Orthotics Best Practice Group
Spinal Manual

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The Axial Skeleton

At birth a newborn baby has over 300 bones, whereas an adult has 206 bones. The difference comes from the number of small bones that fuse during growth.

The human skeleton is divided into two main groups, the axial skeleton and the appendicular skeleton. The axial skeleton consists of 80 bones which make up the head and trunk of the body. The appendicular skeleton consists of 106 bones and includes the shoulder girdle, arms, hands, pelvis, legs and feet (Figure 1).
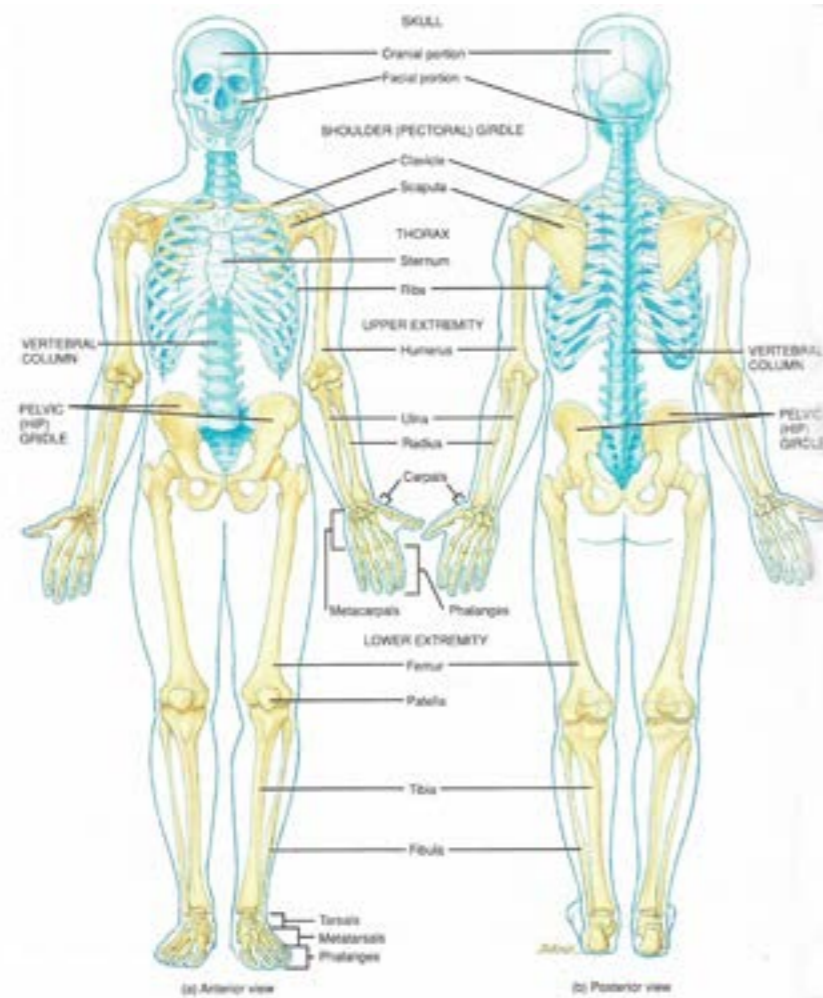

Figure 1 - The Skeleton (axial skeleton in blue)

The Skull

The skull contains 22 bones (8 cranial, 14 facial) and rests on the top (superior end) of the vertebral column. The skull supports the structures of the face and protects the head against injury especially the brain. Most of the bones in the skull are flat bones and are of the fibrous type.
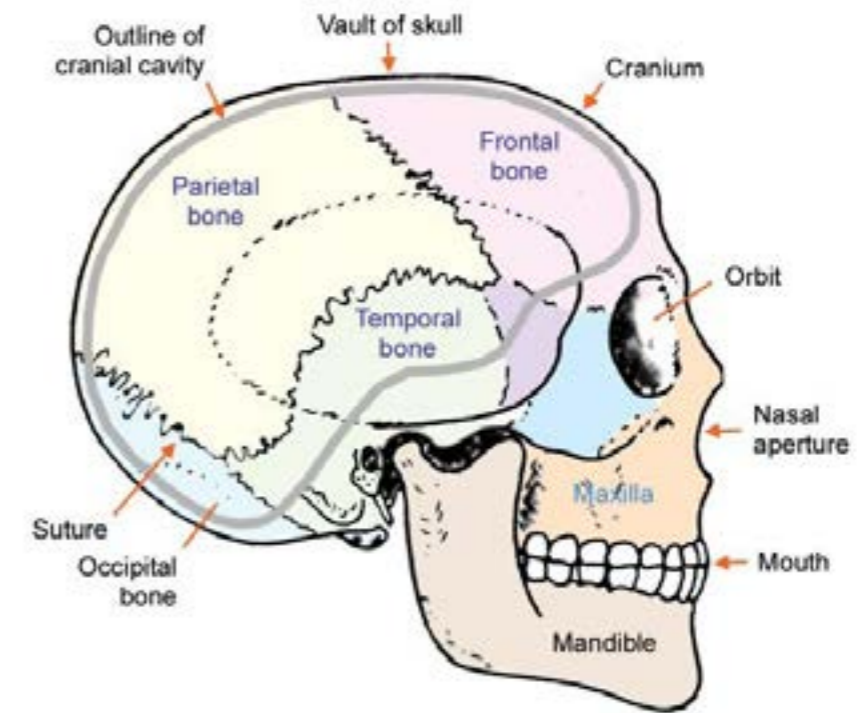

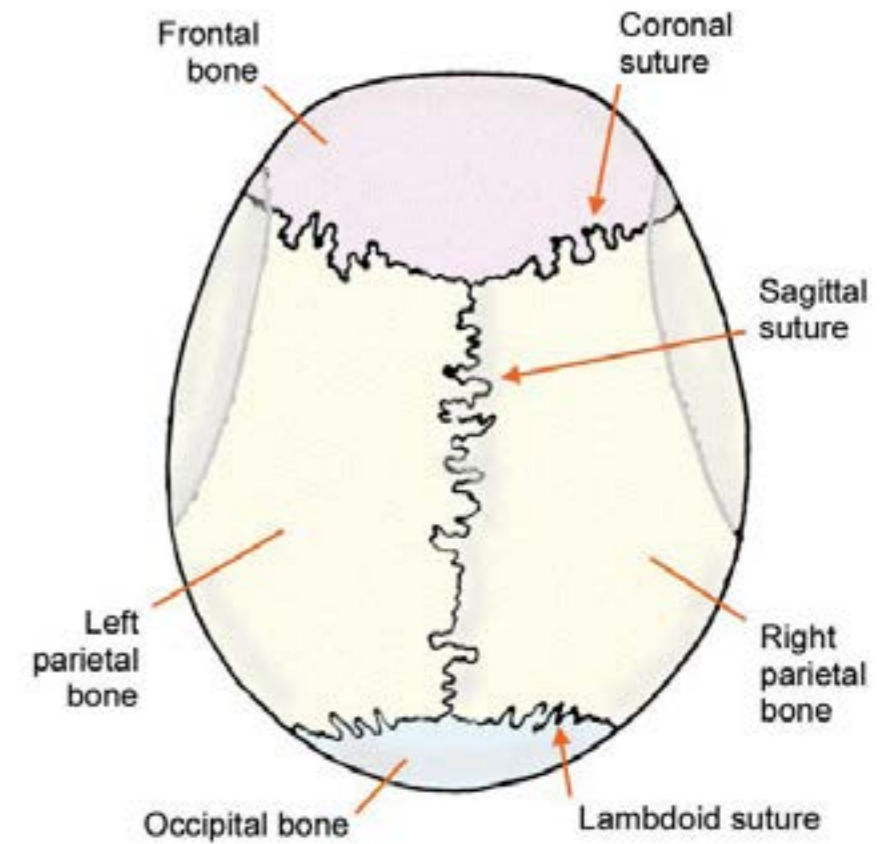Figure 2 - Right Lateral View of the Skull

Figure 3 - Superior View of the Skull

The Spinal (Vertebral) Column

The vertebral column (spine), together with the sternum and ribs, forms the skeleton of the trunk of the body. The vertebral column makes up about two-fifths of the total height of the body and is composed of a series of bones called **vertebrae.**

The vertebral column is effectively a strong, flexible rod that can bend in all directions and allows rotation. The column encloses and protects the spinal cord, supports the head, and serves as a point of attachment for the ribs and muscles of the back. It also helps transmit the weight of the trunk to the lower limbs.

The vertebral column is composed of 33 vertebrae, some of which are fused so that there are 26 bones after fusion.
It is split into five regions. The cervical, thoracic, lumbar, sacral and coccygeal (Figure 4).

The regions have different numbers of vertebrae:-

- Cervical region (neck) – 7 vertebrae
- Thoracic region (chest)– 12 vertebrae
- Lumbar region (lower back) – 5 vertebrae
- Sacral region – 5 fused vertebrae to form sacrum
- Coccygeal region – 4 fused vertebrae to form coccyx

The vertebral column is the central axis of the body. There are only small amounts of movement between each vertebra, but because there are a number of bones, the summation of the movement over the column as a whole gives a wide range of movement.

When viewed from the side (lateral) aspect, the vertebral column shows four normal curves, cervical, thoracic, lumbar and sacrum.

The thoracic and sacral curves are primary curves. This is because they are anteriorly concave in the developing foetus and maintain the same curvature after birth.

The cervical and lumbar curves are secondary (compensatory) curves. The cervical curve starts to occur late in intra-uterine life. When the child is able to hold its head up, particularly in prone lying, the curve becomes more pronounced. This happens about 3 months after birth. When the child starts to sit upright at about 9 months, the curve becomes more accentuated. The lumbar curve appears at about 12 to 18 months when the child starts to walk.

The cervical curve begins at the atlas and ends at the middle of the 2nd thoracic vertebra. It is convex forwards and is the least marked of the four.

The thoracic curve is concave forwards. It reaches from the middle of the 2nd to the middle of the 12th vertebrae.

The lumbar curve extends from the middle of the 12th thoracic vertebra to the lumbosacral angle. It is convex forwards and this convexity tends to be more pronounced in the female.

Figure 4 - Anterior, Lateral and Posterior views of the Spinal Column

Typical Vertebra

The vertebrae in each region of the spinal column vary in size, shape and detail but are similar enough in structure that we can discuss the function and parts of a typical vertebra

1. The Vertebral Body
The vertebral body is the biggest part of the vertebra. It is the anterior portion of the vertebra which means it faces forwards. This is the weight bearing portion of the bone and is an hourglass shape, thinner in the centre with thicker ends. The size of the body depends on the area it is in and the weight it supports. The lumbar vertebrae are larger than the thoracic and cervical with the sacral portion smaller again.

2. The Vertebral (neural) Arch
The vertebral arch extends posteriorly from the body of the vertebra. With the body of the vertebra, it surrounds the spinal cord. It is formed by the pedicles, two short rounded processes that extend posteriorly from the lateral margin of the dorsal surface of the body and unite with the laminae, two flattened plates of bone extending medially from the pedicles to form the posterior wall of the vertebral foramen. The vertebral foramina of all vertebrae together form the spinal (vertebral) canal. The pedicles exhibit superior and inferior notches. When they are stacked on top of one another, there is an opening between vertebrae on each side of the column. Each opening called an intervertebral foramen, permits the passage of a single spinal nerve.

3. The Spinous Process
The spinous process projects posteriorly and inferiorly from the laminae and can be felt by running your hands down a person's back. They serve as points of attachment for ligaments and muscles that can pull the vertebral column into extension and possible rotation.

4. The Transverse Processes
The paired Transverse processes project laterally from the junctions of the pedicles and laminae. They serve as attachments to various muscles and ligaments and function as levers by means of which lateral and rotary movements of the vertebrae can be brought about. In the thoracic region their articulations with the ribs limit movement.

5. The Articular Processes
There are two superior and two inferior processes which arise from the junction of the pedicles and laminae to restrict movement. The superior articular processes project upwards and the articular surfaces face posteriorly. The inferior articular processes project downwards and the articular surfaces face anteriorly. When the vertebrae are articulated the superior processes of the inferior vertebra will meet the inferior processes of the superior vertebra. They therefore permit a certain degree of movement but restrict and control its range. The articulating surfaces of the articular processes are referred to as facets.

The cervical processes have articular surfaces which face obliquely, upwards and backwards. They therefore allow the movements of flexion and extension, looking sideways and upwards. The thoracic processes are set vertically on the arc of a circle and allow rotation. The lumbar processes change direction from above downwards. The inferior processes of L1 face laterally and the inferior processes of L5 lie forwards. The Lumbar processes allow flexion. They also help prevent the bodies from slipping forward.

6. Vertebral Column Articulations
Intervertebral joints are designed for safety and security. Their opposing bony surfaces are firmly bound together. This minimises the risk of dislocation but greatly restricts movement. Between the laminae of adjacent vertebrae are yellow elastic bands called the ligamentum flava. They relieve the spinal musculature of some of the load they have to bear and assist in returning the body to the upright position after forward bending. They are strongest in the lumbar region.

The adjacent borders of spinous processes are united by relatively weak ligaments called the interspinous ligaments. The tips of the spinous processes are joined by much stronger supraspinous ligaments. The supraspinous ligaments in the neck form the powerful ligamentum nuchae. The transverse processes are connected by weak intertransverse ligaments.

7. Synovial Joints
The synovial joints between the articular processes of the vertebrae are gliding joints. They have thin, loose articular capsules.

Joints of the Vertebral Body

The joints are classified a symphyses (cartilaginous) joints. The bodies are united by intervertebral discs of fibrocartilage and by the anterior and posterior longitudinal ligaments.

Intervertebral Discs

Intervertebral discs are interposed between the adjacent surfaces of the vertebral bodies from the axis to the sacrum. There are no discs between the atlas (C1), axis (C2) and coccyx. Discs are not vascular and therefore depend on the end plates to diffuse needed nutrients. The cartilaginous layers of the end plates anchor the discs in place.

The discs make up a ¼ of the spinal columns length with the other ¾ made up of the vertebral bodies. The discs are thickest where the movement is most free, i.e. the cervical and lumbar regions. The discs function as buffers between different segments and neutralise the effect of shocks or jarring through the vertebral column. Each disc has an outer laminated portion, the annulus fibrosis and an inner core, the nucleus pulposus (Figure 5).
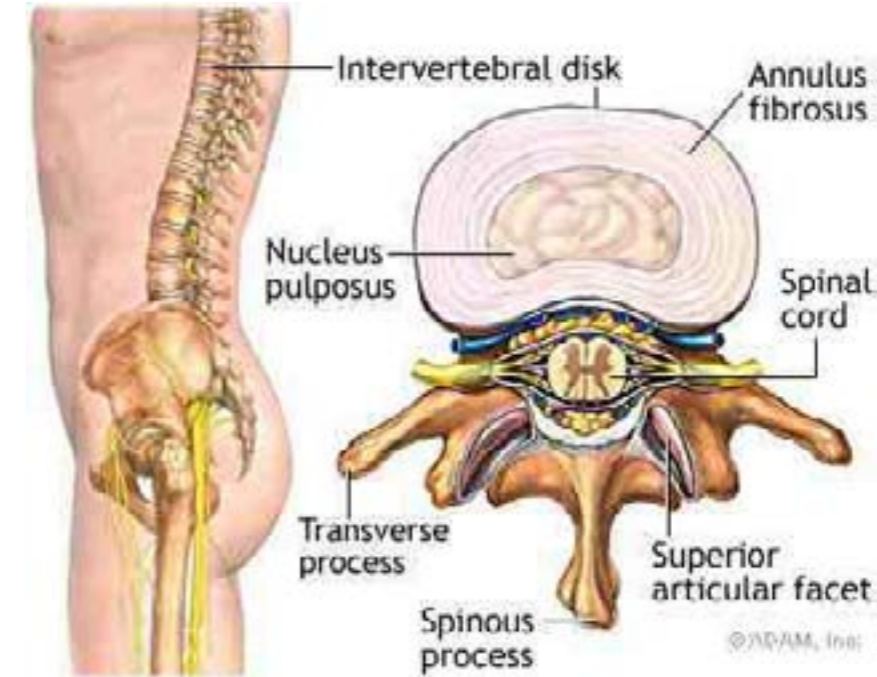

Figure 5 - Superior View of Intervertebral Disc

The annulus fibrosis is a strong fibrous band made up of lamellae, concentric sheets of collagen fibres connected to the vertebral end plates. The sheets are orientated at various angles. It exercises control over rotary movements of the vertebral column but allows degrees of flexion and extension. The annulus fibrosis encloses the nucleus pulposus.

The nucleus pulposus contains a hydrated gel like matter that resists compression. It is soft and gelatinous at birth and lies near the posterior surface of the disc. After the first decade of life, the soft material begins to be replaced by fibro-cartilage. The amount of water in the nucleus varies throughout the day depending on activity.

Although both the annulus fibrosis and the nucleus pulposus are composed of water, collagen and proteoglycans (PG's), the amount of fluid (water and PG's) is greatest in the nucleus pulposus.

Ligaments

Ligaments are fibrous bands or sheets of connective tissue linking two or more bones, cartilages, or structures together. One or more ligaments provide stability to a joint during rest and movement. Excessive movements such as hyperextension or hyperflexion, may be restricted by ligaments. Further, some ligaments prevent movement in certain directions. Three of the more important ligaments in the spine are the Ligamentum Flavum, Anterior Longitudinal Ligament and the Posterior Longitudinal Ligament.

1. Ligamentum Flavum
The Ligamentum Flavum forms a cover over the dura mater: a layer of tissue that protects the spinal cord. This ligament connects under the facet joints to create a small curtain over the posterior openings between the vertebrae.

2. The Anterior and Posterior Longitudinal Ligaments
The anterior ligament is a strong band of fibres and extends along the anterior surface of the vertebral bodies. The posterior longitudinal ligament is found within the vertebral canal on the posterior surfaces of the bodies of the vertebrae (Figure 6a).
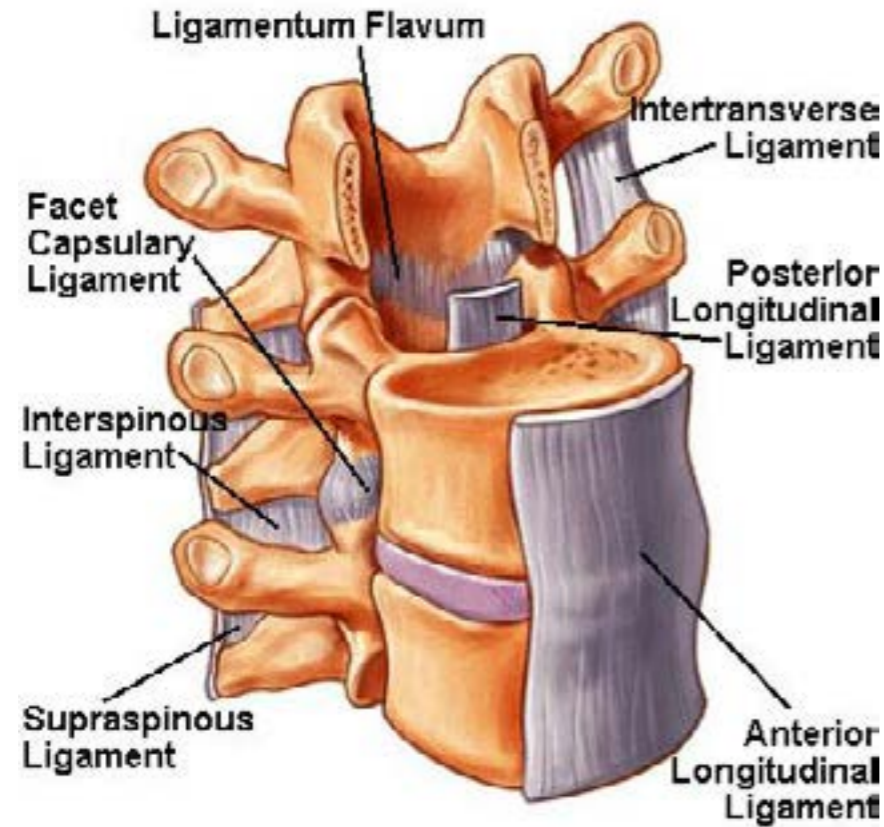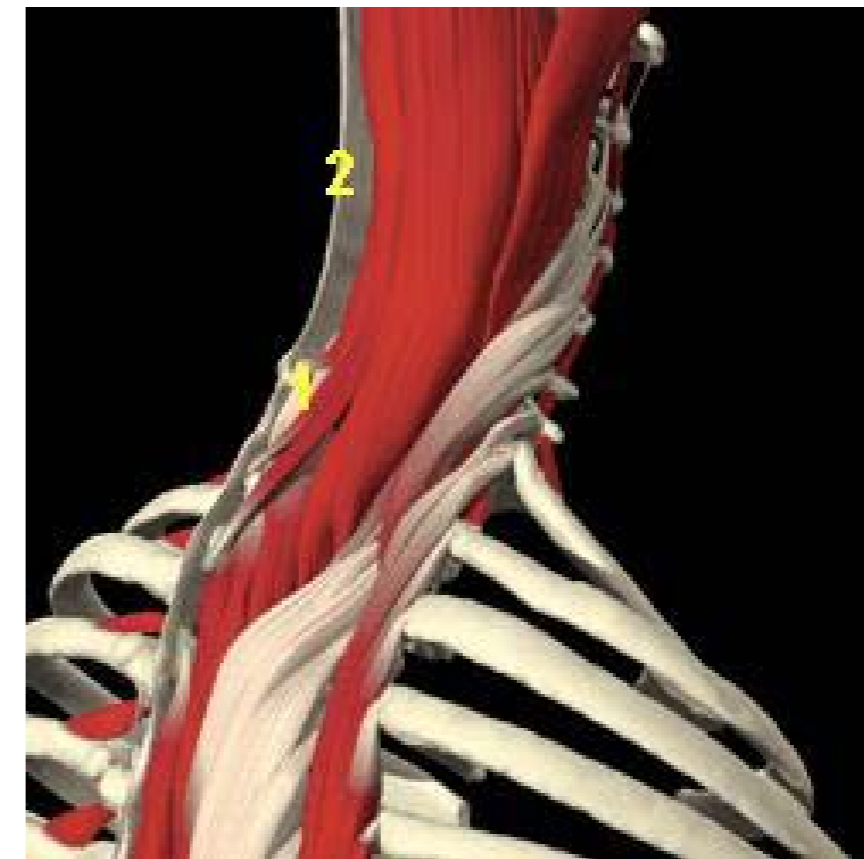

Figure 6a - Ligaments of the Vertebral Column

Primary Spinal Ligaments Include:

Ligament	Spinal Region	Limits...
Alar	Axis – skull	Head rotation & lateral flexion
Anterior Atlantoaxial	Axis & Atlas	Extension
Posterior Atlantoaxial	Axis & Atlas	Flexion
Ligamentum Nuchae	Cervical	Flexion
Anterior Longitudinal	Axis – Sacrum	Extension & reinforces front of annulus fibrosis
Posterior Longitudinal	Axis – Sacrum	Flexion & reinforces back of annulus fibrosis
Ligamentum Flavum	Axis – Sacrum	Flexion
Supraspinous	Thoracic & Lumbar	Flexion
Interspinous	Lumbar	Flexion
Intertransverse	Lumbar	Lateral flexion
Iliolumbar	Sacroiliac joints	Stability & some motion
Sacroiliac	Sacroiliac joints	Stability & some motion
Sacrospinous	Sacroiliac joints	Stability & some motion
Sacrotuberous	Sacroiliac joints	Stability & some motion

1. Supraspinous Ligament (flexion)
2. Ligamentum Nuchae (fibrous membrane)

Figure 6b - Posterior Ligaments of the Cervical and Upper Thoracic Spine

Ligament Systems – Atlas and Axis

As mentioned in the Vertebral Column, the Atlas (C1) and Axis (C2) are different from the other spinal vertebrae. The upper cervical ligament system is especially important in stabilizing the upper cervical spine from the skull to C2. Although the cervical vertebrae are the smallest, the neck has the greatest range of motion.

Occipitoatlantal Ligament Complex (Atlas)

These four ligaments run between the Occiput and the Atlas:
• Anterior Occipitoatlantal Ligament
• Posterior Occipitoatlantal Ligament
• Lateral Occipitoatlantal Ligaments (2)

Occipitoaxial Ligament Complex (Axis)

These four ligaments connect the Occiput to the Axis:
• Occipitoaxial Ligament
• Alar Ligaments (2)
• Apical Ligament

Altantoaxial Ligament Complex (Axis)

These four ligaments extend from the Atlas to the Axis:
• Anterior Atlantoaxial Ligament
• Posterior Atlantoaxial Ligament
• Lateral Ligaments (2)

Cruciate Ligament Complex

These ligaments help to stabilize the Atlantoaxial (Axis) complex:
• Transverse Ligaments
• Superior Longitudinal Fascicles
• Inferior Longitudinal Fascicles

Cervical Region

The cervical bones (C1-C7) are smaller and lighter than the thoracic and lumbar vertebrae. Cervical vertebrae C3-C7 have the following distinguishing features:

- The body is oval – broader from side to side than in the anteroposterior dimension.
- Except in C7 (including C2), the spinous process is short, projects posteriorly, and is bifid, or split at its tip.
- The vertebral foramen is large and triangular like.
- Each tranverse process contains a transverse foramen through which the vertebral blood vessels pass to service the brain.

The seventh cervical vertebrae (C7) called the vertebra prominens, is marked by a large, non bifid spinous process that may be seen and felt at the base of the neck and is therefore used as a landmark for identifying the cervical region.

The first two cervical vertebrae C1 (atlas) and C2 (axis) differ considerably from the others. They have no intervertebral disc between them and are highly modified, reflecting their special functions.

The atlas (C1) is a ring of bone with anterior and posterior arches and large lateral masses. It has no body and no spinous process. The superior surfaces of the lateral masses, called superior articular facets, are concave and articulate with the occipital condyles of the occipital bone of the skull. This articulation permits the movement seen when nodding the head to say yes. The inferior surfaces of the lateral masses, the inferior articular facets, articulate with the second cervical vertebrae. The transverse processes and transverse foramina of the atlas are quite large.
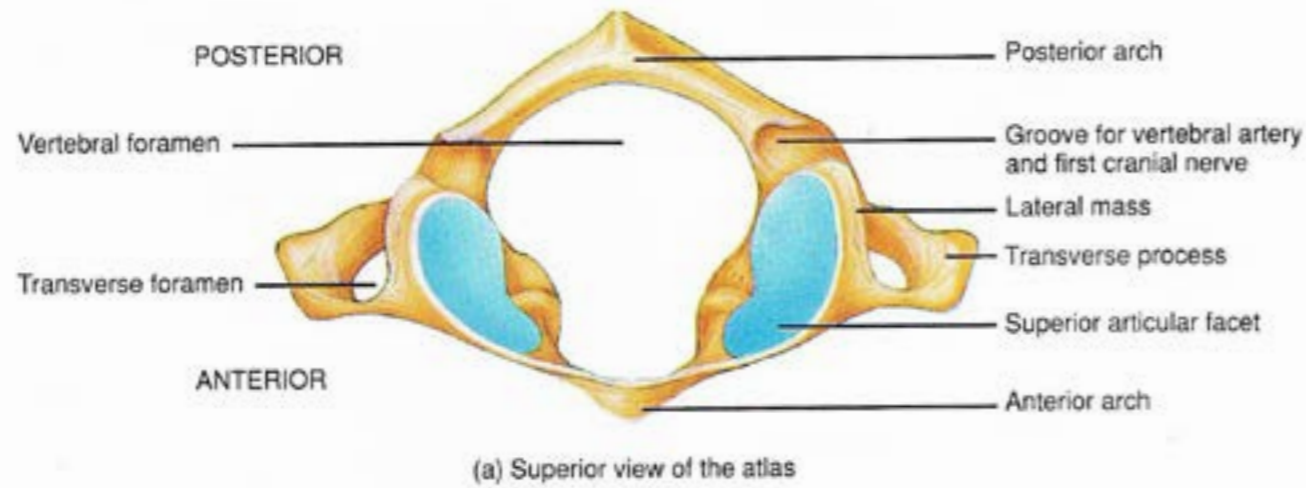

Figure 7a - Superior View of the Atlas (C1)

The Axis (C2) has a body, spine and other typical vertebral processes. It has a peg-like structure called the **dens** (tooth) or **odontoid process** which projects superiorly from its body. The dens is actually the missing body of the atlas, which fuses with the axis during embryonic development. The dens is cradled in the anterior arch of the atlas by the transverse ligaments (Figure 8), the dens acts as a pivot for the rotation of the atlas. This joint allows you to rotate your head from side to side to say no. In certain cases of head trauma, the dens may be driven up into the brain stem causing death e.g. severe whiplash injury.
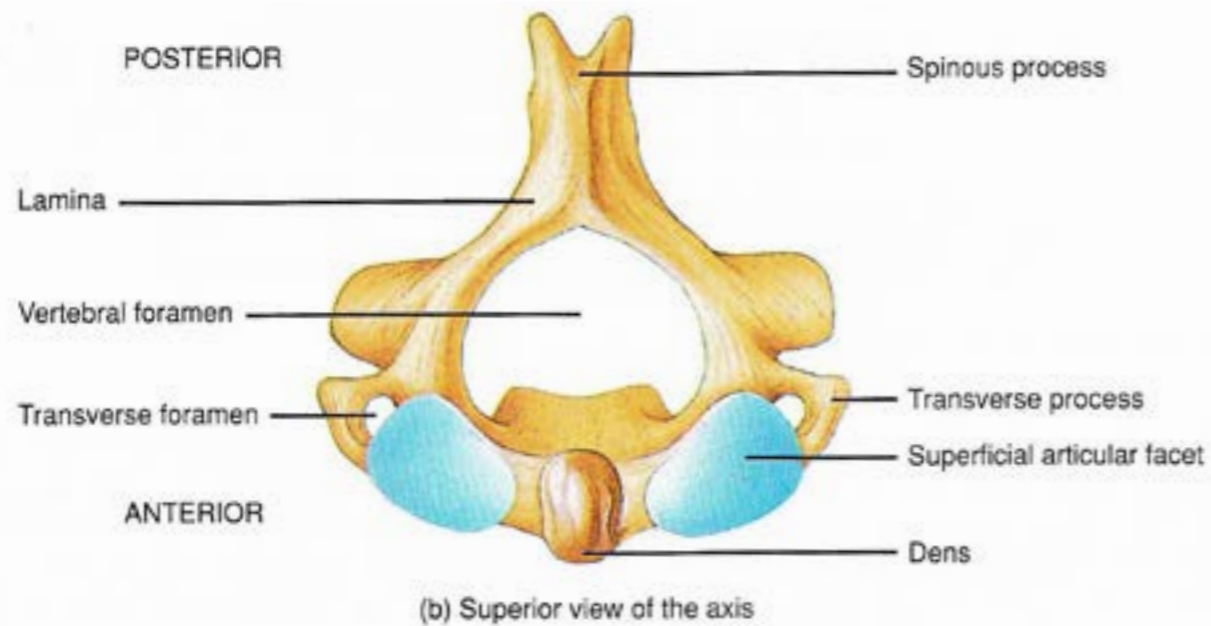

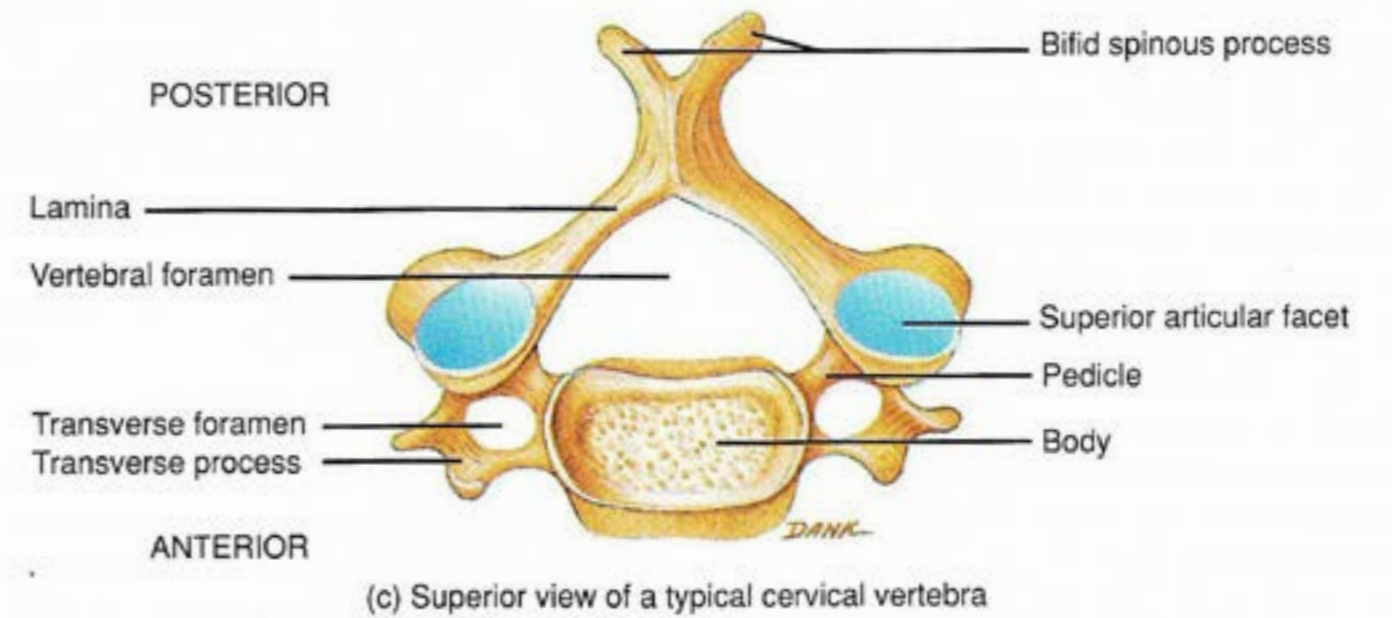Figure 7b - Superior View of the Atlas (C2)

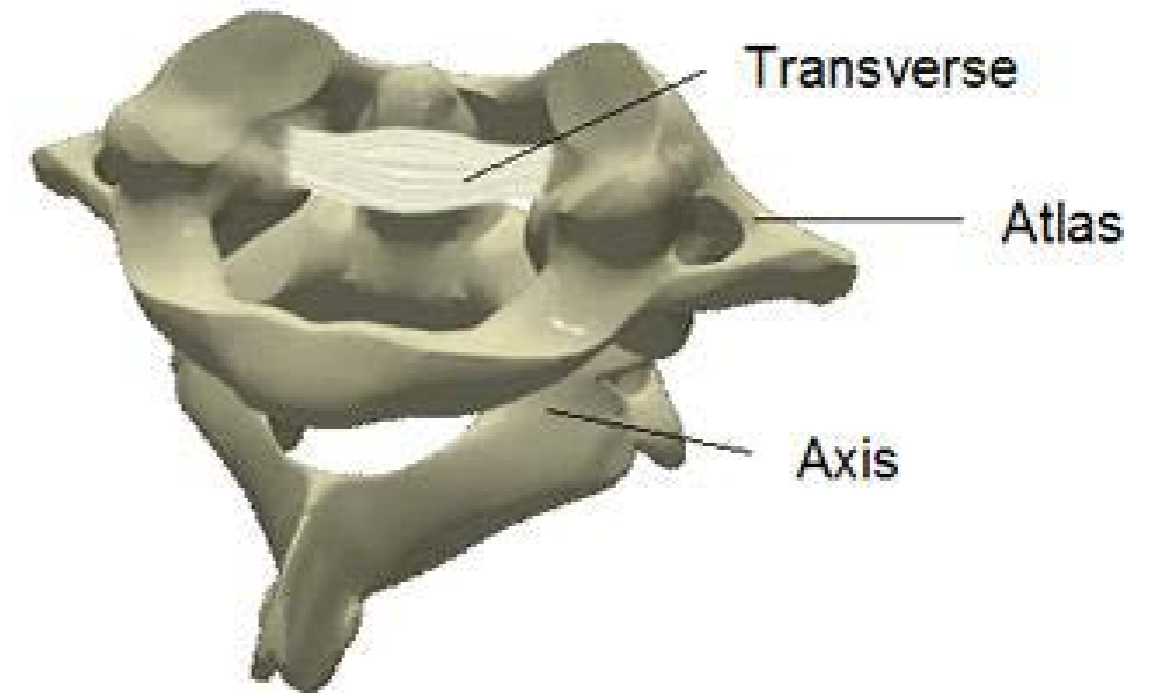Figure 7c - Superior View of Cervical Vertebrae

Figure 8 - Posterior View of Transverse Ligament of Atlas (C1)

Thoracic Region

Thoracic vertebrae (T1-T12) are considerably larger and stronger than cervical vertebrae. They all articulate with the ribs and increase in size from first to last (Figure 9). Unique characteristics of these vertebrae are:

- The body is heart shaped. It typically bears demifacets (half-facets) on each side, one at the superior edge and the other at the inferior edge. The demifacets receive the heads of the ribs; however the bodies of T10-T12 vary from this pattern by having only a single demifacet for their respective ribs.
- The vertebral foramen is circular.
- The spinous process is long, laterally flattened and directed inferiorly.
- With the exception of T11 and T12, the transverse processes have facets that articulate with the tubercules of the ribs.
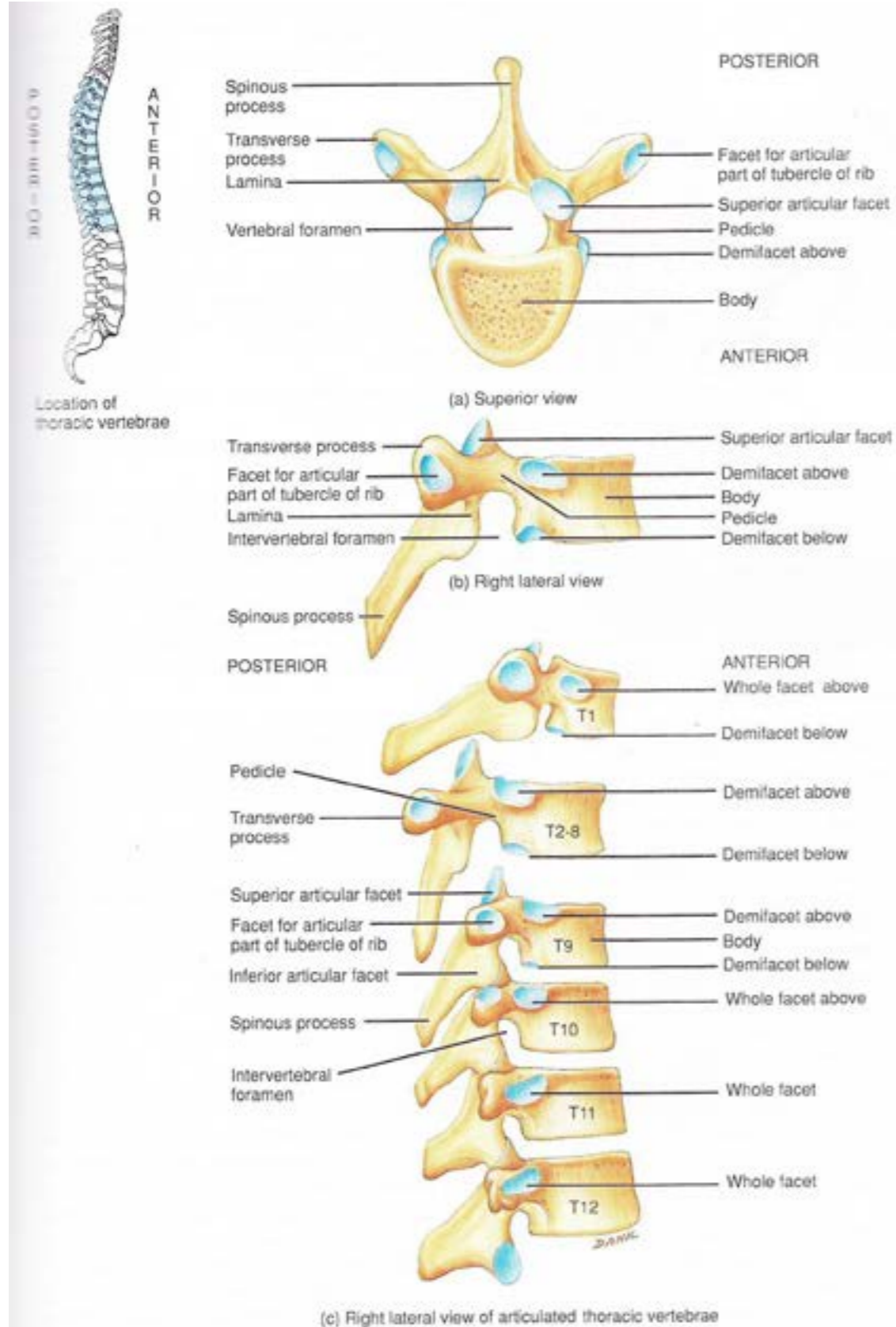
Figure 9 - Thoracic Vertebrae

Lumbar Region

The lumbar vertebrae (L1-L5) are the largest and strongest in the column because the body weight supported by the vertebrae increases towards the lower end of the back (Figure 10). Typical characteristics of lumbar vertebrae are:

- Bodies are large and kidney shaped.
- The pedicles and laminae are shorter and thicker than those of other vertebrae.
- The spinous processes are short, flat and hatchet shaped and are easily seen when a person bends forward. These processes are robust and project posteriorly and serve as attachments for large back muscles.
- The vertebral foramen is triangular.
- The orientation of the facets of the articular processes of the lumbar vertebrae differ from other vertebrae. These help lock the lumbar spine together and provide stability by preventing rotation of the lumbar spine.
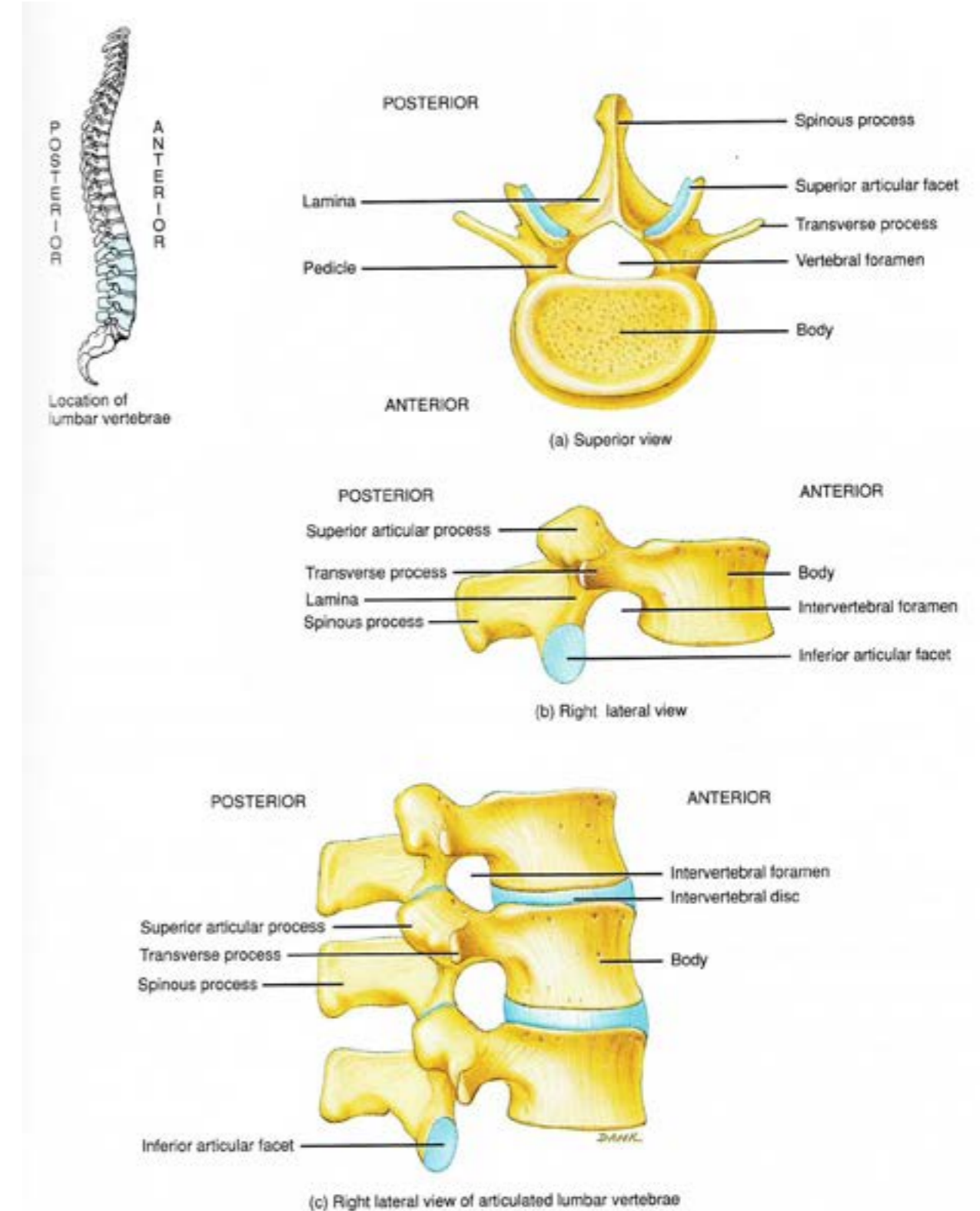
Figure 10 - Lumbar Vertebrae
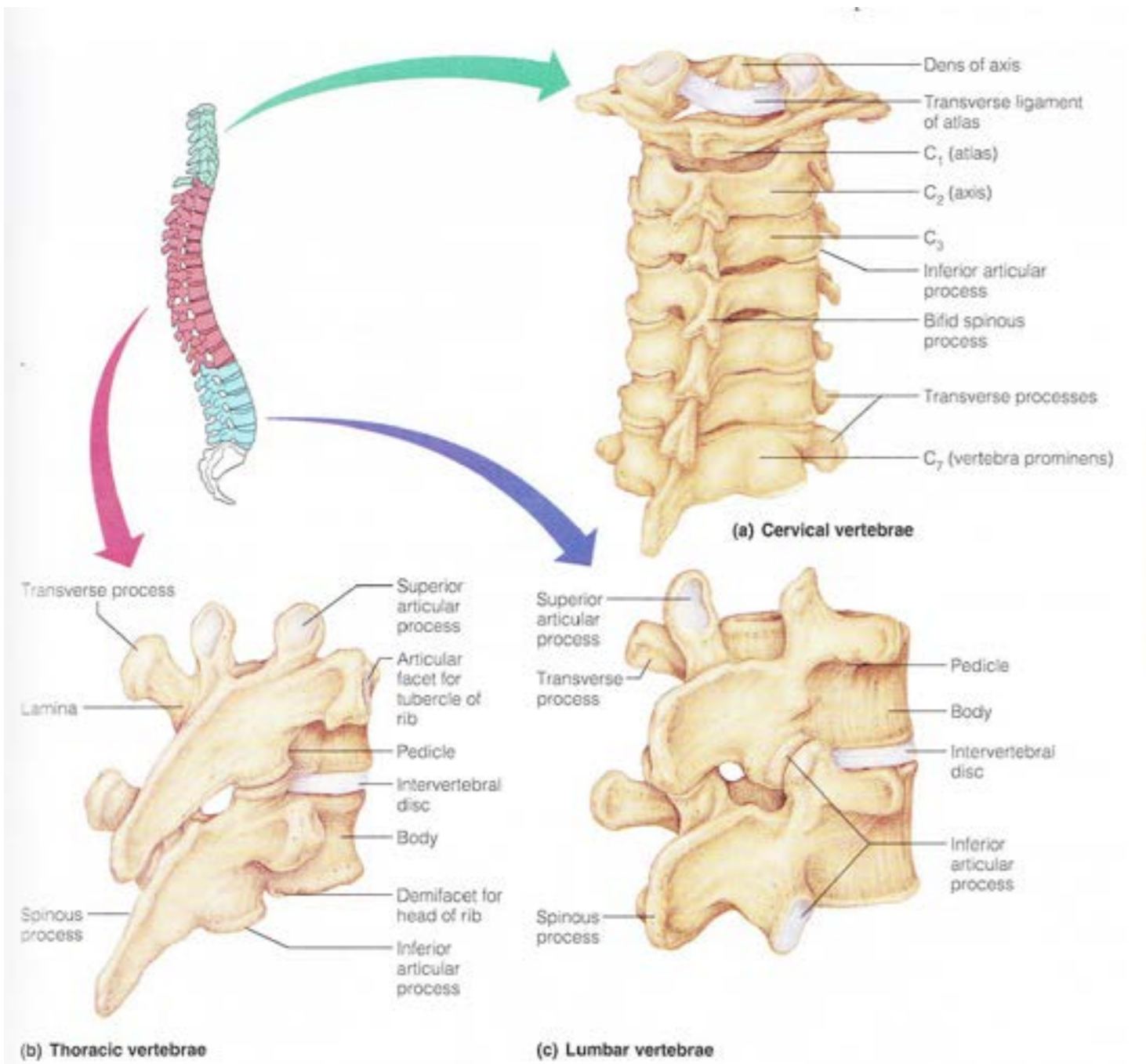
Posterolateral views of articulated vertebrae. Notice the bulbous tip on the spinous process of C₇, the vertebra prominens.

Figure 11 - Posterolateral View of Articulated Vertebrae

Sacrum

The sacrum is a triangular bone formed by the union of 5 sacral vertebrae. Fusion begins between 16 and 18 years of age and is usually completed by mid twenties. The sacrum serves as a strong foundation for the pelvis. It articulates superiorly via its superior articular processes with L5 and inferiorly with the coccyx. Laterally, the sacrum's two wing like alae articulate with the hip bones to form the sacroiliac joints of the pelvis.
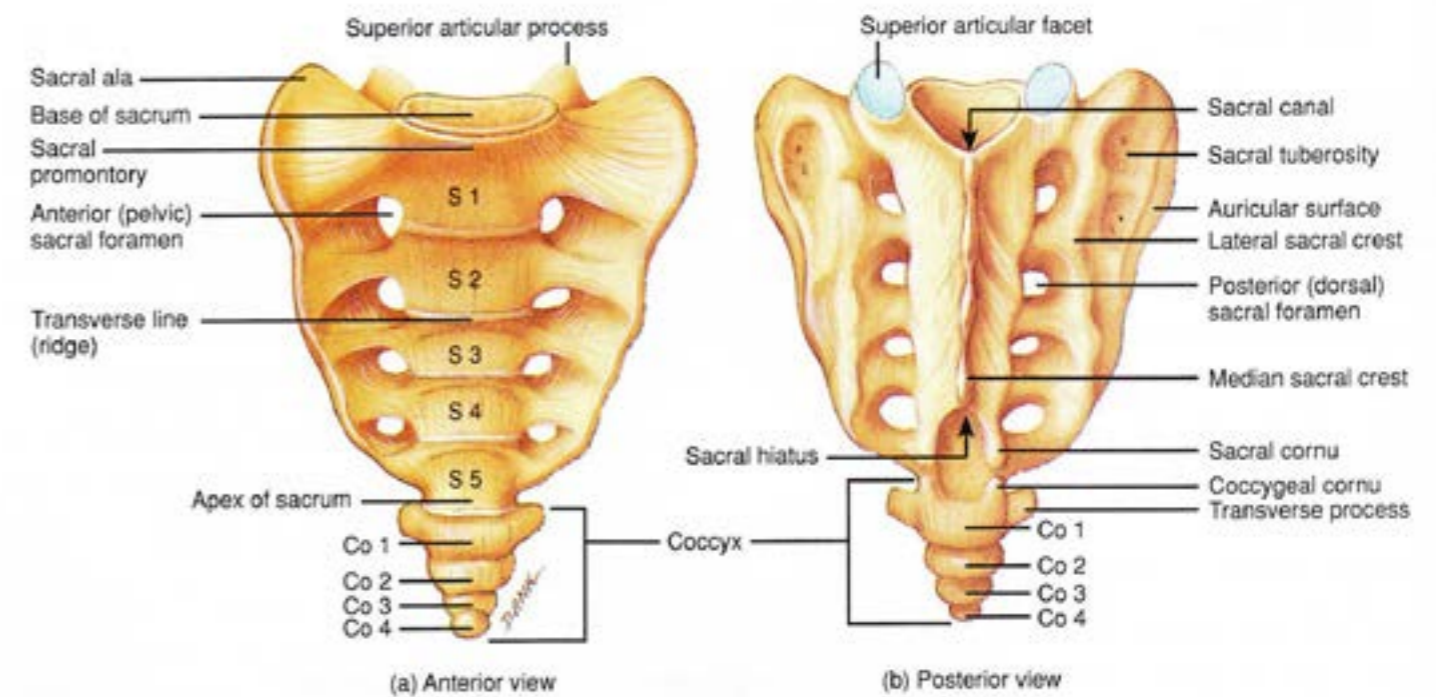
Figure 12 - The Sacrum and Coccyx

Coccyx

The coccyx is triangular in shape and is formed by the fusion of four coccygeal vertebrae. Fusion generally occurs between 20 and 30 years of age. On the lateral surfaces of the coccyx are a series of transverse processes, the first pair being the largest. The coccyx articulates superiorly with the sacrum. The coccyx serves as an attachment point for muscles and ligaments

Thorax

The thorax refers to the entire chest which includes the sternum, costal cartilages, ribs and bodies of the thoracic vertebrae (Figure 13).
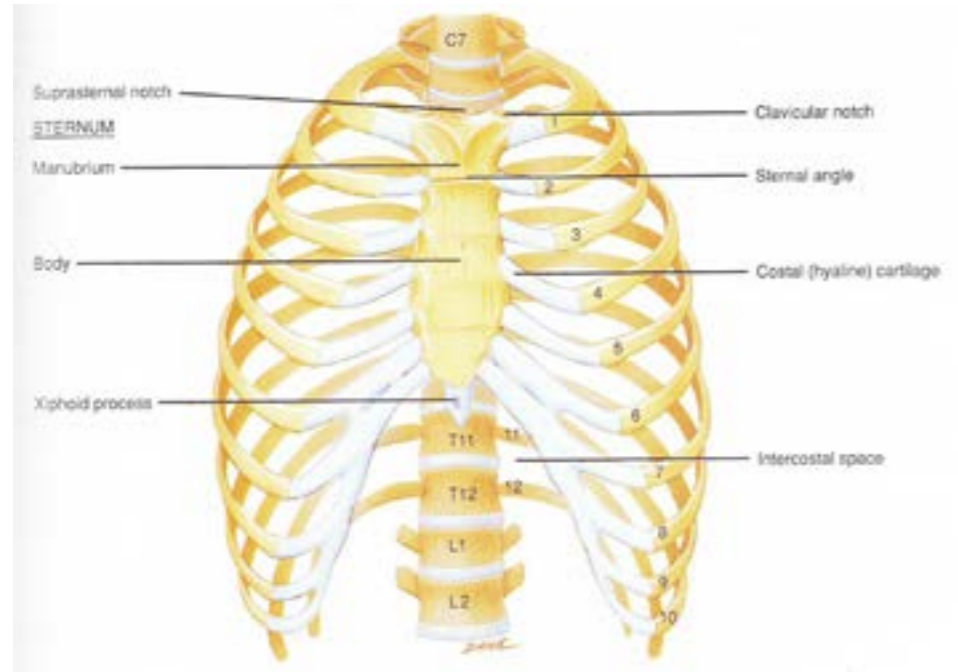
Figure 12 - The Sacrum and Coccyx

The thorax is roughly cone shaped. It forms a protection for vital organs (heart, lungs etc), supports the shoulder girdles and upper limbs and provides attachment points for the muscles of the back, chest and shoulders.

Sternum

The sternum or breastbone is a flat, narrow bone measuring about 15cm. It is located on the anterior thoracic wall and results from the fusion of three bones: the manubrium superiorly, the body in the middle and the xiphoid process inferiorly. The superior portion of the manubrium articulates via its clavicular notches with the clavicles laterally; it also articulates with the first two pairs of ribs. The body articulates directly or indirectly with the second through tenth ribs. The xiphoid process has no ribs attached to it but provides attachment for some abdominal muscles. The xiphoid process consists of hyaline cartilage during infancy and does not ossify completely until about the age of 40.

Ribs

Twelve pairs of ribs make up the sides of the thoracic cavity. The ribs increase in length from the first through seventh, then decrease in length to the twelfth rib. Each articulates posteriorly with its corresponding thoracic vertebrae.

The first through seventh pairs of ribs have a direct attachment to the sternum by a strip of hyaline cartilage called costal cartilage. These ribs are called true ribs. The remaining five pairs are called false ribs because their costal cartilages either attach indirectly to the sternum or do not attach to the sternum at all. The cartilages of the eighth, ninth, and tenth pairs of ribs attach to each other and then to the cartilages of the seventh pair of ribs. These false ribs are called vertebrochondral ribs. The eleventh and twelfth pairs of ribs are false ribs designated as floating ribs because their anterior ends do not attach to the sternum at all. They attach only posteriorly to the thoracic vertebrae.
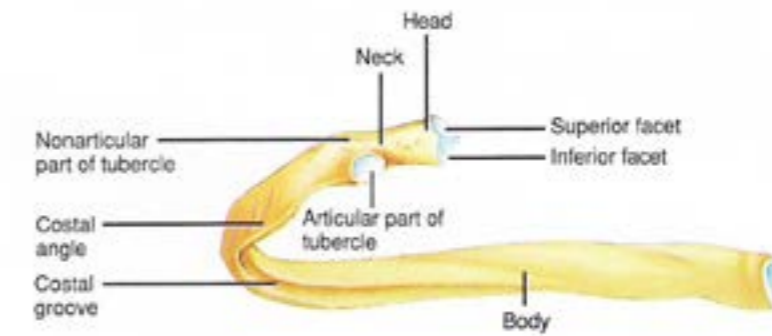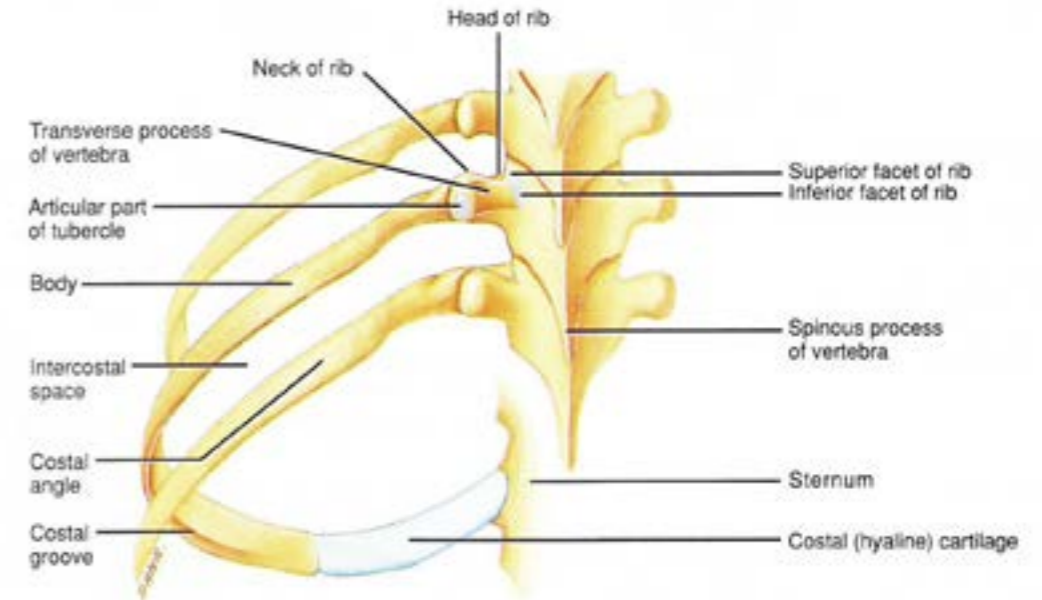
Figure 14 - Typical Rib

Spinal Cord

The spinal cord is connected to the brain and is about the diameter of a human finger. From the brain the cord runs down the middle of the back in a canal formed by the vertebrae which provides it with protection. The spinal cord is surrounded by a clear fluid called Cerebral Spinal Fluid (CSF). This acts as a cushion to protect the delicate nerve tissues from damage when banging against the vertebral walls. The spinal canal has two enlargements in the lumbar and cervical regions where the nerves to the lower and upper limb originate. The spinal cord is a long, thin, tubular bundle of nervous tissue and support cells that extends from the brain (the medulla specifically). The brain and spinal cord together make up the central nervous system. The spinal cord extends down to the space between the first and second lumbar vertebrae; it does not extend the entire length of the vertebral column. It is around 45 cm (18 in) in men and around 43 cm (17 in) long in women.

The enclosing bony vertebral column protects the relatively shorter spinal cord. The spinal cord functions primarily in the transmission of neural signals between the brain and the rest of the body but also contains neural circuits that can independently control numerous reflexes and central pattern generators. The spinal cord has three major functions:

A. Serve as a conduit for motor information, which travels down the spinal cord.
B. Serve as a conduit for sensory information, which travels up the spinal cord.
C. Serve as a center for coordinating certain reflexes.

Structure

The spinal cord is the main pathway for information connecting the brain and peripheral nervous system. The length of the spinal cord is much shorter than the length of the bony spinal column. The human spinal cord extends from the medulla oblongata and continues through the conus medullaris near the first or second lumbar vertebra, terminating in a fibrous extension known as the filum terminale. It is about 45 cm (18 in) long in men and around 43 cm (17 in) in women, ovoid-shaped, and is enlarged in the cervical and lumbar regions. The cervical enlargement, located from C4 to T1, is where sensory input comes from and motor output goes to the arms. The lumbar enlargement, located between T9 and T12, handles sensory input and motor output coming from and going to the legs. You should notice that the name is somewhat misleading. However, this region of the cord does indeed have branches that extend to the lumbar region. In cross-section, the peripheral region of the cord contains neuronal white matter tracts containing sensory and motor neurons. Internal to this peripheral region is the gray, butterfly-shaped central region made up of nerve cell bodies. This central region surrounds the central canal, which is an anatomic extension of the spaces in the brain known as the ventricles and, like the ventricles, contains cerebrospinal fluid.

The spinal cord has a shape that is compressed dorso-ventrally, giving it an elliptical shape. The cord has grooves in the dorsal and ventral sides. The posterior median sulcus is the groove in the dorsal side, and the anterior median fissure is the groove in the ventral side. Running down the center of the spinal cord is a cavity, called the central canal. The three meninges that cover the spinal cord, the outer dura mater, the arachnoid mater, and the innermost pia mater, are continuous with that in the brainstem and cerebral hemispheres. Similarly, cerebrospinal fluid is found in the subarachnoid space. The cord is stabilized within the dura mater by the connecting denticulate ligaments, which extend from the enveloping pia mater laterally between the dorsal and ventral roots. The dural sac ends at the vertebral level of the second sacral vertebra.

The spinal cord is protected by three layers of tissue, called spinal meninges that surround the cord. The dura mater is the outermost layer, and it forms a tough protective coating. Between the dura mater and the surrounding bone of the vertebrae is a space, called the epidural space. The epidural space is filled with adipose tissue, and it contains a network of blood vessels. The arachnoid is the middle protective layer. Its name comes from the fact that the tissue has a spider web-like appearance. The space between the arachnoid and the underlying pia mater is called the subarachnoid space. The subarachnoid space contains cerebrospinal fluid (CSF). The medical procedure known as a "spinal tap" involves use of a needle to withdraw CSF from the subarachnoid space, usually from the lumbar region of the spine. The pia mater is the innermost protective layer. It is very delicate and it is tightly associated with the surface of the spinal cord.

Spinal Nerves

The spinal nerves arise from the medulla spinalis and are transmitted through the intervertebral foramina. There are 31 pairs which are grouped as follows: Cervical, 8; Thoracic, 12; Lumbar, 5; Sacral, 5; Coccygeal 1. The first cervical nerve emerges from the vertebral canal between the occipital bone and the atlas, and is therefore called the suboccipital nerve; the eighth issues between the seventh cervical and first thoracic vertebrae.

Nerve Roots – Each nerve is attached to the medulla spinalis by two roots, an anterior or ventral, and a posterior or dorsal, the latter being characterized by the presence of a ganglion, the spinal ganglion. The Anterior root emerges from the anterior surface of the medulla spinalis as a number of rootlets of filaments, which coalesce to form two bundles near the intervertebral foramen.

The Posterior Root is larger than the anterior owing to the greater size and number of its rootlets; these are attached along the postero-lateral furrow of the medulla spinalis and unite to form two bundles which join the spinal ganglion. The posterior root of the first cervical nerve is exceptional in that it is smaller than the anterior.

The Spinal Ganglia are collections of nerve cells on the posterior roots of the spinal nerves. Each ganglion is oval in shape, reddish in colour, and its size bears a proportion to that of the nerve root on which it is situated; it is bifid medially where it is joined by the two bundles of the posterior nerve root. The ganglia are usually placed in the intervertebral foramina, immediately outside the points where the nerve roots perforate the duramater, but there are exceptions to this rule; thus the ganglia of the first and second cervical nerves lie on the vertebral arches of the atlas and axis respectively, those of the sacral nerves are inside the vertebral canal, while that on the posterior root of the coccygeal nerve is placed within the sheath of the duramater.

Spinal Cord Segments

The human spinal cord is divided into 31 different segments. At every segment, right and left pairs of spinal nerves (mixed; sensory and motor) form. Six to eight motor nerve rootlets branch out of right and left ventro lateral sulci in a very orderly manner. Nerve rootlets combine to form nerve roots. Likewise, sensory nerve rootlets form off right and left dorsal lateral sulci and form sensory nerve roots. The ventral (motor) and dorsal (sensory) roots combine to form spinal nerves (mixed; motor and sensory), one on each side of the spinal cord. Spinal nerves, with the exception of C1 and C2, form inside intervertebral foramen (IVF). Note that at each spinal segment, the border between the central and peripheral nervous system can be observed. Rootlets are a part of the peripheral nervous system.

In the upper part of the vertebral column, spinal nerves exit directly from the spinal cord, whereas in the lower part of the vertebral column nerves pass further down the column before exiting. The terminal portion of the spinal cord is called the conus medullaris. The pia mater continues as an extension called the filum terminale, which anchors the spinal cord to the coccyx. The cauda equina ("horse's tail") is the name for the collection of nerves in the vertebral column that continue to travel through the vertebral column below the conus medullaris. The cauda equina forms as a result of the fact that the spinal cord stops growing in length at about age four, even though the vertebral column continues to lengthen until adulthood. This results in the fact that sacral spinal nerves actually originate in the upper lumbar region. The spinal cord can be anatomically divided into 31 spinal segments based on the origins of the spinal nerves. Each segment of the spinal cord is associated with a pair of ganglia, called dorsal root ganglia, which are situated just outside of the spinal cord. These ganglia contain cell bodies of sensory neurons. Axons of these sensory neurons travel into the spinal cord via the dorsal roots. Ventral roots consist of axons from motor neurons, which bring information to the periphery from cell bodies within the CNS. Dorsal roots and ventral roots come together and exit the intervertebral foramina as they become spinal nerves.

The gray matter, in the centre of the cord, is shaped like a butterfly and consists of cell bodies of interneurons and motor neurons. It also consists of neuroglia cells and unmyelinated axons. Projections of the gray matter (the "wings") are called horns. Together, the gray horns and the gray commissure form the "gray H."

The white matter is located outside of the gray matter and consists almost totally of myelinated motor and sensory axons. "Columns" of white matter carry information either up or down the spinal cord. Within the CNS, nerve cell bodies are generally organized into functional clusters, called nuclei. Axons within the CNS are grouped into tracts.

There are 33 (some EMS text say 25, counting the sacral as one solid piece) spinal cord nerve segments in a human spinal cord:

8 cervical segments forming 8 pairs of cervical nerves (C1 spinal nerves exit spinal column between occiput and C1 vertebra; C2 nerves exit between posterior arch of C1 vertebra and lamina of C2 vertebra; C3-C8 spinal nerves through IVF above corresponding cervica vertebra, with the exception of C8 pair which exit via IVF between C7 and T1 vertebra)
12 thoracic segments forming 12 pairs of thoracic nerves (exit spinal column through IVF below corresponding vertebra T1-T12)
5 lumbar segments forming 5 pairs of lumbar nerves (exit spinal column through IVF, below corresponding vertebra L1-L5)
5 (or 1) sacral segments forming 5 pairs of sacral nerves (exit spinal column through IVF, below corresponding vertebra S1-S5)
3 coccygeal segments joined up becoming a single segment forming 1 pair of coccygeal nerves (exit spinal column through the sacral hiatus).

Because the vertebral column grows longer than the spinal cord, spinal cord segments do not correspond to vertebral segments in adults, especially in the lower spinal cord. In the fetus, vertebral segments do correspond with spinal cord segments. In the adult, however, the spinal cord ends around the L1/L2 vertebral level, forming a structure known as the conus medullaris. For example, lumbar and sacral spinal cord segments are found between vertebral levels T9 and L2.

Although the spinal cord cell bodies end around the L1/L2 vertebral level, the spinal nerves for each segment exit at the level of the corresponding vertebra. For the nerves of the lower spinal cord, this means that they exit the vertebral column much lower (more caudally) than their roots. As these nerves travel from their respective roots to their point of exit from the vertebral column, the nerves of the lower spinal segments form a bundle called the cauda equina.

There are two regions where the spinal cord enlarges:
Cervical enlargement - corresponds roughly to the brachial plexus nerves, which innervate the upper limb. It includes spinal cord segments from about C4 to T1. The vertebral levels of the enlargement are roughly the same (C4 to T1).

Lumbosacral enlargement - corresponds to the lumbosacral plexus nerves, which innervate the lower limb. It comprises the spinal cord segments from L2 to S3 and is found about the vertebral levels of T9 to T12.

Embryology
The spinal cord is made from part of the neural tube during development. As the neural tube begins to develop, the notochord begins to secrete a factor known as Sonic hedgehog or SHH. As a result, the floor plate then also begins to secrete SHH, and this will induce the basal plate to develop motor neurons. Meanwhile, the overlying ectoderm secretes bone morphogenetic protein (BMP). This induces the roof plate to begin to secrete BMP, which will induce the alar plate to develop sensory neurons. The alar plate and the basal plate are separated by the sulcus limitans.

Additionally, the floor plate also secretes netrins. The netrins act as chemoattractants to decussation of pain and temperature sensory neurons in the alar plate across the anterior white commissure, where they then ascend towards the thalamus.
Lastly, it is important to note that the past studies of Viktor Hamburger and Rita Levi-Montalcini in the chick embryo have been further proven by more recent studies which demonstrated that the elimination of neuronal cells by programmed cell death (PCD) is necessary for the correct assembly of the nervous system.

Overall, spontaneous embryonic activity has been shown to play a role in neuron and muscle development but is probably not involved in the initial formation of connections between spinal neurons.

Somatosensory Organisation

Somatosensory organization is divided into the dorsal column-medial lemniscus tract (the touch/proprioception/vibration sensory pathway) and the anterolateral system, or ALS (the pain/temperature sensory pathway). Both sensory pathways use three different neurons to get information from sensory receptors at the periphery to the cerebral cortex. These neurons are designated primary, secondary and tertiary sensory neurons. In both pathways, primary sensory neuron cell bodies are found in the dorsal root ganglia, and their central axons project into the spinal cord.

In the dorsal column-medial leminiscus tract, a primary neuron's axon enters the spinal cord and then enters the dorsal column. If the primary axon enters below spinal level T6, the axon travels in the fasciculus gracilis, the medial part of the column. If the axon enters above level T6, then it travels in the fasciculus cuneatus, which is lateral to the fasiculus gracilis. Either way, the primary axon ascends to the lower medulla, where it leaves its fasiculus and synapses with a secondary neuron in one of the dorsal column nuclei: either the nucleus gracilis or the nucleus cuneatus, depending on the pathway it took. At this point, the secondary axon leaves its nucleus and passes anteriorly and medially. The collection of secondary axons that do this are known as internal arcuate fibers. The internal arcuate fibers decussate and continue ascending as the contralateral medial lemniscus. Secondary axons from the medial lemniscus finally terminate in the ventral posterolateral nucleus (VPL) of the thalamus, where they synapse with tertiary neurons. From there, tertiary neurons ascend via the posterior limb of the internal capsule and end in the primary sensory cortex. The anterolateral system works somewhat differently. Its primary neurons enter the spinal cord and then ascend one to two levels before synapsing in the substantia gelatinosa. The tract that ascends before synapsing is known as Lissauer's tract. After synapsing, secondary axons decussate and ascend in the anterior lateral portion of the spinal cord as the spinothalamic tract. This tract ascends all the way to the VPL, where it synapses on tertiary neurons. Tertiary neuronal axons then travel to the primary sensory cortex via the posterior limb of the internal capsule.

It should be noted that some of the "pain fibers" in the ALS deviate from their pathway towards the VPL. In one such deviation, axons travel towards the reticular formation in the midbrain. The reticular formation then projects to a number of places including the hippocampus (to create memories about the pain), the centromedian nucleus (to cause diffuse, non-specific pain) and various parts of the cortex. Additionally, some ALS axons project to the periaqueductal gray in the pons, and the axons forming the periaqueductal gray then project to the nucleus raphe magnus, which projects back down to where the pain signal is coming from and inhibits it. This helps control the sensation of pain to some degree.

Motor Organisation

The corticospinal tract serves as the motor pathway for upper motor neuronal signals coming from the cerebral cortex and from primitive brainstem motor nuclei.

Cortical upper motor neurons originate from Brodmann areas 1, 2, 3, 4, and 6 and then descend in the posterior limb of the internal capsule, through the crus cerebri, down through the pons, and to the medullary pyramids, where about 90% of the axons cross to the contralateral side at the decussation of the pyramids. They then descend as the lateral corticospinal tract. These axons synapse with lower motor neurons in the ventral horns of all levels of the spinal cord. The remaining 10% of axons descend on the ipsilateral side as the ventral corticospinal tract. These axons also synapse with lower motor neurons in the ventral horns. Most of them will cross to the contralateral side of the cord (via the anterior white commissure) right before synapsing.

The midbrain nuclei include four motor tracts that send upper motor neuronal axons down the spinal cord to lower motor neurons. These are the rubrospinal tract, the vestibulospinal tract, the tectospinal tract and the reticulospinal tract. The rubrospinal tract descends with the lateral corticospinal tract, and the remaining three descend with the anterior corticospinal tract. The function of lower motor neurons can be divided into two different groups: the lateral corticospinal tract and the anterior cortical spinal tract. The lateral tract contains upper motor neuronal axons which synapse on dorsal lateral (DL) lower motor neurons. The DL neurons are involved in distal limb control. Therefore, these DL neurons are found specifically only in the cervical and lumbosaccral enlargements within the spinal cord. There is no decussation in the lateral corticospinal tract after the decussation at the medullary pyramids.

The anterior corticospinal tract descends ipsilaterally in the anterior column, where the axons emerge and either synapse on lower ventromedial (VM) motor neurons in the ventral horn ipsilaterally or descussate at the anterior white commissure where they synapse on VM lower motor neurons contralaterally. The tectospinal, vestibulospinal and reticulospinal descend ipsilaterally in the anterior column but do not synapse across the anterior white commissure. Rather, they only synapse on VM lower motor neurons ipsilaterally. The VM lower motor neurons control the large, postural muscles of the axial skeleton. These lower motor neurons, unlike those of the DL, are located in the ventral horn all the way throughout the spinal cord.

Motor Organisation

Proprioceptive information in the body travels up the spinal cord via three tracts. Below L2, the proprioceptive information travels up the spinal cord in the ventral spinocerebellar tract. Also known as the anterior spinocerebellar tract, sensory receptors take in the information and travel into the spinal cord. The cell bodies of these primary neurons are located in the dorsal root ganglia. In the spinal cord, the axons synapse and the secondary neuronal axons decussate and then travel up to the superior cerebellar peduncle where they decussate again. From here, the information is brought to deep nuclei of the cerebellum including the fastigial and interposed nuclei. From the levels of L2 to T1, proprioceptive information enters the spinal cord and ascends ipsilaterally, where it synapses in Clarke's nucleus. The secondary neuronal axons continue to ascend ipsilaterally and then pass into the cerebellum via the inferior cerebellar peduncle. This tract is known as the dorsal spinocerebellar tract.

From above T1, proprioceptive primary axons enter the spinal cord and ascend ipsilaterally until reaching the accessory cuneate nucleus, where they synapse. The secondary axons pass into the cerebellum via the inferior cerebellar peduncle where again, these axons synapse on cerebellar deep nuclei. This tract is known as the cuneocerebellar tract.

Motor information travels from the brain down the spinal cord via descending spinal cord tracts. Descending tracts involve two neurons: the upper motor neuron (UMN) and lower motor neuron (LMN). A nerve signal travels down the upper motor neuron until it synapses with the lower motor neuron in the spinal cord. Then, the lower motor neuron conducts the nerve signal to the spinal root where efferent nerve fibers carry the motor signal toward the target muscle. The descending tracts are composed of white matter. There are several descending tracts serving different functions. The corticospinal tracts (lateral and anterior) are responsible for coordinated limb movements

Vertebrae	Areas
ATLAS AXIS	
1C	Blood supply to the head, pituitary gland, scalp, bones of the face, brain, inner and middle ear, sympathetic nervous system.
2C	Eyes, optic nerves, auditory nerves, sinuses, mastoid bones, tongue, forehead.
3C	Cheeks, outer ear, face bones, teeth, trifacial nerve.
4C	Nose, lips, mouth, eustachian tube.
5C	Vocal cords, neck glands, pharynx.
6C	Neck muscles, shoulders, tonsils.
7C	Thyroid gland, bursae in the shoulders, elbows.
1T	Arms from the elbows down, including hands, wrists, and fingers, esophagus and trachea.
2T	Heart, including its valves and covering, coronary arteries.
3T	Lungs, bronchial tubes, pleura, chest, breast.
4T	Gall bladder, common duct.
5T	Stomach.
6T	Pancreas, duodenum.
7T	Spleen.
8T	Liver, solar plexus, blood.
9T	Adrenal and supra-renal glands.
10T	Small intestines, lymph circulation.
11T	Kidneys.
12T	Kidneys, ureters.
1L	Appendix.
2L	Larger intestines, inguinal rings.
3L	Sex organs, uterus, bladder, knees.
4L	Lower legs, ankles, feet.
5L	Prostate gland, muscles of the lower back, sciatic nerve.
SACRUM	Hip bones, buttocks.
COCCYX	Rectum, anus.

Figure 15 - Spinal Nerves and Areas of Innervation

CERVICAL PLEXUS (C1–C5)
Lesser occipital nerve
Ansa cervicalis
Transverse cervical nerve
Supraclavicular nerve
Phrenic nerve

BRACHIAL PLEXUS (C5–T1)
Musculocutaneous nerve
Median nerve
Axillary nerve
Radial nerve
Ulnar nerve

INTERCOSTAL (THORACIC NERVES)

LUMBAR PLEXUS (L1–L4)
Iliohypogastric nerve
Ilioinguinal nerve
Genitofemoral nerve
Lateral femoral cutaneous nerve
Femoral nerve
Obturator nerve

SACRAL PLEXUS (L4-S4)
Common peroneal nerve
Tibial nerve
Posterior femoral cutaneous nerve
Pudendal nerve

Atlas (first cervical vertebra)
C1, C2, C3, C4, C5, C6, C7, C8
Cervical nerves (8 pairs)
Cervical enlargement
First thoracic vertebra
T1–T12
Thoracic nerves (12 pairs)
Lumbar enlargement
First lumbar vertebra
Conus medullaris
L1, L2, L3, L4, L5
Lumbar nerves (5 pairs)
Cauda equina
Ilium
S1, S2, S3, S4, S5
Sacrum
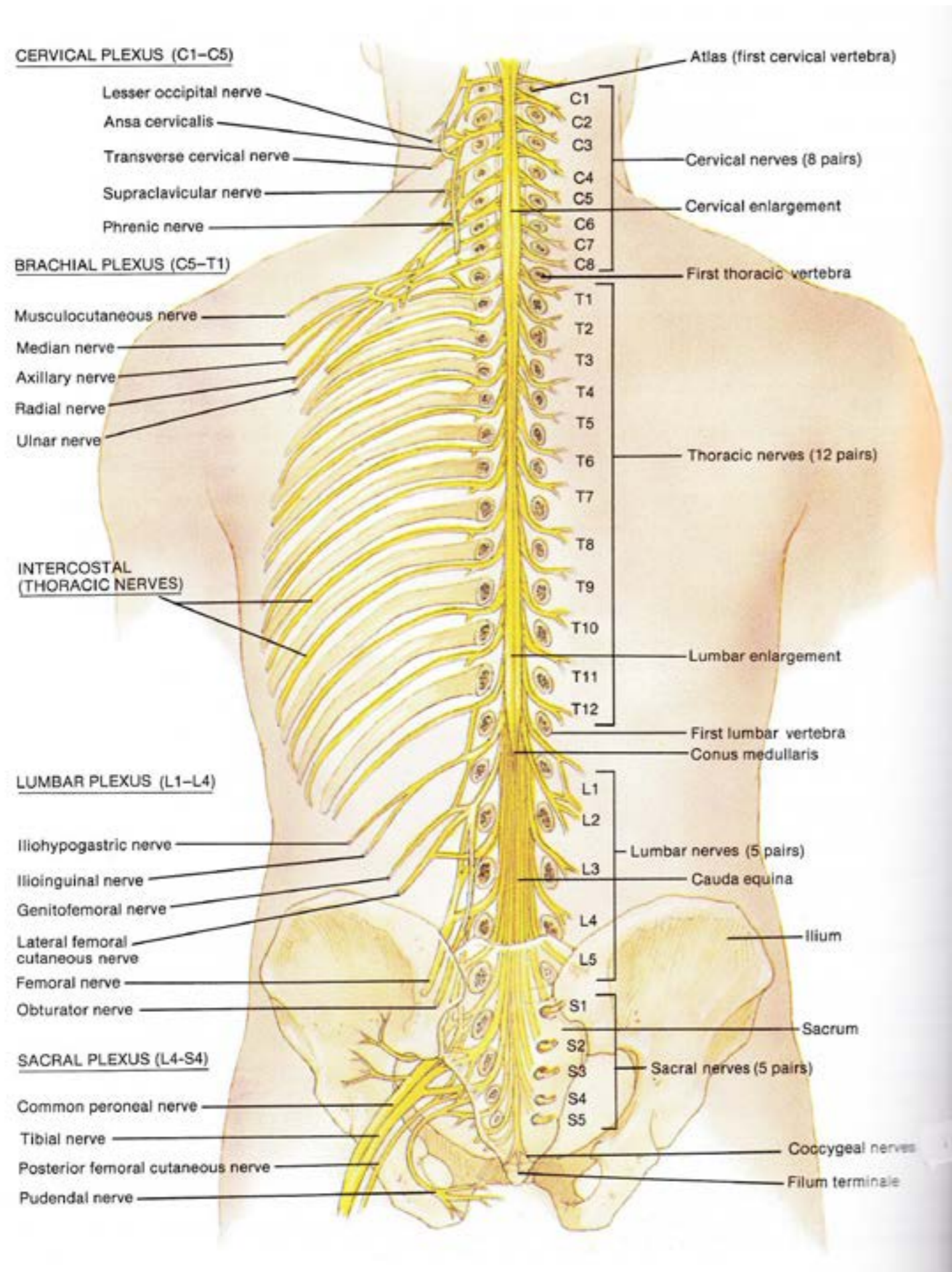Sacral nerves (5 pairs)
Coccygeal nerves
Filum terminale

Figure 16 - Posterior View of Spinal Column and Nerves

Muscles of the Vertebal Column

The muscles that move the vertebral column are quite complex because they have multiple origins and insertions and there is considerable overlap among them. One way to group the muscles is on the basis of the general direction of the muscle bundles and their approximate lengths. For example, the splenius muscles arise from the midline and run laterally and superiorly to their insertions. The erector spinae muscle arises from either the midline or more laterally but usually runs almost longitudinally, with neither a marked outward or inward direction as it is traced superiorly. The transversospinalis muscles arise laterally but run towards the midline as they are traced superiorly. Deep to these three muscle groups are small segmental muscles that run between spinous processes or transverse processes of vertebrae. Since the scalene muscles also assist in moving the vertebral column, they are included in this table. Note that in the abdominal wall table that some of these muscles also play a part in moving the vertebral column.

Muscle	Origin	Insertion	Action	Nerve Supply	Blood Supply
SPLENIUS CAPITIS	LIGAMENTUM NUCHAE AND SPINOUS PROCESSES OF SEVENTH CERVICAL VERTEBRA AND FIRST THREE OR FOUR THORACIC VERTEBRAE	OCCIPITAL BONE AND MASTOID PROCESS OF TEMPORAL BONE	EXTEND HEAD AND NECK; LATERALLY FLEXES AND ROTATES HEAD TO SAME SIDE	DORSAL RAMI OF MIDDLE CERVICAL NERVES	MUSCULAR BRANCH OF AORTA
SPLENIUS CERVICIS	SPINOUS PROCESSES OF T3-T6	TRANSVERSE PROCESS OF C2-C5	EXTEND HEAD AND NECK; LATERALLY FLEXES AND ROTATES HEAD TO SAME SIDE	DORSAL RAMI OF SPINAL NERVES	MUSCULAR BRANCH OF AORTA
ILIOCOSTALIS LUMBORUM	ILIAC CREST	LOWER SIX RIBS	EXTENDS LUMBAR REGION OF VERTEBRAL COLUMN	DORSAL RAMI OF LUMBAR NERVES	MUSCULAR BRANCH OF AORTA
ILIOCOSTALIS THORACIS	LOWER SIX RIBS	UPPER SIX RIBS	MAINTAINS ERECT POSITION OF SPINE	DORSAL RAMI OF THORACIC (INTERCOSTAL) NERVES	MUSCULAR BRANCH OF AORTA
ILIOCOSTALIS CERVICIS	FIRST SIX RIBS	TRANSVERSE PROCESSES OF FOURTH TO SIXTH CERVICAL VERTEBRAE	EXTENDS CERVICAL REGION OF VERTEBRAL COLUMN	DORSAL RAMI OF CERVICAL NERVES	MUSCULAR BRANCH OF AORTA
LONGISSIMUS THORACIS	TRANSVERSE PROCESSES OF LUMBAR VERTEBRAE	TRANSVERSE PROCESSES OF ALL THORACIC AND UPPER LUMBAR VERTEBRAE AND NINTH AND TENTH RIBS	EXTENDS THORACIC REGION OF VERTEBRAL COLUMN	DORSAL RAMI OF SPINAL NERVES	MUSCULAR BRANCH OF AORTA
LONGISSIMUS CERVICIS	TRANSVERSE PROCESSES OF FOURTH AND FIFTH THORACIC VERTEBRAE	TRANSVERSE PROCESSES OF SECOND TO SIXTH CERVICAL VERTEBRAE	EXTENDS CERVICAL REGION OF VERTEBRAL COLUMN	DORSAL RAMI OF SPINAL NERVES	MUSCULAR BRANCH OF AORTA
LONGISSIMUS CAPITIS	TRANSVERSE PROCESSES OF UPPER FOUR THORACIC VERTEBRAE AND ARTICULAR PROCESSES OF LAST FOUR CERVICAL VERTEBRAE	MASTOID PROCESS OF TEMPORAL BONE	EXTENDS HEAD AND ROTATES IT TO SAME SIDE	DORSAL RAMI OF MIDDLE AND LOWER CERVICAL NERVES	MUSCULAR BRANCH OF AORTA
SPINALIS THORACIS	SPINOUS PROCESSES OF UPPER LUMBAR AND LOWER THORACIC VERTEBRAE	SPINOUS PROCESSES OF UPPER THORACIC VERTEBRAE	EXTENDS VERTEBRAL COLUMN	DORSAL RAMI OF SPINAL NERVES	MUSCULAR BRANCH OF AORTA
SPINALIS CERVICAS	LIGAMENTUM NUCHAE AND SPINOUS PROCESSES OF SEVENTH CERVICAL VERTEBRAE	SPINOUS PROCESS OF AXIS	EXTENDS VERTEBRAL COLUMN	DORSAL RAMI OF SPINAL NERVES	MUSCULAR BRANCH OF AORTA
SPINALIS CAPITIS	ARISES WITH SEMISPINALIS CAPITIS	INSERTS WITH SPINALIS CAPITIS	EXTENDS VERTEBRAL COLUMN	DORSAL RAMI OF SPINAL NERVES	MUSCULAR BRANCH OF AORTA

Muscle	Origin	Insertion	Action	Nerve Supply	Blood Supply
SEMISPINALIS THORACIS	TRANSVERSE PROCESSES OF SIXTH TO TENTH THORACIC VERTEBRAE	SPINOUS PROCESSES OF FIRST FOUR THORACIC AND LAST TWO CERVICAL VERTEBRAE	EXTENDS VERTEBRAL COLUMN AND ROTATES IT TO THE OPPOSITE SIDE	DORSAL RAMI OF THORACIC AND CERVICAL SPINAL NERVES	MUSCULAR BRANCH OF AORTA
SEMISPINALIS CERVICIS	TRANSVERSE PROCESSES OF FIRST FIVE OR SIX THORACIC VERTEBRAE	SPINOUS PROCESSES OF FIRST TO FIFTH CERVICAL VERTEBRAE	EXTENDS VERTEBRAL COLUMN AND ROTATES IT TO THE OPPOSITE SIDE	DORSAL RAMI OF THORACIC AND CERVICAL SPINAL NERVES	MUSCULAR BRANCH OF AORTA
SEMISPINALIS CAPITIS	TRANSVERSE PROCESSES OF FIRST SIX OR SEVEN THORACIC VERTEBRAE AND SEVENTH CERVICAL VERTEBRA AND ARTICULAR PROCESSES OF FOURTH, FIFTH AND SIXTH CERVICAL VERTEBRAE	OCCIPITAL BONE	EXTENDS VERTEBRAL COLUMN AND ROTATES IT TO OPPOSITE SIDE	DORSAL RAMI OF CERVICAL NERVES	MUSCULAR BRANCH OF AORTA
MULTIFIDUS	SACRUM, ILIUM, TRANSVERSE PROCESSES OF LUMBAR, THORACIC AND LOWER FOUR CERVICAL VERTEBRAE	SPINOUS PROCESS OF A HIGHER VERTEBRA	EXTENDS VERTEBRAL COLUMN AND ROTATES IT TO THE OPPOSITE SIDE	DORSAL RAMI OF SPINAL NERVES	MUSCULAR BRANCH OF AORTA
ROTATORES	TRANSVERSE PROCESSES OF ALL VERTEBRAE	SPINOUS PROCESSES OF VERTEBRA ABOVE THE ONE OF ORIGIN	EXTENDS VERTEBRAL COLUMN AND ROTATES IT TO THE OPPOSITE SIDE	DORSAL RAMI OF SPINAL NERVES	MUSCULAR BRANCH OF AORTA
INTERSPINALES	SUPERIOR SURFACE OF ALL SPINOUS PROCESSES	INFERIOR SURFACE OF SPINOUS PROCESS OF VERTEBRA ABOVE THE ONE OF ORIGIN	EXTENDS VERTEBRAL COLUMN	DORSAL RAMI OF SPINAL NERVES	MUSCULAR BRANCH OF AORTA
INTER-TRANSVERSARII	TRANSVERSE PROCESSES OF ALL VERTEBRAE	TRANSVERSE PROCESS OF VERTEBRA ABOVE THE ONE OF ORIGIN	LATERALLY FLEXES VERTEBRAL COLUMN	DORSAL AND VENTRAL RAMI OF SPINAL NERVES	MUSCULAR BRANCH OF AORTA
ANTERIOR SCALENE	TRANSVERSE PROCESSES OF THIRD THROUGH SIXTH CERVICAL VERTEBRAE	FIRST RIB	FLEXES AND ROTATES NECK AND ASSISTS IN INSPIRATION	VENTRAL RAMI OF FIFTH AND SIXTH CERVICAL NERVES	ASCENDING CERVICAL ARTERY
MIDDLE SCALENE	TRANSVERSE PROCESSES OF LAST SIX CERVICAL VERTEBRAE	FIRST RIB	FLEXES AND ROTATES NECK AND ASSISTS IN INSPIRATION		ASCENDING CERVICAL ARTERY
POSTERIOR SCALENE	TRANSVERSE PROCESSES OF FOURTH THROUGH SIXTH CERVICAL VERTEBRAE	SECOND RIB	FLEXES AND ROTATES NECK AND ASSISTS IN INSPIRATION	VENTRAL RAMI OF LAST THREE CERVICAL NERVES	ASCENDING CERVICAL ARTERY

Muscles of the Abdominal Wall

The anterolateral abdominal wall is composed of skin, fascia, and four pairs of flat, sheetlike muscles; rectus abdominis, external oblique, internal oblique, and transverus abdominis. The anterior surfaces of the rectus abdominis muscles are interrupted by three transverse, fibrous bands of tissue called tendinous intersections, believed to be remnants of septa that separated myotomes during embryological development. The aponeuroses of the external oblique, internal oblique and transverses abdominis muscles form the rectus sheath, which encloses the rectus abdominis muscle, and meet at the midline to form the linea alba (white line), a tough, fibrous band that extends from the xiphoid process of the sternum to the pubic symphyses. The inferior free border of the external oblique aponeurosis, plus some collagen fibres, forms the inguinal ligament, which runs from the anterior superior iliac spine to the pubic tubercule. The ligament demarcates the thigh and body wall. Just superior to the medial end of the inguinal ligament is a triangular slit in the aponeurosis referred to as the superficial inguinal ring, the outer opening of the inguinal canal. The canal contains the spermatic cord and ilioinguinal nerve in males and round ligament of the uterus and ilioinguinal nerves in females.

The posterior abdominal wall is formed by the lumbar vertebrae, parts of the ilia of the hipbones, psoas major muscle, quadrates lumborum muscle, and iliacus muscle. Whereas the anterolateral abdominal wall is contractile and distensible, the posterior abdominal wall is bulky and stable by comparison.

Muscle	Origin	Insertion	Action	Nerve Supply	Blood Supply
RECTUS ABDOMINIS	PUBIC CREST AND PUBIC SYMPHYSIS	CARTILAGE OF FIFTH TO SEVENTH RIBS AND XIPHOID PROCESS	COMPRESSES ABDOMEN TO AID IN DEFECATION, URINATION, FORCED EXPIRATION, AND CHILDBIRTH AND FLEXES VERTEBRAL COLUMN	BRANCHES OF THORACIC NERVES T7-T12	INFERIOR AND SUPERIOR EPIGASTRIC ARTERIES, INTERCOSTAL ARTERIES
EXTERNAL OBLIQUE	LOWER EIGHT RIBS	ILIAC CREST AND LINEA ALBA (MIDLINE APONEUROSIS)	CONTRACTION OF BOTH COMPRESSES ABDOMEN; CONTRACTION OF ONE SIDE ALONE BENDS VERTEBRAL COLUMN LATERALLY; LATERALLY ROTATES VERTEBRAL COLUMN	BRANCHES OF THORACIC NERVES T7-T12 AND ILIOHYPOGASTRIC NERVE	LOWER INTERCOSTAL ARTERIES, DEEP CIRCUMFLEX ILIAC ARTERY, ILIOLUMBAR ARTERY
INTERNAL OBLIQUE	ILIAC CREST, INGUINAL LIGAMENT, AND THORACO-COLUMBAR FASCIA	CARTILAGE OF LAST THREE OR FOUR RIBS AND LINEA ALBA	COMPRESSES ABDOMEN; CONTRACTION OF ONE SIDE ALONE BENDS VERTEBRAL COLUMN LATERALLY; LATERALLY ROTATES VERTEBRAL COLUMN	BRANCHES OF THORACIC NERVE T8-T12, ILIOHYPOGASTRIC, AND ILIOINGUINAL NERVES	INFERIOR AND SUPERIOR EPIGASTRIC ARTERIES, INTERCOSTAL ARTERIES
TRANSVERSUS ABDOMINIS	ILIAC CREST, INGUINAL LIGAMENT, LUMBAR FASCIA, AND CARTILAGES OF LAST SIX RIBS	XIPHOID PROCESS, LINEA ALBA, AND PUBIS	COMPRESSES ABDOMEN	BRANCHES OF THORACIC NERVE T8-T12, ILIOHYPOGASTRIC, AND ILIOINGUINAL NERVES	INFERIOR AND SUPERIOR EPIGASTRIC ARTERIES, INTERCOSTAL ARTERIES
QUADRATUS LUMBORUM	ILIAC CREST AND ILIOLUMBAR LIGAMENT	LOWER BORDER OF TWELFTH RIB AND TRANSVERSE PROCESSES OF FIRST FOUR LUMBAR VERTEBRAE	DURING FORCED EXPIRATION, IT PULLS DOWNWARD ON THE TWELFTH RIB; DURING DEEP INSPIRATION, IT FIXES THE TWELFTH RIB TO PREVENT ITS ELEVATION; CONTRACTION OF ONE SIDE BENDS VERTEBRAL COLUMN LATERALLY	BRANCHES OF THORACIC NERVE T12 AND LUMBAR NERVES L1-L3 OR L1-L4	LUMBAR ARTERY, LUMBAR BRANCH OF ILIOLUMBAR ARTERY

Muscles Used in Breathing

The muscles described here are attached to the ribs and by their contraction and relaxation alter the size of the thoracic cavity during normal breathing. In forced breathing, other muscles are involved as well. Essentially, inspiration occurs when the thoracic cavity increases in size. Expiration occurs when the thoracic cavity decreases in size.

The diaphragm, one of the muscles used in breathing, is dome-shaped and has three major openings through which various structures pass between the thorax and abdomen. These structures include the aorta along with the thoracic duct and azygos vein, which pass through the aortic hiatus, the esophagus with accompanying vagus (x) nerves, which pass through the esophageal hiatus, and the inferior vena cava, which passes through the foramen for the vena cava.

Muscle	Origin	Insertion	Action	Nerve Supply	Blood Supply
DIAPHRAGM	XIPHOID PROCESS, COSTAL CARTILAGES OF LAST SIX RIBS, AND LUMBAR VERTEBRAE	CENTRAL TENDON (STRONG APONEUROSIS THAT SERVES AS THE TENDON OF INSERTION FOR ALL MUSCULAR FIBRES OF THE DIAPHRAGM)	FORMS FLOOR OF THORACIC CAVITY; PULLS CENTRAL TENDON DOWNWARDS DURING INSPIRATION AND AS DOME OF DIAPHRAGM FLATTENS INCREASES VERTICAL LENGTH OF THORAX	PHRENIC NERVE	INTERNAL THORACIC ARTERY AND PHRENIC ARTERIES
EXTERNAL INTERCOSTALS	INFERIOR BORDER OF RIB ABOVE	SUPERIOR BORDER OF RIB BELOW	MAY ELEVATE RIBS DURING INSPIRATION AND THUS INCREASE LATERAL AND ANTEROPOSTERIOR DIMENSIONS OF THORAX	INTERCOSTAL NERVES	ANTERIOR INTERCOSTAL ARTERIES
INTERNAL INTERCOSTALS	SUPERIOR BORDER OF RIB BELOW	INFERIOR BORDER OF RIB ABOVE	MAY DRAW ADJACENT RIBS TOGETHER DURING FORCED EXPIRATION AND THUS DECREASE LATERAL AND ANTEROPOSTERIOR DIMENSIONS OF THORAX	INTERCOSTAL NERVES	ANTERIOR INTERCOSTAL ARTERIES

Arterial and Vascular Supply of Axial Skeleton

Vascular System of the Spine

Red = Artery
Blue = Vein

1 Carotid Artery
2 Aortic Arch
3 Thoracic Aorta
4 Abdominal Aorta
5 Iliac Artery
6 Internal Jugular Vein
7 Superior Vena Cava
8 Inferior Vena Cava
9 Iliac Vein
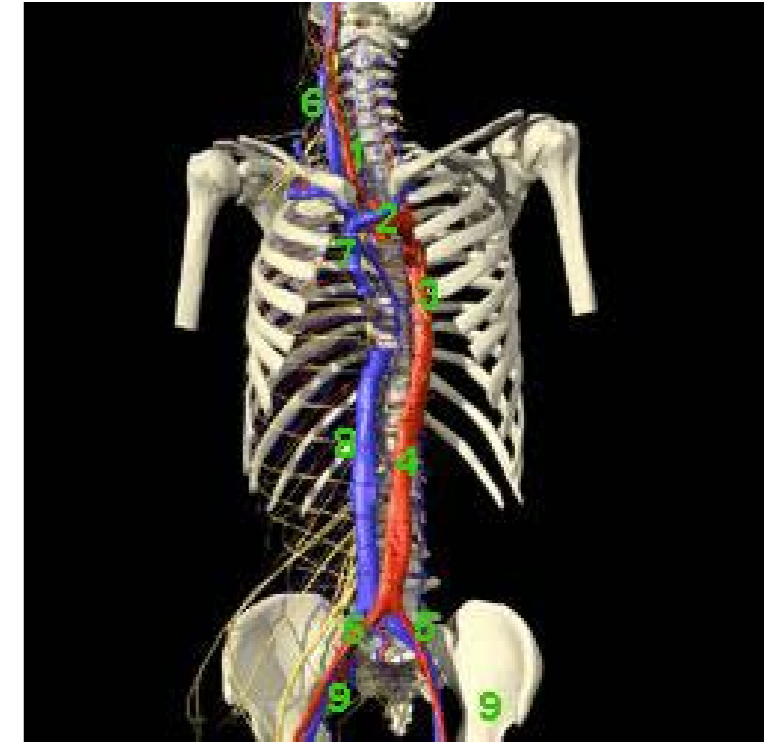
Arteries Supplying Spinal Column

Arteries	Region
Vertebral	Cervical (Head)
Basilar	Basilar Cervical (Head)
Carotid	Cervical/Thoracic
Thoracic Aorta	Thoracic cavity
Intercostal	Thoracic wall
Spinal Branch	Thoracic/Lumbar
Anterior Spinal	Thoracic/Lumbar
Abdominal Aorta	Thoracic/Lumbar cavities
Posterior Branch	Thoracic to Sacrum
Lumbar Segmental	Lumbar
Left Common Iliac	Lumbar/pelvic organs, legs
Right Common Iliac	Lumbar/pelvic organs, legs
Segmental	Lumbar to Sacrum
Middle Sacral	Lumbosacral
Iliolumbar	Lumbosacral
Internal Iliac	Lumbosacral

Circle of Willis

The Vertebral and Internal Carotid Arteries provide blood to the brain. These arteries give off branches that form a circle in the region of the pituitary gland. If the other two arteries are blocked, the blood vessels in the Circle of Willis provide an alternate way to feed blood to the brain.

Veins Supplying Spinal Column

Veins	Region/Comment
Internal Jugular	Cervical – returns blood from the head
External Jugular	Cervical – returns blood from the head
Superior Vena Cava	Cervical/Upper Thoracic Returns blood from upper body to heart
Thoracic Segmental	Thoracic
Inferior Vena Cava	Thoracic/Lumbosacral Returns blood from lower body to heart
Azygous	Lumbar – Returns blood from lower body when inferior vena cava obstructed
Hemiazygous	Lumbar
Lumbar Segmental	Lumbar
Left Common Iliac	Lumbar
Right Common Iliac	Lumbar
Batson's Plexus	Lumbar – Valveless vein, provides alternate route for blood return to heart
Common Iliac	Lumbosacral

Arterial Branches of the Spine

Veins	Region/Comment	Source – Branch From
Anterior Radicular	Meninges Spinal Cord	Vertebral Posterior Intercostal Lumbar Lateral Sacral
Anterior Spinal	Meninges Spinal Cord	Vertebral Posterior Intercostal Lumbar Lateral Sacral
Aortic Arch	Entire Body Except Heart	Ascending Aorta
Basilar	Cranial Nerves Cerebellum	Vertebral
Brachiocephalic Trunk	Right side of head, neck, upper limb, chest wall	Aortic Arch
Cerebral Arterial Circle	Brain – Midbrain	Posterior Cerebral Anterior Cerebral
Common Carotid	Head – upper neck	Brachiocephalic Trunk Aortic Arch
External Carotid	Upper neck	Common Carotid
Great Anterior Radicular	Lower Spinal Cord	Lower Posterior Intercostal
Internal Carotid	Brain	Common Carotid
Lateral Sacral	Sacrum Sacral Nerve Roots Meninges	Internal Iliac
Lumbar	Spinal Cord Vertebral Column	Abdominal Aorta
Median Sacral	Sacrum	Abdominal Aorta
Middle Meningeal	Dura Mater	Maxillary
Posterior Radicular	Meninges, Spinal Cord	Vertebral Posterior Intercostal Lumbar Lateral Sacral
Posterior Spinal	Spinal Cord	Posterior Inferior Cerebellar Vertebral Posterior Intercostal Lumbar Lateral Sacral
Subclavian	Neck Brain Spinal Cord	Brachiocephalic Aortic Arch
Vertebral	Spinal Cord Neck	Subclavian

Venous Branches of the Spine

Vein	Spinal Region	Source(s)
Anterior Jugular	Neck	Submental
Azygos	Chest Wall	Lumbar Subcosta Posterior Intercostal
Brachiocephalic	Head Neck Upper Limbs	Subclavian Internal Jugular Vertebra
Cavernous Sinus	Brain	Superior Ophthalmic Middle Cerebral
External Jugular	Head Neck	Posterior Auricular Posterior External Jugular Transverse Cervical Anterior Jugular
External Vertebral Plexus	Vertebral Column Vertebral Muscles	Internal Vertebral Plexus
Hemiazygos	Lower Chest Wall	Lumbar Subcostal
Internal Vertebral Plexus	Spinal Cord Meninges Vertebral Column	External Vertebral Plexus
Posterior Intercostal	Spinal Cord Vertebra Ribs	Spinal Tributary Posterior Tributary
Pterygoid Plexus	Meninges	Middle Meningeal