CHAPTER 7
Joints of the Axial Body

CHAPTER OUTLINE

| Section 7.1 | Suture Joints of the Skull |
| Section 7.2 | Temporomandibular Joint (TMJ) |
| Section 7.3 | Spine |
| Section 7.4 | Spinal Joints |
| Section 7.5 | Atlanto-Occipital and Atlantoaxial Joints |
| Section 7.6 | Cervical Spine (the Neck) |
| Section 7.7 | Thoracic Spine (the Thorax) |
| Section 7.8 | Rib Joints of the Thoracic Spine (More Detail) |
| Section 7.9 | Lumbar Spine (the Abdomen) |
| Section 7.10 | Thoracolumbar Spine (the Spine) |
| Section 7.11 | Thoracolumbar Fascia and Abdominal Aponeurosis |

CHAPTER OBJECTIVES

After completing this chapter, the student should be able to perform the following:

1. Describe the relationship between cranial suture joints and childbirth.
2. List the major muscles of mastication, and describe their role in mastication.
3. Explain the possible relationship between TMJ dysfunction and the muscular system.
4. Describe the structure and function of the spine.
5. Define the curves of the spine, and describe their development.
6. Describe the structure and function of the median and lateral joints of the spine.
7. State the major difference between the function of the disc joint and the function of the facet joints.
8. Describe the orientation of the planes of the facets in the cervical, thoracic, and lumbar regions of the spine. In addition, explain and give examples of how the plane of the facet joints determines the type of motion that occurs at that segmental level.
9. Describe the structure and function of the atlanto-occipital and atlantoaxial joints of the cervical spine.
10. Describe the general structure and function of the cervical spine, thoracic spine, and lumbar spine.
11. List the joints at which rib motion occurs; explain how the movement of a bucket handle is used to illustrate rib motion.
12. Describe the roles of the muscles of respiration.
13. Explain the mechanism of thoracic breathing versus abdominal breathing.
14. Describe the structure and function of the thoracolumbar fascia and abdominal aponeurosis.
15. Classify structurally and functionally each joint covered in this chapter.
16. List the major ligaments and bursae of each joint covered in this chapter. In addition, explain the major function of each ligament.
17. State the closed-packed position of each joint covered in this chapter.
18. List and describe the actions possible at each joint covered in this chapter.
19. State the range of motion for each axial action of each joint covered in this chapter.
20. List and describe the reverse actions possible at each joint covered in this chapter.
21. List the major muscles/muscle groups and their joint actions for each joint covered in this chapter.
22. Define the key terms of this chapter.
23. State the meanings of the word origins of this chapter.

Indicates a video demonstration is available for this concept.
OVERVIEW

Chapters 5 and 6 laid the theoretical basis for the structure and function of joints. Chapters 7 through 9 now examine the structure and function of the joints of the human body regionally. Chapter 7 addresses the joints of the axial body; Chapter 8 addresses the joints of the lower extremity; and Chapter 9 addresses the joints of the upper extremity. Within this chapter, Sections 7.1 and 7.2 cover the suture joints and temporomandibular joints (TMJs) of the head, respectively. Sections 7.3 through 7.10 then cover the spine. Of these, Section 7.3 begins with a study of the spinal column as an entity, and Section 7.4 covers the general structure and function of spinal joints. Sections 7.5 through 7.10 then sequentially address the various regions of the spine (e.g., cervical, thoracic, lumbar). The last section of this chapter (Section 7.11) addresses the thoracolumbar fascia and abdominal aponeurosis of the trunk.

KEY TERMS

Abdomen (AB-do-men)
Abdominal aponeurosis (ab-DOM-i-nal)
Accessory atlantoaxial ligament (at-LAN-to-AK-see-al)
Alar ligaments of the dens (A-lar)
Annulus fibrosus (AN-you-lus fi-BROS-us)
Anterior atlanto-occipital membrane (an-TEER-ee-or at-LAN-to-ok-SIP-i-tal)
Anterior longitudinal ligament
Apical dental ligament (A-pi-kal)
Apical odontoid ligament (o-DONT-oid)
Apophyseal joint (a-POF-i-SEE-al)
Arcuate line (ARE-kew-it)
Atlantoaxial joint (at-LAN-to-AK-see-al)
Atlanto-occipital joint (at-LAN-to-ok-SIP-i-tal)
Atlanto-odontoid joint (at-LAN-to-o-DONT-oid)
Bifid spinous processes (BYE-fid)
Bifid transverse processes
Bucket handle movement
Cervical spine (SERV-i-kul)
Chondrosternal joints (KON-dro-STERN-al)
Costochondral joints (COST-o-KON-dral)
Costocorporeal joint (COST-o-kor-PO-ree-al)
Costospinal joints (COST-o-SPINE-al)
Costotransverse joint (COST-o-TRANS-verse)
Costotransverse ligament
Costovertebral joint (COST-o-VERT-i-bral)
Craniosacral technique (CRANE-ee-o-SAY-kral)
Cruciate ligament of the dens (KRU-shee-it, DENS)
Disc joint
Facet joint (fa-SET)
False ribs
Floating ribs
Forward-head posture
Hyperkyphotic (HI-per-kFOT-ik)
Hyperlordotic (HI-per-lor-DOT-ik)
Hypokyphotic (HI-po-kFOT-ik)
Hypolordotic (HI-po-lor-DOT-ik)
Interchondral joints (IN-ter-KON-dral)
Interchondral ligament
Interspinous ligaments (IN-ter-SPINE-us)
Intertransverse ligaments (IN-ter-TRANS-verse)
Intervertebral disc joint (IN-ter-VERTi-bral)
Superior costotransverse ligament (sue-PEER-ee-or COST-o-TRANS-verse)
Supraspinous ligament (SUE-pra-SPINE-us)
Swayback (SWAY-back)
Tectorial membrane (tek-TOR-ee-al)
Temporomandibular joint (TEM-po-ro-man-DIB-you-lar)
Temporomandibular joint dysfunction (dis-FUNK-shun)
Thoracic spine (thor-AS-ik)
Thoracolumbar fascia (thor-AK-o-LUM-bar FASH-ee-a)
Thoracic endplate (thur-AS-ik)
Thoracolumbar spine

WORD ORIGINS
❍ Alba—From Latin albus, meaning white
❍ Annulus—From Latin anulus, meaning ring
❍ Arcuate—From Latin arcuatus, meaning bowed
❍ Bifid—From Latin bifi dus, meaning cleft in two parts
❍ Cervical—From Latin cervicalis, meaning neck
❍ Concavity—From Latin con, meaning with, and cavus, meaning hollow, concavity
❍ Convexity—From Latin convexus, meaning vaulted, arched
❍ Corporeal—From Latin corpus, meaning body
❍ Costal—From Latin costa, meaning rib
❍ Cruciate—From Latin crux, meaning cross
❍ Flavum—From Latin flavus, meaning yellow
❍ Kyphosis—From Greek kyphosis, meaning bent, humpback
❍ Linea—From Latin linea, meaning line
❍ Lordosis—From Greek lordosis, meaning a bending backward
❍ Lumbar—From Latin lumbus, meaning loin
❍ Mastication—From Latin masticare, meaning to chew (Note: This originates from Greek masten,
meaning to feed, which in turn originates from Greek mastos, meaning breast, the first place from which a person receives sustenance.)
❍ Nuchal—From Latin nucha, meaning back of the neck
❍ Nucleus—From Latin nucleus, meaning little kernel, the inside/center of a nut (Note: Nucleus is diminutive for the Latin word nux, meaning nut.)
❍ Pulposus—From Latin pulpa, meaning flesh
❍ Radiate—From Latin radius, meaning ray, to spread out in all directions
❍ Scoliosis—From Greek scoliosis, meaning curvature, crooked
❍ Thoracic—From Greek thorax, meaning breastplate, chest
❍ Uncinate—From Latin uncinatus, meaning shaped like a hook
❍ Zygopophyseal—From Greek zygon, meaning yoke or joining, and apophysis, meaning offshoot

7.1 SUTURE JOINTS OF THE SKULL

❍ The suture joints of the skull are located between most bones of the cranium and also between most bones of the face (Figure 7-1).

BONES:
❍ Suture joints are located between adjacent bones of the cranium and face.
❍ All joints between the major bones of the cranium and face (except the temporomandibular joints
[TMJs]) are suture joints. Other nonsuture joints of the skull are the joints of the teeth and the joints between middle ear ossicles.

Joint structure classification: Fibrous joint
❍ Subtype: Suture joint
❍ Joint function classification: Synarthrotic

MAJOR MOTIONS ALLOWED:
❍ Nonaxial
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Miscellaneous:
- Movement at these joints is important during the birth process when the child must be delivered through the birth canal of the mother. Movement of the suture joints allows the child’s head to be compressed, allowing for an easier and safer delivery.
- Suture joints of the skull allow very little movement in an adult. As a person ages, many suture joints ossify and lose all ability to move (Box 7-1).

**FIGURE 7-1** Suture joint of the skull. Suture joints are structurally classified as fibrous joints and allow nonaxial motion.

<table>
<thead>
<tr>
<th>BOX 7-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Although suture joints allow little motion, practitioners of craniosacral technique and sacro-occipital technique assert that this motion is very important. When blockage of this motion occurs, these practitioners manipulate the suture joints of the skull.</td>
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### 7.2 TEMPOROMANDIBULAR JOINT (TMJ)

**BONES:**
- The temporomandibular joint (TMJ) is located between the temporal bone and the mandible (Figure 7-2).
- More specifically, it is located between the mandibular fossa of the temporal bone and the condyle of the ramus of the mandible.
- Joint structure classification: Synovial joint
  - Subtype: Modified hinge
- Joint function classification: Diarthrotic
  - Subtype: Uniaxial

**MAJOR MOTIONS ALLOWED:**
- The TMJ allows elevation and depression (axial movements) within the sagittal plane about a mediolateral axis (Figure 7-3).
- The TMJ allows protraction and retraction (nonaxial anterior and posterior glide movements) (Figure 7-4).
- The TMJ allows left and right lateral deviation (nonaxial lateral glide movements) (Figure 7-5; Box 7-2).
- Lateral deviation of the TMJ is actually a combination of spinning and glide. The condyle on the side to which the deviation is occurring spins, and the other condyle glides.

**MAJOR LIGAMENTS OF THE TEMPOROMANDIBULAR JOINT (BOX 7-3):**

**Fibrous Joint Capsule:**
- The fibrous capsule (Figure 7-6) thickens medially and laterally, providing stability to the joint. These thickenings are often referred to as the medial...
Mandibular fossa of the temporal bone

Temporomandibular joint (TMJ)

Condyle of the mandible

**FIGURE 7-2** Lateral view of the right temporomandibular joint (TMJ). The TMJ is the joint located between the temporal bone and the mandibular bone, hence TMJ.

**FIGURE 7-3** Lateral views that illustrate depression and elevation, respectively, of the mandible at the temporomandibular joints (TMJs). These are axial motions.
**FIGURE 7-4** Lateral views that illustrate protraction and retraction, respectively, of the mandible at the temporomandibular joints (TMJs). These are nonaxial glide motions.

**FIGURE 7-5** Anterior views that illustrate left lateral deviation and right lateral deviation, respectively, of the mandible at the temporomandibular joints (TMJs). These are nonaxial glide motions.
FIGURE 7-6  A, Left lateral view of the temporomandibular joint (TMJ). The temporomandibular ligament is located on and stabilizes the lateral side of the TMJ. B, Medial view illustrating the right stylomandibular and sphenomandibular ligaments. C, Coronal (i.e., frontal) section through the TMJ. The articular disc can be seen to divide the joint into two separate joint cavities: upper and lower. D, Sagittal section of the TMJ in the open position. The articular disc can be seen to move anteriorly along with the condyle of the mandible.

**collateral ligament** and the **lateral collateral ligament** of the TMJ.
- However, the capsule is fairly loose anteriorly and posteriorly, allowing the condyle and disc to freely translate forward and back.
- When the mandible depresses at the TMJs, it also protracts (i.e., glides anteriorly). Because the disc attaches into the anterior joint capsule, this motion pulls the disc anteriorly along with the condyle of the mandible.

**BOX 7-3 Ligaments of the Temporomandibular Joint (TMJ)**
- Fibrous capsule (thickened medially and laterally as the medial and lateral collateral ligaments)
- Temporomandibular ligament (located laterally)
- Stylomandibular ligament (located medially)
- Sphenomandibular ligament (located medially)

**Temporomandibular Ligament:**
- Location: The temporomandibular ligament is located on the lateral side of the joint (see Figure 7-6, A).
- The temporomandibular ligament is primarily composed of obliquely oriented fibers.
- Function: It limits depression of the mandible and stabilizes the lateral side of the joint.
- The temporomandibular ligament is also known as the **lateral ligament** of the TMJ.
- In addition to stabilizing the lateral side of the capsule of the temporomandibular joint (TMJ), the temporomandibular ligament also stabilizes the intra-articular disc. The superior head of the lateral pterygoid muscle attaches into the disc and exerts a medial pulling force on it. The temporomandibular ligament, being located laterally, opposes this pull, thereby stabilizing the medial-lateral placement of the disc within the joint.

**Stylomandibular Ligament:**
- Location: The stylomandibular ligament is located on the medial side of the joint (see Figure 7-6, A and B).
- More specifically, it is located from the styloid process of the temporal bone to the posterior border of the ramus of the mandible.

**Sphenomandibular Ligament:**
- Location: The sphenomandibular ligament is located on the medial side of the joint (see Figure 7-6, B).
More specifically, it is located from the sphenoid bone to the medial surface of the ramus of the mandible.

Function: Both the stylomandibular and sphenomandibular ligaments function to limit protraction (i.e., forward translation) of the mandible.

The term mastication means to chew, hence muscles of mastication involve moving the mandible at the temporomandibular joints (TMJs), because mandibular movement is necessary for chewing.

Four major muscles of mastication exist: (1) temporalis, (2) masseter, (3) lateral pterygoid, and (4) medial pterygoid. The temporalis and masseter are located superficially and can be easily accessed when palpating and doing bodywork. The lateral and medial pterygoids are located deeper, and addressing these muscles with bodywork is best done from inside the mouth (see figures in this box on the next page).

Another group of muscles that is involved with mastication is the hyoid group. The hyoid muscle group is composed of eight muscles: four suprahyoids and four infrahyoids. Three of the four suprahyoids attach from the hyoid bone inferiorly to the mandible superiorly. When these suprahyoids contract, if the hyoid bone is fixed, they move the mandible, hence assisting in mastication. The infrahyoid muscles are also important with respect to mastication. Because the hyoid bone does not form an osseous joint with any other bone of the body (it is the only bone in the human body that does not articulate with another bone), it is quite mobile and needs to be stabilized for the suprahyoids to contract and move the mandible. Therefore when the suprahyoids concentrically contract and shorten to move the mandible at the TMJs, the infrahyoids simultaneously contract isometrically to fix (i.e., stabilize) the hyoid bone. With the hyoid bone fixed, all the force of the pull of the contraction of the suprahyoids will be directed toward moving the mandible.

In addition to mandibular movement at the TMJs, mastication also involves muscular action by the tongue to move food within the mouth to facilitate chewing. Therefore muscles of the tongue may also be considered to be muscles of mastication.
MISCELLANEOUS:

- An intra-articular fibrocartilaginous disc is located within the TMJ (see Figure 7-6, C and D).
- The purpose of this disc is to increase the congruence (i.e., improve the fit and stability) of the joint surfaces of the temporal bone and mandible.
- Being a soft tissue, the disc also serves to cushion the TMJ.
- The disc divides the TMJ into two separate joint cavities: (1) an upper cavity and (2) a lower cavity.
- Technically, the lower joint of the temporomandibular joint (TMJ) (between the condyle of the mandible and the intra-articular disc) is a uniaxial joint. The upper joint of the TMJ (between the disc and the temporal bone) is a gliding nonaxial joint. Motions of the TMJ may occur solely at one of these joints or may occur as a combination of movements at both of these joints.
- The intra-articular disc is attached to and moves with the condyle of the mandible.
- The intra-articular disc also has attachments into the joint capsule of the TMJ.

- The lateral pterygoid muscle has tendinous attachments directly into the fibrous joint capsule and the intra-articular disc of the TMJ.
- **TMJ dysfunction** is a general term that applies to any dysfunction (i.e., abnormal function) of the TMJ (Box 7-5).

**Temporomandibular joint (TMJ) dysfunction** has many possible causes. Of these many causes, two may be of special interest to massage therapists and bodyworkers. One is tightness or imbalance of the muscles that cross the TMJ (especially the lateral pterygoid because of its attachment directly into the capsule and disc). The second is **forward-head posture**, a common postural deviation in which the head and often the upper cervical vertebrae are translated anteriorly (i.e., forward). This forward-head posture is believed to create tension on the TMJs as a result of the hyoid muscles being stretched and pulled taut, resulting in a pulling force being placed on the mandible, consequently placing a tensile stress on the TMJs.
The spine, also known as the spinal column or vertebral column, is literally a column of vertebrae stacked one on top of another.

### ELEMENTS OF THE SPINE:

- The spine has four major regions (Figure 7-7).
- These four regions contain a total of 26 movable elements.
- The following are the four regions:
  1. **Cervical spine** (i.e., the neck), containing seven vertebrae (C1-C7)
  2. **Thoracic spine** (i.e., the upper and middle back), containing 12 vertebrae (T1-T12)
  3. **Lumbar spine** (i.e., the low back), containing five vertebrae (L1-L5)
  4. **Sacrococcygeal spine** (within the pelvis), containing one sacrum, which is formed by the fusion of five vertebrae (S1-S5) that have never fully formed, and one coccyx, which is usually four bones (Co1-Co4) that may partially or fully fuse as a person ages.

### SHAPE OF THE ADULT SPINE VIEWED POSTERIORITY:

- Viewed posteriorly, the adult spine should ideally be straight (see Figure 7-7, A, Box 7-6).

**BOX 7-6**

By definition, any spinal curve that exists from a posterior view is termed a scoliosis; a scoliotic curve is a C-shaped curvature of the spine that exists within the frontal plane. Ideally the spine should be straight within the frontal plane; therefore a scoliosis is considered to be a postural pathology of the spine. A scoliosis is named *left* or *right*, based on the side of the curve that is convex. For example, if a curve in the lumbar spine exists that is convex to the left (therefore concave to the right), it is called a *left lumbar scoliosis.* A scoliosis may even have two or three curves (called an S or double-S scoliosis, respectively); again, each of the curves is named for the side of the convexity.

![Figure 7-7](image-url)  
**FIGURE 7-7**  
A. Posterior view of the entire spine.  
B. Right lateral view of the entire spine.  
The spine is composed of the cervical region containing C1-C7, the thoracic region containing T1-T12, the lumbar region containing L1-L5, and the sacrococcygeal region containing the sacrum and coccyx.
SHAPE OF THE ADULT SPINE VIEWED LATERALLY:

- Viewed laterally, the adult spine should have four curves in the sagittal plane (see Figure 7-7, B).
- It has two primary spinal curves that are formed first (before birth) and two secondary spinal curves that are formed second (after birth).
- The two primary curves of the spine are the thoracic and sacrococcygeal curves.
  - These curves are kyphotic (i.e., concave anteriorly and convex posteriorly).
- The two secondary curves of the spine are the cervical and lumbar curves.
  - These curves are lordotic (i.e., concave posteriorly and convex anteriorly).

DEVELOPMENT OF THE SPINAL CURVES:

- When a baby is born, only one curve to the entire spine exists, which is kyphotic. In effect, the entire spinal column is one large C-shaped kyphotic curve (Figure 7-8).
- Two activities occur during our childhood development that create the cervical and lumbar lordoses:
  1. When a child first starts to lift his or her head to see the world (which is invariably higher), the spinal joints of the neck must extend, creating the cervical lordosis. This cervical lordosis is necessary to bring the position of the head posteriorly so that the head’s weight is balanced over the trunk (see Figure 7-8, B).
  2. Next, when the child wants to sit up (and later stand up), the spinal joints of the low back must extend, creating the lumbar lordosis. This lumbar lordosis is necessary to bring the position of the trunk posteriorly so that the trunk’s weight is balanced over the pelvis (see Figure 7-8, C). Otherwise, when the child tries to sit up, he or she would fall forward.
- In effect, the cervical and lumbar lordotic secondary curves are formed after birth, whereas the thoracic and sacrococcygeal regions retain their original primary kyphotic curves. The net result is a healthy adult spine that has four curves in the sagittal plane.

- The four kyphotic and lordotic curves of an adult spine are usually attained at approximately the age of 10 years (Box 7-7).

BOX 7-7 Spotlight on Sagittal Plane Spinal Curves

A kyphotic curve is a kyphosis; a lordotic curve is a lordosis. The terms kyphosis and lordosis are often misused in that they are used to describe an individual who has an excessive kyphotic or lordotic curve. It is normal and healthy to have a kyphosis in the thoracic and sacral spines and to have a lordosis in the cervical and lumbar spines. An excessive kyphosis should correctly be termed a hyperkyphosis or a hyperkyphotic curve; an excessive lordosis should correctly be termed a hyperlordosis or a hyperlordotic curve. Similarly, decreased curves would be termed hypolordotic and hypokyphotic curves. Many people have a hypolordotic lower cervical spine (i.e., decreased lower cervical lordotic curve) — either because the curve never fully developed or because it was lost after it developed — with a compensatory hyperlordotic upper cervical curve. This is largely because of the posture of sitting with the head forward when writing (e.g., at a desk). At a very early age we give our children crayons to draw with; then they graduate to pencils in elementary school and pens in high school and beyond. The tremendous number of hours sitting with the neck and head bent (i.e., flexed) over a piece of paper causes a decrease in the extension of the lower cervical spinal joints, which is a decrease in the cervical lordotic curve. (Note: Many other postures also contribute to a loss of the lower cervical lordosis.)

FUNCTIONS OF THE SPINE:

The spine has four major functions (Figure 7-9):

1. To provide structural support for the body (see Figure 7-9, A)
   - The spine provides a base of support for the head and transmits the entire weight of the head, arms, neck, and trunk to the pelvis.
2. To allow for movement (see Figure 7-9, B)
   - As with all joints, the spine must find a balance between structural stability and movement. Generally, the more stable a joint is, the less...
FIGURE 7-9 The four major functions of the spine. A, Posterior view illustrating its weight-bearing function; the lines drawn indicate the weight of the head, arms, and trunk being borne through the spine and transmitted to the pelvis. B, Lateral view demonstrating the tremendous movement possible of the spine (specifically, flexion and extension of the spinal joints are shown). C, The spine surrounds and protects the spinal cord, located within the spinal canal. D, Lateral view that illustrates how the spine can function to absorb shock and compressive forces; both the disc joints themselves and the spinal curves contribute to shock absorption (i.e., absorbing compression force). (B modeled after Kapandji IA: Physiology of the joints: the trunk and the vertebral column, ed 2, Edinburgh, 1974, Churchill Livingstone.)
mobile it is; and the more mobile a joint is, the less stable it is. The spine is a remarkable structure in that it can provide so much structural support to the body and yet also afford so much movement!

- Although each spinal joint generally allows only a small amount of movement, when the movements of all 25 spinal segmental levels are added up, the spine allows a great deal of movement in all three planes (see Table 7-1).

- The spine allows for movement of the head, neck, trunk, and pelvis. (Illustrations of these motions are shown in Sections 7.5 [head], 7.6 [neck], 7.10 [trunk], and 8.3 through 8.5 [pelvis].)

- The head can move relative to the neck at the atlanto-occipital joint (AOJ).

- The neck can move at the cervical spinal joints located within it (and/or relative to the head at the AOJ, or relative to the trunk at the C7-T1 joint).

- The trunk can move at the thoracic and lumbar spinal joints located within it (or relative to the pelvis at the lumbosacral joint).

### TABLE 7-1 Average Ranges of Motion of the Entire Spine from Anatomic Position (Including the Atlanto-Occipital Joint [AOJ] between the Head and the Neck) *

<table>
<thead>
<tr>
<th></th>
<th>Flexion 135 Degrees</th>
<th>Extension 120 Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right lateral flexion</td>
<td>90 Degrees</td>
<td>Left lateral flexion</td>
</tr>
<tr>
<td>Right rotation</td>
<td>120 Degrees</td>
<td>Left rotation 120 Degrees</td>
</tr>
</tbody>
</table>

*No exact agreement exists among sources as to the average or ideal ranges of motion of joints. The ranges given in this text are approximations. Actual ranges of motion vary somewhat from one individual to another. Furthermore, ranges of motion vary enormously with age.

### 7.4 SPINAL JOINTS

- Spinal joints are joints that involve two contiguous vertebrae (i.e., two adjacent vertebrae) of the spine.

- Naming a spinal joint is usually done by simply naming the levels of the two vertebrae involved. For example, the joint between the fifth cervical vertebra (C5) and the sixth cervical vertebra (C6) is called the **C5-C6 joint**.

- Again, using this example, the C5-C6 joint is one segment of the many spinal joints and is often referred to as a **segmental level** of the spine. The C6-C7 joint would be another, C7-T1 would be the next, and so forth.

- At any one typical segmental level of the spine, one median joint and two lateral joints exist (the median joint is located in the middle, and the lateral joints are located to the sides, hence the names).

- Typically the median joint is an intervertebral disc joint and the lateral joints are the two vertebral facet joints (Figure 7-10).

- The pelvis can move relative to the trunk at the lumbosacral joint.

- To protect the spinal cord (see Figure 7-9, C)
  - Neural tissue is very sensitive to damage. For this reason, the spinal cord is hidden away within the spinal canal and thereby afforded a great degree of protection from damage.

- To provide shock absorption for the body (see Figure 7-9, D)
  - Being a weight-bearing structure, the spine provides shock absorption to the body whenever a compression force occurs, such as walking, running, or jumping. This is accomplished in two ways:
    - The nucleus pulposus in the center of the discs absorb this compressive force.
    - The curves of the spine bend and increase slightly, absorbing some of this compressive force. They then return to their normal posture afterward.

![Figure 7-10](image) The median and lateral spinal joints. The median spinal joint is the disc joint; the lateral spinal joints are the facet joints.
INTERVERTEBRAL DISC JOINT:

- An intervertebral disc joint is located between the bodies of two contiguous vertebrae. This joint is often referred to simply as the disc joint.
- Joint structure classification: Cartilaginous joint
  - Subtype: Symphysis
- Joint function classification: Amphiarthrotic

Miscellaneous:

- A disc joint is composed of three parts: (1) an outer annulus fibrosus, (2) an inner nucleus pulposus, and (3) the two vertebral endplates (Figure 7-11).
- Discs are actually quite thick, accounting for approximately 25% of the height of the spinal column. The thicker a disc is, the greater its shock absorption ability and the more movement it allows.
- In addition to allowing movement, two major functions of the disc joint are (1) to absorb shock and (2) to bear the weight of the body.
- The spinal disc joint bears approximately 80% of the weight of the body above it (the other 20% is borne through the facet joints).
- The presence of a disc is also important because it maintains the opening of the intervertebral foramina (through which the spinal nerves travel) by creating a spacer between the two vertebral bodies (Box 7-8).

The outer annulus fibrosus is a tough fibrous ring of fibrocartilaginous material that encircles and encloses the inner nucleus pulposus.

- The annulus fibrosus is composed of up to 10 to 20 concentric rings of fibrous material.
- These rings are arranged in a basket weave configuration that allows the annulus fibrosus to resist forces from different directions (Figure 7-12).
- More specifically, the basket weave configuration of the fibers of the annulus fibrosus gives the disc a great ability to resist distraction forces (i.e., a vertical separation of the two vertebrae), shear forces (i.e., a horizontal sliding of one vertebra on the other), and torsion forces (i.e., a twisting of one vertebra on the other).

- The inner nucleus pulposus is a pulplike gel material that is located in the center of the disc and is enclosed by the annulus fibrosus.
- The nucleus pulposus has a water content that is 80% or greater (Box 7-9).

- The vertebral endplate is composed of both hyaline articular cartilage and fibrocartilage, and it lines the surface of the vertebral body. Each disc joint contains two vertebral endplates: one lining the inferior surface of the superior vertebra, and the other lining the superior surface of the inferior vertebra.

If a disc thins excessively, the decreased size of an intervertebral foramen may impinge on the spinal nerve that is located within it. This is commonly known as a pinched nerve and may result in referral of pain, numbness, or weakness in the area that the nerve innervates.

(Models after Kapandji IA: Physiology of the joints: the trunk and the vertebral column, ed 2, Edinburgh, 1974, Churchill Livingstone.)

FIGURE 7-11 The three major components of the intervertebral disc joint: (1) the annulus fibrosus, (2) the nucleus pulposus, and (3) the vertebral endplates of the vertebral bodies.

FIGURE 7-12 The basket weave configuration of the concentric layers of the annulus fibrosus of the intervertebral disc joint. The reader should note how each successive layer has a different orientation to its fibers than the previous layer. Each layer is optimal at resisting the force that runs along its direction. The sum total of having all these varying fiber directions is to resist and stabilize the disc joint along almost any line of force to which the joint may be subjected. (Models after Kapandji IA: Physiology of the joints: the trunk and the vertebral column, ed 2, Edinburgh, 1974, Churchill Livingstone.)
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When a pathologic condition of the disc occurs, it usually involves damage to the annulus fibrosus, allowing the inner nucleus pulposus to bulge or rupture (i.e., herniate) through the annular fibers. The term slipped disc is a nonspecific lay term that does not really mean anything. Discs do not “slip”; they either bulge or rupture. When this does occur, the most common danger is that the nearby spinal nerve may be compressed in the intervertebral foramen, resulting in a pinched nerve that refers symptoms to whatever location of the body that this nerve innervates. Another common pathologic condition of the disc is disc thinning. The reason that the nucleus pulposus has such a high water content is that it is largely composed of proteoglycans. Therefore, given the principle of thixotropy (see Section 3.16), movement of the spine is critically important toward maintaining proper disc hydration and health. Because disc hydration is responsible for the thickness of the disc, loss of disc hydration would result in thinning of the disc height (disc thinning) and approximation of the vertebral bodies, resulting in an increased likelihood of spinal nerve compression in the intervertebral foramina.

**BOX 7-9  Spotlight on Pathologic Disc Conditions**

When a pathologic condition of the disc occurs, it usually involves damage to the annulus fibrosus, allowing the inner nucleus pulposus to bulge or rupture (i.e., herniate) through the annular fibers. The term slipped disc is a nonspecific lay term that does not really mean anything. Discs do not “slip”; they either bulge or rupture. When this does occur, the most common danger is that the nearby spinal nerve may be compressed in the intervertebral foramen, resulting in a pinched nerve that refers symptoms to whatever location of the body that this nerve innervates. Another common pathologic condition of the disc is disc thinning. The reason that the nucleus pulposus has such a high water content is that it is largely composed of proteoglycans. Therefore, given the principle of thixotropy (see Section 3.16), movement of the spine is critically important toward maintaining proper disc hydration and health. Because disc hydration is responsible for the thickness of the disc, loss of disc hydration would result in thinning of the disc height (disc thinning) and approximation of the vertebral bodies, resulting in an increased likelihood of spinal nerve compression in the intervertebral foramina.

**VERTEBRAL FACET JOINTS:**

- Technically, the correct name for a facet joint is an apophyseal joint or a zygapophyseal joint. However, these joints of the spine are usually referred to as simply the facet joints.
- Because a facet is a smooth flat surface (think of the facets of a cut stone ring), and the facet joints are formed by the smooth flat surfaces (i.e., the facets) of the articular processes, the name facet joint is usually used to refer to these apophyseal (or zygapophyseal) joints of the spine. However, it must be kept in mind that in referring to these joints as facet joints, the context must be clear because other joints in the body involve facets. Facet joints are also often referred to as Z joints (Z for zygapophyseal).
  - A vertebral facet joint is located between the articular processes of two contiguous vertebrae.
  - More specifically, a facet joint of the spine is formed by the inferior articular process of the superior vertebra articulating with the superior articular process of the inferior vertebra (Figure 7-13).
  - The actual articular surfaces of a facet joint are the facets of the articular processes, hence the name facet joint.
  - There are two facet joints, paired left and right, between each two contiguous vertebrae.
  - Joint structure classification: Synovial joint
    - Subtype: Plane
  - Joint function classification: Diarthrotic

**Miscellaneous:**

- The main purpose of a facet joint is to guide movement.
- The planes of the facets of the facet joint determine the movement that is best allowed at that level of the spine (Figure 7-14).
- The cervical facets are generally oriented in an oblique plane that is approximately 45 degrees between the transverse and frontal planes. Therefore, these facet joints freely allow transverse and frontal plane motions (i.e., right rotation and left rotation within the transverse plane, and right lateral flexion and left lateral flexion within the frontal plane).
- The orientation of the cervical facets is often compared with the angle of roof shingles. However, as good

![Figure 7-13](image-url)  
**Figure 7-13**  A, Vertebral facet joints. A, Posterior view of two contiguous vertebrae. On the left side, the facet joint capsule is seen intact. On the right side, the facet joint capsule has been removed, showing the superior and inferior articular processes; the articular facets of these processes articulate to form a facet joint. The superior articular facet surface of the right articular process of the inferior vertebra is also visible. B, Cross-section through a facet joint showing the articular cartilage, fibrous capsule, and synovial lining.
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FIGURE 7-14  General orientation of the planes of the facets for the three regions of the spine. A, Lateral view of a cervical vertebra demonstrating the oblique plane of the cervical facet joints, which is approximately 45 degrees between the transverse and frontal planes. B, Posterolateral view of a thoracic vertebra demonstrating the frontal plane orientation of the thoracic facet planes. C, Posterolateral view of a lumbar vertebra demonstrating the sagittal plane orientation of the lumbar facet planes.

as these regional rules for facet orientation are, it should be pointed out that they are generalizations. For example, the facet orientation at the upper cervical spine is nearly perfectly in the transverse plane, not a 45-degree angle like the midcervical region. Furthermore, the orientation of the facet planes is a gradual transition from one region of the spine to the next region. For example, the facet plane orientation of C6-C7 of the cervical spine is more similar to the facet plane orientation of T1-2 of the thoracic spine than it is similar to C2-3 of the cervical spine. To determine what motion is best facilitated by the facet planes at any particular segmental level, the facet joint orientation at that level should be observed.

The thoracic facets are generally oriented within the frontal plane. Therefore these facet joints freely allow right lateral flexion and left lateral flexion within the frontal plane.

The lumbar facets are generally oriented within the sagittal plane. Therefore these facet joints freely allow flexion and extension within the sagittal plane.

SPINAL JOINT SEGMENTAL MOTION—COUPLING DISC AND FACET JOINTS:

Comparing and contrasting motion allowed by the disc and facet joints, the following can be stated:

- The disc joint and the two facet joints at any particular spinal joint level work together to create the movement at that segmental level.
- Disc joints are primarily concerned with determining the amount of motion that occurs at a particular segmental level; facet joints are primarily concerned with guiding the motion that occurs at that segmental level.
- The thicker the disc is, the more motion it allows; the orientation of the plane of the facets of that segmental level determines what type of motion is best allowed at that level.
MAJOR MOTIONS ALLOWED:

☞ Spinal joints allow flexion and extension (i.e., axial movements) within the sagittal plane around a mediolateral axis (Figure 7-15).
☞ Spinal joints allow right lateral flexion and left lateral flexion (i.e., axial movements) within the frontal plane around an anteroposterior axis (Figure 7-16).
☞ Spinal joints allow right rotation and left rotation (i.e., axial movements) within the transverse plane around a vertical axis (Figure 7-17).
☞ Spinal joints allow gliding translational movements in three directions (Figure 7-18):
  1. Right-side and left-side (lateral) translation (Perhaps the best visual example of lateral translation of the spinal joints of the neck is the typically thought of “Egyptian” dance movement wherein the head is moved from side to side.)
  2. Anterior and posterior translation
  3. Superior and inferior translation

Reverse Actions:

☞ Generally when we speak of motion at spinal joints, it is usually the more superior vertebra that is thought of as moving on the more fixed inferior vertebra; this is certainly the usual scenario for a person who is either standing or seated, because the lower part of our body is more fixed in these positions. However, it is possible, especially when we are lying down, for the more superior vertebrae to stay fixed and to move the more inferior vertebrae relative to the more fixed superior vertebrae of the spine.

MAJOR LIGAMENTS OF THE SPINAL JOINTS:

The following ligaments provide stability to the spine by limiting excessive spinal motions (Figures 7-19 and 7-20; Box 7-10).

<table>
<thead>
<tr>
<th>Ligaments of the Spine</th>
</tr>
</thead>
<tbody>
<tr>
<td>☞ Fibrous capsules of the facet joints</td>
</tr>
<tr>
<td>☞ Annulus fibrosus of the disc joints</td>
</tr>
<tr>
<td>☞ Anterior longitudinal ligament</td>
</tr>
<tr>
<td>☞ Posterior longitudinal ligament</td>
</tr>
<tr>
<td>☞ Ligamenta flava</td>
</tr>
<tr>
<td>☞ Interspinous ligaments</td>
</tr>
<tr>
<td>☞ Supraspinous ligament</td>
</tr>
<tr>
<td>☞ Intertransverse ligaments</td>
</tr>
<tr>
<td>☞ Nuchal ligament</td>
</tr>
</tbody>
</table>

FIGURE 7-15  Flexion and extension within the sagittal plane of a vertebra on the vertebra that is below it.  A, Flexion of the vertebra.  B, Neutral position.  C, Extension of the vertebra. These motions are a combination of disc and facet joint motion. (Note: All views are lateral.)

FIGURE 7-16  Left lateral flexion and right lateral flexion within the frontal plane of a vertebra on the vertebra that is below it.  A, Left lateral flexion of the vertebra.  B, Neutral position.  C, Right lateral flexion of the vertebra. These motions are a combination of disc and facet joint motion. (Note: All views are posterior.)
Left rotation and right rotation within the transverse plane of a vertebra on the vertebra that is below it. A, Left rotation of the vertebra. B, Neutral position. C, Right rotation of the vertebra. These motions are a combination of disc and facet joint motion. The reader should note that rotation of a vertebra is named for where the anterior aspect of the vertebra (i.e., the body) points. (Note: All views are superior.)

Translation motions of a vertebra on the vertebra that is below it. A, Anterior translation of the vertebra. B, Posterior translation. C, Lateral translation to the right of the vertebra (lateral translation to the left would be the opposite motion). D, Superior translation of the vertebra (inferior translation would be the opposite motion). All translation motions are a combination of disc and facet joint motion. A and B are lateral views; C and D are anterior views.

Note that in all cases the ligaments of the spine limit motion that would occur in the opposite direction from where the ligament is located (this rule is true for all ligaments of the body). For example, anterior ligaments limit the posterior motion of vertebral extension; posterior ligaments limit the anterior motion of vertebral flexion. The dividing line for anterior versus posterior is determined by where the center of motion is (i.e., where the axis of motion is located). For sagittal plane motions of the spine, the axis of motion is located between the bodies.

Annulus Fibrosus of the Disc Joints:
- Location: The annulus fibrosus is located between adjacent vertebral bodies (see Figures 7-11 and 7-19, A).
- Function: It stabilizes the disc joints and limits the extremes of all spinal motions (except inferior translation).

Anterior Longitudinal Ligament:
- Location: The anterior longitudinal ligament runs along the anterior margins of the bodies of the vertebrae (see Figure 7-19, A).
- Function: It limits extension of the spinal joints.

Posterior Longitudinal Ligament:
- Location: The posterior longitudinal ligament runs along the posterior margins of the bodies of the vertebrae (within the spinal canal) (see Figure 7-19, A).
- Function: It limits flexion of the spinal joints.

Ligamenta Flava:
- Two ligamenta flava (singular: ligamentum flavum) are located on the left and right sides of the spinal column.
- Location: They run along the anterior margins of the laminae of the vertebrae within the spinal canal (see Figure 7-19).
- Function: They limit flexion of the spinal joints.
**Intervertebral foramen**

**Spinous process**

**Supraspinous ligament**

**Interspinous ligament**

**Lamina**

**Pedicle**

**Body**

**Intervertebral disc**

**Anterior longitudinal ligament**

**Posterior longitudinal ligament**

**Ligamentum flavum**

**Transverse process**

**Lamina**

**Pedicle**

**Intervertebral foramen**

**Body**

**Intervertebral disc**

**Anterior longitudinal ligament**

**Posterior longitudinal ligament**

**Supraspinous ligament**

**Interspinous ligament**

**Ligamentum flavum A**

**Ligamentum flavum B**

**Transverse process**

**Lamina**

**Pedicle**

**Intervertebral foramen**

**Posterior longitudinal ligament**

**Ligamentum flavum**

**Intertransverse ligament**

**Supraspinous ligament**

**Interspinous ligament**

**Ligamentum flavum**

**FIGURE 7-19**  Ligaments of the spine.  
*A*  Later al view of a sagittal cross-section.  
*B*  Posterior view of a coronal (frontal) plane cross-section in which all structures anterior to the pedicles have been removed.  This view best illustrates the ligamenta flava running along the anterior aspect of the laminae within the spinal canal.

**FIGURE 7-20**  Demonstration of how ligaments of the spine limit motion.  
*A*  The superior vertebr a in extension.  The anterior longitudinal ligament located anteriorly becomes taut, limiting this motion.  
*B*  The superior vertebra in flexion.  All ligaments on the posterior side (supraspinous, interspinous, ligamentum flavum, and posterior longitudinal ligaments) become taut, limiting this motion.  
*C*  The superior vertebr a in (right) lateral flexion.  The intertransverse ligament on the opposite (left) side becomes taut, limiting this motion.  (Note: In this position the opposite side [left] facet joint capsule would also become taut, limiting this motion.  
*A*  and  
*B*  are lateral views;  
*C*  is a posterior view.)

**Interspinous Ligaments:**

- **Location:** The **interspinous ligaments** are separate short ligaments that run between adjacent spinous processes of the vertebrae (see Figure 7-19, A).
- **Function:** They limit flexion of the spinal joints.

**Supraspinous Ligament:**

- **Location:** The **supraspinous ligament** runs along the posterior margins of the spinous processes of the vertebrae (see Figure 7-19, A).
- **Function:** It limits flexion of the spinal joints.

**Intertransverse Ligaments:**

- **Location:** The **intertransverse ligaments** are separate short ligaments that run between adjacent transverse processes of the vertebrae (see Figure 7-20, C).
- **Function:** They limit contralateral (i.e., opposite-sided) lateral flexion of the spinal joints. They also limit rotation away from anatomic position.
- **Intertransverse spinal ligaments are usually absent in the neck.**

**Nuchal Ligament:**

- **Location:** The **nuchal ligament** is a ligament that runs along and between the spinous processes from C7 to the external occipital protuberance (EOP) of the skull. The nuchal ligament is a thickening of the supraspinous ligament of the cervical region.
- **Function:** It limits flexion of the spinal joints and provides a site of attachment for muscles of the neck (Figure 7-21).
The trapezius, splenius capitis, rhomboids, serratus posterior superior, and cervical spinales (of the erector spinae group) all attach into the nuchal ligament of the neck (Box 7-11).

The nuchal ligament is especially taut and stable in four-legged animals, such as dogs and cats. Their posture is such that their head is imbalanced in thin

**FIGURE 7-21** The nuchal ligament. **A,** Posterior view of a young woman. The nuchal ligament of the cervical region is seen to be taut as she flexes her head and neck at the spinal joints. **B,** Lateral view of the nuchal ligament. (A from Neumann DA: Kinesiology of the musculoskeletal system: foundations for physical rehabilitation, ed 2 St Louis, 2010, Mosby. B modeled from Muscolino J: The muscle and bone palpation manual, with trigger points, referral patterns, and stretching, St Louis, 2009, Mosby.)
air (whereas our bipedal posture allows for the center of weight of our head to be centered and balanced on our trunk), allowing gravity to pull on their head and neck, making them fall into flexion. This requires a constant opposition pulling force toward extension to maintain their head in its position. The nuchal ligament gives them a strong passive force toward extension, allowing their posterior neck extensor musculature to not have to work as hard. Certainly, even with a nuchal ligament, most dogs and cats still love to have their posterior neck musculature rubbed, given its role in maintaining their neck and head posture.

**MAJOR MUSCLES OF THE SPINAL JOINTS:**

Many muscles cross the spinal joints. Regarding the actions of these muscles, the following general rules can be stated:

- **Muscles that extend the spine** are located in the posterior trunk and neck and run with a vertical direction to their fibers. The erector spinae group, transversospinalis group, and other muscles in the posterior neck are examples of spinal extensors.

- **Muscles that flex the spine** are located in the anterior body and run with a vertical direction to their fibers. The muscles of the anterior abdominal wall and the muscles in the anterior neck are examples of spinal flexors.

- **Muscles that laterally flex the spine** are located on the side of the body and run with a vertical direction to their fibers. Almost all flexors and extensors are also lateral flexors, because they are usually located anterior and lateral or posterior and lateral. It should be noted that all lateral flexors are ipsilateral lateral flexors (i.e., whichever side of the body that they are located on is the side to which they laterally flex the body part [head, neck, and/or trunk]).

- **Muscles that rotate the spine** are more variable in their location. For example, muscles that provide right rotation of the head, neck, or trunk may be located anteriorly or posteriorly; furthermore, they may be located on the right side of the body (in which case they are ipsilateral rotators) or the left side of the body (in which case they are contralateral rotators). Prominent rotators of the trunk include the external and internal abdominal obliques and the transversospinalis group muscles. Prominent rotators of the head and/or neck include the sternocleidomastoid (SCM), upper trapezius, and splenius capitis and cervicis muscles, as well as the transversospinalis group muscles.

### 7.5 ATLANTO-OCcipital and Atlantoaxial Joints

Two cervical spinal joints merit special consideration:

- The **atlanto-occipital joint** (AOJ), located between the atlas (C1) and the occiput.
- The **atlantoaxial joint** (AAJ or C1-C2 joint), located between the atlas (C1) and the axis (C2).

#### ATLANTO-OCcipital Joint:

- The AOJ (Figure 7-22) is formed by the superior articular facets of the atlas (the first cervical vertebra [i.e., C1]) meeting the occipital condyles.

- Therefore, the AOJ has two lateral joint surfaces (i.e., two facet joints). Because the atlas has no body, no median disc joint exists as is usual for spinal joints.

- The occipital condyles are convex, and the facets of the atlas are concave. This allows the occipital condyles to rock in the concave facets of the atlas.

- Movement of the AOJ allows the cranium to move relative to the atlas (i.e., the head to move on the neck).

- Joint structure classification: Synovial joint
  - Subtype: Condyloid
  - Joint function classification: Diarthrotic

**FIGURE 7-22** Posterior view of the atlanto-occipital joint (AOJ). In this photo, the occipital bone is flexed (i.e., lifted upward) to better show this joint. The AOJ is composed of two lateral joint articulations between the superior articular processes of the atlas and the condyles of the occiput.
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❍ Subtype: Triaxial
❍ Note: The amount of rotation possible at the atlanto-occipital joint (AOJ) is considered to be negligible by many sources. Therefore these sources place the AOJ as being biaxial.

Movement of the Head at the Atlanto-Occipital Joint:

Even though the head usually moves with the neck, the head and neck are separate body parts and can move independently of each other. The presence of the AOJ allows the head to move independently of the neck. When the head moves, it is said to move relative to the neck at the AOJ (Figures 7-23 to 7-25). Following are the movements of the head at the AOJ (the ranges of motion are given in Table 7-2):

<table>
<thead>
<tr>
<th>Flexion</th>
<th>5 Degrees</th>
<th>Extension</th>
<th>10 Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right lateral flexion</td>
<td>5 Degrees</td>
<td>Left lateral flexion</td>
<td>5 Degrees</td>
</tr>
<tr>
<td>Right rotation</td>
<td>5 Degrees</td>
<td>Left rotation</td>
<td>5 Degrees</td>
</tr>
</tbody>
</table>

TABLE 7-2  Average Ranges of Motion of the Head at the Atlanto-Occipital Joint (AOJ) from Anatomic Position

FIGURE 7-23  Lateral view illustrating sagittal plane motions of the head at the atlanto-occipital joint (AOJ). A illustrates flexion; B illustrates extension. The sagittal plane actions of flexion and extension are the primary motions of the AOJ.

ATLANTOAXIAL (C1-C2) JOINT:

❍ The AAJ allows the atlas (C1) to move on the axis (C2) (Figure 7-26).
❍ The AAJ is composed of one median joint and two lateral joints.
❍ The median joint of the AAJ is the atlanto-odontoid joint.
❍ The atlanto-odontoid joint is formed by the anterior arch of the atlas meeting the odontoid process (i.e., dens) of the axis.
❍ Articular facets are located on the joint surfaces of the atlas and axis (i.e., on the posterior surface of the anterior arch of the atlas and the anterior surface of the dens of the axis).
The atlanto-odontoid joint actually has two synovial cavities, one anterior to the dens and the other posterior to the dens.

The two lateral joints are the facet joints.
- The facet joints of the AAJ are formed by the inferior articular facets of the atlas (C1) meeting the superior articular facets of the axis (C2).

Joint structure classification: Synovial joints
- Subtype: Atlanto-odontoid joint: Pivot joint
- Lateral facet joints: Plane joints

Joint function classification: Diarthrotic
- Subtype: Biaxial
- The atlanto-odontoid joint itself is often described as a uniaxial pivot joint. However, the atlantoaxial joint (AAJ) complex (i.e., the median and two lateral joints) allows motion in two planes around two axes. Therefore all three AAJs together including the atlanto-odontoid joint, technically are biaxial joints.
- Note: Intervertebral disc joints are located between bodies of adjacent vertebrae. Because the atlas has no
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FIGURE 7-26 Oblique (superior posterolateral) view of the atlantoaxial joint (AAJ) (C1-C2). The AAJ is composed of three joints: a median atlanto-odontoid joint and two lateral facet joints.

body, there cannot be an intervertebral disc joint between the atlas and axis at the atlantoaxial (C1-C2) joint, and there cannot be an intervertebral disc joint between the atlas and occiput at the atlanto-occipital joint.

Movements of the Atlantoaxial Joint:

- Right rotation/left rotation (i.e., axial movements) in the transverse plane around a vertical axis are the primary motions of the AAJ.
- Approximately half of all the rotation of the cervical spine occurs at the atlantoaxial joint (AAJ). When you turn your head from side to side indicating no, the majority of that movement occurs at the AAJ.
- Flexion/extension (i.e., axial movements) in the sagittal plane around a mediolateral axis are also allowed.
- Right lateral flexion/left lateral flexion (i.e., axial movements) are negligible.
- The ranges of motion of the AAJ are given in Table 7-3.

MAJOR LIGAMENTS OF THE OCCIPITO-ATLANTOAXIAL REGION:

The following ligaments all provide stability to the AOJ and AAJ by limiting excessive motion of these joints (Box 7-12):

<table>
<thead>
<tr>
<th>BOX 7-12</th>
<th>Ligaments of the Upper Cervical (Occipito-Atlantoaxial) Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Nuchaligament</td>
<td></td>
</tr>
<tr>
<td>- Facet joint fibrous capsules of the atlanto-occipital joint (AOJ)</td>
<td></td>
</tr>
<tr>
<td>- Facet joint fibrous capsules of the atlantoaxial joint (AAJ)</td>
<td></td>
</tr>
<tr>
<td>- Superior atlanto-occipital membrane</td>
<td></td>
</tr>
<tr>
<td>- Tectorial membrane</td>
<td></td>
</tr>
<tr>
<td>- Accessory atlantoaxial ligament</td>
<td></td>
</tr>
<tr>
<td>- Cruciate ligament of the dens</td>
<td></td>
</tr>
<tr>
<td>- Alar ligaments of the dens</td>
<td></td>
</tr>
<tr>
<td>- Apical odontoid ligament</td>
<td></td>
</tr>
<tr>
<td>- Anterior atlanto-occipital membrane</td>
<td></td>
</tr>
<tr>
<td>- Anterior longitudinal ligament</td>
<td></td>
</tr>
<tr>
<td>- Anterior atlanto-occipital membrane</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 7-3  Average Ranges of Motion of the Atlas at the Atlantoaxial Joint (AAJ) (C1-C2 Joint) from Anatomic Position

<table>
<thead>
<tr>
<th>Flexion</th>
<th>Right lateral flexion</th>
<th>Extension</th>
<th>Left rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Degrees</td>
<td>Negligible</td>
<td>10 Degrees</td>
<td>40 Degrees</td>
</tr>
<tr>
<td>Right rotation</td>
<td>40 Degrees</td>
<td>Negligible</td>
<td></td>
</tr>
</tbody>
</table>

Nuchal Ligament:

- The nuchal ligament (see Figure 7-21) of the cervical spine continues through this region to attach onto the occiput.
- Functions: It limits flexion in this region and provides an attachment site for many muscles of the neck.

Facet Joint Fibrous Capsules of the Atlanto-Occipital Joint:

- Location: The facet joint fibrous capsules are located between the condyles of the occiput and the superior articular processes of the atlas (Figure 7-27).
- Function: They stabilize the atlanto-occipital facet joints.

Facet Joint Fibrous Capsules of the Atlantoaxial Joint:

- Location: The facet joint fibrous capsules are located between the inferior articular processes of the atlas and the superior articular processes of the axis (see Figure 7-27).
- Function: They stabilize the atlantoaxial facet joints.

Posterior Atlanto-Occipital Membrane:

- Location: The posterior atlanto-occipital membrane is located between the posterior arch of the atlas and the occiput.
- The posterior atlanto-occipital membrane between the atlas and occiput is the continuation of the ligamentum flavum of the spine (see Figure 7-27).
- Function: It stabilizes the AOJ.

Tectorial Membrane:

- Location: The tectorial membrane is located within the spinal canal, just posterior to the cruciate ligament of the dens (Figure 7-28, A).
- The tectorial membrane is the continuation of the posterior longitudinal ligament in the region of C2 to the occiput.
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FIGURE 7-27  Posterior view of the upper cervical region demonstrating the facet joint capsules of the atlanto-occipital joint (AOJ) and atlantoaxial joint (AAJ), as well as the posterior atlanto-occipital membrane between the atlas and occiput. The posterior atlanto-occipital membrane is the continuation of the ligamentum flavum.

FIGURE 7-28  Posterior views of the upper cervical region within the spinal canal. A, Tectorial membrane that is the continuation of the posterior longitudinal ligament. B, Cruciate ligament of the dens located between the axis, atlas, and occiput. The cruciate ligament of the dens has three parts: (1) a superior vertical band, (2) an inferior vertical band, and (3) a transverse band. C, Apical odontoid and alar ligaments between the odontoid process of the axis and the atlas and occiput.
The accessory atlantoaxial ligament (which runs from C2-C1) is considered to be composed of deep fibers of the tectorial membrane (see Figure 7-28, A and B).

Function: It stabilizes the AAJ and AOJ; more specifically, it limits flexion in this region.

**Cruciate Ligament of the Dens:**

- The cruciate ligament of the dens attaches the dens of the axis to the atlas and occiput (see Figure 7-28, B).
- The cruciate ligament is given this name because it has the shape of a cross; cruciate means cross.
- It has three parts: (1) a transverse band, (2) a superior vertical band, and (3) an inferior vertical band.
- The transverse band of the cruciate ligament is often called the transverse ligament of the atlas; the superior vertical band of the cruciate ligament is often called the apical dental ligament (located directly posterior to the apical odontoid ligament).
- Location: It is located within the spinal canal, between the tectorial membrane and the alar ligaments (anterior to the tectorial membrane and posterior to the alar ligaments).
- Functions: It stabilizes the dens and limits anterior translation of the atlas at the AAJ and the head at the AOJ.

**Alar Ligaments of the Dens:**

- Two alar ligaments of the dens (left and right) exist.
- Location: They run from the dens to the atlas and occiput (see Figure 7-28, B and C).
- Functions: They stabilize the dens by attaching it to the atlas and occiput, limit right and left rotation of the head at the AOJ and the atlas at the AAJ, and limit superior translation of the head at the AOJ and the atlas at the AAJ.

**Apical Odontoid Ligament:**

- Location: The apical odontoid ligament runs from the dens to the occiput (see Figure 7-28, C).
- Functions: It stabilizes the dens by attaching it to the occiput and limits superior and anterior translation of the head at the AOJ.

**Anterior Longitudinal Ligament:**

- Location: The anterior longitudinal ligament continues through this region, attaching to the body of the axis, the anterior tuber cle of the atlas, and ultimately onto the occiput (Figure 7-29).
- Function: It limits extension in this region.

**Anterior Atlanto-Occipital Membrane:**

- Location: The anterior atlanto-occipital membrane is located between the anterior arch of the atlas and the occiput (see Figure 7-29).
- Function: It stabilizes the AOJ.

**MAJOR MUSCLES OF THE OCCIPITO-ATLANTOAXIAL REGION:**

Many muscles cross the AOJ and AAJ. (A complete atlas of all muscles of the body is located in Chapter 15.) Although the functional groups of spinal muscles were addressed in Section 7.4, the following muscles should be specially noted:

- Suboccipital group
  - Rectus capitis posterior major
  - Rectus capitis posterior minor
  - Obliquus capitis inferior
  - Obliquus capitis superior
  - Rectus capitis anterior and rectus capitis lateralis of the prevertebral group
The cervical spine defines the neck as a body part.

**FEATURES OF THE CERVICAL SPINE:**

**Composition of the Cervical Spine:**
- The cervical spine is composed of seven vertebrae (Figure 7-30).

**Superior**

- C1 (atlas)
- C2 (axis)
- C3
- C4
- C5
- C6
- C7
- T1

**Inferior**

- C2 spinous process
- C7 spinous process

**FIGURE 7-30** Right lateral view of the cervical spine. The reader should note the lordotic curve, which is concave posteriorly (and therefore convex anteriorly).

- From superior to inferior, these vertebrae are named C1 through C7.
- C1: The first cervical vertebra (C1) is also known as the atlas, because it holds up the head, much as the Greek mythologic figure Atlas is depicted as holding up the world (Figure 7-31, A).
- Actually, the Greek mythologic figure Atlas was forced by Zeus to hold up the sky, not the Earth. However, in artworks, Atlas is more often depicted as holding up the Earth.
- C2: The second cervical vertebra (C2) is also known as the axis, because the toothlike dens of C2 creates an axis of rotation around which the atlas can rotate (Figure 7-31, B). The spinous process of C2 is quite large and is a valuable landmark for palpation.
- C7: The seventh cervical vertebra (C7) is also known as the vertebral prominens because it is the most prominent cervical vertebra (and often a valuable landmark for palpation).

**Special Joints of the Cervical Spine:**
- The joint between the atlas and the occiput is known as the AOJ.
- The joint between the atlas and the axis is known as the AAJ (or the C1-C2 joint). (See Section 7.5 for more information on the AOJ and AAJ.)

**Transverse Foramina:**
- Cervical vertebrae have transverse foramina in their transverse processes (Figure 7-32, A; Box 7-13).

**Bifid Spinous Processes:**
- The cervical spine has bifid spinous processes (i.e., they have two points instead of one) (see Figure 7-32, Box 7-14).

**FIGURE 7-31** A, Greek mythologic figure Atlas supporting the world on his shoulders. Similarly, the first cervical vertebra (C1) supports the head. For this reason, C1 is known as the atlas. B, Dens of the second cervical vertebra (C2) forming an axis of rotation that the atlas can move around. For this reason, C2 is known as the axis.
CHAPTER 7  Joints of the Axial Body

Joints of the Axial Body

Spinous process
Posterior tubercle of transverse process
Anterior tubercle of transverse process
Lamina
Superior articular facet of superior articular process
Pedicle
Transverse foramen
Superior lip (uncinate process) of vertebral body
Vertebral body

A

Superior articular process
Superior lip (uncinate process) of vertebral body
Spinous process

B

Anterior tubercle of transverse process
Inferior articular process
Superior lip (uncinate process) of vertebral body
Posterior tubercle of transverse process

FIGURE 7-32  A, Superior view of a typical cervical vertebra.  B, Lateral view. The reader should note the bifid spinous and transverse processes.

Bifid Transverse Processes:
- Most transverse processes of the cervical spine are **bifid transverse processes**. The two aspects are called the *anterior* and *posterior tubercles* (see Figure 7-32).

Uncinate Processes:
- The superior surfaces of the bodies of cervical vertebrae are not flat as in the rest of the spine; rather their lateral sides curve upward. This feature of the superior cervical body is called an **uncinate process**.
- Where the lateral sides of two contiguous cervical vertebrae meet each other is called an **uncovertebral joint**. (Uncovertebral joints are often called the **joints of Von Luschka**, after the person who first described them.) These uncovertebral joints provide additional stability to the cervical spine because they serve to mildly limit frontal and transverse plane motions of the cervical vertebrae (see Figure 7-32).

Curve of the Cervical Spine:
- The cervical spine has a lordotic curve (i.e., it is concave posteriorly) (see Figure 7-30).
FUNCTIONS OF THE CERVICAL SPINE:

- Because only the head is superior to the neck, the cervical region has less of a weight-bearing function than the thoracic and lumbar regions. Having less weight-bearing function means that the cervical spine does not need to be as stable and can allow more movement.
- The cervical spine is the most mobile region of the spine, moving freely in all three planes (Tables 7-4 to 7-6).
- One reason that the cervical spine is so very mobile is the thickness of the intervertebral discs. The discs of the cervical spine account for approximately 40% of the height of the neck.
- The orientation of the cervical facet joints begins in the transverse plane at the top of the cervical spine; this accounts for the tremendous ability of the upper neck to rotate in the transverse plane.
- The cervical facet joints gradually transition from the transverse plane toward the frontal plane so that the facets of the mid to lower neck are obliquely oriented (similar to shingles on a 45-degree sloped roof) approximately halfway between the transverse and frontal planes (see Section 7.4, Figure 7-14, A).

MAJOR MOTIONS ALLOWED:

- The cervical spinal joints allow flexion and extension (i.e., axial movements) of the neck in the sagittal plane around a mediolateral axis (Figure 7-33, A and B).
- The cervical spinal joints allow right lateral flexion and left lateral flexion (i.e., axial movements) of the neck in the frontal plane around an anteroposterior axis (Figure 7-33, C and D).
- The cervical spinal joints allow right rotation and left rotation (i.e., axial movements) of the neck in the transverse plane around a vertical axis (Figure 7-33, E and F; Box 7-15).
- The cervical spinal joints allow gliding translational movements in all three directions (see Section 7.4, Figure 7-18).

### TABLE 7-4 Average Ranges of Motion of the Lower Cervical Spine (C2-C3 through C7-T1 Joints) from Anatomic Position

<table>
<thead>
<tr>
<th>Motion</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>40 Degrees</td>
</tr>
<tr>
<td>Right lateral flexion</td>
<td>40 Degrees</td>
</tr>
<tr>
<td>Right rotation</td>
<td>40 Degrees</td>
</tr>
<tr>
<td>Extension</td>
<td>60 Degrees</td>
</tr>
<tr>
<td>Left lateral flexion</td>
<td>40 Degrees</td>
</tr>
<tr>
<td>Left rotation</td>
<td>40 Degrees</td>
</tr>
</tbody>
</table>

### TABLE 7-5 Average Ranges of Motion of the Entire Cervical Spine (i.e., the Neck; C1-C2 through C7-T1 Joints) from Anatomic Position (Numbers Include the Atlantoaxial Joint [AAJ] [C1-C2] and the Lower Cervical Spine Joints [C2-C3 through C7-T1])

<table>
<thead>
<tr>
<th>Motion</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>45 Degrees</td>
</tr>
<tr>
<td>Right lateral flexion</td>
<td>40 Degrees</td>
</tr>
<tr>
<td>Right rotation</td>
<td>80 Degrees</td>
</tr>
<tr>
<td>Extension</td>
<td>70 Degrees</td>
</tr>
<tr>
<td>Left lateral flexion</td>
<td>40 Degrees</td>
</tr>
<tr>
<td>Left rotation</td>
<td>80 Degrees</td>
</tr>
</tbody>
</table>
### TABLE 7-6  
**Average Ranges of Motion of the Entire Cervicocranial Region from Anatomic Position (the Neck and the Head) (Numbers Include the Entire Cervical Spine [C1-C2 through C7-T1 Joints] and the Head at the Atlanto-Occipital Joint [AOJ])**

<table>
<thead>
<tr>
<th>Motion</th>
<th>Flexion</th>
<th>50 Degrees</th>
<th>Extension</th>
<th>80 Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right lateral flexion</td>
<td>45 Degrees</td>
<td>Left lateral flexion</td>
<td>45 Degrees</td>
<td></td>
</tr>
<tr>
<td>Right rotation</td>
<td>85 Degrees</td>
<td>Left rotation</td>
<td>85 Degrees</td>
<td></td>
</tr>
</tbody>
</table>

### BOX 7-15  
**Spotlight on Coupled Cervical Motions**

Because the facet joints of the cervical spine are oriented between the transverse and frontal planes, when the cervical spine laterally flexes, it ipsilaterally rotates as well. (Note: Remember that vertebral rotation is named for the direction in which the anterior bodies face; the spinous processes would therefore point in the opposite direction.) Therefore these two joint actions of lateral flexion and ipsilateral rotation are coupled together. Consequently, lateral flexion with rotation to the same side is a natural motion for the neck. A and B, Posterior views. A depicts the entire neck and head; B is a close-up of two cervical vertebrae.
FIGURE 7-33 Motions of the neck at the spinal joints. A and B are lateral views that depict flexion and extension in the sagittal plane, respectively. C and D are posterior views that depict left lateral flexion and right lateral flexion in the frontal plane, respectively. E and F are anterior views that depict right rotation and left rotation in the transverse plane, respectively. Note: A through F depict motions of the entire cranio-cervical region (i.e., the head at the atlanto-occipital joint and the neck at the spinal joints).
7.7 THORACIC SPINE (THE THORAX)

- The thoracic spine defines the thorax of the body (i.e., the upper part of the trunk).
- Note: The trunk of the body is made up of the thorax and the abdomen. The **thorax** is the region of the thoracic spine, and the **abdomen** is the region of the lumbar spine.

**FEATURES OF THE THORACIC SPINE:**

**Composition of the Thoracic Spine:**
- The thoracic spine is composed of 12 vertebrae (Figure 7-34).
- From superior to inferior, these vertebrae are named T1 through T12.

- The 12 thoracic vertebrae correspond to the 12 pairs of ribs that articulate with them.

**Special Joints (Costospinal Joints):**
- The ribs articulate with all 12 thoracic vertebrae. Generally each rib has two costospinal articulations with the spine: (1) the costovertebral joint and (2) the costotransverse joint (see Section 7.8, Figure 7-35). (For more detail on the rib joints of the thoracic spine, see Section 7.8.)
- The **costovertebral joint** is where the rib meets the bodies/discs of the spine.
- The **costotransverse joint** is where the rib meets the transverse process of the spine.

**FIGURE 7-34** Right lateral view of the thoracic spine. The reader should note the kyphotic curve, which is concave anteriorly (and therefore convex posteriorly).
Collectively, the costovertebral and costotransverse joints may be called the **costospinal joints**.

Both the costovertebral and costotransverse joints are synovial joints.

These joints are nonaxial and allow gliding.

These joints both stabilize the ribs by giving them a posterior attachment to the spine and allow mobility of the ribs relative to the spine.

Note: Ribs #1 through #10 also articulate with the sternum anteriorly; these joints are called **sternocostal joints**.

**Curve of the Thoracic Spine:**

The thoracic spine has a kyphotic curve; in other words, it is concave anteriorly (see Figure 7-34, Box 7-16).

**FUNCTIONS OF THE THORACIC SPINE:**

The thoracic region of the spine is far less mobile than the cervical and lumbar regions (Table 7-7).

Being less mobile, the thoracic spine is more stable than the cervical and lumbar regions and therefore is injured less often.

The major reason for the lack of movement of the thoracic spine is the presence of the ribcage in this region.

The ribcage primarily limits lateral flexion motion in the frontal plane and rotation motion in the transverse plane.

Lateral flexion is limited as a result of the ribs of the ribcage crowding into one another on the side to which the trunk is laterally flexed.

Rotation is limited as a result of the presence of the rib lateral to the vertebra.

**TABLE 7-7**  
**Average Ranges of Motion of the Thoracic Spine (T1-T2 through T12-L1 joints) from Anatomic Position**

<table>
<thead>
<tr>
<th>Motion</th>
<th>Flexion</th>
<th>Extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>35 Degrees</td>
<td>25 Degrees</td>
</tr>
<tr>
<td>Right lateral flexion</td>
<td>25 Degrees</td>
<td>25 Degrees</td>
</tr>
<tr>
<td>Right rotation</td>
<td>30 Degrees</td>
<td>30 Degrees</td>
</tr>
</tbody>
</table>

*As in the cervical spine, when the thoracic spine laterally flexes, it ipsilaterally rotates to some degree as well. Therefore these two actions are coupled together.*

The spinous processes also limit range of motion of the thoracic spine. Because they are long and oriented inferiorly, they obstruct and limit extension of the thoracic spine.

The orientation of the thoracic facet joints is essentially in the frontal plane (see Section 7.4, Figure 7-14, B), which should allow for ease of lateral flexion motion within the frontal plane; however, because of the presence of the ribcage, lateral flexion is limited.

In the lower thoracic region, the facet plane orientation gradually begins to change from the frontal plane to the sagittal plane (which is the orientation that the lumbar facets have). This sagittal orientation facilitates sagittal plane actions (i.e., flexion and extension).

**MAJOR MOTIONS ALLOWED:**

For motions of the thoracic spine, see Section 7.10; illustrations in Figure 7-42 demonstrate thoracolumbar motion of the trunk at the spinal joints.

The thoracic spinal joints allow flexion and extension (i.e., axial movements) of the trunk in the sagittal plane around a mediolateral axis.

The thoracic spinal joints allow right lateral flexion and left lateral flexion (i.e., axial movements) of the trunk in the frontal plane around an anteroposterior axis.

The thoracic spinal joints allow right rotation and left rotation (i.e., axial movements) of the trunk in the transverse plane around a vertical axis.

The thoracic spinal joints allow gliding translational movements in all three directions (see Section 7.4, Figure 7-18).

As stated in Section 7.7, the ribs articulate with all 12 thoracic vertebrae posteriorly. The joints between the ribs and the spinal column are known collectively as the **costospinal joints**. Usually each rib has two articulations with the spine: (1) the costovertebral joint and (2) the costotransverse joint (Figure 7-35, A).

The costovertebral joint is where the rib meets the vertebral bodies/discs.

The costovertebral joint where a rib articulates with the vertebral body is also known as the **costocorpo-real joint**. *Corpus* is Latin for body.
CHAPTER 7 Joints of the Axial Body

The costotransverse joint is where the rib meets the transverse process of the spinal vertebra.

Furthermore, most of the ribs articulate with the sternum anteriorly at the sternocostal joints.

The proper movement of all rib joints is extremely important during respiration. (For more information on respiration, see Box 7-17.)

COSTOSPINAL JOINTS IN MORE DETAIL:

Costovertebral Joint:

The typical thoracic vertebral body has two costal hemifacets: one superiorly and one inferiorly (see Figure 7-35, B).

The head of the rib therefore forms a joint with the inferior costal hemifacet of the vertebra above and the superior costal hemifacet of the vertebra below, as well as the inter vertebral disc that is located between the two vertebral bodies (see Figure 7-35, A).

The costovertebral joint is stabilized by two ligamentous structures:

- Its fibrous joint capsule
- The radiate ligament (see Figure 7-35, B and C)

The typical costotransverse joint occurs between ribs #2 through #10 and the spine.

The costovertebral joint of rib #1 meets a full costal facet at the superior end of the body of the T1 vertebra (i.e., no hemifacet on the body of C7 exists).

The costovertebral joints of ribs #11 and #12 meet a full costal facet located at the superior body of T11 and T12, respectively.

Costotransverse Joint:

The typical thoracic vertebra has a full costal facet on its transverse processes (see Section 4.2, Figure 4-27, E).

The costotransverse joint is where the tubercle of the rib meets the transverse process of the thoracic vertebra.

The costotransverse joint is stabilized by four ligamentous structures:

- A fibrous joint capsule
- A costotransverse ligament: This long ligament firmly attaches the neck of the rib with the entire length of the transverse process of the same level vertebra (see Figure 7-35, C).
- A lateral costotransverse ligament: This ligament attaches the costal tubercle of the rib to the lateral...
Inspiration/Expiration

Respiration is the process of taking air into and expelling air out of the lungs. Taking air into the lungs is called inspiration (i.e., inhalation); expelling air from the lungs is called expiration (i.e., exhalation). When air is taken into the lungs, the volume of the thoracic cavity expands; when air is expelled from the lungs, the volume of the thoracic cavity decreases. Therefore any muscle that has the ability to change the volume of the thoracic cavity is a muscle of respiration. Generally the volume of the thoracic cavity can be affected in two ways.

One way is to affect the ribcage by moving the ribs at the sternocostal and costospinal joints. As a general rule, elevating ribs increases thoracic cavity volume (see figure); therefore muscles that elevate ribs are generally categorized as muscles of inspiration. The primary muscle of inspiration is the diaphragm because it elevates the lower six ribs. Other inspiratory muscles include the external intercostals, scalenes, pectoralis minor, levatores costarum, and the serratus posterior superior. Conversely, muscles that depress the ribs are generally categorized as expiratory muscles and include the internal intercostals, subcostales, and serratus posterior inferior.

The other way in which the volume of the thoracic cavity can be affected is via the abdominal region. In addition to increasing thoracic cavity volume by having the thoracic cavity expand outward when the ribcage itself expands, the thoracic cavity can also expand downward into the abdominal cavity region. Conversely, if the contents of the abdominal cavity push up into the thoracic cavity, the volume of the thoracic cavity decreases. In this regard the diaphragm is again the primary muscle of inspiration; when it contracts, in addition to raising the lower ribs, its central dome also drops down against the abdominal contents, thereby increasing the volume of the thoracic cavity. Muscles of expiration that work via the abdominal region are muscles of the abdominal wall; principal among these are the rectus abdominis, external abdominal oblique, internal abdominal oblique, and transversus abdominis.

Relaxed versus Forceful Breathing

Breathing is often divided into two types: (1) relaxed (i.e., quiet) breathing and (2) forceful breathing. During normal healthy relaxed breathing, such as when a person is calmly reading a book, the only muscle that is recruited to contract is the diaphragm. For normal healthy relaxed expiration, no muscles need to contract; instead, the diaphragm simply relaxes and the natural recoil of the tissues that were stretched during inspiration (tissues of the ribcage and abdomen) push back against the lungs, expelling the air. However, when we want to breathe forcefully, such as would occur during exercise, many other muscles of respiration are recruited. These muscles, as already mentioned, act on the thoracic cavity via the ribcage or the abdominal region. Generally speaking, whenever a pathology exists that results in labored breathing (any chronic obstructive pulmonary disorder such as asthma, emphysema, or chronic bronchitis), accessory muscles of respiration are recruited and may become hypertrophic.

Diaphragm Function

As has been stated, the diaphragm is an inspiratory muscle and increases thoracic cavity volume in two ways: (1) it expands the ribcage by lifting lower ribs, and (2) it drops down, pushing against the abdominal contents in the abdominal cavity. The manner in which the diaphragm is generally considered to function is as follows.

When the diaphragm contracts, the bony peripheral attachments are more fixed and the pull is on the central tendon, which causes the center (i.e., the top of the dome) to drop down (against the abdominal viscera). This raises the volume of the thoracic cavity to allow the lungs to inflate and expand for inspiration. This aspect of the diaphragm’s contraction is usually called abdominal breathing.

As the diaphragm continues to contract, the pressure caused by the resistance of the abdominal viscera prohibits the central dome from dropping any farther and the dome now becomes less able to move (i.e., more fixed). The pull exerted by the contraction of the fibers of the diaphragm is now exerted peripherally on the ribcage, elevating the lower ribs and causing the anterior ribcage and sternum to push anteriorly. This further increases the volume of the thoracic cavity to allow the lungs to inflate and expand. This aspect of the diaphragm’s contraction is usually called thoracic breathing.
margin of the transverse process of the same level vertebra (see Figure 7-35, C).

- A superior costotransverse ligament: This ligament attaches the rib to the transverse process of the vertebra that is located superiorly (see Figure 7-35, B).
- The typical costotransverse joints occur between ribs #1 through #10 and thoracic vertebrae #1 through #10 of the spine.
- Ribs #11 and #12 do not articulate with transverse processes of the thoracic spine; hence they have no costotransverse joints.

**BOX 7-18  Ligaments of the Costospinal Joints**

<table>
<thead>
<tr>
<th>Costovertebral joint:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibrous joint capsule</td>
</tr>
<tr>
<td>Radiate ligament</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Costotransverse joint:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibrous joint capsule</td>
</tr>
<tr>
<td>Costotransverse ligament</td>
</tr>
<tr>
<td>Lateral costotransverse ligament</td>
</tr>
<tr>
<td>Superior costotransverse ligament</td>
</tr>
</tbody>
</table>

**STERNOCOSTAL JOINTS:**

- Seven pairs of **sternocostal joints** (Figure 7-36) attach ribs to the sternum anteriorly.
- The first seven pairs of ribs attach directly to the sternum via their costal cartilages.
- These ribs are called **true ribs**.
- The ribs that do not attach directly into the sternum via their own costal cartilages are termed **false ribs**.
- The eighth through tenth pairs of ribs join into the costal cartilage of the seventh rib pair. These ribs are termed **false ribs**.
- The eleventh and twelfth rib pairs do not attach to the sternum at all; hence they are free floating anteriorly. These ribs are floating false ribs but are usually referred to simply as **floating ribs**.

**Sternocostal Rib Joints:**

- Joint structure classification: Cartilaginous joint
  - Subtype: Synchondrosis
- Joint function classification: Amphiarthrotic
  - Subtype: Gliding

**Miscellaneous:**

- A sternocostal joint can be divided into three separate joints (Figure 7-37):
  1. **Costochondral joints** are located between the ribs and their cartilages.
     - A costochondral joint unites a rib directly with its costal cartilage. Neither a joint capsule nor any ligaments are present. The periosteum of the rib gradually transforms into the perichondrium of the costal cartilage. These joints permit very little motion.
     - Ten pairs of costochondral joints exist (between ribs #1 through #10 and their costal cartilages).
  2. **Chondrosternal joints** are located between the costal cartilages of the ribs and the sternum.
     - A chondrosternal joint is a gliding synovial joint (except the first one, which is a synarthrosis)

**FIGURE 7-36** Anterior view of the ribcage. The sternocostal joint is located between a rib and the sternum. Seven pairs of sternocostal cartilages exist.

**FIGURE 7-37** Anterior view of the sternum and part of the ribcage on one side of the body. Each sternocostal joint is actually composed of two articulations: (1) the costochondral joint located between a rib and its costal cartilage and (2) the chondrosternal joint located between the costal cartilage and the sternum (in addition, interchondral joints are located between adjacent costal cartilages of lower ribs). Furthermore, the manubriosternal and sternoxiphoid joints are located among the three parts of the sternum.
reinforced by its fibrous joint capsule and a radiate ligament.

- Seven pairs of chondrosternal joints exist between costal cartilages and the sternum.

3. **Interchondral joints** are located between the costal cartilages of ribs #5 through #10.
- These joints are synovial lined and reinforced by a capsule and an interchondral ligament.

**INTRASTERNAL JOINTS:**

Two intrasternal joints are located between the three parts of the sternum (see Figure 7-37).

1. The **manubriosternal joint** is located between the manubrium and body of the sternum.
2. The **sternoxiphoid joint** is located between the body and xiphoid process of the sternum.
- These joints are fibrocartilaginous amphiarthrotic joints that are stabilized by the manubriosternal ligament and the sternoxiphoid ligament, respectively.

**BOX 7-19 Ligaments of the Sternocostal and Intrasternal Joints**

<table>
<thead>
<tr>
<th>Chondrosternal Joint</th>
<th>Fibrous Joint Capsule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interchondral Joint</td>
<td>Fibrous Joint Capsule</td>
</tr>
<tr>
<td></td>
<td>Interchondral Ligament</td>
</tr>
<tr>
<td>Intrasternal Joints</td>
<td>Manubriosternal and sternoxiphoid ligaments</td>
</tr>
</tbody>
</table>

**MUSCLES OF THE RIB JOINTS:**

- Muscles of the rib joints move the ribs at the sternocostal and costospinal joints. Moving the ribs is necessary for the process of respiration (i.e., breathing). Therefore muscles that move ribs are called *muscles of respiration*. To move the ribs, these muscles attach onto the ribs. Any muscle that attaches onto the ribcage may be considered to be a muscle of respiration.

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**7.9 LUMBAR SPINE (THE ABDOMEN)**

- The lumbar spine defines the abdomen of the body (i.e., the lower part of the trunk).
- Most people think of the abdomen as being located only anteriorly. Actually, the abdomen is the lower (lumbar) region of the trunk that wraps 360 degrees around the body.

**FEATURES OF THE LUMBAR SPINE:**

**Composition of the Lumbar Spine:**

- The lumbar spine is composed of five vertebrae (Figure 7-38).
- From superior to inferior, these vertebrae are named L1-L5.

**Curve of the Lumbar Spine:**

- The lumbar spine has a lordotic curve; in other words, it is concave posteriorly (Box 7-20).

**Functions of the Lumbar Spine:**

- The lumbar spine needs to be stable because it has a greater weight-bearing role than the cervical and thoracic spinal regions.
- The lumbar spine is also very mobile. Generally the lumbar spine moves freely in all ranges of motion except rotation (Table 7-8).
- The orientation of the lumbar facet joints is essentially in the sagittal plane (see Section 7-4, Figure 7-14, C), which allows for ease of flexion and extension motions within the sagittal plane. This is why it is so easy to bend forward and backward from our low back.
- In the lower lumbar region, the facet plane orientation changes from the sagittal plane back toward the frontal plane. Clinically, this can create problems, because the upper lumbar region facilitates flexion/extension.

**TABLE 7-8 Average Ranges of Motion of the Lumbar Spine (L1-L2 through L5-S1 Joints) from Anatomic Position**

<table>
<thead>
<tr>
<th>Motion</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>50 Degrees</td>
</tr>
<tr>
<td>Right rotation</td>
<td>5 Degrees</td>
</tr>
<tr>
<td>Left rotation</td>
<td>5 Degrees</td>
</tr>
<tr>
<td>Right lateral flexion</td>
<td>20 Degrees</td>
</tr>
<tr>
<td>Left lateral flexion</td>
<td>20 Degrees</td>
</tr>
</tbody>
</table>

When the lumbar spine has a greater than normal lordotic curve, it is called a hyperlordosis. The common lay term for a hyperlordotic lumbar spine is swayback. (For more information on swayback, see Section 17.6.)
movements in the sagittal plane, but the lumbosacral joint region does not allow these sagittal plane motions as well because their facets are oriented in the frontal plane.

- Being both mobile and stable is difficult, because mobility and stability are antagonistic concepts. Usually a joint tends to be either primarily mobile or primarily stable. Having to be stable for weight bearing and yet also allowing a great amount of mobility is one of the reasons that the low back is so often injured.

**MAJOR MOTIONS ALLOWED:**

For motions of the lumbar spine, see Section 7.10; illustrations in Figure 7-41 demonstrate thoracolumbar motion of the trunk.

- The lumbar spinal joints allow flexion and extension (i.e., axial movements) of the trunk in the sagittal plane around a mediolateral axis.

- The lumbar spinal joints allow right lateral flexion and left lateral flexion (i.e., axial movements) of the trunk in the frontal plane around an anteroposterior axis.

- Unlike the cervical and thoracic spinal regions, which couple lateral flexion with ipsilateral rotation, the lumbar spine couples lateral flexion with contralateral rotation. An interesting clinical application of this is that when a client has a lumbosacral scoliosis (a lateral flexion deformity of the spine in the frontal plane), it can be difficult to pick this up on visual examination or palpation because the result of contralateral rotation coupling with lateral flexion is that the spinous processes rotate into the concavity, making it more difficult to see and feel the curvature of the scoliosis (Figure 7-39).

- The lumbar spinal joints allow right rotation and left rotation (i.e., axial movements) of the trunk in the transverse plane around a vertical axis.
The lumbar spinal joints allow gliding translational movements in all three directions (see Section 7.4, Figure 7-18).

SPECIAL JOINT:

- The joint between the fifth lumbar vertebra and the sacrum is known as the **lumbosacral joint** (see Figure 7-38).
- The lumbosacral joint is also known as the L5-S1 joint because it is between the fifth lumbar vertebra and the first element of the sacrum. The sacrum is made up of five vertebrae that fused embryologically. Therefore the sacrum can be divided into its five elements, S1-S5 (from superior to inferior).
- The lumbosacral joint is not structurally (i.e., anatomically) special. As is typical for intervertebral joints, it is made up of a median disc joint and two lateral facet joints. However, the lumbosacral joint is functionally (i.e., physiologically) special because the lumbosacral joint is not just a joint at which the spine (specifically the fifth lumbar vertebra) can move relative to the pelvis. It is also the joint at which the pelvis can move relative to the trunk.
- The pelvis can also move relative to the thighs at the hip joints. (For motions of the pelvis relative to adjacent body parts, please see Sections 8.3 through 8.5.)
- Other than the usual ligaments of the spine, stabilization to the lumbosacral joint is provided by the iliolumbar ligaments (see Figure 8-4) and the thoracolumbar fascia (see Section 7-11, Figure 7-42).
- The lumbosacral joint region is also important because the angle of the sacral base, termed the **sacral base angle** (Figure 7-40), determines the base that the spine sits on; this determines the curvature that the spine has. Therefore the sacral base angle is an important factor toward assessing the posture of the client’s spine. (See Section 8.8 for more information on the effect of the sacral base angle on the spine.)

### 7.10 THORACOLUMBAR SPINE (THE TRUNK)

- Given that the thoracic spine and lumbar spine are both located in the trunk, movements of these two regions (i.e., the **thoracolumbar spine**) are often coupled together and often assessed together (Box 7-21). Table 7-9 provides the average ranges of motion of the thoracolumbar spine; Figure 7-41 shows the major motions of the thoracolumbar spine (i.e., the trunk).
Spotlight on Reverse Actions of the Trunk

There are many reverse actions of the trunk that can occur. Reverse actions of the muscles of the thoracolumbar spine (i.e., the trunk) create actions of the pelvis at the lumbosacral joint relative to the trunk (and/or movement of the inferior vertebrae relative to the more superior vertebrae). Reverse actions of the pelvis relative to the trunk are covered in Section 8.6.

Reverse actions in which the trunk moves relative to the arm at the shoulder joint are also possible. In the accompanying illustration, the trunk is seen to move relative to the arm at the shoulder joint. A and B illustrate neutral position and right lateral deviation of the trunk at the right shoulder joint, respectively; C and D illustrate neutral position and right rotation of the trunk at the right shoulder joint, respectively; E and F illustrate neutral position and elevation of the trunk at the right shoulder joint, respectively. In all three cases, note the change in angulation between the arm and trunk at the shoulder joint (for lateral deviation B and elevation F, the elbow joint has also flexed.)
TABLE 7-9  Average Ranges of Motion of the Thoracolumbar Spine (i.e., the Entire Trunk from Anatomic Position) (Numbers Include the T1-T2 through L5-S1 Joints)

<table>
<thead>
<tr>
<th>Motion</th>
<th>Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>85</td>
</tr>
<tr>
<td>Right lateral flexion</td>
<td>45</td>
</tr>
<tr>
<td>Right rotation</td>
<td>35</td>
</tr>
<tr>
<td>Extension</td>
<td>40</td>
</tr>
<tr>
<td>Left lateral flexion</td>
<td>45</td>
</tr>
<tr>
<td>Left rotation</td>
<td>35</td>
</tr>
</tbody>
</table>
FIGURE 7-41  Motions of the thoracicolumbar spine (trunk) at the spinal joints.  A and B are lateral views that illustrate flexion and extension of the trunk, respectively, in the sagittal plane.
FIGURE 7-41, cont'd  C and D are anterior views that illustrate right lateral flexion and left lateral flexion of the trunk, respectively, in the frontal plane.  E and F are anterior views that illustrate right rotation and left rotation of the trunk, respectively, in the transverse plane.
7.11 THORACOLUMBAR FASCIA AND ABDOMINAL APONEUROSIS

The thoracolumbar fascia and abdominal aponeurosis are large sheets of fibrous connective tissue located in the trunk. The thoracolumbar fascia is located posteriorly in the trunk. The abdominal aponeurosis is located anteriorly in the trunk. The functional importance of these structures is twofold:

- They provide attachment sites for muscles.
- They add to the stability of the trunk.

THORACOLUMBAR FASCIA:

- The thoracolumbar fascia (Figure 7-42, A) is located posteriorly in the trunk; as its name implies, it is a layer of fascia located in the thoracic and lumbar regions.
- The thoracolumbar fascia is also known as the lumbo-dorsal fascia.
- A sheet of thoracolumbar fascia exists on the left and right sides of the body. In other words, two sheets of thoracolumbar fascia exist.

- The thoracolumbar fascia is especially well developed in the lumbar region, where it is divided into three layers: (1) anterior, (2) middle, and (3) deep (Figure 7-42, B).
- The anterior layer is located between the psoas major and quadratus lumborum muscles and attaches to the anterior surface of the transverse processes (TPs).
- The middle layer is located between the quadratus lumborum and erector spinae group musculature and attaches to the tips of the transverse processes.
- The posterior layer is located posterior to the erector spinae and latissimus dorsi musculature and attaches to the spinous processes (SPs).
- The quadratus lumborum and erector spinae group muscles are encased within the thoracolumbar fascia. The latissimus dorsi attaches into the spine medially via its attachment into the thoracolumbar fascia.
- All three layers of the thoracolumbar fascia meet posterolaterally where the internal abdominal

**FIGURE 7-42**  A, Posterior view of the trunk depicting the thoracolumbar fascia in the thoracolumbar region. B, Transverse plane cross-section illustrating the three layers (anterior, middle, and posterior) of the thoracolumbar fascia. IAO, Internal abdominal oblique; TA, transversus abdominis. (From Cramer GD, Darby SA: Basic and clinical anatomy of the spine, spinal cord, and ANS, ed 2, St Louis, 2005, Mosby.)
oblique (IAO) and transversus abdominis (TA) muscles attach into it.
- Inferiorly, the thoracolumbar fascia attaches onto the sacrum and iliac crest.
- Because of its attachments onto the sacrum and ilium, the thoracolumbar fascia helps to stabilize the lumbar spinal joints and the sacroiliac joint.

**ABDOMINAL APONEUROSIS:**

- The abdominal aponeurosis is located anteriorly in the abdominal region (Figure 7-43).
- An abdominal aponeurosis exists on the left and right sides of the body. In other words, two abdominal aponeuroses (left and right) exist.
- The abdominal aponeurosis provides a site of attachment for the external abdominal oblique, the internal abdominal oblique, and the transversus abdominis muscles.
- The abdominal aponeurosis is often viewed as being an attachment site into which the abdominal wall muscles attach. Viewed another way, it can also be considered to actually be the aponeuroses of these abdominal wall muscles (namely, the external abdominal oblique, internal abdominal oblique, and transversus abdominis muscles bilaterally).
- The superior aspect of the abdominal aponeurosis has two layers (anterior and posterior), which encase the rectus abdominis.
- The inferior aspect of the abdominal aponeurosis has only one layer, which passes superficially (anteriorly) to the rectus abdominis.
- The border where the abdominal aponeurosis changes its relationship to the rectus abdominis is the arcuate line. The arcuate line is a curved line that is located approximately halfway between the umbilicus and the symphysis pubis.
- Because the abdominal aponeurosis covers and/or encases the rectus abdominis, it is also known as the rectus sheath.
- Where the left and right abdominal aponeuroses meet in the midline is called the linea alba, which means white line.
- The left and right abdominal aponeuroses, by binding the two sides of the anterior abdominal wall together, add to the stability of the trunk.

![Figure 7-43](https://example.com/figure7-43.png)

**FIGURE 7-43** A, View of the anterior trunk illustrating the abdominal aponeurosis. The abdominal aponeurosis is a thick layer of fibrous tissue that is an attachment site of the transversus abdominis and external and internal abdominal oblique muscles. B and C, Transverse plane cross-section illustrating the abdominal aponeurosis superiorly and inferiorly in the trunk, respectively. The abdominal aponeurosis is also known as the rectus sheath because it ensheathes the rectus abdominis muscle. EAO, External abdominal oblique; IAO, Internal abdominal oblique; RA, Rectus abdominis; TA, transversus abdominis. (From Muscolino JE: The muscular system manual: the skeletal muscles of the human body, ed 3, St Louis, 2010, Mosby.)
REVIEW QUESTIONS

Answers to the following review questions appear on the Evolve website accompanying this book at: http://evolve.elsevier.com/Muscolino/kinesiology/.

1. What is the relationship between cranial sutures and childbirth?
2. What are the four major muscles of mastication?
3. What are the four major regions of the spine, and which type of curve is found in each?
4. How many cervical vertebrae are there? How many thoracic vertebrae are there? How many lumbar vertebrae are there?
5. Developmentally, what creates the cervical lordotic curve?
6. Regarding spinal segmental motion, compare and contrast the purpose of the disc joint and the purpose of the facet joints.
7. What is the general orientation of the facet planes of the cervical, thoracic, and lumbar spinal regions?
8. Explain why the anterior longitudinal ligament limits extension of the spinal joints, and the supraspinous ligament limits flexion of the spinal joints.
9. Why is the second cervical vertebra called the axis?
10. Name three ligaments of the upper cervical region that stabilize the dens of the axis.
11. Which upper cervical spinous process is the most easily palpable and useful as a palpatory landmark?
12. Why are the coupled actions of extension and rotation of the upper cervical spine potentially contraindicated for clients?
13. The presence of what structure greatly decreases the range of motion of extension of the thoracic spine?
14. What are the two types of costospinal joints?
15. Why is elevation of a rib described as a bucket handle movement?
16. Describe the two manners in which the thoracic cavity can expand for inspiration.
17. In which plane is the lumbar spine least mobile?
18. What is the lay term for a hyperlordotic lumbar spine?
19. How is the sacral base angle measured? What is its importance?
20. How many layers does the thoracolumbar fascia have in the lumbar region?
21. Why is the abdominal aponeurosis also known as the rectus sheath?