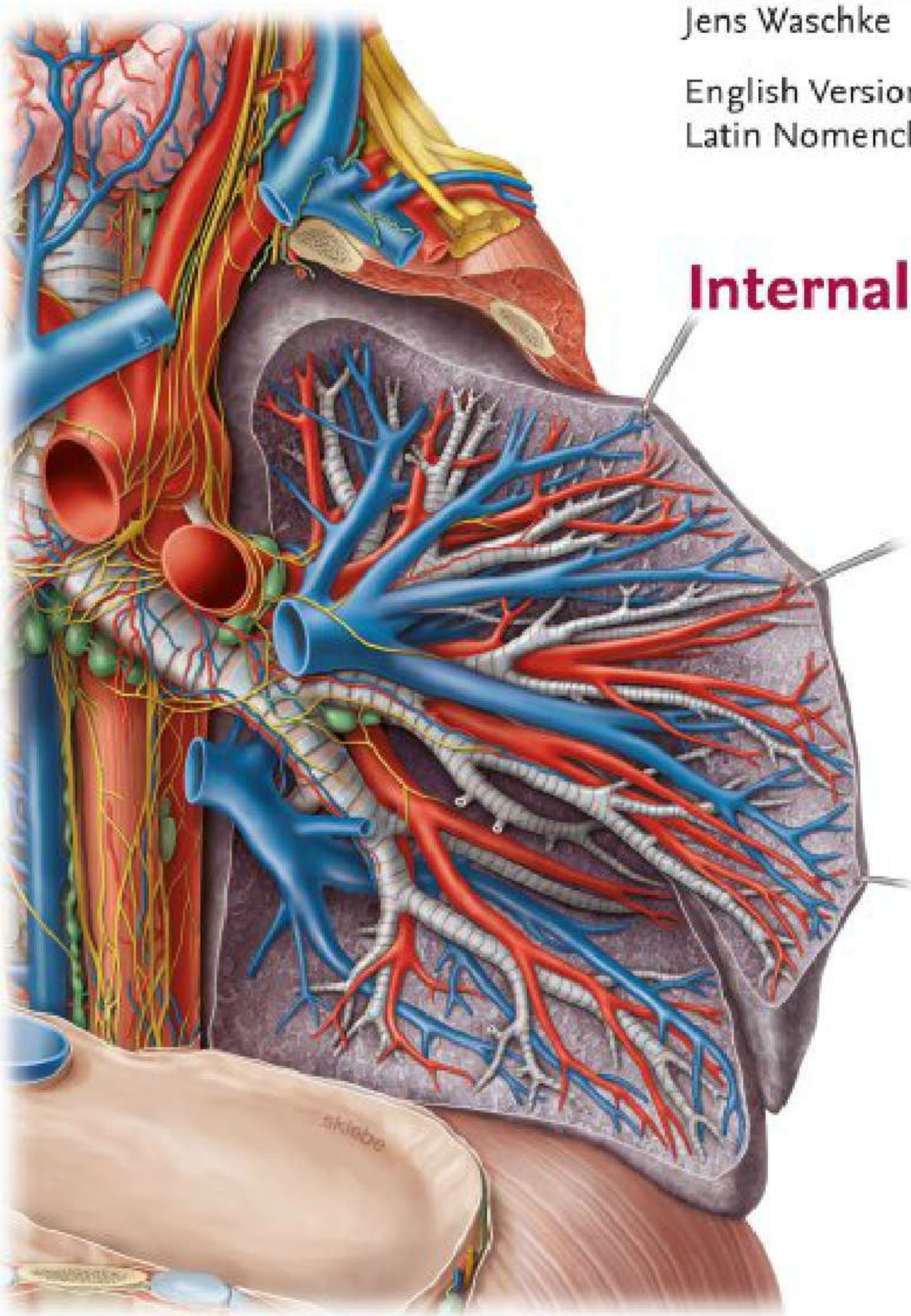
ATLAS OF ANATOMY

Sobotta

16th Edition

Edited by
Friedrich Paulsen and
Jens Waschke

English Version with
Latin Nomenclature



Internal Organs

ELSEVIER

F. Paulsen, J. Waschke

Sobotta

Atlas of Anatomy

Friedrich Paulsen, Jens Waschke (Eds.)

Sobotta

Atlas of Anatomy

English Version with Latin Nomenclature

Internal Organs

16th Edition

ELSEVIER

ELSEVIER
Hackerbrücke 6, 80335 Munich, Germany
All business correspondence should be made with:
books.cs.muc@elsevier.com

Original Publication
Sobotta Atlas der Anatomie
© Elsevier GmbH, 2017.
All rights reserved.
ISBN 978-3-437-44022-9

This translation of Sobotta Atlas der Anatomie, 24th edition by Friedrich Paulsen and Jens Waschke was undertaken by Elsevier GmbH.

ISBN 978-0-7020-5270-5

Notice
The translation has been undertaken by Elsevier GmbH at its sole responsibility.
Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.
Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds or experiments described herein.
Because of rapid advances in the medical sciences, in particular, independent verification of diagnoses and drug dosages should be made.
To the fullest extent of the law, no responsibility is assumed by Elsevier, authors, editors or contributors in relation to the translation or for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutschen Nationalbibliografie; detailed bibliographic data is available on the Internet at http://www.d-nb.de/.

18 19 20 21 22 5 4 3 2 1

Content Strategist: Dr Konstanze Knies, Susanne Szczepanek
Content Project Management: Dr Andrea Beilmann, Sibylle Hartl
Translation: Lingo24 Ltd., Edinburgh, United Kingdom
Production Management: Dr Andrea Beilmann, Sibylle Hartl
Layout: Nicola Kerber, Olching, Germany
Composed by: abavo GmbH, Buchloe, Germany
Printed and bound by: Drukarnia Dimograf Sp. z o. o., Bielsko-Biała, Poland
Cover Design: Stefan Hilden, hilden_design, München, Germany; SpieszDesign, Neu-Ulm, Germany

More information at www.elsevier.de

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

German Editions:
1st Edition: 1904–1907 J. F. Lehmanns Verlag, Munich, Germany
2nd–11th Edition: 1913–1944 J. F. Lehmanns Verlag, Munich, Germany
12th Edition: 1948 and following editions
Urban & Schwarzenberg, Munich, Germany
13th Edition: 1953, ed. H. Becher
14th Edition: 1956, ed. H. Becher
15th Edition: 1957, ed. H. Becher
16th Edition: 1967, ed. H. Becher
17th Edition: 1972, eds. H. Ferner and J. Staubesand
18th Edition: 1982, eds. H. Ferner and J. Staubesand
19th Edition: 1988, ed. J. Staubesand
20th Edition: 1993, eds. R. Putz and R. Pabst, Urban & Schwarzenberg, Munich, Germany
21st Edition: 2000, eds. R. Putz and R. Pabst, Urban & Fischer, Munich, Germany
22nd Edition: 2006, eds. R. Putz and R. Pabst, Urban & Fischer, Munich, Germany
23rd Edition: 2010, eds. F. Paulsen and J. Waschke, Urban & Fischer, Elsevier, Munich, Germany
24th Edition: 2017, eds. F. Paulsen and J. Waschke, Elsevier, Munich, Germany

Foreign Editions:
Arabic
Chinese
Croatian
Czech
English (nomenclature in English or Latin)
French
Greek
Hungarian
Indonesian
Italian
Japanese
Korean
Polish
Portuguese
Russian
Spanish
Turkish
Ukrainian

Prof. Friedrich Paulsen

Dissection course for students

In his teaching, Friedrich Paulsen puts great emphasis on ensuring that the students in his dissection classes can actually work on body donation cadavers. *'Carrying out dissection yourself is not only extremely important for gaining a three-dimensional understanding of anatomy, forming the fundamental basis of virtually any field of medical science. In dissection classes you will also experience for the first time the touch and feeling of the human body, the organs and individual tissues, but in most cases it will also be your first intensive encounter with issues around death and dying, and the clinical causes of death. You will not only study anatomy, but also learn how to deal with a quite unique and challenging situation as part of a team. Never again will you be in such close contact with your fellow students and teaching staff.'*

Friedrich Paulsen was born in Kiel in 1965 and, after completing his 'Abitur' in Brunswick, he initially trained as a nurse. He then studied medicine at the Christian Albrecht University (CAU) in Kiel. After his house officer training at the Oromaxillofacial Surgery Clinic and a period as resident physician at the ENT Clinic of CAU, in 1998 he moved to the Anatomical Institute of CAU where he graduated as medical doctor in 1997 and further qualified by performing his State doctorate in anatomy in 2001. In 2003 he was offered full professorship at the Anatomy Departments of the Ludwig Maximilians University (LMU) in Munich and the Martin Luther University (MLU) in Halle/Wittenberg. In Halle, he founded a clinical anatomy training centre. After declining yet another professorship, this time at the University of Saarland, he accepted a post at the Friedrich Alexander University (FAU) in Nürnberg as Professor of Anatomy and Head of its Anatomical Institute, a post he has held since 2010. He has continued to decline professorships offered by a number of other renowned universities.

Friedrich Paulsen is an honorary member of the Anatomical Society of Great Britain and Ireland as well as Romania and has been granted numerous scientific awards including the Dr Gerhard Mann Sicca research prize, the Sicca research prize of the German Federation of Ophthalmologists, and the Commemorative Medal of the Comenius University in Bratislava. Additionally, he received several teaching awards.

The key focus of his research is on the innate immune response of the eye surface, and on investigating the causes of dry eyes. Visiting research fellowships have taken him to Spain and the United Kingdom. He is the editor of the journal *Annals of Anatomy* and, as vice-president of Learning and Teaching (until 3/2018), and now People (since 4/2018) also a member of the FAU university administration since 2016.

Prof. Dr. Friedrich Paulsen
Institute of Anatomy, Department of Functional and Clinical Anatomy
Friedrich Alexander University Erlangen-Nürnberg
Universitätsstr. 19
91054 Erlangen
Germany

Prof. Jens Waschke

Making courses more clinically relevant

For Jens Waschke, one of the most important challenges in the teaching of modern anatomy is how to optimally adapt the courses to meet the requirements of clinical training and subsequent professional practice.

'The clinical aspects of the Atlas give students in the first semesters of medical school a grounding in anatomy and at the same time show them the importance of having a thorough understanding of human anatomy for their subsequent clinical practice, instead of just learning anatomical structures by rote. On the other hand, we prefer to avoid covering highly specialised details that are only needed by a few specialists for occasional diagnostic procedures or surgery, as is the case in other contemporary anatomy books. Since students at the beginning of their training are unable to distinguish between the necessary basics and specialised details, this can cause a mental overload and prevent them from focusing on the essentials.'

Jens Waschke (born in 1974 in Bayreuth) studied medicine at the University of Würzburg, achieving a doctorate in anatomy under Prof. Detlev Drenckhahn in the year 2000. After his intership training in the Anatomy and Internal Medicine Departments, he qualified as a professor of anatomy and cell biology in 2007. Jens Waschke spent nine months as a visiting scholar at the Davis campus of the University of California under Prof. Fitz-Roy Curry in 2003–2004. From 2008 onward he chaired the newly established Department III of the University of Würzburg before being appointed professor at the Ludwig Maximilians University in Munich, where he has been the head of Department I (Vegetative Anatomy) of the Anatomical Institute since 2011. Jens Waschke is heavily involved in the German Anatomical Society as an examiner in specialist anatomy and a member of its Study Commission, and he heads their working group on reducing formaldehyde exposure. He is a representative of the IFAA (International Federation of Associations of Anatomists) and an honorary member of the Anatomical Society of Ethiopia (ASE).

In his research he primarily investigates the biological mechanisms regulating cell adhesion and the external and internal barrier functions of the human body. His research predominantly focuses on the regulation of the endothelial barrier during inflammation, and also the mechanisms behind the impaired cell adhesion seen in diseases such as the blistering skin disorder pemphigus, Crohn's disease and arrhythmogenic cardiomyopathy. The aim is to better understand cell adhesion and to discover new treatment approaches.

Prof. Dr. Jens Waschke
Institute of Anatomy
Department I – Vegetative Anatomy
Ludwig Maximilians University (LMU)
Pettenkoferstr. 11
80336 Munich
Germany

Preface of the 24th German Edition

In the preface of the first edition of his atlas in May 1904, Johannes Sobotta writes: ‘Long-standing experience in cadaver dissection classes has prompted the author to ensure that the illustrations of the peripheral nervous system and the blood vessels depict the relevant structures in the same way that the student is accustomed to seeing them on the cadaver, i.e. that they depict the vessels and nerves from the same region together. Furthermore, the atlas alternates between pages of text and full-page diagrams. The latter contain the key illustrations in the atlas, while the former – in addition to sketches and schematic drawings and legends – contain a brief, concise text to help the student find information quickly when using the book in the dissection hall.’
Just as fashions change on a regular basis, so do students' reading and studying habits. The ubiquitousness of multi-media and the ready availability of information and stimuli are surely the main reasons why these habits are changing at a much faster rate than ever before. Publishers and publishing houses must stay abreast of these developments and of students' changing expectations regarding atlases and textbooks they wish to use, as well as ensuring the digital availability of the contents. In addition to interviews with students and systematic surveys, a publisher can sometimes gauge students' expectations from the textbook market itself. Detailed textbooks claiming to be completely comprehensive are increasingly being abandoned in favour of textbooks that didactically meet students' educational needs and cover the contents of their courses and exams – whether they are studying medicine, dentistry or biomedical science. Likewise, although the images in atlases such as Sobotta have fascinated many generations of doctors and medical professionals around the world with their precise naturalistic representations of real dissections, they are sometimes perceived by students as being too complicated and too detailed. This realisation requires us to consider how we can build upon the obvious strengths of an atlas – which in the course of over 100 years of tradition and 23 German editions, has become a benchmark of accuracy and quality – to meet modern didactic concepts without the overall work losing its unique, exclusive characteristic and its originality.
For educational reasons, we have maintained the Sobotta's original concept and chosen to publish the atlas, as it has been since the first edition, in three volumes: General Anatomy and Musculoskeletal System (1); Internal Organs (2); and Head, Neck and Neuroanatomy (3). And while the concept mentioned in the preface of the first edition, i.e. linking the pictures in the Atlas with an explanatory text, may be old-fashioned, it has now come back into fashion – we have simply modernised the concept. Each picture is thus completed with a short explanatory text to introduce the students to the structure depicted and to explain why those particular dissection and depiction methods have been chosen for that particular region. The individual chapters have been systematically structured to follow today's methods of studying, while various illustrations have been updated or replaced. The majority of these new illustrations have been designed from the point of view of the learner, to make it easier to study the key pathways of blood supply and innervation. We have furthermore revised numerous existing illustrations and reduced the number of labels, using bold type to facilitate access to the anatomical content. The numerous clinical practice examples (‘Clinical Remarks‘) show the somewhat 'dry' subject of anatomy at its most vibrant best, demonstrating to beginners how relevant anatomy is for their subsequent professional life and giving them a tantalising taste of their clinical training to come. Another revised feature is the introductory preface to the individual chapters, which sum up the content and the key issues, and include a real-life clinical case. In addition, each chapter ends with a summary of questions which would typically be asked in oral anatomy exams and exam tests. As in the 23rd edition, each chapter contains a brief introduction to the embryology of each body region.

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

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

Friedrich Paulsen and Jens Waschke

Acknowledgements of the 24th German Edition

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

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

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

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

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

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

1. List of Abbreviations

Singular:

A.	=	Arteria
Lig.	=	Ligamentum
M.	=	Musculus
N.	=	Nervus
Proc.	=	Processus
R.	=	Ramus
V.	=	Vena
Var.	=	Variation

Plural:

Aa.	=	Arteriae
Ligg.	=	Ligamenta
Mm.	=	Musculi
Nn.	=	Nervi
Procc.	=	Processus
Rr.	=	Rami
Vv.	=	Venae

♀ = female
♂ = male

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

2. General Terms of Direction and Position

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

General terms

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

Terms of direction and position for the limbs

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

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

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

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

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

3. Use of Brackets

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

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

Colour Chart

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

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

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

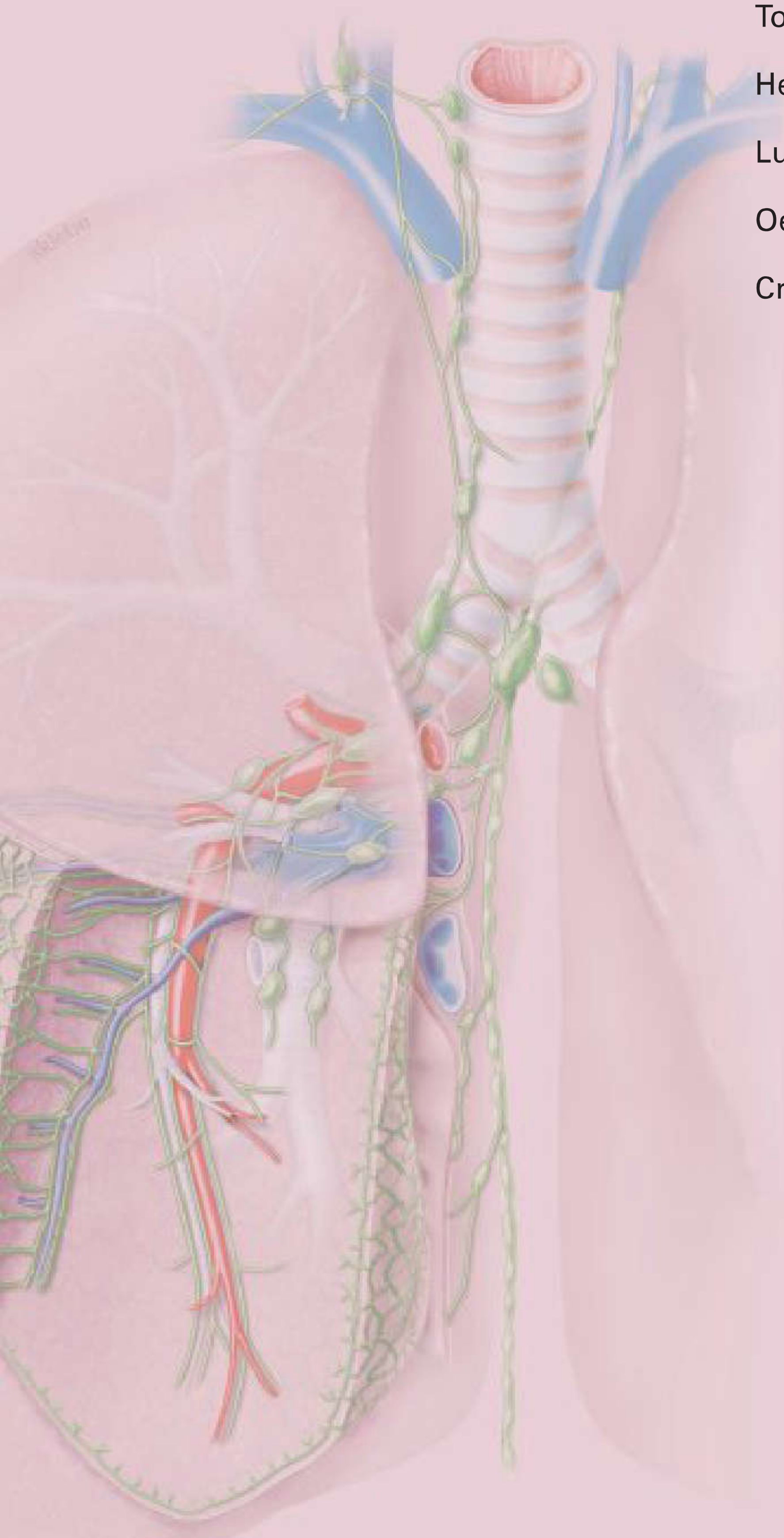
Table of Content

Organs of the Chest Cavity

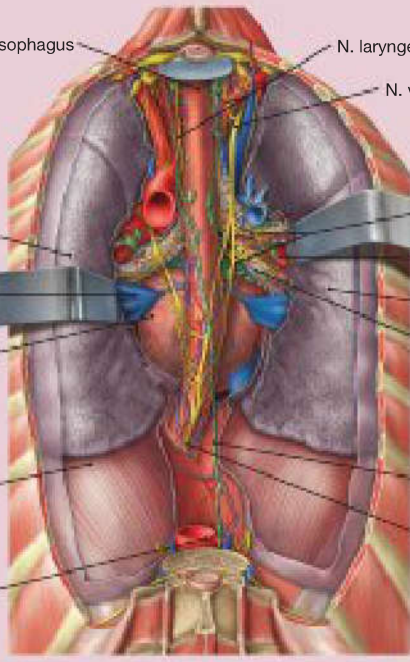
Organs of the Abdominal Cavity

Retroperitoneal Space and Pelvic Cavity

Organs of the Chest Cavity



5



Overview

In a dissection course, the opening of the **chest cavity** is one of the key operations which is met by teachers and students with a mixture of awe, suspense and interest. Exposing the heart and lungs as well as being allowed to grasp (literally and metaphorically) these vital organs of the body with one's own hands is considered a great privilege in these lessons.

The chest cavity (Cavitas thoracis) is enclosed by the thoracic cage (Cavea thoracis), consisting of ribs, thoracic spine and sternum. It is separated **below** by the **diaphragm; above** there is **no clear** boundary separating the neck. If the anterior thoracic wall, which is made up of important **muscles to aid breathing**, is removed, we can see the division of the Cavitas thoracis into **two pleural cavities** (Cavitates pleurales) containing the lungs with the connective tissue space of the **mediastinum** lying between becomes visible.

Directly behind the sternum, the **thymus** is embedded in the mediastinum. The **superior vena cava (V. cava superior)** is shifted to the right. The curved **main artery (aorta)** dominates the upper mediastinum. Among the major vessels are the **trachea,** which divides into the right and left main bronchi (Bronchi principales), and, dorsally of the trachea, the **oesophagus.** Within the inferior mediastinum facing the diaphragm the **heart (Cor)** in its pericardial sac (pericardium), resting broadly on the diaphragm, dominates. The **lungs (Pulmones)** are located in both pleural cavities.

Main Topics

After studying this chapter, you should be able to:

Chest cavity
- describe the composition of the chest cavity with the mediastinum and pleural cavities, including their neurovascular pathways on a dissection;
- describe the location and function of the thymus;

Heart
- explain the development of the heart, including foetal circulation with any possible fundamental malformations;
- illustrate the location, orientation and projection of the heart, clearly showing the margins, on a dissection and an X-ray;
- describe the inner and outer structures of the heart chambers, as well as the wall layers, the pericardial sac and the cardiac skeleton on a dissection;
- explain the structure, function and projection as well as the auscultation type of the various heart valves with their malfunctions on a dissection;
- show the conduction system with accurate localisation of the sinuatrial and AV nodes on a dissection and understand the autonomic innervation of the heart;
- indicate the Aa. coronariae with all the important branches on a dissection and describe their importance in the development, diagnosis and treatment of coronary heart disease; the main features will be sufficient with the veins;

Trachea and lung
- describe the structure of the lower respiratory tract and its development and describe the sections of the trachea;
- indicate the projection of the lungs and their division into lobes and segments on a dissection, and also indicate the systematics of the bronchial tree;
- describe vasa publica and privata of the lungs including origin, course and function, as well as the lymphatic vessel systems and the autonomic innervation;

Oesophagus
- indicate the sections and constrictions of the oesophagus with their positional relationships on a dissection;
- describe the closing mechanisms of the proximal and distal oesophagus and their clinical significance
- explain the neurovascular pathways of the different sections of the oesophagus including the relationship of the veins to the portal venous system.

Clinical Relevance

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

Pulmonary Embolism

Case Study
A 22-year-old student is brought into the emergency department. She reports having woken up in the morning with shortness of breath and coughing the day after she had returned from a flight to the USA. When getting up she noticed that her left lower leg was significantly thicker.

Result of Examination
Cardiac (120/min) and respiratory rates (35/min) are significantly raised. The patient is conscious, awake and fully oriented. She has severe pain in the region of her left leg and is complaining of shortness of breath and chest pain. The left leg is reddened at the shank and shows expanded veins; the area has extended to the ankle and thigh.

Diagnostic Procedure
The blood gas analysis shows a lowering of oxygen content in the blood. Due to a suspected pulmonary embolism, it is primarily coagulation values and D-dimers, formed by cleaved products of blood clots (thrombi), which are determined in blood sampling. The CT angiography of the Cavitas thoracis shows that several branches of the pulmonary arteries are displaced. The ultrasound examination of the heart (echocardiography) indicates stress on the right ventricle. A colour coded duplex ultrasound confirms that the deep leg veins in the area of the femoral vein on the left-hand side are displaced by a blood clot (thrombus).

Diagnosis
Pulmonary embolism from deep vein thrombosis (Fig. a). The clot from the V. femoralis seems to have detached in part and blocked the pulmonary arteries as an embolism. The transatlantic flight, taking oral contraceptives ('the pill') and smoking are already present as risk factors before the exclusion of a coagulation disorder.

Treatment
Via venous access, a breakdown (thrombolysis) of the blood clots is initiated with a plasminogen activator. In addition, the patient is supplied with oxygen via a nasogastric tube. The thrombolysis is successful and the patient is largely symptom-free after a week.

Dissection Lab
To understand this clinical case, we need to look at two body regions: the veins of the leg and the organs of the Cavitas thoracis. Veins are generally a little neglected in anatomy lessons and are usually just reduced to supporting structures of the arteries, which correspond to them in the course that they follow and, therefore, often also in description. In some regions there are, however, deviations from this rule or certain clinical references that require an explanation. At the extremities there is a **superficial (epifascial)** venous system, that flows independently of the arteries, and a **deep venous system (subfascial)** in which two veins usually accompany the corresponding artery distally (in the forearm/lower leg) and proximally merge further on. However, since the superficial veins are connected to the deep venous system via **perforating veins**, which have in the inner semilunar valves and thus allow blood flow only in the direction of the deep veins, the majority (approximately 75%) of venous blood flows through this deep vein system back to the heart.

Blood clots in the veins are potentially life-threatening, as they can be broken off by the blood stream. As embolisms they then move through the **inferior vena cava (V. cava inferior)** into the right atrium of the heart (Atrium dextrum) and through the **right ventricle (Ventriculus dexter)** into the **pulmonary arteries (Aa. pulmonales)** which channel deoxygenated blood into the lungs.

On the right-hand side the main bronchus is located above the artery; the veins right at the front underneath. The black nodes on the surface of a removed lung are the hilum lymph nodes of the lung.

If you remove the parenchyma of the lung from the hilum onwards, you can see that the pulmonary arteries follow the branching of the bronchial tree, while the **pulmonary veins** (Vv. pulmonales) proceed independently. The yellow colour of the pulmonary arteries is characteristic because they, like all heart-related arteries, are counted as an elastic type due to the many elastic fibres in their muscle layer. If, in the case of a pulmonary embolism, a considerable part of the vessel diameter is displaced, then a drastic diminution of the gas exchange surface results in acute laboured breathing. What is life threatening, however, is the rise in pressure in the pulmonary circulation, which the right ventricle is either not immediately or permanently immune to, so death can ensue through right-sided heart failure (cor pulmonale). Therefore, in the dissecting laboratory, when preparing the heart you should always pay attention

The first time you hold a heart in your hands is a special feeling! In order to orientate yourself, you must always hold the heart in the same way that it lies in the mediastinum. Then the right ventricle is in front!

to the wall strength of the right ventricle, which is normally 3–5 mm thick, approximately one third of the thickness of the left wall. A larger wall diameter can be a sign of chronic damage to the right side of the heart.

Back in the Clinic
The treatment was changed to a six-month oral administration of Marcumar® for anticoagulation. Molecular biological investigation reveals a mutation of clotting factor V and thus an inherited genetic predisposition. Therefore, 'the pill' and smoking were advised against. For long trips and in the case of a planned pregnancy, a subcutaneous injection of low molecular weight heparin and the wearing of compression hosiery were recommended to the patient.

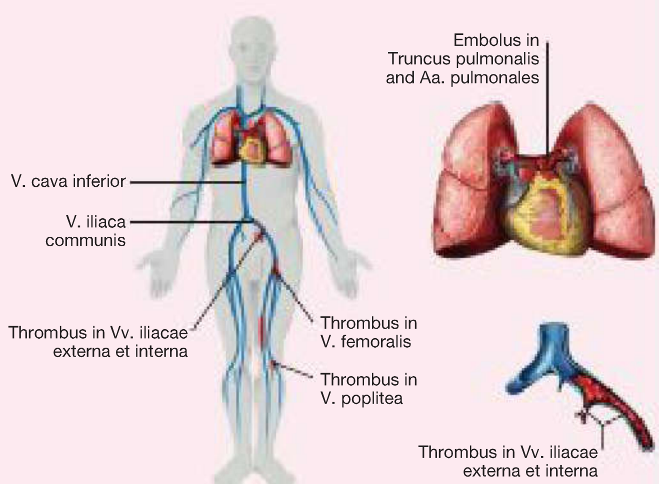


Fig. a Deep vein thrombosis with complication of a pulmonary embolism. [L266]

Pleural Cavities and Mediastinum

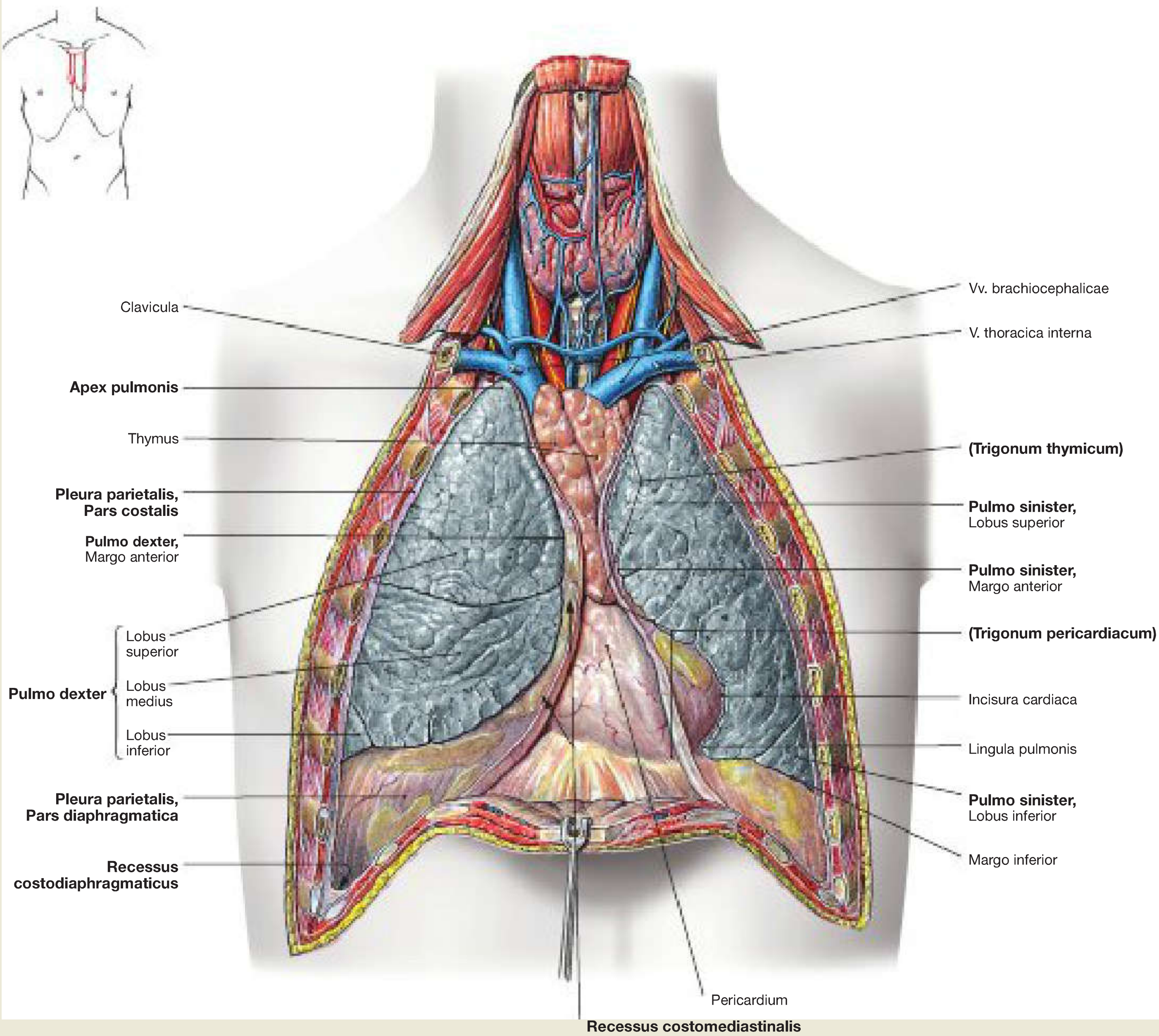


Fig. 5.1 Mediastinum and pleural cavities, Cavitates pleurales of an adolescent boy; ventral view; after removal of the thoracic wall.

After opening of the **thoracic cage, Cavea thoracis,** the two pleural cavities, in which both lungs lie, become visible. The pleural cavities are separated in the middle by a connective tissue space, which is called the **mediastinum**. The mediastinum contains the heart, which is embedded in the **pericardium,** as well as the **thymus** and a number of **neurovascular pathways,** which connect the Cavitas thoracis with the neck via the upper thoracic aperture and with the abdomen via the diaphragm.

The pleural cavity (Cavitas pleuralis) is covered by the parietal **pleura (Pleura parietalis).** The parietal pleura is divided into the Pars mediastinalis, Pars costalis and Pars diaphragmatica. The **visceral pleura (Pleura visceralis)** covers the outer surface of the lungs. Both pleural membranes form a capillary cleft space that contains 5 ml in total of serous fluid, which helps the lung adhere to the wall of the torso.

Above, the pleural cavities protrude on both sides with its **cervical pleura (Cupula pleurae)** over the upper thoracic aperture by up to 5 cm. The medial pleural boundaries leave free between them the thymic trigone above and the pericardial trigone below. The pleural cavities have four paired **pleural recesses (Recessus pleurales),** in which the lung expands during deeper inspiration:

- **Recessus costodiaphragmaticus:** lateral, in the midaxillary line up to 5 cm deep
- **Recessus costomediastinalis:** on both sides ventral between mediastinum and thoracic wall
- **Recessus phrenicomediastinalis:** caudal between diaphragm and mediastinum
- **Recessus vertebromediastinalis:** dorsal, adjacent to the vertebral column (→ Fig. 5.104)

Clinical Remarks

Increased fluid in the Cavitas pleuralis **(pleural effusion)** may be caused by inflammatory reactions in the case of pneumonia (pleuritis), by congestion in the case of (left-sided) heart failure or with tumours of the lung and the pleura. There are also chylous pleural effusions, in which lymphs burst from the Ductus thoracicus into the Cavitas pleuralis. Pleural effusions cause a dull knocking sound. They are aspirated in the costodiaphragmatic recess to clarify the cause and to improve respiratory excursion.

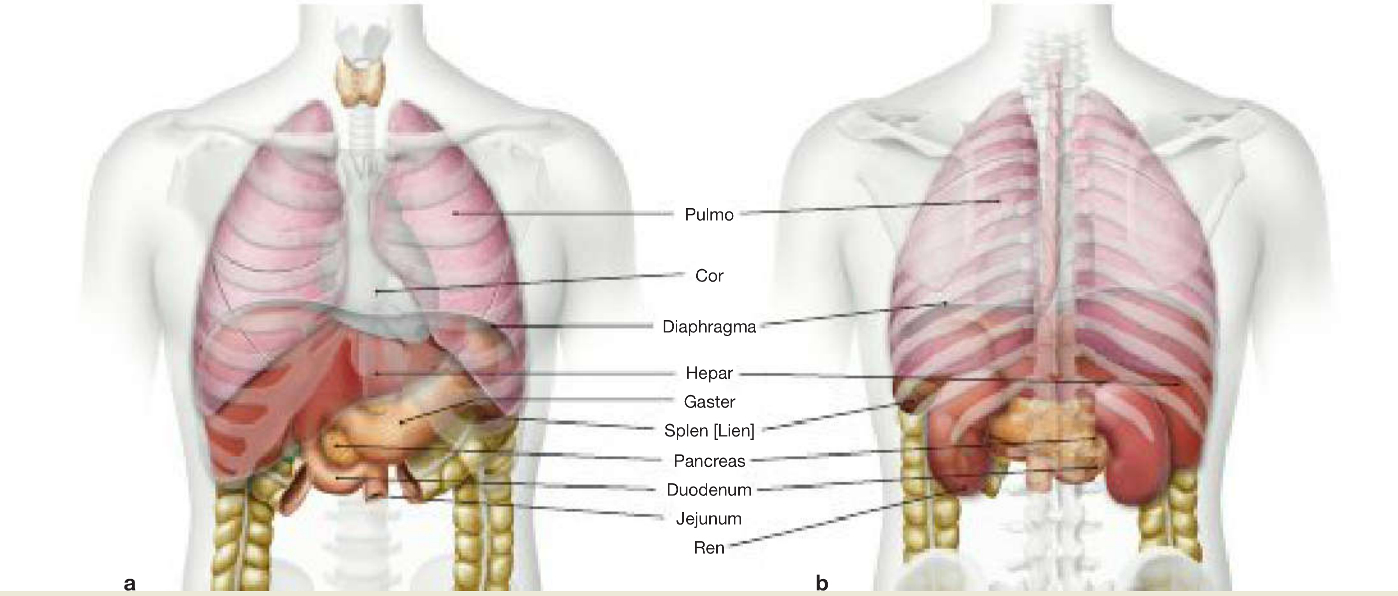


Fig. 5.2a and b Chest cavity, Cavitas thoracis, and organs of the upper abdomen; ventral view **(a)** and dorsal view **(b);** schematic diagram. [L275]
Lying in the Cavitas thoracis are the **heart, Cor,** in its pericardium, the **mediastinum** and thereby between the two **pleural cavities, Cavitates pleurales,** which house the right and left **lungs,** Pulmo dexter and Pulmo sinister. Since the diaphragmatic domes are relatively high (right: during expiration in the 4th intercostal space, ICS; left: one half to a full ICS deeper), in addition to the organs of the Cavitas thoracis, the ribs also protect the **organs of the upper abdomen** (right: liver and gallbladder; left: stomach and spleen; both sides dorsal: kidneys and adrenal glands). These organs are thereby relatively well protected from mechanical impacts.

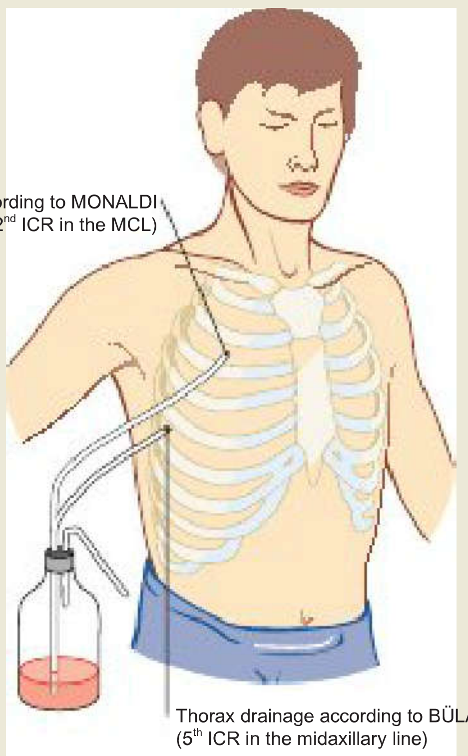


Fig. 5.3 Chest tube; ventral view from the right side; schematic diagram. [L126]
With a chest tube there are two approaches: Following the **MONALDI's method,** the puncture is made in the 2nd intercostal space (2nd ICS) in the midclavicular line (MCL); following the **BÜLAU's method** in the 5th ICS in the midaxillary line.

Clinical Remarks

If lung excursion is impaired by accumulation of blood in the Cavitas pleuralis (hemothorax) or by air congestion in the Cavitas pleuralis (tension pneumothorax), or if the lung collapses in the case of a pneumothorax, a **chest tube** is applied in order to siphon off the blood and re-inflate the lung. For this there are two access routes, whereby the risk of damage to the surrounding organs is as small as possible:
MONALDI drainage: in the 2nd ICS in the MCL. There should not be further medial insertion in order not to damage the parasternal flowing thoracic artery and vein. The axillary neurovascular pathways and the intercostobrachial nerves lie laterally against them.
BÜLAU drainage: in the 5th ICS in the midaxillary line. The liver, which is located under the right diaphragmatic dome, must not be punctured here. In maximum expiration, the latter may extend up into the 4th ICS. In preclinical emergency care both access routes make sense; however, in hospital the MONALDI's access method is chosen in the case of a pneumothorax.

Mediastinum

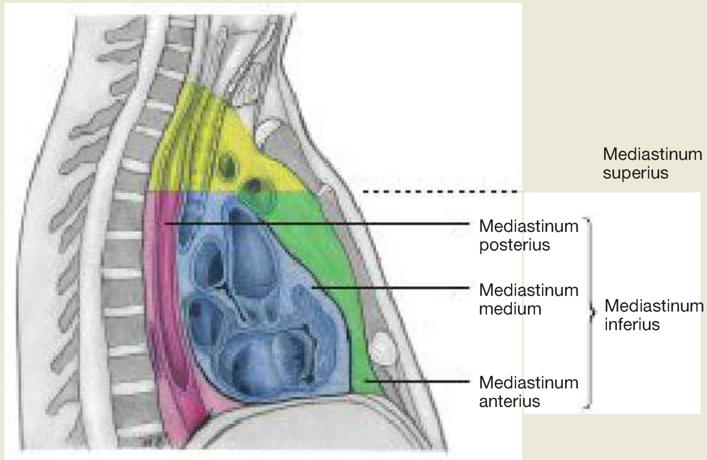


Fig. 5.4 Structure of the mediastinum.
The connective tissue space that separates the two pleural cavities is referred to as the **mediastinum.** The mediastinum is divided into the mediastinum inferius, where the heart is, and into the mediastinum superius. The lower mediastinum is further divided into the anterior mediastinum in front of the heart, into the mediastinum medium with the pericardium, and into the mediastinum posterius behind the pericardium.

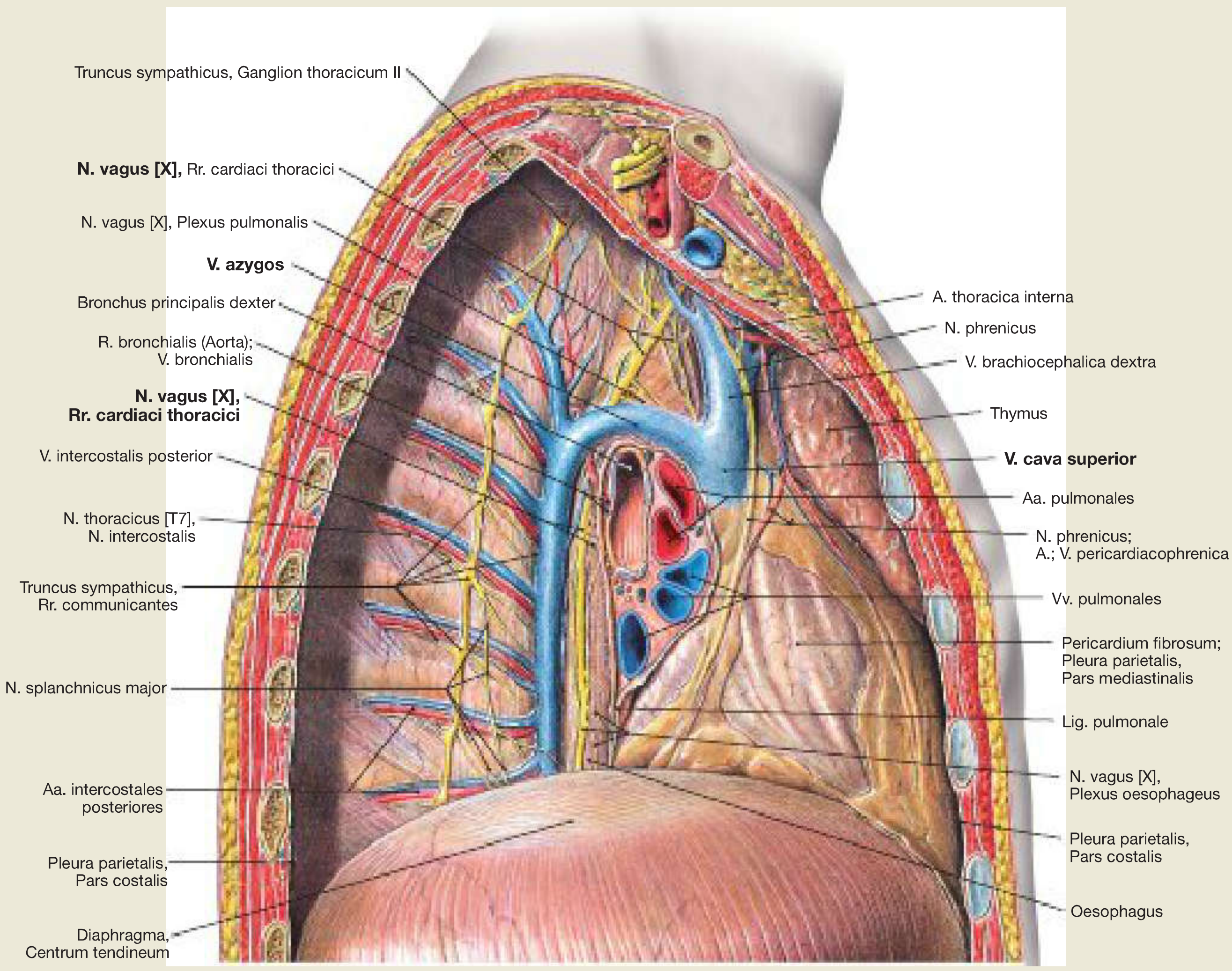


Fig. 5.5 Mediastinum and pleural cavity, Cavitas pleuralis, of an adolescent boy; view from the right side; after removal of the lateral thoracic wall and the right lung.
In the view from the right, what is particularly prominent in the posterior mediastinum is the **V. azygos,** which ascends alongside the spine, crosses the root of the right lung and then at the level of the $4^{th}/5^{th}$ thoracic vertebrae flows dorsally into the V. cava superior. The N. vagus [X] stretches behind the right main bronchus (Bronchus principalis dexter) to the oesophagus, while the N. phrenicus in front of the V. cava superior reaches the pericardium.

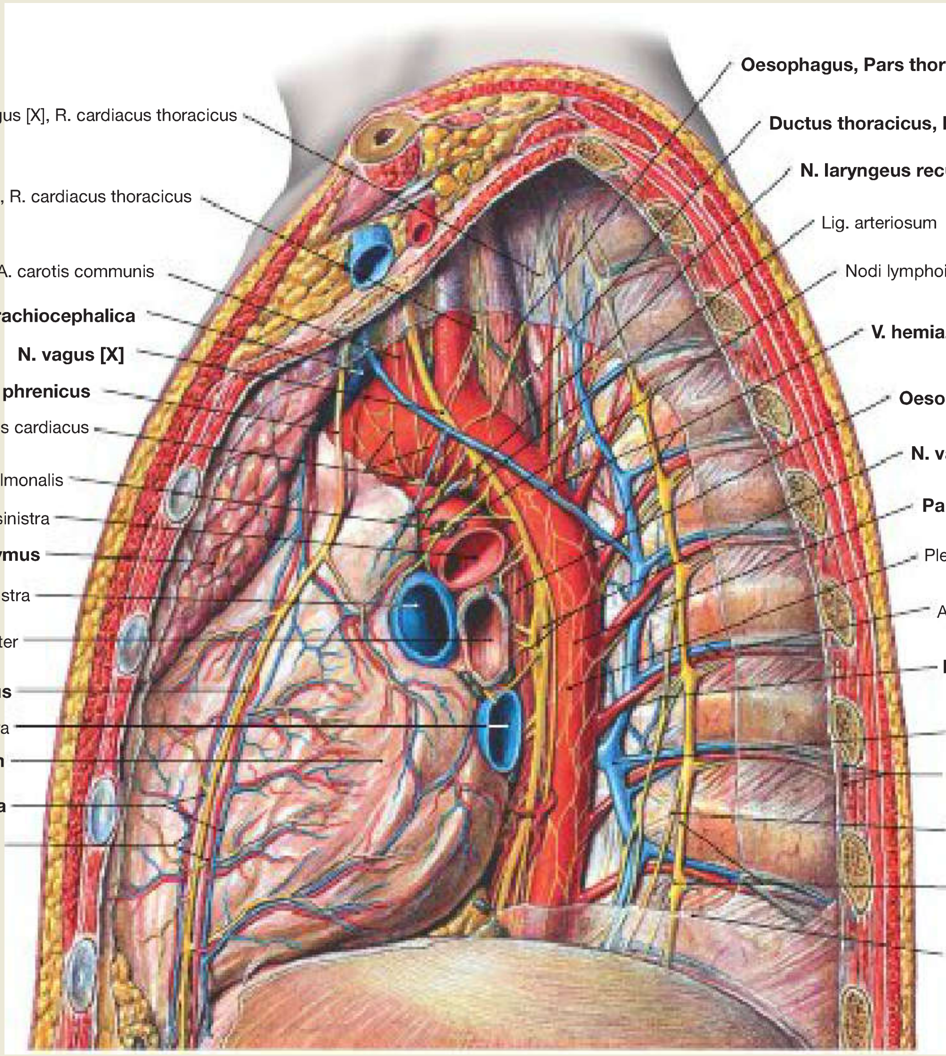
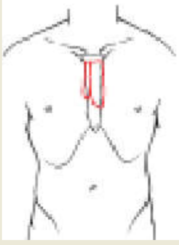


Fig. 5.6 Mediastinum and pleural cavity, Cavitas pleuralis, of an adolescent boy; view from the left side; after removal of the lateral thoracic wall and the left lung.

In the view from the left the posterior mediastinum is dominated by the aorta which descends to the left in front of the spine. Laterally on the vertebral bodies lies the V. hemiazygos, which flows between the 10^{th} and 7^{th} thoracic vertebrae into the V. azygos. It usually communicates with the V. hemiazygos accessoria which receives the blood of the upper Vv. intercostales. Even further laterally, on the rib heads, are the ganglia of the **Truncus sympathicus** of the **sympathetic nervous system** from which the Nn. splanchnici major and minor proceed. The N. vagus [X] approaches behind the root of the lung to the oesophagus, after it has given rise to the N. laryngeus recurrens, which loops around the Arcus aortae on the left-hand side. In the middle mediastinum is the pericardium and on this the N. phrenicus, which is accompanied by the Vasa pericardiacophrenica. In the superior mediastinum the thymus covers the great vessels ventrally.

Contents of the Mediastinum superius	Content of the Mediastinum inferius
• Thymus • Trachea • Oesophagus • Aorta and Truncus pulmonalis • Vv. brachiocephalicae and V. cava superior • Lymphatic pathways: lymphatic trunks (Ductus thoracicus, Trunci bronchomediastinales) and mediastinal lymph nodes • Autonomic nervous system (Truncus sympathicus, N. vagus [X] with the N. laryngeus recurrens) • N. phrenicus	• **Mediastinum anterius:** retrosternal lymphatic drainage of the mammary gland • **Mediastinum medium:** pericardium with vessels near the heart (Aorta ascendens, Truncus pulmonalis, V. cava superior) N. phrenicus with the Vasa pericardiacophrenica • **Mediastinum posterius:** Aorta descendens, Oesophagus with Plexus oesophageus of the N. vagus [X], Ductus thoracicus, Truncus sympathicus with Nn. splanchnici, V. azygos and V. hemiazygos as well as intercostal neurovascular pathways

Thymus



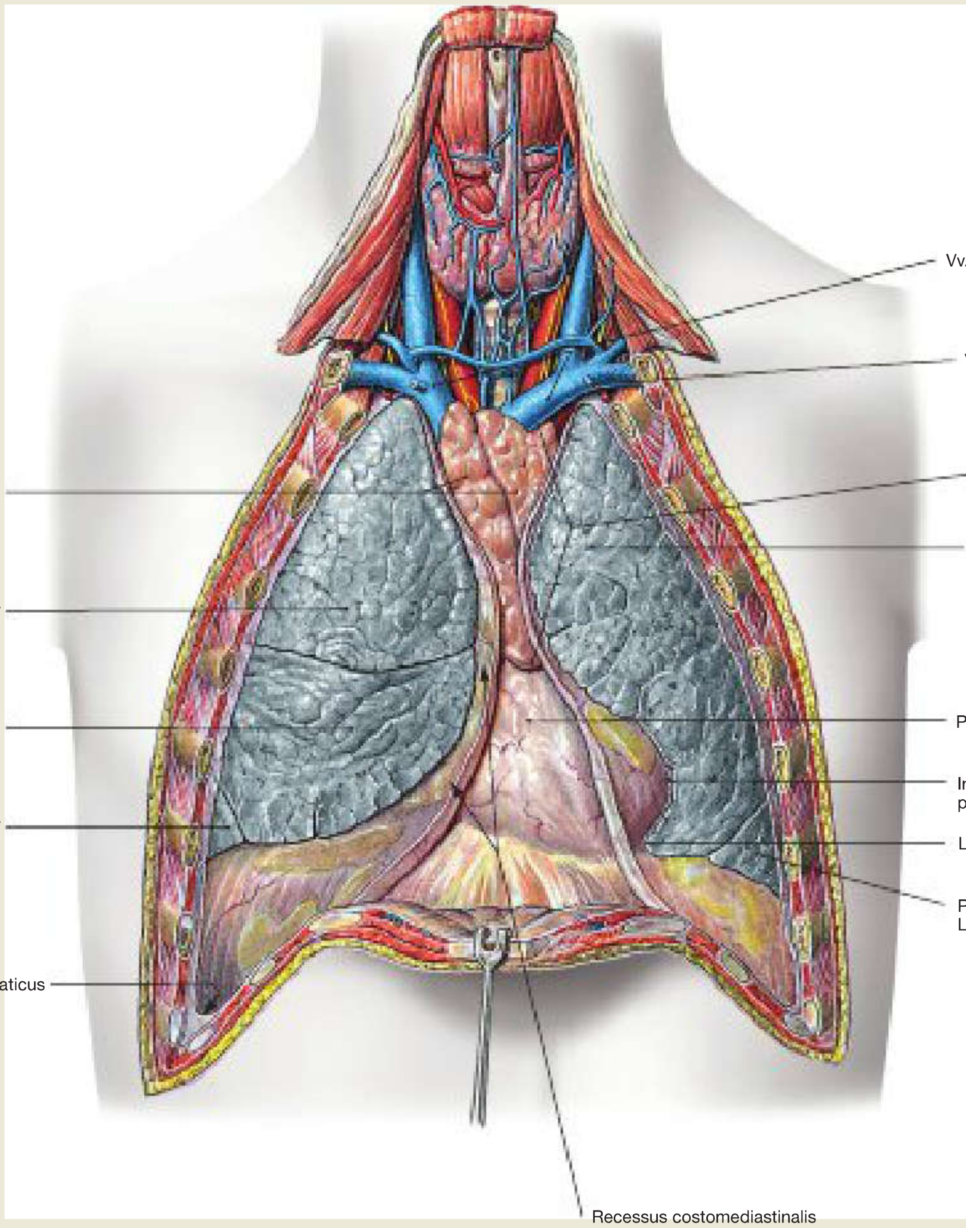


Fig. 5.7 Upper mediastinum with thymus of an adolescent boy; ventral view; after removal of the ventral thoracic wall.

The **thymus** lies in the upper mediastinum in the Trigonum thymicum between the medial walls of the pleural cavities. The thymus changes in its tissue composition for its entire life cycle. Since its total volume remains almost the same in the process, it is much larger relatively speaking in a newborn than in an adult (→ Fig. 5.9). The thymus is still relatively large in a young adult. After puberty, adaptive thymus tissue is increasingly replaced by fat tissue so that the thymus as an organ is often difficult to identify in old people. In old people, it is almost completely replaced by two fat lobes. For this reason, often only the thymus carcass is found in dissections, which can be identified macroscopically solely on the basis of small arterial branches from the A. thoracica interna and venous connections to the Vv. brachiocephalicae. Nevertheless, adaptive thymus tissue always remains extant to allow for an immune response.

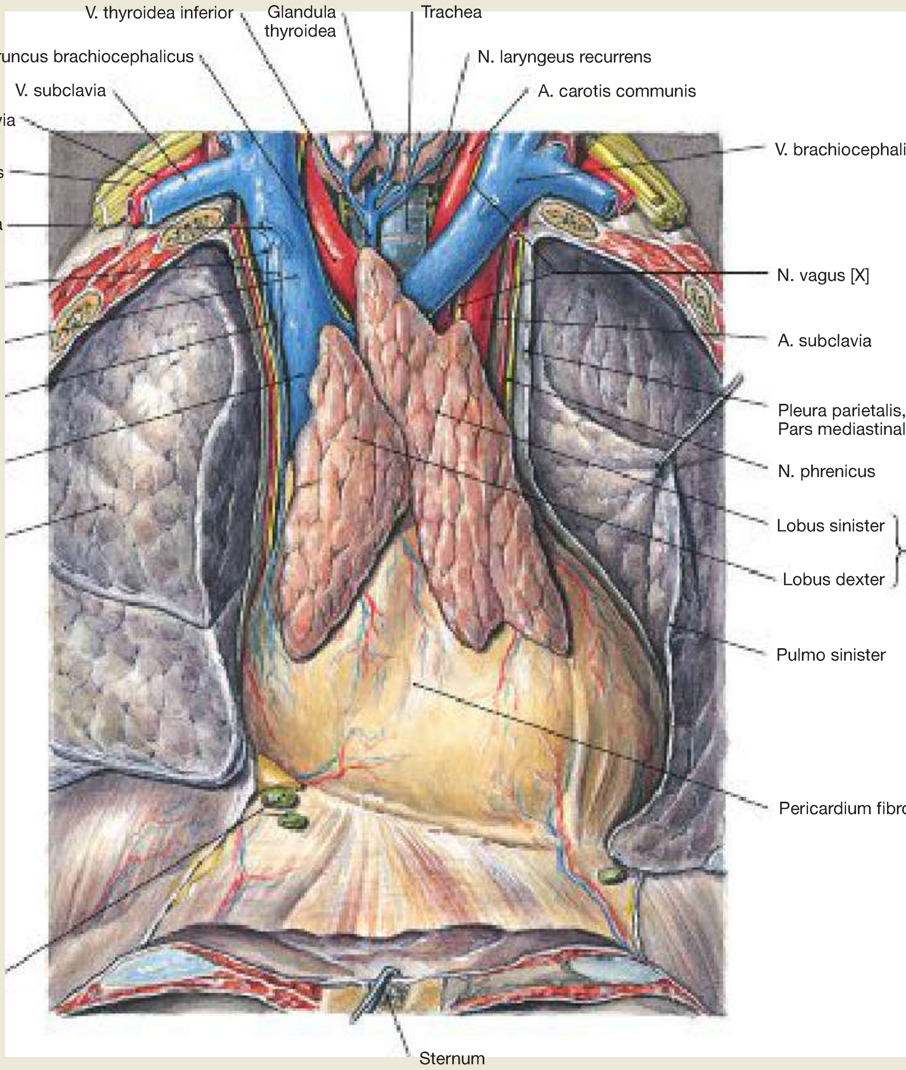


Fig. 5.8 Thymus of an adolescent boy; ventral view.
The thymus is a primary **lymphatic organ.** It serves for the proliferation and selection of T-lymphocytes which then leave the thymus in order to settle in secondary lymphatic organs to function in the adaptive immune responses.

The thymus develops from the entoderm of the 3rd pharyngeal pouch and the ectoderm of the 3rd pharyngeal furrow. Macroscopically it consists of two lobes (Lobi dexter and sinister), which overlie the great vessels in the front section of the upper mediastinum. Microscopically these lobes are divided into lobules.

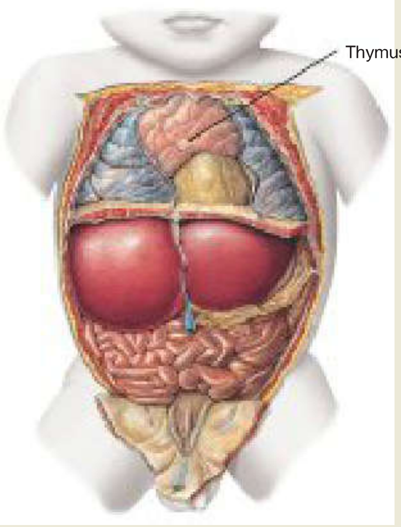


Fig. 5.9 Position of the thymus of a newborn; ventral view; after removal of the ventral abdominal wall.

N. phrenicus

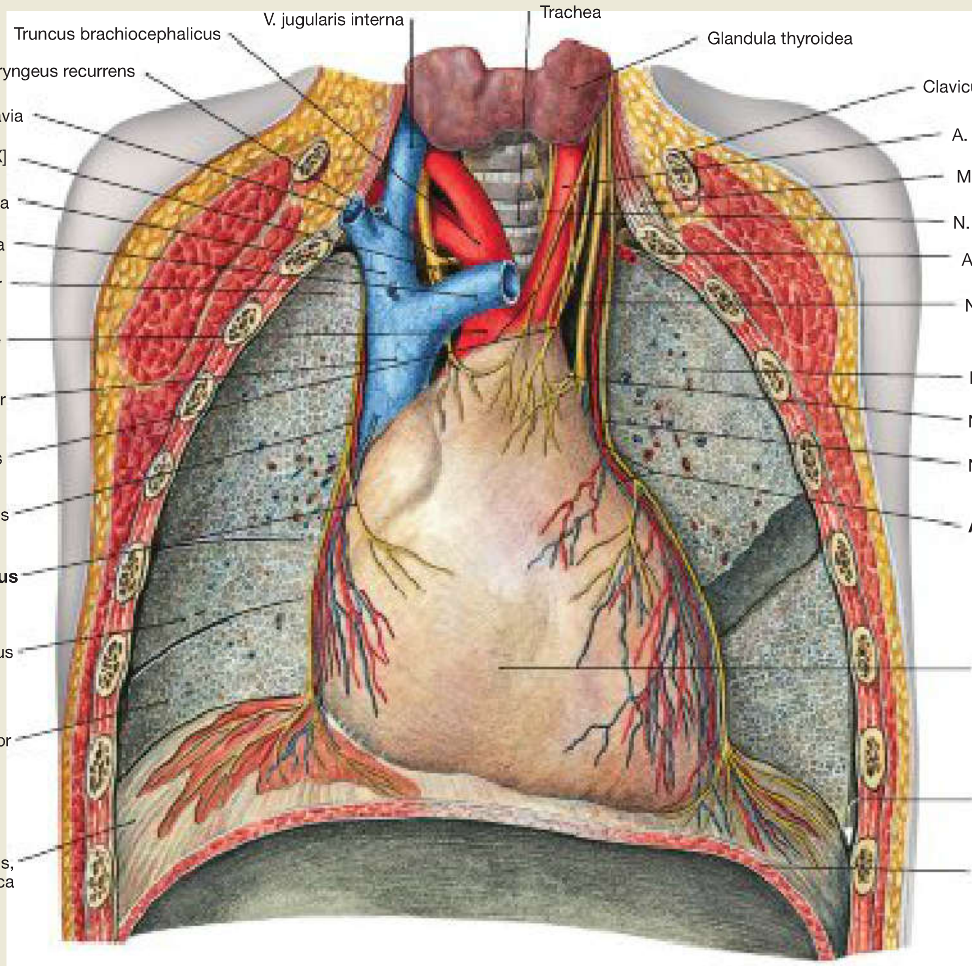


Fig. 5.10 Middle mediastinum; ventral view; after removal of the ventral thoracic wall, lungs dissected in the frontal plane.

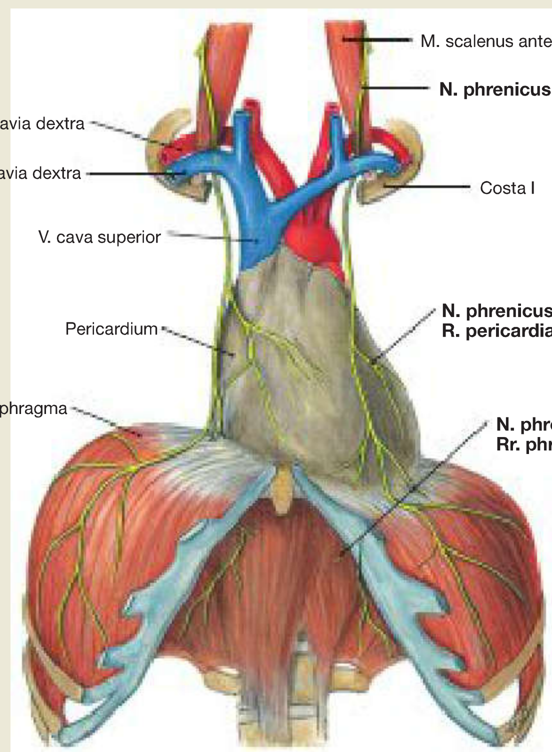


Fig. 5.11 Course of the N. phrenicus.
The **N. phrenicus** originates from segments C3 to C5 (mainly C4) of the cervical plexus, stretches caudally at the neck on the M. scalenus anterior (leading muscle!) and then in the lower **middle mediastinum** in front of the root of the lung it reaches the pericardial sac **(pericardium),** where, accompanying the vasa pericardiacophrenica, and covered by the Pleura mediastinalis, it descends to the diaphragm which it innervates in a motor fashion. In addition, it has sensory branches to the pericardial sac (R. pericardiacus), for the Pleura diaphragmatica as well as the parietal peritoneum on the underside of the diaphragm (Rr. phrenicoabdominales). The Rr. phrenicoabdominales innervate the visceral peritoneum on the liver and gallbladder.

Clinical Remarks

The evolutionary course of the **N. phrenicus** has clinical significance in paraplegia. Caudal spinal cord lesions from C4 do not lead to breathing dysfunction, while an injury to the C4 segment can lead to suffocation.

The innervation of **liver and gallbladder** via the phrenicoabdominal branches can lead to **referred pain in the right shoulder** (in the case of liver aspiration, gallbladder inflammation). In the case of spleen ruptures there can be similar radiating pain in the left shoulder.

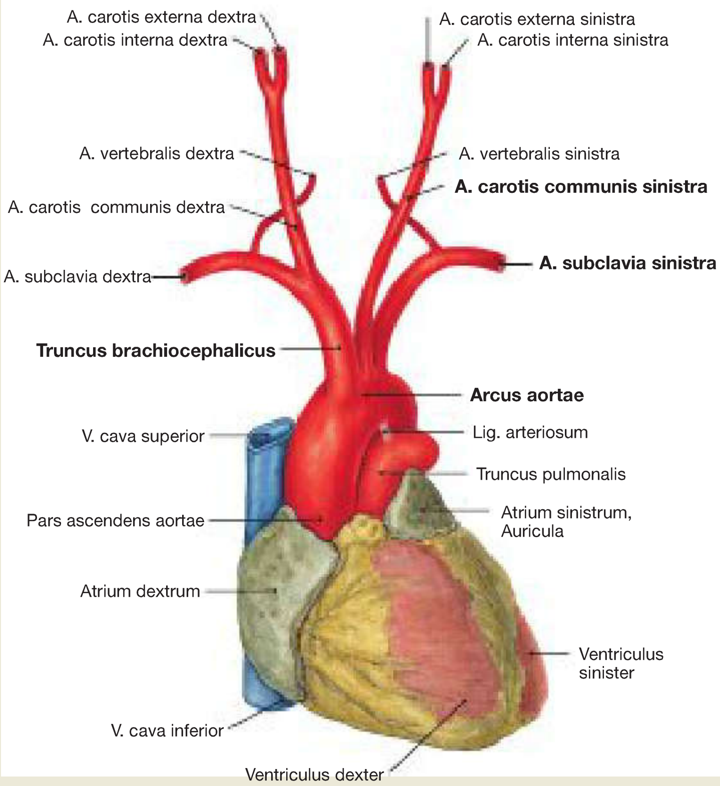


Fig. 5.12 Aorta ascendens and Arcus aortae with outlets of the great arteries; ventral view.

The **ascending aorta (Pars ascendens aortae** or **Aorta ascendens)** is still in the pericardium and thus in the lower mediastinum. It merges in the upper mediastinum into the **Arcus aortae,** which is connected to the Truncus pulmonalis via the Lig. arteriosum, and then continues in the descending side (Pars descendens aortae) of the Aorta thoracica (→ Fig. 5.15). The Arcus aortae gives rise to the following branches:

- Truncus brachiocephalicus (right), which branches into the A. subclavia dextra and the A. carotis communis dextra
- A. carotis communis sinistra
- A. subclavia sinistra

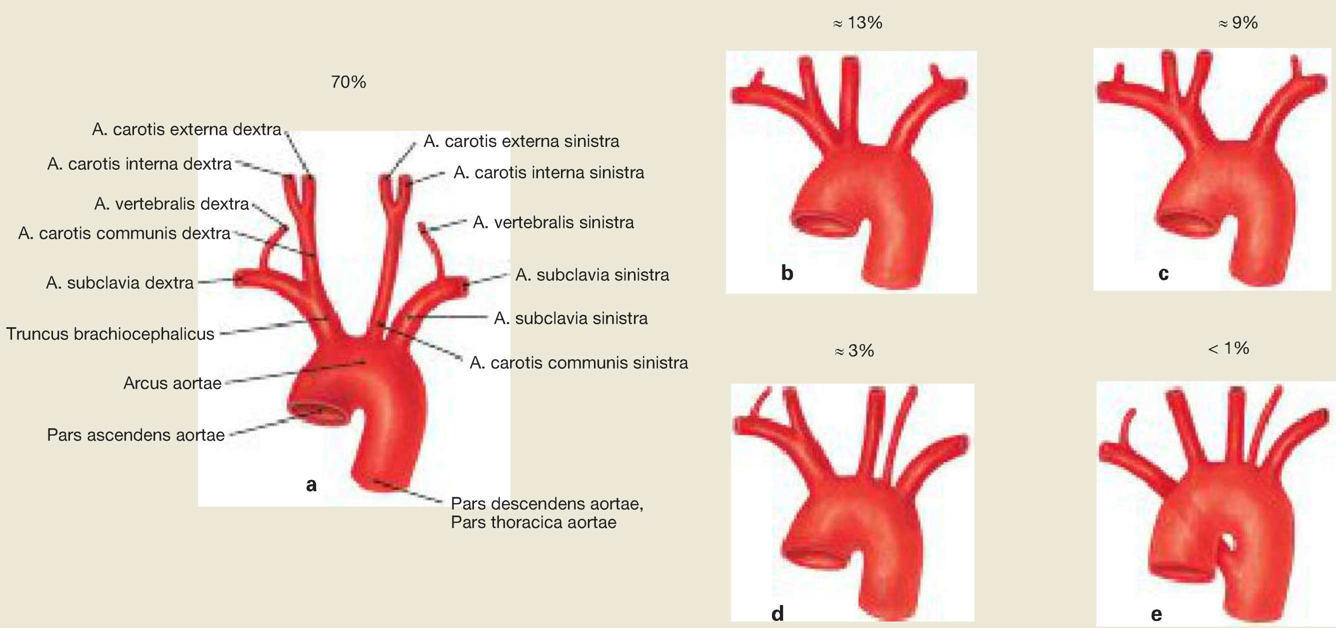


Fig. 5.13a to e Outlet variations of the great vessels from the Arcus aortae.

a 'Textbook case'

b Common origin of Truncus brachiocephalicus and A. carotis communis sinistra

c Common branch for Truncus brachiocephalicus and A. carotis communis sinistra

d Independent outlet of the A. vertebralis sinistra from the Arcus aortae

e Outlet of the A. subclavia dextra as the last branch out of the Arcus aortae. This unusual artery mostly runs behind the oesophagus to the right and may cause problems with swallowing (dysphagia) **(arteria lusoria).**

The occurrence of a stand-alone **Arcus aortae** stretching to the thyroid gland, which originates from the Truncus brachiocephalicus or from the Arcus aortae as a second branch, is relatively rare.

Arteries of the Upper Mediastinum – Arcus aortae with Outlets

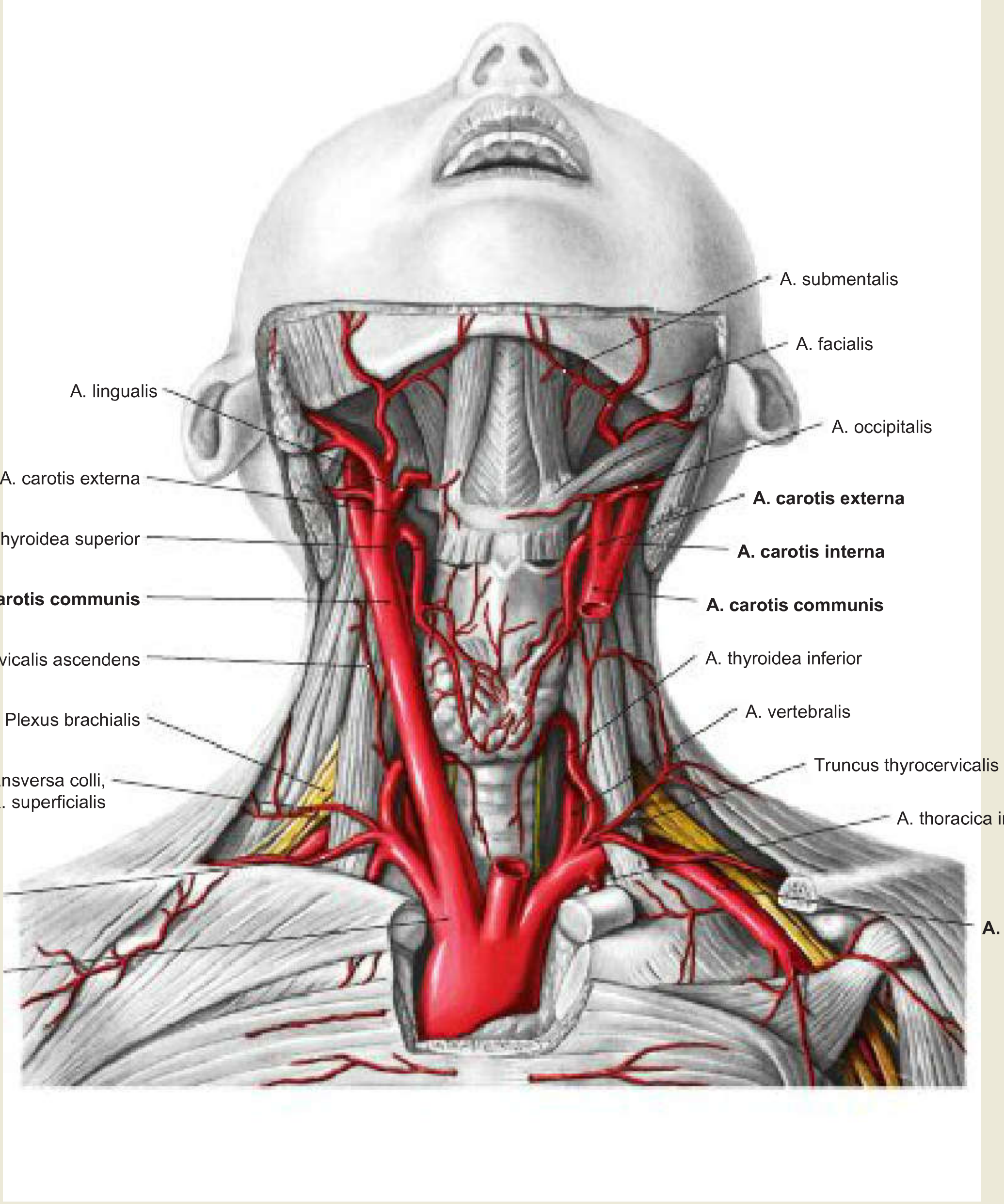


Fig. 5.14 Arcus aortae with outlets of the great arteries; ventral view; after removal of the Manubrium sterni. [S010-2-16]
In the upper mediastinum, the **Arcus aortae** firstly provides the right Truncus brachiocephalicus dividing into the A. subclavia dextra and the A. carotis communis dextra. The A. carotis communis sinistra and the A. subclavia sinistra then follow as outlets.
A distinction is made between a **Pars thoracica** of the aorta (Pars thoracica aortae or Aorta thoracica) and a **Pars abdominalis** (Pars abdominalis aortae or Aorta abdominalis).

The **Aorta thoracica** is divided into:
- **ascending aorta** (Pars ascendens aortae or Aorta ascendens) with the Aa. coronariae
- **Arcus aortae:** → above
- **descending aorta** (Pars descendens aortae or Aorta descendens) with parietal branches to supply the thoracic wall and visceral branches for the thoracic organs

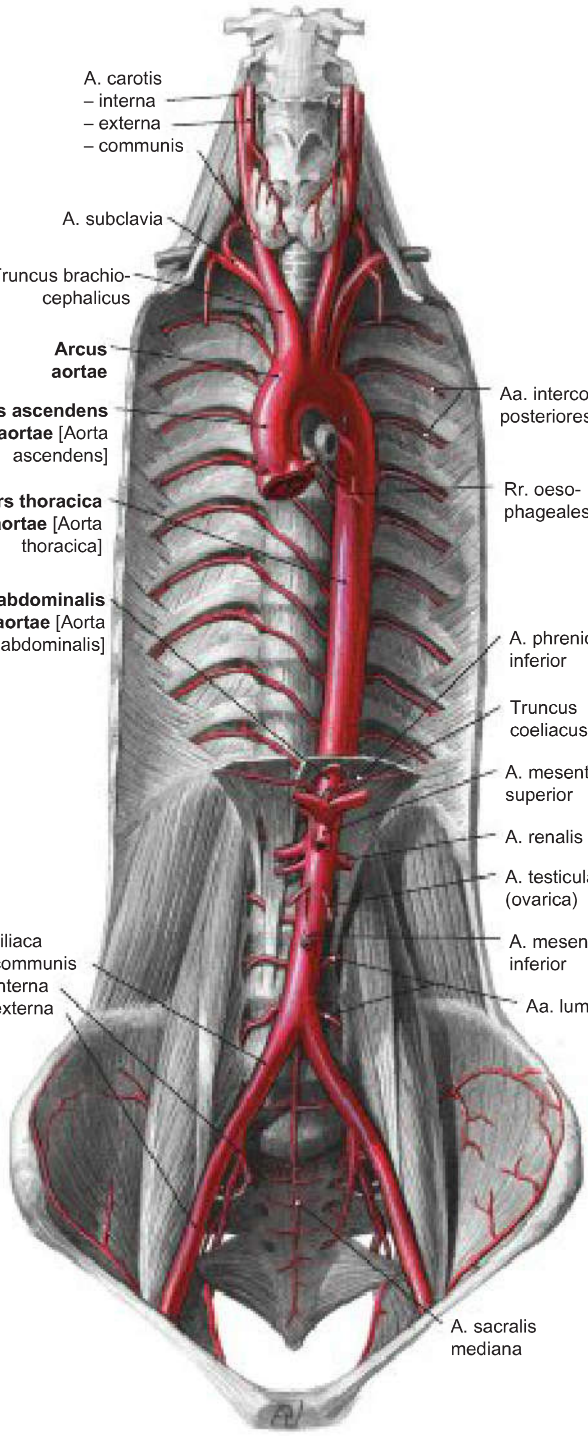


Fig. 5.15 Sections of the aorta with outlets of the great arteries; ventral view; after removal of the ventral thoracic wall, all organs and all other neurovascular pathways of the thoracic, abdominal and pelvic cavities. [S010-2-16]

Parietal branches of the Aorta thoracica:

- Posterior Aa. intercostales: nine pairs (the first two Aa. intercostales emerge from the Truncus costocervicalis of the A. subclavia)
- A. subcostalis (under the 12th rib)
- A. phrenica superior: to the upper side of the diaphragm

Visceral branches of the Aorta thoracica:

- Rr. bronchiales: vasa privata of the lung
- Rr. oesophageales: 3–6 branches to the oesophagus
- Rr. mediastinales: fine branches to supply the mediastinum and the pericardium

The aorta emerges at the level of the 12th thoracic vertebra through the aortic hiatus of the diaphragm, which is formed by the two lumbar arms of the diaphragm, and which continues within the **abdominal aorta.** This also has parietal and visceral branches, whereby the abdominal parietal branches continue the branch system in the Pars thoracica, and then divides at the level of the 4th lumbar vertebra into its terminal branches.

Parietal branches of the Aorta thoracica:

- A. phrenica inferior: to the underside of the diaphragm
- Aa. lumbales (four pairs; the last pair originates from the A. sacralis mediana)

Visceral branches of the abdominal aorta:

- Truncus coeliacus: first unpaired branch at the level of the 12th thoracic vertebra directly beneath the aortic hiatus (→ Fig. 5.15)
- Aa. suprarenales mediae: fine branches to the adrenal glands
- A. mesenterica superior: unpaired vessel at the level of the 1st lumbar vertebra (→ Fig. 5.15)
- Aa. renales: the Aa. renales originate at the level of the 2nd lumbar vertebra
- Aa. testiculares/ovaricae: descending vessels to supply the testes in men and the ovaries in women
- A. mesenterica inferior: unpaired vessel at the level of the 3rd lumbar vertebra (→ Fig. 5.15)

The two **iliac arteries** (Aa. iliacae communes) and the unpaired **A. sacralis mediana** on the ventral side of the sacrum are **terminal branches** of the abdominal aorta.

Veins of the Upper Mediastinum

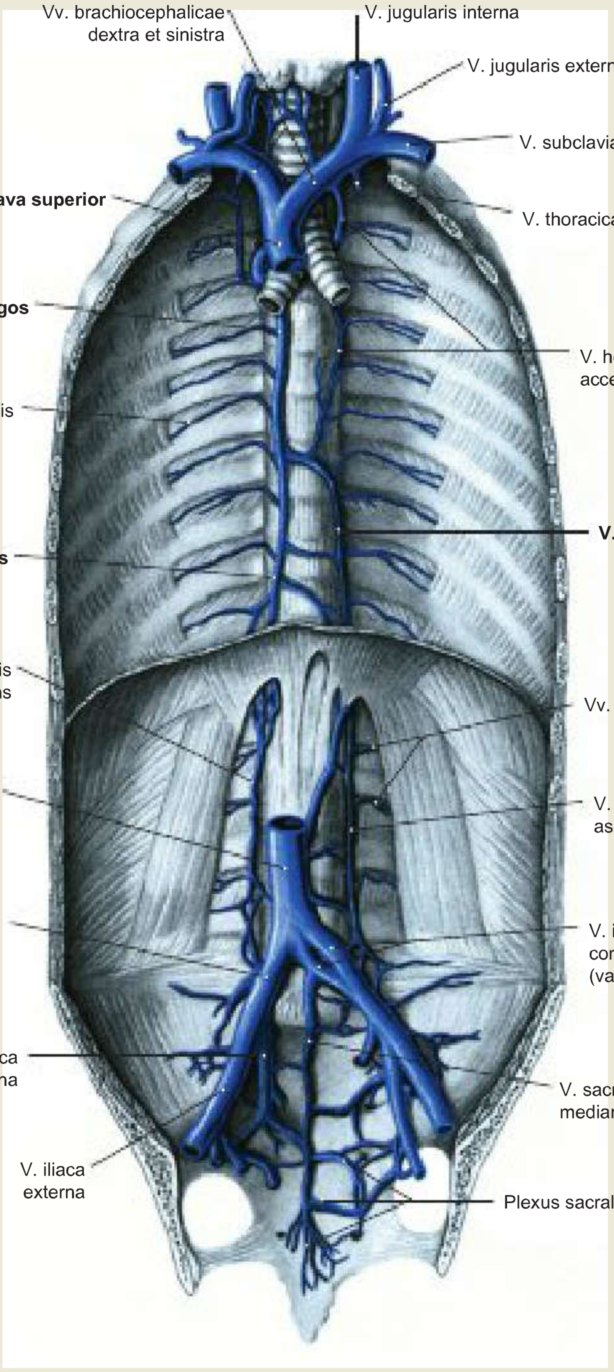


Fig. 5.16 V. cava superior and V. cava inferior with tributaries; ventral view; after removal of the anterior thoracic wall, all organs and all other neurovascular pathways of the thoracic, abdominal and pelvic cavities. [S010-2-16]

The **V. cava superior** forms to the right of the spine behind the first sternocostal joint through the merging of the two Vv. brachiocephalicae. Before discharging into the right atrium of the heart at the level of the 4th and 5th thoracic vertebrae it receives the V. azygos, which crosses the right main bronchus beforehand. The V. azygos, together with the corresponding V. hemiazygos, forms the **azygos system.** The system with its parietal and visceral tributaries corresponds to the branches of the Aorta descendens.

Parietal branches of the V. azygos:

- Vv. intercostales posteriores: from the posterior thoracic wall
- V. subcostalis: below the lowest pair of ribs
- Vv. phrenicae superiores: from the top side of the diaphragm

Visceral branches of the V. azygos:

- venous inflows from the mediastinum with all its organs (Vv. mediastinales, Vv. oesophageales, Vv. bronchiales, Vv. pericardiacae)

The V. azygos runs in the lower half of the mediastinum often ventrally of the spine, or even to its right, so that a **V. hemiazygos** is not always formed. If present, this enters between the 10th and 7th thoracic vertebrae into the V. azygos, whereby its course continues up through the V. hemiazygos accessoria.

The **V. cava inferior** forms to the right of the aorta at the level of the 5th lumbar vertebra out of the two pelvic veins (Vv. iliacae communes). To a large extent, it is similar in its tributaries to the parietal and paired visceral branches of the abdominal aorta and receives the Vv. phrenicae inferiores on the underside of the diaphragm.

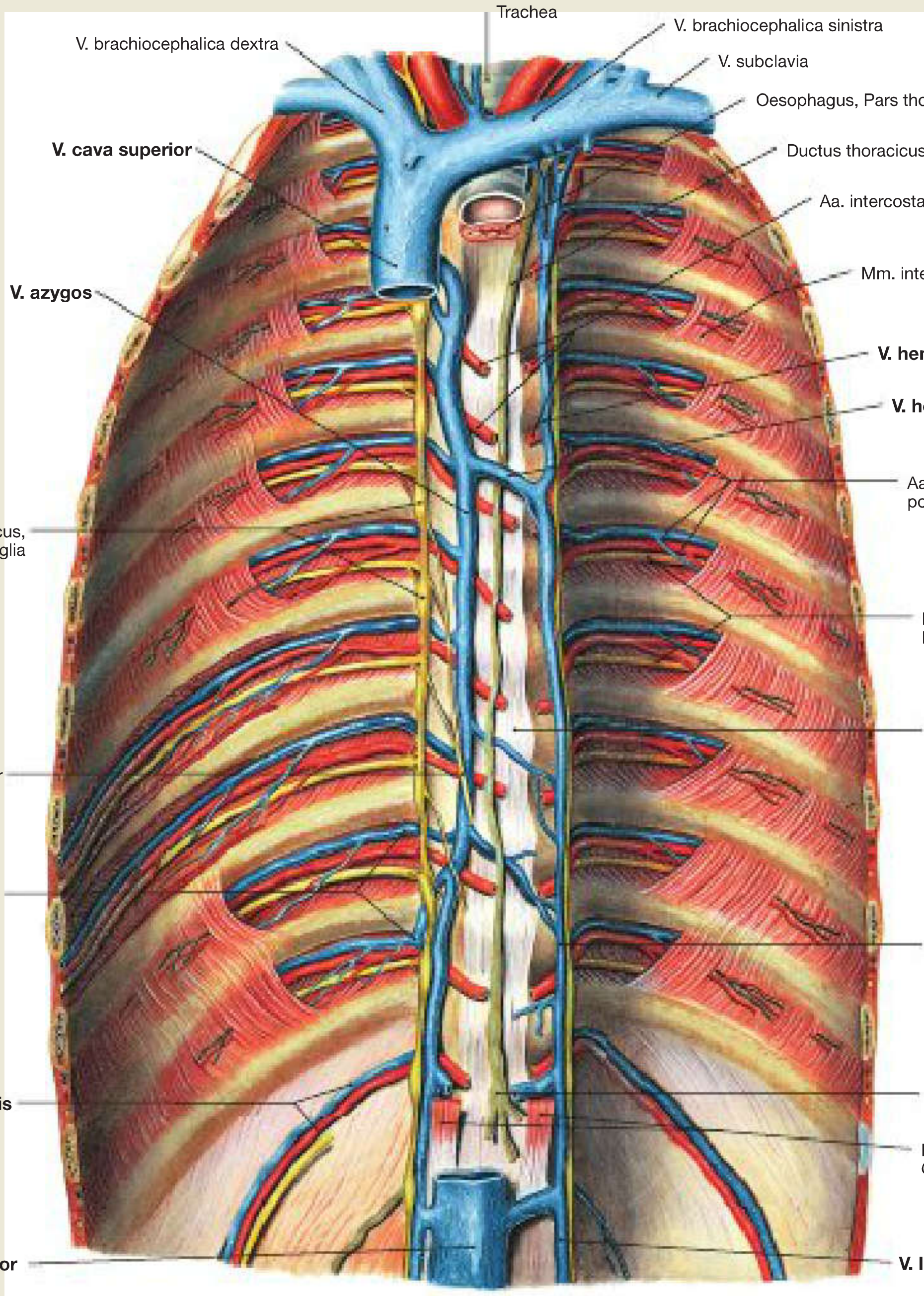


Fig. 5.17 Veins of the azygos system; ventral view of the posterior thoracic wall; after removal of the diaphragm.

The azygos system connects Vv. cavae superior and inferior and its tributaries correspond to the branches of the Aorta thoracica. It is on the **right side** of the spine that the **azygos vein** ascends and it flows dorsally at the level of the 4th/5th thoracic vertebrae into the V. cava superior. Correspondingly **on the left** to it is the **V. hemiazygos,** which drains between the 10th and 7th thoracic vertebrae into the V. azygos. The blood is received by a **V. hemiazygos accessoria** from the upper Vv. intercostales. Below the diaphragm a V. lumbalis ascendens continues the course of the left and right azygos veins respectively and links up in the V. cava inferior. In this way the azygos system is involved in a collateral circulation system between the two Vv. cavae. These **cavocaval anastomoses** include the following **inlets:**

- V. epigastrica superior (connection to V. thoracica interna) and V. epigastrica inferior (connection to V. iliaca externa)
- V. thoracoepigastrica (connection to axillary vein) and superficial epigastric vein (connection to femoral vein)
- Vv. azygos/hemiazygos (confluence into V. cava superior) and Vv. lumbales (confluence into V. cava inferior)
- Plexus venosus vertebralis with confluence via Vv. intercostales/Vv. lumbales into the azygos system, into the V. iliaca interna or directly into the V. cava inferior.

Arteries of the Posterior Mediastinum

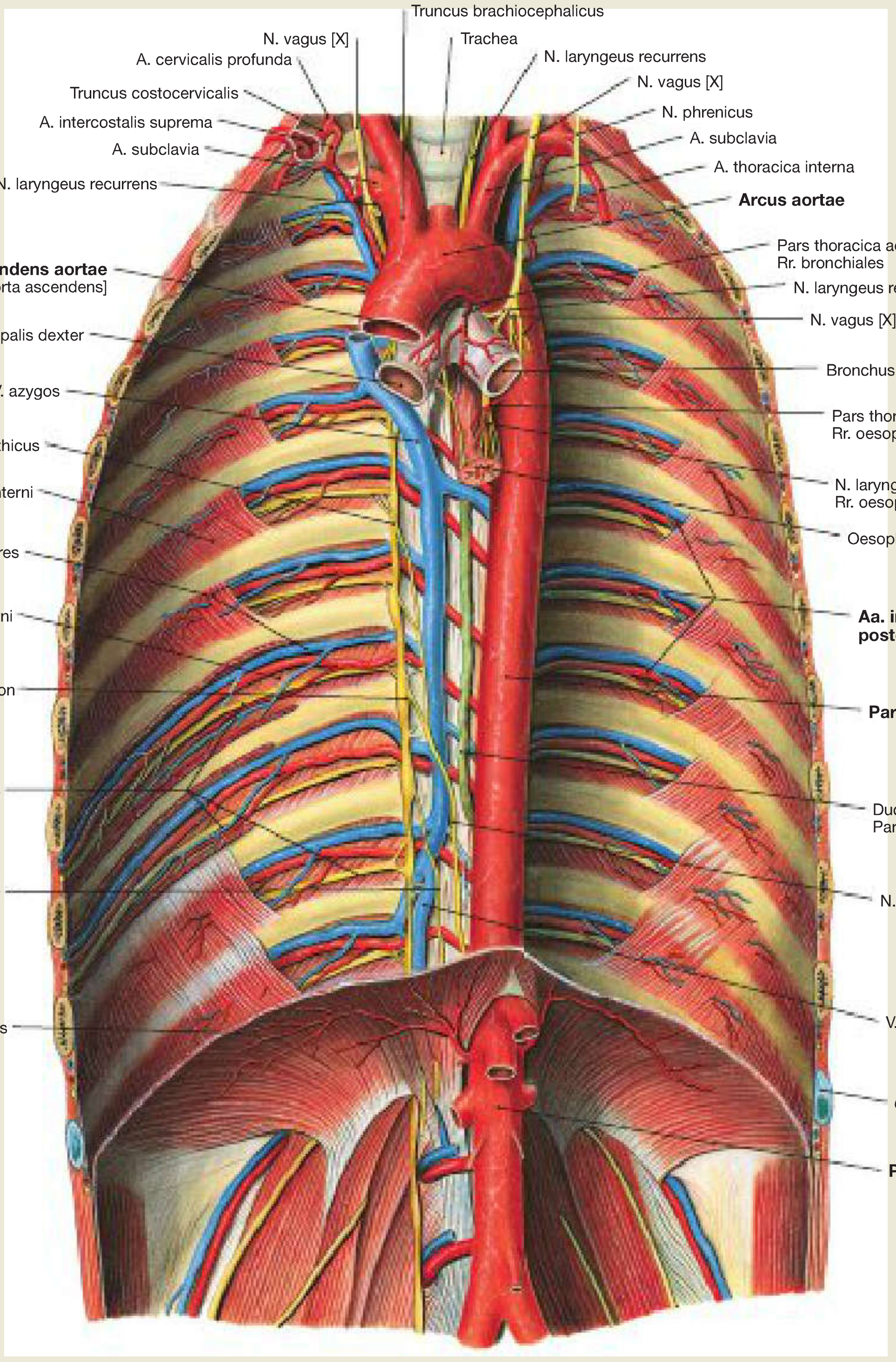


Fig. 5.18 Aorta descendens in thoracic section; ventral view of the posterior thoracic wall.
The descending part of the aorta descends into the posterior mediastinum (Pars thoracica) and then traverses the diaphragm (Pars abdominalis).

Branches of the Pars thoracica aortae	
Parietal branches to the thoracic wall	• Aa. intercostales posteriores: nine pairs (the first two are branches of the costocervical trunk of the A. subclavia) • A. subcostalis: the last pair under the 12^{th} rib • A. phrenica superior: to the upper side of the diaphragm
Visceral branches to the chest viscera	• Rr. bronchiales: vasa privata of the lung (on the right side mostly from the A. intercostalis posterior dextra III) • Rr. oesophageales: three to six branches to the oesophagus • Rr. mediastinales: small branches to mediastinum and pericardium

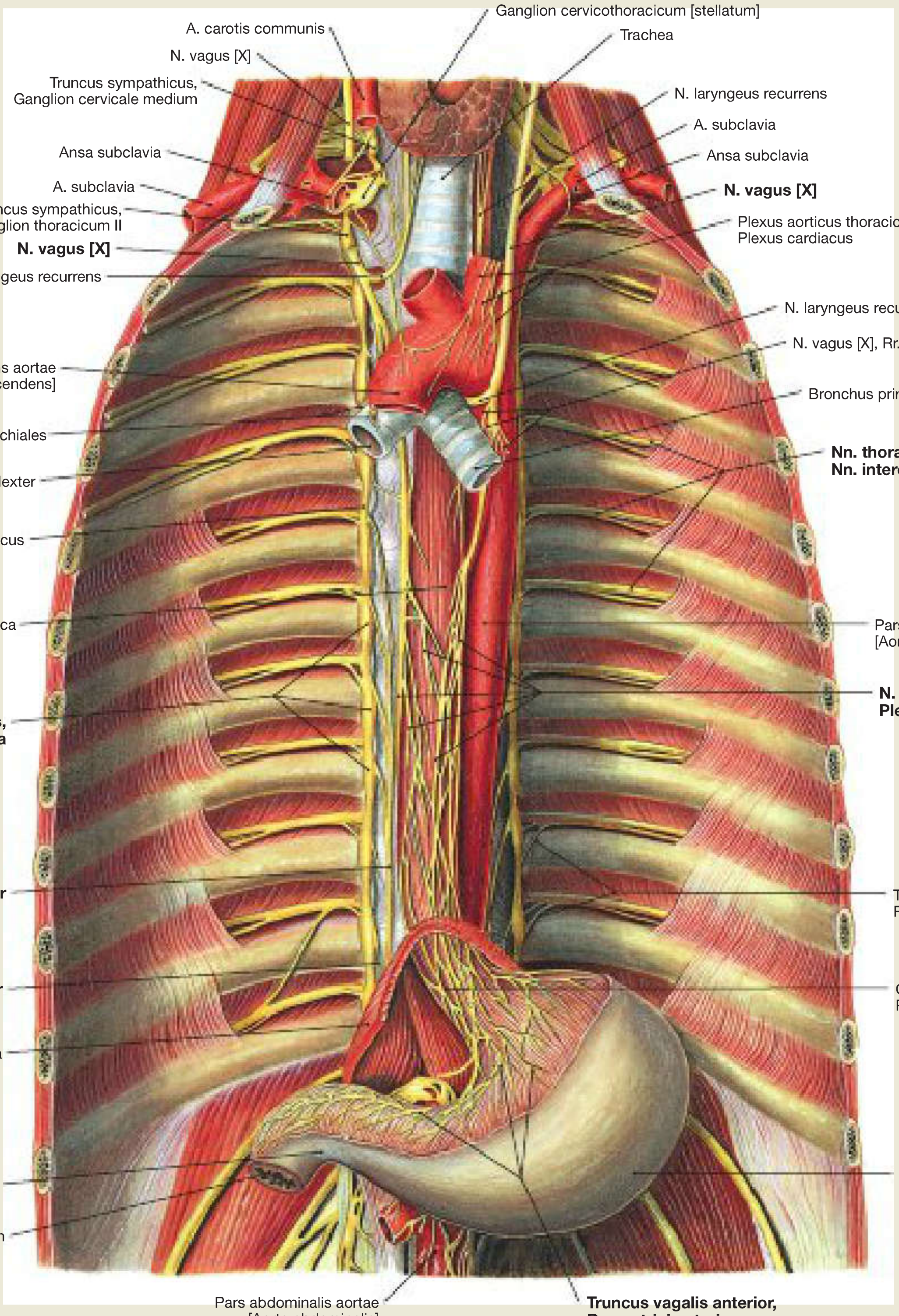


Fig. 5.19 Nerves of the posterior mediastinum; ventral view of the posterior thoracic wall; after removal of the diaphragm.

In the posterior mediastinum are, on the one hand, the intercostal nerves (Nn. intercostales) of the **somatic nervous system** and, on the other hand, sections of the sympathetic nervous system (Truncus sympathicus) and the parasympathetic nervous system (Nn. vagi) as part of the **autonomic nervous system.** The **Truncus sympathicus** forms a paravertebral chain of twelve thoracic ganglia in the posterior mediastinum, which are connected by Rr. interganglionares. The preganglionic neurons of the sympathetic nervous system are located in the lateral horns (C8–L3) of the spinal cord and exit the spinal canal with the spinal nerves. The white Rr. communicantes guide the fibres to the ganglia of the Truncus sympathicus, in which the perikarya of postganglionic neurons are located. Their axons return via grey Rr. communicantes to the spinal nerves and their branches. Some preganglionic neurons are not switched in the Truncus sympathicus, but instead stretch with the Nn. splanchnici major and minor to the nerve plexuses on the Aorta abdominalis, where the switch happens. The preganglionic neurons of the **Nn. vagi** adduct behind the root of the lung to the oesophagus and form the Plexus oesophageus. Two trunks, the Trunci vagales anterior and posterior, are formed here which proceed with the oesophagus through the diaphragm to the autonomic nerve plexuses of the abdominal aorta. Here, however, there is no interconnection, as the postganglionic neurons are usually found in the vicinity of the respective organs.

Lymphatic Vessels and Lymph Nodes of the Mediastinum

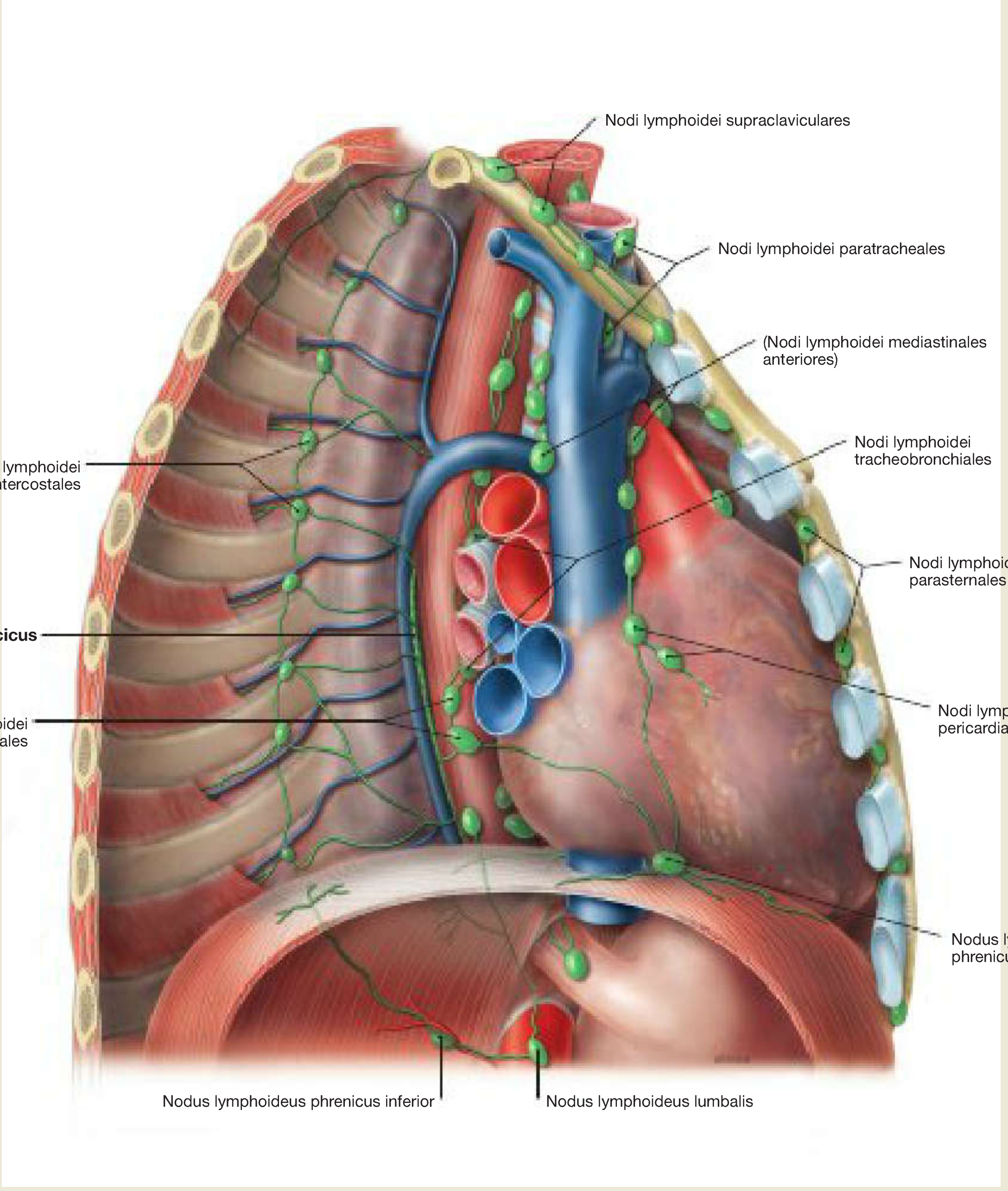


Fig. 5.20 Lymphatic vessels and lymph nodes of the mediastinum; view from the right ventrolateral side; after removal of the lateral thoracic wall. [L238]

There are various groups of lymph nodes in the mediastinum which are categorised into parietal lymph nodes (drainage of the thoracic walls) and visceral lymph nodes (drainage of the chest viscera). From there, the lymph flows into the major lymphatic trunks.

Parietal lymph nodes:

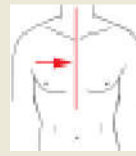
- Nodi lymphoidei parasternales: on both sides of the sternum. They receive lymph from the anterior thoracic wall, the mammary gland, and the diaphragm. The lymph passes from them into the Truncus subclavius.
- Nodi lymphoidei intercostales: between the rib heads. They filter lymph of the posterior thoracic wall. The efferent lymphatic vessels drain directly into the Ductus thoracicus.

Visceral lymph nodes with connection to the Trunci bronchomediastinales:

- Nodi lymphoidei mediastinales anteriores: on both sides of the great vessels, tributaries from lungs and pleura, diaphragm (Nodi lymphoidei phrenici superiores), heart and pericardium (Nodi lymphoidei pericardiaci), and thymus.
- Nodi lymphoidei mediastinales posteriores: on bronchi and trachea (Nodi lymphoidei tracheobronchiales and paratracheales) and oesophagus (Nodi lymphoidei juxtaoesophageales)

Lymphatic trunks:

The Ductus thoracicus traverses the diaphragm at the front of the spine (→ Fig. 5.17) and ascends in the posterior mediastinum, firstly behind the aorta, then behind the oesophagus, up to the 7th cervical vertebra; crosses the left pleural dome and ends its flow from the dorsal side in the area of the left venous angle (between the V. subclavia and the V. jugularis interna). Shortly before draining, it receives the Truncus bronchomediastinalis sinister, which runs independently in the mediastinum, and also the left Truncus subclavius (from the arm) and the Truncus jugularis sinister (from the neck). On the right side, a short (1 cm) Ductus lymphaticus dexter mostly connects the respective lymphatic trunks and flows within the right venous angle.



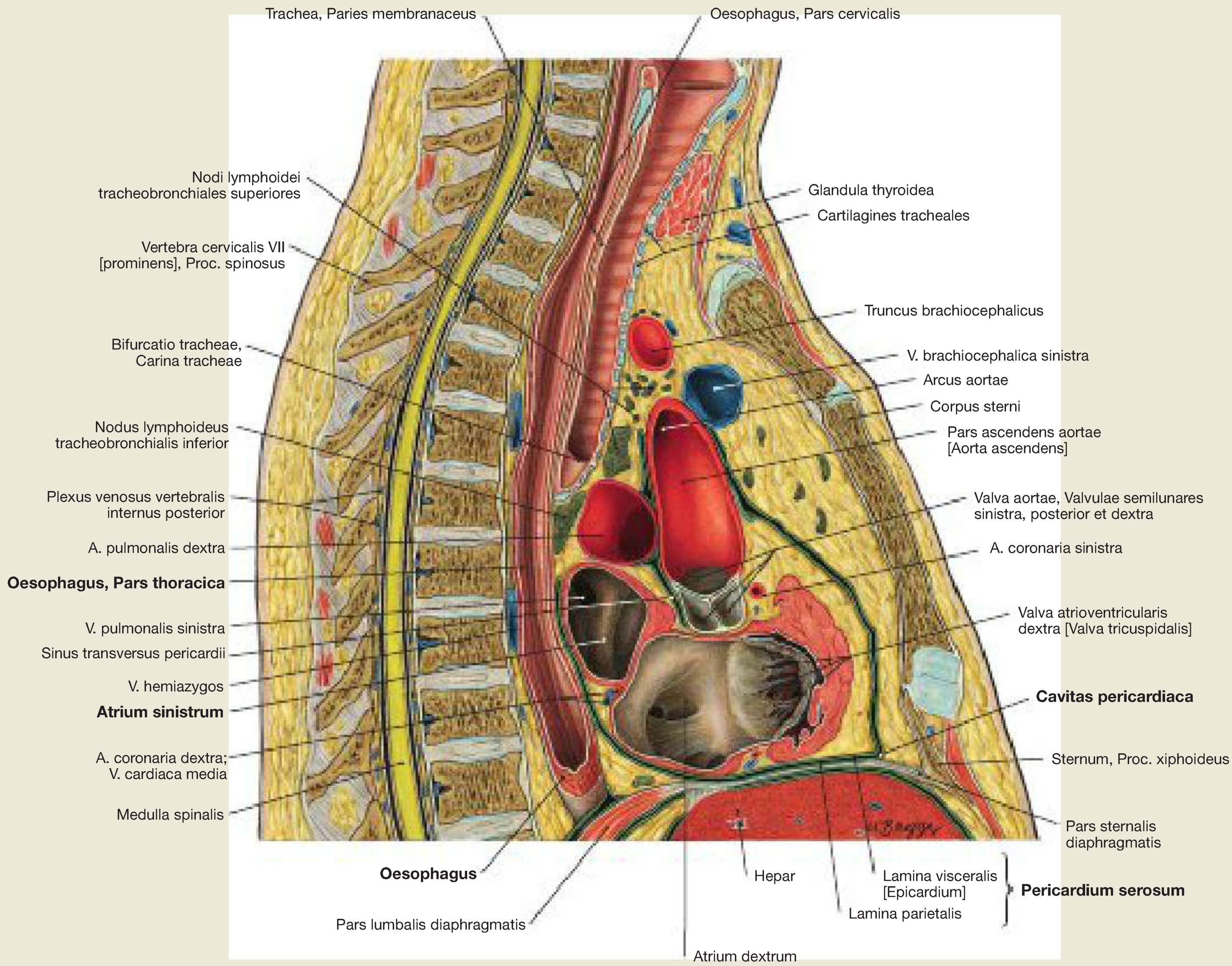


Fig. 5.21 Cavitas thoracis; midsagittal section; lateral view on the right side.
In this type of section the proximity of the oesophagus, in the posterior mediastinum, to the left atrium of the heart, in the middle mediastinum, becomes particularly clear. Both structures are only separated by the pericardial cavity (Cavitas pericardiaca).

Clinical Remarks

In **transoesophageal echocardiography** the spatial proximity of the oesophagus to the heart is used. A depiction of the heart and particularly the heart valves using an ultrasound probe inserted into the oesophagus is achieved much more accurately than through an examination of the outer side of the thoracic cage.

Posterior Mediastinum

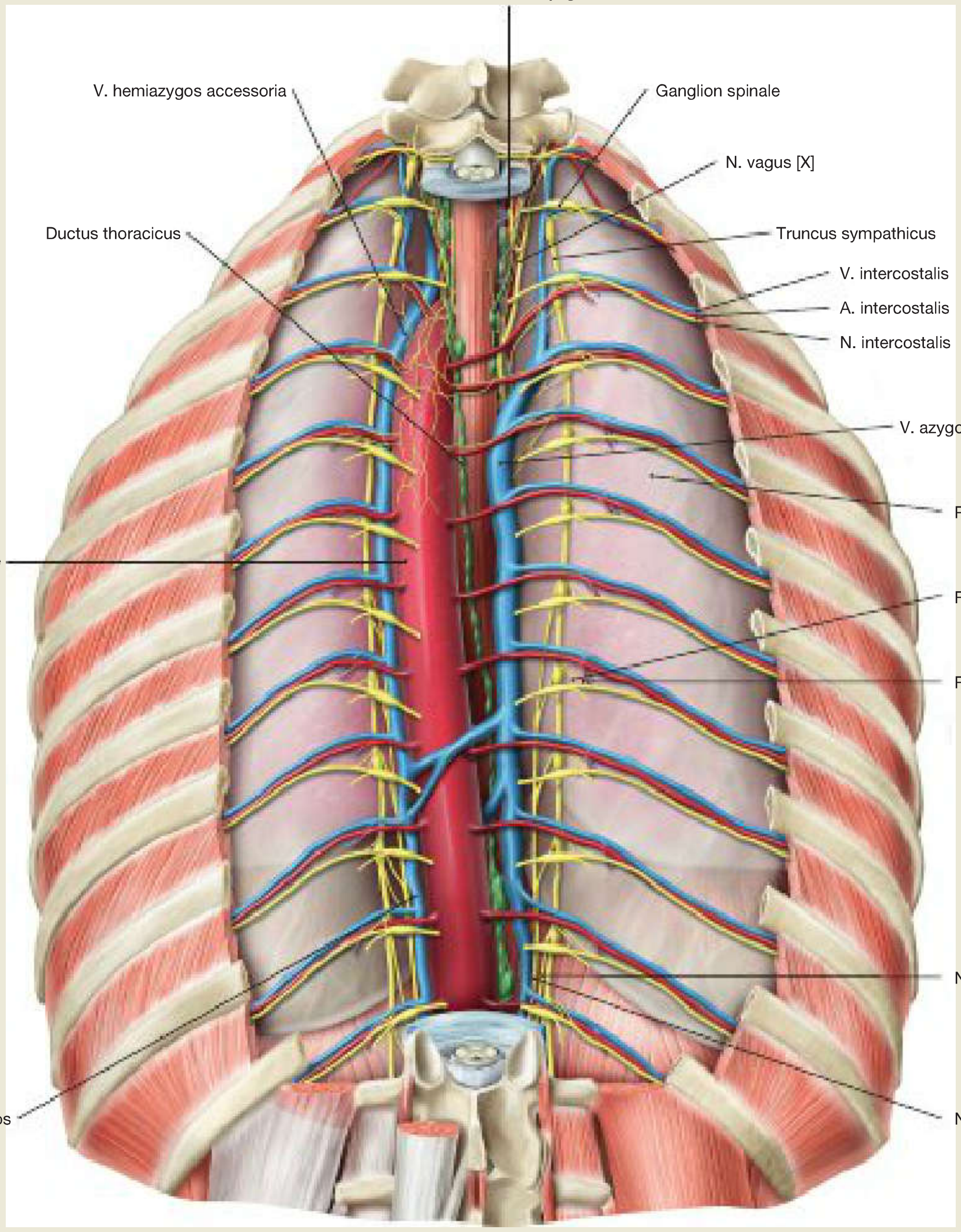


Fig. 5.22 Posterior mediastinum, Mediastinum posterius; dorsal view; after removal of the posterior thoracic wall including the spine. [L275]

This view illustrates the topography of the neurovascular pathways in the posterior mediastinum. Because this depiction is generally not used in dissection courses, it is particularly useful for understanding positional relationships. The intercostal vascular, lymphatic and nervous systems (from cranial to caudal: **V.** intercostalis, **A.** intercostalis, **N.** intercostalis; **VAN**), which are situated on the lower rim of the respective ribs, run dorsally of the Pleura costalis to the lateral side. The Aa. intercostales originate segmentally from the **Aorta descendens,** which runs to the left of the median plane. To the right of the spine, which was displaced to the lumbar and cervical area, ascends the **V. azygos,** which receives the Vv. intercostales. Corresponding to it on the left-hand side is the **V. hemiazygos** which here, at the level of the 8th and 9th ribs features anastomoses with the V. azygos, and corresponding cranially is the **V. hemiazygos accessoria.** The Nn. intercostales correspond to the Rr. anteriores of the spinal nerves. From the spinal nerves the Rr. communicantes stretch to connect to the **Truncus sympathicus** of the autonomic nervous system. The main lymphatic vessel of the human body, the **Ductus thoracicus,** ascends between the aorta and V. azygos ventral to the spine. In the superior mediastinum, the oesophagus lies directly against the spine.

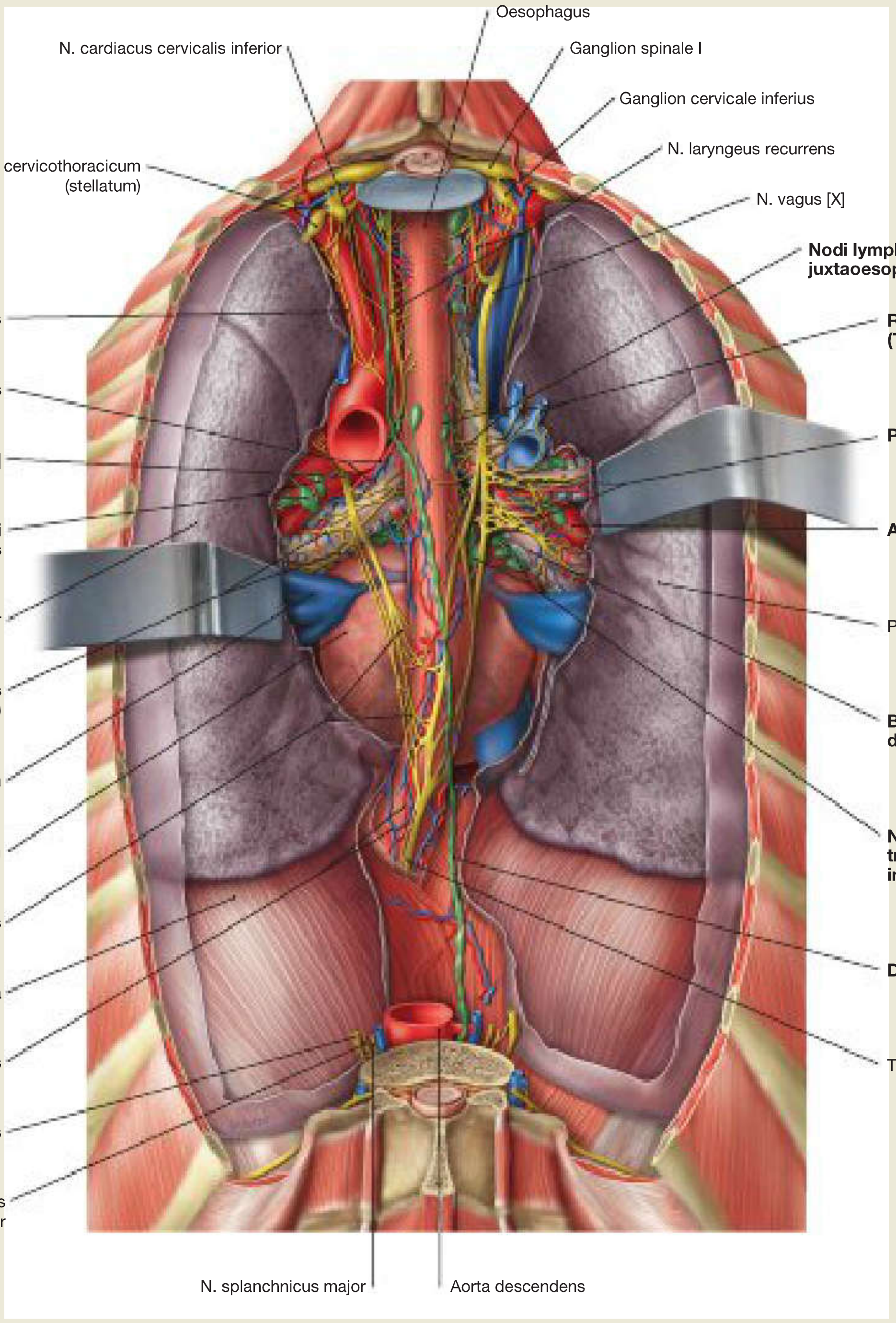


Fig. 5.23 Posterior mediastinum, Mediastinum posterius; dorsal view; after removal of the posterior thoracic wall including the spine. The Pleura costalis is opened, and the lungs are fixed on both sides to lateral. In addition, the Aorta descendens and the azygos system as well as the Truncus sympathicus have been displaced on their passage through the diaphragm. [L238]

The **Ductus thoracicus** ascends ventrally of the spine. It is formed from the lumbar and intestinal trunks under the diaphragm and emerges right dorsal of the aorta via the Hiatus aorticus. The entire Pars thoracica of the **oesophagus** and, ventrally from this, of the **pericardium** and the root of the lung **(Radix pulmonis)** are visible here. The oesophagus emerges through the oesophageal hiatus in the lumbar part of the diaphragm. It is accompanied by an autonomic nerve plexus **(Plexus oesophageus),** the parasympathetic parts of which become condensed above the oesophageal hiatus to the **vagal trunks.** The Truncus vagalis posterior visible here emerges during development, predominantly from the fibres of the right N. vagus, due to stomach rotation. The autonomic **Plexus pulmonalis** is formed particularly strongly dorsally and accompanies the main bronchi to the hilum of the lung. It receives its parasympathetic fibres from the Nn. vagi and its sympathetic neurons from the Truncus sympathicus (not shown here).

Upper Thoracic Aperture

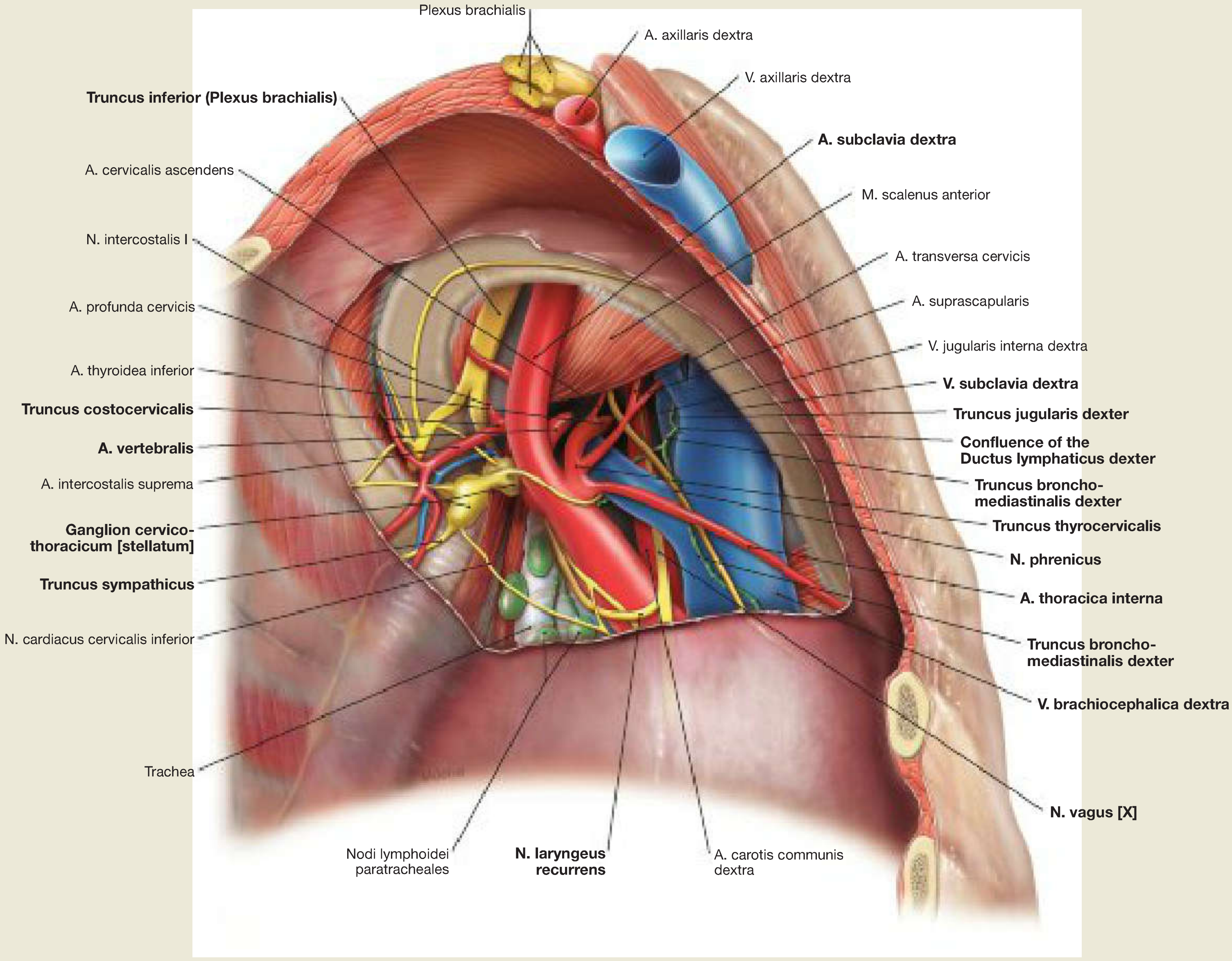


Fig. 5.24 Neurovascular pathways of the upper thoracic aperture, right side; caudal view; after removal of the pleural dome. [L238]
The pleural dome is bridged in front of the M. scalenus anterior by the V. subclavia and behind the muscle **(scalene gap)** by the A. subclavia and Plexus brachialis. Originating from the A. subclavia are the A. thoracica interna, which descends to the lateral surface of the sternum; the A. vertebralis; and the Truncus thyrocervicalis with its branches. Emerging dorsally of the M. scalenus anterior is the Truncus costocervicalis, which divides into the A. profunda cervicis and the A. intercostalis suprema. The N. phrenicus lies ventrally on the V. brachiocephalica. Further dorsally the N. vagus releases the N. laryngeus recurrens, which winds around the A. subclavia on the right side, before it ascends again to the neck. Behind the A. subclavia lies the Truncus sympathicus with its Ganglion cervicothoracicum (stellate ganglion). Most difficult to identify is the short Ductus lymphaticus dexter, which drains into the right venous angle (between the V. subclavia and the V. jugularis interna) after merging with the Truncus bronchomediastinalis and the Truncus subclavius.

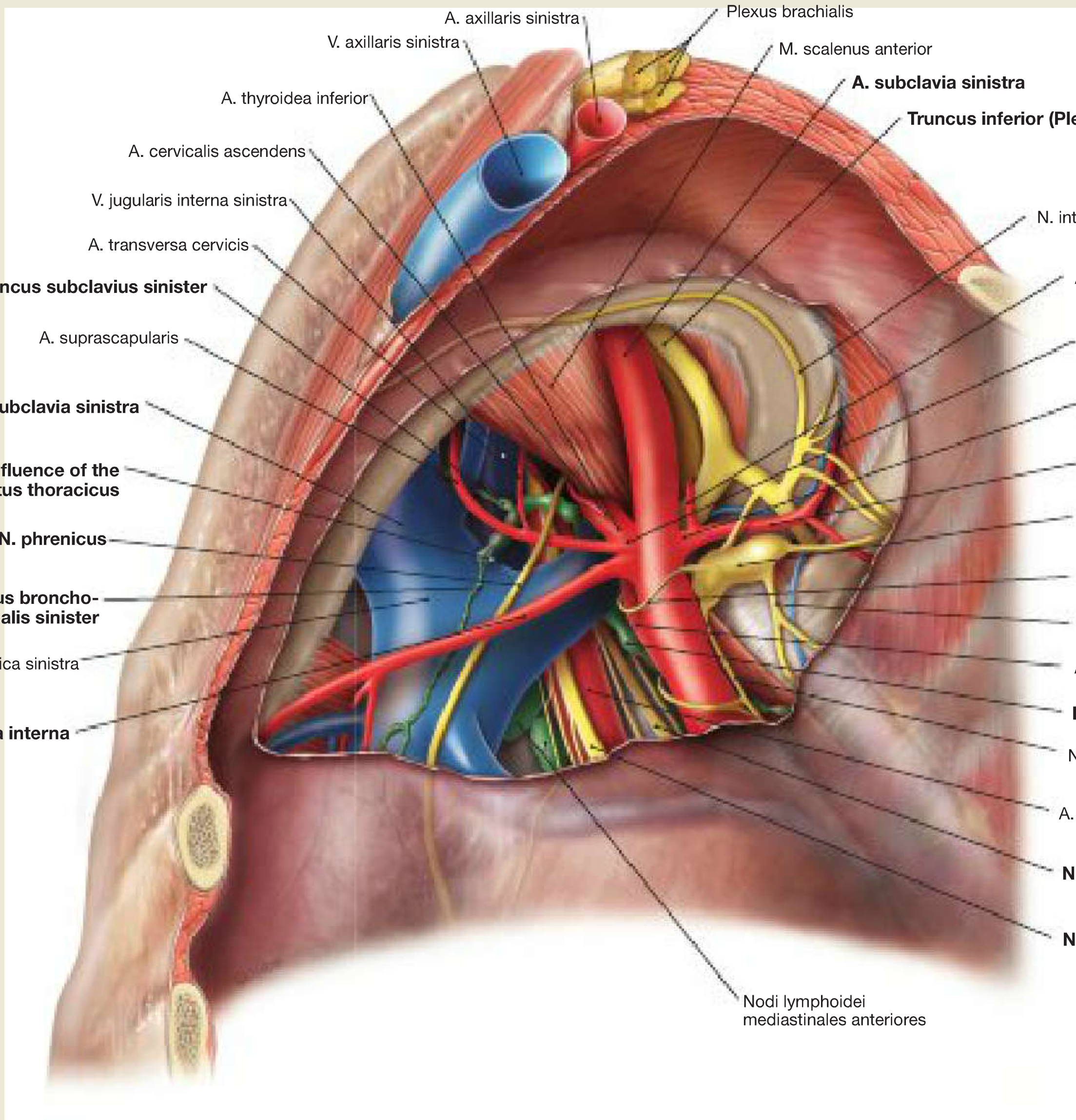


Fig. 5.25 Neurovascular pathways of the upper thoracic aperture, left side; caudal view; after removal of the pleural dome. [L238]
Only those structures that vary in their course from the neurovascular pathways of the right side will be described here (→ Fig. 5.24). On the left side of the body, the **N. vagus [X]** descends further caudally before releasing its N. laryngeus recurrens, which then winds around the Arcus aortae (not in view) before it ascends again to the neck. Particular attention should be paid to the course of the **Ductus thoracicus,** as it is often injured during dissection in this area. The **Ductus thoracicus** ascends in the posterior mediastinum and stretches over the left pleural dome, before draining dorsally into the left venous angle (between the V. subclavia and the V. jugularis interna). Before reaching its outlet it receives the Truncus bronchomediastinalis, the Truncus subclavius and the Truncus jugularis (not shown).

Organisation of the Cardiovascular System

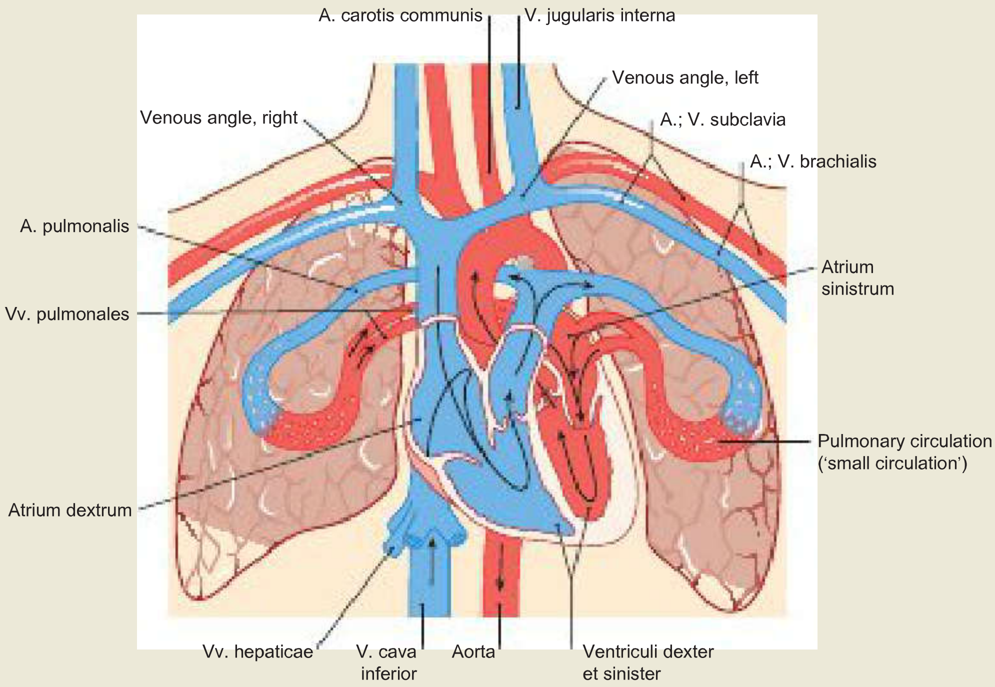


Fig. 5.26 Organisation of the cardiovascular system; blue: deoxygenated blood, red: oxygenated blood. [L126]

The cardiovascular system consists of the heart and blood vessels. A distinction is made between a **systemic circulation** (= large circulation) and a **pulmonary circulation** (= small circulation), which are connected in a series. The heart is the parent organ of the cardiovascular system and drives the circulation as a suction and pressure pump. Accordingly, the heart is divided into two halves, which each consist of an atrium and a ventricle (Ventriculus).

In this way, blood is pumped from the heart into **arteries** and returned via **veins** back to the heart. Oxygen content for this division is negligible! In the systemic circulation, oxygenated blood from the left ventricle (Ventriculus sinister) is directed via the main artery (aorta) and downstream arteries into outlying areas, where the oxygen is used and carbon dioxide absorbed. The venous blood is correspondingly deoxygenated and is returned to the heart via the veins, which join to the superior and inferior venae cavae (Vv. cavae superior and inferior) prior to entering the right atrium (Atrium dextrum). This blood is then pumped from the right ventricle (Ventriculus dexter) via the Truncus pulmonalis and the pulmonary arteries into the pulmonary circulation, where renewed oxygen absorption into the blood and exhalation take place. The pulmonary veins transport the oxygenated blood back into the left atrium (Atrium sinistrum) so that the circulation is completed.

As the heart circulates blood around the body, its functions are identical to those of blood.

The **most important functions** of the cardiovascular system are:
- oxygen and nutrient supply of the organism (transport of respiratory gases and nutrients)
- thermal regulation (heat transfer in blood)
- defence function (transport of immune cells and antibodies)
- hormonal control (transport of hormones)
- haemostasis (transport of blood platelets and coagulation factors)

The heart is divided into a **left and right half** by the cardiac septum. The two halves of the heart are each subdivided by valves (atrioventricular valves) into a right and left **atrium** and a right and left **ventricle**. Thus, the septum is also differentiated into two parts:
- **Septum interatriale** between the atria
- **Septum interventriculare** between the ventricles. It consists of a narrow cranial membranous part (Pars membranacea), whereas the largest part consists of cardiac muscle (Pars muscularis).

Arteries and veins are referred to as vessels of **macrocirculation** since they are visible to the naked eye. Within the periphery of the body and the organs the vessels of **microcirculation** are connected between arteries and veins. Here blood pressure is reduced in the arterioles so that oxygen and gas exchange can take place in the capillaries. The venules collect the blood again and join the veins.

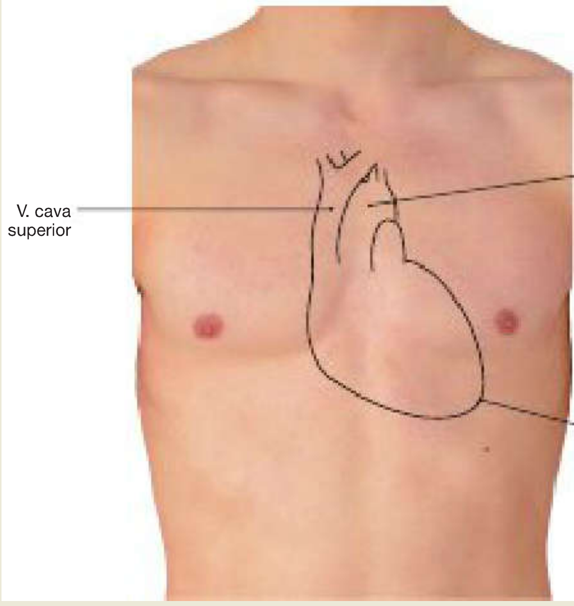


Fig. 5.27 Projection of the heart contour onto the ventral thoracic wall.
The heart is displaced to the left side and thus does not lie in the centre of the chest cavity.
The right margin of the heart projects from the third to sixth costal cartilage in a line which is 2 cm lateral to the right sternal border. **The left margin of the heart** projects onto a connecting line between the lower rim of the 3rd rib (2–3 cm parasternal) and the midclavicular line on the left.

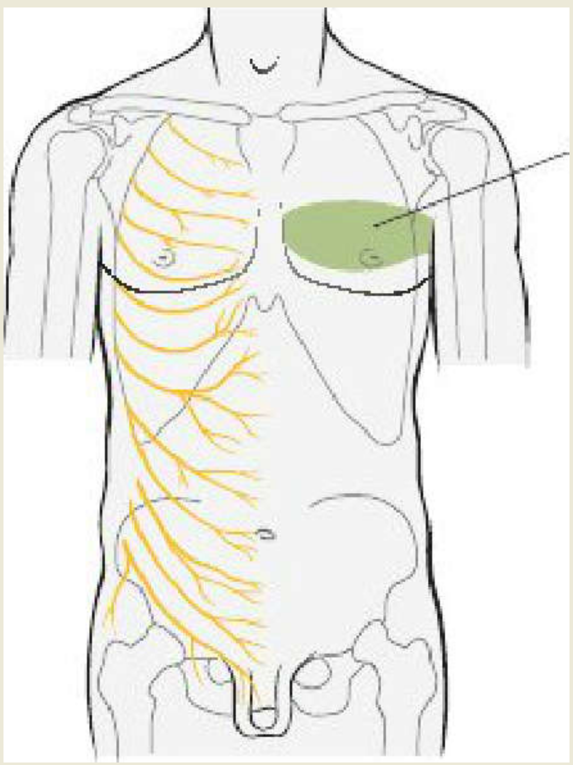


Fig. 5.28 Zone of referred pain (HEAD's zone) of the heart. [L126]
Afferent nerve pathways from the heart, through which stimuli are transmitted to the central nervous system, run in the respective spinal cord segments together with nerve fibres that originate from the dedicated skin areas (dermatomes). At the heart, these are the dermatomes T3 and T4. This organ-related skin area, where pain is perceived, is referred to as **HEAD's zone** of the heart.

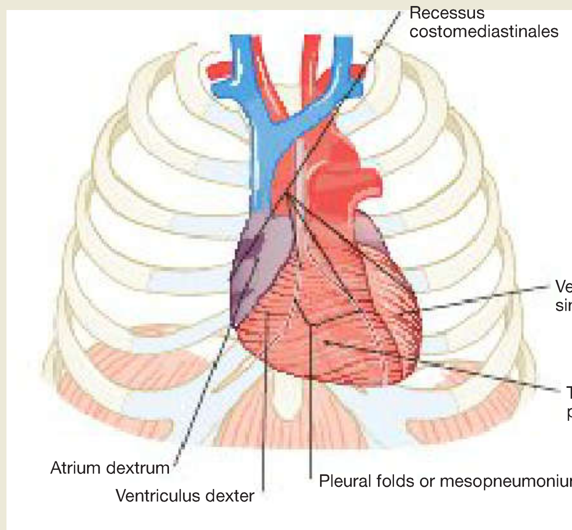


Fig. 5.29 Projection of the heart onto the thorax; schematic drawing. [L126]

Clinical Remarks

In the HEAD's zone of the heart, diseases such as, e.g. a circulation deficiency in **angina pectoris** or **myocardial infarction,** sometimes cause pain and hypersensitivity to touch, which are perceived in the corresponding dermatomes T3 and T4 (= radiating pain).

Heart

Projection of the Heart

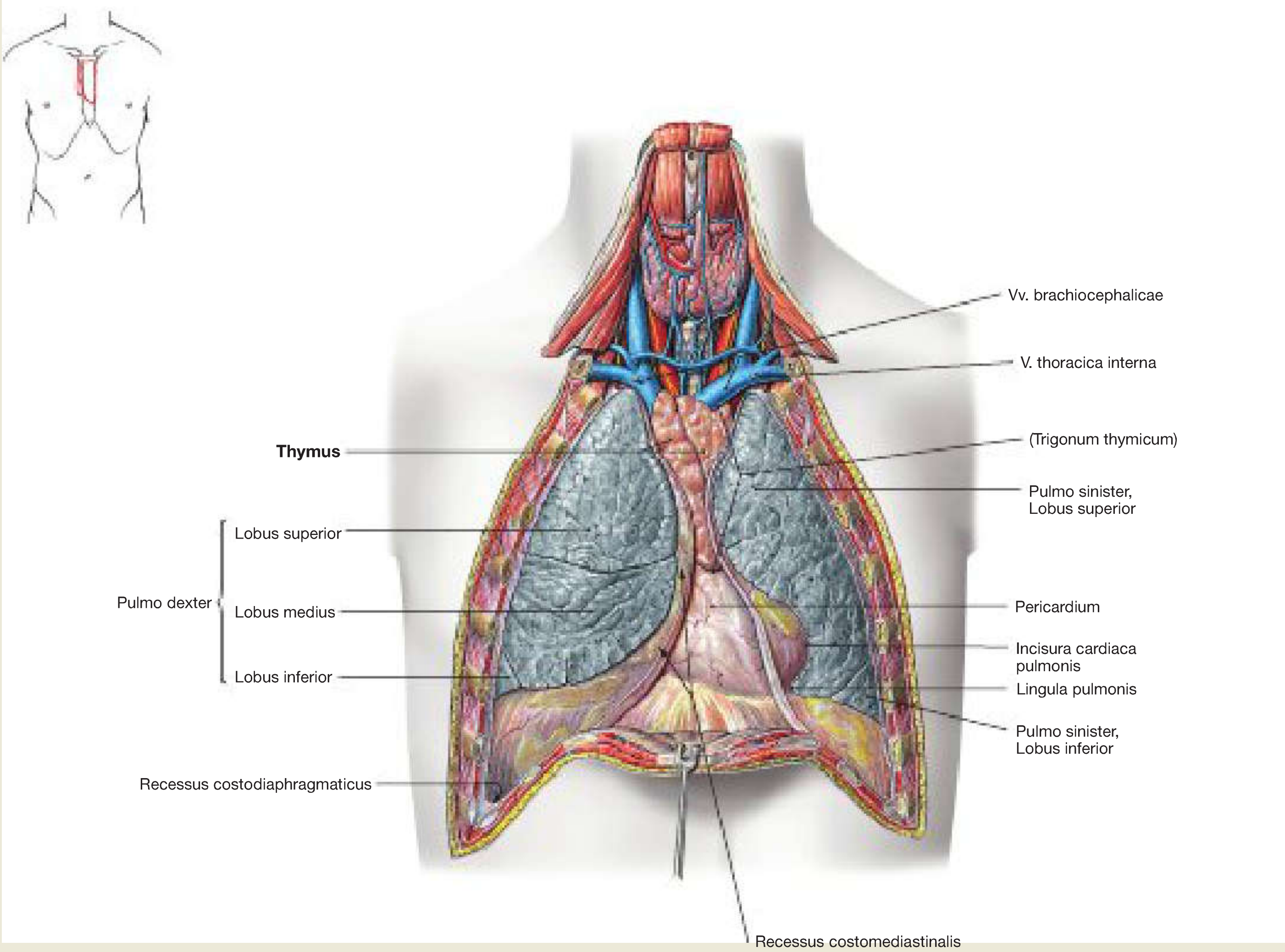


Fig. 5.30 Projection of the heart onto the thorax; mediastinum and Cavitates pleurales after removal of the thoracic wall; ventral view.

The heart is a cone-shaped, four-chambered, muscular hollow organ. Its size corresponds to the fist of each respective person; the weight is on average 250–300 g. The heart has **four sides:** The ventrally oriented **Facies sternocostalis** corresponds predominantly to the right ventricle. The caudally pointing **Facies diaphragmatica** is composed of parts from both ventricles. The **Facies pulmonalis** is formed to the right by the right atrium and to the left predominantly by the left ventricle. The result of this is that the right ventricle is not involved in the formation of the margin of the heart either to the right or the left. The posterior side of the heart has no official anatomical description. This surface is taken up by the left atrium. Since the atria were viewed for a long time as part of the upstream veins, naming the posterior side was apparently dispensed with.

The largest part of the Facies sternocostalis is covered on both sides by lung and pleura. These areas correspond to the **Recessus costomediastinales** of the Cavitas pleuralis. Underneath the 4th rib, the pleural edges move apart from each other and confine between them the Trigonum pericardiacum, in which the pericardium lies directly against the ventral thoracic wall.

Clinical Remarks

From a **heart weight of 500 g (critical heart weight),** blood flow to the heart muscle is no longer sufficient so that blood flow deprivation (ischemia) and death of cardiac tissue can ensue (heart attack). Enlargements of up to 1,100 g are known as **cor bovinum** (bovine heart). Tapping of the heart **(percussion)** can give an initial indication of the **size** of the heart. The projection of the heart contours, which are covered by the pleura of the costomediastinal recess, corresponds to the field of **relative cardiac dullness** since the percussion sound is less dampened by the air-filled lung. When this field extends to the left over the midclavicular line, it is an indication of left ventricular hypertrophy. The area where the heart lies against the anterior thoracic wall is referred to as Trigonum pericardiacum and is the area of **absolute cardiac dullness** since the percussion sound is muffled to the maximum (→ Fig. 5.29). This area has no diagnostic relevance, but can be used in case of emergency for injection into the right ventricle **(intracardiac injection),** without leading to an injury of the pleura risking the forming of a pneumothorax. Intracardiac injections are performed in the fourth or fifth intercostal space, approximately 2 cm left parasternally. However, this measure is relatively risky and has therefore largely been abandoned.

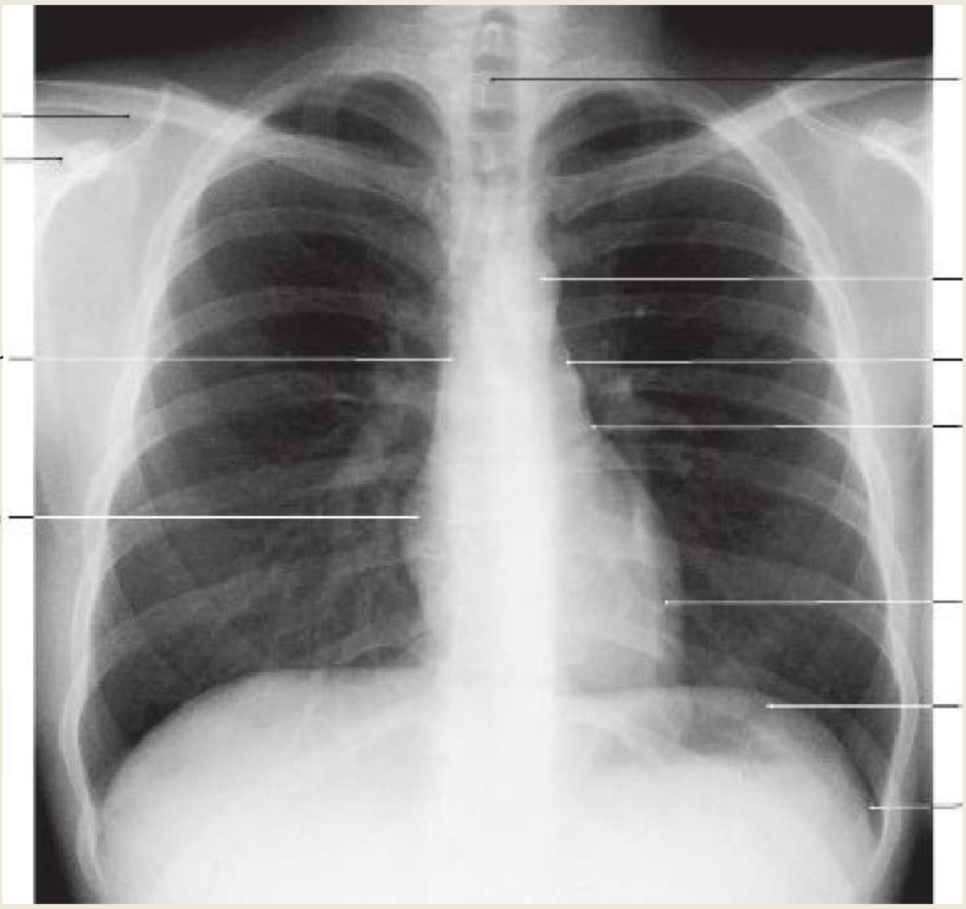


Fig. 5.31 Thoracic cage, Cavea thoracis, with thoracic viscera; X-ray in posteroanterior (PA) beam projection.

The X-ray can be used to estimate the size of the heart. In addition to the overall size, knowledge of the structures contributing to the heart contours is of importance (v. i.).

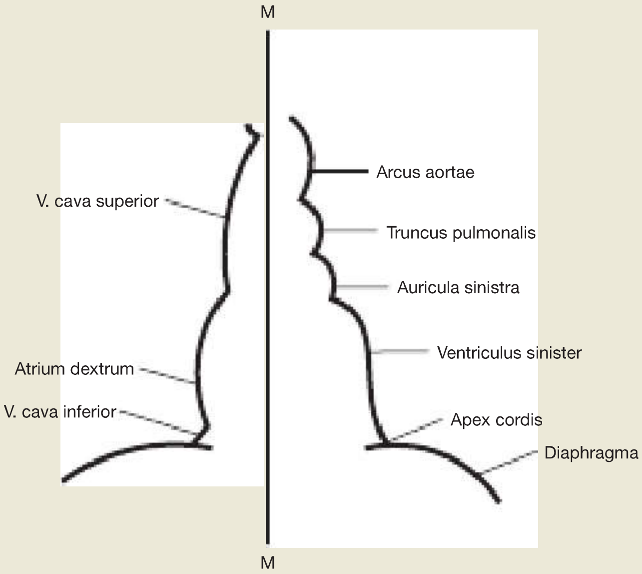


Fig. 5.32 Schema of heart contours on an X-ray.
The **right margin of the heart** is formed from top to bottom by:
- V. cava superior
- right atrium (Atrium dextrum)

The **left margin of the heart** is bordered from top to bottom by:
- Arcus aortae
- Truncus pulmonalis
- left auricle (Auricula sinistra)
- left ventricle (Ventriculus sinister)

The right ventricle is, therefore, not forming a margin on any side!
M = median plane of the body

Clinical Remarks

An X-ray overview of the thorax provides information on the size of the heart. The transverse heart diameter is interindividually different. However, if it is larger than half of the diameter of the thorax, an enlargement of the heart is present which may be caused by **hypertrophy** of the musculature or by **dilation** of the wall. In most cases an enlargement to the left side (left pulmonary surface) is present, which points to damage to the left ventricle. This can be caused by **high blood pressure** (hypertension) in the systemic circulation or a **stenosis** or **aortic** or **mitral insufficiency.** However, enlargements of the right ventricle, e. g. in pulmonary hypertension, in chronic obstructive pulmonary disease (asthma) or with occlusion of the pulmonary arteries (pulmonary embolism), are not visible on an X-ray in a sagittal beam projection, because the right ventricle is not forming a margin. In this case, lateral or tomographic images such as computed tomography (CT) or magnetic resonance tomographic imaging (MRI) are required.

Development

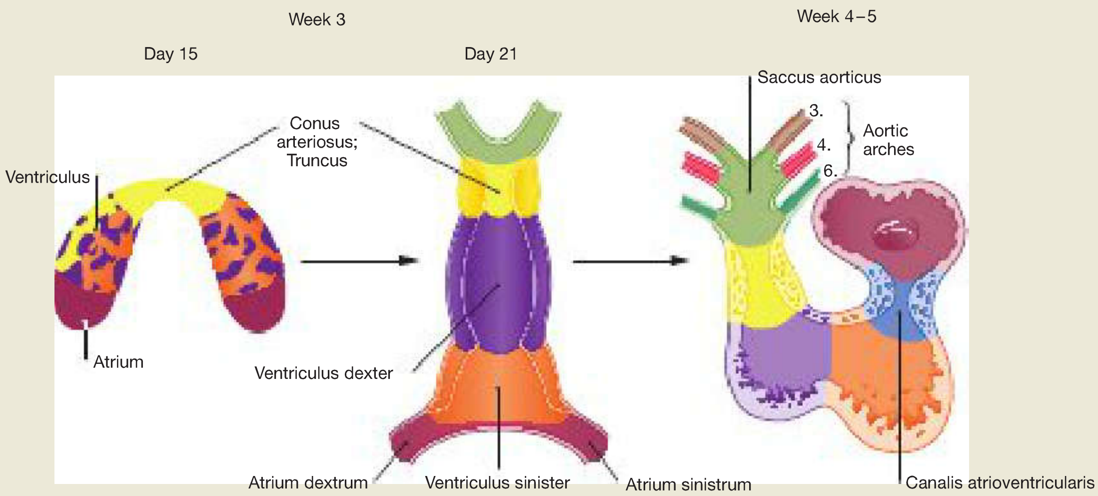


Fig. 5.33 Stages of heart development in the third to fifth week. [L126]
In the **third week,** the initially horseshoe-shaped **endocardial tube** forms from a vessel plexus in the mesoderm of the cardiogenic zone. Gaps around the endocardial tube lead to the formation of the pericardial cavity which unites with the visceral cavity. The inner layer of the pericardial cavity condenses into the myocardium. The epicardium develops from cells which migrate from the septum transversum and the liver primordium. The sides of the endocardial tube fuse into a **tubular heart,** which from the end of the third week contracts rhythmically. The tubular heart is divided into what is first a paired atrium with Sinus venosus as inflow segment, a ventricle and a Conus arteriosus as outflow segment. Through varied lengthening of the individual parts and through redistribution, the tubular heart is transformed into the S-shaped **heart loop** in the fourth to fifth week. The connection between atrium and ventricle is restricted to the unpaired atrioventricular canal which firstly flows into the left part of the left ventricle, but later is diverted into the midline and divided by endocardial cushions into a right and a left atrioventricular opening. The endocardial cushions form the atrioventricular valves.

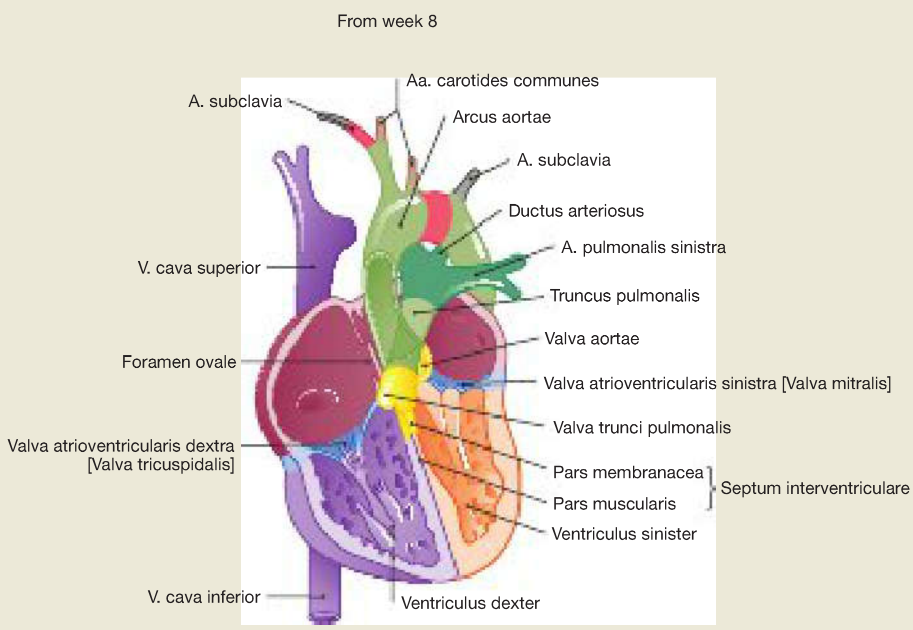


Fig. 5.34 Stages of heart development in the fifth to seventh week. [L126]
In the fifth to seventh week there develops a **Septum interventriculare** (Pars muscularis), which partially separates the two ventricles. They communicate with each other, however, until the end of the seventh week, when both ventricles are finally separated by the unification of the Pars membranacea of the septum. The conus arteriosus of the outflow tract is divided spirally and, together with the adjacent saccus aorticus, forms the **Truncus pulmonalis** and the **aorta.**

Pharyngeal arch arteries originate from the saccus aorticus. Of the six pharyngeal arch arteries, however, only the third, fourth and sixth develop and become part of the arteries near the heart. The A. carotis communis emerges from the third pharyngeal arch artery; from the fourth pharyngeal arch artery parts of the A. subclavia emerge to the right and the aortic arch emerges to the left. The pulmonary arteries and the Ductus arteriosus develop from the sixth pharyngeal arch artery.

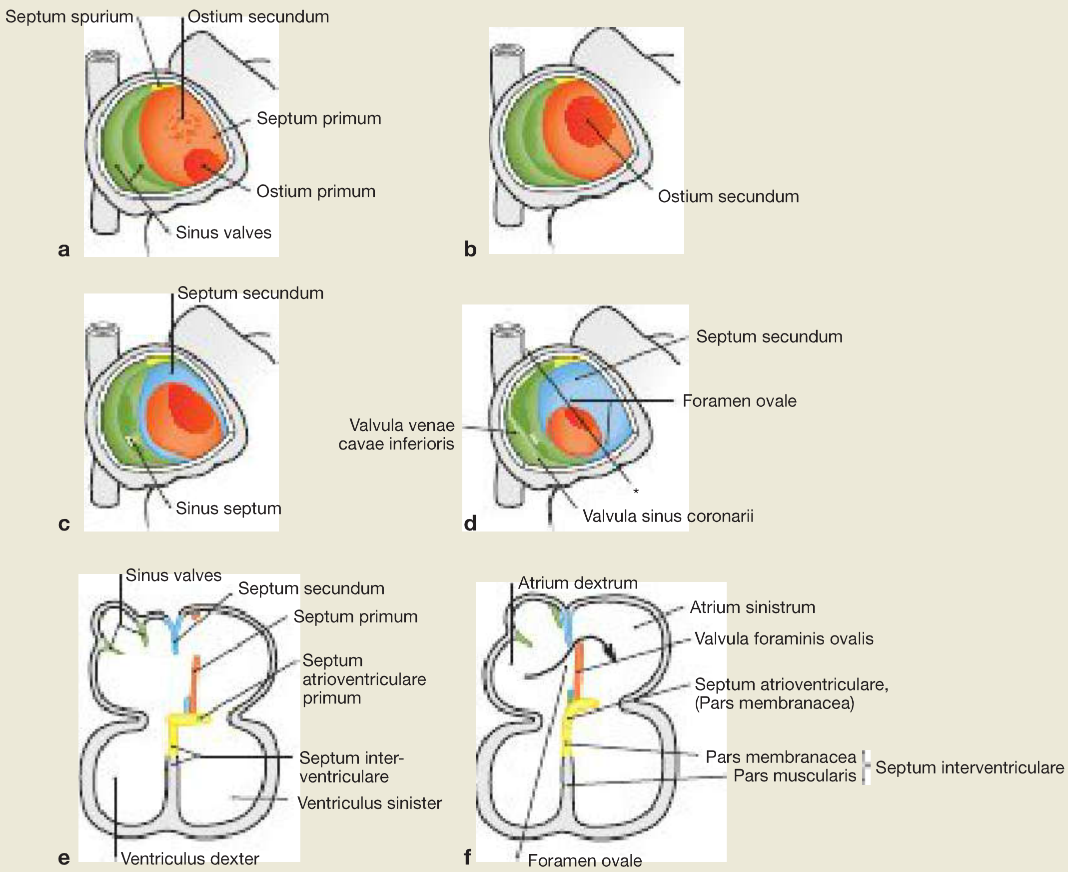


Fig. 5.35a to f Steps of atrial septation in the fifth (a, b), sixth (c, e), seventh and eighth (d, f); view from the opened right atrium **(a–d)** and in the four chamber plane **(e** and **f).**
[L126]
a Atrial septation occurs in the fifth to seventh week and begins with the formation of the **Septum primum,** which grows and leaves the **Ostium primum** free below.
b Within the upper part of the Septum primum, the **Ostium secundum** is created through programmed cell death (apoptosis).
c, e The **Septum secundum** develops to the right of the Septum primum. Both septa lie adjacent to each other and close off the foramen ovale together.
d, f The Septum primum forms the **Valvula foraminis ovalis** which facilitates the directional blood flow from the right into the left atrium (→ Fig. 5.37). After birth, the Valvula foraminis ovalis closes the foramen ovale due to the increased blood pressure in the left atrium (→ Fig. 5.39).

*sectional plane e, f

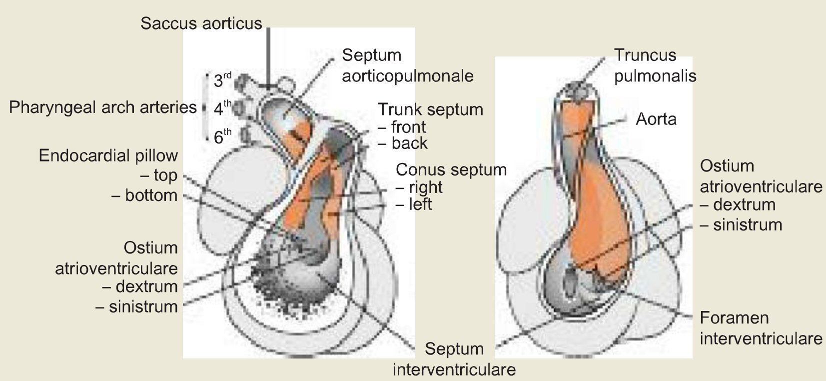
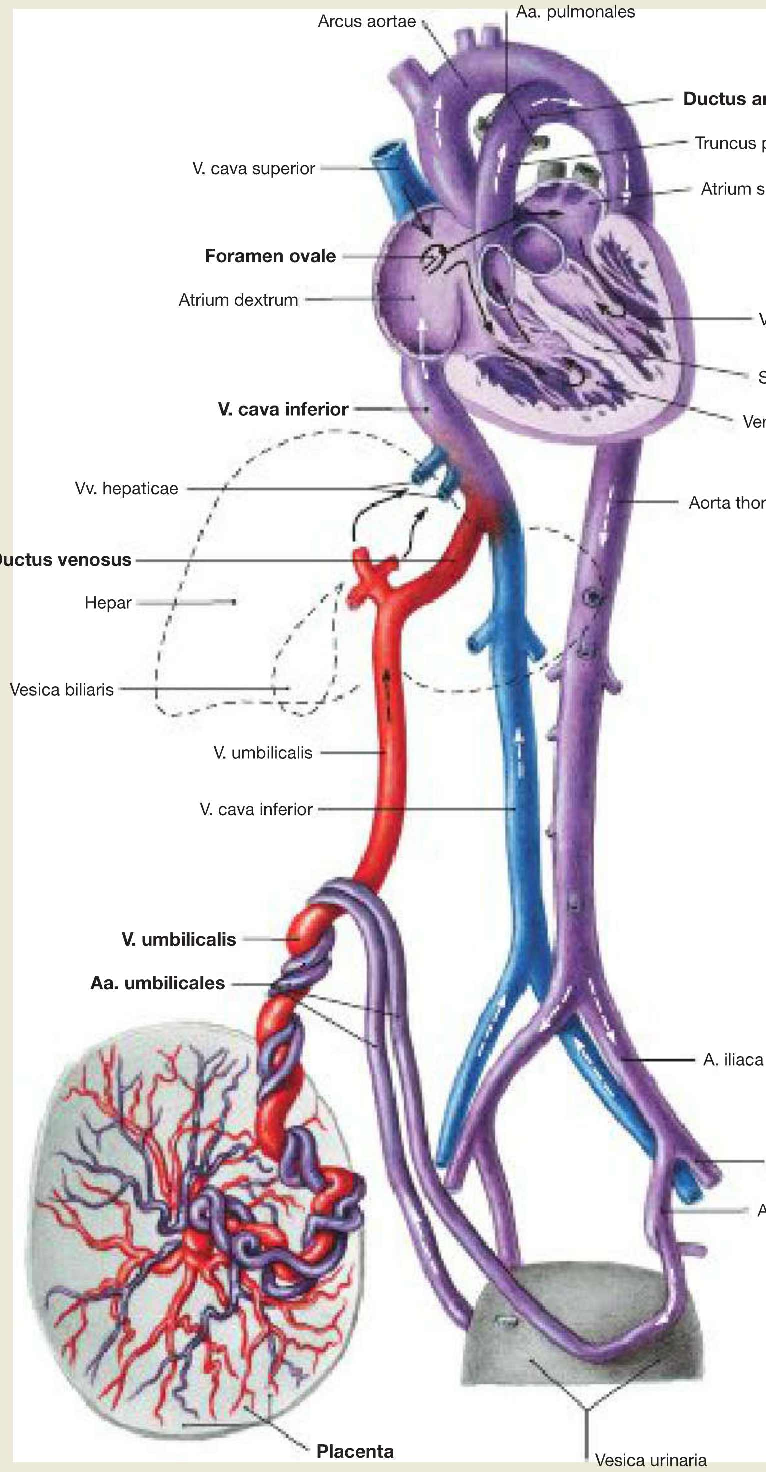


Fig. 5.36a and b Septation of the outflow tract.
[L126]
In the fifth to seventh week the outflow tract is also subdivided. In the process, the individual parts (Conus cordis, Truncus arteriosus, Saccus aorticus), which are already visible in the tubular heart (→ Fig. 5.33), are separated by bulges. Since these bulges are aligned perpendicularly to each other, the result is a twisted **Septum aorticopulmonale.** This divides the outflow tract into Aorta ascendens and Truncus pulmonalis.

Clinical Remarks

If the spiral-like subdivision of the outflow tract fails to appear, the Aorta ascendens and Truncus pulmonalis flow directly next to each other. Thereby the aorta originates incorrectly from the right ventricle and the Truncus pulmonalis from the left ventricle (= transposition of the great vessels). This malformation leads to the systemic and pulmonary circulations being completely separated from each other with no oxygenated blood going into the systemic circulation and thereby reaching the organs. In these cases, therefore the ventricular and atrial septum do not close, which means that ventricular defects are present at birth. It is possible to survive without these openings! These heart defects, comprising 5% of all heart defects, are however relatively rare.

Prenatal Circulation



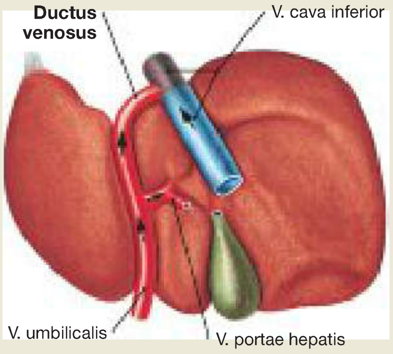
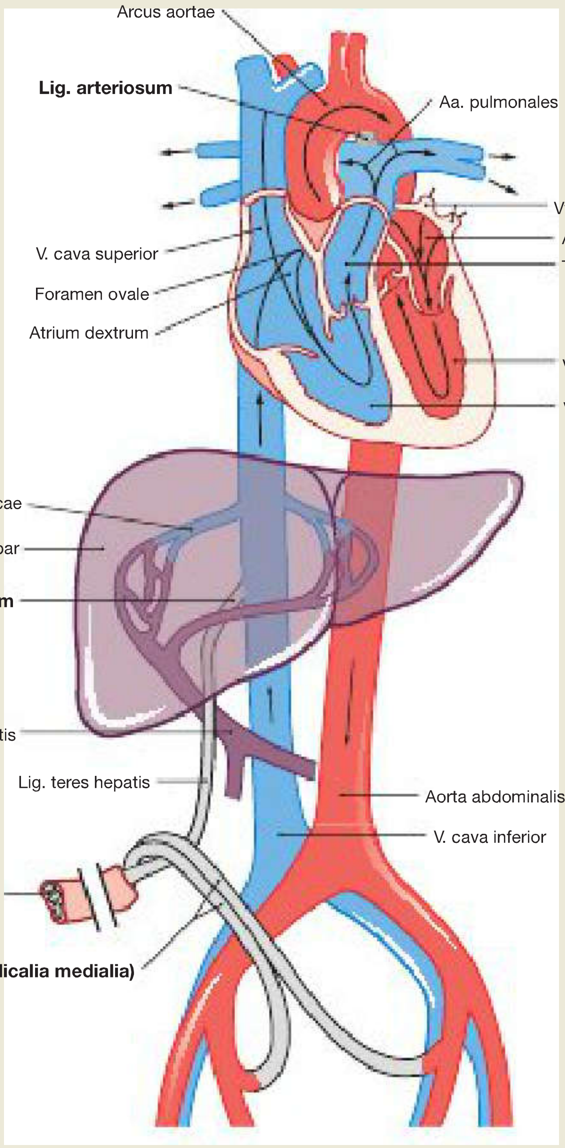


Fig. 5.38 Liver of a foetus; dorsal view.
Arrows indicate the direction of blood flow.
The **Ductus venosus** obliterates after birth into the **Lig. venosum (ARANTII)** of the porta hepatis.

Fig. 5.37 Prenatal circulation (foetal circulation); schematic diagram.
In this illustration, the oxygen content of the blood is represented by colours: oxygenated (red), deoxygenated (blue), mixed blood (purple). Arrows indicate the direction of blood flow.
Foetal circulation differs from postnatal circulation, i. a. by umbilical vessels, the Ductus venosus, the Ductus arteriosus and the Foramen ovale (→ Fig. 5.39).
The deoxygenated blood of the foetus reaches the placenta via the **Aa. umbilicales,** which are provided by the Aa. iliacae internae. From there it is brought back to the foetus after oxygenation via the V. umbilicalis and circumvents the liver via the **Ductus venosus (ARANTII)** since flow resistance in the liver is relatively high. Through a valve at the confluence of the V. cava inferior (Valvula venae cavae inferioris), the blood is channelled predominantly through the **Foramen ovale** into the left atrium. The oxygenated blood is thus taken on the shortest route to the organs. The blood of the V. cava superior enters the right ventricle and is channelled from there via the **Ductus arteriosus** (BOTALLI) as a bypass vessel from the Truncus pulmonalis into the aorta and thereby circumvents the non-functional pulmonary circulation.



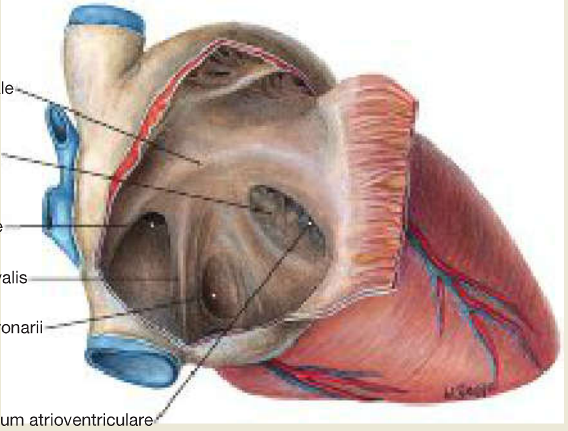


Fig. 5.40 Right atrium of a newborn; ventral view from the right side.
After birth, the Foramen ovale is initially only closed by pressure and is still visible as an opening at this time in a dissected heart.

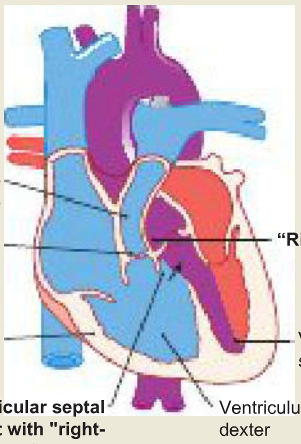
Fig. 5.39 Schematic illustration of postnatal circulation. [L126]
At birth, the placental circulation is interrupted. Breathing inflates the lungs and pulmonary circulation is opened, so that pressure in the left atrium increases. With the change from foetal to postnatal circulation, the following changes happen:
The valve-like connection of the Foramen ovale between the right and left atria is passively closed by the increased pressure in the left atrium. Later, the Valvula foraminis ovalis fuses with the septum secundum. The **Fossa ovalis** is left over from the Foramen ovale.
The Ductus arteriosus closes within a few days and becomes the **Lig. arteriosum** (→ Fig. 5.45).
The Ductus venosus obliterates after birth into the **Lig. venosum** of the porta hepatis.
The umbilical vein obliterates into the **Lig. teres hepatis** between the liver and the abdominal wall.
The distal part of the umbilical arteries becomes the right and left **Lig. umbilicale mediale** which each forms the foundation of the Plica umbilicalis medialis on the inner surface of the abdominal wall.

Clinical Remarks

Patent ductus arteriosus: since prostaglandin E_2 has a dilating effect on the ductus, an inhibitor of prostaglandin synthesis may cause a closure and possibly help avoid an operation. However, since these active substances are used to some extent as anti-inflammatory agents and analgesics, they can also cause a premature closure of the foetal Ductus arteriosus in a pregnant woman.

Patent foramen ovale: An opening in the Foramen ovale remains present in approximately 20% of adults. This is usually not relevant from a functional point of view, but can lead to thrombi in the form of emboli from the leg veins entering the systemic circulation and causing organ infarctions and strokes in the brain.

Heart Defects



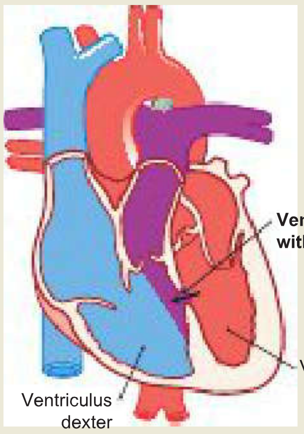


Fig. 5.41a and b Heart defect: Tetralogy of FALLOT (→ Fig. 5.41a) and ventricular septal defect (→ Fig. 5.41b), schematic diagram; ventral view. [L126]

When the relatively complicated septation processes during heart development do not take place, children with heart defects are born. Understanding of the development is necessary for diagnostics and the most of the operative treatment.

If the outlet flow is not divided symmetrically, **tetralogy of FALLOT** ensues. This is the most common malformation (9% of all heart defects) with **right-to-left shunting,** where blood from the right ventricle flows out into the systemic circulation. The **ventricular septal defect** is the most common malformation of the heart overall (25% of all heart defects). Here, the Septum interventriculare, mostly in the area of the Pars membranacea, does not close completely, so that blood from the left ventricle is pumped into the pulmonary circulation described as **left-to-right shunting**.

Clinical Remarks

Congenital heart defects occur in 0.75% of all newborn babies and thus are the most common developmental disorders. Fortunately, however, not all heart defects **(vitia)** require treatment, as they are often not functionally relevant. In order to understand the genesis and clinical symptoms of major heart defects in paediatric and adolescent medicine, you have to become familiar with the fundamental development of the heart at the very least. Due to their medical importance and exam relevance in various subjects, the most important congenital heart defects will be discussed briefly here. Pathophysiologically, the most common heart defects can be divided into three groups:

- The most common group comprises defects with **left-to-right shunting** (ventricular septal defect 25%, atrial septal defect 12%, patent Ductus arteriosus 12%) where, due to increased pressure in the systemic circulation, blood flows from left to right into the pulmonary circulation. Pulmonary hypertension leads to right heart insufficiency if no operational restructuring is taken.
- Defects with **right-to-left shunting** (Tetralogy of FALLOT 9%, transposition of the great vessels 5%) are, in contrast, characterised by a bluish colouring of the skin (cyanosis) because deoxygenated blood from the pulmonary circulation enters the systemic circulation.
- The third group comprises **defects with obstruction** (pulmonary valve stenosis, aortic valve stenosis, coarctation of the aorta, 6% each), where hypertrophy of the respective ventricle occurs.

Tetralogy of FALLOT is a combination of ventricular septal defect, pulmonary valve stenosis, right ventricular hypertrophy and 'overriding' aorta. Because of asymmetric septation of the Conus arteriosus, the pulmonary valve is too narrow and the aorta too wide and displaced over the septum ('overriding'). Because of the narrow pulmonary valve, right ventricular hypertrophy ensues, which is responsible for the right-to-left shunting through the ventricular septal defect and thus the cyanosis.

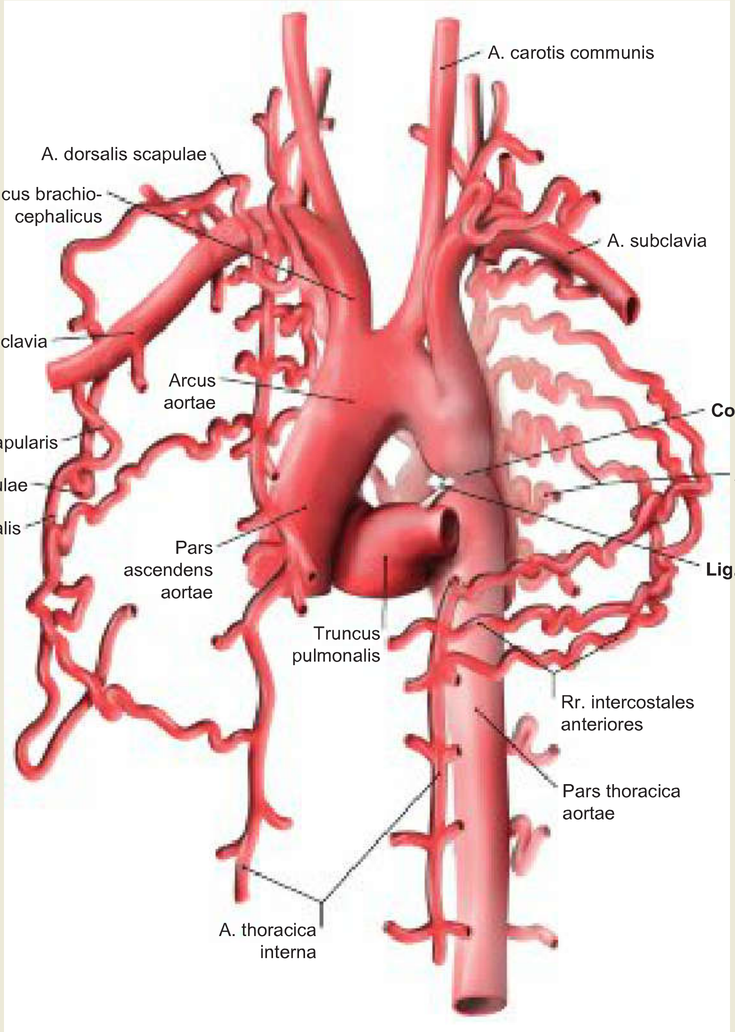


Fig. 5.42 Coarctation of the aorta, semi-schematic diagram; ventral view. [L266]
After birth, the Ductus arteriosus closes due to increased oxygen content in the blood. When the occlusion of the Ductus arteriosus encroaches upon the surrounding parts of the Arcus aortae, a coarctation of the aorta ensues.

Clinical Remarks

Coarctation of the aorta: in a coarctation of the aorta, hypertrophy of the left heart with hypertension in the upper half of the body ensues. In contrast, pressure in the lower half of the body is too low. What stands out diagnostically is a systolic cardiac murmur between the shoulder blades as well as radiographically visible rib defects because of bypass circulations of the Aa. intercostales to the A. thoracica interna. The stenosis must be corrected via an operation or by dilation, otherwise heart failure and strokes can ensue even at a young age. Since prostaglandins in the blood keep the Ductus arteriosus open by atony of the muscle, an inhibitor of prostaglandin synthesis may be used to facilitate a closure still outstanding after birth. Since these active substances are included to some extent in medication for inflammation and pain relief, in pregnant women they can cause premature occlusion of the Ductus arteriosus with damage to the foetus.

Heart Position

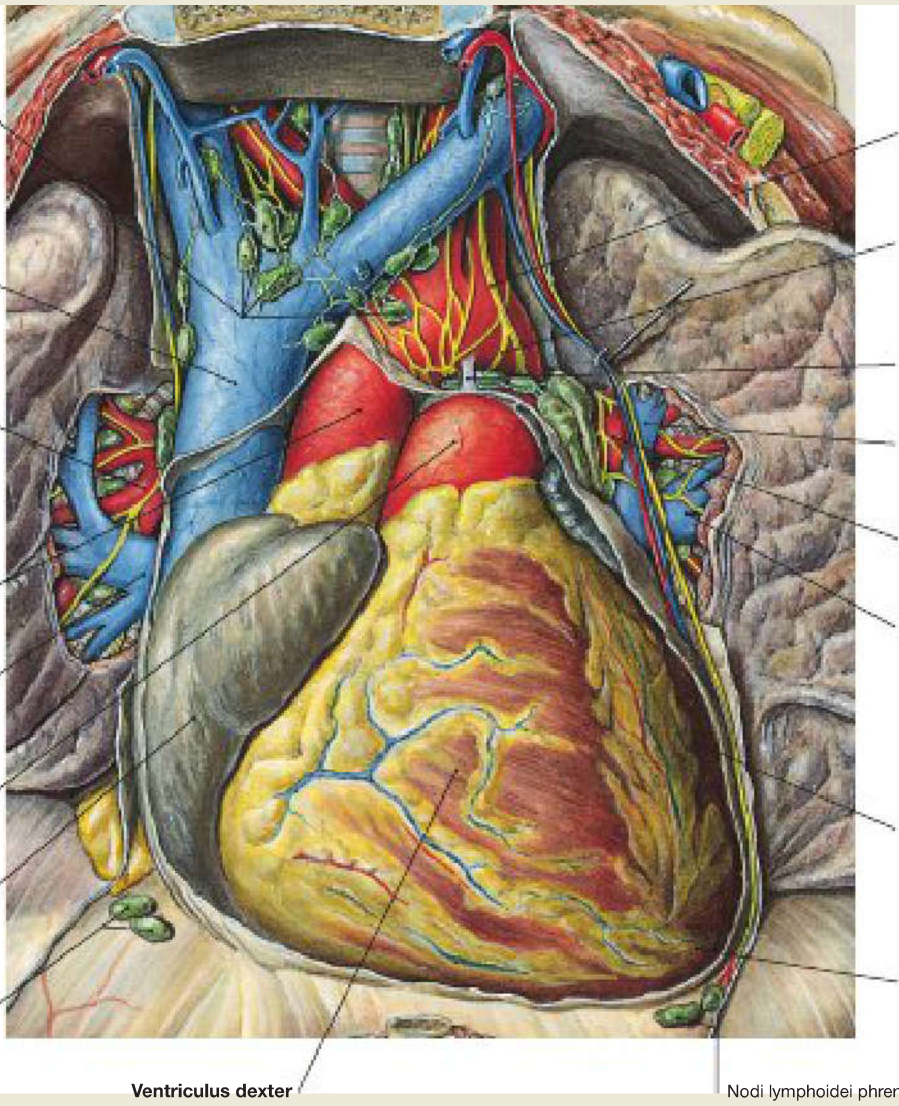


Fig. 5.43 Location of the heart, Cor, in the thorax, Situs cordis; ventral view; after opening of the pericardium.

The heart lies in the pericardial cavity (Cavitas pericardiaca) in the lower middle mediastinum. The heart has a broad base which is aligned upwards and to the right and which corresponds to the valve level at the source of the great vessels. The apex of the heart (Apex cordis) points downwards to the left and to the front. Base and apex are connected by the **longitudinal axis** (12 cm) which runs an oblique course in the thorax from right dorsal top to the left ventral bottom and thus forms an angle of approximately 45° with all three spatial planes. The heart has four surfaces (→ Fig. 5.29). The anterior surface of the heart **(Facies sternocostalis)** is formed predominantly by the right ventricle. The inferior surface lies adjacent to the diaphragm **(Facies diaphragmatica)** and consists of parts of the right and left ventricles. Clinically, the inferior surface corresponds in this to the 'posterior wall' in ECG diagnostics, if, for example it is a matter of posterior wall myocardial infarction. The **Facies pulmonalis** is encased by the right atrium on the right side and by the left ventricle on the left side.

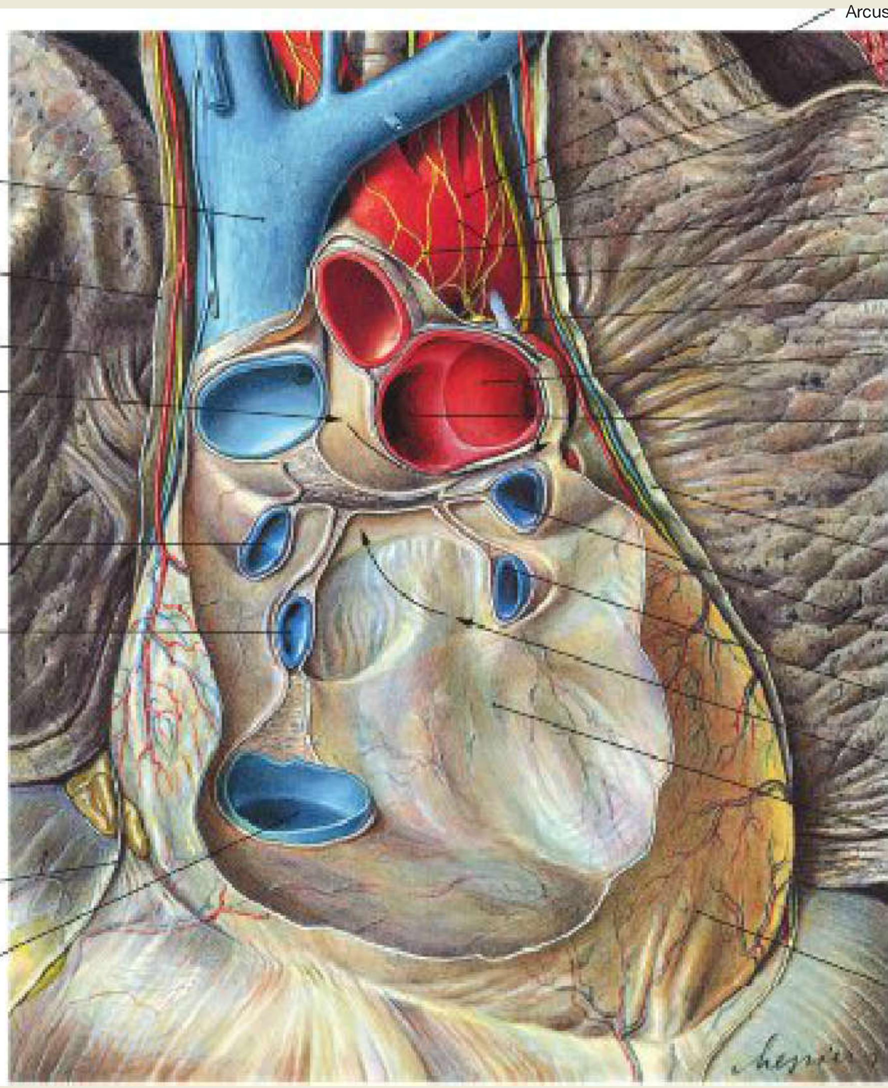


Fig. 5.44 Pericardium; ventral view; after removal of the posterior wall of the pericardium and the heart.

The pericardium surrounds the heart, stabilises its position and enables the heart to contract without friction. The pericardium consists on the outside of a **Pericardium fibrosum** of dense connective tissue, adjacent to which on the inside lies a serosa as the **Pericardium serosum**. This part of the Pericardium serosum constitutes the Lamina parietalis, which, ventrally at the outflow of the great vessels, folds back onto the upper surface of the heart as the visceral layer (= **epicardium**). On the posterior side of the atria, the reflecting folds of the pericardium onto the epicardium form a vertical fold between the Vv. cavae inferior and superior and a horizontal fold between the upper pulmonary veins of the right and left sides. This creates two recesses on the posterior side of the pericardium (Sinus pericardii, arrows):

- **Sinus transversus pericardii:** above the horizontal fold between the V. cava superior or aorta and Truncus pulmonalis
- **Sinus obliquus pericardii**: below the horizontal fold between the pulmonary veins on both sides

The **Pericardium fibrosum** is connected with:

- the Centrum tendineum of the diaphragm
- the posterior side of the sternum (Ligg. sternopericardiaca)
- the tracheal bifurcation (Membrana bronchopericardiaca)

On the outside, the **Pleura parietalis, Pars mediastinalis** cover the pericardium. The N. phrenicus and the Vasa pericardiacophrenica run between these two layers.

The epicardium is the visceral layer of the Pericardium serosum.

Clinical Remarks

The pericardial cavity usually contains 15–35 ml of serous fluid. The pericardium, including the heart, has a total volume of 700–1,100 ml. In heart failure or inflammation of the pericardium **(pericarditis),** fluid can accumulate **(pericardial effusion)** and even affect heart action.

In the case of rupture of the heart wall after a heart attack or through an injury (knife stab), **cardiac tamponade** can ensue, in which blood inhibits cardiac function and which, therefore, generally has a fatal result.

Heart

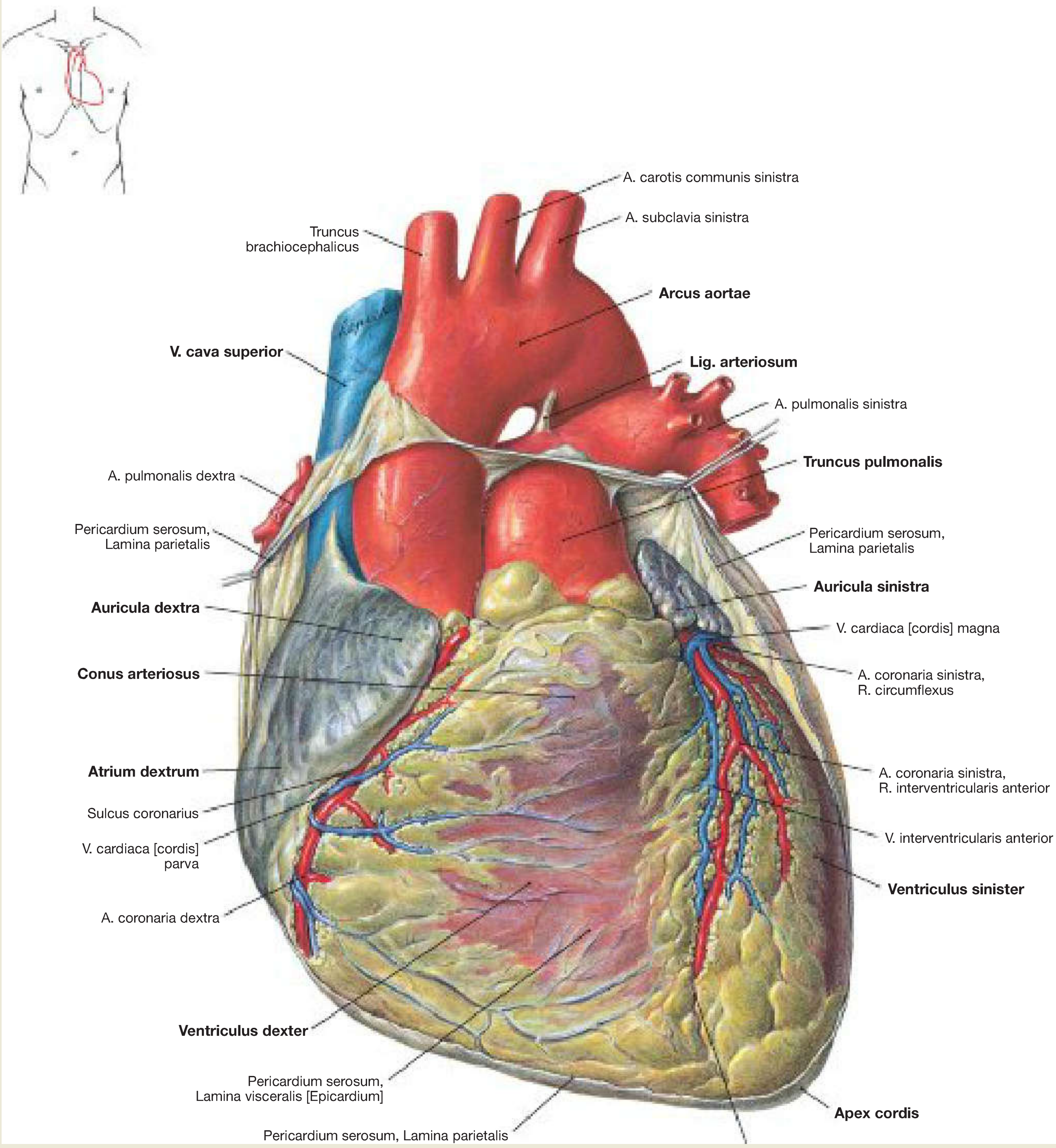


Fig. 5.45 Heart, Cor; ventral view.
The heart weighs 250–300 g and is approximately the size of the fist of the respective person. The apex of the heart (Apex cordis) faces downwards and to the left. The base corresponds to the position of the **Sulcus coronarius,** in which, i.a., the A. coronaria dextra flows. The heart consists of a ventricular chamber (ventricle) and an atrial chamber (atrium) on the right and left side, respectively. On the anterior side (Facies sternocostalis), the **Sulcus interventricularis anterior** reveals the position of the cardiac septum (Septum interventriculare) in which the R. interventricularis anterior of the A. coronaria sinistra flows. The boundary of the ventricle in the **Sulcus interventricularis posterior** (→ Fig. 5.46) is on the inferior side (Facies diaphragmatica). Prior to its transition into the Truncus pulmonalis, the right ventricle is expanded to the Conus arteriosus. In contrast, the source of the aorta from the left ventricle is not visible from outside due to the spiralling course of the aorta behind the Truncus pulmonalis. Therefore, the aorta originates to the right of the Truncus pulmonalis. This is connected to the Arcus aortae via the Lig. arteriosum, a developmental remnant of the Ductus arteriosus of the foetal circulation (→ Fig. 5.37). Both atria have a blind pouch, which are referred to as the right and left auricle (Auriculae dextra and sinistra). The Vv. cavae superior and inferior enter the right atrium, and the four pulmonary veins enter the left atrium.

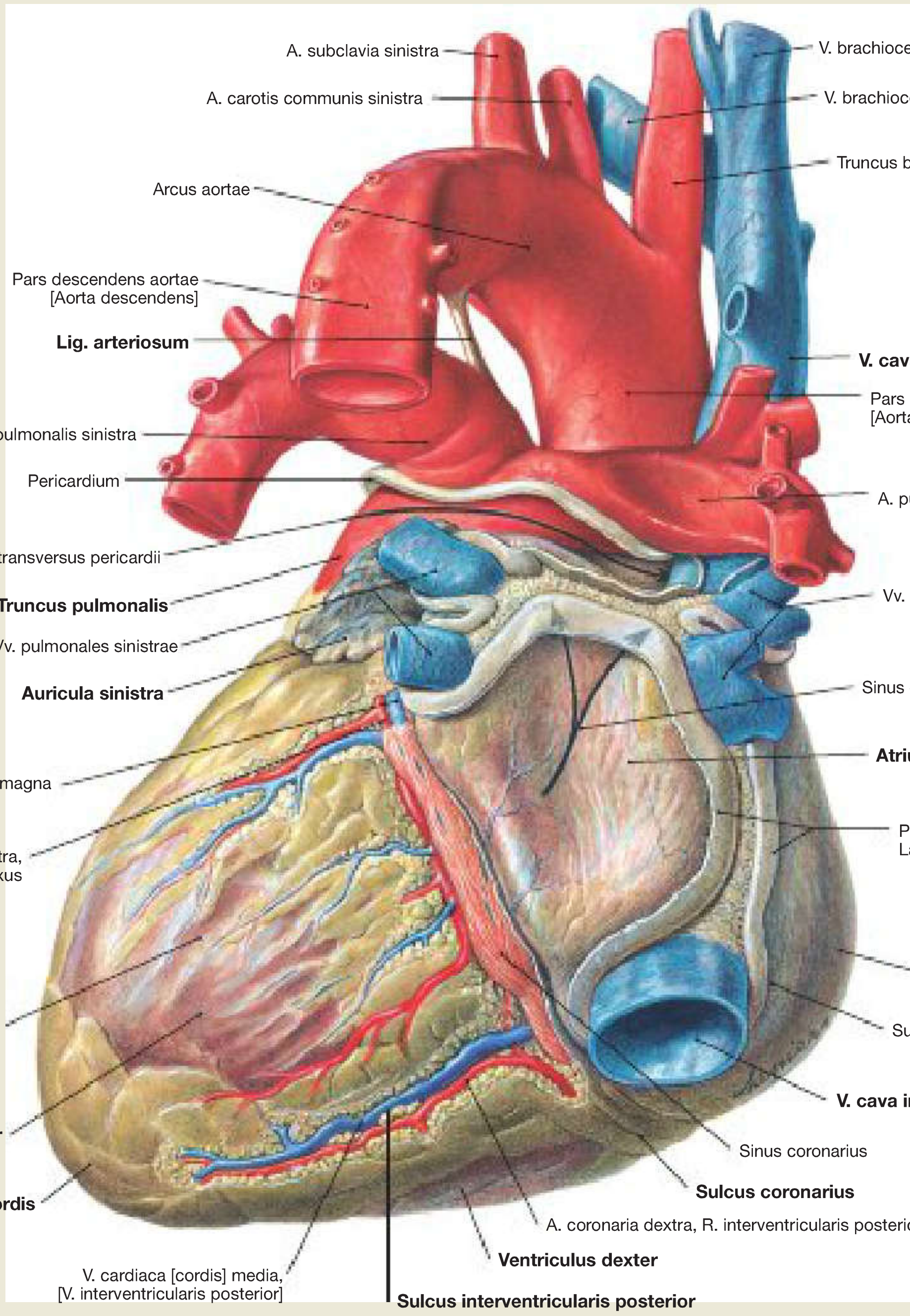


Fig. 5.46 Heart, Cor; dorsal view (explanation → Fig. 5.45).

Clinical Remarks

Most of the hearts seen in dissection lectures are enlarged. This indicates how frequently diseases accompanied by **hypertrophy** (e.g. hypertension) or **dilation** (e.g. alcohol abuse, viral diseases, genetic causes) of the heart occur.

The weight of the heart in professional athletes (through training, anabolic substances) may reach 500 g. This is seen as a **critical heart weight** since sufficient blood supply is not guaranteed above this weight and can lead to myocardial infarction.

Heart Wall

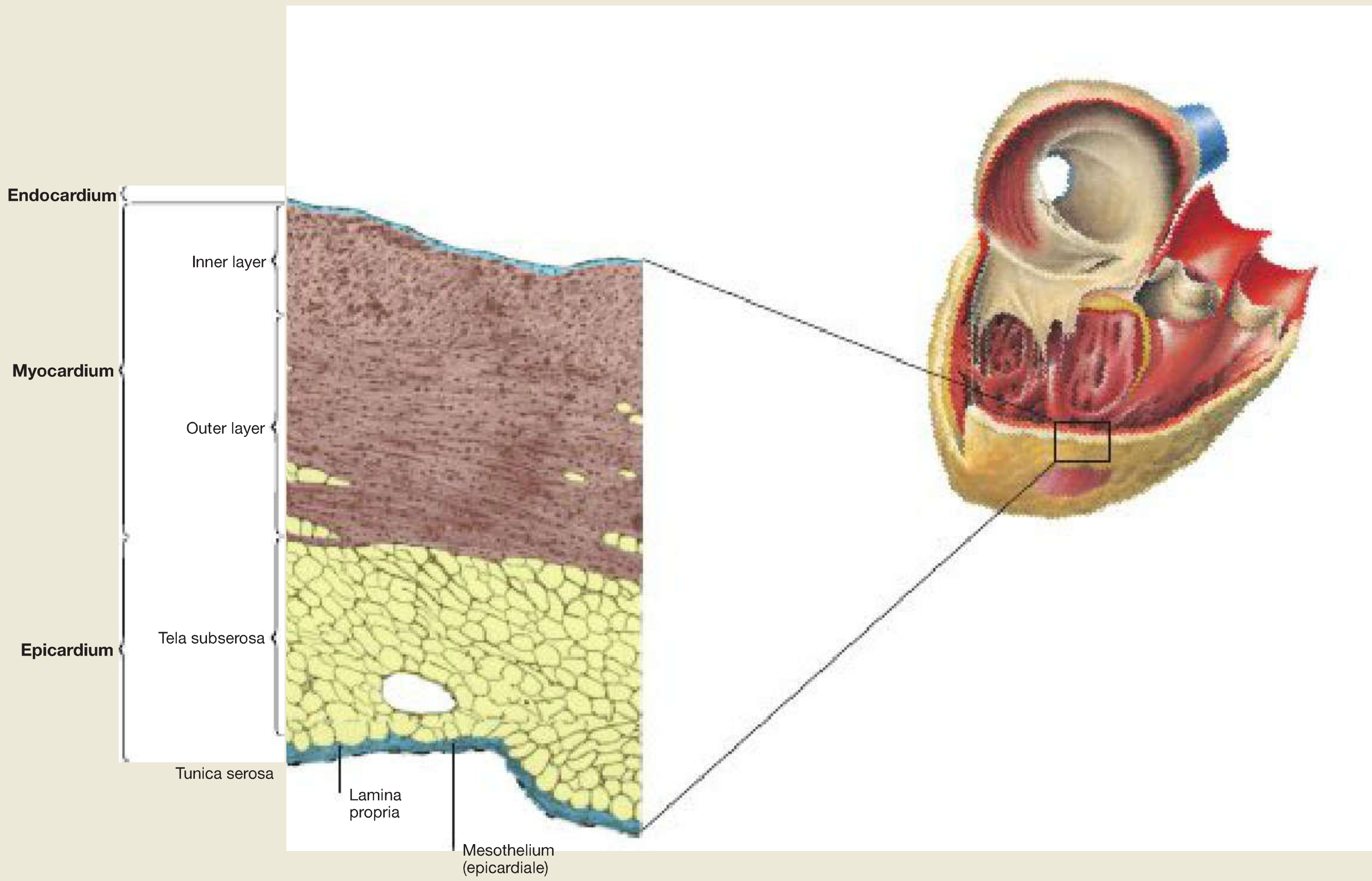


Fig. 5.47 Construction of the heart wall; extract from the right atrium. (according to [S010-2-16])
The wall of the heart is composed of three layers:

- **Endocardium:** inner surface consisting of endothelium and connective tissue
- **Myocardium:** cardiac muscle made from cardiomyocytes
- **Epicardium:** serosa and subserosa on the outer surface correspond to the visceral layer of the Pericardium serosum. In people, the subserosa contains a lot of fat tissue, in which the blood vessels and nerves of the heart are embedded.

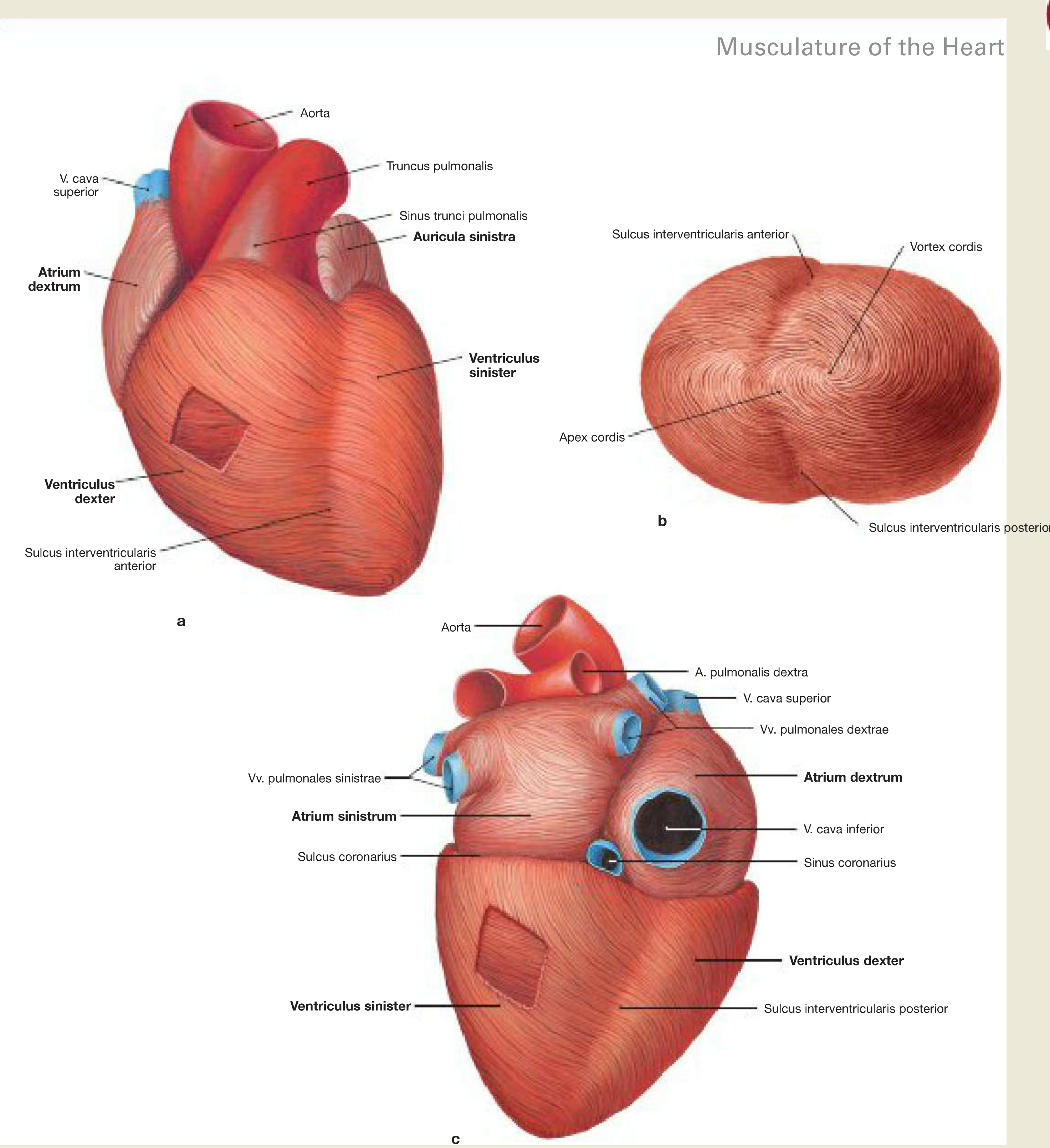


Fig. 5.48a to c Cardiac musculature, Myocardium; ventral view (→ Fig. 5.48a) from the apex of the heart (→ Fig. 5.48b), and dorsal caudal view (→ Fig. 5.48c).
The heart muscle fibres are made up of individual cardiomyocytes and run spirally around the heart. In the wall of the atria and the right ventricle they form two layers; in the case of the left ventricle even three layers. The myocardium and thereby also the entire heart wall are much thicker in the area of the left ventricle because the left ventricle has to pump blood into the systemic circulation at a higher pressure than the right ventricle. Wall thickness to the right is 3–5 mm, to the left, however, 8–12 mm.

Clinical Remarks

Hypertrophy presents when the wall thickness of the **left ventricle is over 15 mm,** which may be caused by hypertension or an aortic valve stenosis. With the **right ventricle,** hypertrophy is already present at **more than 5 mm.** In addition to pulmonary valve stenosis, another cause that should be considered is pulmonary hypertension caused by chronic obstructive pulmonary diseases such as asthma or by a pulmonary embolism.

Heart

Chambers of the Heart

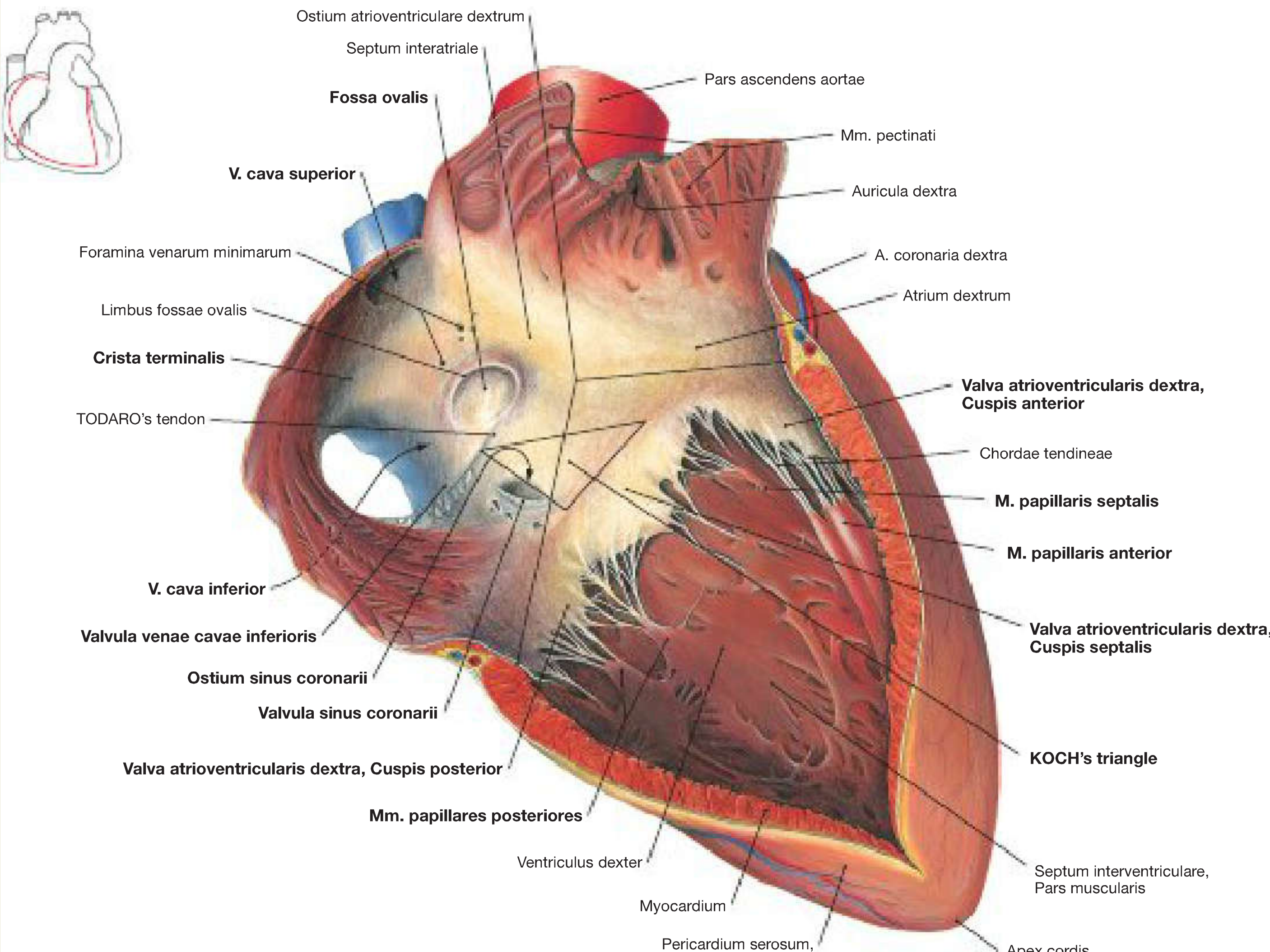
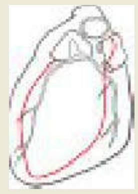


Fig. 5.49 Right atrium, Atrium dextrum, and right ventricle, Ventriculus dexter; ventral view.

The right atrium consists of a part with a smooth inner surface, the atrial sinus (Sinus venarum cavarum), and a muscular part, the rough inner surface of which consists of pectinate muscles (Mm. pectinati). Between the two parts lies the **Crista terminalis,** constituting an important landmark because the sinus node of the electrical stimulation and conduction system lies at its height on the outside (subepicardial) between the confluence of the V. cava superior and the right auricle (Auricula dextra; → Fig. 5.51). In the interatrial septum (Septum interatriale) is a remnant of the Foramen ovale, the **Fossa ovalis,** the edge of which is raised to the Limbus fossae ovalis. The opening of the **Sinus coronarius** (Ostium sinus coronarii), which constitutes the largest cardiac vein, has a valve (Valvula sinus coronarii) and the opening of the V. cava inferior is also flanked by a valve (Valvula venae cavae inferioris); both of them, however, do not seal the lumen. Even small cardiac veins discharge directly into the right atrium (Foramina venarum minimarum). The TODARO's tendon (Tendo valvulae venae cavae inferioris) is an extension of the Valvula venae cavae inferioris. This also serves as a significant landmark because it, together with the confluence of the coronary sinus and the tricuspid valve (Valva atrioventricularis dextra), delineates the **KOCH's triangle,** in which the AV node is located (→ Figs. 5.61 to 5.63). In the right ventricle, the three cusps are attached via tendinous cords (Chordae tendineae) to three papillary muscles (Mm. papillares anterior, posterior and septalis). Of the Septum interventriculare only the muscular part is visible here. Fibres (not visible here) of the electrical conduction system (Leonardo Da Vinci's moderator band) stretch from here to the anterior papillary muscle. This connection is referred to as the **Trabecula septomarginalis** (→ Fig. 5.63).

Fig. 5.50 Left and right ventricles, Ventriculus sinister and Ventriculus dexter; cross-section, cranial view.

Because of the substantially stronger muscle layer, the wall of the left ventricle is thicker than the wall of the right ventricle. The arrangement of the heart muscle cells indicates that the Septum interventriculare is functionally a part of the left ventricle.



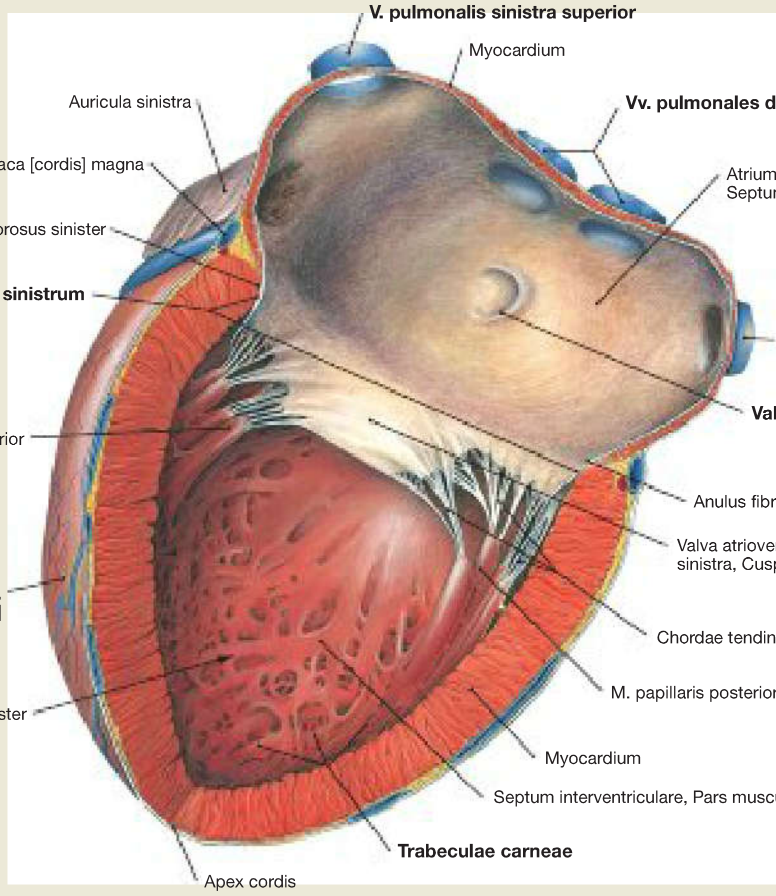
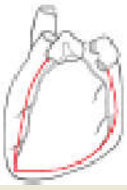


Fig. 5.51 Left atrium, Atrium sinistrum, and left ventricle, Ventriculus sinister; lateral view.
The left atrium contains the left auricle (Auricula sinistra). The four pulmonary veins (Vv. pulmonales) flow into it. The Valvula foraminis ovalis obtrudes as a crescent-shaped leaflet at the septal wall. It is a remnant of the Septum primum of heart development (→ Fig. 5.35). The Ostium atrioventriculare sinistrum contains the Valva mitralis and constitutes the connection to the left ventricle. The wall of the ventricle is not smooth but roughened by muscle trabeculae (Trabeculae carneae).

Chambers of the Heart



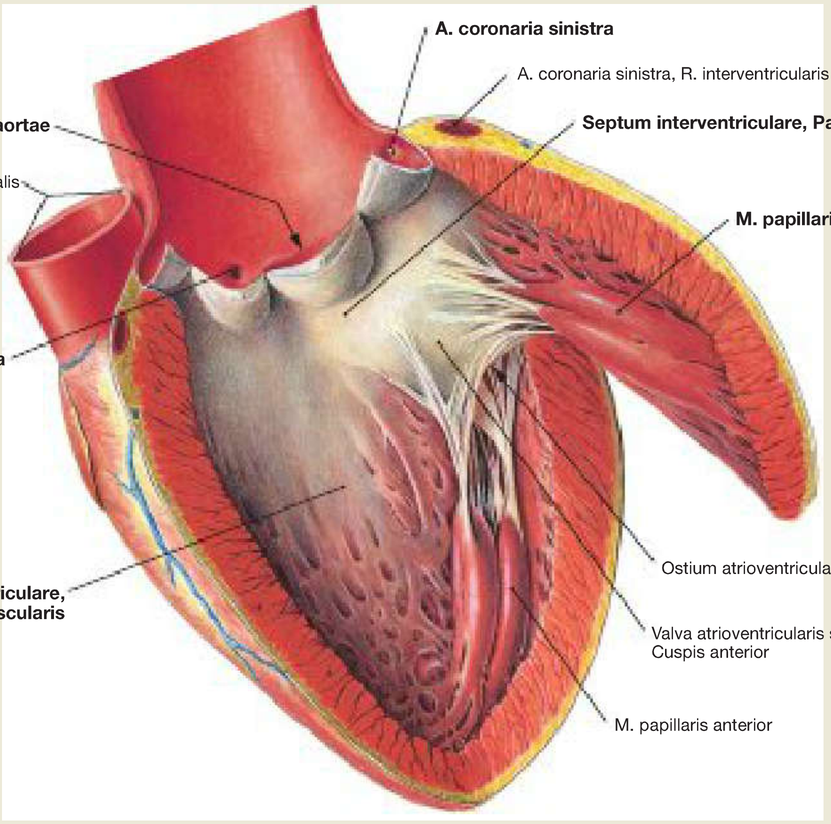


Fig. 5.52 Left ventricle, Ventriculus sinister; lateral view.
Beneath the left atrioventricular valve lies the roughly 1 cm^2 large area of the **membranous part** of the ventricular septum. In contrast, the largest part of the ventricular septum consists of the muscular part (Pars muscularis). Behind the semilunar valves of the aortic valve lie the Sinus aortae, in which the right and left **coronary arteries** (Aa. coronariae dextra and sinistra) originate.

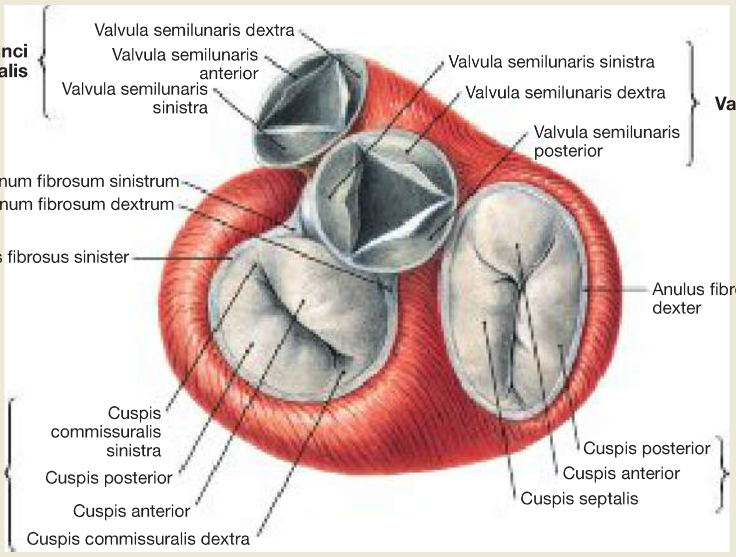


Fig. 5.53 Heart valves, Valvae cordis; cranial view, after removal of the atria, aorta and Truncus pulmonalis.

The heart has two **cuspidal valves (Valvae cuspidales),** one between the atria and one between the ventricles. The right atrioventricular valve (Valva atrioventricularis dextra) consists of three cusps **(tricuspid valve).** The left atrioventricular valve (Valva atrioventricularis sinistra) is formed of two cusps **(mitral valve).** The cuspidal valves are anchored to the papillary muscle via tendinous cords (Chordae tendineae), which prevent prolapse of the valves. Between the ventricles and great vessels there is also the **aortic valve** (Valva aortae) to the left and on the right side is the **pulmonary valve (Valva trunci pulmonalis),** both of which are formed from three semilunar cusps (Valvulae semilunares). In the expulsion phase of the **systole,** when blood is ejected from the ventricles into the great vessels, the **semilunar valves are opened** and the cuspidal valves closed. In the filling phase of the **diastole,** the **cuspidal valves are open** in order to take blood from the atria into the ventricles. The semilunar valves are closed.

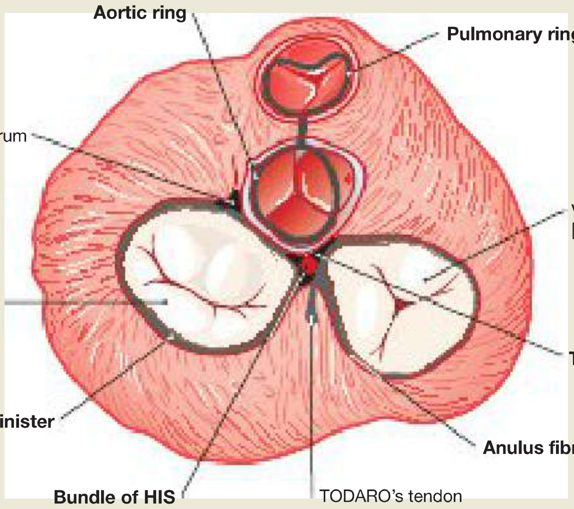
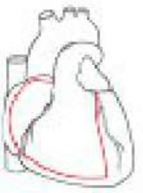


Fig. 5.54 Skeleton of the heart; cranial view, schematic diagram. [L126]

The cardiac valves are anchored to the cardiac skeleton. This consists of connective tissue that respectively forms a ring (Anuli fibrosi dexter and sinister) around the atrioventricular valves (Valvae atrioventriculares) as well as a fibrous ring around the semilunar valves. Between the Anuli fibrosi lies the Trigonum fibrosum dextrum through which the bundle of HIS of the electrical conduction system passes from the right atrium into the Septum interventriculare. In addition to the **stabilisation of the heart valves** the cardiac skeleton also serves as an **electrical insulation of the atria and ventricles,** because all the muscle cells of the heart are attached to the cardiac skeleton and thus do not encroach on the ventricles from the atria. Thus the stimulus is transmitted to the ventricles only via the bundle of HIS.

Heart Valves



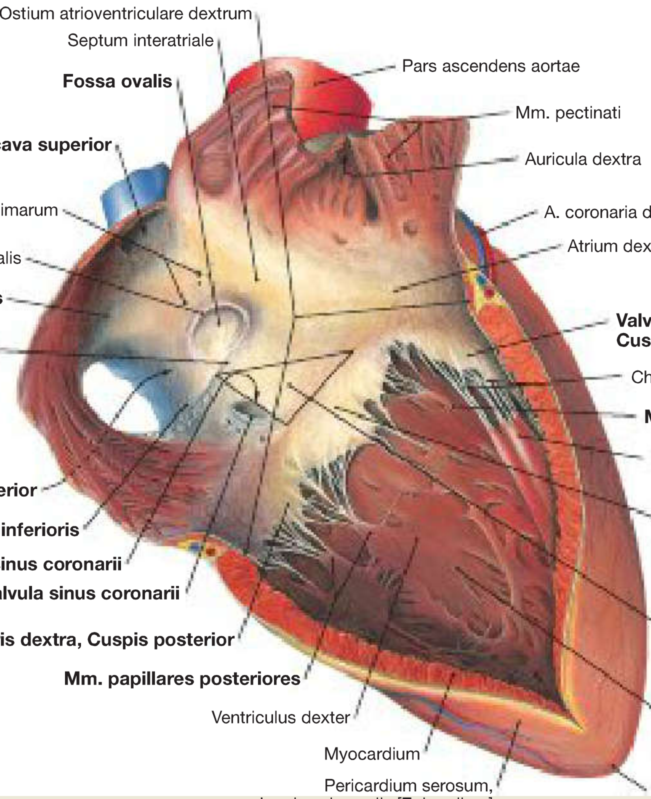
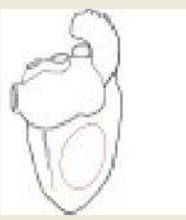


Fig. 5.55 Right atrioventricular valve, Valva atrioventricularis dextra; ventral view.
The right atrium and the right ventricle are separated by the tricuspid valve (Valva atrioventricularis dextra). This consists of three cusps which are attached via tendinous cords (Chordae tendineae) to three **papillary muscles** (anterior, posterior and septal). Through active contraction of the papillary muscles during ventricle contraction, the cusps can be prevented from shooting back into the atrium.



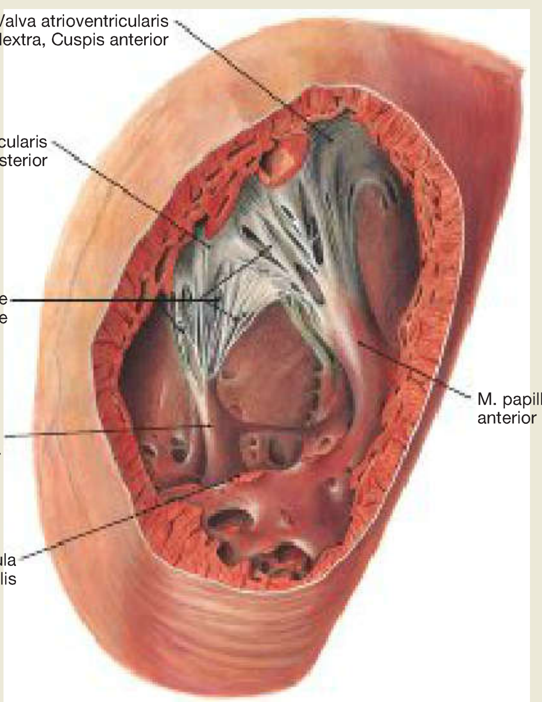


Fig. 5.56 Papillary muscles of the right atrioventricular valve, Valva atrioventricularis dextra; dorsal view.
The right ventricle is opened from the septum onwards, showing two of the three **papillary muscles** (Mm. papillares). The **tendinous cords** (Chordae tendineae) connect the M. papillaris anterior with the anterior cusp (Cuspis anterior) of the tricuspid valve (Valva atrioventricularis dextra) and the posterior papillary muscle with the posterior cusp (Cuspis posterior).

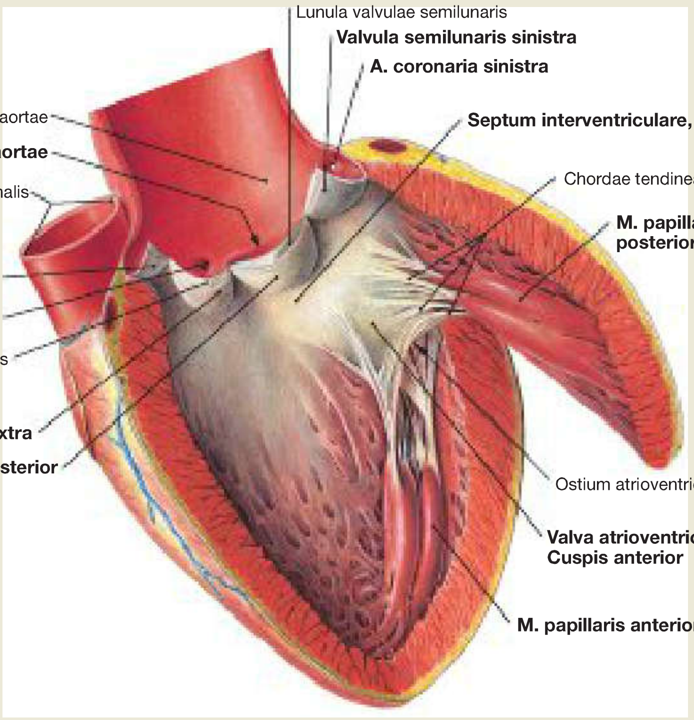


Fig. 5.57 Left atrioventricular valve, Valva atrioventricularis sinistra, and aortic valve, Valva aortae; lateral view.
The mitral valve (Valva atrioventricularis sinistra) is only composed of two cusps; correspondingly there are only two **papillary muscles** (Mm. papillares anterior and posterior). Blood is pumped via the **aortic valve (Valva aortae),** which consists of three semilunar valves (Valvulae semilunares), into the expanded part of the aorta (Bulbus aortae).

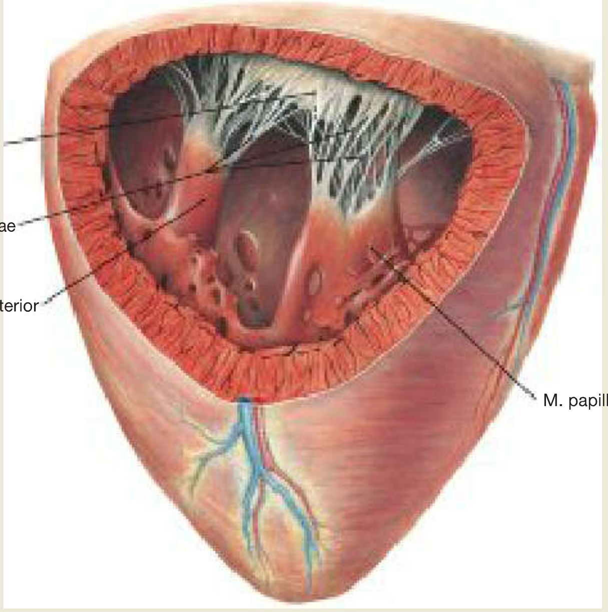


Fig. 5.58 Papillary muscles of the left atrioventricular valve, Valva atrioventricularis sinistra; ventral cranial view.
The left ventricle is opened in such a way that the two **papillary muscles** of the mitral valve can be identified. The **tendinous cords (Chordae tendineae)** connect the M. papillaris anterior with the anterior cusp (Cuspis anterior) of the Valva atrioventricularis sinistra and the M. papillaris posterior with the posterior cusp (Cuspis posterior).

Projection of the Heart Valves

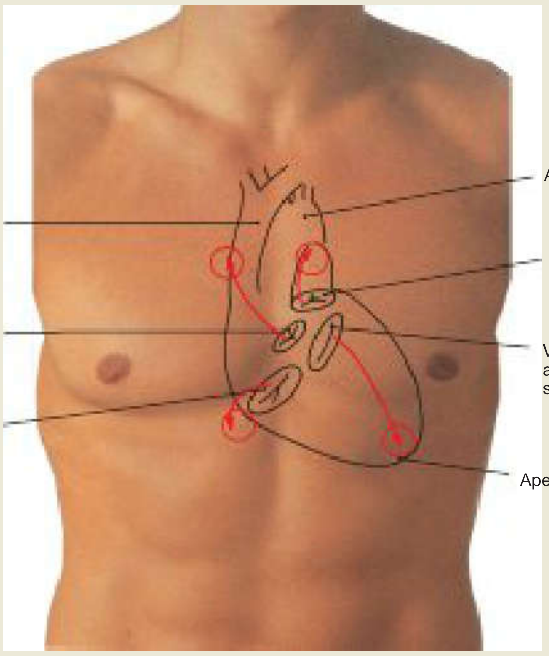


Fig. 5.59 Projection of the heart valves and auscultation sites on the anterior thoracic wall.
The **projection of the four heart valves** forms a cross, slightly shifted to the left from the median plane. The projection of the valves is of minor practical importance since heart sounds and also heart murmurs which may arise in the area of the valves are transmitted (arrows) with the blood stream to points of maximum impulse (circles), where the heart is sounded (auscultated).

	Projection Points of the Heart Valves	Auscultation Sites of the Heart Valves
Pulmonary Valve	Left (!) sternal border, 3rd costal cartilage	2nd ICS left parasternal
Aortic Valve	Left sternal border, 3rd ICS	2nd ICS right parasternal
Mitral Valve	4th–5th costal cartilages left	5th ICS left in the midclavicular line
Tricuspid Valve	behind the sternum, 5th costal cartilage	5th ICS right parasternal

ICS = intercostal space

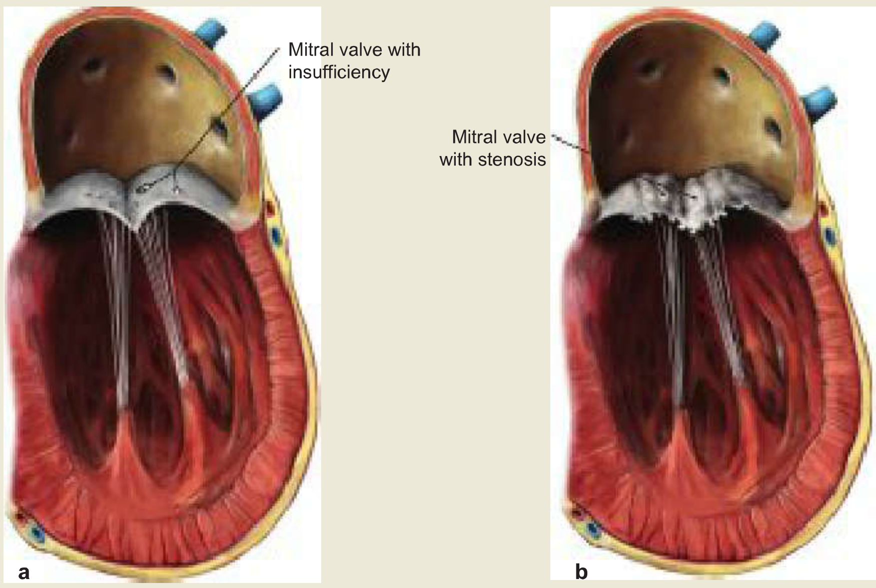


Fig. 5.60 Pathological change of the heart valves using the example of the mitral valve. a Mitral insufficiency, **b** Mitral stenosis. [L266]

Besides congenital stenoses of the heart valves, which are regarded as heart defects (vitia), other defects or deformations of the heart valves, which accompany an insufficiency or stenosis, can ensue, caused e.g. by inflammatory processes.

Clinical Remarks

When sounding the heart with a stethoscope **(auscultation)**, one hears at various points the **heart sounds,** which result from the action of the heart:

- The **first heart sound** is created at the beginning of the systole by ventricular contraction and recoiling of the cuspidal valves.
- The **second heart sound** is generated at the beginning of the diastole by the closure of the semilunar valves.

Heart murmurs, however, are not present in healthy people and are caused by malfunction of the valves. Both narrowing (stenosis) as well as insufficient closure (failure) of the valves may cause murmurs. The timing of the murmur and its localisation give information on the malfunction of the respective valves.

The murmurs are loudest at the respective auscultation points of the valves. If during the **systole** (i.e. between the first and second heart sounds) a murmur occurs above a **cuspidal valve,** this means there is a **failure** because the valve should be closed at this stage. If a murmur can be heard in the **diastole** above the cuspidal valve, this suggests a **stenosis** since the valve should be open in the filling phase. With the **semilunar valves** it is exactly **the opposite.** Stenoses can be either congenital or acquired (rheumatic diseases, bacterial endocarditis). Failures are usually acquired and can also be caused by heart attacks if the papillary muscles, which anchor the cuspidal valves, are damaged.

Electrical Stimulation and Conduction System of the Heart

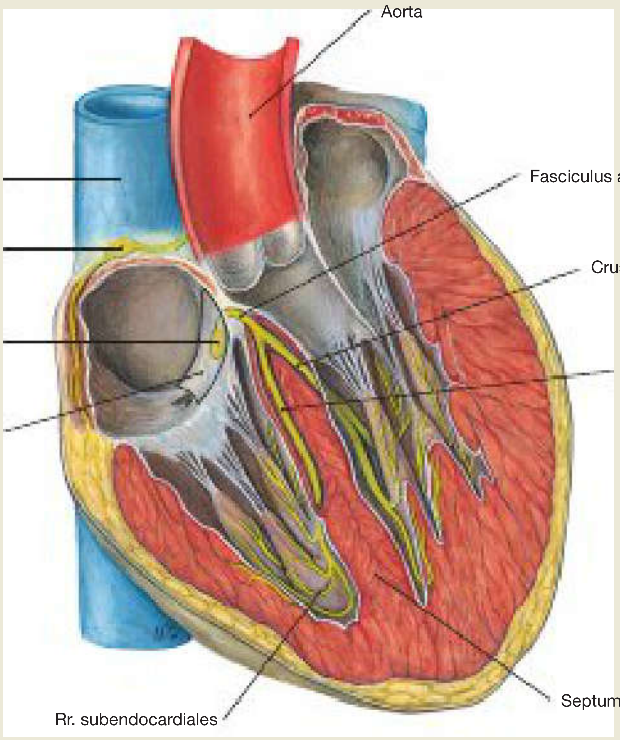


Fig. 5.61 Electrical stimulation and conduction system along the cardiac axis of a sectioned heart.
The heart has an electrical stimulation and conduction system that is built from modified heart muscle cells (no nerve fibres!). It is divided into four parts:

- **Sinus node** (Nodus sinuatrialis, KEITH-FLACK node)
- **AV node** (Nodus atrioventricularis, ASCHOFF-TAWARA node)
- **Atrioventricular bundle** (Fasciculus atrioventricularis, bundle of HIS)
- **Bundle branches** (Crura dextrum and sinistrum, TAWARA branches)

The electrical stimulation is initiated independently within the sinus node by spontaneous depolarisation of the muscle cells and has a frequency of approximately 70/min. The **Nodus sinuatrialis (sinus node)** is approximately 3 × 10 mm large and is located in the wall of the right atrium subepicardially between the confluence of the V. cava superior and the right auricle within a groove (Sulcus terminalis cordis), to which the crista terminalis corresponds on the inner surface. Sometimes the node is covered by subepicardial fat so that it is visible to the naked eye. The sinus node has its own artery (R. nodi sinuatrialis), which usually originates from the A. coronaria dextra. From the Nodus sinuatrialis stimulation is conducted via the myocardium of the atrium to the **AV node,** which slightly delays the stimulation in order to allow adequate filling of the ventricle.
The AV node is approximately 5×3 mm large and located in the KOCH's triangle, embedded into the myocardium of the atrioventricular septum. The KOCH's triangle is confined by TODARO's tendon, the opening of the sinus coronarius and the septal cusp of the tricuspid valve (→ Fig. 5.55). The AV node also has its own arterial supply (R. nodi atrioventricularis), which usually originates from the dominant coronary artery (in most cases the A. coronaria dextra) near the outflow of the R. interventricularis posterior.
From the AV node, the electrical signal is conveyed by the **bundle of HIS** (approx. 4×20 mm), which passes through the right fibrous trigone, into the ventricular septum.
In the membranous part of the septum, the bundle of HIS divides into the **bundle branches.** The left TAWARA branch divides into an anterior, a septal and a posterior fascicle to the respective parts of the myocardium including the papillary muscles as well as to the apex of the heart. The right bundle branch descends subendocardially within the septum to the apex of the heart and reaches the anterior papillary muscle via the Trabecula septomarginalis (→ Fig. 5.63).

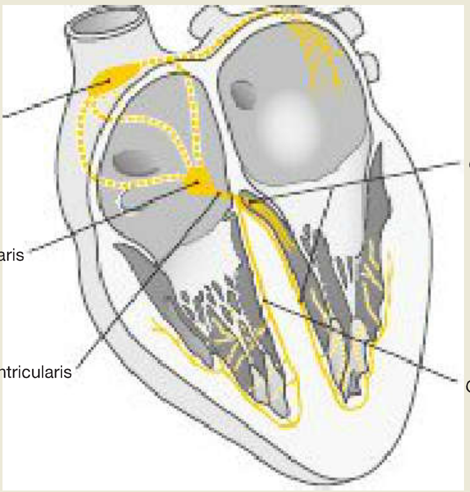


Fig. 5.62 Electrical stimulation and conduction system of the heart; schematic diagram. [L126]
The dotted lines in the area of the atria indicate that the area of stimulation here does not occur through specialised myocardial tissue, but by the normal working myocardium.

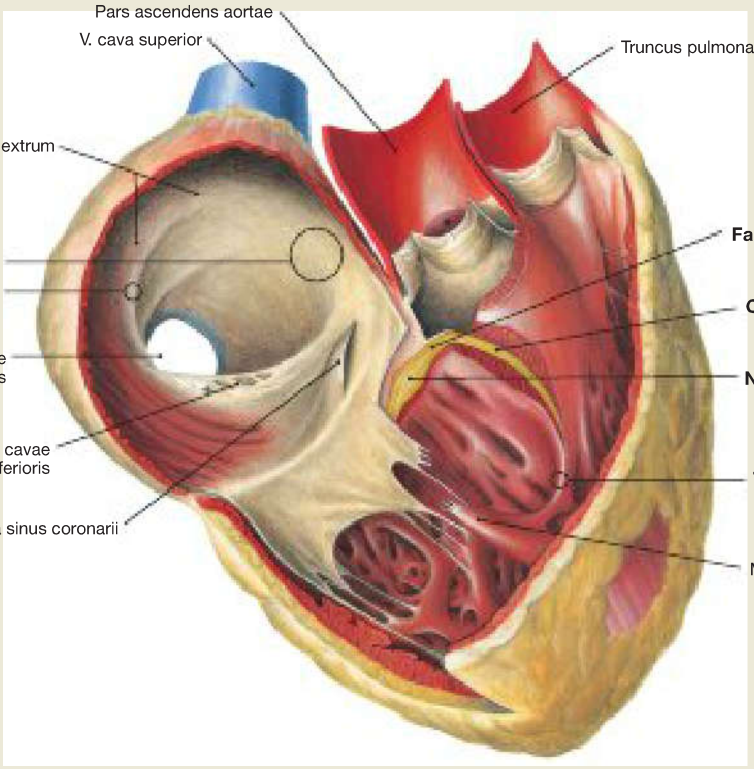


Fig. 5.63 Electrical stimulation and conduction system of the heart.
The electrical stimulation and conduction system is divided into **four parts** (→ Fig. 5.61).

In the illustration it is clearly visible how a part of the right bundle branch (Crus dextrum) reaches the right anterior papillary muscle via the **Trabecula septomarginalis**.

Electrical Stimulation and Conduction System of the Heart

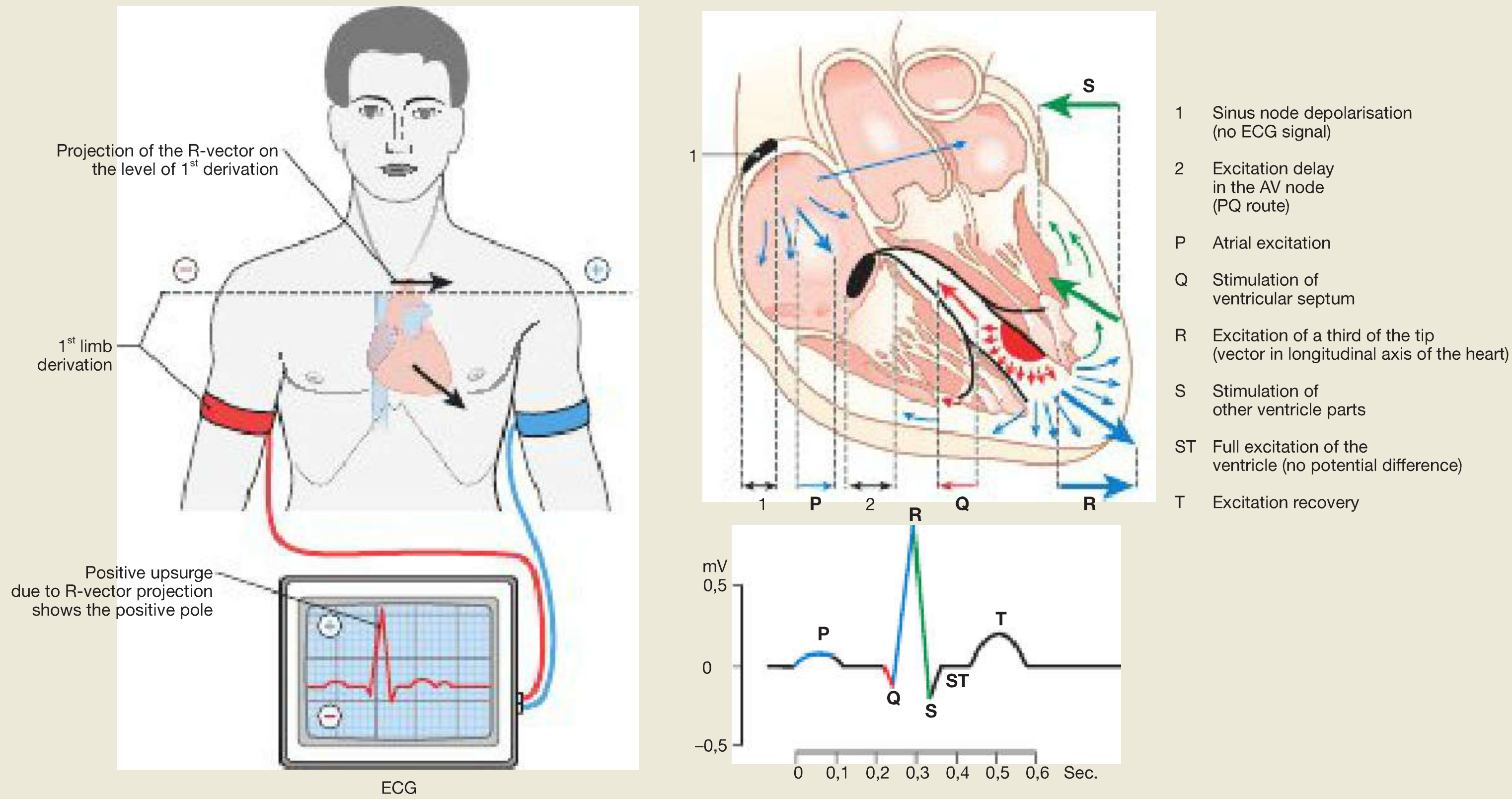


Fig. 5.64 Anatomical fundamentals of an electrocardiogram (ECG). [L126]
The excitation spreads from the sinus node and, after conduction delay in the AV node, is transmitted by the bundle of HIS to the Septum interventriculare. The bundle branches divide and finally stimulate the ventricle muscles. This excitation propagation can be diverted by electrodes to the surface of the body. If the excitation travels towards the electrodes on the surface of the body, a positive upsurge ensues. Sinus node stimulation is not discernible due to the small volume of the node. The **P wave** corresponds to the stimulation of the atria. The stimulation delay in the AV node occurs during the PQ segment, in which the entire atrial myocardium is stimulated and thus no change in potential is discernible. The **Q wave** results from a temporary downward excitation propagation in the interventricular septum. The ascending branch of the **R wave** is caused by excitation propagation to the apex of the heart, the descending branch and the **S wave** due to propagation away from the apex of the heart. During the ST segment the entire ventricular myocardium is stimulated. Since repolarisation occurs in reverse order, the **T wave** shows a positive upsurge on the ECG again. Because typically at least three limb leads are taken up, one can determine the electrical axis and thereby the normal axis from the deflection with the largest R wave. The electrical cardiac axis is, however, not identical to the anatomical cardiac axis, because the muscle mass of the two ventricles and the electrical excitability of the tissue also have an influence.

Clinical Remarks

An ECG can establish heart rhythm disorders, where the heart beats too quickly **(tachycardia, >100/min.),** too slowly **(bradycardia, <60/min.)** or simply irregularly **(arrhythmia).** In addition, however, circulatory disorders in coronary heart disease (e.g. heart attack) and other diseases, such as inflammation of the myocardium, also influence excitation propagation. The ECG is of particular importance for the identification of myocardial infarction.

If atrial fibres bypass the AV node and directly link to the bundle of HIS or the ventricular myocardium (bundle of KENT), cardiac arrhythmias can also ensue **(WOLFF-PARKINSON-WHITE syndrome).** If these arrhythmias produce unpleasant symptoms and do not respond to medication, then the accessory pathways must by cut off by cardiac catheters.

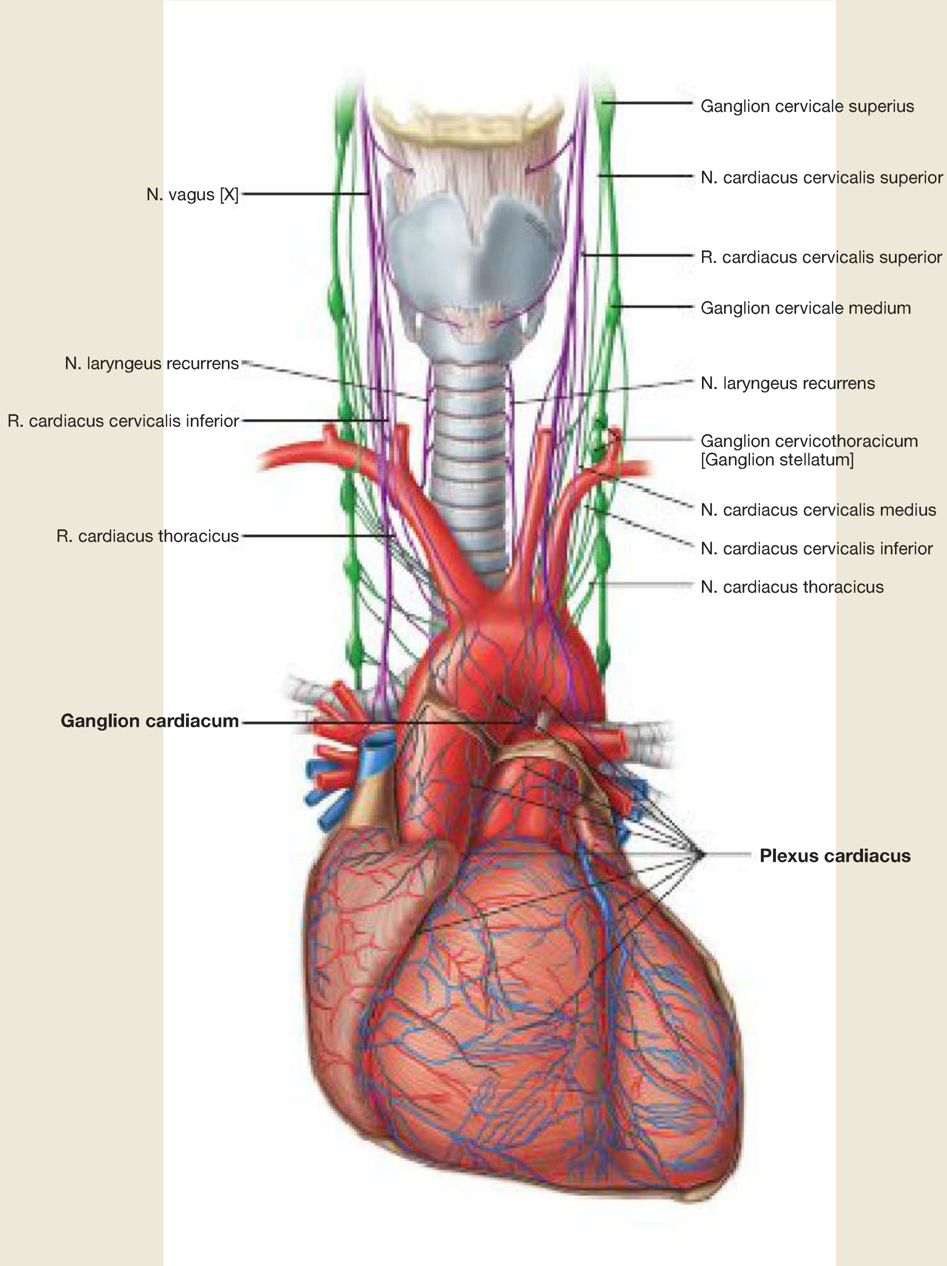
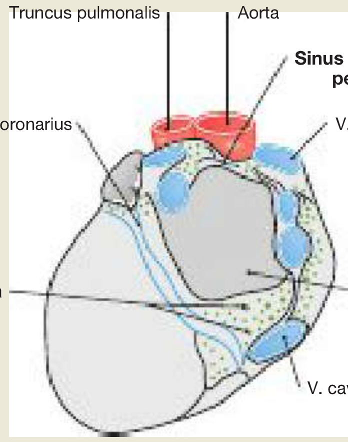


Fig. 5.65 Innervation of the heart: Plexus cardiacus with sympathetic (green) and parasympathetic (purple) nerve fibres; schematic diagram. [L238]
The function of the electrical conduction system and the working myocardium can be adapted by autonomic innervation to the capacity needs of the whole body. This part of the autonomic nervous system is the **Plexus cardiacus,** which contains both sympathetic and parasympathetic nerve fibres. The **sympathetic fibres** are postganglionic nerve fibres, the cell bodies (perikarya) of which are localised within the neck ganglia of the Truncus sympathicus, and reach the Plexus cardiacus via three nerves (the Nn. cardiaci cervicales superior, medius and inferior). The **sympathetic nervous system** increases heart rate (positive chronotropic effect), conduction speed (positive dromotropic effect), and the excitability (positive bathmotropic effect) of the cardiomyocytes. In addition, contractile force (positive inotropic effect) is increased, atony is accelerated (positive lusitropic effect), and cell cohesion is enhanced (positive adhesiotropic effect). The **parasympathetic nervous system** has negative chronotropic, dromotropic and bathmotropic effects and also has negative inotropic effects on the atria. The **parasympathetic nerve fibres** are preganglionic nerve fibres from the N. vagus [X] and reach the Rr. cardiaci cervicales superior and inferior or the Rr. cardiaci thoracici of the Plexus cardiacus, where they are converted from up to 500 mostly microscopic ganglia (Ganglia cardiaca) into postganglionic neurons.

Clinical Remarks

An increased sympathetic tone, e.g. caused by stress, is accompanied by an increased heart rate **(tachycardia)** and rise in blood pressure **(hypertension)**. Damage of the parasympathetic nerve fibres can also lead to tachycardia. The escalation of cardiac output increases the oxygen requirements of the cardiomyocytes and with narrowing of the coronary vessels (coronary heart disease) can lead to angina pectoris and myocardial infarction.

Innervation of the Heart



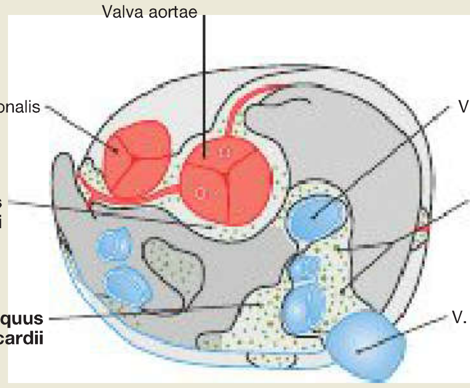


Fig. 5.66a and b Plexus cardiacus with ganglia; dorsal view (→ Fig. 5.66a) and cranial view (→ Fig. 5.66b), schematic diagram. [L126]
The switching of the **parasympathetic nerve fibres** of the **Plexus cardiacus** is carried out in its own ganglia **(Ganglia cardiaca).** As with other organs, in which these ganglia are often embedded in the wall of the organs, the parasympathetic Ganglia cardiaca are usually microscopically small and therefore not visible to the naked eye in a dissection. The ganglia contain the cell bodies (perikarya) of the postganglionic parasympathetic neurons and lie in large numbers predominantly on the great vessels as well as embedded in the epicardium on the surface of the heart. The up to 500 small ganglia thus allow a **superficial, anterior group** that is located on the ascending aorta to be identified. The **deep, posterior group** extends into the Sinus transversus pericardii and therefore between the arterial vessels (Aorta ascendens and Truncus pulmonalis) and the venous vessels (V. cava superior and Vv. pulmonales). This posterior group spreads caudally to the dorsal layer of the pericardium into the Sinus obliquus pericardii.

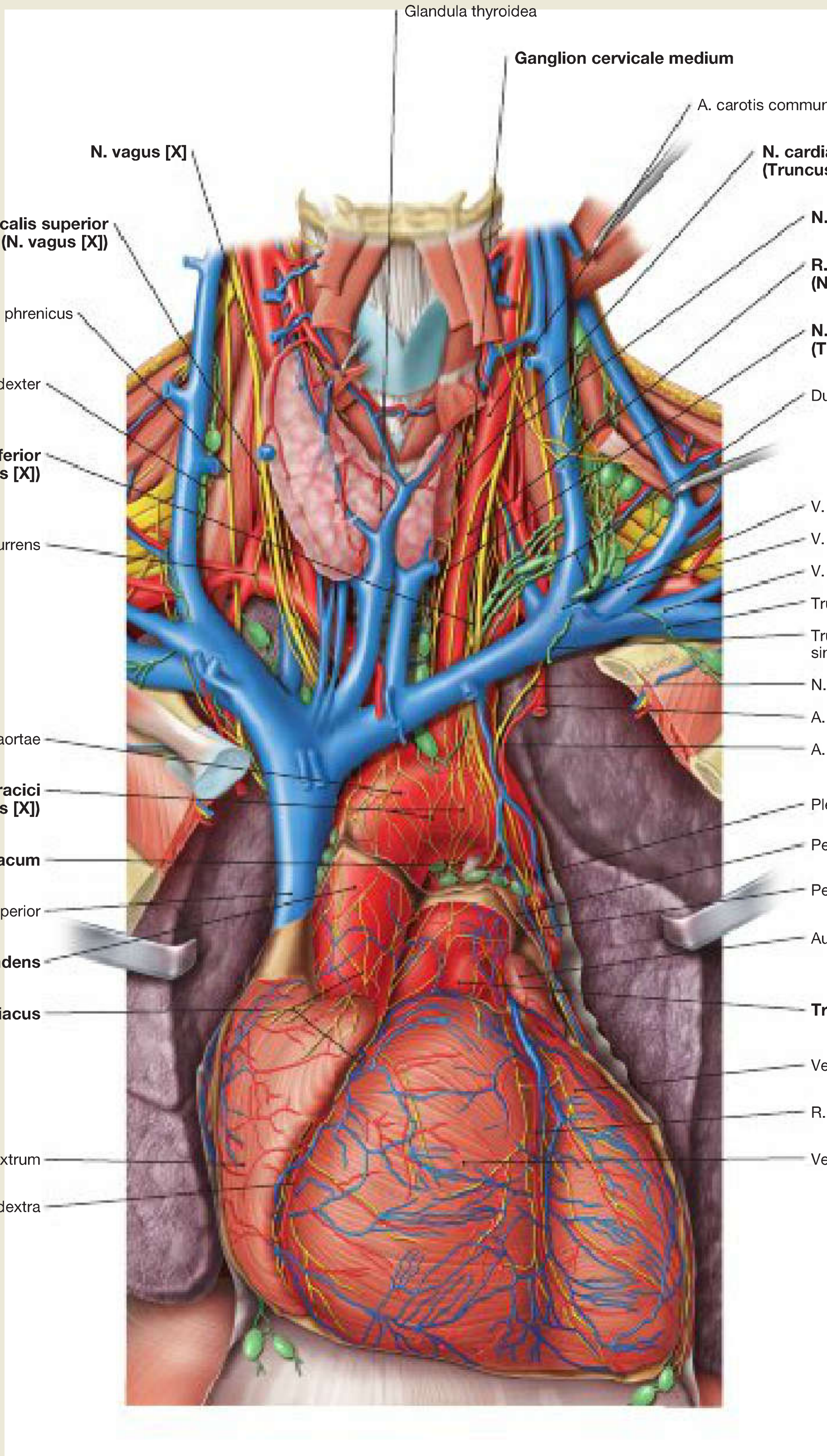


Fig. 5.67 Plexus cardiacus in situ; ventral view; the anterior thoracic wall is removed, the mediastinum and pericardium have been opened to reveal the heart. [L238]

The illustration shows the Mediastinum superius as well as the lower middle mediastinum (Mediastinum medium). The **Plexus cardiacus** in the centre is in its natural position (in situ) and shows the course of autonomic neurons. The postganglionic **sympathetic neurons** run as the **Nn. cardiaci cervicales superior, medius and inferior** from the Truncus sympathicus to the Plexus cardiacus. The superficial, anterior part of the plexus spreads forwards on the Aorta ascendens and the Truncus pulmonalis. The neurons then follow the branches of the cardiac vessels and spread from there onto the surface of the heart. The **parasympathetic neurons**, on the other hand, are preganglionic nerve fibres from the N. vagus [X] and its N. laryngeus recurrens. They reach the Plexus cardiacus as **Rr. cardiaci cervicales superior and inferior** or as **Rr. cardiaci thoracici** of the Plexus cardiacus, where they are converted from up to 500 mostly microscopic **ganglia (Ganglia cardiaca)** into postganglionic neurons. A larger ganglion is noticeable to the right of the Lig. pulmonale between the Truncus pulmonalis and the Arcus aortae.

Coronary Arteries

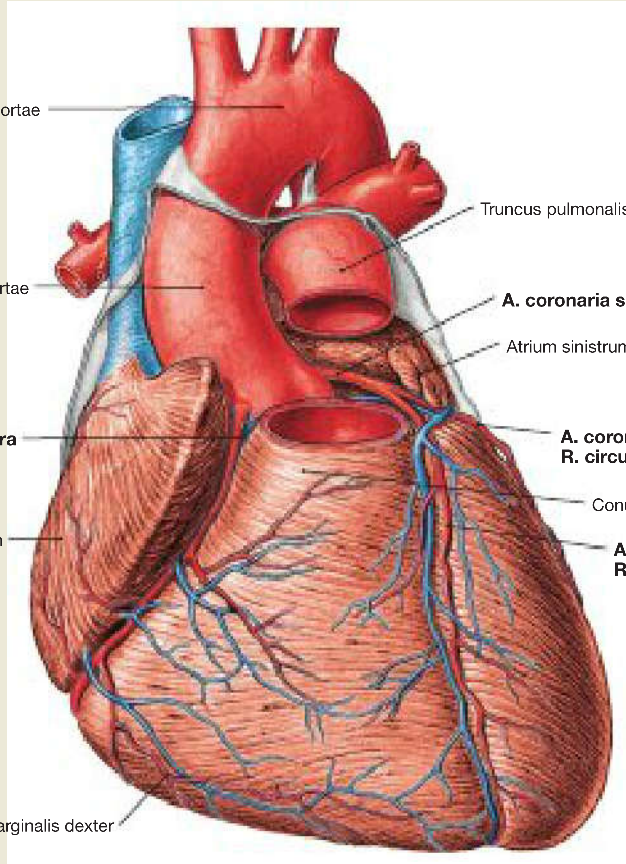


Fig. 5.68 Coronary arteries, Aa. coronariae; ventral view.

The **right coronary artery** (A. coronaria dextra) originates in the right coronary sinus of the aorta, flows within the Sulcus coronarius to the right border (Margo dexter), and changes over to the Facies diaphragmatica, where the **R. interventricularis posterior** usually originates as a terminal branch.

The **left coronary artery** (A. coronaria sinistra) emerges from the left coronary sinus of the aorta and divides after 1 cm into the **R. interventricularis anterior,** which stretches to the apex of the heart, and into the **R. circumflexus,** which flows within the Sulcus coronarius around the left ventricle border onto the posterior surface.

Usually, the coronary artery that provides the R. interventricularis posterior is referred to as 'dominant'. Usually (in balanced and right-dominant coronary circulation, connected in 75% of cases → p. 56 and p. 57) the A. coronaria dextra is therefore dominant.

Important Branches of the A. coronaria dextra
• R. coni arteriosi • R. nodi sinuatrialis (two-thirds of cases): to the **sinus node** (Nodus sinuatrialis) • R. marginalis dexter • R. posterolateralis dexter • R. nodi atrioventricularis: to the **AV node** (in dominance) • The R. interventricularis posterior (in dominance) and the Rr. interventriculares septales supply the **bundle of HIS**
Important Branches of the A. coronaria sinistra
R. interventricularis anterior: • R. coni arteriosi • R. lateralis (clin.: R. diagonalis) • Rr. interventriculares septales **R. circumflexus:** • R. nodi sinuatrialis (one-third of cases): to the **sinus node** (Nodus sinuatrialis) • R. marginalis sinister • R. posterior ventriculi sinistri

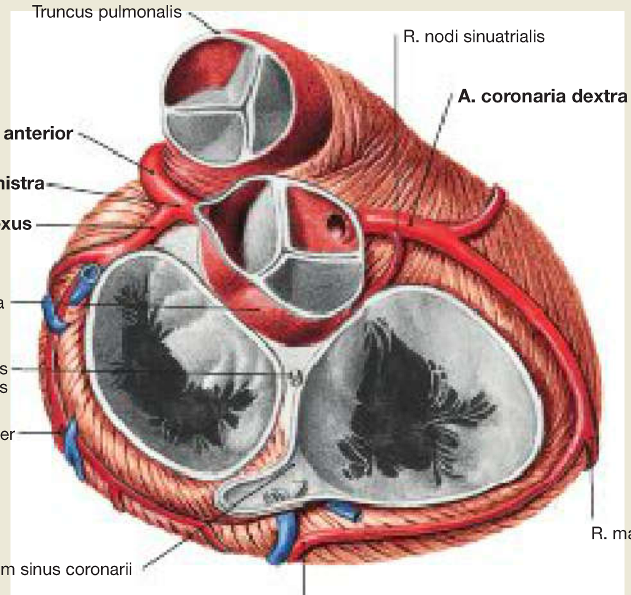


Fig. 5.69 Coronary arteries, Aa. coronariae; cranial view.

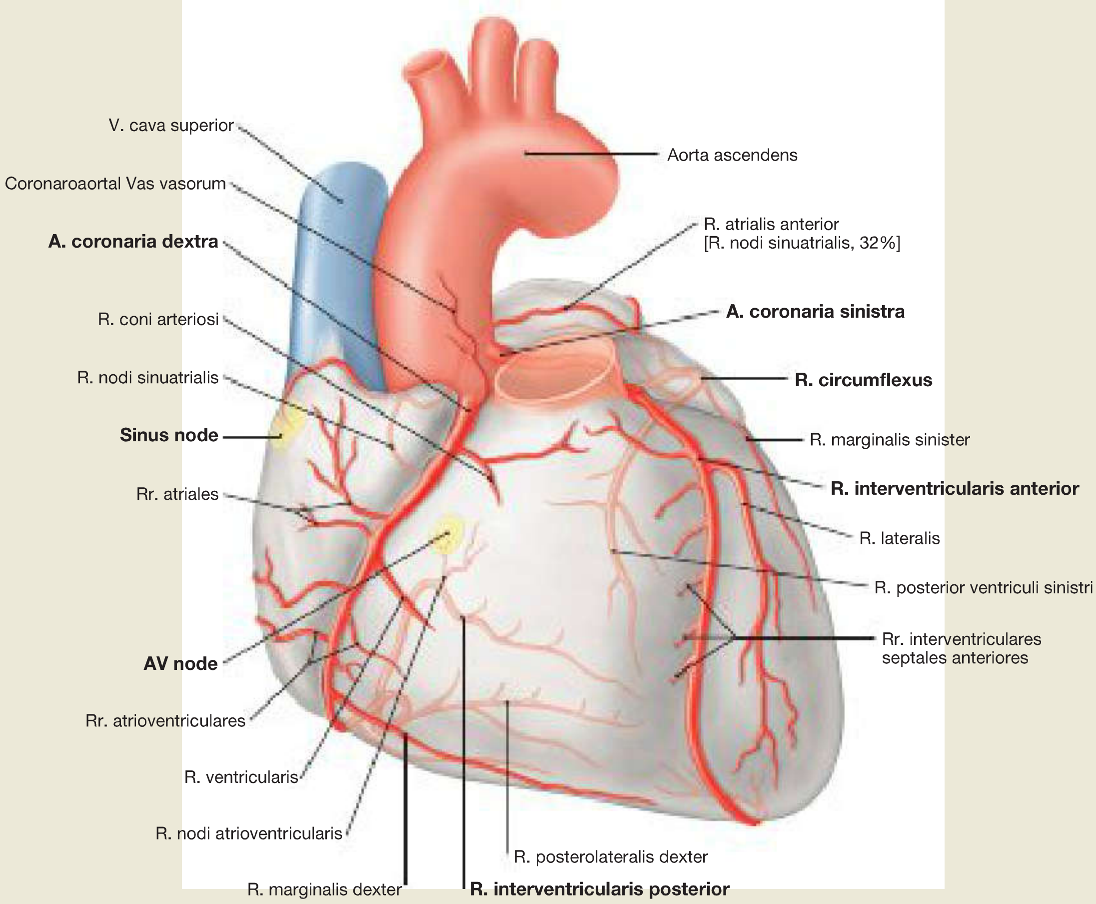


Fig. 5.70 Branches of the coronary arteries, Aa. coronariae. [L238]
The **A. coronaria dextra** descends within the Sulcus coronarius almost completely perpendicularly. Here, branching off to the right as the first branch is the **R. nodi sinuatrialis,** which stretches, initially covered, from the right auricle to the sinus node. In addition, further branches on the Facies sternocostalis supply the right atrium and ventricle. Before the A. coronaria dextra switches over to the Facies diaphragmatica, the **R. marginalis dexter** emerges. On the caudal surface of the heart, the A. coronaria dextra usually (balanced circulation) flows into the **R. interventricularis posterior.** The **R. nodi atrioventricularis** starts where the R. interventricularis posterior bends almost perpendicularly into the Sulcus interventricularis posterior.
In contrast to the A. coronaria dextra, the **A. coronaria sinistra** divides soon into its two main branches: the **R. interventricularis anterior** continues its course caudally on the Facies sternocostalis and provides the **R. lateralis** in the direction of the apex of the heart. The **R. circumflexus,** together with the **left marginal artery,** supplies the left pulmonary surface, before it turns onto the Facies diaphragmatica. There, the R. circumflexus forms the **posterior left ventricular branch** as a terminal branch.

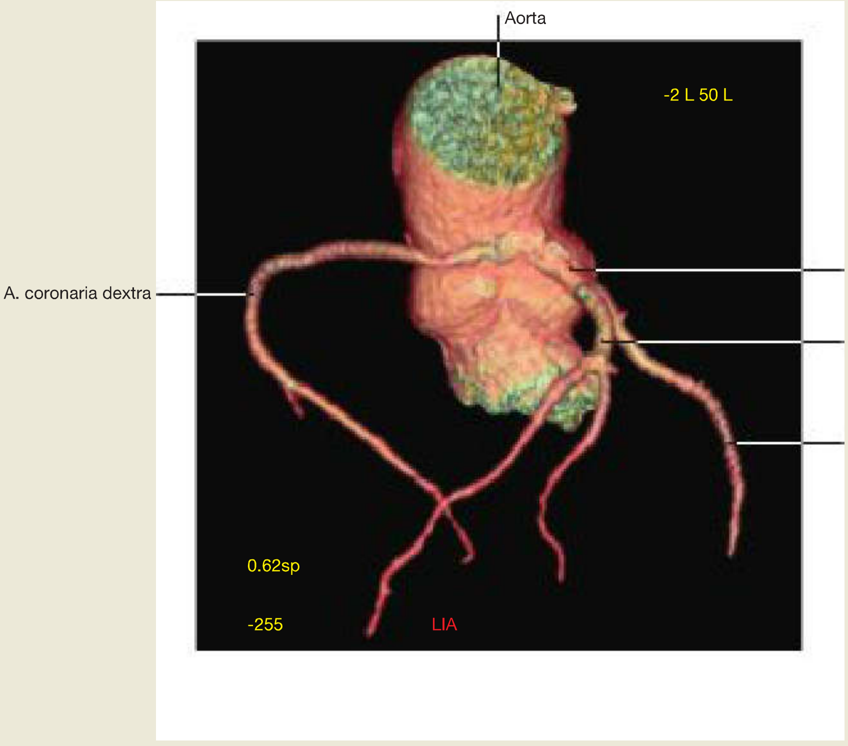


Fig. 5.71 CT angiography of the heart: volume rendering for non-invasive 3D representation of the coronary tree in a 55-year-old woman. [T832]

Types of Coronary Circulation

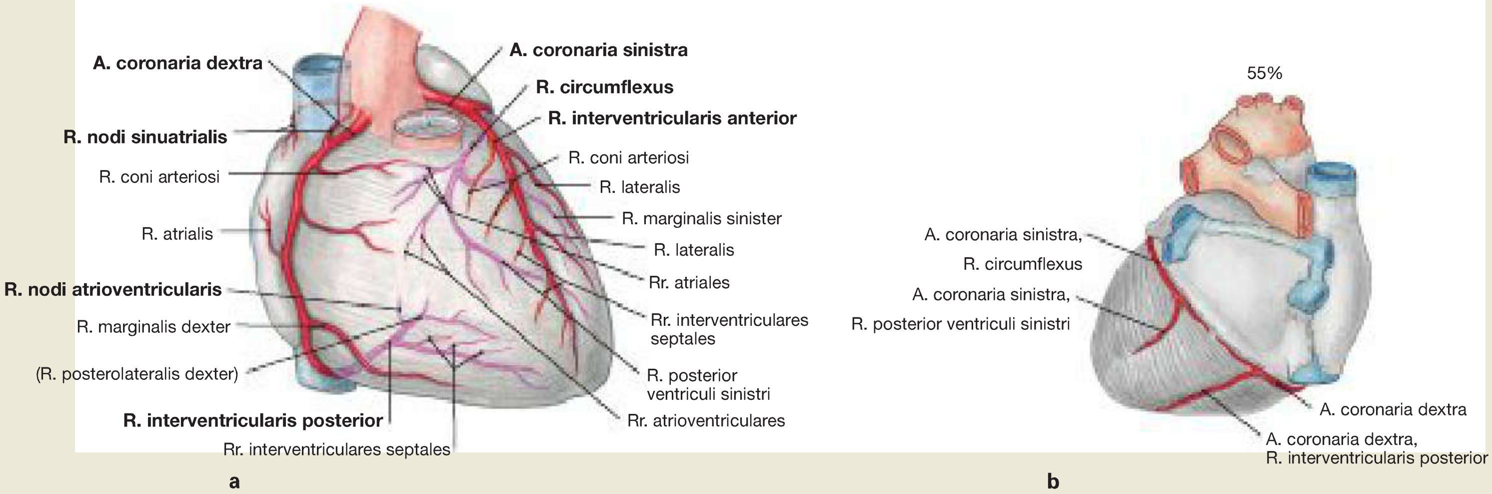


Fig. 5.72a and b Balanced circulation of the Aa. coronariae; ventral view (→ Fig. 5.72a) and dorsal view (→ Fig. 5.72b).

Generally (in 55% of cases), the R. interventricularis posterior originates from the A. coronaria dextra but does not overlap onto the posterior aspect of the left ventricle. This is referred to as **balanced circulation.**

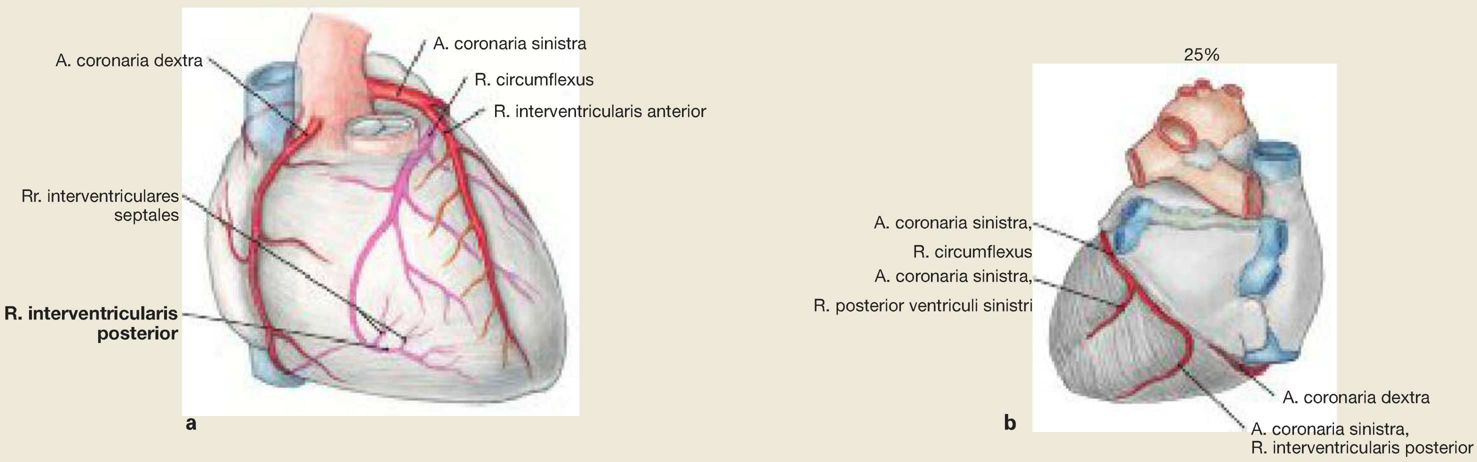


Fig. 5.73a and b Left-dominant circulation of the Aa. coronariae; ventral view (→ Fig. 5.73a) and dorsal view (→ Fig. 5.73b).

In 11–20% of cases, the R. interventricularis posterior originates from the left coronary artery, which is referred to as **left-dominant circulation.**

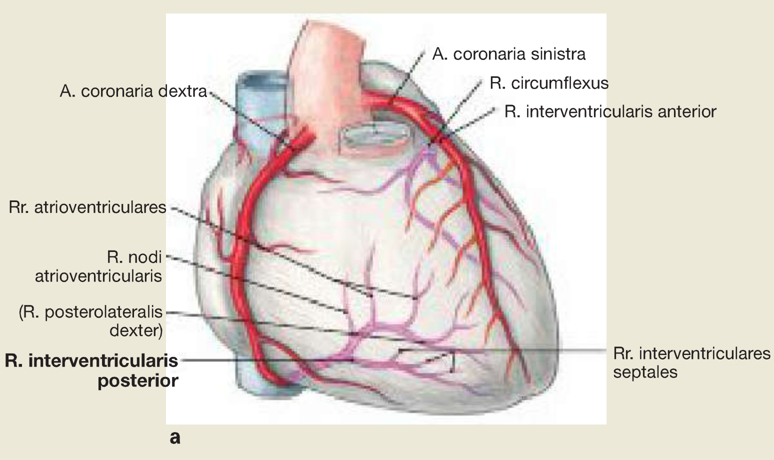


Fig. 5.74a and b Right-dominant circulation of the Aa. coronariae; ventral view (→ Fig. 5.74a) and dorsal view (→ Fig. 5.74b).

In 14 –25% of cases, the A. coronaria dextra provides not only the R. interventricularis posterior, but also supplies parts of the posterior aspect of the left ventricle. In this case it is referred to as **right-dominant circulation.**

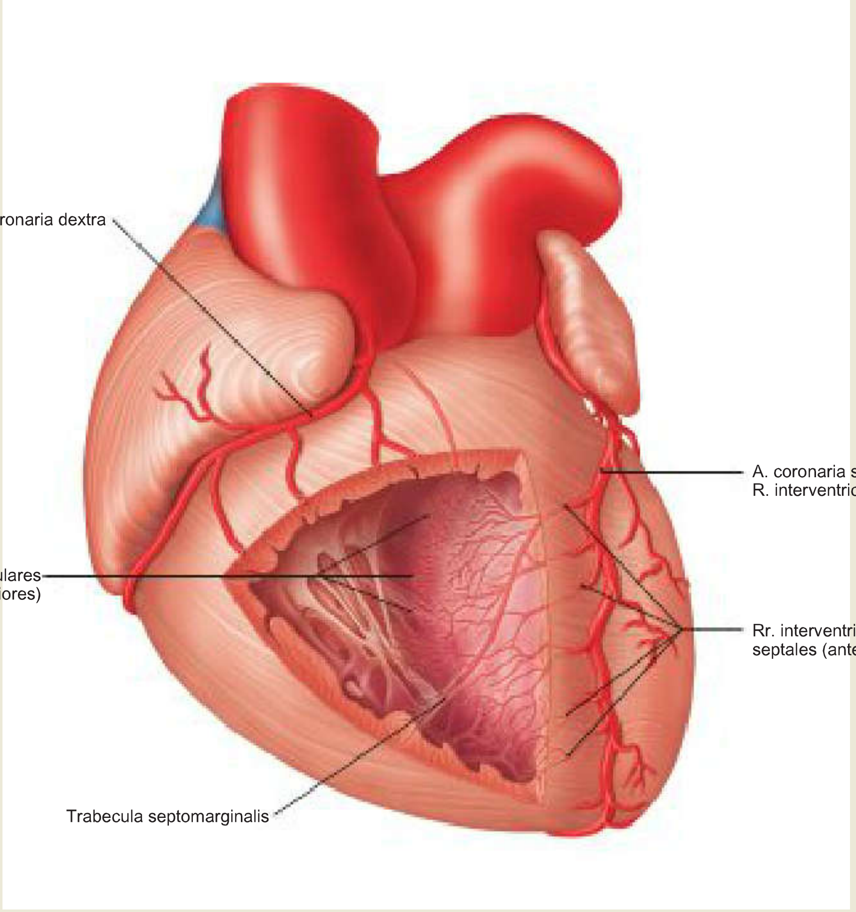


Fig. 5.75 Arterial supply of the Septum interventriculare, balanced circulation; ventral view. [L238]

The anterior **two thirds of the interventricular septum,** including the moderator band and the right anterior papillary muscle, are supplied by the septal branches of the **R. interventricularis anterior.** Only the **posterior third** receives blood from the septal branches of the R. interventricularis posterior, which emerges from the A. coronaria dextra in balanced and right-dominant circulation. Therefore, as well as differentiating between the types of circulation there is another classification according to the 'dominance' of a coronary artery, which is mainly used clinically above all. Here, the differentiation depends on which coronary artery provides the R. interventricularis posterior and is thus involved in the supply of the posterior part of the Septum interventriculare and of the subsequent part of the left ventricle on the Facies diaphragmatica ('posterior wall' of clinicians). In over 80% of the cases in balanced and right-dominant circulation the dominant artery is the A. coronaria dextra. Only in up to 20% of cases is the A. coronaria sinistra dominant.

The **dominant artery** also supplies the **AV node** and the **bundle of HIS.** The branch to the AV node usually penetrates into the heart wall, where the R. interventricularis posterior from the Sulcus coronarius branches off into the Sulcus interventricularis posterior. The bundle of HIS is fed by the proximal septal branches of the R. interventricularis posterior. Thus, in the majority of cases ('general rule') the sinus node, as primary cardiac pacemaker, as well as the AV node and the bundle of HIS are supplied by the A. coronaria dextra.

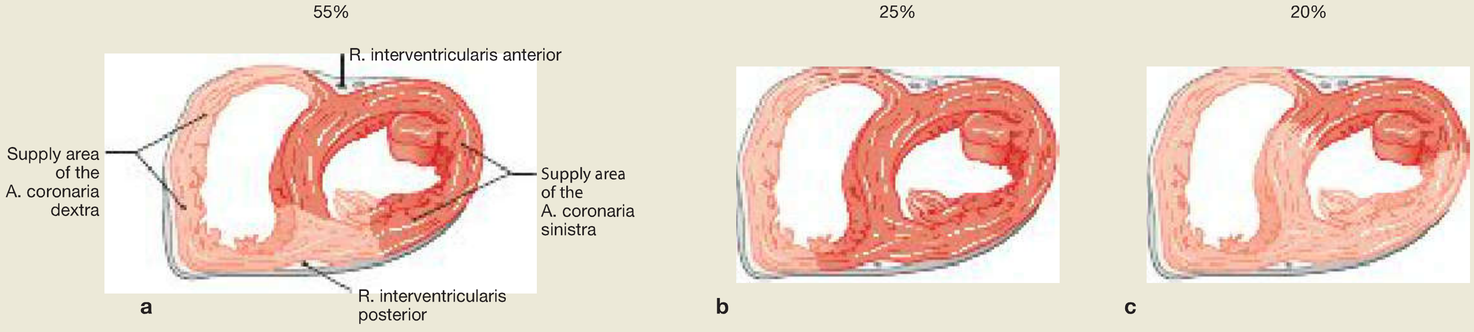


Fig. 5.76a to c Supply areas of the A. coronaria dextra (light red) and the A. coronaria sinistra (dark red) in cross-sections; caudal view. [L126]

a Balanced circulation: The A. coronaria sinistra supplies approximately two anterior thirds of the septum from the R. interventricularis anterior via the Rr. interventriculares septales. Corresponding branches from the R. interventricularis posterior of the A. coronaria dextra reach the posterior third of the Septum interventriculare.

b Left-dominant circulation: The A. coronaria sinistra supplies the entire septum and also the AV node.

c Right-dominant circulation: Two thirds of the septum and large areas of the posterior aspect of the left ventricle are supplied with blood by the A. coronaria dextra.

This distribution pattern has implications for the severity of a heart attack when there is an occlusion of one of the Aa. coronariae.

Coronary Heart Disease and Supply Areas of the Coronary Arteries

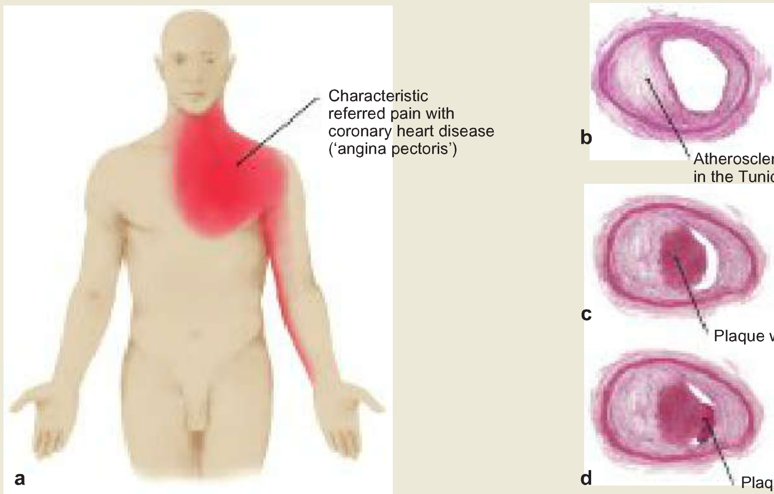


Fig. 5.77a to d Coronary heart disease (CHD). [L266]
a Symptomatology: In coronary heart disease (CHD) when there is underperfusion (ischemia) of the myocardium, tightness of the chest is often felt and is known as **angina pectoris**. This symptomatology allows no distinction as to whether a minor perfusion of the myocardium is still possible or whether in the case of a complete closure there is the threat of muscle cell destruction (necrosis). If the myocardium is collapsing, then a **heart attack (myocardial infarction)** is present. In accordance with the area of the referred pain (HEAD's zone), pain is mainly perceived in the left-hand chest region and radiates into the left arm and the left half of the neck. It should however be noted, that pain radiation to the right side, or no pain at all, is also possible, since the risk factors which result in CHD often also damage the afferent nerve fibres, e.g. diabetes mellitus. It is therefore impossible to exclude a heart attack without thorough diagnostics!
b to d Arteriosclerosis as the cause of CHD: In most cases, CHD is caused by **atherosclerosis** of the Aa. coronariae and their branches. Accompanying risk factors are diabetes mellitus, high blood pressure (hypertension), elevated cholesterol levels in the blood (hypercholesterolemia) and smoking. In these cases, an inflammatory process originates in the tunica intima of the Aa. coronariae, which is triggered by cholesterol-containing lipid deposits. This **chronic inflammatory process** forms atherosclerotic plaques (b) which narrow the vessel lumen and into which haemorrhages can occur (c). Due to flow conditions, the outlets of the Aa. coronariae from the ascending aorta or the outlets of the branches of the Aa. coronariae are often particularly affected by the plaque formation. If these plaques rupture, the protective layer of endothelial cells is lost, so that blood clots (thrombi) form (d) that can completely displace the lumen. If the occlusion is complete and a recanalisation does not occur spontaneously, myocardial tissue disintegrates and **myocardial infarction results.** It is important to note that arteriosclerosis is often a **systemic disease** and affects the whole systemic circulation, in which blood pressure is high. Therefore, myocardial infarction patients have an increased risk of stroke, kidney or bowel infarction or peripheral artery disease (PAD), in which walking is painfully restricted due to inadequate blood flow.

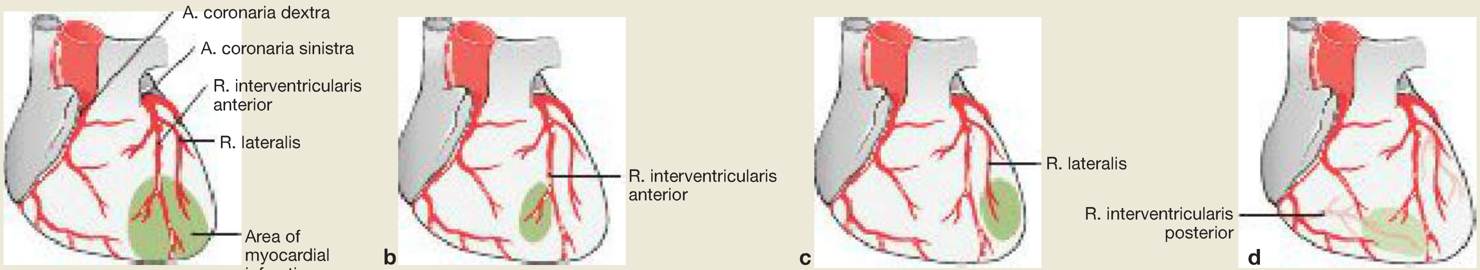


Fig. 5.78a to d Infarction pattern in occlusion of the coronary arteries. [L126]
- **a** With isolated occlusion of the R. interventricularis anterior it is a case of **anterior wall myocardial infarction.**
- **b** In the case of distal occlusion of the R. interventricularis anterior the result is an **apical myocardial infarction.**
- **c** If only the R. lateralis is affected, this leads to a **lateral wall myocardial infarction.**
- **d** An occlusion of the R. interventricularis posterior leads to an infarction the inferiorly located Facies diaphragmatica, referred to as **posterior wall myocardial infarction.**

Clinical Remarks

As the Aa. coronariae are functional terminal arteries, an occlusion of individual branches leads to certain infarction patterns. These can often already be determined in the various deflections of an ECG. The safest confirmation method is achieved by cardiac catheter examination, using an X-ray contrast agent. In **posterior wall myocardial infarction** the perfusion of the AV node is typically also impaired because the perfusing artery usually originates at the outlet of the R. interventricularis posterior (→ Fig. 5.70). This can result additionally in bradycardiac arrhythmias. Since the muscle wall of the right ventricle has a lower oxygen demand than that of the left ventricle, due to pressure conditions, an isolated posterior wall myocardial infarction often also results in a proximal occlusion of the right coronary artery (A. coronaria dextra). In this case, the bradycardia can be very pronounced due to insufficient perfusion of the SA node.

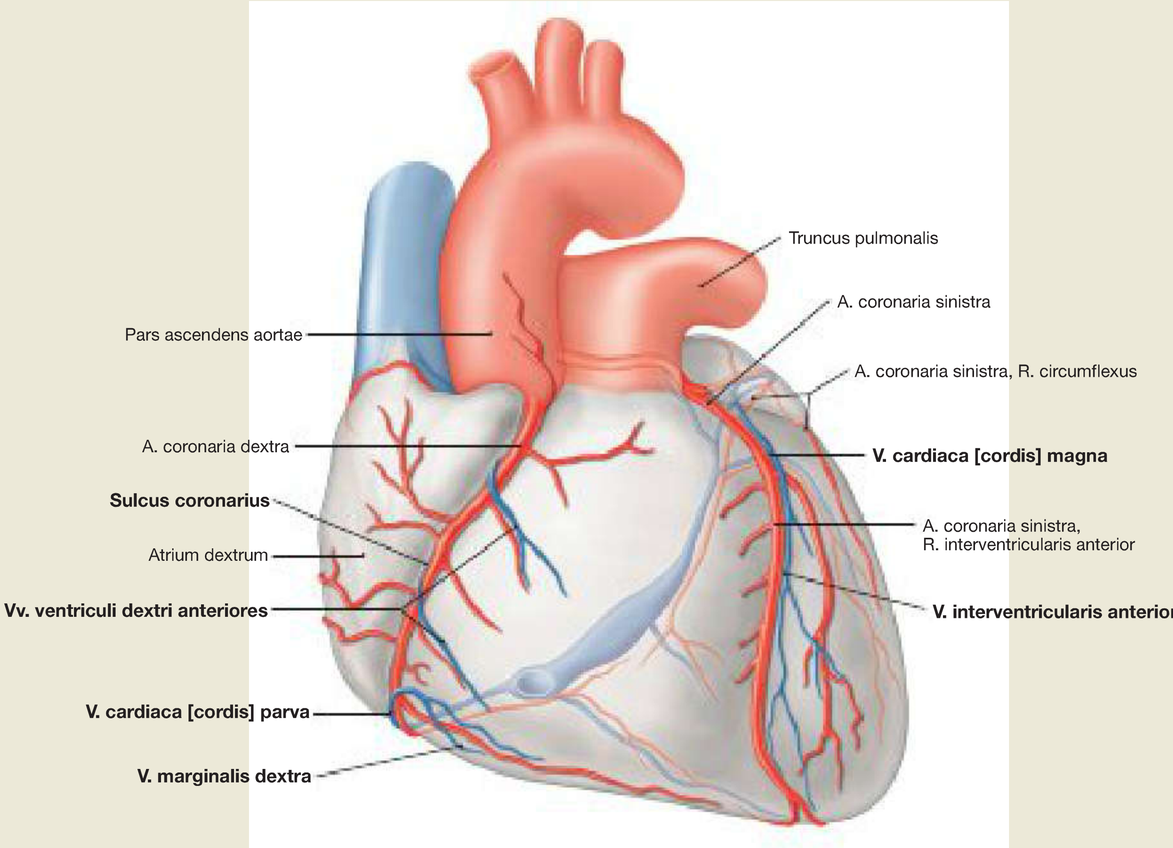


Fig. 5.79 Cardiac veins, Vv. cordis; ventral view. [L238]
Venous blood from the heart flows via **three major systems.** 75% of the venous blood is received by the **coronary sinus** and carried into the right atrium. The remaining 25% of the venous blood reaches the atria and ventricles directly via the **transmural** and **endomural** systems.

Cardiac Veins
Coronary Sinus System: • V. cardiaca magna: corresponds to the supply area of the A. coronaria sinistra – V. interventricularis anterior – V. marginalis sinistra – Vv. ventriculi sinistri posteriores • V. cardiaca media: in the Sulcus interventricularis posterior • V. cardiaca parva: in the right Sulcus coronarius, present in 50% • V. obliqua atrii sinistri
Transmural System: • Vv. ventriculi dextri anteriores • Vv. atriales
Endomural System: • Vv. cardiacae minimae (THEBESIAN veins)

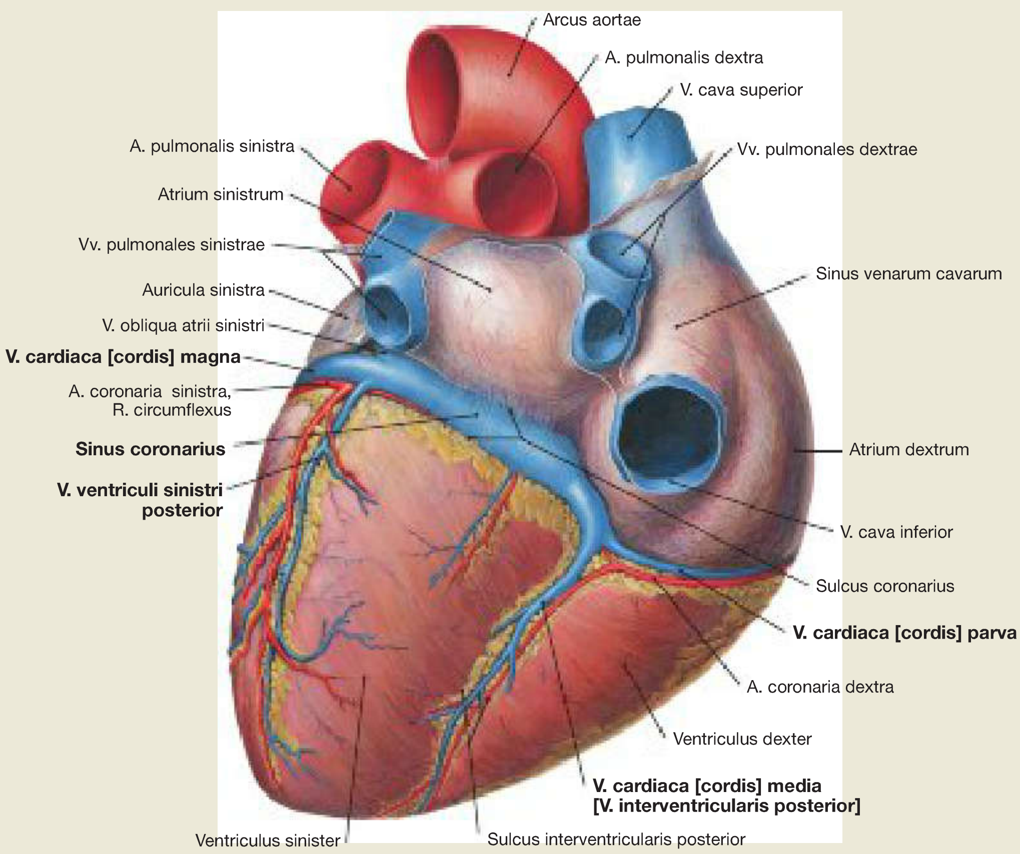


Fig. 5.80 Cardiac veins, Vv. cordis; dorso-caudal view.

Projection of the Trachea and Bronchi

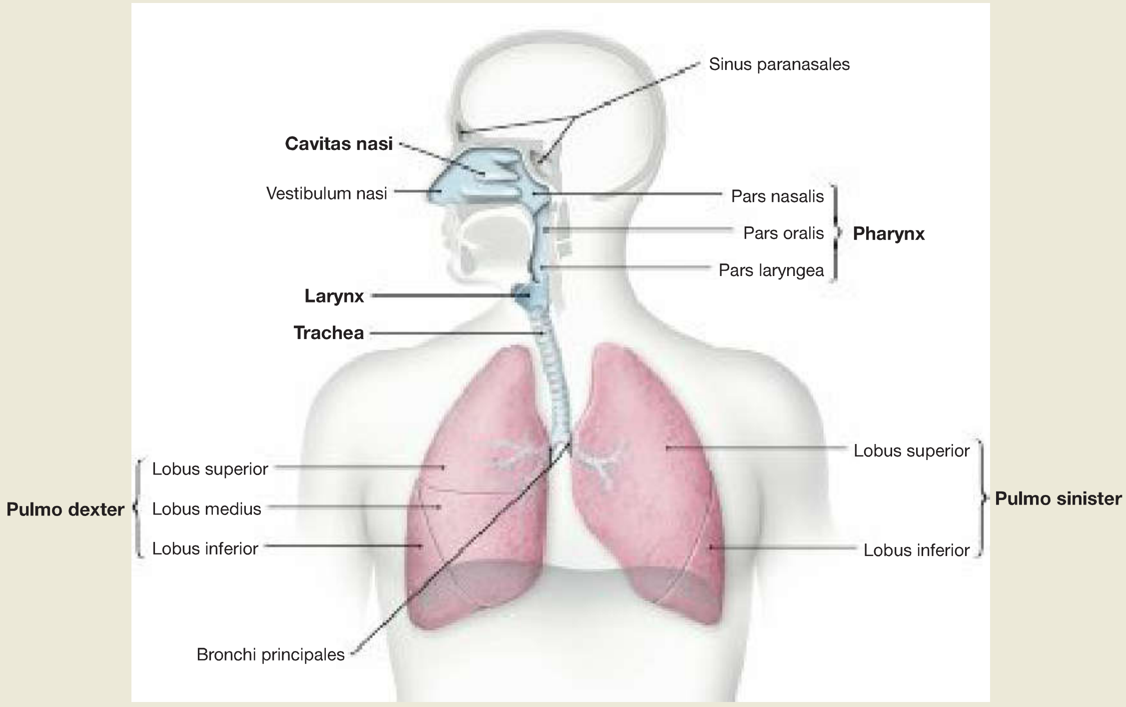


Fig. 5.81 Upper and lower respiratory tracts; schematic diagram. [L275]
The respiratory system is divided into the upper and lower respiratory tracts.
The **upper** respiratory tract includes:
- Nasal cavity (Cavitas nasi)
- Pharynx

The **lower** respiratory tract comprises:
- Larynx
- Trachea
- Lungs (Pulmones)

The right lung (Pulmo dexter) has three lobes, the left lung (Pulmo sinister) has two.

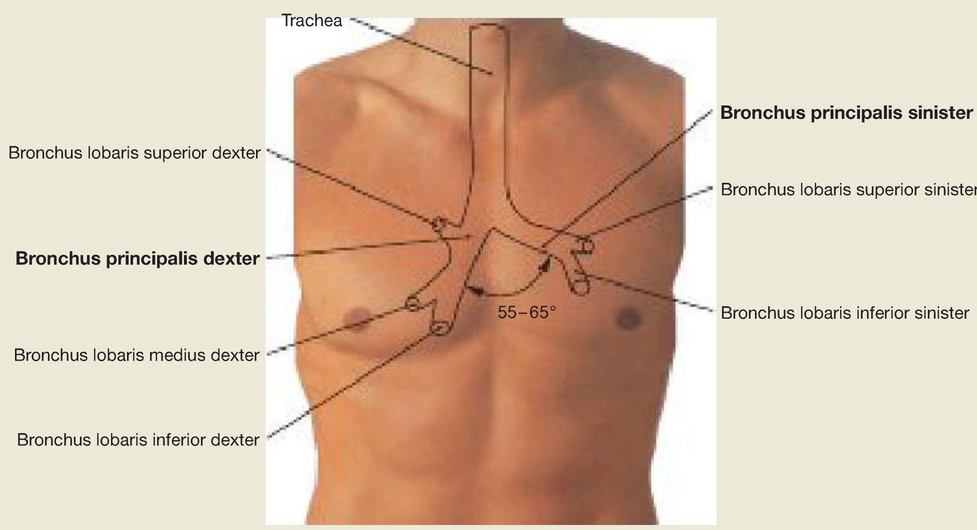
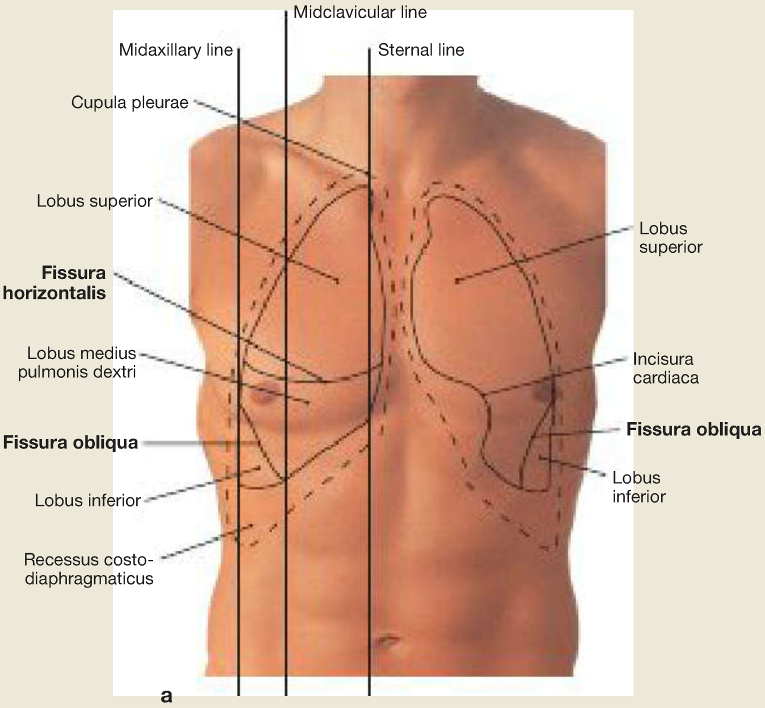


Fig. 5.82 Projection of the trachea and main bronchi onto the anterior thoracic wall.
The trachea is 10–13 cm long and during deep inspiration extends by up to 5 cm. Its commencement at the cricoid cartilage of the larynx projects onto the 7th cervical vertebra; its bifurcation, where it divides into the two main bronchi, projects onto the 4th–5th thoracic vertebrae (2nd–3rd ribs). The angle between the main bronchi is 55° to 65°. The **right main bronchus (Bronchus principalis dexter)** is stronger, 1–2,5 cm long and stands **almost vertically,** while the **left main bronchus (Bronchus principalis sinister)** is almost twice as long and stands diagonally.

Clinical Remarks

Because of the steep position of the right main bronchus, during inspiration **(aspiration)** of foreign bodies the aspirated material usually enters the **right lung.** In the event of imminent suffocation this knowledge may provide a doctor with a crucial time advantage!
The asymmetrical position of the main bronchi should also be taken into account in **intubation:** with this, a rubber hose (tubus) is inserted via the mouth up to the lower respiratory tract in order to enable ventilation. If this tube is inserted too far, it usually goes into the steeply positioned right main bronchus, so that only the right lung is ventilated during ventilation. After applying the tube, one should therefore use sounding of the lung (auscultation) to ensure the correct position of the tube in the trachea!



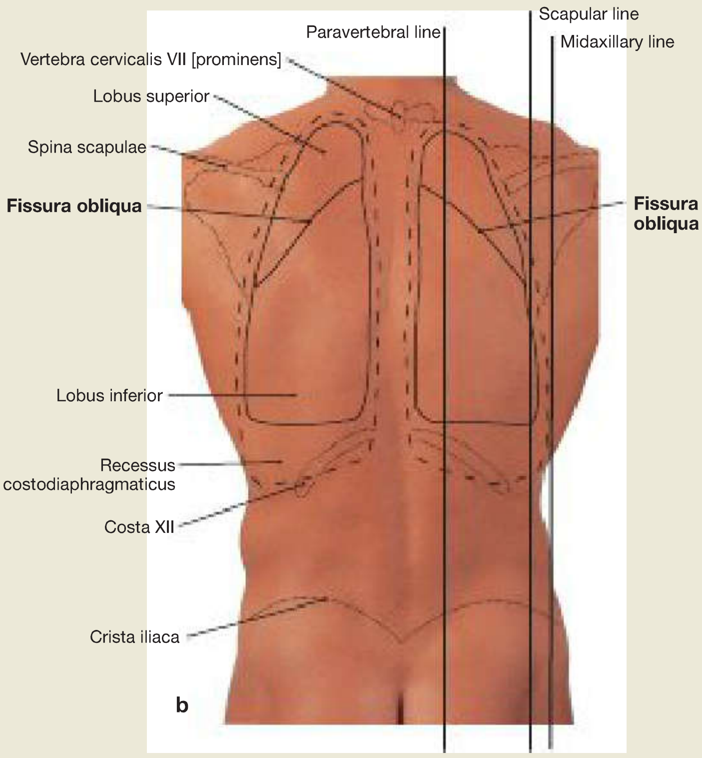


Fig. 5.83a and b Projection of pulmonary and pleural boundaries onto the anterior thoracic wall (→ Fig. 5.83a) and onto the back (→ Fig. 5.83b).
The **right lung** has three lobes which are demarcated by the **Fissura obliqua** and the **Fissura horizontalis**. In this, the Fissura obliqua follows the fourth rib dorso-laterally and separates the upper and lower lobes. From the midaxillary line it then descends steeply and reaches the sixth rib in the midclavicular line. On the anterior surface of the lung, the Fissura obliqua therefore divides the middle and lower lobes from each other (→ Fig. 5.90a and b). Anteriorly, the Fissura horizontalis continues the course along the fourth rib and separates upper and middle lobes.

The **left lung** only has two lobes which are separated by the **Fissura obliqua**. Because the heart causes the mediastinum to distend to the left (Incisura cardiaca), the volume of the left lung is smaller and its position also differs in the sternal and midclavicular lines from the right lung (see table).
Each **Cavitas pleuralis** is covered by **parietal pleura** (Pleura parietalis). The Pleura parietalis is divided into the Pars mediastinalis, Pars costalis and Pars diaphragmatica (→ Fig. 5.1). The pleural cavities feature four pleural recesses (Recessus pleurales). The largest is the **Recessus costodiaphragmaticus** which expands laterally up to 5 cm within the midaxillary line.
Lung boundaries = solid line, pleural boundaries = dashed line

	Right Lung Boundaries	Left Lung Boundaries
Sternal Line	6th rib cut	4th rib cut
Midclavicular Line	Parallel to the 6th rib	6th rib cut
Midaxillary Line	8th rib cut	as to the right
Scapular Line	10th rib cut	as to the right
Paravertebral Line	11th rib cut	as to the right

Pleural boundaries: one rib deeper respectively

Clinical Remarks

The boundaries of the lungs and the pleura play a role in physical examination in order to determine the **size and respiratory motility** of the lungs and the **localisation of pathological changes,** which can be indicative of a pulmonary inflammation (pneumonia) or an increased volume of fluid in the Cavitas pleuralis (pleural effusion). **Pleural effusions** are punctured in the costodiaphragmatic recess. Only the **Pleura parietalis** is nociceptively innervated and therefore **sensitive to pain.** If pneumonia or lung tumours are accompanied by chest pain, then one can assume involvement of the parietal pleura.
If air penetrates the Cavitas pleuralis, the lung partially or completely collapses **(pneumothorax).** During percussion, one hears a loud (hypersonorous) percussion sound.

Organs of the Chest Cavity

Development

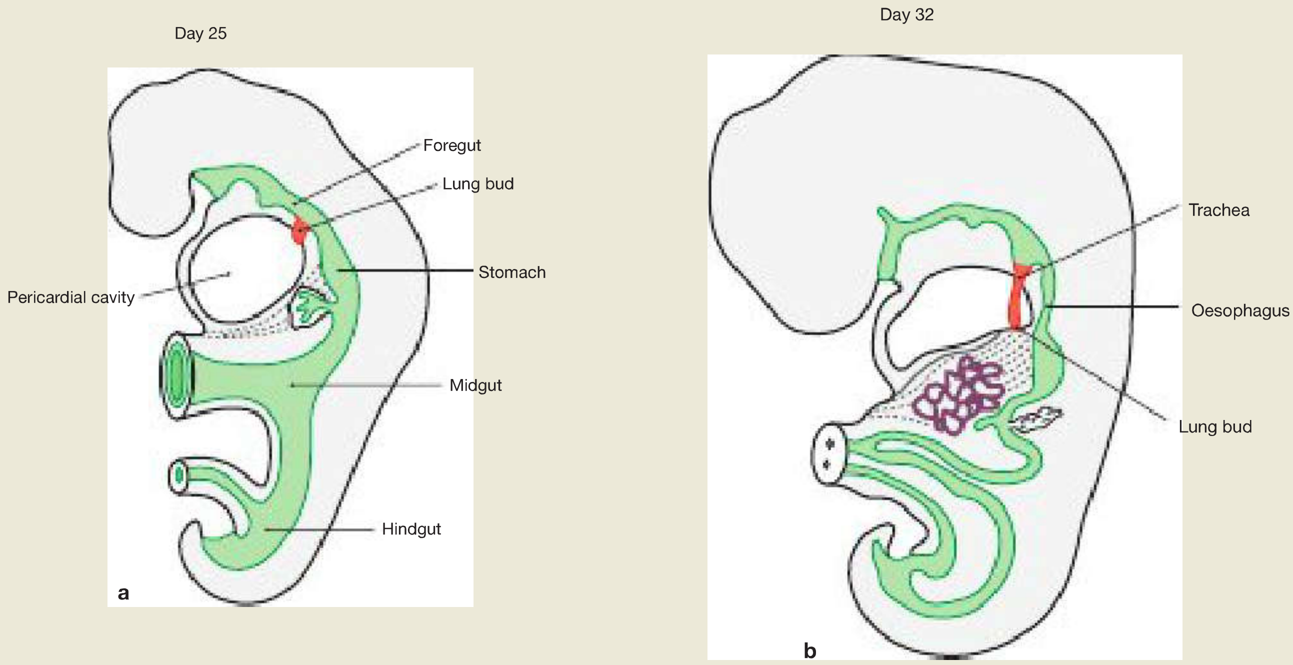


Fig. 5.84a and b Development of the lower respiratory tract on the 25th (→ Fig. 5.84a) and 32nd day (→ Fig. 5.84b). [L126]

Epithelial tissues of the larynx, trachea and lungs develop from the 4th week from the entoderm of the foregut. Connective tissue, smooth muscles and blood vessels are derived from the surrounding mesoderm. Firstly, a **lung bud forms,** which extends to the **laryngotracheal groove**, where at its lower end, the **bronchial buds** as precursors of the main bronchi emerge.

Clinical Remarks

A disruption of the division of oesophagus and trachea can cause abnormal collateral circulation connections **(tracheo-oesophageal fistula)**, often associated with a blind-ended oesophagus **(oesophageal atresia).**
From the **28th week surfactant** is produced in the pulmonary alveoli, a secretion that reduces the surface tension of the alveoli. From the 35th week the production is usually sufficient to enable **spontaneous breathing** if necessary. Insufficient surfactant production results in **Respiratory Distress Syndrome** (RDS) which is the most common cause of death in premature babies. In the case of birth before the 30th week, up to 60% of premature babies develop RDS. Because the lungs are only filled with air at birth, a coroner can use a **flotation test** to establish whether the child was born dead (lung sinks), or died after birth (lung floats).

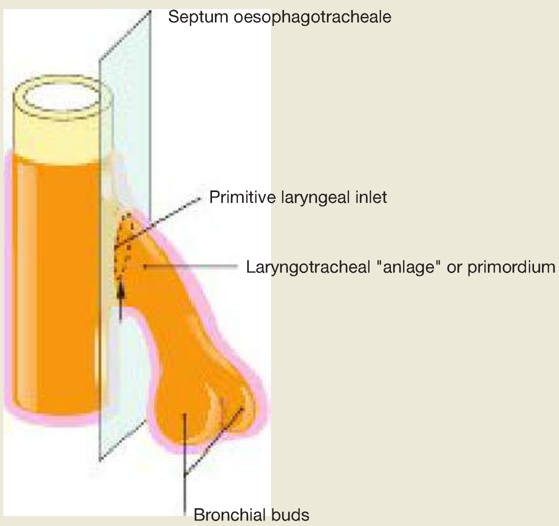


Fig. 5.85 Development of the Septum oesophagotracheale. [E347-09]
During the fourth and fifth weeks mesenchymal folds form on both sides; the folds join to the Septum oesophagotracheale and thereby separate the primordium of the lower respiratory tract from the oesophagus.

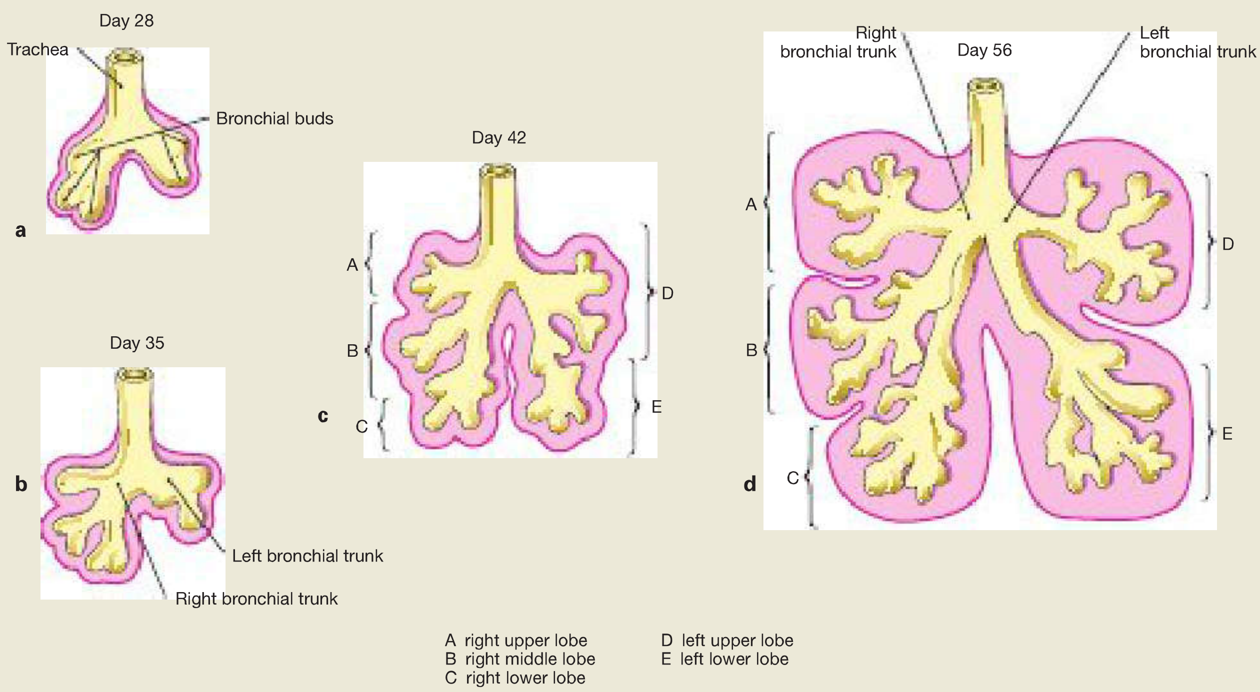


Fig. 5.86a to d Stages of lung development. [E347-09]
A distinction is made between three phases of lung development, which partially overlap:
- **Pseudoglandular phase** (7th–17th week): formation of the conducting part of the respiratory system
- **Canalicular phase** (13th–26th week): early development of the respiratory part (gas exchange) of the respiratory system
- **Alveolar phase** (23rd week–8th year of life): formation of the alveoli. Lung development is therefore not completed at birth, but continues into childhood!

Lung

Trachea and Bronchi

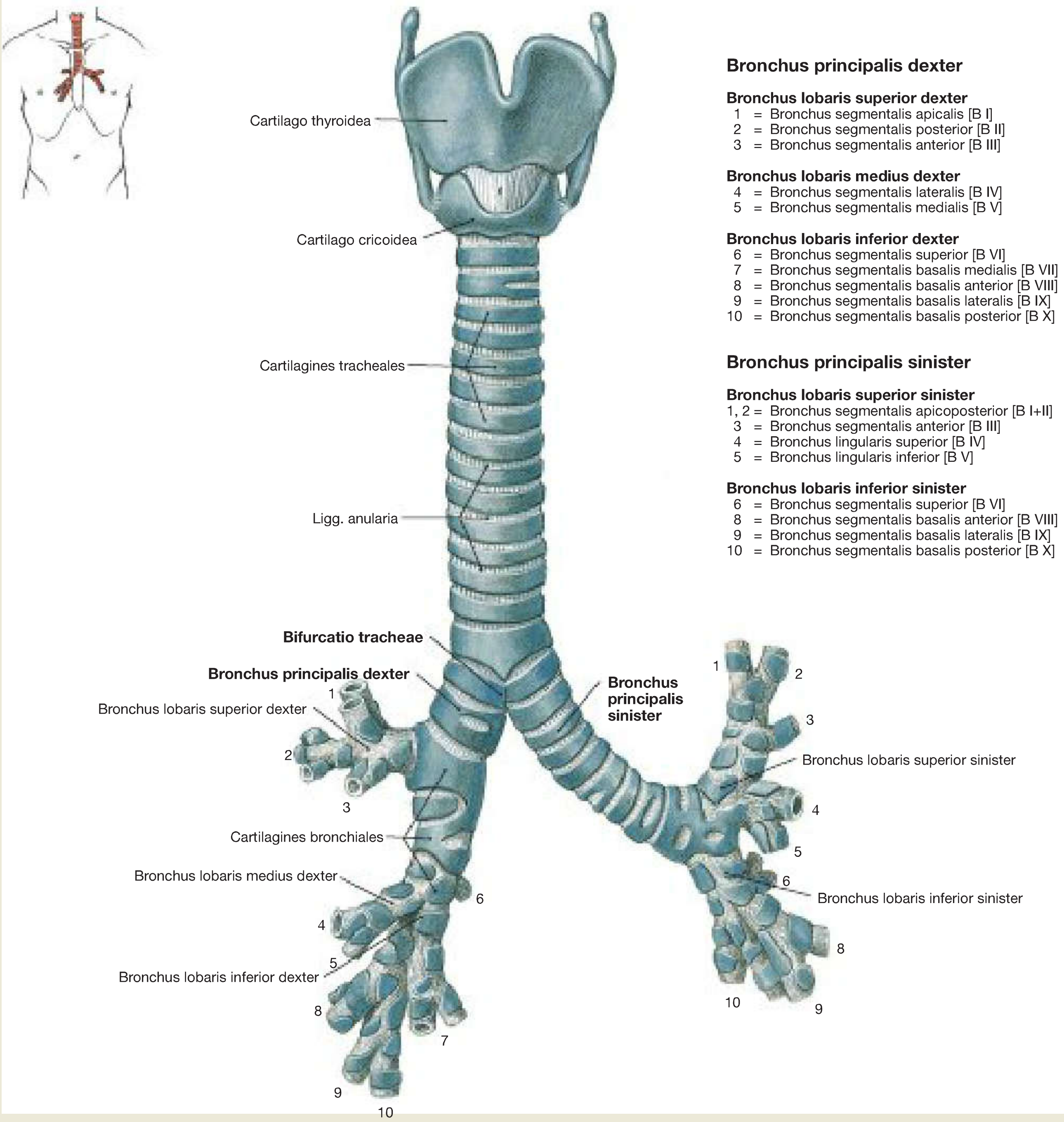


Fig. 5.87 Lower respiratory tract with larynx, trachea and bronchi; ventral view.

The trachea is 10–13 cm long and extends from the cricoid cartilage of the larynx to its division (Bifurcatio tracheae) into the two main bronchi **(Bronchi principales).** It is divided into a neck part (Pars cervicalis) and a sternum part (Pars thoracica). Projection and topography are described in → Figure 5.81. The main bronchi further divide into three right-sided and two left-sided lobar bronchi **(Bronchi lobares).** The segmental bronchi **(Bronchi segmentales)** emerge from the lobar bronchi. On the right-hand side, there are ten lung segments and thus ten segmental bronchi. In the left lung, however, segment 7 and the respective bronchus are missing.

More detailed systematic description of the bronchial tree is not illustrated here. The bronchi divide six to twelve times and then pass into the **bronchioles,** which have a diameter < 1 mm and are therefore only clearly visible with a microscope. Bronchioles are easily distinguished from bronchi as they no longer contain cartilage and glands in their walls. Each bronchiole supplies a pulmonary lobule (Lobulus pulmonis) and further divides three to four times to become **terminal bronchioles.** These represent the last one of the **conducting parts** of the respiratory system which has a volume of 150–170 ml. A terminal bronchiole supplies a pulmonary acinus **(Acinus pulmonis),** which generates ten further generations of respiratory bronchioles with Ductus and Sacculi alveolares. All parts of the acinus have alveoli and therefore belong to the **respiratory or gas exchange part** of the respiratory system.

Clinical Remarks

The volume of the conducting parts of the respiratory system **(150–170 ml)** is equivalent to the **anatomic dead airspace** and has practical relevance for **resuscitation.** During ventilation, a volume greater than 170 ml needs to be exchanged, otherwise no oxygenated air reaches the alveoli; used air is simply moved into the respiratory tract. Therefore, it is better to ventilate slowly with more volume than quickly with too little volume.

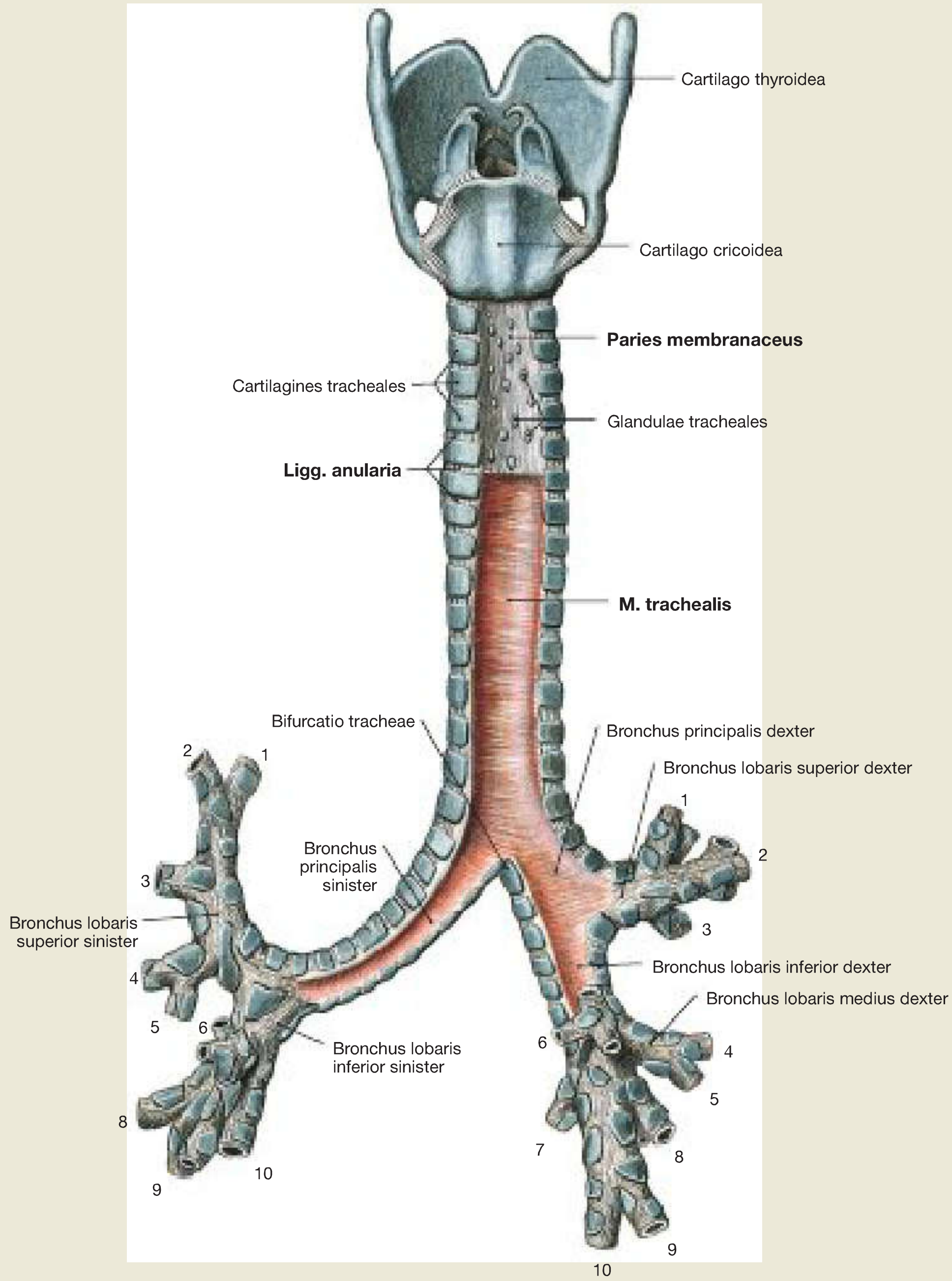


Fig. 5.88 Lower respiratory tract with larynx, trachea, and bronchi; dorsal view.
The systematic composition of the bronchial tree is described in → Fig. 5.87. The dorsal view clearly shows that the dorsal walls of the trachea and the main bronchi do not have any cartilage (Paries membranaceus) but consist predominantly of smooth muscles (M. trachealis). The individual links are connected by Ligg. anularia of elastic connective tissue, so that the trachea can extend during deep inhalation by up to 5 cm.

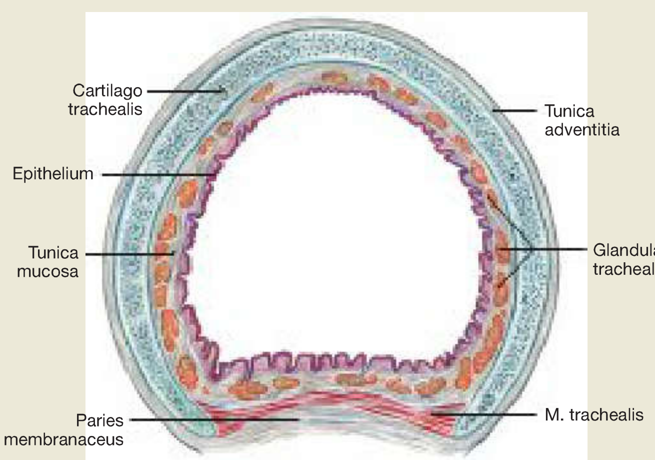
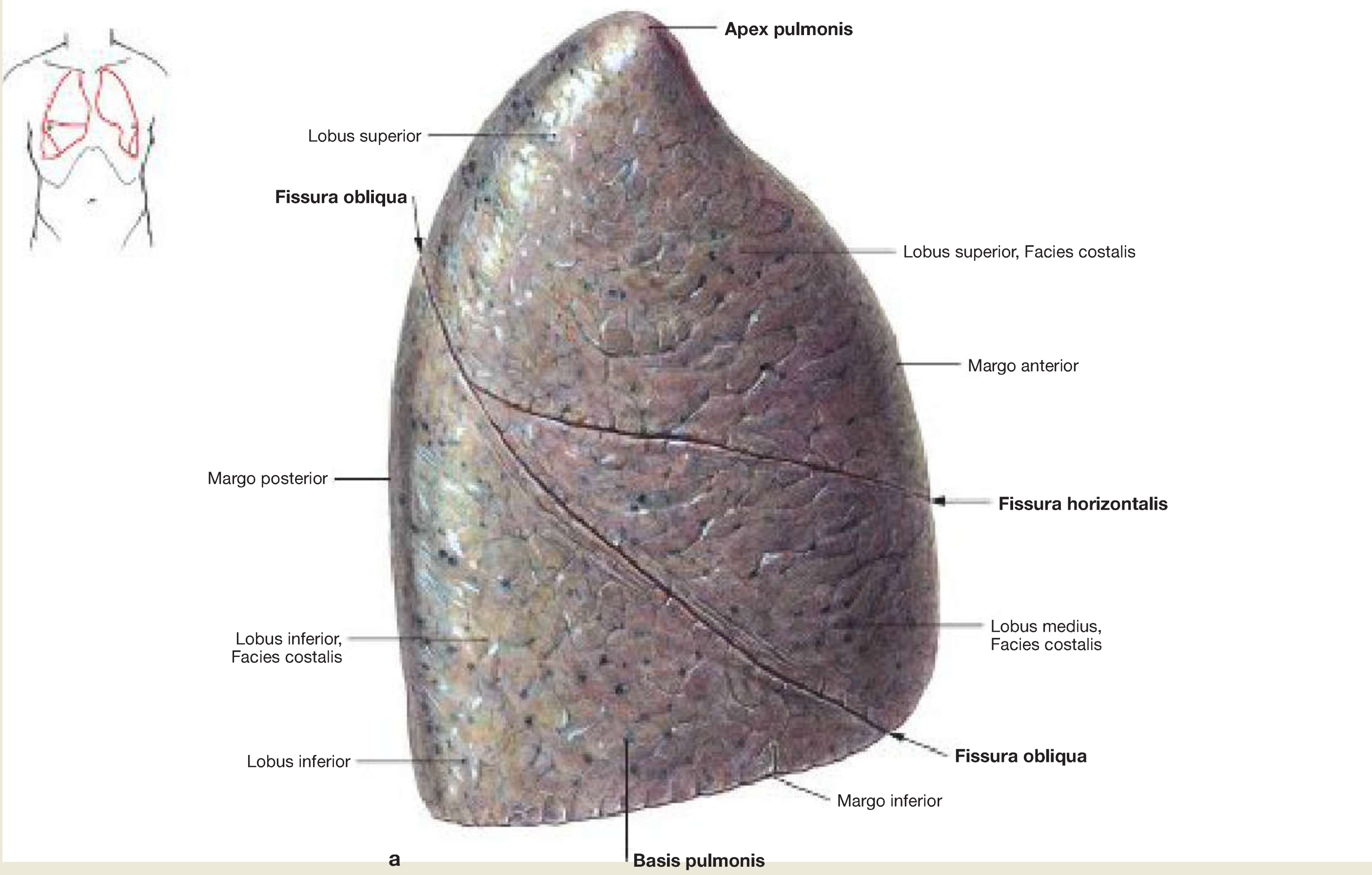


Fig. 5.89 Trachea; cross-section, microscopic view.
The wall of the trachea and main bronchi comprises a mucous membrane (Tunica mucosa), to which the Tunica fibromusculocartilaginea and the Tunica adventitia attach themselves on the outside. The Tunica fibromusculocartilaginea consists of 16 to 20 horseshoe-shaped tracheal cartilages of hyaline cartilage, which are open at the back where they are bridged posteriorly by smooth muscles (M. trachealis).

Lung



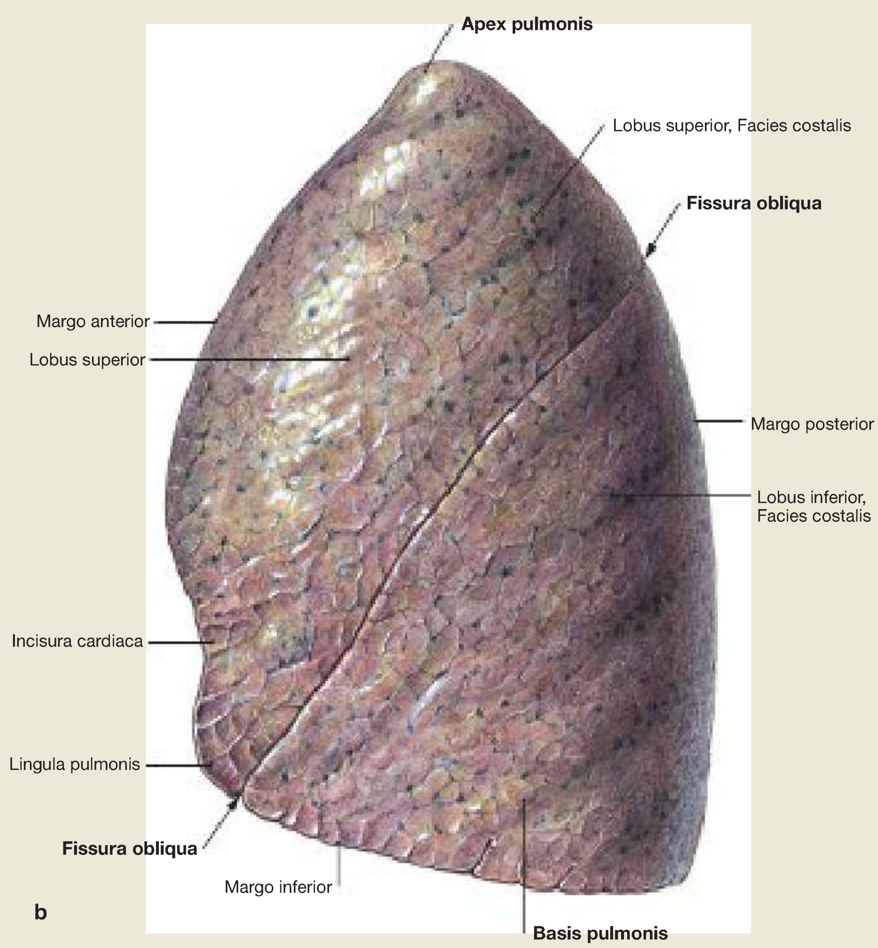
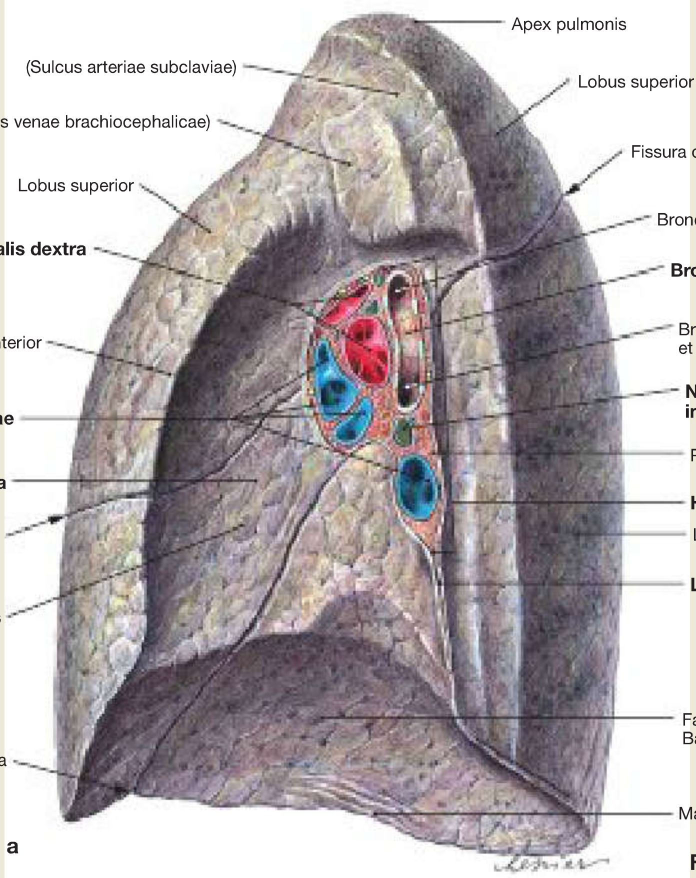


Fig. 5.90a and b Right lung, Pulmo dexter (→ Fig. 5.90a), and left lung, Pulmo sinister (→ Fig. 5.90b); lateral view.

The **right lung** has **three lobes (Lobi superior, medius, and inferior),** which are separated by the oblique fissure and the horizontal fissure. The **left lung,** however, consists of **two lobes (Lobi superior and inferior)** and has just a Fissura obliqua. Corresponding to the middle lobe is the lingula pulmonis of the superior lobe; the lingula forms a tongue-shaped projection underneath the Incisura cardiaca.

The volume of the right lung encompasses 2–3 l, and even 5–8 l during maximum inspiration. Corresponding to this volume is a gas exchange surface area of 70–140 m^2. The volume of the left lung, due to the heart tilting slightly to the left, has a 10–20% smaller volume.

Cranially the lungs have a **apex (Apex pulmonis)** and caudally a wide area **base (Basis pulmonis).** The surface is covered by the Pleura visceralis and can be divided into three areas in accordance with the topographical relationships. The lateral **Facies costalis** passes below at the Margo inferior into the **Facies diaphragmatica** (→ Fig. 5.91), at the Margo anterior and at the blunt Margo posterior into the **Facies mediastinalis** on the medial side.



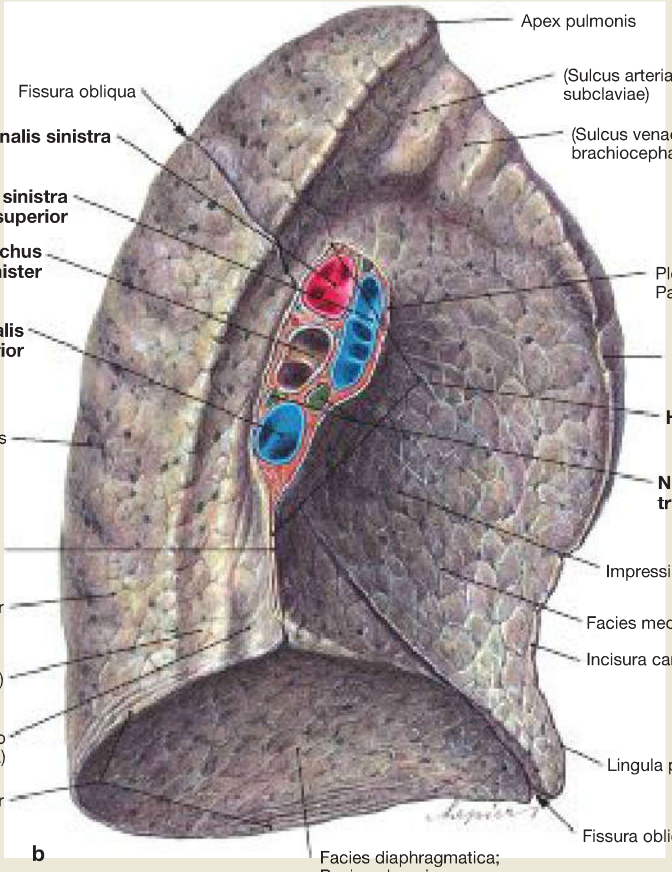


Fig. 5.91a and b Right lung, Pulmo dexter (→ Fig. 5.91a), and left lung, Pulmo sinister (→ Fig. 5.91b); medial view.

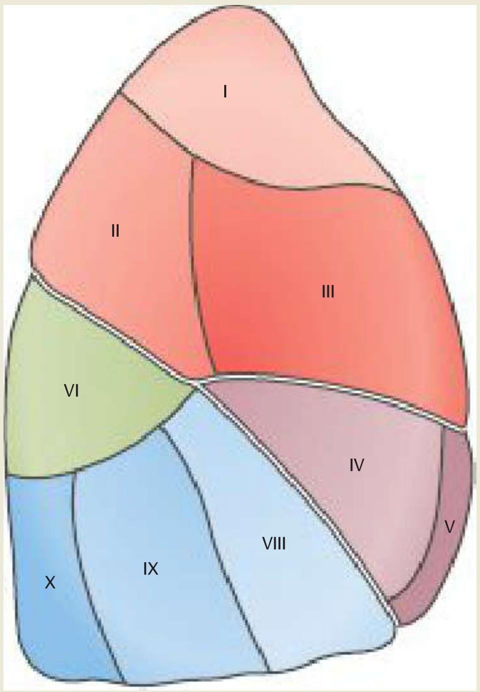
In the medial aspect lies the **hilum of the lung (Hilum pulmonis),** where the main bronchi and the neurovascular pathways of the lung enter and exit, and is the so-called **root of the lung (Radix pulmonis).** At the hilum the **visceral pleura (Pleura visceralis)** also passes from the lung surface onto the **parietal pleura (Pleura parietalis),** that covers the Cavitas pleuralis. This pleural fold extends inferiorly into the Lig. pulmonale.

The arrangement of the main bronchi and the great vessels in the hilum of the lung is characteristic in both lungs. On the **right lung,** the **Bronchus principalis** lies farthest **above,** while on the left side it is located underneath the A. pulmonalis. The Vv. pulmonales are in front and below. During dissection of the root of the lung some tracheobronchial lymph nodes (Nodi lymphoidei tracheobronchiales) in the area of the hilum of the lung are usually also cut; these nodes are usually black due to coal dust deposits. The mediastinal surface (left more than right) is concave through the heart (Impressio cardiaca). Both lungs exhibit depressions which are caused by adjacent blood vessels or, on the left side, by the oesophagus. These indentations are, like the margins of the lung, only visible in the fixed lung (fixation artefacts), but they clarify the positional relationships of the lungs.

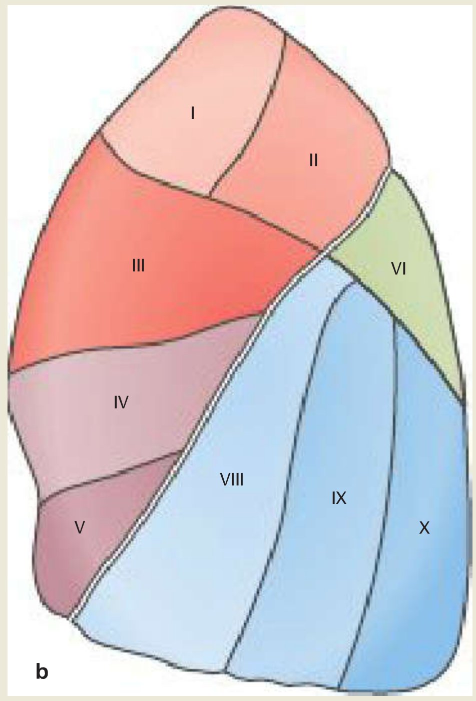
Clinical Remarks

Since the apex of the lung sticks out over the upper thoracic aperture by up to 5 cm, when applying a **central venous catheter** (CVC) via the V. subclavia there is the danger of injuring the lung and of 'lancing', as clinicians say, a **pneumothorax** and causing lung collapse by opening of the pleural gap. This danger also exists in principle with a CVC in the V. jugularis interna at the neck since it is a case of stabbing in the direction of the sternoclavicular joint and thus into the apex of the lung. However, the danger is much greater when applying a CVC in the V. subclavia since it lies directly in contact with the Cavitas pleuralis (→ Fig. 5.117) before it continues into the V. brachiocephalica.

Lung Segments



a



b

Pulmo dexter

Lobus superior
- Segmentum apicale [S I]
- Segmentum posterius [S II]
- Segmentum anterius [S III]

Lobus medius
- Segmentum laterale [S IV]
- Segmentum mediale [S V]

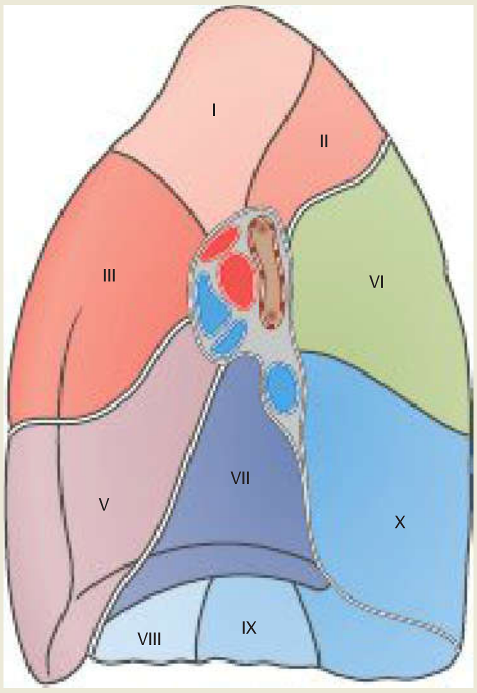
Lobus inferior
- Segmentum superius [S VI]
- Segmentum basale mediale [cardiacum] [S VII]
- Segmentum basale anterius [S VIII]
- Segmentum basale laterale [S IX]
- Segmentum basale posterius [S X]

Pulmo sinister

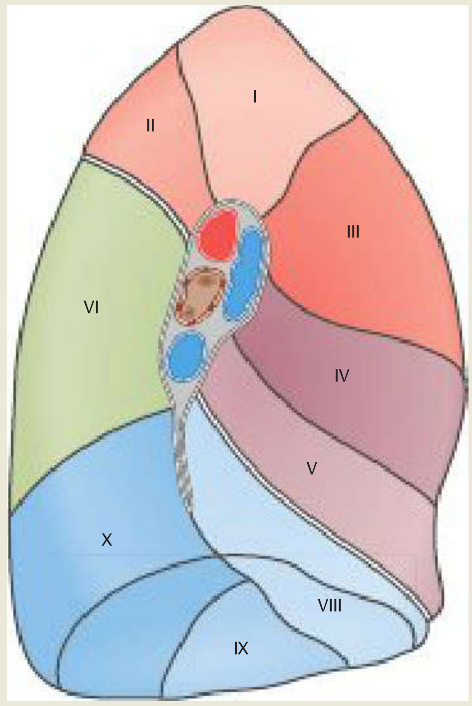
Lobus superior
- } Segmentum apicoposterius [S I + II]
- Segmentum anterius [S III]
- Segmentum lingulare superius [S IV]
- Segmentum lingulare inferius [S V]

Lobus inferior
- Segmentum superius [S VI]
- Segmentum basale anterius [S VIII]
- Segmentum basale laterale [S IX]
- Segmentum basale posterius [S X]

Fig. 5.92a and b Bronchopulmonary segments, Segmenta bronchopulmonalia, of the right (→ Fig. 5.92a) and the left (→ Fig. 5.92b) lung; lateral view. [L126]
The lung lobes subdivide into cone-shaped lung segments, which are separated incompletely from each other by connective tissue septa, so that the segment boundaries are not discernible on the surface of the lungs. The segments have their own **segmental bronchi** and segmental branches of the pulmonary arteries. The **right lung** has **ten segments:** three in the superior, two in the middle and five in the inferior lobe. The **left lung** only has **nine segments** because, due to the larger distension of the mediastinum on the left-hand side, the segment VII (Segmentum basale mediale, → Fig. 5.93a) is missing or severely reduced in size and merged with segment VIII. Otherwise, the segmental subdivision is relatively similar, since the segments of the middle lobe on the right side correspond to two segments on the left in the Lingula pulmonis.



a



b

Fig. 5.93a and b Bronchopulmonary segments, Segmenta bronchopulmonalia, of the right (→ Fig. 5.93a) and the left (→ Fig. 5.93b) lung; medial view. [L126]

The right lung has ten segments. In contrast, the left lung has only nine segments, as segment VII (Segmentum basale mediale) is missing.

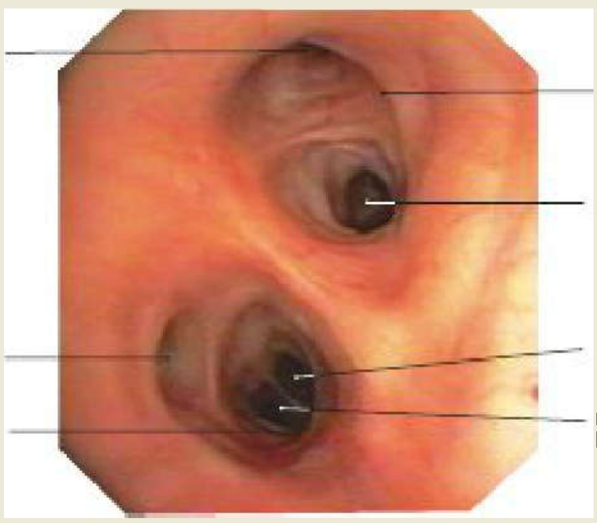


Fig. 5.94 Bronchi; bronchoscopy with view of the segmental bronchi of the left lung. As can be seen, segmental bronchus VII is missing on the left side (→ Fig. 5.93b).

Clinical Remarks

To aid orientation when performing a **bronchoscopy,** knowledge of the lung segments is important. A bronchoscopy is performed when diagnostic imaging reveals unclear mass lesions that need to be clarified through a biopsy in order, e.g. to exclude or diagnose a tumour. Another indication is a treatment-resistant pneumonia. Here the aim is to verify the pathogen.

Blood Vessels of the Lung

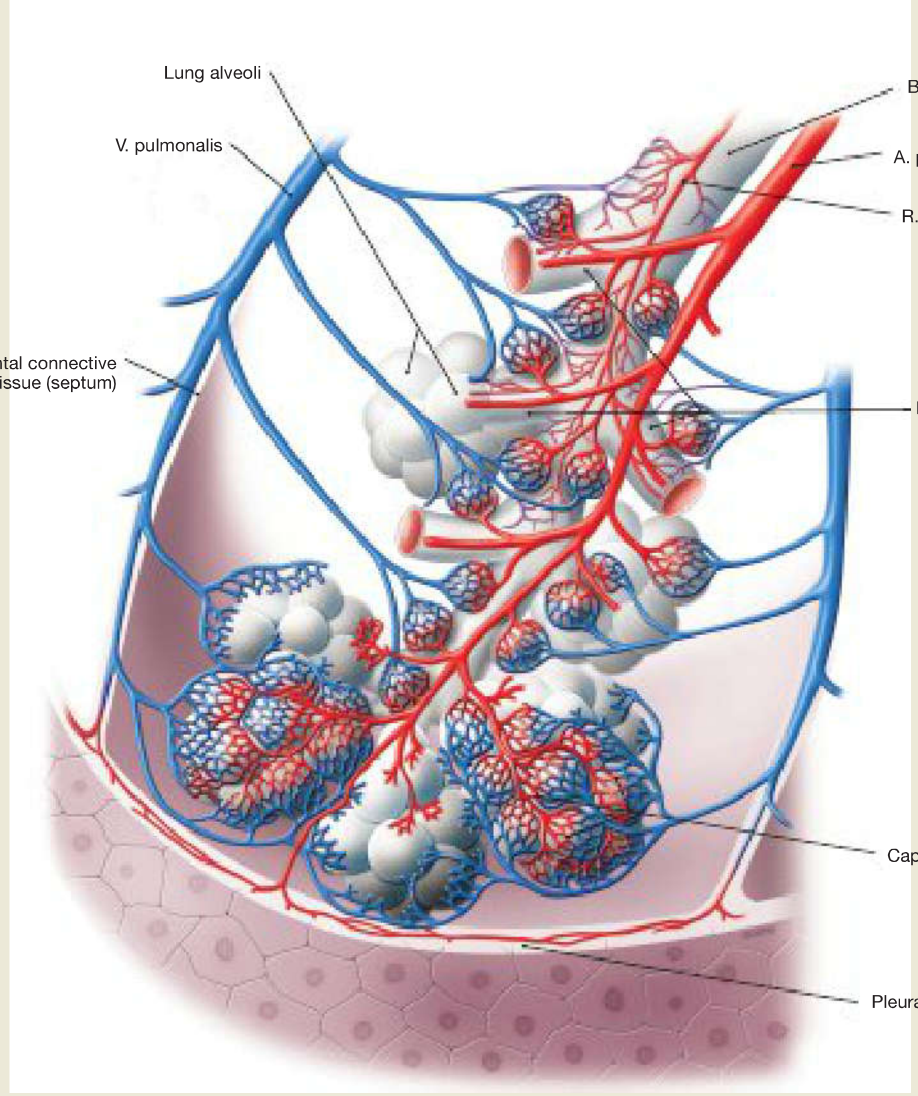


Fig. 5.95 Acinus of the lung, Acinus pulmonis, with blood supply. [L238]

The lung has two blood vessel systems which communicate through their terminal branches in the wall of the alveoli (alveolar septa). The Aa. and Vv. pulmonales of the pulmonary circulation constitute the **Vasa publica** which take care of the gas exchange of the blood. The branches of the Aa. pulmonales run in the peribronchial and subpleural connective tissue and transport the deoxygenated blood from the right heart to the alveoli. In contrast, the Vv. pulmonales are located in the intersegmental connective tissue and transport the oxygenated blood to the left atrium.

The **Vasa privata** of the lung supply the lung tissue itself. The arterial Rr. bronchiales and the Vv. bronchiales run together with the bronchi. The Vv. bronchiales discharge into the veins of the azygos system (→ Fig. 5.111).

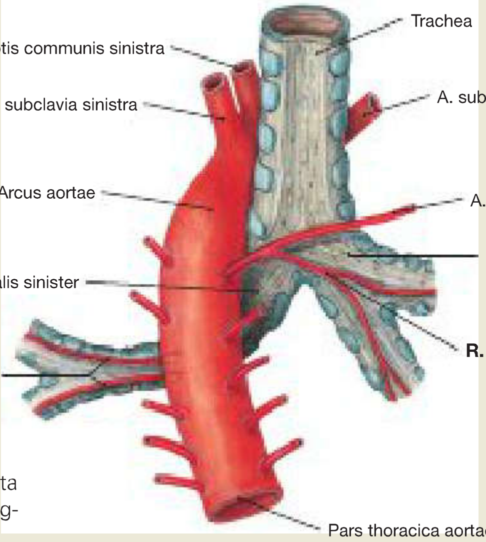


Fig. 5.96 Vasa privata of the lung; dorsal view.

The arterial Rr. bronchiales originate on the left directly from the Aorta thoracica; on the right, however, the R. bronchialis dexter usually originates from the A. intercostalis dextra III.

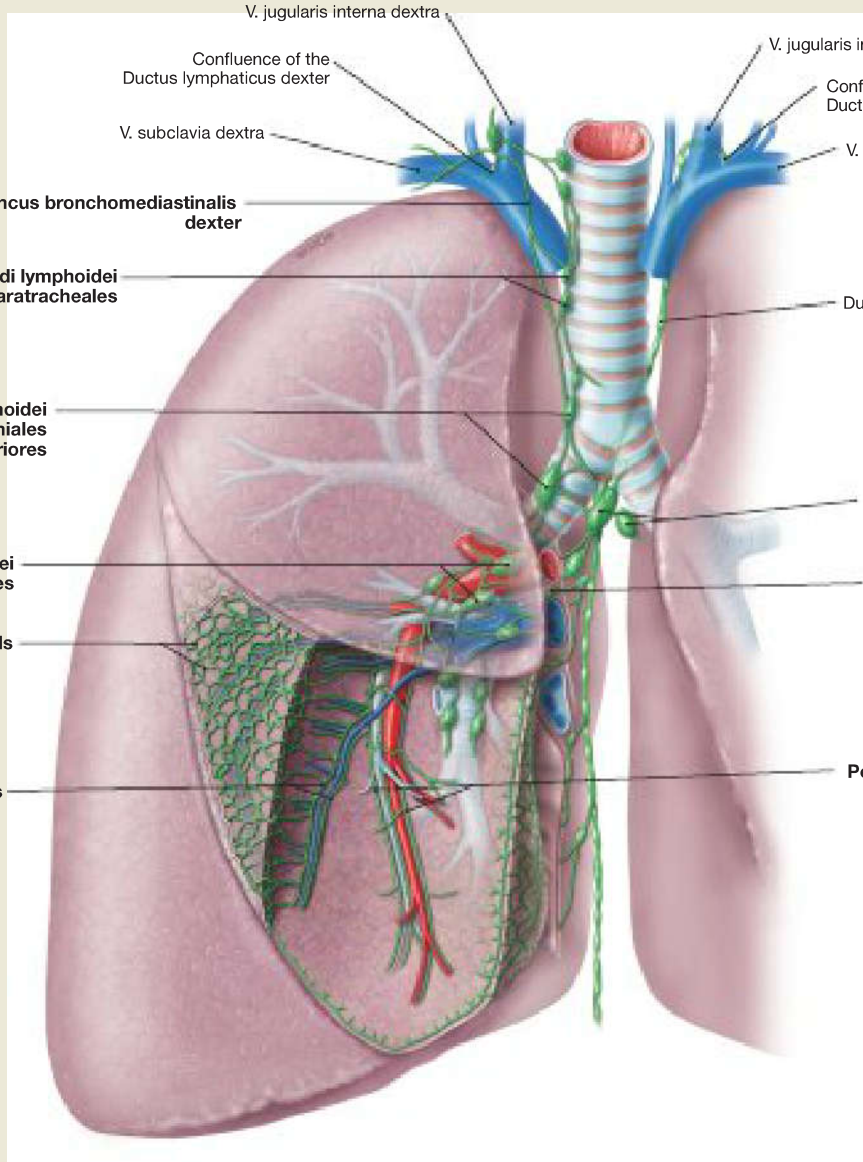


Fig. 5.97 Lymphatic vessels, Vasa lymphatica, and lymph nodes, Nodi lymphoidei, of the lung; ventral view; schematic drawing. [L238]
The lung has two lymphatic vessel systems which converge at the hilum. The **peribronchial system** follows the bronchi and includes several lymph nodes on its way. The first station are the **Nodi lymphoidei,** which lie adjacent to the arborisation of the lobes into the segmental bronchi. The second station are the **Nodi lymphoidei bronchopulmonales** in the hilum of the lung. The **Nodi lymphoidei tracheobronchiales** that follow are already in the lung root. A distinction is made between Nodi lymphoidei tracheobronchiales superiores and inferiores above and below the tracheal bifurcation. From there, the lymph flows into the **Nodi lymphoidei paratracheales** or into the **Trunci bronchomediastinales** of both sides, so that there is no strict side alignment of the lymphatic pathways.
In contrast, the first station for the **subpleural** and the **septal lymphatic vessel systems** are the Nodi lymphoidei tracheobronchiales. The fine lymphatic pathways form a polygonal network on the surface of the lung, the mesh of which corresponds to the boundaries of the individual lung lobules. Due to carbon dust deposits (exhaust fumes and cigarette smoke) these lymphatic pathways and thus the boundaries of the lobules are clearly visible in a dissection.

Clinical Remarks

Clinicians usually collectively call all lymph nodes of the lung **hilar lymph nodes.** This is deceptive as the Nodi lymphoidei intrapulmonales spread relatively widely into the lung parenchyma. Due to these linguistic inexactitudes, mass lesions in the parenchyma may be considered prematurely as independent disease processes and not as enlargements of the lymph nodes, and unnecessary diagnostic steps for their clarification are initiated.

Neurovascular Pathways of the Lung in-situ and Innervation of the Lung

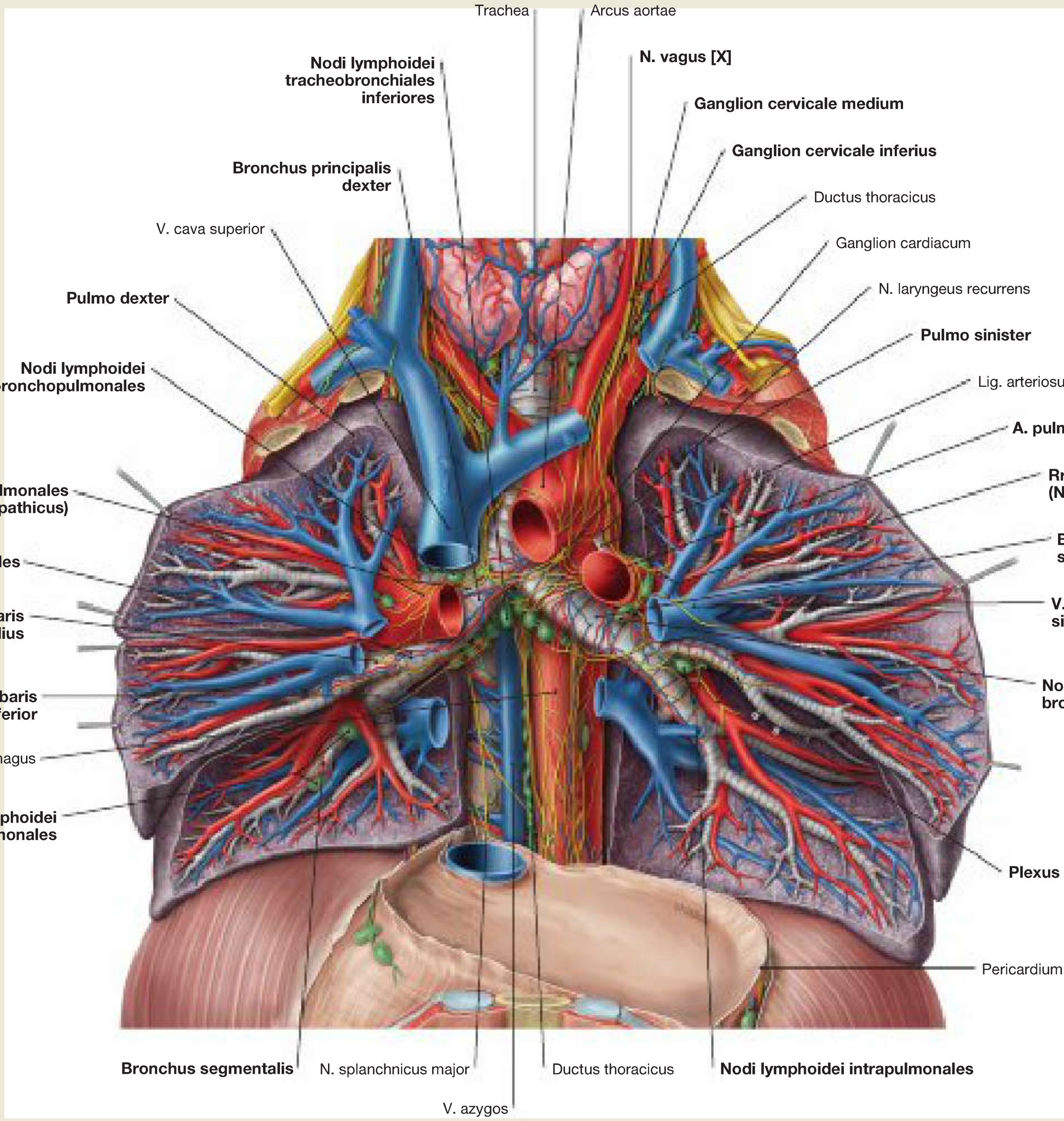


Fig. 5.98 Bronchial tree of the lungs with neurovascular pathways; ventral view; after removal of the heart with pericardium. [L238]

The **main bronchi (Bronchi principales)** commence at the hilum of the lungs. Together with the neurovascular pathways of the lungs these form the **root of the lung (Radix pulmonis).** The main bronchi divide into the **lobar and segmental bronchi (Bronchi lobares and Bronchi segmentales)** accompanied by the branches of the **pulmonary arteries (Aa. pulmonales)**. In contrast, the **pulmonary veins (Vv. pulmonales)** are isolated within the subpleural and intersegmental connective tissue, that has been removed. These large vessels are merged as vasa publica, as they serve to oxygenate the blood and thus the supply of the whole body. They can be seen clearly in a dissection. The illustration shows also the finer neurovascular pathways that are usually not distinct in a dissection: The arterial **Rr. bronchiales** and the **Vv. bronchiales** constitute the vasa privata of the lung since they supply the lung tissue. They run directly along the bronchi. The lymphatic pathways of the peribronchial lymphatic vessel system are connected to the Nodi lymphoidei intrapulmonales, which are located as the first lymph node station at the arborisation of the lobes into the segmental bronchi. The second station of the **Nodi lymphoidei bronchopulmonales** is right in the hilum.

The autonomic nerve fibres of the **Plexus pulmonalis** form a network on the main bronchi that includes both efferent as well as afferent nerve fibres. The sympathetic nerve fibres **(Rr. pulmonales)** are postganglionic and come from the lower ganglion of the sympathetic chain (Ganglion cervicale inferius) as well as the upper ganglia of the thoracic sympathetic chain. The parasympathetic nerve fibres **(Rr. bronchiales)** from the N. vagus [X] and N. laryngeus recurrens are still preganglionic. Their synaptic switch happens in the mostly microscopically small ganglia of the Plexus pulmonalis. The **Truncus sympathicus** effects an expansion of the bronchi **(bronchial dilation)** for better ventilation of the lung, while the **parasympathetic trunk** narrows the bronchi **(bronchial constriction)** and activates the secretion of mucous-forming glands. The N. vagus [X] also leads afferent nerve fibres from the lung to the brain stem in order to be able to convey stretch and pain stimuli.

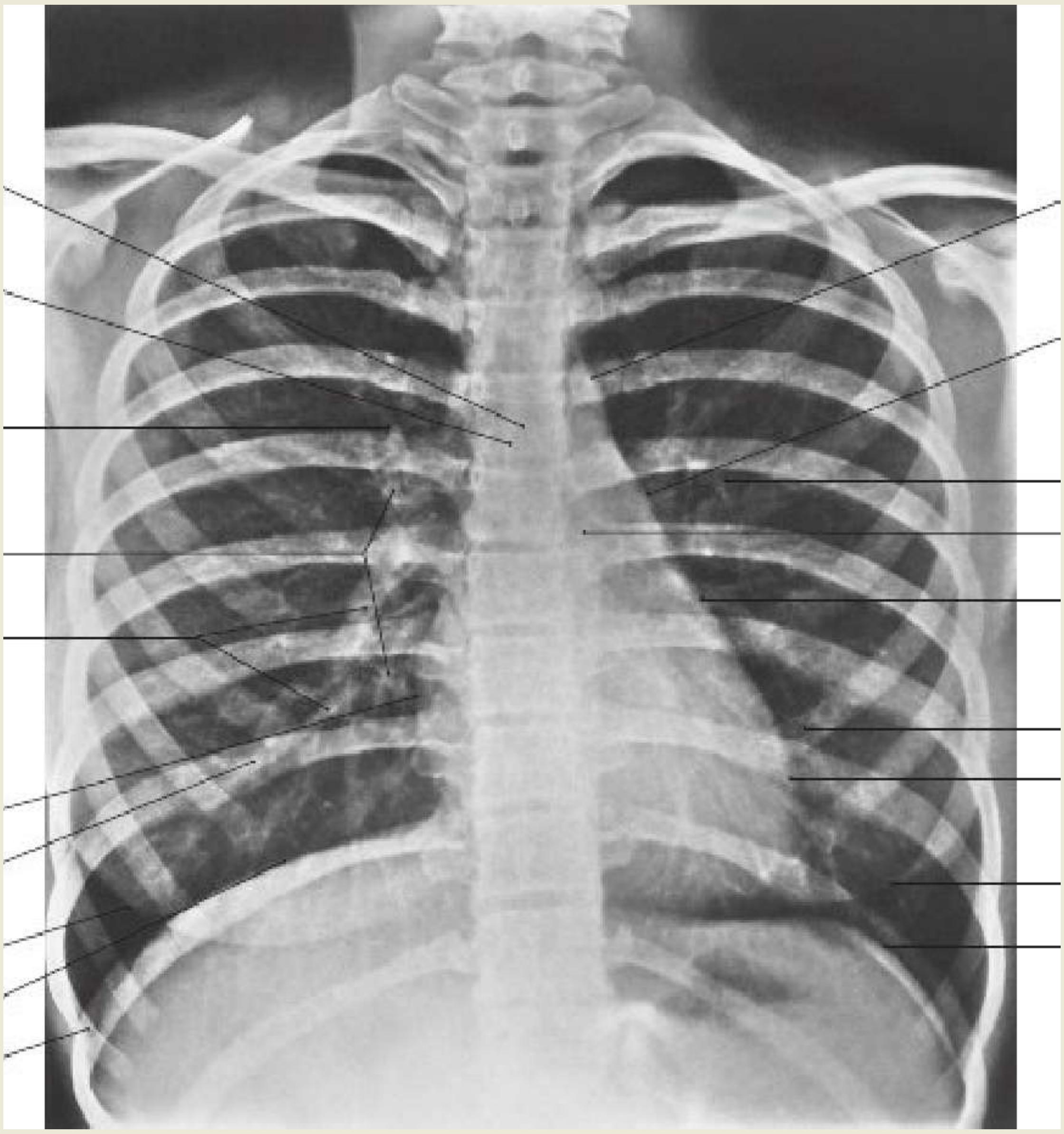


Fig. 5.99 Thoracic cage, Cavea thoracis, with organs of the Cavitas thoracis; X-ray in posteroanterior (PA) beam projection. [R316-007]

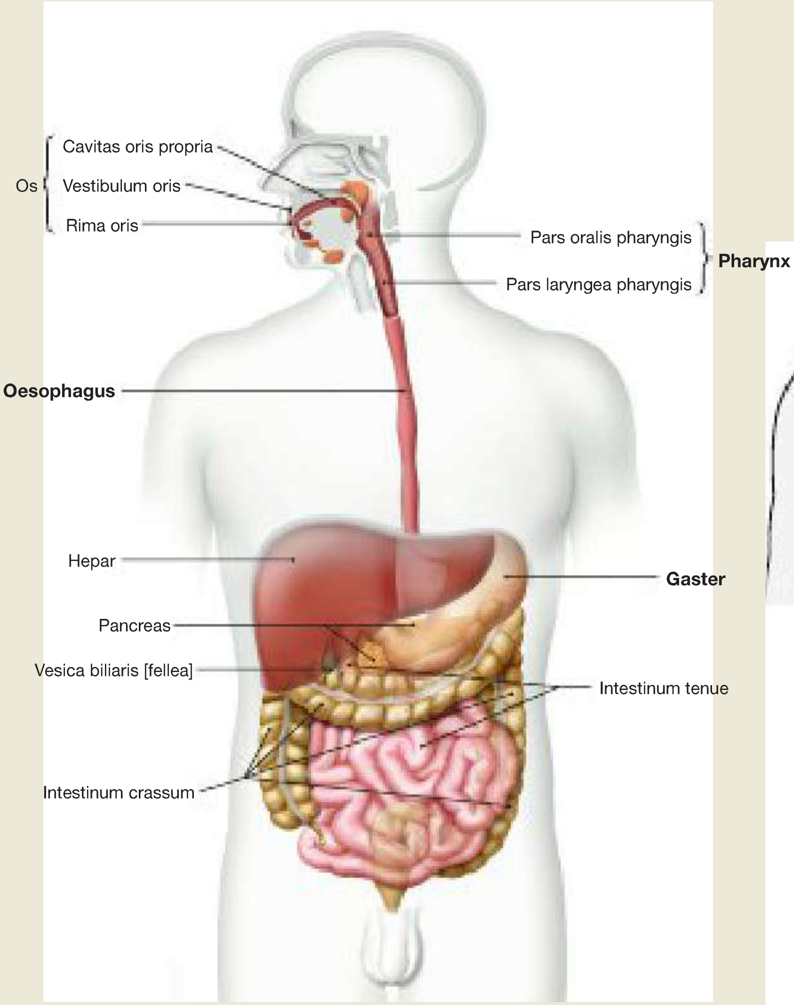
The bronchi are partially discernible in the course. On the right side, clusters of lymph nodes in the area of the hilum of the lung are also discernible.

* mammary shadow (contour)
** clinical term: hilar lymph nodes

Clinical Remarks

X-ray images of the thorax are frequently taken if **pathological processes** of the lungs and the pleura are suspected, such as inflammations (pneumonia, pleuritis) or tumours (bronchial carcinoma). Changes in the parenchyma often stand out as 'shadows' because radiation permeability is usually lower than in intact lung tissue. In the case of a pleural effusion, the costodiaphragmatic angle is blunted with an upright body position, resulting in a horizontal fluid level.

Projection of the Oesophagus



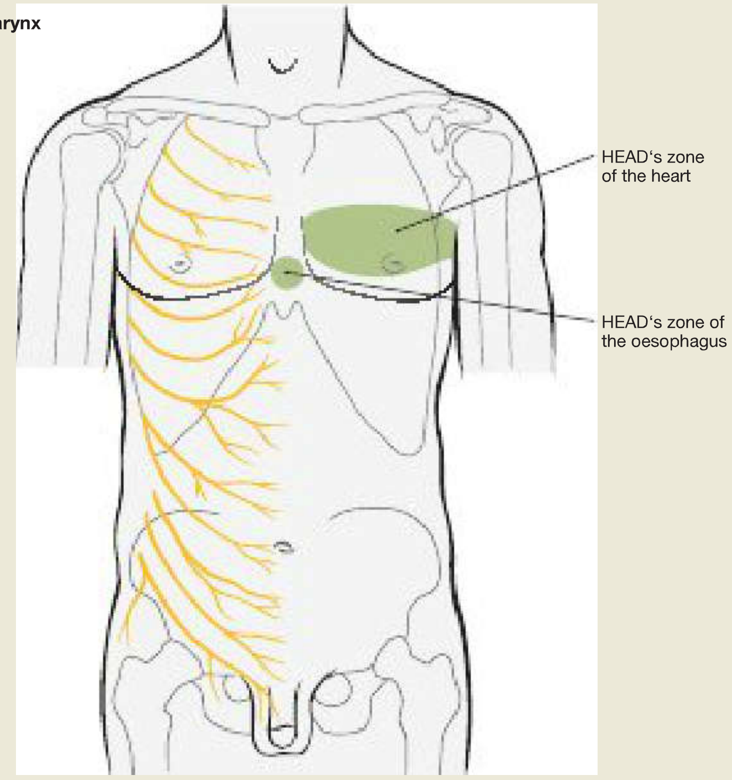


Fig. 5.100 Overview of the digestive system. [L275]
The digestive system extends from the oral cavity via the pharynx to the gastrointestinal tract and also comprises the accessory glands, such as oral and pancreatic glands, liver and gallbladder.
The **oesophagus** is a muscle tube, which connects the **pharynx** with the **stomach (Gaster)** and serves the transportation of swallowed food. The oesophagus is **25 cm long** and reaches from the cricoid cartilage which projects onto the 6^{th} cervical vertebra, to the stomach entrance (cardia) at the height of the 10^{th} thoracic vertebra (below the Proc. xiphoideus of the breastbone). The anatomical length of the oesophagus is relatively negligible for diagnostics. Here, the distance from the dental arch is given, since in an endoscopic examination of the upper gastrointestinal tract (gastroscopy) the length of the oral cavity and pharynx must be taken into account.

Fig. 5.101 HEAD's zone of the oesophagus and the heart; schematic diagram of the sensory innervation of the ventral torso wall; ventral view. [L126]
Afferent nervous pathways from the heart, through which stimuli are transmitted to the central nervous system, run in the respective spinal cord segments together with nerve fibres that originate from the dedicated skin areas (dermatomes). In the oesophagus, these are the dermatomes T4 and T5. This organ-dependent skin area where pain is perceived is referred to as **HEAD's zone of the oesophagus.** Since the **HEAD's zone of the heart** is closely adjacent, pain in the area of the ventral thoracic wall is always initially regarded as angina pectoris until coronary heart disease (CHD) is excluded.

Clinical Remarks

The projection of the oesophagus makes it understandable why an inflammation caused by gastric juice **(reflux oesophagitis)** causes pain and retrosternal burning in a similar location as a heart attack. From these two organs the afferent nerve fibres go into the same spinal cord segments as nerve fibres of the anterior thoracic wall, so that the brain cannot properly differentiate whether the pain stems from the body surface or from one of the internal organs.

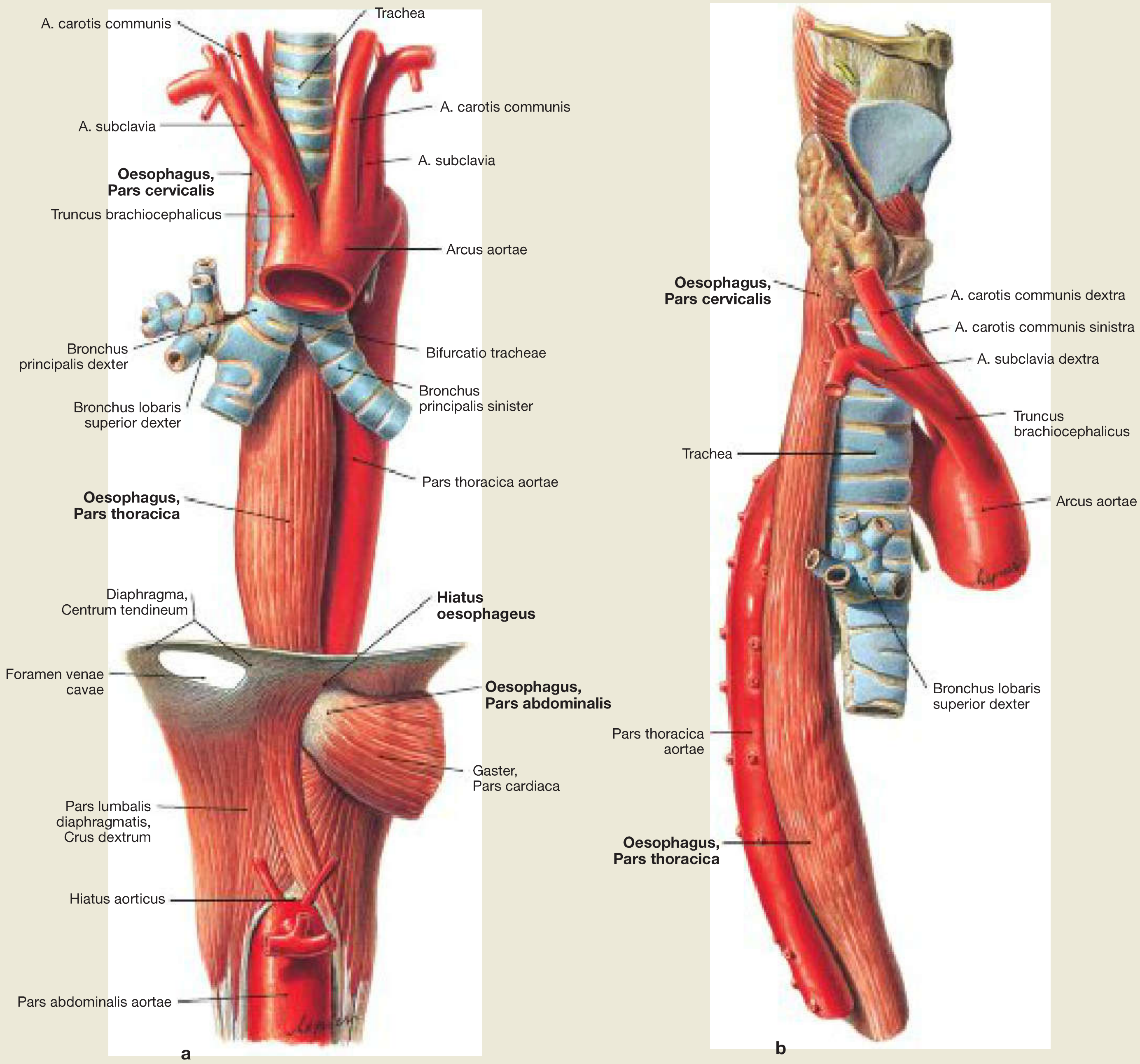


Fig. 5.102a and b Oesophagus, trachea, and Pars thoracica of the aorta; ventral view (→ Fig. 5.102a) and view from the right (→ Fig. 5.102b). The oesophagus is 25 cm long and is divided into three parts:

- Pars cervicalis (5–8 cm)
- Pars thoracica (16 cm)
- Pars abdominalis (1–4 cm)

The **Pars cervicalis** is located in the spine. The **Pars thoracica** crosses the Arcus aortae, which is situated dorsally from the left, runs past the left main bronchus and moves increasingly away to the ventral side of the spine. In the dorsal view, it is clear that the Pars thoracica has direct contact to the pericardium and therefore enters into close proximity to the left atrium (→ Fig. 5.103). The short intraperitoneally located Pars abdominalis commences after passing through the oesophageal hiatus.

Structure of the Oesophagus

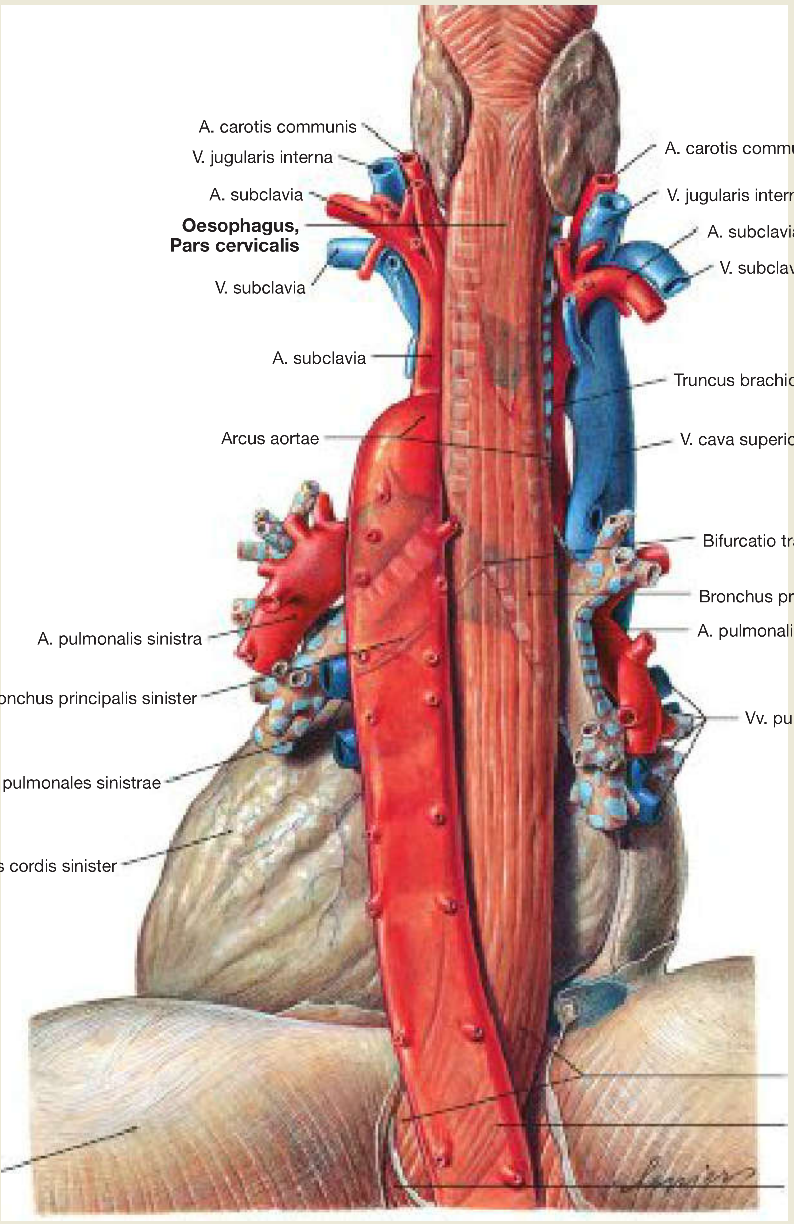


Fig. 5.103 Oesophagus, pericardium and Pars thoracica aortae; dorsal view.
The Pars thoracica of the oesophagus runs adjacent and to the right of the **Aorta descendens.** The neck part and the upper part of the Pars thoracica are situated directly on the dorsal side of the **trachea.** The caudal part of the Pars thoracica, which is situated below the tracheal bifurcation, dorsally abuts the left atrium **(Atrium sinistrum),** which is only separated by the pericardium. The tracheal bifurcation abuts the oesophagus at a distance of approximately 23 cm from the dental arch.

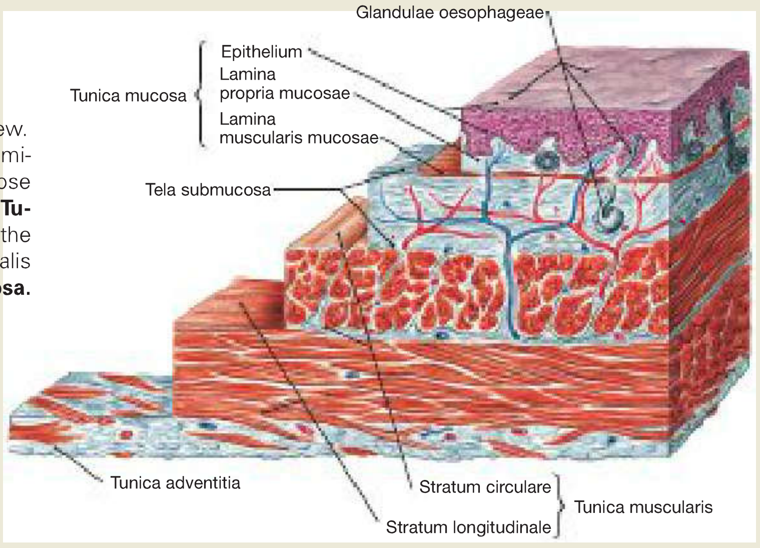
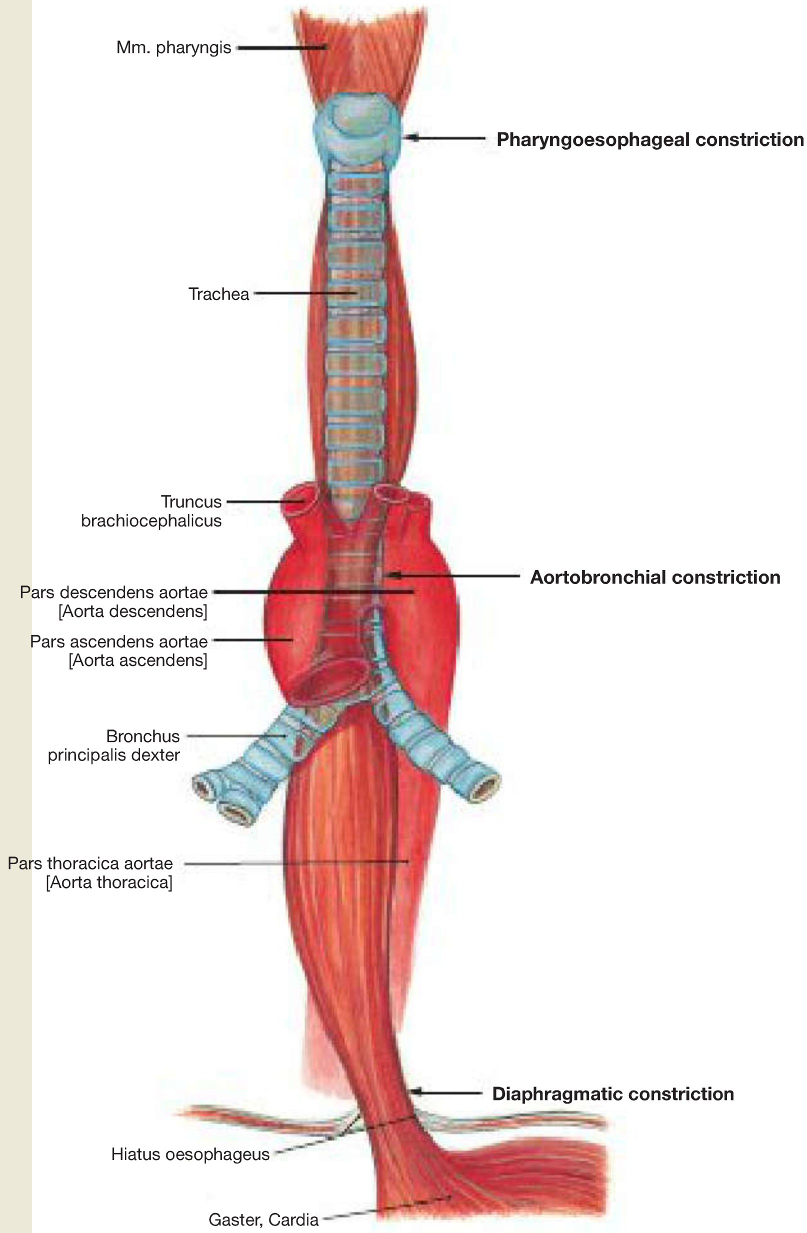


Fig. 5.104 Wall construction of the oesophagus; microscopic view.
Similar to the entire gut, the wall of the oesophagus consists of a luminal mucous membrane **(Tunica mucosa)** which is separated by a loose connective tissue layer **(Tela submucosa)** from the muscular layer **(Tunica muscularis).** The cervical and thoracic parts are covered by the **Tunica adventitia.** Only in the intraperitoneally located Pars abdominalis is the outer surface covered by visceral peritoneum, the **Tunica serosa.**



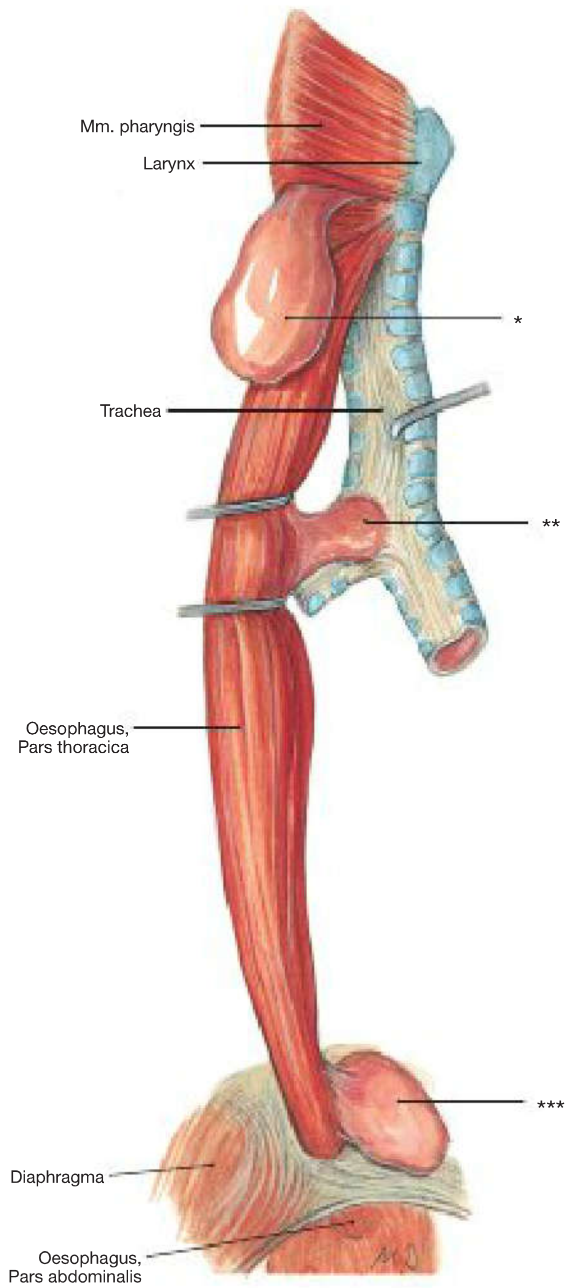


Fig. 5.105 Constrictions, Angustiae, of the oesophagus; ventral view.

The oesophagus has three constrictions:

- Pharyngoesophageal constriction (Angustia cricoidea)
- Aortic constriction (Angustia aortica)
- Diaphragmatic constriction (Angustia diaphragmatica)

The **pharyngoesophageal constriction** is the narrowest point in the area of the upper oesophageal sphincter at the level of the 6th cervical vertebra. The **aortic constriction** is brought forth dorsally on the left by the accretion of the Arcus aortae (height 4th thoracic vertebra). The **diaphragmatic constriction** lies in the oesophageal hiatus of the diaphragm (height 10th thoracic vertebra). There is no real sphincter here, but only an angiomuscular extension closure. The oesophagus is fixed by elastic connective tissue (Lig. phrenicooesophageale) to the outside of the Hiatus oesophageus.

Fig. 5.106 Diverticula of the oesophagus; dorsal right view.

* clinical term: ZENKER's diverticulum
** clinical term: traction diverticulum
*** clinical term: epiphrenic diverticulum

Clinical Remarks

Swallowed foreign bodies (e.g. fish bones) can get stuck at the constrictions. Diverticula of the entire oesophageal wall can occur at different points. **ZENKER's diverticula** (70%) are the most common. These diverticula bulge through the KILLIAN's triangle of the hypopharynx and are only falsely regarded as diverticula of the oesophagus. The cause is a defective weakening of the lower pharyngeal constrictor muscle. **Traction diverticula** (22%) are phylogenetically caused by a defective separation of oesophagus and trachea (→ Fig. 5.85). **Epiphrenic diverticula** (8%) are believed to be caused by a fault of the lower oesophageal sphincter.

Closing Mechanisms of the Oesophagus – Upper Oesophageal Sphincter

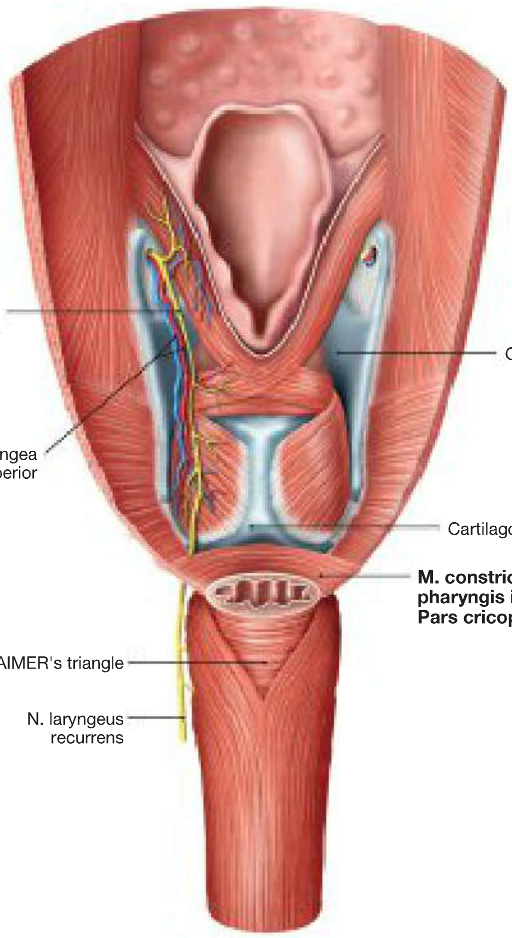
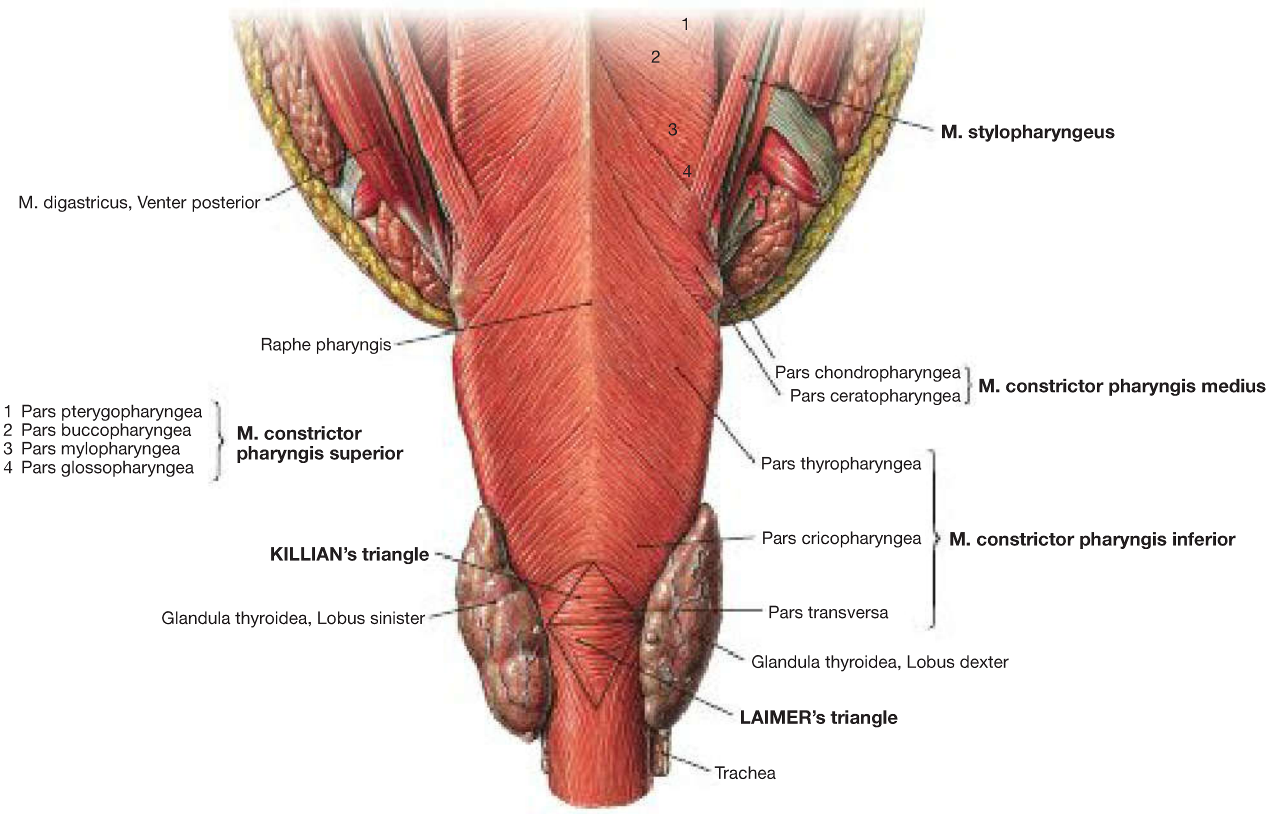


Fig. 5.107 Upper oesophageal sphincter; dorsal view onto the opened pharynx; the mucous membrane of which was resected on the anterior side. [L275]
The oesophagus starts at the cricoid cartilage constriction. This narrowest part of the oesophagus projects onto the 6th cervical vertebra. Located here is a true sphincter **(upper oesophageal sphincter),** which is also morphologically distinguishable. It is formed **inside** by the transversely running striated muscle fibres (Stratum circulare) of the **muscular layer of the oesophagus**. On the **outside** running muscle fibres (Pars transversa) of the **M. constrictor pharyngis inferior, Pars cricopharyngea** lie against them.

Fig. 5.108 KILLIAN's triangle and LAIMER's triangle; dorsal view.
In the transition area between the pharynx and oesophagus are two muscular weak triangles. **Cranially** of the transverse part of the inferior pharyngeal constrictor muscle lies the **KILLIAN's triangle. Caudally** of the transverse fibres, the **LAIMER's triangle** as an area with weak muscles can be distinguished.



Clinical Remarks

If during swallowing the transversely running fibres of the inferior pharyngeal constrictor do not weaken in time and thereby cause a pressure increase above the sphincter, **ZENKER's diverticula can emerge as protrusions.** They can lead to swallowing difficulties (dysphagia) since they compress the oesophagus from the outside.

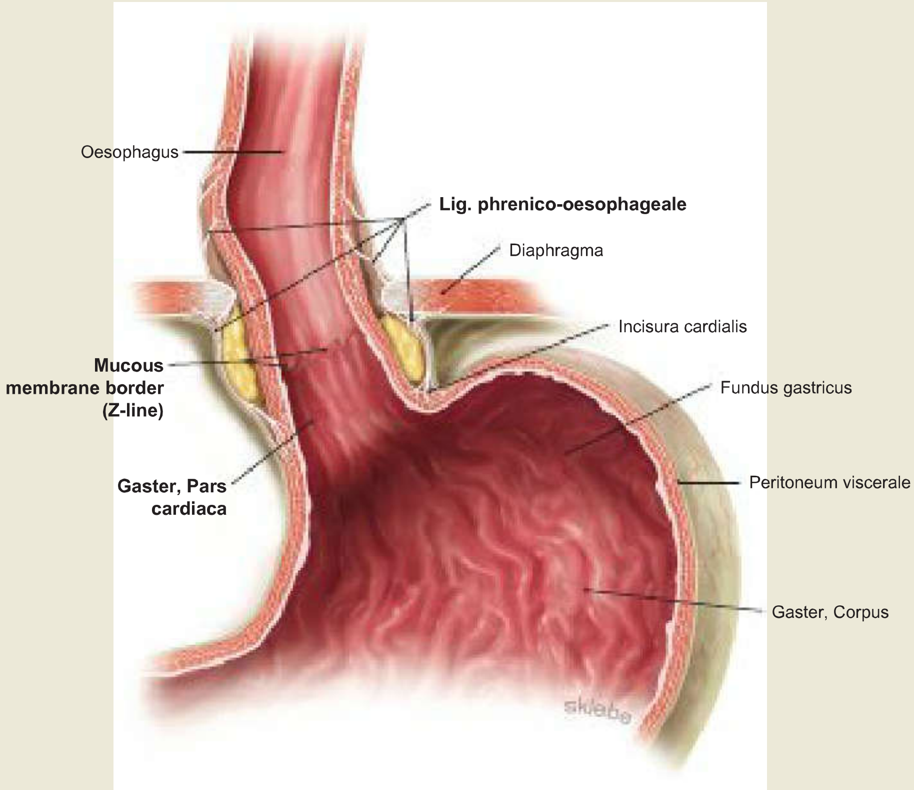


Fig. 5.109 Anchoring of the oesophagus in the oesophageal hiatus of the diaphragm; ventral view, after removal of the anterior wall of the oesophagus and stomach. [L238]

At its caudal aspect the oesophagus does not have a morphologically demarcated sphincter. There is, however, a functional closure which relies on different mechanisms.

- **Neuromuscular oesophageal sphincter:** The spirally running muscle fibres of the Tunica muscularis (Stratum longitudinale) are twisted due to the longitudinal tension of the oesophagus. Together with venous cushions under the mucous membranes this results in a closure.
- **Mucosal fold in the angle of HIS:** Between the stomach entrance (Cardia) and fundus of the stomach is a constriction (Incisura cardialis) with a sharp angle of 65°. In this angle of HIS a mucosal fold which is raised by the notch (Incisura cardialis) emerges into the lumen of the stomach and prevents the reflux of stomach contents.
- **Lig. phrenico-oesophageale:** This fibrous anchoring of the oesophagus in the Hiatus oesophageus of the diaphragm stabilises its position and counteracts a reflux.
- **Pressure gradient between abdominal and thoracic cavities:** The higher pressure in the abdominal cavity supports the closure.

The mucosal transition between the oesophagus and stomach is macroscopically visible due to the epithelial change. Due to its jagged structure, it is called the **Z-line.** This line is mostly located in the area of the oesophagus (70%) and thus proximal to the supposed border on the outside between the oesophagus and stomach.

Clinical Remarks

If the inferior closing mechanism fails, a reflux of the stomach contents and, longer term, an inflammation of the oesophageal mucosa **(oesophageal reflux)** ensue. A typical symptom is heartburn. As a result, the oesophageal mucosa within the stomach lining may convert so that the Z-line no longer presents regularly or it deflects proximally. This metaplasia is referred to as a **BARRETT's oesophagus.** It is associated with an increased risk for development of oesophageal cancer. These **adenocarcinomas of the oesophagus** are not very common, but represent one of the most rapidly growing tumour diseases in the Western world since the risk factors for reflux are associated with nutritional habits. Since the Z-line can shift in pathological processes, it cannot be used clinically as a border between the oesophagus and stomach. On the other hand, an unambiguous boundary is important since treatment in the case of **oesophageal cancer** (removal of the oesophagus with stomach interposition or small intestine interponation) fundamentally differs from treatment of gastric cancer (removal of the stomach, gastrectomy). Therefore, the first mucosal fold is used as the boundary between stomach and oesophagus.

Oesophagus

Vessel Supply of the Oesophagus

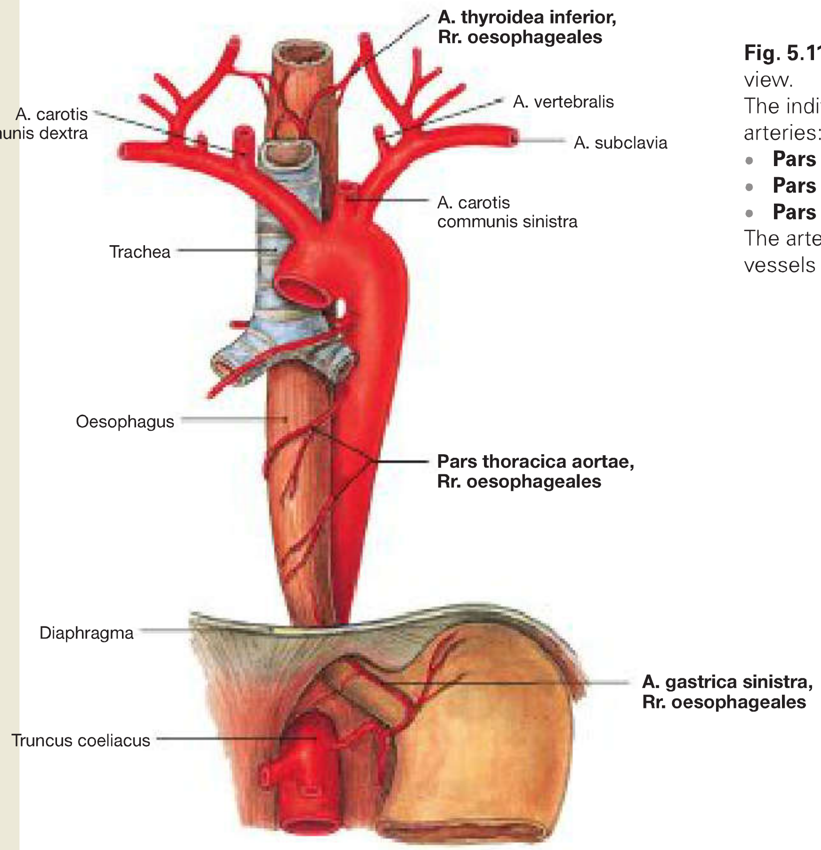


Fig. 5.110 Arteries of the oesophagus, Aa. oesophageae; ventral view.
The individual parts of the oesophagus are supplied by surrounding arteries:
- **Pars cervicalis:** A. thyroidea inferior
- **Pars thoracica:** Rr. oesophageales of the Aorta thoracica
- **Pars abdominalis:** A. gastrica sinistra and A. phrenica inferior

The arterial and venous supply of the trachea correspond to the blood vessels of the cervical and thoracic parts of the oesophagus.

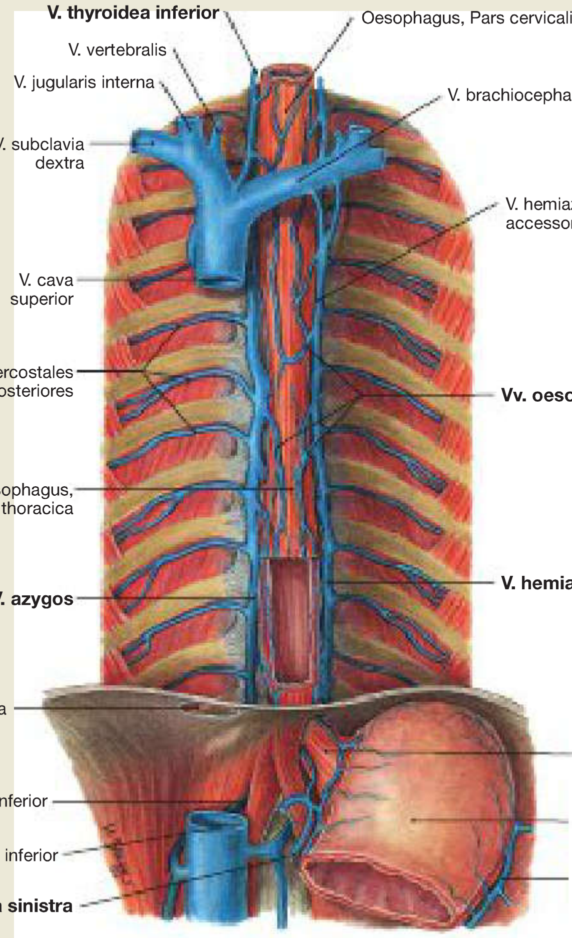


Fig. 5.111 Oesophageal veins, Vv. oesophageae; ventral view.
The strong venous plexus in the adventitia is drained into different veins:
- **Pars cervicalis:** V. thyroidea inferior
- **Pars thoracica:** via the V. azygos and V. hemiazygos in the V. cava superior
- **Pars abdominalis:** the inferior part of the oesophagus has via the gastric veins (V. gastrica sinistra) **connections to the portal vein system.** These connections may be utilised in the case of high pressure in the hepatic portal vein (portal hypertension) as **portocaval anastomoses** (→ Fig. 6.90).

Clinical Remarks

The **oesophagus,** in contrast to the other organs of the gastrointestinal tract, has **no dedicated arteries** but is supplied by the blood vessels that surround it. This complicates operability and contributes to the fact that oesophageal surgery is considered challenging.

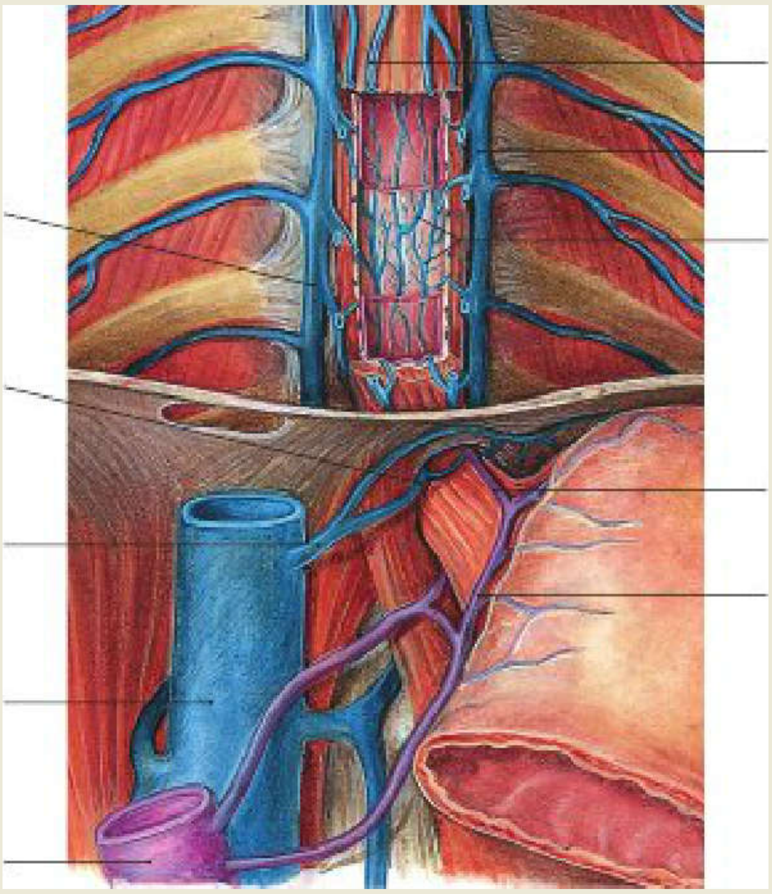


Fig. 5.112 Oesophageal veins, Vv. oesophageae, illustrating the portocaval anastomoses between the V. portae hepatis and V. cava superior; ventral view.
The strong venous plexus in the Tunica adventitia has connections to the submucous veins (Plexus venosus submucosus). Blood flows via the **V. azygos** (right) and the **V. hemiazygos** (left) upwards to the **V. cava superior.** In the lower parts of the oesophagus, descending via the veins of the lesser curvature of the stomach **(Vv. gastricae dextra and sinistra),** it is also connected to the **V. portae hepatis.**

Clinical Remarks

If the pressure in the portal vein system rises **(portal hypertension),** e.g. because the flow resistance in the liver is increased by scarred reorganisation (cirrhosis), then blood is fed via collateral circulation connections of the superior and inferior venae cavae **(portocaval anastomoses).** The most clinically important portocaval anastomoses are the connections via the gastric veins to the oesophagus, since these can cause expansions of the submucous veins (**oesophageal varices** → Fig. 5.116). Rupture of these varices is associated with a mortality of approximately 50% and is thus the most frequent cause of death in patients with liver cirrhosis. In the case of rupture inwards the stomach is filled with mostly black blood; in rarer ruptures the blood flows outside into the abdominal cavity.

Lymphatic Vessels of the Oesophagus

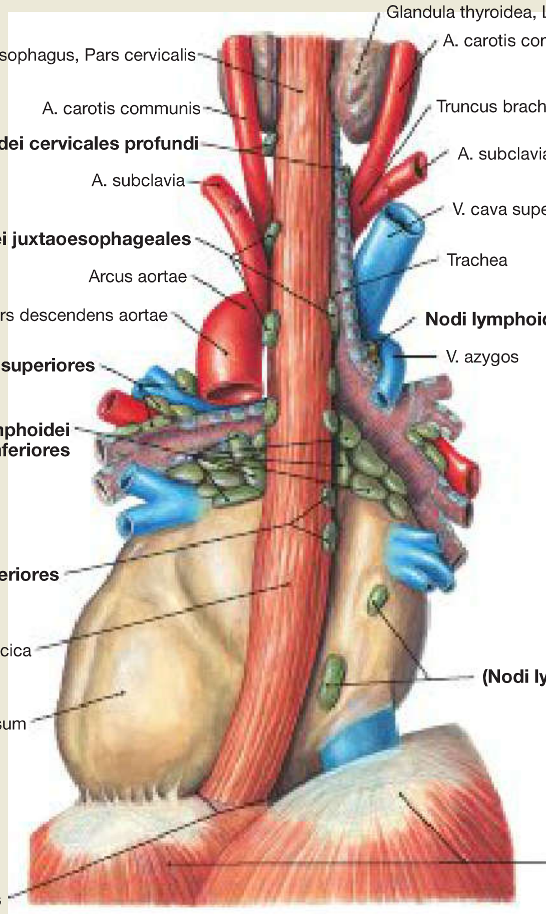


Fig. 5.113 Lymph nodes, Nodi lymphoidei, of the posterior mediastinum, dorsal view.
The lymph of the oesophagus is drained via the lymph nodes which are located directly at the oesophagus (Nodi lymphoidei juxtaoesophageales).

- **Pars cervicalis:** Nodi lymphoidei cervicales profundi
- **Pars thoracica:** Lymph nodes of the mediastinum (Nodi lymphoidei mediastinales posteriores, Nodi lymphoidei tracheobronchiales and paratracheales)
- **Pars abdominalis:** Lymph nodes on the bottom of the diaphragm (Nodi lymphoidei phrenici inferiores) and at the lesser curvature of the stomach (Nodi lymphoidei gastrici)

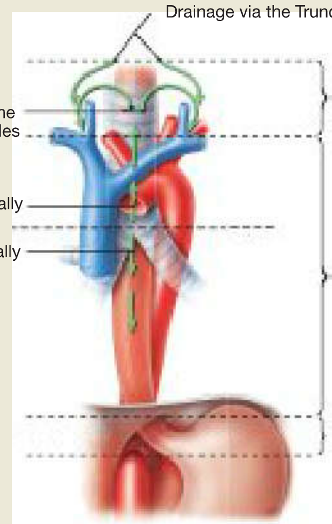


Fig. 5.114 Lymphatic drainage of the oesophagus; ventral view. [L238]
The lymph of the cervical part goes via the deep cervical lymph nodes to the **Truncus jugularis.** In the Pars thoracica, there are two flow directions: the top half above the tracheal bifurcation drains upwards into the mediastinal lymph nodes and from there into the **Truncus bronchomediastinalis.** The bottom half below the tracheal bifurcation has connections to the lymph nodes of the abdominal cavity, which also constitute the regional lymph nodes for the Pars abdominalis. From here, the lymph goes via the Nodi lymphoidei coeliaci into the **Truncus intestinalis.**

Clinical Remarks

The direction of lymphatic drainage plays a role in the metastasis of **oesophageal and gastric cancers.** In the case of tumours of the lower oesophageal half, metastasis into the lymph nodes of the abdomen is possible. Similar drainage ways appear to exist for the venous blood of the oesophagus as well, since oesophageal cancer below the tracheal bifurcation causes liver metastases more frequently, while in the case of tumours above the tracheal bifurcation lung metastases are more common.

Fig. 5.115 Oesophagus; oesophagoscopy, normal finding. [G159]

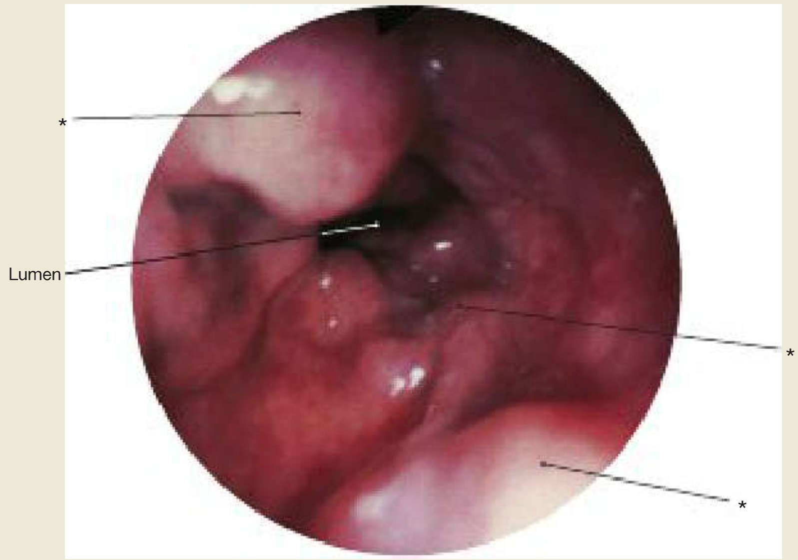


Fig. 5.116 Oesophagus; oesophagoscopy, oesophageal varices in liver cirrhosis. [G159]

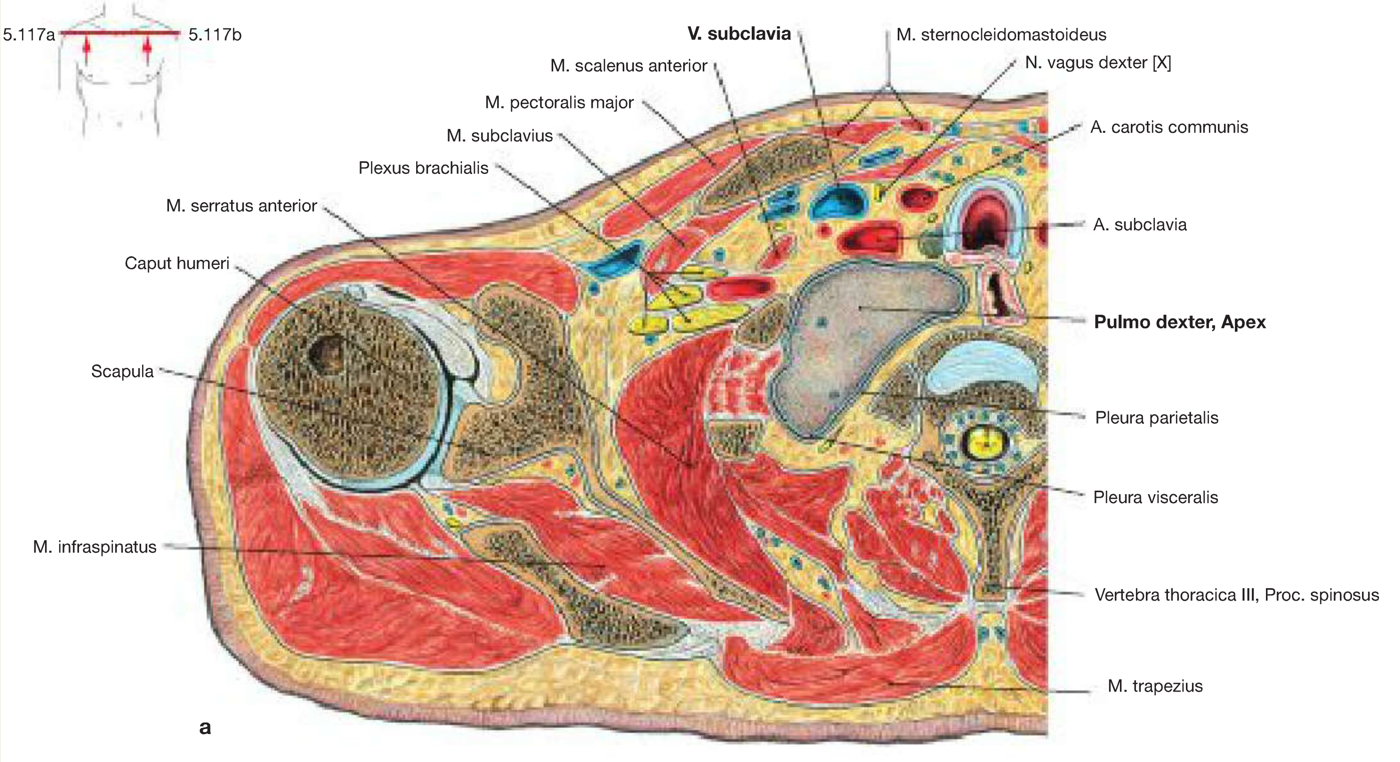
* clinical term: varices

Clinical Remarks

In **portal hypertension, the dilation of portocaval anastomoses** involving the veins of the oesophagus may develop into **oesophageal varices.** A rupture of these varices often leads to **life-threatening bleeding.** Therefore, oesophageal varices are tethered prophylactically (endoscopic band ligation) or treated with vessel-cauterising substances (sclerotised).

Cross-Sectional Images

Cavitas thoracis, Cross-Sections



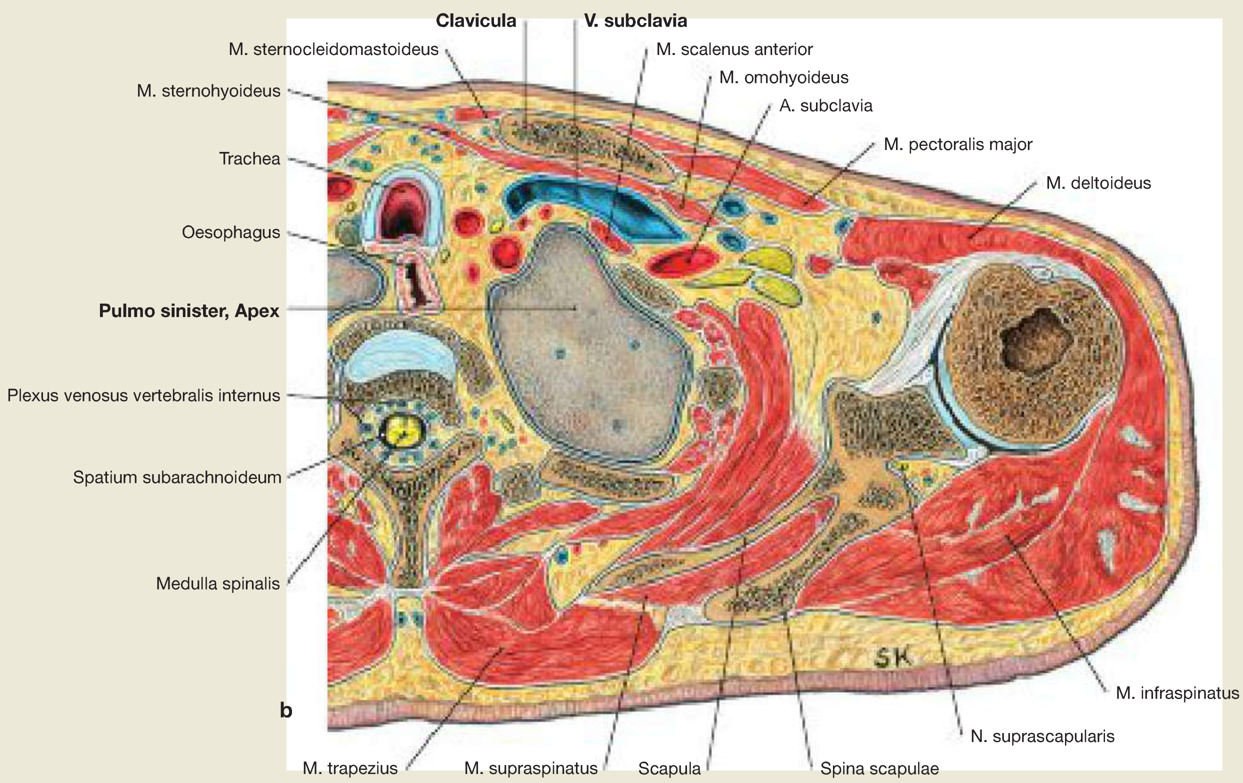
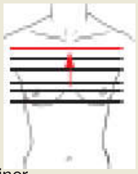


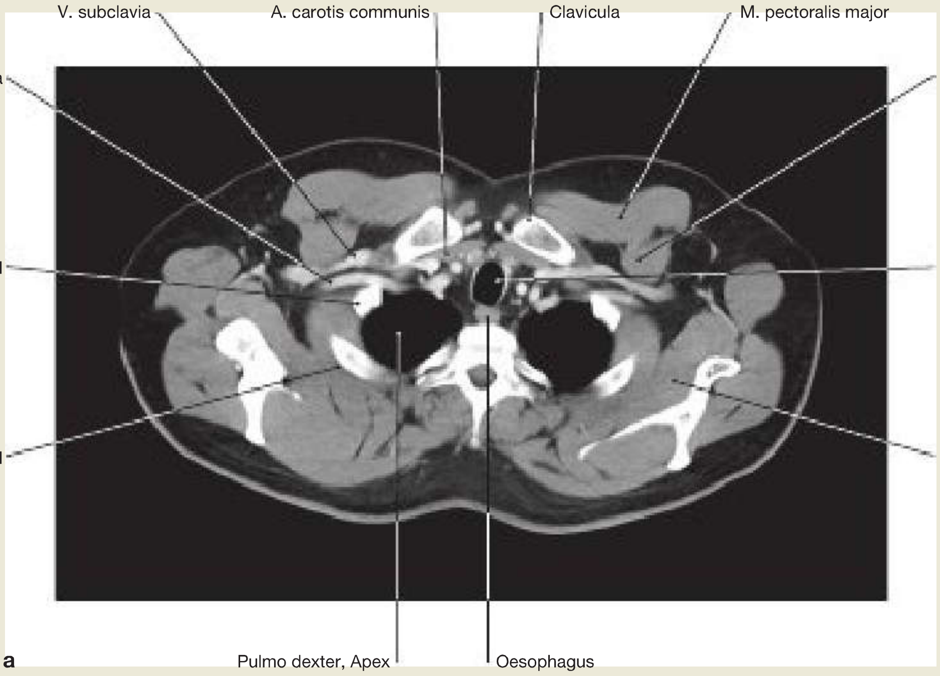
Fig. 5.117a and b Pleural dome, Cupula pleurae; cross-sections at the level of the shoulder joint; caudal view. [L238]

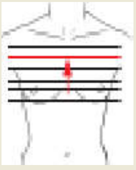
These sections illustrate that the pleural dome extends behind the neurovascular bundle of the arm above the upper thoracic aperture. As a result, the apex of the lung is positioned directly behind the A. and V. subclavia.

Clinical Remarks

When inserting a **central venous catheter** (CVC) into the **V. subclavia,** the distension of the pleural dome must be considered. For the procedure the cannula is placed just below the anterior convexity of the clavicle in the direction of the sternoclavicular joint. If the cannula is positioned too steeply, the Cavitas pleuralis may be injured, and an inflow of air into the cavity can result in collapsing of the lung **(pneumothorax).**







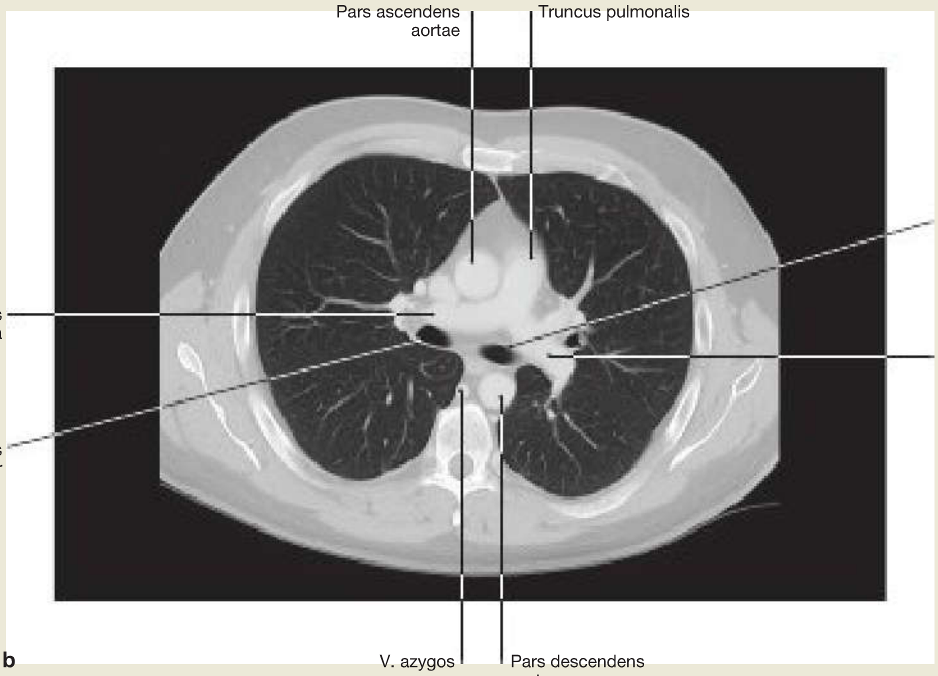


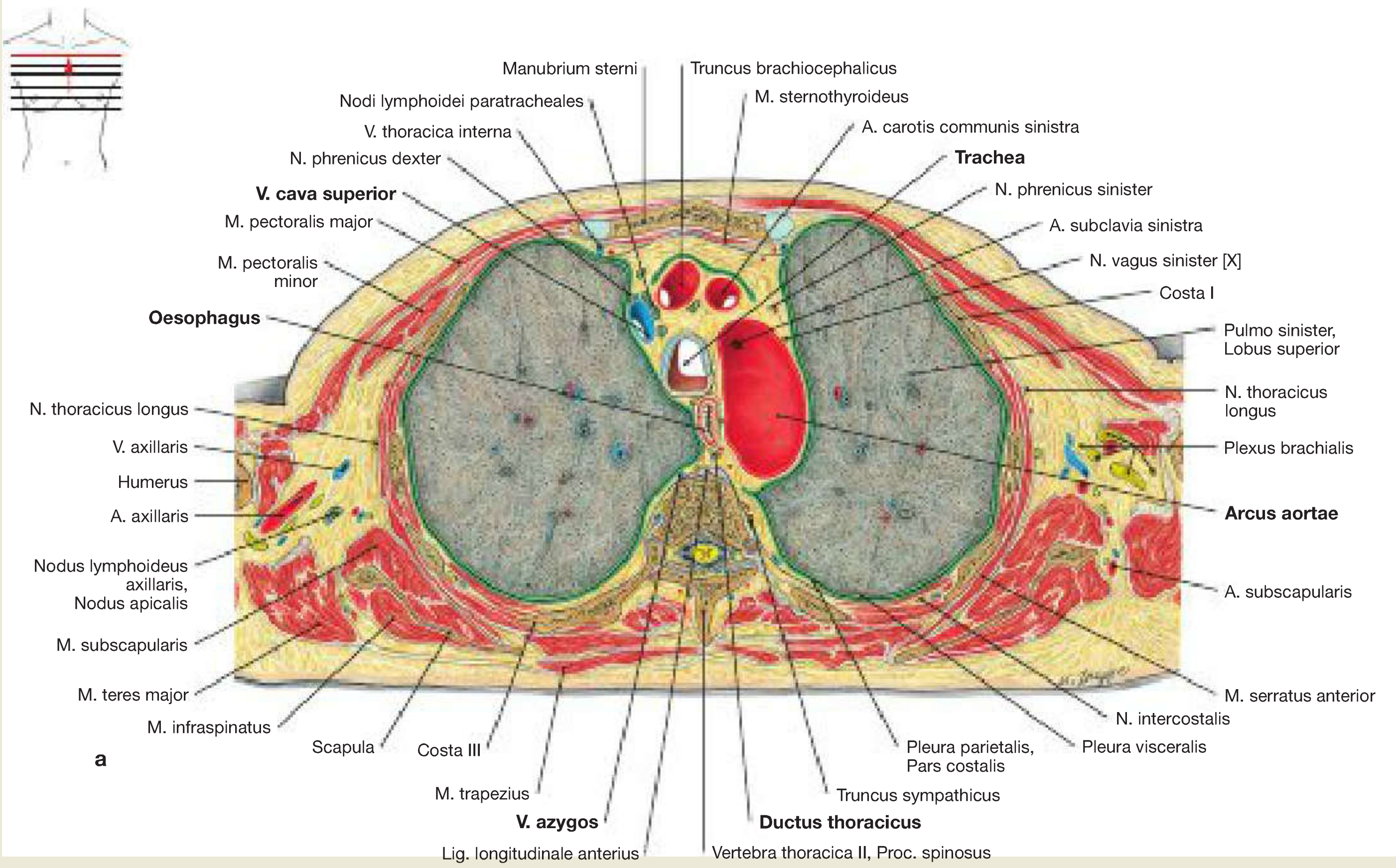
Fig. 5.118a and b Upper thoracic aperture; contrast enhanced CT of the thorax in portal venous phase (46-year-old man) (→ Fig. 5.118a) and contrast enhanced CT of the thorax in portal venous phase at the level of the Truncus pulmonalis (→ Fig. 5.118b). [T832]

Clinical Remarks

Cross-sectional imaging with **computed tomography** (CT) or **magnetic resonance imaging** (MRI) is of great importance in medical diagnostics. According to convention, images are always reproduced from a caudal direction.
The advantage of **computed tomography** (CT) versus conventional X-ray images is, i.a. that all the structures are not projected on top of each other as is the case with summation structures. All structures are individually recognisable in their spatial distensions on a set of cuts with a thickness of a few millimeters. In tomography, the density of pathological structures already provides information regarding the tissue composition.

Cross-Sectional Images

Cavitas thoracis, Cross-Sections



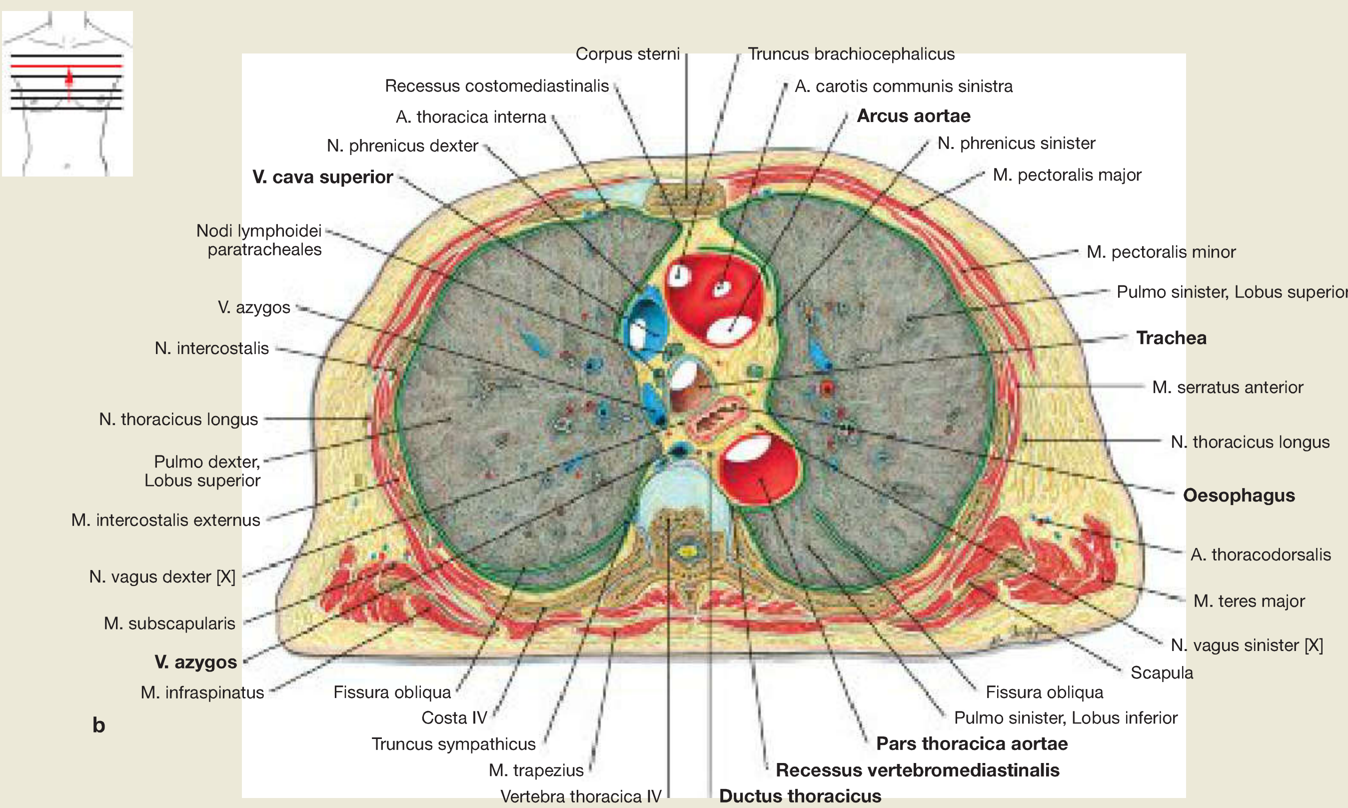
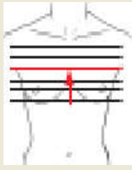
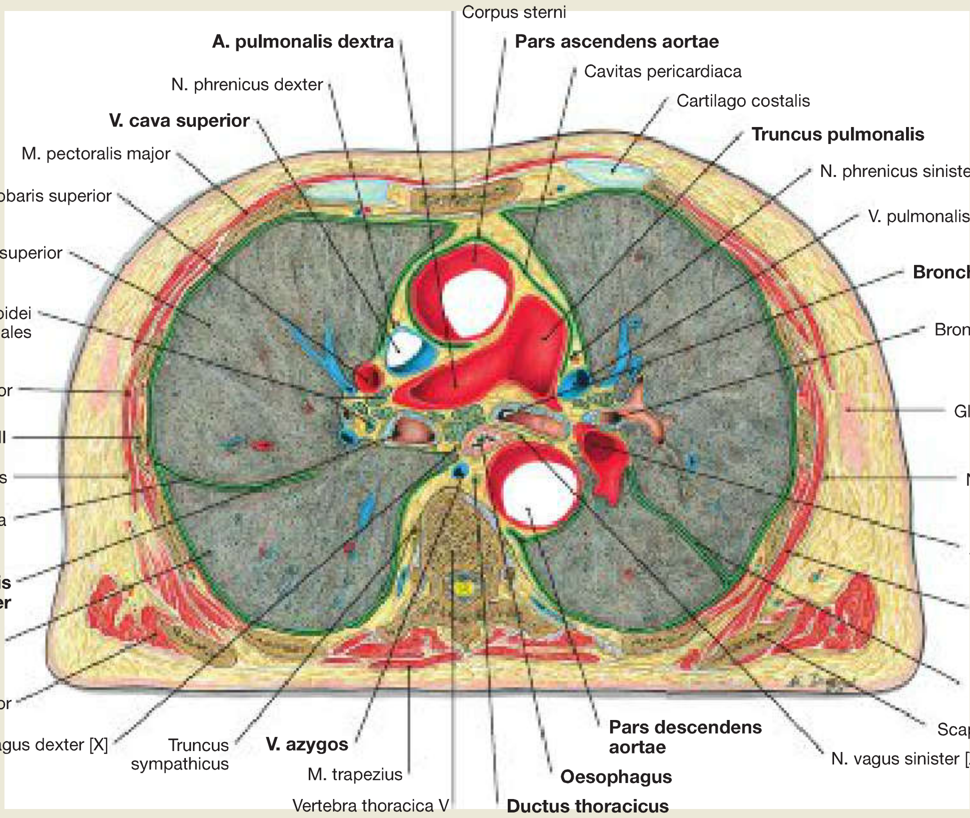


Fig. 5.119a and b Chest cavity, Cavitas thoracis; cross-sections at the level of the Arcus aortae; caudal view.
In the superior mediastinum, the Arcus aortae is located ventrally and the V. cava superior is located at the right side of the Arcus aortae. Positioned dorsally to these blood vessels are the trachea and, to the left side, the oesophagus and the Pars thoracica of the aorta. To the posterior the aorta borders on the Recessus vertebromediastinalis of the Cavitas pleuralis. Lying directly on the vertebral column are the V. azygos to the right and the Ductus thoracicus to the left of that.





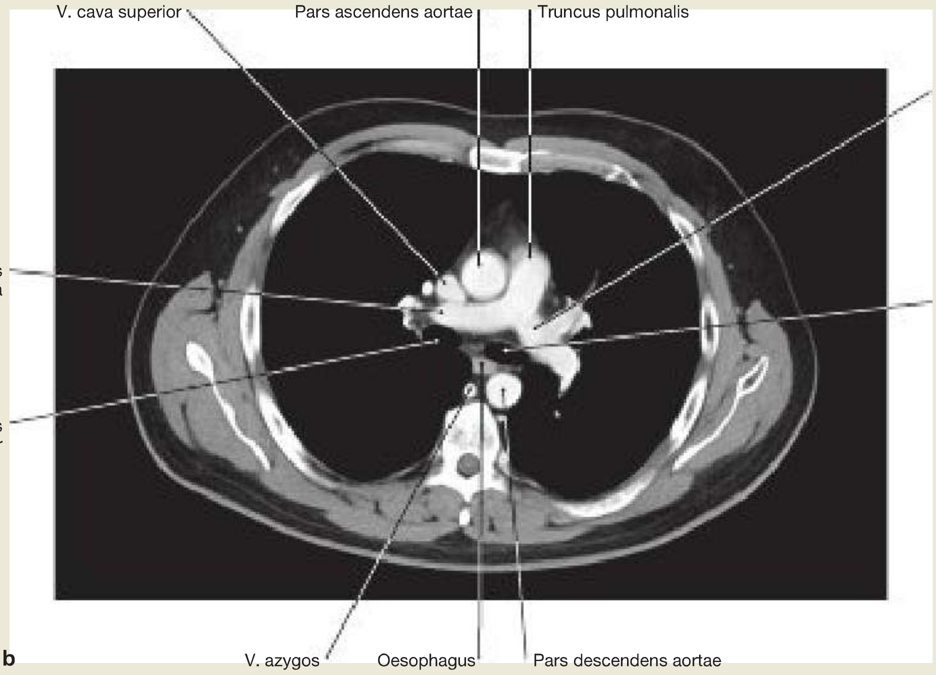


Fig. 5.120a and b Chest cavity, Cavitas thoracis; cross-section at the level of the ascending aorta (→ Fig. 5.120a) and contrast enhanced computed tomography (CT) of the thorax in portal venous phase at the level of the Truncus pulmonalis (→ Fig. 5.120b); caudal view. (b [T832])
Lying at the furthest ventral point in the superior mediastinum is the ascending aorta; behind it to the left is the Truncus pulmonalis with arborisation into the pulmonary arteries; to the right of the aorta is the V. cava superior. The main bronchi (Bronchi principales) and the oesophagus lie to the posterior of the pulmonary arteries (Aa. pulmonales). The Aorta descendens descends to the left next to the spine; the V. azygos is truncated to the right in front of the spine.

Clinical Remarks

Using **CT-guided aspiration**, biopsies themselves can be obtained from individual enlarged lymph nodes. Thus, a pathological and microbiological diagnosis is possible.

Cross-Sectional Images

Chest Cavity, Cross-Section

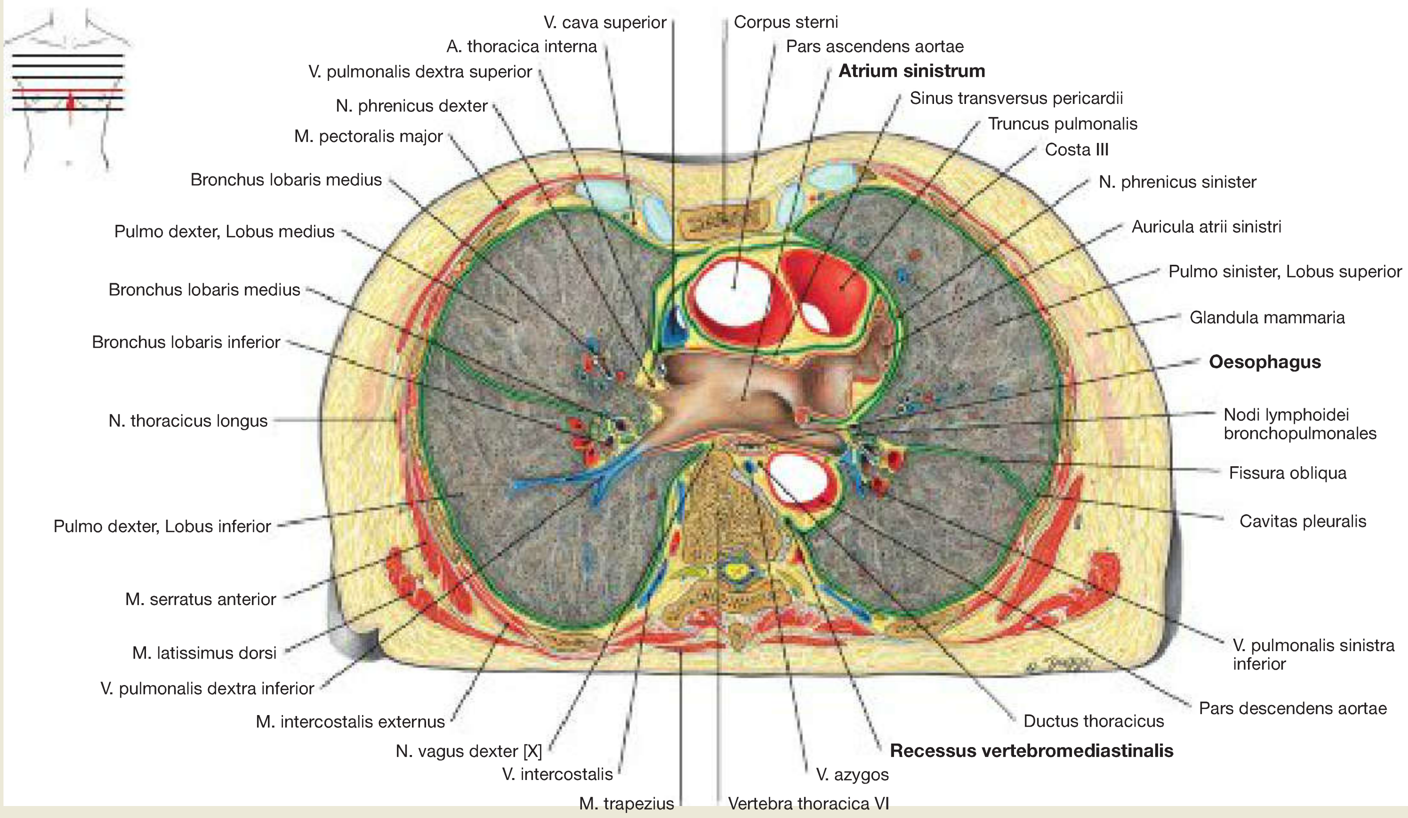


Fig. 5.121 Chest cavity, Cavitas thoracis; cross-section at the level of the left atrium; caudal view.

The left atrium (Atrium sinistrum) extends further cranially than the right atrium and is located behind the great vessels. The oesophagus borders directly on the left atrium dorsally.

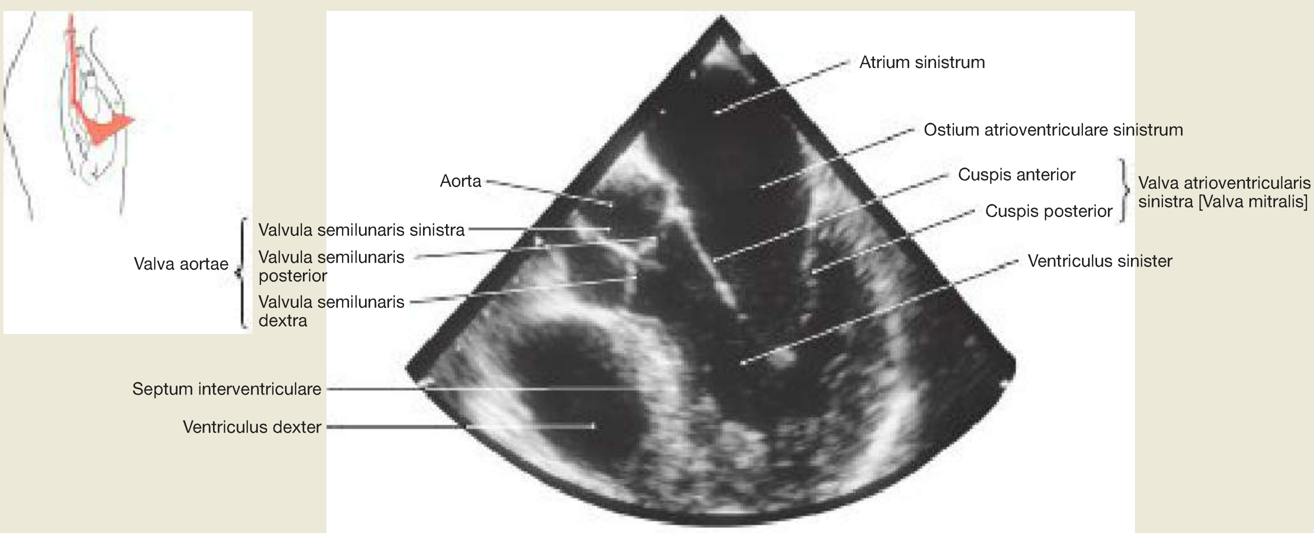
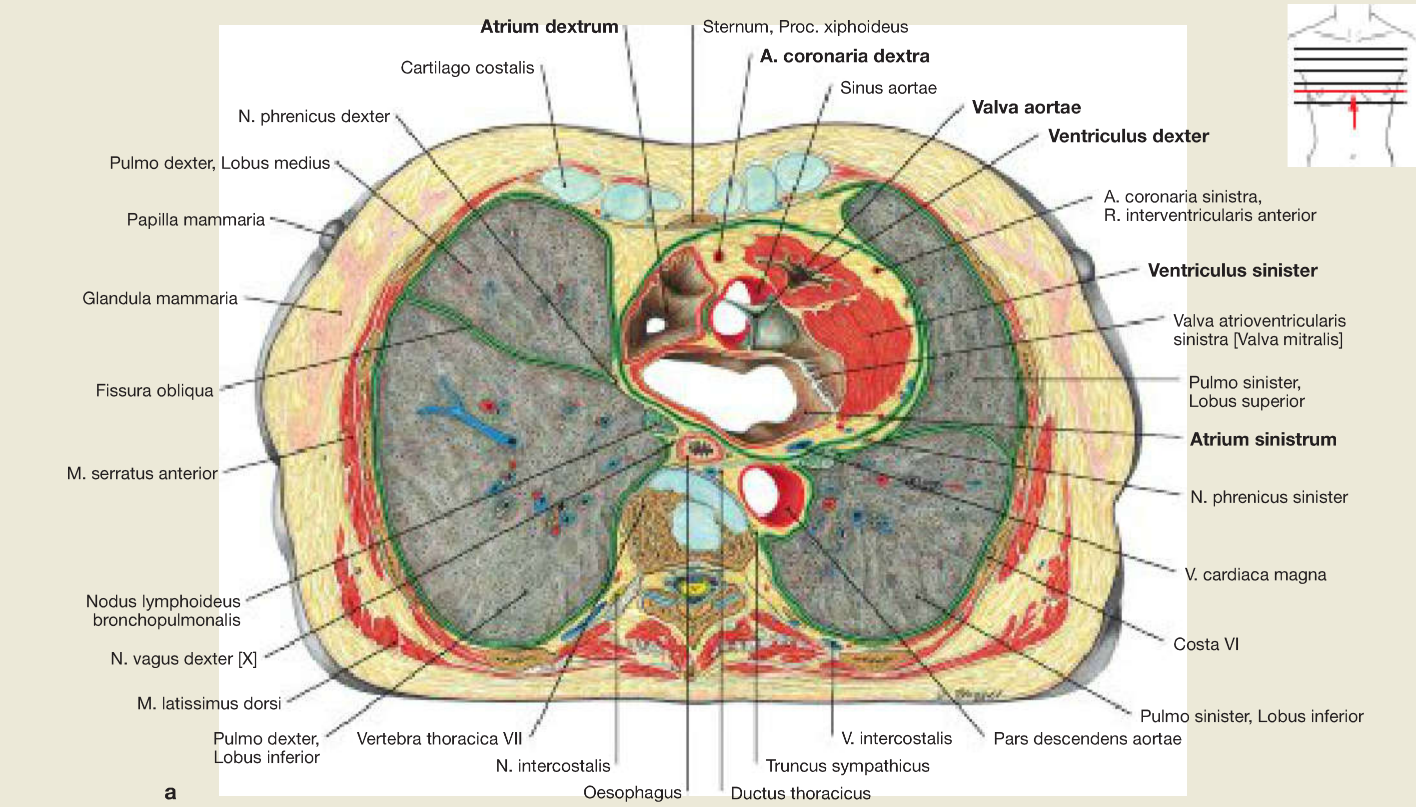


Fig. 5.122 Heart, Cor; ultrasound image of the oesophagus (transoesophageal echocardiography).

Clinical Remarks

When performing a **transoesophageal echocardiography,** the spatial proximity of the oesophagus to the heart is useful (→ Fig. 5.21) An image of the heart and particularly the heart valves is achieved much more accurately using an ultrasound probe inserted into the oesophagus than through an examination from the outside of the thoracic cage.



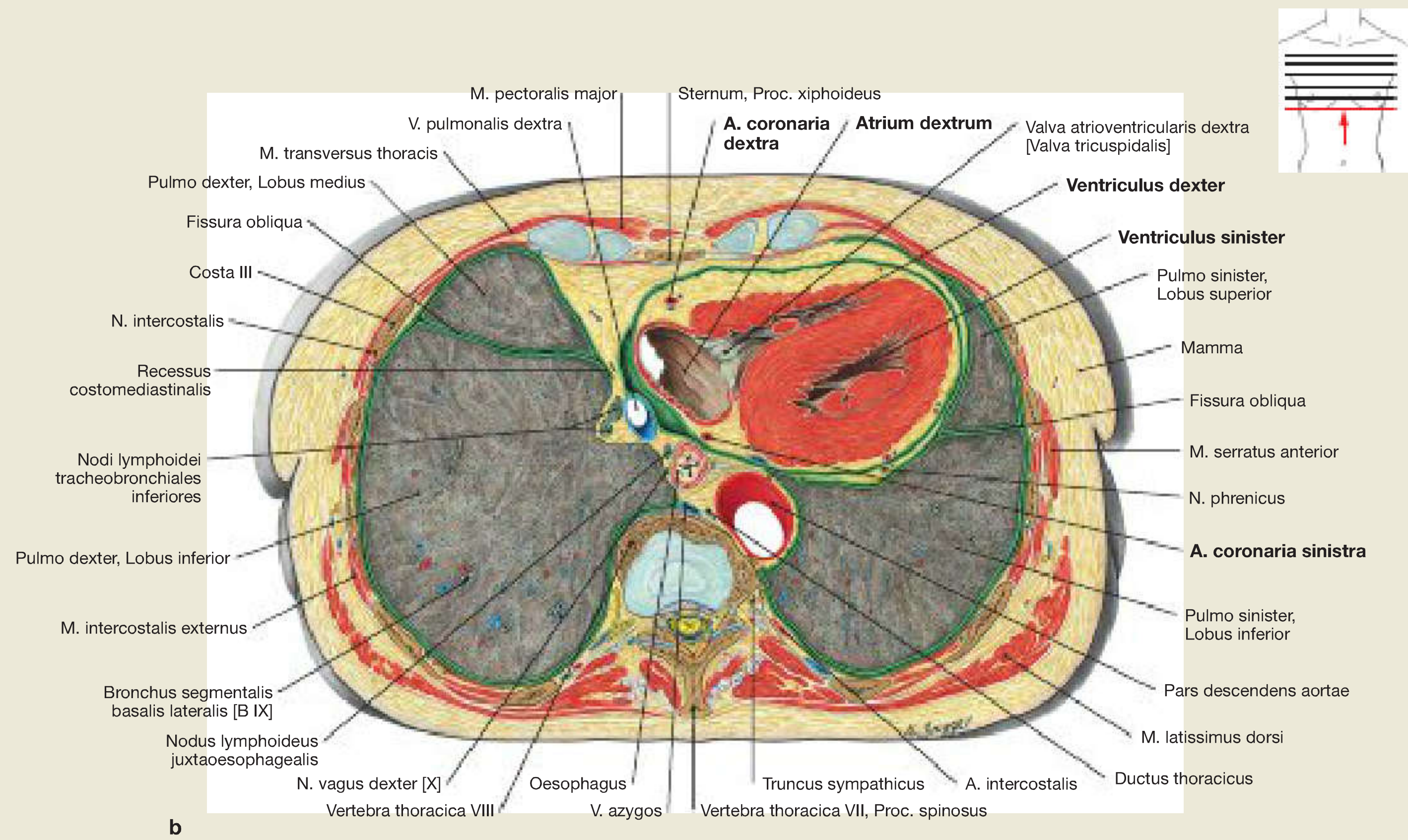


Fig. 5.123a and b Chest cavity, Cavitas thoracis; cross-sections at the level of the aortic valve (→ Fig. 5.123a) and below the aortic valve (→ Fig. 5.123b); caudal view.

These cross-sections show that the middle mediastinum, which contains the heart and the pericardium, extends further to the left side than to the right side. This means the lung has a smaller volume. In the pericardium, a thick layer of subepicardial adipose tissue with embedded Aa. coronariae is evident. The coronary edge of the heart (Facies pulmonalis cordis) at this sectional level is formed by the right atrium on the right side and the left ventricle on the left side. The right ventricle, however, does not confine the margin of the heart but is positioned towards the front (Facies sternocostalis).

Cavitas thoracis, Frontal Section

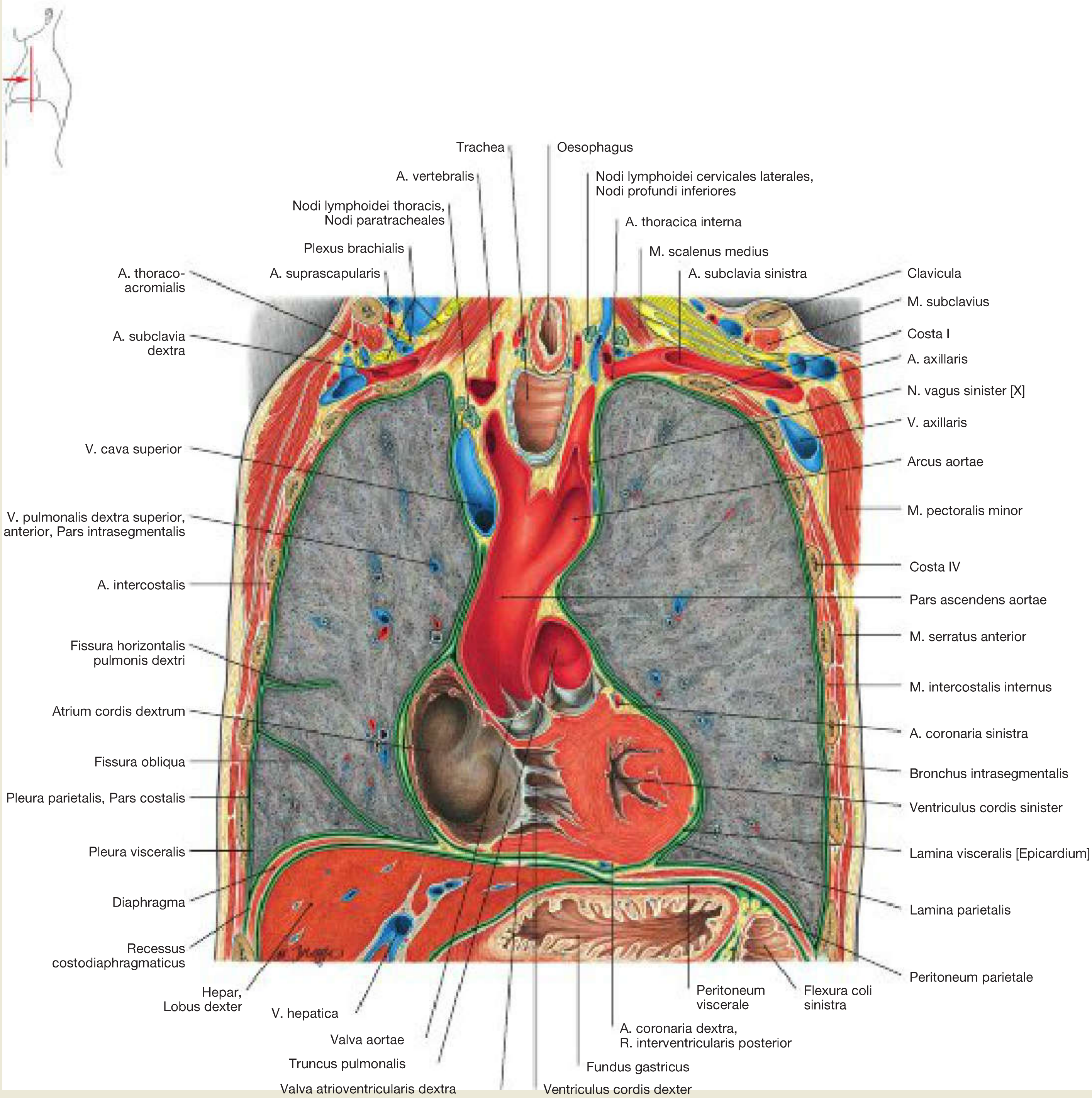
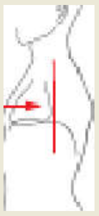


Fig. 5.124 Chest cavity, Cavitas thoracis; frontal section at the level of the aortic and pulmonary valves; ventral view.
The frontal section clearly shows the twisting of the aorta and Truncus pulmonalis after its outflow from the two ventricles. From the aorta, beginning at the aortic valve (Valva aortae), the entire ascending part (Pars ascendens) and the Arcus aortae are truncated. From the Truncus pulmonalis, however, its origin is visible only after the pulmonary valve (Valva trunci pulmonalis), because it then passes from the sectional plane to the posterior, where it branches into the two pulmonary arteries (Aa. pulmonales). The right ventricle (Ventriculus dexter) itself, however, lies ventrally to the sectional plane, while the left ventricle (Ventriculus sinister) is reached.



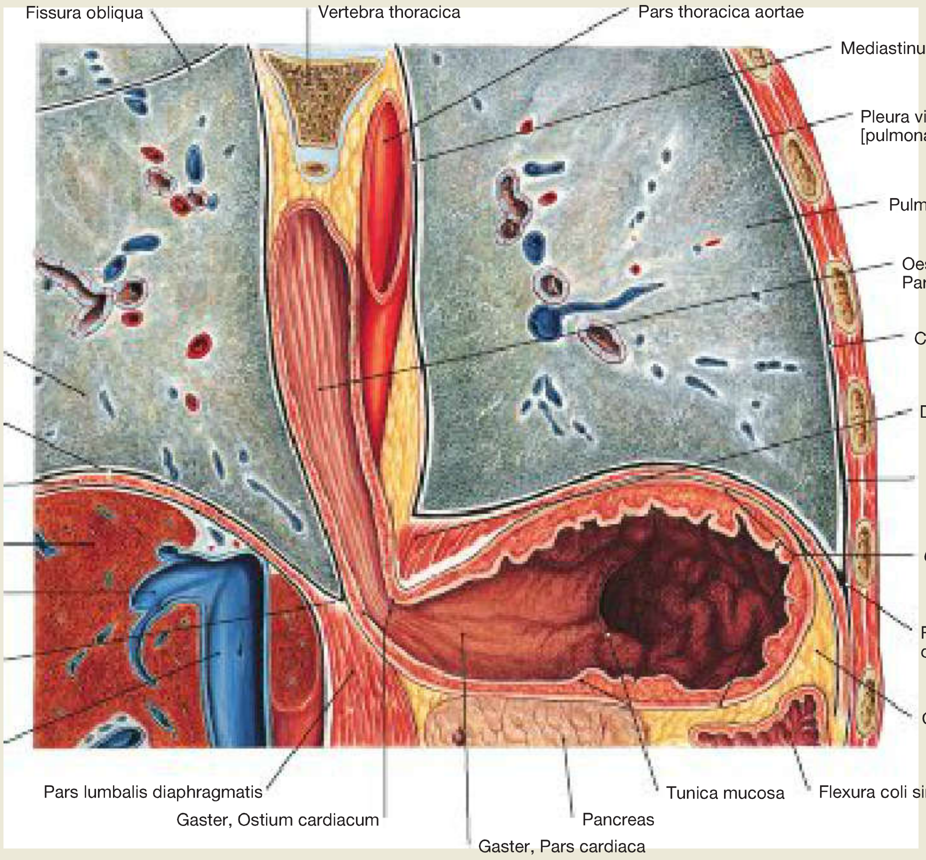
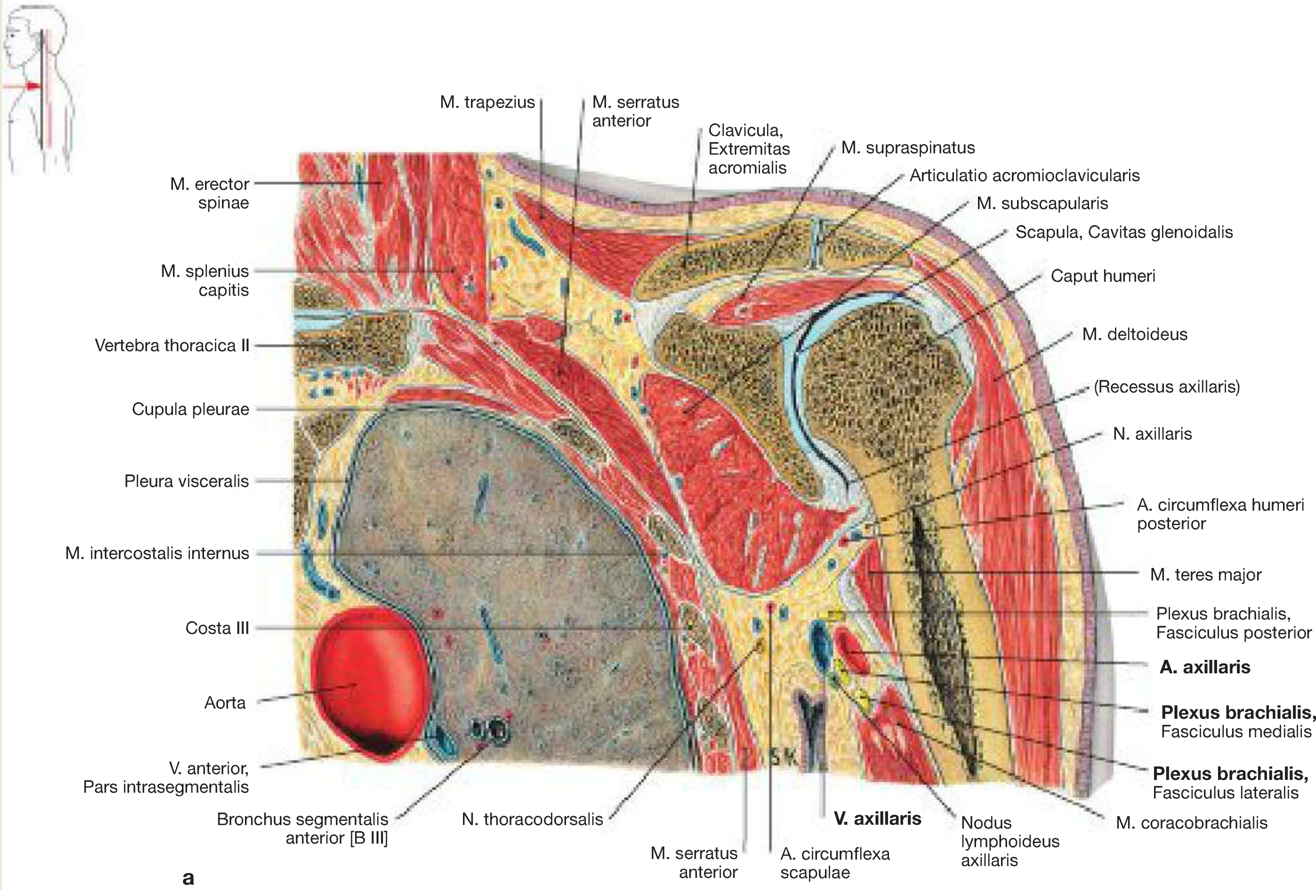


Fig. 5.125 Chest cavity, Cavitas thoracis; frontal section at the level of the oesophageal hiatus of the diaphragm; ventral view.

The frontal section shows the arrangement of the oesophagus and aorta in the lower mediastinum. The Pars thoracica of the oesophagus lies initially to the right of the Pars thoracica aortae. Before passing through the oesophageal hiatus, the oesophagus goes in front of the aorta. The Pars abdominalis of the oesophagus is very short and flows out into the cardial part of the stomach. The mucosal transition between stomach and oesophagus is on a slightly jagged line (Z-line) that is located here relatively wide distal. It lies, therefore, distally to the first gastric mucosal fold in the cardiac notch. Through the notch, the angle of HIS between the cardial part of the stomach and the stomach fundus is demarcated. The mucosal fold in the angle of HIS contributes to the locking mechanisms of the lower oesophageal part.

Cross-Sectional Images

Cavitas thoracis, Frontal Sections



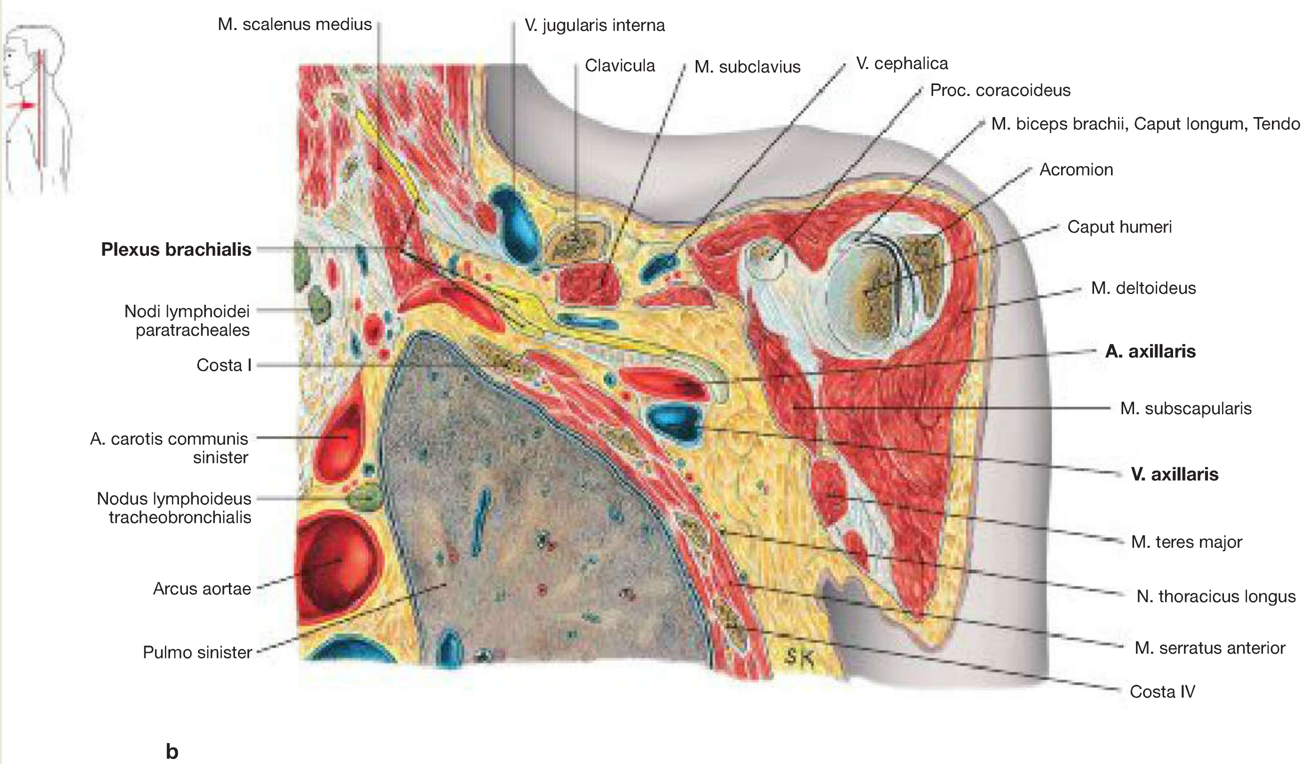


Fig. 5.126a and b Chest cavity, Cavitas thoracis, armpit cavity, Axilla, and shoulder joint, Art. humeri; frontal sections at the level of the shoulder joint (→ Fig. 5.126a) and anterior to the shoulder joint (→ Fig. 5.126b); ventral view. [L238]

The illustrations show clearly that ventrally of the shoulder joint, the A. and V. axillaris as well as the Plexus brachialis, are closely positioned to the apex of the lung as neurovascular pathways for the arm.

Practice Exam Questions

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

Indicate the parts of the mediastinum and show the pleural cavities.

- Which organs and neurovascular pathways lie within?
- Which recesses have the pleural cavities and where are they located?
- Indicate the Ductus thoracicus: how does it run through the Cavitas thoracis?
- Explain the course of the azygos system on a dissection.
- Where is the thymus located and what is its function?

Where does the heart project and which parts of the heart form its surfaces?

- Indicate on a dissection which structures of the heart can be defined by their margins on an X-ray.

Explain the construction of the heart valves on a dissection.

- Onto what do they project and where do you auscultate for a suspected aortic valve stenosis?

Indicate all important branches of the Aa. coronariae.

- What type of circulation is present in this dissection?
- How are the parts of the cardiac conducting system supplied with blood?

How are the lungs divided and where do the lung lobe boundaries project onto the skeleton?

Explain the functions of the Vasa publica and Vasa privata of the lung.

Which lymphatic drainage systems do the lungs have and which lymph nodes are incorporated into these?

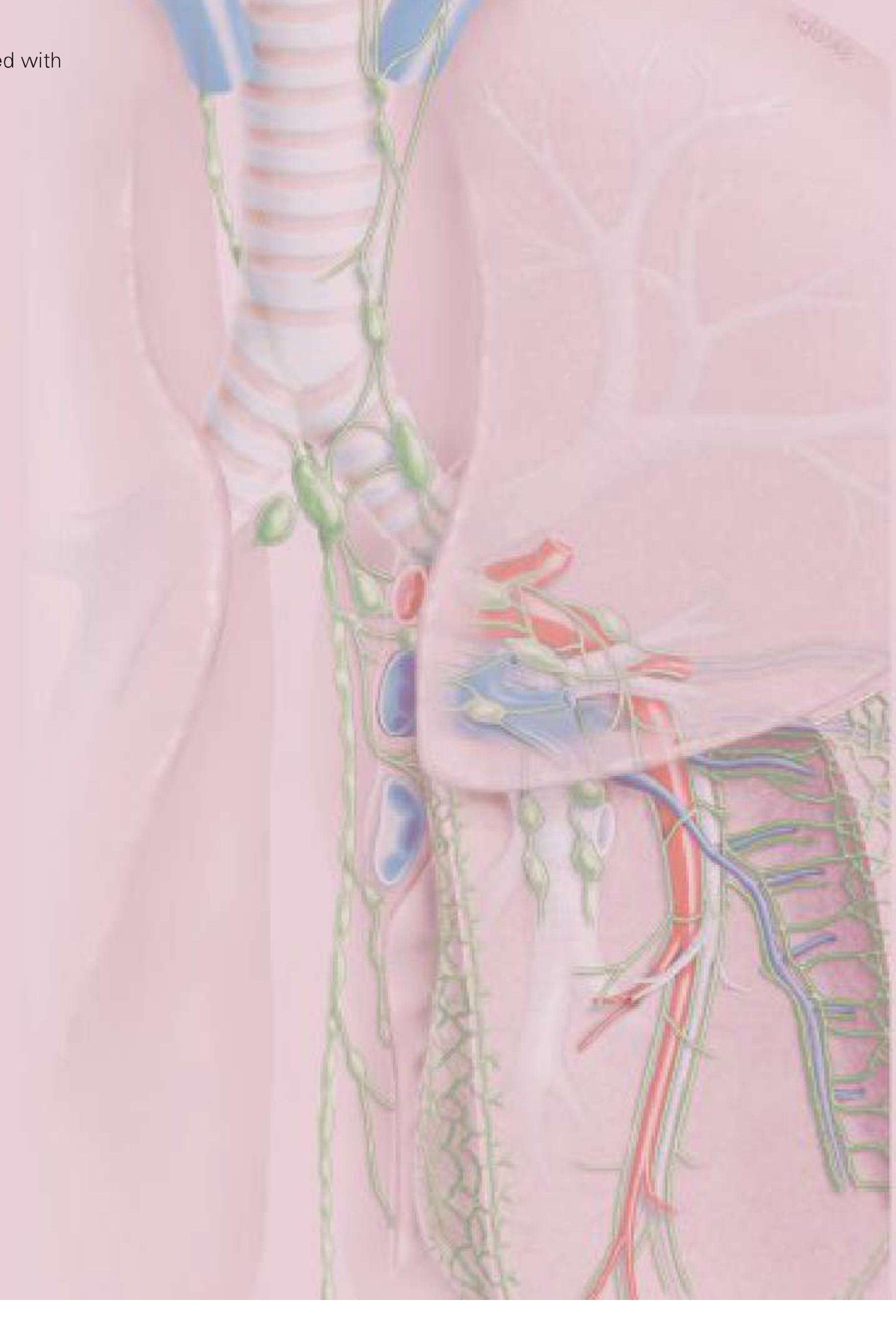
Where are the constrictions of the oesophagus?

How is the oesophagus closed at both ends and what clinical relevance does this have?

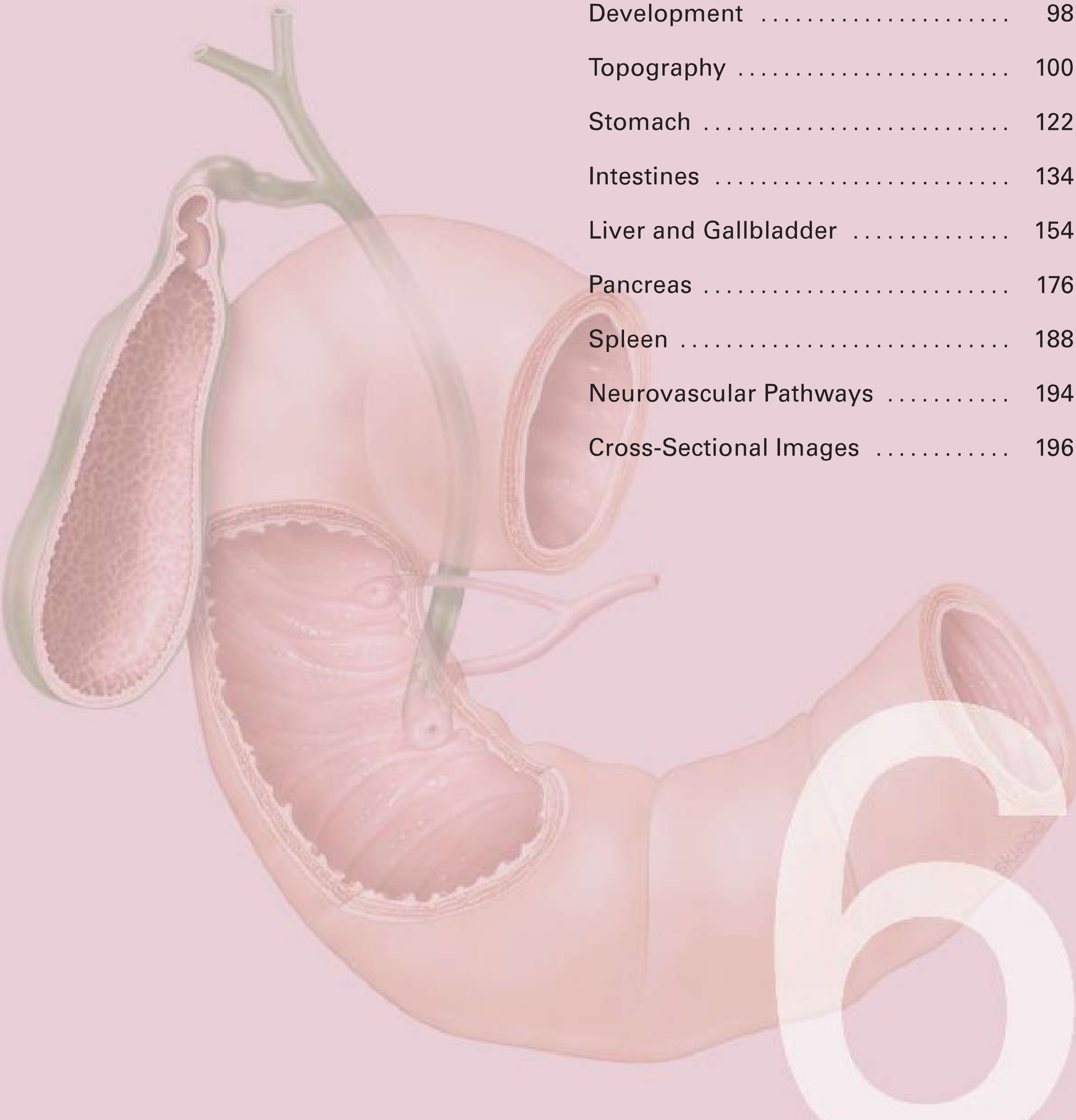
Which blood vessels supply the oesophagus and why does this play a role?

- What are oesophageal varices and how are these determined anatomically?

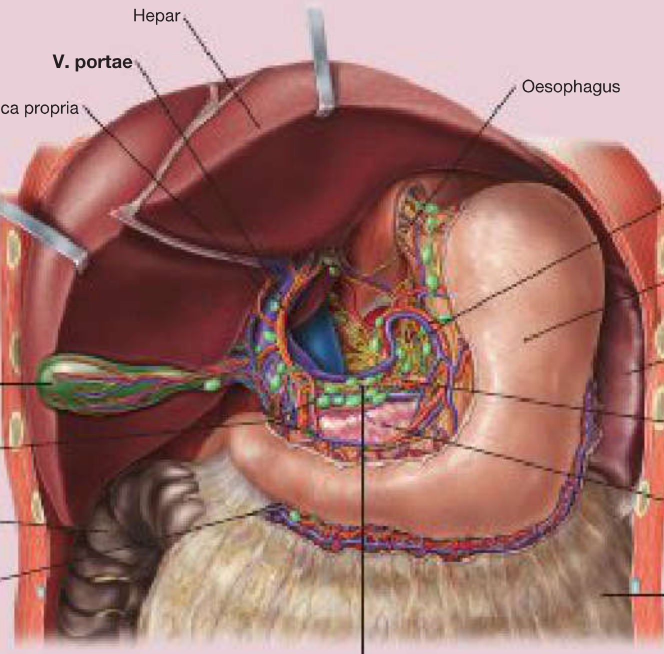
Clarify the lymphatic drainage of the oesophagus on a dissection.



Organs of the Abdominal Cavity



6



Overview

Opening the abdominal wall reveals a cavity filled with some smooth and some partially solid organs (viscera). In its entirety it is called the 'situs' of the abdominal organs. The inside of the abdominal wall and the surfaces of the organs are covered with a thin, wet, shiny membrane **(Peritoneum)**. The lining on the inside of the abdominal wall is referred to as the parietal sheet of the peritoneum, while the visceral sheet covers the different organs. Therefore, this largest part of the abdominal cavity is known as the peritoneal cavity **(Cavitas peritonealis)** from which the retroperitoneal space is distinct as a flat section behind the parietal peritoneum, which e. g. contains the kidneys. The smooth peritoneum guarantees that e. g. the stomach and intestines change shape in the peristalsis so that the intestinal loops can shift against each other. The middle transverse part of the large intestine (Colon transversum) divides the peritoneal cavity into an **upper abdominal situs** and a **lower abdominal situs.**

The situs of the upper abdomen is called the **gland abdomen,** because it contains, among other things, the liver (Hepar) with the closely positioned gallbladder (Vesica biliaris), and the Pancreas as the biggest glands found in the human body. The stomach (Gaster) nestles up against the liver, which is on the right. On the left, behind the stomach, is the spleen in its own niche. The lower abdomen is 'captured' by the loops of the small intestine (Intestinum tenue), wich are held in place by the large intestine (Intestinum crassum) as if in a picture frame.

Main Topics

After studying this chapter, you should be able to:

Peritoneal cavity
- explain the structure of the abdominal cavity with recesses as well as the peritoneal duplicatures;
- explain the neurovascular pathways for all organs, with clinical relevance and organ specific peculiarities;

Stomach
- show the positional relationship of the stomach to the rest of the upper abdominal organs and describe its development;

Intestines
- show sections of the small and large intestines on the dissection and explain their structural features;
- describe the origin of the individual intestinal segments, including the boundaries of their areas supplied by neurovascular pathways, and the positional changes they undergo during their development;
- demonstrate the clinical importance of the positional relationships of the appendix with projection onto the body surface;

Liver and gallbladder
- explain the vital importance of the liver with its different functions;
- show the location and projection of the liver and gallbladder and to describe their development;
- show the functional structure of the liver, including the liver segments on a dissection and explain their clinical significance;
- describe the opening and closure mechanisms of the common bile duct (Ductus choledochus) and to show the topography of the CALOT's triangle on a dissection;

Pancreas
- explain the vital importance and function of the pancreas;
- show the classification and topography of the pancreas, including the gear system on a dissection and explain their development, including malformations;

Spleen
- understand the various functions of the spleen and its location and structure.

Clinical Relevance

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

Colon Cancer

Case Study
A 63-year old man visits the family doctor because he has had blood in his stools for several weeks. He also suffers more and more from constipation, which surprises him as he is losing his appetite and doesn't eat much. He mentions that he has lost 5 kg in weight in the last three months.

Result of Examination
The physical examination is unremarkable, including the rectal palpation. Bowel sounds are buoyant and there is no pressure pain on the stomach.

Diagnostic Procedure
The blood seepage can be confirmed with a stool test. The colonoscopy conducted by a resident gastroenterologist reveals an ulcerated tumour of 2 cm in diameter in the descending colon; tissue biopsies are taken and sent to the pathology department. In the blood, raised levels of the tumour markers CEA and CA 19-9 are found, typically produced by adenocarcinomas. After admission to a surgical clinic and a computed tomography (CT) of the abdominal and pelvic cavity and skull, diagnostics can exclude metastases.

Diagnosis
Colon cancer (→ Fig. a). Metastases have not been found in the liver, lung and brain. Colon carcinomas are the most common malignant tumours overall, together with tumours of the lung, breast and prostate. These can be detected very easy in the early stages through screening with a colonoscopy. Therefore, the mortality rates have fallen significantly in recent years.

Treatment
With a hemicolectomy, the Colon descendens and the Colon sigmoideum, including the lymph nodes along the A. mesenterica inferior, were removed and sent to the pathology department. The colon can be connected with the rectum maintaining continence, so that no artificial anus (Anus praeter) is required.

Further Developments
On the following day the patient starts taking in nutrition and is pain-free apart from pain where the scar is healing well. Since several lymph nodes in the pathological examination are identified as affected by the tumour, the patient is referred to the ambulatory oncology unit. There he will receive intravenous chemotherapy over the next few months on a regular basis which he will tolerate very well after initial nausea. Postoperatively, the blood level of the tumour markers is lowered, so that any new increase could indicate a potential recurrence of the tumour. After 10 years in complete remission the patient can be considered as healed.

Dissection Lab
The large intestine is to be found immediately after opening the abdominal cavity

Here you have to look closely at the positions of the individual organs to each other.

because it surrounds the small intestine and separates the upper from the lower abdomen. It is divided into several sections: The **caecum (Caecum)** with its **appendix (Appendix vermiformis)** is followed by the colon sections **(Colon ascendens, Colon transversum, Colon descendens and Colon sigmoideum)** and then the **rectum,** and the **anal canal (Canalis analis).** Since the descending colon is shifted to the rear body wall during development, it is secondarily retroperitoneal. In contrast, the Colon sigmoideum is covered on all sides by the visceral peritoneum and is thus intraperitoneal. For the implementation of a hemicolectomy, the knowledge of the neurovascular pathways supplying the individual intestinal segments is essential. This change developmentally affects the left colic flexure which marks the transition from the transverse colon to the descending colon. The 'left-hand side' colon sections (Colon descendens and Colon sigmoideum) are therefore fed by branches of the **A. mesenterica inferior,** which originate from the abdominal part of the aorta and initially run retroperitoneally. The 'right-hand side' sections up to the transverse colon, in contrast, are supplied by the **A./V. mesenterica superior.**

The clinically important anastomosis of the A. mesenterica superior with the A. mesenterica inferior is called RIOLAN's anastomosis. You can see it very clearly after preparation of the vascular arcades!

The corresponding vein (V. mesenterica inferior) ascends on the dorsal side of the pancreas and combines with the other main veins which then build the **portal vein (V. portae).** Therefore colon tumour cells often spread (by metastasis) via the venous blood into the liver. The regional lymph nodes along the colon connect to the collecting lymph nodes at the origin of the A. mesenterica inferior **(Nodi lymphoidei mesenterici inferiores).**

The lymph nodes are often not easy to find. You can track their location very well along the A. mesenterica.

Back in the Clinic
During surgery, the entire A. mesenterica inferior with surrounding lymph nodes can be removed because it only provides the remote sections of the large intestine. On the other hand, in the case of a tumour in the Colon ascendens, you could not remove the entire A. mesenterica superior, as it also supplies the small intestine and the pancreas.

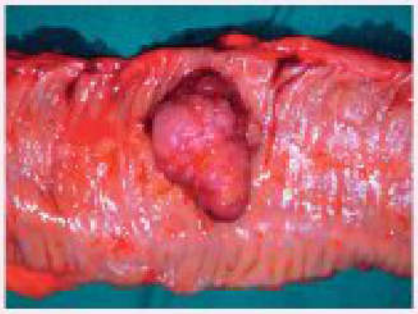


Fig. a Polypous colon carcinoma. [O892, M526]

Development of the Upper Abdominal Situs

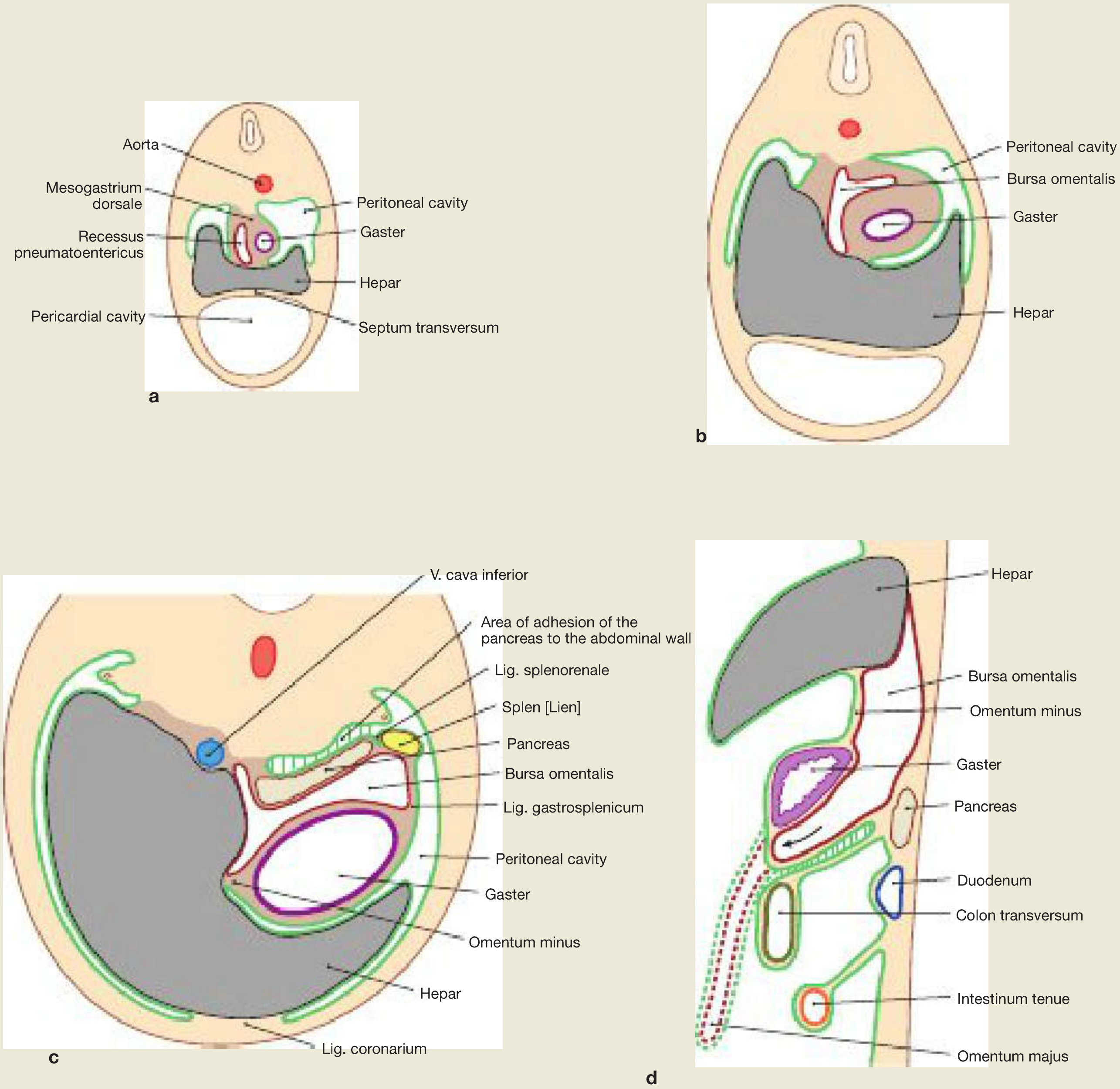


Fig. 6.1a to d Development of the upper abdominal situs at the end of the 4th (a), at the beginning of the 5th (b) and the beginning of the 7th week (c); cross-sections **(a** to **c)** and paramedian section **(d)** through the upper abdomen. Peritoneum (green); peritoneum of the Recessus pneumatoentericus and the Bursa omentalis (dark red). [L126]

The **foregut** predominantly derives from the entoderm and parts of the yolk sac. In the surrounding mesoderm, there are gaps for the abdominal cavity. The mesoderm covers the intestinal tube from the outside, where it later forms on the visceral peritoneum as parietal peritoneum. The visceral peritoneum lines the abdominal cavity and also forms the mesenteries which serve as attachments and contain the neurovascular pathways. The dorsal mesentery connects the intestinal tube with the posterior abdominal wall. In the upper abdomen, there is an additional ventral mesentery.

At the beginning of the **fourth week** the entoderm sprouts develop ventrally from the intestinal tube at the level of the future duodenum, forming the epithelial tissues of liver, gallbladder, pancreas and bile duct. Finally there is the following redistribution:

1. The **liver** expands into the Mesogastrium ventrale and divides it thus into a Mesohepaticum ventrale (between the anterior wall of the trunk and the liver) and a Mesohepaticum dorsale (between liver and stomach; **a** and **b**). From the Mesohepaticum ventrale the **Lig. coronarium** runs cranially, and the **Lig. falciforme hepatis.** At the caudal aspect is a remnant of the umbilical vein, the **Lig. teres hepatis.** The dorsal mesohepaticum becomes the Omentum minus.
2. In the dorsal mesogastrium a split occurs on the right (Recessus pneumatoentericus) which becomes the **Bursa omentalis (a** and **b).**
3. The **stomach** turns **90° clockwise** (view from above) and thus arrives on the left side of the body in a transverse position **(c).** The Omentum minus also connects the liver and lesser curvature of the stomach in the frontal plane and forms the front wall of the Bursa omentalis to the left behind the stomach.
4. In the Mesogastrium dorsale the **pancreas** forms and shifts retroperitoneally, and the **spleen,** which remains intraperitoneally.
5. The Mesogastrium dorsale finally subdivides into a **Lig. gastrosplenicum** (from the greater curvature of the stomach to the spleen) and a **Lig. splenorenale** (from the splenic hilum to the dorsal abdominal wall) and forms the remaining parts of the **Omentum majus** (hanging skirt-like on the greater curvature of the stomach; **d).** This means that the Omentum majus is part of the upper abdominal situs because of its evolutionary development and its neurovascular pathways.

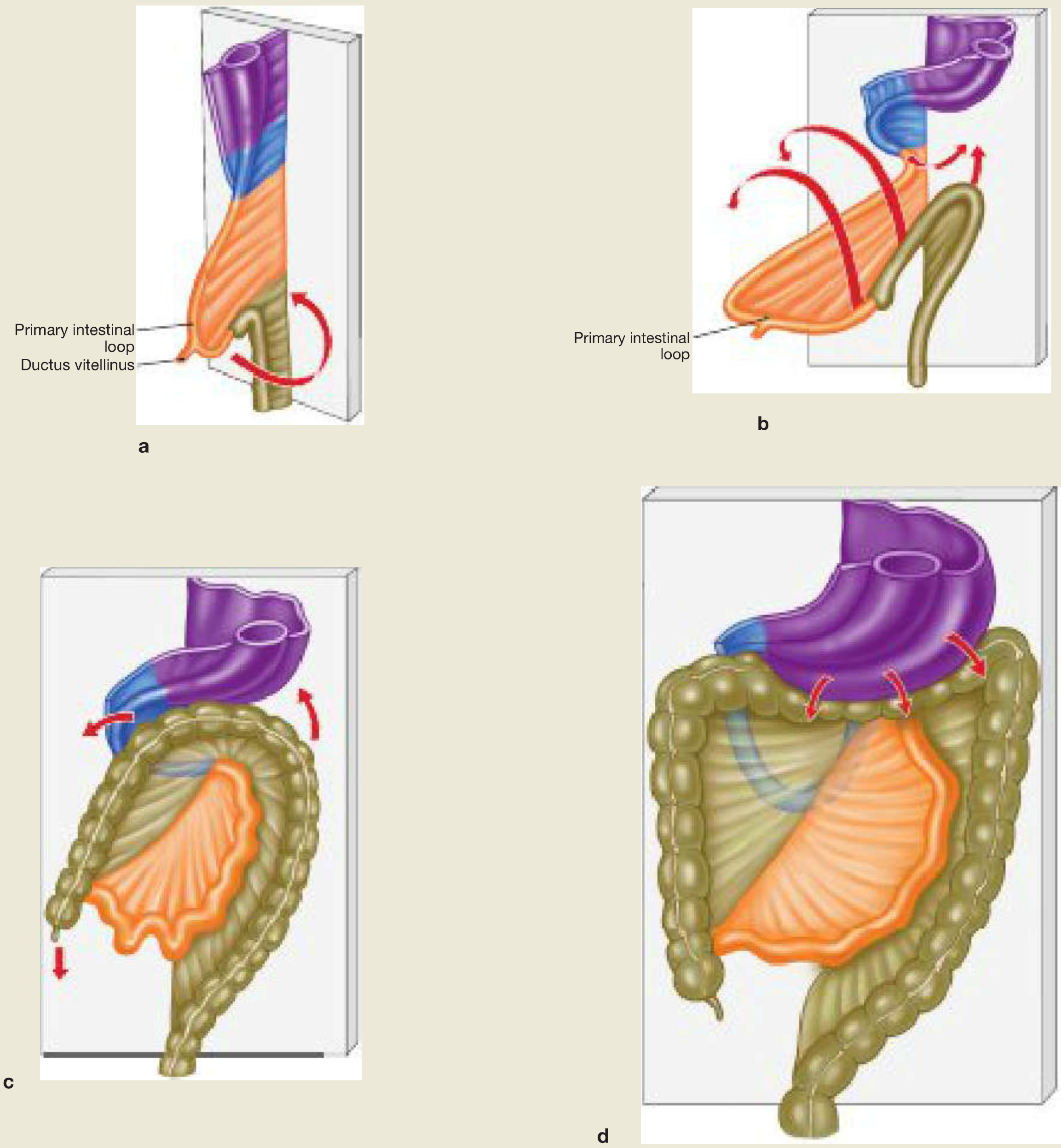


Fig. 6.2a to d Schematic representation of the intestinal rotation. Intestinal segments and their mesenteries are highlighted in different colours: stomach and mesogastrium (purple), duodenum and mesoduodenum (blue), jejunum and ileum with associated mesenteries (orange), colon and mesocolon (ochre). [L126]

1. Through the length of the gut, a ventrally pointing sling **(primary intestinal loop)** develops. The proximal (upper) crus of this loop develops into the major part of the small intestine, the distal (lower) crus develops into the colon including the Colon transversum. The distal colon develops from the rectum and is differentiated in terms of its neurovascular pathways.
2. Due to a lack of space, the primary intestinal loop is temporarily shifted from the embryo to the umbilical cord **(physiological umbilical hernia)** and remains connected to the yolk sac via the Ductus vitellinus. If the gut is not completely shifted back into the embryo, there remains a congenital umbilical hernia **(omphalocele),** which contains intestinal segments with mesentery. Because it moves outside through the later navel ring, it is only covered by amnion and not abdominal wall musculature.
3. Remnants of the Ductus vitellinus can remain as **MECKEL's diverticulum** in the small intestine.
4. By lengthening a counter-clockwise rotation of the intestine of **270°** is induced. As a result, the large intestine surrounds the small intestine like a frame.
5. Colon ascendens and Colon descendens are secondarily shifted into a retroperitoneal position. Here, the embryonic mesocolon merges with the Peritoneum parietale (TOLDT's fusion fascia).

Clinical Remarks

MECKEL's diverticula are common (3% of the population) and usually occur in the segment of the small intestine that is located approximately 100 cm cranial of the ileocaecal valve. Because they often contain disseminated gastric mucosa, inflammation and bleeding may mimic the clinical picture of appendicitis. Disturbances of the intestinal rotation can cause a **malrotation** (hypo- and hyperrotation). This can cause a blockage (ileus), but also lead to an abnormal situation of gut portions, which, for example can complicate the diagnosis of appendicitis. With **Situs inversus** all organs are inverted.

Abdominal Situs

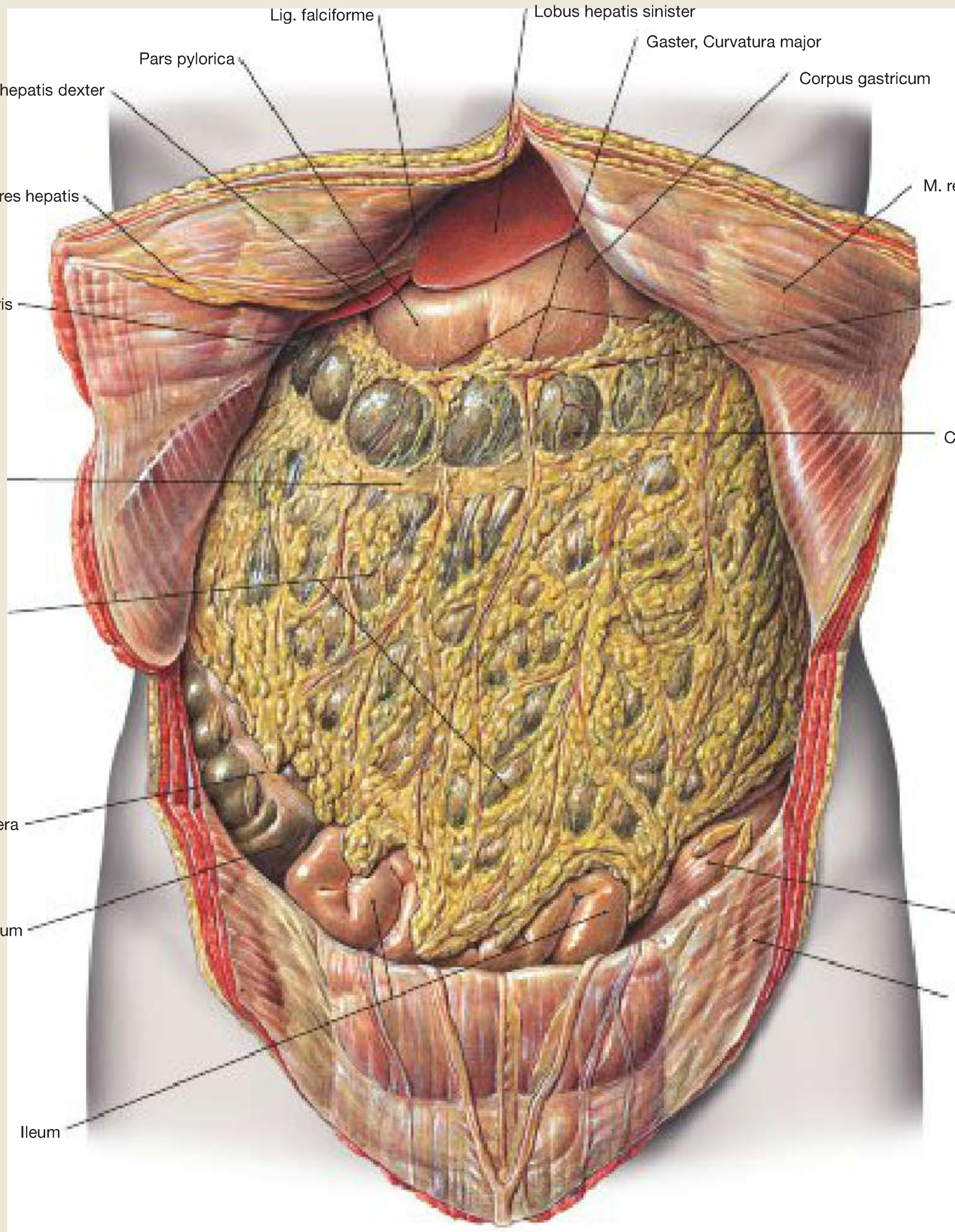


Fig. 6.3 Position of the viscera, Situs viscerum, in the upper abdomen, and greater omentum, Omentum majus; ventral view. Opening the abdominal cavity reveals the Colon transversum, which divides the abdomen in an **upper abdomen** (so-called glandular stomach) and a **lower abdomen** (so-called intestinal abdomen). Here the navel was excised on the left side, in order to prevent an injury of the Lig. teres hepatis, which connects the liver to the anterior abdominal wall. The viscera of the lower abdomen are almost completely covered by the **greater omentum (Omentum majus)** which is attached to the greater curvature of the stomach.

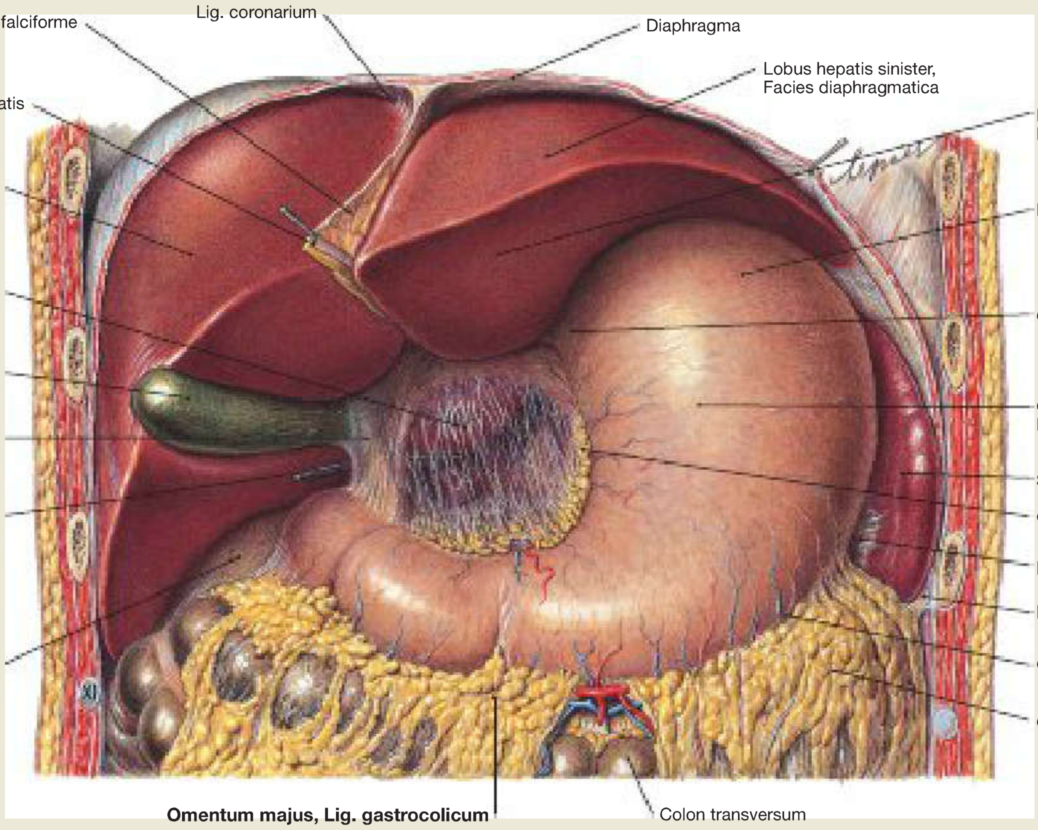


Fig. 6.4 Position of the viscera, Situs viscerum, in the upper abdomen; ventral view. The ventral abdominal wall and the rostral parts of the diaphragm have been removed.

If one raises the lower edge of the liver, the lesser omentum **(Omentum minus)** is visible. It spans the area between the liver and the lesser curvature of the stomach and the superior part of the duodenum. The lesser omentum is composed of the **Lig. hepatogastricum** and the **Lig. hepatoduodenale,** which conduct the Ductus choledochus, the portal vein (V. portae hepatis) and the A. hepatica propria to the Porta hepatis. Behind the Lig. hepatoduodenale is the entrance of the **Bursa omentalis** (Foramen omentale, marked here by a probe), a shifting space between the stomach and the pancreas anteriorly confined by the Omentum minus.

The **Omentum majus** is attached to the greater curvature of the stomach and to the Taenia omentalis of the Colon transversum. The spleen sits in the niche on the **Lig. phrenicocolicum** between the left colic flexure and the diaphragm.

Greater Omentum

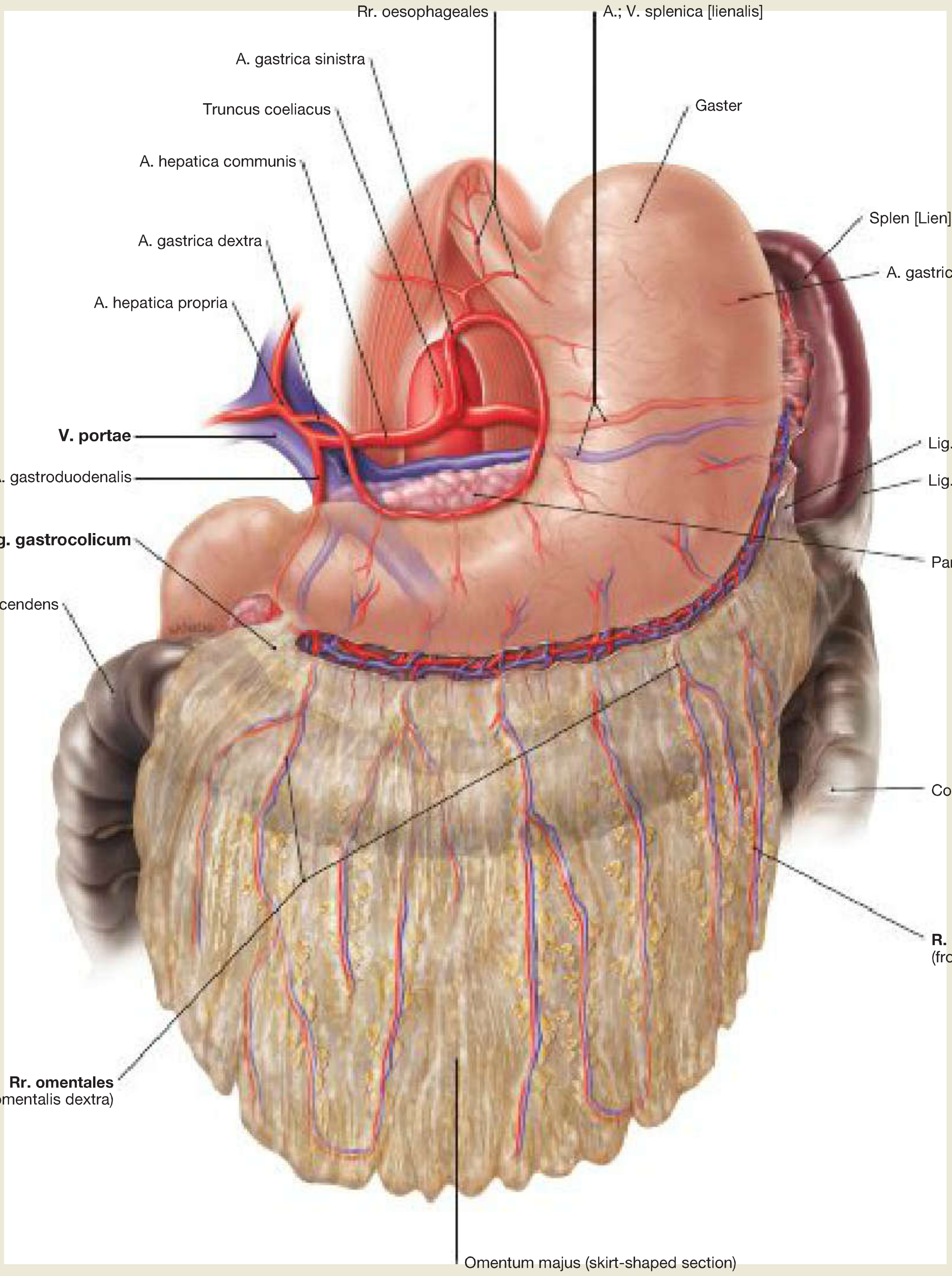


Fig. 6.5 Sections and neurovascular pathways of the greater omentum, Omentum majus; semi-schematic representation; ventral view. [L238]

The greater omentum **(Omentum majus)** is divided into a **gastrocolic ligament** (for the Colon transversum), a **Lig. gastrosplenicum** (for the spleen) and a **Lig. gastrosplenicum** (for the posterior abdominal wall). Caudally, these sections continue in a **skirt-shaped manner.** The Omentum majus plays a role in the mechanical protection and thermal insulation as well as in the secretion and absorption of the peritoneal fluid; it also has immunological functions, because it is populated by lymphatic tissue.

The greater omentum belongs to the upper abdominal situs, as it is supplied by the neurovascular pathways of the greater curvature of the stomach. In so doing, five to eight **branches (Rr. omentales)** are provided by the **A. gastroomentalis dextra,** usually only **one branch** is provided by the **A. gastroomentalis sinistra.** The venous branches flow correspondingly into the Vv. gastroomentales on which the Nodi lymphoidei gastroomentales also drain the lymph from the greater omentum.

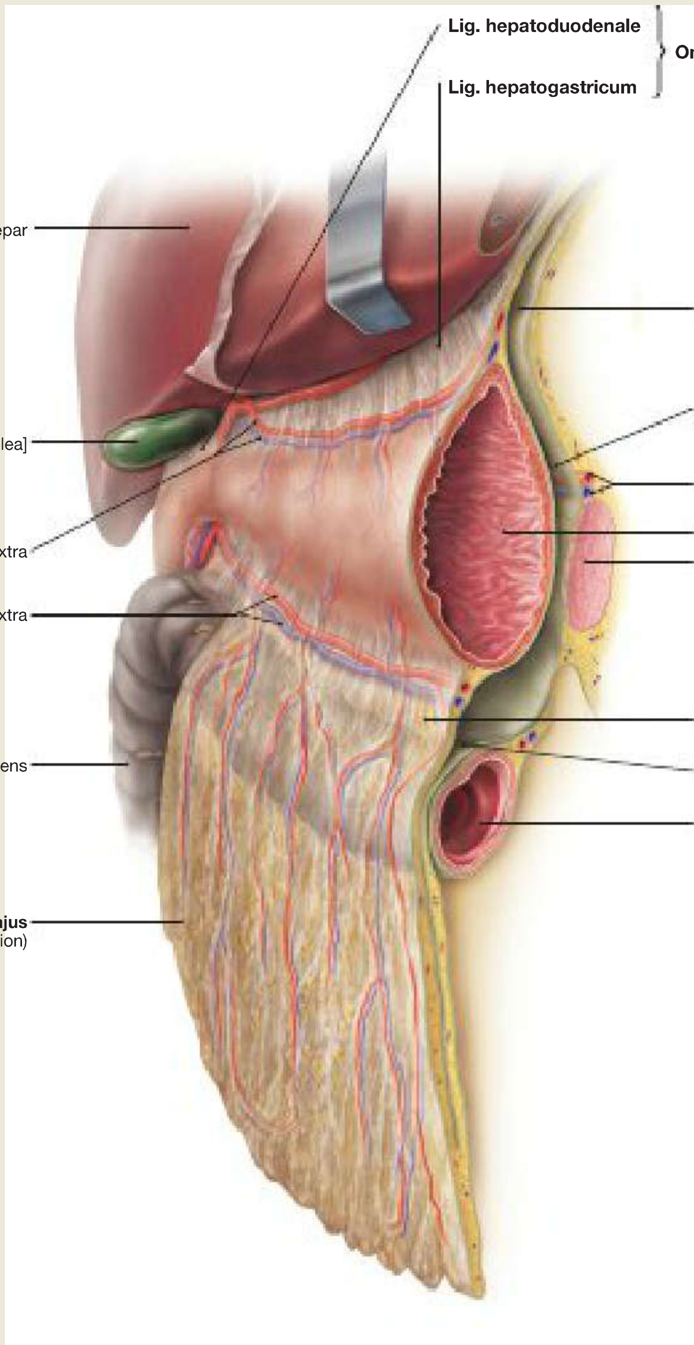


Fig. 6.6 Sections and neurovascular pathways of the greater omentum, Omentum majus; sagittal section of the stomach, pancreas, Colon transversum, Bursa omentalis and Omentum majus; semi-schematic representation; lateral view from the left side. [L238]
The greater omentum **(Omentum majus)** originates with a **Lig. gastrocolicum,** then runs caudally from the transverse colon in the highly variably constructed skirt-shaped part. The Omentum majus is a peritoneal duplicature, which becomes easily recognisable as a lower projection (Recessus inferior) of the **Bursa omentalis** which extends from above into the Lig. gastrocolicum (→ Fig. 6.8). The Bursa omentalis is a protrusion of the peritoneal cavity, originating at the Lig. hepatoduodenale and inserting between the stomach (ventral) and the pancreas (dorsal). Mostly the inferior recess does not reach as far as shown in this image into the skirt-shaped part of the Omentum majus.

Upper Abdominal Situs with Bursa omentalis

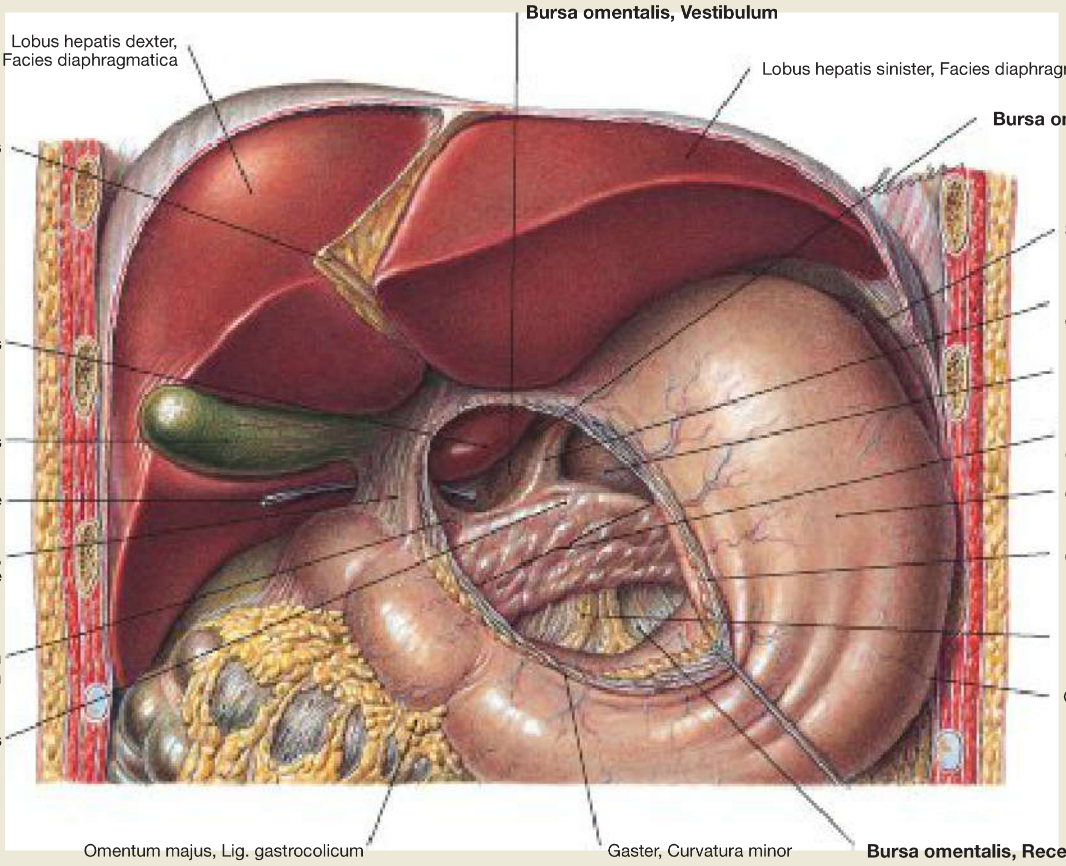


Fig. 6.7 Position of the viscera, Situs viscerum, in the upper abdomen; ventral view.

The lesser omentum (Omentum minus) between the liver and the lesser curvature of the stomach has been cut in order to look into the Bursa omentalis.

The **Bursa omentalis** is a shifting space between the stomach and the pancreas, which only communicates with the abdominal cavity via the Foramen omentale which lies behind the Lig. hepatoduodenale. Due to its expansion, the Bursa omentalis is also referred to in Anglo-American language usage as a 'small abdominal cavity' ('lesser sac of the peritoneal cavity').

The Bursa omentalis is divided into four sections:

- **Foramen omentale:** the entrance to the Bursa omentalis is bordered from the front by the Lig. hepatoduodenale, above from the Lobus caudatus, below from the Bulbus duodeni and from behind by the V. cava inferior.
- **Vestibulum:** the front of the vestibule is confined by the Omentum minus and reaches behind the liver with a superior recess.
- **Isthmus:** the narrowing between the first and main space is confined by two peritoneal folds, on the right side by the Plica hepatopancreatica which is raised by the A. hepatica communis, and on the left side by the Plica gastropancreatica, which marks the course of the A. gastrica sinistra.
- **Main space:** it lies between the stomach (in front) and the pancreas or the Mesocolon transversum (behind). On the left side the Recessus splenicus extends to the hilum of the spleen, and the Recessus inferior extends below the Lig. gastrocolicum to the root of the mesocolon at the Colon transversum.

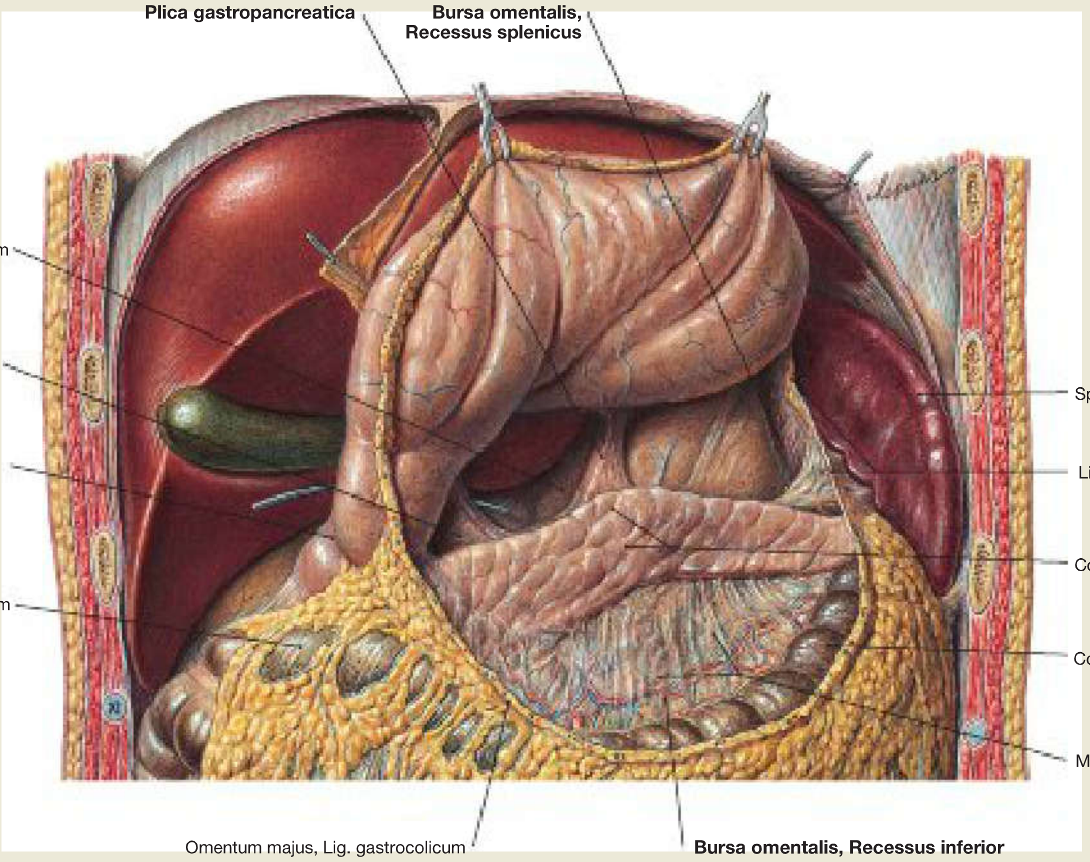


Fig. 6.8 Position of the viscera, Situs viscerum, in the epigastrium; ventral view.
The Lig. gastrocolicum as been divided, and the stomach folded back to open up the main space of the Bursa omentalis. The posterior wall of the Bursa omentalis is formed by the pancreas and the Mesocolon transversum. On the left side, it extends into the hilum of the spleen (Recessus splenicus) and downwards to the origin of the mesocolon at the Colon transversum (Recessus inferior).

Clinical Remarks

Like other recesses of the peritoneal cavity, the Bursa omentalis is of clinical significance as a site where small intestinal loops **(internal hernias)** can be trapped or where tumour cells, in the case of **peritoneal carcinosis,** or bacterias, in the case of **peritonitis,** can settle. During operations in the abdomen, the surgeon therefore inspects the Bursa omentalis, in order to avoid missing any symptoms.

For **operations** in the epigastrium, e.g. surgical interventions on the pancreas, there are **three access routes** into the Bursa omentalis:

- via the Omentum minus (→ Fig. 6.7)
- via the Lig. gastrocolicum (see above)
- via the Mesocolon transversum

Abdominal Situs

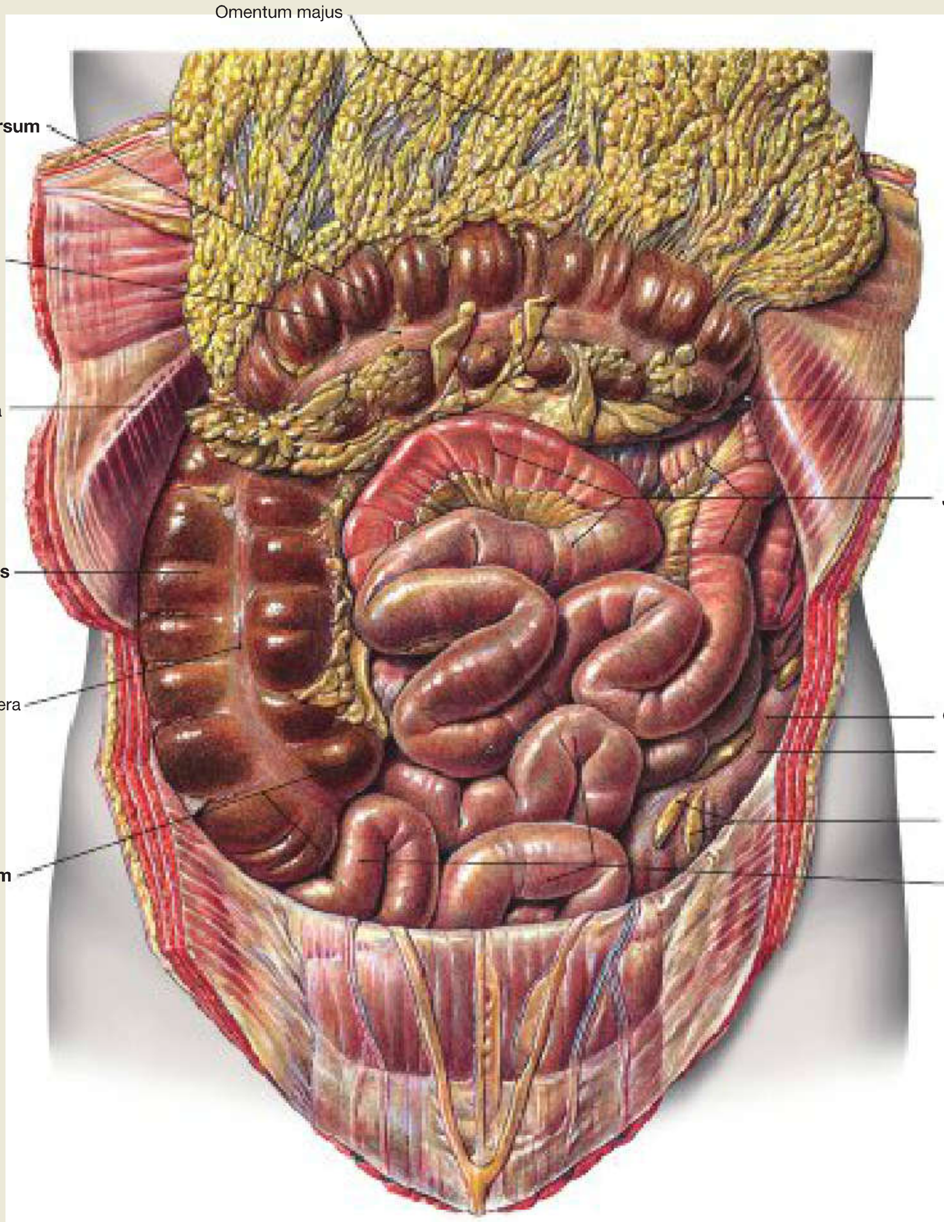


Fig. 6.9 Position of the viscera, Situs viscerum, in the hypogastrium; ventral view.
The Omentum majus has been folded back cranially to reveal the small and large intestines in the **hypogastrium,** which reveals the intraperitoneal segments: the **Jejunum** and **Ileum** of the small intestine as well as the **Caecum, Colon transversum**, and **Colon sigmoideum** of the Intestinum crassum. This figure also shows that the retroperitoneal segments of the colon are shifted to the posterior wall of the abdomen to a variable extent. In this case, the **Colon ascendens** is clearly visible, but the **Colon descendens** is shifted further dorsally and is partially covered by the small intestine. The Intestinum crassum frames the bundle of the Jejunum and Ileum.

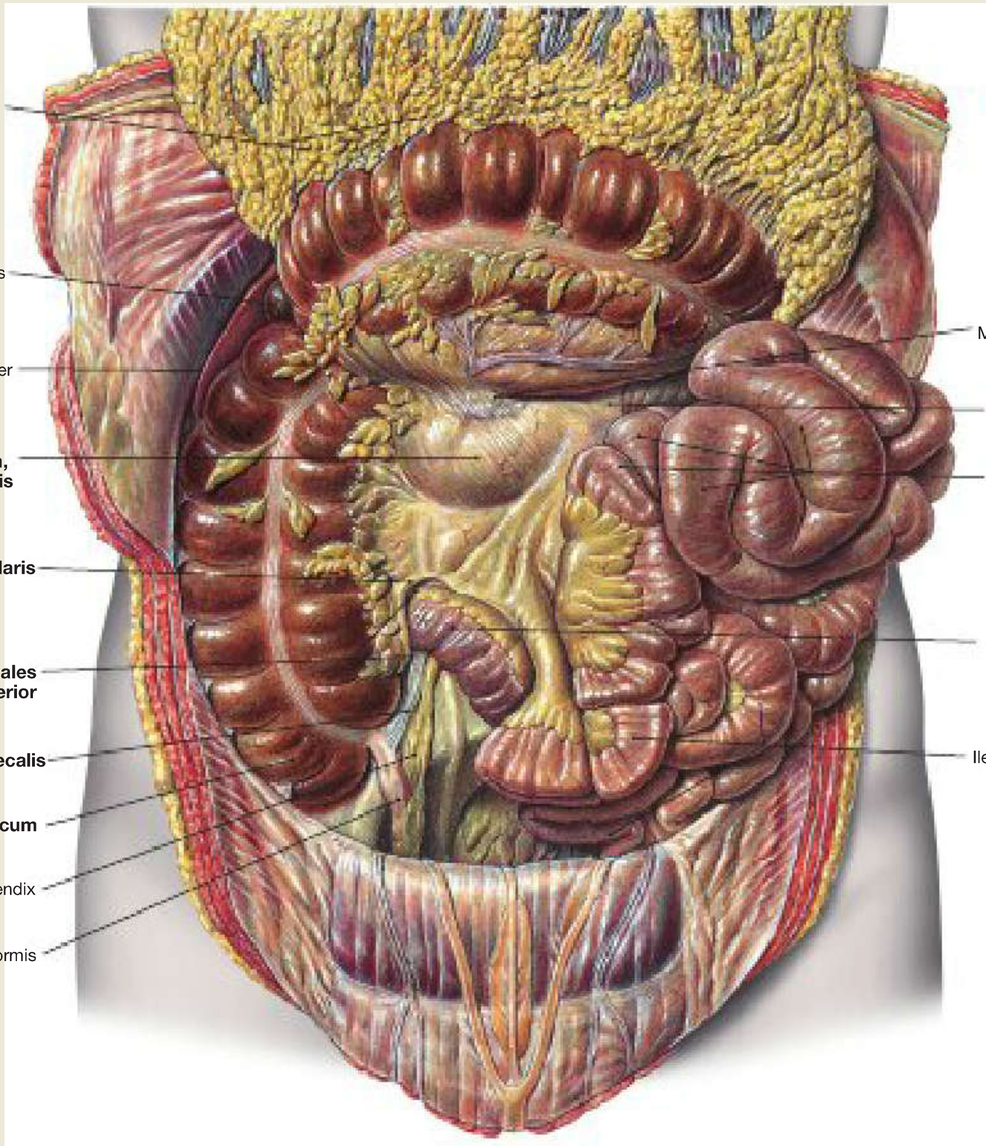


Fig. 6.10 Position of the viscera, Situs viscerum, in the hypogastrium; ventral view.
The Omentum majus has been folded cranially and the loops of the small intestine have been moved to the left side to visualise the secondary retroperitoneal Pars horizontalis of the duodenum. Between the individual organs, the peritoneal cavity forms **recesses.** At the junction of the ileum with the caecum, there are two of these spaces. The **Recessus ileocaecalis superior** is covered by the Plica caecalis vascularis (containing a branch of the A. ileocolica), and the **Recessus ileocaecalis inferior** is covered by the Plica ileocaecalis, located between the ileum and the Appendix vermiformis. In the same way as in the Bursa omentalis and in other recesses, the trapping of small intestinal loops (internal hernia) can occur.

Abdominal Situs with Recesses of the Peritoneal Cavity

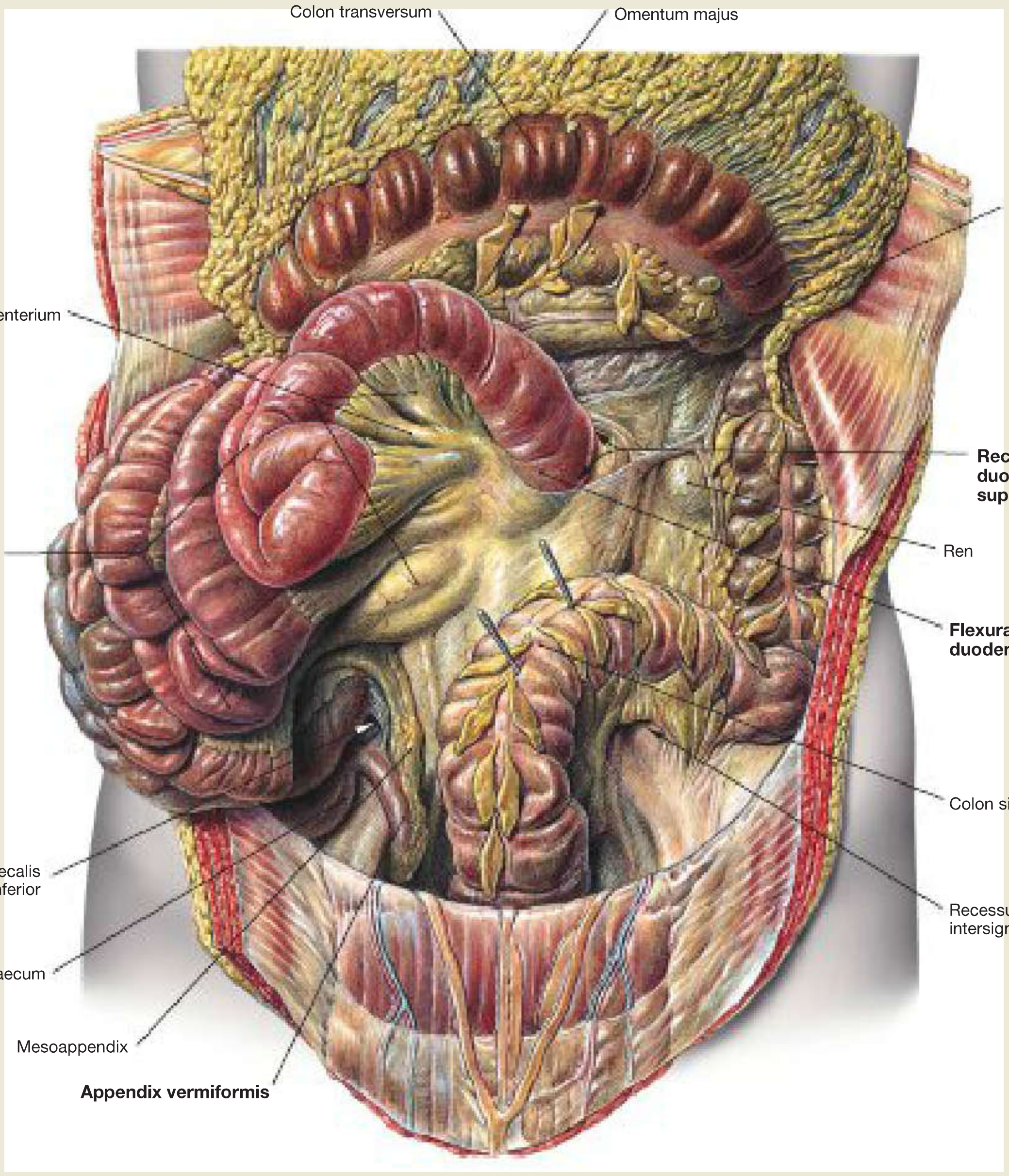


Fig. 6.11 Position of the viscera, Situs viscerum, in the hypogastrium; ventral view.
The Omentum majus has been folded cranially and the loops of the small intestine have been shifted to the right, so that the Flexura duodenojejunalis is visible, in which the retroperitoneal duodenum continues into the intraperitoneal jejunum. This area also contains two recesses: the **Recessus duodenales superior** and **inferior.** In the right hypogastrium, the Appendix vermiformis is visible, the tip of which descends into the small pelvis (descending type).

Clinical Remarks

In the Recessus duodenales superior and inferior there are frequently areas with gaps which can entrap small intestinal appendages **(TREITZ' hernia).** This entrapment can cause a blockage (ileus) and bowel infarction.

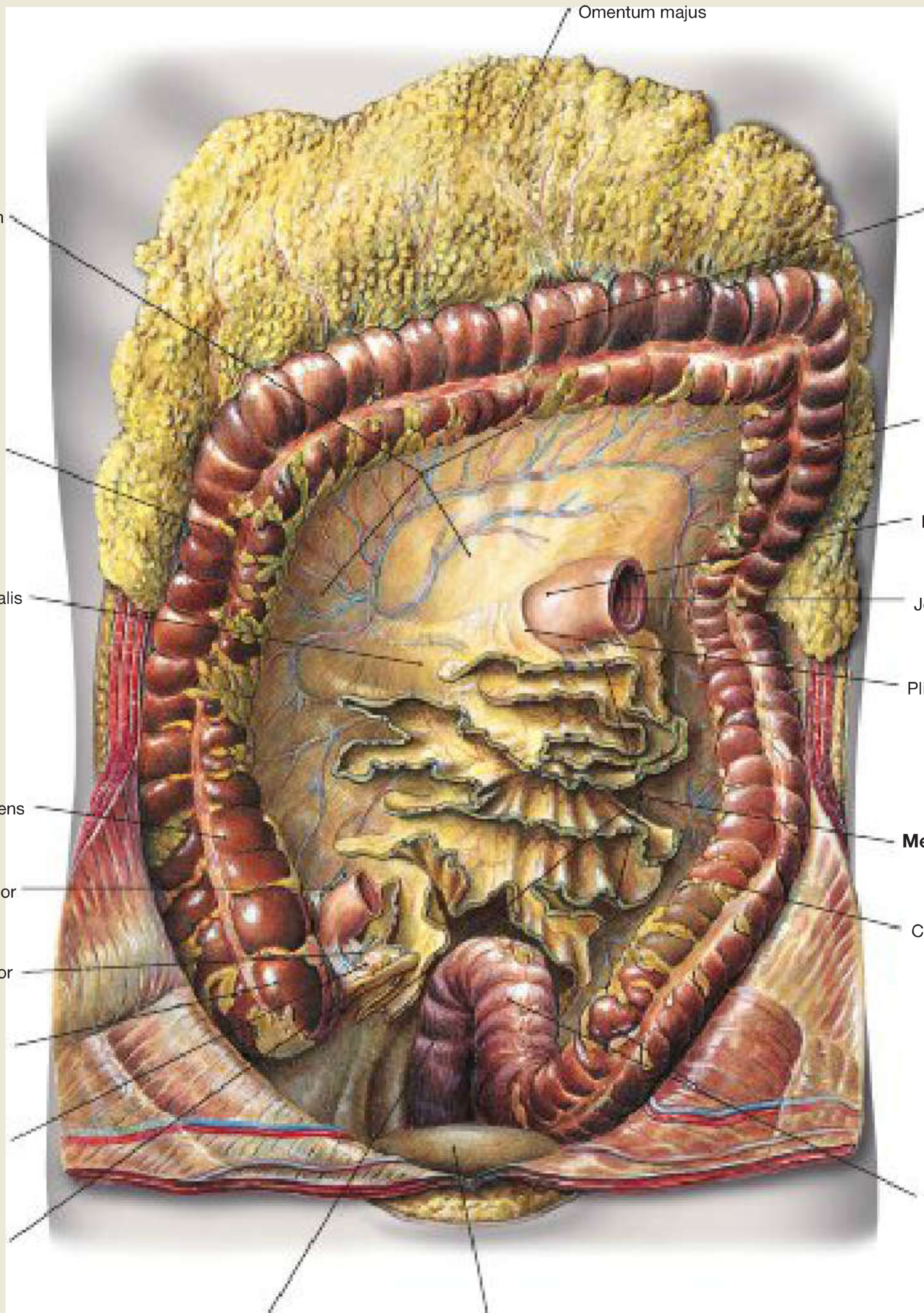


Fig. 6.12 Mesentery of the small intestine, Mesenterium, and large intestine, Intestinum crassum; ventral view.
The Omentum majus and the Colon transversum have been folded back. The intraperitoneal small intestinal convolute of jejunum and ileum was removed at the **mesentery.** The mesentery is a peritoneal duplicature which provides a flexible suspension of the small intestine and contains the neurovascular pathways.

Secondary Retroperitoneal Organs

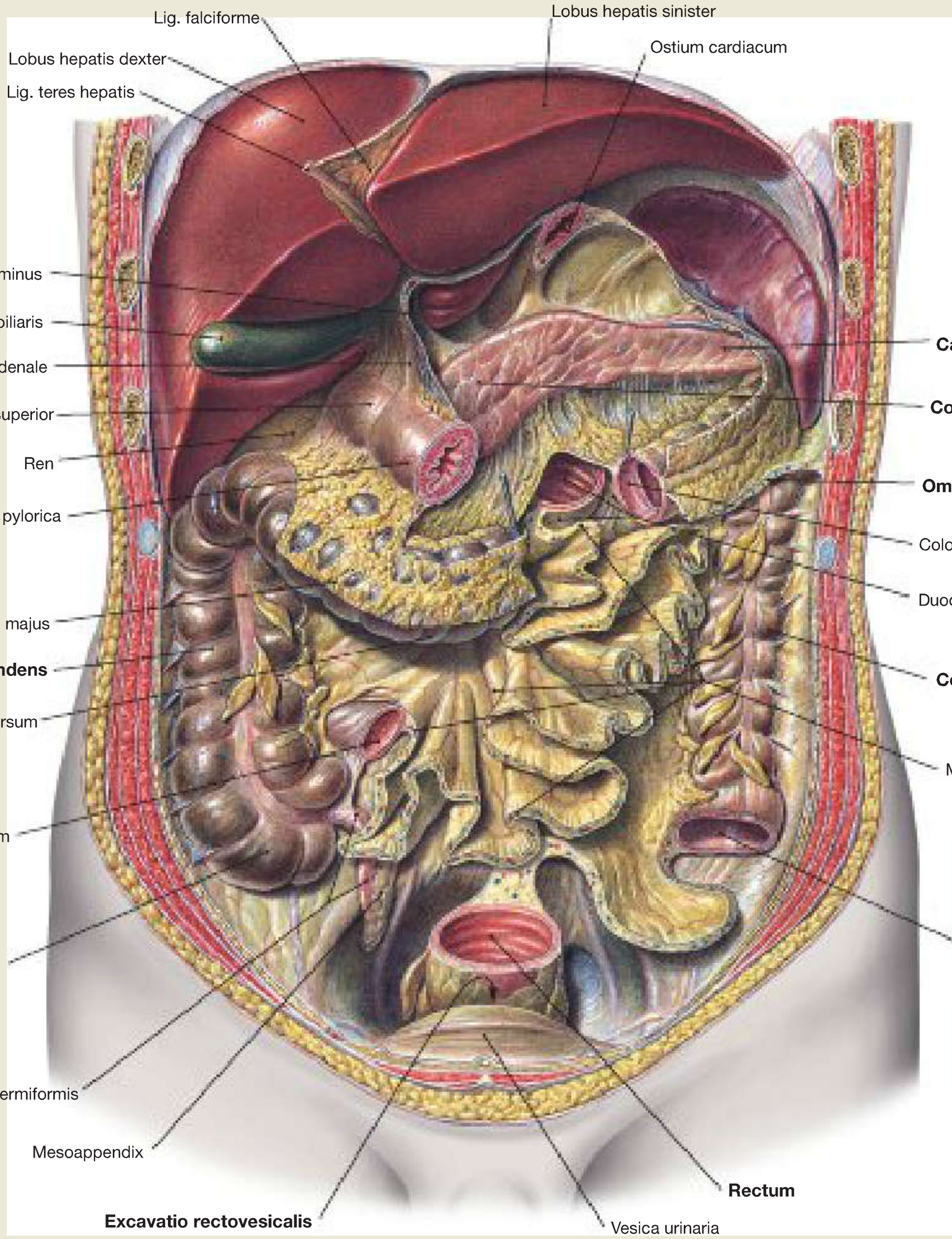


Fig. 6.13 Position of the secondary retroperitoneal organs; ventral view.
The stomach has been removed, the Jejunum and Ileum were resected at the mesentery, and the Colon transversum and Colon sigmoideum were severed. Most of the secondary retroperitoneal organs are now visible. These include the **Duodenum** (except its Pars superior), **Pancreas, Colon ascendens** and **Colon descendens** as well as the **proximal Rectum up to the Flexura sacralis.** In front of the rectum, the entrance of the **Excavatio rectovesicalis** can be seen, a recess which is the lowest point of the abdominal cavity in men.

Clinical Remarks

In an upright position (seldom in bedridden patients), in the most inferior extension of the peritoneal cavity, the **Excavatio rectovesicalis** in men, and the **Excavatio vesicouterina** (pouch of DOUGLAS) in women (→ Fig. 6.14), may accumulate inflammatory exudate or pus in cases of inflammation in the hypogastrium. Ultrasound may be used to check if the liquid is clear or not.

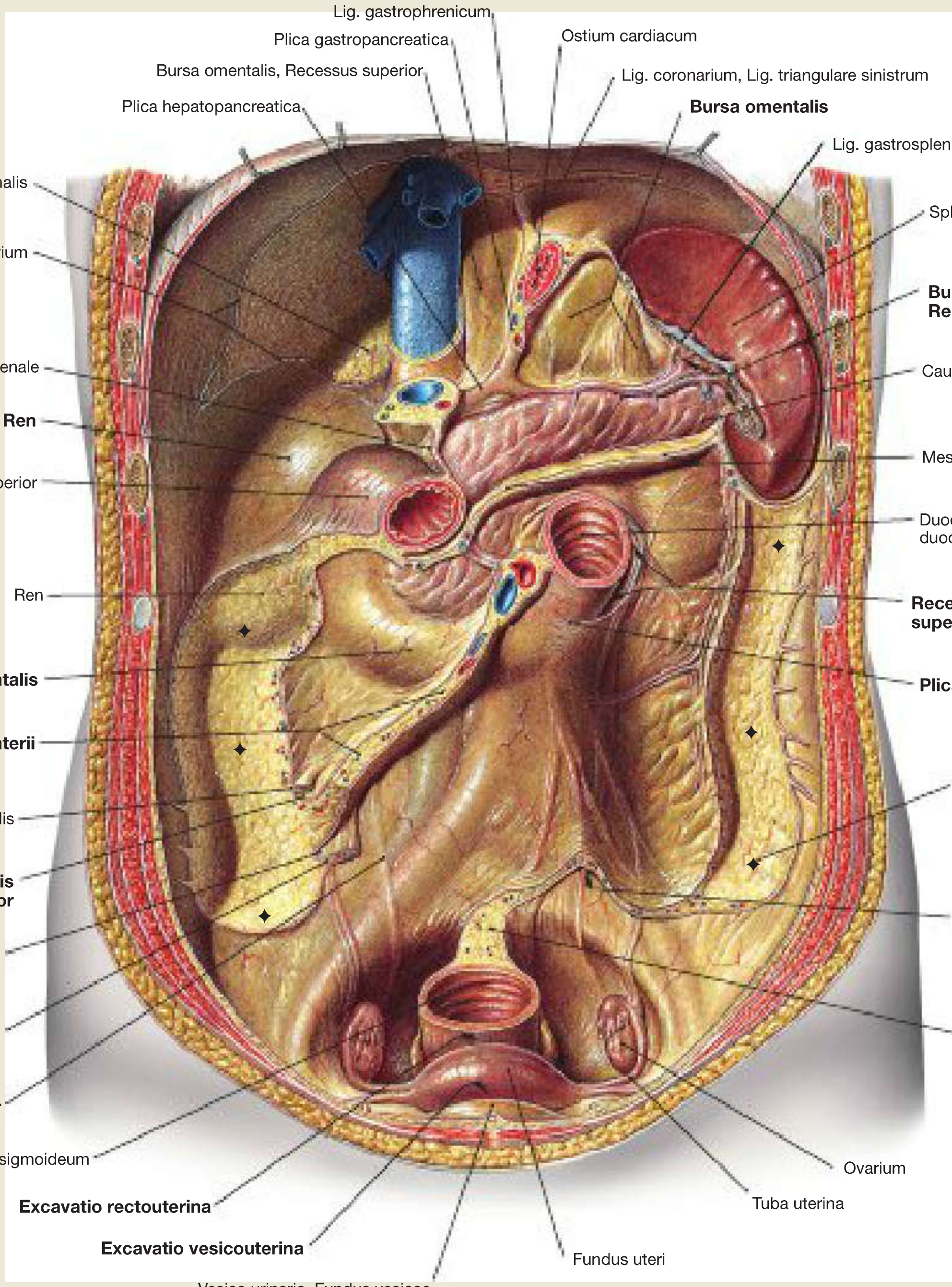


Fig. 6.14 Dorsal wall of the Cavitas peritonealis, with recesses, Recessus, and spleen, Splen [Lien]; ventral view.

The liver, as well as the small and large intestines have been removed up to the duodenum to expose the back of the peritoneal cavity. On the right kidney and on the Pars horizontalis of the duodenum is the Peritoneum parietale which is easily recognised by its shimmering lustre. The adhesion sites of the secondary retroperitoneal Colon ascendens and Colon descendens lack the coating of the parietal peritoneum.

Peritoneal duplicatures, which raise up the relief of the posterior wall of the peritoneal cavity as folds (Plicae) and ligaments (Ligamenta), form the various **recesses (Recessus).** The largest of these recesses is the **Bursa omentalis** (→ Fig. 6.7), of which the sections and offshoots can be seen here. In the area of the Flexura duodenojejunalis, the Plicae duodenales superior and inferior form two recesses, the **Recessus duodenales superior** and **inferior.** There are further recesses at the confluence of the ileum into the caecum **(Recessus ileocaecales superior** and **inferior)** and occasionally below the sigmoid mesocolon **(Recessus intersigmoideus).**

There is a deep peritoneal space anterior to the rectum, which is confined at the ventral side by the uterus. This **Excavatio rectouterina** (pouch of DOUGLAS) is the lowest point of the female peritoneal cavity. The **Excavatio vesicouterina** located ventrally between the bladder and uterus does not go quite as far caudally. Between the Flexura duodenojejunalis and the right Fossa iliaca, the approximately 12–16 cm long **mesentery root (Radix mesenterii)** is extended, in which the neurovascular pathways of the small intestine (A./V. mesenterica superior) have been truncated. The mesenteric root crosses the Pars horizontalis of the duodenum and the right ureter.

* **TOLDT's fusion fascia;** dorsal of the Colon ascendens and the Colon descendens, which have been removed here.

Arteries of the Abdomen

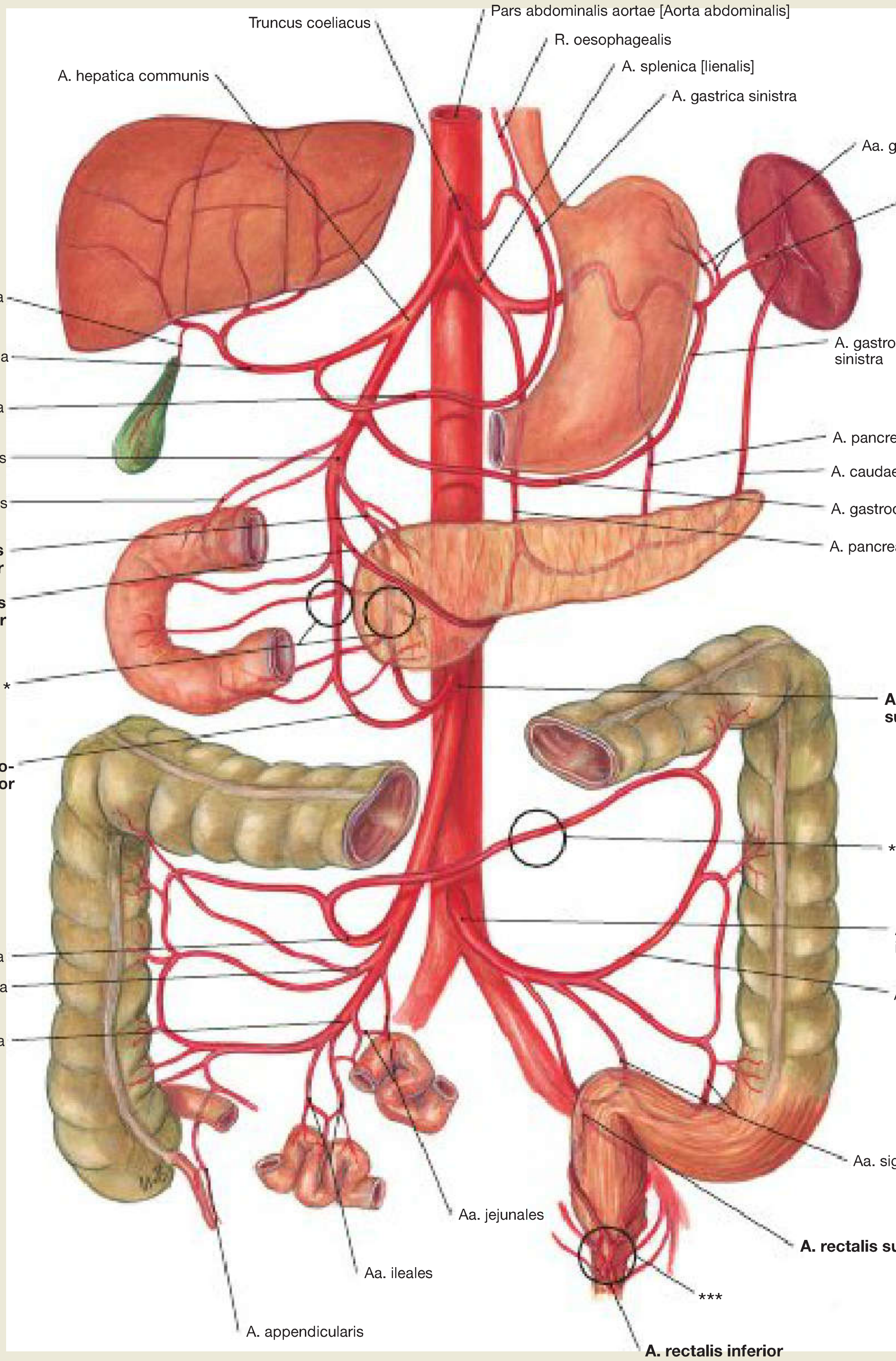


Fig. 6.15 Arteries of the abdominal viscera; semi-schematic illustration; ventral view.

The most important anastomoses are marked with black circles. The three unpaired arteries of the abdominal viscera branching off the abdominal aorta are the Truncus coeliacus, the A. mesenterica superior and the A. mesenterica inferior. The A. mesenterica superior originates directly below the Truncus coeliacus (due to the semi-schematic representation it is not included here). Their individual branches are described on the following pages. The three arteries form **anastomoses** with each other and with branches of the A. iliaca interna, which in the case of an occlusion of one of these vessels can prevent an ischemic infarction.

Specifically, these are:

- connections between the Truncus coeliacus and the A. mesenterica superior via the Aa. pancreaticoduodenales: **BÜHLER's anastomosis** (*)
- connections between the A. mesenterica superior and the A. mesenterica inferior: **RIOLAN's anastomosis** of the Aa. colicae media and sinistra (**)
- the plexus of rectal arteries: this connects the A. rectalis superior from the A. mesenterica inferior with the Aa. rectales media and inferior from the drainage area of the A. iliaca interna (***).

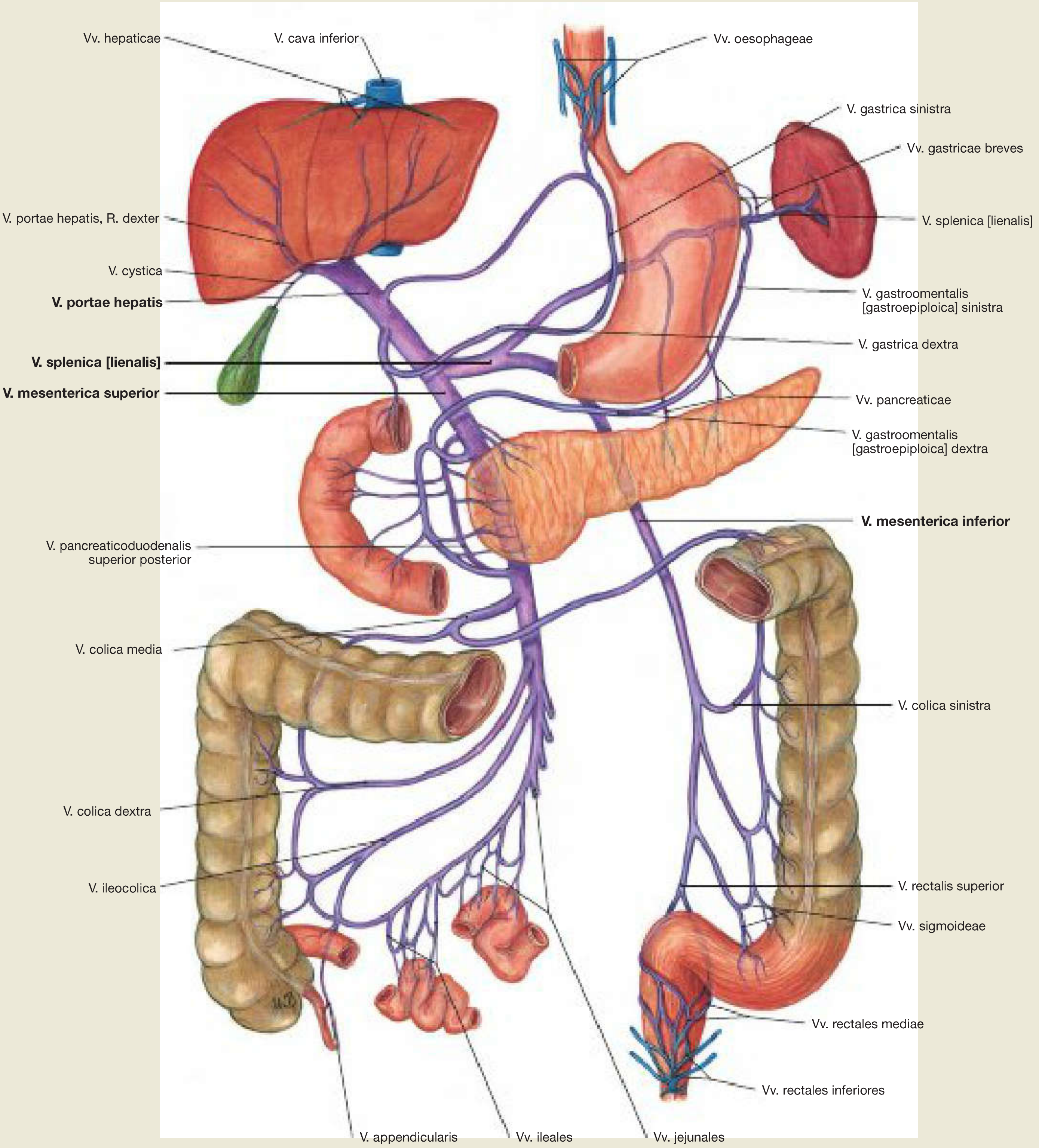


Fig. 6.16 Portal vein, V. portae hepatis, with tributaries; semi-schematic illustration; ventral view.

The **V. portae hepatis** collects the nutrient-rich blood from the unpaired abdominal organs (stomach, intestines, pancreas, spleen) and takes this to the liver.

The V. portae hepatis has three **main tributaries:** behind the head of the pancreas, the V. mesenterica superior merges with the V. splenica to form the V. portae hepatis. The V. mesenterica inferior mostly drains into the V. splenica (70% of all cases) or into the V. mesenterica superior (30%). In addition, some branches lead directly into the V. portae hepatis (detailed description → Fig. 6.89).

Nerves of the Abdominal Organs

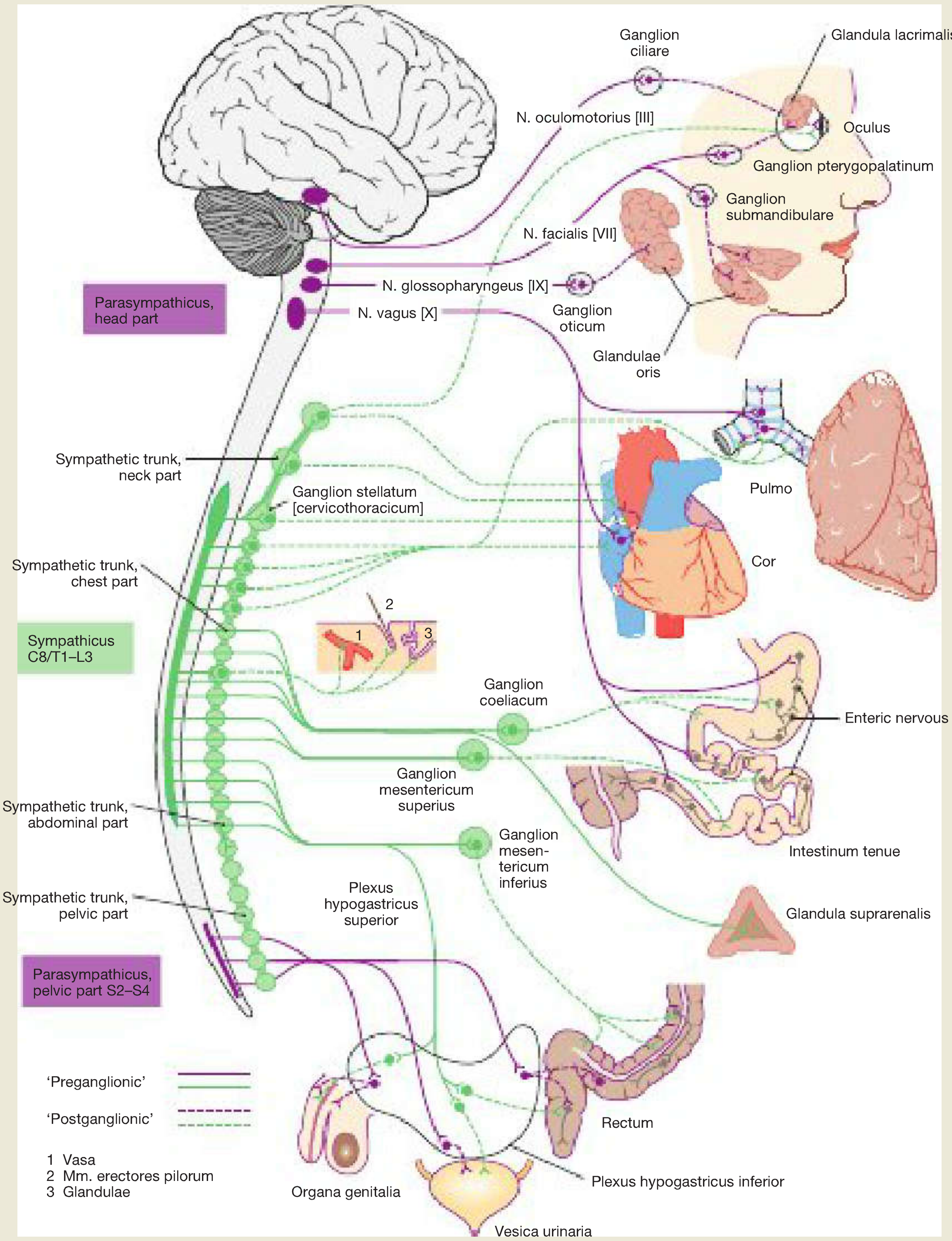


Fig. 6.17 Autonomic innervation of the abdominal organs; schematic drawing. [L106, L126]

The abdominal organs are autonomically innervated by the **sympathicus** and the **parasympathicus.** The first so-called **preganglionic** neuron is positioned with its nerve cell body in the central nervous system and sends its axons as nerve fibres to node-shaped structures **(ganglions),** which are introduced by second **postganglionic** neurons (→ Fig. 12.216). The **sympathetic ganglia,** located close to the spine **(paravertebral),** form a chain, the sympathetic trunk (Truncus sympathicus), and they also lie on the aorta **(prevertebral),** near the openings of the visceral branches. Conversely, the ganglia of the **parasympathicus** are usually mostly found directly on the effector organs **(close to organs).** The nerves to the abdominal organs form a network on the abdominal aorta **(Plexus aorticus abdominalis)** and reach their target organs mainly as periarterial plexuses embedded in the peritoneal duplicatures of the mesenteries (→ Fig. 7.5).

- **Sympathicus**
  Preganglionic neurons: lateral horn of the thoracic and lumbar portions of the spinal cord **(C8–L3) = thoracolumbar** part of the autonomic nervous system.

  The nerve fibres for the abdomen are however not switched onto the ganglia of the **sympathicus;** instead they run through the two visceral nerves **(N. splanchnicus major,** T5–T9, and **N. splanchnicus minor,** T10–T11) to the **ganglia of the Plexus aorticus abdominalis,** where they are switched onto the postganglionic neurons.
- **Parasympathicus**
  Preganglionic neurons: nuclei of the **N. vagus** as well as in the sacral part of the spinal cord **(S2–S4) = craniosacral** part of the autonomic nervous system. Preganglionic neurons for the abdominal organs run with the **N. vagus** and eventually as **Trunci vagales anterior and posterior,** together with the Oesophagus, pass through the diaphragm to the Plexus aorticus abdominalis. The innervation area of the cranial parasympathicus includes all of the upper abdominal organs and ends in the area of the left colic flexure (traditionally referred to as the CANNON-BÖHM point). The 'left-sided colon sections' receive their nerve fibres, as do all the pelvic organs, from the sacral parasympathetic trunk (S2–S4), which they exit as the **Nn. splanchnici pelvici,** and are then switched onto postganglionic neurons in the **Plexus hypogastricus inferior** in the rectum.

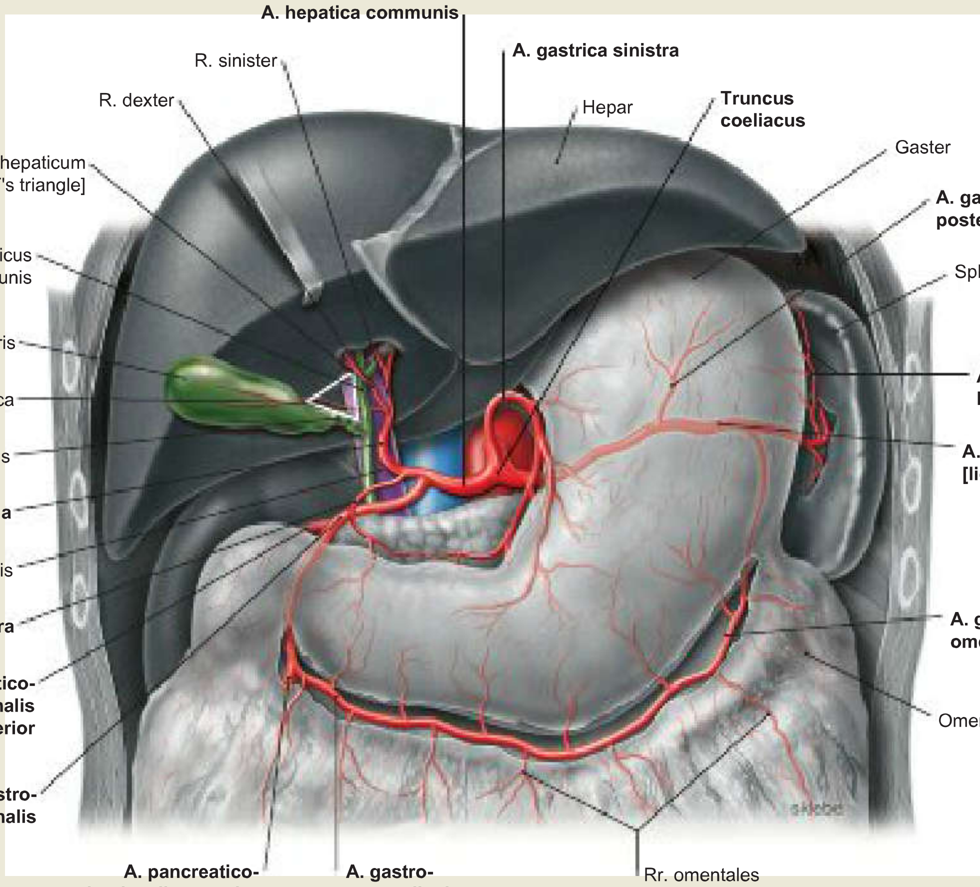


Fig. 6.18 Branches of the Truncus coeliacus; semi-schematic illustration; the liver is mobilised upwards; ventral view after removal of the Omentum minus. [L238]

The Truncus coeliacus is the first unpaired visceral branch of the abdominal aorta. It has three main branches supplying the upper abdominal organs (stomach, duodenum, liver, gallbladder, pancreas and spleen):

- **A. gastrica sinistra:** goes to the left, top and is usually stronger than the A. gastrica dextra by which it is connected to the lesser curvature of the stomach
- **A. hepatica communis:** turns to the right and is divided into the
  - A. hepatica propria: supplies the A. gastrica dextra, then supplies the liver and gallbladder (cystic artery)
  - A. gastroduodenalis: rises behind the pylorus or duodenum, divides into the A. gastroomentalis dextra to the greater curvature of the stomach and into the Aa. pancreaticoduodenales superiores anterior and posterior, which anastomose with the A. pancreaticoduodenalis inferior from the A. mesenterica superior and supply the pancreatic head and the duodenum
- **A. splenica [lienalis]:** passes to the inferior left side, and runs to the superior border of the pancreas, and on its way to the spleen provides the following branches:
  - Rr. pancreatici to the pancreas
  - A. gastrica posterior to the stomach (in 30–60% of all cases)
  - A. gastroomentalis sinistra: passes from the left side to the greater curvature of the stomach curvature and anastomoses with the A. gastroomentalis dextra
  - Aa. gastrici breves: short branches to the fundus of the stomach
  - Rr. splenici: terminal branches to the spleen

Truncus coeliacus

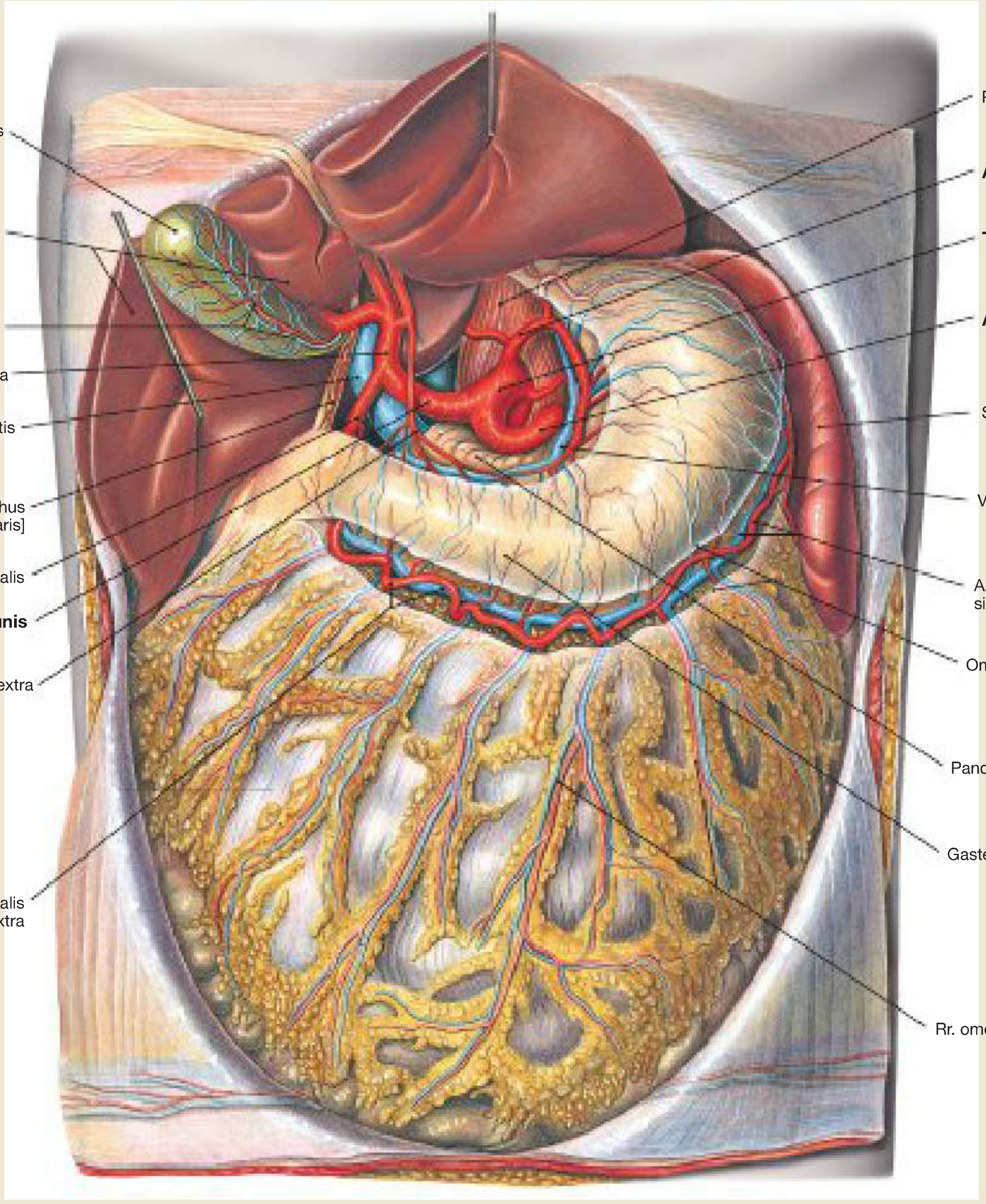


Fig. 6.19 Topography of the Truncus coeliacus; ventral view; after removal of the Omentum minus.

The Truncus coeliacus originates from just below the Hiatus aorticus at the level of the 12th thoracic vertebra as the first unpaired branch of the aorta. In the retroperitoneal space behind the Bursa omentalis its short (mostly 1–2 cm) trunk divides into the three major arteries:

- The **A. gastrica sinistra** branches off to the top left and emerges on the posterior wall of the Bursa omentalis as the **Plica gastropancreatica** before moving up into the **Lig. hepatogastricum** to the lesser curvature of the stomach.
- The **A. hepatica communis** turns right and forms the **Plica hepatopancreatica** of the Bursa omentalis, before dividing into its main branches:
  - The A. hepatica propria supplies the A. gastrica dextra and then passes into the **Lig. hepatoduodenale** to the hilum of the liver.
  - The A. gastroduodenalis rises retroperitoneally behind the pylorus or duodenum and continues into the Aa. pancreaticoduodenales superiores anterior and posterior.
  - The A. gastroomentalis dextra goes into the **Lig. gastrocolicum** to the greater curvature of the stomach.
- The **A. splenica [lienalis]** enters the retroperitoneum on the inferior left side and runs along the superior border of the pancreas.
- Their branches supplying the greater curvature of the stomach (A. gastroomentalis sinistra).
  - Short branches (Aa. gastrici breves) to the fundus of the stomach enter the hilum of the spleen in the **Lig. gastrosplenicum.**

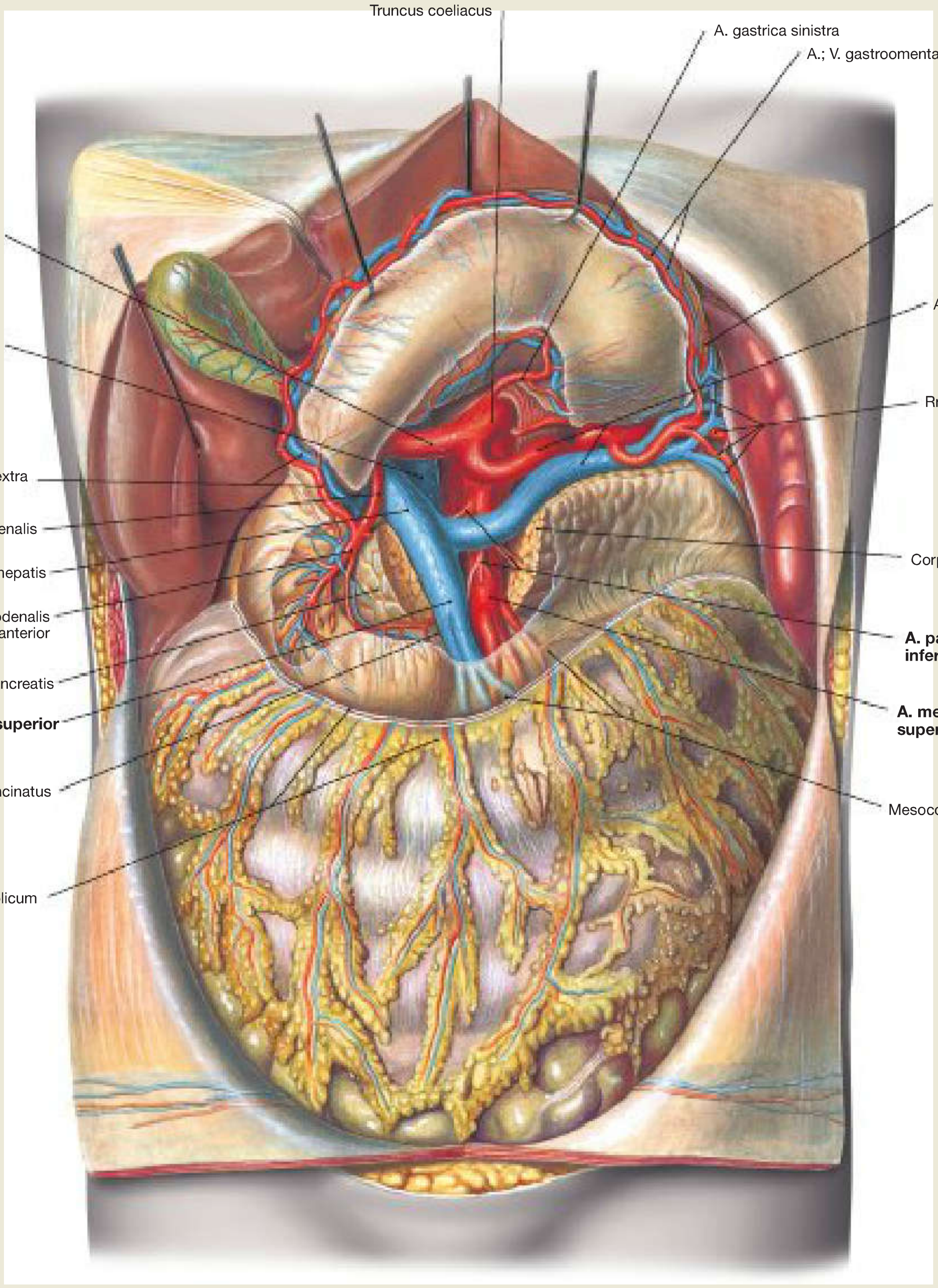


Fig. 6.20 Origin of the A. mesenterica superior and branches of the Truncus coeliacus; ventral view; the stomach is folded back cranially and the pancreas is divided.

After originating from the aorta, the **A. mesenterica superior** rises to the level of the first lumbar vertebra and then goes below the Truncus coeliacus, behind the pancreas and enters the mesentery. The pancreas is cut through to show the course of the A. and V. mesenterica superior, which are supported by the Proc. uncinatus of the pancreas. As the first branch, the A. mesenterica superior provides the **A. pancreaticoduodenalis inferior** towards the top right. It anastomoses with the **Aa. pancreaticoduodenales superiores anterior and posterior** from the circulatory area of the Truncus coeliacus. These arteries continue into the A. gastroduodenalis of the A. hepatica propria.

As the stomach is folded back cranially, the vascular arcades on both sides of the curvatures of the stomach are clearly recognisable, and consist of the branches of the Truncus coeliacus.

The **Truncus coeliacus** leads directly into the **A. gastrica sinistra** to the lesser curvature of the stomach. It is connected with the **A. gastrica dextra,** which mostly branches off the A. hepatica propria. The **A. gastroomentalis dextra** from the A. gastroduodenalis connects to the greater curvature of the stomach with the **A. gastroomentalis sinistra** from the A. splenica. From which emerges the **Aa. gastrici breves,** making their way up to the fundus of the stomach.

A. mesenterica superior

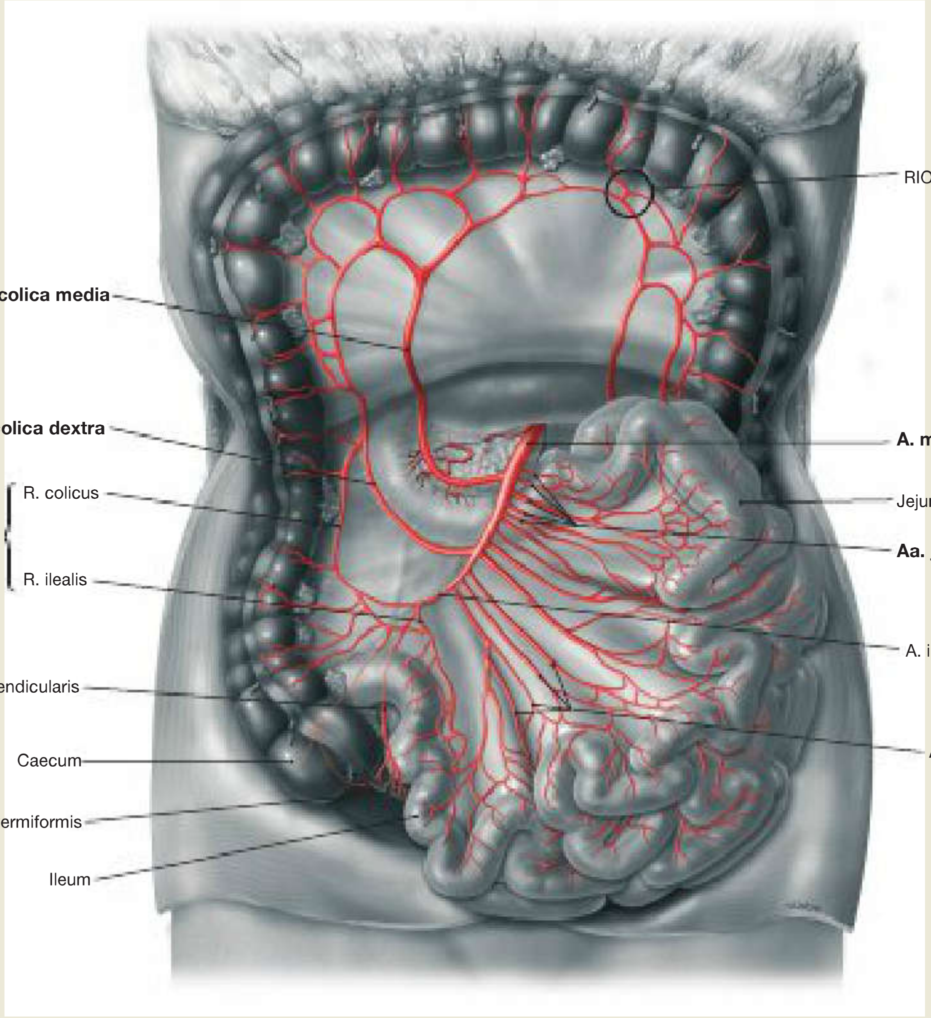


Fig. 6.21 A. mesenterica superior; ventral view; Colon transversum folded upwards. [L238]

The A. mesenterica superior originates unpaired from the aorta directly below the Truncus coeliacus, initially running retroperitoneally behind the pancreas and then passes into the mesentery. Its branches can be displayed if the mesentery is opened and the adipose tissue between the vascular arcades is removed. It supplies parts of the pancreas and duodenum, the entire small intestine, and the Intestinum crassum up to the left colic flexure (splenic flexure).

Branches of the A. mesenterica superior:

- **A. pancreaticoduodenalis inferior:** branches off to the superior right side; the R. anterior and R. posterior anastomose with the Aa. pancreaticoduodenales superiores anterior and posterior (→ Fig. 6.20).
- **Aa. jejunales** (4–5) and **Aa. ileales** (12): directed to the left side
- **A. colica media:** originates from the right side, connected with the A. colica dextra and the A. colica sinistra (RIOLAN's anastomosis)
- **A. colica dextra:** runs on the Colon ascendens
- **Ileocolic artery:** supplies the distal ileum, caecum and Appendix vermiformis (A. appendicularis)

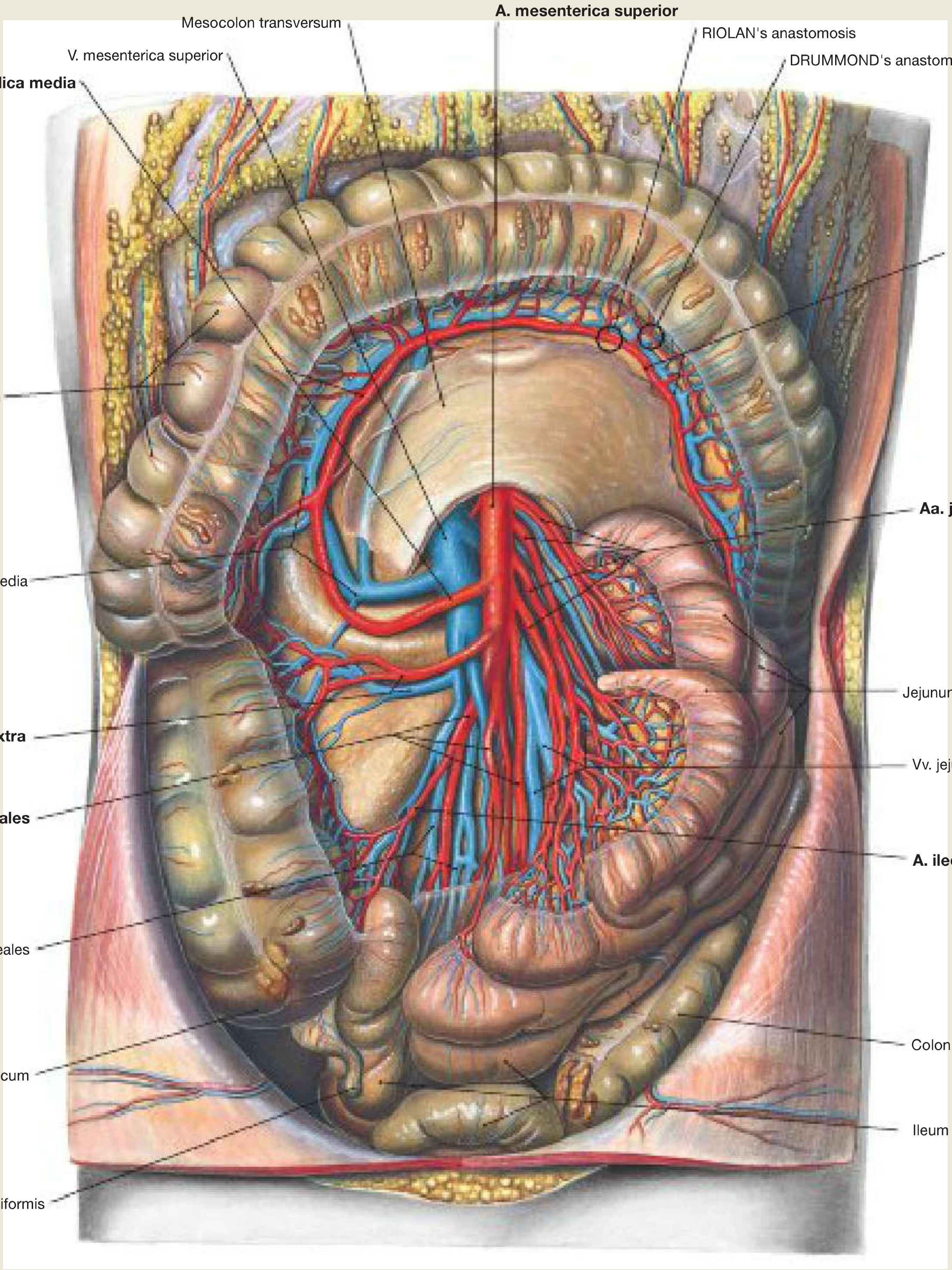


Fig. 6.22 Course of the A. and V. mesenterica superior; ventral view; after opening of the mesentery with the Colon transversum folded back. Within the mesentery, to the left of the A. mesenterica superior, are the Aa. jejunales and Aa. ileales; to the right, the A. colica media, A. colica dextra and A. ileocolica. All arteries form arcades on the intestines on various branching levels; these enable the movement of the intestinal loops. The A. colica media forms functionally **important anastomoses (RIOLAN's anastomosis)** with the A. colica sinistra from the A. mesenterica inferior, in the area of the left colic flexure, which in the case of the blockage of an artery can form a circulatory bypass. The anastomosis between the two arteries in one of the arcades close to the intestines is occasionally referred to as DRUMMOND's anastomosis. In clinical jargon, all anastomoses in the area of the left colic flexure are summarised as RIOLAN's anastomosis.
The venous branches correspond to the arteries.

A. mesenterica inferior

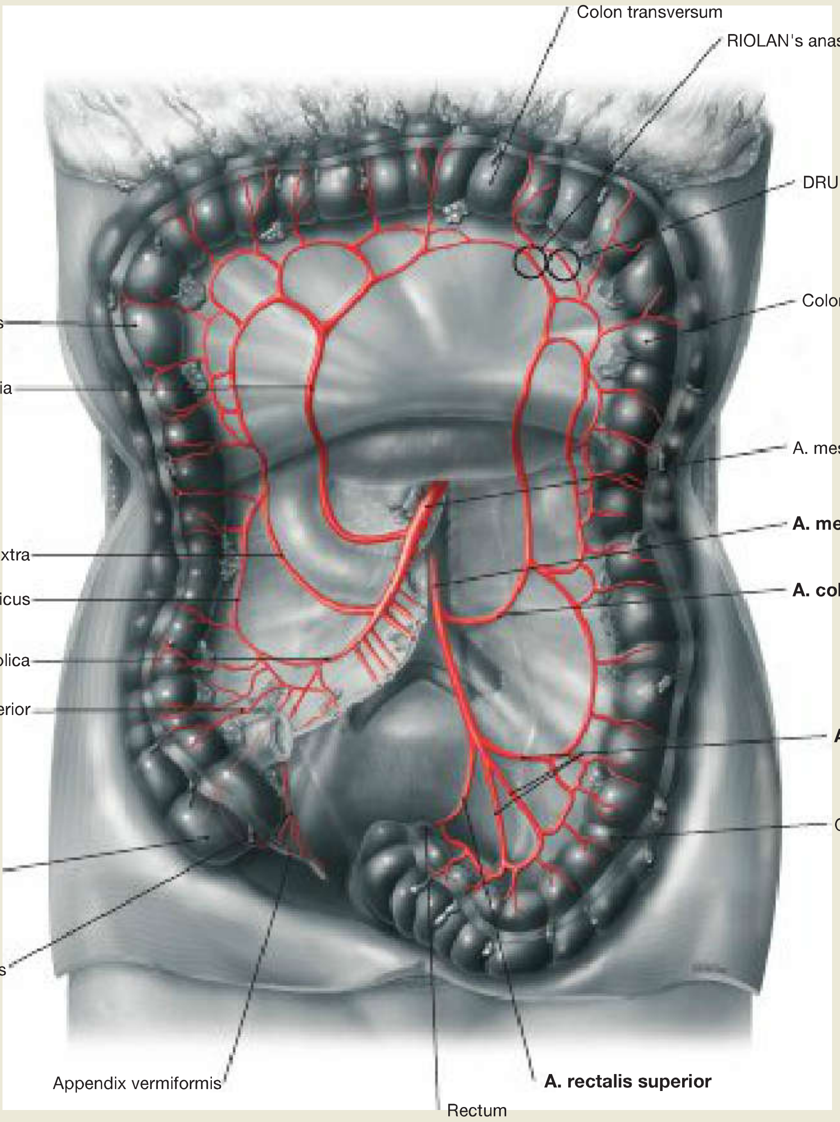


Fig. 6.23 A. mesenterica inferior; ventral view; Colon transversum folded back cranially. [L238]
The unpaired A. mesenterica inferior branches off the aorta approximately 5 cm above its bifurcation, turns to the left side and then descends, so that it has a short terminal part inside the retroperitoneal space. It supplies the Colon descendens and the upper rectum.

Branches of the A. mesenterica inferior:
- **A. colica sinistra:** ascends to the Colon descendens, anastomoses with the A. colica media from the A. mesenterica superior (RIOLAN's anastomosis)
- **Aa. sigmoideae:** several branches to the Colon sigmoideum
- **A. rectalis superior:** supplies rectum and upper Canalis analis and, amongst other things, mainly feeds the cavernous body (Corpus cavernosum recti), which is part of the continence organ

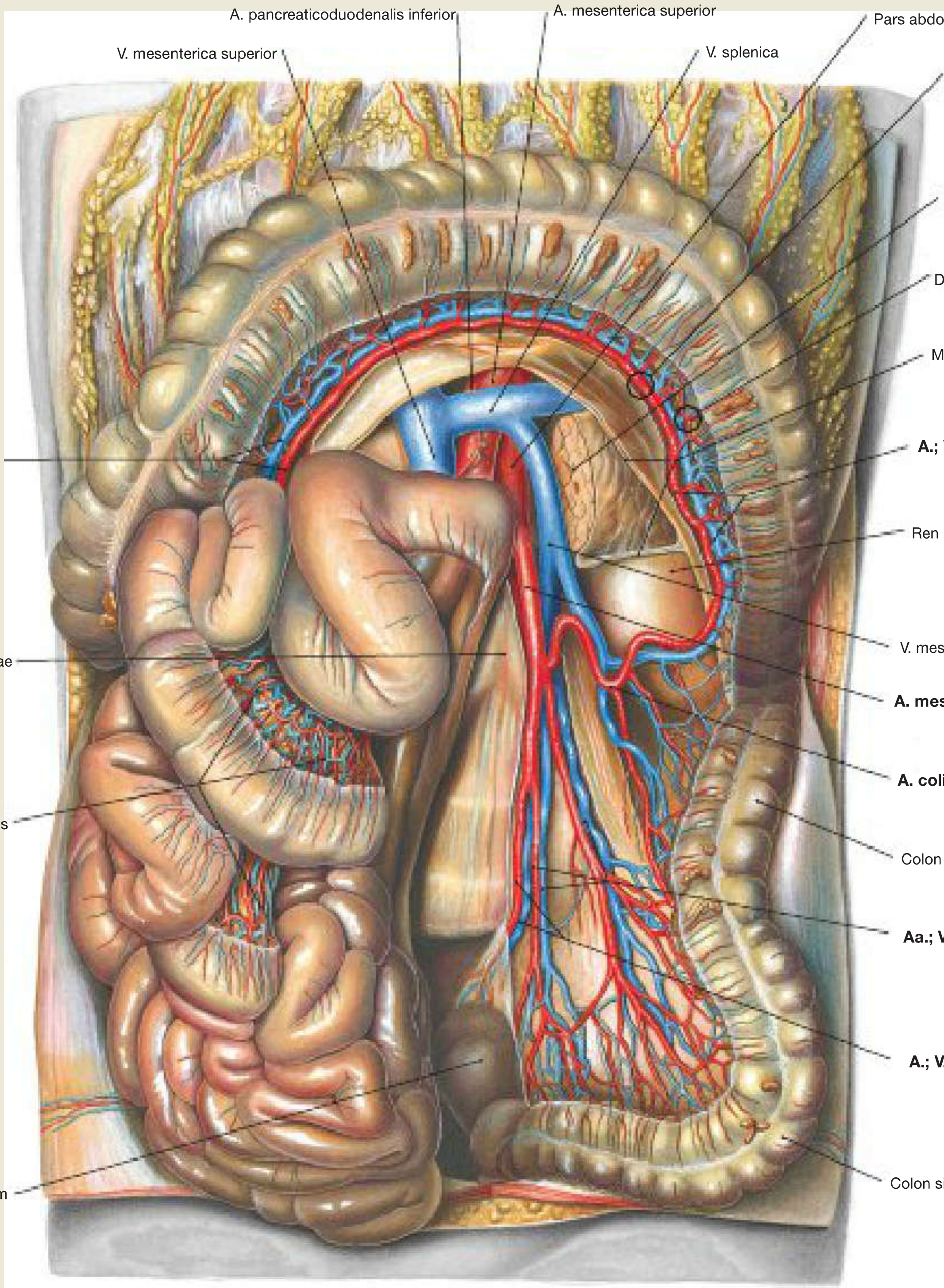
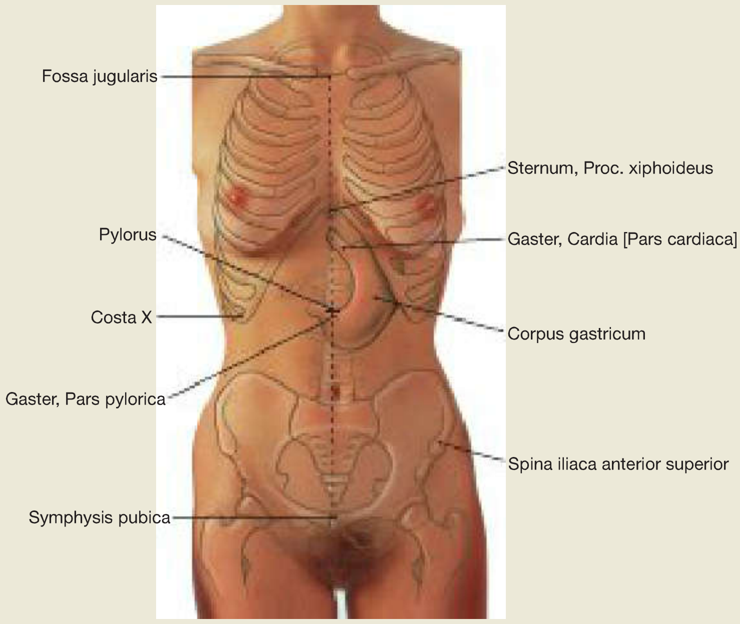


Fig. 6.24 Course of the A. and V. mesenterica inferior in the Retroperitoneum; ventral view; Colon transversum shifted upwards and small intestinal loops shifted to the right.
From its origin above the bifurcation of the aorta, the A. mesenterica inferior descends into the Retroperitoneum and provides the A. colica sinistra as first branch to the left side, then several Aa. sigmoideae and finally the (unpaired) A. rectalis superior.

The A. colica sinistra rises to the Colon descendens, forms arcades and anastomoses with the A. colica media from the A. mesenterica superior **(RIOLAN's anastomosis).** Occasionally, the connection in one of the arcades near the intestines is referred to as DRUMMOND's anastomosis.

Stomach

Projection of the Stomach



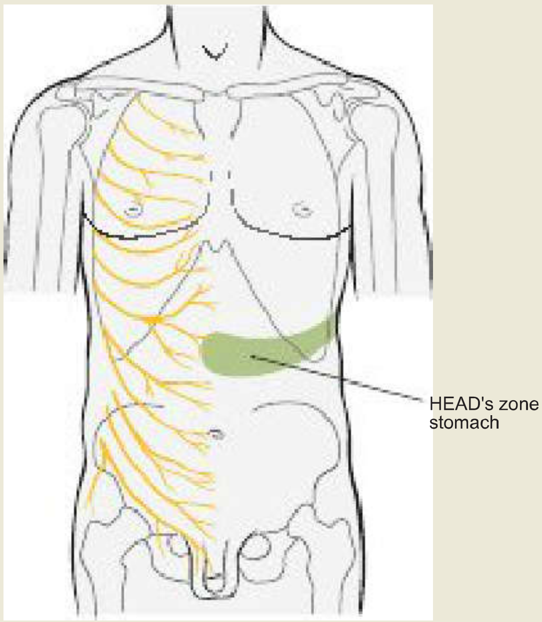


Fig. 6.25 Projection of the stomach, Gaster, onto the ventral abdominal wall; ventral view.
The entrance of the stomach (Cardia) projects approximately to the height of the 10th thoracic vertebra and ventrally below the xiphoid process of the breastbone. The caudal portion is relatively variable at the level of the second to third lumbar vertebrae. Conversely the pylorus relatively consistently is found at the mid-point of a line between the pubic symphysis (Symphysis pubica) and jugular fossa (Fossa jugularis). This central point projects approximately to the first lumbar vertebra.

Fig. 6.26 HEAD's zone of the stomach, schematic drawing; ventral view. [L126]
The organ-related area or the **HEAD's zone** of the stomach lies in the area of the dermatome T8, where pain perceptions with stomach diseases are communicated. This is because the afferent nerve fibres from the stomach converge at the spinal cord level with those from the eighth cutaneous field, so it is not possible to differentiate.

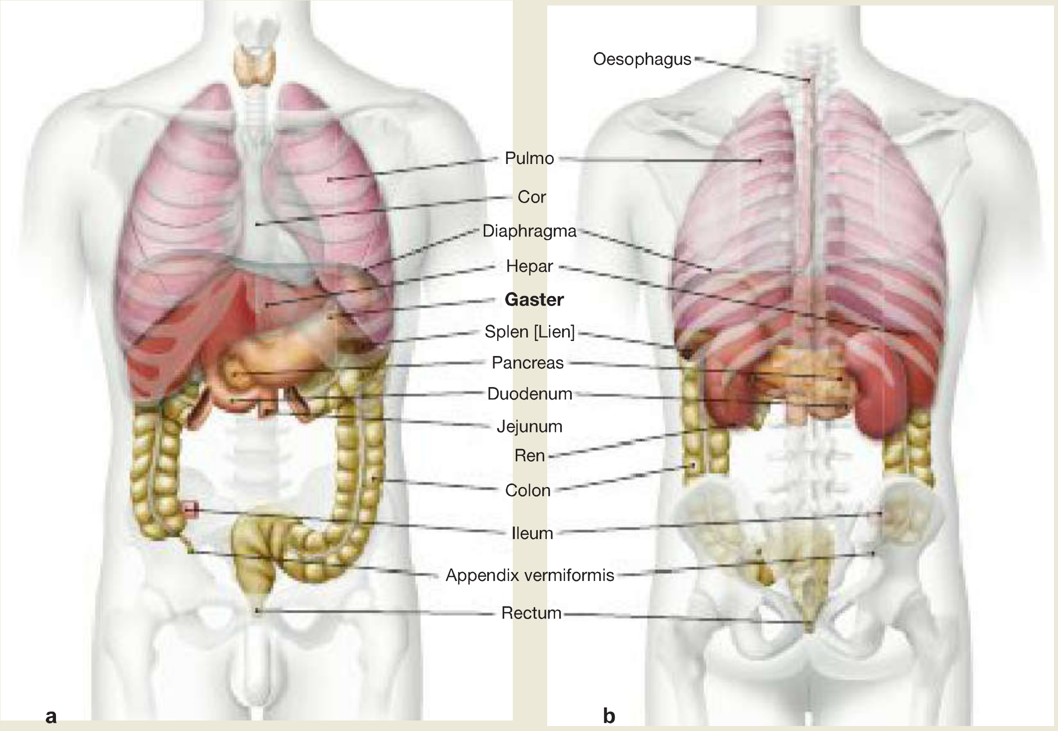
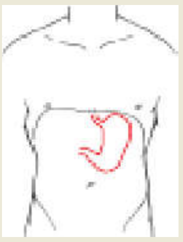
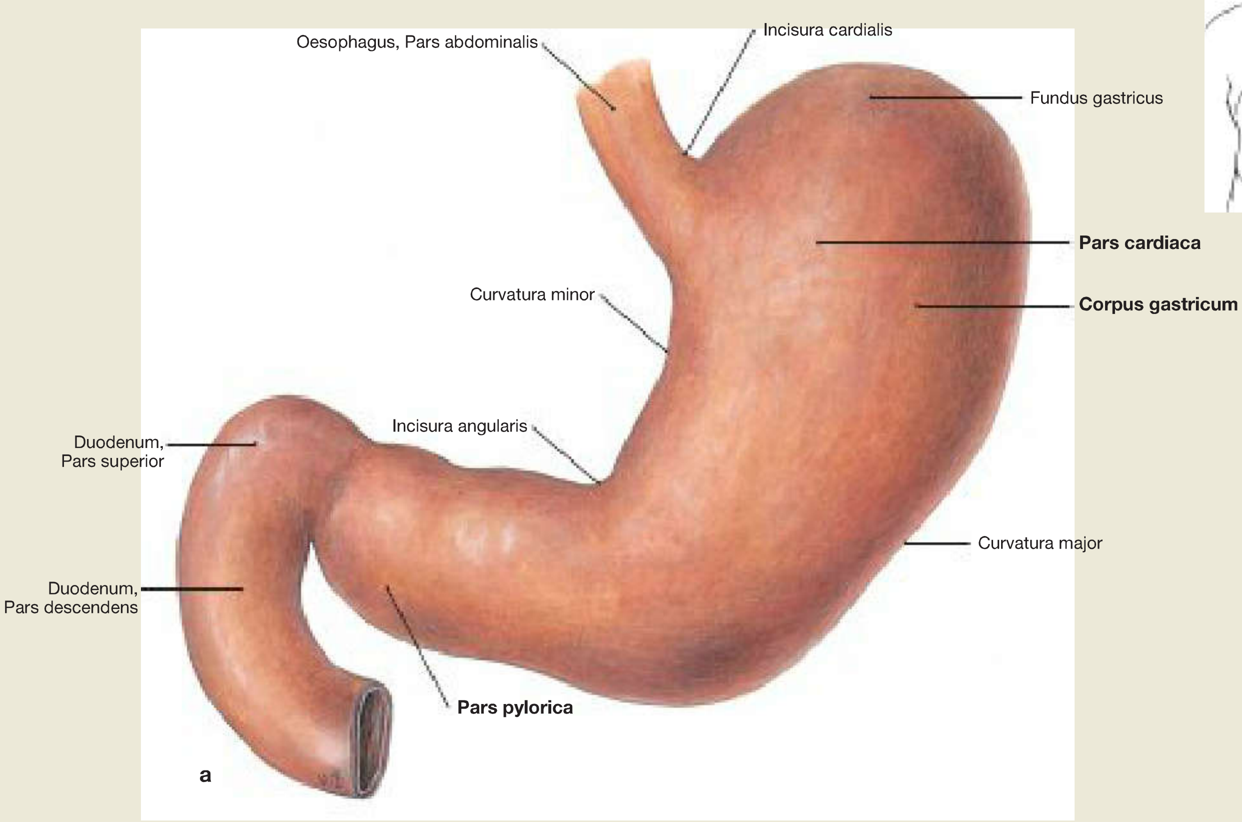


Fig. 6.27a and b Projection of inner organs onto the body surface; ventral view (→ Fig. 6.27a) and dorsal view (→ Fig. 6.27b). [L275]
The stomach is positioned **intraperitoneally** in the left epigastrium between the left lobe of the liver and the spleen. The stomach is mostly covered by the left costal arch but a small area is directly adjacent to the ventral abdominal wall. This area is clinically relevant since PEG tubes (**p**ercutaneous **e**ndoscopic **g**astrostomy) can be placed here for parenteral nutrition.





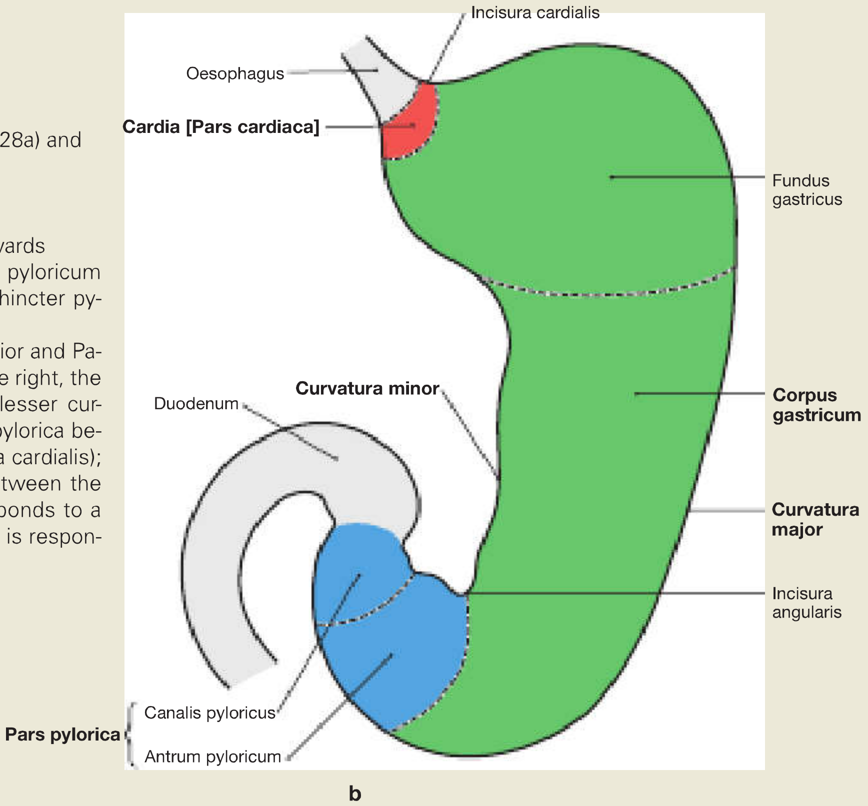


Fig. 6.28a and b Stomach, Gaster; ventral view (→ Fig. 6.28a) and schematic illustration (→ Fig. 6.28b). b [L126]
The stomach is divided into three parts:
- **Pars cardiaca:** stomach entrance
- **Corpus gastricum:** main part with Fundus gastricus upwards
- **Pars pylorica:** pylorus, which continues into the Antrum pyloricum and into the Canalis pyloricus, surrounded by the M. sphincter pyloricus.

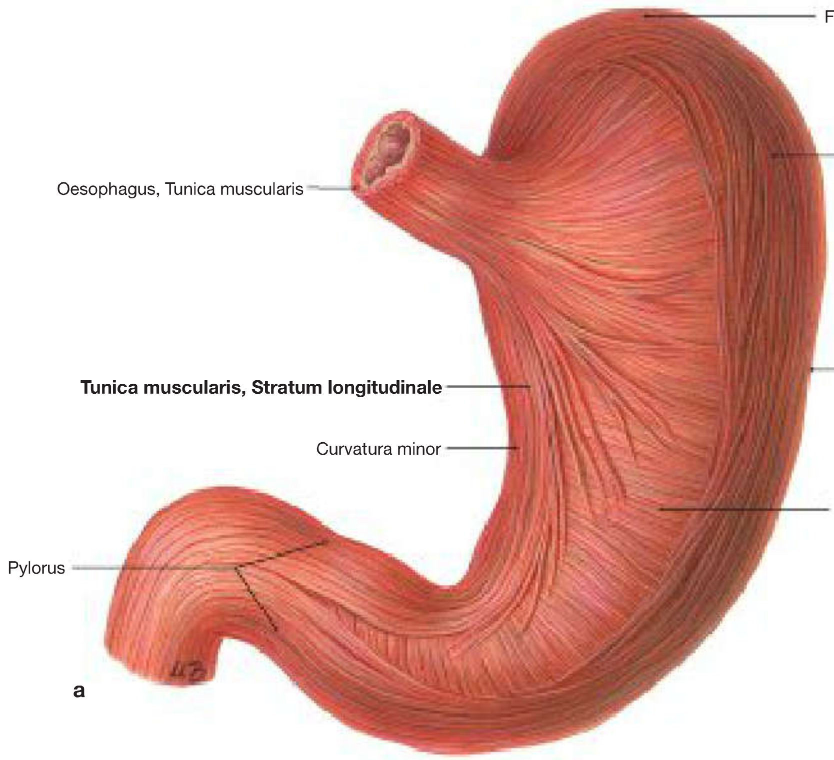
The stomach has an anterior and posterior wall (Paries anterior and Paries posterior). The lesser curvature (Curvatura minor) is to the right, the greater curvature (Curvatura major) is to the left. On the lesser curvature there is a notch (Incisura angularis), where the Pars pylorica begins. The greater curvature also starts with a recess (Incisura cardialis); this is responsible for the formation of the angle of HIS between the stomach and the oesophagus. Internally, this angle corresponds to a mucosal fold which, in addition to the oesophageal sphincter is responsible for the closure of the stomach.

Clinical Remarks

If the angle of HIS is lost, e.g. due to faulty fixation in the diaphragm (axial hiatus hernia), this may lead to reflux of gastric juices with inflammation of the oesophagus **(reflux oesophagitis).** If drug therapy for reducing the acid production with proton pump blockers fails, an operation will be needed to improve the closure by looping the fundus of the stomach around the oesophagus (NISSEN's fundoplication).

Stomach

Muscles of the Stomach



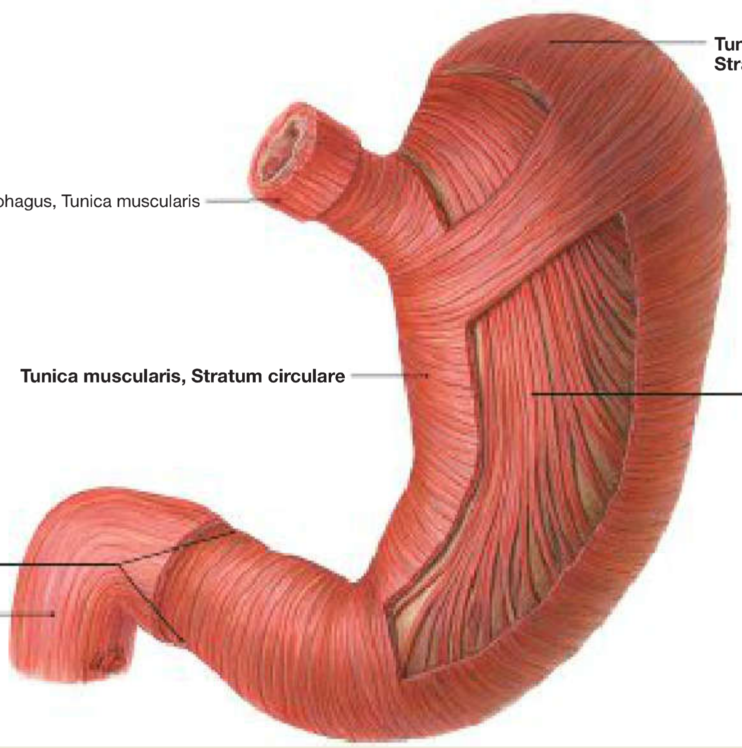


Fig. 6.29a and b Outer (→ Fig 6.29a) and inner (→ Fig. 6.29b) muscular layers of the stomach; ventral view.
The wall of the stomach comprises three muscular layers (Tunica muscularis); however, these are not consistently found throughout the stomach. The external longitudinal muscular layer (Stratum longitudinale) is adjacent to the circular muscular layer (Stratum circulare). At its lowest point there are running as oblique muscle fibres (Fibrae obliquae); however, in the lesser curvature these are missing.

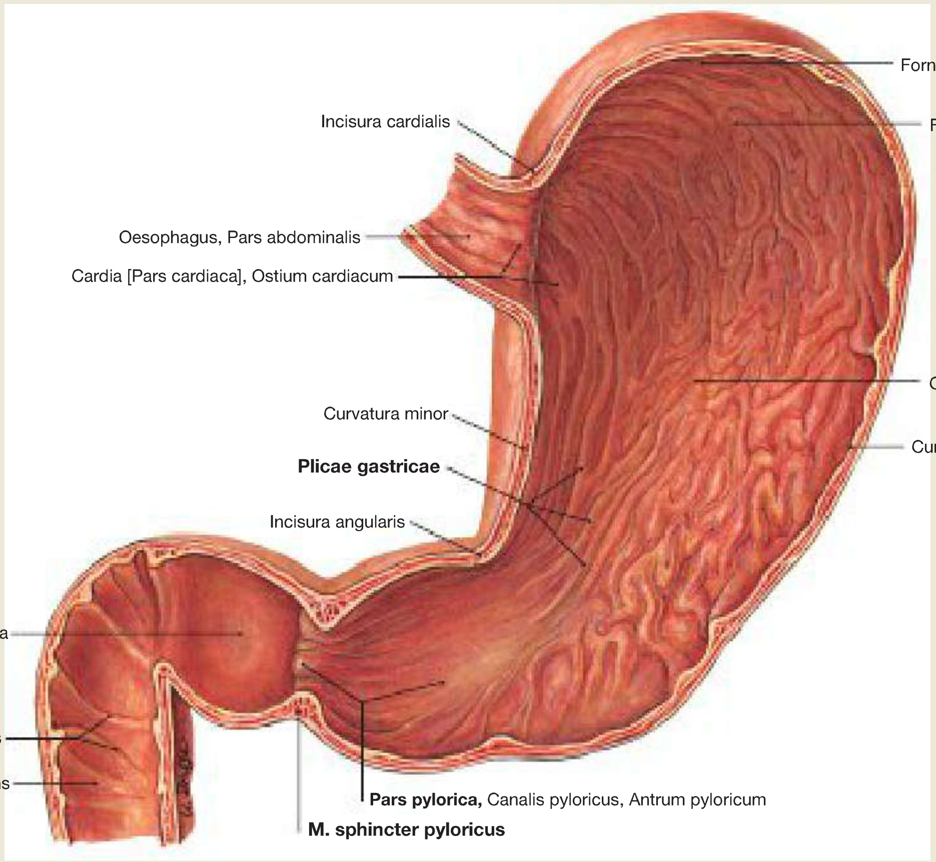


Fig. 6.30 Stomach, Gaster, and duodenum; ventral view.
The gastric mucous membrane has a characteristic surface which can expand. Macroscopically, however, only the **gastric folds (Plica gastricae)** are visible, and these run lengthways. With a magnifying glass, small, slightly elevated **polygonal areas (Areae gastricae)** are visible on these folds (→ Fig. 6.31). At the exit of the stomach (pylorus) the circular muscular layer is thickened to form the pyloric sphincter muscle (M. sphincter pyloricus).

Structure of the Wall of the Stomach

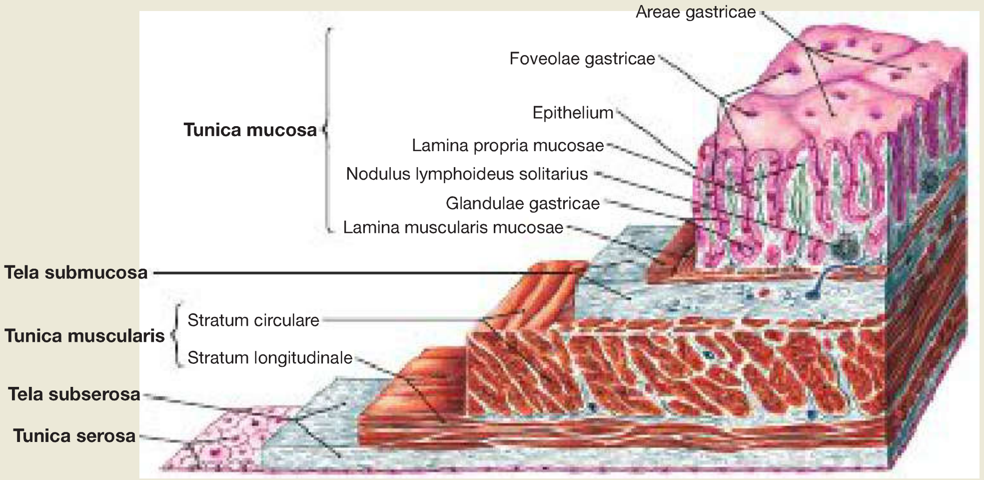


Fig. 6.31 Structure of the wall of the stomach, Gaster; microscopic view.
Similar to the whole of the intestines, the wall of the stomach comprises an inner mucosal layer (Tunica mucosa) which is separated from the muscular layer (Tunica muscularis, → Fig.6.29a and b) by a layer of loose connective tissue (Tela submucosa). As an intraperitoneal organ, the stomach is covered on its outer surface by visceral peritoneum (Peritoneum viscerale), which forms a Tunica serosa.

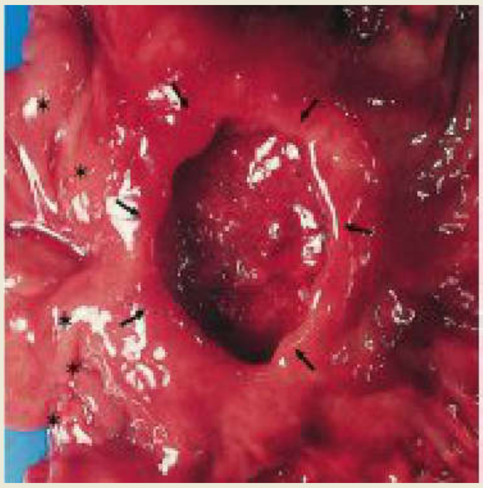


Fig. 6.32 Gastric ulcer, Ulcus ventriculi. [R235]
Gastric ulcers are sores which can affect the entire mucous membrane of the stomach.
Asterisks mark the pylorus ring, and arrows mark the edges of the ulcer.

Clinical Remarks

More than 80% of all gastric and duodenal ulcers are caused by the bacterium *helicobacter pylori*. In addition, increased gastric acid production or a reduced formation of surface mucus, e.g. after taking painkillers containing the active substance acetylsalicylic acid, encourage the formation of gastric ulcers. Accordingly, treatment involves removing bacteria with antibiotics, together with inhibiting the secretion of gastric acid. In the case of complications, surgical treatment is indicated. Complications may include a perforation into adjacent organs or the abdominal cavity, resulting in life-threatening peritonitis, or the erosion of a gastric artery (→ p. 128) with subsequent severe bleeding.

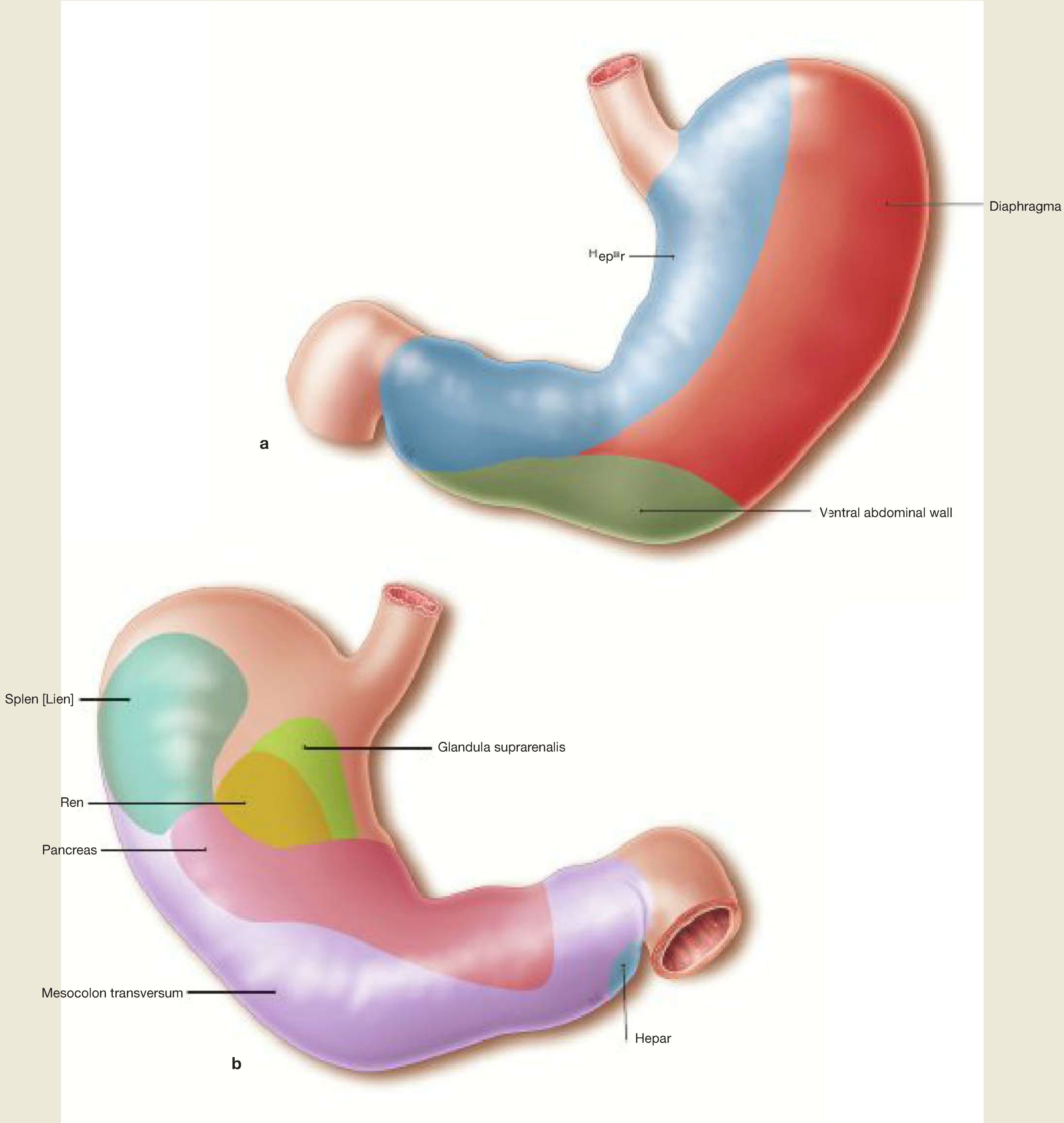


Fig. 6.33a and b Contact areas, Facies, of the anterior wall (→ Fig. 6.33a) and the posterior wall (→ Fig. 6.33b) of the stomach with adjacent organs. [L238]

- **Ventral:** liver, diaphragm, abdominal wall
- **Dorsal:** spleen, kidney, adrenal gland, pancreas, Mesocolon transversum

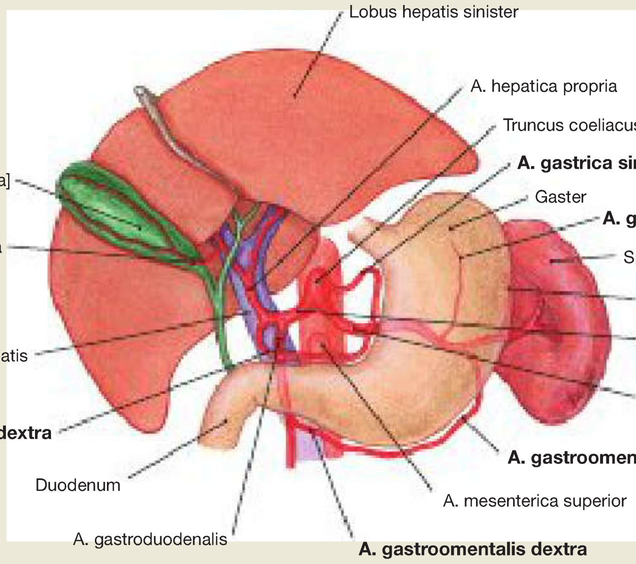
The stomach can move easily in comparison to its adjacent organs. Contact areas are also heavily dependent on the extent to which the stomach is full.

Clinical Remarks

The contact areas have a certain amount of clinical relevance, as gastric ulcers or gastric tumours may lead to a **perforation into adjacent organs,** which can lead to organ damage or can complicate the removal of tumours.

Stomach

Arteries of the Stomach



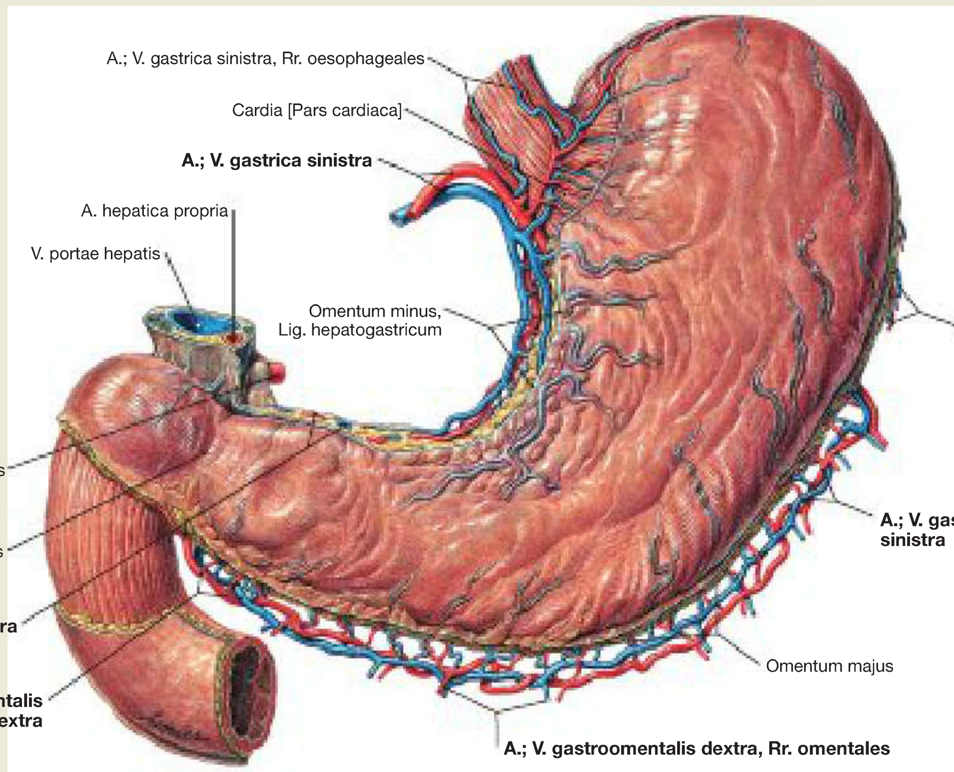


Fig. 6.34a and b Arteries of the stomach, Gaster, in a schematic diagram (→ Fig. 6.34a) and on the curvatures of the stomach (→ Fig. 6.34b); ventral view.

The three main branches of the Truncus coeliacus (A. gastrica sinistra, A. hepatica communis, A. splenica) give rise to a total of six gastric arteries (→Table).

Arteries of the Stomach	
Lesser curvature	• A. gastrica sinistra (directly from the Truncus coeliacus) • A. gastrica dextra (from the A. hepatica propria)
Greater curvature	• A. gastroomentalis sinistra (from the A. splenica [lienalis]) • A. gastroomentalis dextra (from the A. gastroduodenalis of the A. hepatica communis) The vessels also supply the Omentum majus!
Fundus	• Aa. gastrici breves (in the area of the hilum of the spleen from the A. splenica)
Posterior side	• A. gastrica posterior (in 30–60% of cases, originates behind the stomach from the A. splenica)

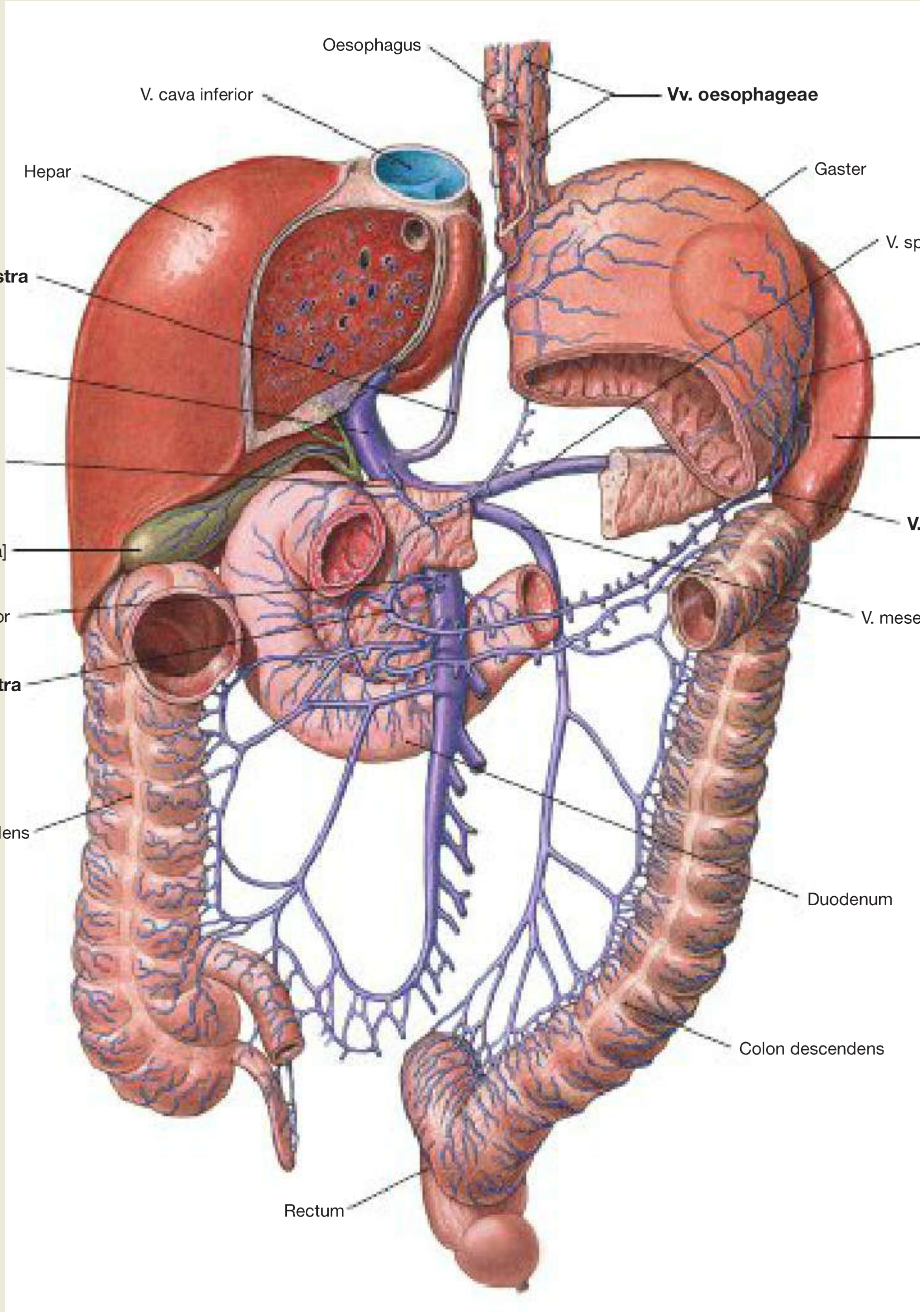


Fig. 6.35 Veins of the stomach, Gaster, with reference to the portal vein, V. portae hepatis; ventral view.

The veins correspond to the arteries, but the veins at the lesser curvature enter directly into the portal vein, whereas the veins at the greater curvature drains into the larger branches of the portal vein.

Veins of the Stomach	
Lesser curvature	• V. gastrica sinistra • V. gastrica dextra Drainage into the V. portae hepatis: these veins anastomose via the Vv. oesophageae with the azygos system and therefore, with the V. cava superior!
Greater curvature	• V. gastroomentalis sinistra (to V. splenica) • V. gastroomentalis dextra (to the V. mesenterica superior)
Fundus	• Vv. gastricae breves (to V. splenica)
Posterior side	• V. gastrica posterior (present in 30–60%, to V. splenica)

Clinical Remarks

Increased pressure in the portal vein (portal hypertension), e.g. in the case of cirrhosis of the liver, may form **portocaval anastomoses** via the Vv. oesophageae. These may become enlarged **(oesophageal varices)** and cause life-threatening internal bleeding if they rupture (→ Fig. 5.116).

Lymphatic Vessels of the Stomach

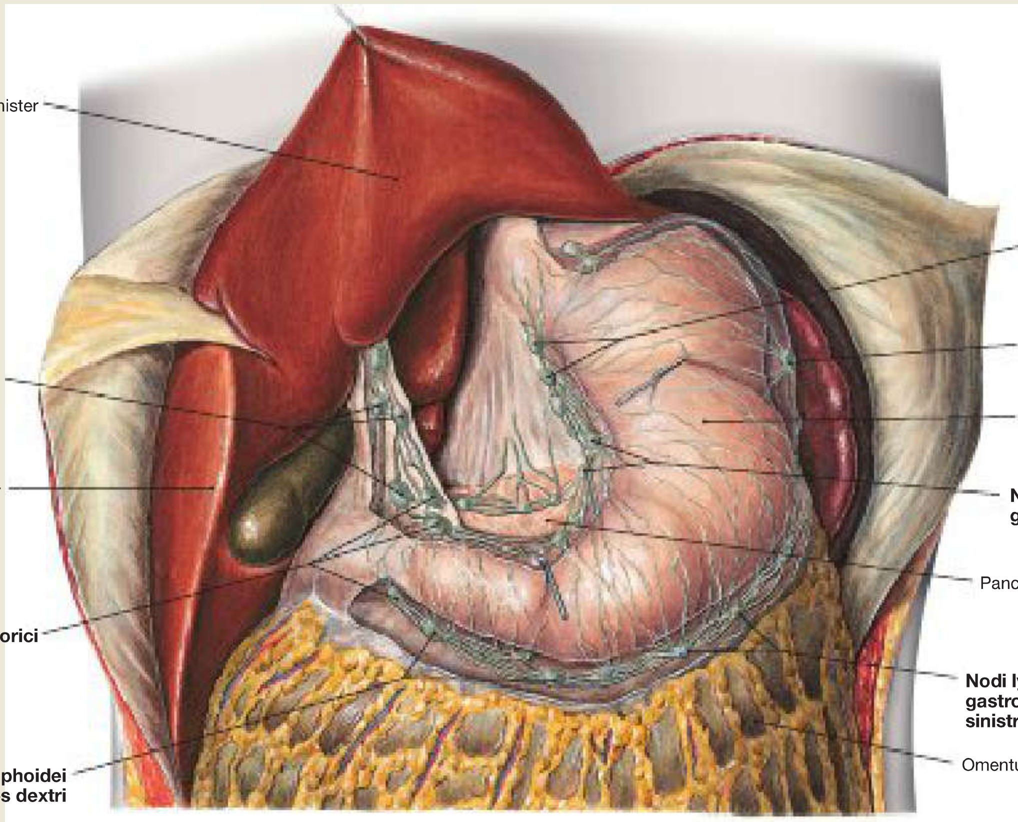


Fig. 6.36 Lymphatic vessels and lymph nodes of the stomach, Gaster, and liver, Hepar; ventral view.
The lymphatic vessels and lymph nodes of the stomach run alongside both **curvatures** and the **pylorus:** on the lesser curvature are located the **Nodi lymphoidei gastrici,** on the greater curvature one finds cranially the **Nodi lymphoidei splenici** and caudally the **Nodi lymphoidei gastroomentales.** The **Nodi lymphoidei pylorici** in the pyloric area are connected to the Nodi lymphoidei hepatici of the liver.
There are three large drainage areas with three different stations arranged in parallel (→ Fig. 6.37).

Clinical Remarks

The lymphatic drainage stations (→ Fig. 6.38) of the stomach are of clinical relevance in the **surgical treatment of gastric cancer.** The lymph nodes of the first and second stations are usually removed together with the stomach. If lymph nodes of the third station are also affected by metastatic cancer cells, curative therapy is not possible. In this case the patient should therefore be spared the removal of the stomach.

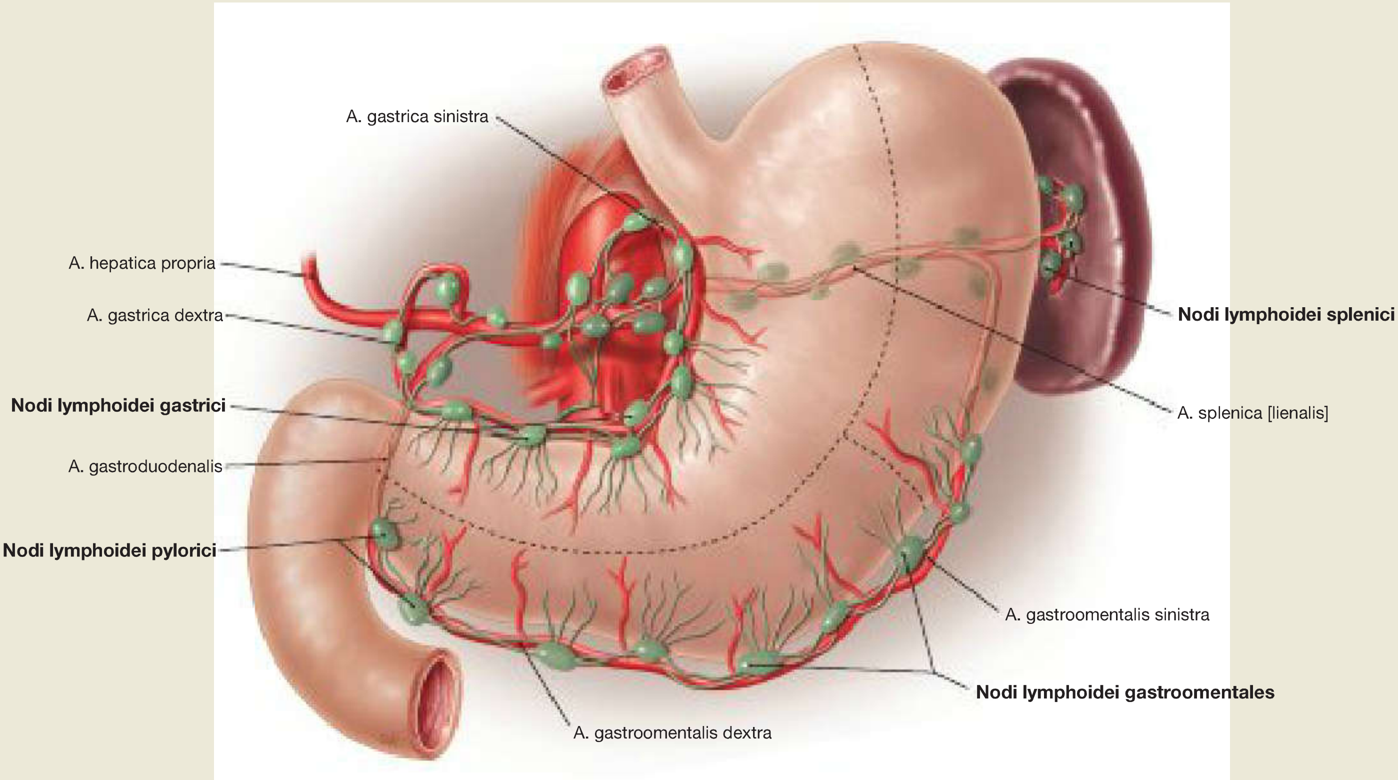


Fig. 6.37 Drainage areas of the lymph and regional lymph nodes of the stomach, Gaster; ventral view. [L238]
There are **three large drainage pathways** of the lymph **(territories of the lymphatic drainage),** shown here with dotted lines:

- **Cardiac area** and **lesser curvature:** Nodi lymphoidei gastrici
- **Upper left quadrant:** Nodi lymphoidei splenici
- **Lower two-thirds of the greater curvature and pylorus:** Nodi lymphoidei gastroomentales and Nodi lymphoidei pylorici

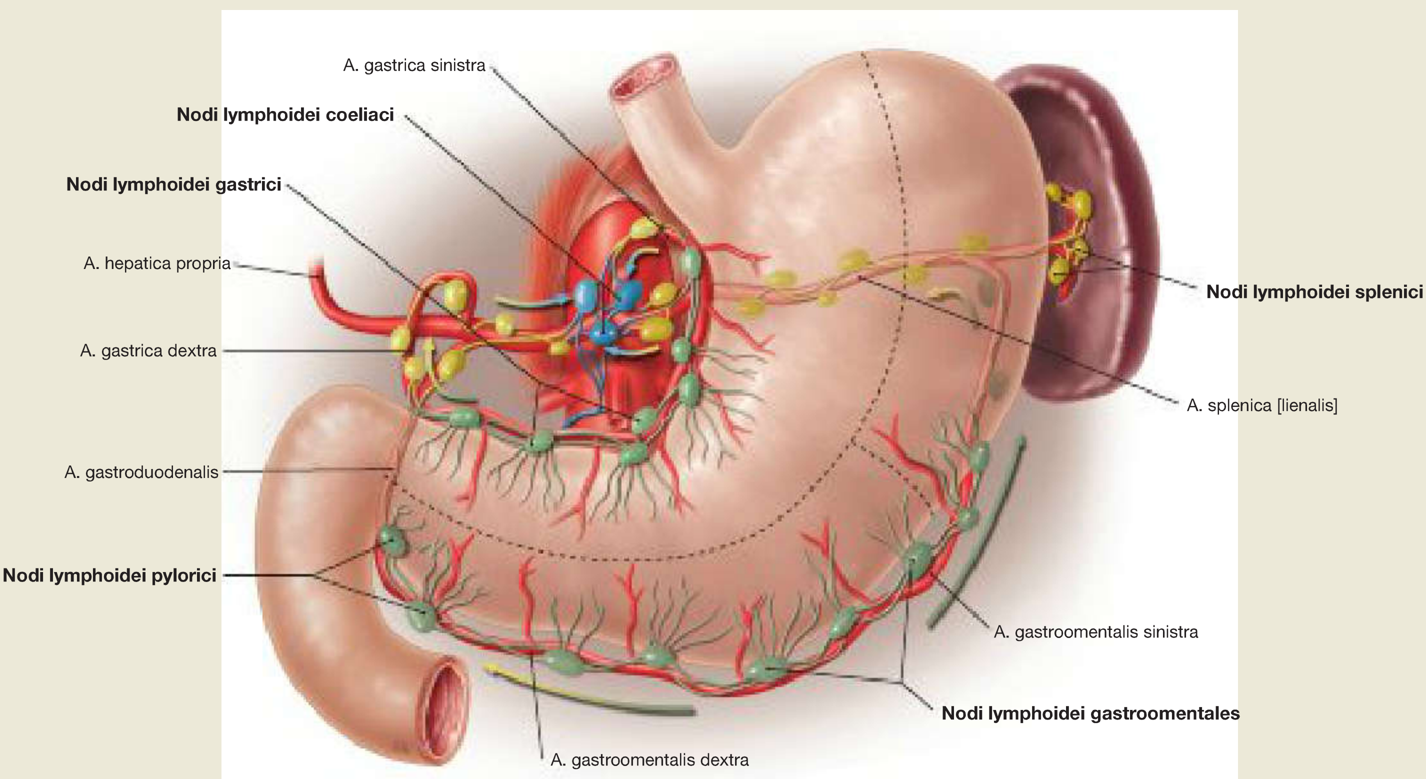


Fig. 6.38 Lymphatic drainage stations of the stomach, Gaster; ventral view. [L238]
In the three major drainage areas, there are **three connected stations one behind the other:**

- First station (green): lymph nodes along the curvatures (→ Fig. 6.37)
- Second station (yellow): lymph nodes along the branches of the Truncus coeliacus
- Third station (blue): lymph nodes at the opening of the Truncus coeliacus (Nodi lymphoidei coeliaci); from there, the lymph flows via the Truncus intestinalis into the Ductus thoracicus

Autonomic Innervation of the Stomach

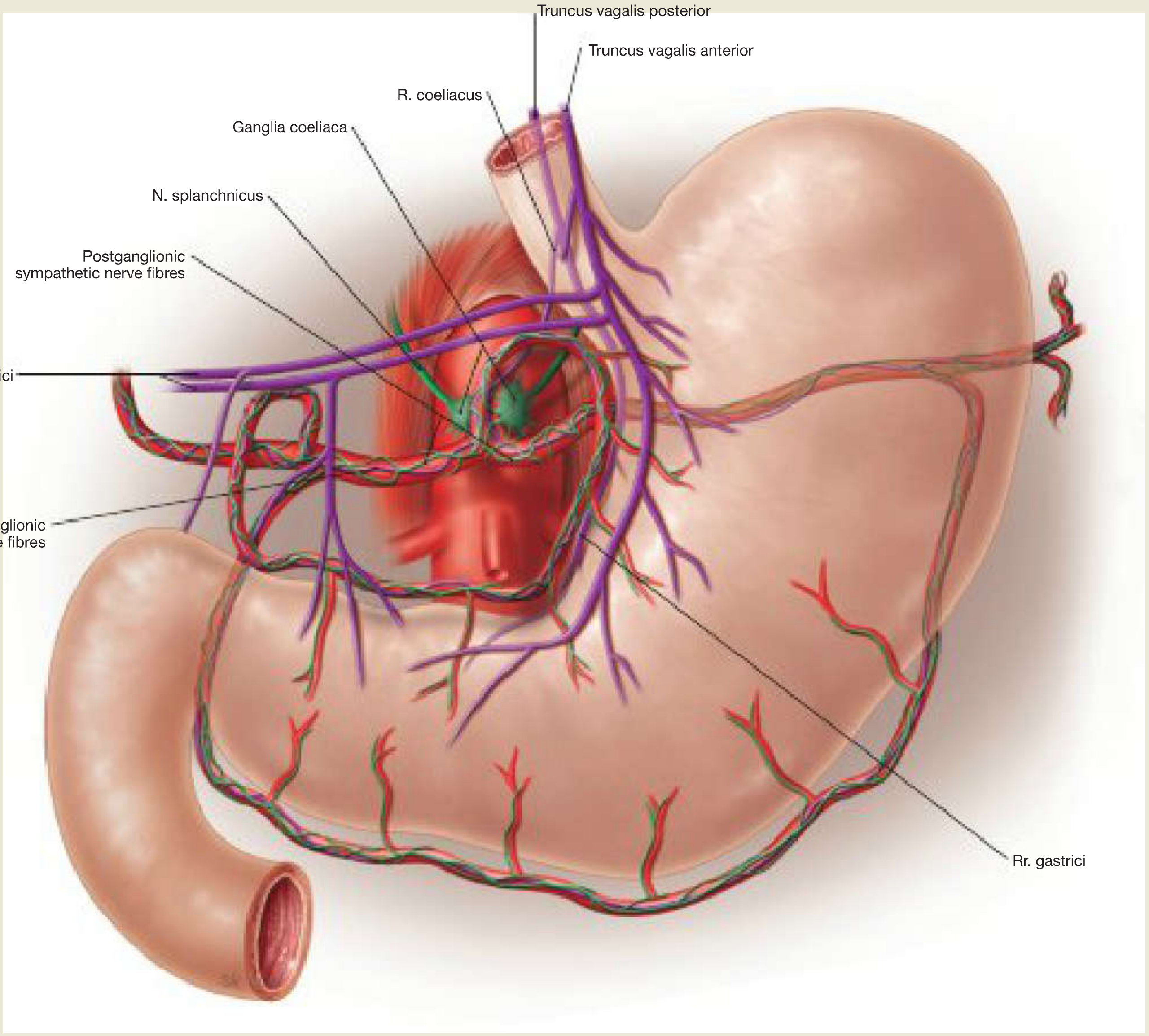


Fig. 6.39 Autonomic innervation of the stomach; semi-schematic illustration. Sympathetic innervation (green), parasympathetic innervation (purple). [L238]

Preganglionic **parasympathetic fibres** (Rr. gastrici) reach the stomach as Trunci vagales anterior and posterior, descending along the oesophagus and running along the lesser curvature. As a result of the gastric rotation during development, the Truncus vagalis anterior is predominantly derived from the N. vagus [X] on the left and the Truncus vagalis posterior from the N. vagus [X] on the right. The Pars pylorica is reached through its own branches (Rr. hepatici), which also derive from the vagal trunk. Postganglionic neurons are mostly in the stomach wall. The **parasympathetic trunk promotes** the gastric acid production and peristalsis of the stomach.

Preganglionic **sympathetic fibres** pass as Nn. splanchnici major and minor on both sides through the diaphragm and reach the Ganglia coeliaca at the opening of the Truncus coeliacus, where they are switched to postganglionic neurons. These reach the different sections of the stomach as periarterial nerve plexuses. The sympathicus has an antagonistic effect to the parasympathicus by **dampening** the gastric acid secretion, peristalsis and circulation.

Clinical Remarks

A former treatment for patients with peptic ulcers was to sever the entire N. vagus [X] inferior to the diaphragm **(total vagotomy)** or its branches to the stomach **(selective vagotomy)** to reduce the production of gastric acid. However, since it has become possible to block acid with medication and to stop the triggering *helicobacter pylori* bacteria with antibiotics, this procedure has become significantly less important.

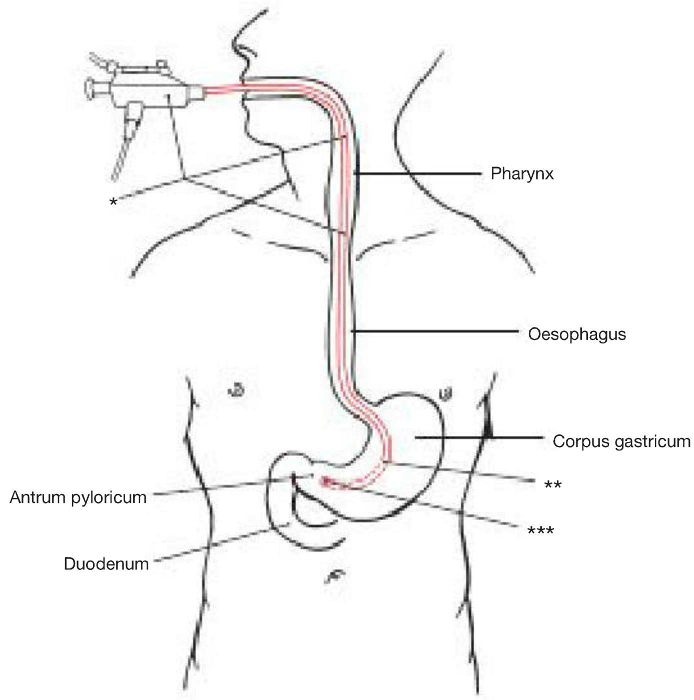
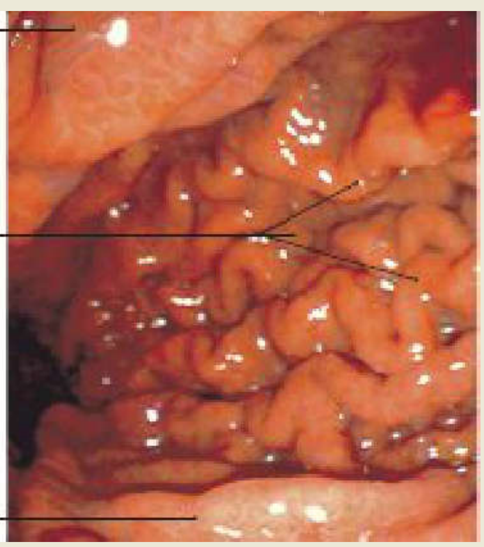


Fig. 6.40 Technique of the oesophagoscopy and gastroscopy.

* endoscope
** gastroscope, tip in the Corpus gastricum (→ Fig. 6.22a)
*** gastroscope, tip in the Antrum pyloricum (→ Fig. 6.41b)



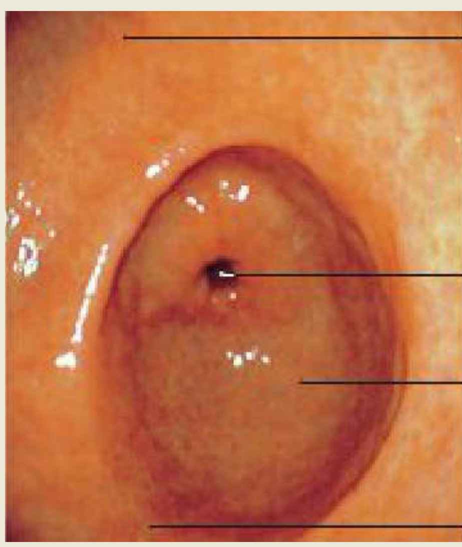


Fig. 6.41a and b Stomach, Gaster gastroscopy; view from cranial. [T901]
a View from the Corpus gastricum with pronounced longitudinal folds of the mucosa (Plicae gastricae)
b View from the Antrum pyloricum with a largely smooth mucosa

Clinical Remarks

Gastroscopy enables the **inspection** of the stomach lining. Pathological findings such as erosive gastric lesions or ulcers (→ Fig. 6.11) require tissue biopsies for further pathological diagnostics to distinguish between a benign peptic ulcer and a gastric carcinoma.

Organs of the Digestive System

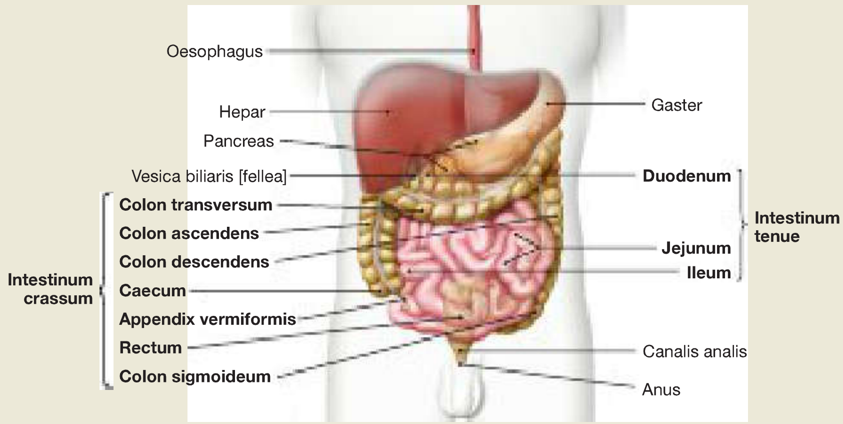


Fig. 6.42 Organs of the digestive system; ventral view. [L275]

The digestive system is made up of organs forming a unit, all of which serve the digestion and regulate each other for this purpose. The exact understanding of this regulation process is only possible after the additional study of microscopic anatomy, since individual organs create hormones and chemical messengers, which partly make it possible for the organs to communicate and coordinate with each other via the blood. The apparent autonomy suggested by the macroscopic demarcation of the individual organs is therefore conditional. The digestive system includes the oral cavity, the **hollow organs,** which are connected to it, and reaches up to the Canalis analis:

- Pharynx
- Oesophagus
- Stomach
- Small intestine
- Intestinum crassum

Also included in the digestive system are the **accessory glands** of the gastrointestinal tract:

- Liver
- Gallbladder
- Pancreas

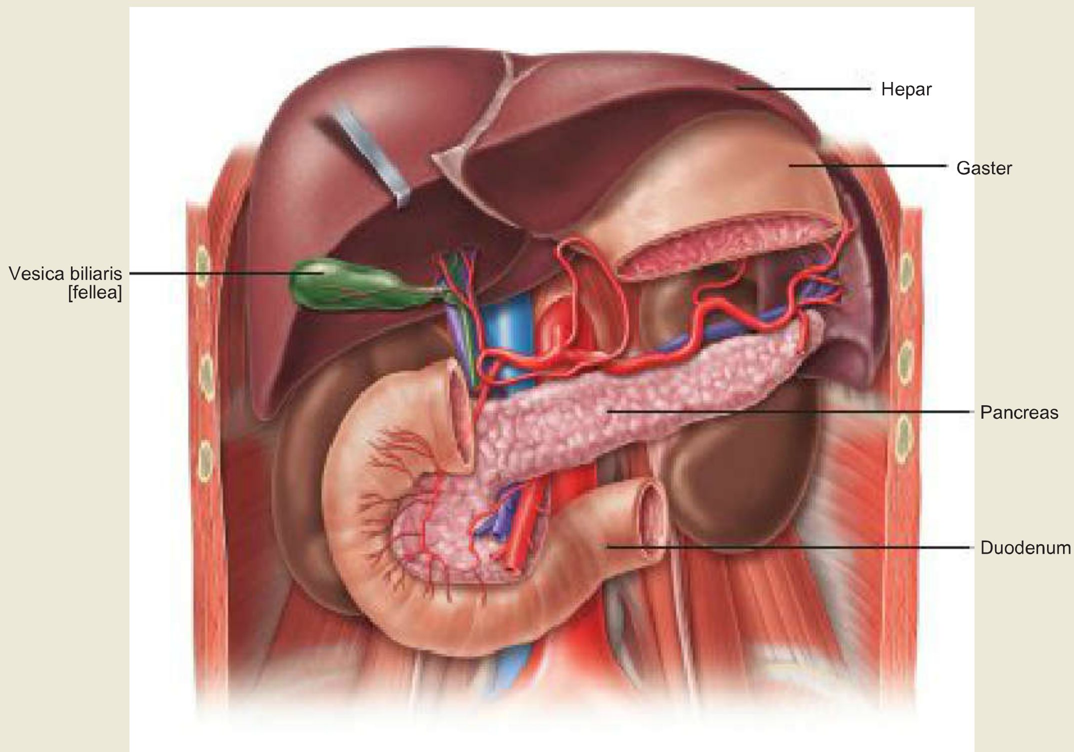
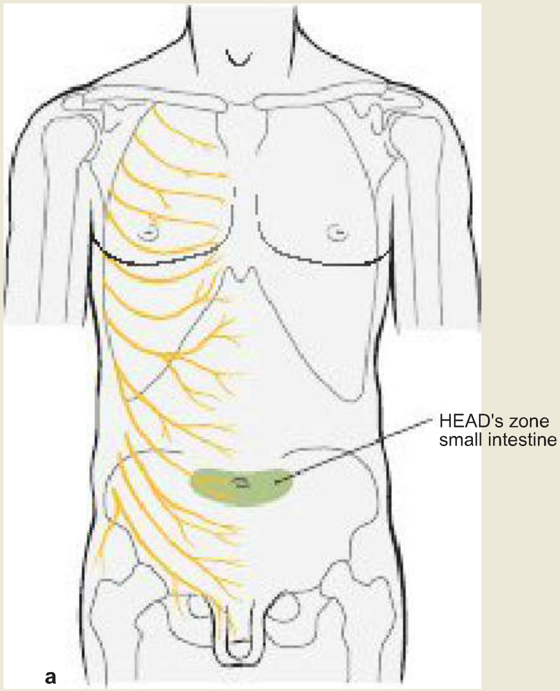


Fig. 6.43 Organs of the upper abdomen, semi-schematic illustration; ventral view. [L238]

The stomach, small intestine, liver, gallbladder and pancreas very markedly communicate with each other in the digestive process. This reciprocal regulation largely occurs via hormones and chemical messengers, and complements the control of the central nervous system by parasympathetic nerves, which also promote digestion. The **parasympathetic system** is already activated by the sight, smell and taste of food and often by the sheer thought of food. Filling of the **stomach** stimulates the formation of gastric acid. When the acidified stomach contents with their nutrients are passed into the first section of the **small intestine** (Duodenum), this stimulates the release of hormones from the intestinal mucosa. This induces the delivery of bile from the **gallbladder** and the secretion of digestive juice from the **pancreas.** Through the ductal systems, bile and pancreatic juice are directly added to the food bolus in the duodenum and facilitate the digestion and absorption of nutrients. The nutrients are transporting to the liver via the portal vein, as well as the lymphatic vessel system and the blood. The **liver** finally produces chemical messengers that generate a feeling of satiety in the brain. The hormones are also produced by the intestinal mucosa and stimulate the afferent nerve fibres of the N. vagus [X], coupled with the gastric stretch receptors, this leads to the cessation of food intake.



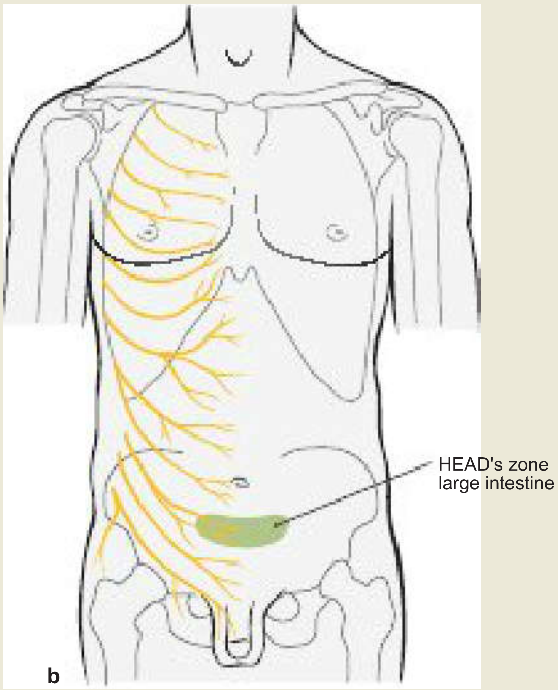


Fig. 6.44a and b HEAD's zones of the small and large intestines, schematic representation; ventral view. [L126]

The body surface is innervated segmentally by afferent neurons from the individual spinal cord segments. These areas are known as cutaneous areas or **dermatomes.** In the spinal cord segments, the afferent neurons of the surface of the body converge with those of the internal organs, so irritation of the organs often leads to discomfort and pain which are perceived on the surface of the body in the corresponding dermatomes. We therefore denote this as projected pain. These organ-related areas are the **HEAD's zones.** For the small intestine, the **HEAD's zone** is in the dermatome T10 (→ Fig. 6.44a), but for the Intestinum crassum it is in T11 (→ Fig. 6.44b). These projection areas should be understood only as maximal points and they often overlap, so that it is impossible to make precise distinctions between the individual intestine sections.

Structure of the Small Intestine and Projection of the Duodenum

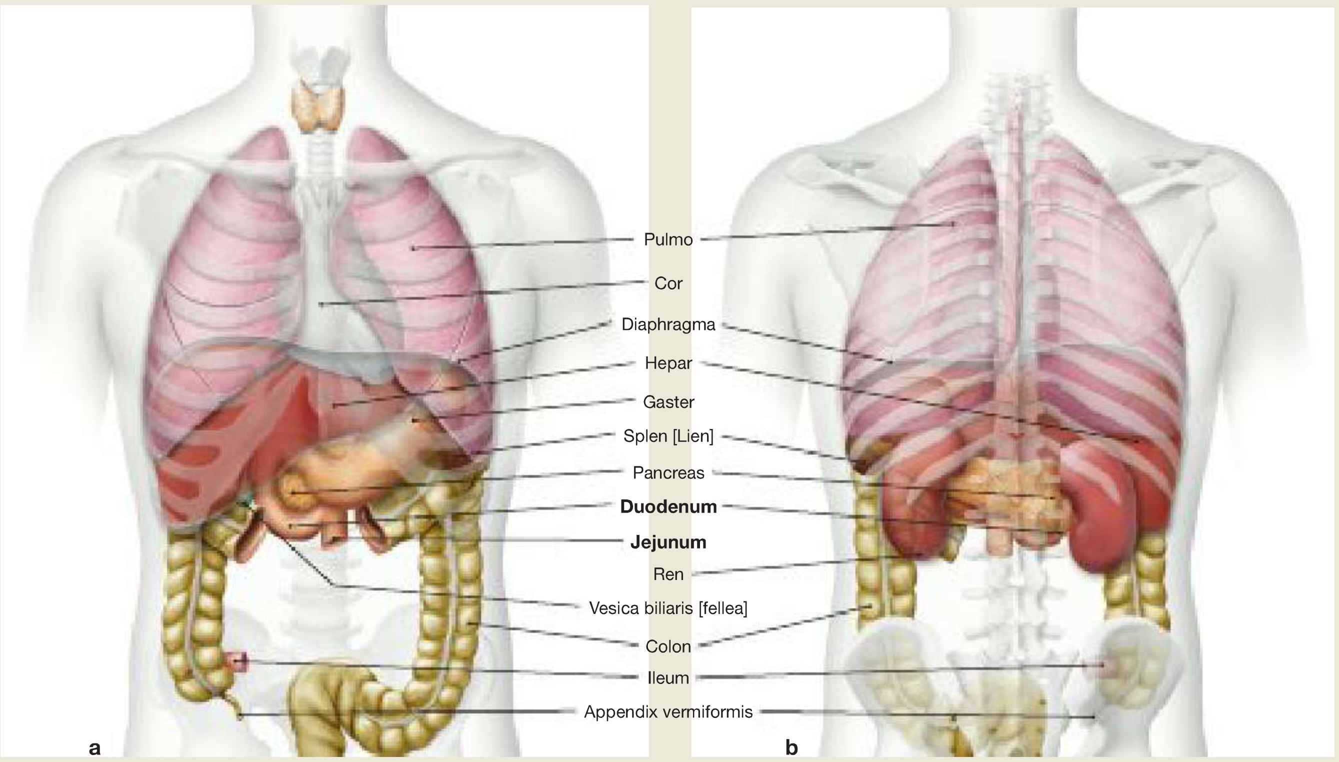


Fig. 6.45a and b Projection of the duodenum onto the body surface; ventral view (→ Fig. 6.45a) and dorsal view (→ Fig. 6.45b). Jejunum and ileum have been completely removed. [L275]
The small intestine (4–6 m) has three parts:
- **Duodenum:** 25–30 cm
- **Jejunum:** two-fifths of the total length
- **Ileum:** three-fifths of the total length

The duodenum begins on the pylorus of the stomach and goes to the Flexura duodenojejunalis. Except for its first part (Pars superior), the duodenum is fixed in its retroperitoneal position and due to its relatively fixed position is distinct from the other parts of the small intestine.
Therefore, the Pars superior typically projects onto the first lumbar vertebra and the Flexura duodenojejunalis onto the second lumbar vertebra.
In contrast, the **intraperitoneal convoluted parts** of the jejunum and ileum are not separable macroscopically and reach distally to the Valva ileocaecalis (BAUHIN's valve) at the transition to the Intestinum crassum.

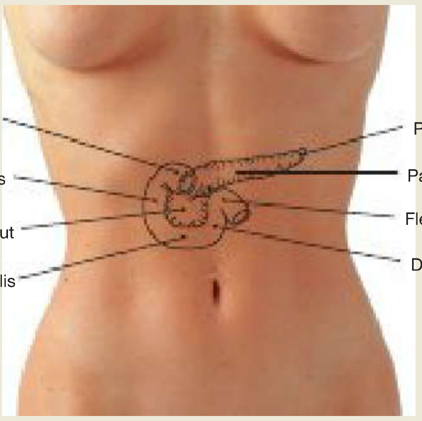
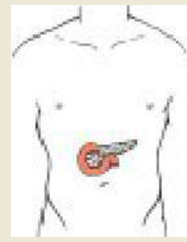
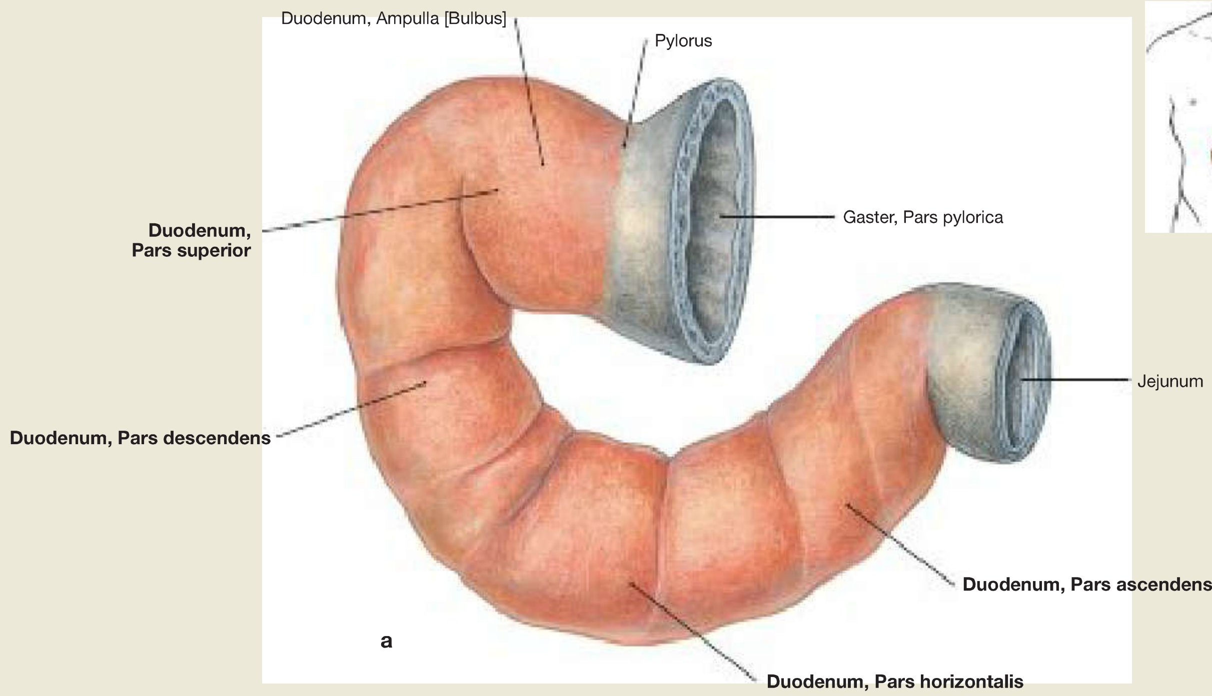


Fig. 6.46 Projection of the duodenum and pancreas onto the ventral abdominal wall.
The **intraperitoneal Pars superior** of the duodenum projects onto the level of the first lumbar vertebra. All **other parts** are located **secondarily retroperitoneally** and encompass the head of the pancreas in a C-shaped manner. The head of the pancreas is adjacent to the Pars descendens of the duodenum. The Pars horizontalis traverses at the level of the third lumbar vertebra and continues in the Pars ascendens up to the Flexura duodenojejunalis at the level of the second lumbar vertebra. This flexure marks the transition to the intraperitoneal jejunum.





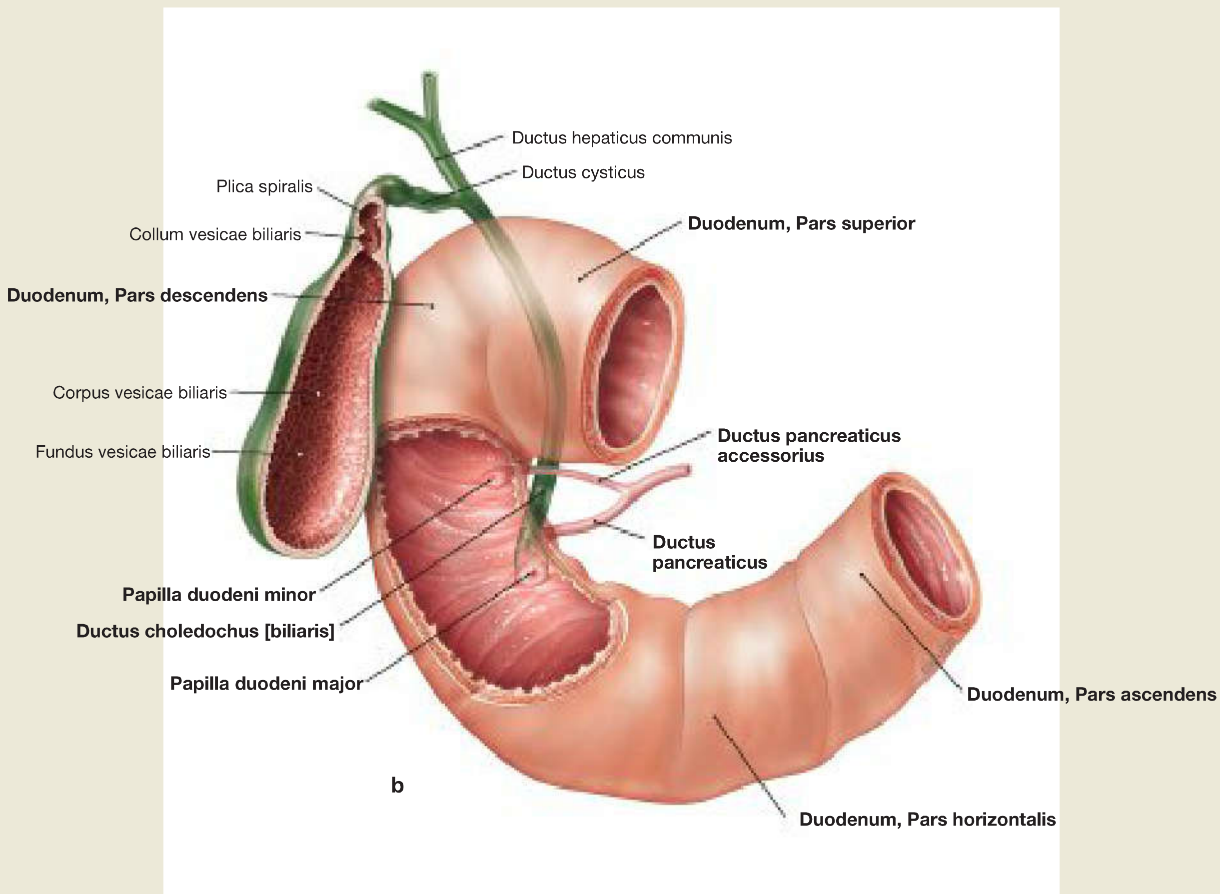


Fig. 6.47a and b Parts of the duodenum, isolated (→ Fig. 6.47a) and together with the extrahepatic bile ducts (→ Fig. 6.47b); ventral view. b [L238]
The duodenum is divided into **four parts:**

- Pars superior
- Pars descendens
- Pars horizontalis
- Pars ascendens

The **Pars superior** is the only intraperitoneal part and its wider proximal lumen is referred to as the duodenal ampulla (Bulbus duodeni).

The excretory duct of the pancreas (Ductus pancreaticus, duct of WIRSUNG) enters the **Pars descendens** of the duodenum frequently, together with the common bile duct (Ductus choledochus) on a mucosal papilla (Papilla duodeni major, Papilla VATERI) which is found 8–10 cm distal to the pylorus. Often, 2 cm proximal to the latter, a Papilla duodeni minor is found, into which the Ductus pancreaticus accessorius (SANTORINI's duct) empties its secretion.
The **Pars horizontalis** crosses the spine, and then continues as the **Pars ascendens.**

Structure of the Wall of the Small Intestine

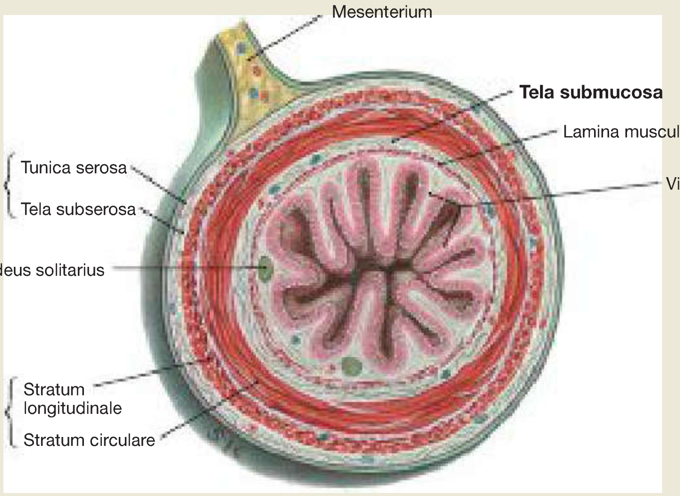


Fig. 6.48 Small intestine, Intestinum tenue; cross-section. [L238]
The different parts of the small intestine have basically the same wall structure. The layers are described in → Fig. 6.49.

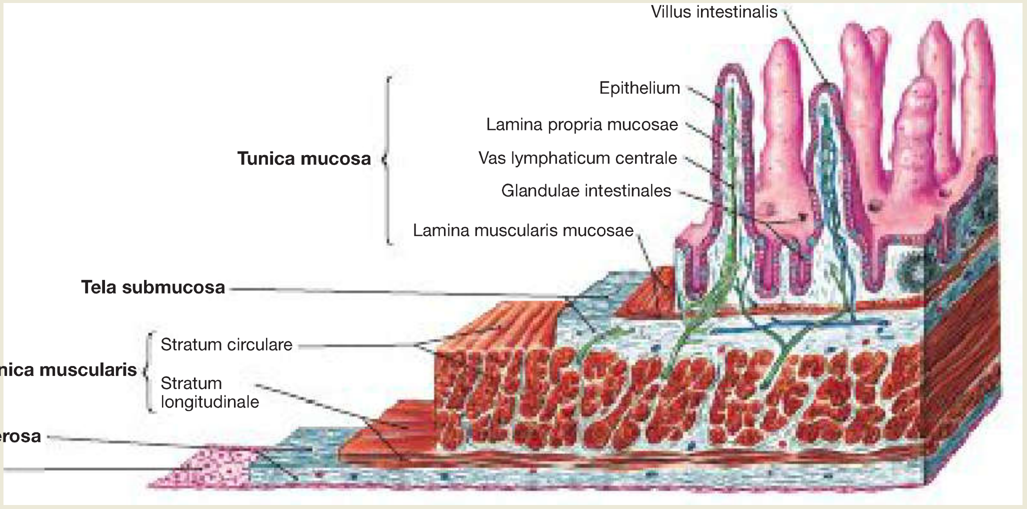


Fig. 6.49 Structure of the wall of the small intestine, Intestinum tenue; microscopic view.
Similar to other parts of the intestines, the wall of the small intestine consists of an inner mucosal layer **(Tunica mucosa)** with intestinal villi (Villi intestinales) visible with magnification. Separated by a loose connective tissue layer **(Tela submucosa),** the muscular layer **(Tunica muscularis)** consists of the inner circular layer and the outer longitudinal layer. This is divided into an internal circular muscle layer (Stratum circulare) and an external longitudinal muscle layer (Stratum longitudinale). The intraperitoneal parts (Pars superior of the duodenum, jejunum and ileum) are covered on the outside by visceral peritoneum (Peritoneum viscerale), which forms a **Tunica serosa.** In contrast, the retroperitoneal parts of the duodenum are anchored by the **Tunica adventitia** in the connective tissue of the retroperitoneal space.

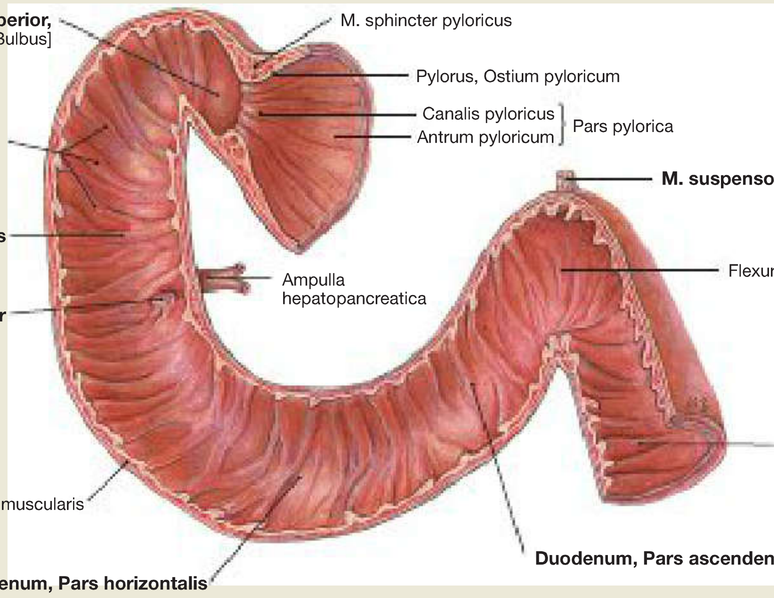
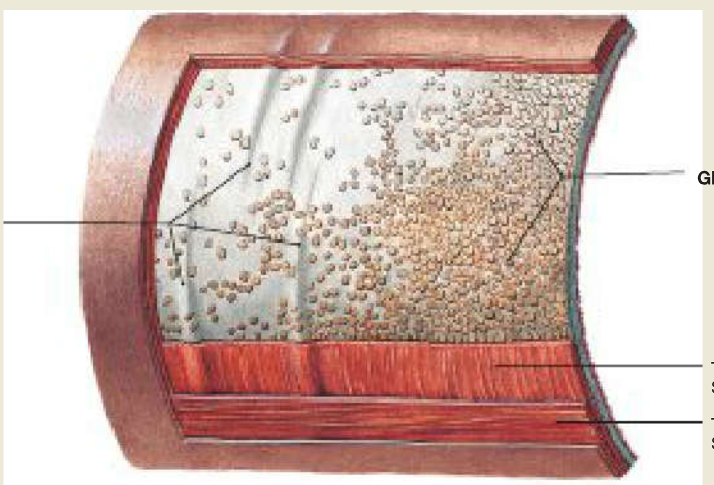


Fig. 6.50 Inner surface of the duodenum; frontal section; ventral view.
The inner surface of the duodenum, as well as of the remaining small intestine is raised with **circular folds (Plicae circulares, KERCKRING's folds)**. The duodenum is divided into four parts: 1. Pars superior, 2. Pars descendens, 3. Pars horizontalis, 4. Pars ascendens. In the Pars descendens is the **Papilla duodeni major (Papilla VATERI)** as a confluence of Ductus pancreaticus (duct of WIRSUNG) and Ductus choledochus, which together, for the most part, form the Ampulla hepatopancreatica. The Pars ascendens is attached with smooth muscle **(M. suspensorius duodeni, muscle of TREITZ)** and dense **connective tissue (Lig. suspensorium duodeni)** where the A. mesenterica superior leaves the aorta, before the duodenum in the Flexura duodenojejunalis passes over into the intraperitoneal jejunum.



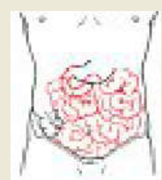


Fig. 6.51 Structure of the wall of the duodenum with Glandulae duodenales; view from outside.

In the Tela submucosa there are the mucous-producing Glandulae duodenales (BRUNNER's glands). These allow (under the microscope!) a unique identification of the duodenum.

Clinical Remarks

The muscle of TREITZ defines the border between **upper and lower intestinal tract** in the case of **bleeding (IT bleeding).** This is because the suspension of the Pars ascendens of the duodenum where it branches off distally of the Flexura duodenojejunalis, to the A. mesenterica superior, prevents the reflux of intestinal contents and hence also a returning blood flow. This classification is of clinical relevance since both forms of haemorrhage have different causes and require different diagnostic steps. In the case of **upper IT bleeding** the blood is usually discoloured and very dark due to contact with gastric acid. Therefore, in this case, gastroduodenal imaging (gastroduodenoscopy) would be used for clarification. With **lower IT bleeding** on the other hand, the blood is light red. If the associated colonoscopy provides no clue to the source of the bleeding, an endoscopy of the entire gut can be performed by swallowing a video capsule.

Duodenum, Imaging

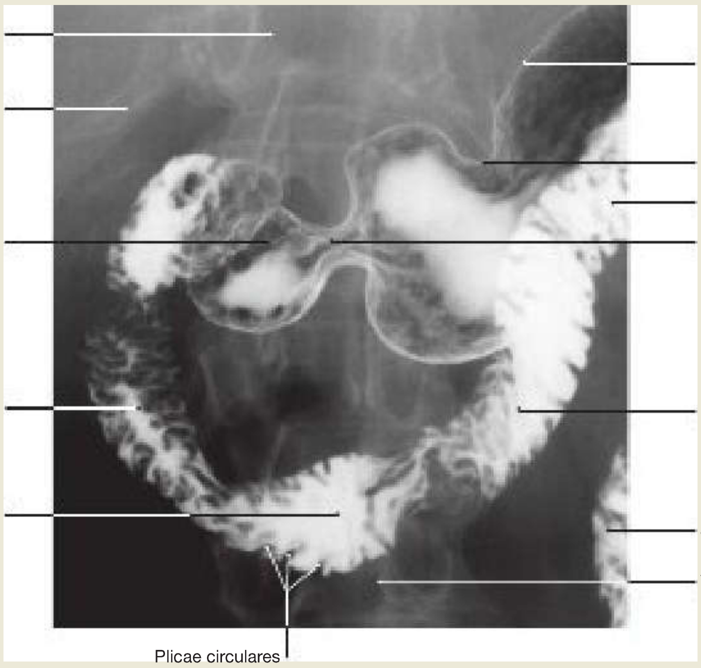


Fig. 6.52 Duodenum; X-ray with an anteroposterior (AP) beam projection after oral application of a contrast agent; patient in upright position; ventral view. [T893]

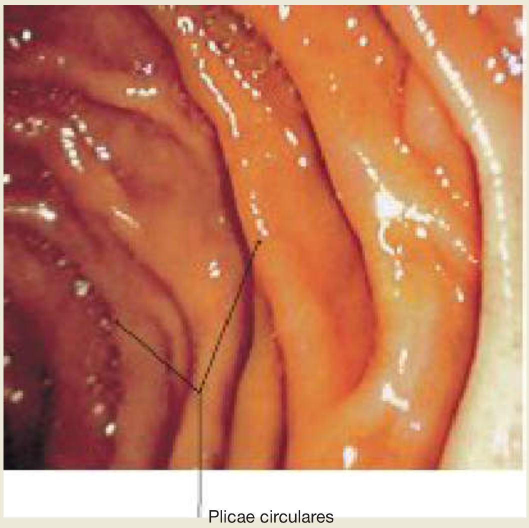
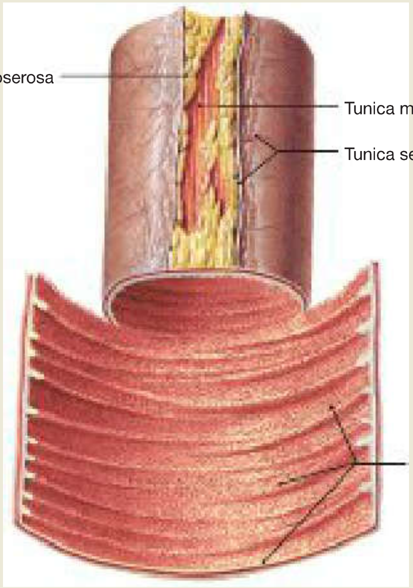


Fig. 6.53 Duodenum; endoscopic image.
Here the circular **mucosal folds (Plicae circulares, KERCKRING's folds)** are clearly visible. [T901]

Clinical Remarks

Like the stomach, the duodenum is often the location for ulcers (Ulcera duodeni), which are not clinically differentiated from gastric ulcers (→ p. 126). Malignant tumours, however, are rare in the duodenum.

For the evaluation of these diseases, there are various diagnostic options. **X-ray contrast imaging** has become less important in recent years, as it is inferior to **colonoscopy** (duodenoscopy), which includes inspecting the mucous membrane as well as allowing a biopsy to be taken.



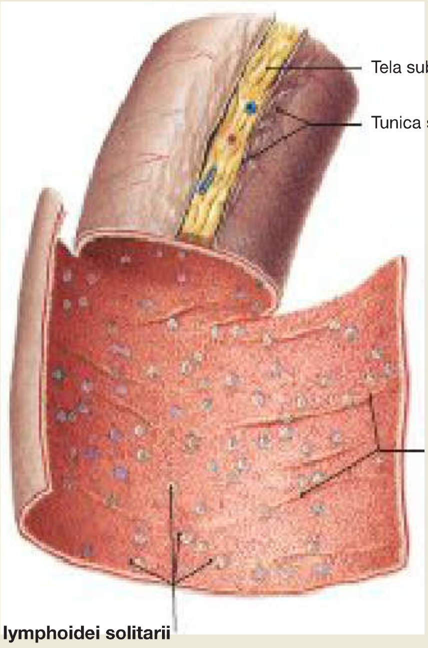
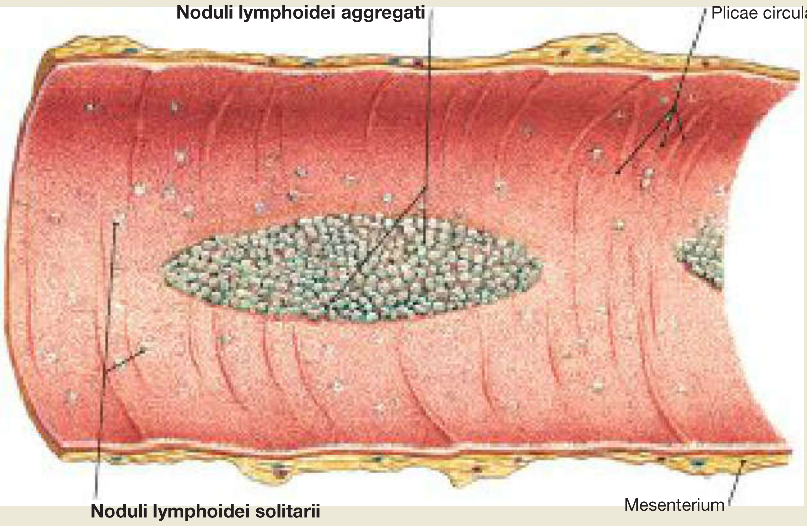


Fig. 6.54 Detail of the jejunum.
The structure of the jejunum is very similar to the duodenum but does not contain the **Glandulae duodenales (BRUNNER's glands).**

Fig. 6.55 Detail of the proximal ileum.
There are far fewer **circular folds (Plicae circulares, KERCKRING's folds)** in the ileum compared to the upper small intestine.



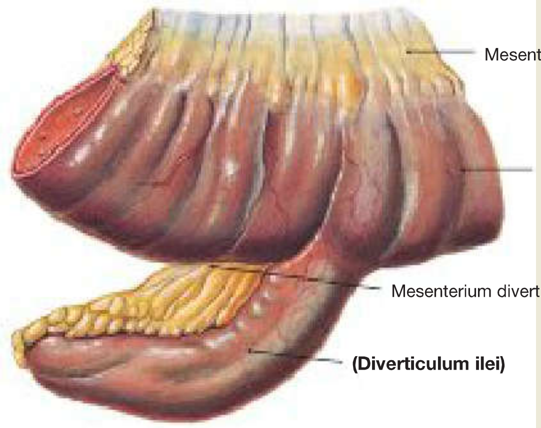


Fig. 6.56 Detail of the ileum.
The large number of lymph follicles that serve the immune system is characteristic. These are either found individually in the Tela submucosa (Noduli lymphoidei solitarii; → Fig. 6.55) or in groups (Noduli lymphoidei aggregati, **PEYER's plaques**), formed within the mucosa.

Fig. 6.57 MECKEL's diverticulum, Diverticulum ilei.
In up to 3% of people, one can find a diverticulum, mostly in the 100 cm long ileocaecal valve located opposite the mesenteric root; this is the developmental remnant of the embryological Ductus vitellinus (Ductus omphaloentericus; → Fig. 6.2).
MECKEL's diverticula can contain disseminated gastric mucosa and can simulate the clinical symptoms of appendicitis when inflamed and bleeding.

Intestines

Projection of the Large Intestine

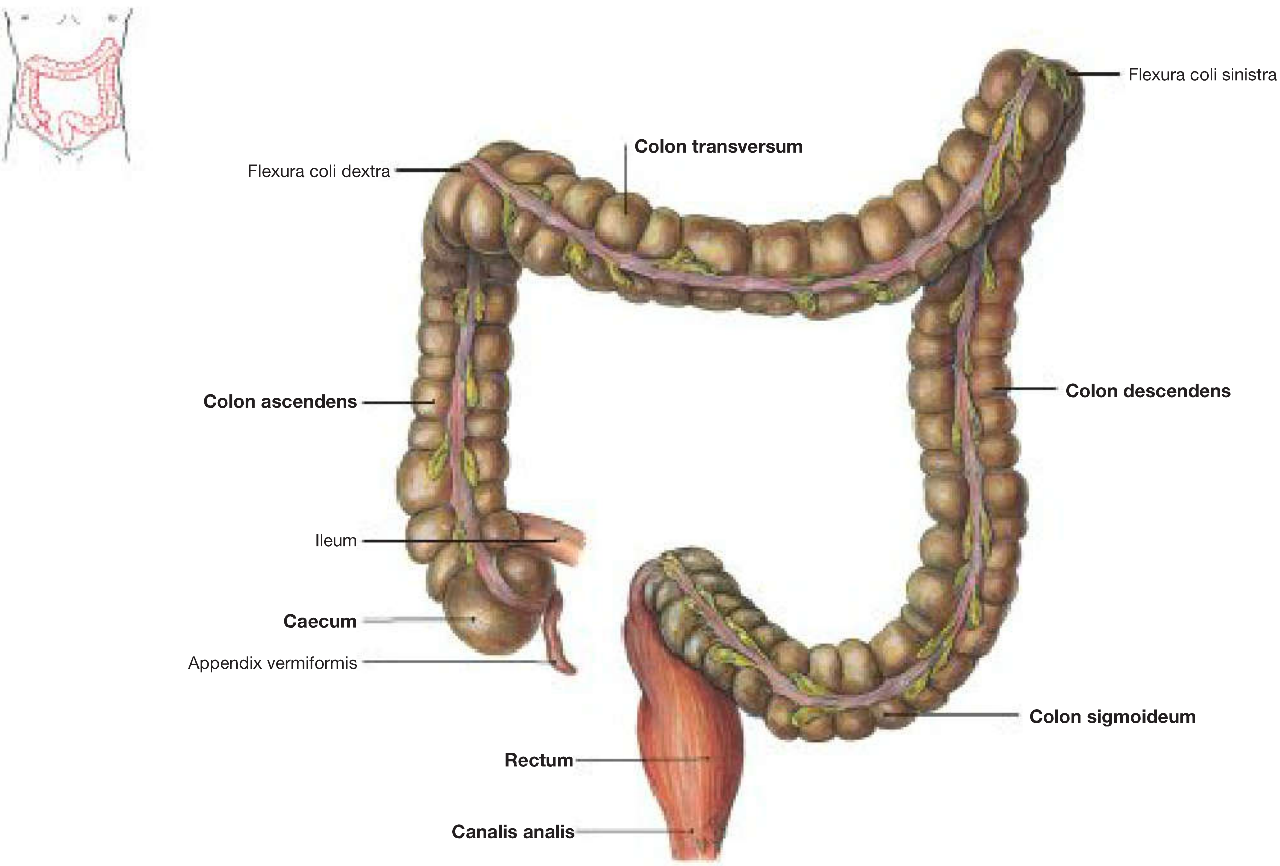


Fig. 6.58 Structure of the large intestine, Intestinum crassum; ventral view.
The Intestinum crassum is about 1.5 m long and consists of **four parts:**
- Caecum with Appendix vermiformis
- Colon with Colon ascendens, Colon transversum, Colon descendens, and Colon sigmoideum
- Rectum
- Canalis analis (anal canal)

The Canalis analis is described with the pelvic organs (→ chapter 7).

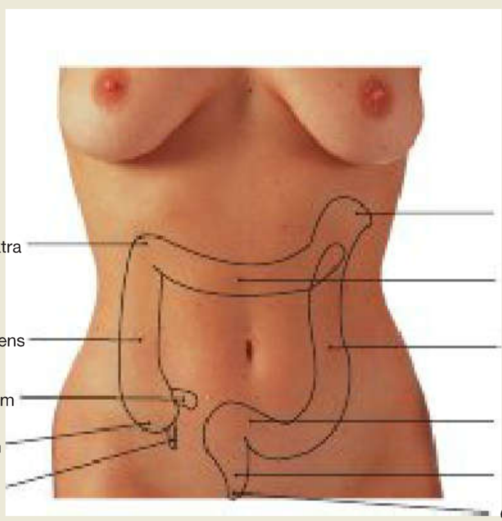
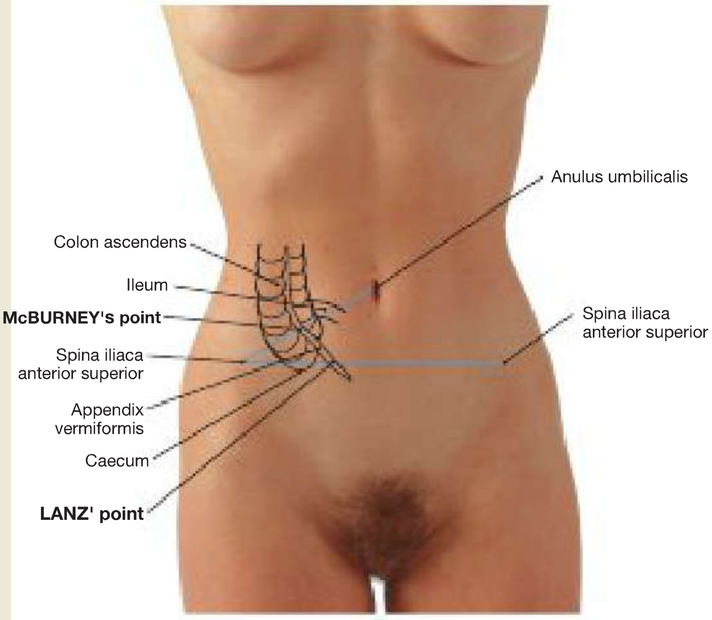


Fig. 6.59 Projection of the large intestine, Intestinum crassum, onto the ventral abdominal wall.
Caecum with Appendix vermiformis, Colon transversum, and Colon sigmoideum are positioned **intraperitoneally,** and each has its own respective mesentery. The caecum and the Appendix vermiformis can also lie retroperitoneally (Caecum fixum) when a mesentery is missing. **Colon ascendens, Colon descendens** and the major part of the **rectum** are usually secondary **retroperitoneal organs,** and the distal rectum and the **Canalis analis** are **subperitoneal.** The projection and the length of the individual segments of the Intestinum crassum are highly variable and the retroperitoneal segments are often inconsistently fused with the posterior abdominal wall. Due to the position of the liver on the right side, the splenic or left colic flexure (Flexura coli sinistra) is generally positioned further cranially than the hepatic or right colic flexure (Flexura coli dextra; → Fig. 6.75).

Projection and Positional Variants of the Appendix



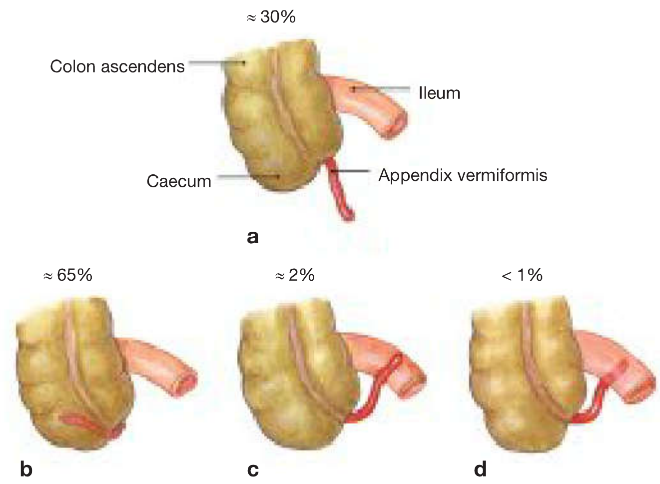


Fig. 6.60 Projection of the caecum and the appendix, Appendix vermiformis, onto the ventral abdominal wall.
The base of the Appendix vermiformis projects onto the **McBURNEY's point** (the transition between the lateral third and the medial two-thirds on a line connecting the umbilicus with the Spina iliaca anterior superior). The location of the tip of the appendix is more variable and projects onto the **LANZ' point** (the transition between the right third and the left two-thirds on a line connecting both the Spinae iliacae anteriores superiores; 30%; → Fig. 6.61 and → Fig. 6.62).

Fig. 6.61a to d Positional variants of the Appendix vermiformis; ventral view.
a Descending in the lesser pelvis (pendulous)
b Retrosacral (most frequently!)
c Preileal
d Retroileal

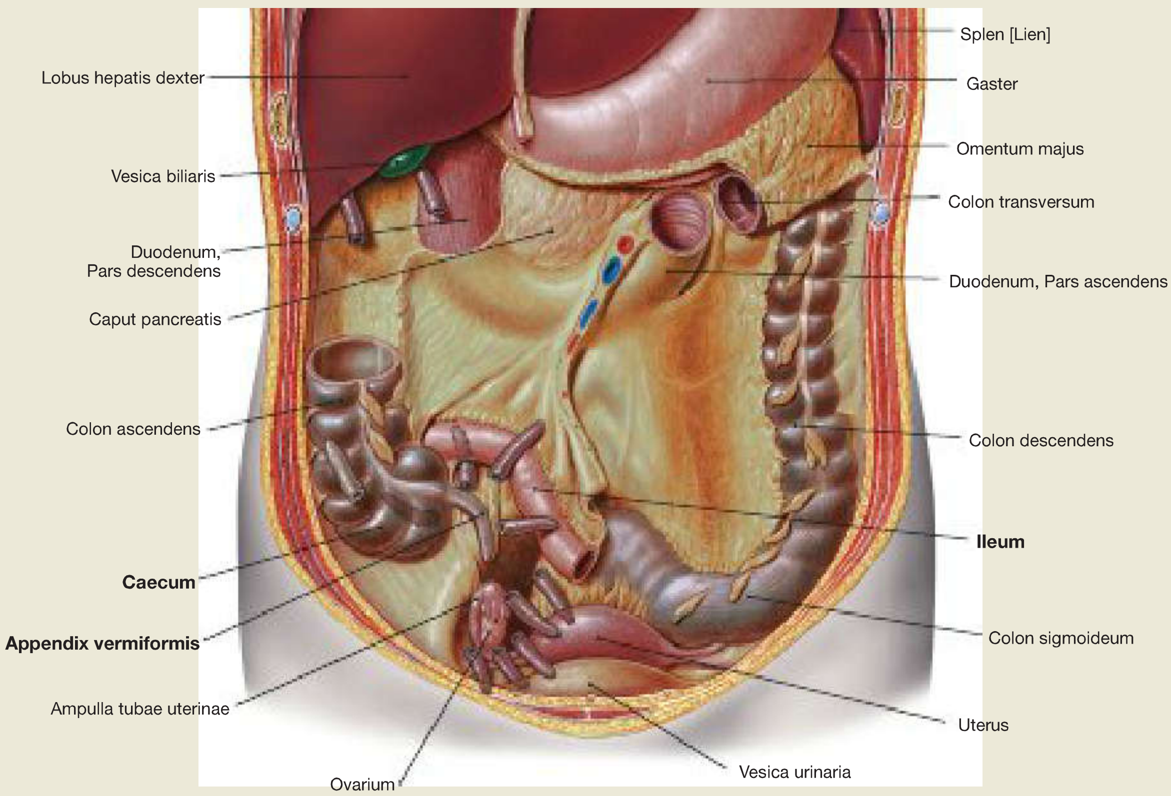


Fig. 6.62 Positional variants of the Appendix vermiformis; ventral view.

Clinical Remarks

It is often difficult to diagnose **appendicitis** (often falsely referred to as 'inflammation of the appendix'), as pain in the right lower abdomen can be a result of enteritis, or can be caused in women by inflammation of the ovaries and FALLOPIAN tubes. Tenderness or pain from touching McBURNEY's or LANZ' point can therefore be an important diagnostic sign.

Structure of the Large Intestine

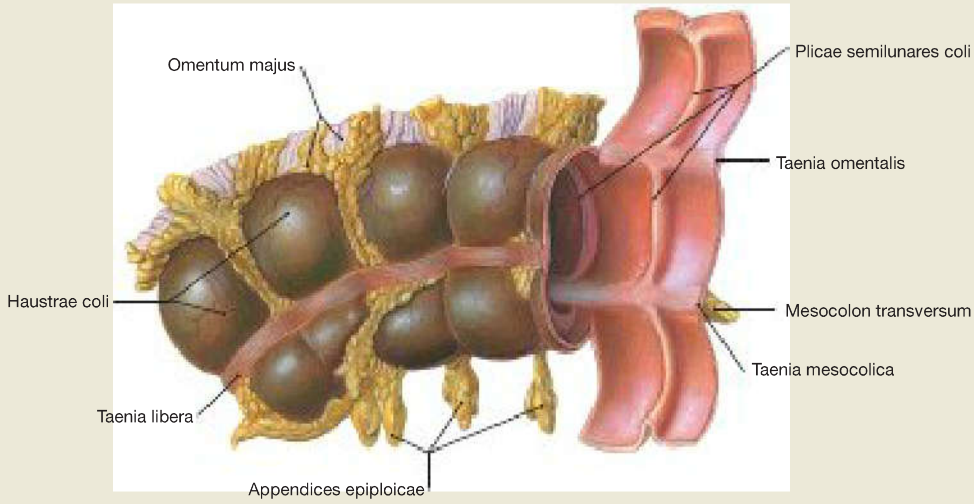


Fig. 6.63 Structural features of the large intestine, Intestinum crassum, as an example, of the Colon transversum; ventral caudal view.

The large intestine has four characteristic differences to the small intestine:

- **Larger diameter** (it is 'thick' rather than 'thin')
- **Taenia:** the longitudinal muscle layer is reduced to three bands. Of these the Taenia libera is visible, while the Mesocolon transversum is attached to the Taenia mesocolica and the Omentum majus is attached to the Taenia omentalis.
- **Haustrae** and **Plicae semilunares:** the haustrae of the colon (Haustrae coli) are protrusions, caused by the sacculations on the inside which look like halfmoon-shaped folds.
- **Appendices epiploicae:** tags caused by the adipose tissue contained in the Tela subserosa.

These structural features apply to all parts of the Intestinum crassum apart from the Appendix vermiformis, rectum and Canalis analis. These sections have no taenia, haustrae and omental appendices.

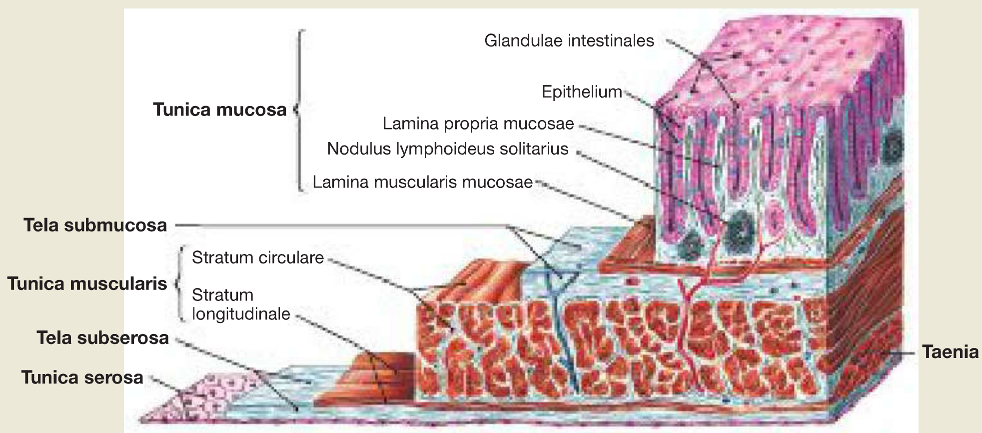


Fig. 6.64 Structure of the wall of the large intestine, Intestinum crassum; microscopic view.

Similar to the other parts of the intestines, the wall of the Intestinum crassum consists of an inner mucosal layer **(Tunica mucosa)** which, in contrast to the duodenum, has no mucosal villi. Separated by a loose connective tissue layer **(Tela submucosa),** the muscular layer **(Tunica muscularis)** consists of the inner circular layer and the outer longitudinal layer. This is divided into an internal circular muscle layer **(Stratum circulare)** and an external longitudinal muscle layer **(Stratum longitudinale).** However, the longitudinal layer is not continuous but is reduced to three bands **(Taenia).** The intraperitoneal segments (caecum with appendix, Colon transversum, and Colon sigmoideum) are covered on the outside by visceral peritoneum (Peritoneum viscerale), forming a **Tunica serosa.** In contrast, the retroperitoneal parts (Colon ascendens, Colon descendens, and upper rectum) are anchored by the **Tunica adventitia** in the connective tissue of the retroperitoneal space.

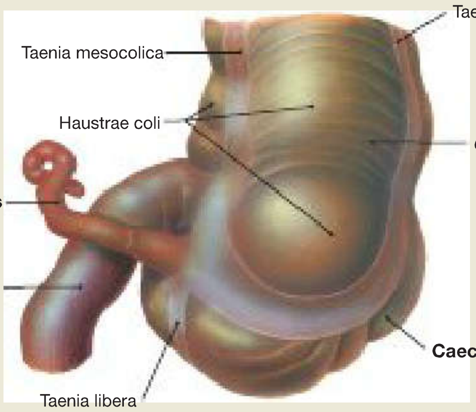


Fig. 6.65 Caecum with Appendix vermiformis and terminal ileum, Pars terminalis ilei; dorsal view.
The **caecum** is approximately 7 cm long. The 8–9 cm long Appendix vermiformis is attached to the caecum in most cases and has its own Mesoappendix (not shown here), with the supplying neurovascular pathways. The taenia of the colon converge in the appendix, so that this again has a closed longitudinal muscle layer.

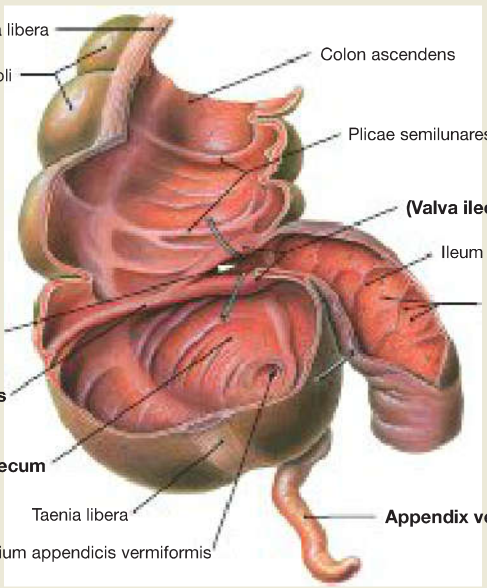
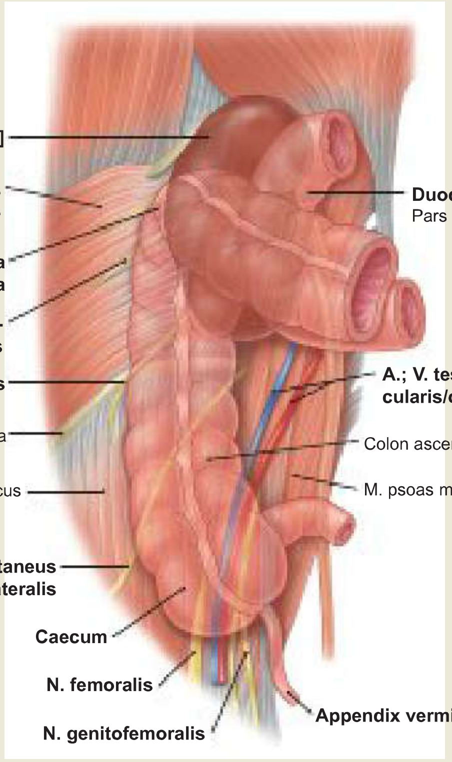


Fig. 6.66 Caecum with Appendix vermiformis and terminal ileum, Pars terminalis ilei; ventral view; after removal of the anterior parts of the wall.
The caecum joins the terminal ileum and is separated by the **ileocaecal valve** (BAUHIN's valve). Inside, the two lips of the valve are raised by Papilae ileales and together they border the opening (ileal orifice). Laterally, the lips continue in the Frenulum ostii ilealis. The terminal ileum contains aggregations of lymph follicles (Noduli lymphoidei aggregati) which are referred to as **PEYER's plaques** and serve the immune system. The appendix also has many lymph follicles and serves the immune system.

Clinical Remarks

Appendicitis is a common disease in the second and third decades of life. It is an endogenous inflammation, mostly caused by the obstruction of the lumen of the appendix by faeces, or (rarely) by other foreign bodies with a resulting transmural inflammation due to intestinal microorganisms. This can result in perforation with a life-threatening peritonitis. The terminal ileum is particularly important for the absorption of vitamin B_{12} and bile acids as well as due to its immunological functions. It is often affected by **CROHN's disease,** a chronic bowel disease with an autoimmune component, which can also lead to anaemia due to a vitamin B_{12} deficiency.

Topography of the Small and Large Intestines



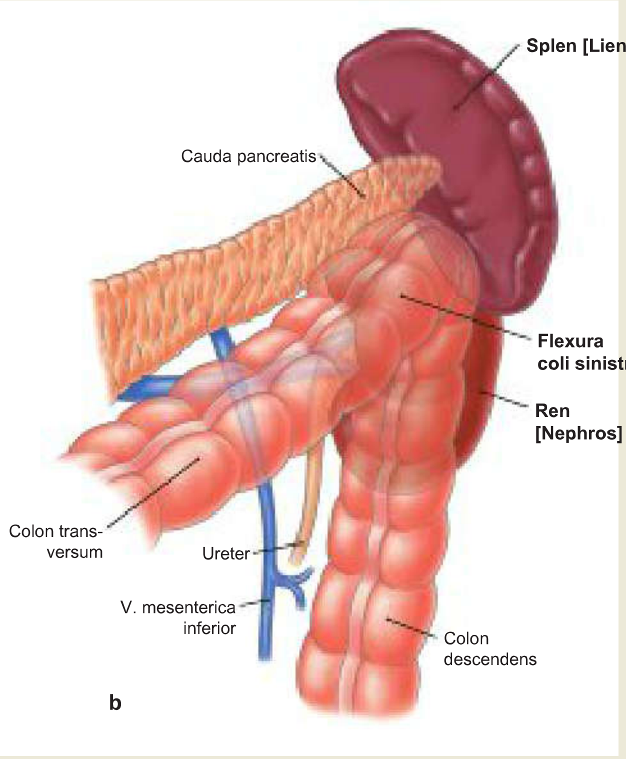
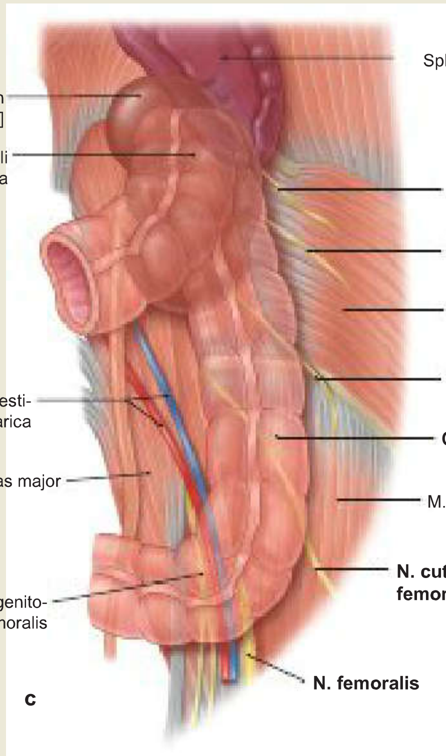


Fig. 6.67a and b Topography of the duodenum and the 'right-sided' parts of the colon (Caecum with Appendix vermiformis, Colon ascendens and Colon transversum); semi-schematic representation; after removal of the small intestine, ventral view. [G210]

Topography of the parts of the small intestine:
For the position of the duodenum, see also the following figures: → Fig. 6.88, → Fig. 6.104, → Fig. 6.112, → Fig. 6.132 and → Fig. 6.133. The **Pars superior** of the duodenum is located behind the gallbladder, Vesica biliaris, and has direct contact with the visceral surface of the liver (Hepar). The **Pars descendens** is directly adjacent to the right kidney (Ren) and adrenal gland, but it is separated by the capsules enveloping the kidneys. The head of the pancreas nestles medially on the Pars descendens. The **Pars horizontalis** crosses the pancreatic head below the spine, and prior to this, the Aorta abdominalis as well as the V. cava inferior and the right Vasa testicularia/ovarica and the right ureter. The **Pars ascendens** ascends to the Flexura duodenojejunalis and thereby covers the left kidney (Ren) with the left ureter and the left Vasa testicularia/ovarica. The **jejunum and ileum** (not shown here) come into contact with both kidneys and with various parts of the large intestine, and lie in the pelvis on the urinary bladder and, in women, the uterus and its appendages (ovaries and FALLOPIAN tubes).

Topography of the 'right-sided' parts of the large intestine:
The **caecum and Appendix vermiformis** are positioned ventrally to the M. psoas major and thus cover different nerves of the Plexus lumbalis and the right Vasa testicularia/ovarica. In the pendulous or descending position illustrated here, the appendix can come in close proximity to the right ovary and FALLOPIAN tube. The **Colon ascendens** then ascends to the right colic flexure and crosses the N. cutaneus femoris lateralis as well as the N. ilioinguinalis and N. iliohypogastricus. The right **colic flexure (Flexura coli dextra)** touches the inferior surface of the liver (Hepar) and is therefore referred to as the 'hepatic' flexure; it comes into contact with the fundus of the gallbladder. It is located ventral to the right kidney (Ren) and lateral to the Pars descendens of the duodenum. The **Colon transversum** passes caudally of the stomach (Gaster) to the left colic flexure. At the same time it is ventrally to the right of the Pars descendens of the duodenum and the head of the pancreas, in the centre and in front of the small intestinal loops of the jejunum and ileum and to the right of the Flexura duodenojejunalis. The left colic flexure **(Flexura coli sinistra)** touches the visceral surface of the spleen and is therefore also called the 'splenic' flexure. Dorsally from these are the left kidney (Ren) and the tail of the pancreas (Cauda pancreatis).



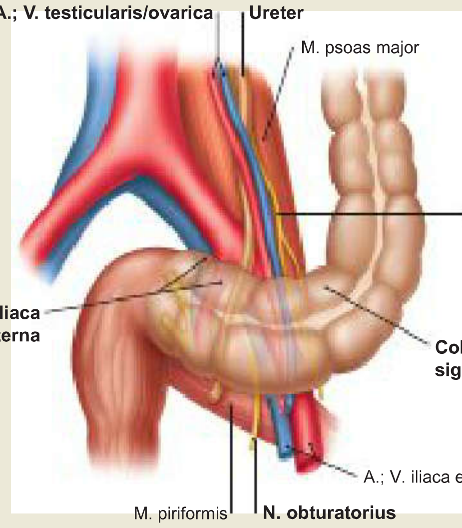


Fig. 6.67c and d Topography of the 'left-sided' parts of the large intestine (Colon descendens and Colon sigmoideum) and rectum and Canalis analis; semi-schematic representation; after removal of most of the small intestine, ventral view. [G210]

Topography of the 'left-sided' parts of the large intestine:
The **Colon descendens** descends ventrally of the left kidney (Ren) and crosses the nerves of the left Plexus lumbalis. The **Colon sigmoideum** turns to the right and crosses the nerves of the lumbar plexus, the right ureter and the Vasa testicularia/ovarica as well as the Vasa iliaca externa and interna. In the pelvis it touches the surface of the urinary bladder and in women the uterus with its appendages (ovaries and FALLOPIAN tubes).

Topography of the rectum and anal canal:
For the topography of the rectum and anal canal, please also refer to the following figures: → Fig. 7.96, → Fig. 7.99, → Fig. 7.115 and → Fig. 7.116. The **rectum** is located directly at the anterior aspect of the sacrum. In men the rectum is ventral from the bladder, in women from the uterus and vagina. The **Canalis analis** enters through the pelvic floor.

Arteries of the Small Intestine

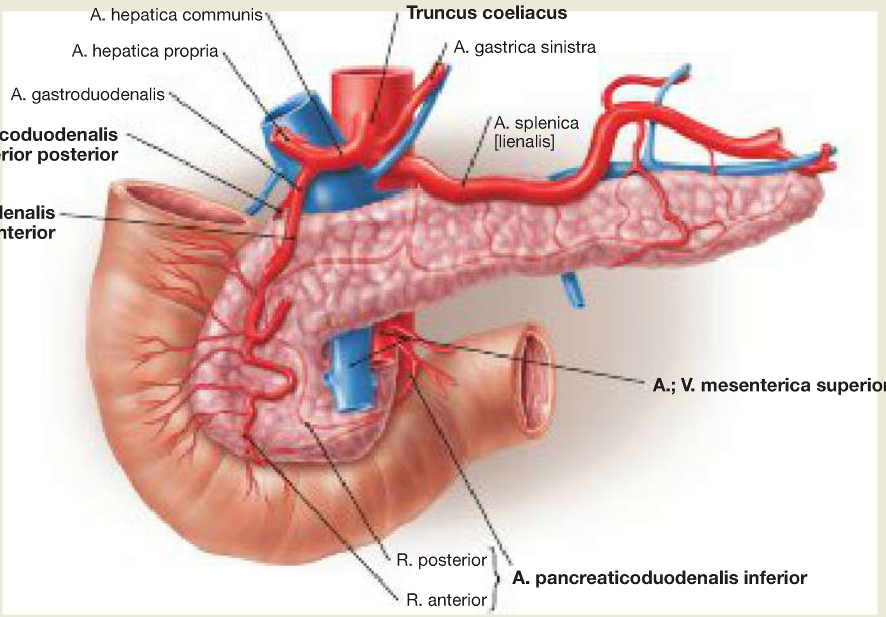


Fig. 6.68 Arteries of the duodenum; ventral view. [L238]
The blood supply of the duodenum is accomplished ventrally and dorsally through a double arterial arch. This is fed cranially by the **Aa. pancreaticoduodenales superiores anterior and posterior,** from the circulatory area of the Truncus coeliacus, and caudally by the **A. pancreaticoduodenalis inferior** (R. anterior and R. posterior) from the A. mesenterica superior. The connection between the cranial and caudal arcades is referred to as **BÜHLER's anastomosis.**

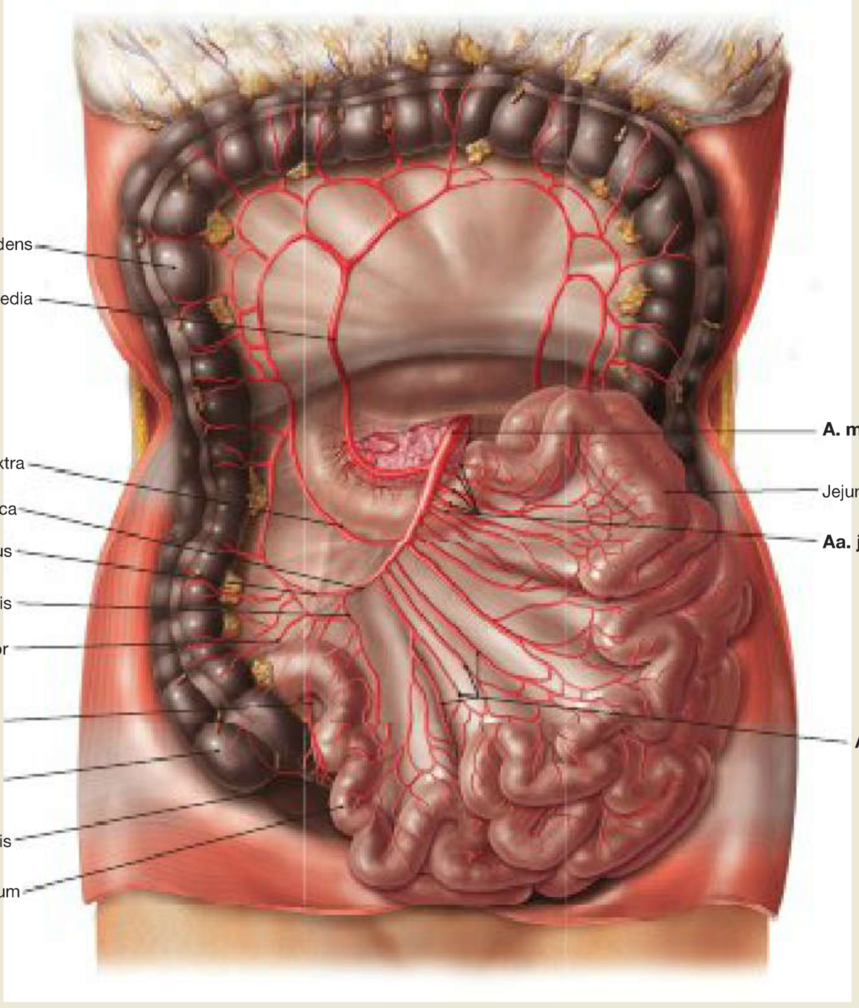


Fig. 6.69 Arteries of the jejunum and ileum; ventral view; Colon transversum folded upwards. [L238]
The intraperitoneal convolute of the jejunum and ileum is supplied by the A. mesenterica superior which distributes its branches (usually four to five **Aa. jejunales** and twelve **Aa. ileales)** within the mesentery of the small intestine (→ Fig. 6.21).

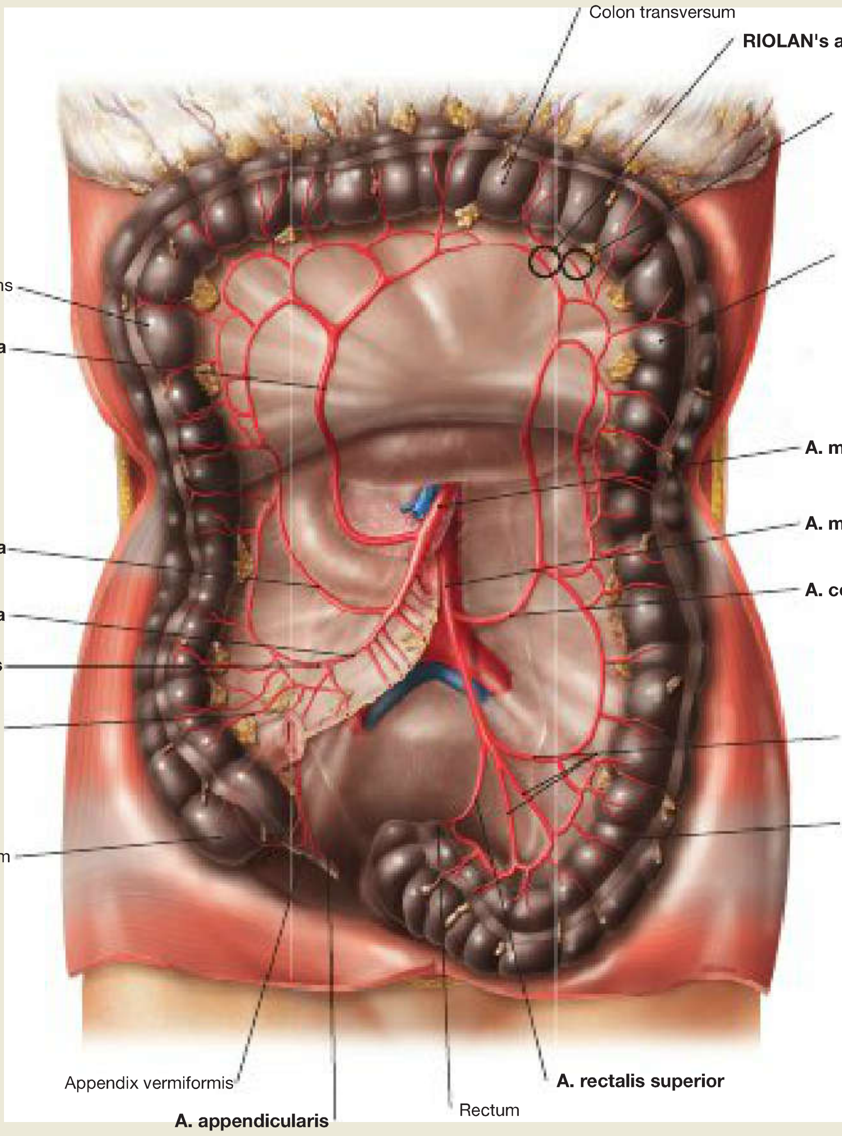


Fig. 6.70 Arteries of the large intestine, Intestinum crassum; ventral view; Colon transversum folded upwards. [L238]

- **Caecum and Appendix vermiformis: A. ileocolica** with a R. ilealis to the terminal ileum (anastomoses with the last A. ilealis) and a R. colicus (connected with the A. colica dextra). Then the artery divides into an A. caecalis anterior and an A. caecalis posterior on both sides of the caecum and into the A. appendicularis, which runs inside the Mesoappendix and supplies the Appendix vermiformis.
- **Colon ascendens and Colon transversum: A. colica dextra** and **A. colica media** (from the A. mesenterica superior) anastomose with each other. The A. colica media is connected to the A. colica sinistra **(RIOLAN's anastomosis).** Occasionally, the connection in one of the arcades close to the intestines is referred to as DRUMMOND's anastomosis.
- **Colon descendens and Colon sigmoideum: A. colica sinistra** and **Aa. sigmoideae** from the A. mesenterica inferior. The A. rectalis superior, also derived from the A. mesenterica inferior, supplies the upper rectum.

Note: Due to **developmental changes,** all areas supplied by neurovascular pathways **switch** at the **left colic flexure.** Regarding the arteries: from the **A. mesenterica superior** which supplies the Colon ascendens and Colon transversum, to the **A. mesenterica inferior** for the Colon descendens.

Clinical Remarks

The short collateral connections between the A. colica media and the A. colica sinistra, which clinically are collectively called **RIOLAN's anastomosis,** play a role in circulatory disorders, e.g. in arteriosclerosis or embolism (by a displaced blood clot). Similar connections exist in the area of the duodenum and the rectum (→ Fig. 6.15). Even the complete occlusion of one of the three unpaired abdominal arteries (Truncus coeliacus, A. mesenterica superior and A. mesenterica inferior) can largely be compensated for without intestinal infarction. Circulatory disorders of the intestines are usually characterised by abdominal pain which occurs after eating (postprandial pain).

Veins of the Small and Large Intestines

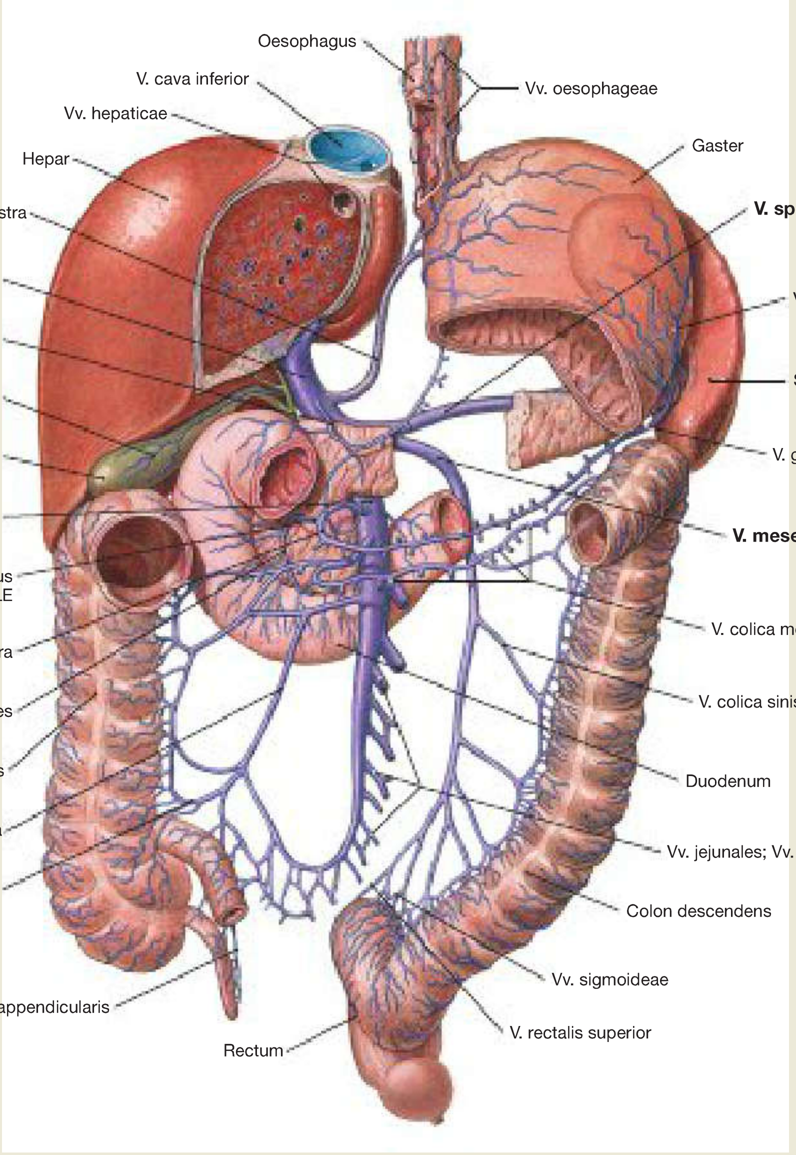


Fig. 6.71 Veins of the small intestine, Intestinum tenue, and the large intestine, Intestinum crassum; ventral view.
The veins correspond to the arteries and all flow into the three **major tributaries of the portal vein:** behind the Caput pancreatis, the V. mesenterica superior merges with the V. splenica to form the V. portae hepatis. The V. mesenterica inferior drains into the V. splenica (70% of all cases) or into the V. mesenterica superior (30%).

Note: Due to **developmental changes** all areas supplied by neurovascular pathways **switch** at the **left colic flexure.** Regarding the veins: from the **V. mesenterica superior** which supplies the Colon ascendens and Colon transversum, to the **V. mesenterica inferior** for the Colon descendens.

Branches of the V. mesenterica superior:
- V. gastroomentalis dextra with Vv. pancreaticoduodenales, usually take a vein from the right colic flexure (cut off here). The venous trunk formed in this way is known by abdominal surgeons as the **HENLE's venous trunk** and often also includes the confluence of the V. colica dextra.
- Vv. pancreaticae
- Vv. jejunales and ileales
- V. ileocolica
- V. colica dextra
- V. colica media

Branches of the V. mesenterica inferior:
- V. colica sinistra
- Vv. sigmoideae
- V. rectalis superior: the vein is connected to the V. rectalis media and the V. rectalis inferior, which belong to the drainage area of the V. cava inferior.

Clinical Remarks

In the case of high pressure in the portal vein (portal hypertension), e.g. in cirrhosis of the liver (Hepar), connections to the drainage area of the V. cava superior and V. cava inferior **(portocaval anastomoses)** can open up or form (→ Fig. 6.90). This also includes connections of the V. rectalis superior to the V. rectalis media and V. rectalis inferior, which take blood to the V. cava inferior. They are clinically less important and do not cause, as was previously assumed, the formation of haemorrhoids. When applying rectal suppositories, it is helpful to know that the drugs are absorbed by the rectal veins to bypass the liver and to enter the general circulation via the V. cava inferior, thus, preventing hepatic metabolism and potential degradation of the drugs in the liver.

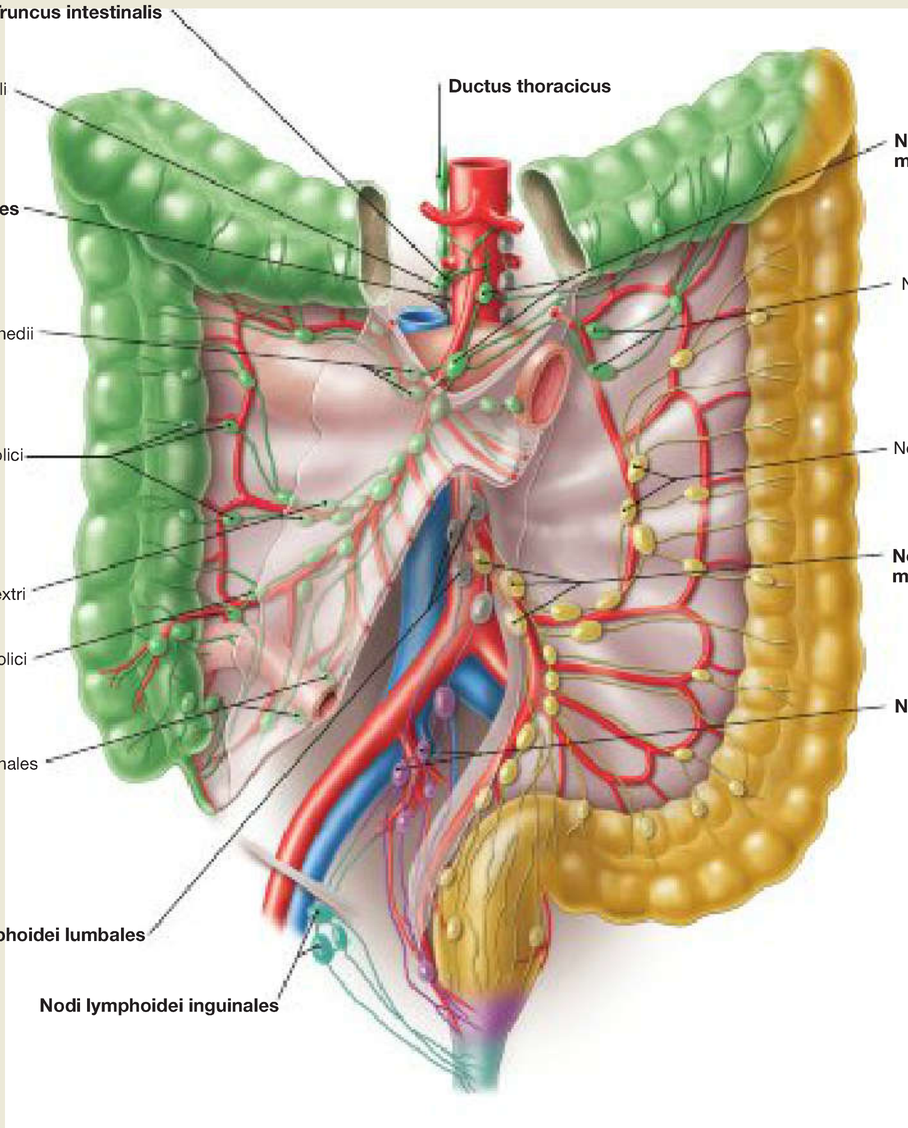


Fig. 6.72 Lymphatic vessels and regional lymph nodes of the small intestine, Intestinum tenue, and the large intestine, Intestinum crassum.
The respective groups of lymph nodes (a total of 100 to 200 lymph nodes) are coloured differently according to their drainage areas. [L238]
The **Nodi lymphoidei juxtaintestinales** are positioned directly on the small intestine; next to the large intestine are the **Nodi lymphoidei paracolici.** The lymph flows via various lymph node stations along the vascular arcades (e. g. **Nodi lymphoidei colici dextri, colici medii, colici sinistri, ileocolici, mesocolici**) in two separate drainage systems:

- From the entire **small intestine** as well as the **caecum, Colon ascendens, and Colon transversum,** the lymph drains into the **Nodi lymphoidei mesenterici superiores** at the origin of the A. mesenterica superior and further via the Truncus intestinalis into the Ductus thoracicus (green).
- From the **Colon descendens, Colon sigmoideum, and proximal rectum,** the lymph reaches the **Nodi lymphoidei mesenterici inferiores** at the origin of the A. mesenterica inferior (yellow) and further via the retroperitoneal para-aortic lymph nodes (Nodi lymphoidei lumbales, grey) into the Trunci lumbales (grey).

The **distal rectum** and the **anal canal** are also attached to the drainage area of the Trunci lumbales. The first lymph node stations, however, are the **Nodi lymphoidei iliaci interni** (pink), and the **Nodi lymphoidei inguinales** (turquoise) for the terminal parts of the anal canal, respectively.

Note: Due to **developmental changes** all areas supplied by neurovascular pathways **switch** at the **left colic flexure.** Regarding the lymphatic drainage: the **Nodi lymphoidei mesenterici superiores** are the regional lymph nodes for the Colon ascendens and Colon transversum, whereas the **Nodi lymphoidei mesenterici inferiores** drain the Colon descendens.

Clinical Remarks

The **lymphatic drainage** plays a clinically important role in the diagnosis of colon carcinomas since the therapeutic approach depends on the stage of the disease (staging). In the case of a tumour in the Colon ascendens or the Colon transversum, lymph nodes metastases are expected to appear in the drainage area of the Nodi lymphoidei mesenterici superiores. However, in the case of a tumour in the Colon descendens, the lymph nodes in the drainage area of the inferior mesenteric lymph nodes are relevant, which, based on the retroperitoneal course of the A. mesenterica inferior, which they accompany, frequently prove to be attached to other retroperitoneal lymph nodes.

Innervation of the Small and Large Intestines

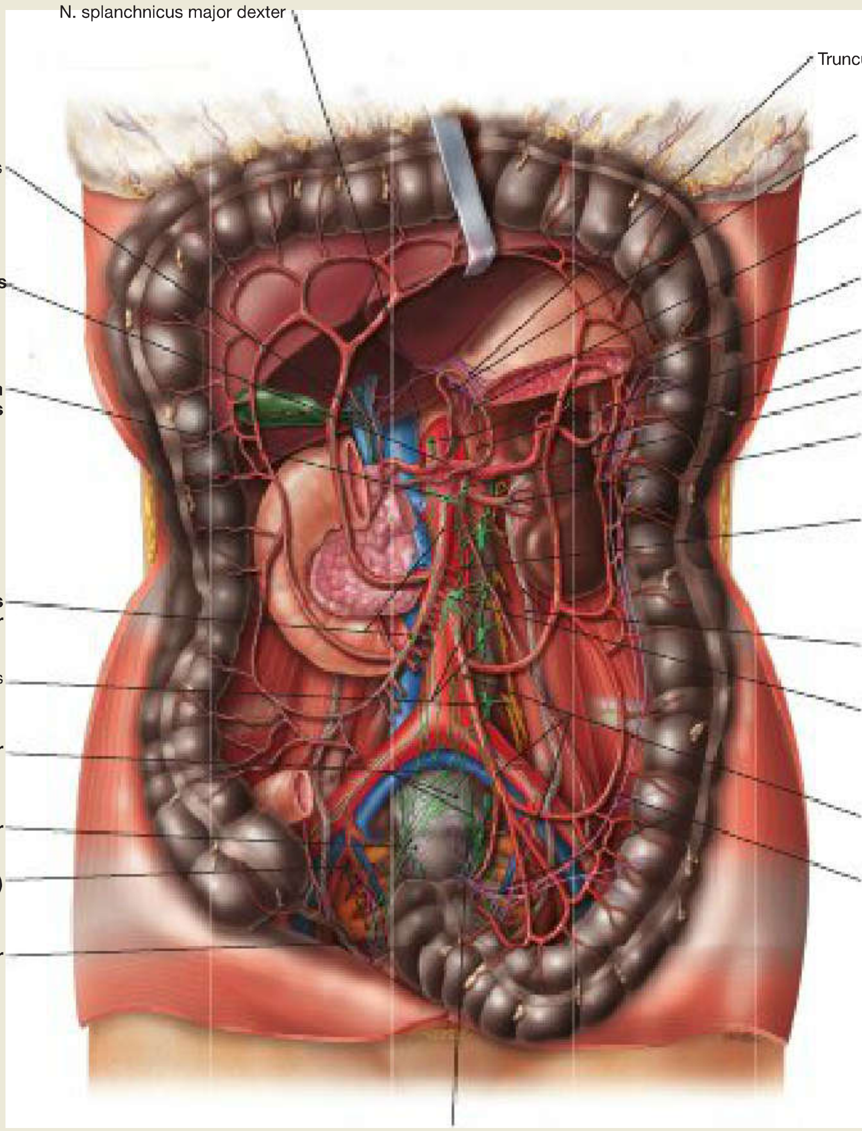


Fig. 6.73 Autonomic innervation of the small intestine and the large intestine; ventral view. [L238]

On the anterior side of the aorta, the autonomic sympathetic (green) and parasympathetic (purple) nerve fibres generate a plexus **(Plexus aorticus abdominalis),** which forms its own plexuses around the openings of the aortic branches, and these nerve fibres accompany the respective blood vessels to their target organs. The small and large intestines are innervated by fibres derived from the plexus around the three major visceral branches of the aorta **(Plexus coeliacus, Plexus mesenterici superior and inferior).**

The perikarya of the **preganglionic sympathetic neurons** sit in the lateral horns of the spinal cord, their axons reaching the Truncus sympathicus and continue without switching via the Nn. splanchnici major and minor to the aortic plexuses, where they become synapsed in the ganglia bearing the same name **(Ganglion coeliacum, Ganglion mesentericum superius** and **Ganglion mesentericum inferius)** and switch over to postganglionic neurons, the axons of which together with the branches of the respective arteries reach the intestinal parts.

The **preganglionic parasympathetic neurons** of the **Nn. vagi [X]** descend along the oesophagus as Trunci vagales anterior and posterior, traverse the diaphragm and travel within the autonomic nerve plexuses around the aorta without synapsing to reach their target organs. The innervation area of the Nn. vagi [X] ends in the Plexus mesentericus superior and, thus, in the area of the left colic flexure (traditionally known as the CANNON-BÖHM point).

By contrast, the Colon descendens is supplied by the **sacral part of the parasympathicus;** its preganglionic neurons are within the spinal cord (S2–S4), emerging from the spinal nerves as Nn. splanchnici pelvici, and then transferred in the Plexus hypogastricus inferior in the area of the rectum onto postganglionic neurons. The postganglionic nerve fibres ascend only a small part of the Plexus mesentericus inferior (not shown); the others mostly reach the Colon descendens as direct branches.

The **parasympathicus promotes,** and the **sympathicus inhibits** peristalsis and blood flow to the bowel.

Note: Due to **developmental changes** all areas supplied by neurovascular pathways **switch** at the **left colic flexure.** Regarding the autonomic nerves: the **Plexus mesentericus superior** innervates the Colon ascendens and Colon transversum, while the **Plexus mesentericus inferior** and **Plexus hypogastricus inferior** innervate the Colon descendens and Colon sigmoideum. The origin of the parasympathetic neurons switches from the cranial part (N. vagus) to the sacral part (Nn. splanchnici pelvici).

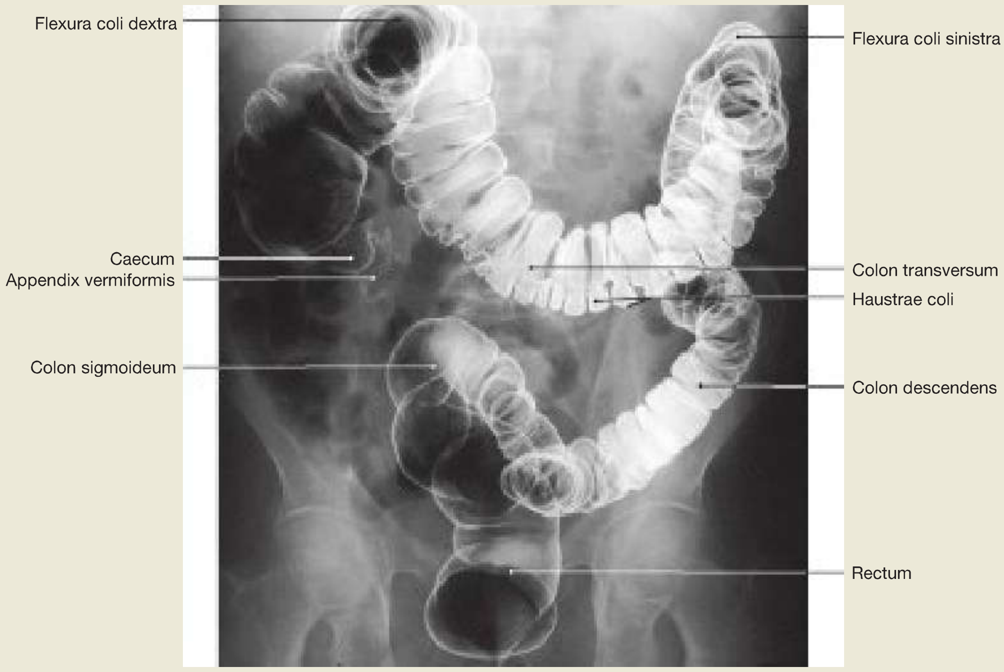


Fig. 6.74 Large intestine, Intestine crassum; X-ray in anteroposterior (AP) beam projection after filling it with contrast agent and air (double contrast method). In the X-ray image various positional variants of the Colon transversum can be verified (→ Fig. 6.75).

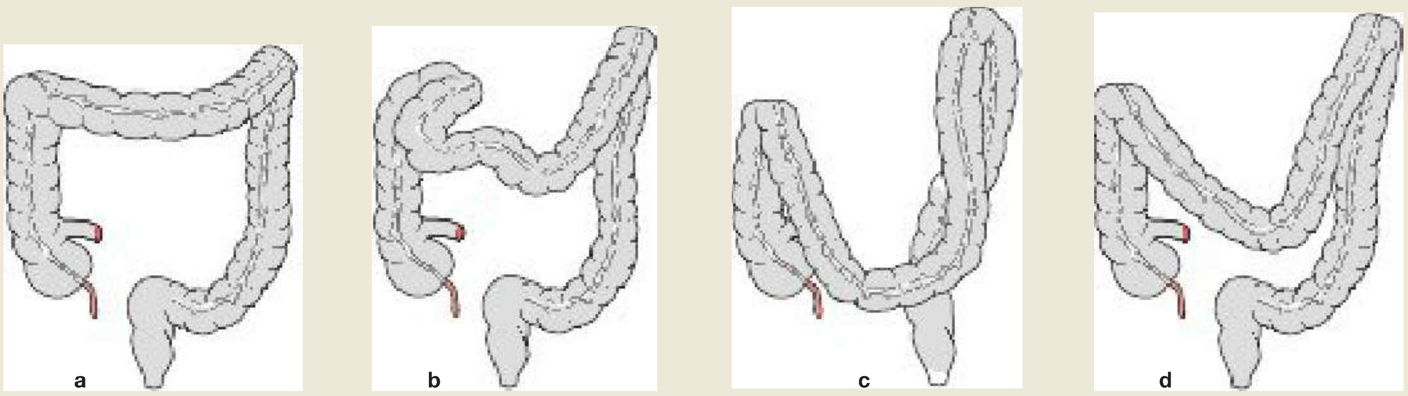


Fig. 6.75a to d Positional variants of the transverse colon, Colon transversum; ventral view. [L126]

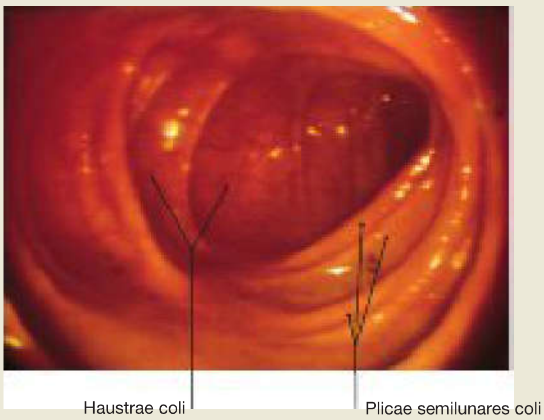


Fig. 6.76 Ascending colon, Colon ascendens; colonoscopy (endoscopy).
In contrast to the circular mucosal folds of the small intestine, the mucosal folds of the large intestine are crescent-shaped (semilunar folds).

Clinical Remarks

Malignant tumours of the colon **(colon carcinomas)** are among the most common malignancies in both men and women, and therefore contribute substantially to the causes of death in the Western world. These deaths can largely be prevented by taking suitable precautions. The diagnosis of choice for the evaluation of colon cancers is the colonoscopy, and screening is therefore recommended as a precautionary measure at regular intervals and reimbursed by health insurers. Not only does colonoscopy enable the inspection of the mucosa but it also allows for the taking of biopsies for the definitive diagnosis by a pathologist. The importance of radiological contrast-imaging has declined. However, in the case of an occluded lumen, e.g. by a stenotic tumour or a submucosal disease process which is endoscopically not accessible due to characteristic changes of shape and position of the lumen, it allows for a relatively reliable diagnosis.

Projection of the Liver and Gallbladder

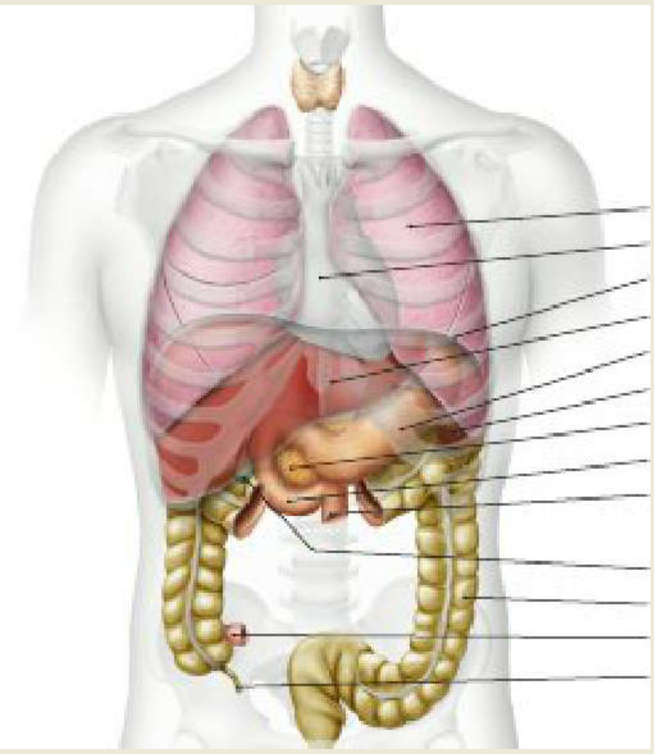


Fig. 6.77 Projection of the internal organs onto the body surface; ventral view. [L275]
The liver (Hepar) and gallbladder (Vesica biliaris) are located **intraperitoneally** in the right epigastrium. The upper margin of the liver (Hepar) projects to the right on the fourth intercostal space (ICS), on the left somewhat deeper onto the intercostal vein. The fundus of the gallbladder, Vesica biliaris, projects onto the right midclavicular line at the level of rib IX. The left lobe of the liver (Hepar) is located in the left epigastrium (approximately up to the left midclavicular line) where it is anterior to the stomach (Gaster). Its location depends on breathing (lowers on breathing in, rises on breathing out) as its surface area grows with the diaphragm. Therefore, its position is also dependent on the size of the lungs. Because of the domed shape of the diaphragm, the anterior and posterior sides of the liver (Hepar) are partially covered by the pleural cavity (→ Fig. 6.136). The lower margin of the liver (Hepar) in normal anatomy comes right up to the midclavicular line together with the costal arch, so that it is not possible to palpate the liver (Hepar).

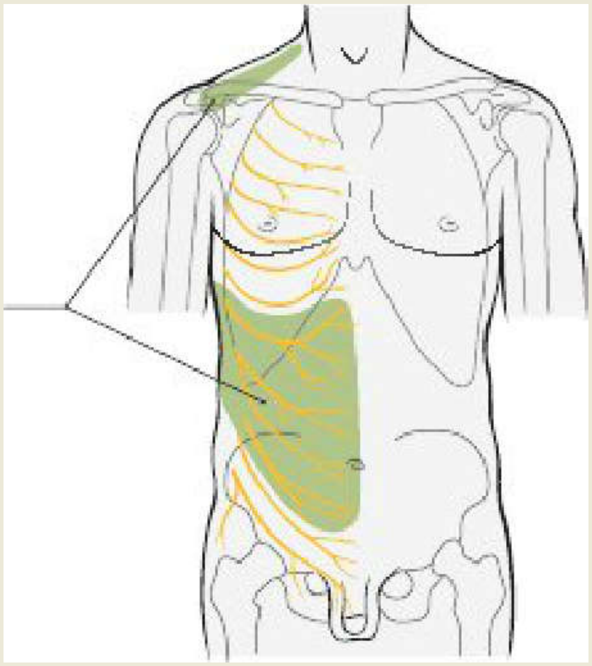


Fig. 6.78 HEAD's zones of the liver, Hepar, and gallbladder, Vesica biliaris, schematic drawing; ventral view. [L126]
The organ-related skin areas or **HEAD's zones** for the liver (Hepar) and gallbladder (Vesica biliaris) project into the dermatomes (cutaneous areas) T8–T11 of the right side of the body. Dermatome C4 in the area of the right shoulder is also a HEAD's zone of the liver and gallbladder, because the N. phrenicus of the Plexus cervicalis is mainly fed by C4, and with its terminal branch (R. phrenicoabdominalis) on the right side also sensorily innervates the peritoneum on the surface of the liver and gallbladder.

Clinical Remarks

The **determining of the liver size** is part of each complete physical examination, as its consistency and size can provide the first evidence of abnormal changes, e. g. **hepatic steatosis** (in diabetes mellitus, alcohol abuse), **inflammation** (hepatitis) due to hepatitis viruses or alcohol abuse or **liver cirrhosis** as the terminal stage in most chronic liver diseases. Not only the bottom margin of the liver should be palpated when breathing in, but also the upper margin of the liver by tapping (percussion) on the chest. As a rule of thumb, the liver in the right midclavicular line should not occupy the cranio-caudal diameter by any more than 12 cm.
In cases of liver and gallbladder inflammation (hepatitis or cholecystitis) or after a **liver biopsy** performed to enable diagnosis, pain in the right shoulder can result due to the HEAD's zones.

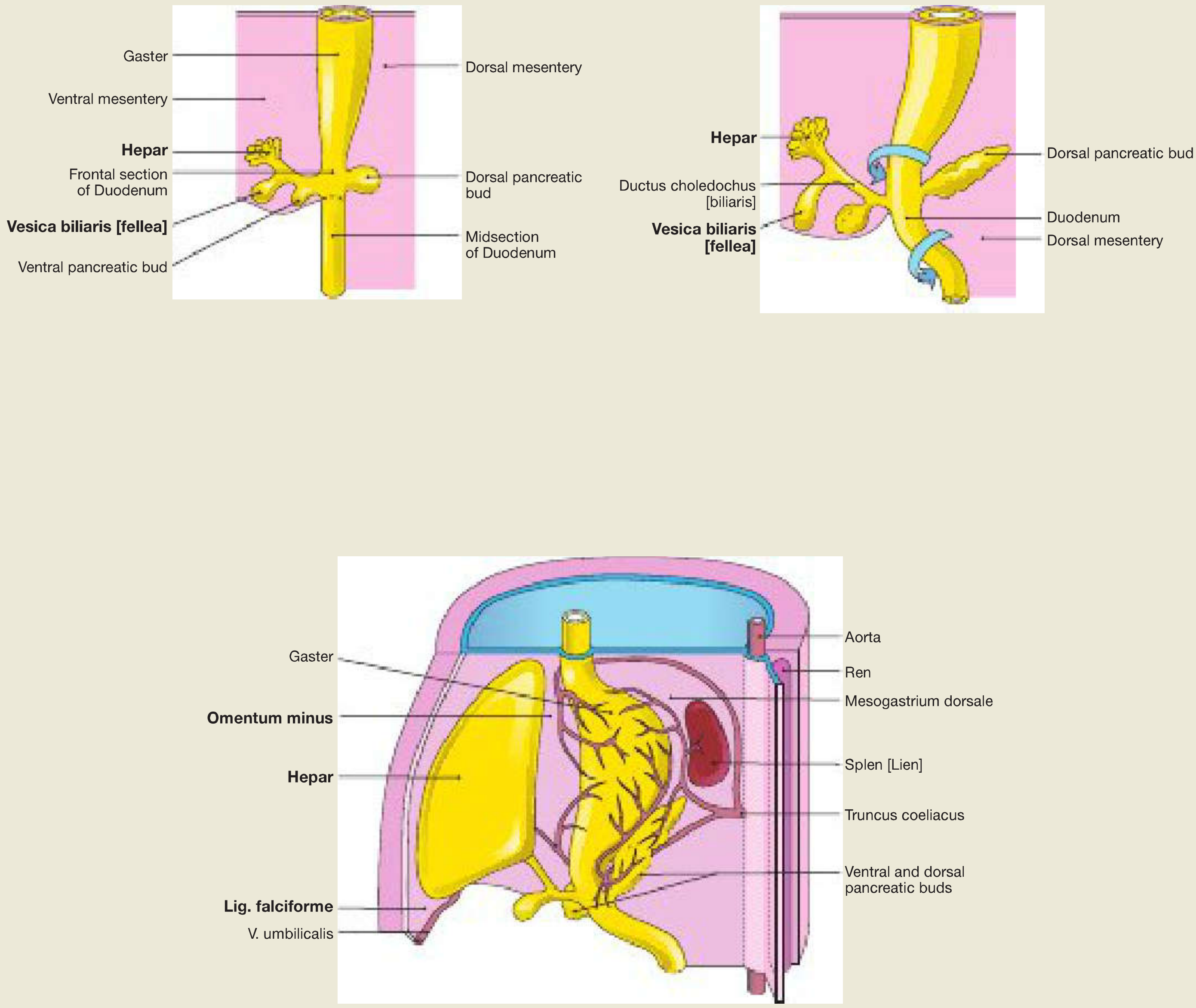
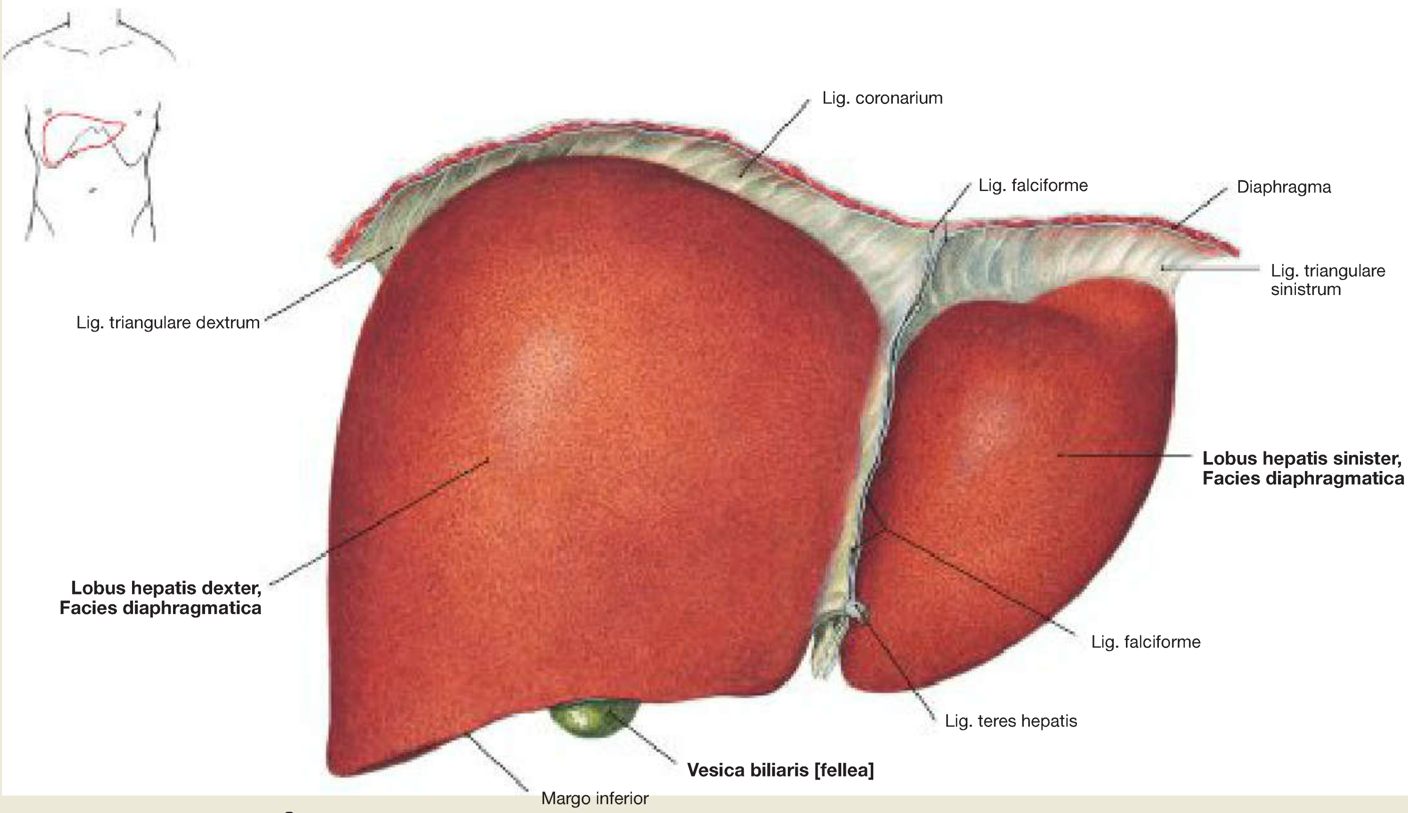


Fig. 6.79a to c Developmental stages of the liver, Hepar, and gallbladder, Vesica biliaris, in the 4th–5th week. [E347-09]

The epithelial tissues of the liver and the gallbladder derive from the entoderm of the primordial gut at the level of the future duodenum. The entoderm, in the fourth week (from the 22nd day onwards), forms a thickening **(hepatic diverticulum)** which divides into a superior liver primordium and an inferior primordium for the bile duct system **(a** and **b).** The epithelium of the liver system grows in the connective tissue of the Septum transversum, in which islets of haematopoiesis develop. Thus the connective tissue components and the regional blood vessels (sinusoids) enter into the liver system. The liver then grows into the Mesogastrium ventrale **(c)** and thereby splits into a Mesohepaticum ventrale and a Mesohepaticum dorsale (→ Fig. 6.1). The Mesohepaticum ventrale develops into the **Lig. falcifome hepatis** and connects to the ventral body wall. The Mesohepaticum dorsale becomes the **Omentum minus** connecting the liver with the stomach and the duodenum.

Liver and Gallbladder

Liver, Overview



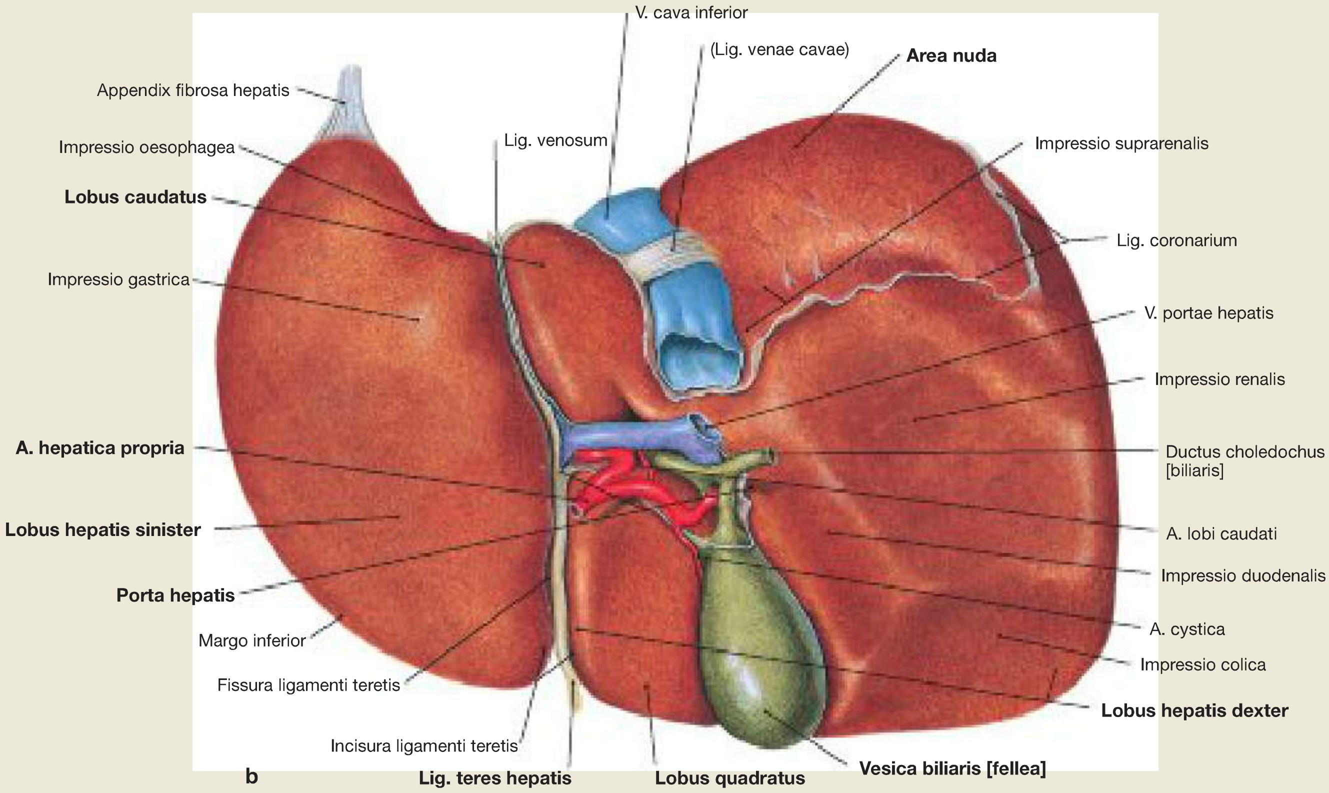


Fig. 6.80a and b Liver, Hepar; ventral view (→ Fig. 6.80a) and dorsal caudal view (→ Fig. 6.80b). For a description → Fig. 6.81.

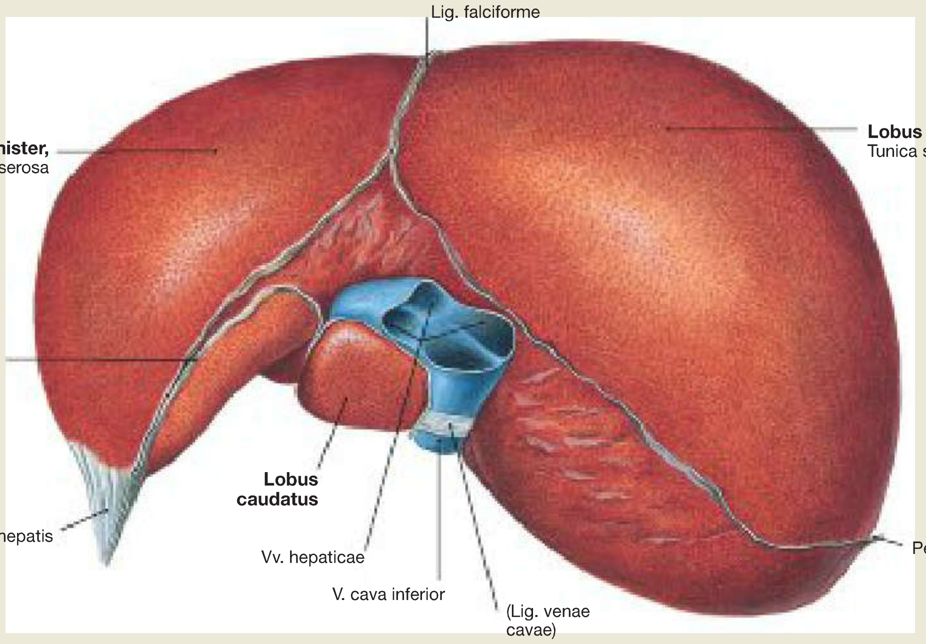


Fig. 6.81 Liver, Hepar; cranial view.
The liver is the largest gland (1,200–1,800 g) and the main metabolic organ of the body. The Facies diaphragmatica lies adjacent to the diaphragm and the Facies visceralis with the anterior lower margin (Margo inferior) points towards the abdominal viscera (→ Fig. 6.80a and b).
The **Facies diaphragmatica** has partially grown into the diaphragm and is not covered with visceral peritoneum **(Area nuda).** The liver is divided into a large **right lobe** and a small **left lobe** (Lobus dexter and Lobus sinister), separated at the front by the **Lig. falciforme.** This continues cranially into the **Lig. coronarium,** which ends on the right and left in a **Lig. triangulare** connected to the diaphragm. The left Lig. triangulare passes into the pointed Appendix fibrosa hepatis. Below, the **Lig. teres hepatis** (a remnant from the foetal circulation of the V. umbilicalis) joins with the falciform ligament. Both bands reach the ventral wall.
On the **Facies visceralis,** the Fissura ligamenti teretis hepatis continues to the hilum of the liver (Porta hepatis), into which the neurovascular pathways of the liver (V. portae hepatis, A. hepatica propria, Ductus hepaticus communis) enter and exit. The **Lig. venosum** (**ARANTII,** a remnant of the foetal circulatory Ductus venosus) is shown cranially. On the right side of the Porta hepatis (hilum of the liver), the V. cava inferior is located in a superior groove, and the **gallbladder (Vesica biliaris)** is embedded in the inferior fossa for the gallbladder (Fossa vesicae biliaris). The Lig. teres hepatis, Lig. venosum, V. cava inferior, and gallbladder delineate two rectangular areas on both sides of the Porta hepatis at the inferior side of the right hepatic lobe, the ventral **Lobus quadratus** and the dorsal **Lobus caudatus.** The liver is not covered by peritoneum in four larger areas: Area nuda, the hilum of the liver, the bed of the gallbladder, and the groove of the V. cava inferior.
In living patients the liver is malleable and adjusts to the shape of the surrounding organs. In a fixed state the organs leave marks (impressions), which are regarded as fixation artefacts and are without significance. However, they provide information about the positions of the liver.

Structure of the Liver

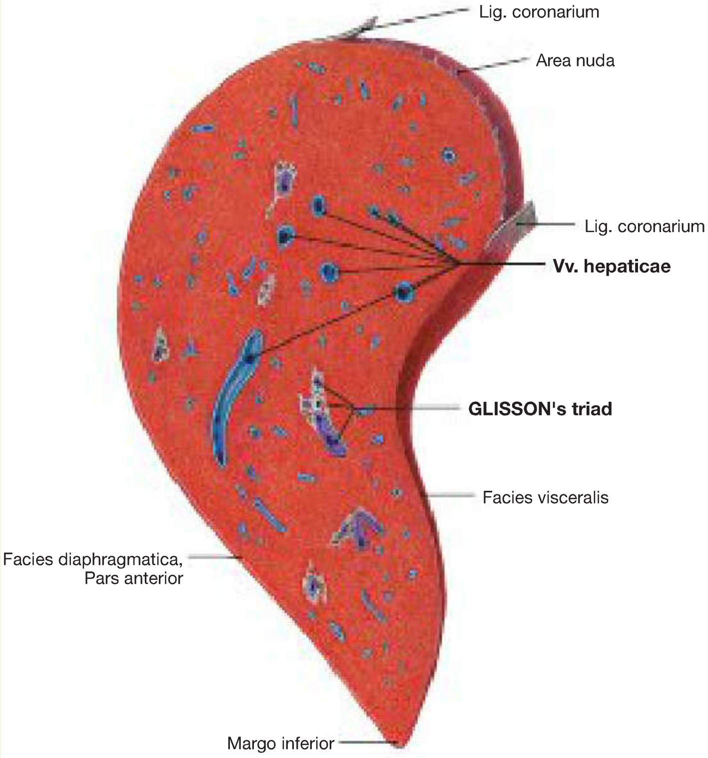


Fig. 6.82 Liver, Hepar; sagittal section through the right liver lobe.
The entry and exit of the vascular and bile duct structures at the **Porta hepatis (V. portae hepatis, A. hepatica propria, Ductus hepaticus communis)** branch, surrounded by connective tissue, into the parenchyma of the liver and form the **GLISSON's triad** (→ Fig. 6.83) in the periportal field.
The liver veins **(Vv. hepaticae)** and their tributaries, which take the blood from the liver to the V. cava inferior course separately from the vessels of the GLISSON's triad.

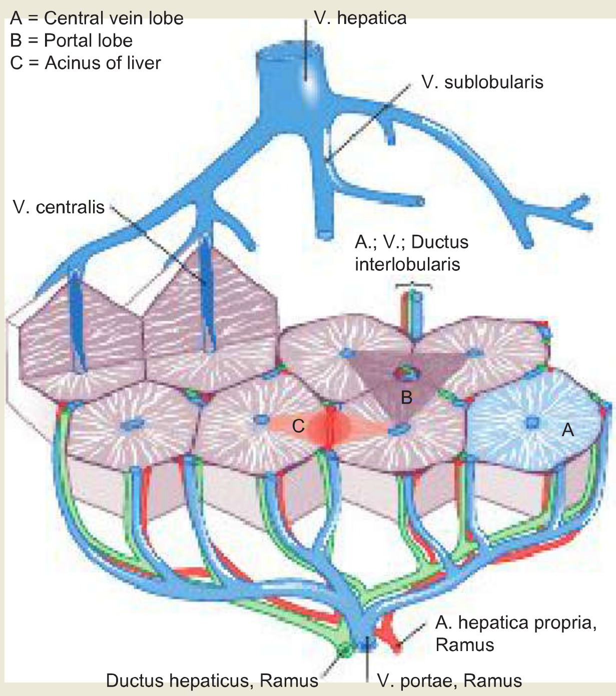
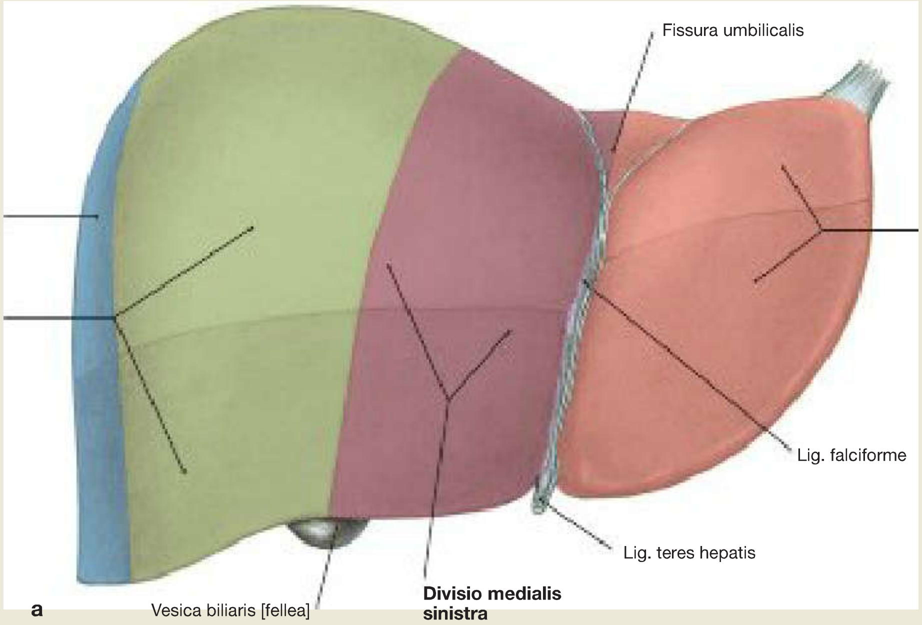


Fig. 6.83 Lobular structure of the hepatic parenchyma; schematic representation of a histological section. [L126]
The hepatic parenchyma is divided into liver lobes which are made up of radially arranged trabeculae of **hepatocytes.** The almost hexagonal **classic hepatic lobule** is surrounded by **portal tracts** at three to six corners. In the portal tract is the **GLISSON's triad** (A./V. interlobularis, Ductus interlobularis bilifer) which is covered by connective tissue. The blood vessels constitute the terminal branches of the A. hepatica propria/portal vein, while the interlobular bile duct forms the beginning of the bile duct system, which unites at the hilum of the liver with the Ductus hepaticus communis. In the centre of the liver lobe is the **V. centralis.** The blood of the peripheral lobular arteries and veins, which enters the liver sinusoids between the liver trabeculae, is collected by the central lobular veins and drained via the Vv. sublobulares into the liver veins (Vv. hepaticae). This allows the hepatocytes to extract nutrients and substances to be eliminated from the blood and to secrete synthesised substances, such as plasma proteins, into the blood. The bile flows between the liver cells to the portal fields. Therefore the bile duct lies in the centre of the triangular **portal lobe,** while the three corners are formed by the central veins. The **acinus of the liver** is rhomboid and bordered by two portal fields and two central lobular veins. Along the axis of the connection between the portal fields is where oxygen and nutrient supply is best, so that the hepatocytes in different zones of the acinus can play their part.

Clinical Remarks

The blood flow in the hepatic lobules is extremely important for the liver function. In the case of **liver cirrhosis**, the lobular structure is destroyed when it is altered by nodular connective tissue remodelling, so the blood flow is compromised. The high parenchymal resistance in the liver results in an increased blood pressure in the portal vein **(portal hypertension).** As a result, the formation of collateral circulations **(portocaval anastomoses)** may occur (→ Fig. 6.91).



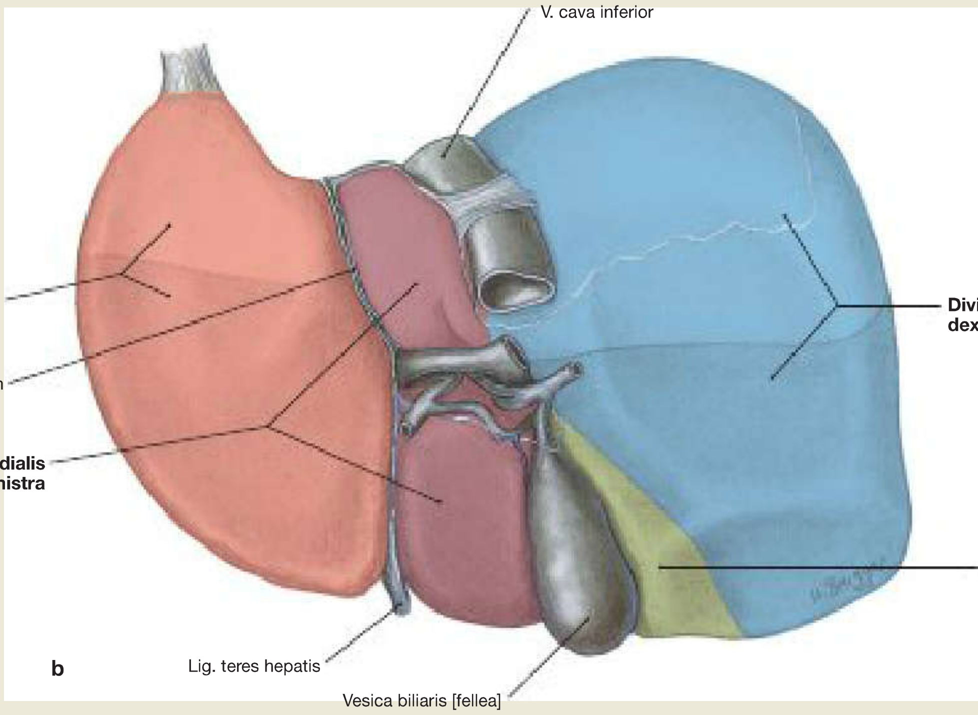
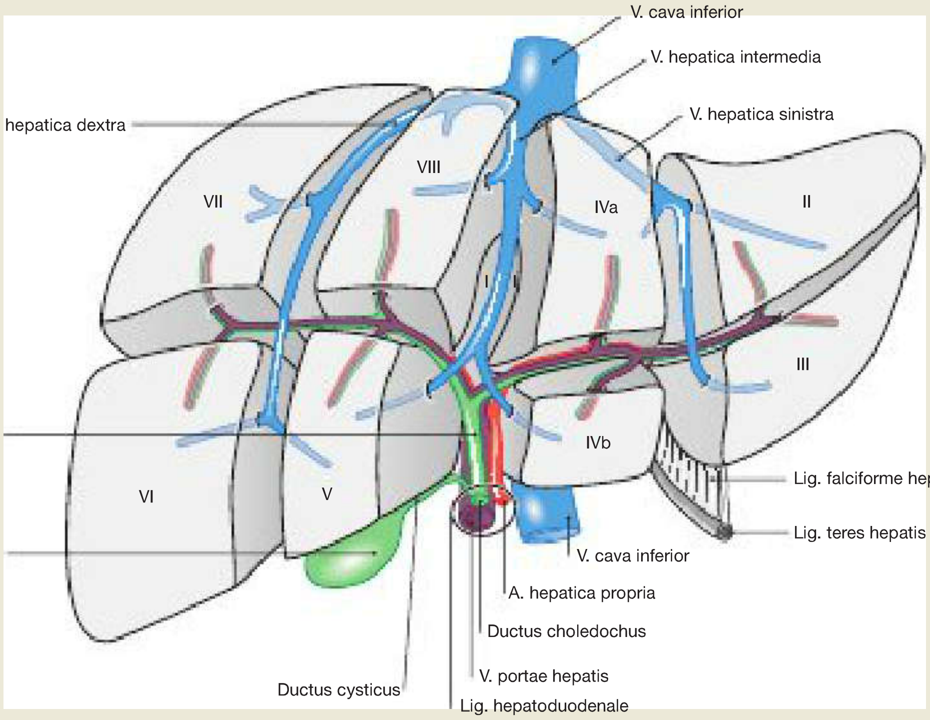


Fig. 6.84a and b Segments of the liver, Hepar; ventral view (→ Fig. 6.84a) and dorsal view (→ Fig. 6.84b). Segments of the liver lobes are highlighted in colour.

The **three** almost vertically oriented **hepatic veins (Vv. hepaticae;** → Fig. 6.85) divide the liver into **four adjacent divisions.** The **Divisio lateralis sinistra** corresponds to the left anatomical lobe of the liver and thus reaches the Lig. falcifome hepatis, behind the left hepatic vein. Between the Lig. falciforme and the gallbladder at the level of the V. hepatica intermedia, the **Divisio medialis sinistra** extends. Then to the right side follow the **Divisio medialis dextra** and the **Divisio lateralis dextra,** which are separated by the right hepatic vein; but there is no visible landmark for this on the outer surface. The neurovascular pathways of the **portal triad** organise these liver segments into **eight functional** and clinically very important **liver segments** (→ Fig. 6.85) which are indicated here with different colours.

Liver Segments



I	Lobus caudatus	V	Segmentum anterius mediale dextrum
II	Segmentum posterius laterale sinistrum	VI	Segmentum anterius laterale dextrum
III	Segmentum anterius laterale sinistrum	VII	Segmentum posterius laterale dextrum
IV (a/b)	Segmentum mediale sinistrum	VIII	Segmentum posterius mediale dextrum

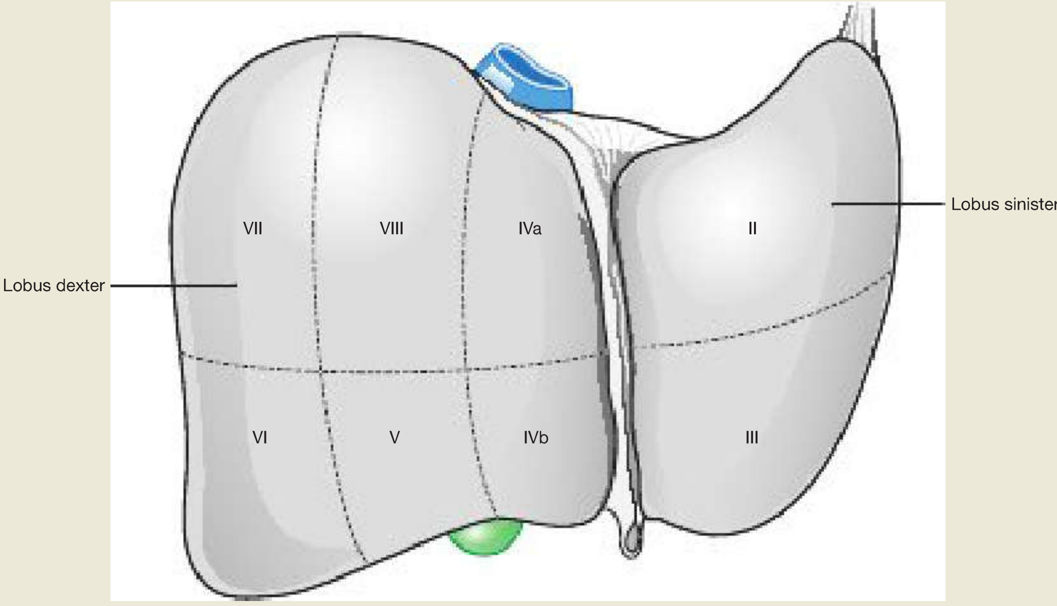
Fig. 6.85 Schematic illustration of the liver segments and their relationship with the regional vessels and bile ducts; ventral view. [L126]

The liver is divided into **eight functional segments** which are supplied by one branch of the portal triad (V. portae hepatis, A. hepatica propria, Ductus hepaticus communis) each and therefore are functionally independent. Two segments each are combined by the vertically oriented three hepatic veins to four adjacent liver segments (→ Fig. 6.84a and b).

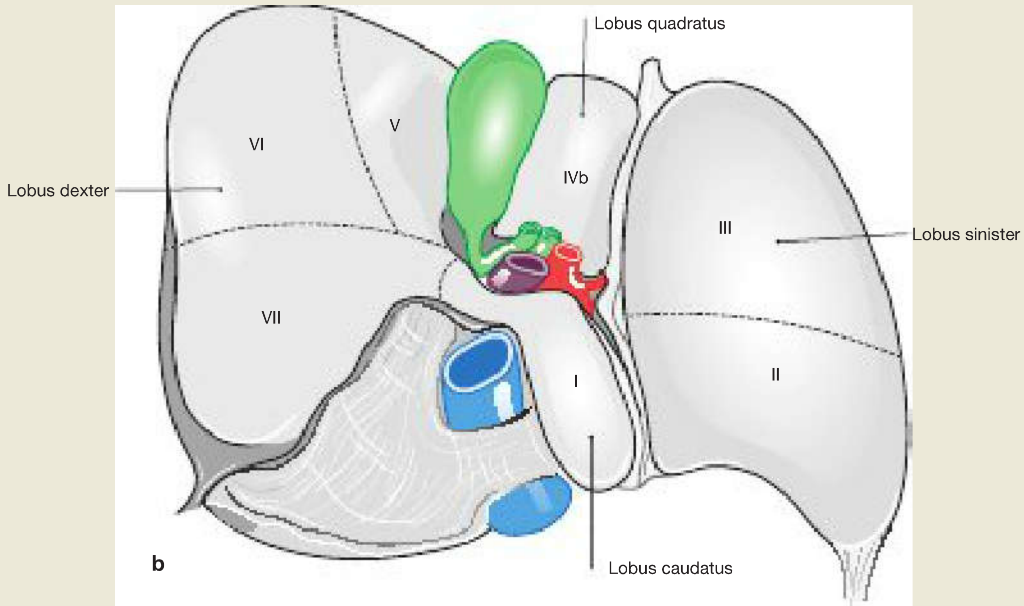
Functionally it is important that the **segments I to IV** are supplied by the left branches of the portal triad and are thus combined into a **functional left liver lobe,** while the **segments V to VIII** are dependent on the right branches of the blood vessels and represent the **functional right liver lobe.** As a result, the border between the functional right and left liver lobes is located in the sagittal plane between the V. cava inferior and the gallbladder **(cava-gallbladder line)** and not at the level of the Lig. falcifome hepatis. The segment I (Lobus caudatus) is regularly supplied from the branches on both sides.

Clinical Remarks

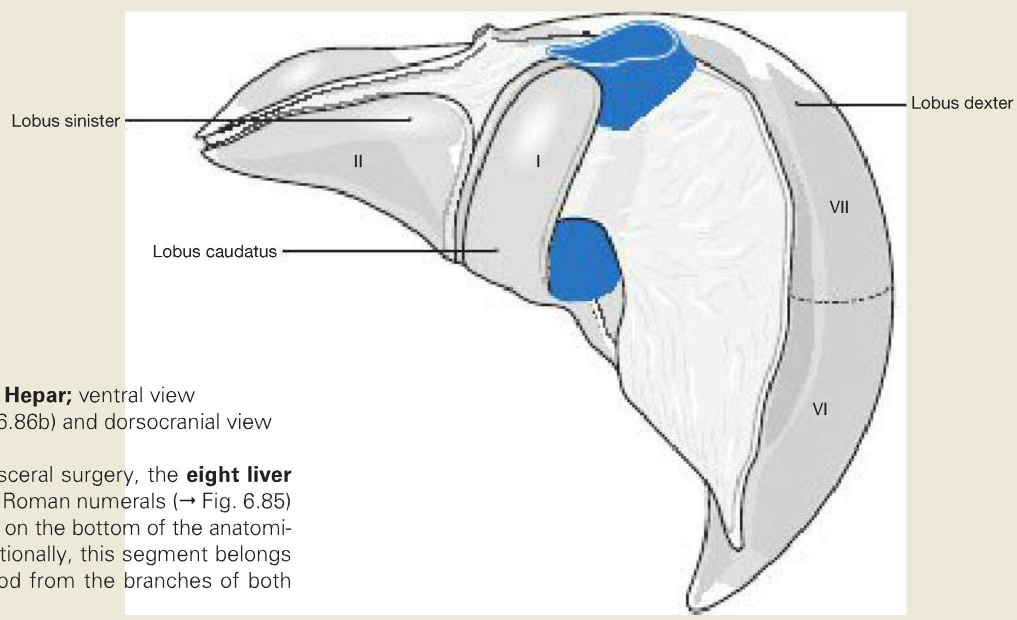
The liver segments are clinically very significant in **visceral surgery,** since, as long as the borders of the segments are maintained, they make it possible to carry out resections of individual parts of the liver with little loss of blood. This means that pathologies such as liver metastases can be treated by the surgical resection of individual segments in different parts of the liver without compromising the liver function as a whole. The ligation of the individual branches of the supplying vessels and the subsequent discolouration of the respective segment due to lack of perfusion enables the surgeon to identify each segment.



a



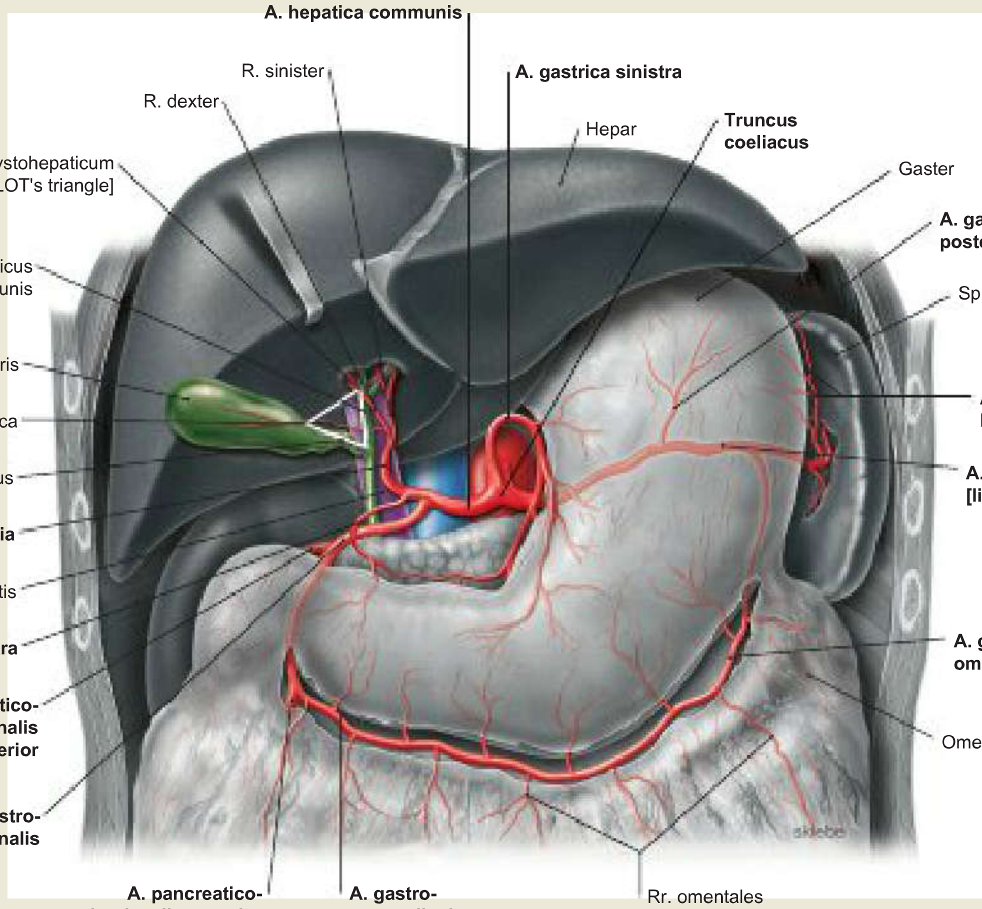
b



c

Fig. 6.86a to c Segments of the liver, Hepar; ventral view (→ Fig. 6.86a), dorsocaudal view (→ Fig. 6.86b) and dorsocranial view (→ Fig. 6.86c). [L126]
Because of their clinical relevance for visceral surgery, the **eight liver segments** are marked in this figure with Roman numerals (→ Fig. 6.85) on the liver surface. The Lobus caudatus on the bottom of the anatomical right liver lobe forms segment I. Functionally, this segment belongs to the left liver lobe, but it receives blood from the branches of both sides.

Arteries of the Liver and Gallbladder



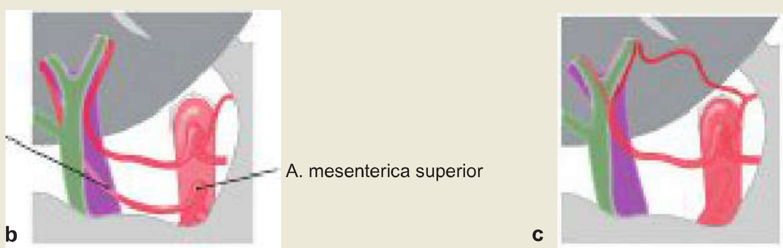


Fig. 6.87a to c Arteries of the liver, Hepar, and gallbladder, Vesica biliaris. a [L238], b, c [L281]
The liver is supplied with blood by the **A. hepatica propria.** This is the continuation of the A. hepatica communis, which represents a main branch of the Truncus coeliacus. After delivering the A. gastrica dextra, the A. hepatica propria passes into the Lig. hepatoduodenale together with the V. portae hepatis and the Ductus choledochus to the Porta hepatis. There it is generally divided into a R. dexter and a R. sinister for the two lobes of the liver. From the R. dexter originates the **A. cystica,** supplying the gallbladder. In 10–20% of all cases, the A. mesenterica superior contributes to the blood supply of the right liver lobe, and the A. gastrica sinistra contributes to the supply of the left liver lobe.
Variations of the blood supply of the liver:
a Textbook case (≈ 50%)
b Contribution of the A. mesenterica superior to the blood supply of the right liver lobe (≈ 10–20%)
c Contribution of the A. gastrica sinistra to the blood supply of the left liver lobe (10–20%)

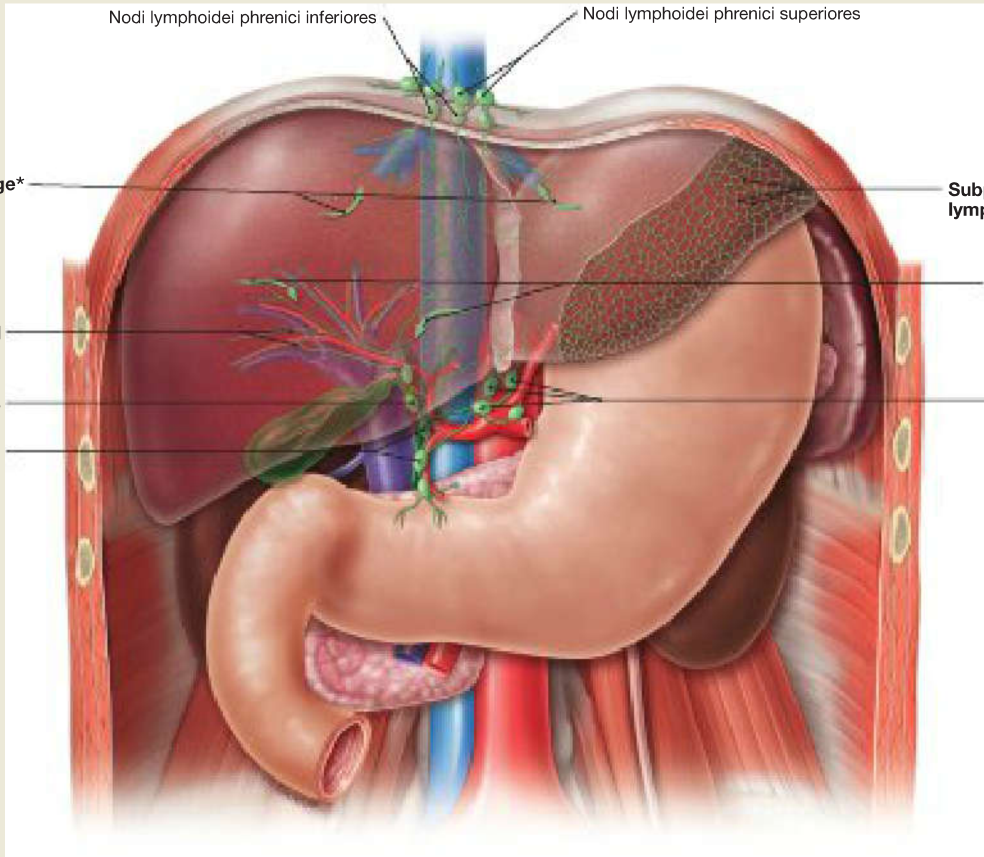


Fig. 6.88 Lymphatic vessels and lymph nodes of the liver and bile duct system. [L238]

The **liver** has **two lymphatic vessel systems:**
- the subperitoneal system on the surface of the liver
- the intraparenchymal system that follows the structures in the portal triad to the hilum of the liver.

With respect to the regional lymph nodes, there are **two major lymphatic drainage routes:**
- in the **caudal direction to the hilum of the liver** (most important) via the Nodi lymphoidei hepatici (→ Fig. 6.36) and from there via the Nodi lymphoidei coeliaci to the intestinal trunk
- in the **cranial direction through the diaphragm** via the Nodi lymphoidei phrenici inferiores and superiores into the Nodi lymphoidei mediastinales anteriores and posteriores which drain into the Trunci bronchomediastinales; using this pathway liver carcinomas may metastasise into thoracic lymph nodes

There are also **two further routes** of lesser importance:
- to the anterior abdominal wall via lymphatic vessels in the Lig. teres hepatis to the inguinal and axillary lymph nodes
- to the stomach and pancreas from the left lobe of the liver

The **gallbladder** usually has its own Nodus lymphoideus cysticus in the area of the neck, which drains into the lymph nodes at the hilum of the liver (in the caudal direction).

* The arrows depict the direction of lymphatic drainage from the liver parenchyma via the cranial or caudal route.

For the autonomic innervation of the liver and gallbladder → Fig. 6.132

Veins of the Liver and Gallbladder

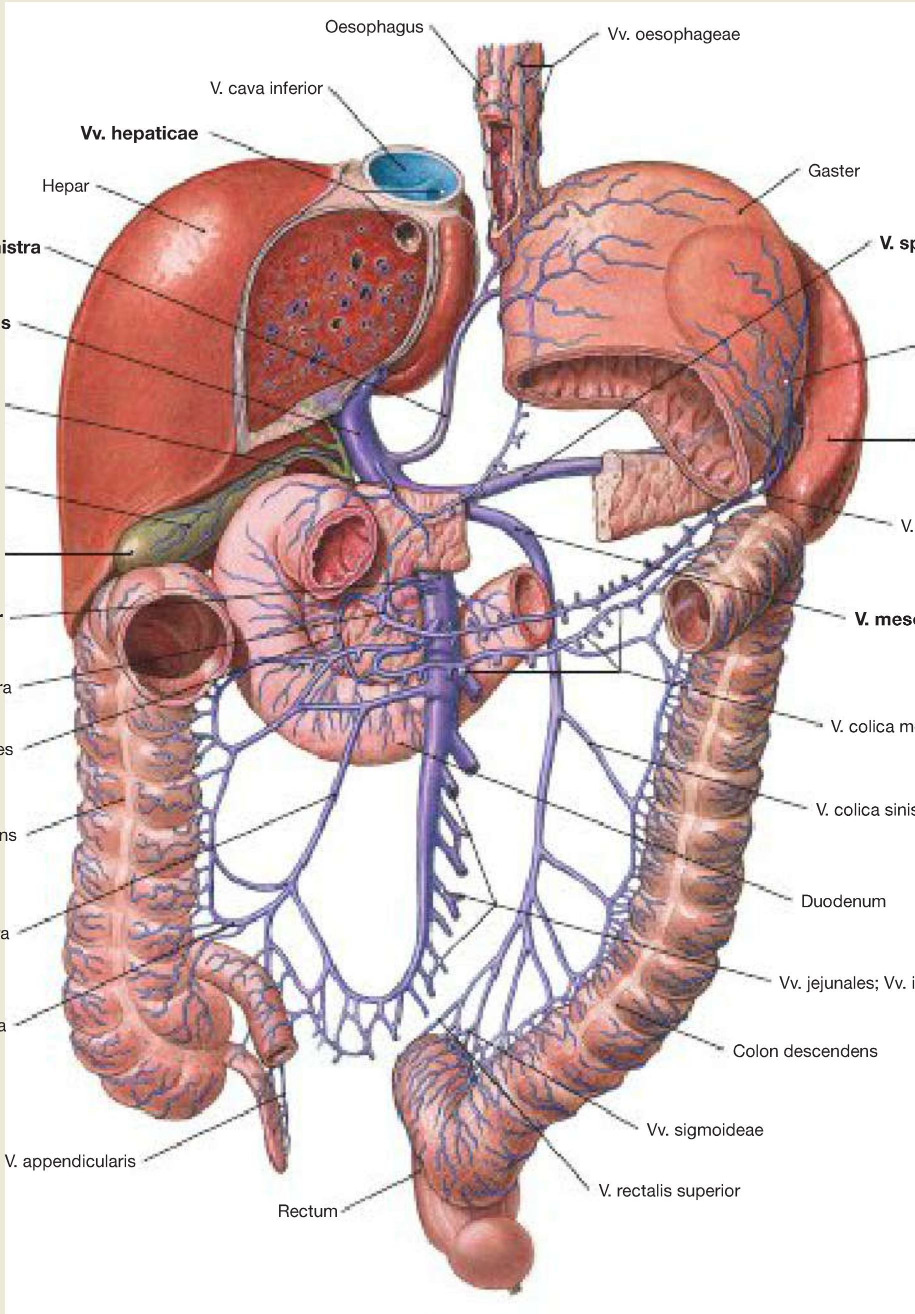


Fig. 6.89 Veins of the liver, Hepar, and the gallbladder, Vesica biliaris; ventral view.

The liver has an incoming and an outgoing venous system. The **V. portae hepatis** collects the nutrient-rich blood from the unpaired abdominal organs (stomach, intestines, pancreas, spleen) and feeds this blood, together with the arterial blood from the A. hepatica communis, into the sinusoids of the liver lobules. Three **Vv. hepaticae** (→ Fig. 6.85) transport the blood from the liver to the V. cava inferior.

The portal vein has three main tributaries: behind the Caput pancreatis, the V. mesenterica superior merges with the V. splenica to form the V. portae hepatis. The V. mesenterica inferior drains into the V. splenica (70 % of all cases) or into the V. mesenterica superior (30 %).

Branches of the V. splenica (collecting blood from the spleen and from parts of the stomach and pancreas):
- Vv. gastricae breves
- V. gastroomentalis sinistra
- Vv. pancreaticae (from the tail and body of the pancreas)

Branches of the V. mesenterica superior (collecting blood from parts of the stomach and pancreas, from the entire small intestine, the Colon ascendens, and Colon transversum):
- V. gastroomentalis dextra with Vv. pancreaticoduodenales
- Vv. pancreaticae (from the neck and body of the pancreas)
- Vv. jejunales und ileales
- V. ileocolica
- V. colica dextra
- V. colica media

Branches of the V. mesenterica inferior (collecting blood from the Colon descendens and the upper rectum):
- V. colica sinistra
- Vv. sigmoideae
- V. rectalis superior: the vein is connected to the V. rectalis media and the V. rectalis inferior, which count as a drainage area of the V. cava inferior.

In addition, there are **veins** which drain **directly into the portal vein** once the main venous branches have merged:
- V. cystica (from the gallbladder)
- Vv. paraumbilicales (via veins in the Lig. teres hepatis from the abdominal wall around the umbilicus)
- Vv. gastricae dextra and sinistra (from the lesser curvature of the stomach)

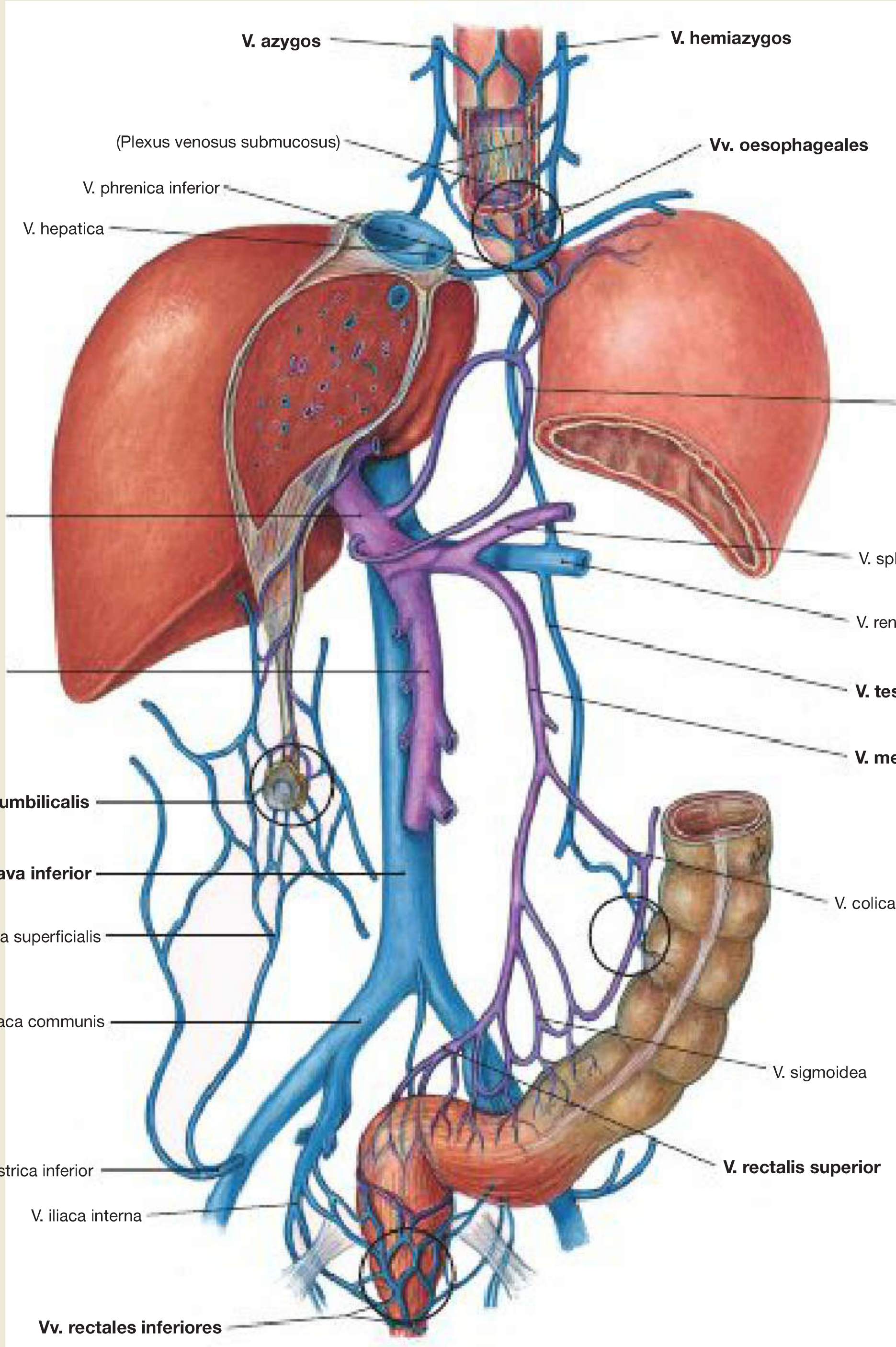
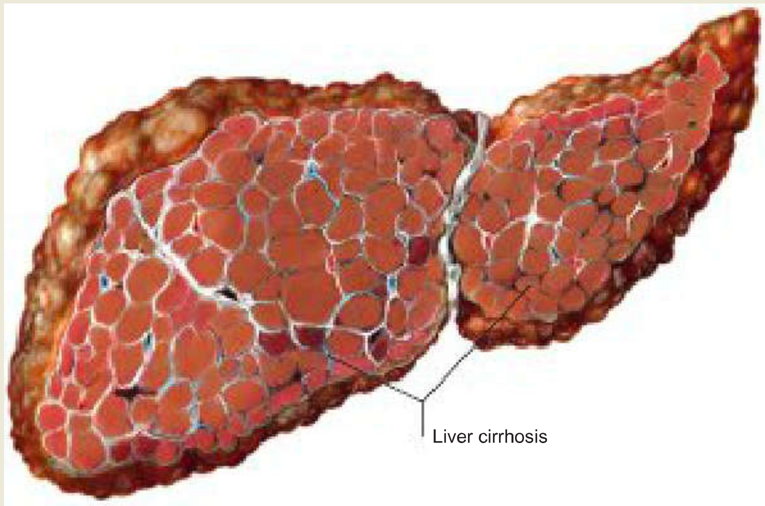


Fig. 6.90 Portocaval anastomoses (connections between V. portae hepatis and V. cava superior/inferior). Tributaries to the V. cava superior/inferior (blue) and the V. portae hepatis (purple). There are four possible collateral circulations via portocaval anastomoses (marked with black circles), through which the blood from the portal vein can bypass the liver on its way to the heart:

- Vv. gastricae dextra and sinistra through oesophageal veins and azygos veins to the V. cava superior. In this case, expansion of the submucosal veins of the oesophagus **(oesophageal varices)** can occur.
- Vv. paraumbilicales via the veins of the ventral abdominal wall (deep: Vv. epigastricae superior and inferior; superficial: V. thoracoepigastrica and V. epigastrica superficialis) to the Vv. cavae inferior and superior. The extension of the superficial veins may lead to **Caput medusae.**
- V. rectalis superior via veins of the distal rectum and the V. iliaca interna to the V. cava inferior
- retroperitoneal anastomoses via the V. mesenterica inferior to the V. testicularis/ovarica with connection to the V. cava inferior

Liver Cirrhosis

a



b

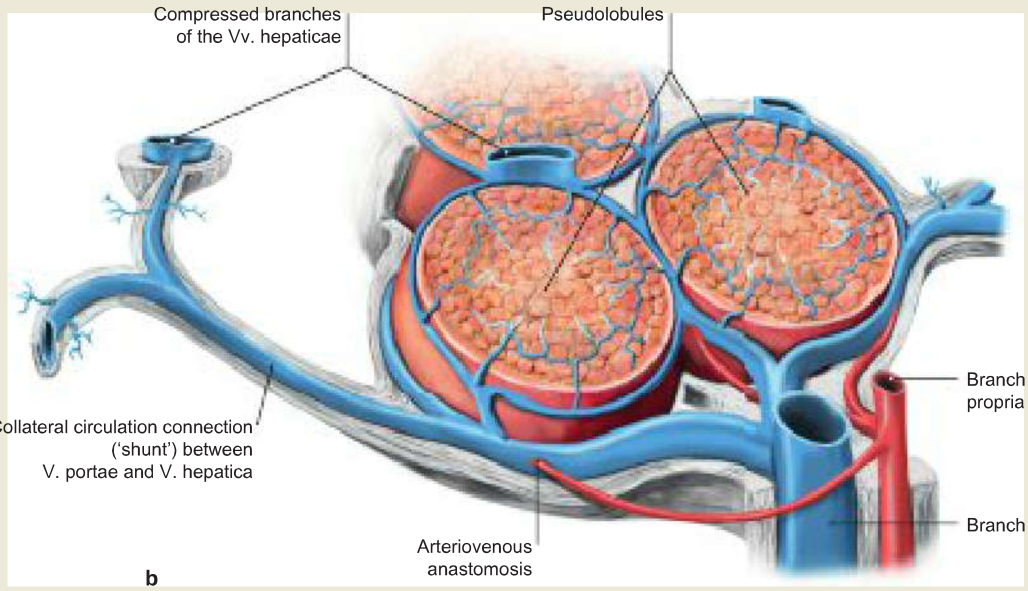


Fig. 6.91a and b Morphological changes in liver cirrhosis. [L266]
a Macroscopically visible node formation; frontal section through the liver.
b Formation of pseudolobules; schematic representation, partly with microscopic view.

Clinical Remarks

Cirrhosis is the end stage of many chronic liver diseases, when the liver is not acutely destroyed like e. g. in the case of poisoning with a amanita mushroom, but 'scarred' due to slowly progressing inflammation or persistent damage caused by connective tissue storage. The global perspective is therefore that liver cirrhosis is most frequently caused by viral hepatitis (hepatitis B, C and D), whereas in the industrialised world it is usually metabolically related, on the grounds of alcohol-induced hepatitis or increasingly also by hepatic steatosis in diabetes mellitus or obesity (adipositas). The scarring is already macroscopically visible in the formation of **nodes** on the surface. Although this node formation suggests an apparent regularity of the morphological changes, on closer examination, it can be recognised that the lobular structure of the liver parenchyma will be disappeared. Retention in the connective tissue results in the formation of **pseudolobules,** where the venous branches are compressed and the blood flow is disturbed. This results in high parenchymal resistance in the portal vein.

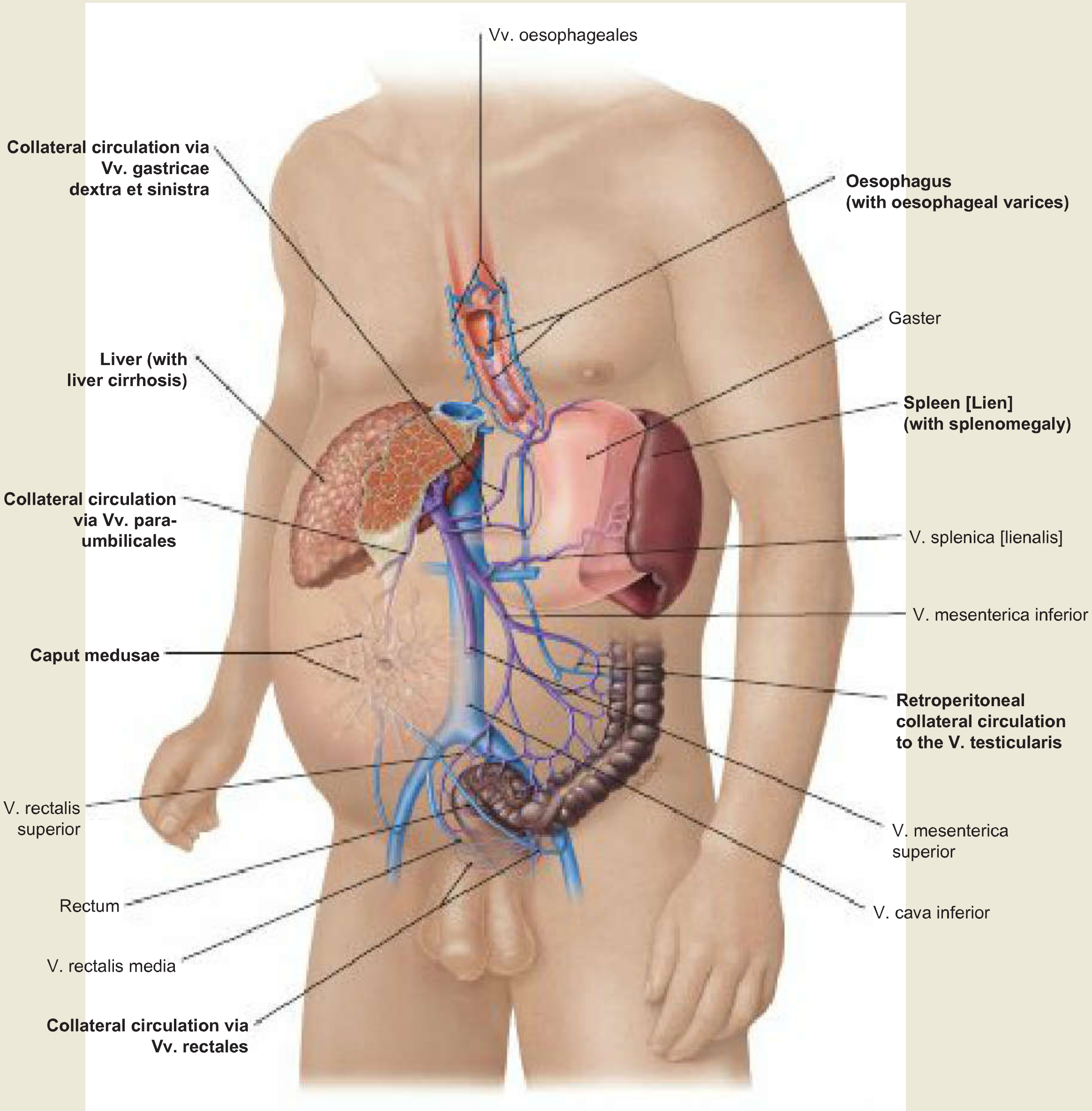


Fig. 6.92 Clinical view of the portocaval anastomoses by cirrhosis of the liver; schematic illustration, ventral view from the left side. [L238]

Clinical Remarks

In the case of cirrhosis there is a high parenchymal resistance in the V. portae hepatis (→ Fig. 6.91) and thus high blood pressure in the portal vein circulation **(portal hypertension).** As a result, the connections that have already been created to the supplying areas of the Vv. cavae superior and inferior **(portocaval anastomoses)** can open up or form. Clinically important are the connections to the **oesophageal veins** because rupture of oesophageal varices may result in **life-threatening haemorrhage**, the most common cause of death in patients with liver cirrhosis. The connections to superficial veins of the ventral abdominal wall are only of diagnostic value. Although the **Caput medusae** is rare, the appearance is so characteristic that liver cirrhosis cannot be overlooked. In contrast, the retroperitoneal connections and anastomoses between the veins of the rectum are not clinically significant.

Liver, Imaging

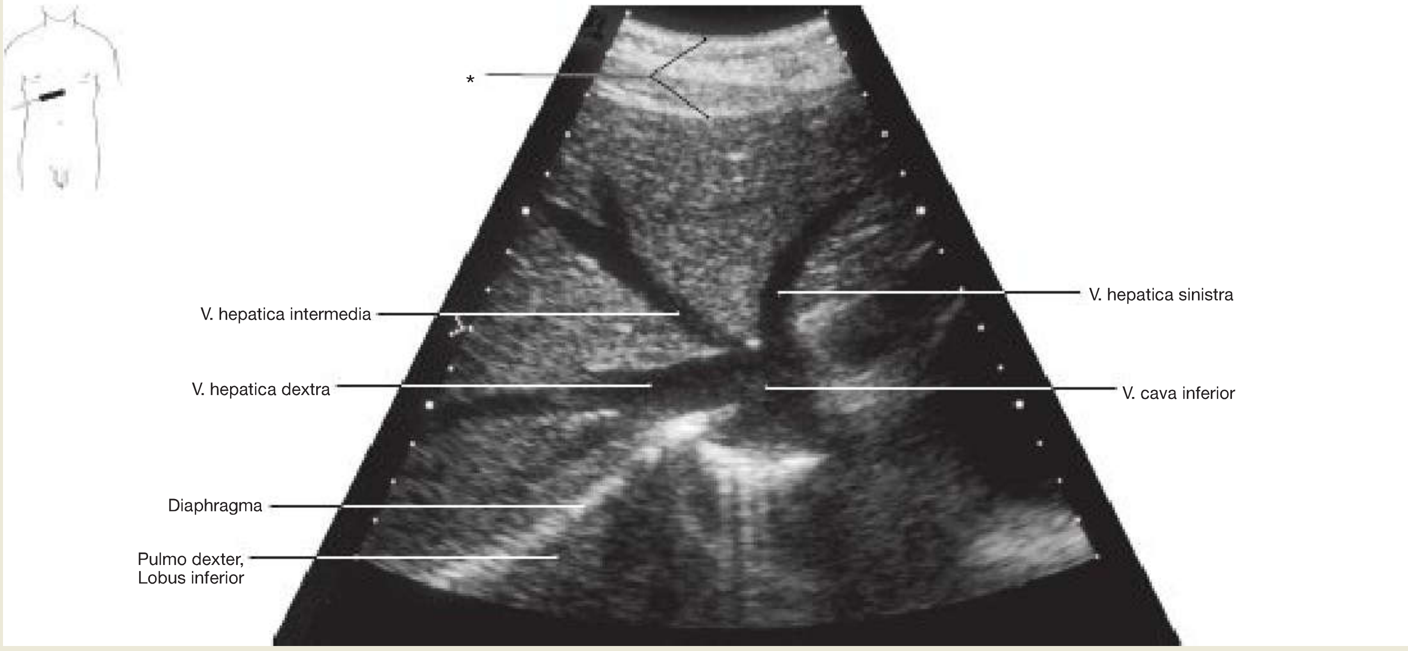


Fig. 6.93 Confluence of the Vv. hepaticae into the V. cava inferior; ultrasound image; caudal view. [T894]

* abdominal wall

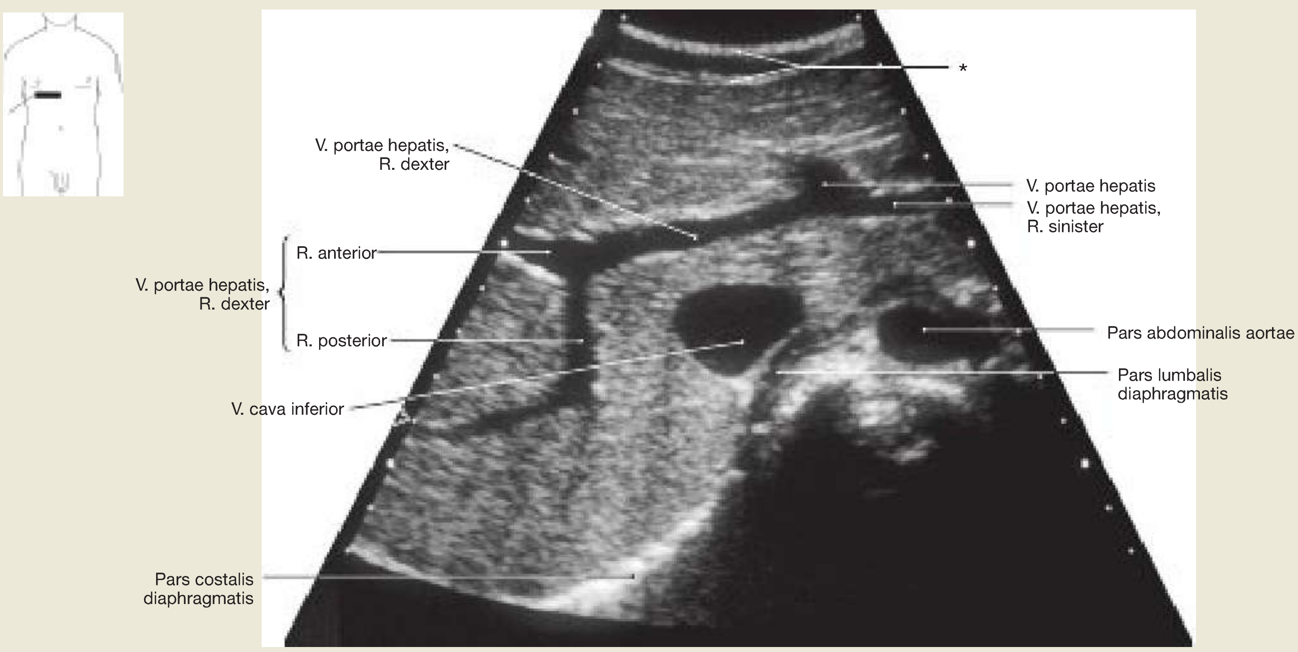


Fig. 6.94 Liver, Hepar, and V. portae hepatis; presentation of the branching of the portal vein; ultrasound image; caudal view. [T894]

* abdominal wall

Clinical Remarks

Ultrasound examination of the liver is a standard diagnostic tool used by specialists in internal medicine and by radiologists. It permits noninvasive investigation of the liver parenchyma; 'echo dense' steatosis (low echo) or fibrosis (increased echo) can be detected in hepatitis or liver cirrhosis. Focal tumours or cysts can also be captured. Where findings are unclear, liver biopsies (→ Fig. 6.94) or a laparoscopic examination of the liver (→ Fig. 6.98) will subsequently be carried out for further clarification.

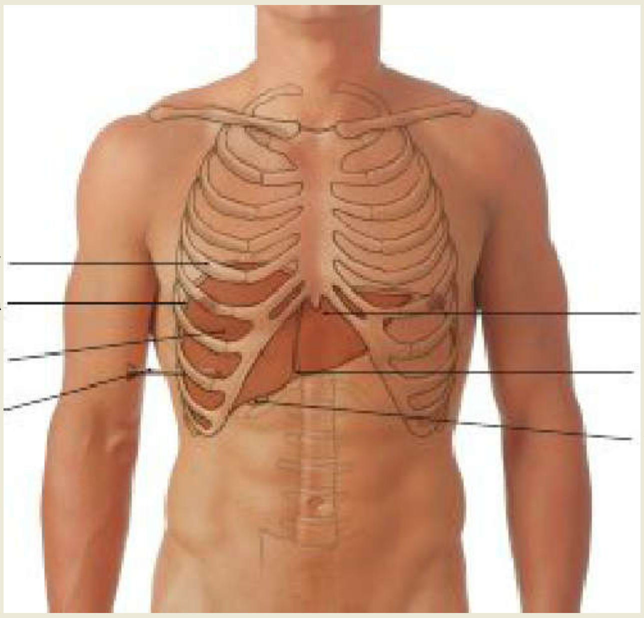


Fig. 6.95 Projection of the liver, Hepar, and gallbladder, Vesica biliaris, onto the ventral abdominal wall in mid-respiration position.

* position of the needle during puncture of the liver

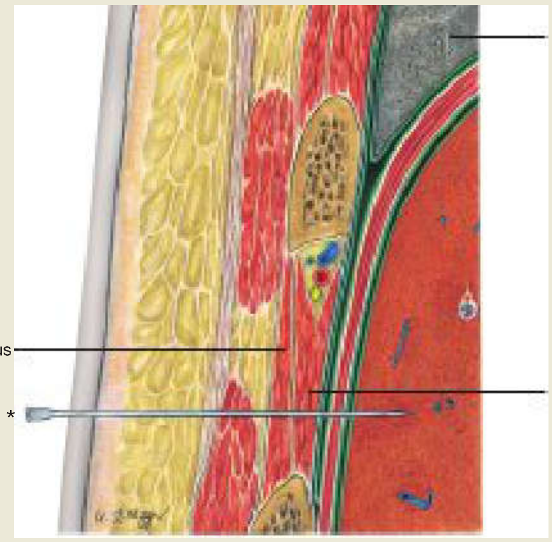


Fig. 6.96 Layers of the chest wall and liver, Hepar; frontal section; puncture biopsy of the liver.
The biopsy is carried out using ultrasound technology in expiration through one of the lower intercostal spaces. Otherwise there is the danger of causing a pneumothorax, since the liver is covered from above by the pleural cavity. In order to preserve the intercostal neurovascular structures, the puncture is always made at the superior costal margin. Since the peritoneum covering the liver capsule is innervated by the N. phrenicus (C3–C5) from the Plexus cervicalis, patients often feel a referred pain in the right shoulder.

* position of the needle during puncture biopsy of the liver

Clinical Remarks

A puncture biopsy of the liver is often performed to determine the nature of **suspicious tumours,** or the stage of a **hepatitis** or **liver cirrhosis,** respectively. Biopsies only enable a definitive diagnosis by a pathologist.

Structure of the Gallbladder and Extrahepatic Bile Ducts

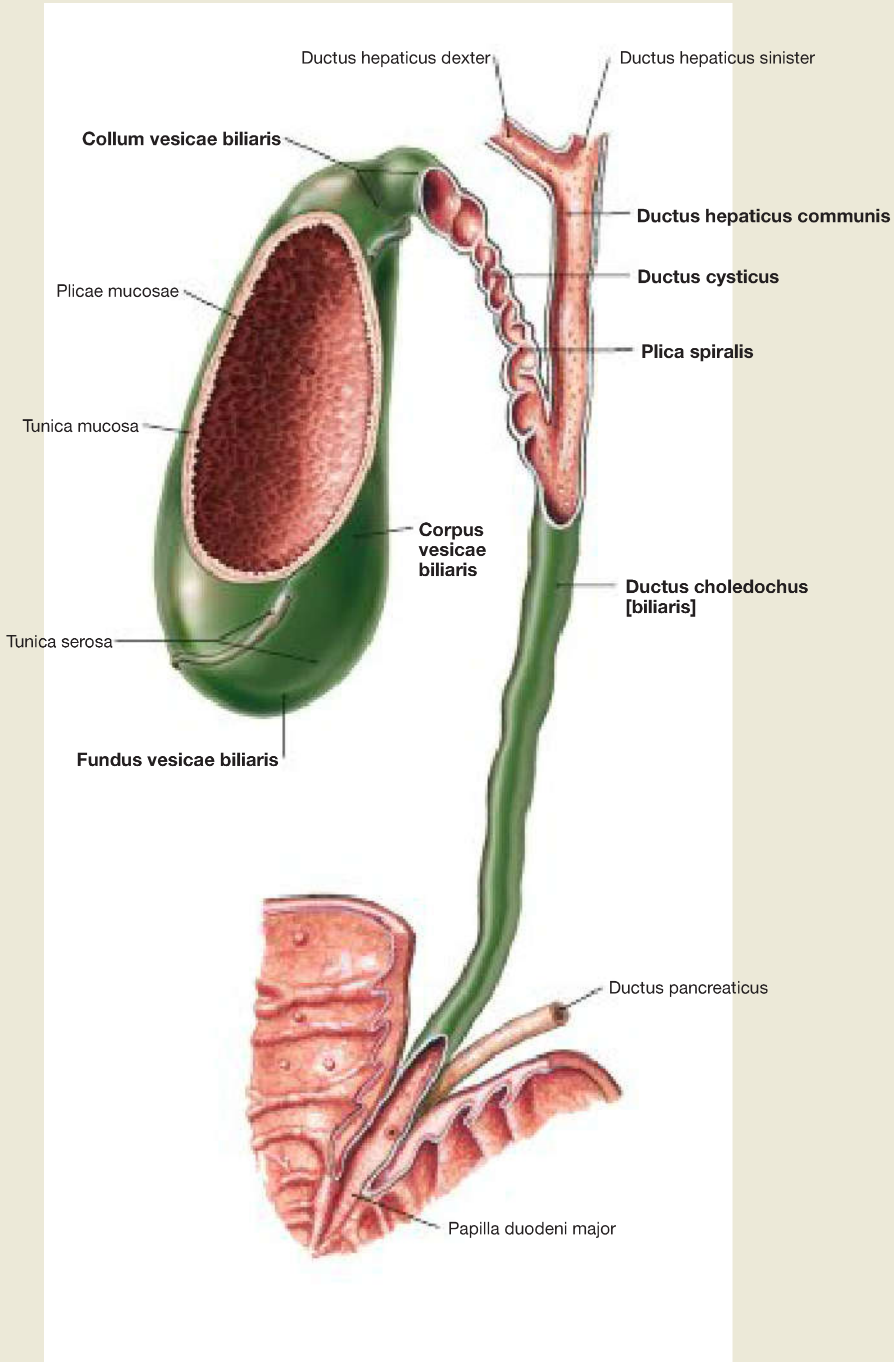


Fig. 6.97 Gallbladder, Vesica biliaris, and extrahepatic bile ducts; ventral view.
The gallbladder usually holds approximately 40–70 ml of bile. It consists of a **body (Corpus vesicae biliaris)** with a fundus and a **neck (Collum vesicae biliaris).** At the terminal end of the neck is the **excretory cystic duct (Ductus cysticus)**, which is closed by a **spiral fold (Plica spiralis HEISTERI)**, before fusing with the common hepatic duct (Ductus hepaticus communis) to form the common bile duct (Ductus choledochus).

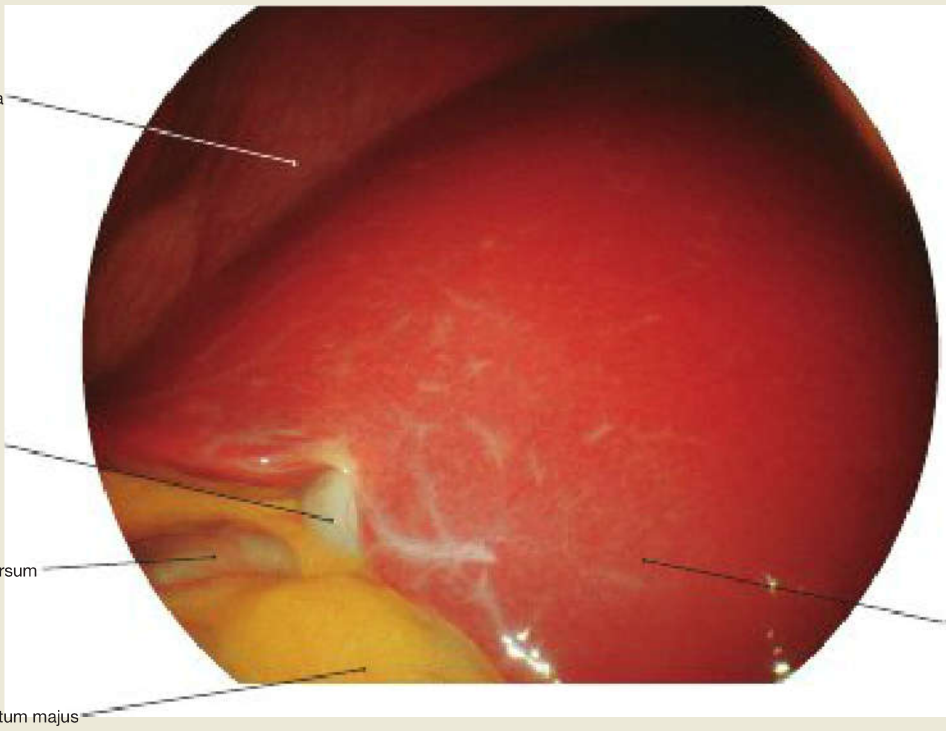


Fig. 6.98 Gallbladder, Vesica biliaris, and liver, Hepar; laparoscopy; oblique caudal view from the left side. [T894]

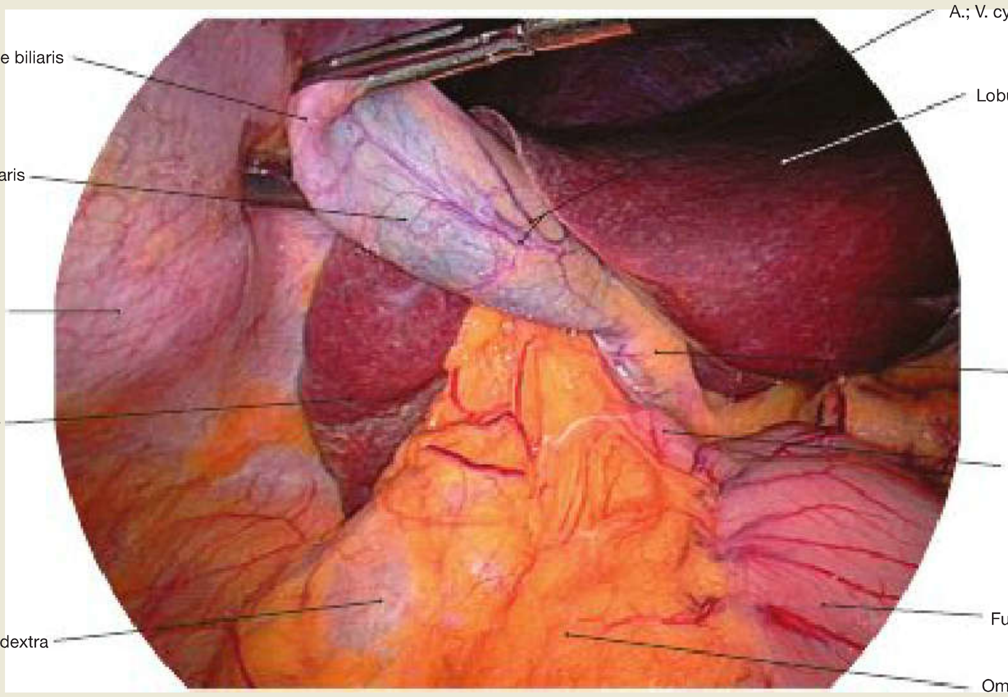


Fig. 6.99 Gallbladder, Vesica biliaris, and liver, Hepar; laparoscopy; ventral view. [T894]

Clinical Remarks

Laparoscopy enables the diagnostic imaging and resection of the gallbladder, without any surgical opening of the abdominal wall being required. Using a laparoscope and one or two additional entrance ports for light sources, camera, or biopsy instruments, the entire abdominal cavity (Cavitas abdominalis) can be inspected. A further indication for laparoscopy is the assessment of the liver for targeted biopsy. If imaging methods and also the liver blind puncture (→ Fig. 6.95 and → Fig. 6.96) are not successful, laparoscopically targeted biopsies can be taken.

Extrahepatic Bile Ducts

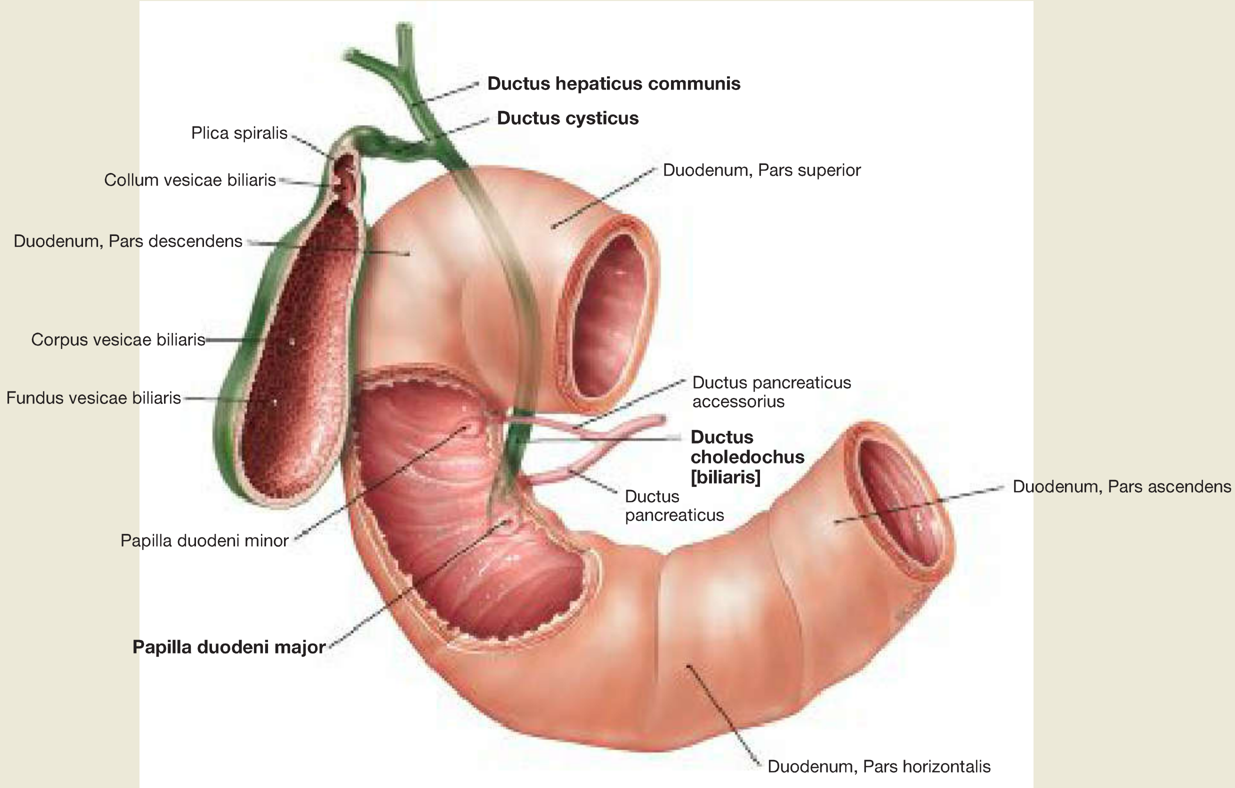


Fig. 6.100 Gallbladder, Vesica biliaris, extrahepatic bile ducts and duodenum; ventral view. [L238]
The **Ductus hepaticus communis** is formed in the liver by unifying two regional bile ducts (Ductus hepatici dexter and sinister). It receives the **Ductus cysticus** of the gallbladder in the Lig. hepatoduodenale, becoming the Ductus choledochus.

The **Ductus choledochus** is usually 6 cm long and 0.4–0.9 cm in diameter. It firstly runs ventrally of the portal vein in the Lig. hepatoduodenale, then behind the superior part of the duodenum to reach the Pars descendens of the duodenum via the head of the pancreas. It usually connects with the Ductus pancreaticus and culminates in a small mucosal papilla, **Papilla duodeni major (Papilla VATERI).**

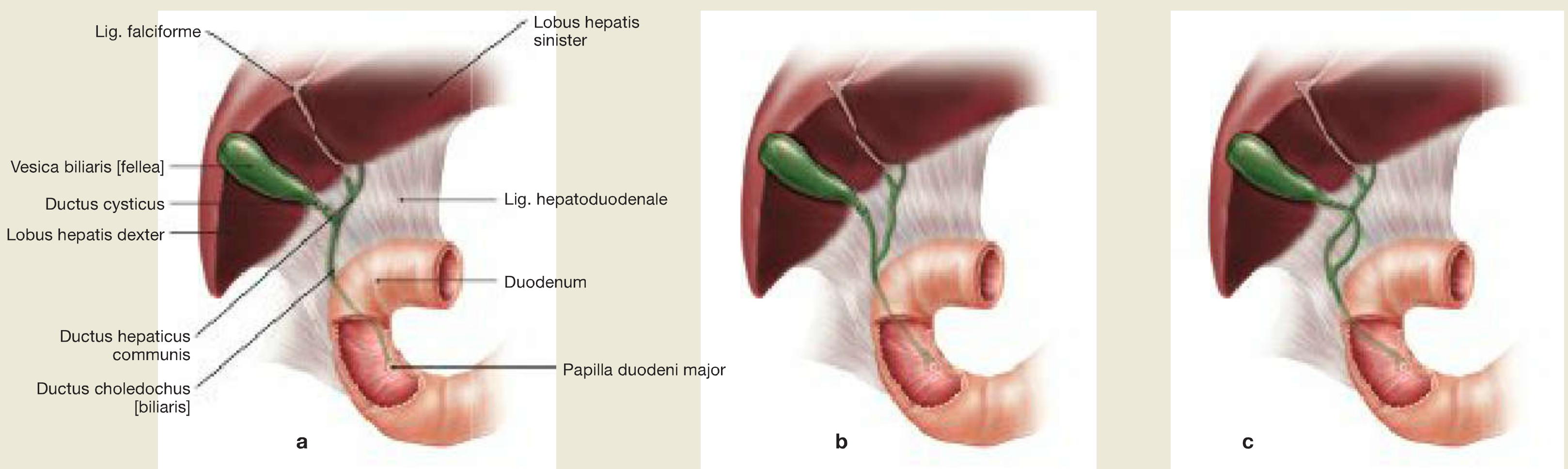


Fig. 6.101a to c Variations of bile ducts regarding the confluence of Ductus hepaticus communis and Ductus cysticus. [L238]
a High junction
b Low junction
c Low junction with crossing over

Clinical Remarks

The variability of the bile ducts must be borne in mind in the diagnosis and treatment of **gallstones (cholecystolithiasis)** and during the surgical **removal of the gallbladder (cholecystectomy).** For diagnostic evaluation, endoscopic X-ray contrast imaging (endoscopic retrograde cholangiopancreatography, ERCP) is often used. Where there is an enlarged diameter of the Ductus choledochus of over 1 cm this suggests **cholestasis.**

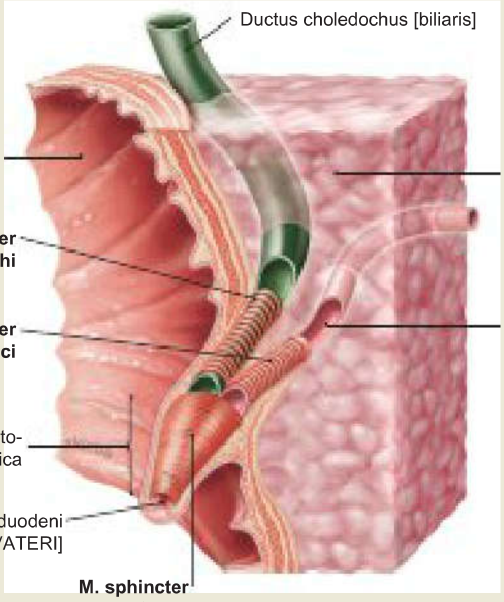


Fig. 6.102 Ampulla hepatopancreatica converging with the Ductus choledochus and Ductus pancreaticus; semi-schematic illustration; ventral view. [L238]
Typically (in 60% of cases) the Ductus choledochus joins with the Ductus pancreaticus to the **Ampulla hepatopancreatica,** which flows to the **Papilla duodeni major (Papilla VATERI)** into the duodenum. The papilla is 8–10 cm away from the pylorus of the stomach (Gaster) and is located in the dorsomedial wall in the middle third of the Pars descendens of the duodenum.

On the Papilla duodeni major, underneath the mucous membrane, there is a sphincter system. The smooth muscles of the excretory ducts continue on the ampulla. The circular muscle fibres of the Ductus choledochus form a smooth M. sphincter ductus choledochi. Accordingly, there is a M. sphincter ductus pancreatici. The distal sections of the closing muscles include the ampulla and its junction as the M. sphincter ampullae (ODDI).

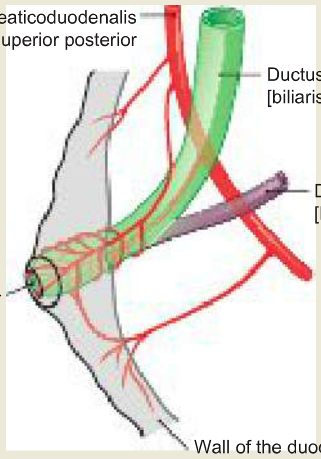


Fig. 6.103 Arterial blood supply of the Ampulla hepatopancreatica and the Ductus choledochus; schematic drawing; ventral view. [L126]
The Ductus choledochus is supplied both by fine branches of the **A. cystica** and the R. dexter of the **A. hepatica propria** as well as by ascending branches of the **A. gastroduodenalis.** The distal third of the Ductus choledochus, including the Ampulla hepatopancreatica, receives blood from the **A. pancreaticoduodenalis superior posterior.**

Clinical Remarks

The way of unification of the Ductus choledochus and Ductus pancreaticus is clinically highly relevant. **Gallstones** from the gallbladder **(cholecystolithiasis)** can exit it spontaneously and remain stuck to the Papilla duodeni major and cause an obstruction. This can lead to a **backflow of bile** entering into the blood **(cholestasis),** which is most commonly associated with a painful swelling of the gallbladder, with its fundus projecting on the right-hand side of rib IX. Due to deposits of bile pigment called bilirubin in the connective tissue, there is a yellowing of the sclera of the eye and skin **(jaundice).** In this case, the gallstone must be removed endoscopically. Due to the good blood supply in the area of the Papilla duodeni major, strong bleeding may occur. In the case of cholestasis, a **pancreatic cancer** in the area of the pancreatic head should also always be considered. In this case, the swelling of the gallbladder is not associated with inflammation and therefore is mostly painless.

CALOT's Triangle

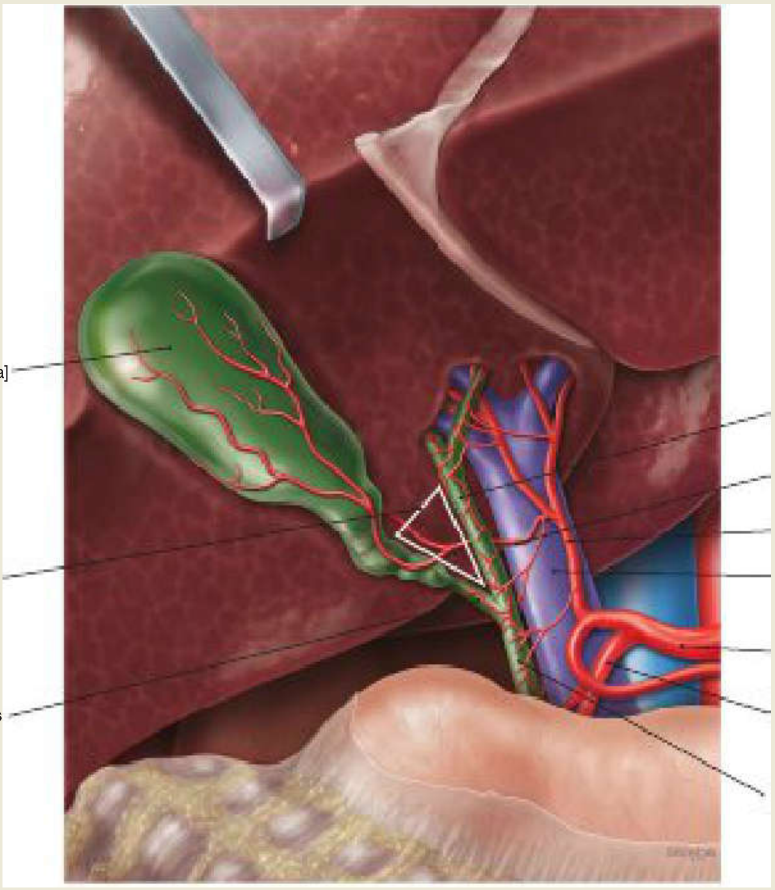


Fig. 6.104 CALOT's triangle, Trigonum cholecystohepaticum; caudal view. [L238]
The Ductus cysticus, the Ductus hepaticus communis, and the inferior area of the liver together form the **Trigonum cholecystohepaticum,** also referred to as **CALOT's triangle**. In 75% of all cases, the A. cystica originates in this triangle from the R. dexter of the A. hepatica propria and runs posteriorly through this triangle to reach the Ductus cysticus and the neck of the gallbladder.

Clinical Remarks

If gallstones repeatedly lead to an **inflammation of the gallbladder (cholecystitis),** it is usually indicated to surgically remove the **gallbladder (cholecystectomy)**. The **CALOT's triangle** is an important landmark during the surgical removal of the gallbladder. Prior to removal of the gallbladder all structures are identified before the A. cystica and the Ductus cysticus are ligated. This way, the risk of an accidental ligation of the Ductus choledochus with subsequent stasis of the bile (cholestasis) is reduced.

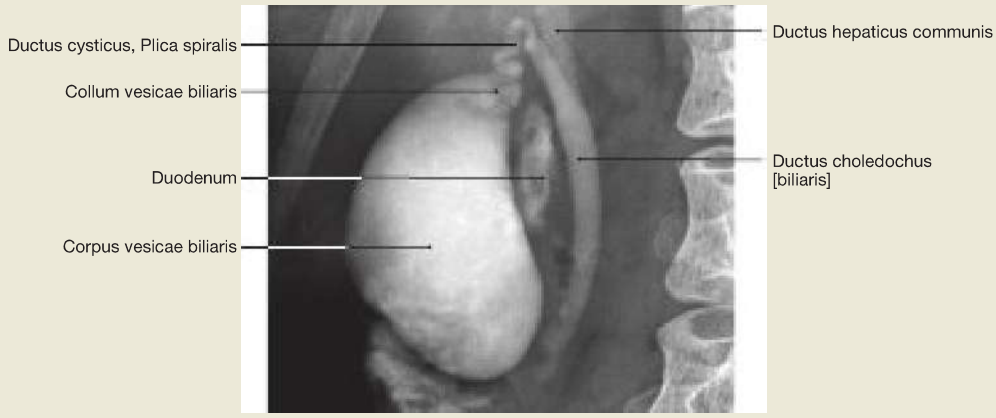


Fig. 6.105 Gallbladder, Vesica biliaris, and extrahepatic bile ducts; X-ray in anteroposterior (AP) beam projection after application of contrast agent; patient in upright position; ventral view.

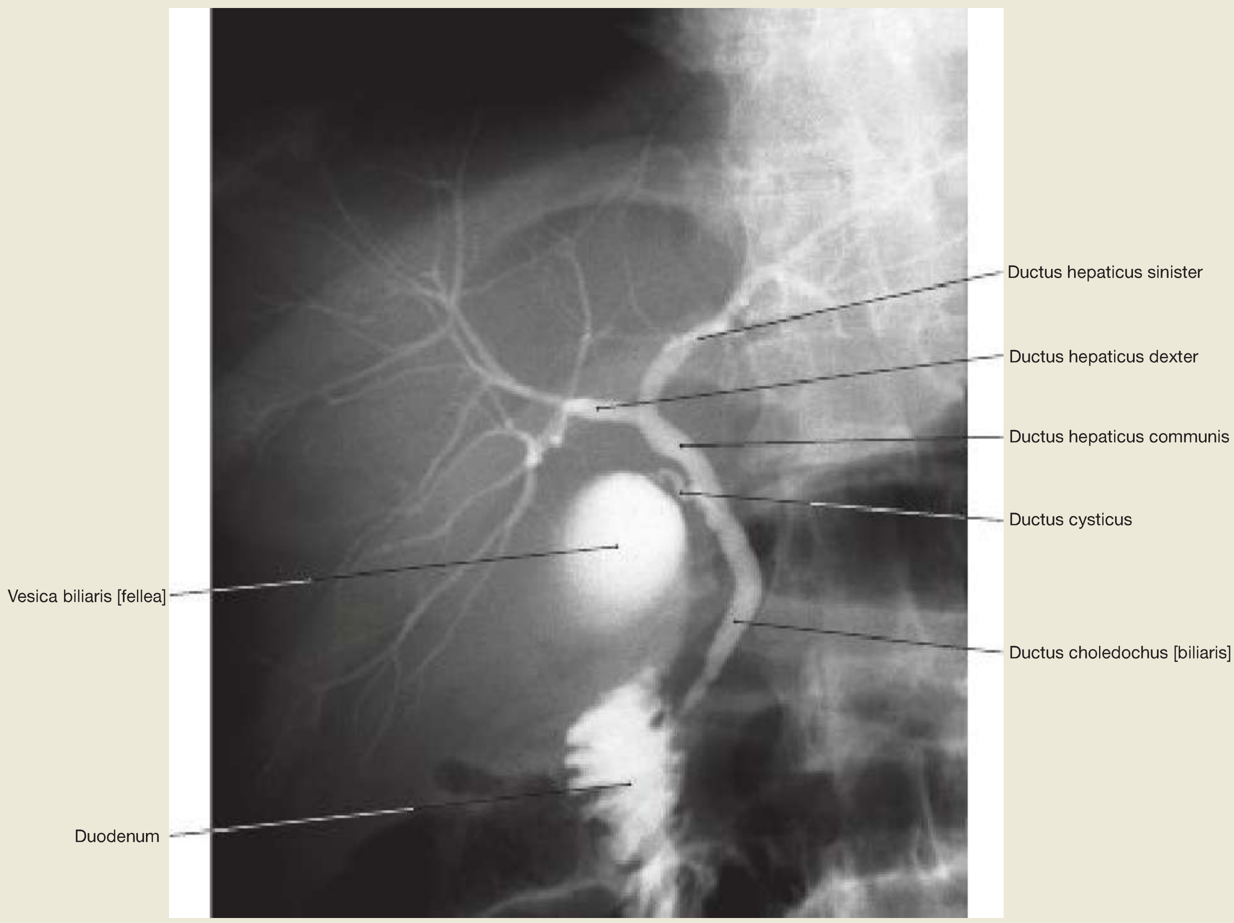


Fig. 6.106 Gallbladder, Vesica biliaris, as well as intra- and extrahepatic bile ducts; X-ray in anteroposterior (AP) beam projection after application of contrast agent; patient in upright position; ventral view.

Clinical Remarks

Radiography after intravenous application of contrast agent allows the visualisation of the gallbladder and bile ducts, including the detection of noncalcified bile concrements. Malignant tumours of the bile ducts (cholangiocarcinoma) or of the pancreas (pancreatic carcinoma) may cause cholestasis which appears as dilation of the bile ducts.

Projection of the Pancreas

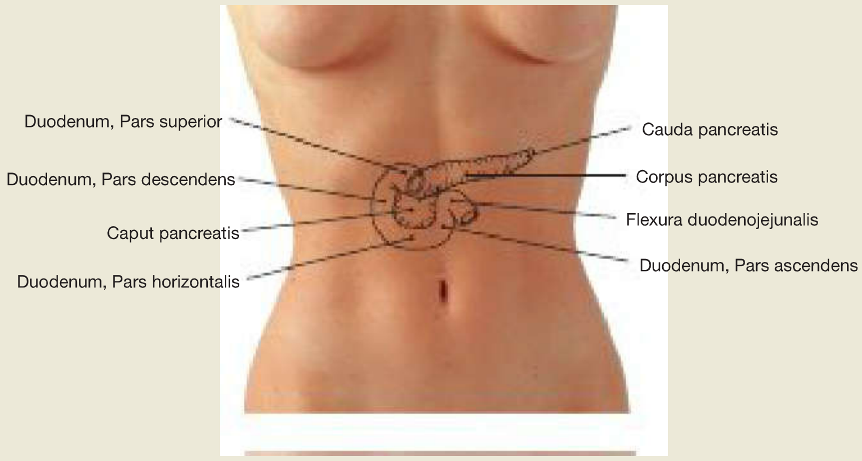


Fig. 6.107 Projection of the pancreas and duodenum onto the ventral abdominal wall.
The pancreas is in a **secondary retroperitoneal** position and projects approximately on the first to second lumbar vertebrae. The head (Caput pancreatis) is adjacent to the Pars descendens of the duodenum and continues as the body of the pancreas (Corpus pancreatis), which crosses the vertebral column to continue as the tail of the pancreas (Cauda pancreatis), which then reaches up to the hilum of the spleen.

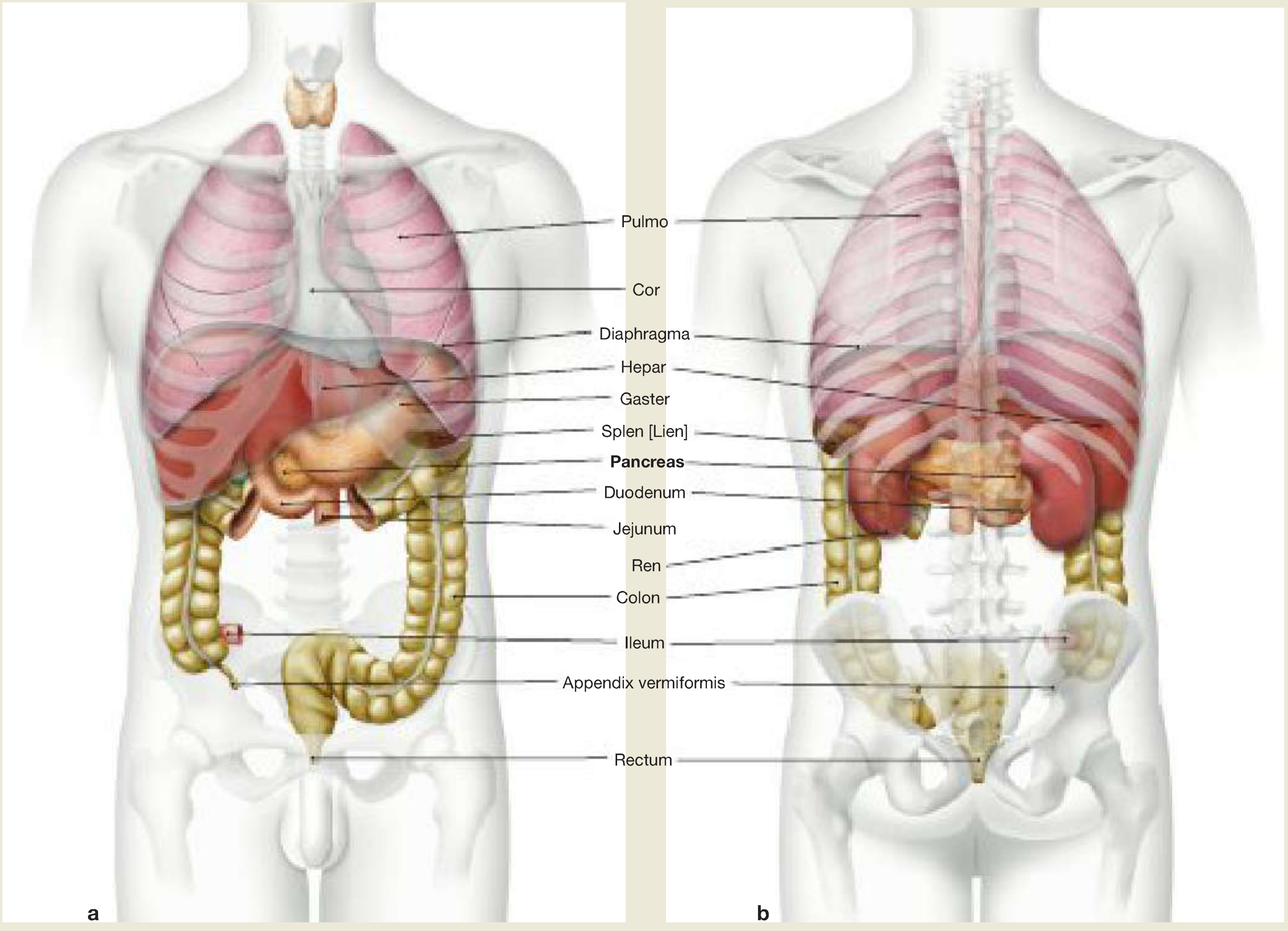


Fig. 6.108a and b Projection of inner organs onto the body surface; ventral view (→ Fig. 6.108a) and dorsal view (→ Fig. 6.108b). [L275]

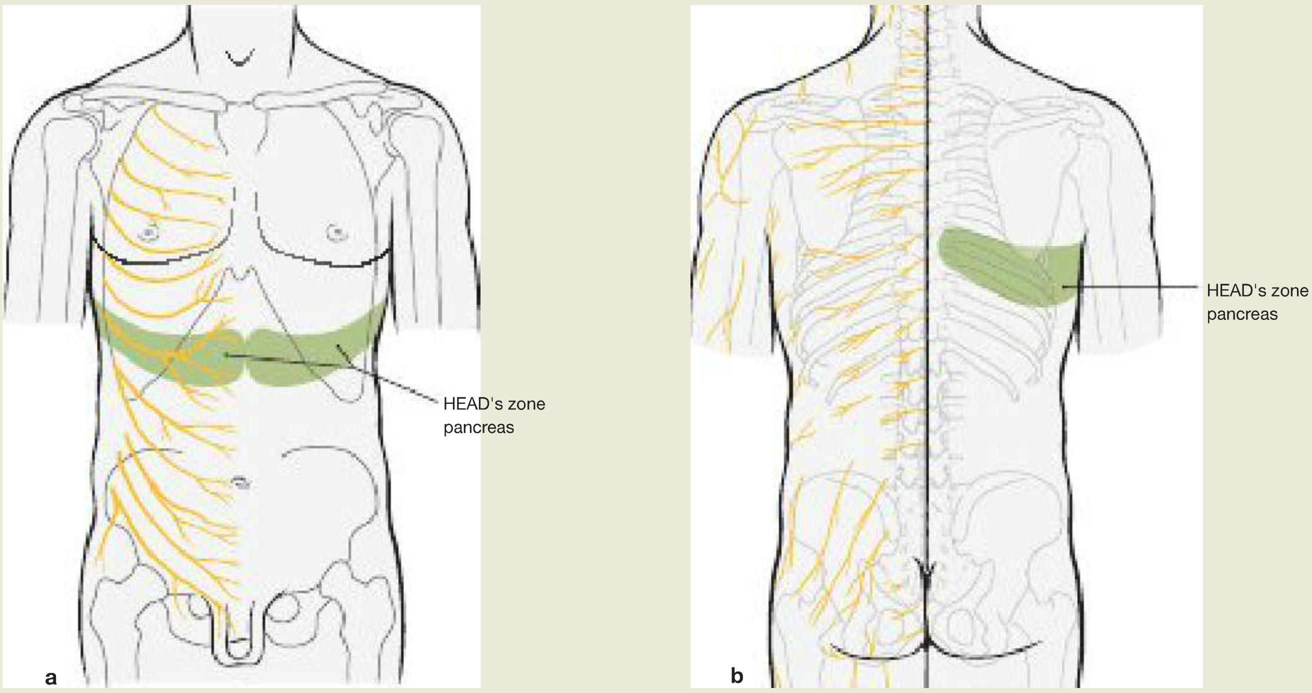


Fig. 6.109a and b HEAD's zone of the pancreas, schematic drawing; ventral view (→ Fig. 6.109a) and dorsal view (→ Fig. 6.109b). [L126]
The organ-related area or the **HEAD's zone** of the pancreas is usually not exactly localised. If pain occurs in a defined area, in diseases of the pancreas, it is often projected into the T8 dermatome. This is because in the corresponding spinal cord segment, afferent neurons from the pancreas converge with those of the body surface, so that in cases of (mostly inflammatory) diseases of the pancreas, pain is perceived on the body surface in the dermatomes T8 and T9. Hence we talk about projected pain. A special feature of the pancreas is that the pain is also projected dorsally onto the same dermatome due to the retroperitoneal position of the organ.

Clinical Remarks

Inflammation of the pancreas (pancreatitis), which is most commonly related to a gallstone being in the papillae with causing a backflow of secretions or with alcohol abuse, is typically associated with belt-shaped radiating pain.

Development of the Pancreas

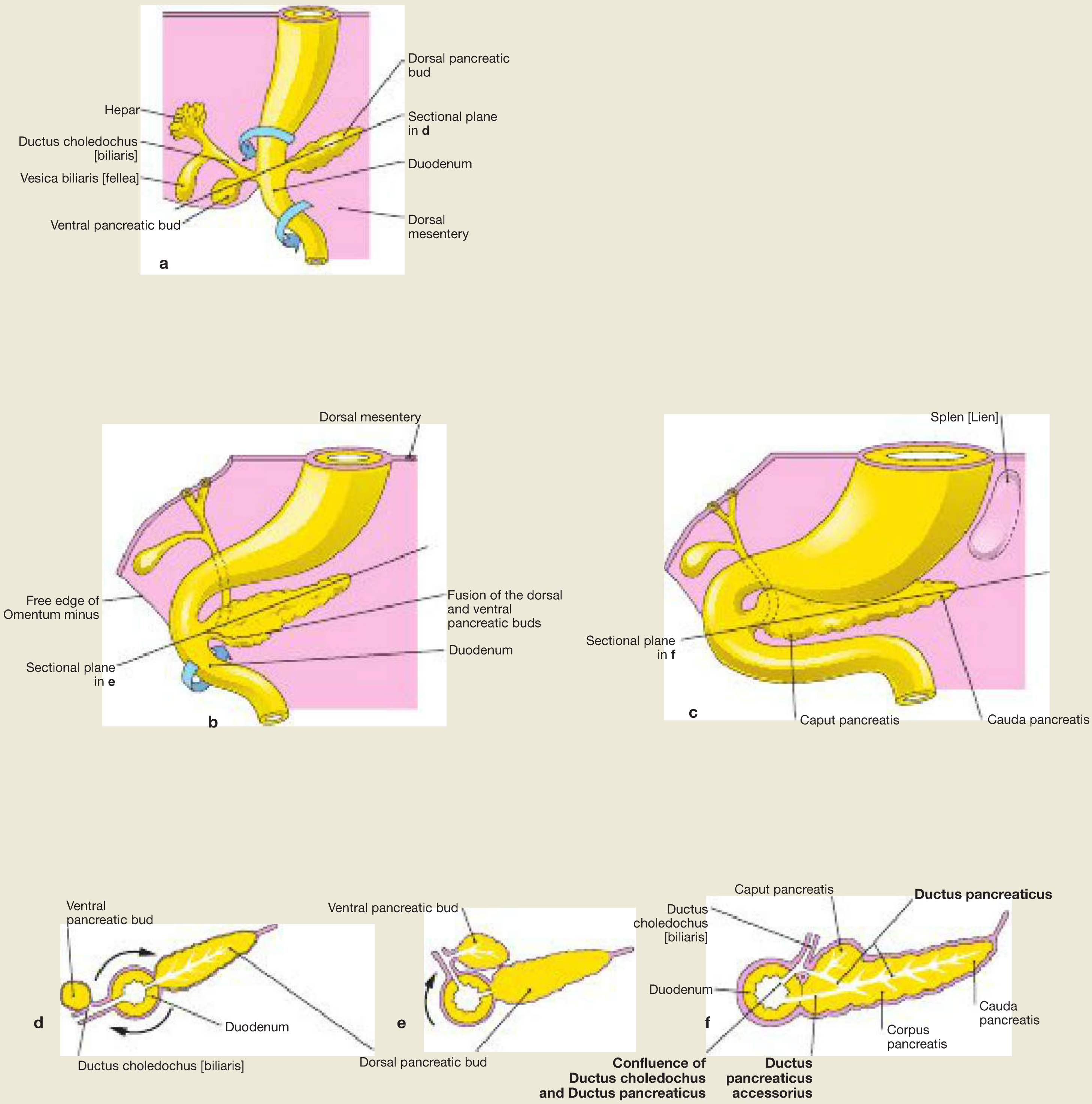


Fig. 6.110a to f Developmental stages of the pancreas in the 5th–8th week. [E347–09]

a to **c** Ventral view

d to **f** Schematic cross-sections through the duodenum and pancreatic system: rotations marked by arrows

On the 28th day, a ventral and a dorsal pancreatic bud emerge from the entoderm of the primordial gut **(a, d),** inferior to the primordium of the liver and gallbladder at the level of the duodenum. The ventral pancreatic bud folds dorsally **(b, e)** and fuses, together with the excretory ducts, with the dorsal pancreatic bud **(c, f)** in the 6th–7th week.

The excretory duct of the pancreas is formed by the union of the distal dorsal Ductus pancreaticus and the ventral Ductus pancreaticus and enters the Papilla duodeni major. The proximal portion of the dorsal Ductus pancreaticus develops (in 65% of all cases) into the Ductus pancreaticus accessorius which joins the duodenum at the Papilla duodeni minor.

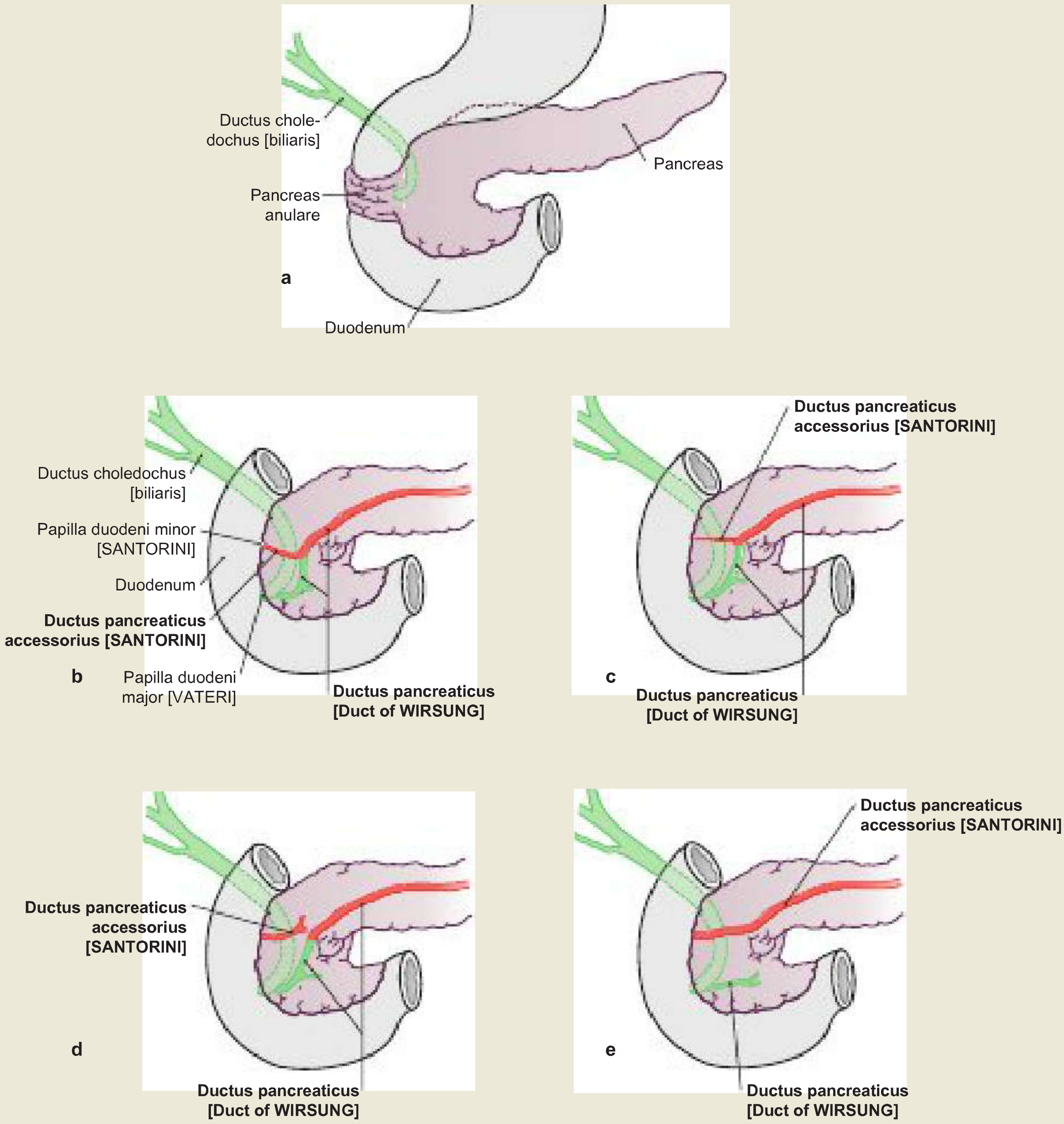


Fig. 6.111a to e Malformations of pancreatic development; schematic illustration, ventral view. [L126]

a Ring-shaped formation of the pancreas system around the descending part of the duodenum **(annular pancreas),** which can lead to passage disorders of the food bolus

b and **c** Normal union of the pancreatic ducts, whereby the Ductus pancreaticus accessorius (in b) is stenosed at its opening into the duodenum

d and **e** Incomplete union of the excretory ducts **(pancreas divisum)** with the Ductus pancreaticus and Ductus pancreaticus accessorius remaining separate, independently discharging into the duodenum

Clinical Remarks

If the pancreatic parenchyma grows as a circular gland around the duodenum **(annular pancreas),** ileus with vomiting may occur which is particularly evident in newborns. The symptoms often occur only when switching from milk to solid foods. In this case, the duodenum has to be cut and sewn back next to the pancreatic duct system.
If the fusion of both pancreatic buds is incomplete **(pancreas divisum),** the dorsal Ductus pancreaticus may constitute the main excretory duct (10% of all cases) which may cause repetitive pancreatitis due to a stasis of secretions. In the case of recurring inflammation, it needs to be considered whether gallstones and alcohol abuse can be ruled out as the cause.
If the merging of the two Ductus pancreatici does not take place, a relocation of the Papilla duodeni major by a **gallstone (cholelithiasis)** may occur. In this case no outflow of pancreatic secretions is possible via the Papilla duodeni minor, so that as well as the **bile backflow (cholestasis),** an extreme inflammatory involvement of the pancreas **(pancreatitis)** may also occur in pancreas divisum.

Structure and Topographical Relationships of the Pancreas

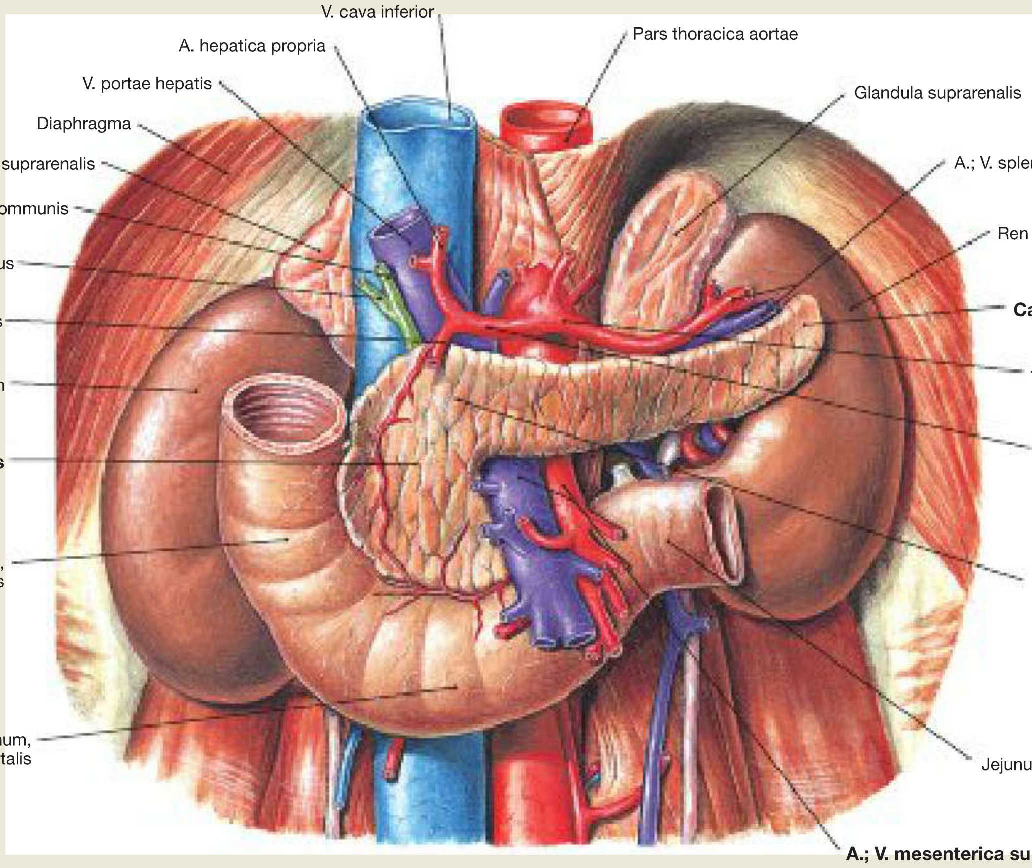


Fig. 6.112 Retroperitoneal organs of the epigastrium: pancreas, duodenum, and on both sides kidney, Ren, and adrenal gland, Glandula suprarenalis; ventral view.

The pancreas is in a secondary retroperitoneal position. The head of the pancreas **(Caput pancreatis)** lies on the descending part of the duodenum and has a dorsal uncinate process **(Proc. uncinatus),** which comprises the A. and V. mesenterica superior. The horizontal part of the duodenum is positioned caudally.

To the left side sits the head of the pancreas above a short neck **(Collum pancreatis),** ventral to the A./V. mesenterica superior in the body **(Corpus pancreatis)**, which crosses the vertebral column. The subsequent tail of the pancreas **(Cauda pancreatis)** passes on the dorsal side of the left colic flexure before the left kidney and extends to the hilum of the spleen.

The pancreas has an anterior and a posterior surface (Facies anterior and Facies posterior), which are separated from each other by the dull upper and lower margins (Margo superior and Margo inferior). The anterior aspect of the pancreas is covered by parietal peritoneum and forms the posterior wall of the Bursa omentalis. The posterior aspect of the pancreas is fused to the original parietal peritoneum of the posterior abdominal wall because the pancreas was repositioned into the retroperitoneal space during its development. The adhesion surface presentes during dissection as fascia (TOLDT's fusion fascia, → Fig. 6.125).

Clinical Remarks

The close topographical relationship of the pancreatic head and the A./V. mesenterica superior to the portal vein imposes the risk of injury of the vessels being damaged in the case of an **endoscopic examination of the Papilla duodeni major** to remove a gallstone or when performing contrast imaging of the bile and pancreatic ducts (ERCP, endoscopic retrograde cholangiopancreatography); in most cases this can only be resolved with emergency surgery.

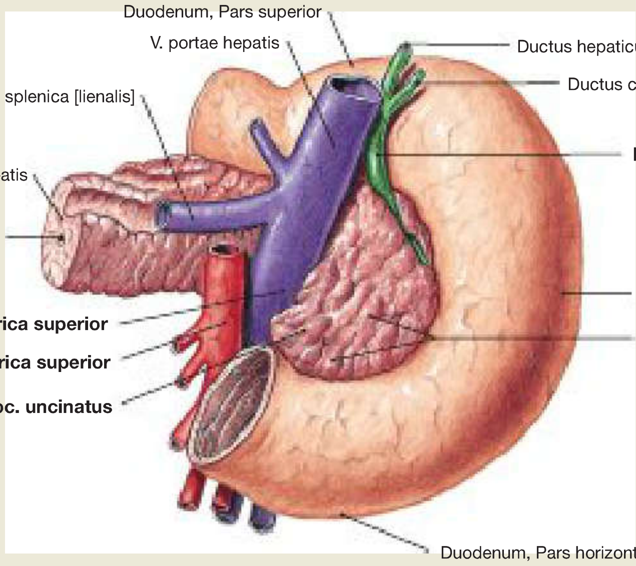


Fig. 6.113 Pancreas and duodenum; dorsal view.
The figure illustrates the **Caput pancreatis** located in the C-shaped descending part of the duodenum where it is obliquely pierced by the common bile duct (Ductus choledochus) in its course to the Papilla duodeni major. Dorsally, the unicate process **(Proc. uncinatus)** of the pancreatic head comprises the A./V. mesenterica superior.

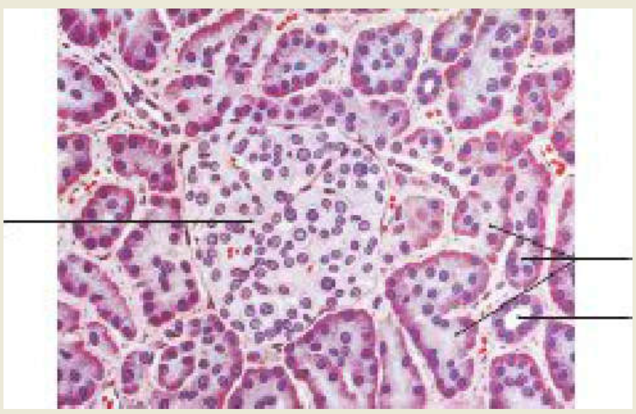


Fig. 6.114 Structure of the pancreas; microscopic view. [R252]
The pancreas is a mixed exocrine and endocrine gland. The **exocrine** part uses its tail end (acini) to produce digestive enzymes which are provided as precursors via the system of ducts into the intestinal lumen. The **endocrine** part form the islets of LANGERHANS (Insulae pancreaticae) which are embedded into the parenchyma of the exocrine part, especially in the tail of the pancreas. Besides other hormones, the islets produce insulin and glucagon which are secreted into the blood and serve to regulate the blood glucose level.

Clinical Remarks

The function of the pancreas makes it clear how, through tissue-destruction (necrosis), e.g. inflammation **(pancreatitis),** to **indigestion,** diarrhoea and in cases of very extensive damage (loss of 80–90% of the tissue), **diabetes mellitus** can also occur: due to the insufficient insulin production

Excretory Ducts of the Pancreas

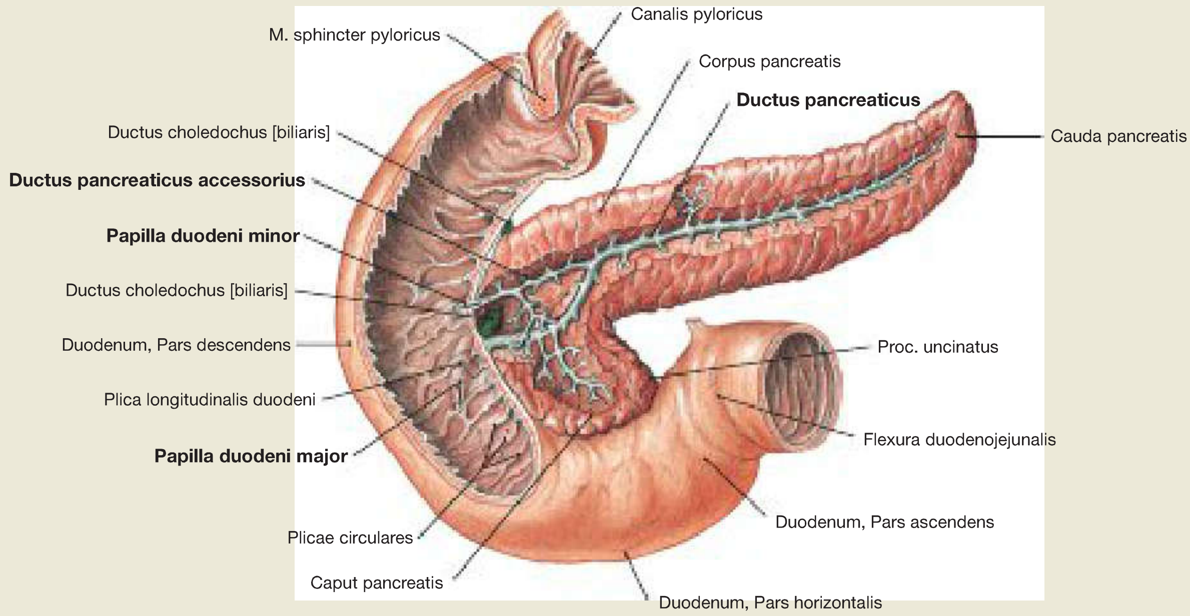


Fig. 6.115 Excretory duct system of the pancreas; ventral view; Ductus pancreaticus after partial resection of the pancreas and duodenum.
The main **excretory duct (Ductus pancreaticus [Duct of WIRSUNG])** fuses with the terminal segment of the Ductus choledochus in 60% of all cases to form the **Ampulla hepatopancreatica** which then flows via the Papilla duodeni major (Papilla VATERI) into the Pars descendens of the duodenum. Developmentally (→ Fig. 6.110), an accessory duct **(Ductus pancreaticus accessorius [SANTORINI])** exists in 65% of all cases opening into the duodenum 2 cm proximal to the Papilla duodeni minor.

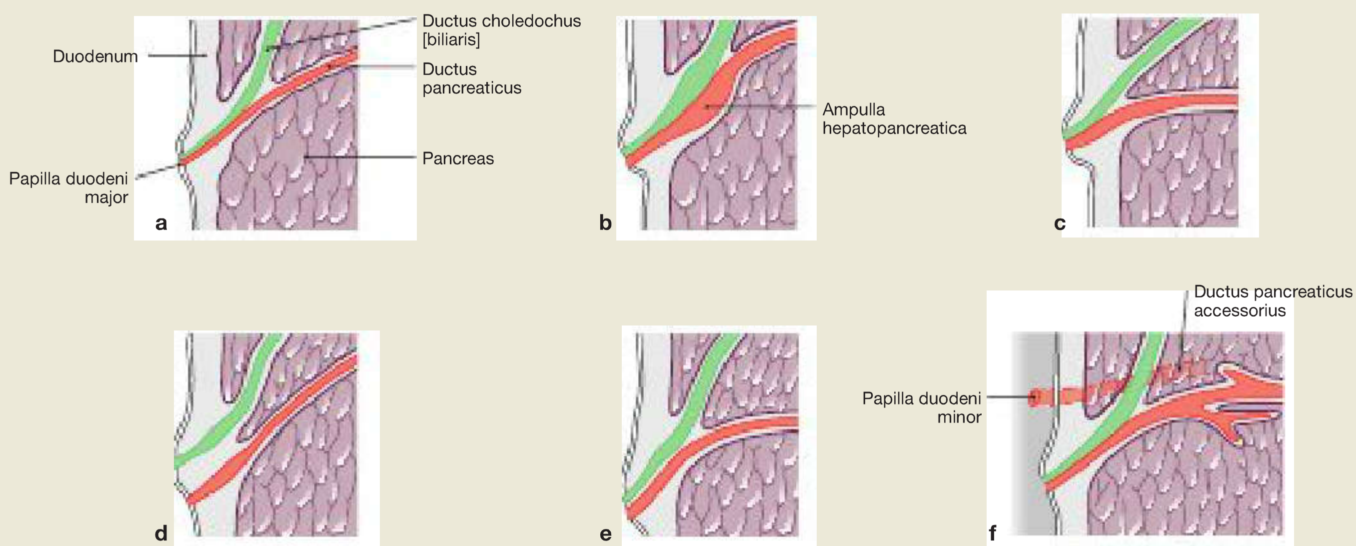


Fig. 6.116a to f Variations of the junction of the Ductus pancreaticus and Ductus choledochus. [L126]
- **a** Long common portion
- **b** Ampullary dilation of the terminal part (60% of all cases), → Fig. 6.102
- **c** Short common portion
- **d** Separate opening
- **e** Unified opening with septation of the common duct
- **f** Ductus pancreaticus accessorius (65% of all cases)

Clinical Remarks

The variation in the opening of the excretory ducts has an impact on the **progression of pancreatic diseases.** In addition to alcohol abuse, damage to the Papilla duodeni major by gallstones is the most common cause of the inflammation of the pancreas (pancreatitis), which is caused by a backflow of secretions with autodigestion. A Ductus pancreaticus accessorius with a separate opening can then prove to be useful when it communicates with the main duct, permitting an outflow of the digestive secretions.

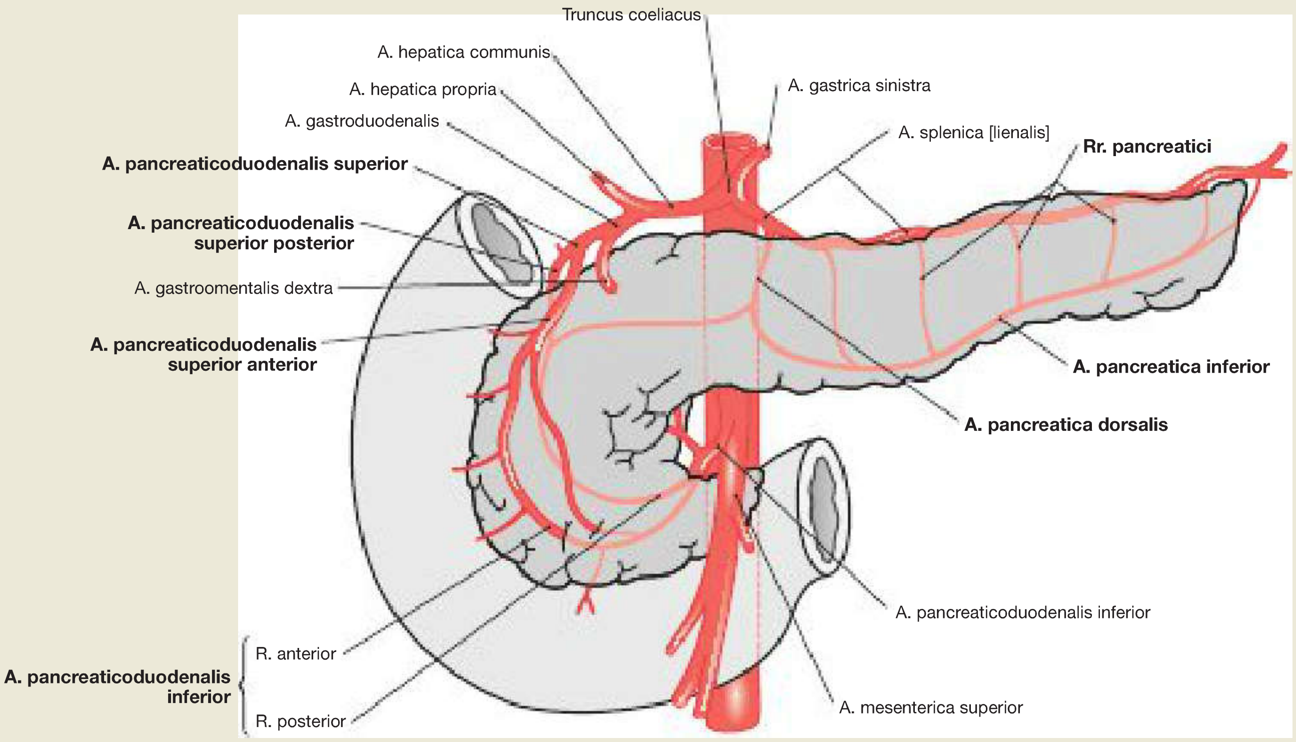


Fig. 6.117 Arteries of the pancreas; schematic illustration, ventral view. [L126]

The pancreas is supplied by **two separate arterial systems,** for the pancreatic head and for the pancreatic body and tail areas, respectively.

- **Head:** double arterial arches from the Aa. pancreaticoduodenales superiores anterior and posterior (from the A. gastroduodenalis) and from the A. pancreaticoduodenalis inferior with a R. anterior and a R. posterior (from the A. mesenterica superior). Thus its supply is ensured from the drainage areas of the Truncus coeliacus and A. mesenterica superior.
- **Body and tail:** Rr. pancreatici from the A. splenica, which form the A. pancreatica dorsalis behind the pancreas and the A. pancreatica inferior to the inferior border of the gland. The A. pancreatica inferior is usually connected with the posterior vascular arcades of the pancreatic head, so that there is a marked redundancy of the supply.

The **veins** of the pancreas correspond to the arteries and drain via the V. mesenterica superior and the V. splenica into the V. portae hepatis (→ Fig. 6.69).

Clinical Remarks

This **intensive arterial blood supply** via two arteries of the Truncus coeliacus and, in addition, by the A. mesenterica superior clearly explains why infarctions of this vital gland are rare.

Lymphatic Vessels of the Pancreas

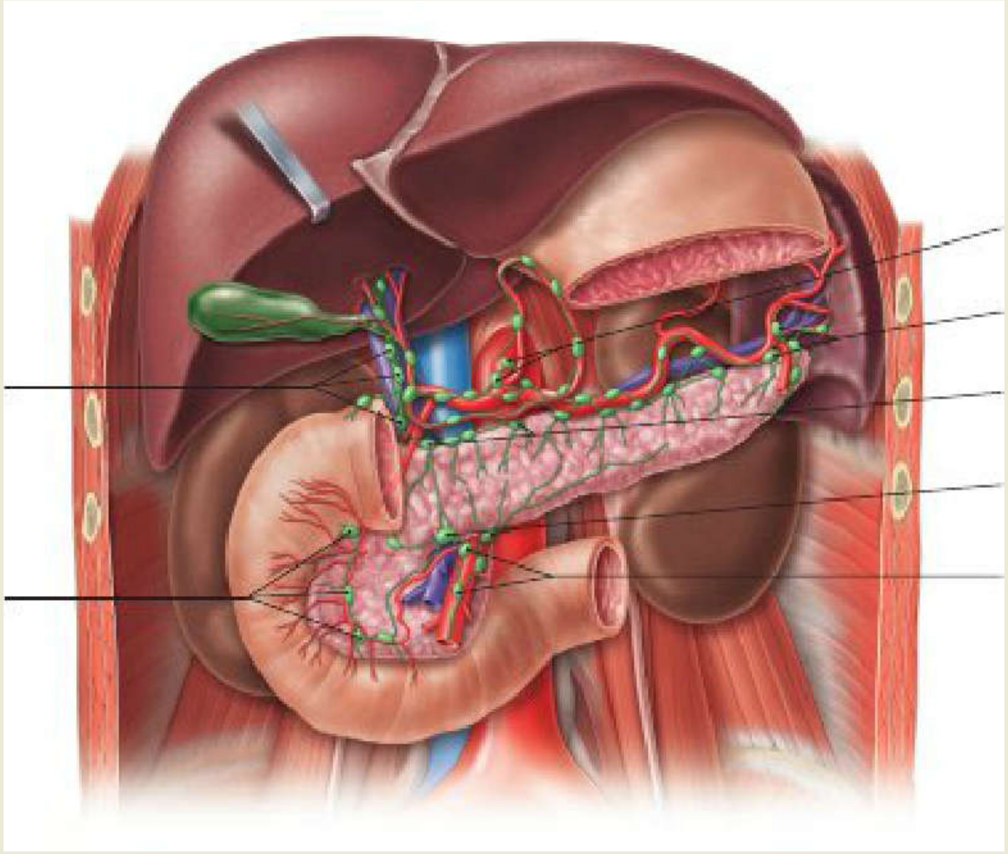


Fig. 6.118 Lymphatic vessels and lymph nodes of the pancreas; ventral view. [L238]
The distinct parts of the pancreas have separate regional lymph nodes.

- **Head: Nodi lymphoidei pancreaticoduodenales anteriores and posteriores** along the identically named arteries (Aa. pancreaticoduodenales superiores anterior and posterior)
- **Body: Nodi lymphoidei pancreatici superiores and inferiores** along the A. and V. splenica
- **Tail:** Nodi lymphoidei splenici

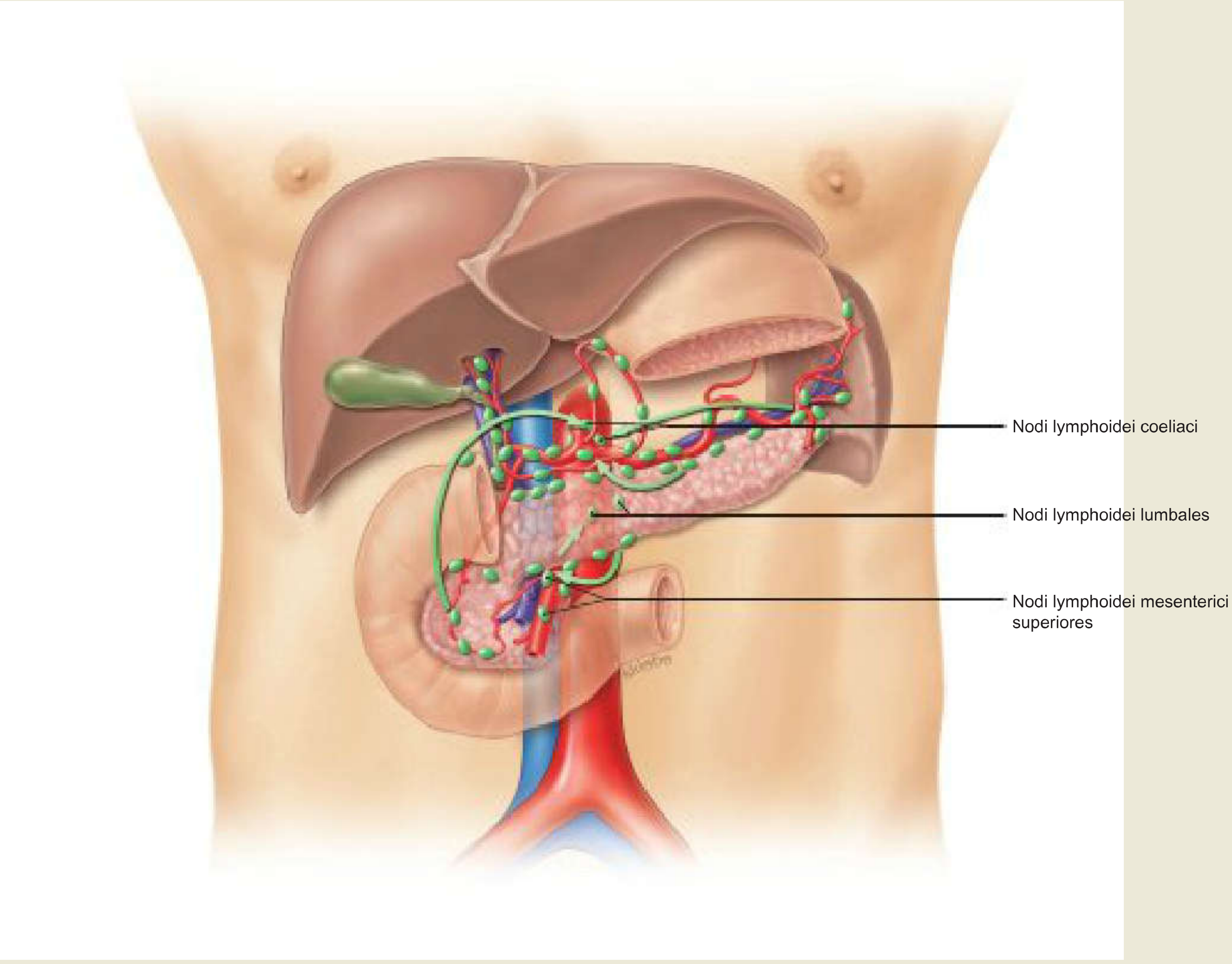


Fig. 6.119 Lymphatic drainage pathways of the pancreas; ventral view. [L238]
The regional groups of lymph nodes are strongly connected with each other and with lymph nodes in the surrounding area:

- **Head:** The Nodi lymphoidei pancreaticoduodenales drain via the Nodi lymphoidei hepatici to the **Nodi lymphoidei coeliaci** or directly to the **Nodi lymphoidei mesenterici superiores.** The other connection is made via the **Trunci intestinales** to the Ductus thoracicus.
- **Body and tail:** The regional lymph nodes at the upper edge of the gland are the Nodi lymphoidei pancreatici; conversely for the tail area these are the Nodi lymphoidei splenici. These are connected via lymphatic vessels along the A. and V. splenica to the **Nodi lymphoidei coeliaci.** From the inferior margin of the gland, the Nodi lymphoidei pancreatici are connected to the **Nodi lymphoidei mesenterici superiores.** Due to the retroperitoneal position, there are also connections to the **retroperitoneal Nodi lymphoidei lumbales.** Drainage is then carried out via **Trunci lumbales.**

Clinical Remarks

The diverse lymphatic drainage pathways explain why in cases of **pancreatic carcinoma** extensive **lymph node metastases** usually exist at the time of diagnosis. Because they cannot be completely removed, a surgical cure is seldom achievable.

Innervation of the Pancreas

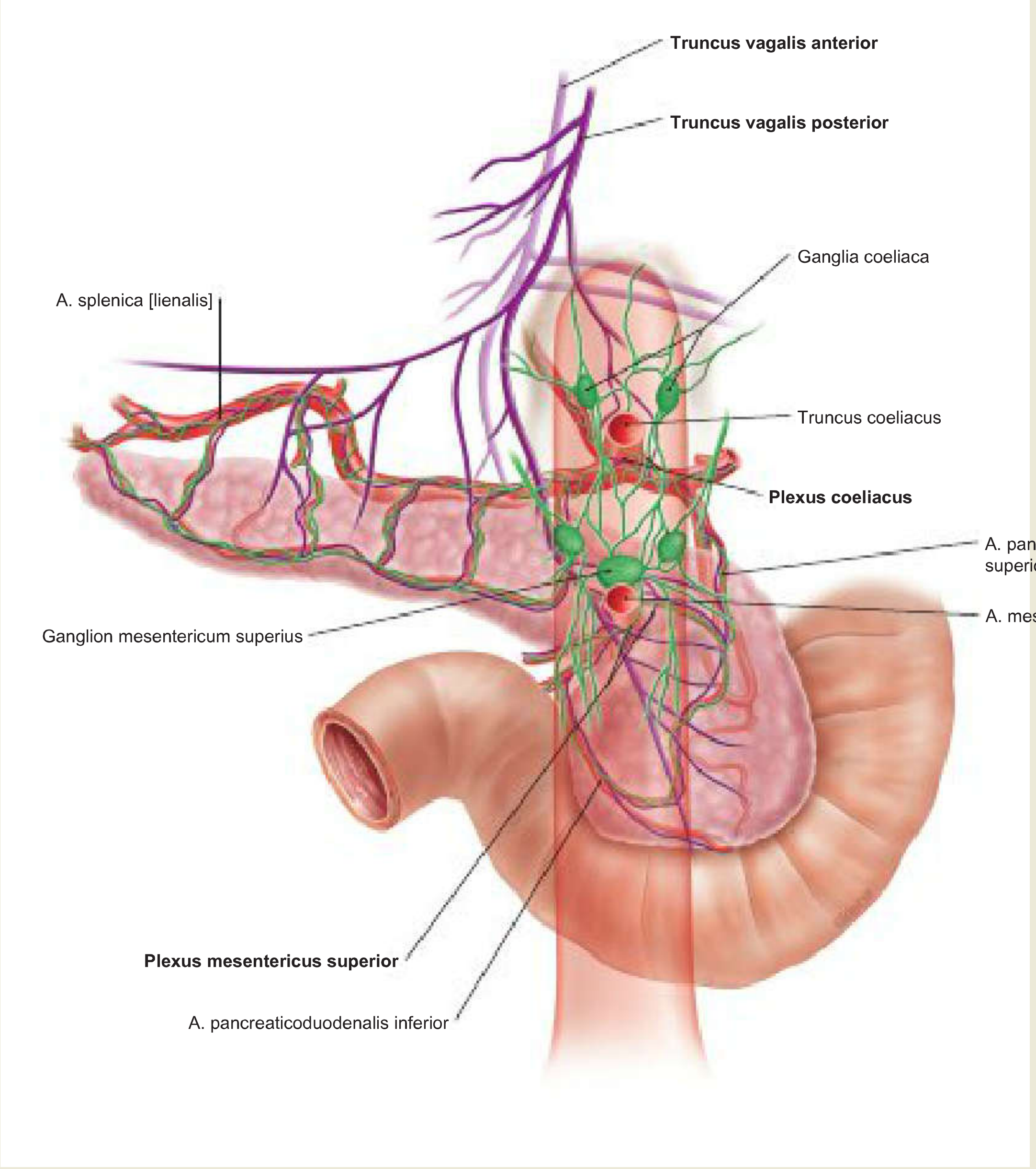


Fig. 6.120 Autonomic innervation of the pancreas; schematic illustration, dorsal view. [L238]

The pancreas is sympathetically and parasympathetically innervated. The **parasympathicus** promotes the release of the digestive secretions and insulin formation, and the **sympathicus** inhibits these functions. The sympathetic postganglionic neurons and the parasympathetic preganglionic nerve fibres reach the pancreas from the **Plexus coeliacus** predominantly via perivascular plexuses. Particularly for the head area, nerve fibres from the **Truncus vagalis posterior** and occasionally from the **Truncus vagalis anterior** go directly to the gland. Synaptic switching of the parasympathetic fibres is performed by microscopically small ganglia, which are partially embedded in the pancreas.

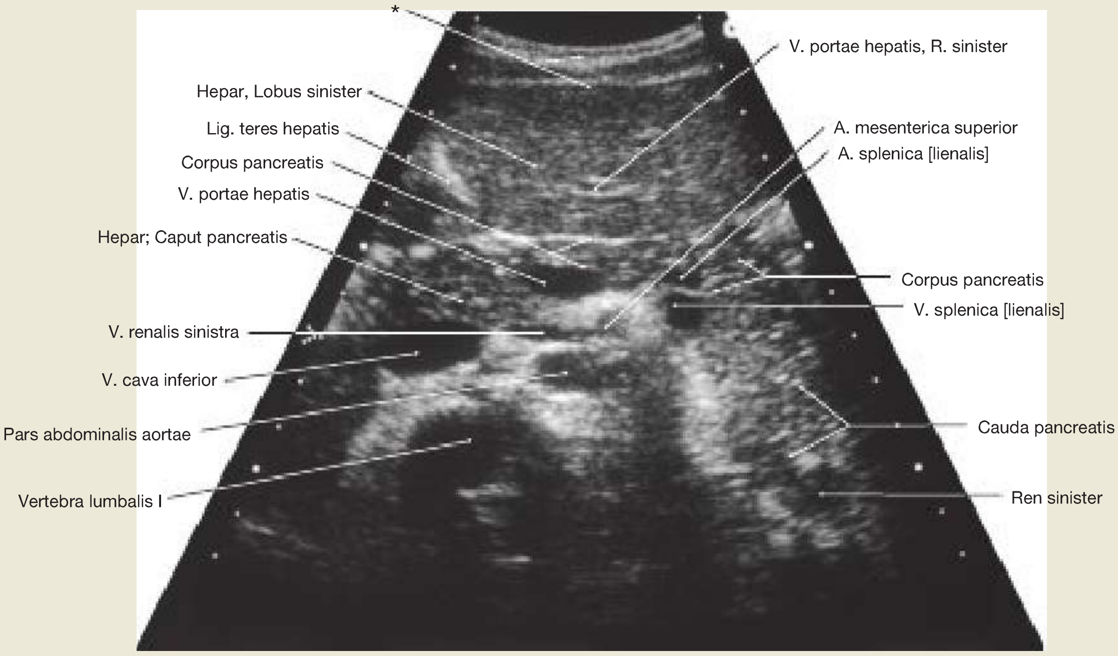


Fig. 6.121 Pancreas; ultrasound image; oblique caudal view; in deep inspiration. [T894]
Ultrasound examination of the pancreas is often unsatisfactory since it is often obstructed by the air-filled intestines, due to its location in the retroperitoneum.
* abdominal wall

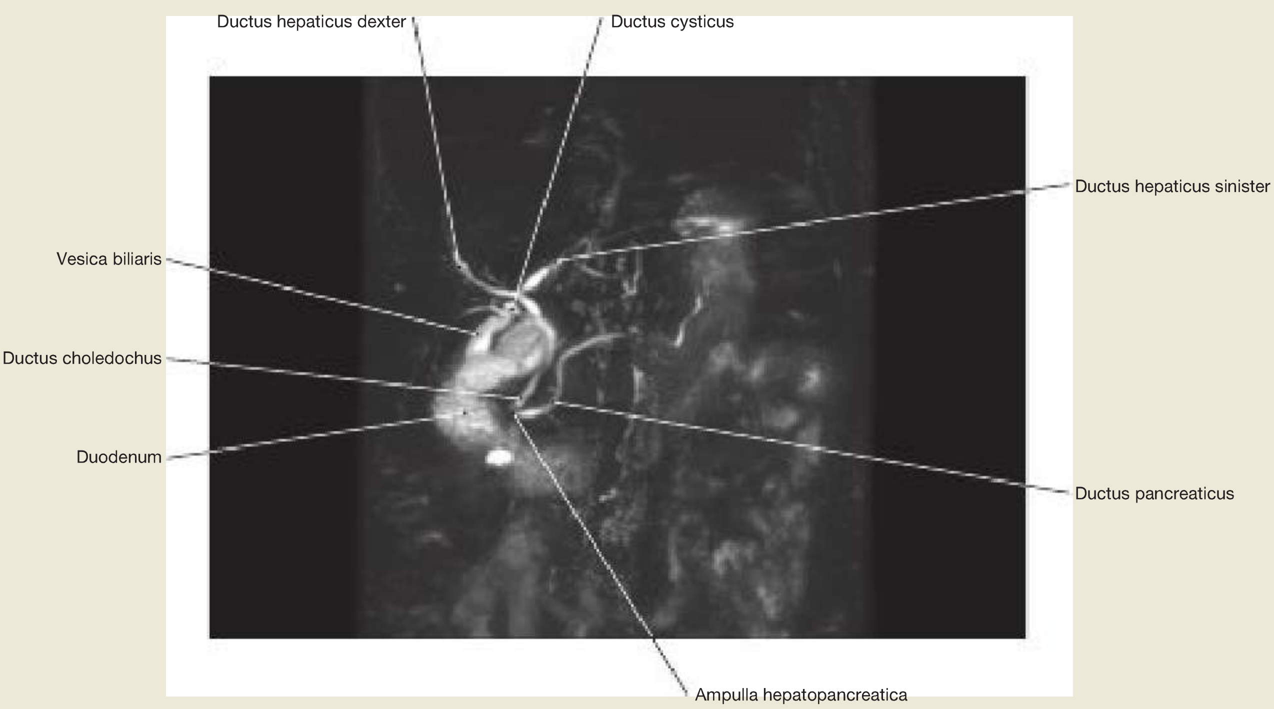


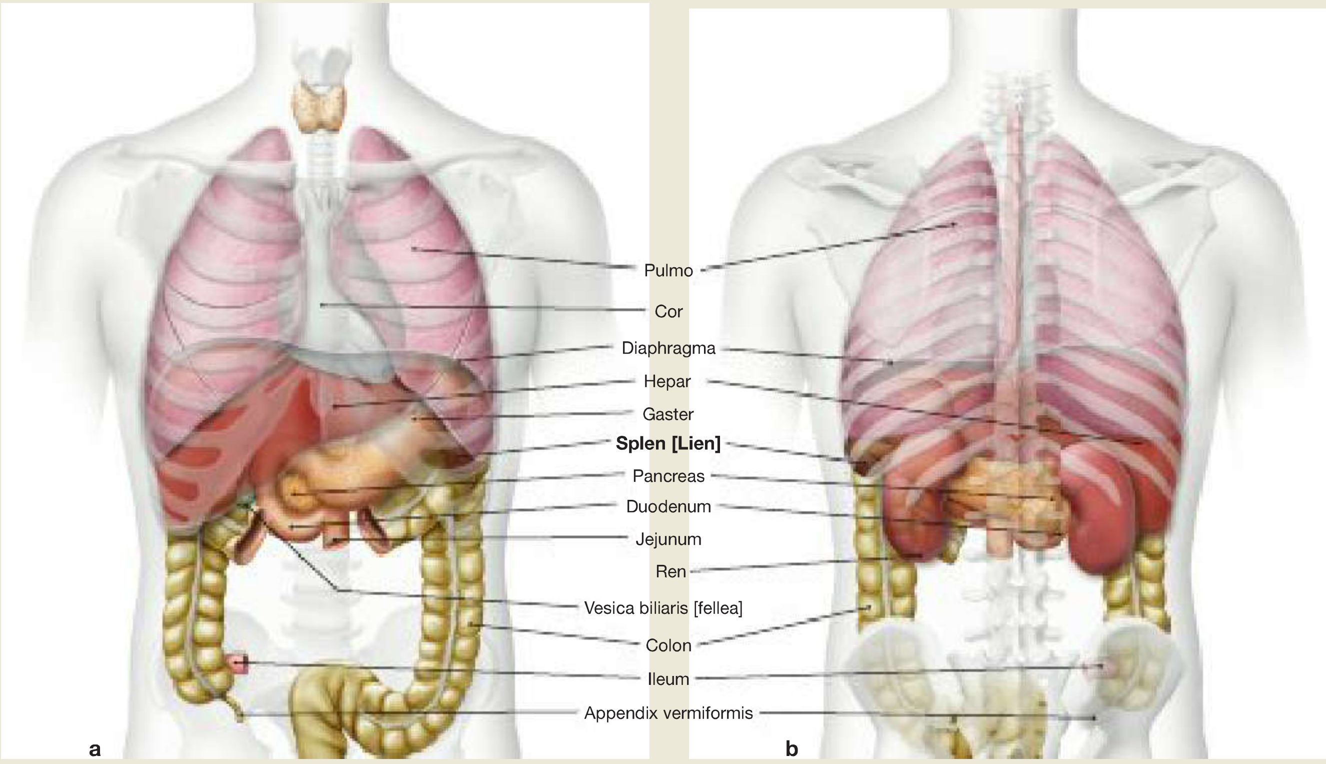
Fig. 6.122 Pancreas and bile ducts; endoscopic retrograde cholangiopancreatography (ERCP); ventral view. [T832]

To visualise the duct systems by X-ray, the excretory duct of the pancreas and the Ductus choledochus were filled with contrast medium from the Papilla duodeni major via an endoscope.

Clinical Remarks

Imaging of the pancreas is often carried out by ultrasound examination, e.g. to demonstrate a swelling of the organ indicating pancreatitis. If this is not clear due to air interference, computed tomography (CT) becomes necessary. By using ERCP for example, a pancreas divisum can be diagnosed as the cause of recurrent pancreatitis. With the breakdown of the ducts, there is suspicion of malignant pancreatic tumours.

Projection of the Spleen



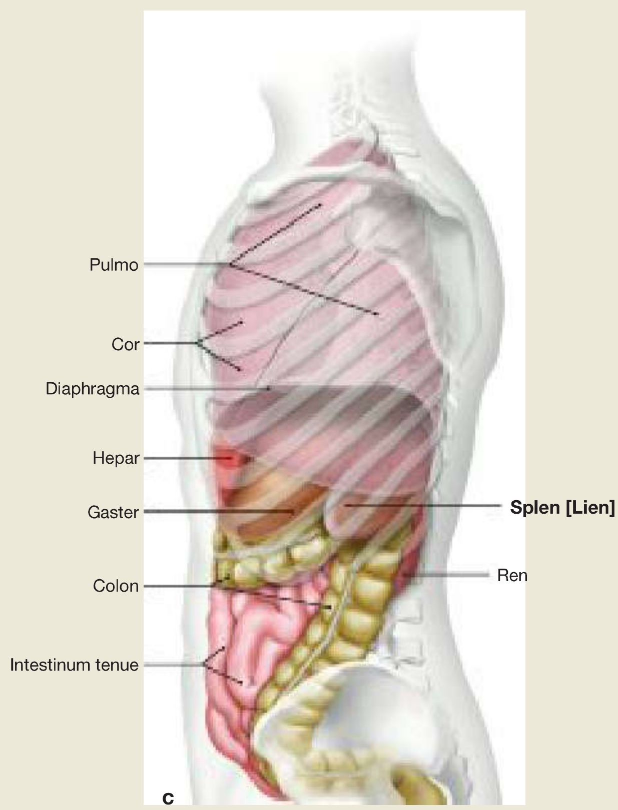


Fig. 6.123a to c Projection of inner organs onto the body surface; ventral view (→ Fig. 6.123a), dorsal view (→ Fig. 6.123b) and view from the left side (→ Fig. 6.123c). [L275]

The spleen is located **intraperitoneally** in the left epigastrium. Its longitudinal axis is projected along the course of rib X. Therefore, a normal-sized spleen cannot be palpated under the costal arch. Due to the large contact area with the diaphragm, the position of the speen is highly dependent on breathing. The spleen lies in the so-called **splenic niche,** which is confined inferiorly by the Lig. phrenicocolicum between the left colic flexure and diaphragm (→ Fig. 6.4).

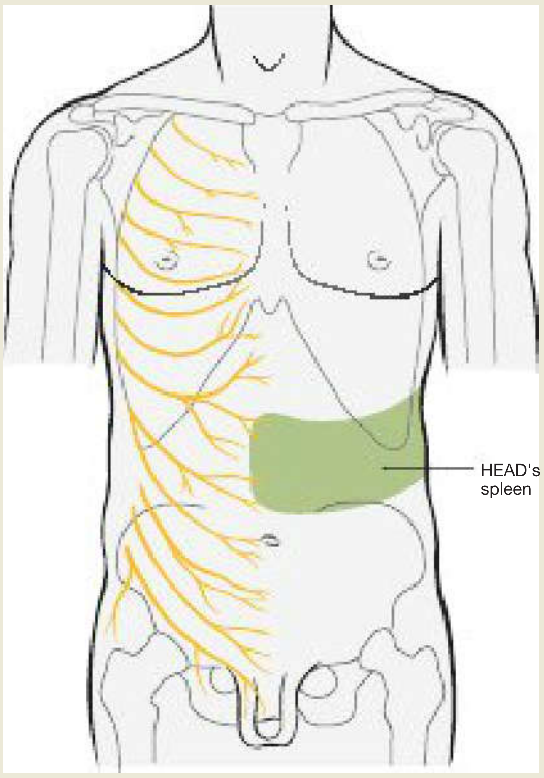


Fig. 6.124 HEAD's zone of the spleen; schematic drawing; ventral view. [L126]
The organ-related skin area or the **HEAD's zone** of the spleen is not clearly bordered and projects into dermatomes T8–T9 of the upper left abdomen. This is because in the corresponding spinal cord segments, afferent neurons from the spleen converge with those from the body surface, so if there is swelling or rupture of the spleen, pain is perceived on the body surface in dermatomes T8 and T9. Hence we talk about projected pain.

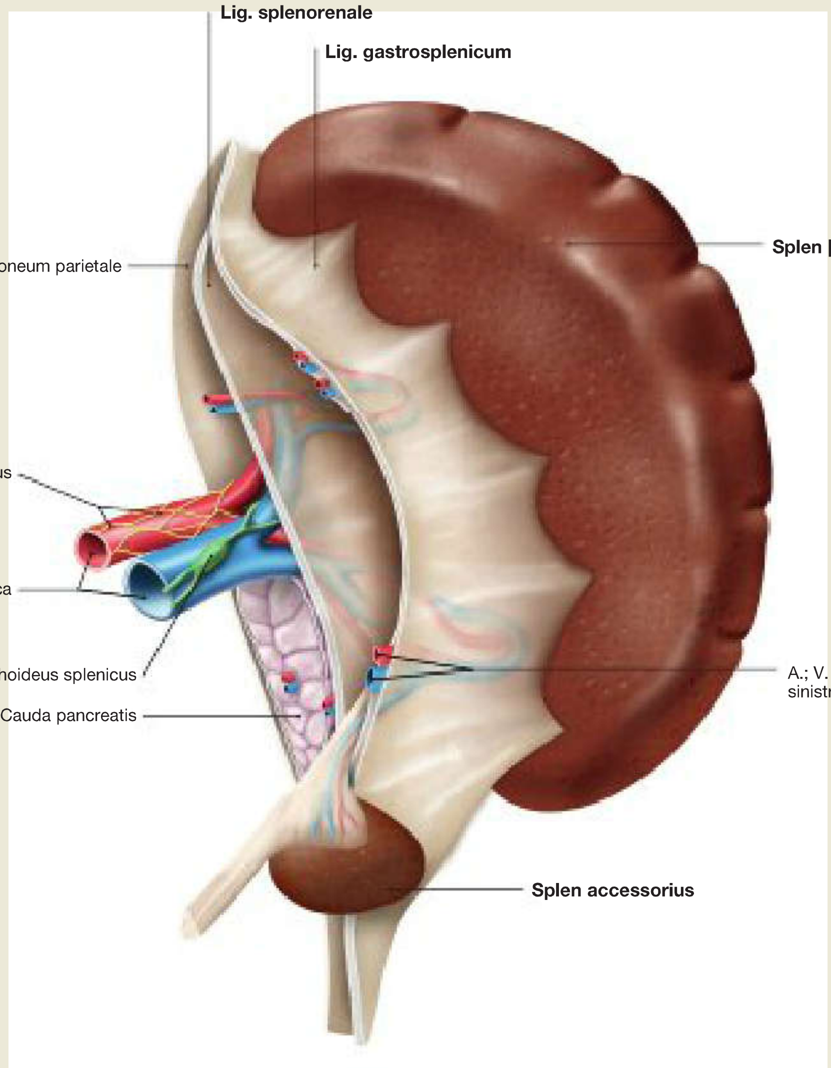
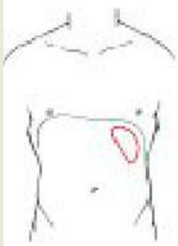
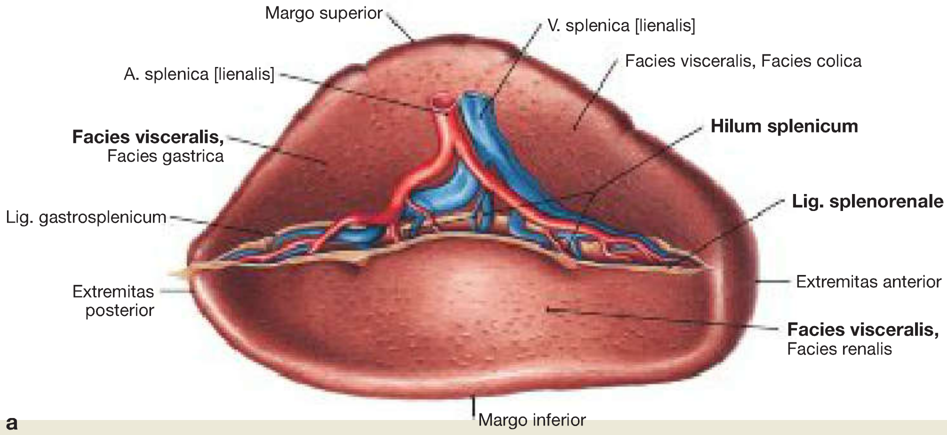


Fig. 6.125 Peritoneal duplicatures of the spleen; and accessory spleen in the Lig. splenorenale; spleen folded laterally upwards; ventromedial view. [L275]
The spleen is anchored to the surroundings by two **peritoneal duplicatures,** both of which insert at the Hilum splenicum. Coming from the stomach is the **gastrosplenic ligament,** which then continues as the **Lig. splenorenale** to the posterior abdominal wall. Between these two peritoneal duplicatures, the Recessus splenicus of the omental bursa extends up to the hilum of the spleen. Posterior to the Lig. splenorenale, and therefore in the retroperitoneal space, the neurovascular pathways (A. splenica with the autonomic Plexus splenicus, V. splenica and the lymphatic vessels of the Nodi lymphoidei splenici) reach the spleen cranially of the tail of the pancreas.

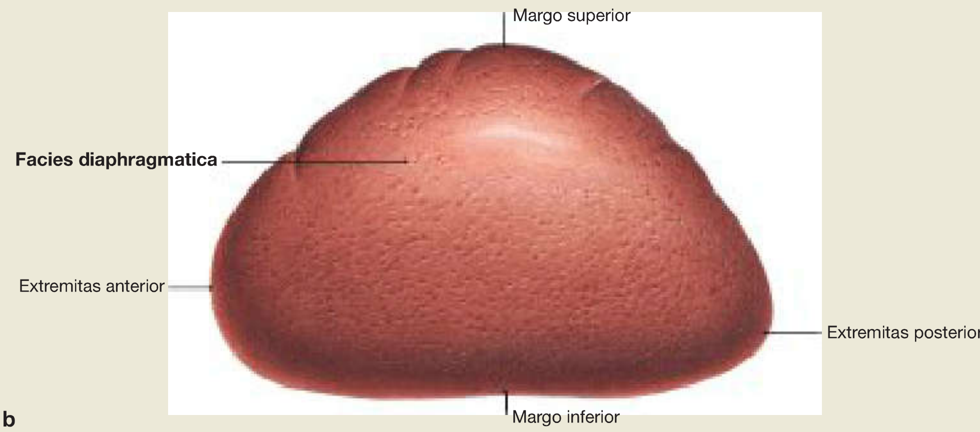
Spleen

Structure of the Spleen





a



b

Fig. 6.126a and b Spleen, Splen [Lien]; medial ventral view (→ Fig. 6.126a) and lateral cranial view (→ Fig. 6.126b).

The spleen is a **secondary lymphatic organ** and plays a role in the immune system as well as in filtering of the blood. The spleen weighs 150 g, is 11 cm long, 7 cm wide and 4 cm high. The spleen has a convex side, **Facies diaphragmatica,** running along the diaphragm, and a concave side, **Facies visceralis,** facing the intestines. This fits with the left kidney, the left colic flexure and the stomach. The edge facing upwards (Margo superior) between the two areas is usually grooved, while the bottom edge (Margo inferior) is rather smooth. Blood vessels enter and exit through the Hilum splenicum. The branching pattern of the blood vessels results in segmentation of the spleen, which, however, cannot be outlined on the surface.

Clinical Remarks

Since the spleen sits relatively far cranially in the left epigastrium and projects onto rib X, it is also completely covered by the ribs during inspiration. In the course of pathological alteration such as a malignant transformation of white blood cells in **leukaemia** or **lymphoma,** as well as in viral infections, such as **infectious mononucleosis** ('kissing disease', because asymptomatic carriers transfer it in their saliva) the spleen can become massively enlarged and weigh several kilograms, and can then appear as a mass when examining the left epigastrium.

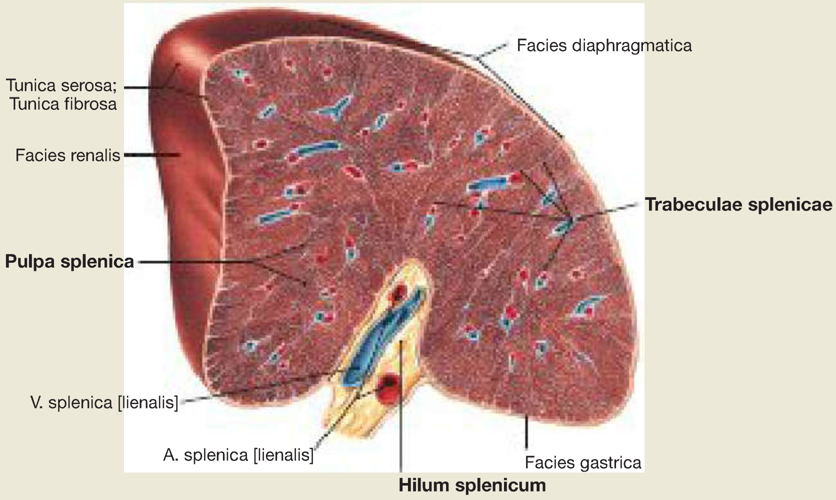


Fig. 6.127 Spleen, Splen [Lien]; cross-section through the hilum; medial cranial view.
The spleen is surrounded by a fixed capsule from trabeculations of connective tissue in the parenchyma (Pulpa splenica). In these trabeculae run larger branches of the A. and V. splenica. The Pulpa splenica consists of the blood-filled **red pulp** and disseminated 'white' nodules which are collectively referred to as **white pulp.** The white pulp contains lymphatic tissue.

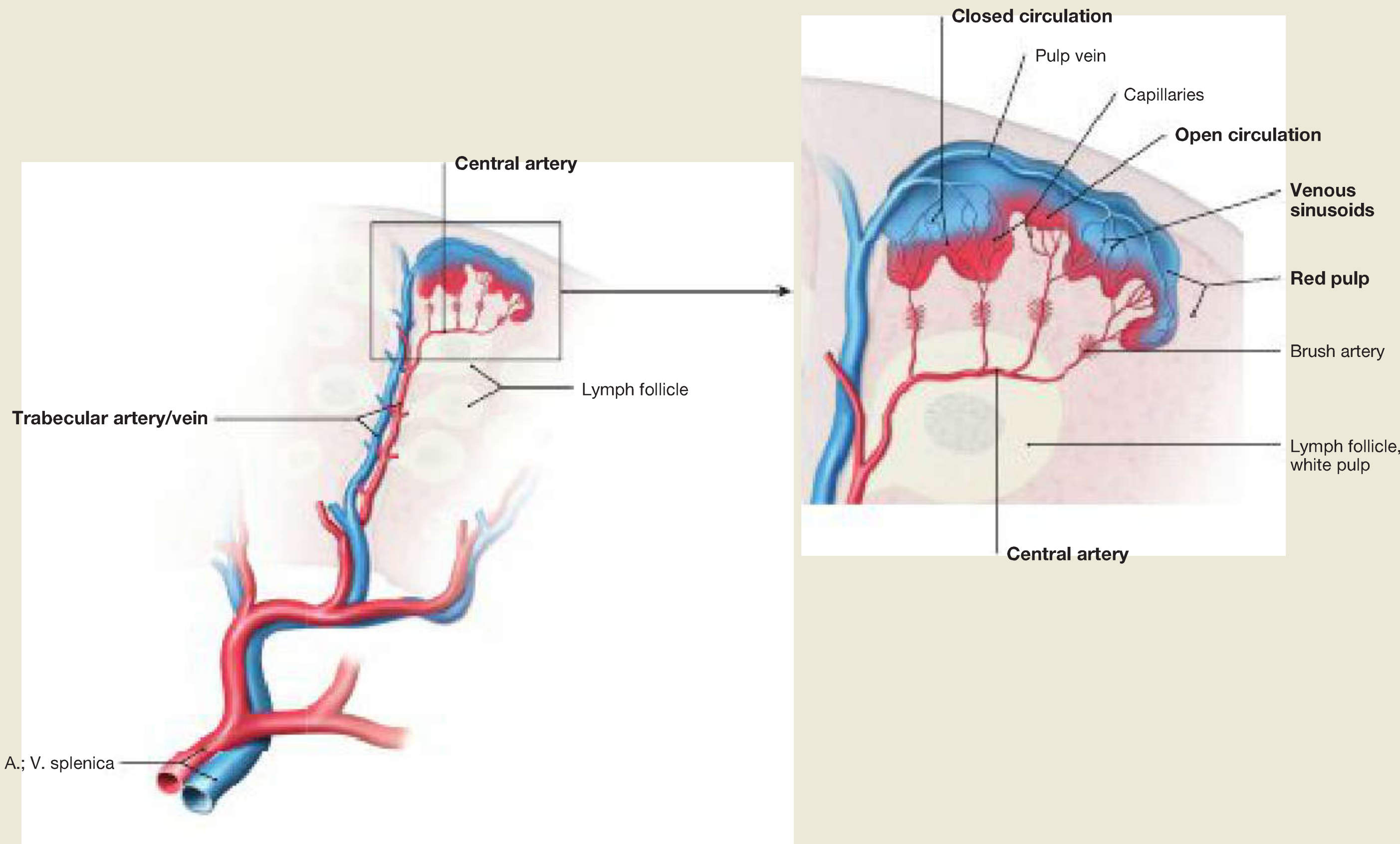


Fig. 6.128 Parenchyma and blood vessel system of the spleen; schematic representation. [L275]
The **parenchyma of the spleen (Pulpa splenica)** consists of a basic fibrous framework into which blood from blood vessels of the 'open' circulatory system flows. This **red pulp** helps with the breakdown of red blood cells (rbc) and the storage of platelets, and is responsible, together with the liver, for the formation of the blood in the foetal period. Stored in the red pulp there are white nodules which are visible microscopically as **white pulp.** Within the white pulp there is lymphatic tissue which on the one hand forms a lymph follicle and on the other hand forms periarterial lymphatic sheaths (PALS).
The course and the branching patterns of the blood vessels are functionally and clinically significant: **A. splenica** and **V. splenica** branch off in the hilum, and their branches penetrate through trabeculae of connective tissue **(trabecular arteries and veins)** into the parenchyma. Since the terminal branches of the A. splenica do not anastomose with each other, they form functional terminal arteries and subdivide the spleen into segments. From the trabecular arteries, vessels branch off, surrounded by lymphocytes of the white pulp and accordingly are designated as **central arteries.** They branch off somewhat like brushes and lead into capillaries. They either terminate as open vessels and the blood flow into the connective tissue mesh of the red pulp **(open circulation)** or pass directly into **venous sinusoids (closed circulation).** The blood cells, which pass via open circulation in the red pulp, have to enter back into the circulatory system between the endothelial cells in the wall of the sinusoids. Thus 'old' or pathologically altered red blood cells (erythrocytes) can be intercepted and filtered out. From the sinusoids, the blood passes via the pulp veins back into the trabecular veins and thus to the V. splenica.

Neurovascular Pathways of the Spleen

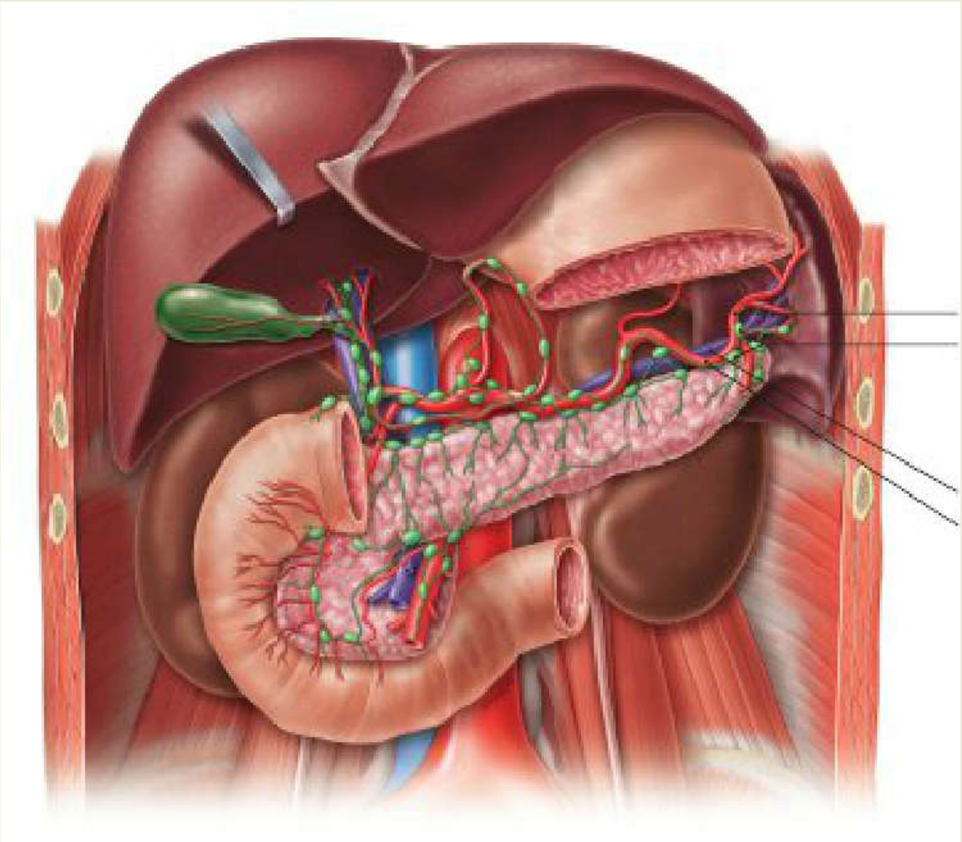


Fig. 6.129 Neurovascular pathways of the spleen, Splen [Lien]; ventral view. [L238]
The spleen has its own neurovascular pathways which enter and exit at the hilum. After exiting the Truncus coeliacus, the **A. splenica** turns to the left and passes retroperitoneally at the upper edge of the pancreas to the spleen. In doing so, it is accompanied by autonomic nerve fibres of the **Plexus splenicus** (not shown here, → Fig. 6.125). At the hilum it divides into two to three main branches and then up to six terminal branches. Before branching off, in 30–60% of cases, the A. splenica branches off a A. gastrica posterior to the posterior side of the stomach. Then at the hilum, the A. gastroomentalis sinistra and the Aa. gastricae breves branch off to the stomach.
The **V. splenica** usually passes along the dorsal side of the pancreas up to the neck part where it links with the V. mesenterica superior to go to the portal vein. In the majority of all cases (70%), the V. mesenterica inferior is incorporated. The **Nodi lymphoidei splenici** at the hilum are not only the regional lymph nodes for the spleen, but also for the tail of the pancreas and the upper part of the greater curvature of the stomach. They drain via the Nodi lymphoidei coeliaci to the Trunci intestinales.

Clinical Remarks

In case of a surgical **removal of the spleen (splenectomy),** the A. and V. splenica are also removed. Since the spleen can store large quantities of platelets, the formation of **blood clots** must be prevented before surgery; otherwise there is an increased risk of stroke or heart attack.

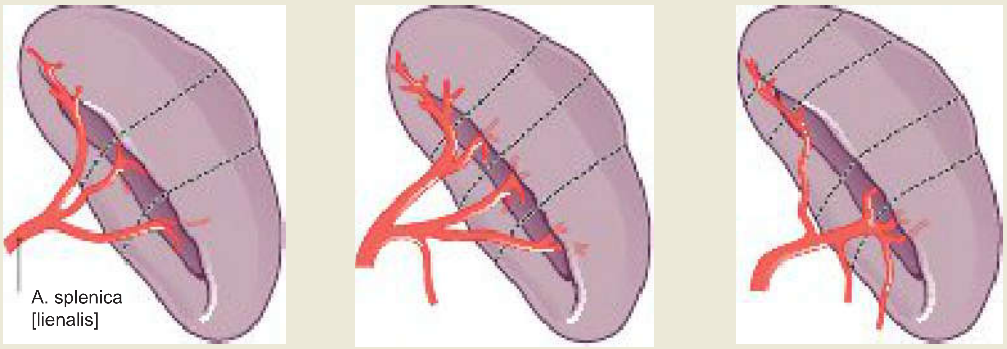


Fig. 6.130 Segments of the spleen; schematic illustration of three, four or five segments; ventral view. [L126]

The terminal branches of the A. splenica are functional terminal arteries and divide the spleen variably in **three to six tapered segments.**

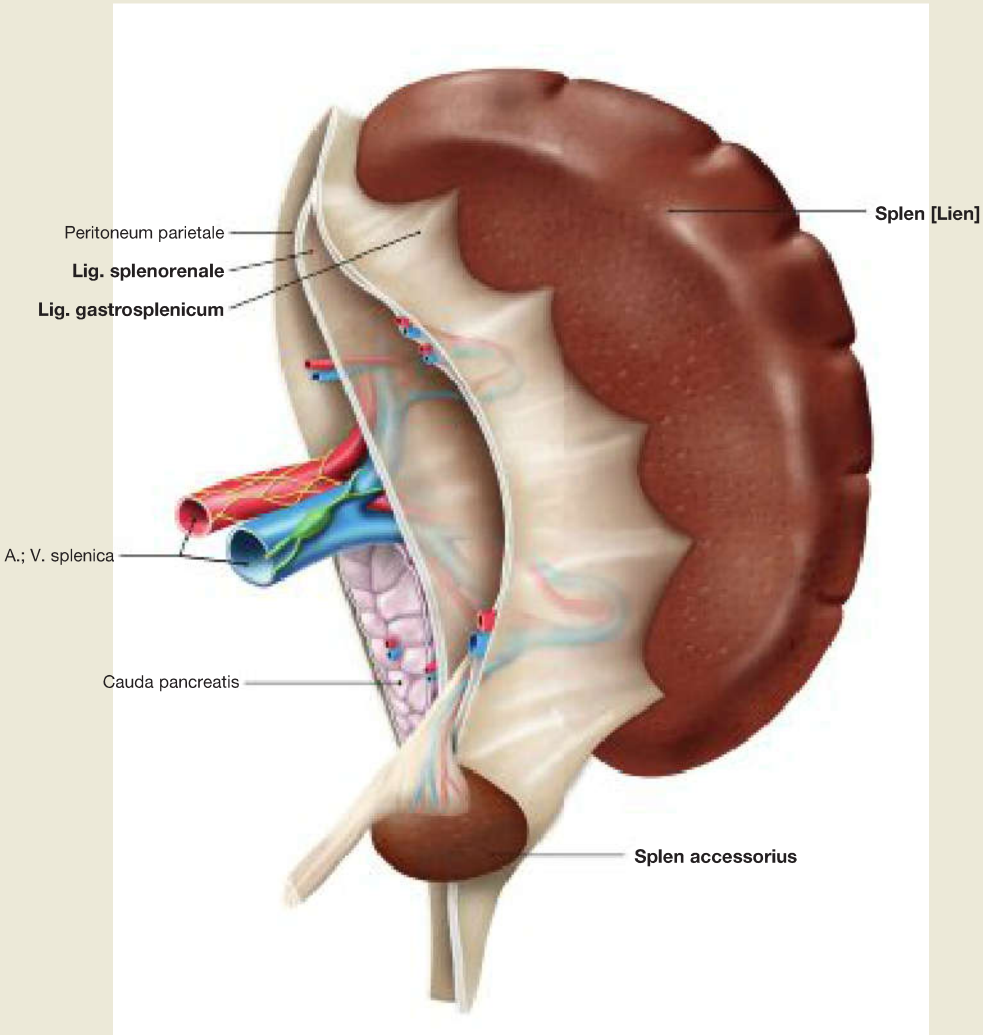


Fig. 6.131 Accessory spleen in the Lig. splenorenale; spleen folded upwards; ventral view. [L275]

In 5–30% of cases, an **accessory spleen** occurs as an independent organ usually close to the hilum, embedded into one of the peritoneal duplicatures.

Clinical Remarks

Falling onto the abdomen may cause **splenic rupture,** which can lead to life-threatening bleeding. Here the spleen segments are significant: particularly vertical tears, which incorporate multiple segments, bleed heavily; conversely, horizontal tears bleed relatively little, since the splenic arteries are functionally terminal arteries. This also explains why **infarctions of the spleen** usually expand wedge-shaped between the borders of the segments.

An accessory spleen may be clinically significant after the surgical **removal of the spleen (splenectomy),** so its presence should therefore be clarified. If the spleen has to be removed due to a traumatic rupture, the accessory spleen can take on its function so that no immune deficiency occurs. If a splenectomy is therapeutically indicated, e. g. due to genetically modified red blood cells being broken down too strongly, leading to anaemia, the accessory spleen should also be removed, otherwise the symptoms may recur.

Topography of the Upper Abdominal Organs with Neurovascular Pathways

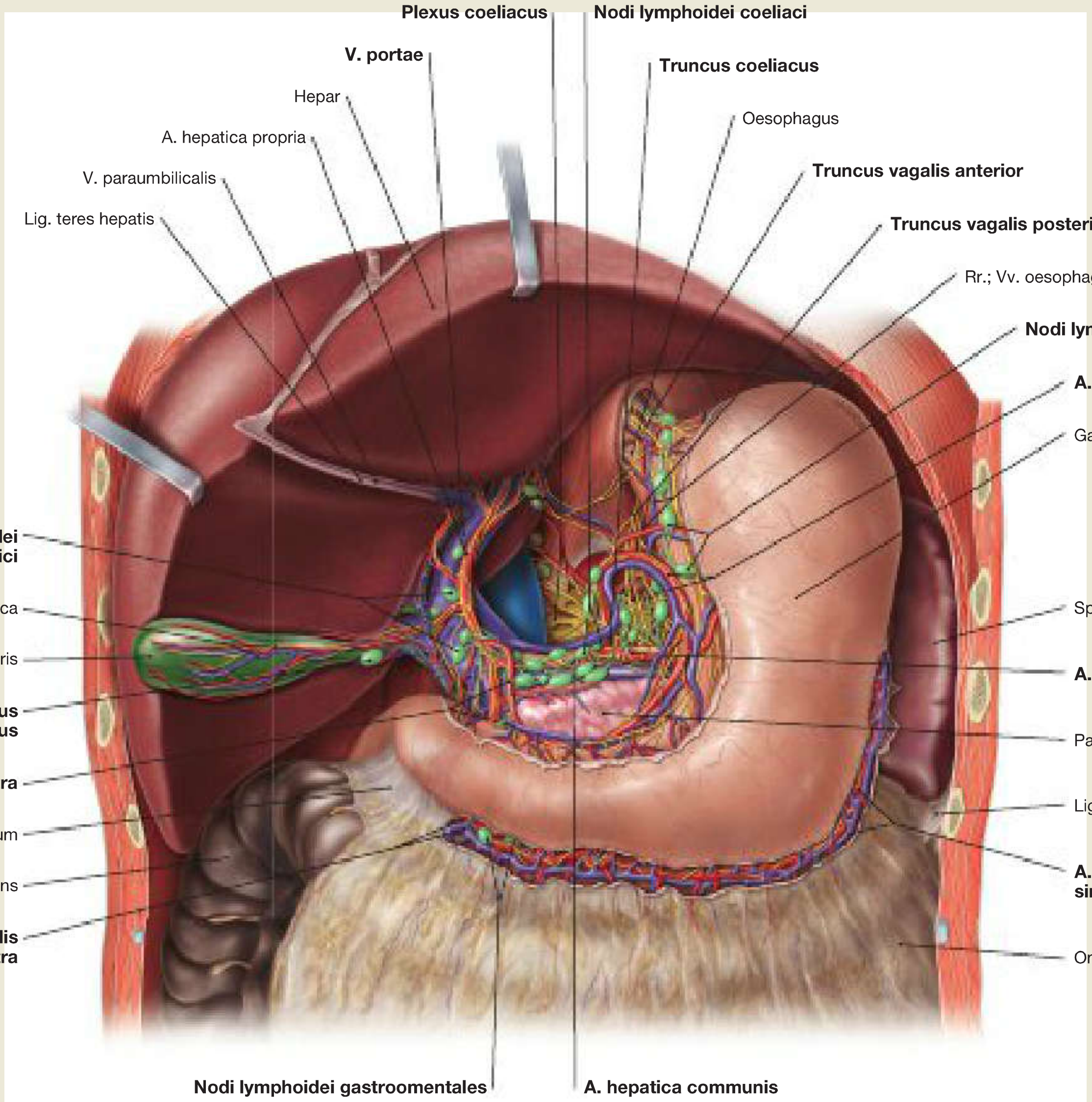


Fig. 6.132 Situs of the upper abdominal organs; the liver has been mobilised upwards, the Omentum minus has been removed and the Lig. gastrocolicum has been cut open to display the neurovascular pathways; ventral view. [L238]

This view is very useful for the dissection of the upper abdominal organs, as it also shows all their neurovascular pathways. First, the liver has to be mobilised upwards in order to remove the Omentum minus. By doing this, the branches of the **Truncus coeliacus** and the tributaries to the **V. portae hepatis** become visible. The **A. hepatica communis** turns to the right, the **A. splenica** to the left. The **A. gastrica sinistra** turns cranially to reach the lesser curvature of the stomach. Usually it is divided into two trunks and connected with the **A. gastrica dextra.** The accompanying veins drain directly into the portal vein. The fine branches of the A. gastrica sinistra supply the Pars abdominalis of the oesophagus and here, the left lobe of the liver with an additional branch, occurring in 10–20% of cases. The **Aa./Vv. gastroomentales dextra and sinistra** are connected to the greater curvature of the stomach.

The illustration also shows the lymphatic vessels and autonomic nerves, which are often not clearly displayed in dissections. On the lesser curvature of the stomach are located the **Nodi lymphoidei gastrici;** their collectors are clearly visible where they are connected with the **Nodi lymphoidei coeliaci** at the opening of the Truncus coeliacus. These collecting lymph nodes also drain the **Nodi lymphoidei hepatici** and the **Nodus lymphoideus cysticus** at the neck of the gallbladder (Vesica biliaris). From the autonomic network around the Truncus coeliacus **(Plexus coeliacus),** the autonomic nerve fibres of the sympathicus and parasympathicus lay next on the blood vessels and reach their target organs as perivascular plexus. Preganglionic sympathetic neurons pass as the **Nn. splanchnici major and minor** through the diaphragm and are synaptically interconnected in the **Ganglia coeliaca.** Conversely the parasympathetic neurons reach the Plexus coeliacus via the **Trunci vagales anterior and posterior,** which together with the oesophagus pass through the diaphragm and run along the lesser curvature of the stomach.

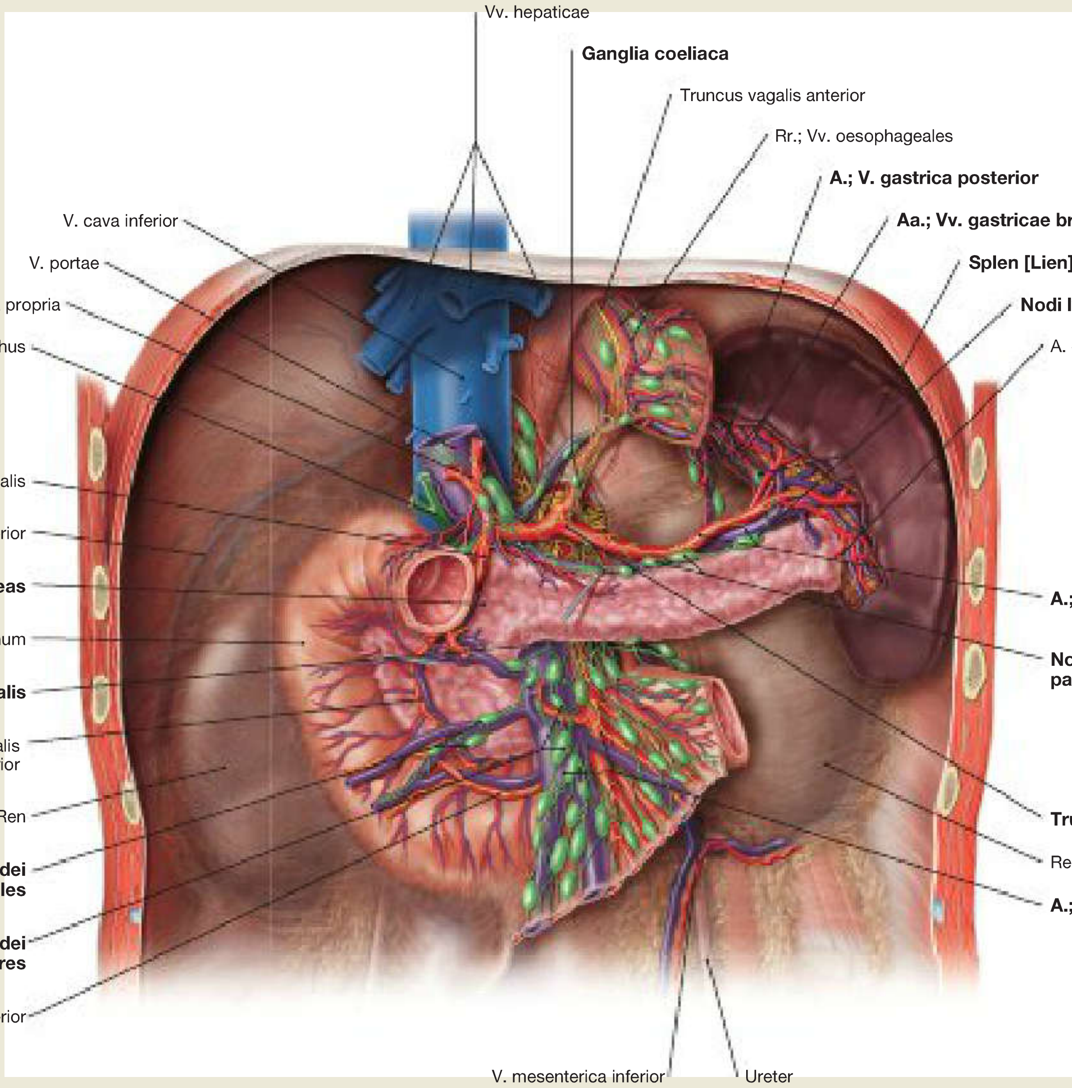


Fig. 6.133 Situs of the upper abdominal organs with representation of the retroperitoneal organs; the liver has been removed completely, to see the retroperitoneal organs and the neurovascular pathways of the upper abdomen, the stomach has been removed. The mesentery has been cut from its root and resected with the small intestinal loops of the jejunum and ileum; ventral view. [L238]

Of the intraperitoneal upper abdominal organs, only the spleen has been left. This makes the pancreas and also the duodenum visible. The branches of the **A. splenica** leading to the stomach **(A. gastrica posterior, A. gastroomentalis sinistra and Aa. gastricae breves)** can be recognised. The **A. gastrica sinistra** branches out to the oesophagus, into which the **Trunci vagales anterior and posterior** enter into the abdominal cavity (Cavitas abdominalis). The **A. gastroduodenalis** branches off from the **A. hepatica communis** with its terminal branch joining the A. pancreaticoduodenalis superior anterior with the A. pancreaticoduodenalis inferior from the A. mesenterica superior. The **A. and V. mesenterica superior** run behind the neck of the pancreas, and join the mesentery. They are accompanied by the **Nodi lymphoidei mesenterici superiores;** its collectors amalgamate as corresponding lymph vessels along the Truncus coeliacus to the **Trunci intestinales.** With the Trunci lumbales these form the **Ductus thoracicus.**

Abdomen and Pelvis, Median Section

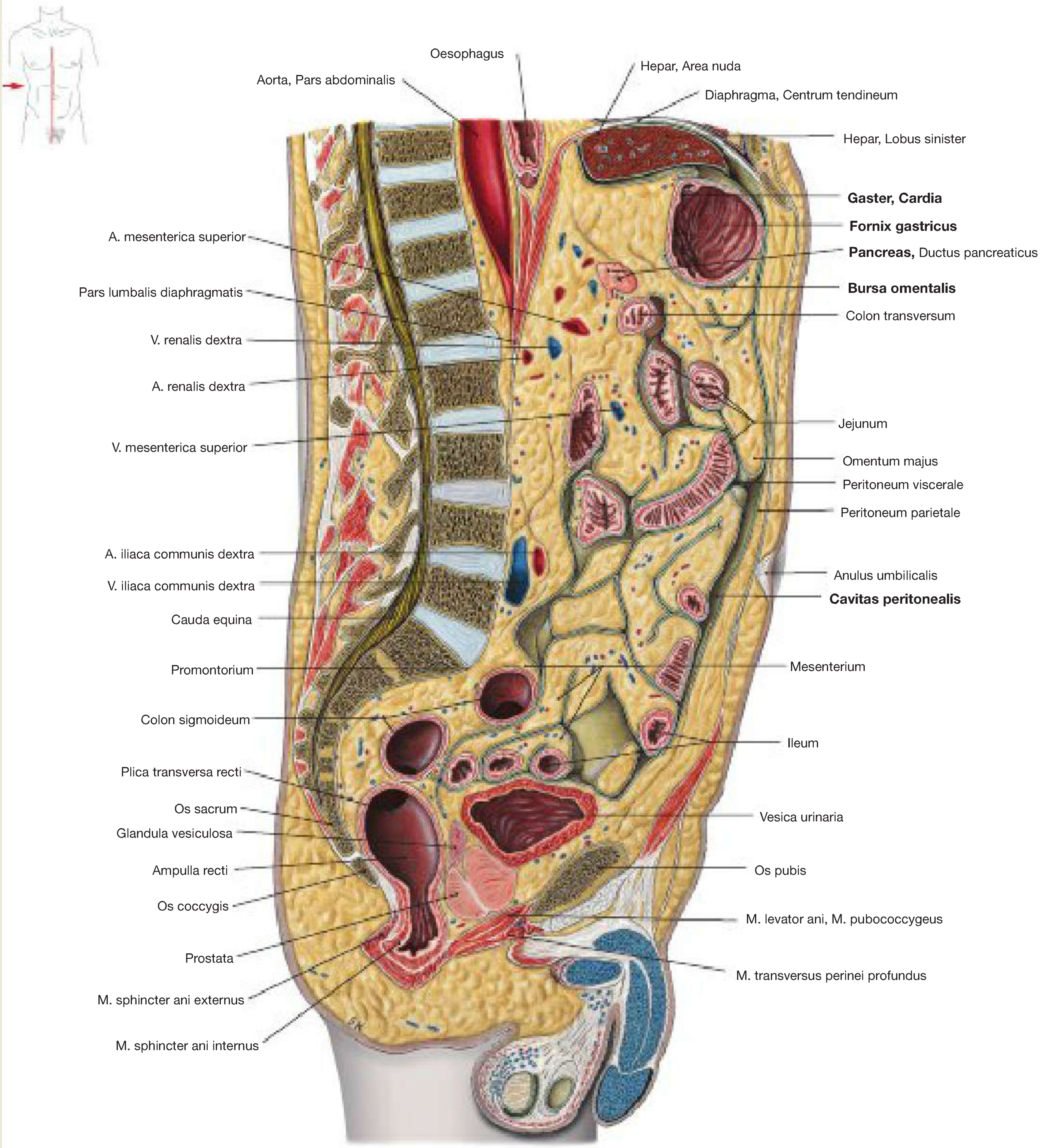


Fig. 6.134 Abdomen and pelvis of a man; median section; view from the right side. [L238]
It is clear from the illustration that the peritoneal cavity (Cavitas peritonealis) is not a wide, empty space but instead is made up of small recesses between the intraperitoneal organs. Also the omental bursa between the stomach and the pancreas is only a narrow, peritoneum-lined gap. A large part of the abdomen is taken up by the mesentery, where very large amounts of adipose tissue can be stored.

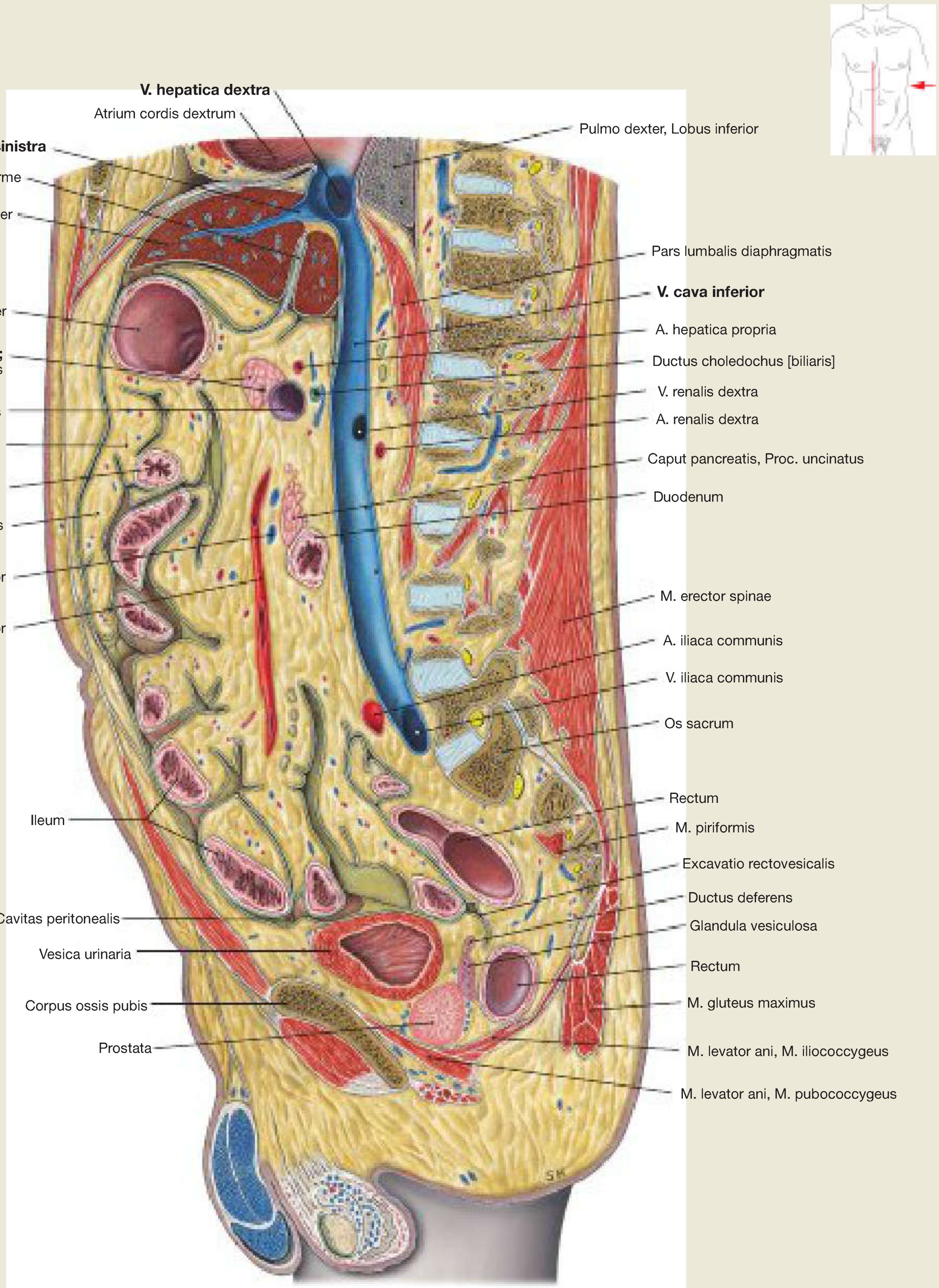


Fig. 6.135 Abdomen and pelvis of a man; sagittal section; view from the left side. [L238]
The sectional plane runs right paramedially at the level of the V. cava inferior. Thus, the confluence of the Vv. hepaticae, which drain the venous blood from the liver, is clearly visible. The V. portae hepatis, which takes the nutrient-rich blood of the unpaired abdominal organs to the liver, comes from its main veins behind the head of the pancreas.

Abdomen and Pelvis, Frontal Section

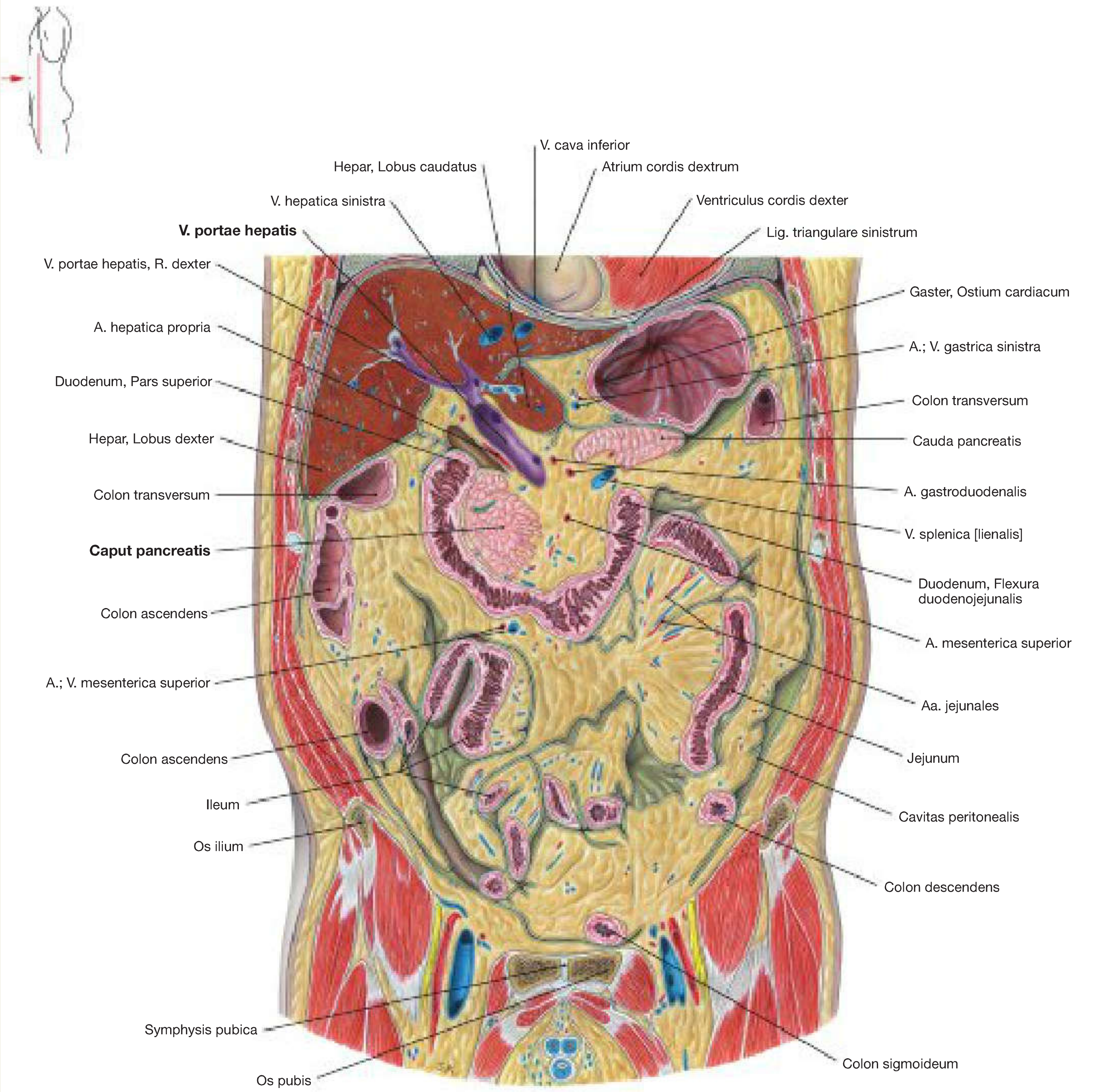
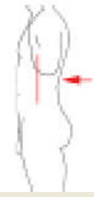


Fig. 6.136 Abdomen and pelvis of a man; frontal section through the anterior part; ventral view. [L238]

This frontal section passes through the V. portae hepatis, which passes above the head of the pancreas (Caput pancreatis) to the hilum of the liver and there divides into its right and left branches.



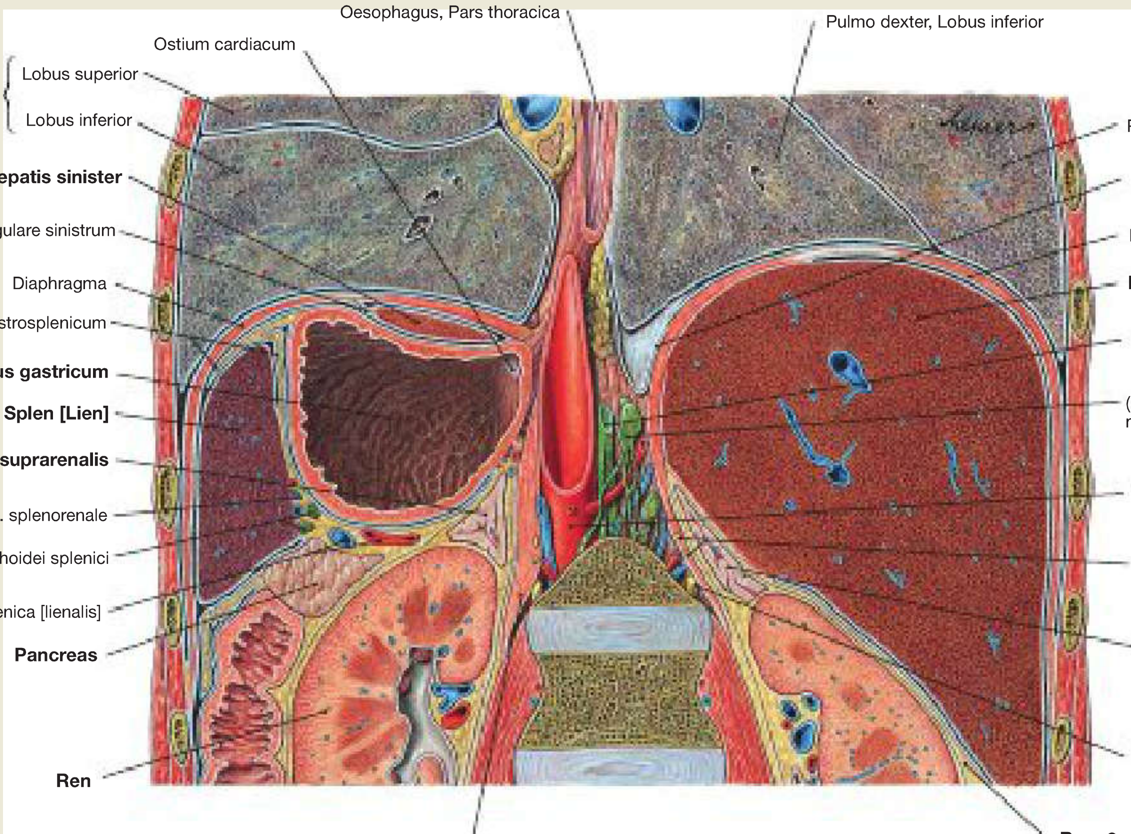
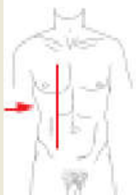


Fig. 6.137 Abdominal cavity, Cavitas abdominalis, and thoracic cavity, Cavitas thoracis; frontal section at the level of the kidneys; dorsal view.

The section shows the positions of the individual upper abdominal organs in relation to each other. The right upper abdomen is completely filled by the right lobe of the liver (Lobus hepatis dexter), which is caudally in contact with the right kidney (Ren) and the right adrenal gland (Glandula suprarenalis). On the left side, the cranial part of the left hepatic lobe covers the stomach (Gaster) which, in turn, is in contact with the spleen on the left and caudally with the left kidney, the left adrenal gland and the pancreas. The tail of the pancreas extends to the spleen.

Epigastrium, Sagittal Section



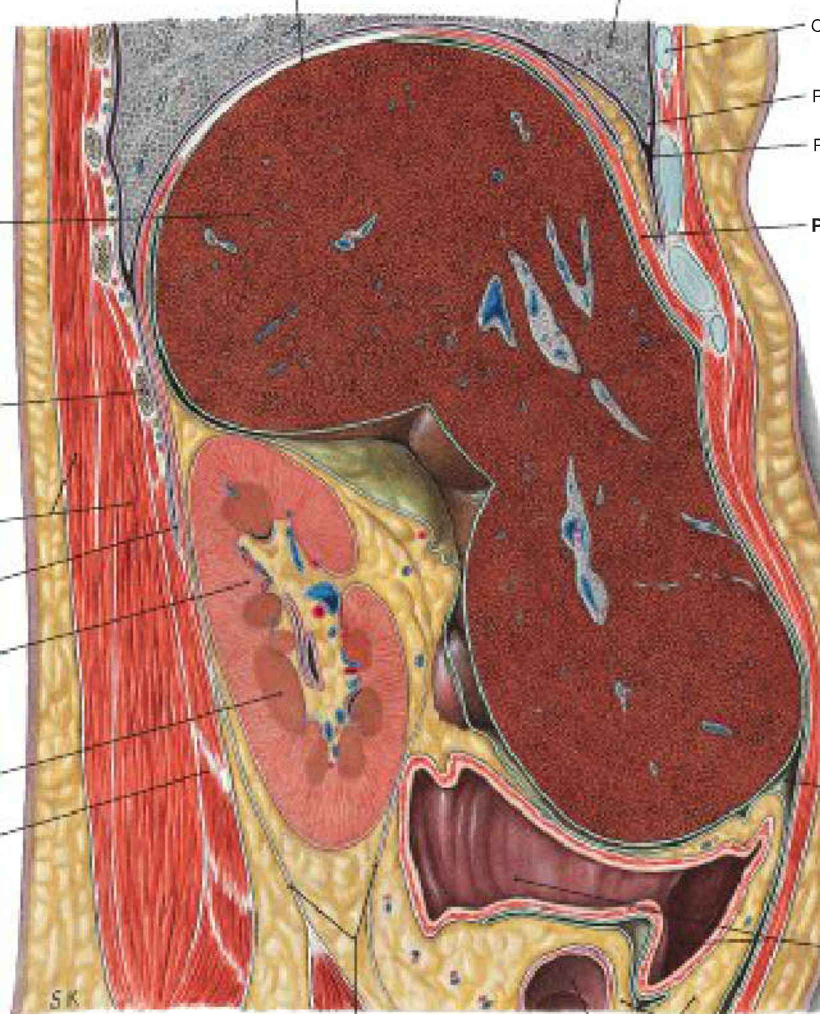
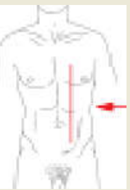


Fig. 6.138 Abdomen; sagittal section through the right epigastrium at the level of the kidney; view from the right side. [L238]
In the right epigastrium is the right lobe of the liver (Hepar, Lobus dexter), lying extensively beneath the diaphragm. The right kidney (Ren) is positioned dorsally below the liver (Hepar) in the retroperitoneal space, and ventrally thereof the Pars pylorica of the stomach (Gaster) in the intraperitoneal cavity.



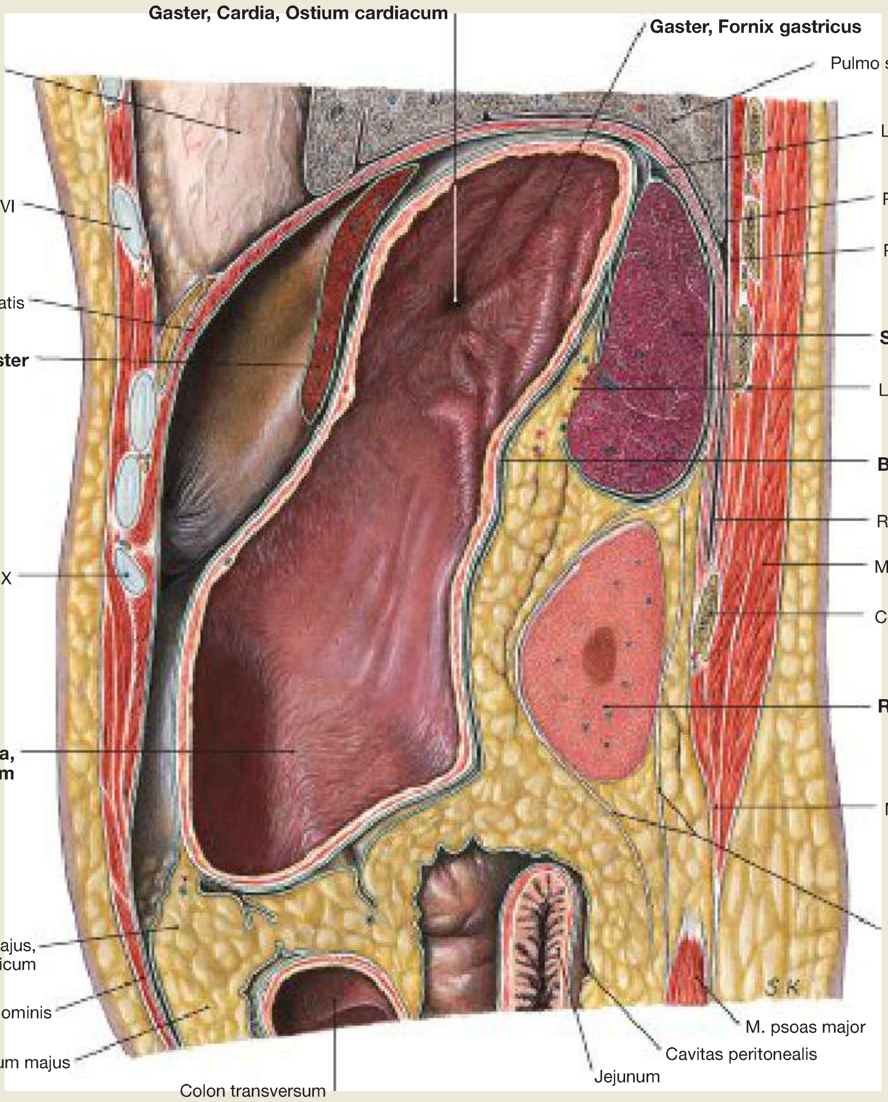
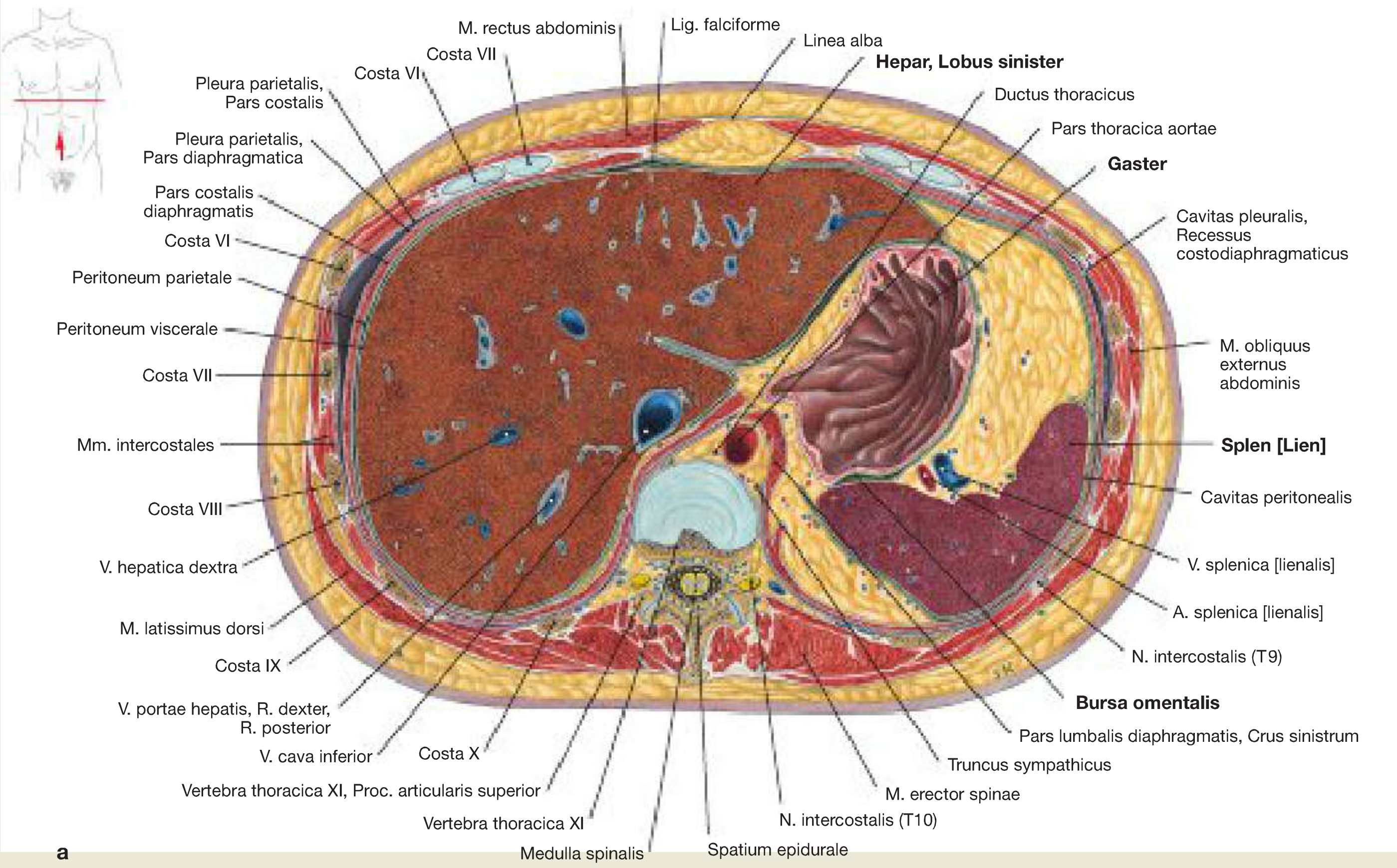


Fig. 6.139 Abdomen; sagittal section through the left epigastrium at the level of the spleen; view from the left side. [L238]
The stomach (Gaster) occupies the majority of the left upper abdomen. Ventrally it is covered by the left lobe of the liver (Hepar, Lobus sinister) and dorsally it has broad contact with the spleen (Splen) and the left kidney (Ren), which is located in the retroperitoneal space. The Bursa omentalis forms a small recess, lined with peritoneum, behind the stomach.

Epigastrium, Cross-Sections



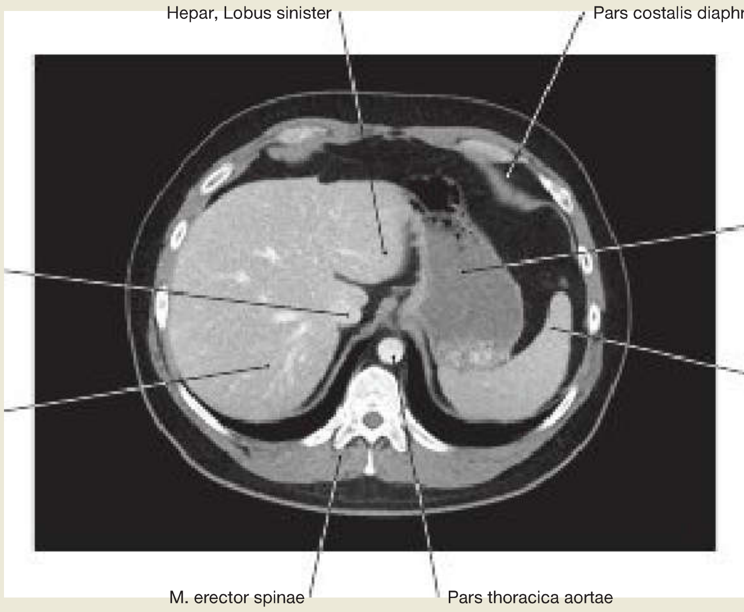
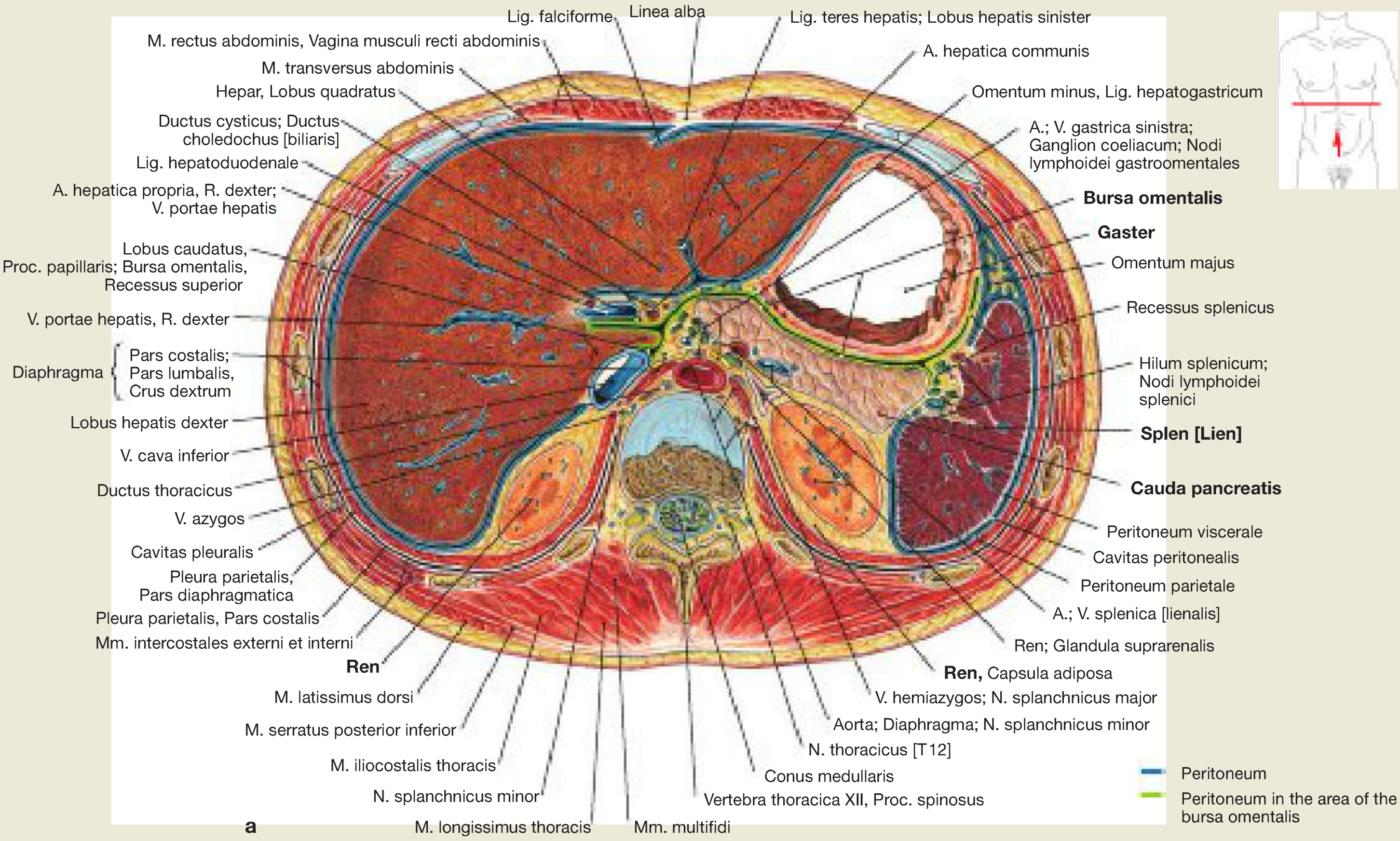


Fig. 6.140a and b Abdominal cavity, Cavitas abdominalis; cross-section at the level of the 11th thoracic vertebra (→ Fig. 6.140a) and corresponding computed tomographic cross-section (CT; → Fig. 6.140b); caudal view. a [L238], b [T832]

The liver (Hepar) occupies the whole right upper abdomen and with its left lobe extends left to the stomach (Gaster). Behind the stomach is the Bursa omentalis, lined by peritoneum. The spleen is cut in the left epigastrium.

Clinical Remarks

Sectional diagnostic imaging, e.g. by **computed tomography** (CT), has now become a routine imaging procedure. Without the use of a contrast agent, it gives an image of the soft tissue and is not as susceptible to interference, for example by air-filled intestinal loops, as ultrasound. Therefore CT scans are carried out for further diagnostic clarification, or for the planning of surgery. According to general convention, CT scans are **always shown in caudal view.** Therefore, it is always advisable to look at anatomical cross-sectional images from a caudal view.



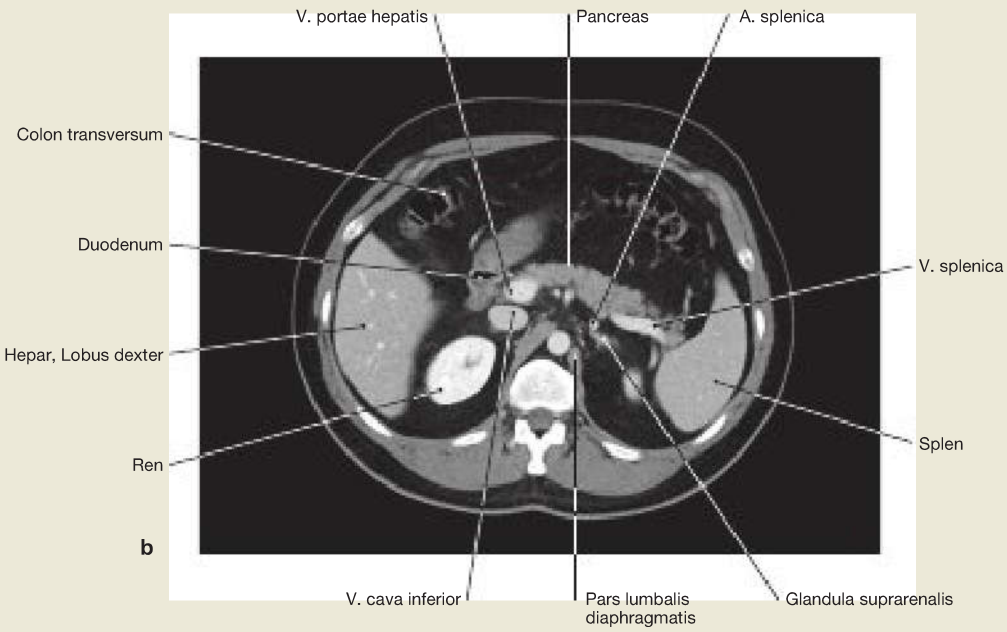


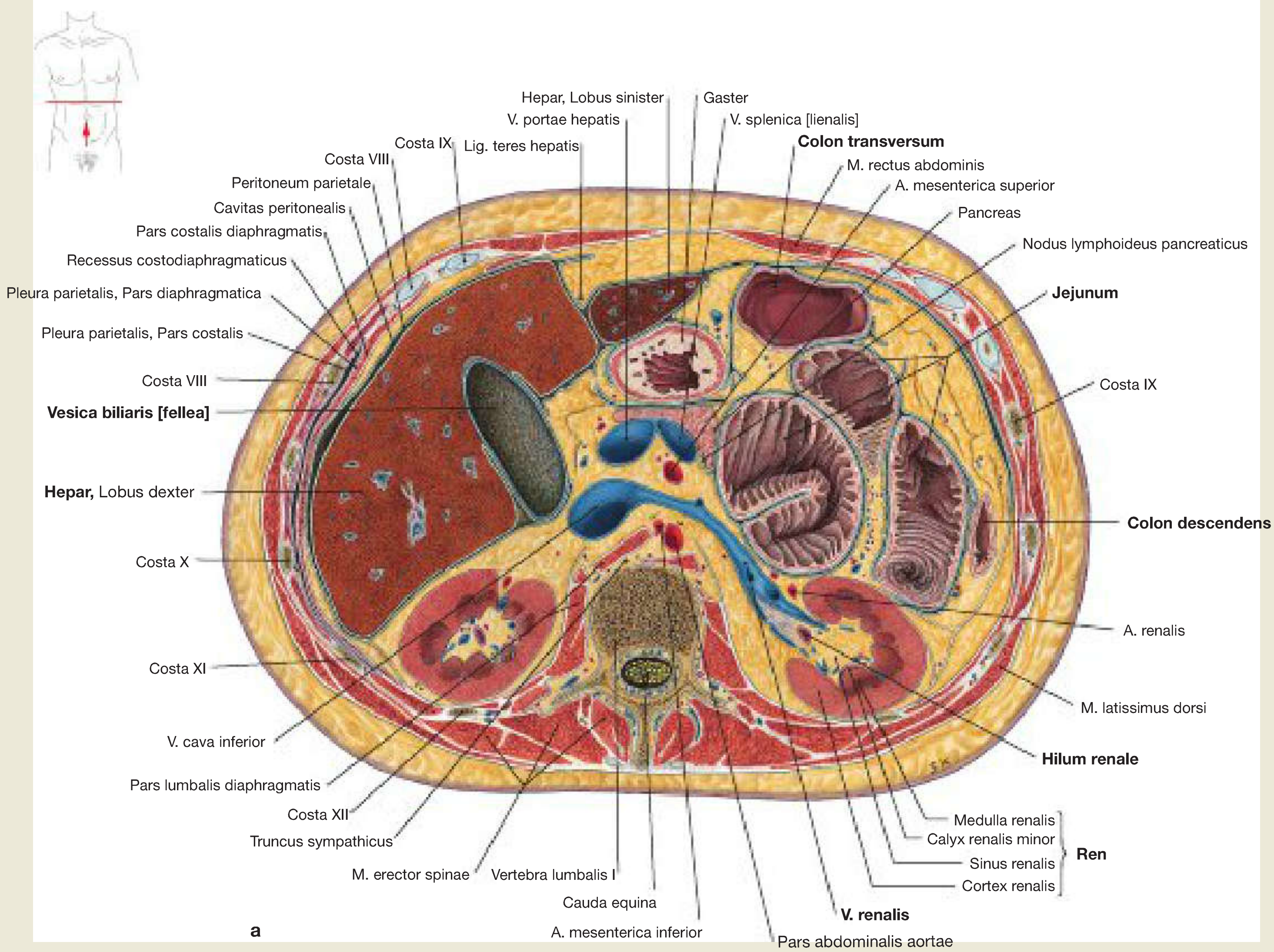
Fig. 6.141a and b Abdominal cavity, Cavitas abdominalis; cross-section at the level of the first lumbar vertebra (→ Fig.6.141a) and corresponding computed tomographic cross-section (CT; → Fig.6.141b); caudal view. b [T832]

At the level of the first lumbar vertebra, the posterior poles of the kidneys (Renes) and the pancreas have also been truncated. The pancreas is located posterior to the stomach (Gaster), separated by the Bursa omentalis, and extends to the left side to reach the hilum of the spleen.

Clinical Remarks

For the examination of the pancreas**,** ultrasound imaging is often not very informative due to the air-filled intestinal loops, and requires CT scans for clarification. These CT scans, e.g. in cases of inflammation **(pancreatitis),** often enable oedematous and cystic swelling of the organ to be visualised, and they can be consulted to evaluate progression.

Epigastrium, Cross-Sections



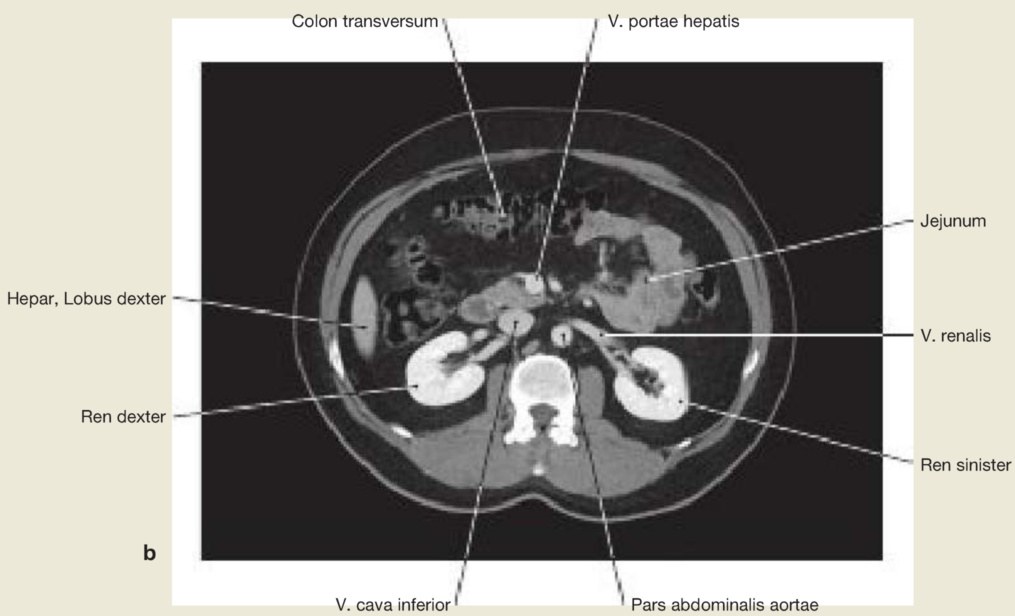
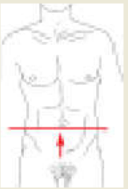


Fig. 6.142a and b Abdominal cavity, Cavitas abdominalis; cross-section at the level of the first lumbar vertebra (→ Fig. 6.142a) and corresponding computed tomographic cross-section (CT; → Fig. 6.142b); caudal view. a [L238], b [T832]

The hilum of the kidney (Ren) is typically at the level of the first to second lumbar vertebrae (can be seen at the opening of the left V. renalis). On the lower margin of the liver (Hepar), the gallbladder (Vesica biliaris) is truncated. In the left epigastrium, portions of the small intestinal loops (jejunum) and portions of the large intestine (Colon transversum and Colon descendens) are visible.



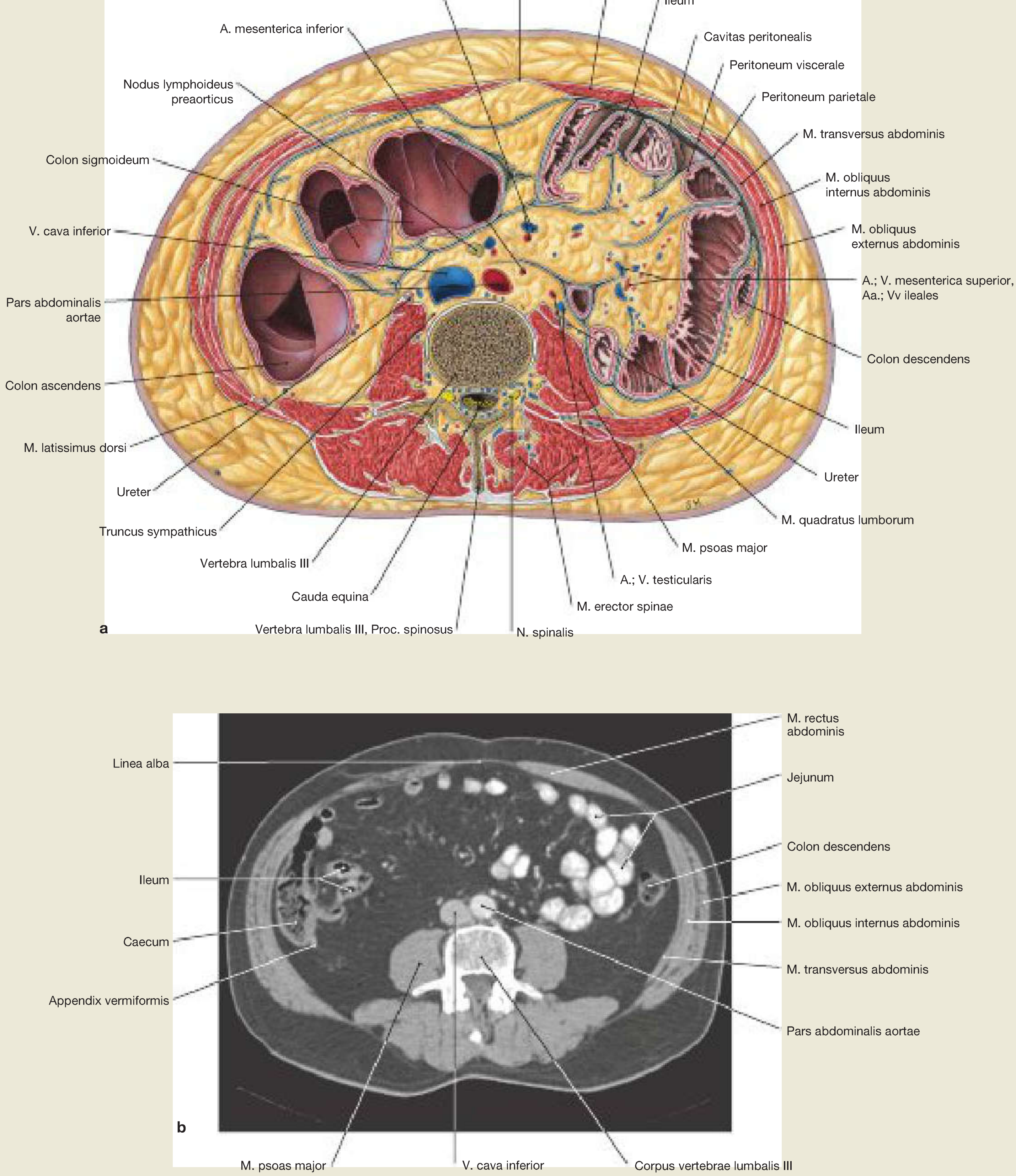


Fig. 6.143a and b Abdominal cavity, Cavitas abdominalis; cross-section at the level of the third lumbar vertebra (→ Fig. 6.143a) and the corresponding computed tomographic cross-section (CT; → Fig. 6.143b); caudal view. a [L238]

Practice Exam Questions

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

Explain the significance of the relative positions of the individual abdominal organs.

Which peritoneal ligaments anchor the liver?

What is the relevance of the peritoneal cavity recesses?

- Explain the structure of the Bursa omentalis in detail.

What is the Omentum majus and what is its function?

How is the stomach (Gaster) structured?

Which vessels provide the stomach with blood?

- Show these and explain their origins.

Explain the stations of the lymphatic drainage of the stomach on the specimen, along with its clinical importance.

Show the relative positions of the individual intestinal segments on the specimen.

- By which projection points is the appendix characterised and why do you need these?

Where is the RIOLAN's anastomosis and why is it good?

Seen from the developmental point of view, which sections of the intestine are responsible for the different aspects of nourishment?

Explain the anatomy and function of the liver.

- What is meant by the segmental structure of the liver?

Which portocaval anastomoses do you know?

How is the liver supplied with blood?

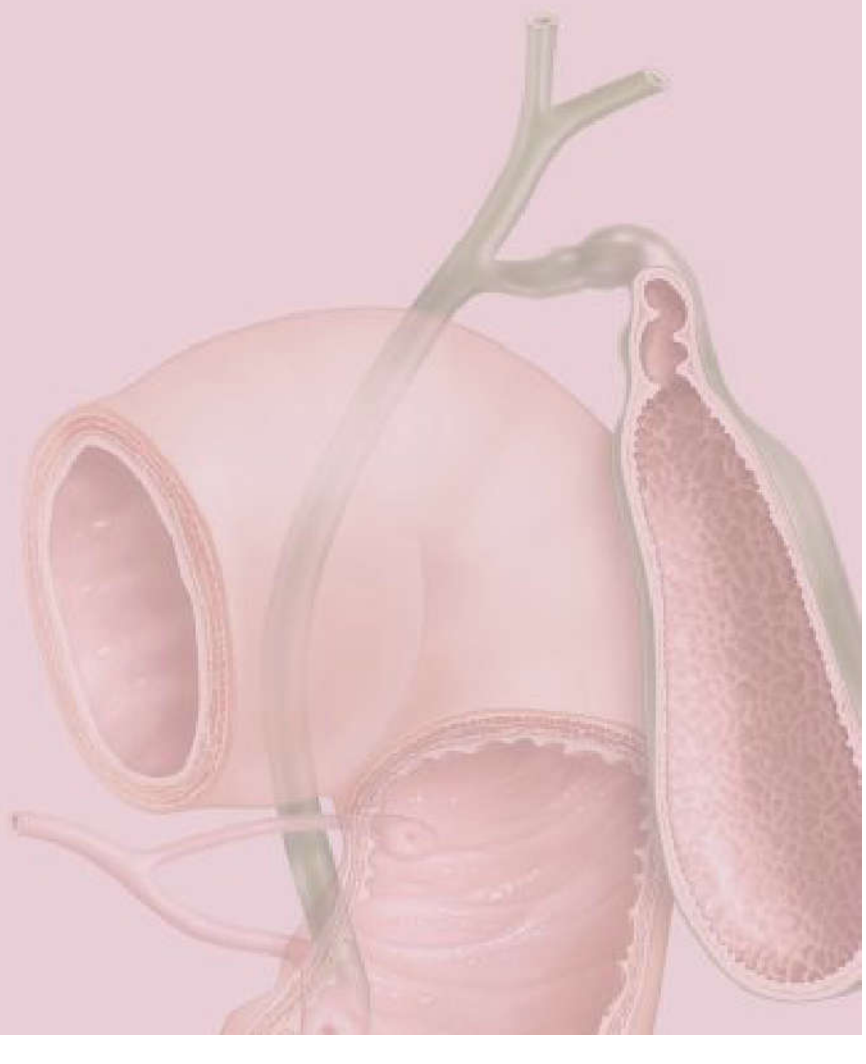
Where is the portal vein and from where does it originate?

Explain the position, classification and projection of the pancreas, using the specimen.

How is the pancreatic duct system structured and how does it work?

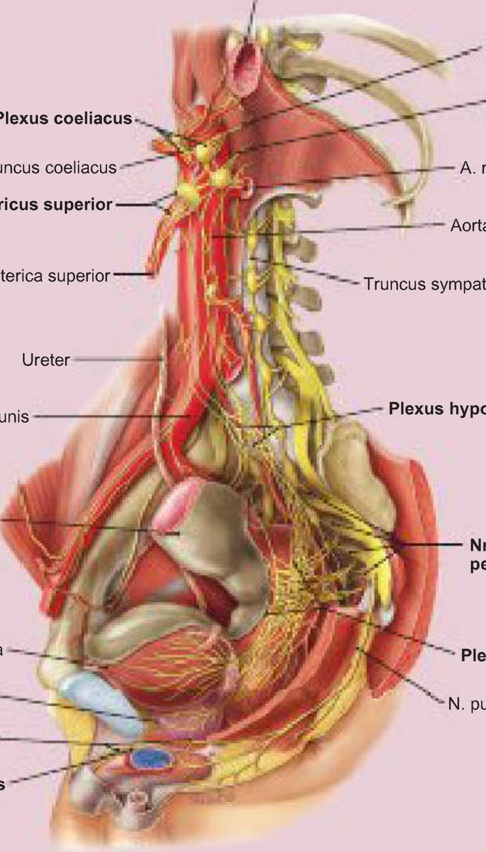
Where is the spleen and where does it project onto the body surface?

What is the importance of the segmental structure of the spleen?



Retroperitoneal Space and Pelvic Cavity

7



Overview

There are good reasons to deal with the **retroperitoneal situs of the abdomen** – i.e. all the organs not located in the peritoneal cavity, but at the dorsal wall – in combination with the pelvis. The kidneys, which are the major organs of the retroperitoneal space, initially develop in the pelvis and later ascend to a level just below the ribs. In contrast, the gonads, i.e. the testicles and ovaries, descend from the abdomen into the pelvis and, in men, even further down into the scrotum. Therefore, the subperitoneal connective tissue spaces of the pelvis and the retroperitoneal space form a continuum.

In the retroperitoneal space, a **kidney (Ren)** with a superior adjacent **adrenal gland (Glandula suprarenalis)** lies on each side. The **ureter (Ureter)** connects the kidney to the urinary bladder in the pelvis. The ureter runs on both sides of the major blood vessels, the aorta and the inferior vena cava (V. cava inferior), accompanied by lymphatic vessels and autonomic nerves.

The **pelvis** is made up of three levels. Cranially, the **peritoneal cavity** extends from the abdominal cavity into the pelvis. The so-called **greater pelvis** lies between the wings of the ilium and essentially contains intestinal loops and thus abdominal organs. Caudally it is joined by the conical **lesser pelvis,** which contains the actual pelvic organs. Here the parietal peritoneum marks the limit of the **subperitoneal space** as the second level of the pelvis. This level is caudally bordered by the pelvic floor, which is connected to the **perineal region**. The pelvic organs include the internal genitalia, the urinary bladder (Vesica urinaria) and urethra as well as the rectum and anal canal (Canalis analis), as the distal portions of the large intestine.

Main Topics

After studying this chapter, you should be able to:

Retroperitoneal space and pelvic cavity
- describe the structure of the retroperitoneal space and pelvic cavity, and to show their neurovascular pathways on a specimen;
- explain the neurovascular pathways of all organs, including their clinical relevance and organ-specific peculiarities;

Kidney and adrenal gland
- demonstrate their vital importance based on their functions;
- explain the development and possible malformations;
- show their position and projection including the membranous system on a specimen;

Urinary system
- explain the structure of the urinary tract and its development;
- describe sections, constrictions and sphincter mechanisms in both sexes, as well as the basic processes during micturition;

Rectum and anal canal
- show the sections and topographic relationships of the rectum and anal canal on a specimen, and explain their development;
- explain the continence organ with the functions of its different parts, and describe the key processes in defecation;

Genitalia
- explain the sections and positions of the internal and external male and female genitalia as well as their development and function;
- demonstrate the membranes and contents of the spermatic cord on a specimen;
- explain all peritoneal duplicatures and ligaments of the internal genitalia with their course and content;
- explain the structure, innervation and function of the pelvic floor and the perineal muscles, and show the Fossa ischioanalis on a specimen.

Clinical Relevance

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

Pelvic Floor Insufficiency

Case Study
A 78-year-old female patient has an appointment with her gynaecologist because when she coughs or sneezes, she increasingly passes urine. She has had these symptoms for a long time and so far managed it well with pads, but now the involuntary passing of urine is becoming increasingly uncomfortable. The patient has four children, all born naturally (by vaginal delivery).

Result of Examination
The physical examination is largely unremarkable. When her abdominal muscles contract (abdominal pressure), a mucus-coated enlargement prolapses into the vaginal orifice.

Diagnostic Procedure
The vaginal examination (colposcopy) shows that the posterior wall of the urinary bladder has dropped (cystocele). When the intra-abdominal pressure increases, the anterior wall of the uterus also protrudes (uterine prolapse).

Diagnosis
Incontinence due to insufficiency of the pelvic floor with cystocele and prolapse of the uterus (→ Fig. a). These issues are very common in elderly women and often caused by pregnancies. As the delivery mode apparently does not play an important role, caesarean sections would not significantly reduce the risk.

Treatment
The patient is recommended to practice pelvic floor exercises under the guidance of a physiotherapist. After two months the patient can increasingly better control the passing of urine.

Further Developments
After five years, the incontinence gets worse again. The patient is admitted for a surgical treatment with so-called tension-free tapes on the gynaecology ward. After this, she is largely symptom-free.

Dissection Lab
The **pelvic floor (Diaphragma pelvis)** and the adjacent **Perineum (Regio perinealis)** are anatomically and clinically challenging regions. The pelvic floor can be easily dissected from the lesser pelvis, once the pelvis has been split in the middle and one half has been removed with the bone. The Diaphragma pelvis is then visible as a striated muscle plate composed of three muscle parts.

Compare in various dissections the different thickness of the pelvic floor in men and women. As the majority of body donors are elderly, the pelvic floor is often very poorly developed.

These parts are predominantly innervated by direct branches of the Plexus sacralis, and designated ventrally as **M. levator ani** (consisting of the M. pubococcygeus and M. iliococcygeus) and dorsally as **M. ischiococcygeus.** The term 'pelvic floor' (Diaphragma pelvis) was chosen because this muscle plate caudally closes a body cavity, in the same way as the diaphragm closes the lower opening of the thorax. The muscles of both sides leave an opening medially, the **Hiatus levatorius** for the passage of the anal canal, urethra and, in women, the vagina. The designation of the muscles largely reflects their course from the hip bone to the sacrum and coccyx. The M. iliococcygeus has no bony origin, but is only indirectly attached to the pelvic bones, because it originates from a duplicature of the fascia of the M. obturatorius internus **(Arcus tendineus m. levatoris ani).** This muscle can be easily identified due to the **Canalis obturatorius,** the muscle penetrates the canal and leads the **A./V. obturatoria** and the **N. obturatorius** from the pelvic cavity to the anterior aspect of the thigh. Caudally of the Arcus tendineus m. levatoris ani it disappears below the pelvic floor,

Here you can put your hand between the M. levator ani and the M. obturatorius internus to feel the different courses of the two muscles.

nestling against the lateral pelvic wall, where it is redirected at the ischium and then passes through the **Foramen ischiadicum minus** to the Trochanter major of the femur. This opening can be exposed better dorsally and caudally. To do this, the M. gluteus maximus must be detached medially from its origin in the dorsal gluteal region and folded back laterally. Then the M. piriformis becomes visible and also the **Lig. sacrotuberale** which bridges the Foramen ischiadicum minus. Through this opening, the **A./V. pudenda interna** and the **N. pudendus** pass caudally from the gluteal region into the **Fossa ischioanalis**, which occupies the posterior half of the perineal region on both sides of the anus. They are embedded here in another duplicature of the fascia of the M. obturatorius **(Canalis pudendalis, ALCOCK's canal).**

Once you have seen the dimensions of this space, you will understand how septic foci (abscesses) almost the size of a fist can form here, most of which spread from fistulas in the anal canal.

The Fossa ischioanalis is a pyramid-shaped space largely filled with adipose tissue, which at the top is limited medially by the lower surface of the M. levator ani and laterally by the M. obturatorius internus with the ALCOCK's canal. In front it extends up to the perineal muscles and forms very variable prolongations up to the **pubic symphysis (Symphysis pubica).**

Back in the Clinic
The pelvic floor supports all the pelvic organs stacked on top of it. This explains why it is important for urinary and faecal continence, although it does not form a sphincter like the muscles of the perineum. An aggravating factor in perineal operations for stabilising the pelvic floor is the fact that the patients are mostly in the supine 'lithotomy' position, which you have to keep in mind when visualising the anatomical relationships.

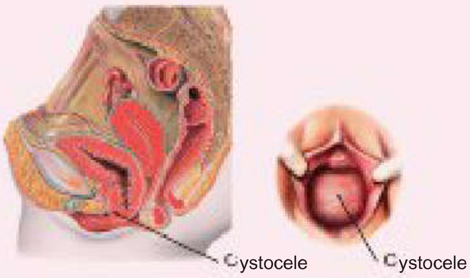


Fig. a On the left: pelvic floor insufficiency with sinking (ptosis) of the bladder (cystocele); view from the left side, sagittal section; **on the right:** cystocele; vaginal view. (right [L266])

Blood Vessels of the Retroperitoneal Space

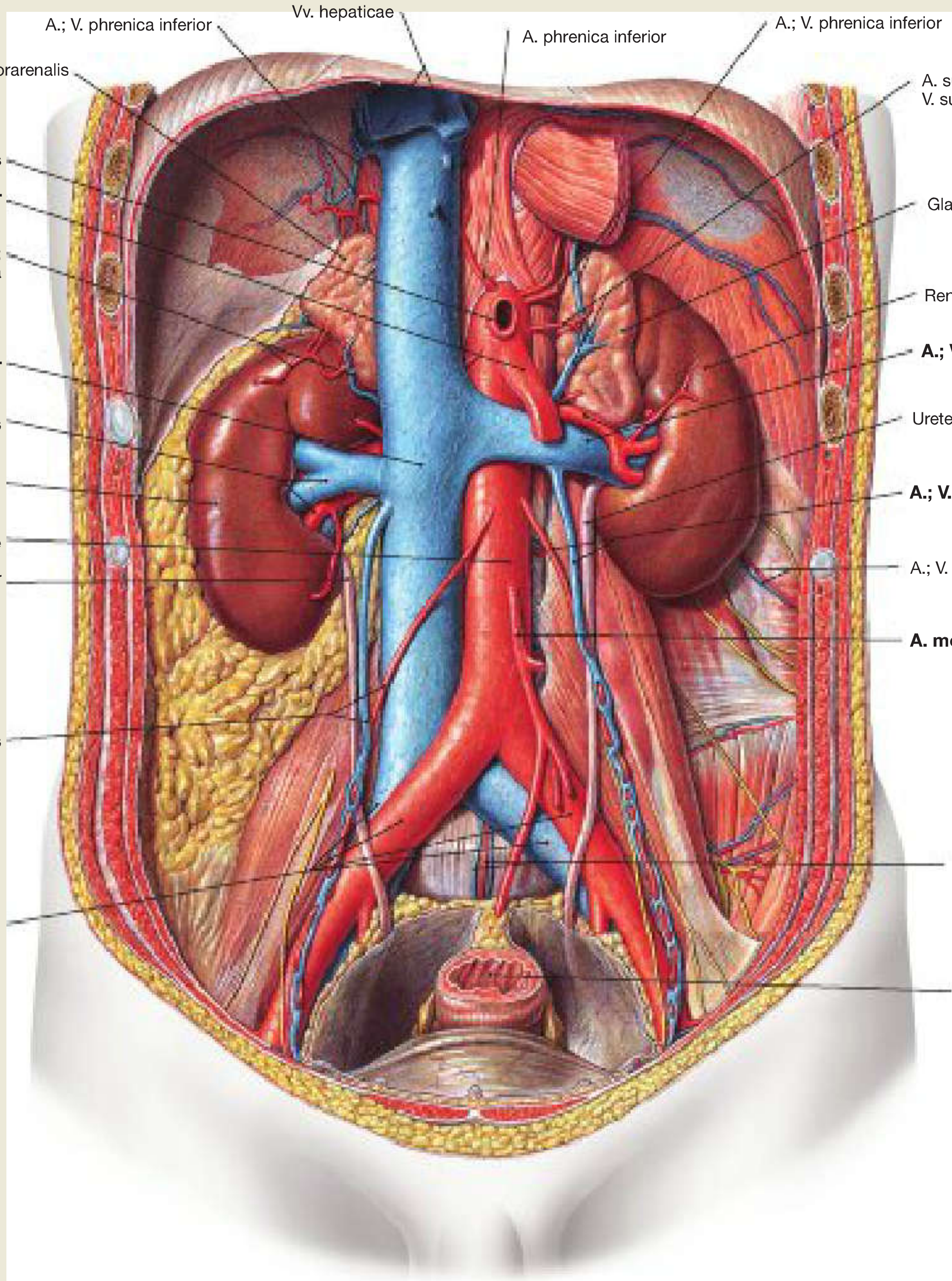


Fig. 7.1 Blood vessels of the retroperitoneal space; the intraperitoneal and secondary retroperitoneal abdominal organs have been removed, as well as lymphatic vessels and autonomic nerves; ventral view. The illustration shows a so-called **retroperitoneal situs,** i.e. the site of the organs and neurovascular pathways in the retroperitoneal space. This view is obtained in the dissection lab by removing all intraperitoneal and secondary retroperitoneal organs. As has occurred here, the organs can be removed all at once with the supplying structures. For this, it is necessary to cut the three **unpaired visceral branches (Truncus coeliacus, A. mesenterica superior, A. mesenterica inferior)** of the **aorta (Pars abdominalis aortae)** near their origin or in the case of the A. mesenterica inferior, more distally. As the veins of the removed abdominal organs belong to the portal system, and thus are connected to the liver, they can be completely removed. Only the **hepatic veins (Vv. hepaticae)** were cut close to their opening into the **inferior vena cava (V. cava inferior).**

This dissection has been selected to present the neurovascular pathways of the retroperitoneal space and the organs located within it: **kidney (Ren)** with **ureter** and the **adrenal gland (Glandula suprarenalis).** After its passage through the diaphragm, the **aorta** continues as the **Pars abdominalis aortae,** and is located in the retroperitoneal space on the left side of the V. cava inferior in front of the spine. The **inferior vena cava (V. cava inferior)** emerges on the right side of the aorta at the level of the fifth lumbar vertebra, where the two Vv. iliacae communes unite.

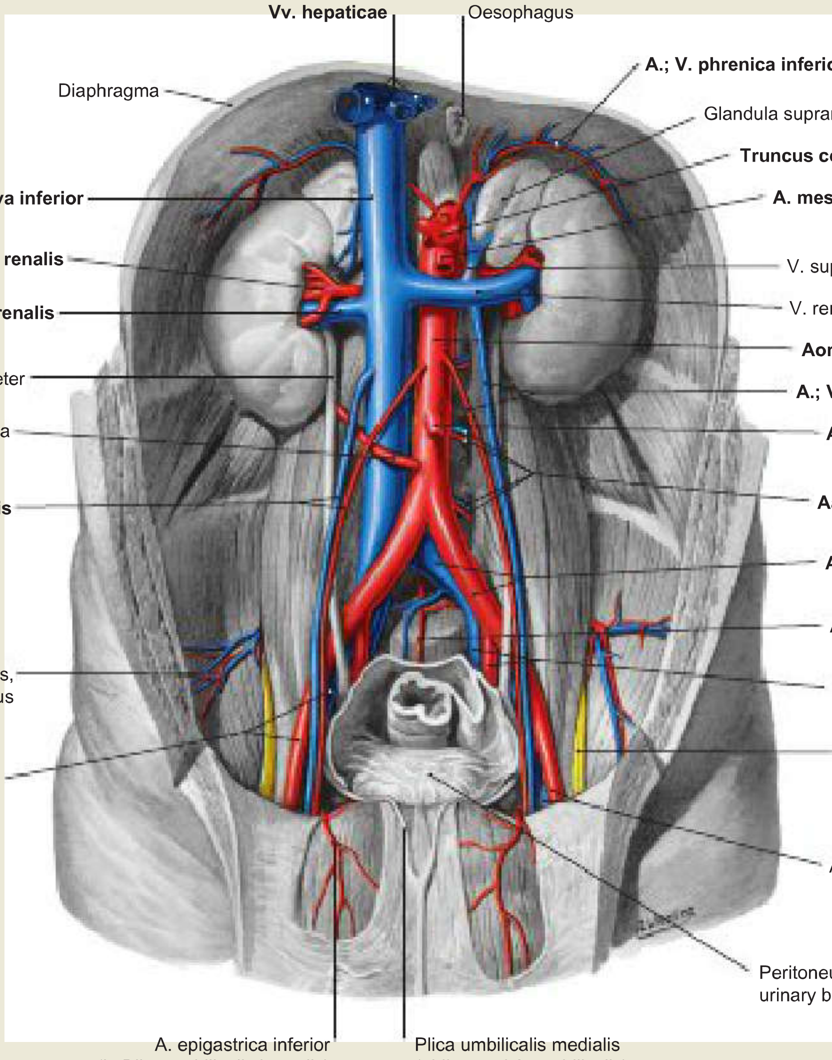


Fig. 7.2 Blood vessels of the retroperitoneal space; the blood vessels are highlighted in colour, in order to categorise the arterial and venous systems; ventral view. [S010-2-16]

The branches of the **Pars abdominalis aortae** are listed in the table. They can be divided into **parietal branches** for the abdominal wall, **visceral branches** for the organs and into **terminal branches.**

The tributaries of the **V. cava inferior** (apart from the unpaired visceral branches, as these veins drain into the portal vein) largely correspond to the arterial branches of the aorta. It should be noted, however, that the bilateral three veins flowing directly into the V. cava on the right side, are connected to the V. renalis on the left side of the body:

- V. phrenica inferior
- V. suprarenalis
- V. testicularis/ovarica

Tributaries of the V. cava inferior
• Vv. iliacae communes • V. sacralis mediana • Vv. lumbales • V. phrenica inferior dextra, the left vein to the V. renalis • V. testicularis/ovarica dextra, the left vein to the V. renalis • V. suprarenalis dextra, the left vein to the V. renalis • Vv. renales dextra and sinistra • three Vv. hepaticae (dextra, intermedia and sinistra)

Branches of the Pars abdominalis aortae	
Parietal branches for the abdominal wall	• A. phrenica inferior: underneath the diaphragm, gives off the A. suprarenalis superior to the adrenal gland • Aa. lumbales: four pairs directly branching off the aorta, the fifth pair originates from the A. sacralis mediana
Visceral branches for the viscera	• Truncus coeliacus: unpaired, originates directly beneath the Hiatus aorticus and supplies the viscera of the epigastrium (→ Fig. 6.19) • A. suprarenalis media: supplies the adrenal gland • A. renalis: to the kidney, also gives off the A. suprarenalis inferior to the adrenal gland • A. mesenterica superior: unpaired, supplies parts of the pancreas, the entire small intestine and the large intestine up to the left colic flexure (→ Fig. 6.21) • A. testicularis/ovarica: supplies the testis and epididymis in men and the ovary in women • A. mesenterica inferior: unpaired, supplies the Colon descendens, the Colon sigmoideum and the upper rectum (→ Fig. 6.23)
Terminal branches	• A. iliaca communis: for the pelvis and leg • A. sacralis mediana: descends to the sacrum

Lymphatic Vessels of the Retroperitoneal Space

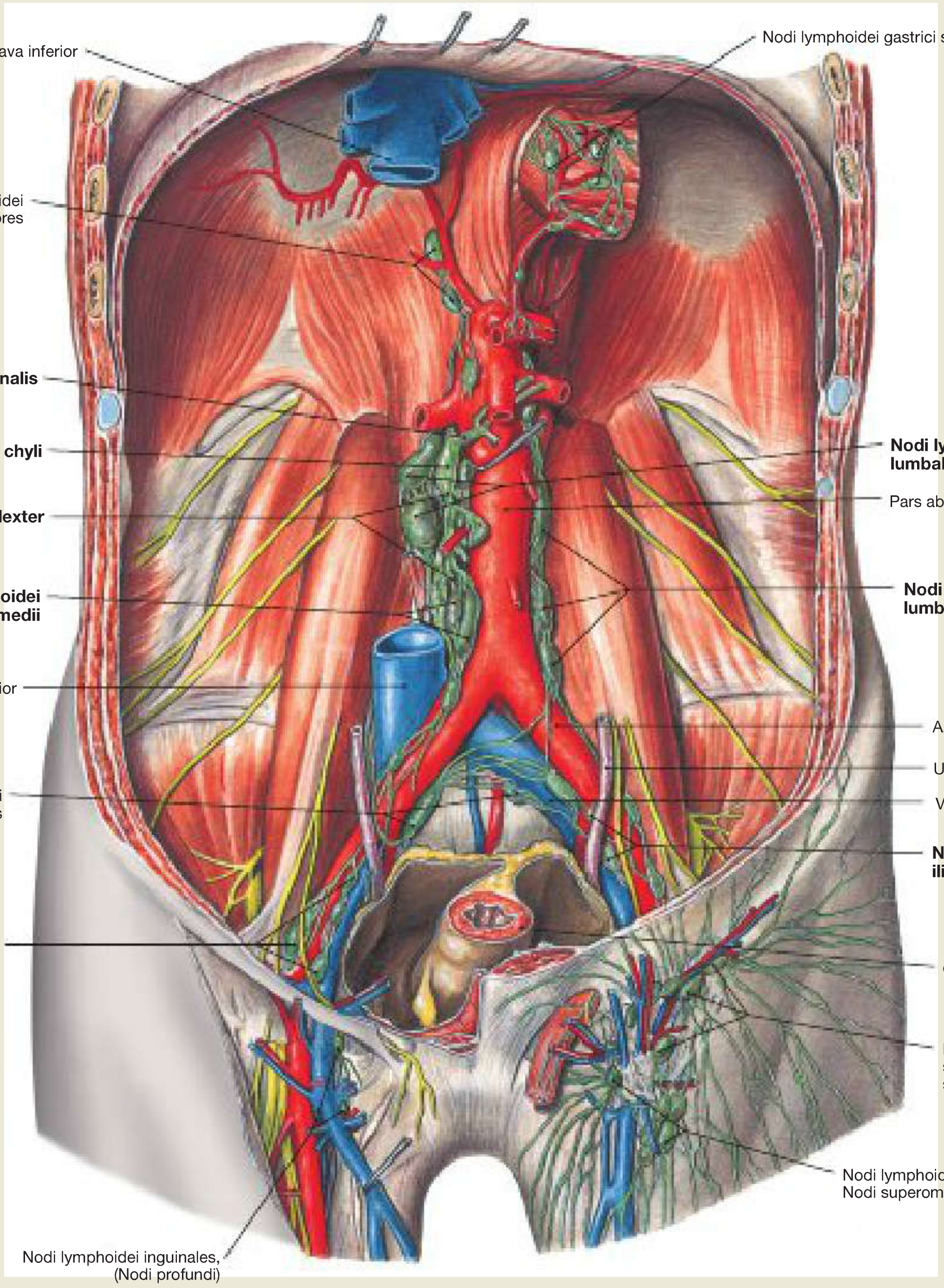


Fig. 7.3 Lymphatic vessels and lymph nodes of the retroperitoneal space; ventral view.
Via the Nodi lymphoidei iliaci communes, the lymph from the pelvis is drained into the parietal lymph nodes of the retroperitoneal space, summarised as **Nodi lymphoidei lumbales.** These form three chains as the Nodi lymphoidei lumbales sinistri, located around the aorta, as Nodi lymphoidei lumbales dextri to both sides of the V. cava inferior, and as Nodi lymphoidei lumbales intermedii in between both blood vessels. The lumbar lymph nodes do not only represent the collecting lymph nodes of the lower limbs, the pelvic viscera and the Colon descendens, but also the regional lymph nodes of the kidneys, adrenal glands and testicles/ovaries.
From the efferent lymphatic vessels of the lumbar lymph nodes, the **Trunci lumbales** emerge on both sides uniting in the Cisterna chyli with the **Truncus intestinalis** (collecting the lymph of the visceral lymph nodes in the abdominal cavity), and continue as **Ductus thoracicus.** Thus, the Ductus thoracicus contains the entire lymph of the lower half of the body below the diaphragm.

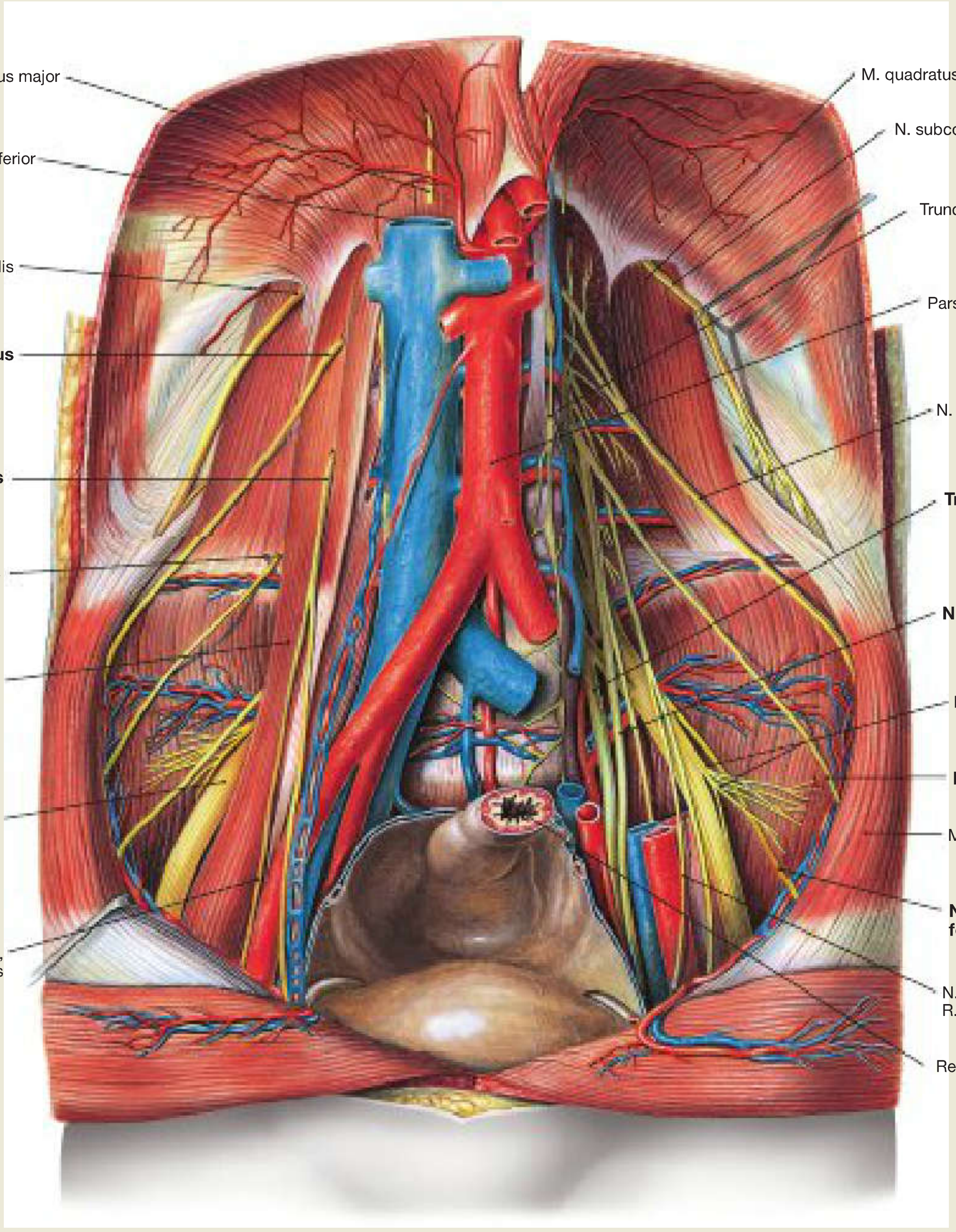


Fig. 7.4 Somatic nerves of the retroperitoneal space; ventral view after removal of the M. psoas major on the left side, the course of the nerves of the Plexus lumbalis is more clearly visible.
In addition to the blood and lymphatic vessels, the nerves of the **Plexus lumbalis,** which provide the innervation of the inguinal region and the anterior aspect of the bone, also pass through the retroperitoneal space (→ Fig. 4.127). The **Truncus lumbosacralis** is connected to the Plexus sacralis (→ Fig. 7.7) in the lesser pelvis, so that the two nerve plexuses are united in the **Plexus lumbosacralis** (→ Fig. 4.123).

Branches of the Plexus lumbalis (T12–L4):
- Motor branches to the M. iliopsoas and the 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)

→ T 40

Autonomic Nerves of the Retroperitoneal Space

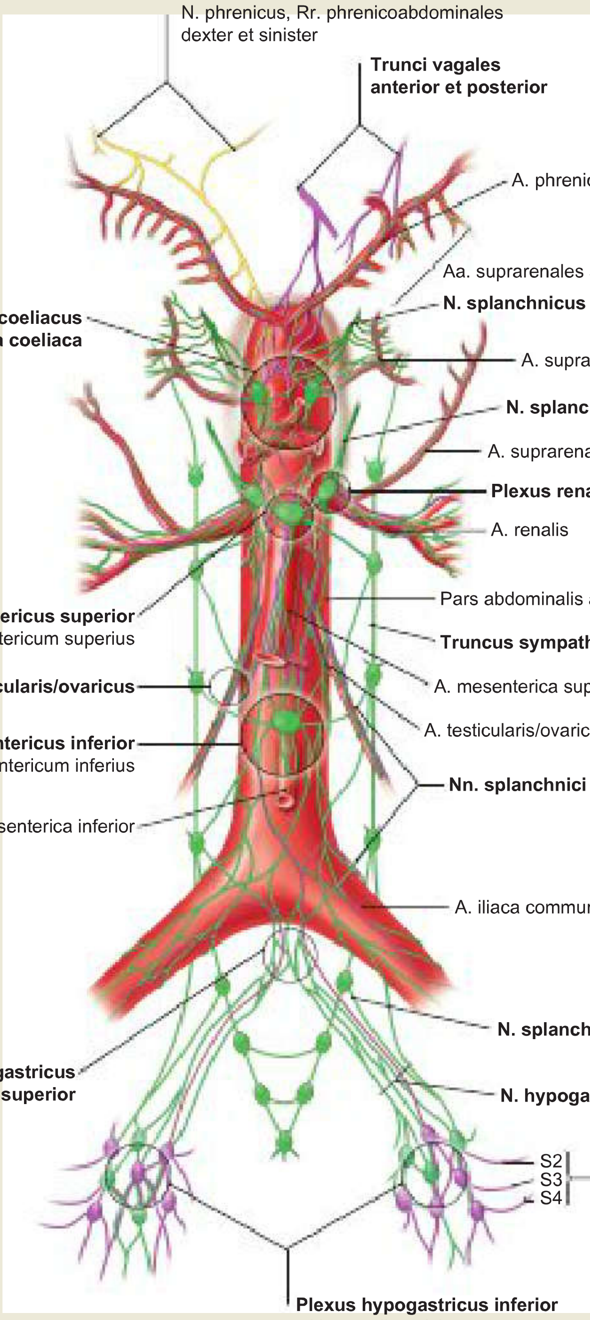


Fig. 7.5 Plexus aorticus abdominalis and Plexus hypogastricus inferior; schematic illustration, ventral view. [L238]

In front of the aorta, the autonomic sympathetic and parasympathetic nerve fibres form a plexus **(Plexus aorticus abdominalis),** which provides the branching-off vessels of the aorta with their own plexuses, and these nerve fibres accompany the respective vessels to their target organs. These plexuses are located at the bifurcations of the three unpaired visceral branches of the aorta: the **Plexus coeliacus, and the Plexus mesenterici superior and inferior** (→ Fig. 6.73). Caudally, the nerve plexuses continue bilaterally from the Plexus hypogastricus superior via a bundle of nerve fibres designated as **N. hypogastricus** to the **Plexus hypogastricus inferior** in the lesser pelvis, which innervates the pelvic viscera.

The preganglionic neurons of the **sympathicus** are located in the lateral horns of the spinal cord, and when reaching the **sympathetic trunk (Truncus sympathicus),** they continue without synaptic switching via the Nn. splanchnici major and minor to the aortic plexuses, where they become synaptically interconnected with postganglionic neurons (the axons of which accompany the branches of the respective arteries to their target organs) in various ganglia (Ganglia coeliaca, Ganglia mesenterica superius and inferius, Ganglia aorticorenalia, Ganglia pelvica of the Plexus hypogastricus inferior).

The preganglionic parasympathetic neurons of the **Nn. vagi [X]** descend along the oesophagus as **Trunci vagales anterior and posterior,** and continue through the diaphragm to the autonomic nerve plexuses around the abdominal aorta; however, they pass through these plexuses without synapsing until they reach their target organs, where the postganglionic neurons are located in the wall or nearby. The area supplied by the N. vagus [X] ends in the Plexus mesentericus superior and thus, in the area of the left colic flexure (splenic flexure or CANNON-BÖHM point). By contrast, the **Colon descendens** is supplied by the **sacral part of the parasympathicus;** its preganglionic neurons are located within the spinal cord (S2–S4), emerge with the spinal nerves as **Nn. splanchnici pelvici**, and then are interlinked to postganglionic neurons in the **Plexus hypogastricus inferior** in the rectal area. The postganglionic nerve fibres ascend to the Colon descendens and Colon sigmoideum.

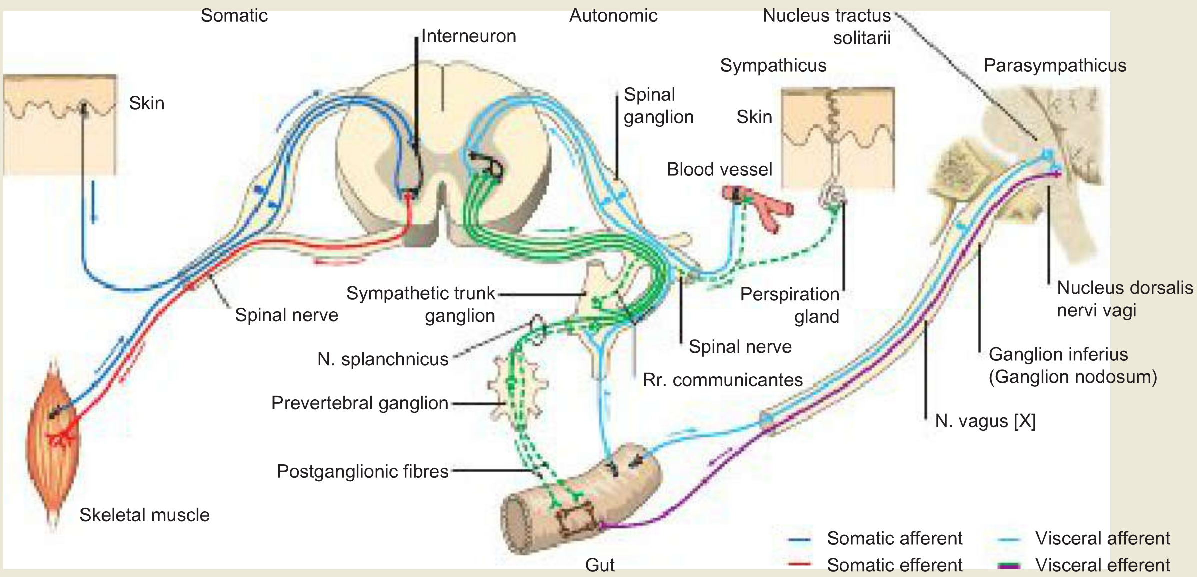


Fig. 7.6 Organisation of the autonomic nervous system in comparison with the somatic nervous system; schematic illustration of the course and the synaptic interconnection of a spinal cord segment. [L126]

In contrast to the somatic nervous system, in the autonomic nervous system two **visceral efferent neurons** are interconnected in a series by synapses on their way from the central nervous system to the target organ. The preganglionic neurons of the **sympathetic system (sympathicus)** are located in the lateral horns of the spinal cord and enter the spinal nerves together with somatic efferent fibres via the ventral root. Via the **Rami communicantes** they reach the **sympathetic trunk (Truncus sympathicus)** and turn back as postganglionic neurons after their synaptic interconnection. These neurons run with somatic nerves into the periphery, where they produce a narrowing (vasoconstriction) of the blood vessels **(vasomotor effect),** activation of the sweat glands **(sudomotor effect)** and bristling of the vellus hair on the body **(pilomotor effect,** not shown here). Postganglionic neurons also pass from the sympathetic trunk to the organs in the neck region and thoracic cavity, such as the heart and lungs. In contrast, the neurons to the abdominal organs are not switched in the sympathetic trunk, but pass via the **Nn. splanchnici major and minor** to the aortic plexuses, where they are interconnected synaptically with postganglionic neurons in various prevertebral ganglia; the axons of these neurons reach their target organs together with the branches of the respective arteries.

The preganglionic parasympathetic neurons, however, pass with the **Nn. vagi [X],** without switching, through the autonomic nerve plexuses of the abdominal aorta, and only become interlinked to short postganglionic neurons in the wall of the aorta or surrounding areas.

Visceral afferent neurons also reach the central nervous system via the sympathetic trunk or the N. vagus [X].

Autonomic Nerves of the Retroperitoneal Space

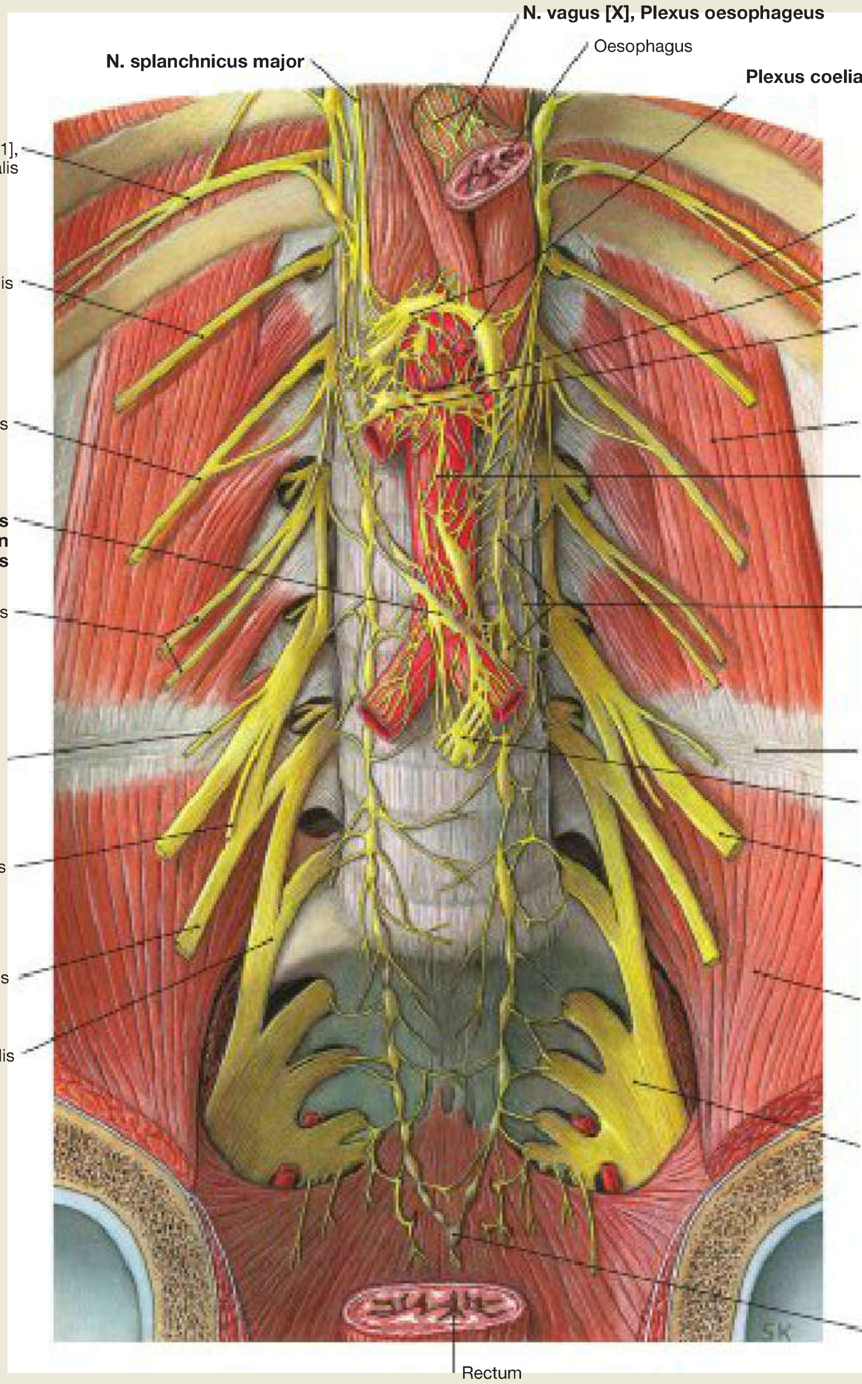


Fig. 7.7 Autonomic nerves of the retroperitoneal space; ventral view; after removal of the viscera. [L238]

Here the autonomic nerves on the aorta **(Plexus aorticus abdominalis)** are exposed. The plexus consists of the sympathetic and parasympathetic neurons, which reach it in different ways and also show different synaptic interlinks within the nerve plexus.

The preganglionic **sympathetic neurons** pass from the sympathetic trunk (Truncus sympathicus) via the **Nn. splanchnici major and minor** to the aortic plexuses, where they are synaptically interlinked to postganglionic neurons in various ganglia (Ganglia coeliaca, Ganglia mesenterica superius and inferius, Ganglia aorticorenalia). This means that the ganglia in the plexuses, which are located around the bifurcations of the three unpaired visceral branches of the aorta **(Plexus coeliacus, Plexus mesenterici superior and inferior)** are sympathetic ganglia. In contrast, the preganglionic parasympathetic neurons of the **Nn. vagi [X]** pass along the oesophagus as **Trunci vagales anterior and posterior** to the Plexus aorticus abdominalis.

The preganglionic sympathetic nerve fibres descend from the Plexus aorticus abdominalis into the lesser pelvis up to the **Plexus hypogastricus inferior** via which they supply the pelvic viscera. The parasympathetic neurons, on the other hand, only reach the Plexus mesentericus superior. In contrast, the pelvic organs are innervated by the **sacral part of the parasympathetic system (parasympathicus),** whereby the preganglionic nerve fibres leave the spinal cord as **Nn. splanchnici pelvici,** and then become interlinked in the Plexus hypogastricus inferior.

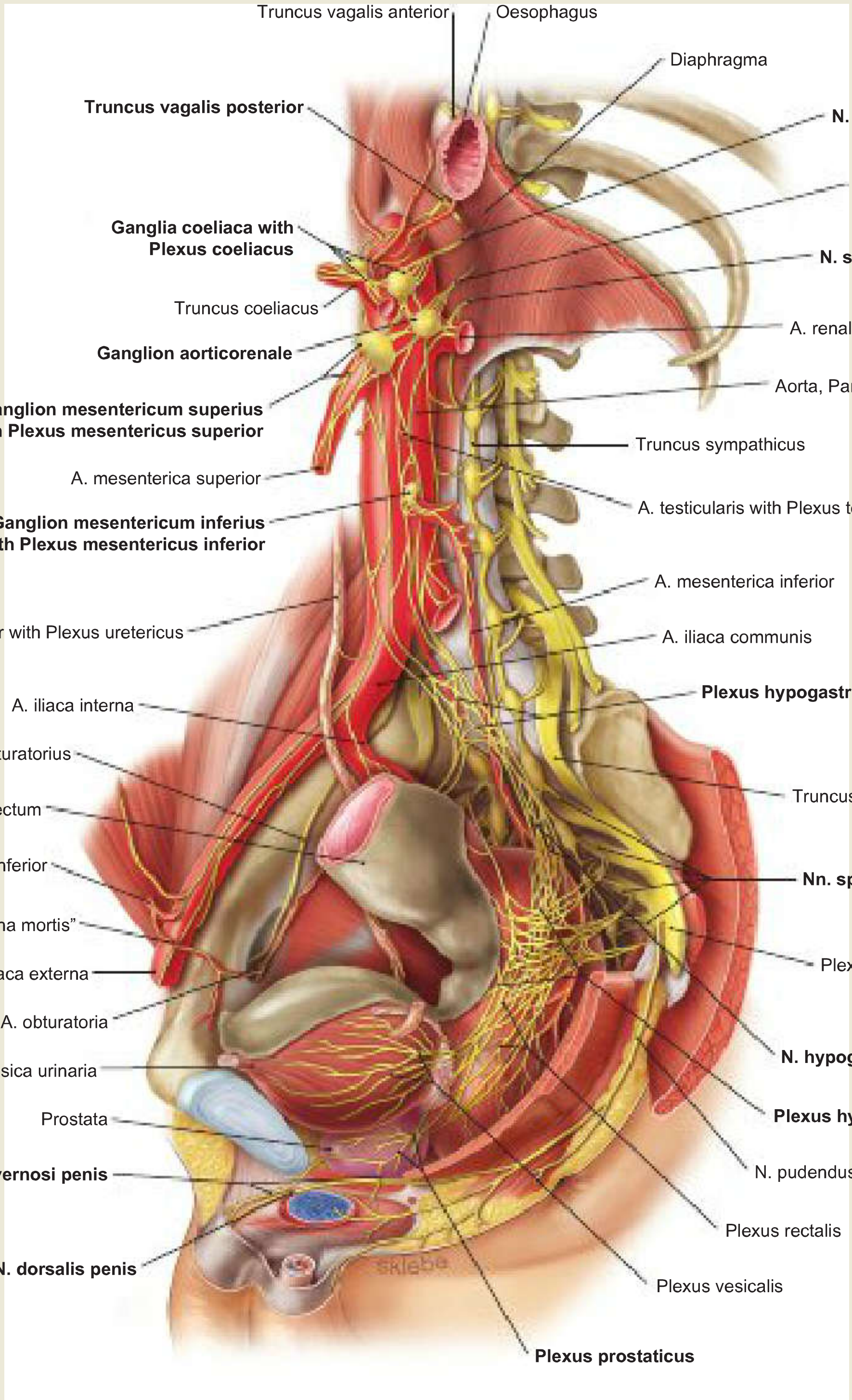


Fig. 7.8 Autonomic nerves of the pelvic cavity; semi-schematic illustration after removal of the retroperitoneal organs as well as of the veins and lymphatic vessels; ventral view. [L238]

The illustration shows the course of the autonomic neurons in the pelvis. The sympathetic neurons descend from the Plexus aorticus abdominalis into the lesser pelvis, where they are switched synaptically in the **Plexus hypogastricus inferior** and reach the pelvic organs. The Plexus hypogastricus inferior forms smaller local plexuses around the pelvic organs, such as the Plexus rectalis, Plexus vesicalis and Plexus prostaticus (or the Plexus uterovaginalis in women).

In contrast, the parasympathetic neurons reach the plexus via the **Nn. splanchnici pelvici.** After switching, they reach the pelvic organs and the left-sided colon up to the left colic flexure via their own nerve branches.

It should be noted that the course of the parasympathetic neurons to the cavernous bodies of the penis is similar to the course they reach the cavernous body of the female genitalia. The neurons form the **Nn. cavernosi penis,** which pass along the Prostata through the pelvic floor and perineal muscles into the Corpora cavernosa of the penis. The longer branches join the somatic N. dorsalis penis, which represents the terminal branch of the N. pudendus, and together with it enter the cavernous bodies. These neurons facilitate the erection of the penis by dilating the vessels in the cavernous bodies.

A. iliaca interna

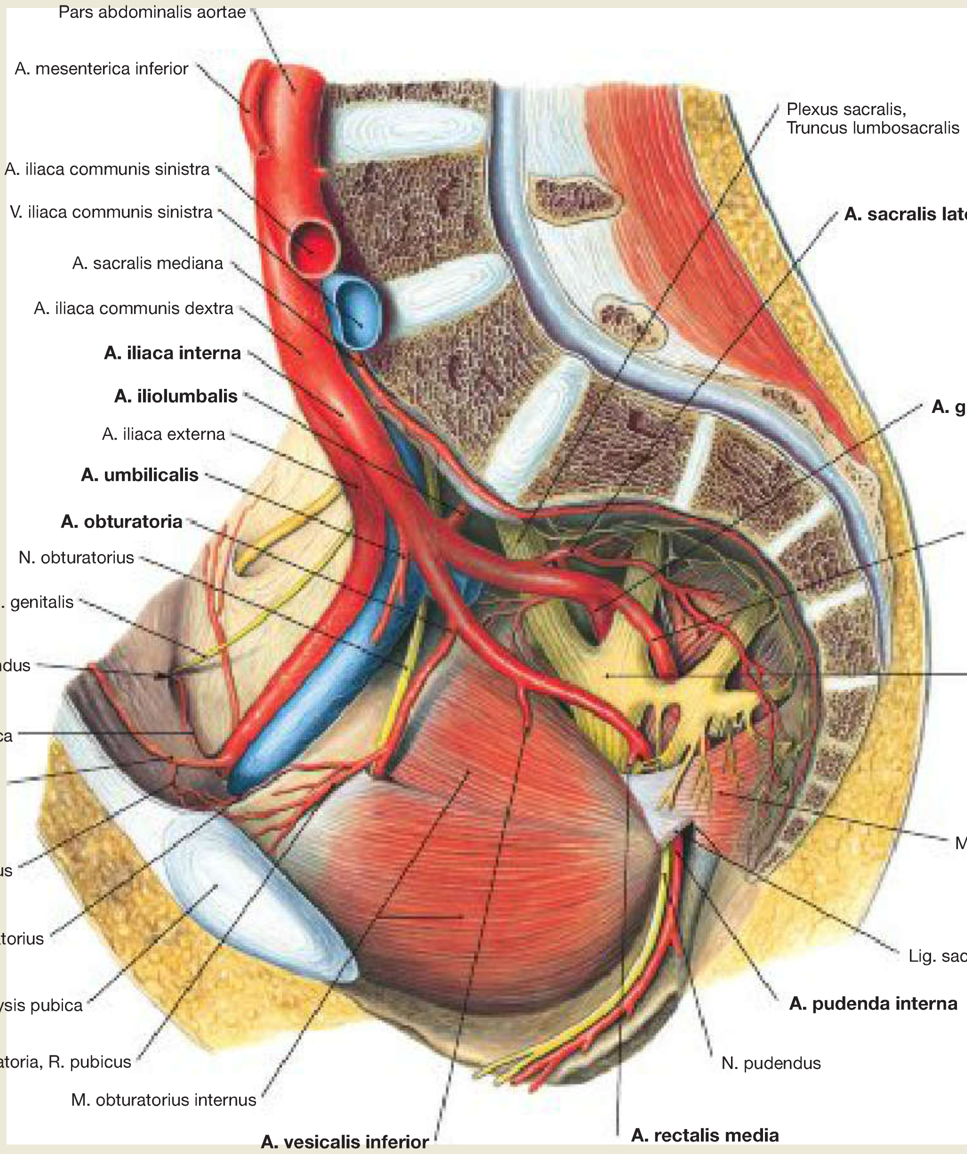


Fig. 7.9 A. iliaca interna; lateral view from the left side.
Mostly (in 60% of all cases), the A. iliaca interna divides into an anterior and a posterior trunk. Because the branching off occurs in a rather variable sequence, the arterial branches are categorised according to their perfusion area in **parietal branches** for the pelvic wall and the external genitalia, and in **visceral branches** for the pelvic viscera. While the parietal branches are the same in both sexes, the visceral branches differ, since they supply the sexual organs.

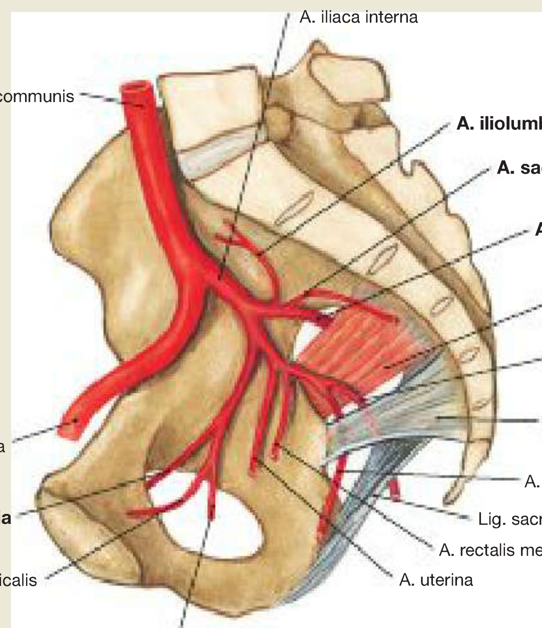


Fig. 7.10 Parietal branches of the A. iliaca interna.
- A. iliolumbalis: supplies the Fossa iliaca and the lumbar region
- Aa. sacrales laterales: supply the sacral canal
- A. obturatoria: passes through the Canalis obturatorius
- A. glutea superior: passes through the Foramen suprapiriforme into the gluteal region
- A. glutea inferior: passes through the Foramen infrapiriforme into the gluteal area

In up to 20%, the A. obturatoria does not originate from the A. iliaca interna, but is a descending branch of the A. epigastrica inferior out of the circulatory region of the A. iliaca externa.
For the visceral branches (different in men and women) → Fig. 7.11 and → Fig. 7.12.

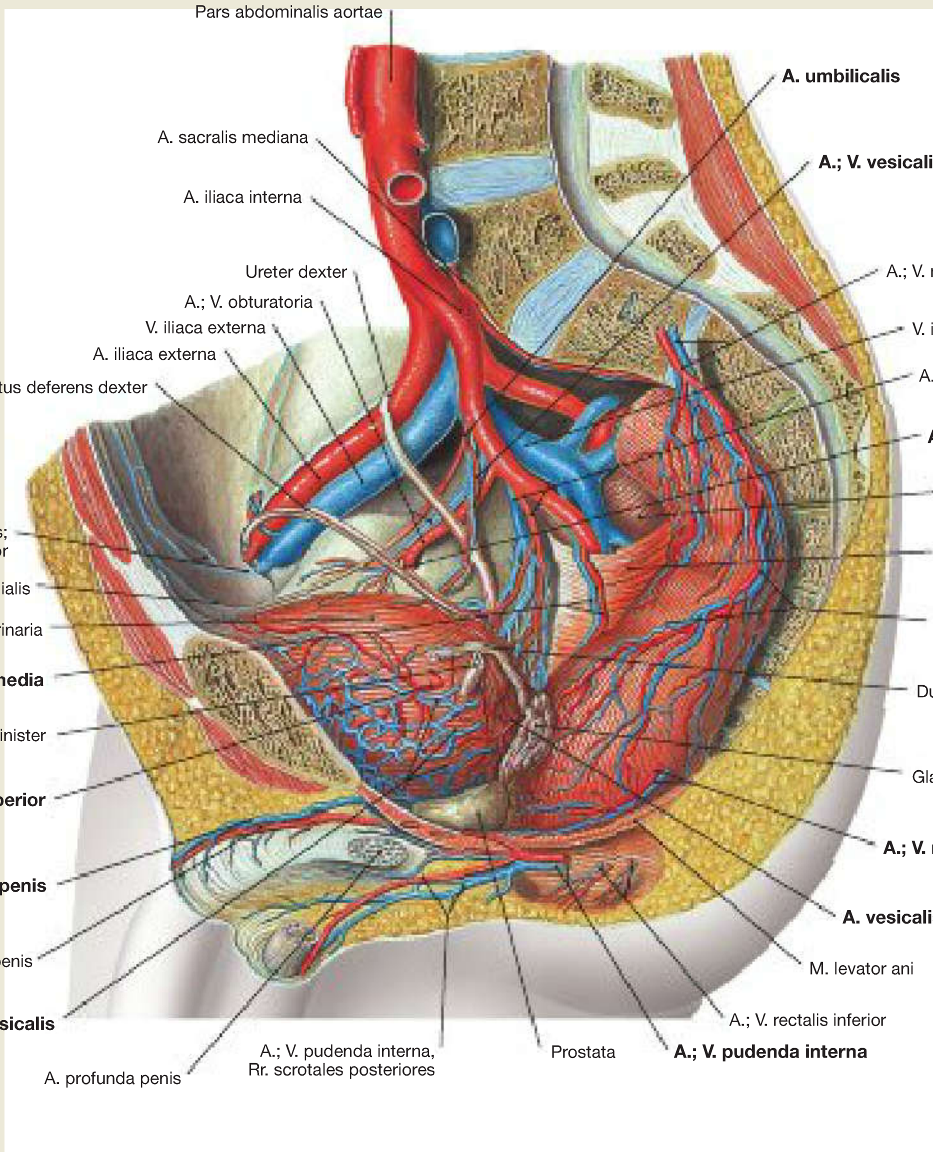


Fig. 7.11 Blood supply of the pelvic viscera in men; lateral view from the left side.

The pelvic viscera are supplied by the **visceral branches** of the A. iliaca interna. The **parietal branches** for the pelvic wall are identical in both sexes (→ Fig. 7.10).

Visceral branches of the A. iliaca interna in men:

- **A. umbilicalis:** gives off the A. vesicalis superior to the urinary bladder, and mostly (not here) the A. ductus deferentis to the spermatic duct (Ductus deferens), before its obliterated part (Lig. umbilicale mediale) forms the Plica umbilicalis medialis.
- **A. vesicalis inferior:** supplies the bladder, prostate and seminal vesicle, and occasionally (as shown here) gives off the A. ductus deferentis.
- **A. rectalis media:** above the pelvic floor to the rectum
- **A. pudenda interna:** passes through the Foramen infrapiriforme and the Foramen ischiadicum minus into the lateral wall of the Fossa ischioanalis (Canalis pudendalis, ALCOCK's canal). Here, the A. rectalis inferior branches off to the lower anal canal, before the A. pudenda divides into its superficial and deep terminal branches to supply the external genitalia. The superficial A. perinealis supplies the perineum and sends the Rr. scrotales posteriores to the scrotum. The deep branches supply the penis and its spongy tissue (A. bulbi penis, A. dorsalis penis, A. profunda penis).

The venous blood flows to the **V. iliaca interna,** forming venous plexuses (Plexus venosi) with its afferent branches around the individual organs, all of which are connected with each other. Most of these plexuses have to be removed during dissection to display the arteries and nerves of the pelvis:

- **Plexus venosus rectalis:** via the V. rectalis superior it is connected to the portal vein system and via the Vv. rectales media and inferior to the drainage area of the V. cava inferior (portocaval anastomosis).
- **Plexus venosus vesicalis:** located at the fundus of the bladder, also collects the venous blood of the accessory sex glands
- **Plexus venosus prostaticus:** collects the blood of the prostate, and of the cavernous bodies of the penis (V. dorsalis profunda penis). Connections to the venous plexuses of the spine explain in part why prostate cancer is often associated with spinal metastases.

Blood Vessels of the Female Pelvis

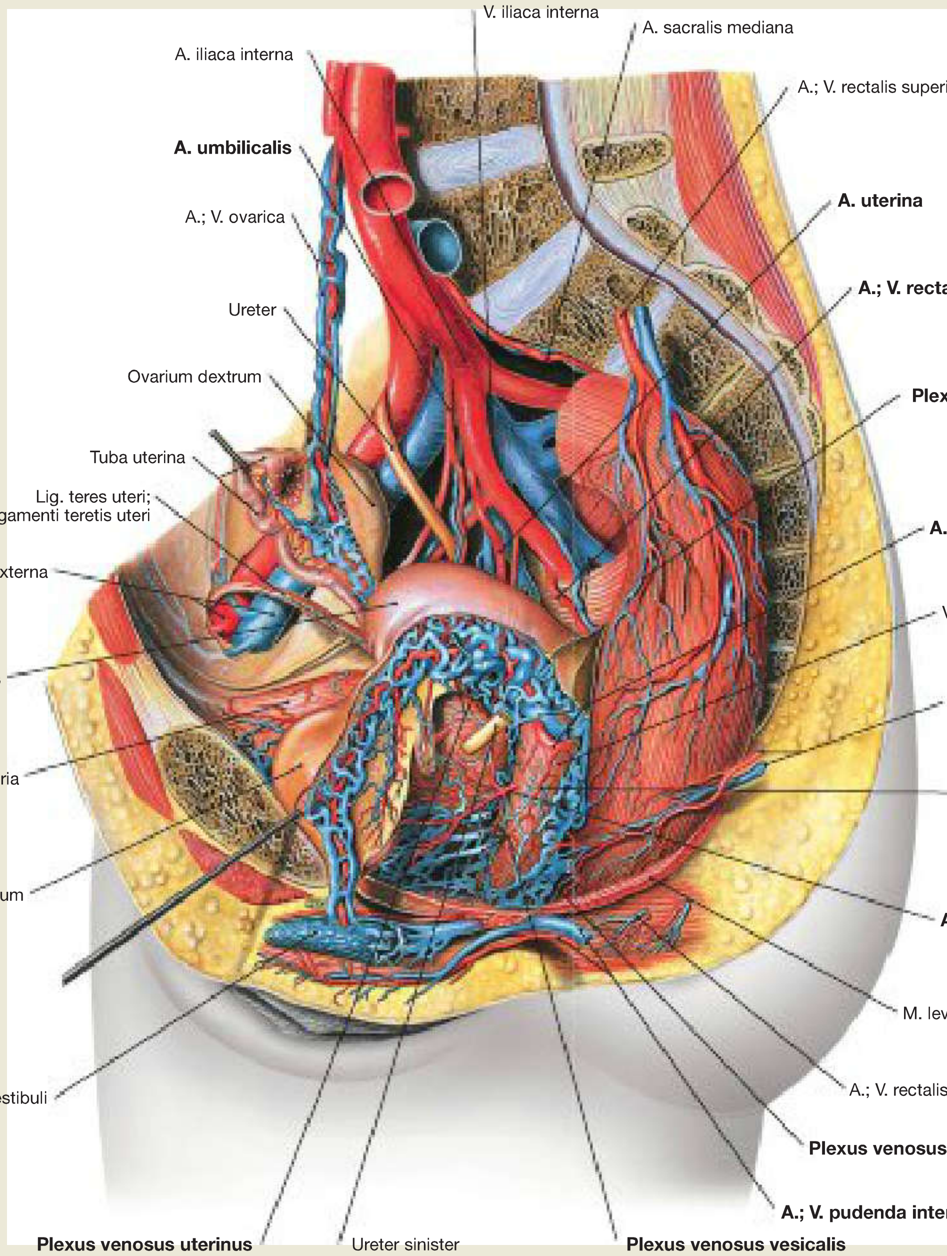


Fig. 7.12 Blood supply of the pelvic viscera in women; lateral view from the left side.
The pelvic viscera are supplied by the **visceral branches** of the A. iliaca interna. The **parietal branches** for the pelvic wall are identical in both sexes (→ Fig. 7.10).

Visceral branches of the A. iliaca interna in women:

- **A. umbilicalis:** gives off the A. vesicalis superior to the urinary bladder, and the A. uterina before its obliterated part (Lig. umbilicale mediale) forms the Plica umbilicalis medialis.
- **A. vesicalis inferior:** supplies the urinary bladder and the vagina, may be absent and is then replaced by the A. vaginalis
- **A. uterina:** supplies with own branches the uterus, Tuba uterina, ovary and vagina
- **A. vaginalis:** sometimes replaces the A. vesicalis inferior
- **A. rectalis media:** above the pelvic floor to the rectum
- **A. pudenda interna:** passes through the Foramen infrapiriforme and the Foramen ischiadicum minus into the lateral wall of the Fossa ischioanalis (Canalis pudendalis, ALCOCK's canal). Here, the A. rectalis inferior branches off to the lower anal canal, before the A. pudenda divides into its superficial and deep terminal branches to supply the external genitalia. The superficial A. perinealis supplies the perineum and sends the Rr. labiales posteriores to the labia. The deep branches supply the clitoris with its cavernous body and the vestibular erectile tissue in the Labia majora (A. bulbi vestibuli, A. dorsalis clitoridis, A. profunda clitoridis).

The venous blood flows to the **V. iliaca interna,** forming venous plexuses (Plexus venosi) with its afferent branches around the individual organs, all of which are connected with each other. Most of these plexuses have to be removed during dissection to display the arteries and nerves of the pelvis:

- **Plexus venosus rectalis:** via the V. rectalis superior it is connected to the portal vein system and via the Vv. rectales media and inferior to the drainage area of the V. cava inferior (portocaval anastomosis).
- **Plexus venosus vesicalis:** located at the fundus of the bladder, also collects the blood of the cavernous bodies (V. dorsalis profunda clitoridis).
- **Plexus venosi uterinus and vaginalis:** collect the blood of the uterus and vagina

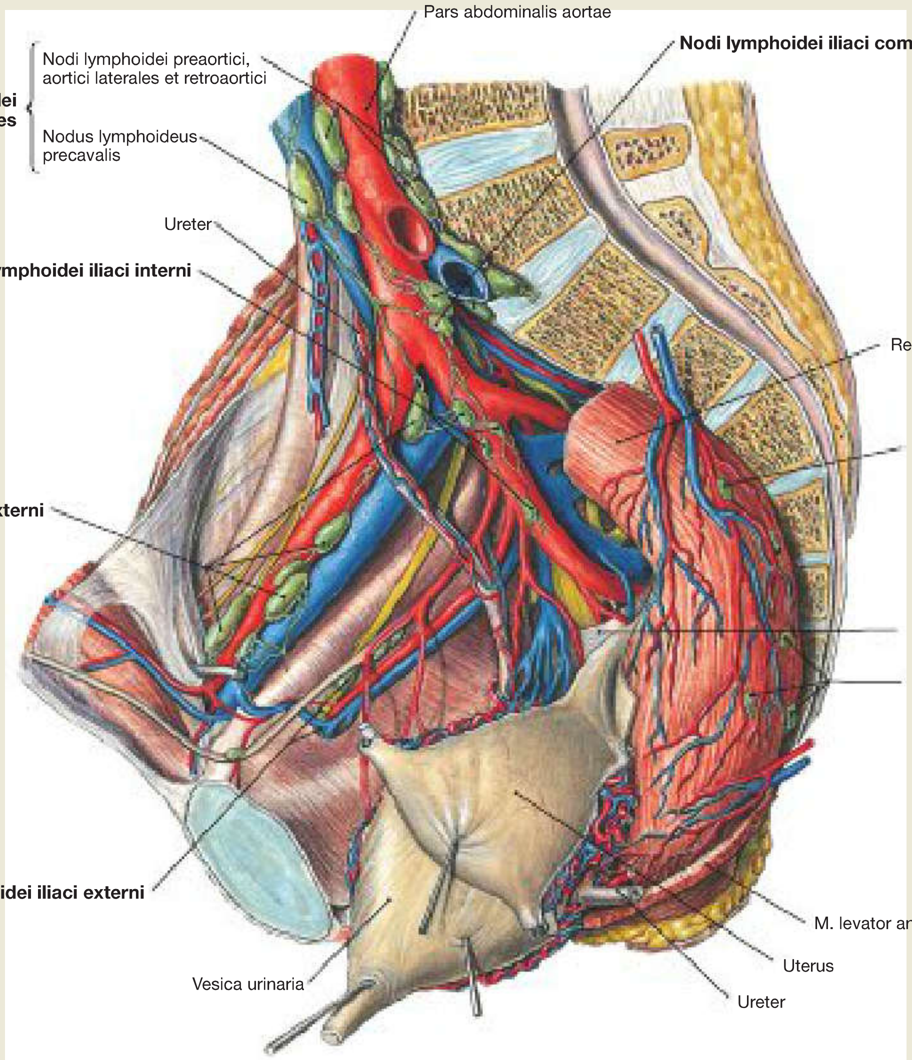


Fig. 7.13 Lymph nodes and lymphatic vessels of the pelvis (shown here in a woman); lateral view from the left side.

In the pelvis, the Nodi lymphoidei iliaci interni and externi are located along the respective blood vessels, and the Nodi lymphoidei sacrales on the ventral side of the sacrum. Due to their close proximity a strict separation between parietal lymph nodes in the pelvic wall and visceral lymph nodes around the pelvic viscera is not possible. Thus, the pelvic viscera (rectum, urinary bladder, internal genitalia) are connected to all the groups of lymph nodes.

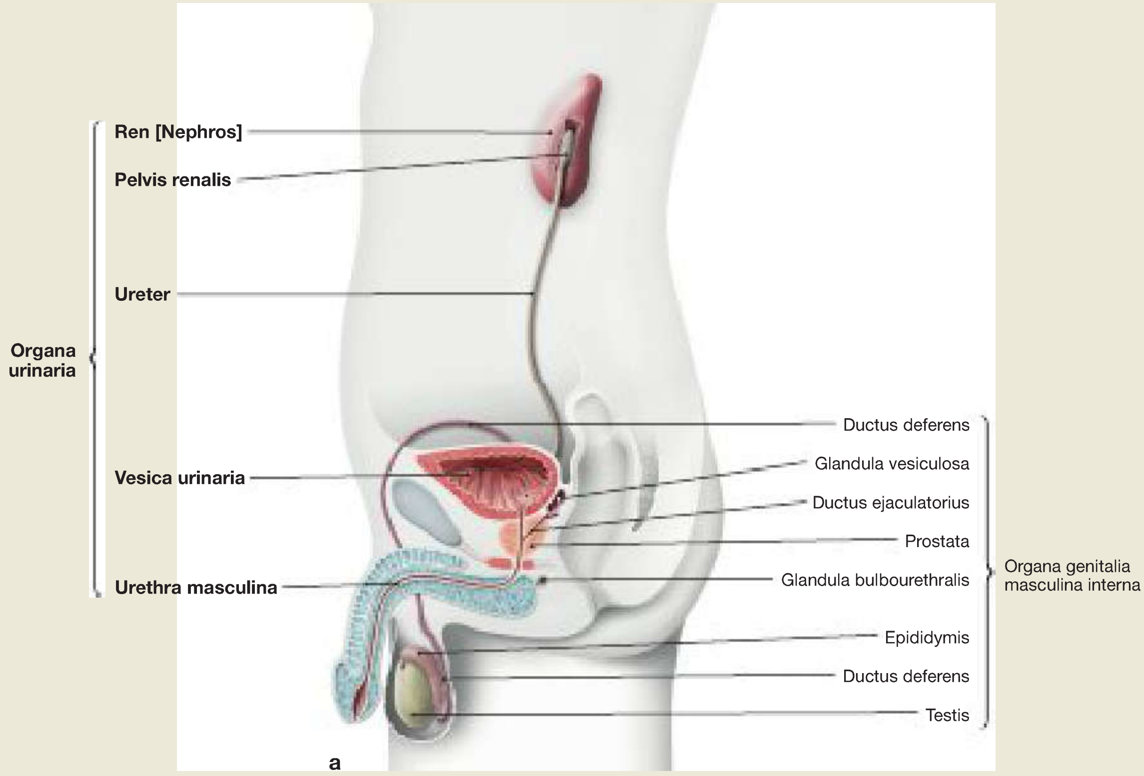
The lymph of the upper **rectum** is drained via the Nodi lymphoidei rectales superiores to the Nodi lymphoidei mesenterici inferiores in the retroperitoneal space, and to the Nodi lymphoidei iliaci interni in the pelvis. In contrast, the lymph of the lower rectum is drained to the Nodi lymphoidei inguinales superficiales. This explains why the lymph node metastases of proximal rectal carcinomas are found in the retroperitoneal space and in the pelvis, but those of distal rectal carcinomas are found in the inguinal region.

The regional lymph nodes of the **urinary bladder** are predominantly the Nodi lymphoidei iliaci interni.

The lymphatic drainage of the **female genitalia** (→ p. 300) and the **male genitalia** (→ p. 277) is described in detail in the context of the respective organs.

Via the Nodi lymphoidei iliaci communes, the lymph finally drains into the parietal lymph nodes of the retroperitoneal space, which are summarised as Nodi lymphoidei lumbales on both sides of the aorta and the V. cava inferior.

Structure of the Urinary System



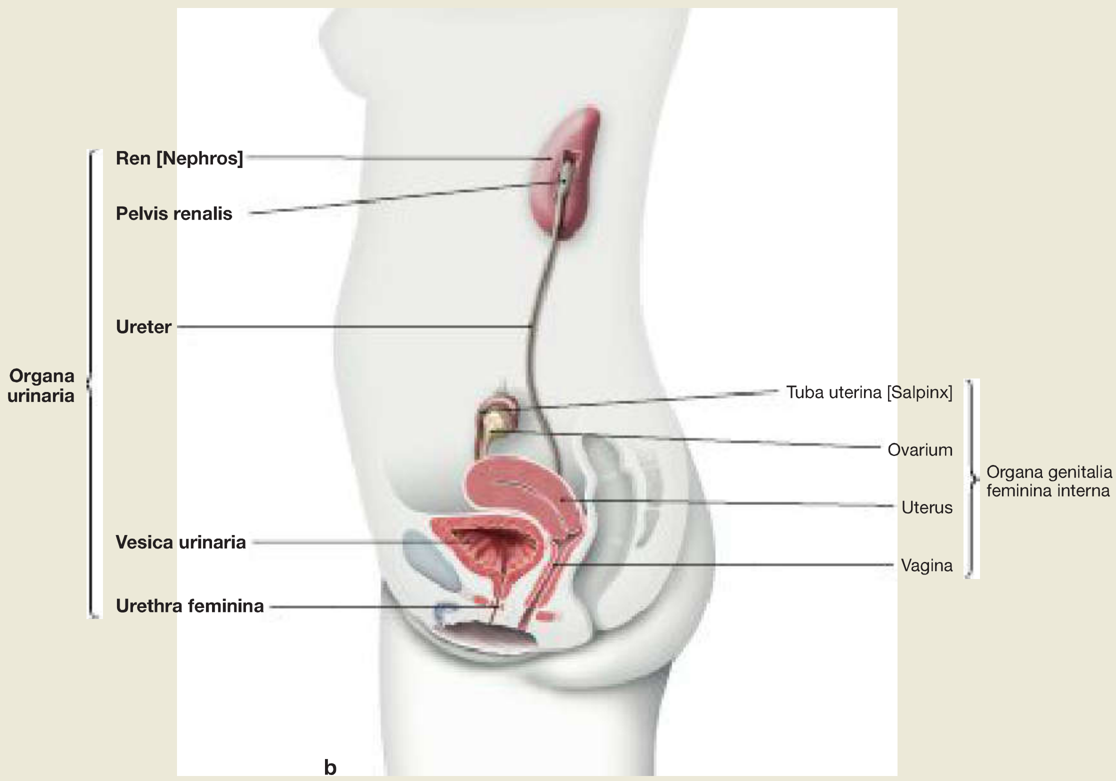


Fig. 7.14a and b Structure of the urinary system in men (→ Fig. 7.14a) and women (→ Fig. 7.14b); lateral view from the left side. [L275]

The organs in the retroperitoneal space are the **kidneys,** which via the **ureters** are connected to the **urinary bladder** in the lesser pelvis, and are part of the urinary system. The **adrenal glands** are endocrine organs (→ Fig. 7.15).

The **urinary system** is divided into the paired **kidneys (Ren [Nephros]),** which produce the urine, and the **efferent urinary tract,** which serves to excrete the urine. This includes:

- renal pelvis (Pelvis renalis)
- ureter
- urinary bladder (Vesica urinaria)
- urethra

With the exception of the urethra, the urinary system is identically formed in both sexes. In a man, the urethra is a tube for **urine and semen** in the penis, as it also serves to transport the ejaculate, and thus is part of the external male genitalia (→ Fig. 7.73a).

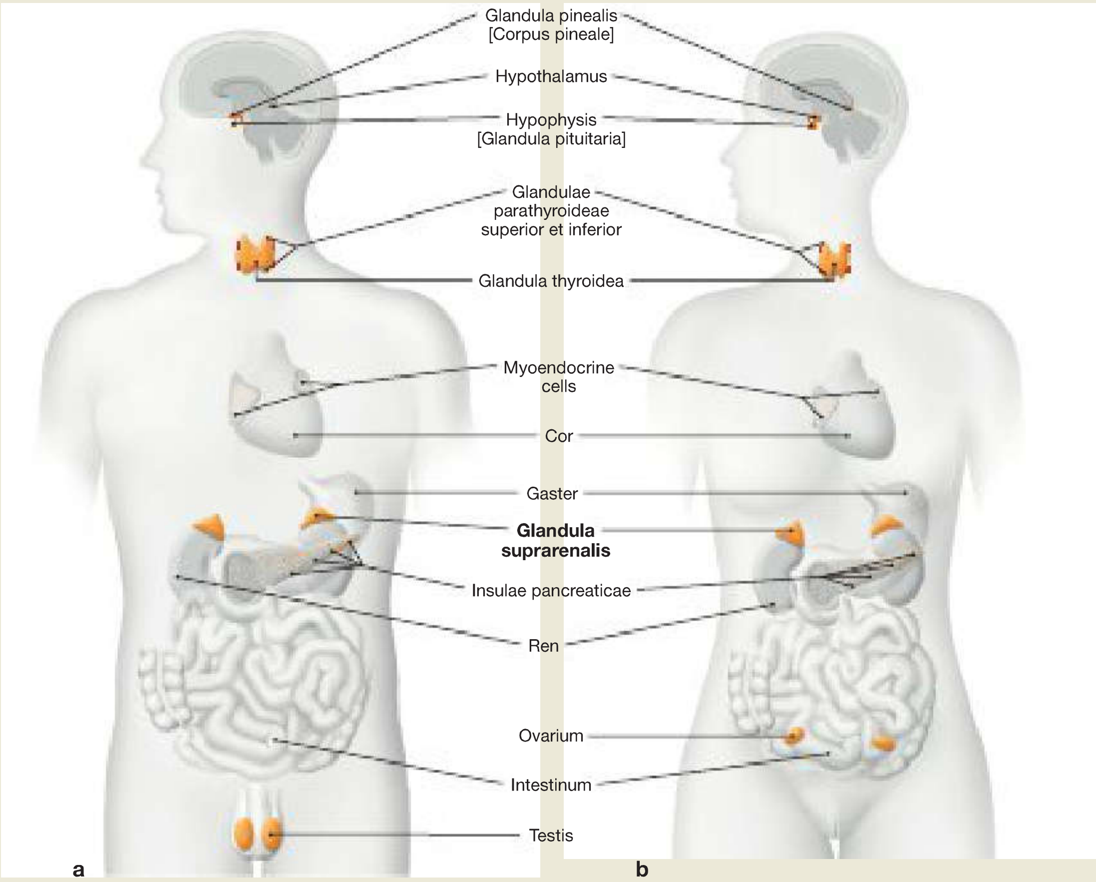


Fig. 7.15a and b Endocrine organs in men and women; ventral view. [L275]

The **adrenal gland (Glandula suprarenalis)** is not part of the urinary organs, but part of the hormone glands, which are endocrine organs and defined as the hormone system.

Since the adrenal glands adhere to the kidneys and are partly supplied by the same neurovascular pathways, the adrenal glands will be treated together with the kidneys.

Nevertheless, a brief introductory overview of the **hormone system** is necessary to explain the function and regulation of the adrenal gland. Due to their development, the adrenal glands consist of two different parts (→ Fig. 7.33), the external layer (cortex) and the medulla, which produce different types of hormones and secrete them into the blood. The release of the hormones is also regulated in a different way. The cortex produces various, partly vital **steroid hormones,** such as aldosterone (mineralocorticoid) and cortisol (glucocorticoid), whereas the **medulla** produces **catecholamines** (adrenaline and noradrenaline). The release of cortisol, a stress hormone for providing energy, for example by breaking down sugars (glycogen) stored in the liver, is controlled by the **hypothalamic-pituitary axis.** In the hypothalamus as part of the diencephalon, regulatory hormones (e.g. CRH, corticotropin-releasing hormone) are produced which induce the release of other hormones in the pituitary gland, which then in turn control the peripheral hormone glands. CRH for example acts on the anterior lobe of the pituitary gland (adenohypophysis) and stimulates the release of corticotropin (ACTH, adrenocorticotropic hormone), which induces the release of cortisol in the adrenal cortex. The production of regulatory hormones in the hypothalamus and pituitary gland is inhibited by cortisol in a regulatory circuit. This principle is referred to as **negative feedback.** It is of great importance for medical diagnostics, as measuring the concentrations of individual hormones and of their regulatory hormones allows conclusions on the causes of hormone production disorders. In contrast, the release of aldosterone effecting an increase in blood pressure, is not controlled by the pituitary gland, but by another regulatory system including the enzymes and hormones of kidneys and liver **(renin-angiotensin-aldosterone system, RAAS),** as the blood pressure may be perceived in the kidneys. The different regulatory systems of the hormones are a matter for microscopic anatomy.

The catecholamines produced in the medulla of the adrenal glands also have the effect of raising blood pressure; however their release is activated by the **sympathetic nervous system.** Since in developmental terms the adrenal medulla corresponds to a sympathetic ganglion, the preganglionic neurons end directly at the hormone-producing cells (→ Fig. 7.39).

Projection of Kidney and Adrenal Gland

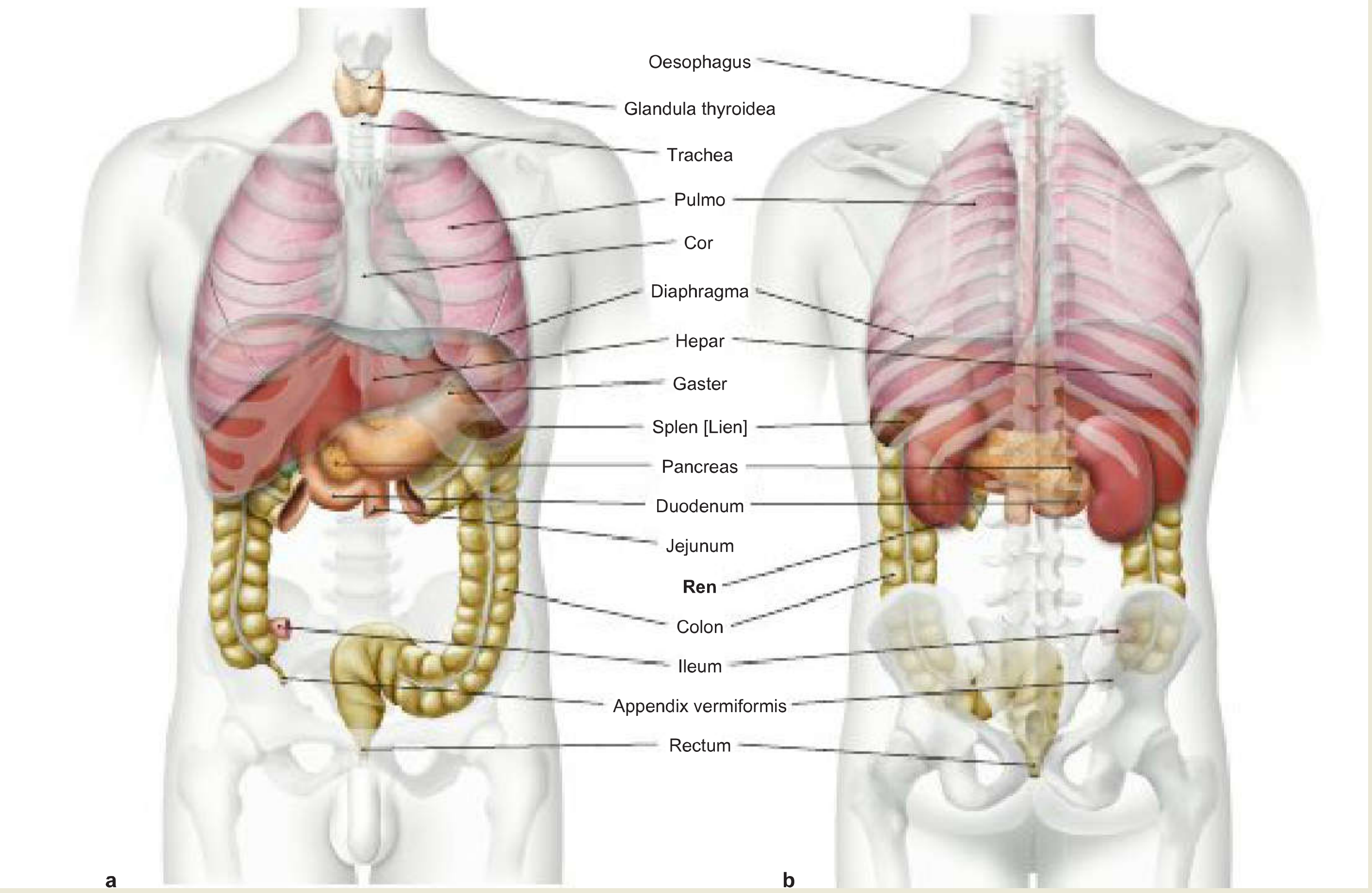


Fig. 7.16a and b Projection of internal organs onto the body surface; ventral view (→ Fig. 7.16a) and dorsal view (→ Fig. 7.16b). [L275]

Kidneys and adrenal glands are located in the **retroperitoneal space.** The adrenal glands adhere to the upper pole of the kidneys, and both structures share a common enveloping system (→ Fig. 7.24).

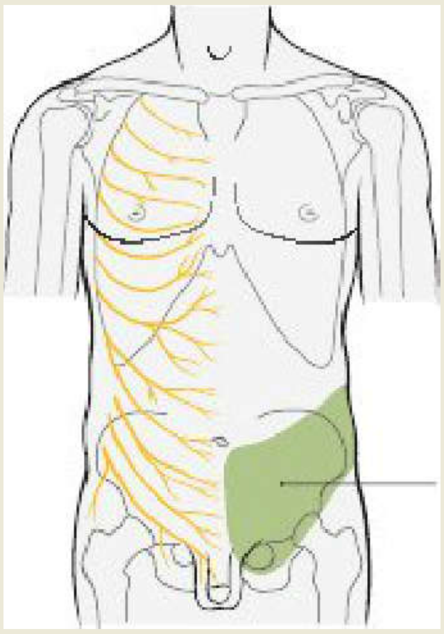


Fig. 7.17 HEAD's zone of the kidney, Ren [Nephros]; ventral view. [L126]
The organ-related projection area or the **HEAD's zone** of the kidney are the cutaneous areas (dermatomes) T10–L1. Renal diseases can therefore lead to pain perceived in these skin areas (projected pain). This is due to the fact that in the spinal cord segments T10–L1 the visceral afferent neurons from the kidney converge with the somatic afferent neurons from the surface of the body, so that the cause cannot be precisely discriminated.

Clinical Remarks

Testing the kidneys on pain sensitivity is performed with a well-judged punch in the lumbar region (in the back, at the level of each kidney just below the ribs). However, the patient should not be alerted, as otherwise the punch would be attenuated too effectively by the guarding tension of the back muscles. In the case of an inflammation of the renal pelvis (pyelonephritis), the patient will wince and report considerable pain in response to the punch. Even when properly done, this diagnostic test always imposes a certain stress for the doctor-patient relationship.

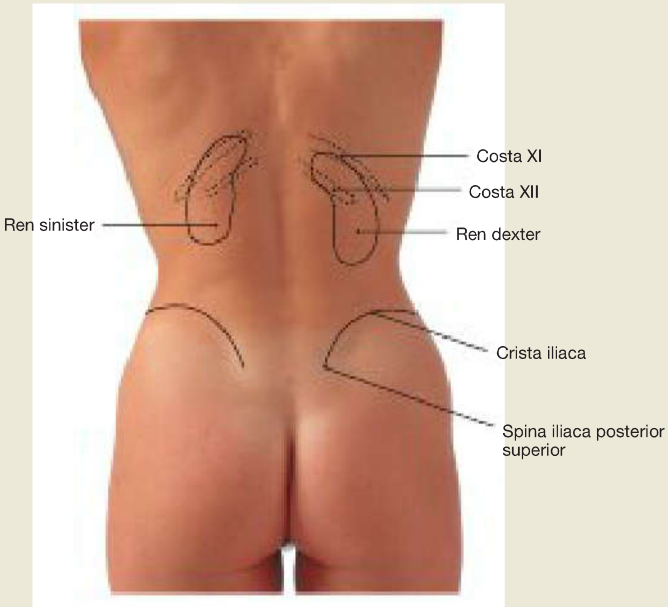


Fig. 7.18 Projection of the kidney onto the dorsal body wall.

- superior pole: 12th thoracic vertebra (T12), rib XI
- hilum: 2nd lumbar vertebra (L2)
- inferior pole: 3rd lumbar vertebra (L3)

These positional relations only apply for the left kidney.
Due to the size of the liver, the right kidney is located about half a vertebra deeper (caudally). Hence its superior pole lies just below rib XI on the right side.
Due to their proximity to the diaphragm, the position of the kidneys varies with breathing, so that they can both descend up to 3 cm during inhalation.
The adrenal glands project onto the neck of the 11th and 12th ribs.

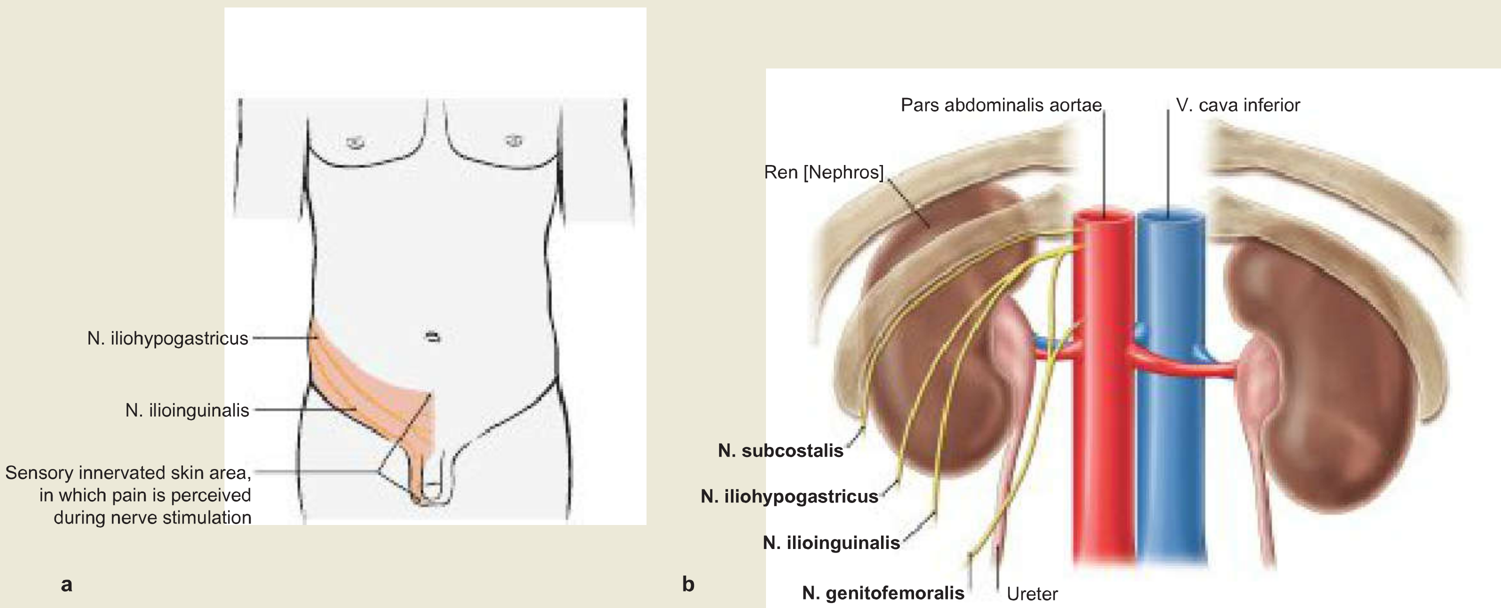


Fig. 7.19a and b Proximity of the kidneys to the nerves of the Plexus lumbalis and radiation of pain. a [L126], b [L238]
a Radiation of pain into the inguinal region, due to irritation of the nerves of the Plexus lumbalis; schematic illustration; ventral view;
b Nerves of the Plexus lumbalis in relation to the kidney, semischematic illustration of their course, dorsal view.

Among others, the **N. iliohypogastricus** and **N. ilioinguinalis** from the Plexus lumbalis, which run between the renal fascia in the inferior pole region of the kidney and the muscles of the dorsal abdominal wall, provide the sensory innervation of the inguinal region. More cranially on the dorsal side of the kidneys, just below the two lowest ribs, the 11th and 12th intercostal nerves are found (12th intercostal nerve = **N. subcostalis**). In contrast, the **N. genitofemoralis** runs further caudally and therefore has no contact to the kidney, but only to the ureter.

Clinical Remarks

The close proximity of the kidney to the N. iliohypogastricus and N. ilioinguinalis explains why renal diseases such as inflammation of the renal pelvis (pyelonephritis) or entrapped renal calculi (nephrolithiasis) may cause **pain radiating into the inguinal region.**

Development of the Kidney

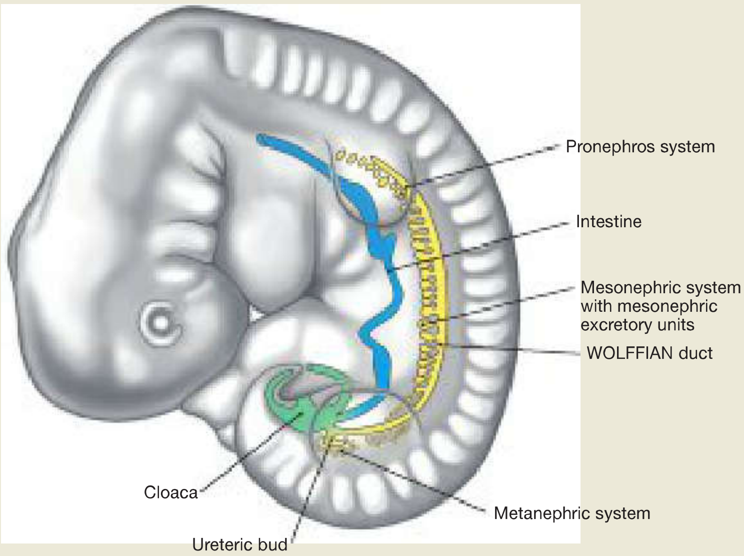


Fig. 7.20 Development of the kidneys in week 5. [L126]
The kidneys and the efferent urinary tract derive from the mesoderm which initially, on both sides of the somites, forms **nephrogenic cell clusters or strands.** From these the kidneys develop successively **in three generations and in a cranial to caudal sequence:**

- The first generation is the **pronephros,** an immature form which completely regresses.
- The **mesonephros** is a kidney with temporary excretory function, but also regresses, with the exception of its primitive ureter (WOLFFIAN duct). In men, the mesonephros generates a part of the small ducts between the testis and epididymis.
- Beginning in week 5, the **metanephros** develops after induction by the ureteric bud from the WOLFFIAN duct into the parenchyma of the definitive kidney (nephrons).
  The collecting ducts and the proximal parts of the efferent urinary tract (renal pelvis and ureter) develop directly from the ureteric bud.

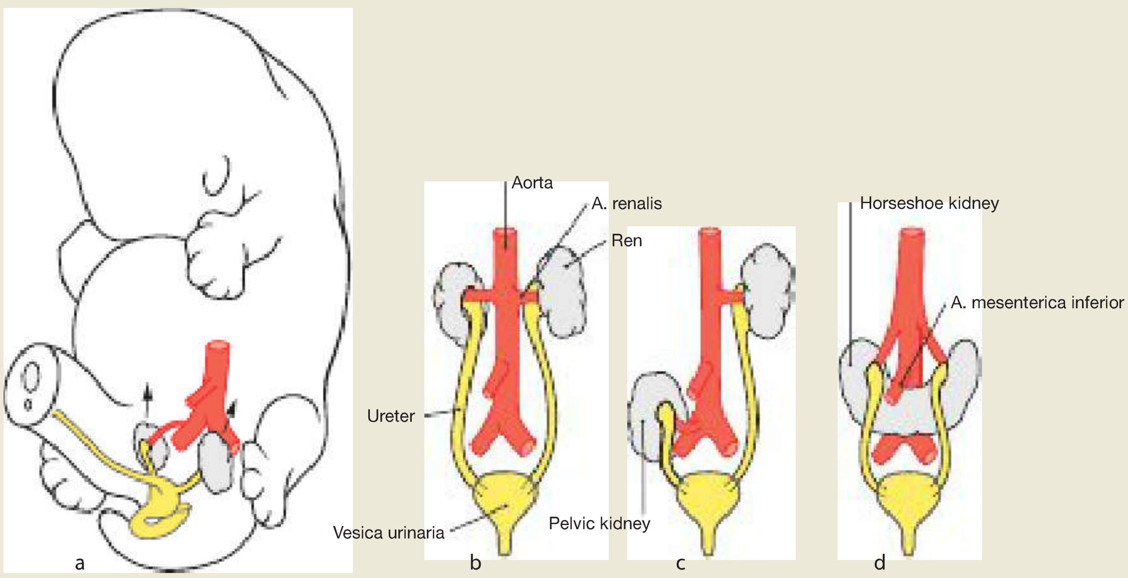


Fig. 7.21a to d Ascensus of the kidneys. [L126]
The metanephros develops at the level of the first to fourth sacral vertebrae and ascends during weeks 6 to 9 of the development (ascensus). This is actually a relative ascent since the part located caudally to the inferior pole of the kidneys **(a** and **b)** develops more quickly. In the absence of this ascensus, a pelvic kidney will develop **(c).** If both kidneys are too close together during their ascent, they may become fused to form a horseshoe kidney **(d).** This deformity usually does not reach the definitive position because its ascensus is impeded by the A. mesenterica inferior.

Clinical Remarks

Pelvic kidneys and also **horseshoe kidneys** are usually accidental findings and have no clinical relevance, if the ureter is not compromised. Displacement of the ureter, however, can cause a urinary stasis, which may result in renal damage due to the increased pressure and ascending infections.

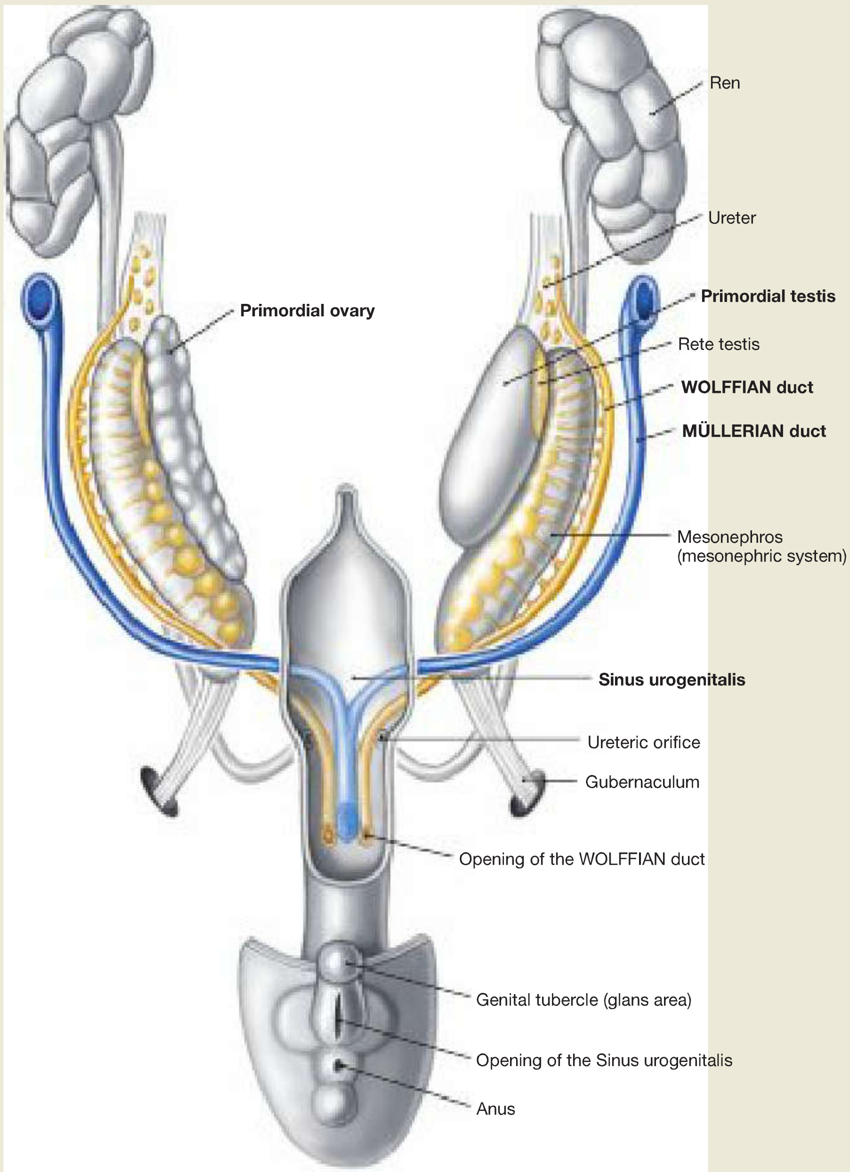


Fig. 7.22 Development of the urinary organs and early development of the internal genital organs in both sexes in week 8. [L126]
The kidneys develop from the metanephros and the ureteric bud which arises from the WOLFFIAN duct. The ureteric bud gives rise to the proximal efferent urinary tract (renal pelvis and ureter), whereas the urinary bladder and urethra develop from the Sinus urogenitalis (ventral part of the cloaca of the hindgut).
The internal genitalia develop in both sexes in the same way until week 7 (sexually indifferent gonadal stage). Besides the gonad which has not yet differentiated to testicle or ovary, there are two parallel pairs of ducts: the Ductus mesonephricus or **WOLFFIAN duct** and the Ductus paramesonephricus or **MÜLLERIAN duct.** In contrast to the WOLFFIAN duct, the distal ends of the MÜLLERIAN duct fuse prior to entering the Sinus urogenitalis. At the end of week 7, the indifferent gonad develops into the male testis or the female ovary. The testicular hormones (testosterone and anti-MÜLLERIAN hormone) induce the differentiation of the WOLFFIAN ducts to the male internal genitalia (→ Fig. 7.80) and suppress the further development of the MÜLLERIAN ducts. If both hormones are lacking, female internal genitalia will develop (→ Fig. 7.106).

Topography of the Kidney and Adrenal Gland

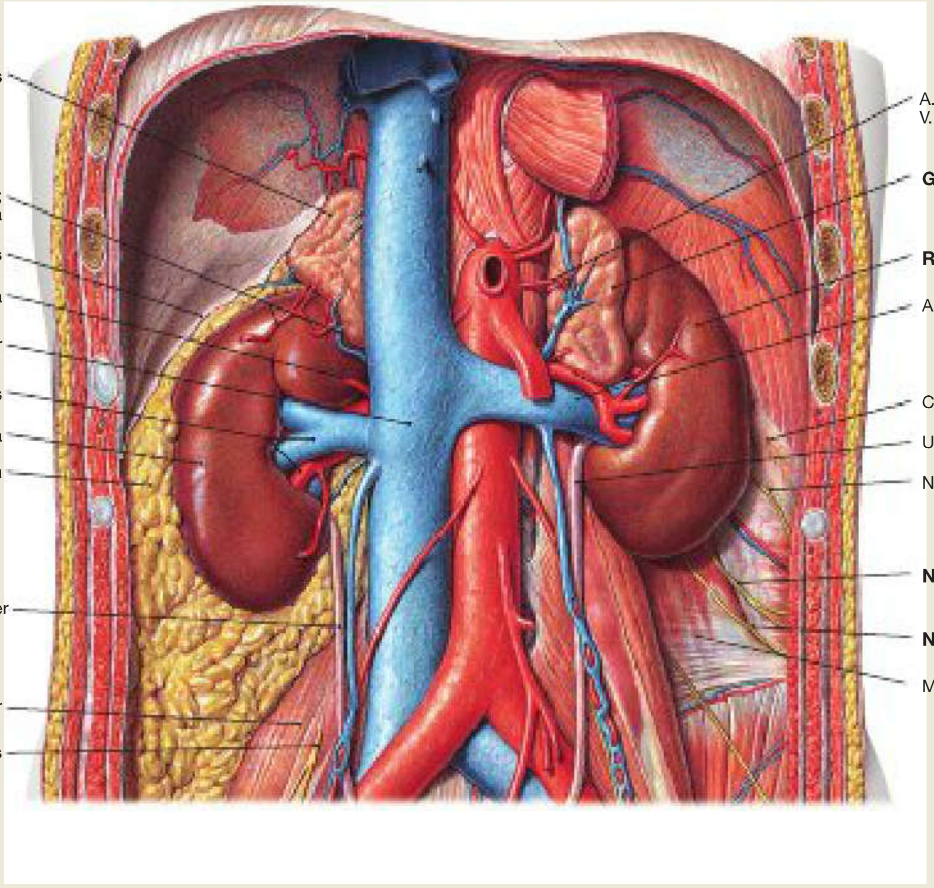


Fig. 7.23 Position of the kidney, Ren [Nephros], and adrenal gland, Glandula suprarenalis, in the retroperitoneal space; ventral view.
Kidney and adrenal gland are located in the retroperitoneal space ventrally of the M. psoas major and the M. quadratus lumborum. The kidney and the adrenal gland are embedded in a capsule of adipose tissue (Capsula adiposa), which is surrounded by a sheath of connective tissue (Fascia renalis, GEROTA's fascia). On the dorsal side of the renal fascia, the M. psoas major is located medially and the M. quadratus lumborum, as muscle of the dorsal abdominal wall, is located laterally. Running between the renal fascia and the muscles, the N. iliohypogastricus and the N. ilioinguinalis from the Plexus lumbalis provide sensory innervation to the inguinal region, among others.

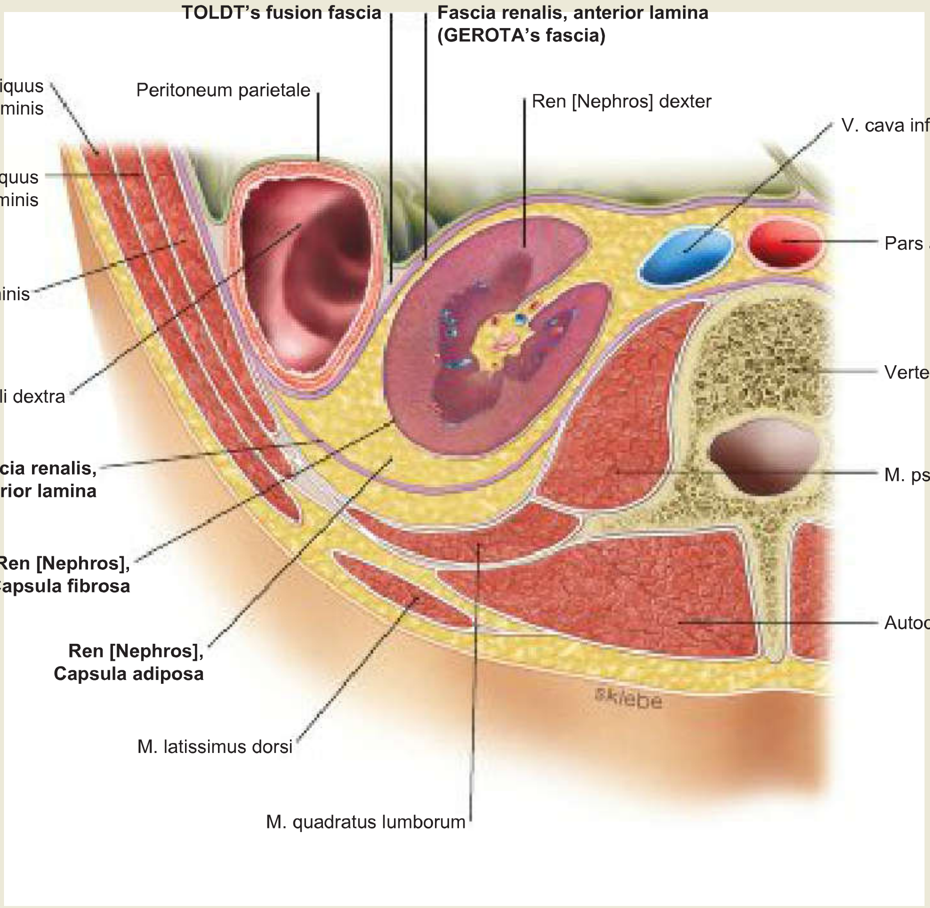


Fig. 7.24 Fascial systems of the kidney, Ren [Nephros], in the retroperitoneal space; horizontal section at the level of the third lumbar vertebra; caudal view. [L238]
The kidney and adrenal gland are located in the retroperitoneal space ventrally of the M. psoas major and the M. quadratus lumborum.
The surface of the kidney is covered by an **organ capsule** of dense connective tissue **(Capsula fibrosa).** Together with the adrenal gland, the kidney is enclosed in a **capsule of adipose tissue (Capsula adiposa).** This capsule is surrounded by a **fascial sheath (Fascia renalis)** which opens in the medial-inferior direction to allow the passage of the neurovascular pathways and the ureter. The **anterior lamina of the renal fascia** is referred to by clinicians as **GEROTA's fascia.**

The illustration shows the topographic relationships of the **Colon ascendens.** Like the **Colon descendens,** it shifted to the dorsal body wall during the development of the lower abdominal situs and came into a **secondary retroperitoneal position.** This means that only its ventral surface is covered by parietal peritoneum. As the embryonic mesocolon fused with the embryonic peritoneal coating of the posterior abdominal wall, the so-called **TOLDT's fusion fascia** was formed. This fascia merged with the anterior lamina of the Fascia renalis **(GEROTA's fascia).**

Clinical Remarks

The fascial systems and topographic relationships of the kidneys are clinically relevant. In cases of **malignant tumours,** the kidney is always removed together with the adrenal gland as well as the GEROTA's fascia (nephrectomy).

Structure of the Kidney

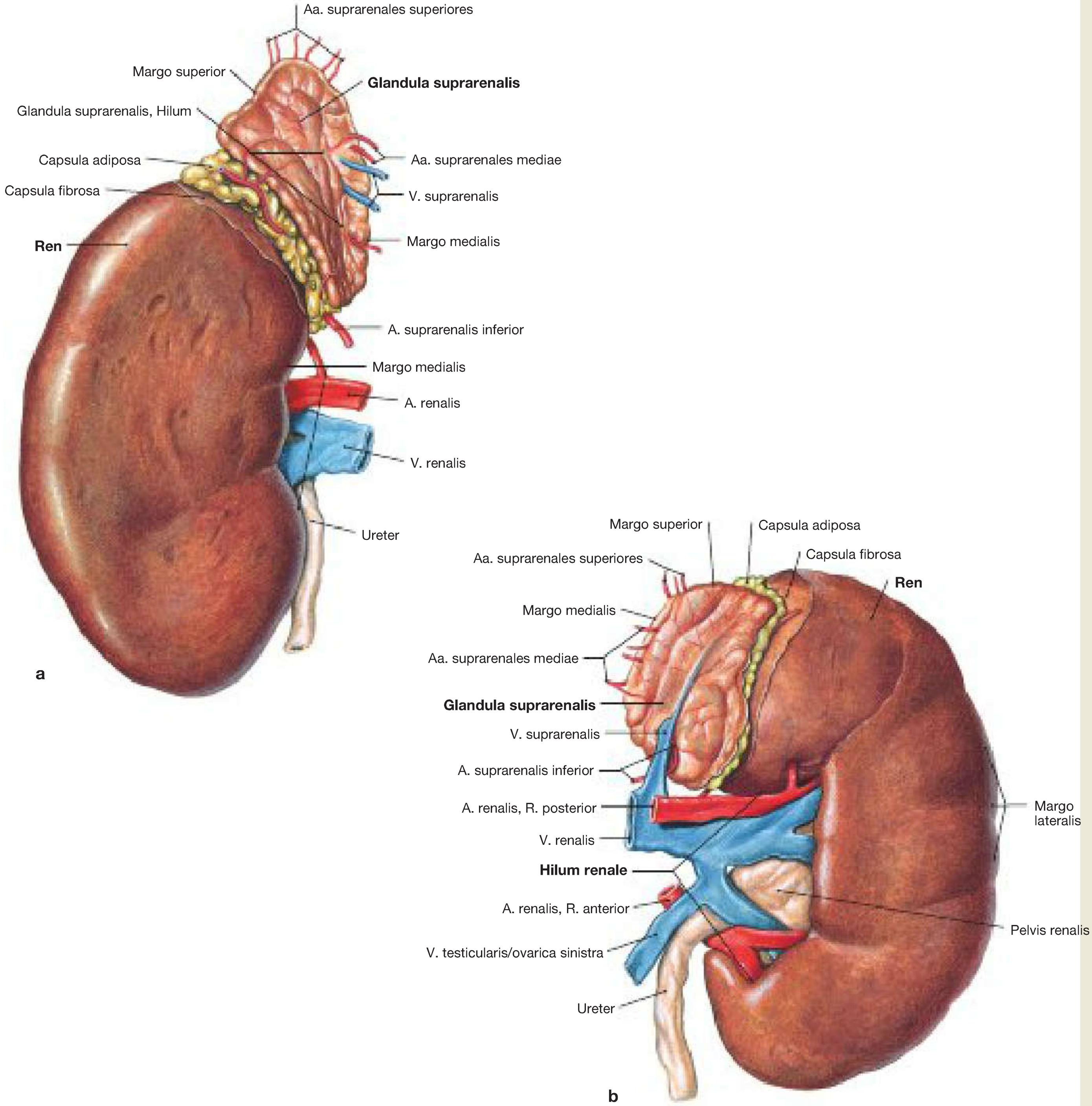


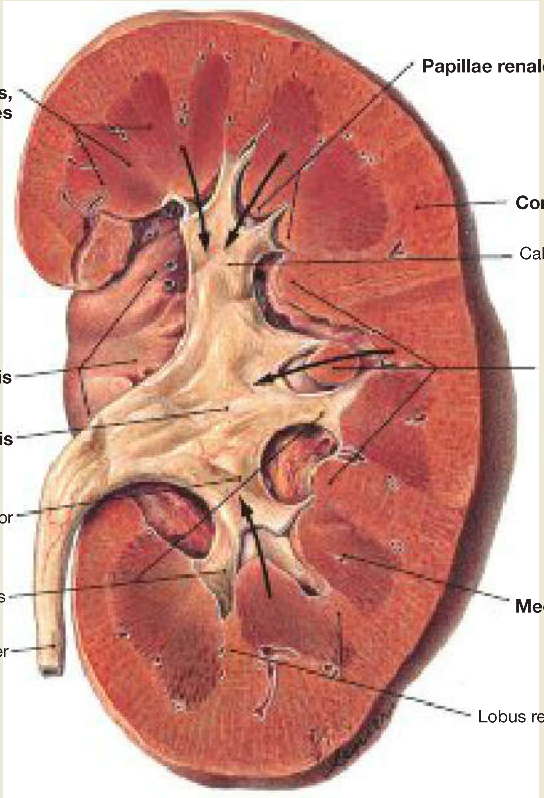
Fig. 7.25a and b Kidney, Ren [Nephros], and adrenal gland, Glandula suprarenalis; right kidney (→ Fig. 7.25a) and left kidney (→ Fig. 7.25b); ventral views.

The kidney is 'kidney-shaped' and 10–12 cm long, 5–6 cm wide and 4 cm thick. Its average weight is 150 g (120–200 g). It has a superior and an inferior pole with the medially oriented **hilum of the kidney (Hilum renale)** in between, which represents the access to an internal cavity **(Sinus renalis).** This is an opening for the passage of blood vessels and ureter entering or leaving the kidney.

The flat basis of the **adrenal gland** adheres to the kidney. Sometimes the entrance of the blood vessels at the medial margin is also referred to as the **hilum.**

Clinical Remarks

In clinical terms, the evaluation of the renal volume is of great importance, as it also has prognostic relevance for the outcome of diseases. The **normal renal volume** is **120–200 ml,** when determined by ultrasound. In **polycystic kidney disease** the volume can exceed 1,500 ml. With volumes of more than 1,000 ml a reduction of the renal function is to be expected. Autosomal dominant polycystic kidney disease (ADPKD) occurs with a frequency of 1:500–1:1,000 live births, and is one of the most common genetic disorders.



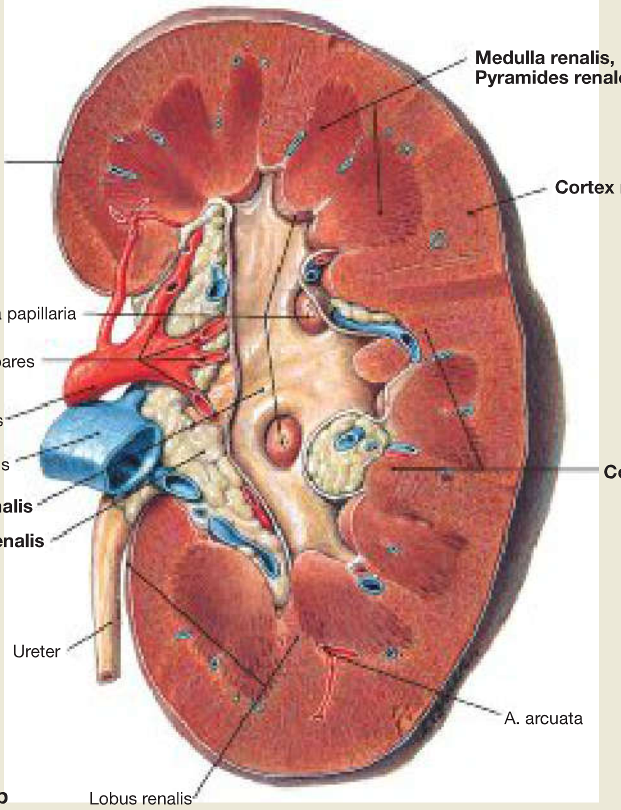


Fig. 7.26a and b Kidney, Ren [Nephros], left side; ventral view; after cutting in half vertically (→ Fig. 7.26a) and with exposed and opened (→ Fig. 7.26b) renal pelvis.

The kidney is divided into the **cortex** (Cortex renalis) and **medulla** (Medulla renalis). The medulla has different sections, designated according to their shape as **medullary pyramids** (Pyramides renales). Between the pyramids are cortical parts, the renal columns (Columnae renales). A pyramid with adjoining renal columns is called a **renal lobe** (Lobus renalis). In general, the border between the approx. 14 lobes is not visible at the surface of an adult human kidney. The tips of the pyramids (Papillae renales) open into the **renal calices** (Calices renales majores and minores) to release the urine (arrows). Together with adipose tissue and renal blood vessels, the **renal pelvis** (Pelvis renalis) is located in a deep indentation or sinus of the parenchyma of the kidney (Sinus renalis).

Structure of the Kidney

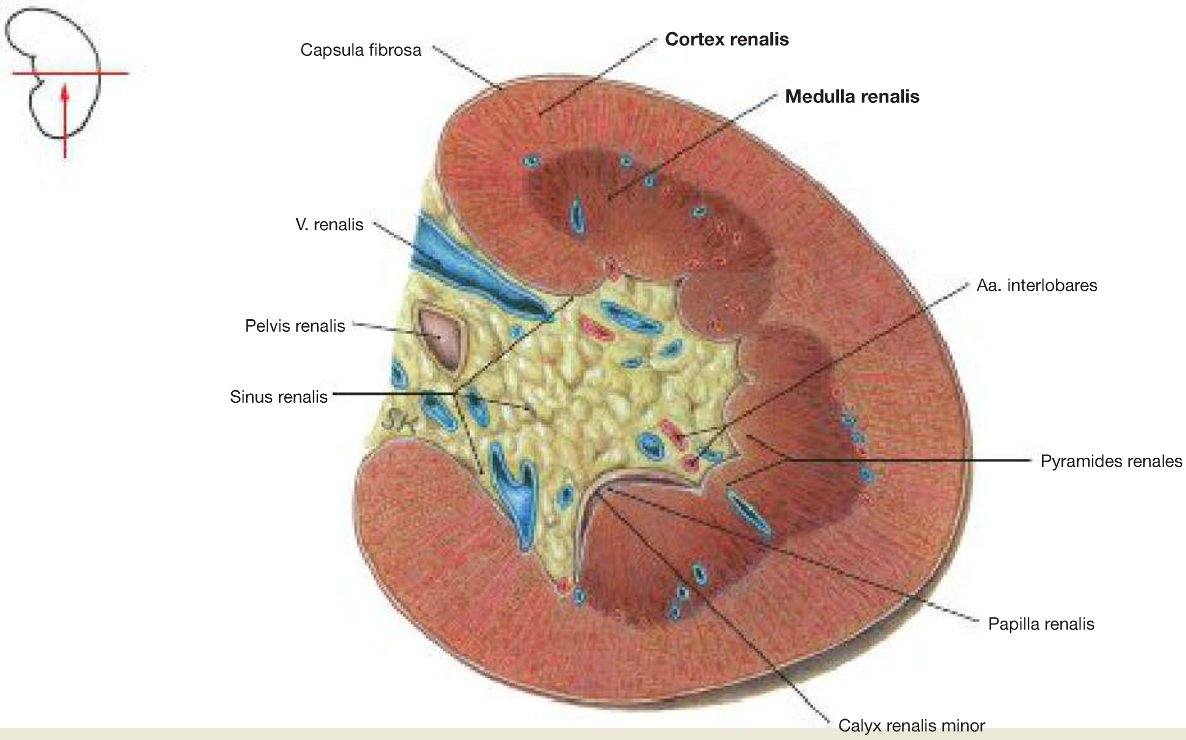


Fig. 7.27 Kidney, Ren [Nephros]; cross-section through the renal sinus (Sinus renalis); caudal view. [L238]

The parenchyma of the kidney is divided into the **cortex (Cortex renalis)** and the **medulla (Medulla renalis).**

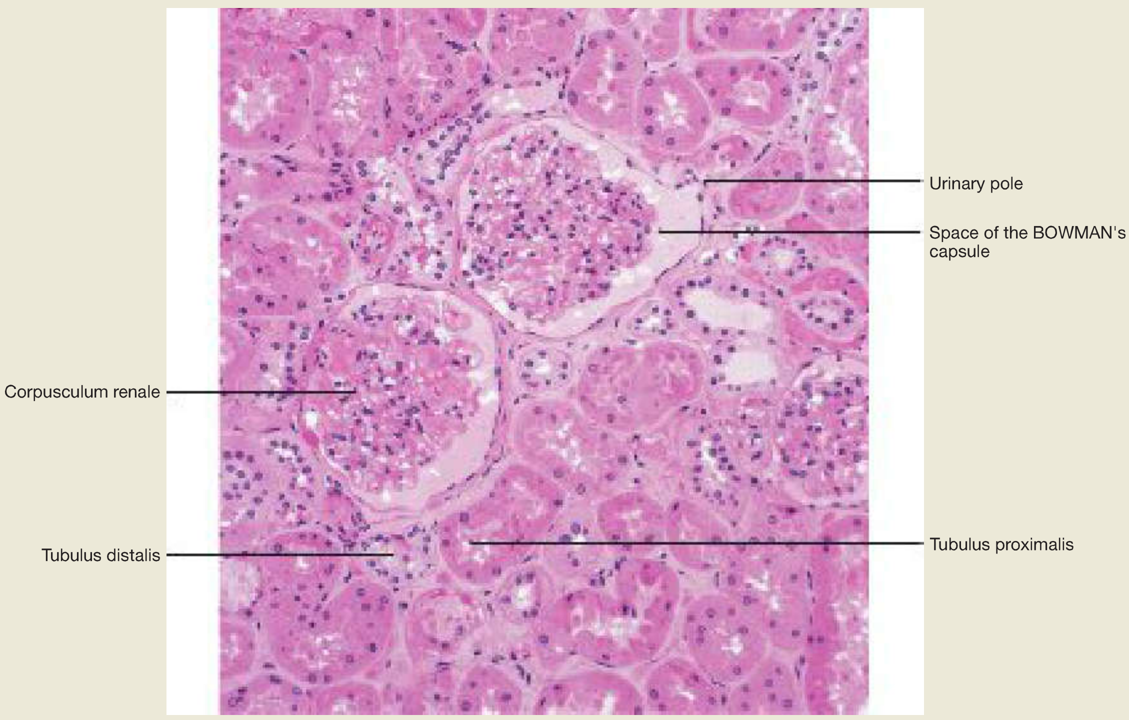


Fig. 7.28 Renal cortex, Cortex renalis; microscopic image, 100-fold. [R252]

The entire parenchyma of the kidney consists of **nephrons** and **collecting ducts.** The nephrons consist of the **renal corpuscles** and a **tubular system.** In contrast to the medulla, in the cortex there are renal corpuscles (Corpuscula renalia). In the **convoluted capillaries (Glomerulus)** of the renal corpuscles, the primary urine is filtered from the blood into the space of the BOWMAN's capsule (170 l/day). From here the urine enters the proximal tubule (Tubulus proximalis) at the urinary pole. In the tubular system and collecting ducts the major part of the primary urine is reabsorbed, and additionally its composition is altered by secretion before the final urine is released into the renal pelvis at the renal papillae (1.7 l/day).

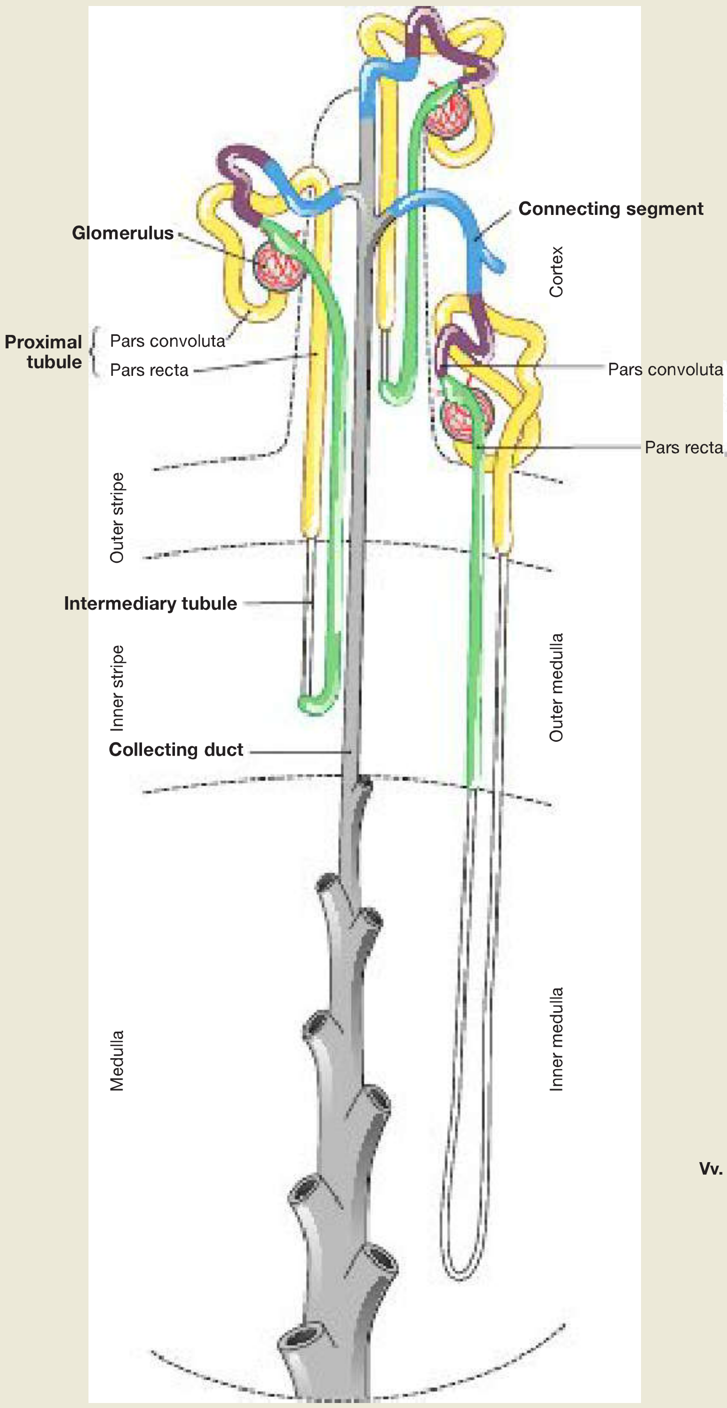


Fig. 7.29 Organisation of nephron and collecting duct; schematic illustration. [L126]

At the **renal corpuscle,** where the primary urine is produced, the **proximal tubule** begins with a convoluted part (Pars convoluta) and a consecutive straight part (Pars recta). This is followed by the **intermediate tubule,** having a descending (Pars descendens) and an ascending limb (Pars ascendens), which continues as the **distal tubule** (again with Pars recta and Pars convoluta). The **connecting or collecting tubule** is the transition to the **collecting duct,** from which the final urine passes into the renal pelvis.

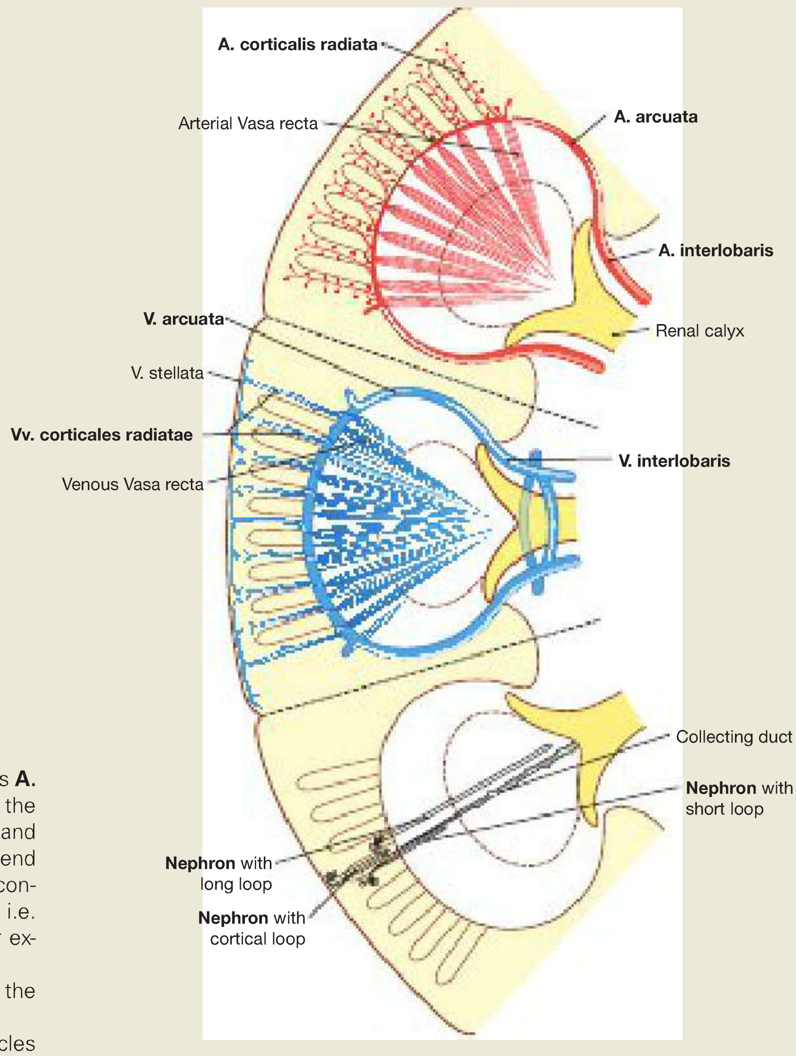


Fig. 7.30 Course of arteries (red), veins (blue), and nephrons (grey) in the renal parenchyma; schematic illustration. [L126]

The **A.** and **V. renalis** bifurcate in the area of the hilum and ascend as **A.** and **V. interlobaris** along the edge of the pyramids, arching along the cortical-medullary border of the pyramids as **A.** and **V. arcuata,** and leaving them at the base as **A.** and **V. corticalis radiata,** which ascend to the capsule. These sections are still macroscopically visible. In contrast to the veins, the arteries do not form closed vascular arches, i.e. they are terminal arteries. Therefore, an occlusion of the arteries, for example by a protracted blood clot (embolus) leads to **renal infarction.**

For understanding the renal function, the following microlevels of the vascular system are also important:

The small arterioles of the A. corticalis radiata to the renal corpuscles (Vasa afferentia) form the convoluted capillaries of the **glomerulus.** In the glomeruli, the primary urine is pressed out and filtered from the blood into the tubular system of the nephrons. Then the capillary loops continue via a second system of arterioles (Vasa efferentia) into the peritubular capillaries and, in the renal medulla, into the venous Vasa recta, which have descending and ascending parts. These vessels are ultimately connected to the veins. The Vasa recta, which are accompanied by arterial vessels in the medulla, are important for the absorption and secretion of substances in the tubular parts of the nephron and in the collecting duct.

Segments and Topographical Relationships of the Kidney

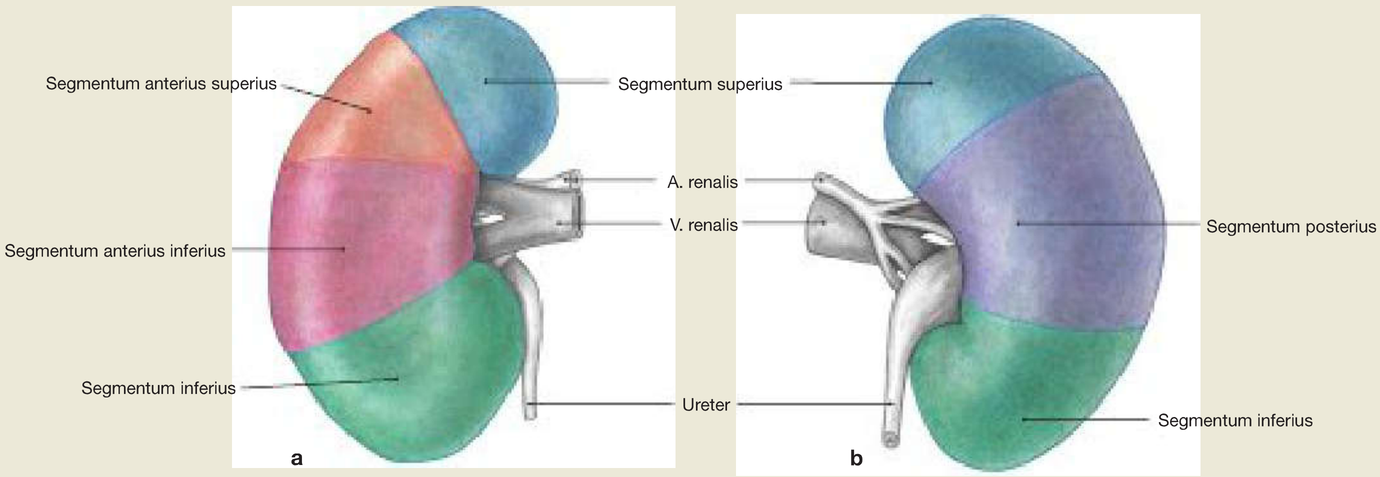


Fig. 7.31a and b Kidney (renal) segments, Segmenta renalia, right side; ventral view (→ Fig. 7.31a) and dorsal view (→ Fig. 7.31b).
Through the branching of the arterial vessels, the kidney is divided into **segments** (Segmenta renalia). If branches of the A. renalis are occluded, the size and extension of **renal infarctions** correspond to the limits of the affected segments. However, the branching patterns are highly variable.

The renal artery (A. renalis) bifurcates in the area of the hilum into a R. principalis anterior, supplying with its different branches the superior, the two anterior and the inferior segments, and a R. principalis posterior for the posterior segment.

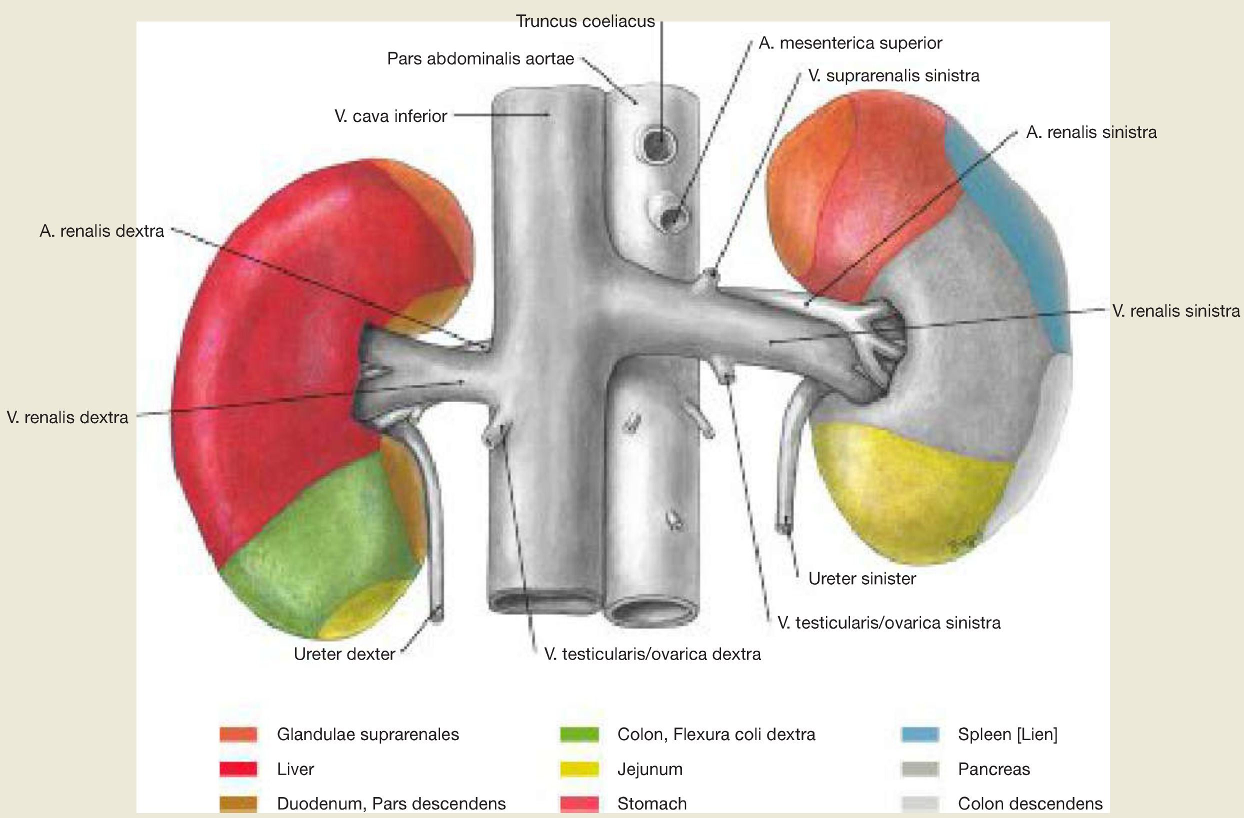


Fig. 7.32 Surfaces of the kidney, Ren [Nephros], in contact with adjacent organs; ventral view.
Whereas the dorsal side of the kidney is adjacent to the posterior abdominal wall, its ventral side has contact with various other organs. Together with the adrenal glands, the kidneys are separated from the other abdominal organs by the Peritoneum parietale, the renal fascia, and the adipose capsule, so that these surfaces have no clinical relevance.

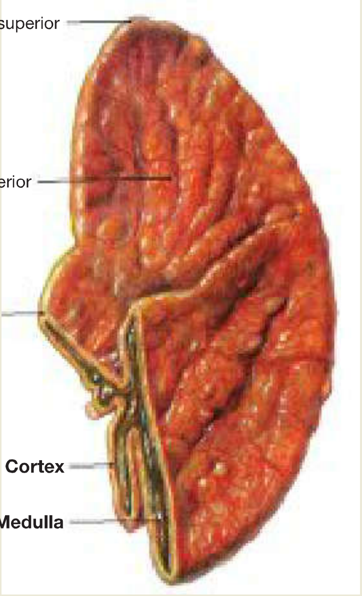


Fig. 7.33 Adrenal gland, Glandula suprarenalis, right side; ventral view.
The adrenal gland consists of its **cortex** and **medulla,** which are completely different in developmental and functional terms. The **cortex** develops from the **mesoderm** of the dorsal abdominal cavity (intraembryonic coeloma), whereas the **medulla** derives from the **neural ectoderm** of the neural crest, and therefore is equivalent to a modified sympathetic ganglion.

Macroscopically, a distinction is made between its medial and superior margins **(Margo medialis and Margo superior),** which delimit the anterior and posterior surfaces **(Facies anterior and Facies posterior),** as well as a basis **(Facies renalis).** At the medial margin there is also the **hilum** for entering and exiting neurovascular pathways.

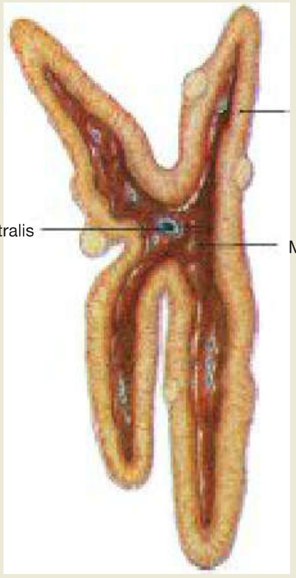


Fig. 7.34 Adrenal gland, Glandula suprarenalis, right side; sagittal section; lateral view.
The adrenal gland is a vital endocrine gland. The **cortex** produces **steroid hormones** (mineralocorticoids, glucocorticoids, androgens) and the **medulla** produces **catecholamines** (adrenaline and noradrenaline) which regulate the metabolism and blood pressure.

Clinical Remarks

If both adrenal glands have to be removed in the case of disease, a therapeutic substitution of mineralocorticoids and glucocorticoids is necessary, otherwise **life-threatening conditions** can cause low blood sugar levels (hypoglycaemia) and a decrease in blood pressure (hypotension). This may also be the case with insufficiency of the adrenal glands (ADDISON's disease).

Blood Vessels of the Kidney and Adrenal Gland

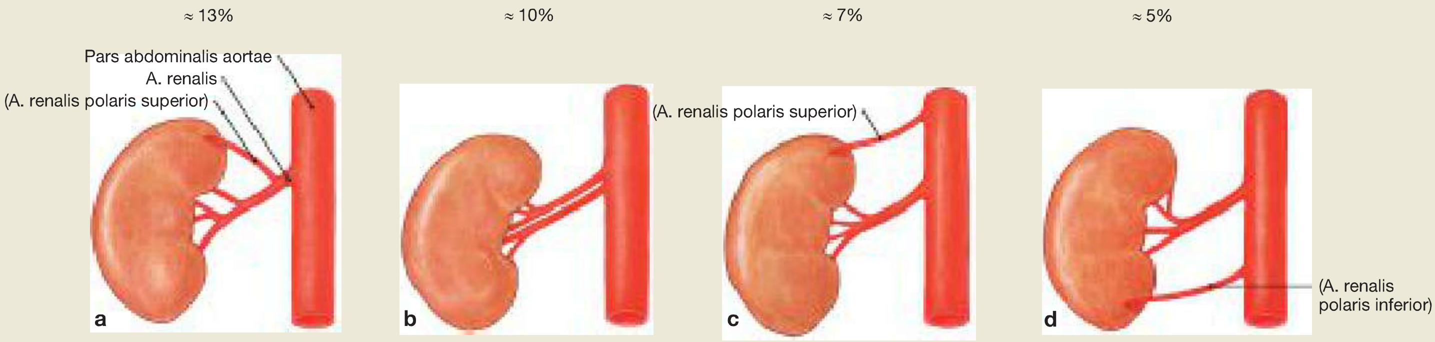


Fig. 7.35a to d Renal artery, A. renalis, with variations; ventral view.
In general, the **renal artery (A. renalis)** originates on both sides from the aorta and passes through the hilum into the kidney. The **polar arteries** of the kidneys do not enter via the hilum, but pass directly into the renal parenchyma. **Accessory arteries,** however, arise independently from the aorta.

a A. renalis with a superior polar artery
b two Aa. renales to the hilum of the kidney
c accessory superior polar artery
d accessory inferior polar artery

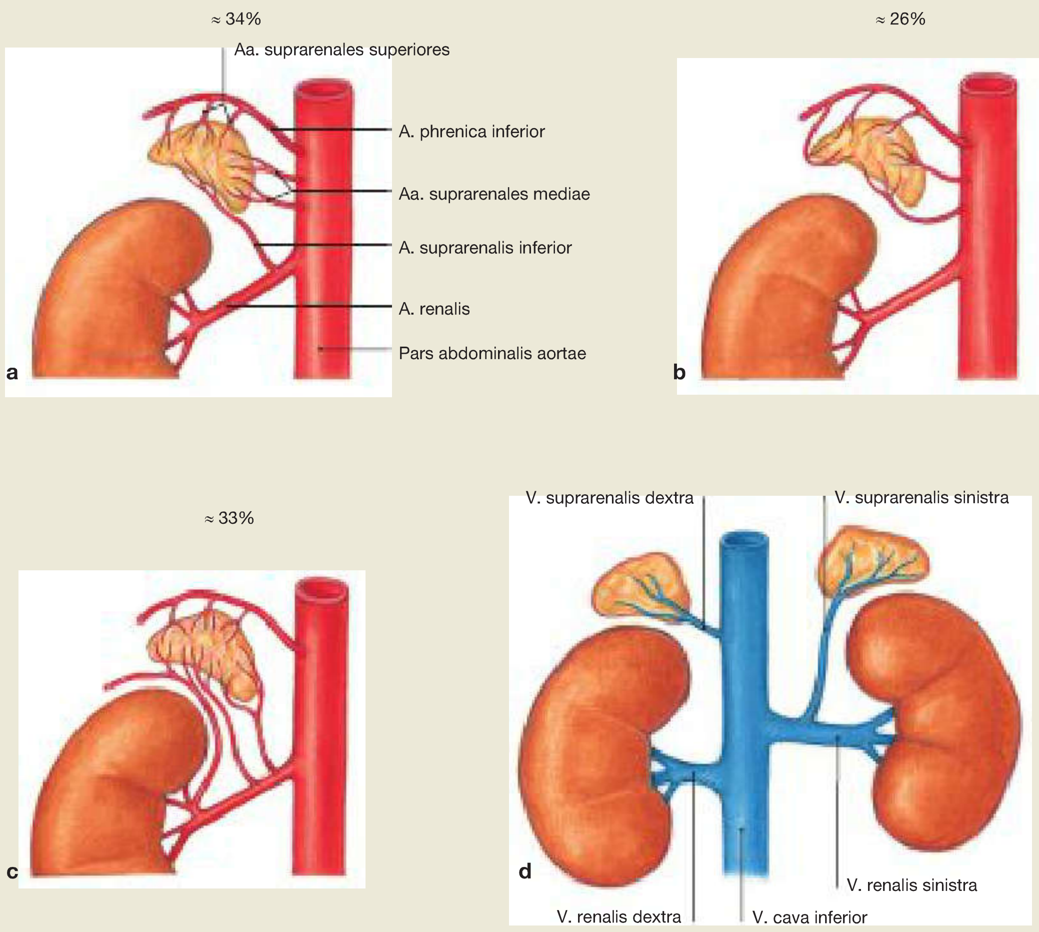


Fig. 7.36a to d Suprarenal arteries, Aa. suprarenales, with variations, renal vein, V. renalis, and suprarenal vein, V. suprarenalis; ventral view.
Usually **three arteries supply the adrenal gland:**

- **A. suprarenalis superior:** originates from the A. phrenica inferior
- **A. suprarenalis media:** directly from the aorta
- **A. suprarenalis inferior:** branch of the A. renalis

This 'luxury perfusion' or hyperperfusion prevents infarctions that could jeopardise the vital organ. However, all arteries of the adrenal gland are present in only a third of the cases. The various arteries of the adrenal gland penetrate the cortex of the organ. From there, the blood flows to the medulla and is collected by the V. suprarenalis. The blood-flow directed from the cortex to the medulla is functionally important because the hormones of the adrenal cortex regulate the differentiation and function of the cells in the medulla.

Variations of the arterial supply of the adrenal gland:
a arterial supply via three arteries (textbook case)
b arterial supply without inflow from the A. renalis
c arterial supply without a direct branch of the aorta

The **V. renalis** of both sides flows to the V. cava inferior. Similarly, there is only one vein in each adrenal gland, the **V. suprarenalis,** which collects the blood and drains into the V. cava inferior on the right side and into the V. renalis on the left side **(d).**

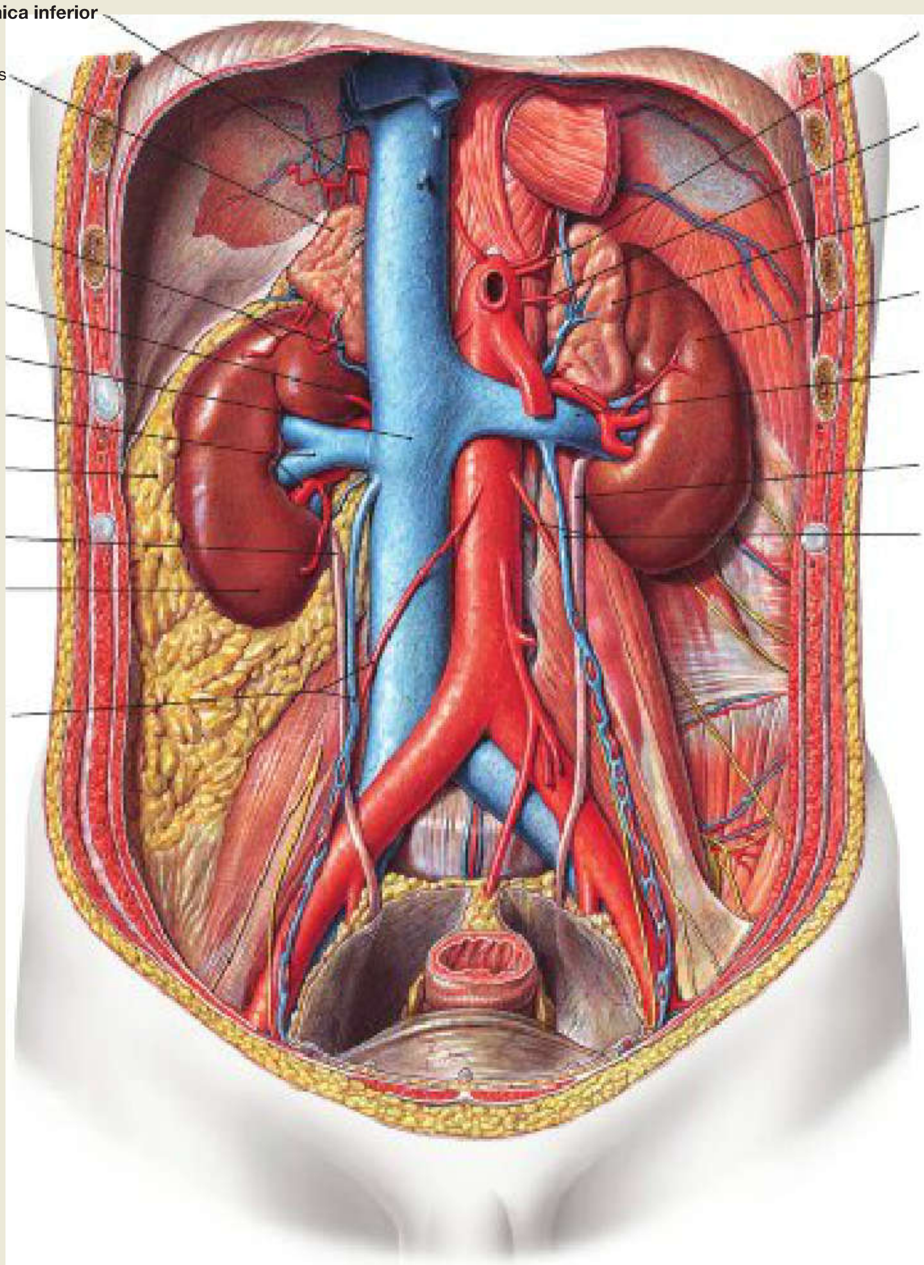


Fig. 7.37 Course of the A. and V. renalis; ventral view.
The **Aa. renales** originate at the level of the second lumbar vertebra as paired arteries from the abdominal aorta and run dorsally of the veins to the hilum of the kidney, whereby the A. renalis on the right passes behind the V. cava inferior. At the hilum, they divide into several branches.

The **Vv. renales** drain on both sides into the V. cava inferior. The **left** V. renalis receives three veins, while the corresponding veins on the right side drain independently into the V. cava inferior:
- V. suprarenalis sinistra
- V. testicularis/ovarica sinistra
- V. phrenica inferior sinistra

Clinical Remarks

As renal carcinomas often invade the renal veins, in men a tumour growth on the left side can cause a venous stasis in the V. testicularis, with convoluted and dilated veins in the scrotum **(varicocele).** Therefore, in a left-sided varicocele a kidney tumour must always be excluded!

Arteries of the Kidney and Adrenal Gland

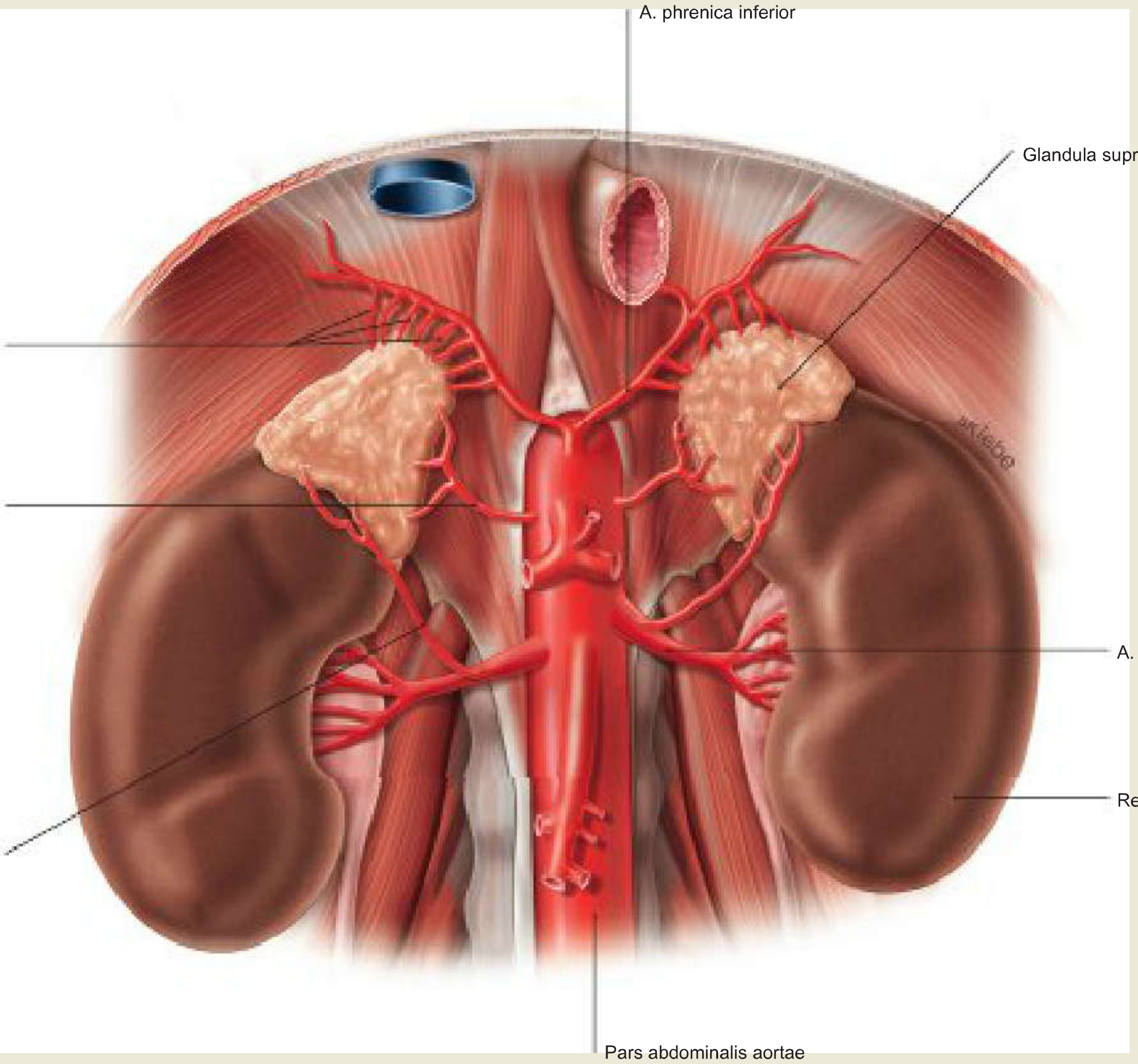


Fig. 7.38 Arterial blood supply of the kidney and adrenal gland; ventral view. With exception of the kidney and adrenal gland, all organs of the abdominal cavity as well as the veins, lymphatic vessels and nerves of the retroperitoneal space have been removed. [L238]

The **A. renalis** originates bilaterally from the aorta and runs to the hilum of the kidney, where it divides very variably into several terminal branches. Usually the **A. suprarenalis inferior** also branches off. In contrast, the A. suprarenalis superior arises in most cases with several smaller branches of the A. phrenica inferior. The **A. suprarenalis media** is an independent branch of the aorta, but just like the A. suprarenalis inferior, it is relatively often missing.

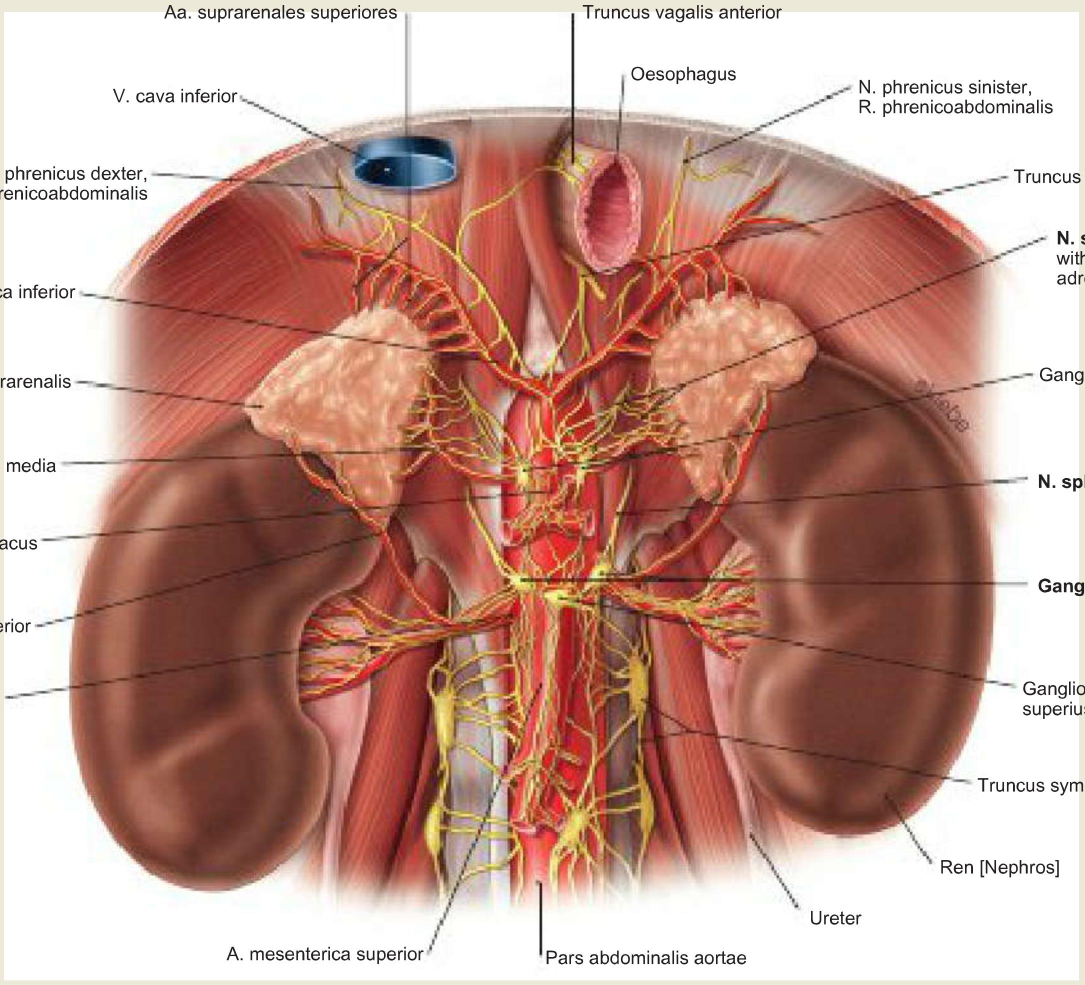


Fig. 7.39 Autonomic innervation of the kidney and adrenal gland; ventral view. With exception of the kidney and adrenal gland, all organs of the abdominal cavity as well as the veins and lymphatic vessels of the retroperitoneal space have been removed. [L238]

The **autonomic innervation** of the kidney and adrenal gland is provided largely by the sympathetic system. But there are fundamental differences between both organs:

The **kidney** is innervated by its own plexus **(Plexus renalis)** which extends along the A. renalis. The cell bodies of the **postganglionic** neurons are located in the **Ganglia aorticorenalia,** which lie near the outlets of the renal arteries from the aorta and therefore belong to the Plexus aorticus abdominalis.

By contrast, the **adrenal gland** is supplied by **preganglionic** (!) sympathetic nerve fibres from the Nn. splanchnici. The nerve endings are located on medullary cells of the adrenal gland and induce the release of catecholamines. Thus the medulla of the adrenal gland corresponds to a modified sympathetic ganglion.

Kidney, Imaging

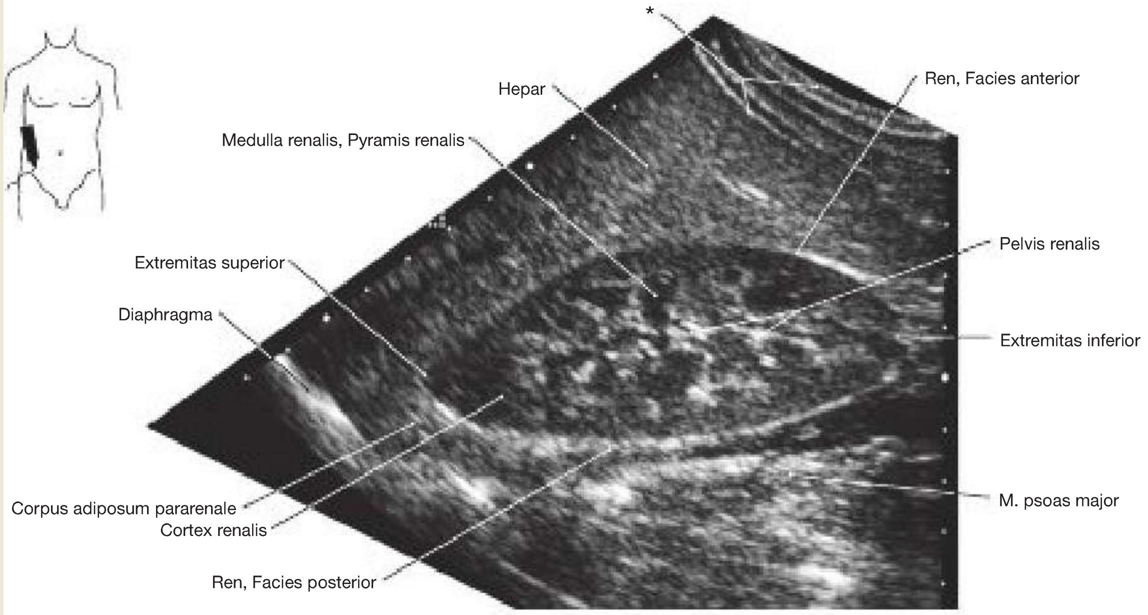


Fig. 7.40 Kidney, Ren [Nephros], right side; ultrasound image; lateral view; nearly vertical position of the transducer. [T894]

* abdominal wall

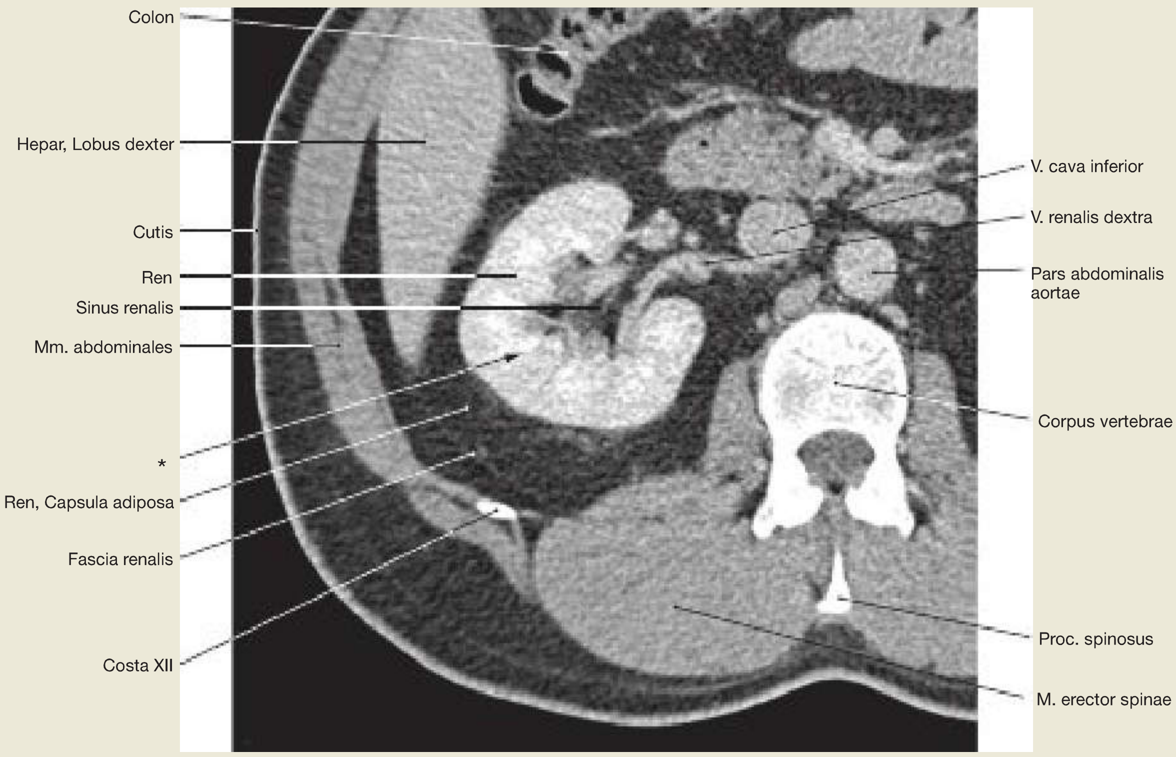


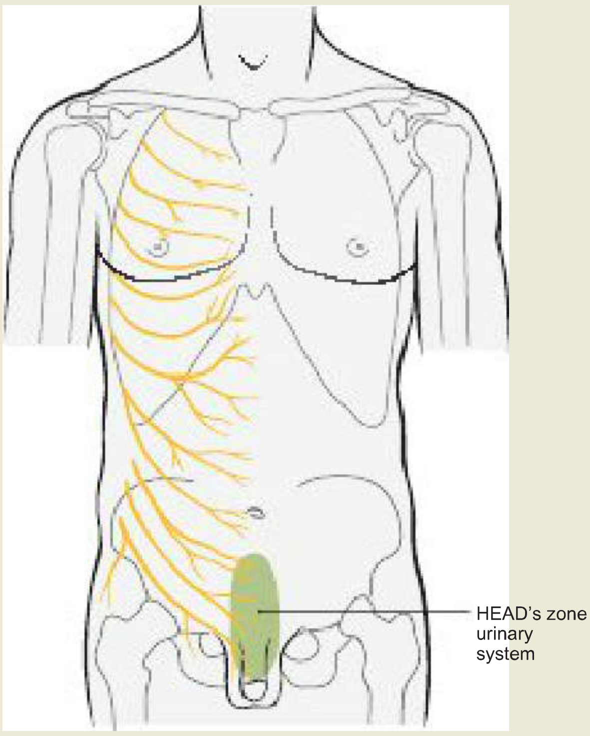
Fig. 7.41 Kidney, Ren [Nephros], right side; computed tomography (CT) scan; caudal view. [T900]

It is also possible to perform a CT-guided biopsy, e.g. to assess unclear dysfunctions.

* route of the needle for kidney biopsy

Clinical Remarks

The **ultrasound** is a particularly suitable imaging technique for the kidneys. Masses, such as cysts or tumours can generally be well-detected. Where findings are inconclusive, **CT examination** is available, and with this, lymph node metastases can be reliably identified in lumbar lymph nodes as can an onset of tumours in the renal vein.



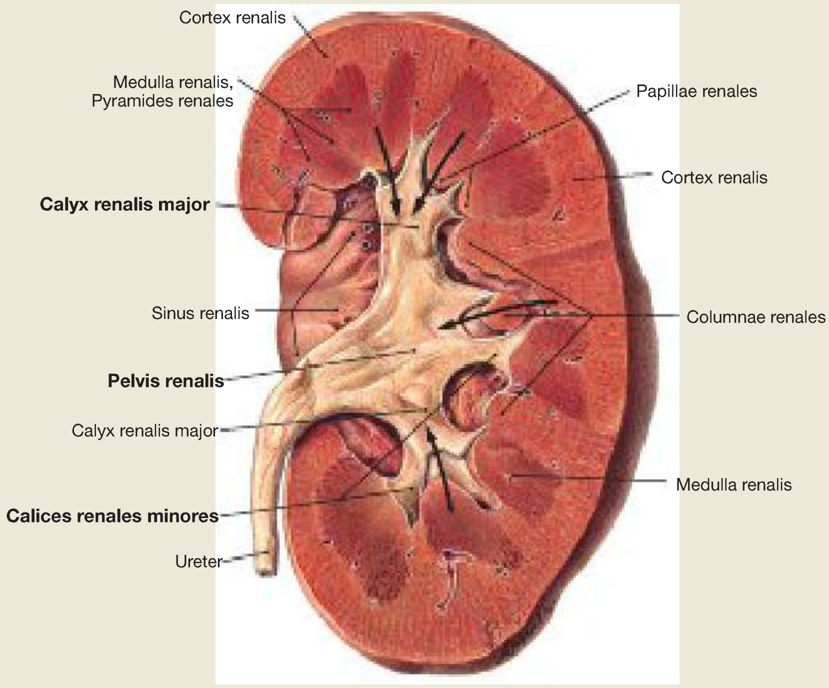


Fig. 7.42 HEAD's zone of the urinary system; ventral view. [L126]
The **efferent urinary system** includes:

- renal pelvis (Pelvis renalis)
- ureter
- urinary bladder (Vesica urinaria)
- urethra

The organ-related area or the **HEAD's zone** of the renal pelvis corresponds to that of the kidney and projects onto the cutaneous areas (dermatomes) T10–L1; the HEAD's zone of the urinary bladder projects medianally onto the dermatomes T11–L1. Diseases like an inflammation of the renal pelvis (pyelonephritis) or a bladder inflammation (cystitis) can therefore lead to pain, which is perceived in these cutaneous areas (projected pain).

Fig. 7.43 Renal pelvis, Pelvis renalis, left side; ventral view.
After the urine has been separated from the blood as primary urine in the renal corpuscles, then it is concentrated in the collecting ducts of the nephron and changes its composition by absorption and secretion processes. This final urine passes at the top of the **medullary pyramids (Pyramides renales),** the perforated areas of which are called **renal papillae (Papillae renales),** into the **renal calices** (Calices renales) of the **renal pelvis (Pelvis renalis)** (arrows).
For the neurovascular pathways of the urinary system in the pelvis → Fig. 7.8, → Fig. 7.11, → Fig. 7.12 and → Fig. 7.13.

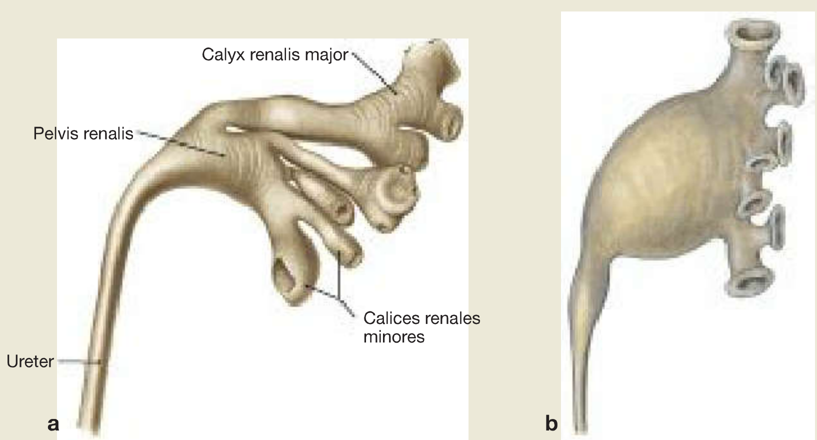


Fig. 7.44a and b Renal pelvis, Pelvis renalis, left side; cast dissection, ventral view.

According to the width and the length of the renal calices, a dendritic type (→ Fig. 7.44a) and an ampullary type (→ Fig. 7.44b) of the renal pelvis are distinguished.

Ureter

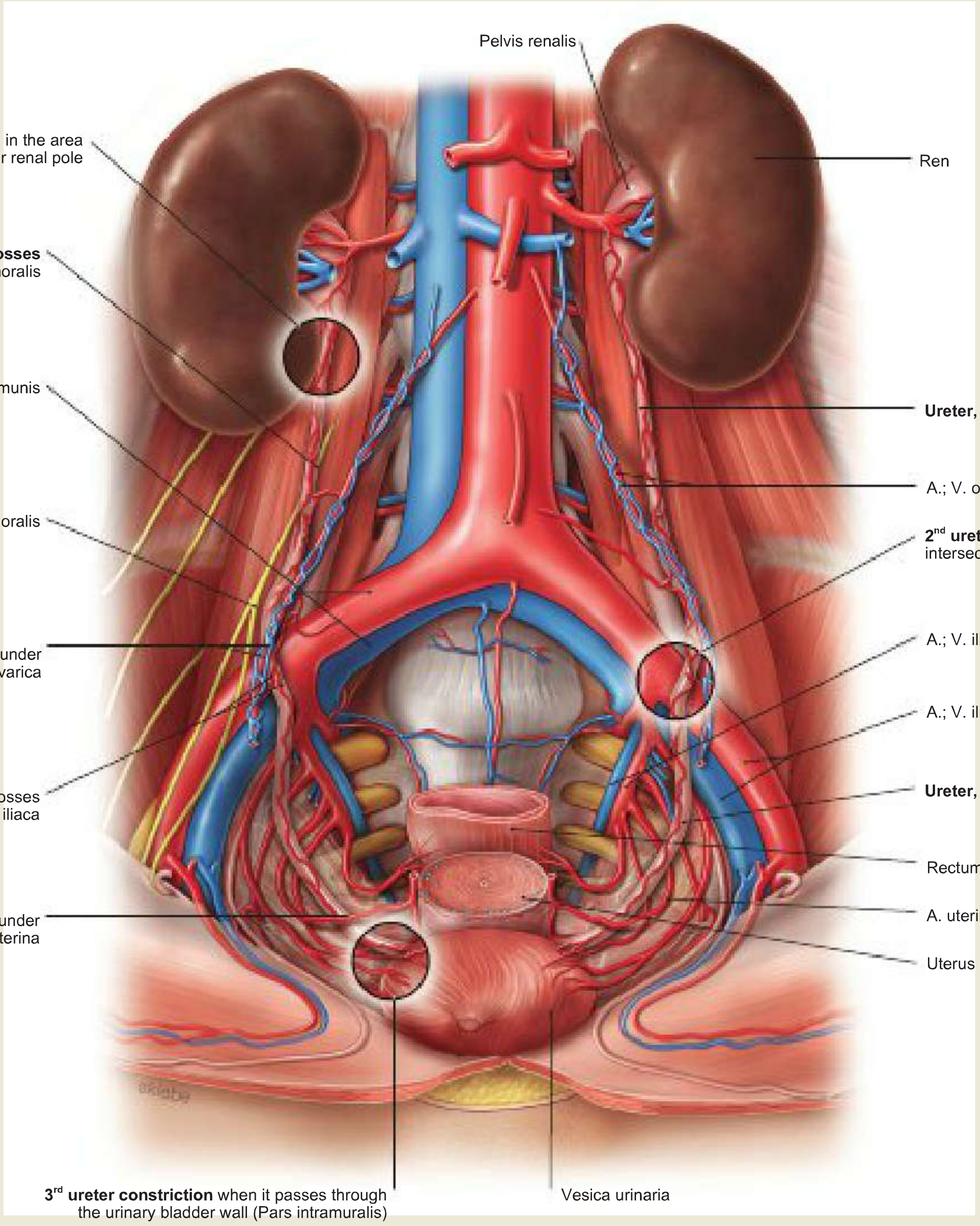


Fig. 7.45 Parts, constrictions and course of the ureter; ventral view. [L238]

From the renal pelvis the urine passes via the **ureter** into the **urinary bladder (Vesica urinaria).** After leaving the medulla of the kidney, the urine remains unchanged in its composition and in its volume. Transport through the ureter is carried out by peristaltic waves of smooth muscles in its wall. The ureter is divided into three parts and has three constrictions.

Parts:
- Pars abdominalis: in the retroperitoneal space
- Pars pelvica: in the lesser pelvis
- Pars intramuralis: traverses the wall of the urinary bladder

Constrictions:
- at the exit from the renal pelvis
- at the intersection of the A. iliaca communis or A. iliaca externa
- at the passage through the wall of the urinary bladder (narrowest part)

This passage through the wall of the urinary bladder is a physiologically important constriction because it prevents a reflux of urine from the bladder.

Course:

In its course, the ureter comes into contact with various structures. Its **Pars abdominalis** usually crosses over the genitofemoral nerve and crosses underneath the A./V. testicularis/ovarica. On the right side it is covered by the duodenum, the A. colica dextra and the mesenteric root (Radix mesenterii), and on the left side by the A./V. mesenterica inferior or the A. colica sinistra. At the transition to the **Pars pelvica** the ureter crosses over the A./V. iliaca communis. In the male it crosses in the lesser pelvis under the vas deferens (Ductus deferens) and in the female the A. uterina.

'Over-under' rule: the ureter firstly passes **over** the N. genitofemoralis, crossing **under** the A. and V. testicularis/ovarica, then crosses **over** the A. and V. iliaca, and in men crosses **under** the Ductus deferens and in women the A. uterina.

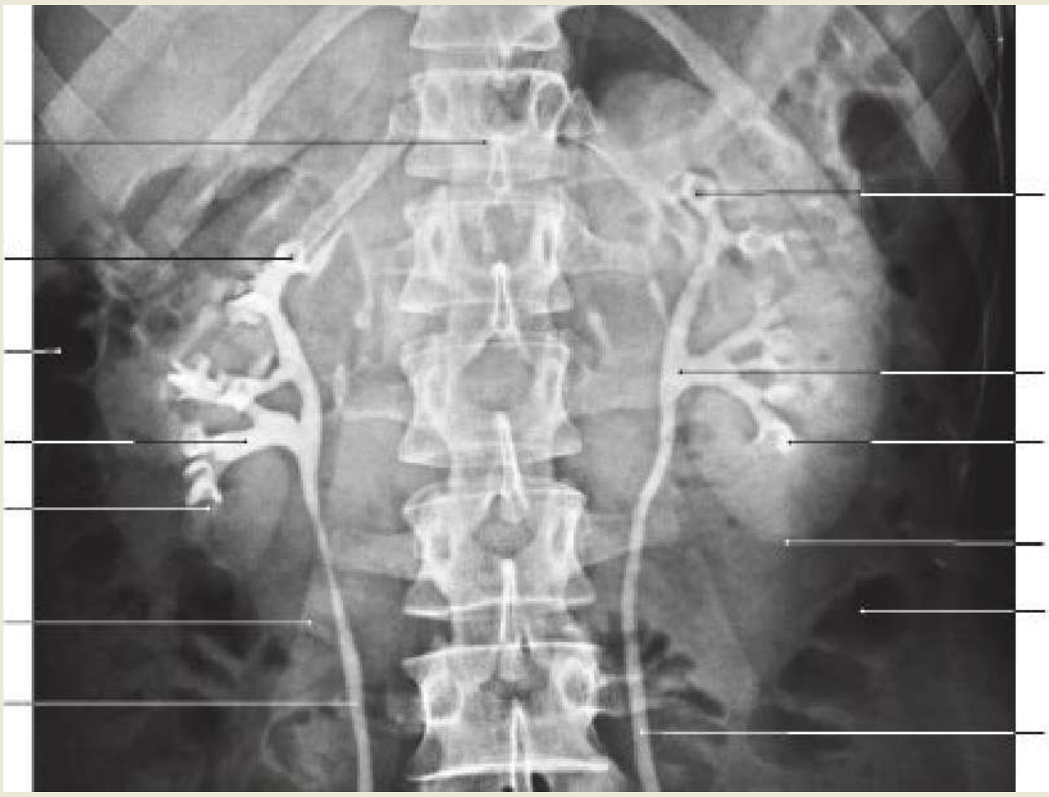


Fig. 7.46 Renal pelvis, Pelvis renalis, and ureter; X-ray in anteroposterior (AP) beam projection after retrograde injection of contrast medium via both ureters; ventral view.

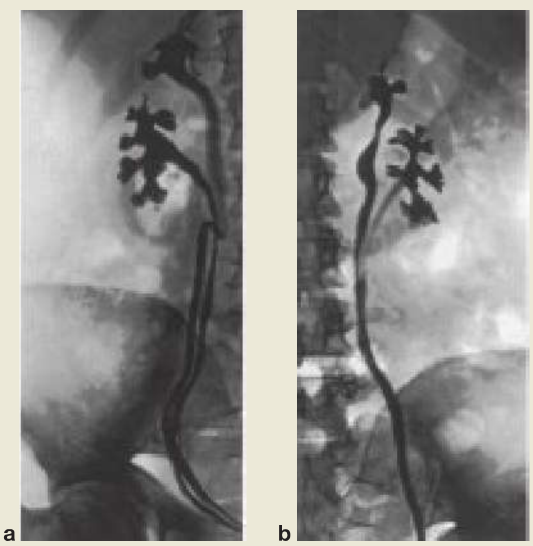


Fig. 7.47a and b Common variations of the ureter; X-rays in anteroposterior (AP) beam projection after retrograde injection of contrast medium; ventral view. [S002-7]
a Double ureter (ureter duplex)
b Split ureter (ureter fissus)
In both cases two renal pelvises are present.

Clinical Remarks

Eliminated **kidney stones** can remain stuck at the constrictions, and then cause very strong waves of pain (renal colic). The proximity of the ureter to the uterine artery has to be taken into account in the **removal of the uterus** (hysterectomy), so that the ureter is not ligated along with the artery. Urine retention would lead to irreversible damage to the kidney.
The **ureter fissus** is often an accidental finding and has no clinical relevance. Conversely, with **ureter duplex** this often results in incorrect openings in the area of the urinary bladder, which can lead to urine reflux or incontinence. Frequently, both ureters cross each other (MEYER-WEIGERT rule). As a rule, the ureter arising from the higher-positioned renal pelvis drains at a lower point into the urinary bladder or even further distally into the urethra, which can result in incontinence. Contrastingly, the ureter from the lower renal pelvis often has a much shorter intramural part within the wall of the urinary bladder, facilitating reflux of urine. Urinary reflux promotes ascending urinary tract infections potentially resulting in permanent damage to the kidney parenchyma.

Structure of the Urinary Bladder

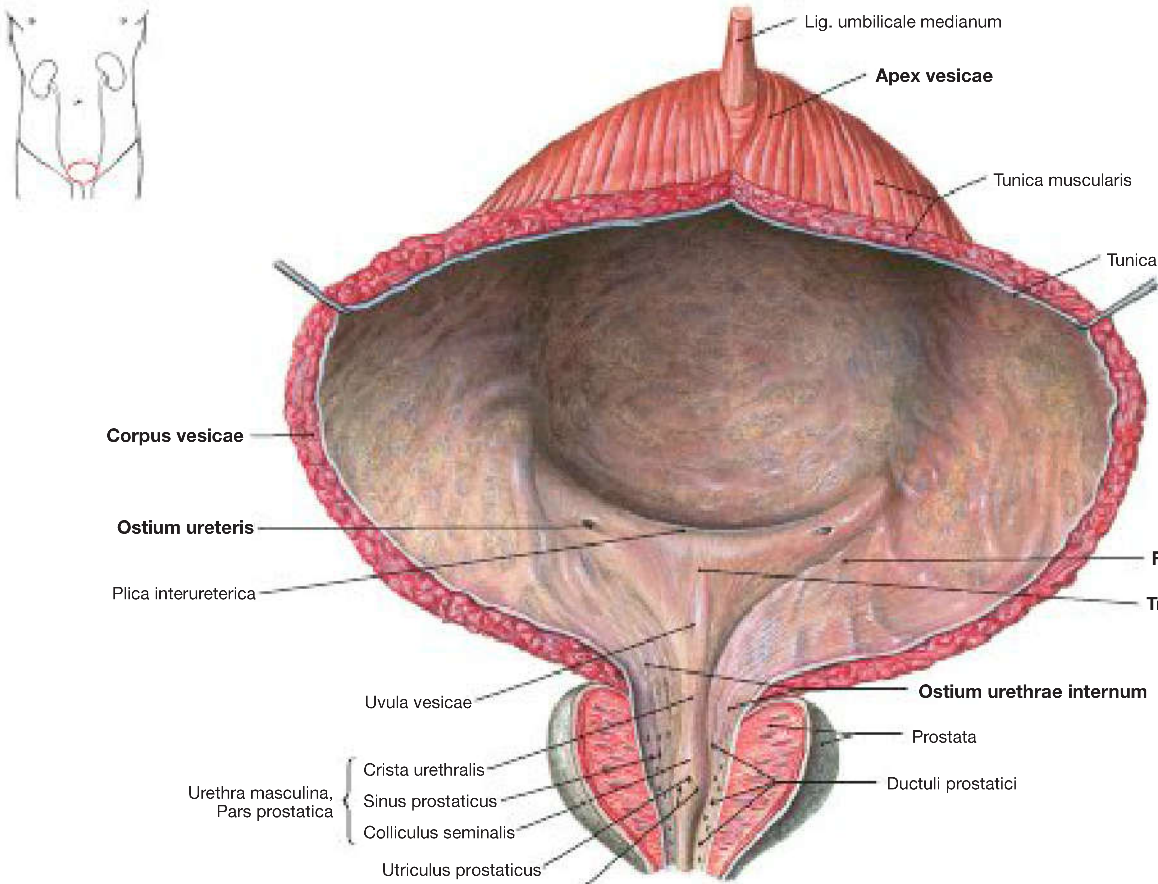
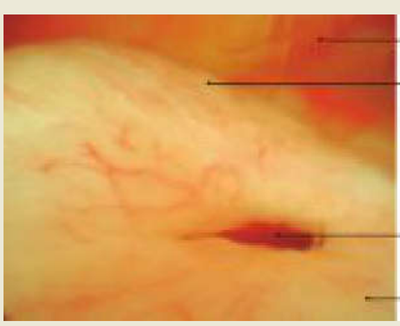


Fig. 7.48 Urinary bladder, Vesica urinaria, and opening into the male urethra; ventral view.

The bladder is positioned **subperitoneally** and is divided into a **body (Corpus vesicae),** which drains upwards to the **apex (Apex vesicae)** and has a **bladder fundus (Fundus vesicae)** at the bottom. At the base is the internal urethral orifice (Ostium urethrae internum) with the junction of the ureters located on both sides (Ostium ureteris) and the **trigone of the bladder (Trigonum vesicae).** The urinary bladder holds about 500–1500 ml of urine, although the urge to urinate starts when a volume of 250–500 ml is reached. The wall consists of the internal mucosal layer (Tunica mucosa) followed by three layers of smooth muscles with parasympathetic innervation **(Tunica muscularis = M. detrusor vesicae),** and the external Tunica adventitia or the cranial serous layer (peritoneum), respectively.

The bladder is surrounded by paravesical adipose tissue fixed by different **ligaments.** From the top, the **Lig. umbilicale medianum** (containing the Urachus = a remnant of the embryonic connection of the allantois) runs to the umbilicus. In women, the bilateral **Lig. pubovesicale** (→ Fig. 7.138), and in men the bilateral Lig. puboprostaticum (→ Fig. 7.137) ensures anchorage to the bony pelvis. In men, the prostate gland is directly under the fundus of the bladder and is traversed by the urethra.

a



b

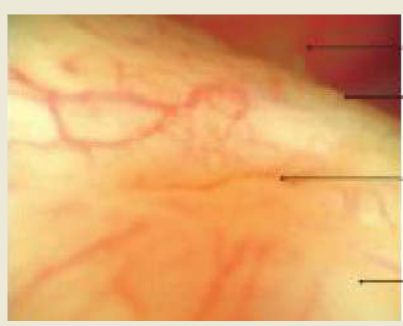


Fig. 7.49a and b Ureteric orifice, Ostium ureteris; cystoscopy. [T898]

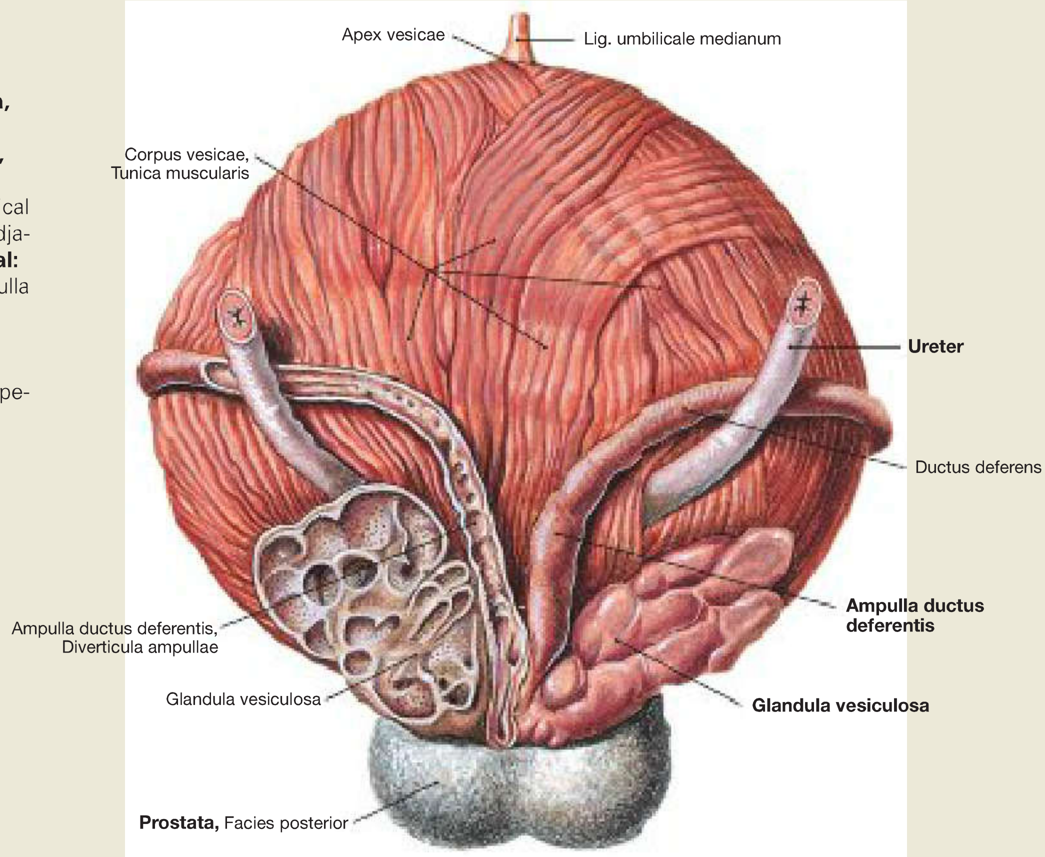
- **a** Ureteric orifice open, a peristaltic wave transports urine into the bladder
- **b** Ureteric orifice closed

The valve-shaped form of the ureter opening is crucial for avoiding urinary reflux, which due to ascending infections may endanger the kidney.

Fig. 7.50 Urinary bladder, Vesica urinaria, Vasa deferentes, Ductus deferentes, seminal vesicles, Glandulae vesiculosae, and prostate gland; dorsal view.

In men, the following paired anatomical structures are positioned posterior and adjacent to the bladder, from **medial to lateral:**
- dilated part of the vas deferens (Ampulla ductus deferentis)
- seminal vesicle (Glandula vesiculosa)
- ureter

The urinary bladder is positioned directly superior to the prostate gland.



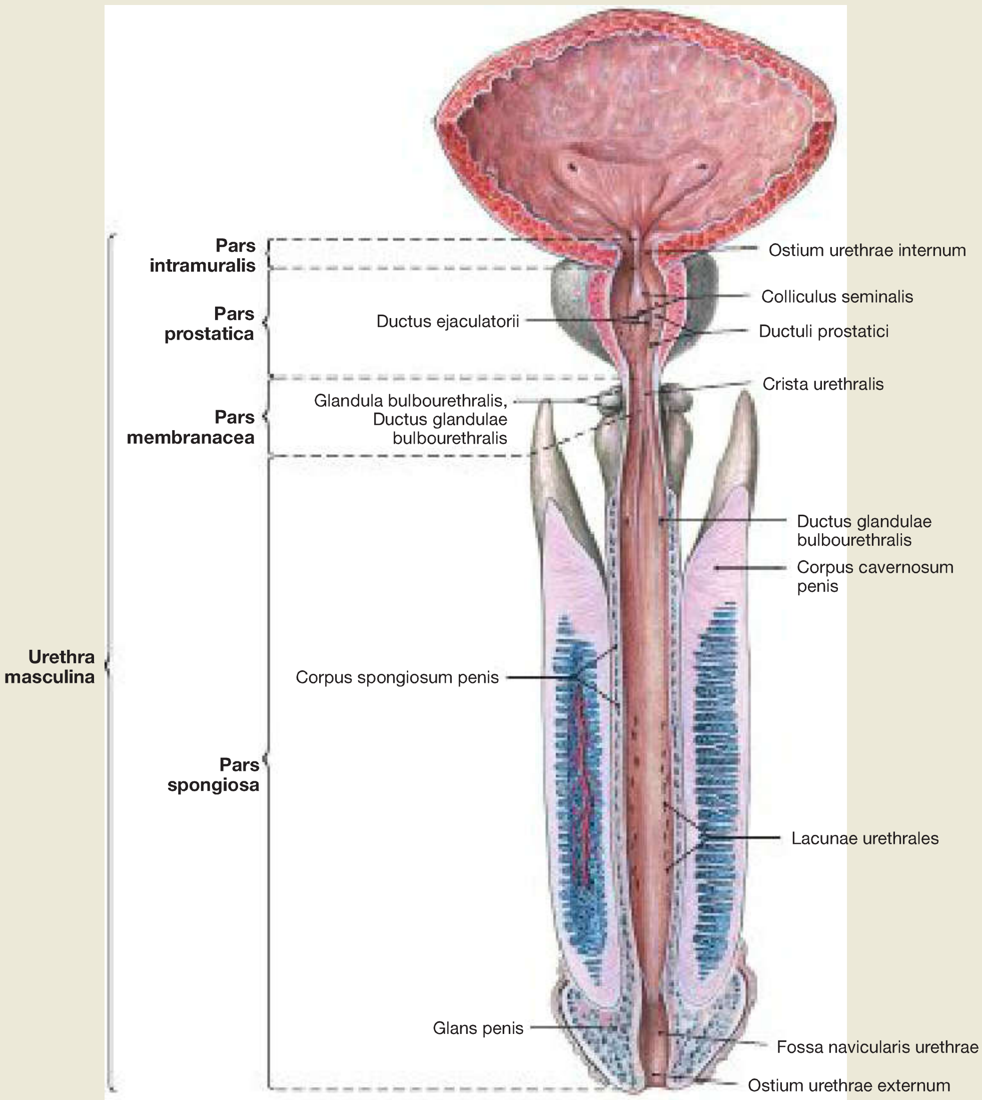


Fig. 7.51 Urinary bladder, Vesica urinaria, and male urethra, Urethra masculina; ventral view; urinary bladder and urethra opened ventrally.

Parts of the urethra:
- **Pars intramuralis** (1 cm): within the wall of the urinary bladder
- **Pars prostatica** (3.5 cm): crosses the prostate gland. Here, the Ductus ejaculatorii (common duct of vas deferens and seminal vesicle) flow into the Colliculus seminalis and on both sides of the prostate gland.
- **Pars membranacea** (1–2 cm): crosses the pelvic floor.
- **Pars spongiosa** (15 cm): runs in the Corpus spongiosum of the penis, continues to the external urethral orifice (Ostium urethrae externum). The COWPER's glands (Glandulae bulbourethrales) and LITTRÉ's glands (Glandulae urethrales), which are only visible under the microscope, drain here. The terminal part extends to the Fossa navicularis.

The urethra has the following **constrictions:**
- Ostium urethrae internum
- Pars membranacea
- Ostium urethrae externum

In comparison, the urethra is wide in the
- proximal Pars spongiosa ('Ampulla urethrae')
- Fossa navicularis

Urethra in Men

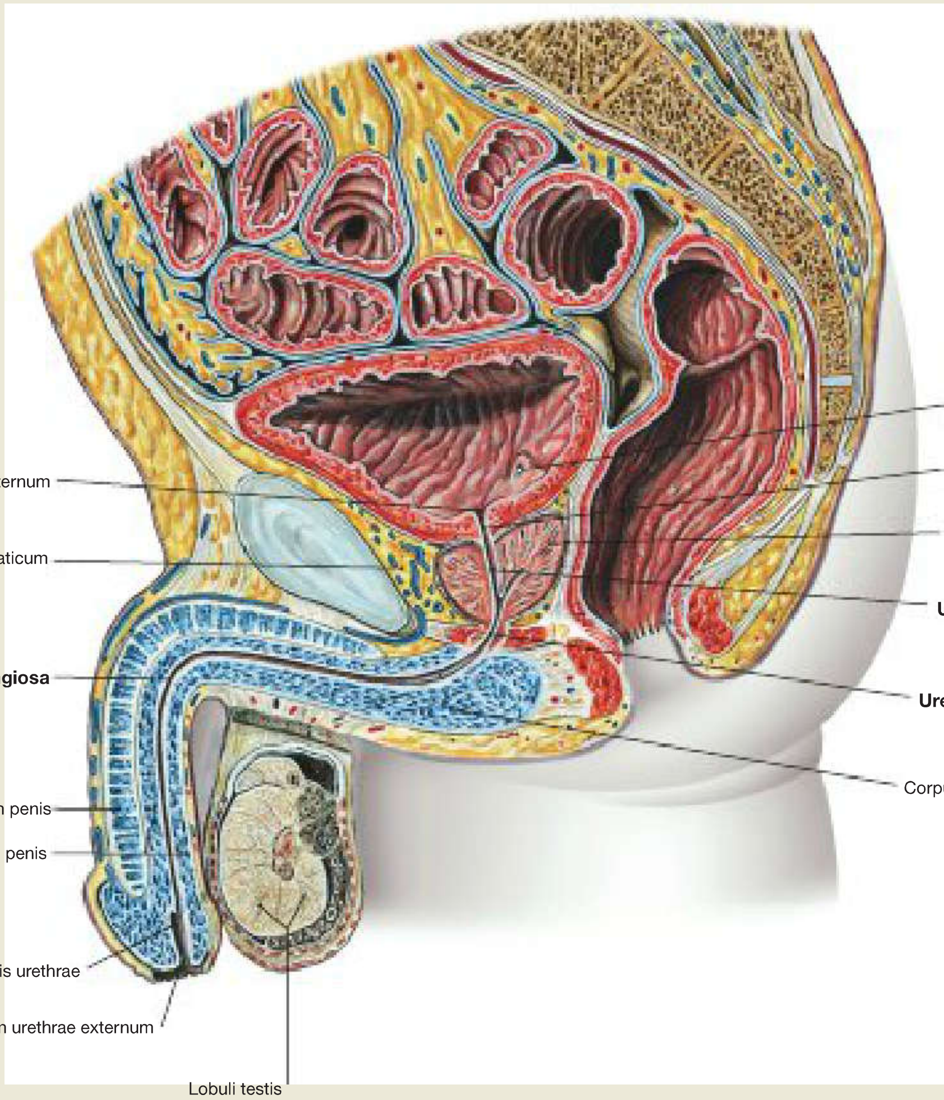


Fig. 7.52 Pelvis of a man; median section; view from the left side.
The illustration shows the course and the parts of the male urethra (Urethra masculina):
- **Pars intramuralis:** within the wall of the urinary bladder
- **Pars prostatica:** crosses the prostate gland
- **Pars membranacea:** penetrates the pelvic floor
- **Pars spongiosa:** embedded in the Corpus spongiosum of the penis, exits at the Glans penis

The urethra has two **bends:**
- at the transition of Pars membranacea and Pars spongiosa
- in the middle part of the Pars spongiosa

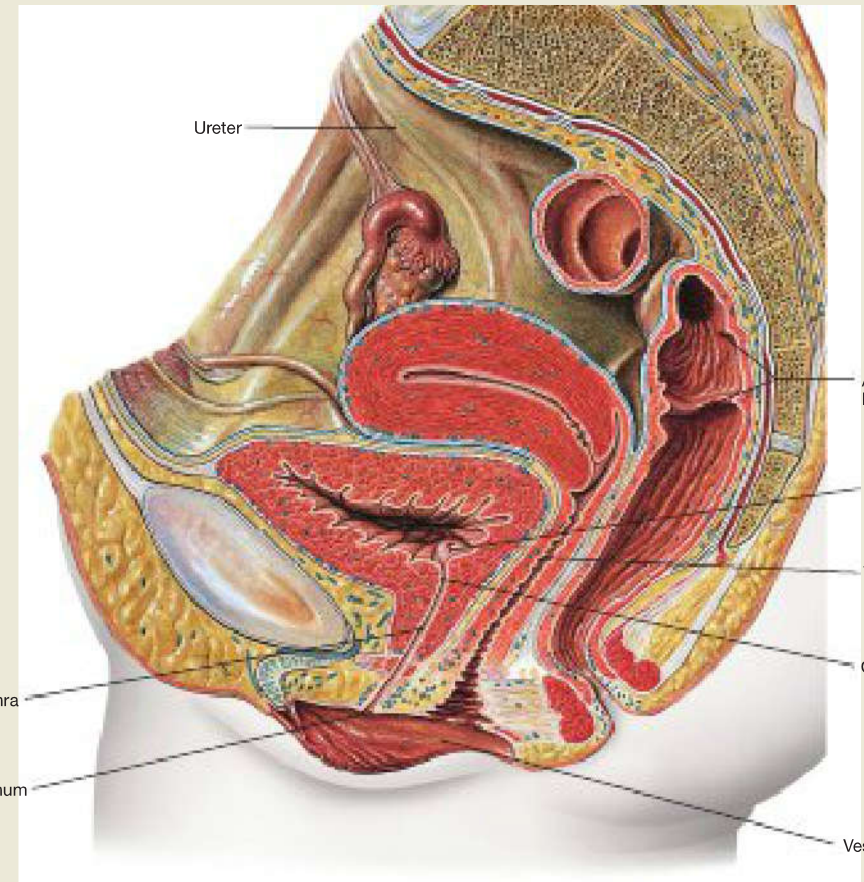


Fig. 7.53 Pelvis of a woman; median section; view from the left side.

The illustration shows the course and the external orifice of the female urethra. The female urethra is 3–5 cm long and enters directly in front of the vagina in the **vestibule of the vagina (Vestibulum vaginae).**

Clinical Remarks

Because of the shorter length of the female urethra, ascending infections of the urinary bladder (cystitis) are more common in women than in men.

Inserting a Catheter

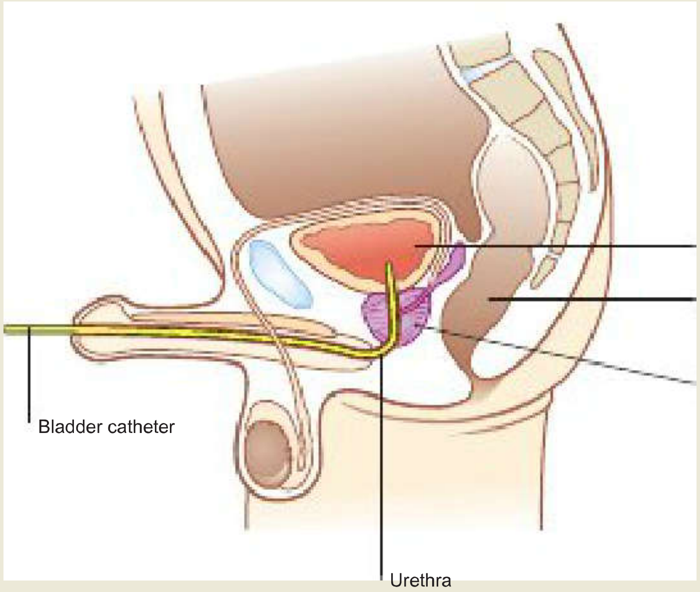


Fig. 7.54 Catheterisation of the urinary bladder in men; schematic illustration of a median section; view from the left side. [L126]

For the procedure of catheterising the urinary bladder, the parts and curvatures of the urethra are significant.

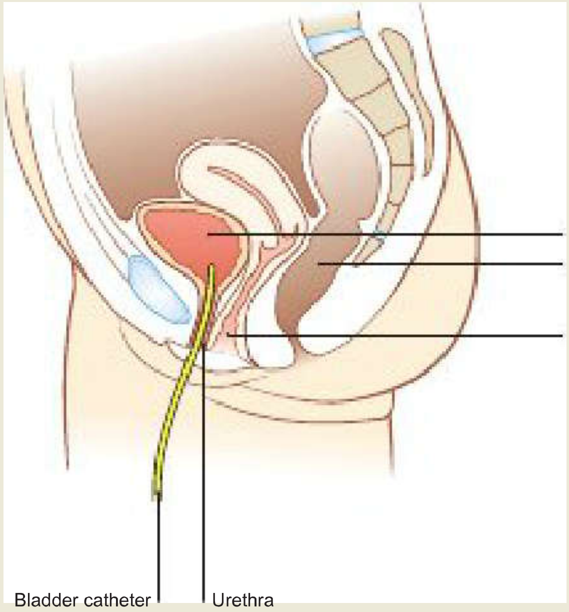
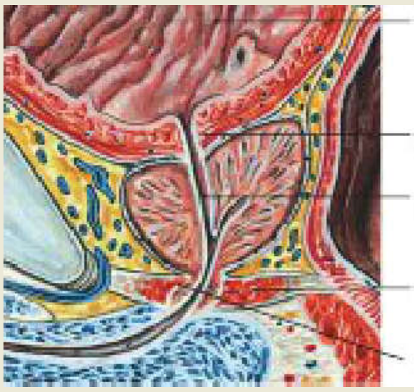


Fig. 7.55 Catheterisation of the urinary bladder in women; schematic illustration of a median section; view from the left side. [L126]

In the catheterisation of the urinary bladder in women, it is important that the external urethral orifice is ventral to the opening of the vagina.

Clinical Remarks

The inserting of a **bladder catheter** is one of the first procedures that you as a medical student in nursing or clinical internships can perform. In these situations it is very important to concentrate on working in a very sterile manner, and it is helpful if you have mastered the anatomical basics. Placing the bladder catheter in **men** is made more difficult by the length and the curvature of the urethra. The curvature of the urethra must therefore be compensated for by aligning the penis, to prevent perforations especially in the tissue of the prostate, which are painful and can lead to severe bleeding. First, the catheter is passed through the tip of the Glans penis into the urethra, where the penis of the supine patient is straightened (→ Fig. 7.54) to compensate for the curvature of the urethra in the Pars spongiosa. This allows the catheter to advance up to the second curvature at the transition to the Pars membranacea. Now you place the penis diagonally downwards between the legs, in order to avoid a perforation of the urethra in the Corpus spongiosum penis (→ Fig. 7.52). Then you can move the catheter forwards into the bladder, where you should be careful not to damage the surrounding prostate tissue in the Pars spongiosa, which can lead to scar constrictions.
Due to the elongated course of the relatively short female urethra, the placing of a bladder catheter is much easier in women. However, care must be taken that the vaginal vestibule (Vulva) is positioned **ventrally** to the opening of the vagina.



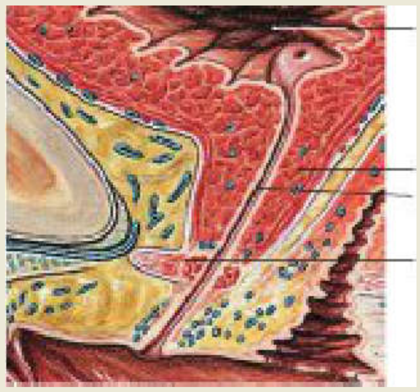


Fig. 7.56a and b Sphincter mechanisms of the urinary bladder, Vesica urinaria, and urethra in men (→ Fig. 7.56a) and in women (→ Fig. 7.56b); median section; view from the left side.

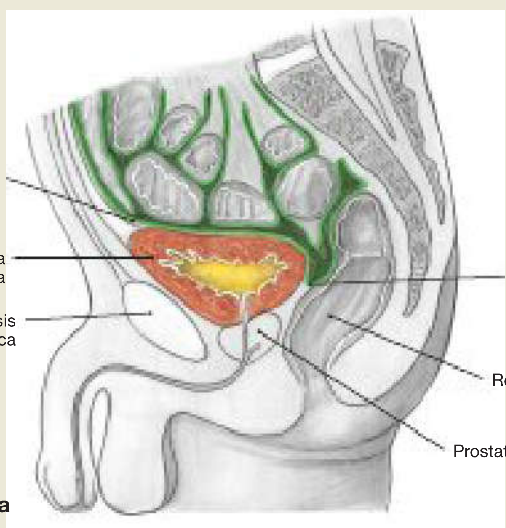
The sphincter mechanisms both involve contracting by smooth muscles in the wall of the urethra and by striated muscles of the perineal area:

- **smooth muscles** of the circular muscle layer of the **urethra** (M. sphincter urethrae internus): morphologically, a true sphincter muscle is not identified.
- **M. sphincter urethrae externus:** in men there is a separation of the M. transversus perinei profundus, in women there is no independent muscle.

In addition, the shape of the **pelvic floor (Diaphragma pelvis)** is crucial for continence because it supports the bladder.

When **passing water (micturition)** it contracts, activated by the sacral parasympathicus, the smooth muscles in the wall of the urinary bladder (M. detrusor vesicae). At the same time, the striated muscles of the pelvic floor relax allowing the bladder to descend, the sphincter muscles to relax, and urination to occur.

* smooth muscles of the urethra



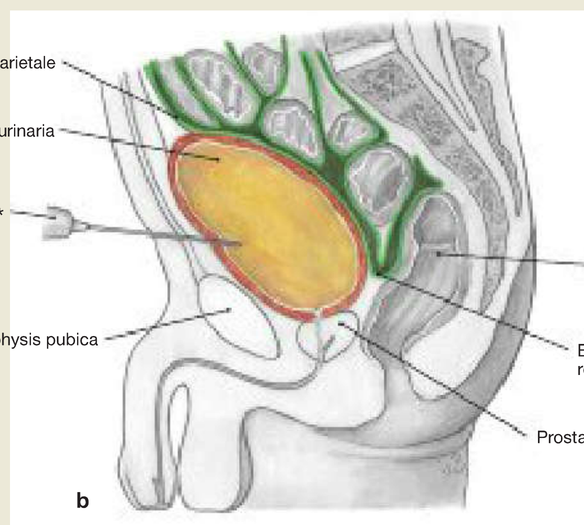


Fig. 7.57a and b Urinary bladder, Vesica urinaria, empty (→ Fig. 7.57a) and urine-filled (→ Fig. 7.57b); schematic median section; view from the left side.

The bladder is positioned subperitoneally and is covered on the upper side of the Peritoneum parietale. The empty bladder is positioned behind the pubic symphysis (Symphysis pubica). However, when filled it passes above the pubic bone and can be punctured without opening the peritoneal cavity **(suprapubic urinary catheter).**

* puncture needle

Projection of the Rectum and Anal Canal

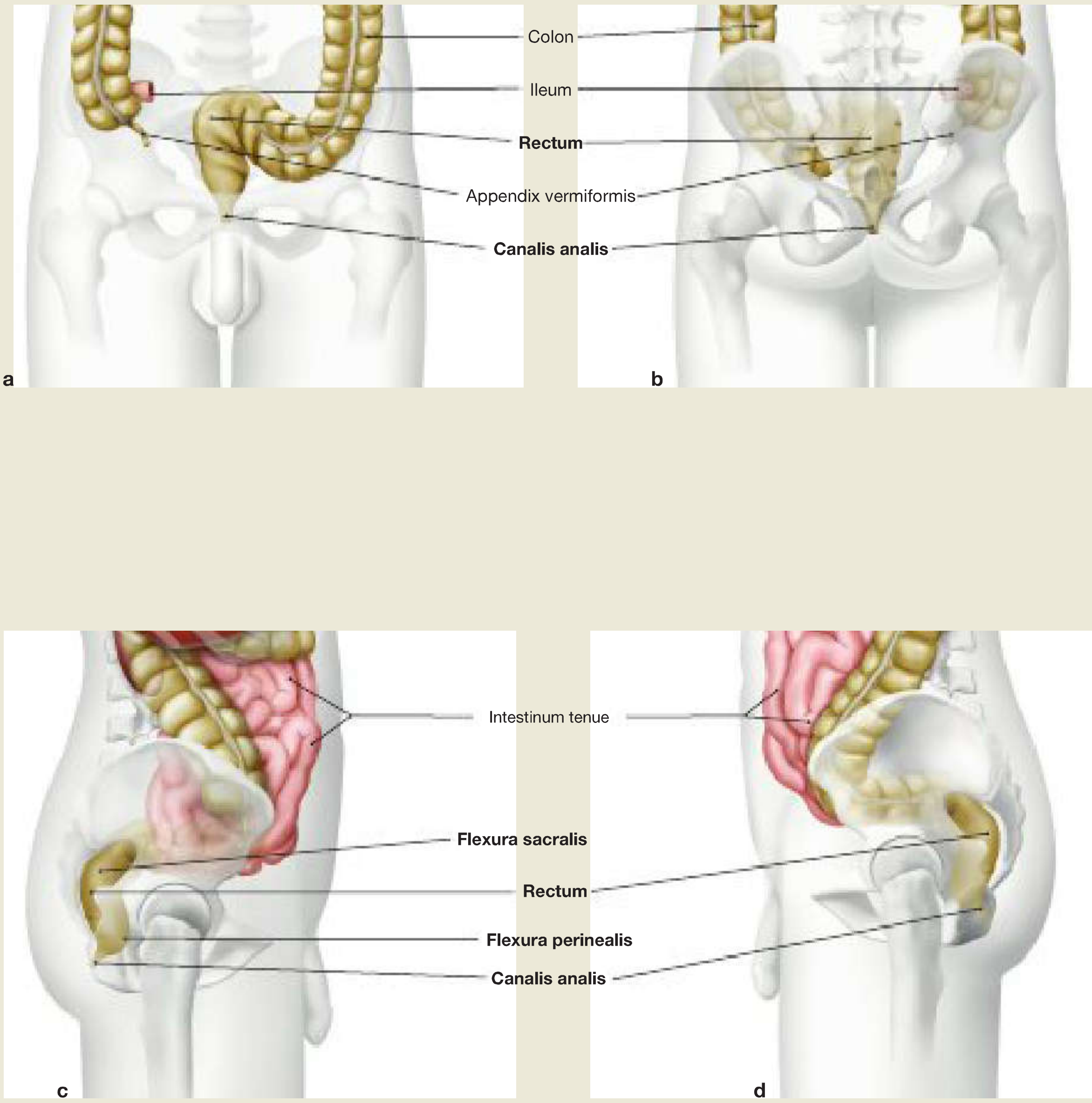


Fig. 7.58a to d Projection of the rectum, and the anal canal, Canalis analis, onto the body surface; ventral view (→ Fig. 7.58a), dorsal view (→ Fig. 7.58b) and lateral view (→ Fig. 7.58c and d). [L275]

The **rectum** and **anal canal (Canalis analis)** are the last two parts of the large intestine (Intestinum crassum). Since these two parts are situated in the lesser pelvis, there are specifities in the topographical relationships and neurovascular pathways, so that it is sensible to treat them separately as pelvic organs. The rectum begins at the level of the second to third sacral vertebrae and ends at the pelvic floor through which the anal canal passes. In the sagittal plane, the rectum has two bends: the dorsally convex **Flexura sacralis** and the ventrally convex **Flexura perinealis.** The upper part of the rectum up to the Flexura sacralis is in a **secondary retroperitoneal position,** and the distal part and the anal canal are located in the **subperitoneal space.**

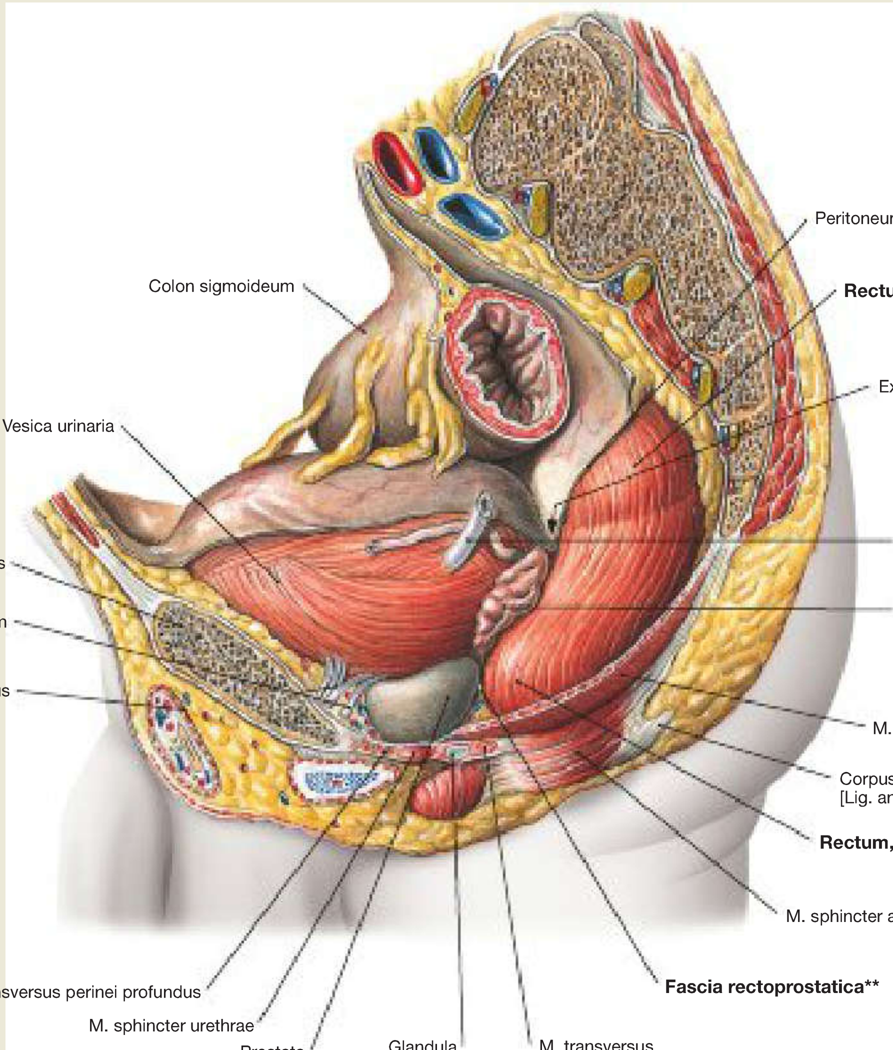


Fig. 7.59 Rectum and anal canal, Canalis analis, in the male pelvis; view from the left side.
The illustration shows the two bends of the rectum in the sagittal plane. In the upper secondary retroperitoneal portion, the rectum adjusts to the curvature of the sacrum and displays the **dorsally convex Flexura sacralis.** Then the rectum loses its covering of the parietal peritoneum and enters the subperitoneal space. Here it turns back, thus forming the **ventrally convex Flexura perinealis.** Passing through the pelvic floor, the rectum continues into the anal canal. In men, it adheres to the anterior aspect of the rectum, initially from the posterior wall of the urinary bladder (Vesica urinaria) and the seminal vesicles (Glandulae vesiculosae) and further caudally to the prostate gland. Here, the rectum is separated from the prostate gland only by the thin **Fascia rectoprostatica.** In women, the rectum is positioned in close relation to the posterior aspect of the vagina and is only separated from it by the Fascia rectovaginalis (→ Fig. 7.138).

* clinical term: COWPER's glands
** clinical term: DENONVILLIER's fascia

Clinical Remarks

Because the prostate gland is separated from the rectum only by the thin Fascia rectoprostatica (DENONVILLIER's fascia), the prostate gland can be assessed by **digital rectal examination (DRE)**. Due to the high incidence of benign prostatic hyperplasia (BPH) and prostatic carcinoma, the digital rectal examination is part of a complete physical examination in men over 50 years of age.

Position of the Rectum in the Mesorectum

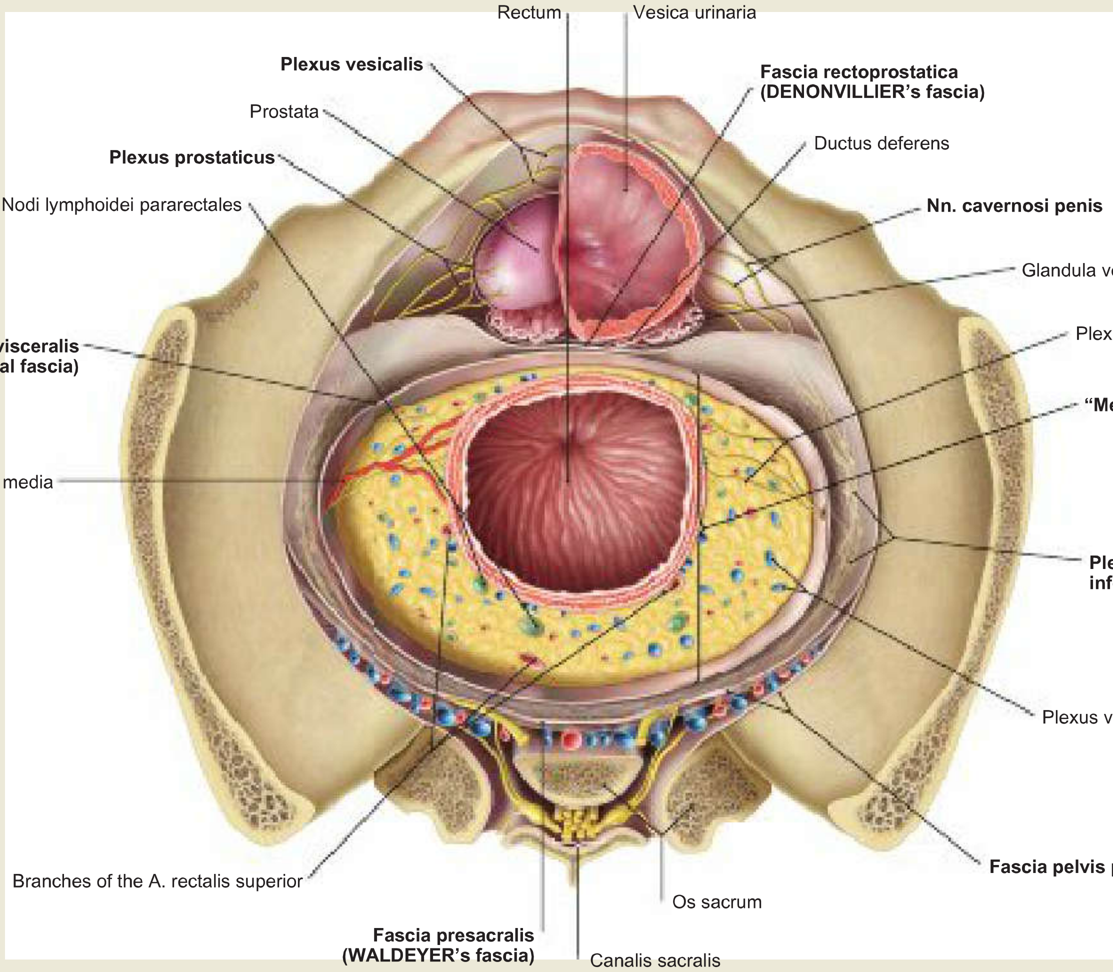


Fig. 7.60 Positional relationship of the rectum in the male pelvis; semi-schematic drawing; cranial view. [L238]

The lesser pelvis contains connective tissue consolidations at various points including **fascia.** They are of major clinical relevance, but unfortunately cannot be represented in conventional, formalin-fixed bodies. Therefore, their arrangement as shown in this illustration needs to be explained.

The bony pelvis is on the inside of a **parietal fascia (Fascia pelvis parietalis)**. Its dorsal part on the ventral surface of the sacrum is the **Fascia presacralis** (clinical term **WALDEYER's fascia).** In the pelvic cavity, each organ is covered by an **intestinal fascia (Fascia presacralis).** The intestinal fascia around the rectum is called the **mesorectal fascia** and surrounds the rectum together with adipose tissue and the neurovascular pathways in this area. The space enclosed by the mesorectal fascia is clinically called the **mesorectum.** This name is anatomically incorrect since the space is in the subperitoneum and is therefore positioned extraperitoneally, whereas 'mesos' describes peritoneal duplicatures within the peritoneal cavity. Lateral to the mesorectum, the **Plexus hypogastricus inferior,** which is responsible for the autonomic innervation of all the pelvic organs, extends. The neuronal plexus is enveloped by the connective tissue of the parietal fascia.

Embedded in the mesorectum, the rectum is ventrally in contact with the posterior wall of the urinary bladder (Vesica urinaria), which in men touches the seminal vesicles (Gll. vesiculosae). Caudally from here the rectum is only separated by a further thin **Fascia rectoprostatica** (clinical term **DENONVILLIER's fascia**) from the prostate gland.

Clinical Remarks

The mesorectum plays a role in coloproctological surgery, as the mesorectal fascia forms a structural border in operations for **carcinoma of the rectum.** It enables bloodless resection of the rectum and its regional lymph nodes **(total mesorectal excision, TME).** The Plexus hypogastricus inferior is outside the mesorectal fascia. It is required for urinary and faecal continence, and in men for erection and ejaculation; or in women for the function of the cavernous bodies and the BARTHOLIN's glands of the external genitalia; conversely it is not damaged, because it is integrated into the parietal fascia.

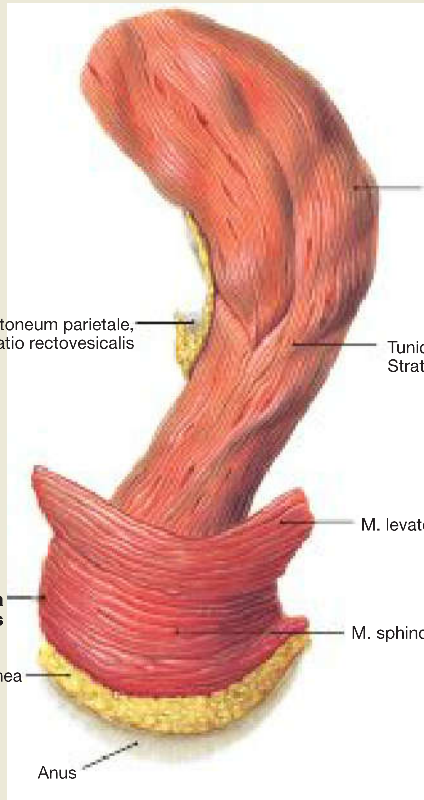


Fig. 7.61 Rectum; view from the left side.
The rectum cranially forms the dorsal convex **Flexura sacralis** and caudally passes through the M. levator ani of the pelvic floor, forming the ventrally convex **Flexura perinealis.**

Unlike the colon, the muscular layer (Tunica muscularis) of the rectum not only contains the circular layer (Stratum circulare) but also a continuous longitudinal layer (Stratum longitudinale).

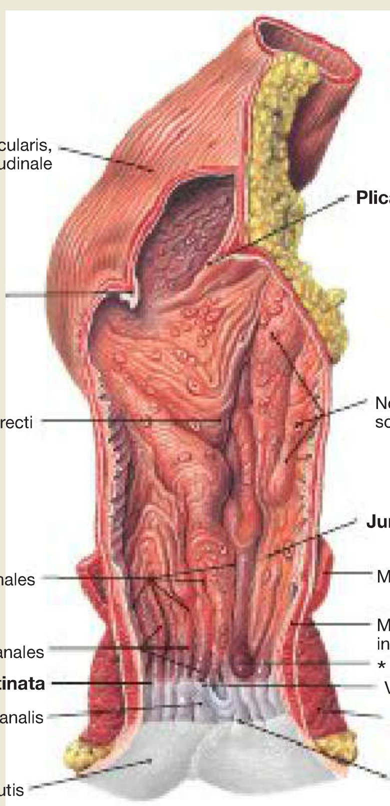


Fig. 7.62 Rectum and anal canal, Canalis analis; ventral view.
On the inner relief, the rectum has transverse folds, Plicae transversae recti. One of up to three folds is relatively reliably palpable at about 6–7 cm above the anus **(KOHLRAUSCH's fold).** Under this fold the rectum expands to the Ampulla recti. The Linea anorectalis forms the transition to the anal canal. It is caused by the transition from the transverse folds of the rectum to the longitudinal folds of the anal canal and is therefore actually less of a line than a transitional zone (Junctio anorectalis).
The **anal canal** itself is divided into **three segments:**

- **Zona columnaris:** contains longitudinal folds (Columnae anales) introduced by the Corpus cavernosum recti/ani
- **Zona alba:** as a result of multi-layered non-cornified squamous epithelium, the mucous membrane has an off-white colour; the upper limit of this transitional zone which is also referred to as the **Pecten analis** is marked by the **Linea pectinata** (clinical term: **Linea dentata**); its course is 'serrated', as the anal valves from the bottom meet here the whitish squamous epithelium running along the longitudinal folds from the top.
- **Zona cutanea:** external skin, which is bordered by the fuzzy Linea anocutanea

* haemorrhoidal nodes

Structure of the Anal Canal

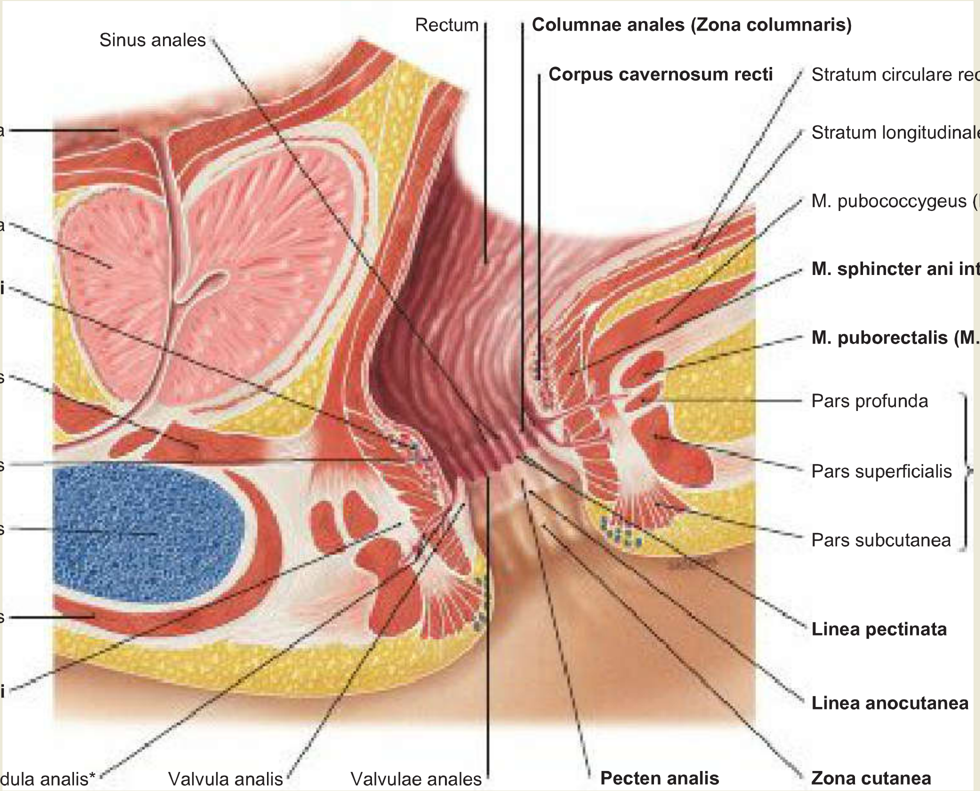


Fig. 7.63 Rectum and anal canal, Canalis analis, in men; median section; view from the left side. [L238]
The figure illustrates the parts of the anal canal and the structure of the continence organ. The anal canal is divided into **three segments** (→ Fig. 7.62).
The pectinate line **(Linea pectinata)** is the developmental border between the hindgut and the proctodeum and marks the border between the Zona columnaris and the Pecten analis in the adult. Similar to the left colic flexure, the pectinate line represents the watershed for several neurovascular structures and serves as clinically important landmark in the anal canal. Therefore, the pectinate line an important orientation line in the anal canal.
The anal canal possesses a **continence organ** controlled by the CNS which is composed of the anus, sphincter muscles and the Corpus cavernosum recti. Apart from defecation, the anus is closed by the permanent contractions of the internal anal sphincter muscles. The Corpus cavernosum is supplied by the A. rectalis superior and ensures a gas-tight closure.

The **sphincter muscles** include:
- **M. sphincter ani internus** (smooth muscle, involuntary sympathetic innervation): continuation of the circular muscular layer
- **M. corrugator ani** (smooth muscle): continuation of the longitudinal muscular layer
- **M. sphincter ani externus** (striated muscle, voluntary control via the N. pudendus): includes various parts (Partes subcutanea, superficialis and profunda)
- **M. puborectalis** (striated muscle, voluntary control via the N. pudendus and direct branches of the Plexus sacralis): part of the M. levator ani; forms a loop behind the rectum to pull it ventrally and creates the Flexura perinealis.

For lymphatic drainage → p. 151

* proctodeal glands

→ T 20

Clinical Remarks

Although the rectum has transverse folds (Plicae transversae recti), the anal canal has longitudinal folds (Columnae anales), allowing you to recognise with the naked eye, whether it is a **rectal** or an **anal prolapse,** if gut portions are bulging from the anus (prolapses). Both of these result in faecal incontinence. Due to the change of the supply areas of the neurovascular pathways, the pectinate line is an important orientation line in **operations for carcinomas of the anal canal.** Proximal tumours metastasise to the pelvic lymph nodes, distal carcinomas spread first to the inguinal lymph nodes. However, the classification currently depends on the distance of the tumours to the Linea anocutanea. Dilations of the Corpus cavernosum of the rectum are referred to as **haemorrhoids** (→ Fig. 7.69 and → Fig. 7.70). Behind the anal valves are the anal sinuses (Sinus anales) seen as depressions, from which the anal glands (Glandulae anales) arise. These can push through the sphincter muscles and in the case of an inflammation can lead to the formation of **fistulas,** which can spread into the ischioanal fossa.

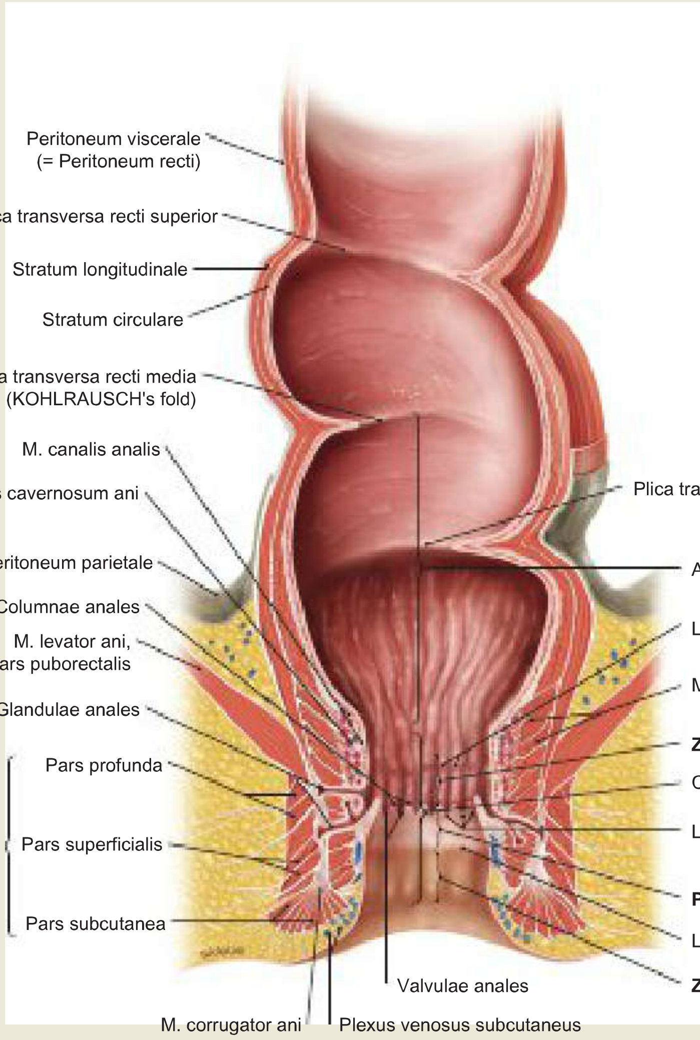


Fig. 7.64 Rectum and anal canal, Canalis analis, with continence organ; frontal section; ventral view. [L238]

The **continence organ** extends from the Ampulla recti down to the anus. With filling of the ampulla, via visceral-afferent and -efferent neurons in the Nn. splanchnici pelvici by short-term relaxation of the M. sphincter ani internus an **anal-rectal relaxation reflex** is triggered, and this leads to an increase in tone of all the sphincter muscles. The voluntarily innervated muscles allow conscious control of faecal continence:

- **M. puborectalis:** this part of the M. levator ani is found in a state of permanent contraction.
- **M. sphincter ani externus:** It has a regulatory function because it induces an increase in tone in the M. sphincter ani internus when the defecation needs to be arbitrarily prevented.

Additionally, there are involuntarily innervated muscles that enable closure of the continence organ without conscious control:

- **M. sphincter ani internus:** in the resting state it ensures 70% of the continence performance and is therefore the **centre of the continence organ.** Its fibres partially interlace the Corpus cavernosum recti and are anchored in the mucosa of the anal canal. Hence they are separately highlighted as the **M. canalis analis.**
- **M. corrugator ani:** the longitudinal muscle fibres insert in the perianal skin and pull this inwards.

All the sphincter muscles may not provide complete closure of the anus. Therefore, the **cavernous body of the rectum (Corpus cavernosum recti/ani)** is needed, and is located under the mucous membrane, and fed from the A. rectalis superior, it is providing a gas-tight closure (another 10% of the continence performance in the resting state). The cavernous bodies form, together with the interlacing muscle fibres of the M. canalis analis, an **angiomuscular closure apparatus.**

Arteries of the Rectum and Anal Canal

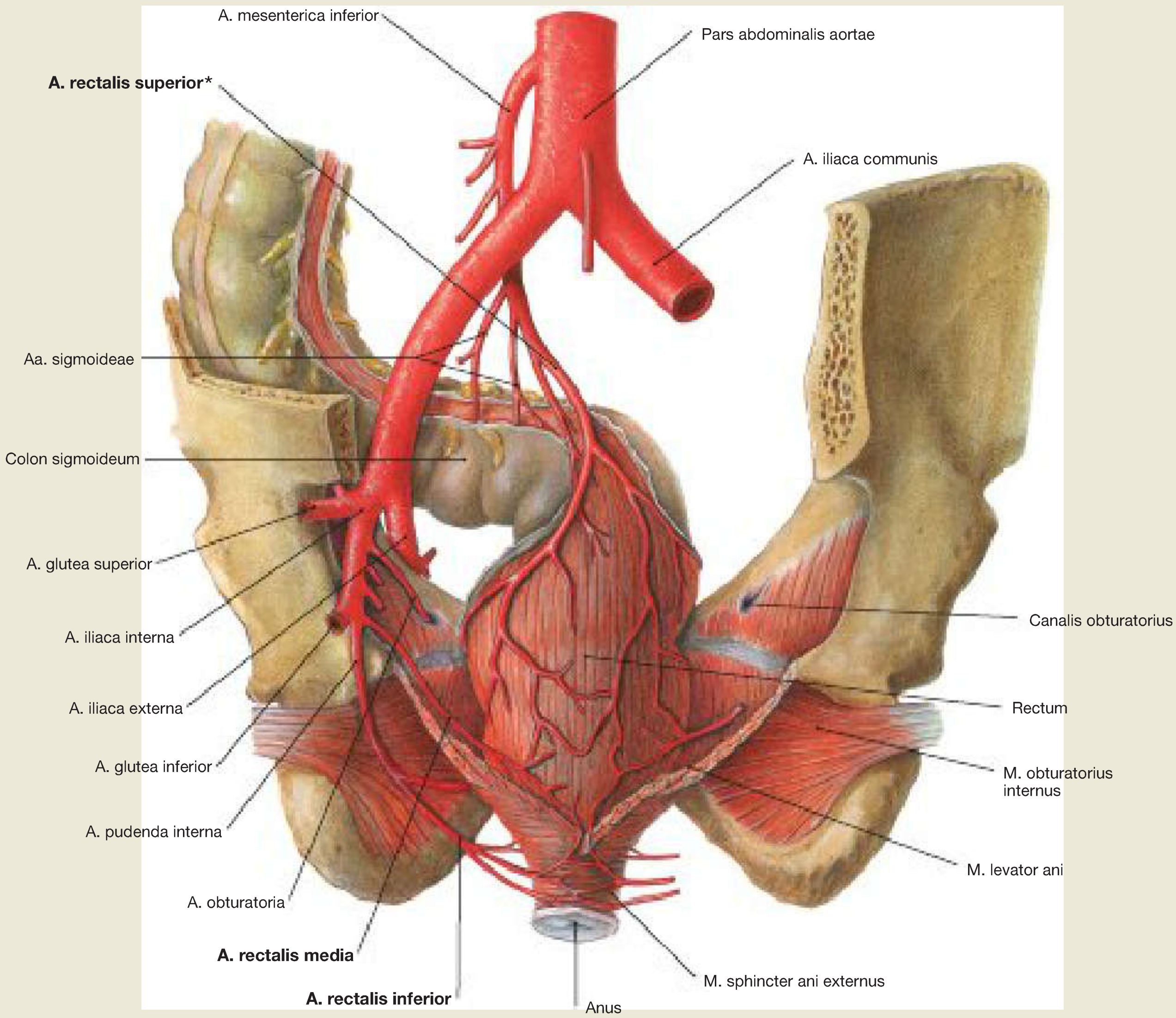
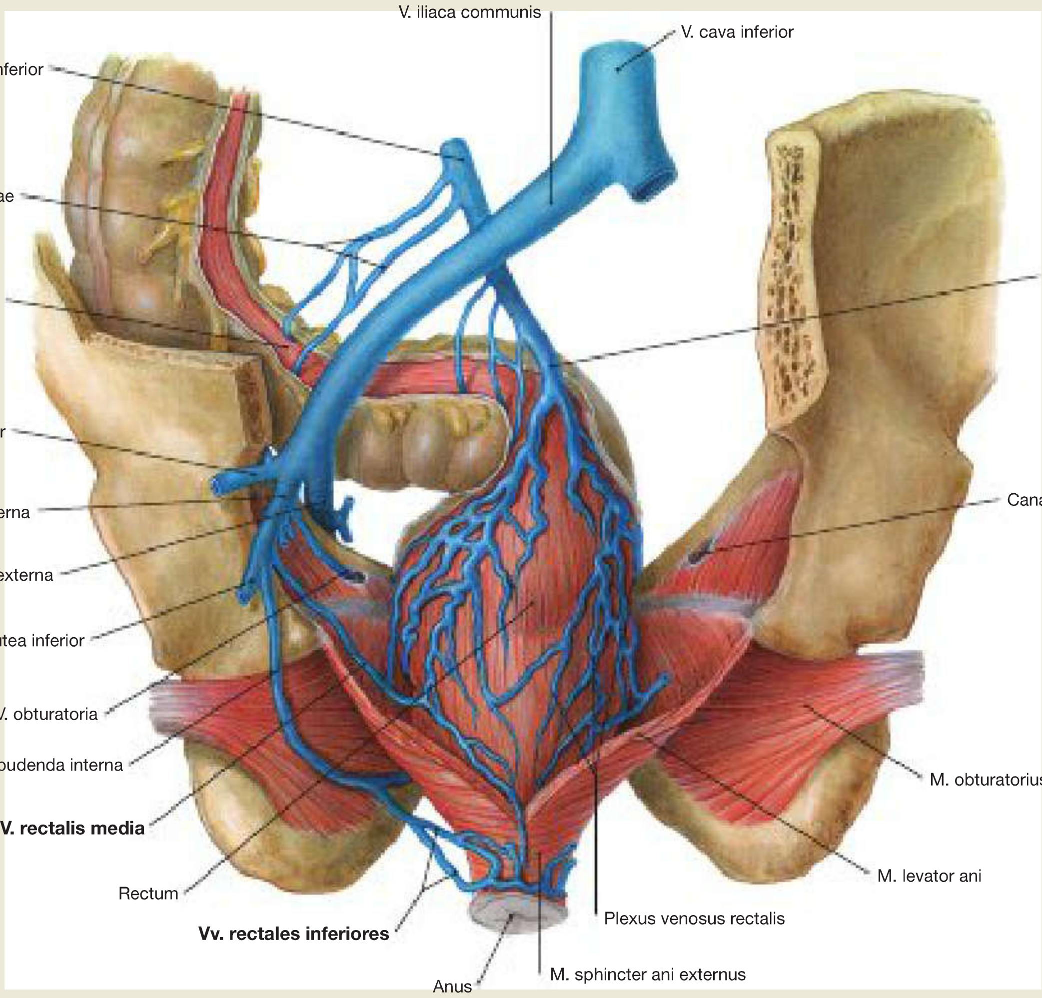


Fig. 7.65 Rectal arteries, Aa. rectales; dorsal view.
The rectum and anal canal are supplied by three arteries:

- **A. rectalis superior** (unpaired): from the A. mesenterica inferior. It supplies the major part of the rectum and the anal canal above the Linea pectinata, so it is vital for the filling of the **Corpus cavernosum recti/ani**.
- **A. rectalis media** (paired; mostly only on one side or completely missing): from the A. iliaca interna above the pelvic floor (M. levator ani). When present, it supplies only a small area of the lower rectum.
- **A. rectalis inferior** (paired): from the A. pudenda interna beneath the pelvic floor. The artery supplies the **sphincter muscles of the anal canal** from outside and the mucosa below the Linea pectinata.

The border between the corresponding arterial supply by the A. mesenterica inferior and the A. iliaca interna is located in the area of the **Linea pectinata,** where usually numerous anastomoses exist between the different arteries. The A. rectalis superior is the last branch of the A. mesenterica inferior and provides a branch for the anastomosis with the Aa. sigmoideae. From this position (clinical term: SUDECK's point [*]) it is a terminal artery. The Corpus cavernosum recti is fed by the A. rectalis superior. Therefore, bleeding from haemorrhoids, representing the dilated rectal cavernous bodies, is an arterial bleeding which can be identified by its bright red colour.



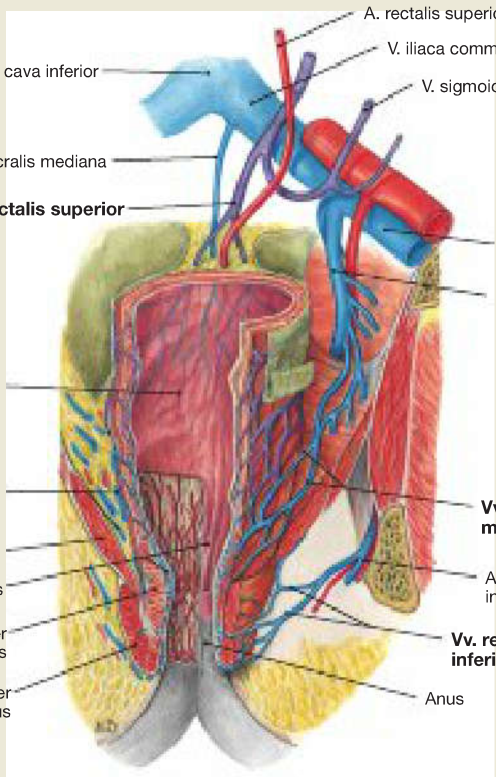


Fig. 7.66 Rectal veins, Vv. rectales; dorsal view.
Depending on the rectal arteries, the venous blood from the rectum and anal canal flows through three veins:

- **V. rectalis superior** (unpaired): connection via the V. mesenterica inferior to the portal vein (V. portae hepatis)
- **V. rectalis media** (paired): connection via the V. iliaca interna to the V. cava inferior
- **V. rectalis inferior** (paired): connection via the V. pudenda interna and the V. iliaca interna to the V. cava inferior

The watershed between the venous drainage of the V. portae hepatis and the V. cava inferior is located in the area of the Linea pectinata. However, there are numerous anastomoses.

Fig. 7.67 Venous drainage of the rectum and anal canal, Canalis analis; ventral view. Tributaries to the V. portae hepatis (purple) and to the V. cava inferior (blue).
This illustration demonstrates that the venous drainage pathways to the portal vein and to the inferior vena cava have formed numerous anastomoses. In the case of an increase in blood pressure in the portal system **(portal hypertension),** e.g. in cirrhosis of the liver, the blood can travel via these connections **(portocaval anastomoses)** to the V. cava inferior. Haemorrhoids do not arise. Therefore, these anastomoses are not clinically significant.

Innervation of the Rectum and Anal Canal

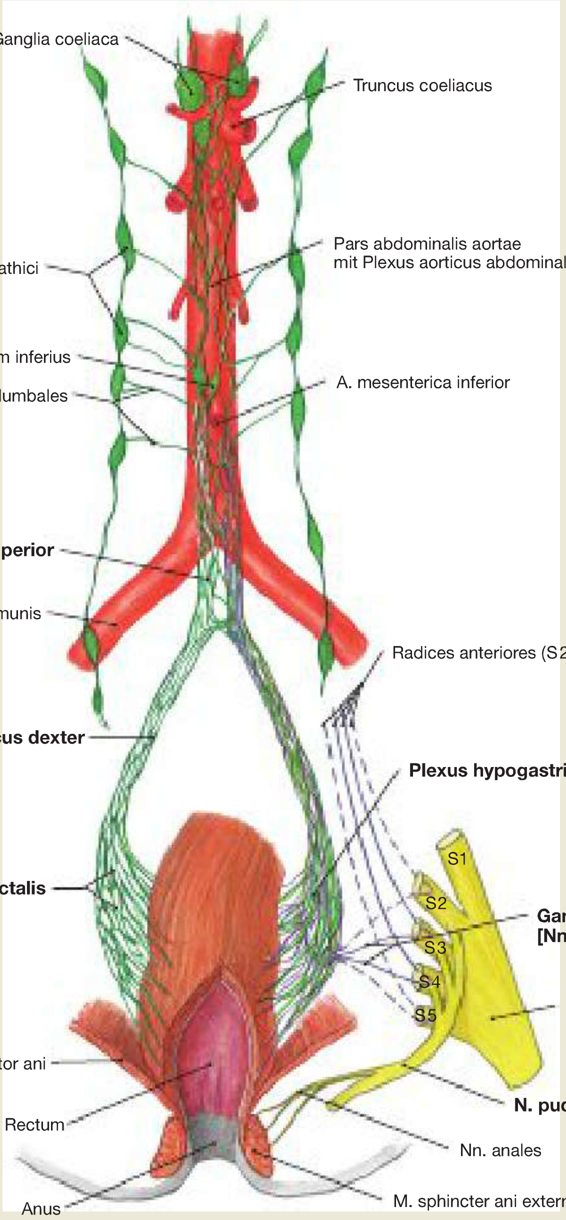


Fig. 7.68 Innervation of the rectum and anal canal, Canalis analis; ventral view; schematic drawing. The Plexus rectalis contains sympathetic (green) and parasympathetic (purple) nerve fibres.
The Plexus rectalis is a continuation of the Plexus hypogastricus inferior. The preganglionic **sympathetic nerve fibres** (T10–L3) descend from the Plexus aorticus abdominalis via the Plexus hypogastricus superior and from the sacral ganglia of the sympathetic trunk (Truncus sympathicus) via the Nn. splanchnici sacrales to be synapsed to postganglionic neurons in the ganglia of the **Plexus hypogastricus inferior.** As **Plexus rectalis** this serves the rectum and the anal canal. The sympathetic fibres activate the sphincter muscles.
The preganglionic **parasympathetic nerve fibres** pass from the sacral parasympathetic nervous system (S2–S4) through the **Nn. splanchnici pelvici** into the ganglia of the **Plexus hypogastricus inferior.** They are switched either here or in the vicinity of the intestine to postganglionic fibres, which promote peristalsis and inhibit the sphincter muscles (M. sphincter ani internus) to facilitate defecation.
The autonomic innervation ends approximately in the area of the Linea pectinata. The inferior portion of the anal canal is somatically innervated by the **N. pudendus** with sensory fibres. Thus, anal carcinomas inferior to the Linea pectinata are extremely painful, whereas carcinomas located above the demarcation line are not.
In addition, the N. pudendus activates with motor nerve fibres the M. sphincter ani externus and M. puborectalis, and allows voluntary closure of the anus.

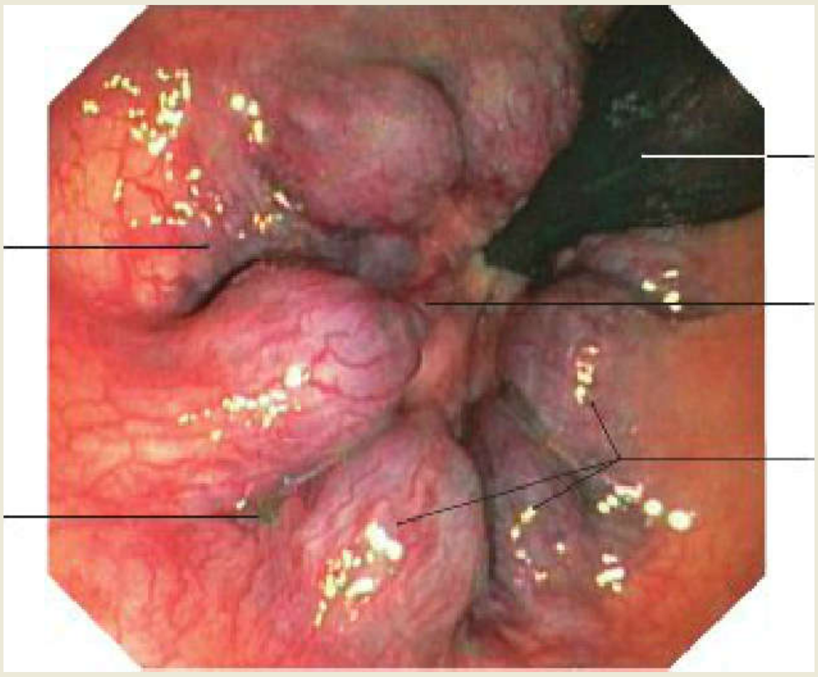


Fig. 7.69 Anal canal, Canalis analis; colonoscopy; cranial view. [T901]
You can see six considerably larger nodes of the Corpus cavernosum recti (haemorrhoids).

* colonoscope
** three haemorrhoidal nodes

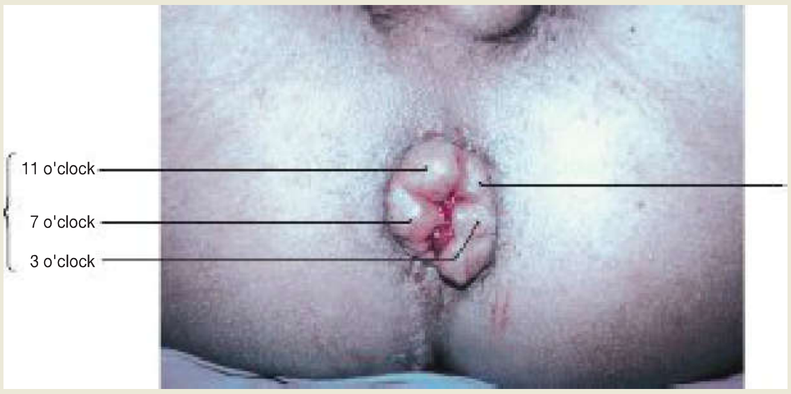


Fig. 7.70 Haemorrhoids stage IV; caudal view in the lithotomy position, when the patient is in a supine position and the examining person can see the perineum. [O892, M526]
The location of each haemorrhoidal node is indicated using the hands of a watch. Due to the branching pattern of the main branches of the A. rectalis superior on entering the Corpus cavernosum recti, the major nodes are typically at 3, 7 and 11 o'clock. In addition, corresponding 'accessory nodes' may derive from the smaller arterial branches. Here an 'accessory node' is shown at 1 o'clock.

Clinical Remarks

Haemorrhoids are abnormal enlargements of the Corpus cavernosum recti and are common. The causes are unclear, but appear to be associated with nutritional habits in industrialised nations (too much fat, too little dietary fibre). Haemorrhoids occur in different **stages:**
- Stage I: only visible endoscopically
- Stage II: protrude during bearing down for defecation; afterwards retract into the anal canal.
- Stage III: protrude spontaneously, but can be repositioned manually.
- Stage IV: cannot be repositioned.

From stage II onwards they should be treated: either by sclerotherapy or rubber band ligation (stage II), or by surgical removal (stages III and IV).

External Male Genitalia

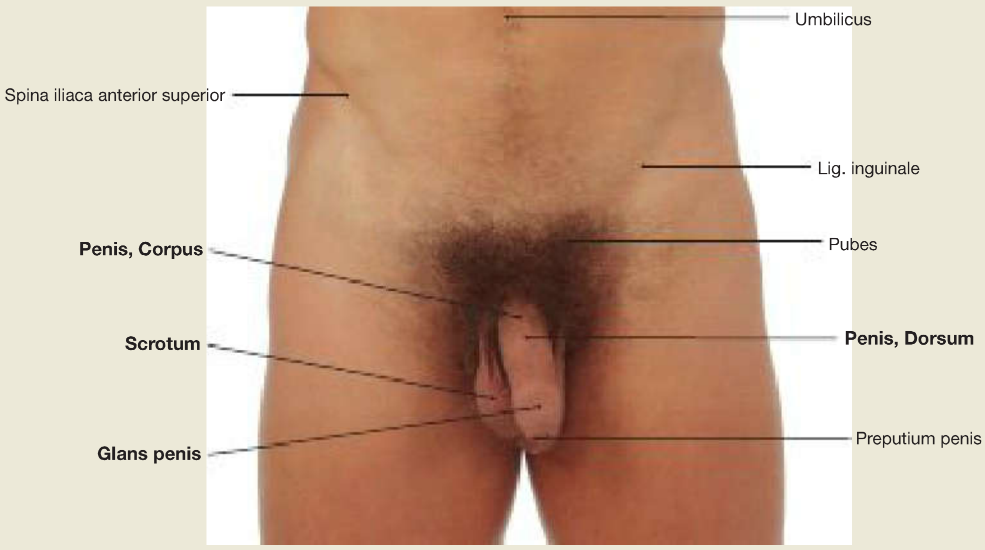


Fig. 7.71 External male genitalia, Organa genitalia masculina externa; ventral view.

In the male genitalia it is important to distinguish between the external genitalia (Organa genitalia masculina externa) and the internal genitalia (Organa genitalia masculina interna → Fig. 7.79).

The **external genitalia** include:

- Penis
- Urethra masculina
- Scrotum

The external genitalia are the **sexual organs.** The penis is used for sexual intercourse.

The urethra is described along with the efferent urinary system (→ Fig. 7.50 to → Fig. 7.57).

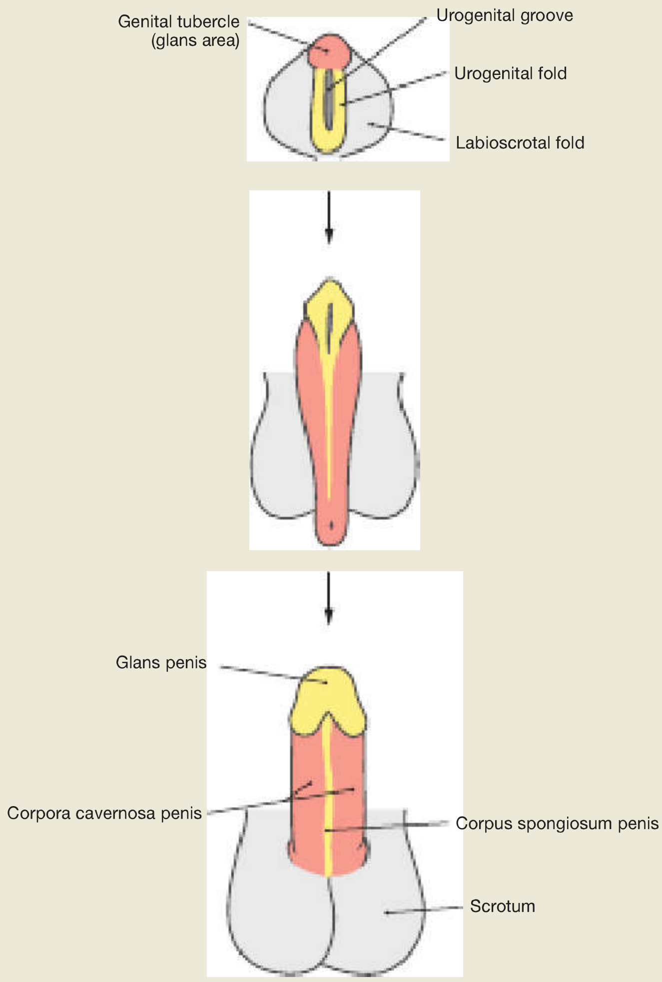


Fig. 7.72 Development of the external male genitalia, Organa genitalia masculina externa. [L126]
The external genitalia develop from the caudal part of the Sinus urogenitalis. The Sinus urogenitalis develops from the cloaca of the hindgut and gives rise amongst other things to the urinary bladder and parts of the urethra (→ Fig. 7.22). Alongside there is also the ectoderm with the connective tissue (mesenchyme) beneath. Firstly, the external genitalia develop identically in both sexes (indifferent gonad). The anterior wall of the Sinus urogenitalis indents to form the **urethral groove** which is bordered on both sides by the **urethral folds.** Lateral of these are the **labioscrotal folds** and anterior to the groove is the **genital tubercle.**

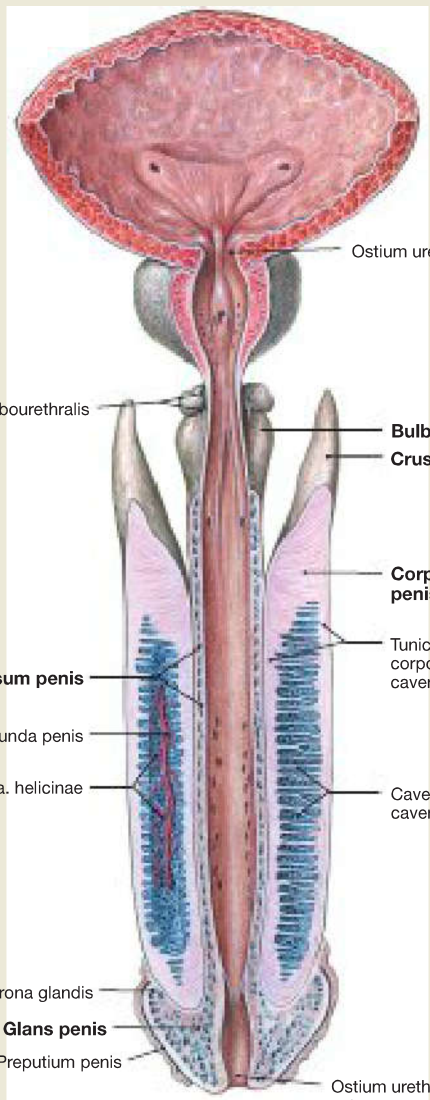
Subsequently, in men the **genital tubercle** develops into the **penis shaft** (Corpora cavernosa) due to the influence of the male sex hormone testosterone which is produced in the testes. The **genital folds** merge above the urethral groove to form the Corpus spongiosum and the **Glans penis.** This creates the Pars spongiosa of the **urethra.** The Pars prostatica and the Pars membranacea derive proximally from the Sinus urogenitalis. The **labioscrotal folds** enlarge and unite to become the **scrotum.**

Clinical Remarks

If incomplete fusions of the urethral folds occur, the opening of the urethra is not located at the tip of the Glans penis but further down proximally. In **hypospadias,** the urethra exits at the inferior side of the penis between the scrotum and the glans.

In **epispadias,** the urethra opens into a ridge at the dorsal side of the penis. In addition to problems with urination, this condition may involve a distortion of the penile body requiring surgical correction within the first years of life.

Penis



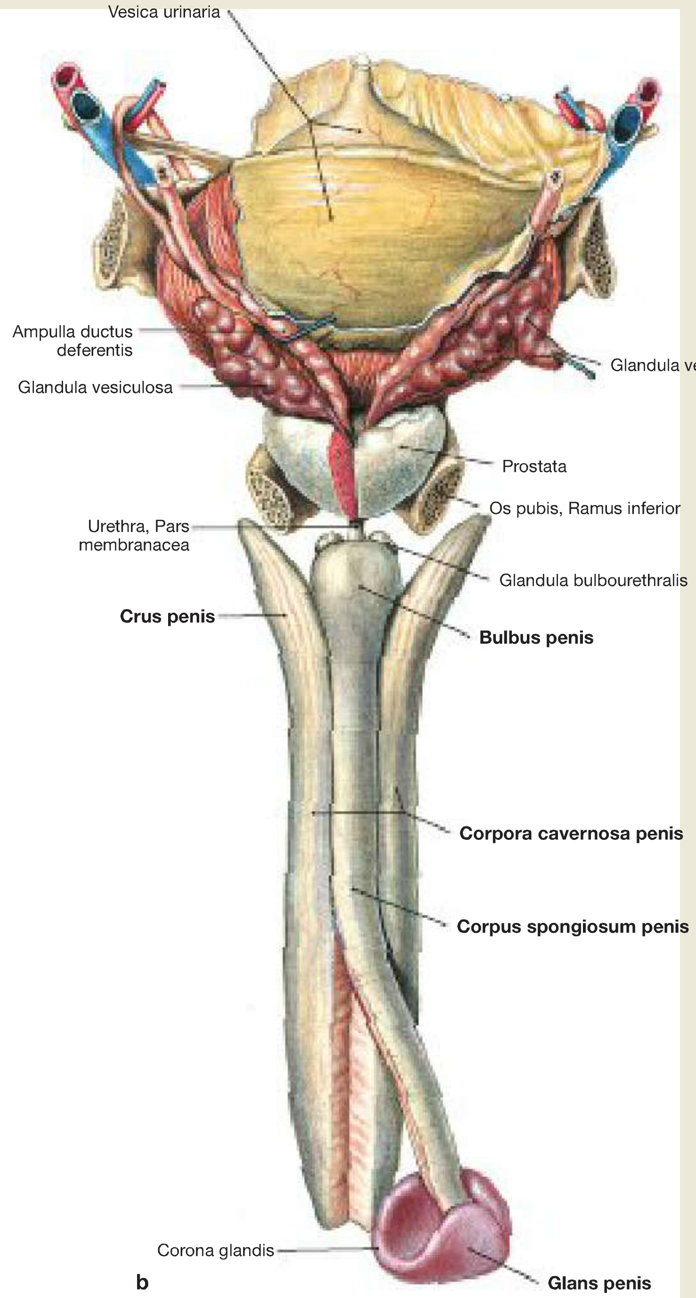


Fig. 7.73a and b Urinary bladder, Vesica urinaria, prostate gland, Prostata, and penis, with exposed spongy tissue; ventral view, urinary bladder and urethra opened (→ Fig. 7.73a) and dorsal view (→ Fig. 7.73b).
In a flaccid state, the penis is usually about 10 cm long and divided into the **Corpus penis, Glans penis** and a base or root **(Radix penis).** It consists of the paired **Corpora cavernosa** of the penis which are enclosed in a dense fibrous covering **(Tunica albuginea)** and separated by a septum penis, and of the **Corpus spongiosum** which surrounds the urethra. The proximal parts (Crura penis) of the Corpora cavernosa are fixed to the inferior pubic rami. The Corpus spongiosum is enlarged proximally to the Bulbus penis and distally forms the Glans penis. All cavernous bodies together are ensheathed by the **fascia of the penis (Fascia penis),** which was removed in this illustration.
Structure of the male urethra (Urethra masculina): → Fig. 7.51 and → Fig. 7.52.

Clinical Remarks

If the prepuce is too tight **(phimosis)** and cannot be pulled back, there may be problems with urination and infections. Then the prepuce must be removed by circumcision.

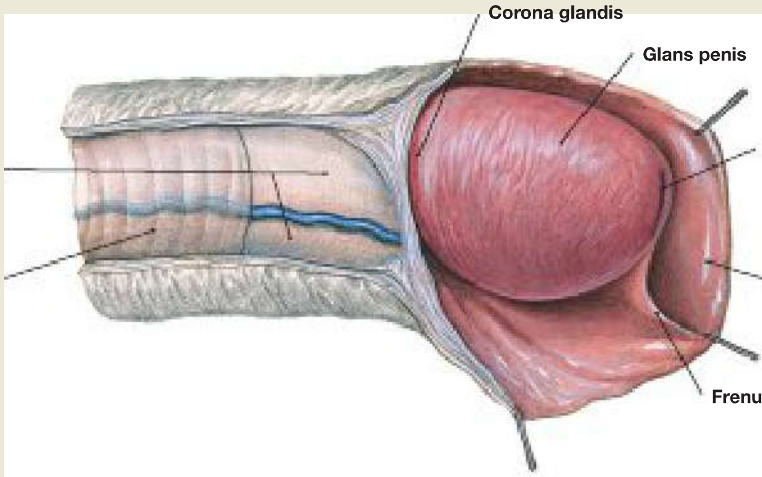


Fig. 7.74 Penis, with glans, Glans penis, and prepuce, Preputium penis; view from the right side.
The distal end of the penis is enlarged to form the **Glans penis** and shows a ridge (Corona glandis) at its base. In the flaccid state of the penis the glans is covered by the **prepuce (Preputium penis)**, which is attached at the bottom by a ribbon-like frenulum (Frenulum preputii).

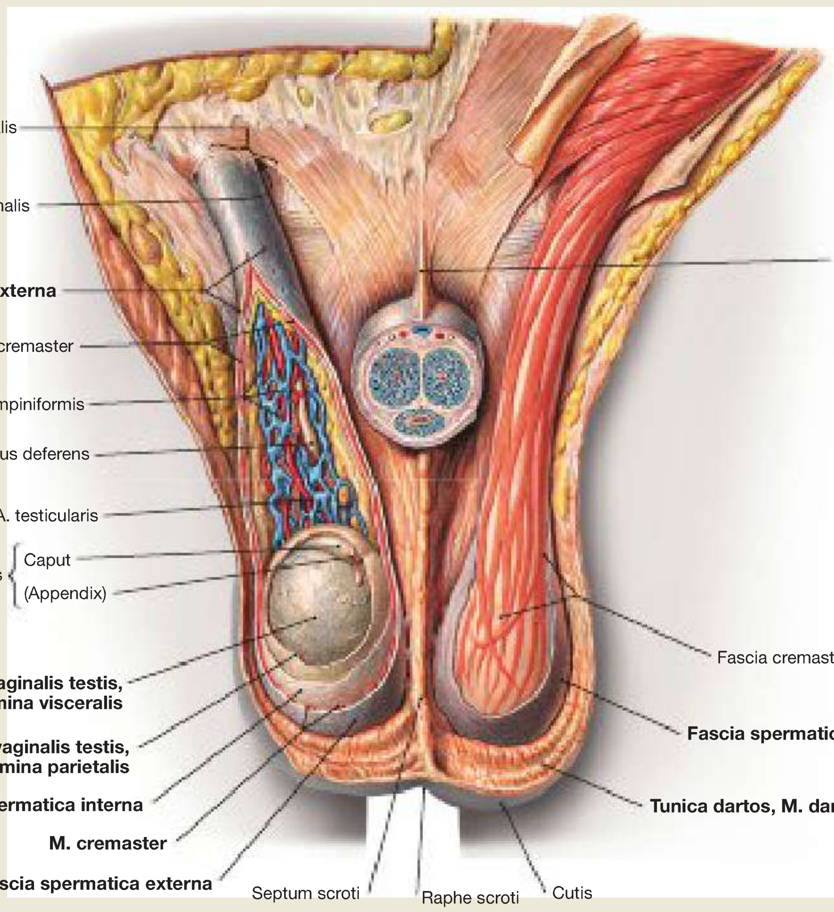


Fig. 7.75 Scrotum; ventral view; the scrotum is opened and the penis is frontally separated.
The root of the penis is attached to the anterior body wall by the superficial **Lig. fundiforme penis** and, underneath it, the deep **Lig. suspensorium penis.** The scrotum is divided internally by a septum which externally corresponds to the scrotal raphe (Raphe scroti) of skin.
Testes and **spermatic cord** present the following **coverings:**
- scrotal skin
- Tunica dartos: subcutaneous layer with smooth muscle cells
- Fascia spermatica externa: continuation of the superficial body fascia (Fascia abdominalis superficialis)
- M. cremaster with Fascia cremasterica
- Fascia spermatica interna: continuation of the Fascia transversalis

The testis has the **Tunica vaginalis testis** as a further covering on its surface, with an external Lamina parietalis (periorchium) outside and an internal Lamina visceralis (epiorchium), connected to each other by the mesorchium with the **Cavitas serosa scroti** between them.

Blood Vessels and Nerves of the Penis

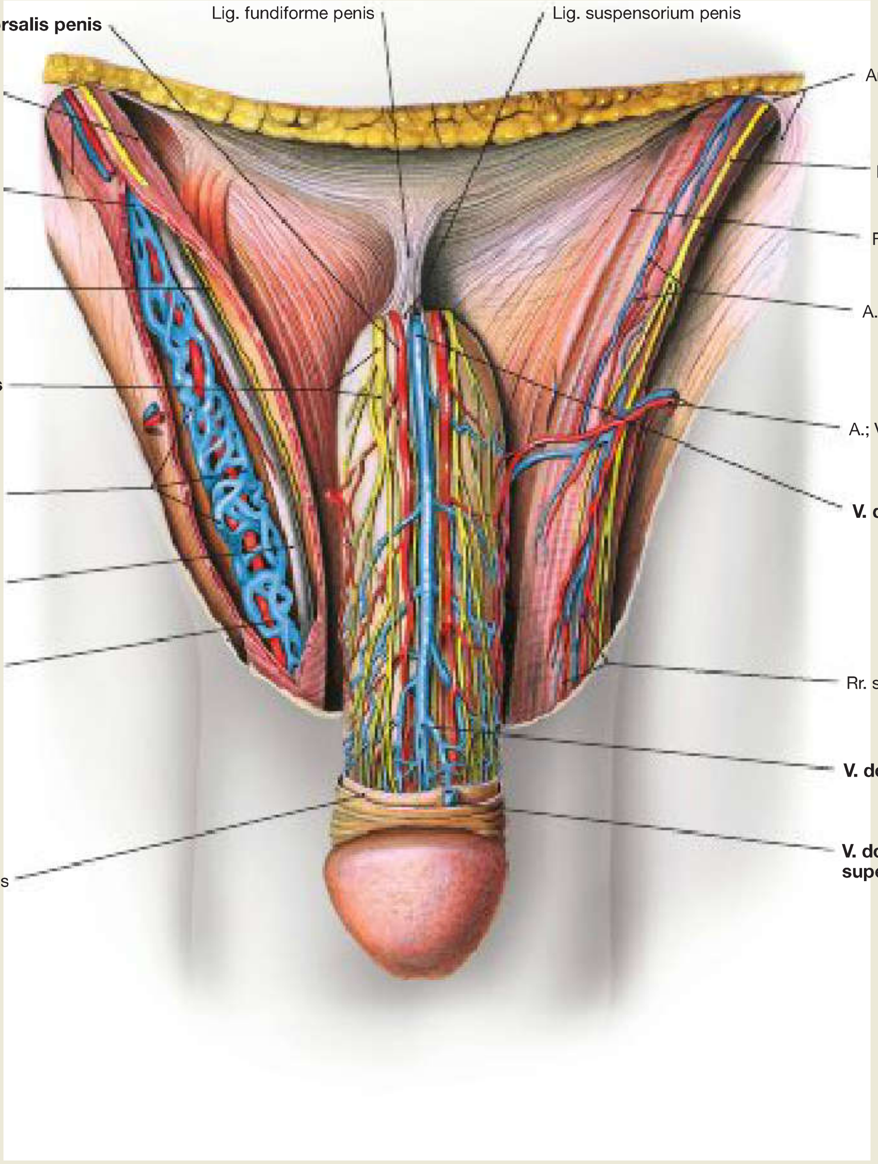


Fig. 7.76 External male genitalia, Organa genitalia masculina externa, with neurovascular pathways; ventral view; after removal of the fascia of the penis.

The penis is supplied by **three paired arteries** from the A. pudenda interna and **three venous systems** (→ Fig. 7.77). Here just the subfascially located blood vessels are visible after the fascia of the penis has been removed.

The A. dorsalis penis is arranged in pairs and supplies the skin and the glans of the penis. Between the arteries of both sides runs the unpaired **V. dorsalis profunda penis,** which drains the cavernous bodies into the Plexus venosus prostaticus.

The illustration shows the **nerves of the penis:**

- sensory: N. dorsalis penis (from the N. pudendus)
- autonomic: mainly parasympathetic Nn. cavernosi penis (from the Plexus hypogastricus inferior) pierce the pelvic floor and join the N. dorsalis penis (sympathetic stimulation causes vasoconstriction; parasympathetic stimulation causes vasodilation and consecutive erection).

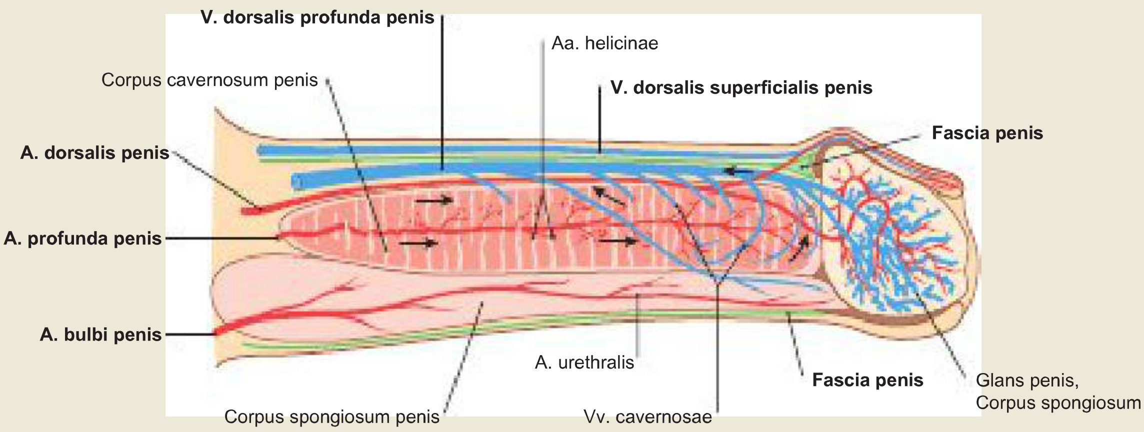


Fig. 7.77 Blood vessels of the penis; schematic illustration of a median section; view from the right side. [L126]

The penis is supplied by **three paired arteries** from the A. pudenda interna:

- A. dorsalis penis: runs subfascially, supplies skin and glans of the penis
- A. profunda penis: in the Corpora cavernosa, is responsible for filling them with blood
- A. bulbi penis: penetrates the bulb of the penis, supplies the Glandula bulbourethralis and continues, as the A. urethralis, to the urethra and Corpus spongiosum

The venous blood is collected by **three venous systems:**

- V. dorsalis superficialis penis: paired or unpaired, epifascial, transfers blood from the penile skin to the V. pudenda externa
- V. dorsalis profunda penis: unpaired, subfascial, drains the cavernous bodies into the Plexus venosus prostaticus
- V. bulbi penis: paired, brings blood from the bulb of the penis to the V. dorsalis profunda penis

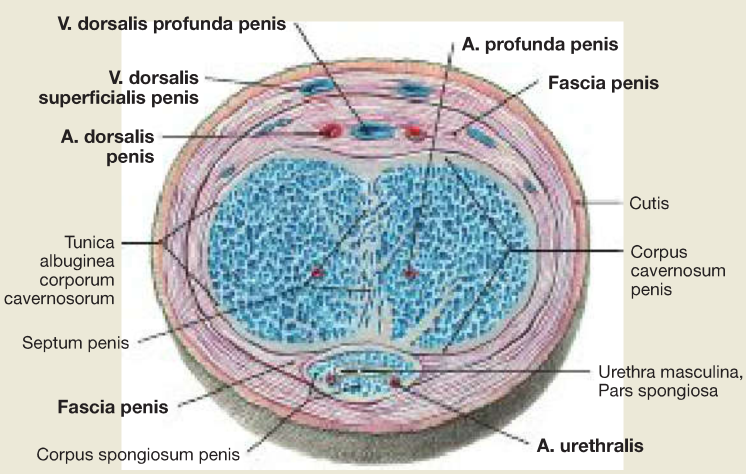


Fig. 7.78 Penis; cross-section in the area of the centre of the shaft; ventral view.

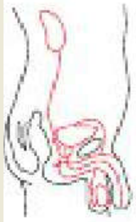
The location of the blood vessels is important for the **erection** of the penis. Activated parasympathetically, there is a dilation of the **A. profunda penis** which fills the Corpora cavernosa. This compresses the **V. dorsalis penis** under the tough fascia of the penis (Fascia penis), so that the blood cannot drain away. Due to additional contraction of the **Mm. ischiocavernosi** (innervated by the N. pudendus), this results in the penile erection.

Clinical Remarks

The parasympathetic nerve fibres release nitric oxide (NO), which in the smooth muscle cells of the blood vessels leads to an increase of the second messenger cGMP, which inhibits the contraction of the cells. **Inhibitors of phosphodiesterase** (e.g. Viagra®) delay the degradation of cGMP, thus enhancing the **erection.**

Retroperitoneal Space and Pelvic Cavity

Internal Male Genitalia



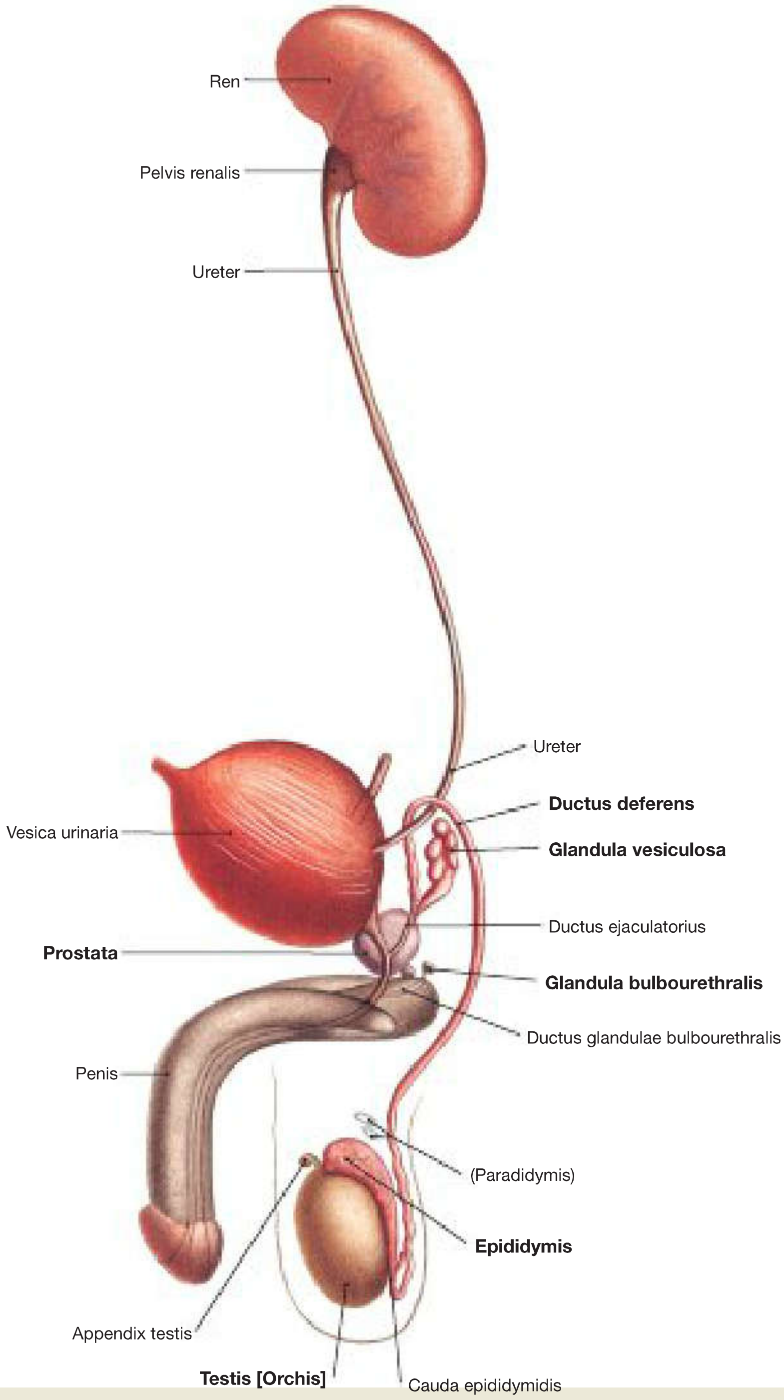


Fig. 7.79 Male urinary and reproductive organs, Organa urogenitalia masculina; view from the right side.
The **internal male genitalia** include:
- testis
- epididymis
- spermatic duct (Ductus deferens)
- spermatic cord (Funiculus spermaticus)
- accessory sex glands:
  - prostate gland
  - seminal vesicle (Glandula vesiculosa), paired
  - COWPER's gland (Glandula bulbourethralis), paired

The testis and epididymis belong to the internal genitalia because they were relocated during development from the intra-abdominal cavity into the scrotum (Cavitas serosa scroti) forming the future serosal cavity of the scrotum.
The internal genitalia are **reproductive organs.** They serve the production, maturation, and transport of spermatozoa and the production of seminal fluid. The testes also produce male sex hormones (testosterone).

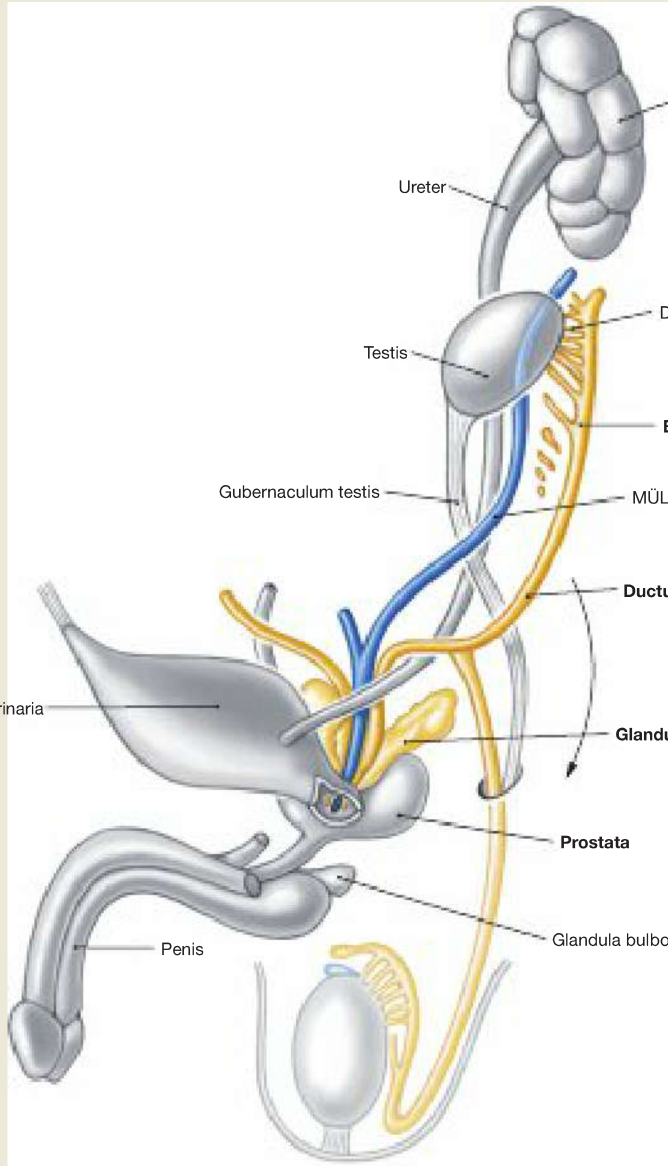


Fig. 7.80 Development of the internal male genitalia, Organa genitalia masculina interna. [L126]
The internal genitalia develop in both sexes in the same way until the seventh week (indifferent gonad → Fig. 7.22). In the male, the primordial gonad then develops into the testis. The testis develops in the lumbar region at the level of the mesonephros which contributes several canaliculi as a connection between the testis and the epididymis. In the course of the body growth the testis then moves caudally **(Descensus testis),** accompanied by its neurovascular pathways. Along the inferior mesenchymal gubernaculum (Gubernaculum testis) a peritoneal space is formed (Proc. vaginalis peritonei) which reaches down to the future scrotum and serves in guiding the descent of the testis, a process normally completed at birth. At the birth, the Proc. vaginalis closes in the area of the Funiculus spermaticus. The distal part of the Proc. vaginalis remains and forms a part of the testicular coverings (Tunica vaginalis testis).
The sex hormones of the testis (mainly testosterone) induce the final **differentiation of the WOLFFIAN ducts** to the internal male genitalia (Epididymis, Vas deferens), the seminal vesicles, and other accessory sex glands (prostate gland, COWPER's glands) from the Sinus urogenitalis. The anti-MÜLLERIAN hormone suppresses the differentiation of the MÜLLERIAN ducts in female genitalia.

Clinical Remarks

The descent of the testis explains why the testicular blood vessels arise at the level of the kidneys and why their regional lymph nodes are positioned at this level in the retroperitoneal space. Hence it is here rather than in the groin where the first lymph node metastases should be expected in **testicular cancer.** If the testes do not fully descend within the first years of life **(undescended testicles, cryptorchidism),** this can lead to infertility. This is associated with an increased risk of testicular cancer. More recent findings indicate that hormonal treatment or an operation in the first year of life can prevent infertility. However, the risk of cancer cannot be clearly influenced therapeutically. If the Proc. vaginalis fails to obliterate, accumulation of fluids may occur (even in adulthood) in the scrotum **(hydrocele testis)** or abdominal organs may prolapse into the scrotum **(congenital inguinal hernia).**

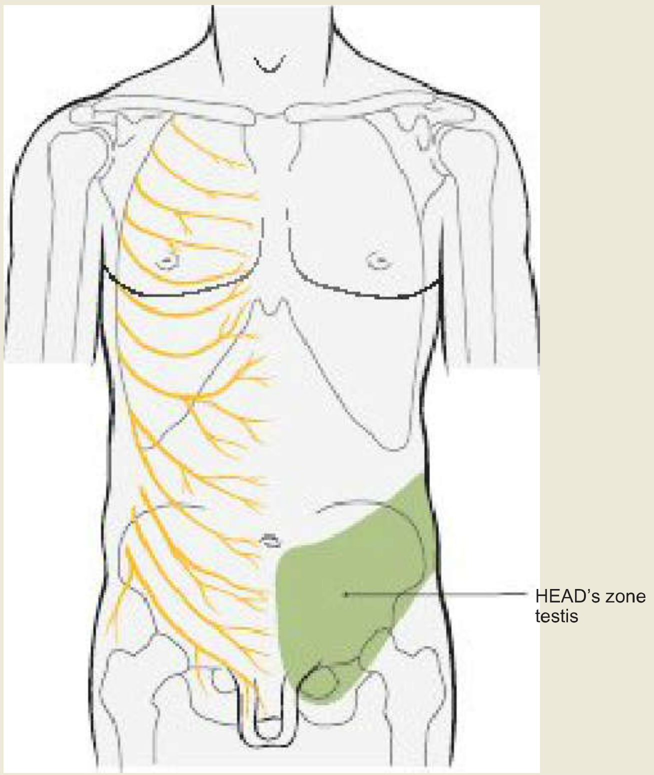
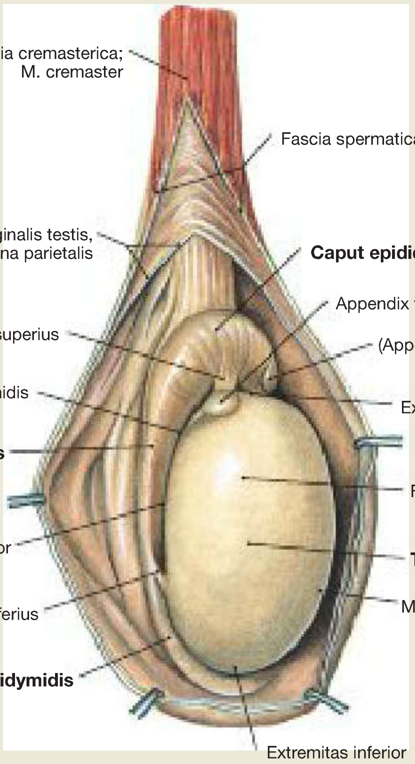
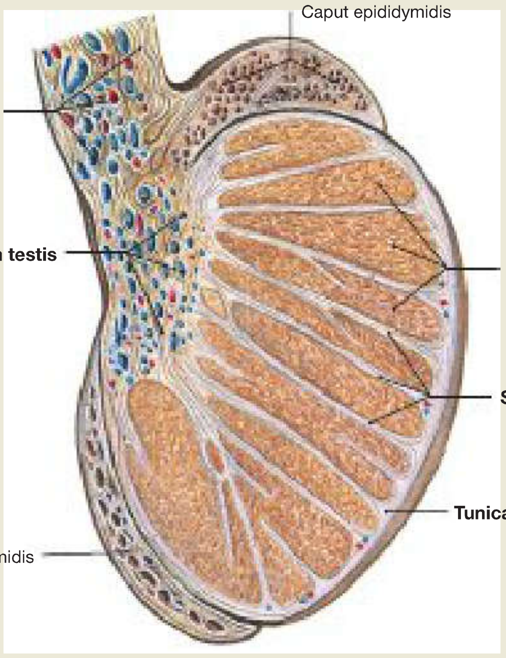


Fig. 7.81 HEAD's zone of the testis [Orchis]; ventral view. [L126]
The organ-related area **(HEAD's zone)** of the testis projects onto the cutaneous areas (dermatomes) T10–L1 and thus corresponds to the kidney. This localisation is due to the fact that the testis becomes located later on in the lumbar region and when it descends (Descensus) into the scrotum it takes with it the neurovascular pathways, including its autonomic innervation (Plexus testicularis). Diseases of the testis, such as an inflammation (orchitis) or a torque of its pathways (testicular torsion), can lead to severe pain which will be perceived in the dermatomes T10–L1 (projected pain).



a



b

Fig. 7.82a and b Testis [Orchis] and epididymis; view from the right side (→ Fig. 7.82a) and sagittal section (→ Fig. 7.82b); view from the right side.

The testis is egg-shaped and 4 × 3 cm in size (20–30 g). It has a **superior** and an **inferior pole** (Extremitas superior and inferior). The dense Tunica albuginea surrounding the testis sends septa into the parenchyma of the testis and thus subdivides it into 370 **lobules of testis (Lobuli testis).** Within the lobules the sperm is produced in the **seminiferous tubules.** Between the tubules are the testosterone-producing cells (LEYDIG's cells). The tubules are in the area of the **mediastinum testis,** where the neurovascular pathways enter and exit, connected with the head of the epididymis. The **epididymis** sits above and dorsal to the testis and is attached to it by an upper and a lower band (Ligg. epididymides superius and inferius). The epididymis is divided into the **head (Caput), body (Corpus), and tail (Cauda),** and continues into the spermatic duct (Vas deferens).

Testis and Epididymis

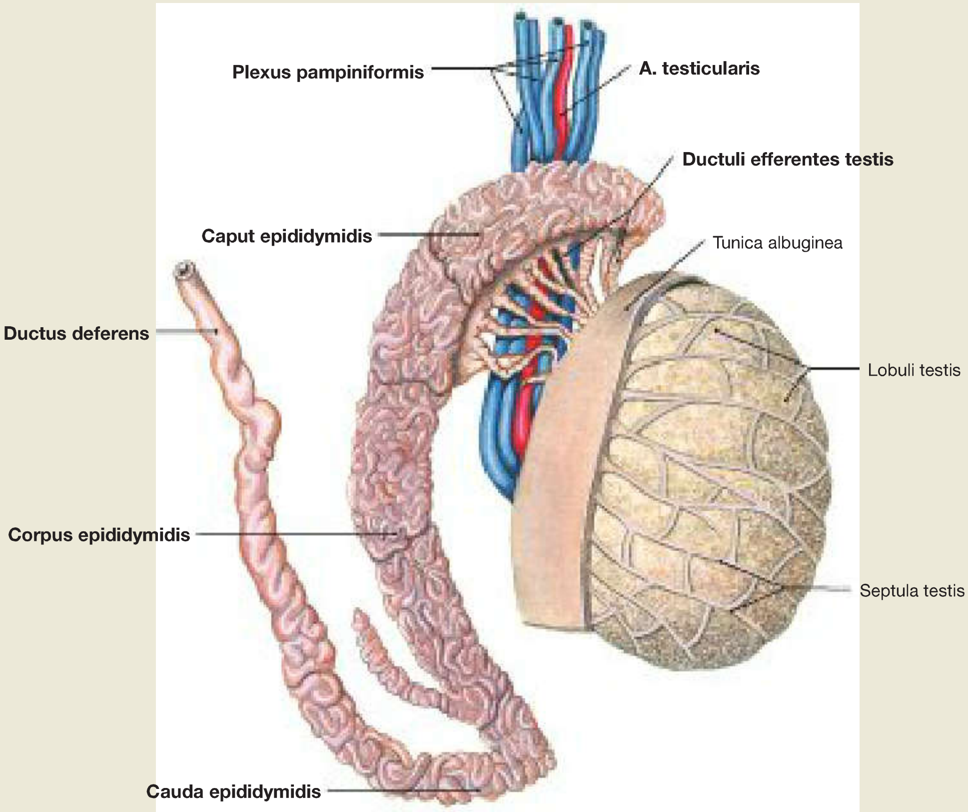


Fig. 7.83 Testis [Orchis] and epididymis, with blood vessels; view from the right side.
The **testis** is linked by fine tubules (Ductuli efferentes testis) with the head of the epididymis (Caput epididymidis). The **epididymis** itself consists of a 6 m long convoluted duct which continues as **vas deferens (Ductus deferens)** at the tail of the epididymis. The vas deferens is 35–40 cm long and 3 mm thick and passes through the spermatic cord and the inguinal canal to the dorsal side of the urinary bladder, before joining together with the seminal vesicle in the ejaculatory duct into the Pars prostatica of the urethra.
Testis and epididymis are supplied by the **A. testicularis** and a plexus of veins **(Plexus pampiniformis).**

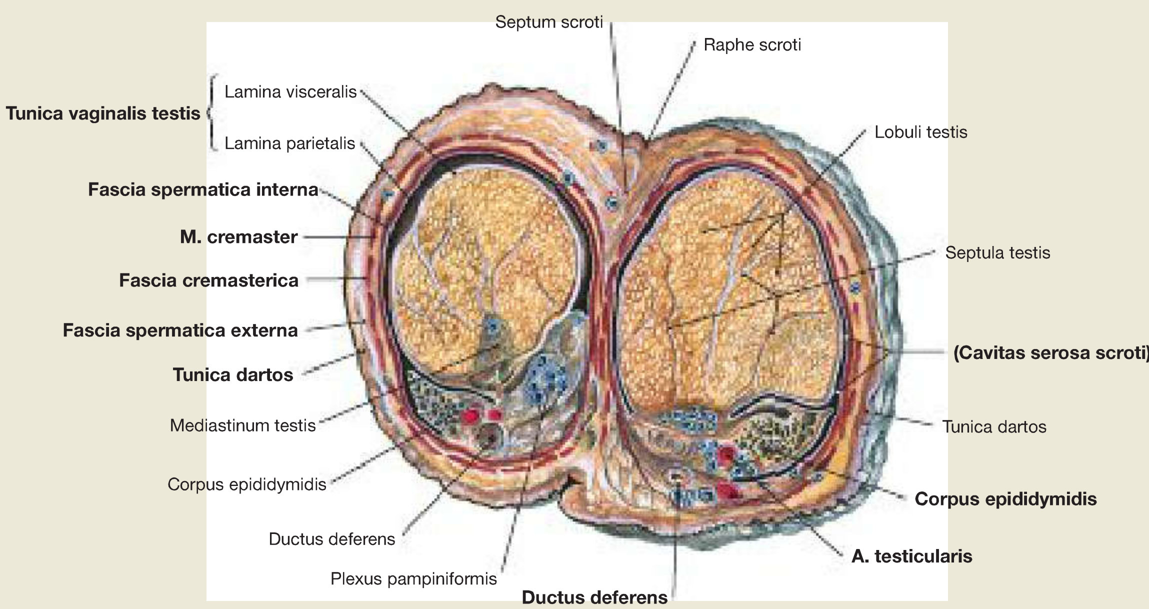


Fig. 7.84 Testis [Orchis] and epididymis; cross-section; cranial view.

In addition to the testicular coverings (→ Fig. 7.87), the neurovascular pathways and the vas deferens (Ductus deferens) are sectioned.

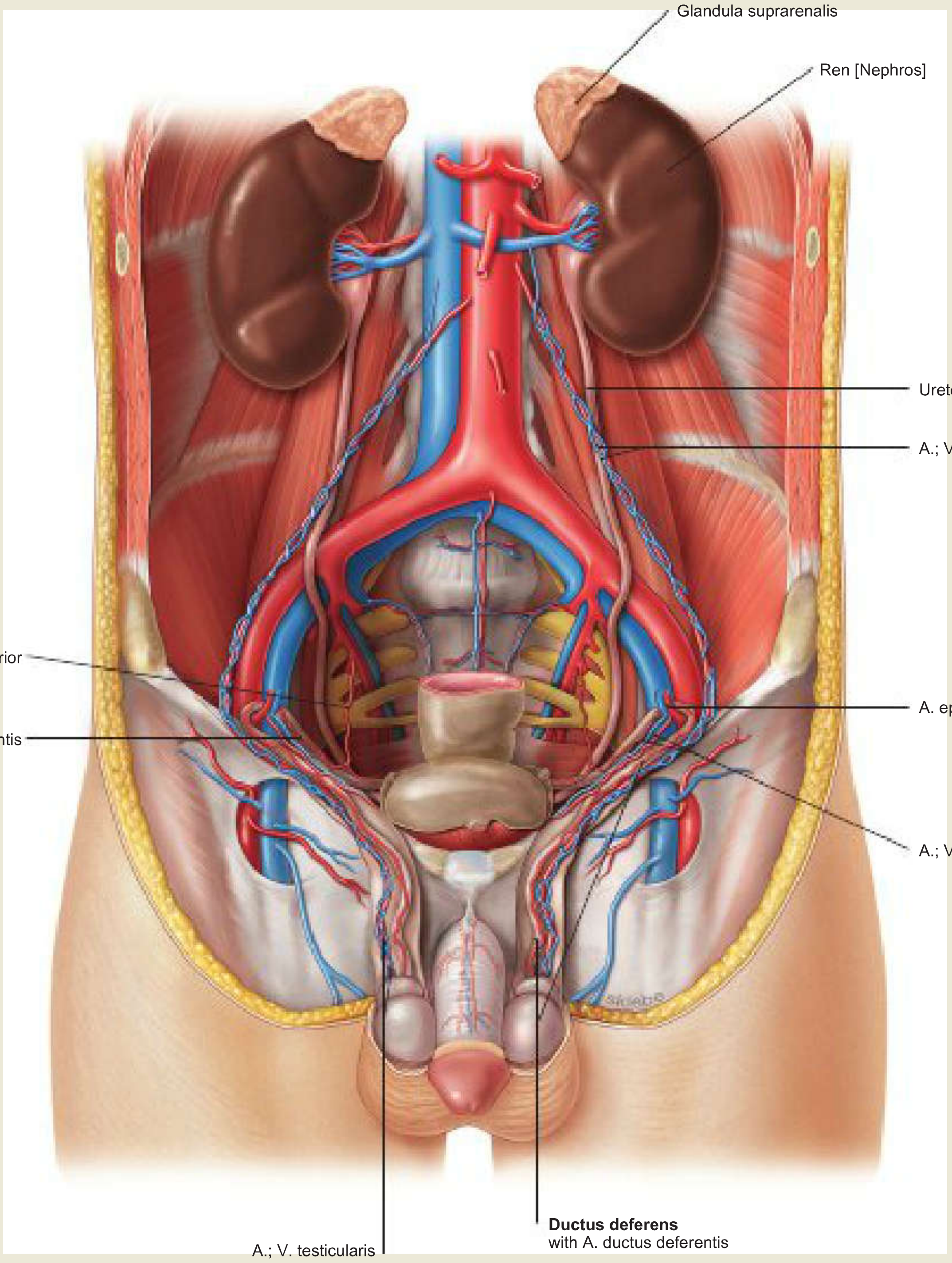


Fig. 7.85 Parts and course of the vas deferens, Ductus deferens. The abdominal wall and all intra- and secondary retroperitoneal organs have been removed; the vas deferens is opened full-length; ventral view. [L238]

The **vas deferens (Ductus deferens)** is 35–40 cm long and has a diameter of 3 mm. It arises from the tail of the epididymis (Cauda epididymidis) and then ascends into the scrotum **(scrotal part),** before it continues into the Funiculus spermaticus **(funicular part).** The vas deferens goes through the inguinal canal **(inguinal part)** and then passes into the lesser pelvis **(pelvic part).**

In the lesser pelvis it crosses the ureters before adhering to the dorsal side of the urinary bladder. It extends here to the **Ampulla ductus deferentis** and combines with the duct of the seminal vesicle (Gl. vesiculosa) to the **Ductus ejaculatorius.** This traverses the prostate and exits at the Colliculus seminalis into the Pars prostatica of the urethra (→ Fig. 7.51 and → Fig. 7.52). Here spermatozoa are spilled by emission into the urethra. Therefore, the vas deferens has a very strong layer of smooth muscles (→ Fig. 7.86).

Spermatic cord

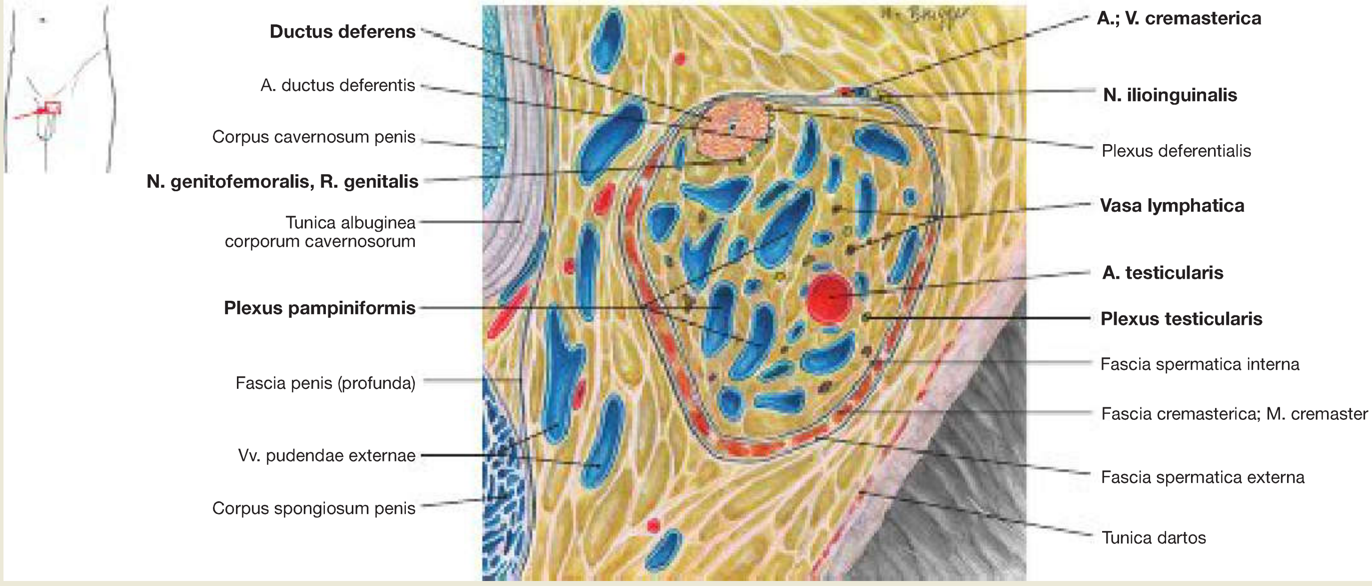


Fig. 7.86 Spermatic cord, Funiculus spermaticus, left side; frontal section; ventral view, magnification 2.5-fold.
The spermatic cord contains the following**:**
- Vas deferens (Ductus deferens) with A. ductus deferentis (from the A. umbilicalis)
- A. testicularis from the abdominal aorta and, as the Plexus pampiniformis, the accompanying veins
- N. genitofemoralis, R. genitalis (→ Fig. 7.76)
- lymphatic vessels (Vasa lymphatica) to the lumbar lymph nodes
- autonomic nerve fibres (Plexus testicularis) from the aortic plexus

Externally, the **N. ilioinguinalis** and the **A. and V. cremasterica** are adjacent to the spermatic cord (→ Fig. 7.76 and → Fig. 7.87).

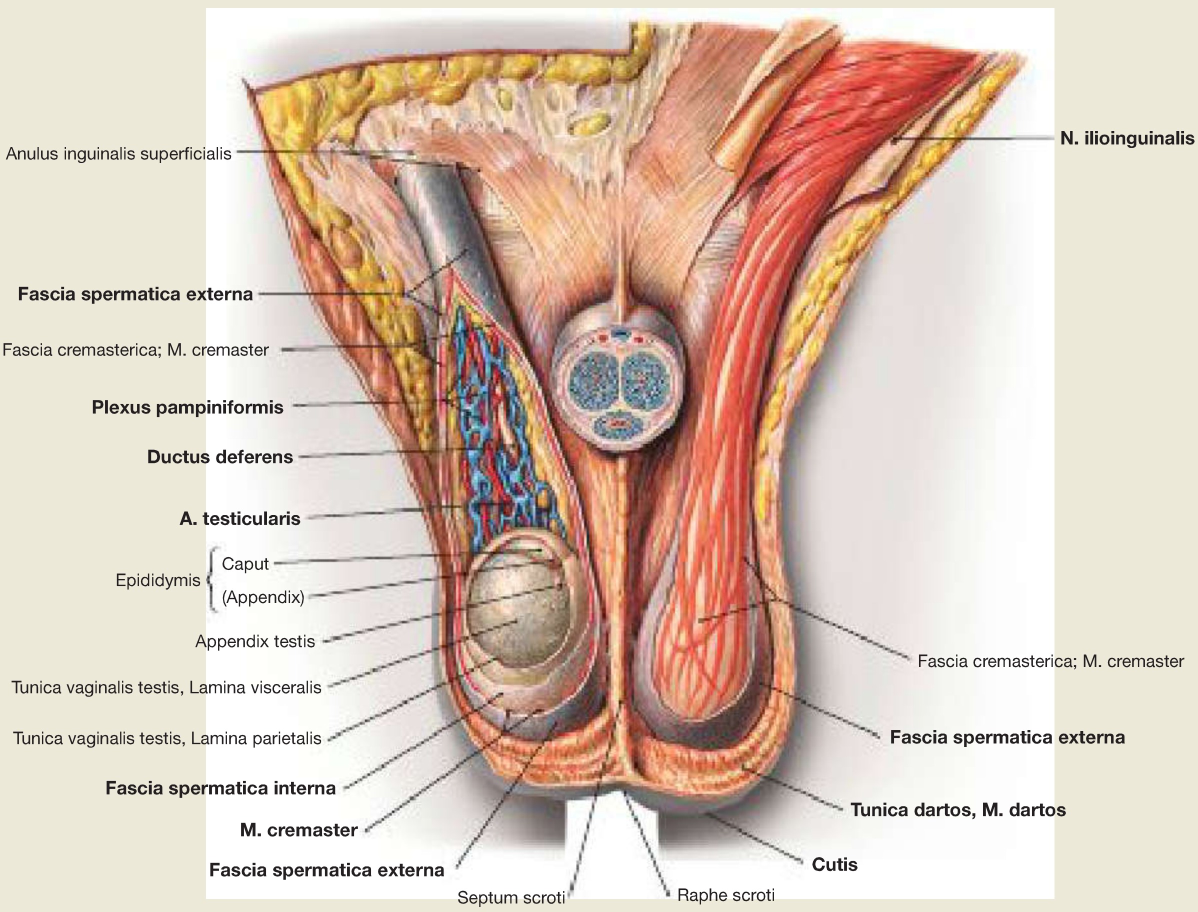
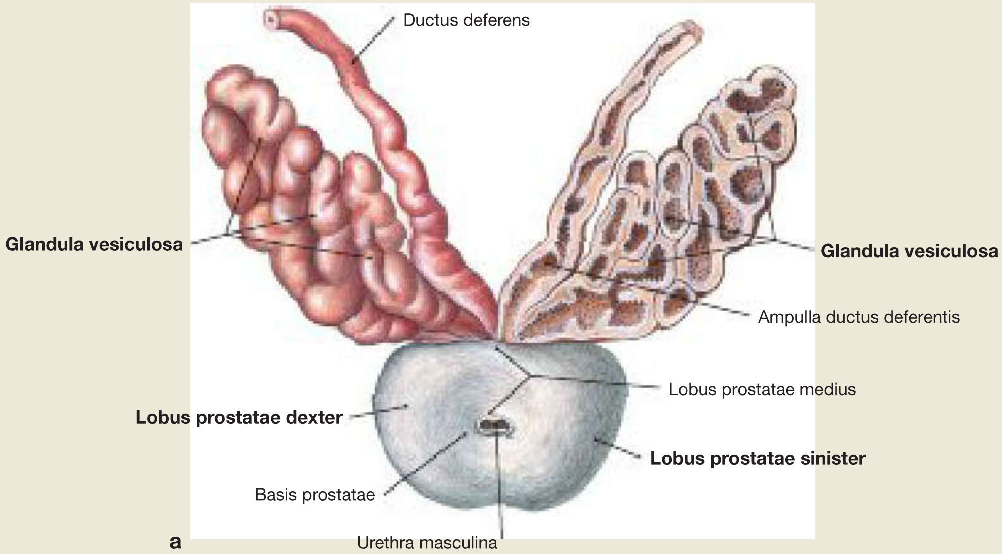


Fig. 7.87 Covering of the spermatic cord, Funiculus spermaticus, and the testis; ventral view; scrotum opened.
Testes and **spermatic cord** have the following **coverings:**
- Fascia spermatica externa: continuation of the superficial body fascia (Fascia abdominalis superficialis)
- M. cremaster with Fascia cremasterica
- Fascia spermatica interna: continuation of the Fascia transversalis

In the area of the **scrotum** two more layers join from the outside enveloping the testes only:
- scrotal skin (cutis)
- Tunica dartos: subcutis with smooth muscle cells



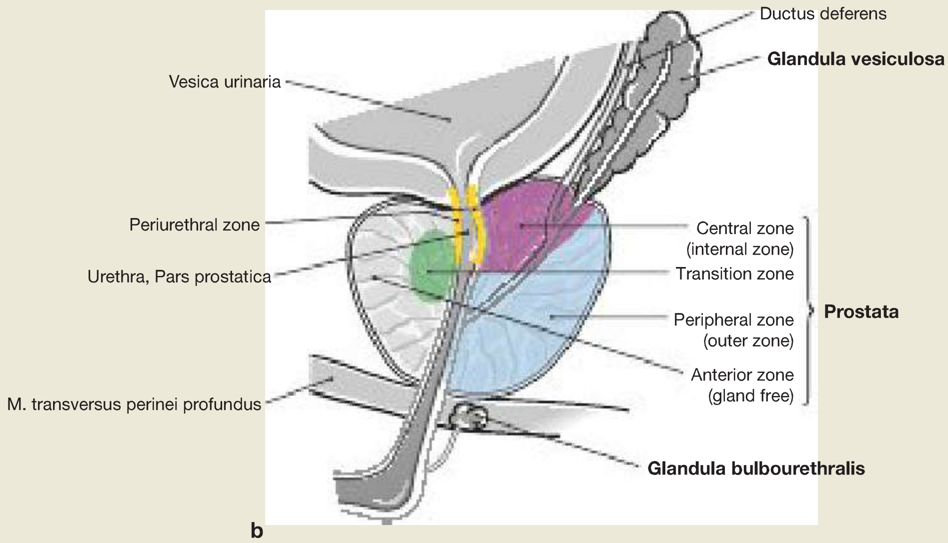


Fig. 7.88a and b Seminal vesicles, Glandulae vesiculosae, and prostate gland, Prostata; cranial view (→ Fig. 7.88a) and view from the left side; median section (→ Fig. 7.88b). b [L126]

The internal male genitalia also include the **accessory sex glands.** They contribute to the formation of ejaculate and form secretions to moisten the female genitalia during sexual intercourse.

The **accessory sex glands** consist of:

- **prostate gland:** unpaired gland below the base of the bladder. The prostate gland measures 4 × 3 × 2 cm (20 g) and has a superior base and an inferior apex. It has a right and a left lobe (Lobus dexter and sinister), which are separated by a shallow groove, as well as being divided into a middle lobe (Lobus medius). The prostate gland discharges its secretion into the centrally traversing urethra (Pars prostatica). Histologically, the prostate is made up of 35–50 individual glands, all of which deliver their secretions via excretory ducts into the **Pars prostatica of the urethra.** The openings of the excretory ducts are on both sides of the Colliculus seminalis.
- **seminal vesicle** (Glandula vesiculosa): paired gland at the dorsal aspect of the urinary bladder (→ Fig. 7.50). The seminal vesicles have an elongated oval shape (5 × 1 × 1 cm) and consist of a single winding pathway, approx. 15 cm in length. The respective excretory duct combines with the vas deferens in the Ductus ejaculatorius and ends in the **Pars prostatica of the urethra** on the Colliculus seminalis.
- **COWPER's gland** (Glandula bulbourethralis): paired gland located within the perineal muscles (→ Fig. 7.51). The COWPER's glands are the size of lentils (up to approx. 1 cm) and drain with their 3 cm long excretory ducts into the **Pars spongiosa of the urethra.**

The seminal vesicles and the prostate form the liquid of the ejaculate, which is used for the nutrition of the spermatozoa. The COWPER's glands emit their secretions which act as a lubricant before ejaculation.

Accessory Male Sex Glands

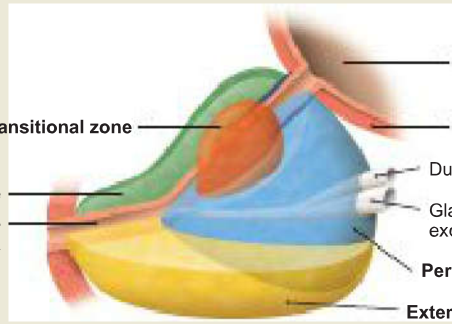


Fig. 7.89 Structure of the prostate gland; schematic illustration of the zones; view in supine position of the patient (as is usual in rectal examinations) from the left side. [L127]

The **prostate gland,** in addition to its macroscopic structure dividing into a right and left as well as a median lobe, also presents a histological structure in **zones,** which are of major clinical significance:

- **central zone or internal zone** (25% of the glandular tissue): wedge-shaped segment between Ductus ejaculatorii and urethra
- **peripheral zone or external zone** (70% of the glandular tissue): it is coat-like and surrounds the inner zone on the dorsal side
- **periurethral zone:** narrow strip of tissue to the proximal urethra
- **transitional zone** (5% of the glandular tissue): lateral on both sides to the periurethral zone in the transition area to the internal zone
- **anterior zone:** gland-free area ventral to the urethra, which contains only stroma of connective tissue and smooth muscles

It should be noted that in former publications the only distinction made is between internal and external zones. Hence the transitional zone was treated as part of the internal zone.

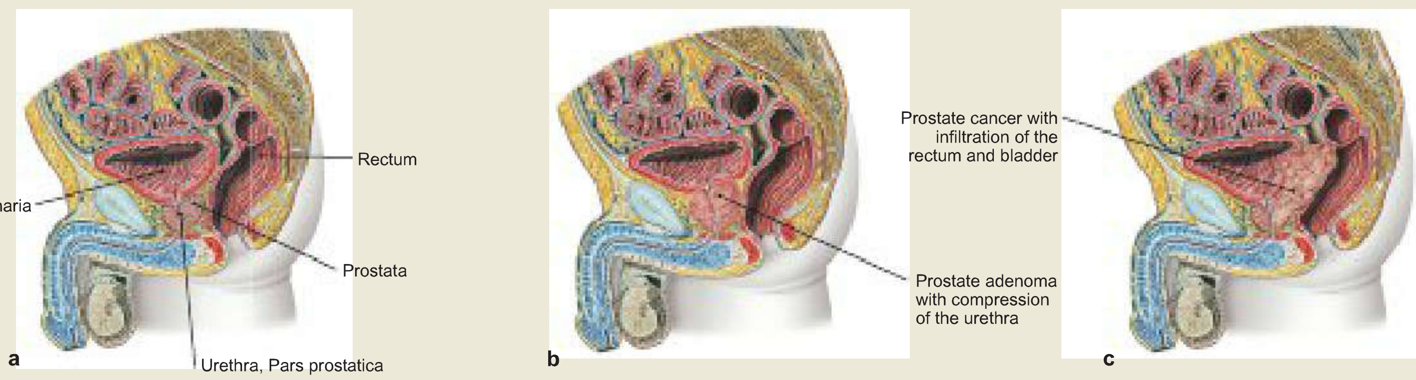


Fig. 7.90 Tumours of the prostate related to the zones of the prostate gland; sagittal section through a male pelvis, view from the left side. [L266]

a Normal prostate

b Prostate adenoma originating from the transitional zone and compression of the urethra

c Prostate cancer originating from the peripheral zone and infiltration of the rectum and bladder

Clinical Remarks

Benign prostatic hypertrophy or adenoma (BPH; hyperplasia) is a benign tumour of the prostate gland, causing it to enlarge up to a weight of 100 g, and occurring in almost all men over the age of 70. Since these adenomas originate from the **transitional zone** (→ Fig. 7.90b), which for several years now has been distinguished from the inner zone, problems arise here with urination and urinary retention at an early stage.

Prostate cancers are among the three most common malignant tumours in men. They usually develop from the **peripheral zone** of the prostate gland (→ Fig. 7.91c), which can be differentiated under the microscope. Therefore, symptoms only arise later on. Due to the fact that the prostate gland is separated from the rectum only by the thin Fascia rectoprostatica (DENONVILLIER's fascia; → Fig. 7.59) tumours are usually palpable through the rectum by clinical examination. The digital rectal examination (DRE) is therefore part of a complete physical examination in men over 50 years of age.

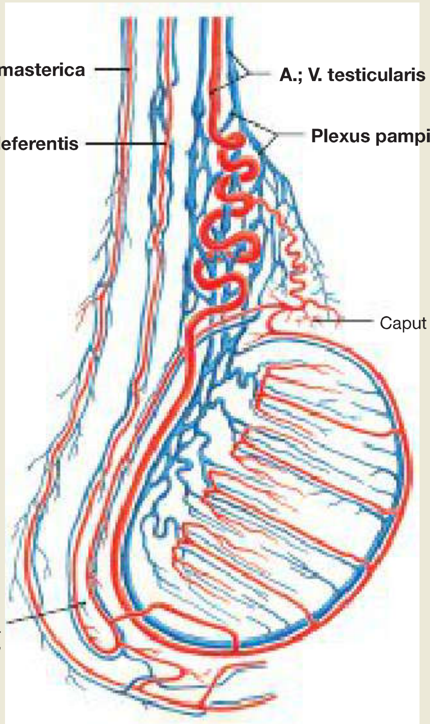


Fig. 7.91 Blood vessels of the internal male genitalia; view from the right side.
Testis and epididymis are supplied by the **A. and V. testicularis.** The V. testicularis is expanded distally to a plexus (Plexus pampiniformis). The vas deferens is supplied by the **A. ductus deferentis,** the spermatic cord is supplied by the **A. cremasterica.**

Blood Vessels of the Internal Genitalia

	Organ	**Blood Vessel**
Arteries	testis and epididymis	A. testicularis (from the Pars abdominalis of the aorta)
	vas deferens	A. ductus deferentis (mostly from the A. umbilicalis)
	spermatic cord (M. cremaster)	A. cremasterica (from the A. epigastrica inferior)
	accessory sex glands	A. vesicalis inferior and A. rectalis media (from the A. iliaca interna)
Veins	testes, epididymidis, vas deferens and spermatic cord	Plexus pampiniformis: venous plexus, with its branches uniting to form the V. testicularis, which on the right side enters the V. cava inferior, and on the left side the V. renalis sinistra
	accessory sex glands	Plexus venosi vesicalis and prostaticus with connection to the V. iliaca interna

Clinical Remarks

Outflow obstructions at the junction in the V. renalis sinistra or **renal cancers** growing in the renal vein can cause a backflow of blood and thus a visual and tactile extension of the pampiniform plexus in the left half of the scrotum **(varicocele).** Therefore, in a left-sided varicocele a kidney tumour must be excluded. In addition, a longer existing varicocele can cause infertility.

Blood Vessels of the Internal Male Genitalia

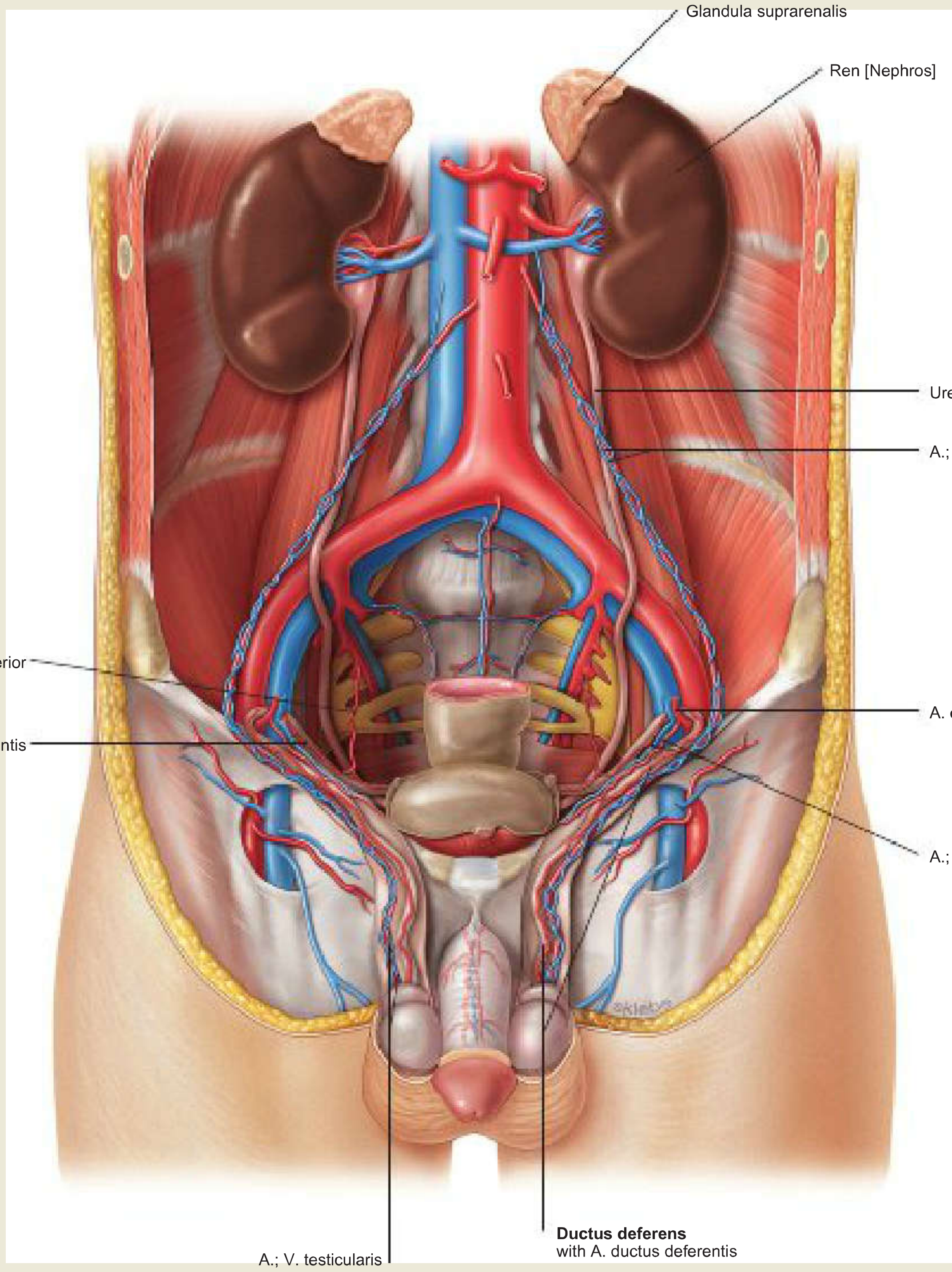


Fig. 7.92 Blood vessels of the internal male genitalia. The abdominal wall and all intra- and secondary retroperitoneal organs have been removed; the spermatic cord is opened full-length; ventral view. [L238]

Testis and epididymis are supplied by the **A. testicularis** that originates as a visceral branch of the abdominal aorta (Pars abdominalis aortae). It runs retroperitoneally up to the inguinal canal through which the spermatic cord enters into the scrotum. The venous blood passes through the **V. testicularis** in the same way. This continues on the right into the V. cava inferior and on the left, on the other hand, into the V. renalis sinistra. The **vas deferens** receives alongside the **A. ductus deferentis** its own very fine artery originating either directly from the A. umbilicalis or from the outgoing A. vesicalis superior. The A. ductus deferentis attaches directly to the vas deferens up to its origin in the epididymis.

The coverings of the **spermatic cord** are supplied by the **A. cremasterica,** which originates as a branch of the A. epigastrica inferior from outside the spermatic cord, before it penetrates in its further course between its coverings.

Not shown here are the **accessory sex glands,** which receive their blood supply from the **A. vesicalis inferior** and the **A. rectalis media,** branches of the A. iliaca interna. Only the COWPER's glands are supplied by the **A. pudenda interna,** which with its deep branches passes through the perineal space.

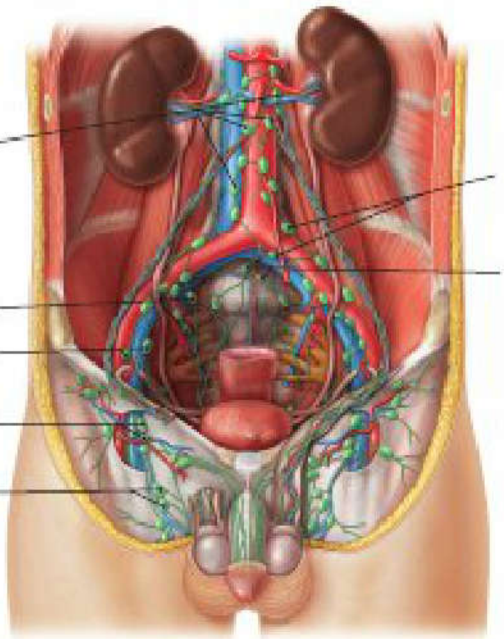


Fig. 7.93 Lymphatic vessels and lymph nodes of the external and internal male genitalia; ventral view. [L238]
The regional lymph nodes for the external genitalia are the **inguinal lymph nodes (Nodi lymphoidei inguinales).** By contrast, the first regional lymph nodes of the testis and epididymis are in a retroperitoneal position at the level of the kidneys **(Nodi lymphoidei lumbales).**

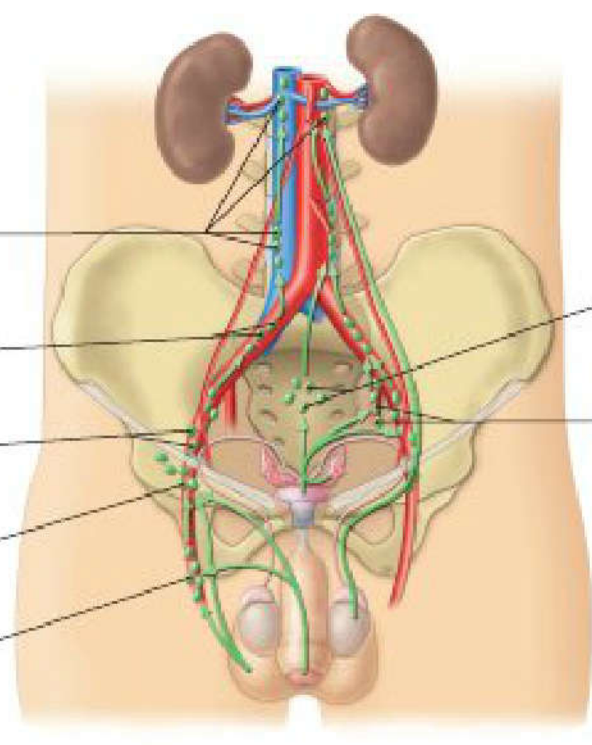


Fig. 7.94 Lymphatic drainage pathways of the external and internal male genitalia; ventral view. [L238]
External and internal genitalia in men have completely separated lymphatic pathways.
External genitalia:
- penis and scrotum: Nodi lymphoidei inguinales

Internal genitalia:
- testes and epididymis: Nodi lymphoidei lumbales at the level of the kidneys
- vas deferens, spermatic cord and accessory sex glands: Nodi lymphoidei iliaci interni/externi and Nodi lymphoidei sacrales

Clinical Remarks

Due to the different lymphatic drainage pathways, the first **lymph node metastases** in penile carcinomas are found in the groin, whereas metastases of testicular tumours are found in the retroperitoneal space. Since the lymphatic drainage pathways of the internal and external genitalia do not communicate with each other, **no transscrotal biopsy** can be made, where there is a suspected **testicular tumour,** because this can result in spreading of the tumour cells via the lymphatic vessels into the inguinal lymph nodes. In this case, the biopsy must always be taken from the inguinal canal.

Innervation of the Male Genitalia

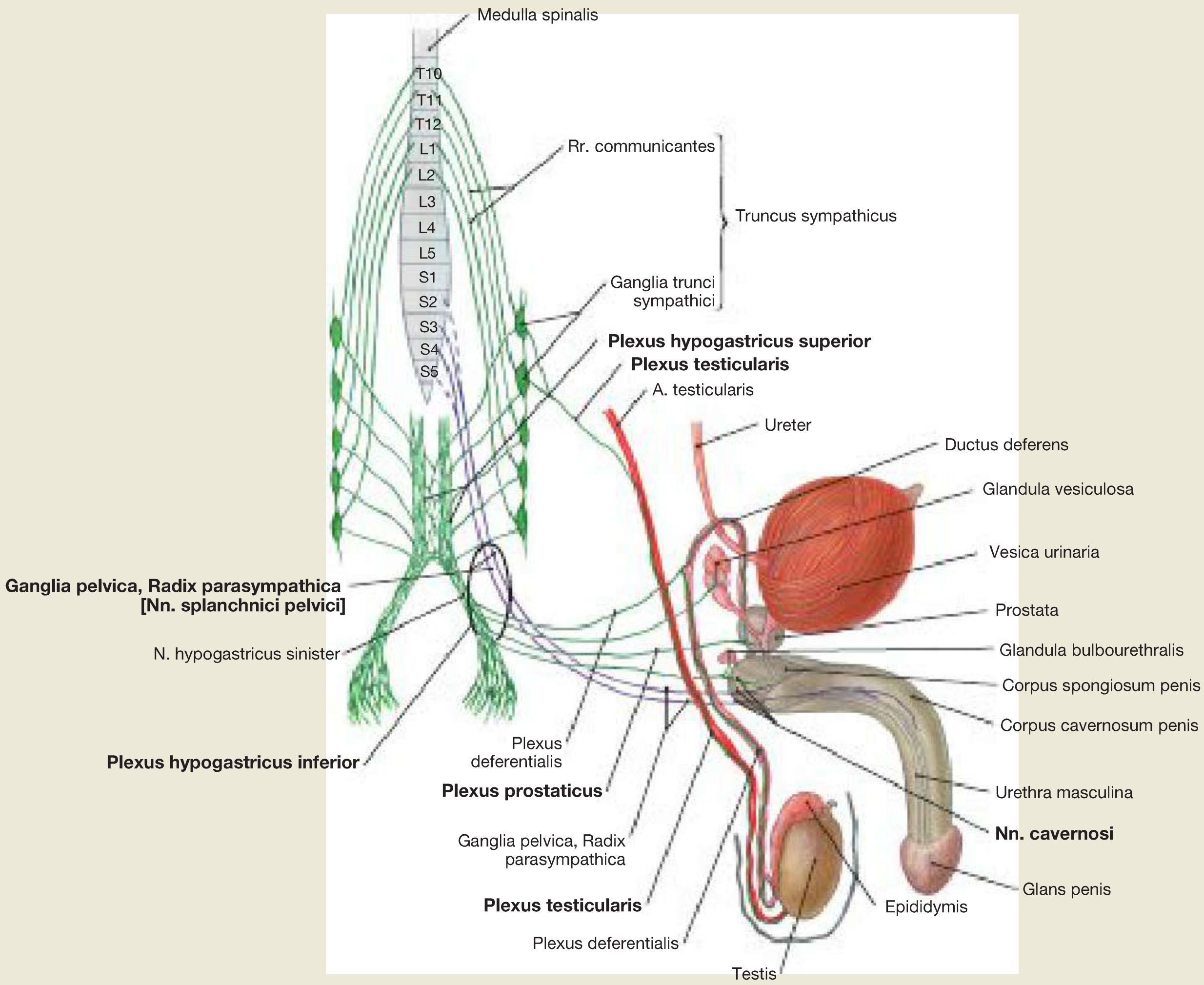


Fig. 7.95 Innervation of the male genitalia; ventral as well as lateral view; schematic illustration. The Plexus hypogastricus inferior contains sympathetic (green) and parasympathetic (purple) nerve fibres.

Preganglionic **sympathetic nerve fibres** (T10–L2) descend from the Plexus aorticus abdominalis via the Plexus hypogastricus superior and from the sacral ganglia of the sympathetic trunk (Truncus sympathicus) via the Nn. splanchnici sacrales to be synapsed to postganglionic neurons in the ganglia of the **Plexus hypogastricus inferior.** These postganglionic fibres reach the pelvic viscera, including the accessory sex glands. Sympathetic fibres to the vas deferens **(Plexus deferentialis)** activate smooth muscle contractions for the **emission** of spermatozoa into the urethra. Some fibres also join the Nn. cavernosi and penetrate the pelvic floor to reach the Corpora cavernosa of the penis. The (mostly) postganglionic sympathetic fibres to the testis and epididymis run in the **Plexus testicularis** alongside the A. testicularis after being already synapsed in the Ganglia aorticorenalia or the Plexus hypogastricus superior.

Preganglionic **parasympathetic nerve fibres** pass from the sacral parasympathicus (S2–S4) through the **Nn. splanchnici pelvici** into the ganglia of the **Plexus hypogastricus inferior.** They are synapsed either here or in the vicinity of the pelvic viscera (here: Ganglia pelvica) to postganglionic neurons which innervate the accessory glands. The **Nn. cavernosi penis** penetrate the pelvic floor and pass (partly in combination with the N. dorsalis penis) into the cavernous bodies, where they trigger the **erection.**

Somatic innervation via the **N. pudendus** conveys sensory innervation to the penis via the N. dorsalis penis and, along with the motor fibres of the Nn. perineales on the M. bulbospongiosus and the M. ischiocavernosus in the perineal area, it effects the **ejaculation** of sperm from the urethra.

The **parasympathetic stimulation** induces the **erection,** the **sympathetic fibres** initate the **emission** and the **N. pudendus** causes the **ejaculation.**

Clinical Remarks

During surgical resection of the para-aortal lymph nodes, e.g. when there are testicular or colon carcinomas in the area of the descending colon or in the case of operations on the aorta and the large iliac arteries, the sympathetic fibres can be damaged, which can make an emission, and hence ejaculation, impossible **(Impotentia generandi).** During operations on the prostate gland, e.g. for prostate cancer or pronounced hyperplasia, the parasympathetic fibres to the penis may be cut making an erection no longer possible **(Impotentia coeundi).**

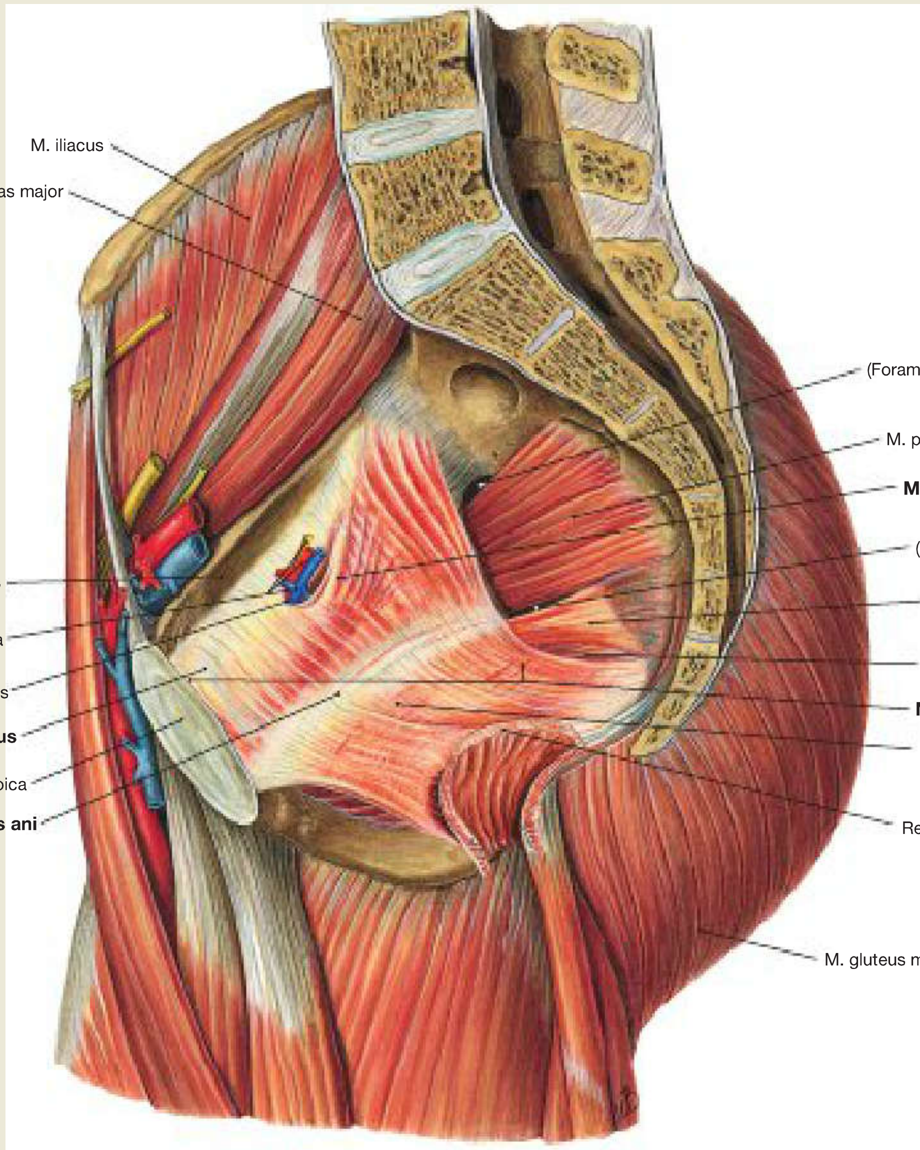


Fig. 7.96 Muscles of the pelvic floor, Diaphragma pelvis, thigh and hip in men; view from the left side.
The pelvic floor closes the pelvic cavity caudally.
Structure:
- **M. levator ani,** comprising M. pubococcygeus, M. iliococcygeus, and M. puborectalis
- **M. ischiococcygeus**

In contrast to the M. pubococcygeus and the M. ischiococcygeus, the M. iliococcygeus does not originate from the Os coxae but from the **Arcus tendineus musculi levatoris ani,** a reinforcement of the fascia of the M. obturatorius internus.

The muscles of both sides spare the levator hiatus (Hiatus levatorius) (→ Fig. 7.128) between them. This muscular gap is divided by the connective tissue of the perineal body (Centrum perinei) in a **Hiatus urogenitalis** (anterior) as a passage for the urethra and a **Hiatus analis** (posterior) for the rectum.
The pelvic floor is innervated by direct branches of the Plexus sacralis (S3–S4).
Function: The pelvic floor stabilises the position of the pelvic organs and is thus essential for urinary and faecal continence. Pelvic floor weakness with incontinence is relatively rare in men, since potential injuries due to repetitive strain during childbirth is lacking.

→ T 20a

Perineal Muscles in Men

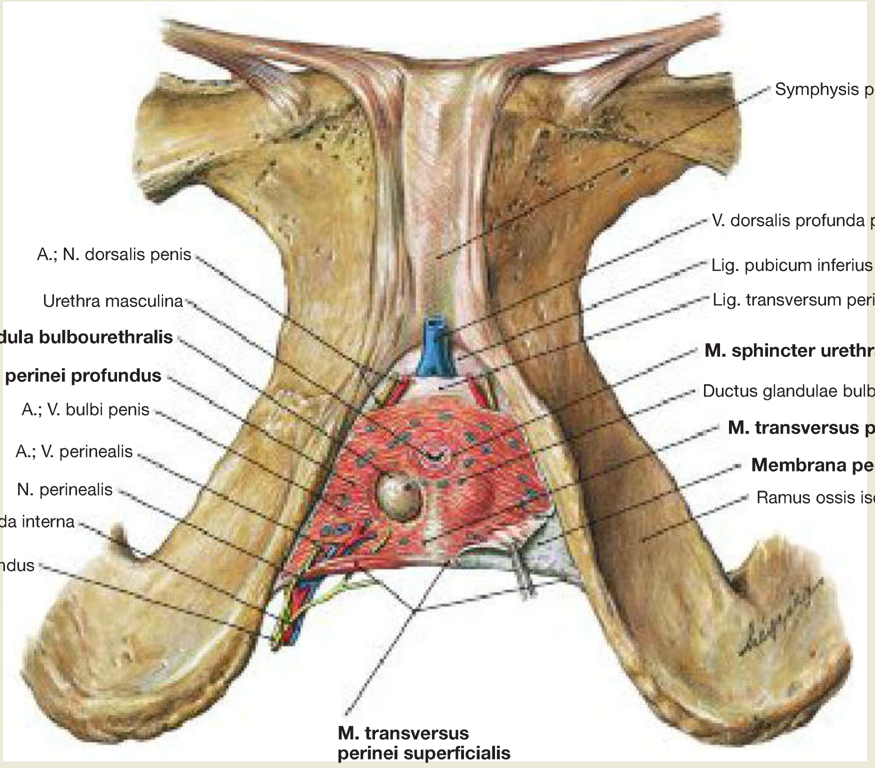


Fig. 7.97 Perineal muscles in men; caudal view; after removal of all other muscles.

In men, the levator hiatus (Hiatus levatorius) is almost entirely closed by the connective tissue of the underlying perineal muscles, so that only the passage of the urethra (Urethra masculina) remains free.

The perineal muscles in men consist of a relatively strong **M. transversus perinei profundus,** located at the posterior margin of the thin **M. transversus perinei superficialis.** Since these muscles form a kind of muscle plate, the term 'Diaphragma urogenitale' was used to compare it to the Diaphragma pelvis of the pelvic floor. However, since there is no real diaphragm and a comparable muscle plate in women is not present, the term was dropped.

The M. transversus perinei profundus also forms the M. sphincter urethrae externus which represents the voluntary sphincter of the urinary bladder.

On the top and underside, the M. transversus perinei profundus is covered by a fascia. On the bottom it is reinforced and here is referred to as the **Membrana perinei.**

The space between the two fascias, which is almost completely filled by the M. transversus perinei profundus, is the **deep perineal space** (Spatium profundum perinei). In men, this contains the COWPER's glands (Glandulae bulbourethrales) next to the urethra which are traversed by the deep branches of the N. pudendus and the A. and V. pudenda interna on the way to the root of the penis.

The **superficial perineal space** (Spatium superficiale perinei) lies caudally to the Membrana perinei and contains amongst others the M. transversus perinei superficialis.

→ T 20b

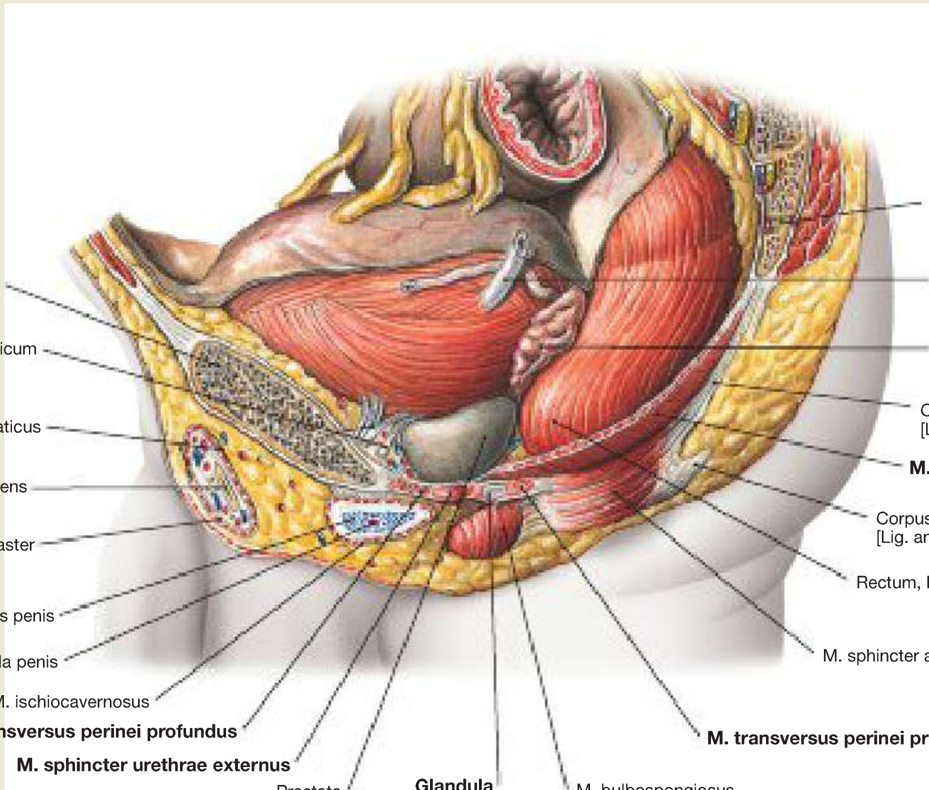


Fig. 7.98 Pelvic floor, Diaphragma pelvis, and perineal muscles in men; view from the left side.

At its anterior and posterior aspect, the pelvic floor consists of the **M. levator ani** and the **M. ischiococcygeus,** respectively. Under the pelvic floor is the **M. transversus perinei profundus** of the perineal muscle system, which also forms the **M. sphincter urethrae externus** as the sphincter for the urinary bladder. In the M. transversus perinei profundus, the COWPER's glands (Glandulae bulbourethrales) are embedded.

→ T 20

Perineal Region in Men

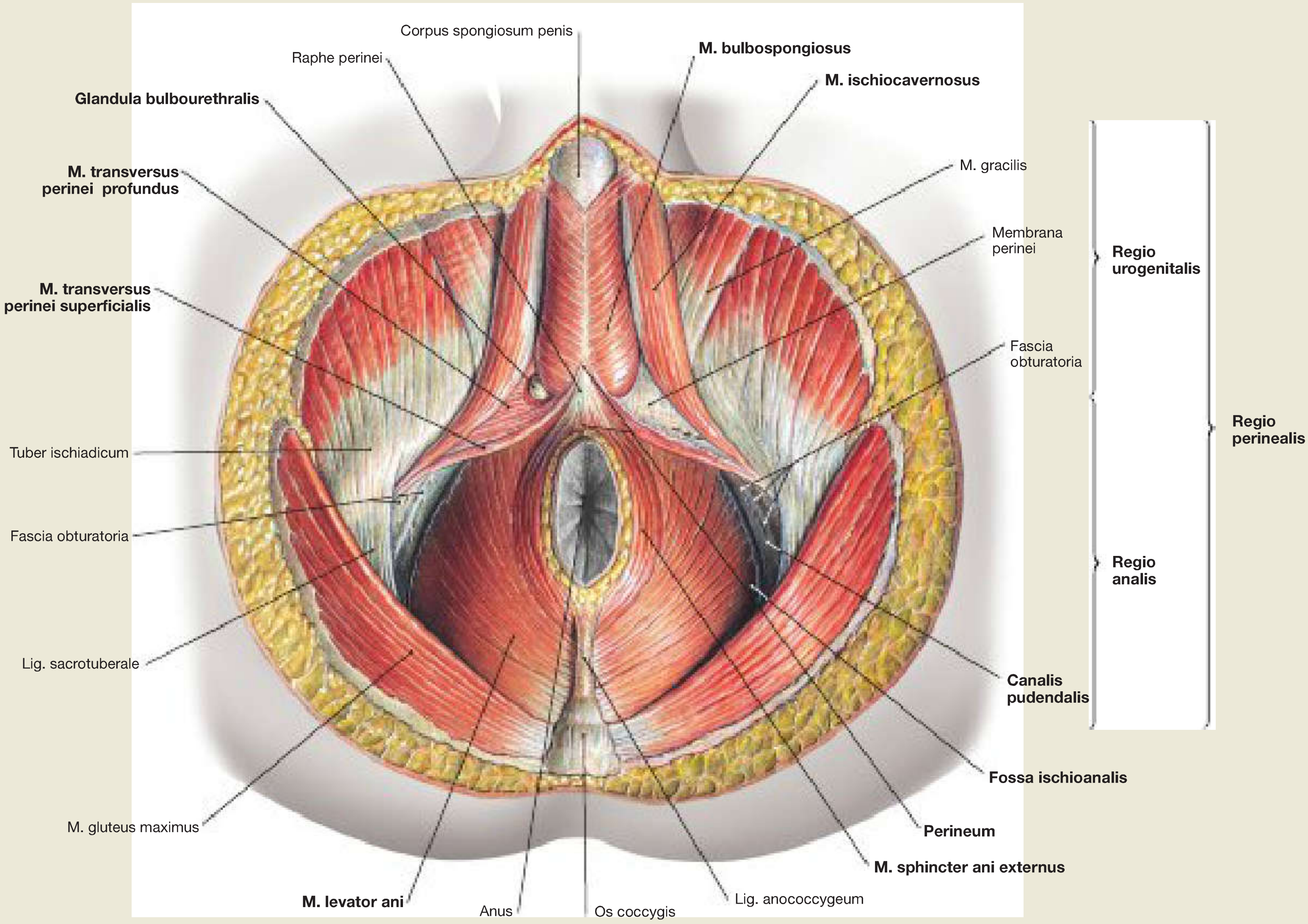


Fig. 7.99 Perineal region, Regio perinealis in men; caudal view; after removal of all neurovascular pathways.

The **perineal region** extends from the inferior margin of the pubic symphysis (Symphysis pubica) to the tip of the coccyx (Os coccygis). The term **perineum** in men, however, exclusively describes the small connective tissue bridge between the root of the penis and the anus. The perineal region can be divided into a ventral **Regio urogenitalis** with external genitalia and urethra, and a dorsal **Regio analis** around the anus. Both areas include the following spaces:

- The Regio analis contains the **Fossa ischioanalis** (→Table), which constitutes a pyramid-shaped space on both sides of the anus. Cranially the space is delimited by the M. levator ani of the pelvic floor. The lateral wall encloses the fascial duplicature of the M. obturatorius internus (Fascia obturatoria), the pudendal canal (ALCOCK's canal). Inside this the A. and V. pudenda interna and the N. pudendus run after their passage from the gluteal region through the Foramen ischiadicum minus.

The Regio urogenitalis contains the two **perineal spaces:**

- The **deep perineal space** (Spatium profundum perinei) is extensively taken up by the M. transversus perinei profundus and also contains the COWPER's glands (Glandulae bulbourethrales).
- In the **superficial perineal space** (Spatium superficiale perinei) there are the M. transversus perinei superficialis, the M. bulbospongiosus and the M. ischiocavernosus, which stabilise the cavernous bodies of the Radix penis and enable ejaculation.

Delimitation of the Fossa ischioanalis	
medial and cranial	M. sphincter ani externus and M. levator ani
lateral	M. obturatorius internus
dorsal	M. gluteus maximus and Lig. sacrotuberale
ventral	posterior margin of the superficial and the deep perineal spaces, anterior recess reaches the pubic symphysis
caudal	fascia and skin of the perineum

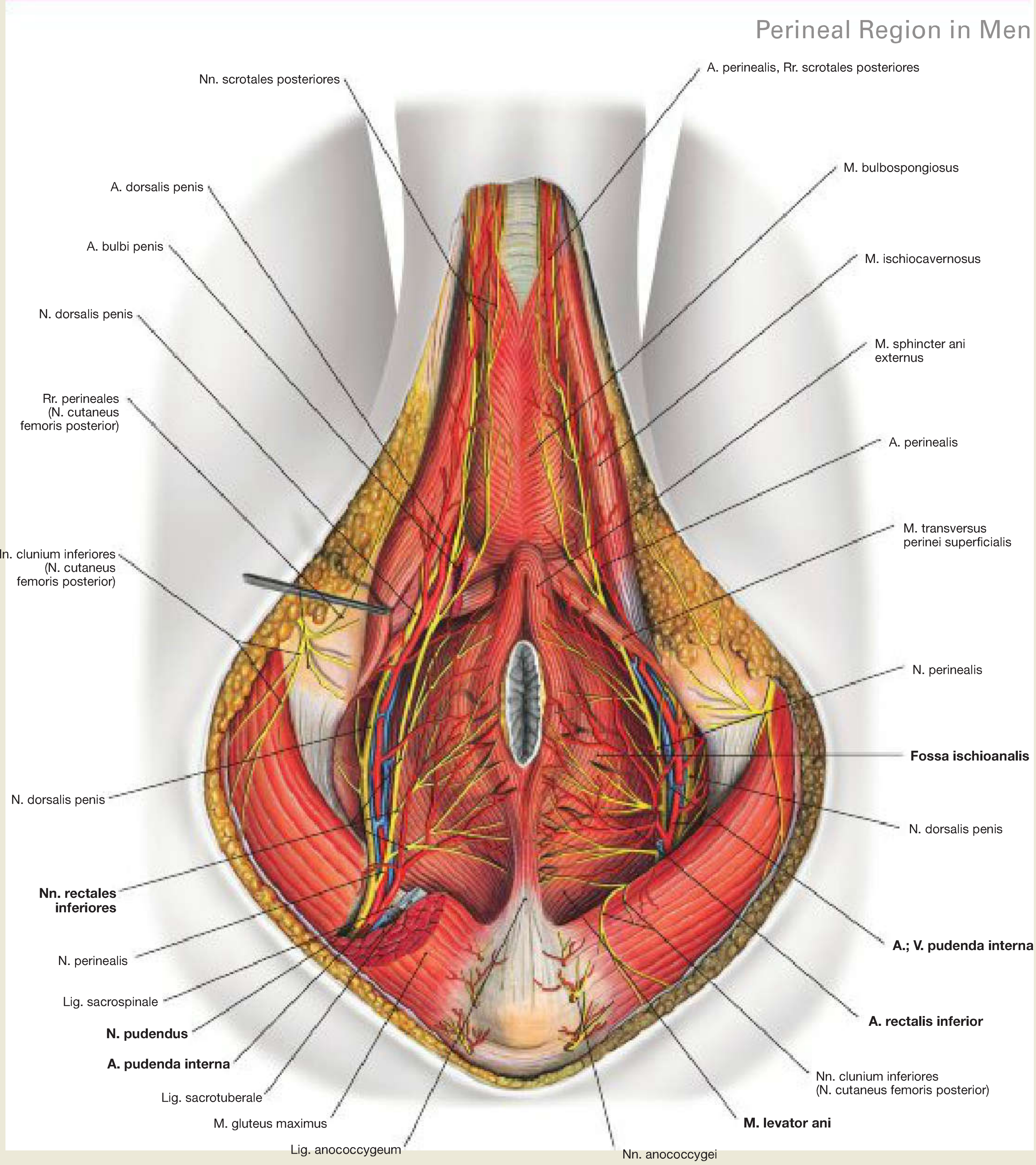


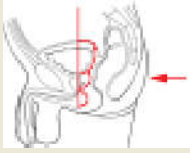
Fig. 7.100 Vessels and nerves of the perineal region, Regio perinealis, in men; caudal view.
The neurovascular pathways run dorsolaterally in the Canalis pudendalis (ALCOCK's canal) formed by a fascial duplicature of the M. obturatorius internus, into the pyramid-shaped **Fossa ischioanalis** which is filled with fat. Next they form the branches to the anus and anal canal, and traverse the space ventrally to pass through the two perineal spaces to the Radix of the penis.

Contents of the Fossa ischioanalis:
- A. and V. pudenda interna and N. pudendus: in the Canalis pudendalis (ALCOCK's canal)
- A., V. and N. rectalis inferior: to the anal canal

Clinical Remarks

The Fossa ischioanalis is clinically highly relevant because of its expansion on both sides of the anus. **Collection of pus** (abscesses), e.g. where there are fistulas from the anal canal, can extend throughout the Fossa ischioanalis up to the front of the pubic symphysis. These kinds of abscesses not only generate non-specific inflammatory signs but also cause intense pain in the perineal region.

Perineal Spaces in Men



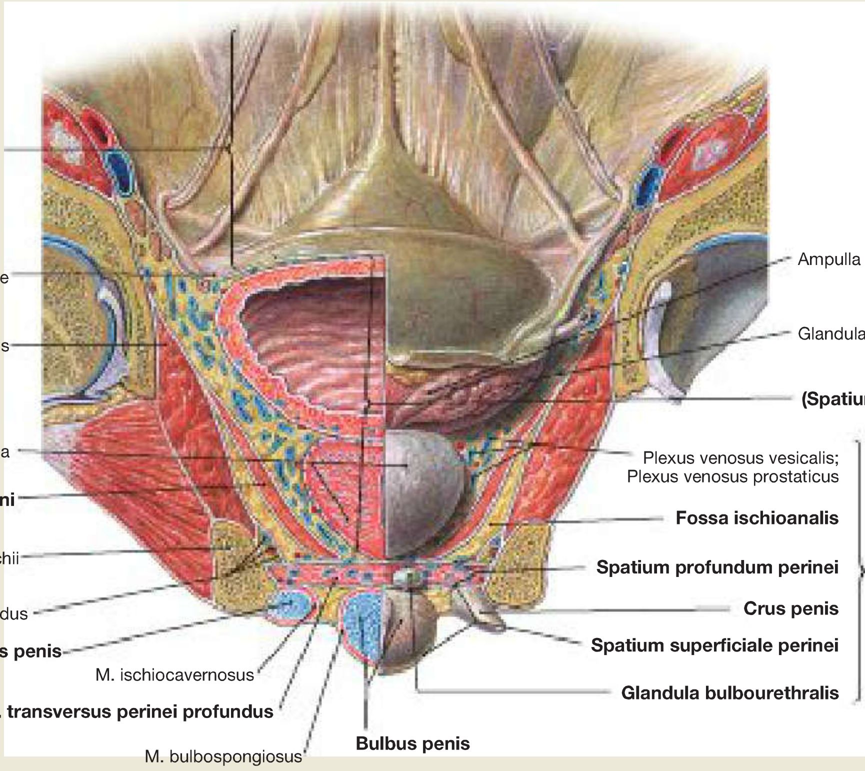


Fig. 7.101 Perineal spaces in men; on the left side, frontal section at the level of the femoral head; right side: dorsal view. (See also section in → Fig. 7.142a)

The frontal section shows **three levels** of the male pelvis:

- **peritoneal cavity of the pelvis (Cavitas peritonealis pelvis),** which is caudally delimited by the parietal peritoneum
- **subperitoneal space (Spatium extraperitonale pelvis)** passing down to the M. levator ani of the pelvic floor
- **perineal region (Regio perinealis)** below the pelvic floor. The anterior portion is generally taken up by the two perineal spaces; however it also still contains the very variable anterior recesses of the Fossa ischioanalis (shown here separately on the right and left).

The **deep perineal space** (Spatium profundum perinei) is almost completely filled by the M. transversus perinei profundus. It also contains the COWPER's glands (Glandulae bulbourethrales) and the passage of the urethra. It is traversed by the deep branches of the N. pudendus (N. dorsalis penis), and of the A. and V. pudenda interna (A. bulbi penis, A. dorsalis penis, A. profunda penis) before reaching the root of the penis. The Nn. cavernosi penis pierce the perineum and enter the Corpora cavernosa of the penis.

The **superficial perineal space** (Spatium superficiale perinei) is located between the Membrana perinei at the underside of the M. transversus perinei profundus and the body fascia (Fascia perinei). In addition to the M. transversus perinei superficialis, it contains the proximal parts of the cavernous bodies of the penis. The Bulbus penis is surrounded by the M. bulbospongiosus and the Crura penis on both sides by the M. ischiocavernosus. The superficial branches (N. perinealis with Nn. scrotales posteriores) of the N. pudendus and the A. and V. pudenda interna (A. perinealis with Rr. scrotales posteriores) continue through this space to the scrotum.

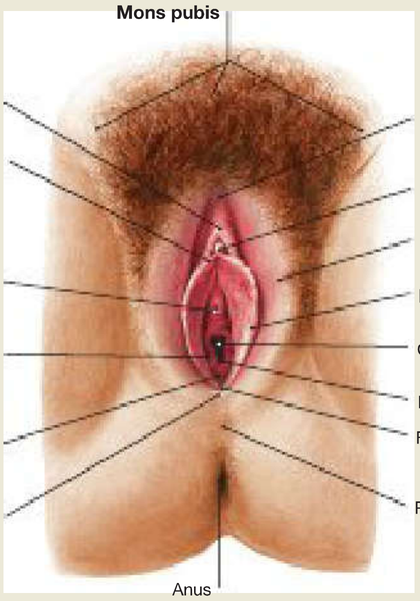


Fig. 7.102 External female genitalia, Organa genitalia feminina externa; caudal view.

In the female genitalia it is important to distinguish between the external genitalia (Organa genitalia feminina externa) and the internal genitalia (Organa genitalia feminina interna → Fig. 7.105).

The **external genitalia,** grouped together as the **Vulva,** include:

- Mons pubis
- Labia majora pudendi
- Labia minora pudendi
- Clitoris
- Vestibulum vaginae
- Glandulae vestibulares majores (BARTHOLIN's glands) and minores

The vaginal vestibule extends to the hymen, which borders the vaginal orifice (Ostium vaginae). Ventrally thereof is the external urethral orifice (Ostium urethrae externum).

The external genitalia are the **sex organs** and serve for intercourse.

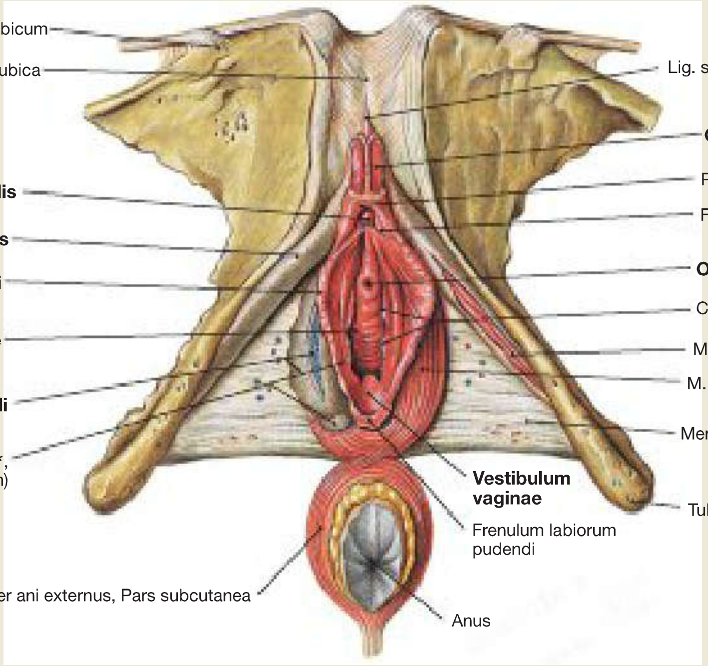


Fig. 7.103 External female genitalia, Organa genitalia feminina externa; caudal view, after removal of the body fascia and the neurovascular pathways.

The **Labia majora pudendi,** which have been removed here, contain the bulb of the vestibule (Bulbus vestibuli). Between these are the **Labia minora pudendi,** surrounding the **vaginal vestibule (Vestibulum vaginae),** into which lead laterally the **vestibular glands (Glandulae vestibulares majores [BARTHOLIN's glands] and minores).** In front, the labia minora pass with a ribbon of tissue (Frenulum clitoridis) to the glans of the clitoris (Glans clitoridis). The clitoris is the sensory organ for sexual arousal. The two cavernous bodies (Corpora cavernosa clitoridis) form a short body (Corpus clitoridis), which caudally ends with the glans before separating into the Crura clitoridis which are anchored to the inferior ischiopubic rami. The crura are surrounded by the Mm. ischiocavernosi. The M. bulbospongiosus stabilises the **bulb of the vestibule (Bulbus vestibuli).**

Developmentally there exist some similarities between the structure of the clitoris, which also has a prepuce (Preputium clitoridis), and the structure of the penis. Also the filling mechanisms of the erectile tissue and erection are similar in both sexes.

* clinical term: BARTHOLIN's gland

Development of the External Female Genitalia

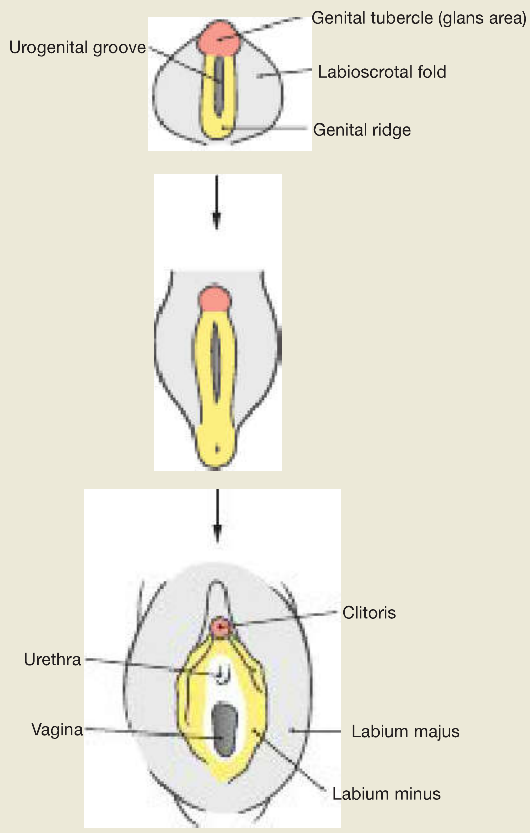


Fig. 7.104 Development of the external female genitalia, Organa genitalia feminina externa. [L126]
The external genitalia develop from the caudal part of the Sinus urogenitalis. The urogenital sinus develops from the cloaca of the hindgut and forms the urinary bladder and parts of the urethra (→ Fig. 7.22). Alongside, there is also the ectoderm with the lower connective tissue (mesenchyme) beneath. The first part in the development of the external genitalia is identical in both sexes (indifferent gonad). The anterior wall of the Sinus urogenitalis indents to form the **urethral groove** which is bordered on both sides by the **urethral folds.** To the lateral of these are the **labioscrotal folds** and anterior is the **genital tubercle.**
Subsequently, the genital tubercle develops into the **clitoris** (Corpora cavernosa) under the influence of the female sex hormone oestrogen which is produced in the ovary. Unlike in men, the urethral folds and the labioscrotal folds do not close. The urethral folds become the **Labia minora,** the labioscrotal folds form the **Labia majora.** The short female urethra and the BARTHOLIN's glands develop from the **Sinus urogenitalis.**

Clinical Remarks

The common developmental stages of the external genitalia in both sexes explain the occurrence of penis-like hyperplasias of the clitoris in cases of excessive production of male sex hormones such as in **adrenogenital syndrome** (production of androgens in the cortex of the adrenal glands).

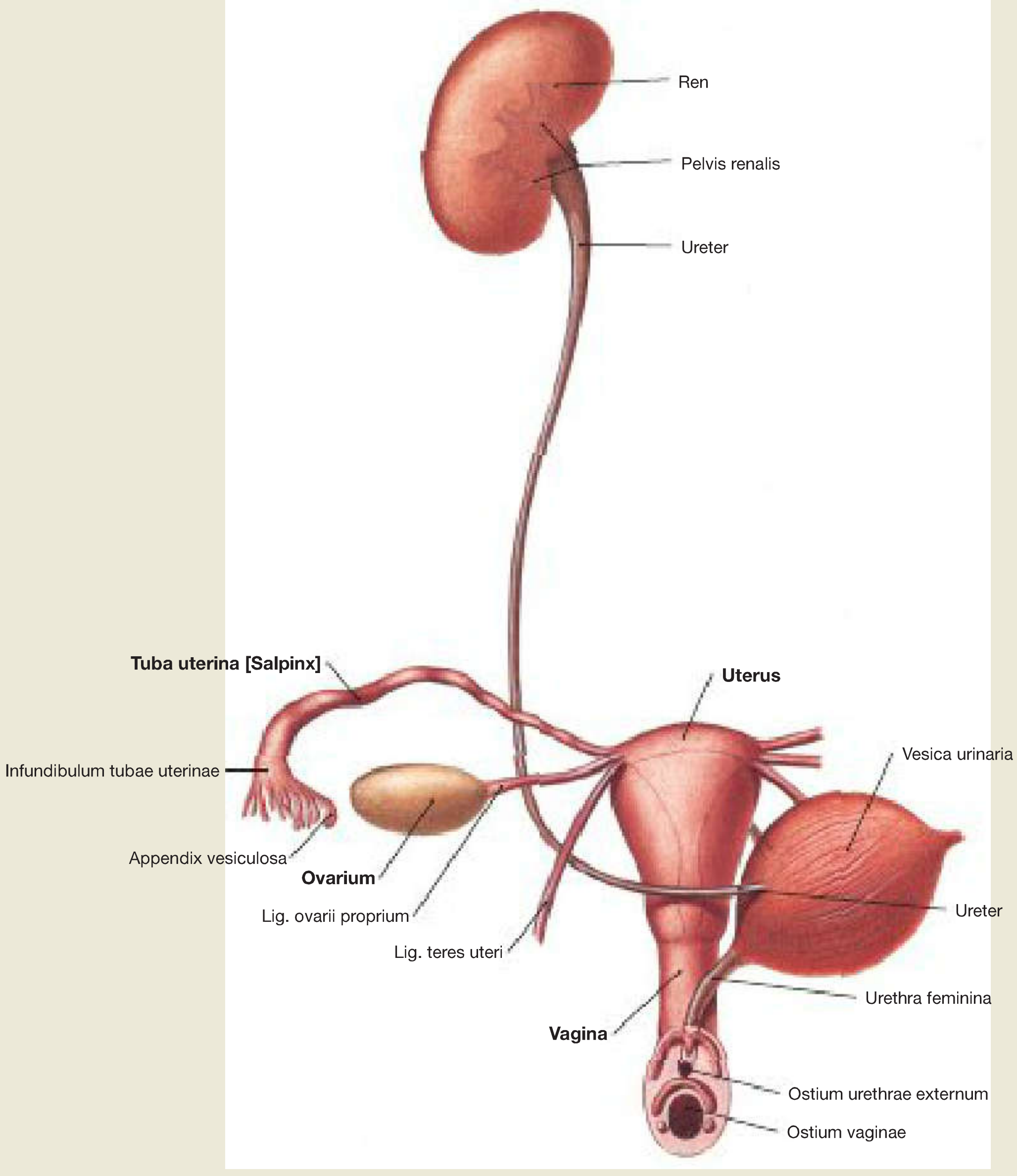


Fig. 7.105 Female urinary and genital organs, Organa urogenitalia feminina; ventral view.
The **internal genitalia** include:
- vagina
- uterus
- uterine tube (Tuba uterina)
- ovary

Uterine tubes and ovaries are paired organs and are collectively regarded as uterine **adnexa.**

The internal genitalia in women are both **reproductive** and **sexual.** Functionally, the ovary serves to mature follicles (and ovulation) and to produce female sex hormones (oestrogens and progesterone). The uterine tubes are the location for insemination. They transport the ovum into the uterus, where the development of the child takes place during pregnancy. The vagina is used for sexual intercourse and is the birth canal.

Development of the Internal Female Genitalia

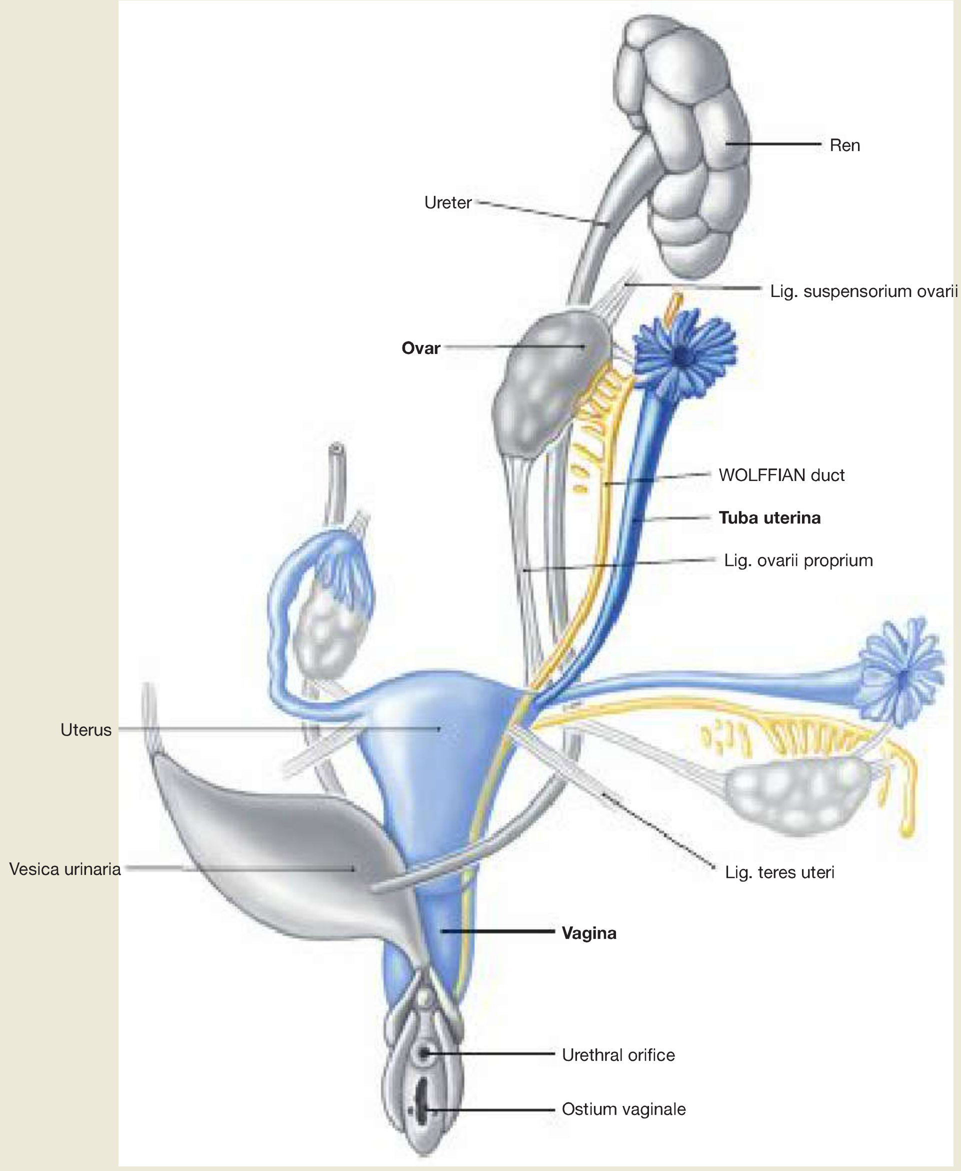


Fig. 7.106 Development of the internal female genitalia, Organa genitalia feminina interna. [L126]
The internal genitalia develop in both sexes in the same way until week 7 (indifferent gonad → Fig. 7.22). In the female, the primordium of the primitive gonad then develops into the ovary. Similar to the testis, the ovary also develops in the lumbar region at the level of the mesonephros. In the course of the body growth, the ovary moves but only up to the lesser pelvis and it does not leave the peritoneal cavity. Hence the ovary and adnexa are **intraperitoneal.**

Without the suppressing effects of the anti-MÜLLERIAN hormone from the testis, the MÜLLERIAN ducts differentiate into female genitalia. From the 12th week, these form the uterine tubes and in the distal amalgamated area the uterus and vagina. The lower part of the vagina develops from the urogenital sinus. If the MÜLLERIAN ducts do not merge with each other, there may be **septation** of the lumen of the uterus (uterus septus or subseptus) or even **double uterus** (uterus duplex).

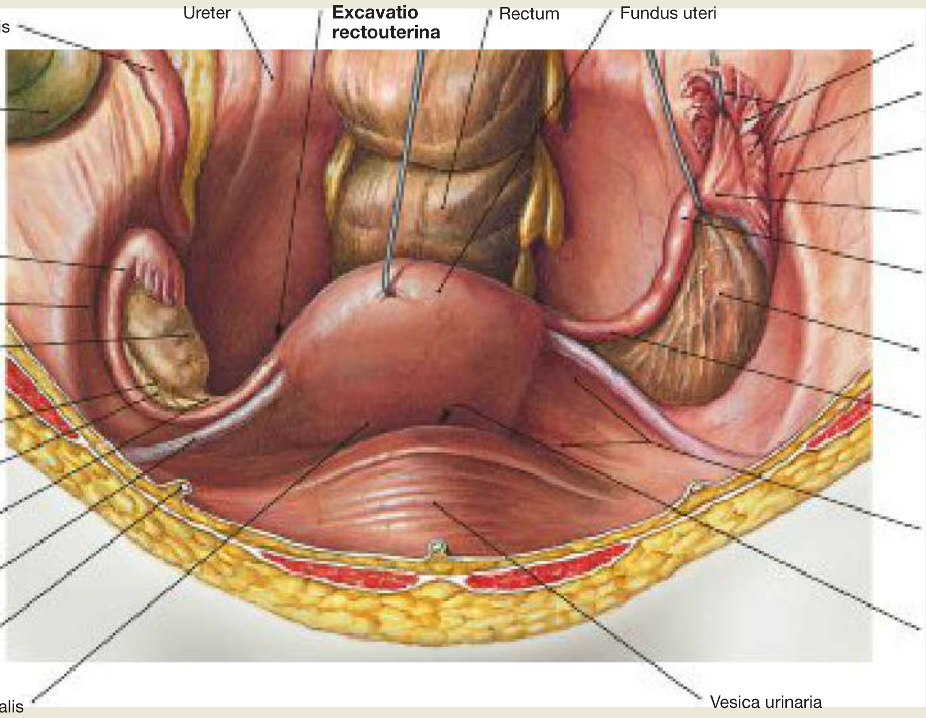


Fig. 7.107 Uterus, ovary, Ovarium, and uterine tube, Tuba uterina, with peritoneal duplicature; ventral view.
Uterus, uterine tubes and ovaries are positioned intraperitoneally. Their peritoneal duplicatures (Lig. latum uteri, Mesosalpinx, Mesovarium) form a transverse fold in the lesser pelvis. The Lig. teres of the uterus passes from the angle of the uterine tubes to the front of the lateral pelvic wall and into the inguinal canal, to finally end in the connective tissue of the Labia majora. The Lig. ovarii proprium also originates from the uterotubal junction and links the uterus and ovaries. The ovary nestles into an indentation, which is created by the branching of the A. and V. iliaca communis (Fossa ovarica). The Lig. suspensorium ovarii runs laterally. It is attached to the side of the pelvic wall and contains the A. and V. ovarica.

The close topographical relationships between the adnexa (ovary and Tuba uterina) and the vermiform appendix (Appendix vermiformis) of the colon explain why inflammations of the appendix (appendicitis) as well as those of the uterine tube (salpingitis) may cause similar pain in the right lower abdominal quadrant. Between the uterus and urinary bladder is the **Excavatio vesicouterina** as an enlargement of the abdominal cavity. The **Excavatio rectouterina** (pouch of DOUGLAS) behind the uterus is the most caudal extension of the peritoneal cavity in women and may collect fluids and pus in cases of inflammatory processes in the lower abdomen.

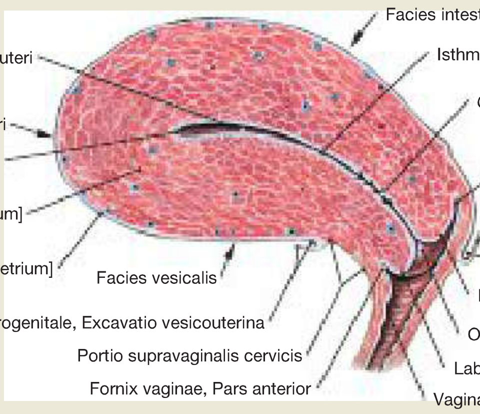


Fig. 7.108 Layers of the wall of the uterus, sagittal section; view from the left side.
Internally the wall of the uterus is made from a mucous membrane **(endometrium),** which structure and thickening change during the female menstrual cycle, in order to enable the implantation after fertilisation of an ovum. It is attached to a thick layer of **smooth muscles (myometrium),** of which the muscle fibres show different arrangements. On the outside is the peritoneal coating of visceral peritoneum **(perimetrium).**

Parts of ligaments are referred to according to the nomenclature of the layers of the wall. The **Lig. latum uteri (mesometrium)** is the continuation of the peritoneal coating and forms a frontal abdominal peritoneal duplicature from the intraperitoneally located body of the uterus to both sides of the lesser pelvis. The **Lig. cardinale (parametrium),** on the other hand, anchors the cervix of the uterus lying in a subperitoneal position on both sides on the pelvic bone.

Internal Genitalia – Structure

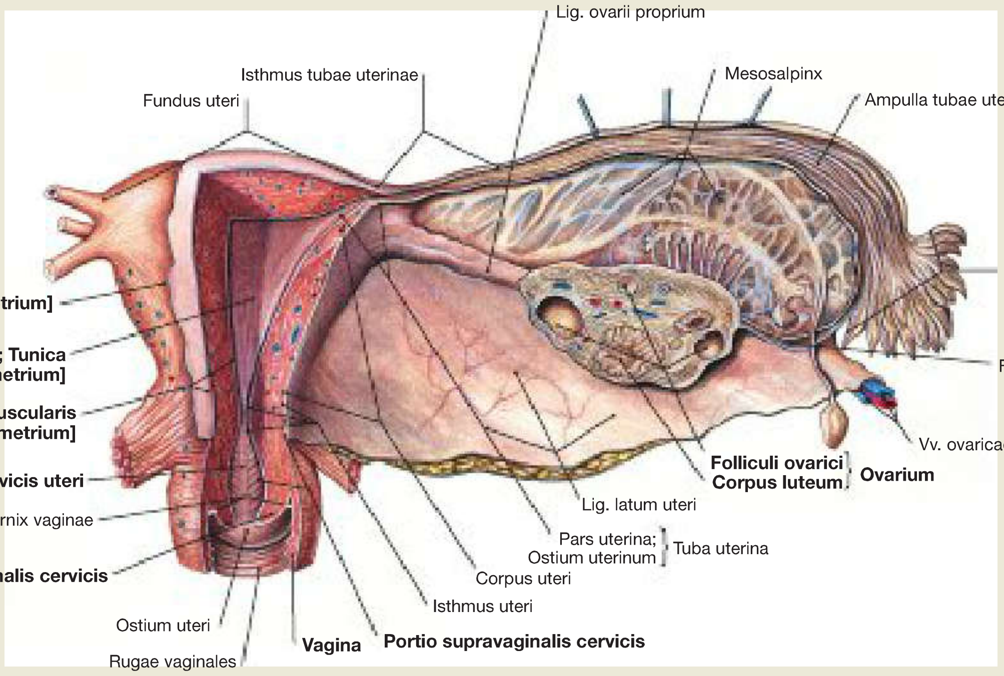


Fig. 7.109 Uterus, vagina, ovary, Ovarium, and uterine tube, Tuba uterina; frontal section; dorsal view.

The space inside the **uterus** is divided into the Cavitas uteri in the body and the Canalis cervicis uteri in the Cervix of the uterus. The cervix culminates with its lower portion in the vagina, and is therefore referred to as the Portio vaginalis cervicis. The upper portion is the Portio supravaginalis cervicis. The **vagina** is a hollow muscular organ of about 10 cm in length in a **subperitoneal location.** Adjacent to the Portio vaginalis cervicis is the vaginal vault (Fornix vaginae). At the inner surface, both the anterior and posterior walls of the vagina (Paries anterior and Paries posterior) reveal transverse mucosal folds (Rugae vaginales).

The frontal section also shows the structure of the **uterine wall:** the internal mucosal layer (Tunica mucosa, endometrium), then the strong muscular layer (Tunica muscularis, myometrium) of smooth muscles, and the outermost peritoneal lining (Tunica serosa, perimetrium).

The stroma of the **ovary** contains the follicles (Folliculi ovarici), which contain the egg cells, and later in the female cycle turns into the yellow body called Corpus luteum. Follicles and Corpora lutea produce the female sex hormones (oestrogen and progesterone) which regulate the cycle-dependent differentiation of the endometrium.

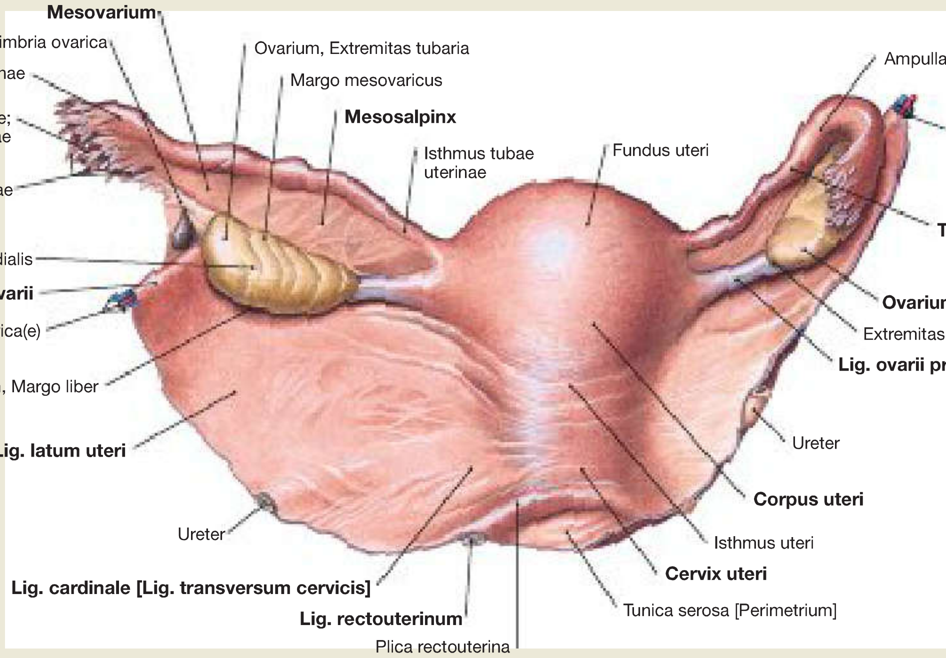


Fig. 7.110 Uterus, ovary, Ovarium, and uterine tube, Tuba uterina, with peritoneal duplicature; ventral view.

The **uterus** (Metra) is 8 cm long, 5 cm wide and 2–3 cm thick. It is divided into a body (Corpus uteri) with a superior fundus (Fundus uteri) and a neck (Cervix uteri) which are distinct from each other by a constriction (Isthmus uteri). The uterine tubes are attached to the body of the uterus (Tuba uterina) on both sides providing a connection to the ovary. The **uterine tube** (Tuba uterina [Salpinx]) is 10–14 cm long and has several parts:

- **Infundibulum tubae uterinae:** 1–2 cm long, contains the opening to the abdominal cavity (Ostium abdominale tubae uterinae) and fringe- like appendages (Fimbriae tubae uterinae) for holding the ovum during ovulation
- **Ampulla tubae uterinae:** 7–8 cm long, crescent-shaped around the ovary
- **Isthmus tubae uterinae:** 3–6 cm long, constriction at the transition to the uterus
- **Pars tubae uterinae:** enters the uterus (Ostium uterinum)

The **ovary (Ovarium)** is 3 × 1.5 × 1 cm in size and oval. A distinction is made between an upper pole (Extremitas tubaria) and a lower pole (Extremitas uterina). At its anterior margin, the mesovarium is attached (Margo mesovaricus), while the posterior margin remains free (Margo liber).

Uterus, uterine tubes and ovary are **intraperitoneal** and therefore have their own **peritoneal duplicatures** covered by a serous membrane and also have additional **small ligaments,** which are of clinical relevance during gynaecological operations:

- **Lig. latum uteri:** frontally positioned peritoneal folds
- **mesovarium** and **mesosalpinx:** peritoneal duplicatures of ovary and uterine tube to the Lig. latum
- **Lig. cardinale (Lig. transversum cervicis):** connective tissue attaching the cervix to the lateral pelvic wall
- **Lig. rectouterinum** (clinical term: Lig. sacrouterinum): connective tissue attaching the cervix dorsally
- **Lig. teres uteri** (clinical term: Lig. rotundum): the round ligament running from the uterotubal junction through the inguinal canal to the Labia majora
- **Lig. ovarii proprium:** joins ovary and uterus
- **Lig. suspensorium ovarii** (clinical term: Lig. infundibulopelvicum): attaches the ovary to the lateral pelvic wall, guides A. and V. ovarica

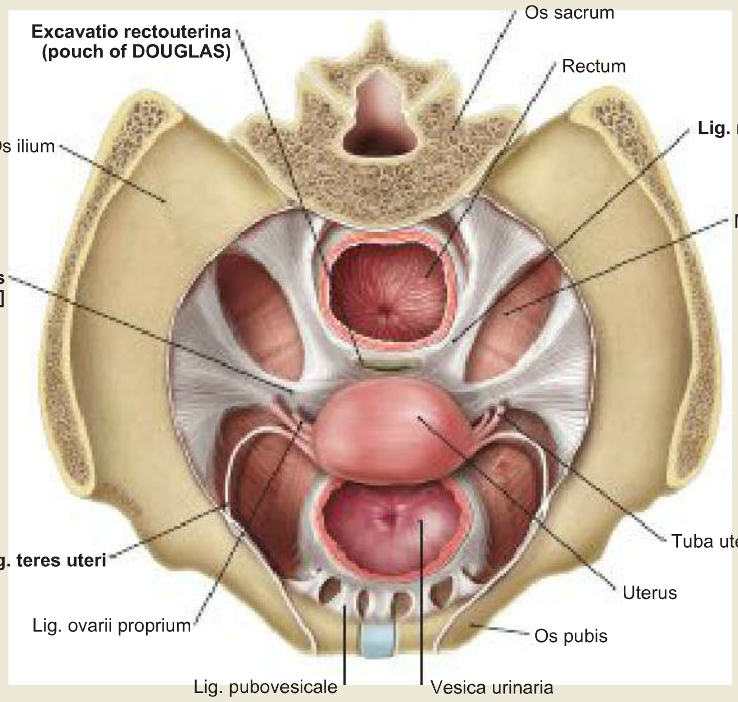


Fig. 7.111 Ligaments of the uterus; cross-section at the level of the cervix of the uterus; cranial view; semi-schematic illustration. [L238]

In some locations, the connective tissue in the lesser pelvis is condensed to the so-called ligaments. These ligaments serve for fixing the various sections of the uterus in place. The **Lig. transversum cervicis (Lig. cardinale)** fixes the Portio supravaginalis of the cervix on both sides to the pelvic bone. The **Lig. rectouterinum** (clinical term: **Lig. sacrouterinum)** moves dorsally from the cervix and continues on both sides of the rectum to reach the inside of the sacrum. The **Lig. teres uteri,** however, is a remnant of the Gubernaculum and runs from the uterotubal junction ventrally through the inguinal canal to the connective tissue above the labia majora. It is also accompanied by lymphatic vessels to the inguinal lymph nodes. The band is important for fixing the uterus in place, because it stabilises it in its anteversion in relation to the vagina and hence prevents the uterus from prolapsing as a result of an increase in intra-abdominal pressure, for example due to coughing and sneezing (→ Fig. 7.114).

The **pouch of DOUGLAS (Excavatio rectouterina)** is the deepest space of the peritoneal cavity, reaching into the connective tissue of the lesser pelvis.

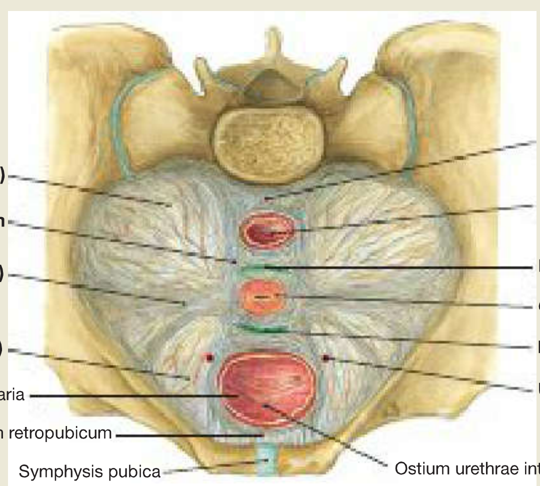


Fig. 7.112 Ligaments and connective tissue spaces of the uterus; cross-section at the level of the cervix of the uterus; cranial view; semi-schematic illustration.

The connective tissue in the lesser pelvis is divided from the clinical point of view in the vicinity of the individual organs; individual fibres are referred to as bands, even though such a distinction in anatomical terms is clearly impossible.

- **Parametrium:** fibres attaching the cervix to the lateral pelvic wall (Lig. cardinale)
- **Paraproctium:** connective tissue around the rectum
- **paravesical space:** connective tissue around the bladder
- **Paracolpium:** connective tissue around the vagina

Only the **Lig. rectouterinum** of the cervix is dorsally better delineated and is also exposed for gynaecological operations, in order to conserve the nerve fibres of the Plexus hypogastricus inferior.

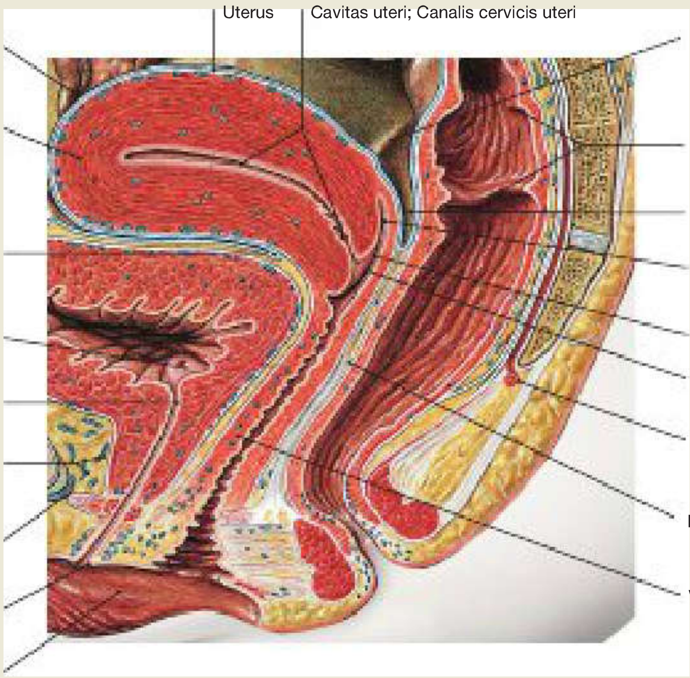


Fig. 7.113 Vagina and uterus; median section; view from the left side. The **neck of the uterus (Cervix uteri)** is divided into two parts: the inferior part (Portio vaginalis) extends into the vaginal vault and goes with the lumen (Canalis cervicis uteri) at the external cervical os (Ostium uteri) into the vagina. The superior part (Portio supravaginalis) goes via a constriction (Isthmus) at the internal cervical os (Ostium anatomicum uteri internum) into the cavity of the uterus (Cavitas uteri). The **vagina** has anterior and posterior walls (Parietes anterior and posterior), both revealing transverse folds (Rugae vaginales). It culminates in the vestibule (Vestibulum vaginae), which is already regarded as one of the external genitalia. At the cranial end, the Portio vaginalis of the cervix surrounds the vagina with the vaginal vault (Fornix vaginae), which is divided into a frontal, posterior and anterior section. The posterior vaginal vault is in direct contact with the pouch of DOUGLAS (*), which represents a caudal enlargement of the peritoneal cavity.

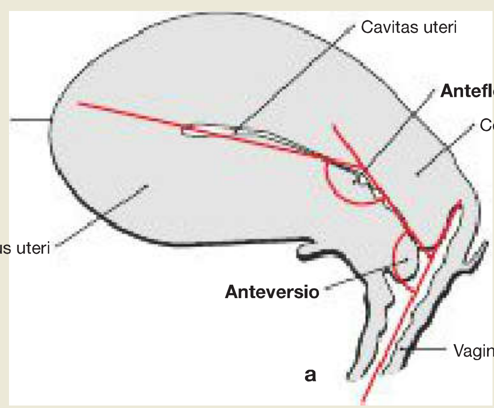
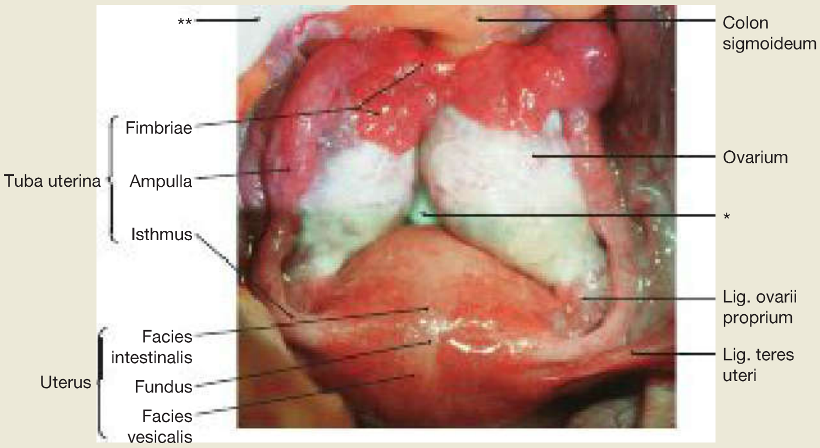


Fig. 7.114a to d Location of uterus and vagina; view from the right side.

- **a** In normal position, the uterus is angled in its ventral aspect in relation to the vagina **(anteversion)** and the body is tilted anteriorly in relation to the neck **(anteflexion).** This position acts as protection and prevents the uterus from bulging out through the vagina due to an increase in intraabdominal pressure (sneezing, coughing).
- **b** Anteversion, anteflexion = normal position
- **c** Anteversion, missing anteflexion
- **d** Retroversion, retroflexion



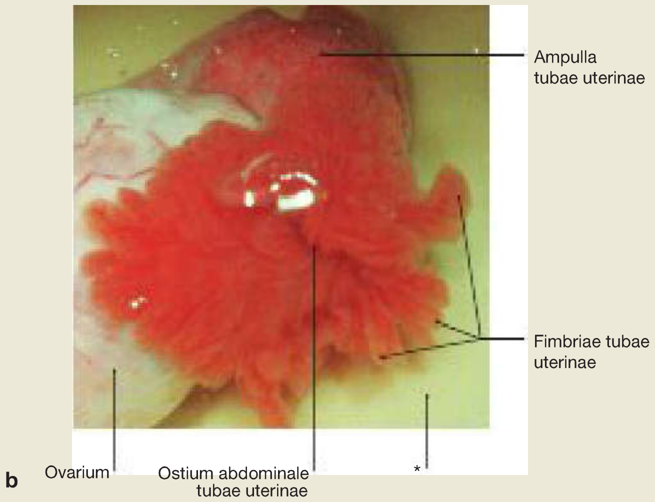


Fig. 7.115a and b Ovary, Ovarium, uterine tube, Tuba uterina, and uterus; surgical situs in a young woman. [T911]
a The ovaries are medially pushed up by compresses (*); ventral view.
b For the representation of the tube funnel, the pelvic cavity was filled with saline; dorsal view.
The **tube funnel** at its abdominal end is open towards the abdominal cavity. The fimbriae, which are arranged around this opening, are in contact with the surface of the ovary and receive the bouncy ovum during ovulation. In the uterine tube, if applicable, fertilisation occurs. The ovum is then transported by the uterine tube motility to the uterus, where it is implanted if insemination has taken place. The size of the ovaries should be noted; this is typical in a young woman. Most other images in textbooks are mainly from dissections of elderly women, in whom the ovaries and uterus are often atrophied.

** swab

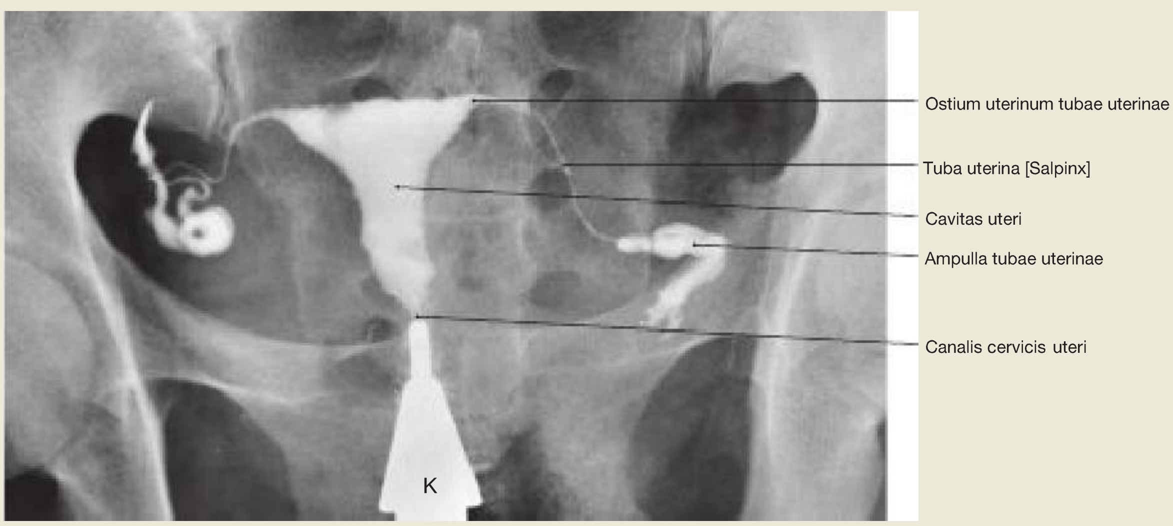
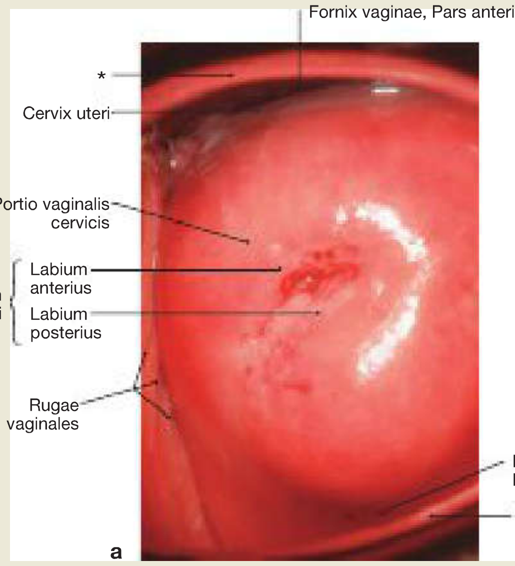


Fig. 7.116 Uterus and uterine tube, Tuba uterina; X-ray imaging with contrast agent, ventral view.
The tubal patency can be checked with an X-ray contrast imaging of uterus and tubes **(hysterosalpingography),** in order to rule out stenosis of the uterine tubes in the case of infertility, which for example can result from inflammation. Today this procedure is usually carried out using ultrasound imaging in which a contrast agent is also used.

K = portio adapter of the injection probe for the contrast agent



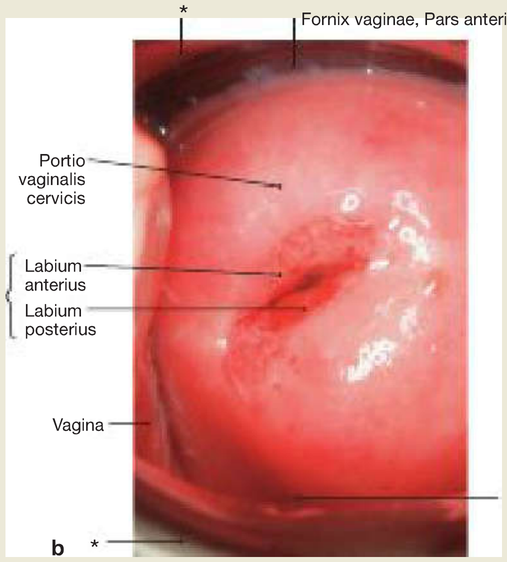


Fig. 7.117a and b Portio vaginalis cervicis; caudal view.
a Portio vaginalis cervicis of a young woman who has not yet delivered a child (nullipara)
b Portio vaginalis cervicis of a young woman who has delivered two children

To inspect the Portio vaginalis cervicis, it is pulled wide open from the normal slit-shaped form by two specula.

* speculum

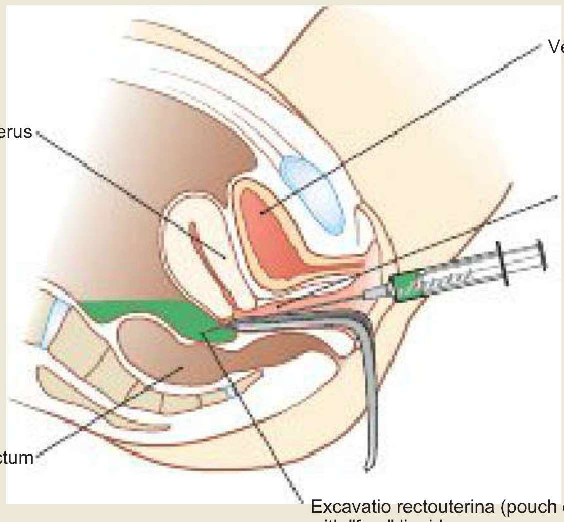


Fig. 7.118 Puncturing of the rectouterine pouch, the pouch of DOUGLAS; schematic illustration of a median section, view in lithotomy position from the right side. [L126]

Due to the direct contact of the **Excavatio rectouterina (pouch of DOUGLAS)** with the posterior vaginal vault, it is possible to examine the peritoneal cavity from the vaginal perspective by using ultrasound or to puncture free fluid in the pouch of DOUGLAS.

Clinical Remarks

Inspection and smears of the cervix are included in gynaecology for routine diagnosis of women under the public health system, and is covered by health insurance funds for women from 20 years of age. The examination should be carried out at least once a year for early detection and removal of any degeneration as a precursor of a malignant tumour **(cervical cancer).** Cervical cancer is among the most common malignant tumours in women under the age of 40. As the cancer can be triggered by viruses of the Human Papilloma Virus (HPV) family, a vaccination has been developed that is recommended for girls in puberty. Vaccination is a relatively sure way to prevent infection. However, due to limited experience to date, it is unclear how many cancers actually can be prevented, so the benefits of the vaccination are currently under discussion.

Since the rectouterine space represents the lowest section of the peritoneal cavity, in upright patients it can be a concentration point for inflammation of the peritoneum **(peritonitis)** or the spread of tumour cells, e.g. free fluid in the pouch of DOUGLAS from the ovary **(peritoneal cancer)**. Also blood from a **ruptured spleen** can be detected by ultrasound. Performing a puncture of the pouch of DOUGLAS has lost significance, since the cause of such findings can usually be clarified by imaging. If this is not successful, free fluid from a puncture can be screened for white blood cells, bacteria and tumour cells..

Uterus during Pregnancy

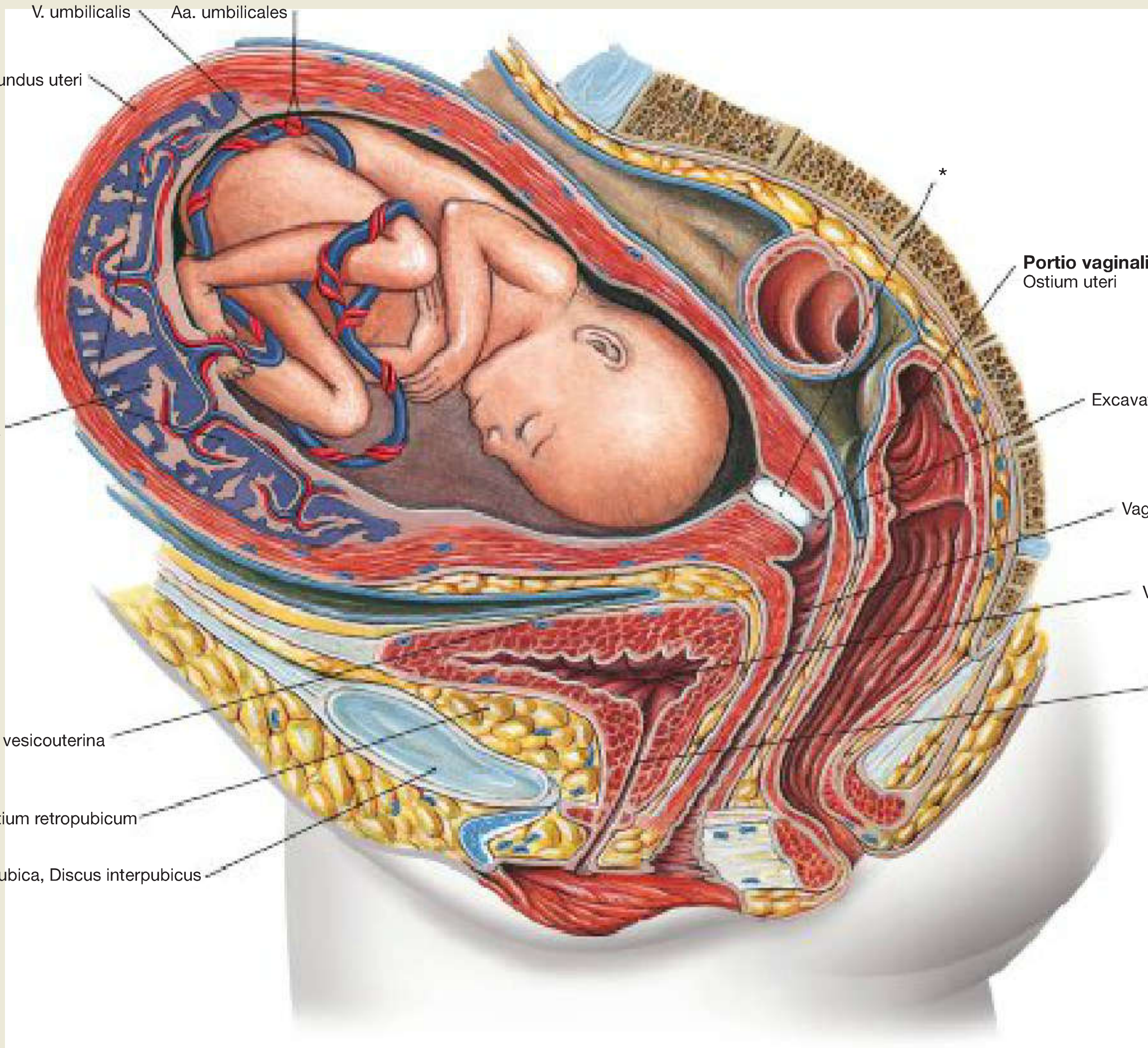


Fig. 7.119 Uterus with placenta and foetus; with the exception of the foetus median section of the pelvis; view from the left side.
The developing child in the uterus is nourished via the placenta which develops from maternal and foetal tissues after implantation. The cervix of the uterus is closed during pregnancy by the KRISTELLER's mucous plug (*).

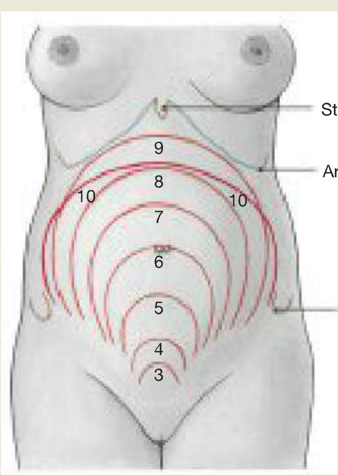


Fig. 7.120 Level of the Fundus uteri during pregnancy; ventral view.
The numbers represent the end of the respective month of pregnancy. In the 6th month (24th week), the Fundus uteri is at the level of the umbilical region, and in the 9th month (36th week) at the costal arch. Up to parturition, the uterine volume increases 800–1,200 times and the uterine weight increases from 30–120 g to 1,000–1,500 g.

a

b

Fig. 7.121a and b Placenta, and umbilical cord, Funiculus umbilicalis, after the birth; view from the foetal side (→ Fig. 7.121a), view from the maternal side (→ Fig. 7.121b).

The **placenta** is excreted after the child, at birth. On the foetal side, the **umbilical cord (Funiculus umbilicalis)** is inserted onto the chorionic plate of the placenta. Here, the two umbilical cord arteries (Aa. umbilicales) originate from the internal iliac artery (A. iliaca interna) of the child and transport de-oxygenated and nutrient-poor blood to the placenta. After the gas and nutrient exchange, the blood is fed back through a single vein in the umbilical cord (V. umbilicalis) to the child. On the maternal side, the placenta is anchored in the mucous lining of the uterus. It can be seen in the image that the placenta is divided into 10–40 **functional folds (cotyledons)**. After the birth, it must be ensured by inspection that the placenta is complete, as any placental residues remaining in the uterus can lead to severe bleeding and infection.

Arteries of the Internal Female Genitalia

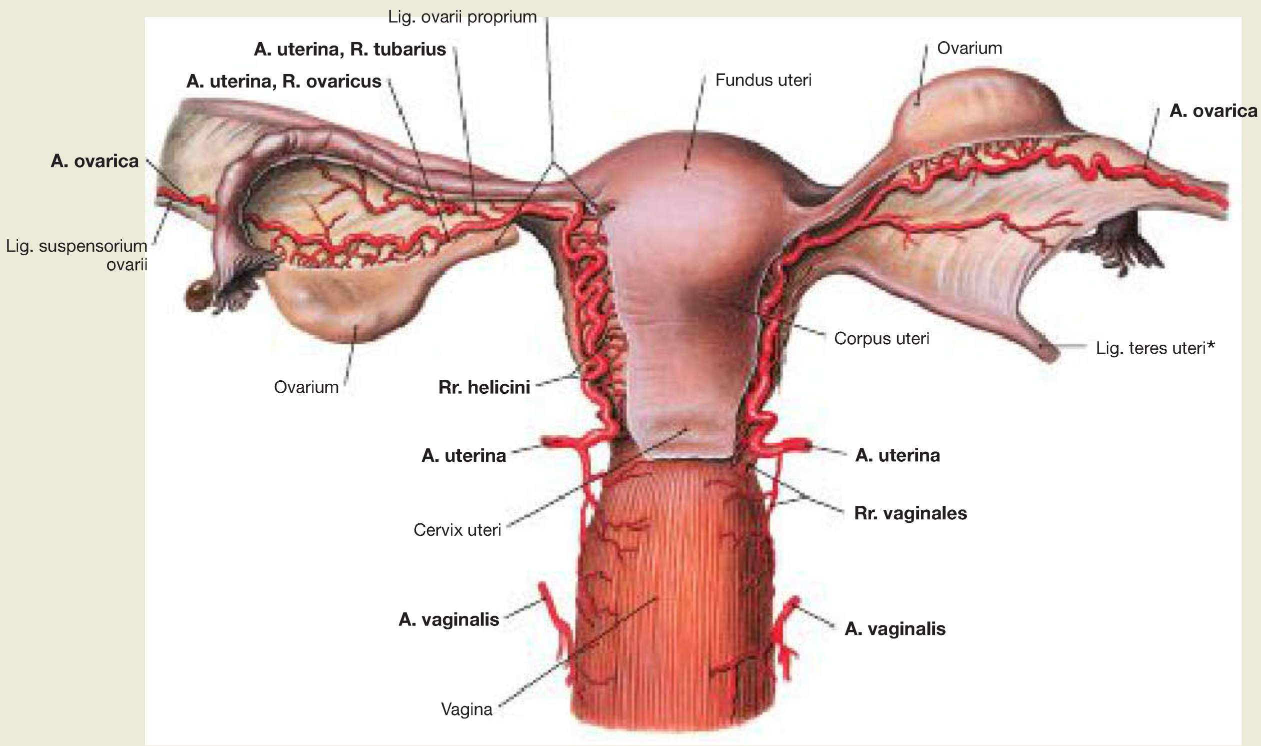


Fig. 7.122 Arteries of the internal female genitalia; dorsal view.
The internal female genitalia are supplied by **three paired arteries**:
- **uterus:** A. uterina (from the A. iliaca interna) with Rr. helicini
- **ovary:** A. ovarica (from the Pars abdominalis of the aorta) and A. uterina with R. ovaricus (ovarian branch)
- **Tuba uterina (uterine tube):** A. uterina with R. tubarius and A. ovarica
- **vagina:** A. vaginalis (from A. iliaca interna) and A. uterina with Rr. vaginales

* clinical term: Lig. rotundum

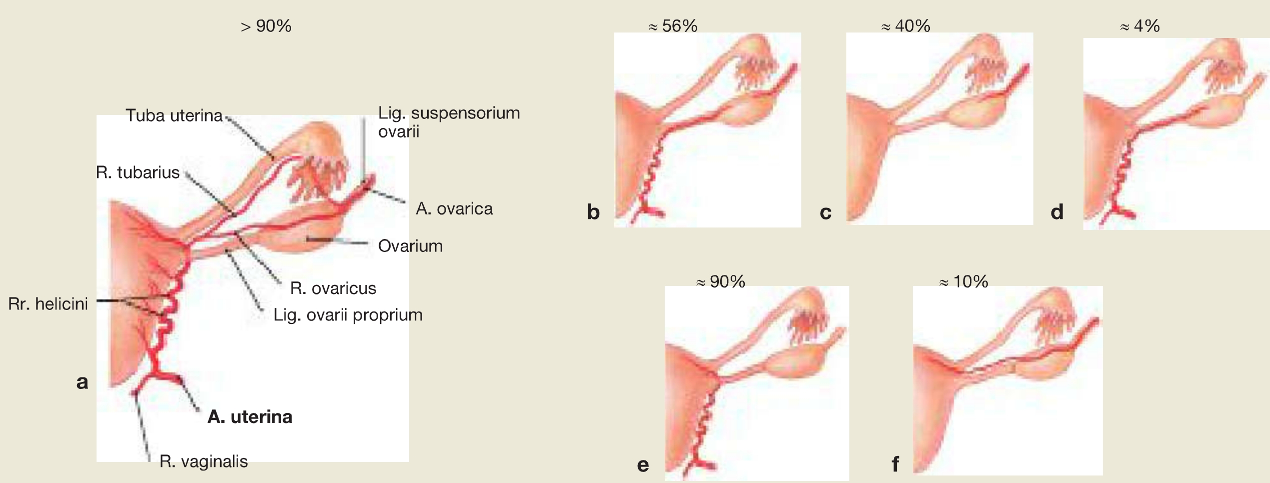


Fig. 7.123a to f Variations of the arterial supply of the internal female genitalia; dorsal view.

a Arterial supply of the uterus (textbook case)
b, c and **d** Arterial supply of the ovary (**b** textbook case)
e and **f** Arterial supply of the Fundus uteri (**e** textbook case)

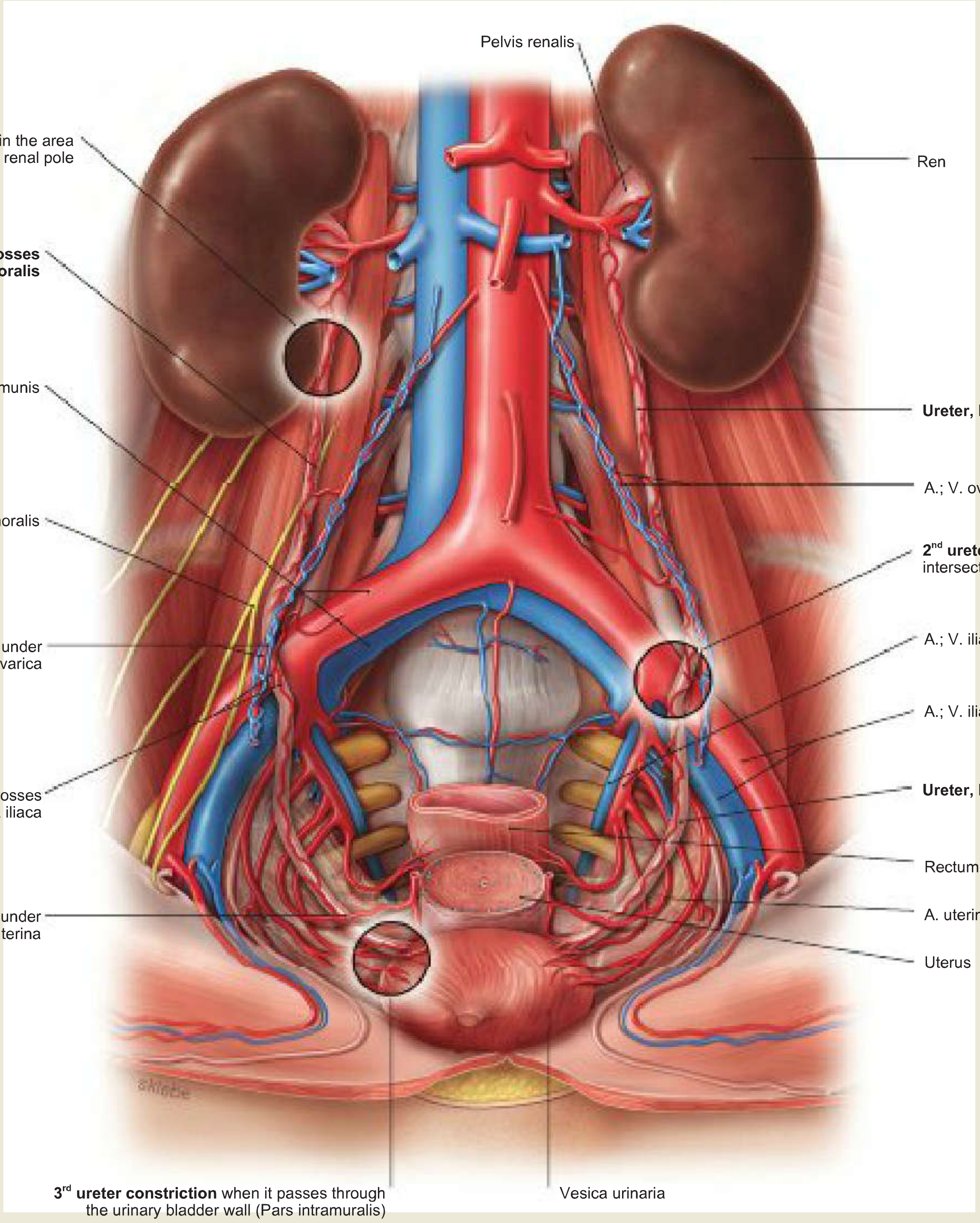


Fig. 7.124 Arteries of the internal female genitalia; ventral view. [L238]

All internal female genitalia receive their blood supply via **three paired arteries.**

The **A. ovarica** originates from the Pars abdominalis of the aorta and descends in the retroperitoneal space first and then through the Lig. suspensorium ovarii into the lesser pelvis. As well as the ovary, it also supplies the adjacent part of the uterine tube. The **A. uterina** is a visceral branch of the A. iliaca interna. It approaches in the Lig. latum uteri of the lower part of the Cervix uteri, where it runs across the ureter. Here it provides the **Rr. vaginales** for the vagina and then it ascends to the body of the uterus, which it supplies via the **Rr. helicini.** The uterine tube receives its own branch with the **R. tubarius** before the **R. ovaricus** anastomoses as a terminal branch with the A. ovarica.

Venous drainage takes place via **two venous systems:**
- the venous plexuses in the lesser pelvis **(Plexus venosi uterinus and vaginalis)** with connection to the V. iliaca interna
- **V. ovarica,** entering on the right into the V. cava inferior and on the left into the V. renalis sinistra

Genitalia

Lymphatic Vessels of the Female Genitalia

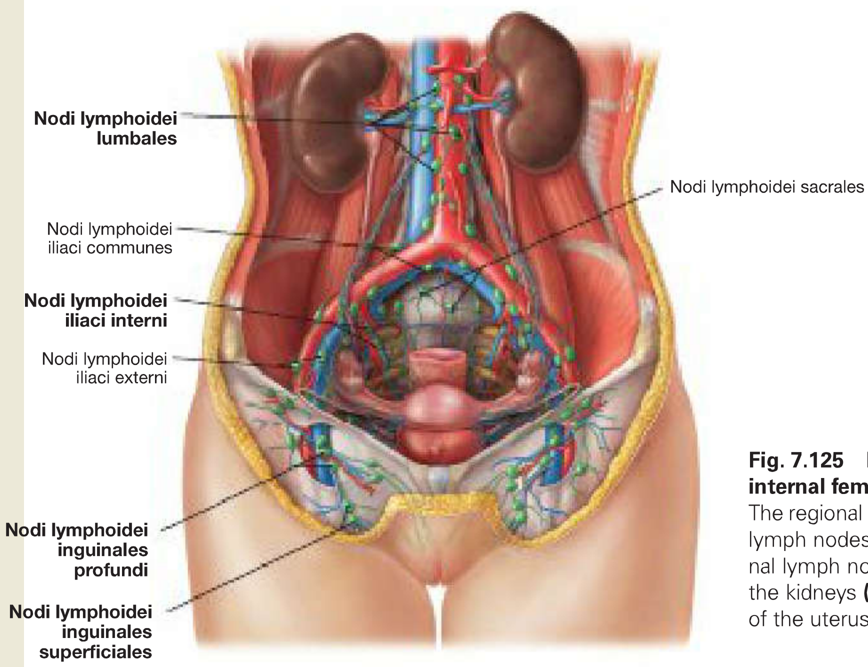


Fig. 7.125 Lymphatic vessels and lymph nodes of the external and internal female genitalia; ventral view. [L238]
The regional lymph nodes for the external female genitalia are the inguinal lymph nodes **(Nodi lymphoidei inguinales).** In contrast, the first regional lymph nodes of the ovary are located retroperitoneally at the level of the kidneys **(Nodi lymphoidei lumbales)** and the regional lymph nodes of the uterus are in the lesser pelvis **(Nodi lymphoidei iliaci interni).**

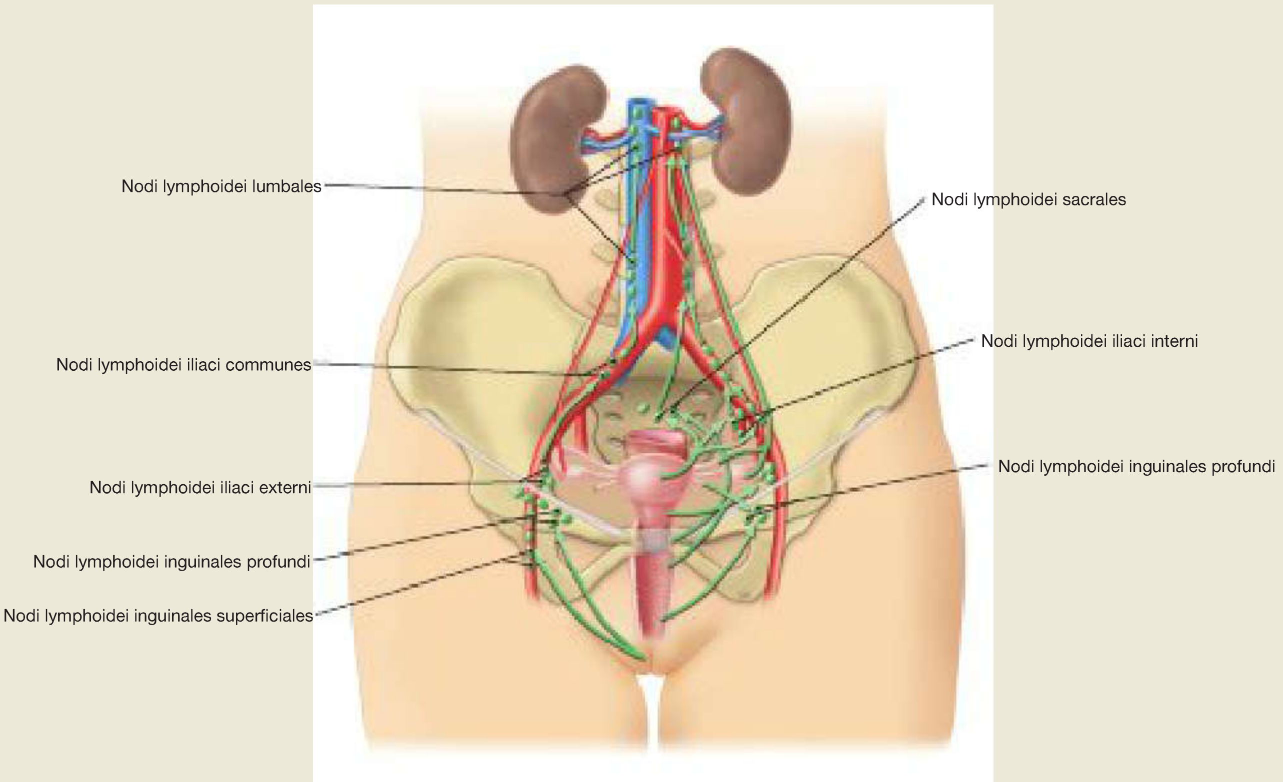


Fig. 7.126 Lymphatic drainage pathways of the external and internal female genitalia; ventral view. [L238]
Unlike in men, the lymphatic drainage pathways of the external and internal female genitalia are not completely separate, as parts of the lymph of the internal genitalia also drain into the inguinal lymph nodes.
External genitalia:
- Nodi lymphoidei inguinales: Vulva

Internal genitalia:
- **Nodi lymphoidei lumbales** at the level of the kidneys: ovaries, Tuba uterina, uterus (uterotubal junction), lymphatic vessels within the Lig. suspensorium ovarii
- **Nodi lymphoidei iliaci interni/externi** and **Nodi lymphoidei sacrales:** uterus, vagina, Tuba uterina
- **Nodi lymphoidei inguinales:** lower vagina, uterus (uterotubal junction), lymphatic vessels within the Lig. teres uteri

Clinical Remarks

Due to the different lymphatic pathways the first **lymph node metastases** of vulvar carcinomas occur in the groin; in the case of endometrial carcinoma of the uterus and cervical cancer metastases occur in the lesser pelvis, and in the case of ovarian tumours in the retroperitoneal space.

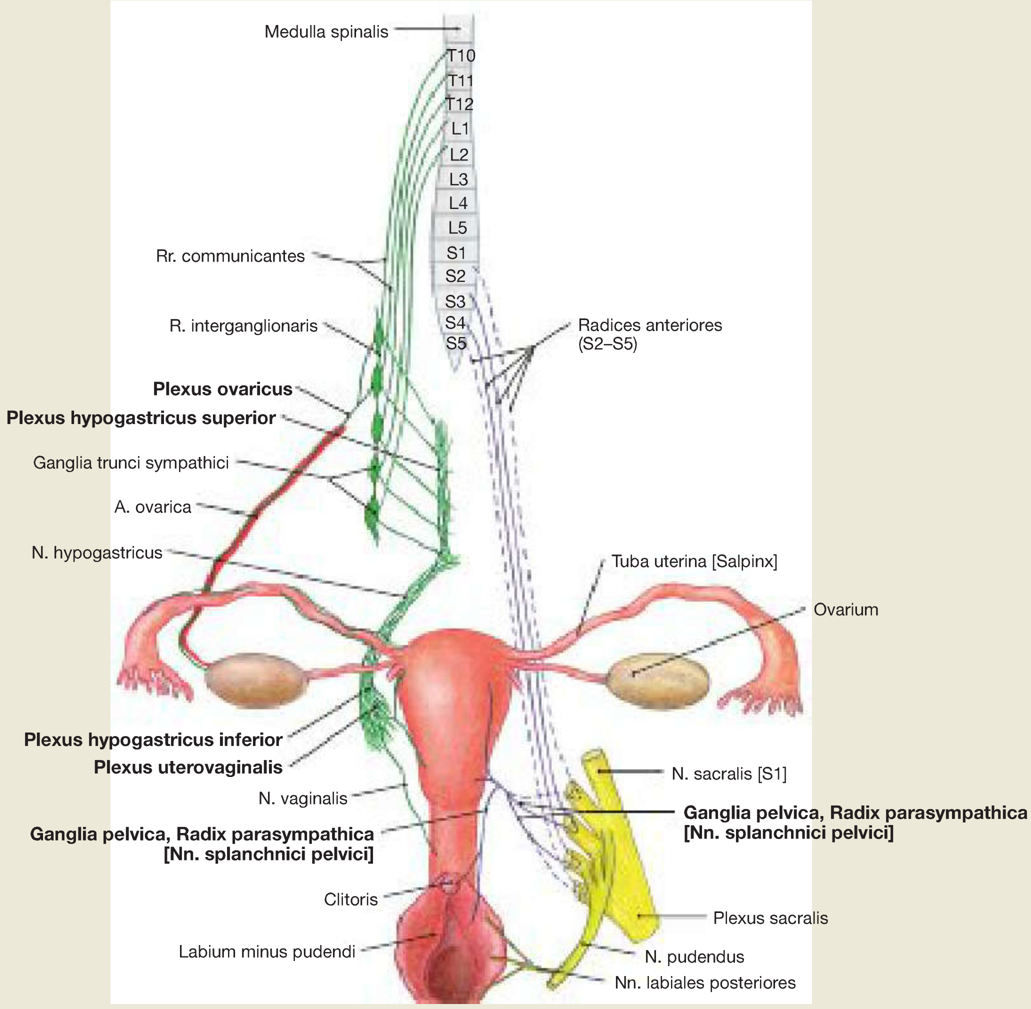


Fig. 7.127 Innervation of the female genitalia; ventral view; schematic illustration. The Plexus hypogastricus inferior and Plexus uterovaginalis contain sympathetic (green) and parasympathetic (purple) nerve fibres.

Preganglionic **sympathetic nerve fibres** (T10–L2) descend from the Plexus aorticus abdominalis via the Plexus hypogastricus superior, and from the sacral ganglia of the sympathetic trunk (Truncus sympathicus) via the Nn. splanchnici sacrales to be synapsed to postganglionic neurons in the ganglia of the **Plexus hypogastricus inferior.** Their axons reach the pelvic organs, and continue in the **Plexus uterovaginalis (FRANKENHÄUSER's plexus),** innervating the uterus, uterine tubes and vagina. The (mostly) postganglionic sympathetic fibres to the ovary pass through the Plexus ovaricus alongside the A. ovarica after being already synapsed in the Ganglia aorticorenalia or the Plexus hypogastricus superior.

Preganglionic **parasympathetic nerve fibres** pass from the sacral parasympathicus (S2–S4) via the Nn. splanchnici pelvici into the ganglia of the Plexus hypogastricus inferior. They are synapsed either here or in the vicinity of the pelvic viscera (Ganglia pelvica) to postganglionic neurons which innervate the uterus, uterine tubes and vagina.

Somatic innervation by the **pudendal nerve** conveys sensory innervation to the lower part of the vagina, the vaginal vestibule (Vestibulum vaginale) and the Labia minora and majora via the Rr. labiales posteriores, and to the clitoris via the N. dorsalis clitoridis.

Pelvic Floor in Women

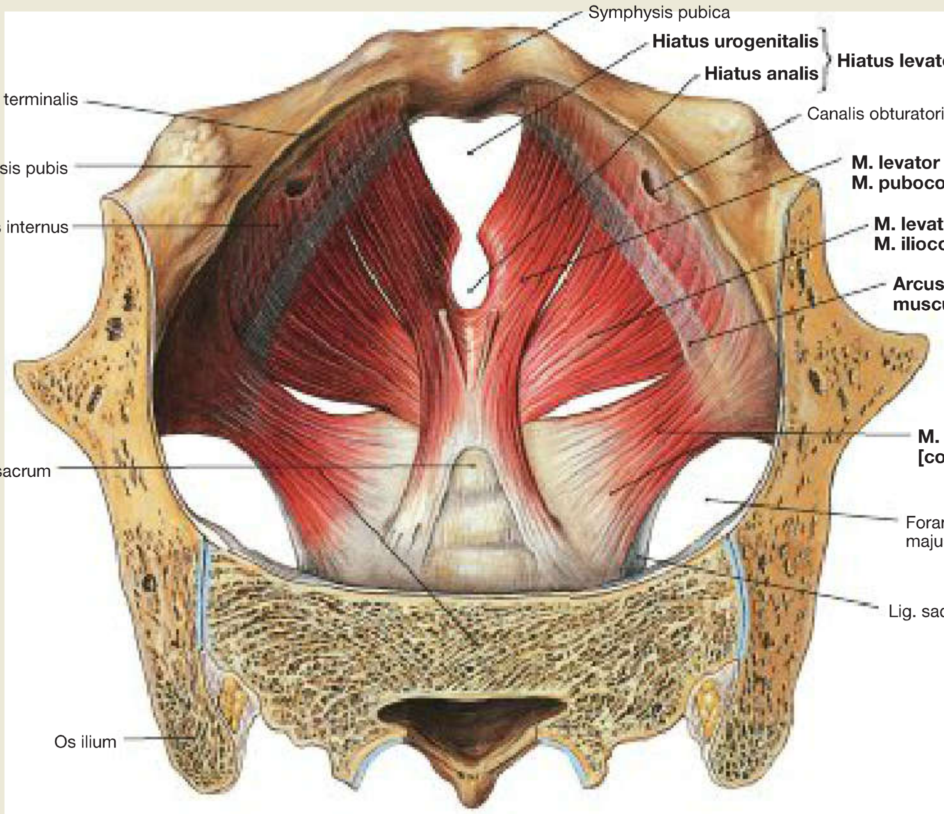


Fig. 7.128 Pelvic floor, Diaphragma pelvis, in women; cranial view. The pelvic floor of women is similar in its structure to the pelvic floor of men and closes the pelvic cavity caudally.

Structure:

- **M. levator ani,** comprising M. pubococcygeus, M. iliococcygeus, and M. puborectalis
- **M. ischiococcygeus**

In contrast to the M. pubococcygeus and the M. ischiococcygeus, the M. iliococcygeus does not originate from the hip bone but from the Arcus tendineus musculi levatoris ani, a reinforcement of the fascia of the M. obturatorius internus.

The muscles of both sides spare the **levator hiatus (Hiatus levatorius;** → Fig. 7.129). This muscular gap is subdivided by the connective tissue of the perineum (Centrum perinei) into the anterior **Hiatus urogenitalis** for the passage of the urethra and vagina and the posterior **Hiatus analis** for the passage of the rectum.

The pelvic floor is innervated by direct branches of the Plexus sacralis (S3–S4).

Function: The pelvic floor stabilises the position of the pelvic organs and is thus essential for urinary and faecal continence.

→ T 20a

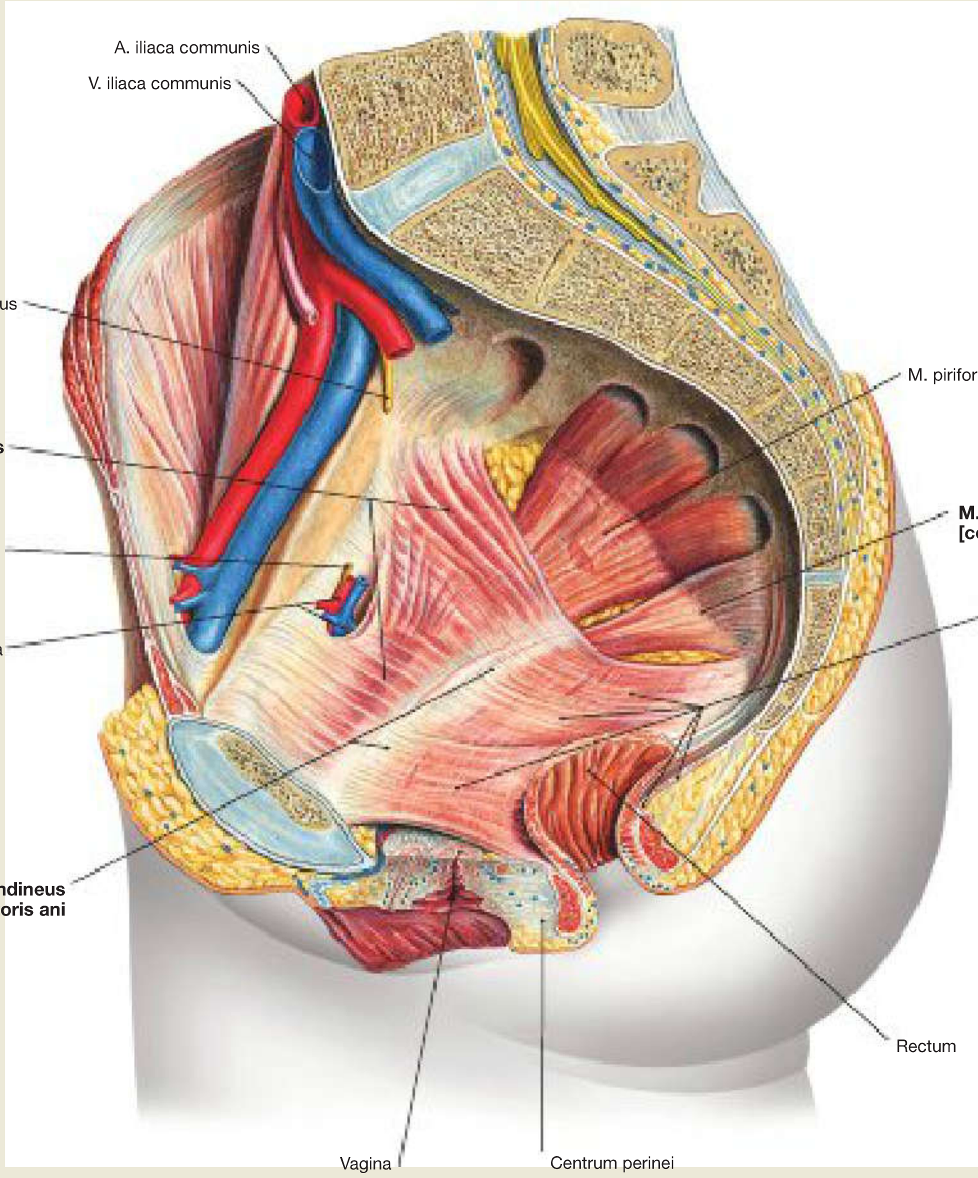


Fig. 7.129 Pelvic floor, Diaphragma pelvis, in women; view from the left side.
The pelvic floor consists of the **M. levator ani** and the **M. ischiococcygeus.** The M. iliococcygeus of the M. levator ani originates from the **Arcus tendineus musculi levatoris ani.** This is a reinforcement of the fascia of the M. obturatorius internus. The M. obturatorius internus originates at the front of the superior pubic ramus, where it is clearly identifiable because it is perforated by the Canalis obturatorius with the A. and V. obturatoria and the N. obturatorius. At the Arcus tendineus musculi levatoris ani, the M. obturatorius internus then turns laterally and exits the pelvis via the Foramen ischiadicum minus. The M. levator ani extends to the sacrum and the coccyx and closes the pelvic cavity caudally.

→ T 20a

Pelvic Floor Insufficiency in Women

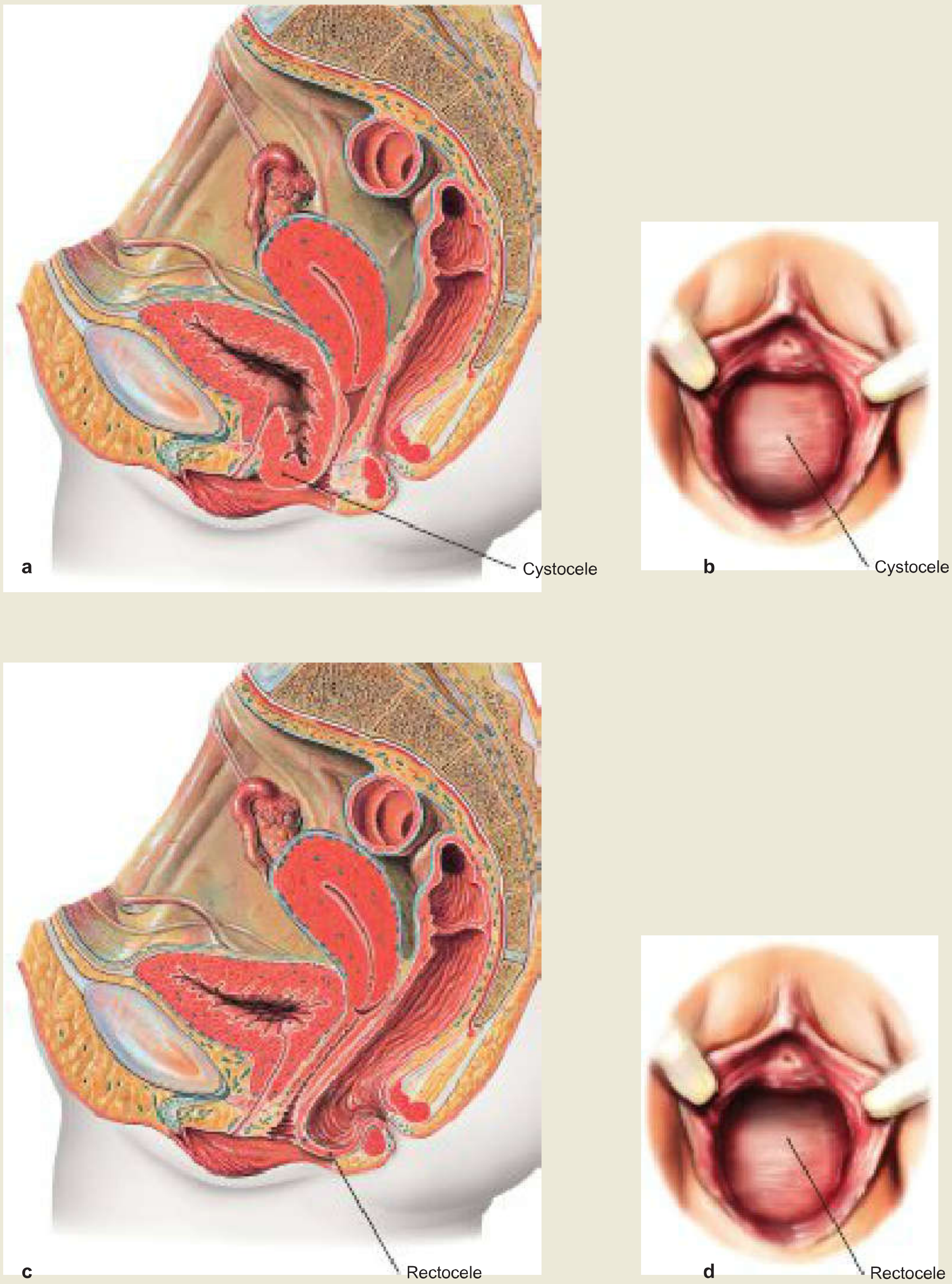


Fig. 7.130a to d Pelvic floor insufficiency in women; median section, view from the left side. [L266]
If the stabilising function of the pelvic floor fails, this leads to pelvic floor insufficiency. In this case, the posterior wall of the urinary bladder **(a, b)** or the anterior wall of the rectum **(c, d)** can prolapse. Both the **cystocele (a)** and the **rectocele (c)** are visible vaginally as bulging; from their appearance it is not always obvious to differentiate between them. The topographic relationships are highlighted here by a shadow which delineates the dorsal cystocele **(b)** and the ventral rectocele **(d)** of the prolapsed tissue.

Clinical Remarks

In women, weakness of the pelvic floor **(pelvic floor insufficiency)** is much more frequent, because the pelvic floor is strained by vaginal births, where the levator hiatus is stretched significantly. As a result, a **drop** (Descensus) may occur, leading to **prolapses** of the uterus and vagina. Since the uterus is linked to the posterior wall of the urinary bladder and the vagina is linked to the anterior wall of the rectum, this is often accompanied by a prolapse of the urinary bladder (cystocele) and rectum (rectocele) and therefore associated with **urinary** and **faecal incontinence.**

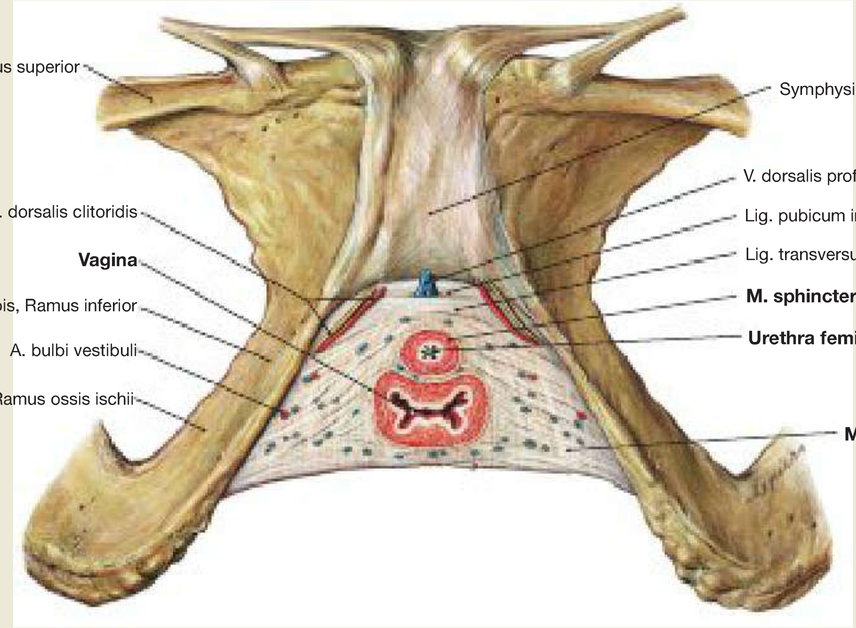


Fig. 7.131 Perineal muscles in women; caudal view; after the removal of all other muscles.

In women, the levator hiatus (Hiatus levatorius) is largely closed by connective tissue, so that only the passage of the vagina and urethra (Urethra feminina) remains open. Unlike in men, the perineal muscles in women are weak (→ Fig. 7.97). Because the **M. transversus perinei profundus,** which only consists of single muscle fibres embedded within connective tissue (→ Fig. 7.132), and the thin **M. transversus perinei superficialis** do not constitute a muscle plate, the old term of 'Diaphragma urogenitale' has been dropped.

While in men the deep perineal space (Spatium profundum perinei) largely corresponds to the extension of the M. transversus perinei profundus, the delimitation of the perineal spaces is more difficult in women. The **deep perineal space (Spatium profundum perinei)** is however bordered inferiorly as in men by the **Membrana perinei** (→ Fig. 7.136). In women this space also contains the vagina next to the urethra and is traversed by the deep branches of the N. pudendus and the A. and V. pudenda interna on their way to the vulva.

→ T 20b

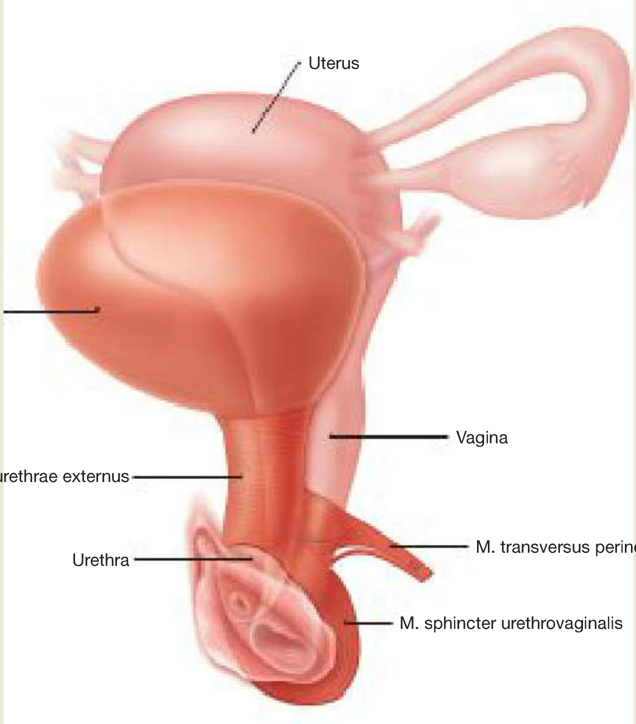


Fig. 7.132 Voluntary sphincter muscles of the urinary bladder. [L238]

In women, the M. transversus perinei profundus does not form a solid muscle plate below the pelvic floor. Conversely, in the area of the urethra individual striated muscle fibres form the **M. sphincter urethrae externus,** constituting the voluntary sphincter of the urinary bladder (→ Fig. 7.131). Some distal fibres continue to surround the distal vagina and are referred to as **M. sphincter urethrovaginalis.**

→ T 20b

Perineal Muscles in Women

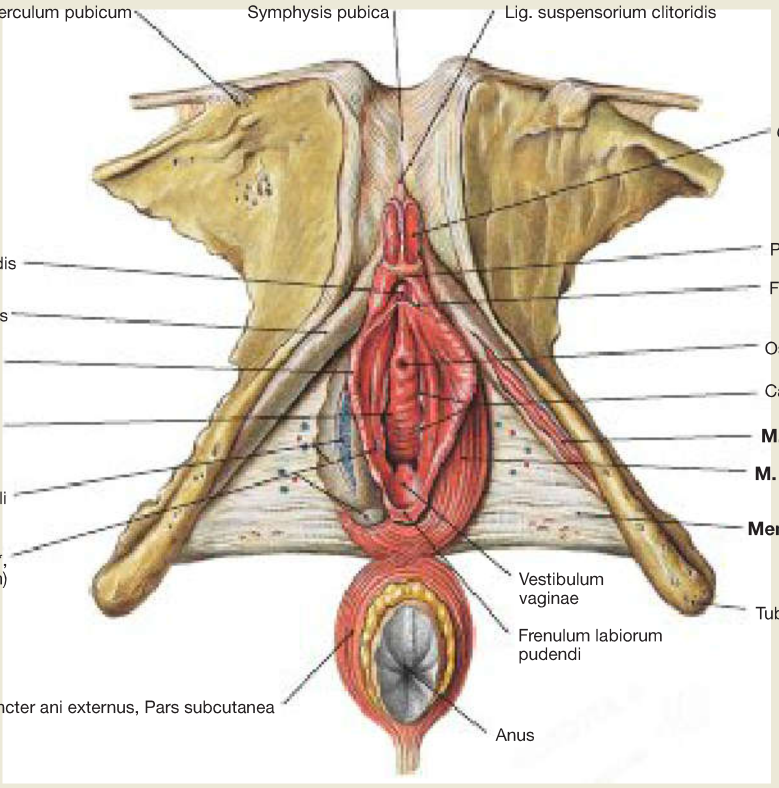


Fig. 7.133 Superficial perineal muscles in women; caudal view.
The **Membrana perinei** borders the deep perineal space caudally. Below it joins with the **superficial perineal space (Spatium superficiale perinei)** (→ Fig. 7.136). This contains the M. transversus perinei superficialis and the external genitalia, the parts of which come together as the vulva. The two cavernous bodies of the vulva are also covered by the superficial perineal muscles: the crus of the clitoris is bilaterally accompanied by the **M. ischiocavernosus** on the inferior pubic ramus, and the bulb of the vestibule (Bulbus vestibuli) is covered by the **M. bulbospongiosus.**

* clinical term: BARTHOLIN's gland

→ T 20b

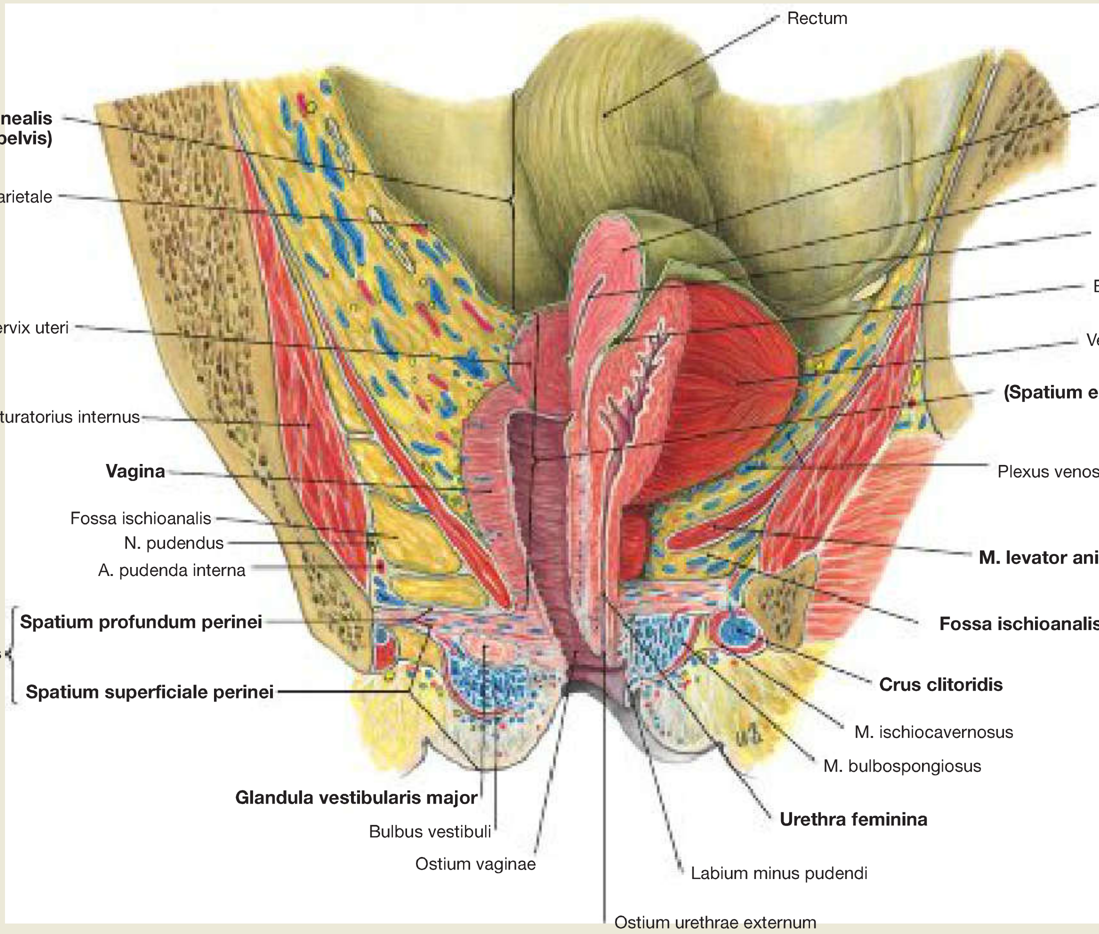


Fig. 7.134 Perineal spaces in women; median section, and frontal section at the right side; ventral view. See also the section in → Fig. 7.143b.

The frontal section shows **three levels** of the female pelvis:

- **peritoneal cavity of the pelvis (Cavitas peritonealis pelvis),** which is caudally delimited by the parietal peritoneum
- **subperitoneal space (Spatium extraperitonale pelvis),** which reaches down to the M. levator ani of the pelvic floor
- **perineal region (Regio perinealis)** below the pelvic floor. The anterior portion is generally taken up by the two perineal spaces; however it also still contains the very variable anterior recesses of the Fossa ischioanalis (shown here separately on the right and left).

The **deep perineal space (Spatium profundum perinei)** consists of the connective tissue and single muscle fibres of the M. transversus perinei profundus. It also contains the passage of the vagina and urethra. The deep perineal space is traversed by the deep branches of the N. pudendus (N. dorsalis clitoridis), and of the A. and V. pudenda interna (A. bulbi vestibuli, A. dorsalis clitoridis, A. profunda clitoridis) before they reach the vulva. The Nn. cavernosi clitoridis pierce the perineum and enter the Corpora cavernosa of the clitoris.

The **superficial perineal space (Spatium superficiale perinei)** is located between the perineal membrane (Membrana perinei) and the body fascia (Fascia perinei). In addition to the M. transversus perinei superficialis and the proximal parts of the Corpora cavernosa clitoridis, it contains the Glandulae vestibulares majores (BARTHOLIN's glands) and the bulb of the vestibule (Bulbus vestibuli). This is surrounded on both sides by the M. bulbospongiosus, and the Crura clitoridis by the M. ischiocavernosus. The superficial branches of the N. pudendus (N. perinealis with Nn. labiales posteriores) and of the A. and V. pudenda interna (A. perinealis with Rr. labiales posteriores) continue through this space to the vulva.

Perineal Region in Women

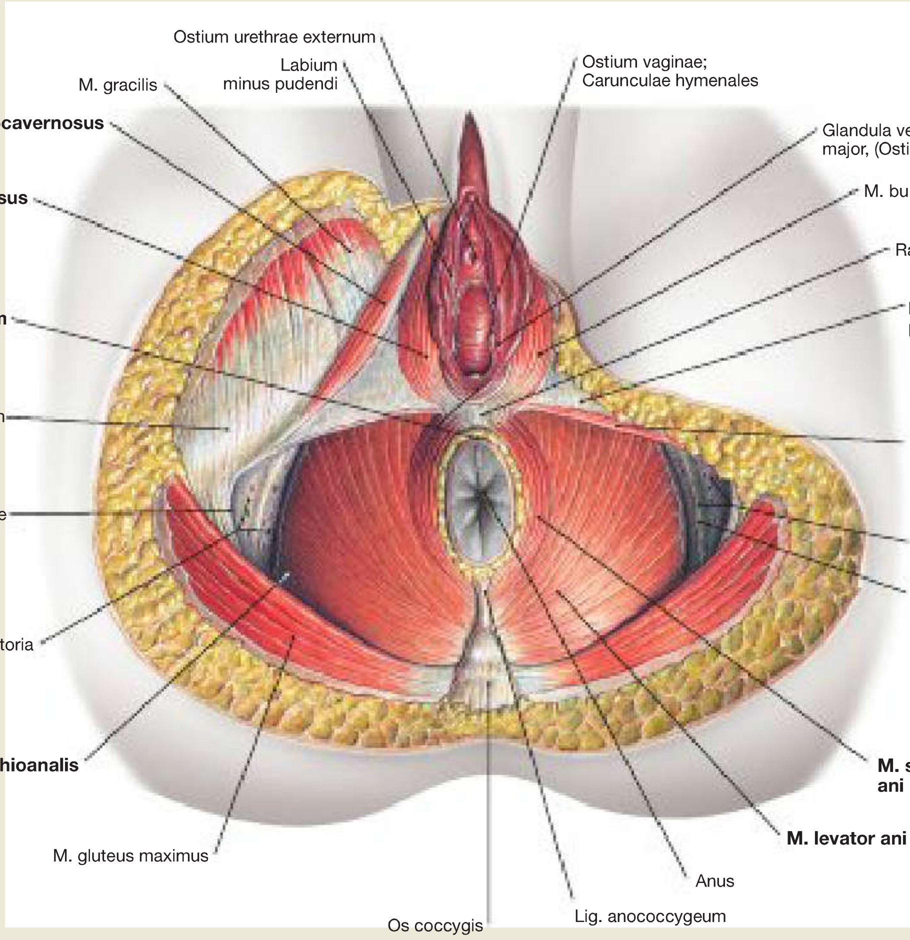


Fig. 7.135 Perineal region, Regio perinealis, in women; caudal view; after removal of all neurovascular pathways.

The **perineal region** extends from the inferior margin of the pubic symphysis (Symphysis pubica) to the tip of the coccyx (Os coccygis). The term **perineum** in women, however, describes exclusively the small connective tissue bridge between the posterior margin of the Labia majora and the anus. The perineal region can be divided into an **anterior Regio urogenitalis** with external genitalia and urethra, and a **posterior Regio analis** around the anus. Both regions include spaces:

- The Regio analis contains the **Fossa ischioanalis** (→ table), which constitutes a pyramid-shaped space on both sides of the anus. The Fossa ischioanalis is similar in men and women. The lateral wall contains the Canalis pudendalis (ALCOCK's canal) in a fascial duplicature of the M. obturatorius internus (Fascia obturatoria). In this canal the A. and V. pudenda interna and the N. pudendus are arriving via the Foramen ischiadicum minus from the Regio glutealis.
- The Regio urogenitalis contains the two **perineal spaces:**
  – The deep perineal space (Spatium profundum perinei) is delimited caudally by the Membrana perinei; and in women it contains the weak M. transversus perinei profundus and the M. sphincter urethrae externus.
  – In the superficial perineal space (Spatium superficiale perinei) between the Membrana perinei and the body fascia (Fascia perinei), are the M. transversus perinei superficialis, the M. bulbospongiosus and the M. ischiocavernosus, which stabilise the cavernous bodies of the vestibule and clitoris as well as the Glandulae vestibulares majores (BARTHOLIN's glands).

Borders of the Fossa ischioanalis	
medial and cranial	M. sphincter ani externus and M. levator ani
lateral	M. obturatorius internus
dorsal	M. gluteus maximus and Lig. sacrotuberale
ventral	posterior margin of the superficial and deep perineal spaces, anterior recesses reach up to the pubic symphysis
caudal	fascia and skin of the perineum

Clinical Remarks

Childbirth can lead to uncontrolled tearing of the skin and muscles of the perineum up to the sphincter muscles of the anus **(perineal tearing),** which in some cases can be prevented through targeted incision to the lateral side or in the median plane (episiotomy).

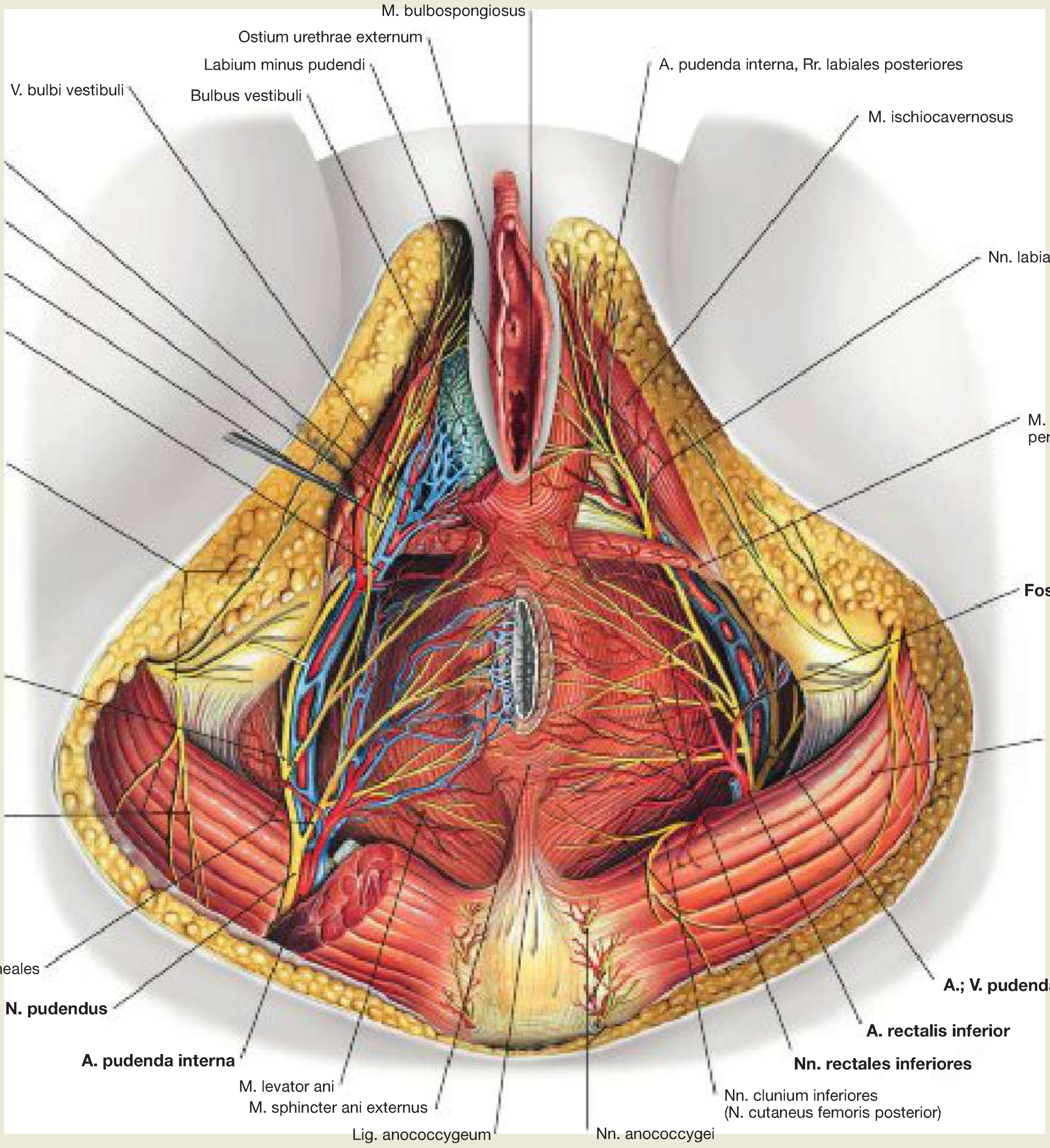


Fig. 7.136 Vessels and nerves of the perineal region, Regio perinealis, in women; caudal view.

The **Fossa ischioanalis** is similar in men and women. The neurovascular pathways run dorsolaterally in the Canalis pudendalis (ALCOCK's canal) formed by a fascial duplicature of the M. obturatorius internus, into the pyramid-shaped Fossa ischioanalis which is filled with adipose tissue. Next they provide the branches to the anus and anal canal, and traverse the Fossa ischioanalis ventrally to pass through both the perineal spaces to the vulva.

Contents of the Fossa ischioanalis:

- A. and V. pudenda interna and N. pudendus: in the Canalis pudendalis (ALCOCK's canal)
- A., V. and N. rectalis inferior: to the anal canal

Clinical Remarks

As in men, the Fossa ischioanalis is clinically highly relevant because of its expansion on both sides of the anus. **Collection of pus** (abscesses), e.g. where there are fistulas from the anal canal, can extend throughout the Fossa ischioanalis up to the front of the pubic symphysis. They not only generate non-specific inflammatory symptoms but also cause intense pain in the perineal region.

Male Pelvis, Median Section

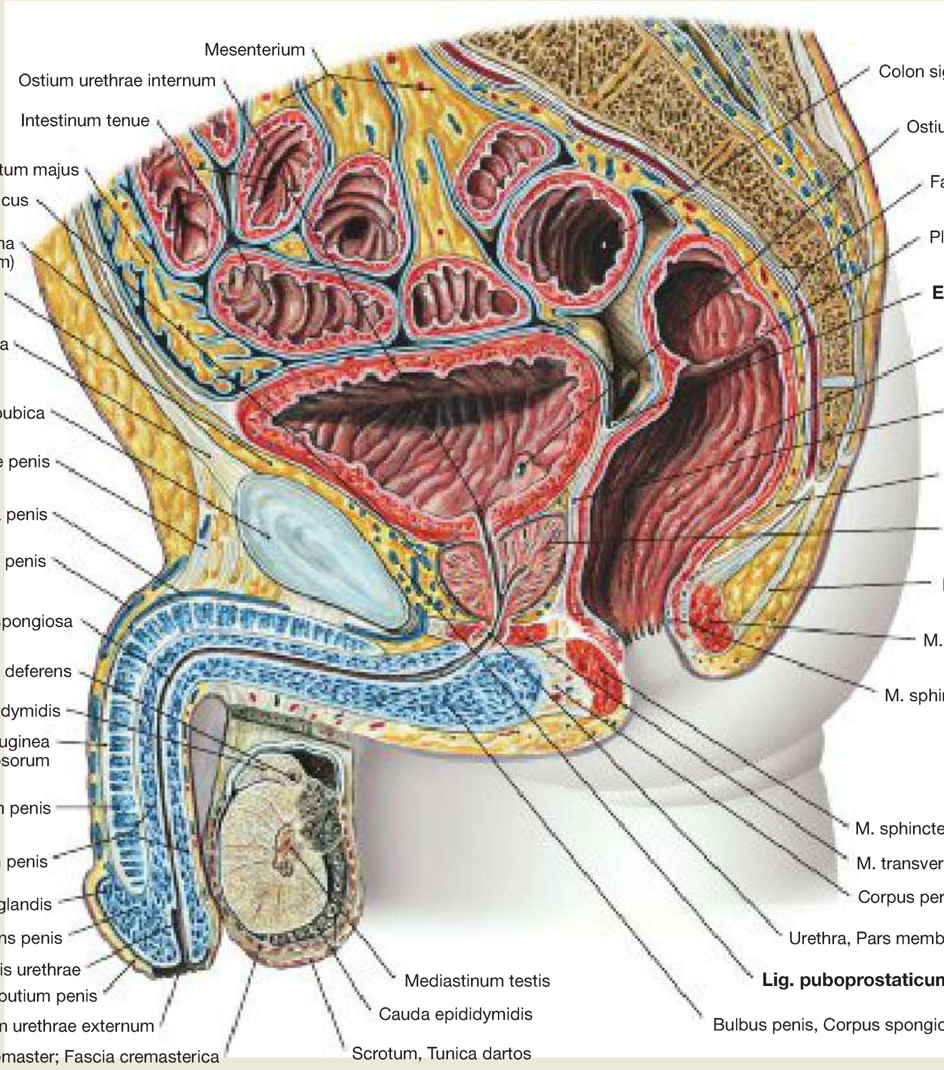


Fig. 7.137 Pelvis of a man; median section; view from the left side.
In men the most inferior pouch of the peritoneal cavity is the **Excavatio rectovesicalis.** This is laterally delimited by the **Plica rectovesicalis** in which the Plexus hypogastricus inferior is found. Caudally there follows the **Fascia rectoprostatica** (**clinical term: DENONVILLIER's fascia) in the subperitoneal space, separating the rectum and prostate. Behind the pubic symphysis lies a space filled with connective tissue **(Spatium retropubicum,** *clinical term: RETZIUS' space) in which the thin Lig. puboprostaticum attaches the prostate and the urinary bladder to the pelvic bone. In the inferior part of the Spatium retropubicum, the **V. dorsalis profunda penis** opens to drain the blood of the cavernous bodies of the penis into the **Plexus venosus prostaticus,** which is connected to the V. iliaca interna.

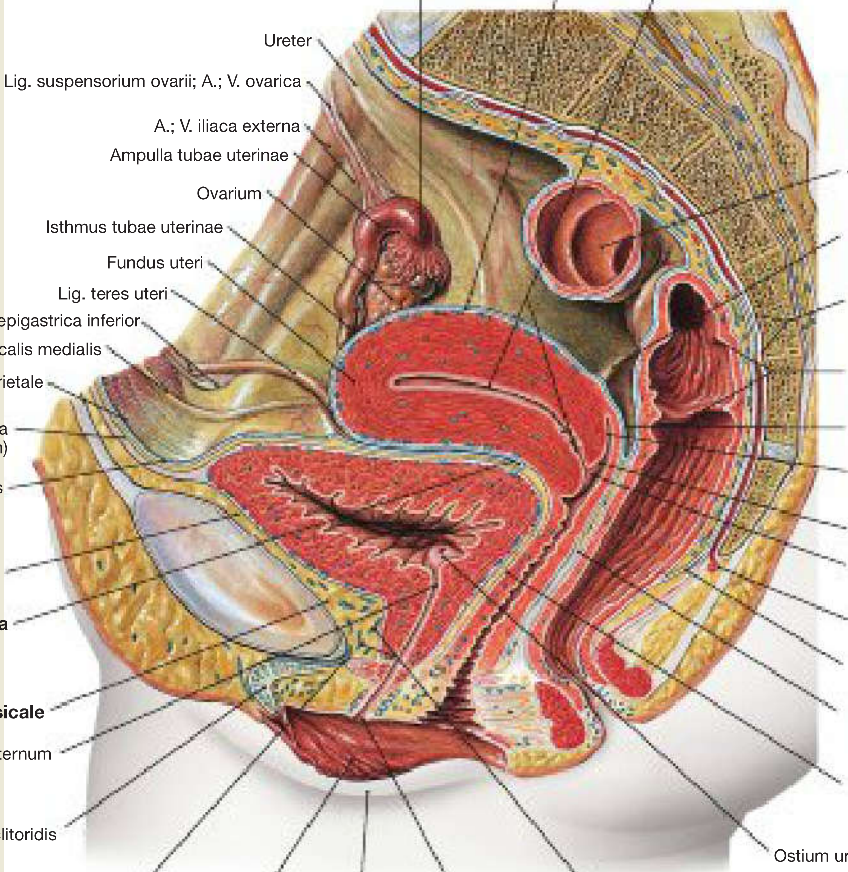


Fig. 7.138 Pelvis of a woman; median section; view from the left side.
Because the uterus is inserted between the urinary bladder and the rectum, the peritoneal cavity in women has two caudal pouches. The most caudal pouch is the **Excavatio rectouterina** (** clinical term: pouch of DOUGLAS). It extends to the posterior vaginal vault (Fornix vaginae, Pars posterior). It is laterally delimited by the **Plica rectouterina** in which the Plexus hypogastricus inferior is found. The **Fascia rectovaginalis** caudally follows in the subperitoneal space separating the rectum from the vagina. The **Excavatio vesicouterina** between the bladder and uterus is not as deep and covers the subperitoneal Septum vesicovaginale. Behind the pubic symphysis lies a space filled with connective tissue **(Spatium retropubicum),** in which the thin Lig. pubovesicale attaches the urinary bladder to the pelvic bone. In the inferior part of the Spatium retropubicum, the **V. dorsalis profunda clitoridis** opens, draining the blood of the cavernous bodies of the clitoris to the **Plexus venosus vesicalis,** which is connected to the V. iliaca interna.

* clinical term: Septum vesicovaginale

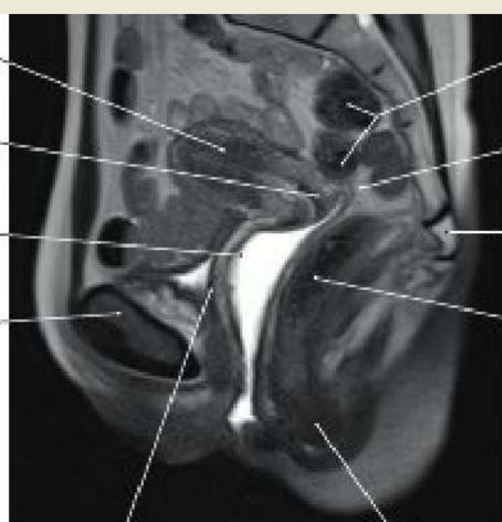
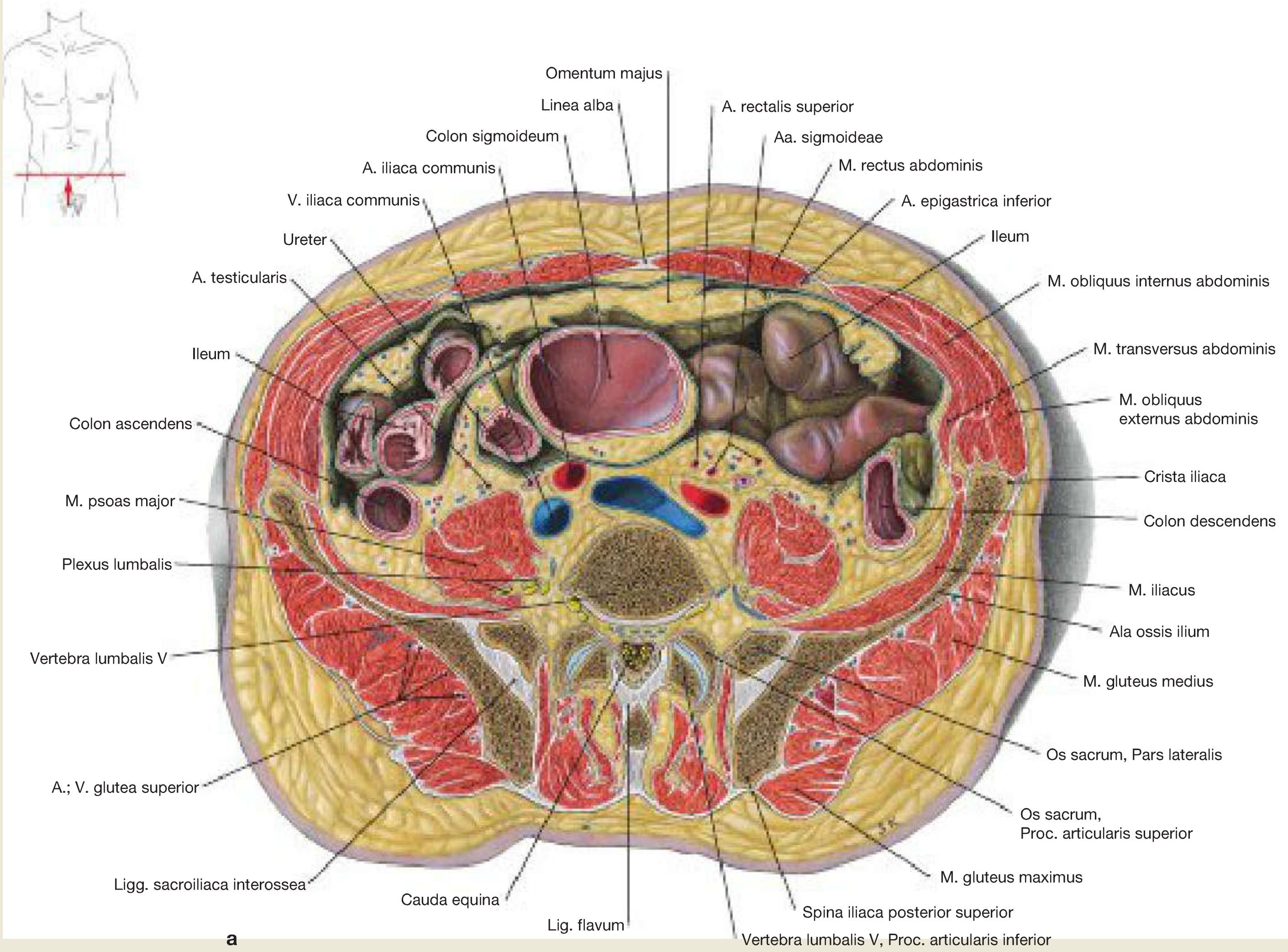
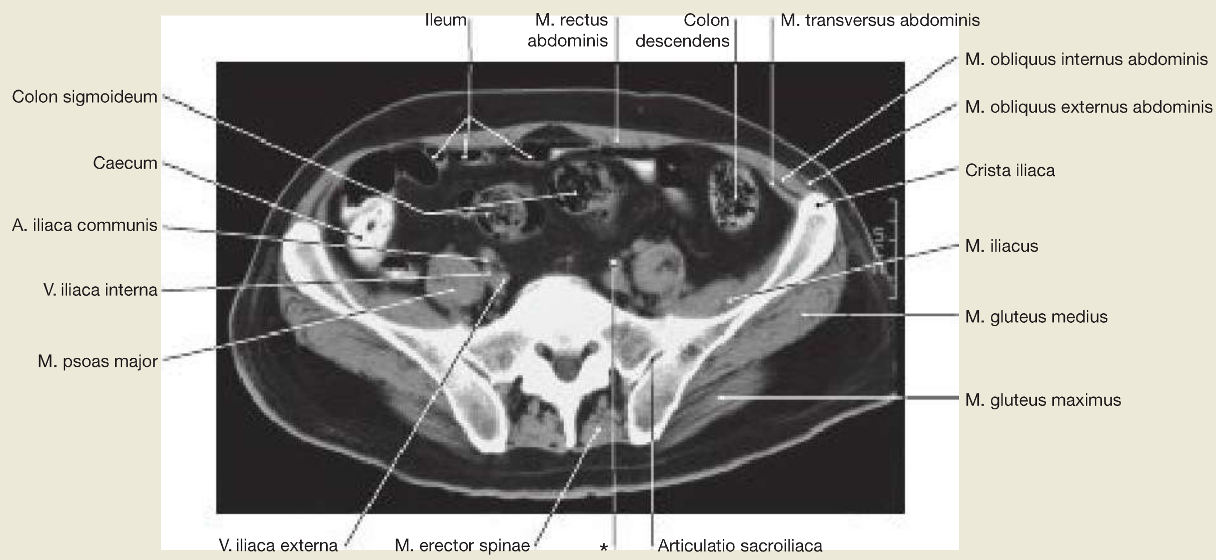


Fig. 7.139 Pelvis of a woman; sagittal section, T2w MRI sequence. The vagina was filled with ultrasound gel to achieve a better contrast. [T832]

Male Pelvis, Cross-Sections



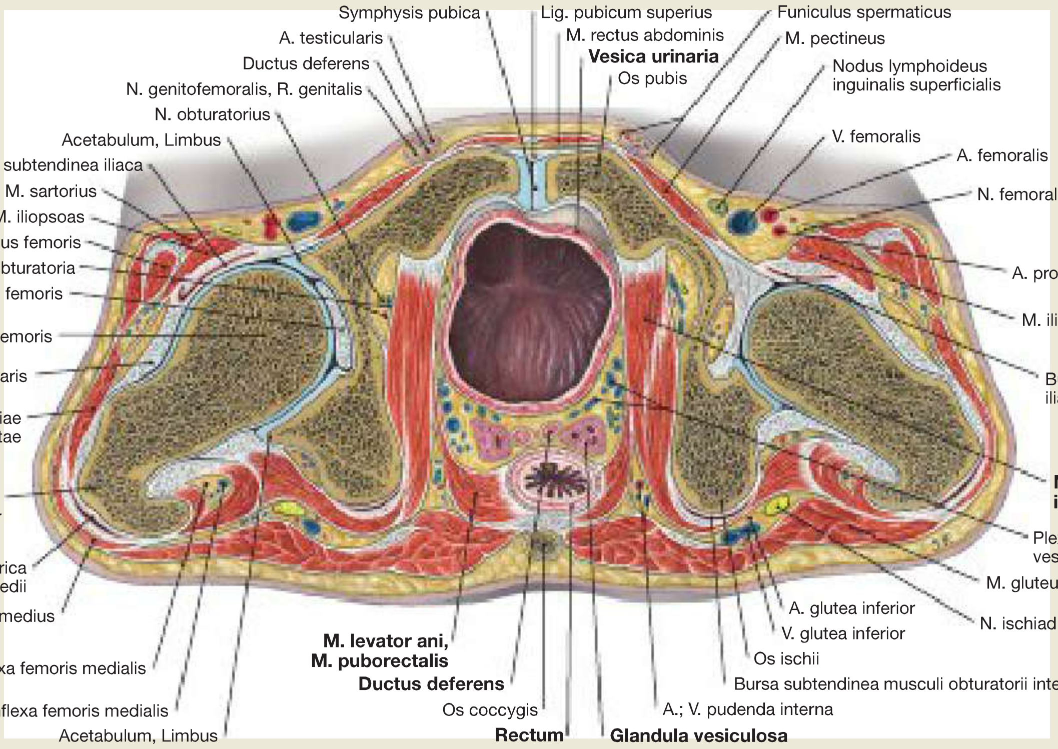
a



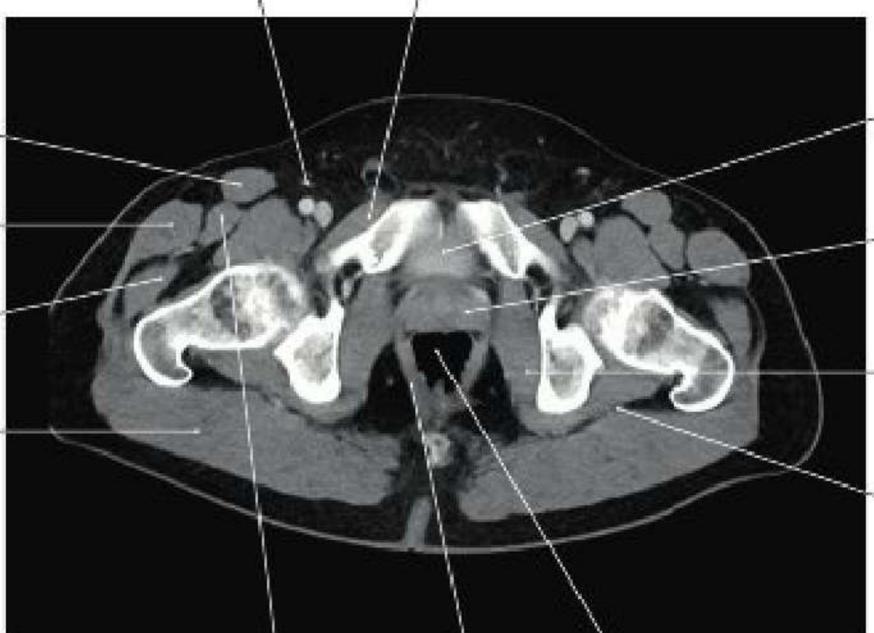
b

Fig. 7.140a and b Pelvis of a man; cross-section at the level of the fifth lumbar vertebra (→ Fig. 7.140a) and corresponding computed tomography scan (→ Fig. 7.140b); caudal view. a [L238]; b [T893]
According to convention, CT scans are always viewed from caudal. Since the section is at the level of the **pelvis major,** the actual pelvic organs are not to be seen. However, it is clear that the iliac bone (Os ilium) with the extensive pelvic bones (Alae ossis ilii) surrounds both the small intestinal loops of the ileum and the Colon sigmoideum, which continues its S-shaped loop in the median plane and then at the level of the second to the third sacral vertebrae in the rectum.

* calcification in the wall of the A. iliaca communis



a

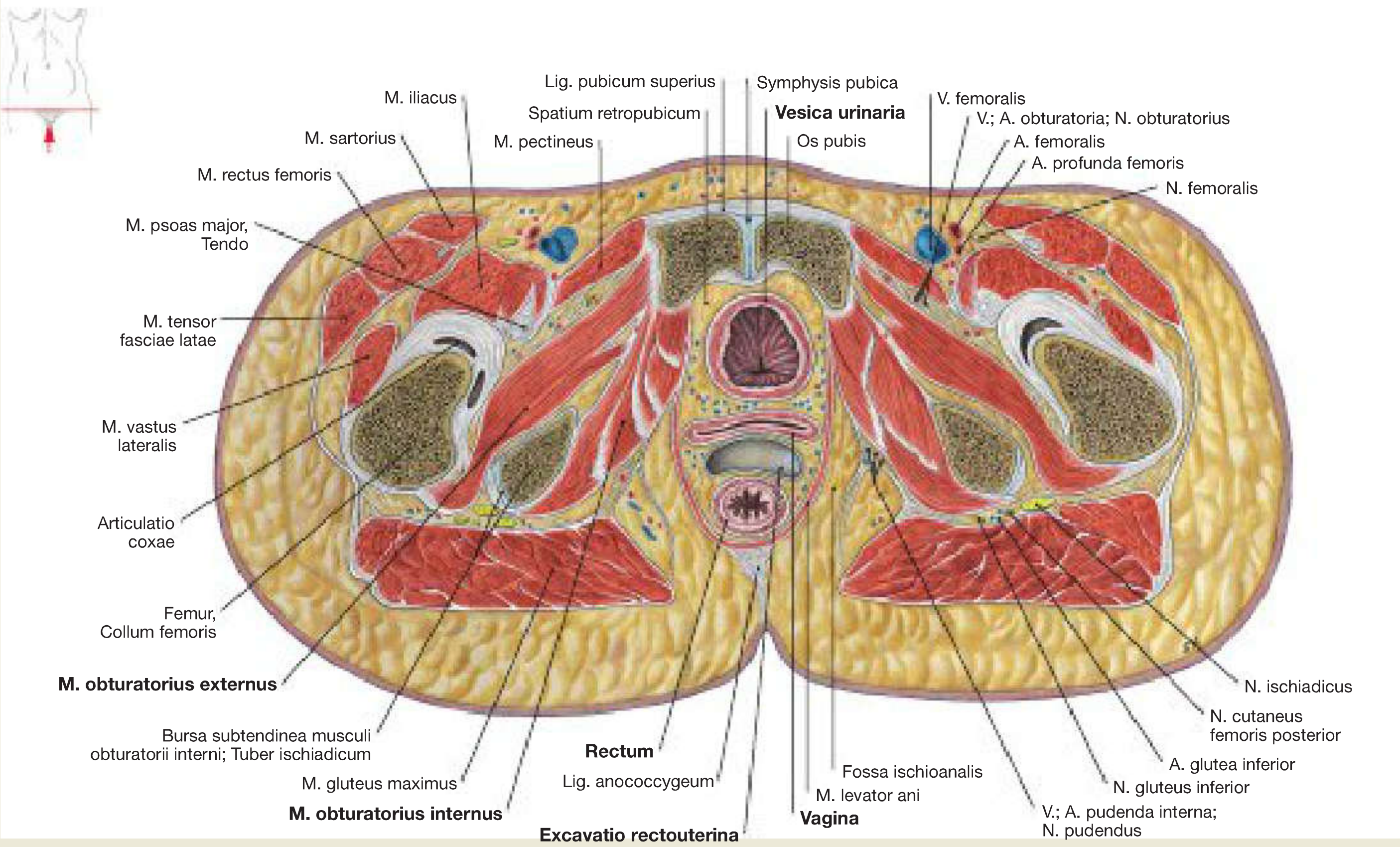


b

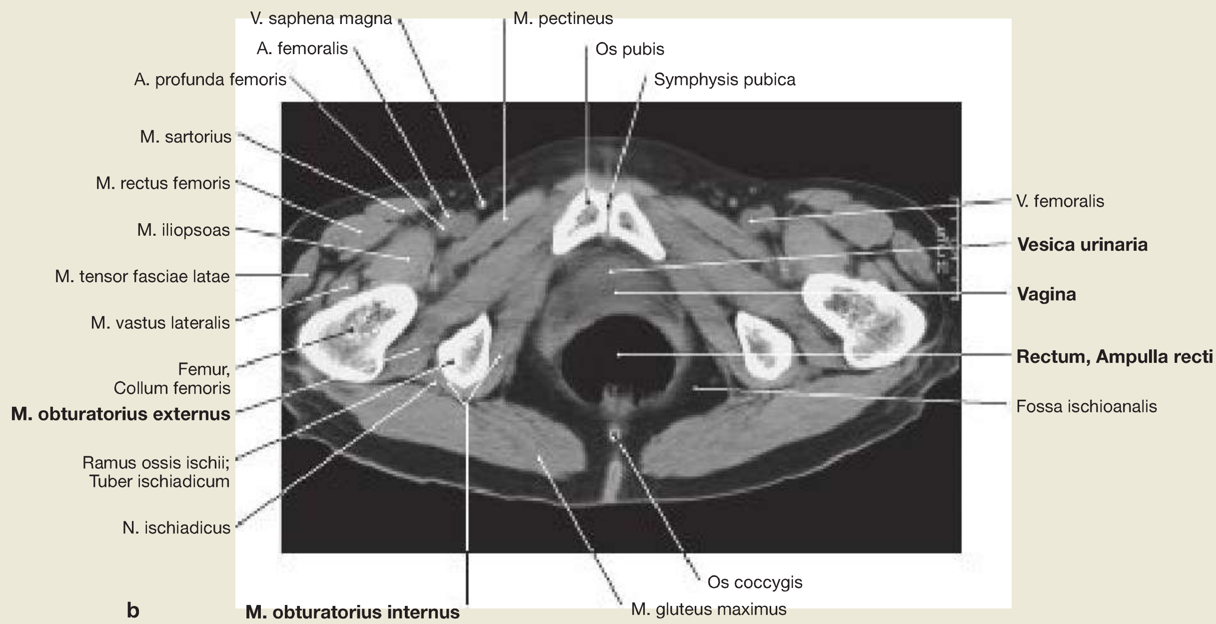
Fig. 7.141a and b Pelvis of a man; cross-section at the level of the lesser pelvis (→ Fig. 7.141a) and corresponding computed tomography scan of the male pelvis in portal venous phase (→ Fig. 7.141b); caudal view. a [L238]; b [T832]

The cross-section makes it possible to show the course of several muscles. For instance, the M. puborectalis of the M. levator ani is shown, forming a loop behind the rectum and pulling it forwards. As a result, this creates the Flexura perinealis in the rectum. This mechanism contributes to the closure of the rectum and is important for faecal continence. Furthermore, the complicated course of the M. obturatorius internus is very easily understandable: the muscle originates from the inner aspect of the pelvic bone and goes dorsally. It is then deflected by the Os ischii, which acts as a hypomochlion, and ends up on the inner aspect of the Trochanter major.

Female Pelvis, Cross-Sections

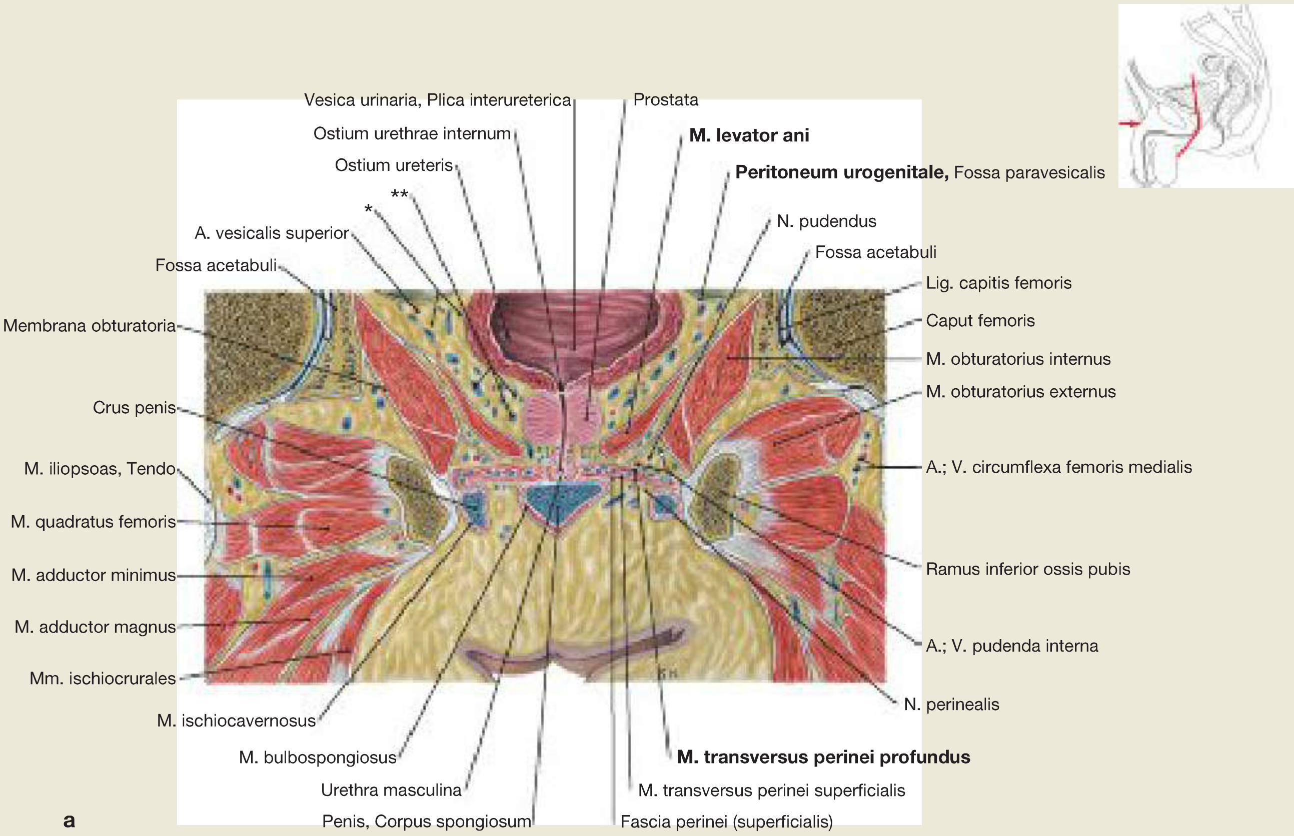


a

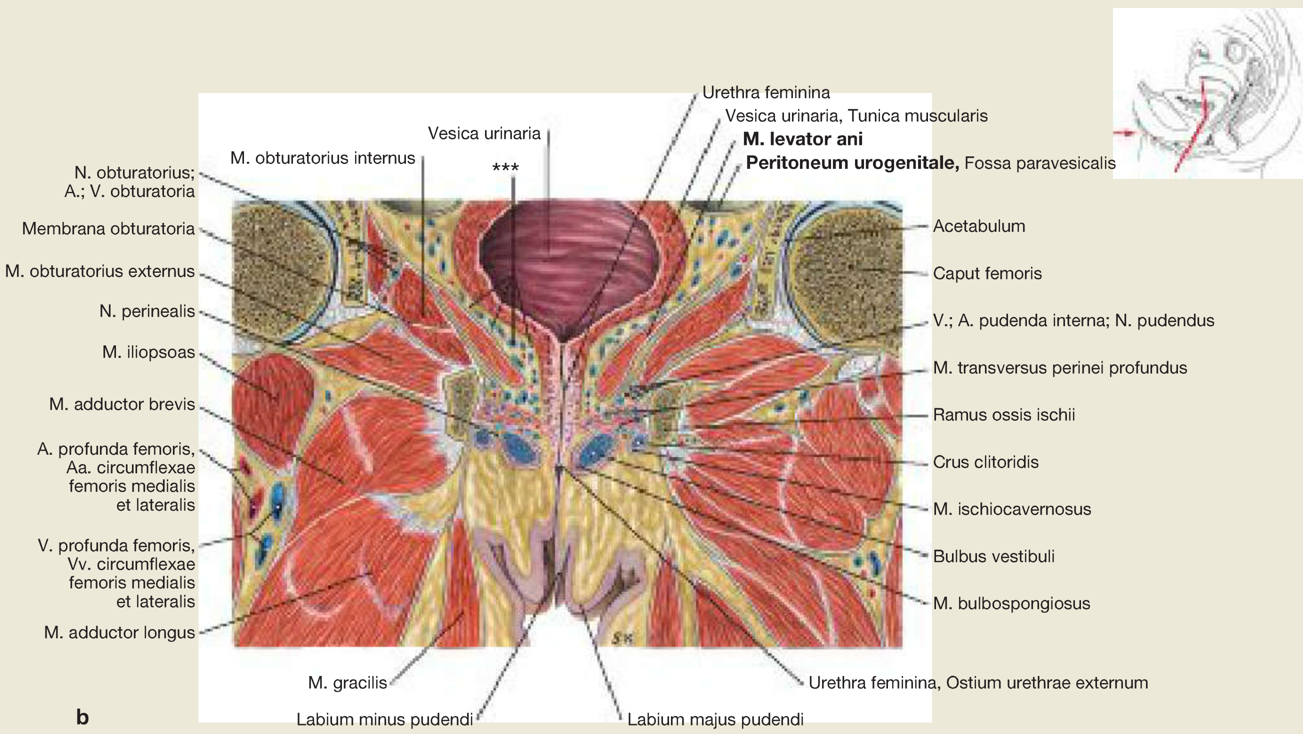


b

Fig. 7.142a and b Pelvis of a woman; cross-section at the level of the lesser pelvis (→ Fig. 7.142a) and corresponding computed tomography scan (→ Fig. 7.142b); caudal view. a [L238]; b [T893]
Of the pelvic viscera the following are recognisable: urinary bladder (Vesica urinaria), rectum, and between them the vagina and the Excavatio rectouterina (pouch of DOUGLAS) as the deepest part of the peritoneal cavity. Compared to the cross-section of the male pelvis (→ Fig. 7.114a), the cross-section here is further caudal. Therefore, in addition to the M. obturatorius internus, the M. obturatorius externus can also be seen at the front on the opposite side of the pelvic bone.



a



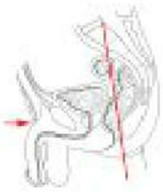
b

Fig. 7.143a and b Pelvis of a man (→ 7.143a) and of a woman (→ 7.143b); angled frontal section through the urinary bladder. [L238]
The section shows the pelvic floor and perineal muscles with the perineal spaces in a male (→ Fig. 7.101) and female (→ Fig. 7.136) pelvis. It shows the lower levels of the pelvic cavity clearly. Caudally of the **Peritoneum parietale** (here the Peritoneum urogenitale) the **subperitoneal space** expands up to the pelvic floor, formed here by the **M. levator ani.** Below it connects with the **perineal region. In men,** the M. transversus perinei profundus forms a solid muscle plate which fills the deep perineal space. Caudal to the Membrana perinei on the underside of the muscle is the superficial perineal space. **In women,** the perineal spaces are arranged in a similar way, but the M. transversus perinei profundus is predominantly permeated with connective tissue, so that there is usually no solid muscle plate present.

* clinical term: paracystium
** clinical term: Plexus venosus prostaticus
*** paracystium with venous plexus

Cross-Sectional Images

Male Pelvis, Frontal Section



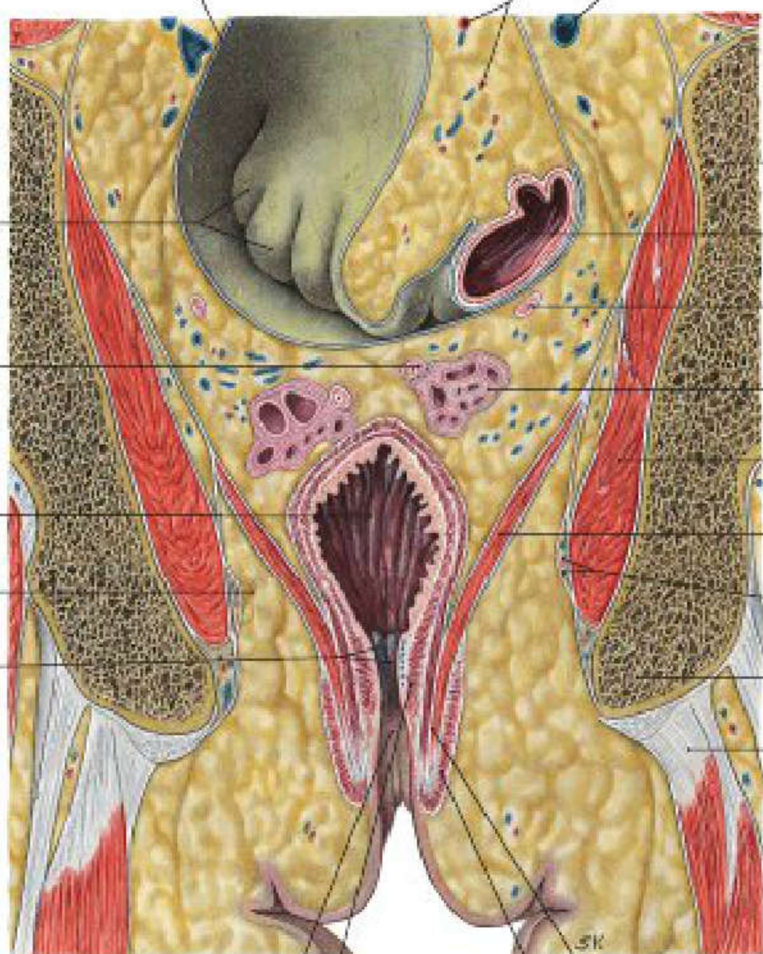


Fig. 7.144 Pelvis of a man; oblique frontal section through the lesser pelvis. [L238]

The A. and V. pudenda interna run jointly with the N. pudendus in the fascial duplicature of the M. obturatorius internus (clinical term: ALCOCK's canal) in the Fossa ischioanalis.

Practice Exam Questions

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

Which organs are in the retroperitoneal space (Retroperitoneum)?

- Explain the **topographical relationships** of the pelvic viscera.

How do the kidneys develop and how are they structured?

What are the parts of the adrenal gland and what differentiates them in terms of functionality and regulation?

What functions do the kidneys have?

Which fascial systems surround them?

What blood vessels supply the kidney and adrenal gland and which variations are you aware of?

Which parts does the urinary system have?

- From what do these develop?

What are the constrictions of the ureter?

How is the urinary bladder closed?

How is the anal canal structured?

- Show the zones on the specimen.

How is the continence organ structured?

What are the arteries supplying the rectum and the anal canal?

Where are the regional lymph nodes for the individual parts?

How do the internal female genitalia develop and how do they differ from the male genitalia?

Explain the blood vessels of the penis on the specimen.

What is the spermatic cord?

Which neurovascular pathways supply the testes?

- Where are the regional lymph nodes?

What accessory sex glands are you aware of?

- Show these on the specimen.

Into which zones is the prostate divided?

Which ligaments fix the uterus in place?

Where is the pouch of DOUGLAS and what significance does it have?

How is the uterus supplied with blood?

Where are the regional lymph nodes of the ovary?

How is the pelvic floor structured?

- How is it innervated?

Show the perineal muscles.

- What function do they have?

Appendix

Picture Credits

Reference to the source for each figure in this work is given at the end of each caption in square brackets. All figures and graphics without a reference © Elsevier GmbH, Munich.
The editors sincerely thank all clinical colleagues that made ultrasound, computed tomographic and magnetic resonance images as well as endoscopic and intraoperative pictures available.

E282	Kanski, J.: Clinical Ophthalmology: A Systemtic Approach. 5th Ed., Butterworth-Heinemann, 2003
E347-09	Moore, K.L./Persaud, T.V.N./Torchia, M.G.: The Developing Human. 9th Ed., Elsevier/Saunders 2013
E402	Drake, R.L./Vogl, A. W./Mitchell A.W.M./Tibbitts, R.M./ Richardson, P.E.: Gray's Anatomy for Students. 1st Ed., Elsevier/Churchill Livingstone, 2005
E460	Drake, R.L./Vogl, A. W./Mitchell A.W.M./Tibbitts, R.M./ Richardson, P.E.: Gray's Atlas of Anatomy. 1st Ed., Elsevier/ Churchill Livingstone, 2008
E838	Mitchell, B./Sharma, R.: Embryology. An Illustrated Colour Text. Elsevier/Churchill Livingstone, 1st Ed., 2005
E943	Kanski, J.: Clinical Ophthalmology: A Systemic Approach. 6th Ed., Butterworth-Heinemann, 2007
F885	Senger, M./Stoffels, HJ./Angelov DN: Topography, syntopy and morphology of the human otic ganglion: A cadaver study. Ann Anat 2014;196(5):327–35
G159	Forbes, A. et al.: Atlas of Clinical Gastroenterology. 3rd Ed., Mosby 2004
G198	Mettler, F.: Essentials of Radiology. 2nd Ed., Saunders 2005
G210	Standring, S.: Gray's Anatomy. 40th Ed., Elsevier/Churchill Livingstone, 2008
G617	Folkerth, R.D./Lidov H.: Neuropathology, Elsevier 2012
J803	Biederbick & Rumpf, Adelsdorf
L106	Henriette Rintelen, Velbert
L107	Michael Budowick, USA
L126	Dr. med. Katja Dalkowski, Erlangen
L127	Jörg Mair, München
L131	Stefan Dangl, München
L141	Stefan Elsberger, Planegg
L157	Susanne Adler, Lübeck
L238	Sonja Klebe, Löhne
L240	Horst Ruß, München
L266	Stephan Winkler, München
L271	Matthias Korff, München
L275	Martin Hoffmann, Neu-Ulm
L280	Johannes Habla, München
L281	Luitgard Kellner, München
L284	Marie Davidis, München
L285	Anne-Katrin Hermanns, „Ankats Art", Maastricht, NL
M502	Prof. Dr. med O. Trentz, Zürich
M519	Prof. Dr. med. G. A. Wanner, Zürich
M526	Prof. Dr. med. T.H.K. Schiedeck, Ludwigsburg
O548	Prof. Dr. med. Andreas Franke, Kardiologie, Klinikum Region Hannover
O892	PD Dr. med. habil. L. Mirow, Landkreis Mittweida Krankenhaus GmbH
P319	Frau Dr. med. Berit Jordan, Uniklinik Halle
P320	Prof. Dr. med. Frank Hanisch, Uniklinik Halle
R132	Classen, M./Diehl, V./Kochsiek, K.: Innere Medizin. 5. A., Elsevier/Urban & Fischer, 2003
R170	Welsch, U.: Sobotta Lehrbuch der Histologie. 2. A., Elsevier/Urban & Fischer, 2006
R235	Böcker, W./Denk, H./Heitz, P./Moch, H.: Pathologie. 4. A., Elsevier/Urban & Fischer, München 2008
R236	Classen, M./Diehl, V./Kochsiek, K.: Innere Medizin. 6. A., Elsevier/Urban & Fischer, 2009
R242	Franzen, A.: Kurzlehrbuch Hals-Nasen-Ohren-Heilkunde. 3. A., Elsevier/Urban & Fischer, 2007
R247	Deller, T./Sebestény, T.: Fotoatlas Neuroanatomie. 1. A., Elsevier/Urban & Fischer, 2007
R252	Welsch, U.: Sobotta: Atlas Histologie: 7. A., Elsevier/Urban & Fischer, 2005
R254	Garzorz, N.: Basics Neuroanatomie. 1. A., Elsevier/Urban & Fischer, 2009
R316-007	Wicke, L.: Atlas der Röntgenanatomie. 7. A., Elsevier/Urban & Fischer, 2005
R317	Trepel, M.: Neuroanatomie. 5. A., Elsevier/ Urban & Fischer, 2011
R331	Fleckenstein, P./Tranum-Jensen, J.: Röntgenanatomie. Elsevier/Urban & Fischer, 2004
R349	Raschke, M. J./Stange, R.: Alterstraumatologie – Prophylaxe, Therapie und Rehabilitation. 1. A., Elsevier/Urban & Fischer, 2009
S002-7	Lippert, H.: Lehrbuch Anatomie. 7. A., Urban & Fischer, 2006
S008-3	Kauffmann, G. W./Moser, E./Sauer, R.: Radiologie. 3. A., Elsevier/Urban & Fischer, 2006
S010-2-16	Benninghoff, A./Drenckhahn, D.: Anatomie. 16. A. Band 2, Urban & Schwarzenberg, 2004
S010-1-17	Benninghoff, A./Drenckhahn, D.: Anatomie. 17. A., Band 1, Elsevier/Urban & Fischer, 2008
T534	Prof. Dr. med. Matthias Sitzer, Klinik für Neurologie, Klinikum Herford
T127	Prof. Dr. med. Dr. Peter Scriba, München
T719	Prof. Dr. med. Norbert Kleinsasser, HNO-Klinik, Universität Würzburg
T720	PD Dr. med. Hannes Kutta, Universitätsklinikum Hamburg-Eppendorf
T786	Dr. med. Stephanie Lescher/Prof. Dr. med. Joachim Berkefeld, Institut für Neuroradiologie, Klinikum der Goethe Universität Frankfurt
T832	PD Dr. med. Frank Berger, Institut für Klinische Radiologie der LMU München
T863	Dr. med. C. Markus, Uniklinik Würzburg
T867	Prof. Dr. med. Gerd Geerling, Düsseldorf
T872	Prof. Dr. med. M. Uder, Erlangen
T882	Prof. Dr. med. Christopher Bohr, Erlangen
T884	Dr. med. dent. Tobias Wicklein, Erlangen
T887	Prof. Dr. med Stephan Zierz, Uniklinik Halle
T890	Prof. Dr. med. Jakob Altaras†, Zentrum Radiologie, Universität Gießen
T891	Prof. Dr. med. Hartmut Brückmann/PD Dr. med. Jennifer Linn, Neuroradiologie, Institut für radiologische Diagnostik, Universität München
T892	Prof. Dr. med. Werner Daniel, Abteilung Kardiologie, Universität Erlangen
T893	Prof. Dr. med. Michael Galanski/Dr. Schäfer, Abteilung Diagnostische Radiologie, Med. Hochschule Hannover
T894	Prof. Dr. med. Michael Gebel, Abteilung Gastroenterologie und Hepatologie, Med. Hochschule Hannover
T895	Dr. Gabriele Greeven, St.-Elisabeth-Krankenhaus, Neuwied
T896	Prof. Dr. med. Dr. rer. nat. Matthias Hoffmann/Prof. Dr. med. Hüseyin Bektas, Klinik für Viszeral- und Transplantationschirurgie, Med. Hochschule Hannover
T897	Prof. Dr. med. Jens Hohlfeld, Klinik für Pneumologie, Med. Hochschule Hannover
T898	Prof. Dr. med. Udo Jonas, Urologie, Med. Hochschule Hannover
T899	Prof. Dr. med. Anselm Kampik/Prof. Dr. med. Arthur Müller, Augenklinik, Universität München
T900	PD Dr. med. Tim Kirchhoff/Dr. med. Jürgen Weidemann, Abteilung Diagnostische Radiologie, Med. Hochschule Hannover
T901	Dr. Meyer, Abteilung Gastroenterologie und Hepatologie, Med. Hochschule Hannover
T902	Prof. Pfeifer, Radiologie Innenstadt, Institut für radiologische Diagnostik, Universität München
T903	Prof. Dr. med. Kurt Possinger/Prof. Dr. med. Ulrich Bick, Medizinische Klinik und Poliklinik II mit Schwerpunkt Onkologie und Hämatologie, Charité Campus Mitte, Berlin
T904	Prof. Dr. Alfred Ravelli†, ehem. Institut für Anatomie, Universität Innsbruck
T905	Prof. Dr. med. Dr. med. dent. Rudolf H. Reich, Klinik für Mund-Kiefer-Gesichtschirurgie, Universität Bonn
T906	Prof. Dr. med. Maximilian Reiser/Dr. Wagner, Institut für radiologische Diagnostik, Universität München
T907	Dr. Scheibe, Chirurgische Abteilung, Rosmann-Krankenhaus Breisach
T908	Prof. Dr. med. Georg F. W. Scheumann, Klinik für Viszeral- und Transplantationschirurgie, Med. Hochschule Hannover
T909	Prof. Dr. med. Helmut Schillinger, Frauenklinik, Universität Freiburg
T910	Prof. Dr. med. Dr. med. dent. Henning Schliephake, Mund-Kiefer-Gesichtschirurgie, Universität Göttingen
T911	Prof. Dr. med. Hans Walter Schlößer, Zentrum Frauenheilkunde, Med. Hochschule Hannover
T912	cand. med. Carsten Schröder, Kronshagen
T916	Prof. Dr. med. Thomas J. Vogl, Radiologische Poliklinik, Universität München
T917	Prof. Witt, Klinik für Neurochirurgie, Universität München

A

Index

D

E

F

M

N

O

P

Index

S

Index

T

U

V

Index

W

Z

Sobotta

Discover your Personal Digital Ancillary Content at e-Sobotta

NOTE:
The atlas cannot be returned once panel is scratched off.

How to Register:

1. Gently scratch off the surface of the sticker above to reveal your personal, non-transferable PIN.
2. Access your e-Sobotta content at **www.sobotta.com**, by first registering to create a digital bookshelf. Follow the simple registration instructions on the page.
3. Once you have created your digital bookshelf, redeem your ancillary content with your personal PIN printed above.
4. On future visits you will simply need to log-in to access your redeemed content.

Your e-Sobotta ancillary content enables you to systematically deepen and test your knowledge for all anatomical structures present within this atlas. Access world-class anatomy content digitally, wherever you are, whenever you choose.

Important Note:
Access to, and use of, content through the website is for individual, non-commercial use only and non-transferable. The license and access to the online version operates strictly on the basis of a single user per PIN.

The sharing of login credentials is strictly prohibited, and any attempt to do so will invalidate the access. Access may not be shared, resold, or otherwise circulated.

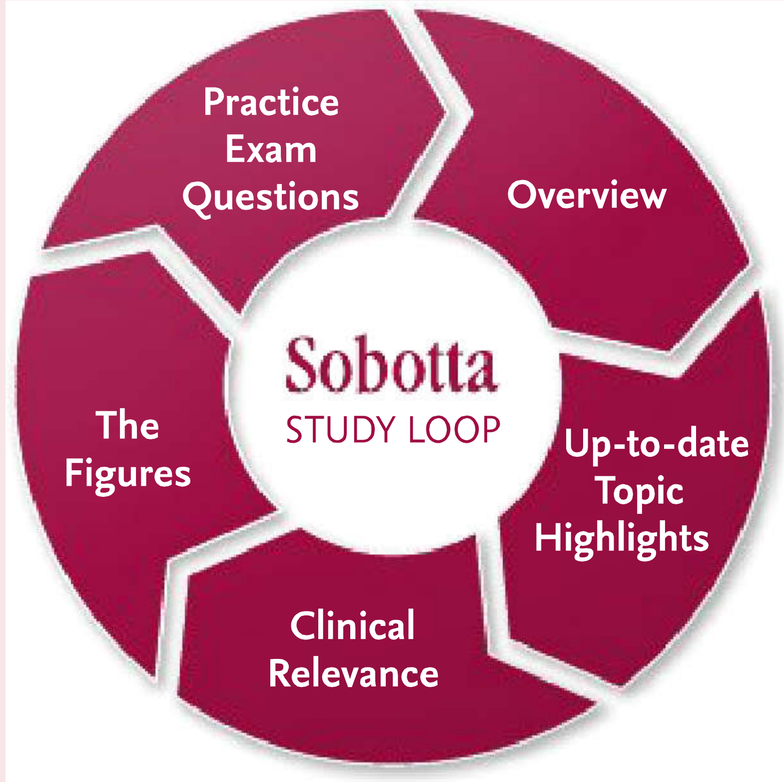
Full Terms and Conditions of use are available upon registration, and access will be subject to your acceptance of these terms of use. Access is granted for the lifespan of **www.sobotta.com** and terminates on its end of service, as this is a non-binding offer.

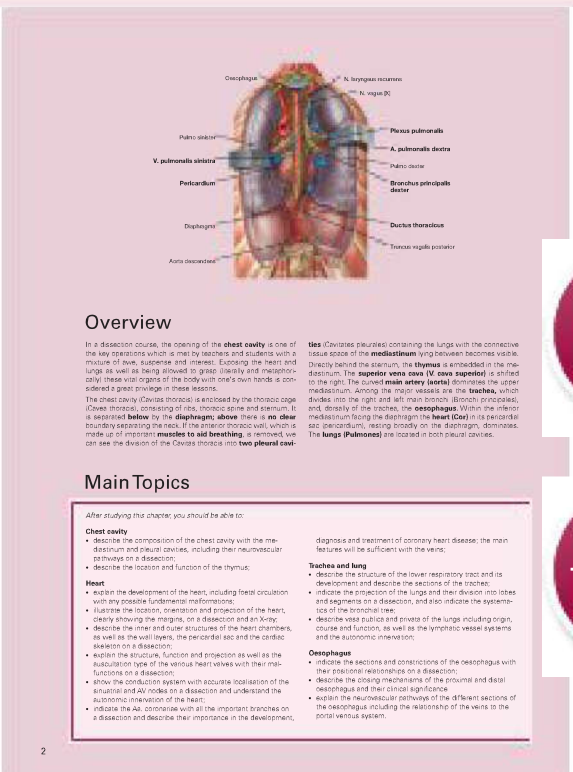
Library and institutional access and use are strictly prohibited. For information on products and services available for institutional access, please contact **lizenzen@elsevier.com**.

ELSEVIER

The Sobotta Study Loop

The **Sobotta Study Loop** guides you through each chapter, introducing you to the relevant content as you go. The initial introductory page gives you an insight into the individual chapters and highlights their most important themes.





Overview

The chapter's core topics clearly presented – crucial anatomical information is highlighted.

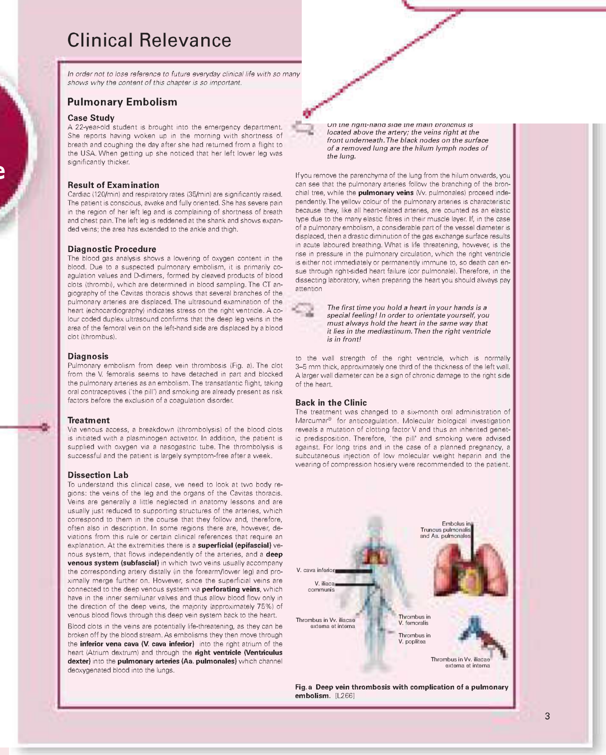
Focused Topic Highlights

Enable interconnected competencies – via explaining anatomical content in context, thus indicating clear study objectives.

Clinical Relevance

Actual clinical cases showcase practical application of the anatomical knowledge gained beyond the lecture hall.

Useful hints and tips for your dissection course

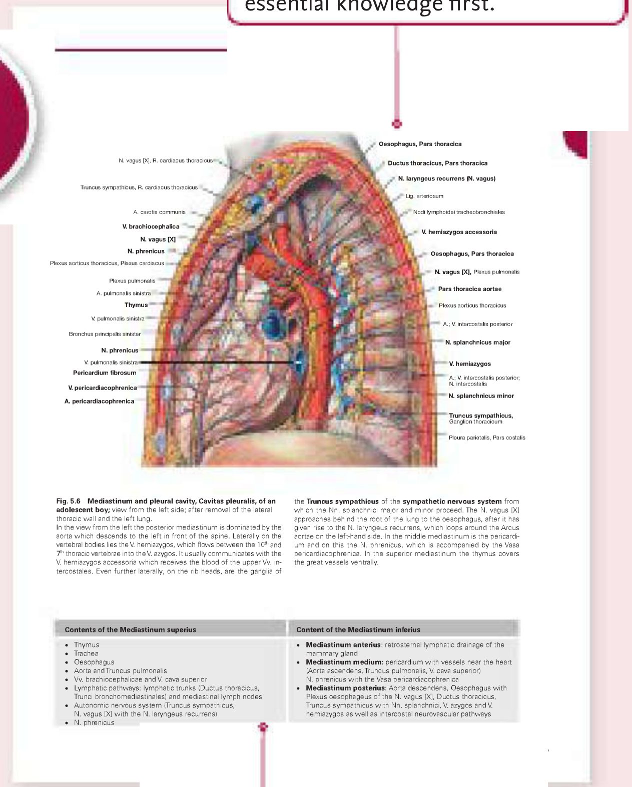


Each case report includes:
- A Case Study
- Examination Results
- Diagnostic Procedure
- Diagnosis
- Treatment
- Dissection Lab Tips
- In the Clinic

A common theme runs through each chapter, from the surface to the detail. Clinical hints and teaching tables help you to understand and classify. Captions explain the relationships between the depicted anatomical structures. Individual structures that are relevant for tests and examinations are highlighted in bold.

The Figures

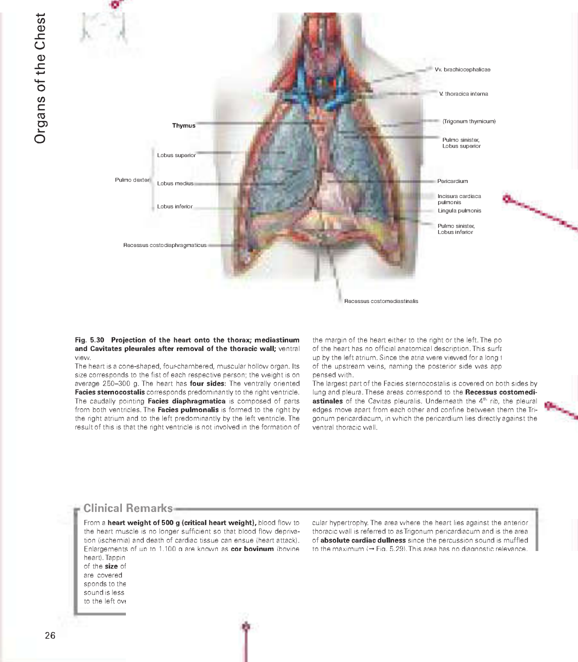
Important anatomical structures are highlighted to help you focus on the essential knowledge first.



Sobotta's quick regional anatomical reference on every page aids quick orientation and helps you find your way around the chapters and their topics.

An orientation sketch points you to the current view or section depicted in the anatomical figure at a glance.

Clearly arranged tables enable you to memorise knowledge in a structured and contextualised approach.



Various types of images are used in the atlas:

- realistic and detailed anatomical illustrations for a deeper insight
- schematic drawings highlighting functional relationships
- photos showcasing surface anatomy
- in-depth medical imaging scans

Each figure has a detailed caption which highlights the most important structures and the systematic and topographical relationships.

Clinical Remarks present a typical clinical case and symptoms relevant to the depicted condition or illness. This acts as an aide-mémoire contextualising the displayed structure.

Practice Exam Questions

Every chapter closes with a sampling of typical oral exam questions enabling you to test your knowledge gained within the chapter.

You will find these in the 16th edition

Volume 1 – General Anatomy and Musculoskeletal System

1 General Anatomy

Anatomical Planes and Positions → Surface Anatomy → Development → Musculoskeletal System → Neurovascular Pathways → Imaging Methods → Skin and its Appendages

2 Trunk

Surface Anatomy → Development → Skeleton → Imaging Methods → Muscles → Neurovascular Pathways → Topography, Dorsal Trunk Wall → Female Breast → Topography, Ventral Trunk Wall

3 Upper Limb

Surface Anatomy → Development → Skeleton → Imaging Methods → Muscles → Neurovascular Pathways → Topography → Cross-Sectional Images

4 Lower Limb

Surface Anatomy → Skeleton → Imaging Methods → Muscles → Neurovascular Pathways → Topography → Cross-Sectional Images

Volume 2 – Internal Organs

5 Organs of the Chest Cavity

Topography → Heart → Lung → Oesophagus → Cross-Sectional Images

6 Organs of the Abdominal Cavity

Development → Topography → Stomach → Intestines → Liver and Gallbladder → Pancreas → Spleen → Neurovascular Pathways → Cross-Sectional Images

7 Retroperitoneal Space and Pelvic Cavity

Topography → Kidney and Adrenal Gland → Urinary System → Rectum and Anal Canal → Genitalia → Cross-Sectional Images

Volume 3 – Head, Neck and Neuroanatomy

8 Head

Overview → Skeleton and Joints → Muscles → Topography → Neurovascular Pathways → 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

Development → General Principles → Brain → Meninges and Blood Supply → Cerebral Areas → Cranial Nerves → Spinal Cord → Sections

Tables

Tables of Muscles, Joints and Nerves

Head → Neck → Trunk → Upper Limb → Lower Limb → Cranial Nerves