

# Chapter 2

## Anatomy of the Pediatric Spine



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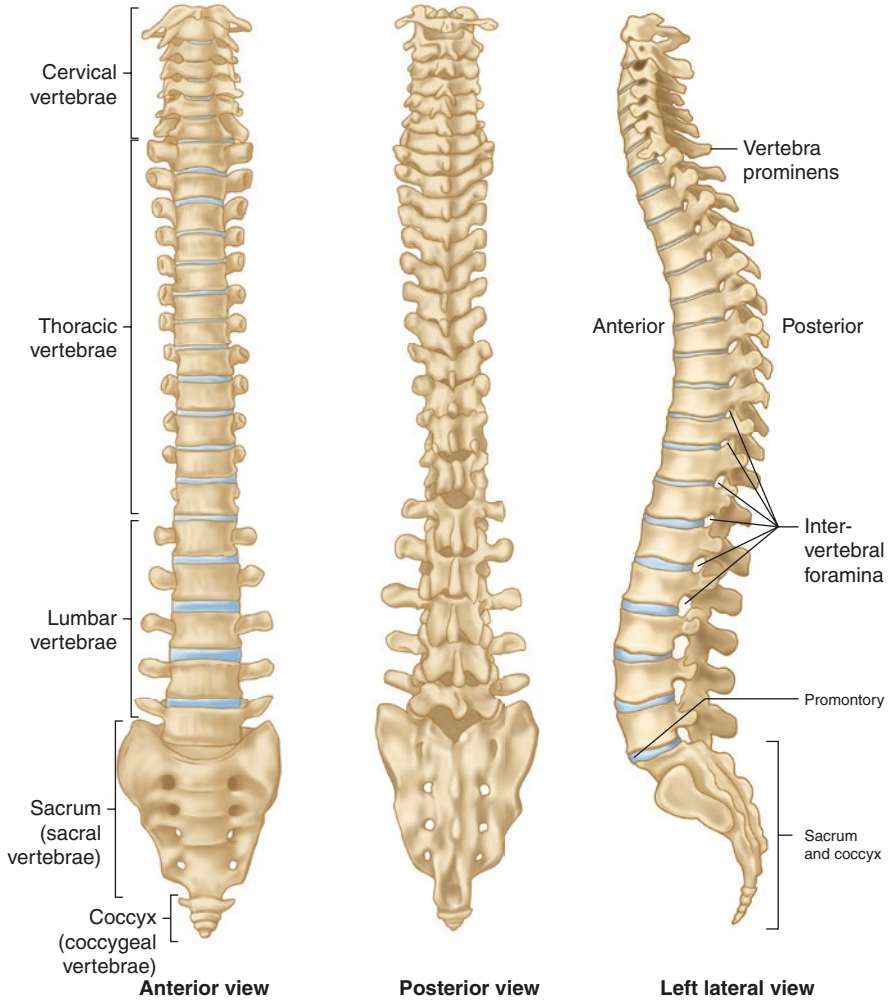
The spinal column is a series of vertebrae, stacked one on another, forming a central canal to house the spinal cord. The spine serves multiple purposes, including support for the skull, as a scaffold for the appendicular skeleton, and as a conduit which provides protection for the central nervous system. Normally, the spine is straight in the coronal plane and has four curvatures in the sagittal plane – cervical lordosis, thoracic kyphosis, lumbar lordosis, and sacropelvic kyphosis (Fig. 2.1). Thus, the human spine permits bipedal ambulation while maintaining the center of gravity in optimal alignment over the centers of the hip joints. Neuromuscular maturation determines alignment and growth. At birth the spine is aligned in mild kyphosis. Cervical lordosis develops as the infant achieves head control, and lumbar lordosis develops as standing is achieved (Fig. 2.2) [1, 2]. Vertebral and disc growth and development are impaired in children with neuromuscular diseases that prevent ambulation such as cerebral palsy [3].

The vertebral column is divided into five regions based on morphology and location. These are the cervical, thoracic, lumbar regions, the sacrum, and the coccyx (see Fig. 2.1). There are seven cervical vertebrae, with eight associated cervical spinal nerves. The 12 thoracic vertebrae are typically associated with paired ribs that articulate with the thoracic vertebral bodies and disc spaces. Five lumbar vertebrae are below the thoracic spine. The sacrum is composed of five vertebrae, fused at maturity, which articulate with the iliac bones through the sacroiliac joints. The coccygeal segments consist of 3–5 vestigial vertebral bodies caudal to the sacrum and which may be fused to each other.

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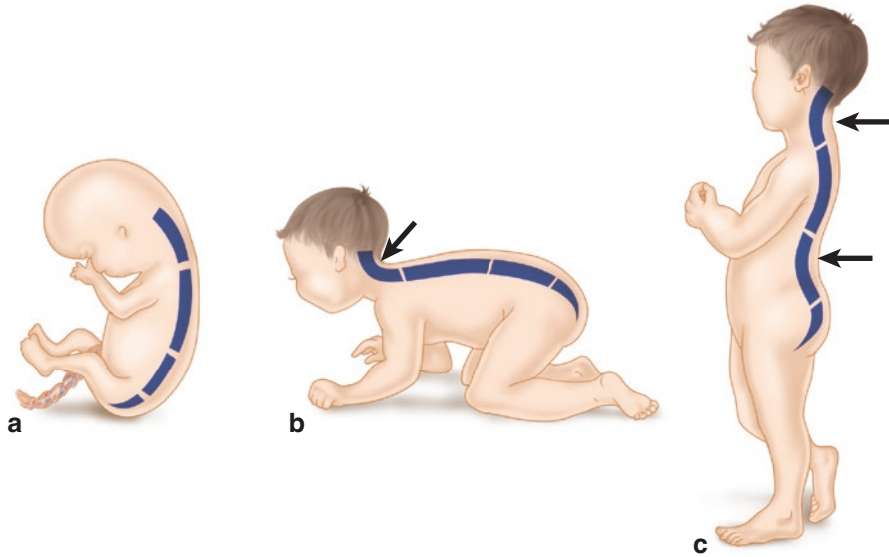
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**Fig. 2.1** The spinal column

Although there are distinguishing features in each region, much of the bony anatomy is common to each vertebra. An individual vertebra has the following components (Fig. 2.3): the vertebral body, two pedicles projecting posteriorly, two transverse processes project in a lateral direction, and the posterior neural arch which includes the laminae, a spinous process, and superior and inferior articular processes with their associated facet joints [4]. The spinous process is the only structure which can be palpated beneath the skin. The main portion of the vertebra is the cylinder-shaped body, which bears the majority of axial loads applied to the spine. The intervertebral discs are between each of the vertebral bodies.



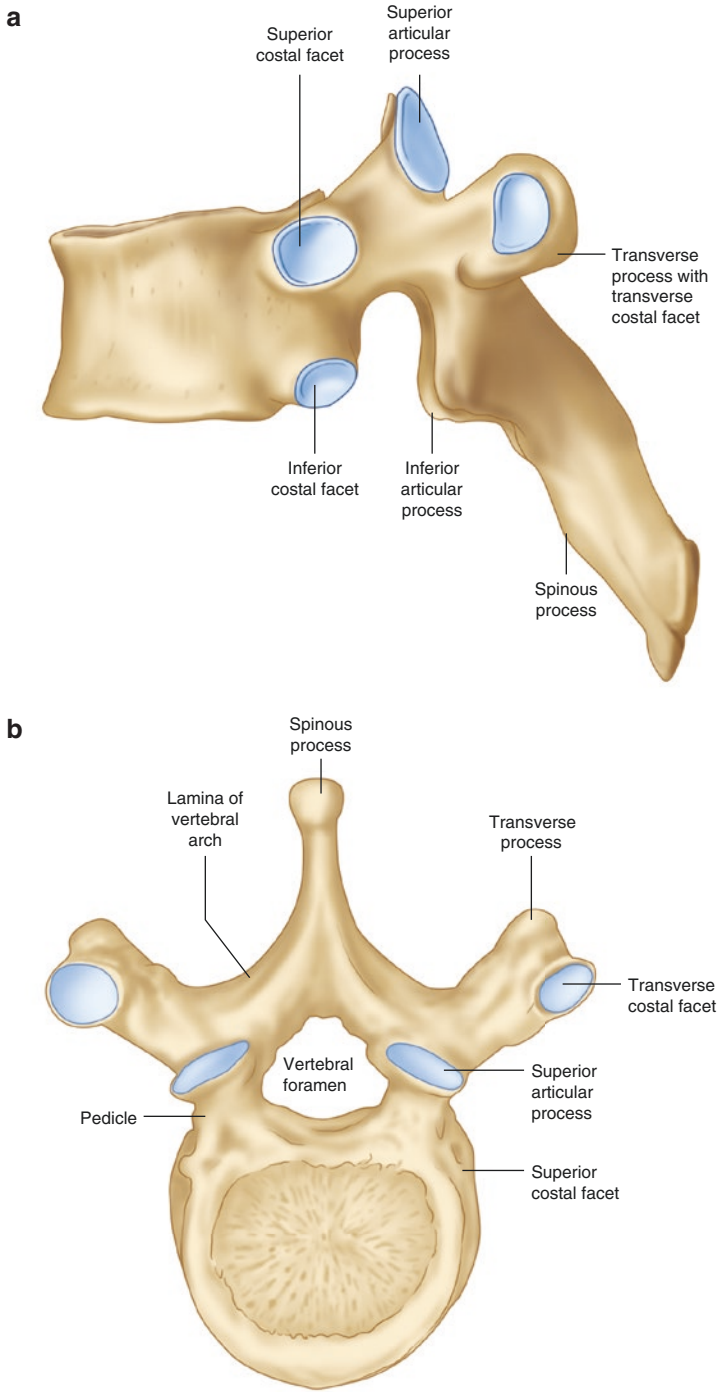
**Fig. 2.2** Spine alignment in the fetus (a), infant (b), and toddler (c)

The vertebral segments are stabilized by their bony architecture and by ligaments. Each vertebra typically has six joints: two superior articular facets, two inferior facets, and the disc spaces between vertebral bodies. Further stability is a consequence of ligamentous and muscular attachments (Fig. 2.4). Structurally, the most important ligaments of the spinal column include the anterior and posterior longitudinal ligaments, the annulus fibrosus, the intertransverse ligaments, ligamentum flavum, and interspinous ligaments.

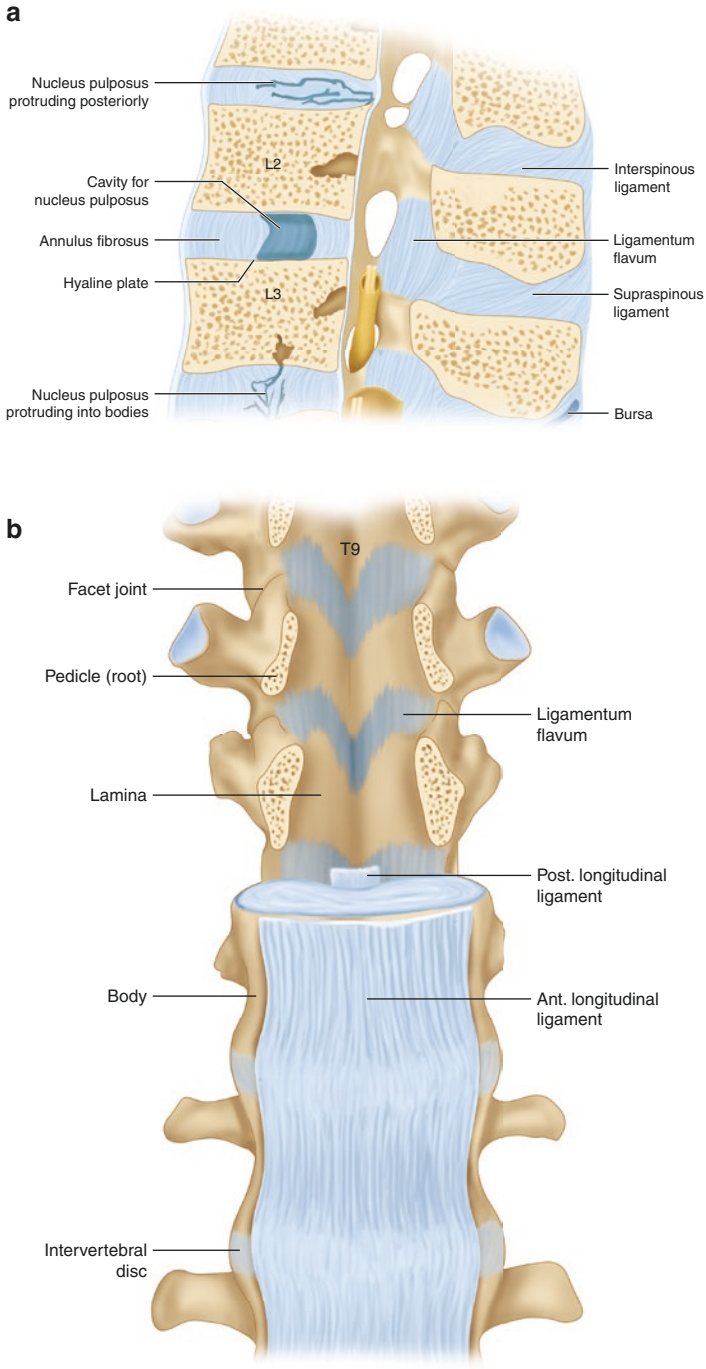
The anterior longitudinal ligament (ALL) is a thick band contiguous with the periosteum along the anterior aspect of the vertebral bodies. It spans from the sacral bodies to the cervical spine where it becomes confluent with the anterior atlanto-occipital membrane at C1. The ALL is an important stabilizer, limiting extension of the spinal column, and serves to reinforce the annulus fibrosus.

Located between each pair of vertebral bodies are the intervertebral discs, each of which is composed of the annulus fibrosus and nucleus pulposus. The annulus fibers are thick and arranged in layers at oblique angles to each other [2]. The annular ligaments are mainly composed of type I collagen, which is optimal for resisting tensile loads [5]. The nucleus pulposus is located within the central portion of the disc and is a gelatinous material made of type II collagen and proteoglycans. The disc anatomy is conducive to the absorption of compression forces, such as axial loading of the spine, while allowing mobility [5].

The posterior longitudinal ligament (PLL) is located on the posterior aspects of the vertebral bodies and annulus within the spinal canal. The PLL prevents excessive flexion and reinforces the intervertebral disc. The intertransverse ligament is located between the transverse processes and limits side bending. The ligamentum



**Fig. 2.3** Sixth thoracic vertebra. (a) Lateral aspect and (b) cranial aspect



**Fig. 2.4** Ligaments of the spine. (a) Lateral aspect and (b) anterior aspect

flavum, named for its distinctive yellow hue, is oriented in the coronal plane and connects the laminae of adjacent vertebrae. It functions as an important stabilizer and provides some protection to the contents of the spinal canal, especially at the lumbar spine.

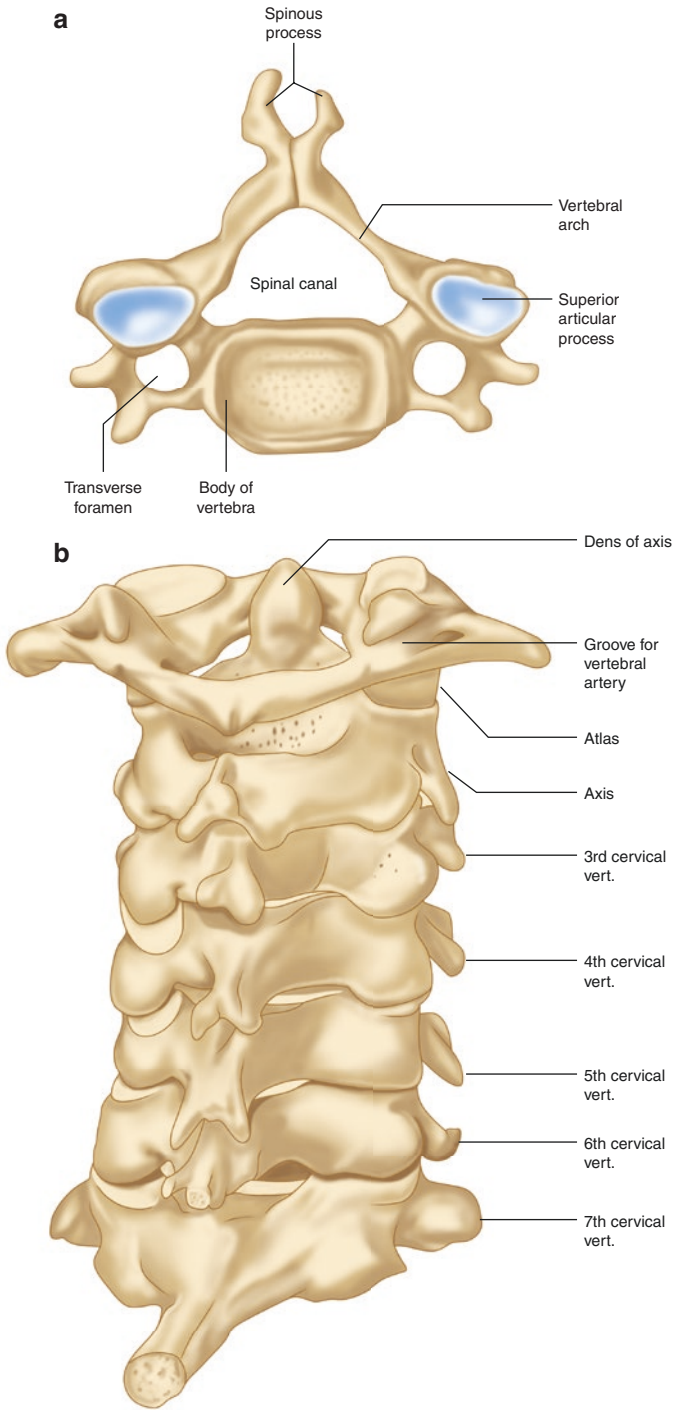
The interspinous ligament is superficial to the ligamentum flavum. It is a thick, sagittal oriented ligament between the superior and inferior aspects of adjacent spinous processes. At the thoracic and lumbar levels, the supraspinous ligament is a thin structure, of little mechanical consequence, located between and along the tips of the spinous processes. In the cervical region, the ligament thickens to become the more significant nuchal ligament.

## Cervical Spine (Fig. 2.5)

At maturity, the cervical spine is aligned in lordosis of 20–40 degrees [6]. Along with the spinal cord and exiting nerves, the cervical region houses the vertebral arteries, which course from the subclavian arteries into the occipital cortex of the brain. The vertebral arteries travel within the transverse foramina, located at the lateral aspects of the cervical vertebrae. The vertebral arteries can be injured during cervical spine trauma that involves excessive forward flexion or distraction, since the pediatric spinal column can stretch more than the spinal cord or vertebral arteries.

The first two cervical vertebrae are adapted to allow mobility of the skull and upper spine. The first cervical vertebra, also known as the atlas, has two large cup-shaped superior articular facets, oriented in the transverse plane and which articulate with the occipital condyles of the skull. The occipito-atlanto joints permit approximately 50% of the flexion and extension of the head, with the remaining movement coming through the subaxial cervical vertebrae [6, 7]. The second cervical vertebra, also known as the axis, has an odontoid process that projects cranialward from the anterior aspect of its vertebral body. The odontoid articulates with the posterior aspect of the body of atlas. The atlas is attached to the odontoid by several strong ligaments oriented vertically and transversely. In the normal child, the interval between the odontoid and C1 is less than 4 mm (ADI = atlanto-dens interval). Rotation is permitted, and flexion and extension are minimal [2, 7]. Fifty percent of the rotation, about 35 degrees of the total 70 degrees, of the C-spine occurs through the atlanto-axial joints.

During infancy, the cervical vertebrae are ovoid in shape. During childhood the vertebral bodies may appear wedge-shaped on plain lateral radiographs [8]. The naturally wedged appearance occasionally may be mistaken for a compression fracture. As the child matures, the vertebral bodies assume adult configuration and become more squared. In the young child, there is increased mobility of the cervical spine in part because the orientation of the cervical facet joints, particularly at the upper C-spine, is more horizontal. Pseudosubluxation between C2 and C3, caused by the horizontal orientation of the facet joints, occurs between ages 1 and 7 years



**Fig. 2.5** (a) The cervical spine. (b) Fifth cervical vertebra

[9]. With growth and maturation, the subaxial cervical articular facets become oriented more vertically. Typically, the mature individual has considerable neck mobility including flexion of 80–90 degrees, extension to 70 degrees, 70–90 degrees of axial rotation, and 20–45 degrees of lateral flexion [2, 7].

### **Thoracic Spine (Fig. 2.3)**

The thoracic region of the spine is aligned in kyphosis of 20–50 degrees at maturity. The thoracic articular facets are oriented in the coronal plane at an angle of 60 degrees. This and the fact the thoracic spine supports the chest wall result in limited segmental mobility from T1 to T10 [2, 7]. The upper and mid-thoracic spinous processes each project posteriorly, at an angle of approximately 30 degrees caudally. The thoracic laminae overlap one another, like shingles on a roof, protecting the thoracic spinal cord. Thirty degrees flexion and 20 degrees extension may occur in the thoracic spine of mature individuals [2, 7]. The ribs articulate with the spine at the vertebral bodies and the facet joints, which defines an axis of rotation. The upper ribs rotate upward with respiration; the lower ribs rotate up- and outward. This rotation determines the movement of the chest wall, most noticeable with labored breathing such as in asthma, croup, or respiratory failure.

### **Lumbar Spine (Fig. 2.6)**

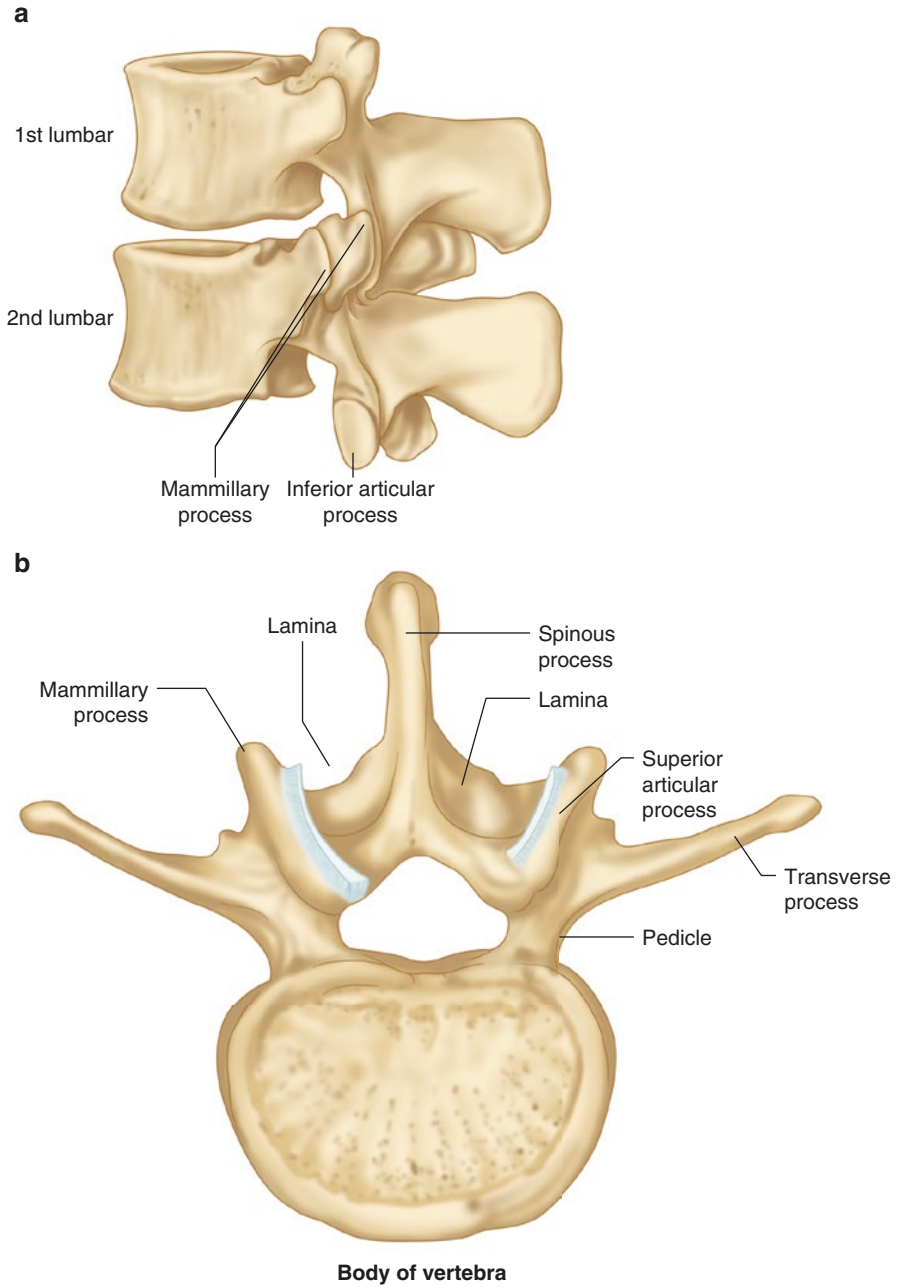
The five lumbar vertebrae configure a lordotic curve in the sagittal plane, permitting 30 and 50 degrees of flexion and extension, respectively, 10–20 degrees of lateral bending in each direction, and 10 degrees of axial rotation to the left and right [2, 7, 9].

At birth only about 1/3 of the spine is ossified, the majority being cartilaginous. By age 5 years, 65% of the spine is ossified [1]. Vertical growth of the spine is a consequence of growth plates at the superior and inferior aspects of the vertebral bodies. Each vertebra contributes about 1 mm per year to height, with some variation according to age and region [10, 11]. Damage to the vertebral growth centers may result in deformity. For example, Scheuermann's kyphosis may be result of excessive pressure on the periphery of the vertebral epiphysis [12].

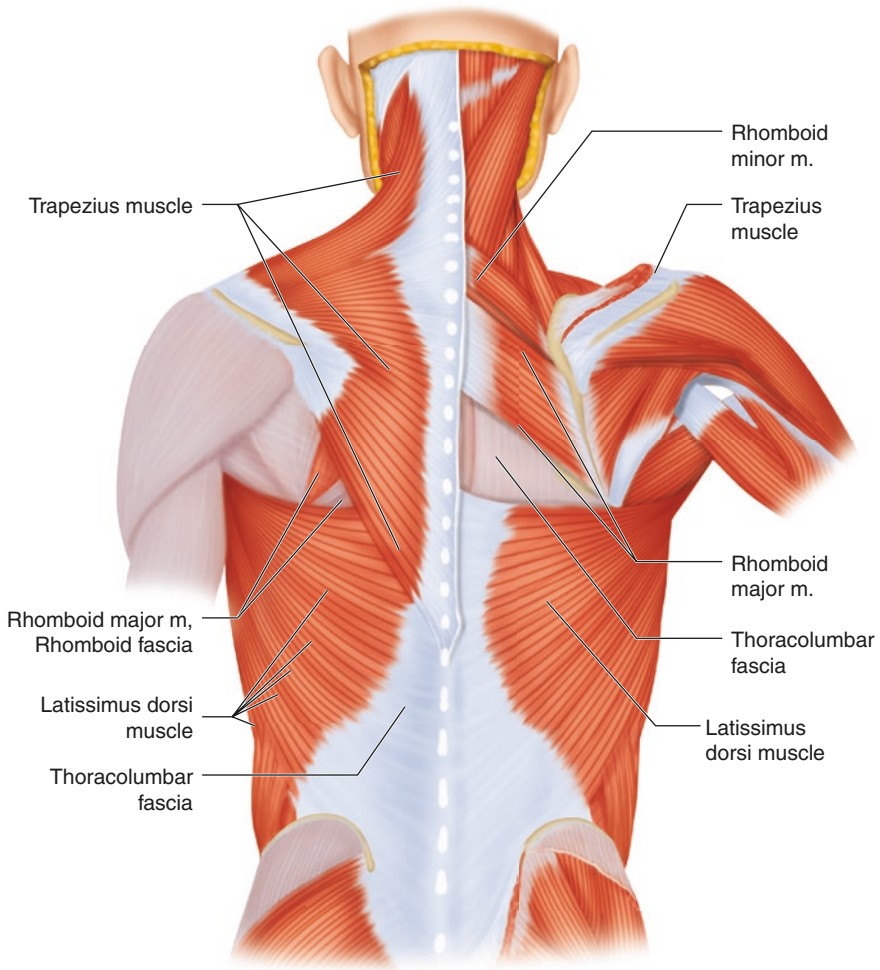
The "ring apophysis" is a secondary center of ossification contained within the periphery of the vertebral body epiphysis [12]. It generally becomes radiographically apparent at 12–15 years of age and may remain visible in the lumbar spine until vertebral growth is complete, up to age 20–22 years in males. Spina bifida occulta is a consequence of failure of bony fusion of the posterior arch. It is most commonly seen at L5 and is considered to be a normal variant [12].

Along with the bony and ligamentous anatomy, muscular attachments provide stability to the spine and allow for motion throughout the spine, as well as the ability





**Fig. 2.6** Lumbar vertebrae. (a) Lateral aspect and (b) cranial aspect



**Fig. 2.7** Muscles of the spine – superficial layer

to maintain an erect posture. These muscles can be subdivided into superficial and deep layers.

The superficial layers can be seen and palpated beneath the skin (Fig. 2.7). These are the latissimus dorsi, serratus posterior superior and inferior, levator scapulae, rhomboid major and minor, and the trapezius. Most muscles of this layer attach to the posterior spinal elements and scapula; they are important in stabilizing and providing mobility to the shoulder girdle.

The deep layer of back muscles includes the multifidus, semispinalis, iliocostalis, longissimus, spinalis, and splenius muscles. These muscles are generally

categorized as erector spinae muscles and attach from the pelvis, ribs, and skull to the spinal column. Most span the majority of the posterior spinal column and have variations depending on location. These are critical in maintaining an erect posture, as well as contributing to head and neck movement. They are type I fibers and therefore are slow twitch, have high oxidative and low glycolytic capacity, and are relatively resistant to fatigue [13].

The spinal cord is composed of millions of neurons that carry transmissions to and from the brain and which control the diverse functions of the body. It begins at the foramen magnum of the skull and terminates around L1, where it divides into the cauda equina [14]. It has different sections in which specific neurons travel, much like a highway system. Some of these tracts course efferently away from the brain and spinal cord to the body. Other tracts course afferently from the body toward the spinal cord and brain.

The spinal cord is comprised of gray and white matter. Gray matter is central in the cord and is composed of unmyelinated neurons and interneurons and generally is where chemical transmissions occur between neurons. White matter surrounds the gray matter and contains myelinated neurons that are traveling up and down the cord. The specific sections within the white matter include the ventral and lateral corticospinal tracts, dorsal columns, and spinothalamic tracts. The corticospinal tracts contain motor neurons, which transmit efferent signals to muscles throughout the body. The dorsal columns carry afferent sensory fibers from specialized neurons that detect light touch, proprioception, and vibration. Lastly, the spinothalamic tracts carry pain and temperature sensations to the sensory cortex.

Along the length of the spinal cord, spinal nerves exit within the cervical, thoracic, lumbar, and sacral regions. At each of these levels, a ventral and dorsal root are found, which exit the spinal column via the intervertebral or neural foramen. These nerves then combine to form the spinal nerve trunk, after which they again branch off into the ventral and dorsal rami. Housed within the dorsal root is the dorsal root ganglion, which contains the cell bodies of the afferent sensory nerves as they convey signals from the peripheral nerves to the brain. These rami also connect with the sympathetic chain, which houses sympathetic neurons.

## Editor Discussion

Although the study of anatomy has been unfortunately de-emphasized by some medical schools, anatomy remains the framework onto which all physicians build their knowledge and learn their craft. Understanding spine anatomy is key to making an accurate diagnosis and planning appropriate treatment for any patient with back pain. The authors of this chapter have written a clear and practical guide to spine anatomy for the primary care physician.

*W. L. Hennrikus*

Unique to the pediatric spine is developmental anatomy. The spinal column also provides length to the developing thorax. At birth the spine is longer and growing faster than the lower limbs, so there is a bias to early development of the thorax. Thoracic volume in a neonate is only 6% that of an adult. By age 5 years, the growth velocity of the spine

decreases, and the lower limbs start to grow faster than the trunk. The spinal canal is 95% the dimensions of the adult, although the chest is only 30% adult volume. By age 10 years, the thorax is still only 50% the volume of an adult. The spine more than doubles in length from birth to adulthood. The pediatric spine also has variations (such as age-dependent different shape of vertebra), anomalies (such as spina bifida occulta of L5 or six instead of five lumbar vertebra), and abnormalities (such as congenital hemivertebra or cervical fusions seen in Klippel Feil syndrome). Parents are often quite nervous about any deviation from normal, so it is important to explain the benign nature of most of these variations and anomalies and to adequately understand and evaluate the significance of abnormalities.

*R. M. Schwend*

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