
PATHOPHYSIOLOGY

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Overview

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What is low back pain?

- Pain below the costal margin and above the gluteal folds, with or without radiation to the lower extremity¹
- **Acute** vs. **chronic** low back is pain classified according to duration:
 - **Acute:** less than 3 months^{2,3}
 - **Chronic:** more than 3 months^{2,3}



The Pain Continuum



Insult

Time to resolution

Acute pain

*Normal, time-limited response
to 'noxious' experience
(less than 3 months)*

- Usually obvious tissue damage
- Serves a protective function
- Pain resolves upon healing

Chronic pain

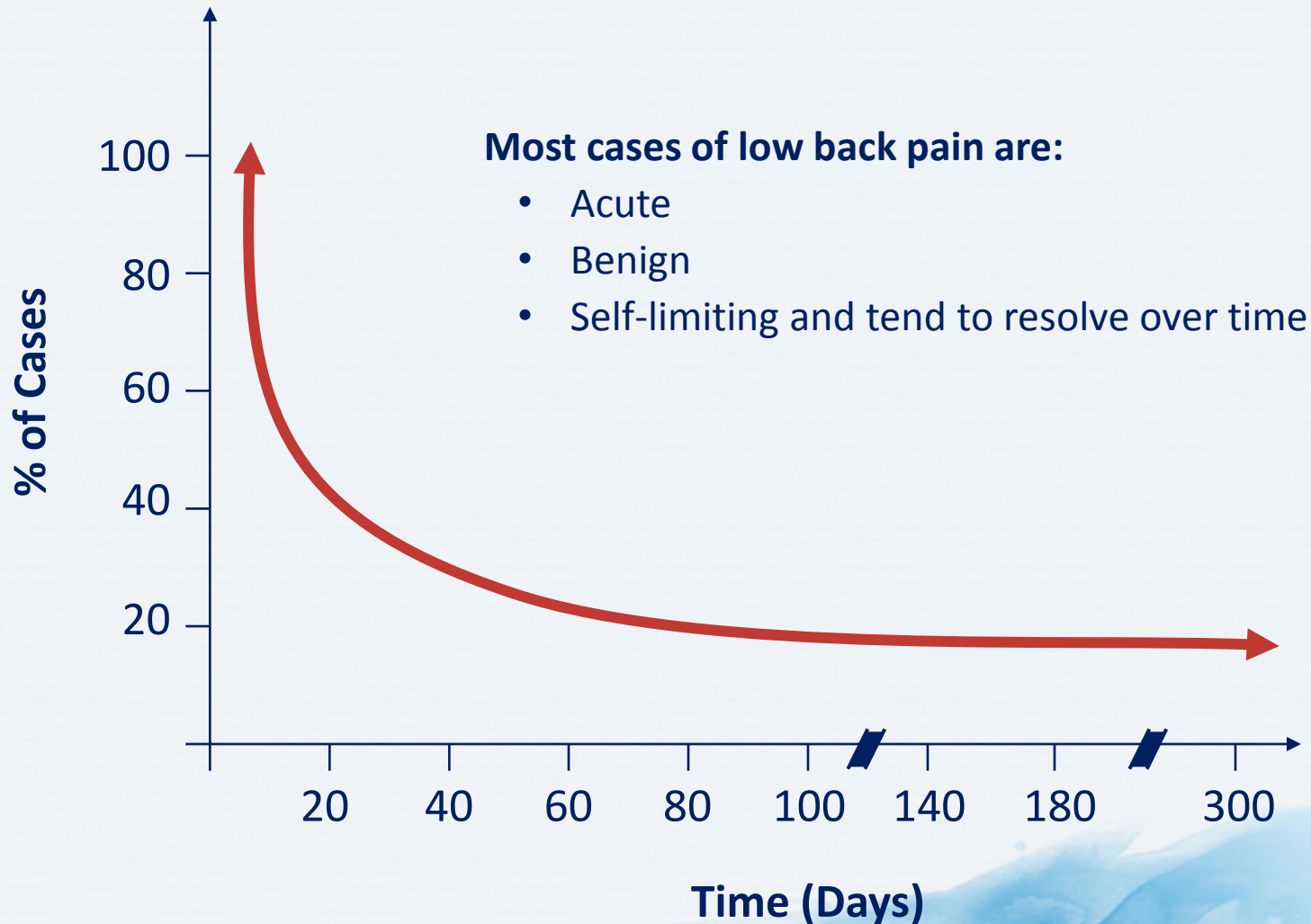
*Pain that has persisted beyond
normal tissue healing time
(usually more than 3 months)*

- Usually has no protective function
- Degrades health and function

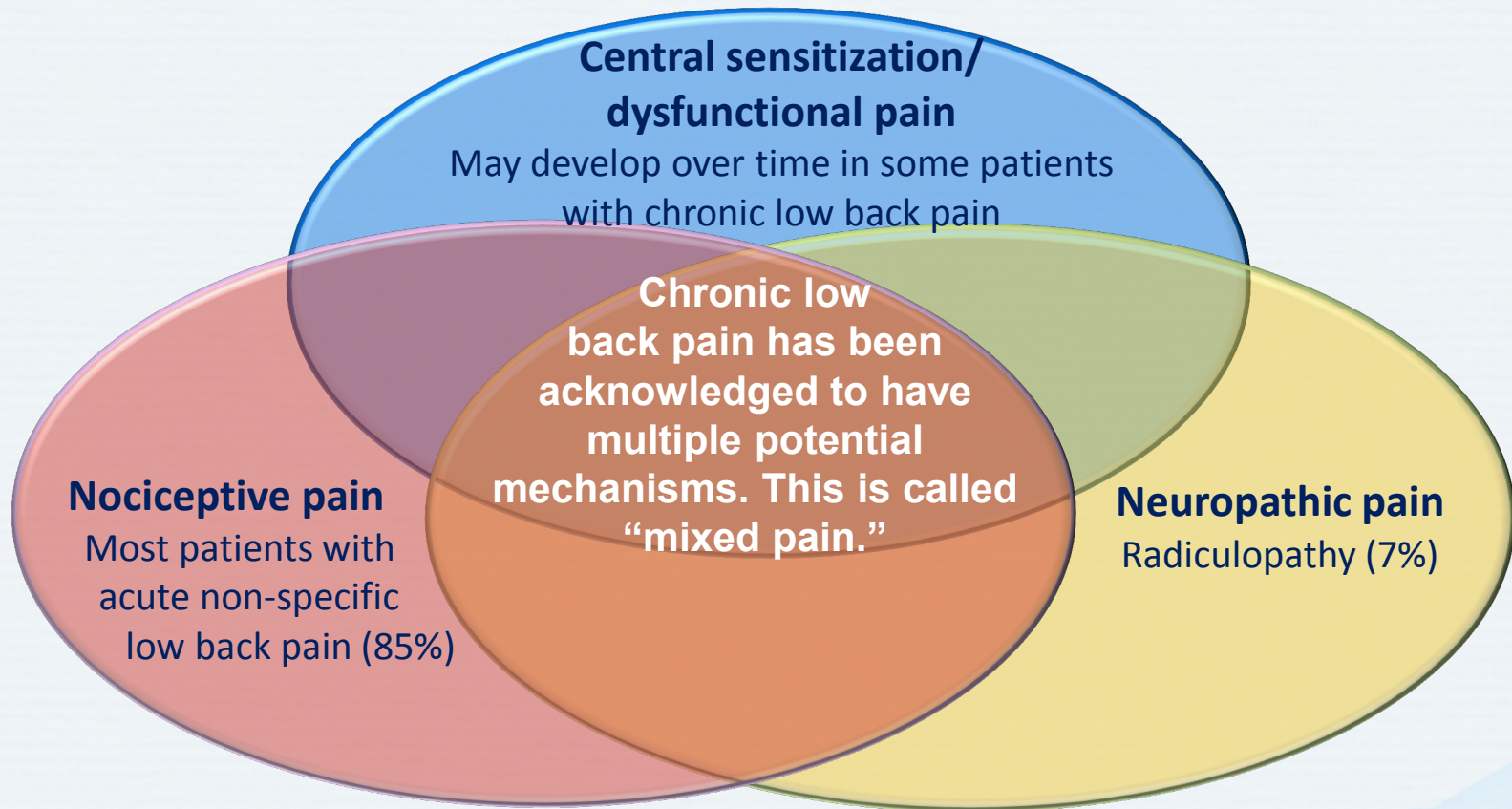


Acute pain may become chronic

Natural History of Low Back Pain



Pathophysiology of Low Back Pain



Low Back Pain

Simple classification of low back pain:

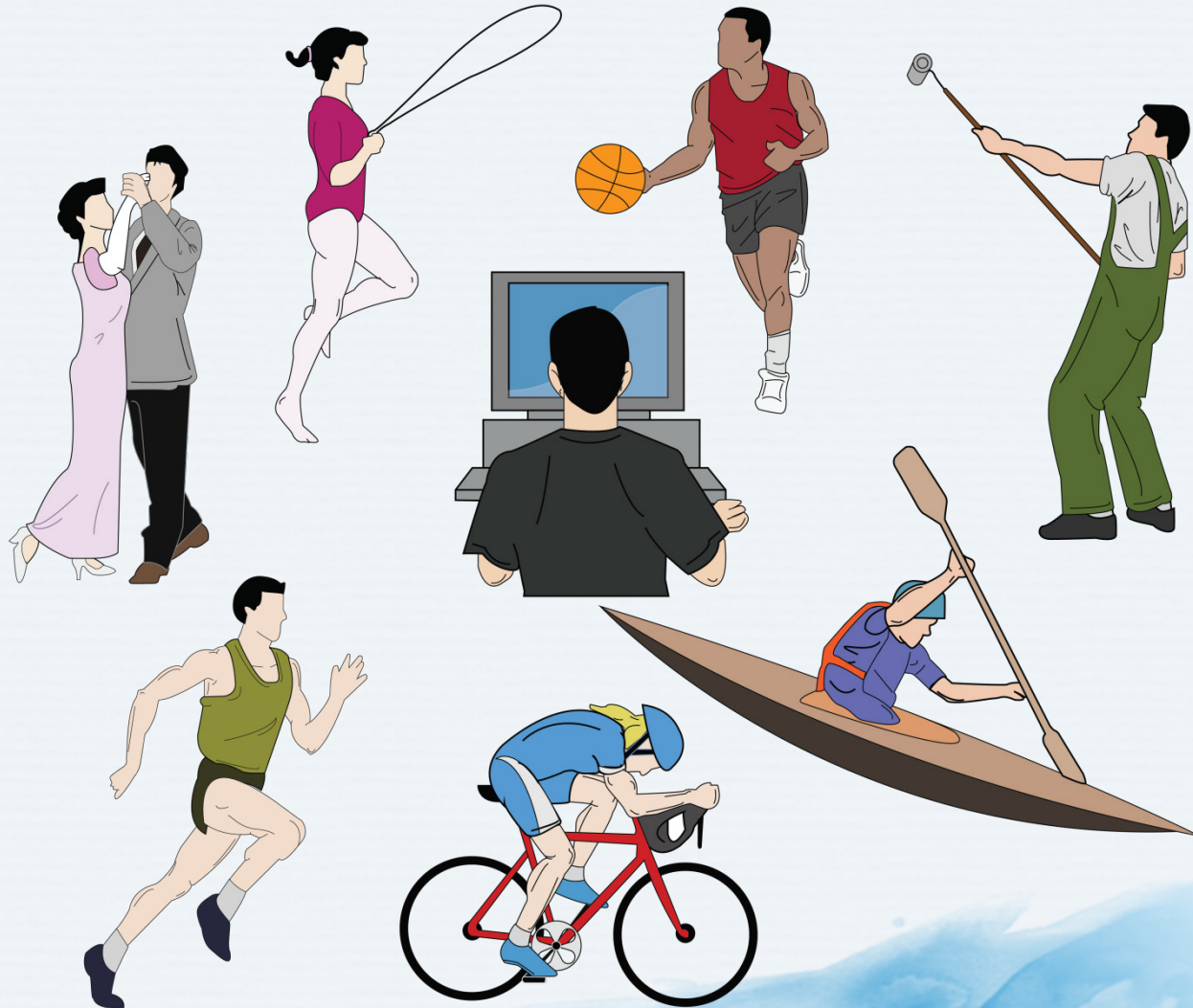
- Specific spinal pathology
- Radiculopathy
- Non-specific low back pain



Etiology

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Causes of Low Back Pain: Repetitive Trauma (Overuse)



Common Causes of Low Back Pain

Mechanical (80-90%)

(e.g., disc degeneration, fractured vertebrae, instability, unknown cause [most cases])

Neurogenic (5-15%)

(e.g., herniated disc, spinal stenosis, osteophyte damage to nerve root)

Non-mechanical spinal conditions (1-2%)

(e.g., neoplasm, infections, inflammatory arthritis, Paget's disease)

Referred visceral pain (1-2%)

(e.g., gastrointestinal disease, kidney disease, abdominal aortic aneurism)

Other (2-4%)

(e.g., fibromyalgia, somatoform disorder, "faking" pain)

Etiology of Low Back Pain with Nerve Root Involvement

| Cause | % of cases |
|---|------------|
| Herniated disc | 4 |
| Spinal stenosis (narrow canal) | 3 |
| Other <ul style="list-style-type: none">• Fractures/crushing due to osteoporosis• Joint diseases (e.g., degenerative osteoarthritis, rheumatoid arthritis, ankylosing spondylitis)• Congenital (e.g., scoliosis or kyphosis)• Spondylolisthesis• Overuse syndromes• Iatrogenic (e.g., post-chemotherapy fibrosis)• Infection (e.g., vertebral [epidural])• Tumor (primary or metastatic) | -1% |

Etiopathogenic Theories of Nerve Root Pain

1. Anatomic

- Deficient root protection
- Blood/cerebrospinal fluid mixed nutrition
- Vulnerability of capillary barrier

2. Compressive/edema

- Ease of inducing vascular stasis
- Situation in nerve root canal
- Time of onset of compression
- Situation of dorsal root ganglion

3. Congestive/edema

- Microvascular injury due to venous congestion
- Decreased fibrinolytic activity

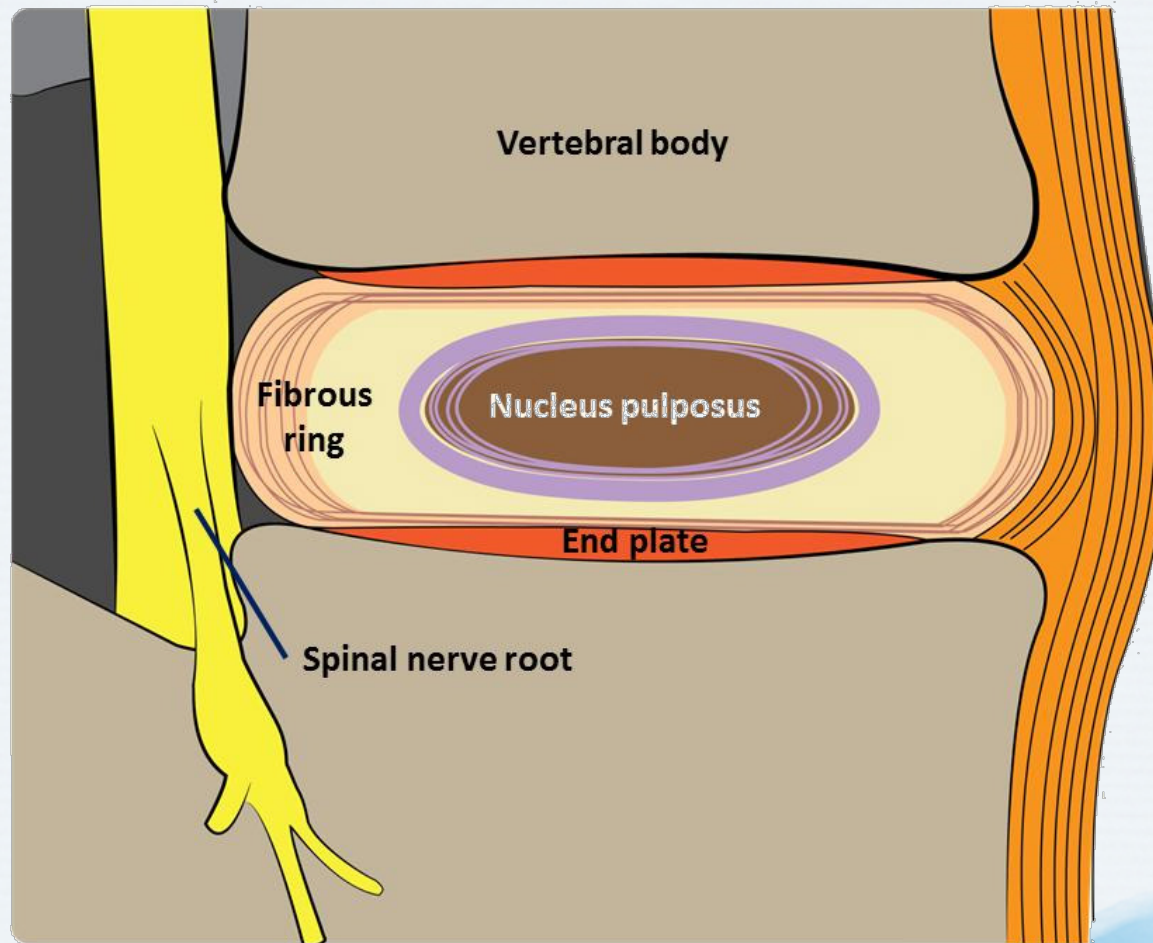
4. Immune

5. Inflammatory

6. Neural

- Sensitivity of nociceptors
- Neurogenic inflammation
- Dorsal root ganglion disease
- Altered pool of endogenous neuropeptides
- Ectopic discharge from ischemic axons
- Centralization of pain

Relationship between Vertebral Body and Longitudinal Ligament*

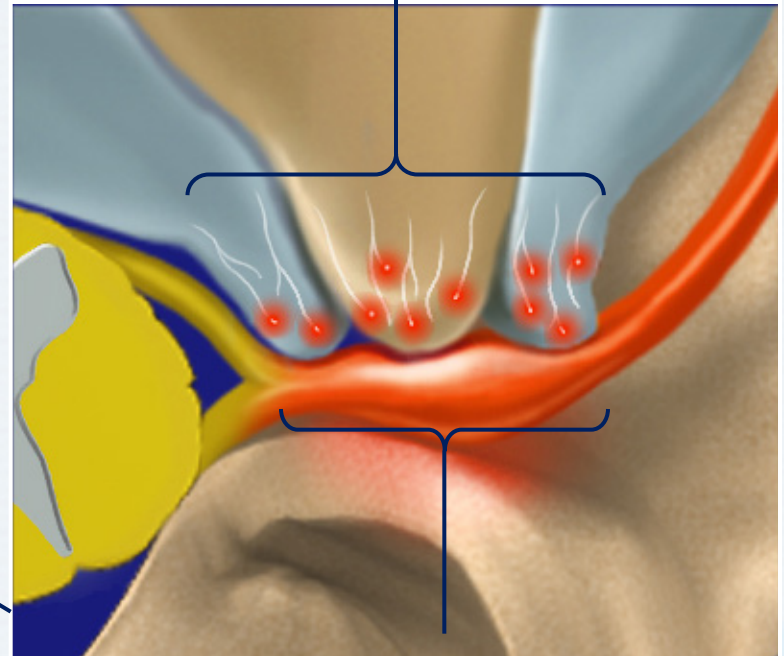
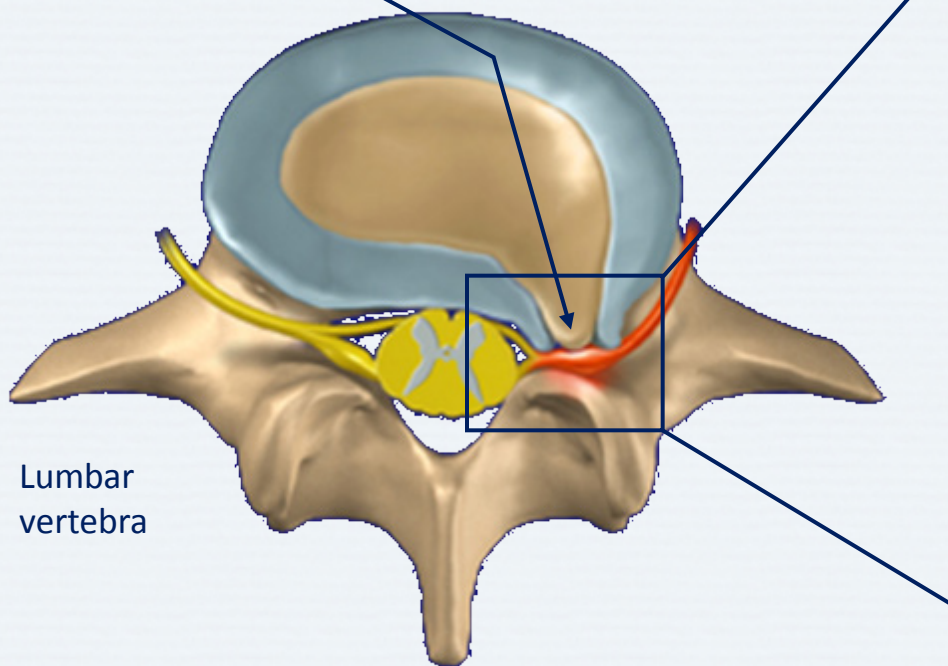


Example of Coexisting Pain: Herniated Disc Causing Low Back Pain and Lumbar Radicular Pain

Disc herniation

Activation of peripheral nociceptors –
cause of nociceptive pain component¹

Lumbar
vertebra



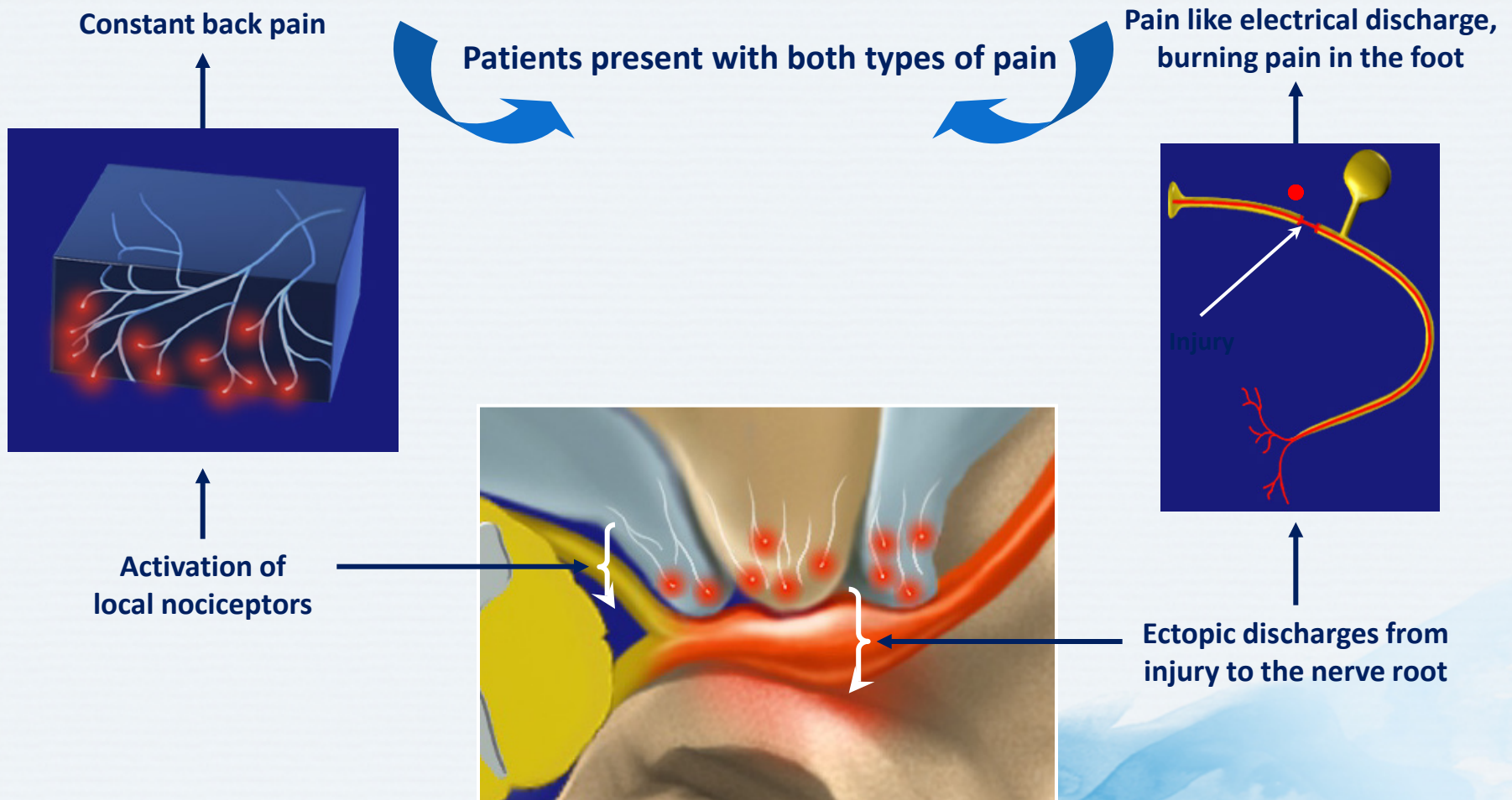
Compression and inflammation of nerve root –
cause of neuropathic pain component²

1. Brisby H. *J Bone Joint Surg Am* 2006; 88(Suppl 2):68-71.

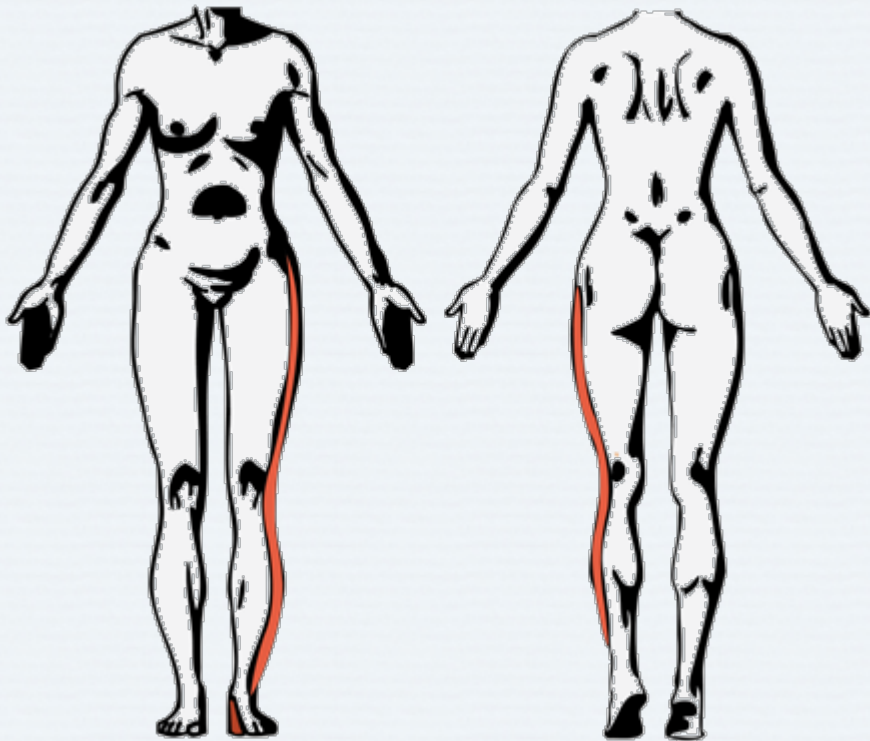
2. Freynhagen R, Baron R. *Curr Pain Headache Rep* 2009; 13(3):185-90.

Mixed Pain Example

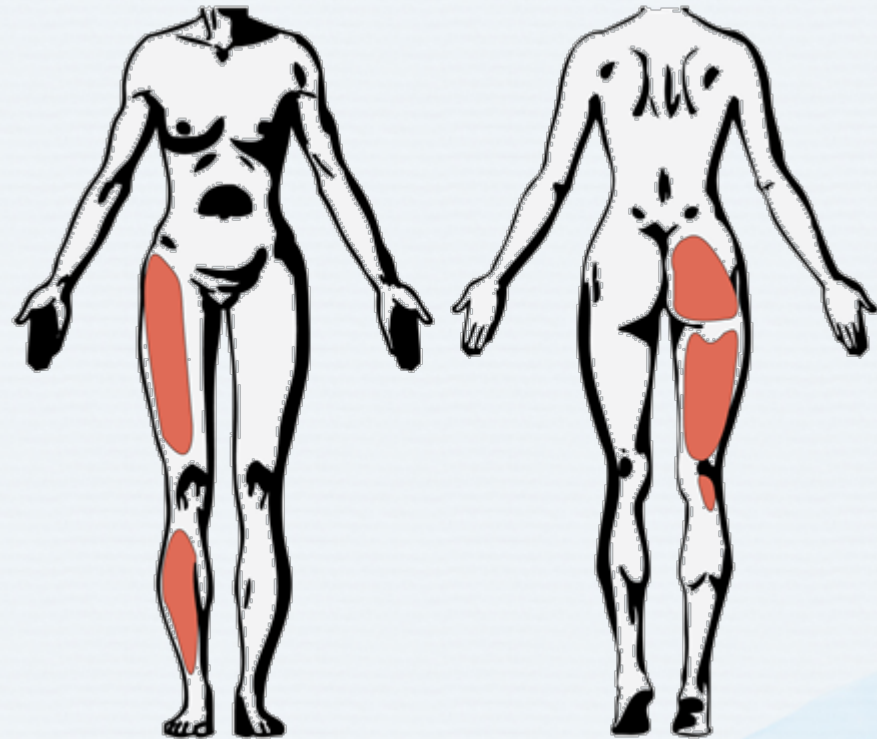
Herniated disc = low back pain + nerve root pain



Topographic Patterns of Pain Projection



Radiating Pain



Referred Pain

Potential Causes of Radiculopathy and Pseudoradiculopathy

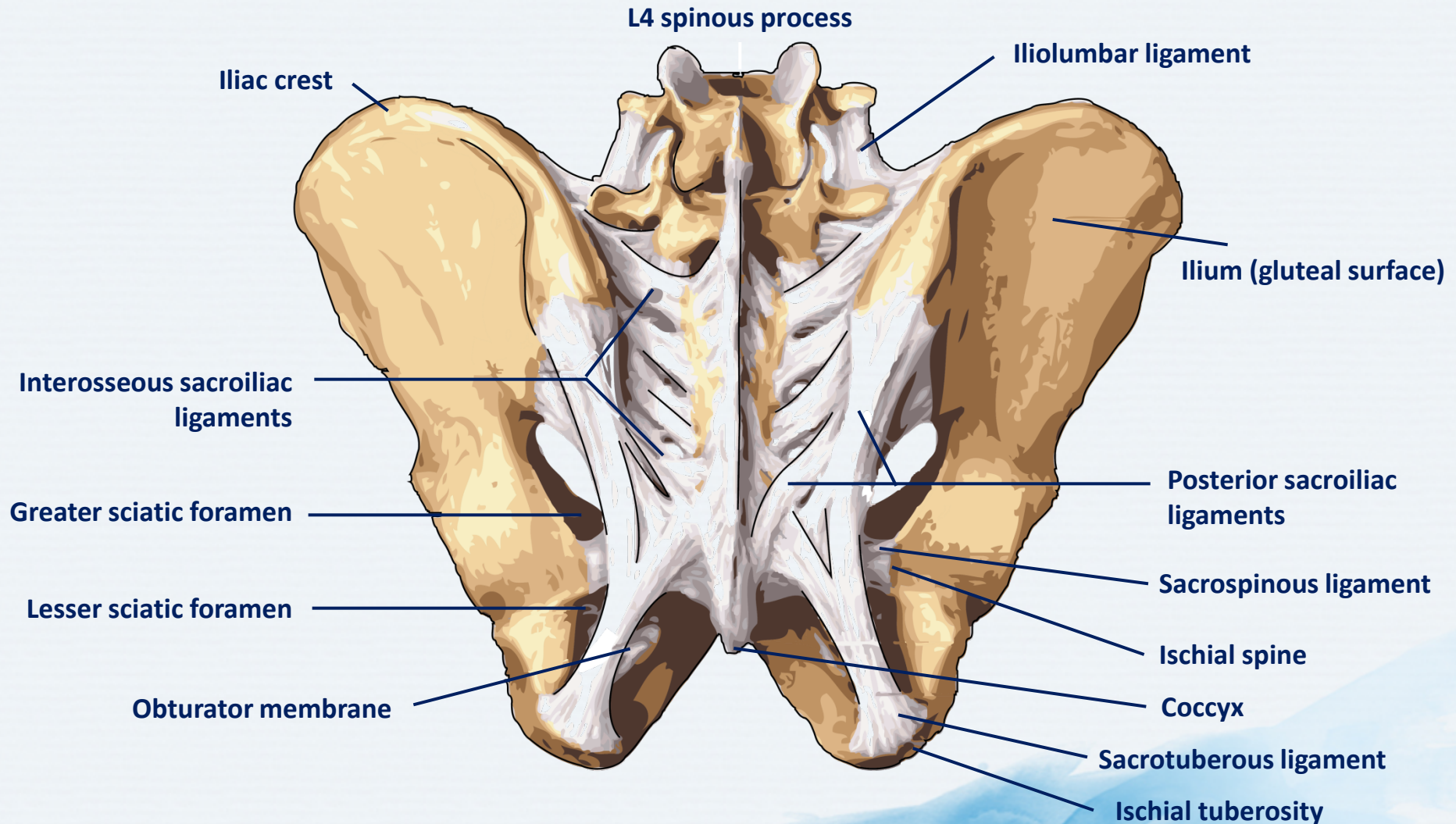
Radiculopathy

- Herniated disc with nerve compression
- Lumbar spinal stenosis
- Foraminal stenosis
- Diabetes mellitus
- Degenerative disc disease
- Residual adhesions from previous surgery
- Nerve root inflammation
- Spondylolisthesis

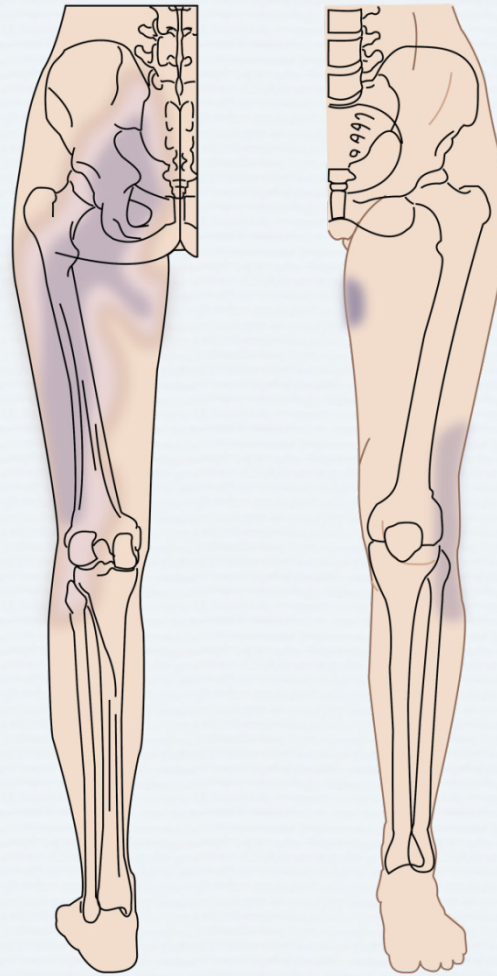
Pseudoradiculopathy

- Muscle contracture
- Facet pain
- Sacroiliac disease
- Osteochondrosis
- Trochanteric bursitis
- Local or systemic inflammation
- Infarction (can mimic root pain)

Normal Anatomy of the Sacroiliac Joint



Typical Reference Pattern of Sacroiliac Pain



Soft Tissue Causes of Low Back Pain

| Soft Tissue Condition | Clinical Features | Pain Pattern |
|------------------------------|---|---|
| Myofascial pain syndrome | <ul style="list-style-type: none">• Rope-like nodularity on physical examination | <ul style="list-style-type: none">• Low back, buttocks, thighs (localized or regional) |
| Paraspinal muscle injury | <ul style="list-style-type: none">• Muscle atrophy on MRI, ultrasound and CT | <ul style="list-style-type: none">• Low back |
| Injury to quadratus lumborum | <ul style="list-style-type: none">• Decreased and painful lumbar flexion and rotation | <ul style="list-style-type: none">• Flank, low back, buttocks, lateral hip |
| Ischiatic bursitis | <ul style="list-style-type: none">• Local tenderness at the ischial tuberosity | <ul style="list-style-type: none">• Buttocks |
| Cluneal nerve entrapment | <ul style="list-style-type: none">• Resolution of pain with local nerve block | <ul style="list-style-type: none">• Unilateral, iliac crest and buttocks |
| Sacroiliitis | <ul style="list-style-type: none">• Inflammation of one or both sacroiliac joints | <ul style="list-style-type: none">• Pain in buttocks or low back and may extend to groin and one or both legs• Often aggravated by prolonged standing or climbing stairs |

CT = computed tomography; MRI = magnetic resonance imaging

Borg-Stein J, Wilkins A. *Curr Pain Headache Rep* 2006; 10(50:339-44.

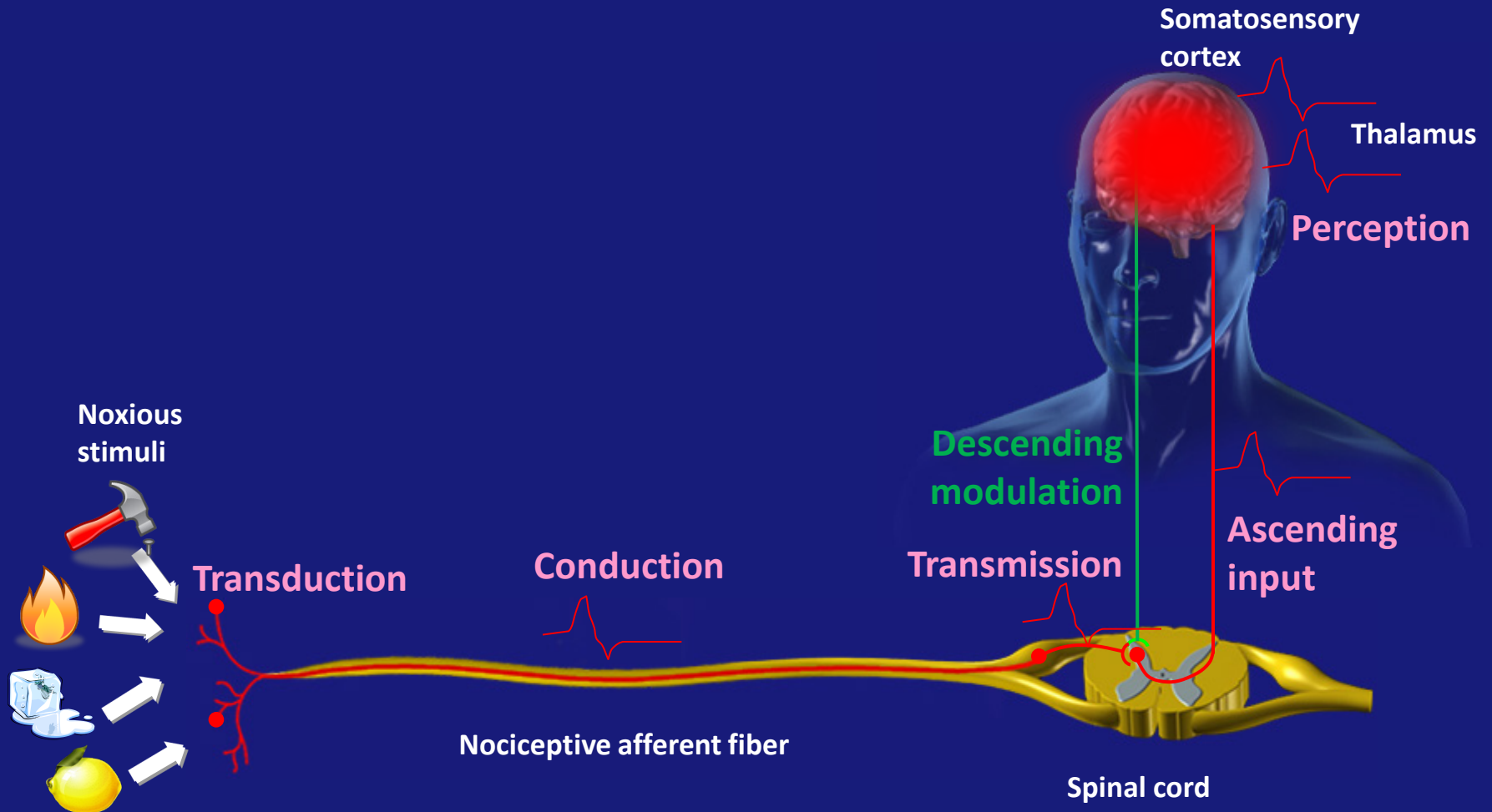
Soft Tissue Causes of Low Back Pain (cont'd)

| Soft Tissue Condition | Clinical Features | Pain Pattern |
|----------------------------------|--|---|
| Painful syndrome of hip abductor | <ul style="list-style-type: none"> • Tender gluteal muscles lateral to posterior-superior iliac spine • Hip abductor muscle weakness • Trendelenburg sign | <ul style="list-style-type: none"> • Buttocks, lateral aspect of thigh |
| Bursitis of the psoas | <ul style="list-style-type: none"> • Most painful movement is passive adduction in flexion • Appearance on musculoskeletal ultrasound is consistent with inflammation | <ul style="list-style-type: none"> • Groin, anterior thigh, knee, leg |
| Bursitis of the trochanter | <ul style="list-style-type: none"> • Positive “jump” sign secondary to thumb pressure over most prominent ridge of greater trochanter | <ul style="list-style-type: none"> • Pseudoradiculopathy: pain does not extend distal to proximal tibia (insertion of iliotibial tract at Gerdy’s tubercle) |
| Gluteal bursitis | <ul style="list-style-type: none"> • Pain on: <ul style="list-style-type: none"> – Passive external rotation and passive abduction – Passive abduction and either resisted external rotation or resisted abduction | <ul style="list-style-type: none"> • Gluteal and trochanteric region, sometimes spreading to outer or posterior thigh and down to calf and lateral malleolus |

Pathophysiology

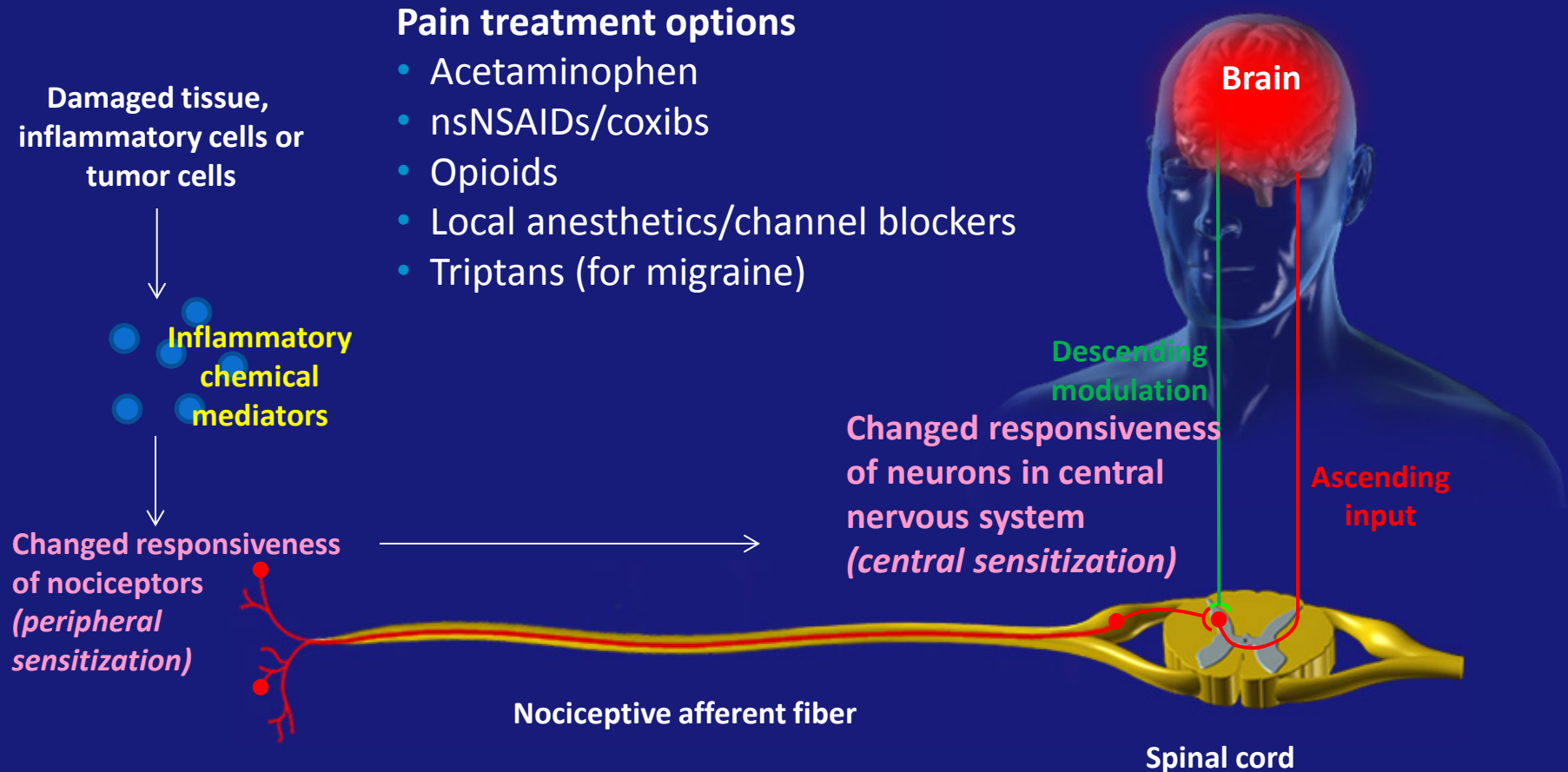
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Nociception: Neural Process of Encoding Noxious Stimuli



Consequences of encoding may be autonomic (e.g., elevated blood pressure) or behavioral (motor withdrawal reflex or more complex nocifensive behavior). Pain perception is not necessarily implied.

Treatment of Inflammatory Pain



Coxib = COX-2-specific inhibitor; nsNSAID = non-specific non-steroidal anti-inflammatory drug

Scholz J, Woolf CJ. *Nat Neurosci* 2002; 5(Suppl):1062-7.

Pain Types Related to Spinal Disorders

Localized

Damage to ligaments, muscles, degenerative changes in spinal column

Radiating (radicular)

Entrapment of a nerve root, compression and inflammation

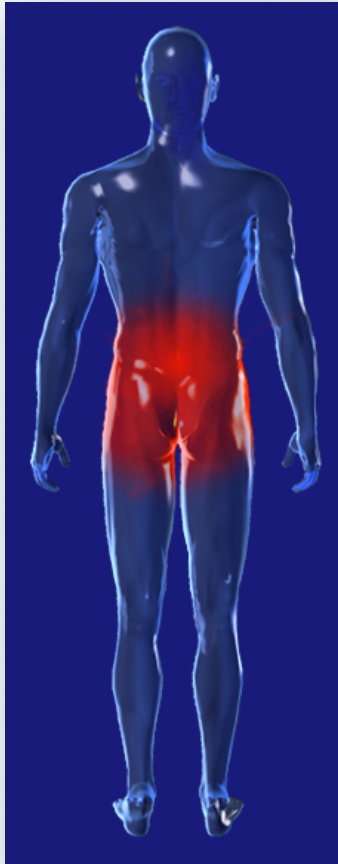
Referred

Pain projected to sites distant from the origin

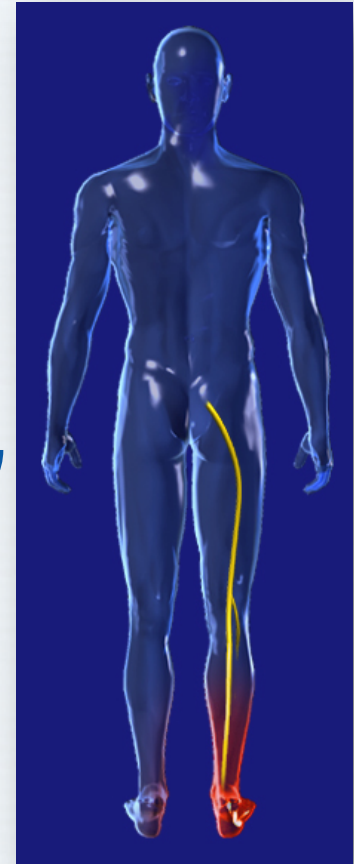
Low Back Pain Syndromes and Clinical Entities

| Neuropathic (Nerve root) | Nociceptive (Musculoskeletal) |
|----------------------------|-------------------------------------|
| Lumbar nerve root syndrome | Internal disc tear |
| Herniated lumbar disc | Lumbar facet syndrome |
| Lumbar spinal stenosis | Dysfunction of the sacroiliac joint |

Nociceptive and Neuropathic Components May Be Present in Low Back Pain



Nociceptive Component

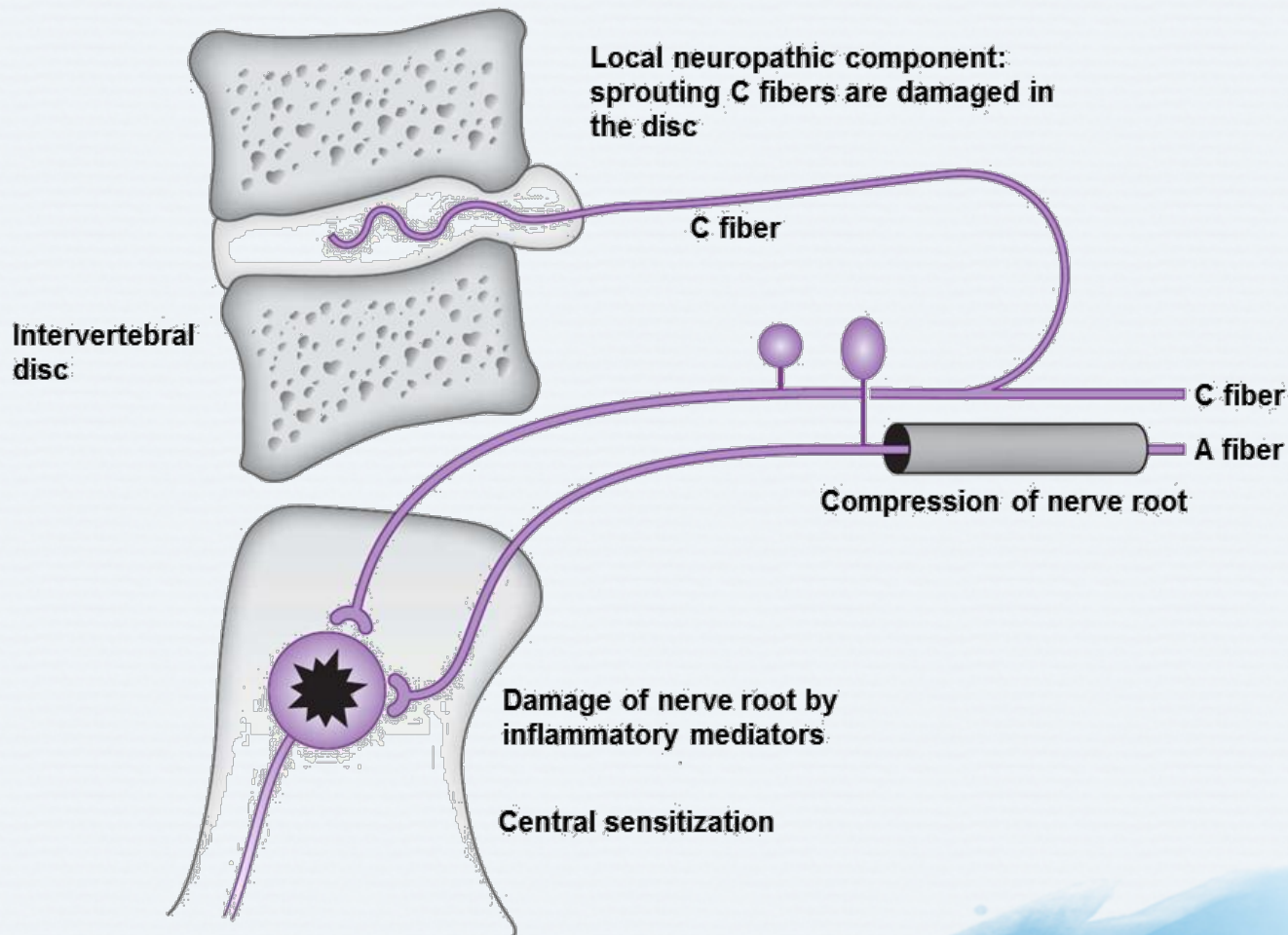


Neuropathic Component

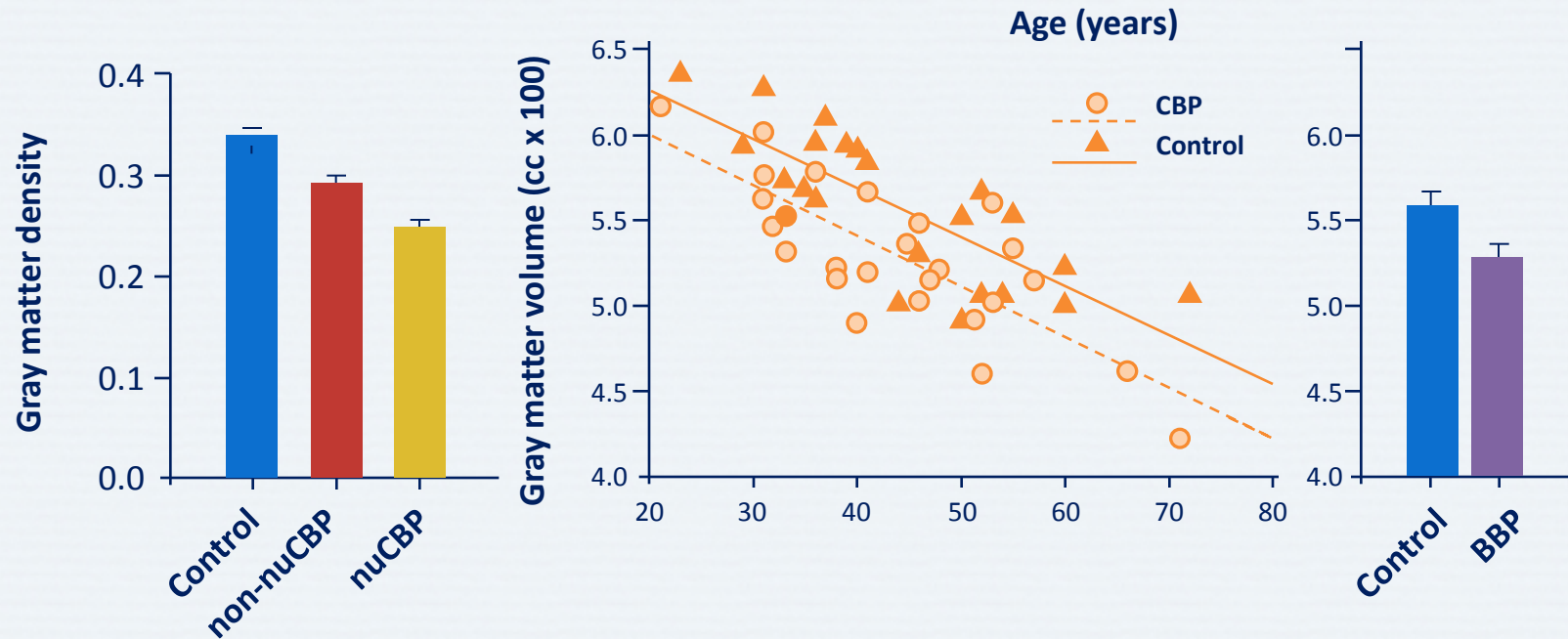
Neuropathic Component of Low Back Pain

- Neuropathic component of low back pain may be caused by:
 - Mechanical compression of nerve root (*mechanical neuropathic nerve root pain*)
 - Damage to sprouting C-fibers within the degenerated disc (*localized neuropathic pain*)
 - Action of inflammatory mediators released from the degenerated disc (*inflammatory neuropathic nerve root pain*), even without mechanical compression

Pathophysiological Mechanisms in Neuropathic Low Back Pain



Grey Matter Density and Volume Is Reduced in Chronic Back Pain

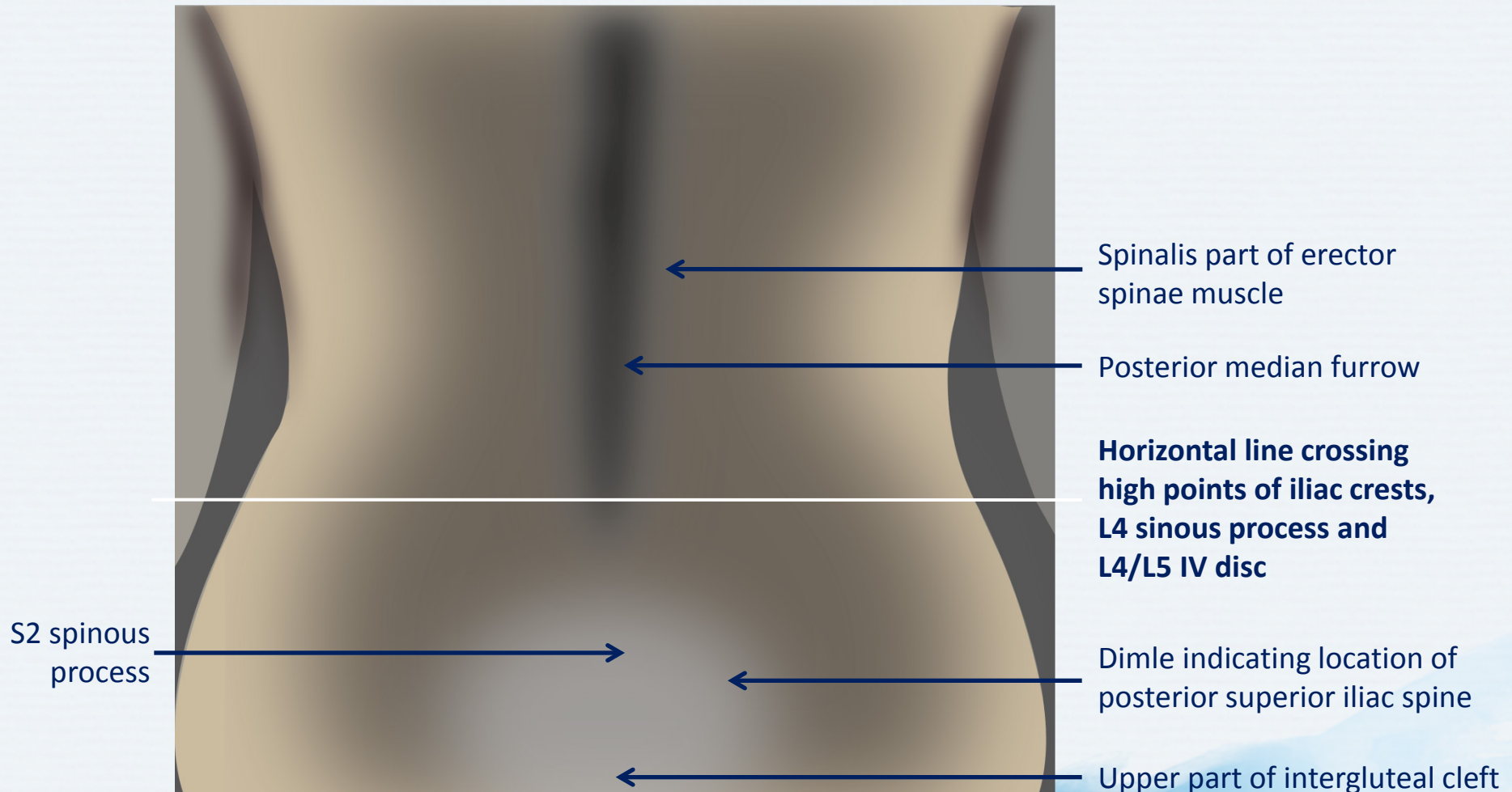


- 11% reduction in volume in patients with chronic back pain vs. controls
- Reduction may be reversible with proper treatment

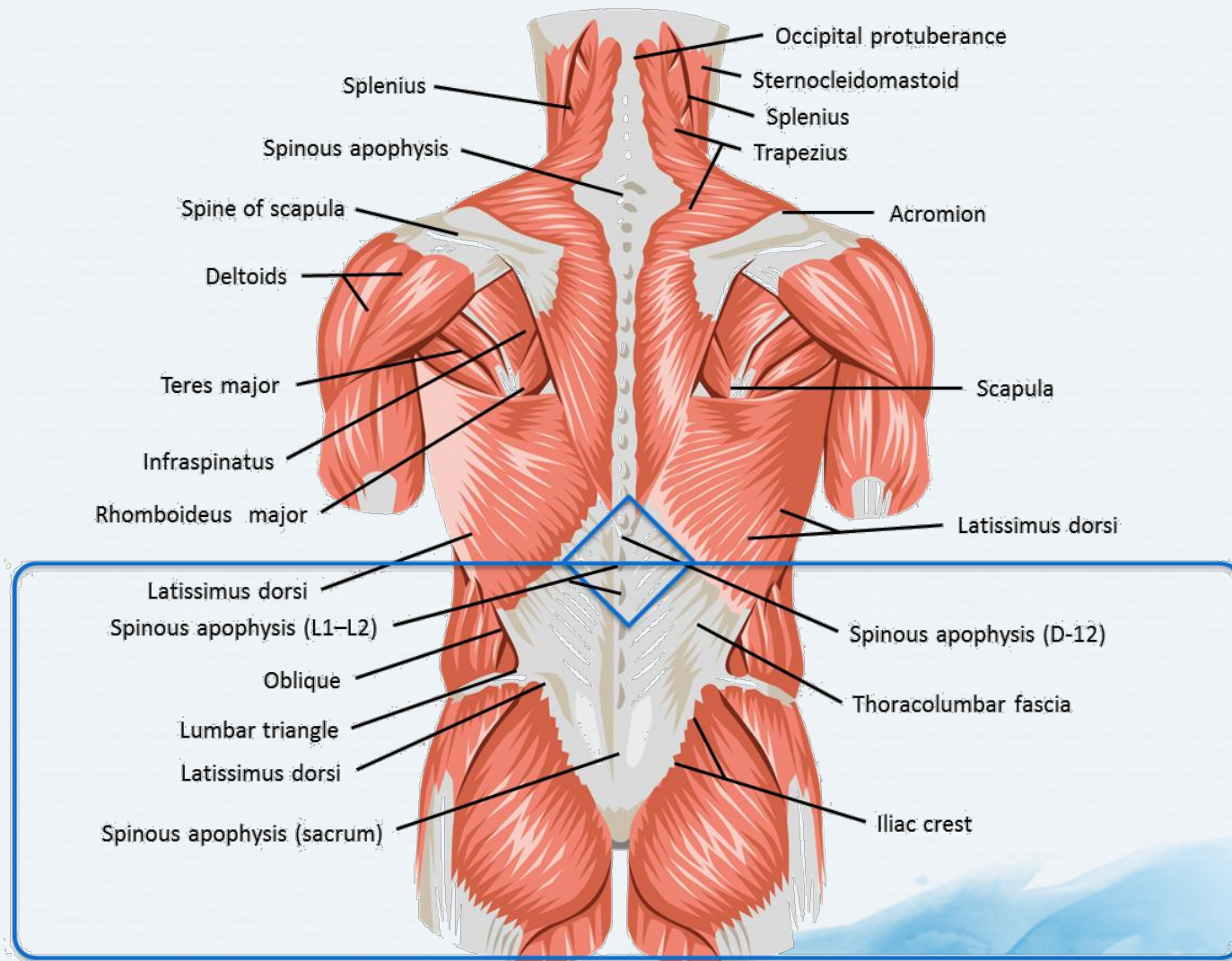
ANATOMY, IMAGING, AND SIMPLIFIED BIOMECHANICS



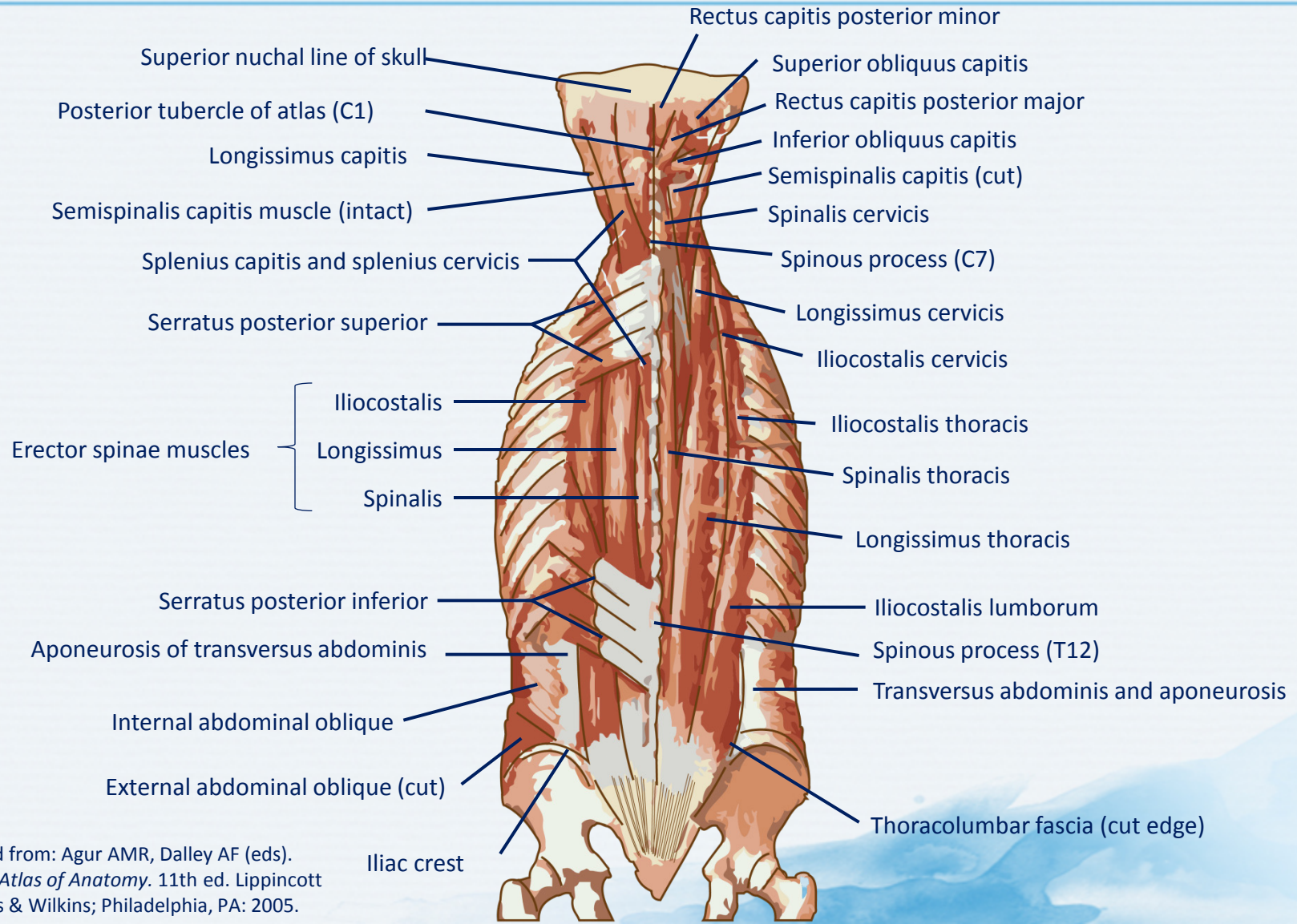
Superficial Anatomy of the Lumbar Spine



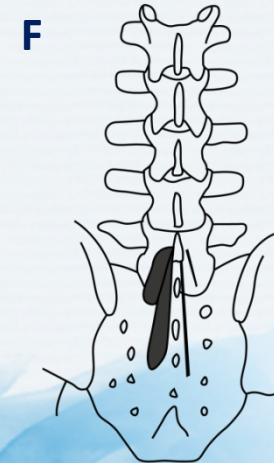
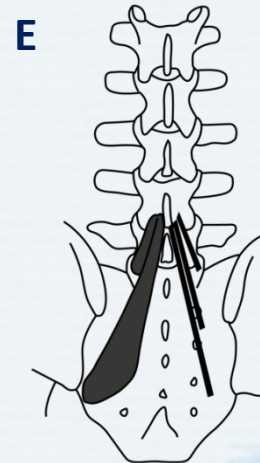
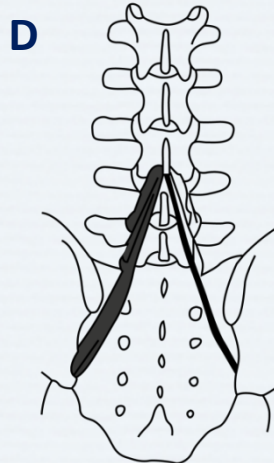
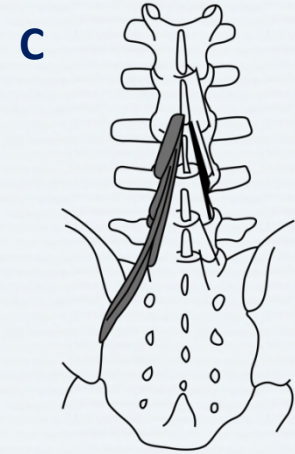
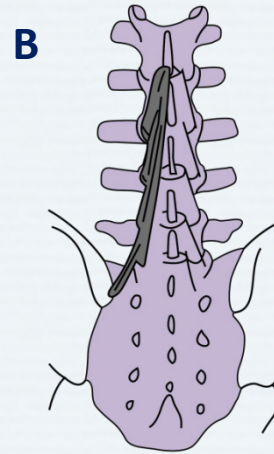
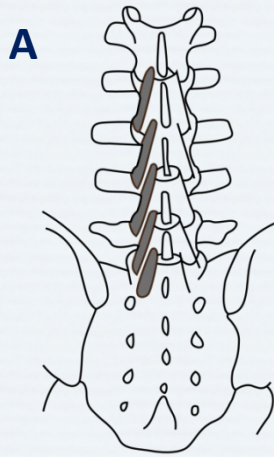
Superficial Muscles of the Back



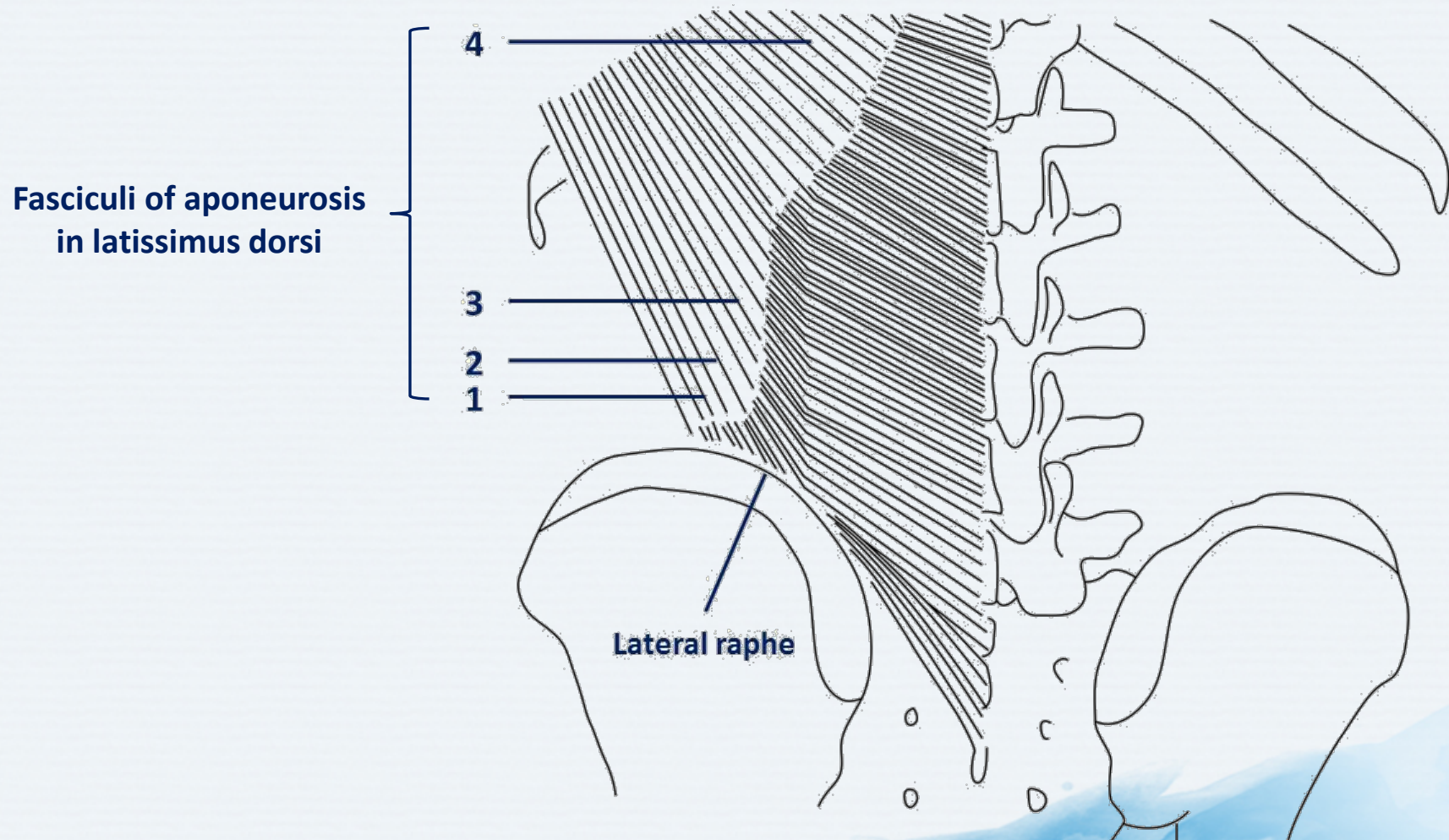
Intermediate Layers of the Muscles of the Back



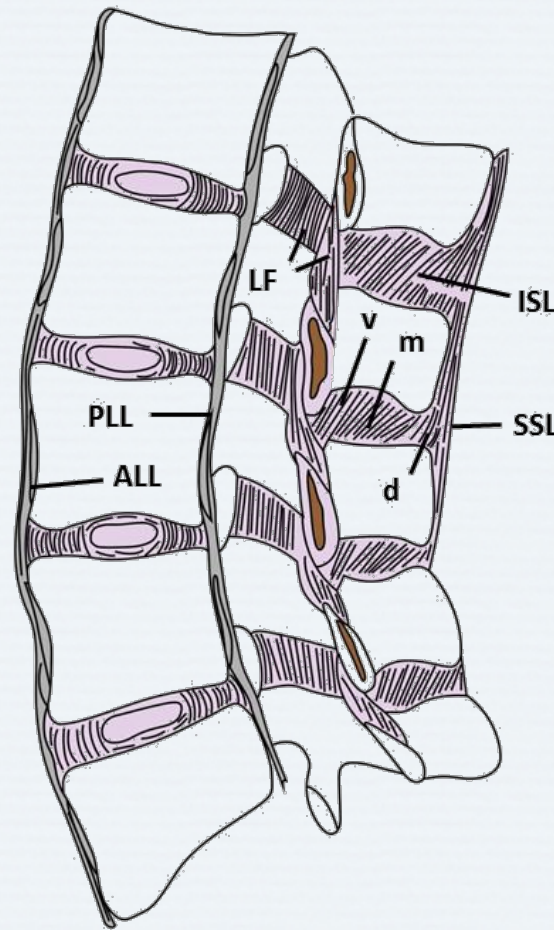
Anatomy of the Lumbar Muscles and their Fascias



Superficial Thoracolumbar Fascia

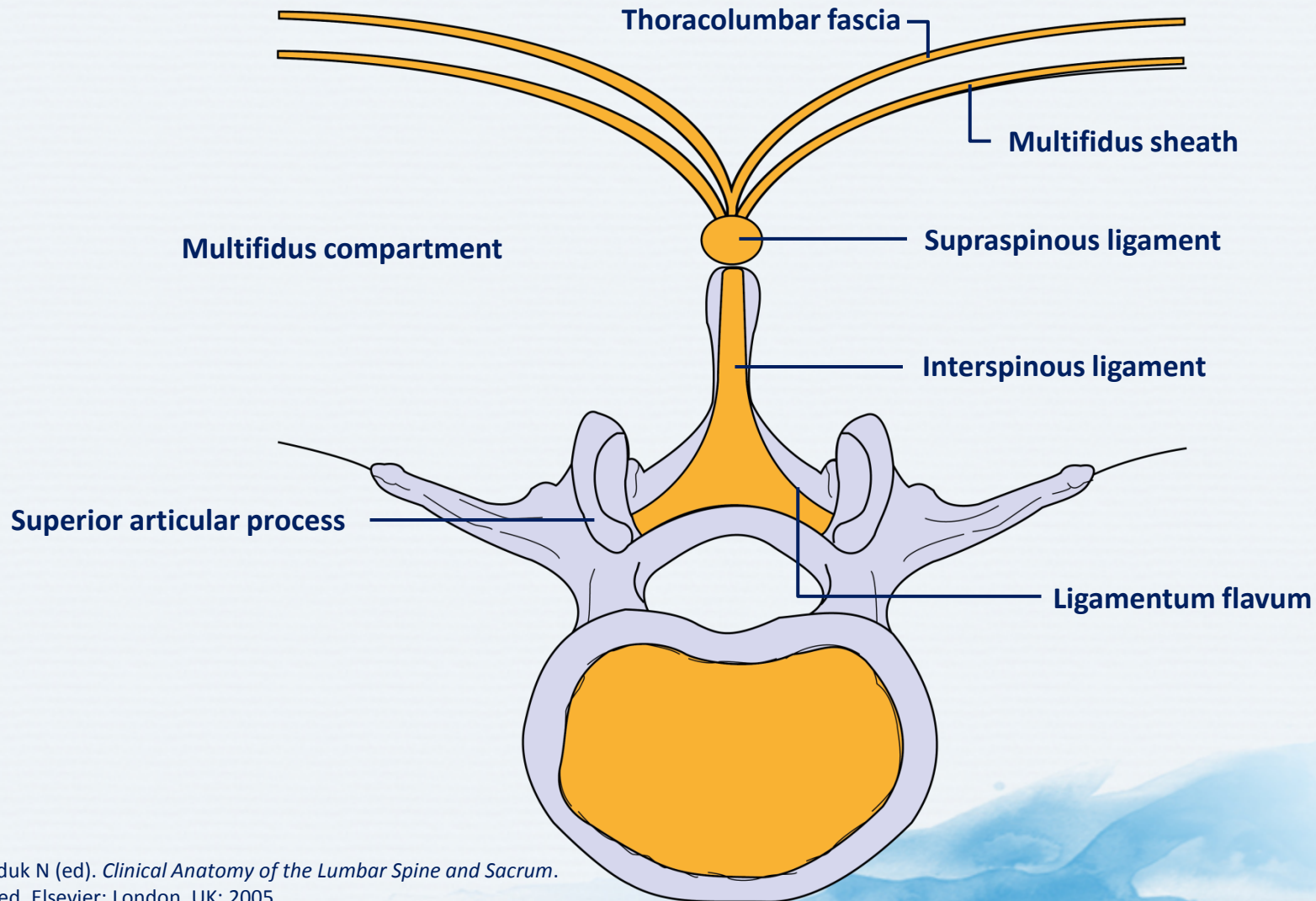


Sagittal View of Ligaments of the Lumbar Spine

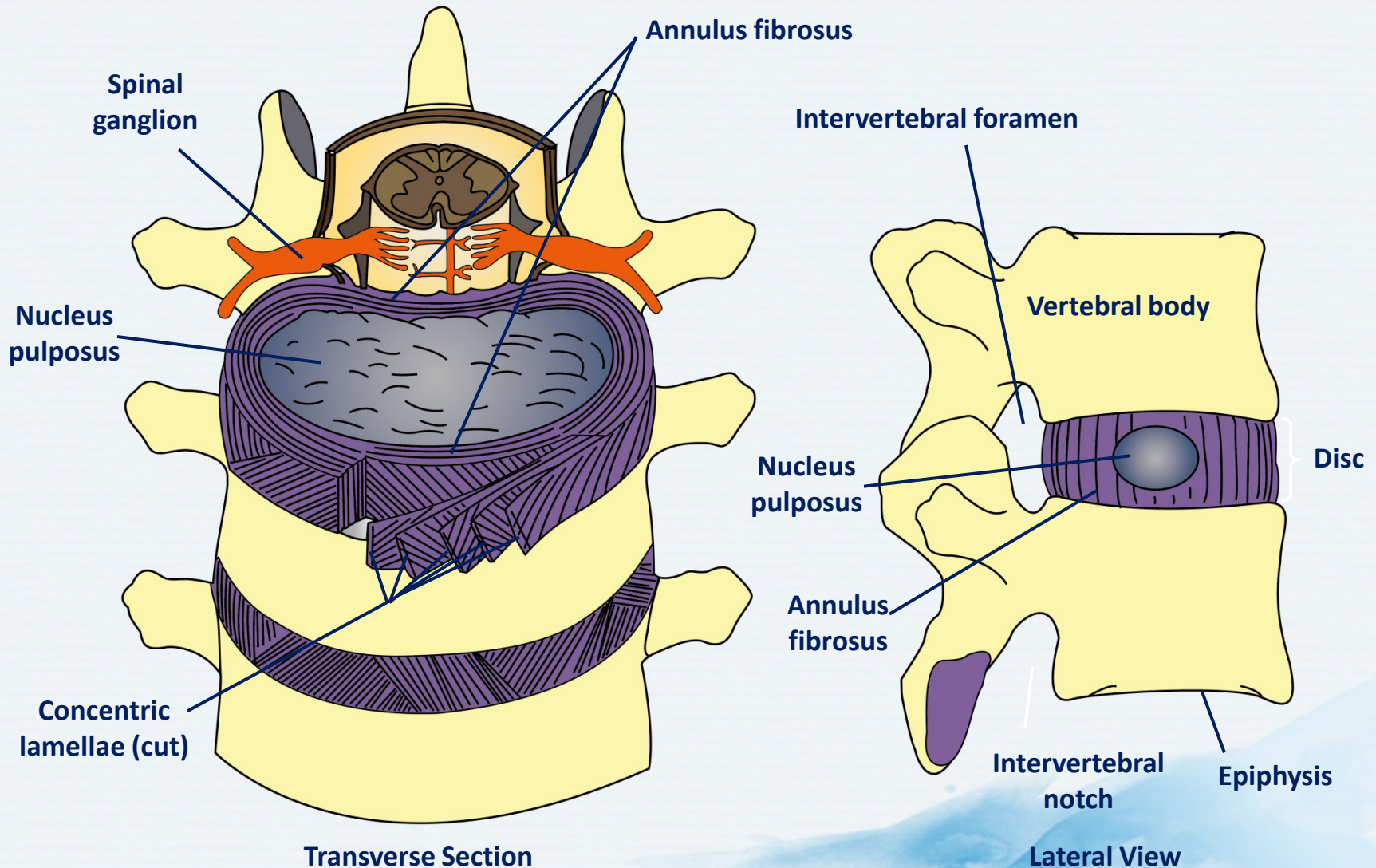


ALL = anterior longitudinal ligament; **ISL** = interspinous ligament; **LF** = ligamenta flava (yellow ligament);
PLL = posterior longitudinal ligament; **SSL** = supraspinous ligament; **v, m, and d** are fasciculi of the ISL
Bogduk N (ed). *Clinical Anatomy of the Lumbar Spine and Sacrum*. 4th ed. Elsevier; London, UK: 2005.

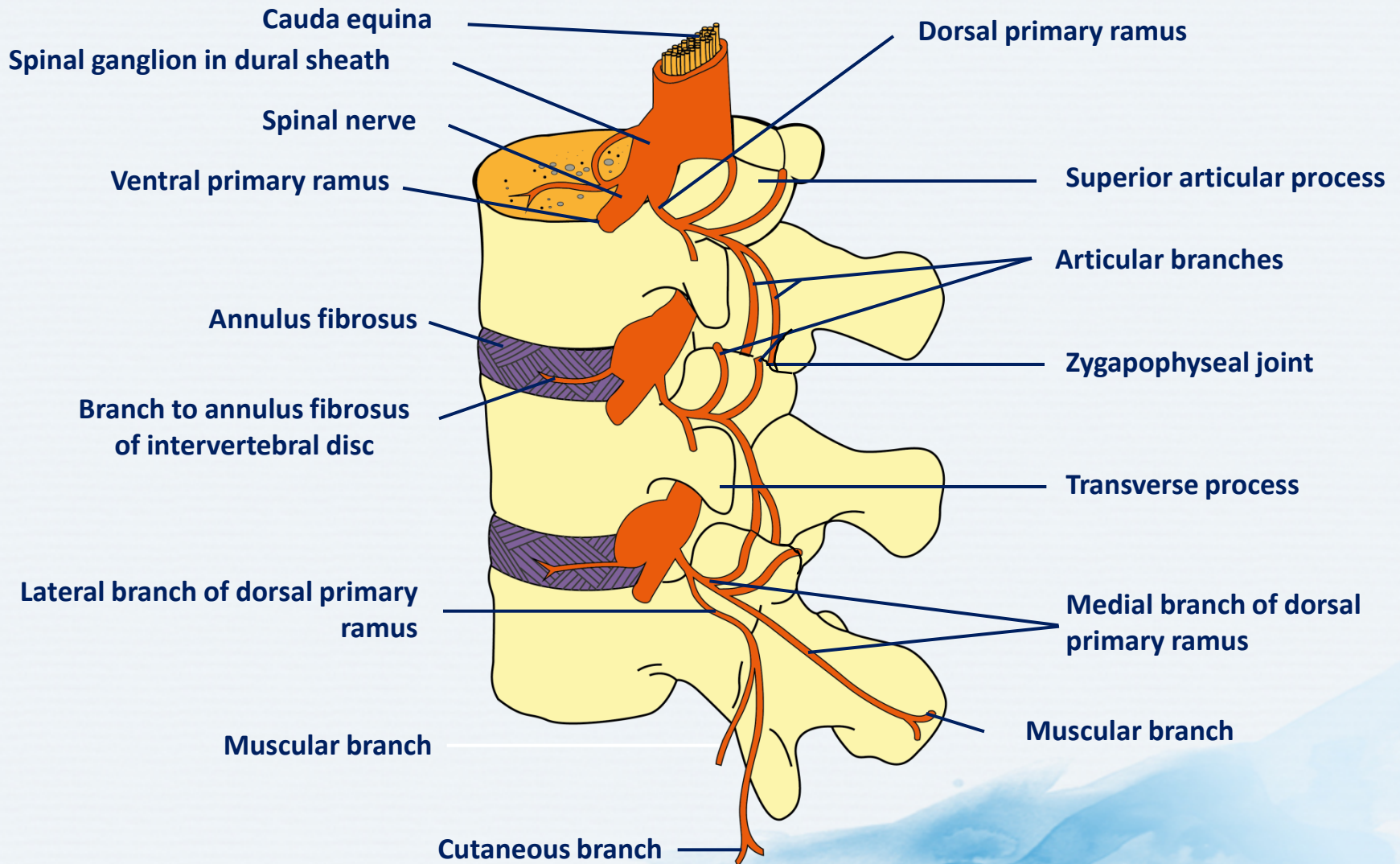
Complex Muscles, Ligaments, and Nerve Structures Associated with Low Back Pain



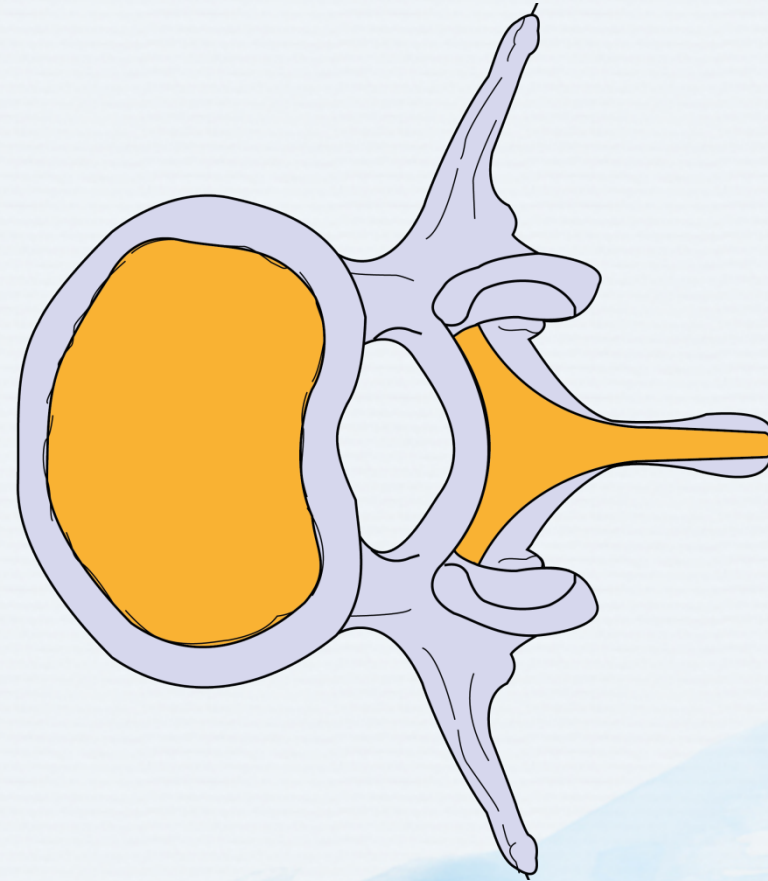
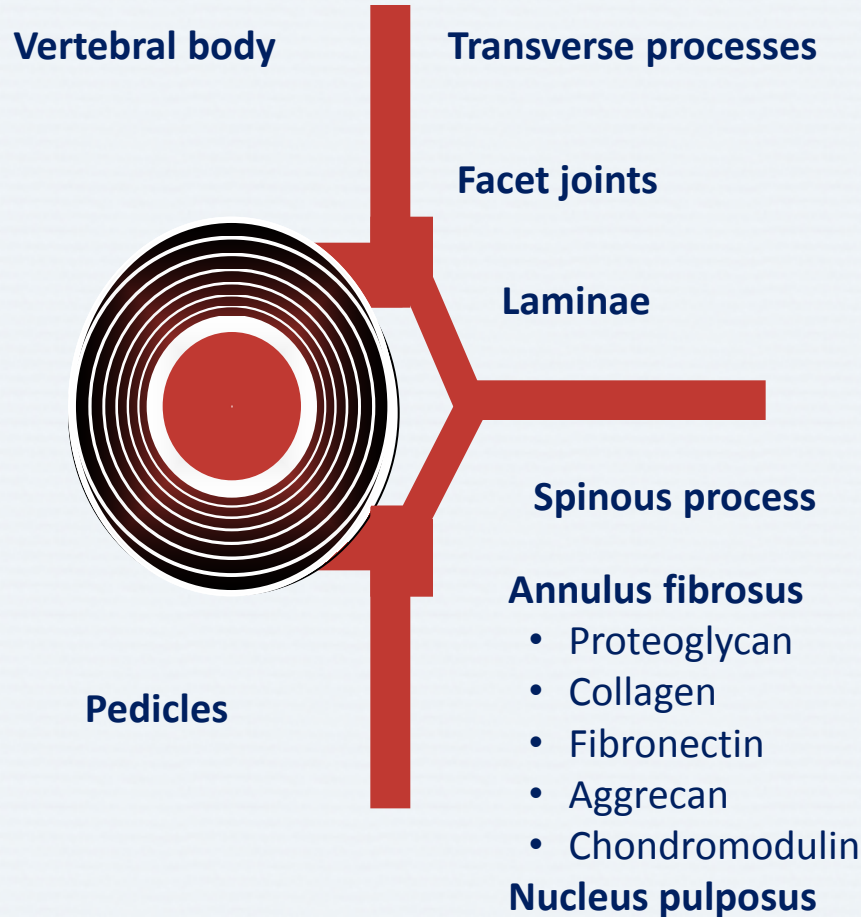
Anatomy of Intervertebral Disc and Ligaments: Transverse Section and Lateral View



Anatomy of Intervertebral Disc and Ligaments: Posterolateral View



Simplified Axial Anatomy of the Spinal Column



Intervertebral Disc Components: Structure and Location

| | Annulus fibrosus | Nucleus pulposus | Vertebral end plates |
|-------------------------------|--|---|---|
| Structure and location | <ul style="list-style-type: none">• Fibers arranged in 10 to 12 layers (lamellae) forming concentric rings encircling nucleus pulposus• Lamellae are thicker anteriorly and laterally and thinner posteriorly• Fibers lie parallel within each lamella but are oriented at 65–70 degrees from vertical, successively in opposite directions between layers | <ul style="list-style-type: none">• Oval-shaped mass in central or posterior-central disc• Enclosed by collagen fibers from inner layers of annulus fibrosus | <ul style="list-style-type: none">• Boundary between cancellous core of vertebral body and intervertebral disc• Vertebral end plates extend centrally from an apophyseal ring and completely enclose nucleus pulposus from above and below |

Intervertebral Disc Components: Composition and Properties

| | Annulus fibrosus | Nucleus pulposus | Vertebral End plates |
|--------------------|--|--|---|
| Composition | <ul style="list-style-type: none"> • 60–70% water • Dry components are 50–60% collagen (mostly type I) and 20% proteoglycans to bind water • Chondrocytes near nucleus and fibroblasts near annular periphery synthesize collagen and proteoglycans | <ul style="list-style-type: none"> • Hydrated, gelatinous, semifluid mass (70–90% water) • Dry components are 65% proteoglycans and 15–20% collagen (mostly type II) • Chondrocytes near vertebral end plates synthesize proteoglycans and collagen | <ul style="list-style-type: none"> • Primarily hyaline cartilage in area closest to vertebral body and fibrocartilage near nucleus pulposis • Also contain proteoglycans, collagen fibers and chondrocytes, with more water and proteoglycans and less collagen centrally |
| Properties | <ul style="list-style-type: none"> • Resists tensile loads • Half the lamellae resist torsional loads in each direction | <ul style="list-style-type: none"> • Deforms under pressure but cannot be compressed. | <ul style="list-style-type: none"> • Strongest and stiffest posterolaterally and weakest centrally |

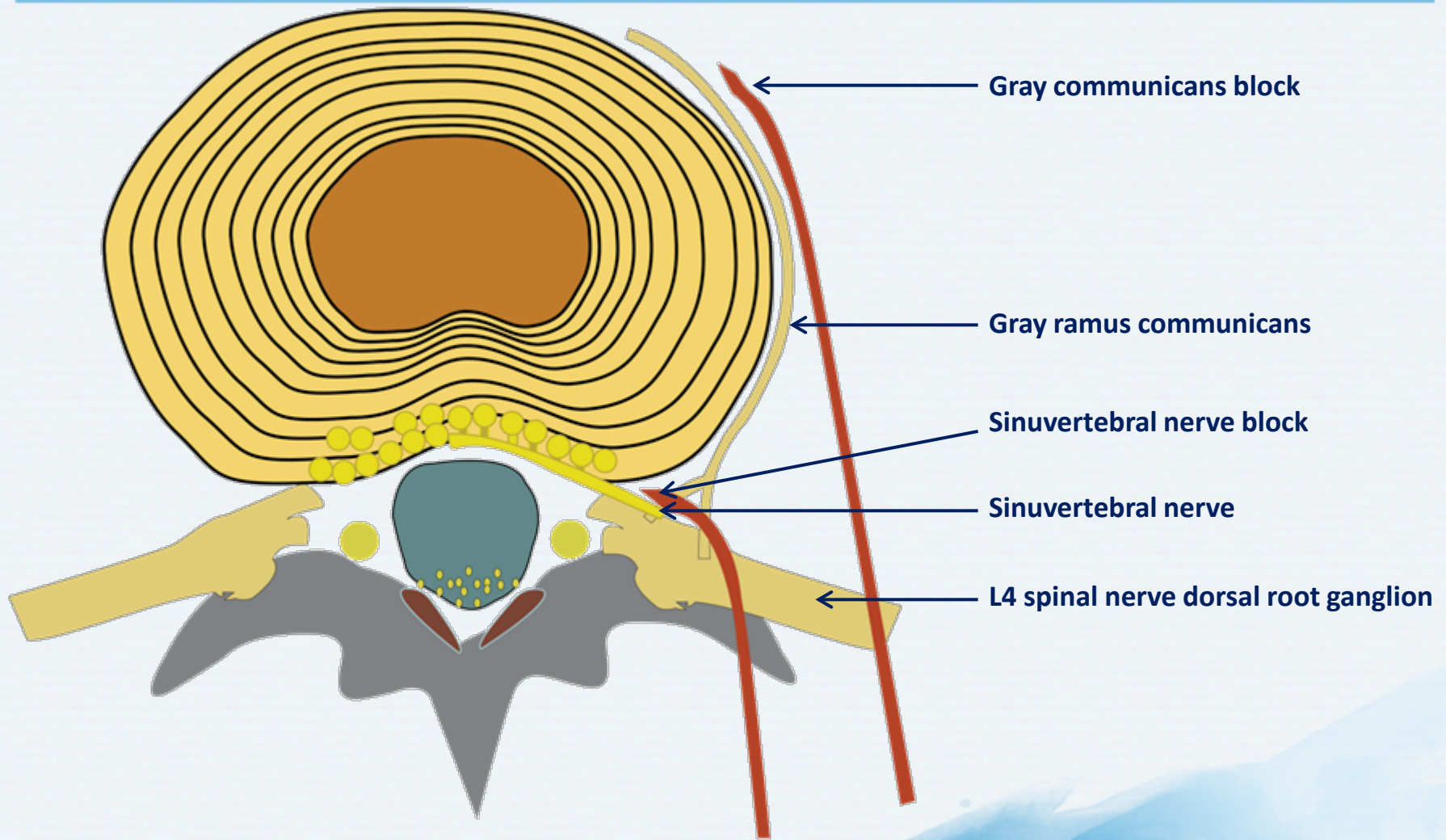
Intervertebral Disc Components: Function

| | Annulus fibrosus | Nucleus pulposus | Vertebral end plates |
|-----------------|---|--|--|
| Function | <ul style="list-style-type: none">• Principal load-bearing component of intervertebral disc | <ul style="list-style-type: none">• Reallocates applied loads in all directions to annulus fibrosus and vertebral end plates | <ul style="list-style-type: none">• Anchor intervertebral disc to vertebral bodies• Prevent extrusion of nucleus pulposus into vertebral body• Distribute and transfer load to vertebral body• Site for diffusion of nutrients to intervertebral disc |

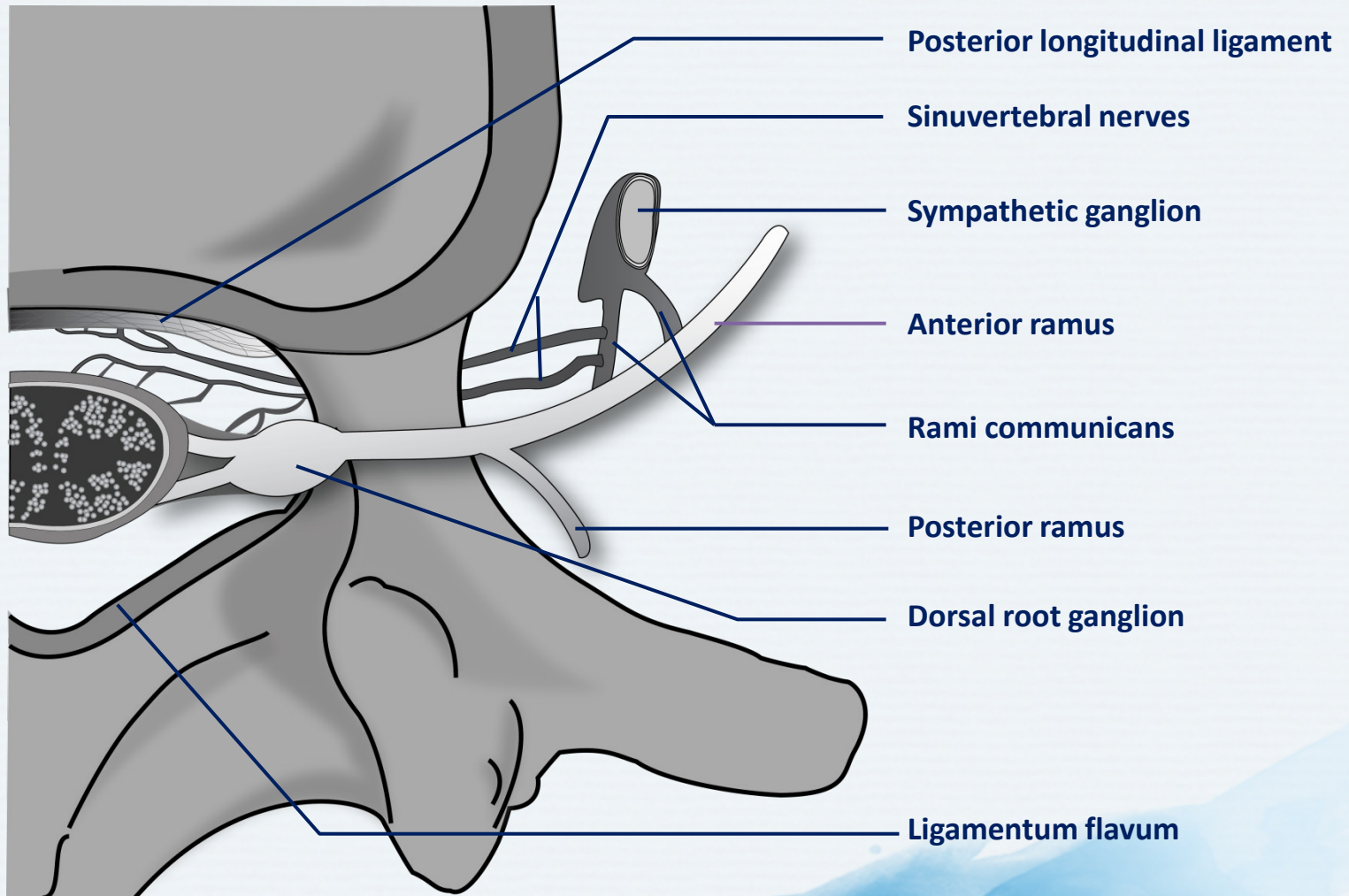
Intervertebral Disc Components: Degenerative Changes

| | Annulus fibrosus | Nucleus pulposus | Vertebral end plates |
|-----------------------------|---|---|---|
| Degenerative changes | <ul style="list-style-type: none">• Border between nucleus pulposus and annulus fibrosus becomes difficult to differentiate• 3 types of tears occur:<ol style="list-style-type: none">1) Peripheral: isolated to outer layers, parallel and adjacent to vertebral end plates2) Circumferential: rupture between lamellae3) Radial: continuous with clefts that radiate from nucleus pulposus | <ul style="list-style-type: none">• As water and proteoglycan levels decrease, nucleus pulposus becomes dryer, more fibrotic and less distinct from annulus fibrosus• Disc becomes weaker as nucleus pulposus becomes less able to distribute loads• Horizontal clefts develop between vertebral end plates and disc center | <ul style="list-style-type: none">• Thinning, fissures, horizontal cleft formation and fractures increase with age• Ossification and local calcification reduce disc nutrition |

Intervertebral Disc Innervation

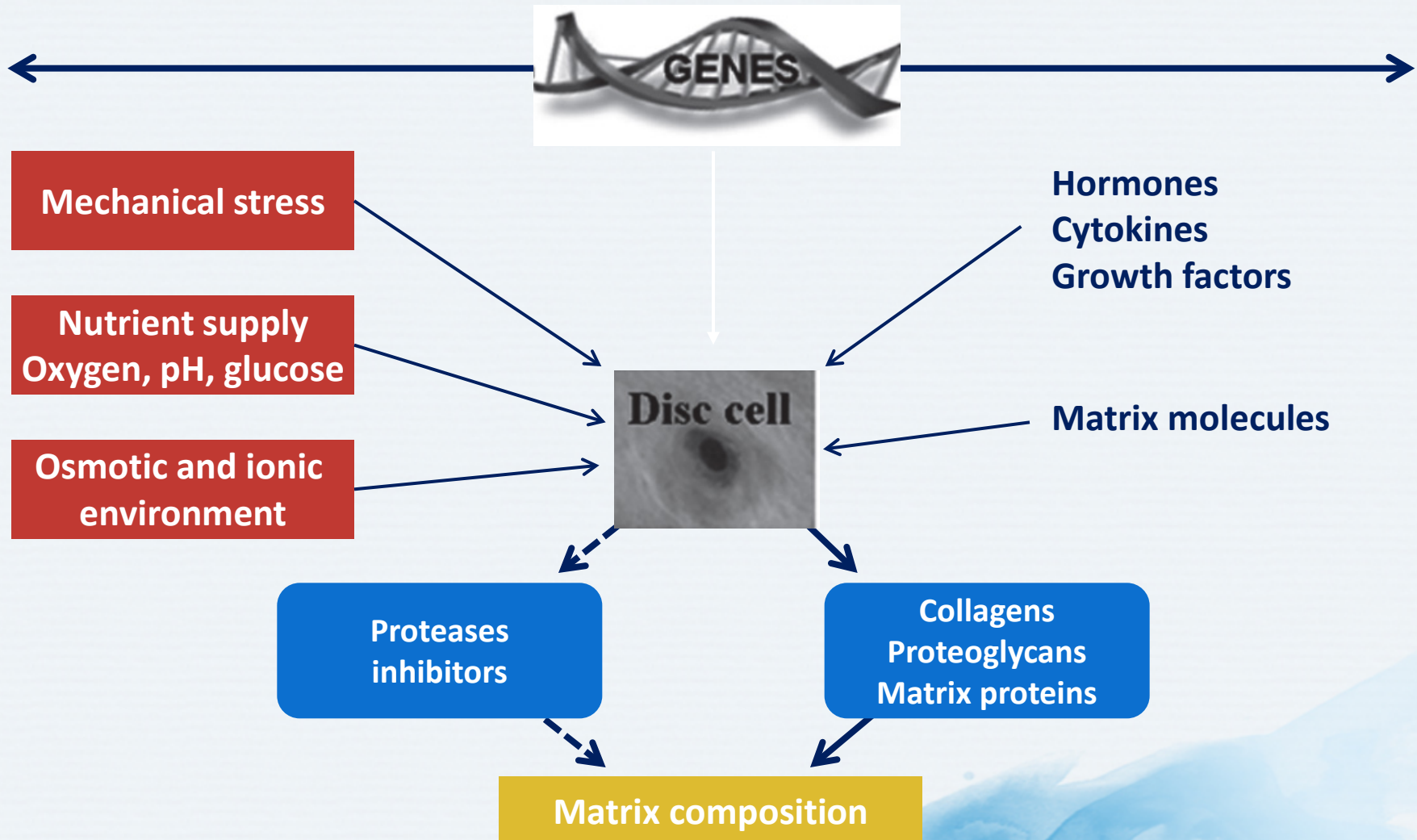


Sinuvevertebral Nerves

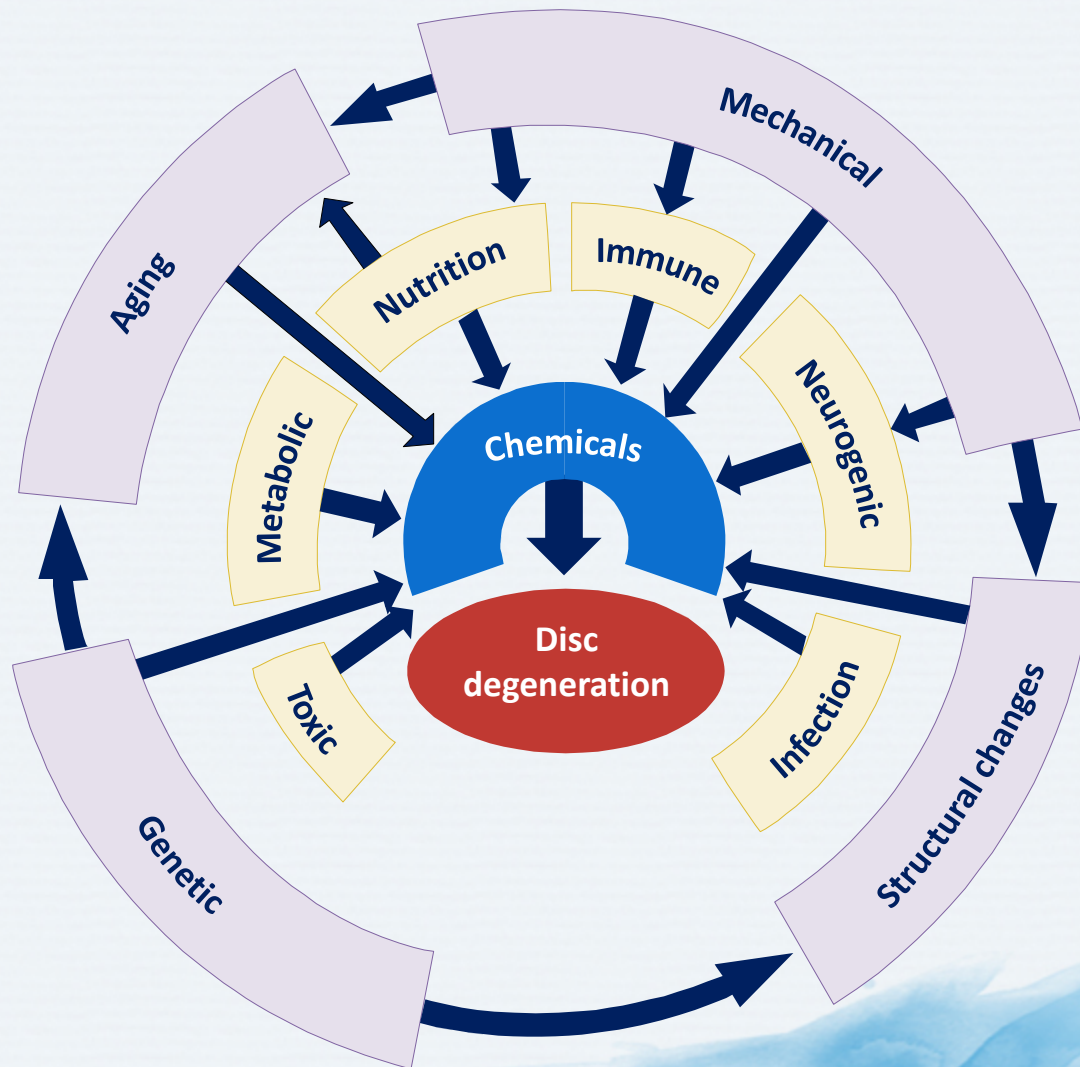


Cellular Activity of the Disc

Influence of Environmental Factors as Potent Modifiers



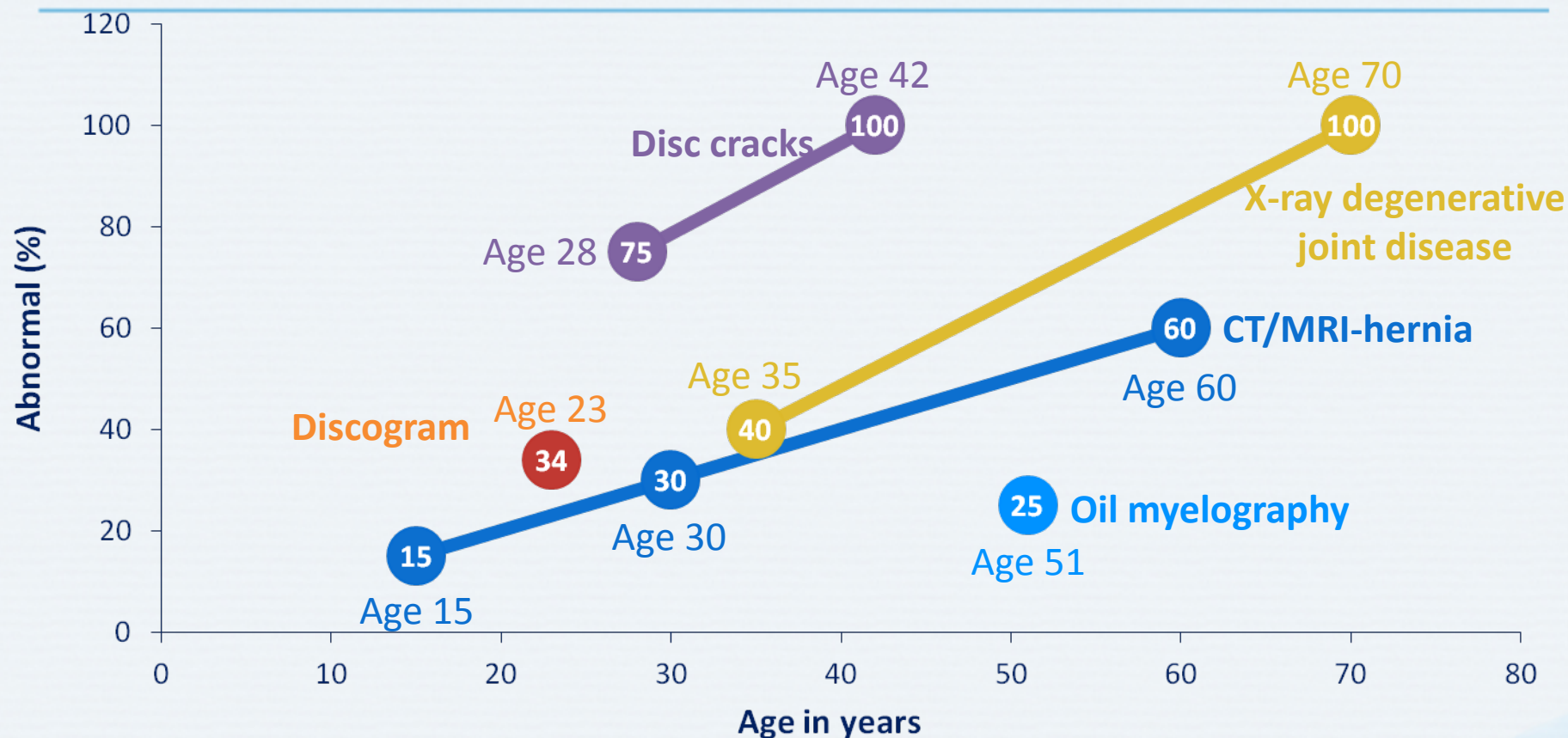
Multifactorial Pathophysiology of Disc Degeneration Model: Initiators, Promoters or Both



NORMAL IMAGING OF THE LUMBAR SPINE

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Disc Findings in Normal Subjects



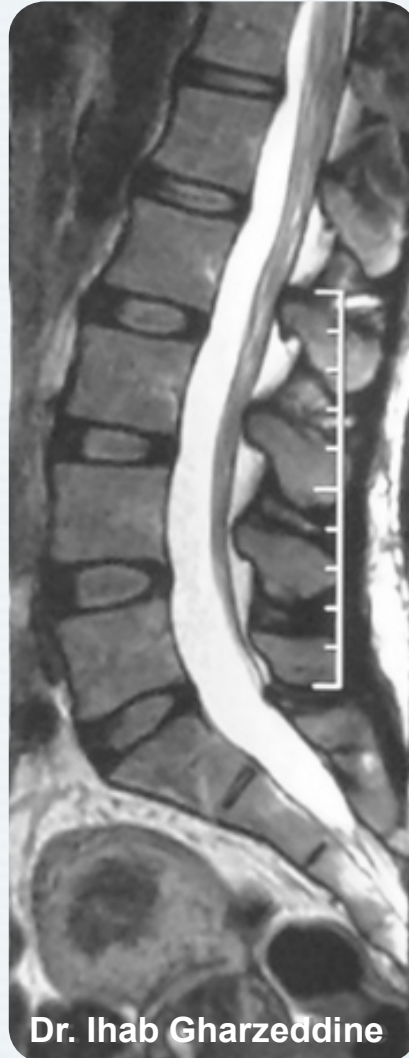
Find the patient's *age in years line* to determine the chance of a finding being present before symptoms begin.

Plain-Film Radiology of a Normal Spinal Column with Physiological Lordosis



Magnetic Resonance Imaging of Sagittal Slices in T1 and T2

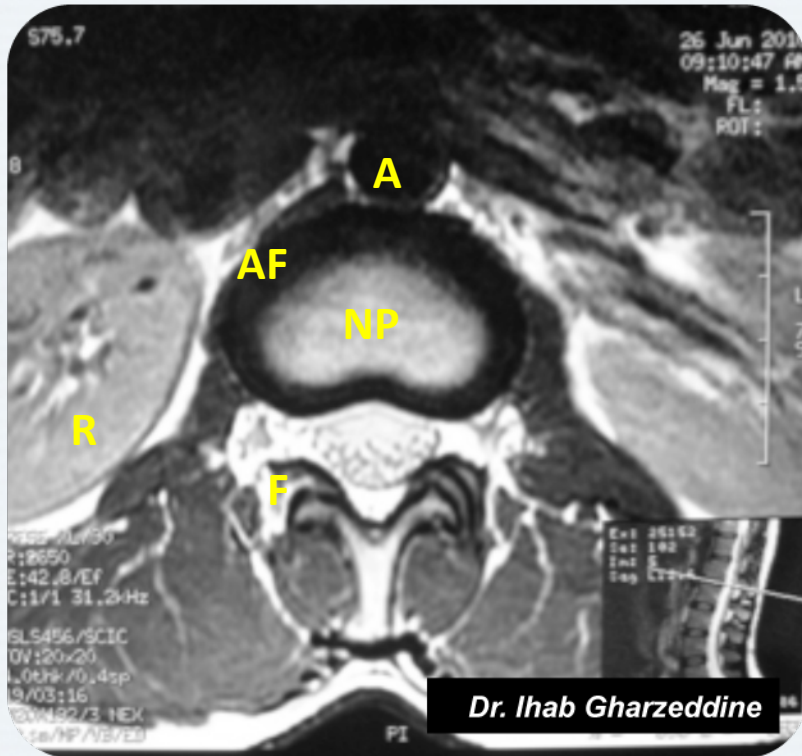
T2



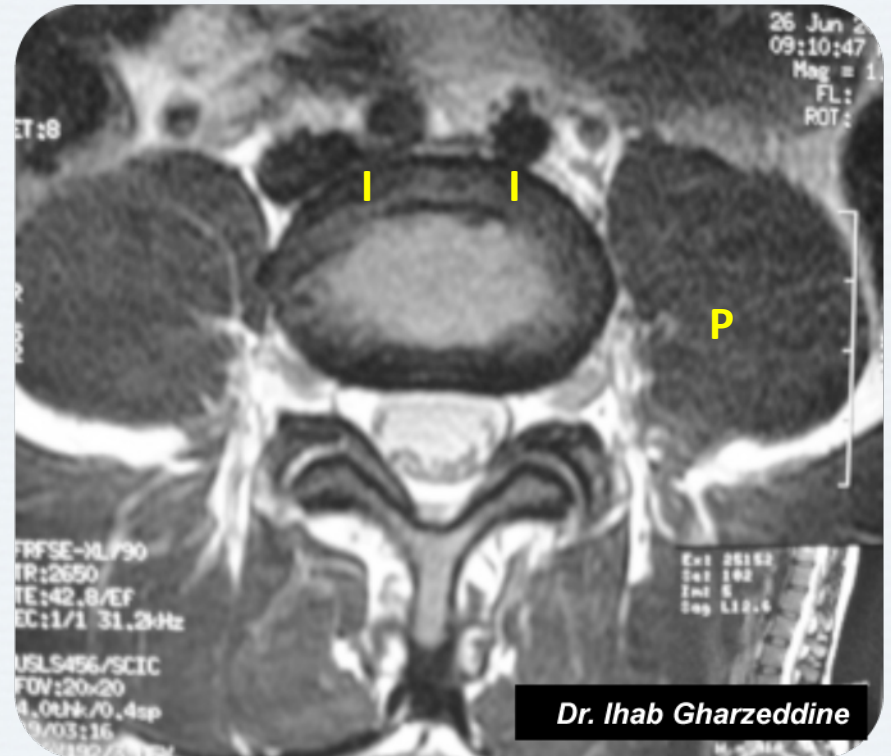
T1 and T2 refer to repetition period during imaging.

Images courtesy of Dr. Ihab Gharzeddine
FONAR. *MRI Glossary*. Available at:
<http://fonar.com/glossary.htm>.
Accessed: October 15, 2013.

Axial Slices



A

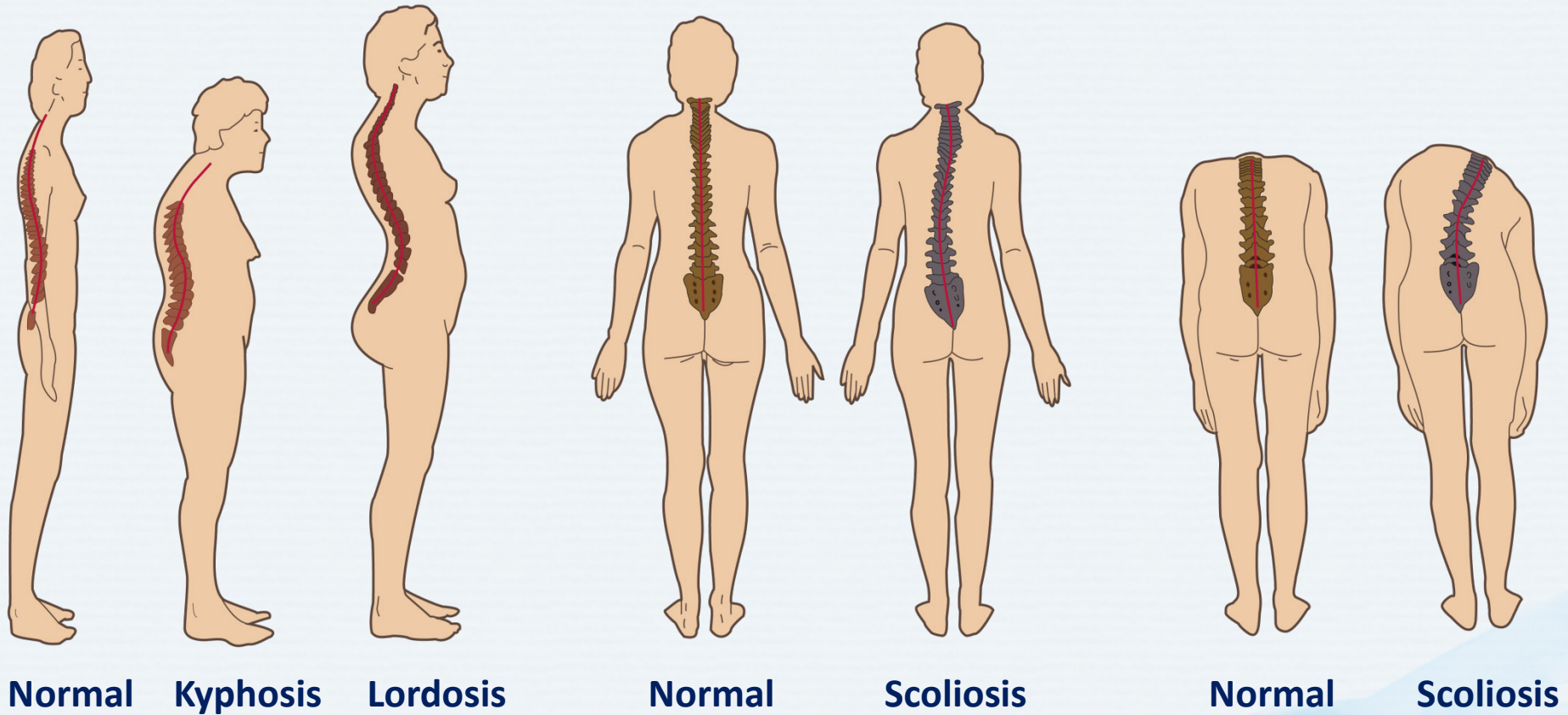


B

A = aorta; AF = annulus fibrosus; F = joint facet; I = bifurcation of the iliac artery; NP = nucleus pulposus; R = right kidney

Images courtesy of Dr. Ihab Gharzeddine

Normal and Pathological Variants of the Vertebral Axis



Simplified Spinal Anatomy in Sagittal View

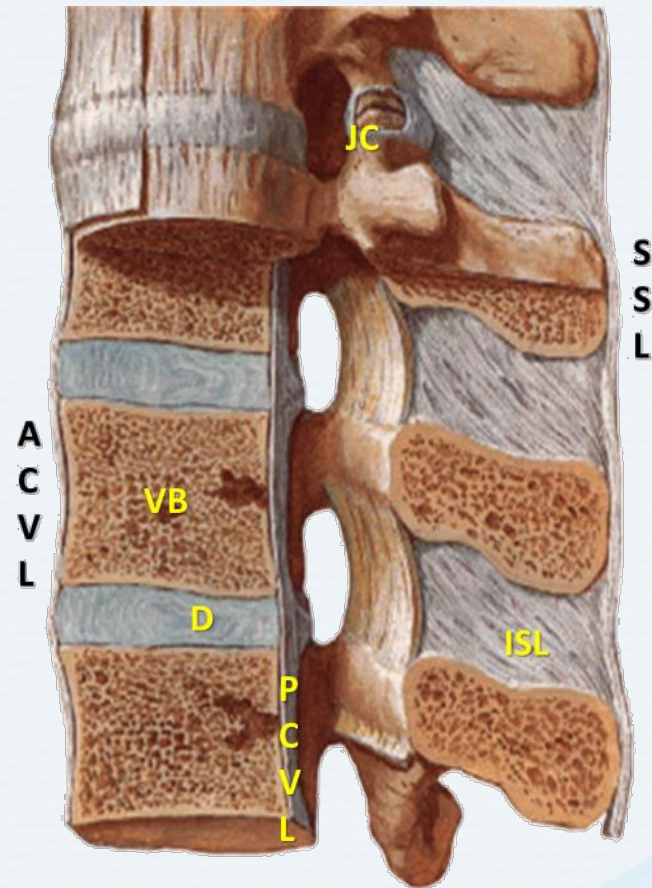
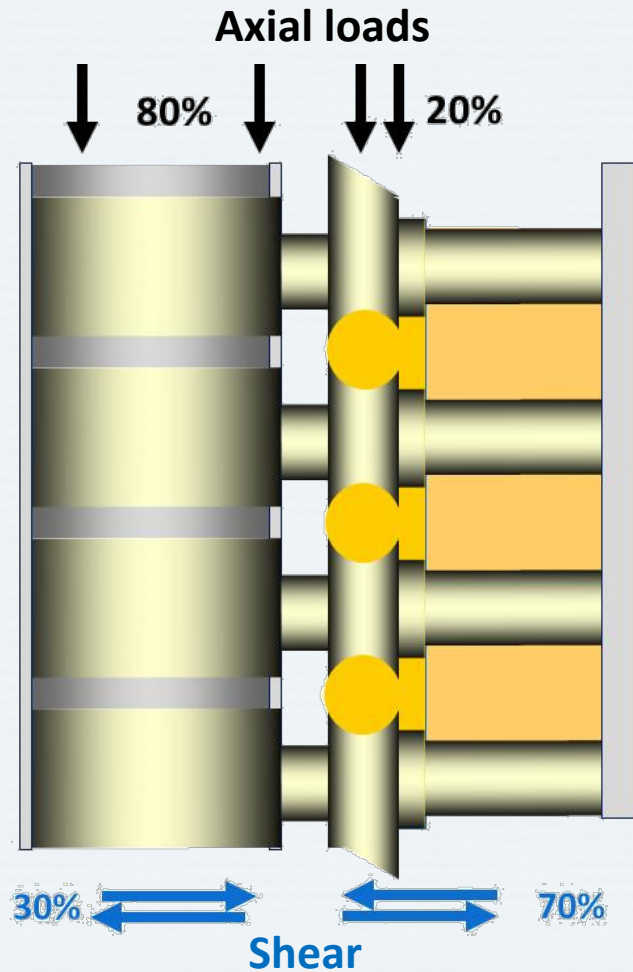
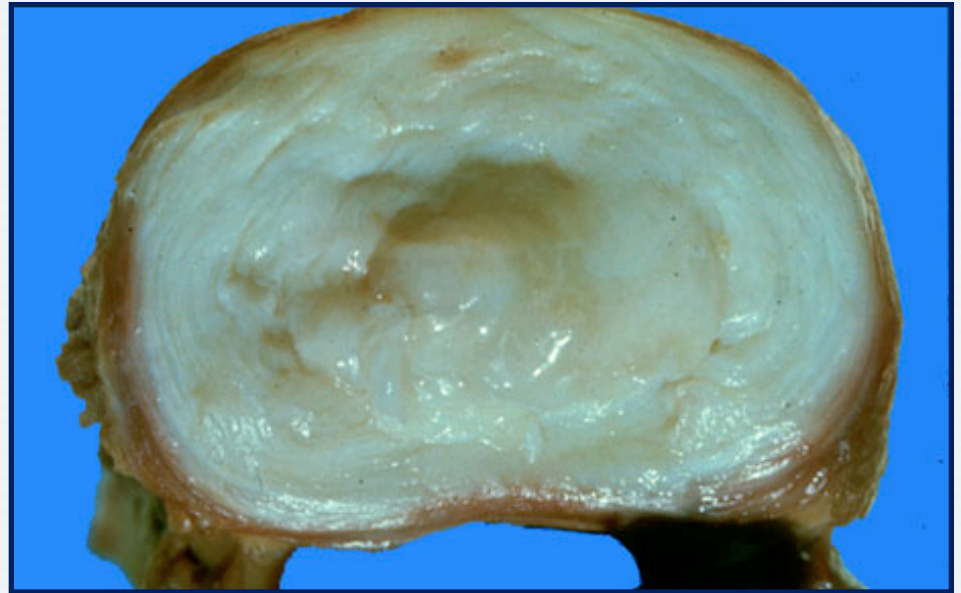


Image courtesy of Dr. Ihab Gharzeddine

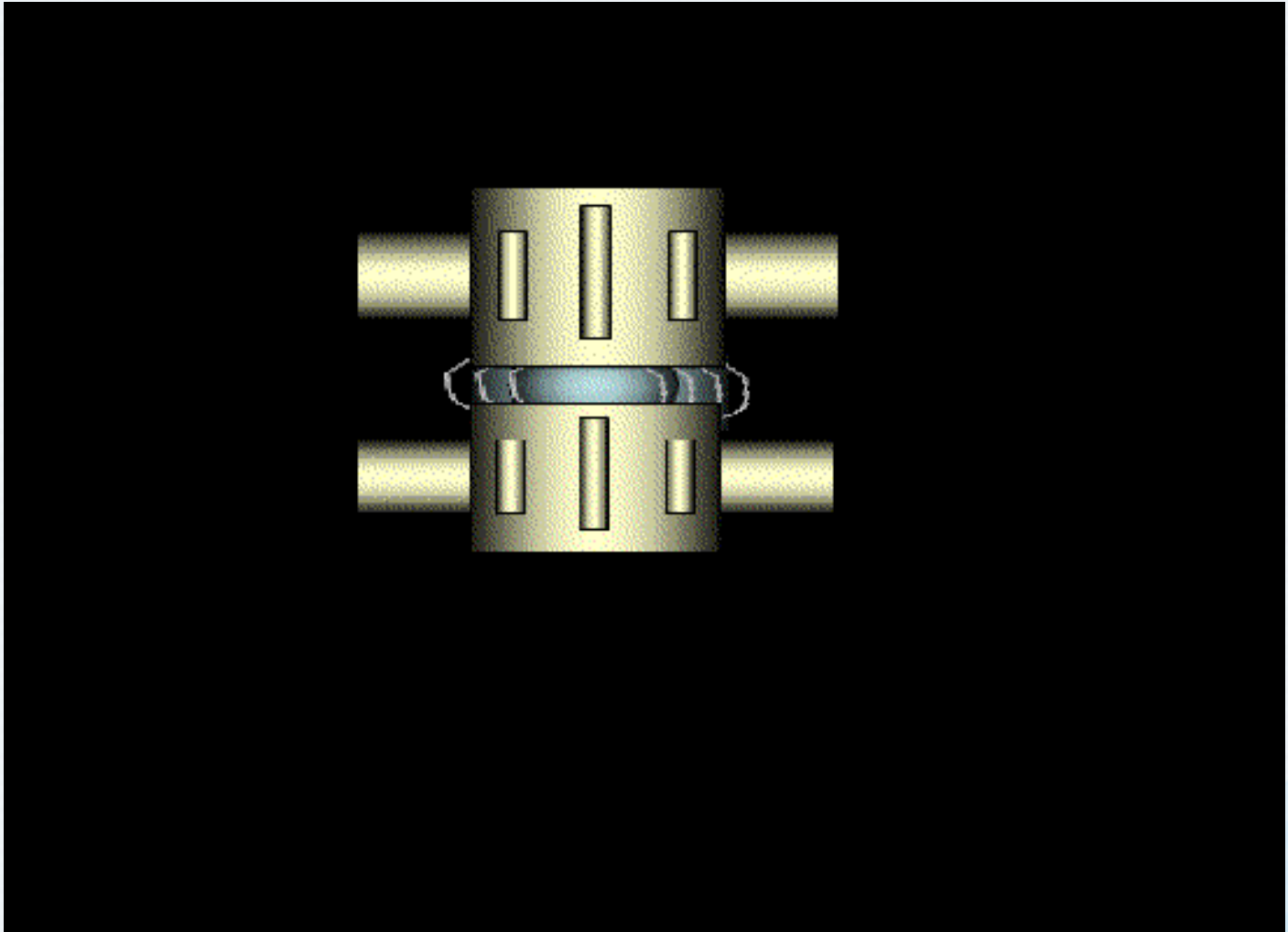
ACVL = anterior common vertebral ligament; D = intervertebral discs; ISL = interosseous sacroiliac ligament; JC = joint capsule; LF = yellow ligament; LIE = interspinous ligaments; LCVP = posterior common vertebral ligament; SSL = supraspinous ligaments; VB = vertebral bodies

Images courtesy of Dr. Ihab Gharzeddine

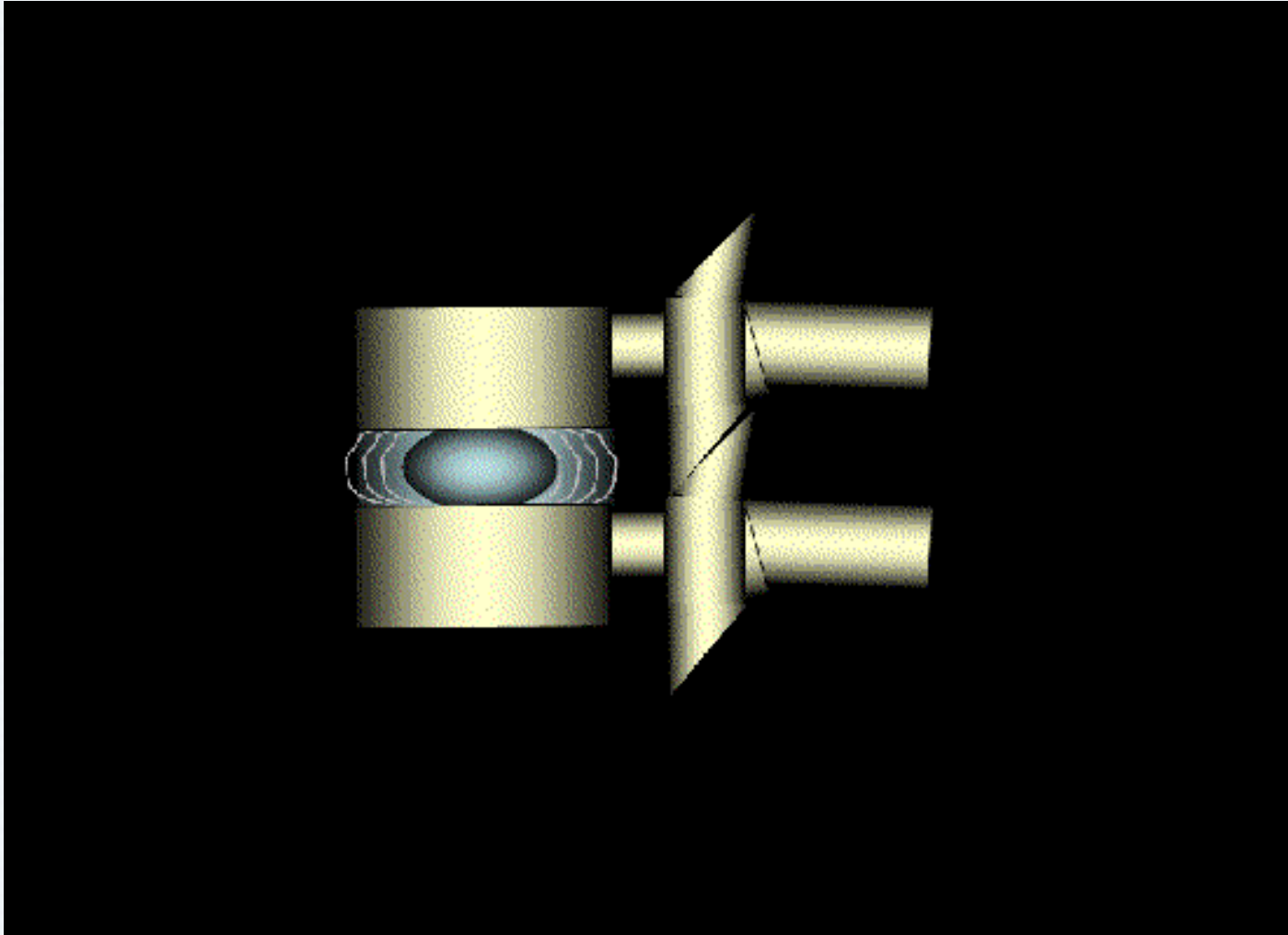
Pathological Anatomy of the Spine



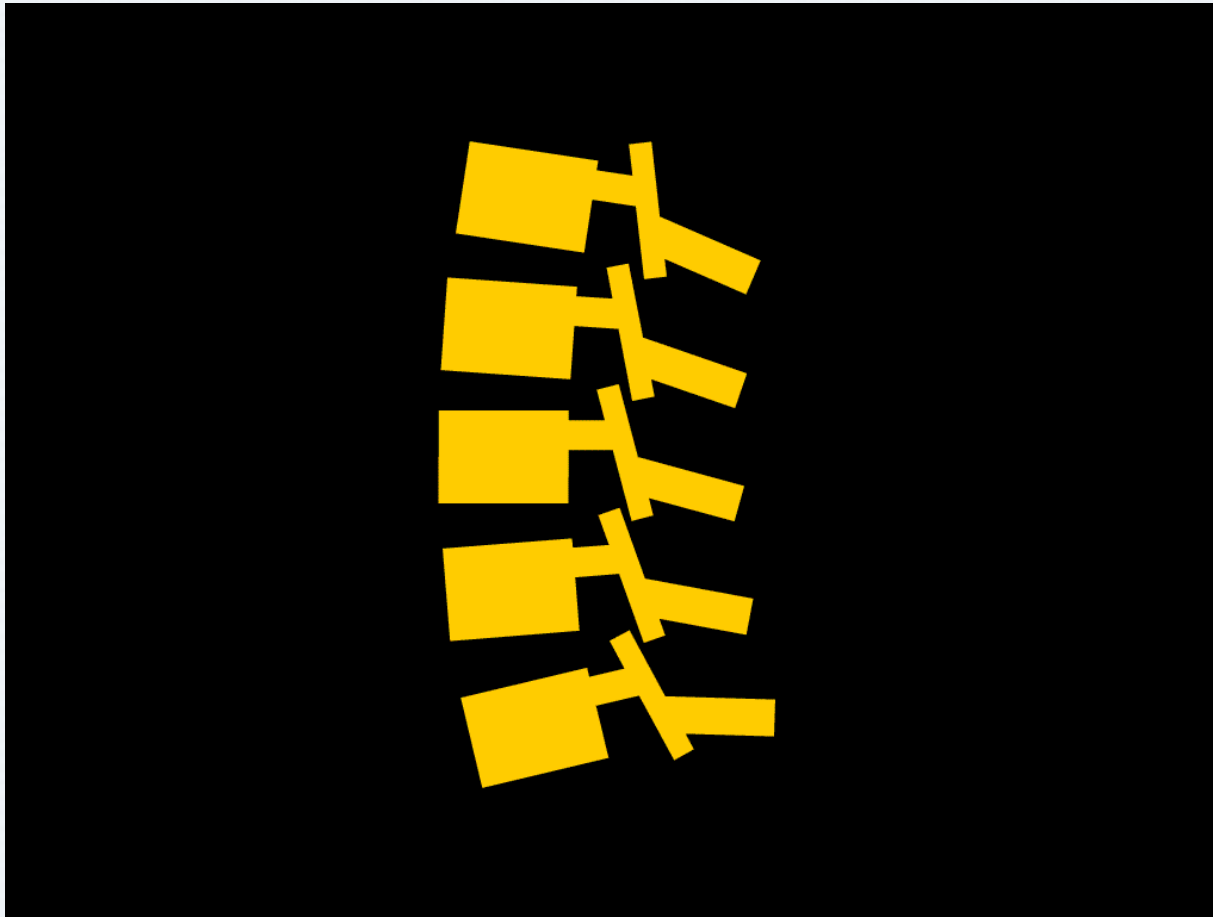
Vertebral Unit under Pressure or Compression



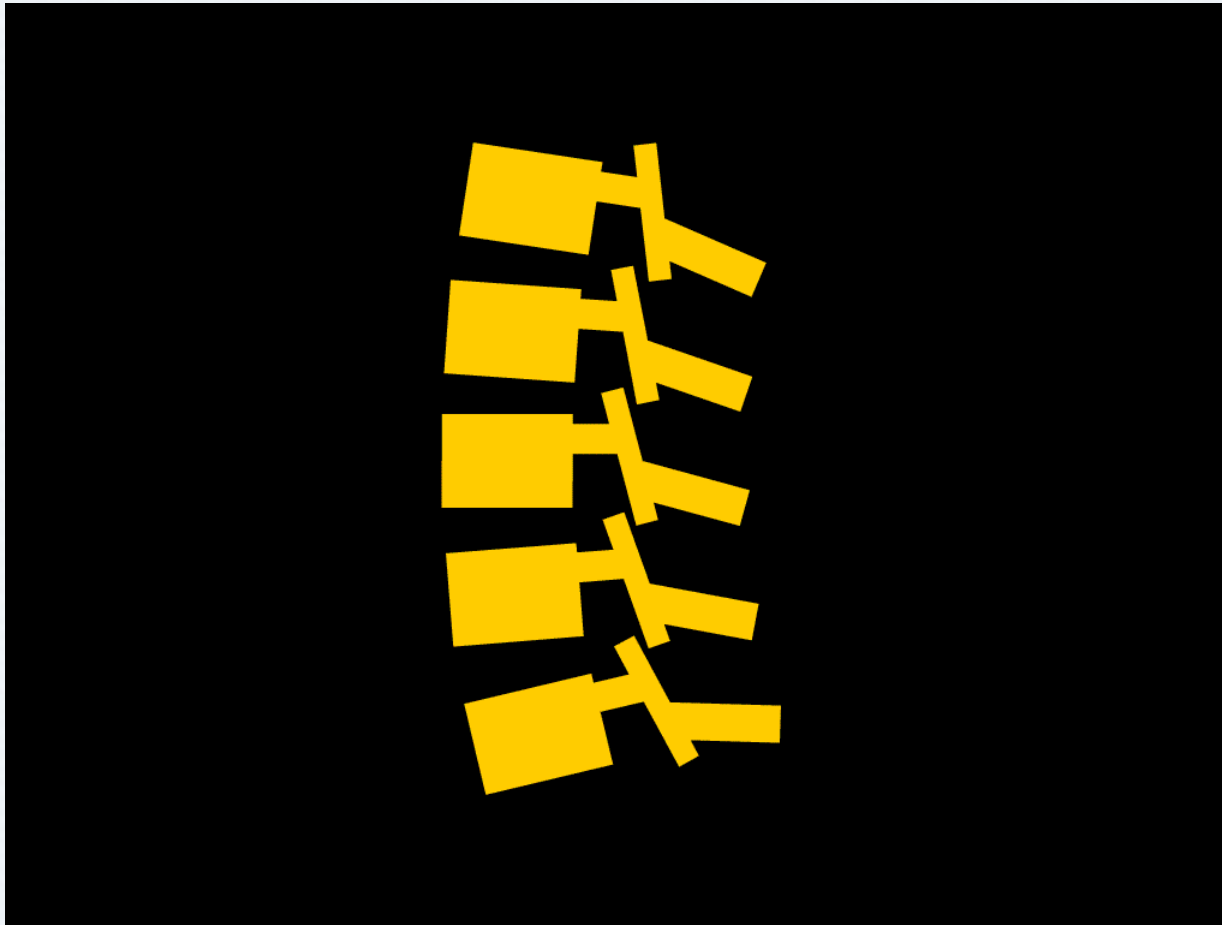
Vertebral Unit during Flexion and Extension



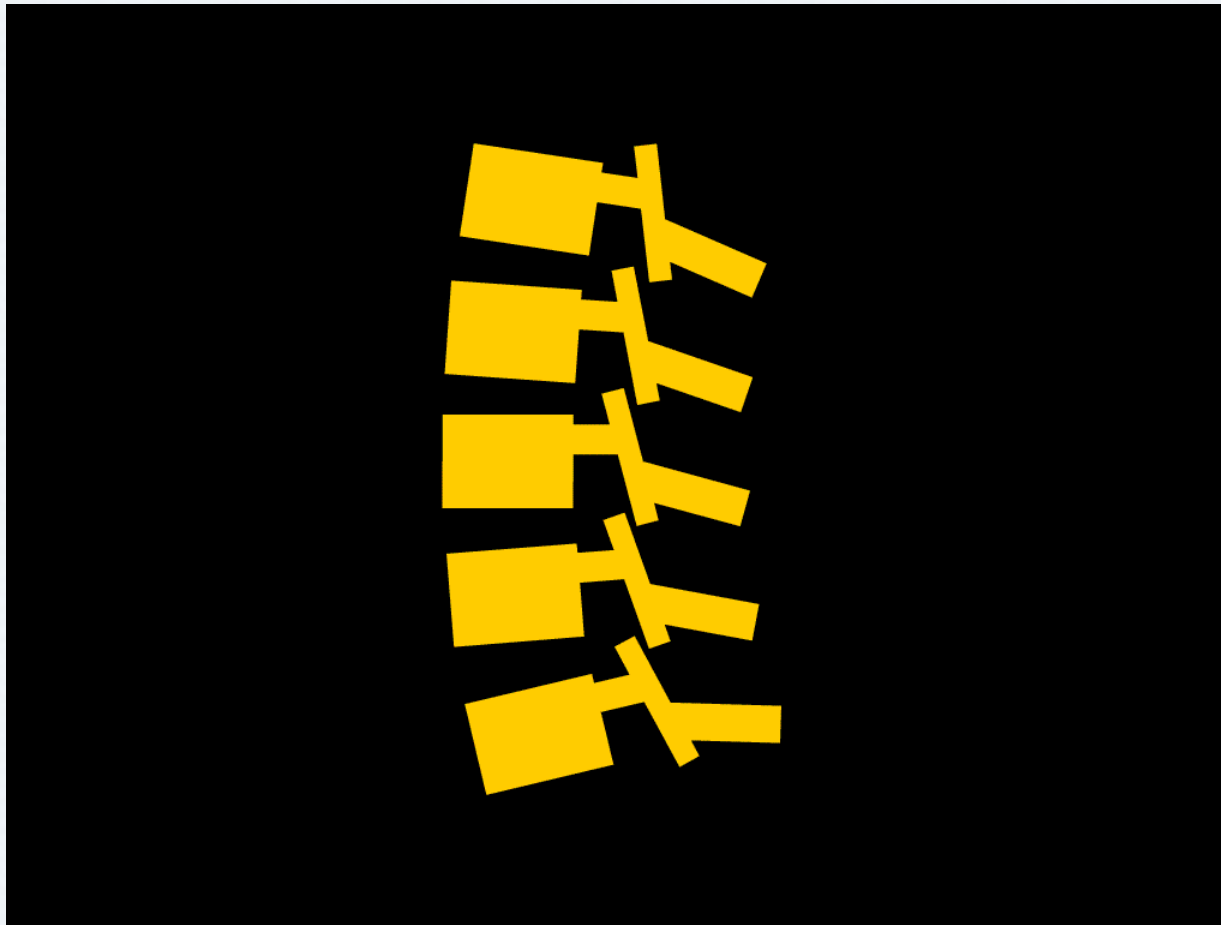
Combined Rotation and Translation in Normal Flexion-Extension in the Lumbar Spine



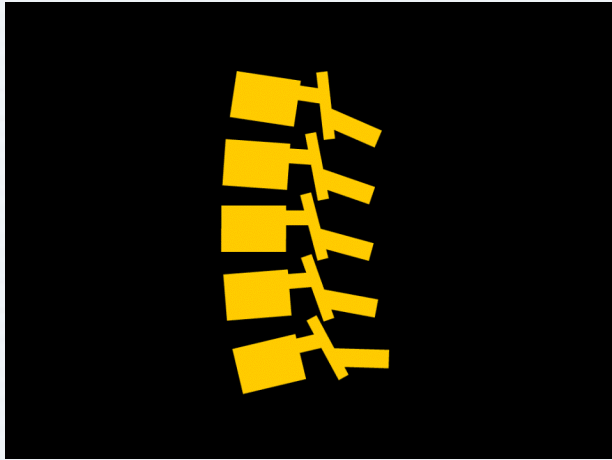
Theoretical Isolation of Rotational Movement during Flexion-Extension in the Lumbar Spine



Theoretical Isolation of Translational Movement during Flexion-Extension in the Lumbar Spine

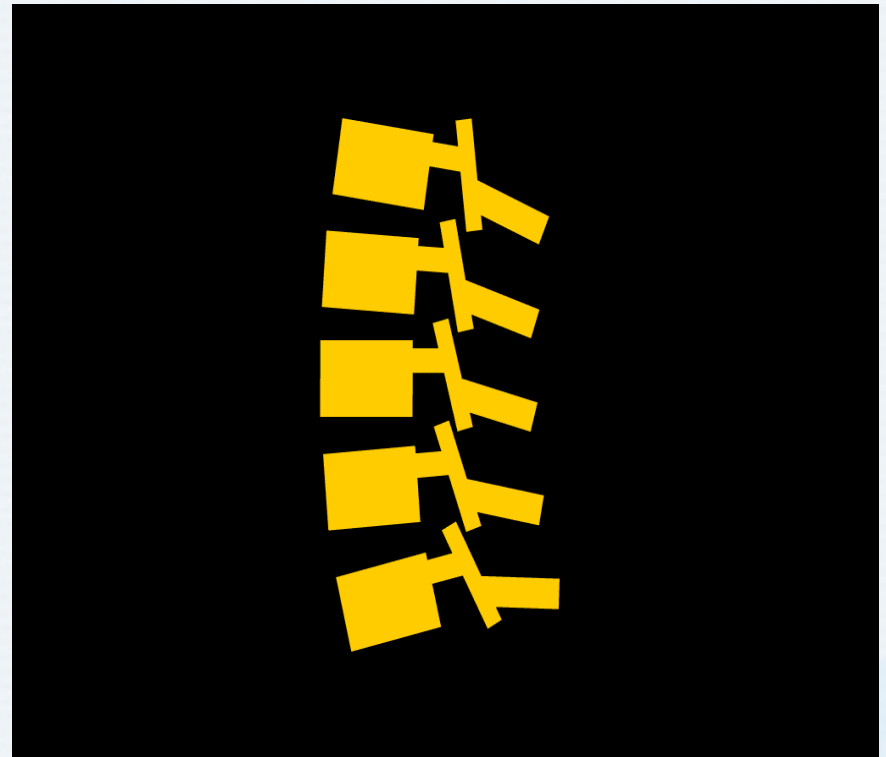


Flexion-Extension of the Spinal Column



+

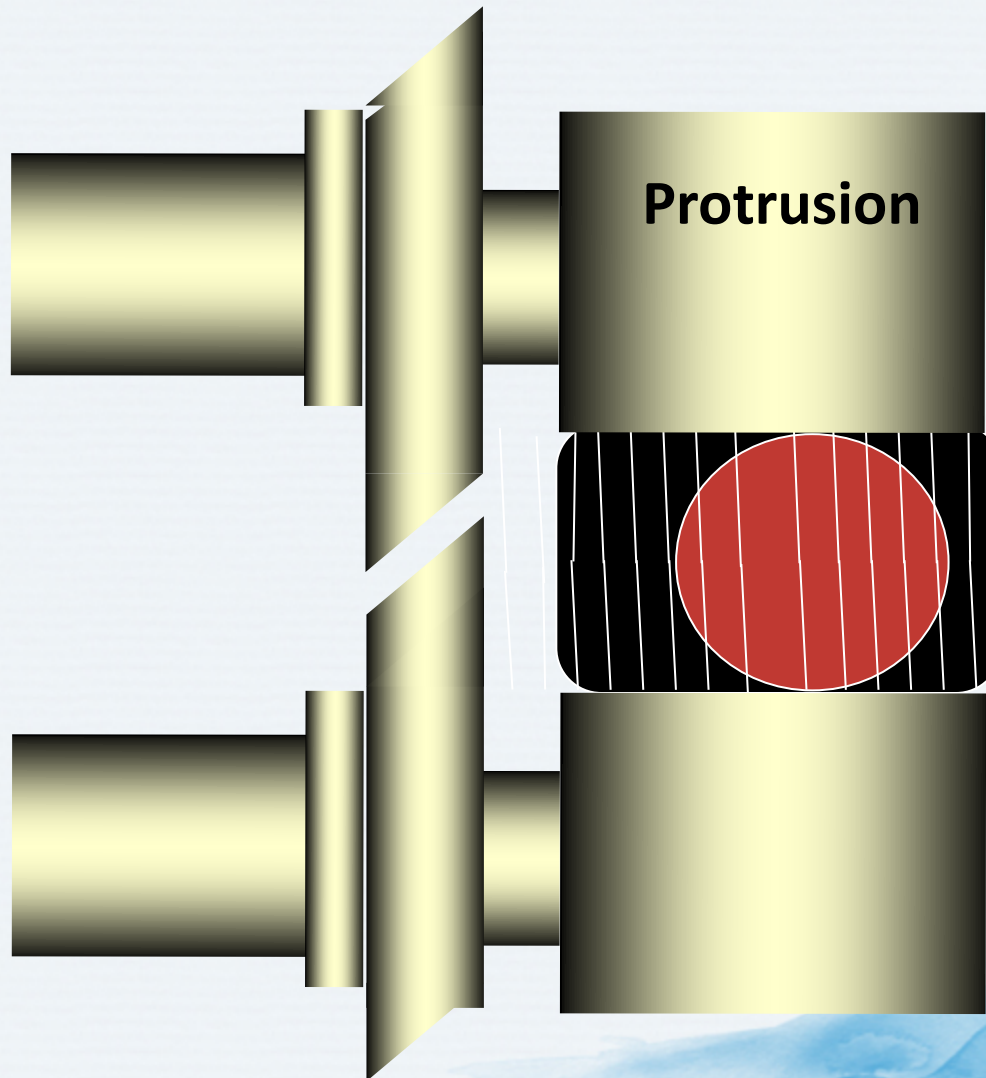
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PROTRUSION, EXTRUSION AND SEQUESTRATION



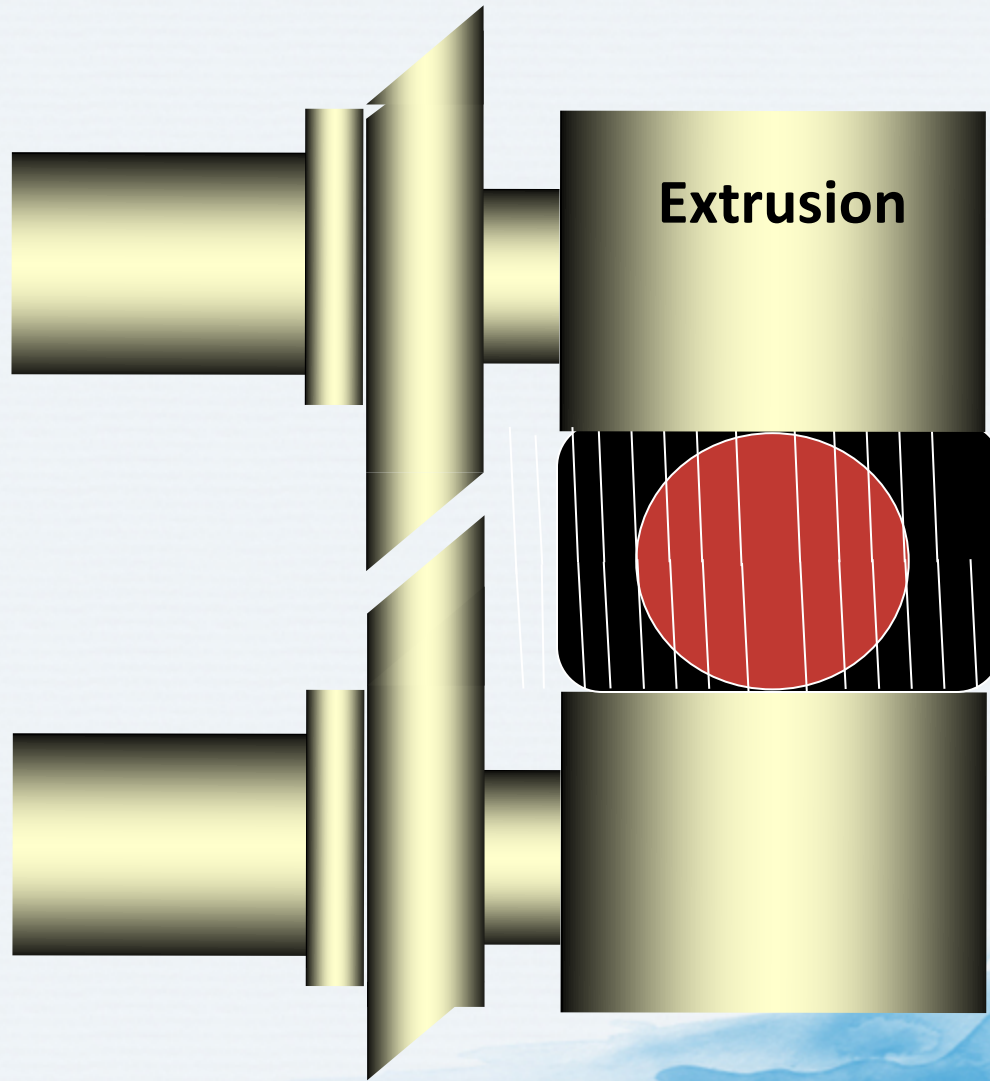
Protrusion of the Spinal Column



Sagittal and Axial Views of Central Protrusion



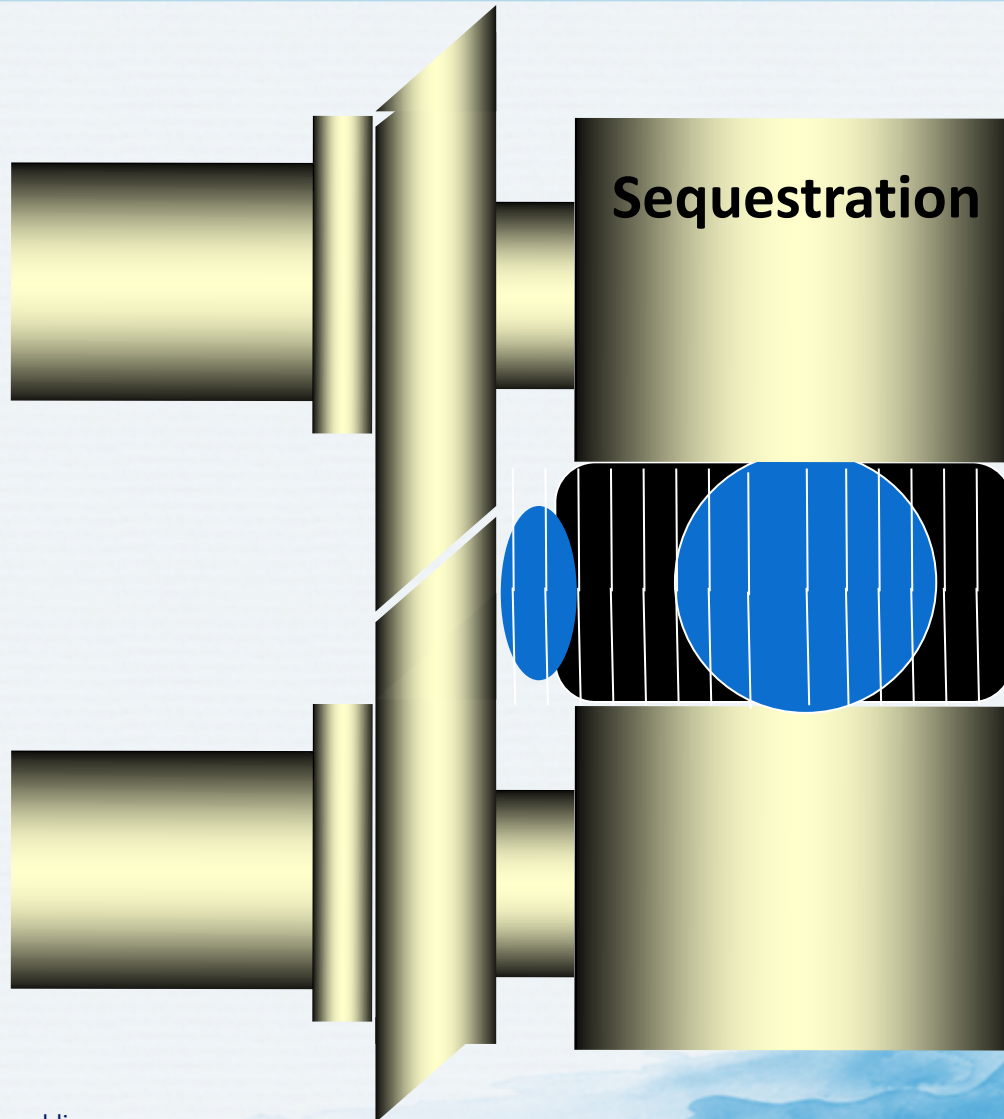
Extrusion of the Spinal Column



Disc Extrusion



Disc Sequestration



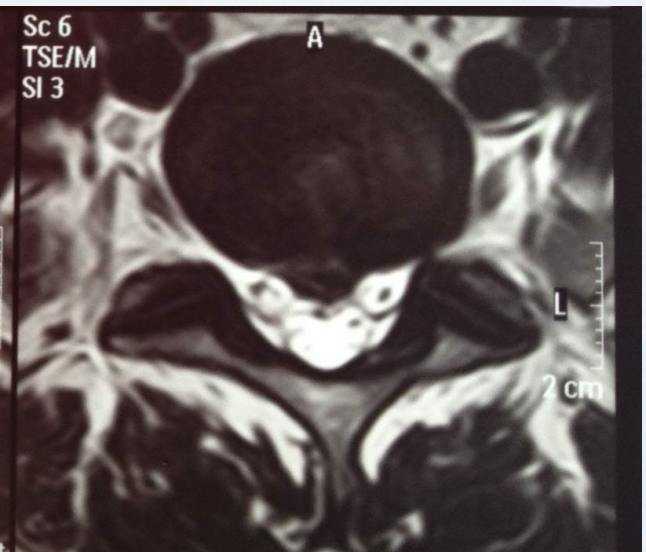
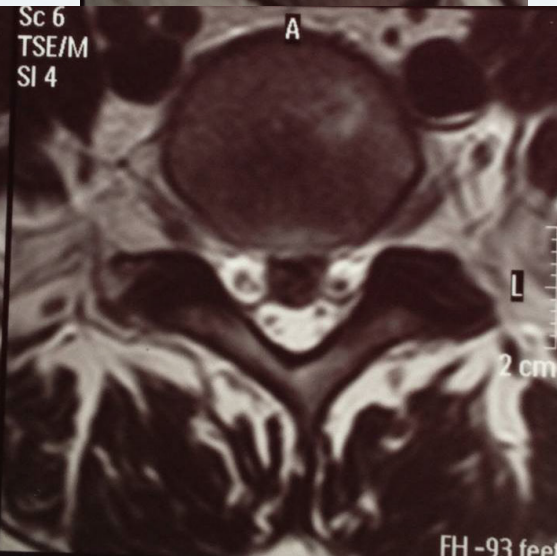
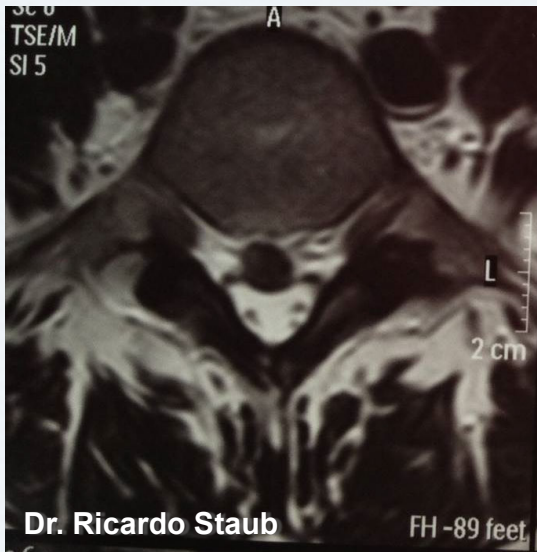
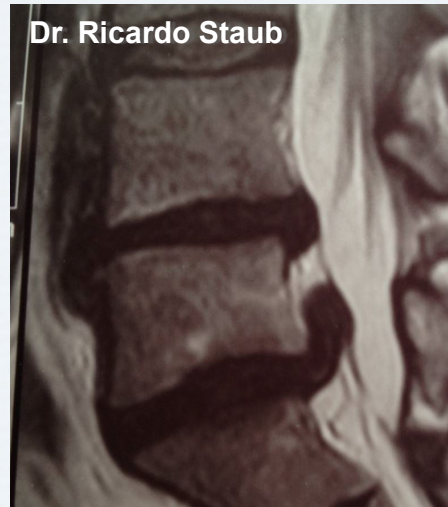
Disc Sequestration



Schmorl Nodules



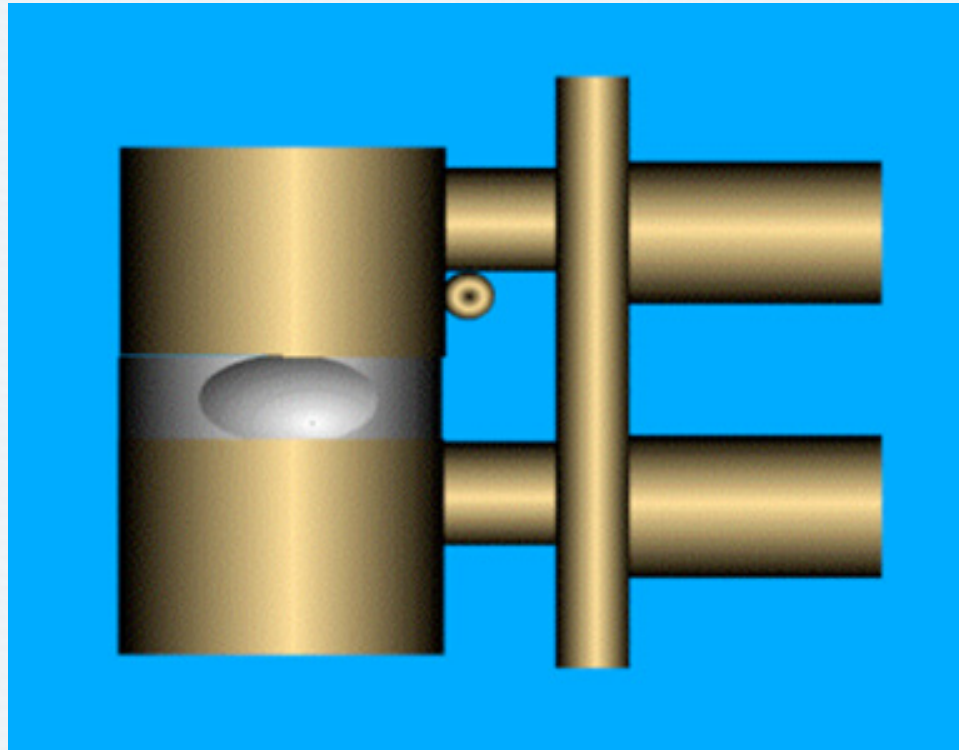
What is this?



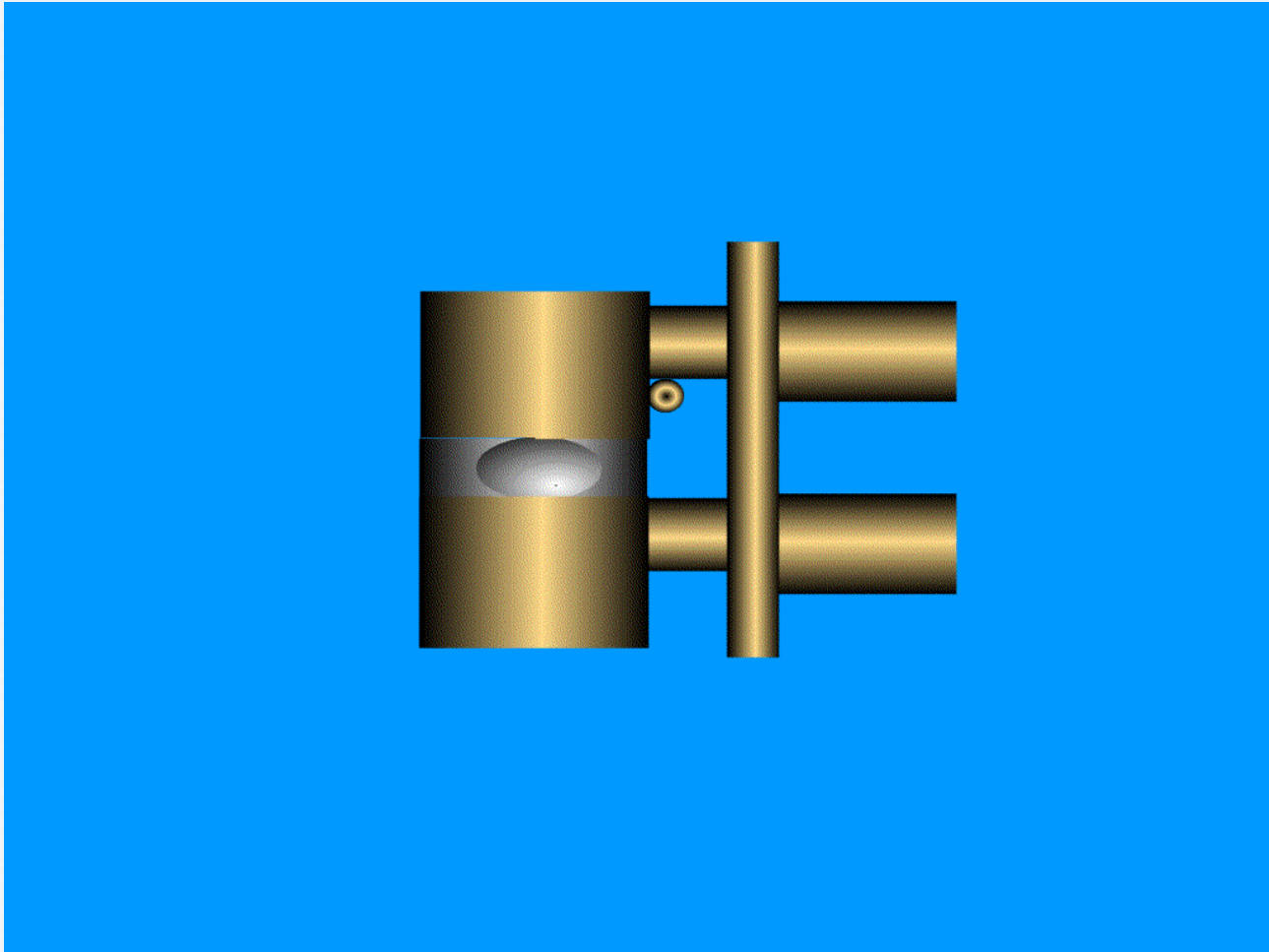
DEGENERATIVE DISC DISEASE ON MULTIPLE LEVELS



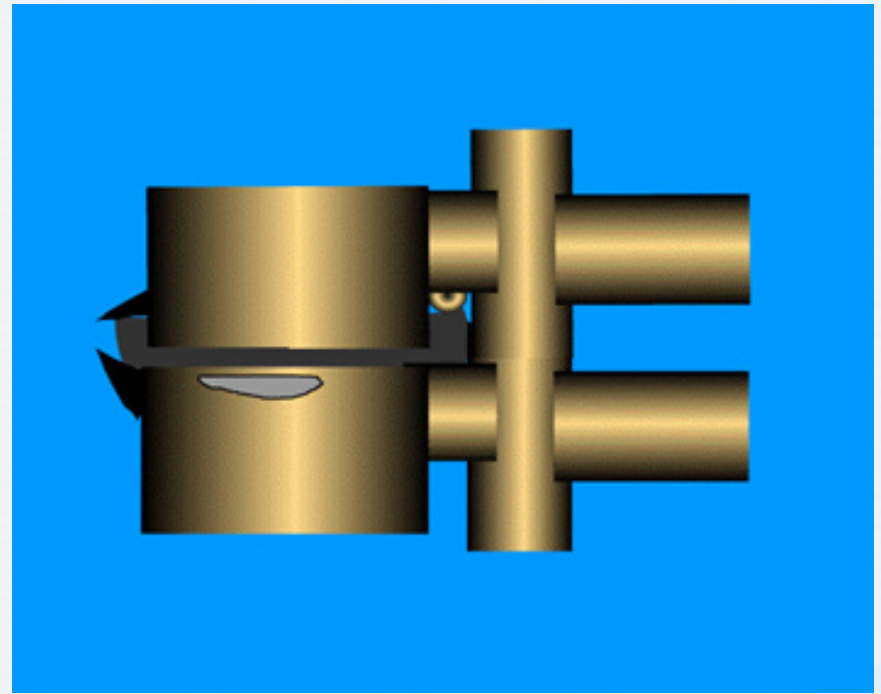
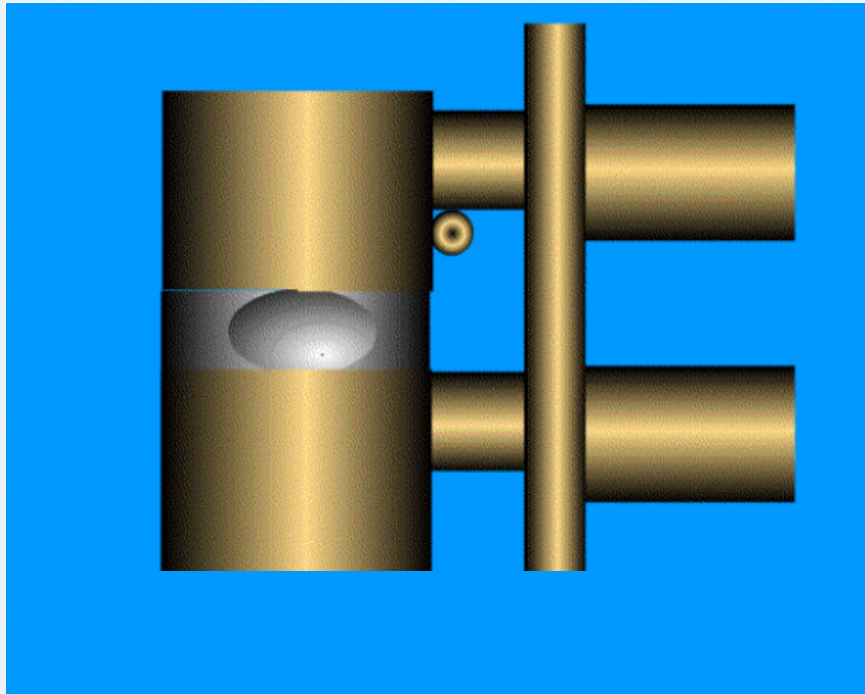
Vertebra-Disc-Vertebra Functional Unit



History of the Vertebral Column



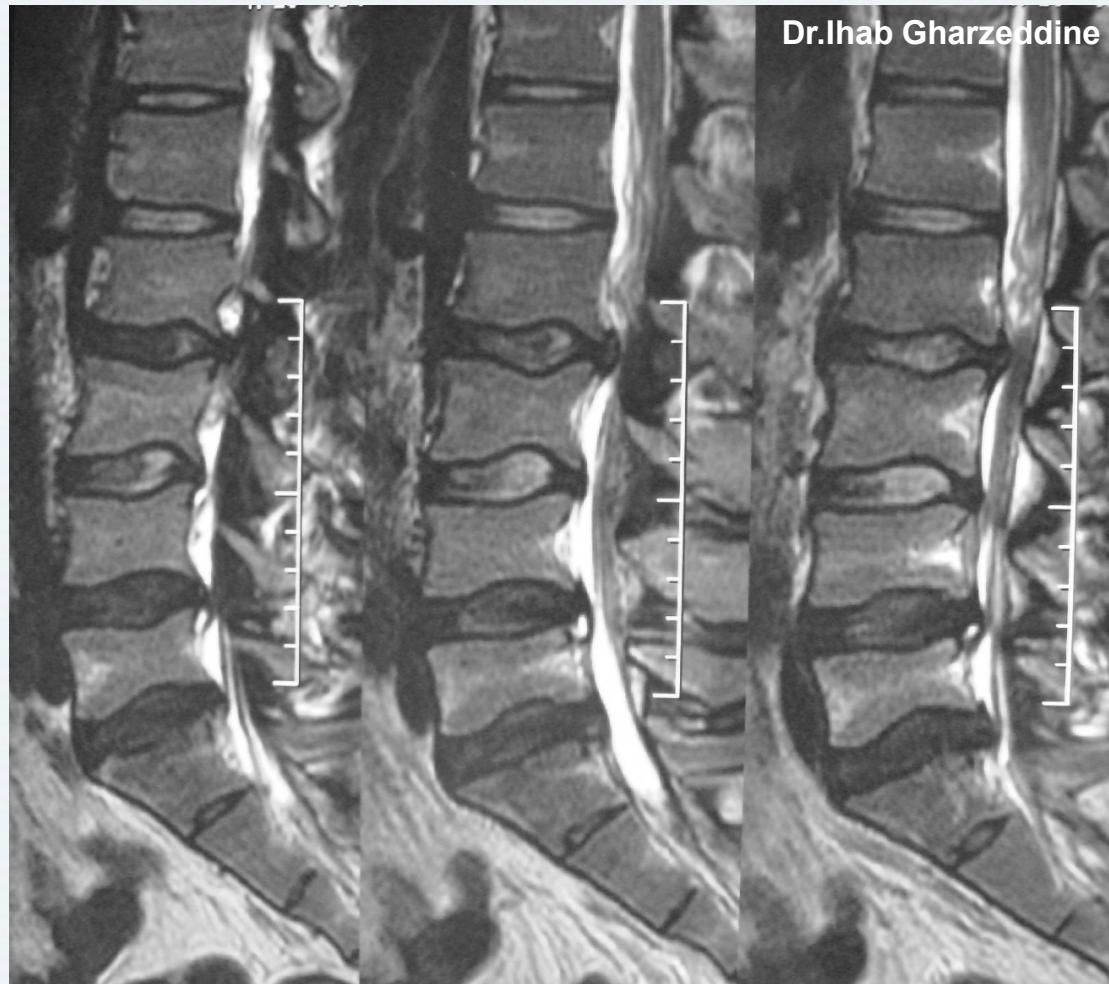
Normal vs. Degenerated Functional Unit of the Vertebral Column



PATHOLOGICAL DISC DEGENERATION

A decorative blue watercolor splash is located in the bottom right corner of the slide, blending into the light blue background.

Disc Degeneration on Multiple Levels

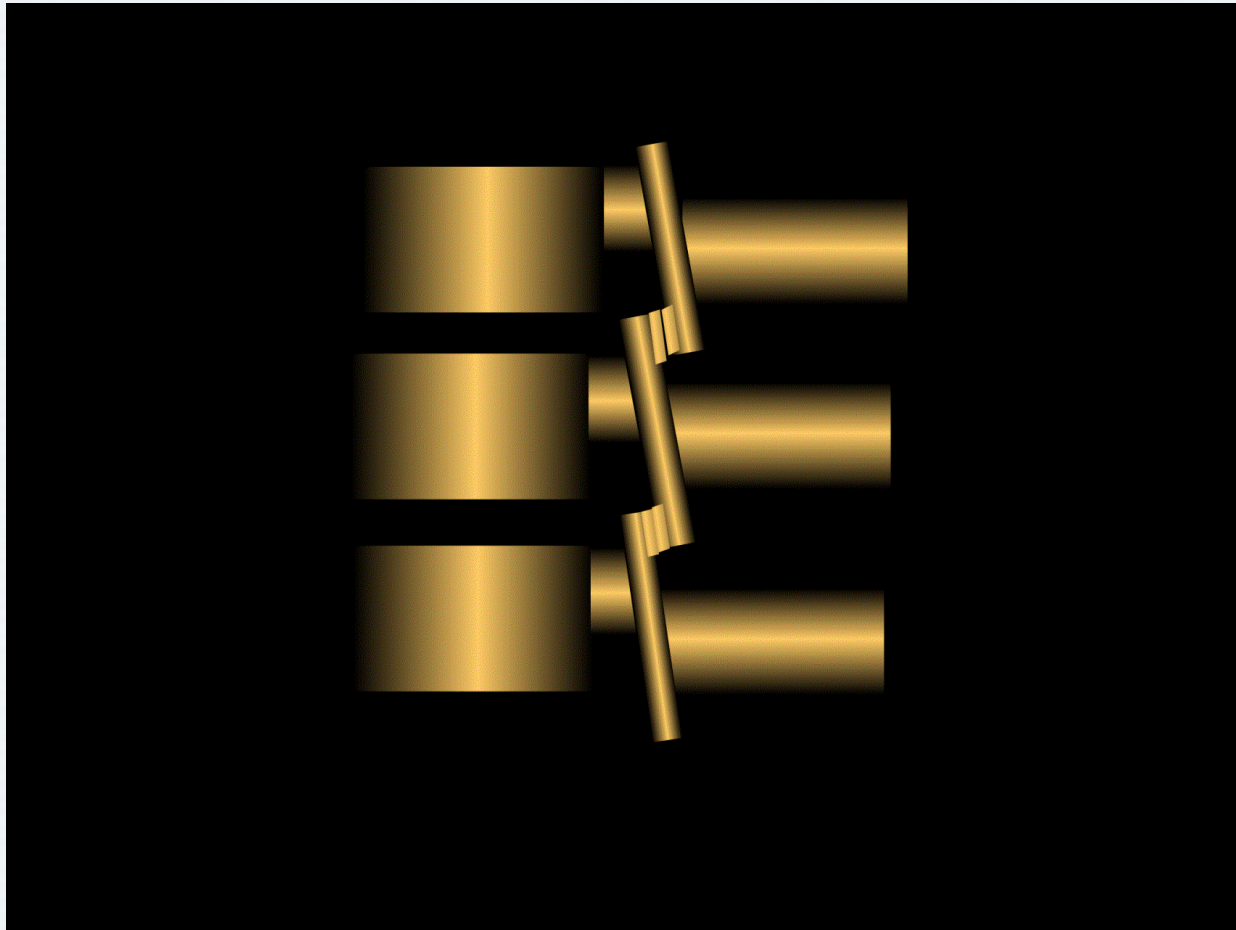


Narrow Lumbar Canal (Lumbosacral Stenosis)

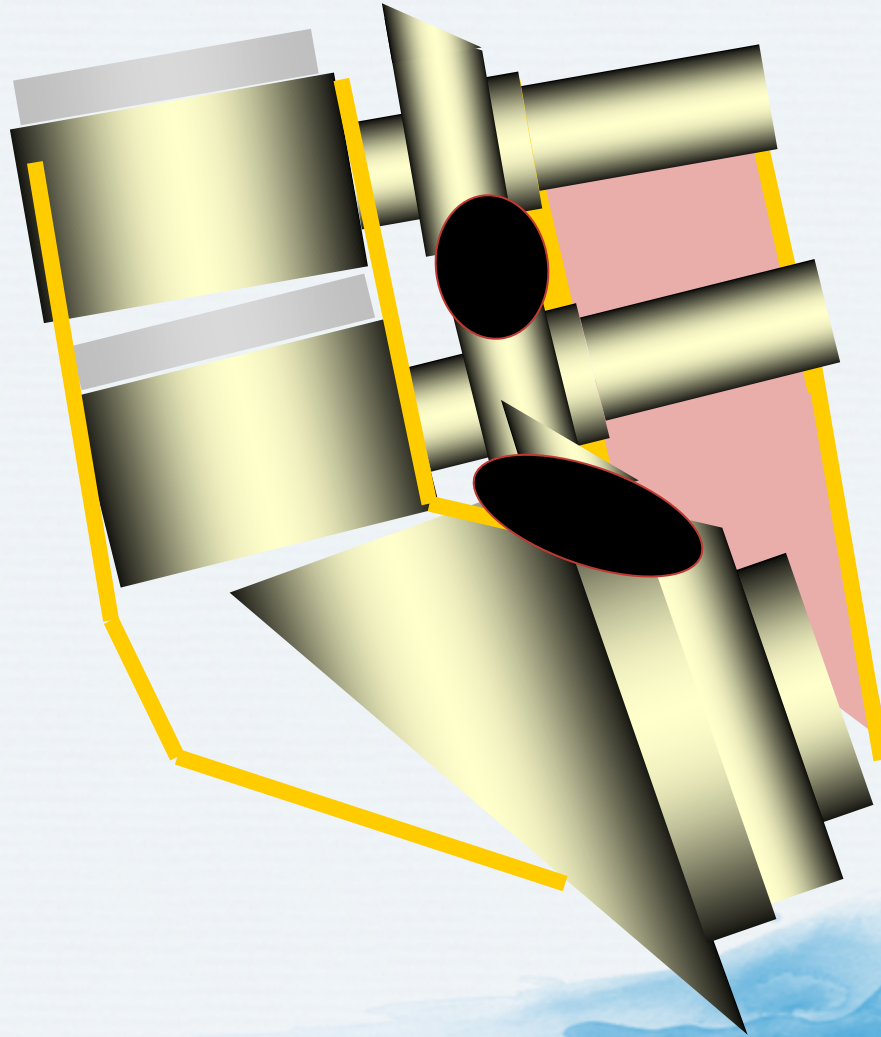


Dra. Argelia Lara 2006

Spondylolysis and Spondylolisthesis



Applied Anatomy and Biomechanics: Situation of Anatomical Structures in Listhesis



Degenerative Disc Disease with Spondylolisthesis



Disc Herniation, Narrow Canal and Spondylolisthesis



Degenerative Scoliosis

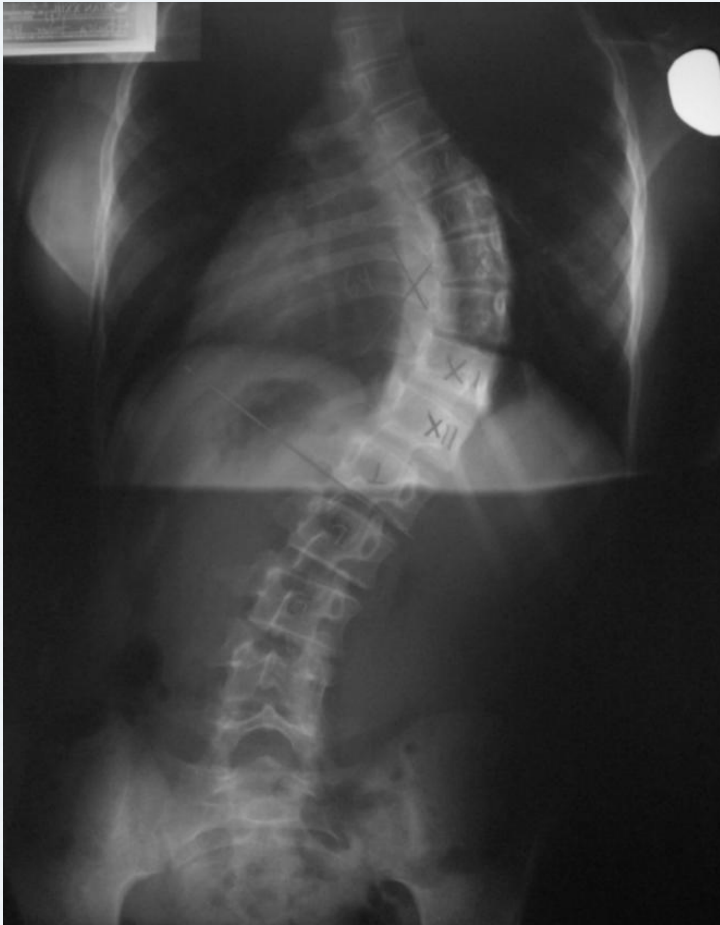


De Novo Scoliosis



Scoliosis and Scoliotic Posture

Idiopathic Scoliosis



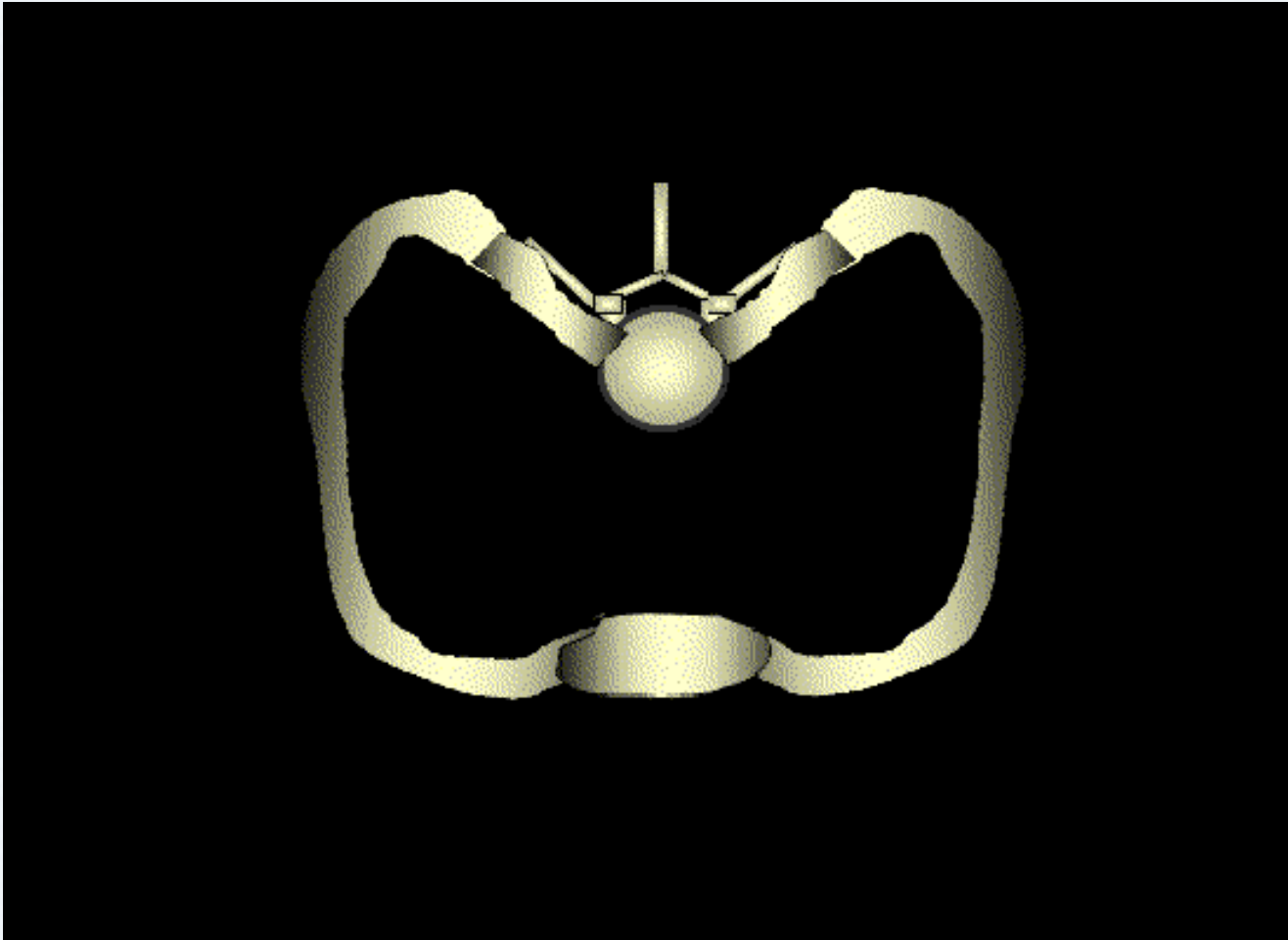
Scoliotic Posture



Scoliosis



Rotation of Thoracic Vertebrae



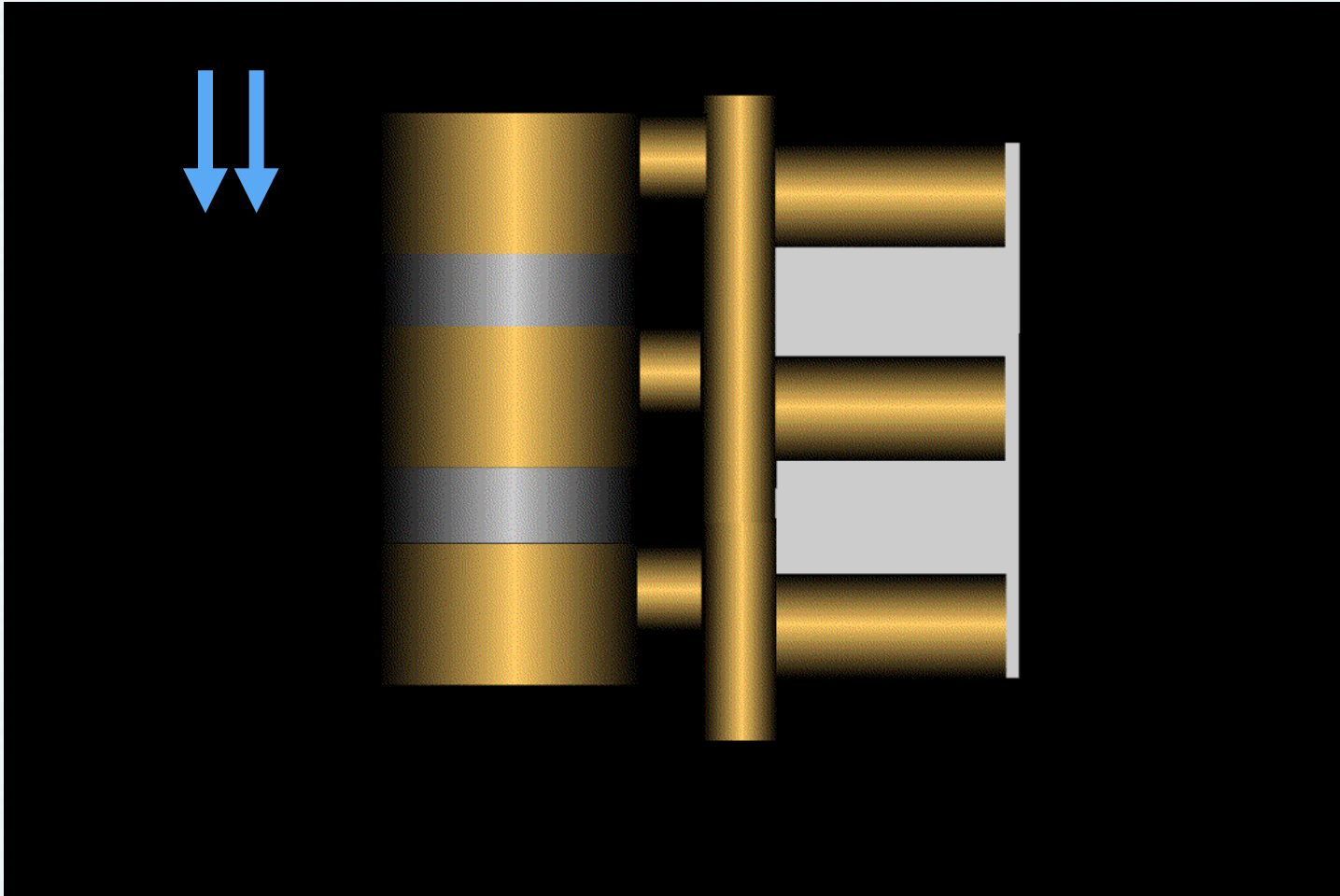
Asymmetrical Rib Cage in Scoliosis



FRACTURES

A decorative blue watercolor splash is located in the bottom right corner of the slide, blending into the light blue background.

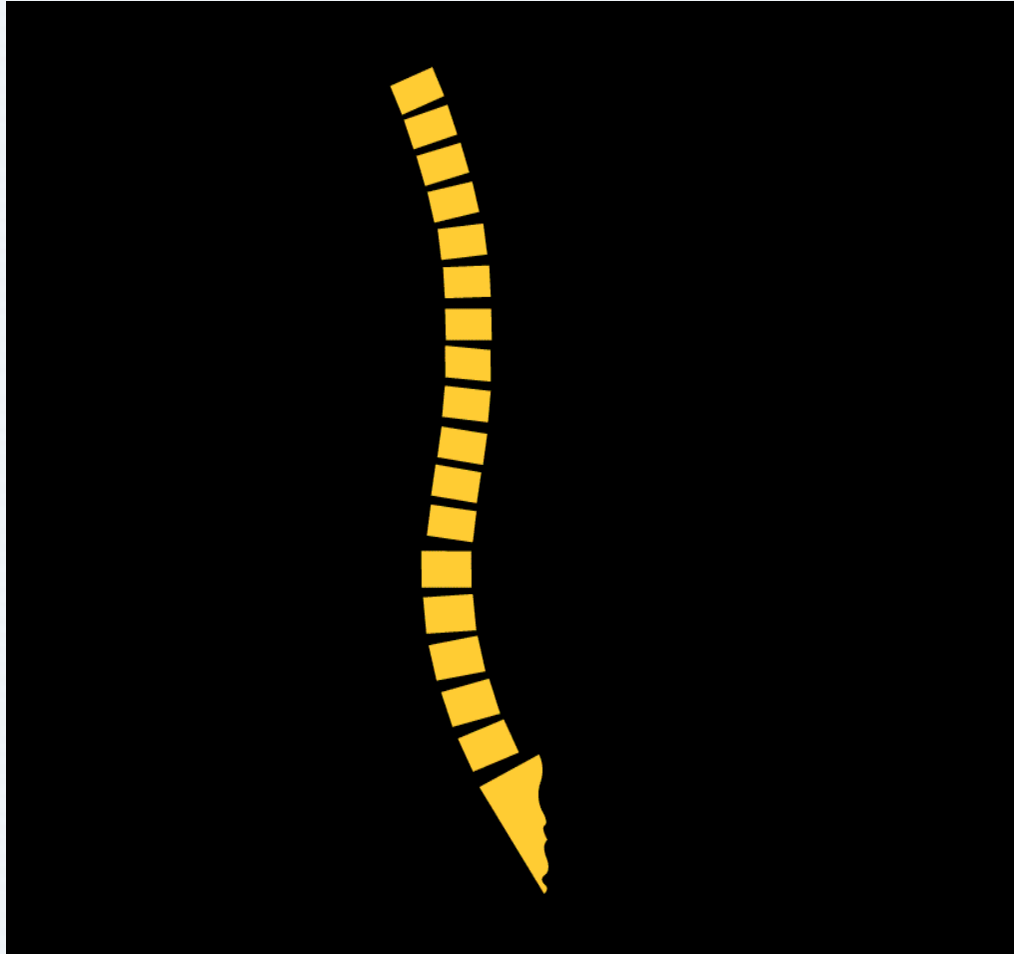
Compression Fractures



Vertebral Fracture



Domino Effect in Vertebral Fractures



Summary

A decorative blue watercolor splash is located in the bottom right corner of the slide, blending into the light blue background.

Pathophysiology of Low Back Pain: Summary

- Low back pain is most frequently attributable to a mechanical cause brought on by overuse or repetitive trauma
 - Other potential causes include neurogenic causes, referred visceral pain or non-mechanical spinal conditions
- Low back pain may be classified according to duration as acute, subacute or chronic
- Low back pain may also be classified according to pathophysiology
- Multiple mechanisms may be involved in low back pain in what is referred to as a “mixed pain” state