1. INTRODUCTION

The back forms the axis (central line) of the human body and consists of the vertebral column, spinal cord, supporting muscles, and associated tissues (skin, connective tissues, vasculature, and nerves). A hallmark of human anatomy is the concept of “segmentation,” and the back is a prime example. Segmentation and bilateral symmetry of the back will become obvious as you study the vertebral column, the distribution of the spinal nerves, the muscles of the back, and its vascular supply. Functionally, the back is involved in three primary tasks, as follows:

- **Support.** The vertebral column forms the axis of the body and is critical for upright posture (standing or sitting), as a support for the head, as an attachment point and brace for movements of the upper limbs, and as a support for transferring the weight of the trunk to the lower limbs.

- **Protection.** The vertebral column protects the spinal cord and proximal portions of the spinal nerves before they distribute throughout the body.

- **Movements.** Muscles of the back function in movements of the head and upper limbs and in support and movements of the vertebral column.

2. SURFACE ANATOMY

Fig. 2.1 shows key surface landmarks of the back, including the following bony landmarks:

- **Vertebrae prominens:** the spinous process of the C7 vertebra, usually the most prominent process in the midline at the posterior base of the neck.

- **Scapula:** a part of the pectoral girdle that supports the upper limb; note its spine, inferior angle, and medial border.

- **Iliac crests:** felt best when you place your hands “on your hips.” An imaginary horizontal line connecting the iliac crests passes through the spinous process of vertebra L4 and the intervertebral disc of L4-L5, providing a useful landmark for a lumbar puncture or an epidural block (see Clinical Focus 2-11).

- **Posterior superior iliac spines:** an imaginary horizontal line connecting these two points passes through the spinous process of S2 (second sacral segment).

3. VERTEBRAL COLUMN

The vertebral column (spine) forms the central axis of the human body, highlighting the segmental nature of all vertebrates, and usually is composed of 33 vertebrae distributed as follows (Fig. 2.2):

- **Cervical:** seven vertebrae; the first two called the atlas (C1) and axis (C2).

- **Thoracic:** 12 vertebrae; each articulates with a pair of ribs.

- **Lumbar:** five vertebrae; large vertebrae for support of the body’s weight.

- **Sacral:** five fused vertebrae for stability in the transfer of weight from the trunk to the lower limbs.

- **Coccyx:** four vertebrae, but variable; Co1 often is not fused, but Co2-Co4 are fused (a remnant of the embryonic tail).

The actual number of vertebrae can vary, especially the number of coccygeal vertebrae. Viewed from the lateral aspect (Fig. 2.2), one can identify the following:

- **Cervical curvature** (cervical lordosis): a secondary curvature acquired when the infant can support the weight of the head.

- **Thoracic curvature** (thoracic kyphosis): a primary curvature present in the fetus (imagine the spine in the “fetal position”).

- **Lumbar curvature** (lumbar lordosis): a secondary curvature acquired when the infant assumes an upright posture and supports its own weight.
Chapter 2  Back

FIGURE 2.1 Key Bony and Muscular Landmarks of the Back. (From Atlas of human anatomy, ed 7 Nuchal lig. Plate 161).

FIGURE 2.2 Vertebral Column. (From Atlas of human anatomy, ed 7, Plate 162.)

<table>
<thead>
<tr>
<th>Level</th>
<th>Corresponding structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2-3</td>
<td>Mandible</td>
</tr>
<tr>
<td>C3</td>
<td>Hyoid bone</td>
</tr>
<tr>
<td>C4-5</td>
<td>Thyroid cartilage</td>
</tr>
<tr>
<td>C6</td>
<td>Cricoid cartilage</td>
</tr>
<tr>
<td>C7</td>
<td>Vertebra prominens</td>
</tr>
<tr>
<td>T3</td>
<td>Spine of scapula</td>
</tr>
<tr>
<td>T8</td>
<td>Level that IVC pierces respiratory diaphragm</td>
</tr>
<tr>
<td>T10</td>
<td>Xiphisternal junction</td>
</tr>
<tr>
<td>T10</td>
<td>Level that esophagus pierces respiratory diaphragm</td>
</tr>
<tr>
<td>T12</td>
<td>Level that aorta pierces respiratory diaphragm</td>
</tr>
<tr>
<td>L1</td>
<td>End of spinal cord (conus medullaris)</td>
</tr>
<tr>
<td>L3</td>
<td>Subcostal plane</td>
</tr>
<tr>
<td>L3-4</td>
<td>Umbilicus</td>
</tr>
<tr>
<td>L4</td>
<td>Bifurcation of abdominal aorta</td>
</tr>
<tr>
<td>L4</td>
<td>Iliac crests</td>
</tr>
<tr>
<td>S2</td>
<td>End of dural sac</td>
</tr>
</tbody>
</table>
Scoliosis

Scoliosis is abnormal lateral curvature of the spine, which also includes an abnormal rotation of one vertebra upon another. In addition to scoliosis, accentuated curvatures of the spine include kyphosis (hunchback) and lordosis (swayback).

Pathologic anatomy of scoliosis

<table>
<thead>
<tr>
<th>Several Common Abnormal Curvatures of the Spine</th>
<th>Disorder</th>
<th>Definition</th>
<th>Etiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoliosis (illustrated)</td>
<td>Accentuated lateral and rotational curve of thoracic or lumbar spine</td>
<td>Genetic, trauma, idiopathic; occurs in adolescent girls more than boys</td>
<td></td>
</tr>
<tr>
<td>Kyphosis</td>
<td>Hunchback, accentuated flexion of thoracic spine</td>
<td>Poor posture, osteoporosis</td>
<td></td>
</tr>
<tr>
<td>Lordosis</td>
<td>Swayback, accentuated extension of lumbar spine</td>
<td>Weakened trunk muscles, late pregnancy, obesity</td>
<td></td>
</tr>
</tbody>
</table>

- **Sacral curvature**: a primary curvature present in the fetus.

**Typical Vertebra**

A "typical" vertebra has the following features (Fig. 2.3):

- **Arch**: a projection formed by paired pedicles and laminae and the spinous processes; the arch serves as the site for articulation with adjacent vertebrae and also as the attachment point for ligaments and muscles.
- **Articular processes** (facets): two superior and two inferior facets for articulation with adjacent vertebrae.
- **Body**: the weight-bearing portion of a vertebra that tends to increase in size as one descends the spine.
- **Intervertebral foramen** (foramina): the opening formed by the vertebral notches that is traversed by spinal nerve roots and associated vessels.
- **Lamina** (laminae): paired portions of the vertebral arch that connect the transverse processes to the spinous process.
- **Pedicle**: paired portions of the vertebral arch that attach the transverse processes to the body.
- **Transverse foramina**: apertures that exist in transverse processes of cervical vertebrae only and transmit the vertebral vessels.
- **Transverse processes**: the lateral extensions from the union of the pedicle and lamina.
- **Spinous process**: a projection that extends posteriorly from the union of two laminae.
Chapter 2  
Back

Regional Vertebrae  

Cervical Vertebrae  
The cervical spine is composed of seven cervical vertebrae. The first two cervical vertebrae are unique and called the atlas and axis (Fig. 2.4). The atlas (C1) holds the head on the neck (the titan Atlas of Greek mythology held the heavens on his shoulders as punishment by Zeus). The axis (C2) is the point of articulation where the head turns on the neck, providing an “axis of rotation.”

Table 2.1 summarizes key features of the cervical vertebrae. The cervical region is a fairly mobile portion of the spine, allowing for flexion and extension as well as rotation and lateral bending.

Thoracic and Lumbar Vertebrae  
The thoracic spine is composed of 12 thoracic vertebrae (Fig. 2.5 and Table 2.2). The 12 pairs of ribs articulate with the thoracic vertebrae. This region of the spine is more rigid and inflexible than the cervical region.

The lumbar spine is composed of five lumbar vertebrae (see Figs. 2.3 and 2.5 and Table 2.2). The lumbar vertebrae are comparatively large for bearing the weight of the trunk and are fairly mobile, but not nearly as mobile as the cervical vertebrae.

Sacroccocygeal Region  
The sacrum is composed of five fused vertebrae that form a single, wedge-shaped bone (Fig. 2.5 and Table 2.2). The sacrum provides support for the pelvis. The coccyx is a remnant of the embryonic
Cervical Fractures

Fractures of the axis (C2) often involve the dens and are classified as types I, II, and III. Type I fractures are usually stable, type II fractures are unstable, and type III fractures, which extend into the body, usually reunite well when immobilized. The hangman fracture, a pedicle fracture of the axis, can be stabilized, if survived, with or without spinal cord damage. A Jefferson fracture is a burst fracture of the atlas (C1), often caused by a blow to the top of the head.
tail and usually consists of four vertebrae, with the last three often fused into a single bone. The coccyx lacks vertebral arches and has no vertebral canal. The features and number of vertebrae can vary, and clinicians must always be aware of subtle differences, especially on radiographic imaging, that may be variants within a normal range.

**Joints and Ligaments of Craniovertebral Spine**

The craniovertebral joints include the **atlanto-occipital** (atlas and occipital bone of the skull) and **atlantoaxial** (atlas and axis) joints. Both are synovial joints that provide a relatively wide range of motion compared with other joints of the vertebral column. The atlanto-occipital joint permits one to nod the head up and down (flexion and extension), as if to indicate “yes,” whereas the atlantoaxial joint is a pivot joint that permits one to rotate the head from side to side, as if to indicate “no” (Fig. 2.6 and Table 2.3).

**Joints and Ligaments of Vertebral Arches and Bodies**

The joints of the vertebral arches (zygapophysial joints) occur between the superior and inferior
TABLE 2.2 Key Features of Thoracic, Lumbar, Sacral, and Coccygeal Vertebrae

<table>
<thead>
<tr>
<th>VERTEBRAE</th>
<th>DISTINGUISHING CHARACTERISTICS</th>
<th>VERTEBRAE</th>
<th>DISTINGUISHING CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic  (T1-T12)</td>
<td>Heart-shaped body, with facets for rib articulation Small circular vertebral foramen Long transverse processes, with facets for rib articulation in T1-T10 Long spinous processes, which slope posteriorly and overlap next vertebra</td>
<td>Sacrum (S1-S5)</td>
<td>Large, wedge-shaped bone that transmits body weight to pelvis Five fused vertebrae, with fusion complete by puberty Four pairs of sacral foramina on dorsal and ventral (pelvic) side Sacral hiatus, the opening of sacral vertebral foramen Co1 often is not fused. Co2 to Co4 are fused. No pedicles, laminae, or spines Remnant of our embryonic tail</td>
</tr>
<tr>
<td>Lumbar (L1-L5)</td>
<td>Kidney-shaped body, massive for support Midsized triangular vertebral foramen Facets face medial or lateral direction, which permits good flexion and extension Spinous process is short, strong, and horizontal. L5: largest vertebra with massive transverse processes</td>
<td>Coccyx (Co1-Co4)</td>
<td></td>
</tr>
</tbody>
</table>

Clinical Focus 2-3

Osteoarthritis

Osteoarthritis is the most common form of arthritis and often involves erosion of the articular cartilage of weight-bearing joints, such as those of the vertebral column.

**Characteristics of Osteoarthritis**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etiology</td>
<td>Progressive erosion of cartilage in joints of spine, fingers, knee, and hip most commonly</td>
</tr>
<tr>
<td>Prevalence</td>
<td>Significant after age 65 years</td>
</tr>
<tr>
<td>Risk factors</td>
<td>Age, female sex, joint trauma, repetitive stress, obesity, genetic, race, previous inflammatory joint disease</td>
</tr>
<tr>
<td>Complications</td>
<td>In spine, involves intervertebral disc and facet joints, leading to hyperextension deformity and spinal nerve impingement</td>
</tr>
</tbody>
</table>
called the **nucleus pulposus**, which is surrounded by concentric lamellae of collagen fibers that compose the **anulus fibrosus** (see Clinical Focus 2-6). The inner gelatinous nucleus pulposus (remnant of the embryonic notochord) is hydrated and acts as a “shock absorber,” compressing when load bearing and relaxing when the load is removed. The outer fibrocartilaginous anulus fibrosus, arranged in concentric lamellae, is encircled by a thin ring of collagen and resists compression and shearing forces.

The lumbar intervertebral discs are the thickest and the upper thoracic ones are the thinnest intervertebral discs. The anterior and posterior longitudinal ligaments help to stabilize these joints (see Table 2.4).
Chapter 2  Back

**FIGURE 2.6** Craniovertebral Joints and Ligaments. (From Atlas of human anatomy, ed 7, Plate 30; radiograph from Major N: A practical approach to radiology, Philadelphia, 2006, Saunders-Elsevier.)

**FIGURE 2.7** Joints of Vertebral Arches and Bodies. (From Atlas of human anatomy, ed 7, Plate 168.)
Clinical Focus 2-4

Osteoporosis

Osteoporosis (porous bone) is the most common bone disease and results from an imbalance in bone resorption and formation, which places bones at a great risk for fracture.

<table>
<thead>
<tr>
<th>Characteristics of Osteoporosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristic</strong></td>
</tr>
<tr>
<td>Etiology</td>
</tr>
<tr>
<td>Risk factors</td>
</tr>
<tr>
<td>Complications</td>
</tr>
</tbody>
</table>

**Axial**

Vertebral compression fractures cause continuous (acute) or intermittent (chronic) back pain from midthoracic to midlumbar region, occasionally to lower lumbar region.

**Appendicular fractures caused by minimal trauma**

Proximal femur, proximal humerus, distal radius

Osteoporosis is the thinning of the bones. Bones become fragile and loss of height is common as the back bones begin to collapse.
Clinical Focus 2-5

Spondylolysis and Spondylolisthesis

Spondylolysis is a congenital defect or an acquired stress fracture of the lamina that presents with no slippage of adjacent articulating vertebrae (most common at L5-S1). Its radiographic appearance suggests a “Scottie dog” (terrier) with a collar (fracture site shown as red collar).

Spondylolisthesis is a bilateral defect (complete dislocation, or luxation) resulting in an anterior displacement of the L5 body and transverse process. The posterior fragment (vertebral laminae and spinous process of L5) remains in proper alignment over the sacrum (S1). This defect has the radiographic appearance of a dog with a broken neck (highlighted in yellow, with the fracture in red). Pressure on spinal nerves often leads to low back and lower limb pain.

Clinical Focus 2-6

Intervertebral Disc Herniation

The intervertebral discs are composed of a central nuclear zone of collagen and hydrated proteoglycans called the **nucleus pulposus**, which is surrounded by concentric lamellae of collagen fibers that compose the **anulus fibrosus**. The nucleus pulposus is hydrated and acts as a "shock absorber," compressing when load bearing and relaxing when the load is removed. Over time, the repeated compression-relaxation cycle of the intervertebral discs can lead to peripheral tears of the anulus fibrosus that allow for the extrusion and herniation of the more gelatinous nucleus pulposus. This often occurs with age, and the nucleus pulposus becomes more dehydrated, thus transferring more of the compression forces to the anulus fibrosus. This added stress may cause thickening of the anulus and tears. Most disc herniations occur in a posterolateral direction because the anulus fibrosus tears often occur at the posterolateral margins of the disc (rim lesions). Moreover, the posterior longitudinal ligament reinforces the anulus such that posterior herniations are much less common; otherwise, the disc would herniate into the vertebral canal and compress the spinal cord or its nerve roots.

*Continued*
The most common sites for disc herniation in the cervical region are the C5-C6 and C6-C7 levels, resulting in shoulder and upper limb pain. In the lumbar region the primary sites are the L4-L5 and L5-S1 levels. Lumbar disc herniation is much more common than cervical herniation and results in pain over the sacroiliac joint, hip, posterior thigh, and leg.

### Clinical Focus 2-6

**Intervertebral Disc Herniation—cont’d**

Intervertebral disc composed of central nuclear zone of collagen and hydrated proteoglycans surrounded by concentric lamellae of collagen fibers. 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.

<table>
<thead>
<tr>
<th>Level of herniation</th>
<th>Clinical features of herniated lumbar disc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pain</td>
</tr>
<tr>
<td>L4-L5 disc; 5th lumbar n. root</td>
<td>Over sacroiliac joint, hip, lateral thigh, and leg</td>
</tr>
<tr>
<td>L5-S1 disc; 1st sacral n. root</td>
<td>Over sacroiliac joint, hip, posterior lateral thigh, and leg to heel</td>
</tr>
</tbody>
</table>

Herniation of L4–L5 intervertebral disc (white arrows) with some displacement of the posterior longitudinal ligament (black arrow). The two discs above this site show the normal hydrated appearance of the nucleus pulposus.
Clinical Focus 2-7

Back Pain Associated With the Zygopophyial (Facet) Joints

Although changes in the vertebral facet joints are not the most common cause of back pain (~15%), such alterations can lead to chronic pain. Although the articular surfaces of the synovial facet joints are not directly innervated, sensory nerve fibers derived from the posterior rami of spinal nerves do supply the synovial linings of the capsules surrounding the joints. Two examples of painful conditions associated with facet joints are degeneration of the articular cartilage and osteophyte overgrowth of the articular processes.
Low back pain, the most common musculoskeletal disorder, can have various causes. Physical examination, although not always revealing a definite cause, may provide clues to the level of spinal nerve involvement and relative sensitivity to pain. The following causes are identified most often:

- Intervertebral disc rupture and herniation
- Nerve inflammation or compression
- Degenerative changes in vertebral facet joints
- Sacroiliac joint and ligament involvement
- Metabolic bone disease
- Psychosocial factors
- Abdominal aneurysm
- Metastatic cancer
- Myofascial disorders

### A. Standing

- Walking on heels (tests foot and great toe dorsiflexion)
- Walking on toes (tests calf muscles)
- Body build
- Posture
- Deformities
- Pelvic obliquity
- Spine alignment
- Palpate for: muscle spasm
- trigger zones
- myofascial nodes
- sciatic nerve tenderness
- Compress iliac crests for sacroiliac tenderness

### B. Kneeling on chair

- Ankle jerk
- Sensation on calf and sole

### C. Seated on table

- Straight leg raising
- Palpate for peripheral pulses and skin temperature
- Knee jerk
- Measure calf circumference

### D. Supine

- Spinal column movements: flexion
  - extension
  - side bending
  - rotation
- Palpate abdomen; listen for bruit (abdominal and inguinal)
- Palpate for flattening of lumbar lordosis during leg raising
- Measure leg lengths (anterior superior iliac spine to medial malleolus) and thigh circumferences
- Test sensation and motor power

### E. Prone

- Test for renal tenderness
- Spine extension
- Palpate for local tenderness or spasm

### F. Rectal and/or pelvic examination

### G. MRI and/or CT and/or myelogram of

1. lumbosacral spine
2. abdomen/pelvis

### H. Laboratory studies

- Serum Ca\(^{2+}\) and PO\(_4\)\(^{3-}\), alkaline phosphatase, prostate-specific antigen (males over 40), CBC, ESR, and urinalysis
Movements of the Spine
The essential movements of the spine are flexion, extension, lateral flexion (lateral bending), and rotation (Fig. 2.8). The greatest freedom of movement occurs in the cervical and lumbar spine, with the neck having the greatest range of motion. Flexion is greatest in the cervical region, and extension is greatest in the lumbar region. The thoracic region is relatively stable, as is the sacrum.

Again, the atlantooccipital joint permits flexion and extension (e.g., nodding in acknowledgment), and the atlantoaxial joint allows side-to-side movements (rotation; e.g., indicating “no”). This is accomplished by a uniaxial synovial joint between the dens of the axis and its articulation with the anterior arch of the atlas. The dens functions as a pivot that permits the atlas and attached occipital bone of the skull to rotate on the axis. Alar ligaments limit this side-to-side movement so that rotation of the atlantoaxial joint occurs with the skull and atlas rotating as a single unit on the axis (see Fig. 2.6).

Movements of the spine are a function of the following features:
- Size and compressibility of the intervertebral discs.
- Tightness of the joint capsules.
- Orientation of the articular facets (zygapophysial joints).
- Muscle and ligament function.
- Articulations with the thoracic cage.
- Limitations imposed by the adjacent tissues and increasing age.

FIGURE 2.8 Movements of the Spine.
Clinical Focus 2-9

Whiplash Injury

“Whiplash” is a nonmedical term for a cervical hyperextension injury, which is usually associated with a rear-end vehicular crash. The relaxed neck is thrown backward, or hyperextended, as the vehicle accelerates rapidly forward. Rapid recoil of the neck into extreme flexion occurs next. Properly adjusted headrests can greatly reduce the occurrence of this hyperextension injury, which often results in stretched or torn cervical muscles and, in severe cases, ligament, bone, and nerve damage.

Blood Supply to the Spine

The spine receives blood from spinal arteries derived from branches of larger arteries that serve each midline region of the body (Fig. 2.9). These major arteries include the following:

- **Vertebral arteries**: arising from the subclavian arteries in the neck.
- **Ascending cervical arteries**: arising from a branch of the subclavian arteries.
- **Posterior intercostal arteries**: arising from the thoracic aorta.
- **Lumbar arteries**: arising from the abdominal aorta.
- **Lateral sacral arteries**: arising from pelvic internal iliac arteries.

**Spinal arteries** arise from these branches and divide into small posterior branches that supply the vertebral arch and small anterior branches that supply the vertebral body (see Fig. 2.9). Also, longitudinal branches of **radicular arteries**, which arise from these spinal arteries, course along the inside aspect of the vertebral canal and supply the vertebral column. (Do not confuse these arteries with those that supply the spinal cord, discussed later. In some cases, arteries that do supply the spinal cord also contribute branches that supply the vertebrae.)

**Radicular veins** receive tributaries from the spinal cord and the internal vertebral veins that course within the vertebral canal; this **internal venous plexus** also anastomoses with a network of **external vertebral veins** (see Fig. 2.9). The internal vertebral venous plexus lacks valves, whereas the external vertebral venous plexus has recently been shown to possess some valves, directing blood flow toward the internal venous plexus. The radicular veins then drain blood from the vertebral venous plexus to segmental and intervertebral veins, with the blood ultimately collecting in the segmental branches of the following major venous channels:

- **Superior vena cava**: drains cervical vertebral region.
- **Azigos venous system**: drains thoracic region.
- **Inferior vena cava**: this large vein drains lumbosacral regions of the spine.

4. MUSCLES OF THE BACK

Although the spine is the axis of the human body and courses down the body’s midline, dividing it
into approximately equal right and left halves, it is not midway between the anterior and posterior halves of the body. In fact, most of the body’s weight lies anterior to the more posteriorly aligned vertebral column. Consequently, to support the body and spine, most of the muscles associated with the spine attach to its lateral and posterior processes, assisting the spine in maintaining an upright posture that offsets the uneven weight distribution.

The muscles of the back are divided into two major groups, as follows:

**Extrinsic back muscles**: involved in movements of the upper limb and with respiration.

**Intrinsic back muscles**: involved in movements of the spine and maintenance of posture.

### Extrinsic Back Muscles

The extrinsic muscles of the back are considered “extrinsic” because embryologically they arise from hypaxial myotomes (see Fig. 2.22). The extrinsic back muscles are divided into the following two functional groups (Fig. 2.10 and Table 2.5):

- **Superficial muscles**: involved in movements of the upper limb (trapezius, latissimus dorsi, levator scapulae, two rhomboids), attach the pectoral girdle (clavicle, scapula, humerus) to the axial skeleton (skull, ribs, spine).
- **Intermediate muscles**: thin accessory muscles of respiration (serratus posterior superior and inferior) that assist with movements of the rib cage, lie deep to the superficial muscles, and extend from the spine to the ribs.
<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>PROXIMAL ATTACHMENT (ORIGIN)</th>
<th>DISTAL ATTACHMENT (INSERTION)</th>
<th>INNERVATION</th>
<th>MAIN ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extrinsic Back Muscles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trapezius</td>
<td>Superior nuchal line, external occipital protuberance, nuchal ligament, and spinous processes of C7-T12</td>
<td>Lateral third of clavicle, acromion, and spine of scapula</td>
<td>Accessory nerve (cranial nerve XI)</td>
<td>Elevates, retracts, and rotates scapula; lower fibers depress scapula</td>
</tr>
<tr>
<td>Latissimus dorsi</td>
<td>Spinos processes of T7-1.5, sacrum, thoracolumbar fascia, iliac crest, and last three ribs</td>
<td>Humerus (intertubercular groove)</td>
<td>Thoracodorsal nerve (C6-C8)</td>
<td>Extends, adducts, and medially rotates humerus</td>
</tr>
<tr>
<td>Levator scapulae</td>
<td>Transverse processes of C1-C4</td>
<td>Superior angle of scapula</td>
<td>C3-C4 and dorsal scapular (C5) nerve</td>
<td>Elevates scapula and tilts glenoid cavity inferiorly</td>
</tr>
<tr>
<td>Rhomboid minor and major</td>
<td><em>Minor</em>: nuchal ligament and spinous processes of C7-T1</td>
<td>Medial border of scapula</td>
<td>Dorsal scapular nerve (C4-C5)</td>
<td>Retract scapula, rotate it to depress glenoid cavity, and fix scapula to thoracic wall</td>
</tr>
<tr>
<td>Serratus posterior superior</td>
<td>Ligamentum nuchae and spinous processes of C7-T3</td>
<td>Superior aspect of ribs 2-5</td>
<td>T1-T4 anterior rami</td>
<td>Elevates ribs</td>
</tr>
<tr>
<td>Serratus posterior inferior</td>
<td>Spinos processes of T11-L3</td>
<td>Inferior border of ribs 9-12</td>
<td>T9-T12 anterior rami</td>
<td>Depresses ribs</td>
</tr>
<tr>
<td><strong>Intrinsic Back Muscles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Splenius capitis</td>
<td>Nuchal ligament, spinous processes of C7-T4</td>
<td>Mastoid process of temporal bone and lateral third of superior nuchal line</td>
<td>Middle cervical nerves*</td>
<td>Bilaterally: extends head Unilaterally: laterally bends (flexes) and rotates face to same side</td>
</tr>
<tr>
<td>Splenius cervicis</td>
<td>Spinos processes of T3-T6</td>
<td>Transverse processes of C1-C3</td>
<td>Lower cervical nerves*</td>
<td>Bilaterally: extends neck Unilaterally: laterally bends (flexes) and rotates neck toward same side</td>
</tr>
<tr>
<td>Erector spinae</td>
<td>Posterior sacrum, iliac crest, sacrospinous ligament, supraspinous ligament, and spinous processes of lower lumbar and sacral vertebrae</td>
<td><em>Iliocostalis</em>: angles of lower ribs and cervical transverse processes <em>Longissimus</em>: between tubercles and angles of ribs, transverse processes of thoracic and cervical vertebrae, mastoid process <em>Spinalis</em>: spinous processes of upper thoracic and midcervical vertebrae</td>
<td>Respective spinal nerves of each region*</td>
<td>Extends and laterally bends vertebral column and head</td>
</tr>
<tr>
<td>Semispinalis</td>
<td>Transverse processes of C4-T12</td>
<td>Spinos processes of cervical and thoracic regions</td>
<td>Respective spinal nerves of each region*</td>
<td>Extends head, neck, and thorax and rotates them to opposite side Stabilizes spine during local movements</td>
</tr>
<tr>
<td>Multifidi</td>
<td>Sacrum, ilium, and transverse processes of T1-T12 and articular processes of C4-C7</td>
<td>Spinos processes of vertebrae above, spanning two to four segments</td>
<td>Respective spinal nerves of each region*</td>
<td></td>
</tr>
<tr>
<td>Rotatores</td>
<td>Transverse processes of cervical, thoracic, and lumbar regions</td>
<td>Lamina and transverse process or spine above, spanning one or two segments</td>
<td>Respective spinal nerves of each region*</td>
<td>Stabilize, extend, and rotate spine</td>
</tr>
</tbody>
</table>

*Posterior rami of spinal nerves.
Intrinsic Back Muscles

The intrinsic back muscles are the “true” muscles of the back because they develop from epaxial myotomes (see Fig. 2.22), function in movements of the spine, and help maintain posture. The intrinsic muscles are enclosed within a deep fascial layer that extends in the midline from the medial crest of the sacrum to the ligamentum nuchae (a broad extension of the supraspinous ligament that extends from the spinous process of the C7 vertebra to the external occipital protuberance of the skull) (Fig. 2.10) and skull, and that spreads laterally to the transverse processes and angles of the ribs. In the thoracic and lumbar regions, the deep fascia makes up a distinct sheath known as the thoracolumbar fascia (Figs. 2.10 and 2.11; see also Fig. 4.31).

In the lumbar region, this fascial sheath has the following three layers (see also Fig. 4.31):

- **Posterior layer:** extending from the lumbar and sacral spinous processes laterally over the surface of the erector spinae muscles.
- **Middle layer:** extending from the lumbar transverse processes to the iliac crest inferiorly and to the 12th rib superiorly.
- **Anterior layer:** covering the quadratus lumbarum muscle of the posterior abdominal wall and extending to the lumbar transverse processes, and iliac crest, and superiorly, forming the lateral arcuate ligament for attachment of the respiratory diaphragm.

The intrinsic back muscles also are among the few muscles of the body that are innervated by posterior rami of a spinal nerve. From superficial to deep, the intrinsic muscles include the following three layers (Fig. 2.11 and Table 2.5):

- **Superficial layer:** including the splenius muscles that occupy the lateral and posterior neck (spino-transversales muscles).
- **Intermediate layer:** including the erector spinae muscles that mainly extend and laterally bend the spine.
- **Deep layer:** including the transversospinales muscles that fill the spaces between the transverse processes and spinous processes.

The intermediate, or erector spinae, layer of muscles is the largest group of the intrinsic back muscles and is important for maintaining posture, extending the spine, and laterally bending the spine. These muscles are divided into three major groups, as follows (Fig. 2.11 and Table 2.5):

- **Iliocostalis:** most laterally located and associated with attachments to the ribs and cervical transverse processes.
The superficial and intermediate (erector spinae) layers of the intrinsic back muscles

- Longissimus capitis m.
- Semispinalis capitis m.
- Spinalis cervicis m.
- Splenius capitis and splenius cervicis mm.
- Serratus posterior superior m.
- Iliocostalis mm.
- Longissimus m.
- Spinalis m.
- Erector spinae mm.
- Longissimus cervicis m.
- Iliocostalis cervicis m.
- Iliocostalis thoracis m.
- Longissimus thoracis m.
- Longissimus thoracis m.
- Iliocostalis lumbarum m.
- Serratus posterior inferior m.

**Note:** Deep dissection shown on right side.

The deep (transversospinal) layer of the intrinsic back muscles

- Longus
- Brevis
- Rotatores cervicis mm.
- Levator costarum m.
- Semispinalis thoracis m.
- Multifidus thoracis mm.
- Longus
- Brevis
- Rotatores thoracis mm.
- Multifidus lumborum mm.

**Note:** Deep dissection shown on right side.

**FIGURE 2.11** Intrinsic Muscles of the Back. (From *Atlas of human anatomy*, ed 7, Plates 181 and 182.)
Deep to the transversospinal muscles lies a relatively small set of segmental muscles that assist in elevating the ribs (levatores costarum) and stabilizing adjacent vertebrae while larger muscle groups act on the spine (interspinales, intertransversarii) (Fig. 2.11).

**Suboccipital Muscles**

In the back of the neck, deep to the trapezius, splenius, and semispinalis muscles, lie several small muscles that move the head; they are attached to the skull, the atlas, and the axis (Fig. 2.12 and Table 2.6). These muscles are the **suboccipital muscles**, innervated by the suboccipital nerve (posterior ramus of C1) and forming a (suboccipital) triangle with the following muscle boundaries:

- **Rectus capitis posterior major**.
- **Obliquus capitis superior** (superior oblique muscle of head).
- **Obliquus capitis inferior** (inferior oblique muscle of head).

Deep within the suboccipital triangle, the **vertebral artery**, a branch of the subclavian artery in the lower anterior neck, passes through the transverse foramen of the atlas and loops medially to enter the foramen magnum of the skull to supply...
### TABLE 2.6 Suboccipital Muscles

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>PROXIMAL ATTACHMENT (ORIGIN)</th>
<th>DISTAL ATTACHMENT (INSERTION)</th>
<th>INNERVATION</th>
<th>MAIN ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus capitis posterior major</td>
<td>Spine of axis</td>
<td>Lateral inferior nuchal line</td>
<td>Suboccipital nerve (C1)</td>
<td>Extends head and rotates to same side</td>
</tr>
<tr>
<td>Rectus capitis posterior minor</td>
<td>Tubercle of posterior arch of atlas</td>
<td>Median inferior nuchal line</td>
<td>Suboccipital nerve (C1)</td>
<td>Extends head</td>
</tr>
<tr>
<td>Obliquus capitis superior</td>
<td>Atlas transverse process</td>
<td>Occipital bone</td>
<td>Suboccipital nerve (C1)</td>
<td></td>
</tr>
<tr>
<td>Obliquus capitis inferior</td>
<td>Spine of axis</td>
<td>Atlas transverse process</td>
<td>Suboccipital nerve (C1)</td>
<td>Rotates head to same side</td>
</tr>
</tbody>
</table>

The 31 spinal segments and associated pairs of spinal nerves are regionally arranged as follow:
- 8 cervical pairs
- 12 thoracic pairs
- 5 lumbar pairs
- 5 sacral pairs
- 1 coccygeal pair

Key nerve plexuses include:
- Cervical: C1–4
- Brachial: C5–T1
- Lumbar: L1–4
- Sacral: L4–S4

**FIGURE 2.13** Spinal Cord and Nerves In Situ. (From *Atlas of human anatomy*, ed 7, Plate 169.)
the brainstem. The first three pairs of spinal nerves are also found in this region (Fig. 2.12).

5. SPINAL CORD

The spinal cord is a direct continuation of the medulla oblongata, extending below the foramen magnum at the base of the skull and passing through the vertebral (spinal) canal formed by the articulated vertebrae (Fig. 2.13).

The spinal cord has a slightly larger diameter in the cervical and lumbar regions, primarily because of increased numbers of neurons and axons in these regions for innervation of the muscles in the upper and lower limbs. The spinal cord ends as a tapered region called the conus medullaris, which is situated at about the L1-L2 vertebral level (or L3 in neonates). From this point inferiorly, the nerve rootlets course to their respective levels and form a bundle called the cauda equina (“horse’s tail”). The spinal cord is anchored inferiorly by the terminal filum, which is attached to the coccyx. The terminal filum is a pial extension that picks up a layer of dura mater after passing through the dural sac (at the L2 vertebral level) before attaching to the coccyx (see Spinal Meninges). Features of the spinal cord include the following:

- The 31 pairs of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, and 5 sacral pairs and 1 coccygeal pair).
- Each spinal nerve is formed by a posterior (dorsal) and anterior (ventral) root.
- Motor neurons reside in the spinal cord gray matter (anterior horn).
- Sensory neurons reside in the spinal ganglia.
- Anterior rami of spinal nerves often converge to form plexuses (mixed networks of nerve axons organized into a cervical, brachial, lumbar, or sacral plexus) or segmental thoracic nerves (intercostal nerves and the subcostal nerve).
- Posterior rami of spinal nerves are small and only innervate the intrinsic back muscles and the muscles of the suboccipital region (epaxial muscles of embryo); they receive sensory fibers from a narrow strip of skin above the intrinsic muscles that extends down the back about 3 to 4 cm lateral to the midline.

Typical Spinal Nerve

The typical scheme for a somatic (innervates skin and skeletal muscle) peripheral nerve shows a motor neuron in the spinal cord anterior horn (gray matter) sending a myelinated axon through an anterior (ventral) root and a spinal nerve, and then into posterior and anterior rami of a peripheral nerve, which ends at a neuromuscular junction on a skeletal muscle (Figs. 2.14 and 2.15). Likewise, a nerve ending in the skin sends a sensory axon toward the spinal cord in a peripheral nerve. (Sensory axons also arise from the muscle spindles and joints and are similarly conveyed back to the spinal cord.) Thus, each peripheral nerve contains hundreds or thousands of motor and sensory axons. The sensory neuron is a pseudounipolar neuron with its cell body in a spinal ganglion (a ganglion in the periphery is a collection of neuronal cell bodies, just as a “nucleus” is in the brain) and sends its central axon into the posterior horn (gray matter) of the spinal cord. At each level of the spinal cord, the gray matter is visible as a butterfly-shaped central collection of neurons that possesses a posterior and an anterior horn (Fig. 2.14).

The spinal cord gives rise to 31 pairs of spinal nerves, which then form two major branches (rami), as follows:

- **Posterior ramus:** a small ramus (branch) that courses dorsally to the back and conveys motor and sensory information to and from the skin and the intrinsic back muscles and suboccipital skeletal muscles.
- **Anterior ramus:** a much larger ramus (branch) that courses laterally and ventrally and innervates all the remaining skin and skeletal muscles of the neck, limbs, and trunk.

Once nerve fibers (sensory or motor) are beyond, or peripheral to, the spinal cord proper, the fibers then reside in nerves of the peripheral nervous system (PNS). Components of the PNS include the following (see Nervous System, Chapter 1):

- **Somatic nervous system:** sensory and motor fibers to skin, skeletal muscle, and joints (Fig. 2.15, left side).
- **Autonomic nervous system** (ANS): sensory and motor fibers to all smooth muscle (including viscera and vasculature), cardiac muscle (heart), and glands (Fig. 2.15, right side).
- **Enteric nervous system:** intrinsic plexuses and ganglia of the gastrointestinal tract that regulate bowel secretion, absorption, and motility (originally, considered part of the ANS), linked to the ANS for optimal regulation (see Fig. 1.27).

Thus, most peripheral nerves arising from the spinal cord contain hundreds or thousands of three types of axons (Fig. 2.15, left and right sides):
Each of the 31 pairs of spinal nerves exits the spinal cord and passes through an opening in the vertebral column (intervertebral foramen) to gain access to the periphery. The C1 nerve pair passes between the skull and the atlas, with subsequent cervical nerve pairs exiting the intervertebral foramen above the vertebra of the same number;
Chapter 2  Back

The C2 nerve exits via the intervertebral foramen superior to the C2 vertebra, and so on, until one reaches the C8 nerve, which then exits the intervertebral foramen above the T1 vertebra. All the remaining thoracic, lumbar, and sacral nerves exit via the intervertebral foramen below the vertebra of the same number (Fig. 2.16).

As it divides into its small posterior ramus and larger anterior ramus, the spinal nerve also gives off several small recurrent meningeal branches that reenter the intervertebral foramen and innervate the dura mater, intervertebral discs, ligaments, and blood vessels associated with the spinal cord and vertebral column (see Fig. 2.18).

**Dermatomes**

The region of skin innervated by the somatic sensory nerve axons associated with a single spinal ganglion at a single spinal cord level is called a dermatome. (Likewise, over the anterolateral head, the skin is innervated by one of the three divisions of the trigeminal cranial nerve, as discussed later.) The neurons that give rise to these sensory fibers are pseudounipolar neurons that reside in the single spinal ganglion associated with the specific spinal cord level (Figs. 2.14 and 2.15). (Note that for each level, we are speaking of a pair of nerves, roots, and ganglia, with 31 pairs of spinal nerves, one pair for each spinal cord level.) The first cervical spinal cord level, C1, does possess sensory fibers, but these provide minimal if any contribution to the skin, so at the top of the head the dermatome pattern begins with the C2 dermatome (Fig. 2.17 and Table 2.7).

The dermatomes encircle the body in segmental fashion, corresponding to the spinal cord level that receives sensory input from that segment of skin. The sensation conveyed by touching the skin is largely that of pressure and pain. Knowledge of the dermatome pattern is useful in localizing specific spinal cord segments and in assessing the integrity of the spinal cord at that level (intact or “lesioned”).

The sensory nerve fibers that innervate a segment of skin and constitute the “dermatome” exhibit some overlap of nerve fibers. Consequently, a segment of skin is innervated primarily by fibers from a single spinal cord level, but there will be some overlap with sensory fibers from the level above and below the primary cord level. For example, dermatome T5 will have some overlap with sensory fibers associated with the T4 and T6 spinal levels. Thus, dermatomes provide a good approximation of spinal cord levels, but variation is common and overlap exists (Table 2.7).
Spinal Meninges

The brain and spinal cord are covered by three membranes called the meninges and are bathed in cerebrospinal fluid (CSF) (Fig. 2.18). The three meningeal layers are the dura, arachnoid, and pia mater.

Dura Mater

The dura mater (“tough mother”) is a thick outer covering that is richly innervated by sensory nerve fibers from exiting cranial and spinal nerves. It is loosely adherent to the underlying bone, preventing its complete removal at surgery.

Dural sinuses

These are sinuses through which blood drains from the cranial cavity to the heart. They are lined with endothelial cells and filled with blood. The major ones are the internal vertebral venous plexus, superior sagittal sinus, and lateral sinus (transverse sinus).

Arachnoid Matter

This is the innermost meningeal layer, located between the dura and the pia mater. It is a highly vascularized layer that contains the arachnoid trabeculae, which are a network of fibrous strands that provide structural support and regulate the flow of cerebrospinal fluid (CSF).

Pathway of CSF

The CSF is produced by the choroid plexus, which is richly supplied with blood and is located in the ventricles of the brain. It flows through the ventricles, then exits the brain through the foramen of Monro and the aqueduct of Sylvius. It then enters the subarachnoid space, where it circulates around the brain and spinal cord. Finally, it is absorbed into the venous system through the arachnoid granulations.

Pia Mater

This is the innermost layer of the meninges, tightly adherent to the surface of the brain and spinal cord. It provides a protective layer and is the site of attachment for the blood vessels that supply the brain and spinal cord. The pia mater is continuous with the dura mater and is separable from the arachnoid mater by the subarachnoid space.

Termination of spinal dura mater

The termination of the spinal dura mater is the dural expansion, which is a thin, transparent membrane that covers the spinal cord. It is attached to the dura mater at the base of the spinal cord and is continuous with the dura mater at the top of the spinal cord. The dural expansion is separated from the spinal cord by the subarachnoid space, which contains cerebrospinal fluid (CSF) and is lined with the arachnoid mater.

TABLE 2.7 Key Dermatomes as Related to Body Surface

<table>
<thead>
<tr>
<th>VERTEBRA(E)</th>
<th>BODY SURFACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>Clavicles</td>
</tr>
<tr>
<td>C5-C7</td>
<td>Lateral upper limb</td>
</tr>
<tr>
<td>C6</td>
<td>Thumb</td>
</tr>
<tr>
<td>C7</td>
<td>Middle finger</td>
</tr>
<tr>
<td>C8</td>
<td>Little finger</td>
</tr>
<tr>
<td>C8-T2</td>
<td>Medial upper limb</td>
</tr>
<tr>
<td>T4</td>
<td>Nipple</td>
</tr>
<tr>
<td>T10</td>
<td>Umbilicus (navel)</td>
</tr>
<tr>
<td>T12-L1</td>
<td>Inguinal/grain region</td>
</tr>
<tr>
<td>L1-L4</td>
<td>Anterior and inner surfaces of lower limbs</td>
</tr>
<tr>
<td>L4</td>
<td>Knee; medial side of big toe</td>
</tr>
<tr>
<td>L5</td>
<td>2nd to 4th toes</td>
</tr>
<tr>
<td>L4-S1</td>
<td>Foot</td>
</tr>
<tr>
<td>S1-S2</td>
<td>Posterior lower limb</td>
</tr>
<tr>
<td>S2-S4</td>
<td>Perineum</td>
</tr>
</tbody>
</table>
Chapter 2

2

Clinical Focus 2-10

Herpes Zoster

Herpes zoster, or shingles, is the most common infection of the peripheral nervous system. It is an acute neuralgia confined to the dermatome distribution of a specific spinal or cranial sensory nerve root.

Painful erythematous vesicular eruption in distribution of ophthalmic division of right trigeminal (V) n.

Herpes zoster following course of 6th and 7th left thoracic dermatomes

<table>
<thead>
<tr>
<th>Features of Shingles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
</tr>
<tr>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Etiology</td>
</tr>
<tr>
<td>Presentation</td>
</tr>
<tr>
<td>Sites affected</td>
</tr>
</tbody>
</table>

endings and that extends around the spinal cord down to the level of the S2 vertebra, where the dural sac ends. The **epidural (extradural) space** lies between the vertebral canal walls and the spinal dural sac and contains fat, small nerves, and blood vessels (Fig. 2.18).

**Arachnoid Mater**

The fine, weblike arachnoid membrane is avascular and lies directly beneath, but is not attached to, the dura mater. The arachnoid mater also ends at the level of the S2 vertebra. Wispy threads of connective tissue extend from this layer to the underlying pia mater and span the **subarachnoid space**, which is filled with CSF. The subarachnoid space ends at the S2 vertebral level.

**Pia Mater**

The pia mater is a delicate, transparent inner layer that intimately covers the spinal cord. At the cervical and thoracic levels, extensions of pia form approximately 21 pairs of triangular **denticulate** ("having small teeth") **ligaments** that extend laterally and help to anchor the spinal cord by inserting into the dural mater. At the conus medullaris, the pia mater forms the **terminal filum**, a single cord of thickened pia mater that pierces the dural sac at the S2 vertebral level, acquires a dural covering, and then attaches to the tip of the coccyx to anchor the spinal cord inferiorly.

**Subarachnoid Space and Choroid Plexus**

Cerebrospinal fluid fills the **subarachnoid space**, which lies between the arachnoid and pia meningeal
layers (Figs. 2.18 and 2.19). Thus, CSF circulates through the brain ventricles and then gains access to the subarachnoid space through the lateral and median apertures, where it flows around and over the brain and inferiorly along the spinal cord to the most caudal extent of the dural sac, which ends at the S2 vertebral level.

Cerebrospinal fluid is secreted by the choroid plexus, and most CSF is absorbed primarily by the arachnoid granulations (associated with the superior sagittal dural venous sinus) (Figs. 2.19 and 8.8), and secondarily by small veins that also contain microscopic arachnoid granulations on the surface of the pia mater throughout the central nervous system (CNS) (Fig. 2.19). With about 500-700 mL produced daily, CSF supports and cushions the spinal cord and brain, fulfills some of the functions normally provided by the lymphatic system, and fills the 150 mL volume of the brain's ventricular system and the subarachnoid space.

It should be noted that recent microscopic evidence provides support for the claim that some CNS regions do possess lymphatics. Future studies may elucidate a larger role for lymphatic drainage in some regions of the CNS.

**Blood Supply to Spinal Cord**

The spinal cord receives blood from spinal arteries derived from branches of larger arteries that serve each midline region of the body (Fig. 2.20). These major arteries include the following:

- **Vertebral arteries**: arising from the subclavian arteries in the neck.
- **Ascending cervical arteries**: arising from a branch of the subclavian arteries.
- **Posterior intercostal arteries**: arising from the thoracic aorta.
- **Lumbar arteries**: arising from the abdominal aorta.
- **Lateral sacral arteries**: arising from pelvic internal iliac arteries.

A single anterior spinal artery and two posterior spinal arteries, originating intracranially from the vertebral arteries, run longitudinally along the length of the cord and are joined segmentally in each region by segmental arteries (Fig. 2.20). The largest of these segmental branches is the major segmental artery (of Adamkiewicz), found in the lower thoracic or upper lumbar region; it is the major blood supply for the lower two thirds of the spinal cord. The posterior and anterior roots are supplied by segmental radicular (medullary) arteries.

Multiple anterior and posterior spinal veins run the length of the cord and drain into segmental (medullary) radicular veins (see Fig. 2.9). Radicular veins receive tributaries from the internal vertebral veins that course within the vertebral canal.
Cerebrospinal fluid circulation

Choroid plexus of lateral ventricle (phantom)
Dura mater
Arachnoid mater
Superior sagittal sinus
Subarachnoid space
Arachnoid granulations
Interventricular foramen (of Monro)
Choroid plexus of 3rd ventricle
Cerebral aqueduct (of Sylvius)
Lateral aperture (foramen of Luschka)
Choroid plexus of 4th ventricle
Median aperture (foramen of Magendie)
Dura mater
Arachnoid mater
Subarachnoid space
Central canal of spinal cord

FIGURE 2.19  Cerebrospinal Fluid Circulation. (From Atlas of human anatomy, 7th ed, Plate 120; MR images from Kelley LL, Petersen C: Sectional anatomy for imaging professionals, St Louis, 2007, Mosby-Elsevier.)

Clinical Focus 2-11

Lumbar Puncture and Epidural Anesthesia

Cerebrospinal fluid may be sampled and examined clinically by performing a lumbar puncture (spinal tap). A spinal needle is inserted into the subarachnoid space of the lumbar cistern, in the midline between the L3 and L4 or the L4 and L5 vertebral spinal processes. Because the spinal cord ends at approximately the L1 or L2 vertebral level, the needle will not pierce and damage the cord. Anesthetic agents may be directly delivered into the epidural space (above the dura mater) to anesthetize the nerve fibers of the cauda equina; this common form of anesthesia is used during childbirth in most Western countries. The epidural anesthetic infiltrates the dural sac to reach the nerve roots and is usually administered at the same levels as the lumbar puncture.
Radicular veins then drain into segmental veins, with the blood ultimately collecting in the following locations:
- Superior vena cava.
- Azygos venous system of the thorax.
- Inferior vena cava.

6. EMBRYOLOGY

Most of the bones inferior to the skull form by endochondral bone formation, that is, from a cartilaginous precursor that becomes ossified. The embryonic development of the musculoskeletal components of the back represents a classic example of segmentation, with each segment corresponding to the distribution of peripheral nerves. This process begins around the end of the third week of embryonic development (day 19), during the period called gastrulation (see Chapter 1).

Development of Myotomes, Dermatomes, and Sclerotomes

The bones, muscles, and connective tissues of the embryo arise from the following sources:

- Primitive streak mesoderm (somites).
- Lateral plate mesoderm.
- Diffuse collections of mesenchyme.

As the neural groove invaginates along the posterior midline of the embryonic disc, it is flanked on either side by masses of mesoderm called somites. About 42 to 44 pairs of somites develop along this central axis and subsequently develop into the following (Fig. 2.21):

- Dermomyotomes: divide further to form dermatomes, which become the dermis of the skin, and myotomes, which differentiate into segmental masses of skeletal muscle.

- Sclerotomes: the medial part of each somite that, along with the notochord, migrates around the neural tube and forms the cartilaginous precursors of the axial skeleton.

Myotomes have a segmental distribution, just like the somites from which they are derived. Each segment is innervated by a pair of nerves originating from the spinal cord segment. A small dorsal portion of the myotome becomes an epimere (epaxial) mass of skeletal muscle that will form the true intrinsic muscles of the back (e.g., erector spinae muscles).
and are innervated by a posterior ramus of the spinal nerve (Fig. 2.22).

A much larger anterior segment becomes the hypomere (hypaxial) mass of skeletal muscle, which will form the muscles of the trunk wall and limb muscles, all innervated by an anterior ramus of the spinal nerve. Adjacent myotome segments often merge so that an individual skeletal muscle derived from those myotomes is innervated by more than one spinal cord segment. For example, the latissimus dorsi muscle is innervated by the thoracodorsal nerve, which is composed of nerves from the anterior rami of spinal cord segments C6-C8.

**Vertebral Column Development**

Each vertebra first appears as a hyaline cartilage model that then ossifies, beginning in a **primary ossification center** (Fig. 2.23). Ossification centers include the following:

- **Body:** forms the vertebral body; important for support of body weight.
Costal process: forms the ribs, or in vertebrae without rib articulation, part of the transverse process; important for movement and muscle attachment.

Neural arch: includes the pedicle and lamina, for protection of the spinal cord, and the spinous process, for muscle attachment.

The body of the vertebra does not develop from a single sclerotome but rather from the fusion of two adjacent sclerotomes (i.e., fusion of caudal half of sclerotome above with cranial half of sclerotome below). The intervertebral foramen thus lies over this fusion and provides the opening for the spinal roots that will form the spinal nerve that will innervate the myotome at that particular segment.

The notochord initially is in the central portion of each vertebral body but disappears. The notochord persists only as the central portion (nucleus pulposus) of each intervertebral disc, surrounded by concentric lamellae of fibrocartilage.

**Neurulation and Development of the Spinal Cord**

Neurulation (neural tube formation) begins concurrently with gastrulation (formation of the trilaminar embryonic disc during the third week of development). As the primitive streak recedes caudally, the midline surface ectoderm thickens to form the neural plate, which then invaginates to form the neural groove (Fig. 2.24, A). The neural crest forms at the dorsal aspect of the neural groove (Fig. 2.24, B) and fuses in the midline as the groove sinks below the surface and pinches off to form the neural tube (Fig. 2.24, C). The neural tube forms the following:

- Neurons of central nervous system (CNS: brain, spinal cord).
- Supporting cells of CNS.
- Somatomotor neurons (innervate skeletal muscle) of PNS.
Mantle: intermediate zone that develops into gray matter of spinal cord.
Marginal zone: outer layer that becomes white matter of spinal cord.

Glia cells are found primarily in the mantle and marginal zone. The neural tube is distinguished by a longitudinal groove on each side that forms the sulcus limitans and divides the tube into a dorsal alar plate and a ventral basal plate (Fig. 2.25). The dorsal alar plate forms the sensory derivatives of the spinal cord, and the ventral basal plate gives rise to the somatic and autonomic motor neurons, whose axons will leave the spinal cord and pass into the peripheral tissues. The sensory neurons of the spinal ganglia are formed from neural crest cells.

Presynaptic autonomic neurons of PNS.
The neural crest gives rise to the following (Fig. 2.24, D and E):
- Sensory neurons of PNS found in dorsal root ganglia.
- Postsynaptic autonomic neurons.
- Schwann cells of PNS.
- Adrenal medullary cells, in each adrenal gland.
- Head mesenchyme and portions of heart.
- Melanocytes in skin.
- Arachnoid mater and pia mater meninges (dura mater is formed from mesenchyme).

The cells in the walls of the neural tube compose the neuroepithelium, which develops into three zones, as follows:
- Ependymal zone: inner layer lining central canal of spinal cord (also lines ventricles of brain).
Clinical Focus 2-13

Myofascial Pain

Myofascial pain syndrome is pain associated with a muscle or its adjacent fascia that may be felt at a single point or at multiple active “trigger” points, sending a signal to the central nervous system. Trauma, muscle overuse, poor posture, and disease may precipitate the pain. The trigger site may be tender to palpation and may initiate a muscle spasm-pain-spasm cycle. Common trigger points include the following muscles:

- **Neck**: levator scapulae, splenius capitis, trapezius, sternocleidomastoid
- **Shoulder**: infraspinatus, supraspinatus, rhomboid
- **Lower back**: quadratus lumborum, gluteus medius, tensor fasciae latae
- **Thigh**: biceps femoris, vastus lateralis, adductor longus
- **Leg**: gastrocnemius, soleus

Deconditioning of lumbar extensors, particularly longissimus and multifidus mm. Injury to m. attachments may result in pain and delayed healing.

Muscle spindles provide feedback mechanism for m. tension. Sensitivity of spindles modulated by gamma efferent system and by sympathetic innervation of spindles. Sympathetic hyperactivity can result in painful spasm of spindles.
Acute Spinal Syndromes

Acute spinal cord myelopathies may be caused by several epidural (extradural) lesions, including metastatic tumors that invade the vertebral body (top panel) or an epidural abscess resulting from a variety of infections (lower panel). Likewise, intradural myelopathies can occur from trauma, inflammation, and vascular infarction (shown in this image, middle panel).

**Metastatic lesion**

Common primary sites, noted on history examination:
- Breast
- Prostate
- Lung
- Melanoma (skin or mucous membrane)
- Lymphoma (may be primary)

**X-ray film showing destruction of pedicle and vertebral body by metastatic carcinoma**

**Bone scan showing multiple metastases**

**Infarction**

Posterior columns intact (position sense intact)
- Lateral corticospinal tract infarcted (motor function lost)
- Spinothalamic tract infarcted (pain and temperature sensation lost)

because of infarction of anterolateral spinal cord due to:
- Thrombosis of artery of Adamkiewicz, central (sulcal) artery, anterior spinal artery, intercostal artery or to:
- Aortic obstruction by dissecting aneurysm or clamping during heart surgery

**Sensory dissociation**

Loss of pain and temperature sensation
- Position sense retained
- Dissecting aortic aneurysm obstructing artery of Adamkiewicz by blocking intercostal artery

**Epidural abscess**

**Sources of infection**

- Hematogenous: Skin: furuncle, carbuncle, Urinary tract: renal, perirenal, prostatic abscess, pyelonephritis
- Direct: Psoas abscess, Dermal sinus

**Pain on percussion of spine. Local warmth may be noted.**

**Transverse myelitis** Cause and specific pathologic process undetermined. Diagnosis by exclusion of other causes.
Chapter 2

5 1/2 weeks (transverse section)

Mature (transverse section)

Dorsal alar plate (sensory and coordinating)

Ventral basal plate (motor)

Central canal

Ependymal layer

Mantle layer

Marginal layer

Sulcus limitans

Sensory

Motor

Tracts (white matter)

Lateral gray column (horn)

Anterior gray column (horn)

Tracts (white matter)

Central canal

Posterior gray column (horn)

Motor neuroblasts growing out to terminate on motor end plates of skeletal m.

Differentiation and growth of neurons at 26 days

Neural crest

Spinal cord (thoracic part)

Ependymal layer

Mantle layer

Marginal layer

FIGURE 2.25 Alar and Basal Plates of Spinal Cord.
Clinical Focus 2-12

Spina Bifida

Spina bifida, one of several neural tube defects, is linked to low folic acid ingestion during the first trimester of pregnancy. Spina bifida is a congenital defect in which the neural tube remains too close to the surface such that the sclerotome cells do not migrate over the tube and form the neural arch of the vertebra (spina bifida occulta). This defect occurs most often at the L5 or S1 vertebral level and may present with neurologic findings. If the meninges and CSF protrude as a cyst (meningocele) or if the meninges and the cord itself reside in the cyst (meningomyelocele), significant neurologic problems often develop.

Types of spina bifida cystica with protrusion of spinal contents

- Spina bifida occulta
- Meningocele
- Meningomyelocele

Available Online

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Additional figures available online (see inside front cover for details).
Challenge Yourself Questions

1. Besides his apparent mental deficits, the “hunchback of Notre Dame” also suffered from which of the following conditions?
   A. Halitosis
   B. Kyphosis
   C. Lordosis
   D. Osmosis
   E. Scoliosis

2. You are asked to assist a resident with a lumbar puncture procedure to withdraw a cerebrospinal fluid sample for analysis. Which of the following surface landmarks will help you determine where along the midline of the spine you will insert the spinal needle?
   A. An imaginary line crossing the two iliac crests
   B. An imaginary line crossing the two posterior superior iliac spines
   C. At the level of the 5th lumbar spinous process
   D. At the level of the umbilicus
   E. At the level of the vertebra prominens

3. A 56-year-old man presents with a history of pain for the last 18 months over the right buttock and radiating down the posterior aspect of the thigh and leg. A radiographic examination reveals a herniated disc between the L5 and the S1 vertebral levels. Which of the following nerves is most likely affected by this herniated disc?
   A. L3
   B. L4
   C. L5
   D. S1
   E. S2

4. A 19-year-old man sustained an apparent cervical spine hyperextension (“whiplash”) injury after a rear-end roller-coaster crash at a local amusement park. Radiographic examination reveals several cervical vertebral body fractures and the rupture of an adjacent vertebral ligament. Which of the following vertebral ligaments was most likely ruptured during this hyperextension injury?
   A. Anterior longitudinal ligament
   B. Cruciate ligament
   C. Interspinous ligament
   D. Ligamentum flavum
   E. Nuchal ligament

5. A 34-year-old woman presents with a spider bite and a circumscribed area of inflammation on the back of her neck over the C4 dermatome region. Which of the following types of nerve fibers mediate this sensation?
   A. Somatic afferents in C4 anterior root
   B. Somatic afferents in C4 posterior root
   C. Somatic afferents in C4 anterior ramus
   D. Somatic efferents in C4 anterior root
   E. Somatic efferents in C4 posterior root
   F. Somatic efferents in C4 anterior ramus

6. A newborn female presents with a congenital neural tube defect likely caused by a folic acid deficiency and characterized by the failure of the sclerotome to form the neural arch. Which of the following conditions is consistent with this congenital defect?
   A. Osteophyte overgrowth
   B. Osteoporosis
   C. Scoliosis
   D. Spina bifida
   E. Spondylolysis

Multiple-choice and short-answer review questions available online; see inside front cover for details.
7. After an automobile crash, a 39-year-old man presents with a headache and midback pain. A radiographic examination reveals trauma to the thoracic spine and bleeding from the anterior and posterior internal vertebral venous plexus. In which of the following regions is the blood most likely accumulating?

A. Central spinal canal
B. Epidural space
C. Lumbar triangle
D. Subarachnoid space
E. Subdural space

8. A high school football player receives a helmet-to-helmet blow to his head and neck and is brought into the emergency department. A radiographic examination reveals a mild dislocation of the atlantoaxial joint. When you examine his neck, you notice his range of motion is decreased. Which of the following movements of the head would most likely be affected?

A. Abduction
B. Adduction
C. Extension
D. Flexion
E. Rotation

9. A patient is admitted to the emergency department with a sharp penetrating wound in the upper back region just lateral to the thoracic spine. Based on a quick examination, the physician concludes that several of the spinal ganglia are clearly damaged. Which of the following neural elements are most likely compromised by this injury?

A. Postganglionic efferents
B. Somatic afferents only
C. Somatic afferents and efferents
D. Somatic and visceral afferents
E. Somatic efferents only

10. A congenital defect that involves the neural crest cells would potentially involve the normal development of which of the following structures?

A. Anterior spinal artery
B. Choroid plexus
C. Dura mater
D. Intrinsic back muscles
E. Schwann cells

For each of the following conditions (11-20), select the muscle (A-K) most likely responsible.

A. Erector spinae
B. Latissimus dorsi
C. Levator scapulae
D. Obliquis capsitis inferior
E. Rectus capsitis posterior major
F. Rhomboid major

_____ 11. A work-related injury results in a weakness against resistance in elevation of the scapula and atrophy of one of the lateral neck muscles. The physician suspects damage to a cranial nerve.

_____ 12. An injury results in significant weakness in extension and lateral rotation along the entire length of the spine.

_____ 13. After an automobile crash, a patient presents with radiating pain around the shoulder blades and weakness in elevating the ribs on deep breathing.

_____ 14. An injury to the back results in a weakened ability to extend and medially rotate the upper limb.

_____ 15. Sharp trauma to the back of the neck damages the suboccipital nerve, resulting in a weakened ability to extend and rotate the head to the same side against resistance.

_____ 16. Malformation of the craniocervical portion of the embryonic epaxial (epimere) muscle group that attaches to the ligamentum nuchae results in a weakened ability to extend the neck bilaterally.

_____ 17. Trauma to the lateral neck results in a lesion to the dorsal scapular nerve and a weakened ability to shrug the shoulders.

_____ 18. The loss of innervation to this pair of hypaxial (hypomere) muscles results in a bilateral weakened ability to retract the scapulae but does not affect the ability to elevate the scapulae.
19. During spinal surgery, these small intrinsic back muscles must be retracted from the lamina and transverse processes of one or two vertebral segments.

20. During surgery in the neck, the vertebral artery is observed passing just deep to this muscle prior to the artery entering the foramen magnum.

21. A woman presents with a painful neck. Imaging reveals spinal stenosis (narrowing of the vertebral foramen). Hypertrophy of which of the following ligaments would most likely result in this syndrome?
   A. Anterior longitudinal ligament
   B. Interspinous ligament
   C. Ligamentum flavum
   D. Nuchal ligament
   E. Supraspinous ligament

22. A 51-year-old man is admitted to the emergency department following a bicycle accident. His physical examination reveals weakened medial rotation, extension, and adduction of an upper limb. Which of the following nerves is most likely injured?
   A. Accessory nerve (CN XI)
   B. Axillary nerve
   C. Dorsal scapular nerve
   D. Radial nerve
   E. Thoracodorsal nerve

23. A 54-year-old woman presents with a case of shingles (herpes zoster infection) that affects the sensory spinal nerve roots innervating the skin on her back overlying the inferior angle of her scapula. Which of the following dermatomes is most likely involved?
   A. C5-C6
   B. T1-T2
   C. T6-T7
   D. T10-T11
   E. L1-L2

24. During a routine lumbar puncture to sample the CSF, which of the following ligaments normally would be penetrated by the spinal needle?
   A. Anterior longitudinal ligament
   B. Denticulate ligament
   C. Nuchal ligament
   D. Posterior longitudinal ligament
   E. Supraspinous ligament

25. A 26-year-old woman involved in an automobile crash presents with a headache and back pain. Imaging reveals a hematoma from rupture of her internal vertebral venous plexus. The blood is most likely present in which of the following areas or spaces?
   A. Central canal
   B. Epidural space
   C. 4th ventricle
   D. Subarachnoid space
   E. Subdural space

26. The erector spinae muscles are derived from which of the following embryonic tissues?
   A. Ectoderm
   B. Endoderm
   C. Epimeres
   D. Hypomeres
   E. Neural crest

27. During surgery involving the posterior abdominal wall, it is important to not damage the primary blood supply to the lower two thirds of the spinal cord, which usually is supplied by which of the following arteries?
   A. Lateral sacral arteries
   B. Lumbar arteries
   C. Major anterior segmental medullary arteries
   D. Posterior intercostal arteries
   E. Vertebral arteries

28. Extreme exercise and/or physical trauma may easily damage the spinal cord. However, it is tethered laterally by several important structures that prevent side-to-side excursions of the cord. Which of the following structures is responsible for this stabilization of the cord?
   A. Denticulate ligaments
   B. Interspinous ligament
   C. Ligamentum flavum
   D. Supraspinous ligament
   E. Terminal filum
29. Trauma involving the intervertebral foramen between the C3 and C4 vertebrae results in damage to the anterior root of a spinal nerve. Which of the following nerve fibers are damaged?

A. Motor fibers of the C3 spinal cord level  
B. Motor fibers of the C4 spinal cord level  
C. Sensory fibers of the C3 spinal cord level  
D. Sensory fibers of the C4 spinal cord level  
E. Motor and sensory fibers of the C3 spinal cord level  
F. Motor and sensory fibers of the C4 spinal cord level

For questions 30 to 35, refer to the midsagittal MRI of the lumbar spine and provide the letter that correctly answers the question or identifies the structure described.

30. Which letter points to the cauda equina?

31. Where is the nucleus pulposus?

32. Where is the CSF located?

33. Where is the spinous process of the L3 vertebra located?

34. Identify the supraspinous ligament.

35. Identify the ligamentum flavum.


Answers to Challenge Yourself Questions

1. B. Kyphosis, or “humpback (hunchback),” is one of several accentuated spinal curvatures. It is commonly observed in the thoracic spine. Halitosis refers to bad breath, and lordosis to the lumbar curvature, either the normal curvature or an accentuated lordosis similar to that observed in women during the third trimester of pregnancy. Osmosis is the passage of a solvent through a semipermeable membrane based on solute concentration, and scoliosis is an abnormal lateral curvature of the spine.

2. A. An imaginary line connecting the two iliac crests demarcates the space between the L3 and L4 spinous processes with patients on their side and the spine flexed. Lumbar punctures are usually performed between the L3-L4 or L4-L5 levels to avoid injury to the spinal cord proper, which usually ends as the conus medullaris at the L1-L2 vertebral levels. Below the L2 vertebral level, the nerve roots comprise the cauda equina, and are suspended in the CSF-filled subarachnoid space.

3. D. The nucleus pulposus of the intervertebral discs usually herniates in a posterolateral direction, where it can impinge on the nerve roots passing through the intervertebral foramen. A disc herniating at the L4-L5 level usually impinges on the L5 roots, and herniation at the L5-S1 level involves the S1 roots.

4. A. Hyperextension-hyperflexion (whiplash) of the cervical spine can occur when the relaxed neck is thrown backward (hyperextension), tearing the anterior longitudinal ligament. Hyperflexion is usually limited when one’s chin hits the sternum. Properly adjusted car seat headrests can limit the hyperextension.

5. B. Sensation from the skin is mediated by somatic afferents (fibers in the posterior root), and the cell bodies of these sensory neurons (pseudounipolar neurons) associated with the T4 dermatome reside in the T4 spinal ganglion.

6. D. Mesoderm derived from the sclerotome normally contributes to the formation of the neural arch (pedicle, lamina, and spinous process), and a folic acid deficiency in the first trimester of pregnancy may contribute to this congenital malformation (spina bifida occulta).

7. B. The internal vertebral venous plexus (Batson’s plexus) resides in the epidural fat surrounding the meningeal-encased spinal cord. The epidural space lies between the bony vertebral spinal canal and the dura mater surrounding the spinal cord.
8. E. The atlantoaxial joint (atlas and axis) functions in the axial rotational movements of the head. The cranium and atlas move as a unit and rotate side to side on the uniaxial synovial pivot joint between the axis (C2) and atlas (C1).

9. D. The spinal ganglia between T1 and L2 contain sensory neurons for both somatic and visceral (autonomic) afferent fibers, so both of these modalities would be compromised. Efferent (motor) fibers are not associated with the spinal ganglia.

10. E. Of the options, only Schwann cells are derived from the neural crest. While the arachnoid mater and pia mater are derived from neural crest cells (neither of these choices are options), the dura mater is derived from mesoderm.

11. K. The only muscle of this group innervated by a cranial nerve is the trapezius muscle by the accessory nerve (CN XI). The other neck muscle innervated by CN XI is the sternocleidomastoid muscle in the lateral neck.

12. A. The major extensors along the entire length of the spine, also involved in lateral rotation or bending when unilaterally contracted, are the erector spinae group of muscles (spinalis, longissimus, and iliocostalis muscles).

13. I. The only muscles in the list that are associated with the shoulder blade (scapula), attach to the ribs, and elevate them during inspiration are the serratus posterior superior group. These muscles are considered respiratory muscles because they assist in respiratory movements of the ribs.

14. B. The latissimus dorsi muscle extends and medially rotates the upper limb at the shoulder and is the only muscle in this list with these combined actions on the upper limb.

15. E. The suboccipital nerve (posterior ramus of C1) innervates the suboccipital muscles in the posterior neck, and the rectus capitis posterior major muscle is the only one in the list that extends and rotates the head to the same side.

16. J. The splenius capitis muscle is the only epaxial muscle (intrinsic back muscles innervated by posterior rami of the spinal nerves) in this list that has significant attachment to the ligamentum nuchae (origin) and exclusively extends the neck when it contracts bilaterally.

17. C. The levator scapulae muscle is innervated by the posterior scapular nerve (C5) and assists the superior portion of the trapezius muscle in shrugging the shoulders.

18. F. Hypaxial muscles are innervated by the anterior rami of spinal nerves, and the rhomboid major muscle is a hypaxial muscle that retracts the scapulae.

19. G. The rotatores muscles are part of the transversospinales group of muscles that largely fill the spaces between the transverse processes and the spinal processes. Specifically, the rotatores muscles extend between the lamina and transverse processes and stabilize, extend, and rotate the spine.

20. E. The vertebral arteries ascend in the neck by passing through the transverse foramina of the C6-C1 vertebrae, then loop medially and superiorly to the posterior arch of the atlas (C1), pass deep (anterior) to the rectus capitis posterior major muscle, and enter the foramen magnum to supply the posterior portion of the brainstem and brain, and the cerebellum by forming the basilar artery and its branches.

21. C. Of all the ligaments listed, only the ligamentum flavum is found in the vertebral foramen, where it connects adjacent laminae of two vertebrae.

22. E. The thoracodorsal nerve innervates the latissimus dorsi muscle. This muscle can medially rotate, adduct, and extend the humerus; extension of the humerus is its primary action. It is a muscle well developed in competitive swimmers.

23. C. Herpes zoster infection affects the sensory distribution of spinal and cranial nerves in a pattern generally following a dermatome. In this instance, it affects the dermatomes associated with the skin overlying the inferior angle of the scapula, or, approximately, the dermatomes of T6-T7. See Clinical Focus 2-10.

24. E. As the spinal needle descends in the midline of the back, it would normally encounter the supraspinous ligament and ligament flavum before it enters the vertebral foramen. It would then pierce the dura mater and arachnoid mater before reaching the CSF in the subarachnoid space.

25. B. The internal vertebral plexus (of Batson) of veins lies within the vertebral foramen and just outside the dura mater and epidural fat. The other spaces lie beneath the dura mater (subdural or subarachnoid space). The central canal is within the spinal cord itself.

26. C. The erector spinae muscles are true intrinsic back muscles innervated by posterior rami of the spinal nerves. They are derived from myotomes (mesoderm) forming the epimeres. Hypomeres give rise to skeletal muscle innervated by the anterior rami of spinal nerves.
27. C. The major anterior segmental medullary artery (of Adamkiewicz) is in the lower thoracic or upper lumbar region. It usually provides the major blood supply to the lower two thirds of the spinal cord. The other options include arteries that provide blood to more discrete regions of the spinal cord or to the brainstem and cerebellum (the vertebral arteries).

28. A. The spinal cord is anchored cranially by its continuation intracranially as the brainstem and caudally by the terminal filum, which attaches to the coccyx. However, its lateral movement is limited by approximately 21 pairs of triangular-shaped pia mater extensions that pierce the arachnoid mater and insert into the dura mater. These attachments limit side-to-side movements of the cord.

29. B. The anterior root of a spinal nerve contains only motor (efferent) nerve fibers. The first spinal nerve exits the spinal cord between the C1 vertebra (the atlas) and the skull, and each subsequent spinal nerve exits the vertebral canal above the vertebra of the same number. So the anterior root of the C4 spinal nerve exits between the C3 and C4 vertebrae. However, because there are eight cervical nerves and only seven cervical vertebrae, the C8 spinal nerve exits above the T1 vertebra; hence, all remaining thoracic, lumbar, and sacral nerves exit via the intervertebral foramen below the vertebra of the same number (e.g., the T1 nerve exits the intervertebral foramen between the T1 and T2 vertebrae). See Fig. 2.16.

30. B. See Fig. 2.19.

31. E. The nucleus pulposus lies within the center of the intervertebral disc. See Clinical Focus 2-6.

32. A. The CSF is located in the subarachnoid space, seen here surrounding the cauda equina.

33. G. The spinous process of the L3 vertebra is slanted slightly posteroinferior to the more anterior L3 vertebral body.

34. D. The supraspinous ligament is stretching between adjacent spines of the vertebrae.

35. H. The ligamentum flavum is connecting adjacent laminae of the vertebrae. The ligament also contains some elastic fibers.