscles comprises the M. supraspinatus and the M. deltoideus. The M. pectoralis major is the only one in a **ventral** position. The **M. pectoralis major** is the strongest muscle for anteversion and adduction of the arm. Its action is essential to cross the arms in front of the trunk (ventrally). In addition to the M. latissimus dorsi, the M. pectoralis major supports a strong retroversion movement of the arm when started from an anteverted position.

The **M. deltoideus** is the most important abductor of the arm and supports all other movements of the shoulder joint through its functionally distinct parts. The **M. supraspinatus** supports the action of the M. deltoideus in abduction.

→ T 25, 26

Muscles of shoulder and shoulder girdle

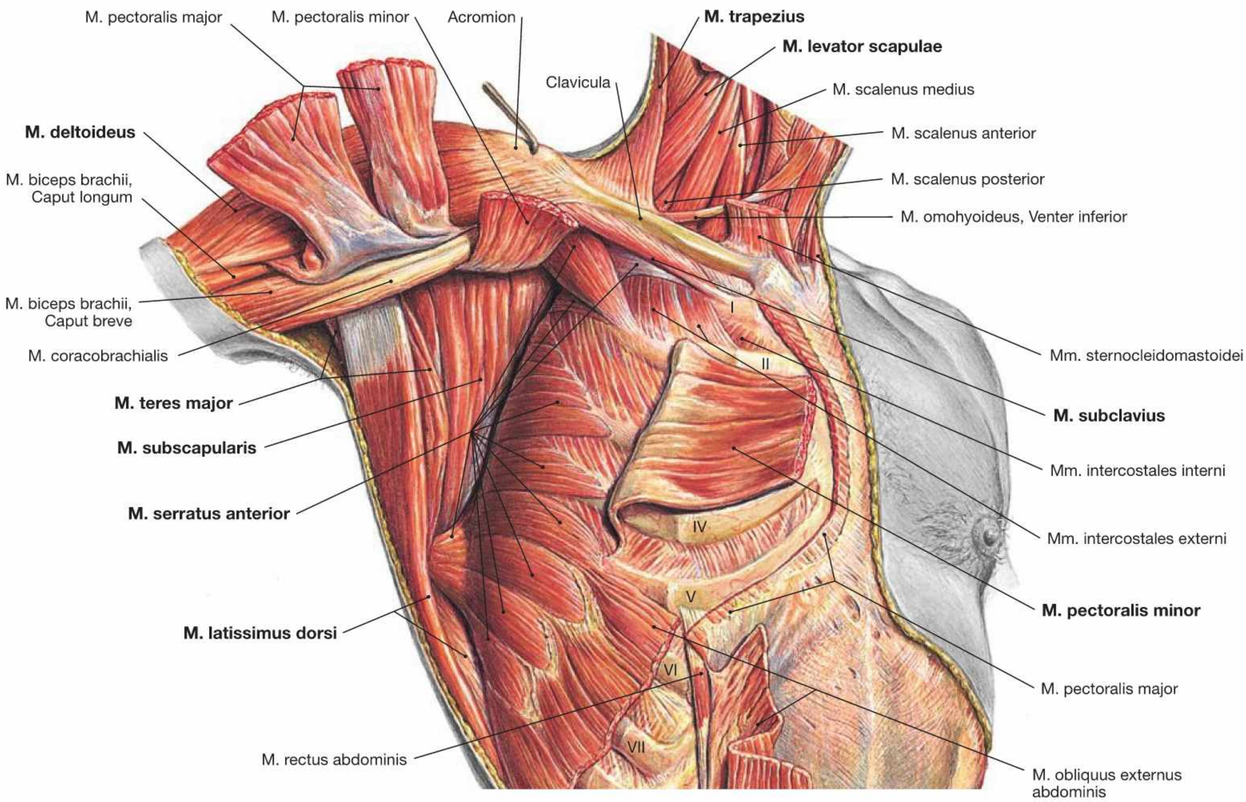


Fig. 3.68 Muscles of the shoulder girdle and the shoulder, right side; ventral view, corresponding ribs are labeled with Roman numerals.
This ventral view mainly shows the ventral muscle group of the shoulder girdle (M. serratus anterior, M. pectoralis minor, and M. subclavius). Of the dorsal group, only the M. levator scapulae and part of the insertion of the M. trapezius are illustrated. The M. pectoralis minor is reflected anteriorly to provide a better view of the M. serratus anterior and its origins on ribs I to IX. The abduction position of the arm allows a good view of the M. subscapularis which broadly covers the ventral area of the Scapula.

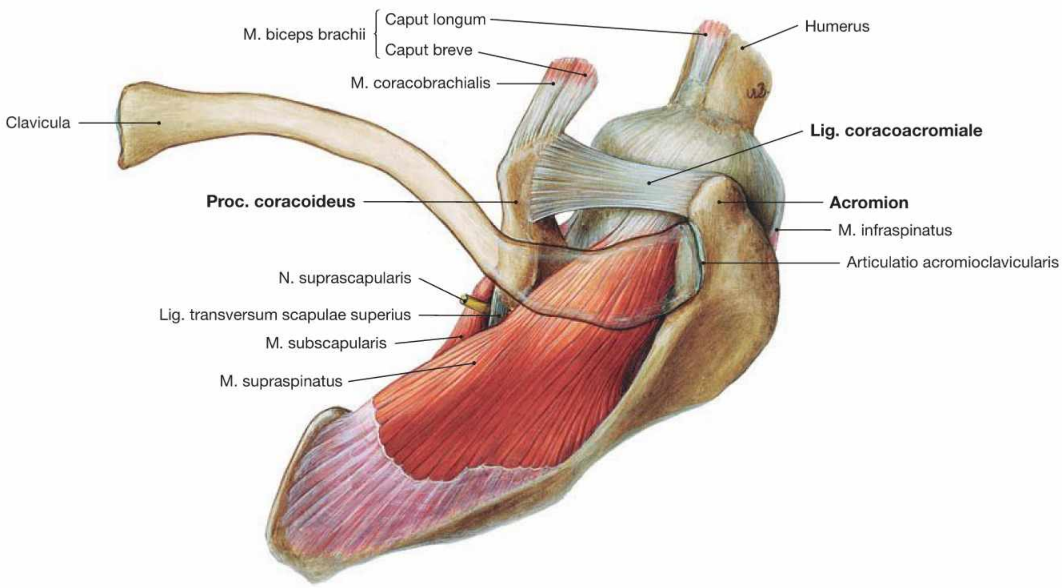
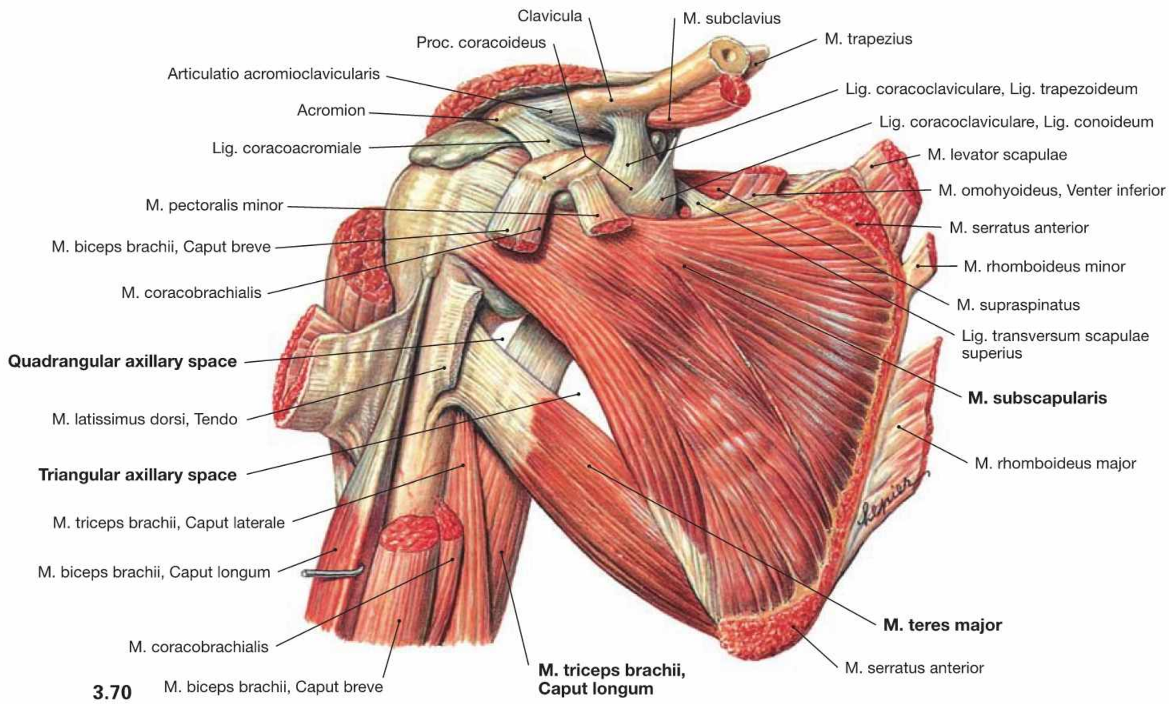


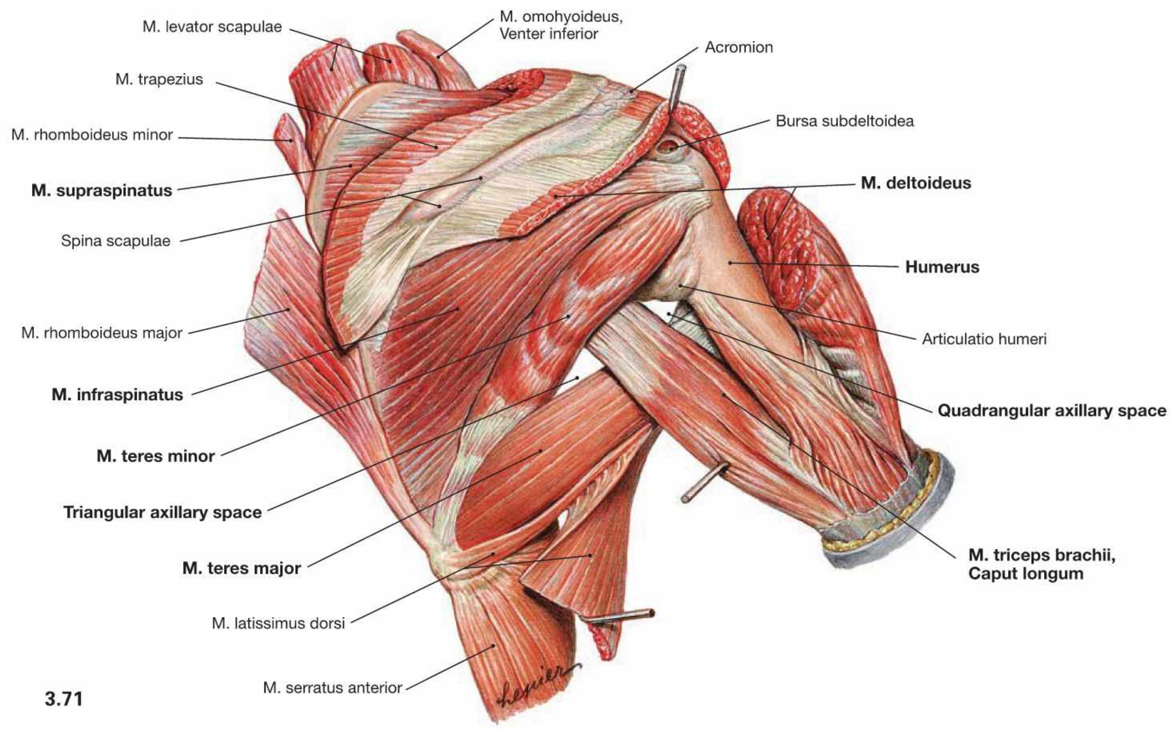
Fig. 3.69 Position of the M. supraspinatus in relation to the roof of the shoulder.
Acromion and Proc. coracoideus form the roof of the shoulder. They are connected by the Lig. coracoacromiale. Prior to its insertion into the joint capsule, the tendon of M. supraspinatus courses beneath the roof of the shoulder. Therefore the tendon can be compressed in abducted position of the arm and frequently painful degenerative conditions of the supraspinatus tendon are observed.

→ T 26, 28, 29

Muscles of shoulder and shoulder girdle



3.70



3.71

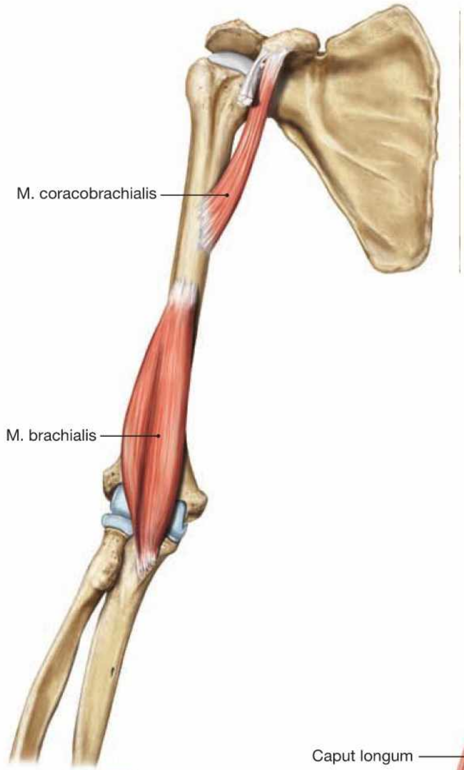
Fig. 3.70 and Fig. 3.71 Muscles of the shoulder girdle and the shoulder, right side; ventral (→ Fig. 3.70) and dorsal (→ Fig. 3.71) view.

Except for their origins, the muscles of the shoulder girdle are removed to visualise the shoulder muscles. The ventral view particularly shows the complete course of the M. subscapularis and the M. teres major. From its origin at the Angulus inferior of the Scapula, the latter crosses the Humerus anteriorly before inserting on the Crista tuberculi minoris. On the dorsal side of the Scapula, the M. supraspinatus is in part covered by the M. trapezius and courses (not visible here) under the roof of the shoulder to insert on the upper portion of the Tuberculum majus. Beneath are the insertions of M. infraspinatus and M. teres minor.

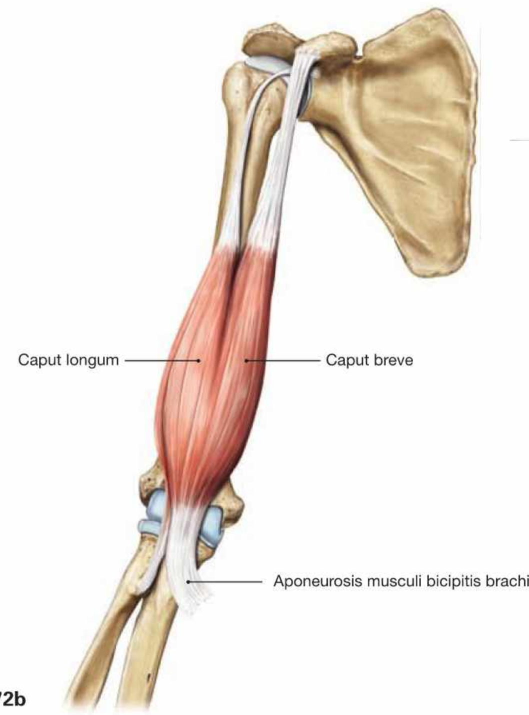
This illustration also visualises the axillary gaps between M. teres major and M. teres minor with the Humerus as their lateral border. Both muscles diverge in a Y-shaped way from their origins on the Scapula and leave a gap which is divided by the long head of the M. triceps brachii into a medially positioned **triangular axillary space** (Spatium axillare mediale) and the laterally positioned **quadrangular axillary space** (Spatium axillare laterale). The (medial) triangular axillary space serves as passage for the A. and V. circumflexa scapulae to the dorsal side of the Scapula. The (lateral) quadrangular axillary space is traversed by the N. axillaris and by the A. and V. circumflexa humeri posterior.

→ T 25, 26, 28, 30

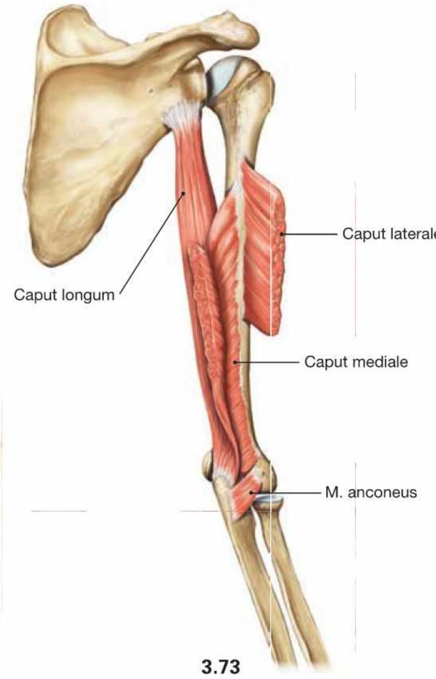
Muscles of the upper arm



3.72a



3.72b



3.73

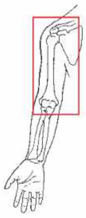
Figs. 3.72a and b Ventral muscles of the upper arm, right side; ventral view.
a M. coracobrachialis and M. brachialis
b M. biceps brachii
The ventrally positioned M. coracobrachialis has its origins at the Proc. coracoideus and inserts medially at the Humerus. In contrast to the other two ventral muscles of the upper arm, its action is restricted to the shoulder joint contributing to movements of adduction, medial rotation, and anteversion without a major impact on these movements of the arm. Originating distally from the anterior surface of the Humerus, the M. brachialis inserts into the joint capsule and the Tuberositas ulnae. The M. brachialis exclusively acts on the elbow joint by supporting its flexion.

In contrast to the M. coracobrachialis and M. brachialis, both the M. biceps brachii and the M. triceps brachii (→ Fig. 3.73) **span two joints** and thus are able to promote movements in the shoulder and the elbow joints. The M. triceps brachii is the most important muscle on the dorsal side of the arm. The Caput breve of the M. biceps brachii originates from the Proc. coracoideus and has similar functions as the M. coracobrachialis. The Caput longum originates from the Tuberculum supraglenoidale of the Scapula and functions as abductor of the arm. However, its most important action is on the elbow joint. With its major insertion at the Tuberositas radii, the M. biceps brachii serves as the **most important flexor in the elbow joint** and the strongest **supinator of the forearm** in a flexed position.

Fig. 3.73 Dorsal muscles of the upper arm, M. triceps brachii and M. anconeus, right side; dorsal view.
The M. triceps brachii is positioned on the dorsal side of the upper arm. Its Caput longum originates from the Tuberculum infraglenoidale, whereas the Caput laterale and Caput mediale have a broad origin on the dorsal side of the Humerus. In addition to its supportive function in adduction and retroversion of the shoulder joint, the M. triceps brachii is the **most important extensor of the elbow joint** due to its common insertion on the Olecranon. This function is supported to a certain extent by the action of the M. anconeus which spans from the Condylus lateralis of the Humerus to the Olecranon and the dorsal side of the Ulna.

→ T 29, 30

Muscles of the upper arm



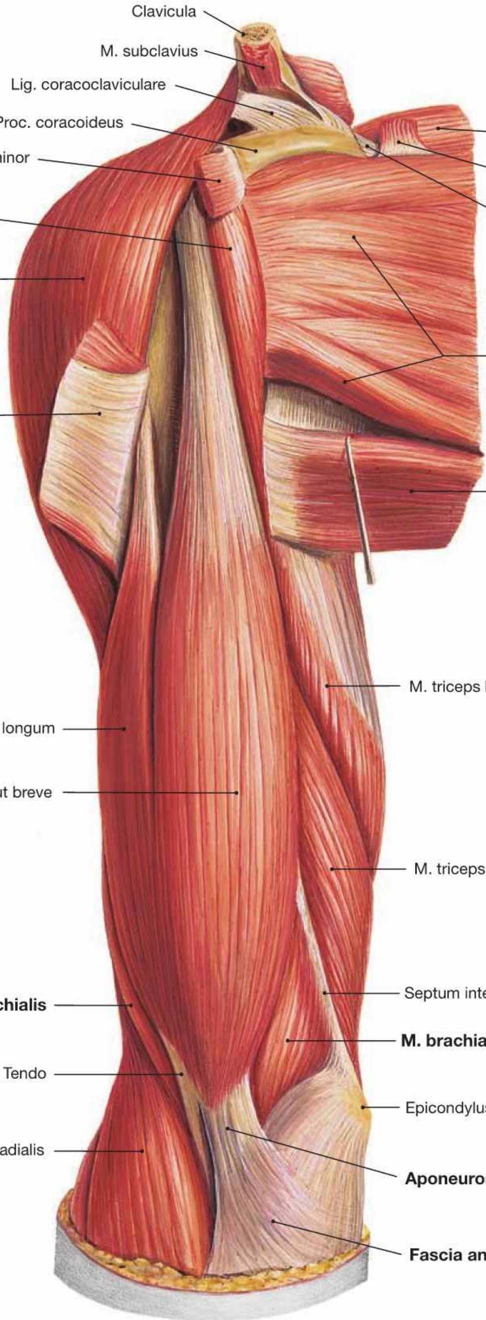
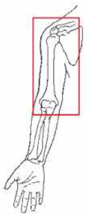


Fig. 3.74 Ventral muscles of the upper arm, right side; ventral view.
The M. coracobrachialis is positioned ventrally to the M. biceps brachii. The short head (Caput breve) of the M. biceps brachii originates from the Proc. coracoideus, the long head (Caput longum) from the Tuberculum supraglenoidale. In addition to its principal insertion site at the Tuberositas radii, the Aponeurosis musculi bicipitis brachii radiates into the fascia of the forearm (Fascia antebrachii). The M. brachialis is positioned beneath the M. biceps brachii and is only visible with its muscle belly on both sides of the biceps tendon.

→ T 29, 30

Muscles of the upper arm



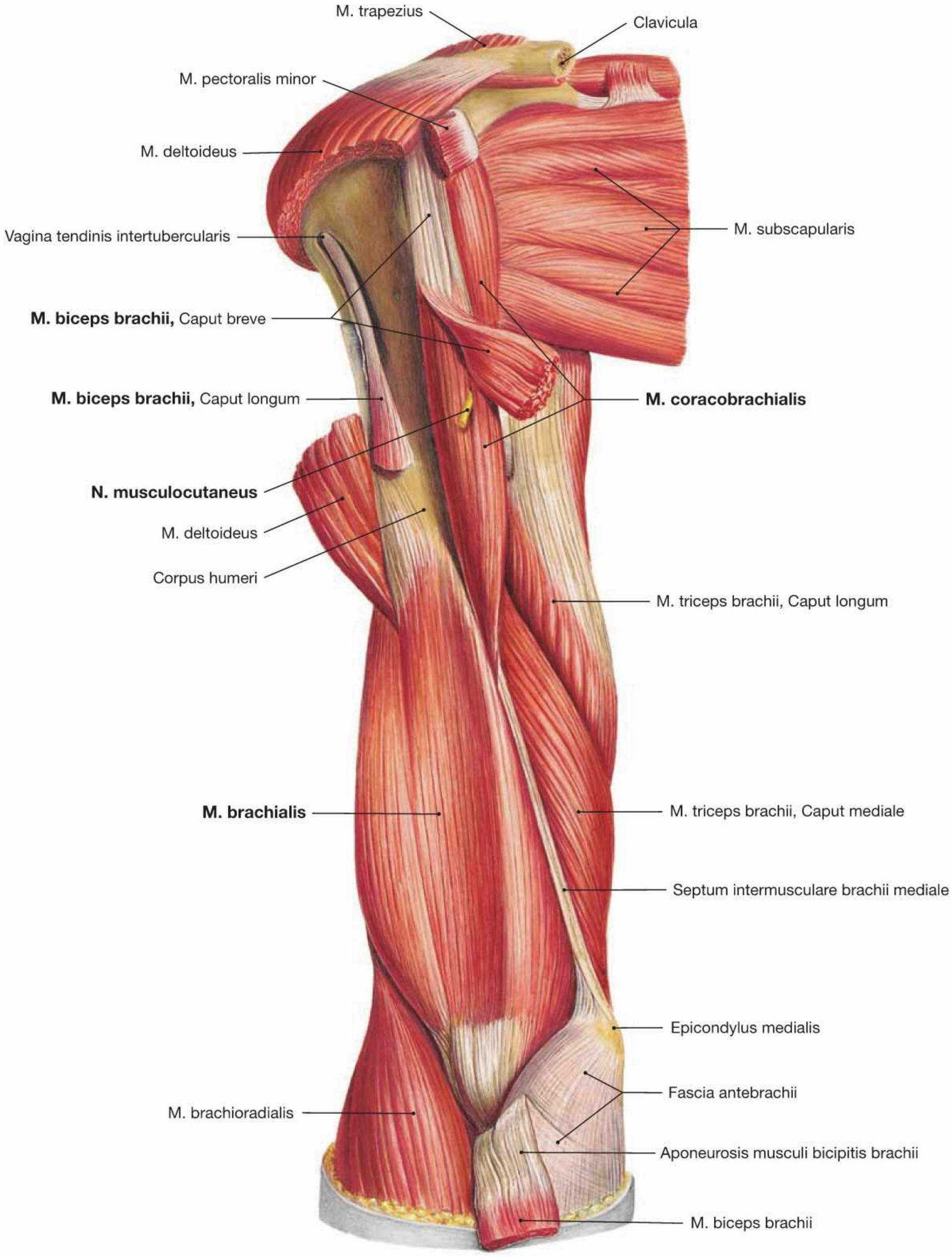
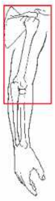


Fig. 3.75 Ventral muscles of the upper arm, right side; ventral view; after removal of the M. biceps brachii.
The M. biceps brachii was removed to demonstrate the underlying M. brachialis. The M. coracobrachialis is easily identified since it is pierced by the N. musculocutaneus, the nerve which innervates all three muscles of the ventral side of the upper arm (M. biceps brachii, M. coracobrachialis, and M. brachialis).

→ T 29, 30

Muscles of the upper arm



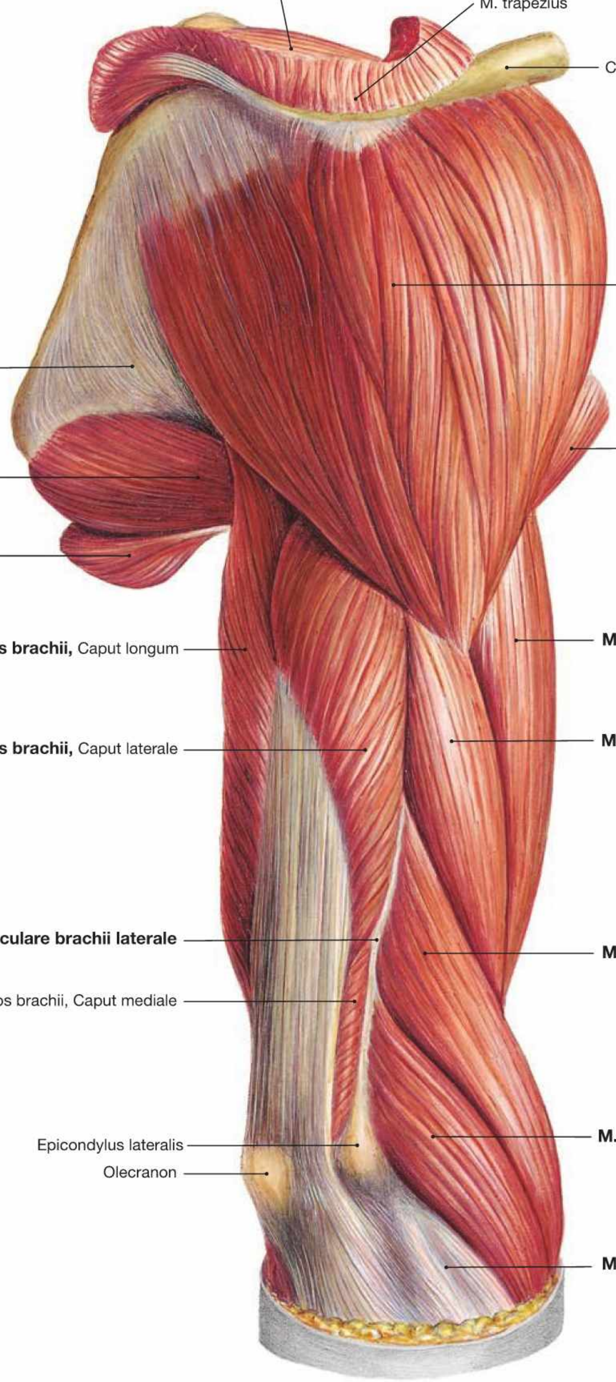
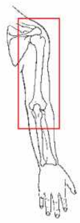


Fig. 3.76 Dorsal muscles of the shoulder and upper arm, and ventral muscles of the upper arm, right side; dorsolateral view.
The M. triceps brachii almost completely covers the posterior aspect of the upper arm. Visible here are Caput longum and Caput laterale which both cover the Caput mediale. All three heads of this muscle have a common insertion at the Olecranon. The M. triceps brachii is separated by the Septum intermusculare laterale from the flexor muscles (M. brachialis, M. biceps brachii) on the ventral side of the upper arm. The radial extensor muscles of the forearm have their origins on the lateral aspect of the distal upper arm. From proximally to distally, these comprise the M. brachioradialis, M. extensor carpi radialis longus, and M. extensor carpi radialis brevis. The following shoulder muscles are also visible here: M. deltoideus, M. teres major, M. latissimus dorsi and M. supraspinatus.

→ T 26, 28, 29, 33

Muscles of the upper arm



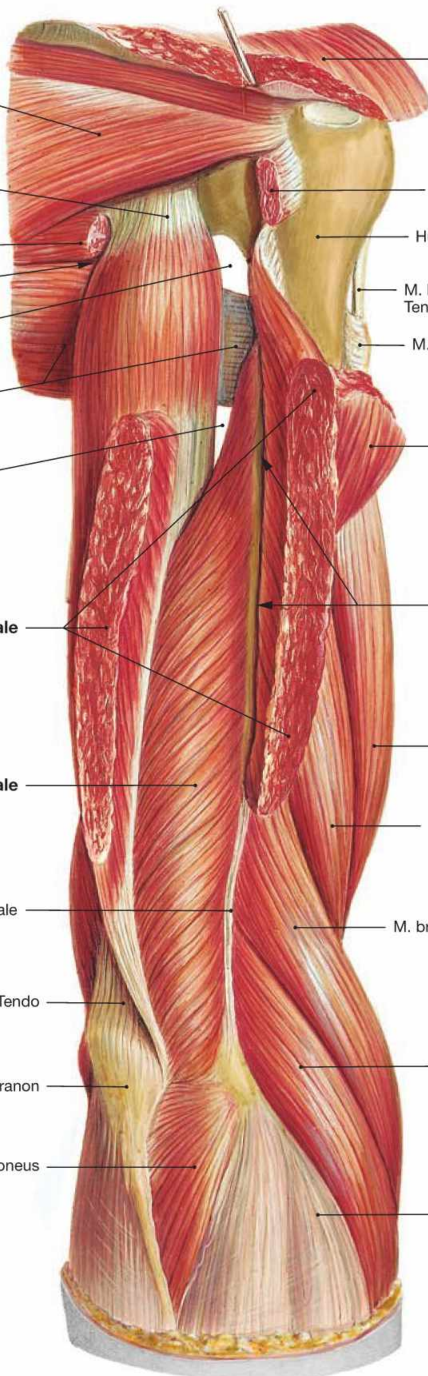
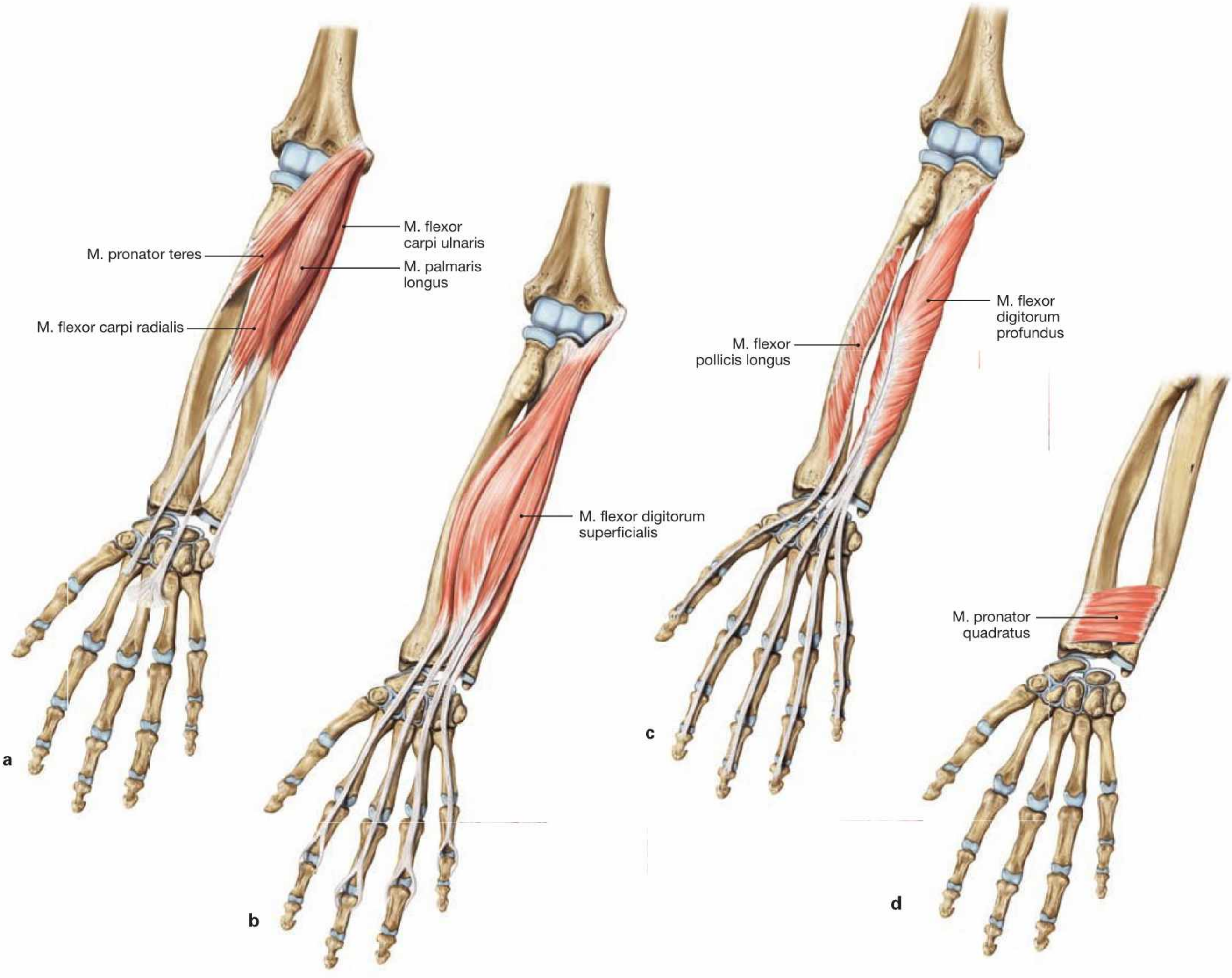


Fig. 3.77 Dorsal muscles of the shoulder and upper arm, right side; dorsolateral view; the Caput laterale of the M. triceps brachii was cut.

The Caput longum of the M. triceps brachii originates from the Tuberculum infraglenoidale of the Scapula. The Caput laterale originates proximal and lateral of the Sulcus nervi radialis. When the Caput laterale is cut open, the Caput mediale can be seen which originates from the Humerus distal and medial of the Sulcus nervi radialis. In addition, the **triangular** and the **quadrangular spaces (axillary gaps)** are visible between the M. teres minor and M. teres major (→ Figs. 3.70 and 3.71), which are separated by the Caput longum. Distal of the M. teres major the **triceps slit** is visible which is used by the N. radialis to reach the dorsal side of the Humerus.

→ T 28, 30



Figs. 3.78a to d Ventral muscles of the forearm, right side; ventral view.

The flexors of the forearm are positioned on the ventral side. They are separated by the radial and ulnar neurovascular bundles into a superficial and a deep group of muscles. Each of these two groups consists again of two layers, thus, **four distinct layers** can be separated:

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

a superficial layer

From radial to ulnar, the superficial layer consists of M. pronator teres, M. flexor carpi radialis, M. palmaris longus, and M. flexor carpi ulnaris. All these muscles have their origin at the Epicondylus medialis of the Humerus and function as **flexors of the elbow joint** and, with the exception of the M. pronator teres, also of the wrist. The **M. pronator teres** crosses the diagonal axis of the forearm and therefore is the **most important pronator,** together with the M. pronator quadratus in the deepest layer. The M. palmaris longus may be missing uni- or bilaterally in up to 20% of the people and functions in stretching the palmar aponeurosis in addition to flexing the wrist. When acting together with its antagonist on the extensor side, the M. flexor carpiulnaris mediates ulnar abduction and the M. flexor carpi radialis enables radial abduction.

b middle layer

The **M. flexor digitorum superficialis** makes up the middle layer. The tendons of its four parts insert on the palmar aspects of the middle phalanges of the second to fifth fingers. Thus, this muscle also flexes the **middle interphalangeal joints** and, with lesser strength, the **metacarpophalangeal joints,** in addition to its support in flexion of the elbow and wrist joints.

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. Both muscles originate from the ventral aspect of the bones of the forearm As their tendons reach the palmar aspects of the distal phalanges, they do not act on the elbow joint but flex the wrist and the **distal interphalangeal joints of fingers and thumb** and to a lesser extent the **metacarpophalangeal and proximal interphalangeal joints.**

d deepest layer

Beneath the tendons of the long flexor muscles of the forearm the **M. pronator quadratus** connects the ventral aspects of Radius and Ulna.

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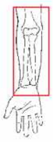
→ T 31, 32

Muscles of the forearm



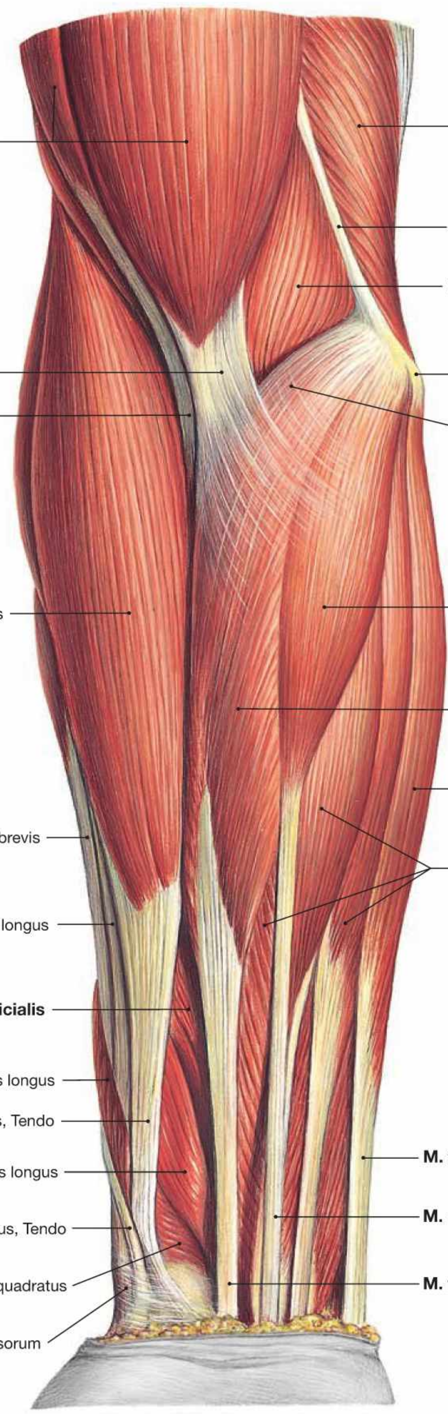


Fig. 3.79 Superficial layer of the ventral muscles of the forearm, right side; ventral view.
From radial to ulnar, the superficial muscle layer of the forearm consists of M. pronator teres, M. flexor carpi radialis, M. palmaris longus, and M. flexor carpi ulnaris. Parts of the M. flexor digitorum superficialis of the middle layer are visible between the M. palmaris longus and M. flexor carpi ulnaris and between the tendons of the other muscles. The radial group of muscles of the forearm functionally belongs to the extensors of the wrist and lies on the radial side in relation to the superficial flexors.

→ T 31

Muscles of the forearm

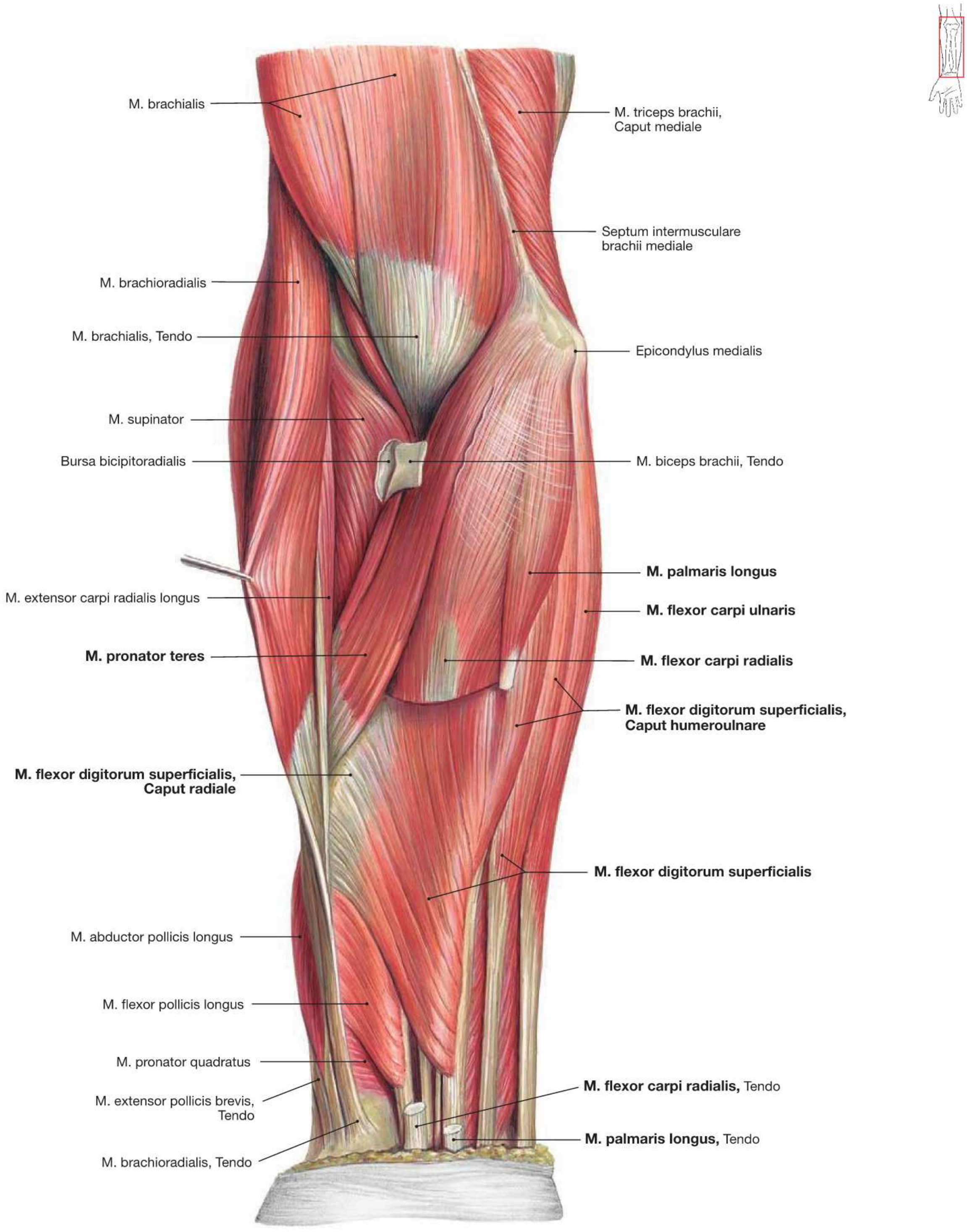


Fig. 3.80 Middle layer of the ventral muscles of the forearm, right side; ventral view; M. flexor carpi radialis and M. palmaris longus were partially removed.

The M. pronator teres is visible in its full length after removal of the Aponeurosis musculi bicipitis brachii and reflection of the M. brachioradialis. Beneath the superficial flexors, the middle layer of ventral muscles of the forearm is visible which consists of the four muscle bellies of the M. flexor digitorum superficialis. Its whole dimension can only be appreciated upon removal or deviation of the M. flexor carpi radialis and M. palmaris longus, as illustrated 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 has its origin at the anterior aspect of the Radius.

Strictly speaking, the different muscle bulges of M. flexor digitorum superficialis are not positioned exactly in one plane. Thus, this illustration only shows the muscle parts for the third and fourth fingers which cover the muscle parts of the second and fifth fingers.

→ T 31

Muscles of the forearm

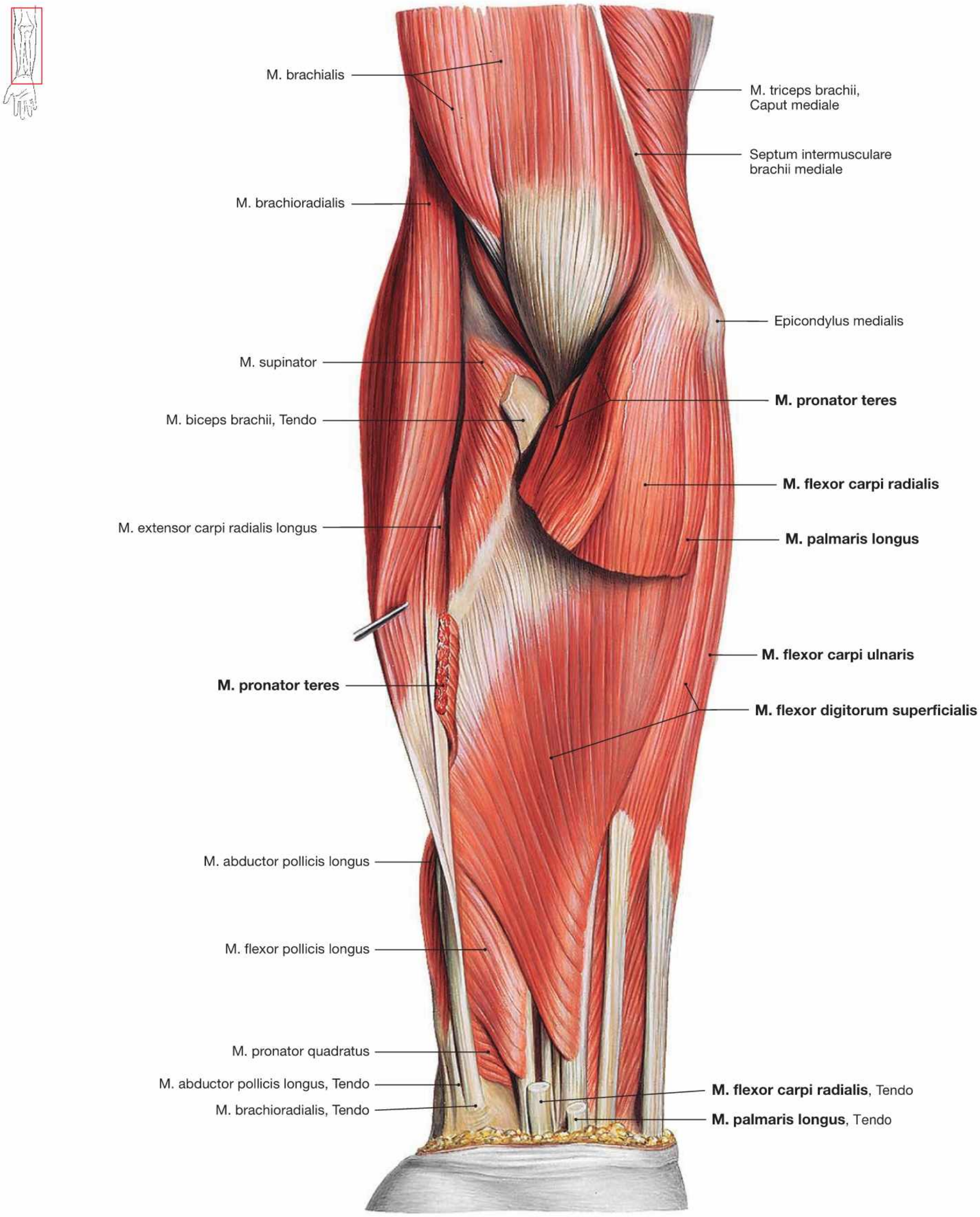


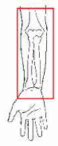
Fig. 3.81 Middle layer of the ventral muscles of the forearm, right side; ventral view; M. flexor carpi radialis, M. palmaris longus, and M. pronator teres were almost completely removed.
In contrast to the illustration in → Fig. 3.80, the M. pronator teres was also cut to demonstrate the origins of 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 has its origin at the anterior aspect of the Radius.

→ T 31

Clinical Remarks

Abnormal increase in muscle tone in the form of **spasticity** may occur after stroke or damage to the central nervous system (CNS). An increase in muscle tone may also occur without major injury with **dystonia.** Spasticity often affects entire muscle groups. However, dystonia may affect selectively individual flexor muscles, such as in writer's cramp, and sometimes only a single muscle belly such as of the M. flexor digitorum superficialis. To enable targeted treatment, such as the inhibition of signal transmission at the motor end plates by injection of botulinum toxin, a very precise understanding of the function and the topography of the muscles is necessary.

Muscles of the forearm



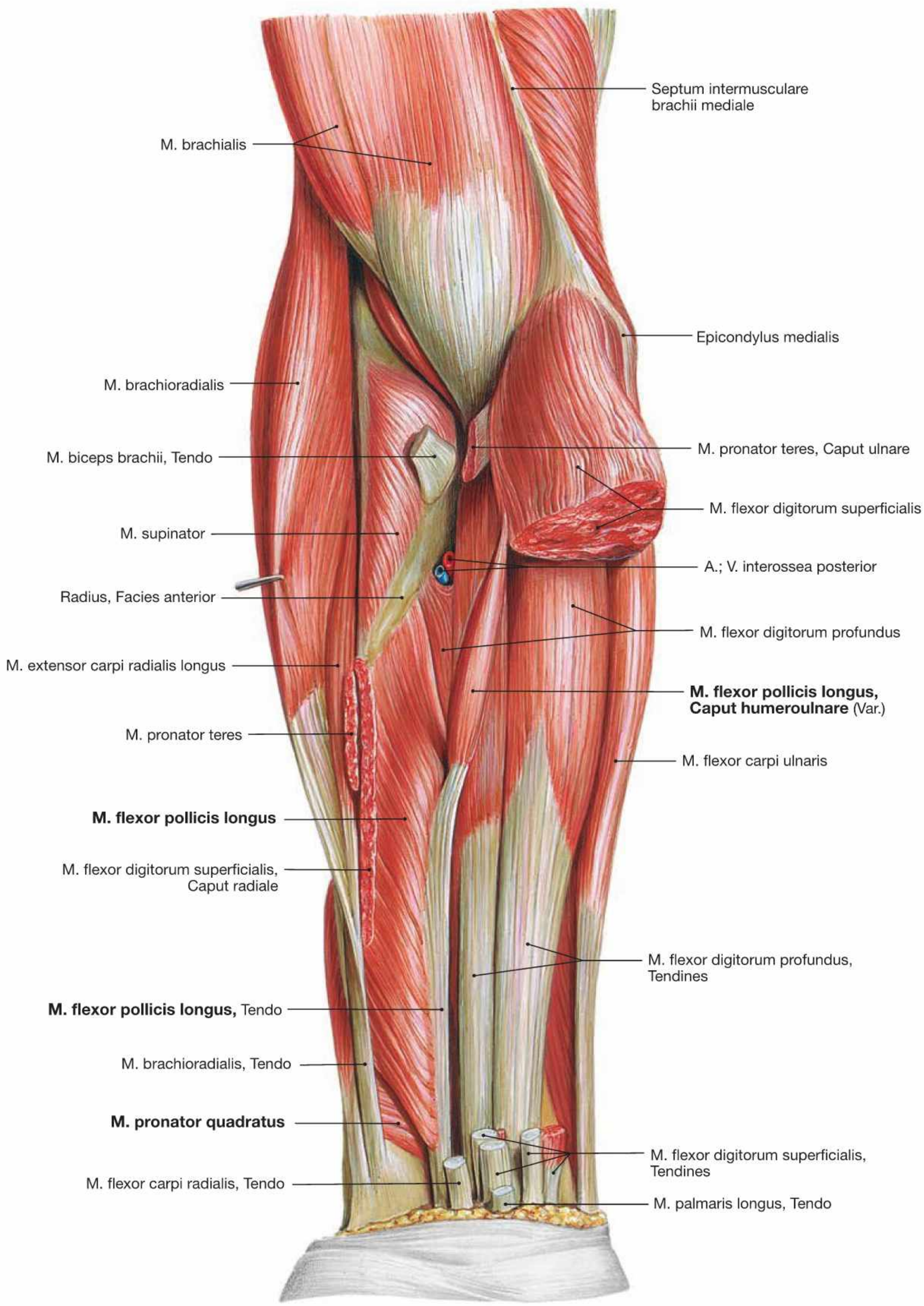
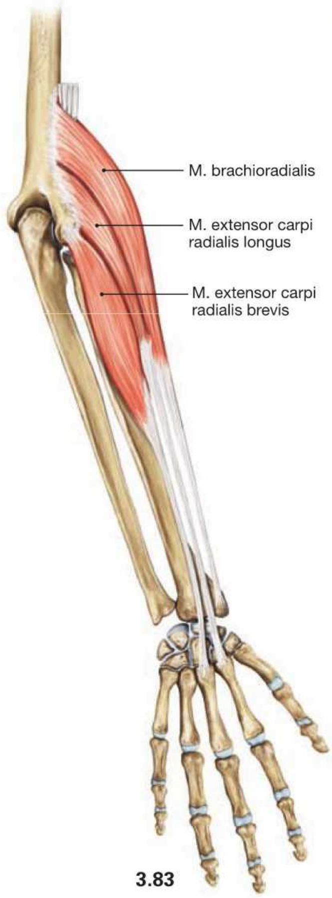


Fig. 3.82 Deep and deepest layer of the ventral muscles of the forearm, right side; ventral view; after removal of the superficial flexors.

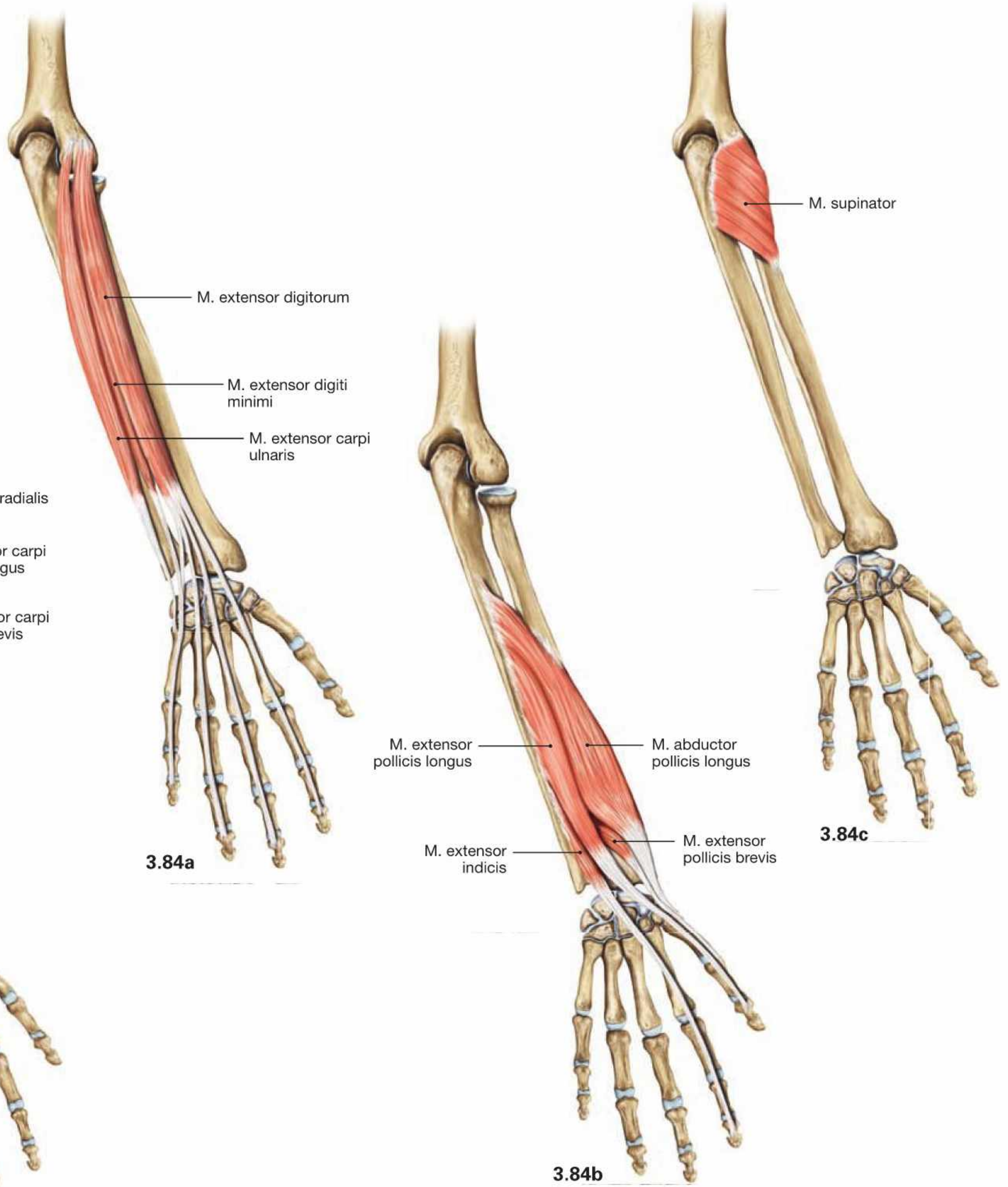
With the removal of all superficial flexors, the deep flexors become visible as shown here. The M. flexor digitorum profundus has its origin at the anterior aspect of the Ulna and the Membrana interossea antebrachii. The M. flexor pollicis longus originates from the anterior aspect of the Radius and 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 covered by the tendons of the flexor muscles and connects Radius and Ulna at the distal forearm.

→ T 32

Muscles of the forearm



3.83



3.84a 3.84b 3.84c

Fig. 3.83 Radial muscles of the forearm, right side; dorsal view. From proximal to distal, the radial group of muscles comprises the M. brachioradialis and the Mm. extensores carpi radialis longus and brevis. These muscles originate from the lateral aspect of the Humerus and run anterior to the transversal axis of the elbow joint which makes them flexors of this joint. The M. brachioradialis inserts at the distal end of the Radius and, thus, only spans one joint. Its function depends on the given position of the forearm and may support supination or pronation. The Mm. extensores carpi radialis longus and brevis function as extensors of the wrist joints and enable radial abduction.

→ T 33

Figs. 3.84a to c Dorsal muscles of the forearm, right side; dorsal view.

a superficial layer

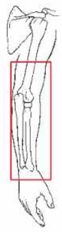
All superficial extensors have a common origin at the Epicondylus lateralis. Excessive use of the extensor tendons may cause intensive pain in the elbow ("tennis elbow"). From radial to ulnar, this muscle group comprises the M. extensor digitorum, M. extensor digiti minimi, and M. extensor carpi ulnaris. The M. extensor digitorum and M. extensor digiti minimi radiate into the dorsal aponeuroses of digits two to five. Therefore, these muscles serve as extensors of the wrist, the metacarpophalangeal joints, and the proximal interphalangeal joints. As the dorsal aponeurosis ends at the middle phalanges, these muscles do not participate in extension of the distal interphalangeal joints.

b and c deep layer

From radial to ulnar, the distal layer consists of the M. abductor pollicis longus, M. extensor pollicis brevis, M. extensor pollicis longus, and M. extensor indicis (→ Fig. 3.84b). The M. abductor pollicis longus abducts in the saddle joint of the thumb, and the Mm. extensores pollicis brevis and longus extend this joint as well as the interphalangeal joint of the thumb. The M. extensor indicis extends the metacarpophalangeal and the proximal interphalangeal joints of the index finger. Proximal, the deep layer of extensor muscles comprises the M. supinator (→ Fig. 3.84c) which winds around the Radius. It is the strongest supinator during extension of the elbow joint.

→ T 34, 35

Muscles of the forearm



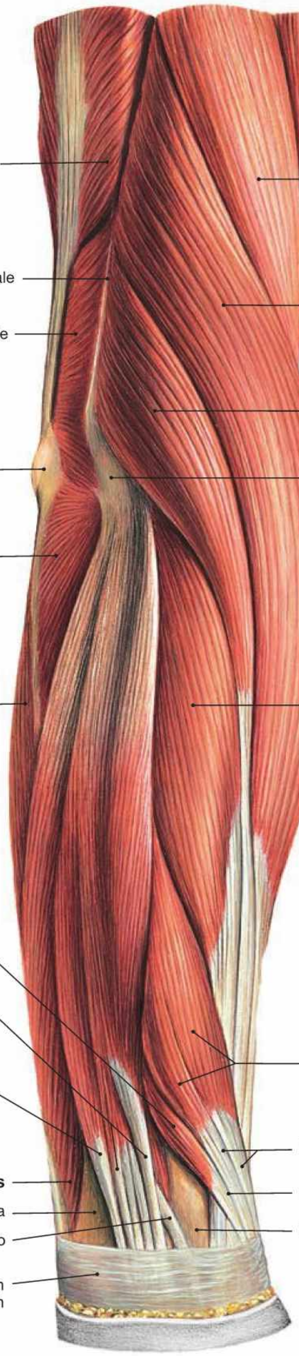
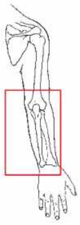


Fig. 3.85 Superficial layer of the dorsal muscles of the forearm and distal part of upper arm, right side; lateral view.
The lateral view best shows the **radial group of muscles.** From proximal to distal there are the M. brachioradialis, and the Mm. extensores carpi radialis longus and brevis. Further to the ulnar side, the **superficial extensor muscles** are positioned (M. extensor digitorum, M. extensor digiti minimi, and M. extensor carpi ulnaris). Distally between these muscle groups the distal parts of the **deep extensor muscles** are visible (thus, they are not completely covered by the superficial extensors). In this illustration, the fascia of the M. anconeus at the distal part of the upper arm was removed. The M. anconeus belongs to the extensor muscles of the upper arm.

→ T 33–35

Muscles of the forearm



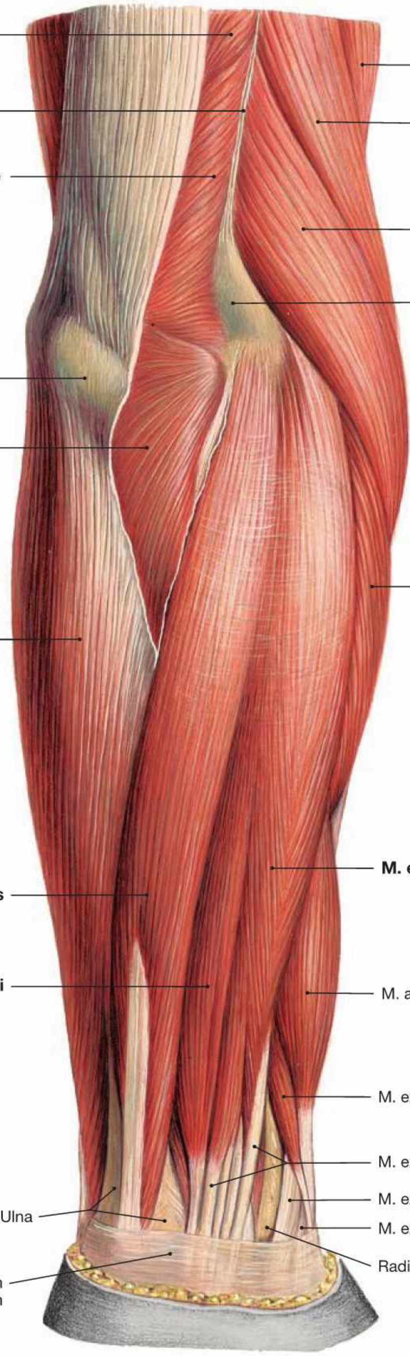


Fig. 3.86 Superficial layer of the dorsal muscles of the forearm and distal part of upper arm, right side; dorsal view.
The **superficial extensor muscles** of the forearm comprise the M. extensor digitorum, M. extensor digiti minimi, and M. extensor carpi ulnaris.

On the ulnar side, the M. flexor carpi ulnaris of the superficial flexor group is adjacent to the M. extensor carpi ulnaris.

→ T 34

Muscles of the forearm

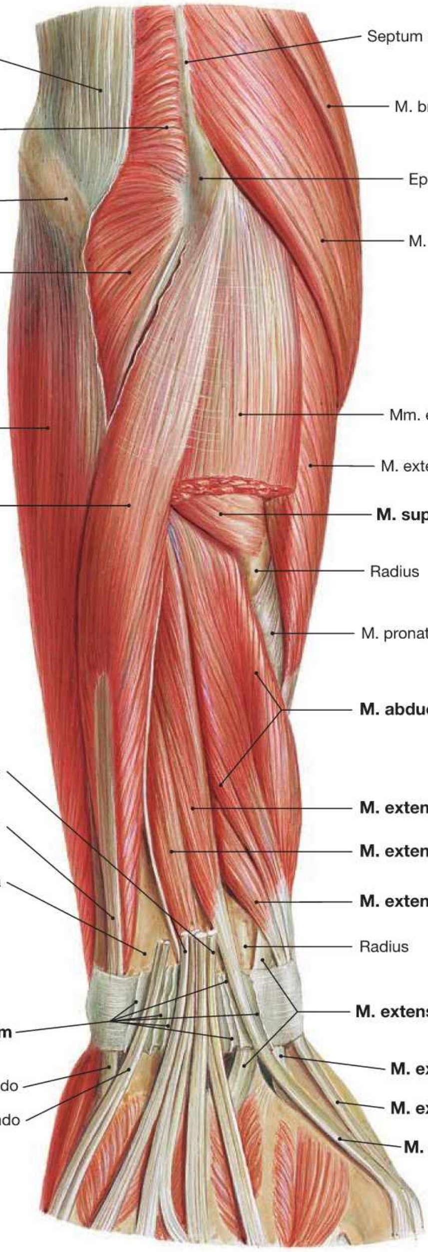


Fig. 3.87 Deep layer of the dorsal muscles of the forearm, right side; dorsal view; after partial removal of the Mm. extensores digitorum and digiti minimi.

Removal of the superficial extensors of the forearm enables the view of proximal parts of the deep extensor muscles. The deep layer consists proximally of the M. supinator, and distally from radial to ulnar of the M. abductor pollicis longus, M. extensor pollicis brevis, M. extensor pollicis longus, and M. extensor indicis.

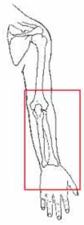
The Retinaculum musculorum extensorum forms **six osseofibrous tunnels** for the passage of the extensor muscle tendons to the dorsum of the hand. This illustration shows the third, fourth, and fifth osseofibrous tunnel cut open.

Osseofibrous tunnels on the dorsum of the hand, from radial to ulnar:

- first tunnel: M. abductor pollicis longus and M. extensor pollicis brevis
- second tunnel: Mm. extensores carpi radialis longus and 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



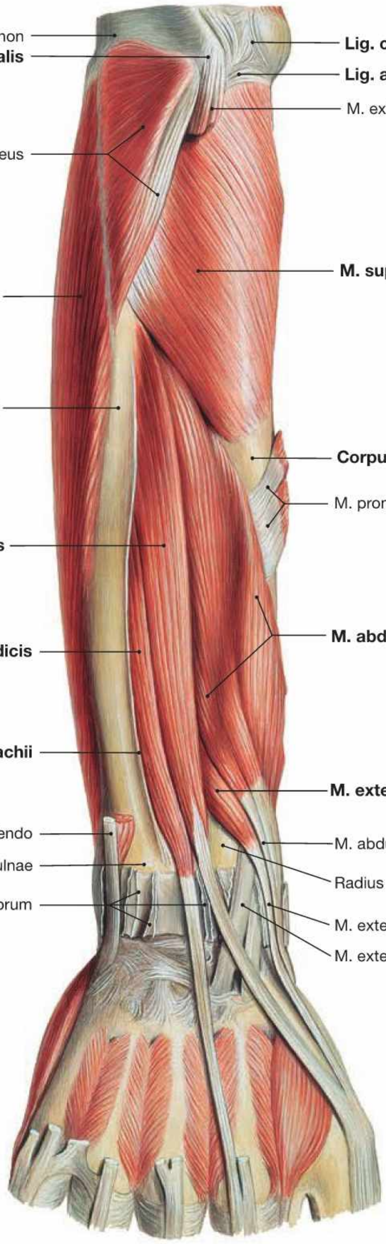
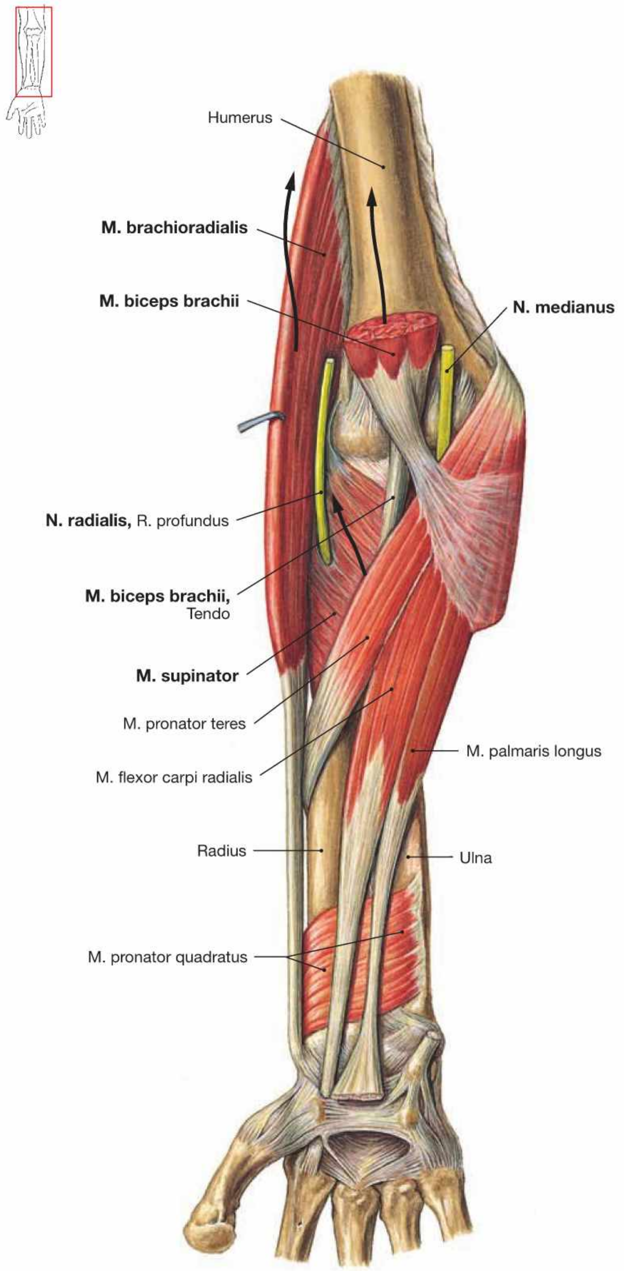


Fig. 3.88 Deep layer of the dorsal muscles of the forearm, right side; dorsal view; after complete removal of the superficial extensor muscles.

Superficial extensor muscles have been completely removed to visualise the origins of the deep extensor muscles. The M. supinator origins from the Epicondylus lateralis of the Humerus, the radial ligaments (Lig. collaterale radiale and Lig. anulare radii) and from the Crista m. supinatoris of the Ulna. The muscle then winds around the Radius above and below the Tuberositas radii. Both muscles on the radial side (M. abductor pollicis longus, M. extensor pollicis brevis) originate from the dorsal side of Radius and Ulna and from the Membrana interossea antebrachii. Their tendons pass through the first osseofibrous tunnel. 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 osseofibrous tunnel, respectively. The illustration here shows all osseofibrous tunnels opened.

→ T 35

Muscles of the forearm



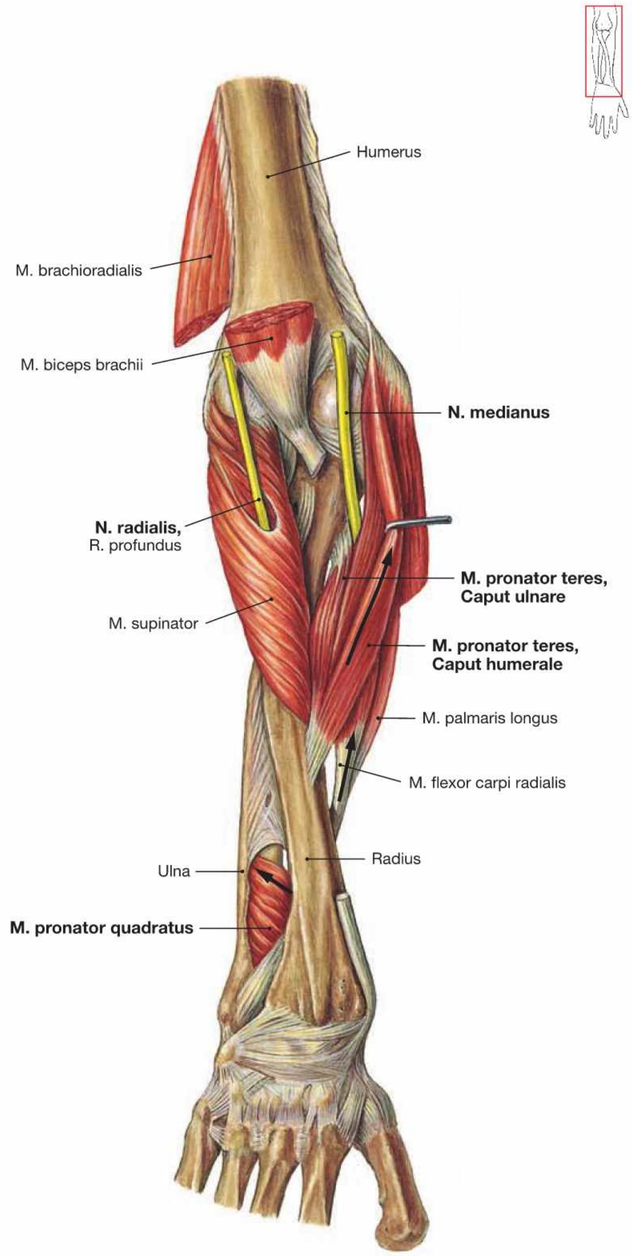


Fig. 3.89 Forearm, Antebrachium, in supination position, right side; ventral and palmar view. Arrows indicate the traction vectors for the most important supinators.

In general, all muscles capable of promoting pronation or supination **cross the diagonal axis of the forearm** (→ Fig. 3.8) which corresponds-its rotational axis. In addition, all important supinator and pronator muscles **insert on the Radius.** Important supinators are the M. biceps brachii (from a flexed position), M. supinator (with extended arm), and M. brachioradialis (from a pronated position). The M. supinator is pierced by the Ramus profundus of the radial nerve (N. radialis) which may be compressed at this location with resulting paralysis of the deep extensor muscles (→ p. 203).

Fig. 3.90 Forearm, Antebrachium, in pronation position, right side; ventral view near the elbow and dorsal view near the hand. Arrows indicate the traction vectors for the most important pronators.

The most important pronators 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 weakly promote pronation.

The N. medianus passes between the two heads of the M. pronator teres but is rarely compressed at this location (→ p. 205).

→ T 32, 33, 35

Tendons of the dorsum of the hand

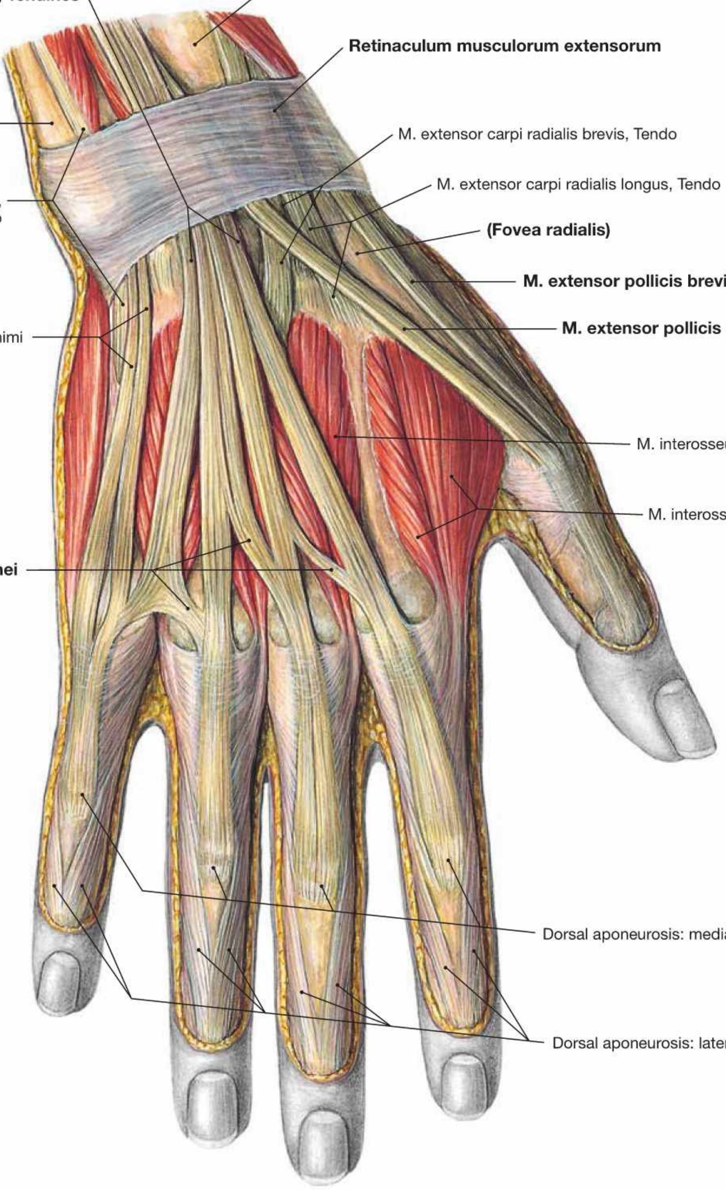


Fig. 3.91 Tendons of the dorsum of the hand, Dorsum manus, right side; dorsal view.
The tendons of the extensor muscles run beneath the Retinaculum musculorum extensorum to reach the dorsum of the thumb and the dorsal aponeuroses of the digits. The distinct tendons of the M. extensor digitorum are linked by intertendinous connections (Connexus intertendinei) which limit the separate mobility of each finger. There are no intrinsic muscles at the dorsum of the hand.

According to their developmental origins and innervation, the Mm. interossei dorsales belong to the palmar muscles. When the thumb is extended, tendons of the M. extensor pollicis brevis and M. extensor pollicis longus form the borders of an indented space which is referred to as the anatomical snuff box **(Tabatière).**

→ T 34, 35, 37

Tendinous sheaths of the dorsum of the hand

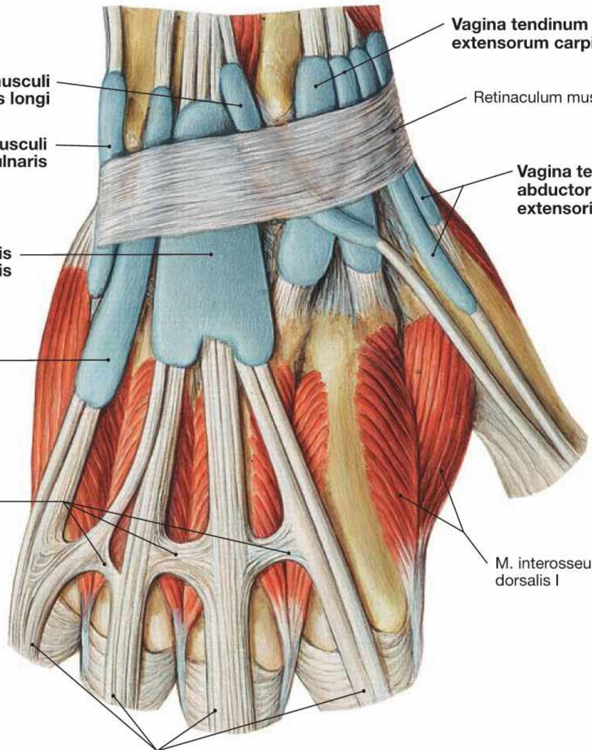


Fig. 3.92 Dorsal carpal tendinous sheaths, Vaginae tendinum, of the dorsum of the hand, right side; dorsal view.

Beneath the Retinaculum musculorum extensorum the tendons of the extensor muscles are positioned in six osseofibrous tunnels (→ Fig. 3.87). The respective tendons are covered in mostly individual tendinous sheaths to reduce friction during movements of the tendons between the retinaculum and the bones of the wrist.

Extensor muscles of the finger joints:

With the exception of the tendon of the M. extensor pollicis longus, which reaches the distal phalanx, the tendons of the Mm. extensores digitorum, extensor digiti minimi, and extensor indicis insert together with the middle tract of the dorsal aponeuroses (→ Fig. 3.91) at the middle phalanx and therefore cannot extend the distal interphalangeal joints. However, tendons of the Mm. lumbricales and to some extent of the Mm. interossei palmares and dorsales radiate into the lateral tracts of the digital dorsal aponeuroses. They reach the dorsal side of the transverse axis of the distal interphalangeal joints and act as extensors thereof. This explains why the Mm. lumbricales are the main extensors of the distal interphalangeal joints.

- **metacarpophalangeal joints and proximal interphalangeal joints:** M. extensor digitorum, M. extensor digiti minimi, M. extensor indicis
- **distal interphalangeal joints:** Mm. lumbricales, weakly also Mm. interossei palmares and dorsales
- **carpometacarpal joint of the thumb:** M. extensor pollicis brevis
- **proximal and distal interphalangeal joints of the thumb:** M. extensor pollicis longus

Muscles of the hand

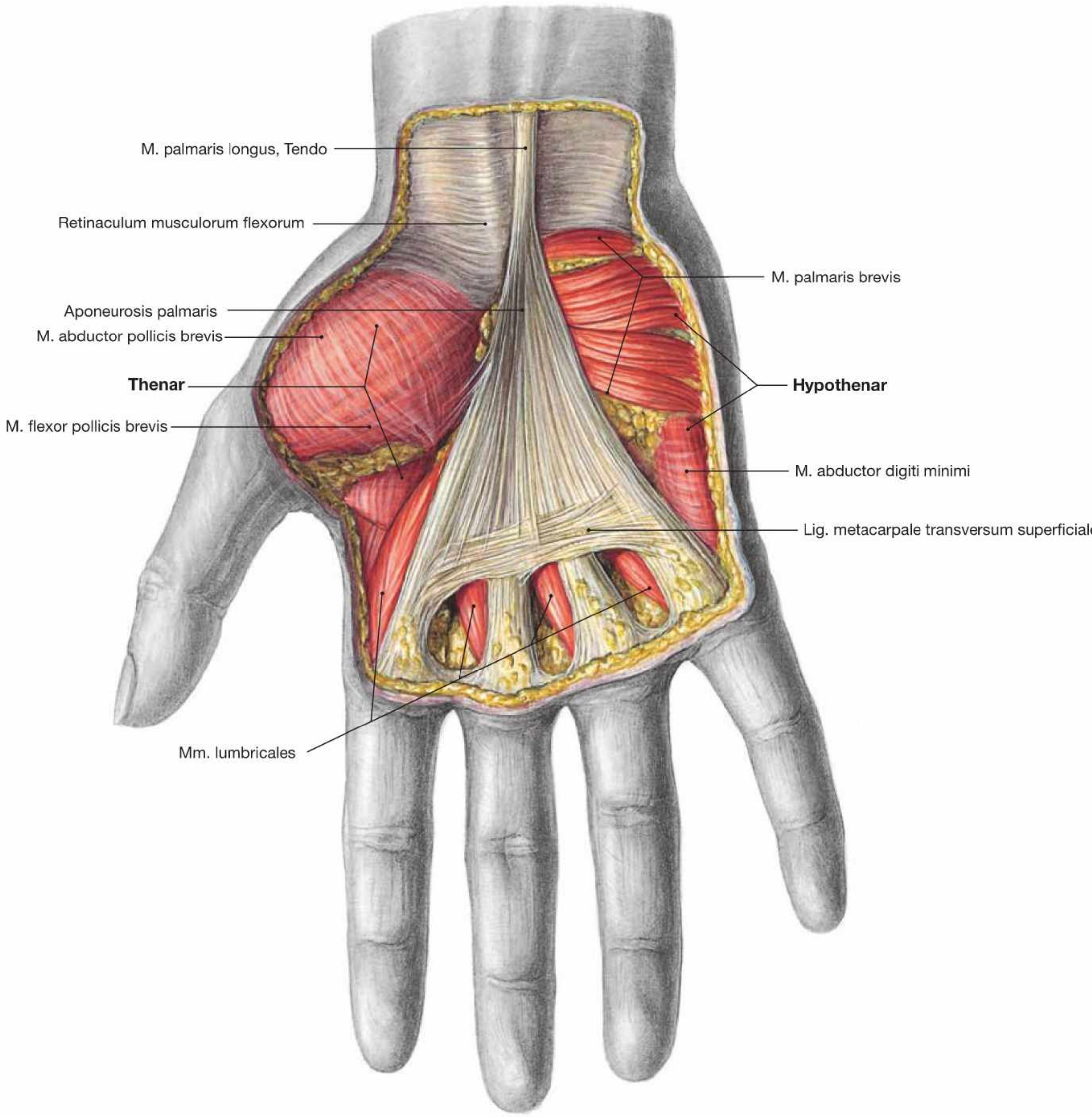


Fig. 3.93 Superficial layer of muscles in the palm of the hand, Palma manus, right side; palmar view.

There are **three groups of muscles** in the palm of the hand. On both sides of the palm, muscles of the thumb and the fifth finger form the thenar and hypothenar, respectively. Between the two groups are the muscles of the palm of the hand. These three groups are arranged in **three consecutive muscle layers**. The neurovascular structures between these layers need to be considered when dissecting the palm of the hand (→ pp. 235–237). Located most superficially is the **palmar aponeurosis** (Aponeurosis palmaris) which consists of longitudinal and transverse fibres; the latter being prominent just below the metacarpophalangeal joints (Lig. metacarpale transversum superficiale). The palmar aponeurosis is fixed proximally to the Retinaculum musculorum flexorum und stretched by the M. palmaris longus. Distally, it is fixed to the tendinous sheaths of the finger flexors and to the ligaments of the metacarpophalangeal joints.

At the thenar, the M. abductor pollicis brevis is located on the radial side and the M. flexor pollicis brevis is located Ulnar to the abductor muscle. At the Hypothenar, the M. palmaris brevis and M. abductor digiti minimi are superficial.

→ T 31, 36–38

Muscles of the hand

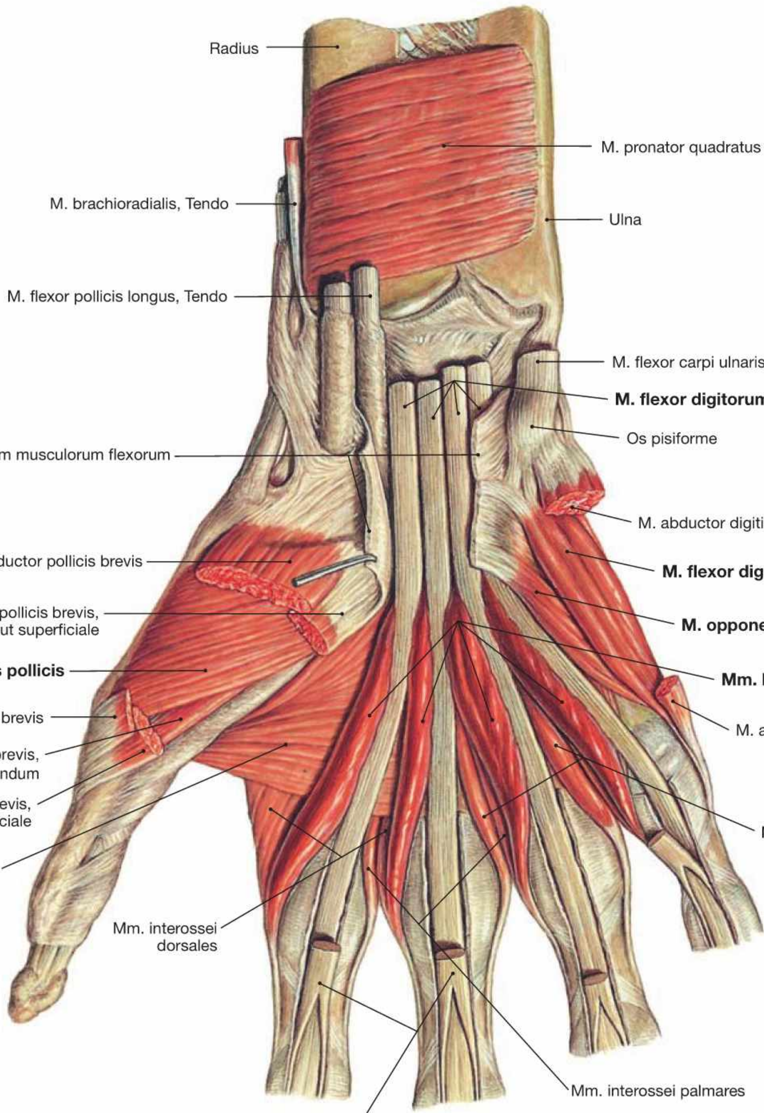


Fig. 3.94 Intermediate layer of muscles in the palm of the hand, Palma manus, right side; palmar view; after removal of the palmar aponeurosis and the superficial muscles.

The three muscle groups of the palm of the hand (Palma manus) are arranged in three consecutive layers. When the superficial muscles are removed, the muscles of the intermediate layer are visible. These comprise the M. opponens pollicis and M. abductor pollicis at the Thenar, and the M. flexor digiti minimi and M. opponens digiti minimi at the Hypothenar, both of which are positioned radial to the superficial M. abductor digiti minimi. In the palm of the hand, the tendons of the M. flexor digitorum superficialis (cut in this illustration) insert at the middle phalanx with a split tendon.The tendons of M. flexor digitorum profundus pass through the split tendon to reach the distal phalanx of the fingers. The tendons of the M. flexor digitorum profundus serve as origin for the four Mm. lumbricales which also belong to the intermediate layer of muscles (for the function of Mm. lumbricales → Fig. 3.101). The tendon of the M. flexor pollicis longus inserts at the distal phalanx of the thumb.

→ T 32, 36–38

Tendinous sheaths of the palmar hand

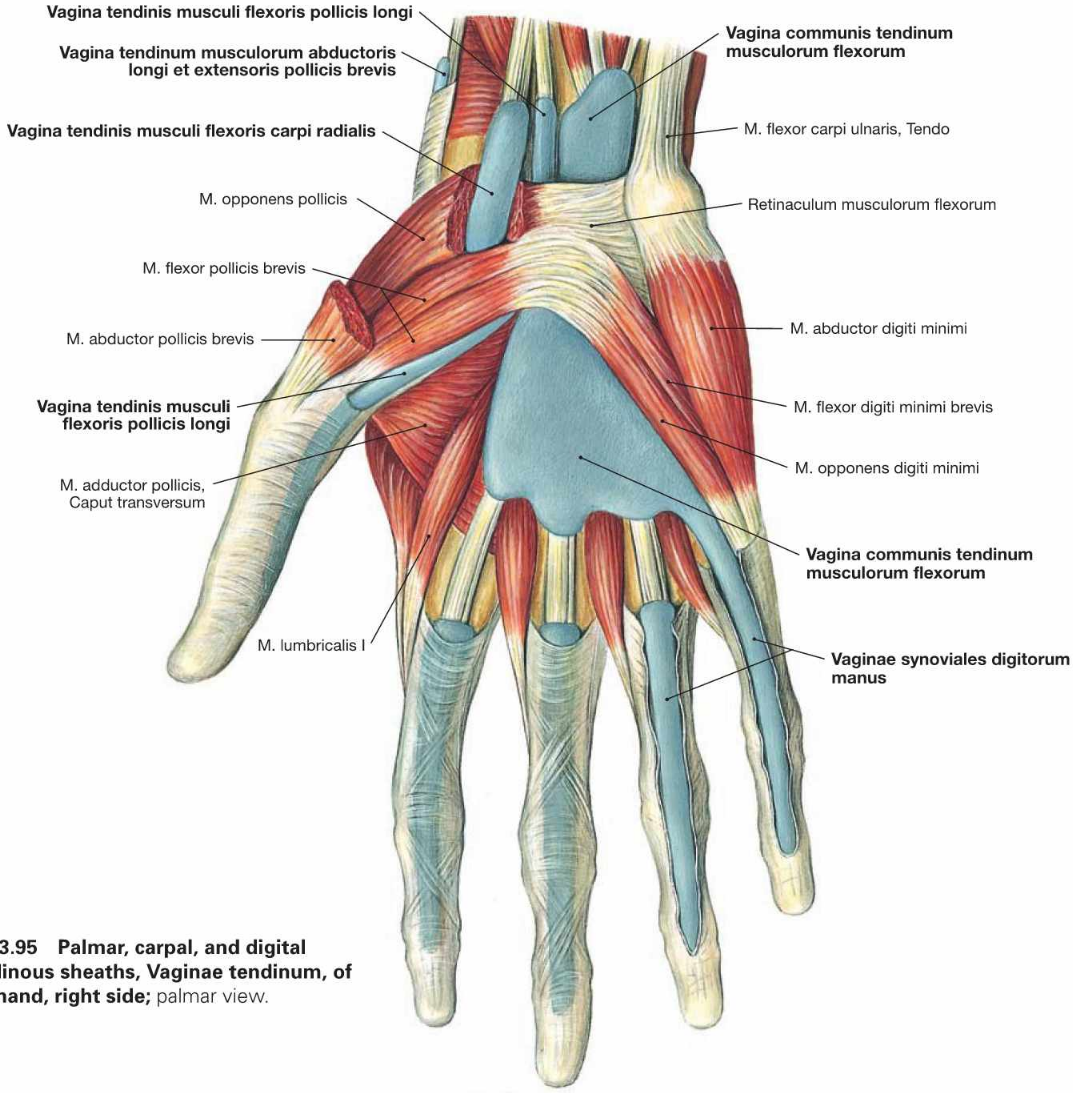
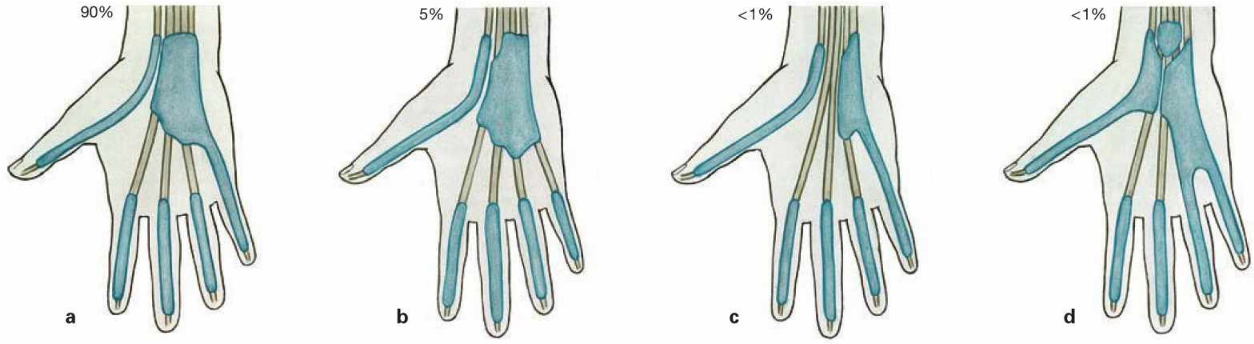


Fig. 3.95 Palmar, carpal, and digital tendinous sheaths, Vaginae tendinum, of the hand, right side; palmar view.



Figs. 3.96a to d Variants of palmar tendinous sheaths.
In contrast to the situation in the dorsal aspect of the hand, tendons of the finger flexors usually have only two tendinous sheaths. The **radial** tendinous sheath surrounds the tendon of the M. flexor pollicis longus and reaches to its distal phalanx. The **ulnar** tendinous sheath surrounds all tendons of the Mm. flexores digitorum superficialis and profundus at the wrist and reaches the distal phalanx only at the fifth digit. The other fingers have independent tendinous sheaths surrounding the flexor tendons.

Clinical Remarks

The arrangement of the tendinous sheaths is of clinical importance as **bacterial infections** (phlegmon) quickly spread in the tendinous sheaths. An inflammation involving the ulnar tendinous sheath can spread to the fifth finger. Inadequate antibiotic therapy may result in stiffening of the entire hand.

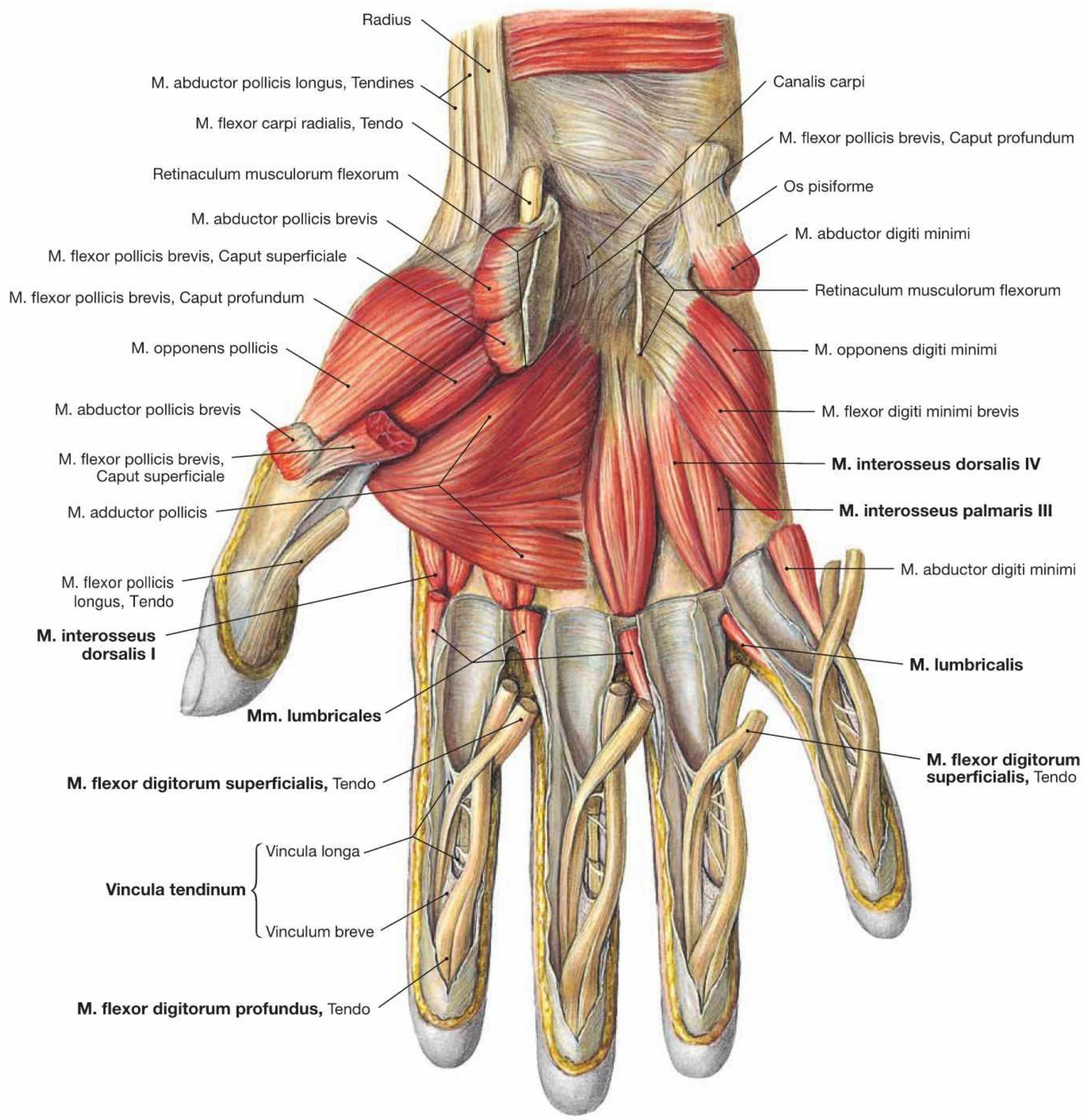


Fig. 3.97 Deep layer of muscles of the palm of the hand, Palma manus, right side; palmar view; after removal of the tendons of the long flexors of the fingers.

The three muscle groups of the palm of the hand are arranged in three consecutive layers. Upon removal of the tendons of the long flexors the muscles of the deep layer become visible. The Mm. interossei and Mm. lumbricales are flexors of the metacarpophalangeal joints (for course and function of Mm. interossei → Figs. 3.98 to 3.100). The tendons of the Mm. interossei and Mm. lumbricales are positioned at the palmar side to the transverse axis of the metacarpophalangeal joints. Thus, the Mm. interossei and, to a lesser extent, also the Mm. lumbricales are the main flexors of the metacarpophalangeal joints.

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

→ T 31, 36, 37

Clinical Remarks

Knowledge of the function and the course of the flexor muscle tendons at the fingers is important when **examining cuts.** The M. flexor digitorum profundus is affected if flexion of the distal interphalangeal joints is impossible. If, however, flexion of the proximal interphalangeal joints is reduced while flexion of the distal interphalangeal joints is possible an isolated injury of M. flexor digitorum superficialis is indicated.

Muscles of the hand

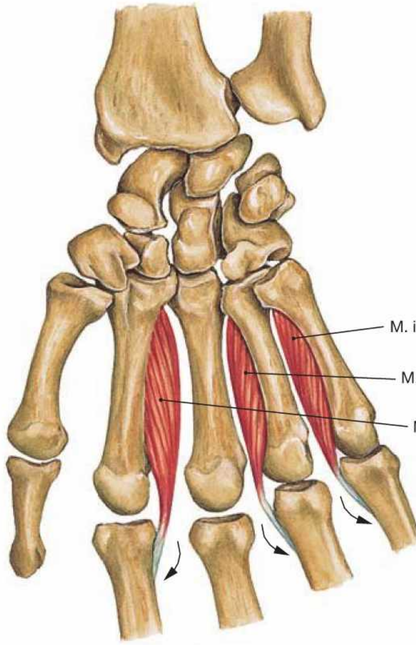


Fig. 3.98 Mm. interossei palmares, right side; palmar view.
The three Mm. interossei palmares originate from the ulnar aspect of the Os metacarpi II and from the radial aspect of the Ossa metacarpi IV and V. They insert on the same side of the corresponding proximal phalanx of the fingers and radiate into the lateral tracts of the dorsal aponeurosis (arrows).

→ T 37

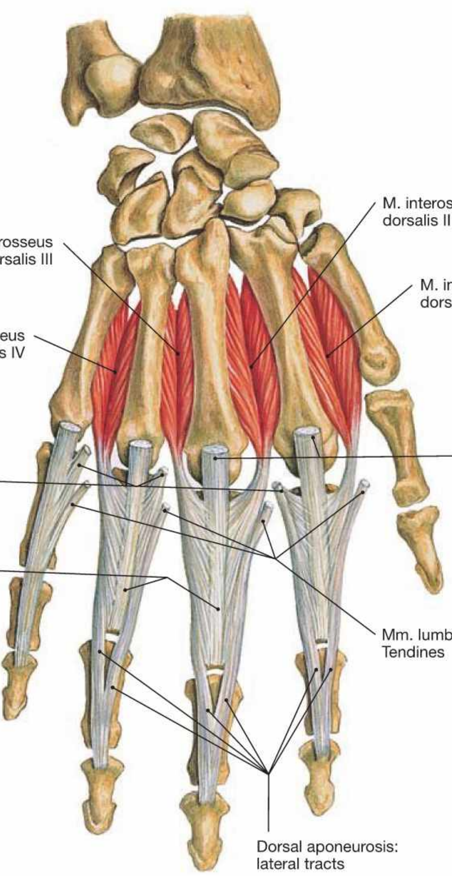


Fig. 3.99 Mm. interossei dorsales, right side; dorsal view.
The four Mm. interossei dorsales have their origin with two heads from the opposing surfaces of the Ossa metacarpi I–V. They insert on both sides of the proximal phalanx of the middle finger, on the ulnar side of the ring finger, and on the radial side of the index finger. A small portion of their tendons also merges with the lateral tracts of the dorsal aponeurosis. Thus, these muscles are flexors of the metacarpophalangeal joints and extensors of the proximal and distal interphalangeal joints.

Flexor muscles of the interphalangeal joints:
Each joint has a predominant flexor muscle. The exclusive flexor for the distal interphalangeal joints is the M. flexor digitorum profundus.

- **metacarpophalangeal joints:** Mm. interossei palmares and dorsales, also Mm. lumbricales, but weaker
- **proximal interphalangeal joints:** Mm. flexor digitorum superficialis
- **distal interphalangeal joints:** M. flexor digitorum profundus

→ T 37

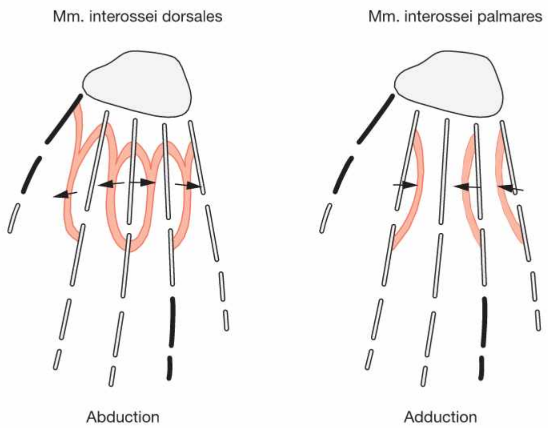


Fig. 3.100 Schematic drawing of the positions of the Mm. interossei and their actions on abduction and adduction of the fingers. (according to [1])
According to their course described on → p. 192, the Mm. interossei dorsales spread the fingers (abduction) and can move the middle finger medially and laterally. In contrast, the Mm. interossei palmares adduct the fingers. Their effects on the movements of flexion and extension can be deduced from the course of their tendons in relation to the transverse axis of the finger joints and is explained on → pages 191 and 192.

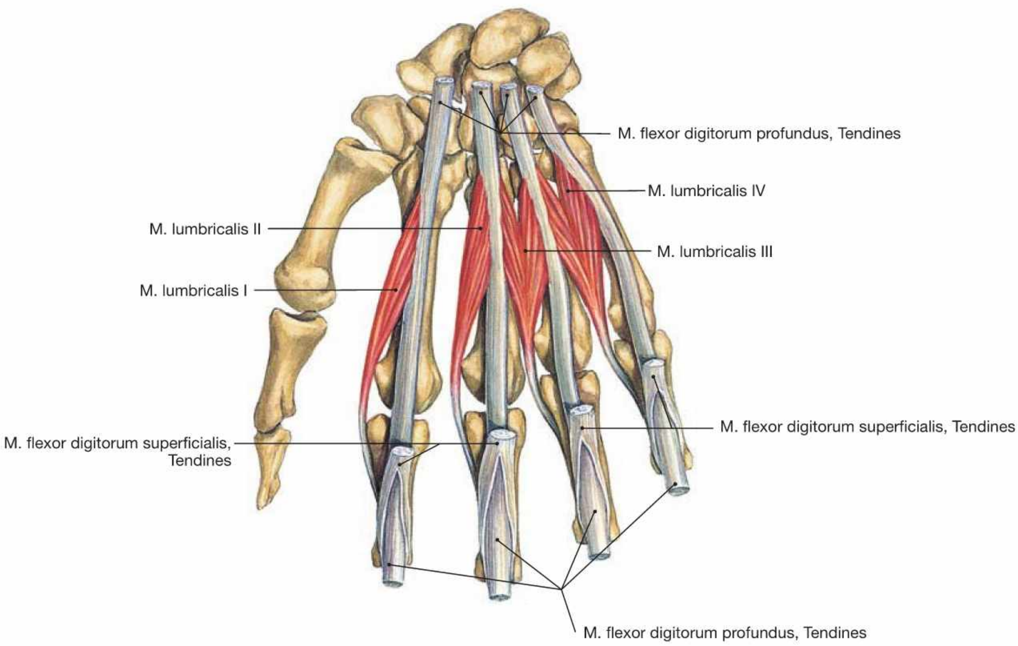


Fig. 3.101 Mm. lumbricales, right side; palmar view.
The two radial Mm. lumbricales originate with one head, the two ulnar Mm. lumbricales with two heads from the tendons of M. flexor digitorum profundus. All muscles insert on the radial side of the proximal phalanx of the fingers II–V and their tendons merge with the lateral fibres of the dorsal aponeurosis of the fingers. They weakly flex the metacarpophalangeal joints and extend the proximal and distal interphalangeal joints.

→ T 37

Plexus brachialis

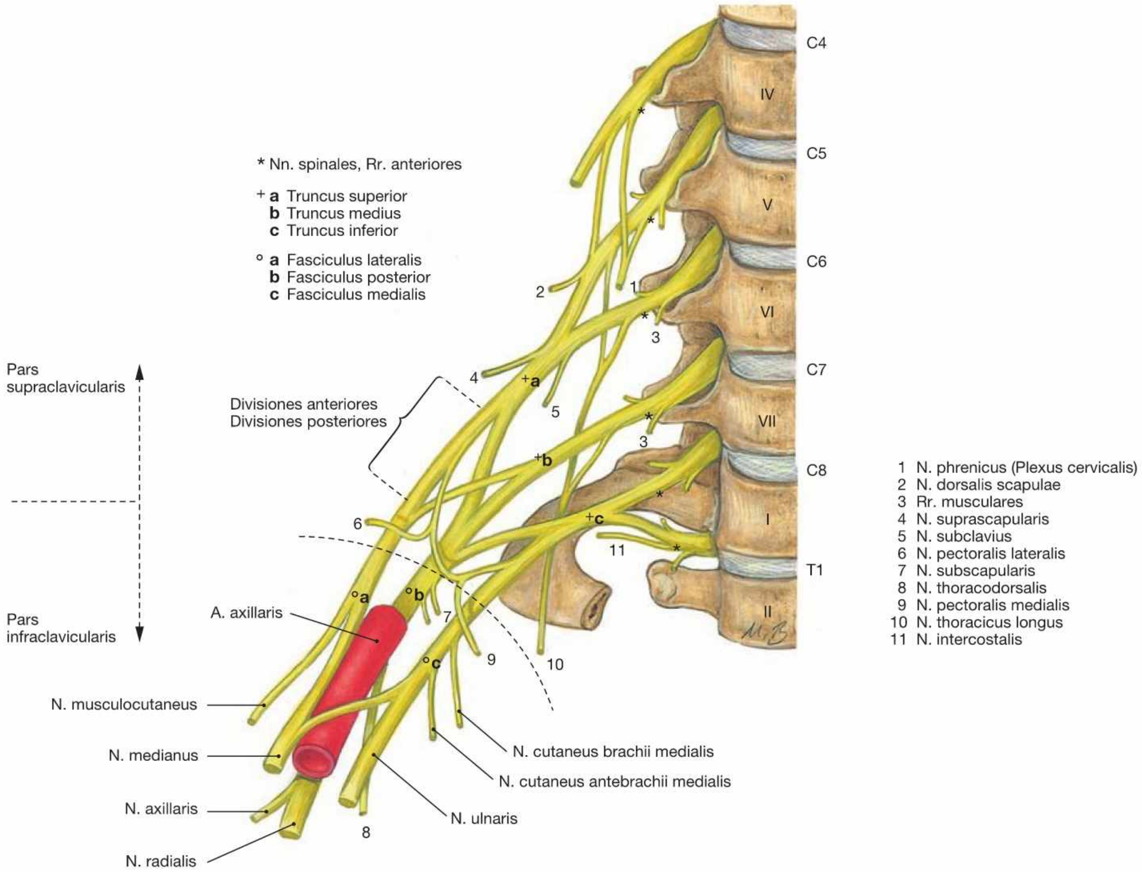


Fig. 3.102 Brachial plexus, Plexus brachialis (C5–T1): segmental arrangement of nerves, right side; ventral view.

Innervation of the upper extremity is derived from the Plexus brachialis. The brachial plexus is formed by Rr. anteriores of spinal nerves of the lower cervical and upper thoracic spinal cord segments (C5–T1). First, the Rr. anteriores combine to form three **trunks** (Trunci) which then rearrange at the level of the clavicle to form three **cords** (Fasciculi). These are named according to their position in relation to the A. axillaris as lateral, medial, and posterior cords. Nerve fibres from C5 and C6 assemble into the Truncus superior, from C7 into the Truncus medius, and from C8 to T1 into the Truncus inferior. The dorsal divisions (Divisiones posteriores) of all three trunks form the posterior cord (Fasciculus posterior; fibres from C5–T1). The ventral divisions (Divisiones anteriores) of Truncus superior and Truncus medius continue as lateral cord (Fasciculus lateralis; lateral of A. axillaris; nerve fibres from C5–C7), the ventral part of Truncus inferior continues as medial cord (Fasciculus medialis, medial of A. axillaris, nerve fibres from C8–T1). Understanding this structure of the brachial plexus allows to easily memorise and deduct the composition of the different peripheral nerves, with a few exceptions only.

The Plexus brachialis has two topographical parts: The **supraclavicular part** (Pars supraclavicularis) comprises the trunks and those peripheral nerves derived from the trunks or the Rr. anteriores of the spinal nerves (C5–T1). The **infraclavicular part** (Pars infraclavicularis) consists of the fascicles (Fasciculi). The nerves of the arm (→ Fig. 3.103) branch off the infraclavicular part. Nerves to the shoulder, however, branch off the supraclavicular part.

Pars supraclavicularis:
- Nerve branches for 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)

→ T 22, 23

Clinical Remarks

Severe injuries of the shoulder and arm (motorcycle accidents, malposition at birth, improper positioning during surgery) can lead to lesions of the Plexus brachialis. Depending on the affected trunks one distinguishes:
- **Upper brachial plexus paralysis (ERB's palsy, roots of C5–C6)** with paresis (paralysis) of the abductors and lateral rotators of the shoulder, and the upper arm flexors as well as the M. supinator. As a result, there is an adduction and medial rotation of the arm with extended elbow joint but normal hand function. Pathomechanism: increase of the distance between neck and shoulder.
- **Lower brachial plexus paralysis (KLUMPKE's palsy, roots of C8–T1)** with paresis of the long flexors of the fingers and short muscles of the hand, partially with HORNER's syndrome (miosis, ptosis, enophthalmus) due to additional lesion of the cervical sympathetic chain with normal shoulder and elbow function. Pathomechanism: increase of the distance between the trunk and shoulder.

The Truncus medialis (C7) may be involved in both, the upper and the lower lesion, and this is indicated by paralysis of the M. triceps brachii and the extensors of the fingers. In case of a **complete lesion,** movements of the entire arm including the hand are affected.

Nerves to the arm derived from the Plexus brachialis

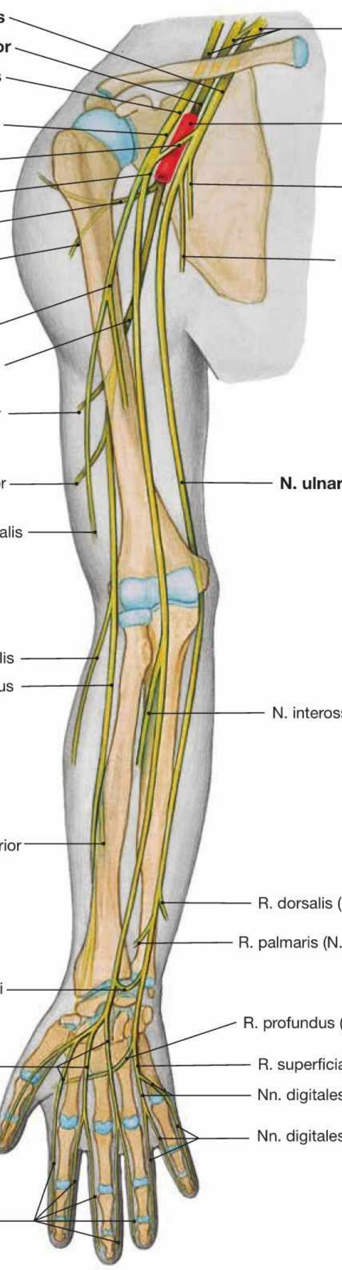


Fig. 3.103 Brachial plexus, Plexus brachialis (C5–T1); nerves of the arm, right side; ventral view.

The nerves of the arm derive from the infraclavicular part of the brachial plexus. The Fasciculus posterior gives rise to the N. axillaris and the N. radialis. The Fasciculus lateralis contributes to the N. musculocutaneus and the lateral root (Radix lateralis) of the N. medianus. The Fasciculus medialis gives rise to the N. ulnaris, the medial root (Radix medialis) of the N. medianus, and the cutaneous nerves of the medial upper arm (N. cutaneus brachii medialis) and forearm (N. cutaneus antebrachii medialis).

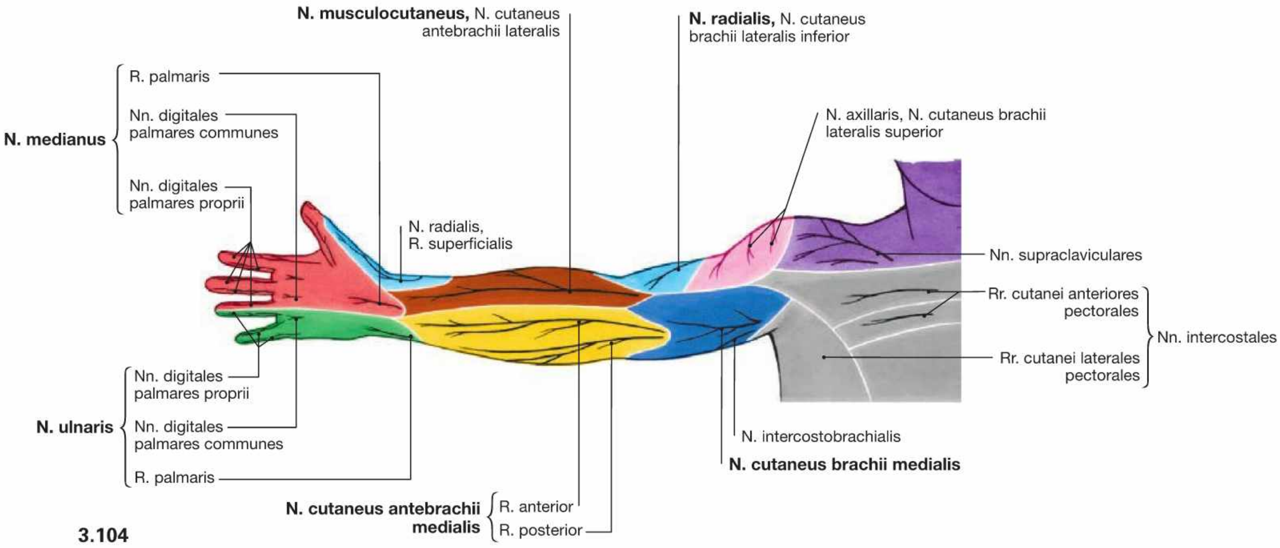
→ T 22, 23

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

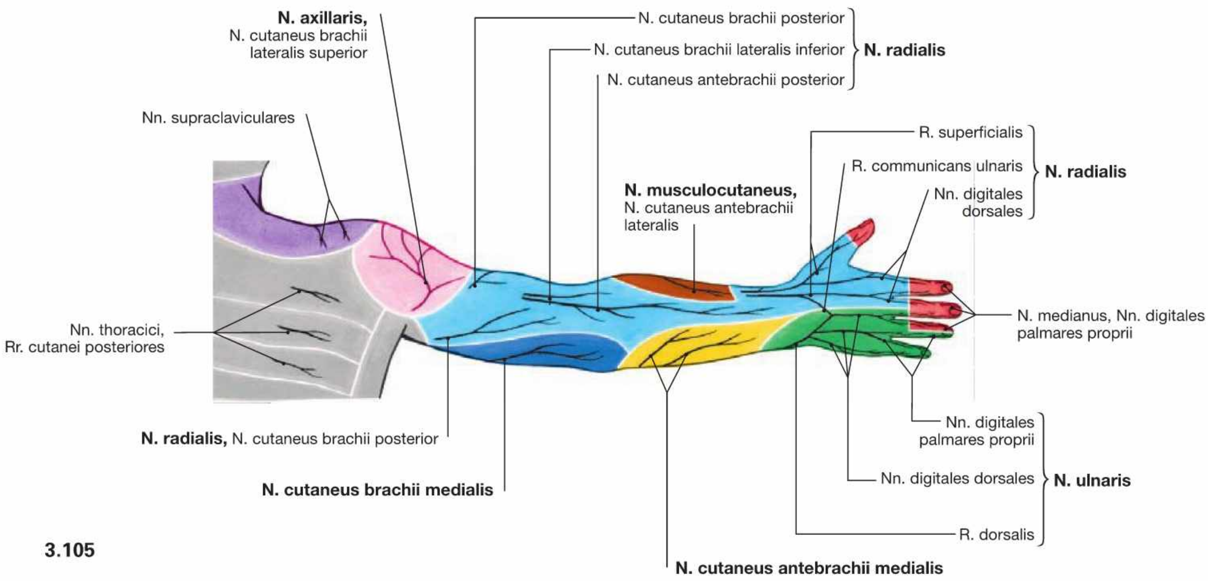
Fasciculus lateralis (C5–C7):
- N. musculocutaneus (C5–C7)
- N. medianus, Radix lateralis (C6–C7)
- N. pectoralis lateralis (C5–C7)

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)

Innervation of the skin



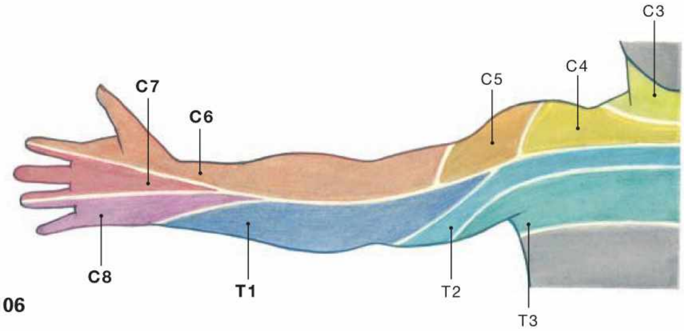
3.104



3.105

Fig. 3.104 and Fig. 3.105 Cutaneous nerves of the upper extremity, right side; ventral (→ Fig. 3.104) and dorsal (→ Fig. 3.105) view.
All nerves of the infraclavicular part of the **Plexus brachialis** contribute to the sensory innervation of **shoulder** and **arm.** The lateral aspect of the shoulder is innervated by the N. axillaris. The lateral and dorsal sides of the upper arm, the dorsal side of the forearm, and the dorsal side of the radial 2½ fingers are innervated by the N. radialis. The N. musculocutaneus conveys sensory innervation to the lateral aspect of the forearm. The N. cutaneus brachii medialis and N. cutaneus antebrachii medialis innervate the medial aspect of the arm. The N. medianus (palmar side of the radial 3½ fingers) and N. ulnaris (palmar side of the ulnar 2½ fingers) innervate the hand.

→ T 23



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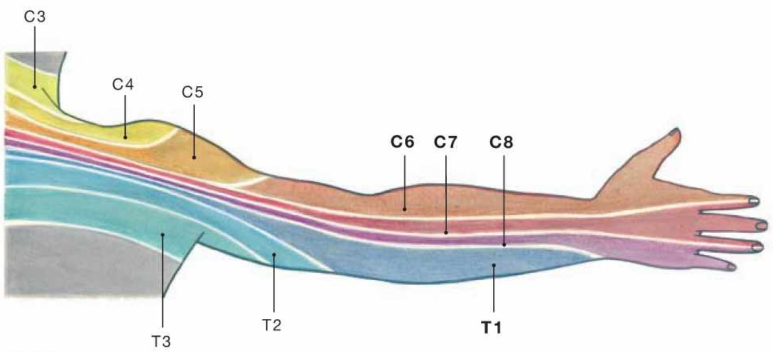


3.107

Fig. 3.106 and Fig. 3.107 Segmental cutaneous innervation (dermatomes) of the upper extremity, right side; ventral (→ Fig. 3.106) and dorsal (→ Fig. 3.107) view.
Specific areas of the skin are innervated by one single spinal cord segment. These areas of the skin are termed **dermatomes.** As peripheral cutaneous nerves of the arm contain sensory nerve fibres from several spinal cord segments, dermatomes are not exactly congruent with the cutaneous area supplied by the peripheral nerves (→ p. 196). In contrast to the belt-like orientation of the dermatomes of the trunk, dermatomes of the arm are oriented along the **longitudinal axis** (see Development, → Fig. 3.7).

→ T 23

Clinical Remarks

The demarcation of dermatomes is of great significance in the diagnosis of **herniated discs** and narrowing **(stenosis) of the vertebral canal** and intervertebral foramina for exiting spinal nerves: while the segment C6 innervates the radial forearm and thumb, C7 supplies the third finger and the adjacent halves of the fourth and second fingers. Sensory innervations of the fifth finger and the ulnar side of the forearm are linked to segments C8 and T1, respectively.

Nerves to the shoulder from the Pars supraclavicularis of the Plexus brachialis

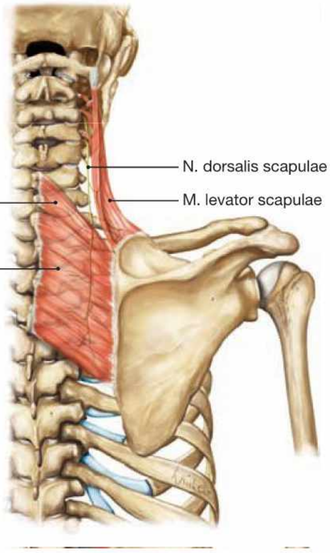


Fig. 3.108 N. dorsalis scapulae (C3–C5), right side; dorsal view.
The N. dorsalis scapulae innervates the Mm. rhomboidei and M. levator scapulae, both of which fix the Scapula to the trunk and pull it medially and superiorly. The N. dorsalis scapulae is the most cranial nerve to branch off the Plexus brachialis, it pierces through the M. scalenus medius, and runs dorsally along the inferior border of the M. levator scapulae (indicator muscle).

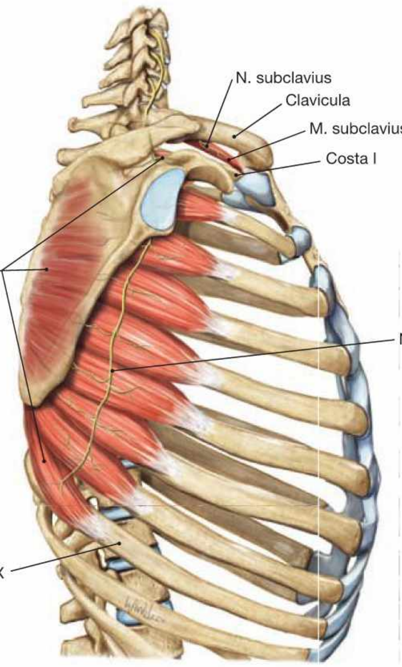


Fig. 3.109 N. thoracicus longus (C5–C7) and N. subclavius (C5–C6), right side; lateral view from the right side.
The N. thoracicus longus innervates the M. serratus anterior which is responsible for the elevation of the arm. This nerve pierces the M. scalenus medius and courses underneath the Plexus brachialis and Clavicula to the lateral side of the thorax to descend along the outer surface of the M. serratus anterior. The N. subclavius innervates the corresponding muscle which actively stabilises the sternoclavicular joint. The N. subclavius runs adjacent to the M. subclavius and often sends a branch to the N. phrenicus ("accessory phrenic nerve").
The nerves to the shoulder derive from the Pars supraclavicularis (→ Figs. 3.108 to 3.110) and the Pars infraclavicularis (→ Figs. 3.111 to 3.113) of the Plexus brachialis.

Nerves to the shoulder from the Pars supraclavicularis:
- N. dorsalis scapulae (C3–C5)
- N. thoracicus longus (C5–C7)
- N. suprascapularis (C4–C6)
- N. subclavius (C5–C6)

→ T 22, 23

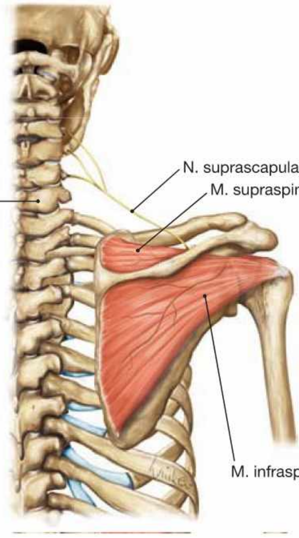


Fig. 3.110 N. suprascapularis (C4–C6), right side; dorsal view.
The N. suprascapularis innervates the M. supraspinatus (supports abduction) and M. infraspinatus (most important lateral rotator of the arm!). The N. suprascapularis derives from the Truncus superior, runs dorsally along the clavicle, and reaches the dorsal aspect of the shoulder blade by traversing the Incisura scapulae underneath the Lig. transversum scapulae superius.

Clinical Remarks

Lesions of the shoulder nerves from the Pars supraclavicularis:
- **N. dorsalis scapulae:** The Scapula is displaced laterally and slightly protruding from the thorax. An isolated injury is rare because of its sheltered position.
- **N. thoracicus longus:** Elevation is impossible! The medial border of the Scapula protrudes wing-like from the body (Scapula alata; winged scapula). This lesion is relatively common when carrying heavy loads on the back ("backpacker's palsy") because this nerve can be pinched under the clavicle.
- **N. suprascapularis:** Affects lateral rotation (M. infraspinatus is the most important muscle) and, to a lesser degree, abduction (M. supraspinatus). In addition to injuries of the lateral neck, pinching of nerves in the suprascapular notch (Incisura scapulae) is also possible.
- The isolated lesion of the N. subclavius is very rare and has no clear clinical symptoms.

Nerves to the shoulder from the Pars infraclavicularis of the Plexus brachialis

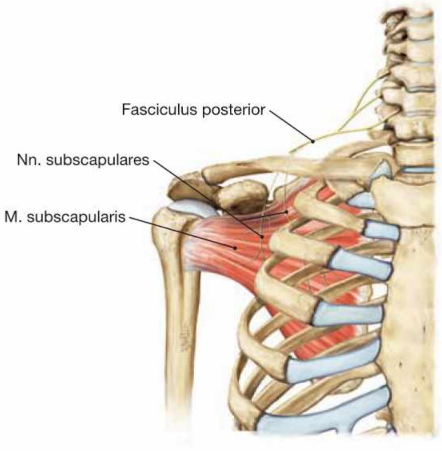


Fig. 3.111 Nn. subscapulares (C5–C7), right side; ventral view.
Both nerves innervate the M. subscapularis (most important medial rotator of the arm!). The Nn. subscapulares are well protected since they branch off the posterior cord and immediately descend to the anterior side of the Scapula.

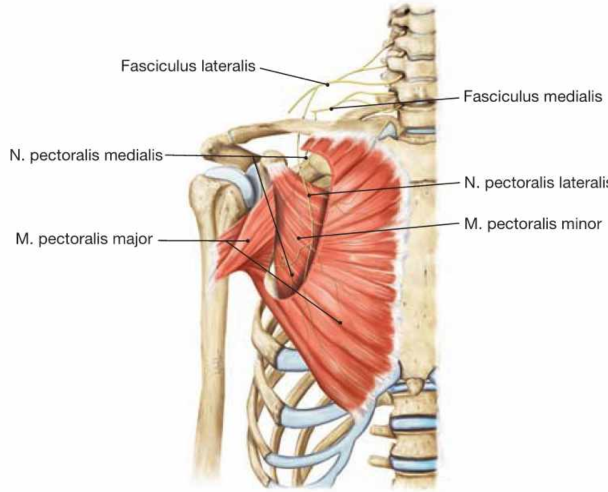


Fig. 3.112 Nn. pectorales lateralis (C5–C7) and medialis (C8–T1), right side; ventral view.
The terms "lateralis" and "medialis" are related to their origins from the lateral or medial cord, respectively, not to their topographical position (the N. pectoralis medialis is often positioned lateral). Both nerves innervate the Mm. pectorales major and minor. The M. pectoralis major is the most important muscle for the adduction and anteversion of the arm.

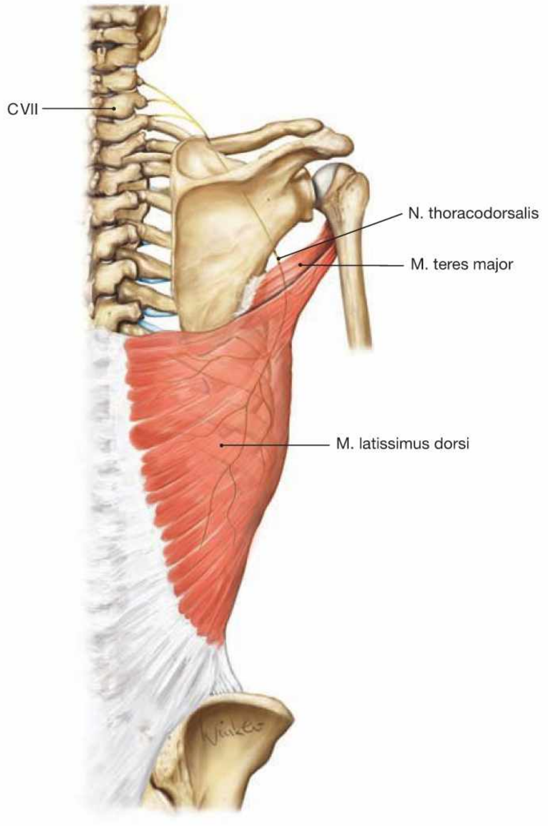


Fig. 3.113 N. thoracodorsalis (C6–C8), right side; dorsal view.
Together with the corresponding artery, the N. thoracodorsalis courses to the medial side of the M. latissimus dorsi and innervates this muscle and the M. teres major.
The nerves to the shoulder derive from the Pars supraclavicularis (→ Figs. 3.108 to 3.110) and the Pars infraclavicularis (→ Figs. 3.111 to 3.113) of the Plexus brachialis.

Nerves to the shoulder from the Pars infraclavicularis:
- Nn. subscapulares (C5–C7) from Fasciculus posterior
- N. thoracodorsalis (C6–C8) from Fasciculus posterior
- N. pectoralis lateralis (C5–C7) from Fasciculus lateralis
- N. pectoralis medialis (C8–T1) from Fasciculus medialis

→ T 22, 23

Clinical Remarks

Lesions of the shoulder nerves from the Pars infraclavicularis: In general, isolated injuries of individual infraclavicular nerves of the brachial plexus are rare due to their sheltered location.
- **Nn. subscapulares:** Weak medial rotation of the Humerus
- **N. thoracodorsalis:** Impaired adduction of the retroverted arm. Arms cannot be crossed **behind** the back. The posterior axillary fold is collapsed. Considering the size of the M. latissimus dorsi, the symptoms are mostly minor!
- **Nn. pectorales:** Impairment of adduction and anteversion. The arms cannot be crossed **in front of** the trunk. The anterior axillary fold is collapsed.

N. axillaris

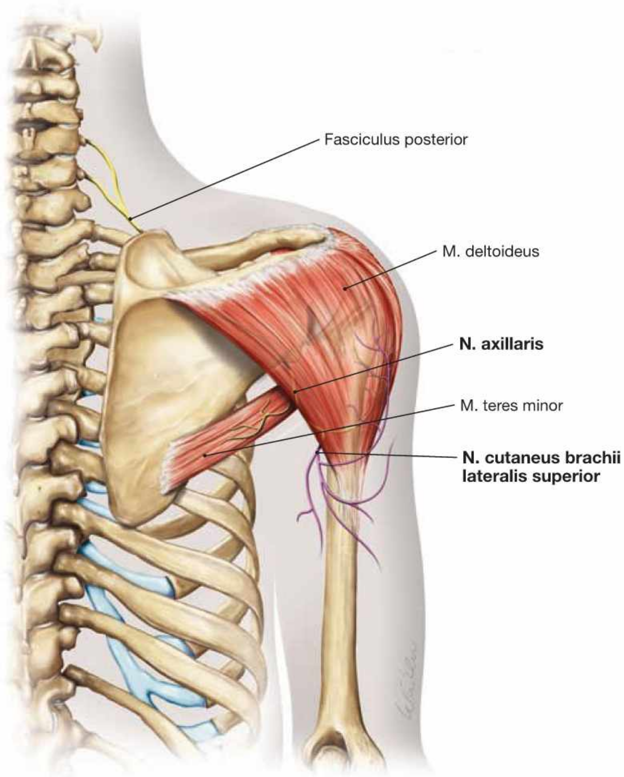


Fig. 3.114 Course, motor and sensory innervation of the N. axillaris, right side; dorsal view.
The N. axillaris originates from the Fasciculus posterior, traverses the **quadrangular space** in the Axilla together with the A. circumflexa humeri posterior and courses around the Collum chirurgicum of the Humerus to reach the dorsal side of the arm. The axillary nerve innervates the M. deltoideus (most important abductor of the arm) and the M. teres minor. The sensory terminal branch (N. cutaneus brachii lateralis superior [purple]) emerges at the inferior dorsal border of the M. deltoideus and innervates the lateral aspect of the shoulder.

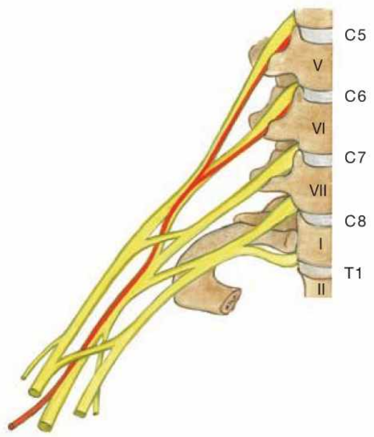


Fig. 3.115 Segmental organisation of the N. axillaris, right side; ventral view.

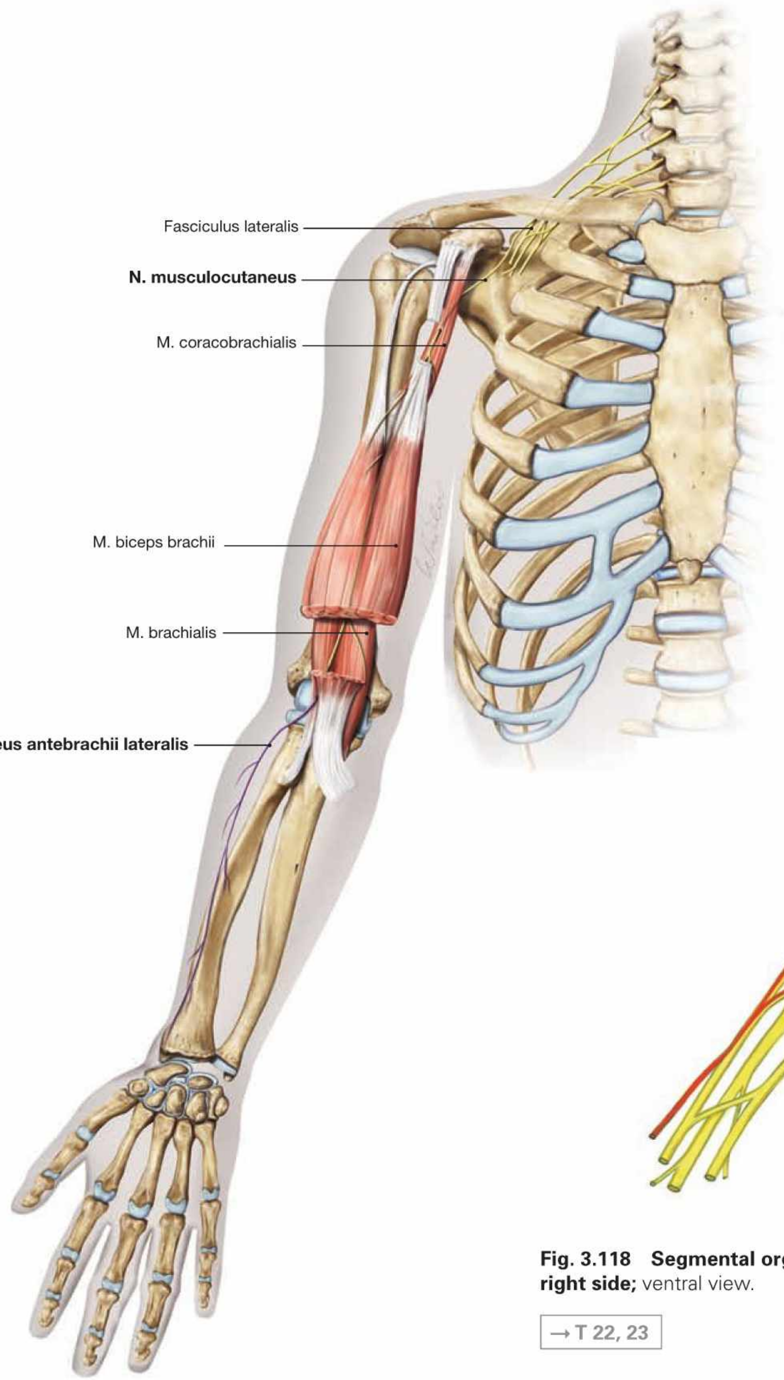
→ T 22, 23

Fig. 3.116 Lesion of the N. axillaris: paralysis and atrophy of the M. deltoideus.

Clinical Remarks

Lesions of the N. axillaris: The N. axillaris may be injured in proximal humeral fractures and shoulder luxations. Abduction of the arm is severely impaired and sensory input from the lateral side of the shoulder is lost. Long-lasting injury causes muscle atrophy, such that the dome shape of the shoulder is gone (→ Fig. 3.116).

N. musculocutaneus



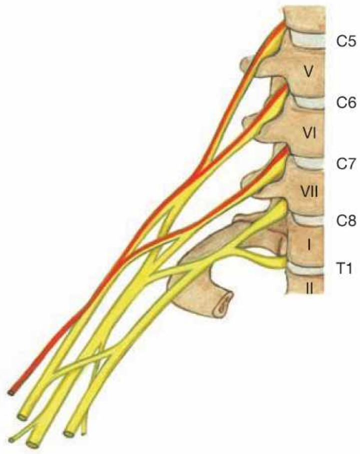


Fig. 3.118 Segmental organisation of the N. musculocutaneus, right side; ventral view.

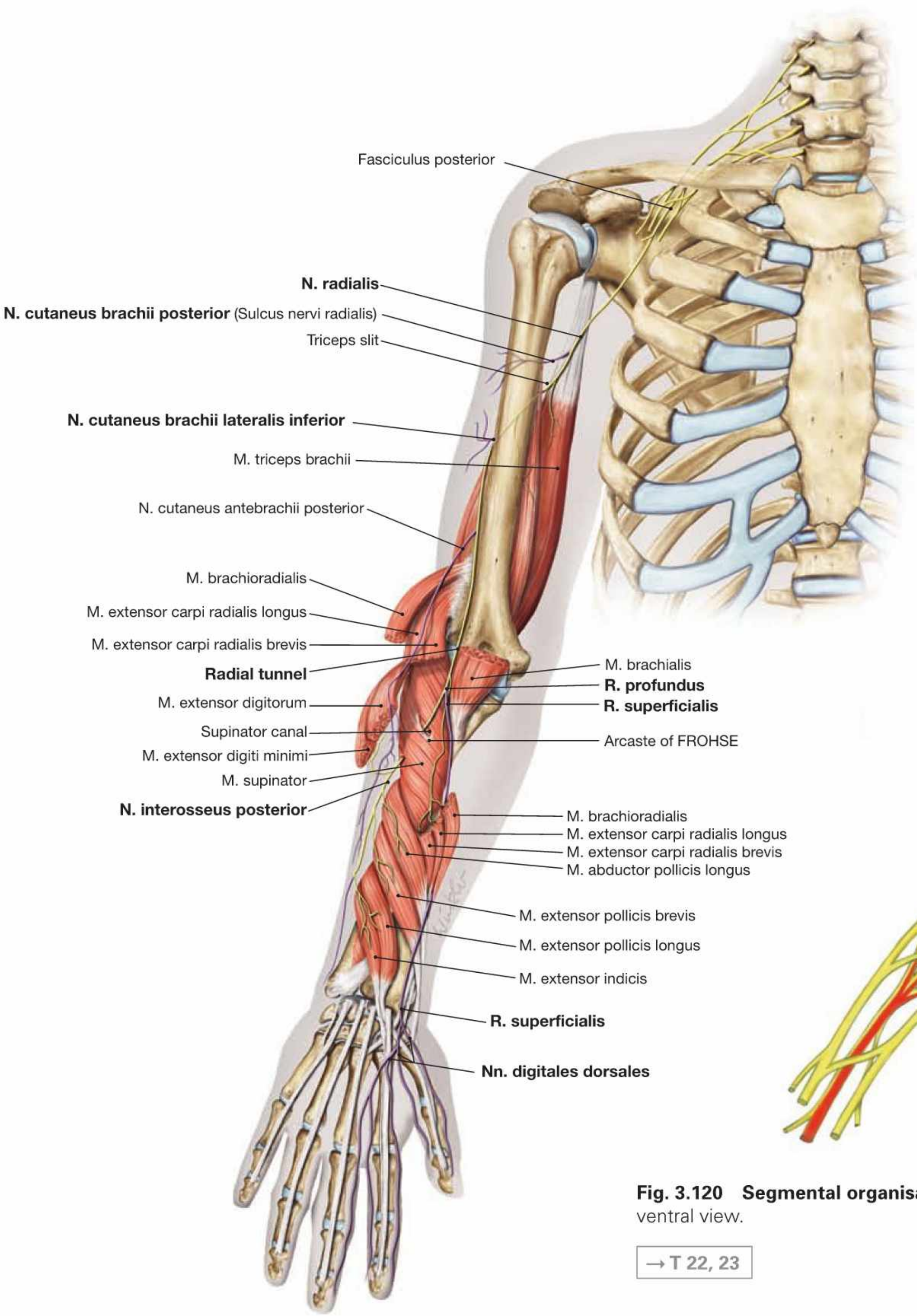
→ T 22, 23

Fig. 3.117 Course, motor and sensory innervation of the N. musculocutaneus (C5–C7), right side; ventral view.
Originating from the Fasciculus lateralis, the N. musculocutaneus **pierces the M. coracobrachialis,** descends distally between the M. biceps brachii and M. brachialis, and appears with its sensory branch (N. cutaneus antebrachii lateralis [purple]) between these two muscles at the elbow. The N. musculocutaneus provides motor innervation to the three ventral muscles of the upper arm and sensory innervation to the radial forearm.
Because the N. musculocutaneus pierces the M. coracobrachialis, finding the nerve during dissection helps to get oriented in dissecting the Plexus brachialis (→ Figs. 3.148 and 3.149).

Clinical Remarks

Lesions of the N. musculocutaneus: The N. musculocutaneus is at risk during shoulder luxations. Flexion of the elbow is significantly reduced as a result of injury, but remains weakly preserved because the radial group of the forearm extensors (innervated by the N. radialis) and the superficial flexors of the forearm (innervated by the N. medianus) also promote flexion in the elbow joint. 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 mild, because overlap occurs with the innervations of the medial and the dorsal sensory nerves.

N. radialis



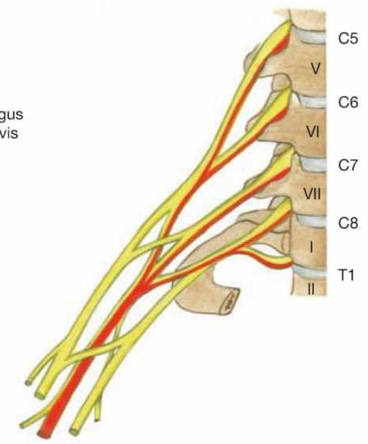


Fig. 3.120 Segmental organisation of the N. radialis, right side; ventral view.

→ T 22, 23

Fig. 3.119 Course, motor and sensory innervation of the N. radialis (C5–T1), right side; dorsal view. Sensory cutaneous branches are shown in purple.

The N. radialis derives from the Fasciculus posterior and reaches the dorsal side of the Humerus through the **"triceps slit"** (→ Fig. 3.77) between the Caput longum and Caput laterale of the M. triceps brachii. **Before** winding around the Humerus in the Sulcus nervi radialis, the N. radialis sends motor branches to the M. triceps brachii and a sensory branch to the dorsal side of the upper arm. The sensory branch to the forearm branches off during its course in the Sulcus nervi radialis. The N. radialis then enters the cubital fossa from laterally between the M. brachioradialis and M. brachialis **(radial tunnel)**, and divides into a R. superficialis and R. profundus. Before this division, motor branches to the M. brachioradialis and Mm. extensores carpi radialis longus and brevis branch off. Together with the A. radialis, the **R. superficialis** descends beneath the M. brachioradialis. Further distally, the R. superficialis courses to the dorsal side of the hand for the sensory innervation of the skin between the thumb and the index finger (Spatium interosseum; autonomic area!) and the dorsal side of the radial 2½ fingers. Inferior to the elbow, the **R. profundus** pierces the M. supinator **(supinator canal)** and reaches the dorsal side of the forearm to provide motor innervation to all extensor muscles of the forearm. The M. supinator reveals a sharp-edged tendinous arch (arcade of FROHSE). The terminal branch is the N. interosseus antebrachii posterior which provides sensory innervation to the dorsal wrist joints.
Sensory autonomic area: first interdigital space.

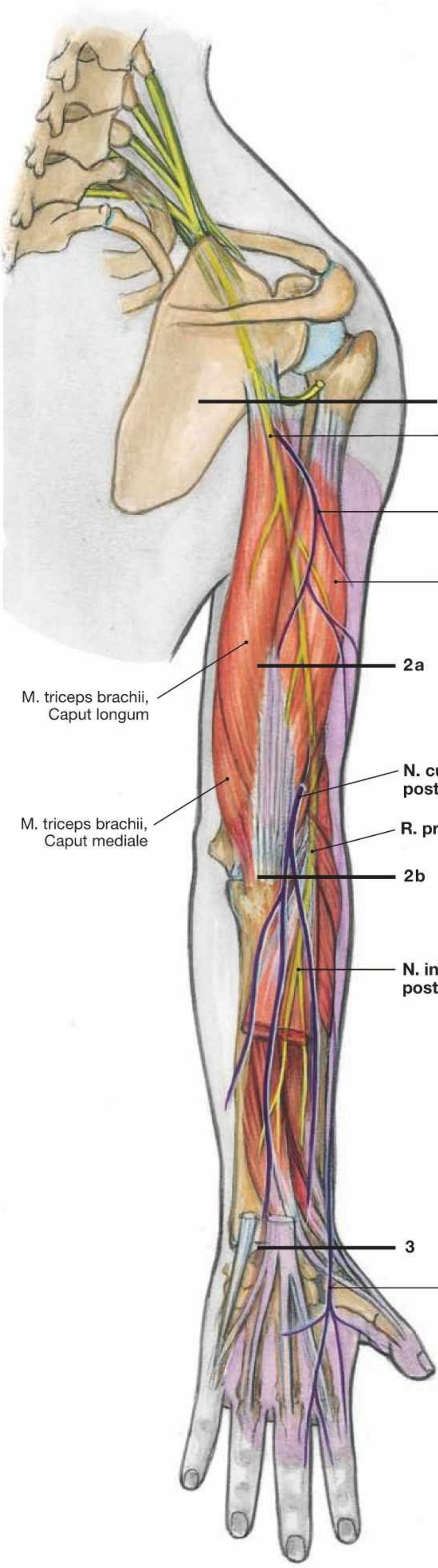


Fig. 3.121 Locations of common N. radialis lesions (C5–T1), right side; dorsal view (marked by bars). The skin areas of sensory innervation are highlighted (purple shading).
Sensory autonomic area: first interdigital space
1 proximal lesion in the **axilla**
2 intermediate lesion near the **shaft of Humerus** (**a**) or **cubital fossa** (**b**)
3 distal lesion near the **wrist joints**

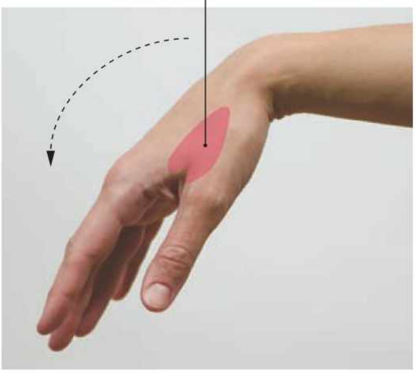


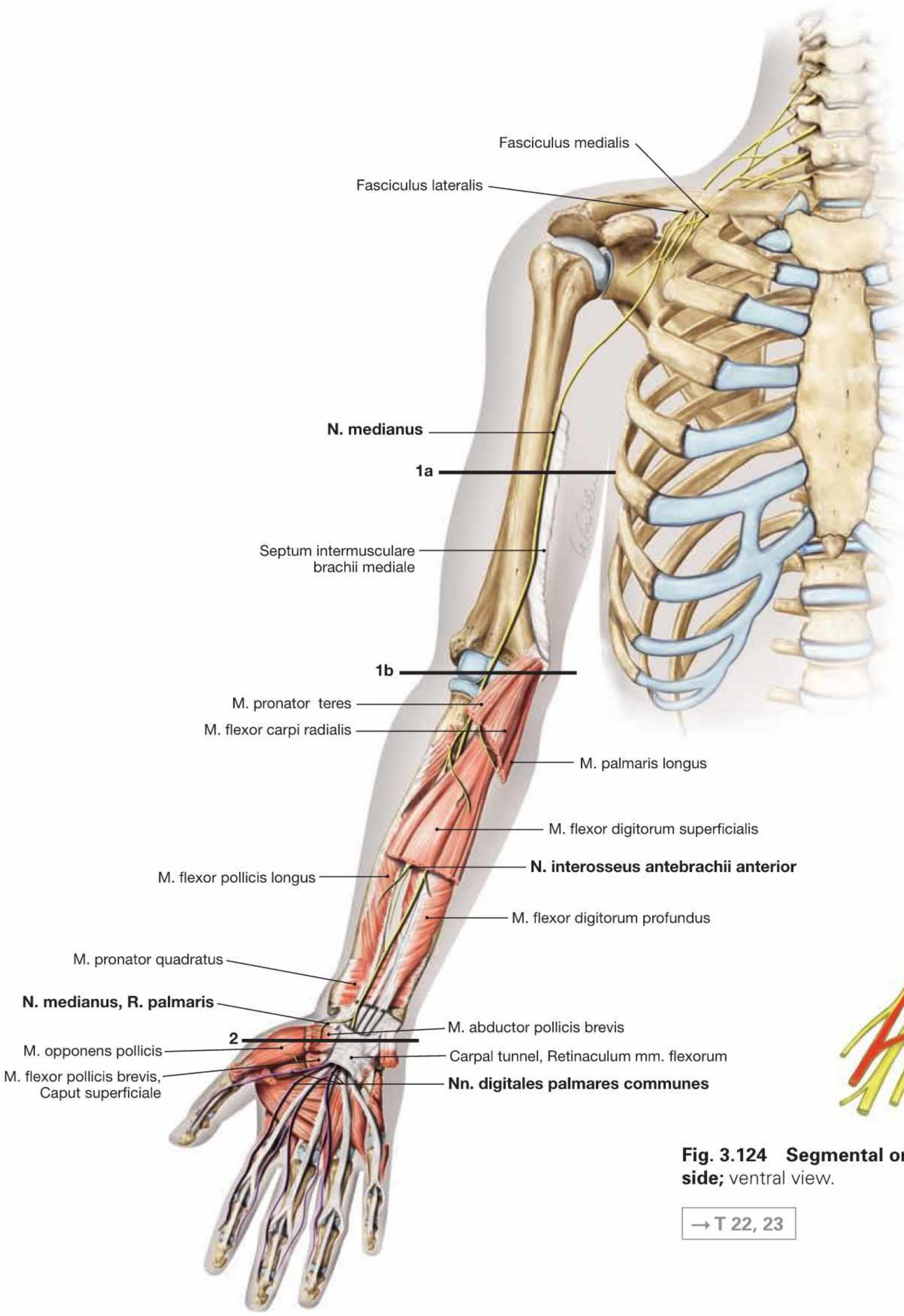
Fig. 3.122 Proximal lesion of the N. radialis: "wrist drop" with sensory deficits in the first interdigital space.

Clinical Remarks

Lesions of the N. radialis: There are three types of lesions:

- **Proximal lesion** in the region of the **axilla:** In the past, often caused by crutches; however, presently this type of injury occurs mainly due to improper positioning in the OR. In addition to the symptoms associated with damage in the area of the humeral shaft, impairment of the M. triceps with reduction of elbow extension exclusively occurs with proximal lesions. This also affects the triceps tendon reflex and causes loss of sensation on the back of the upper arm, as these nerve fibres branch off before entering the Sulcus nervi radialis.
- **Intermediate lesion** in the region of the **humeral shaft or elbow:** caused by a humeral shaft fracture or crush injuries (contusion) against the Humerus. In the elbow region, Radius dislocations or proximal fractures may contribute to the intermediate lesion as well as a compression by the arcade of FROHSE. Lesions in the region of the **humeral shaft** (→ Fig. 3.121, 2a) result in a **"wrist drop"** (→ Fig. 3.122) due to impairment 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 at the back of the forearm, in the first interdigital space (autonomic region), and on the back of the radial 2½ fingers. If only the **R. profundus** is pinched while passing through the M. supinator (→ Fig. 3.121, 2b), sensory deficits are missing and the lack of innervation of the wrist is negligible. A **"wrist drop"** does **not** occur since only the finger extensors are impaired, whereas the Mm. extensores carpi radiales as part of the intact radial muscle group can sufficiently stabilise the wrist. 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** regions due to a distal Radius fracture (most common fracture in humans): The sensory deficit is confined to the first interdigital space and to the back of the radial 2½ fingers. Motor deficits are absent!

N. medianus



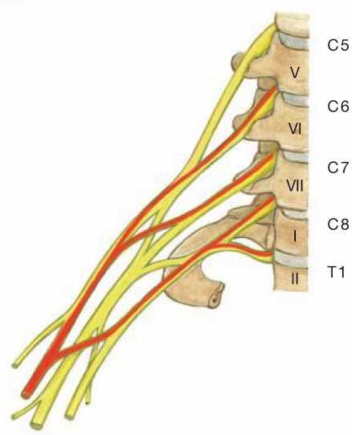


Fig. 3.124 Segmental organisation of the N. medianus, right side; ventral view.

→ T 22, 23

Fig. 3.123 Course, motor and sensory innervation and locations of lesions of the N. medianus (C6–T1), right side; ventral view.
Sensory cutaneous branches are shown in purple.
The N. medianus originates from a lateral and a medial root, which derive from the corresponding cords, and initially descends along the medially side of the upper arm in the Sulcus bicipitalis medialis without providing any branches. The nerve then enters the cubital fossa from medially and traverses **between both heads of M. pronator teres** into the intermuscular layer between the superficial and deep flexor muscles of the forearm. With the exception of the M. flexor carpi ulnaris and the ulnar part of M. flexor digitorum profundus, the N. medianus innervates all flexor muscles of the forearm. The deep flexors are innervated by the N. interosseus antebrachii anterior which also provides sensory innervation to the palmar side of the wrist joints. The N. medianus then enters the palm of the hand via the **carpal tunnel** (Canalis carpalis) between the tendons of the flexor muscles. In the palm of the hand, the median nerve divides into three Nn. digitales palmares communes. These provide motor innervation to the muscles of the thumb (except for the M. adductor pollicis and Caput profundum of the M. flexor pollicis brevis) and the two radial Mm. lumbricales. Their terminal branches provide sensory innervation of the respective palmar side of the radial 3½ fingers and the dorsal side of the distal phalanges.
Sensory autonomic area: distal phalanges of the second and third fingers.
Common locations of lesions (marked by bars):
1 **proximal lesion** in the **Sulcus bicipitalis medialis (a)** and in the **cubital fossa (b)**
2 **distal lesion** near the **wrist joints** and the **carpal tunnel**

N. medianus

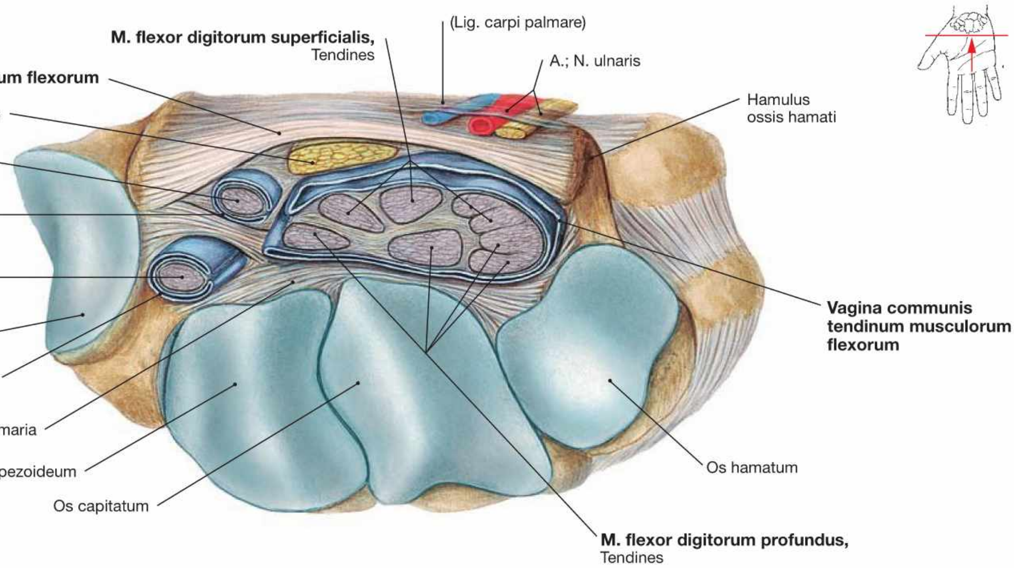


Fig. 3.125 Carpal tunnel, Canalis carpalis, right side; distal view; transverse section at the level of the carpometacarpal joints.
Together with the carpal bones the Retinaculum musculorum flexorum forms the carpal tunnel which is traversed by the N. medianus and the tendons of the long flexor muscles (→ Fig. 3.164). Inflammatory reactions of the tendinous sheaths or swellings in the area of the carpal tunnel may result in 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.**

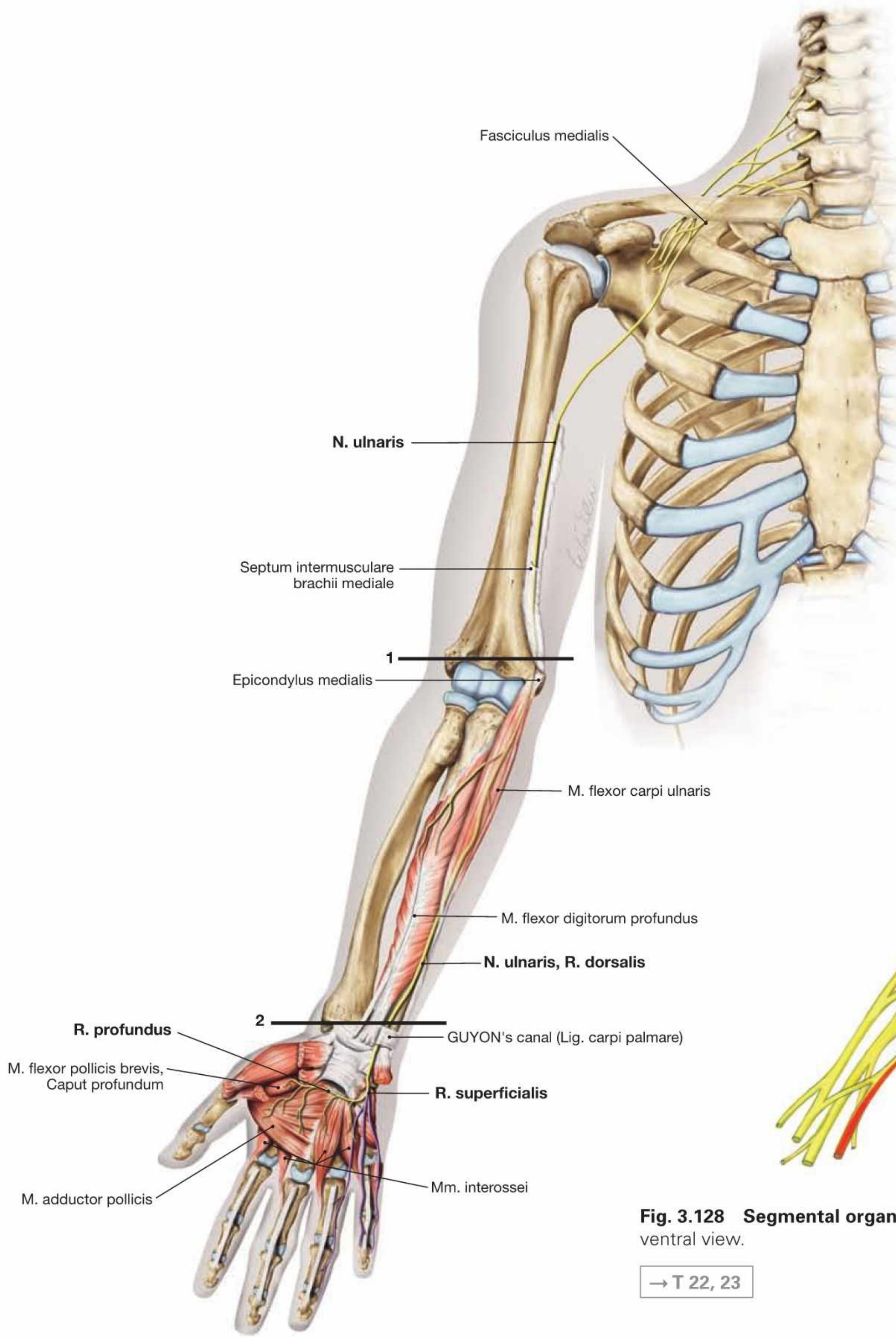
Fig. 3.126 Proximal lesion of the N. medianus: "hand of benediction" with sensory deficits at the distal phalanx of the second and third fingers.

Clinical Remarks

Lesions of the N. medianus: There are proximal and distal lesions:

- **Proximal lesions** in the area of the Sulcus bicipitalis medialis (→ Fig. 3.123, 1a; e.g. cuts) or in the cubital fossa (→ Fig. 3.123, 1b): In the cubital fossa, the N. medianus may be pinched by distal fractures of the Humerus, employing incorrect procedures during phlebotomy or intravenous injections, or at its passage between the two heads of the M. pronator teres (pronator syndrome; median nerve entrapment syndrome). Only the proximal lesion presents with the **"hand of benediction"** position, characterised by the inability to flex the proximal and distal interphalangeal joints of the first, second and third fingers (→ Fig. 3.126). The reason is the absence of innervation to the superficial finger flexor and the radial component of the deep finger flexor. All other symptoms are similar to those of the distal lesion.
- **Distal lesions** in the **wrist region** (such as "cutting the arteries" in a suicide attempt) or by compression of the N. medianus in the carpal tunnel **(carpal tunnel syndrome):** These do not result in a "hand of benediction" because the motor branches of the finger flexors already separate at the forearm! However, this lesion presents with an **"ape hand"** displaying thenar atrophy and an adducted thumb due to the predominating effects of the M. adductor pollicis (innervated by the N. ulnaris). Grasping an object between the thumb and the index finger is impossible because of the inability to oppose the thumb (deficit of M. opponens pollicis) and the distal phalanges of both fingers cannot approximate. In addition, the impaired ability to abduct the thumb (M. abductor pollicis brevis) does not allow complete enclosure of an object with the hand. **Sensory deficiencies** occur on the palmar side of the radial 3½ fingers. Proximally radiating pain typically occurs at night.

N. ulnaris



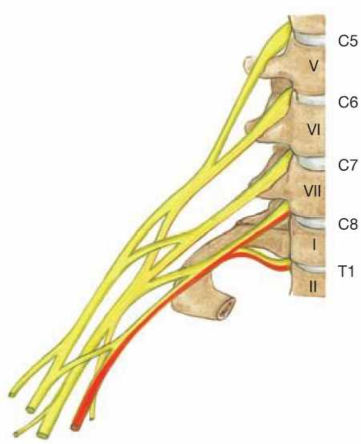


Fig. 3.128 Segmental organisation of the N. ulnaris, right side; ventral view.

→ T 22, 23

Fig. 3.127 Course, motor and sensory innervation and locations of lesions of the N. ulnaris (C8–T1), right side; ventral view.
Sensory cutaneous branches are shown in purple.
The N. ulnaris originates from the Fasciculus medialis and courses along the medial upper arm in the Sulcus bicipitalis medialis. After piercing the Septum intermusculare brachii medialis, the N. ulnaris appears on the dorsal side of the Epicondylus medialis and runs directly adjacent to the bone in the Sulcus nervi ulnaris ("funny bone"). The N. ulnaris has no branches in the upper arm. In the forearm, it courses together with the A. ulnaris beneath the M. flexor carpi ulnaris to the wrist and enters the palm of the hand through the GUYON's canal. Its R. dorsalis reaches the dorsal side of the hand and supplies sensory innervation to the ulnar 2½ digits. In the forearm, the ulnar nerve provides motor innervation to the M. flexor carpi ulnaris and the ulnar head of the M. flexor digitorum profundus. In the palm of the hand, the R. profundus branches off following the deep palmar arterial arch to provide motor innervation to the muscles of the Hypothenar, all interossous muscles, the ulnar Mm. lumbricales, M. adductor pollicis, and the deep head of the M. flexor pollicis brevis. The R. superficialis provides motor innervation to the M. palmaris brevis and continues as sensory R. digitalis palmaris communis, which divides into the final branches innervating the palmar side of the ulnar 1½ digits (and the dorsal sides of their distal phalanges).
Sensory autonomic area: distal phalanx of the fifth finger
Frequent locations of lesions (marked by bars):
1 proximal lesion at the Epicondylus medialis ("funny bone")
2 distal lesion in the area of **GUYON's canal**

N. ulnaris

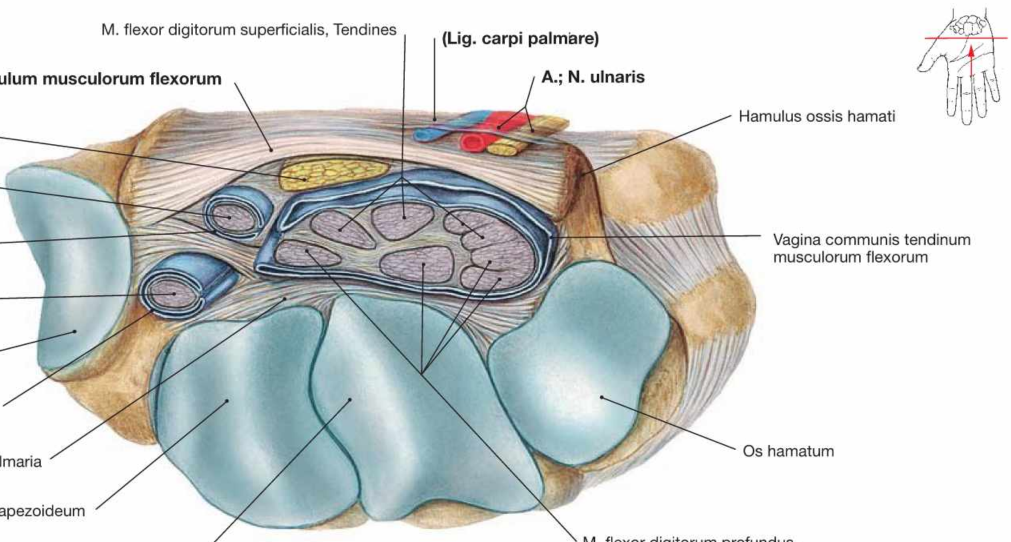


Fig. 3.129 GUYON's canal, right side; distal view; transverse section at the level of the metacarpophalangeal joints.
The GUYON's canal is formed by the Retinaculum musculorum flexorum and its superficial separation, the "Lig carpi palmare". The N. ulnaris, together with the A. and V. ulnaris traverse the GUYON's canal (→ Fig. 3.164). Swelling or chronic pressure in this area may cause a compression of the N. ulnaris **(GUYON's canal syndrome).**

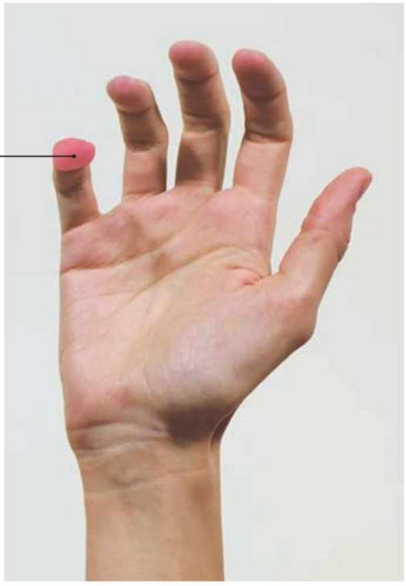


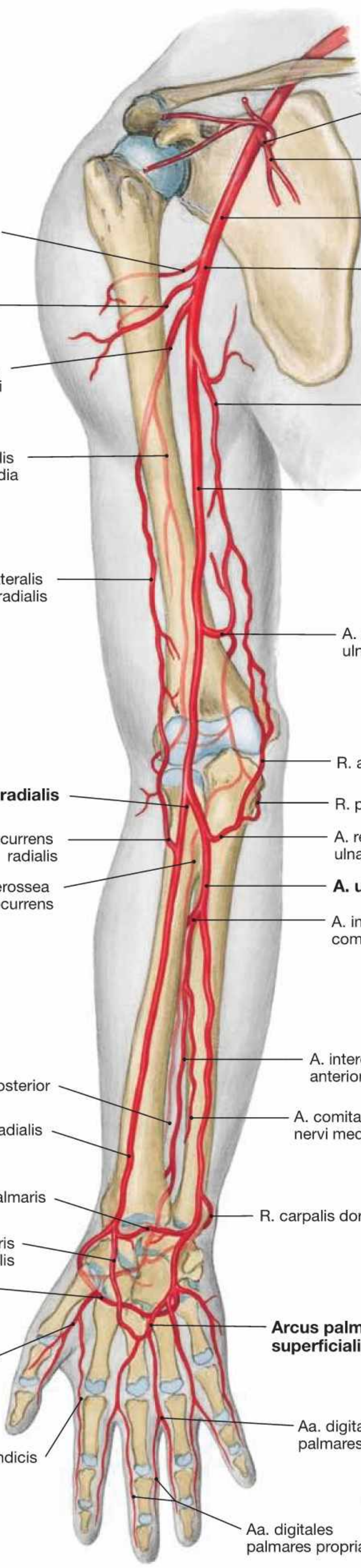
Fig. 3.130 Proximal and distal lesions of the N. ulnaris: "clawed hand" with impaired sensation at the distal phalanx of the fifth finger.

Clinical Remarks

Lesions of the N. ulnaris: Although proximal and distal lesions are distinguished, a clear clinical differentiation between them is not possible:

- **Proximal lesions** in the area of the Sulcus nervi ulnaris **("funny bone"),** usually due to chronic compression when leaning on the arm: This is the most common nerve lesion of the upper extremity.
- **Distal lesions** in the region of **GUYON's canal,** usually due to chronic pressure. Both cases present with a **"clawed hand"**. Atrophy of the Mm. interossei (visible) and the two ulnar Mm. lumbricales results in the inability for flexion in the metacarpophalangeal joints and for extension in the distal interphalangeal joints. Bringing the finger tips of the thumb and fifth digit in contact is impossible because of the deficit of M. opponens digiti minimi with resulting inability to oppose the fifth digit. The **FROMENT's sign** (holding a sheet of paper between the thumb and index finger) proves that the lack of adduction of the thumb is compensated by flexing its distal phalanx (M. flexor pollicis longus is innervated by the median nerve). **Sensory deficits** occur in the palmar side of the ulnar 1½ fingers. Sensory symptoms may be absent, if the lesion only affects the R. profundus, such as in compression injuries in the palm (jackhammer).

Arteries of the arm



Arteries of the Upper Extremity
Branches of the A. axillaris: • A. thoracica superior (inconsistent) • A. thoracoacromialis • A. thoracica lateralis • A. subscapularis – A circumflexa scapulae – A. thoracodorsalis • A. circumflexa humeri posterior • A. circumflexa humeri anterior
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 mit A. interossea recurrens • R. carpalis dorsalis • R. carpalis palmaris • R. palmaris profundus → Arcus palmaris profundus • Arcus palmaris superficialis → Aa. digitales palmares

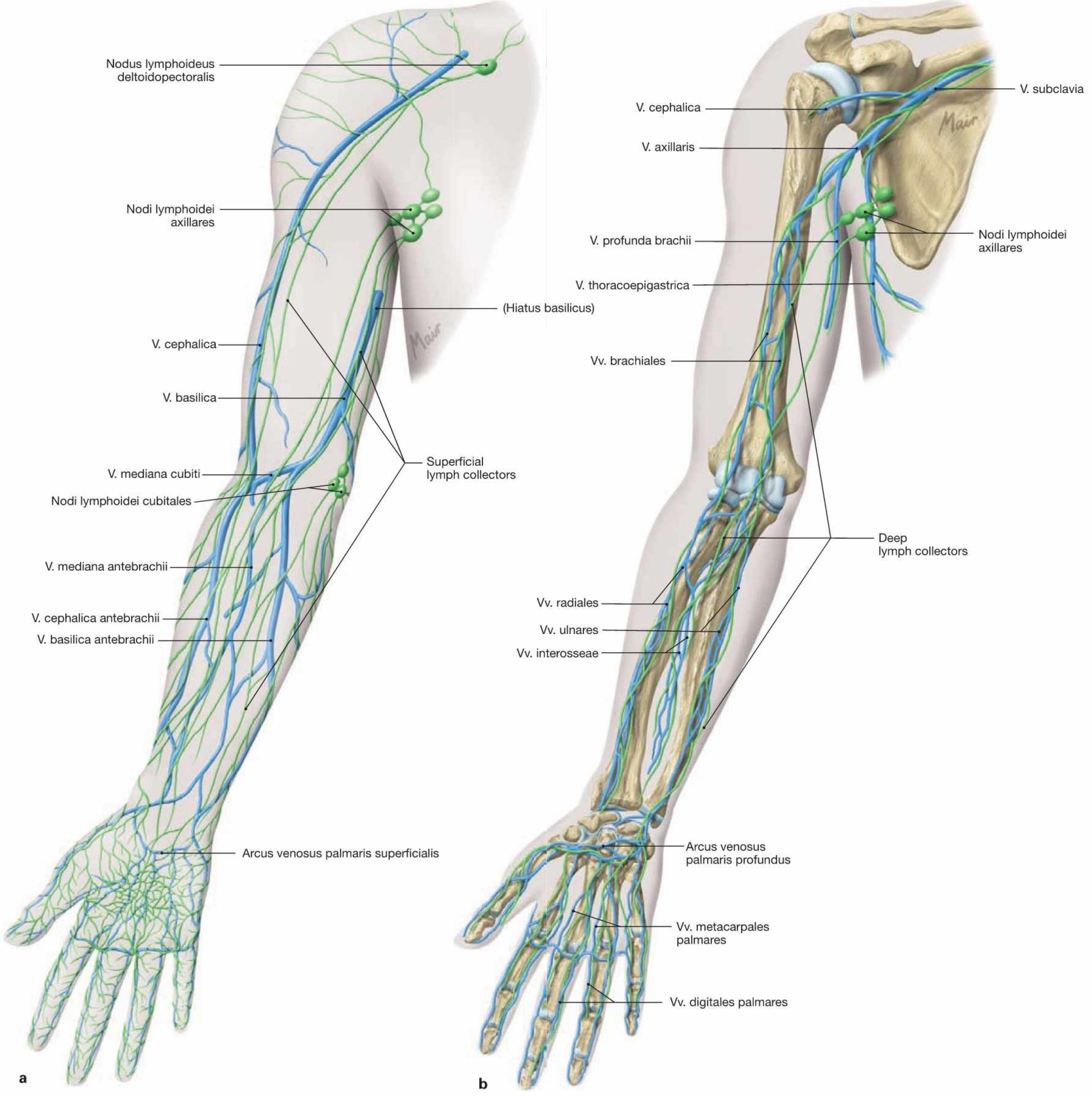
Rete articulare cubiti:
Collateral arteries (A. collateralis media, A. collateralis radialis, A. collateralis ulnaris superior, A. collateralis ulnaris inferior) and **recurrent arteries** (A. recurrens radialis, A. recurrens ulnaris, A. interossea recurrens) contribute to a collateral circulation in the elbow area (Rete articulare cubiti).

Fig. 3.131 Arteries of the upper extremity, right side; ventral view.
The **A. axillaris** is a continuation of the A. subclavia and stretches from the first rib to the inferior margin of the M. pectoralis major. It is positioned between the three cords of the brachial plexus and the two roots of the median nerve. At the level of the upper arm, the A. axillaris continues as **A. brachialis** and courses together with the N. medianus in the Sulcus bicipitalis medialis to enter medially the cubital fossa where it divides into the A. radialis and A. ulnaris. The **A. radialis** descends between the superficial and deep flexor muscles of the forearm to the wrist. Traversing the Fovea radialis (anatomical snuff box; Tabatière), the A. radialis then runs between both heads of the M. interosseus dorsalis I and enters the palm of the hand to provide the major input for the deep palmar arterial arch **(Arcus palmaris profundus).** The **A. ulnaris** sends out the A. interosseus communis and runs together with the N. ulnaris to the wrist joints and through the GUYON's canal to the palm of the hand. Here, it continues in the superficial palmar arterial arch **(Arcus palmaris superficialis).**

Clinical Remarks

In a complete physical exam, the **pulses** of the A. radialis and A. ulnaris are palpated on the radial and ulnar side of the proximal wrist, respectively, to exclude an occlusion of the blood vessels by **arteriosclerosis** and blood clots **(emboli).** The existing vascular network of collateral and recurrent arteries allows for the ligation of the **A. brachialis in the cubital fossa** in case of injury, without jeopardizing the blood supply to the forearm.

Veins and lymph vessels of the arm



Figs. 3.132a and b Superficial (a) and deep (b) veins and lymph vessels, right side; ventral view.

The **superficial venous system** of the arm consists of two major lines which collect venous blood from the hand:

On the dorsal side of the thumb, the **V. cephalica antebrachii** collects blood from the dorsal venous network of the hand and runs on the radial ventral side of the forearm to the cubital fossa to join the V. basilica antebrachii via the V. mediana cubiti. On the upper arm, the V. cephalica courses in the Sulcus bicipitalis lateralis and merges in the Trigonum clavipectorale (MOHRENHEIM's fossa) with the V. axillaris. In the upper arm, this superficial vein may be very weak or missing.

The **V. basilica antebrachii** begins on the ulnar dorsum of the hand, continues on the ulnar ventral side of the forearm and enters the Vv. brachiales at the Hiatus basilicus on the distal portion of the upper arm.

The **superficial epifascial lymph collectors** form a radial, ulnar and medial bundle in the forearm. In the upper arm, the medial bundle follows the V. basilica and drains into the axillary lymph nodes. The dorsolateral bundle courses along the V. cephalica and additionally drains into the supraclavicular lymph nodes.

The regional lymph node stations for both systems are positioned in the axilla (Nodi lymphoidei axillares). There are only few lymph nodes in the cubital fossa (Nodi lymphoidei cubitales).

The **deep venous system** and the deep subfascial lymph collectors accompany the respective arteries.

Lymph nodes and lymph vessels of the axilla

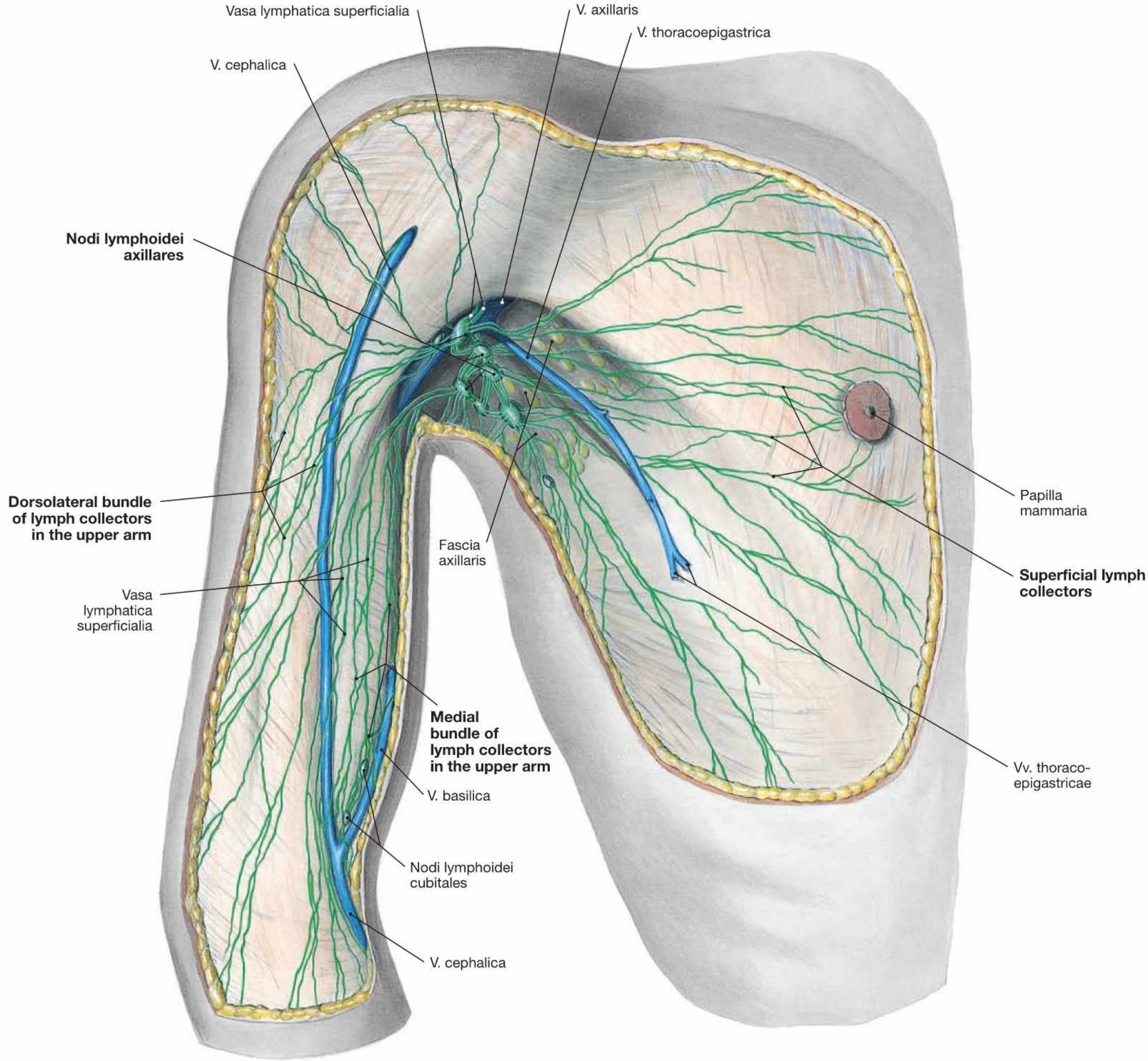


Fig. 3.133 Superficial lymph vessels and lymph nodes in the axilla, Fossa axillaris, and the lateral wall of the thorax, Regio thoracica lateralis, right side; ventral view.

In the upper arm, the superficial epifascial lymph collectors constitute a medial bundle along the V. basilica and a dorsolateral bundle along the V. cephalica, both of which connect to the axillary lymph nodes. The axillary lymph nodes (Nodi lymphoidei axillares) not only serve as regional lymph nodes for the arm but also for the wall of the upper quadrants of the trunk, namely thorax and back.

Axillary lymph nodes

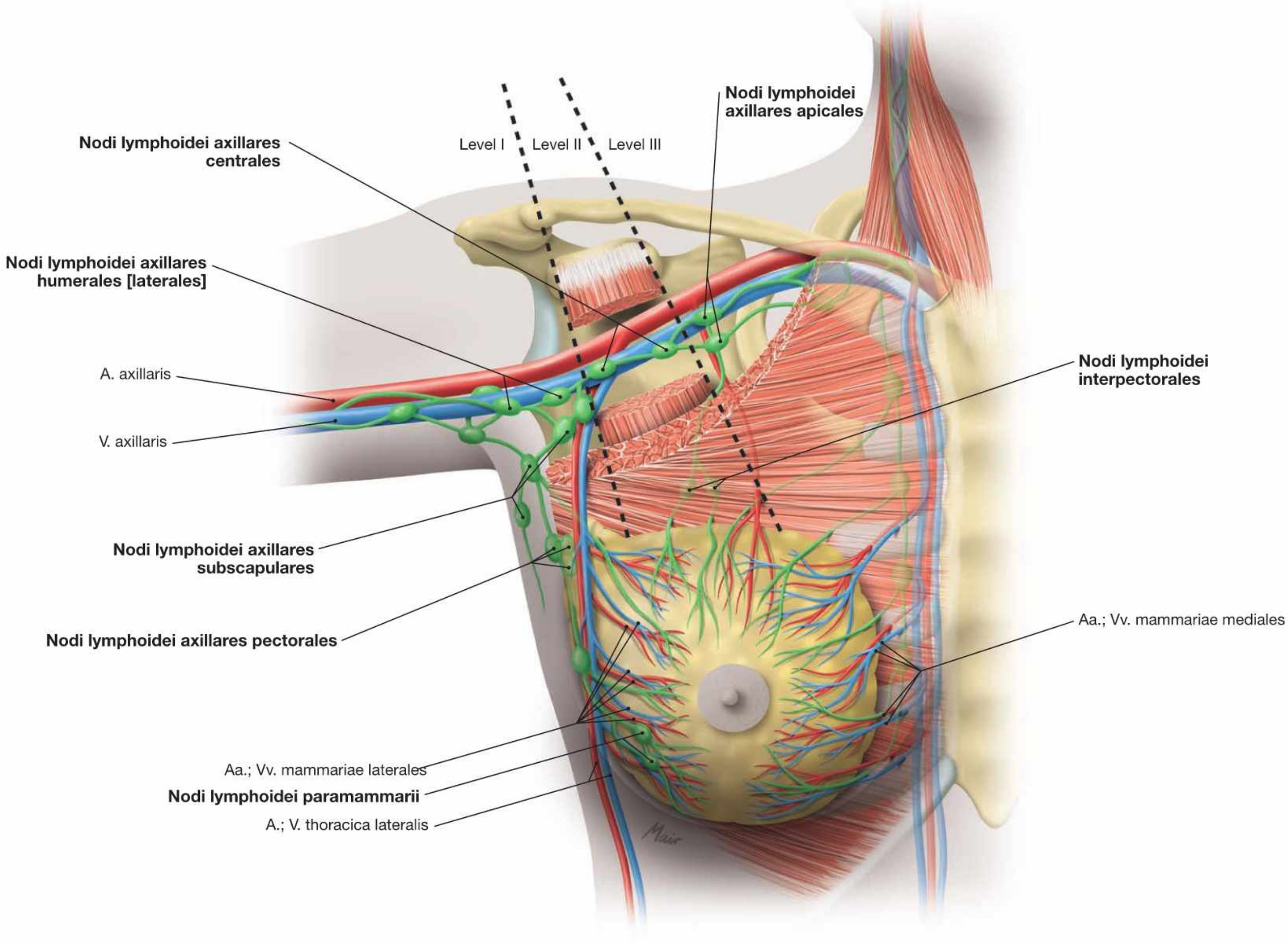


Fig. 3.134 Levels of lymph node hierarchy in the axilla, Fossa axillaris, right side; ventral view.
The adipose tissue of the axilla harbours up to 50 lymph nodes (Nodi lymphoidei axillares) which collect lymph from the arm, the upper thoracic wall including the breast, and the wall of the upper back. Because of their clinical relevance in breast cancer, these lymph nodes are categorised in three levels in topographical relation to the M. pectoralis minor. Superficial and deep lymph nodes are associated with all three levels, but often their affiliation with either level is not clear. However, the apical lymph nodes from level III collect lymph from all other lymph nodes in this region 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. 3.147).

Levels of axillary lymph nodes: Level I, inferior group lateral of the M. pectoralis minor:
- Nodi lymphoidei paramammarii (lateral of the breast)
- Nodi lymphoidei axillares pectorales (along A. and V. thoracica lateralis)
- Nodi lymphoidei axillares subscapulares (along A. and V. subscapularis and thoracodorsalis)
- Nodi lymphoidei axillares laterales (along A. and V. axillaris)

Level II, intermediate group above and below the M. pectoralis minor:
- Nodi lymphoidei interpectorales (between M. pectoralis minor and M. pectoralis major)
- Nodi lymphoidei axillares centrales (beneath 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 keep in mind that axillary lymph nodes are the regional lymph nodes of the arm as well as of the wall of the upper trunk. Because of the high incidence of breast cancer (about one in ten women acquires breast cancer, but it may also affect men), any palpable axillary lymph node enlargement in a woman is considered indicative of potential breast cancer.
Currently, the surgical removal of axillary lymph nodes **(lymphadenectomy)** as part of the surgical treatment in breast cancer patients is discussed controversially since it is not proven that this procedure, in addition to removal of the primary tumour, increases the survival rate in patients. However, the diagnostic lymphadenectomy to determine potential metastases (staging) of the tumour is of great importance and requires knowledge of the topography of the axillary lymph nodes.

Superficial vessels and nerves of the axilla

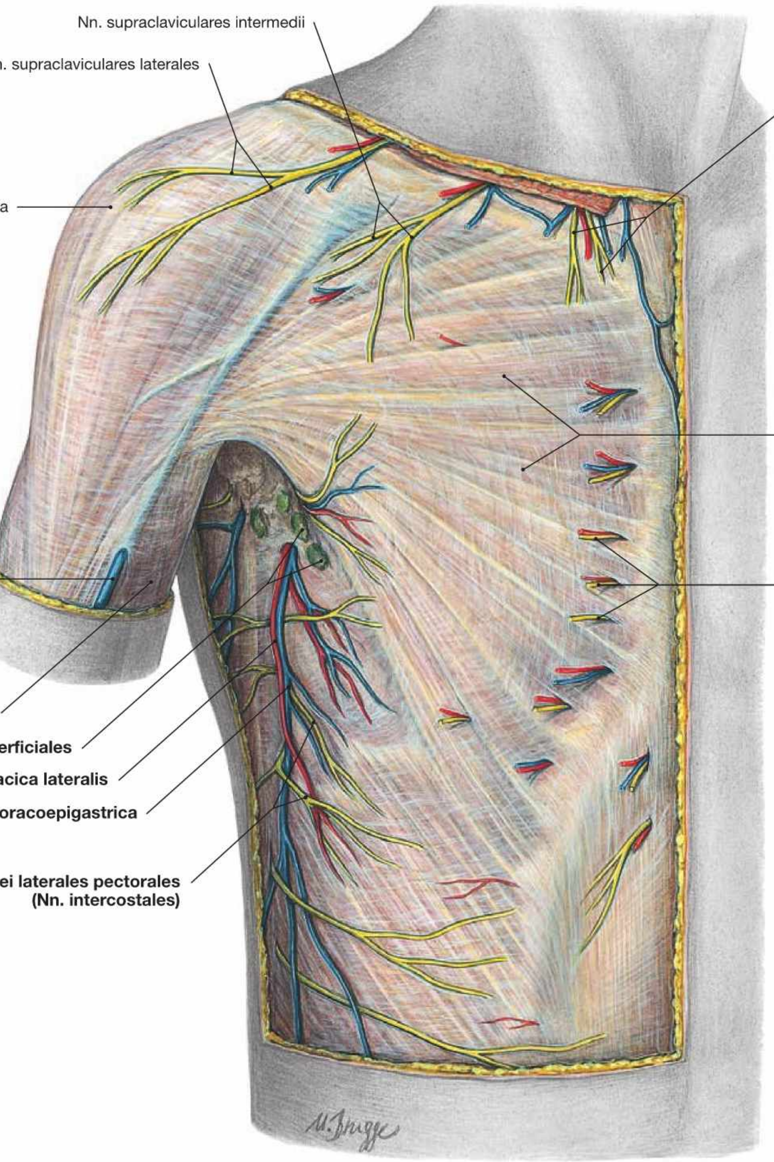
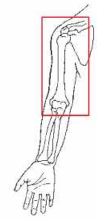


Fig. 3.135 Epifascial vessels and nerves of the axilla, Fossa axillaris, and the lateral thoracic wall, Regio thoracica lateralis, right side; ventral view.
Next to the superficial axillary lymph nodes (Nodi lymphoidei axillares superficiales), blood vessels and nerves are located in the axilla and in the lateral wall of the thorax. The V. thoracoepigastrica is variable and descends at the level of the anterior axillary fold formed by the M. pectoralis major. A branch of the A. thoracica lateralis may accompany this vein. Cutaneous branches of the Nn. intercostales exit from the respective intercostal spaces into the axilla (Rr. cutanei laterales pectorales).

Superficial vessels and nerves of the upper arm and shoulder



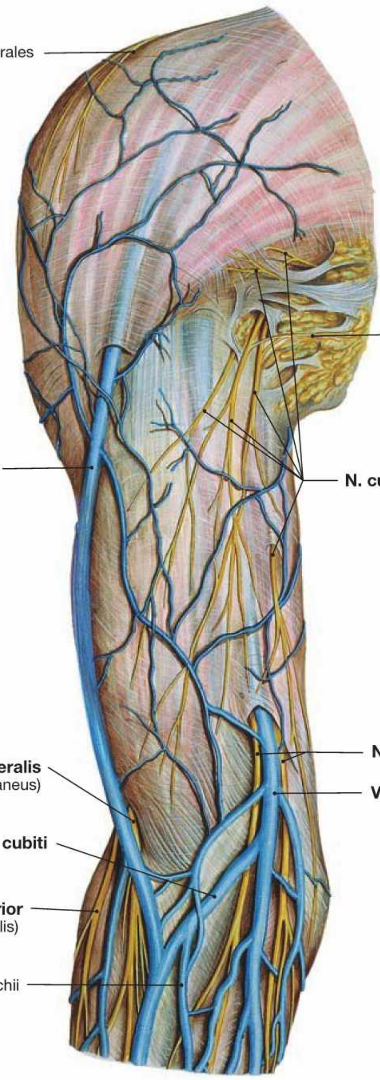
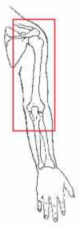


Fig. 3.136 Epifascial veins and nerves of the shoulder, Regio deltoidea, of the upper arm, Regio brachii anterior, and cubital fossa, Regio cubitalis anterior, right side; ventral view.
In the upper arm, the **V. cephalica** ascends in the Sulcus bicipitalis lateralis and runs between the origins of the M. deltoideus and M. pectoralis major. In the cubital fossa, it connects with the V. basilica via the **V. mediana cubiti.** In the inferior part of the upper arm, the **V. basilica** courses in the Sulcus bicipitalis medialis and pierces through the Fascia brachii to enter one of the Vv. brachiales. Several cutaneous branches of the **N. cutaneus brachii medialis** penetrate the fascia at the level of the axilla to distribute along the medial aspect of the upper arm. There are connections to the **Nn. intercostobrachiales** of the Nn. intercostales. In the distal part of the upper arm, the cutaneous branches for the forearm exit the fascia. The **N. cutaneus antebrachii medialis** accompanies the V. basilica, and the **N. cutaneus antebrachii lateralis** descends next to the V. cephalica. As the sensory terminal branch of the N. musculocutaneus running between the M. biceps brachii and the more deeply positioned M. brachialis, the N. cutaneus antebrachii lateralis pierces the fascia between these two muscles. The **N. cutaneus antebrachii posterior** appears further lateral.

Clinical Remarks

Due to the accessibility, the **V. cephalica** is frequently used for the implantation of **cardiac pacemakers** and **port systems** (for application of chemotherapeutics or parenteral nutrition). **Central venous catheters (CVC, "central line")** may be inserted through the V. cephalica into the superior V. cava.

Superficial vessels and nerves of the upper arm and shoulder



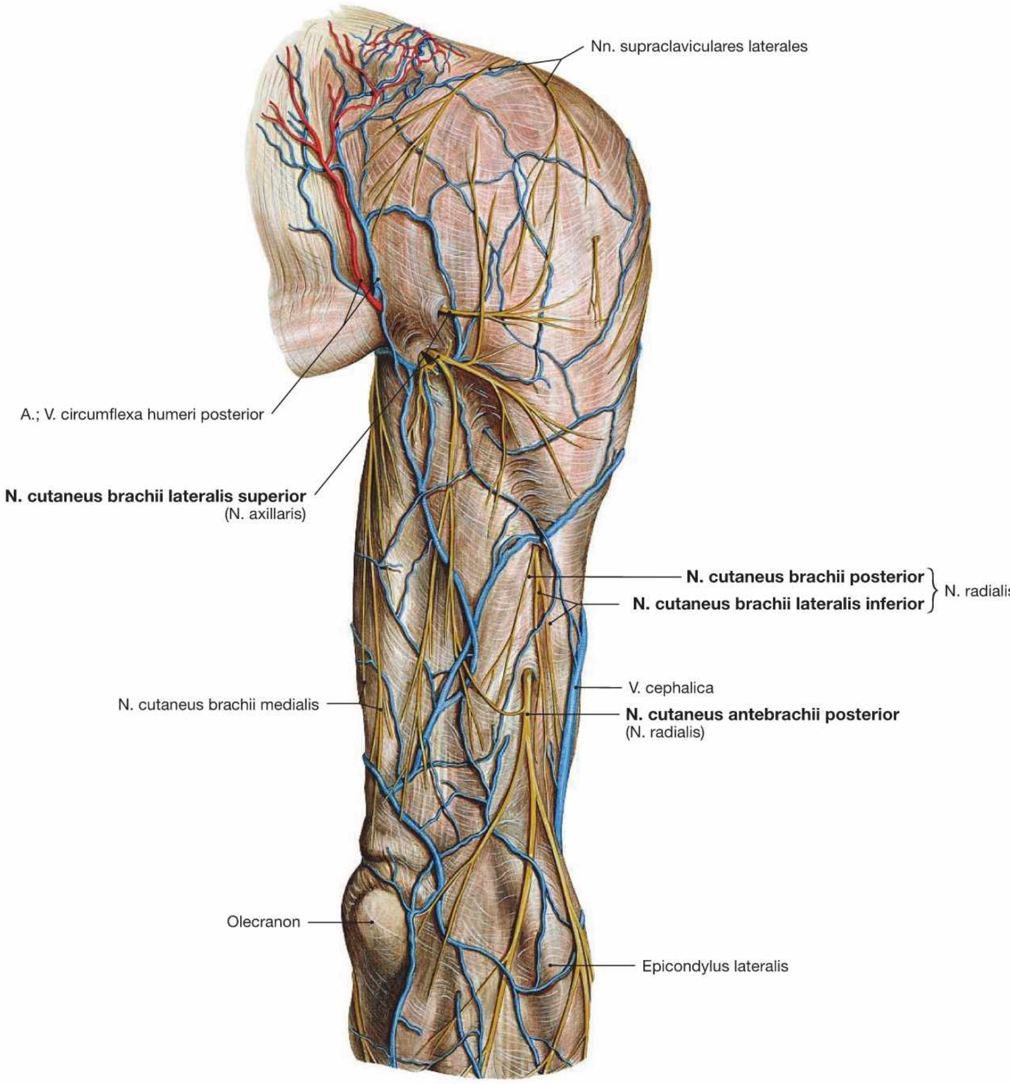
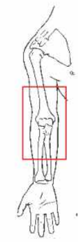
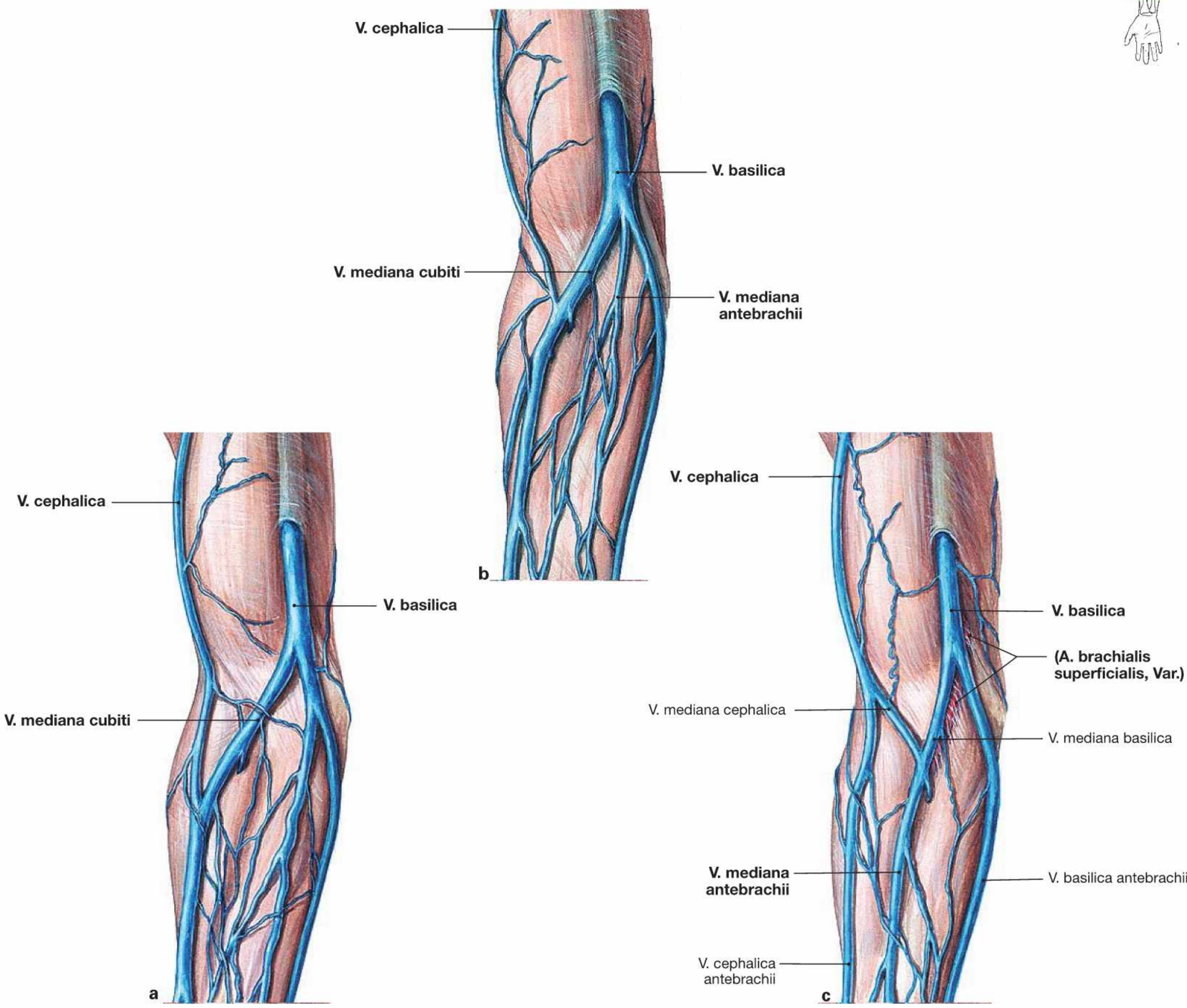


Fig. 3.137 Epifascial vessels and nerves of the shoulder, Regio deltoidea, of the upper arm, Regio brachii posterior, and cubital fossa, Regio cubitalis posterior, right side; dorsolateral view.

The **N. cutaneus brachii lateralis superior** is the terminal sensory branch of the N. axillaris. It pierces the fascia at the inferior margin of the M. deltoideus which is innervated by the axillary nerve. **N. cutaneus brachii lateralis inferior, N. cutaneus brachii posterior** and **N. cutaneus antebrachii posterior** are terminal branches of the N. radialis and pierce through the fascia lateral to the M. triceps brachii. The exit of the N. cutaneus antebrachii posterior is often localised between the M. triceps brachii and the ventrally located M. brachialis.

Veins of the cubital fossa



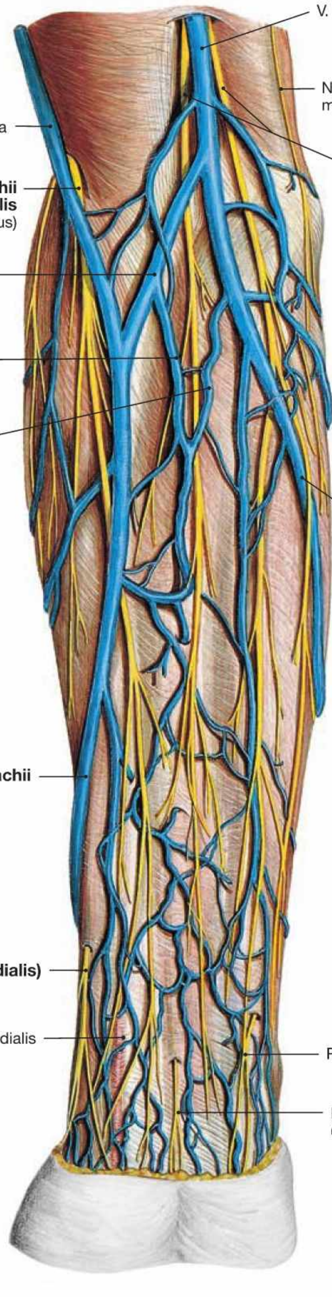


Figs. 3.138a to c Variations of the epifascial veins in the cubital fossa, Regio cubitalis anterior, right side; ventral view.
The V. cephalica may vary substantially in the upper arm (→ Figs. 3.138a and b). Occasionally, the V. mediana cubiti is missing, and instead, the V. cephalica antebrachii and V. basilica antebrachii communicate via indirect connections with a V. mediana antebrachii on the anterior aspect of the forearm (→ Fig. 3.138c). Of importance is the potential existence of an additional A. brachialis superficialis in the cubital fossa with a course in parallel to the veins.

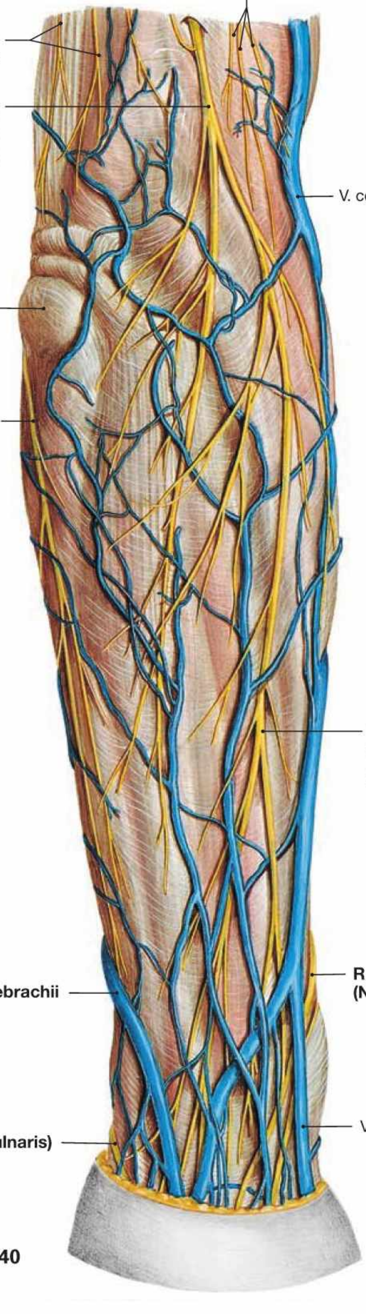
Clinical Remarks

The veins in the cubital fossa are important for **drawing blood** and for **intravenous administration** of drugs. Because of their extensive variability, it is recommended to examine the exact course of the veins and palpate them. If an arterial pulse is palpated, one should consider the existence of a superficial A. brachialis. Drugs should not be injected into the artery, because some substances may have toxic effects upon intra-arterial injection due to lack of dilution.

Superficial vessels and nerves of the forearm



3.139



3.140

Fig. 3.139 and Fig. 3.140 Epifascial veins and nerves of the forearm, Regio antebrachii anterior and Regio antebrachii posterior, and of the cubital fossa, Regio cubitalis anterior, right side; ventral (→ Fig. 3.139) and dorsal (→ Fig. 3.140) view.

At the dorsal side of the thumb, the **V. cephalica antebrachii** emerges from the superficial venous network (Rete venosum dorsale manus) and then courses on the radial and ventral side of the forearm, whereas the **V. basilica antebrachii** continues from the ulnar dorsum of the hand to the ulnar ventral side of the forearm. In the cubital fossa, both veins usually communicate via the **V. mediana cubiti.** The cutaneous nerves of the forearm radiate with their branches to both sides of the forearm. Upon exiting the fascia, the **N. cutaneus antebrachii medialis** runs adjacent to the V. basilica; the **N. cutaneus antebrachii lateralis** starts its course together with the V. cephalica. The **N. cutaneus antebrachii posterior** pierces the fascia between the M. triceps brachii and M. brachialis. At the distal forearm, the **R. superficialis of the N. radialis** pierces the fascia beneath the tendon of the M. brachioradialis and thus reaches the dorsum of the hand. Similarly, the **R. dorsalis of the N. ulnaris** exits beneath the tendon of the M. flexor carpi ulnaris to reach the dorsal side. The palmar branches of N. medianus and N. ulnaris proximal of the wrists are usually not easily shown in the dissection.

Superficial vessels and nerves of the dorsum of the hand

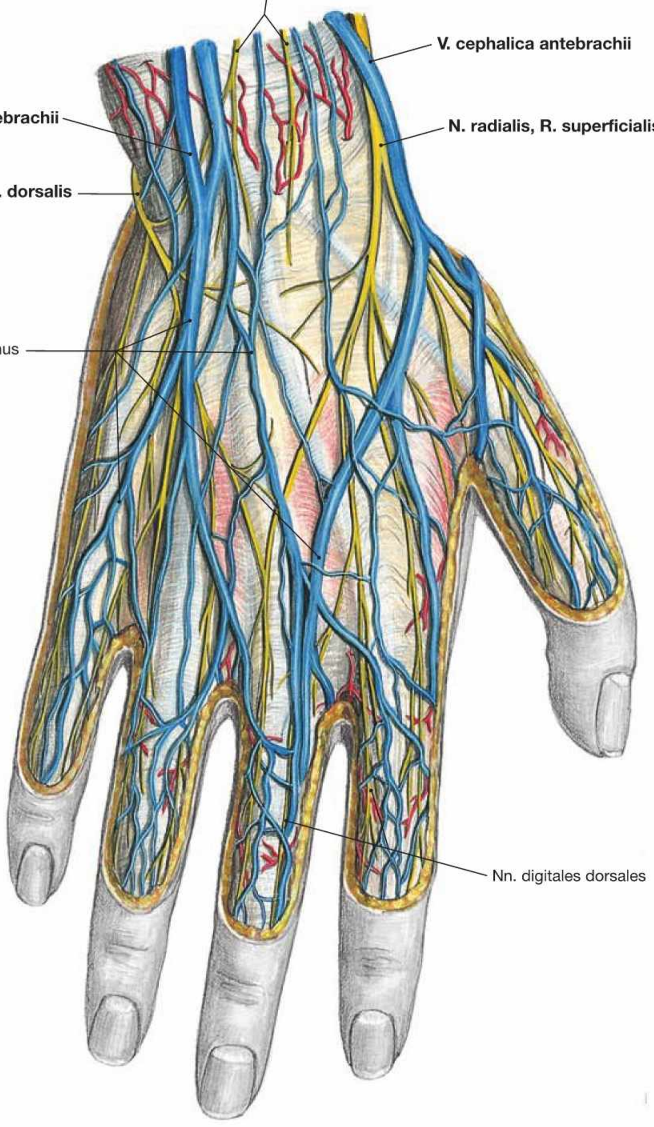


Fig. 3.141 Epifascial vessels and nerves on the dorsum of the hand, Dorsum manus, right side; dorsal view.
At the dorsal side of the thumb, the **V. cephalica antebrachii** emerges from the superficial venous network on the dorsum of the hand, and the **V. basilica antebrachii** emerges on the veins from on ulnar dorsum of the hand. Above the proximal wrist joint, the **R. superficialis of the N. radialis** pierces the fascia beneath the tendon of the M. brachioradialis. Its divisions, the Nn. digitales dorsales, convey sensory innervation of the radial 2½ digits. The ulnar 2½ digits are innervated by the **R. dorsalis of the N. ulnaris** emerging beneath the tendon of the M. flexor carpi ulnaris.

Trigonum clavipectorale

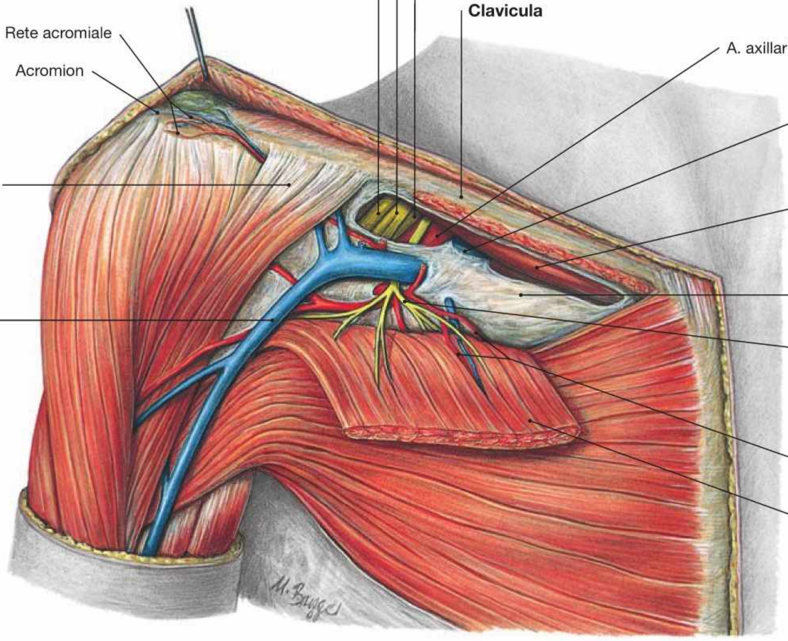


Fig. 3.142 Trigonum clavipectorale (MOHRENHEIM's fossa) on the right side.
The Trigonum clavipectorale is a small triangular space between the clavicle and and the origins of the M. pectoralis major and M. deltoideus. To reveal the Trigonum clavipectorale during dissection, the origin of the M. pectoralis major is separated from the clavicle and reflected laterally and the Fascia clavipectoralis is removed. At the trigone, the **V. cephalica** pierces the Fascia clavipectoralis to empty into the V. axillaris. In addition, the **A. thoracoacromialis** emerges from the A. axillaris and divides into four terminal branches. The **Nn. pectorales medialis and laterales** which originate from the respective cords of the brachial plexus course together with the arterial branches to the pectoral muscles which they supply.

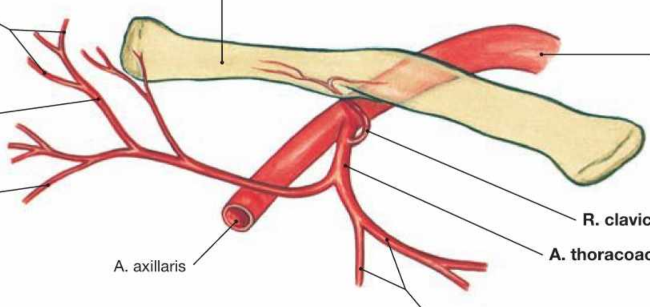


Fig. 3.143 Branches of the A. thoracoacromialis.
The four terminal branches of the A. thoracoacromialis are:
- Rr. pectorales to the Mm. pectorales
- R. clavicularis to the M. subclavius
- R. deltoideus to the M. deltoideus
- R. acromialis to the Rete acromiale

Axillary fossa

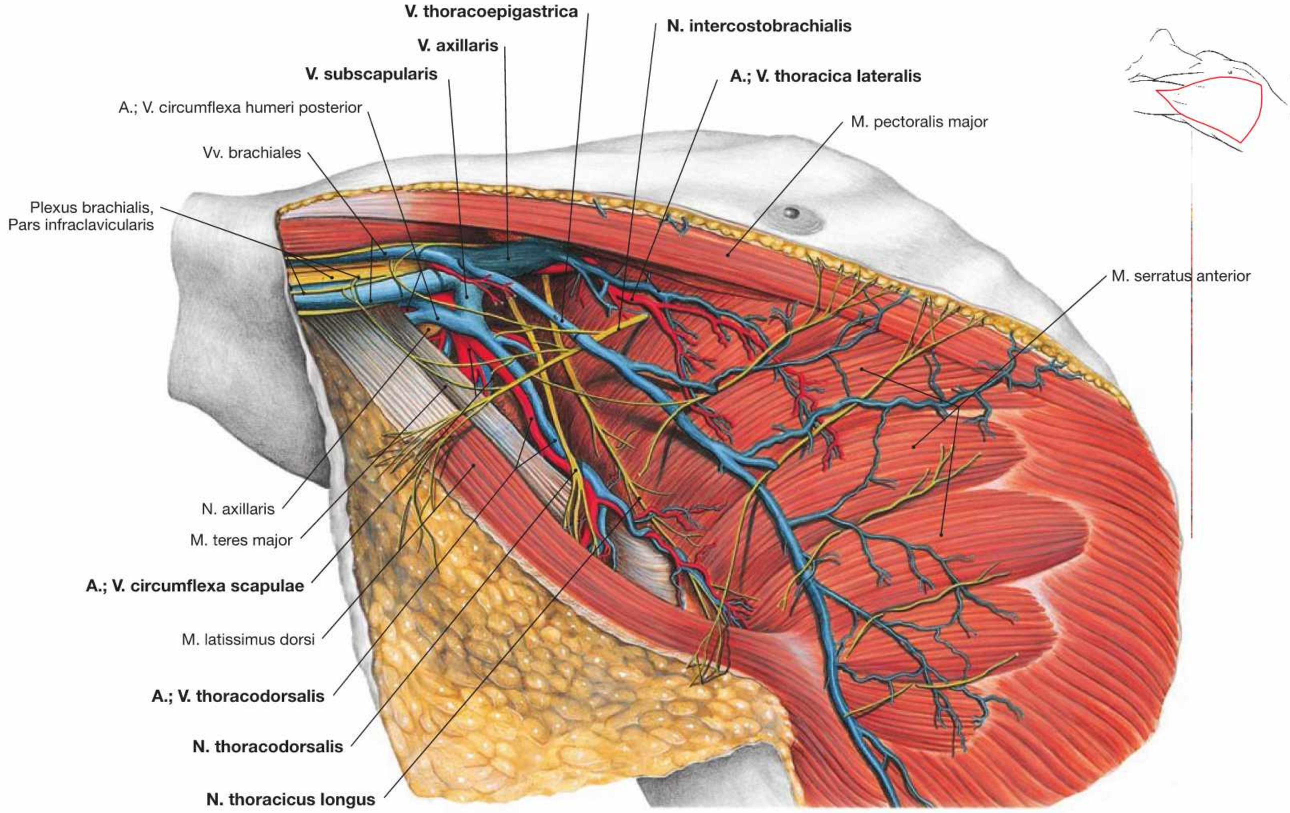


Fig. 3.144 Axillary fossa, Fossa axillaris, right side; laterocaudal view.

The anterior and posterior borders of the axillary fossa are the M. pectoralis major and the M. latissimus dorsi, respectively, both of which are forming the axillary folds. In the axillary fossa, all three cords of the Pars infraclavicularis of the **Plexus brachialis** surround the **A. axillaris** while covered ventrally by the **V. axillaris.** The **Nn. intercostobrachiales** derive from the **Nn. intercostales**, cross the axilla, and run alongside the N. cutaneus brachii medialis. The **N. thoracodorsalis** courses together with the corresponding blood vessels to the medial side of the M. latissimus dorsi. Further ventral, the **N. thoracicus longus** descends on the lateral aspect of the M. serratus anterior which it innervates.

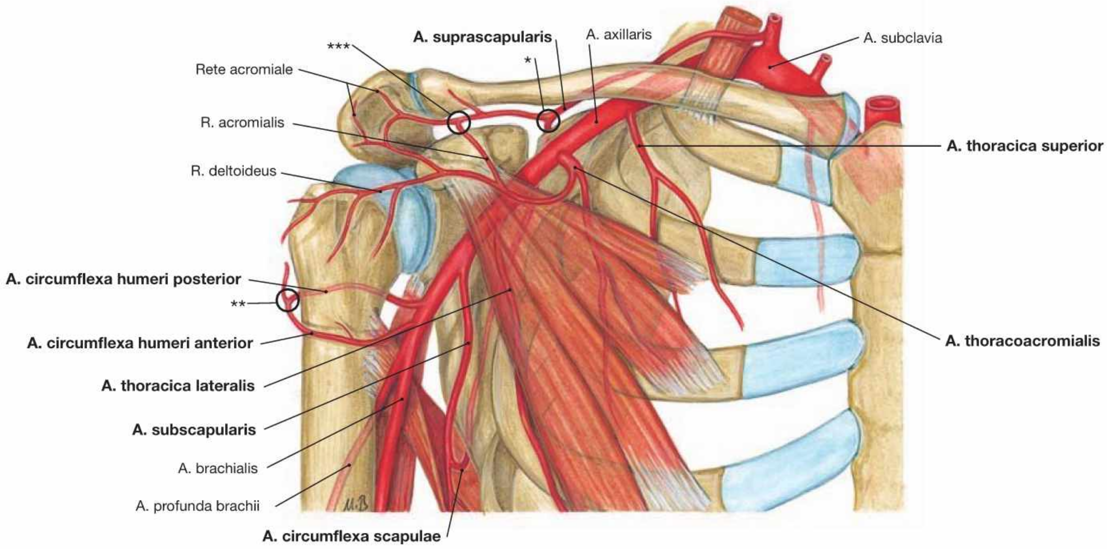
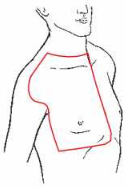


Fig. 3.145 Arteries of the shoulder, right side; ventral view.
Branches of the A. axillaris:

- A. thoracica superior: variable on the Mm. pectorales
- A. thoracoacromialis (→ Fig. 3.143)
- A. thoracica lateralis: lateral of the M. pectoralis minor
- A. subscapularis: divides into the A. thoracodorsalis to the M. latissimus dorsi, and the A. circumflexa scapulae which traverses the triangular axillary space and anastomoses (*) with the A. suprascapularis.
- A. circumflexa humeri anterior: anastomoses (**) with the A. circumflexa humeri posterior which traverses the quadrangular axillary space.

The R. acromialis of the A. thoracoacromialis may also anastomose with the A. suprascapularis (***).

Axillary fossa



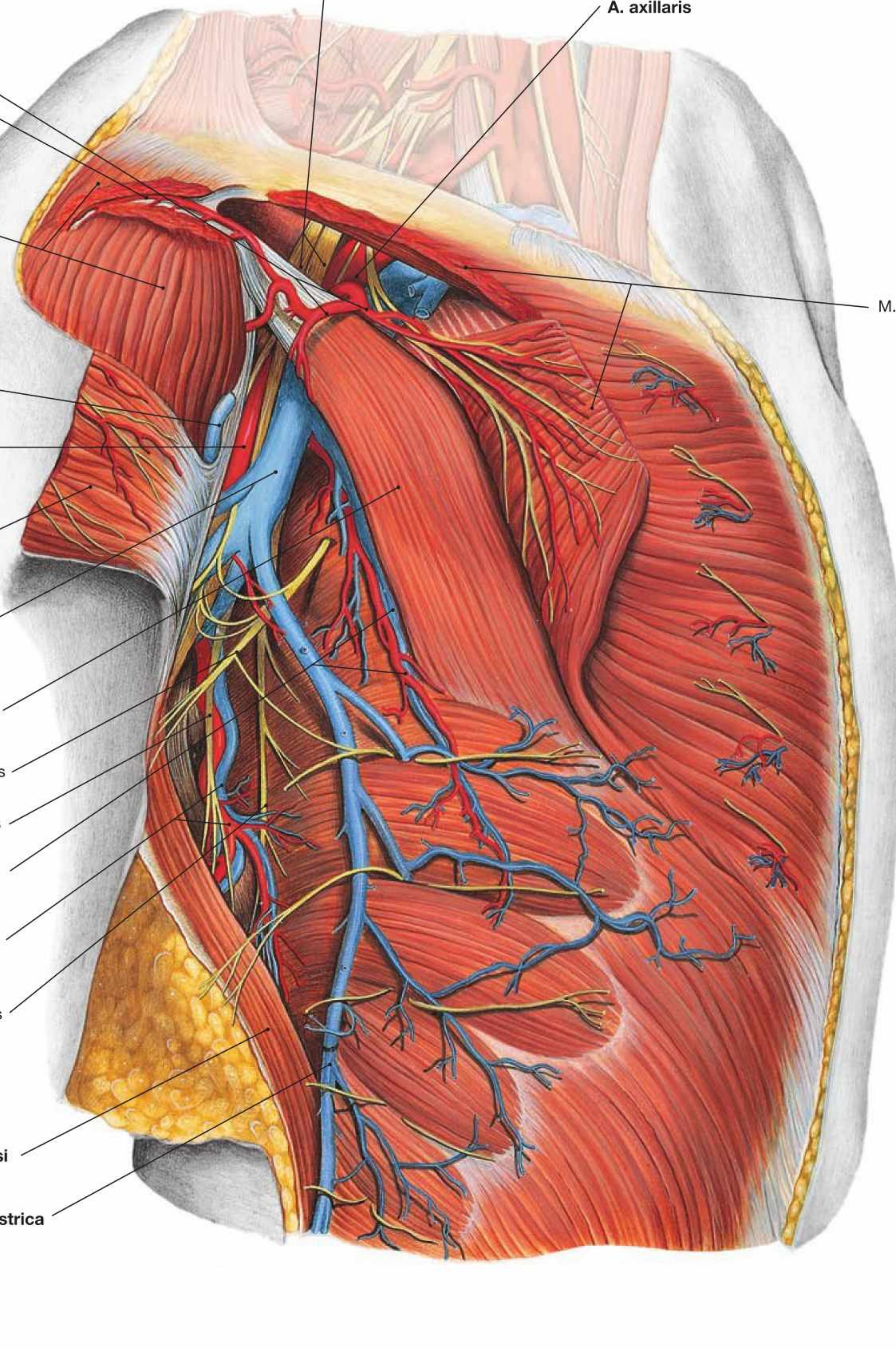


Fig. 3.146 Axillary fossa, Fossa axillaris, and lateral thoracic wall, Regio thoracica lateralis, right side; lateral view.
Compared to → Figure 3.144, the M. pectoralis major is split to visualise the **M. pectoralis minor** underneath and the anatomical structures appearing in the Trigonum clavipectorale. The **A. thoracoacromialis** and its branches are visible at the upper border of M. pectoralis minor. The associated Rr. pectorales course together with the Nn. pectorales of the Plexus brachialis towards the Mm. pectorales major and minor which they innervate. The M. pectoralis minor serves as an important landmark for the classification of axillary lymph nodes (→ Fig. 3.134). The **A. and V. thoracica lateralis** course at its lateral border and lateral thereof, the **A., V. and N. thoracodorsalis** descend to reach the medial aspect of the M. serratus anterior they supply. The V. thoracoepigastrica shows variable dimensions (here shown as a strong vessel) and is not accompanied by an artery during its course in the subcutaneous adipose tissue of the lateral thoracic wall.

Axillary fossa

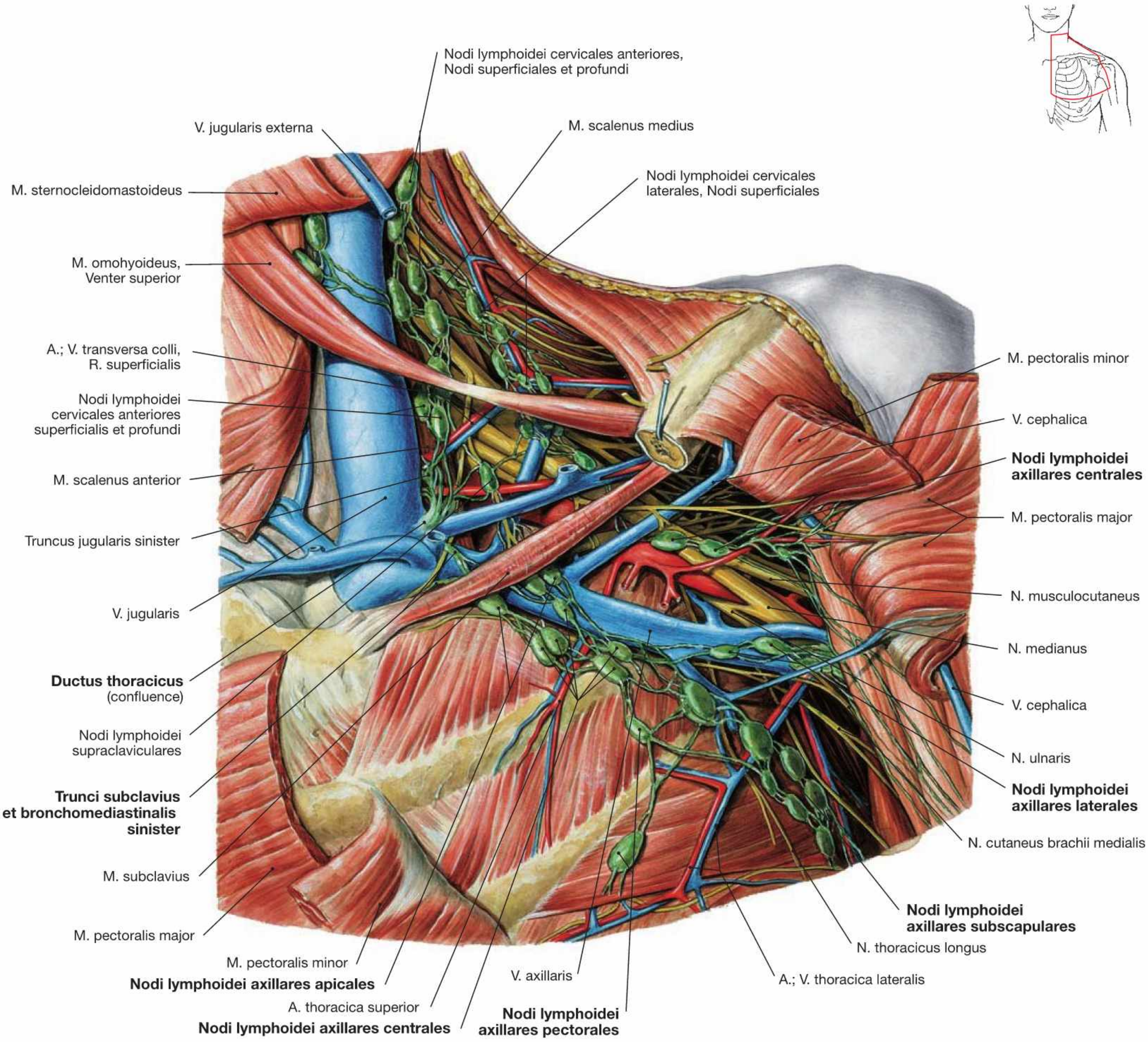


Fig. 3.147 Axillary fossa, Fossa axillaris, and lateral thoracic wall, Regio thoracica lateralis, left side; ventral view.

In contrast to → Fig. 3.146, the left side is shown to demonstrate the confluence of the **axillary lymph vessels** in the Ductus thoracicus. The M. pectoralis minor is split for a better visualisation of the axillary lymph nodes. With respect to their topographical relation to the M. pectoralis minor, the axillary lymph nodes are organised in **three levels** (→ Fig. 3.134). The first level (lateral of M. pectoralis minor) contains the Nodi lymphoidei axillares pectorales alongside the A. and V. thoracica lateralis and, further lateral, the Nodi lymphoidei axillares subscapulares and the Nodi lymphoidei axillares laterales next to the V. axillaris. The second level (at the level of M. pectoralis minor) depicts the Nodi lymphoidei axillares centrales beneath the muscle. Medial of M. pectoralis minor, the third level is positioned as a last filter station prior to the junction with the **Truncus subclavius.** The latter conveys the lymph from the left thorax via the Ductus thoracicus to the left venous angle between V. jugularis interna and V. subclavia.

Clinical Remarks

The **Ductus thoracicus** carries the lymph of the entire lower body (including abdominal and pelvic organs) and empties into the left venous angle. Before doing so, it receives additional lymph via the Truncus bronchomediastinalis sinister from the left thorax, via the Truncus subclavius sinister from the left arm, and via the Truncus jugularis sinister from the left head and neck region. Therefore, metastases of malignant tumours in the abdomen may manifest in the left supraclavicular lymph nodes **VIRCHOW's node.**

Vessels and nerves of the upper arm

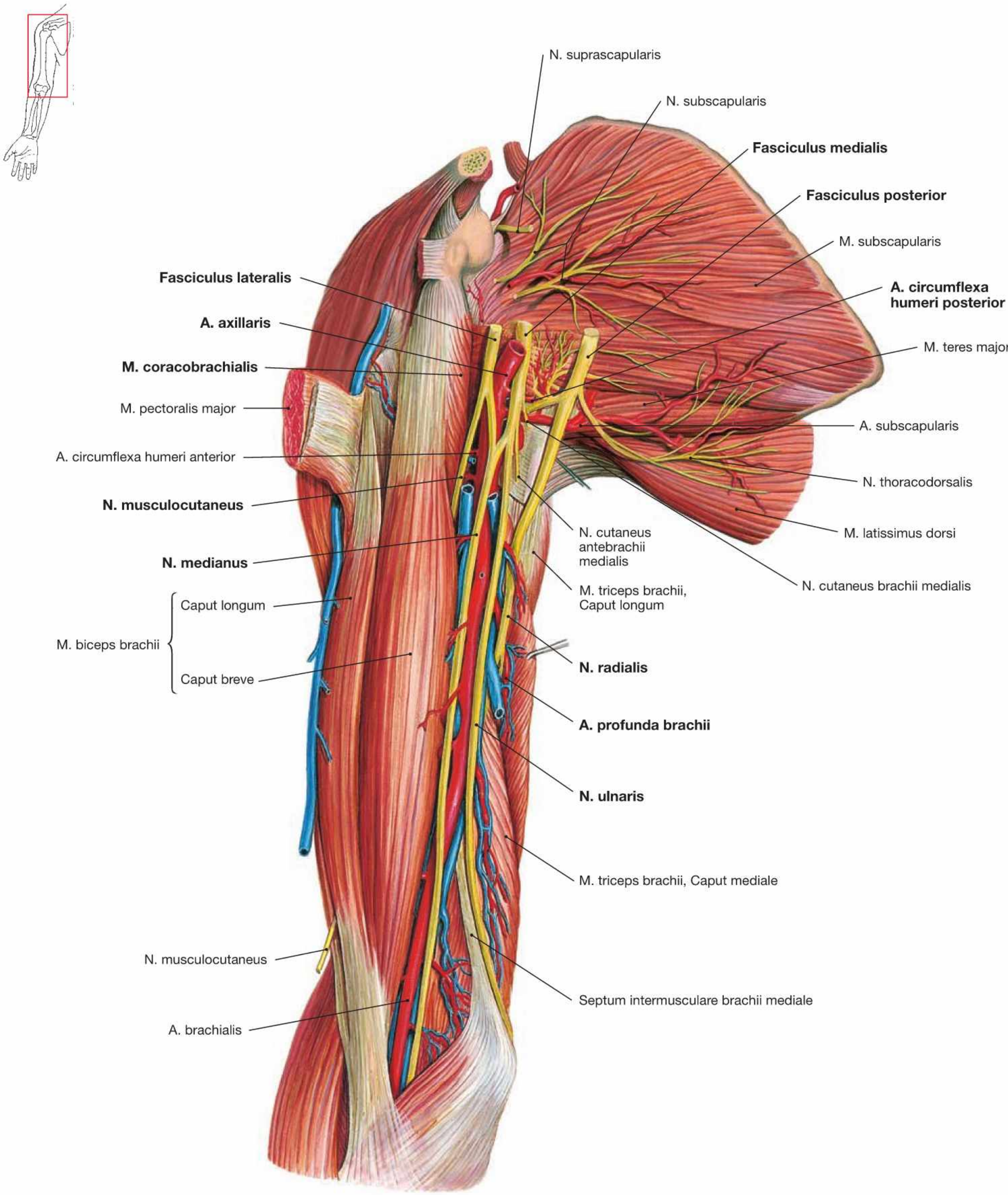
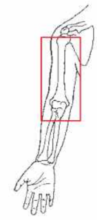


Fig. 3.148 Blood vessels and nerves of the axillary fossa, Fossa axillaris, and of the medial side of the upper arm, Regio brachii anterior, right side; ventromedial view.

To show the infraclavicular part of the **Plexus brachialis**, the M. pectoralis major was cut near its origin on the Crista tuberculi majoris and removed. Proximally, the three "m" are shown. The **Fasciculus lateralis** and **Fasciculus medialis** position to both sides of the A. axillaris and form a M-shaped structure of nerves which serves as helpful orientation during dissection. The lateral stroke of the "m" is formed by the N. musculocutaneus which is easily identified piercing the M. coracobrachialis. The medial and lateral roots of the N. medianus form the middle part of the "m", and the medial stroke of the "m" is formed by the N. ulnaris. While the N. medianus descends in the Sulcus bicipitalis medialis to reach the cubital fossa from medial, the N. ulnaris runs on the posterior side of the Epicondylus medialis. The **Fasciculus posterior** was mobilised from its position behind the A. axillaris. One of its peripheral nerves, the N. axillaris, traverses the quadrangular space together with the A. circumflexa humeri posterior. Then, the Fasciculus posterior continues as N. radialis which courses together with the A. profunda brachii through the triceps slit to reach the posterior aspect of the Humerus.

Vessels and nerves of the upper arm



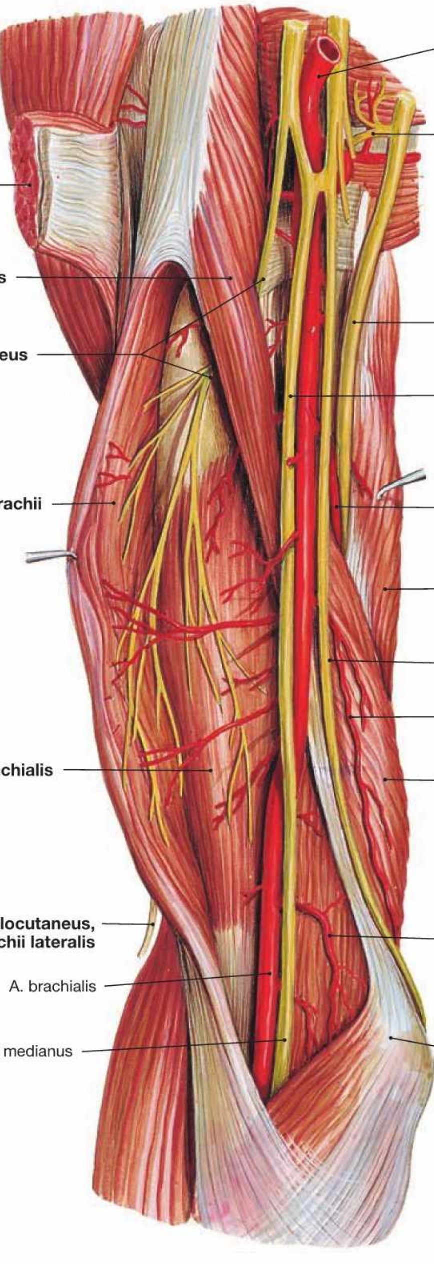
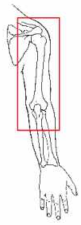


Fig. 3.149 Arteries and nerves of the axillary fossa, Fossa axillaris, and of the medial side of the upper arm, Regio brachii anterior, right side; ventromedial view; M. biceps brachii hold apart. The M. biceps brachii was lifted off laterally to show the course of the **N. musculocutaneus.** The latter pierces and innervates the M. coracobrachialis and descends between the M. brachioradialis and M. brachialis supplying motor innervation. At the distal upper arm, the sensory terminal branch (N. cutaneus antebrachii lateralis) appears between the two muscles and continues on the radial side of the forearm. The **N. medianus** descends together with the A. brachialis in the Sulcus bicipitalis medialis to reach the cubital fossa. The **N. ulnaris** continues together with the A. collateralis ulnaris superior to the posterior side of the Epicondylus medialis. The A. collateralis ulnaris inferior frequently branches proximal of the elbow as a thin vessel from the A. brachialis. The **N. axillaris** branches off the Fasciculus posterior proximally and traverses the quadrangular axillary space. The **N. radialis** courses together with the A. profunda brachii through the triceps slit.

Vessels and nerves of the upper arm



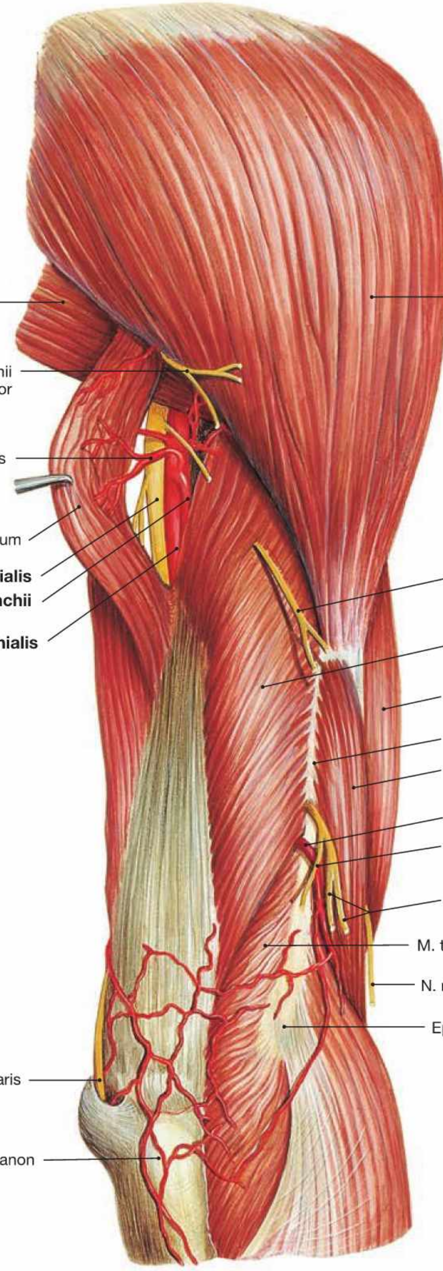


Fig. 3.150 Arteries and nerves of the lateral side of the upper arm, Regio brachii posterior, right side; dorsolateral view.
The Caput longum and Caput laterale of the M. triceps brachii were separated to show the **triceps slit** between both heads. The **N. radialis** and **A. profunda brachii** traverse this gap to course in the Sulcus nervi radialis of the Humerus. The motor branches of the N. radialis for the innervation of the M. triceps and the N. cutaneus brachii posterior already separate at the level of the triceps slit. However, the N. cutaneus brachii lateralis inferior and N. cutaneus antebrachii posterior leave the N. radialis from the Sulcus nervi radialis.

Clinical Remarks

In a **humeral shaft fracture** with injury to the N. radialis the function of the M. triceps brachii usually remains unaffected. The motor nerves to innervate the M. triceps as well as the N. cutaneus brachii posterior already branch off the N. radialis at the passage through the triceps slit. The N. cutaneus brachii lateralis inferior together with the N. cutaneus antebrachii posterior may be affected by this injury because they separate in the region of the Sulcus nervi radialis.

Vessels and nerves of the upper arm

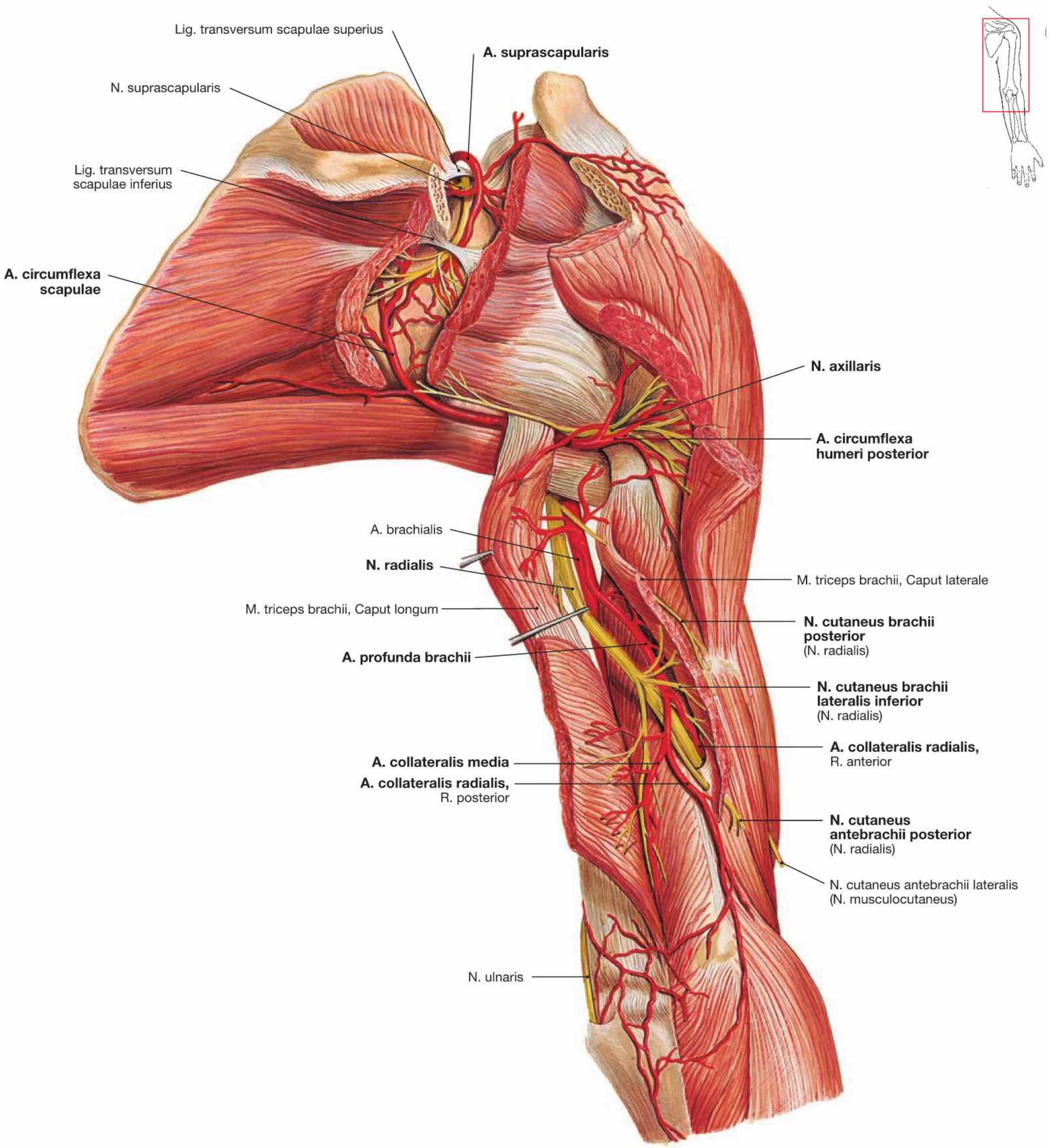


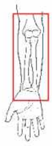
Fig. 3.151 Arteries and nerves of the shoulder, Regio deltoidea, and the lateral side of the upper arm, Regio brachii dorsalis, right side; dorsolateral view.

This illustration depicts again the localisation of the branches of the **N. radialis.** The **triceps slit** was elongated through keen edged separation of the Caput longum and Caput laterale of the M. triceps brachii. The motor branches of the N. radialis for the innervation of the M. triceps and the N. cutaneus brachii posterior already separate at the level of the triceps slit. However, the N. cutaneus brachii lateralis inferior and N. cutaneus antebrachii posterior leave the N. radialis in the Sulcus nervi radialis. The A. profunda brachii runs together with the N. radialis and splits into A. collateralis media (to Epicondylus medialis) and A. collateralis radialis (concomitant with the nerve).

This illustration also demonstrates the **axillary spaces** with traversing structures. N. axillaris and A. circumflexa humeri posterior pass through the quadrangular axillary space. The A. circumflexa scapulae traverses the triangular axillary space to the dorsal side. In the Fossa infraspinata, the A. circumflexa scapulae (derived from A. axillaris) forms an important anastomosis with the A. suprascapularis (derived from A. subclavia). Frequently, anastomoses with the A. dorsalis scapulae (from A. subclavia, not shown) also exist. These arterial anastomoses allow for a collateral arterial circulation to supply the arm, thereby bypassing a proximal occlusion of the A. axillaris.

The A. suprascapularis traverses above the Lig. transversum scapulae superius to the Fossa supraspinata of the Scapula. However, the N. suprascapularis traverses beneath the ligament through the Incisura scapulae. Nerve and artery are then bridged by the Lig. transversum scapulae inferius during their transition into the Fossa infraspinata.

Vessels and nerves of the forearm



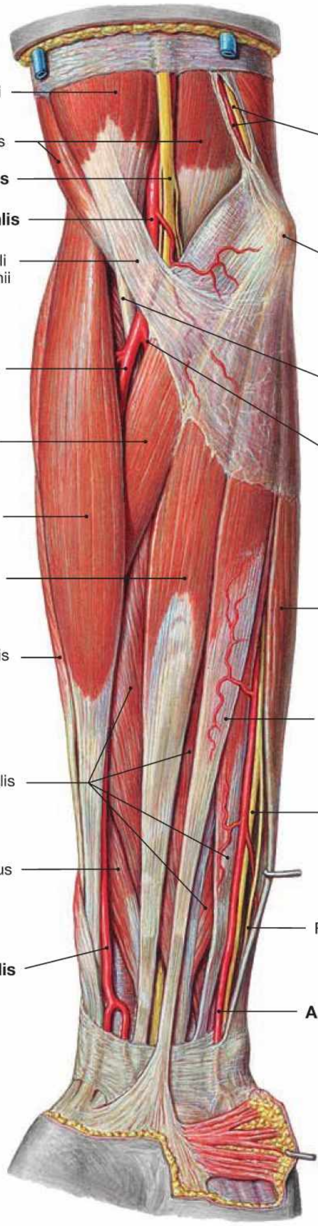
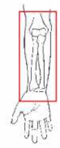


Fig. 3.152 Superficial arteries and nerves of the forearm, Regio antebrachii anterior, right side; ventral view.
The **N. medianus** runs together with the A. brachialis to the cubital fossa from medial. The A. brachialis splits into A. radialis and A. ulnaris, both of which descend to the respective sides of the wrist. Palpation of arterial pulses is predominantly performed on the A. radialis just above the proximal wrist joint. The A. ulnaris and concomitant N. ulnaris are both covered by the M. flexor carpi ulnaris as demonstrated at the distal forearm.

Vessels and nerves of the forearm



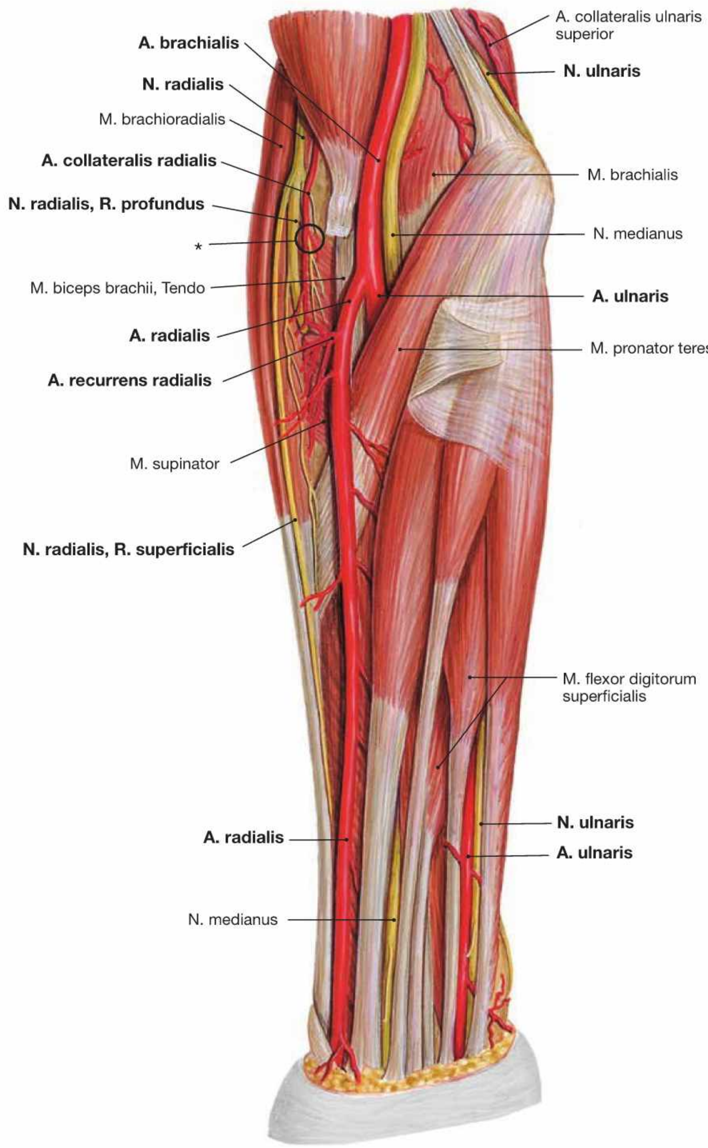
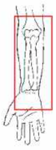


Fig. 3.153 Superficial arteries and nerves of the forearm, Regio antebrachii anterior, right side; ventral view; M. brachioradialis and Aponeurosis bicipitis antebrachii were removed**.**

The M. brachioradialis and the insertion of the M. biceps brachii to the Fascia antebrachii (Aponeurosis musculi bicipitis antebrachii) have been removed to visualise the branching of the **A. brachialis** and to show the course of the A. and N. radialis. As a branch of the A. brachialis, the **A. radialis** continues its course beneath the M. brachioradialis and reaches the radial side of the wrist. The A. recurrens radialis ascends beneath the M. brachioradialis to the arterial network of the elbow (Rete articulare cubiti) and engages in an anastomosis with the A. collateralis radialis (*). The **A. ulnaris** branches off below the M. pronator teres and descends next to the N. ulnaris beneath the M. flexor carpi ulnaris to the ulnar side of the wrist. Between M. brachioradialis and M. brachialis **(radial tunnel)** the **N. radialis** enters the cubital fossa from lateral and splits into R. superficialis and R. profundus. The **R. superficialis** runs adjacent to the A. radialis and deviates to the dorsal side in the distal third of the forearm. The **R. profundus** innervates and pierces the M. supinator **(supinator canal).** The sharp-edged tendinous arch **(arcade of FROHSE)** at the entrance to the muscle may compress the nerve.

Vessels and nerves of the forearm



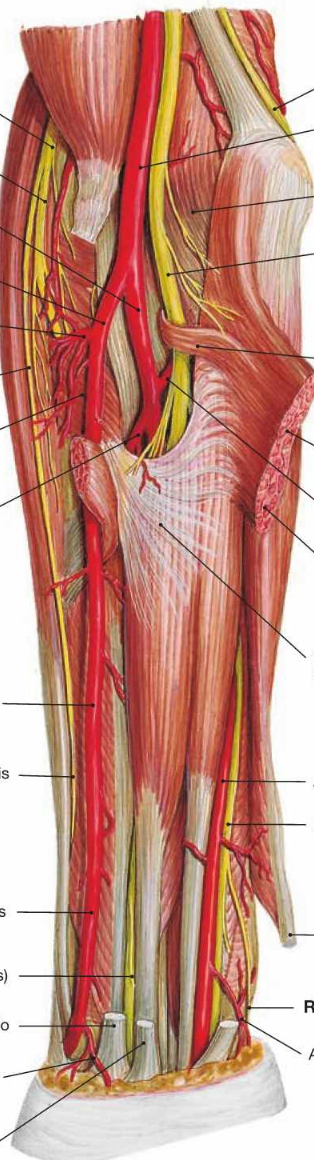
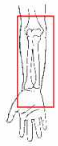


Fig. 3.154 Deep arteries and nerves of the forearm, Regio antebrachii anterior, right side; ventral view; M. pronator teres and M. flexor carpi radialis were split and the M. palmaris longus was removed. Once the superficial flexor muscles of the forearm are separated, the proximal branches of the **A. ulnaris** are visible: the A. interossea communis descends as a strong vessel, and the A. recurrens ulnaris ascends beneath the M. pronator teres. The **N. medianus** appears between both heads of the M. pronator teres to enter the space between the deep and intermediate layers of the flexor muscles of the forearm. At the distal forearm, the tendon of the M. flexor carpi ulnaris was cut to show the branching of the **R. dorsalis of N. ulnaris** and its course to the dorsum of the hand.

Vessels and nerves of the forearm



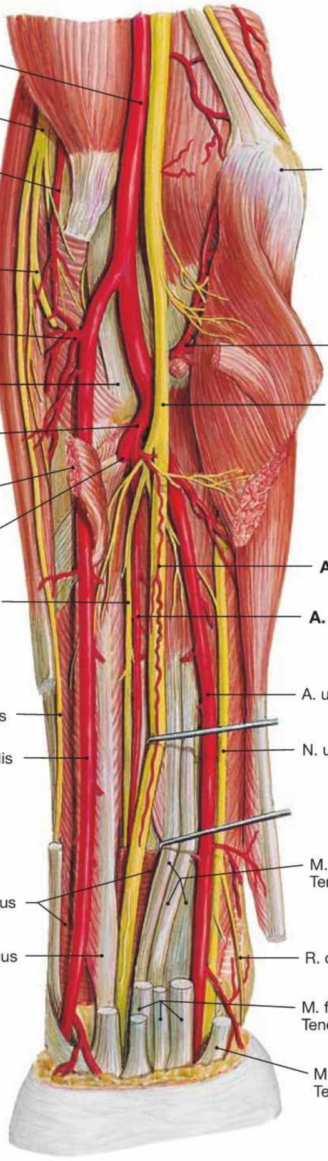
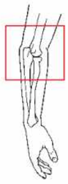
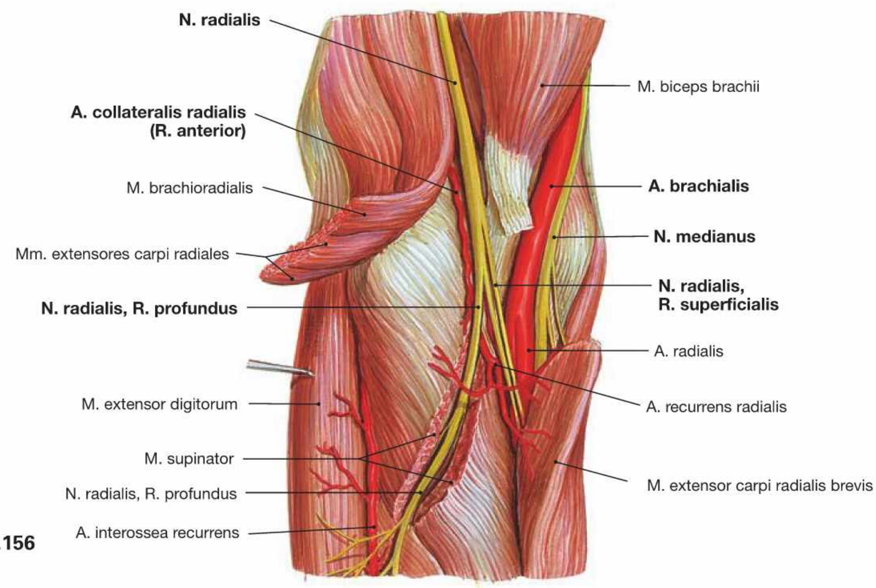


Fig. 3.155 Deep arteries and nerves of the forearm, Regio antebrachii anterior, right side; ventral view; all superficial flexor muscles were removed.

After removal of all superficial flexor muscles, including the M. flexor digitorum superficialis, the complete course of the N. medianus is visible. It descends distally in the midline of the forearm between the deep and superficial flexor muscles and is commonly accompanied by a thin artery (A. comitans nervi mediani). At the proximal forearm, the N. interosseus antebrachii anterior branches off providing motor innervation to the deep flexor muscles and sensory supply to the wrist joints.The A. interossea anterior accompanies this nerve, and the A. interossea posterior traverses through the Membrana interossea antebrachii to the dorsal side.

Vessels and nerves of the cubital fossa and elbow





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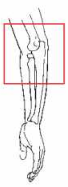
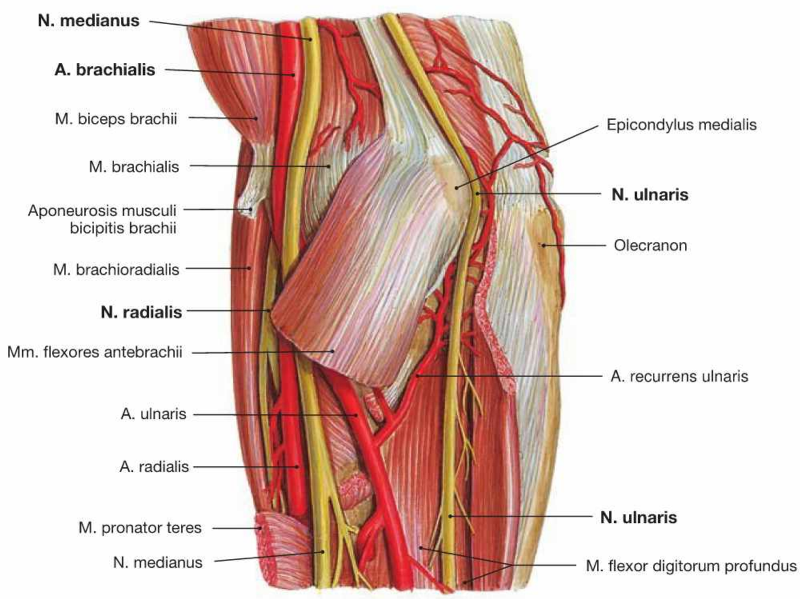
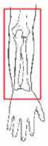




3.157

Fig. 3.156 and Fig. 3.157 Arteries and nerves of the elbow; Regio cubitalis anterior, right side; lateral (radial) view (→ Fig. 3.156).
Arteries and nerves of the elbow, Regio cubitalis posterior, right side; medial (ulnar) view (→ Fig. 3.157).
These illustrations demonstrate the course of the nerves of the arm after splitting the diverse superficial flexors and extensors. Together with the A. brachialis, the **N. medianus** enters the cubital fossa from medial. The **N. radialis** enters the cubital fossa from lateral between the M. brachioradialis and M. brachialis **(radial tunnel)** together with the A. collateralis radialis. Here it divides into the two terminal branches. The R. superficialis continues beneath the M. brachioradialis. The R. profundus reaches the dorsal side through the M. supinator **(supinator canal).** The **N. ulnaris** is directly adjacent to the bone in the Sulcus nervi ulnaris where it is easily irritated **("funny bone").** Then, the N. ulnaris courses beneath the M. flexor carpi ulnaris to the flexor side of the forearm.

Vessels and nerves of the forearm



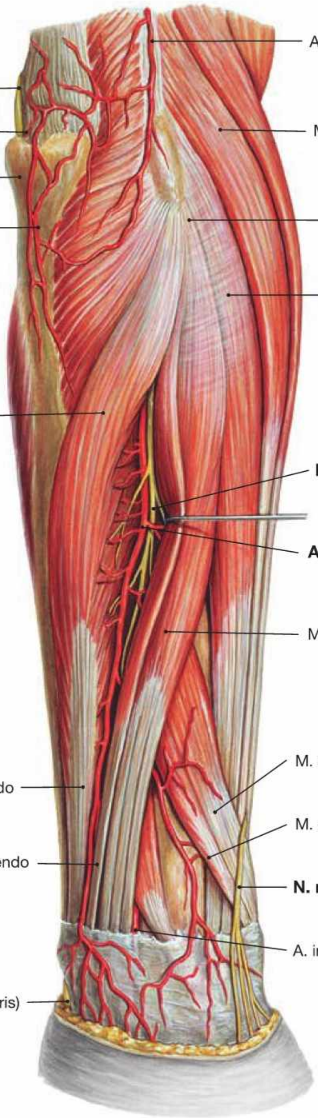
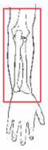


Fig. 3.158 Deep arteries and nerves of the forearm, Regio antebrachii posterior, right side; radial view.
The M. extensor digiti minimi is deviated to the side to show the course of the **R. profundus of the N. radialis** which descends with the A. interossea posterior between the superficial and deep extensors. At the radial side of the wrist, the **R. superficialis of the N. radialis** appears from beneath the M. brachioradialis and enters the dorsum of the hand.

Vessels and nerves of the forearm



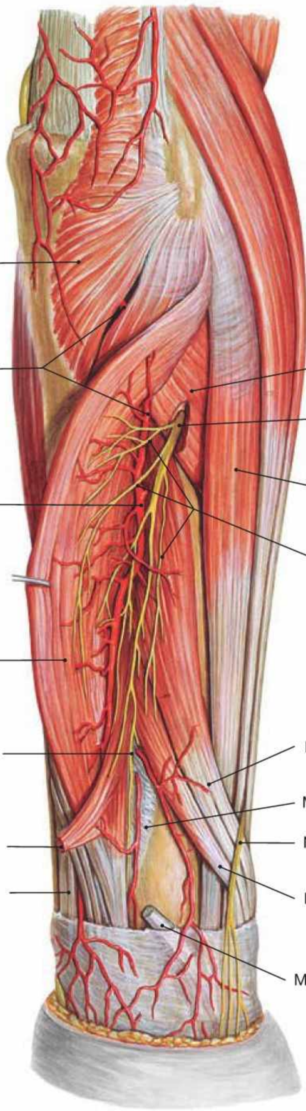


Fig. 3.159 Deep arteries and nerves of the forearm, Regio antebrachii posterior, right side; radial view.
The M. extensor digitorum was lifted sideways to show the branches of the **R. profundus of the N. radialis** and of the **A. interossea posterior.** Following its transition through the supinator muscle, the R. profundus of the N. radialis innervates all superficial and deep extensors of the forearm and terminates as sensory N. interosseus antebrachii posterior at the wrist. After its passage through the Membrana interossea antebrachii, the A. interossea posterior branches off the A. interossea recurrens which reaches the arterial network of the elbow (Rete articulare cubiti) underneath the M. anconeus.

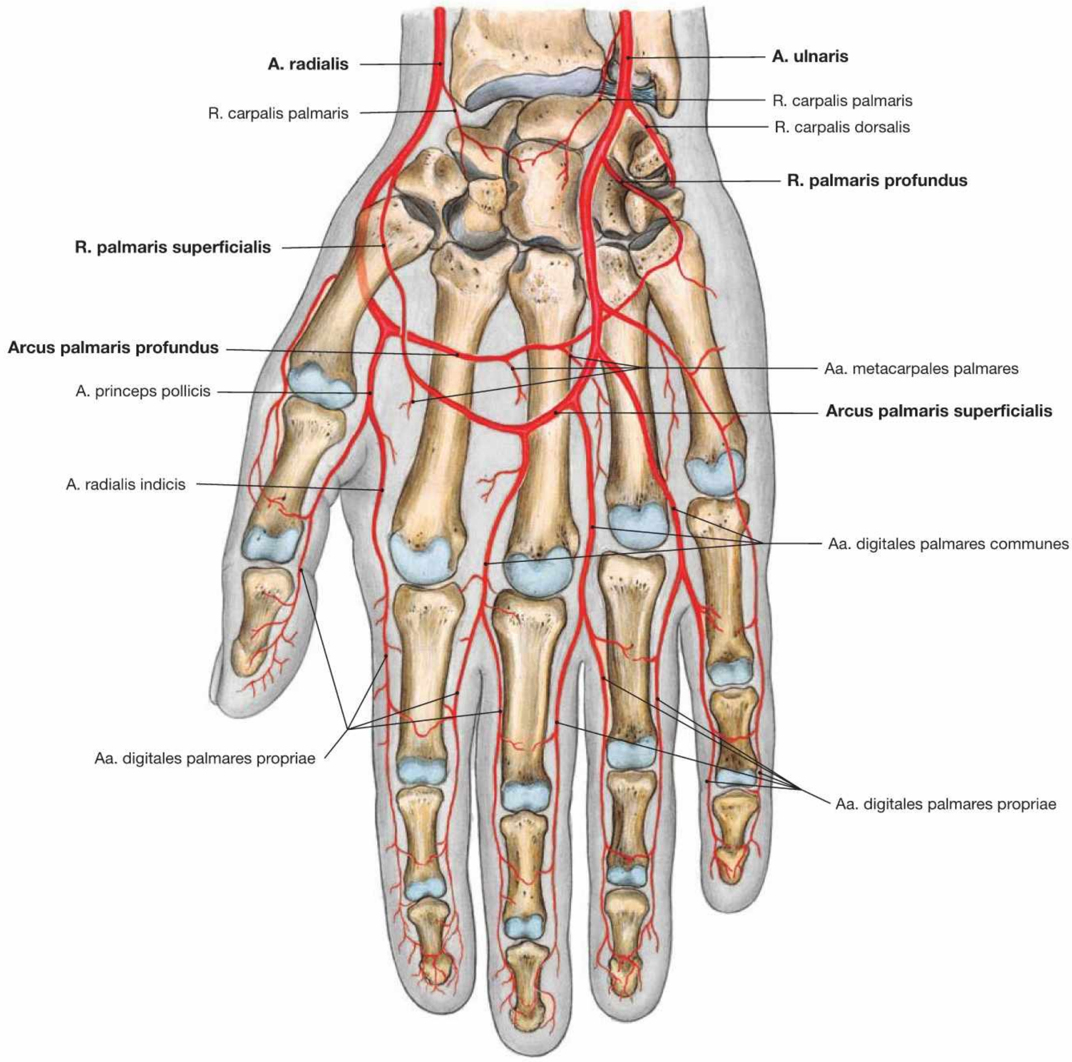
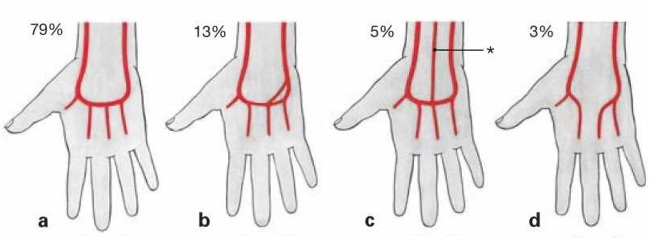
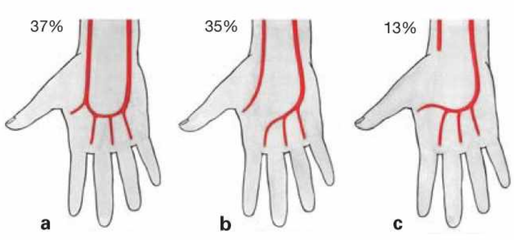


Fig. 3.160 Arteries of the hand, Manus, right side; palmar view.
The palm of the hand is supplied by the A. radialis and A. ulnaris which usually both contribute to the two palmar arterial arches. The **A. radialis** terminates in the **deep palmar arterial arch** (Arcus palmaris profundus, → Fig. 3.161) and contributes a communicating branch to the superficial palmar arterial arch (Arcus palmaris superficialis). whereas, the **A. ulnaris** terminates in the **superficial palmar arterial arch** (→ Fig. 3.162) and provides a branch to the Arcus palmaris profundus.



Figs. 3.161a to d Variations of the deep palmar arterial arch.
The deep palmar arterial arch gives rise to the Aa. metacarpales palmares which supply the palm of the hand including the Mm. interossei. Frequently, in the interdigital spaces the weak Aa. metacarpales palmares join the digital arteries which derive from the superficial palmar arterial arch.
The deep palmar arterial arch is usually closed but the A. interossea anterior may be connected (*).



Figs. 3.162a to c Variations of the superficial palmar arterial arch.
The superficial palmar arterial arch feeds the Aa. digitales palmares for the second to fifth digits. The thumb (A. princeps pollicis) and the radial side of the index finger (A. radialis indicis) are supplied by direct branches of the A. radialis. In summary, the A. radialis supplies the palm of the hand and the radial 1½ digits, and the A. ulnaris supplies the ulnar 3½ digits.
Frequently, a complete superficial palmar arterial arch is missing. In these cases, the A. radialis and A. ulnaris have separate supply zones.

Vessels and nerves of the palm of the hand

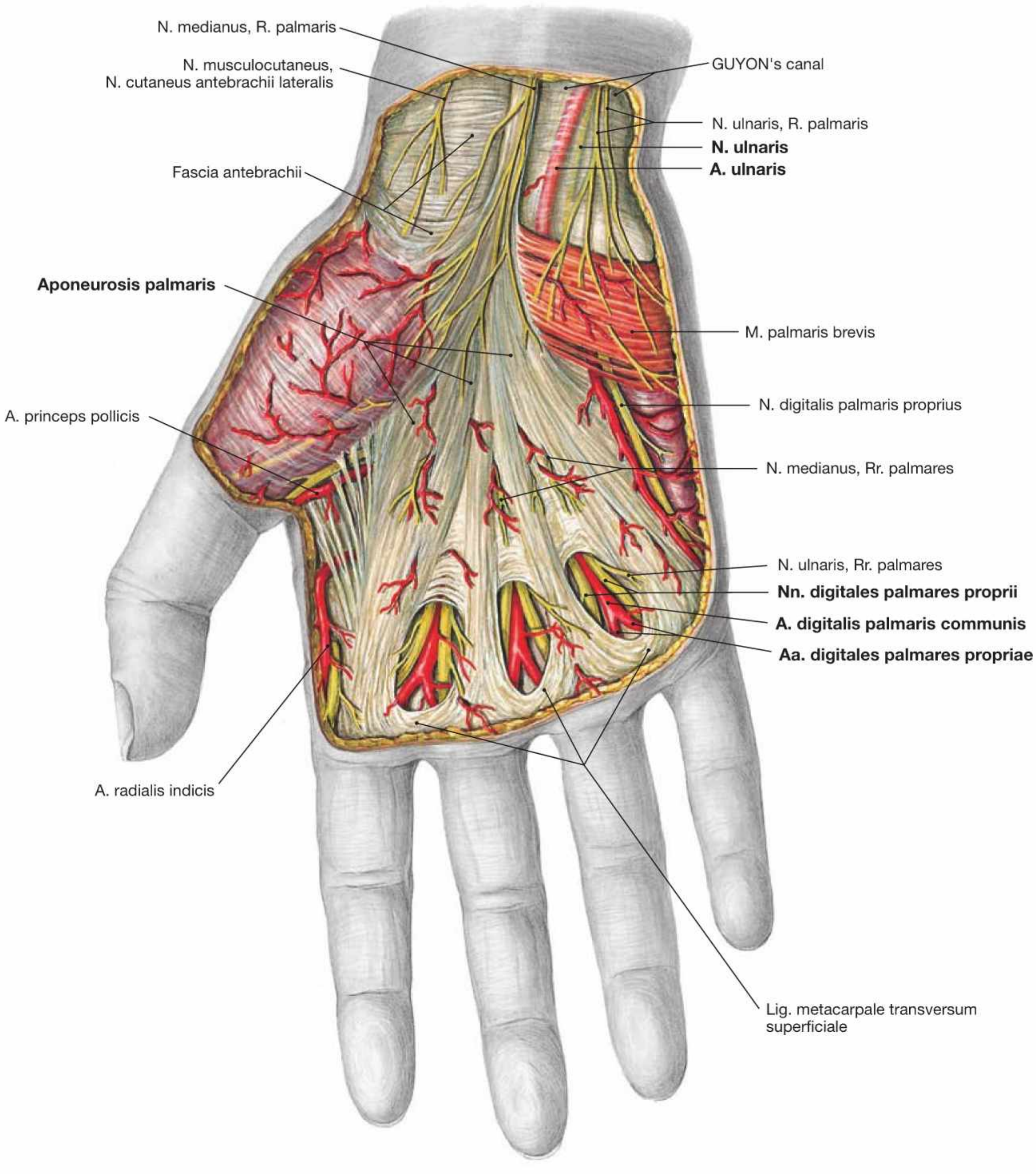


Fig. 3.163 Superficial arteries and nerves of the palm of the hand, Palma manus, right side; palmar view.
In the palm of the hand, blood vessels and nerves are well protected by the **palmar aponeurosis** (Aponeurosis palmaris). Proximal of the metacarpophalangeal joints and between the longitudinal fibres of the aponeurosis, the Nn. digitales palmares derived from the N. medianus and N. ulnaris and the ramifications of the terminal digital branches of the Aa. digitales palmares communes are visible. As the N. ulnaris and A. ulnaris run superficially in the **GUYON's canal,** they may be injured or compressed at this location.

Vessels and nerves of the palm of the hand

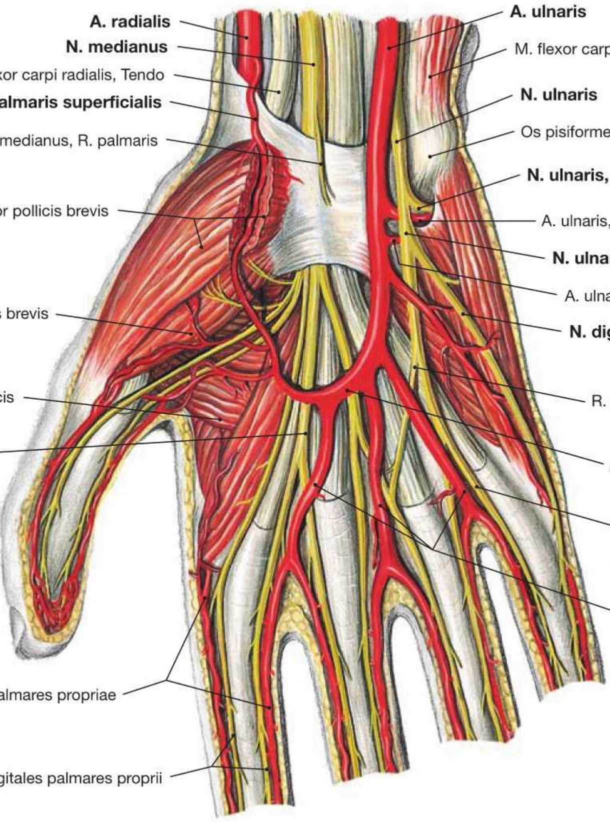


Fig. 3.164 Intermediate layers of arteries and nerves of the palm of the hand, Palma manus, right side; after removal of the palmar view; palmar aponeurosis.

The **superficial palmar arterial arch** (Arcus palmaris superficialis) is essentially formed by the A. ulnaris and frequently anastomoses with a branch from the A. radialis (R. palmaris superficialis). The Aa. digitales palmares for the ulnar 3½ digits branch off 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**. Distal of the Os pisiforme, the N. ulnaris aready splits into its R. profundus and R. superficialis and continues along this direction. The **R. superficialis** divides into Nn. digitales palmares for sensory innervation of the ulnar 1½ digits. The radial 3½ digits are supplied by respective branches of the **N. medianus** which enters the palm of the hand through the **carpal tunnel** (Canalis carpalis) beneath the Retinaculum musculorum flexorum.

Vessels and nerves of the palm of the hand

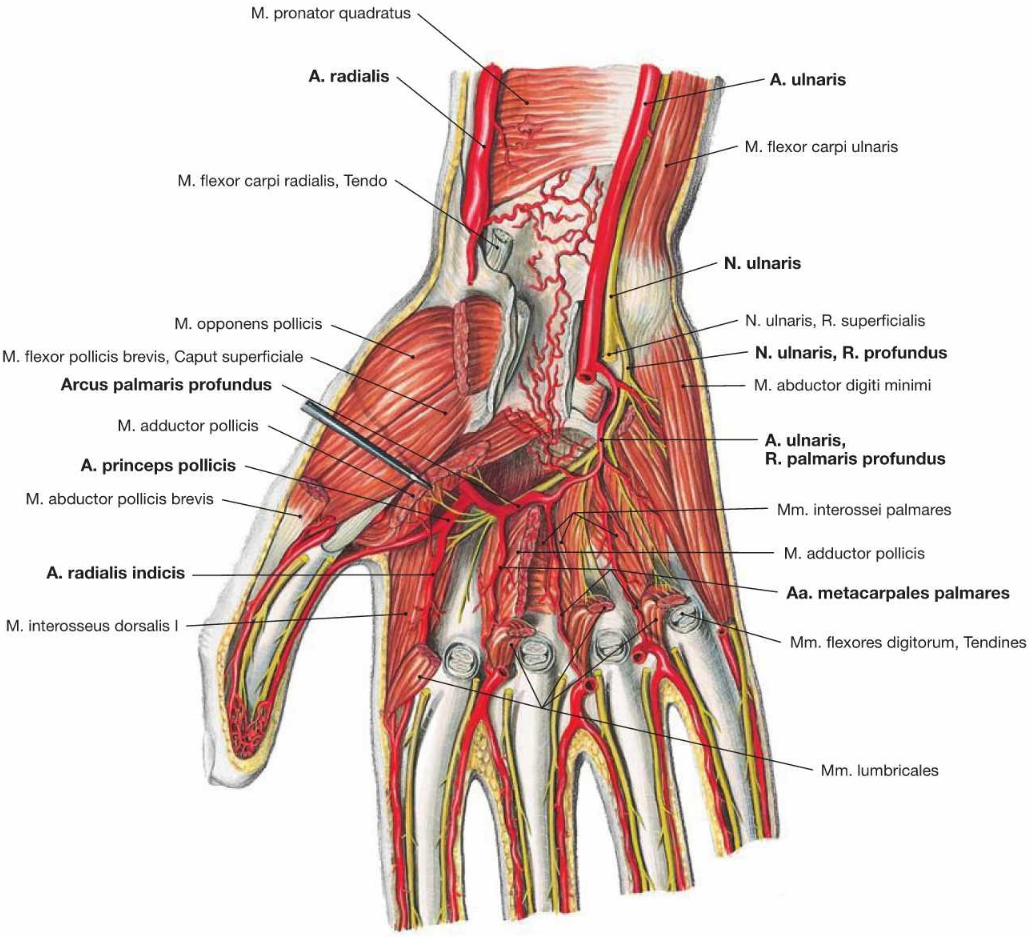


Fig. 3.165 Deep arteries and nerves of the palm of the hand, Palma manus, right side; palmar view; tendons of the flexor muscles and Mm. lumbricales were removed and the M. adductor pollicis was split.

The **deep palmar arterial arch** (Arcus palmaris profundus) derives from the A. radialis and communicates with the R. palmaris profundus of the A. ulnaris. This arch is positioned **beneath** the M. adductor pollicis and in front of the bases of the Ossa metacarpi, thus, further proximal than the superficial palmar arterial arch. The deep palmar arterial arch releases the thin Aa. metacarpales palmares and courses over the Mm. interossei together with the **R. profundus of the N. ulnaris** which innervates the hypothenar 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.

Vessels and nerves of the dorsum of the hand

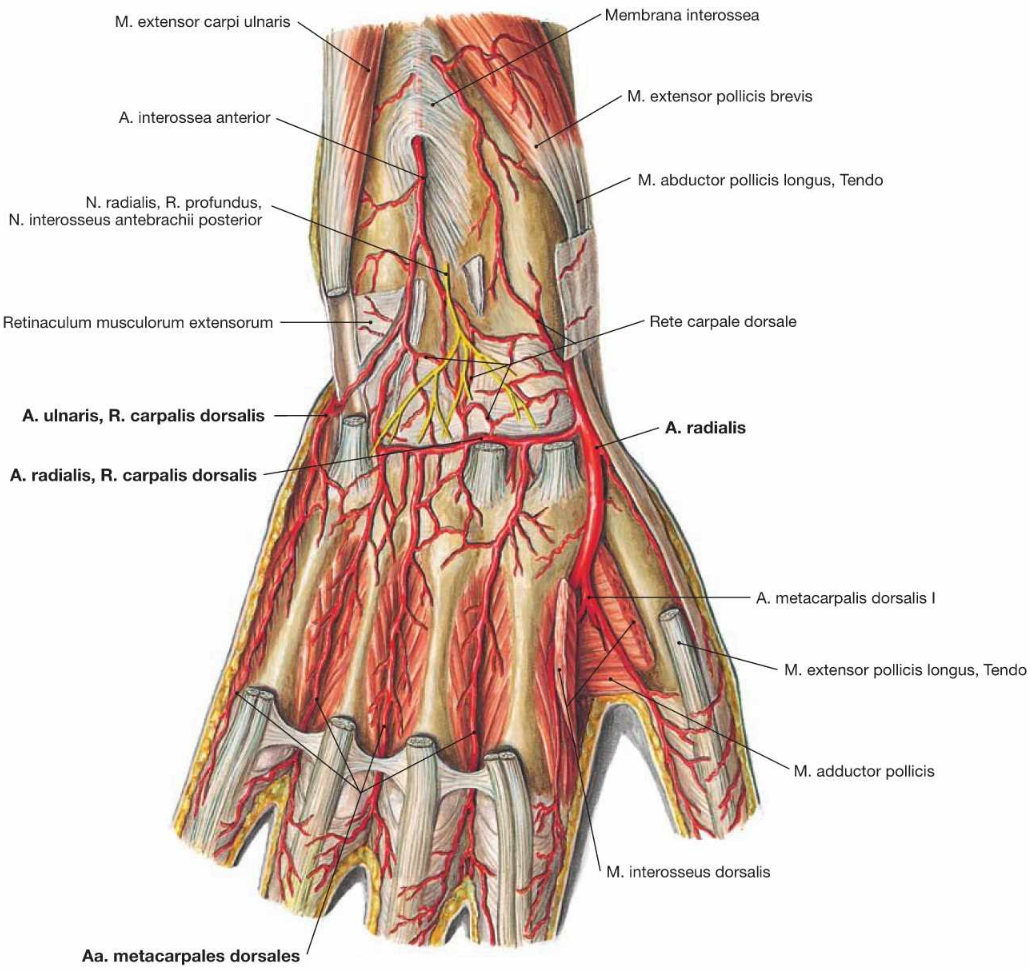


Fig. 3.166 Arteries and nerves of the dorsum of the hand, Dorsum manus, right side; dorsal view; after removal of the long tendons of the extensor muscles.
Both, the **A. radialis** and **A. ulnaris** send a **R. carpalis dorsalis** to the dorsum of the hand where they communicate. The radial branch is usually stronger and predominantly supplies the Aa. metacarpales dorsales for the dorsum of the hand and the Aa. digitales dorsales for the digits up to the proximal interphalangeal joints. The intermediate and distal phalanges are supplied by the palmar digital arteries. Before the A. radialis courses between both heads of the M. interosseus dorsalis I to reach the palm of the hand, the A. metacarpalis dorsalis I directly branches of the A. radialis.

Vessels and nerves of the dorsum of the hand

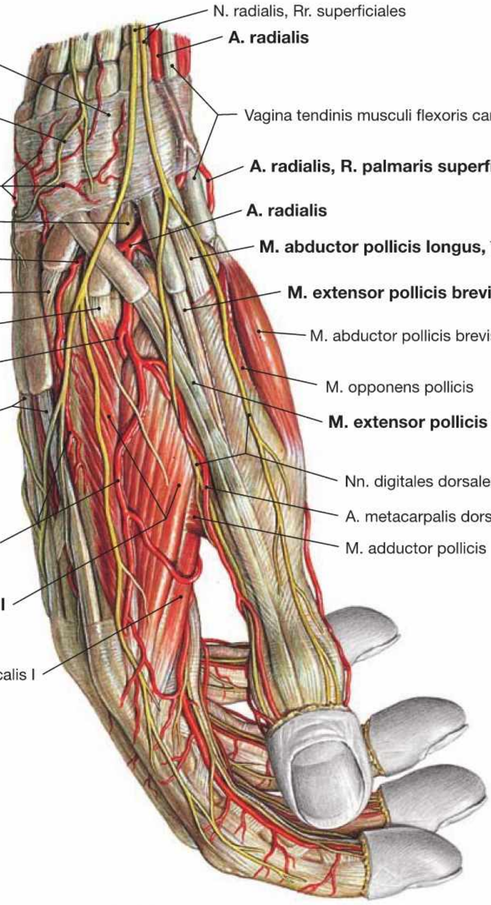
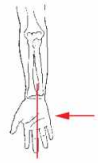


Fig. 3.167 Arteries and nerves of the dorsum of the hand, Dorsum manus, right side; radial view.

The illustration demonstrates the **course of the A. radialis** in the area of the wrist. At the proximal wrist joint, the A. radialis is positioned between the tendons of the M. brachioradialis and M. flexor carpi radialis. After traversing beneath the Retinaculum musculorum extensorum, the A. radialis provides the R. palmaris superficialis which communicates with the superficial arterial palmar arch. The A. radialis then crosses underneath the tendons of the extensor muscles passing through the first osseofibrous tunnel (M. abductor pollicis longus and M. extensor pollicis brevis, → Fig. 3.87) to reach the **Fovea radialis** (**Tabatière;** between the tendons of Mm. extensores pollicis brevis and longus) and delivers a 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. Occasionally, a superficial variant exists and the artery crosses the extensor tendons superficially.

Hand, sagittal section



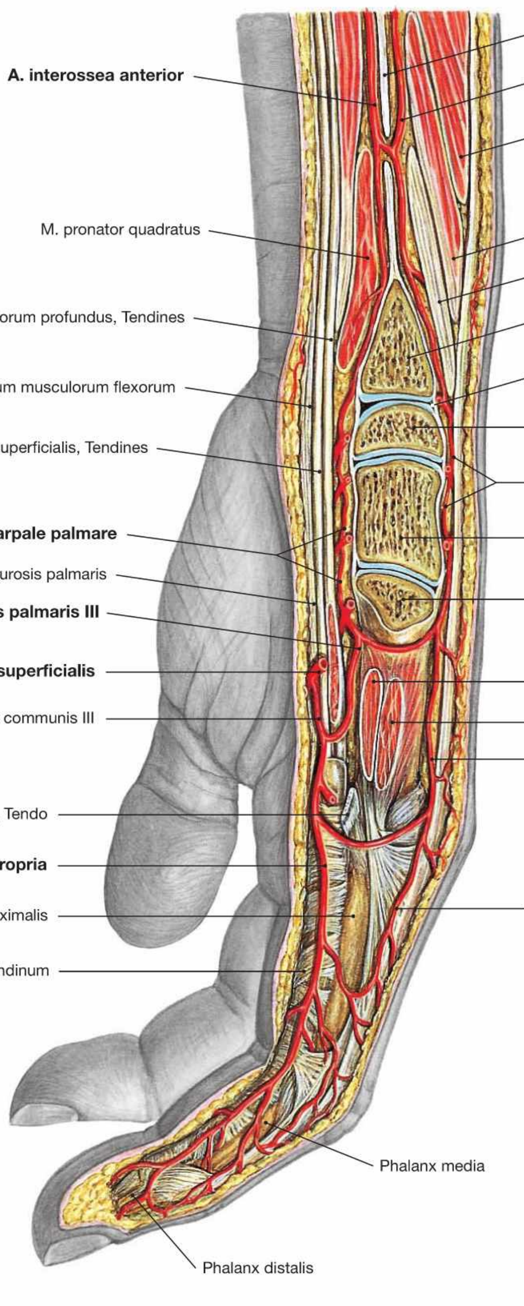
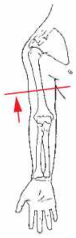


Fig. 3.168 Arteries of the hand, Manus, right side; ulnar view; sagittal section at the level of the Ulnar plane of the third digit.
At the distal forearm, the Aa. interosseae anterior and posterior run on both sides of the Membrana interossea antebrachii. The metacarpus is supplied from palmar and dorsal by arterial networks (Rete carpale palmare and dorsale) which derive from the A. radialis and A. ulnaris. The metacarpal and digital arteries of the dorsum of the hand derive from the dorsal arterial network. At the volar side of the hand, the metacarpal arteries originate from the deep and the digital arteries from the superficial palmar arterial arch. Each finger receives a total of four digital arteries (palmar and dorsal at the radial and ulnar side, respectively). The dorsal digital arteries only reach to the middle phalanx.The middle and distal phalanges are supplied by branches of the palmar digital arteries.

Upper arm, transverse sections



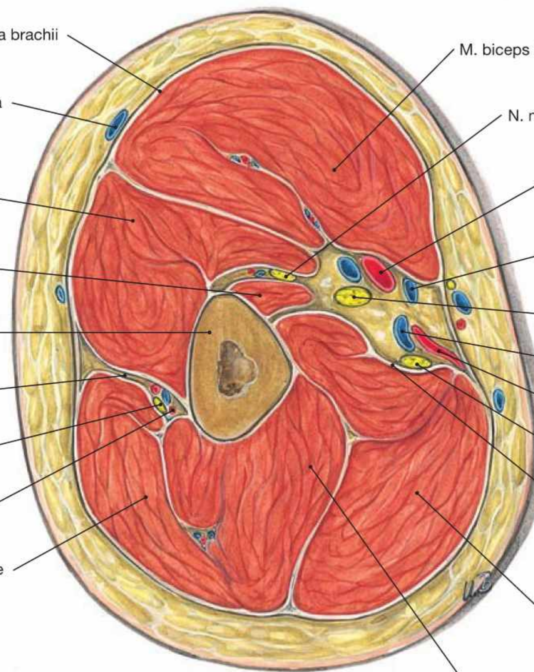


Fig. 3.169 Upper arm, Brachium, right side; distal view; transverse section at the level of the middle part of the upper arm.

The cross-section clearly demonstrates the **two muscle groups** of the upper arm. Located on the ventral side are the flexors of the elbow joint. The M. biceps brachii is positioned anterior to the M. brachialis which originates further lateral. The insertion of the M. coracobrachialis on the medial humeral shaft is delineated. The heads of the M. triceps brachii occupy the posterior side of the upper arm.

Neurovascular structures course in **two passageways.** The N. medianus together with the A. brachialis and concomitant Vv. brachiales are located in the Sulcus bicipitalis medialis and anterior to the Septum intermusculare brachii mediale (medial passageway). The V. basilica has already pierced the fascia and is shown just before merging with the V. brachialis. The N. ulnaris traverses the Septum intermusculare brachii mediale further distal to reach the posterior side of the Epicondylus medialis. Laterally, in the Sulcus nervi radialis the N. radialis winds around the humeral shaft together with the A. profunda brachii (dorsal passageway) and descends between the M. brachialis and M. triceps brachii.

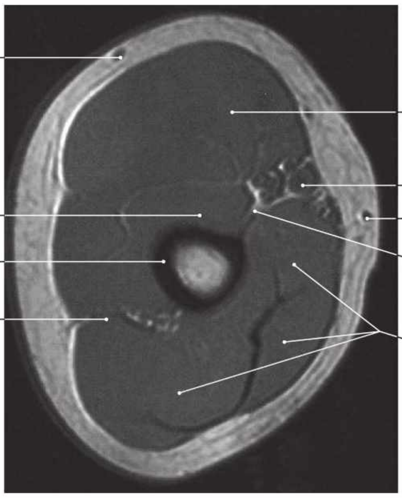


Fig. 3.170 Upper arm, Brachium, right side; distal view; magnetic resonance imaging cross-section (axial MRI) at the level of the middle part of the upper arm.

Forearm and carpus, transverse sections

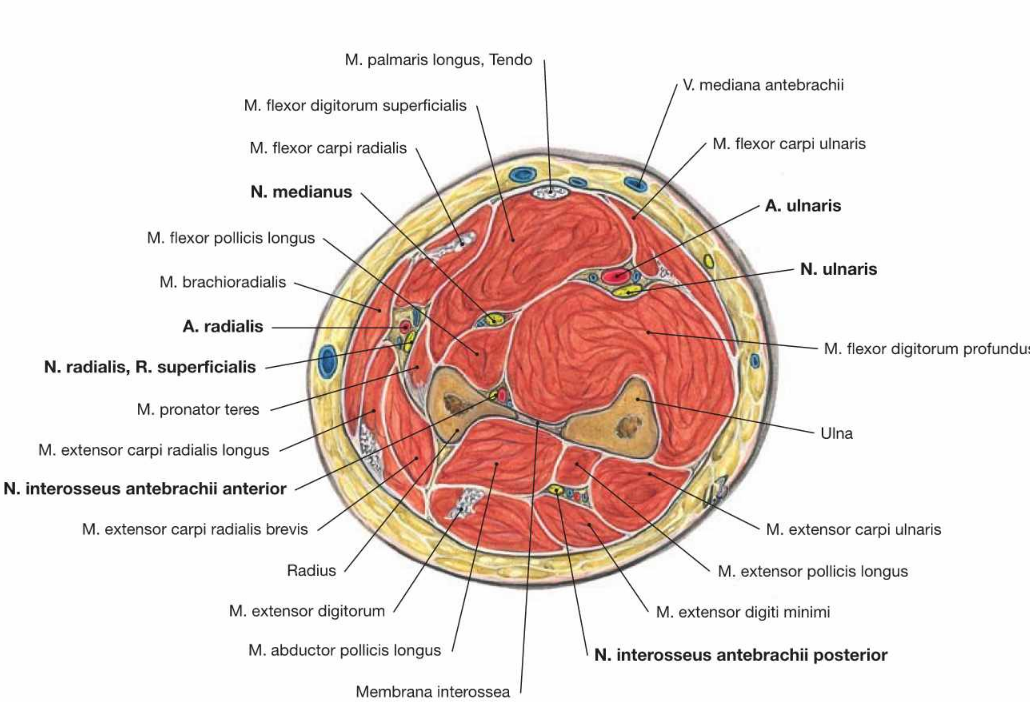
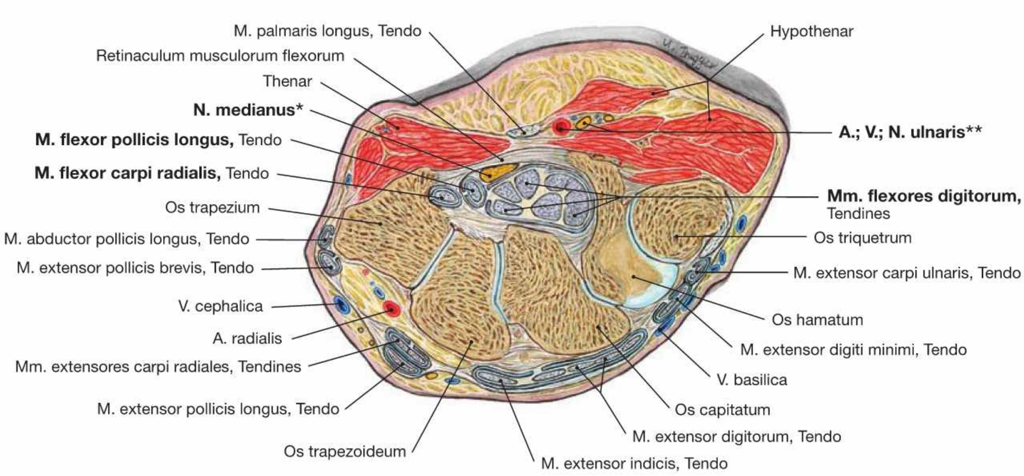


Fig. 3.171 Forearm, Antebrachium, right side; distal view; transverse section at the level of the distal third of the forearm.
The forearm displays **five neurovascular passageways** which are located between the superficial and deep layers of the flexors and extensors, respectively. The A. and V. radialis together with the R. superficialis of the N. radialis course beneath the M. brachioradialis (radial neurovascular passageway).
In the midline, between the superficial and intermediate layers of the flexors, the N. medianus and a delicate concomitant artery (A. comitans nervi mediani) are positioned (medial neurovascular passageway). Beneath the M. flexor carpi ulnaris, the N., A. and V. ulnaris are located (ulnar neurovascular passageway). The A. and V. interossea anterior and the N. interosseus anterior course anterior to the Membrana interossea antibrachii (interosseal neurovascular passageway). The A. and V. interossea posterior and the N. interosseus posterior are located between the superficial and deep extensors (posterior neurovascular passageway).



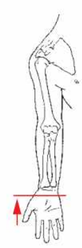


Fig. 3.172 Carpus, right side; distal view; transverse section at the level of the distal row of carpal bones.
The palmar side of the carpus has **two neurovascular passageways** of clinical importance. The carpal bones together with the Retinaculum musculorum flexorum form the carpal tunnel (Canalis carpi). The N. medianus traverses the carpal tunnel together with the tendons of the long flexors of the digits. Therefore swelling of the tendinous sheaths may result in compression of the N. medianus (carpal tunnel syndrome, → Fig. 3.125). The A., V. and N. ulnaris run above the retinaculum in the **GUYON's canal** where they are vulnerable to compression due to the superficial location (distal lesion of the N. ulnaris → Fig. 3.129).

* carpal tunnel
** GUYON's canal

Metacarpus and third digit, transverse sections

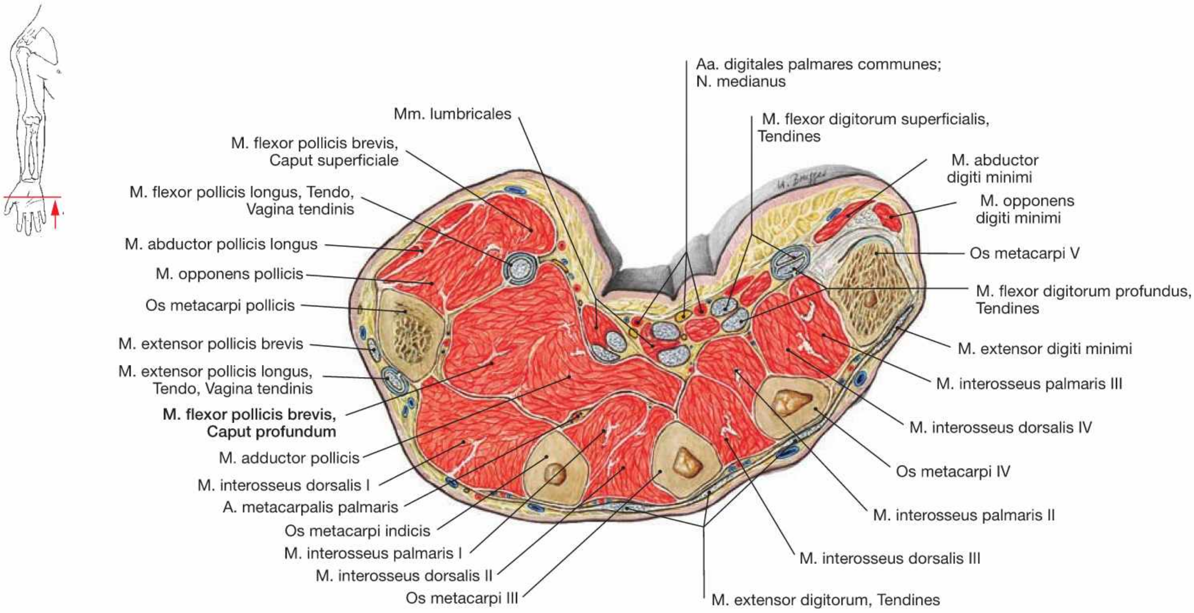


Fig. 3.173 Metacarpus; transverse section at the level of the middle of the third metacarpal bone.

This section demonstrates the position of the muscles in the palm of the hand which are grouped in three layers (→ pp. 188–193).

Superficially, the M. abductor pollicis, M. flexor pollicis brevis, and M. abductor digiti minimi cover the other muscles of the Thenar and Hypothenar, respectively. The **intermediate layer** harbours the tendons of the long flexor muscles of the fingers. Also, the Mm. lumbricales originate from these tendons. The **deep layer** of the palmar muscles is formed by the Mm. interossei palmares and dorsales. Here it is obvious the palmar interosseal muscles lie indeed nearer to the palm of the hand than the dorsal muscles. In addition, this illustration also clearly shows the position of the digital arteries (Aa. digitales palmares communes) and the sensory terminal branches of the N. medianus which run ventrally to the flexor tendons (→ Fig. 3.164).

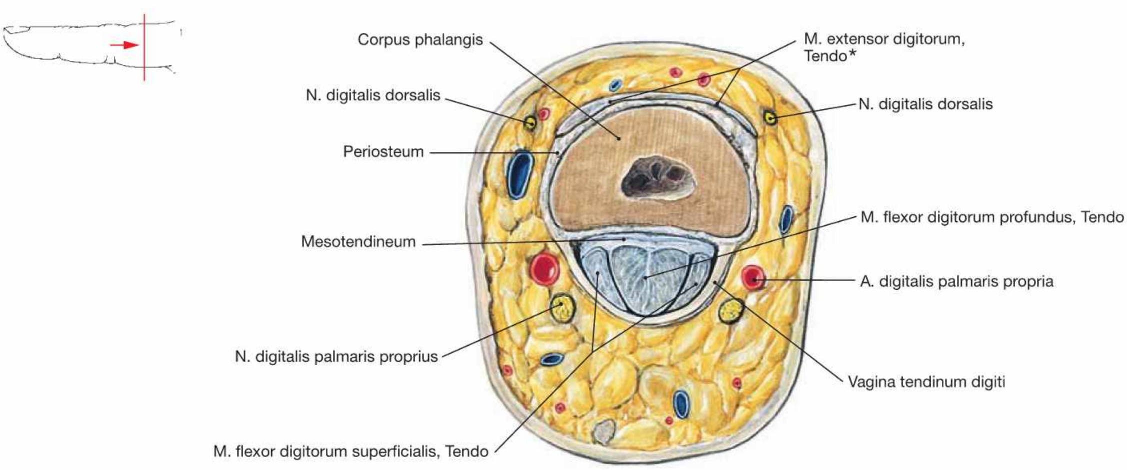


Fig. 3.174 Third digit, Digitus medius [III]; transverse section through the shaft of the middle phalanx.

The tendon of the M. flexor digitorum profundus has pierced the tendon of the M. flexor digitorum superficialis and both tendons are positioned within a common tendinous sheath (Vagina tendinum digiti). The dorsal arteries and nerves at the middle phalanx are much thinner than the corresponding palmar structures. Thus, the middle phalanges are predominantly and the distal phalanges are exclusively supplied by **palmar branches** (A. digitalis palmaris propria and N. digitalis palmaris proprius) (→ Fig. 3.168).

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4

The Lower Limb – the Erect Gait

The bipedal upright gait not only influenced the intellectual and socio-cultural development of humans but also resulted in significant changes of the human anatomy.

In humans, the lower extremities – as seen in hominids – are locomotion and support organs, however, with a more stable and wider **pelvic girdle** and longer **legs:** The extensive pelvic bones bear the weight of the upper body and support the viscera of the abdominal cavity, enabling prolonged standing without much effort. The ability to take larger steps results in accelerated locomotion. Speed and greater range of action caused already the quadrupedal mammals to develop limbs which migrated ventrally underneath the body. The front (upper) extremities were rotated dorsally while the rear (lower) extremities were rotated ventrally. Hence, in humans the extensors of the thigh and lower leg are positioned anteriorly, whereas the upper arm and forearm extensors are located posteriorly.

The **joints** of the free extremity such as hip, knee, and ankle joints are supported by stable ligaments. They ensure steadiness while standing and relieve the muscle groups on buttocks, knee, and calf, which are responsible for body posture.

The **stance stabilizing foot** of humans – in contrast to the grasping hand-like foot in hominids – has led to less mobility of the joints, especially of the interphalangeal joints of the toes; the muscles of the foot contribute to stabilization of the foot and bracing of the plantar arch rather than enabling the fine-tuned movement of individual toes.

Pelvic Girdle

In contrast to the shoulder girdle, the pelvic girdle (Cingulum membri inferioris or pelvicum) is an almost rigid bony ring. Dorsally it consists of the sacrum (Os sacrum), which is a constituent of the spine. The sacrum is unpaired and it connects bilaterally through minimally flexible joints (Articulationes sacroiliacae) with the paired pelvic bones (Ossa coxae). The Ossa coxae form two bony half shells which join ventrally beneath the Mons pubis at the fibrocartilaginous Symphysis pubica. This resembles a bony floorless basin, where the muscles and ligaments form the pelvic floor. Each pelvic bone consists of three single bones which are connected by synostoses once growth is completed: the ilium (Os ilium, cranial), the ischium (Os ischii, caudodorsal) and the pubis (Os pubis, caudoventral).

When investigating the soft tissues of the pelvic girdle, the following picture emerges: At the ventral aspect, the inguinal region (Regio inguinalis) is positioned on either side of the Mons pubis. In the tender inguinal canal, blood vessels, muscles, and nerves (and the spermatic cord in males) descend from the interior of the abdomen to the leg (and scrotum, respectively). The pulse of the femoral artery (A. femoralis) is palpable slightly lateral to both sides of the Mons pubis in the Regio inguinalis. The actual hip region (Regio coxae) is located more laterally. Dorsally, the bilaterally curved buttocks of the gluteal region (Regio glutealis, "ho glutos": the buttocks) rest on the bony pelvic girdle. Their convexity resulted from the adaptive evolution of the gluteal muscles due to the transition to the bipedal gait. Both buttocks are separated by a deep natal cleft (Crena ani) and the gluteal fold (Sulcus glutealis) separates them from the thigh.

Lower limb

The Pars libera membri inferioris consists of the thigh (Femur), the knee (Genu), the leg (Crus), and the foot (Pes).

The **thigh** (Femur) is supported by the identically named bone, which is the largest long bone of the body. In the hip joint (Articulatio coxae), the ball-like head of the Femur articulates with the hemispherical socket of the Os coxae. The range of movement of the hip joint, especially the extension, is restricted by powerful, almost centimetre-thick ligaments which are incorporated into the capsule. Since the Femur is well surrounded by muscles, one can only palpate the two (epi-)condyles (bilaterally superior to the knee) and the greater trochanter (Trochanter major) in the hip region.

In the **knee region** (Regio genus), the thigh bone and Tibia form the knee joint (Articulatio genus). The kneecap (Patella) is the ventral part of the knee joint and articulates with the Femur through its posterior surface. The knee is primarily a hinge joint between Femur and Tibia. In a flexed position, it also allows for a certain rotation of the leg. The posterior region of the knee, the popliteal fossa (Fossa poplitea), is soft and placable when the knee is flexed. Deep in the fossa, branches of the N. ischiadicus and the A. poplitea descend from the thigh to the leg. Therefore, the pulse of the A. poplitea is hardly palpable in a flexed position of the knee.

The **lower leg** (Crus, leg) is supported by a medially and anteriorly located Tibia and a laterally positioned Fibula. The head of the Fibula is easily palpable distal to the knee joint (of which the Fibula is not a part). The N. fibularis communis descends subcutaneously and dorsal to the head of the Fibula. Damage to the N. fibularis communis can occur at this point, e.g. due to pressure of a poorly padded cast.

At the transition to the **foot** (Pes), one can easily palpate the bilateral ankle bulges (Malleolus lateralis and medialis). The Malleolus lateralis (of the Fibula) is always positioned lower than the Malleolus medialis (of the Tibia). Just inferior and posterior to the Malleolus medialis a bundle of blood vessels, nerves and tendons descends from the dorsal aspect of the Crus to the sole of the foot. The pulse of the A. tibialis posterior is palpable near the Malleolus medialis. Both malleoli of the Tibia and Fibula articulate with the Talus, forming the ankle joint (Articulatio talocruralis). It facilitates elevation and depression of the foot. The digital extensor tendons project on the dorsum of the foot. Between them, the pulse of the A. dorsalis pedis is palpable. The skeleton of the foot includes the Tarsus, the Metatarsus, and the phalanges (Digiti). There are seven tarsal bones (Ossa tarsi), the Talus being positioned on top. Just below the Talus lies the heel bone (Calcaneus) to which the ACHILLES tendon (Tendo calcaneus) attaches at its posterior surface. At the medial side, the navicular bone (Os naviculare) lies inferior and anterior to the Talus. The above mentioned three bones form the talocalcaneonavicular joint (Articulatio talocalcaneonavicularis). It permits rotating the foot inwards (supination) and outwards (pronation). The remaining tarsal bones, the three cuneiform bones (Ossa cuneiformia) and the cuboid (Os cuboideum), are interconnected by tight and almost immobile joints. The Metatarsus is supported by five long bones, the Ossa metatarsi. Together with the tarsal bones, they form the arch of the foot. The flexible arch of the foot is mainly supported by muscles and tendons located in the sole of the foot (Planta pedis). The toes I to V (Digiti) are formed by shorter long bones, the phalanges. One starts counting at the great toe (Hallux, Digitus primus); in analogy to the thumb, the Hallux has only two phalanges.

Clinical Remarks

Congenital deformities such as hip dysplasia or clubfoot occur frequently and require therapy during early childhood to enable walking and to warrant normal development. Among the chronic **degenerative diseases,** such as arthrosis, which affect eldery persons with variable severity and which contribute to a substantial amount of the costs in the public health sector, the hip joint (coxarthrosis) and the knee joint (gonarthrosis) are more frequently affected than the joints of the upper extremity. This is caused by the high impact on the weight-bearing joints that is in part due to the erect bipedal posture, but also to civilisation-based conditions such as obesity. In addition, traumatic injuries at work or during recreational activities affect the long bones and predominantly the joints of the lower extremities (injuries to the ligaments and menisci) and frequently require a surgical reconstruction. The primary goal here is to restore the ability to walk and, thus, prevent secondary diseases caused by immobility such as thrombosis and pulmonary infections.

→ Dissection Link

The musculoskeletal system is dissected in **layers** (stratigraphically) from superficial to deep structures.

Ventral dissection: First, the epifascial structures in the subcutaneous adipose tissue are exposed. This involves several cutaneous nerves of the Plexus lumbalis and at the distal leg around the N. fibularis superficialis from the Plexus sacralis. Then follows the dissection of the V. saphena magna ascending from the anterior aspect of the medial malleolus via the medial aspect of the knee up to the Confluens venosus subinguinalis in the groin. The fascia is opened to expose the individual muscles. Immediately beneath the inguinal ligament (Lig. inguinale), the Lacunae musculorum and vasorum together with exiting neurovascular structures are dissected. From here, the A. and V. femoralis as well as the N. saphenus are traced to their entrance into the adductor canal (Canalis adductorius). Next, the origin and the branches of the A. profunda femoris, the main blood vessel supplying the thigh, are dissected. Finally, the individual joints (e.g. knee joint) are exposed.

Dorsal dissection: After exposure of the epifascial cutaneous nerves from the Plexus sacralis, the V. saphena parva is traced from the posterior aspect of the lateral malleolus to its confluence in the popliteal fossa. Next, the opening of the fascia displays the individual muscles. In the gluteal region, the M. gluteus maximus is exposed and reflected, followed by the display of the deep muscles of the gluteal region. The Regio glutealis with pathways is dissected. The N. ischiadicus is traced to its divergence and from there the N. tibialis and the N. fibularis communis with its branches are traced to the foot. The popliteal fossa is dissected including blood vessels. In the leg, the neurovascular pathways are traced along the A. tibialis anterior and posterior to the foot. After the removal of the plantar aponeurosis on the Planta pedis, the individual layers of the short foot muscles are exposed and the associated pathways are visualised.

EXAM CHECK LIST

• Bones with apophyses for muscle origins and insertions • joints and ligaments (in particular: Articulatio genus with Ligg. cruciata and collaterale and menisci) • muscles and their course, function and innervation • nerves with supply area, course and lesions • arteries with branches, course and pulses • veins and their course • lymphatic drainage and Nodi lymphoidei inguinales superficiales • topography: Lacunae musculorum and vasorum, Regio glutealis with intragluteal injection, Canalis obturatorius, Canalis adductorius, Fossa poplitea and Planta pedis • compartment syndrome • cross-sections: Coxa, Femur and Crus • surface anatomy

Surface anatomy

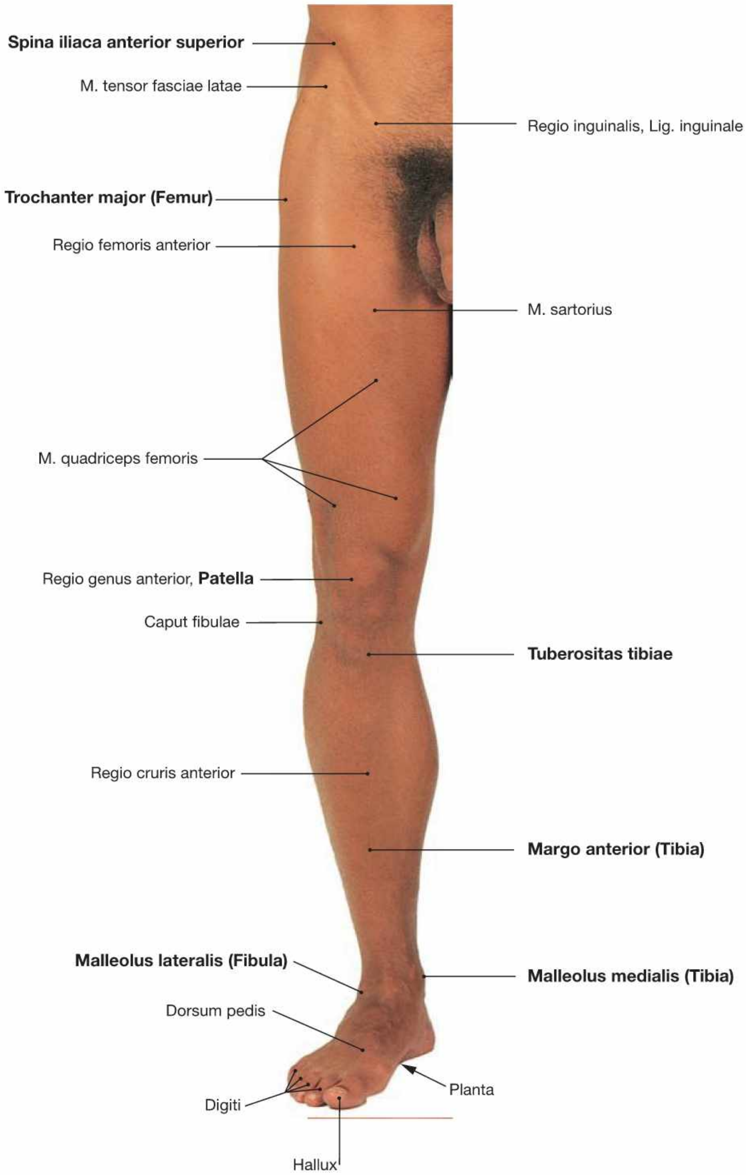


Fig. 4.1 Surface relief of the lower extremity, right side; ventral view.

The surface relief of the legs is determined by muscles and skeletal elements. The skeletal elements which are palpable through the skin are important landmarks for the physical examination.

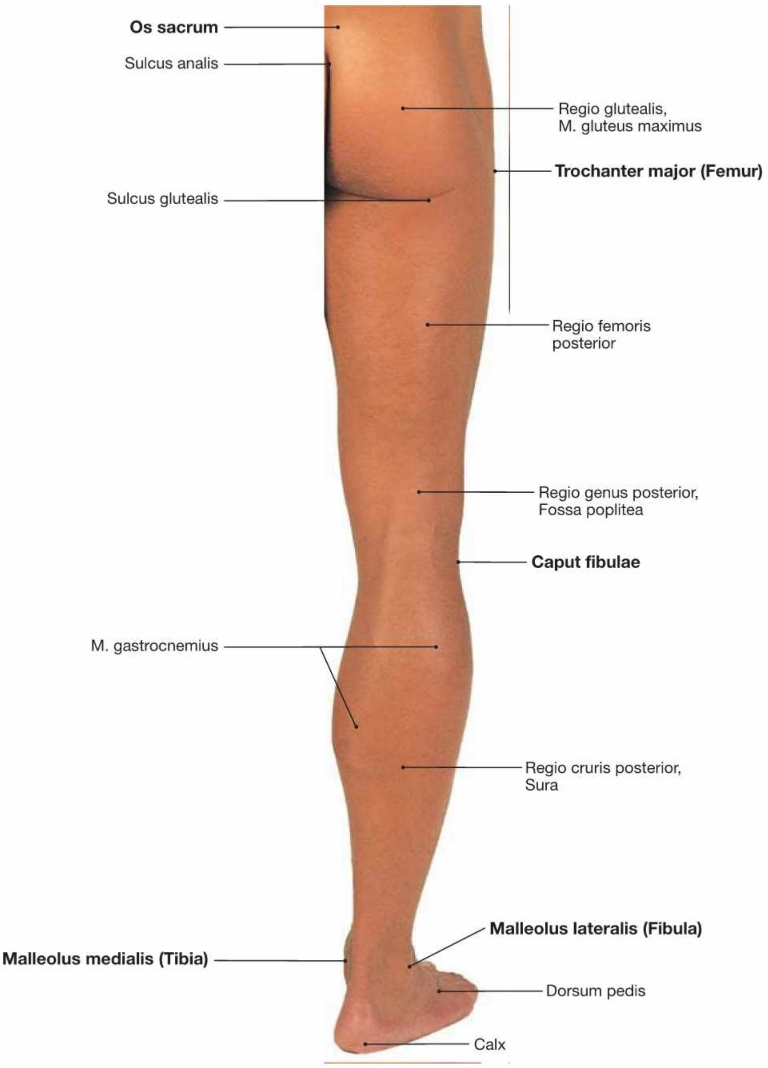


Fig. 4.2 Surface relief of the lower extremity, right side; dorsal view.

Skeleton of the lower extremity

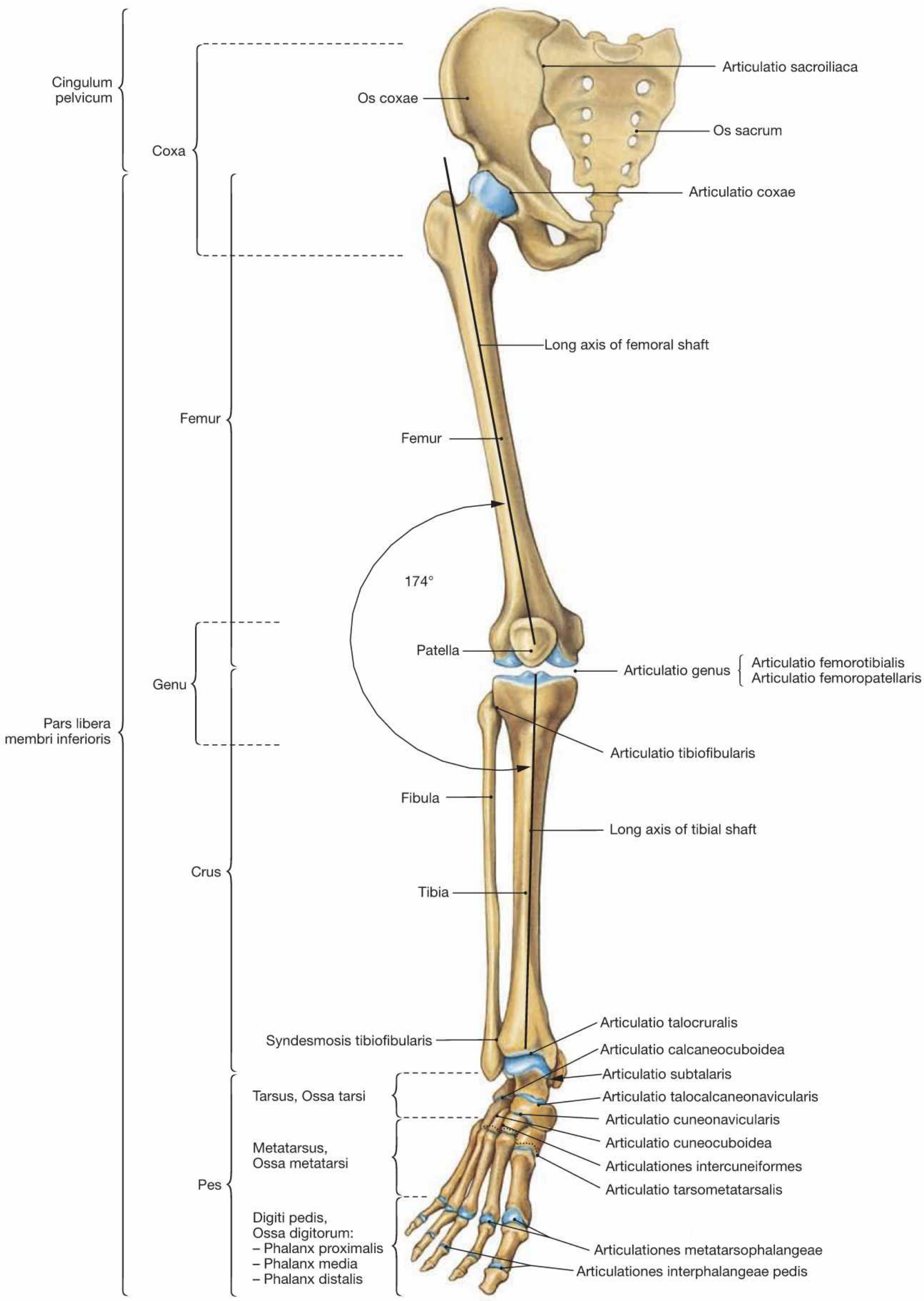


Fig. 4.3 Bones and joints of the lower extremity, Membrum inferius, right side; ventral view.
Whereas the shoulder girdle consists of two bones (Scapula and Clavicula), the pelvic girdle (Cingulum pelvicum) is formed by two hip bones (Os coxae) and the sacrum (Os sacrum). Thigh and leg form a laterally open angle of 174°, referred to as **Q-angle.**

In the **knock-knee** deformity (Genu valgum) the Q-angle is smaller, in the **bowleg** deformity (Genu varum) it is larger. For the development of the lower extremity → pages 132 and 133.

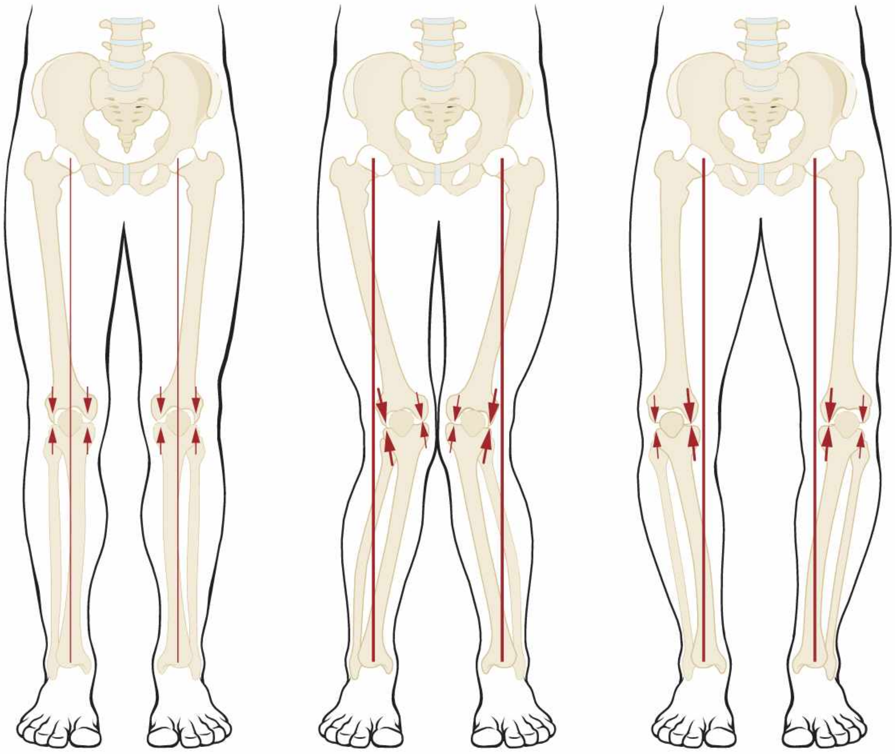


Fig. 4.4 Mechanical axis of the lower extremity (MIKULICZ's line). (according to [1]).
Normally, the great joints of the lower extremity are positioned on a virtual straight line, the mechanical axis of the lower extremity. This axis connects the centre of the femoral head with the middle of the malleolar mortice of the ankle joint.
In the **knock-knee** deformity (Genu valgum), the knee is **shifted medially** away from the mechanical axis, in the **bowleg** deformity (Genu varum), it is **shifted laterally.**
The size of the arrows depicts the stress on the medial and lateral parts of the joint in relation to the mechanical axis.

Clinical Remarks

Since the whole body weight is transferred via the mechanical axis to the soles of the feet, the stress on the joints is even if the joints are aligned along the mechanical axis. Shifting of the knee joint in the case of a **knock-knee** (Genu valgum) or **bowleg** (Genu varum) deformity results in an uneven stress on both compartments of the knee joint (red arrows, → Fig. 4.4). As a consequence, degeneration of the menisci or the joint cartilage may occur, causing arthrosis of the knee joint **(gonarthrosis).** A **Genu valgum** results in **lateral arthrosis** whereas a **Genu varum** causes arthrosis in the medial compartment. For substantial deviations from the mechanical axis, surgical corrections by removal of a bony wedge (osteotomy) may be performed.

Pelvis

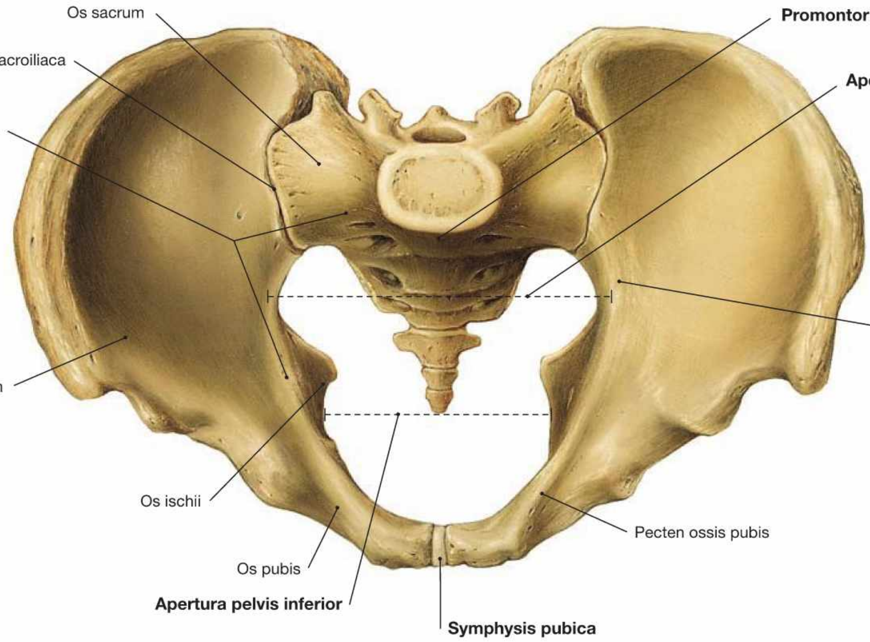
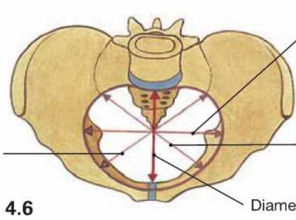


Fig. 4.5 Pelvis, Pelvis; ventral cranial view.
Sacro-iliac joint (Articulatio sacroiliaca) and pubic symphysis (Symphysis pubica) connect the two hip bones (Ossa coxae) and the sacrum (Os sacrum). The resulting stable ring formation encompasses the viscera with its iliac bones and transfers the weight of the body to the lower extremities.
The **Linea terminalis** begins at the pubic symphysis with the Pecten ossis pubis and continues through the Linea arcuata to the promontory **(Promontorium).** The Linea terminalis encircles the pelvic inlet **(Apertura pelvis superior)** and separates the **cranial false (large) pelvis** (Pelvis major) from the **caudal true (small) pelvis** (Pelvis minor). The promontory is the part of the vertebral column that protrudes farthest into the pelvic inlet. The pelvic outlet **(Aperura pelvis inferior)** is confined by the inferior margin of the pubic symphysis anteriorly, the ischial tuberosities laterally, and the tip of the coccyx posteriorly.



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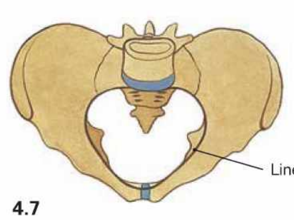


4.7

Fig. 4.6 and Fig. 4.7 Pelvis, Pelvis, of a woman (→ Fig. 4.6) and of a man (→ Fig. 4.7).
The shape of the pelvis shows differences between the sexes. In men, the pelvic inlet is rather heart-shaped. The smaller pubic angle is referred to as Angulus subpubicus (→ Fig. 4.41). In women, the pelvic inlet is transverse oval in shape. In addition, the inferior pubic angle (Arcus pubis, → Fig. 4.42), the distance between the ischial tuberosities, and the wings of ilium are larger than in men.
The following inner diameters 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 lateral points of the Linea terminalis on both sides, and the oblique diameter (Diameter obliqua I and II) which connects the Articulatio sacroiliaca of each side with the corresponding most distal point on the Linea terminalis.

a–b: Diameter (clinical term: Conjugata) anatomica: 11.5 cm, from the promontory to the superior margin of the pubic symphysis
a–c: Diameter vera: 11 cm, from the promontory to the posterior aspect of the pubic symphysis
a–d: Diameter diagonalis: 12.5 cm, from the promontory to the inferior margin of the pubic symphysis

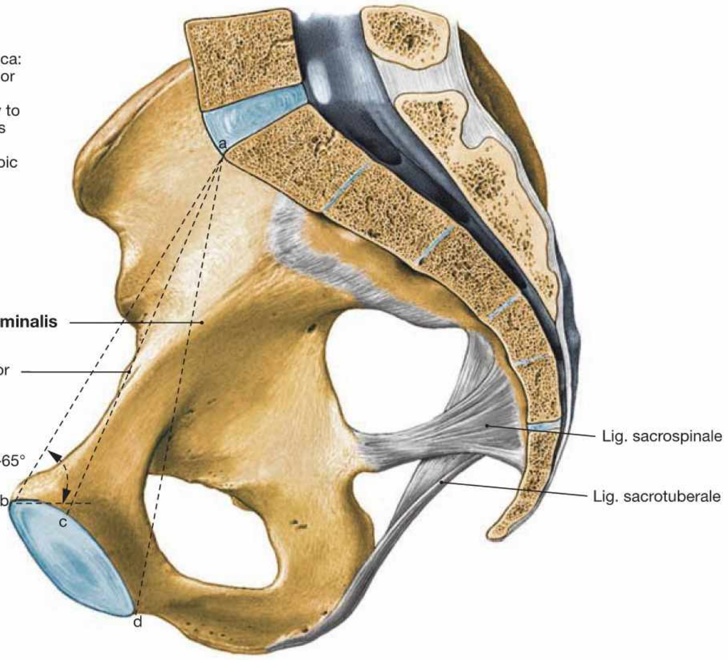
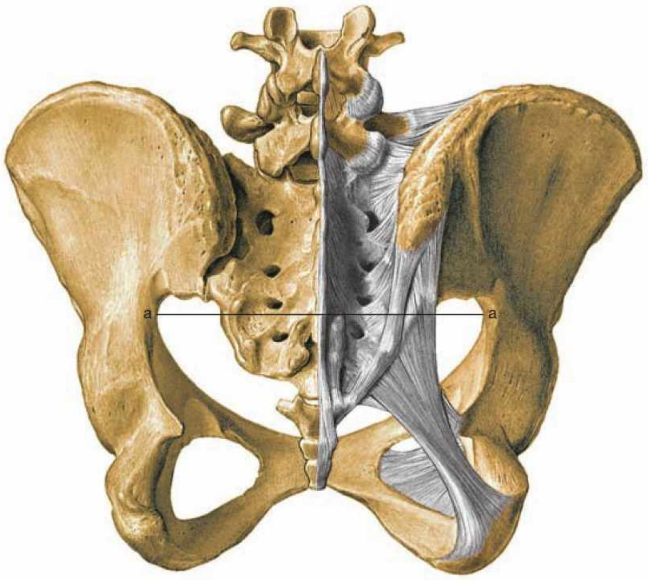


Fig. 4.8 Pelvis, Pelvis, of a woman; medial view; median section with illustration of the diverse straight inner diameters and their normal length which may, however, show interindividual variations.

The most important is the Diameter vera connecting the posterior aspect of the pubic symphysis and the promontory.



a–a: Diameter transversa: 13.5 cm, distance between the most laterally positioned points on each end of the Linea terminalis.

Fig. 4.9 Pelvis, Pelvis, of a woman with measurements; dorsal view.
Another internal diameter with a certain significance is the transverse diameter (Diameter transversa). The different external diameters (Distantiae), however, are of insignificant practical relevance and therefore not shown.

Clinical Remarks

Because the pelvic inlet and the true pelvis encompass the birth canal, the determination of the pelvic diameters is of great importance during **pregnancy** to assess whether a vaginal birth is possible. The most important diameter for the passage of the foetal head is the **Diameter vera** (clinical term: Conjugata vera; at least 11 cm). It can be assessed by vaginal examination of the Diameter diagonalis which spans from the inferior margin of the pubic symphysis to the promontory and is 1.5 cm longer than the Conjugata vera. If an incongruity between the foetal head and the maternal birth canal is suspected, the exact dimensions of the Conjugata vera are determined by magnetic resonance imaging (MRI). During caesarean section the Conjugata vera is routinely calculated to assess whether further vaginal births are possible. During pregnancy, the pubic symphysis and sacro-iliac joints are loosened by the actions of the hormone relaxin which is produced in the placenta and the ovary. Thus, the Conjugata vera is dilated by approximately 1 cm during parturition.

Hip bone

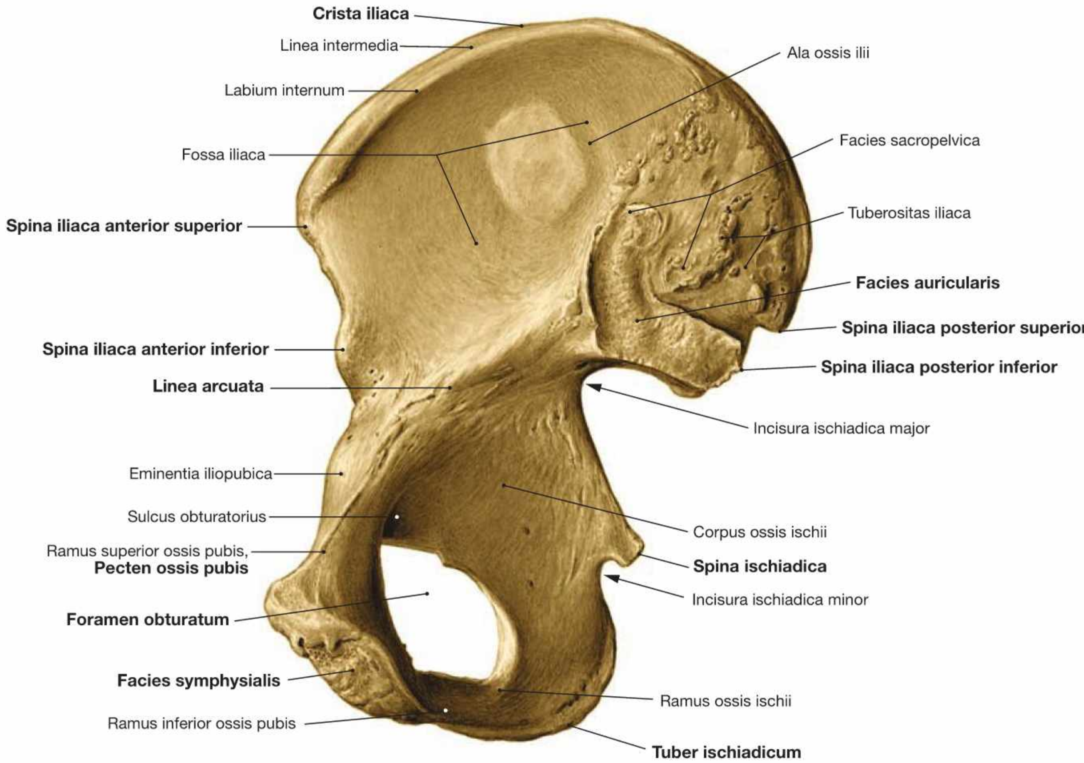


Fig. 4.10 Hip bone, Os coxae, right side; medial view.
The hip bone consists of three parts, the ilium **(Os ilium),** ischium **(Os ischium),** and pubis **(Os pubis).** The ilium forms the false pelvis, ischium and pubis form the bony ring around the obturator foramen from posterior and anterior, respectively. The **Facies auricularis** serves as articular surface for the sacro-iliac joint. The Discus interpubicus is attached to the **Facies symphysialis.**

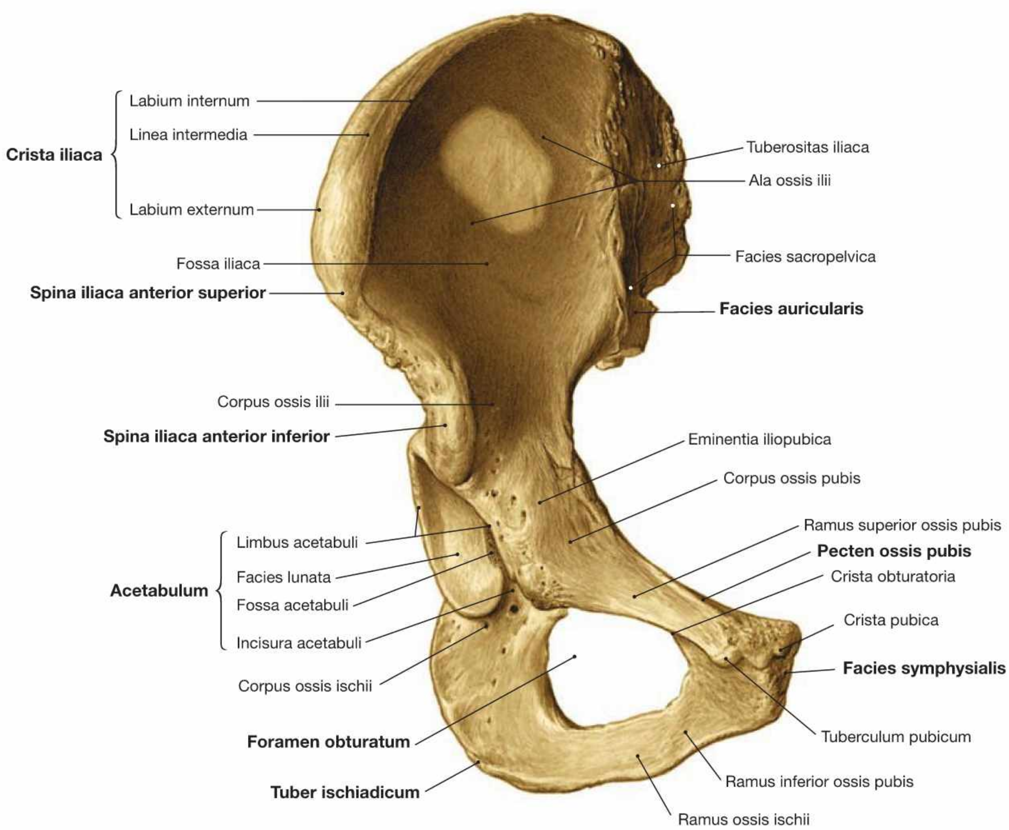


Fig. 4.11 Hip bone, Os coxae, right side; ventral view.

Hip bone

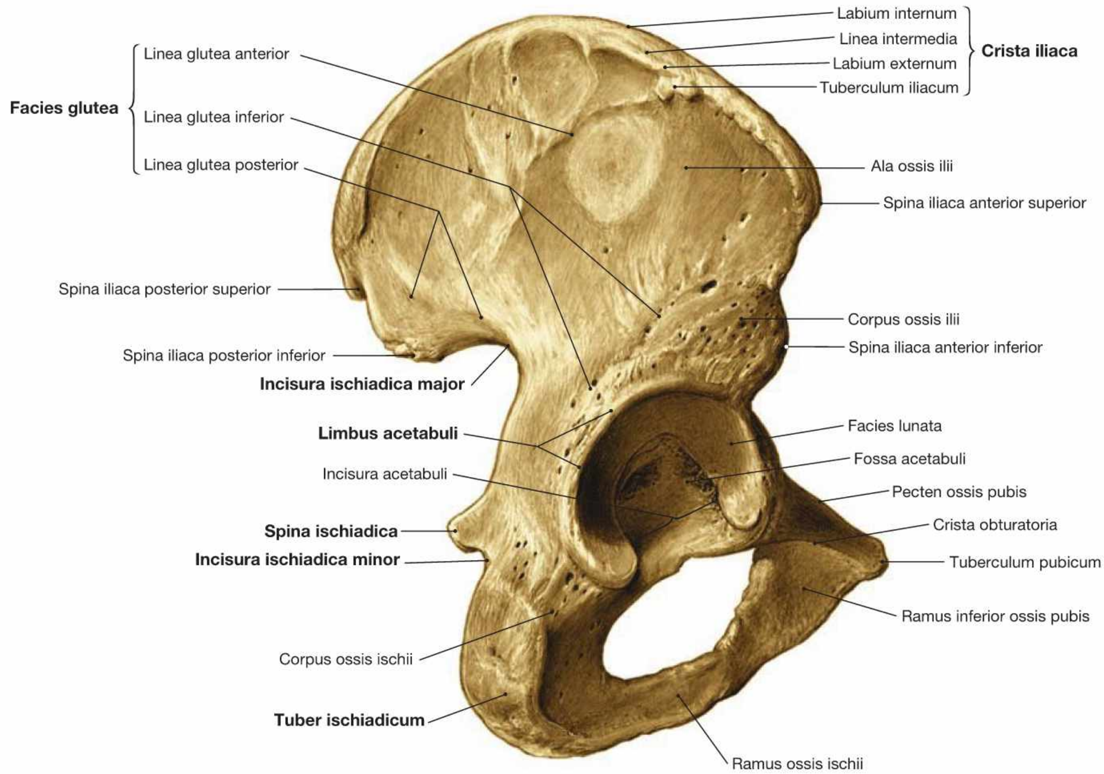


Fig. 4.12 Hip bone, Os coxae, right side; dorsolateral view.
All three parts of the hip bone, namely the ilium (Os ilium), the ischium (Os ischium) and the pubis (Os pubis), contribute to the formation of the acetabular fossa (Acetabulum).

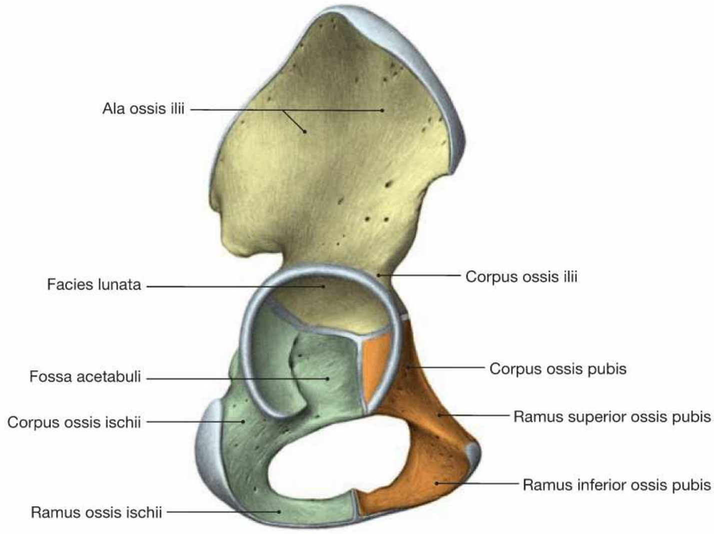


Fig. 4.13 Hip bone, Os coxae, of a 6-year-old child, right side; lateral view.
The three parts of the hip bone (Os ilium, Os ischium, Os pubis) are linked by a Y-shaped cartilaginous synchondrosis in the Acetabulum. This cartilaginous synchondrosis ossifies between the age of 13 to 18.

Clinical Remarks

With high-energy trauma and high impact on the stretched lower limbs, a fracture of the acetabular fossa may occur with dislocation of the femoral head (central fracture-dislocation of the hip).
The development of the juvenile hip bone with ossification of the cartilaginous synchondroses in the area of the Acetabulum needs to be considered for radiographic images in children and adolescents to avoid confusion of the cartilaginous synchondroses with an acetabular fracture cleft.

Thigh bone

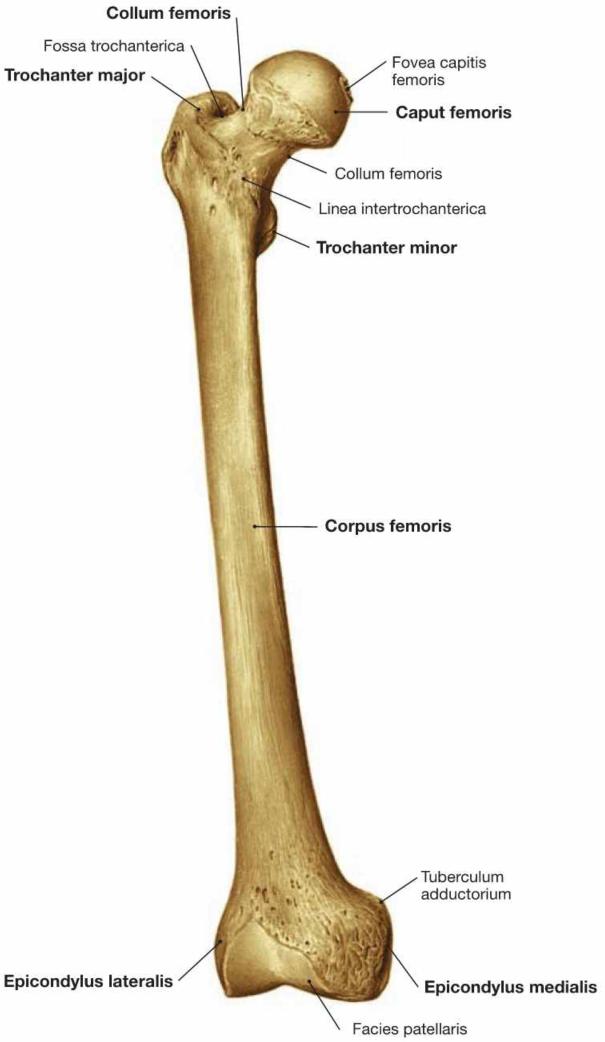


Fig. 4.14 Thigh bone, Femur, right side; ventral view.
Proximal at the femoral shaft the Trochanter major is positioned laterally and the Trochanter minor dorsomedially.

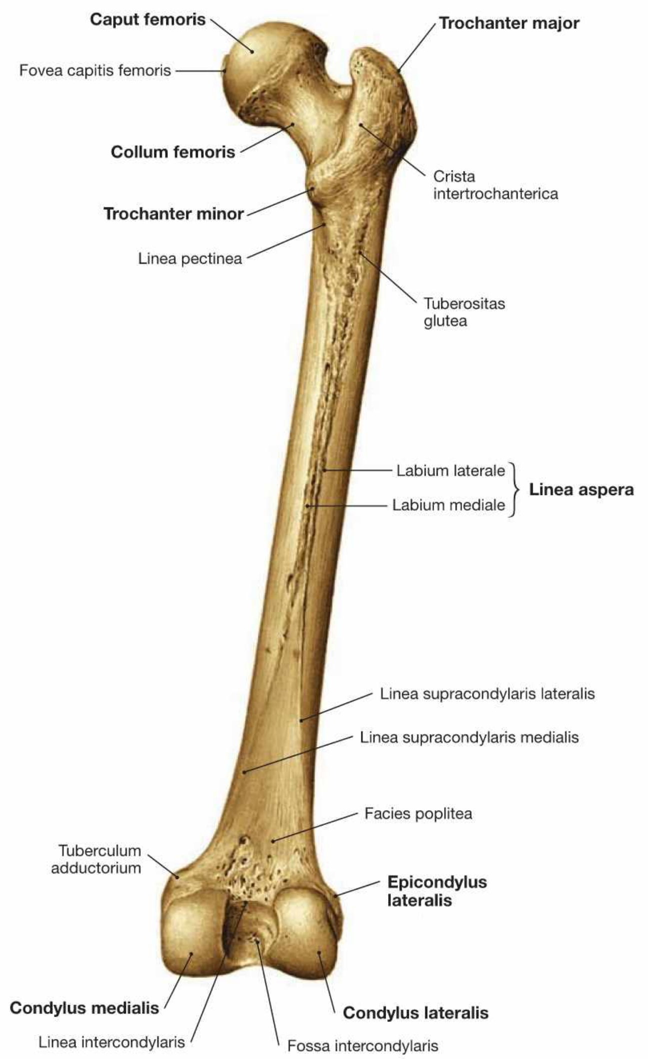


Fig. 4.15 Thigh bone, Femur, right side; dorsal view.
The Linea aspera serves as apophysis for the origin of the M. quadriceps femoris as well as for the insertion of several muscles of the adductor group.

Thigh bone

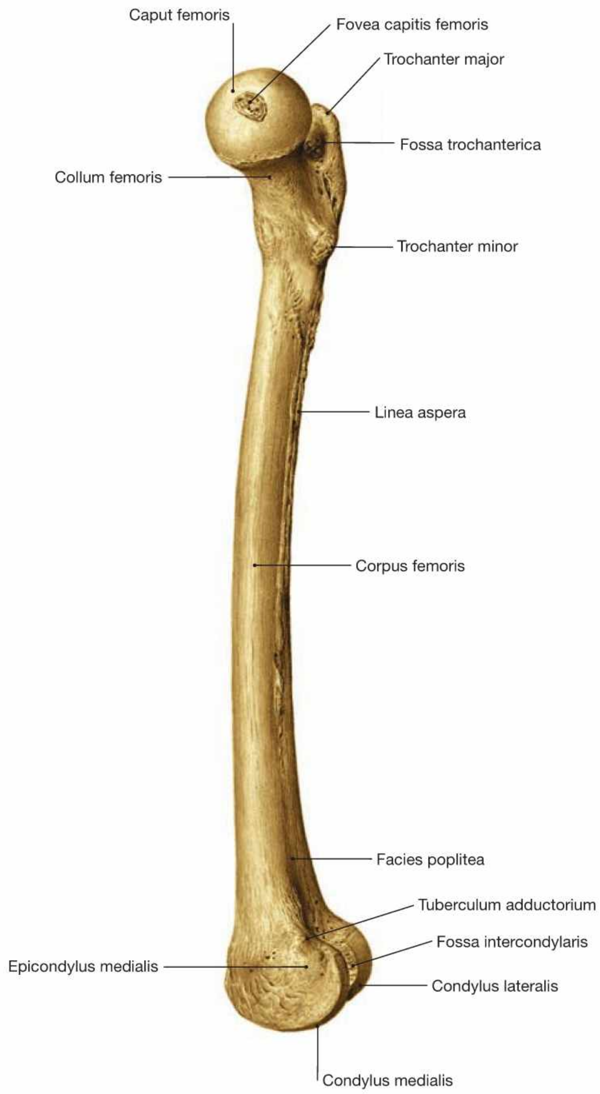


Fig. 4.16 Thigh bone, Femur, right side; medial view.

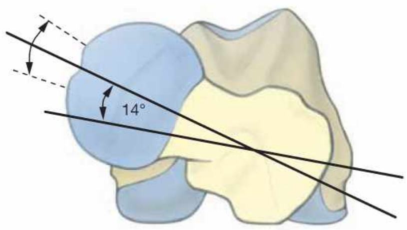


Fig. 4.17 Thigh bone, Femur, right side; proximal view; the proximal and distal ends of the femur are projected on top of each other.
The femoral neck is **rotated anteriorly** by **12–14°** against the axis connecting both femoral condyles (transverse axis of the femoral condyles). This is referred to as **torsion angle of the femur.** In infants, this angle is approximately 30º.
If the torsion angle of the femur is larger, the leg is medially rotated and the toes point inwards during walking. If the torsion angle of the femur is smaller than 12°, the toes point outwards.

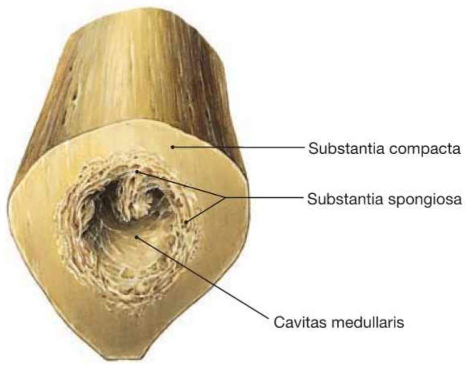


Fig. 4.18 Thigh bone, Femur, right side; cross-section of the femoral shaft at mid-level; distal view.
The outer layer of solid Substantia compacta is followed by an inner layer of Substantia spongiosa and the central medullary cavity (Cavitas medullaris) which contains the bone marrow.

Thigh bone

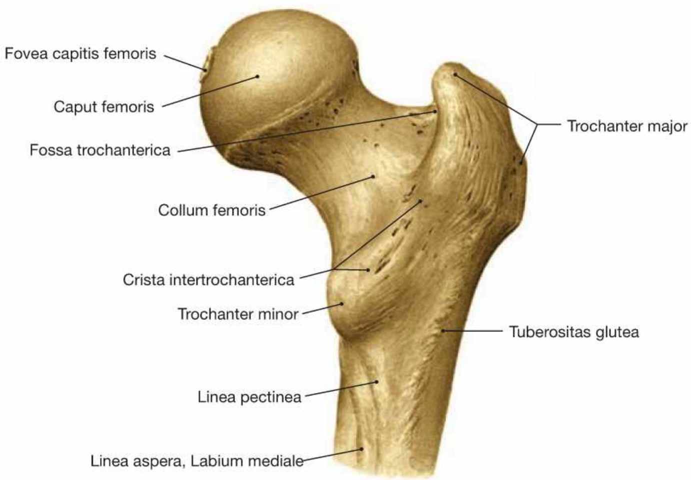


Fig. 4.19 Proximal end of the femur, Femur, right side; dorsal view.

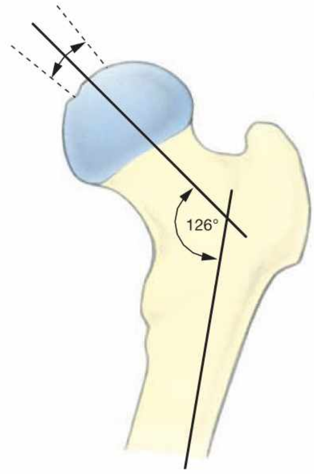


Fig. 4.20 Proximal end of the femur, Femur, right side, with illustration of the angle of inclination of the femur (neck-shaft angle)
The femoral neck forms an angle of **126°** with the femoral shaft. This angle is referred to as the caput-collum-diaphyseal angle or CCD angle. In the newborn, the CCD angle measures 150°. An **increased** CCD angle results in a **Coxa valga,** a **decreased** CCD angle causes a **Coxa vara.**

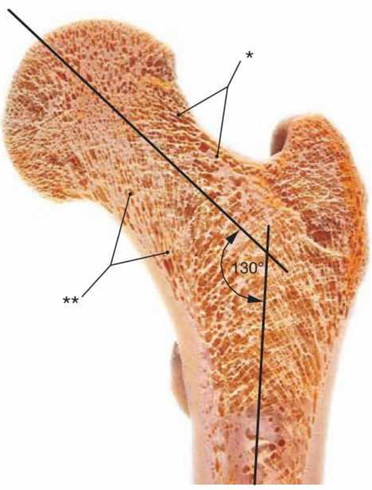


Fig. 4.21 Proximal end of the femur, Femur, right side, with illustration of the spongiosa structure in the case of an increased angle of inclination (neck-shaft angle) (Coxa valga). Section at the level of the torsion angle of the femur.
The **spongiosa trabeculae** are **trajectorial,** i.e. they align with the lines of maximal traction and compression forces (the so-called trajectories). Coxa valga causes higher **compression** forces and leads to a reinforcement of the medial spongiosa trabeculae (**) and at the same time to a reduction of the lateral spongiosa trabeculae (*).

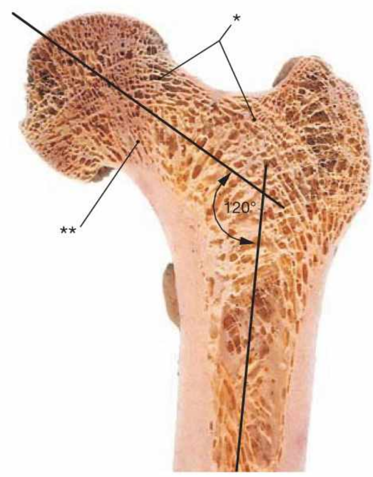


Fig. 4.22 Proximal end of the femur, Femur, right side, with illustration of the spongiosa structure in the case of a decreased angle of inclination (neck-shaft angle) (Coxa vara). Section at the level of the torsion angle of the femur.
In Coxa vara, increased **traction forces** cause a reinforcement of the lateral spongiosa trabeculae (*) and at the same time a reduction of the medial spongiosa trabeculae (**). As a result of an increased **bending stress,** the corticalis at the inner side of the femoral neck is thickened.

Clinical Remarks

Alterations of the caput-collum-diaphyseal (CCD) angle may restrict movements. In Coxa vara, reduced abduction is found. Changes in the forces acting on the articular surfaces of the joint such as in **Coxa valga** or **Coxa vara** may cause an increased attrition resulting in arthrosis of the hip joint **(coxarthrosis)** or the knee joint **(gonarthrosis).** In addition, **Coxa vara** predisposes to **fractures of the femoral neck** due to the increased bending stress.

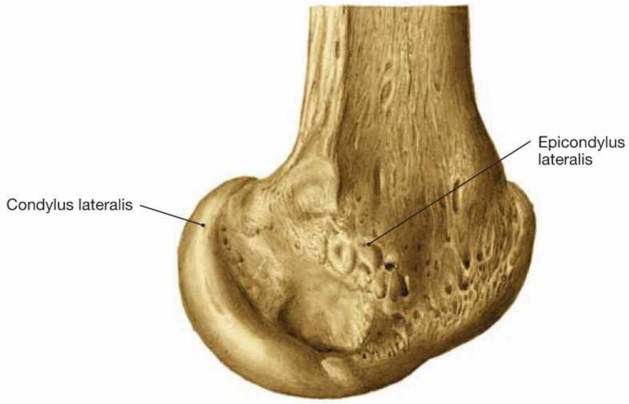


Fig. 4.23 Distal end of the femur, Femur, right side; lateral view.
To understand the flexion-extension movement in the knee joint (→ Fig. 4.69) knowledge about the articular surfaces of the femoral condyles is important. In relation to the axis of the femoral shaft the articular surfaces are positioned dorsally **(retroposition).** In addition, the **curvature** of the femoral condyles is more pronounced posteriorly (smaller radius of curvature) than anteriorly (larger radius of curvature) resulting in a **spiral curvature.** This phenomenon is more distinct in the medial than in the lateral condyle (→ Fig. 4.100).

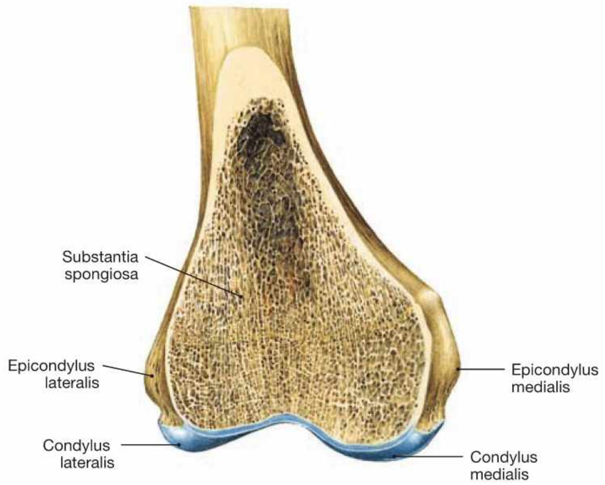


Fig. 4.24 Distal end of the femur, Femur, right side; frontal section at the level of the joint bodies; ventral view.

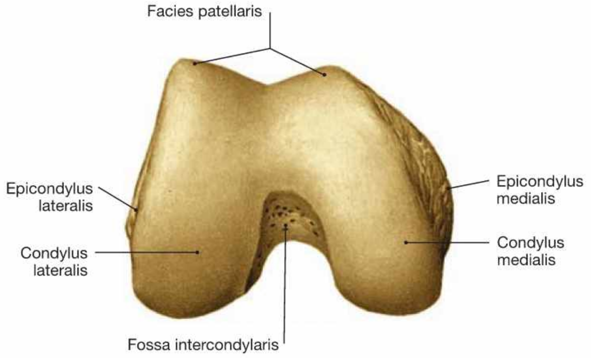


Fig. 4.25 Distal end of the femur, Femur, right side; distal view.

Clinical Remarks

Since degenerative diseases of the knee joints **(gonarthrosis)** are common and frequently require prosthetic surgery (**total knee replacement,** TKR), the knowledge of the anatomy of both articulating bones is of utmost importance. Recent studies have shown that the radius of curvature and the shape of the articular surfaces different on either side of the joint. Thus, knee joint prosthetic surgery aims at constructing articular surfaces with the closest possible similarity in shape to facilitate the natural movements of a healthy knee.

Tibia

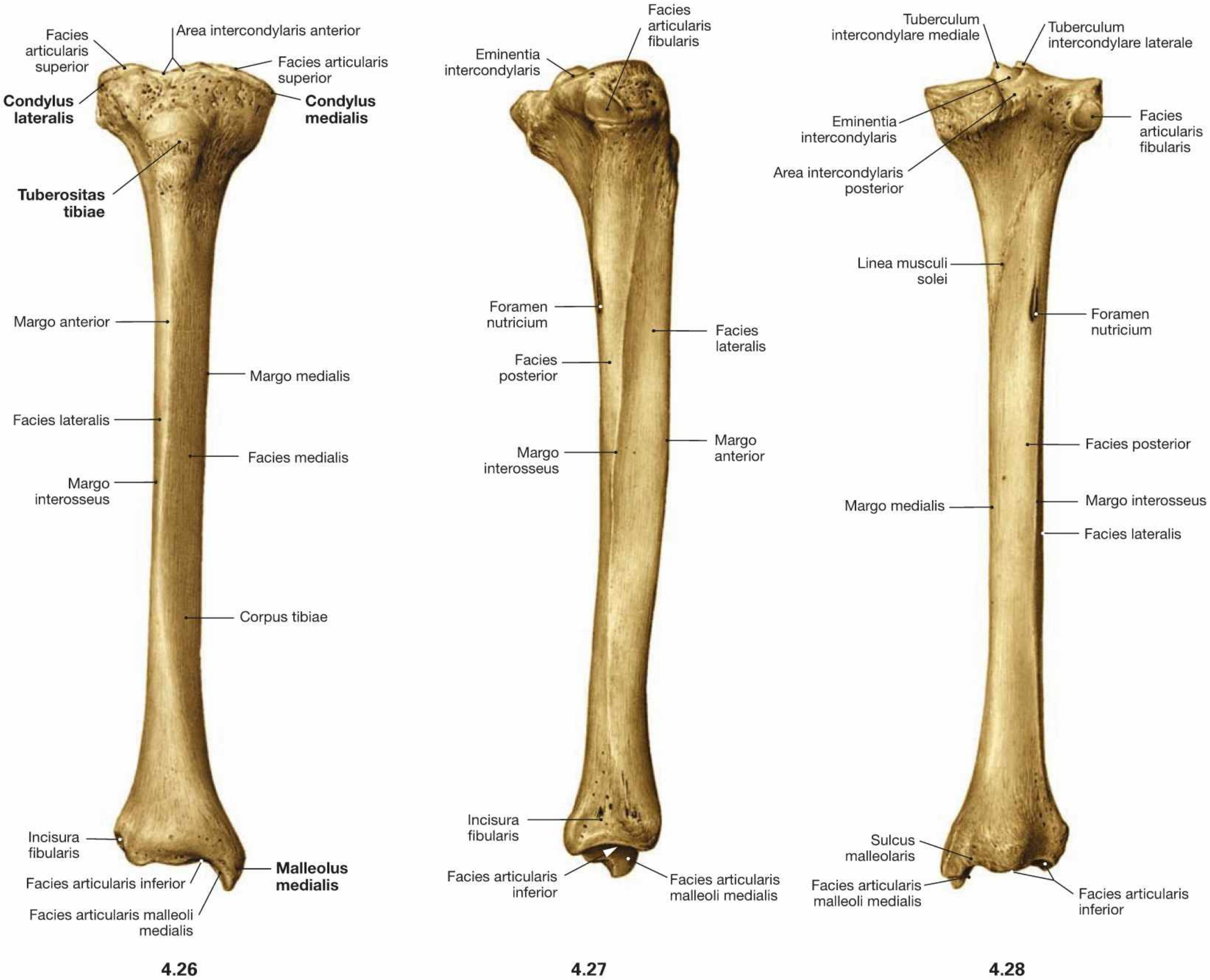


Fig. 4.26 to Fig. 4.28 Tibia, Tibia, right side; ventral (→ Fig. 4.26), lateral (→ Fig. 4.27), and dorsal (→ Fig. 4.28) views.
The proximal articular surface is shifted dorsally from the axis of the tibial shaft **(retroposition).** In addition, the articular surface is tilted dorsally by 3°–7° **(retroversion).** The retroversion is more pronounced at the medial condyle than at the lateral condyle and is here especially distinct at the medial rim of the articular surface.

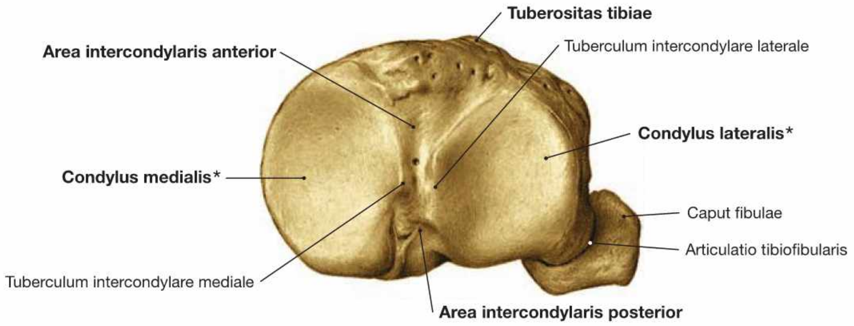
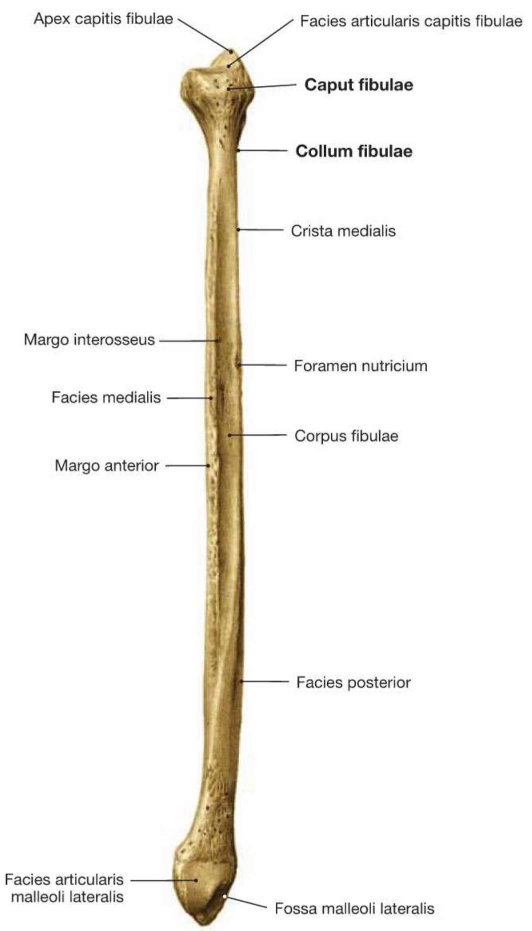
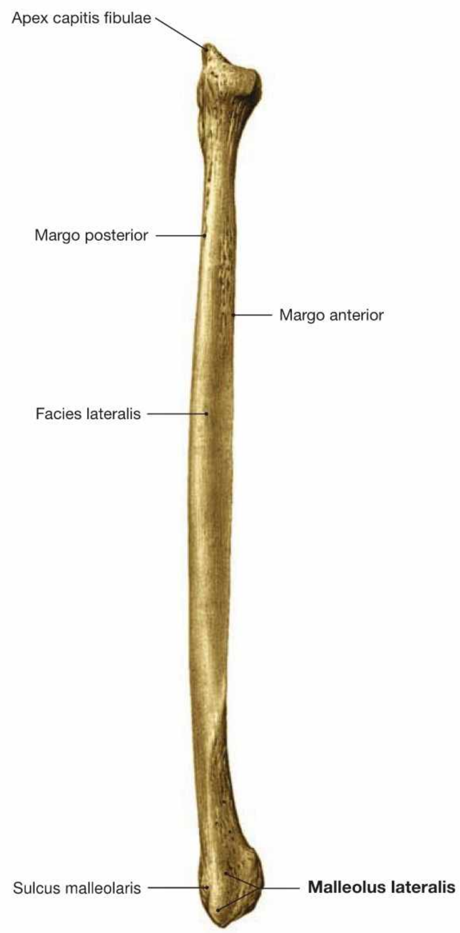


Fig. 4.29 Tibia, Tibia, and fibula, Fibula, right side; proximal view.
The articular surfaces of the condyles (*) are collectively referred to as **Facies articularis superior.**

Fibula



4.30



4.31

Fig. 4.30 and Fig. 4.31 Fibula, Fibula, right side; medial (→ Fig. 4.30) and lateral (→ Fig. 4.31) views.
When positioning an isolated fibula, orientation is given by the fact that the articular surfaces of the fibular head and of the malleus both point medially.

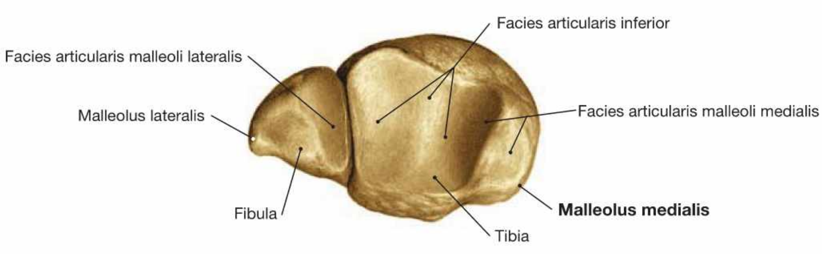


Fig. 4.32 Tibia, Tibia, and fibula, Fibula, right side; distal view.

Skeleton of the foot

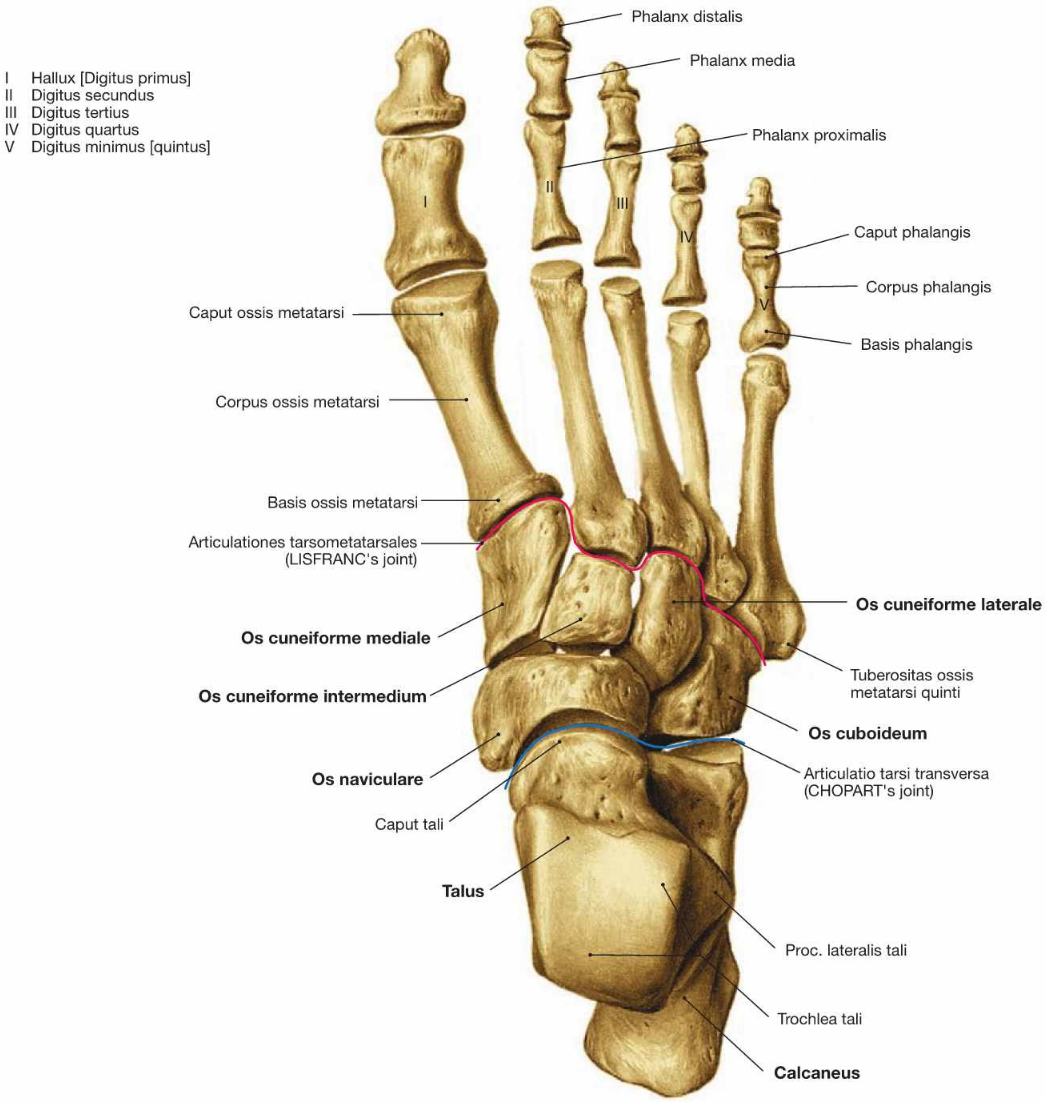


Fig. 4.33 Skeleton of the foot, Ossa pedis, right side; dorsal view. The foot (Pes) is organised in **Tarsus** with Ossa tarsi, **Metatarsus** with Ossa metatarsi, and toes **(Digiti)** which consist of several phalanges. The Tarsus comprises the Talus, the Calcaneus, the navicular (Os naviculare), the cuboid (Os cuboideum), and the three cuneiform bones (Ossa cuneiformia). Clinically, the forefoot is distinguished from the hindfoot. Both are separated by the articular line in the Articulationes tarsometatarsales.

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 perfusion deficits with tissue necrosis. In rare occasions, **luxations** may occur in these joints.

Skeleton of the foot

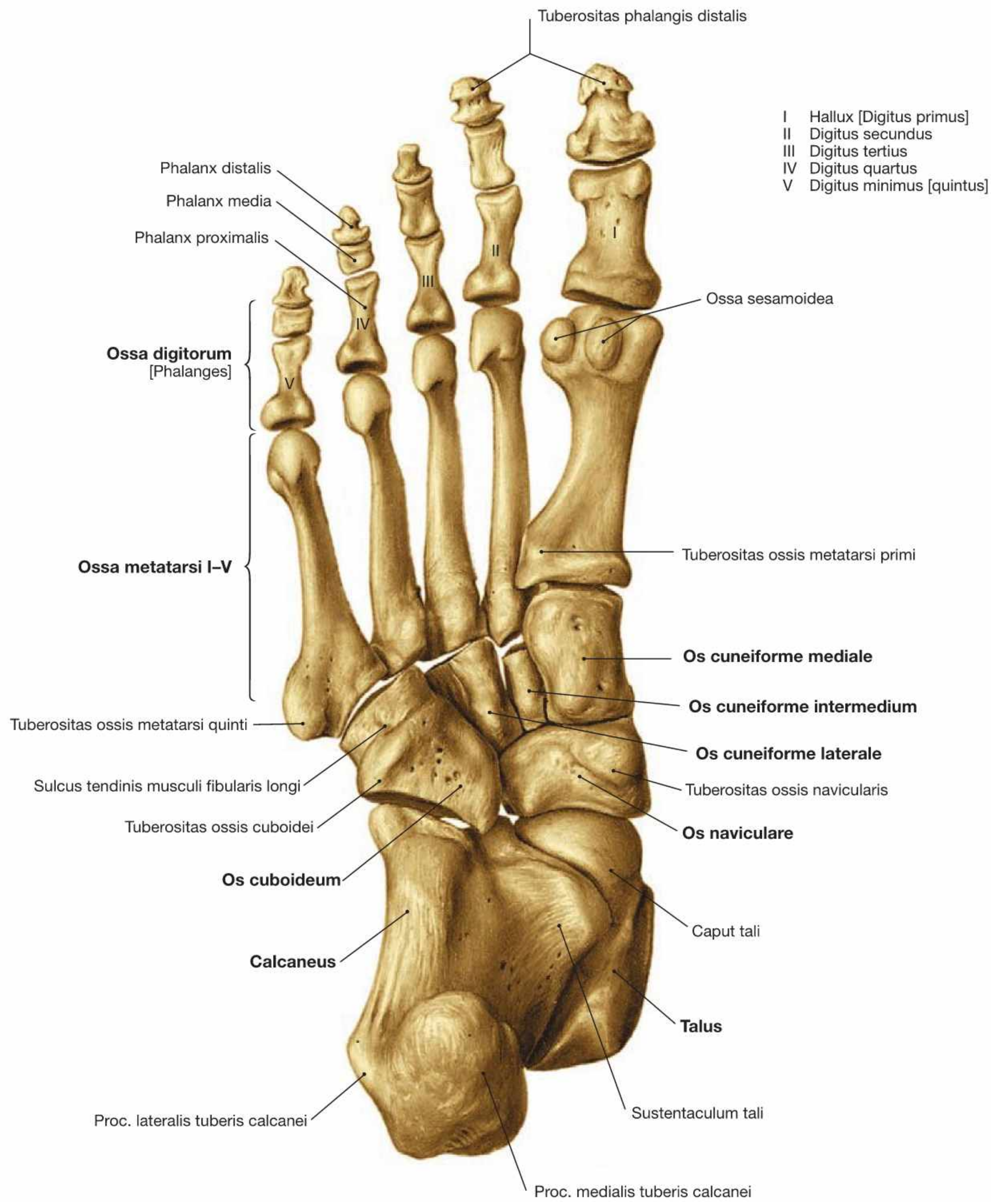
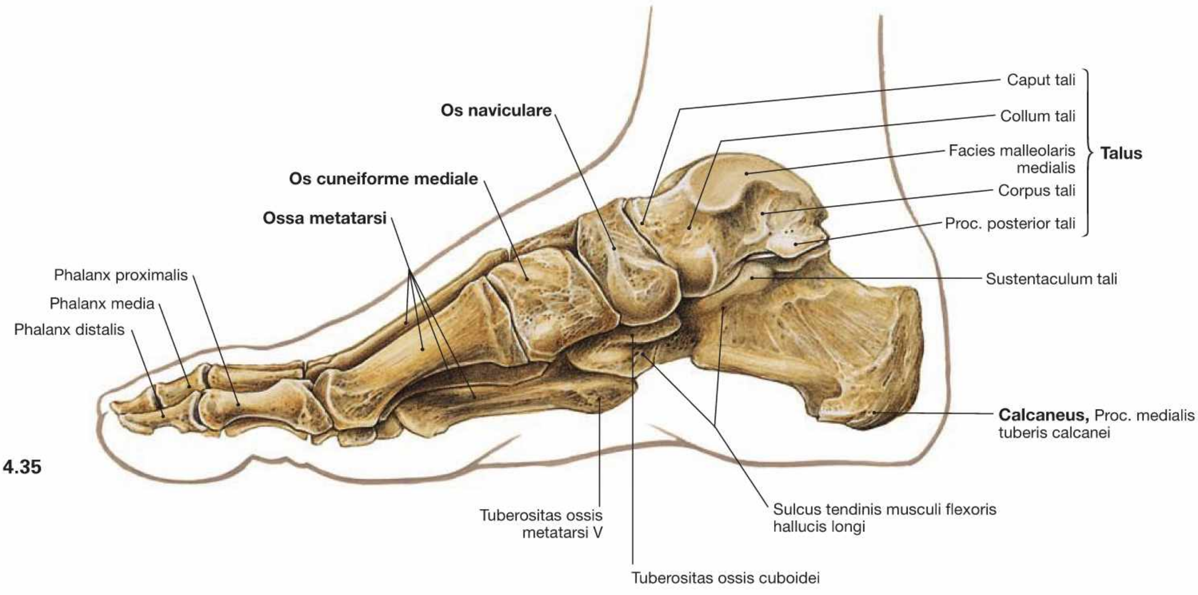


Fig. 4.34 Skeleton of the foot, Ossa pedis, right side; plantar view.

Skeleton of the foot



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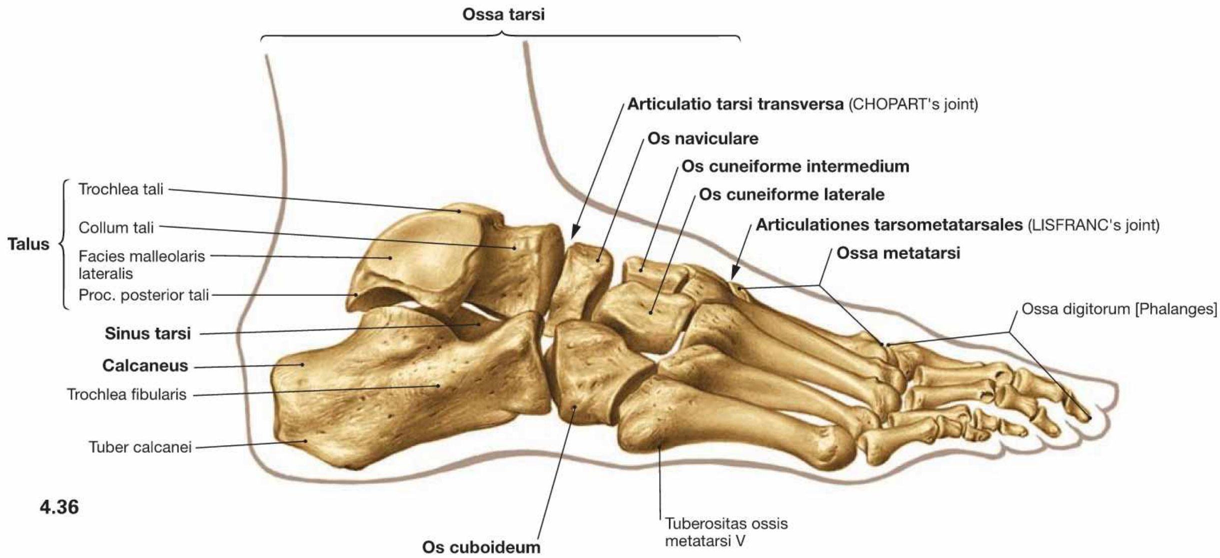
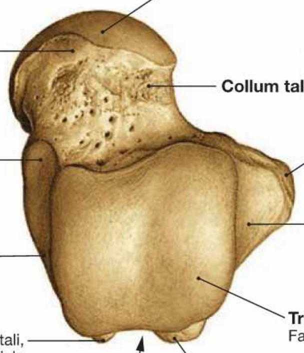


4.36

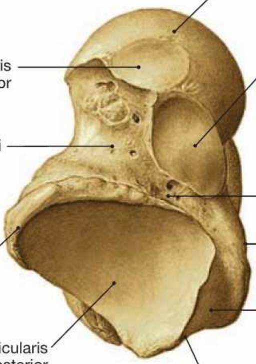
Fig. 4.35 and Fig. 4.36 Skeleton of the foot, Ossa pedis, right side; medial (→ Fig. 4.35) and lateral (→ Fig. 4.36) views.

The Sinus tarsi is a hollow space which is formed by the Sulcus tali and the Sulcus calcanei.

Talus and calcaneus

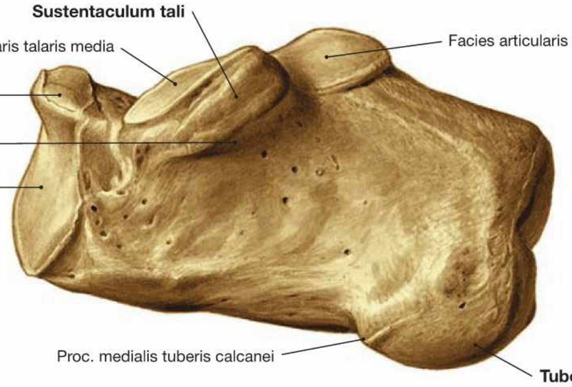


4.37



4.38

Fig. 4.37 and Fig. 4.38 Talus, Talus, right side; dorsal (→ Fig. 4.37) and plantar views (→ Fig. 4.38).
The trochlea is broader at its posterior aspect than at its anterior aspect.



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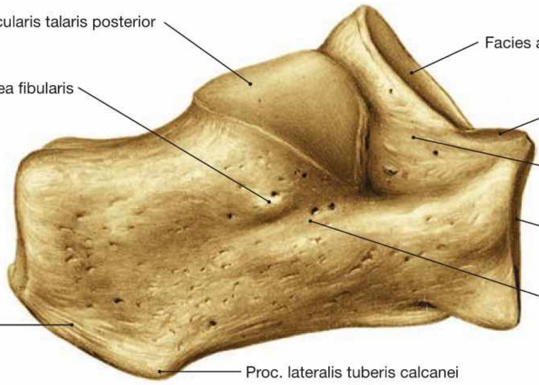
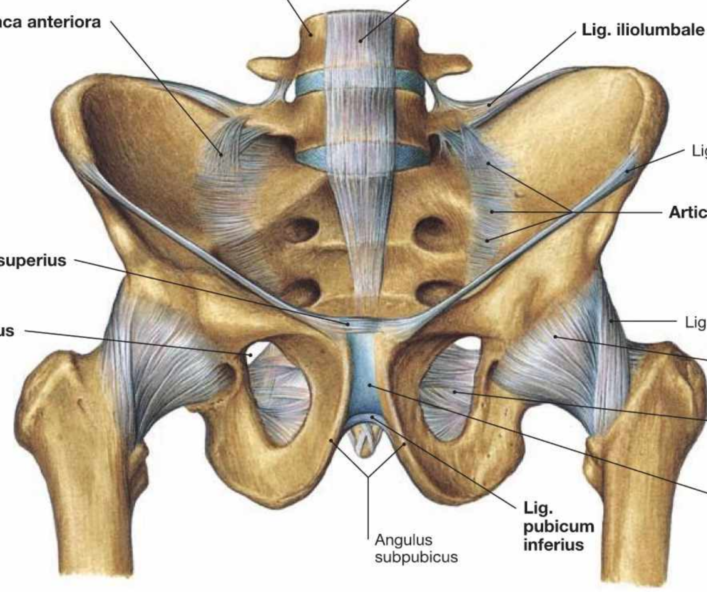


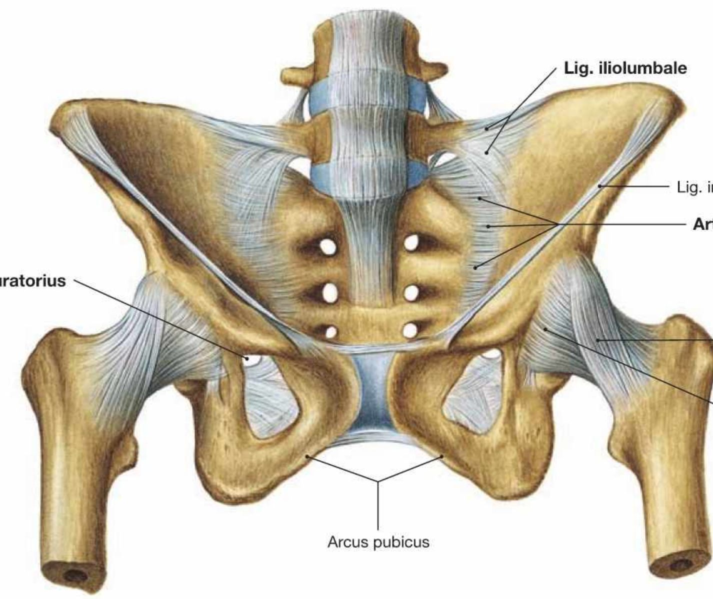
4.40

Fig. 4.39 and Fig. 4.40 Calcaneus, Calcaneus, right side; medial (→ Fig. 4.39) and lateral views (→ Fig. 4.40).

Ligaments of the pelvis



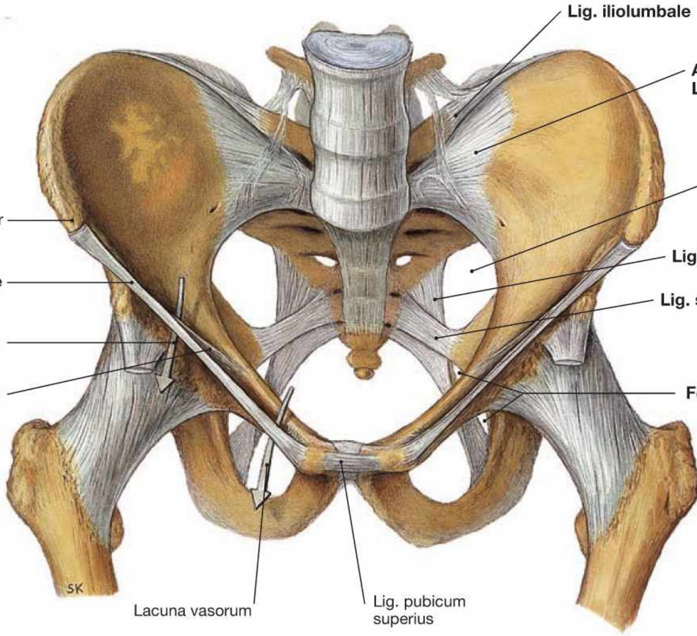
4.41



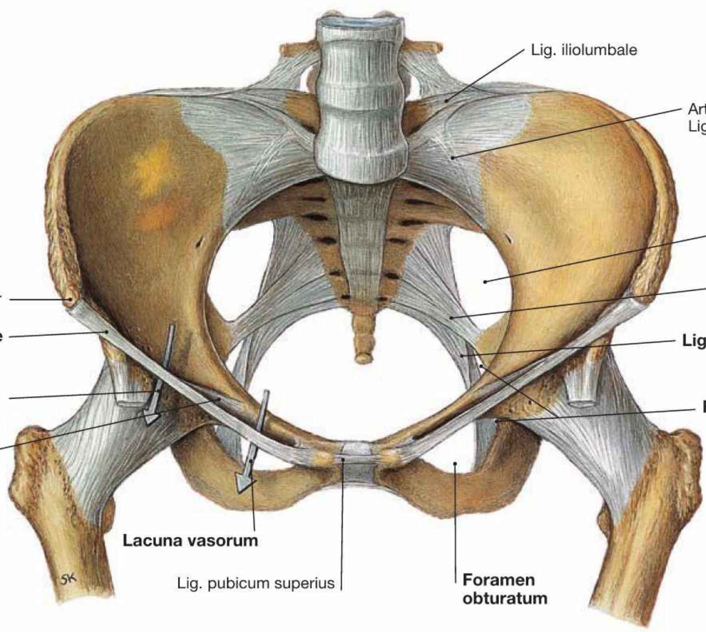
4.42

Fig. 4.41 and Fig. 4.42 Joints and ligaments of the male (→ Fig. 4.41) and the female pelvis (→ Fig. 4.42); ventral view.
The pelvic girdle (Cingulum pelvicum) is a ring-shaped bony construction created by both the dorsal amphiarthroses of the sacro-iliac joints **(Articulationes sacroiliacae)** and by the ventrally located pubic symphysis **(Symphysis pubica).** Each sacro-iliac joint is stabilised by the **Ligg. sacroiliaca anteriores** ventrally, and by the **Lig. iliolumbale** superiorly. The latter connects the Proc. costalis of the lumbar vertebrae IV and V with the Crista iliaca. These strong ligaments only allow small tilting movements of the pelvis of about 10°.
The pubic symphysis is bridged superiorly by the **Lig. pubicum superius,** and inferiorly by the **Lig. pubicum inferius.**
In both sexes the Foramen obturatum is almost completely closed by the **Membrana obturatoria** which only leaves the **Canalis obturatorius** as a passageway for the neurovascular bundles to the inner side of the thigh (A./V. obturatoria, N. obturatorius).

Ligaments of the pelvis



4.43

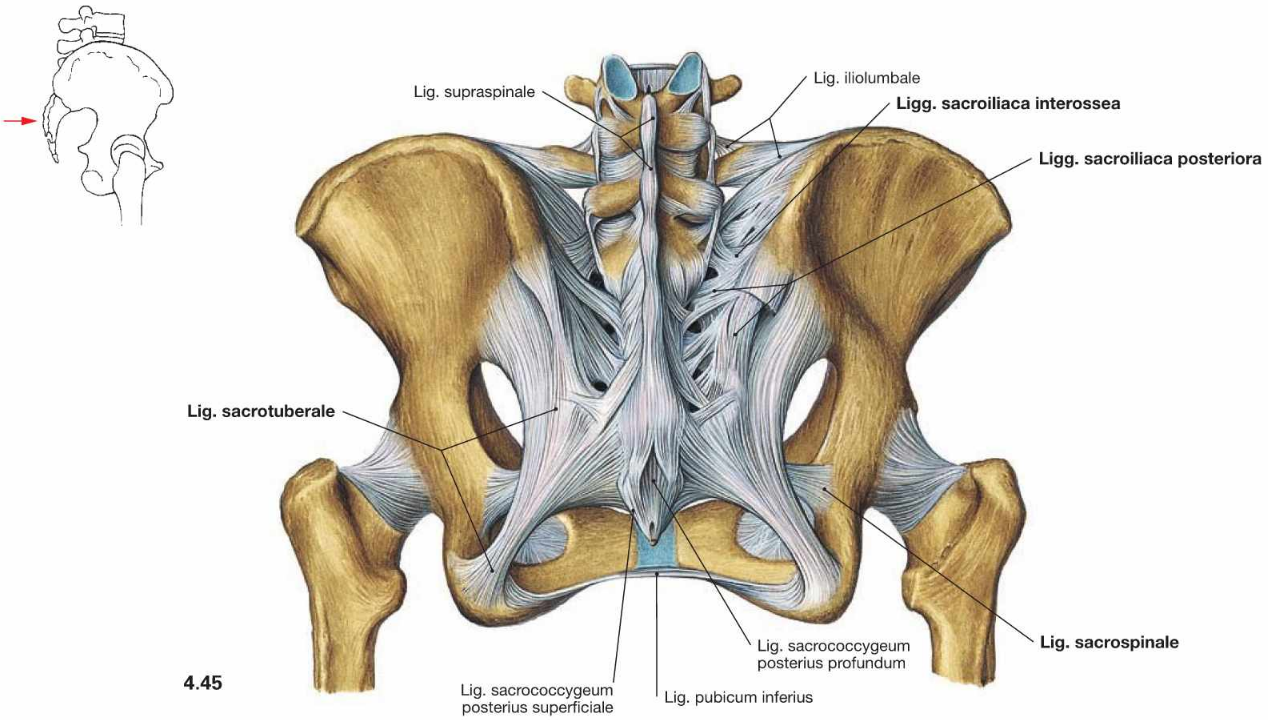


4.44

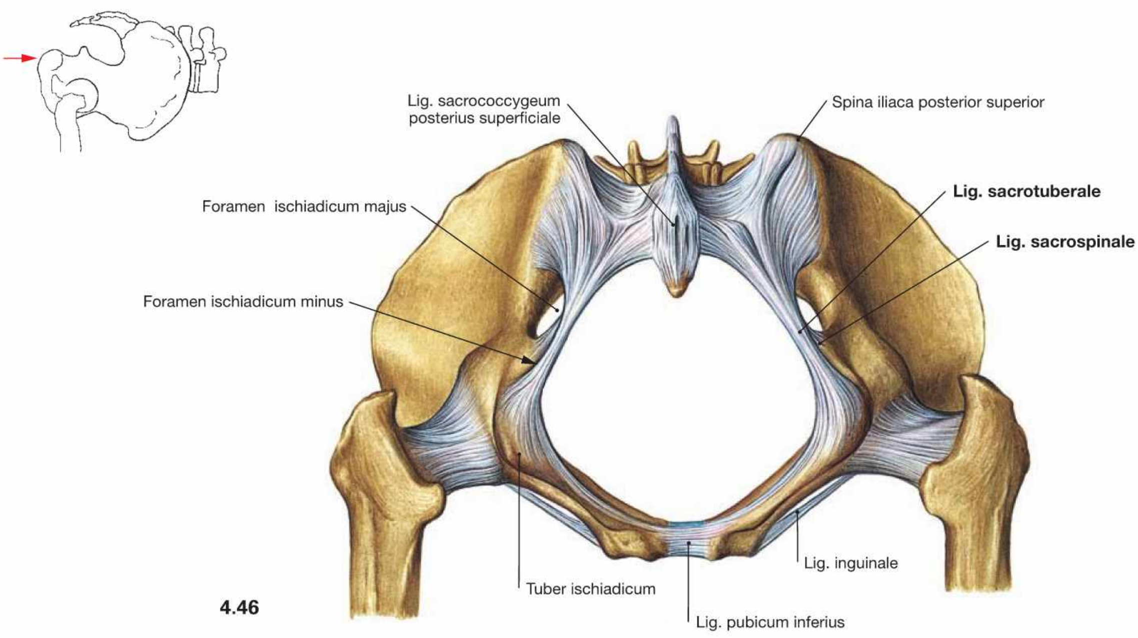
Fig. 4.43 and Fig. 4.44 Joints and ligaments of the male (→ Fig. 4.43) and the female pelvis (→ Fig. 4.44); ventral cranial view.

The almost horizontally oriented Lig. sacrospinale connects the sacrum with the Spina ischiadica, dorsal of which the Lig. sacrotuberale courses obliquely to the Tuber ischiadicum. Both ligaments complement the Incisura ischiadica major and minor to form the **Foramen ischiadicum majus** and **minus.** These openings constitute important passageways for blood vessels and nerves of the Plexus sacralis to the gluteal region (Regio glutealis). The space beneath the inguinal ligament (Lig. inguinale) is divided by the Arcus iliopectineus into the lateral Lacuna musculorum and the medial Lacuna vasorum (→ Fig. 4.177) through which the neurovascular structures course to the anterior side of the thigh.

Ligaments of the pelvis



4.45

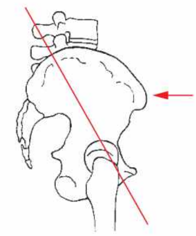


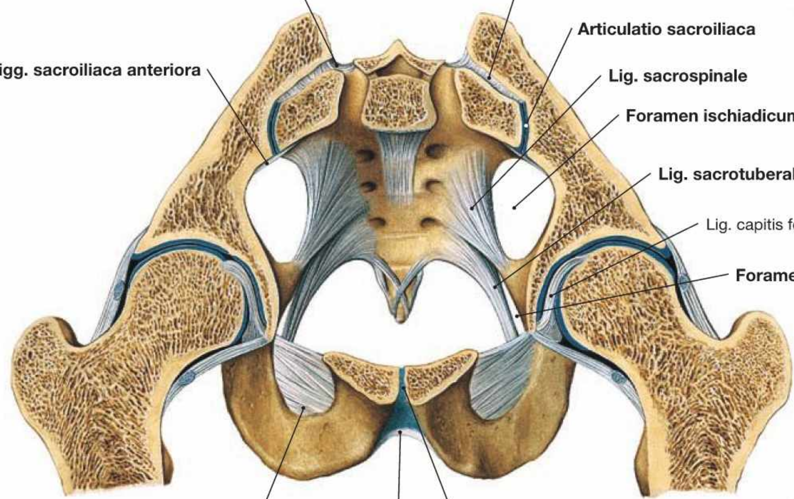
4.46

Fig. 4.45 and Fig. 4.46 Joints and ligaments of the female pelvis; dorsal (→ Fig. 4.45) and caudal views (→ Fig. 4.46).
On the dorsal side, the sacro-iliac joint is stabilised by the **Ligg. sacro-iliaca posteriora** and **interossea.** Due to the strong ligaments on the posterior side of the pelvis, only small tilting movements of up to 10° are possible.

The almost horizontally oriented **Lig. sacrospinale** connects the sacrum with the Spina ischiadica, dorsal of which the **Lig. sacrotuberale** courses obliquely to the Tuber ischiadicum. Both ligaments confine the **Foramina ischiadica majus** and **minus** as passageways for blood vessels and nerves of the Plexus sacralis to the gluteal region.

Ligaments of the pelvis





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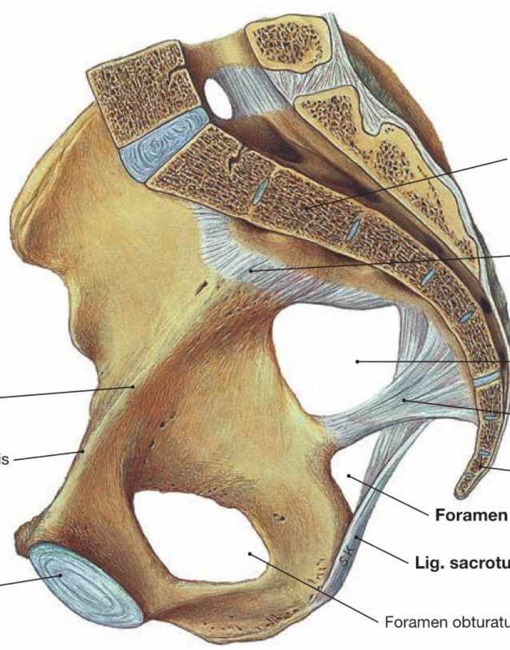


4.48

Fig. 4.47 and Fig. 4.48 Joints and ligaments of the female pelvis; oblique transverse section; ventral caudal view (→ Fig. 4.47) and median section; view from the left side (→ Fig. 4.48).
Illustrated is the sacro-iliac joint with its ligaments (**Ligg. sacroiliaca anteriora, posteriora,** and **interossea** as well as the **Lig. sacrospinale,** and **Lig. sacrotuberale**). The **Lig. iliolumbale** is not visible. The Lig. sacrospinale and Lig. sacrotuberale confine the **Foramina ischiadica majus** and **minus** as passageways for blood vessels and nerves of the Plexus sacralis to the gluteal region.

Ligaments of the pelvis

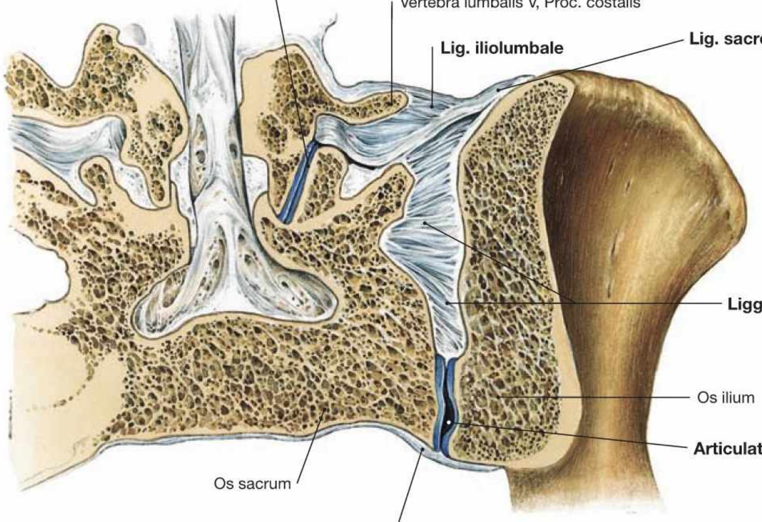
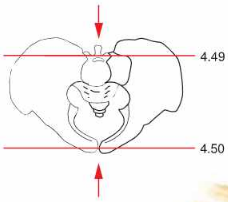


Fig. 4.49 Sacro-iliac joint, Articulatio sacroiliaca; frontal section; dorsal view.

These strong ligaments, of which the **Ligg. sacroiliaca anteriora** and **interossea** and **Lig. iliolumbale** are visible here, stabilise the sacro-iliac joint and enable the transmission of weight from the trunk to the pelvic girdle. In particular, the dorsal **Ligg. sacroiliaca interossea** and **posteriora** broadly connect the Sacrum and Ilium.



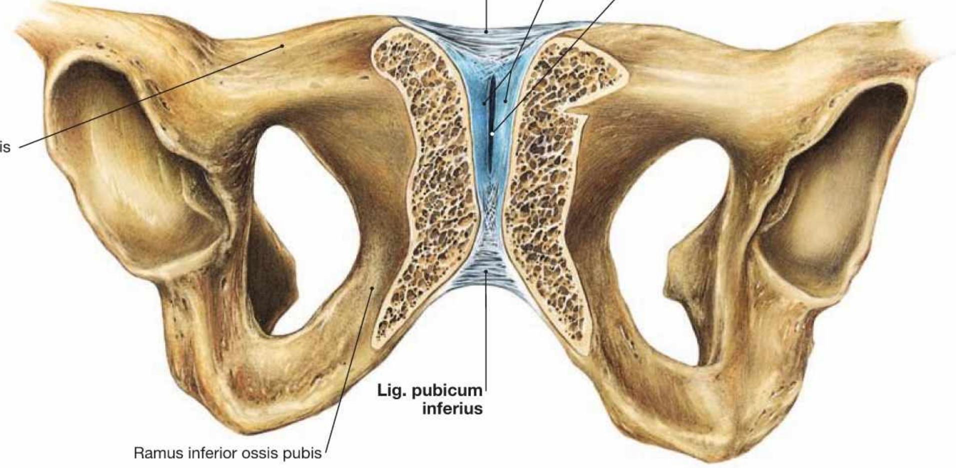


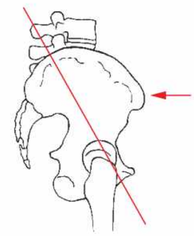
Fig. 4.50 Pubic symphysis, Symphysis pubica; oblique section; ventral caudal view.

The connection of the pubic bones is a symphysis. The **Discus interpubicus** consists of fibrous cartilage; only the surface area to the Facies symphysiales of both pubic bones consists of hyaline cartilage. Following the first decade of life, an oblong gap frequently forms (Cavitas symphysialis). This gap of the joint is bridged superiorly by the **Lig. pubicum superius** and inferiorly by the **Lig. pubicum inferius.**

Clinical Remarks

Pain in the sacro-iliac joint may be caused by **injuries, degenerative conditions**, or rheumatic diseases which in part preferentially affect this joint (BEKHTEREV's disease). Since the sacro-iliac joint is innervated directly by branches of the sacral plexus, pain may radiate into the leg (→ p. 326).

Hip joint



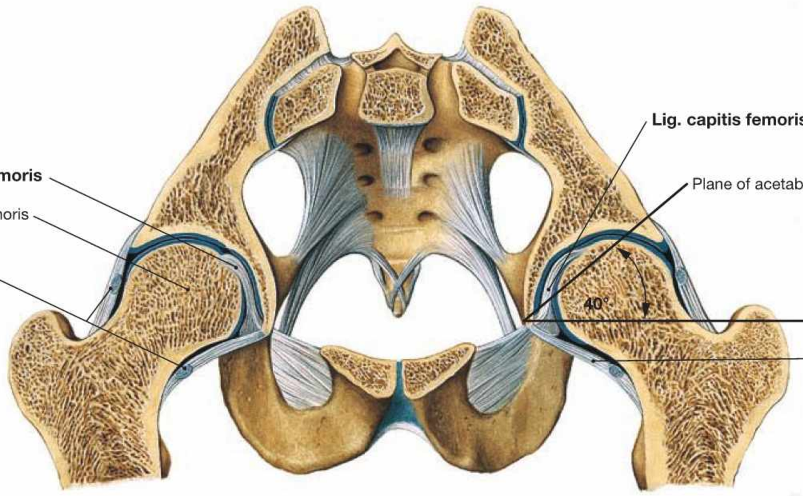
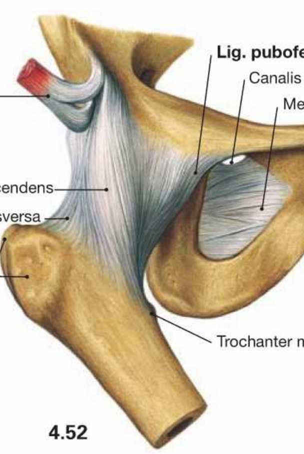


Fig. 4.51 Hip joints, Articulationes coxae; oblique transverse section; ventral cranial view.

In the hip joint, the Acetabulum of the hip bone 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 **cotyloid joint** (Articulatio cotylica, enarthrosis). The **angle** between the plane of the **acetabular rim** and the transverse (axial) plane is **40°.** The hip joint transfers the whole body weight onto the lower extremities. 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** which ligaments of the capsule also join. The Lig. capitis femoris lacks a mechanical function.



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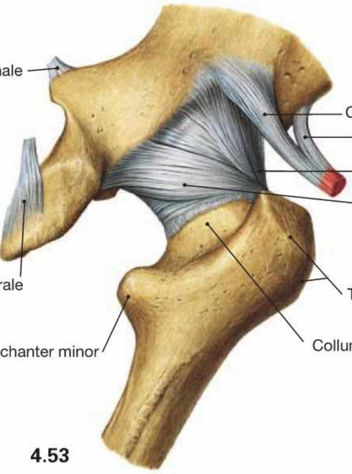


4.53

Fig. 4.52 and Fig. 4.53 Hip joint, Articulatio coxae, right side; ventral (→ Fig. 4.52) and dorsal (→ Fig. 4.53) views.

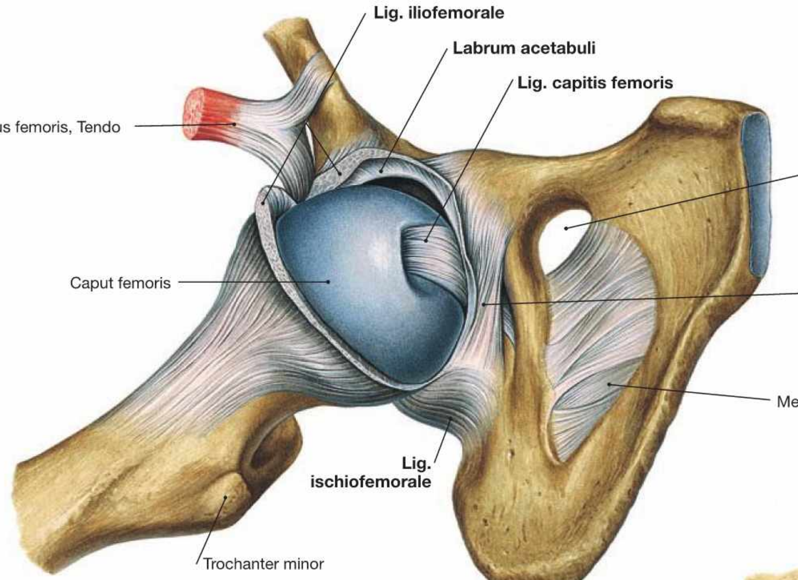
There are three major ligaments of the hip joint which surround the femoral head in a spiral manner. Their principle function is to limit the range of hip extension and to prevent the backward tilting of the pelvis:

- **Lig. iliofemorale** (anterior and superior): inhibits extension and adduction and, thus, supports the small gluteal muscles
- **Lig. pubofemorale** (anterior and inferior): inhibits extension, abduction, and lateral rotation
- **Lig. ischiofemorale** (posterior): inhibits extension, medial rotation, and adduction

Clinical Remarks

Orthopaedic studies have shown that position and shape of the Acetabulum and the femoral head are important factors in degenerative changes of the hip joint **(coxarthrosis).** Premature degenerative changes may be induced by a flattened roof of the joint **(hip dysplasia)** which shows a smaller than usual **angle** between the **acetabular rim** and the horizontal plane as well as by a larger than usual roof of the hip joint. A larger roof of the hip joint may be caused by an anteriorly extended acetabular rim in cases of a dorsally tilted Acetabulum **(retroversion of the Acetabulum)**, or if the articular surface is located very deep in the Acetabulum **(Coxa profunda).**

Hip joint



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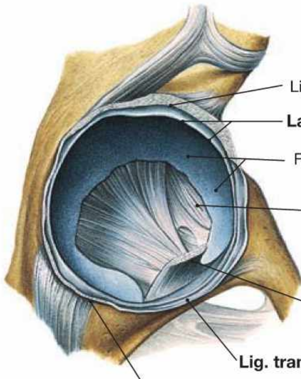
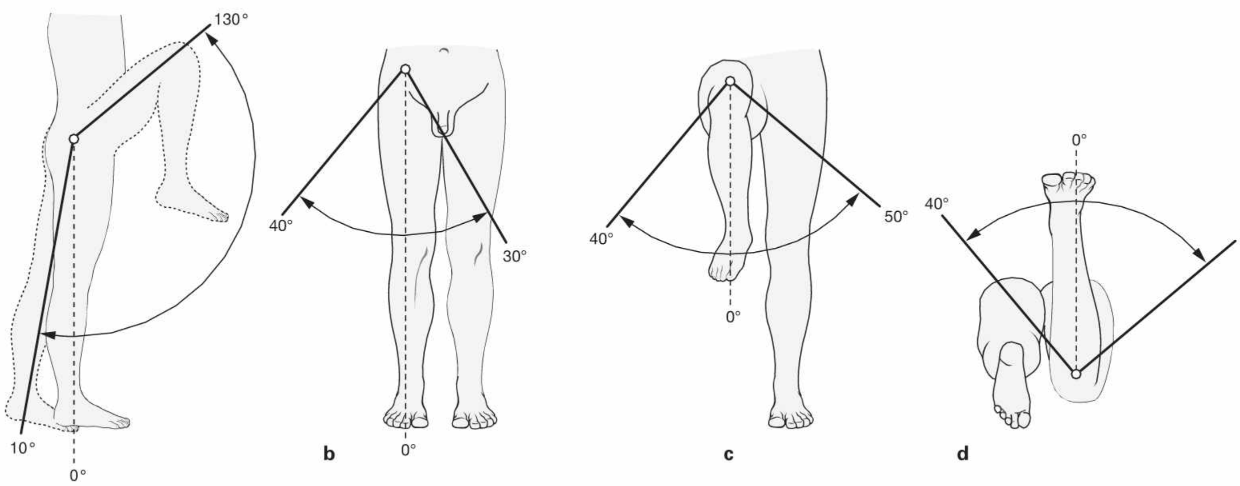


4.55

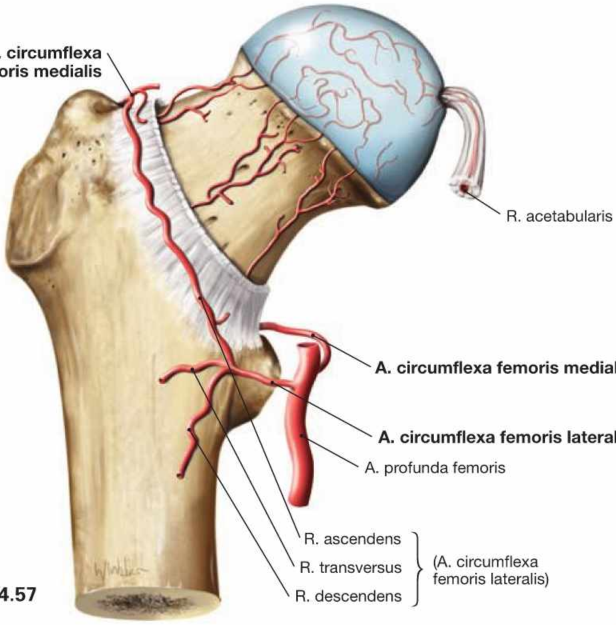
Fig. 4.54 and Fig. 4.55 Hip joint, Articulatio coxae, right side; ventral view; after opening of the capsule and partial (→ Fig. 4.54) or complete (→ Fig. 4.55) exarticulation of the femoral head.
Besides the external ligaments **(Lig. iliofemorale, Lig. pubofemorale, Lig. ischiofemorale)** the internally located **Lig. capitis femoris** is visible which lacks mechanical function in the joint. The **Lig. transversum acetabuli** inferiorly closes the Acetabulum, and together with the **Labrum acetabuli**, which also consists of fibrous connective tissue, it serves to guide the femoral head.



Figs. 4.56a to d Range of movement in the hip joint, Articulatio coxae. (according to [1])
The hip joint is an enarthrosis (Articulatio cotylica) which as a ball-and-socket joint possesses three axes of movement. All axes pass through the centre of the femoral head. The range of movement is limited by the strict guidance of the Acetabulum and the strong ligaments. All ligaments together restrict extension (retroversion) by enclosing the femoral head like a spiral ligamentous screw, thus enabling a stable upright position. Important for walking, the flexion (anteversion) is possible to a much higher degree and exclusively limited by soft tissues. In addition, medial and lateral rotation as well as adduction and abduction are limited by ligaments.

Range of movement:
a extension–flexion: 10°– 0°–130°
b abduction–adduction: 40°– 0°– 30°
c and **d** lateral rotation–medial rotation: 50°– 0°– 40°

Blood supply of the hip joint



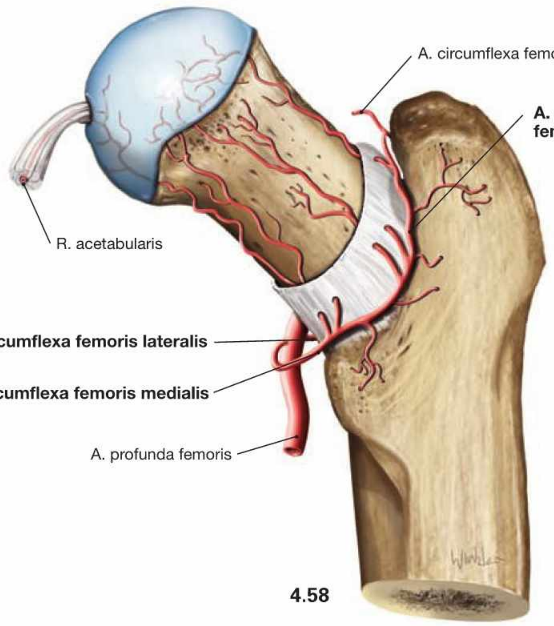
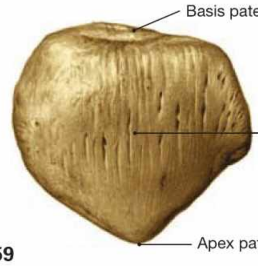


Fig. 4.57 and Fig. 4.58 Blood supply of the hip joint, right side; ventral (→ Fig. 4.57) and dorsal (→ Fig. 4.58) views.
In the adult, the **A. circumflexa femoris medialis** is the major blood vessel supplying the femoral head. In infants, however, the **R. acetabularis** (from A. obturatoria and A. circumflexa femoris medialis), which runs within the Lig. capitis femoris, provides the major part of the blood supply to the femoral head. In the adult, it supplies only one-fifth to one-third of the proximal epiphysis. However, the A. circumflexa femoris medialis supplies the femoral head and neck via several smaller branches coursing on the posterior side within the joint capsule. The **A. circumflexa femoris lateralis** mainly supplies the femoral neck at its anterior side. The Acetabulum is supplied from ventral and dorsal by the A. obturatoria and from cranial by the A. glutea superior.

Clinical Remarks

The arterial blood supply is crucial for the integrity of the femoral head. Oxygen deprivation (ischaemia) results in **necrosis of the femoral head** which, in the worst case scenario, requires the replacement of the head by an **endoprosthesis.** Therefore, the supplying arteries need to be preserved during hip surgery. This is particularly important in cases of arthrosis if not the whole femoral head but only the articular surface is replaced by a prosthesis ("cap prosthesis"). Therefore, the knowledge of the exact anatomy of the arterial supply has gained importance during the last years. One has to consider that the A. circumflexa femoris medialis courses on the posterior side of the femoral neck where it is covered and well protected by the short hip muscles of the pelvitrochanteric group. Hence, these muscles should be preserved during surgery to avoid injury to the artery. Since the Aa. circumflexa femoris medialis and lateralis pass between the layers of the joint capsule they are at risk of injury in intracapsular **fractures of the femoral neck**. As a result an immediate replacement of the femoral head by an endoprosthesis is more commonly performed.
It is suggested that the spontaneous necrosis of the femoral head during early puberty **(PERTHES' disease)** is also caused by a compromised arterial supply.

Knee joint



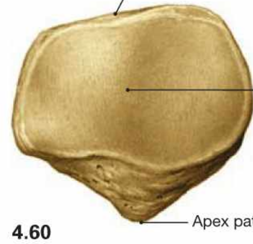
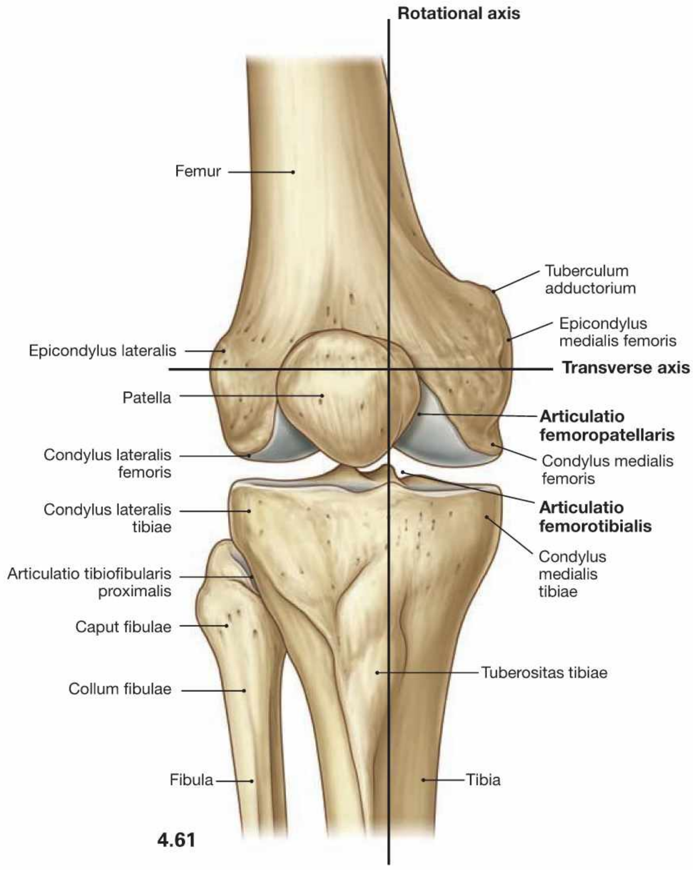


Fig. 4.59 and Fig. 4.60 Patella, Patella, right side; ventral (→ Fig. 4.59) and dorsal (→ Fig. 4.60) views.
The patella is a **sesamoid bone** (Os sesamoideum) within the tendon of the M. quadriceps femoris. It serves as a **hypomochlion** by guiding the tendon on its way to the insertion on the Tuberositas tibiae over the distal end of the femur. This results in an increase of the virtual lever arm and torque of the muscle.



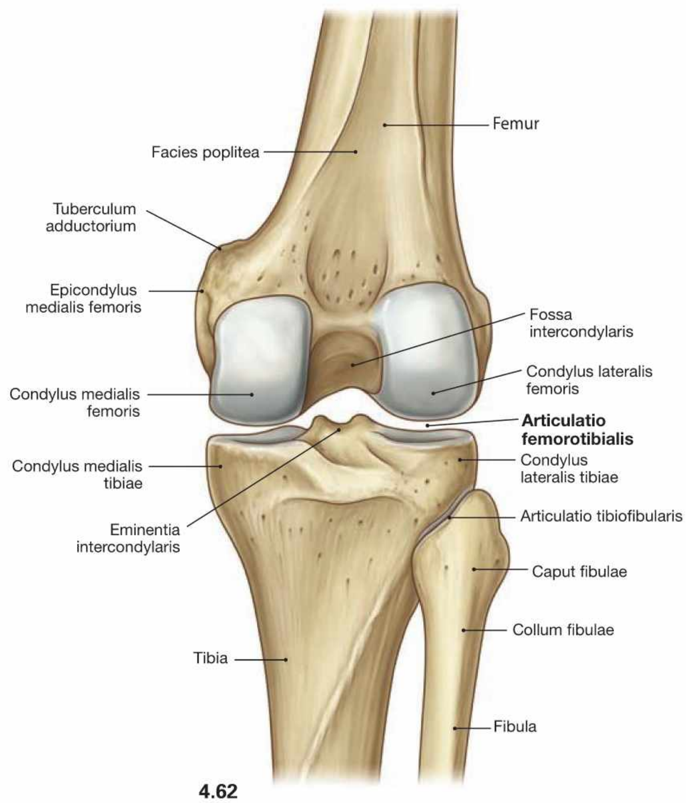
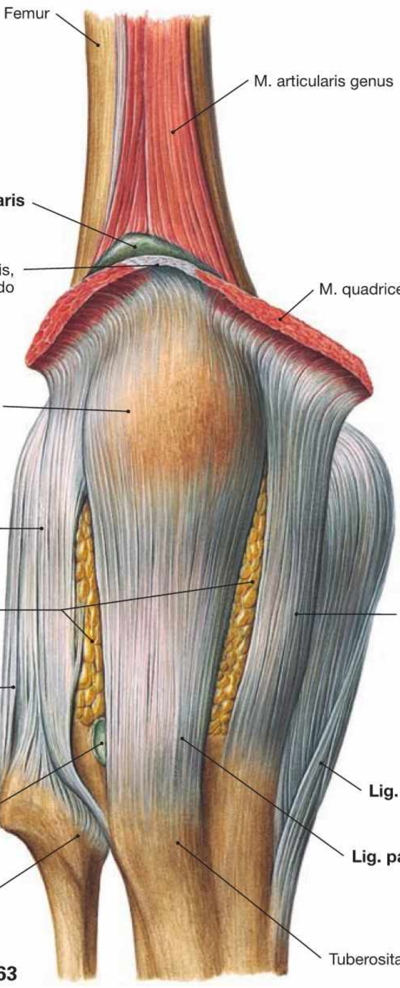


Fig. 4.61 and Fig. 4.62 Knee joint, Articulatio genus, right side; ventral (→ Fig. 4.61) and dorsal (→ Fig. 4.62) views. [10]
In the knee joint the Femur articulates with Tibia **(Articulatio femorotibialis)** and Patella (**Articulatio femoropatellaris;** → Fig. 4.209). All bones are ensheathed by a common joint capsule. In the Articulatio femorotibialis, the femoral condyles constitute the head and the upper articular surface of the Tibia (Facies articularis superior) and both tibial condyles form 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 axes of movement. The transverse axis for **extension** and **flexion** movements extends through both femoral condyles. The longitudinal axis for rotational movements is positioned eccentrically and perpendicular through the Tuberculum intercondylare mediale. For the range of movement in the knee joint → page 276.

Clinical Remarks

In addition to the hip joint, the knee joint is strained by the weight of the body. Thus, degenerative changes **(gonarthrosis)** are a common disease of the knee joint frequently requiring prosthetic substitution of the joint bodies. Since the knee joint lacks a strong muscular guidance, **injuries to the ligaments** and the menisci are common. These may partly be treated minimally-invasive by **arthroscopy,** a process that requires profound knowledge of the anatomy of the knee joint. Dysplasia of the Patella or the femoral Facies patellaris may cause repetitive **patellar luxations.** In addition to the exercise of the respective M. vastus medialis or lateralis, the surgical correction with tightening of the joint capsule (capsulorrhaphy) or displacement of the Lig. patellae is the treatment of choice.



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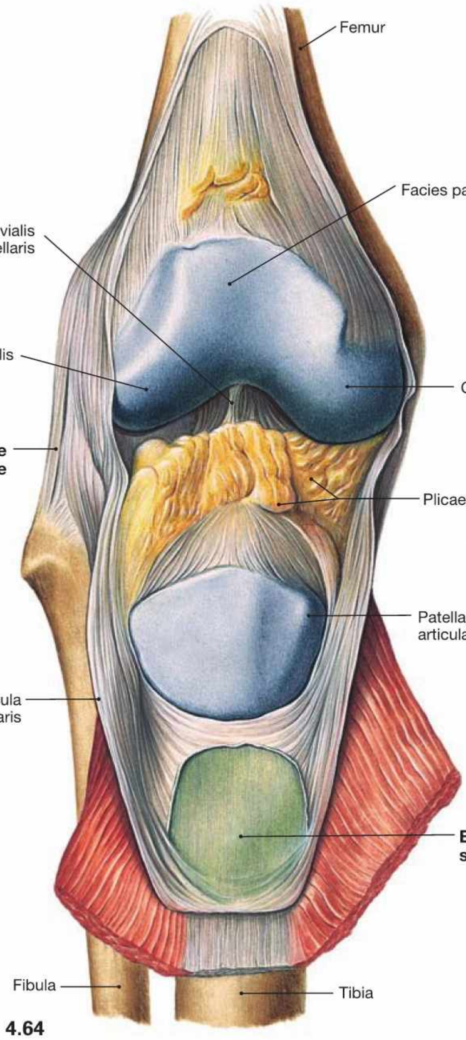
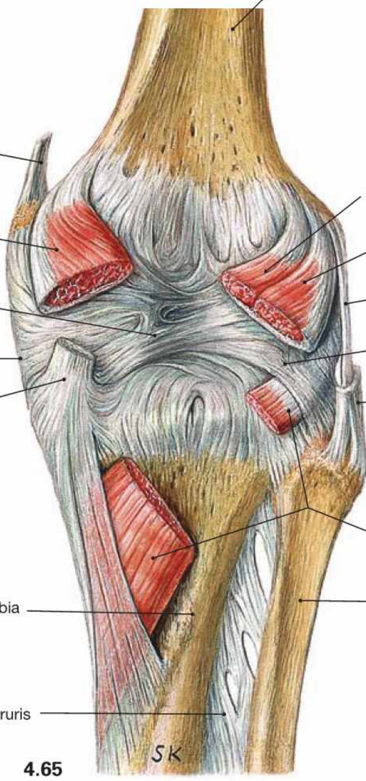


4.64

Fig. 4.63 and Fig. 4.64 Knee joint, Articulatio genus, right side; with closed joint capsule (→ Fig. 4.63), and after opening of the capsule (→ Fig. 4.64); ventral view.

The ligaments of the knee joint consist of **external ligaments** which support the joint from the outside, and **internal ligaments** which are positioned within the Capsula fibrosa. Here, the external ligaments are illustrated. They comprise the **Lig. patellae** as the continuation of the tendon of the M. quadriceps femoris, and the **Retinacula patellae mediale** and **laterale.** Both of these latter ligaments have superficial longitudinal and deep circular fibres and can be viewed as parts of the 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 in the Tibia and Fibula. The joint capsule encloses the articular surfaces. The HOFFA's fat pad (Corpus adiposum infrapatellare) is positioned between the Capsula fibrosa and the Capsula synovialis. This adipose tissue is connected to the anterior cruciate ligament by a fold, the Plica synovialis infrapatellaris, and laterally possesses two Plicae alares. The knee joint is associated with several **bursae** some of which communicate with the joint capsule as shown here for the Bursa suprapatellaris.

Knee joint



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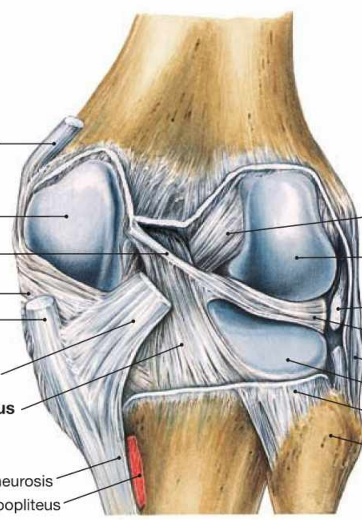


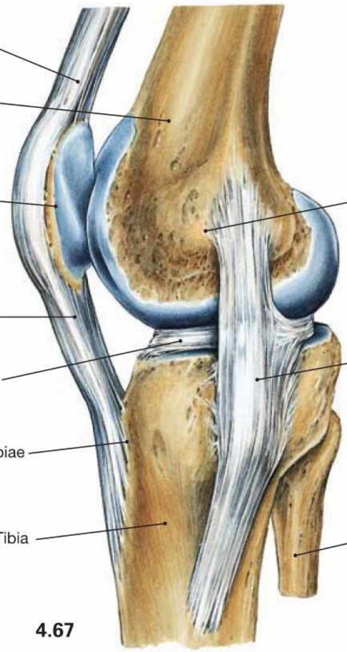
4.66

Fig. 4.65 and Fig. 4.66 Knee joint, Articulatio genus, right side; with closed joint capsule (→ Fig. 4.65), and after opening of the capsule (→ Fig. 4.66); dorsal view.

At the rear side of the knee joint, additional **external ligaments** support the joint capsule. The **Lig. popliteum obliquum** projects medially and inferiorly from the lateral femoral condyle, and the **Lig. popliteum arcuatum** courses in the opposite direction, thus, crossing the M. popliteus. Of the two collateral ligaments, only the **Lig. collaterale tibiale** is connected to the joint capsule. The **Lig. collaterale fibulare** is **separated** from the joint capsule by the tendon of the M. popliteus.

After opening of the joint capsule several **internal ligaments** are visible. The anterior cruciate ligament **(Lig. cruciatum anterius)** courses 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)** courses 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) anterior and posterior to the posterior cruciate ligament with the medial condyle and, thus, support the posterior cruciate ligament.

Knee joint



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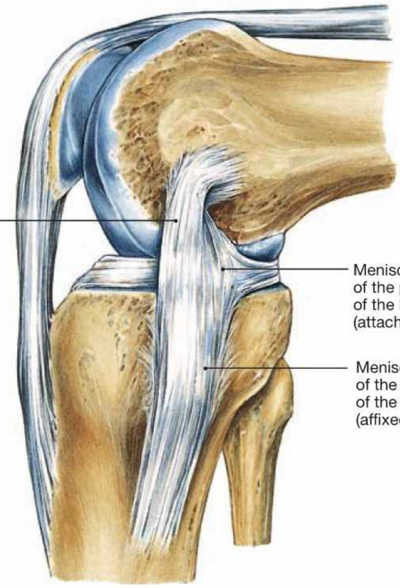


4.68

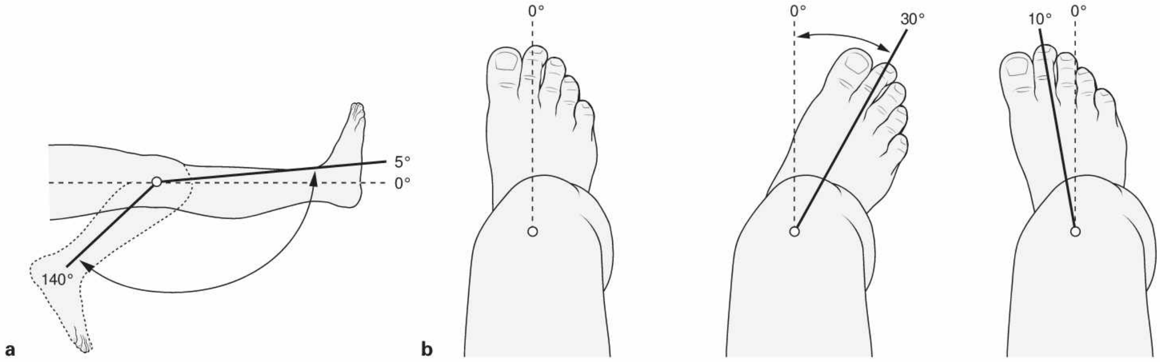
Fig. 4.67 and Fig. 4.68 Inner (medial) collateral ligament, Lig. collaterale mediale, in extension (→ Fig. 4.67), and flexion (→ Fig. 4.68); medial view.

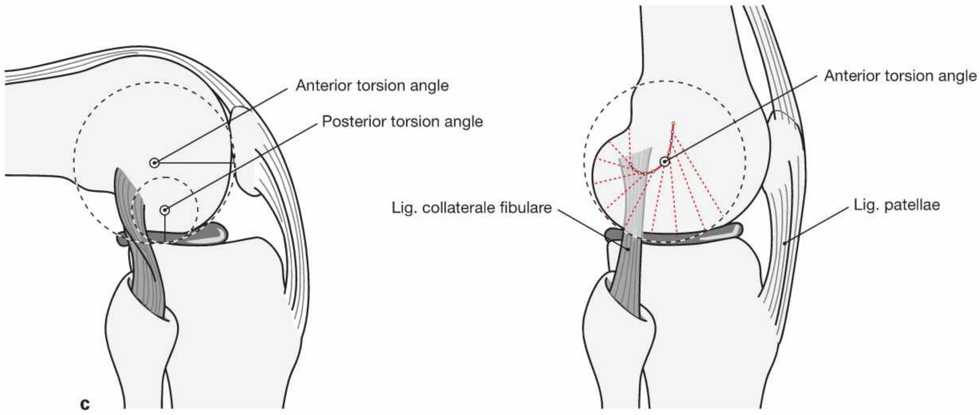
Only the posterior fibres of the inner collateral ligament **(Lig. collaterale tibiale)** are connected to the Meniscus medialis. In flexion, the contortion of the ligament fixes the Meniscus medialis in its position. In contrast, the lateral collateral ligament **(Lig. collaterale fibulare)** is not connected to the Meniscus lateralis. Because of the larger radius of curvature of the femoral condyles in the front, the collateral ligaments are stretched in the extended knee. This position therefore does not allow for rotational movements. In a flexed position of the knee, the collateral ligaments are relaxed due to the smaller radius of curvature of the femoral condyles at the back, thus enabling rotational movements.

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** movements. Injuries to these ligaments increase instability and laxity of the knee joint. This phenomenon is utilised during physical examination to assess potential injuries to the collateral ligaments.

Knee joint





Figs. 4.69a to c Range of movement in the knee joint, Articulatio genus. (c according to [1])

The knee joint is a **bicondylar joint** (Articulatio bicondylaris) which functions similar to a **pivot-hinge joint** (trochoginglymus) and has two axes of movement. The transverse axis for **extension** and **flexion** movements runs through both femoral condyles (**c**). The longitudinal axis for **rotational movements:** projects eccentrically and perpendicular 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 posteriorly and superiorly during flexion in a convex line (**c**). The flexion movement thus is a combined rolling and sliding movement in which the condyles roll up to 20° posteriorly and then turn in this position. Since the shape of the medial and lateral condyles of the Femur and Tibia is not identical, it is the lateral femoral condyle that predominantly rolls (similar to a rocking chair) and the medial condyle remains in its position to rotate (similar to a ball-and-socket joint). At the same time the Femur rotates slightly outwards. In the terminal phase of the extension movement, the tension of the anterior cruciate ligament also causes a forced lateral rotation of 5°–10°, during which the medial condyle even loses its contact with the medial meniscus.

The active flexion up to 120° can be increased up to 140° after pre-extension of the hamstring muscles (**a**). Passive flexion is possible up to 160°, limited only by soft tissues. Extension is possible up to the null-position but can be further increased passively by 5°–10°. Rotational movements are exclusively possible during flexion of the knee because the tension of the collateral ligaments during knee extension prevents rotational movements (**b**). Lateral rotation is possible to a larger extent than medial rotation because the cruciate ligaments twist around each other during medial rotation. Abduction and adduction are almost completely prevented by the strong collateral ligaments.

Range of movement:

a extension–flexion: 5°– 0°–140°

b lateral rotation–medial rotation: 30°– 0°–10°

Cruciate ligaments

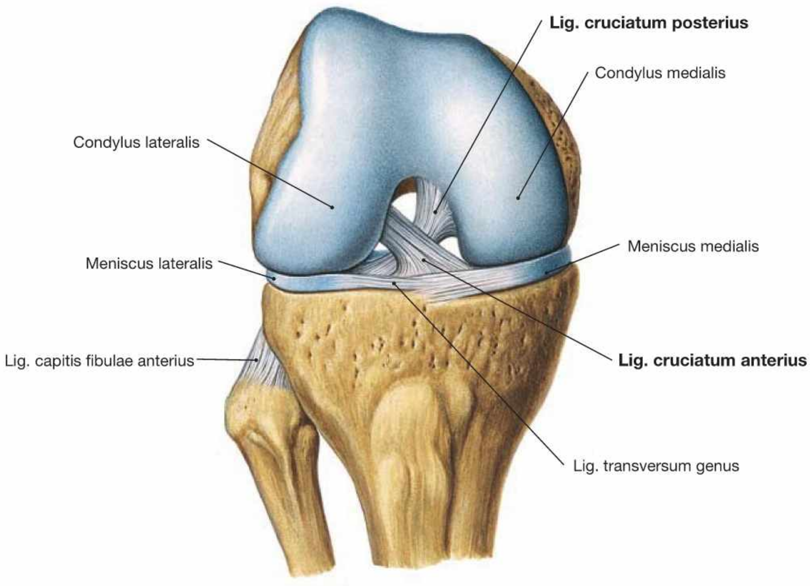
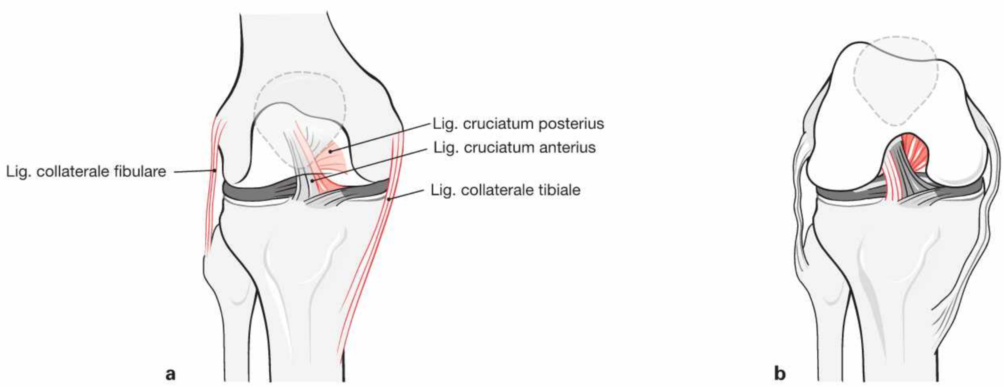


Fig. 4.70 Knee joint, Articulatio genus, right side, in 90°-flexed position; ventral view; after removal of the joint capsule and the collateral ligaments.
The most important inner ligaments are the two cruciate ligaments. The **anterior cruciate ligament** (Lig. cruciatum anterius) courses from the inner surface of the lateral femoral condyle in an anterior direction to the Area intercondylaris anterior of the Tibia (from a superior posterior or lateral to an inferior anterior direction). The **posterior cruciate ligament** (Lig. cruciatum posterius) courses in an opposite direction from the inner surface of the medial femoral condyle to the Area intercondylaris posterior of the Tibia (from a superior anterior medial to a posterior inferior direction). Although the cruciate ligaments are positioned within the fibrous joint capsule (intra-articular) they are outside the Capsula synovialis and thus **extrasynovial.**



Figs. 4.71a to b Stabilisation of the knee joint, Articulatio genus, right side, through collateral and cruciate ligaments in extension (a), and flexion (b); ventral view.
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 in this position against rotational as well as abduction/adduction movements. In contrast, distinct parts of the cruciate ligaments are tense during 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 Femur can slide in 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 in the supine position of the patient. The examiner sits (fixes) on the foot of the 90°- flexed knee and pulls the leg anteriorly or pushes it posteriorly.

Menisci

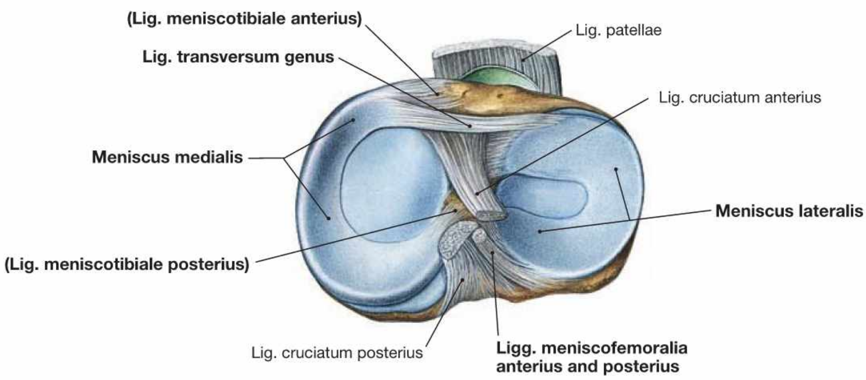
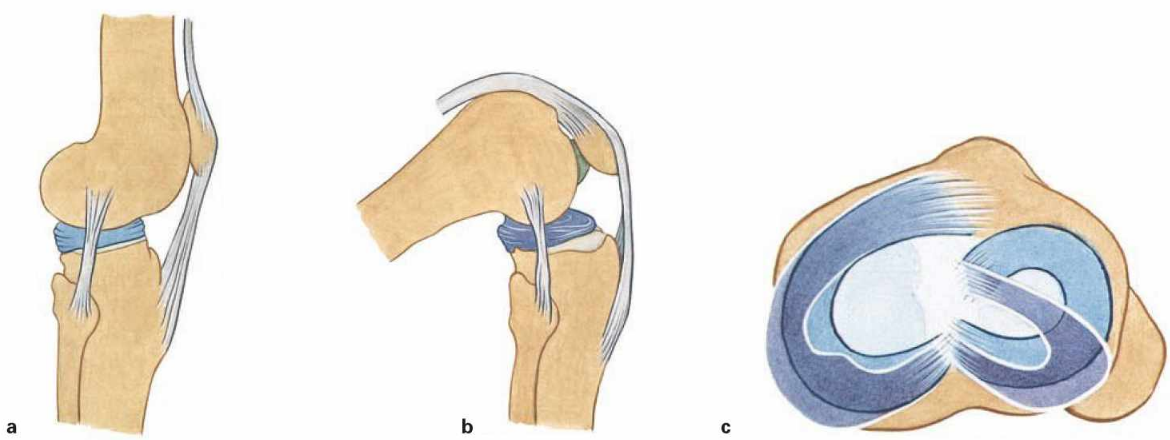


Fig. 4.72 Menisci of the knee joint, right side; cranial view.
Both menisci are roughly C-shaped and appear wedge-shaped in cross-sections. The **medial meniscus** is larger and anchored via the **Ligg. meniscotibialia anterius** and **posterius** to the respective Area intercondylaris of the Tibia. In addition, the medial meniscus is fixed to the medial collateral ligament. In contrast, the **lateral meniscus** is anchored via the **Ligg. meniscofemoralia anterius** and **posterius** to the medial femoral condyle, but it is separated from the lateral collateral ligament by the tendon of the M. popliteus (→ Fig. 4.77). The posterior horn is only indirectly and flexibly fixed to the Tibia via the M. popliteus. Anteriorly, both menisci are connected through the **Lig. transversum genus**. As a result, the range of movement of the lateral condyle is increased in flexion.
Both menisci are composed of fibrous carilage inside and dense connective tissue outside.



Figs. 4.73a to c Sliding range of the menisci, Menisci, during flexion.
In flexion, both menisci are pushed posteriorly over the rims of the tibial condyles. The mobility of the lateral meniscus is higher due to the reduced fixation.

a extended position
b, c flexed position

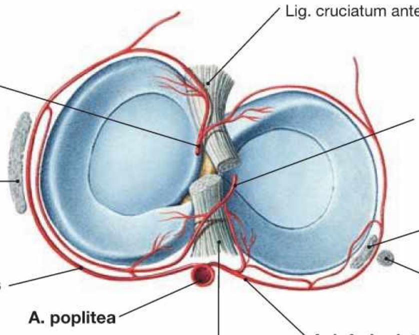
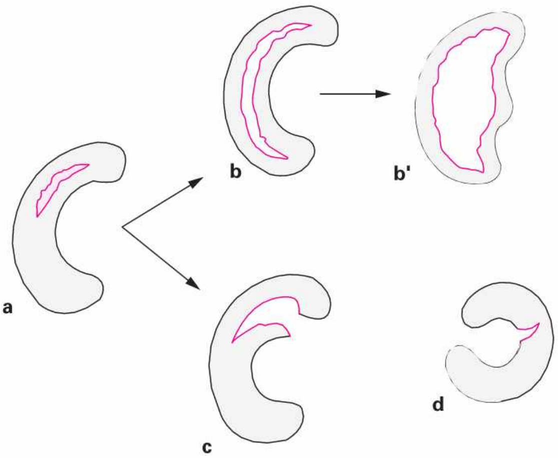


Fig. 4.74 Arterial supply of the menisci, Menisci, right side; cranial view.
The **external portions** of the Menisci are supplied through a **perimeniscal network** of blood vessels that derives from the Aa. inferiores medialis and lateralis genus and from the A. media genus (branches of the **A. poplitea**). The **internal portions** are devoid of blood vessels and are nourished by diffusion from the **synovial fluid.**

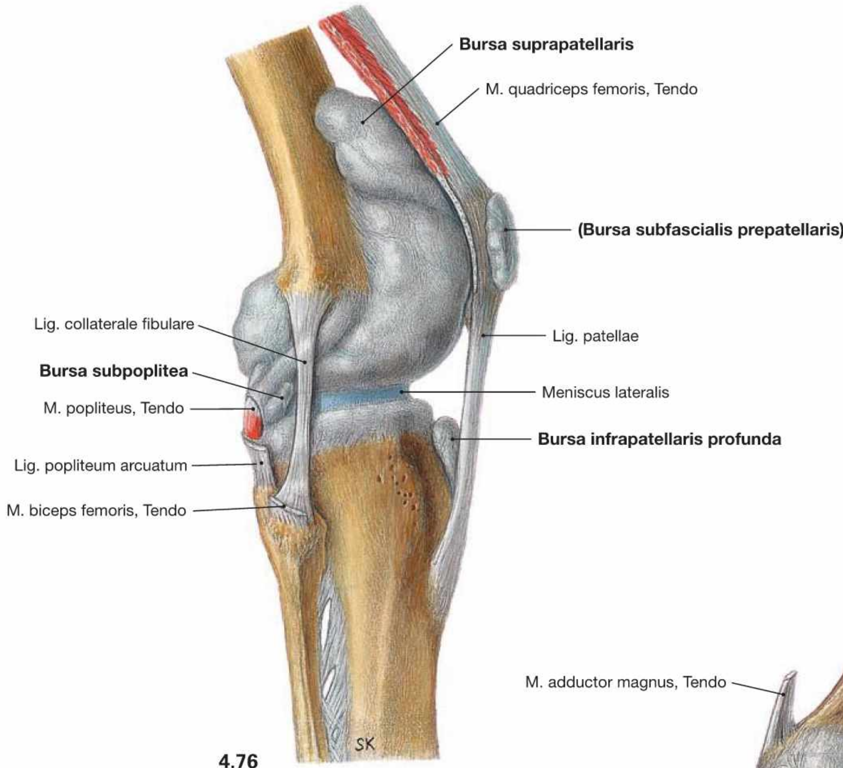


Figs. 4.75a to d Stages in the development of meniscal tears. [4]
a development of a longitudinal tear
b elongation of the tear from the posterior to the anterior horn and shift into the joint ("bucket handle" tear, b') or
c additional radial tear ("parrot beak"; often leading to a posterior or anterior horn avulsion)
d radial tear, lateral C-shaped meniscus most commonly affected

Clinical Remarks

Meniscus injuries are common. The **medial meniscus** is affected most commonly due to its fixation to bone and capsule. Acute injuries occur during sudden rotational movements of the weighted flexed knee and result in a painful inhibition of active and passive extension. Chronic degenerative changes often occur as a result of malpositions. If the injuries affect the well-arterialised periphery of the Menisci, spontaneous repair is possible. Lessions of the central-portions frequently require an arthroscopic removal of the torn parts to restore free movements. Despite treatment, frequently degenerative changes in the knee joint **(gonarthrosis)** can develop.

Knee joint



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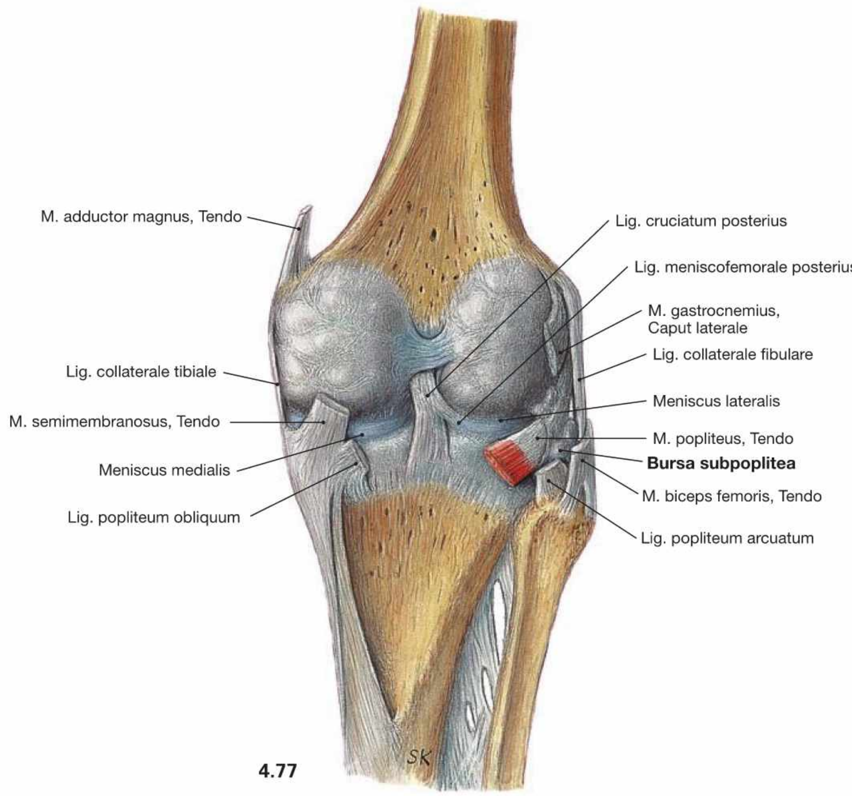


4.77

Fig. 4.76 and Fig. 4.77 Knee joint, Articulatio genus, right side, with bursae; lateral (→ Fig. 4.76) and dorsal (→ Fig. 4.77) views; illustration of the articular cavity by injection of a synthetic polymer.
The knee joint is surrounded by up to 30 bursae **(Bursae synoviales).** Some bursae communicate with the joint capsule, such as the Bursa suprapatellaris (anterior superior) beneath the tendon of the M. quadriceps femoris, or the Bursa subpoplitea (posterior inferior) beneath the M. popliteus. Other bursae are positioned in places with exposure to higher pressure (e.g. when kneeling) such as the Bursa prepatellaris or the Bursa infrapatellaris. Some serve as gliding surface for tendons of muscles such as the Bursa musculi semimembranosi or the Bursae subtendineae musculorum gastrocnemii medialis and lateralis (both not shown).

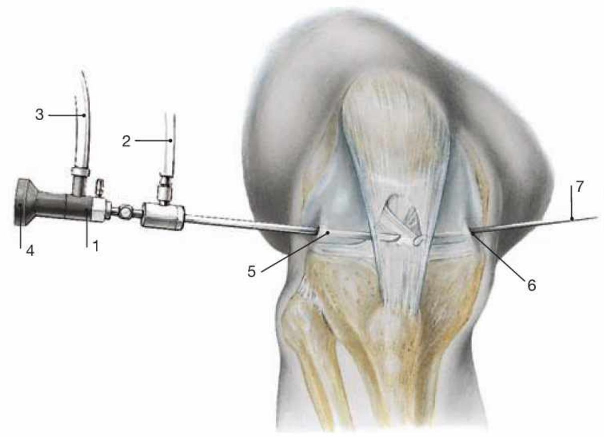
Clinical Remarks

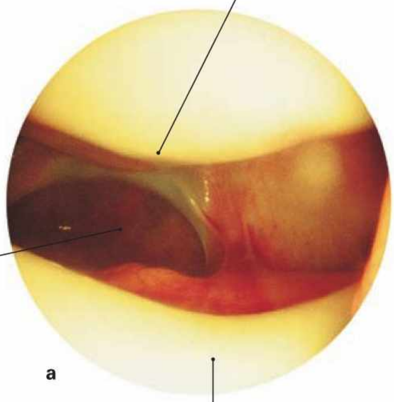
With extensive mechanical stress (activities in kneeling position) inflammation of the bursae may occur **(bursitis).** In the case of chronic inflammatory capsular effusions such as in rheumatic diseases (e.g. rheumatoid arthritis), enlargement and fusion of bursae may occur which appear as swelling in the popliteal fossa. A fusion of the Bursa musculi semimembranosi with the Bursa subtendinea musculi gastrocnemii medialis is referred to as **BAKER's cyst.**

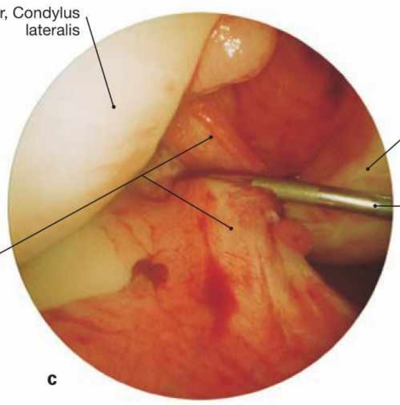
Knee joint, arthroscopy

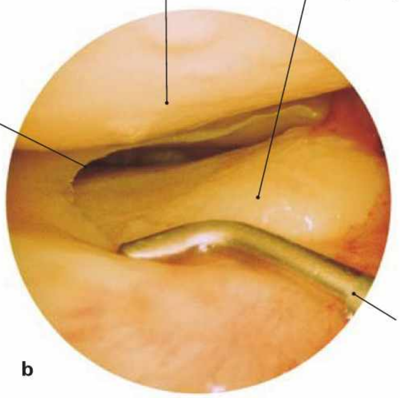
Fig. 4.78 Endoscopic examination (arthroscopy) of the knee joint.
Arthroscopy allows the minimally-invasive access to the articular cavity to assess the intrasynovial structures of the knee joint and to perform minor repairs.

1 arthroscope
2 in- and outgoing wash fluid
3 cold light source
4 ocular and adapter for video system
5 anterolateral access
6 anteromedial access
7 additional instrument









Figs. 4.79 a to c Knee joint, Articulatio genus, right side; arthroscopic images.

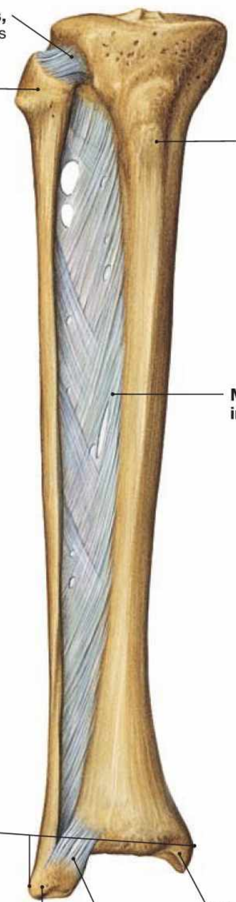
- **a** distal view in the femoropatellar joint
- **b** medial view onto the inner rim of the lateral meniscus
- **c** anterolateral view onto the anterior cruciate ligament

* patellar ridge: ridge between medial and lateral articular surfaces
** clinical term: Recessus suprapatellaris
*** groping hooks

Clinical Remarks

Arthroscopies are frequently performed clinical procedures of the knee joint. They serve as **diagnostic tools,** e.g. if a rupture of a meniscus cannot be excluded by MRI. They are also used for **treatment** such as the removal of torn meniscus parts, the repair of cruciate ligaments (cruciate ligament reconstruction), or to remove floating bodies which painfully inhibit movements.

Ligaments of the leg



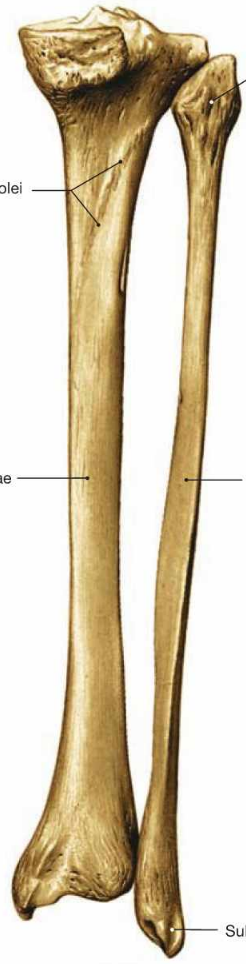


Fig. 4.80 and Fig. 4.81 Ligaments of the tibia, Tibia, and the fibula, Fibula, right side; ventral (→ Fig. 4.80) and dorsal (→ Fig. 4.81) views.

The proximal Ligg. capitis fibulae anterius and posterius create an amphiarthrosis **(Articulatio tibiofibularis).** Distally, both bones are fixed by the Ligg. tibiofibularia anterius and posterius in a syndesmosis **(Syndesmosis tibiofibularis).** Between both bones, the **Membrana interossea cruris** serves as an additional stabiliser with dense connective tissue and collagen fibres, which predominantly course obliquely downwards from the Tibia to the Fibula. Together with the inferior articular surface of the Tibia, the medial and lateral Malleus form the **malleolar fork**. The latter provides the socket for the ankle joint.

* malleolar fork

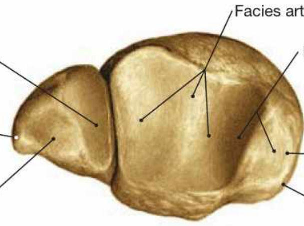


Fig. 4.82 Distal end of the tibia, Tibia, and fibula, Fibula, right side; distal view.

Clinical Remarks

Proximal fractures of the Fibula in the region of its head and neck are referred to as **MAISONNEUVE fractures.**
Fractures of the distal end of the Fibula are called **WEBER fractures** which are classified in three degrees (→ Figs. 4.107 to 4.109) depending on the involvement of the Syndesmosis tibiofibularis. All fractures are treated surgically with plates and screws because minor alterations in the joint position of the ankle joint can cause degenerative changes **(arthrosis).**

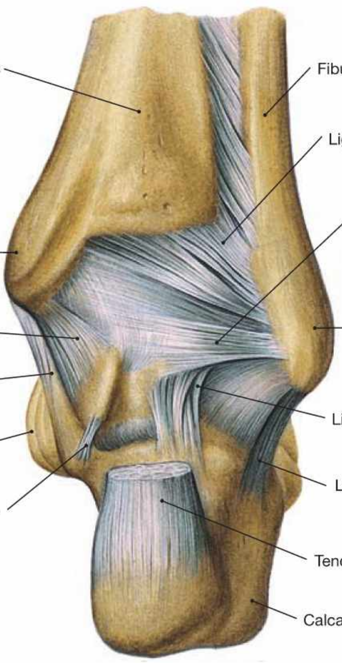


Fig. 4.83 Ankle joint (talocrural joint), Articulatio talocruralis, right side, with ligaments; dorsal view.

Parts of the Lig. collaterale mediale (Pars tibiotalaris posterior, Pars tibiocalcanea) and the lateral Lig. talofibulare posterius support the joint from the posterior side.

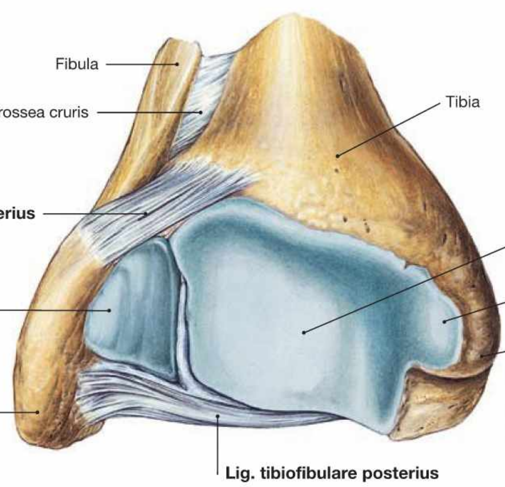
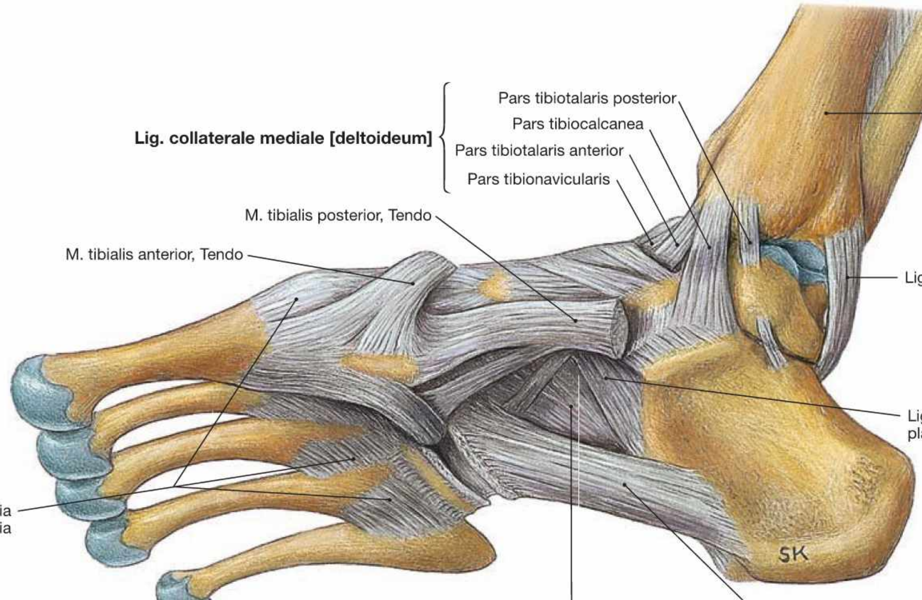


Fig. 4.84 Distal end of the tibia, Tibia, and fibula, Fibula, right side; distal view.

Tibia and Fibula are connected through the Syndesmosis tibiofibularis and together form the malleolar fork, the socket of the ankle joint.

Ankle joint



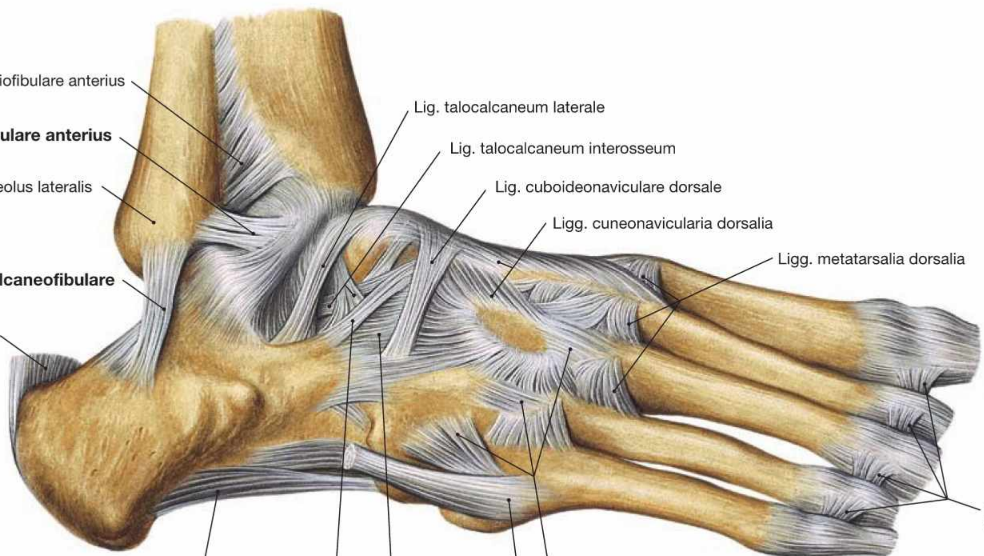


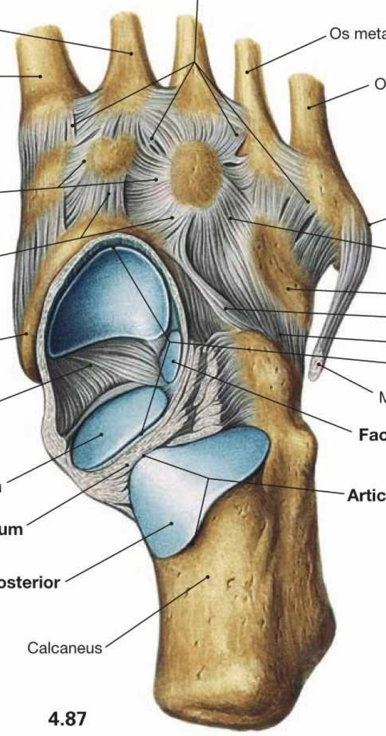
Fig. 4.85 and Fig. 4.86 Ankle joint (talocrural joint), Articulatio talocruralis, right side, with ligaments; medial (→ Fig. 4.85) and lateral (→ Fig. 4.86) views.

The movements of the foot take place in the (upper) ankle joint and in the (lower) talocalcaneonavicular joint. The other joints of the Tarsus and Metatarsus are amphiarthroses which increase the range of movement of the talocalcaneonavicular joint to a certain extent. In the ankle joint, the malleolar fork constitutes the socket and the trochlea of the Talus the ball of the joint. **Medially,** both joints are stabilised by a fan-shaped radiation of ligaments that is referred to as **Lig. collaterale mediale (deltoideum)** and consists of four parts (Pars tibiotalaris anterior, Pars tibiotalaris posterior, Pars tibiocalcanea, and Pars tibionavicularis) which connect the respective bones. There are three single ligaments on the **lateral** side **(Lig. talofibulare anterius, Lig. talofibulare posterius, Lig. calcaneofibulare).** These ligaments provide additional stabilisation of the talocalcaneonavicular joint.

Clinical Remarks

Injuries to the **ankle joint** are **more common** than injuries to the **talocalcaneonavicular joint** because the ligamentous support in the malleolar region is not very strong. Since the trochlea of the Talus is wider in the anterior than the posterior part (→ Fig. 4.37), secure guidance of the bones is only guaranteed in dorsiflexion (-extension) with distension of the malleolar fork. The most common ligamentous injury in the human is the tear of the lateral ligaments (Lig. talofibulare anterius and Lig. calcaneofibulare) in **hypersupination trauma.**

Talocalcaneonavicular joint



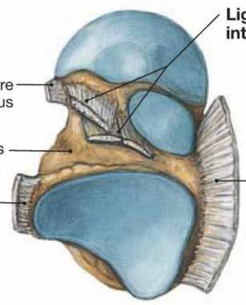


Fig. 4.89 Talocalcaneonavicular joint, Articulatio talocalcaneonavicularis, proximal joint bodies, right side; distal view.

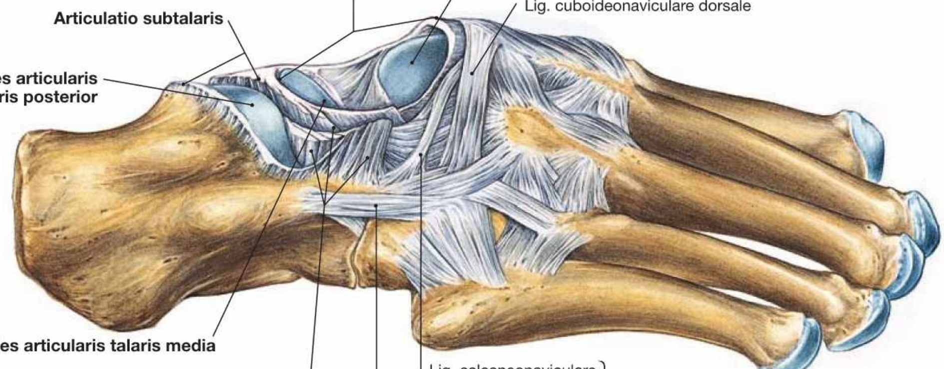


Fig. 4.87 and Fig. 4.88 Talocalcaneonavicular joint, Articulatio talocalcaneonavicularis, distal joint bodies, right side; proximal (→ Fig. 4.87) and lateral (→ Fig. 4.88) views after removal of the Talus.
In the talocalcaneonavicular joint, Talus, Calcaneus and Os naviculare articulate in two independent joints. The posterior joint **(Articulatio subtalaris)** is formed by the posterior corresponding articular surfaces of Talus and Calcaneus. This partial joint is separated by the **Lig. talocalcaneum interosseum,** positioned in the Sinus tarsi, from the anterior partial joint **(Articulatio talocalcaneonavicularis).** In the anterior partial joint, the anterior articular surfaces of Talus and Calcaneus articulate as well as the head of the Talus articulates with the Os naviculare anteriorly and with the **Lig. calcaneonaviculare plantare** inferiorly. At this contact point the latter shows an articular surface of hyaline cartilage and contributes to the plantar arch. Both parts of the joint create a functional unit and are often collectively referred to as **Articulatio talocalcaneonavicularis.**
In addition to the ligaments of the ankle joints, there are several ligaments which stabilize the skeletal elements of the talocalcaneonavicular joint. Besides the Lig. talocalcaneum interosseum, these are the Lig. talocalcaneum mediale and the Lig. talocalcaneum laterale (→ Figs. 4.83 and 4.86). For the range of movement in the talocalcaneonavicular joint → Figure 4.92.

Joints of the foot

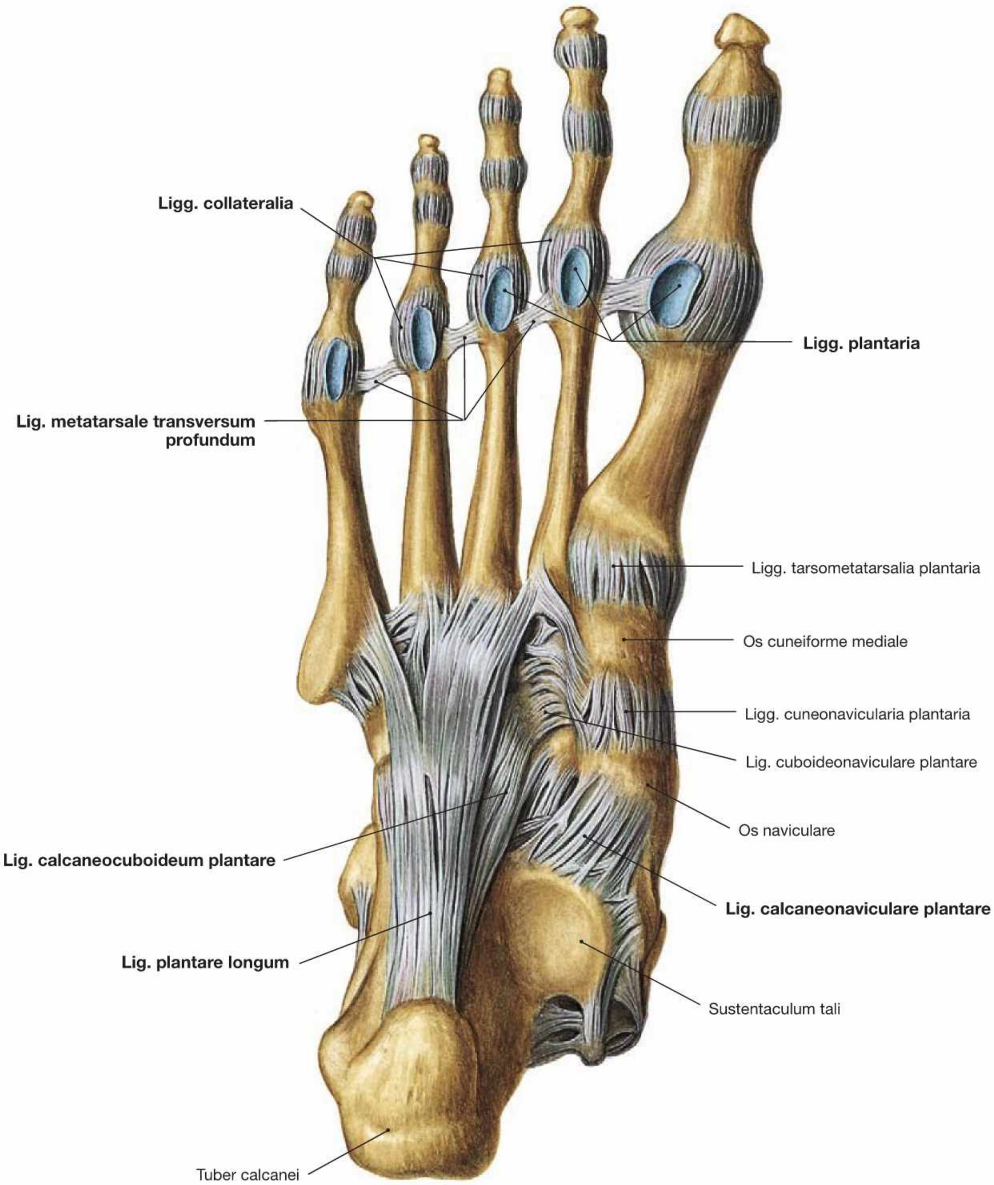


Fig. 4.90 Joints of the foot, Articulationes pedis, right side, with ligaments; plantar view.

The remaining joints of the Tarsus and Metatarsus are **amphiarthroses** which only minimally contribute to the movement of the foot. Together however, they extend the range of movement of the talocalcaneonavicular joint and transform the foot into an elastic base. At the Tarsus, two joints can be emphasized which contribute to 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. 4.33). The **LISFRANC's joint** (Articulationes tarsometatarsales) is the connection to the Metatarsus (→ Fig. 4.33). These two articulation lines have clinical relevance as important amputation lines.

The metatarsal bones articulate in several separate joints. The metatarsal bones are connected proximally by the **Articulationes intermetatarsales** and distally by the **Lig. metatarsale transversum profundum.** The joints of forefoot and midfoot are linked by strong plantar, dorsal, and interosseous ligaments. The CHOPART's joint is stabilised dorsally by the **Lig. bifurcatum** which divides into two ligaments (Lig. calcaneonaviculare and Lig. calcaneocuboideum, → Fig. 4.87) and is opposed on the plantar side by the **Lig. calcaneocuboideum plantare.** Together with the Lig. calcaneonaviculare plantare, the **Lig. plantare longum** serves to stabilise the plantar arch. The latter is more superficial than the other plantar ligaments and spans from the Calcaneus to the Os cuboideum and the Ossa metatarsalia II–IV. The **digital joints** can be categorised in **metatarsophalangeal joints** (Articulationes metatarsophalangeales) and in **proximal and distal interphalangeal joints** (Articulationes interphalangeae proximales and distales). The range of movement in all digital joints is limited by tight collateral ligaments (Ligg. collateralia) and inferiorly by the Ligg. plantaria.

Joints of the foot

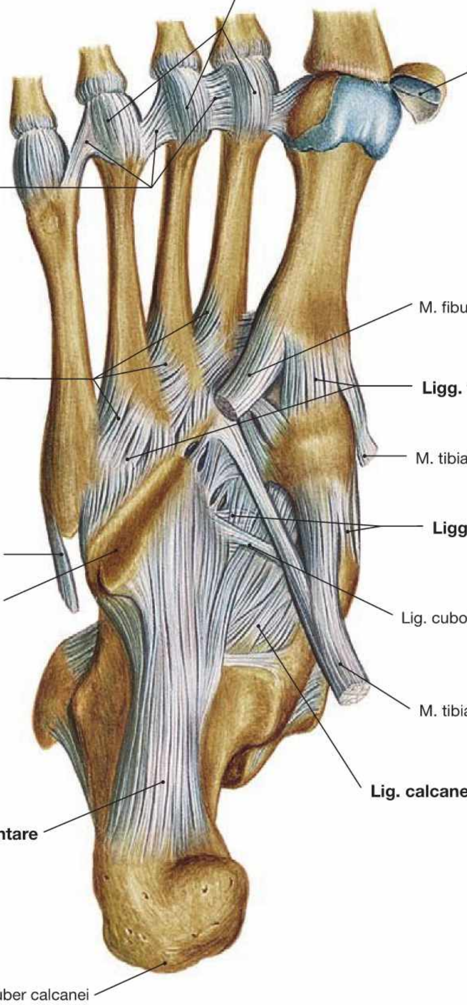
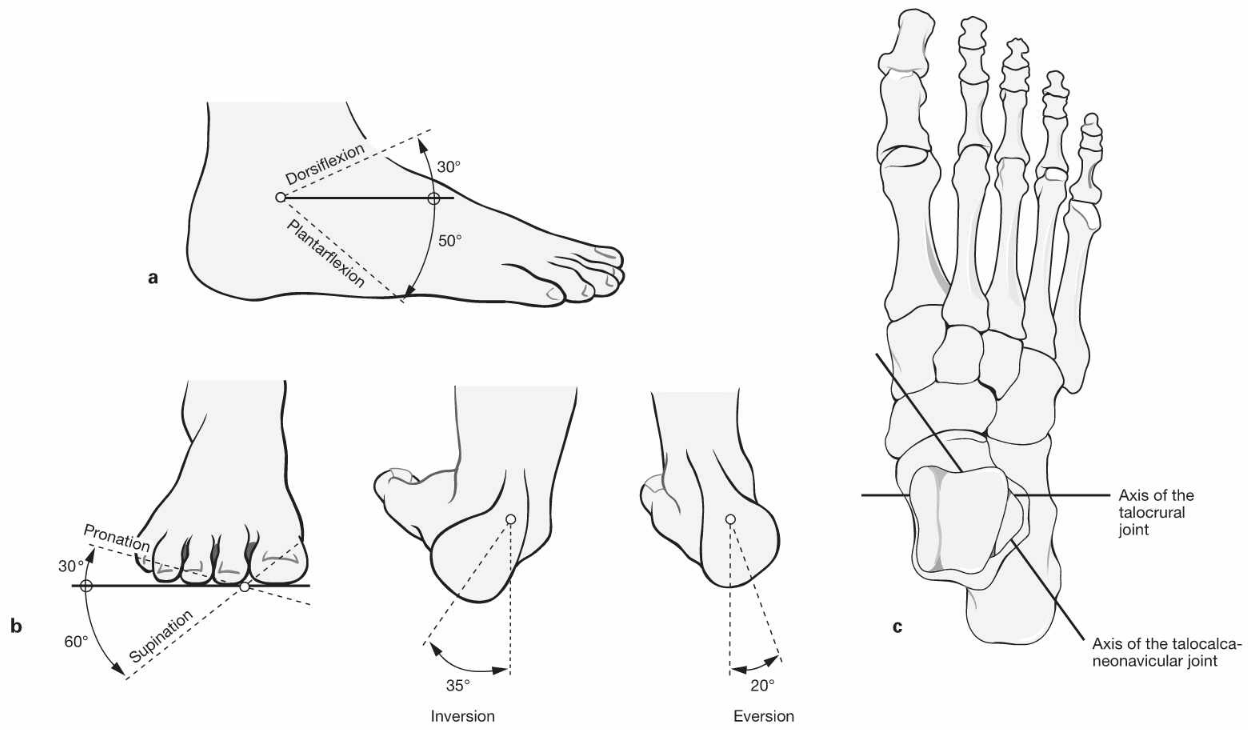


Fig. 4.91 Joints of the foot, Articulationes pedis, right side, with ligaments; plantar view; after removal of the Lig. plantare longum.

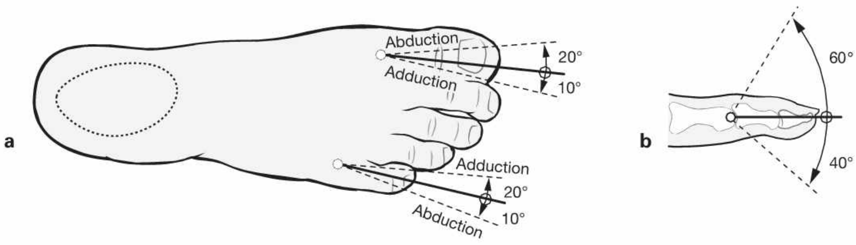
Clinical Remarks

The most common deformity in the first metatarsophalangeal joint is the **hallux valgus,** in which the head of the first metatarsal bone deviates and protrudes medially, whereas the big toe (hallux) is adducted laterally. This condition may cause severe pain in the metatarsophalangeal joint and may cause soft tissue swelling. This frequently requires surgical correction. Current therapeutic approaches attempt to correct the deformity by paralysing the adducting muscle (M. adductor hallucis) with injections of botulinum toxin. In the **hammer toe** deformity, the proximal interphalangeal joint is fixed in a flexed position. In **claw toe** deformities, the metatarsophalangeal joints are hyperextended and the proximal phalanx may even slide above the metatarsals.

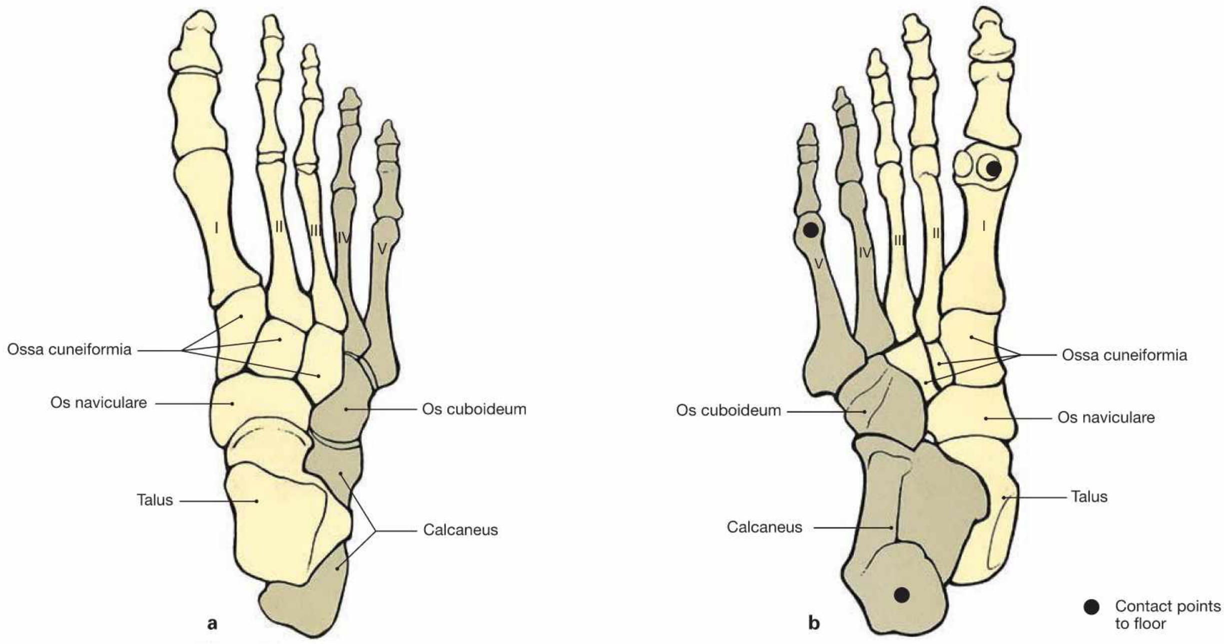
Ankle joint and other joints of the foot



Figs. 4.92a to c Range of movement in the ankle joint and the talocalcaneonavicular joint. (according to [1])
The **ankle joint** is a classical **hinge joint** (ginglymus) allowing for **dorsiflexion (extension)** and **plantarflexion** of the foot (**a**). The transverse axis of the joint projects through both Malleoli (**c**).
The **talocalcaneonavicular joint** is an **atypical pivot joint** (Articulatio trochoidea) for which a simplified axis was defined which enters the neck of the Talus from a medial superior direction and exits the Calcaneus at the lateral posterior side (**c**). This joint enables **inversion** (sole moving towards the median plane) and **eversion** (sole moving outwards) of the foot. These movements of the hindfoot are complemented by the movements of the other foot joints (CHOPART's and LISFRANC's joint) to permit **supination** (lifting the medial margin of the foot) and **pronation** (lifting the lateral margin of the foot) (**b**).
Range of movement:
- ankle joint: dorsiflexion (extension) – plantarflexion: 30°– 0°– 50°
- talocalcaneonavicular joint: eversion – inversion: 20°– 0°–35°
- talocalcaneonavicular joint and foot joints: pronation – supination: 30°– 0°– 60°



Figs. 4.93a and b Range of movement of the phalangeal joints. (according to [1])
The metatarsophalangeal joints are condyloid joints which are limited to two axes of movement by tight ligaments (rotational movements are not possible; **a**). The proximal and intermediate phalangeal joints are hinge joints and only allow for minimal flexion (**b**). More important than the active movements of the toes is their passive resistance during the rolling motion of the foot when walking.
Range of movement of the metatarsophalangeal joints:
- dorsiflexion (extension) – plantarflexion: 60°– 0°– 40°
- adduction – abduction: 20°– 0°–10° (adduction here is the movement to the midline of the foot)



Figs. 4.94a and b Bones of the plantar arch, right side; dorsal (**a**) and plantar (**b**) views.

While the heads of the metatarsal bones are positioned in the plantar plane, the Ossa cuneiformia, Os naviculare and Talus, particularly towards their posterior aspect, position themselves on top of their lateral skeletal parts, resulting in the Talus to be placed on top of the Calcaneus. Thus, a medially open **longitudinal arch** is formed. The **transverse arch** of the foot is formed by the wedge-shaped Ossa cuneiformia and the bases of the metatarsal bones. Due to these arches, the foot has only three contact points with the floor: at the heads of the metatarsal bones I and V and at the Tuber calcanei.

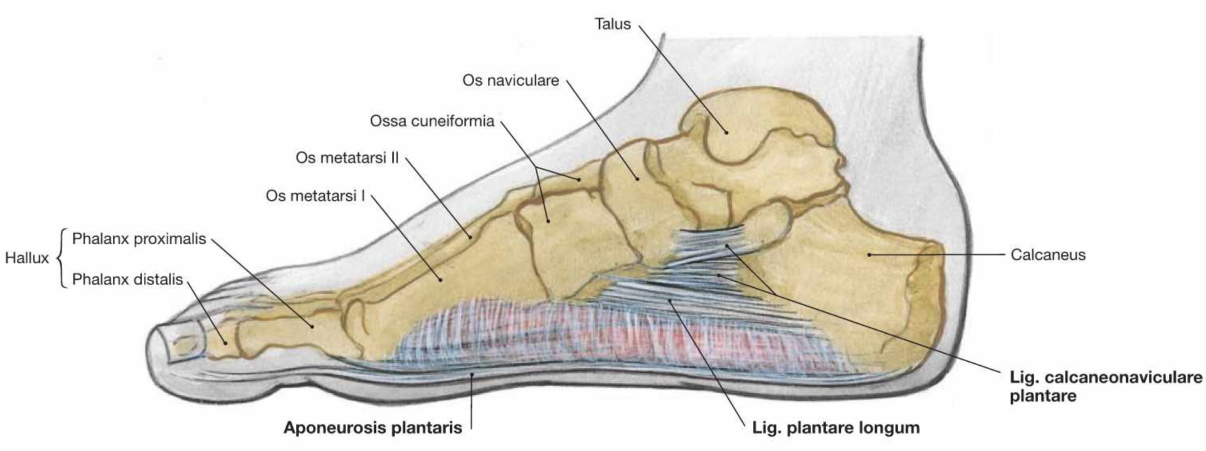


Fig. 4.95 Ligaments of the longitudinal plantar arch, right side; medial view.

The ligaments of the foot passively maintain the longitudinal arch of the foot. They are actively supported by the tendons of the M. tibialis posterior and M. fibularis longus (→ Fig. 4.148) and the short muscles on the sole of the foot. These supporting structures provide the **tension band system** to counteract the body weight. The ligaments can be categorized into three superimposing levels:

- upper level: Lig. calcaneonaviculare plantare
- middle level: Lig. plantare longum
- lower level: Aponeurosis plantaris

Clinical Remarks

Foot deformities are very common. The most common deformity of the extremities is the **congenital clubfoot** in which the foot is fixed in plantarflexion and supination. This position is caused by an insufficient regression of this intrauterine physiological position (→ p. 132). More frequently are the adult deformities caused by a failure of the ligamentous support system. The **acquired flatfoot** buckles medially because the Talus is displaced inferiomedially. This in turn forces the heads of the metatarsal bones apart and results in floor contact of the metatarsal bones II–V. This may cause painful compression symptoms at the sole of the foot.

Pelvis

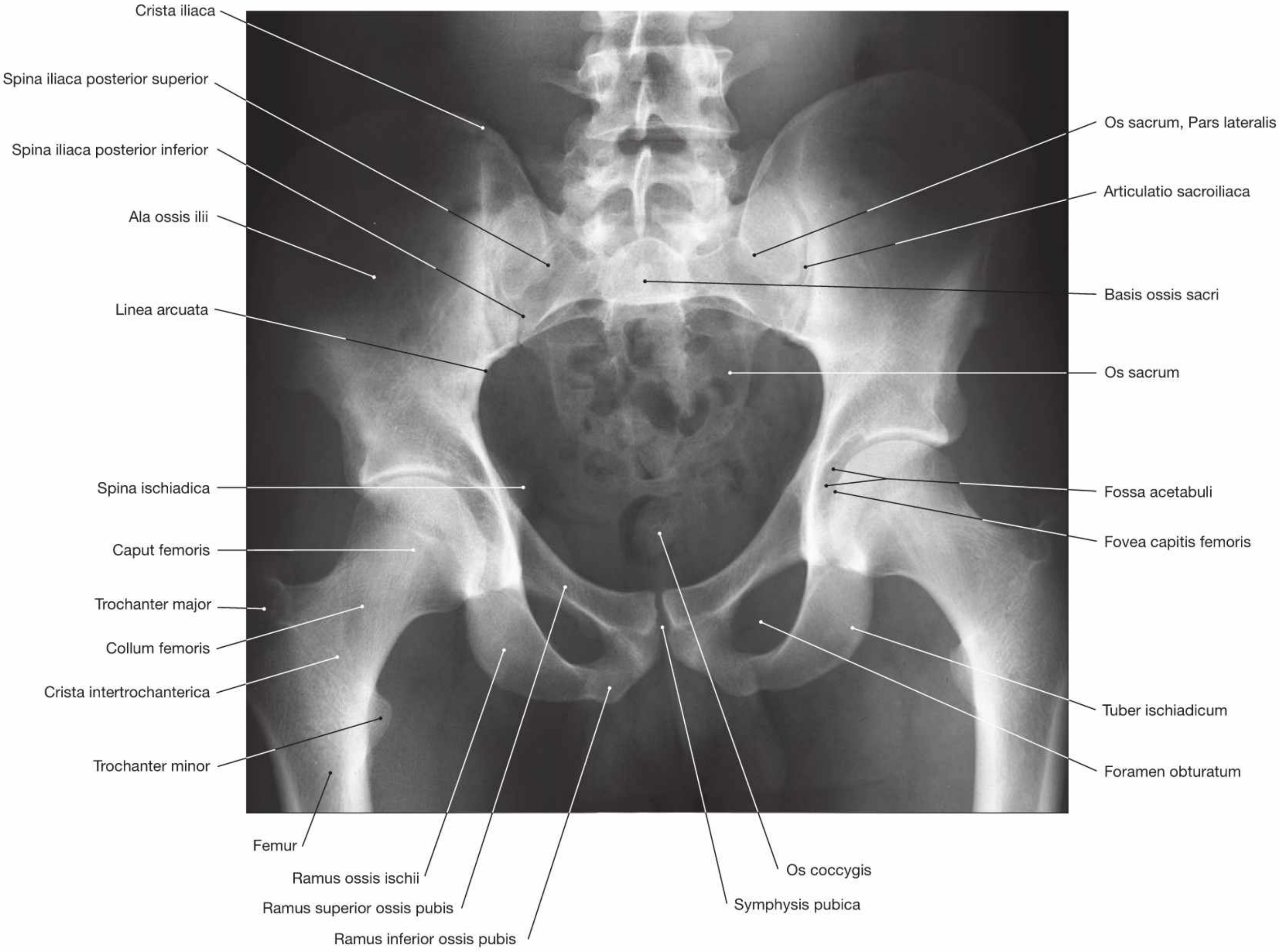


Fig. 4.96 Pelvis of a man; radiograph in anteroposterior (AP) beam projection; upright standing position.

Clinical Remarks

Plain radiological images of the pelvis are taken frequently. They help to diagnose **fractures** and **malpositions** of the skeletal elements of the hip joint and the pelvic girdle. They also enable the detection of degenerative changes **(arthrosis)** or local alterations of the bone, such as **metastases.**

Hip joint

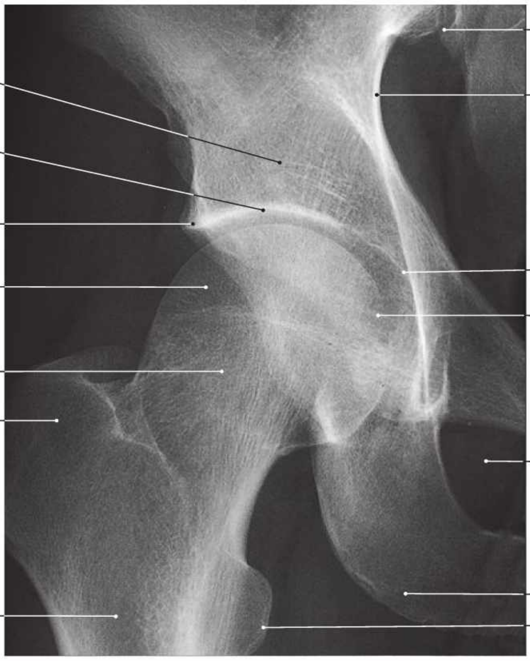


Fig. 4.97 Hip joint, Articulatio coxae, right side; radiograph in anteroposterior (AP) beam projection; upright standing position.

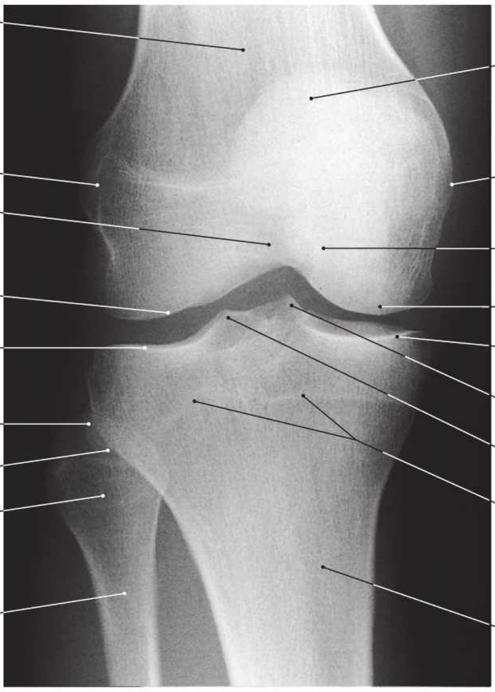
* clinical term: roof of the acetabulum
** clinical term: notch at the roof of the acetabulum

Fig. 4.98 Hip joint, Articulatio coxae, right side; radiograph in LAUENSTEIN projection (abduction and flexion of the thigh in supine position).

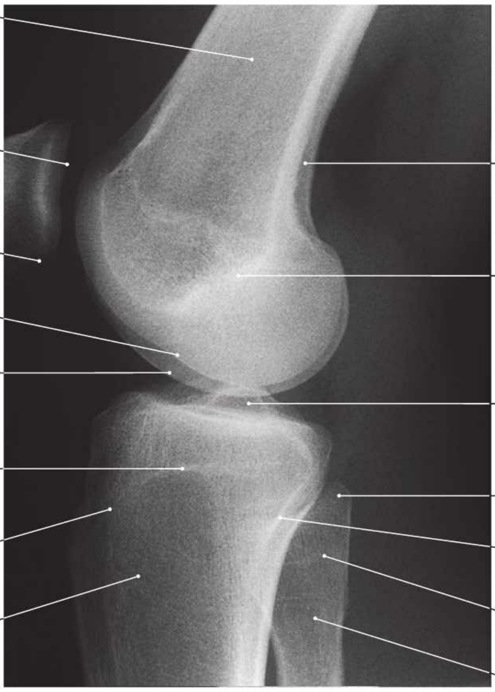
Clinical Remarks

Suspecting a disease of the hip joint, special radiographic images in various joint positions can be performed, such as the **LAUENSTEIN projection** in abduction and flexion of the thigh for a better assessment of the joint bodies.

Knee joint



4.99



4.100

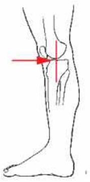
Fig. 4.99 and Fig. 4.100 Knee joint, Articulatio genus, radiograph in anteroposterior (AP) beam projection (→ Fig. 4.99) and in lateral beam projection (→ Fig. 4.100); in supine position.

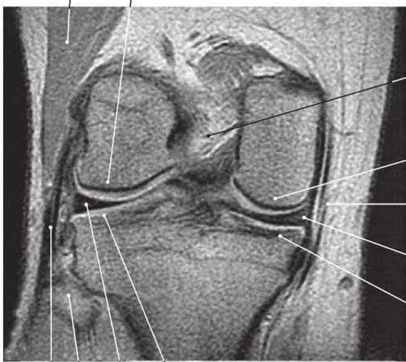
It has to be considered that the contours of the medial and lateral femoral condyles are not congruent.

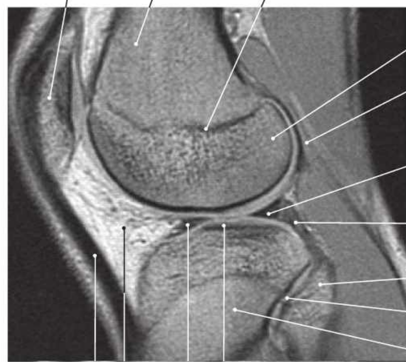
Clinical Remarks

Concerning diseases of the knee joint, radiographic images are generally taken in two planes. The anteroposterior (AP) beam projection allows for the assessment of the articular cavity and the socket of the Tibia. The femoral condyles, however, are better inspected in lateral beam projection. In addition to fractures, also malpositions, and degenerative diseases such as gonarthrosis can be diagnosed.

Knee joint

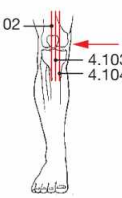


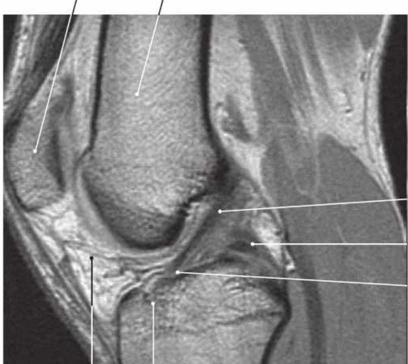




4.102

Fig. 4.101 Knee joint, Articulatio genus, right side; magnetic resonance imaging (MRI) sagittal section; ventral view.





4.103

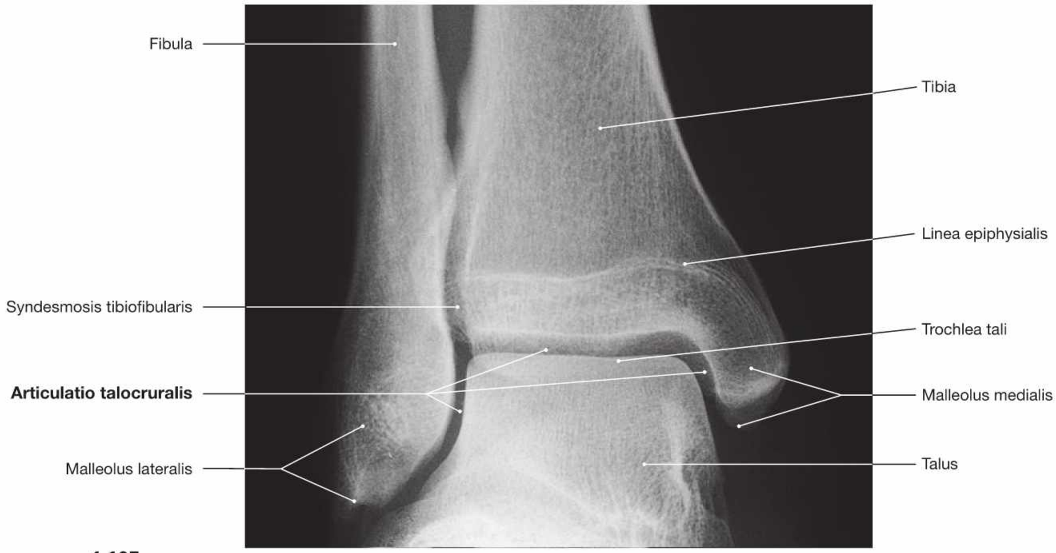
4.104

Fig. 4.102 to Fig. 4.104 Knee joint, Articulatio genus, right side; magnetic resonance imaging (MRI) sagittal sections; medial view. Compact bone appears dark with this imaging technique.

Clinical Remarks

Injuries to ligaments and menisci of the knee joint cannot be imaged with conventional radiographic techniques which only detect bony structures. In case of suspected soft tissue injury, **magnetic resonance imaging (MRI)** is performed. If this technique does not clearly exclude injuries, endoscopic diagnostic procedures (**arthroscopy;** → p. 281) should be considered.

Ankle joint and talocalcaneonavicular joint



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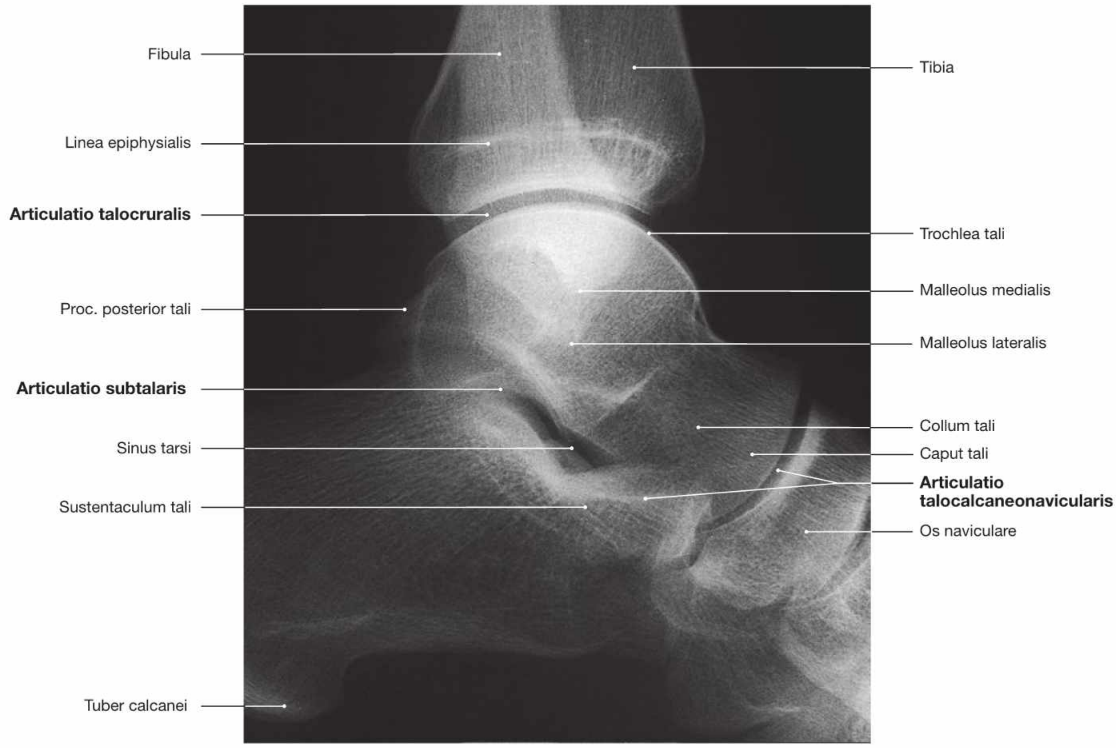


4.106

Fig. 4.105 and Fig. 4.106 Ankle joint (talocrural joint), and talocalcaneonavicular joint, Articulationes talocrurales and talocalcaneonavicularis, right side; radiograph in anteroposterior (AP) beam projection (→ Fig. 4.105), and in lateral beam projection (→ Fig. 4.106).

Fractures of the ankle joint

4.107

4.108

Fig. 4.107 and Fig. 4.108 Ankle joint (talocrural joint), Articulatio talocruralis, right side, with malleolar fracture (WEBER type B); radiograph in anteroposterior (AP) beam projection (→ Fig. 4.107), and in lateral beam projection (→ Fig. 4.108). [17]
Fracture lines are marked with arrows.

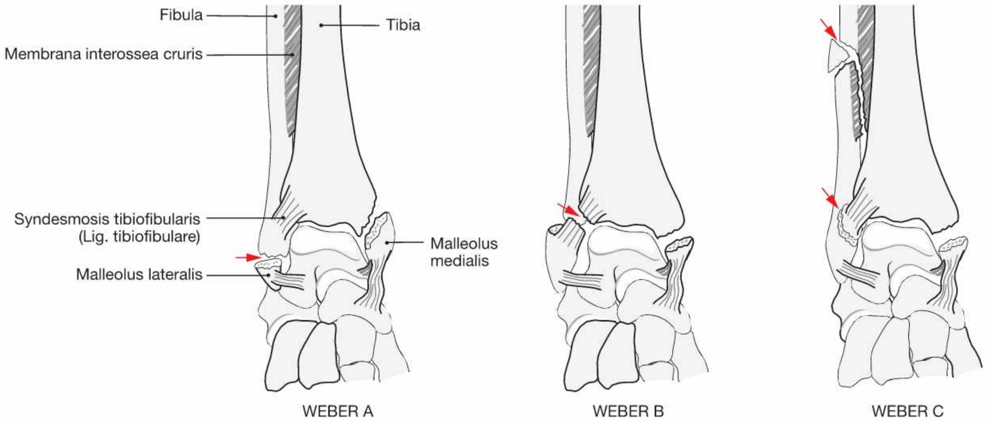


Fig. 4.109 Classification of ankle joint fractures according to WEBER types A, B, and C.

Clinical Remarks

Fractures of the distal end of the Tibia are called **WEBER fractures** and – depending on the involvement of the Syndesmosis tibiofibularis – further classified in three types:

- **WEBER A:** The Malleus lateralis is fractured beneath the intact syndesmosis.
- **WEBER B:** The fracture line goes through the syndesmosis which may be injured.
- **WEBER C:** The fracture is located above the torn syndesmosis. A WEBER C fracture results in a severe instability of the ankle joint.

Fascias of the lower extremity

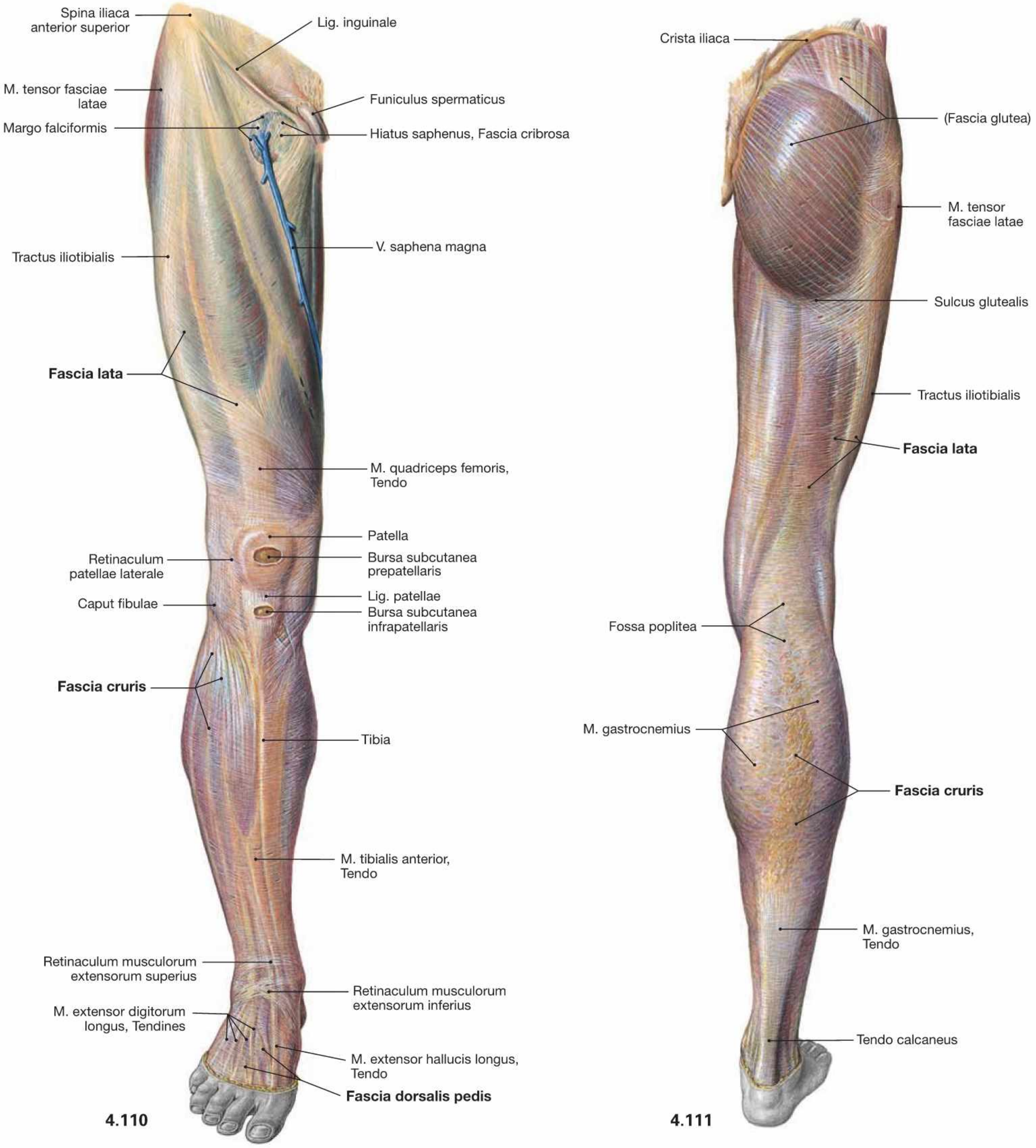


Fig. 4.110 and Fig. 4.111 Fasciae of the thigh, Fascia lata, the leg, Fascia cruris, and the dorsum of the foot, Fascia dorsalis pedis, right side; ventral (→ Fig. 4.110) and dorsal (→ Fig. 4.111) views.

Muscles of the hip and lower extremity

Fig. 4.112 Ventral muscles of the hip, thigh and leg, right side; ventral view.

→ T 42, 44, 45, 47, 48

Muscles of the hip and lower extremity

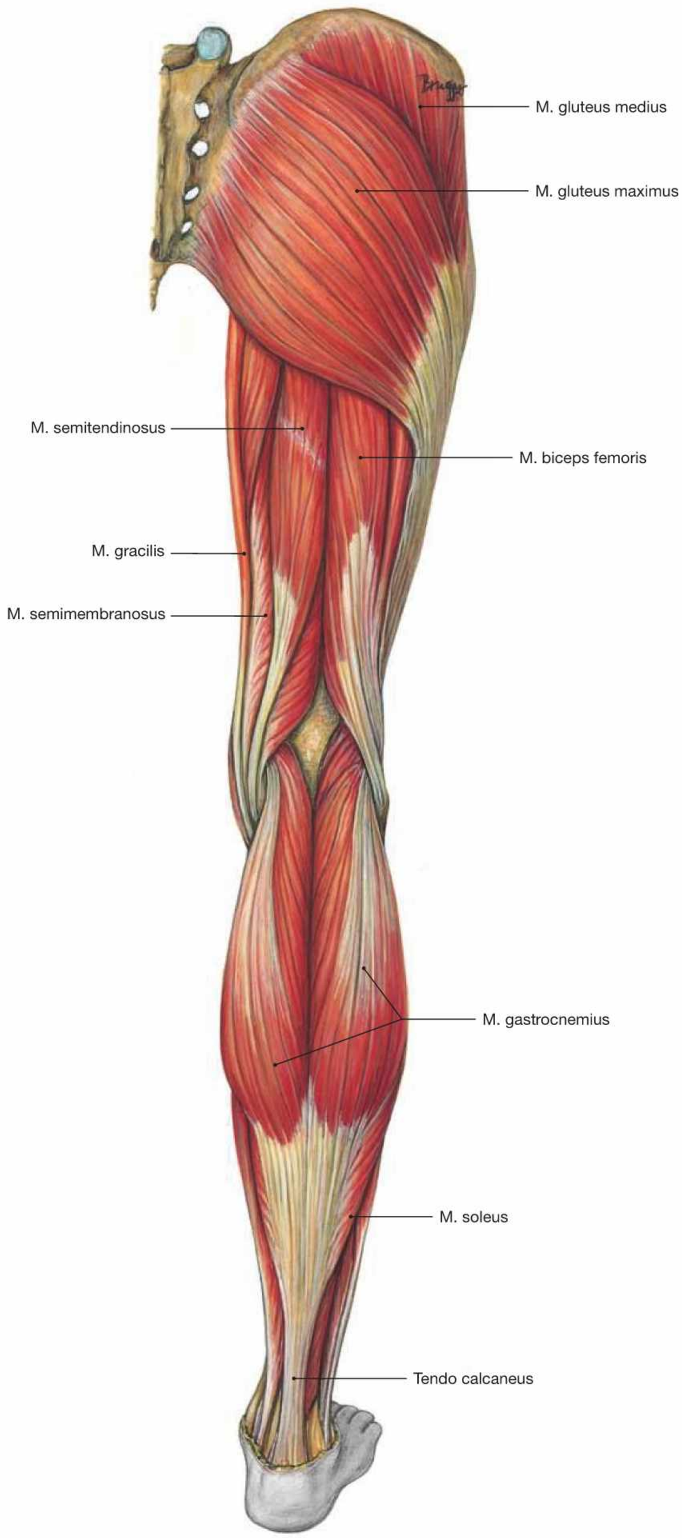


Fig. 4.113 Dorsal muscles of the hip, thigh and leg, right side; dorsal view.

→ T 43, 46, 49

Muscles of the hip and thigh

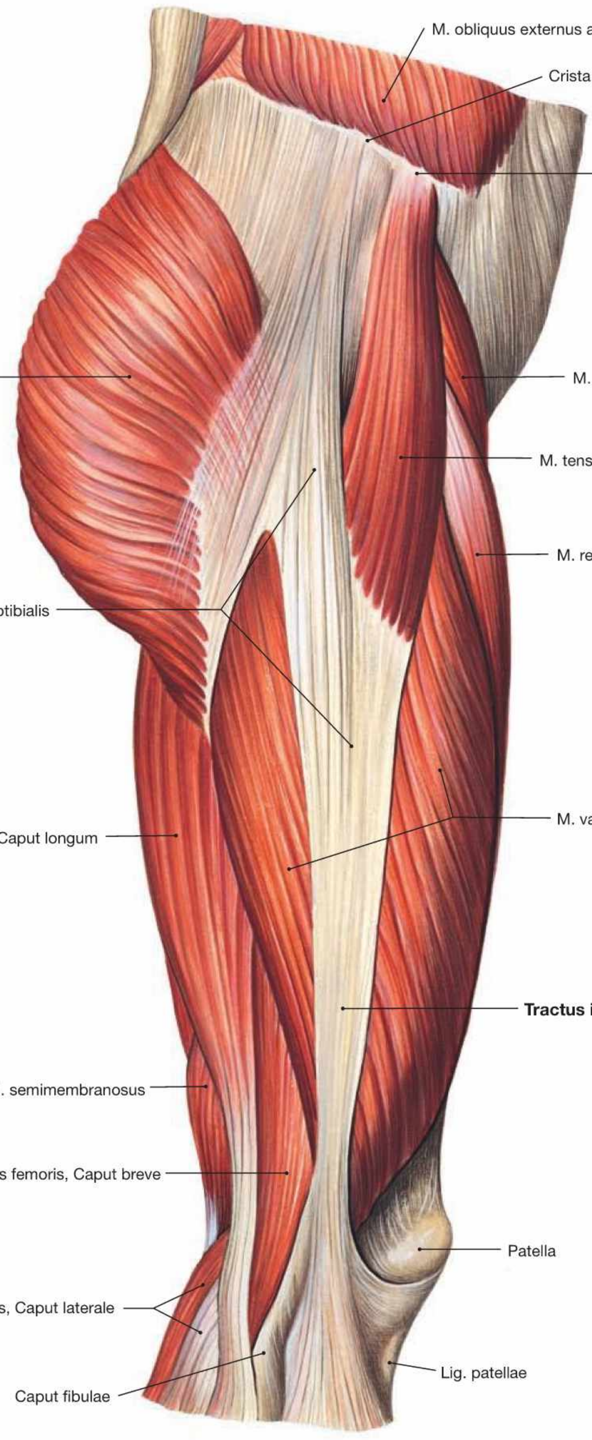


Fig. 4.114 Muscles of the hip and thigh, right side; lateral view. The **Tractus iliotibialis** serves as reinforcement of the fascia of the thigh (Fascia lata) and connects the ilium with the Tibia. It counterbalances the body weight-induced medial forces on the thigh bone. This principle is referred to as **tension band effect.**

→ T 43, 44, 46

Muscles of the hip and thigh

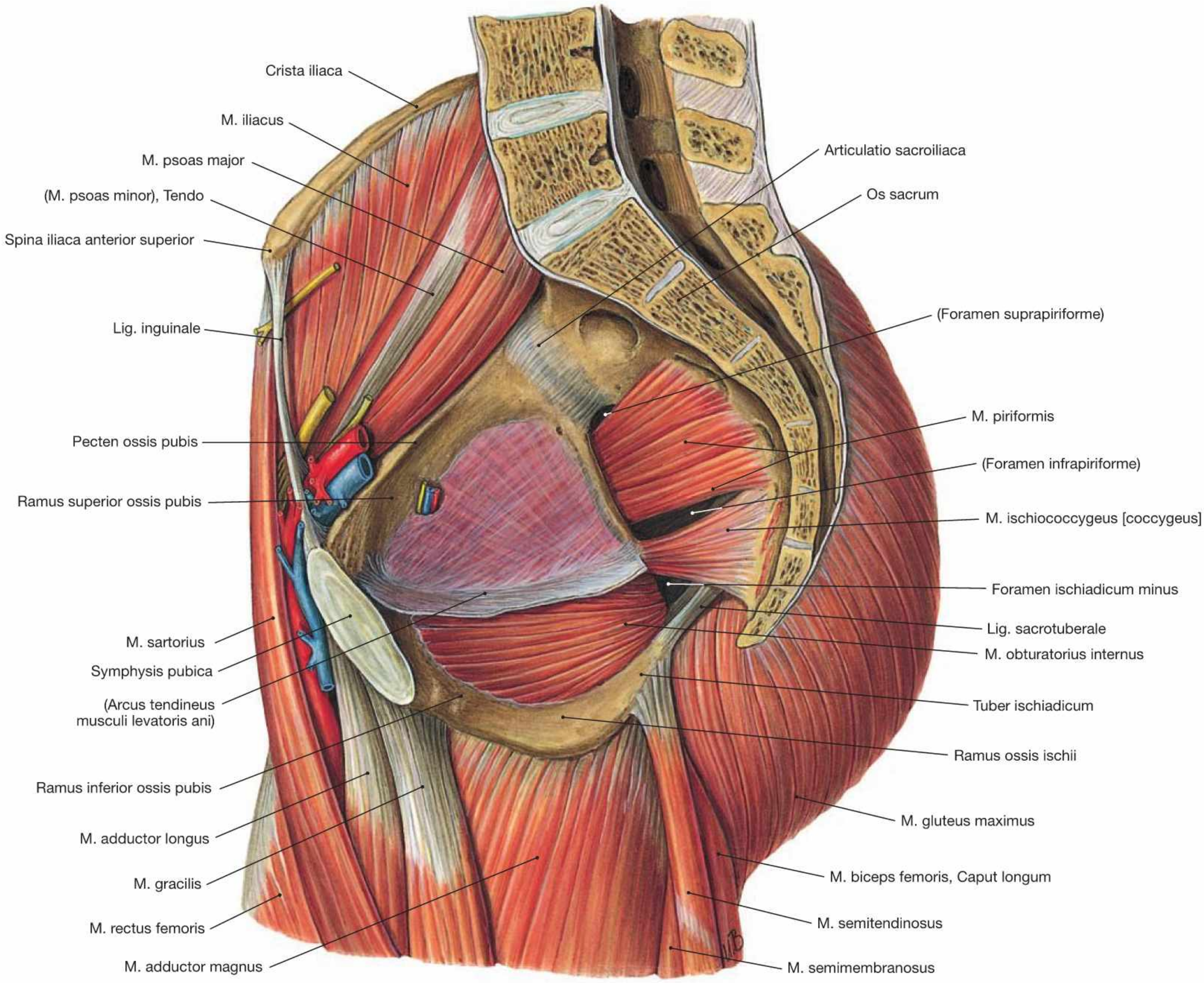
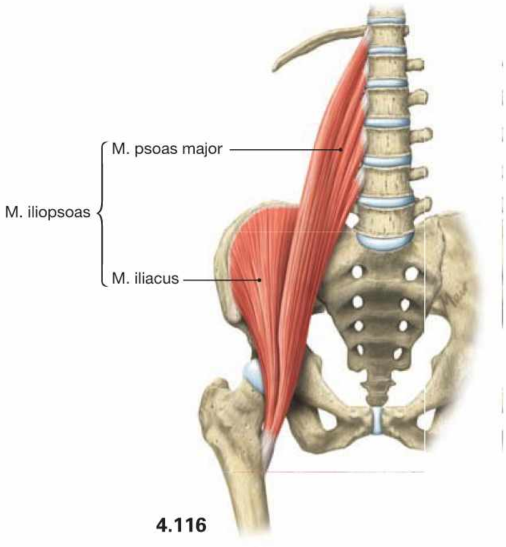


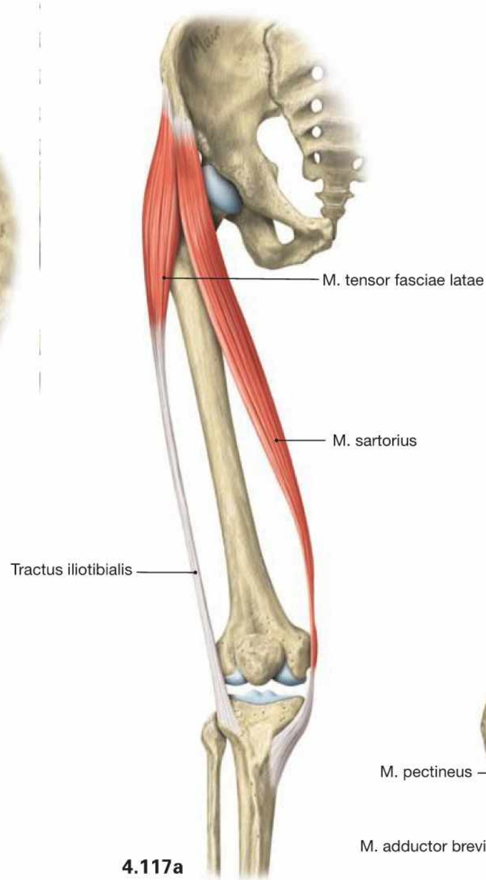
Fig. 4.115 Muscles of the hip and thigh, right side; medial view.

→ T 20a, 42–46

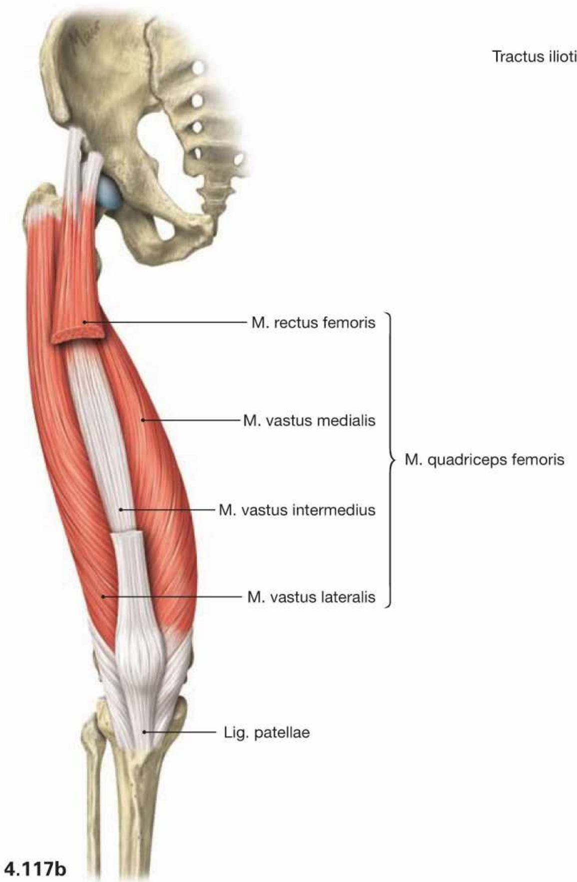
Muscles of the hip and thigh



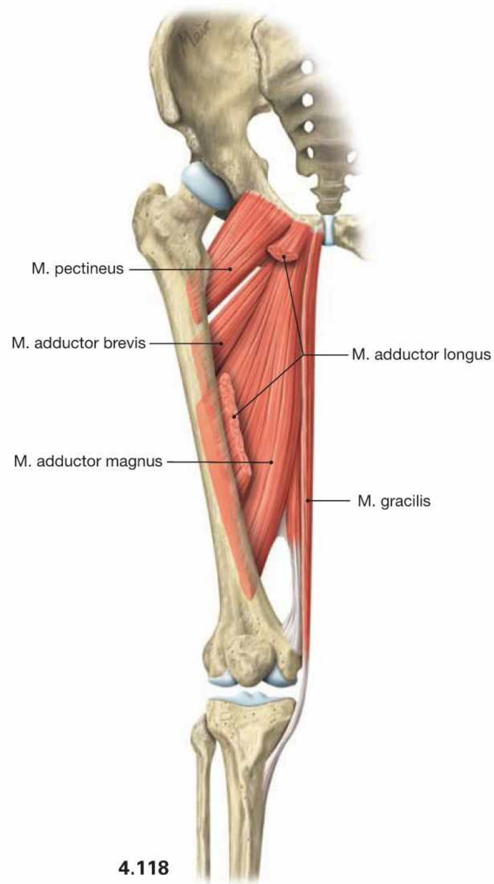
4.116



4.117a



4.117b



4.118

Fig. 4.116 to Fig. 4.118 Ventral muscles of the hip and thigh and medial muscles of the thigh, right side; ventral view.

The muscles of the hip and thigh are equally important to erect the body from the supine position, to maintain an upright position, and for the normal gait. The **ventral muscles** of the hip comprise the M. iliopsoas (→ Fig. 4.116) which functions as **most important flexor** of the hip. Located at the lateral thigh, the M. tensor fasciae latae (→ Fig. 4.117a) functions as **tension band** via its insertion on the iliotibial tract and protects the thigh bone from fractures by reducing bending stress. Together with the M. sartorius (→ Fig. 4.117a), the M. tensor fasciae latae flexes the hip joint. Due to its innervation, the M. tensor fasciae latae is also counted among the dorsolateral hip muscles.

The four-headed M. quadriceps femoris (→ Fig. 4.117b) is the **only extensor of the knee joint** and is essential to **erect the body** from a squatting position. Its M. rectus femoris spans two joints and also flexes the hip.

Located medially, the muscles of the **adductor group** (Mm. adductores, → Fig. 4.118) are the most important adductors of the thigh and stabilise the hip during standing and walking.

→ T 42–45

Muscles of the hip and thigh

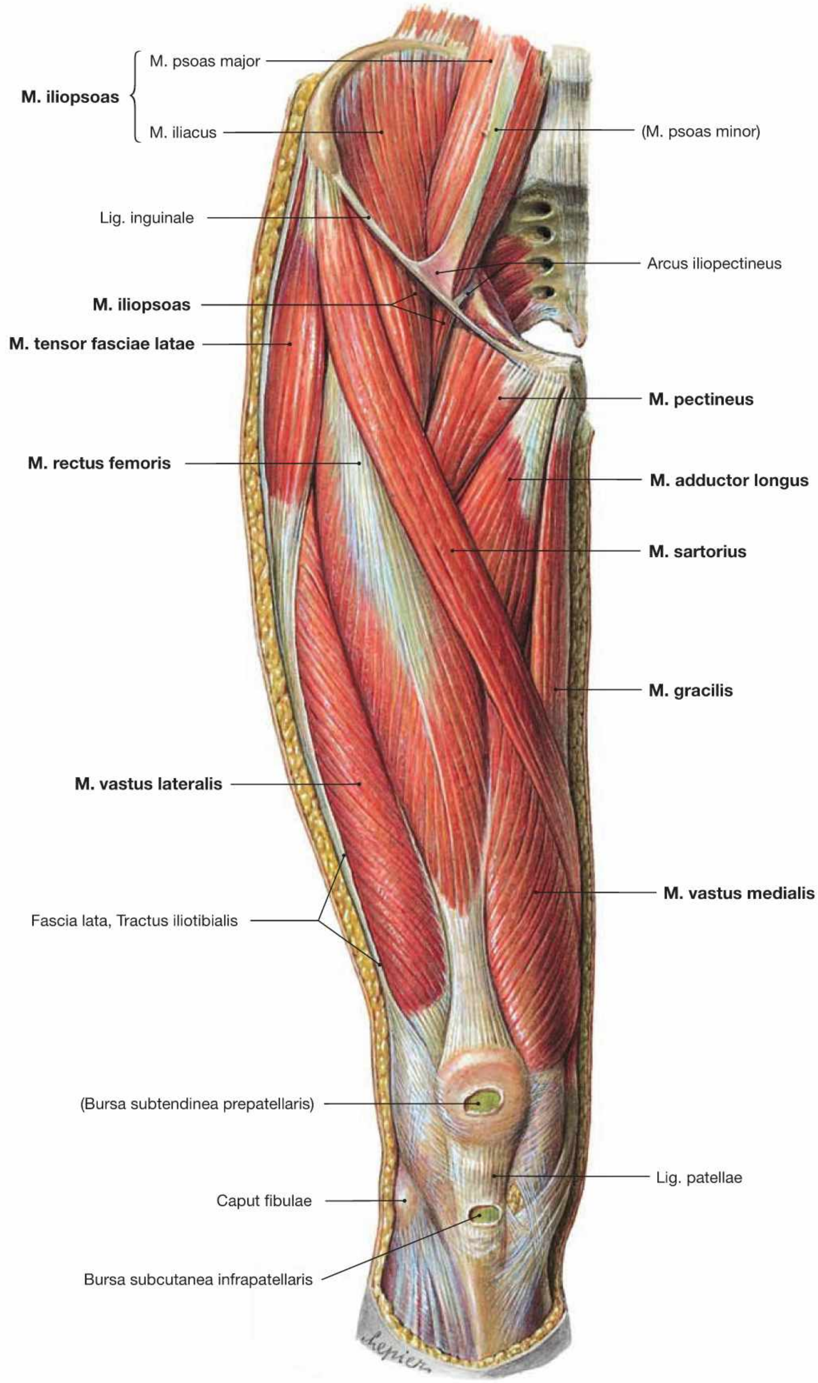


Fig. 4.119 Ventral muscles of the hip and thigh, and medial muscles of the thigh, right side; ventral view; after removal of the Fascia lata ventral to the Tractus iliotibialis.

The **M. iliopsoas** is composed of two different muscles which originate from the lumbar part of the vertebral column (M. psoas) and the Fossa iliaca (M. iliacus). Inferior to the inguinal ligament, only a short portion of both parts of the muscle courses to the common insertion site at the Trochanter minus.

The **M. sartorius** is ensheathed by a split portion of the Fascia lata and crosses the anterior aspect of the thigh to insert at the medial aspect of the Tibia posterior to the transverse axis of the knee. Thus, it flexes the hip and the knee.

Medially, the muscles of the **adductor group** are located on top of each other in several layers of which only the superficial M. pectineus, M. adductor longus, and M. gracilis are visible. The four heads of the **M. quadriceps femoris** (M. rectus femoris, Mm. vasti lateralis, medialis, and intermedius) lie distally and laterally of the M. sartorius. Their common tendon incorporates the Patella as a sesamoid bone before the fibres continue as Lig. patellae to the Tuberositas tibiae.

Most laterally, the **M. tensor fasciae latae** inserts in 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

Muscles of the hip and thigh

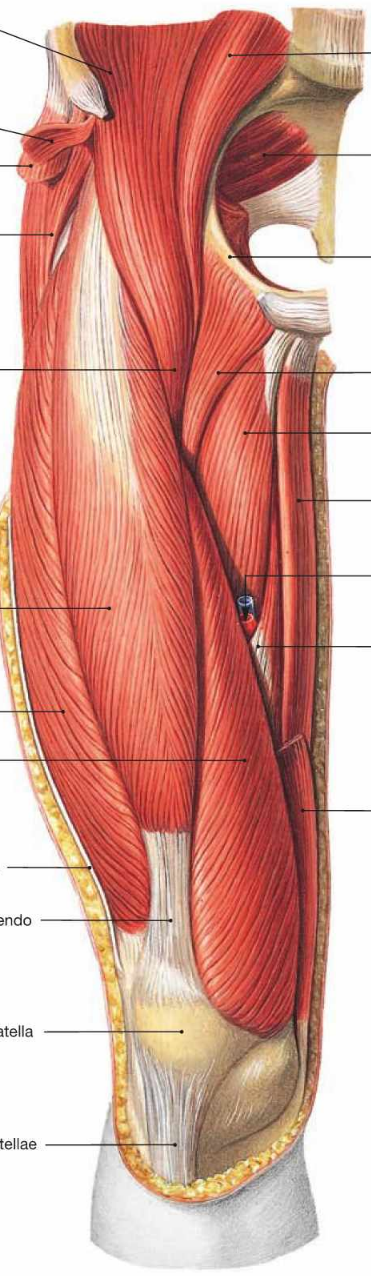


Fig. 4.120 Ventral muscles of the hip and thigh, and medial muscles of the thigh, right side; ventral view; after removal of the Fascia lata, the M. sartorius, and the M. tensor fasciae latae.
After removal of the M. sartorius, the entrance to the **adductor canal** (Canalis adductorius) is visible which is demarcated dorsally by the M. adductor longus. In its anterior portion, the canal is covered by the Septum intermusculare adductorium which connects the fasciae of the M. vastus medialis, Mm. adductores longus and 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 beneath the M. rectus femoris.

→ T 42, 45, 46

Clinical Remarks

In the case of conditions such as **spasticity** or **dystonia,** which involve a permanently flexed hip joint due to the contraction of the M. iliopsoas, standing in an upright position is impossible. Therapeutically, the M. iliopsoas is paralysed by injection of botulinum toxin which relaxes the muscle by blocking cholinergic synapses. Considering the course of the muscle, it is obvious that only a small portion of the muscle fibres can be blocked by injection from beneath the inguinal ligament. Therefore additional injections into the lumbar parts of the M. psoas major may be required.

Muscles of the hip and thigh

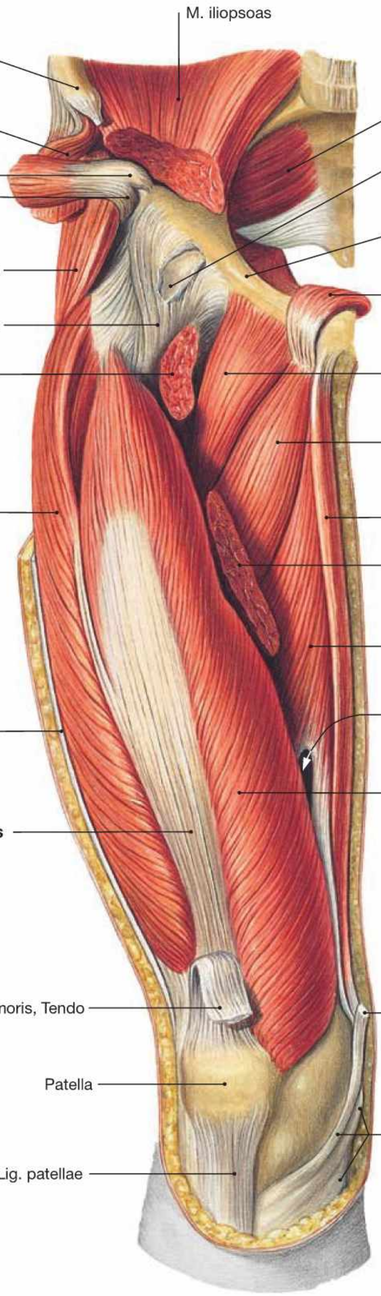


Fig. 4.121 Ventral muscles of the hip and thigh, and deep medial muscles of the thigh, right side; ventral view; after removal of the Fascia lata, Mm. sartorius, rectus femoris, and adductor longus, and partial removal of the M. iliopsoas at the area of the hip joint.
The M. rectus femoris and a part 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

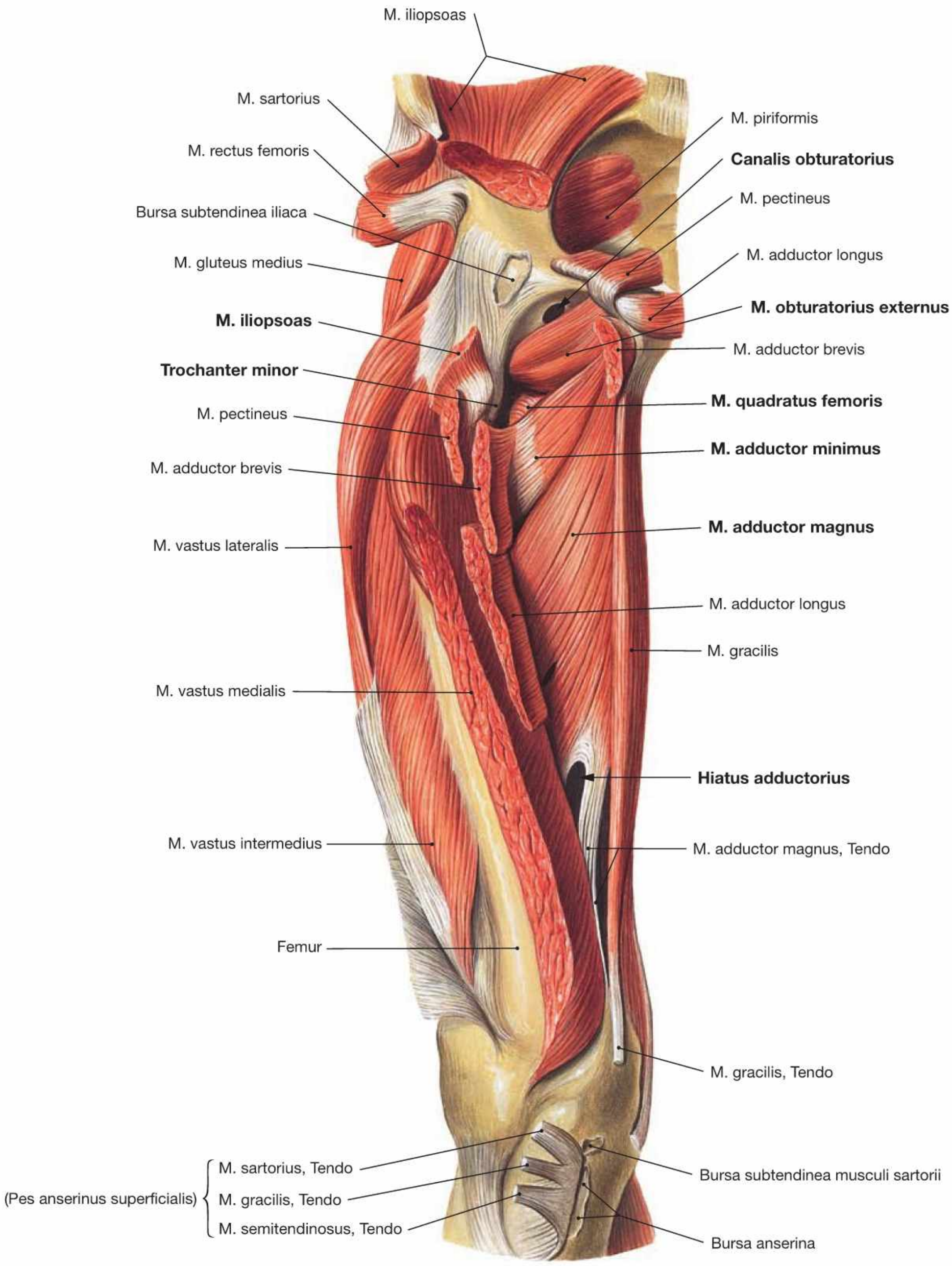
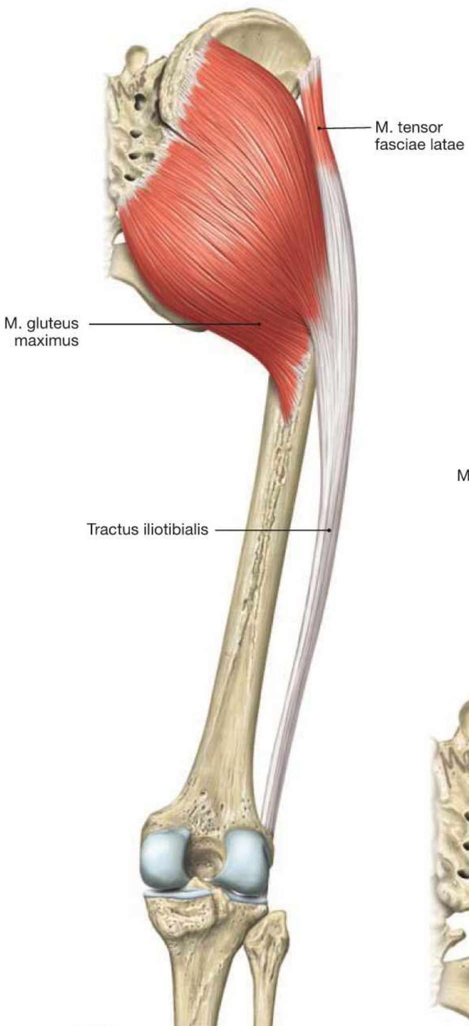


Fig. 4.122 Ventral muscles of the hip and thigh, and deep medial muscles of the thigh, right side; ventral view; after almost complete resection of the superficial and some of the deep muscles.

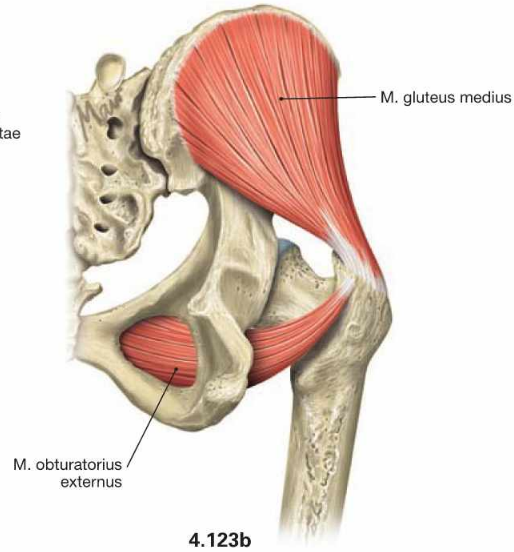
Upon reflecting the superficial adductor muscles and the M. adductor brevis laterally, the **M. adductor magnus** becomes visible. Its upper portion is also referred to as M. adductor minimus. The M. adductor magnus and its tendon form the **adductor hiatus** (Hiatus adductorius) through which the blood vessels of the thigh (A./V. femoralis) pass to reach the popliteal fossa. Proximal, the insertion of the M. iliopsoas at the Trochanter minor is recognisable after resection of the M. pectineus and M. adductor brevis. The **Canalis obturatorius** is displayed as opening within the Membrana obturatoria. It serves as neurovascular passageway between the small pelvis and the thigh. Caudal of this opening, the almost horizontal fibres of the **M. obturatorius externus** and the **M. quadratus femoris** are revealed, both of which belong to the pelvitrochanteric group of dorsal hip muscles (→ p. 306). These muscles are often not displayed during the dissection classes and thus, their classes is more difficult to envision.

→ T 42–45, 47

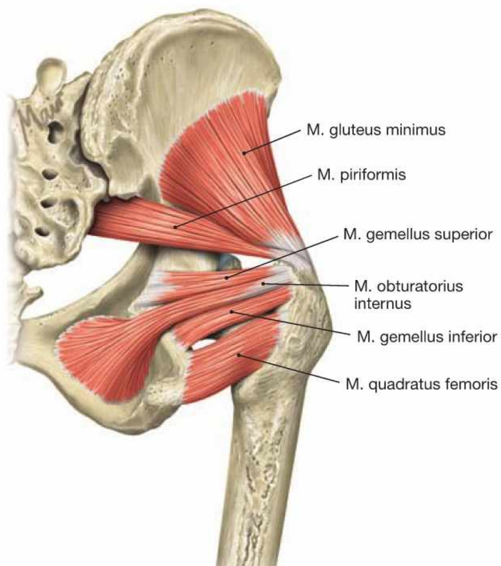
Muscles of the hip and thigh



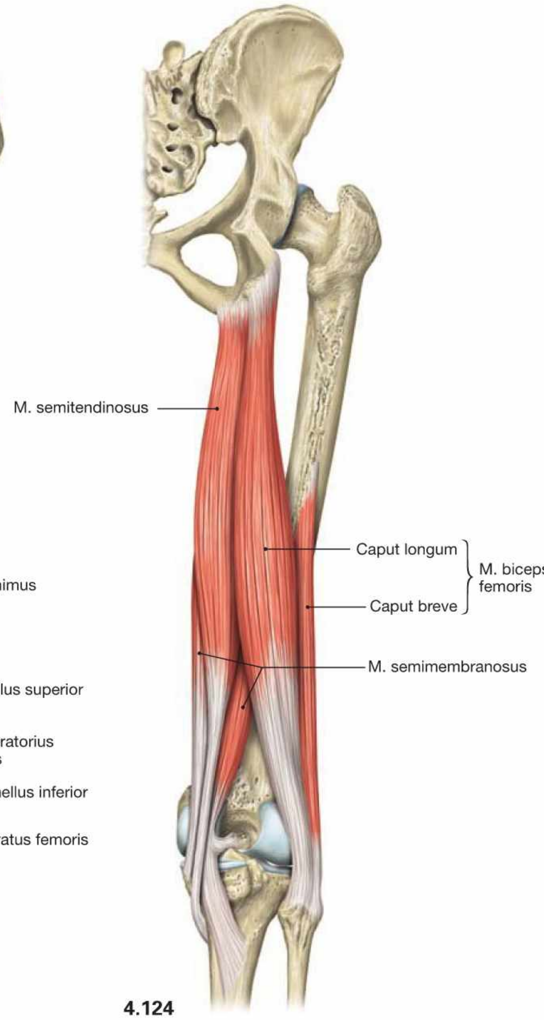
4.123a



4.123b



4.123c

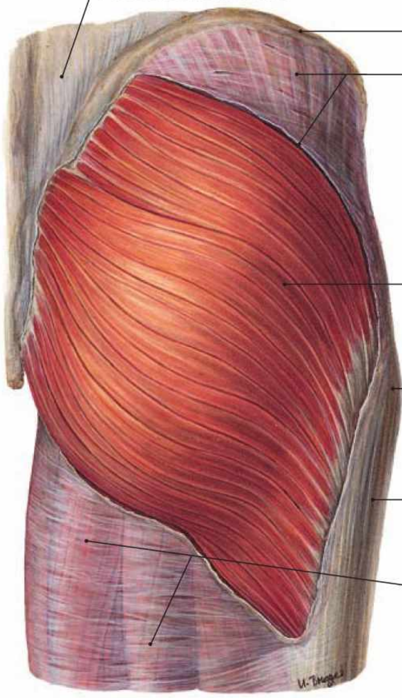


4.124

Figs. 4.123a to c Dorsal muscles of the hip, right side; dorsal view.
The dorsal muscles of the hip are categorized in a dorsolateral and a pelvitrochanteric group.
The **dorsolateral group** comprises the Mm. glutei maximus, medius and minimus. According to its innervation, the **M. tensor fasciae latae** (→ Fig. 4.117a) also may be counted among this group. The **M. gluteus maximus** (→ Fig. 4.123a) is the most important **extensor** and **lateral rotator** of the hip and for example necessary when climbing stairs. In contrast, the **smaller gluteal** muscles (Mm. glutei medius and minimus, → Figs. 4.123b and c) are the most important **abductors** and **medial rotators** of the thigh. Their action stabilises the hip during standing and walking and prevents the tilting of the pelvis to the contralateral side when standing on one leg (for the function of the small gluteal muscles and the TRENDELENBURG's sign → p. 335).
The **pelvitrochanteric group** (M. priformis, Mm. obturatorii internus and externus, Mm. gemelli superior and inferior, M. quadratus femoris → Fig. 4.123c) comprises exclusively **lateral rotators.**

Fig. 4.124 Dorsal (ischiocrural, hamstring) muscles of the thigh, right side; dorsal view.
The dorsal **(ischiocrural, hamstring) muscles** (→ Fig. 4.124) on the posterior side of the thigh originate from the Tuber ischiadicum and insert to both bones of the lower leg. These muscles span two joints and facilitate extension in the hip joint while serving as **strongest flexors** in the knee joint. In addition, the lateral **M. biceps femoris** functions in **lateral rotation** on both joints, whereas the medial **M. semitendinosus** and **M. semimembranosus** function in **medial rotation.**

→ T 43, 44, 47



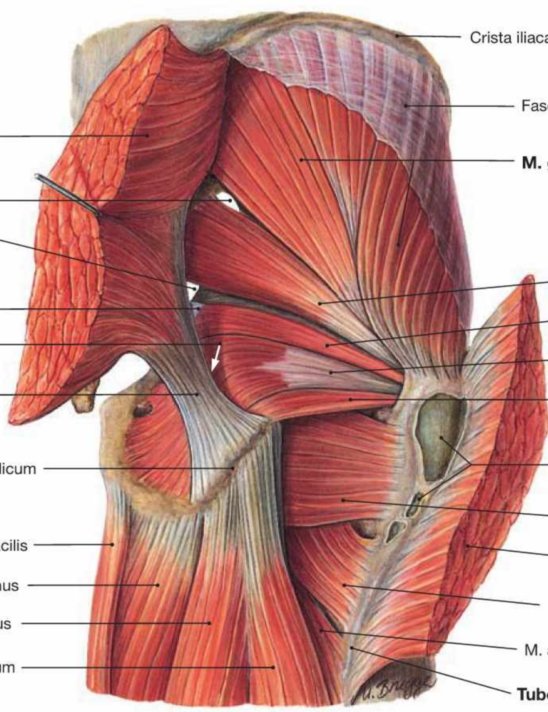
4.125

Fig. 4.125 and Fig. 4.126 Dorsal muscles of the hip and thigh, right side; dorsal view; after splitting of the Fascia lata (→ Fig. 4.125) and separation of the M. gluteus maximus (→ Fig. 4.126).

The illustration shows the superficial and the deep origins and insertions of the **M. gluteus maximus.** Superficially, the muscle originates from the posterior side of the sacrum, the Crista iliaca and the Fascia thoracolumbalis as well as deeply from the Lig sacrotuberale. Its muscle fibres course in an oblique way, whereas the **M. gluteus medius** beneath has an almost vertical orientation. The M. gluteus maximus has superficial insertions at the Fascia lata and the Tractus iliotibialis and deep insertions on the Tuberositas glutea of the Femur. Separation and lateral reflexion of the M. gluteus maximus reveals the other parts of the M. gluteus medius and the **pelvitrochanteric muscles.**

The **M. piriformis** divides the Foramen ischiadicum majus into the **Foramina suprapiriforme** and **infrapiriforme** which serve as important passageways for neurovascular structures from the pelvis. It should be noted that the **M. obturatorius internus** frequently continues as a tendinous structure from its deflecting point (hypomochlion) at the Incisura ischiadica minor to its insertion at the Fossa trochanterica.

→ T 43, 44, 47



4.126

Muscles of the hip and thigh

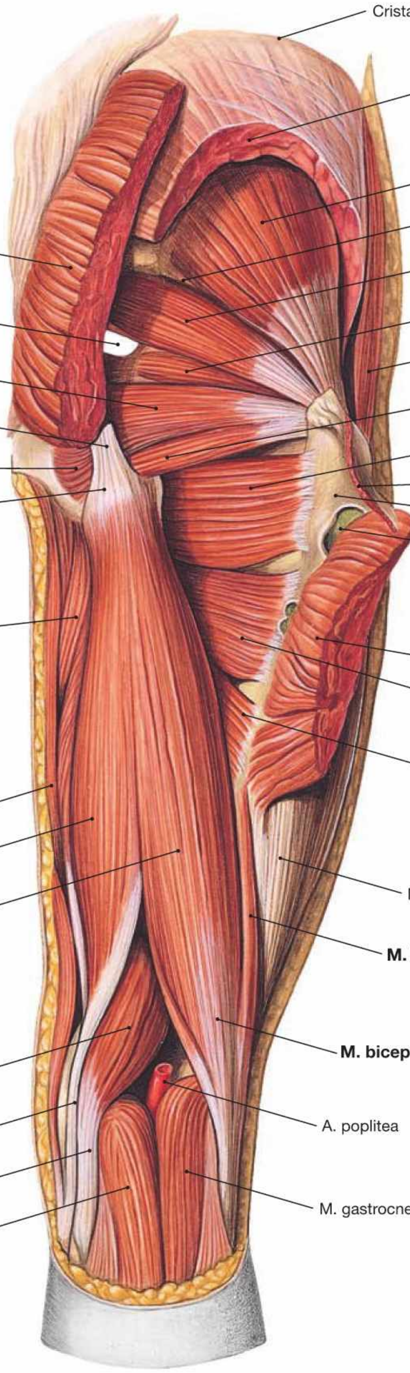


Fig. 4.127 Dorsal muscles of the hip and thigh, right side; dorsal view; after partial resection of the Mm. glutei maximus and medius.
After cutting the M. gluteus medius in addition to the M. gluteus maximus, the **M. gluteus minimus** is visible. Collectively, the Mm. glutei medius and minimus are referred to as **small gluteal muscles.** Both muscles serve for hip abduction and stabilisation of the pelvis during one-leg stand.
The dorsal side of the thigh contains the **hamstring muscles** which span from the Tuber ischiadicum to the bones of the lower leg. Located medially is the **M. semitendinosus** (named after its long tendon) and beneath the **M. semimembranosus** (named after its flat tendon); positioned laterally is the **M. biceps femoris.** The Caput longum of the latter originates from the Tuber ischiadicum, whereas the Caput breve originates from the distal thigh (Labium laterale of the Linea aspera).

→ T 43, 47

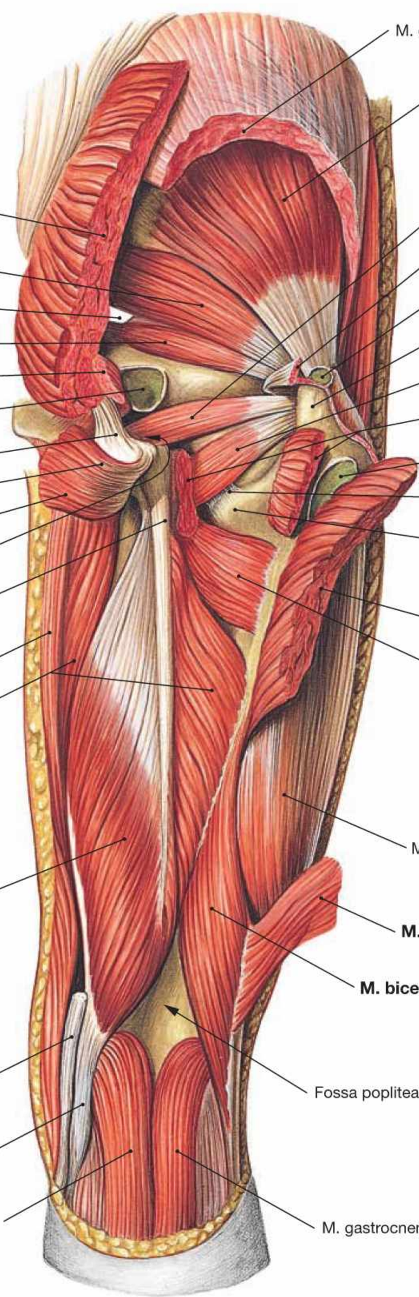
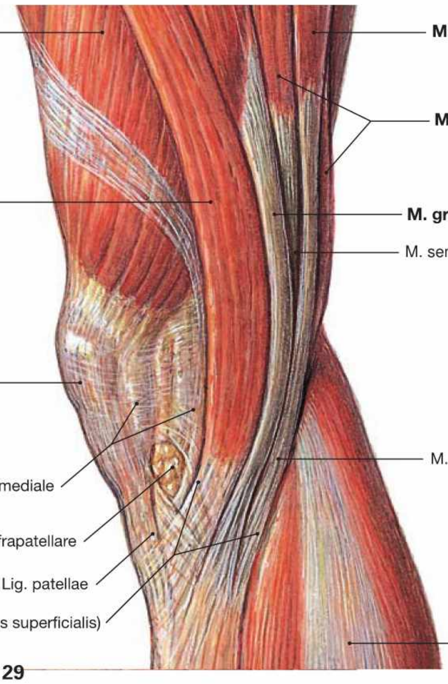


Fig. 4.128 Deep dorsal muscles of the hip and thigh, right side; dorsal view; after almost complete resection of the superficial gluteal and hamstring muscles.

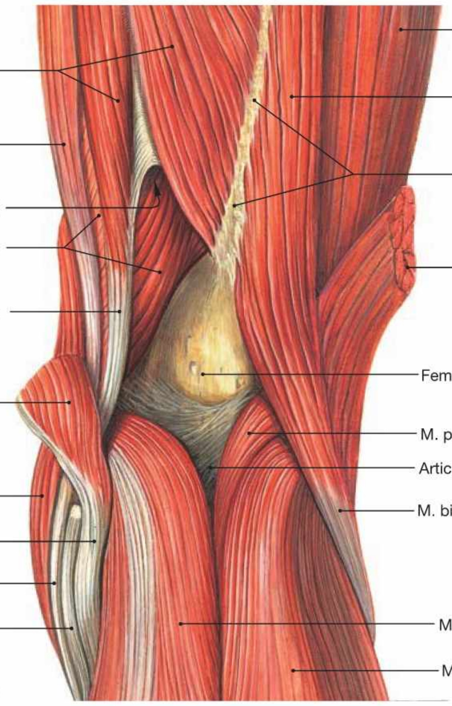
Upon splitting the M. quadratus femoris, the deeper **M. obturatorius externus** is visible; its course is often difficult to imagine. Removal of the long head of the M. biceps femoris exposes the deep components of the adductor group. The **M. adductor magnus** has two functionally independent muscle parts with distinct innervation. Its major component originates from the inferior pubic ramus (this part is sometimes referred to as **M. adductor minimus**) and the ischial ramus. The posterior part derives from the Tuber ischiadicum and, according to its function and innervation, is counted among the hamstring muscles.

→ T 43, 44, 46, 47

Muscles of the thigh



4.129



4.130

Fig. 4.129 and Fig. 4.130 Muscles in the region of the knee joint, right side; medial (→ Fig. 4.129) and dorsal (→ Fig. 4.130) views.
The common insertion of the Mm. sartorius, gracilis, and semitendinosus beneath the medial condyle of the Tibia is referred to as "Pes anserinus superficialis". The deeply located insertion of the M. semimembranosus is called "Pes anserinus profundus".

→ T 45–47

Muscles of the leg

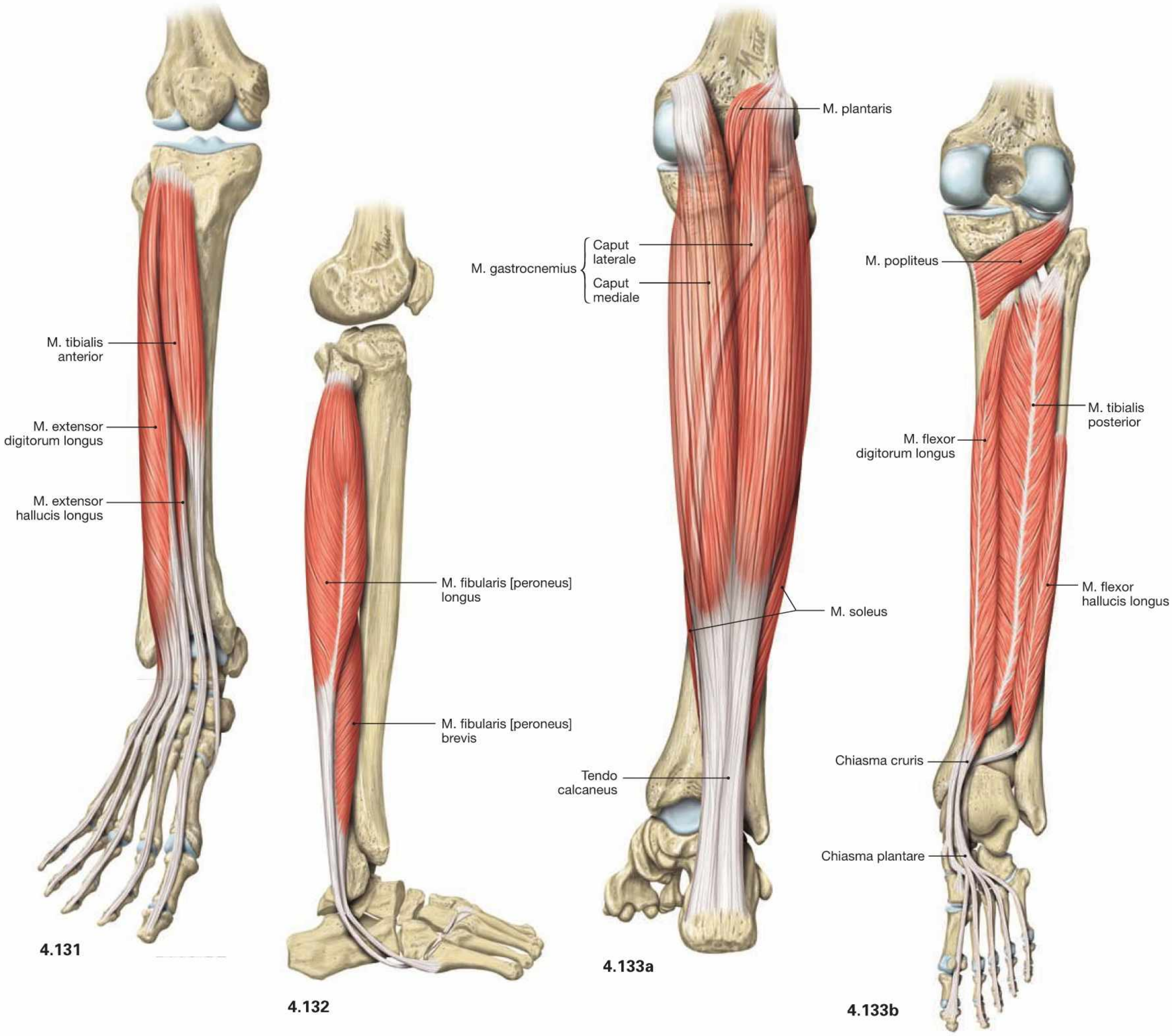


Fig. 4.131 to Fig. 4.133 Muscles of the leg, right side; ventral (→ Fig. 4.131), lateral (→ Fig. 4.132), and dorsal (→ Fig. 4.133) views.

The leg has three muscle groups. To understand their function, the position in relation to the axes of movement in the joints of the ankle and foot are important. All muscles coursing **anterior** to the transverse axis of the ankle joint are **extensors (dorsiflexors)**, all muscles **dorsal** to this axis are **flexors (plantarflexors)** of the foot. All muscles with tendons coursing **medial** to the oblique axis of the talocalcaneonavicular joint function as **supinators** and lift the medial margin of the foot. Muscles with tendons **lateral** to this axis lift the lateral margin of the foot and thus perform **pronation.**

The ventral muscles of the leg function as extensors (→ Fig. 4.131). They extend the ankle joint and the talocalcaneonavicular joint, together with the other joints of the foot, they mainly support pronation. The **M. tibialis anterior** is the most important extensor (→ Fig. 4.131), whereas the **M. extensor digitorum longus** and **M. extensor hallucis longus** also extend the toes.

The lateral (fibular) muscles of the leg (→ Fig. 4.132) comprise the **Mm. fibularis longus and brevis.** They are the most important pronators and function as plantarflexors in the ankle joint due to their tendons positioned behind the flexion-extension axis. Dorsally located are the true flexor muscles (plantarflexors) which can be divided in a superficial and a deep group.

The **M. triceps surae** (→ Fig. 4.133a) is part of the superficial dorsal muscles and comprises the two-headed **M. gastrocnemius** and the **M. soleus** beneath. The M. triceps surae is the strongest flexor and major supinator of the foot. The **M. plantaris** is rather insignificant.

The deep dorsal muscles (flexors; → Fig. 4.133b) are largely equivalent to the extensors on the ventral side. The **M. tibialis posterior** is a flexor and a strong supinator. The **M. flexor digitorum longus** and **M. flexor hallucis longus** flex the phalangeal joints. A special role has the **M. popliteus** which stabilises the knee joint. Above the medial Malleolus, the tendon of the M. flexor digitorum crosses the tendon of the M. tibialis posterior **(Chiasma cruris)** and at the level of the sole of the foot, it crosses the tendon of the M. flexor hallucis longus **(Chiasma plantare).**

→ T 48–51

Muscles of the leg

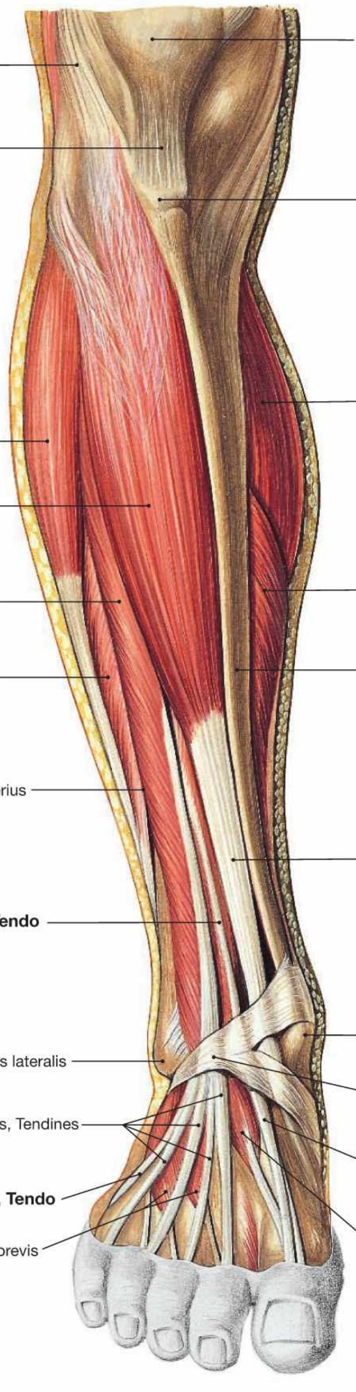


Fig. 4.134 Ventral and lateral muscles of the leg and the foot, right side; ventral view.
The **M. tibialis anterior** of the extensor group can be palpated near the margin of the Tibia. Since its tendon courses medial to the axis of the talocalcaneonavicular joint, it functions as a (although weak) supinator in contrast to the other extensors. The **M. extensor digitorum longus** derives from the proximal Tibia and Fibula, and the **M. extensor hallucis longus** is located between the other two extensors at the distal leg. Occasionally, the M. extensor digitorum longus shows a separation that inserts at the Os metatarsi V and is confusingly called **M. fibularis tertius.** In the distal part, the tendons are guided by a reinforcement of the fascia of the leg, the **Retinaculum musculorum extensorum.** The retinacula of the foot function as retainers and prevent the tendons from lifting off the bones during extension of the foot. Both muscles of the fibularis group (**Mm. fibulares longus** and **brevis**) belong to the lateral group and originate from the proximal and distal Fibula. Clinically, they are often referred to by their old name as peroneal muscles (fibula, greek: perone).

→ T 48, 49

Muscles of the leg

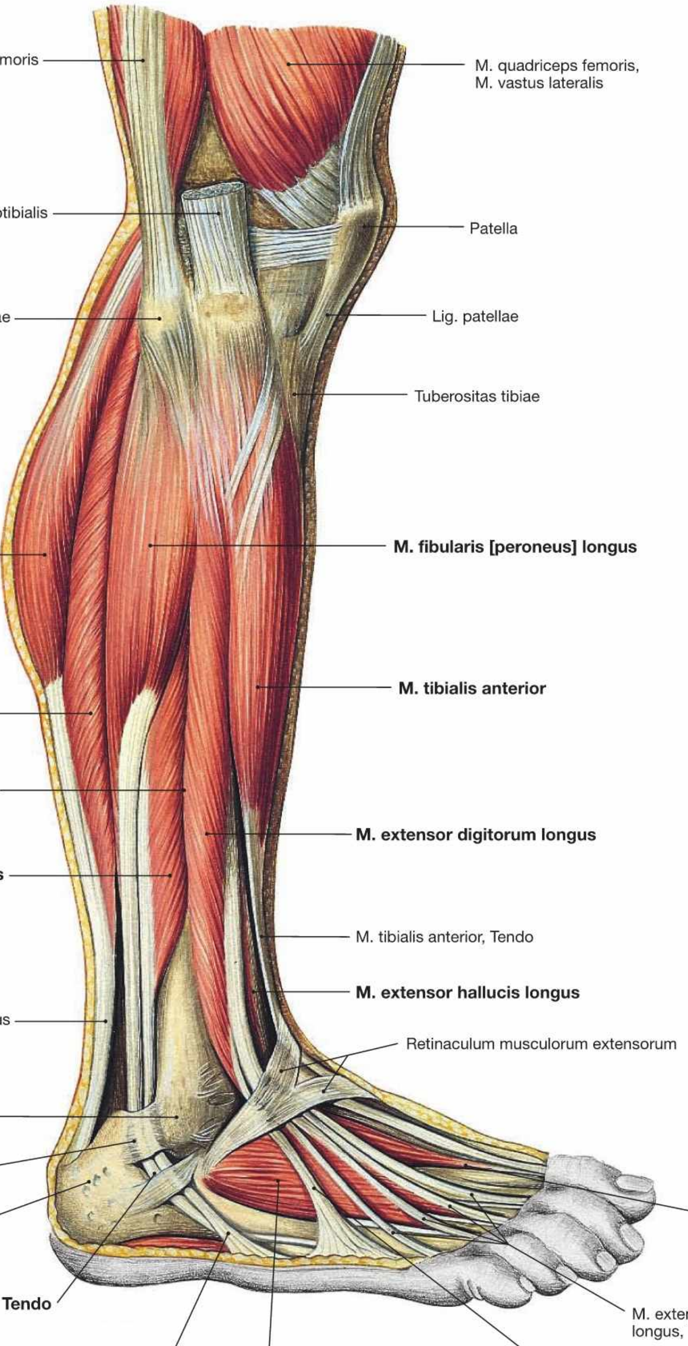


Fig. 4.135 Muscles of the leg and the foot, right side; lateral view. In the lateral view, all three muscle groups of the leg are visible. Laterally behind the anterior group of extensors lie the fibularis muscles, dorsally lie the flexors. Since the deep flexors of the rear side are directly adjacent to the bones of the leg, only the superficial muscles (M. triceps surae), the **M. gastrocnemius** and the **M. soleus,** can be seen. The tendons of the fibularis 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 extends beneath the sole of the foot and inserts at the Os metatarsi I and Os cuneiforme mediale, thus actively supporting the plantar arch. 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

Muscles of the leg

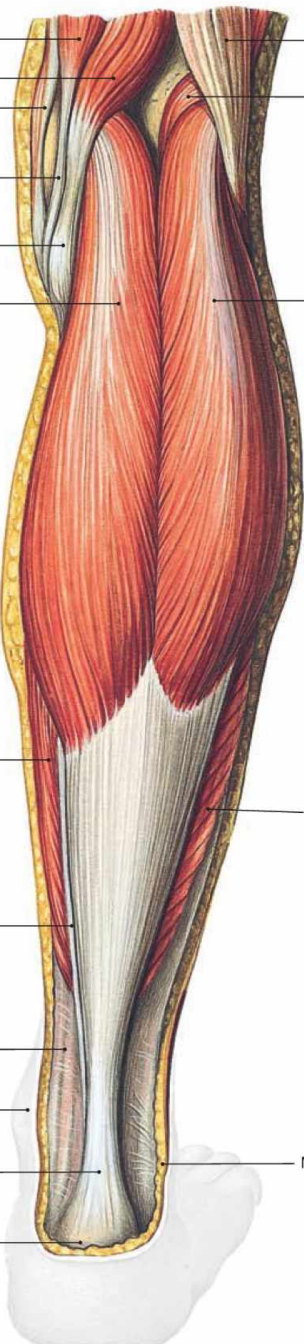


Fig. 4.136 Superficial layer of the dorsal muscles of the lower leg, right side; dorsal view.
The superficial group of flexors comprises the **M. triceps surae** and the **M. plantaris.** The strong M. triceps surae includes the two-headed **M. gastrocnemius** and the subjacent **M. soleus.** All superficial dorsal muscles insert at the Calcaneus 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 is paralysed, such as after a disc herniation with resulting injury to the spinal cord segment S1 or a lesion of the N. tibialis, standing on one's toes is impossible.

→ T 50

Muscles of the leg

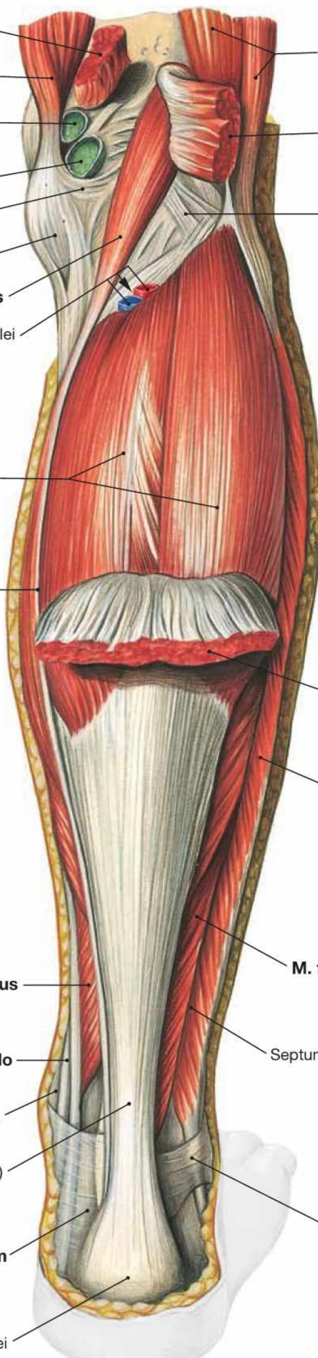


Fig. 4.137 Superficial layer of the dorsal muscles of the lower leg, right side; dorsal view; after dissecting the origins of the M. gastrocnemius.

After reflecting the **M. gastrocnemius** inferiorly, the **M. plantaris** is visible proximal of the **M. soleus.** The muscle bellies of the deep flexors are located further distally and are visible on both sides of the ACHILLES tendon after removal of the Fascia cruris. Their tendons are guided by the **Retinaculum musculorum flexorum** at the medial malleolus.

→ T 51

Muscles of the leg

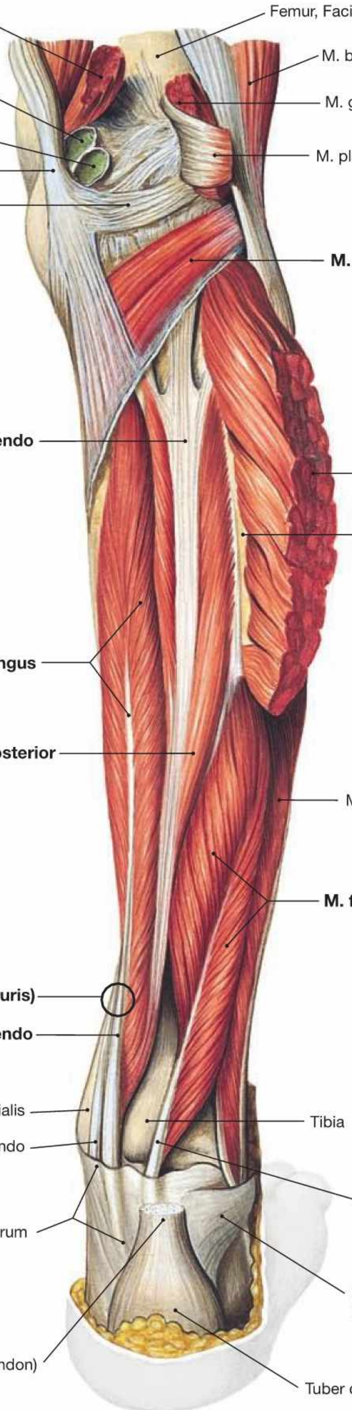


Fig. 4.138 Deep layer of the dorsal muscles of the leg, right side; dorsal view; after removal of the superficial flexors.
After removal of the superficial flexors the deep muscles are visible. The **M. tibialis posterior** is located between both flexor muscles of the toes. The **M. flexor digitorum longus** originates furthest medially followed by the **M. tibialis posterior** and further distal by the **M. flexor hallucis longus**. Their tendons meet beneath the medial malleolus where they are covered by the **Retinaculum musculorum flexorum.** In this course the tendon of the M. flexor digitorum longus crosses the tendon of the M. tibialis posterior **(Chiasma cruris).** Proximal, the **M. popliteus** originates from the Condylus lateralis and from the posterior horn of the lateral meniscus. The muscle inserts on the posterior aspect of the proximal Tibia and functions as a relatively strong **medial rotator**. Thus, the primary function of the M. popliteus is to **actively stabilise** the knee and to prevent an extensive lateral rotation.

→ T 51

Muscles of the leg

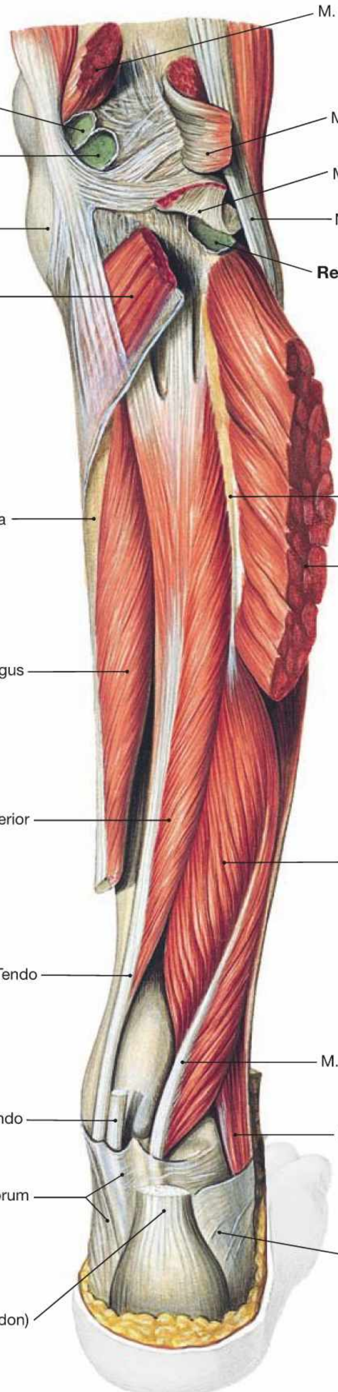


Fig. 4.139 Deep layer of the dorsal muscles of the leg, right side; dorsal view; after removal of the superficial flexors and splitting of the M. popliteus.

Upon splitting of the M. popliteus, the Bursa subpoplitea is exposed. This bursa frequently communicates with the joint cavity of the knee joint and is often referred to as **Recessus subpopliteus.** Additional bursae are present beneath the tendinous origins and insections of the dorsal muscles (**Bursa musculi semimembranosi** and **Bursae subtendineae musculorum gastrocnemii medialis and lateralis**). These also may communicate with the joint cavity (→ p. 280).

→ T 51

Synovial sheaths of the foot

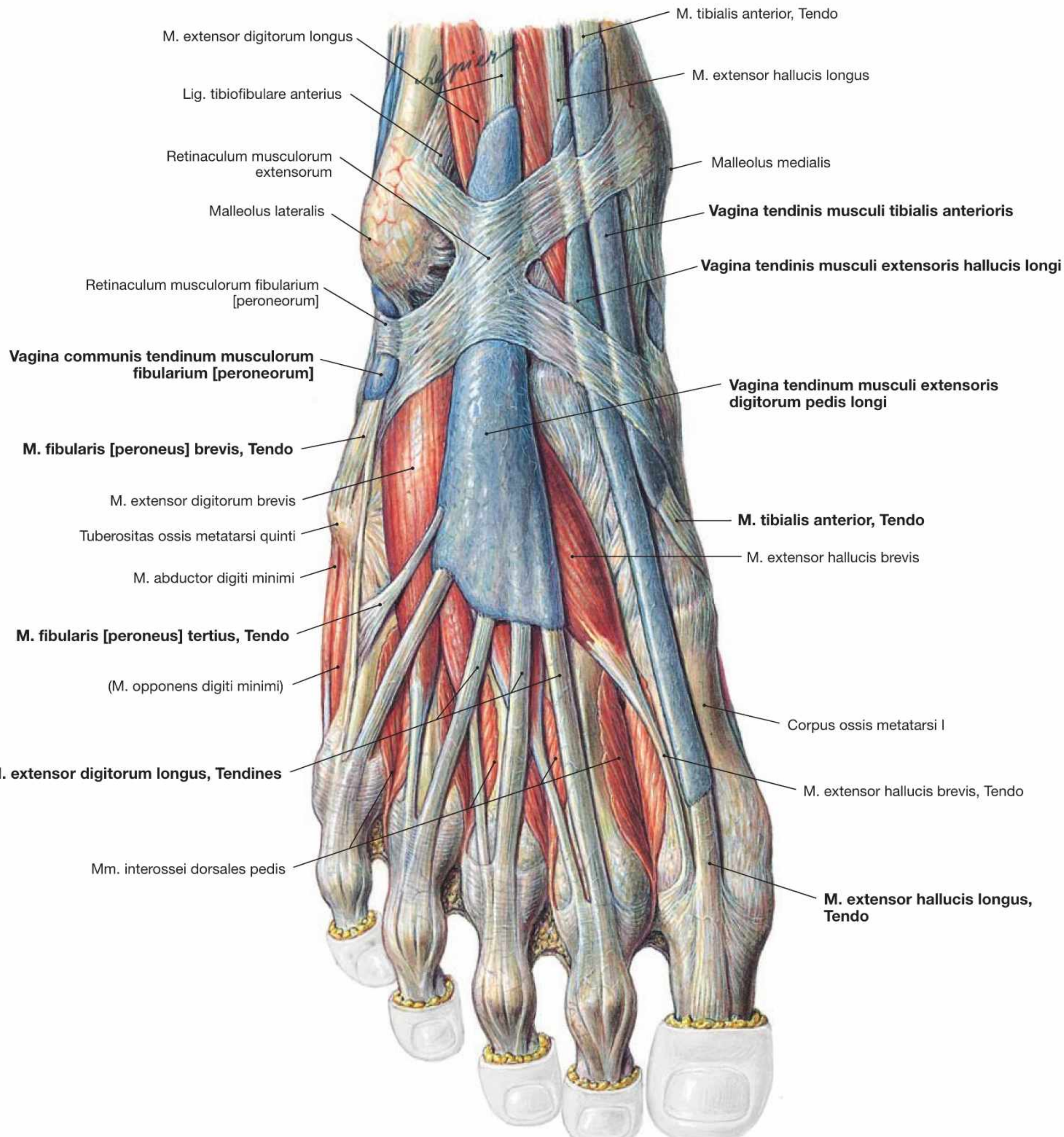
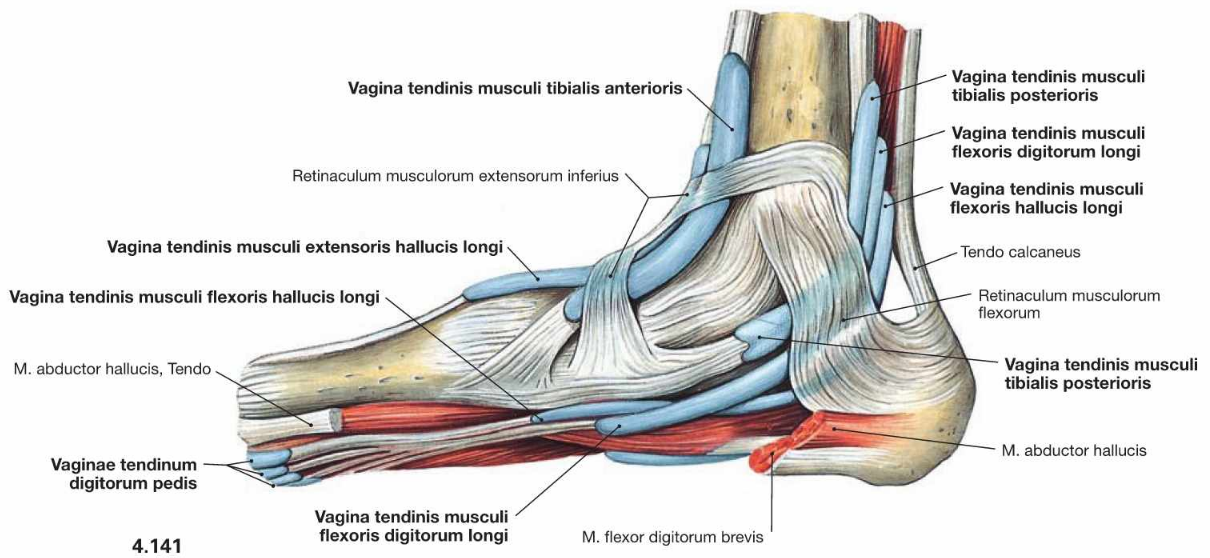
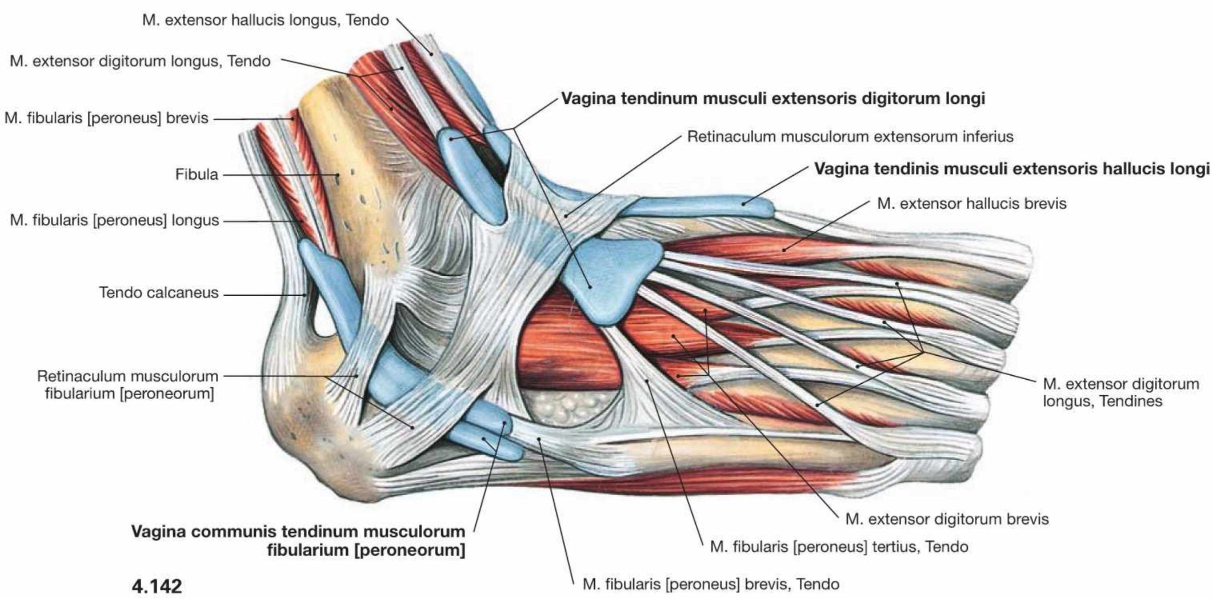


Fig. 4.140 Synovial sheaths, Vaginae tendinum, of the foot, right side; dorsal view in relation to the dorsum of the foot.
The Fascia cruris was removed except for the Retinaculum musculorum extensorum. The **retinacula** of the foot serve as retaining straps and prevent the tendons from lifting off the bones during muscle contractions. Each extensor muscle has its own synovial sheath (Vagina tendinis) which encloses all tendons of the respective muscle and serves as guiding tube as well as gliding surface. In contrast, the tendons of the M. fibularis longus and M. fibularis brevis have a common synovial sheath.

Synovial sheaths of the foot



4.141



4.142

Fig. 4.141 and Fig. 4.142 Synovial sheaths, Vaginae tendinum, of the foot, right side; medial (→ Fig. 4.141) and lateral (→ Fig. 4.142) views.

The synovial sheaths surround the tendons of all three muscle groups of the leg particularly where the tendons are fixed to the bones by the retinacula. The Retinaculum musculorum flexorum forms the **malleolar canal** behind the medial malleolus which serves as a passageway for the neurovascular structures (N. tibialis, A./V. tibialis posterior) to the sole of the foot.

Muscles of the foot

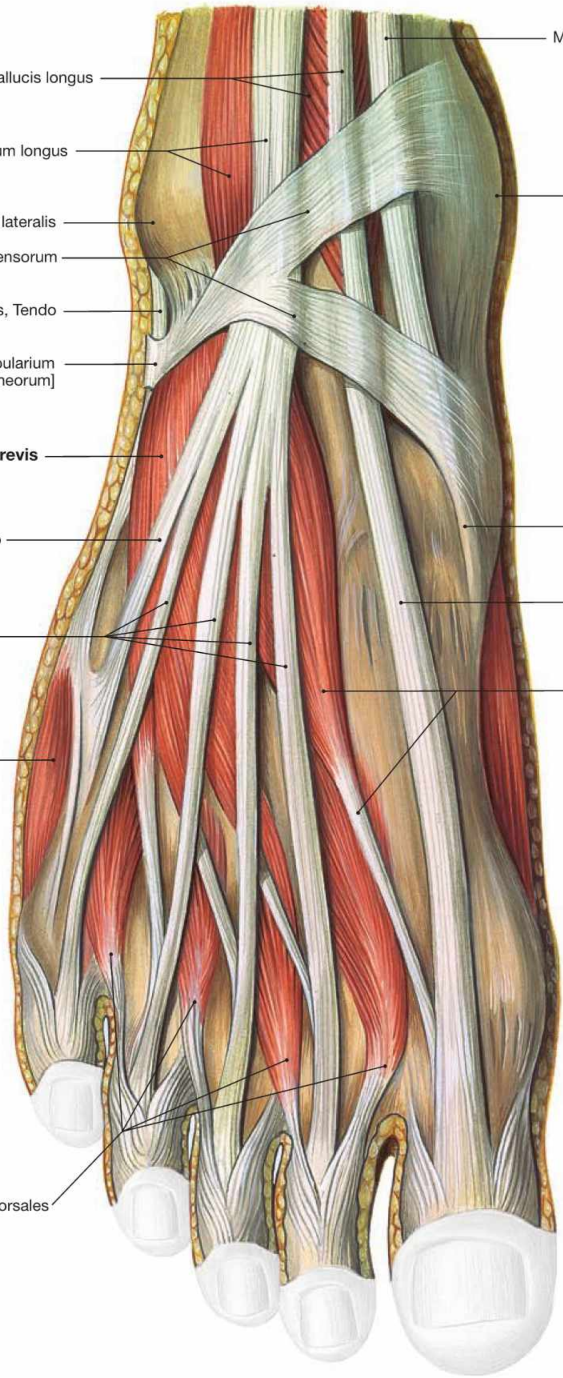


Fig. 4.143 Muscles of the dorsum of the foot, right side; dorsal view.

Beneath the tendons of the long extensor muscles, which have their muscle bellies at the ventral side of the leg, there are two short extensors. The **M. extensor digitorum brevis** and **M. extensor hallucis brevis** originate on the dorsal side of the Calcaneus and their tendons insert from lateral into the tendons of the long extensors and additionally into the dorsal aponeurosis. Therefore, they contribute to the extension in the phalangeal joints and the metatarsophalangeal joint of the big toe. The Mm. interossei dorsales are also visible, but they are grouped with the plantar muscles (→ p. 325).

→ T 48, 52, 54

Muscles of the foot

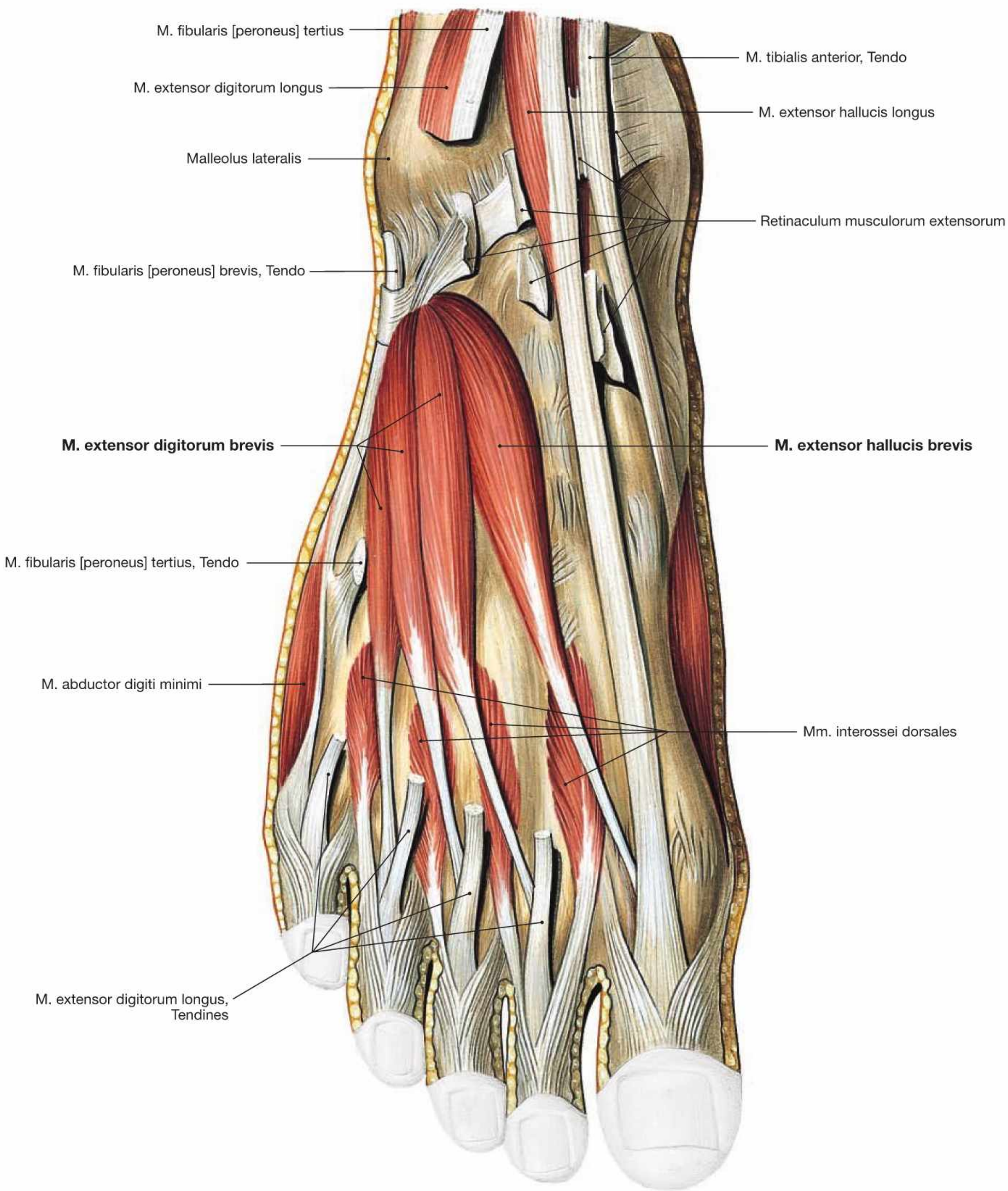


Fig. 4.144 Muscles of the dorsum of the foot, right side; dorsal view.
The Retinaculum musculorum extensorum was split and the tendon of the M. extensor digitorum longus partially removed to demonstrate the muscles of the dorsum of the foot. They comprise the short extensor muscles of the lateral four 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 project to the dorsal aponeurosis of the second to fourth phalanges or to the dorsal side of the big toe.

→ T 48, 52, 54

Muscles of the foot

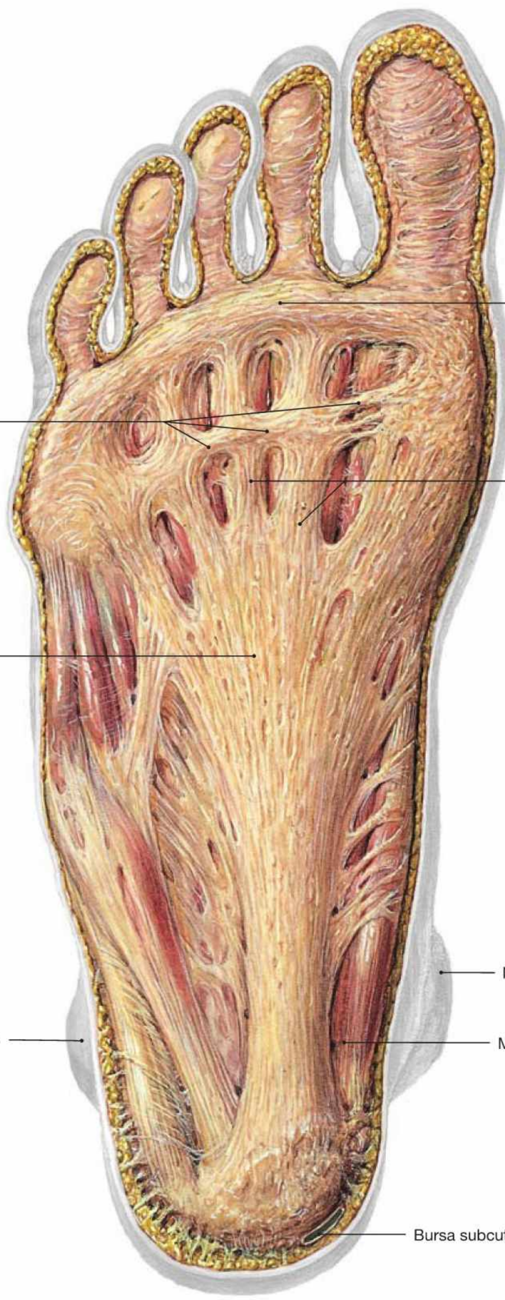


Fig. 4.145 Plantar aponeurosis, Aponeurosis plantaris, of the foot, right side; plantar view.
The plantar aponeurosis is a plate of dense connective tissue with a strong medial and two weaker lateral parts. The **Fasciculi longitudinales** project from the Tuber calcanei to the ligaments of the metatarsophalangeal joints. At the level of the Ossa metatarsi they are connected by transverse fibres **(Fasciculi transversi).** These transverse fibres are collectively referred to as **Lig. metatarsale transversum superficiale.** Two septa course from the plantar aponeurosis to the bones, thus, creating spaces for three plantar muscle groups.

Muscles of the foot

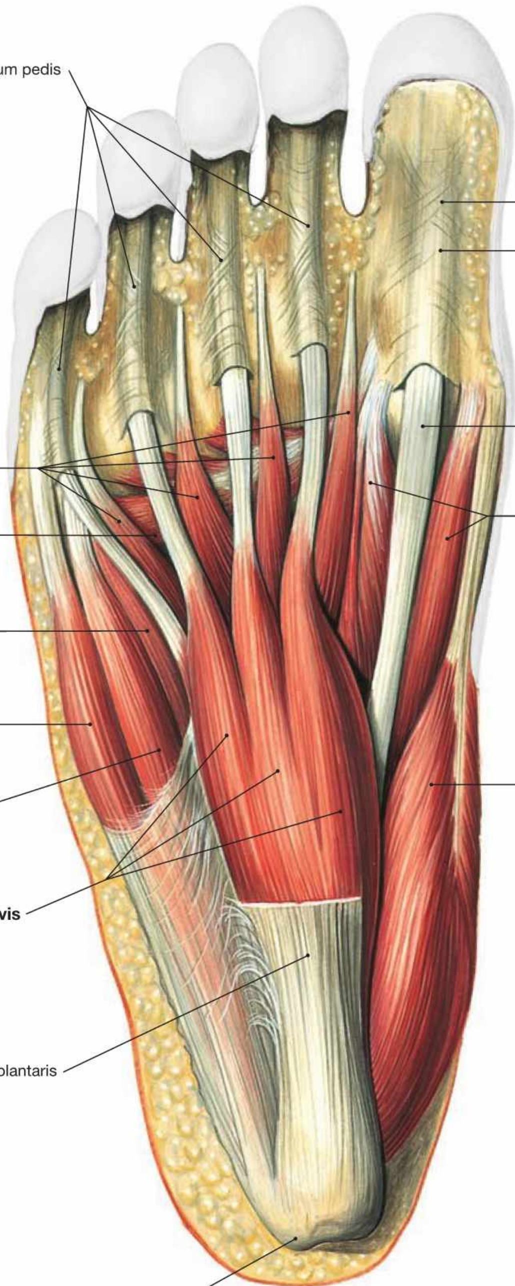


Fig. 4.146 Superficial layer of plantar muscles, right side; plantar view; after removal of the plantar aponeurosis.

In contrast to the hand, the muscles of the sole of the foot do not serve for differentiated movements of individual toes but serve in **actively bracing the plantar arch** as a functional muscle unit. The plantar muscles support the ligaments which accomplish a passive stabilisation. The plantar muscles are separated into **three different groups** (medial, intermediate and lateral) by two septa which project from the plantar aponeurosis to the bones. These groups are not easily separated during dissection, and it is easier to dissect **four layers** of muscles.

The muscles of the **superficial layer** comprise the **M. abductor hallucis, M. flexor digitorum brevis** and **M. abductor digiti minimi**. The tendons of the M. flexor digitorum brevis are pierced by the tendons of the long flexors. At the level of the toes, the tendons of the flexor muscles have separate synovial sheaths (Vaginae tendinum) which do not communicate with those at the tarsal level. The synovial sheaths are reinforced by ligaments containing anular (Pars anularis) and cruciform (Pars cruciformis) components.

→ T 52–55

Muscles of the foot

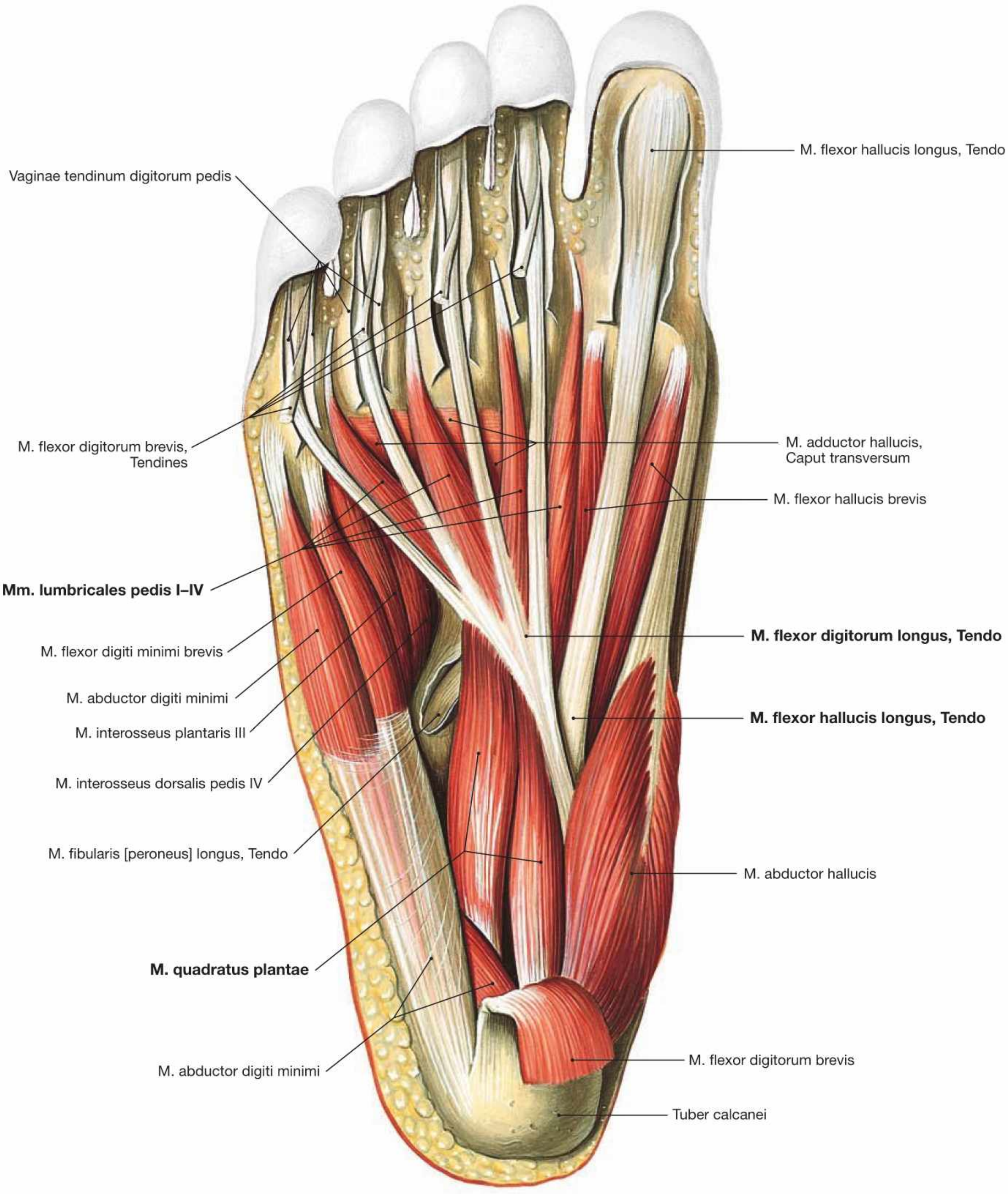


Fig. 4.147 Middle layer of the plantar muscles, right side; plantar view; after dissection of the M. flexor digitorum brevis.
The muscles lie in four layers on top of each other. Upon resection of the M. flexor digitorum brevis, the muscles and **tendons** of the second layer are visible. It consists of the tendons of the long flexors (**M. flexor hallucis longus** and **M. flexor digitorum longus**) and of two muscles of the intermediate group. The tendon of the M. flexor digitorum longus serves as origin for the **M. quadratus plantae** which functions as an accessory flexor supporting the long flexor muscle. The tendon also serves as origin for the four **Mm. lumbricales** which insert from medial on the proximal phalanges of the toes (II–V).

→ T 53–55

Muscles of the foot

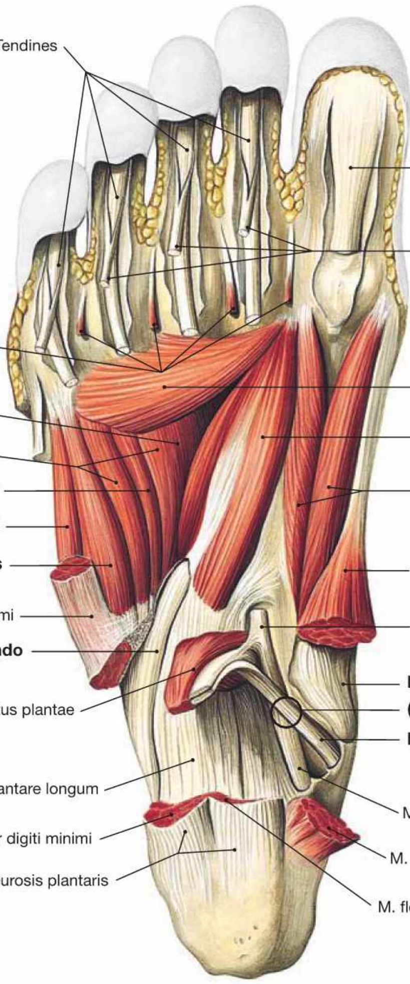
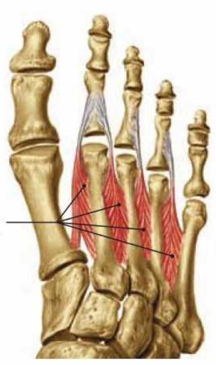


Fig. 4.148 Deep and deepest layers of the plantar muscles, right side; plantar view; after removal of both superficial muscle layers and the long flexor tendons.
Within the **deep layer** the **M. flexor hallucis brevis** and **M. adductor hallucis** are located medially, the **M. flexor digiti minimi brevis** and the inconsistent **M. opponens digiti minimi** laterally.

The **deepest layer** comprises three **Mm. interossei plantares** and four **Mm. interossei dorsales** as well as the **tendons of the M. tibialis posterior** and **M. fibularis longus.**

* The crossing of the M. flexor digitorum longus tendon over the M. flexor hallucis longus tendon is also referred to as Chiasma plantare.

→ T 51, 53–55



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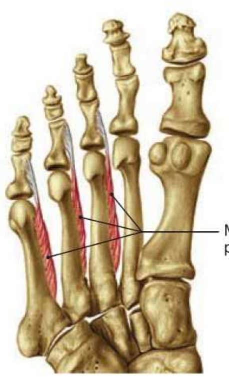


4.150

Fig. 4.149 and Fig. 4.150 Mm. interossei dorsales (→ Fig. 4.149) and plantares (→ Fig. 4.150) of the foot, right side; dorsal (→ Fig. 4.149) and plantar (→ Fig. 4.150) views.
The four **Mm. interossei dorsales** (I–IV) are two-headed 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 project medial and lateral to the second toe, whereas muscles III and IV course lateral to the third and fourth toe. Thus, the muscles can flex the metatarsophalangeal joints, abduct the toes II to IV laterally, and additionally adduct the second toe.
The three **Mm. interossei plantares** (I–III) have only one head and originate from the plantar side of the Ossa metatarsi III to V. They insert on the medial side of the respective toes. They serve for flexion of the metatarsophalangeal joints and adduction of the toes.

→ T 53–55

Plexus lumbosacralis

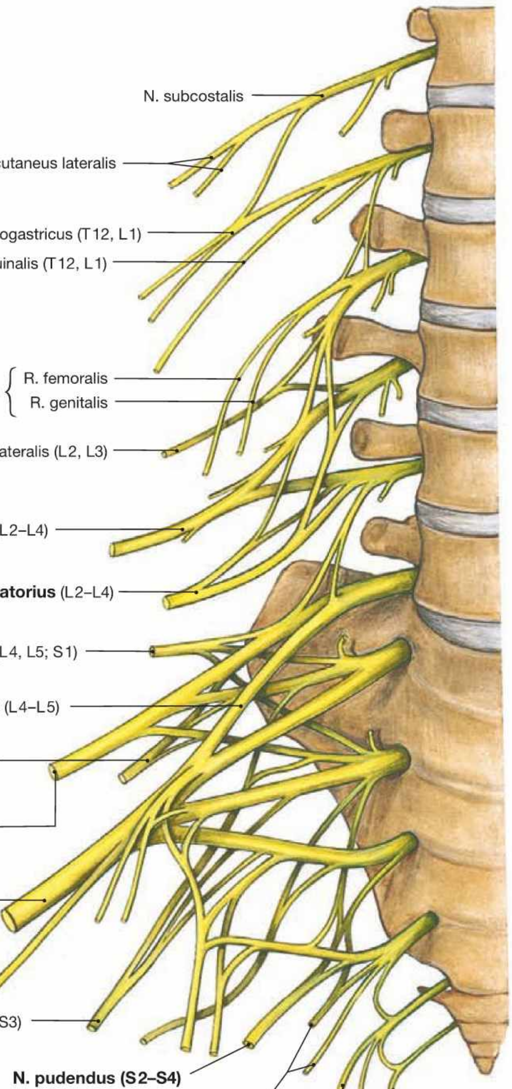


Fig. 4.151 Lumbosacral plexus, Plexus lumbosacralis (T12–S5, Co1): segmental organisation of the nerves, right side; ventral view.

The lower extremity is innervated by the Plexus lumbosacralis. The plexus is composed of Rr. anteriores of the spinal nerves which originate from the lumbar, sacral, and coccygeal segments of the spinal cord and combine 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 from the spinal cord segments L4, L5 from the Plexus lumbalis to the small pelvis. The functionally most important nerves of the Plexus lumbalis are the N. femoralis and the N. obturatorius.

The **N. femoralis** provides motor innervation to the ventral muscle group of the hip and thigh (flexors in the hip and extensors in the knee) and sensory innervation to the ventral aspect of the thigh and the ventromedial aspect of the leg. The **N. obturatorius** conveys motor fibres to the adductor muscles and sensory fibres to the medial thigh. The strongest and longest branch of the Plexus sacralis is the **N. ischiadicus.** With both of its divisions (N. tibialis and N. fibularis) the N. ischiadicus provides motor innervation to the hamstring muscles (extensors in the hip and flexors in the knee) and to all muscles in the leg and the foot as well as 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** provides motor innervation to the muscles of the perineal region and sensory innervation to the external genitalia. The muscles of the pelvic floor are innervated by direct branches (*) of the sacral plexus.

→ T 40

Innervation of the lower extremity by the Plexus lumbosacralis

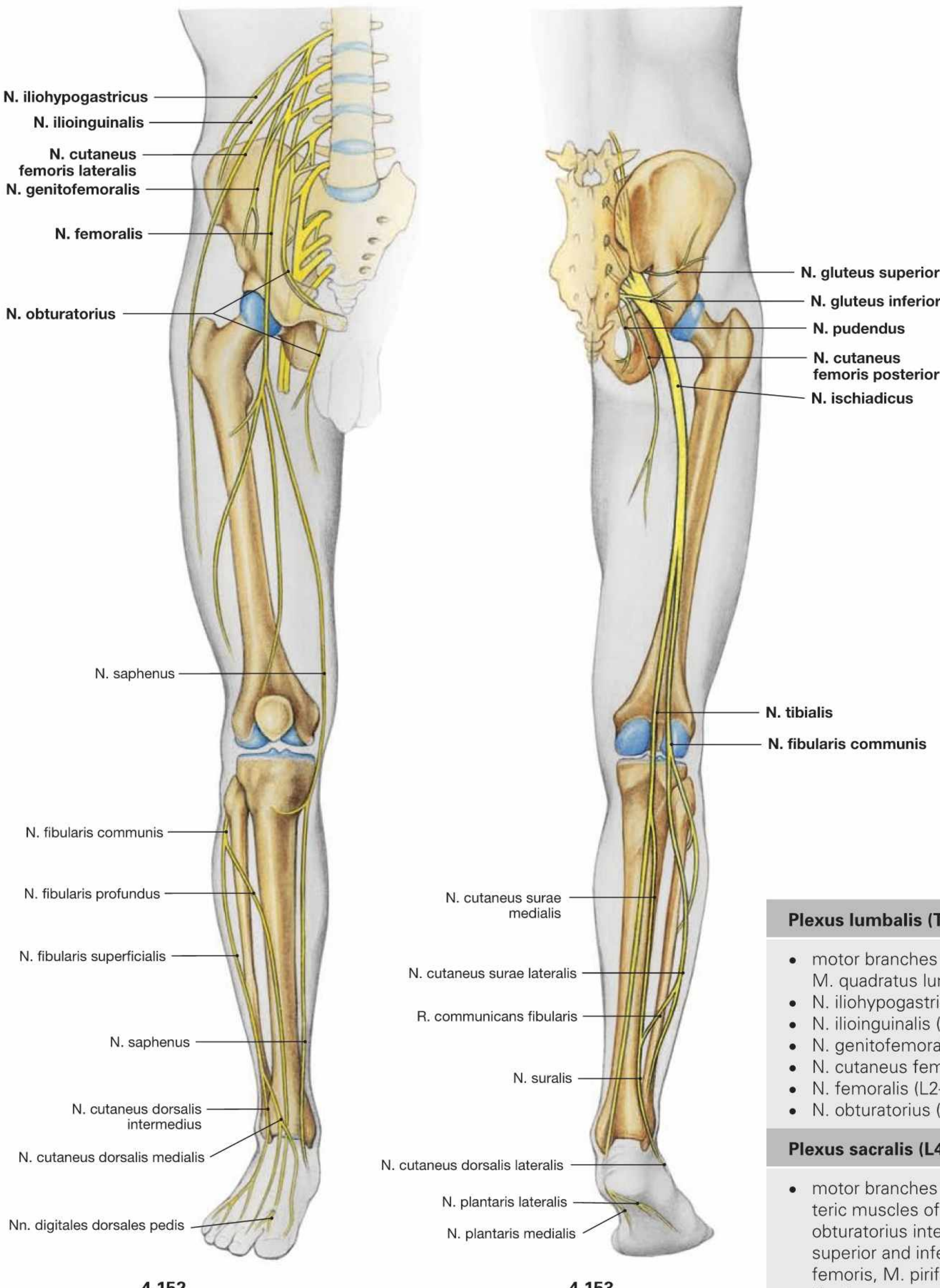


Fig. 4.152 and Fig. 4.153 Lumbosacral plexus, Plexus lumbosacralis (T12–S5, Co1): nerves of the lower extremity, right side; ventral (→ Fig. 4.152) and dorsal (→ Fig. 4.153) views.
The nerves of the **Plexus lumbalis** (T12–L4) course ventral to the hip joint and innervate the inferior part of the anterolateral abdominal wall and the ventral aspect of the thigh. The branches of the Plexus sacralis course dorsal to the hip joint. They innervate the posterior side of the thigh, the major part of the leg and the whole 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 for 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 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

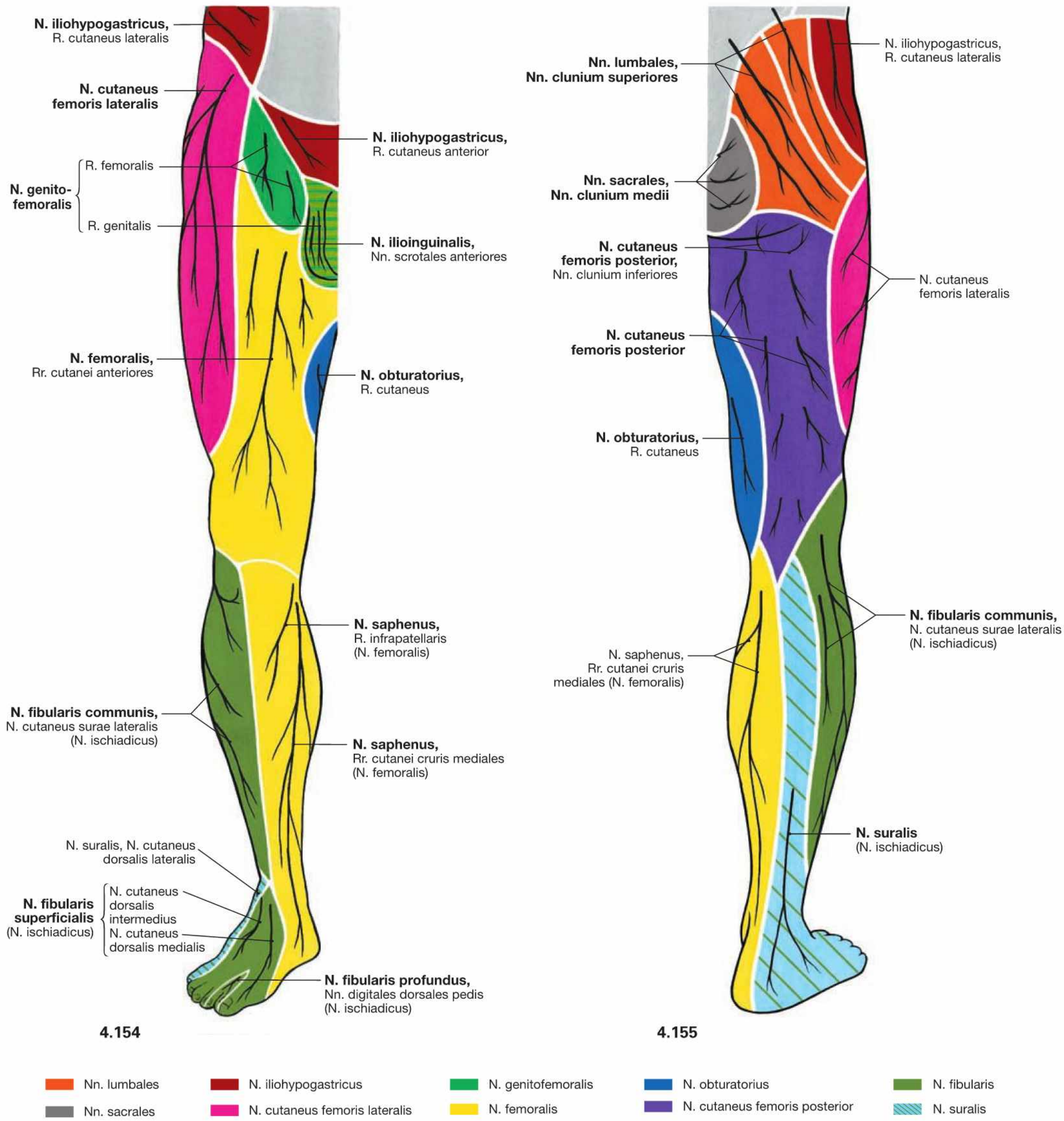


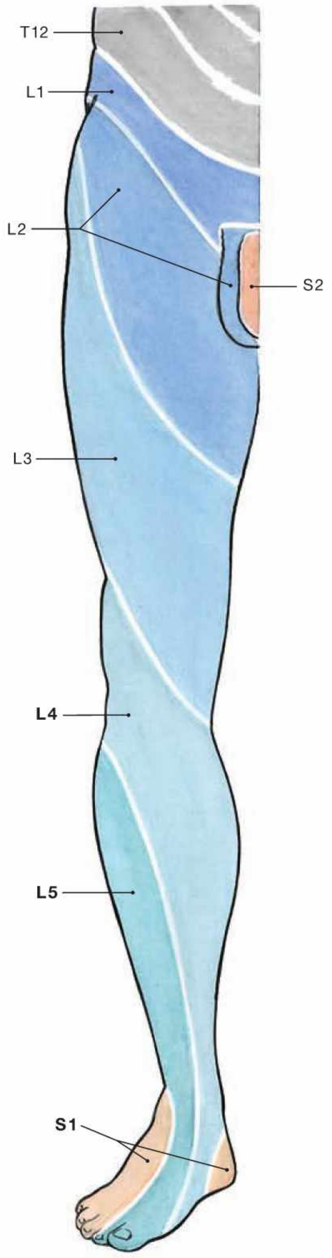
Fig. 4.154 and Fig. 4.155 Cutaneous nerves of the lower extremity, right side; ventral (→ Fig. 4.154) and dorsal (→ Fig. 4.155) views.

All nerves of the **Plexus lumbalis** contribute to the sensory innervation of the **inguinal region** and the **ventral thigh.** The lateral aspect of the leg and the dorsum of the foot are supplied by branches of the Plexus sacralis. The **gluteal region** is innervated by **Rr. posteriores** from the lumbar (Nn. clunium superiores) and sacral (Nn. clunium medii) spinal nerves. The dorsal side of the whole lower extremity and the sole of the foot are innervated by branches of the Plexus sacralis.

Clinical Remarks

The course of the nerves from the Plexus lumbalis and Plexus sacralis influences the **pattern of referred pain** originating in the area of the plexus. If the **Plexus lumbalis** is affected by haematoma or a tumour, the pain is referred to the **anterior aspect** of the thigh. With compression of the **Plexus sacralis,** the pain radiates to the **dorsal side** of the thigh and the leg **(ischialgia).**

Innervation of the skin



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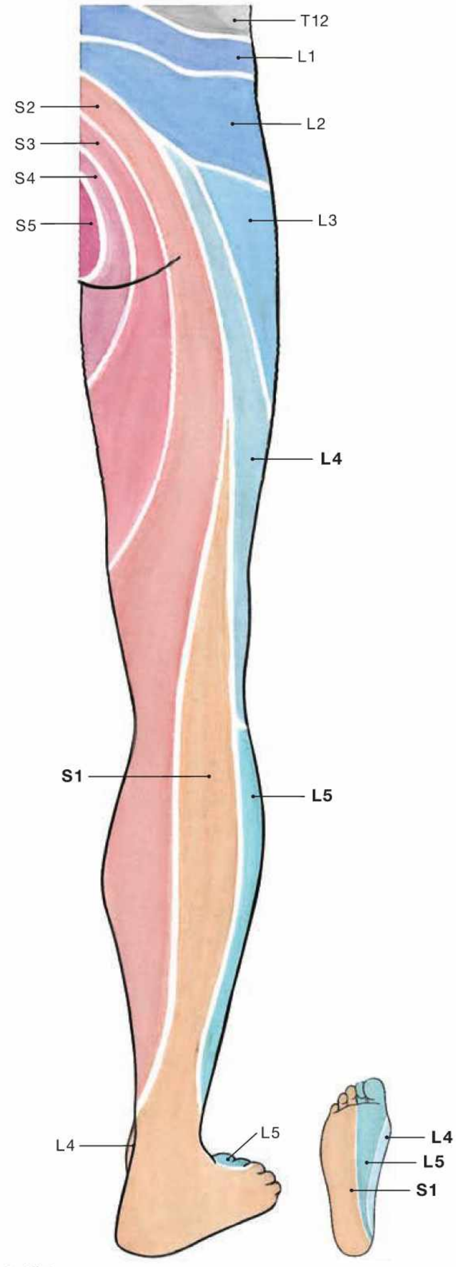


4.157

Fig. 4.156 and Fig. 4.157 Segmental innervation of the skin (dermatomes) of the lower extremity, right side; ventral (→ Fig. 4.156) and dorsal (→ Fig. 4.157) views.
Distinct areas of the skin are supplied by a single spinal cord segment. These cutaneous areas are referred to as dermatomes. Since the peripheral cutaneous nerves of the lower extremity convey sensory fibres from several spinal cord segments, the borders of the dermatomes do not correspond with the cutaneous area supplied by the peripheral nerves (→ p. 328). In contrast to the circular orientation of the dermatomes of the trunk, dermatomes on the **ventral side** of the lower extremity are obliquely oriented in a lateral superior to medial inferior direction. On the **dorsal side** they are oriented in a nearly **longitudinal direction.** (see Development, → p. 133).

Clinical Remarks

The localisation of dermatomes is clinically important in the **diagnostics of frequently occurring cases of disc prolapse.** Disc herniation/prolapse occurs mostly in the lower lumbar vertebral column and may compress the L4–S1 spinal nerve roots. Whereas nerve fibres from the **L4** segment innervate the **medial margin 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 **fifth toe,** is supplied by **S1.**

Plexus lumbalis

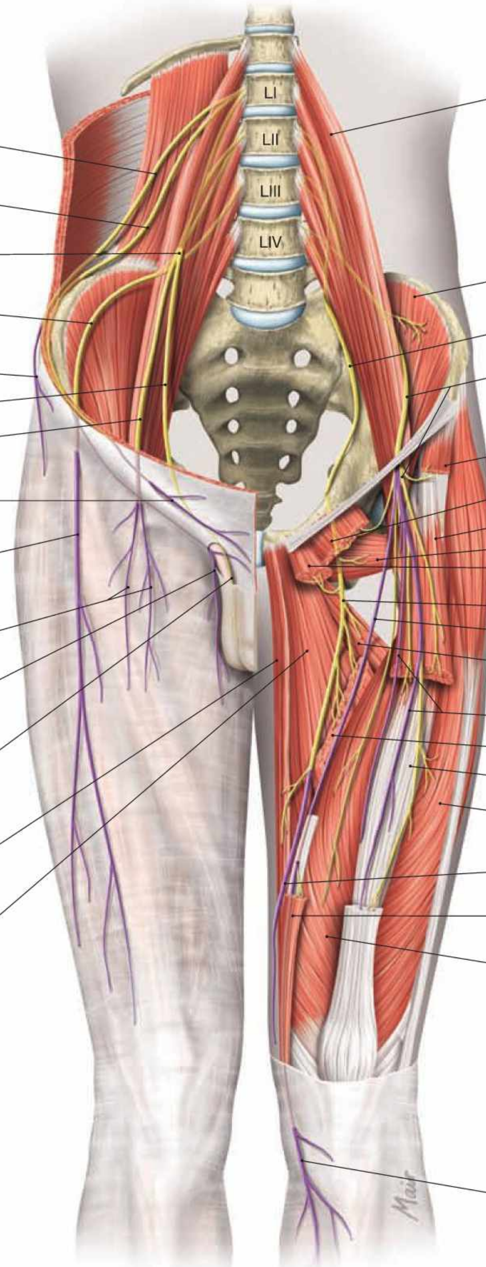


Fig. 4.158 Course and target areas of the nerves of the Plexus lumbalis (T12–L4); ventral view; cutaneous branches are highlighted in purple.

The **N. iliohypogastricus** and **N. ilioinguinalis** (further caudal) cross the M. quadratus lumborum behind the kidney and then pass between the M. transversus abdominis and the M. obliquus internus abdominis to the ventral side. Both innervate the inferior parts of these abdominal muscles. The N. iliohypogastricus also provides sensory innervation to the skin above the inguinal ligament, the N. ilioinguinalis provides sensory innervation to the anterior aspect of the external genitalia. The **N. genitofemoralis** pierces the M. psoas major, crosses posterior to the ureter, and divides into two branches: The lateral **R. femoralis** enters the anterior thigh through the Lacuna vasorum and provides cutaneous innervation inferior to the inguinal ligament. The medial **R. genitalis** courses through the inguinal canal to the Scrotum and conveys sensory fibres to the anterior aspects of the external genitalia and motor fibres to the M. cremaster in men. The **N. cutaneus femoris lateralis** projects laterally through the Lacuna musculorum and provides sensory fibres for the lateral side of the thigh. The **N. femoralis** courses medially through the Lacuna musculorum and immediately splits fan-like into several branches. Rr. cutanei anteriores supply the skin on the ventral side of the thigh. The Rr. musculares provide motor fibres to the anterior muscles of the hip (M. iliopsoas) and the thigh (M. sartorius and M. quadriceps femoris) and in part to the M. pectineus. Its terminal branch is the **N. saphenus** which enters the adductor canal (→ p. 351) and exits it through the Septum intermusculare vastoadductorium at the medial side of the knee joint to supply sensory innervation to the medial and anterior aspects of the leg. The **N. obturatorius** initially courses medial to the M. psoas major and then passes through the Canalis obturatorius (→ p. 351) to the medial aspect of the thigh. One of its branches reaches the M. obturatorius externus. The N. obturatorius then divides into the R. anterior and the R. posterior (anterior and posterior to the M. adductor brevis) which convey motor fibres to the muscles of the adductor group. The R. anterior also provides cutaneous innervation to the skin of the medial thigh.

Plexus lumbalis

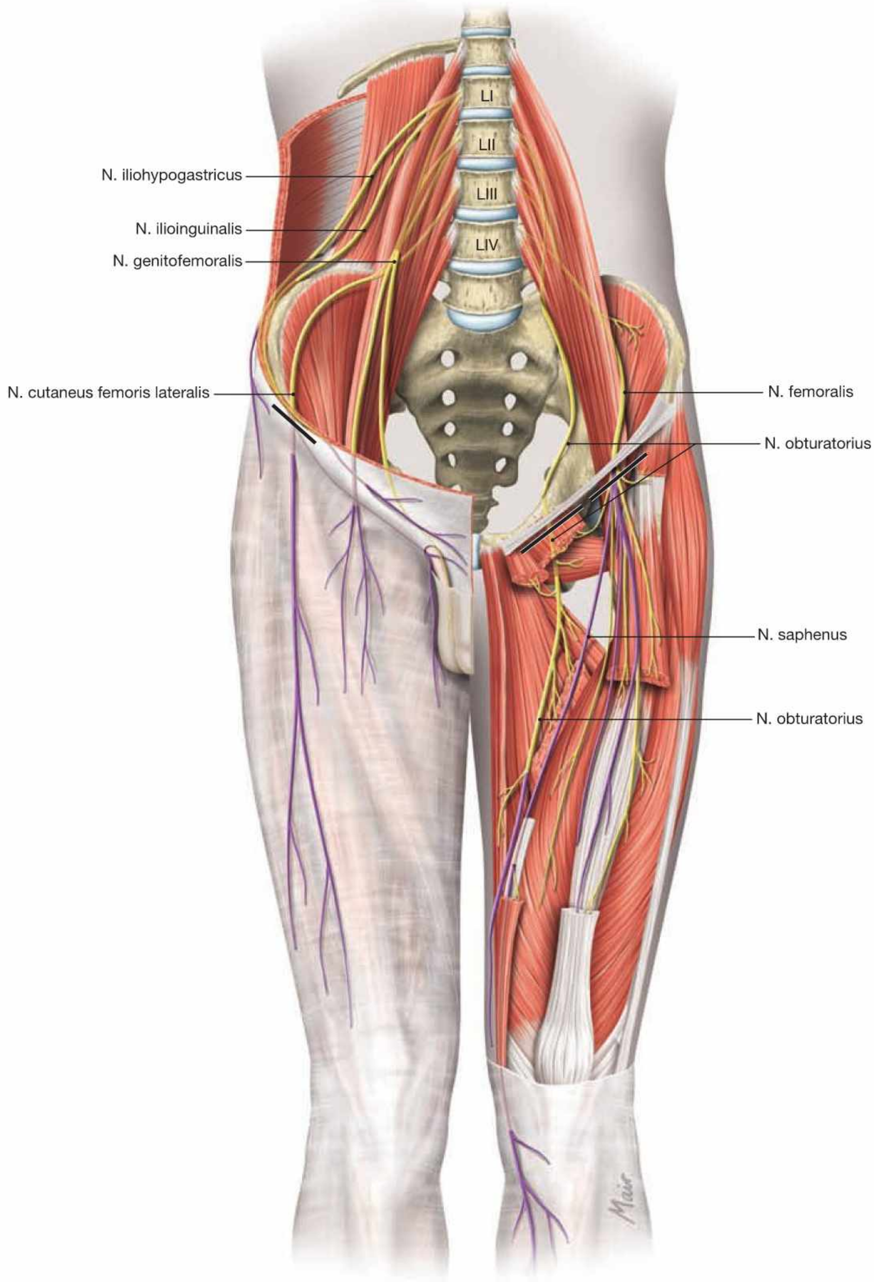


Fig. 4.159 Lesions of nerves of the Plexus lumbalis; ventral view. Cutaneous branches are highlighted in purple. Frequent locations for lesions are marked by black bars.

→ T 40

Clinical Remarks

Lesions of the **N. iliohypogastricus, N. ilioinguinalis** and **N. genitofemoralis** are rare due to their protected position. However, their close proximity to the kidney and the ureter may result in **pain radiating** to the inguinal region or the external genitalia in certain diseases of the kidney (inflammation of the renal pelvis, pyelonephritis, ureter concrements).
The **N. cutaneus femoris lateralis** may be pinched underneath the inguinal ligament by tightly fitting pants or may be injured during hip surgery with an anterior access. This may result in loss of sensation or pain at the lateral aspect of the thigh **(meralgia paraesthetica).**
Injury to the **N. femoralis** most frequently occurs in the groin during surgery or diagnostic manoeuvres (e.g. cardiac catheter). As a result, the restriction of hip flexion and the irability to extend the knee make it impossible to climb stairs. The patellar tendon reflex (knee-jerk reflex) is lacking and sensation on the anterior thigh and medial leg is absent.
The **N. obturatorius** is at risk of injury when passing through the Canalis obturatorius. Pelvic fractures as well as obturator hernias or extensive ovarian carcinomas may cause nerve lesions. Loss of function of the obturator muscles causes unstable standing, weakness with leg adduction and makes it impossible to cross one's legs. Sensory loss may occur at the medial thigh. Pain and paraesthesia may radiate and simulate diseases of the knee joint **(ROMBERG's knee phenomenon).**

Plexus sacralis

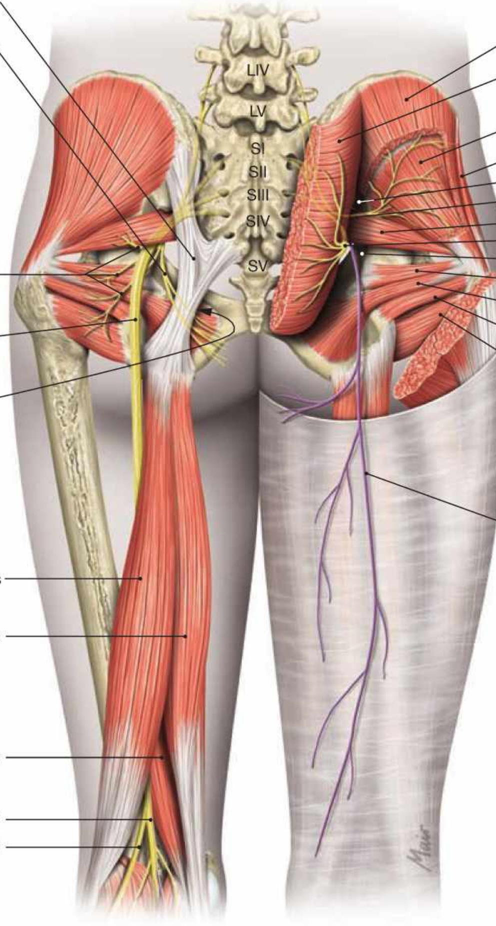


Fig. 4.160 Course and target areas of the nerves of the Plexus sacralis (L4–S5, Co1). Dorsal view; cutaneous nerves are highlighted in purple.

The **N. gluteus superior** exits the small pelvis through the Foramen suprapiriforme and provides motor innervation to the small gluteal muscles (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 combined to one common nerve for a variable distance only by a connective tissue sheath (epineurium). The N. ischiadicus exits the pelvis through the Foramen infrapiriforme and descends to the popliteal fossa underneath the M. biceps femoris.

In most cases, **N. tibialis** and **N. fibularis communis** separate at the level of the distal third of the thigh. Occasionally (12% of cases), both nerves already exit the pelvis separately (high division) in which case the N. fibularis often pierces the M. piriformis. At the level of the thigh, the N. tibialis provides motor innervation to the hamstring muscles and the posterior head of the M. adductor magnus. The N. fibularis innervates the Caput breve of the M. biceps femoris. Both portions of the N. ischiadicus together innervate all muscles of the leg and the foot and provide sensory innervation to the skin of the leg (except for the medial aspect: innervated by the N. saphenus of the N. femoralis) and the foot.

The **N. cutaneus femoris posterior** exits the pelvis through the Foramen infrapiriforme and branches off the sensory Nn. clunium inferiores for the skin of the inferior gluteal region. It descends in the subfascial layer to the middle of the thigh and provides sensory innervation to the posterior thigh.

The **N. pudendus** has a complicated course. It exits the pelvis through the Foramen infrapiriforme and, together with the corresponding blood vessels, winds around the Spina ischiadica and courses through the Foramen ischiadicum minus medially into the ischioanal fossa. The N. pudendus courses in a fascial duplication of the M. obturatorius internus (ALCOCK's canal; pudendal canal). The N. pudendus innervates the external sphincter muscle of the anal canal (M. sphincter ani externus) and all muscles of the perineum. It supplies sensory innervation to the posterior aspects of the external genitalia (posterior scrotum/labia majora; all of penis/clitoris).

The motor branches for the pelvitrochanteric muscles also exit through the Foramen infrapiriforme, whereas those for the pelvic floor do not exit the small pelvis. Parasympathetic nerves also remain within the pelvis. The small cutaneous branches pierce the Lig. sacrotuberale (N. cutaneus perforans) or the M. ischiococcygeus (N. anococcygeus).

→ T 40

Plexus sacralis

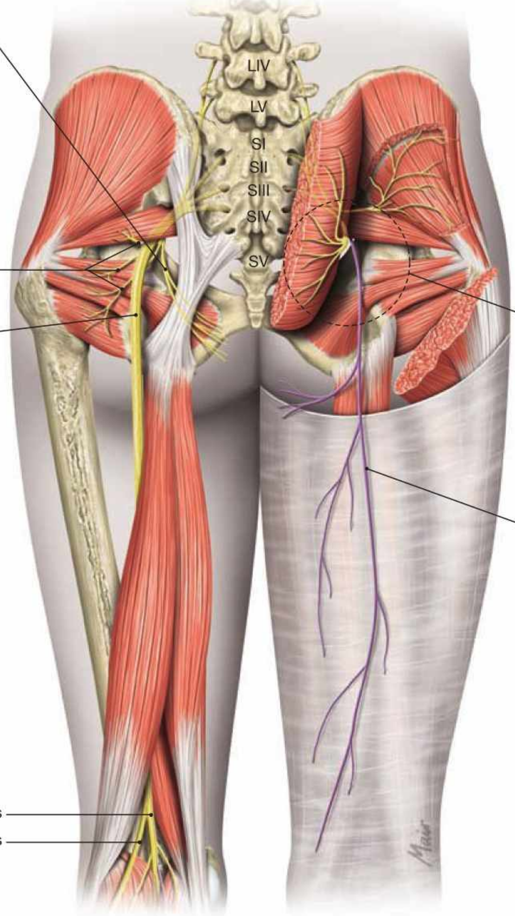


Fig. 4.161 Lesions of the most important nerves of the Plexus sacralis. Dorsal view. Cutaneous branches are highlighted in purple. On the right side, the potential injury, such as wrongly placed intragluteal injections, to the nerves at the level of their exit from the pelvis is shown. On the left side, the possible site of injury to the N. ischiadicus due to fractures of the pelvis or hip surgery is indicated.

* lesion with wrongly placed intragluteal injection

Clinical Remarks

Lesions of the nerves of the Plexus sacralis – part 1 (part 2 → p. 335)
With a **high division** of the N. ischiadicus, the **N. fibularis communis** may be irritated when piercing the M. piriformis (piriformis syndrome). The resulting pain may be very similar to the pain caused by a disc herniation. The **N. ischiadicus** may also be injured during intragluteal injections or by compression during extended sitting periods, after pelvic fractures and in the case of hip luxations or hip surgery. The resulting paralysis of the hamstring muscles affects extension in the hip joint, but more importantly, flexion and rotation in the knee joint. If the N. tibialis and N. fibularis are damaged completely, all muscles of the leg and foot are paralysed and standing or walking is impossible. When lifting the leg, the foot cannot be dorsiflexed and drags along the ground **(foot drop).** As a result, patients increase compensatory hip and knee flexion **(steppage gait).** Standing on one's toes is not possible anymore since plantarflexion is lost. Cutaneous innervation is almost completely absent in the leg (except ventromedial) and foot (for isolated lesions of the N. tibialis and N. fibularis → pages 336 and 337). Lesions of isolated motor branches to the pelvitrochanteric muscles or cutaneous branches are of no functional relevance. Motor branches to the muscles of the pelvic floor and parasympathetic nerves, however, may be injured during surgical procedures in the small pelvis, such as rectum and prostate surgery. **Fecal and urinary incontinence** may result from pelvic floor insufficiency. Injury to the parasympathetic nerves result in **erectile dysfunction** in men and an equally **insufficient filling of the cavernous body of the clitoris** in women.

Intragluteal injections

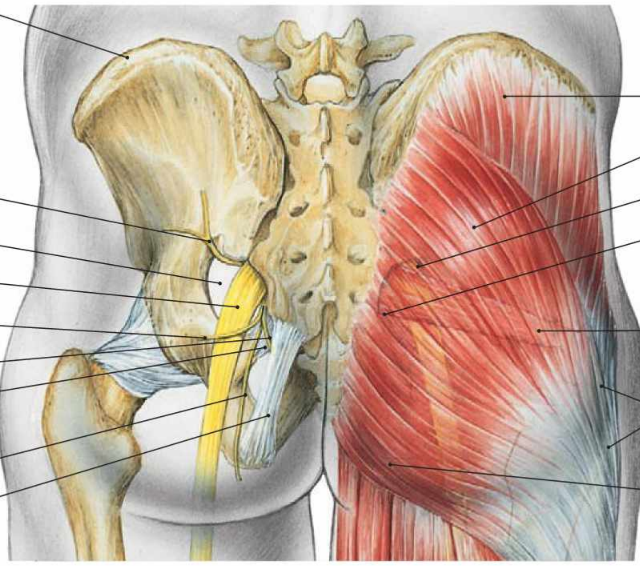


Fig. 4.162 Surface projection of the skeletal contour and the N. ischiadicus in the gluteal region.
With wrongly positioned intragluteal injections in the M. gluteus maximus principally all neurovascular structures passing through the Foramen ischiadicum majus are at risk of injury. Only the A. and V. pudenda interna and the N. pudendus are well protected as then course medially and pass through the Foramen ischiadicum minus to reach the ischioanal fossa. Therefore, injections should always be applied into the M. gluteus medius (→ Fig. 4.163).

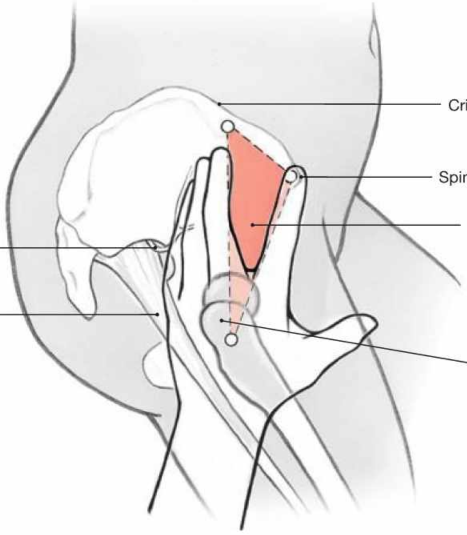
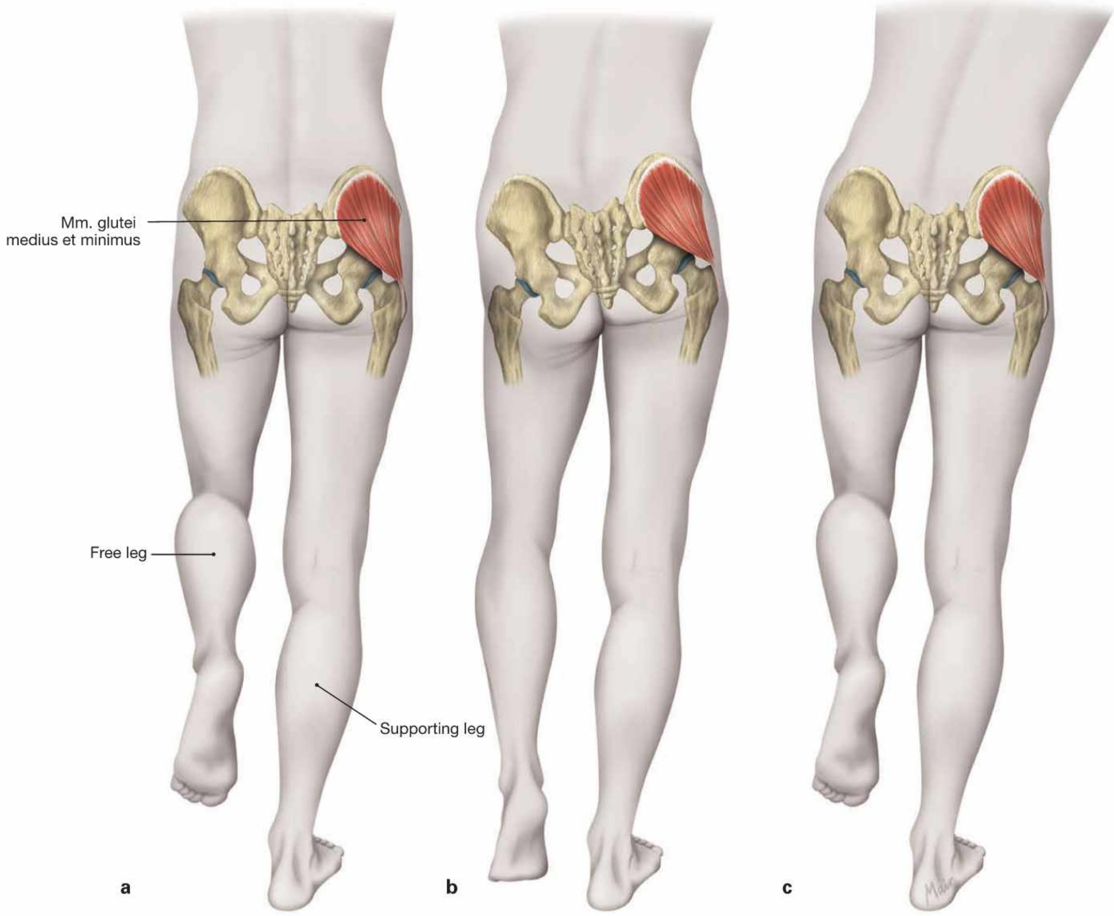


Fig. 4.163 Ventral intragluteal injections (according to HOCHSTETTER)
To avoid damaging of important neurovascular structures in the gluteal region, intragluteal injections are performed within a triangular field between two splayed fingers and the Crista iliaca. The index finger is placed onto at the Spina iliaca anterior superior and the palm of the hand over the Trochanter major. The only nerve remaining at risk is the motor branch projecting from the N. gluteus superior to the M. tensor fasciae latae.



Figs. 4.164a to c TRENDELENBURG's sign and DUCHENNE's gait with loss of function of the small gluteal muscles on the right side (b, c).

a The gluteal muscles abduct the ipsilateral leg if the body weight is shifted to the other leg. In one-legged stand, the ipsilateral muscles stabilise the pelvis and prevent the tilting of the pelvis to the contralateral side.

b With functional insufficiency of the small gluteal muscles, such as in hip dysplasia or with 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 The pelvis of the healthy side is elevated by shifting the trunk towards the affected side (DUCHENNE's gait).

Clinical Remarks

Lesions of the nerves of the Plexus sacralis – part 2 (part 1 → p. 333)

Due to its protected course, lesions of the **N. pudendus** are rare. Symptoms are caused by the malfunction of the perineal muscles and the sphincter muscles of the bladder and rectum and may result in **urinary** and **fecal incontinence.** Sensory loss in the genital region may cause **disturbances** in **sexual functions.** During parturition, loss of sensory function in the perineogenital region is desired and a **pudendal nerve block** may be performed to reduce pain. Thereby, the Spina ischiadica is palpated through the vagina and the N. pudendus is anaesthetised prior to its entrance in the ALCOCK's canal by injections approximately 1 cm lateral and cranial of the ischial spine.

Wrongly placed intramuscular injections in the gluteal region may injure the neurovascular structures which leave the Foramina supra- and infrapiriforme. Not only blood vessels but also the Nn. glutei superior and inferior, the N. cutaneus femoris posterior, and the N. ischiadicus may be affected. The intragluteal injection according to HOCHSTETTER is applied to the M. gluteus medius (→ Fig. 4.163).

Lesions of the **N. gluteus superior** cause paralysis of the small gluteal muscles (most important abductors and medial rotators of the hip) and the M. tensor fasciae latae. Paralysis of the small gluteal muscles makes it impossible to stand one-legged on the affected side because the pelvis tilts to the contralateral side (TRENDELENBURG's sign).

With lesions of the **N. gluteus inferior** the loss of function of the M. gluteus maximus compromises extension in the hip. With normal gait, this deficit can partly be compensated for by the action of the hamstring muscles. However, activities such as climbing stairs, jumping, and a fast walking pace will not be possible.

Lesions of the **N. cutaneus femoris posterior** cause sensory deficits on the posterior side of the thigh.

N. tibialis

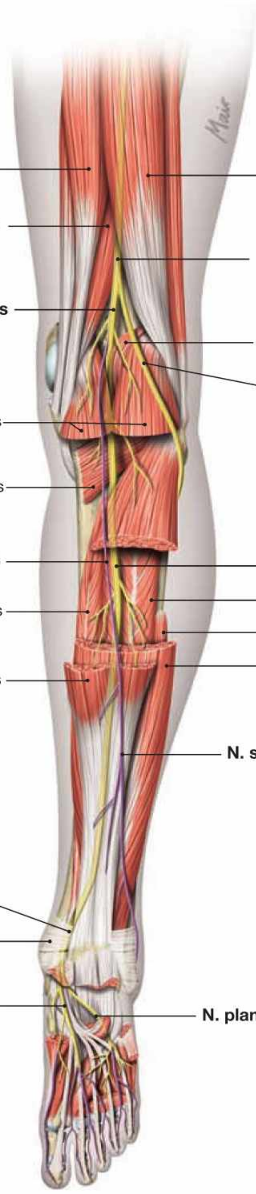


Fig. 4.165 N. tibialis: sensory innervation by cutaneous nerves (purple), and motor innervation by muscular branches, right side; dorsal view.

The **N. ischiadicus** often divides at the transition from the middle to the lower 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 in the direction of the N. ischiadicus to pass the popliteal fossa and descends between the heads of the M. gastrocnemius beneath the tendinous arch of the M. soleus **(Arcus tendineus musculi solei).** It further courses together with the A. and V. tibialis posterior between the superficial and deep flexors to the medial malleolus. In the popliteal fossa the **N. cutaneus surae medialis** branches off to supply the medial calf and splits into the **N. suralis** for the distal calf and the **N. cutaneus dorsalis lateralis** for the lateral margin of the foot. The latter often communicates with a cutaneous branch from the N. fibularis communis. When passing underneath the Retinaculum musculorum flexorum **(malleolar canal),** the N. tibialis splits 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 of the foot as well as sensory innervation to the middle calf and, after forming the N. suralis, to the lower calf and the lateral margin of the foot.

Clinical Remarks

Lesions of the N. tibialis are rare, but may occur during injuries of the knee joint or after compression in the **malleolar canal** to tibial fractures or injuries of the ankle joint **(medial tarsal tunnel syndrome).** The tarsal tunnel syndrome is characterised by burning pain sensations at the sole of the foot and loss of function of the plantar muscles. Flexion, adduction, or splaying of toes is impossible. Paralysis of the Mm. interossei and Mm. lumbricales results in the **claw foot** deformity. Lesions at the level of the popliteal fossa additionally cause a loss of function in all flexors of the leg (negative ACHILLES tendon reflex). Plantarflexion is weak and only supported by the muscles of the fibularis group. An increased **pronation and dorsiflexion position** of the foot is the result. Standing on one's toes is impossible.

N. fibularis communis

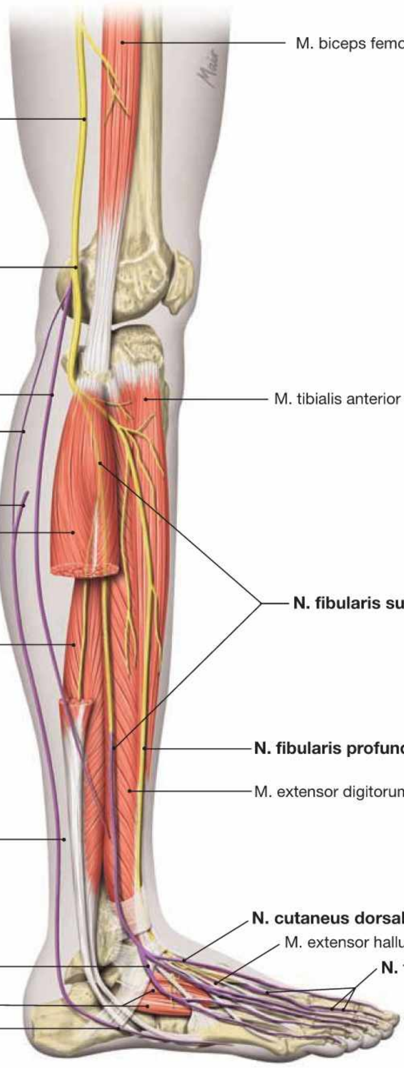


Fig. 4.166 N. fibularis communis: sensory innervation by cutaneous nerves (purple), and motor innervation by muscular branches, right side; lateral view.

After the division of the **N. ischiadicus** at the transition to the distal third of the thigh, the **N. fibularis communis** courses through the popliteal fossa and around the head of the fibula to the fibularis compartment. Here the nerve divides into its two terminal branches (Nn. fibulares superficialis and profundus). At the thigh, the N. fibularis communis provides motor innervation to the Caput breve of the M. biceps femoris only. Prior to its division into the terminal branches, the N. fibularis communis provides the **N. cutaneus surae lateralis** for the skin of the lateral calf and another branch for the communication with the N. cutaneus surae medialis.

The **N. fibularis superficialis** continues in the fibularis compartment and provides motor fibres to the fibularis muscles. Subsequently, it pierces the fascia of the distal leg and splits into the two terminal sensory branches (**Nn. cutanei dorsales medialis** and **intermedius**) for the dorsum of the foot.

The **N. fibularis profundus** enters the extensor compartment and descends together with the A. tibialis anterior to the dorsum of the foot. On its way, it provides motor innervation to the extensor muscles of the leg and the dorsum of the foot. Its terminal branch and provides sensory innervation to the skin of the first interphalangeal space.

Clinical Remarks

Lesions of the N. fibularis communis are the most common nerve lesions of the lower extremity. Potential causes are fractures of the proximal fibula, tight skiing boots or casts, or cross-legged position. Loss of function of the extensor muscles results in a drop of the foot **(footdrop).** As a result, patients increase the compensatory knee flexion **(steppage gait).** Palsy of the fibularis muscles result in **supination position** of the foot. Sensory innervation is compromised for the lateral calf and the dorsum of the foot. The **N. fibularis profundus** may be affected in compartment syndrome as a result of a trauma if the nerve and concomitant blood vessels are compressed by bleeding or swelling of the extensor muscles **(anterior [tibial] compartment syndrome).** This frequently requires splitting of the fascia of the leg (fasciotomy). Paralysis of the N. fibularis profundus also shows with footdrop and steppage gait, but the sensory innervation is only compromised in the first interphalangeal area. In the **anterior tarsal tunnel syndrome,** the cutaneous branches underneath the Retinaculum musculorum extensorum are compressed with resulting numbness at the first interphalangeal space. Isolated injuries of the **N. fibularis superficialis** (as in trauma of the fibularis muscles) are less common and cause a supination position of the foot due to the malfunction of the fibularis muscles. Here, sensory innervation at the dorsum of the foot is compromised with intact skin sensation at the first interphalangeal space.

Arteries of the pelvis and thigh

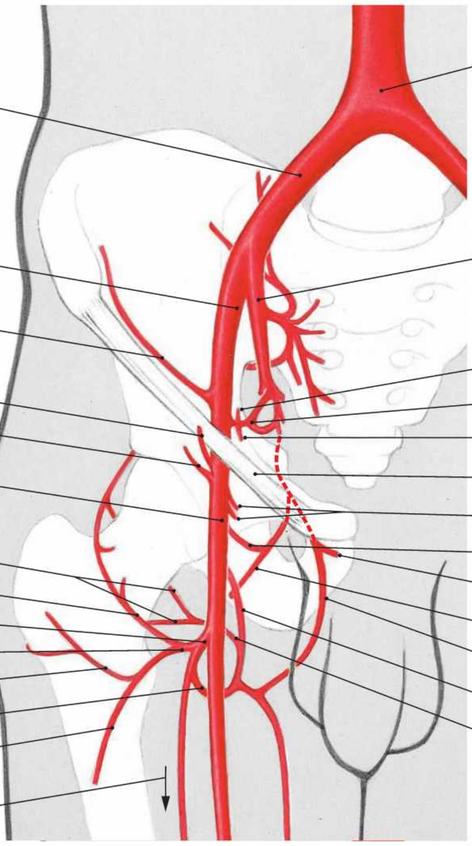


Fig. 4.167 Arteries of the pelvis and the thigh, right side; ventral view.

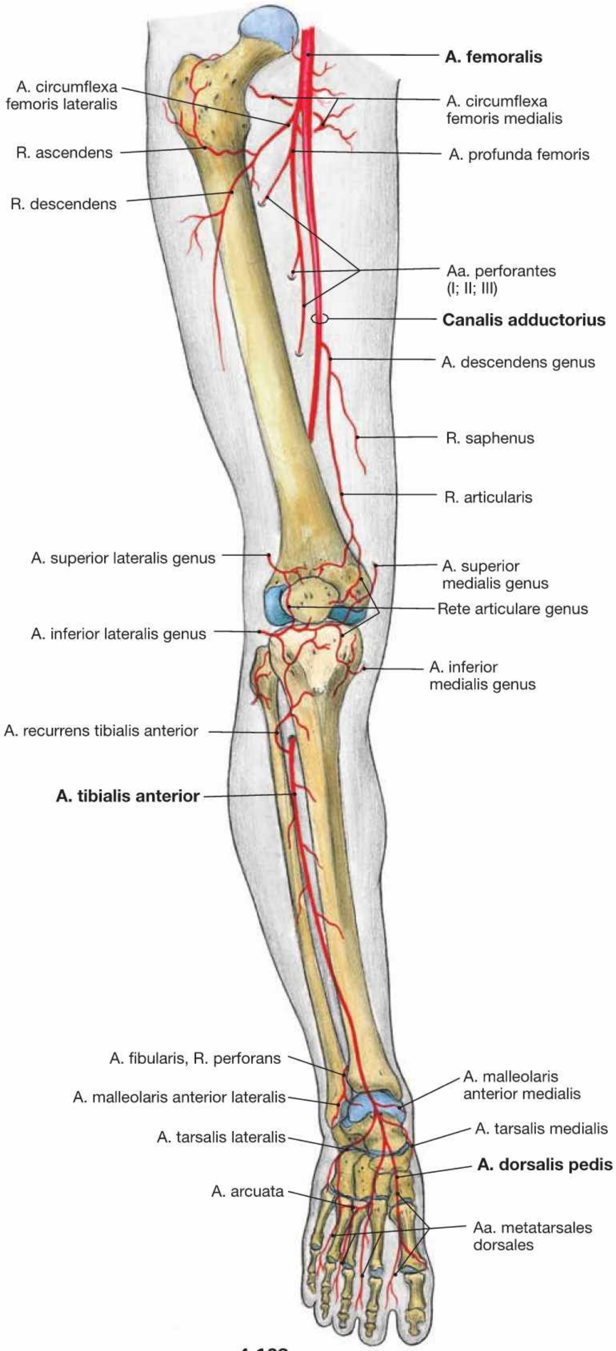
The **A. profunda femoris** is the main artery of the hip joint and the thigh. The other branches of the A. femoralis do not contribute to the arterial supply of the thigh. The A. profunda femoris branches off the A. femoralis 3–6 cm inferior to the inguinal ligament and divides into the **Aa. circumflexae femoris medialis** and **lateralis.** In the adult, the **femoral head** is almost exclusively supplied by the **A. circumflexa femoris medialis** (R. profundus) which loops around the Collum femoris from behind (→ Figs. 4.57 and 4.58). The R. profundus also supplies the adductor muscles and the hamstring muscles. The R. acetabularis anastomoses with the identically named branch of the A. obturatoria. The A. circumflexa femoris lateralis courses anterior to the femoral neck. It supplies the femoral neck and with several branches also the lateral hip muscles and the ventral muscles of the thigh. The Aa. perforantes are terminal branches which supply the adductor and hamstring muscles. All branches anastomose with each other as well as with the A. obturatoria and the Aa. gluteae from the A. iliaca interna which is the basis for potential collateral circulations.

Arteries of the Lower Extremity	
Branches of the A. iliaca externa • A. epigastrica inferior – A. cremasterica/A. ligamenti teretis uteri – R. pubicus (anastomoses with A. obturatoria) • A. circumflexa ilium profunda	**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. femoralis: • A. epigastrica superficialis • A. circumflexa ilium superficialis • Aa. pudendae externae • A. profunda femoris – A. circumflexa femoris medialis – A. circumflexa femoris lateralis – Aa. perforantes (mostly three) • A. descendens genus	**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)
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	

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 (at the level of the talocalcaneonavicular joint lateral of the M. extensor hallucis longus tendon), and the A. tibialis posterior (behind the medial malleolus) to rule out occlusion of the respective blood vessels due to **arteriosclerosis** or **emboli.** Owing to the excellent blood supply of the Tibia (through Vasa nutricia) large fluid volumes may be infused via an **intraosseous access** in emergency situations. Several arterial anastomoses contribute to **collateral circulations** at different levels of the lower extremity. Although the anastomoses between branches of the A. profunda femoris and branches of the A. iliaca interna are variable, in an emergency they allow for the ligation of the A. femoris proximal to the A. profunda femoris. In contrast, the collaterals of the Rete articulare genus around the knee are not sufficient to compensate for the ligation of the A. poplitea. The Rete articulare genus is formed by the recurrent arteries of the leg and the third perforating artery of the A. profunda femoris. The arterial network around the malleoli is well developed and usually warrants sufficient arterial supply to the foot if one of the Aa. tibiales is occluded. (The part of the A. femoralis between the branching off of the A. profunda femoris and the entry into the Canalis adductorius is clinically often referred to as A. femoralis superficialis.)

Arteries of the lower extremity



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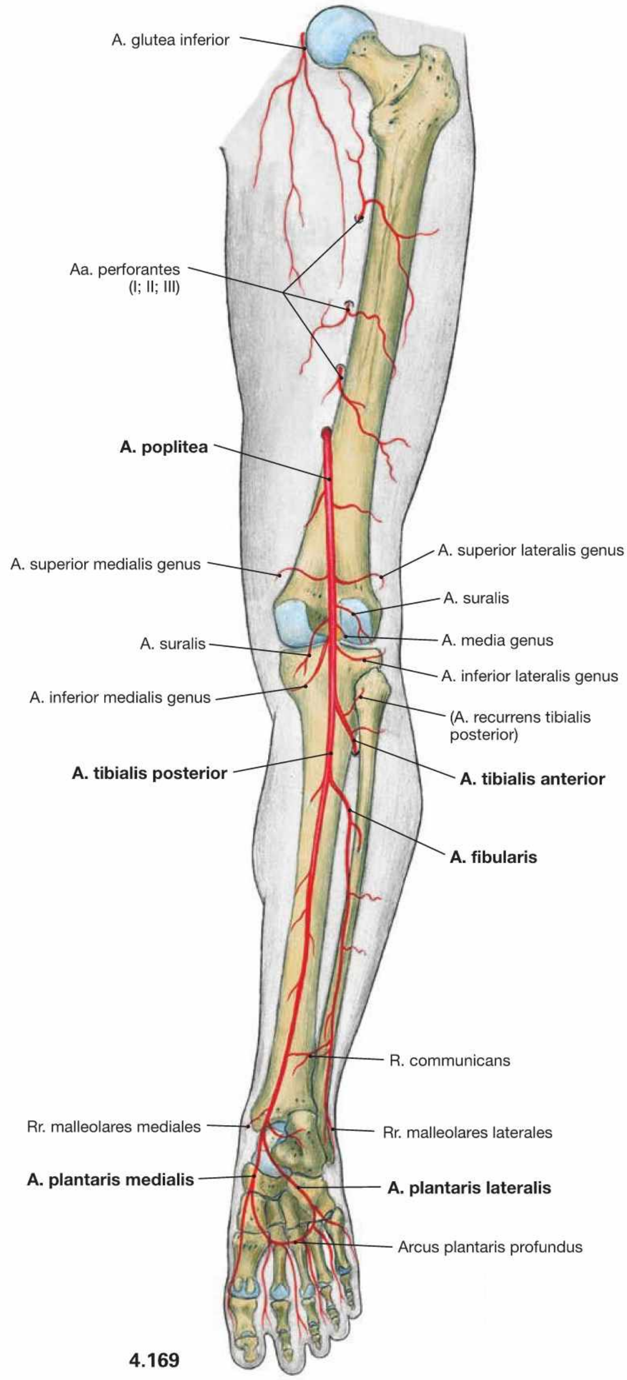


4.169

Fig. 4.168 and Fig. 4.169 Arteries of the lower extremity, right side; ventral (→ Fig. 4.168) and dorsal (→ Fig. 4.169) views.
The A. **iliaca externa** branches off the A. iliaca communis anterior to the sacro-iliac joint and continues beneath the inguinal ligament in the Lacuna vasorum as **A. femoralis.** Following the passage through the adductor canal it is then referred to as **A. poplitea** (arterial supply of the knee joint). The A. poplitea descends underneath the tendinous arch of the M. soleus between the superficial and deep flexors of the leg and divides into the **A. tibialis posterior** which continues its course, and the **A. tibialis anterior** which pierces the Membrana interossea cruris to reach the anterior extensor compartment. The latter continues as **A. dorsalis pedis** on the dorsum of the foot. The A. tibialis posterior provides the strong **A. fibularis** to the lateral malleolus and then continues through the malleolar canal around the medial malleolus to reach the sole of the foot, where it provides two terminal branches (**Aa. plantares medialis** and **lateralis**).

Veins of the lower extremity

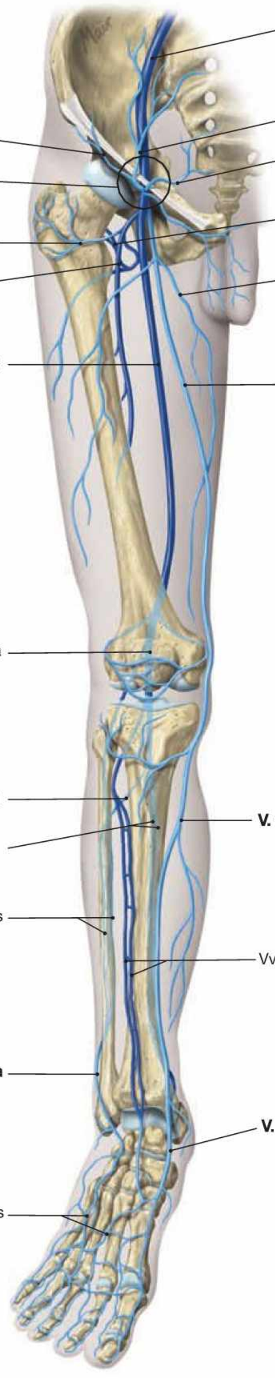


Fig. 4.170 Veins of the lower extremity, right side; ventral view.
The **deep veins** (dark blue) **accompany** the respective **arteries.** In the leg, usually two veins course together with the respective artery, whereas at the thigh and the popliteal fossa only one concomitant vein is found. The **superficial venous system** (light blue) consists of **two main veins** which collect the blood from the dorsum and the sole of the foot.
The **V. saphena magna** originates **anterior** to the medial malleolus and ascends on the medial side of the leg and thigh to the Hiatus saphenus (→ Fig. 4.178). Here, the V. saphena magna receives tributaries from several veins of the inguinal region (see below) and enters the V. femoralis at the femoral triangle.
On the posterior side, the **V. saphena parva** originates from the lateral margin of the foot **posterior** to the lateral malleolus and ascends on the middle of the calf to the popliteal fossa to enter the V. poplitea. The V. saphena magna and parva communicate through variable branches.

Tributaries of the V. saphena magna at the femoral triangle:
- V. epigastrica superficialis
- V. circumflexa ilium superficialis
- V. saphena accessoria
- Vv. pudendae externae

Veins of the lower extremity

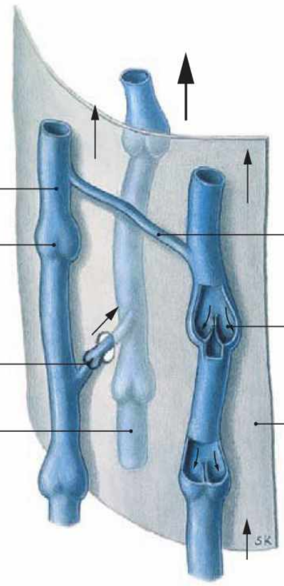


Fig. 4.171 Superficial and deep veins of the lower extremity with venous valves: organisation principle.
The extremities have a **superficial epifascial venous system** and a **deep subfascial venous system** coursing together with the respective arteries. Both systems are connected by perforating veins **(Vv. perforantes). Venous valves** direct the blood flow from the superficial towards the deep veins causing the major part of the blood (85%) to be drained via the deep veins of the lower extremity to the heart. Among the many perforating veins, three groups are of clinical relevance:

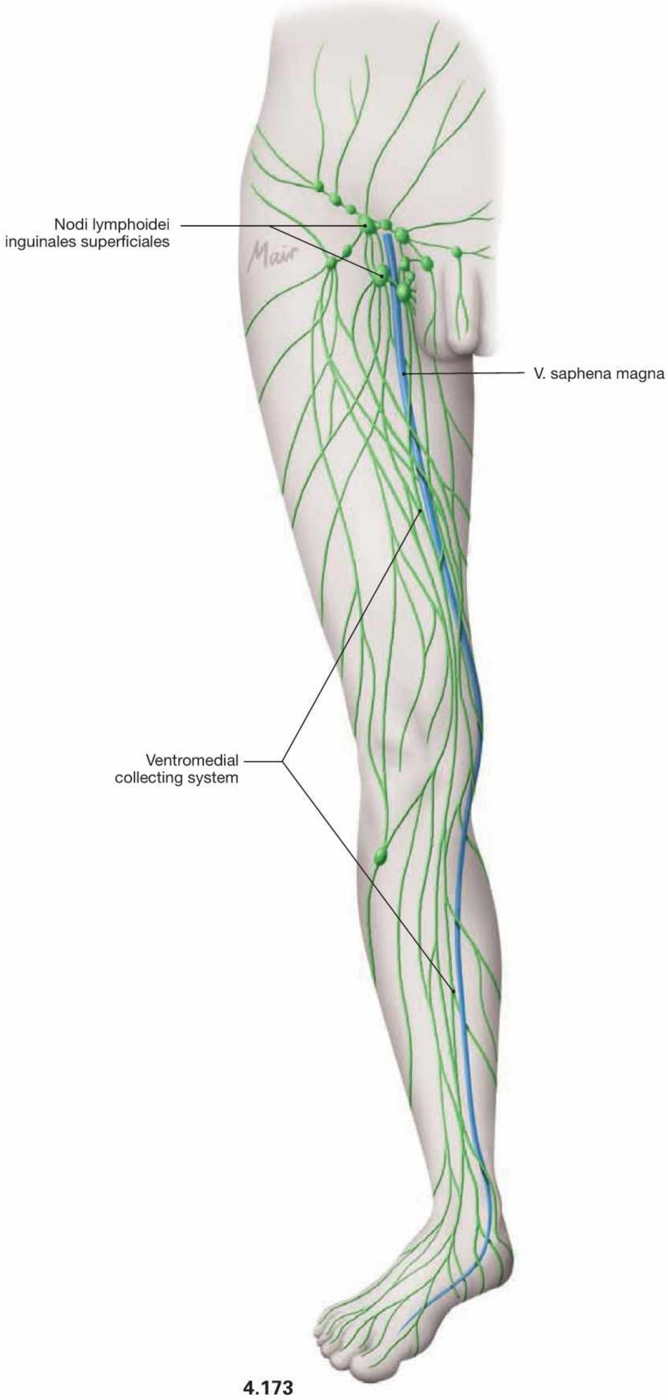
- DODD's perforating veins: intermediate third of the medial thigh
- BOYD's perforating veins: medial aspect of the proximal leg (below the knee)
- COCKETT's perforating veins: medial aspect of the distal leg

Fig. 4.172 Acute crural thrombosis with large thrombus (arrows) in the V. femoralis. [6]

Clinical Remarks

Since the venous blood of the lower extremity is predominantly drained via the deep veins towards the heart, **deep venous thrombosis** bears the risk for potentially lethal **pulmonary emboli** caused by floating parts of the thrombus. Dilation of the superficial veins **(varicosis)** with formation of prominent and dilated superficial veins **(varices)** is a common condition. These are usually the result of a connective tissue weakness with insufficiency of the venous valves. But they may also result from an occlusion of the deep veins due to thrombosis. This needs to be investigated carefully, since surgical removal of the superficial varicose veins can only be performed when the deep veins are not obstructed.

Lymph vessels of the lower extremity



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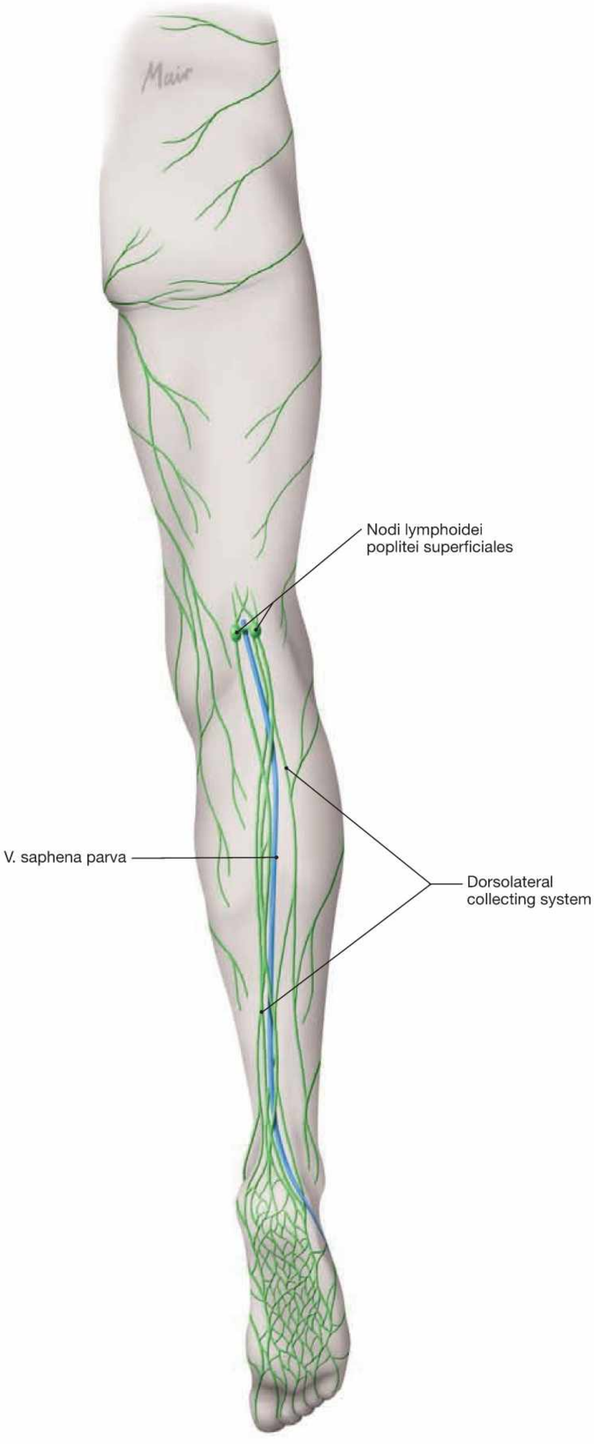
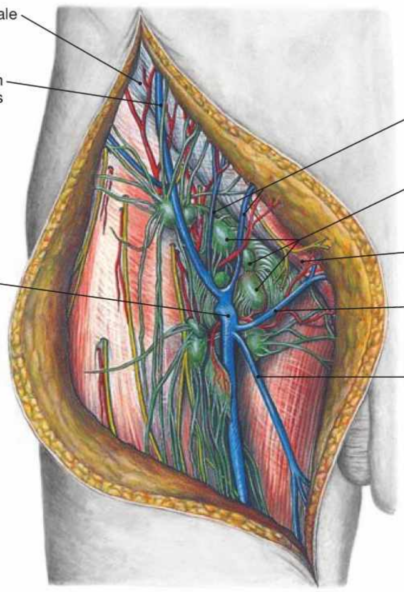


Fig. 4.173 and Fig. 4.174 Superficial lymph vessels of the lower extremity, right side; ventral (→ Fig. 4.173) and dorsal (→ Fig. 4.174) views.

Alongside the veins there are a superficial and a deep system of collecting lymph vessels with incorporated lymph nodes. The superficial **ventromedial system** alongside the V. saphena magna is the main lymphatic drainage of the lower extremity and drains into the superficial inguinal nodes **(Nodi lymphoidei inguinales superficiales)** (→ p. 344). The smaller dorsolateral system parallels the V. saphena parva and drains into the lymph nodes of the popliteal fossa (**Nodi lymphoidei poplitei superficiales** and **profundi**) and continues into the deep inguinal lymph nodes **(Nodi lymphoidei inguinales profundi).** The deep collecting systems directly drain into the deep popliteal and inguinal lymph nodes.

While most of the venous drainage from the lower extremity occurs via the deep veins, the major part of the lymph is drained by the superficial lymph vessels.

Lymph nodes and lymph vessels of the inguinal region



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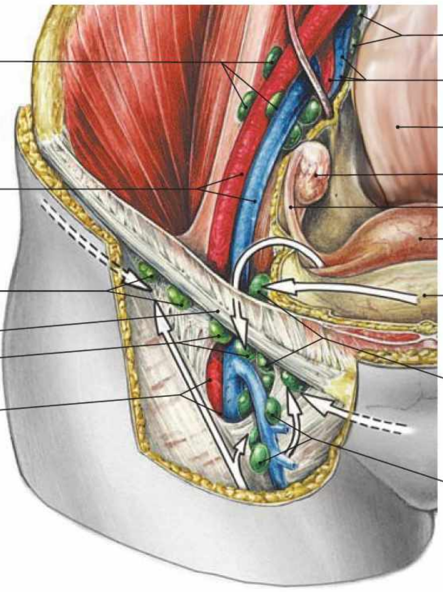


4.176

Fig. 4.175 and Fig. 4.176 Superficial lymph nodes of the inguinal region, Regio inguinalis (→ Fig. 4.175), and their tributaries (→ Fig. 4.176), right side; ventral view.

The inguinal region harbours four to 25 epifascial superficial inguinal lymph nodes **(Nodi lymphoidei inguinales superficiales)** which further drain into one to three inguinal lymph nodes medial of the V. femoralis **(Nodi lymphoidei inguinales profundi),** and 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** beneath the inguinal ligament.

The inguinal lymph nodes not only serve as regional lymph nodes for the major part of the lower extremity but also collect lymph from the lower quadrants of the **abdominal wall** and the **back,** the **perineal region** and the **external genitalia** (→ Figs. 2.111 to 2.114). In addition, lymph from the **lower parts of the Rectum** and the **Vagina** and occasionally from the Uterus and adjacent uterine tubes (along the Lig. teres uteri) drains into the inguinal lymph nodes.

Clinical Remarks

Palpation of the lymph nodes is part of a complete physical examination. The inguinal lymph nodes are regional stations for the major part of the lymph from the lower extremity. Only the drainage of the lateral margin of the foot and the calf occurs into the popliteal nodes as their regional stations which mostly cannot be palpated. Malignant cells from all regions and organs mentioned above, including the Rectum and female reproductive organs, may thus form metastases in the inguinal region. In men, however, only the lymph from the external genitalia (penis, scrotum) drains into the inguinal nodes, but lymph from the testes travels via the spermatic cord into the lumbar lymph nodes.

Vessels and nerves of the inguinal region

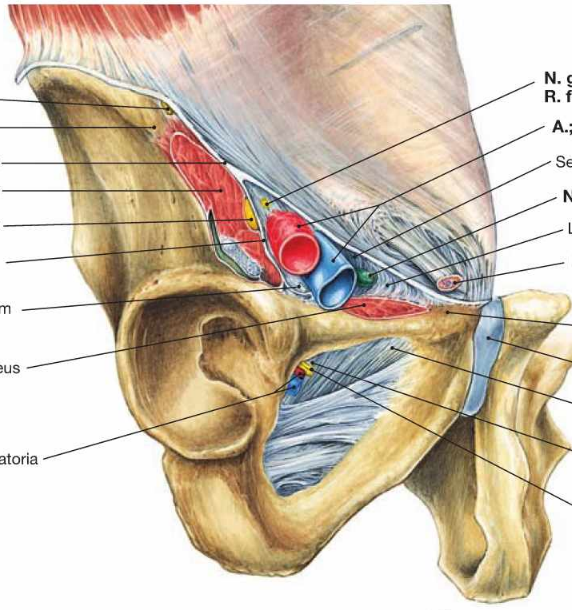


Fig. 4.177 Lacunae musculorum and vasorum, right side; oblique section at the level of the inguinal ligament; ventral view.
The space between Os coxae and the **Lig. inguinale** (Fossa iliopectinea) is divided by the **Arcus iliopectineus,** which spans between the inguinal ligament and the pelvic bone, into the lateral Lacuna musculorum and the medial Lacuna vasorum. The Lacuna musculorum is almost completely occupied by the **M. iliopsoas.** The N. cutaneus femoris lateralis is located lateral to the M. iliopsoas near the Spina iliaca anterior, the N. femoralis is positioned medial to the M. iliopsoas. Passing through the Lacuna vasorum from lateral to medial are the **R. femoralis** of the **N. genitofemoralis,** the **A. femoralis,** and the **V. femoralis.** Located most medially are the deep inguinal lymph nodes **(Nodi lymphoidei inguinales profundi).**

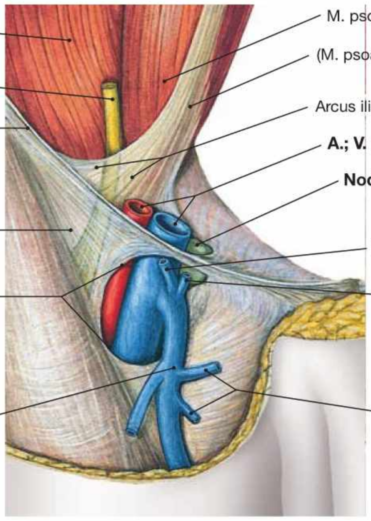


Fig. 4.178 Hiatus saphenus and Lacuna vasorum, right side; ventral view; after removal of the anterior abdominal wall, of the Fascia iliaca and the abdominal viscera.

The Hiatus saphenus is an opening of the Fascia lata through which the V. saphena magna passes prior to entering the V. femoralis. Located most medially are the deep inguinal lymph nodes (Nodi lymphoidei inguinales profundi) the biggest of which is referred to as **ROSENMUELLER's node.**

Clinical Remarks

The **topography of the Fossa iliopectinea** is of relevance for diagnostic and therapeutic interventions. From medial ("**i**nner") to lateral, the large vessels are oriented in the following sequence: **V.** femoralis, **A.** femoralis and **N.** femoralis **(iVAN).** Since the pulse of the A. femoralis is easily palpated, access to the V. femoralis is gained by piercing the skin about 1 cm medial of the artery to insert a right ventricular cardiac catheter through the V. femoralis. The artery is accessed for left ventricular catheterisation or for arterial blood gas analysis. The N. femoralis lies lateral to the artery and may be damaged during these interventions.

Superficial vessels and nerves of inguinal region and thigh

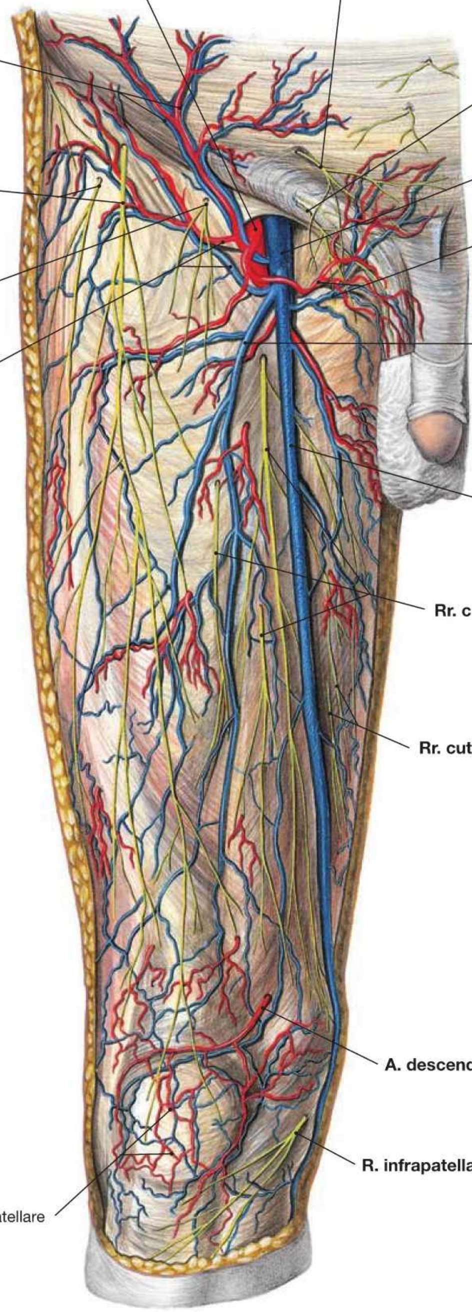


Fig. 4.179 Epifascial vessels and nerves of the inguinal region, Regio inguinalis, the thigh, Regio femoris anterior, and the knee, Regio genus anterior, right side; ventral view.

During the dissection of this region particularly the course of the cutaneous nerves and the epifascial veins need to be considered. The **N. ilioinguinalis** pierces the fascia above the inguinal ligament. Just cranial to it, the **R. cutaneus anterior** of the **N. iliohypogastricus** is found. The **V. saphena magna** ascends at the medial aspect of the thigh and enters into the V. femoralis through the Hiatus saphenus. Here the vein collects several tributaries from the inguinal region (→ p. 341). Most of these veins are accompanied by small branches of the A. femoralis. The **R. femoralis** of the **N. genitofemoralis** passes through the Lacuna vasorum just lateral to the A. femoralis. The **N. cutaneus femoris lateralis** traverses the Lacuna musculorum medially to the Spina iliaca anterior superior and innervates the lateral aspect of the thigh. The **Rr. cutanei anteriores** of the **N. femoralis** pierce the fascia at several locations to innervate the ventral aspect of the thigh. Medial to the V. saphena magna, several small **cutaneous branches of the N. obturatorius** supply a variable area on the medial aspect of the thigh. Medial and inferior to the knee, the **R. infrapatellaris** of the **N. saphenus** passes through the fascia. Just above the patella the thin A. descendens genus courses to the Rete patellare of the knee.

Superficial vessels and nerves of the gluteal region and thigh

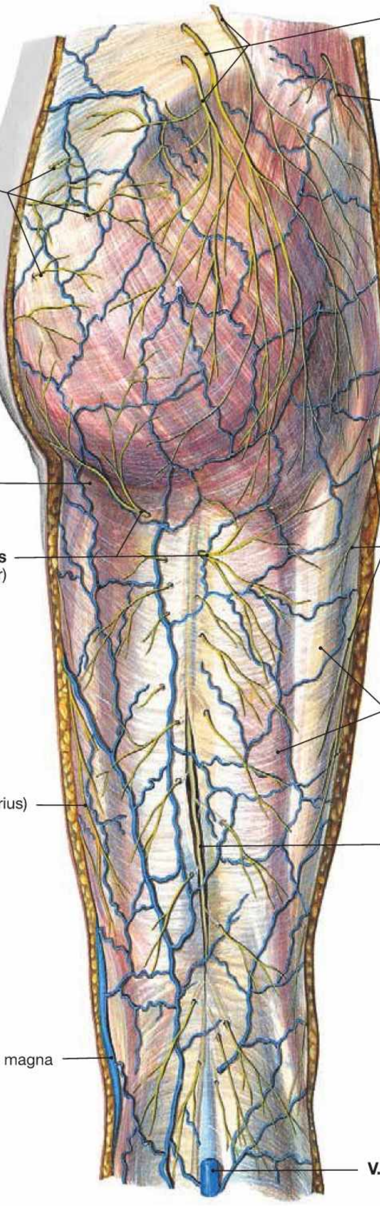


Fig. 4.180 Epifascial vessels and nerves of the gluteal region, Regio glutealis, the thigh, Regio femoris posterior, and the popliteal fossa, Fossa poplitea, right side; dorsal view.

There are no important epifascial veins on the posterior side of the thigh. The V. saphena parva of the leg enters 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) appear laterally to the autochthonous muscles of the back above the iliac crest. The **Nn. clunium medii** (Rr. posteriores from S1–S3) traverse the M. gluteus maximus at its origin from the posterior side of the sacrum. The **Nn. clunium inferiores** are branches of the N. cutaneus femoris posterior and wind around the inferior margin of the M. gluteus maximus. The **N. cutaneus femoris posterior** descends in the middle of the thigh and pierces the fascia at midlength of the thigh to provide sensory innervation to the posterior aspect of the thigh.

Superficial vessels and nerves of the leg

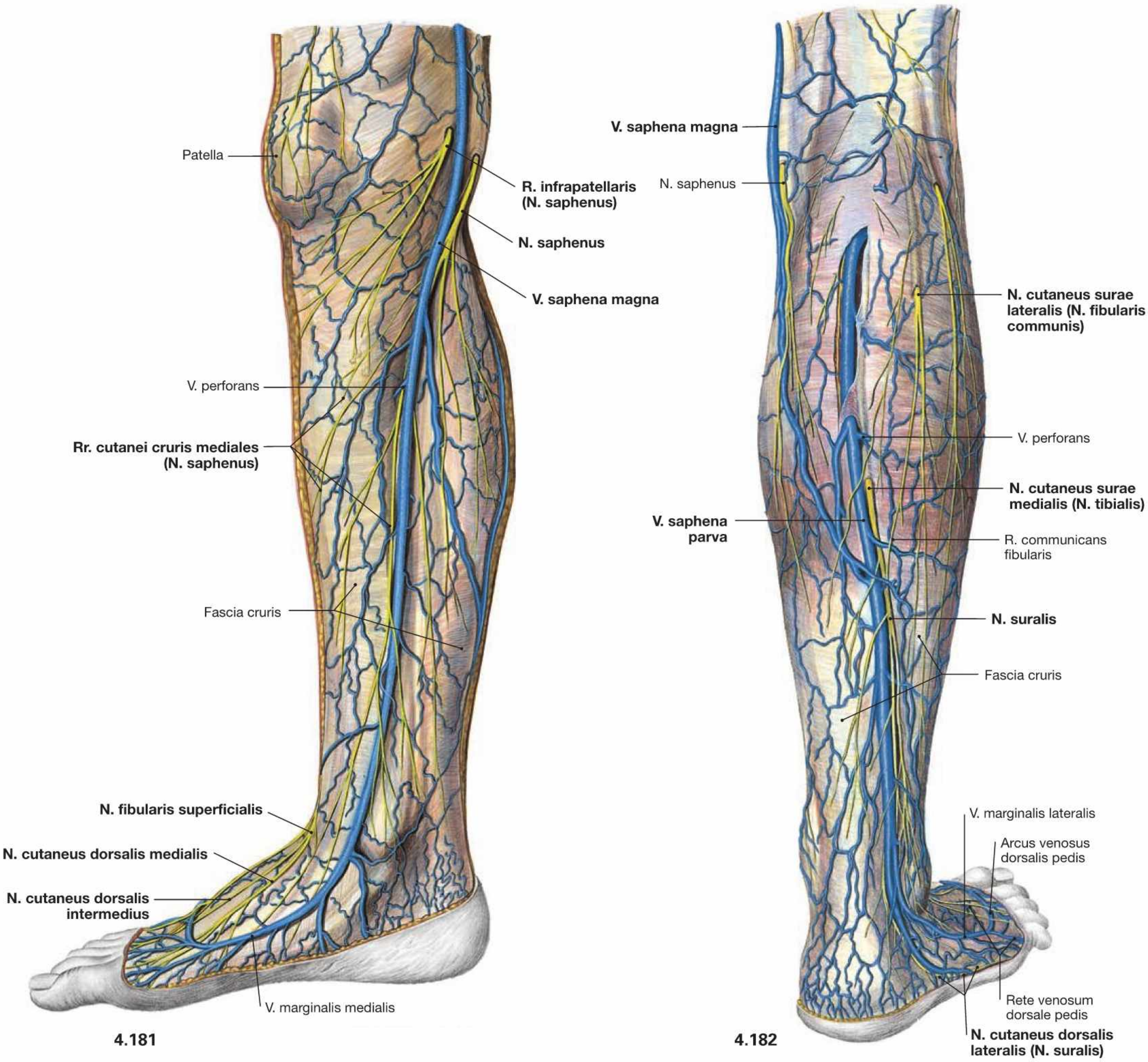


Fig. 4.181 and Fig. 4.182 Epifascial veins and nerves of the leg, Regio cruris, and the foot, Regio pedis, right side; medial (→ Fig. 4.181) and dorsolateral (→ Fig. 4.182) views.

The **V. saphena magna** originates at the medial margin of the foot anterior to the medial malleolus and ascends on the medial side of the leg and thigh. At the medial aspect of the knee, the **N. saphenus** pierces the fascia. Its major branch descends adjacent to the V. saphena magna and splits into the sensory terminal branches, **Rr. cutanei cruris mediales,** for the innervation of the ventral and medial leg and the medial margin of the foot. The **R. infrapatellaris** of the N. saphenus pierces the fascia ventral to the V. saphena magna and supplies the skin beneath the patella. In the distal third of the lateral side of the leg, the **N. fibularis superficialis** perforates the fascia to split into the two terminal cutaneous branches (**Nn. cutanei dorsalis medialis** and **intermedius**) which continue on the dorsum of the foot. On the posterior side of the leg, the **V. saphena parva** emerges from the epifascial veins of the lateral margin of the foot and ascends posteriorly to the lateral malleolus on the dorsal side of the calf, pierces the popliteal fascia, and enters the V. poplitea. Adjacent thereof courses the **N. cutaneus surae medialis,** a branch of the **N. tibialis,** which continues distally at the distal third of the leg as **N. suralis.** It frequently communicates with the N. fibularis directly or via a communicating **N. cutaneus surae lateralis.** The terminal branch of the N. suralis supplies as **N. cutaneus dorsalis lateralis** the lateral margin of the foot.

Superficial vessels and nerves of the dorsum of the foot

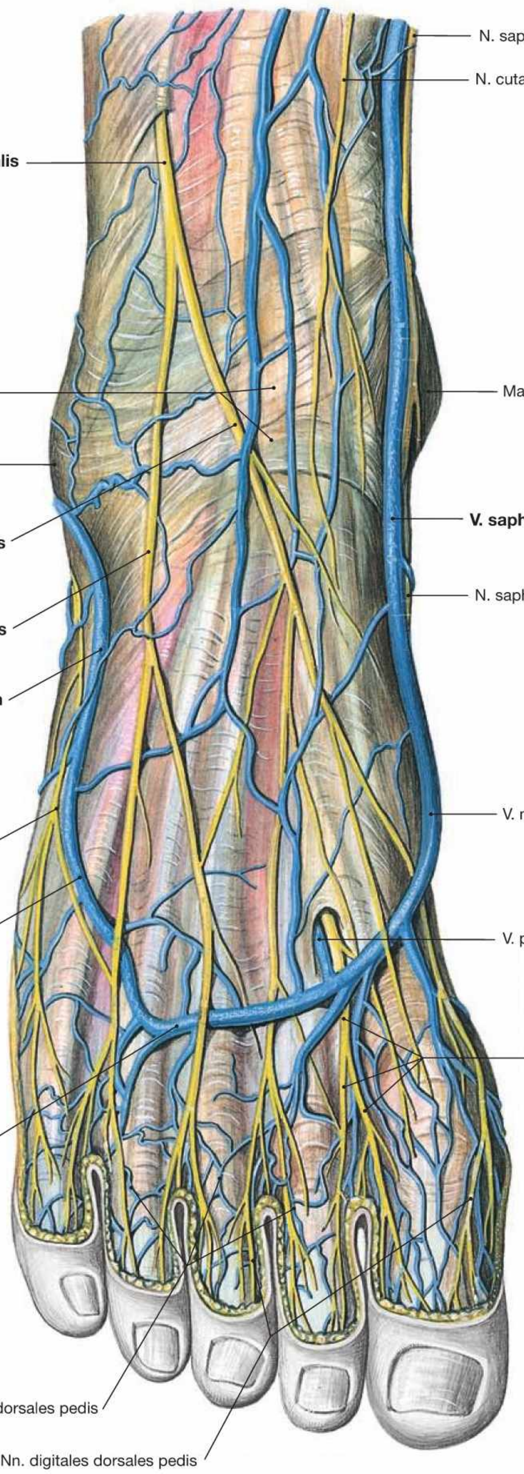


Fig. 4.183 Epifascial veins and nerves of the dorsum of the foot, Dorsum pedis, right side; dorsal view onto the dorsum of the foot.
The **V. saphena magna** originates at the medial margin of the foot from the epifascial veins of the dorsum of the foot and, thus, is a continuation of the Arcus venosus dorsalis. The smaller **V. saphena parva** originates from the lateral margin of the foot. At the lateral aspect of the distal leg the **N. fibularis superficialis** perforates the fascia and splits into the **Nn. cutanei dorsales medialis** and **intermedius** for the sensory innervation of the dorsum of the foot and the toes. The lateral margin of the foot is innervated by the **N. cutaneus dorsalis lateralis** of the N. suralis. Only the first interphalangeal space receives sensory innervation from the terminal branches of the **N. fibularis profundus.**

Vessels and nerves of the thigh

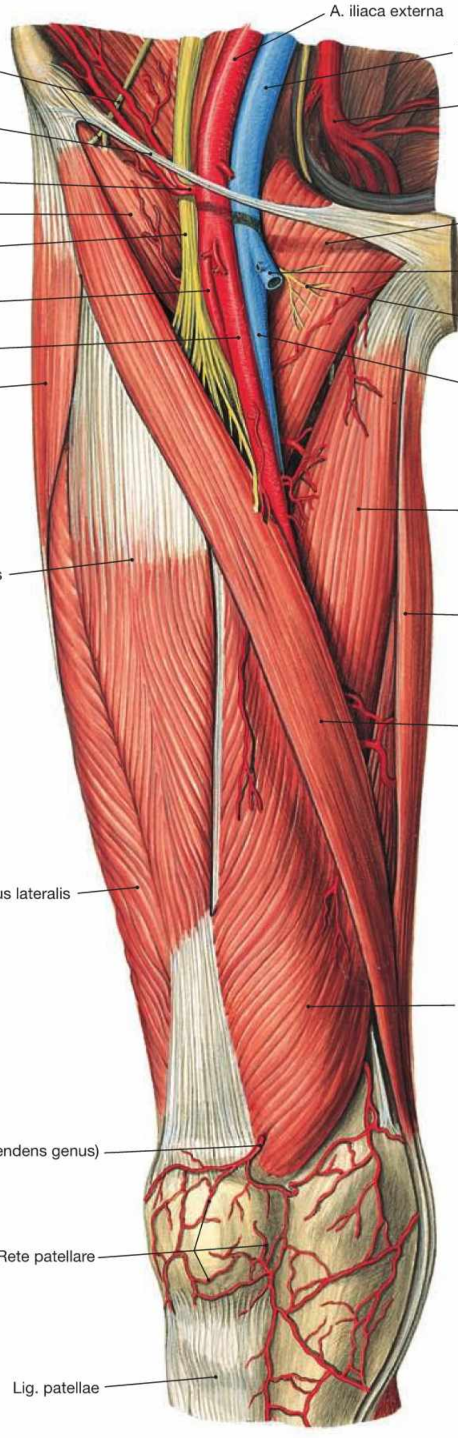


Fig. 4.184 Vessels and nerves of the thigh, Regio femoris anterior, right side; ventral view.

After removal of the fascia, the individual muscles and the subfascial vessels and nerves are displayed in the femoral triangle **(Trigonum femorale).** The boundaries of the traingle are formed by the inguinal ligament (**Lig. inguinale;** proximal), the M. gracilis (medial), and the M. sartorius (lateral).

Beneath the inguinal ligament, the following structures enter the triangle from medial to lateral: V. femoralis, A. femoralis, and N. femoralis. The **V. saphena magna** enters the **V. femoralis.** The **A. femoralis** releases smaller branches to the inguinal region 3–6 cm below the inguinal ligament and as a larger branch the **A. profunda femoris.** In the Fossa iliopectinea, the **N. femoralis** creates a fan-shaped branching and divides into the N. saphenus, several Rr. musculares for motor innervation of the ventral muscles of the thigh and the M. pectineus as well as the **Rr. cutanei anteriores** providing sensory innervation to the skin of the ventral thigh. The large cutaneous **N. saphenus** continues the course of the N. femoralis beneath the M. sartorius. Medial to the Spina iliaca anterior superior, the **N. cutaneus femoris lateralis** enters the Lacuna musculorum beneath the inguinal ligament.

Vessels and nerves of the thigh

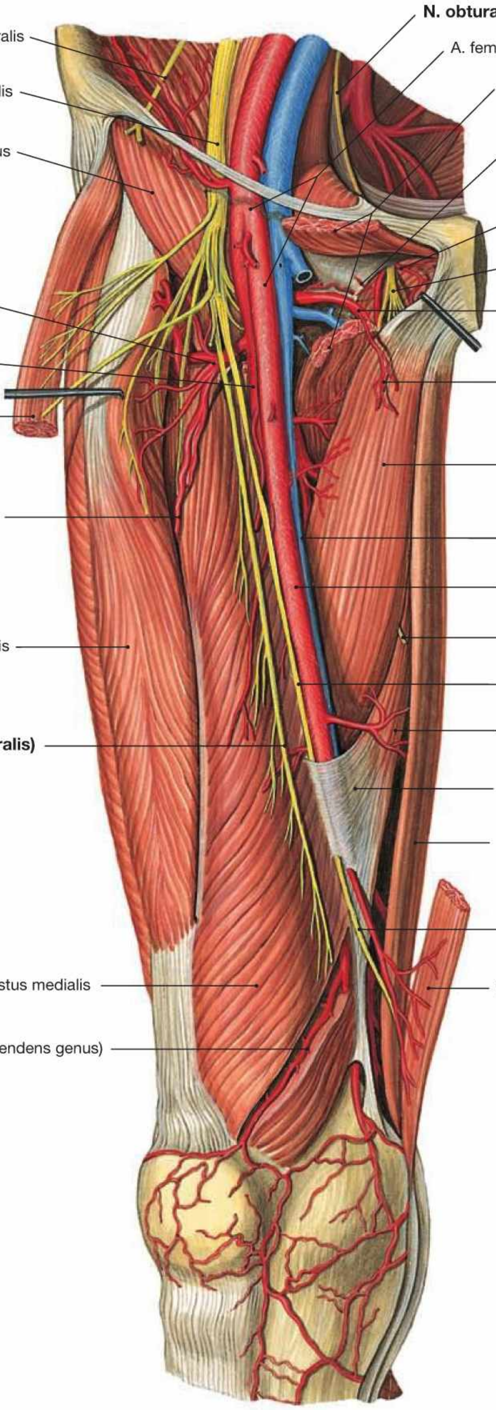


Fig. 4.185 Vessels and nerves of the thigh, Regio femoris anterior, right side; ventral view; after partial removal of the M. sartorius and splitting of the M. pectineus.
The **A. and V. femoralis** and the **N. saphenus** are exposed up to their entrance into the adductor canal **(Canalis adductorius).** The entrance of the adductor canal is formed by the Mm. vastus medialis and adductor longus and the **Septum intermusculare vastoadductorium** which spans between these muscles and the M. adductor magnus. Owing to the splitting of the M. pectineus, the outlet of the **Canalis obturatorius** is visible. Here, the **N. obturatorius** and the **A. and V. obturatoria** exit the pelvis.

Clinical Remarks

In some cases of **spasticity,** the muscle tonus of those muscles innervated by the N. obturatorius is so high that abduction of the legs and, thus, walking and standing are not possible. Injections of botulinum toxin into the adductor muscles reduce the spasticity and may relieve the symptoms. Botulinum toxin blocks the signal transduction at the motor end plates, although, in some cases it is much more effective to irreversibly paralyse the **N. obturatorius by phenol injections.** This is performed by introducing the needle a few centimeters lateral to the pubic symphysis to reach the N. obturatorius exiting from the Canalis obturatorius.

Vessels and nerves of the thigh

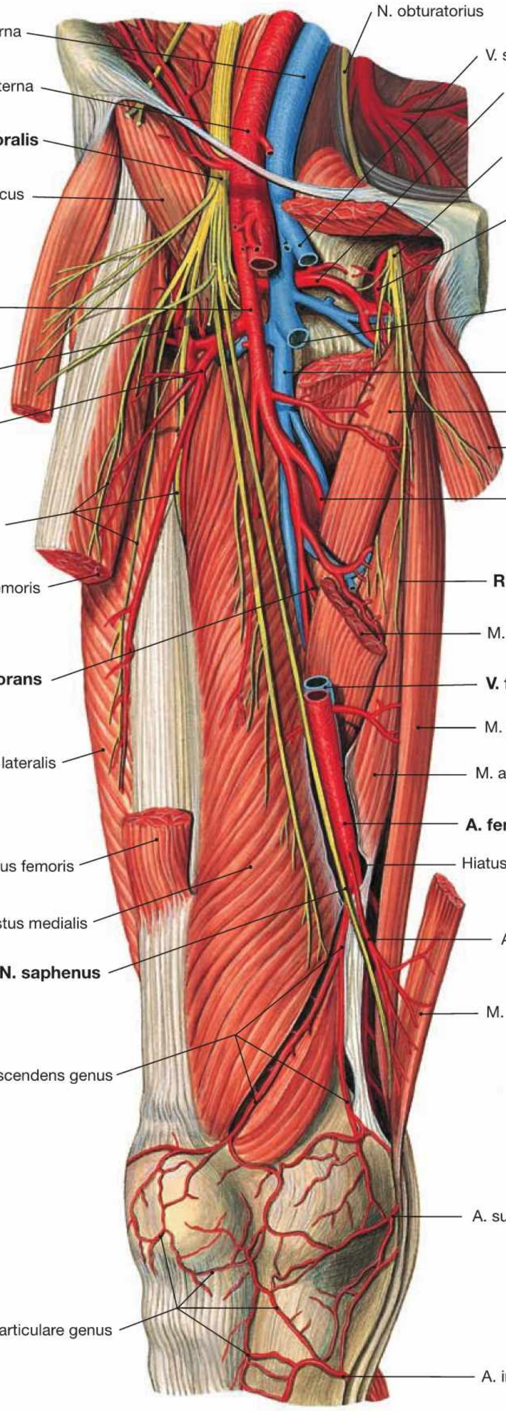


Fig. 4.186 Vessels and nerves of the thigh, Regio femoris anterior, right side; ventral view; after partial removal of the M. sartorius and M. rectus femoris, and splitting of the M. pectineus and M. adductor longus.The adductor canal is opened.

The **A. profunda femoris** with its branches is displayed. This artery branches off the A. femoralis 3–6 cm below the inguinal ligament and serves as main artery for the thigh and the femoral head (→ pp. 271 and 338). The **Aa. circumflexae femoris medialis** and **lateralis** branch off the A. profunda femoris or occasionally derive directly from the A. femoralis. The A. circumflexa femoris medialis has a deep branch to supply the femoral neck and head as well as the adductor muscles and the proximal parts of the hamstring muscles. There are anastomoses with the **A. obturatoria** which contribute to the supply of the acetabular fossa and the adductors. The ascending branch (R. ascendens) of the A. circumflexa femoris lateralis supplies the lateral muscles of the hip, the descending branch (R. descendens). descendens supplies the anterior ventral muscles of the thigh. The main trunk of the A. profunda femoris descends further and provides three **Aa. perforantes** to supply the deep adductor muscles and the hamstring muscles at the dorsal aspect of the thigh.

Vessels and nerves of the gluteal region and thigh

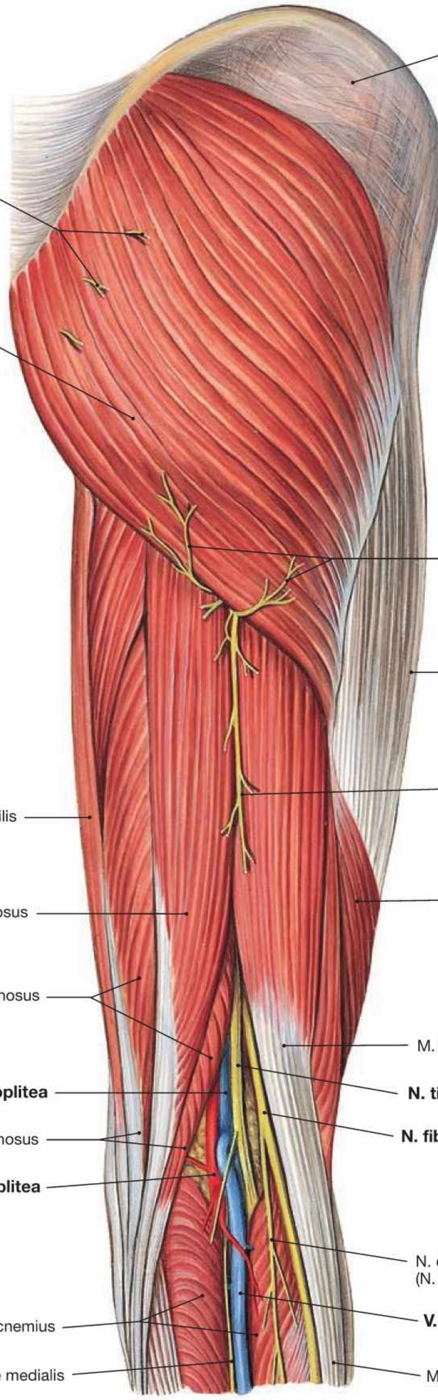


Fig. 4.187 Vessels and nerves of the gluteal region, Regio glutealis, the thigh, Regio femoris posterior, and the popliteal fossa, Fossa poplitea, right side; dorsal view; after removal of the Fascia lata.

The **N. cutaneus femoris posterior** provides sensory innervation to the posterior aspect of the thigh. It enters the groove between the M. biceps femoris and the M. semitendinosus at the inferior margin of the M. gluteus maximus and penetrates the fascia at the midlength of the thigh. This needs to be considered for the dissection. At the distal thigh, both muscles deviate from each other and define the borders of 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. Here, they are joined by the terminal branches of the N. ischiadicus (N. tibialis and N. fibularis communis). In the popliteal fossa, the **N. fibularis communis** courses most laterally and superficially. Located medially and deep within the popliteal fossa are the **N. tibialis, V. poplitea,** and **A. poplitea** (**NVA;** from superficial to deep). The V. saphena parva ascends in the middle of the calf and drains into the V. poplitea in the popliteal fossa.

Vessels and nerves of the gluteal region and thigh

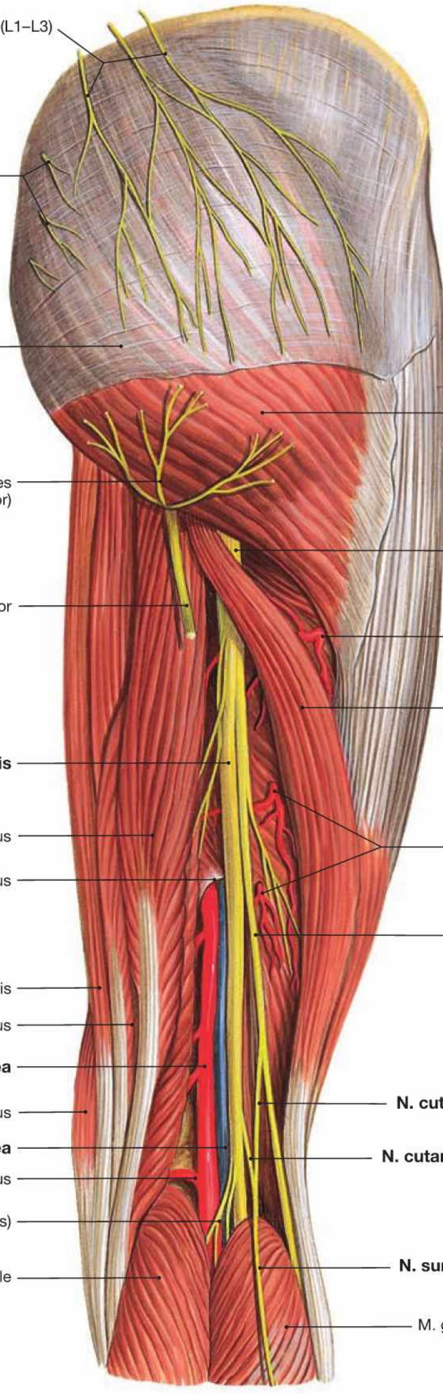


Fig. 4.188 Vessels and nerves of the gluteal region, Regio glutealis, the thigh, Regio femoris posterior, and the popliteal fossa, Fossa poplitea, right side; dorsal view; after removal of the Fascia lata and lateral deflection of the Caput longum of the M. biceps femoris.

The **N. ischiadicus** descends under the guidance of the M. biceps femoris. At the level of the distal third or higher (as shown here), the N. ischiadicus divides into its terminal branches. The **N. tibialis** continues its original course and the **N. fibularis communis** turns laterally to wind around the fibular head and enter the fibularis compartment of the leg below the popliteal fossa. In the region of the popliteal fossa, the **N. cutaneus surae medialis** branches off the N. tibialis, and the **N. cutaneus surae lateralis** branches off the N. fibularis communis for the sensory innervation of the calf. The N. cutaneus surae medialis combines with a branch of the N. cutaneus surae lateralis to form the **N. suralis.** At the thigh, the **Aa. perforantes** of the A. profunda femoris penetrate the M. adductor magnus lateral to the N. ischiadicus to supply the hamstring muscles.

Vessels and nerves of the gluteal region and thigh

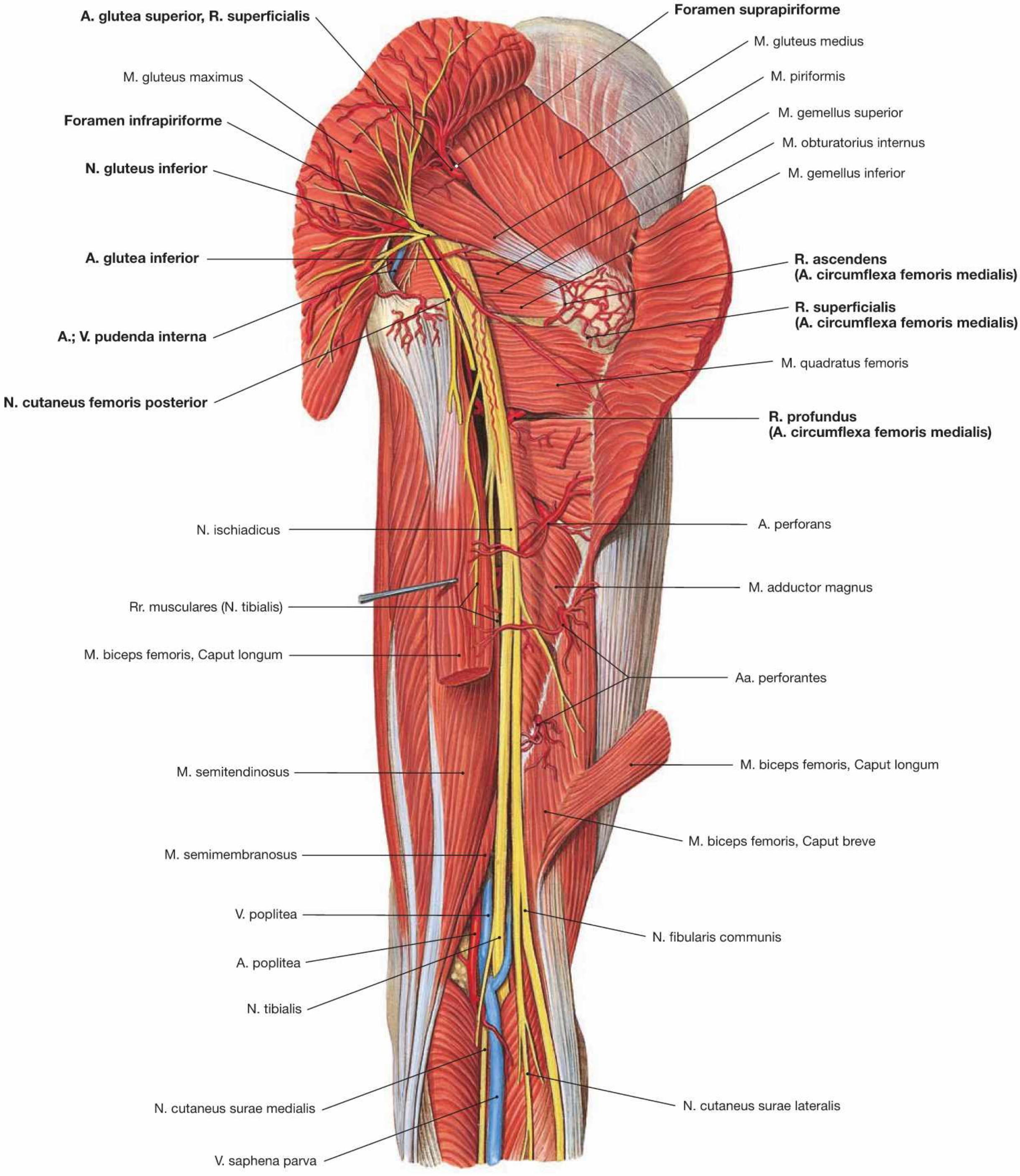
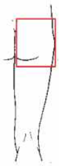


Fig. 4.189 Vessels and nerves of the gluteal region, Regio glutealis, the thigh, Regio femoris posterior, and the popliteal fossa, Fossa poplitea, right side; dorsal view; after dissection of the M. gluteus maximus and Caput longum of the M. biceps femoris.
The **N. ischiadicus** exits the Foramen infrapiriforme together with the **N. cutaneus femoris posterior** and the **N. gluteus inferior** as well as with the **A.** and **V. glutea inferior.** The **N. pudendus** and the **A.** and **V. pudenda interna** also exit here, but immediately wind round the Lig. sacrospinale to enter the Fossa ischioanalis beneath the Lig. sacrotuberale through the Foramen ischiadicum minus. The N. gluteus inferior supplies motor fibres to the M. gluteus maximus. The **N. gluteus superior** together with the **A.** and **V. glutea superior** exits the pelvis through the Foramen suprapiriforme but remains at the deep level beneath the M. gluteus medius which it innervates.

Clinical Remarks

The topography of the gluteal region explains why **intramuscular injections** must be applied into the **M. gluteus medius,** not into the M. gluteus maximus. Wrongly placed injections may cause bleedings and injuries to the nerves which innervate the muscles facilitating movements in the hip (Nn. glutei superior and inferior) and the leg (N. ischiadicus).

Vessels and nerves of the gluteal region



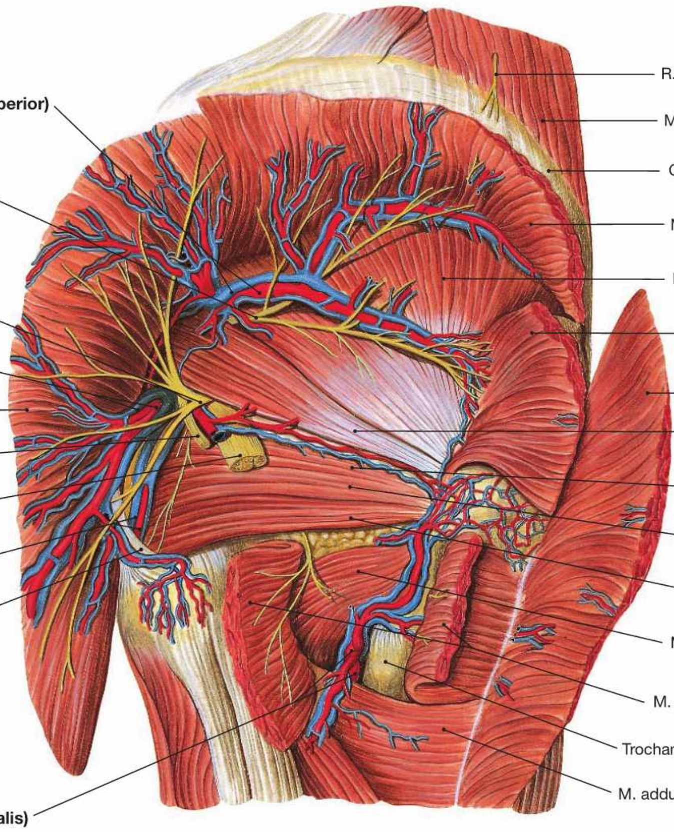
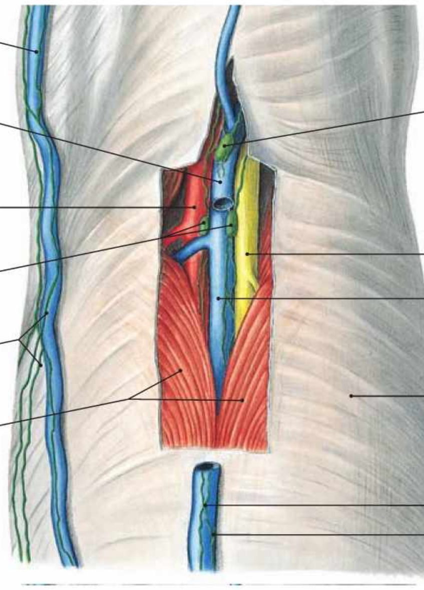


Fig. 4.190 Vessels and nerves of the gluteal region, Regio glutealis, and the thigh, Regio femoris posterior, right side; dorsal view; the Mm. glutei maximus and medius were cut and partially reflected, the N. ischiadicus was removed after its exit from the Foramen infrapiriforme.
After cutting and reflecting the M. gluteus medius, the **N. gluteus superior** is exposed which exits together with the **A. and V. glutea superior** through the Foramen suprapiriforme and then courses laterally between the M. gluteus medius and the deeper M. gluteus minimus to the M. tensor fasciae latae. It supplies motor fibres to all these muscles. Several branches of the **A. circumflexa femoris medialis** appear between the pelvitrochanteric hip muscles and anastomose with the gluteal arteries.

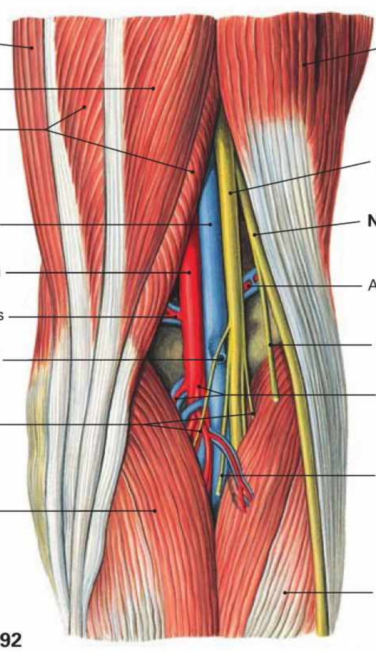
Clinical Remarks

The topography of the gluteal region has particular relevance for **hip joint surgery** with dorsal access. To prevent injury to the A. circumflexa femoris medialis as the major blood vessel supplying the femoral head, dissection of the pelvitrochanteric muscles (in particular of the M. quadratus femoris and M. obturatorius externus) should be avoided.

Vessels and nerves of the popliteal fossa



4.191



4.192

Fig. 4.191 and Fig. 4.192 Vessels and nerves of the popliteal fossa, Fossa poplitea, right side; dorsal view; after partial (→ Fig. 4.191) and complete (→ Fig. 4.192) removal of the fascia.
In the popliteal fossa the **N. fibularis communis** is located most laterally and superficially, followed medially and deeply by the **N. tibialis, V. poplitea,** and **A. poplitea (NVA).** The **V. saphena parva** ascends in the midline of the leg and drains into the V. poplitea in the popliteal fossa. The **dorsolateral lymph vessel system** courses along the V. saphena parva, whereas the **ventromedial lymph vessel system** accompanies the **V. saphena magna.** The first regional lymph nodes for the dorsolateral collecting system are the **Nodi lymphoidei poplitei superficiales** and **profundi** (→ p. 343).

Arteries of the popliteal fossa

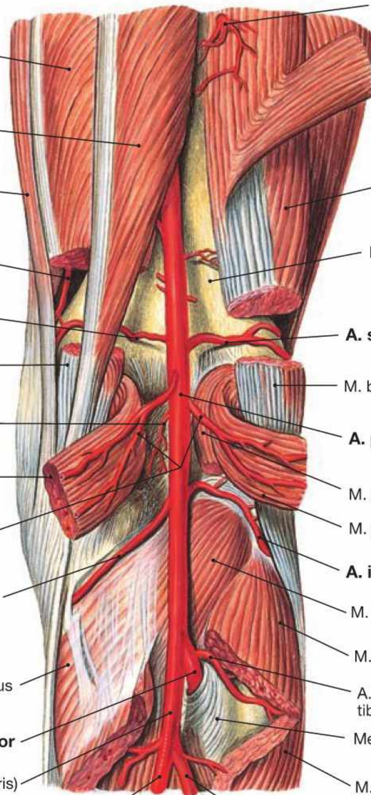


Fig. 4.193 Arteries of the popliteal fossa, Fossa poplitea, right side; dorsal view; after partial resection of the covering muscles.
The **A. poplitea** supplies the knee joint and forms arterial networks with its branches above (Aa. superiores medialis and lateralis genus) and below (Aa. inferiores medialis and lateralis genus) the articular cavity. These arterial networks contribute to the Rete articulare genus on the ventral side of the knee. At the level of the joint, the A. media genus branches off to supply the knee joint. The Aa. surales supply the muscles of the calf. Below the popliteal fossa, the A. poplitea descends between the two heads of the M. gastrocnemius and divides into the two terminal branches just beneath the tendinous arch of its M. soleus. The **A. tibialis posterior** continues its course, and the **A. tibialis anterior** traverses the Membrana interossea cruris to enter the ventral extensor compartment.

Clinical Remarks

The portion of the A. poplitea between the branching off of the A. tibialis anterior and the origin of the A. fibularis derived from the A. tibialis posterior is clinically referred to as **Truncus tibiofibularis.**

Vessels and nerves of the leg

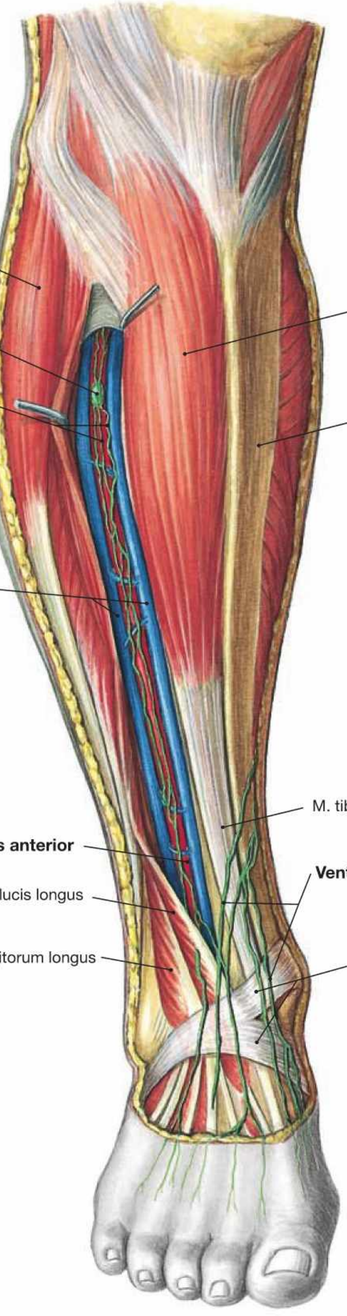


Fig. 4.194 Vessels and nerves of the leg, Regio cruris anterior, right side; ventral view; after spreading apart the extensor muscles. The superficial lymph vessels course as **ventromedial collecting system** from the medial margin of the foot alongside the **V. saphena magna** and as **dorsolateral collecting system** alongside the **V. saphena parva.** The deep lymph vessels accompany the arteries in the three muscular compartments as shown here for the extensor compartment.

Vessels and nerves of the leg

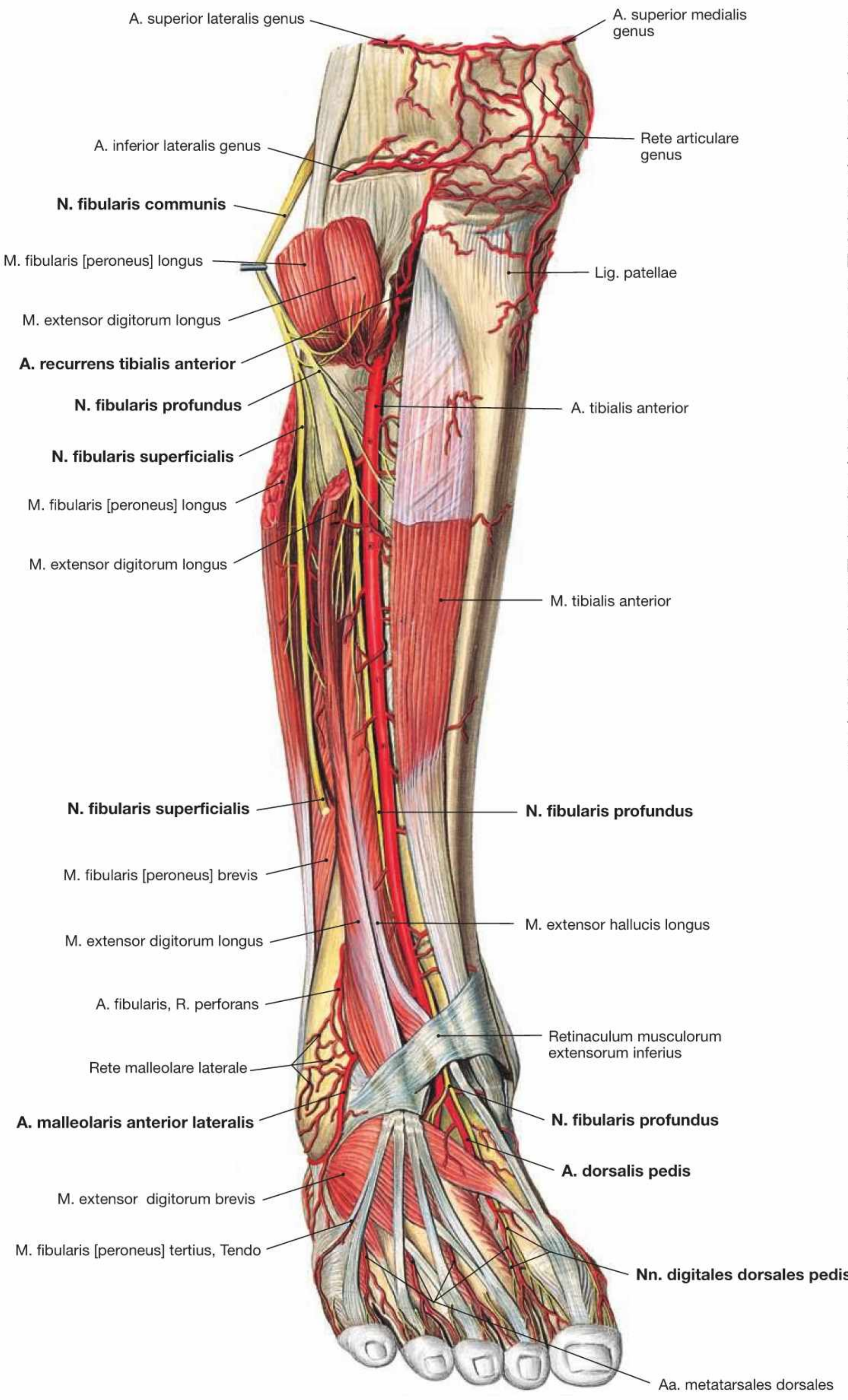


Fig. 4.195 Vessels and nerves of the leg, Regio cruris anterior, right side; ventral view; after removal of the Fascia cruris and dissecting the Mm. extensor digitorum longus and fibularis longus.

The **A. tibialis anterior** descends in the extensor compartment between the M. extensor digitorum longus and M. tibialis anterior and continues as **A. dorsalis pedis** on the dorsum of the foot. After the **A. recurrens tibialis posterior** branches off at the posterior side of the leg, the **A. recurrens tibialis anterior** appears as the next branch after traversing the Membrana interossea cruris. At the malleoli the **Aa. malleolares anteriores medialis** and **lateralis** contribute to the arterial network around the ankle that may provide a sufficient collateral circulation in case of an occlusion of one of the arteries of the leg.

The **N. fibularis communis** winds laterally around the head of the fibula, enters the fibularis compartment, and then divides into its two terminal branches. The **N. fibularis superficialis** descends in the fibularis compartment, provides motor fibres to both fibularis muscles and pierces the fascia at the distal third of the leg. The **N. fibularis profundus** passes over to the extensor compartment and descends adjacent to the A. tibialis anterior. It conveys motor innervation to all extensors of the leg and the dorsum of the foot. Its terminal branches convey sensory fibres to the first interdigital space.

Clinical Remarks

The **N. fibularis communis** may be injured near the fibular head (proximal fibular fractures, casts, crossed legs). The resulting paralysis of the extensor muscles causes the toes to drop (**footdrop,** → p. 337). This is the most common nerve lesion of the lower extremity!

Vessels and nerves of the popliteal fossa and leg

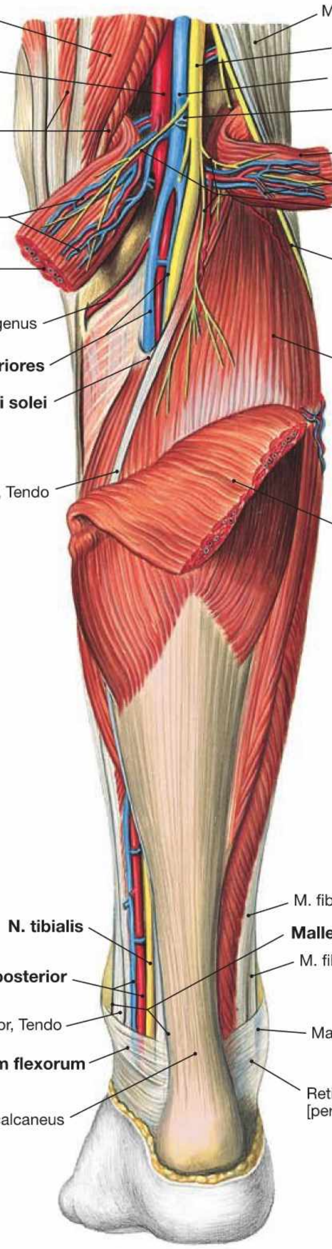


Fig. 4.196 Vessels and nerves of the popliteal fossa, Fossa poplitea, and the leg, Regio cruris posterior, right side; dorsal view; after removal of the Fascia cruris and dissecting the M. gastrocnemius.
Joined by two concomitant veins and the **N. tibialis,** the **A. tibialis posterior** courses beneath the tendinous arch of the M. soleus (Arcus tendineus musculi solei) and descends between the superficial and deep flexor muscles of the leg to the medial malleolus. There, it traverses the **malleolar canal** beneath the Retinaculum musculorum flexorum to reach the sole of the foot.

Clinical Remarks

The **N. tibialis** may be compressed in the **malleolar canal** (**medial tarsal tunnel syndrome,** → p. 336). This causes burning pain sensations at the sole of the foot and a loss of function of the plantar muscles of the foot. Flexion, adduction, or spreading toes is not possible any more.

Vessels and nerves of the popliteal fossa and leg

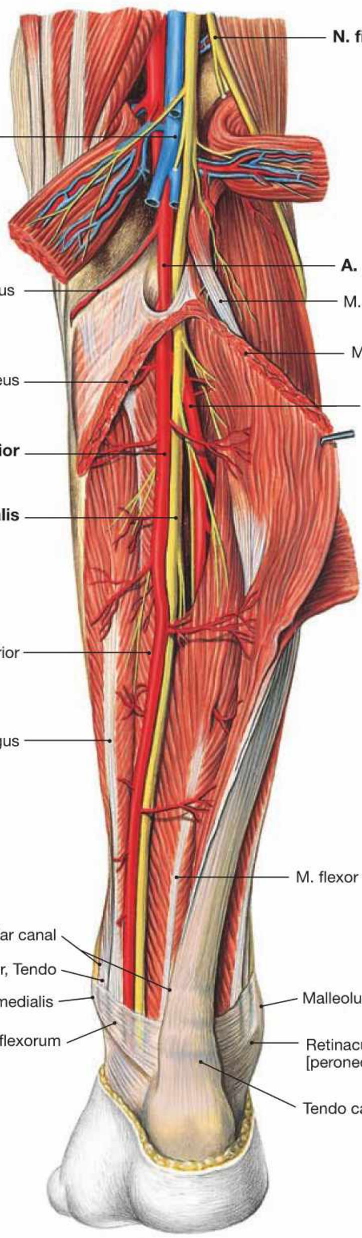


Fig. 4.197 Vessels and nerves of the popliteal fossa, Fossa poplitea, and the leg, Regio cruris posterior, right side; dorsal view; after dissecting the Mm. gastrocnemius and soleus.

Shortly after passing through the tendinous arch of the M. soleus, the **A. tibialis posterior** gives rise to its most important branch, the A. fibularis, which descends to the lateral malleolus.

Vessels and nerves of the leg

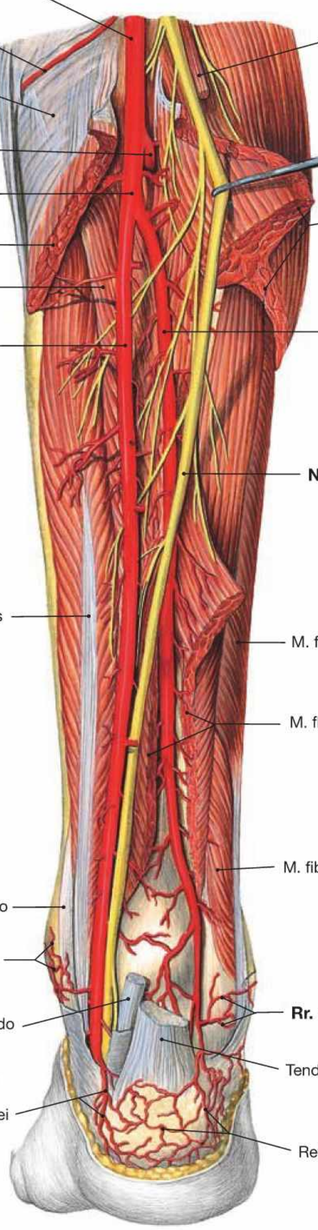


Fig. 4.198 Vessels and nerves of the leg, Regio cruris posterior, right side; dorsal view; after removal of the Fascia cruris and dissecting the Mm. gastrocnemius, soleus, and flexor hallucis longus. The **A. tibialis posterior** descends together with the **N. tibialis** between the superficial and deep flexor muscles of the leg to the medial malleolus and continues through the **malleolar canal** beneath the Retinaculum musculorum flexorum to the plantar side of the foot. **Rr. malleolares mediales** to the medial malleolus derive from this vessel.

The **A. fibularis** pierces the M. flexor hallucis longus and descends in the deepest layer directly on the Membrana interossea cruris to the lateral malleolus. Together with the branches of the Aa. tibiales anterior and posterior, its **Rr. malleolares laterales** complete the arterial network around the ankle which provides sufficient collaterals to compensate for an occluded vessel.

Vessels and nerves of the dorsum of the foot

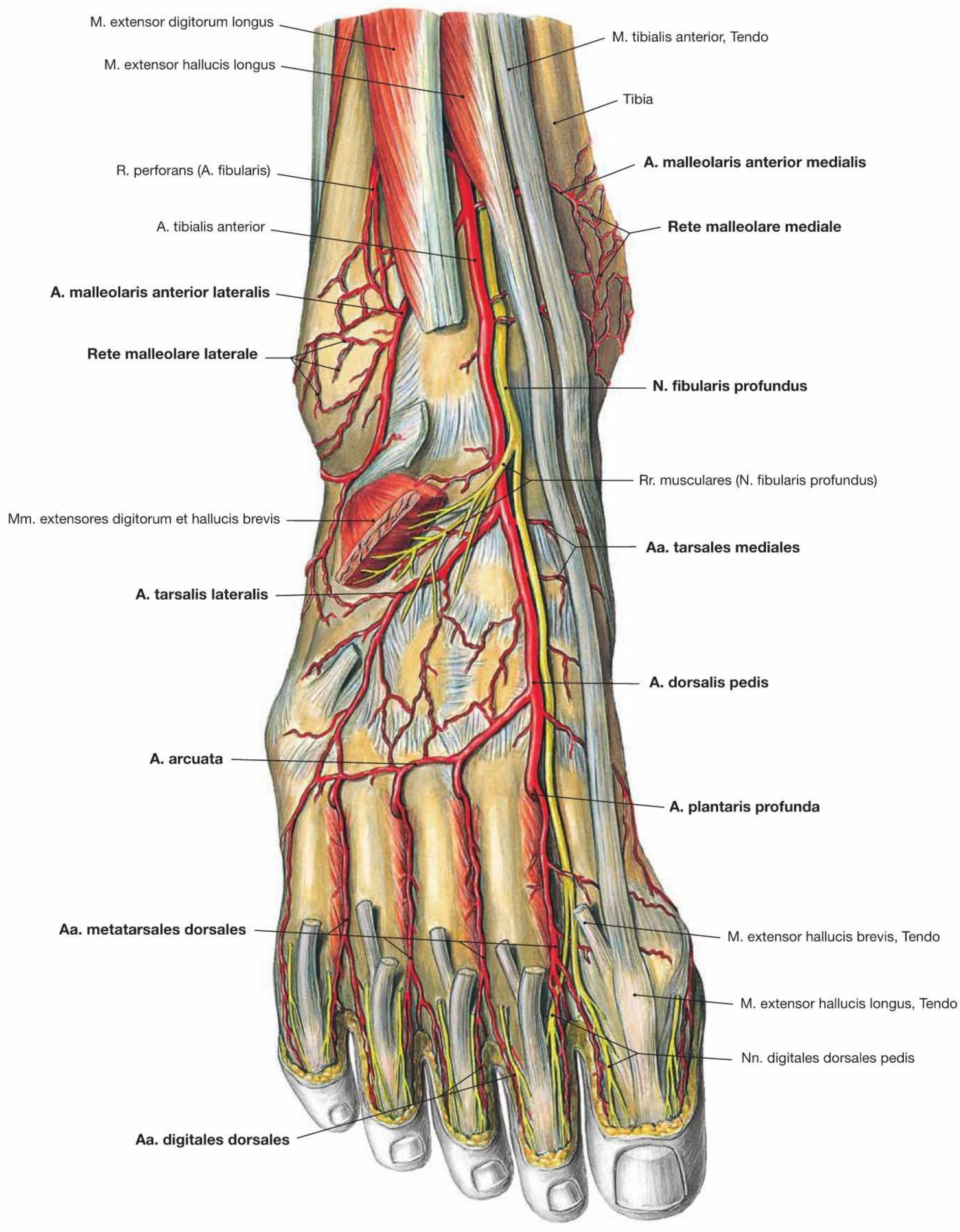


Fig. 4.199 Vessels and nerves of the dorsum of the foot, Dorsum pedis, right side; dorsal view onto the dorsum of the foot after removal of the tendons of the M. extensor digitorum longus and the short extensors of the toes.

The **A. tibialis anterior** continues on the dorsum of the foot as **A. dorsalis pedis.** After the innervation of the extensors of the leg and the dorsum of the foot, the concomitant **N. fibularis profundus** divides into terminal sensory branches which supply the first interdigital space. At the level of the malleoli, the A. tibialis anterior provides the **Aa. malleolares anteriores medialis** and **lateralis** for the arterial networks around the malleoli (Rete malleolare mediale and Rete malleolare laterale). The A. dorsalis pedis provides several smaller Aa. tarsales mediales and one A. tarsalis lateralis to the Tarsus and then continues as A. arcuata. The latter arches to the lateral margin of the foot and gives rise to the Aa. metatarsales dorsales which continue as Aa. digitales dorsales to supply the toes. The A. plantaris profunda participates in the perfusion of the sole of the foot by supplying the Arcus plantaris profundus.

Arteries of the sole of the foot

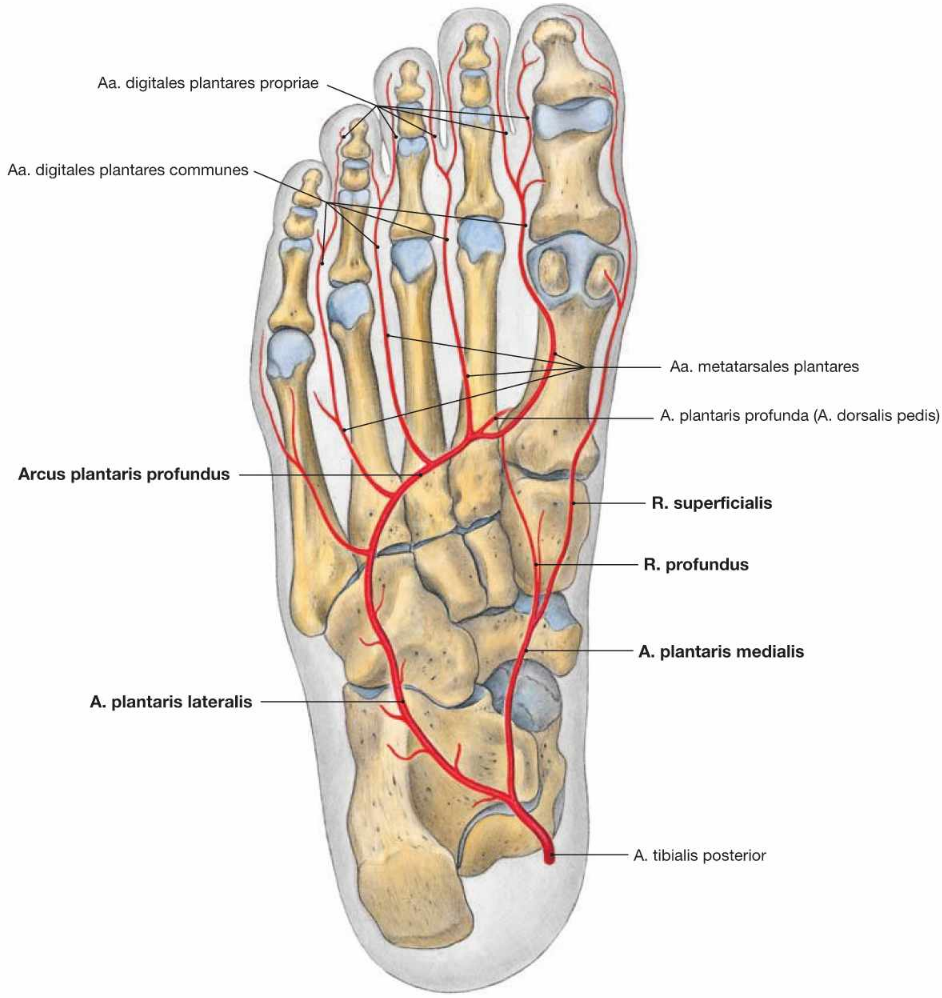
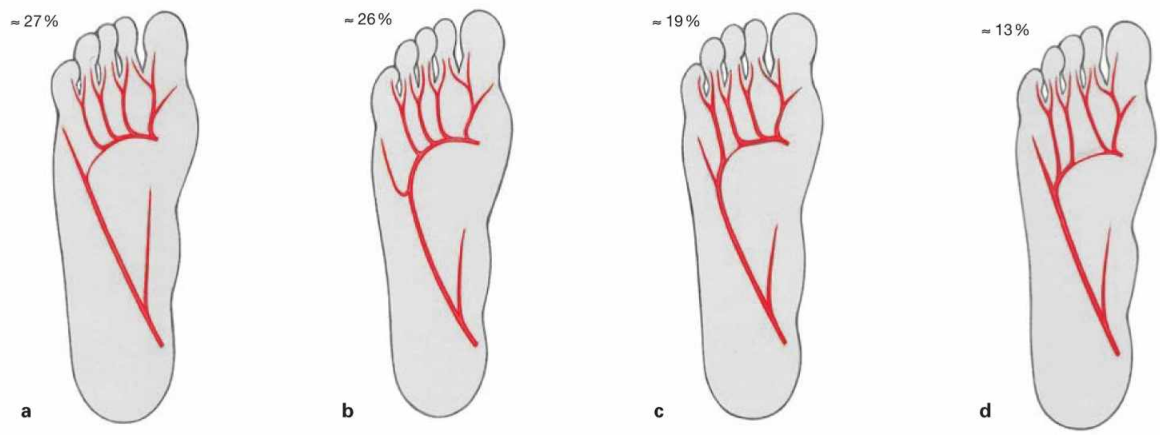


Fig. 4.200 Arteries of the sole of the foot, Planta pedis, right side; plantar view.
The plantar aspect of the foot is perfused by terminal branches of the A. tibialis posterior. The **A. plantaris medialis** provides a **R. superficialis** to the medial margin of the foot and a **R. profundus** which connects to the **Arcus plantaris profundus.** This arterial arch is a direct continuation of the **A. plantaris lateralis.**



Figs. 4.201a to d Variations of the arterial supply of the toes, right side; plantar view.
The Arcus plantaris profundus may receive its main input from the A. dorsalis pedis via the A. plantaris profunda (**a**) or from the A. tibialis posterior (**b**). Alternatively, both arteries may contribute to the arterial supply of the toes (**c** and **d**).

Vessels and nerves of the sole of the foot

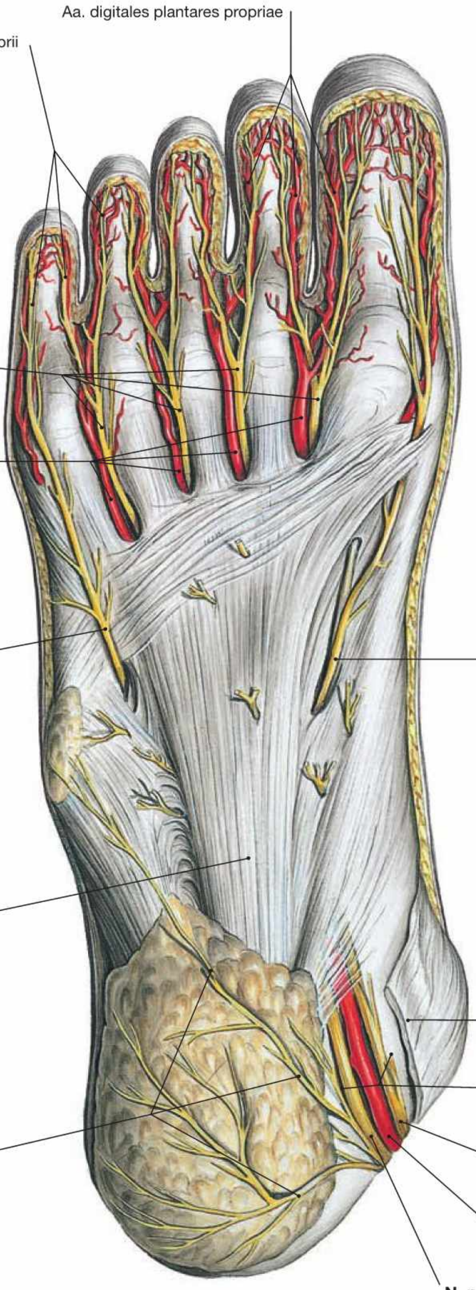


Fig. 4.202 Superficial layer of the arteries and nerves of the sole of the foot, right side; plantar view.

The **N. tibialis** already divides into its two terminal branches (**Nn. plantares medialis** and **lateralis**) at the medial malleolus within the **malleolar canal** beneath the Retinaculum musculorum flexorum. The terminal branches then divide further into several Nn. digitales plantares. Similar to the N. ulnaris at the hand, the N. plantaris lateralis divides into a R. superficialis and a R. profundus. The N. plantaris medialis supplies an additional **N. digitalis plantaris proprius** at the medial margin of the foot. The sensory branches surface between the longitudinal fibres of the plantar aponeurosis (Aponeurosis plantaris). The A. tibialis posterior divides only at the plantar aspect of the foot.

Vessels and nerves of the sole of the foot

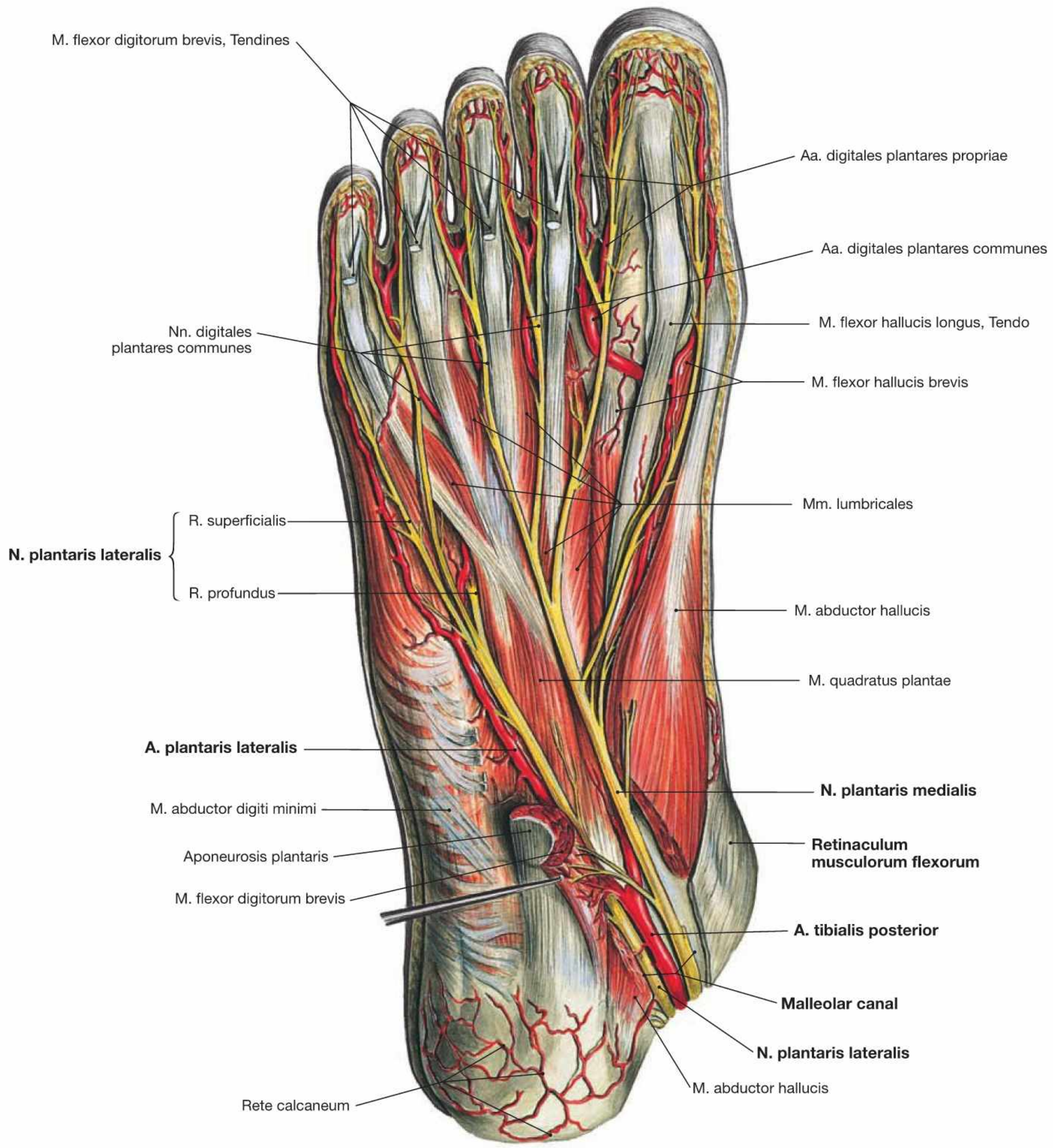


Fig. 4.203 Intermediate layer of the arteries and nerves of the sole of the foot, right side; plantar view.
The M. flexor digitorum brevis and the M. abductor hallucis were cut to expose the neurovascular passageway of the malleolar canal. The **Nn. plantares medialis** and **lateralis** are accompanied by the corresponding vessels from the A. tibialis posterior. The blood vessels continue beneath the M. flexor digitorum brevis to reach the intermediate layer of the neurovascular structures to the toes. On their way, the nerves provide motor fibres to the short muscles of the sole of the foot.

Vessels and nerves of the sole of the foot

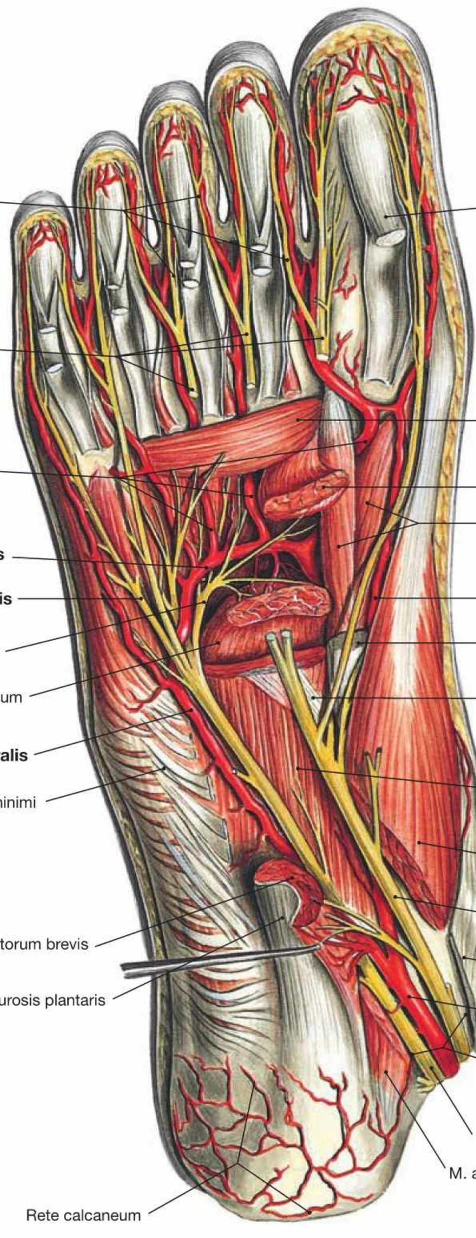
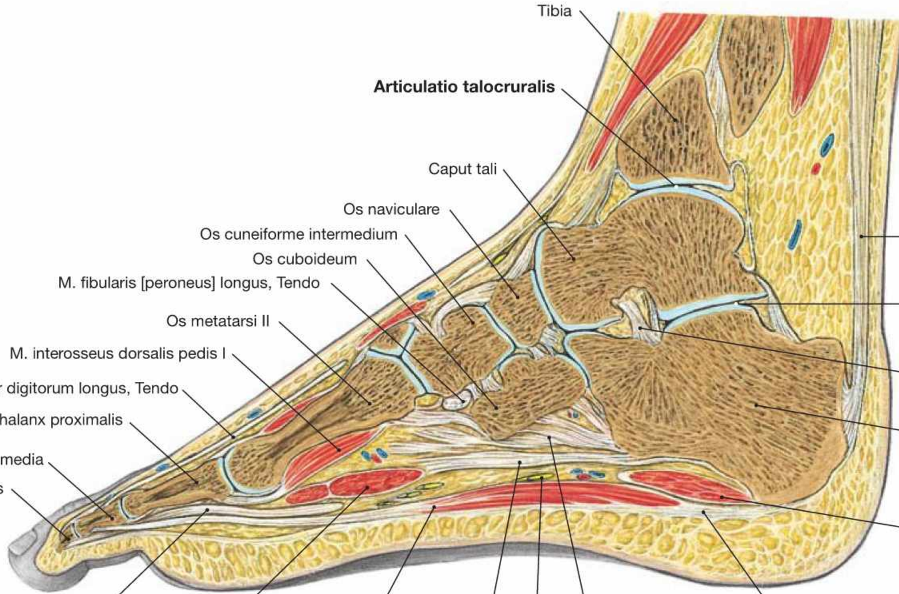
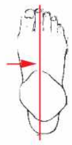


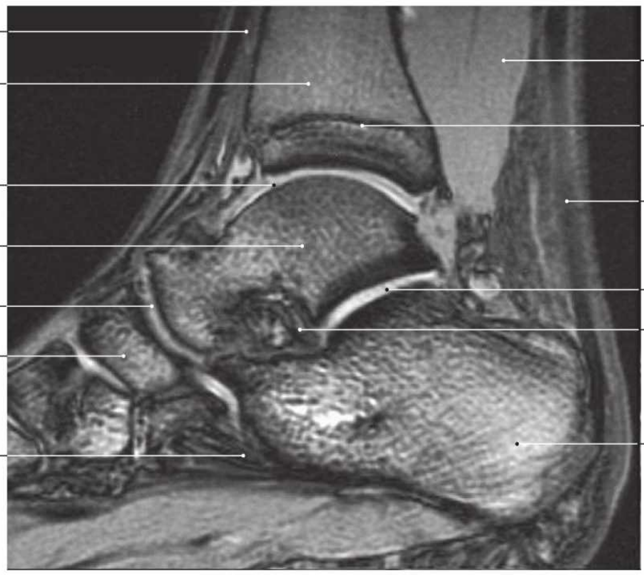
Fig. 4.204 Deep layer of the arteries and nerves of the sole of the foot, right side; plantar view.
The M. flexor digitorum brevis and the M. abductor hallucis were split to expose the neurovascular passageway of the **malleolar canal.** In addition, the Caput obliquum of the M. adductor hallucis was cut to demonstrate the deep plantar arch **(Arcus plantaris profundus)** and the course of the **R. profundus** of the **N. plantaris lateralis.** The Arcus plantaris profundus continues the A. plantaris lateralis und receives blood from the R. profundus of the A. plantaris medialis and from the A. plantaris profunda which derives from the A. dorsalis pedis. Together with the R. profundus from the N. plantaris lateralis it arches over the Mm. interossei of the sole of the foot in the deep layer of the neurovascular structures.

Foot, sagittal sections



4.205





4.206

Fig. 4.205 and Fig. 4.206 Foot, Pes, right side; sagittal section through the second phalanx (→ Fig. 4.205) and corresponding magnetic resonance imaging (MRI) sagittal section (→ Fig. 4.206); medial view.

The section visualises the articular cavity of the ankle joint (Articulatio talocruralis) and the posterior chamber of the talocalcaneonavicular joint (Articulatio subtalaris). The longitudinal arch is stabilised by three overlying ligamentous systems (Aponeurosis plantaris, Lig. plantare longum, Lig. calcaneonaviculare plantare) (→ Fig. 4.95).

Hip joint, oblique section

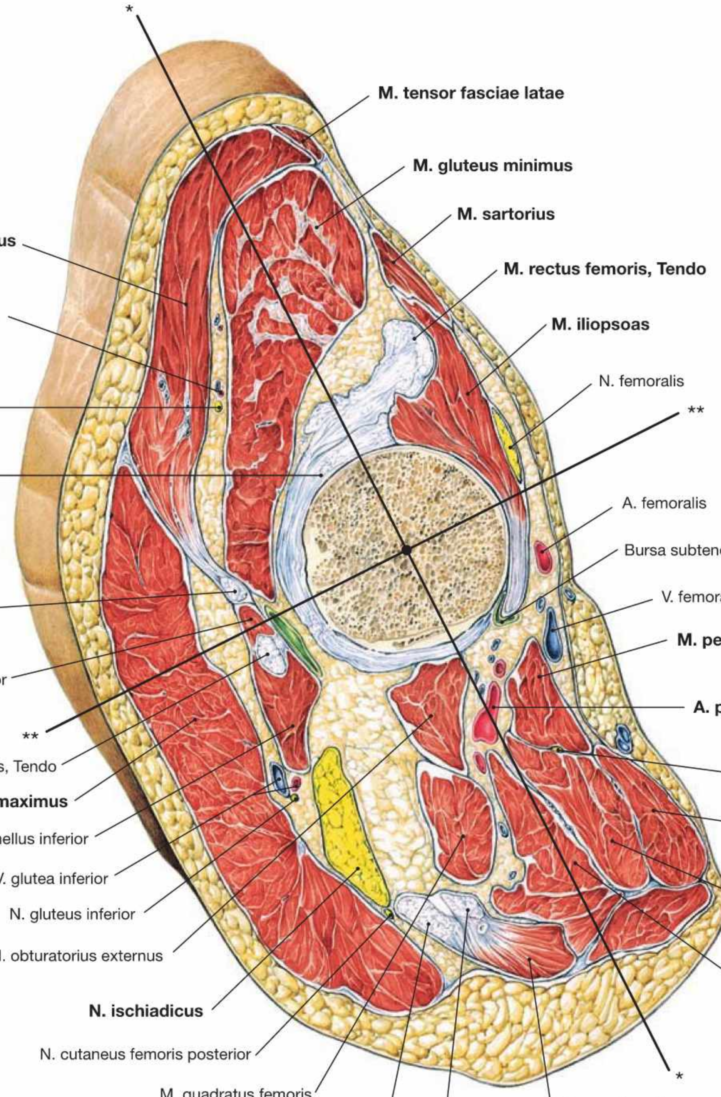
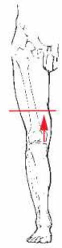


Fig. 4.207 Thigh, Femur, oblique section through the hip joint, right side; distal view illustrating the axes of movement of the hip joint.

The oblique section through the thigh at the level of the femoral head shows the position of the diverse groups of muscles relative to the articular head and the axes of movement. The M. gluteus maximus is located dorsal to the hip joint, whereas the smaller gluteal muscles (Mm. glutei medius and minimus) in part course ventral to the longitudinal and transverse axes of the hip joint. This position explains why the M. gluteus maximus acts as external rotator and extensor of the hip, and the small gluteal muscles function as strongest medial rotators and also as flexors of the hip. The M. iliopsoas is located anterior to the transverse axis and is the most important flexor of the hip joint. It is supported for this function 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). However, the dorsal part of the M. adductor magnus is positioned posterior to the transverse axis and functions as extensor of the hip joint together with the hamstring muscles of which it is a part of given its function and innervation.Cross-sections through the extremities are well suited to comprehend the course of the neurovascular structures in the respective compartments at several levels. After exiting the small pelvis, the N. ischiadicus initially courses beneath the M. gluteus maximus. On the ventral side, 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

Thigh, transverse section



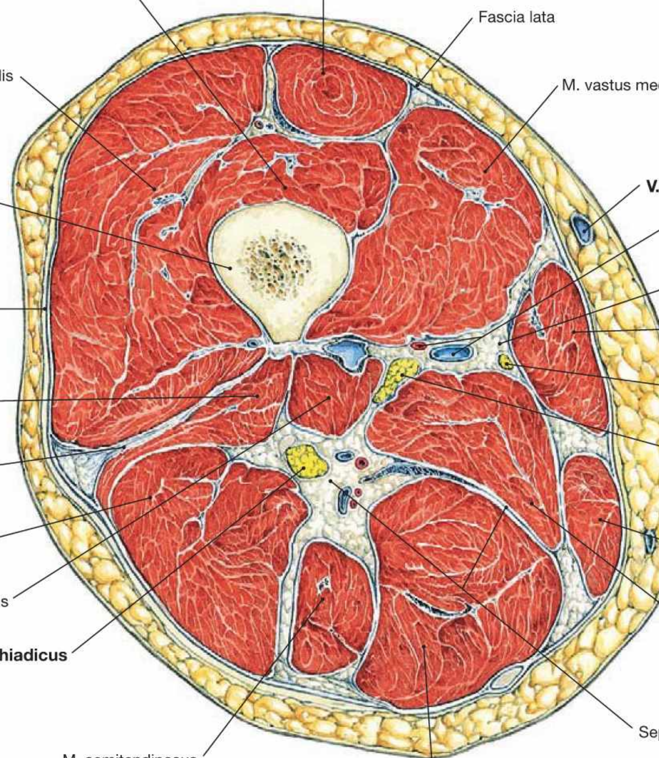
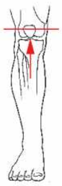


Fig. 4.208 Thigh, Femur, right side; transverse section at the mid-tigh level; distal view.
This cross-section shows the three muscle groups of the thigh. The ventral group comprises the M. quadriceps femoris and the M. sartorius. Medially located are the adductor muscles and dorsally the hamstring muscles.

The V. saphena magna is found in the epifascial subcutaneous adipose tissue on the medial aspect of the thigh. The A. and V. femoralis jointly course with the N. saphenus through the adductor canal (Canalis adductorius) of the M. quadriceps. The adductor canal is demarcated dorsally by the Mm. adductores longus and magnus, medially by the M. vastus medialis, and ventrally by the M. sartorius. The N. ischiadicus is positioned dorsally beneath the M. biceps femoris.

Knee, transverse section



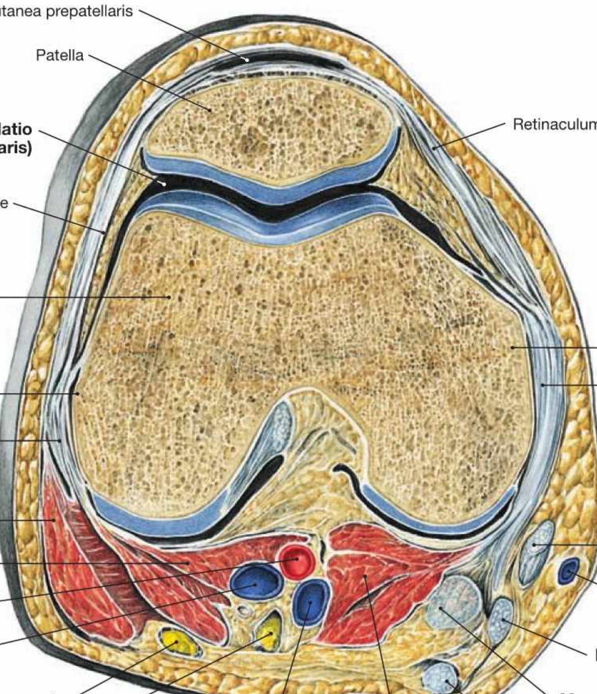
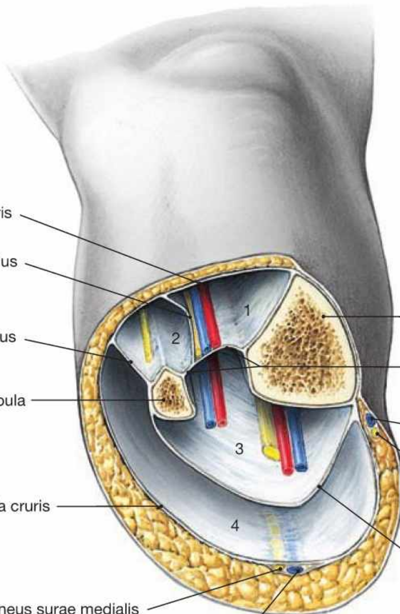


Fig. 4.209 Knee joint, Articulatio genus, right side; transverse section; distal view.

The transverse section through the knee joint shows the articular surfaces of the Articulatio femoropatellaris. On the posterior side, the M. biceps femoris is positioned laterally. Therefore this muscle is the most important lateral rotator. On the medial side, several muscles contribute to medial rotation. The tendons of the Mm. sartorius, gracilis, and semitendinosus are located superficially. They insert further distally with a common aponeurosis at the medial aspect of the Tibia, commonly referred to as "Pes anserinus superficialis". Beneath it, the insertion of the M. semimembranosus tendon 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. Dorsally, the terminal branches of the N. ischiadicus (N. tibialis and N. fibularis communis) are the most superficial structures, followed further beneath by the V. poplitea with the confluence of the V. saphena parva, and deepest within the popliteal fossa the A. poplitea (NVA).

Leg, transverse section



1 Compartimentum cruris anterius:
A.; V. tibialis anterior
N. fibularis profundus
M. tibialis anterior
M. extensor digitorum longus
M. extensor hallucis longus
M. fibularis [peroneus] tertius

2 Compartimentum cruris laterale:
N. fibularis superficialis
M. fibularis [peroneus] longus
M. fibularis [peroneus] brevis

3 Compartimentum cruris posterius, Pars profunda:
A.; V. tibialis posterior
A.; V. fibularis
N. tibialis
M. flexor digitorum longus
M. tibialis posterior
M. flexor hallucis longus

4 Compartimentum cruris posterius, Pars superficialis:
M. triceps surae
M. plantaris

Fig. 4.210 Leg, Crus, right side; transverse section at the mid-leg level with illustration of the osteofibrous compartments; distal view.

The Fascia cruris is attached to the bones of the leg by dense connective tissue septa. They separate osteofibrous compartments in which the neurovascular structures are embedded between the respective muscle groups (→ Fig. 4.211). The Septum intermusculare anterius partitions the extensor compartment anteriorly from the lateral fibularis compartment which in turn is separated from the superficial flexors by the Septum intermusculare posterius. The superficial flexors are isolated from the deep flexors by a deep layer of the Fascia cruris. The deep flexors are directly adjacent to the Membrana interossea cruris. The **anterior (extensor) compartment** harbours the N. fibularis profundus, the A. tibialis and the Vv. tibiales anteriores. The N. fibularis superficialis is located in the **lateral (fibularis) compartment.** In the **deep posterior (flexor) compartment,** the N. tibialis, A. tibialis posterior, Vv. tibialis posteriores, and – covered by the M. flexor hallucis longus – the A. and V. fibularis are embedded in the muscles. The V. saphena magna and V. saphena parva on the dorsal side course in the epifascial layer at the medial aspect of the leg.

* deep part of the Fascia cruris

Leg, transverse section

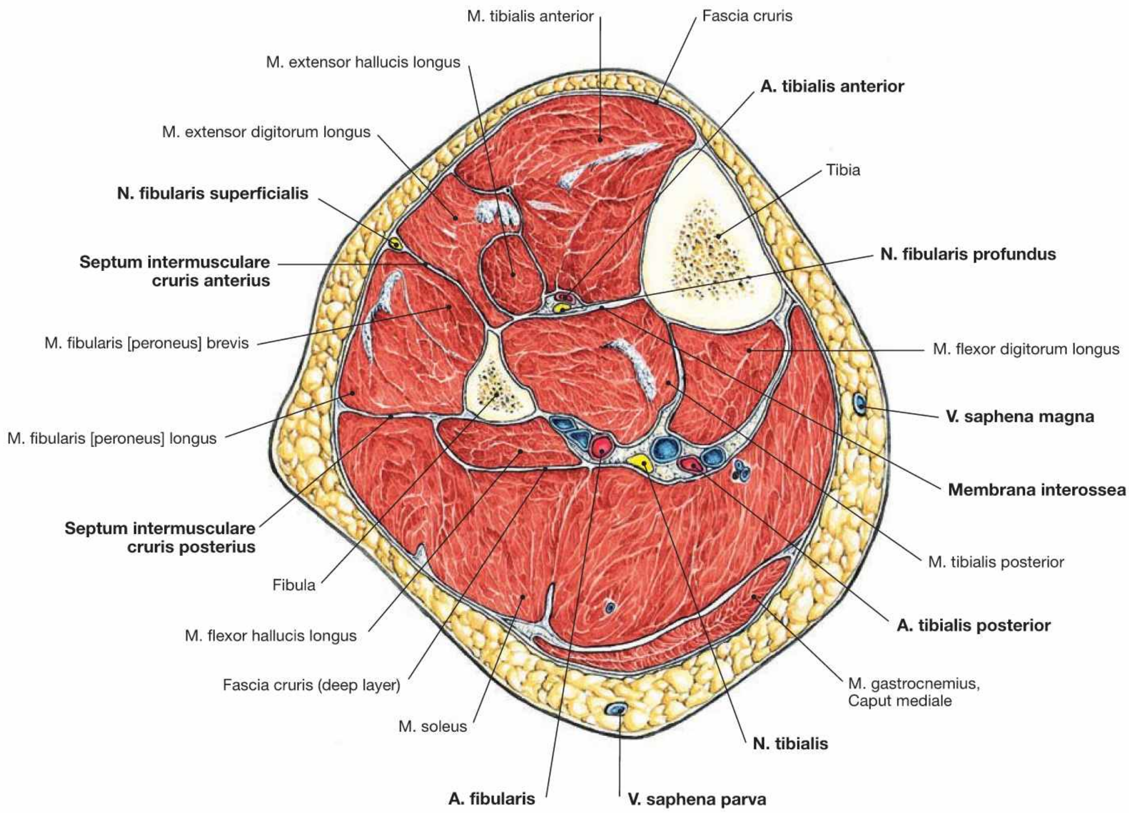


Fig. 4.211 Leg, Crus, right side; transverse section at the mid-leg level, distal view.
Together with the connective tissue septa reaching to the bones of the leg, the Fascia cruris confines the **osteofibrous compartments.** These compartments contain the respective neurovascular structures embedded between the muscle bellies of the individual muscle groups. Of highest clinical relevance is the anterior (extensor) compartment which harbours the N. fibularis profundus together with the A. tibialis anterior.

Clinical Remarks

Compression syndromes most commonly develop in the anterior compartment **(compartment syndrome)**, rarely in the posterior deep compartment. With posttraumatic swelling of the extensor muscles or after a long march the supplying blood vessels and nerves may be compressed and damaged, causing extensive pain. This may also cause the loss of palpable arterial pulses of the A. dorsalis pedis which arises from the A. tibialis anterior. Most frequently, the compression causes a lesion of the N. fibularis profundus (→ p. 337) with resulting functional deficits including the inability to dorsiflex the foot in the ankle joint and loss of sensory innervation in the first interdigital space. This condition requires the immediate decompression by surgical incision of the fascia (fasciotomy). Diagnostically, the pressure within the anterior compartment is determined using a pressure sensor which requires immobilisation of the open leg.

Appendix

Picture Credits 377

Abbreviations, Terms, etc. 379

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Picture Credits

The editors sincerely thank all clinical colleagues that made ultrasound, computed tomographic and magnetic resonance images as well as endoscopic and intraoperative pictures available:

Prof. Altaras, Center for Radiology, University of Giessen (Figs. 2.18; 2.39; 2.40)
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Additional illustrations were obtained from the following textbooks:

1 Benninghoff-Drenckhahn: Anatomie, Band 1 (Drenckhahn D., editor), 17. Aufl., Urban & Fischer 2008
2 Benninghoff-Drenckhahn: Anatomie, Band 2 (Drenckhahn D., editor), 16. Aufl., Urban & Fischer 2004
3 Benninghoff-Drenckhahn: Taschenbuch Anatomie (Drenckhahn D., Waschke, J., editors), Urban & Fischer 2007
4 Berchtold, R., Bruch, H.-P., Trentz, O. (editors): Chirurgie, 6. Aufl., Urban & Fischer 2008
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25 Welsch, U., Deller, T.: Sobotta Lehrbuch Histologie, 3. Aufl., Urban & Fischer 2010
26 Welsch, U.: Atlas Histologie, 7. Aufl., Urban & Fischer 2005
27 Wicke, L.: Atlas der Röntgenanatomie, 7. Aufl., Urban & Fischer 2005
28 Rengier, F.: BASICS Leitungsbahnen, Urban & Fischer 2009

The following illustrators have developed the new illustrations:
Dr. Katja Dalkowski: Figs. 1.22, 1.25, 1.26, 1.30, 1.31, 1.35, 2.94, 2.95, 2.134, 3.10, 3.33, 3.39, 3.48, 3.51, 3.57, 3.58, 3.59, 3.100, 4.4, 4.55, 4.68, 4.70, 4.90, 4.91, 4.107

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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).

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