# SPINE

## BIOMECHANICS

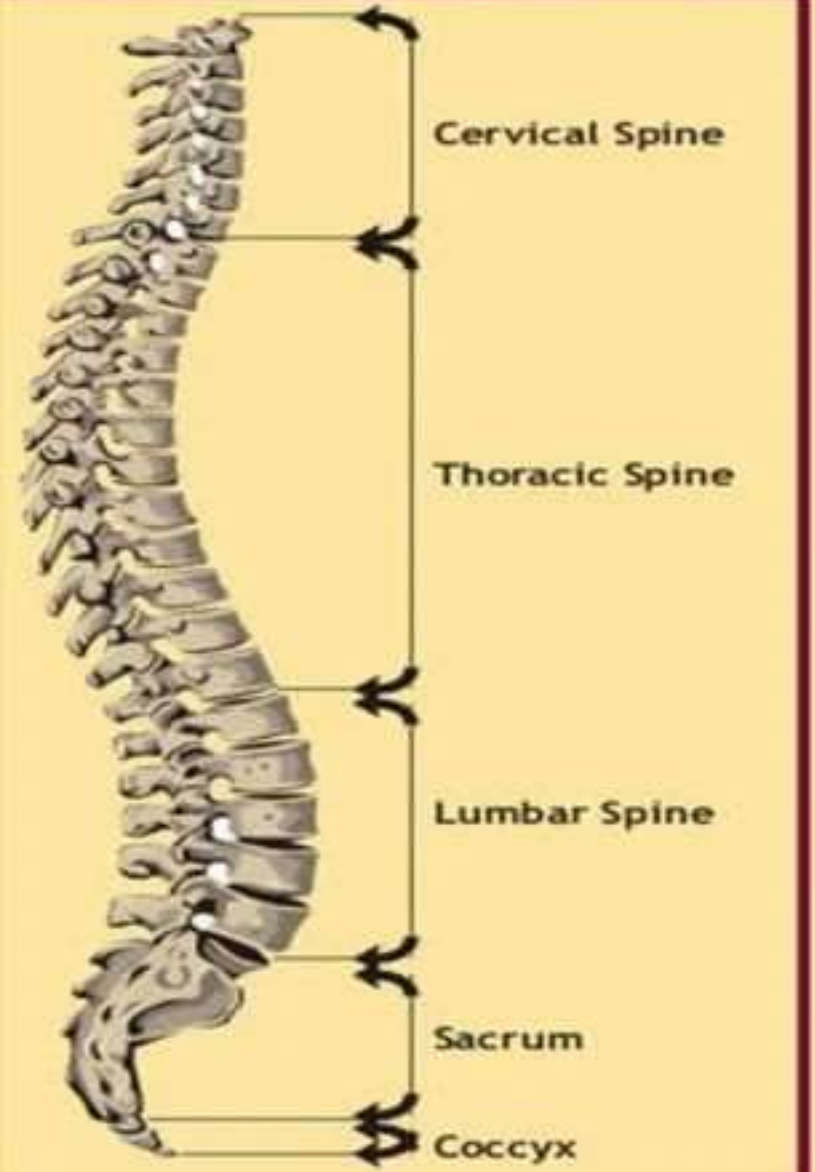
# CONTENTS:


- Basic of human spine
- Spinal curves
- Features of the vertebrae
- Features of the intervertebral disks
- Articulations
- Spinal ligaments
- Kinetics of spine
- Kinematics of spine

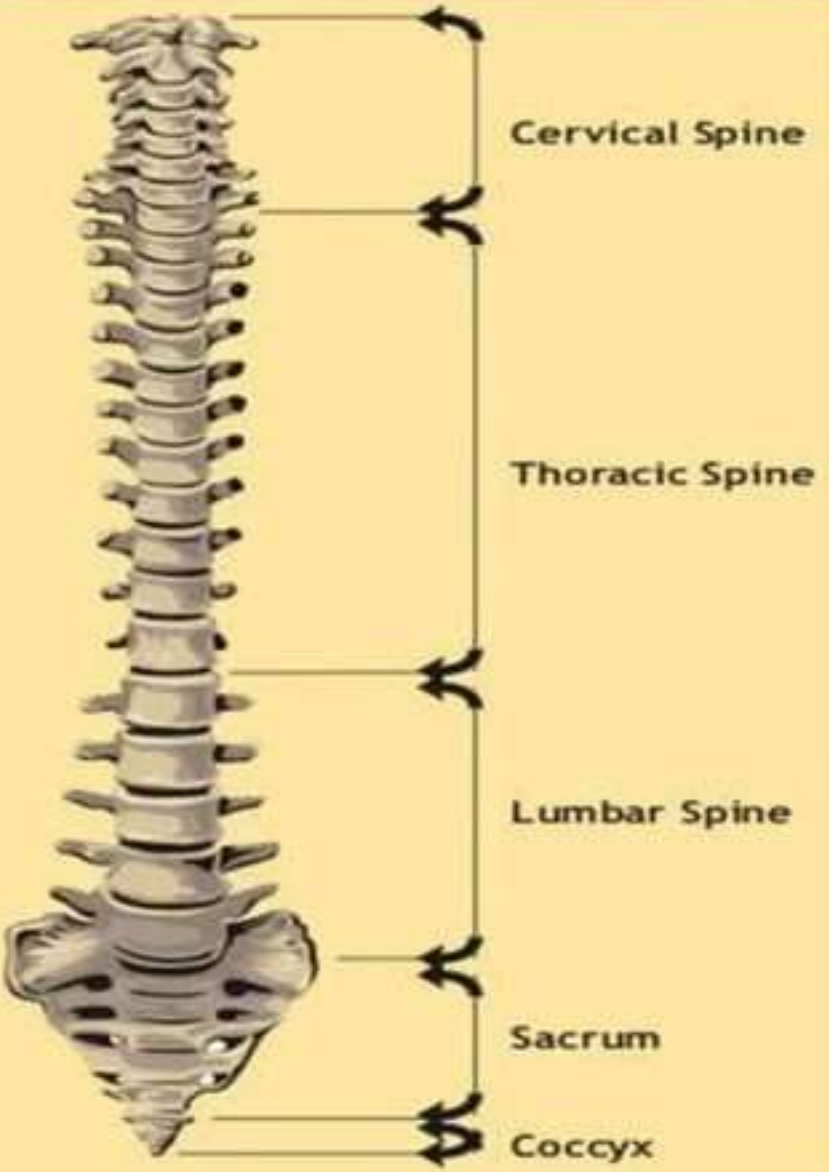
# HUMAN SPINE:

- A curved stack of 33 vertebrae structurally divided into five regions:
  - cervical region - 7 vertebrae
  - thoracic region - 12 vertebrae
  - lumbar region - 5 vertebrae
  - sacrum - 5 fused vertebrae
  - coccyx - 4 fused vertebrae

## Spine - Side View




## Spine - Front View



# SPINAL CURVES:

# CURVES

## ❑Kyphotic Curves

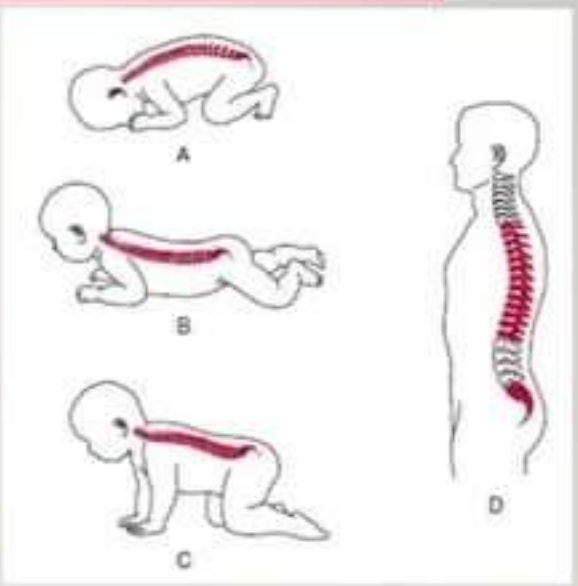
- Curves that have a posterior convexity (anterior concavity)

## ❑Lordotic Curves

- Curves that have an anterior convexity (posterior concavity)

# PRIMARY AND SECONDARY CURVES:

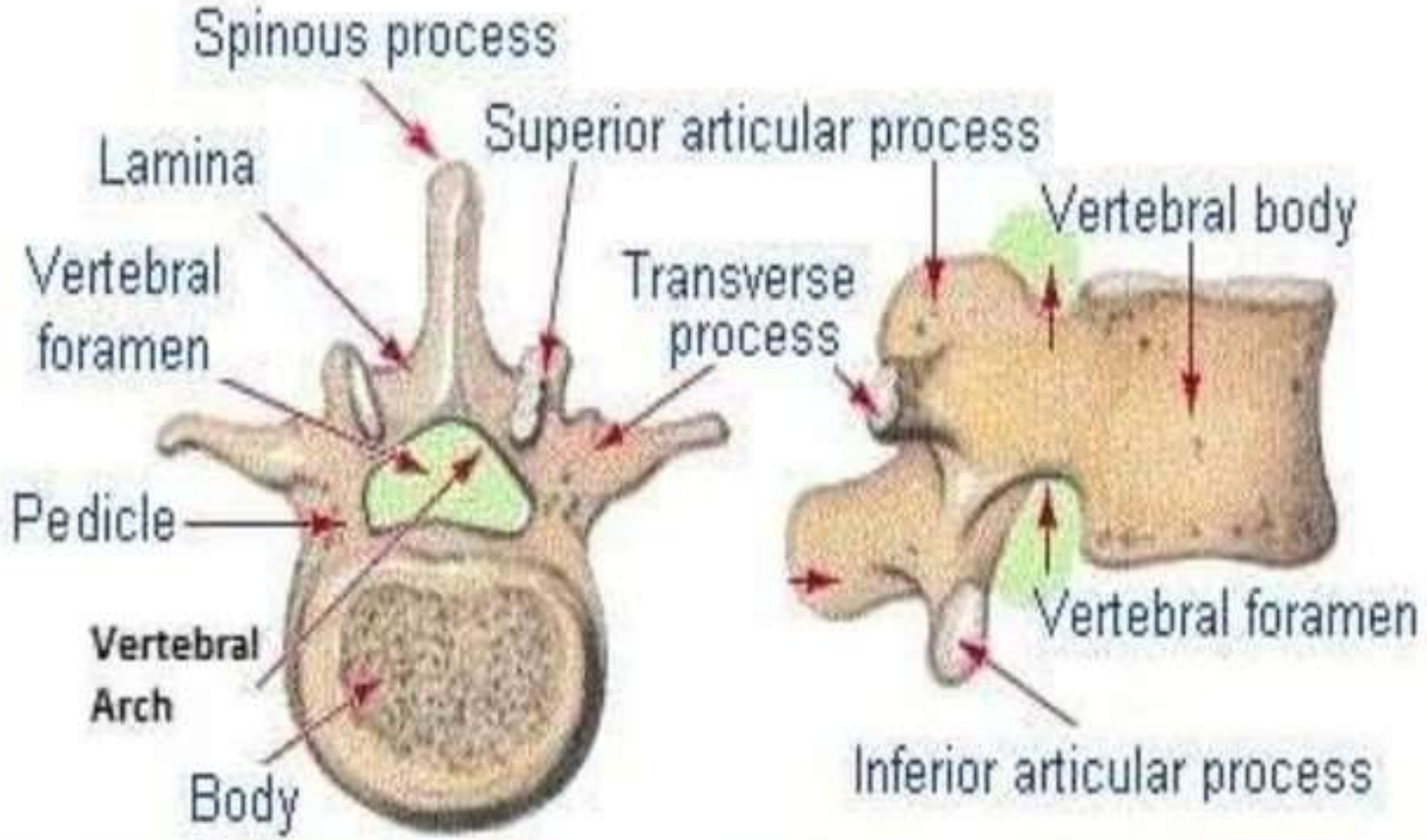
- **PRIMARY CURVES**
  - Two curves
  - **Thoracic and Sacral**
  - Are present at birth
- **SECONDARY CURVES**
  - Two curves
  - **Cervical and Lumbar**
  - **D**evelop from supporting the body in an upright position after young children begin to sit and stand



# ABNORMAL CURVES:

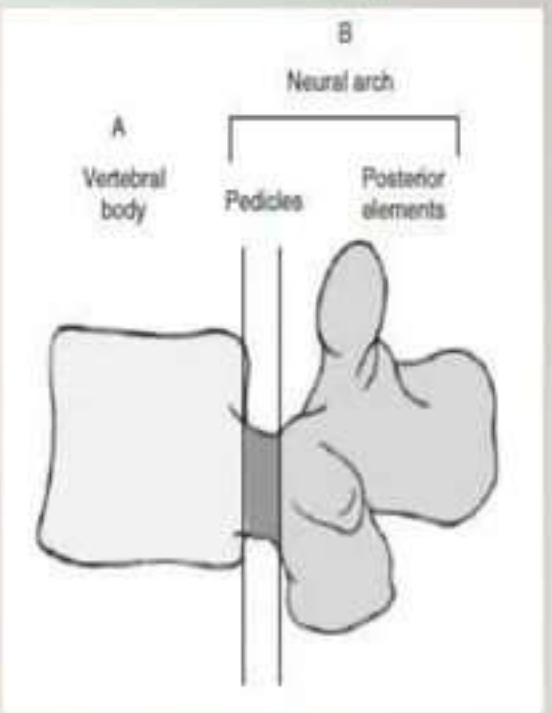
- Scoliosis-abnormal lateral curve of more than 10°
  - "twisted disease"
- Kyphosis-exaggerated thoracic curve
  - "humped disease"
- Lordosis-accentuated lumbar curve
  - "bent-backward disease"

Top (left) and side (right) views of a typical vertebra



# TYPICAL VERTEBRA

- Consists of two major parts:
  - **Anterior**
    - Cylindrically shaped vertebral body
  - **Posterior**
    - Irregularly shaped vertebral or neural arch
      - Pedicles
      - Posterior elements



## Table 4-1 Components of a Typical Vertebra

| | Description | Function |
|---|---|---|
| Body | Block of trabecular bone covered by a layer of cortical bone | To resist compressive loads |
| Pedicle | Short, stout pillars with thick walls that connect the vertebral body to the posterior elements | To transmit the bending forces from the posterior elements to the vertebral body |
| Lamina | The vertical plate that constitutes the central portion of the arch posterior to the pedicles | To transmit the forces from the articular, transverse, and spinous processes to the pedicles |
| Transverse processes | Lateral projections of bone that originate from the laminae | Serve as muscle attachments and provide mechanical lever |
| Spinous process | Posterior projection of bone that originates from the central portion of the lamina, dividing it into two | Serves as muscle attachment and provides mechanical lever; may also serve as a bony block to motion |
| Vertebral foramen | Opening bordered by the posterior vertebral body and the neural arch | Combined with all segments, forms a passage and protection for the spinal cord |

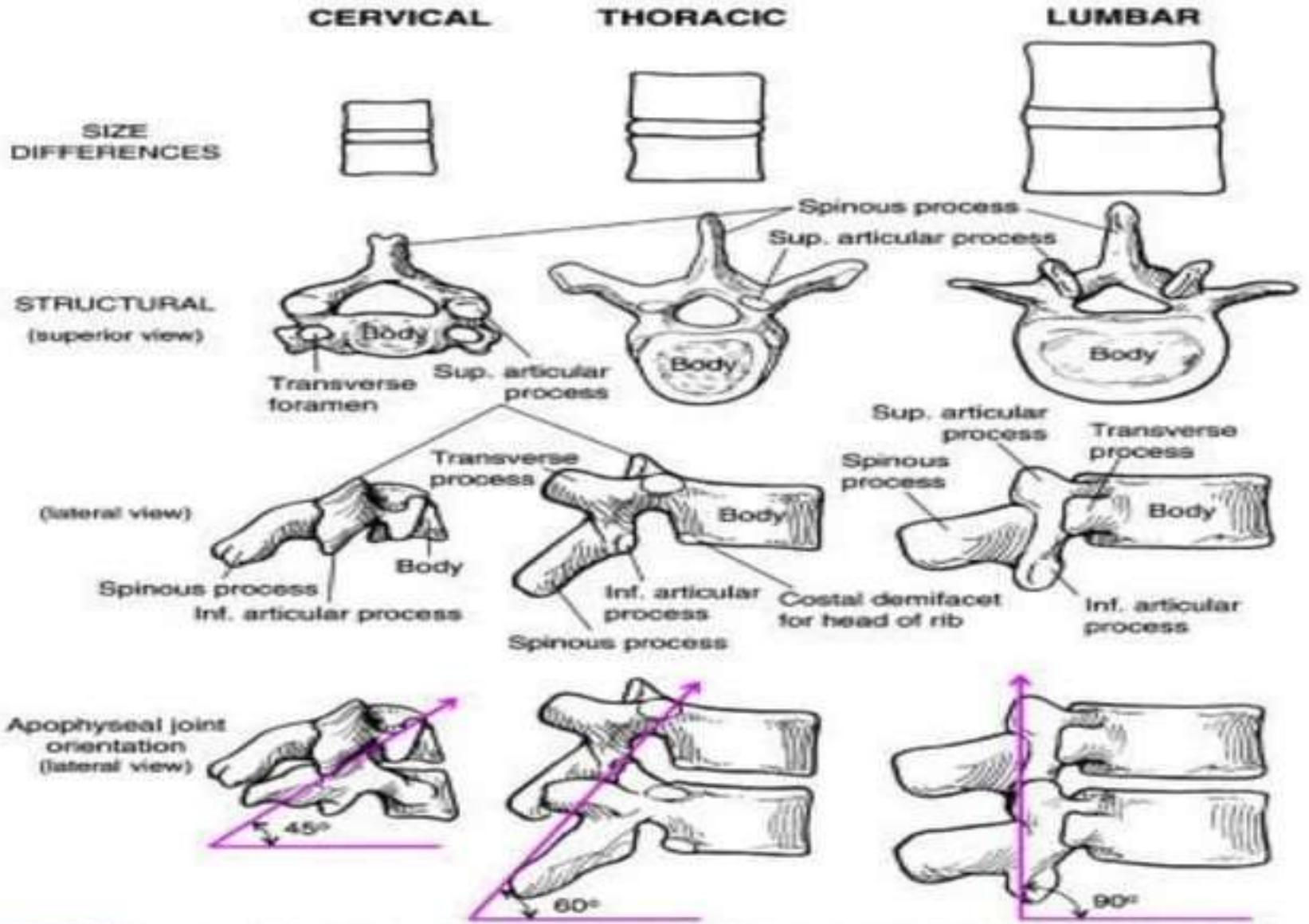



FIGURE 7-11 The cervical, thoracic, and lumbar vertebrae differ from each other. From the cervical to the lumbar region the bodies of the vertebrae become larger, and the transverse processes, spinous processes, and apophyseal joints all change their orientation.

**Table 14-2** Parts of the Vertebra

| | Cervical | Thoracic | Lumber |
|---|---|---|---|
| Size | Smallest | Intermediate | Largest |
| Body shape | Small oval | Heart-shaped, with facets that connect with ribs | Large oval |
| Vertebral foramen | Large, triangular | Smallest | Intermediate |
| Transverse process | Foramen for vertebral artery; laterally | Facets that connect with ribs; long, thick, point posteriorly and laterally | No foramen or articulation |
| Spinous process | Short, stout, bifid | Long, slender, point inferiorly | Thick, point posteriorly |
| Superior articular process | Face medially | Face posteriorly and laterally | Face posteriorly |
| Vertebral notches | Equal depth | Deeper inferior notches | Deeper inferior notches |

# TYPICAL VERTEBRA

- **Articular processes:**
  - Consist of two superior and two inferior facets for articulation with facets from the cranial and caudal vertebrae, respectively.

- In the sagittal plane, these articular processes form a supportive column, frequently referred to as the **articular pillar.**

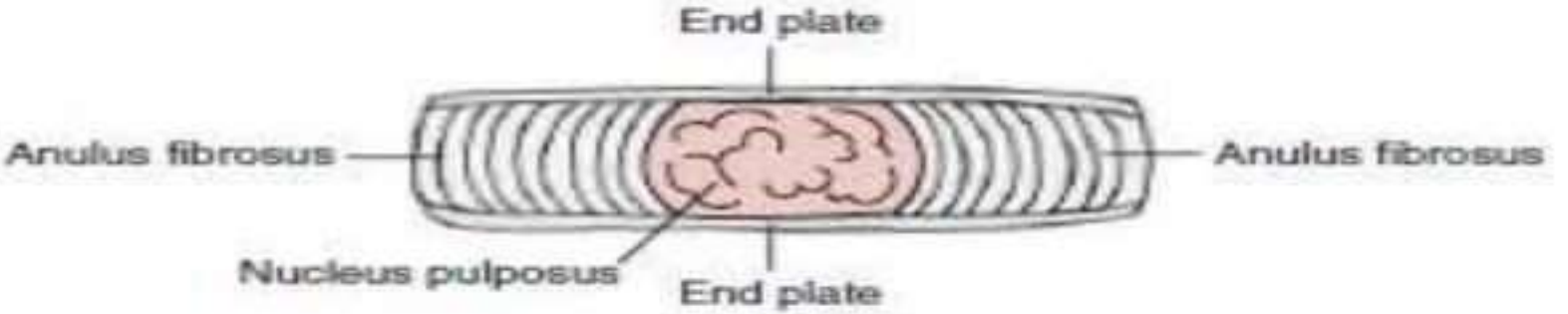
# INTER VERTEBRAL DISK

- Function:
  - It separate two vertebral bodies, so increasing available motion,
  - It transmit load from one vertebral body to the next.
- Size of the inter vertebral disk is related to both:
  - Amount of motion
  - Magnitude of the loads that must be transmitted.

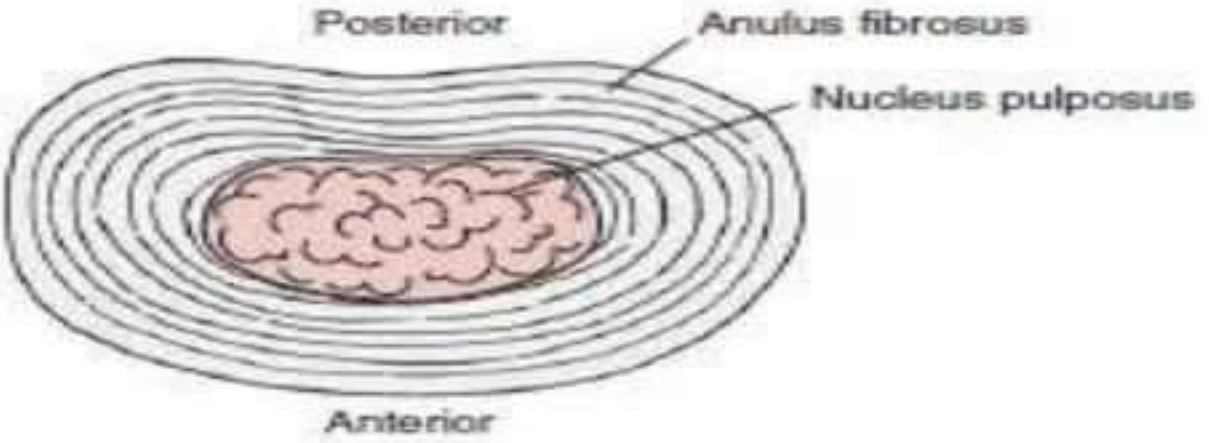
- **Absent between**
  - C1 and C2
  - Sacrum and coccyx
- **Annulus Fibrosus**
  - Outer collar of concentric rings
  - Outer rings = ligaments
  - Inner rings = fibrocartilage
  - Supportive/Structural
- **Nucleus Pulposus**
  - Inner disc, cushiony pad
  - Remnants of notocord
  - Shock Absorber

# INTER VERTEBRAL DISK

- The inter vertebral disks:
  - Make up about 20% to 33% (1/3) of the length of the vertebral column
  - Increase in size from the cervical to the lumbar regions.
- Disk thickness varies:
  - Approxi.3 mm in the cervical region,
    - where the weight-bearing loads are the lowest
  - About 9 mm in the lumbar region,
    - where the weight-bearing loads are the greatest

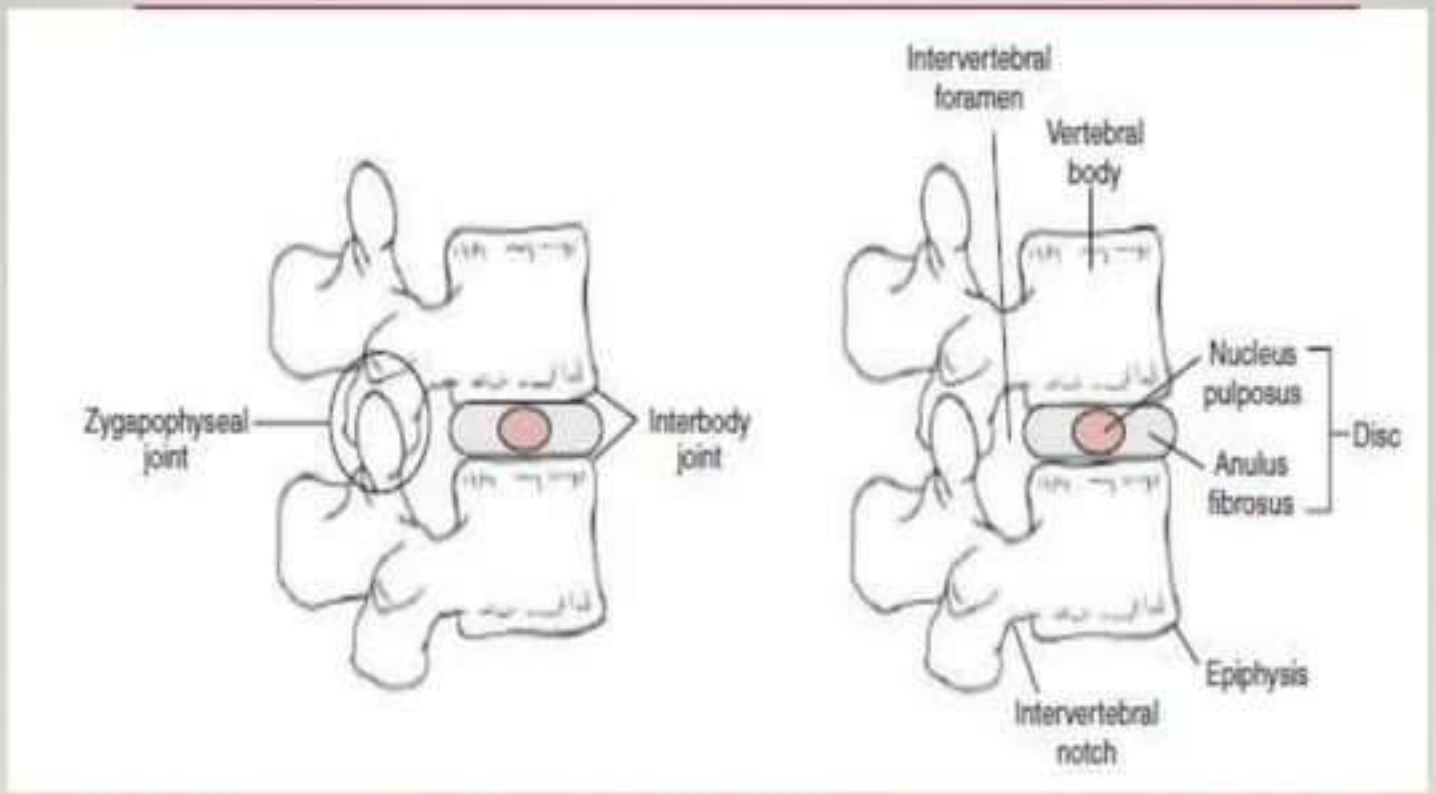



Coronal section




Transverse section

# ARTICULATIONS



# ARTICULATIONS

## Interbody Joints

- **Available movements at the interbody joints**
  - gliding, distraction and compression, and rotation (also called tilt or rocking in the spine)
- **Gliding motions can occur in the following directions:**
  - anterior to posterior, medial to lateral, and torsional.
- **Tilt motions can occur in**
  - anterior to posterior and in lateral directions.
- These motions, together with the distraction and compression, constitute six degrees of freedom

# Interbody Joints

Translations and rotations of one vertebra in relation to an adjacent vertebra.

A. Side-to-side translation (gliding) occurs in the frontal plane.

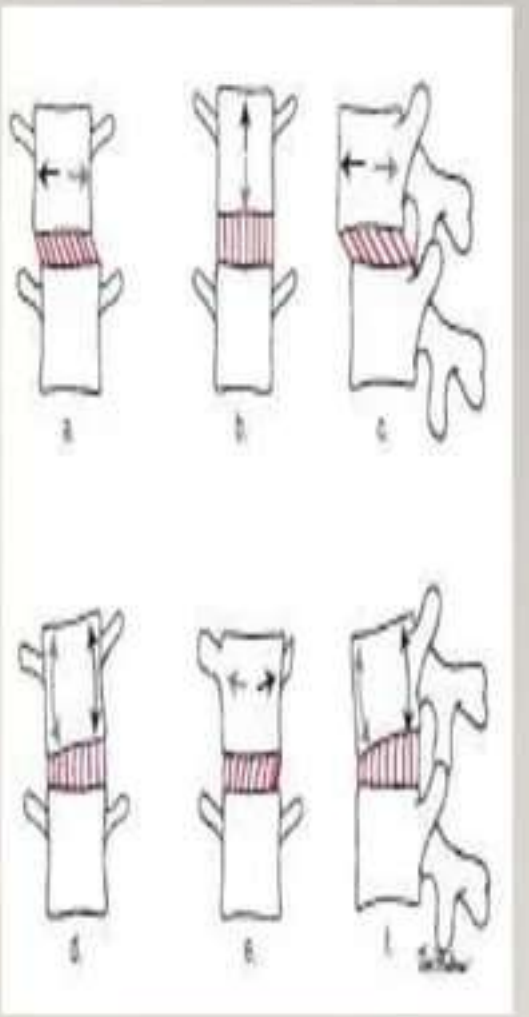
B. Superior and inferior translation (axial distraction and compression) occur vertically.

C. Anteroposterior translation occurs in the sagittal plane.

D. Side-to-side rotation (tilting) in a frontal plane occurs around an anteroposterior axis.

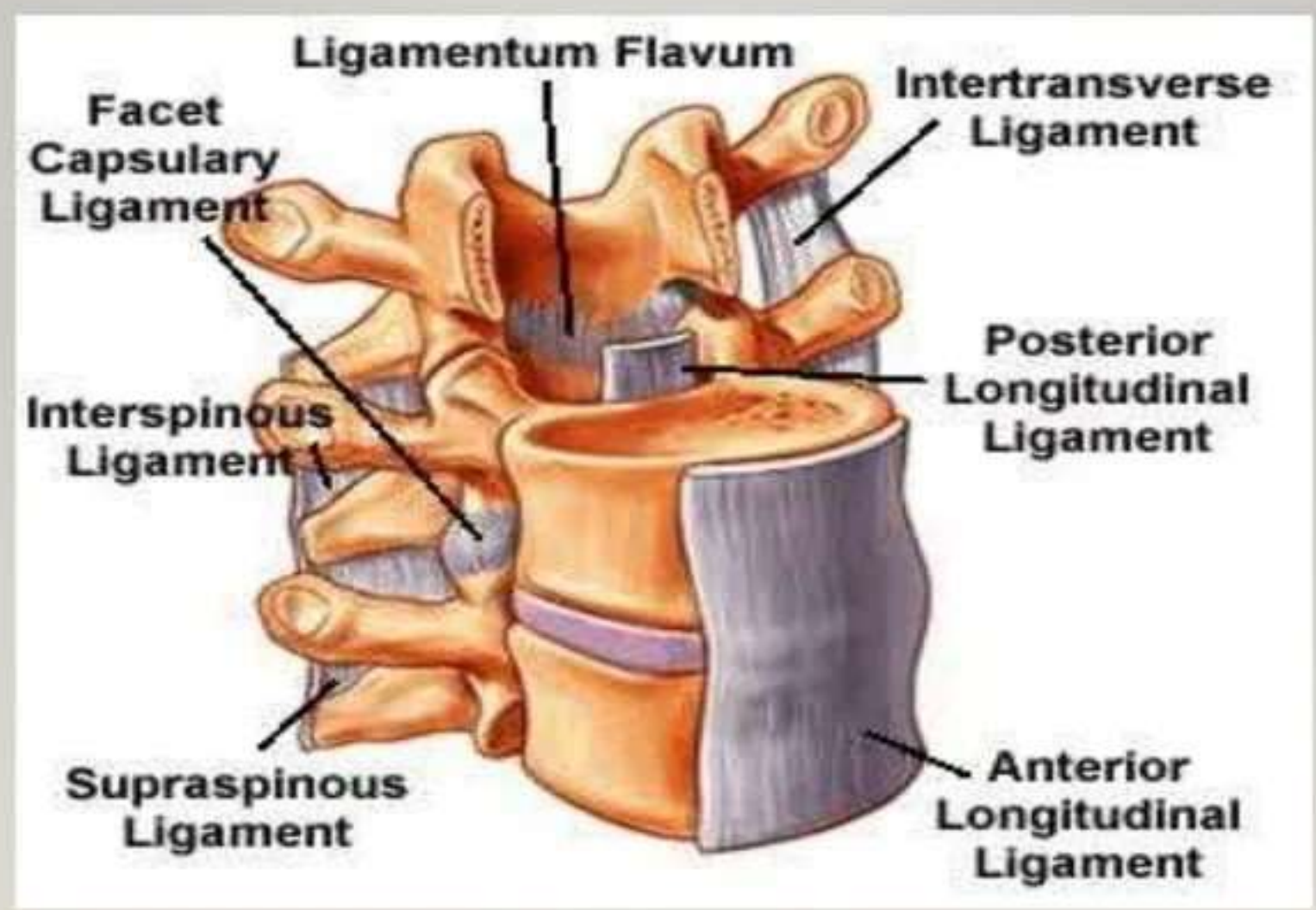
E. Rotation occurs in the transverse plane around a vertical axis.

F. Anteroposterior rotation (tilting) occurs in the sagittal plane around a frontal axis.



# LIGAMENTS AND JOINT CAPSULES

- The ligamentous system of the vertebral column is extensive and exhibits considerable regional variability.
- Six main ligaments are associated with the intervertebral and zygapophyseal joints.
  1. **Anterior longitudinal ligament**
  2. **posterior longitudinal ligament**
  3. **Ligamentum flavum**
  4. **Interspinous ligament**
  5. **Supraspinous ligament**
  6. **Intertransverse ligaments**


Ligamentum Flavum
Intertransverse Ligament
Facet Capsulary Ligament
Posterior Longitudinal Ligament
Interspinous Ligament
Supraspinous Ligament
Anterior Longitudinal Ligament

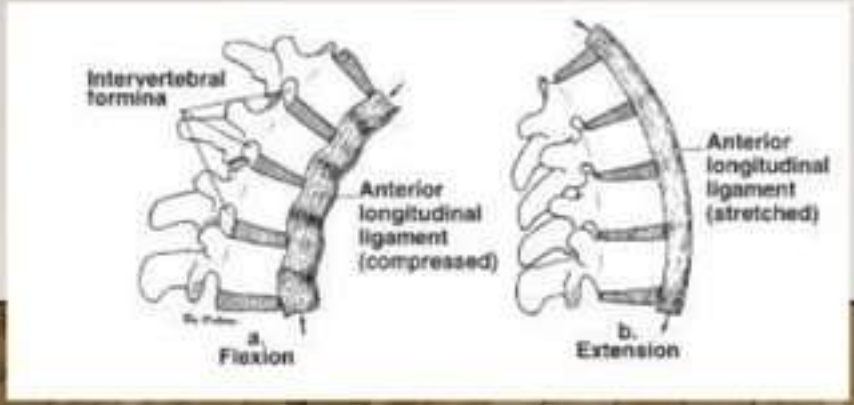
# LIGAMENTS AND JOINT CAPSULES

## Anterior Longitudinal Ligaments

- Well developed in the lordotic sections (cervical and lumbar)
- The tensile strength of the ligament is greatest at the high cervical, lower thoracic, and lumbar regions, with the greatest strength being in the lumbar region.

# LIGAMENTS AND JOINT CAPSULES

- **Anterior Longitudinal Ligaments**
- It is compressed in flexion and stretched in extension
- It may become slack in the neutral position of the spine when the normal height of the disks is reduced,
  - such as might occur when the nucleus pulposus is destroyed or degenerated.
- It is reported to be twice as strong as the PLL.

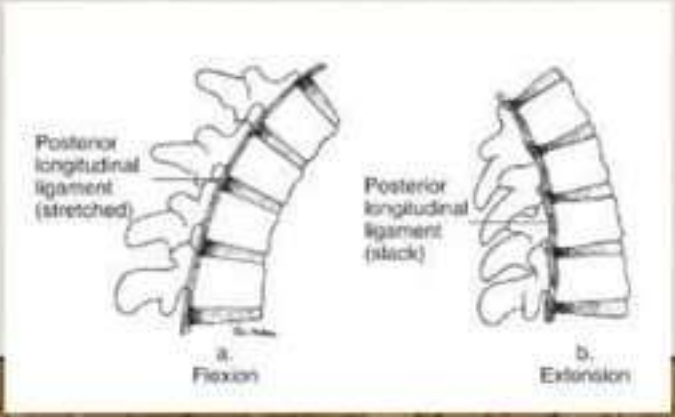



A. Slack and compressed in forward flexion of the vertebral column.
B. Stretched in extension of the vertebral column

# LIGAMENTS AND JOINT CAPSULES

## Posterior Longitudinal Ligaments

- PLL's resistance to axial tension in the lumbar area is only one sixth of that of the anterior longitudinal ligament.
- It is stretched in flexion and is slack in extension




A. Stretched during forward flexion of the vertebral column.
B. Slack and compressed during extension.

# LIGAMENTS AND JOINT CAPSULES

## Ligamentum Flavum

- Thick, elastic ligament
- Strongest in the lower thoracic region and weakest in the midcervical region.
- Highest strain in this ligament occurs during flexion when the ligament is stretched

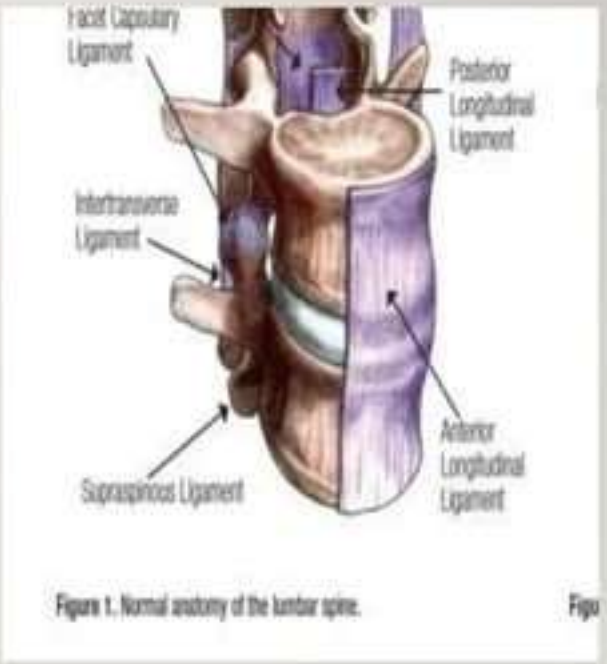


Figure 1. Normal anatomy of the lumbar spine.

# LIGAMENTS AND JOINT CAPSULES

## Interspinous Ligaments

- The interspinous ligament, along with the supraspinous ligament, is the first to be damaged with excessive flexion
- Contribute to lumbar spine stability
- Degenerate with aging

# LIGAMENTS AND JOINT CAPSULES

## Supraspinous Ligament

- The supraspinous ligament, like the interspinous ligament, is stretched in flexion, and its fibers resist separation of the spinous processes during forward flexion.
- During hyperflexion, the supraspinous ligament, along with the interspinous ligament, is the first to fail

# LIGAMENTS AND JOINT CAPSULES

## Intertransverse Ligaments

- The ligaments are alternately stretched and compressed during lateral bending.
- During lateral bending to the left
  - The ligaments on the right side are stretched and offer resistance
  - The ligaments on the left side are slack and compressed during this motion.
- During lateral bending to the right
  - The ligaments on the left side are stretched and offer resistance to this motion

# KINETICS

- **Vertebral column is subjected to**
  - Axial compression, tension, bending, torsion, and shear stress
  - During normal functional activities & also at rest

# KINETICS

- **Vertebral column's ability to resist these loads**
  - Varies among spinal regions and
  - Depends on the
    - Type, duration, and rate of loading
    - Person's age and posture
    - Condition and properties of the various structural elements
      - Vertebral bodies, joints, disks, muscles, joint capsules & ligaments

# AXIAL COMPRESSION

- Force acting through the long axis of the spine at right angles to the disks
- Occurs as a result of the
  - **Force of gravity**
  - **Ground reaction forces**
  - **Forces produced by the ligaments and muscular contractions**
- The disks and vertebral bodies resist most of the compressive force.

# BENDING

- Bending causes both compression and tension on the structures of the spine.
- **In forward flexion:**
  - the anterior structures (anterior portion of the disk, anterior ligaments, and muscles) are subjected to compression;
  - the posterior structures are subjected to tension.
- **The resistance offered to the tensile forces**

  **By:**

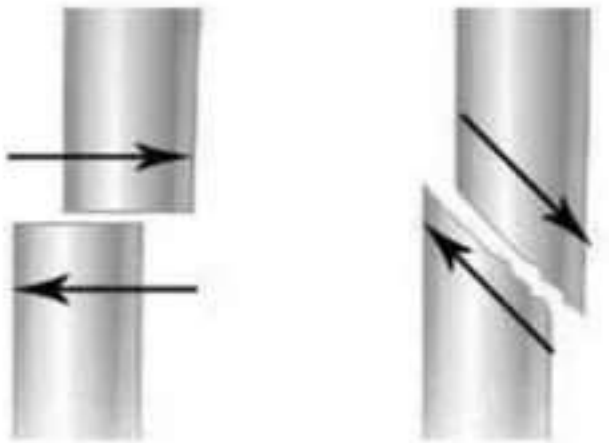
  - collagen fibers in the posterior outer anulus fibrosus, zygapophyseal joint capsules, and posterior ligaments
  - help to limit extremes of motion
  - hence provide stability in flexion

# TORSION

- Torsional forces are created during axial rotation that occurs as a part of the coupled motions that take place in the spine.
- This kind of force tries to twist the bone along its long axis
- Torsional forces generally result in short or long spiral fractures

# SHEAR

- Shear forces act on the mid plane of the disk and tend to cause each vertebra to undergo translation
  - move anteriorly, posteriorly, or from side to side in relation to the inferior vertebra
- In the lumbar spine,
  - Zygapophyseal joints resist some of the shear force, and the
  - Disks resist the remainder.
- When the load is sustained,
  - disks exhibit creep
  - zygapophyseal joints may have to resist all of the shear force.



Example of
Shearing Forces

# KINEMATICS

- The motions available to the column as a whole are flexion and extension, lateral flexion, and rotation.
- These motions appear to occur independently of each other
- At the level of the individual motion segment,
  - these motions are often coupled motions.

# VERTEBRAL COLUMN - MOVEMENTS

**CERVICAL**
Flexion
Extension
Lateral flexion

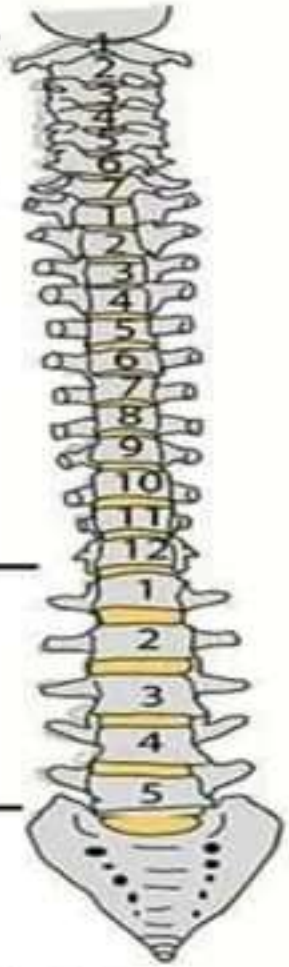
**ATLANTO-OCCIPITAL**
Flexion/extension

**ATLANTO-AXIAL**
Rotation only

**THORACIC**
Rotation only

**LUMBAR**
Flexion/extension
Lateral flexion

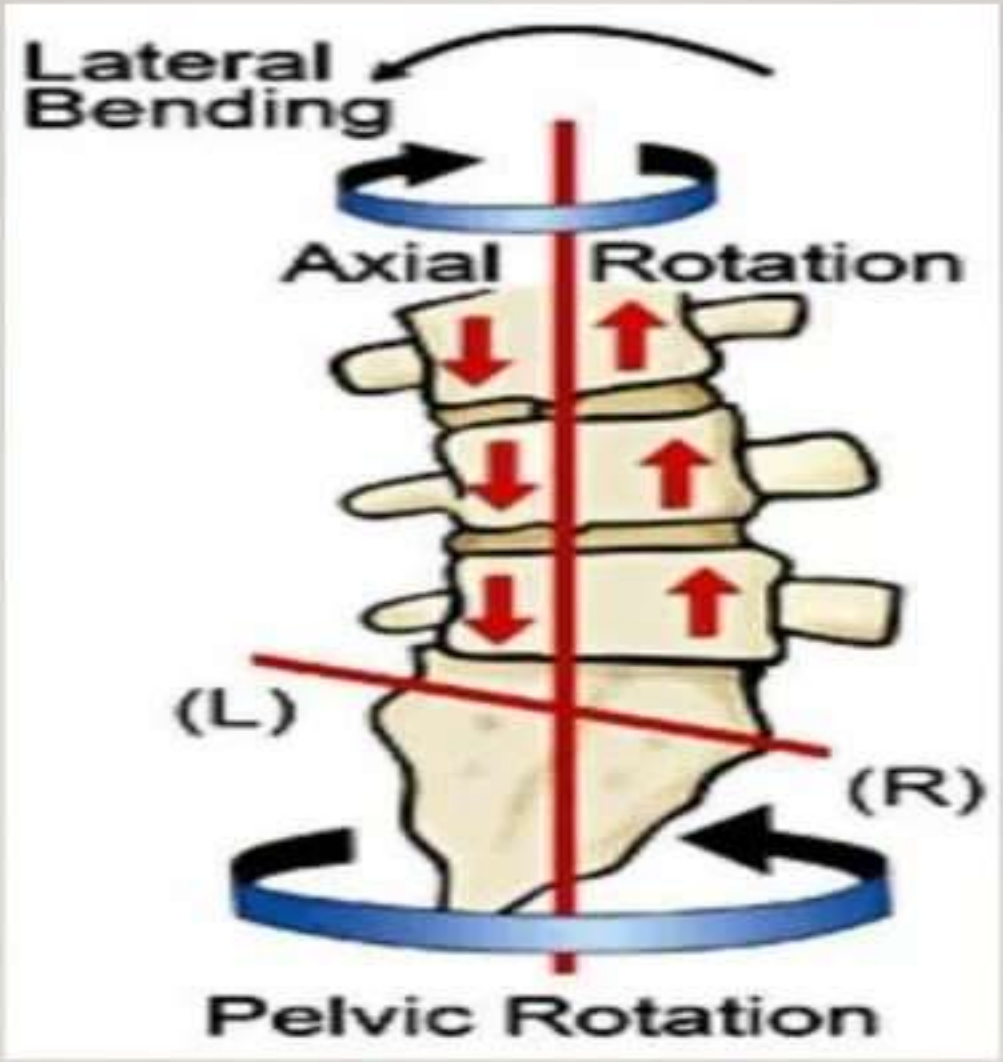
**SACRAL**
No movement



Movements at facet & intervertebral joints are individually small but accumulatively considerable

# COUPLED MOTION

- **Coupling** is defined as the consistent association of one motion about an axis with another motion around a different axis.
- The most predominant motions that exhibit coupled behaviors are
  - lateral flexion and rotation.
- Pure lateral flexion and pure rotation do not occur in any region of the spine.
- In order for either motion to occur, at least some of the other must occur as well

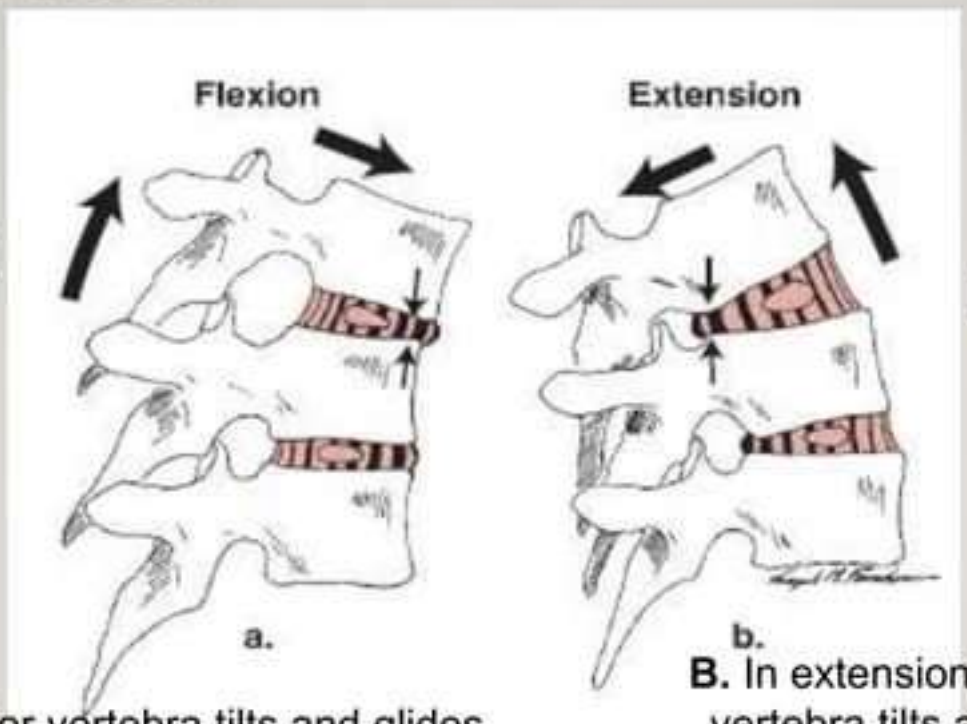

Lateral Bending
Axial Rotation
(L)
(R)
Pelvic Rotation

# KINEMATICS

- Coupling patterns, as well as the types and amounts of motion that are available
  - are complex,
  - differ from region to region
  - depend on the
    - spinal posture, curves,
    - orientation of the articulating facets,
    - fluidity, elasticity, and thickness of the inter-vertebral disks
    - extensibility of the muscles, ligaments, and joint capsules

# KINEMATICS

**Flexion**



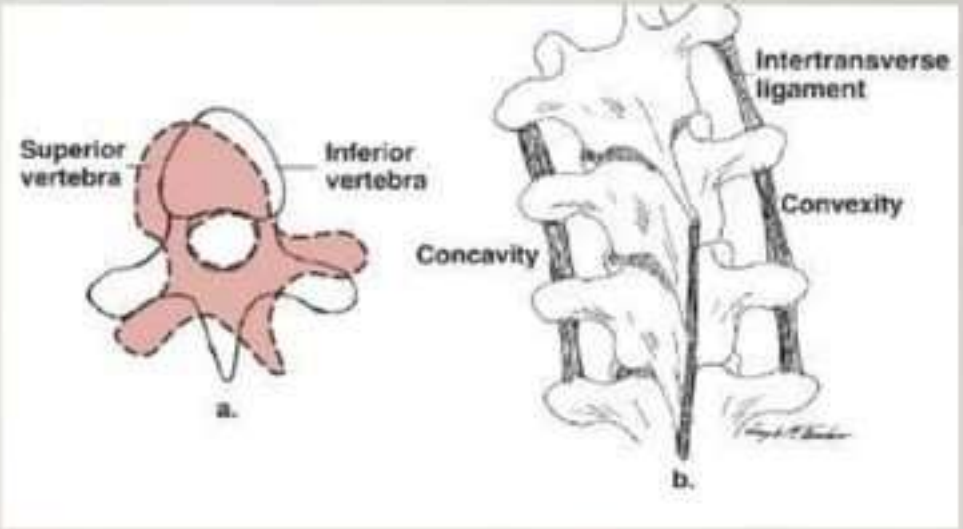

**Extension**

**A.** The superior vertebra tilts and glides anteriorly over the adjacent vertebra below during flexion. The anterior tilti ng and gliding cause compression and bulging of the anterior anulus fibrosus and stretching of the posterior anulus fibrosus.

**B.** In extension, the superior vertebra tilts and glides posteriorly over the vertebra below. The anterior anulus fibers are stretched, and the posterior portion of the disk bulges posteriorly.

# KINEMATICS

## Lateral Flexion




**A.** The superior vertebra tilts laterally and rotates over the adjacent vertebra below during lateral flexion.

**B.** Lateral flexion and rotation of the vertebra are limited by tension in the intertransverse ligament on the convexity of the curve.

# ROLE OF GLOBAL AND CORE MUSCLE ACTIVITY:

**TABLE 14.2** Stabilizing Features of Muscles Controlling the Spine

| Global Muscles | Core Muscles |
|---|---|
| *Characteristics* | |
| • Superficial: farther from axis of motion | • Deep: closer to axis of motion |
| • Cross multiple vertebral segments | • Attach to each vertebral segment |
| • Produce motion and provide large guy wire function | • Control segmental motion; segmental guy wire function |
| • Compressive loading with strong contractions | • Greater percentage of type I muscle fibers for muscular endurance |
| *Cervical region* | |
| • Sternocleidomastoid | • Rectus capitis anterior and lateralis |
| • Scalene | • Longus colli |
| • Levator scapulae | |
| • Upper trapezius | |
| • Erector spinae | |


THANK YOU!