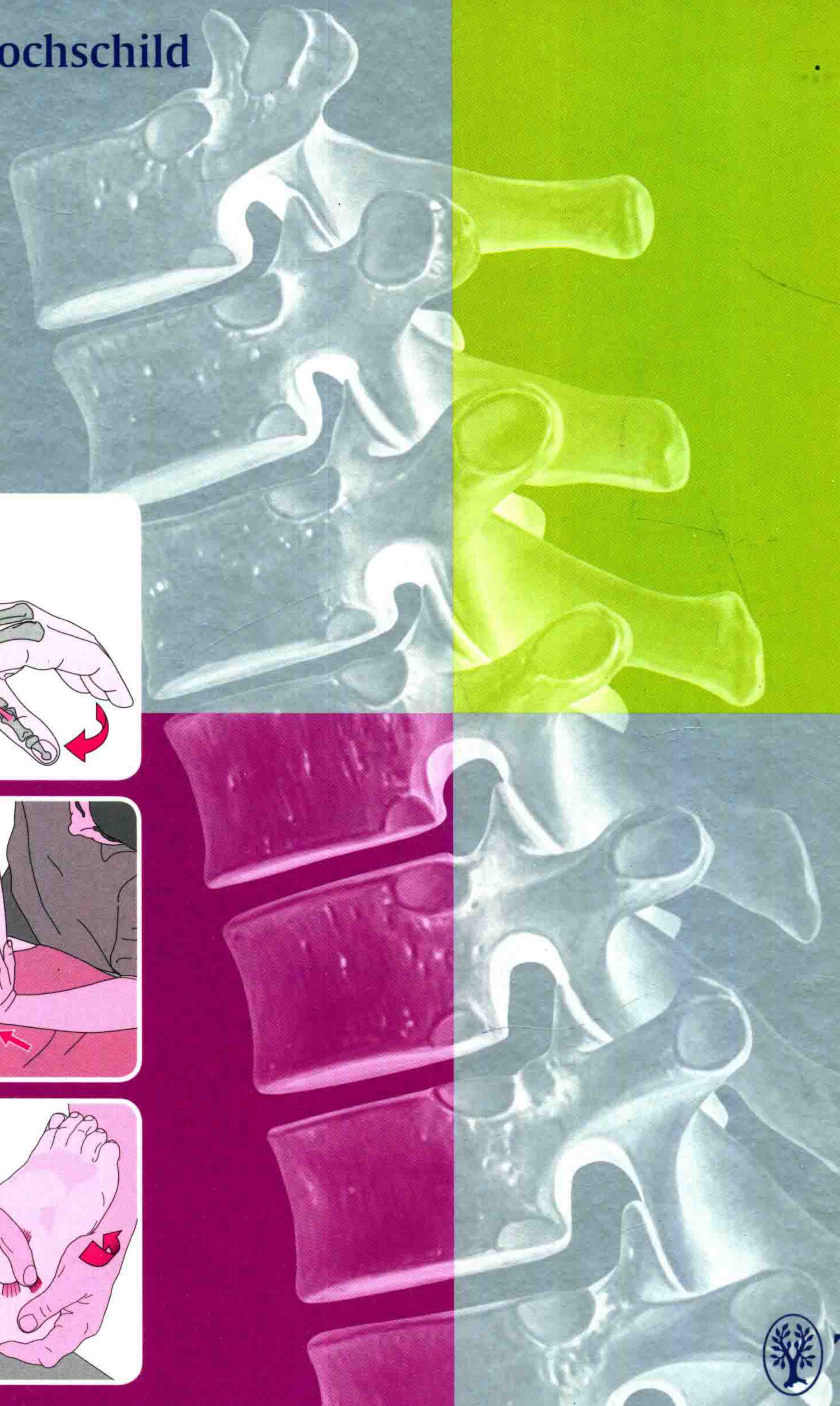
# Functional Anatomy for Physical Therapists

Jutta Hochschild



Thieme

# Functional Anatomy for Physical Therapists

**Jutta Hochschild**
Physical Therapist
Former Head, Physical Therapy School
Department of Orthopaedics
Academic Teaching Hospital
University of Frankfurt
Frankfurt, Germany

1000 illustrations

Georg Thieme Verlag
Stuttgart · New York · Delhi · Rio de Janeiro

**Library of Congress Cataloging-in-Publication Data**

Hochschild Jutta, author.
[Strukturen und Funktionen begreifen. English]
Functional anatomy for physical therapists / Jutta Hochschild.
p. ; cm.
ISBN 978-3-13-176861-2 (alk. paper) –
ISBN 978-3-13-176871-1 (eISBN)
I. Title.
[DNLM: 1. Physical Therapy Modalities. 2. Anatomy. 3. Physiological Phenomena. WB 460]
QM 26
612-dc23
2015034186

This book is an authorized translation of the 2-volume 3rd German edition published and copyrighted 2005 and 2008 by Georg Thieme Verlag, Stuttgart. Title of the German edition: Strukturen und Funktionen begreifen : Funtionelle Anatomie : Therapierelevante Details – T.p. verso.

Translator: Alan Wiser, MD, Ambler, PA, USA
Illustrator: Malgorzata & Piotr Gusta, Champigny sur Marne, France

1st Italian edition 2003
1st Japanese edition 2011



Thieme Publishers Stuttgart
Rüdigerstrasse 14, 70469 Stuttgart, Germany
+49 [0]711 8931 421, customerservice@thieme.de

Thieme Publishers New York
333 Seventh Avenue, New York, NY 10001, USA
+1-800-782-3488, customerservice@thieme.com

Thieme Publishers Delhi
A-12, Second Floor, Sector-2, Noida-201301
Uttar Pradesh, India
+91 120 45 566 00, customerservice@thieme.in

Thieme Publishers Rio, Thieme Publicações Ltda.
Edifício Rodolpho de Paoli, 25° andar
Av. Nilo Peçanha, 50 – Sala 2508
Rio de Janeiro 20020-906 Brasil
+55 21 3172 2297 / +55 21 3172 1896

Cover design: Thieme Publishing Group
Typesetting by Druckhaus Götz GmbH, Ludwigsburg, Germany

Printed in Germany by appl druck, Wemding

ISBN 978-3-13-176861-2　　5 4 3 2 1

Also available as an e-book:
eISBN 978-3-13-176871-1

**Important note:** Medicine is an ever-changing science undergoing continual development. Research and clinical experience are continually expanding our knowledge, in particular our knowledge of proper treatment and drug therapy. Insofar as this book mentions any dosage or application, readers may rest assured that the authors, editors, and publishers have made every effort to ensure that such references are in accordance with **the state of knowledge at the time of production of the book.**
Nevertheless, this does not involve, imply, or express any guarantee or responsibility on the part of the publishers in respect to any dosage instructions and forms of applications stated in the book. **Every user is requested to examine carefully** the manufacturers' leaflets accompanying each drug and to check, if necessary in consultation with a physician or specialist, whether the dosage schedules mentioned therein or the contraindications stated by the manufacturers differ from the statements made in the present book. Such examination is particularly important with drugs that are either rarely used or have been newly released on the market. Every dosage schedule or every form of application used is entirely at the user's own risk and responsibility. The authors and publishers request every user to report to the publishers any discrepancies or inaccuracies noticed. If errors in this work are found after publication, errata will be posted at www.thieme.com on the product description page.
Some of the product names, patents, and registered designs referred to in this book are in fact registered trademarks or proprietary names even though specific reference to this fact is not always made in the text. Therefore, the appearance of a name without designation as proprietary is not to be construed as a representation by the publisher that it is in the public domain.

FSC® www.fsc.org
MIX
Paper from responsible sources
FSC® C004592

# Preface

Anatomy, with all its fascinating facets to investigate and teach, has been and continues to be my calling. To probe more deeply into the interconnections between structures and, through that, to clarify many functional problems that patients have never ceases to engage me.

My students have always had a great deal to learn, but it is important to me that they understand anatomy, not merely memorize it. I dedicate my book to them. Based on 25 years and approximately 7,000 hours teaching functional anatomy—this book evolved from an instructional manual after many years of work.

My book should not and cannot replace the classical anatomy texts. Rather, it is a supplement to them. Thus, I delve thoroughly into joint surfaces and the formation of joints, while only briefly describing the bones. While I have assumed a background knowledge of muscle origins and insertions, I feel it is important to describe the functional aspects of the muscles.

Palpation of the various structures makes up a large portion of the book. It remains an important component of examination and treatment in physical therapy.

I hope that my references to pathology and the practical tips are useful for all my colleagues in everyday practice.

I especially wish to thank the illustrator, Piotr Gusta and his wife, who immersed themselves deeply in their work. The superb, detailed figures found in this book are the result.

I would like to thank Dr. Alan Wiser for his excellent translation. I would also like to extend thanks to Angelika-Marie Findgott and Gabriele Kuhn-Giovannini for their excellent support, and to all the other associates at Thieme Publishers who participated in the production of this book.

I also thank my colleagues at the School of Physical Therapy at the University Hospital Frankfurt. They have always assisted me in gathering important data.

*Jutta Hochschild*

# Contents

# Chapter 1
## Fundamentals of the Spinal Column

# 1 Fundamentals of the Spinal Column

## 1.1 Development and Structure of the Spinal Column (Fig. 1.1)

Viewed laterally, the spinal column develops from being totally kyphotic in the early embryonic phase to the normally curved spine with two areas of kyphosis and two areas of lordosis within the first 7 years of life.

The following events occur **during growth**: Cervical lordosis develops when the infant attempts to lift its head from the prone position while trying to move on all fours. The lordosis in the lumbar spine develops during the process of standing upright. Because of the lack of flexibility of the hip flexors, any extension of the hip joints causes an inclination of the pelvis, which further accentuates the lordosis of the lumbar spine. This process is not complete until near the end of the 6th year of life.

### 1.1.1 Ideal Curvature (Fig. 1.2)

The ideal spinal curvature has been determined with the help of computer analysis. In the erect position, the plumb line cuts through the anterior tubercle of the atlas (**a** in **Fig. 1.2**), the sixth cervical vertebra (**b**), the ninth thoracic vertebra (**c**), the third sacral vertebra, (**d**) and the tip of the coccyx (**e**).

**Practical Tip**

Assessment of the statics of the spine is an important part of the physical therapy record. Among other things, the characteristics of the curvature in the sagittal plane are recorded. Deviations from the norm are the hollow round back with increased lumbar lordosis and thoracic kyphosis, and the flat back with attenuation of the physiologic curvatures.

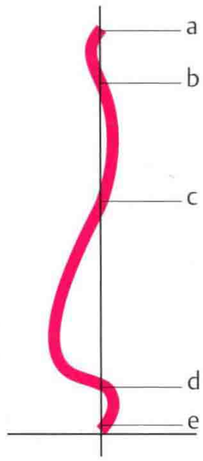



**Fig. 1.2** The ideal curvature of the spine and its intersections with a center of gravity plumb line.

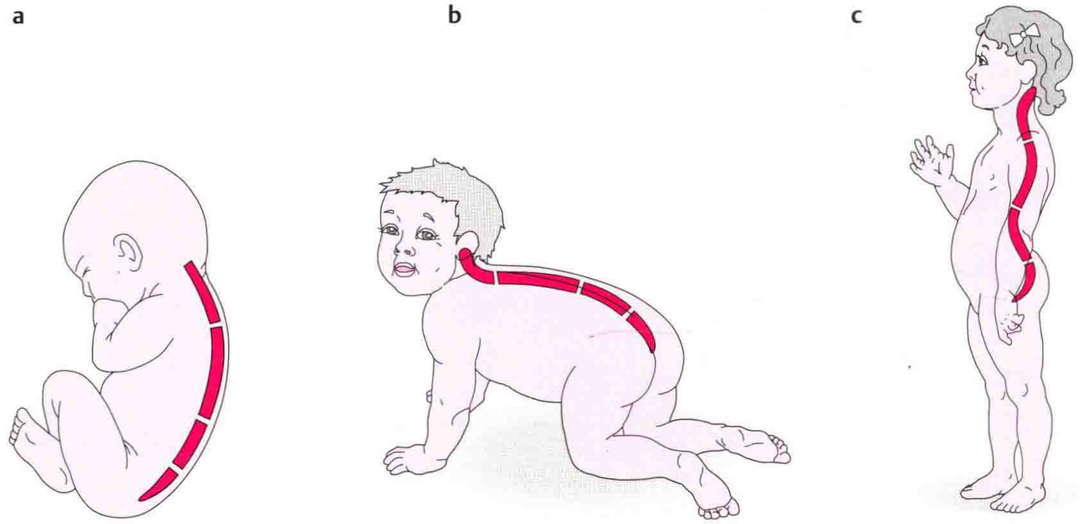



**Fig. 1.1** Development of the spinal curvatures. **(a)** Embryonic period. **(b)** Infancy. **(c)** Early childhood.

## 1.1.2 Architecture of the Cancellous (Trabecular) Bone (Fig. 1.3)

Mechanical stress influences the structural arrangement of trabecular bone. Because of this stress distribution, zones of varying density develop.

A sagittal section through the vertebral body demonstrates an area that is less dense anteriorly. This is caused by lines of stress that run in a fan-shaped curve from the superior edge of the vertebral body to the upper articular processes and the spinous process, as well as from the inferior edge of the vertebral body to the lower articular processes and the spinous process.

In a frontal section, one can also identify fan-shaped stress lines running vertically and horizontally.

The arrangement of the trabecular structure of bone depends on the tensile and compressive load and can adapt to changing forces.

Changes occur if load limits are over- or undershot for a prolonged period of time.

*Examples:*

- Bone structure changes due to poor posture and after fractures that do not heal in the correct axis.
- The skeletal structure becomes fragile if load limits are over- or undershot for a prolonged period of time.
- Structural disorders lead to characteristic vertebral body shapes such as fish vertebrae in osteoporosis and wedge-shaped vertebrae in spondylitis.

**Practical Tip**

Eliminating muscle imbalances, reducing excessive weight, and improving the awareness of body posture lead to balanced tensile and compressive stresses on the bone. The strength and configuration of the trabecular structure can be positively influenced and maintained to accommodate long-term weight-bearing and alterations in weight-bearing status.

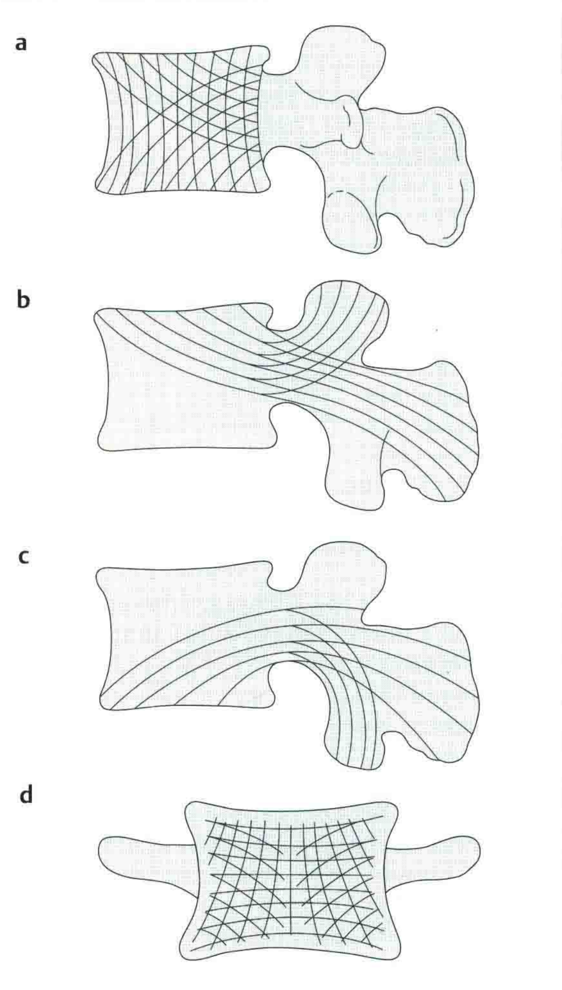



**Fig. 1.3** Architecture of cancellous bone. **(a–c)** In sagittal section. **(d)** In frontal section.

# 1.2 Motion Segment (Fig. 1.4)

The motion segment is a functional unit that corresponds to the movement space between two vertebrae, including the following structures (**Fig. 1.4**):

- **Zygapophysial joints:**
  1 = Joint capsule
  2 = Ligamentum flavum
- **Spinal canal and intervertebral foramen:**
  3 = Spinal nerve
  4 = Meningeal branch of the spinal nerve
  5 = Blood vessels
- **Disk space:**
  6 = Cartilage plate
  7 = Marginal ridge of the vertebral body
  8 = Nucleus pulposus
  9 = Anulus fibrosus
  10 = Anterior longitudinal ligament
  11 = Posterior longitudinal ligament

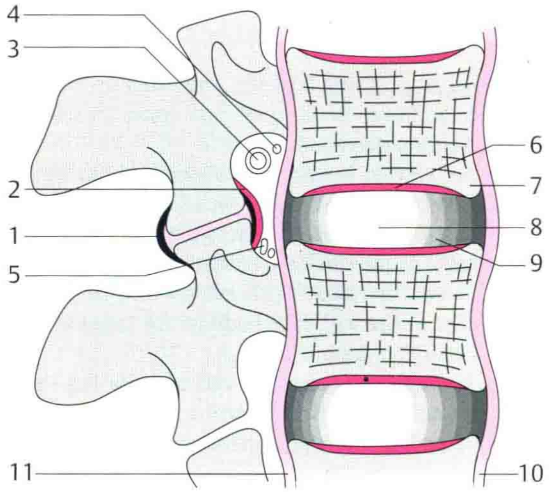



**Fig. 1.4** Motion segment.

The spaces between the overlying vertebral arches, the spinous and transverse processes and all the ligaments and muscles are also included.

This movement complex is anatomically and functionally coordinated. It can be divided into anterior and posterior sections (**Fig. 1.5**). The anterior area, made up of the vertebral bodies and disk spaces, is the support element, absorbing the direct axial compressive forces and passing them on. The posterior area (the facet joints and all that lies between the vertebral arches), determines the direction of motion, i.e., allows certain movements and blocks others. The ligamentous structures and the position of the zygapophysial joints (intervertebral facet joints) and the anulus fibrosus together set the limits of the range of the movement.

The motion segment functions as a unit. An irritation of one part of the segment always has an effect on the other structures.

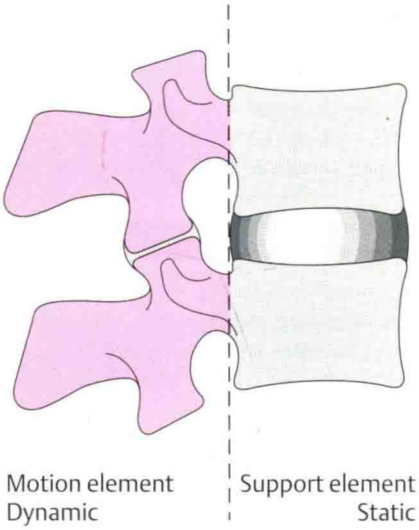



**Fig. 1.5** Division of the motion segment.

## 1.2.1 The Structure of a Vertebra

### Vertebral Body (Fig. 1.6)

The vertebral body consists of a core of cancellous bone that is bounded at the sides by compact bone. The cortical bone is very strong posterolaterally, where the vertebral arches branch off.

The superior and inferior end plates form the transition between the vertebral body and the intervertebral disk. They consist of cartilage and are surrounded by a bony marginal ridge.

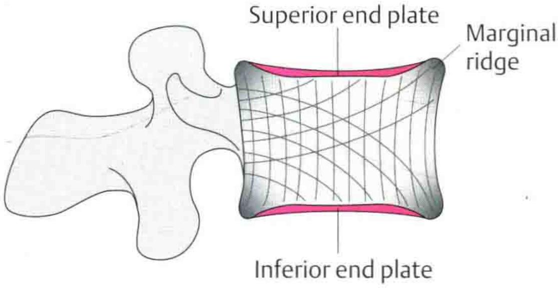



**Fig. 1.6** Vertebral body.

## Vertebral Arch (Fig. 1.7)

The vertebral arches consist of two symmetrical halves that are fused together. In this way, they form the vertebral foramen.

A distinction is made between the anterior section of the vertebral arch (**pedicle**) and the posterior section (**lamina**).

Each vertebral pedicle has bilateral superior and inferior articular processes.

## Transverse Process (Fig. 1.7)

The transverse processes are shaped differently in each section of the spine.

In the **cervical spine**, they come together with the rib rudiment to form the transverse foramen for the vertebral artery.

In the **thoracic spine**, they are very pronounced and articulate with the ribs.

In the **lumbar spine**, they are only present as rudimentary structures, the accessory processes.

## Spinous Process (Fig. 1.7)

The vertebral arches merge posteriorly to form the spinous process, which is an important area for the origin and insertion of the muscles. Its appearance is quite variable. For example, it is split in the cervical spine, while it is very long and projects obliquely downward in the thoracic spine, and is very strongly developed in the lumbar spine.

## Vertebral Foramen (Fig. 1.8)

The size and shape of the vertebral foramina vary from segment to segment. In transverse section, the foramen exhibits a clearly triangular shape in the lumbar spine and a rounded triangle in the cervical spine. In the thoracic spine, it is round and smaller than in the lumbar or cervical areas.

When the vertebrae are stacked one on top of the other, this forms the vertebral canal, within which the spinal cord runs.

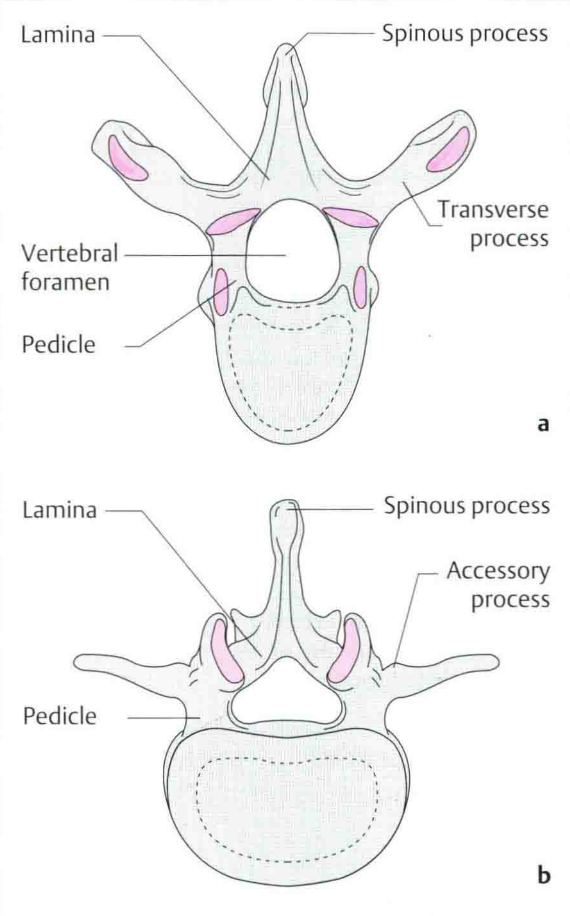



**Fig. 1.7** Vertebral arch, spinous process, and transverse process. **(a)** In the thoracic spine. **(b)** In the lumbar spine.

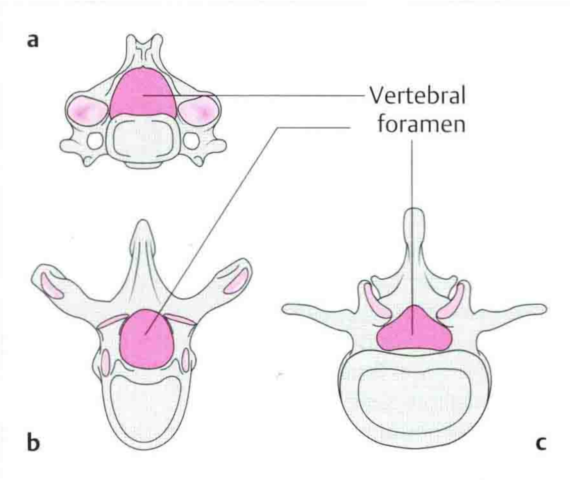



**Fig. 1.8** Vertebral foramen. **(a)** Cervical spine. **(b)** Thoracic spine. **(c)** Lumbar spine.

## Intervertebral Foramen (Fig. 1.9)

The intervertebral foramina lie between two adjacent vertebrae. The superior and inferior borders are formed by the pedicles of both vertebrae. Anteriorly, the borders are the lateral sides of the vertebral bodies and the posterior surfaces of the intervertebral disks. The articular processes form the border posteriorly.

The dura mater of the nerve root sheath merges into the periosteum within the foramen and thus fixes the nerve root. The meningeal branch of the spinal nerve extends back through the foramen into the spinal canal.

During lateral flexion, the ipsilateral foramen narrows and the contralateral foramen widens by one-third. Flexion causes widening, while extension causes narrowing.

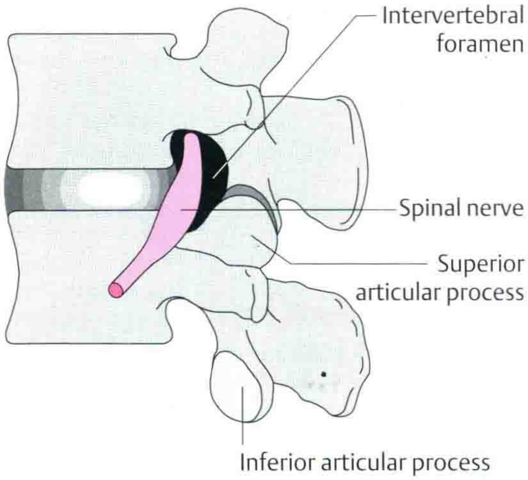



**Fig. 1.9** Intervertebral foramen.

## Articular Process (Fig. 1.9)

Four articular processes (two superior and two inferior) extend from the vertebral arches: two superior and two inferior articular processes. Thus, an inferior articular process of the upper vertebra and the corresponding superior articular process of the lower vertebra form the zygapophysial joint.

# 1.2.2 Zygapophysial Joints (Intervertebral Facet Joints) (Fig. 1.10)

## Joint Surfaces

The zygapophysial joints have the task of absorbing the compressive forces and passing them on. They also help to guide movement, depending on the structure of the joint surfaces and the capsule–ligament apparatus.

**Cervical spine (Fig. 1.10a):** Because the joint surface is inclined, it forms an angle of approximately 45° from the horizontal. The superior articular surface faces posteriorly and superiorly.

**Thoracic spine (Fig. 1.10b):** The articular surfaces lie at an angle of 80° to the horizontal and are rotated 20° outward from the frontal plane, so that the superior articular surface faces posteriorly and slightly superiorly.

**Lumbar spine (Fig. 1.10c):** The articular surfaces form an angle of 90° to the horizontal plane. In the sagittal plane and seen from above, they are oriented 15° toward the anterior, so that the superior articular surface faces medially and slightly posteriorly. This angle increases as one moves down the spine, so that the inferior articular surface of the fifth lumbar vertebra forms an angle of 75° with the sagittal plane.

The spatial position of the joint surfaces determines the range of motion and movement combinations.

*Example:* In the lumbar spine, the position of the joint surfaces allows rotation only if the joint surfaces move apart from each other through flexion. Only then is there leeway for minimal rotation in combination with lateral flexion in the same direction. Therefore one can see that the extent of rotation is very limited when compared with the other directions of movement.

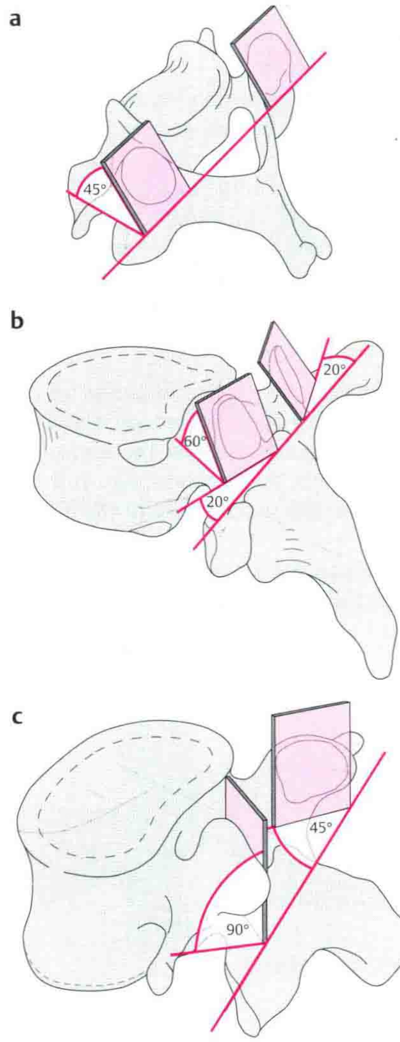



**Fig. 1.10** Position of the zygapophysial joints. **(a)** Cervical spine. **(b)** Thoracic spine. **(c)** Lumbar spine.

## Joint Capsule (Fig. 1.11)

### Synovial Membrane

The synovial membrane extends into the periosteum of the articular process at the bone–cartilage border. It forms recesses or bulges toward the fibrous layer, which represent reserve spaces for extreme movements.

In addition, the synovial membrane forms many eversions that protrude into the interior of the joint. It is assumed that these play a role in so-called blockages of the vertebral joints. These bulges, the synovial folds and villi, are more common in the lordotic sections of the spinal column. In the lumbar spine area, they can protrude up to 6 mm into the joint space. Because of their appearance, they are sometimes termed disks or meniscal folds. They are composed of very thick connective tissue with only a minimal incorporation of fatty tissue. They can become frayed, resulting in small torn pieces of these folds lying within the joint.

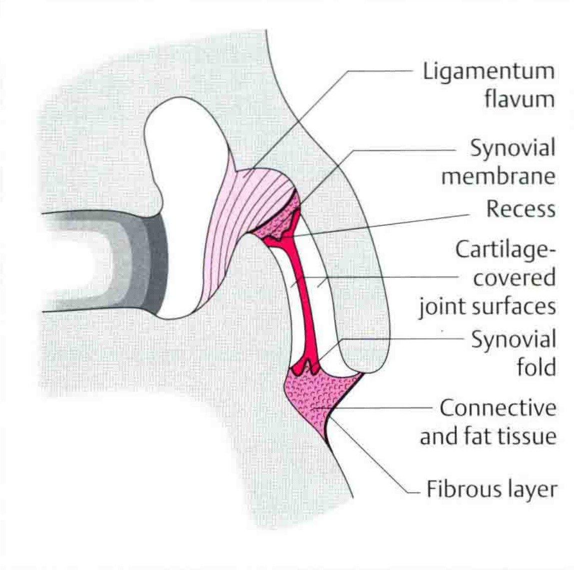



**Fig. 1.11** Joint capsule.

### Fibrous Layer (Figs. 1.11 and 1.12)

Part of the joint capsule arises from the corresponding periosteum. It inserts onto the base of the articular process well away from the edge of the joint surface because of the connective and fatty tissue that is enclosed between the fibrous layer and the synovial membrane.

The fibrous layer has reinforcing bands, which, in the **lumbar spine**, run transversely on the outer edge of the inferior articular process to the mammillary processes and the superior articular processes, which lie inferiorly. The multifidus muscles track onto the reinforcing bands and can tense the capsule.

The orientation of the reinforcing bands is vertical in the **thoracic and cervical spine** areas. In all the vertebral sections, the ligamenta flava lie with their lateral edge against the joint capsule and extend into the joint capsule with a few fibers. The same applies to the intertransverse ligaments with their medial fiber tracts.

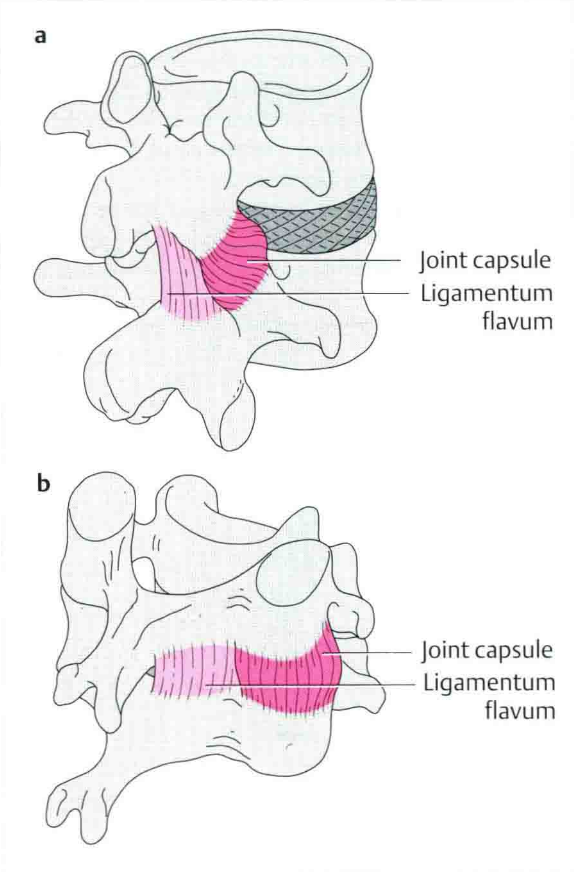



**Fig. 1.12** Course of the fibrous layer. **(a)** In the lumbar spine. **(b)** In the cervical spine.

## Vascular Supply (Fig. 1.13)

The arterial supply of the zygapophysial joints varies depending on the particular region of the spine. In the **thoracic and lumbar spine**, the segmental arteries provide the primary supply:

- Posterior intercostal artery.
- Lumbar artery.
- Iliolumbar artery.

Articular retia form, which also supply the bordering periosteum.

In the **cervical spine**, the primary supply is from the vertebral artery.

### Practical Tip

The large supply channels lying anterior or lateral to the vertebral body give an indication that perfusion of the motion segment can be stimulated by means of *lift-free mobilization* of the entire vertebral section.

### Pathology

Two adjacent segmental arteries provide the blood supply for each of the zygapophysial joints. Thus, if one supply channel is blocked or constricted due to edema forming within the tissues or other causes, the other artery can provide the blood supply.
In the cervical spine area, constriction of the vertebral artery can lead to a unilateral decrease in the perfusion of the capsule–ligament apparatus over several segments.

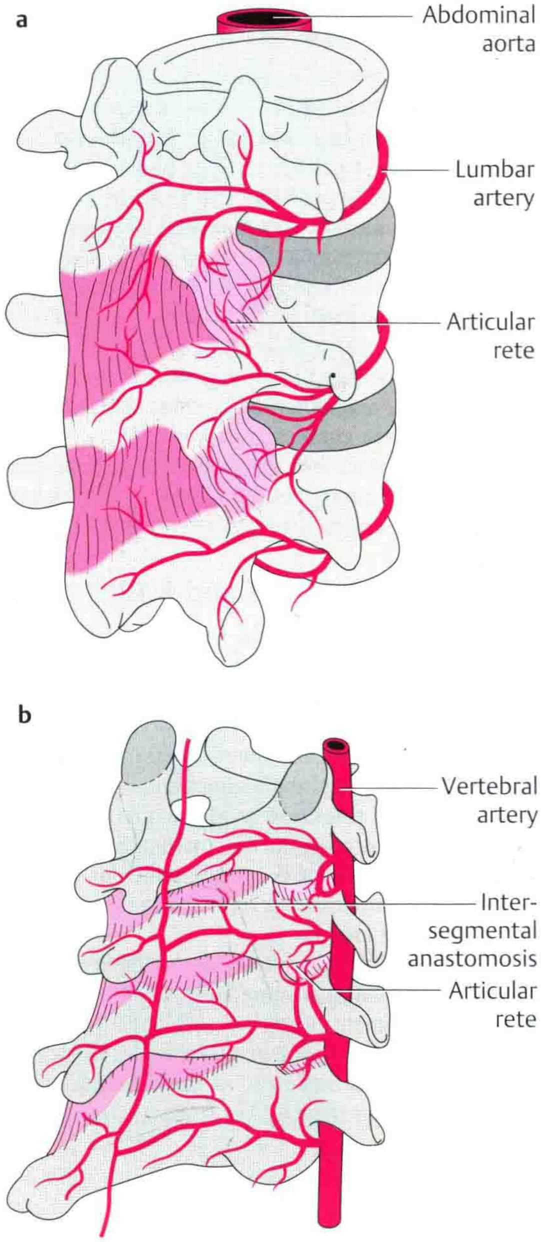



**Fig. 1.13** Vascular supply of the joint capsule. **(a)** In the lumbar and thoracic spine. **(b)** In the cervical spine.