Nutra-Spine

Clinical Study

This clinical study was conducted during the period of Jun 1st 2009 through Oct 30th 2009 under the supervision of Dr. Samuel Joseph in his Spine and Scoliosis clinic in Tampa, Florida.
The total patient participation, 40 with ailments related to back pain and mainly spine pain in specific.

Each patient received 2 tablets a day for 4months…

This study is based on the following symptoms:

- 8 cases of continuous chronic back pain: patients 1 to 8
- 9 cases of severe lower back pain: patients 9 to 17
- 9 cases of moderate pain: patients 18 to 26
- 5 cases of Postural Kyphosis without the ability of standing straight without pain: patients 27 to 31
- 9 cases of moderate cervical pain: patients 32 to 40

Results

After an initial 10 to 20 days adaptation period to the food supplements, all the symptoms progressively decreased and stabilized after an average of 8 weeks:

PRO-BIO USA INC
12 Martha Lane • Selden NY • 11784
Phone: (631) 451-9604 • Fax: (631) 698-7557
www.pro-bio.com

- In 8 cases of continuous chronic back pain, a dramatic improvement was observed with a significant sign of relief.
- In 6 cases of severe lower back pain, the symptoms decreased progressively and the pain was tolerable in week# 9
- In 3 cases of severe lower back pain, there pain persisted and remained the same.
- In 7 cases of moderate pain, the pain practically disappeared; only 2 cases did not observe any changes.
- In 5 cases of Postural Kyphosis, a noticeable angle improvement of more than 5 degree upward was documented in all cases.
- 9 cases of moderate cervical pain: 6 cases said that they felt a tremendous relief and improvement while 3 cases said they did not feel or see any improvement.

We observed that the intake of Nutra-Spine tablets could:

- Reduce dramatically continuous chronic back and spine pain.
- Reduced severe back and spine pain as well.
- Significantly relieve people with moderate spine pain.
- Noticeably improve the angle of curvature.
- Diminish cervical pain in patients with cervical pain.

PRO-BIO USA INC
12 Martha Lane • Selden NY • 11784
Phone: (631) 451-9604 • Fax: (631) 698-7557
www.pro-bio.com

NUTRA-SPINE By Dr. Samuel Joseph

Nutra-Spine is unique in that it targets all aspects of the spine: the vertebral body, the disc and the facet joints. It is both therapeutic and preventative. It is meant to provide the appropriate anti-oxidants (Vit A, VIt C, Vit E and Omega 3). These specifically target the disc to counteract the collection of waste (oxidants) that occurs when the intervertebral disc is no longer functioning properly or becomes degenerated. The vitamin D3 and Calcium are meant to provide the building blocks for bone health and preventative ingredients for osteoporosis and mineral loss. The Glucosamine and chondroitin are meant to provide the building blocks for the production of joint fluid that is crucial to facet joint function. The folic acid, magnesium, copper, zinc oxide, boron, manganese, lysine, iproiflavone and selenium are all mean to supplement the body with the ingredients essential for the everyday biochemical reactions necessary for normal function of the intervertebral disc. The turmeric(active ingredient curcumin) is the therapeutic portion of Nutra-Spine. It is not only an anti-oxidant, but also an anti-inflammatory that can help alleviate the pain that occurs as a result of discogenic and facet disruption.

Research:

Declining nutritional support is the most important event responsible for the changes in the intervertebral disc cells and their matricies.

> **Joseph Jr S**, Boland P. Intervertebral Disc structure, composition and mechanical function. In Damron TA eds. Orthopaedeic Surgery Essentials: Oncology and Basic Science. Philadelphia: Lippincott-Raven, 2008: 452-462.

J. Clin. Biochem. Nutr., 40, 174–183, May 2007

Serial Review
Recent Advances in Indian Herbal Drug Research
Guest Editor: Thomas Paul Asir Devasagayam

Physico-Chemical Studies on the Evaluation of the Antioxidant Activity of Herbal Extracts and Active Principles of Some Indian Medicinal Plants

Soumyakanti Adhikari, Kavirayani Indira Priyadarsini, and Tulsi Mukherjee*
Radiation & Photochemistry Division, Chemistry group, Bhabha Atomic Research Centre, Mumbai 400 085, India

Several studies have shown curcumin to be a potent antioxidant with its activity 10 times more than that of the well-known antioxidant vitamin E [20]. Recent phase I clinical trials indicate that human beings can tolerate a dose of curcumin as high as 8 g/day with no side effects[16, 21]. Curcumin has been shown to be an effective antioxidant under several conditions, where free radicals are generated and since the antioxidant activity is always associated with free radical scavenging activity, curcumin has been examined for free radical scavenging studies.

There are many other studies that demonstrate the anti-oxidant and anti-inflammatory effects of turmeric.

Chondoitin and glucosamine have long been used for knee and hip and shoulder pathology. The rational carries to the spine in the facet joints.

The Calcium and Vit D are also known substances that are vital to promote bone strength.

The vitamin and other nutrients included complement each other to provide nutrition as well as anti-oxidant properties to the pill.

INTERVERTEBRAL DISC STRUCTURE, COMPOSITION, AND MECHANICAL FUNCTION

SAMUEL A. JOSEPH, JR.
PATRICK BOLAND

The spine can be considered a column of relatively rigid vertebrae connected by flexible intervertebral discs. Because of their flexibility, the intervertebral discs allow the spine to twist and bend throughout a wide range of postures. In addition to allowing flexibility, the intervertebral discs function in both absorbing energy and distributing loads applied to the spine. The unique structure and composition of the intervertebral disc allow for a wide array of mechanical functions to be performed. It is the disruption of this relationship that leads to intervertebral disc pathology.

ANATOMY, STRUCTURE, AND COMPOSITION

Anatomy

There are 23 discs in the human spine, which account for 20% to 30% of its length. Apart from the fused vertebrae of the sacrum and coccyx, the only vertebrae not connected by discs are the atlas and axis, which pivot at the specialized atlanto-axial joint, and the articulation between the atlas and the base of the skull, which articulate at the occipito-atlantal joint; this articulation also does not contain a disc (Fig. 23-1).

- Non-disc structures also connecting the vertebral bodies (Fig. 23-2)
  - Anterior and posterior longitudinal ligaments
  - Ligamenta flava
  - Interspinous ligaments
  - Supraspinous ligaments

Structure

- Shape
  - Roughly cylindrical
  - Most discs appear wedge-shaped because the anterior height is greater than posterior.
  - Cross-sectional area increases almost linearly from the cervical to lumbar segments.
  - Unlike cross-sectional area, disc height does not vary regularly along the length of the spine.

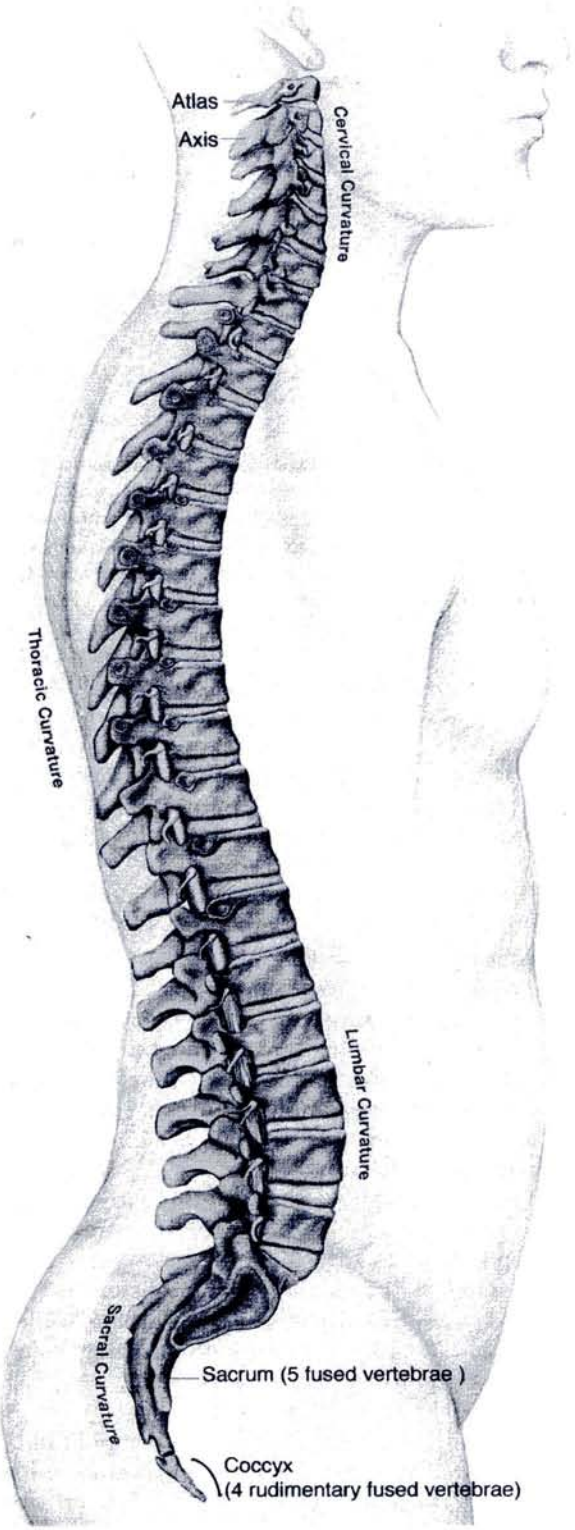

Figure 23-1 Lateral view of the human spine. (Asset provided by Anatomical Chart Co.)

- Components
  - Nucleus pulposus: soft inner region
  - Anulus fibrosus: surrounding tough outer lamellae
    - Consists of 12 concentric coaxial lamellae that form a tube-like structure enclosing the nucleus
    - Arranged into a densely packed outer ring and an inner, larger fibrocartilaginous layer (Fig. 23-3)
- Vascularity: largest avascular organ in the body
  - Small blood vessels found on the surface of the outer anulus penetrate 1 to 2 mm at most.
  - Simple diffusion is the most important mechanism for small-molecule transport into the disc and appears to be the factor most responsible for limiting cell viability.
- Innervation: poorly innervated
  - Sensory nerves do not penetrate deeper than the outer third of the anulus.
  - Main afferent pathway involves the nerve to the vertebral body: sinuvertebral nerve (recurrent nerve of Luschka) (Fig. 23-4).

Composition

- Even though the discs may vary in size, they share the same basic structure and composition.
  - Two main structural components of the intervertebral disc
    - Collagen
      - Accounts for 70% of the dry weight of the anulus and <20% of the nucleus
      - Provides tensile strength
    - Proteoglycans
      - Account for a minimal percentage of the anulus but as much as 50% of the nucleus in the pediatric population
      - Provide stiffness, compressive strength, viscoelasticity
- Collagen arrangement
  - Types I and II collagen fibrils
    - Distributed radially in opposing concentration gradients, with type II mostly in the nucleus pulposus and type I most concentrated in the exterior of the anulus
      - Anulus: I, II, III, V, VI, IX, X
      - Nucleus pulposus: II, VI, IX, X
  - Type I collagen provides strength to the tough lamellar sheets that are anchored into the bone of the adjacent vertebral bodies (Fig. 23-5).
- Water: contained in the matrix of the disc and contributes approximately 65% to 80% of its total weight
- Aggrecan is the main proteoglycan in the disc.
  - High density of negatively charged sulfate and carboxyl groups (cations) on the glycosaminoglycan chains that attract mainly Na+ (anions), which results in a cumulatively increased osmotic pressure of 1 to 3 atmospheres in the nucleus
  - Pressure gradient enables the disc to continually absorb water.
  - Hydration and swelling continue until it is restricted by the collagen network of the disc.

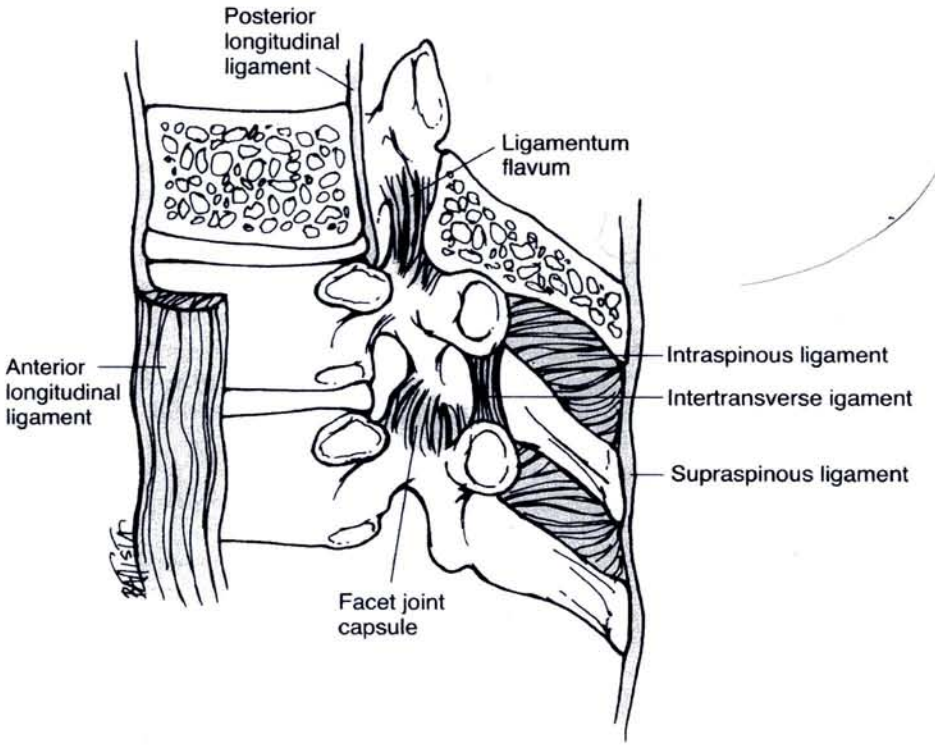

Figure 23-2 The ligaments supporting the thoracic spine consist of the capsular ligaments of the facet joints, the anterior and posterior longitudinal ligaments, the supraspinous and interspinous ligaments, the ligamentum flavum, and the intertransverse ligaments. (From Oatis CA. *Kinesiology: The Mechanics and Pathomechanics of Human Movement*. Baltimore: Lippincott Williams & Wilkins, 2003.)

- Equilibrium between the aggrecan and collagen provides the load-bearing, compression-resisting tissue that holds the other units of the spine in correct position while allowing movement of the spinal column.

MECHANICAL FUNCTION

- Withstands the significant forces of an upright posture
  - Forces up to 17,000 Newtons estimated in lumbar discs
  - Functions within a specialized unit called the *motion segment* (Fig. 23-6), where the basic motions of axial compression, torsional loading, and sagittal and transverse bending or axial torsion occur (Fig. 23-7).
- Biphasic viscoelastic behavior during loading (Table 23-1)
  - Mechanical loading causes fluid movement within the discs, which gives rise to time-dependent mechanical properties.
  - The less dense inner anulus and nucleus pulposus undergo larger volumetric changes in response to loads. This creates flow within the disc that dissipates the energy and causes viscoelastic creep.
  - The stiffer outer anulus converts this compressive load into hoop stresses while the inner layers act as a "shock absorber."
  - The high tensile modulus of the outer anulus helps to prevent any bulging of the disc from the loads applied.
  - Torques on the motion segment distort the shape of the anulus without altering the volume, while bending and compression cause disc bulging, volumetric changes, and endplate deformation.
- Function of the cartilage endplate
  - The hydraulic permeability causes rapid fluid transport and less pressurization in response to loading.
  - This permeability provides a conduit for water to flow from and into the disc and thereby helps transfer loads in a uniform manner across the inner anulus and nucleus pulposus.

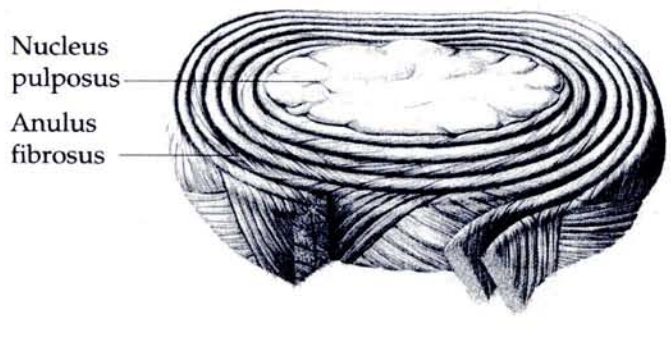

Figure 23-3 Structural features of an intervertebral disc. The nucleus pulposus is the central gelatinous cushioning part of the intervertebral disc enclosed in several layers of cartilaginous laminae. (Asset provided by Anatomical Chart Co.)

DISC AGING

Age-related deterioration of the intervertebral disc leads to two of the most common clinical disorders of the spine:

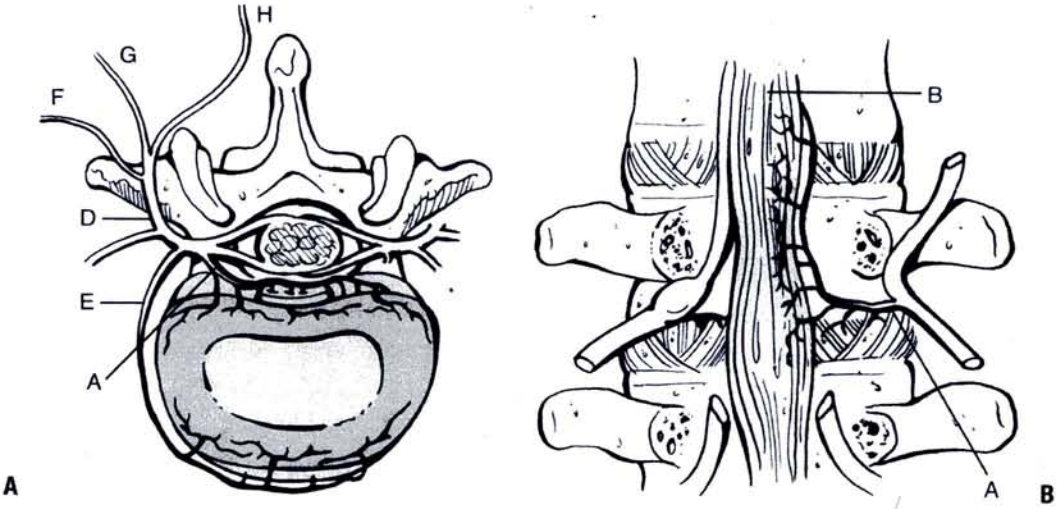

Figure 23-4 The innervation of the disc and facet joints. Sinuvertebral nerve and its branches innervate the dorsal portion of the disc (**A**) and posterior longitudinal ligament (**B**). The ventral ramus (**C**) branches to innervate the ventral disc and anterior longitudinal ligament (**E**). The dorsal ramus (**D**) branches into lateral (**F**), intermediate (**G**), and medial (**H**) branches. (From Wetzel FT. Microinnervation: Pain generators. In Bono CM, Garfin SR, eds. *Orthopaedic Surgery Essentials: Spine*. Philadelphia: Lippincott-Raven, 2004:272–277.)

degenerative disc disease and disc herniation. Changes in volume and shape are accompanied by gross morphologic and microstructural alterations (Table 23-2). The most extensive changes occur after the age of 20 in the nucleus pulposus, where the number of viable cells and the concentration of proteoglycans and water decline.

DEGENERATIVE DISC DISEASE

Disc degeneration is a multifactorial process that is complex and poorly understood. It is the result of an intricate relationship between cellular biology, mechanical factors, and genetics. Aging and degeneration of discs are separate processes: although all discs undergo aging, not all of them degenerate. The end stage of degeneration can be identified by imaging studies and gross examination, but accepted criteria for the diagnosis and the distinguishing factors between degeneration and aging have not been established. It is also unclear as to what degree the degenerative process contributes to pain. Currently disc degeneration is believed to be a source of chronic pain, and over 90% of surgical

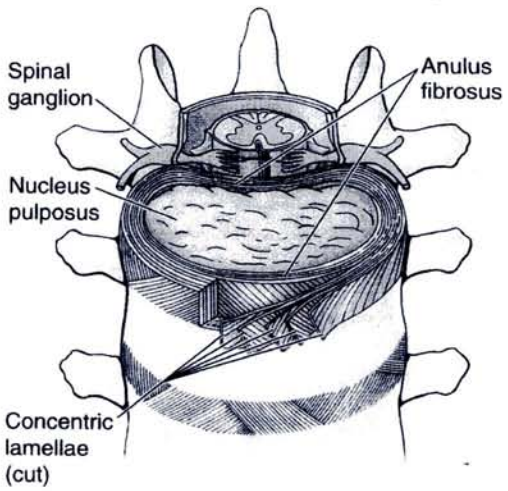

Figure 23-5 Anterosuperior view of the vertebral column, transversely sectioned through an intervertebral disc. The superficial layers of the anulus fibrosus have been cut and spread apart to show the direction of the fibers. (From Moore KL, Dalley AF. *Clinical Oriented Anatomy*, 5th ed. Baltimore: Lippincott Williams & Wilkins, 2006.)

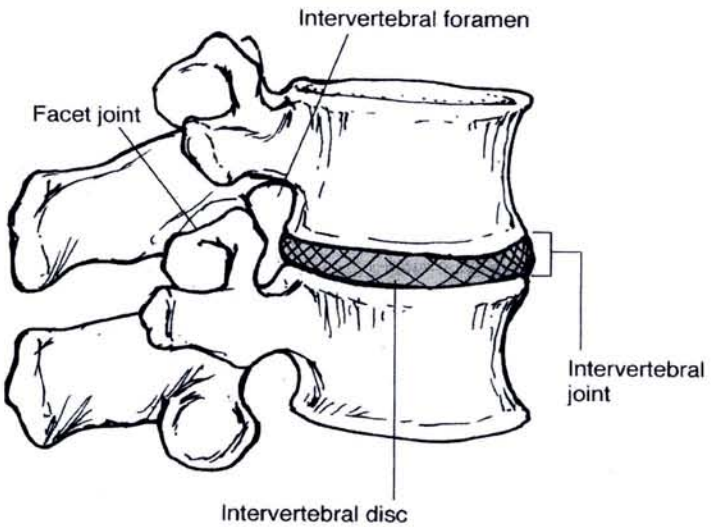

Figure 23-6 A motion segment consists of an intervertebral disc and the two adjacent vertebral bodies. (From Oatis CA. *Kinesiology: The Mechanics and Pathomechanics of Human Movement*. Baltimore: Lippincott Williams & Wilkins, 2004.)

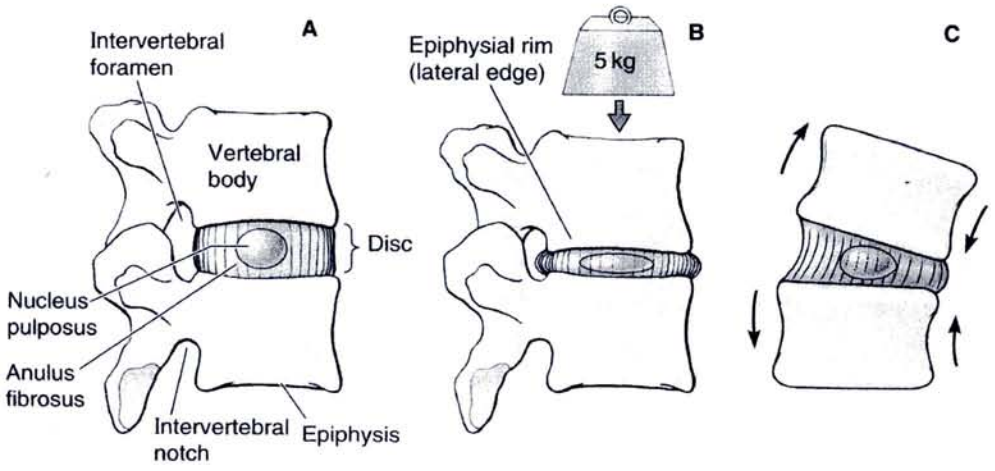

Figure 23-7 (A) The motion segment in cross-section. (B) Under axial compression, the disc bulges. Tensile stresses are generated in the outer anulus and compressive stresses in the nucleus pulposus. High fluid pressures are generated in the nucleus, causing extravasation of fluid. After the cessation of the axial loading, the osmotic pressure causes the extruded fluid to flow back into the disc, restoring its height. (C) Flexion or extension and lateral bending result in eccentric changes of the disc, which results in an alternating suction/extrusion action on the fluids into and out of the disc. (From Moore KL, Dalley AF. *Clinical Oriented Anatomy*, 5th ed. Baltimore: Lippincott Williams & Wilkins, 2006.)

spine procedures are performed because of consequences of the degenerative process.

- Degeneration appears to be the natural consequence of two scenarios:
  - Application of *normal loads* to a disc with *abnormal material properties*
  - Application of *abnormal loads* to disc with *normal material properties*

Biology of Degeneration

- Declining nutritional support is the most important event responsible for the changes in central disc cells and their matrices (Fig. 23-8).
  - Sequence of events resulting in loss of nutritional support
    - Increase in disc volume during growth results in relative decline in the vascular supply.
    - Decreased vascular supply results in impaired diffusion and convection that is necessary for the transport of nutrients and removal of waste.
- Loss of disc tissue results from the action of degradative enzymes within the disc and the inability of disc cells to maintain or restore their extracellular matrix.
  - Cause of this imbalance remains unknown.
  - Mediators of degradation
    - Proteolytic enzymes (cathepsin and lysozyme)
    - Inflammatory cytokine IL-1 decreases rate of proteoglycan production and increases rate of matrix breakdown.
- Extrinsic factors: mediate degeneration of the disc by nutritional and/or vascular means (Box 23-1)
- Mechanical environments
  - Overload hypothesis
    - Demanding mechanical environment produces local trauma of the disc that will be slow to heal due to slow turnover of the disc tissue.
    - Accumulation of injury and microtrauma progressively weakens the disc, making it more susceptible to further injury, thus starting a vicious cycle.
  - Hypomobility hypothesis

TABLE 23-1 SUMMARY OF DISC MECHANICAL FUNCTION

Structure	Composition	Function
Outer anulus	Dense concentric lamellae	Resist tensile loads Hydrostatic barrier that limits deformation Reduce strains across vertebral bodies
Inner anulus	Less dense lamellae Increased water content	"Shock absorbers": viscoelastic dissipation of force
Nucleus pulposus	High concentration of proteoglycans Increased water content	Resist axial compressive loads
Endplate	Hyaline cartilage	Transfer of axial loads to vertebral body

TABLE 23-2 AGE-RELATED CHANGES IN THE DISC

Age Group	Changes
Newborn	Distinct hyaline cartilage endplates Numerous perivascular and free nerve endings Small amounts of collagen in nucleus Small blood vessels present in outer lamellae Proteoglycan in nucleus similar to endplate
Childhood and adolescence	Disc volume and diameter increase. Blood vessels decrease in size and number. Increase in cartilaginous content of anulus Aggrecan becomes predominant proteoglycan.
Adult	Remaining peripheral vessels disappear. Inner anulus expands. Size of nucleus decreases. Myxomatous degeneration of anulus; loss of collagen fiber organization Fissures and cracks in lamellae Concentration of viable cells declines. Proteoglycan and water concentrations decrease. Collagen and noncollagenous protein concentrations increase. Decrease in structural integrity
Elderly	Inner anulus and nucleus become fibrocartilage. Few viable cells remain. Decrease in height

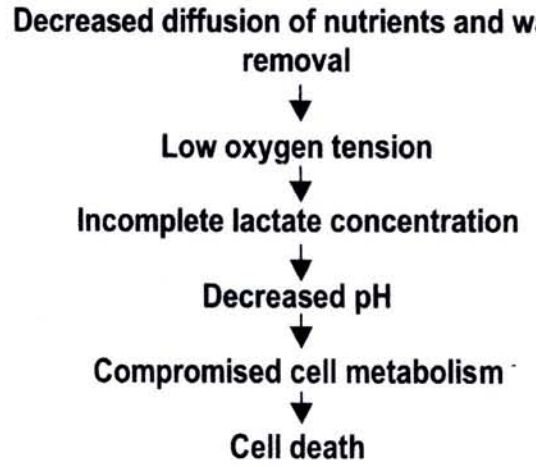

Figure 23-8 Proposed pathway of cellular degeneration of the disc.

BOX 23-1 FACTORS INCREASING AGE-RELATED CHANGES

Nutritional Transport	Vascular Supply
Increased disc loading	Smoking
Immobilization	Vascular disease
Vibration	Diabetes
Spinal deformity	

- Hypomobility results in adaptive changes that may predispose to weakness and degeneration.
- Resultant weakness and degenerative changes can cause pain, which further reduces motion and initiates another vicious cycle.

- Genetics: plays a significant role in the variability of disc degeneration in the population samples studied to date (Box 23-2)
  - First reports of gene forms associated with intervertebral disc degeneration in humans were published in 1998.
    - Low magnetic resonance imaging (MRI) signal intensity of thoracic and lumbar discs (disc desiccation) associated with TaqItt-genotypes of the vitamin D-receptor gene
  - Several mechanisms have been suggested through which genetic factors could influence degenerative disc findings:
    - Size and shape of spinal structures
    - Intracellular processes that maintain disc function
  - Interactions of genetic and environmental factors are complex and continue to be an area of intense study.
- Diminished material and structural properties

As a consequence of degeneration-related alterations in structure and composition of disc tissues, changes occur in the material and structural properties of the components of the disc (Fig. 23-9). The degenerative changes in material properties are most profound in the nucleus and endplate.

- Nucleus pulposus
  - Shear modulus of the nucleus increases eight-fold (becomes stiffer).
  - This decrease in energy dissipation suggests that the nucleus pulposus undergoes a transition from fluid-like to solid-like behavior.
  - These alterations may be explained by the loss of water content and increase in tissue density.

BOX 23-2 GENE FORMS ASSOCIATED WITH DISC DEGENERATION

Vitamin D receptor gene	Metalloproteinase-3
Collagen IX alleles	Aggrecan gene

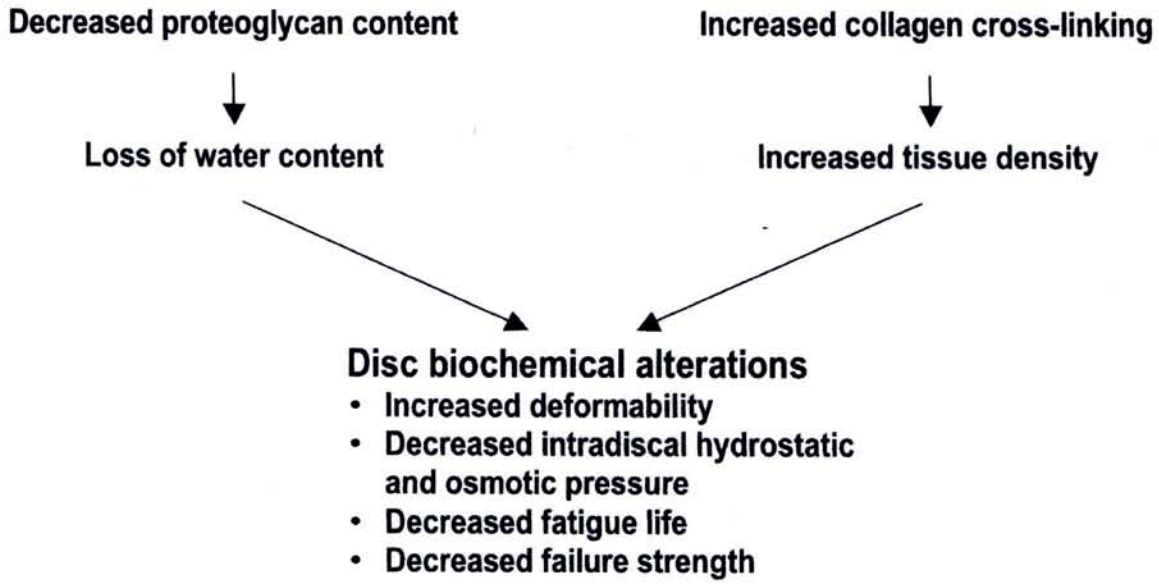

Figure 23-9 Biomechanical property changes of the degenerated disc.

- This transition to more of a solid-like state suggests a more anisotropic (orientation-dependent) stress state with more non-uniform distribution of stresses.
- Anulus fibrosus
  - Significant increase in compressive modulus
  - Decrease in radial permeability
    - Decrease in permeability results from loss of water content and obstruction of pores with debris.
    - Diffusion of nutrients, which relies on this permeability, is hindered.
  - Moderate increase in shear modulus
- Endplate
  - Thinning, microfracture, or damage to the endplate increases its hydraulic permeability, which allows rapid fluid exudation with loading.
  - This leads to a more non-uniform distribution of load as well as higher shear stresses that result in damage to the disc.
  - These compositional and structural changes lead to non-uniform load transfers that result in high shear stresses and material failures.

Disc Degeneration and Back Pain

The relationship between disc degeneration and back pain is poorly understood. Many factors, including structural changes in the spine, soluble mediators that sensitize nerve endings, and nerve/vessel ingrowth into the outer anulus, have all been hypothesized to be possible causes of this chronic pain (Fig. 23-10).

- Changes in the mechanical properties of the disc lead to loss of spinal mobility and abnormal loading of the facet joints, spinal ligaments, and surrounding muscles.
  - The altered alignment and relationship may contribute to spinal pain.
- The degenerated disc has been shown to produce cytokines and mediators that can sensitize surrounding nerve endings.
  - Tumor necrosis factor-alpha (TNF-α) has recently been suggested to play a role in discogenic pain.

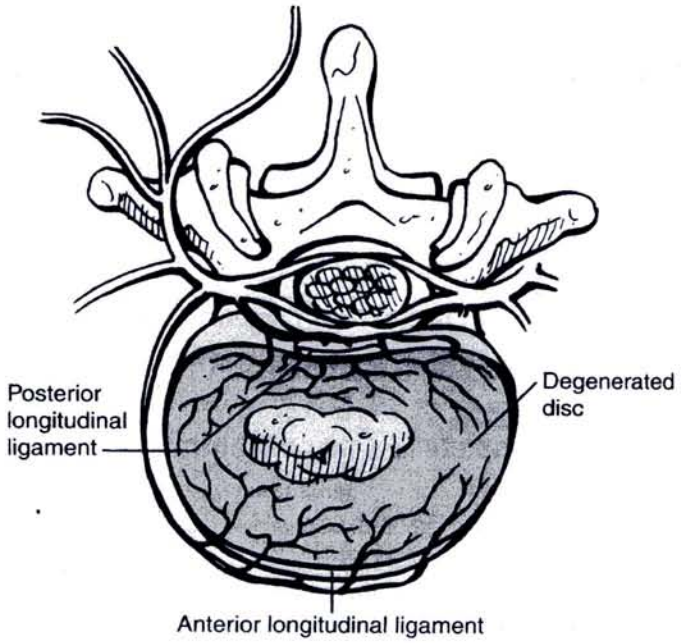

Figure 23-10 Pain fibers can penetrate more deeply into degenerated discs. These fibers may be accompanied by vascular ingrowth. (From Wetzel FT. Microinnervation: Pain generators. In Bono CM, Garfin SR, eds. *Orthopaedic Surgery Essentials: Spine*. Philadelphia: Lippincott-Raven, 2004:272–277.)

- TNF-α and other pro-inflammatory cytokines are a target of current research in pharmacologic intervention.

Medical Imaging

Obvious changes in disc morphology and matrix composition are observable with multiple imaging modalities. Although plain radiographs are nearly always the first step, computed tomography (CT) and MRI provide excellent detailed anatomic images of the spine. Prior to their development, more invasive techniques such as myelography, epidural venography, and epidurography were performed to evaluate intradiscal pathology.

- Early endplate changes preceding established degenerative disc diseases
  - Sclerosis, Schmorl's nodes, calcifications
  - Observed on both radiographs and MRI
- MRI is the advanced imaging modality of choice for intervertebral disc degeneration.
  - Characterizes many of the distinguishing features of the intervertebral disc
  - Does not distinguish between symptomatic and asymptomatic patients
  - Does not differentiate degeneration from age-related changes
  - Most sensitive MRI sign for disc degeneration: nucleus pulposus loses signal intensity on T2-weighted images
    - Loss of proteoglycans and dehydration occurring in degeneration
    - Seen as loss of signal intensity on T2-weighted images
- Plain x-ray and MRI changes of degeneration
  - Loss of disc height
  - Osteophyte formation
    - Attributed to a compensation mechanism to distribute the increasing axial load and shear forces onto a larger bearing surface
    - These osteophytes have been differentiated into two types: traction and claw.
      - Traction osteophytes result from abnormal shear and are a sign of instability.
      - Claw-type osteophytes represent traction at the site of osseous attachment (Sharpey fibers) of the anulus fibrosus.
- Radiographic correlates to morphological degree of degeneration
  - Plain film significant correlates: height loss, osteophytes, and intradiscal calcification (Table 23-3)
  - MRI correlative parameters: DEBIT (*d*isc *e*xtension *b*eyond the *in*terspace), nucleus pulposus shape, anular tears, osteophytes, and endplate irregularity
- New and potentially useful imaging techniques for spine (continue to offer more opportunities to investigate and diagnose back pain and intervertebral disc degeneration)
  - Dynamic CT and MRI
  - Diffusion imaging
  - Magnetic resonance spectroscopy

DISC HERNIATION

- Definition: protrusion of tissue from the nucleus pulposus through a defect in the anulus fibrosus (Fig. 23-11)
- Early clinical course
  - Initially fragmentation rarely perceived due to poor innervation of disc
  - Back pain typically experienced as outer anulus becomes involved with extension of the fissure and fragmentation
  - With the herniation of the discal components, pressure on the anulus is transferred to the nerve root.

TABLE 23-3 THOMPSON GRADING SCHEME FOR GROSS MORPHOLOGY OF THE HUMAN LUMBAR INTERVERTEBRAL DISC

Grade	Nucleus	Anulus	Endplate	Vertebral Body
I	Bulging gel	Discrete fibrous lamellae	Hyaline, uniformly thick	Margins rounded
II	White fibrous tissue peripherally	Mucinous material between lamellae	Thickness irregular	Margins pointed
III	Consolidated fibrous tissue	Extensive mucinous infiltration; loss of anular–nuclear demarcation	Focal defects in cartilage	Early chondrophytes or osteophytes at margins
IV	Horizontal clefts parallel to endplate	Focal disruptions	Fibrocartilage extending from subchondral bone, irregularity and focal sclerosis in subchondral bone	Osteophytes <2 mm
V	Clefts extend through nucleus and anulus	—	Diffuse sclerosis	Osteophytes >2 mm

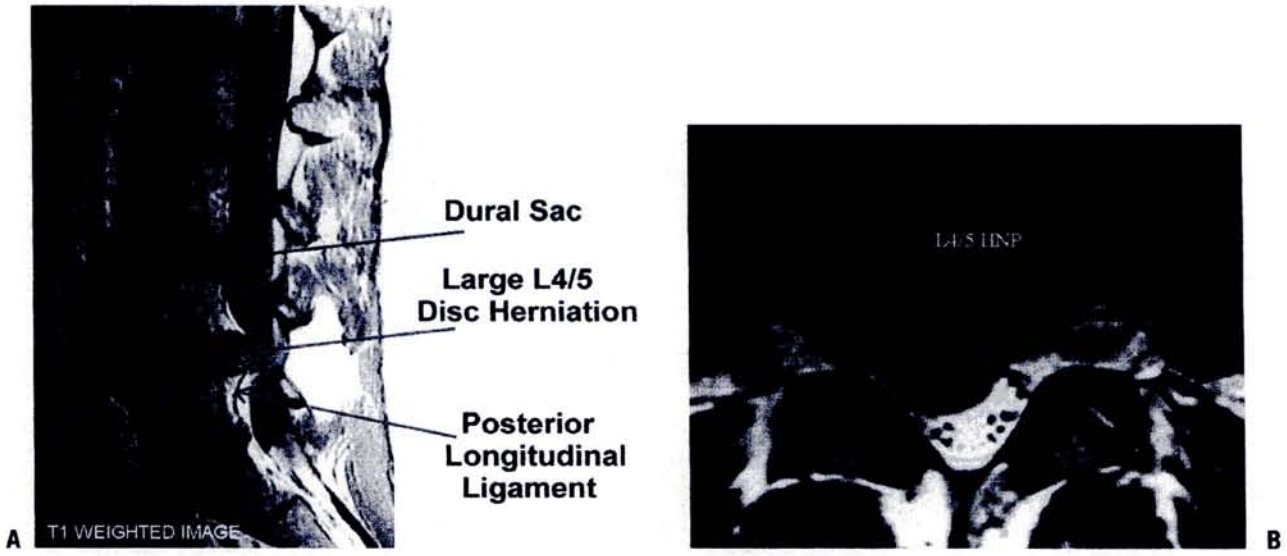

Figure 23-11 Lumbar microdiscectomy. MRI views of a large L4-5 disc herniation, sagittal (A) and axial (B). (From Koval KJ, Zuckerman, JD. *Atlas of Orthopaedic Surgery: A Multimedia Reference*. Philadelphia: Lippincott Williams & Wilkins, 2004.)

- Back pain is typically relieved at this point, yet the radiculopathy (sciatica) may increase in intensity.
- Later clinical course and outcome
  - In >90% of patients with symptomatic disc herniations, the pain subsides within 3 months.
  - In many people (28% to 35%), disc herniation occurs in the absence of symptoms. This relief of symptoms has theoretically been attributed to a spontaneous resorptive process that appears to be modulated by an inflammatory pathway.
- Histopathology and healing process
  - Herniated disc is surrounded by granulation tissues with an inflammatory cell infiltrate and newly formed vessels.
  - Neovascularization is related by MRI to the resorption of the herniated disc.
  - Infiltrating macrophages also play a crucial role in this resorption.
- Terminology from the North American Spine Society (NASS)
  - **Herniation**: localized displacement of disc material beyond the limits of the intervertebral disc space (Fig. 23-12). The disc material may be nucleus, cartilage, fragmented apophyseal bone, anular tissu or any combination. The interspace is defined cr nial and caudad by the vertebral endplates and p ripherally by the outer edges of the vertebral ri apophyses (Fig. 23-13).
  - **Anular tear**: localized radial, concentric, or horizo tal disruption of the anulus without associated di placement of the disc material beyond the limits the intervertebral disc space (see Fig. 23-12)
  - **Extrusion**: In at least one plane, any one distan between the edges of the disc material beyond t disc space is greater than the distance between t edges of the base measured in the same plane; when no continuity exists between the disc materi beyond the disc space and that within the disc spa (Fig. 23-14).
  - **Protrusion**: The greatest plane, in any direction, b tween the edges of the disc material beyond the di space is less than the distance between the edg and the base (see Fig. 23-14).
- Location of the herniation: Wiltse proposed a system anatomic zones and levels to characterize the herniati (Figs. 23-15 and 23-16).

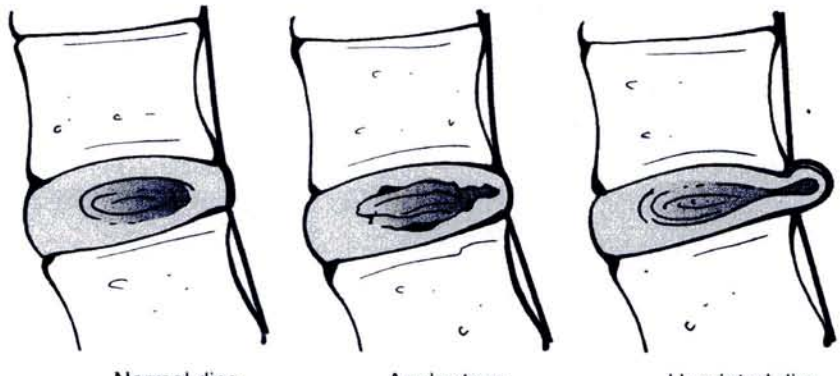

Figure 23-12 Sagittal anatomic sections showing the differentiating features of anular tear and herniated disc (After Milette PC, Fardon DF. Nomenclature and classification of lumbar disc pathology. *Spine* 2001;26: E93–E113.)

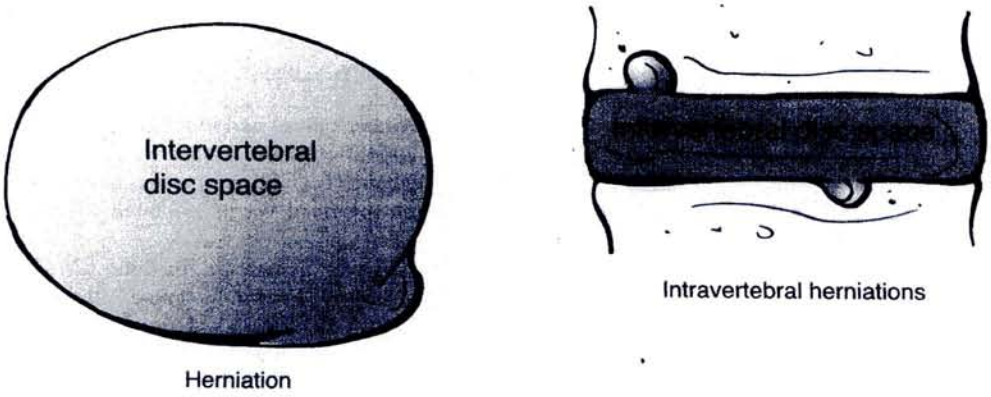

Figure 23-13 Herniation of disc material beyond the interspace can be in either the axial or the caudad/cranial planes. (After Milette PC, Fardon DF. Nomenclature and classification of lumbar disc pathology. *Spine* 2001;26: E93–E113.)

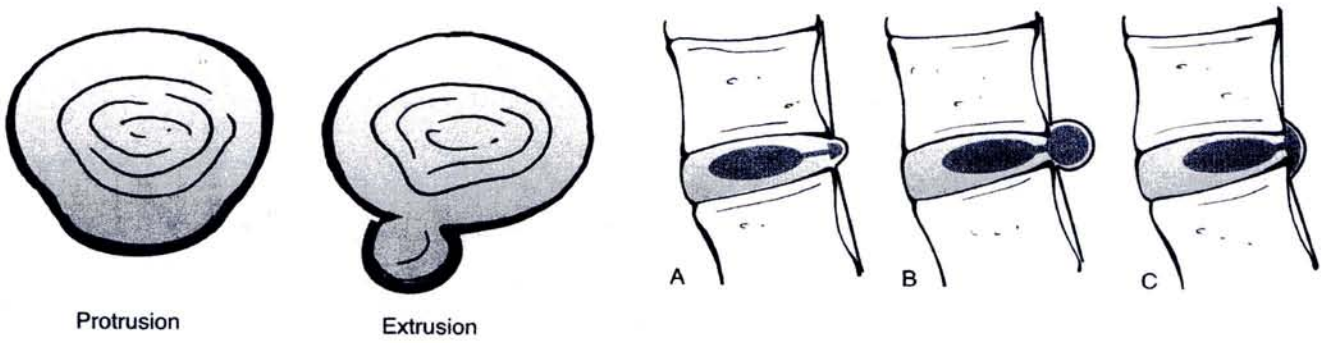

Figure 23-14 Differentiating characteristics of protrusion (A) and extrusion (B,C). (After Milette PC, Fardon DF. Nomenclature and classification of lumbar disc pathology. *Spine* 2001;26:E93–E113.)

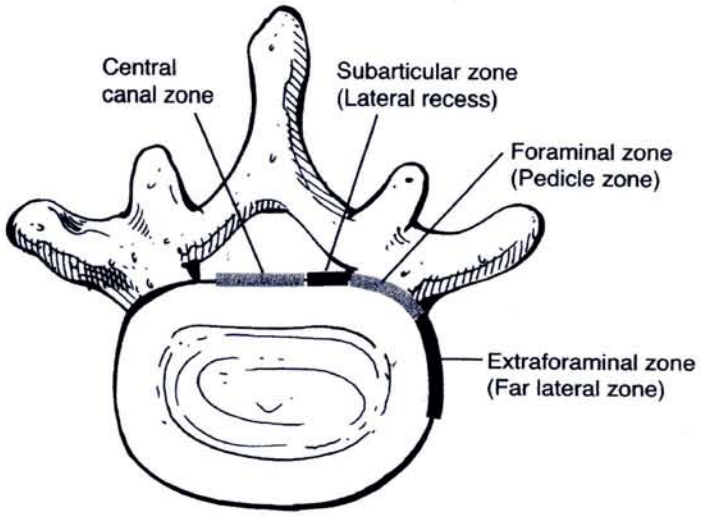

Figure 23-15 The anatomic "zones" identified on axial images. (After Milette PC, Fardon DF. Nomenclature and classification of lumbar disc pathology. *Spine* 2001; 26:E93–E113.)

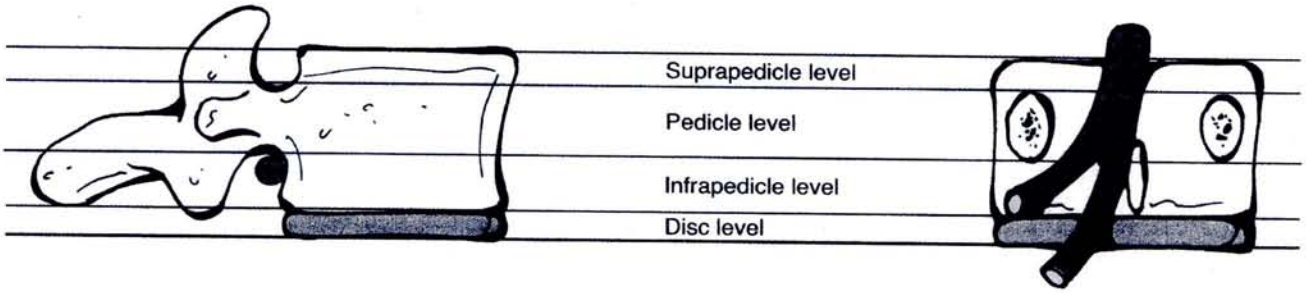

Figure 23-16 The anatomic "levels" identified on cranio–caudad images. (After Milette PC, Fardon DF. Nomenclature and classification of lumbar disc pathology. *Spine* 2001;26:E93–E113.)

SUGGESTED READING

Ashton-Millar JA, Schultz AB. Biomechanics of the human spine. In Mow VC, Hayes WC, eds. *Basic Orthopaedic Biomechanics*. Philadelphia: Lippincott-Raven, 1997:353–393.

Benneker LM, Heini PF, Anderson SE, et al. Correlation of radiographic and MRI parameters to morphological and biochemical assessment of intervertebral disc degeneration. *Eur Spine J* 2005;14:27–35.

Buckwalter JA, Einhorn TA, Simon SR, eds. *Orthopaedic Basic Science: Biology and Biomechanics of the Musculoskeletal System*. Rosemont, IL: AAOS, 1999.

Lotz JC. Animal models of intervertebral disc degeneration. *Spin* 2004;29:2742–2750.

Milette PC, Fardon DF. Nomenclature and classification of lumba disc pathology. *Spine* 2001;26:E93–E113.

Stokes IAF, Iatridis JC. Mechanical conditions that accelerate interve tebral disc degeneration: overload versus immobilization. *Spin* 2004;29:2724–2732.

Wetzel FT. Microinnervation: pain generators. In Bono CM, Garf SR, eds. *Orthopaedic Surgery Essentials: Spine*. Philadelphi Lippincott-Raven, 2004:272–277.