Spinal Anatomy

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First Edition, 2012

ISBN 978-81-323-4538-1

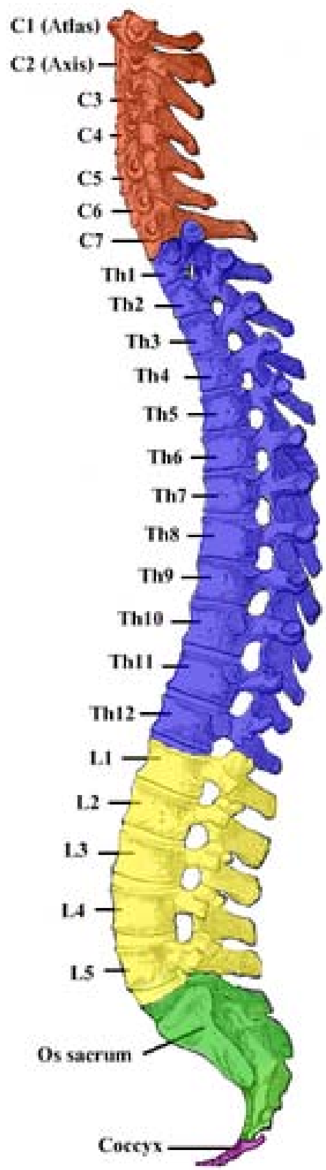
Published by:
The English Press
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
Email: info@wtbooks.com

Table of Contents

Chapter 1

Vertebral Column

Divisions of Spinal Segments



Segmental Spinal Cord Level and Function

Level	Function
C1-C6	Neck flexors
C1-T1	Neck extensors
C3, C4, C5	Supply diaphragm (mostly C4)
C5, C6	Shoulder movement, raise arm (deltoid); flexion of elbow (biceps); **C6** externally rotates the arm (supinates)
C6, C7	Extends elbow and wrist (triceps and wrist extensors); pronates wrist
C7, T1	Flexes wrist
C7, T1	Supply small muscles of the hand
T1 -T6	Intercostals and trunk above the waist
T7-L1	Abdominal muscles
L1, L2, L3, L4	Thigh flexion
L2, L3, L4	Thigh adduction
L4, L5, S1	Thigh abduction
L5, S1, S2	Extension of leg at the hip (gluteus maximus)
L2, L3, L4	Extension of leg at the knee (quadriceps femoris)
L4, L5, S1, S2	Flexion of leg at the knee (hamstrings)
L4, L5, S1	Dorsiflexion of foot (tibialis anterior)
L4, L5, S1	Extension of toes
L5, S1, S2	Plantar flexion of foot
L5, S1, S2	Flexion of toes

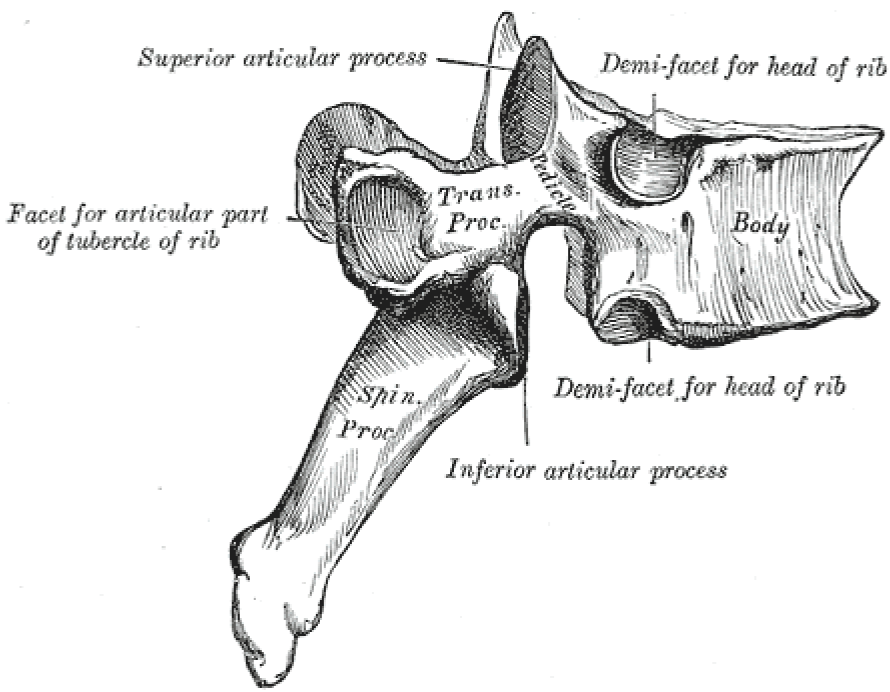
In human anatomy, the **vertebral column** (Latin − *Columna vertebralis*) (**backbone** or **spine**) is a column usually consisting of 24 articulating **vertebrae**, and 9 fused vertebrae in the sacrum and the coccyx. It is situated in the dorsal aspect of the torso, separated by intervertebral discs. It houses and protects the spinal cord in its spinal canal.

In humans

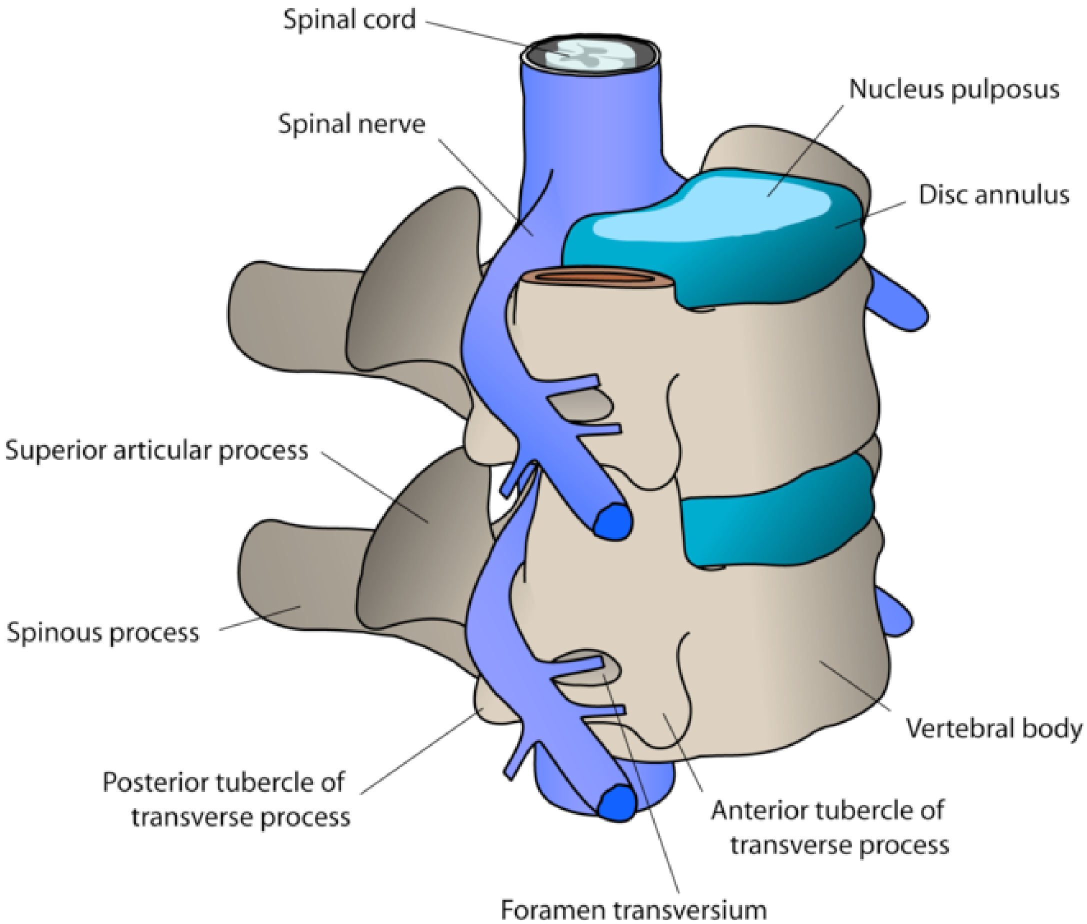
There are normally thirty-three (33) vertebrae in humans, including the five that are fused to form the sacrum (the others are separated by intervertebral discs) and the four coccygeal bones that form the *tailbone*. The upper three regions comprise the remaining 24, and are grouped under the names *cervical* (7 vertebrae), *thoracic* (12 vertebrae) and *lumbar* (5 vertebrae), according to the regions they occupy. This number is sometimes increased by an additional vertebra in one region, or it may be diminished in one region, the deficiency often being supplied by an additional vertebra in another. The number of cervical vertebrae is, however, very rarely increased or diminished.

With the exception of the first and second cervical, the true or movable vertebrae (the upper three regions) present certain common characteristics that are best studied by examining one from the middle of the thoracic region.

Structure of individual vertebrae



A diagram of a human thoracic vertebra. Notice the articulations for the ribs



Oblique view of cervical vertebrae.

A typical vertebra consists of two essential parts: an anterior (front) segment, which is the vertebral body; and a posterior part – the vertebral (neural) arch – which encloses the vertebral foramen. The vertebral arch is formed by a pair of pedicles and a pair of laminae, and supports seven processes, four articular, two transverse, and one spinous, the latter also being known as the neural spine.

When the vertebrae are articulated with each other, the bodies form a strong pillar for the support of the head and trunk, and the vertebral foramina constitute a canal for the protection of the *medulla spinalis* (spinal cord). In between every pair of vertebrae are two apertures, the intervertebral foramina, one on either side, for the transmission of the spinal nerves and vessels.

Two transverse processes and one spinous process are posterior to (behind) the vertebral body. The spinous process comes out the back, one transverse process comes out the left, and one on the right. The spinous processes of the cervical and lumbar regions can be felt through the skin.

Superior and inferior articular facets on each vertebra act to restrict the range of movement possible. These facets are joined by a thin portion of the neural arch called the *pars interarticularis*.

Curves

Viewed laterally the vertebral column presents several curves, which correspond to the different regions of the column, and are called cervical, thoracic, lumbar, and pelvic.

The cervical curve, convex forward, begins at the apex of the odontoid (*tooth-like*) process, and ends at the middle of the second thoracic vertebra; it is the least marked of all the curves.

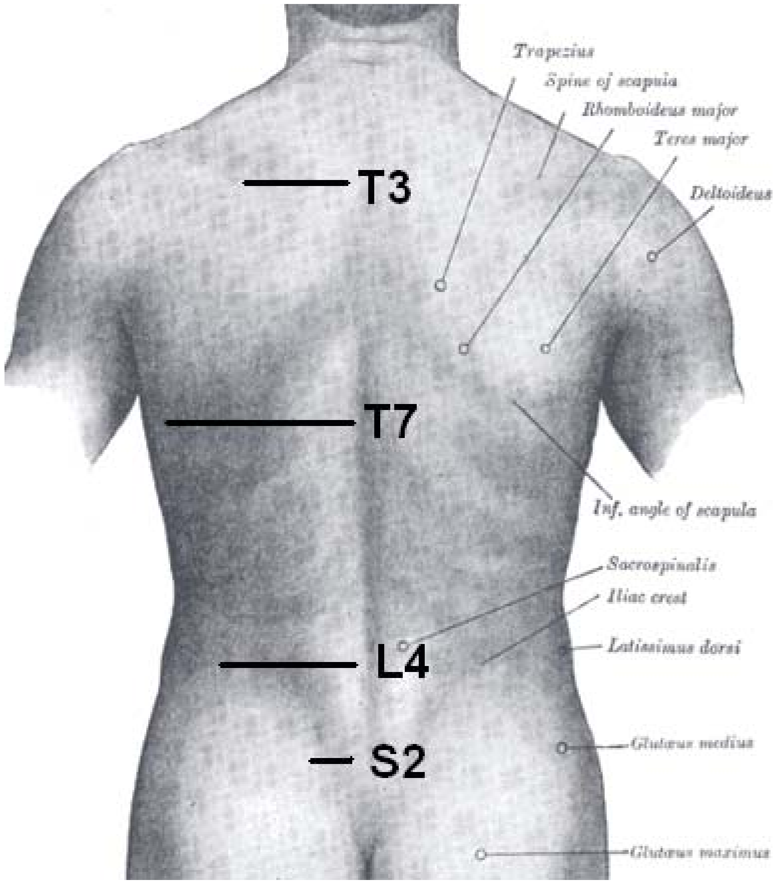
The thoracic curve, concave forward, begins at the middle of the second and ends at the middle of the twelfth thoracic vertebra. Its most prominent point behind corresponds to the spinous process of the seventh thoracic vertebra. This curve is known as a *tt curve.*

The lumbar curve is more marked in the female than in the male; it begins at the middle of the last thoracic vertebra, and ends at the sacrovertebral angle. It is convex anteriorly, the convexity of the lower three vertebrae being much greater than that of the upper two. This curve is described as a *lordotic curve*.

The pelvic curve begins at the sacrovertebral articulation, and ends at the point of the coccyx; its concavity is directed downward and forward.

The thoracic and pelvic curves are termed **primary curves**, because they alone are present during fetal life. The cervical and lumbar curves are *compensatory* or *secondary*, and are developed after birth, the former when the child is able to hold up its head (at three or four months) and to sit upright (at nine months), the latter at twelve or eighteen months, when the child begins to walk.

Regions



Orientation of vertebral column on surface. T3 is at level of medial part of spine of scapula. T7 is at inferior angle of the scapula. L4 is at highest point of iliac crest. S2 is at the level of posterior superior iliac spine. Furthermore, C7 is easily localized as a prominence at the lower part of the neck.

There are a total of 33 vertebrae in the vertebral column, if assuming 4 coccygeal vertebrae.

The individual vertebrae, named according to region and position, from superior to inferior, are:

- Cervical: 7 vertebrae (C1–C7)
- Thoracic: 12 vertebrae (T1–T12)
- Lumbar: 5 vertebrae (L1–L5)
- Sacral: 5 (fused) vertebrae (S1–S5)
- Coccygeal: 4 (3–5) (fused) vertebrae (Tailbone)

Cervical

There are seven (7) cervical bones (but 8 cervical spinal nerves) and these bones are, in general, small and delicate. Their spinous processes are short (with the exception of C2 and C7, which have palpable spinous processes). Numbered top-to-bottom from C1-C7, atlas (C1) and axis (C2), are the vertebrae that allow the neck and head so much movement. For the most part, the atlanto-occipital joint allows the skull to move up and down, while the atlanto-axial joint allows the upper neck to twist left and right. The axis also sits upon the first intervertebral disk of the spinal column. All mammals except manatees and sloths have seven cervical vertebrae, whatever the length of the neck.

Cervical vertebrae possess transverse foramina to allow for the vertebral arteries to pass through on their way to the foramen magnum to end in the circle of Willis. These are the smallest, lightest vertebrae and the vertebral foramina are triangular in shape. The spinous processes are short and often bifurcated (the spinous process of C7, however, is not bifurcated, and is substantially longer than that of the other cervical spinous processes).

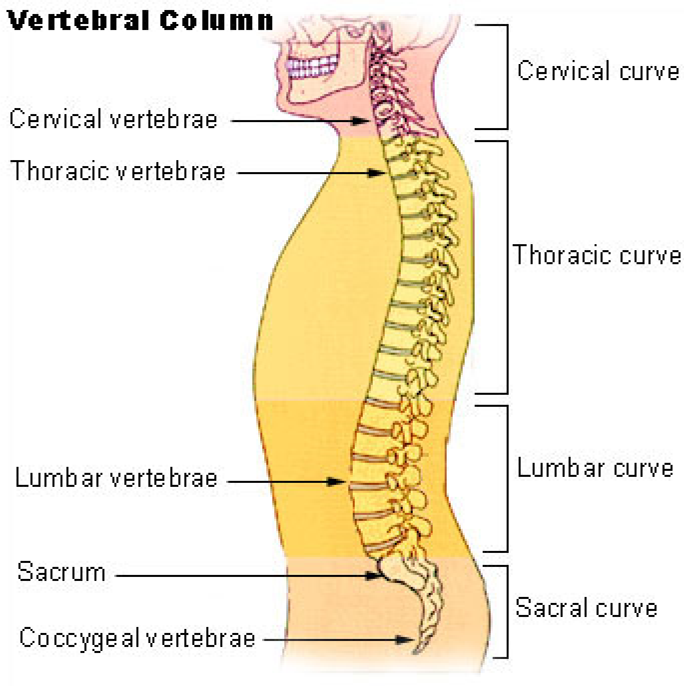
Thoracic

The twelve (12) thoracic bones and their transverse processes have surfaces that articulate with the ribs. Some rotation can occur between the thoracic vertebrae, but their connection with the rib cage prevents much *flexion* or other excursion. They may also be known as 'dorsal vertebrae', in the human context.

Bodies are roughly heart-shaped and are about as wide anterio-posterioly as they are in the transverse dimension. Vertebral foramina are roughly circular in shape.

Lumbar

These five (5) vertebrae are very robust in construction, as they must support more weight than other vertebrae. They allow significant *flexion* and *extension*, moderate lateral flexion (sidebending), and a small degree of rotation. The discs between these vertebrae create a lumbar lordosis (curvature that is concave posteriorly) in the human spine.



Sacral

There are five (5) vertebrae (S1-S5) and they are fused in maturity, with no intervertebral discs.

Coccygeal

There are usually four (4) and rarely 3-5 vertebrae (Co1-Co5), with no intervertebral discs. Many animals have a greater number of "tail vertebrae," and, in animals, they are more commonly known as "caudal vertebrae." Pain at the coccyx (tailbone) is known as coccydynia.

Development

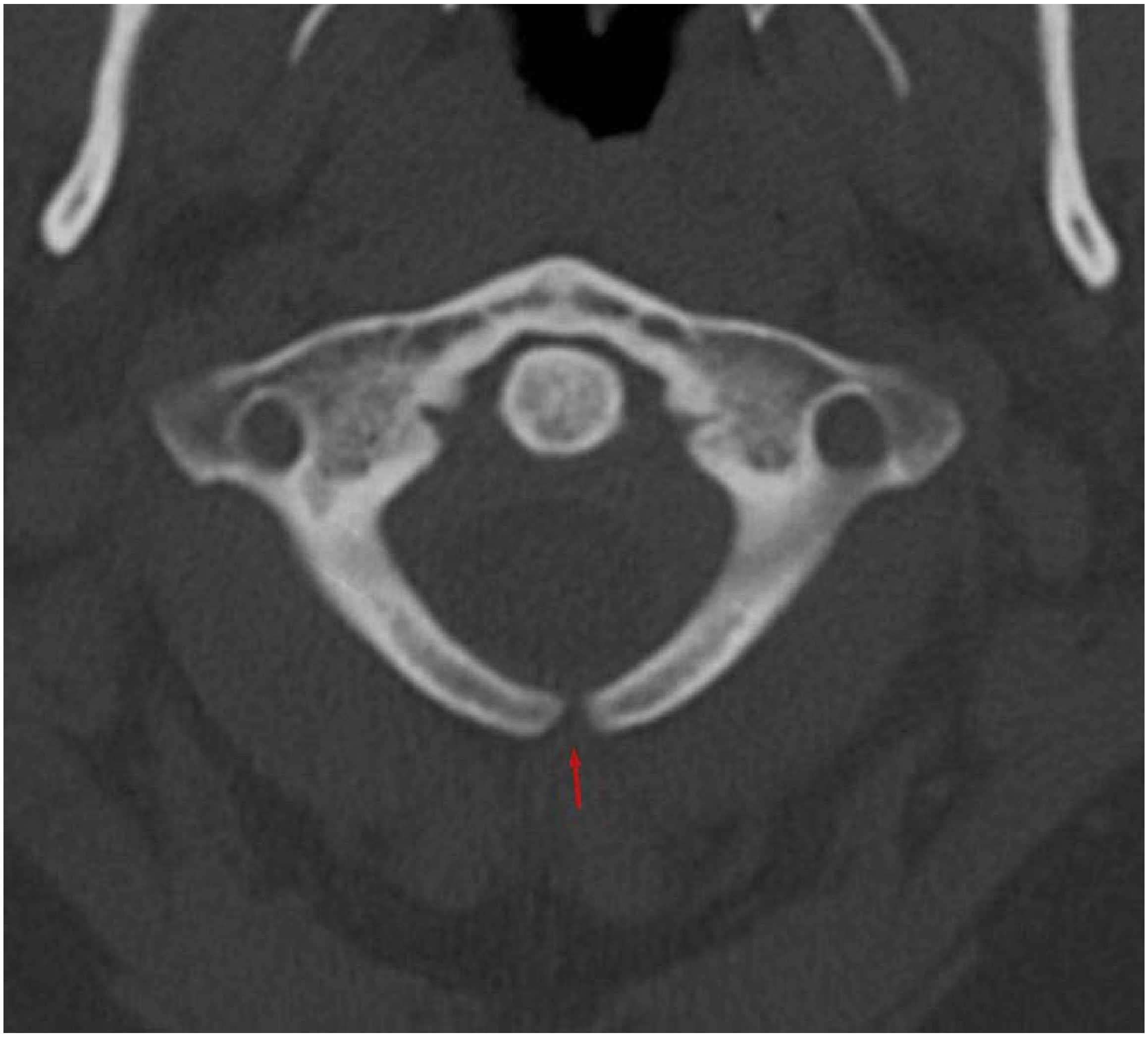
The striking segmented pattern of the human spine is established during embryogenesis when the precursor of the vertebrae, the somites, are rhythmically added to the forming posterior part of the embryo. In humans, somite formation begins around the third week post-fertilization and continues until a total of around 52 somites are formed. The somites are epithelial spheres that contain the precursors of the vertebrae, the ribs, the skeletal muscles of the body wall and limbs, and the dermis of the back. The periodicity of somite distribution and production is thought to be imposed by a molecular oscillator or clock acting in cells of the presomitic mesoderm (PSM). Somites form soon after the beginning of gastrulation, on both sides of the neural tube from a tissue called the presomitic mesoderm (PSM). The PSM is part of the paraxial mesoderm and is generated caudally by gastrulation when cells ingress through the primitive streak, and later, through the tail bud. Soon after their formation, somites become subdivided into the dermomyotome dorsally, which gives rise to the muscles and dermis, and the sclerotome ventrally, which will form the spine components. Sclerotomes become subvidided into an anterior and a posterior compartment. This subdivision plays a key role in the definitive patterning of vertebrae that form when the posterior part of one somite fuses to the anterior part of the consecutive somite during a process termed resegmentation. Disruption of the somitogenesis process in humans results in diseases such as congenital scoliosis. So far, the human homologues of three genes associated to the mouse segmentation clock (MESP2, DLL3 and LFNG) have been shown to be mutated in human patients with human congenital scoliosis suggesting that the mechanisms involved in vertebral segmentation are conserved across vertebrates. In humans the first four somites are incorporated in the basi-occipital bone of the skull and the next 33 somites will form the vertebrae. The remaining posterior somites degenerate. During the fourth week of embryonic development, the sclerotomes shift their position to surround the spinal cord and the notochord. The sclerotome is made of mesoderm and originates from the ventromedial part of the somites. This column of tissue has a segmented appearance, with alternating areas of dense and less dense areas.

As the sclerotome develops, it condenses further eventually developing into the vertebral body. Development of the appropriate shapes of the vertebral bodies is regulated by *HOX genes*.

The less dense tissue that separates the sclerotome segments develop into the intervertebral discs.

The notochord disappears in the sclerotome (vertebral body) segments, but persists in the region of the intervertebral discs as the nucleus pulposus. The nucleus pulposus and the fibers of the annulus fibrosus make up the intervertebral disc.

The primary curves (thoracic and sacral curvatures) form during fetal development. The secondary curves develop after birth. The cervical curvature forms as a result of lifting the head and the lumbar curvature forms as a result of walking.

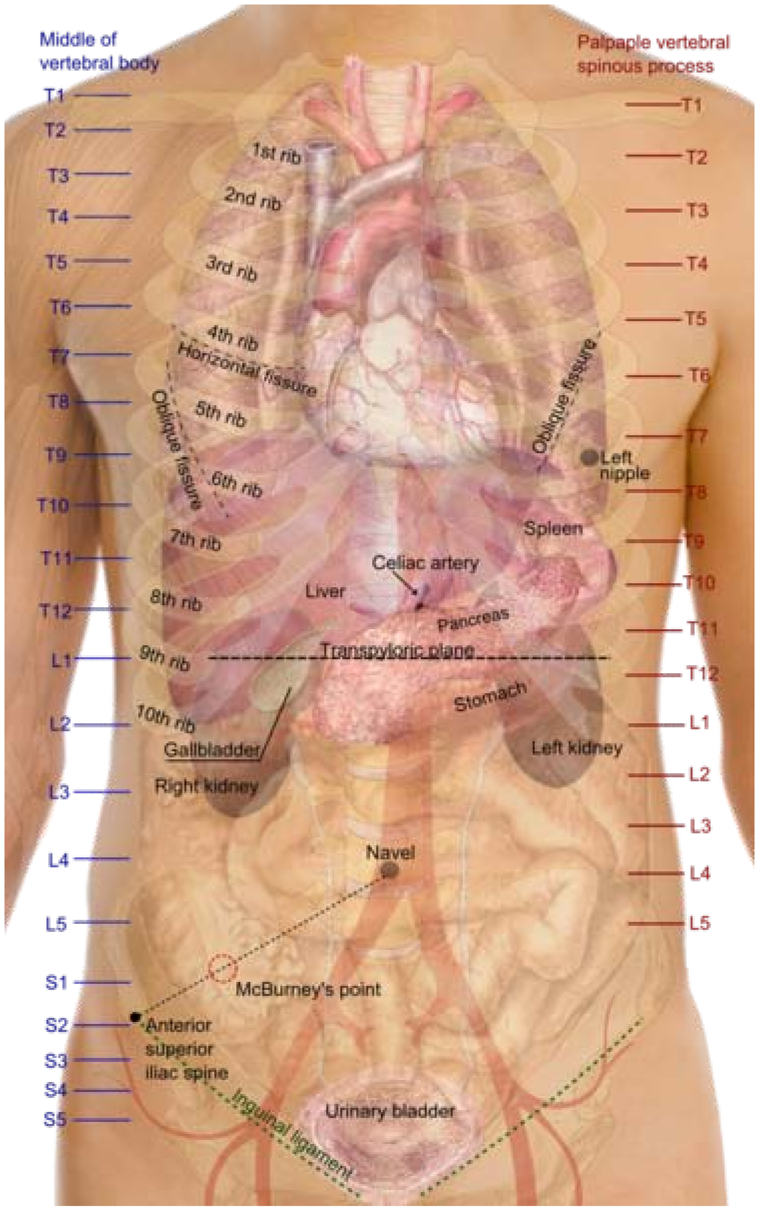


Unfused arch of C1 at CT.

There are various defects associated with vertebral development. Scoliosis will result in improper fusion of the vertebrae. In Klippel-Feil anomaly patients have two or more cervical vertebrae that are fused together, along with other associated birth defects. One of the most serious defects is failure of the vertebral arches to fuse. This results in a condition called spina bifida. There are several variations of spina bifida that reflect the severity of the defect.

Surfaces

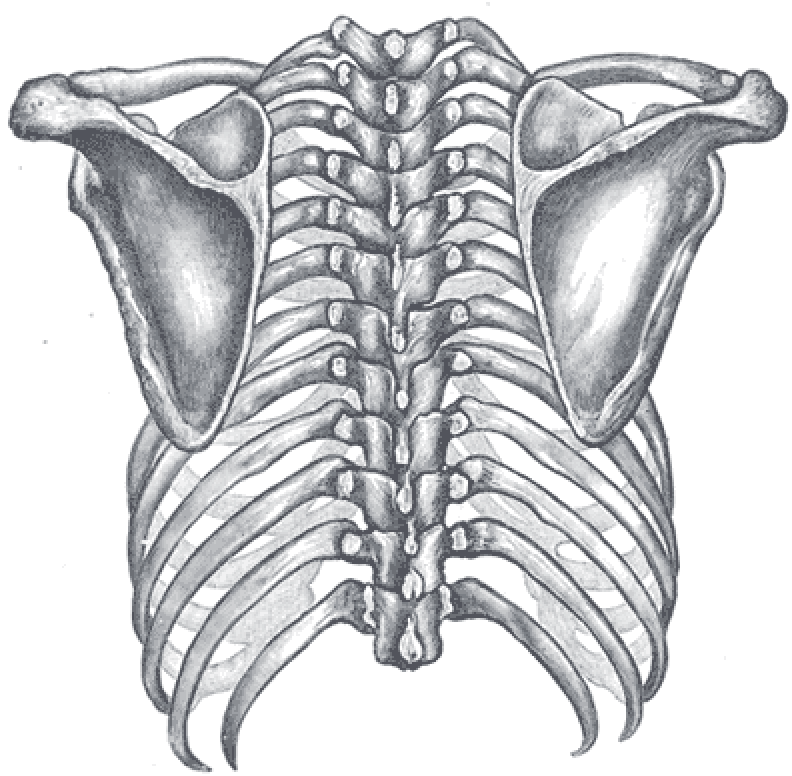
Anterior surface



The vertebrae may be used as vertical reference points to describe the locations of the organs of the trunk, such as with the transpyloric line (seen at body of L1). If not else specified, it is usually the middle of the vertebral body that is used as reference, although the palpable spinous processes may be located considerably lower.

When viewed from in front, the width of the bodies of the vertebrae is seen to increase from the second cervical to the first thoracic; there is then a slight diminution in the next three vertebrae; below this there is again a gradual and progressive increase in width as low as the sacrovertebral angle. From this point there is a rapid diminution, to the apex of the coccyx.

Posterior surface



Orientation of the rib cage on the vertebral column

The posterior surface of the vertebral column presents in the median line the spinous processes. In the cervical region (with the exception of the second and seventh vertebrae) these are short and horizontal, with bifid extremities. In the upper part of the thoracic region they are directed obliquely downward; in the middle they are almost vertical, and in the lower part they are nearly horizontal. In the lumbar region they are nearly horizontal. The spinous processes are separated by considerable intervals in the lumbar region, by narrower intervals in the neck, and are closely approximated in the middle of the thoracic region. Occasionally one of these processes deviates a little from the median line — a fact to be remembered in practice, as irregularities of this sort are attendant also on fractures or displacements of the vertebral column. On either side of the spinous processes is the vertebral groove formed by the laminae in the cervical and lumbar regions, where it is shallow, and by the laminae and transverse processes in the thoracic region, where it is deep and broad; these grooves lodge the deep muscles of the back. Lateral to the vertebral grooves are the articular processes, and still more laterally the transverse processes. In the thoracic region, the transverse processes stand backward, on a plane considerably behind that of the same processes in the cervical and lumbar regions. In the cervical region, the transverse processes are placed in front of the articular processes, lateral to the pedicles and between the intervertebral foramina. In the thoracic region they are posterior to the pedicles, intervertebral foramina, and articular processes. In the lumbar region they are in front of the articular processes, but behind the intervertebral foramina.

Lateral surfaces

The lateral surfaces are separated from the posterior surface by the articular processes in the cervical and lumbar regions, and by the transverse processes in the thoracic region. They present, in back, the sides of the bodies of the vertebrae, marked in the thoracic region by the facets for articulation with the heads of the ribs. More posteriorly are the intervertebral foramina, formed by the juxtaposition of the vertebral notches, oval in shape, smallest in the cervical and upper part of the thoracic regions, and gradually increasing in size to the last lumbar. They transmit the special spinal nerves and are situated between the transverse processes in the cervical region, and in front of them in the thoracic and lumbar regions.

Vertebral canal

The vertebral canal follows the different curves of the column; it is large and triangular in those parts of the column which enjoy the greatest freedom of movement, such as the cervical and lumbar regions; and is small and rounded in the thoracic region, where motion is more limited.

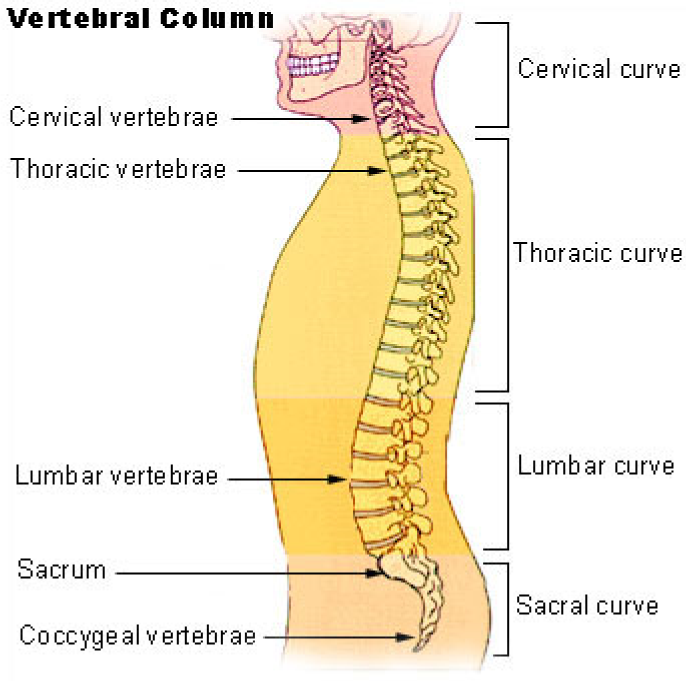
Abnormalities

Occasionally the coalescence of the laminae is not completed, and consequently a cleft is left in the arches of the vertebrae, through which a protrusion of the spinal membranes (*dura mater* and arachnoid), and generally of the spinal cord (*medulla spinalis*) itself, takes place, constituting the malformation known as *spina bifida*. This condition is most common in the lumbosacral region, but it may occur in the thoracic or cervical region, or the arches throughout the whole length of the canal may remain incomplete.

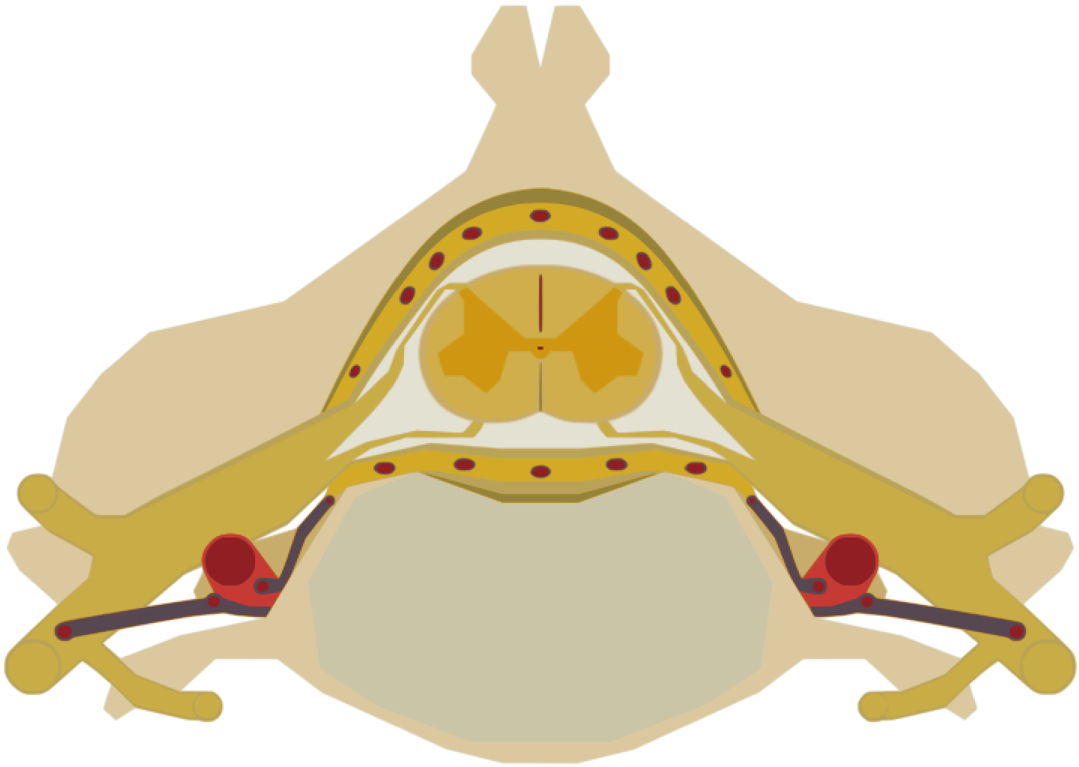
The following abnormal curvatures may occur in some people:

- Kyphosis is an exaggerated kyphotic (posterior) curvature in the thoracic region. This produces the so-called "humpback" or "dowager's hump", a condition commonly observed in osteoporosis.
- Lordosis is an exaggerated lordotic (anterior) curvature of the lumbar region, "swayback". Temporary lordosis is common among pregnant women.
- Retrolisthesis is a posterior displacement of one vertebral body with respect to the adjacent vertebral segment to a degree less than a luxation (dislocation).
- Scoliosis, lateral curvature, is the most common abnormal curvature, occurring in 0.5% of the population. It is more common among females and may result from unequal growth of the two sides of one or more vertebrae. It can also be caused by

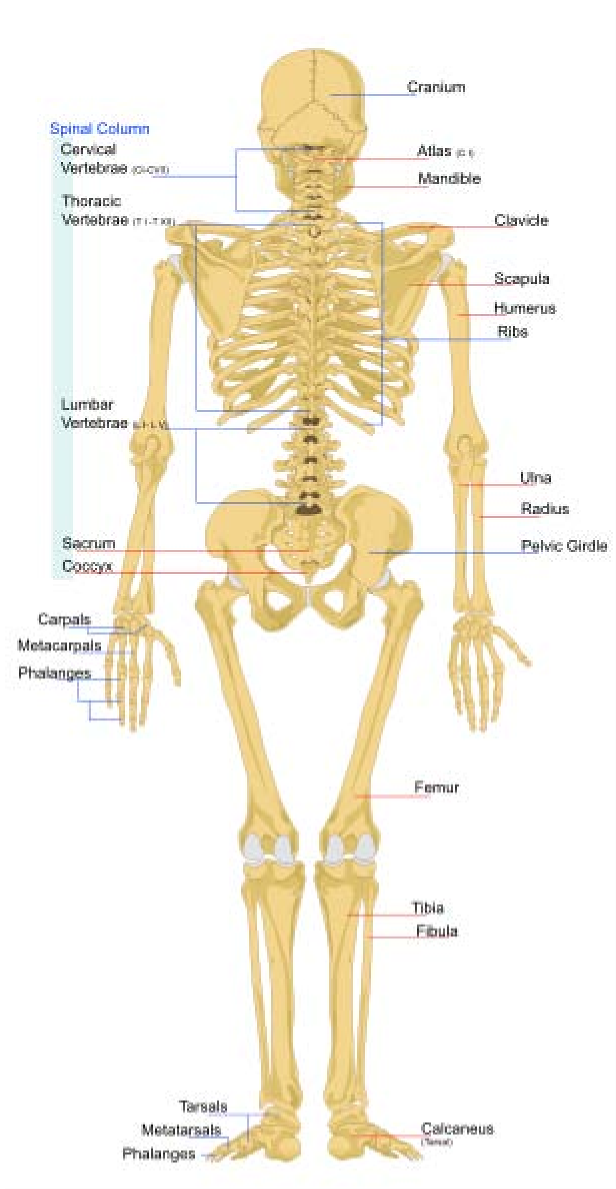
pulmonary atelectasis (partial or complete deflation of one or more lobes of the lungs) as observed in asthma or pneumothorax.



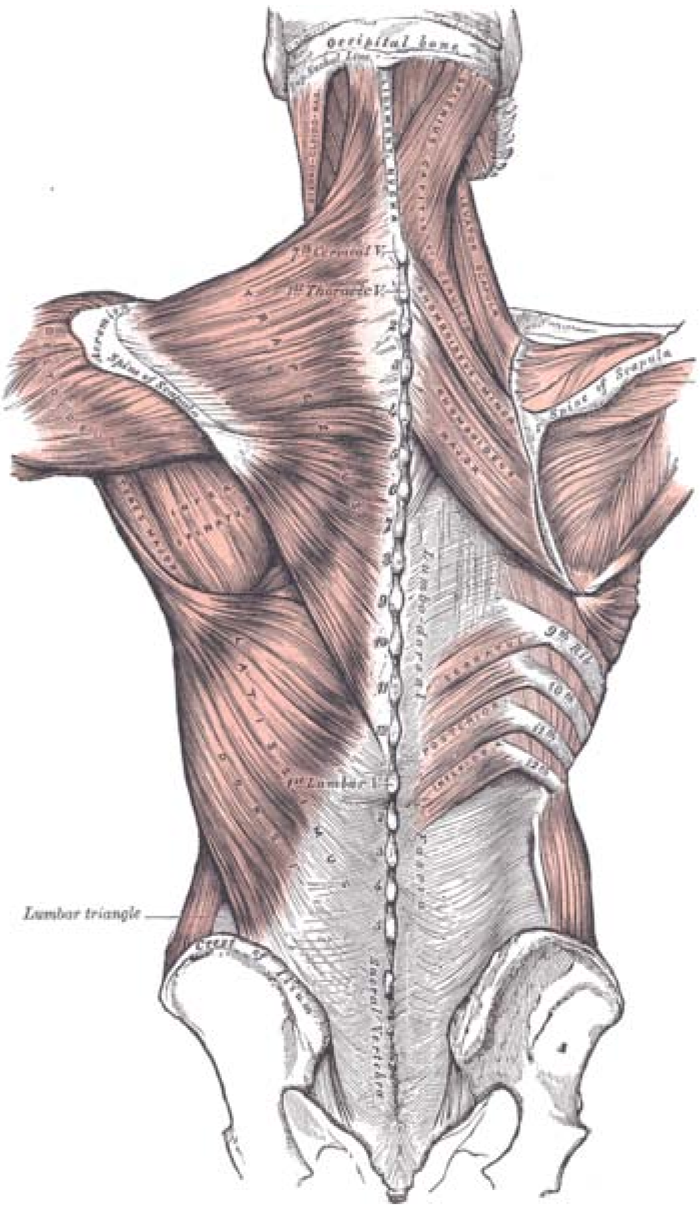
Vertebral column.



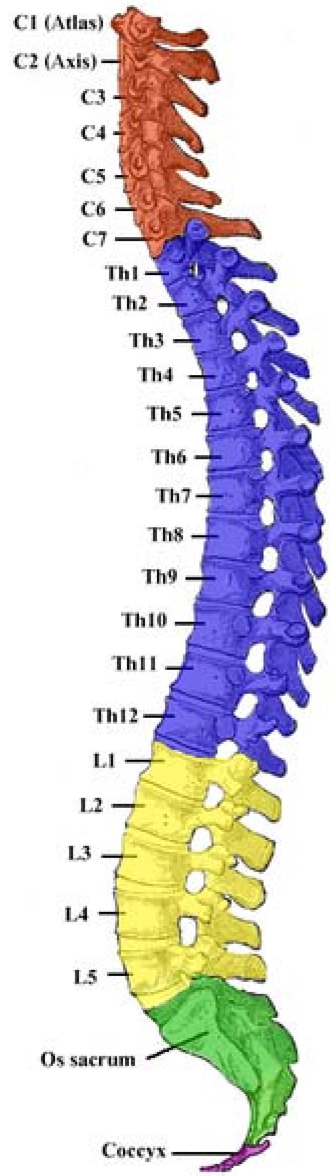
The spinal cord nested in the vertebral column.



Human skeleton back



Relation of the vertebral column to the surrounding muscles.



Vertebral column.

In other animals

In all animals, vertebrae are defined by the regions of the vertebral column they occur in. Cervical vertebrae are those in the neck area. With exception of two sloth species (*Choleopus* and *Bradypus*) and the manatee (*Trichechus*), all mammals have seven cervical vertebrae. In other vertebrates it can range from a single vertebra in amphibians, to as many as 25 in swans or 76 in the extinct plesiosaur *Elasmosaurus*. The dorsal vertebrae range from the bottom of the neck to the top of the pelvis. Dorsal vertebrae attached to ribs are called thoracic vertebrae, while those without ribs are called lumbar vertebrae. The sacral vertebrae are those in the pelvic region, and range from one in amphibians, to two in most birds and modern reptiles, or up to 3 to 5 in mammals. When multiple sacral vertebrae are fused into a single structure, it is called the sacrum. The synsacrum is a similar fused structure found in birds that is composed of the sacral, lumbar, and some of the thoracic and caudal vertebra, as well as the pelvic girdle. Caudal vertebrae compose the tail, and the final few can be fused into the pygostyle in birds, or into the coccygeal or tail bone in chimpanzees (and humans).

Structure of individual vertebrae

Individual vertebrae are composed of a centrum (body), arches protruding from the top and bottom of the centrum, and various processes projecting from the centrum and/or arches. An arch extending from the top of the centrum is called a neural arch, while the hemal arch or chevron is found underneath the centrum in the caudal (tail) vertebrae of fish, most reptiles, some birds, and some mammals with long tails. The vertebral processes can either give the structure rigidity, help them articulate with ribs, or serve as muscle attachment points. Common types are transverse process, diapophyses, parapophyses, and zygapophyses (both the cranial zygapophyses and the caudal zygapophyses).

Classification

The centra of the vertebra can be classified based upon the fusion of its elements. In aspidospondyly, bones such as the neural spine, the pleurocentrum and the intercentrum are separate ossifications. Fused elements, however, classify a vertebra as having holospondyly.

A vertebra can also be described in terms of the shape of the ends of the centra. Centra with flat ends are *acoelous*, like those in mammals. These flat ends of the centra are especially good at supporting and distributing compressive forces. *Amphicoelous* vertebra have centra with both ends concave. This shape is common in fish, where most motion is limited. Amphicoelous centra often are integrated with a full notochord. *Procoelous* vertebrae are anteriorly concave and posteriorly convex. They are found in frogs and modern reptiles. *Opisthocoelous* vertebrae are the opposite, possessing anterior convexity and posterior concavity. They are found in salamanders. *Heterocoelous* vertebrae have saddle-shaped articular surfaces. This type of configuration is seen in turtles that retract their necks, and birds, because it permits extensive lateral and vertical flexion motion without stretching the nerve cord too extensively or wringing it about its long axis.

Fish and amphibians

The vertebrae of lobe-finned fishes consist of three discrete bony elements. The vertebral arch surrounds the spinal cord, and is of broadly similar form to that found in most other vertebrates. Just beneath the arch lies a small plate-like **pleurocentrum**, which protects the upper surface of the notochord, and below that, a larger arch-shaped **intercentrum** to protect the lower border. Both of these structures are embedded within a single cylindrical mass of cartilage. A similar arrangement was found in the primitive

Labyrinthodonts, but in the evolutionary line that led to reptiles (and hence, also to mammals and birds), the intercentrum became partially or wholly replaced by an enlarged pleurocentrum, which in turn became the bony vertebral body.

In most ray-finned fishes, including all teleosts, these two structures are fused with, and embedded within, a solid piece of bone superficially resembling the vertebral body of mammals. In living amphibians, there is simply a cylindrical piece of bone below the vertebral arch, with no trace of the separate elements present in the early tetrapods.

In cartilagenous fish, such as sharks, the vertebrae consist of two cartilagenous tubes. The upper tube is formed from the vertebral arches, but also includes additional cartilagenous structures filling in the gaps between the vertebrae, and so enclosing the spinal cord in an essentially continuous sheath. The lower tube surrounds the notochord, and has a complex structure, often including multiple layers of calcification.

Lampreys have vertebral arches, but nothing resembling the vertebral bodies found in all higher vertebrates. Even the arches are discontinuous, consisting of separate pieces of arch-shaped cartilage around the spinal cord in most parts of the body, changing to long strips of cartilage above and below in the tail region. Hagfishes lack a true vertebral column, and are therefore not properly considered vertebrates, but a few tiny neural arches are present in the tail.

Amniotes

The general structure of human vertebrae is fairly typical of that found in mammals, reptiles, and birds. The shape of the vertebral body does, however, vary somewhat between different groups. In mammals, such as humans, it typically has flat upper and lower surfaces, while in reptiles the anterior surface commonly has a concave socket into which the expanded convex face of the next vertebral body fits. Even these patterns are only generalisations, however, and there may be variation in form of the vertebrae along the length of the spine even within a single species. Some unusual variations include the saddle-shaped sockets between the cervical vertebrae of birds and the presence of a narrow hollow canal running down the centre of the vertebral bodies of geckos and tuataras, containing a remnant of the notochord.

Reptiles often retain the primitive intercentra, which are present as small crescent-shaped bony elements lying between the bodies of adjacent vertebrae; similar structures are often found in the caudal vertebrae of mammals. In the tail, these are attached to chevron-shaped bones called **haemal arches**, which attach below the base of the spine, and help to support the musculature. These latter bones are probably homologous with the ventral ribs of fish. The number of vertebrae in the spines of reptiles is highly variable, and may be several hundred in some species of snake.

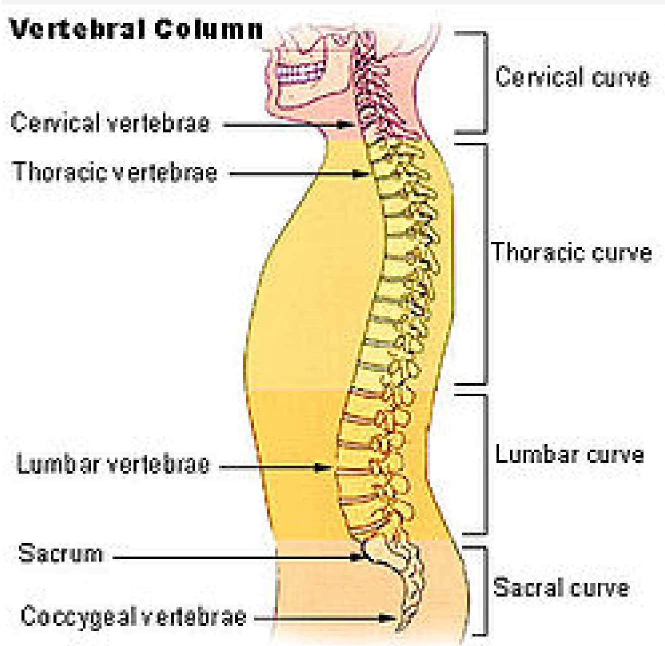
In birds, there is a variable number of cervical vertebrae, which often form the only truly flexible part of the spine. The thoracic vertebrae are partially fused, providing a solid brace for the wings during flight. The sacral vertebrae are fused with the lumbar vertebrae, and some thoracic and caudal vertebrae, to form a single structure, the **synsacrum**, which is thus of greater relative length than the sacrum of mammals. In living birds, the remaining caudal vertebrae are fused into a further bone, the pygostyle, for attachment of the tail feathers.

Aside from the tail, the number of vertebrae in mammals is generally fairly constant. There are almost always seven cervical vertebrae (sloths and manatees are among the few exceptions), followed by around twenty or so further vertebrae, divided between the thoracic and lumbar forms, depending on the number of ribs. There are generally three to five vertebrae with the sacrum, and anything up to fifty caudal vertebrae.

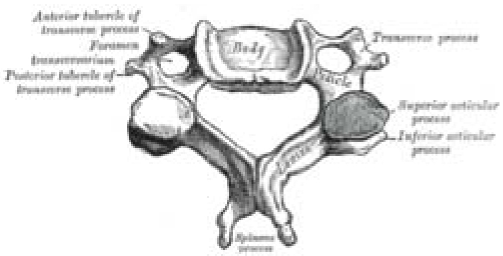
Chapter 2

Cervical Vertebrae

Bone: cervical vertebrae



Vertebral column



A human cervical vertebra

Latin	*vertebrae cervicales*
Gray's	*subject #21 97*
MeSH	*Cervical+vertebrae*

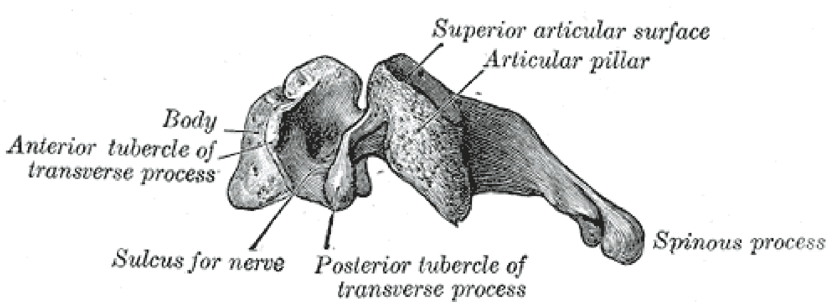
In vertebrates, **cervical vertebrae** (singular: *vertebra*) are those vertebrae immediately inferior to the skull.

Thoracic vertebrae in all mammalian species are defined as those vertebrae which also carry a pair of ribs, and lie caudal to the cervical vertebrae. Further caudally follow the lumbar vertebrae, which also belong to the trunk, but do not carry ribs. In reptiles, all trunk vertebrae carry ribs and are called dorsal vertebrae.

In many species, though not in mammals, the cervical vertebrae bear ribs. In many other groups, such as lizards and saurischian dinosaurs, the cervical ribs are large; in birds they are small and completely fused to the vertebrae. The transverse processes of mammals are homologous to the cervical ribs of other amniotes.

In humans, **cervical vertebrae** are the smallest of the true vertebrae, and can be readily distinguished from those of the thoracic or lumbar regions by the presence of a foramen (hole) in each transverse process, through which passes the vertebral artery.

General characteristics (C3-C6)



Side view of a typical cervical vertebra

These are the general characteristics of the third through sixth cervical vertebrae. (The first, second, and seventh vertebrae are extraordinary, and detailed later.)

- The body of these four vertebrae is small, and broader from side to side than from front to back.
    - The *anterior* and *posterior surfaces* are flattened and of equal depth; the former is placed on a lower level than the latter, and its inferior border is prolonged downward, so as to overlap the upper and forepart of the vertebra below.
    - The *upper surface* is concave transversely, and presents a projecting lip on either side;
    - the *lower surface* is concave from front to back, convex from side to side, and presents laterally shallow concavities which receive the corresponding projecting lips of the underlying vertebra.

- The pedicles are directed laterally and backward, and are attached to the body midway between its upper and lower borders, so that the superior vertebral notch is as deep as the inferior, but it is, at the same time, narrower.

- The laminae are narrow, and thinner above than below; the vertebral foramen is large, and of a triangular form.

- The spinous process is short and bifid, the two divisions being often of unequal size.

- The superior and inferior articular processes of cervical vertebrae have fused on either or both sides to form **articular pillars**, columns of bone which project laterally from the junction of the pedicle and lamina.

- The articular facets are flat and of an oval form:
    - the *superior* face backward, upward, and slightly medially.
    - the *inferior* face forward, downward, and slightly laterally.

- The transverse processes are each pierced by the foramen transversarium, which, in the upper six vertebrae, gives passage to the vertebral artery and vein, as well as a plexus of sympathetic nerves. Each process consists of an anterior and a posterior part. These two parts are joined, outside the foramen, by a bar of bone which exhibits a deep sulcus on its upper surface for the passage of the corresponding spinal nerve.
    - The anterior portion is the homologue of the rib in the thoracic region, and is therefore named the *costal process* or *costal element*. It arises from the side of the body, is directed laterally in front of the foramen, and ends in a tubercle, the anterior tubercle.
    - The posterior part, the true transverse process, springs from the vertebral arch behind the foramen, and is directed forward and laterally; it ends in a flattened vertical tubercle, the posterior tubercle.

Special cervical vertebrae (C1, C2, and C7)

- *C1 or atlas:* The Atlas is the topmost vertebra, and – along with C2 – forms the joint connecting the skull and spine. Its chief peculiarity is that it has no body, and this is due to the fact that the body of the atlas has fused with that of the next vertebra.

- *C2 or axis:* It forms the pivot upon which C1 rotates. The most distinctive characteristic of this bone is the strong odontoid process (dens) which rises perpendicularly from the upper surface of the body. The body is deeper in front than behind, and prolonged downward anteriorly so as to overlap the upper and front part of the third vertebra.

- *C7 or vertebra prominens:* The most distinctive characteristic of this vertebra is the existence of a long and prominent spinous process, hence the name *vertebra prominens*. In some subjects, the seventh cervical vertebra is associated with an abnormal pair of ribs, known as cervical ribs. These ribs are usually small, but may occasionally compress blood vessels (such as the subclavian artery) or nerves in the brachial plexus, causing ischemic muscle pain, numbness, tingling, and weakness in the upper limb.

Movements of the cervical spine

The movement of nodding the head takes place predominantly through flexion and extension at the joint between the atlas and the occipital bone, the atlanto-occipital joint. However, the cervical spine is comparatively mobile, and some component of this movement is due to flexion and extension of the vertebral column itself.

The movement of shaking or rotating the head left and right happens almost entirely at the joint between the atlas and the axis, the atlanto-axial joint. A small amount of rotation of the vertebral column itself contributes to the movement.

Landmarks

Base of Nose and the Hard palate corresponds to C1.

Teeth (when mouth remains closed) correspond to C2.

Mandible and Hyoid bone correspond to C3.

The thyroid cartilage is from C4 to C5.

The cricoid cartilage is from C6 to C7.

Clinical significance

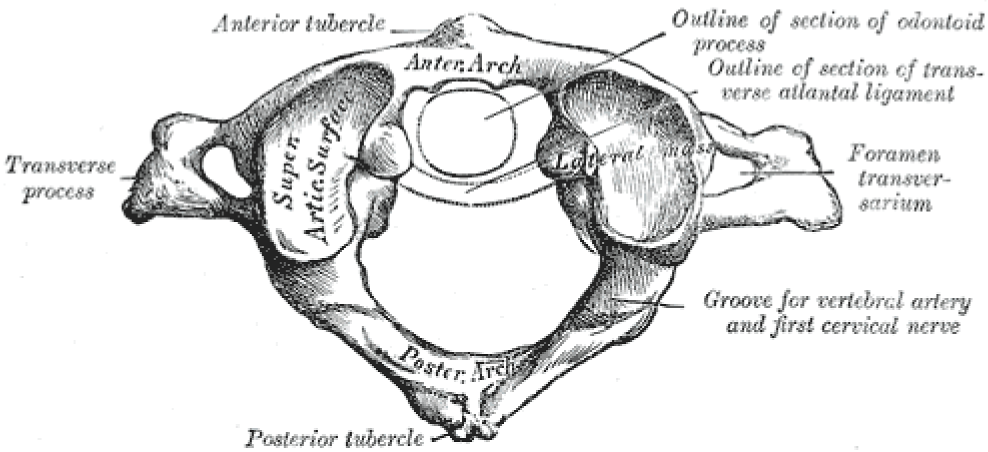
Injuries to the cervical spine are common at the level of the second cervical vertebrae, but neurological injury is uncommon.

If it does occur, however, it may cause death or profound disability, including paralysis of the arms, legs, and diaphragm, which leads to respiratory failure.

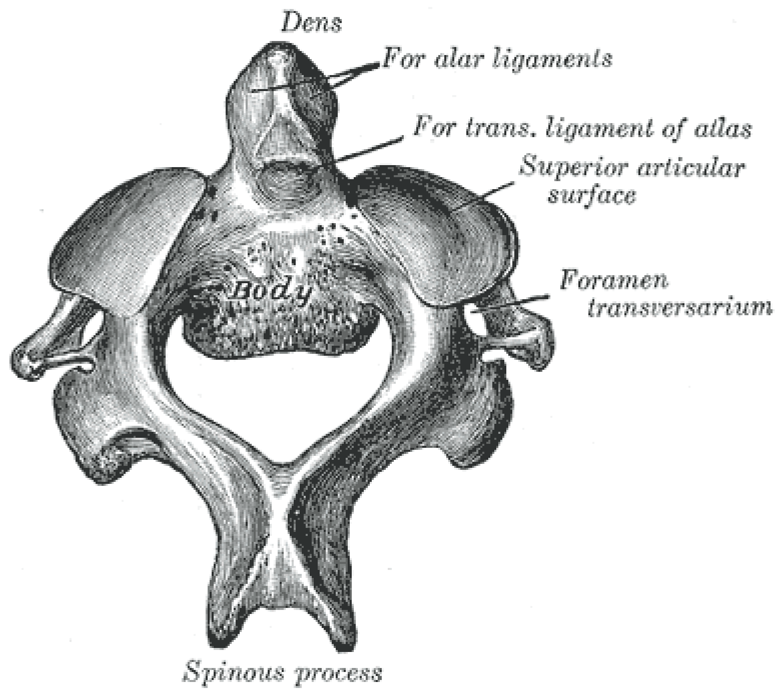
Common patterns of injury include the odontoid fracture and the hangman's fracture, both of which are often treated with immobilization in a cervical collar or Halo brace.

A common EMS practice is to immobilize a patient's cervical spine to prevent further damage during transport to Medical Aid. This practice has come under review recently as incidence rates of unstable spinal trauma can be as low as 2% in immobilized patients. Canadian studies have developed the Canadian C-Spine Rule (CCR) for physicians to decide who should receive radiological imaging.

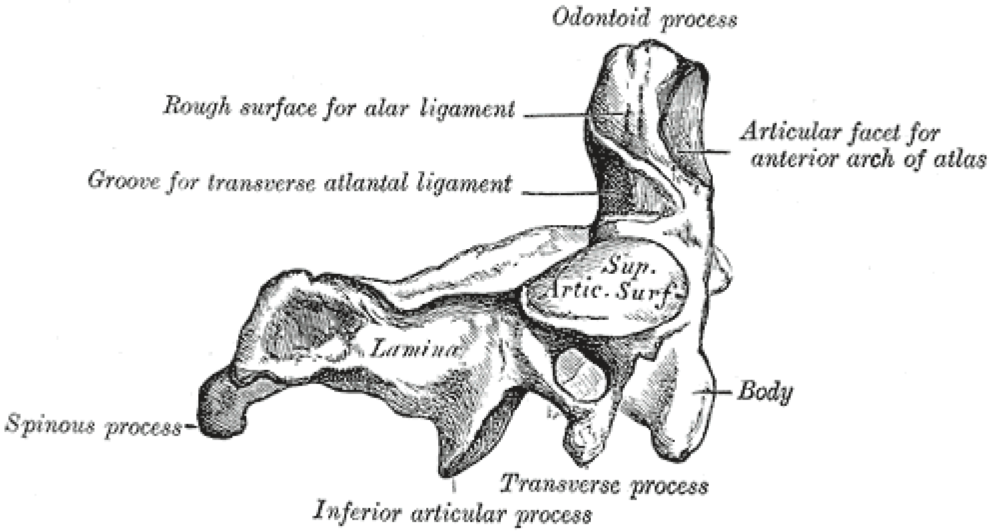
Cervical column



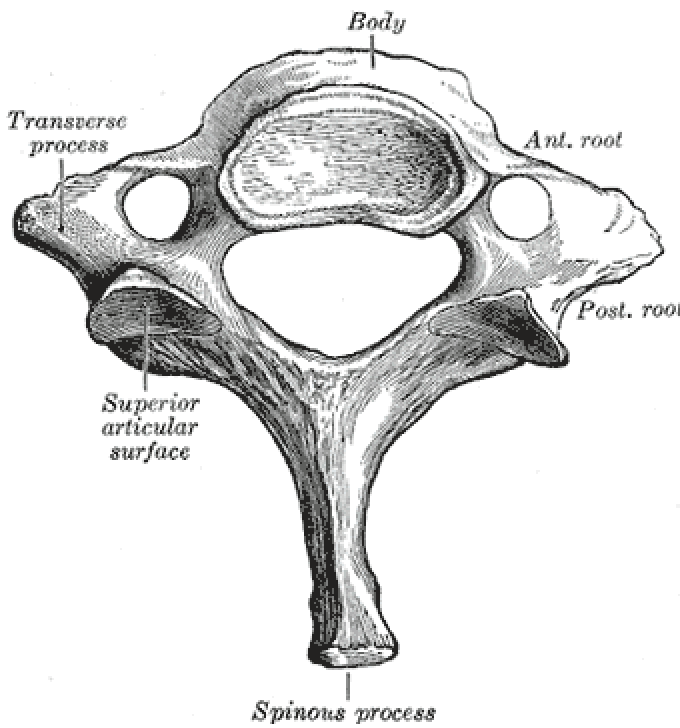
First cervical vertebra, or Atlas



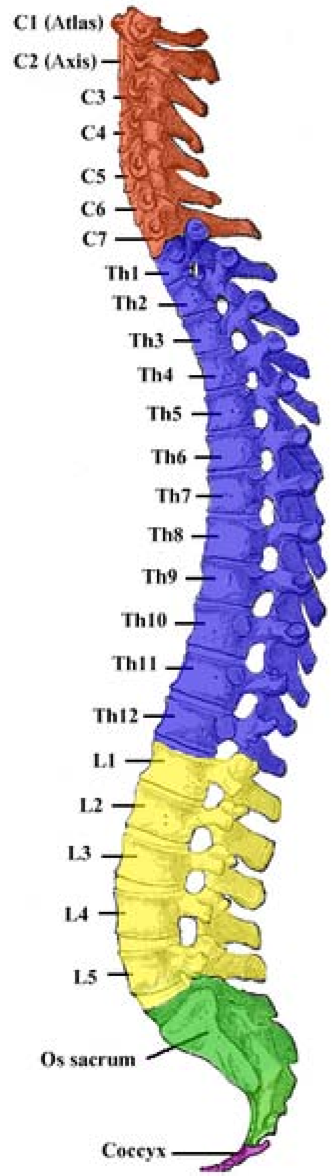
Second cervical vertebra, or epistropheus, from above.



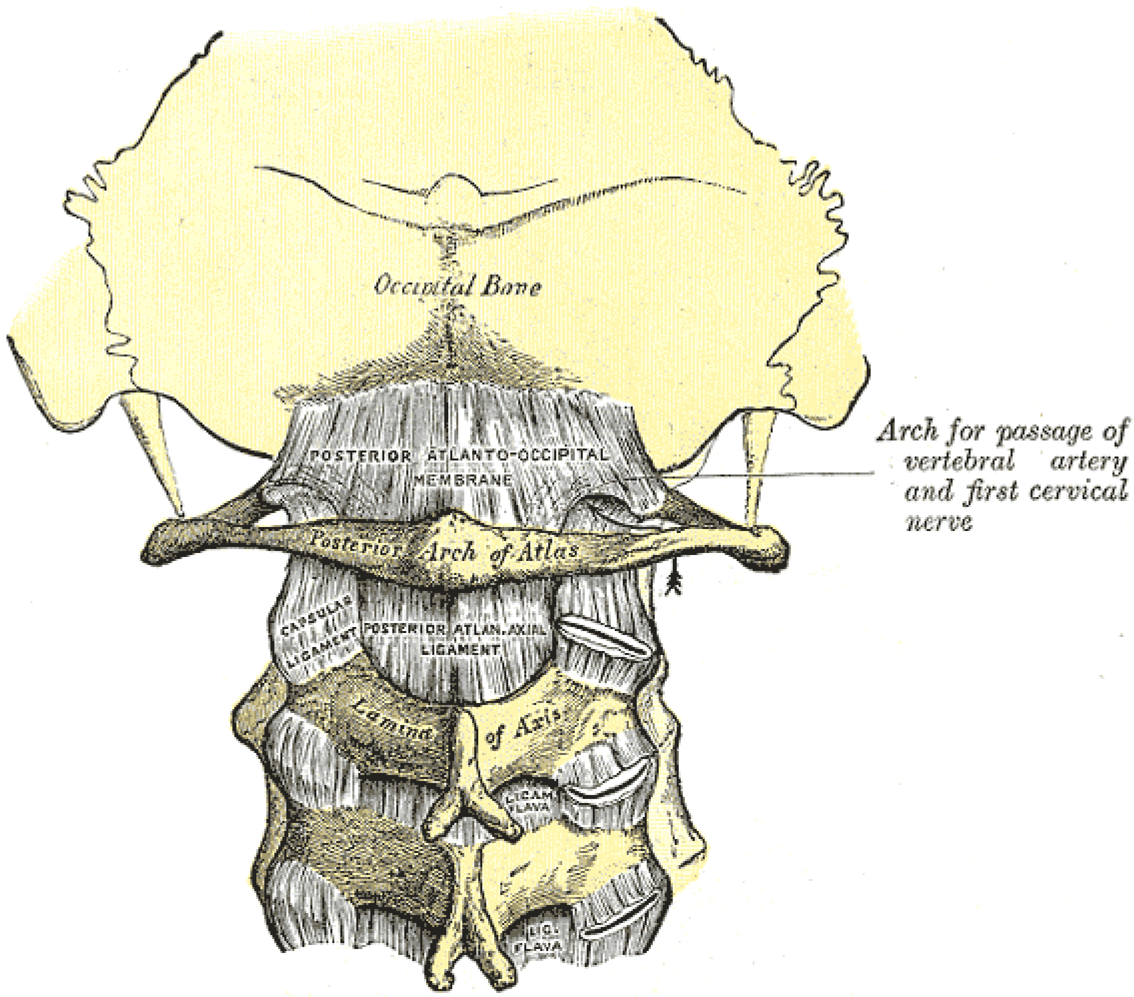
Second cervical vertebra, epistropheus, or axis, from the side.



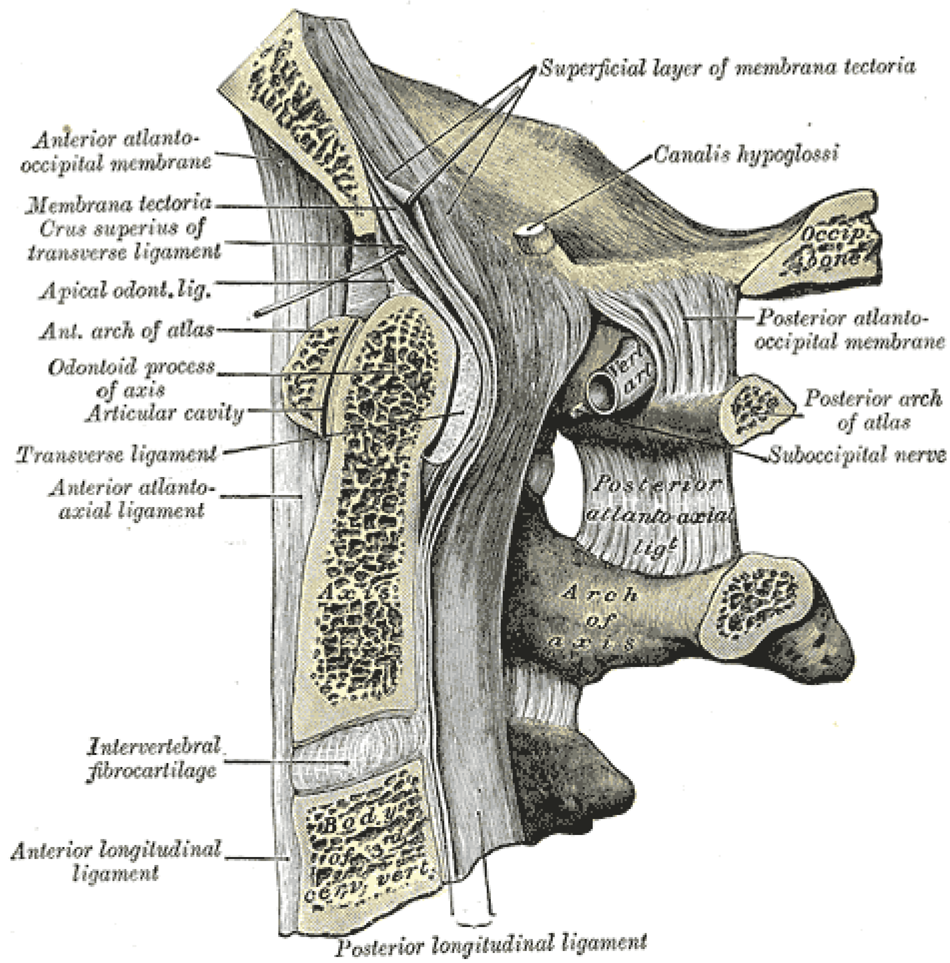
Seventh cervical vertebra.



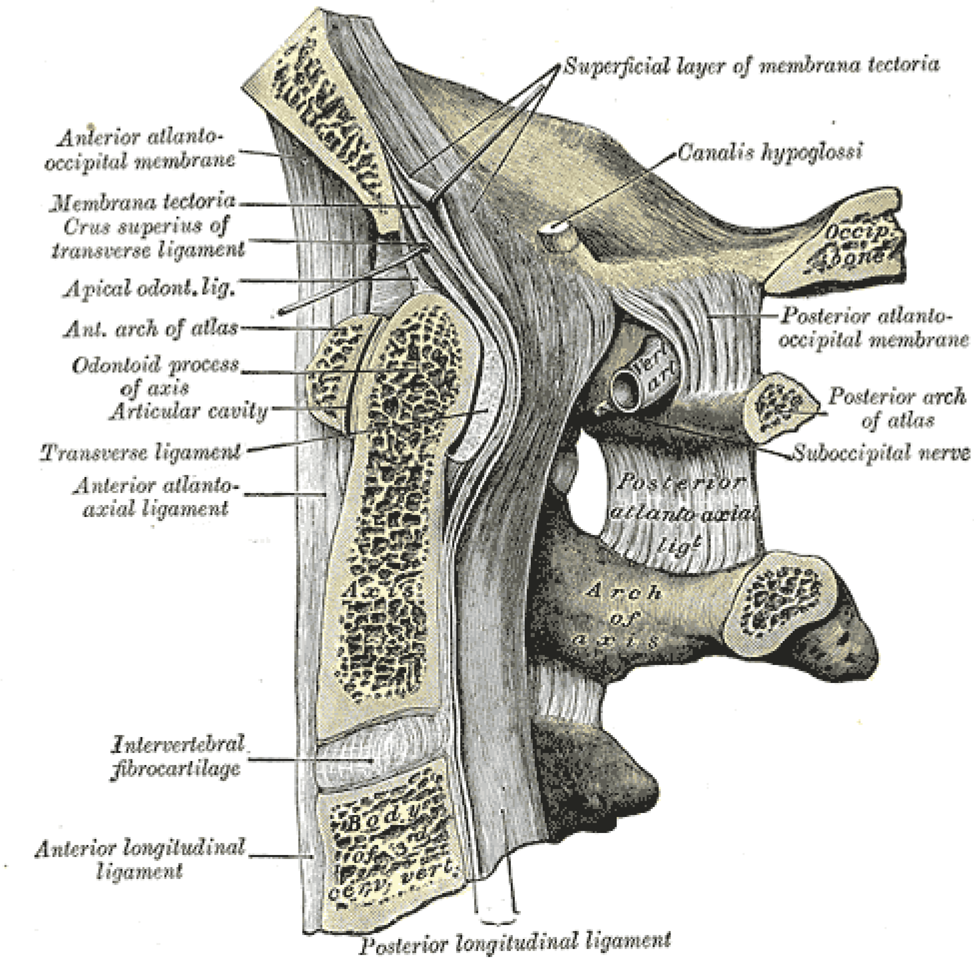
Vertebral column.



Posterior atlantoöccipital membrane and atlantoaxial ligament.



Median sagittal section through the occipital bone and first three cervical vertebræ.

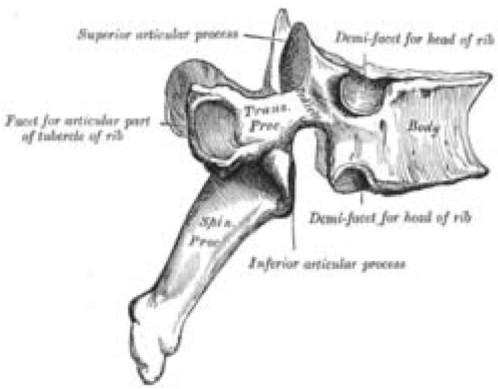


Section of the neck at about the level of the sixth cervical vertebra.

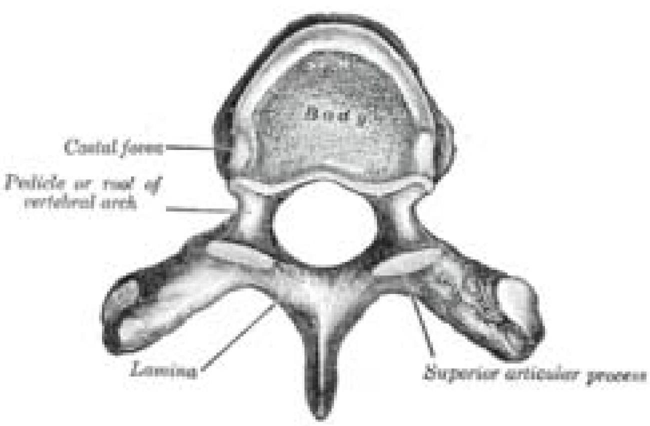
Chapter 3

Thoracic Vertebrae

Bone: thoracic vertebrae



A typical thoracic vertebra



A typical thoracic vertebra, viewed from above.

Latin	*vertebrae thoracales*
Gray's	*subject #22 102*
MeSH	*Thoracic+Vertebrae*

In human anatomy, twelve **thoracic vertebrae** compose the middle segment of the vertebral column, between the cervical vertebrae and the lumbar vertebrae. They are intermediate in size between those of the cervical and lumbar regions; they increase in size as one proceeds down the spine, the upper vertebrae being much smaller than those in the lower part of the region. They are distinguished by the presence of facets on the sides of the bodies for articulation with the heads of the ribs, and facets on the transverse processes of all, except the eleventh and twelfth, for articulation with the tubercles of the ribs.

General characteristics

These are the general characteristics of the second through eighth thoracic vertebrae. The first and ninth through twelfth vertebrae contain certain peculiarities, and are detailed below.

The **bodies** in the middle of the thoracic region are heart-shaped, and as broad in the antero-posterior as in the transverse direction. At the ends of the thoracic region they resemble respectively those of the cervical and lumbar vertebrae. They are slightly thicker behind than in front, flat above and below, convex from side to side in front, deeply concave behind, and slightly constricted laterally and in front. They present, on either side, two costal demi-facets, one above, near the root of the pedicle, the other below, in front of the inferior vertebral notch; these are covered with cartilage in the fresh state, and, when the vertebrae are articulated with one another, form, with the intervening intervertebral fibrocartilages, oval surfaces for the reception of the heads of the ribs.

The **pedicles** are directed backward and slightly upward, and the inferior vertebral notches are of large size, and deeper than in any other region of the vertebral column.

The **laminae** are broad, thick, and imbricated — that is to say, they overlap those of subjacent vertebrae like tiles on a roof.

The **vertebral foramen** is small, and of a circular form.

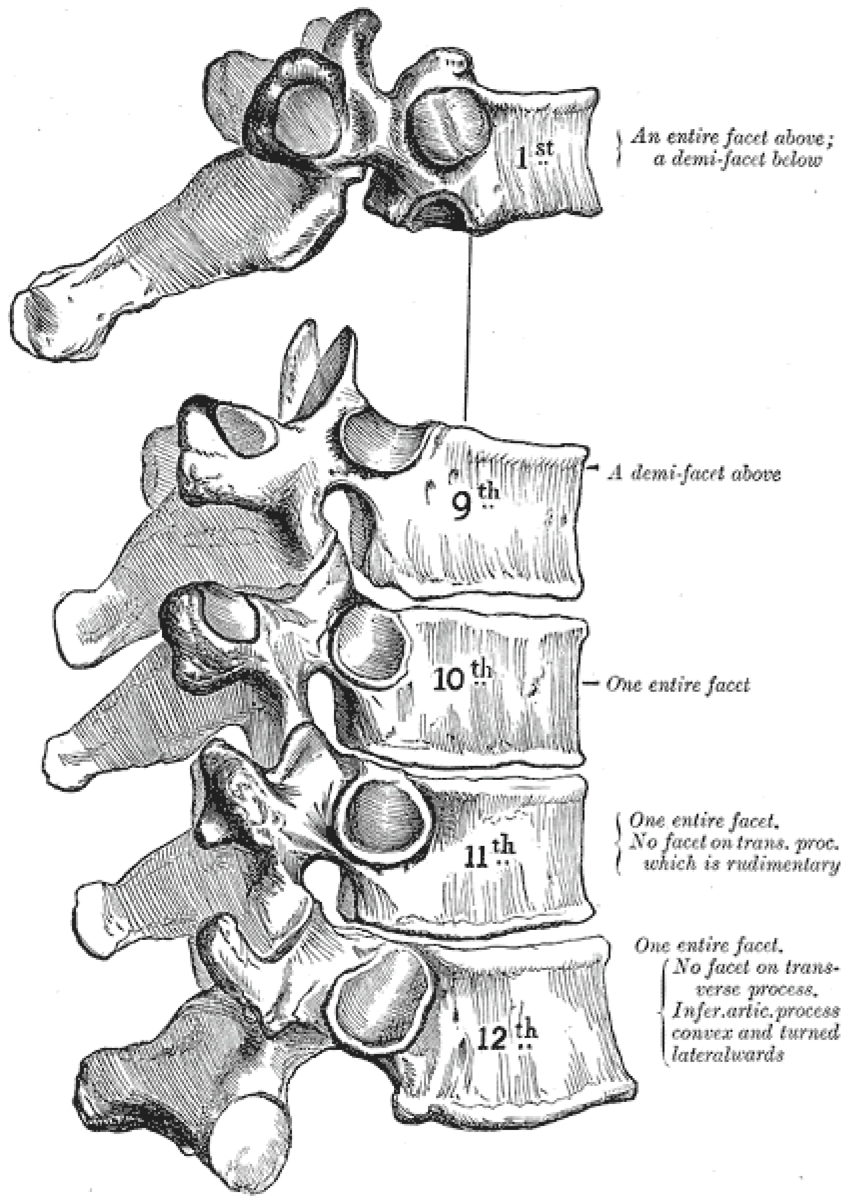
The **spinous process** is long, triangular on coronal section, directed obliquely downward, and ends in a tuberculated extremity. These processes overlap from the fifth to the eighth, but are less oblique in direction above and below.

The **superior articular processes** are thin plates of bone projecting upward from the junctions of the pedicles and laminae; their articular facets are practically flat, and are directed backward and a little lateralward and upward.

The **inferior articular processes** are fused to a considerable extent with the laminae, and project but slightly beyond their lower borders; their facets are directed forward and a little medialward and downward.

The **transverse processes** arise from the arch behind the superior articular processes and pedicles; they are thick, strong, and of considerable length, directed obliquely backward and lateralward, and each ends in a clubbed extremity, on the front of which is a small, concave surface, for articulation with the tubercle of a rib. *

Individual thoracic vertebrae



The first and ninth through twelfth thoracic vertebra have some peculiarities

First thoracic vertebra

The first thoracic vertebra has, on either side of the **body**, an entire articular facet for the head of the first rib, and a demi-facet for the upper half of the head of the second rib.

The body is like that of a cervical vertebra, being broad transversely; its upper surface is concave, and lipped on either side.

The **superior articular surfaces** are directed upward and backward; the **spinous process** is thick, long, and almost horizontal.

The **transverse processes** are long, and the upper vertebral notches are deeper than those of the other thoracic vertebrae.

The thoracic spinal nerve 1 (T1) passes out underneath it.

Second thoracic vertebra

The thoracic spinal nerve 2 (T2) passes out underneath it.

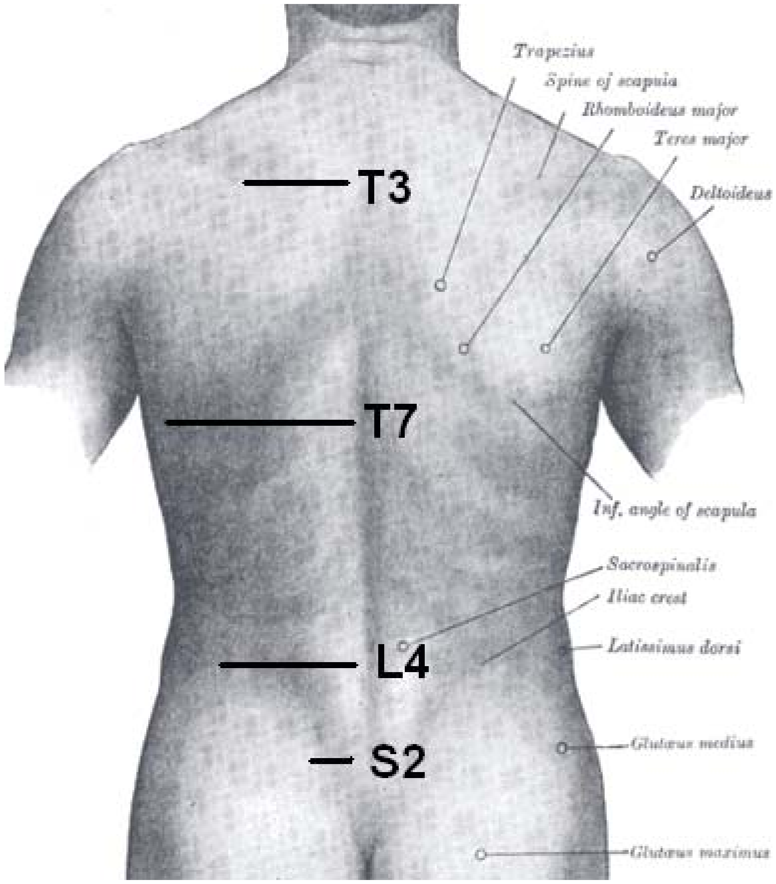
Third thoracic vertebra

The thoracic spinal nerve 3 out underneath it.

Fourth thoracic vertebra

The fourth thoracic vertebra, together with the fifth, is at the same level as the sternal angle.

The thoracic spinal nerve 4 (T4) passes out underneath it.



Surface orientation of T3 and T7, at middle of spine of scapula and at inferior angle of the scapula, respectively.

Fifth thoracic vertebra

The fifth thoracic vertebra, together with the fourth, is at the same level as the sternal angle.

The thoracic spinal nerve 5 (T5) passes out underneath it.

Sixth thoracic vertebra

The thoracic spinal nerve 6 (T6) passes out underneath it.

Seventh thoracic vertebra

The thoracic spinal nerve 7 (T7) passes out underneath it.

Eighth thoracic vertebra

The eighth thoracic vertebra is, together with the ninth thoracis vertebra, at the same level as the xiphoid process.

The thoracic spinal nerve 8 (T8) passes out underneath it.

Ninth thoracic vertebra

The ninth thoracic vertebra may have no demi-facets below. In some subjects however, it has two demi-facets on either side; when this occurs the tenth doesn't have facets but demi-facets at the upper part.

The thoracic spinal nerve 9 (T9) passes out underneath it.

Tenth thoracic vertebra

The tenth thoracic vertebra has (except in the cases just mentioned) an entire articular facet (not demi-facet) on either side, which is placed partly on the lateral surface of the pedicle. It doesn't have any kind of facet below, because the following ribs only have one facet on their heads.

The thoracic spinal nerve 10 (T10) passes out underneath it.

Eleventh thoracic vertebra

In the eleventh thoracic vertebrae the **body** approaches in its form and size to that of the lumbar vertebrae.

The articular facets for the heads of the ribs are of large size, and placed chiefly on the pedicles, which are thicker and stronger in this and the next vertebrae than in any other part of the thoracic region.

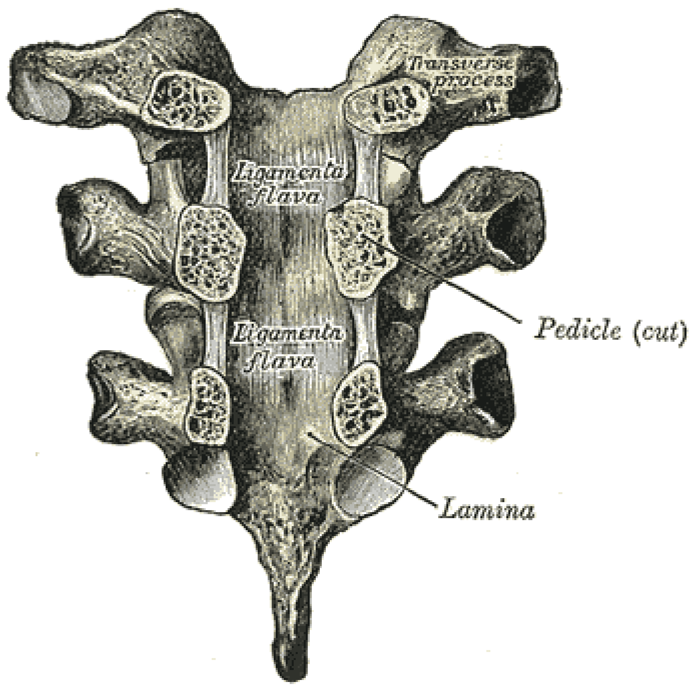
The **spinous process** is short, and nearly horizontal in direction.

The **transverse processes** are very short, tuberculated at their extremities, and have no articular facets.

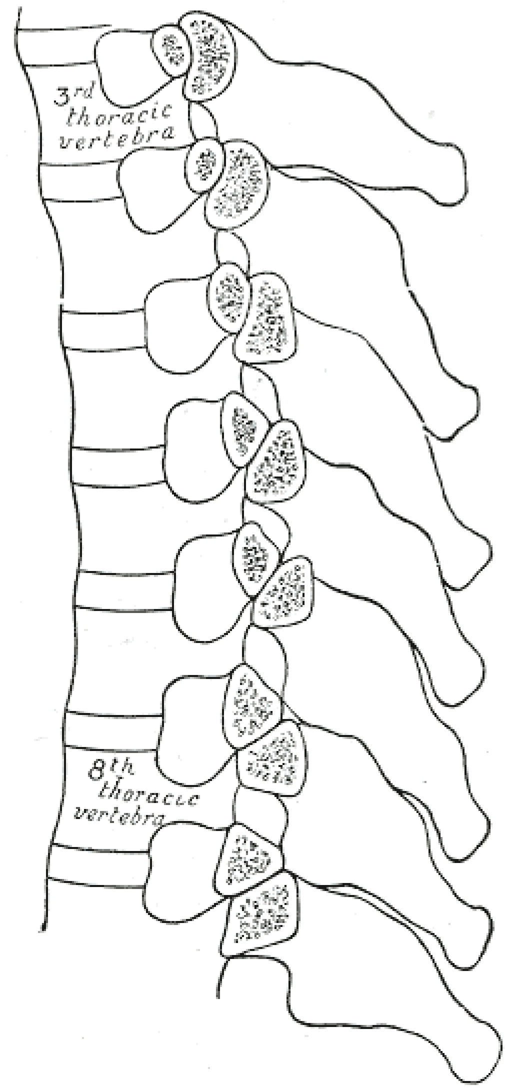
The thoracic spinal nerve 11 (T11) passes out underneath it.

Twelfth thoracic vertebra

The twelfth thoracic vertebra has the same general characteristics as the eleventh, but may be distinguished from it by its inferior articular surfaces being convex and directed lateralward, like those of the lumbar vertebrae; by the general form of the body, laminae, and spinous process, in which it resembles the lumbar vertebrae; and by each transverse process being subdivided into three elevations, the superior, inferior, and lateral tubercles: the superior and inferior correspond to the mammillary and accessory processes of the lumbar vertebrae. Traces of similar elevations are found on the transverse processes of the tenth and eleventh thoracic vertebrae.



Vertebral arches of three thoracic vertebræ viewed from the front.

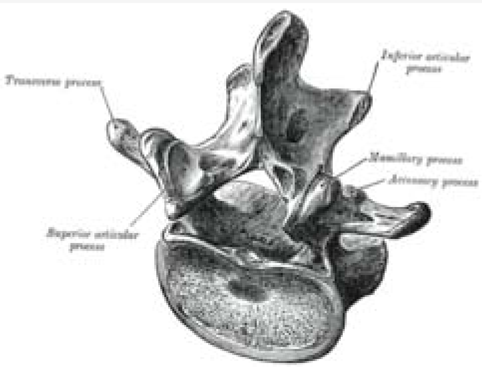


Section of the costotransverse joints from the third to the ninth inclusive.

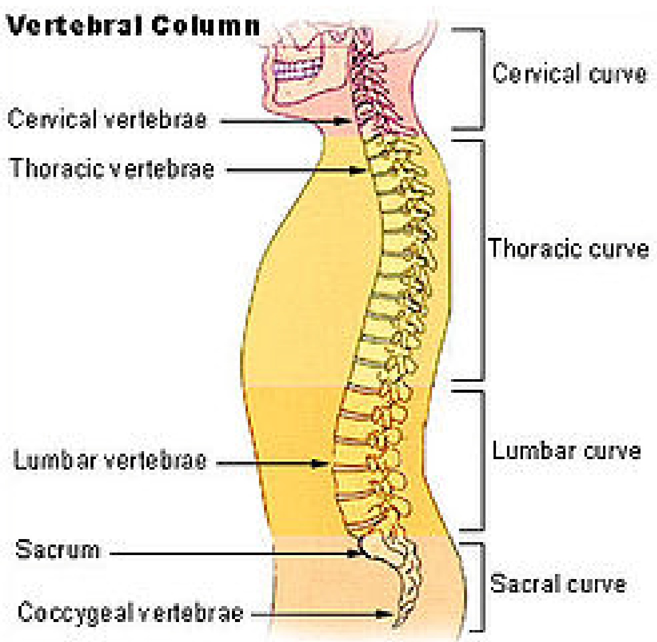
Chapter 4

Lumbar Vertebrae

Bone: Lumbar vertebrae



A typical lumbar vertebra



Vertebral column.

Gray's	*subject #23 104*

The **lumbar vertebrae** are the largest segments of the movable part of the vertebral column, and are characterized by the absence of the foramen transversarium within the transverse process, and by the absence of facets on the sides of the body. They are designated L1 to L5, starting at the top.

General characteristics

These are the general characteristics of the first through fourth lumbar vertebrae. The fifth vertebra contains certain peculiarities, which are detailed below.

As with other vertebrae, each lumbar vertebra consists of a *vertebral body* and a *vertebral arch*. The vertebral arch, consisting of a pair of *pedicles* and a pair of *laminae*, encloses the *vertebral foramen* (opening) and supports seven processes.

Body

The vertebral body of each lumbar vertebra is large, wider from side to side than from front to back, and a little thicker in front than in back. It is flattened or slightly concave above and below, concave behind, and deeply constricted in front and at the sides.

Arch

The pedicles are very strong, directed backward from the upper part of the vertebral body; consequently, the inferior vertebral notches are of considerable depth. The pedicles change in morphology from the upper lumbar to the lower lumbar. They increase in sagittal width from 9 mm to up to 18 mm at L5. They increase in angulation in the axial plane from 10 degrees to 20 degrees by L5. The pedicle is sometimes used as a portal of entrance into the vertebral body for fixation with pedicle screws or for placement of bone cement as with kyphoplasty or vertebroplasty.

The laminae are broad, short, and strong. They form the posterior portion of the vertebral arch. In the upper lumbar region the lamina are taller than wide but in the lower lumbar vertebra the lamina are wider than tall. The lamina connect the spinous process to the pedicles.

The vertebral foramen within the arch is triangular, larger than in the thoracic vertebrae, but smaller than in the cervical vertebrae.

Processes

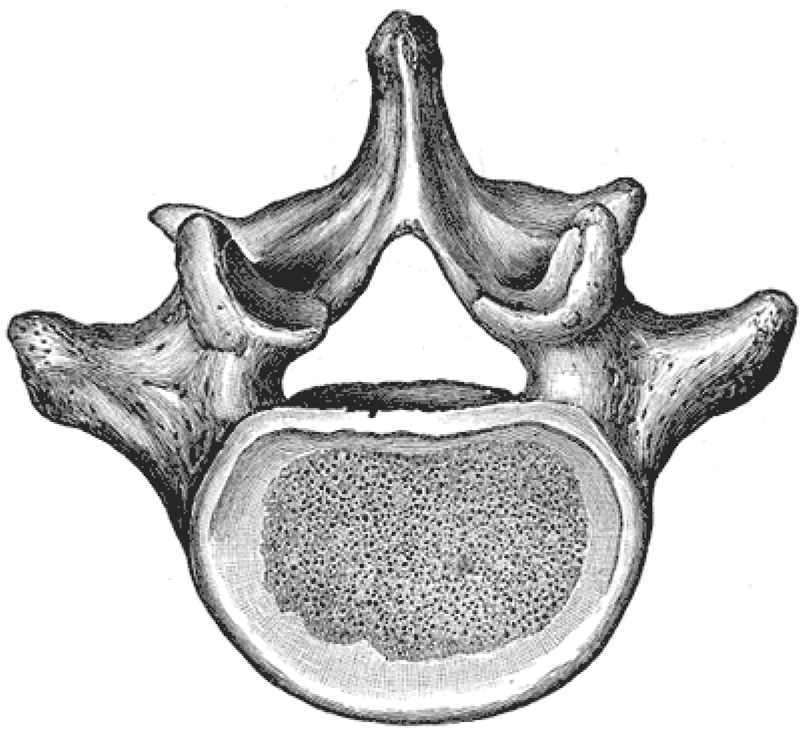
The *spinous process* is thick, broad, and somewhat quadrilateral; it projects backward and ends in a rough, uneven border, thickest below where it is occasionally notched.

The superior and inferior *articular processes* are well-defined, projecting respectively upward and downward from the junctions of pedicles and laminae. The facets on the superior processes are concave, and look backward and medialward; those on the inferior are convex, and are directed forward and lateralward. The former are wider apart than the latter, since in the articulated column the inferior articular processes are embraced by the superior processes of the subjacent vertebra.

The *transverse processes* are long and slender. They are horizontal in the upper three lumbar vertebrae and incline a little upward in the lower two. In the upper three vertebrae they arise from the junctions of the pedicles and laminae, but in the lower two they are set farther forward and spring from the pedicles and posterior parts of the vertebral bodies. They are situated in front of the articular processes instead of behind them as in the thoracic vertebrae, and are homologous with the ribs.

Of the three *tubercles* noticed in connection with the transverse processes of the lower lumbar vertebrae, the superior one is connected in the lumbar region with the back part of the superior articular process, and is named the *mammillary process*. The inferior is situated at the back part of the base of the transverse process, and is called the *accessory process*.

First to fifth lumbar vertebrae



The fifth lumbar vertebra has certain peculiarities.

Some individuals have four lumbar vertebrae, while others have six. Lumbar disorders that normally affect L5 will affect L4 or L6 in these individuals.

The first lumbar vertebra is level with the anterior end of the ninth rib. This level is also called the important transpyloric plane, since the pylorus of the stomach is at this level.

The fifth lumbar vertebra is characterized by its body being much deeper in front than behind, which accords with the prominence of the sacrovertebral articulation; by the smaller size of its spinous process; by the wide interval between the inferior articular processes, and by the thickness of its transverse processes, which spring from the body as well as from the pedicles.

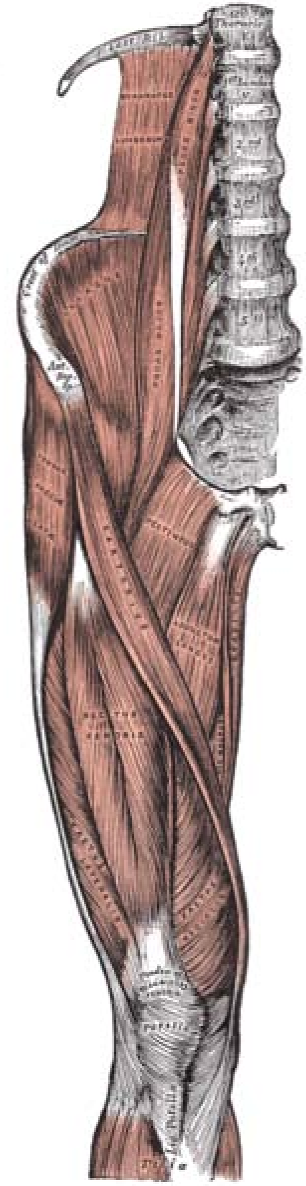
The fifth lumbar vertebra is by far the most common site of spondylolysis and spondylolisthesis.

Segmental movements

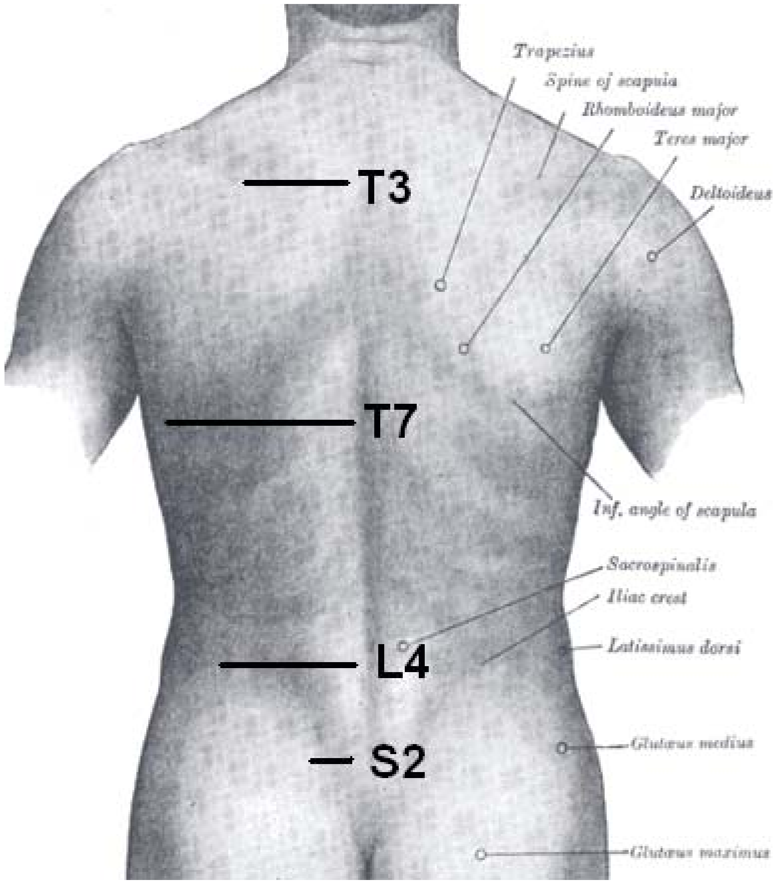
The range of segmental movements in a single segment is difficult to measure clinically, not only because of variations between individuals, but also because it is age and gender dependent. Furthermore, flexion and extension in the lumbal spine is the product of a combination of rotation and translation in the sagittal plane between each vertebra.

Ranges of segmental movements in the lumbal spine (White and Panjabi, 1990) are (in degrees):

	L1-L2	**L2-L3**	**L3-L4**	**L4-L5**	**L5-S1**
Flexion/ Extension	12	14	15	16	17
Lateral flexion	6	6	8	6	3
Axial rotation	2	2	2	2	1



Muscles of the iliac and anterior femoral regions. First lumbar vertebra second highest vertebra seen.

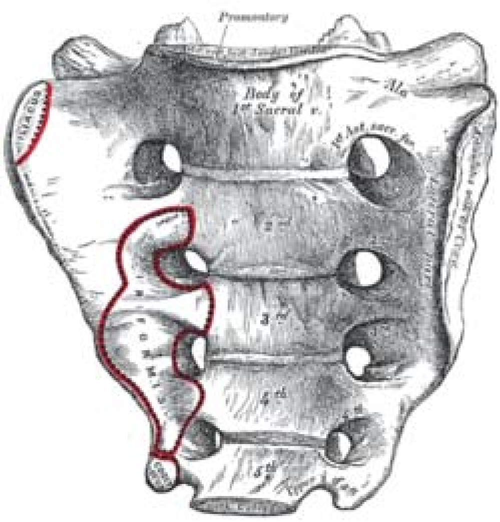


Orientation of vertebral column on surface. T3 is at level of medial part of spine of scapula. T7 is at inferior angle of the scapula. L4 is at highest point of iliac crest. S2 is at the level of posterior superior iliac spine. Furthermore, C7 is easily localized as a prominence at the lower part of the neck.

Chapter 5

Sacrum

Bone: Sacrum



Sacrum, pelvic surface

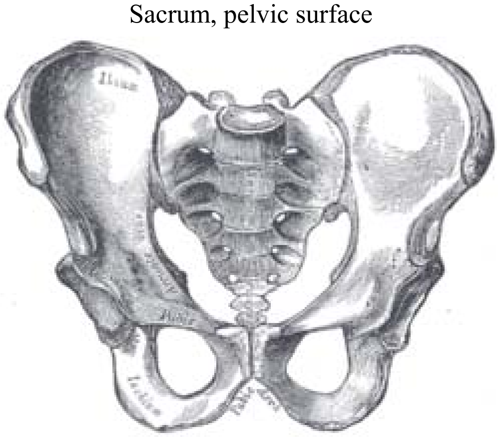


Image of pelvis. Sacrum is in center.

Latin	*os sacrum*

Gray's	*subject #24 106*
MeSH	*Sacrum*

In vertebrate anatomy the **sacrum** (plural *sacrums* or *sacra*) is a large, triangular bone at the base of the spine and at the upper and back part of the pelvic cavity, where it is inserted like a wedge between the two hip bones. Its upper part connects with the last lumbar vertebra, and bottom part with the coccyx (tailbone). In children, it consists of usually five unfused vertebrae which begin to fuse between ages 16–18 and are usually completely fused into a single bone by age 26.

It is curved upon itself and placed obliquely (that is, tilted forward). It is kyphotic — that is, concave facing forwards. The base projects forward as the sacral promontory internally, and articulates with the last lumbar vertebra to form the prominent sacrovertebral angle. The central part is curved outward towards the posterior, allowing greater room for the pelvic cavity.

Etymology

The name is derived from the Latin *sacer*, "sacred", a translation of the Greek *hieron (osteon)*, meaning sacred or strong bone. Since the sacrum is the seat of the organs of procreation, animal sacrums were offered in sacrifices. In Slavic languages and in German this bone is called the "cross bone".

Parts

- The pelvic surface of the sacrum is concave from above downward, and slightly so from side to side.
- The dorsal surface of the sacrum is convex and narrower than the pelvic.
- The lateral surface of the sacrum is broad above, but narrowed into a thin edge below.
- The base of the sacrum, which is broad and expanded, is directed upward and forward.
- The apex (*apex oss. sacri*) is directed downward, and presents an oval facet for articulation with the coccyx.
- The vertebral canal (*canalis sacralis*; sacral canal) runs throughout the greater part of the bone; above, it is triangular in form; below, its posterior wall is incomplete, from the non-development of the laminae and spinous processes. It lodges the sacral nerves, and its walls are perforated by the anterior and posterior sacral foramina through which these nerves pass out.

Articulations

The sacrum articulates with four bones:

- the last lumbar vertebra above
- the coccyx (tailbone) below
- the illium portion of the hip bone on either side

Rotation of the sacrum forward a few degrees vis-à-vis the ilia is sometimes called "nutation" (L. "nodding"), and the reverse motion "counter-nutation."

It is called the *sacrum* when referred to all of the parts combined, but *sacral vertebrae* when referred individually.

Sexual dimorphism

The sacrum is noticeably sexually dimorphic (differently-shaped in males and females).

In the female the sacrum is shorter and wider than in the male; the lower half forms a greater angle with the upper; the upper half is nearly straight, the lower half presenting the greatest amount of curvature. The bone is also directed more obliquely backward; this increases the size of the pelvic cavity and renders the sacrovertebral angle more prominent.

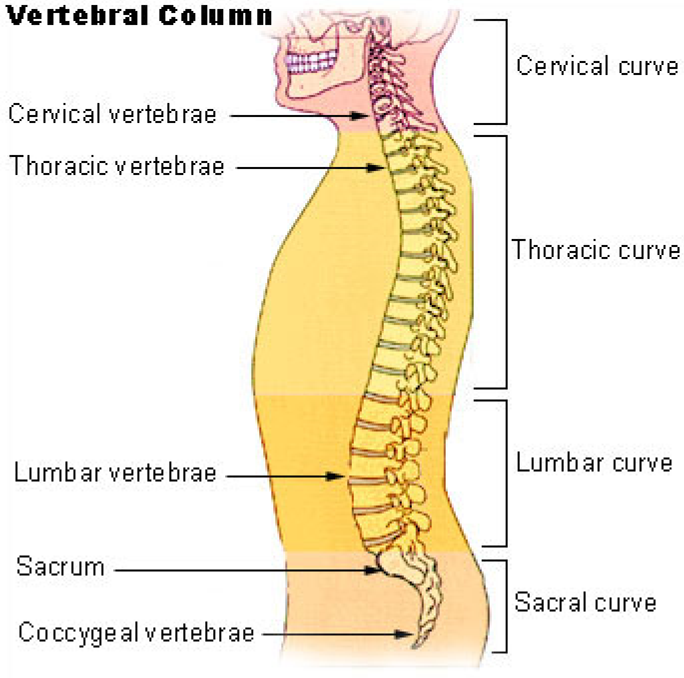
In the male the curvature is more evenly distributed over the whole length of the bone, and is altogether greater than in the female.

Variations

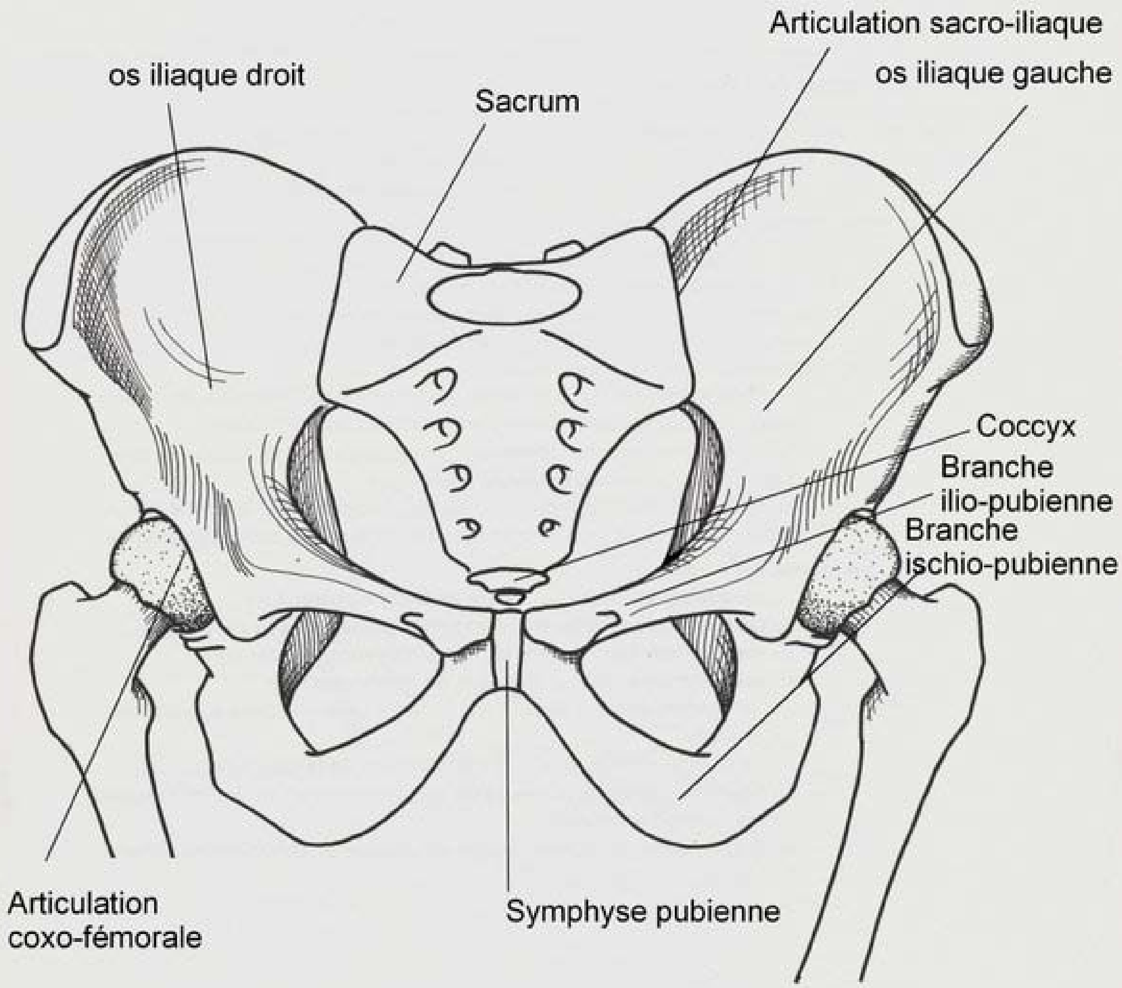
The sacrum, in some cases, consists of six pieces ; occasionally the number is reduced to four . The bodies of the first and second vertebrae may fail to unite.

Sometimes the uppermost transverse tubercles are not joined to the rest of the ala on one or both sides, or the sacral canal may be open throughout a considerable part of its length, in consequence of the imperfect development of the laminae and spinous processes.

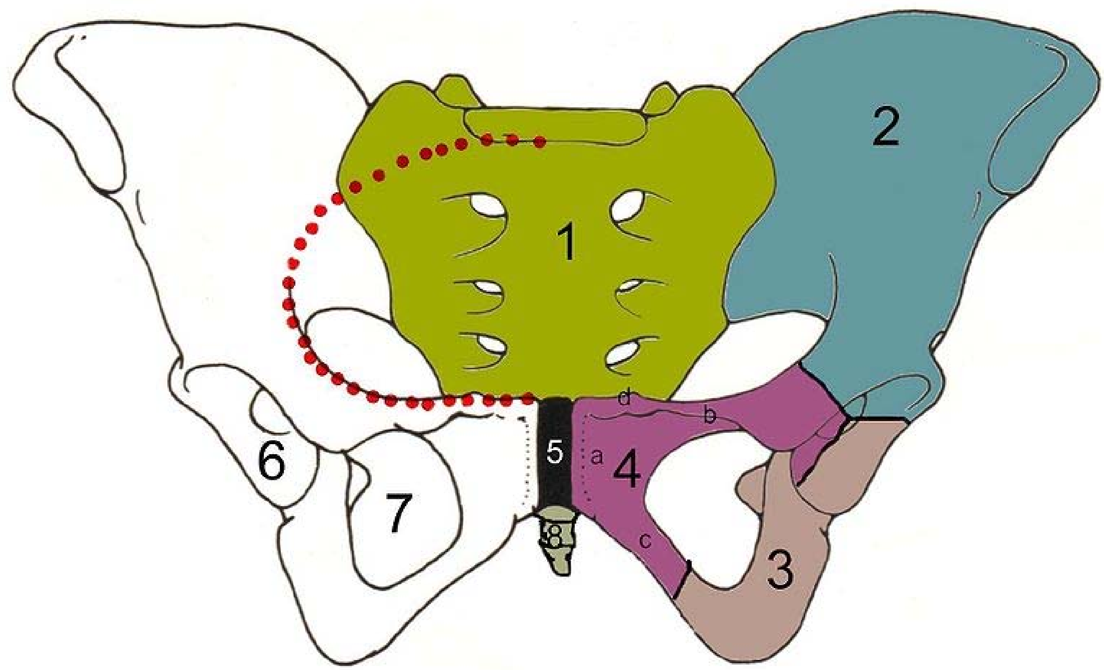
The sacrum also varies considerably with respect to its degree of curvature.



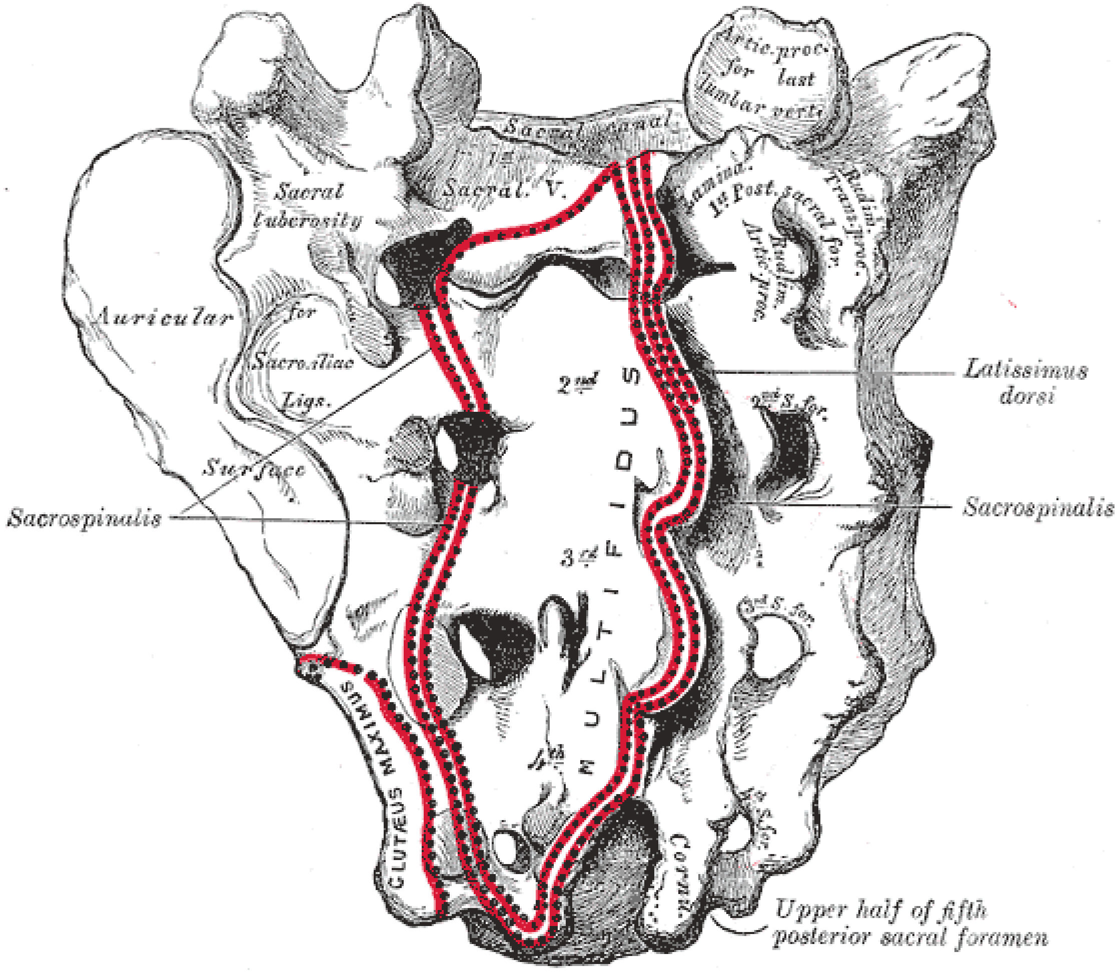
Vertebral column.



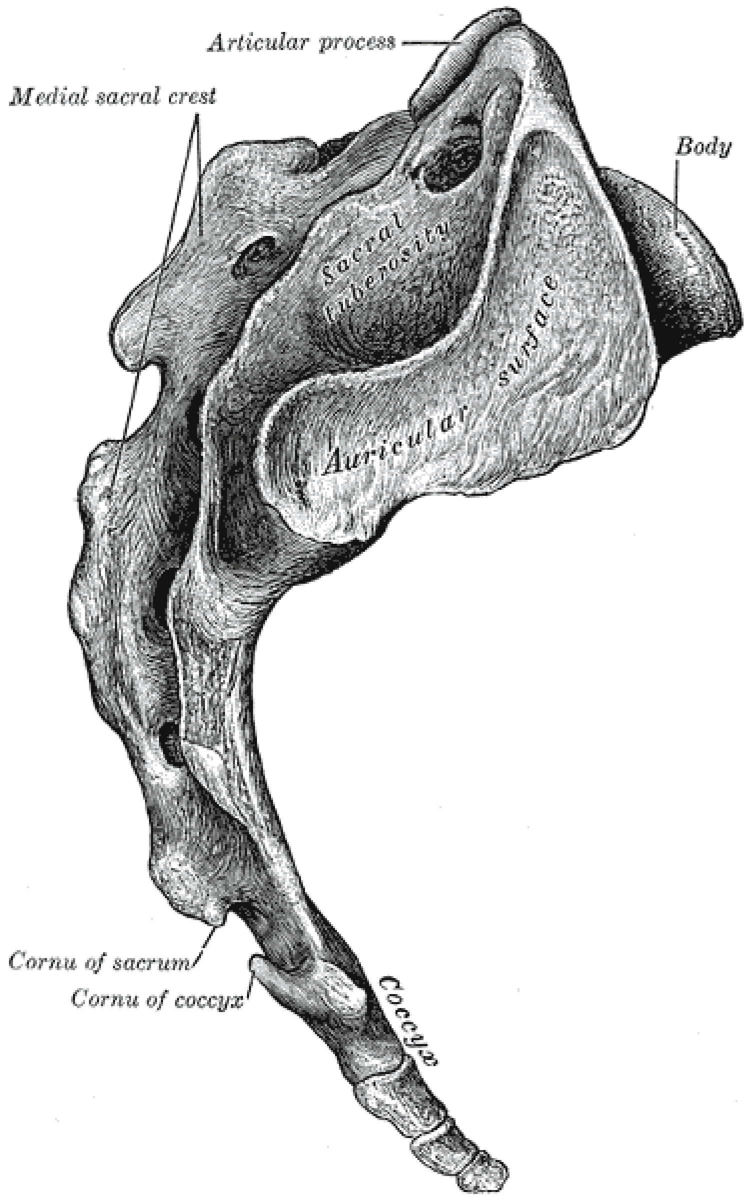
Bassin Osseux de face



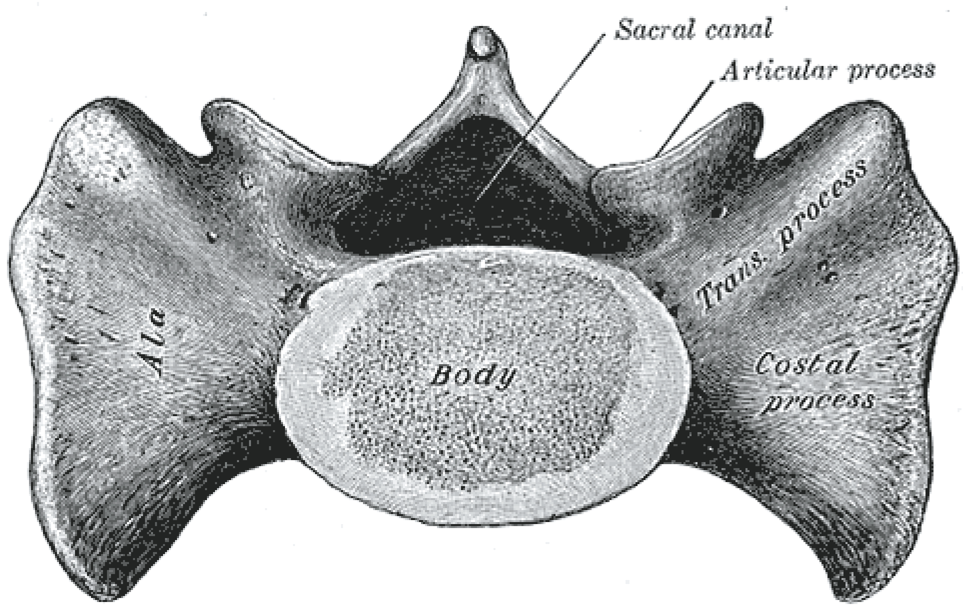
Pelvis



Sacrum, dorsal surface.

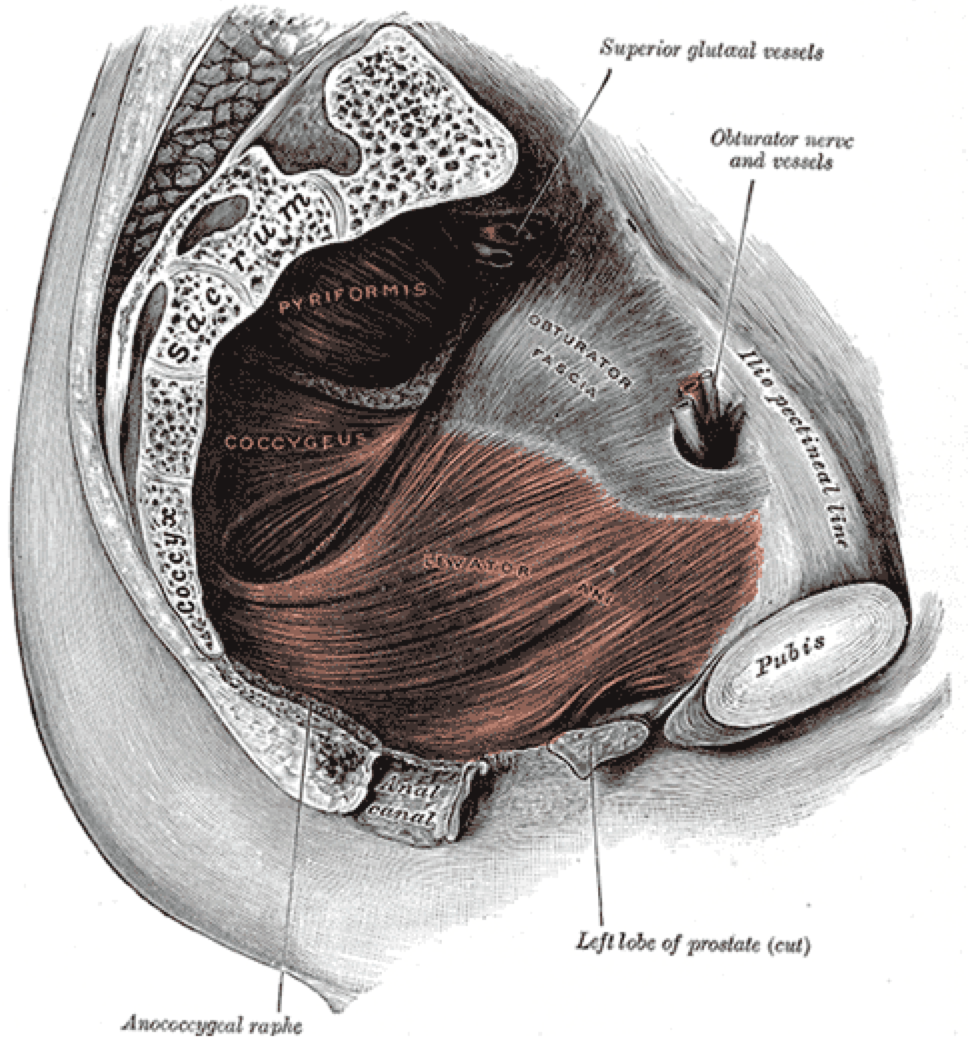


Lateral surfaces of sacrum and coccyx.

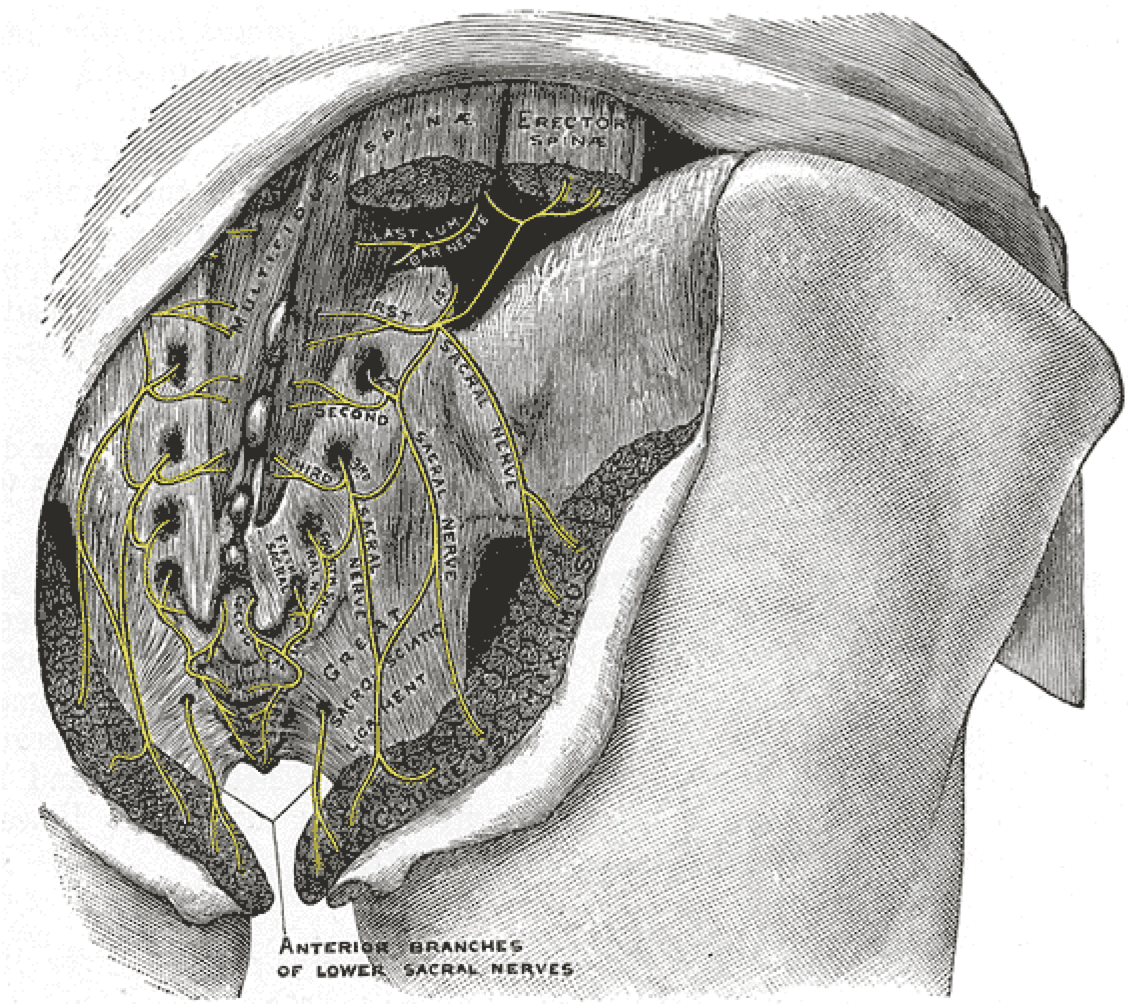


Base of sacrum.

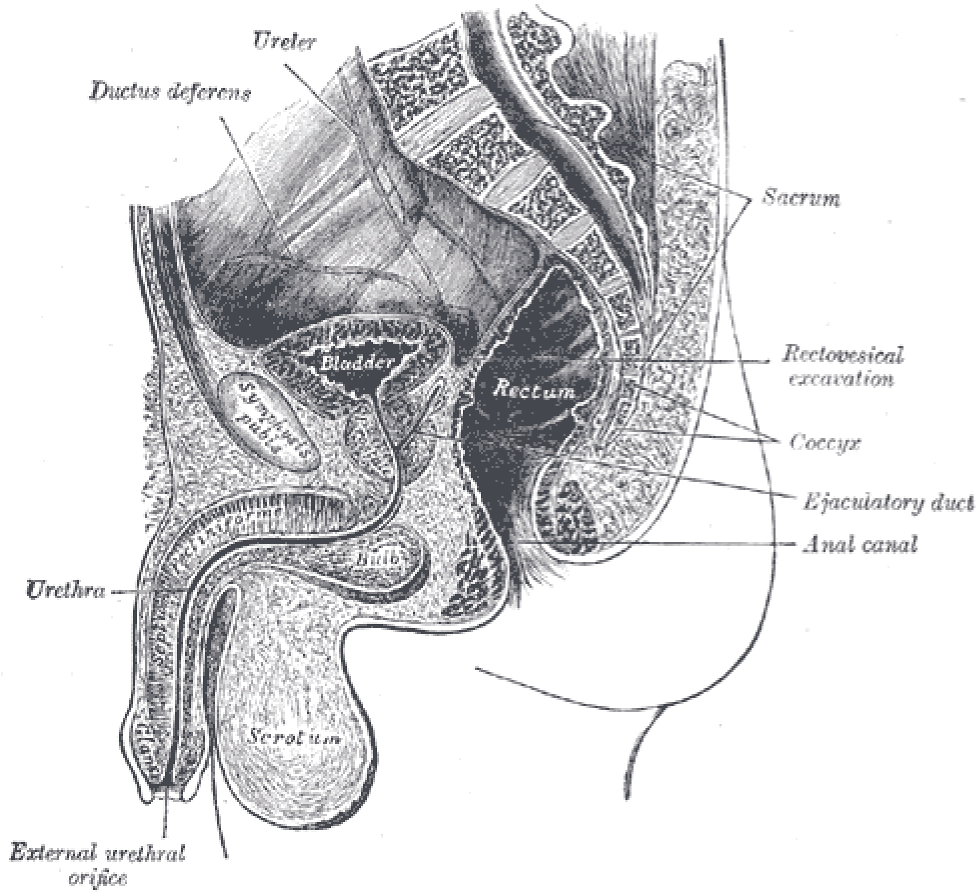
Median sagittal section of the sacrum.



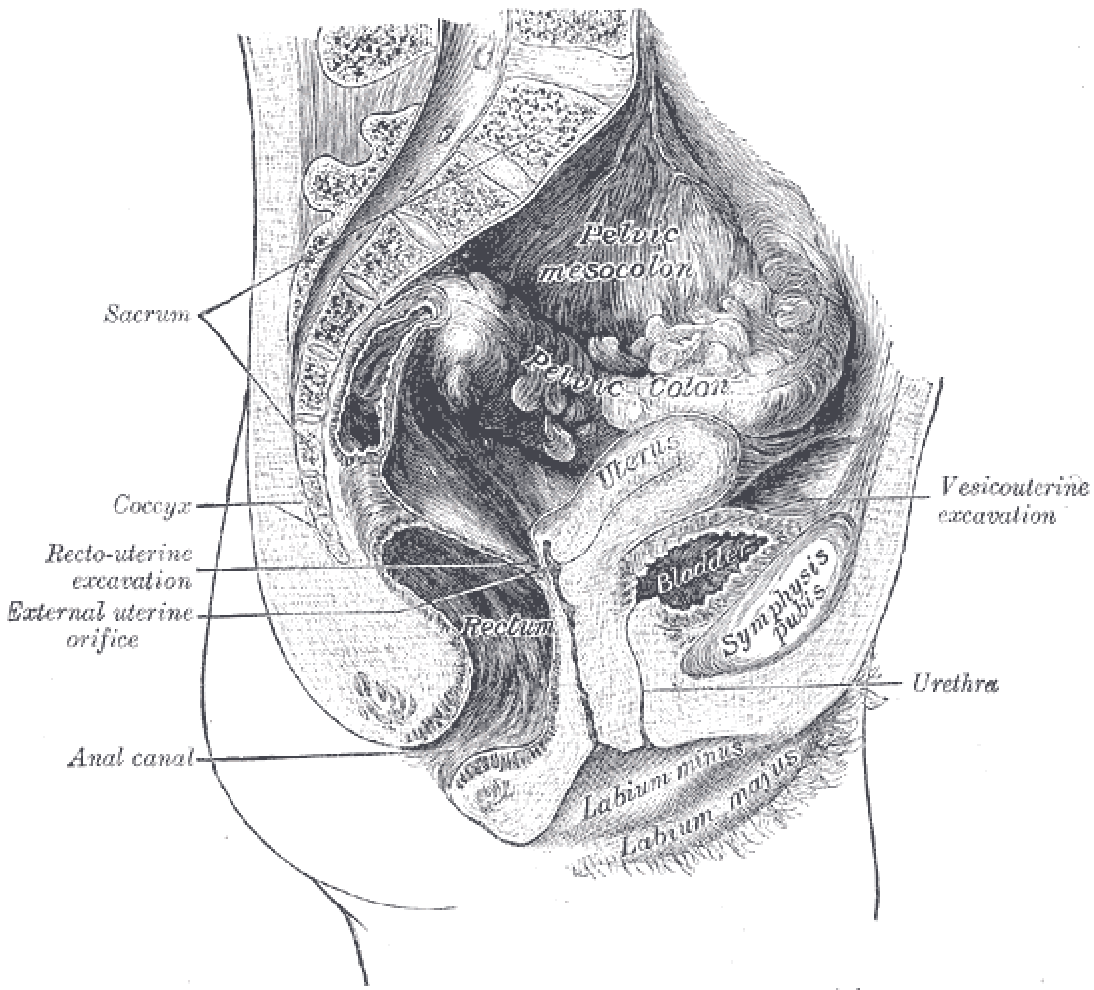
Left Levator ani from within.



The posterior divisions of the sacral nerves.



Median sagittal section of male pelvis.



Median sagittal section of female pelvis.

Chapter 6

Coccyx

Bone: Coccyx

A coccyx with four vertebrae below the sacrum.

Latin	*os coccygis*
Gray's	*subject #24 186*

MeSH	*Coccyx*

The **coccyx** is the final segment of the ape vertebral column. Comprising three to five separate or fused vertebrae (the coccygeal vertebrae) below the sacrum, it is attached to the sacrum by a fibrocartilaginous joint, the sacrococcygeal symphysis, which permits limited movement between the sacrum and the coccyx.

The term *coccyx* comes originally from the Greek κόκκυξ and means "cuckoo", referring to the curved shape of a cuckoo's beak when viewed from the side.

Function

In humans and other tailless primates (e.g. great apes) since *Nacholaphitecus* (a Miocene hominoid), the coccyx is the remnant of a vestigial tail, but still not entirely useless; it is an important attachment for various muscles, tendons and ligaments — which makes it necessary for physicians and patients to pay special attention to these attachments when considering surgical removal of the coccyx. Additionally, it is also part of the weight-bearing tripod structure which act as a support for a sitting person. When a person sits leaning forward, the ischial tuberosities and inferior rami of the ischium take most of the weight, but as the sitting person leans backward, more weight is transferred to the coccyx.

The anterior side of the coccyx serves for the attachment of a group of muscles important for many functions of the pelvic floor (i.e. defecation, continence, etc.): The levator ani muscle, which include coccygeus, iliococcygeus, and pubococcygeus. Through the anococcygeal raphé, the coccyx supports the position of the anus. Attached to the posterior side is gluteus maximus which extend the thigh during ambulation.

Many important ligaments attach to the coccyx: The anterior and posterior sacrococcygeal ligaments are the continuations of the anterior and posterior longitudinal ligaments that stretches along the entire spine. Additionally, the lateral sacrococcygeal ligaments complete the foramina for the last sacral nerve. And, lastly, some fibers of the sacrospinous and sacrotuberous ligaments (arising from the spine of the ischium and the ischial tuberosity respectively) also attach to the coccyx.

An extension of the pia mater, the filum terminale, extends from the apex of the conus, and inserts on the coccyx.

Structure

The coccyx is usually formed of four rudimentary vertebrae (sometimes five or three). It articulates superiorly with the sacrum. In each of the first three segments may be traced a rudimentary body and articular and transverse processes; the last piece (sometimes the third) is a mere nodule of bone. The transverse processes are most prominent and noticeable on the first coccygeal segment. All the segments are destitute of pedicles, laminae and spinous processes. The first is the largest; it resembles the lowest sacral vertebra, and often exists as a separate piece; the last three diminish in size from above downward.

Most anatomy books wrongly state that the coccyx is normally fused in adults. In fact it has been shown that the coccyx may consist of up to five separate bony segments, the most common configuration being two or three segments.

Surfaces

The anterior surface is slightly concave and marked with three transverse grooves that indicate the junctions of the different segments. It gives attachment to the anterior sacrococcygeal ligament and the Levatores ani and supports part of the rectum.The posterior surface is convex marked by transverse grooves similar to those on the anterior surface, and presents on either side a linear row of tubercles, the rudimentary articular processes of the coccygeal vertebrae. Of these, the superior pair are large, and are called the coccygeal cornua; they project upward, and articulate with the cornua of the sacrum, and on either side complete the foramen for the transmission of the posterior division of the fifth sacral nerve.

Borders

The lateral borders are thin and exhibit a series of small eminences, which represent the transverse processes of the coccygeal vertebrae. Of these, the first is the largest; it is flattened from before backward, and often ascends to join the lower part of the thin lateral edge of the sacrum, thus completing the foramen for the transmission of the anterior division of the fifth sacral nerve; the others diminish in size from above downward, and are often wanting. The borders of the coccyx are narrow, and give attachment on either side to the sacrotuberous and sacrospinous ligaments, to the coccygeus in front of the ligaments, and to the gluteus maximus behind them.

Apex

The apex is rounded, and has attached to it the tendon of the Sphincter ani externus. It may be bifid.

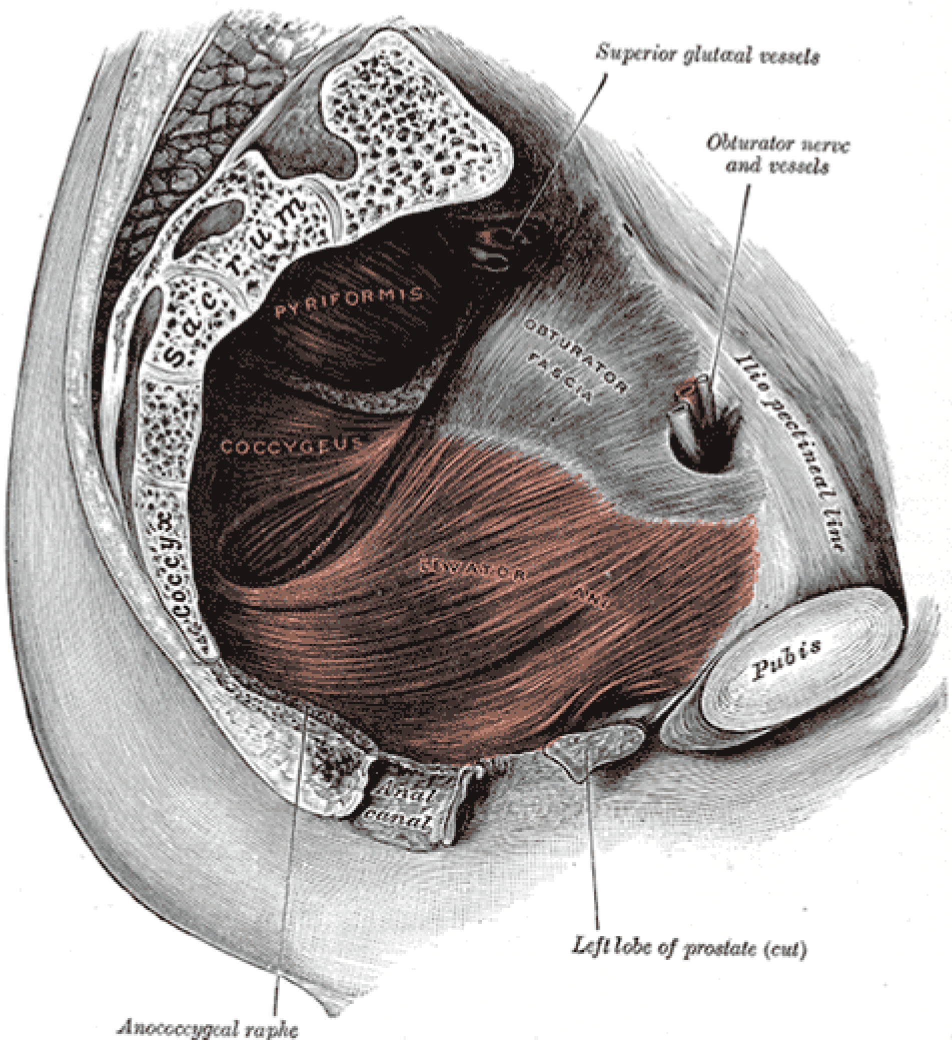
Sacrococcygeal and intercoccygeal joints

The joints are variable and may be: (1) synovial joints; (2) thin discs of fibrocartilage; (3) intermediate between these two; (4) ossified.

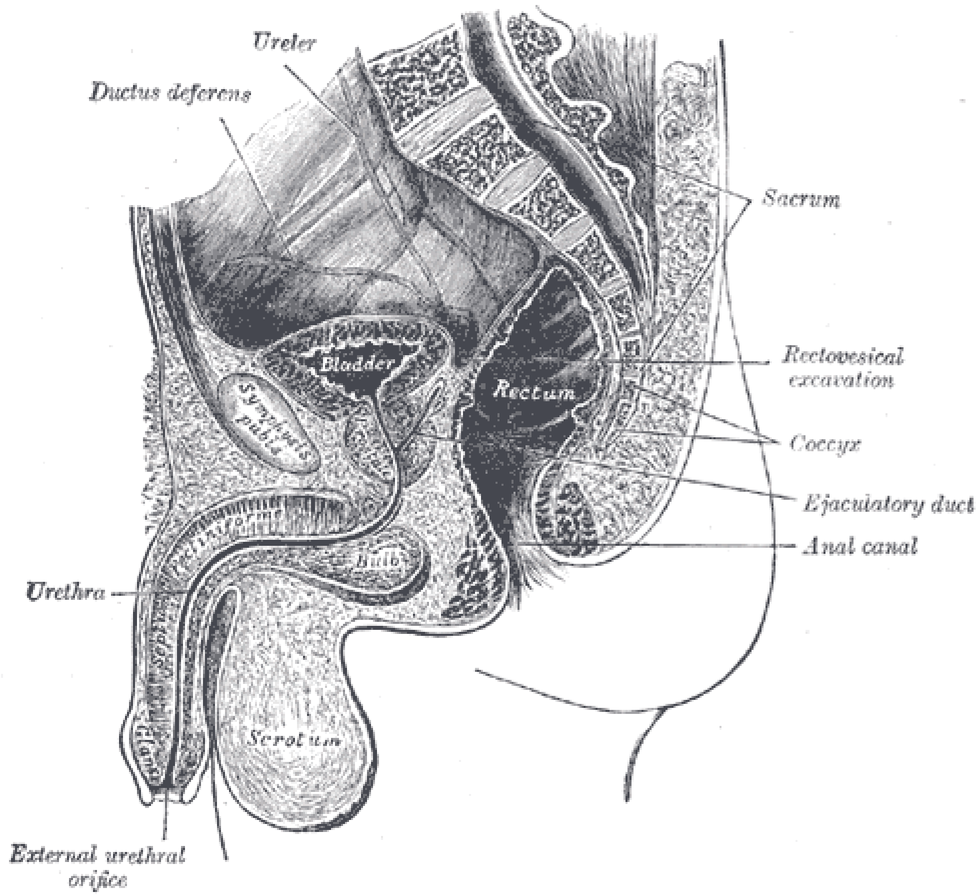
Pathology

Injuring the coccyx can give rise to a condition called coccydynia. A number of tumors are known to involve the coccyx; of these, the most common is sacrococcygeal teratoma.

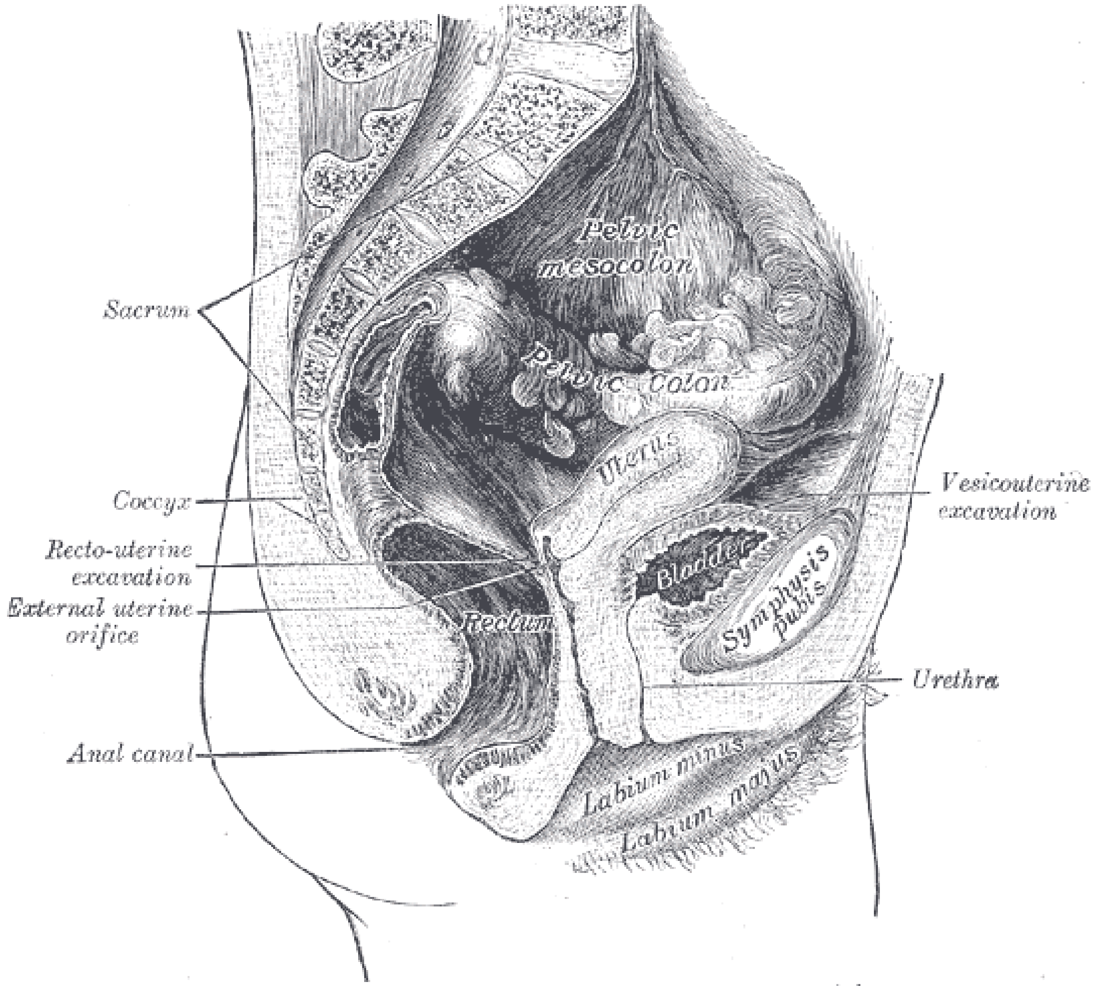
Both coccydynia and coccygeal tumors may require surgical removal of the coccyx (coccygectomy). One complication of cocygectomy is a coccygeal hernia. Fortunately, most cases of coccyx pain respond well to nonsurgical treatment, such as medications given by local injection (often done under fluoroscopic guidance).



Left Levator ani from within.



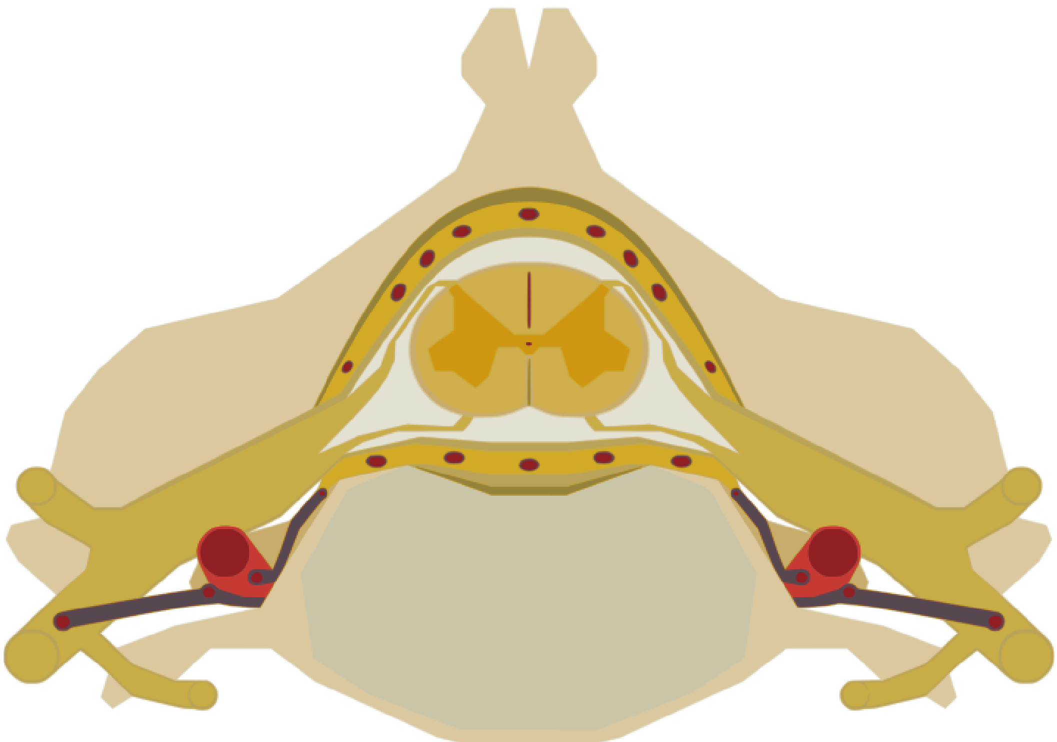
Median sagittal section of male pelvis.



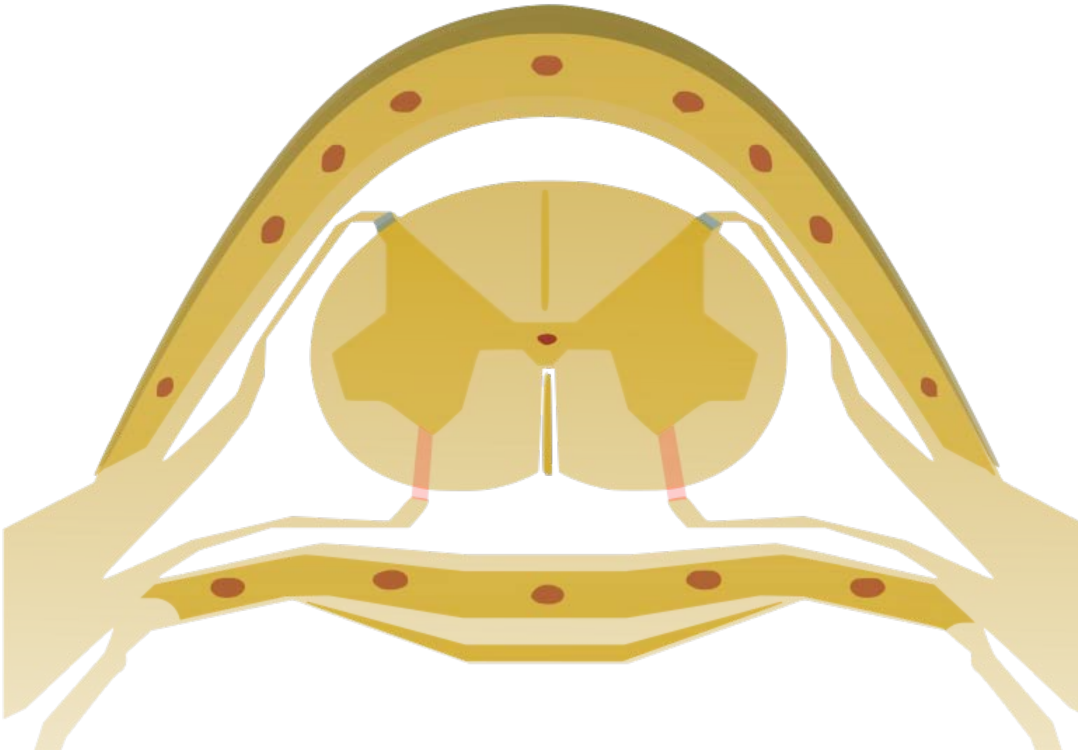
Median sagittal section of female pelvis.

Chapter 7

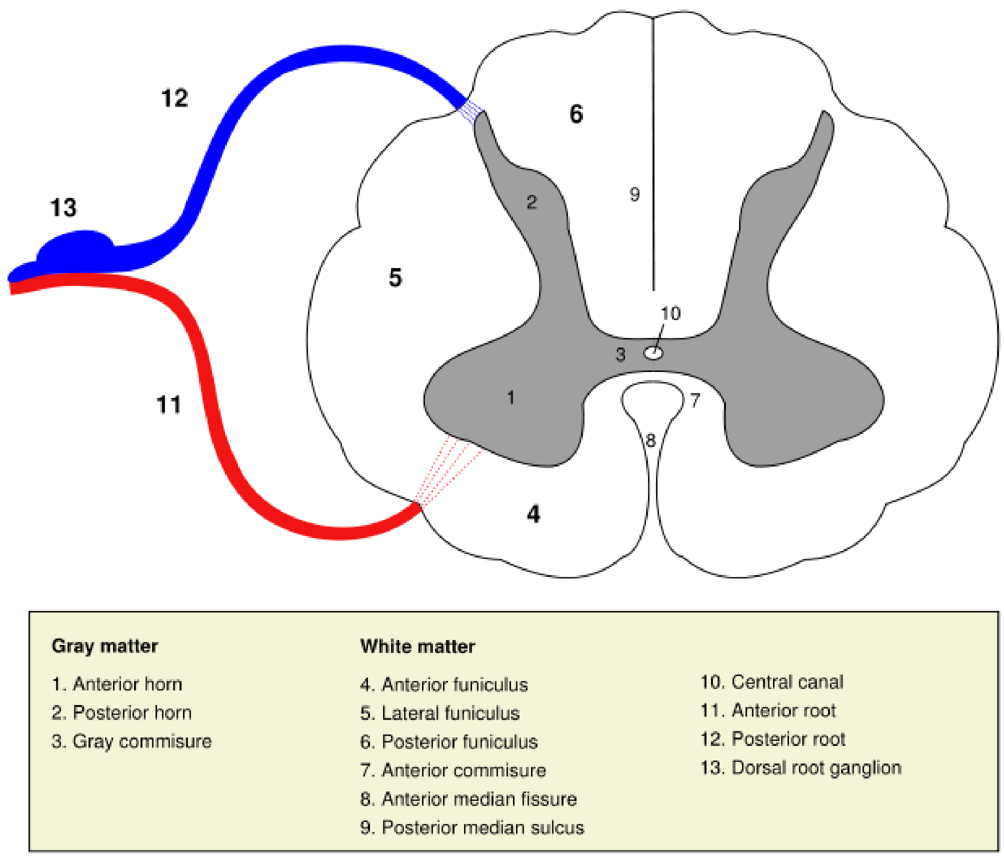
Spinal Cord



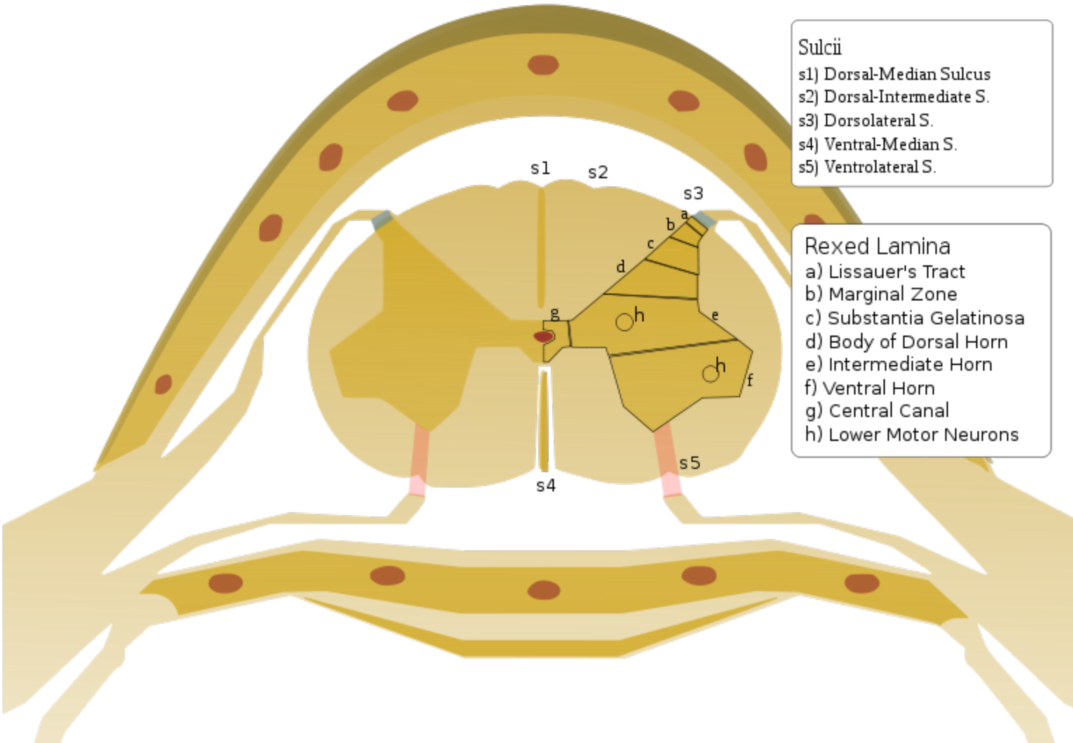
The spinal cord nested in the vertebral column



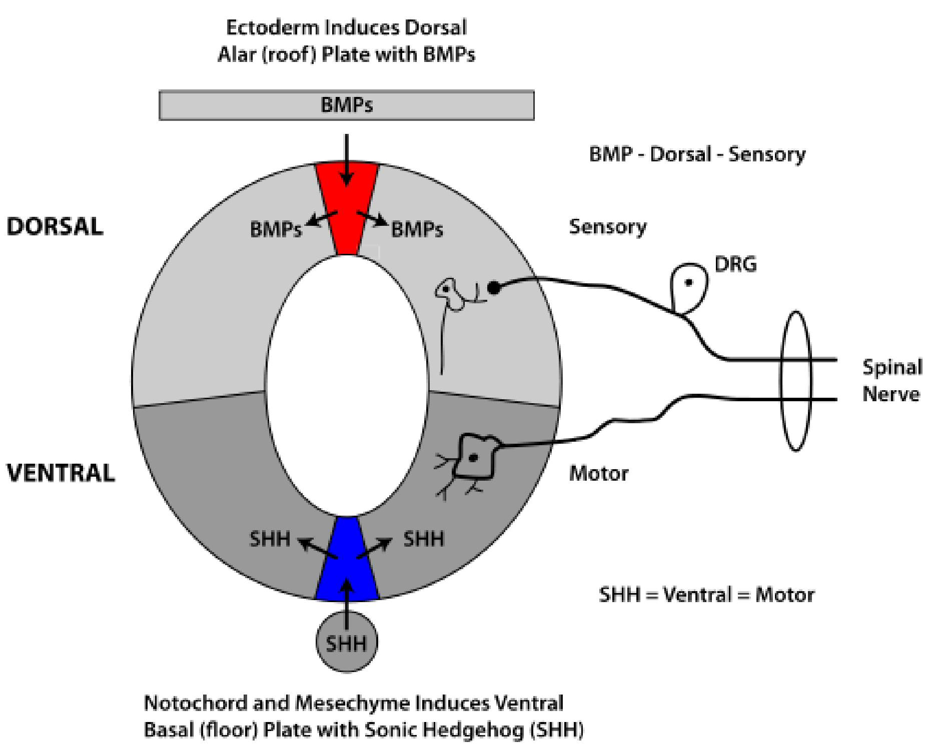
A closer look at the spinal cord



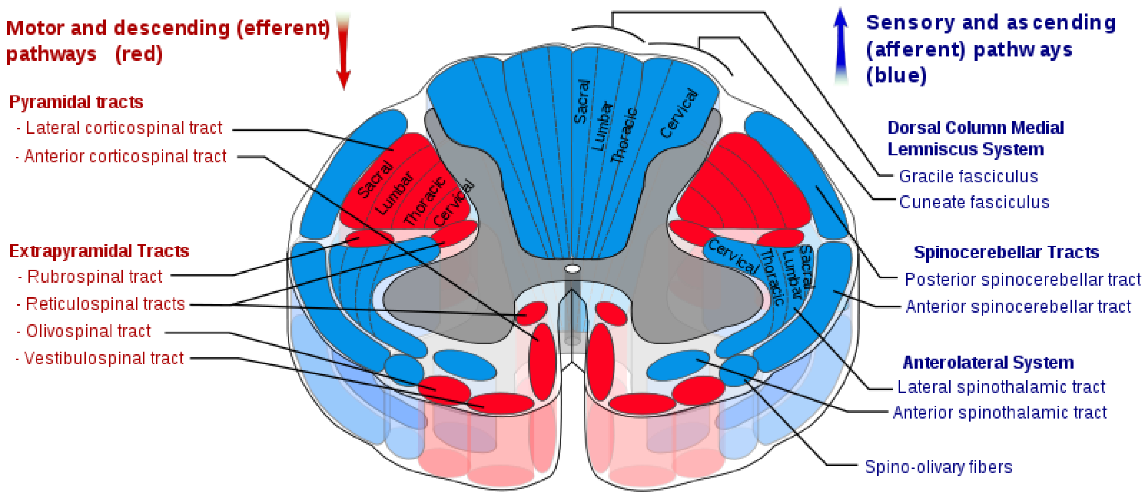
Cross-section through cervical spinal cord



Gray matter's rexed lamina

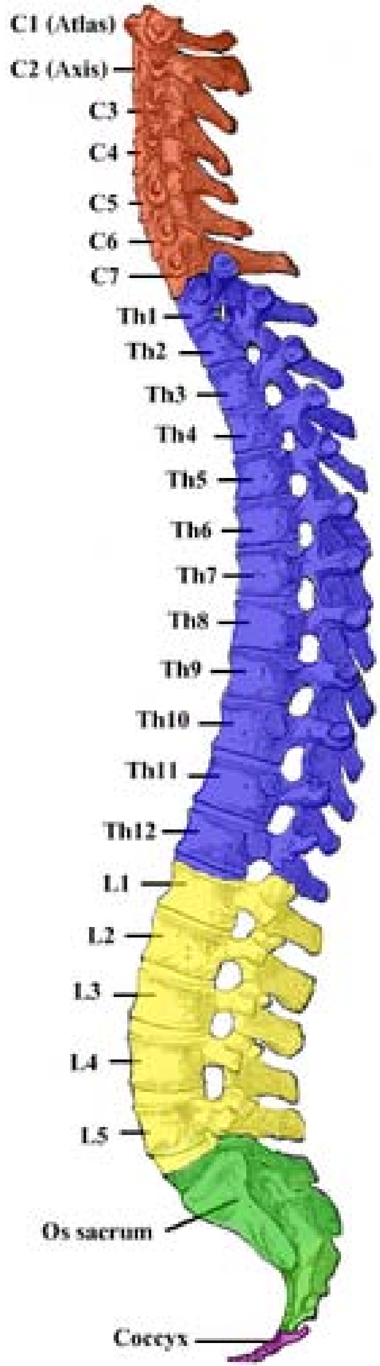


Spinal cord development of the alar and basal plates



Spinal cord tracts

Divisions of Spinal Segments



Segmental Spinal Cord Level and Function	
Level	**Function**
C1-C6	Neck flexors
C1-T1	Neck extensors
C3, C4,	Supply diaphragm (mostly C4)

C5	
C5, C6	Shoulder movement, raise arm (deltoid); flexion of elbow (biceps); **C6** externally rotates the arm (supinates)
C6, C7	Extends elbow and wrist (triceps and wrist extensors); pronates wrist
C7, T1	Flexes wrist
C7, T1	Supply small muscles of the hand
T1 -T6	Intercostals and trunk above the waist
T7-L1	Abdominal muscles
L1, L2, L3, L4	Thigh flexion
L2, L3, L4	Thigh adduction
L4, L5, S1	Thigh abduction
L5, S1, S2	Extension of leg at the hip (gluteus maximus)
L2, L3, L4	Extension of leg at the knee (quadriceps femoris)
L4, L5, S1, S2	Flexion of leg at the knee (hamstrings)
L4, L5, S1	Dorsiflexion of foot (tibialis anterior)
L4, L5, S1	Extension of toes
L5, S1, S2	Plantar flexion of foot
L5, S1, S2	Flexion of toes

The **spinal cord** is a long, thin, tubular bundle of nervous tissue and support cells that extends from the brain (the medulla oblongata specifically). The brain and spinal cord together make up the central nervous system. The spinal cord begins at the Occipital bone and 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. Also, the spinal cord has a varying width, ranging from 1/2 inch thick in the cervical and lumbar regions to 1/4 inch thick in the thoracic area. 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 L4 and S3, handles sensory input and motor output coming from and going to the legs.

The spinal cord is protected by three layers of tissue, called spinal meninges, that surround the canal. 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 mater is the middle protective layer. Its name comes from the fact that the tissue has a spiderweb-like appearance. The space between the arachnoid and the underlyng pia mater is called the subarachnoid space. The subarachnoid space contains cerebrospinal fluid (CSF). The medical procedure known as a lumbar puncture (or *spinal tap*) involves use of a needle to withdraw cerebrospinal fluid 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. 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.

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.

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 center 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 organization

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 organization

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 proprioception of the lower limbs differs from the upper limbs & upper trunk. There is a 4 neuron pathway for lower limbs proprioception. This pathway initially follows the dorsal spino-cerebellar pathway. It is arranged as follows: proprioceptive receptors of lower limb -> peripheral process -> dorsal root ganglion -> central process -> clarks column -> 2nd order neuron -> medulla oblogata (neucleus z of broadal) -> 3rd order neuron -> VPL of thalamus -> 4th order neuron -> posterior limb of internal capsule -> corona radiata -> sensory area of cerebrum.

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.

Spinocerebellar tracts

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 decussates 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.

Injury

Spinal cord injuries can be caused by trauma to the spinal column ,(stretching, bruising, applying pressure, severing, laceration, etc.). The vertebral bones or intervertebral disks can shatter, causing the spinal cord to be punctured by a sharp fragment of bone. Usually, victims of spinal cord injuries will suffer loss of feeling in certain parts of their body. In milder cases, a victim might only suffer loss of hand or foot function. More severe injuries may result in paraplegia, tetraplegia, or full body paralysis (called Quadriplegia) below the site of injury to the spinal cord.

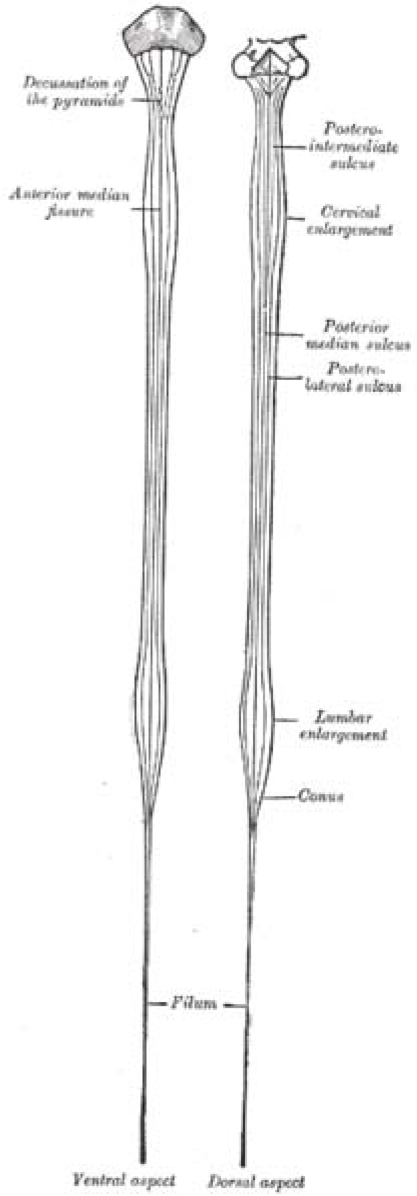
Damage to upper motor neuron axons in the spinal cord results in a characteristic pattern of ipsilateral deficits. These include hyperreflexia, hypertonia and muscle weakness. Lower motor neuronal damage results in its own characteristic pattern of deficits. Rather than an entire side of deficits, there is a pattern relating to the myotome affected by the damage. Additionally, lower motor neurons are characterized by muscle weakness, hypotonia, hyporeflexia and muscle atrophy.

Spinal shock and neurogenic shock can occur from a spinal injury. Spinal shock is usually temporary, lasting only for 24–48 hours, and is a temporary absence of sensory and motor functions. Neurogenic shock lasts for weeks and can lead to a loss of muscle tone due to disuse of the muscles below the injured site.

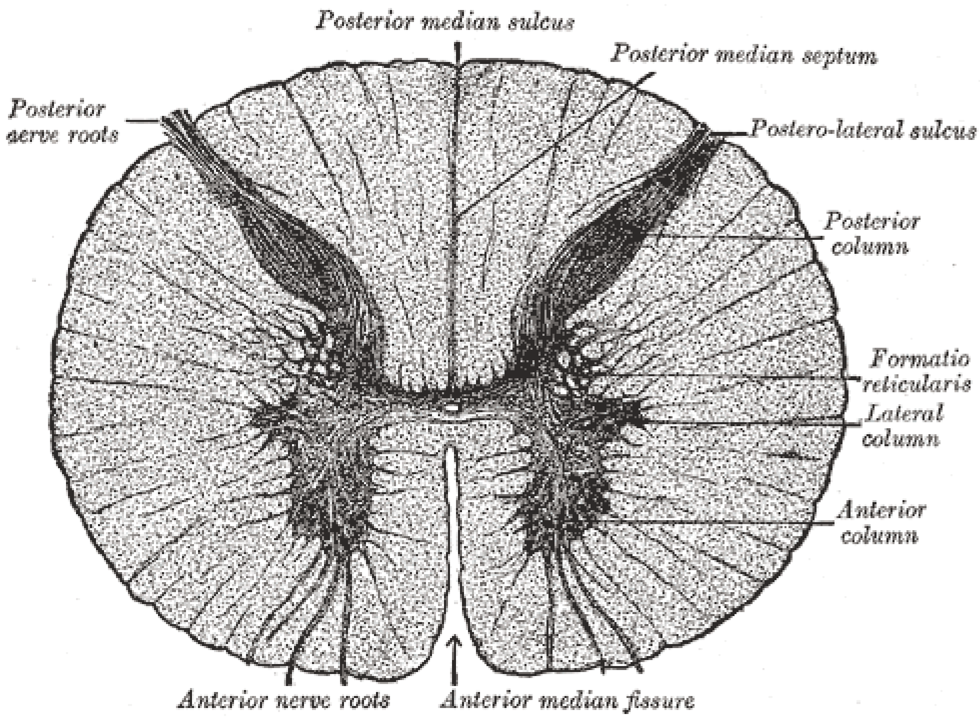
The two areas of the spinal cord most commonly injured are the cervical spine (C1-C7) and the lumbar spine (L1-L5). (The notation C1, C7, L1, L5 refer to the location of a specific vertebra in either the cervical, thoracic, or lumbar region of the spine.)

Spinal cord genomic map

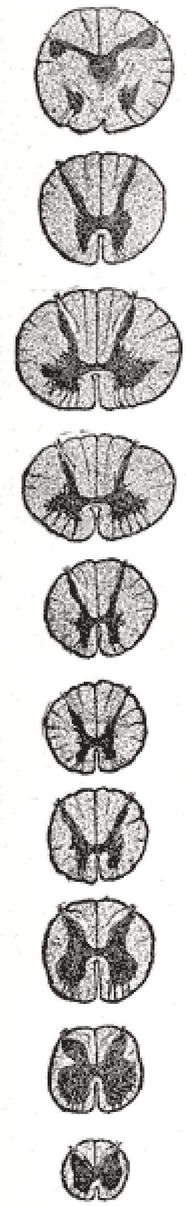
The Allen Institute for Brain Science, on July 16, 2008, launched the online "Allen Spinal Cord Atlas" (backed by Paul Allen). Its first release included 4000 sets of digital images, showing spatial expression patterns for various genes. When complete, it is planned to map 20,000 genes in adult and juvenile mouse spinal cords. The spinal cord atlas is organized like the Allen Institute's earlier atlas of the mouse brain. The Spinal Cord



Diagrams of the spinal cord.



Cross-section through the spinal cord at the mid-thoracic level.



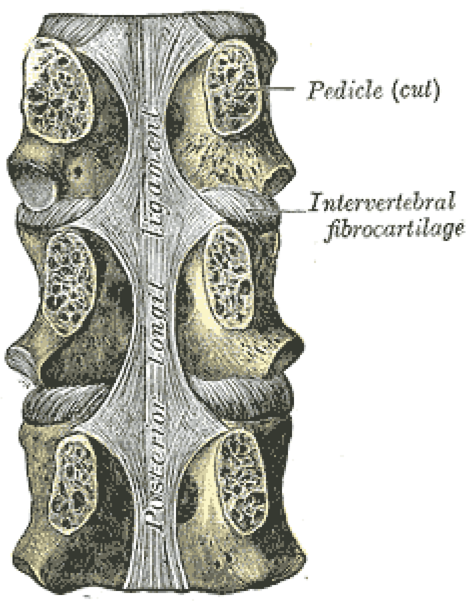
Cross-sections of the spinal cord at varying levels.

Chapter 8

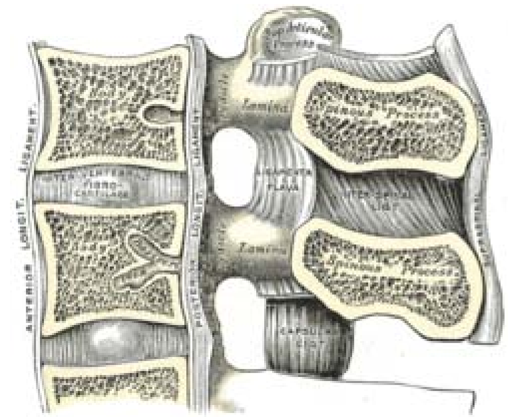
Posterior Longitudinal Ligament and Posterior Mediastinum

Posterior longitudinal ligament

Ligament: Posterior longitudinal ligament



Posterior longitudinal ligament, in the thoracic region.
(Posterior longitudinal ligament runs vertically at center.)



Median sagittal section of two lumbar vertebræ and their ligaments. (Posterior longitudinal ligament runs vertically at center left.)

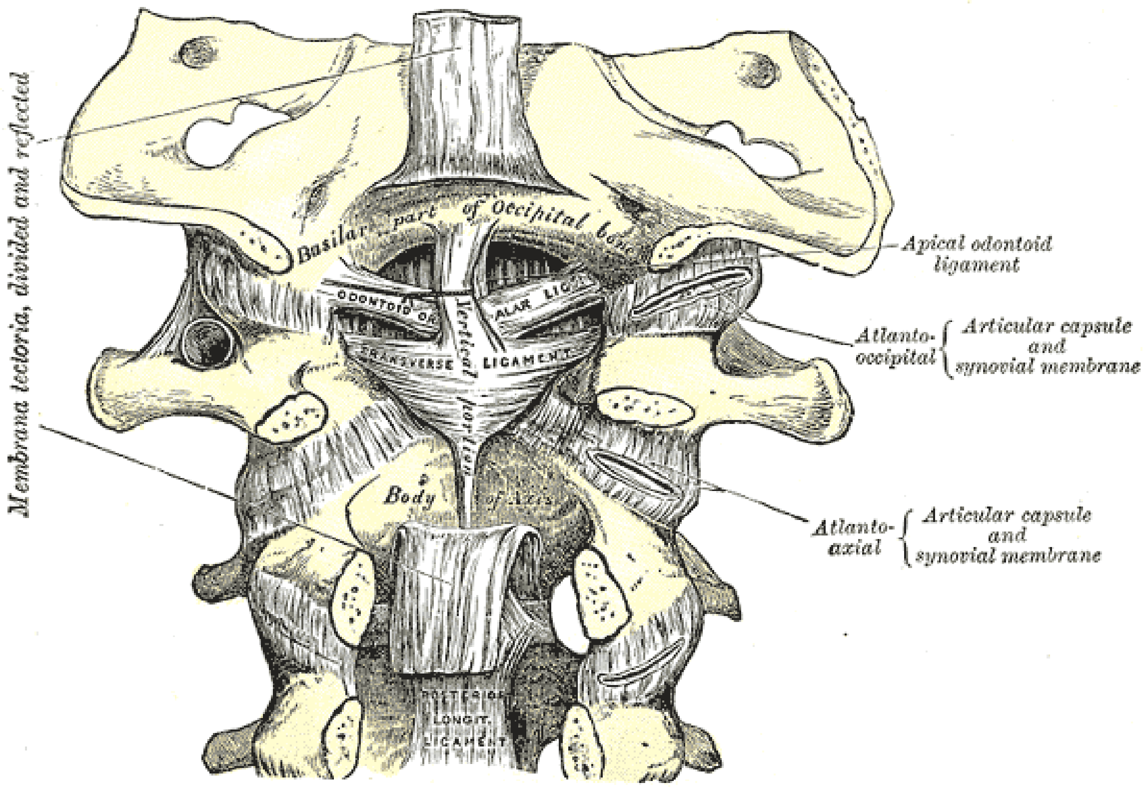
Latin	*ligamentum longitudinale posterius*
Gray's	*subject #72 288*
From	
To	
Dorlands/Elsevier	*l_09/12492528*

The **posterior longitudinal ligament** is situated within the vertebral canal, and extends along the posterior surfaces of the bodies of the vertebræ, from the body of the axis, where it is continuous with the membrana tectoria, to the sacrum.

It is broader above than below, and thicker in the than in the cervical and lumbar regions. The ligament is more narrow at the vertebral bodies and wider at the intervertebral disc space which is more pronounced than the anterior longitudinal ligament. This is significant in understanding certain pathological conditions of the spine such as the typical location for a spinal disc herniation.

In the situation of the intervertebral fibrocartilages and contiguous margins of the vertebræ, where the ligament is more intimately adherent, it is broad, and in the thoracic and lumbar regions presents a series of dentations with intervening concave margins; but it is narrow and thick over the centers of the bodies, from which it is separated by the basivertebral veins.

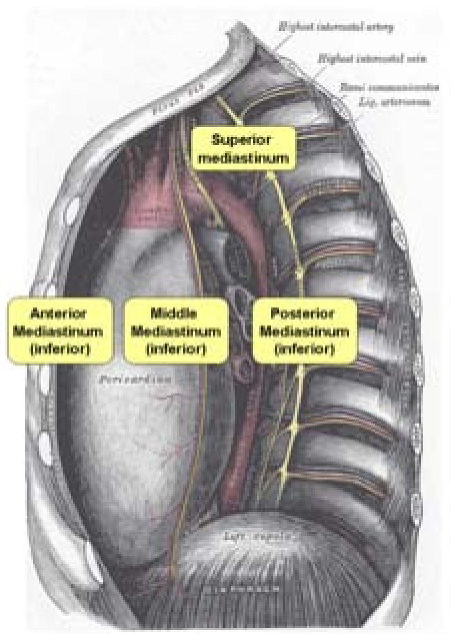
This ligament is composed of smooth, shining, longitudinal fibers, denser and more compact than those of the anterior ligament, and consists of superficial layers occupying the interval between three or four vertebræ, and deeper layers which extend between adjacent vertebræ.



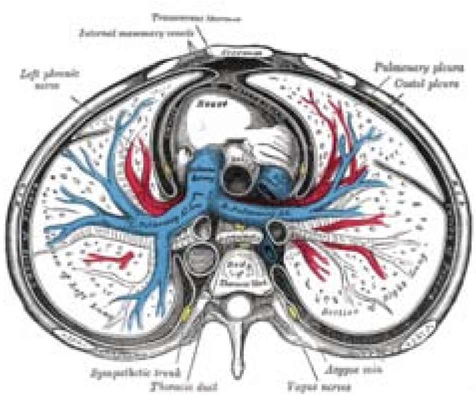
Membrana tectoria, transverse, and alar ligaments.

Posterior mediastinum

Posterior mediastinum



Mediastinum



A transverse section of the thorax, showing the contents of the middle and the posterior mediastinum.

Latin	*mediastinum posterius*
Gray's	*subject #239 1093*

The **posterior mediastinum** is an irregular triangular space running parallel with the vertebral column.

Boundaries

It is bounded:

- anteriorly by the pericardium (in front of)
- inferiorly by the thoracic surface of the diaphragm (below).
- superiorly by the transverse thoracic plane (above). This plane is marked by an imaginary line travelling through the manubriosternal joint to the dividing line between the fourth and fifth thoracic vertebrae.
- posteriorally by the bodies of the vertebral column from the lower border of the fifth to the twelfth thoracic vertebra (behind).
- laterally: by the mediastinal pleura (on either side)

Content

- artery
    - thoracic part of the descending aorta
- veins
    - azygos vein
    - the hemiazygos vein and the accessory hemiazygos vein
- nerves
    - vagus nerve
    - splanchnic nerves (but not the sympathetic chain)
- esophagus
- thoracic duct
- some lymph glands

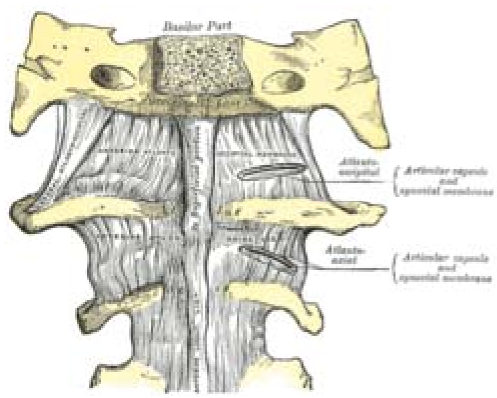
The contents of posterior mediastinum can be remembered using the mnemonic, "**DATES**", for **D**escending aorta, **A**zygous vein and hemiazygos vein, **T**horacic duct, **E**sophagus, **S**ympathetic trunk/ganglia.

Chapter 9

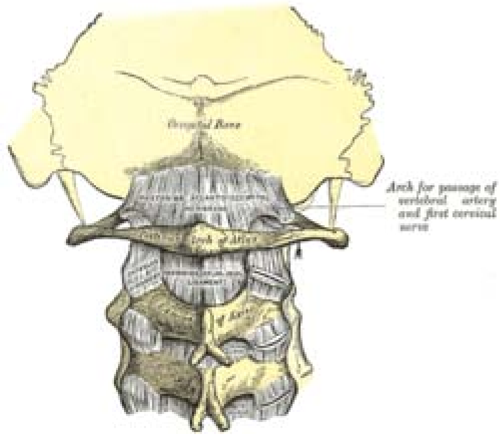
Atlanto-Axial Joint and Cauda Equina

Atlanto-axial joint

Atlanto-axial joint



Anterior atlantoöccipital membrane and atlantoaxial ligament.



Posterior atlantoöccipital membrane and atlantoaxial ligament.

Latin	*articulatio atlantoaxialis mediana, articulatio atlantoaxialis lateralis*
Gray's	*subject #73 292*
MeSH	*Atlanto-Axial+Joint*

The **Atlanto-axial joint** (**articulation of the atlas with the axis**) is of a complicated nature. It consists of no fewer than four distinct joints.

There is a pivot articulation between the odontoid process of the axis and the ring formed by the anterior arch and the transverse ligament of the atlas.

Lateral and medial joints

There are two atlanto-axial joints: median and lateral:

- The median atlantoaxial joint is sometimes considered a double joint:
    - one between the posterior surface of the anterior arch of atlas and the front of the odontoid process
    - one between the anterior surface of the ligament and the back of the odontoid process

- The lateral atlantoaxial joint involves the lateral mass of atlas and axis. Between the articular processes of the two bones there is on either side an arthrodial or gliding joint.

Ligaments

The ligaments connecting these bones are:

- Articular capsules
- Anterior atlantoaxial ligament
- Posterior atlantoaxial ligament
- Transverse ligament of the atlas

The atlantoaxial joint in common terminology is actually a composition of three: two lateral and one median atlantoaxial joints. Because of its proximity to the brain stem and importance in stabilization, fracture or injury at this level can be catastrophic. Common trauma and pathologies include (but are not limited to):

The Dens: significant depression on the skull can push the dens into the brainstem, causing death. The dens itself is vulnerable to fracture due to trauma or ossification.

Transverse ligament: Should the transverse ligament of the atlas fail due to trauma or disease, the dens is no longer anchored and can travel up the cervical spine, causing paralysis. If it reaches the medulla death can result. Alar ligaments: stress or trauma can stretch the weaker alar ligaments, causing an increase in range of motion of approximately 30%.

Posterior Atlanto-Occipital Membrane: genetic traits can sometimes result in ossification, turning the groove into an foramen.

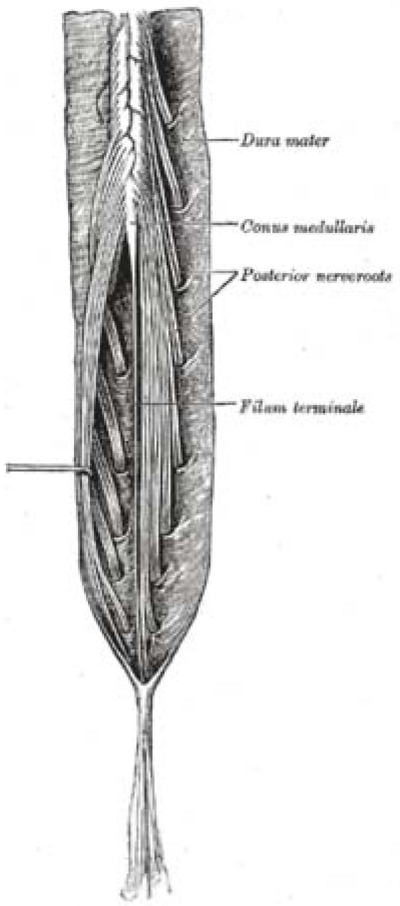
Dalley, Arthur F; Moore, Keith L. Clinically Oriented Anatomy Fourth Edition. Baltimore. Lippincott Williams & Wilkins, 1992. Saladin, Kenneth S. Anatomy &Physiology: the Unity of Form and Function. New York. McGraw Hill, 2007.

Capsule

The atlantoaxial articular capsules are thin and loose, and connect the margins of the lateral masses of the atlas with those of the posterior articular surfaces of the axis.

Each is strengthened at its posterior and medial part by an accessory ligament, which is attached below to the body of the axis near the base of the odontoid process, and above to the lateral mass of the atlas near the transverse ligament.

Cauda equina

Cauda equina	
	
Cauda equina and filum terminale seen from behind.	
Gray's	*subject #208 919*
Artery	Iliolumbar artery
MeSH	*Cauda+Equina*

The **cauda equina** is a structure within the lower end of the spinal column of most vertebrates, that consists of nerve roots and rootlets from above. The space in which the cerebrospinal fluid is present is actually an extension of the subarachnoid space.

In humans, because the spinal cord stops growing in infancy while the bones of the spine continue growing, the spinal cord in adults ends at about the level of the vertebra L1/L2 , and at birth at L3. However there is some variation in adults and the cord may end anywhere between vertebrae T12 to L3. Individual spinal nerve roots arise from the spinal cord as they do closer to the head, but as the differential growth occurs the top end of the nerve stays attached to the spinal cord and the lower end of the nerve exits the spinal column at its proper level, this results in a "bundle"-like structure of nerve fibres that extends caudally from the end of the spinal cord, gradually declining in number further down as individual pairs leave the spinal column. At the base of the Cauda Equina, there are approximately 10 fiber pairs, 3-5 lumbar, 5 sacral, and the single coccygeal nerve.

Etymology

All these roots and rootlets down the vertebral column give the appearance of a horse's tail, which is the meaning of the Latin name *cauda equina*.

Clinical relevance

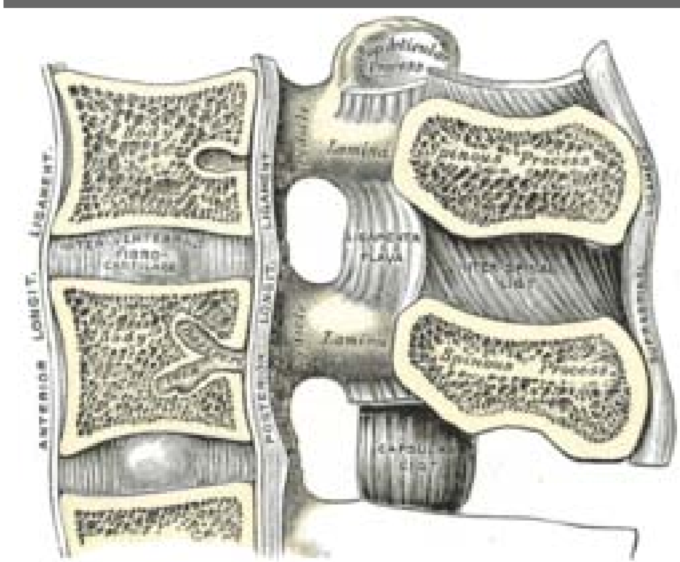
The cauda equina exists within the lumbar cistern, which is the space formed from the surrounding dural sac. Cerebrospinal fluid is drawn from this space during a lumbar puncture.

Chapter 10

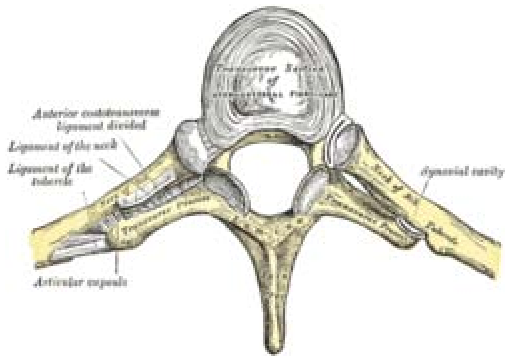
Intervertebral Disc and Ligamenta Flava

Intervertebral disc

Intervertebral disc



Median sagittal section of two lumbar vertebræ and their ligaments. (Intervertebral fibrocartilage labeled at center left.)



Costotransverse articulation. Seen from above.

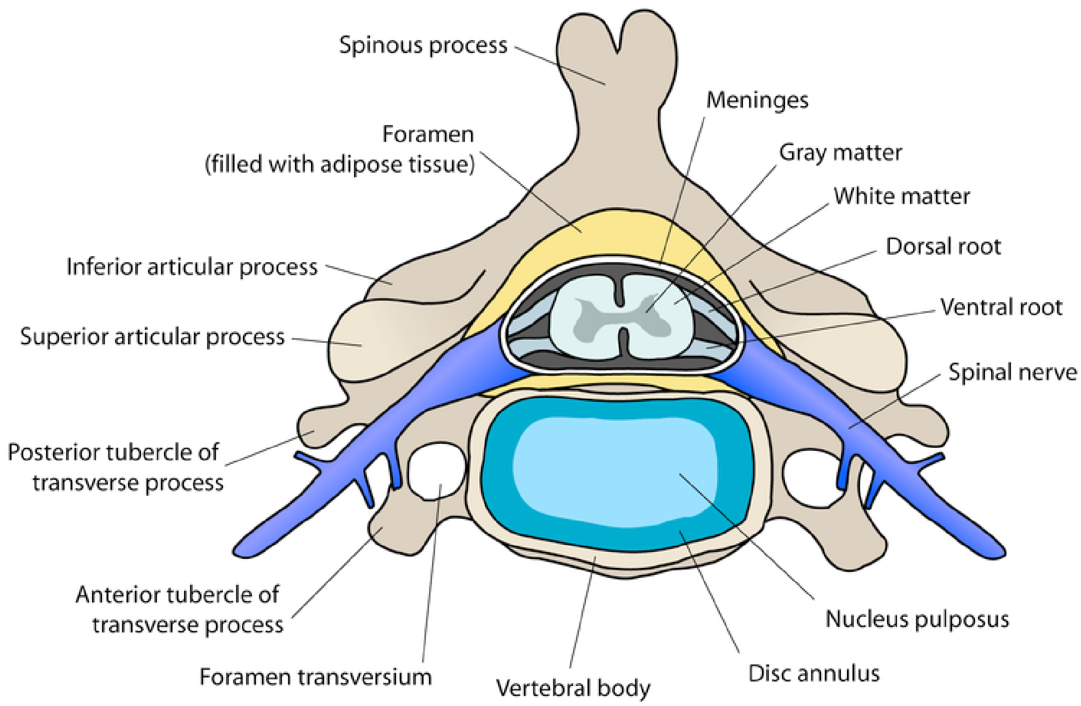
(Intervertebral fibrocartilage labeled at top center .)

Latin	*disci intervertebrales*
Gray's	*subject #72 289*
MeSH	*Intervertebral+Disk*

Intervertebral discs (or **intervertebral fibrocartilage**) lie between adjacent vertebrae in the spine. Each disc forms a cartilaginous joint to allow slight movement of the vertebrae, and acts as a ligament to hold the vertebrae together.

Structure

Discs consist of an outer *annulus fibrosus*, which surrounds the inner *nucleus pulposus*. The *annulus fibrosus* consists of several layers of fibrocartilage. The strong annular fibers contain the *nucleus pulposus* and distribute pressure evenly across the disc. The *nucleus pulposus* contains loose fibers suspended in a mucoprotein gel with the consistency of jelly. The nucleus of the disc acts as a shock absorber, absorbing the impact of the body's daily activities and keeping the two vertebrae separated. The disc can be likened to a doughnut: whereby the annulus fibrosis is similar to the dough and the nucleus pulposis is the jelly. If one presses down on the front of the doughnut the jelly moves posteriorly or to the back. When one develops a prolapsed disc the jelly/ nucleus pulposus is forced out of the doughnut/ disc and may put pressure on the nerve located near the disc. This can give one the symptoms of sciatica.

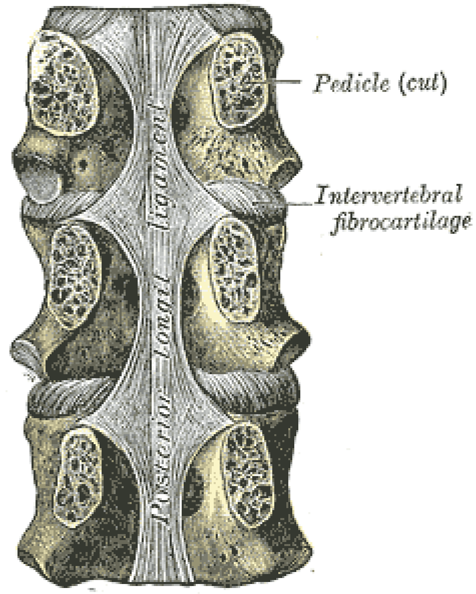


Cervical vertebra with intervertebral disc

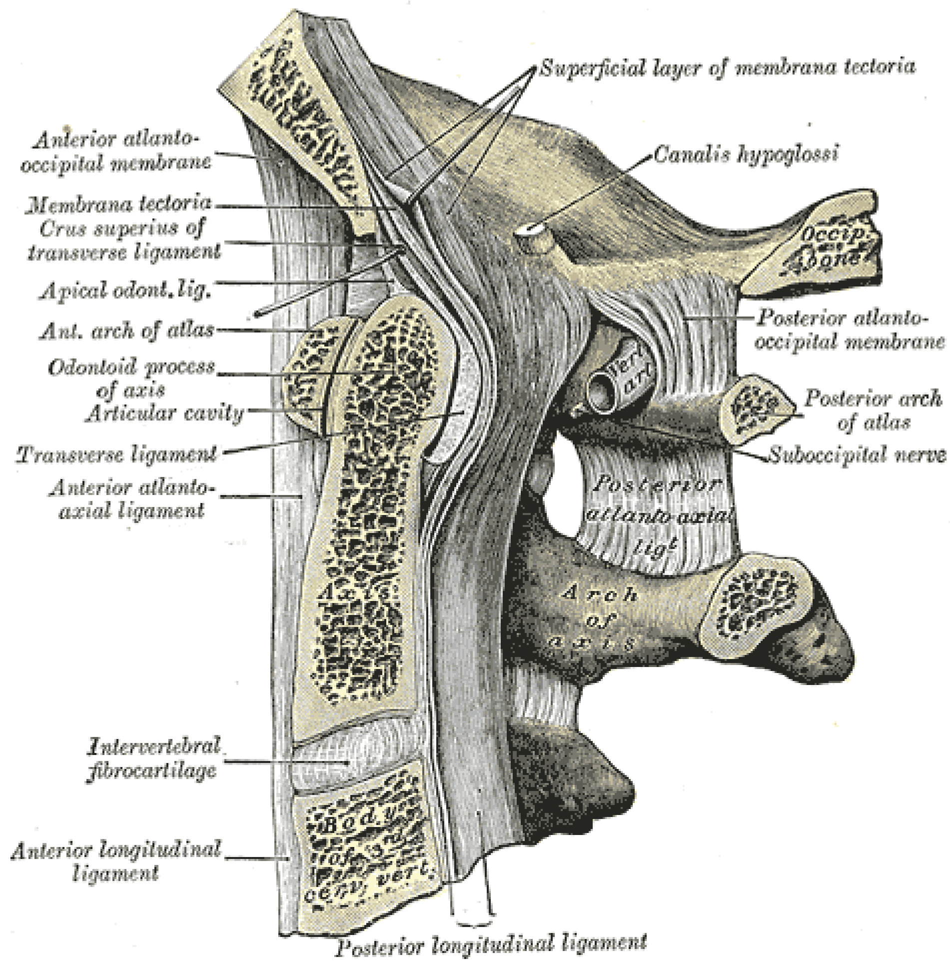
There is one disc between each pair of vertebrae, except for the first cervical segment, the *atlas*. The *atlas* is a ring around the roughly cone-shaped extension of the *axis* (second cervical segment). The axis acts as a post around which the atlas can rotate, allowing the neck to swivel. There are a total of twenty four discs in the human spine, which are most commonly identified by specifying the particular vertebrae they separate. For example, the disc between the fifth and sixth cervical vertabrae is designated "C5-6".

Medical conditions related to the intervertebral disc

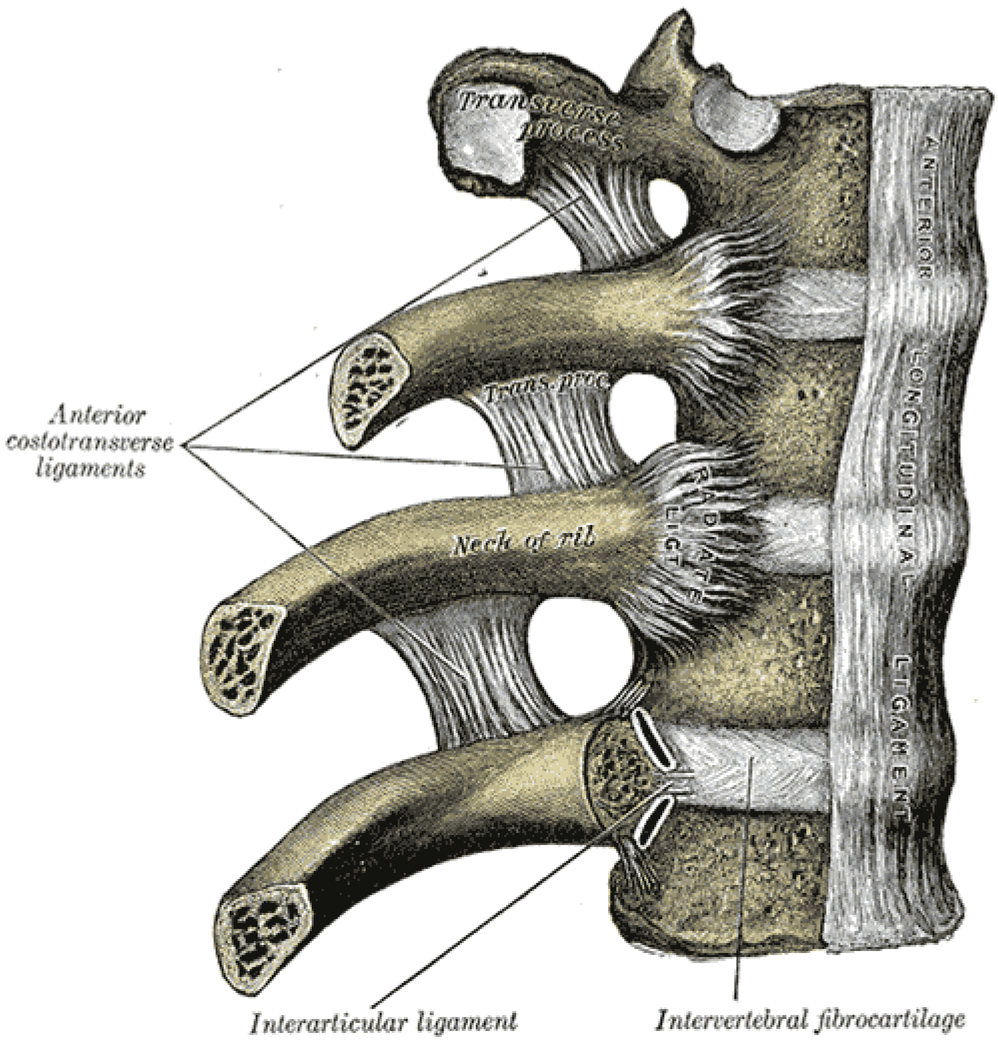
As people age, the *nucleus pulposus* begins to dehydrate, which limits its ability to absorb shock. The *annulus fibrosus* gets weaker with age and begins to tear. While this may not cause pain in some people, in others one or both of these may cause chronic pain.



Posterior longitudinal ligament, in the thoracic region.



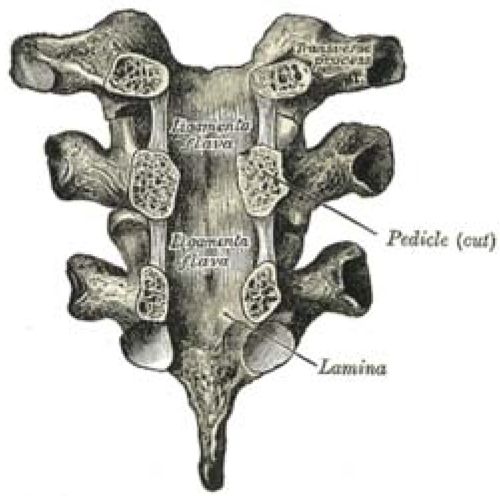
Median sagittal section through the occipital bone and first three cervical vertebræ.



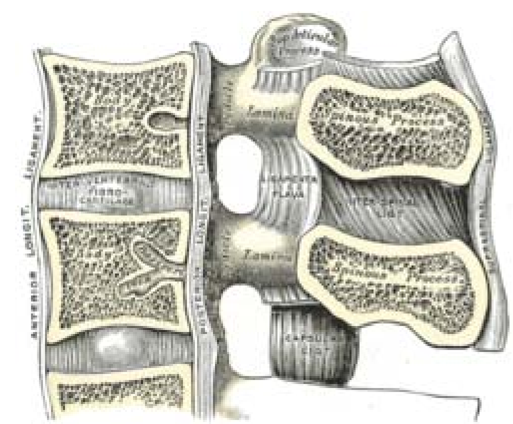
Costovertebral articulations. Anterior view.

Ligamenta flava

Ligament: Ligamenta flava	



Vertebral arches of three thoracic vertebræ viewed from the front.



Median sagittal section of two lumbar vertebræ and their ligaments.

Gray's	*subject #72 290*
From	
To	
MeSH	*A02.513.514.287*
Dorlands/Elsevier	*l_09/12492241*

The **ligamenta flava** (singular, *ligamentum flavum*, Latin for *yellow ligament*) are ligaments which connect the laminae of adjacent vertebrae, all the way from the axis to the first segment of the sacrum (C2 to S1). They are best seen from the interior of the vertebral canal; when looked at from the outer surface they appear short, being overlapped by the laminæ.

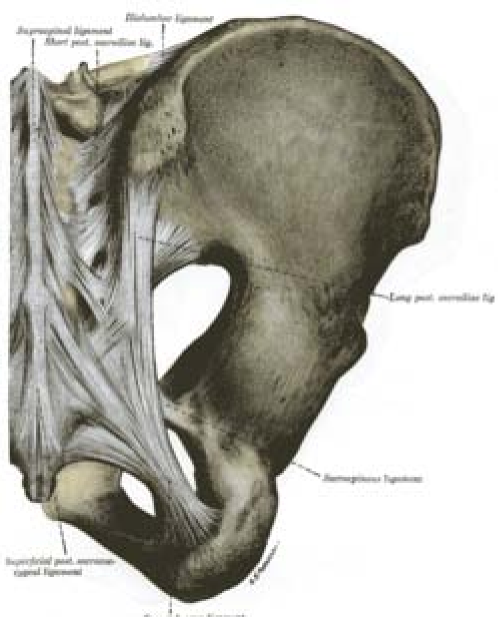
Each ligament consists of two lateral portions which commence one on either side of the roots of the articular processes, and extend backward to the point where the laminæ meet to form the spinous process; the posterior margins of the two portions are in contact and to a certain extent united, slight intervals being left for the passage of small vessels. Each consists of yellow elastic tissue, the fibers of which, almost perpendicular in direction, are attached to the anterior surface of the lamina above, some distance from its inferior margin, and to the posterior surface and upper margin of the lamina below. In the cervical region the ligaments are thin, but broad and long; they are thicker in the thoracic region, and thickest in the lumbar region.

Their marked elasticity serves to preserve the upright posture, and to assist the vertebral column in resuming it after flexion. The elastin prevents buckling of the ligament into the spinal canal during extension, which would cause canal compression. Hypertrophy of this ligament may cause spinal stenosis because it lies in the posterior portion of the vertebral canal.

Chapter 11

Posterior Sacrococcygeal Ligament and Sacrococcygeal Symphysis

Posterior sacrococcygeal ligament

Ligament: Posterior sacrococcygeal ligament	
 Articulations of pelvis. Posterior view. (Superficial posterior sacrococcygeal ligament labeled at bottom left.)	
Latin	*ligamentum sacrococcygeum posterius/dorsale*

	[profundum/superficiale]
Gray's	*subject #80 309*
From	Sacrum
To	Coccyx

The **posterior sacrococcygeal ligament** or **dorsal sacrococcygeal ligament** is a ligament which stretches from the sacrum to the coccyx and thus dorsally across the sacrococcygeal symphysis shared by these two bones.

This ligament is divisible in two parts: A short deep part which unites the two bones, and a larger superficial portion which completes the lower back part of the sacral canal. On either side, two lateral sacrococcygeal ligaments run between the transverse processes of the coccyx and the inferior lateral angle of the sacrum.

It is in relation, behind, with the Glutæus maximus.

Deep part

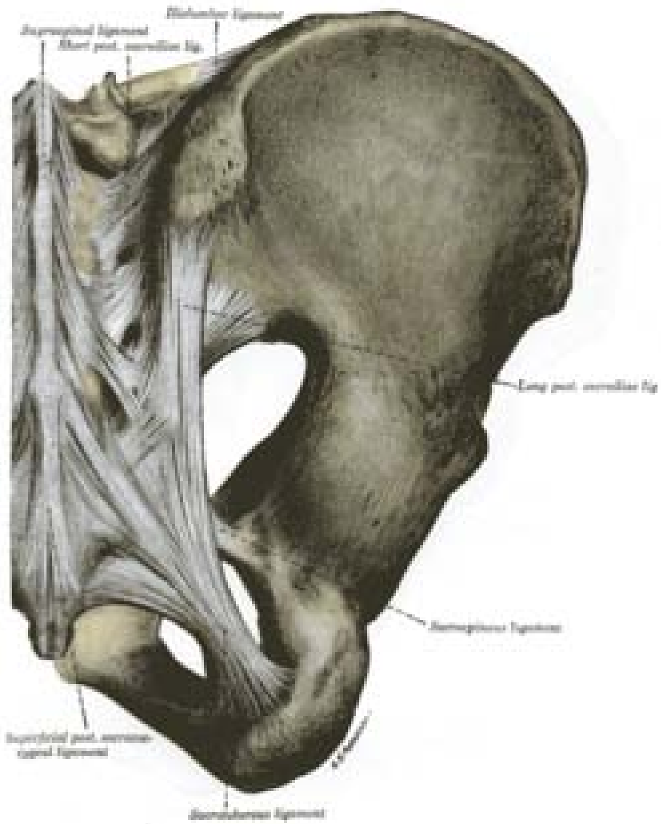
The **deep dorsal sacrocyccygeal ligament** is a continuation of the posterior longitudinal ligament. A flat band arising inside the sacral canal, posteriorly at the orifice of the fifth sacral segment, it descends to the dorsal surface of the coccyx under its longer fellow described below.

Superficial part

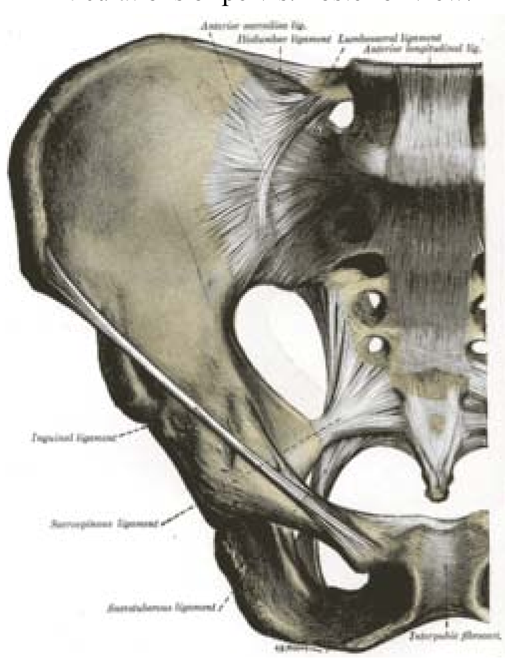
The **superficial dorsal sacrococcygeal ligament** originates on the free margin of the sacral hiatus to attach on the dorsal surface of the coccyx. It closes the posterior aspect of the most distal part of the sacral canal and corresponds to the ligamenta flava.

Sacrococcygeal symphysis

Sacrococcygeal symphysis



Articulations of pelvis. Posterior view.



Anterior view.

Latin *articulatio sacrococcygea, symphysis sacrococcygea*

Gray's *subject #80 309*

The **sacrococcygeal symphysis** (**sacrococcygeal articulation**, **articulation of the sacrum and coccyx**) is an amphiarthrodial joint, formed between the oval surface at the apex of the sacrum, and the base of the coccyx.

It is a slightly moveable joint which is frequently, partially or completely, obliterated in old age, homologous with the joints between the bodies of the vertebrae.

Disc

The sacrococcygeal disc or **interosseus ligament** is similar to the intervertebral discs but thinner, thicker in front and behind than at the sides, and with a firmer texture. The articular surfaces are elliptical with longer transversal axes. The surface on the sacrum is convex and that on the coccyx concave. Occasionally the coccyx is freely movable on the sacrum, most notably during pregnancy; in such cases a synovial membrane is present.

Ligaments

The joint is strengthened by a series of ligaments:

- The **ventral** or **anterior sacrococcygeal ligament** is an extension of the anterior longitudinal ligament (ALL) that runs down along the spine on the anterior sides of the bodies of the vertebrae. It consists of a few irregular fibers that attach to the anterior sides of the sacrum and coccyx and blend with the periosteum.
- The **dorsal** or **posterior sacrococcygeal ligament** has a deep and a superficial part:
    - The **deep dorsal ligament** is a flat band which corresponds to the posterior longitudinal ligament (PLL) that run down inside the vertebral canal on the posterior surfaces of the bodies of the vertebrae. From the posterior side of the fifth sacral body inside the sacral canal, the dorsal ligament stretches to the posterior side of the coccyx, to attach deep to the superficial dorsal ligament.
    - The **superficial dorsal ligament** corresponds to the ligamenta flava and closes the posterior aspect of the distal end of the vertebral canal. It stretches from median sacral crest and the free margin of the sacral hiatus to the dorsal surface of the coccyx.
- The **lateral sacrococcygeal ligaments** run from the lower lateral angles of the sacrum to the transverse processes of the first coccygeal vertebra to complete the foramina for the last sacral nerve. Three lateral ligaments have been reported on either side.

- The **interarticular** or **intercornual sacrococcygeal ligaments** stretches from the cornu of the sacrum to the cornu of the coccyx.

Movements

Movements in the joint are restricted to flexion and extension. These essentially passive movements occurs during defecation and labour. When movements in the sacrum increase the anteroposterior diameter of the pelvic outlet, movements in the sacrococcygeal joint can further increase this diameter.

Palpation

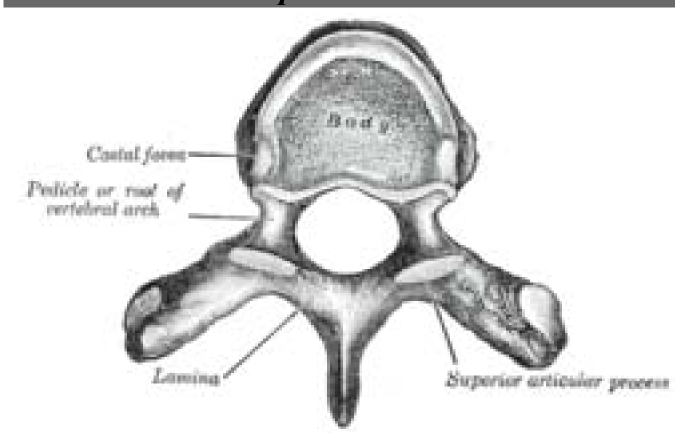
The joint is palpable deep within the natal cleft, and can be felt as a horizontal groove. With the palpating finger on the dorsal surface of the coccyx, a degree of rotation can be produced with an applied forward pressure.

Chapter 12

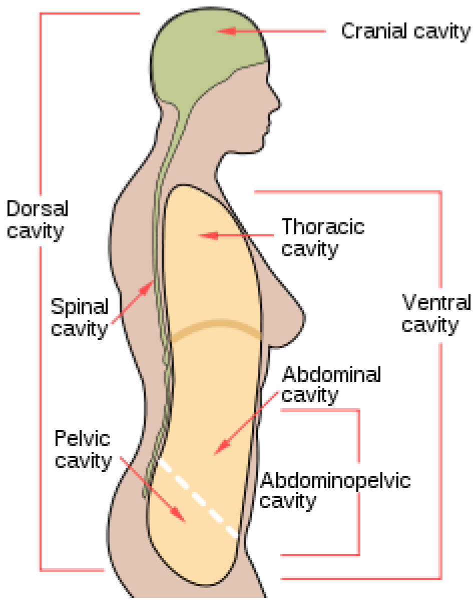
Spinal Canal and Transverse Ligament of Atlas

Spinal canal

Spinal canal



A typical thoracic vertebra, viewed from above. (Spinal canal is not labeled, but the hole in the center would comprise part of a spinal canal.)



Human body cavities: The spinal canal is called **spinal cavity** to the left

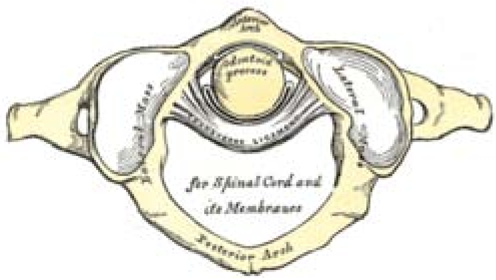
Latin	*c. vertebralis*
MeSH	*Spinal+Canal*

The **spinal canal** (or **vertebral canal** or **spinal cavity**) is the space in vertebrae through which the spinal cord passes. It is a process of the dorsal human body cavity. This canal is enclosed within the vertebral foramen of the vertebrae. In the intervertebral spaces, the canal is protected by the ligamentum flavum posteriorly and the posterior longitudinal ligament anteriorly.

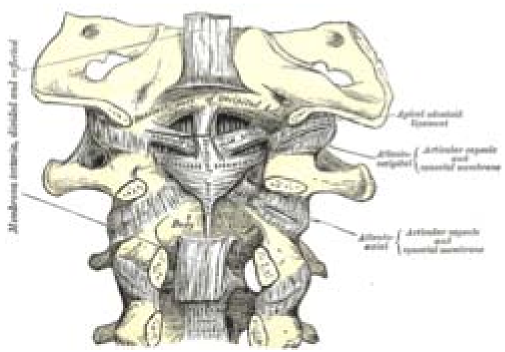
The outermost layer of the meninges, the dura mater, is closely associated with the arachnoid which in turn is loosely connected to the innermost layer of the meninges, the pia mater. The meninges divide the spinal canal into the epidural space and the subarachnoid space. The pia mater is closely attached to the spinal cord. A subdural space is generally only present due to trauma and/or pathological situations. The subarachnoid space is filled with cerebrospinal fluid and contains the vessels that supply the spinal cord, namely the anterior spinal artery and the paired posterior spinal arteries, accompanied by a corresponding spinal veins. The spinal arteries form anastomoses known as the vasocorona of the spinal cord. The epidural space contains loose fatty tissue, and a network of large, thin-walled blood vessels called the internal vertebral venous plexuses.

Transverse ligament of atlas

Ligament: Transverse ligament of the atlas	



Articulation between odontoid process and atlas.
(Transverse ligament visible at center.)



Membrana tectoria, transverse, and alar ligaments.
(Transverse ligament visible at center.)

Latin	*ligamentum transversum atlantis*
Gray's	*subject #73 293*
From	
To	
Dorlands/Elsevier	*l_09/12493416*

The **transverse ligament of the atlas** is a thick, strong band, which arches across the ring of the atlas, and retains the odontoid process in contact with the anterior arch.

It is concave in front, convex behind, broader and thicker in the middle than at the ends, and firmly attached on either side to a small tubercle on the medial surface of the lateral mass of the atlas.

As it crosses the odontoid process, a small fasciculus (*crus superius*) is prolonged upward, and another (*crus inferius*) downward, from the superficial or posterior fibers of the ligament.

The former is attached to the basilar part of the occipital bone, in close relation with the membrana tectoria; the latter is fixed to the posterior surface of the body of the axis; hence, the whole ligament is named the cruciate ligament of the atlas.

The transverse ligament divides the ring of the atlas into two unequal parts: of these, the posterior and larger serves for the transmission of the medulla spinalis and its membranes and the accessory nerves; the anterior and smaller contains the odontoid process.

The neck of the odontoid process is constricted where it is embraced posteriorly by the transverse ligament, so that this ligament suffices to retain the odontoid process in position after all the other ligaments have been divided.

Excessive laxity of the posterior transverse ligament can lead to atlantoaxial instability, a common complication in Down's Syndrome patients.