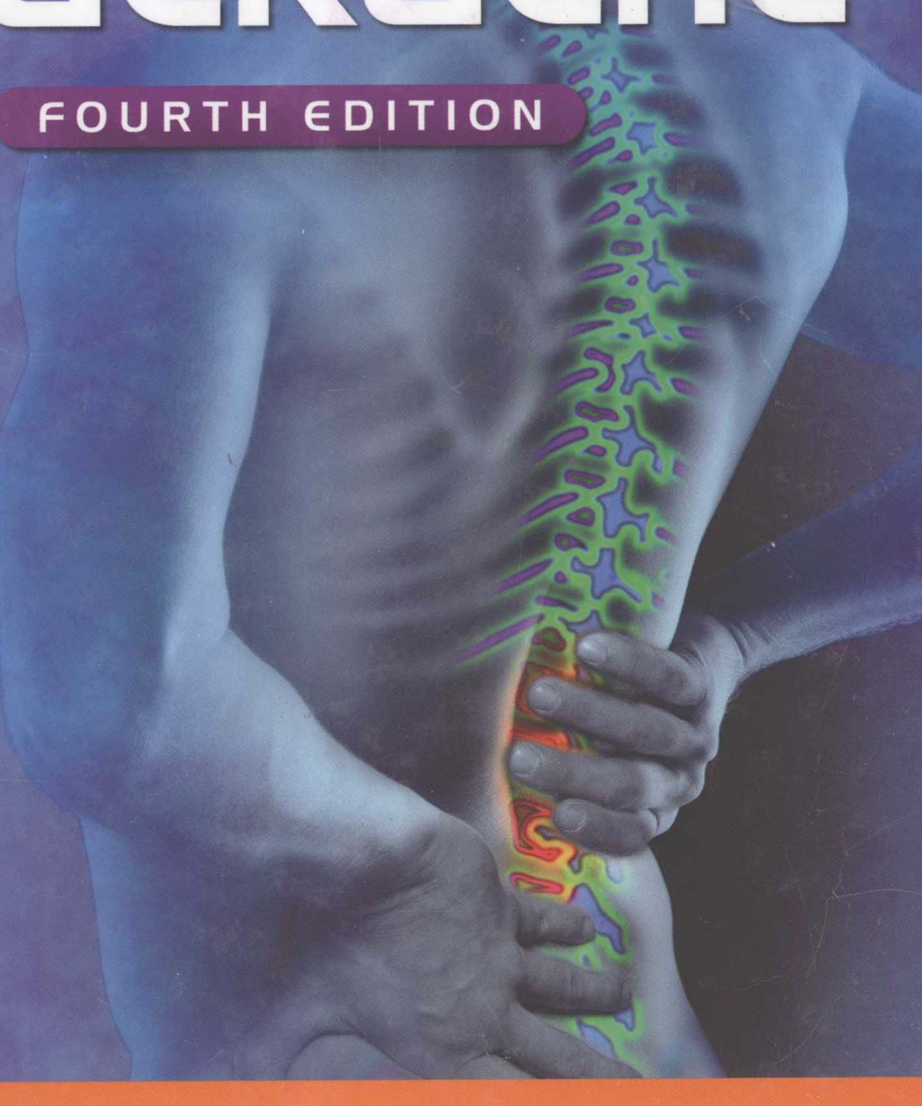
Macnab's Backache

FOURTH EDITION



DAVID A. WONG • ENSOR TRANSFELDT

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To Ian and Gillian
To John and his hero Conor

Dedication

This Textbook is dedicated to the memory of:

The late Ian Macnab, MB, ChB, FRCS
Former Chief, Division of Orthopaedic Surgery
The Wellesley Hospital
Former Emeritus Professor of Surgery
University of Toronto
Toronto, Ontario, Canada

The late John A. McCulloch, MD, FRCS(C)
Former Professor of Orthopaedics
Northeastern Ohio Universities
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Former Director
Advanced Center for Spinal Microsurgery
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Denver, Colorado USA

Preface to the Fourth Edition

The fourth edition of *Macnab's Backache* is an enhancement and update of the concepts Ian committed to paper 30 years ago. Today, those concepts are even more relevant to the serious scholar of clinical back pain.

The diagnosis of patients with spinal complaints has always been a complex affair. The key to accurate evaluation and treatment of patients is a thorough understanding of pathoanatomy. This area was Ian's forte. It is notable that the "Macnab concepts" were formulated in an era before magnetic resonance imaging (MRI), computerized axial tomography (CAT scans), and many other present-day tools of investigation and analysis. These modern technologies have only served to confirm the descriptions published in the first edition of *Backache*. Macnab's basic concepts are, therefore, timeless. As the authors of the fourth edition, our responsibility lies in allowing readers of this edition to embrace these key concepts in a contemporary context. To accomplish this goal, we have shaped the fourth edition in a "back-to-basics" format supplemented by more current imaging and references.

The previous third edition was a wide-ranging expansion of the original *Backache* monograph into a comprehensive reference directed toward the spine surgeon. It remains a valuable tool for that group and for subspecialist physicians. For the fourth edition, part of the governing "back-to-basics" principle includes a return to the core audience that Macnab envisioned for the original work. The first *Backache* monograph was written as a primer for orthopedic residents, fellows, interns, and medical students. The high incidence of back pain in our society today and the diverse clinical settings for spine evaluation and treatment suggest that this edition would also be pertinent to the education of practitioners in a variety of physician subspecialties such as neurosurgery, neurology, physical medicine, and rehabilitation, occupational medicine, radiology, emergency medicine, general internal medicine and family practice. In addition, the book is appropriate for physician's assistants (PAs), nurse practitioners, nurses, workers' compensation case managers, administrative law judges, and industry sales representatives wanting a clearer understanding of the spinal conditions present in patients they encounter and help care for.

The scope of this new fourth edition has been deliberately constructed to emphasize the initial evaluation of the patient with back pain and/or sciatica. There is no detailed description of surgical procedures. With knowledge of Macnab's well-organized thoughts on pathophysiology and its correlation to clinical symptoms, we hope to uniquely empower the reader in the accurate evaluation and effective initial treatment of the spine patient.

David Wong
Ensor Transfeldt

Preface to the First Edition

"In seeking absolute truth we aim at the unattainable and must be content with finding broken portions."

—Sir William Osler

Low back pain is a remarkably common disability. Hirsch stated that 65% of the Swedish population was affected by low back pain at some time during their working lives. Rowe stated that, at Eastman Kodak, back pain was second only to upper respiratory tract infections as the reason for absence from work. In 1967, the US National Safety Council reported that 4,000,000 workers were disabled by back pain each year and, in Ontario, Canada, 20,000 claims for disability resulting from backache are received annually by the Workmen's Compensation Board. However, despite its frequency, backache is not a dramatic disease that arouses the scientific curiosity and interest of medical practitioners. Physicians are understandably disenchanted by the frequently obscure etiology of this irksome syndrome and the commonly disappointing response to treatment.

In an attempt to dispel some of the clouds of confusion that obscure the problem, this book has been designed to present a working classification of the common causes of low back pain and to act as a guide to the examination and management of a few commonly seen syndromes.

Some readers may have no intention of entering into the field of spinal surgery. Surgeons in training always find that a surgical textbook is a poor substitute for experience in the operating room. Because of the rapid changes in the minutiae of surgical technique, a textbook is "dated" as soon as it is written, and a description of surgical techniques is of little value to the practicing surgeon who must depend on articles published in medical journals to modify the surgical procedures employed. However, one has to accept the fact that, on occasion, a patient suffering from discogenic backache comes to the end of the road as far as conservative treatment is concerned. The back becomes a malevolent dictator determining what the patient can do at work and play. The physician directing treatment must then decide whether surgical intervention is indicated. In order that he/she can give intelligent and informed advice to patients, he/she must have some knowledge of the operative procedures, including the preoperative investigation that must be undertaken, factors involved in the postoperative investigations that must be undertaken, and factors involved in postoperative care. The surgeon in training also needs to know the indications for considering operative intervention and, in addition, must have some knowledge of the general principles of operative technique. The practicing surgeon will understandably skip over the descriptions of operative technique but may find value in a detailed description of the preoperative investigation of obscure lesions.

For these reasons, chapters have been devoted to the preoperative evaluation and operative technique of laminectomy and fusion, and space has been devoted to discussion of that bête noire of orthopedic surgeons and neurosurgeons alike, the failure of spinal surgery.

Because this book is designed to discuss only the principles of diagnosis and treatment, it has been illustrated by simple line drawings. No attempt has been undertaken to make this text into an authoritative atlas of clinical syndromes, radiological changes, or operative techniques.

Although diagnosis and treatment are presented with unmitigated dogmatism, it must be remembered that, with the frequent absence of scientific facts, and treatise on the management of back pain must, perforce, be regarded as a philosophy and, moreover, a philosophy that must be modified to fit the needs of the physician's community.

It is almost impossible to acknowledge all of the people who have played a role in the preparation of this book and to thank them adequately. To Mr. Philip Newman, I owe special thanks or initiating my interest in the problem of low back pain while I was still a Registrar at the Royal

National Orthopaedic Hospital in London, England. The late R.I. Harris made it possible for me to investigate the pathological and mechanical changes associated with disc degeneration, and his contagious enthusiasm encouraged me to study the clinical aspects of the problem in greater depth.

It was with considerable reluctance that I later accepted the offer made by Dr. A.W. M. White to study a group of patients under the care of the Workmen's Compensation Board of Ontario, Canada, who continued to be disabled by back pain despite all forms of treatment, including only too often, several surgical assaults. I shall be eternally grateful for Bill White's persistent insistence that I should take on this unenviable task, because it was from this study that I learned of the vital necessity to know as much about the patient who has the backache as about the backache the patient has. Dr. Allan Walters led the world on his observation on pain syndromes, and it was from him that I learned of the varying and variable relationship of the disability complained of to the pain experienced.

For the preparation of the manuscript, I would like to pay my special thanks to: Margot McKay for illustrations; Kathleen Lipnicki for photographic prints; and Jennifer Widger for typing, retyping, and retyping the script without complaint.

Finally, I would like to express my gratitude to Sara Finnegan of Williams & Wilkins, who patiently and gently guided me through the task of transforming my handwritten notes and sketches into a form more suitable for publication.

I sincerely hope that our combined efforts have produced a text that the reader can use as a basis on which he/she can build a personal philosophy of the management of this commonplace syndrome.

Ian Macnab

Acknowledgments

On the Denver end of the paper trail, my wife Lynn filled the primary role of editor, researcher, typist, photographer, and critic. Daughters Katherine and Caroline also provided support for literature searches and general research. The assistance of my medical assistant Marty Goff and physician assistant Ken Gartzke is also much appreciated.

Dr. Ron Hattin provided several images of interventional procedures for the new injections chapter. The staff of the Denver Medical Library assisted in providing full literature articles.

The Lippincott Williams & Wilkins team was particularly helpful and considerate. Bob Hurley and Eileen Wolfberg at the Philadelphia office kept the project on track with their unique brand of support and enthusiasm. Our editors, Martha Cushman and Jenny Koleth and project manager Maria McColligan helped enormously in the final organization and presentation of the material.

Particular thanks to Rita Macnab and Barb McCulloch, the wives of Ian and John. Their encouragement was key in our decision to take on the project of developing a new edition of *Backache*. The support of the members of the Macnab Orthopedic Research Society (The Macnab Club) was also heartening and very much appreciated.

Contents

CHAPTER 1

Musculoskeletal Anatomy, Neuroanatomy, and Biomechanics of the Lumbar Spine

"You will have to learn many tedious things which you will forget the moment you have passed your final examination, but in anatomy it is better to have learned and lost than never to have learned at all."

—Authors

It is a convention observed by most authors of medical texts to start the book with a chapter devoted to the anatomy of the subject covered. In many instances, this is a form of brownian movement having very little purposive significance. Having skipped through many such essays with ill-concealed impatience, it was with considerable trepidation that we continued to follow this well-established precedent. The purpose of this introductory chapter is to remind the reader of anatomic terminology and to correlate the gross anatomic features of the lumbar vertebrae with normal biomechanics and pathologic changes of clinical significance. Remember, the key to understanding disease and completing exacting surgical techniques is an intimate knowledge of anatomy.

FUNCTIONAL MUSCULOSKELETAL ANATOMY

There are five lumbar vertebrae and the sacrum making up the lumbar spine. We can consider each vertebra as having three functional components: the vertebral bodies, designed to bear weight; the neural arches, designed to protect the neural elements; and the bony processes (spinous and transverse), designed as outriggers to increase the efficiency of muscle action.

The vertebral bodies are connected together by the intervertebral discs, and the neural arches are joined by the facet (zygapophyseal) joints (Fig. 1-1). The discal surface of an adult vertebral body demonstrates on its periphery a ring of cortical bone. This ring, the epiphysial ring, acts as a growth zone in the young and in the adult as an anchoring ring for the attachment of the fibers of the anulus. The hyaline cartilage plate lies within the confines of this ring (Fig. 1-2). The size of the vertebral body increases from L1 to L5, which is indicative of the increasing loads that each lower lumbar vertebral level has to absorb.

The neural arch is composed of two pedicles and two laminae (Fig. 1-1). The pedicles are anchored to the cephalad half of the vertebral body and form a protective cover for the cauda equina contents of the lumbar spinal canal. The ligamentum flavum (yellow ligament) fills in the interlaminar space at each level.

The outriggers for muscle attachment are the transverse processes and spinous process.

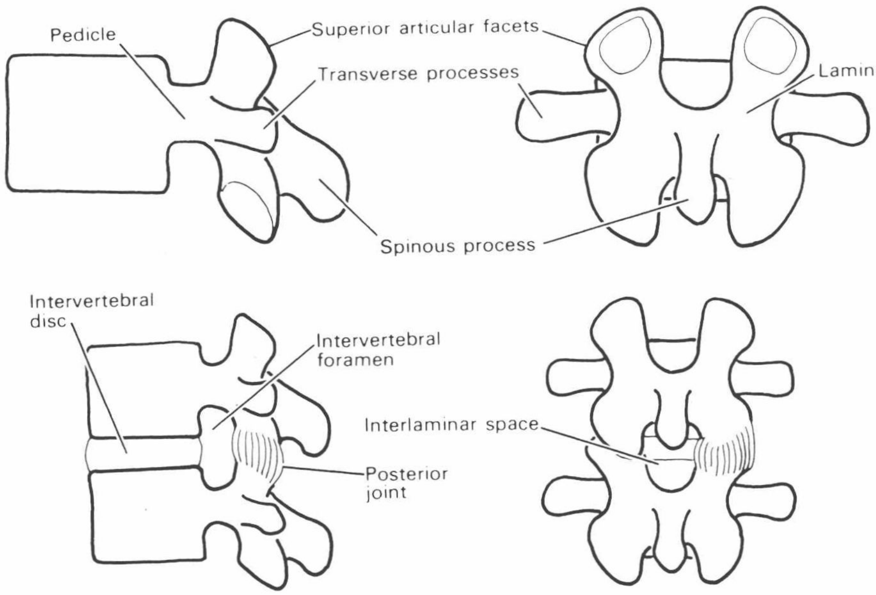

FIGURE 1-1 ● The components of a lumbar vertebra: the body, the pedicle, the superior and inferior facets, the transverse and spinous processes, and the intervertebral foramen and its relationship to the intervertebral disc and the posterior joint.

THE INTERVERTEBRAL DISC

The intervertebral discs (Fig. 1-3) are complicated structures, both anatomically and physiologically. Anatomically, they are constructed in a manner similar to that of a car tire, with a fibrous outer casing, the annulus, containing a gelatinous inner tube, the nucleus pulposus. The fibers of the annulus can be divided into three main groups: the outermost fibers attaching between the vertebral bodies and the undersurface of the epiphysial ring; the middle fibers passing from the epiphysial ring on one vertebral body to the epiphysial ring of the vertebral body below; and the innermost fibers passing from one cartilage endplate to the other. The anterior fibers are strengthened by the powerful anterior longitudinal ligament. The posterior longitudinal ligament affords

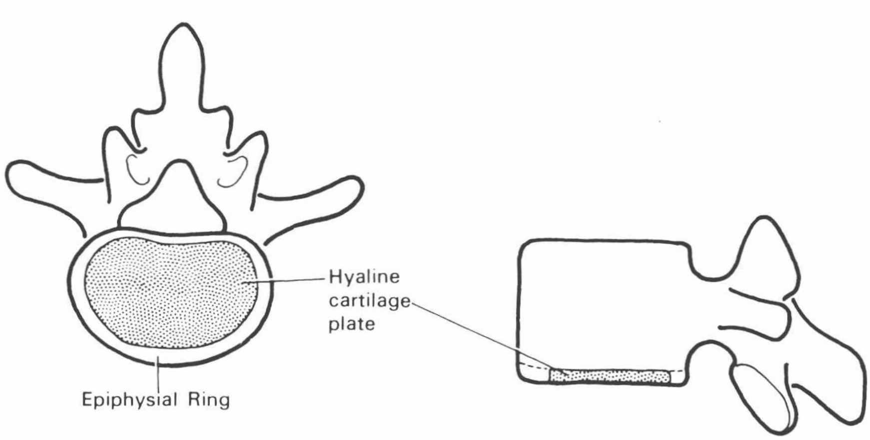

FIGURE 1-2 ● The epiphysial ring is wider anteriorly and surrounds the hyaline cartilaginous plate.

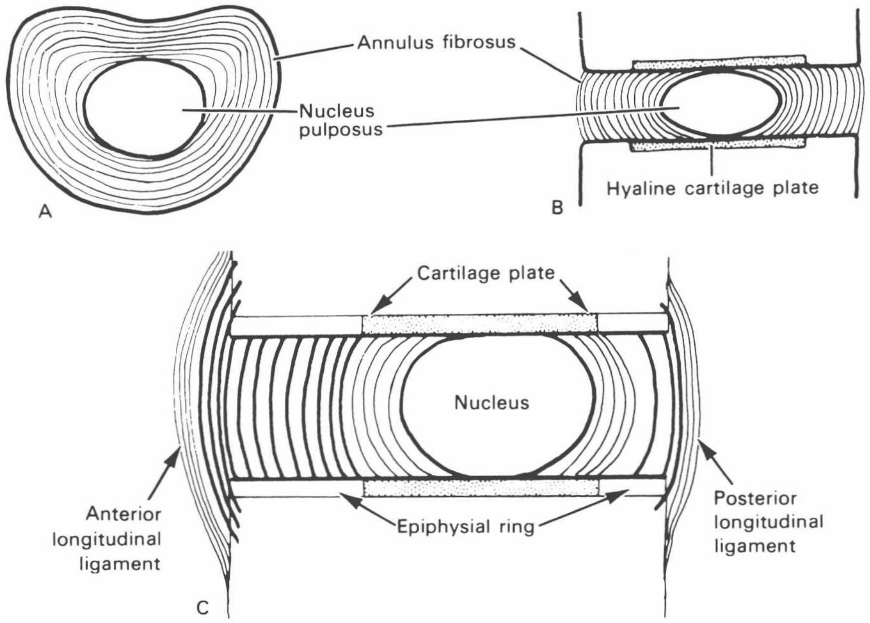

FIGURE 1-3 ● The annulus fibrosus is composed of concentric fibrous rings that surround the nucleus pulposus **(A)**. The nucleus pulposus abuts against the hyaline cartilage plate **(B)**. The outermost annulus fibers are most numerous anteriorly and are attached to the vertebral body immediately deep to the epiphysial ring. **C:** The epiphysial fibers run from one epiphysial ring to the other. The cartilaginous fibers run from one cartilage plate to the other cartilage plate. These comprise 90% of the annulus fibers posteriorly. The anterior fibers of the annulus are strongly reinforced by the powerful anterior longitudinal ligament, but the posterior longitudinal ligament only gives weak reinforcement to the posterior fibers of the annulus.

only weak reinforcement, especially at L4-5 and L5–S1, where it is a midline, narrow, unimportant structure attached to the annulus. The anterior and middle fibers of the annulus are most numerous anteriorly and laterally but are deficient posteriorly, where most of the fibers are attached to the cartilage plate (Fig. 1-3).

With the onset of degenerative changes in the disc, abnormal movements occur between adjacent vertebral bodies. These abnormal movements apply a considerable traction strain on the outermost fibers of the annulus, resulting in the development of a spur of bone, the so-called traction spur (Macnab spur) (6). Because the outermost fibers attach to the vertebral body beneath the epiphysial ring, this spur develops about 1 mm away from the discal border of the vertebral body and projects horizontally. This differs in its radiologic morphology from the common claw-type osteophyte, which develops at the edge of the vertebral body and curves over the outer fibers of the intervertebral disc (Fig. 1-4). The clinical significance of a traction spur lies in the fact that it indicates the presence of a vertebral segment in the early stage of instability.

The first stage of a disc rupture would appear to be detachment of a segment of the hyaline cartilage plate. The integrity of the confining ring of the annulus is then disrupted. Nuclear material can escape between the vertebral body and the displaced portion of the cartilage plate. On occasion, as a result of a compression force, a whole segment of the annulus may be displaced posteriorly, carrying with it the nucleus pulposus and displaced portion of the hyaline plate (Fig. 1-5A). This pathology is more common in younger patients (Fig. 1-5B).

The fibers of the annulus are firmly attached to the vertebral bodies and arranged in lamellae, with the fibers of one layer running at an angle to those of the deeper layer (Fig. 1-6). This anatomic arrangement permits the annulus to limit vertebral movements. This important function is reinforced by the investing vertebral ligaments.

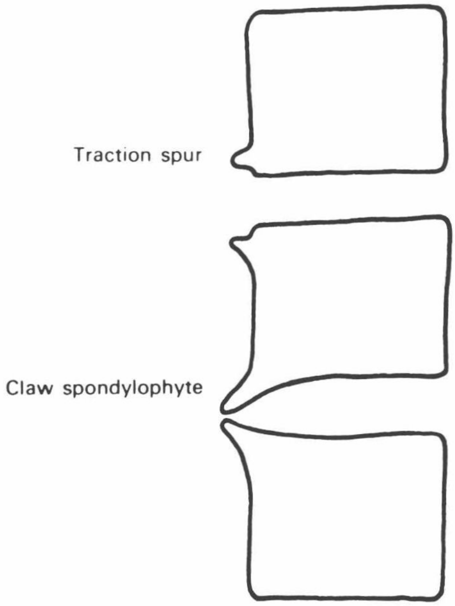

FIGURE 1-4 ● The traction spur projects horizontally from the vertebral body about 1 mm away from the discal border. It is indicative of segmental instability. The common claw spondylophyte, on the other hand, extends from the rim of the vertebral body and curves as it grows around the bulging intervertebral disc. It is associated with disc degeneration. It does not represent the radiologic manifestation of osteoarthritis.

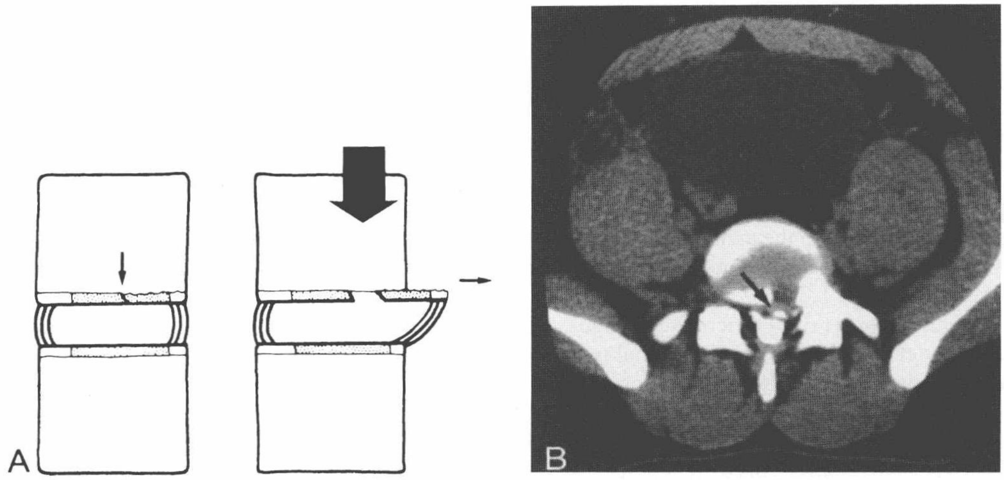

FIGURE 1-5 ● **A:** The first morphologic change to occur in a disc rupture is a separation of a segment of the cartilage plate from the adjacent vertebral body. Fissures run through the annulus on each side of the detached portion of the cartilage. When a vertical compression force is then applied, the detached portion of the cartilage plate is displaced posteriorly, and the nucleus exudes through the torn fibers of the annulus. **B:** Computed tomography (CT) of young patient with end-plate fracture *(arrow)* and herniated nucleus pulposus.

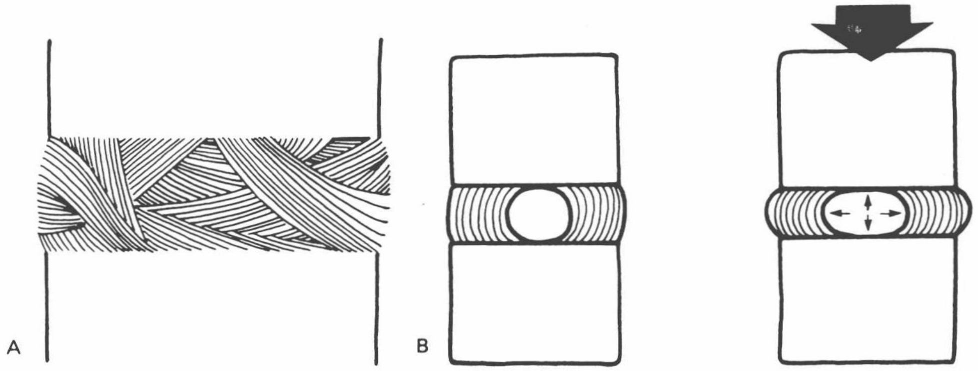

FIGURE 1-6 ● **A:** The annulus is a laminated structure with the fibrous lamellae running obliquely. This disposition of the fibers permits resistance of torsional strains. **B:** The nucleus pulposus is constrained by the fibers of the annulus. When a vertical load is applied to the vertebral column, the force is dissipated radially by the gelatinous nucleus pulposus. Distortion and disruption of the nucleus pulposus are resisted by the annulus.

Because the nucleus pulposus is gelatinous, the load of axial compression is distributed not only vertically but also radially throughout the nucleus (5,8). This radial distribution of the vertical load (tangential loading of the disc) is absorbed by the fibers of the annulus and can be compared with the hoops around a barrel (Fig. 1-7).

Weight is transmitted to the nucleus through the hyaline cartilage plate. The hyaline cartilage is ideally suited to this function because it is avascular. If weight were transmitted through a vascularized structure, such as bone, the local pressure would shut off blood supply, and progressive areas of bone would die. This phenomenon is seen when the cartilage plate presents congenital defects and the nucleus is in direct contact with the spongiosa of bone. The pressure occludes the blood supply, a small zone of bone dies, and the nucleus progressively intrudes into the vertebral body. This phenomenon was first described by Schmorl and Junghanns (9), and the resulting lesion bears the name Schmorl's node (Fig. 1-8).

The annulus acts like a coiled spring, pulling the vertebral bodies together against the elastic resistance of the nucleus pulposus, with the result that when a spine is sectioned sagittally, the unopposed pull of the annulus makes the nucleus bulge. This has been referred to as "turgor" of the

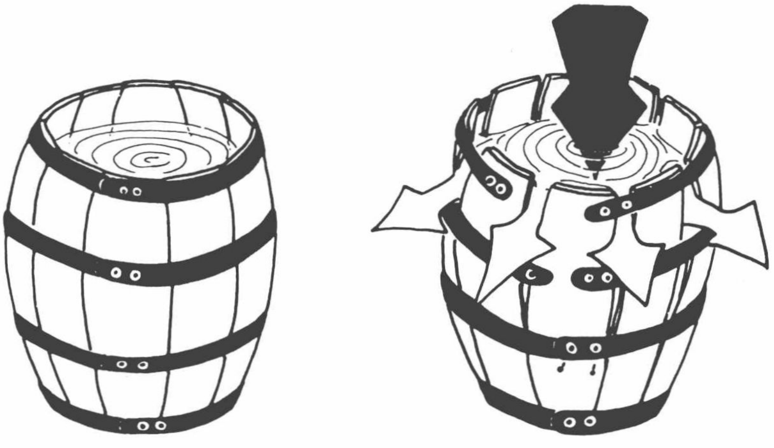

FIGURE 1-7 ● Hoop stress. This diagram shows how the load of water in a barrel is resisted by the hoops around the barrel. When too great a load is applied, the hoops will break. The annulus functions in a manner similar to that of the hoops around a water barrel.

FIGURE 1-8 ● A Schmorl's node (L2–3) *(arrow),* likely of no clinical significance. Have you ever seen a herniated nucleus pulposus at the same disc space as a Schmorl's node?

nucleus, but it is the manifestation of a springlike action, the compressing action of the annulus fibrosus. This makes for a very good coupling unit, provided that all of the structures remain intact. The nucleus pulposus acts like a ball bearing, and in flexion and extension the vertebral bodies roll over this incompressible gel while the posterior joints guide and steady the movements (Fig. 1-9).

The intervertebral discs of a person up to the age of 8 years have a blood supply, but thereafter they are dependent for their nutrition on diffusion of tissue fluids. This fluid transfer is through two routes: (a) the bidirectional flow from vertebral body to disc and from disc to vertebral body and (b) the diffusion through the annulus from blood vessels on its surface. This ability to transfer fluid from the disc to the adjacent vertebral bodies minimizes the rise in intradiscal pressure on sudden compression loading. This fluid transfer acts like a safety valve and protects the disc. Clinical experience supported by experimental observations has shown that the fibers of the annulus are less commonly ruptured by direct compression loading (Fig. 1-10). Sudden severe loading of the spine, however, may produce a rise in fluid pressure within the vertebral body great enough to produce a "bursting" fracture.

Although this has been a very cursory review of the structure and function of the intervertebral disc, one can see that the components of a disc act as an integrated whole, subserving many functions, in addition to being a roller bearing between adjacent vertebral bodies.

THE FACET JOINTS

The zygapophyseal joints are synovial joints that permit simple gliding movements. Although the lax capsule of the zygapophyseal joints is reinforced to some extent by the ligamentum flavum anteriorly and the supraspinous ligament posteriorly (Fig. 1-11), the major structures restraining

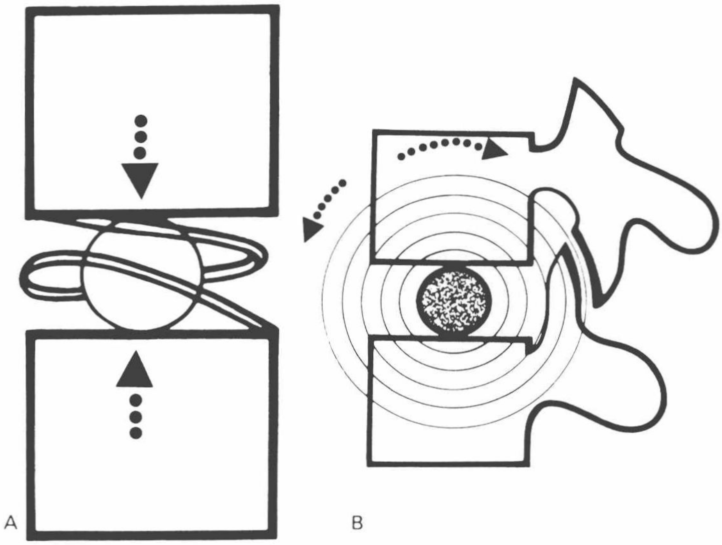

FIGURE 1-9 ● **A:** The annulus acts like a coiled spring, pulling the vertebral bodies together against the elastic resistance of the nucleus pulposus. **B:** The nucleus pulposus acts as a ball bearing, with the vertebral bodies rolling over this incompressible gel in flexion and extension while the posterior joints guide and steady the movement.

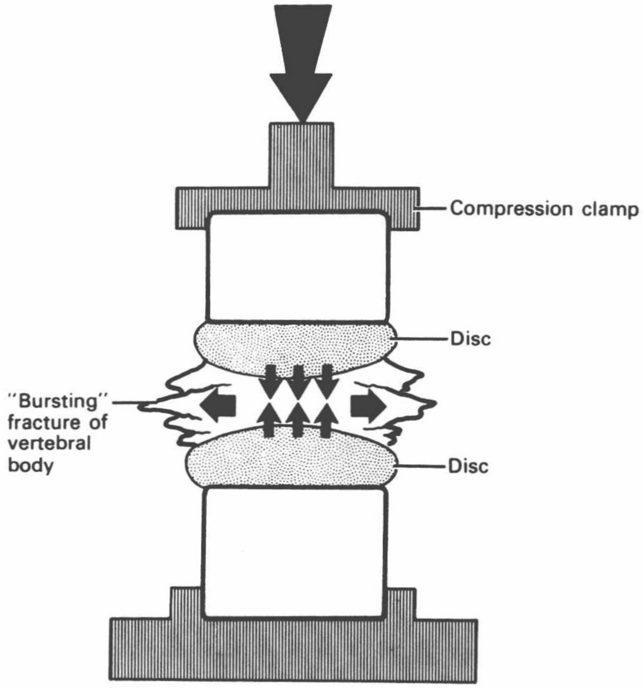

FIGURE 1-10 ● Diagram shows the experimental testing of vertical loading of the spine. When a very high compressive force is applied, the discs will remain intact, but the vertebral body shatters.

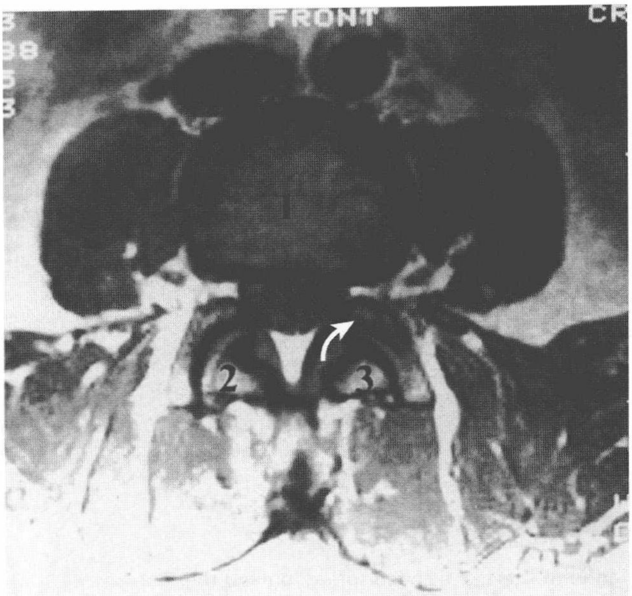

FIGURE 1-11 ● The ligamentum flavum inserts into the capsule on the superior facet *(arrow)*. The three-joint complex is composed of the disc space *(1)* and two facet joints (*2* and *3*).

movement in these joints are the outermost fibers of the annulus. When these annular fibers exhibit degenerative changes, excessive joint play is permitted. This is the reason why degenerative changes within the discs render the related posterior joints vulnerable to strain. The intimate relationship between the disc and its two facet joints has led to Kirkaldy-Willis et al. (4) labeling the unit "the three joint complex" (Fig. 1-11).

THE LIGAMENTS

Although the ligaments of the lumbar spine are no more important than the muscles, their names and functions are required knowledge.

Anterior longitudinal ligament (ALL). Obviously, this ligament runs the length of the anterior aspect of the spine (Fig. 1-12). It is intimately attached to the anterior annular fibers of each disc and is a fairly strong ligament useful in fracture reduction.

Posterior longitudinal ligament (PLL). This is the posterior mate to the anterior longitudinal ligament (Fig. 1-13). It is a significant ligament in all areas of the spine except the lower lumbar region. Although frequently mentioned in the discussion of lumbar disc disease, the ligament itself is rather flimsy and inconsequential in the lower lumbar spine where lumbar disc problems are most common.

Interspinous/supraspinous ligament complex. Although most authors draw these two ligaments backward and as separate structures, it does not take a rocket scientist to figure out that if you want to flex the lumbar spine, the ligaments have to be structured as depicted in Figure 1-14.

Ligamentum flavum (the yellow ligament). This ligament is so named because of the yellowish color that is given to it by the high content of the elastin fibers. The ligamentum flavum bridges the interlaminar interval, attaching to the interspinous ligament medially and the facet capsule laterally. It has a broad attachment to the undersurface of the superior lamina and inserts onto the leading edge of the inferior lamina at each segment. Normally, the ligamentum maintains a taut configuration, stretching for flexion and contracting its elastin fibers in neutral or extension. In this way, it always covers but never infringes on the epidural space. With aging, the ligamentum flavum loses its elastin fibers and the collagen hypertrophies, which results in buckling of the ligamentum flavum and encroachment on the thecal sac, potentially contributing to spinal stenosis.