9

Clinical Anatomy of the Back

OUTLINE

INTRODUCTION

Early on in Chapters 2 to 5 we had an overview of the bones, muscles, nerves, and vessels of the back. We then discussed the histology and physiology of the connective tissues and muscles, before reviewing the embryology of the body and the role of the central nervous system in coordinating bodily sensations and movement in Chapters 6–8. We now shift focus to investigate one region of the body. In the process, we will review the prior content as we remix it in the context of the back. Along the way, we will address the biomechanics of the back and the clinical concerns that arise in this region.

THE VERTEBRAE AND VERTEBRAL COLUMN

The **vertebral column** is made from a series of individual vertebrae that surround and protect the spinal cord and its associated structures. It supports and maneuvers the head, transmits forces from the limbs, and resists compression. There are five distinct regions of the vertebral column. From superior to inferior they are the **cervical** (7 vertebrae), **thoracic** (12), **lumbar** (5), **sacral** (5), and **coccygeal** (3 to 5) regions.

Except for the atlas, all vertebrae have a **vertebral body** on their anterior side that supports the weight of the body superior to it and transmits forces from the vertebrae inferior to it. Extending posteriorly from the vertebral body is the **vertebral arch**, which surrounds and protects the spinal cord and associated structures. The portions of the vertebral arch that connect to the vertebral body are the right and left **pedicles**. The right and left **laminae** extend from the pedicles and meet each other on the midline. The space formed by the vertebral arch and body is the **vertebral foramen**. A single **spinous process** extends posteriorly off the vertebral arch at the point where the right and left laminae meet. The right and left **transverse processes** extend laterally from the arch where the pedicles meet the laminae. Near the transverse processes are the **superior** and **inferior articular processes**. The superior articular process extends superiorly and features a **superior articular facet**. The **inferior articular process** extends inferiorly and hosts an **inferior articular facet** that articulates with the superior articular facet of the neighboring vertebra. On the posterior aspect of each vertebral body is a **basivertebral foramen** (or sometimes a series of foramina) that allows large vessels access to the inside of the bone.

Cervical Vertebrae

There are seven cervical vertebrae connecting the head to the thoracic vertebrae. Their vertebral bodies are relatively small compared to those in other regions of the body since they do not support much of the body's weight. The lower cervical vertebrae (3rd to 7th) have many features in common; however, the upper cervical vertebrae are distinct from the other five. For that reason, the atlas (C1) and axis (C2) will be discussed separately.

Lower Cervical Vertebrae (Figs. 9.1 and 9.2)

Each of the C3–C7 vertebrae have all the typical features of a vertebra (vertebral body, vertebral arch, pedicles, laminae, transverse processes, spinous process, superior and inferior articular processes and facets, intervertebral disc) as well as a few distinctive features. The superior aspect of the vertebral bodies have raised lateral edges, **uncinate processes**, that cradle the nearby intervertebral disc and form synovial **uncovertebral joints** with the inferolateral aspect of the vertebral body above it. The C1–C6 vertebrae typically feature a hole in their transverse processes called **the transverse foramen** that surrounds the left and right vertebral arteries and veins as they travel from the subclavian vessels to the brainstem. The transverse processes also have raised **anterior** and **posterior tubercles** that flank the transverse foramen and are separated by a depression, the **groove for the spinal nerve**. The anterior tubercle of C6 is particularly large and is referred to as the **carotid tubercle**. The spinous processes of C3–C6 are typically **bifid**, split into two posteriorly.

Upper Cervical Vertebrae (Fig. 9.3)

The **axis** (C2) appears very much like a typical cervical vertebra but is unique in that is has a large, thumb-shaped **dens** (odontoid process) extending superiorly from the vertebral body, with

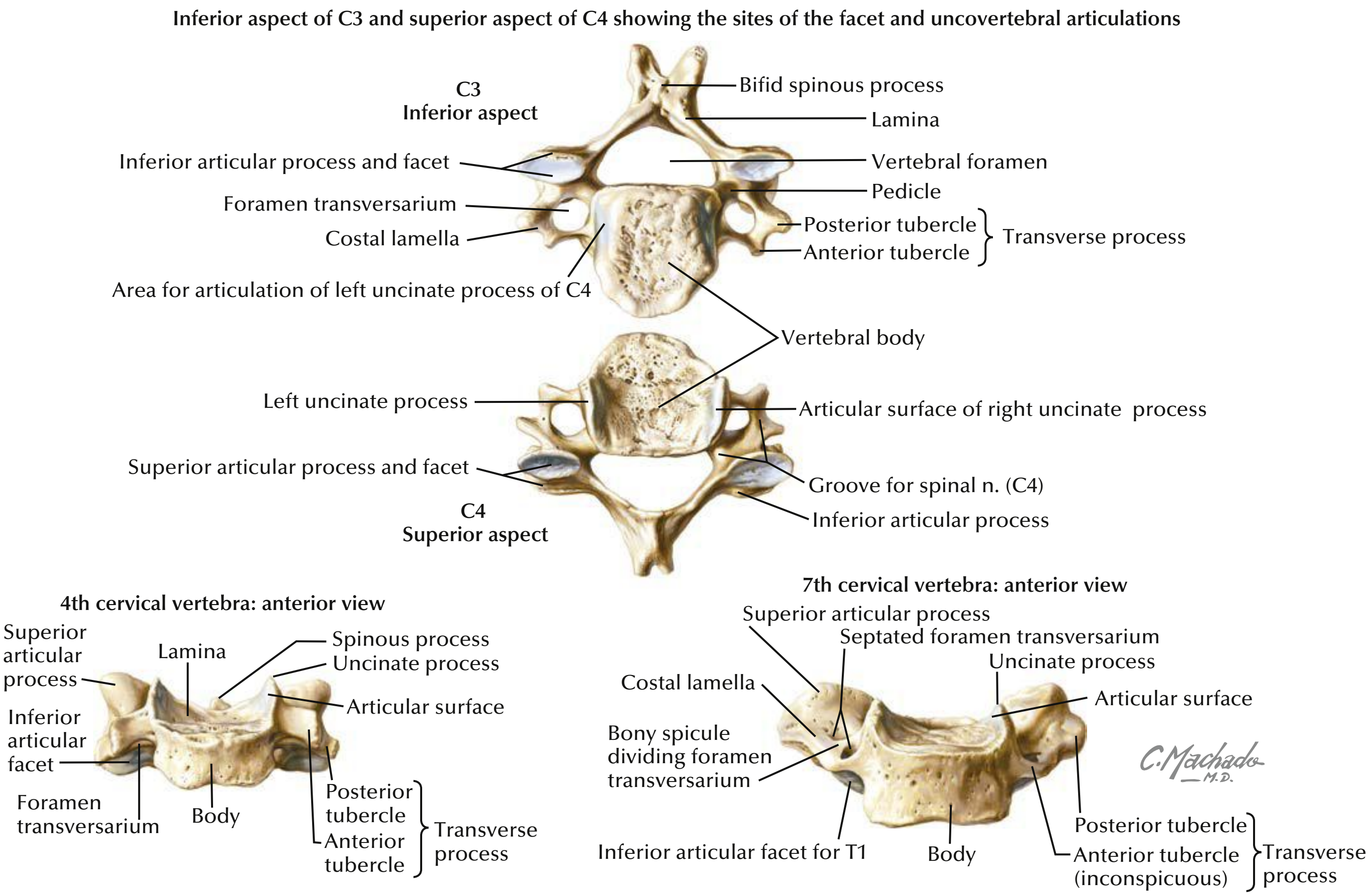

Fig. 9.1 Cervical Vertebrae.

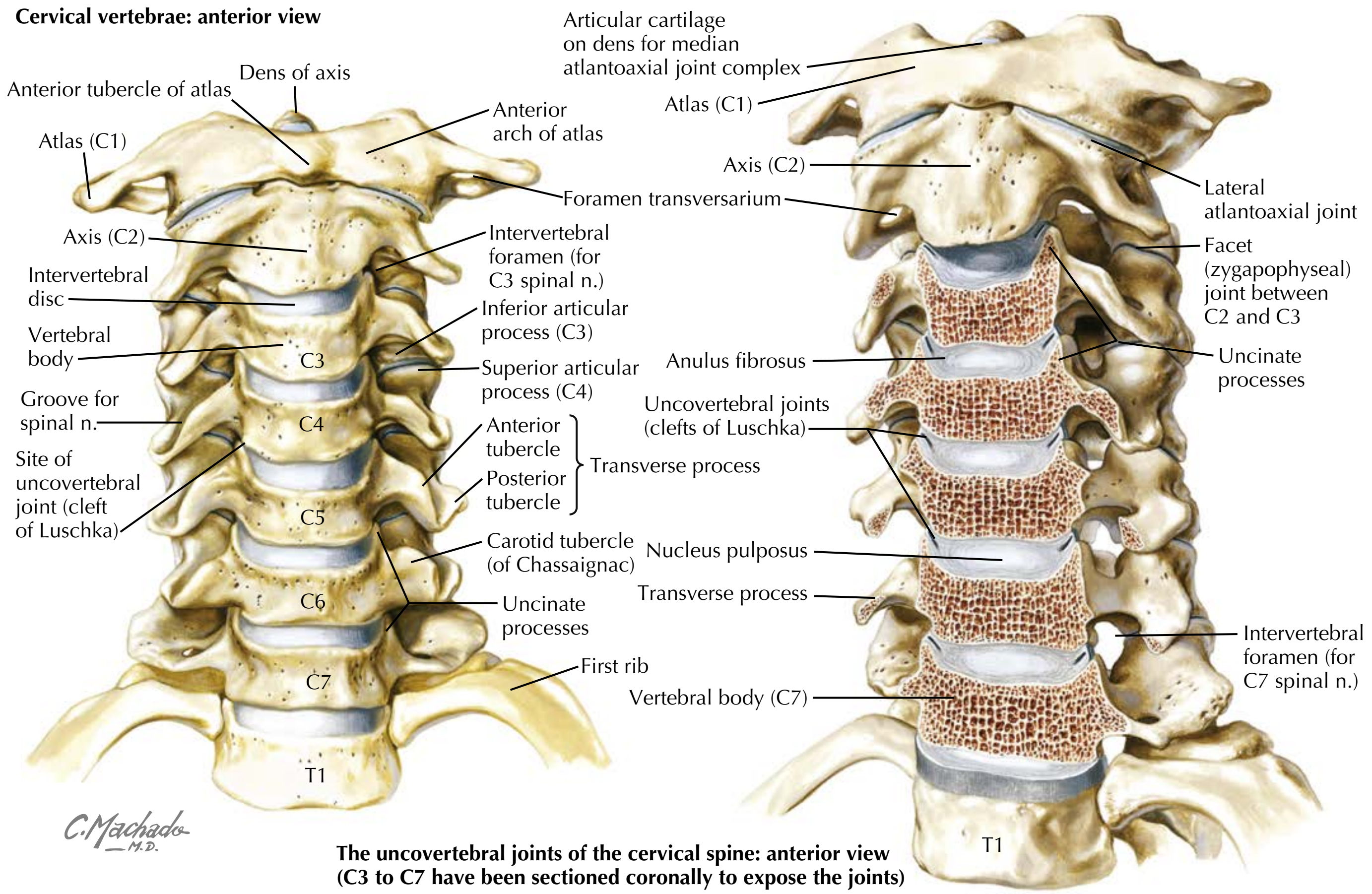

Fig. 9.2 Cervical Vertebrae: Uncovertebral Joints.

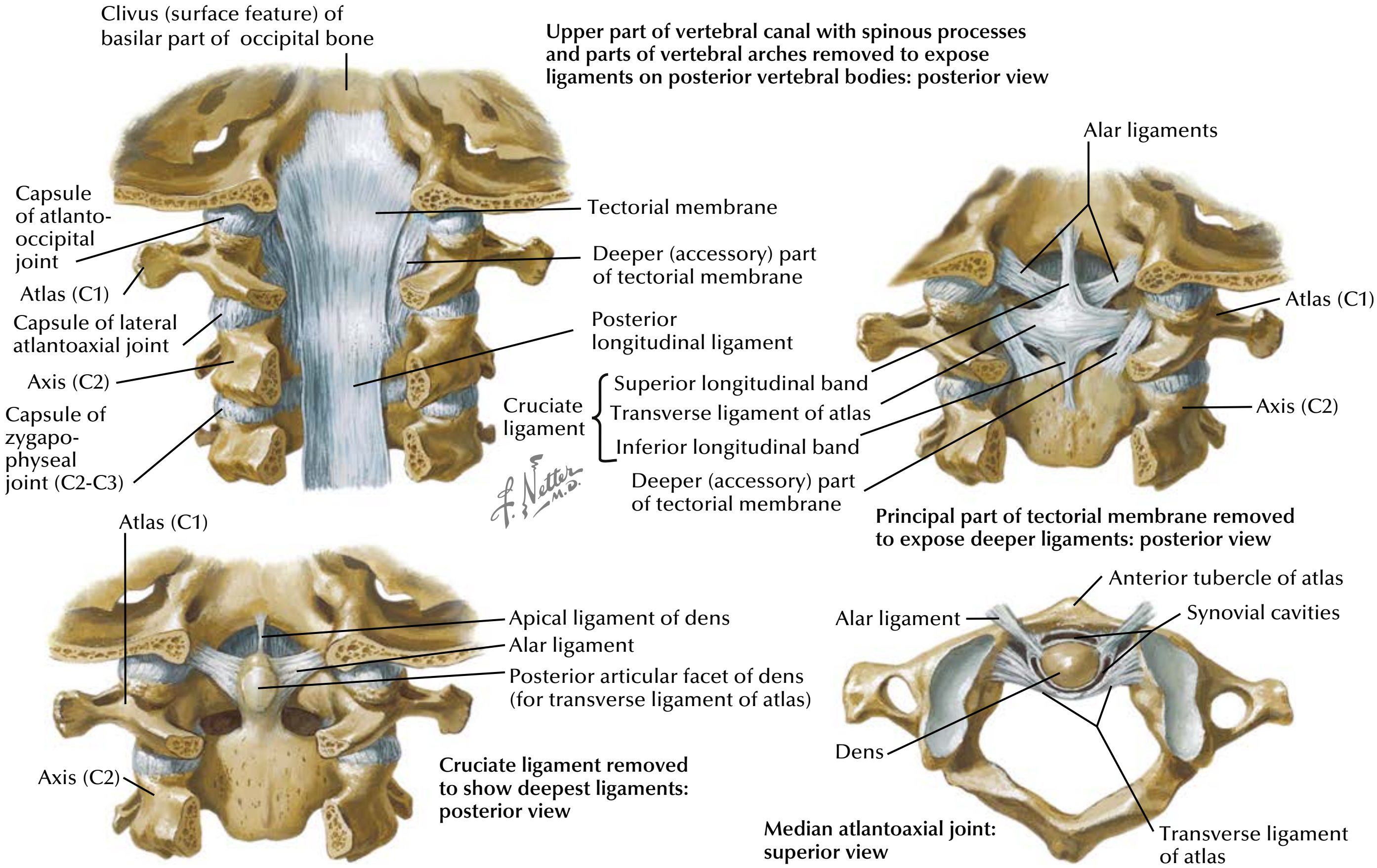

Fig. 9.3 Cervical Vertebrae: Atlas and Axis Spine: Osteology.

the pointed **apex** of the dens at the most superior point. The dens is actually the C1 vertebral body that fused with the vertebral body of C2 while the sclerotomes were separating during development. The dens has **anterior** and **posterior articular facets** that allow it to articulate with the atlas (anterior) and the transverse ligament of the atlas (posterior) as the atlas rotates with the dens as its fulcrum. The axis interacts with the atlas via its superior articular facet and the dens; there is no intervertebral disc between them.

The **atlas** (C1) is an oval-shaped bone that lacks a vertebral body; however, the atlas has large **lateral masses** that host the transverse processes, transverse foramina, as well as superior and inferior articular facets. The superior articular facets articulate with occipital condyles while the inferior articular facets articulate with the superior articular facets of the axis. Anteriorly, the lateral masses are connected by a short **anterior arch**, which has a distinct **anterior protuberance** at its midpoint. The inner surface of the anterior arch has the **articular facet for the dens**. The large **posterior arch** extends from the lateral masses to enclose the vertebral foramen. It has a **posterior protuberance** on its posterior midline as well as a notable **groove for the vertebral artery** running along its superior aspect.

Thoracic Vertebrae (Fig. 9.4)

The twelve thoracic vertebrae have all the typical features of a vertebra as well as a few distinctive features that relate to their interaction with the ribs. Each thoracic vertebra articulates with one or two **ribs** via a **costal facet**, or **inferior** and **superior costal demifacets**. Costal facets (T1, T11, and T12) are seen when the head of a rib articulates with a single vertebral body, whereas superior and inferior demifacets (T1–T10) are seen when a rib head straddles two adjacent vertebral bodies and the intervertebral disc between them. The ribs also articulate with the anterior aspect of vertebral transverse processes at the **transverse costal facet**. The transverse costal facets are generally not present on T11 and T12. Immediately posterior to the costal facets of the T1 vertebral body are stunted left and right **uncinate processes** that interact with C7. None of the other thoracic vertebrae have uncinate processes.

From a lateral view, the upper and middle spinous processes are long and angled inferiorly, especially the middle (T4–T9) thoracic spinous processes. The lower thoracic spinous processes are smaller and square-shaped.

Lumbar Vertebrae (Fig. 9.5)

The five lumbar vertebrae have very large vertebral bodies to support the body's weight. The transverse processes of the lumbar vertebrae are elongated and flat in the coronal plane. The spinous processes of the lumbar vertebrae are very large and square-shaped. There are some special landmarks on the posterior lumbar vertebrae for muscle attachment. **Mammillary processes** project posteriorly from the superior articular processes, and notable **accessory processes** are located on the posterior aspect of the lumbar transverse

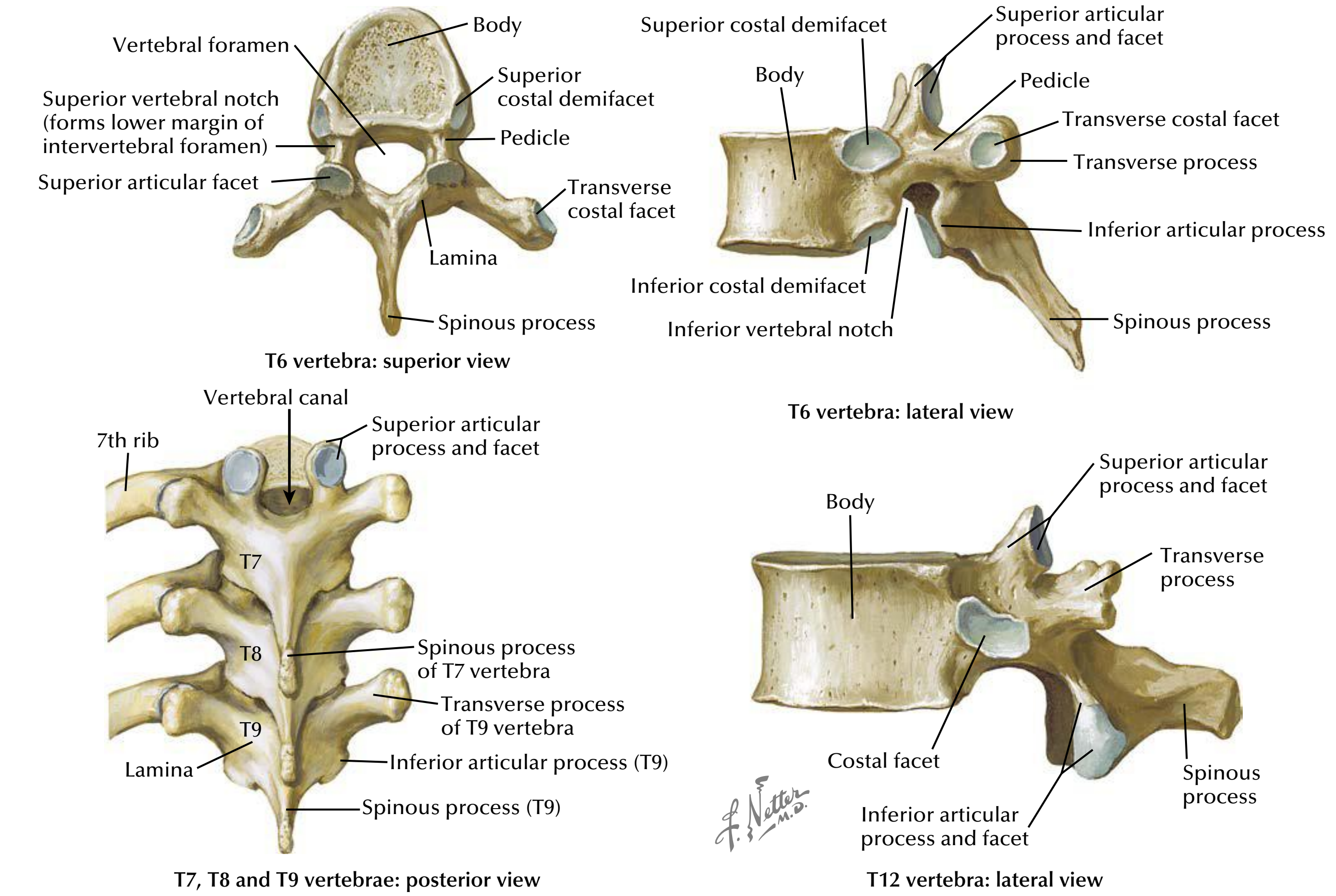

Fig. 9.4 Thoracic Vertebra.

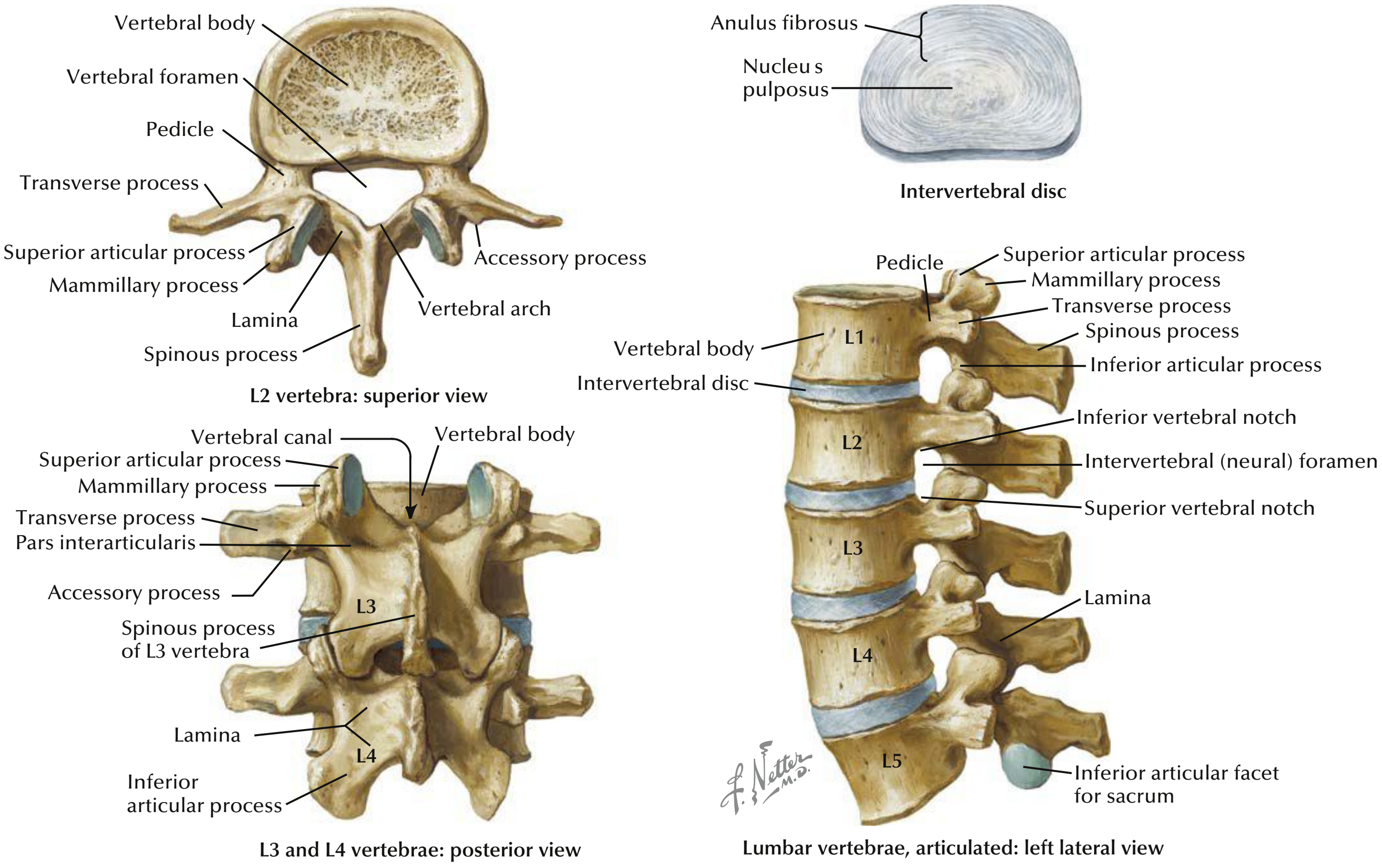

Fig. 9.5 Lumbar Vertebrae and Intervertebral Disc Spine: Osteology.

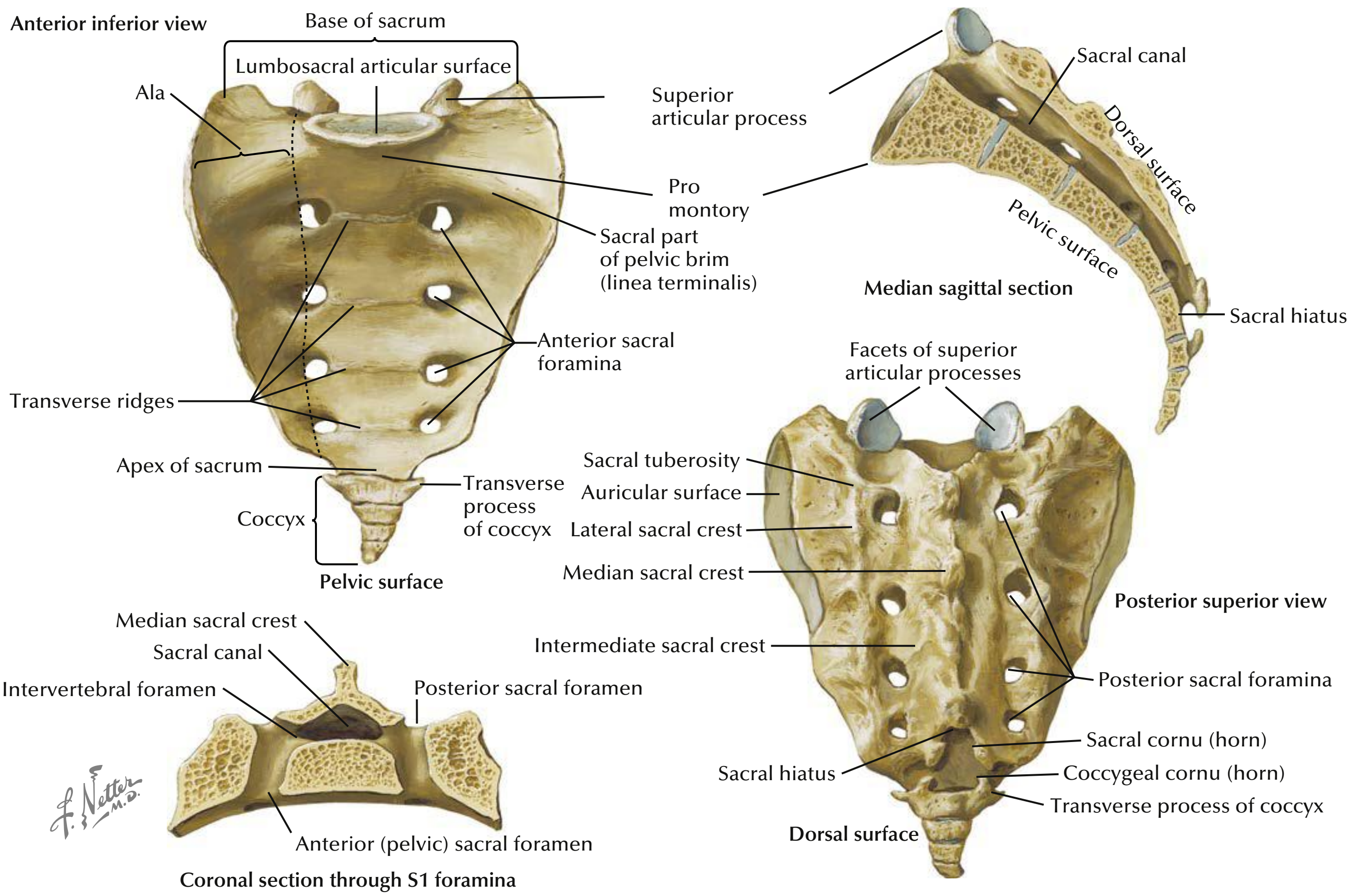

Fig. 9.6 Sacrum and Coccyx: Osteology.

processes. The accessory processes actually mark where the transverse processes would normally have stopped; the rest of the lumbar transverse processes are actually stunted ribs, called **costal processes** when spoken of as a distinct structure. However, most clinicians and anatomists call the whole assembly of accessory process and costal process the **transverse process**.

Sacral Vertebrae (Fig. 9.6)

The **sacrum** consists of five bones that fuse during development. The sites of fusion, marking where intervertebral discs would have been, are the **transverse ridges** on the anterior surface of the sacrum. At the lateral limits of each transverse line are large **anterior sacral foramina** for the anterior rami leaving the sacrum and travelling to the pelvic organs and lower limbs. The large superior portion of the sacrum is the **sacral base**, which terminates anteriorly as the **sacral promontory**. The inferior tip of the sacrum that articulates with the coccyx is called the **apex of the sacrum**. The large bony wings, **alae** (singular **ala**), that extend laterally from the sacral vertebral bodies articulate with the ilium at the sacrum's **auricular surface**.

Because the sacral vertebrae are fused, the vertebral foraminae create a continuous **sacral canal** that surrounds anterior and posterior nerve roots extending from the spinal cord. Its inferior opening is the **sacral hiatus**, which is bounded by two **sacral cornua**. The posterior aspect of the sacrum has a large ridge of bone that covers the midline of the sacral canal, the **median sacral crest**. It is formed by the spinous processes of the fused vertebrae but only extends to S3 or S4. On either side of the median sacral crest are right and left **intermediate sacral crests**, which are formed by fused articular processes and also cover the sacral canal. The intermediate sacral crests terminate superiorly as **superior articular processes** and **facets** that articulate with the inferior articular facets of L5. Further laterally are the right and left **lateral sacral crests**, formed by fusion of the sacral transverse processes. Between the intermediate and lateral sacral crests are the **posterior sacral foramina**, which transmit posterior rami from the sacrum to the lower back. In between the lateral sacral crest of S1–S3 and the auricular surface are a series of three depressions and **three sacral tuberosities** that mark where the posterior sacroiliac ligament attaches to the sacrum.

Coccygeal Vertebrae (See Fig. 9.6)

The **coccyx** (tailbone) is a series of 3 to 5 fused and vestigial vertebrae. These conjoined vertebral bodies have lost all the other characteristic features of vertebrae aside from a stunted **transverse process** on each side of the first coccygeal vertebra. The posterosuperior aspect of the first coccygeal vertebra may also have left and right **coccygeal horns**, or **cornua**, extending superiorly. These nearly insignificant bones serve as an attachment point for muscles of the pelvic diaphragm and anus. They do not seem insignificant when they are fractured, since acute pain is caused by sitting and defecating, activities no one is able to postpone indefinitely (Clinical Correlation 9.1).

Intervertebral Foramen (See Fig. 9.5)

When viewed laterally, the pedicles have small indentations on their superior and inferior surfaces, the **superior vertebral notch** and the larger **inferior vertebral notch**. The inferior and superior vertebral notches of adjacent vertebrae create an **intervertebral foramen** that allows a spinal nerve to exit at each vertebral level. The cervical and upper thoracic intervertebral foramina are narrow, while the lumbar and lower thoracic intervertebral foramina are quite large. Side-bending can narrow the intervertebral foramina on the concave side of the curvature. Bony overgrowth around the intervertebral foramen or osteophytes around the facet joints can also narrow the space (Clinical Correlation 9.2).

Intervertebral Discs (Fig. 9.7, See Also Fig. 9.5)

Neighboring vertebral bodies, except for C1–C2 and the sacral vertebrae, are connected by **intervertebral discs**. These discs serve as shock absorbers for the forces that are transmitted along the vertebral column. They have a gelatinous core, the **nucleus pulposus**, consisting of mucous connective tissue that is rich in proteoglycans and loosely arranged fibers. The nucleus pulposus is the only remnant of the notochord, which occupied the same position at a much earlier stage of development. Surrounding each nucleus pulposus is the **annulus fibrosus**, which is formed by many concentric rings of fibrocartilage. Each ring has laminae of collagen fibers (types I and II) running perpendicular to their neighboring rings. The annulus fibrosus and vertebral bodies are both derived from the sclerotome, but the annulus does not ossify. The annulus surrounds the nucleus and keeps it in a central location. This allows the disc to rebound when it experiences compressive forces.

The interface between the vertebral body and intervertebral disc is the **vertebral endplate**. This fascinating structure also comes from sclerotomal mesenchyme but remains as hyaline cartilage even after the vertebral bodies have ossified. The endplates are fused with the inner rings of the annulus fibrosus as well as the raised superior and inferior rims of the vertebral bodies, the **annular epiphyses**. Small vessels within the endplates allow nutrients to diffuse from the trabecular bone of the vertebral bodies to reach the intervertebral discs, which are otherwise avascular. In dry bone specimens the endplates are not present and this gives the flat surfaces of the vertebral body a spongy appearance. The ossification of the endplates with age and loss of vessels passing through them to the discs may be one factor that contributes to degenerative disc disease (Biomechanics Box 9.1 and Clinical Correlation 9.3).

CLINICAL CORRELATION 9.1 Stable and Unstable Spinal Injuries

Injuries of the vertebral (spinal) column are classified as stable, not requiring immobilization, or unstable, requiring immobilization. To make these designations, the vertebrae are conceptualized as having three columns: (1) the anterior ½ of the vertebral body; (2) the posterior ½ of the vertebral body and pedicles; and (3) the laminae, articular processes, and spinous processes. Injury that involves only one column is classified as stable and unlikely to damage the spinal cord. Injury involving 2 or 3 columns is unstable and the patient must be restrained to minimize the potential for neurologic trauma.

Compression and Burst Fractures (Fig. CC9.1A)

Osteoporosis is the loss of bone density, which is one of several things that can lead to **osteopenia**, bone weakness. Vertebral bodies are particularly vulnerable, since they bear the weight of the body above their level. If they become too weak, they may undergo a **compression fracture** in which the vertebral body collapses in on itself. Since the posterior aspect of the vertebrae are supported by the pedicles and articular processes, the anterior sides become more severely compressed, resulting in a wedge-shaped vertebral body with the narrow end pointing anteriorly. This is one cause of increased thoracic kyphosis with age. In a burst fracture, massive compressive force causes the vertebral body to explode outward, possibly impinging on structures in the vertebral canal and causing neurologic signs.

Fracture of the Atlas and Axis (Fig. CC9.1B)

Sudden compression of the head from above can put tremendous pressure on the articular facets of the atlas. When the atlas is compressed violently, it pushes the lateral masses laterally and can result in snapping of the anterior and posterior arches of the atlas. Like the pelvis, the atlas is a ring of bone and almost always fractures in more than one place.

The articular processes of the axis are stouter than those in the atlas. They are characteristically prone to fracture through the area between superior and inferior articular processes (pars interarticularis) when the head is forcibly extended relative to the upper cervical vertebrae. This is famously (and horrifyingly) used during a hanging, when the knot of the noose is placed alongside the jaw so that when the rope goes taut, the head is jerked into extension, fracturing the axis and destroying the upper spinal cord, causing nearly instantaneous death. More horrendously, if this is not done properly the victim will gradually asphyxiate as the airway and vessels of the neck are compressed.

Spondylolysis and Spondylolisthesis (Fig. CC9.1C)

Fractures of the pars interarticularis are known as **spondylolysis**. This is a relatively common injury in young athletes and tends to occur when the vertebrae are compressed during forceful extension. If this fracture occurs bilaterally, the arch of the affected vertebra remains attached to its inferior neighbor and the vertebral body is attached to its superior neighbor. This instability can result in the vertebral body shifting anteriorly as the supporting ligaments and intervertebral disc weaken and stretch. Fracture of the pars interarticularis, spondylolysis, coupled with displacement is **spondylolisthesis**. It can gradually worsen as the affected vertebral body slides anteriorly, relative to its inferior neighbor. As this condition worsens, the spinal cord posterior to the affected vertebra can become compressed. This can occur at any level but is most common in the lumbar and cervical levels, due to their lordotic (concave posteriorly) curvature, which makes hyperextension injuries more likely. When imaged using a posterior oblique view, this condition has a classic "Scotty dog" sign. The dog's head is formed by the pedicle, superior articular facet, and transverse process. The neck is formed by the pars interarticularis. The foreleg is formed by the inferior articular facet, while the body and hindlimbs are formed by the spinous process and opposite inferior articular process. If the Scotty dog appears well, then the pars interarticularis is intact. If he is wearing a dark collar, there is a spondylolysis. If the dog has been decapitated (sorry, gentle readers) then the pars interarticularis is fractured and there has been significant displacement, a spondylolisthesis. This description is still used although CT scans are being used more frequently to diagnose this condition.

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CLINICAL CORRELATION 9.1 **Stable and Unstable Spinal Injuries—cont'd**

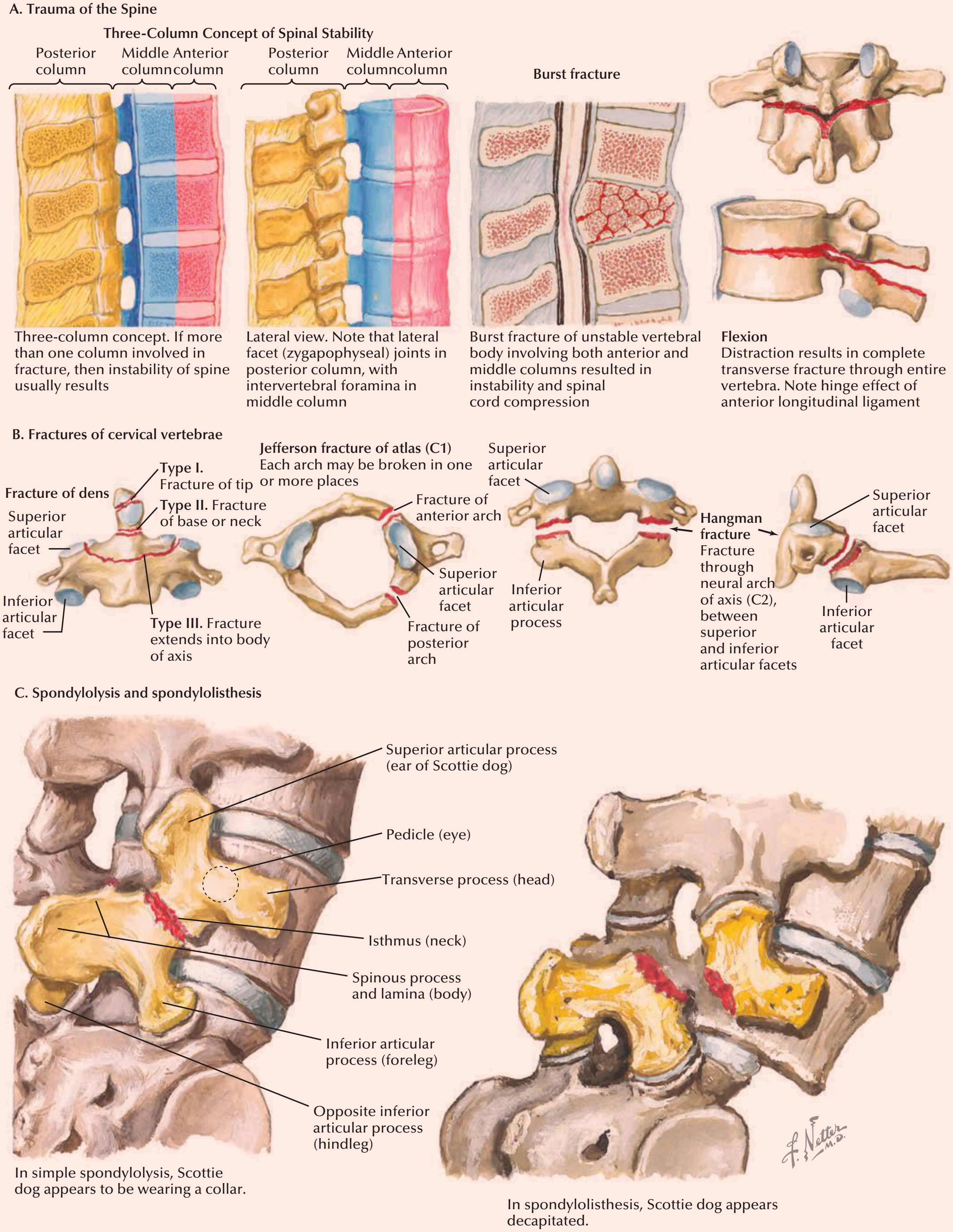


Fig. CC9.1 Stable and Unstable Spinal Injuries (Trauma, Cervical Vertebral Fractures, Spondylolysis).

CLINICAL CORRELATION 9.2 Palpating the Back and Topographical Anatomy

Palpating the spinous processes of the vertebral column is commonly done to identify the exact level of a complaint or vertebral dysfunction. The vertebra prominens (most prominent spinous process) extends the most posteriorly and is usually either C7 or T1. If you wish to determine which, you can palpate it and ask your patient to flex his or her neck. If it moves, the vertebra prominens is C7; if it is stable, it is T1.

However, since the spinous processes do not project perfectly horizontally, it is a bit confusing to identify which spinous process corresponds to which vertebral body.

Clinicians have created the **rule of threes** to keep track of these relationships in the thoracic spine.

- T1–T3: the spinous process of each vertebra is at the same level as its vertebral body
- T4–T6: the spinous process of each vertebra is ½ level inferior to its vertebral body
- T7–T9: the spinous process of each vertebra is 1 level below its vertebral body
- T10: the spinous process of each vertebra is 1 level below its vertebral body (like T7–T9)
- T11: the spinous process of each vertebra is ½ level inferior to its vertebral body (like T4–T6)
- T12: the spinous process of each vertebra is at the same level as its vertebral body (like T1–T3)

However, recent studies have demonstrated that the rule of threes is not as accurate as we might hope and an alternative, **Geelhoed's rule**, has been proposed. This rule states that the spinous processes of all thoracic vertebrae lie in the same horizontal plane as the transverse processes of their inferior neighboring vertebra.

There are a few landmarks of note below the thoracic region. The L4 spinous process is palpable at the same level as the superior-most aspect of the iliac crest, while the S2 spinous process (of the median sacral crest) is palpable at the level of the posterior superior iliac spine. The S3 spinous process is palpable at the superior limit of the gluteal cleft.

THE VERTEBRAL COLUMN AS A WHOLE (FIG. 9.8)

When the entire vertebral column is viewed from the side, the different regions have distinctive curves. The cervical and lumbar regions appear concave (scooped out) posteriorly and convex (bulging) anteriorly; this type of curvature is called a **lordosis.** Conversely, the thoracic and sacral regions appear concave anteriorly and convex posteriorly; this type of curvature is called a **kyphosis.** The thoracic and sacral kyphoses are **primary curvatures** as they are present at birth and are an intrinsic feature of the way these bones develop. The cervical and lumbar lordoses are **secondary curvatures** since they only develop after birth as our body learns to cope with gravity. Since the cervical and lumbar vertebrae are not fused or restricted by the ribcage, these lordotic curvatures can vary considerably from person to person. **Scoliosis** (also called rotoscoliosis) refers to a lateral curvature of the spine. These lateral curves are not a normal feature of the vertebral column but can develop due to poor posture or can be caused by degenerative diseases. Their severity can vary considerably, depending upon their cause.

JOINTS OF THE VERTEBRAL COLUMN (SEE FIGS. 9.2, 9.3, 9.5, AND 9.8)

In addition to the intervertebral discs, vertebrae interact as the facets on their inferior articular processes meet the articular facets on the superior articular processes of the vertebra immediately inferior to it. The interaction creates a vertebral **facet joint** (a.k.a. **zygapophyseal joint**) on each side. Despite the differences in their orientation, the facet joints of the vertebrae from C1 to S1 share several features in common. Like other synovial joints, the facet joints have an outer fibrous layer and an inner, synovial layer that filters blood to create the synovial fluid within the capsule. Within the capsule, the articular surfaces of the bones are typically covered by hyaline (often called "articular") cartilage. This allows their motions to be smooth and minimizes friction and irritation.

The **atlantooccipital joints**, formed by the superior articular facet of the atlas and the occipital condyles, allow a great deal of flexion/extension and are responsible for the majority of the flexions/extension in the cervical region (nod your head "yes" if you understand) as well as a small amount of side-bending. Rotation is limited. There are thickened capsular ligaments on their anterior, posterior, and lateral aspects.

There are several **atlantoaxial joints**. The **median atlantoaxial joint** is formed as the anterior and posterior articular surfaces of the dens articulate with the anterior arch of the atlas and the transverse ligament of the atlas. The inferior articular facet of the atlas connects to the superior articular facet of the axis in a way that is very similar to the lower cervical facet joints, forming the **lateral atlantoaxial joints**. These joints allow a tremendous amount of rotation (shake your head "no" if this is unclear) but limited side-bending and flexion/extension.

The superior and inferior articular facets of the **lower cervical facet joints** are oriented somewhat in the horizontal plane but become more vertically oriented (in the coronal plane) as they get closer to the thoracic vertebrae. On their own, these facet joins would allow a considerable amount of movement. However, the uncinate processes severely limit the amount of rotation and lateral displacement of the lower cervical vertebrae, allowing some flexion/extension, anterior/posterior translation, and a small amount of side-bending in this region. Contact of the spinous processes limits the amount of extension that is possible in the neck; however, the bifid spinous processes of the cervical vertebrae straddle the spinous process of their inferior neighbor, allowing just a bit more extension than would otherwise be possible. Superior and inferior articular facets of the **thoracic facet joints** are largely vertical in the coronal plane. On their own, these would allow a tremendous amount of movement, but the ribcage constrains them considerably, limiting (but not eliminating) flexion/extension, side-bending, and rotation. The overlapping thoracic spinous processes limit extension severely. **Lumbar facet joints** are largely oriented vertically in the sagittal plane with the inferior articular facets surrounded by their neighbor's superior articular facets. They allow a large amount of flexion/extension and side-bending but limit rotation. The **lumbosacral facet joint** is similar to the lumbar facet joints. Finally, the **sacrococcygeal joint** is a small synovial

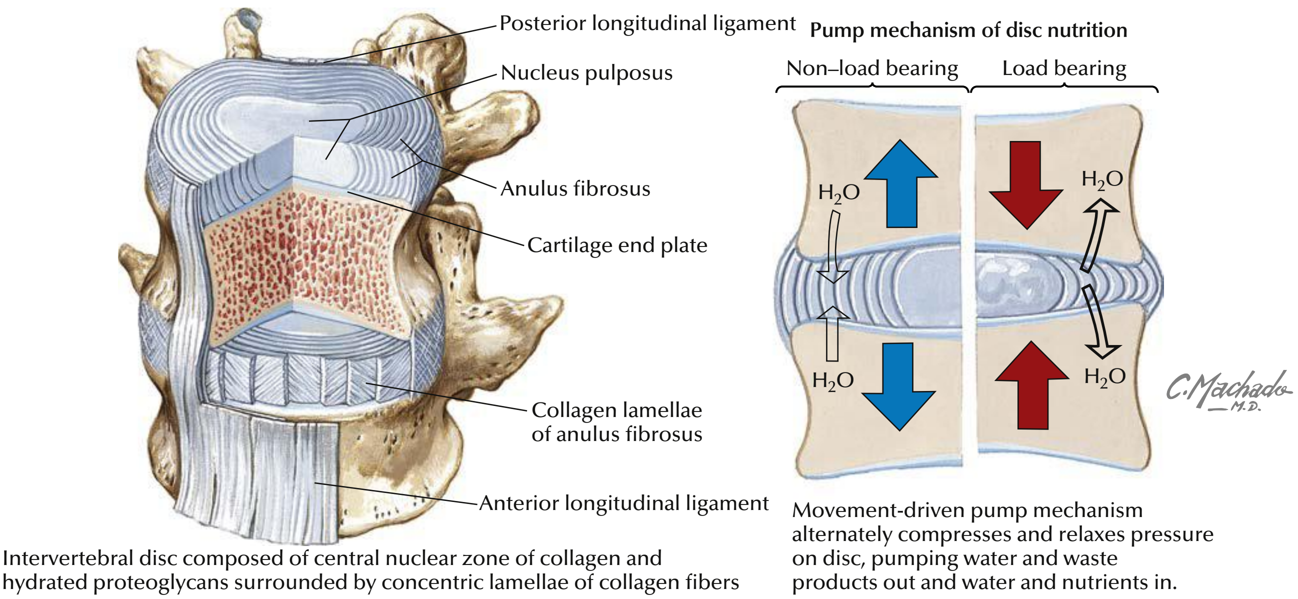


Fig. 9.7 Intervertebral Disc.

> **BIOMECHANICS BOX 9.1 Intervertebral Disc Function**
>
> When standing or sitting upright, the intervertebral discs are compressed and flattened in a uniform manner. Compression of the intervertebral disc creates increased pressure on the nucleus pulposus, which is held within the layers of the anulus fibrosus. As the vertebral column flexes (becomes concave anteriorly) the nucleus pulposus is pinched anteriorly and pushes posteriorly. Conversely, as the vertebral column extends (becomes concave posteriorly), the nucleus pulposus is pushed anteriorly. As one bends to one side, such as leaning to the left, the nucleus pulposus is pushed toward the convexity, in this case, to the right.

joint (not a facet joint since there are no superior or inferior articular facets at this level) between the S5 apex of the sacrum and the body of the Co1 vertebra. The **sacroiliac joint** will be discussed in Chapter 11.

LIGAMENTS OF THE VERTEBRAL COLUMN (FIG. 9.9)

The facet joints and intervertebral discs stabilize the vertebrae and help to prevent excessive motion. However, they are not strong enough on their own to keep the vertebral column stable. Many vertebral ligaments and muscles assist in this endeavor.

Ligaments of the Vertebral Arch

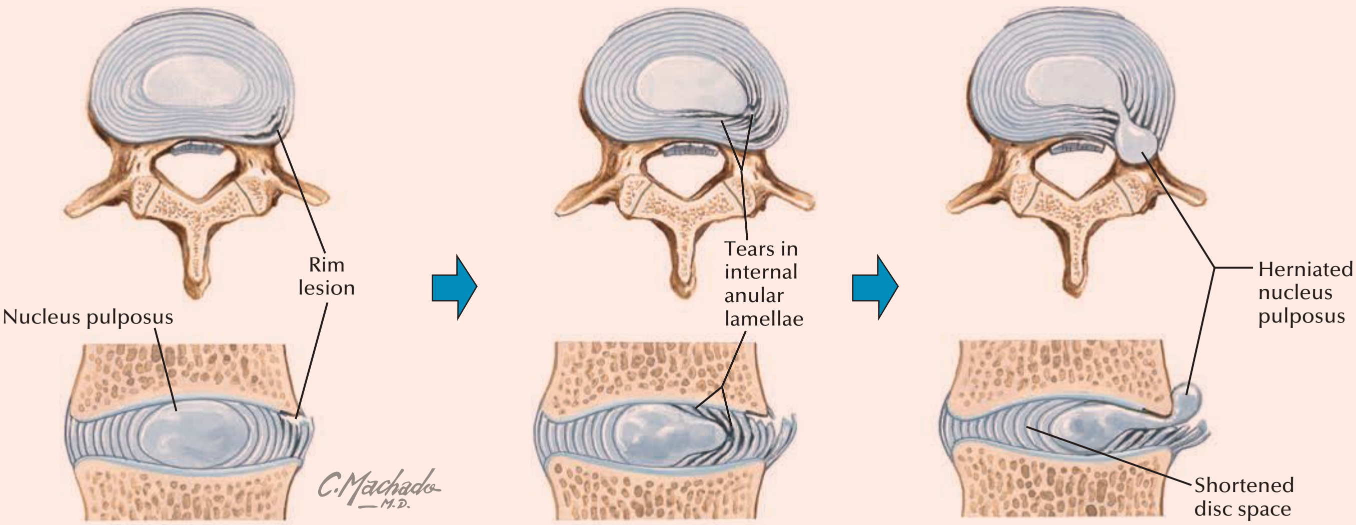
Medial to the facet joints and posterior to the vertebral canal, the laminae of adjacent vertebrae are connected by **ligamenta flava** that allow flexion to occur while keeping the vertebral arches connected. These ligaments are slightly yellow in appearance due to a large number of elastic fibers within them. Since these ligaments are elastic, they do not fold on themselves during extension of the back, which would potentially impinge on the spinal cord. It has been held that since these connect adjacent laminae, they are not present on the midline; however, recent work has shown that they often do cover the midline of the vertebral arch. The ligamenta flava of the atlantoaxial space (C1–C2) are broad and referred to as the **posterior atlantoaxial membrane**. There are no ligamenta flava between the atlas and the occipital bone; instead, there is a **posterior atlantooccipital membrane** that is relatively thin in order to accommodate flexion of the neck. There are gaps in the posterior atlantooccipital membrane on the left and right that allow the vertebral arteries to pierce the membrane and move into the vertebral foramen to supply blood to the brainstem and spinal cord.

Adjacent spinous processes are connected by **interspinous ligaments** that limit flexion. Similarly, transverse processes are connected by small **intertransverse ligaments** that limit side-bending. These are indistinct in the cervical region, form visible bundles between the thoracic vertebrae, and are present as thin sheets in the lumbar region. The L4 and L5 transverse processes have very strong **iliolumbar ligaments** connecting them to the iliac crest.

Most posteriorly a long **supraspinous ligament** runs along the length of the vertebral column, jumping from the tip of each spinous process from C7 to the coccyx. Fibers of the supraspinous and interspinous ligaments are continuous with each other. Because the supraspinous is the most posterior of the ligaments of the vertebral column, it becomes taut in flexion and limits hyperflexion of the back. The supraspinous ligament terminates as the **superficial posterior sacrococcygeal ligament**, which covers the sacral hiatus. The coccyx is more firmly anchored to the sacrum by the **anterior, lateral, and deep posterior sacrococcygeal ligaments**. In the cervical region, the supraspinous ligament is replaced by the very broad, fan-shaped **nuchal ligament**, which runs from the external occipital protuberance to the posterior tubercle of the atlas and the spinous processes of C2–C7. Like the ligamentum flavum, the nuchal ligament contains elastic fibers. Because of that, the ligament allows cervical flexion but becomes taut as the neck is flexed further and further. Because of its large size, the nuchal ligament also provides a site of attachment for the muscles of the posterior neck.

CLINICAL CORRELATION 9.3 Herniated Nucleus Pulposus—Part 1

If the annulus fibrosus weakens or the nucleus pulposus is compressed too forcefully, it can tunnel through the protective laminae of the annulus fibrosus and protrude outward. This does not tend to occur anteriorly, due to the thick anterior longitudinal ligament, but when the back is flexed, the nucleus pulposus migrates posteriorly and can push through the annulus fibrosus. This is called a herniated nucleus pulposus, or a slipped disc. The thin posterior longitudinal ligament tends to deflect it posterolaterally, where it can compress a nearby spinal nerve.



Peripheral tear of anulus fibrosus and cartilage end plate (rim lesion) initiates sequence of events that weaken and tear internal anular lamellae, allowing extrusion and herniation of nucleus pulposus.

Fig. CC9.3 Disc Rupture and Nuclear Herniation.

In the thoracic region there are several ligaments that anchor the vertebrae to the proximal ribs. The **radiate ligament of the head of the rib** forms a continuous circular sheath that connects the head of the rib to the facets or demifacets of the vertebrae. Within the radiate ligament is a small **intra-articular ligament of the head of the rib** that anchors the central part of the rib head to the center of the facet/demifacet. The **costotransverse ligament** extends from the transverse process to the neck of the rib at the same level. A **superior costotransverse ligament** connects the neck of a rib to the transverse process of its superior neighbor (e.g., the superior costotransverse ligament of the 5th rib connects to the transverse process of T4). The **lateral costotransverse ligament** connects the lateral end of the transverse process to the tubercle of the rib, effectively becoming a capsular ligament for the costotransverse joint.

Ligaments of the Vertebral Bodies

Moving on to the vertebral bodies themselves, the broad **anterior longitudinal ligament** travels from the anterior aspect of the axis to the anterior sacrum, connecting the vertebral bodies and their intervertebral discs along its length. This strong ligament becomes taut during extension. In the upper cervical region, the anterior longitudinal ligament is continuous with an **anterior atlantoaxial membrane** and **anterior atlantooccipital membrane**. The anterior atlantooccipital membrane is a stout structure that continues laterally in association with the capsule of the atlantooccipital joint and is continuous with the posterior atlantooccipital membrane, forming a continuous ring of connective tissue running between the atlas and the foramen magnum.

The thinner **posterior longitudinal ligament** connects the posterior aspects of all the vertebral bodies and intervertebral discs from the axis to the sacrum. The **tectorial membrane** continues superiorly from the posterior longitudinal ligament (they are essentially the same ligament but with different names) to cover the dens and its ligaments and the posterior atlas. It runs along the inside of the occipital bone anterior to the foramen magnum.

In general, flexion of the vertebral column is limited by the supraspinous and nuchal ligaments, particularly in the thorax, due to its kyphotic curvature. Extension of the vertebral column is limited by the anterior longitudinal ligament and intervertebral discs. Excessive lordotic curvatures in the cervical and lumbar regions can stretch and eventually weaken the anterior longitudinal ligament (Clinical Correlation 9.4).

Ligaments Related to the Dens (Fig. 9.10)

For such a small structure, the dens of the axis is associated with a bewildering number of ligaments. The small **apical ligament** of the dens extends off its apex to insert on the anterior rim of the foramen magnum. Flanking the apical ligament are two strong **alar ligaments** that extend off the superolateral dens to insert on the anterolateral rim of the foramen magnum. These ligaments allow rotation of the head and atlas using the dens as a pivot point but prevent excessive rotation (e.g., as the head rotates to the right, the right alar ligament will become taut).

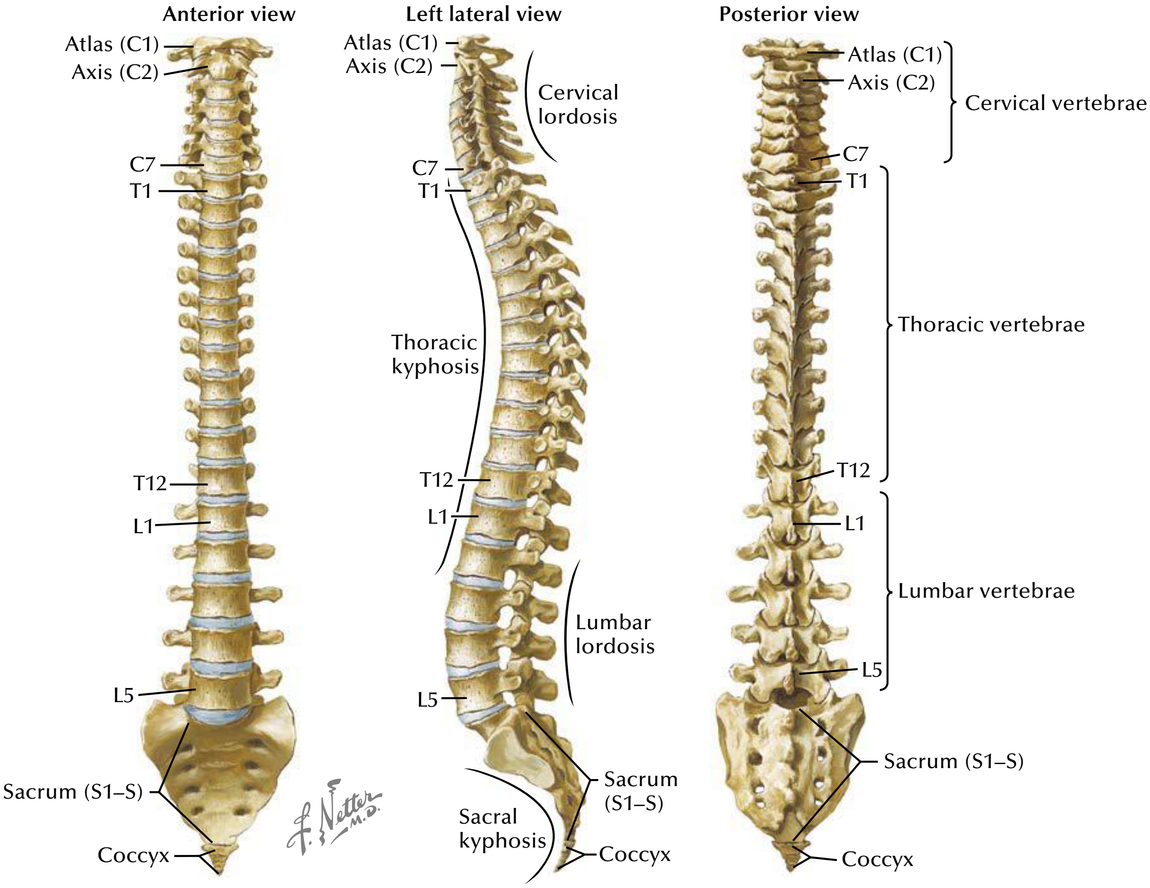


Fig. 9.8 Vertebral Column.

The **cruciate ligament of the atlas** is a composite structure that connects the axis, atlas, and occipital bone. Its horizontal component is the **transverse ligament of the atlas**, which connects the right and left inner sides of the anterior arch, passing posterior to the dens. This ligament actually forms a synovial articulation with the posterior articular facet of the dens. The vertical components of the cruciate ligament of the atlas are the **inferior longitudinal band** (posterior vertebral body of axis to the transverse ligament of atlas) and the **superior longitudinal band** (transverse ligament of atlas to the inner, anterior rim of the foramen magnum), which runs posterior to the apical ligament and anterior to the tectorial membrane (Clinical Correlation 9.5).

MUSCLE GROUPS OF THE BACK (FIG. 9.11A)

The bone, joints, and ligaments of the vertebral column allow the body to balance mobility with stability. However, the large muscles of the back are the structures that actually move and strongly stabilize the vertebral column and the spinal cord within it. The **intrinsic muscles of the back** develop from the epaxial muscles that are derived from the myotome of the somites at that level. These muscles attach to the vertebrae, iliac crest, ribs, and posterior skull. The **extrinsic muscles of the back** are located more superficially and are derived from the hypaxial muscles that migrate to the back. These muscles are attached to the back but primarily act to move the upper limbs, since they also attach to the scapula, clavicle, and/or humerus. One structure that connects many muscles of the back, both intrinsic and extrinsic, is the thoracolumbar fascia.

Thoracolumbar Fascia (See Fig. 9.11)

The lower back contains a unique multilayered connective tissue structure, the **thoracolumbar fascia**, which connects the ilium, vertebrae, and muscles of the back. The posterior layer is subdivided into two laminae: a superficial lamina that forms a broad, flat tendon of the latissimus dorsi and serratus posterior inferior muscles, and a deep lamina that attaches to the erector spinae muscles. The middle layer of the thoracolumbar fascia marks where the epaxial and hypaxial muscles were separated. It separates the erector spinae muscles from the quadratus lumborum, which connects the iliac crest to the 12th rib. The anterior layer of the thoracolumbar fascia surrounds the anterior aspect of the quadratus lumborum muscle. Anteriorly, the thoracolumbar fascia is continuous with the fascia surrounding the abdominal oblique muscles.

Extrinsic Back Muscles

Latissimus Dorsi Muscle

The **latissimus dorsi muscle** (see Fig. 9.11B) is the most superficial muscle of the inferior back. In English, its name means “widest of the back” and it certainly earns that description. This muscle originates broadly from the iliac crest, sacrum, lumbar and thoracic spinous processes (via thoracolumbar fascia) but

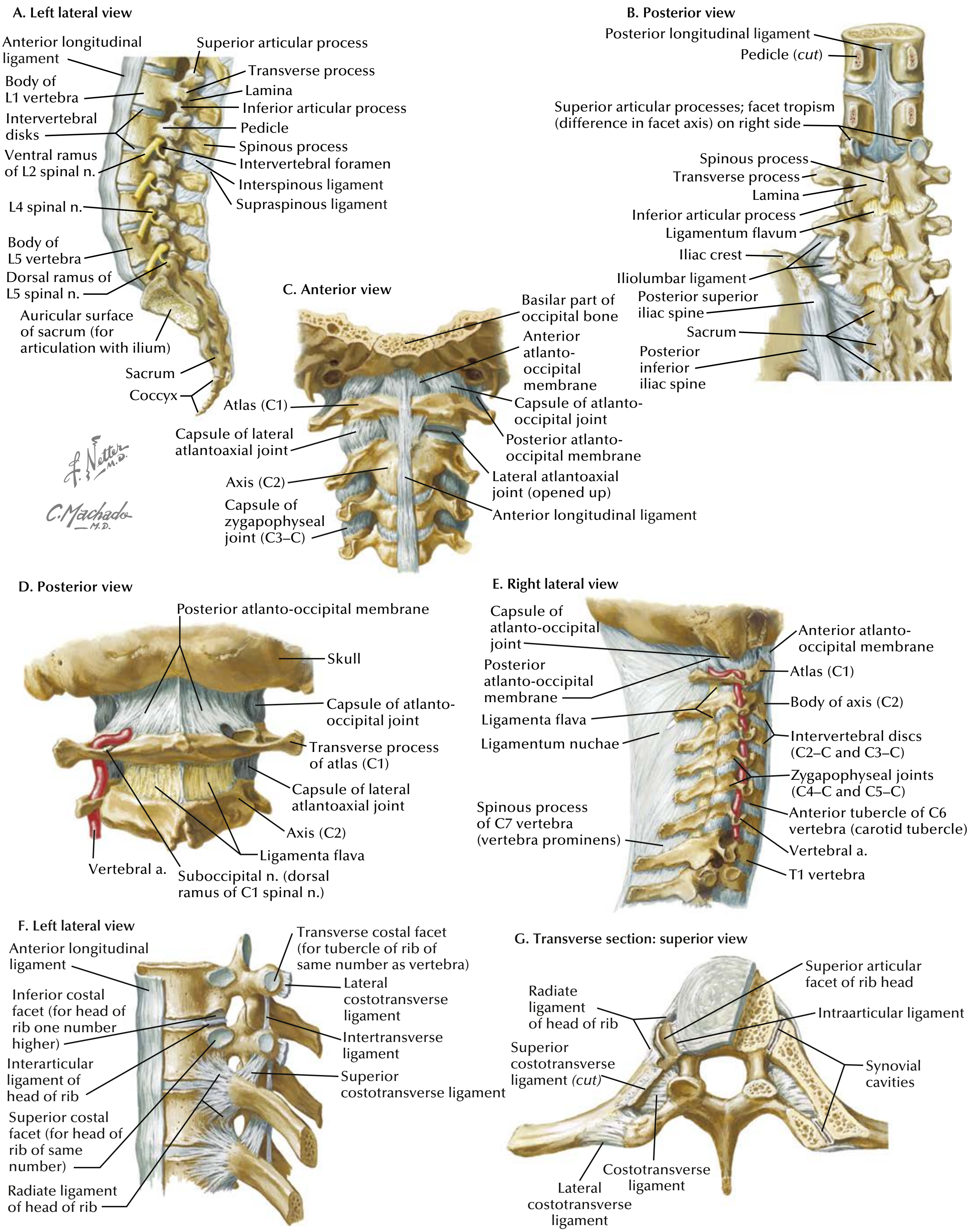


Fig. 9.9 Vertebral Ligaments: Lumbosacral Region.

CLINICAL CORRELATION 9.4
Hyperflexion and Hyperextension Injuries

When the vertebral column is violently extended or flexed, its muscular tissue, connective tissue, and nervous structures may be torn by the sudden motion. Muscular and ligamentous injuries are very painful but muscular injuries tend to heal more quickly, due to the greater vascularity of skeletal muscle compared to small vessels supplying connective tissue. Injuries of this kind can result in long-term debilitating pain.

Sudden hyperflexion (such as a sudden deceleration in a head-on vehicle collision) will stretch and possibly tear the muscles of the posterior neck as well as the ligaments of the posterior neck (in this order): (1) the nuchal ligament or supraspinous ligament, (2) interspinous ligament, and (3) ligamentum flavum. If the stretching continues it can put traction on the cervical spinal cord and possibly even tear the posterior longitudinal ligament and intervertebral disc. The same process can occur in the lumbar region (such as forced flexion during a sudden deceleration when restrained by a lap belt) and can affect muscles of the lower back and ligaments (in this order): (1) supraspinous, (2) interspinous, and (3) ligamentum flavum. As before, continued stretching may traumatize the cauda equina, posterior longitudinal ligament, and intervertebral disc.

Sudden hyperextension (such as being rear-ended in a vehicle collision without a headrest) will stretch and injure muscles of the anterior neck. If the stretch continues, the anterior longitudinal ligament and intervertebral disc may be torn. These are commonly called "whiplash" injuries and can also cause avulsion of part of the vertebral body as the ligament is torn. Another problem with hyperextension, especially in the cervical region, is the "pinching" of articular facets, pedicles, and spinous processes by their neighbors, possibly fracturing the vertebrae.

narrows to insert onto a small region of the proximal humerus. It will pull the arm closer to the lower back and this makes it a strong extensor of the shoulder, especially when the arm begins in a flexed position. Similarly, it strongly adducts the arm at the shoulder from an abducted position. Since its tendon slightly spirals around the anterior aspect of the humerus, it will also medially (internally) rotate the arm at the shoulder. The thoracodorsal nerve and vessels travel on the anterior surface of the latissimus dorsi and provide innervation and blood to it.

Proximal Attachments	• Iliac crest • Superficial lamina of posterior layer of thoracolumbar fascia (T7 to sacrum)
Distal Attachment	• Intertubercular sulcus of proximal humerus
Functions	• Extension of shoulder from a flexed position • Adduction of shoulder from an abducted position • Medial rotation of arm
Muscle Testing and Signs of Damage	• With the arms abducted at the shoulder, ask the patient to adduct them against resistance, assess any asymmetry in strength. • With the arms flexed at the shoulder, ask the patient to extend them against resistance, assess any asymmetry in strength.
Innervation	• Thoracodorsal nerve
Blood Supply	• Primarily thoracodorsal vessels

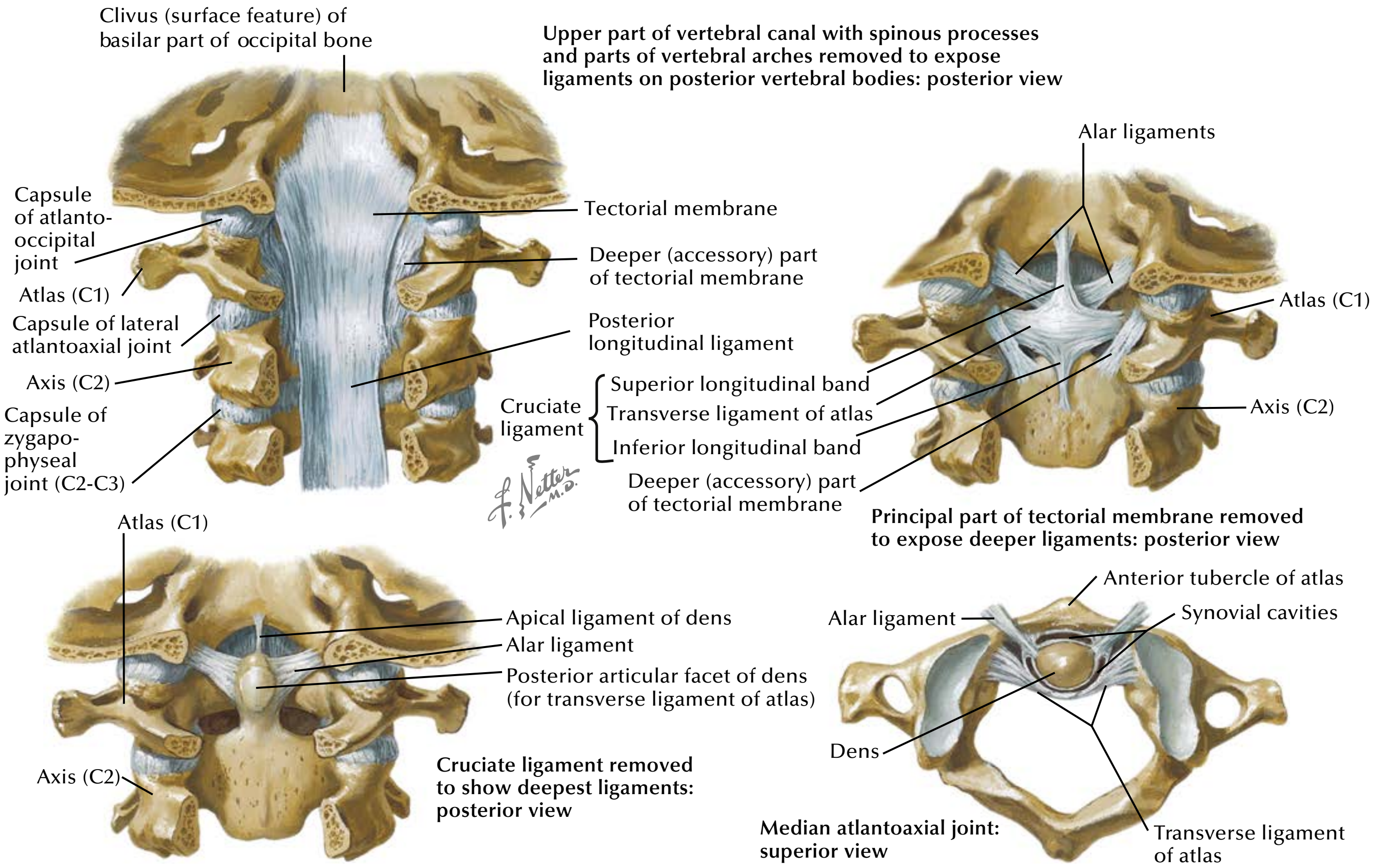


Fig. 9.10 Internal Craniocervical Ligaments.

CLINICAL CORRELATION 9.5 Rupture of the Transverse Ligament of the Atlas and Fracture of the Dens

Sudden compression of the head down onto the neck can put tremendous pressure on the articular facets of the atlas causing it to fracture. The transverse ligament of the atlas is also exposed to rupture when this occurs. Without an intact ligament, the atlas may translocate anteriorly, pinching the spinal cord. A similar problem can occur if the dens is fractured. If the tip of the dens is avulsed by the apical or alar ligaments (type I), there will not be gross instability of the atlas. If the base of the dens (type II) or the anterosuperior body of the axis (type III) is fractured, the dens and atlas are no longer restrained by the transverse ligament of the atlas, allowing anterior translation of the atlas and dens, impinging on the spinal cord.

Trapezius Muscle

The **trapezius** (see Fig. 9.11B) is the most superficial muscle of the superior back. This diamond-shaped muscle originates from the occipital bone, nuchal ligament, and thoracic spinous processes. It focuses this lengthy attachment onto the spine of the scapula, acromion, and distal clavicle. This allows the superior, middle, and inferior parts of the trapezius to elevate, retract, and depress the scapula, respectively. It receives motor innervation from cranial nerve XI (CN XI, spinal accessory nerve) but also has some sensory innervation from cervical spinal nerves. Intriguingly, there are sensory cell bodies (likely proprioceptive from the trapezius and sternocleidomastoid muscles) associated with CN XI, which is traditionally described as a motor-only nerve. The breadth of this muscle is reflected in its blood supply; it receives blood from branches of the external carotid artery and the thyrocervical trunk in the neck.

Proximal Attachments	• Superior fibers: Medial part of superior nuchal line and external occipital protuberance, nuchal ligament • Middle fibers: nuchal ligament, C7–T5 spinous processes • Inferior fibers: T6–T12 spinous processes
Distal Attachment	• Spine of scapula • Acromion • Distal clavicle
Functions	• Superior fibers: elevate scapula and upper limb • Middle fibers: retract scapula • Inferior fibers: depress scapula
Muscle Testing and Signs of Damage	• Ask patient to elevate shoulders against resistance • Weakness on one side may indicate dysfunction of the trapezius or CN XI.
Innervation	• CN XI—spinal accessory nerve
Blood Supply	• Primarily branches of external carotid artery and thyrocervical trunk (transverse cervical and dorsal scapular vessels)

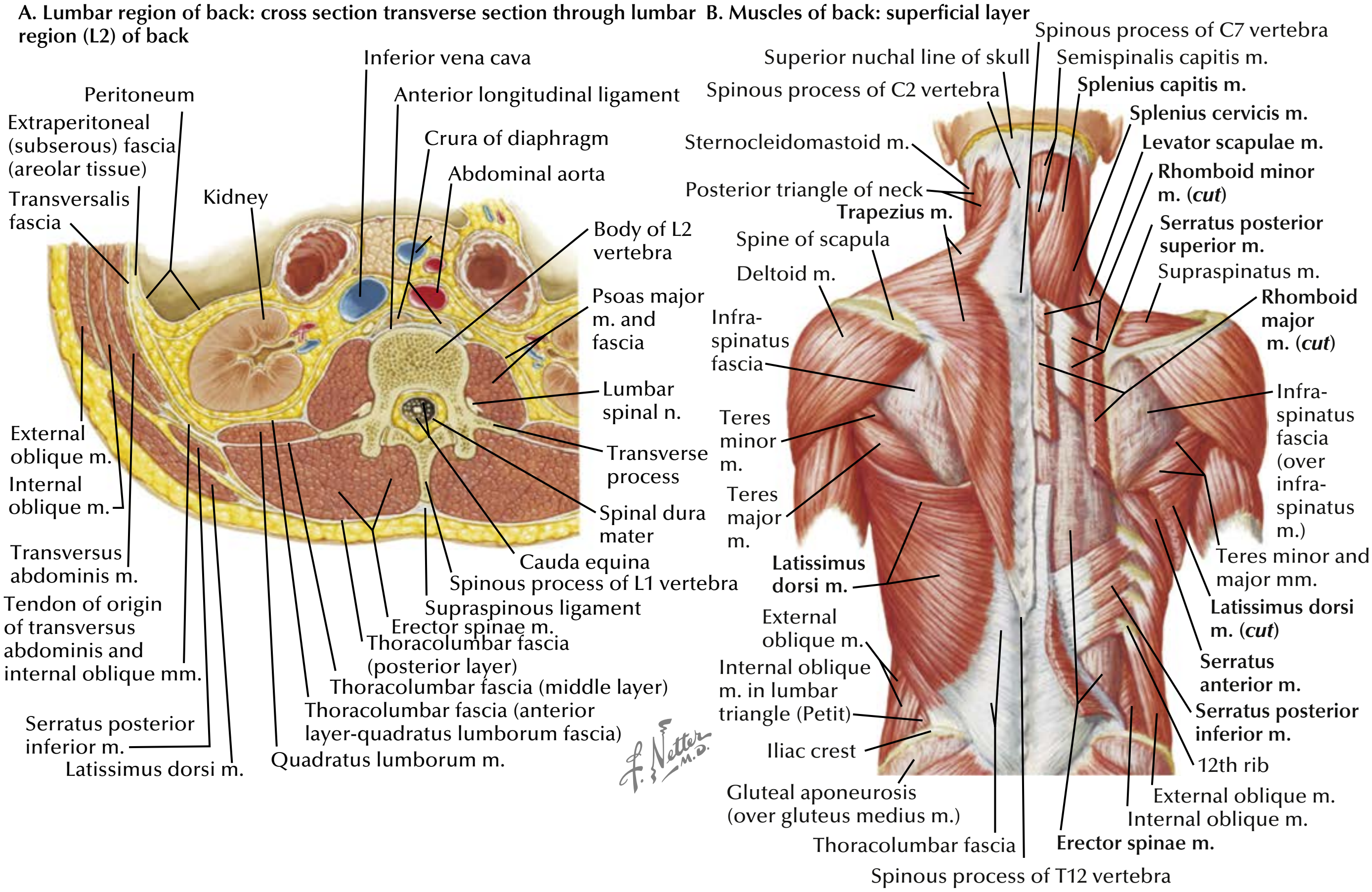


Fig. 9.11 (A) Lumbar region of back: cross-section of transverse section through lumbar region (L2) of back; (B) muscles of back: superficial layer.

Levator Scapulae Muscle

The **levator scapulae muscle** (see Fig. 9.11B) has muscle bellies originating from the transverse processes of the upper cervical vertebrae that fuse and insert onto the superior angle of the scapula. This very steep inferolateral slope makes the levator scapulae good at elevating the scapula (hence its name) but also in rotating the scapula inferiorly, pointing the shoulder "down" and depressing the upper limb. The dorsal scapular nerve passes between the heads of the levator scapulae, innervating it, and is joined by the dorsal scapular artery and vein.

Proximal Attachments	• C1 transverse process • C2–C4 posterior tubercles of the transverse processes
Distal Attachment	• Superior angle of scapula
Functions	• Elevate scapula • Inferior rotation of scapula and glenoid fossa
Muscle Testing and Signs of Damage	• Ask patient to elevate their shoulders bilaterally and watch for asymmetry. • Weakness on one side may indicate weakness of the levator scapulae muscles, but the activity of the superior fibers of the trapezius may mask this weakness.
Innervation	• Dorsal scapular nerve
Blood Supply	• Primarily dorsal scapular vessels

Rhomboid Major and Rhomboid Minor Muscles

The **rhomboid major** and **rhomboid minor muscles** (see Fig. 9.11B) are located deep to the middle and inferior fibers of the trapezius muscle. They travel from the lower cervical and upper thoracic spinous processes to insert on the medial border of the scapula near the scapular spine (minor) and medial to the infraspinatus fossa (major). In the process, both muscles travel in an inferolateral direction. These muscles sometimes fuse, obscuring the exact site of separation between major and minor. Since these muscles travel obliquely, they can retract the scapula but also rotate the scapula inferiorly, which will also shift the entire upper limb inferiorly. These muscles are innervated and perfused by the dorsal scapular nerve and vessels, which continue from the levator scapulae and run along the anterior aspect of the rhomboid muscles.

Proximal Attachments	• Minor: Inferior nuchal ligament, C7 and T1 spinous processes • Major: T2–T5 spinous processes
Distal Attachment	• Minor: Medial border of scapula superior to and at the level of the spine of the scapula • Major: Medial border of scapula from level of the spine of the scapula to near the inferior angle
Functions	• Retraction of scapula. • Inferior rotation of scapula and glenoid fossa.
Muscle Testing and Signs of Damage	• Ask patient to retract their shoulders bilaterally and watch for asymmetry. • Weakness retracting may indicate weakness of the rhomboid muscles, but the activity of the middle fibers of the trapezius may mask this weakness.
Innervation	• Dorsal scapular nerve
Blood Supply	• Primarily dorsal scapular vessels

Serratus Posterior Superior and Inferior Muscles

The **serratus posterior superior and inferior muscles** (Fig. 9.12, see also Fig. 9.11B) are flat, deep muscles that run from spinous processes to the ribs. The serratus posterior superior is located deep to the rhomboid muscles, running in an inferolateral direction. The serratus posterior inferior is deep to the latissimus dorsi muscle, traveling in a superolateral direction. Since the latissimus dorsi and serratus posterior inferior run the same direction and originate from the thoracolumbar fascia, they may fuse to some degree.

Proximal Attachments	• Superior: Inferior aspect of nuchal ligament, C7–T3 spinous processes • Inferior: Superficial lamina of posterior layer of thoracolumbar fascia near T11–L2.
Distal Attachment	• Superior: T2–T5 ribs, at or lateral to the costal angle • Inferior: T9–T12 ribs, lateral to the costal angle
Functions	• Electromyographic studies coupled with their small size suggests that these muscles are primarily proprioceptive in nature. • Superior: may assist in elevating the upper ribs during forced inspiration • Inferior: may assist in depressing the lower ribs during forced expiration
Muscle Testing and Signs of Damage	• These muscles are not typically assessed clinically. • Spasm or irritation of the serratus posterior superior often causes a "trigger point" that does become more painful in forced expiration but is not exacerbated by upper limb movement. This can be treated with manipulation or massage.
Innervation	• Superior: T2–T5 intercostal nerves • Inferior: T9–T11 intercostal nerves, T12 subcostal nerve
Blood Supply	• Superior: T2–T5 intercostal vessels • Inferior: T9–T11 intercostal vessels, subcostal vessels

Intrinsic Back Muscles

The **intrinsic back muscles** are interesting in that many of them do not have distinct origins and insertions. Instead, the erector spinae and transversospinalis groups consist of many small muscles that bundle together, contribute to the body of the muscle, and then leave as their small tendons attach to more superior bones. Other intrinsic back muscles do indeed have well-defined origins and insertions.

Splenius Cervicis and Splenius Capitis Muscles

The **splenius cervicis** and **splenius capitis muscles** (see Figs. 9.11B and 9.12) are located primarily in the cervical region and are immediately superficial to the erector spinae muscles there. They are oriented obliquely in a superolateral direction. These two muscles do not typically have a clear separation between each other and are distinguished by their sites of insertion. One way to distinguish the splenius muscles is that one of the muscle slips of the levator scapulae muscle will travel between the splenius cervicis and capitis to reach the C1 transverse processes.

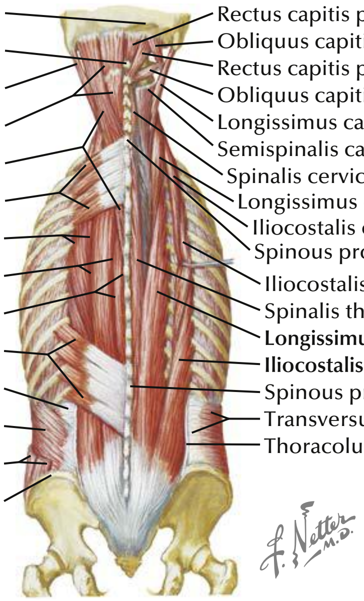


Fig. 9.12 Muscles of the Back: Intermediate Layers.

Proximal Attachments	• Cervicis: T3–T6 spinous processes • Capitis: Inferior portion of nuchal ligament, C7–T2 spinous processes • Note: the distinction between splenius cervicis and capitis tends to be indistinct at their proximal attachments.
Distal Attachment	• Cervicis: transverse process of C1, C2–C4 posterior tubercles of the transverse processes • Capitis: Posterior mastoid process of temporal bone, lateral occipital bone between superior and inferior nuchal lines
Functions	• Unilateral contraction: ipsilateral side-bending and rotation of the head (capitis) and neck (cervicis and capitis) • Bilateral contraction: extension of the head (capitis) and neck (cervicis and capitis)
Muscle Testing and Signs of Damage	• With a patient seated upright, palpate the posterior neck and ask the patient to slowly extend and rotate the neck. The splenius muscles may be palpable but they are difficult to isolate since they are deep to the trapezius and superficial to the semispinalis capitis, the most prominent extensor of the head. • If one side is weak, the patient will side-bend and rotate away from the weak side during extension of the neck. Spasm of these muscles will cause the patient to side-bend and rotate toward the affected side.
Innervation	• Posterior rami of cervical spinal nerves near their level of origin
Blood Supply	• Primarily branches of external carotid artery and thyrocervical trunk (transverse cervical vessels)

Erector Spinae

The **erector spinae** (see Fig. 9.12) group of muscles is located deep to the trapezius, latissimus dorsi, rhomboid, and serratus posterior muscles. They run longitudinally along the vertebral column and for this reason they are sometimes referred to as the **paraspinal muscles**. The erector spinae are surrounded posteriorly by the deep lamina of the posterior layer of the thoracolumbar fascia. They have broad origin from the T11 to L5 transverse processes, posterior sacrum, and iliac crest. These muscles ascend (mostly) superolaterally to insert on more lateral and superior structures such as transverse processes, spinous processes, and ribs. Since these muscles travel obliquely, unilateral contraction will side-bend and rotate the body ipsilaterally, bilateral contraction will strongly extend the vertebral column.

The erector spinae are divided into the **iliocostalis**, **longissimus**, and **spinalis muscles**, which will then become further subdivided (buckle up). The iliocostalis has thoracic and cervical sections. The longissimus has lumbar, thoracic, cervical, and capitis sections. The spinalis has thoracic, cervical, and capitis sections.

Proximal Attachments	• **Iliocostalis Muscle Group** • Iliocostalis lumborum: L4–L5 transverse processes, posterior sacrum, iliac crest • Iliocostalis thoracis: Ribs 7–12 near costal angle • Iliocostalis cervicis: Ribs 3–6 near costal angle • **Longissimus Muscle Group** • Longissimus thoracis: L1–L5 transverse processes, posterior sacrum • Longissimus cervicis: T1–T5 transverse processes • Longissimus capitis: T1–T5 transverse processes, C4–C7 articular processes • **Spinalis Muscle Group** • Spinalis thoracis: spinous processes of T10–L2 • Spinalis cervicis: inferior portion of nuchal ligament and T1 spinous process • Spinalis capitis: middle region of the nuchal ligament
Distal Attachment	• **Iliocostalis Muscle Group** • Iliocostalis lumborum: Ribs 7–12 at (or lateral) to the costal angle • Iliocostalis thoracis: Ribs 1–6 near the costal angle • Iliocostalis cervicis: C4–C7 transverse processes • **Longissimus Muscle Group** • Longissimus thoracis: all thoracic transverse processes and all ribs proximal to the costal angle • Longissimus cervicis: C2–C7 transverse processes • Longissimus capitis: posterior aspect of mastoid process of temporal bone • **Spinalis Muscle Group** • Spinalis thoracis: T1–T8 spinous processes • Spinalis cervicis: C7–C2 spinous processes • Spinalis capitis: between superior and inferior nuchal lines of occipital bone, fused with semispinalis capitis
Functions	• Unilateral contraction: ipsilateral side-bending and rotation • Bilateral contraction: extension of vertebral column
Muscle Testing and Signs of Damage	• With a patient seated upright, palpate the paraspinal muscle columns (erector spinae) on the back. Ask the patient to slowly extend the back. Observe any asymmetry or deviation to one side. • If one side is weak, the patient will side-bend and rotate away from the weak side during extension of the back. Spasm of these muscles will cause the patient to side-bend and rotate toward the affected side. • These muscles are commonly strained during heavy lifting. The patient will commonly adopt a position of ease that passively shortens the muscle. He or she will sit or stand, side-bent towards the affected side, letting gravity shorten the affected muscle. Pain typically results from extension of the back, side-bending away from the affected side (stretching the injured muscle), or ACTIVE side-bending toward the affected side or extension (contracting the injured muscle).
Innervation	• Posterior rami of spinal nerves near their level of origin
Blood Supply	• Posterior segmental arteries accompanying the posterior rami

BIOMECHANICS BOX 9.2
Transversospinalis Muscles

While the members of the transversospinalis group span many vertebral levels, there are some that are particularly important. The **rotatores thoracis** are the best developed of the rotatores and are particularly prone to strain during jerky rotation of the vertebrae. Because of their proprioceptive and sensory function, they are quite painful when injured. The **multifidus lumborum** is a massive wedge of muscle that stretches between the posterior sacrum, iliac crest, lumbar transverse processes, and lumbar spinous processes. It serves to anchor the vertebral column to the pelvis during flexion and standing. If we think of the spinal column as the extended arm of a crane, the multifidus lumborum is the heavy, stable base of the crane. The **semispinalis cervicis** and **semispinalis capitis** are large, nearly vertical muscles that are major extensors of the head and neck. These can become spastic or hyperactive during muscle-tension headaches.

Transversospinalis Muscle Group

The **transversospinalis muscle group** (Fig. 9.13, see also Fig. 9.12) are the deepest of the intrinsic back muscles and are generally nestled in the groove between transverse and spinous processes of the vertebrae, hence their name. This group runs longitudinally along the vertebral column, but unlike the splenius and erector spinae muscles, they travel in a superomedial direction. With a few exceptions, the transversospinalis muscles will side-bend the back ipsilaterally and rotate the back contralaterally when contracted unilaterally. When contracted bilaterally they will extend the back and head.

The transversospinalis muscles are divided into the **semispinalis**, **multifidus**, and **rotatores muscles**. Since these muscles all originate from transverse processes and insert on spinous processes (or the occipital bone), they are not distinguished by differences in their attachments but by how many vertebral segments they span. Semispinalis muscles span greater than 4 vertebral levels as they ascend, multifidus muscles span 2 to 4 levels, rotatores span 1 to 2 levels. As you might already suspect, they will be further subdivided based on the region of the back in which they reside. The semispinalis muscles have thoracic, cervical, and capitis sections. Due to their vertical orientation, the semispinalis muscles are primarily extensors of the back, with the very large **semispinalis capitis muscle**, which is located deep to the trapezius and splenius muscles, being a powerful extensor of the head and neck. The multifidi have lumbar, thoracic, and cervical sections. Due to their oblique course, they can extend and rotate the vertebrae. The rotatores have lumbar, thoracic, and cervical sections but are best developed in the thoracic region. The rotatores that span two vertebral levels are referred to as **rotatores longus** (a bit hyperbolic for such short muscles), while those spanning one level are **rotatores brevis** (Biomechanics Box 9.2).

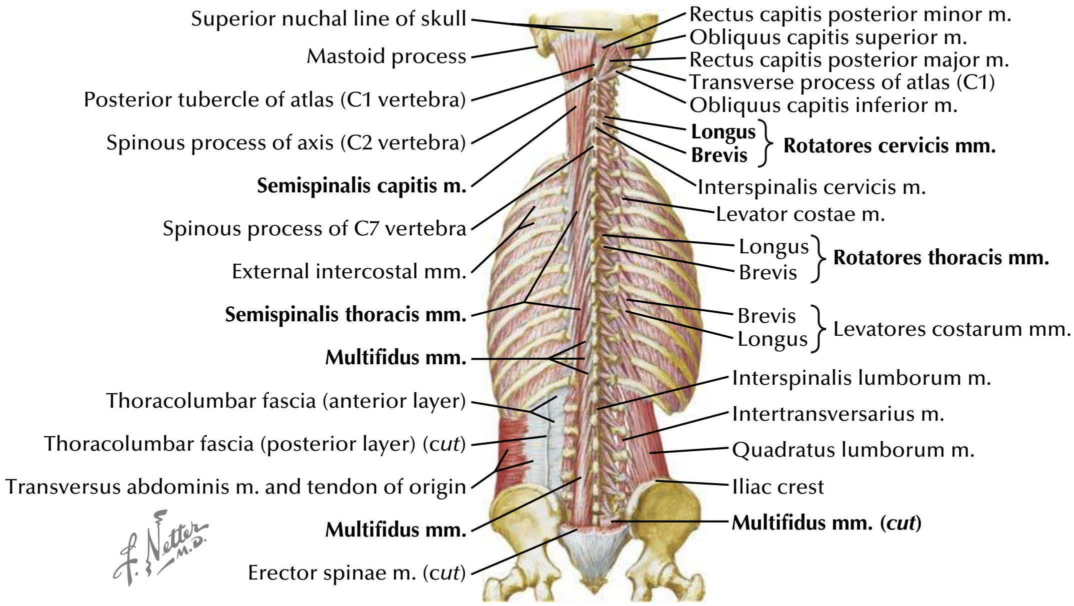


Fig. 9.13 Muscles of the Back: Deep Layers.

Inferior Attachments	• **Semispinalis Muscle Group (spans >4 segments)** • Semispinalis thoracis: T6–T10 transverse processes • Semispinalis cervicis: T1–T5 transverse processes • Semispinalis capitis: C4–T6 transverse processes • **Multifidus Muscle Group (spans 2–4 segments)** • Multifidus lumborum: posterior sacrum, posterior superior iliac spine, lumbar mammillary processes • Multifidus thoracis: thoracic transverse processes • Multifidus cervicis: C4–C7 articular processes • **Rotatores Muscle Group (spans 1–2 segments)** • Rotatores lumborum: L1–L5 transverse processes • Rotatores thoracis: T1–T12 transverse processes • Rotatores cervicis: C3–C7 transverse processes
Superior Attachment	• **Semispinalis Muscle Group (spans >4 segments)** • Semispinalis thoracis: C6–T4 spinous processes • Semispinalis cervicis: C2–C6 spinous processes (C2 insertion is very prominent) • Semispinalis capitis: medial occipital bone between superior and inferior nuchal lines • **Multifidus Muscle Group (spans 2–4 segments)** • Multifidus lumborum: L1–L5 spinous processes • Multifidus thoracis: T1–T12 spinous processes • Multifidus cervicis: C2–C7 spinous processes • **Rotatores Muscle Group (spans 1–2 segments)** • Rotatores lumborum: T12–L4 spinous processes • Rotatores thoracis: C7–T11 spinous processes • Rotatores cervicis: C2–C6 spinous processes

Functions	• **Semispinalis Muscle Group** • Unilateral contraction: ipsilateral side-bending and slight contralateral rotation • Bilateral contraction: extension of the back • The semispinalis capitis strongly extends the head • **Multifidus Muscle Group** • Unilateral contraction: ipsilateral side-bending and contralateral rotation • Bilateral contraction: extension of vertebral column • The multifidus lumborum anchors the lumbar vertebrae to the sacrum and ilium. • **Rotatores Muscle Group** • Unilateral contraction: weak ipsilateral side-bending and contralateral rotation • Bilateral contraction: very weak extension of vertebral column • These muscles are too small to move the vertebrae notably. They may stabilize the vertebral column somewhat but are primarily proprioceptive.
Muscle Testing and Signs of Damage	• These muscles are rarely tested clinically but they are a possible source of back pain due to injury, strain, or atrophy. • If a patient has back pain caused by spasm or injury to one of these muscles, it can be localized by asking the patient to extend his or her back. Thereafter, side-bending away from the affected muscle will stretch it and cause pain. If the pain is localized to the deep back and becomes even worse with ipsilateral rotation, it is probably originating from a transversospinalis muscle.
Innervation	• Posterior rami of spinal nerves near their level of origin
Blood Supply	• Lumbar and thoracic divisions: posterior segmental arteries accompanying the posterior rami • Cervical and capitis divisions: branches of external carotid artery and thyrocervical trunk (transverse cervical and dorsal scapular vessels)

Suboccipital Muscles

The **suboccipital muscles** (Fig. 9.14, see also Figs. 9.12 and 9.13) are a collection of four short muscles clustered between the spinous process of the axis and the posterior occipital bone. The **suboccipital triangle** is formed by **rectus capitis posterior major** (medial border), **obliquus capitis inferior** (inferior), and **obliquus capitis superior** (superior). The **rectus capitis posterior minor** is medial to the triangle. This triangle contains the vertebral artery as it passes across the posterior arch of the atlas to pierce the posterior atlantooccipital membrane. It also contains the posterior ramus of C1, called the **suboccipital nerve**, which innervates the suboccipital muscles. The **greater occipital nerve** (C2 posterior ramus) is a large sensory nerve that passes immediately inferior to the obliquus capitis inferior muscle to reach the posterior scalp (Clinical Correlation 9.6).

Proximal Attachments	• Rectus capitis posterior minor: posterior tubercle of C1 • Rectus capitis posterior major: spinous process of C2 • Obliquus capitis inferior: spinous process of C2 • Obliquus capitis superior: transverse process of C1
Distal Attachment	• Rectus capitis posterior minor: medial aspect of inferior nuchal line • Rectus capitis posterior major: lateral aspect of inferior nuchal line • Obliquus capitis inferior: transverse process of C1 • Obliquus capitis superior: lateral aspect of occipital bone between superior and inferior nuchal lines
Functions	• Unilateral contraction: ipsilateral side-bending • Bilateral contraction: extension of the atlantoaxial and atlantooccipital joints
Muscle Testing and Signs of Damage	• The suboccipital muscles may become spastic or hyperactive during muscle-tension headaches. Patients may complain of their head feeling "locked down." • Manipulation or massage at the base of the skull can help to temporarily relieve this pain.
Innervation	• Suboccipital nerve (C1 posterior ramus)
Blood Supply	• Branches of external carotid artery and vertebral vessels.

Minor Deep Back Muscles (See Fig. 9.13)

There are several very small, mostly proprioceptive muscles in the back. They are not able to move the back appreciably but act to stabilize the vertebrae and ribs and provide proprioceptive feedback based on the tension and stretch they experience. Left and right **interspinales muscles** connect adjacent spinous processes and are separated by the midline interspinous ligament. **Intertransversarii muscles** connect adjacent transverse processes on each side of the vertebrae. The **levatores costarum muscles** extend inferiorly from the transverse processes to the proximal ribs. Those that extend inferiorly by one rib are the **levatores costarum brevis**; those that reach two ribs lower are the **levatores costrum longus**.

Superior Attachments	• Interspinales: inferior aspect of spinous processes (indistinct in thoracic region) • Intertransversarii: inferior aspect of transverse processes (indistinct in thoracic region) • Levatores costarum brevis: transverse processes from C7 to T11 • Levatores costarum longus: transverse processes from C7 to T10
Inferior Attachment	• Interspinales: superior aspect of spinous processes of the neighboring inferior vertebra • Intertransversarii: superior aspect of transverse processes of the neighboring inferior vertebra • Levatores costarum: area near costal tubercle of rib (brevis—1 rib lower; longus—2 ribs lower)
Functions	• Stabilize adjacent vertebrae and proximal ribs. • Proprioceptive feedback regarding tension and position of vertebrae and ribs.
Muscle Testing and Signs of Damage	• Spasm of these muscles may produce focal deep back pain that is exacerbated by flexion (interspinales), contralateral side-bending (contralateral intertransversarii), and deep exhalation (levatores costarum). • Manipulation or massage at the tender area may temporarily relieve this pain.
Innervation	• Interspinales: Posterior rami of C2–L5 • Intertransversarii: anterior (cervical) and posterior (lumbar) rami. Thoracic levels may be indistinct due to possible absence of intertransversarii. • Levatores costarum: Posterior rami of C8–T11
Blood Supply	• Superficial and deep transverse cervical vessels • Posterior divisions of intercostal and lumbar segmental vessels

Other Muscles

There are other muscles that are seen in the back but have their greatest effect elsewhere. The **external abdominal oblique muscle** originates from the ribs and iliac crest before wrapping around the abdomen. Deep to the latissimus dorsi, serratus posterior inferior, and erector spinae muscles is the quadratus lumborum muscle, which is part of the posterior abdominal wall. It originates from the posteromedial iliac crest and inserts on the lumbar transverse processes and inferior aspect of rib 12. It may be a source of tension and deep back pain that is exacerbated by side-bending away from the affected side. These muscles will be discussed in more detail in the section on the abdomen (Clinical Correlation 9.7).

THE VERTEBRAL CANAL

Within the vertebral canal are the three **meninges** that surround the spinal cord and the spinal nerves. The dura mater is the outermost protective layer, but it does not take up all the space within the canal. A great deal of **epidural fat** (adipose tissue) and an extensive **internal vertebral venous plexus** surround the dura mater in the **epidural space** (Fig. 9.15).

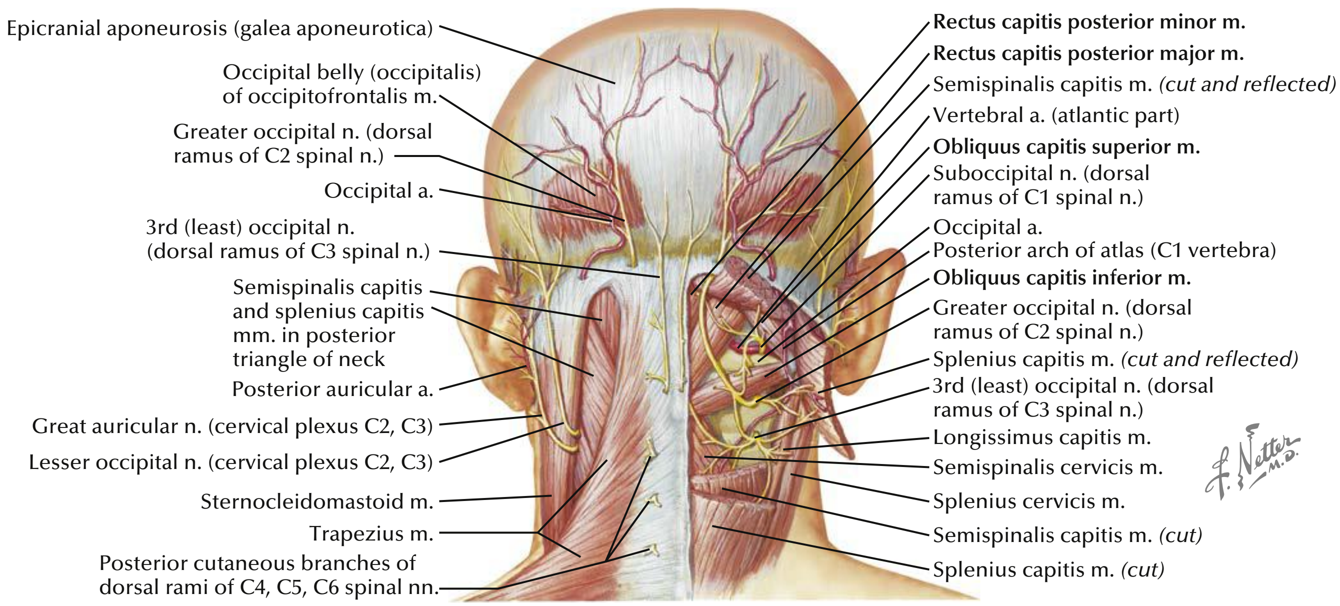


Fig. 9.14 Suboccipital Triangle.

CLINICAL CORRELATION 9.6 Myodural Bridges

The dura mater is exquisitely sensitive to pain and is frequently the source of severe headaches. One intriguing aspect of the suboccipital muscles are the myodural bridges running between the suboccipital muscles and cervical dura mater. Distinct bands of connective tissue extend from the anterior surface of the rectus capitis posterior minor, rectus capitis posterior major, and obliquus capitis inferior to pierce the posterior atlantoaxial and atlantooccipital membranes and fuse with the underlying dura mater. This direct connection may explain how suboccipital muscle spasm or dysfunction can cause headaches that are too severe to be explained by tension of these small muscles alone. The function of the myodural bridges is still being debated. Since the posterior atlantoaxial and atlantooccipital membranes are not as elastic as the ligamentum flavum present at other levels, the myodural bridges may allow the suboccipital muscles to pull the dura mater posteriorly during extension of the neck and prevent it from folding forward to push on the spinal cord.

CLINICAL CORRELATION 9.7 Lumbar Triangle and Lumbar Hernia

The **lumbar triangle** is formed by the latissimus dorsi muscle (medial border), external abdominal oblique (lateral border), and iliac crest (inferior border) (see Fig. 9.11B). The floor of this triangle is made by two other abdominal muscles, the internal oblique and transversus abdominis muscles. The lumbar triangle constitutes a weak spot in the abdominal wall since it is covered by only two muscles instead of three. When intraabdominal pressure rises, portions of the small or large intestines can push through this weak spot, creating a lumbar hernia. The herniated gut may slide in and out of the defect or it may become stuck and strangulated in the narrow opening.

Meninges (See Fig. 9.15)

The **dura mater** sits within the vertebral canal, surrounded by the epidural space and surrounding the spinal cord and spinal nerve roots. The dura mater is a tough and relatively inelastic connective tissue structure made primarily from type I collagen that truly does protect the spinal cord (it is not hyperbole that *dura mater* translates into English as "tough mother"). The entire open space inside the dura mater is referred to as the **dural sac**. The epidural space surrounds the dura mater along the entirety of the vertebral canal. Superiorly, the spinal dura mater becomes the cranial dura mater as it enters the foramen magnum. As this happens the **meningeal dura mater** fuses with the internal periosteum of the skull's calvarium, which is sometimes called the **periosteal dura mater**. As each spinal nerve exits the intervertebral foramen, a sleeve of dura mater surrounds it (and the spinal roots that create it). These **dural root sheaths** fuse with the periosteum of the vertebrae, forming the intervertebral foramen. Inferiorly, the dural sac ends approximately at the S2 vertebral level. However, multiple dural root sheaths continue around the S3–Co1 spinal nerve roots until they each meet their foramina. A single long midline extension of dura mater, the **filum terminale externum**, fuses to the posterior coccyx and anchors the dural sac inferiorly.

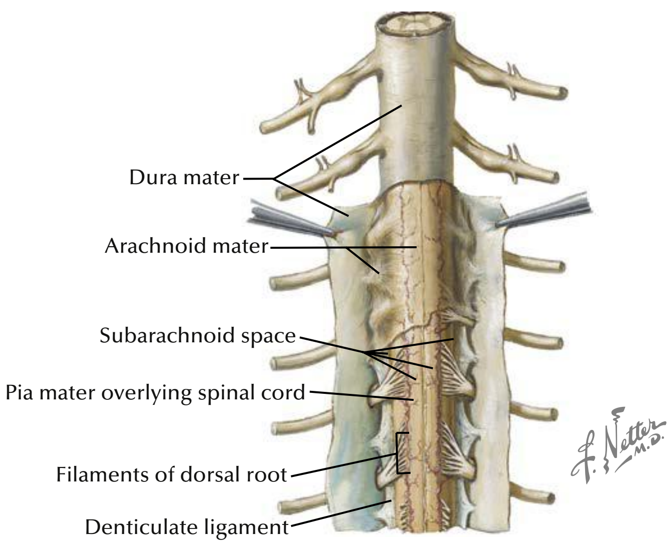


Fig. 9.15 The Spinal Meninges and Their Relationship to the Spinal Cord.

Deep to the dura mater is the next layer of the meninges, the **arachnoid mater**. This structure gets its name ("spidery mother") from the diffuse, cobweb-like nature of its fibers. In the gross anatomy laboratory, this layer is typically seen plastered to the outside of the spinal cord. But in life it is pushed outward by **cerebrospinal fluid (CSF)** in the **subarachnoid space** and into contact with the dura mater. Between the dura and arachnoid mater is a potential space that is only seen when blood or some other mass pushes the two layers apart, the **subdural space**. The arachnoid mater consists of wispy type I collagen fibers alongside elastic fibers. It is avascular and derives nutrition from the CSF, yet it helps support blood vessels as they approach and depart from the spinal cord. **Arachnoid trabeculae** extend from the arachnoid mater and fuse to the next layer, the pia mater.

The **pia mater** is the final, and deepest, layer of the meninges. It is intimately bound to all surfaces of the central nervous system, including the spinal cord, spinal roots, and spinal nerves. The very end of the spinal cord, the conus medullaris, narrows to leave only the outer layer of pia mater, which extends all the way down to the posterior coccyx as the **filum terminale internus** within the filum terminale externum. However, this is not the only way the pia mater stabilizes the spinal cord. Denticulate ligaments are pial extensions that leave the spinal cord on the left and right (≈20 to 22 pairs) to pierce the arachnoid mater and insert onto the dura mater. They are present along the length of the cord and can be identified as they separate into anterior and posterior roots.

My favorite metaphor for appreciating the arrangement of the meninges is to liken them to sleeping in a sleeping bag. The tough sleeping bag surrounds everything in a big sac like the dura mater. The pajamas a person wears are much lighter, much like the arachnoid mater. Finally, the skin beneath the pajamas is just like the pia mater. It cannot be removed without damaging the underlying body/spinal cord.

The subarachnoid space contains the CSF that keeps the spinal cord and spinal nerve roots buoyant. The CSF leaves the ventricular system of the cerebral hemispheres and fills the subarachnoid space around the brain, brainstem, and spinal cord. CSF leaves the subarachnoid space by draining through arachnoid granulations into a huge dural venous sinus (the superior sagittal sinus) in the head. It was long believed that the dural sac was a blind pouch for CSF. But small arachnoid granulations of the dural root sheaths also remove CSF from the spinal subarachnoid space and deposit it into nearby radicular veins (Clinical Correlation 9.8).

INNERVATION OF THE BACK

The neuroanatomy of the spinal cord has been described already. For the rest of this chapter we will discuss how the spinal cord innervates the muscles of the back and the overlying skin with reference to the anatomy, histology, and physiology of the area.

Spinal Levels and the Cauda Equina

The spinal cord gives off a spinal nerve for each vertebral level. In the back, each of these nerves will supply a strip of skin that extends from the midline of the back to the anterior midline (Fig. 9.16).

CLINCAL CORRELATION 9.8 Lumbar Puncture

It is sometimes useful to get a sample of the CSF to diagnose infections of the meninges or to administer anesthetics. To perform a lumbar puncture (spinal tap) the needle is directed through the skin, subcutaneous fat, thoracolumbar fascia (if the needle is inserted off the midline), supraspinous ligament (if the needle is inserted on the midline), interspinous ligament, nuchal ligament, epidural space, dura mater, arachnoid mater, and (finally) the subarachnoid space and CSF. This is done in the lower lumbar region so that the needle cannot accidentally contact the spinal cord but passes between the spinal nerve roots, which are mobile enough to not get stuck by the needle tip. To aid in the process of needle insertion, the patient is asked to flex forward to spread the lumbar laminae away from each other to make it less likely that the needle will impact them. Anesthesia can also be administered into the subarachnoid space using this route.

To numb the sacral nerves during childbirth, anesthetic can be injected into the epidural space around the spinal nerve roots, spinal nerves, and their dural sleeves. Caudal epidural anesthesia is administered by directing a needle through the sacral hiatus using the sacral cornua as palpatory landmarks. Alternatively, the needle can be inserted through a posterior sacral foramen to bathe the nerves via a transsacral epidural anesthesia.

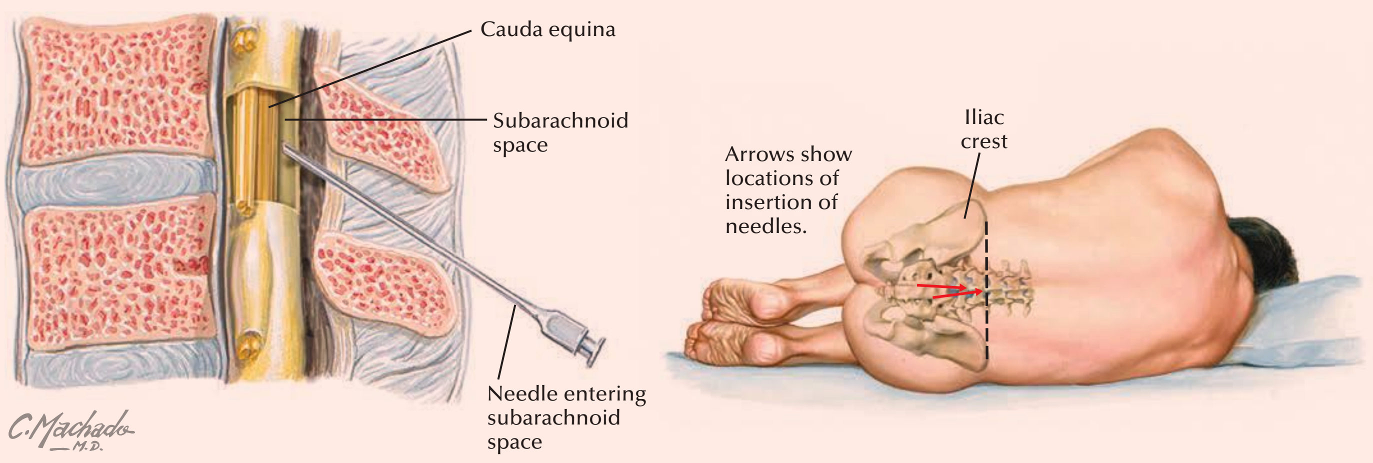


Fig. CC9.8 Lumbar Spinal Puncture.

- 8 cervical spinal nerves exit superior to the corresponding vertebra (e.g., C4 spinal nerve exits between C3 and C4 vertebrae). The one exception is that the C8 spinal nerve exits between C7 and T1 vertebrae.
- 12 thoracic spinal nerves exit inferior to corresponding vertebra (e.g., T4 spinal nerve exits between T4 and T5 vertebrae).
- 5 lumbar spinal nerves exit inferior to the corresponding vertebra (e.g., L4 spinal nerve exits between L4 and L5 vertebrae).
- 5 sacral spinal nerves exit through the intervertebral foramen and anterior and posterior sacral foramina inferior to the corresponding vertebra (e.g., S4 spinal nerve exits between fused S4 and S5 vertebrae).
- 1 to 2 coccygeal spinal nerves exit in the vicinity of the proximal coccyx.

The Spinal Cord in Detail (Fig. 9.17A and B)

The interior of the spinal cord has a core of butterfly-shaped gray matter (nerve cells) with the central canal of the ventricular system at the center.

The internal structures of interest for each spinal nerve are:

- **Posterior horn**: contains neuron cell bodies associated with sensory tracts as well as interneurons that connect to other regions of the spinal gray matter.
- **Anterior horn**: contains lower motor neurons that project their axons out through the anterior spinal roots to innervate skeletal muscle.
- **Intermediate zone:** contains:
  - **Interneurons**: present at all levels, communicate with other regions of the spinal cord.
  - **Spinal accessory nucleus (CN XI):** present in upper cervical region only, provides motor innervation to the trapezius and sternocleidomastoid muscles.
  - **Intermediolateral cell column**: present from T1 to L2, supplies preganglionic sympathetic axons to innervate visceral structures of the body.

The large white-matter regions on the outside of the spinal cord are called **columns** or **lemnisci** and consist of sensory (afferent) axons ascending toward the cortex as well as motor (efferent) axons descending to the gray matter of the cord.

- **Dorsal columns**: contain ascending sensory tracts conveying proprioceptive, vibration, and fine touch stimuli (dorsal column-medial lemniscal system) that synapse with nuclei in the medulla.
- **Lateral columns**: contain descending motor tracts to control willful motion (lateral corticospinal and rubrospinal tracts) that synapse with nerves in the anterior horn. The lateral column also contains ascending sensory tracts (dorsal and ventral spinocerebellar tracts) to the cerebellum.

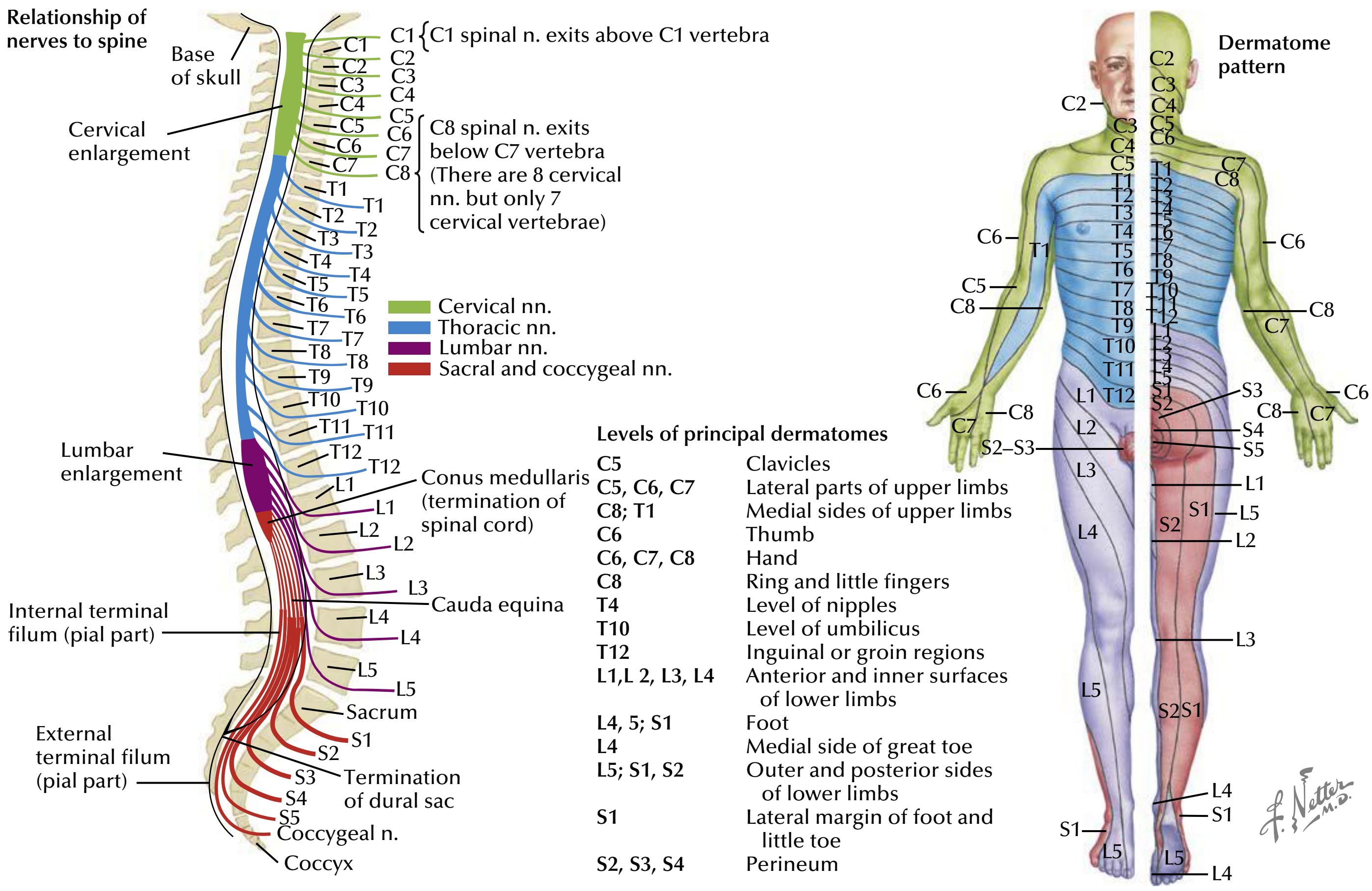


Fig. 9.16 Spinal Nerves and Sensory Dermatomes.

- **Anterior columns**: the most medial portions contain descending motor tracts (anterior corticospinal, medial and lateral vestibulospinal, reticulospinal, and tectospinal tracts) that synapse with nerve cells in the anterior horn. More laterally, where the anterior column overlaps with the lateral column, is the anterolateral system, an ascending sensory tract that conveys pain, temperature, and crude touch stimuli to nuclei in several regions of the brainstem.

Upper motor neurons (see Figs. 8.12, 8.14, and 8.17-8.20) from several parts of the central nervous system descend to reach the gray matter of the spinal cord. Within the spinal cord, these axons are protected by **oligodendrocytes** that send processes outward to surround segments of several nearby axons with **myelin sheaths**.

- **Precentral gyrus of cortex**: projects axons through the lateral corticospinal tracts in the lateral columns, as well as the anterior corticospinal tracts in the anterior columns
- **Red nucleus of midbrain**: sends axons through the rubrospinal tracts in the lateral columns
- **Tectal nuclei in midbrain**: axons descend through the tectospinal tracts of the anterior columns
- **Reticular formation**: projects axons through the reticulospinal tracts in the anterior columns
- **Vestibular nuclei of the medulla**: send axons through the medial and lateral vestibular tracts in the anterior columns

Upper motor neurons that innervate proximal trunk muscles (including intrinsic muscles of the back) leave their tracts and synapse with **lower motor neurons** (see Fig. 8.14) in the medial aspect of the anterior horn. Synapses between upper and lower motor neurons are mediated by interneurons and the neurotransmitter **glutamate**. After being released into the synaptic cleft, glutamate binds to **glutamatergic receptors** that have both ionotropic and metabotropic properties. Ionotropic receptors allow Na^+ and Ca^{2+} to enter the lower motor neuron, causing a net depolarization and making generation of an action potential more likely. Glutamate is cleared from the synaptic cleft by Na+-dependent **glutamate transporters** of the nearby astrocytes.

Lower motor neurons at each level of the spinal cord project their axons out through the anterolateral side of the column through multiple rootlets. At each vertebral level these rootlets combine to form a single **anterior spinal root** that contains somatic lower motor neurons as well as visceral motor preganglionic sympathetic axons. Anterior spinal roots travel laterally from the spinal cord to reach muscles. As they travel, they meet the posterior spinal roots (see below) that convey sensory information from that level and fuse to form a **spinal nerve**.

Just as the anterior spinal roots carry motor axons from neurons in the anterior horn, posterior roots convey sensory axons from the **posterior root ganglia**. These ganglia sit alongside the posterolateral aspect of the spinal cord. The sensory neurons in the ganglia are derived from neural crest cells. These pseudounipolar nerve cells are characterized by the large size of their cell body, central nucleus (making the cell look like an over-easy fried egg), and many small satellite cells located around the body. They also have a single axon that departs from the cell body before splitting into a medial and lateral branch. Together, the medial and lateral branches from the posterior root ganglion are collectively called a **posterior spinal root**.

- **Medial branch**: extends from the posterior root ganglion to the spinal cord. It will ascend briefly before synapsing in the posterior horn or traveling superiorly in the posterior columns.
- **Lateral branch**: extends from the posterior root ganglion through the intervertebral foramen (joining the anterior root in the process and forming the spinal nerve) to reach sensory receptors in the muscles, skin, and organs.

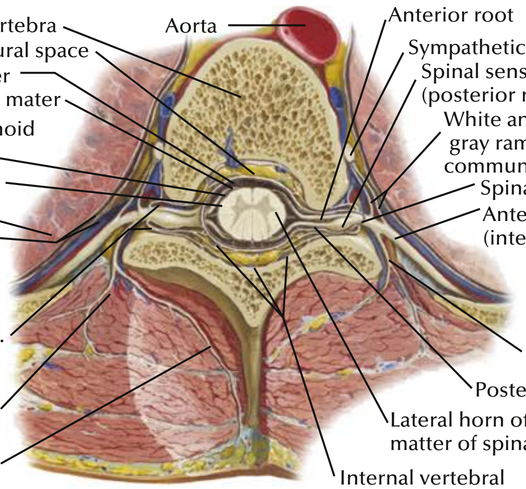
Spinal nerves are formed by the convergence of anterior roots and posterior roots. They leave the vertebral column by traveling through the intervertebral foramen at each level. After a spinal nerve exits an intervertebral foramen it divides to form posterior and anterior rami, which each contain both motor and sensory axons. The dura mater in the vicinity of the intervertebral foramen fuses with the periosteum of the vertebrae that form the foramen. Since the CSF and pia mater are no longer present around the rami, the **epineurium** covers and protects the spinal nerves and all peripheral nerves that are derived from them. Prior to forming anterior and posterior rami, the spinal nerve gives off several **meningeal branches** (also called recurrent meningeal nerves) that convey pain sensations from the nearby vertebral ligaments, intervertebral discs, and dura mater. These meningeal branches also carry postganglionic sympathetic axons to the blood vessels that supply those structures.

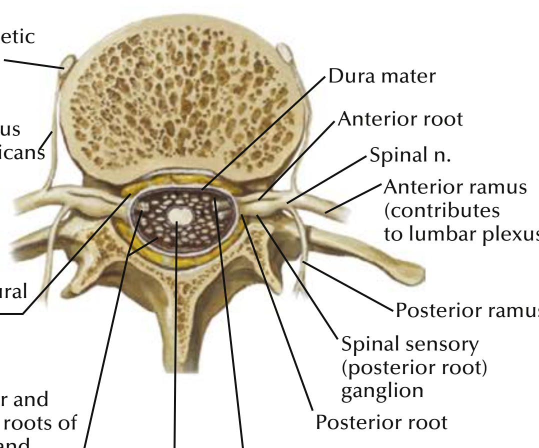
Anterior rami also leave the spinal nerves at each level and project anteriorly. They innervate muscles derived from the hypomere of each myotome, the muscles of the body wall and limbs. Unlike the posterior rami, they do not innervate muscles in a segmental manner. They frequently form interconnected plexi before forming terminal nerves that reach their target muscles.

Posterior rami (see Fig. 9.17C) leave the spinal nerves at each level of the spinal cord and project posteriorly. They provide motor innervation to all the intrinsic back muscles as well as cutaneous sensation from the overlying skin. After leaving the spinal nerve, each posterior ramus will divide into lateral, medial, and (sometimes) intermediate branches. Articular branches from the medial branch of each posterior ramus will innervate vertebral facet joints on both sides of the intervertebral foramen (Clinical Correlation 9.9).

Autonomic Innervation and the Spinal Nerve (See Fig. 9.17A and B)

In addition to controlling blood flow to the organs, the sympathetic nervous system innervates sweat glands in the skin as well as the smooth muscle sphincters that regulate blood flow to skeletal muscles, including those in the back. **Preganglionic sympathetic axons** from the **intermediolateral cell columns** (present at the T1–L2 levels) project their axons through the anterior roots, spinal nerve, and anterior rami. These axons exit the anterior ramus as **white rami communicans** (*white* because these axons are lightly myelinated B fibers) to reach the **paravertebral ganglia** associated with each spinal level within the **sympathetic chain**. Since they come from the intermediolateral cell column, there are only white rami communicans present from T1 to L2. These





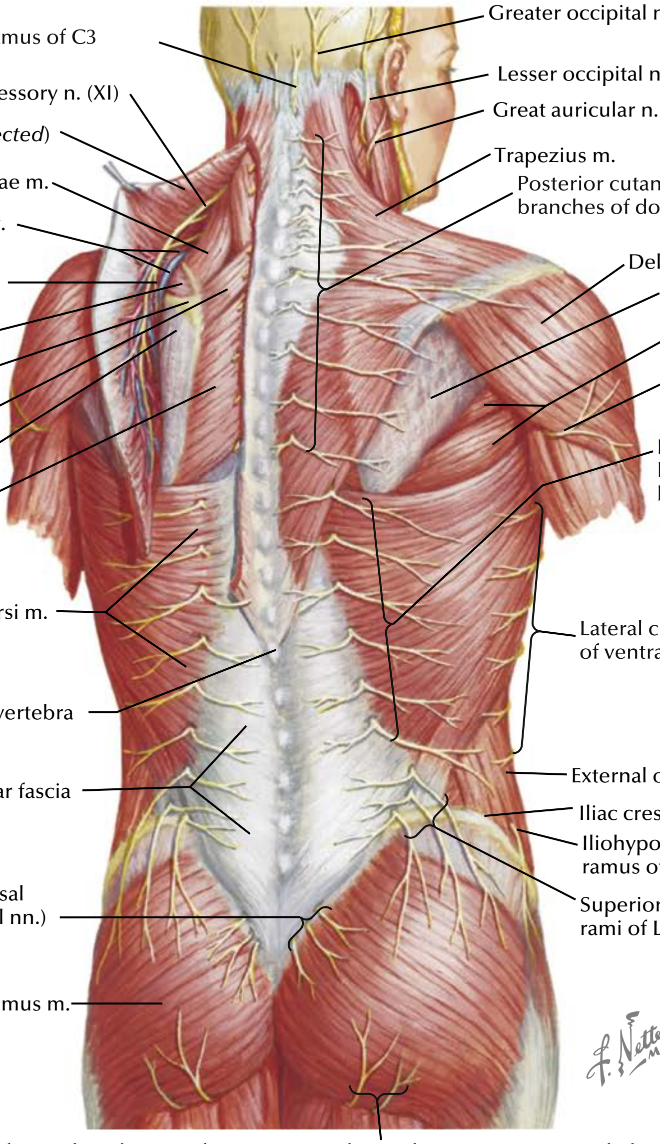


Fig. 9.17 Spinal Nerve Cross Section.

axons may ascend or descend within the sympathetic chain before synapsing or they may synapse at the level at which they entered.

For somatic targets, including the skin and muscles of the back, the preganglionic axons synapse with postganglionic nerve cells in the paravertebral ganglia. The **postganglionic sympathetic axons** leave the chain via **gray rami communicans** (*gray* because these axons are unmyelinated C fibers) that carry them to the spinal nerve at the level of departure. Since the sympathetic chain stretches to all levels of the vertebral column, there are gray rami present at all spinal levels. Once in the spinal nerve, these postganglionic sympathetic axons will follow posterior rami, anterior rami, and the resultant peripheral nerves to reach sweat glands, arrector pili muscles, and precapillary sphincters in the skin, as well as precapillary sphincters and smooth muscles in the vessels to the skeletal muscles of the back.

THE BLOOD SUPPLY TO THE BACK

The vertebrae and spinal cord have an extensive and complex blood supply. In the cervical region, the ascending cervical, deep cervical, and vertebral arteries provide the majority of the arterial blood to the vertebrae. The thoracic and lumbar vertebrae receive blood from the intercostal, subcostal, lumbar segmental, and iliolumbar arteries. The sacrum receives blood from the median sacral, lateral sacral, and iliolumbar arteries (Fig. 9.18).

The large vessels near each vertebra give off **equatorial branches** that pierce the perimeter of the vertebral body to supply it. **Posterior branches** continue from the large vessels and supply the transverse, articular, and spinous processes as well as **muscular branches** to the overlying back muscles. These posterior branches are often found running alongside the posterior rami. **Spinal branches** enter the intervertebral foramina and split into:

- **postcentral (anterior vertebral canal) branch**: located posterior to the vertebral body. It supplies a large **nutrient artery** to the vertebral body through the basivertebral foramen.
- **prelaminar (posterior vertebral canal) branch**: located within the vertebral canal near pedicles and laminae.

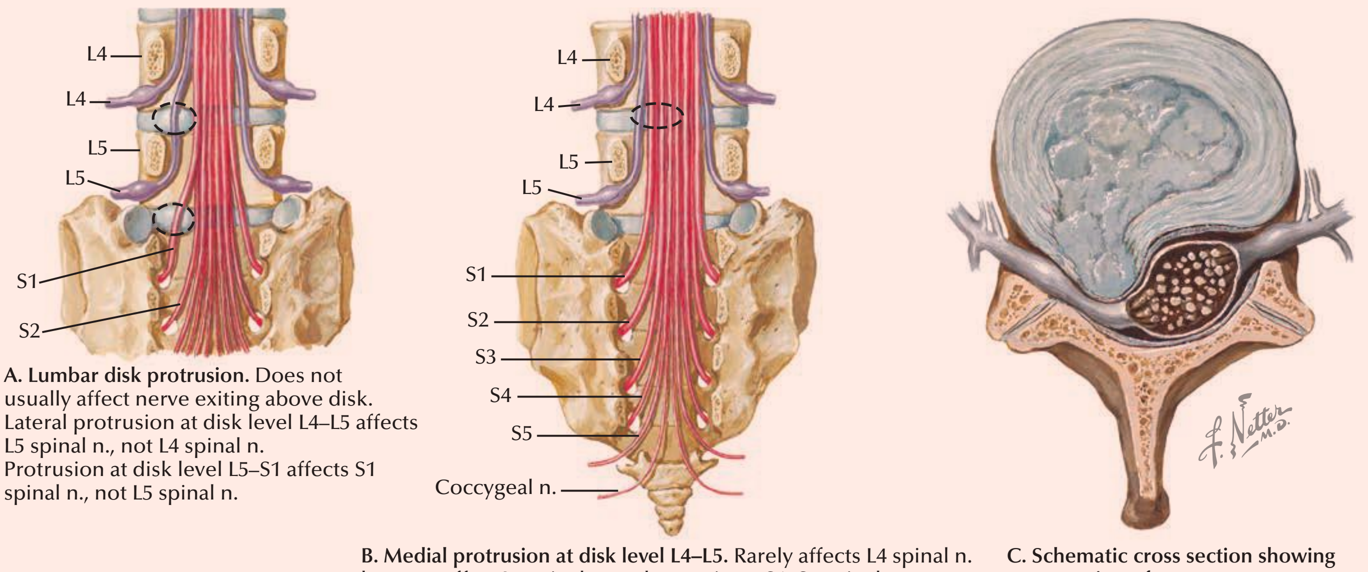
These vessels also have small contributions to the longitudinal arteries of the spinal cord itself, the two **posterior spinal arteries** and one **anterior spinal artery**. These arteries originate at the base of the skull from the large left and right **vertebral arteries**. While the vertebral arteries are very large, they are not able to supply enough blood to perfuse the entire spinal cord. Thankfully, each spinal branch (at each level) gives off **radicular**

CLINICAL CORRELATION 9.9 Herniated Nucleus Pulposus—Part 2

When a herniated nucleus pulposus (HNP) pushes its way out of the annulus fibrosus, it projects posteriorly. Due to the narrow intervertebral foramen in the cervical and upper thoracic levels, it will tend to impinge on the spinal nerve exiting at that level. However, in the lumbar (and lowest thoracic) levels, the intervertebral foramina are elongated from top to bottom. Spinal nerves exit in the superior region of the foramen and the intervertebral disc is in the inferior region of the intervertebral foramen.

Because of this, a cervical HNP will affect the nerve exiting at that level. Since a named cervical spinal nerve exits superior to its named vertebrae (e.g., the C5 spinal nerve exits at the C4–C5 intervertebral level), the nerve affected by an HNP is the one exiting at that level. In contrast, a lumbar HNP will push into the lowest part of an intervertebral foramen and miss the nerve exiting at that level. The nerve exiting at the level immediately inferior is nearby and is likely to be impinged. So, if the L4–L5 disc is herniated, it will miss the L4 spinal nerve (exiting at that level) but impinge on the next nerve, L5.

You will notice that despite the differences in how spinal nerves exit relative to their named vertebrae, it typically works out if you list an intervertebral disc (e.g., C4–C5, L2–L3, or L5–S1), the lowest level will correspond to the spinal nerve that is impinged (C5, L3, and S1, respectively). HNP in the thoracic region are relatively rare due to the stability afforded by the ribcage. HNP cannot occur in the sacrum for (what I hope is) an obvious reason.



A. Lumbar disk protrusion. Does not usually affect nerve exiting above disk. Lateral protrusion at disk level L4–L5 affects L5 spinal n., not L4 spinal n. Protrusion at disk level L5–S1 affects S1 spinal n., not L5 spinal n.

B. Medial protrusion at disk level L4–L5. Rarely affects L4 spinal n. but may affect L5 spinal n. and sometimes S1–S4 spinal nn.

C. Schematic cross section showing compression of nerve root

Fig. CC9.10 Lumbar Disc Herniation.

or **segmental medullary arteries** that travel along the spinal nerve and roots. Radicular arteries only supply the roots and spinal nerve. **Segmental medullary arteries** (either anterior or posterior) are larger and feed into the anterior or posterior spinal arteries perfusing the cord at that level. They are most prominent near the cervical and lumbosacral enlargements. In the lower thoracic or upper lumbar region, there is typically a **great anterior segmental medullary artery (of Adamkiewicz)** that supplies a massive boost to the blood volume in the spinal vessels. It is typically located on the left and must be preserved during operations on the posterior thorax or abdomen, since loss of this vessel will cause ischemia of the inferior spinal cord and possible hemiplegia.

Within the cord, the anterior spinal artery sends a **sulcal branch** through the anterior median fissure of the spinal cord. It provides the majority of blood to the gray matter, anterior columns, and part of the lateral columns. The posterior spinal arteries supply the posterior columns, a small area of the posterior gray matter, and some of the lateral columns.

Multiple **spinal veins** (Fig. 9.19) run parallel to spinal arteries and interconnect as they pass along the length of the cord. Blood in these veins drains to **anterior medullary, posterior medullary, and radicular veins** that empty into an extensive series of veins sitting in the adipose tissue of the epidural space, the **internal vertebral venous plexus**. The posterior and anterior portions of the internal vertebral venous plexus are quite extensive. The large **basivertebral veins** drain the red marrow (an important source of new blood cells) of the vertebral bodies into the anterior portion of the internal vertebral venous plexus. Superiorly, this plexus can drain to cerebral veins or dural venous sinuses. In the rest of the spinal cord, they drain to **intervertebral veins** that carry blood to the **external vertebral venous plexus** that surrounds the vertebrae. From there, the venous blood will drain to any large nearby vein such as deep cervical, vertebral, intercostal, subcostal, or lumbar veins (Clinical Correlation 9.10).

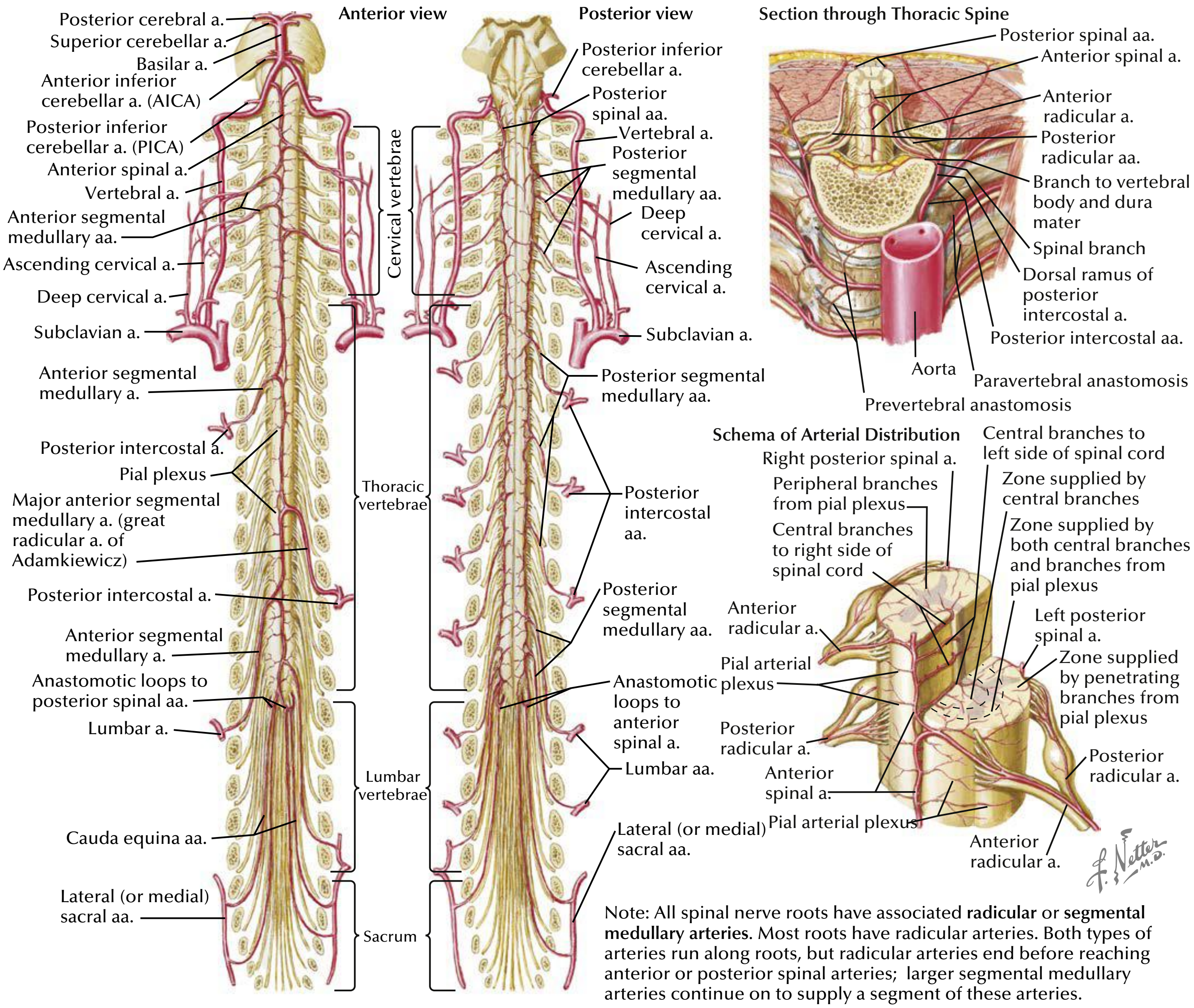


Fig. 9.18 Arteries of the Spinal Cord.

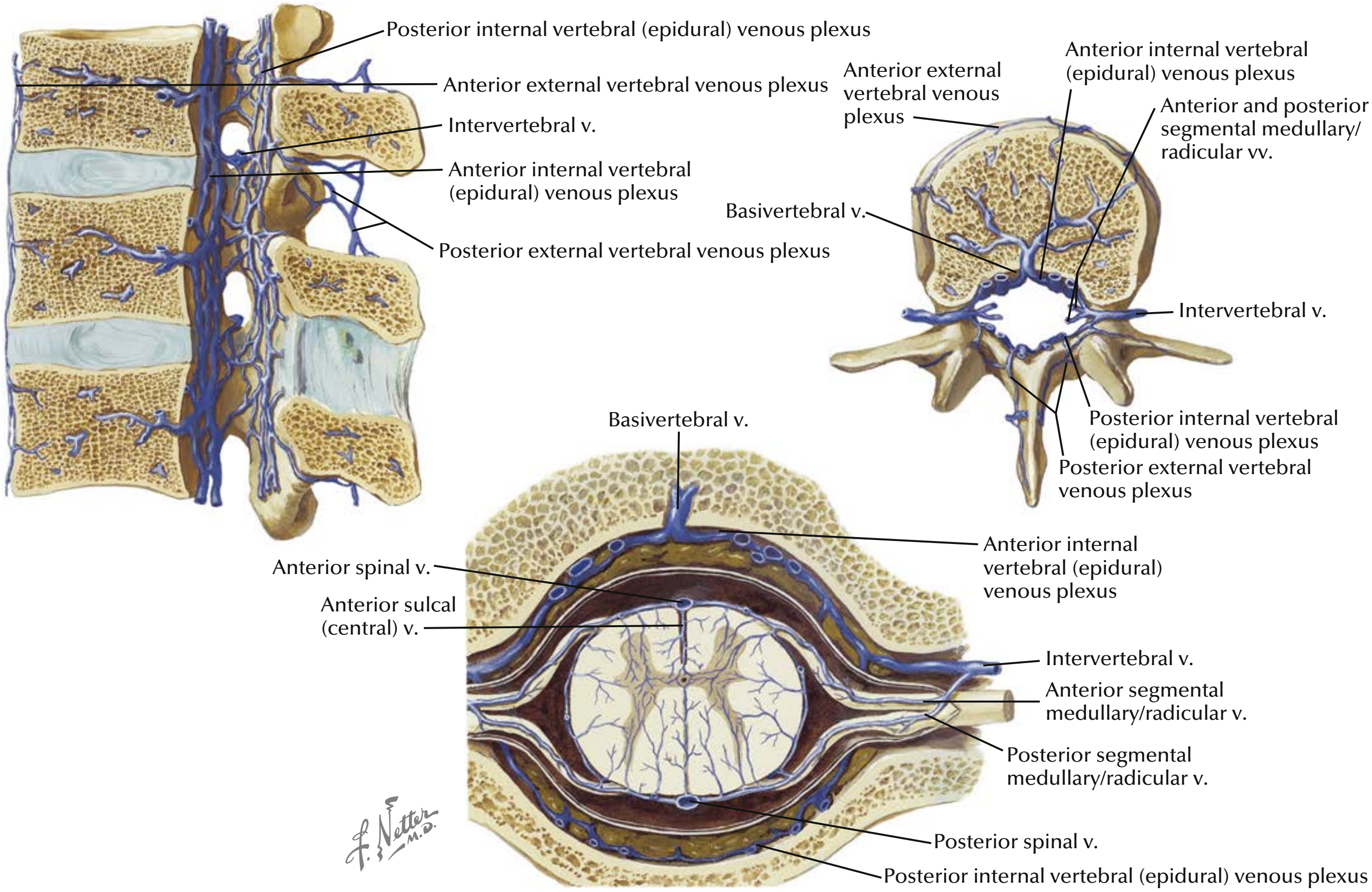


Fig. 9.19 Veins of the Spinal Cord and Vertebrae.

CLINICAL CORRELATION 9.10 **Vertebral Venous Plexi and Tumor Metastasis**

The internal and external vertebral venous plexi form an extensive and interconnected network of veins that stretch from the coccyx to the base of the skull. These veins are interconnected to many of the large veins near the midline of the body and have no valves in their walls. Metastatic tumors that have invaded veins can send tumor cells into the bloodstream. Prostate, breast, and lung cancers frequently spread to the spine, carried by the valveless veins of the external and internal vertebral venous plexus. This entire system is sometimes referred to as the Batson venous plexus.