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Anatomy

Occipitocervical Anatomy

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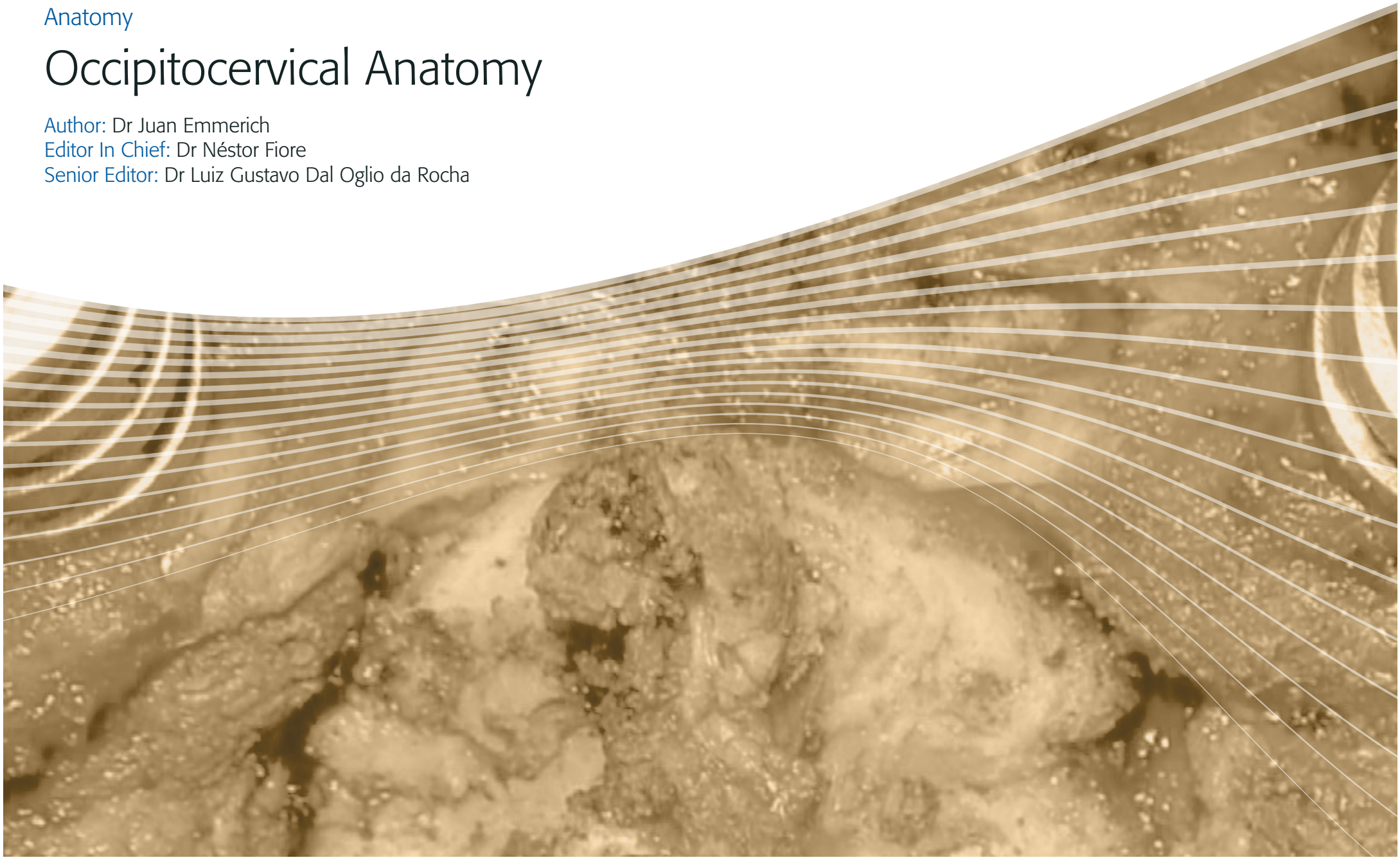

OBJECTIVES

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Anatomy

Occipitocervical Anatomy

- To describe the anatomical areas corresponding to the occipital region and the cervical spine.
- To define the important points in the relationship between the spine and the neural axis.
- To identify relevant data to be taken into account when considering surgical approaches.
- To understand the region's anatomy in terms of practical data prepared for spine surgeons, important for everyday procedures.

CONTENTS

1. INTRODUCTION

Overview

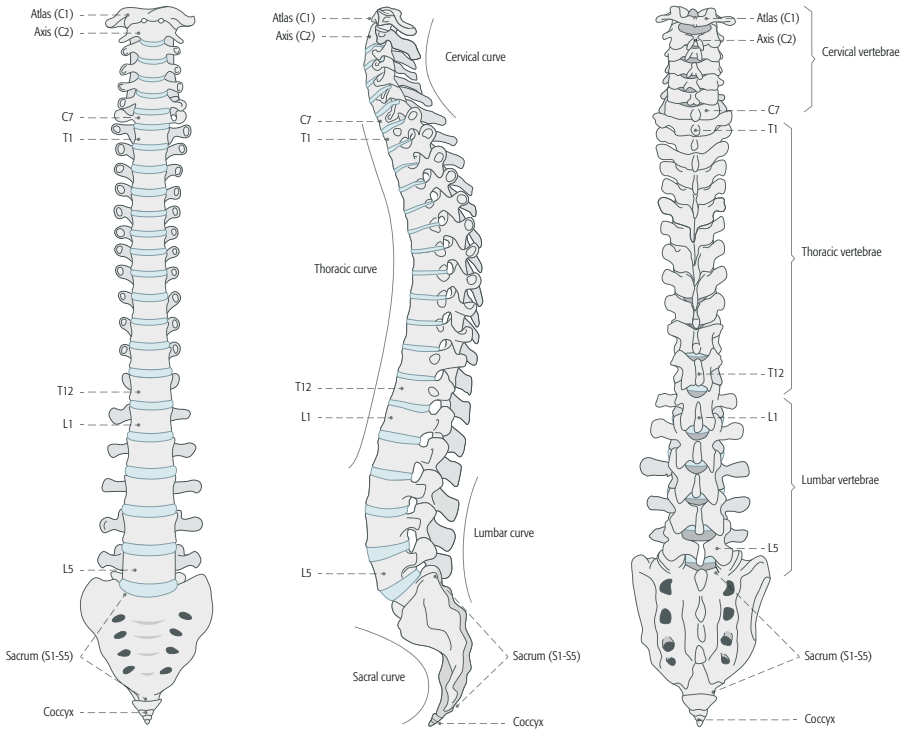
The spinal column consists of a chain of overlapping vertebrae with interconnecting articulations.
It has a dual function.

- On one hand, it forms the body's main axis, serving as a link between the skull, thorax, abdomen and pelvis, transferring the weight in a standing position from the head, upper limbs and trunk, through the sacroiliac joints, to the lower limbs.
- On the other hand, it protects the spinal cord, the most caudal segment of the central nervous system.

These functions define the properties of the spine.

- A long extension that runs along the body's entire axis.
- The spine considered as a complete unit presents the following characteristics:
  - an internal channel – the spinal canal – housing the cord and its protective casings; and
  - intervertebral foramina - lateral openings to allow the passage of spinal nerves.

Overall, the spine has the capacity for flexo-extensional, rotational and lateral movements, as well as the capacity to bear axial loads. These capacities increase at more caudal points of the spine, demonstrated by the regional characteristics of the vertebrae.



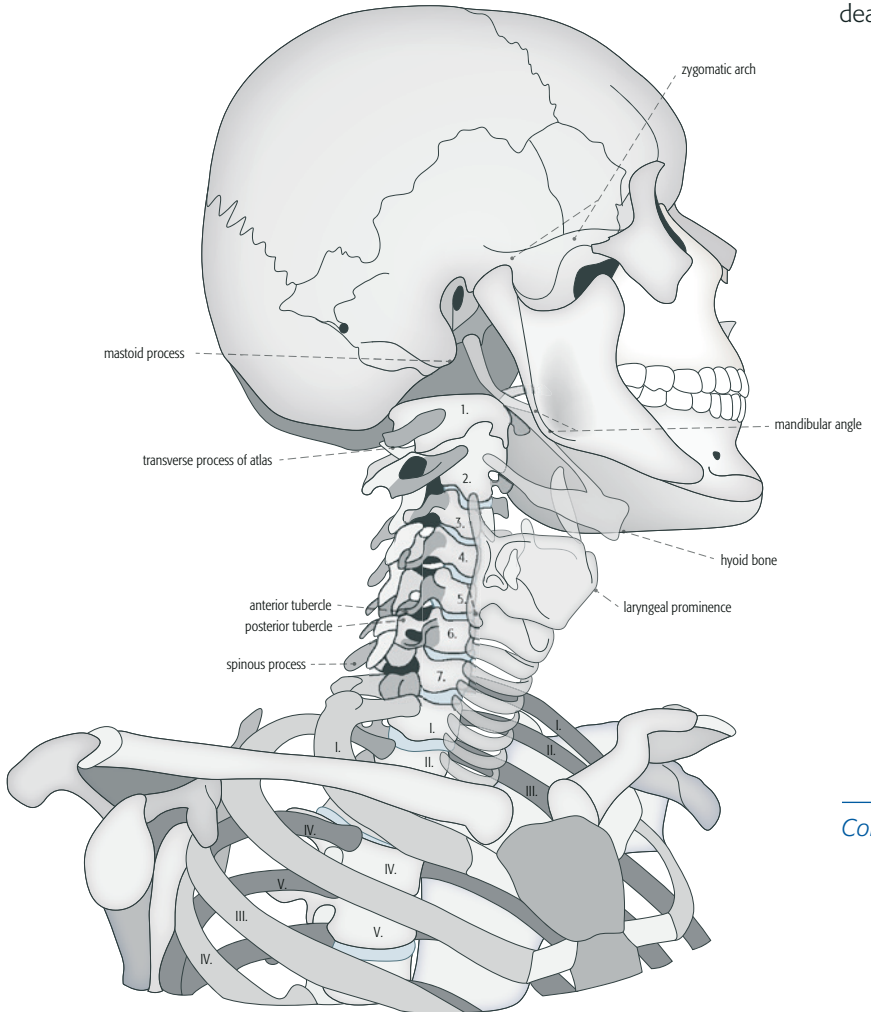
Anterior view *Left lateral view* *Posterior view*

Complete view of the spinal column (Sobotta, 1985)

2. BONE STRUCTURE

The number of vertebrae is usually quite constant, from 33 to 35:

- 7 cervical;
- 12 thoracic;
- 5 lumbar;
- 5 sacral vertebrae; and
- 3 to 5 coccygeal vertebrae



Collective view of the cranium, cervical spine and thorax (Pernkopf, 1963)

This distribution, which is considered typical, is only present in 65% of individuals. While the number of cervical and thoracic vertebrae is almost always constant, any variations that do occur are usually in the number of lumbar and sacral vertebrae. In the general population, there is a high incidence of L5 assimilation by the sacrum (sacralization), and often a lack of S1 fusion with the rest of the sacral vertebrae, resulting in an additional mobile segment (lumbarization).

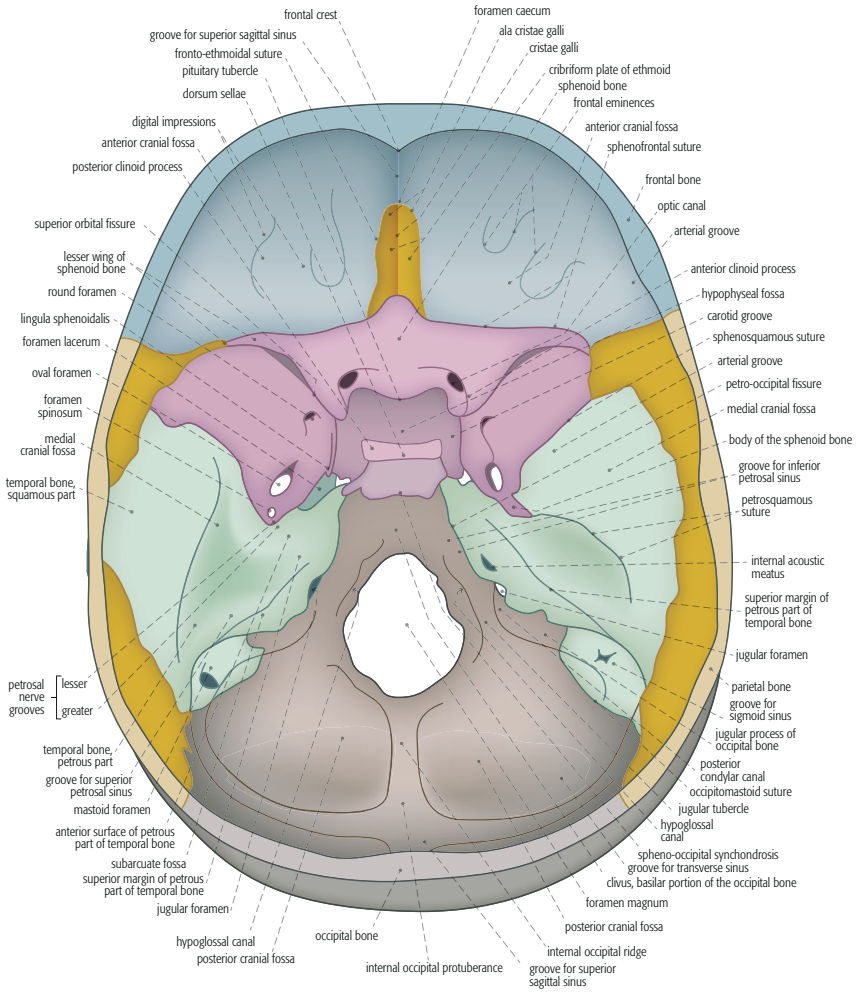
This topic covers the occipital and cervical vertebrae, while the next topic shall deal with the remaining bone structures which make up the spinal axis.

2

Occipital

The occipital is an unpaired, medial bone with the following articulations:

- laterally with the temporal bone;
- posteriorly and superiorly with the parietals bones;
- anteriorly and superiorly with the sphenoid bone; and
- inferiorly with the atlas.



Superior view of the cranium's base after removing the cranial vault (Sobotta, 1985)

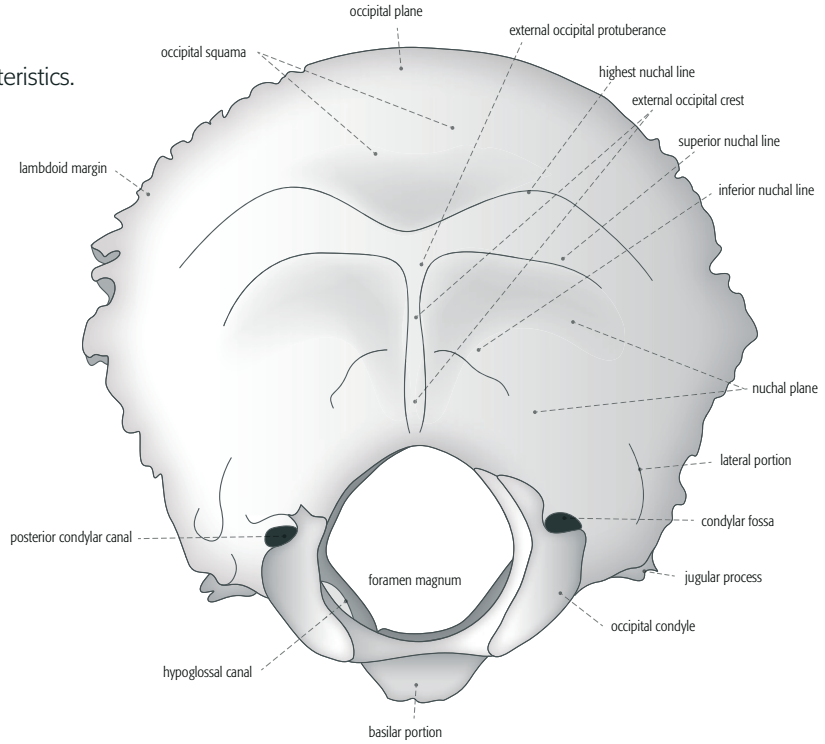
Two surfaces can be differentiated: the posteroinferior, or exocranial, and the anterosuperior, or endocranial.

The foramen magnum (FM), or occipital hole, is an ample, oval-shaped orifice with average dimensions of 35 mm in the anteroposterior direction and 30 mm laterally. It has a rounded posterior margin while the anterior border is angular. The posterior section of the FM is neurovascular and the following elements pass through it:

- meninges;
- medulla oblongata transition;
- vertebral arteries; and
- spinal root of the accessory or spinal nerve.

Exocranial surface

The exocranial surface has its own characteristics.



Exocranial surface of the occipital bone (Sobotta, 1985)

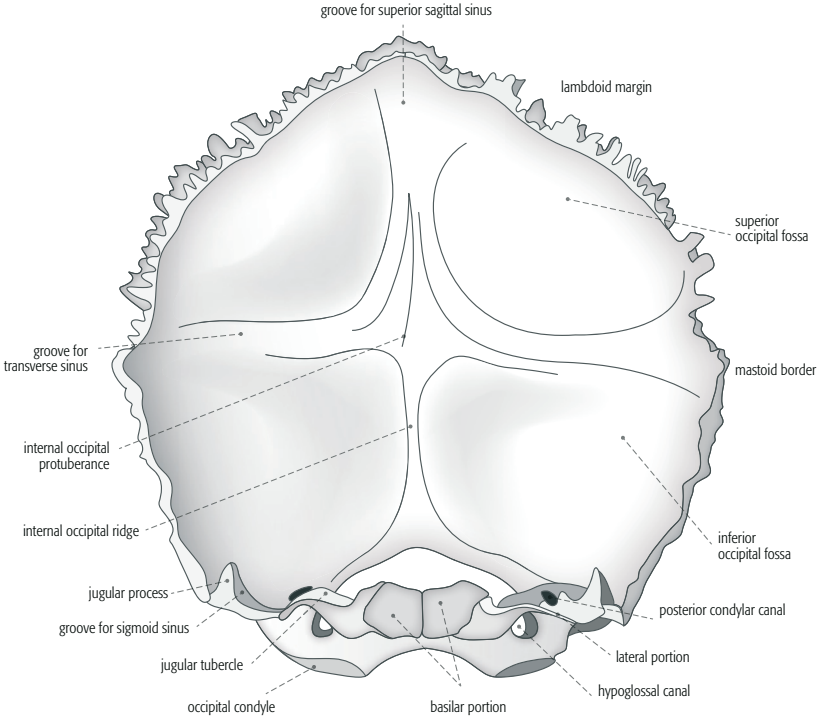
- There is a rectangular lamina known as the basilar process in front of the FM. It runs forwards and upwards from the anterior margin of the FM to finish in the posterior portion of the body of the sphenoid bone, at the dorsum sellae.
- Just in front of the FM is found the pharyngeal tubercle, the fibrous raphe of the pharynx is attached at this point.
- To the sides, the occipital is joined to the petrosal portion of the temporal bone via the petroclival suture. This suture is open along its posterior sector where it forms the jugular foramen. This orifice marks the start of the internal jugular vein, formed by the opening of the sigmoid sinus into the jugular bulb. The glossopharyngeal (IX), vagus (X) and accessory (XI) cranial nerve pairs also pass through the jugular foramen.
- The largest and thinnest portion of the occipital bone, known as the occipital squama, is found behind the FM. Its upper connection is with the parietal bones, forming the occipitoparietal suture or lambdoid suture, and laterally it joins with the mastoid process of the temporal bone.
- Part of the occipital bone is formed by the external occipital protuberance (EOP) or inion (a bony hump running along the median line, varying in size from one person to the other, oscillating from a small prominence up to a significant protrusion). More often than not they are found approximately 1 cm below the internal occipital protuberance on the endocranial surface.
- Running horizontally from the EOP is the superior nuchal line, which serves as the point of insertion for the following muscles:
  - occipitalis;
  - trapezius;
  - sternocleidomastoid; and
  - splenius capitis.

2

- The external occipital crest emerges from the EOP, descending down the median line towards the FM. At the sides, emerging horizontally, approximately 2 cm below the EOP, is the inferior nuchal crest, which serves as the point of insertion for the rectus capitis posterior major and minor muscles.
- The occipital condyles are found to the side of the FM, in the anterior half. They are oval, with their main axis orientated slightly inwards and forwards. They are caudally convex and correspond with the glenoid cavities of the atlas. In the middle portion of their internal surfaces are the alar tubercles which attach to the alar ligaments arising from the odontoid process.
- The condyles have two depressions known as the anterior and posterior condyloid fossae.

Anterior condyloid fossa	Posterior condyloid fossa
Contains the anterior condyloid foramen, through which passes the hypoglossal nerve (cranial nerve pair XII).	Contains an opening of variable size, the posterior condyloid foramen, through which passes a vein connecting the brain's venous system to the posterior cervical veins.

- Endocranial surface
- The endocranial surface also has its own characteristics.



Endocranial surface of the occipital bone (Sobotta, 1985)

- The portion anterior to the FM is known as the clivus and corresponds to the basilar process of the exocranial surface. It also relates to the anterior aspect of the brain stem, specifically to the medulla oblangata, the pons and to the basilar trunk (artery arising from the confluence of the two vertebral arteries).
- As with the exocranial surface, the occipital squama is located behind the FM.

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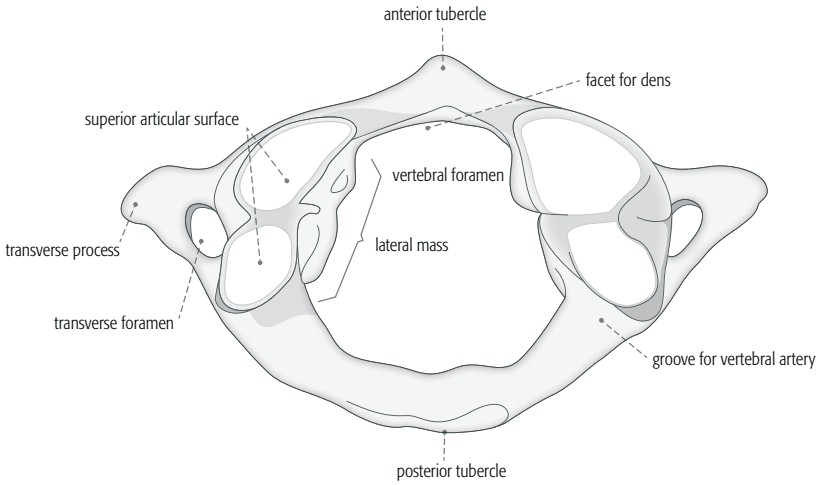
- The internal occipital protuberance (IOP) is a bony protrusion along the median line, about 6 cm above the posterior margin of the FM. The transverse ridges emerge to its sides. These ridges present an upper edge, a lower edge and a shallow channel in the middle running horizontally outwards. They form the point of insertion for the anterior border of the tentorium cerebelli or "tent of the cerebellum" (an extension of the dura mater membrane which divides the endocranial space into supra- and infratentorial areas). The transverse ridges end at the temporal bone, in a 90° downward angle, continuing with the sigmoidal portion that opens into the jugular foramen.
- A median ridge, called the internal occipital ridge, emerges vertically descending from the IOP and ends at the posterior margin of the FM.
- These bony ridges create four fossae in the occipital squama:
  - two superior fossae housing the occipital lobes of the brain; and
  - two inferior fossae corresponding to the cerebellar hemispheres.
- These bony landmarks have a close relation with the venous sinuses, vascular structures that lie between the two membranes of dura mater (the outer most layers of the meninges) and transport venous blood from the brain to the internal jugular veins via a complicated system.
- The IOP is closely related to the torcula, or torcular herophili, a confluence of sinuses that receives blood from the superior longitudinal sinus and straight sinus. The straight sinus is formed from the union of the inferior longitudinal sinus and the great cerebral vein, draining through the tentorium cerebelli at the point where it joins with the falx cerebri then flowing into the torcula.
- The torcular herophili continues towards both sides with the transverse sinuses in the channel formed by the transverse ridges. The transverse sinus follows a descending line before forming the sigmoid sinuses, which end at the jugular bulb.
- With respect to the internal occipital ridge, the occipital sinus (also known as the cerebral venous sinus) is situated within a dural fold known as the falx cerebri. This sinus is particularly developed in children, being smaller in adulthood.

i

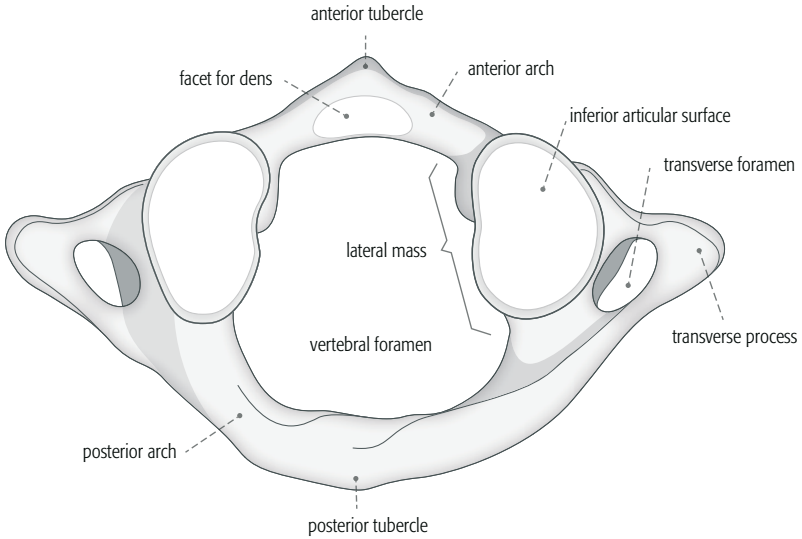
Upper cervical spine: the atlas and axis

Atlas (C1)

The first cervical vertebra is known as the atlas. It is the only vertebra without a vertebral body.
It comprises two lateral masses united by two transverse portions, called the anterior and posterior arches.



Superior view of the atlas (Sobotta, 1985)



Inferior view of the atlas (Sobotta, 1985)

- The anterior arch is shorter and straighter than the posterior one. It has a small tubercle on the median area of its anterior aspect. There is a depression, called the facet of atlas for dens, on the posterior aspect which comprises the articular surface that receives the anterior aspect of the odontoid process, or dens.
- The posterior arch really takes the shape of an arch with anterior concavity. It has a tubercle on its posterior aspect that forms an outline of a spinous process. On its upper aspect is the groove for the vertebral artery.

The size and shape of this sulcus varies, being classified into three types:

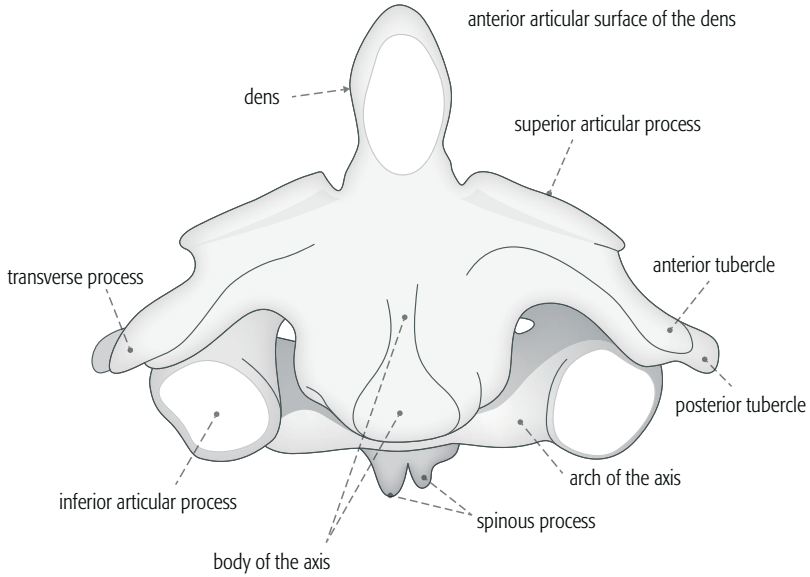
Type 1	A groove on the superior aspect of the posterior arch of the atlas which houses the vertebral artery.
Type 2	A superiorly incomplete channel that partially covers the vertebral artery.
Type 3	A complete bone sulcus that totally covers the vertebral artery.

Percentages of each vertebral canal conformation type

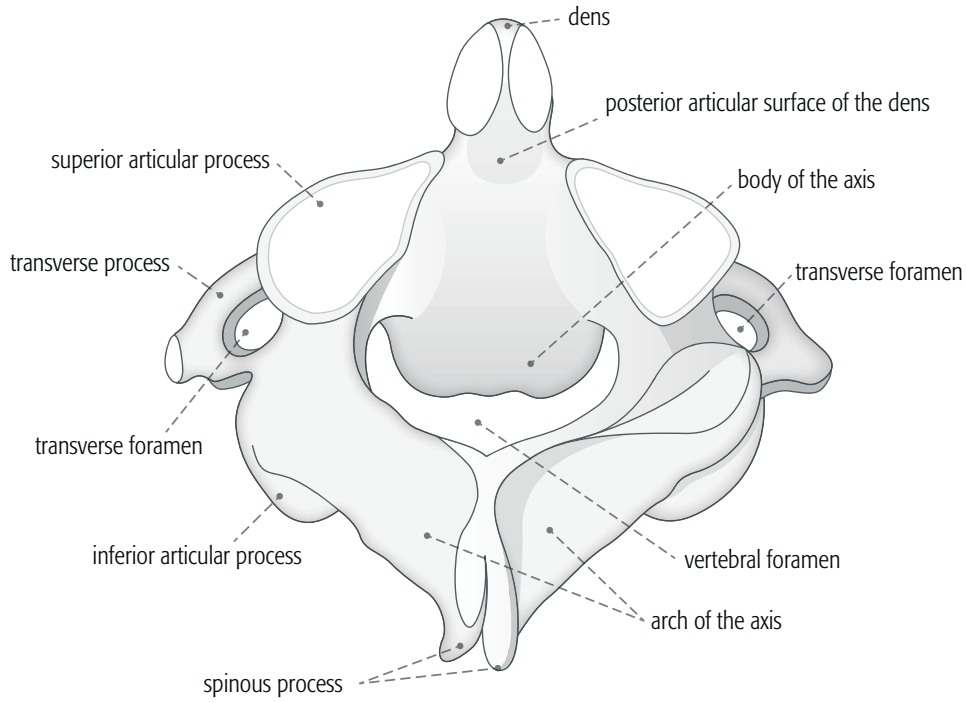
- The glenoid cavity, which receives the occipital condyle, is found on the superior aspect of the lateral mass. It is oval, with its main axis in an anteroposterior direction and upwardly concave.
- Located on the inferior aspect are the articular facets; these are planar, circular and designed to receive the superior articular facets of the axis.
- There is a tubercle, to which attaches the transverse ligament, in the union between the medial aspect of the lateral mass and the anterior arch.

Axis (C2)

The axis or C2 has a body similar to the rest of the cervical vertebrae. However it is notably different because a vertical prominence, unique to this vertebra, known as the odontoid process, or dens, protrudes from its superior aspect.



Anterior view of the axis (Sobotta, 1985)



Posterior and slightly superior view of the axis (Sobotta, 1985)

The odontoid process measures between 10 to 16 mm long and is 10 mm wide. From caudal to cranial it has the following elements:

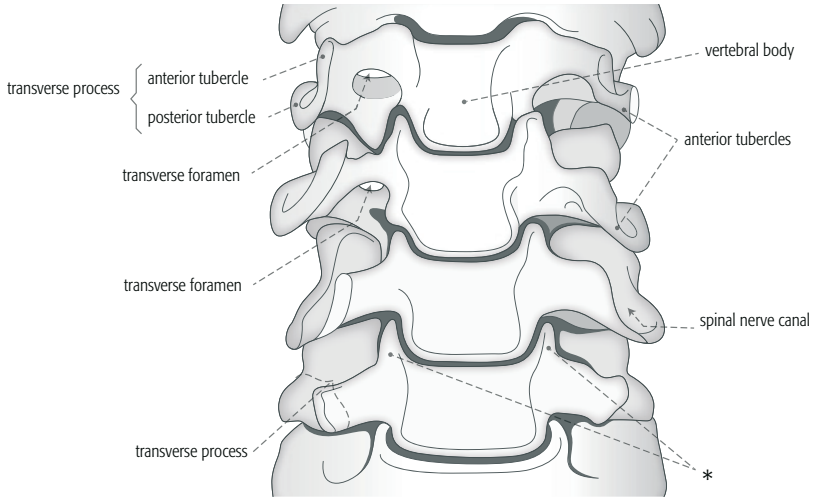
- the base (the widest portion which leads on to form the body);
- the body itself; and
- the apex or tip.
- It has an articular facet on its anterior aspect which articulates with the posterior aspect of the anterior arch of the atlas.
- On the posterior aspect, there is an indent for the transverse ligament.
- On the superior portion, there is an indent for the apical or suspensory ligament. To the sides, there is an indent for the alar ligaments.
- The superior articular facets of the axis are immediately to the sides of the odontoid process. They are flat and face upwards and outwards. The inferior articular facets are located at the union between the pedicle and the lamina.
- The superior articular facets of the axis are in a more anterior plane than the inferior facets, creating a translation of forces through the axis' vertebral body and pedicles. Therefore, the cervical spine goes from having two points of support (the C1 and C1-C2 occipital articular processes) to being supported at three points (the vertebral body and two articular processes).
- The pedicle is very short and easily confused with the lamina.
- The transverse process is small, the transverse foramen faces upwards and outwards due to the route taken by the vertebral artery in search of the transverse foramen of the atlas.
- The spinous process is very long and has a bifurcated ending, as do the rest of the cervical vertebrae.
- The vertebral foramen is smaller than that of the atlas, but larger than in the rest of the cervical vertebrae.

Through these features the axis provides a surface capable of supporting the rotation of C1 over C2.

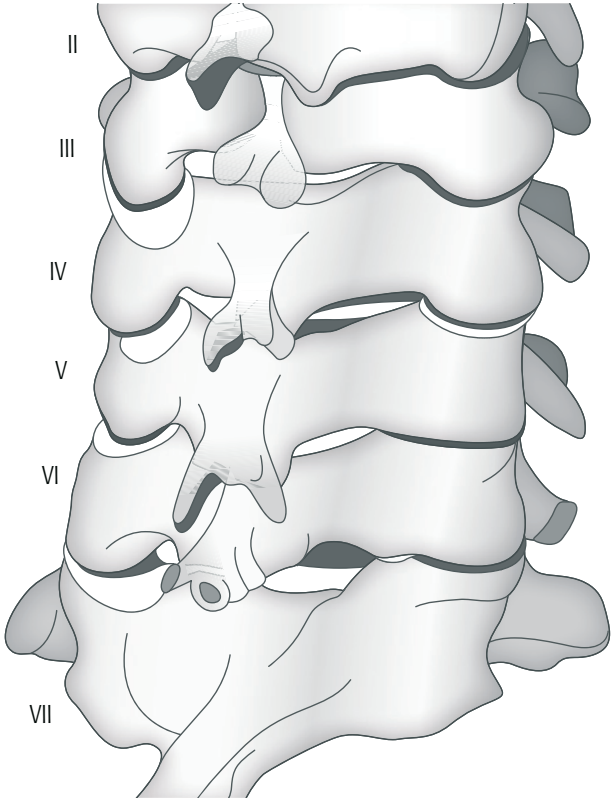
Lower cervical spine (C3 to C7)

C3 to C6

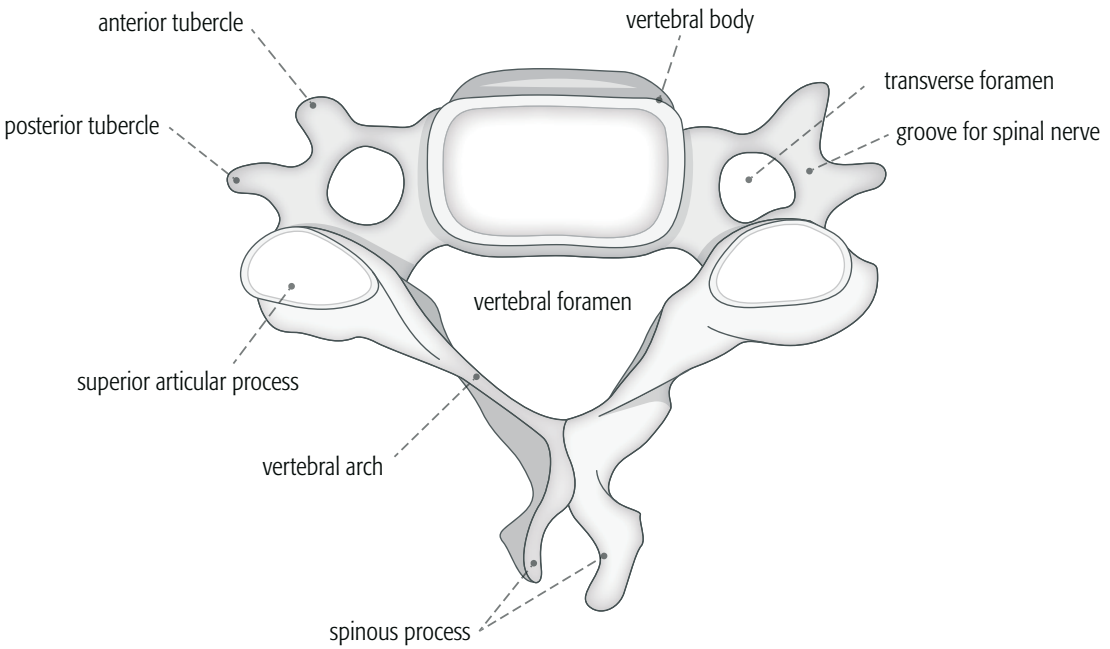
These levels have the smallest bodies of all the vertebrae, given that this section of spine supports the least weight.



Anterior view of the lower cervical spine (Sobotta, 1985)



Posterior view of the lower cervical spine (Sobotta, 1985)



Superior view of C5 cervical vertebra (Sobotta, 1985)

The transverse diameter of the vertebral body is approximately double the anteroposterior diameter.

The superior aspect of the body presents two small prominences with respect to the lateral margins; they are known by several names:

- uncus;
- uncinate processes;
- hooks; or
- semilunar processes.

These processes coincide with and are received by two notches in the inferior aspect of the overlying vertebral body, facilitating articulation between the two vertebral bodies.

- The vertebral foramen is triangular and relatively large

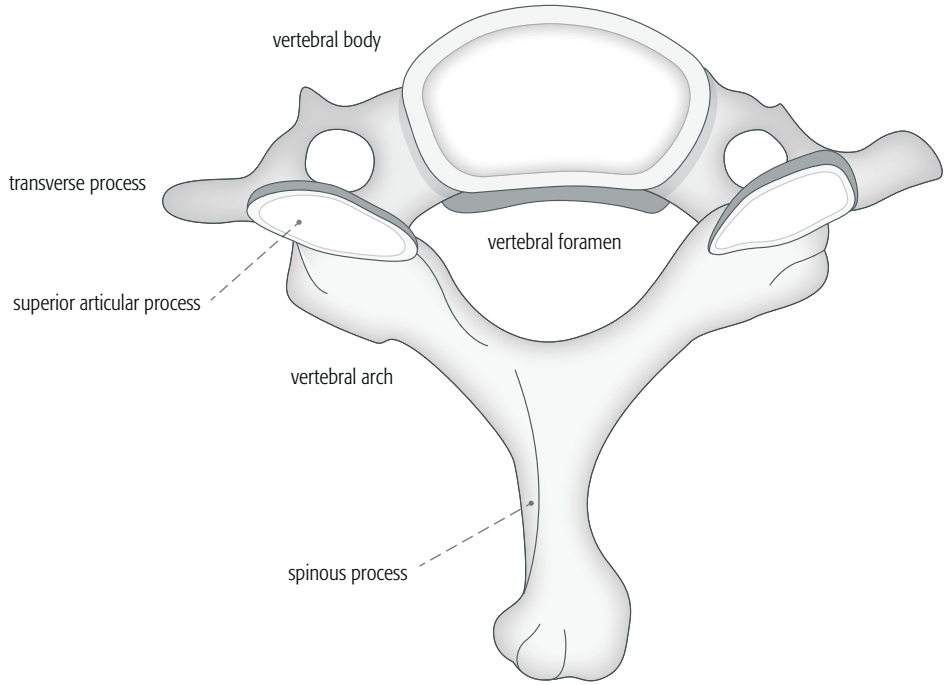
The transverse processes are attached to the sides of the vertebral bodies by means of two portions:

- anterior or costal (outline of a rib); and
- posterior or transverse.
- There is an orifice in the center of the transverse processes called the transverse foramen, through which passes the vertebral neurovascular bundle.
- The articular processes are cylindrical with oblique cuts, the superior facets face backwards and upwards, while the inferior facets face forwards and downwards.
- The laminae are narrow and thin; their superior border is thinner than the inferior.
- The spinous processes are small, short and angled slightly downwards. They characteristically end in two small tubercles giving them a bifid shape.

C7

This is a transitional vertebra situated between the cervical and thoracic regions.

- The spinous process is distinctively large, projecting out from the rest of the cervical vertebrae. C7, therefore, is also known as the vertebra prominens.
- This large spinous process demonstrates some of the characteristics of the thoracic vertebrae, as it is unituberculate and angled backwards and downwards.
- The vertebral foramen is smaller than that of preceding vertebrae. In some cases there may be two small holes instead of one, and, on other occasions, the transverse foramen may not exist at all. The vertebral artery does not pass through this foramen, but, however, through that of C6.

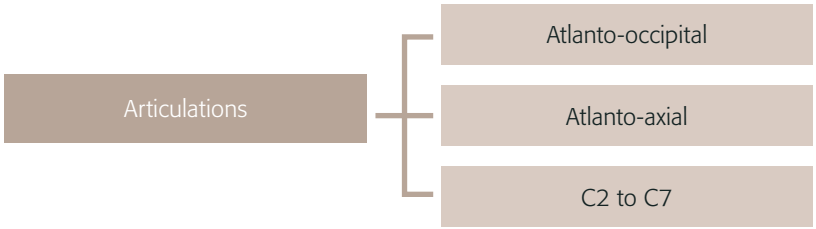


Superior view of C7 (Sobotta, 1985)

3. ARTICULATIONS

The occipital bone and vertebrae described so far are connected together by the occipito-atlanto and intervertebral joints.

The joints can be grouped in the following manner:



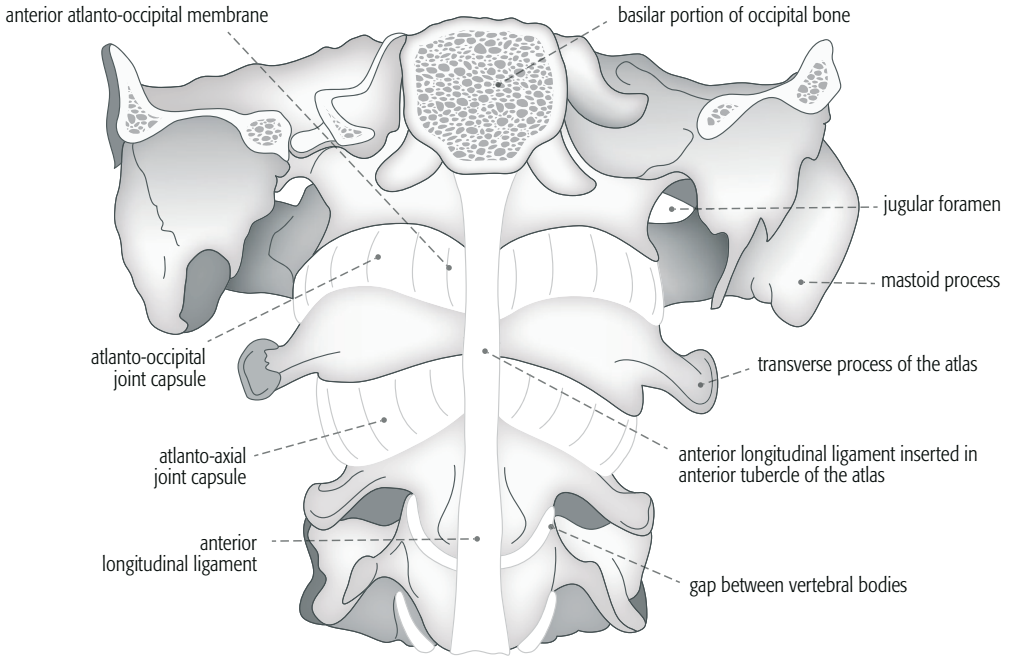
The atlanto-occipital joint

The atlanto-occipital joint is located between the occipital condyles and the glenoid cavities of the atlas which coincide to form a double condyloid joint.

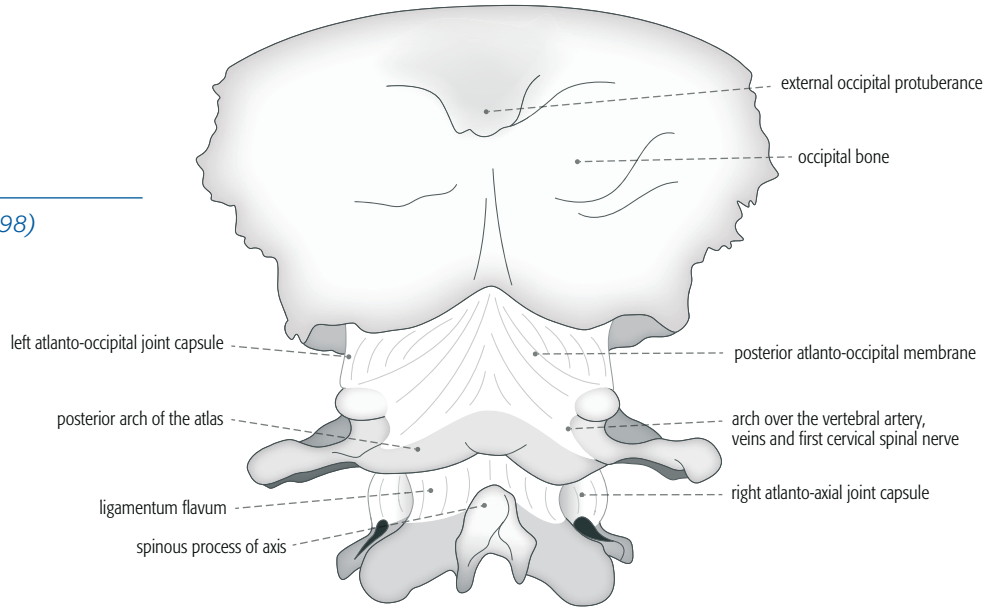
It has a joint capsule that is reinforced by the following ligaments:

- lateral;
- anterior;
- posterior; and
- medial (thin and weak).

There is a wide fibrous lamina called the posterior atlanto-occipital membrane inserted superiorly at the posterior margin of the FM and inferiorly at the superior margin of the posterior arch of the atlas. It is equivalent to the ligamentum flavum and the vertebral arteries pass through it.



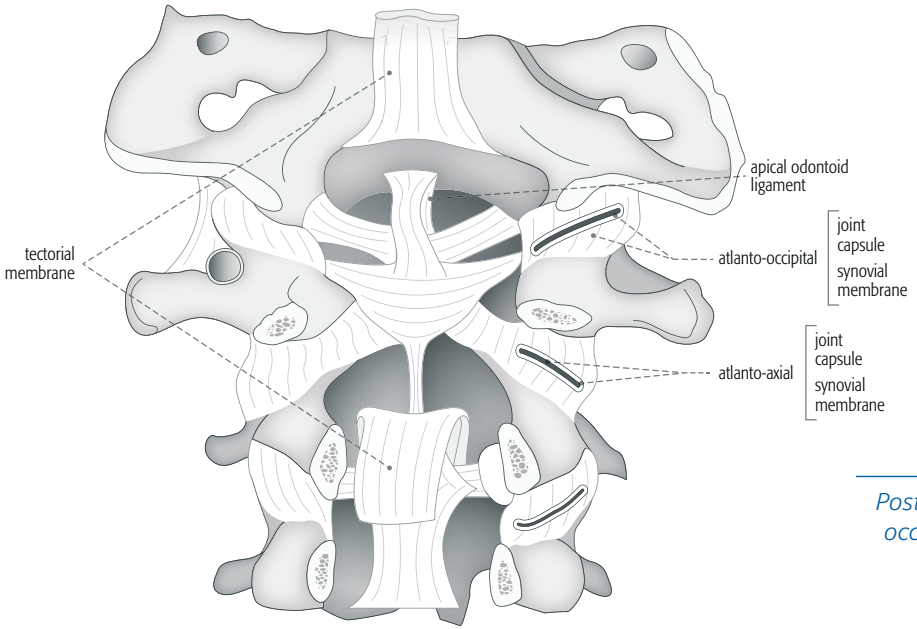
Anterior view of C0, C1 and C2 joints (Williams, 1998)



Posterior view of C0, C1 and C2 joints (Williams, 1998)

The atlanto-axial joint

The atlas and axis are connected by three articulations, two lateral and one medial.



Posterior view of C0, C1 and C2 joints, with the posterior portion of the occipital and the posterior vertebral arches removed (Williams, 1998)

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Lateral joints

The lateral joints are located on each side, between the inferior articular facets of the atlas and the superior articular facets of the axis.

Their joint capsule is fundamentally stabilized by the anterior and posterior ligaments.

Medial joint

The medial joint is located between the odontoid process of the axis and the anterior arch of the atlas. It is a trochoid joint.

- The odontoid process presents an anterior articular facet to receive the posterior arch of the atlas and a posterior facet for the transverse ligament.
- The atlas includes the odontoid fossa, a backward-facing, slightly convex, oval surface, which is found on the posterior aspect of the anterior arch.
- The transverse ligament completes the so-called atlas ring, running posteriorly and surrounding the odontoid process.

C2 to C7 joints

There are three articulations between each level of these vertebrae:

- joints between vertebral bodies (singular, medial);
- joints between articular processes (two, lateral and symmetrical).

Articulation between the vertebral bodies

Articular surfaces

These correspond to the superior and inferior surfaces of the vertebral bodies.

The bone surfaces are covered by a sheet of cartilage which changes as the spine ages. These sheets are formed of hyaline cartilage when young and convert into fibrocartilage upon reaching maturity. They are known as vertebral endplates.

Several authors correctly include the endplates as a component of the intervertebral disc, given the important role they play in disc diseases.

Endplates provide the disc with nutrients through their porous surface, while simultaneously preventing the disc from protruding towards the vertebral bodies.

Intervertebral discs

From a structural point of view, they constitute a quarter of the total length of the spine and fulfill an important role in maintaining the spine's physiological curves. Their biconvex shape means they adapt to the concave surfaces of the vertebral endplates.

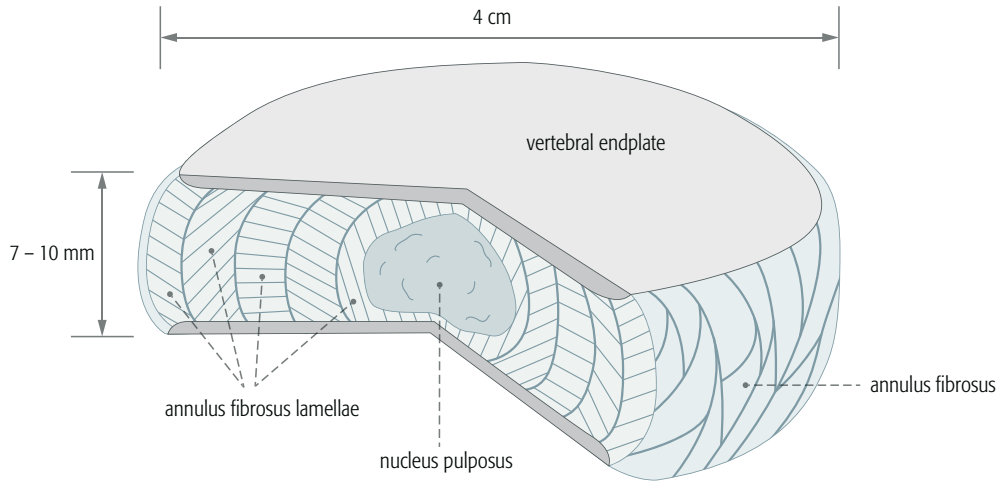
Discs are thicker in cervical and lumbar regions, where they can amount to more than a quarter of the height of a vertebral body. They are subject to a daily process of dehydration during activity and hydration when at rest, meaning their thickness changes continually.

3

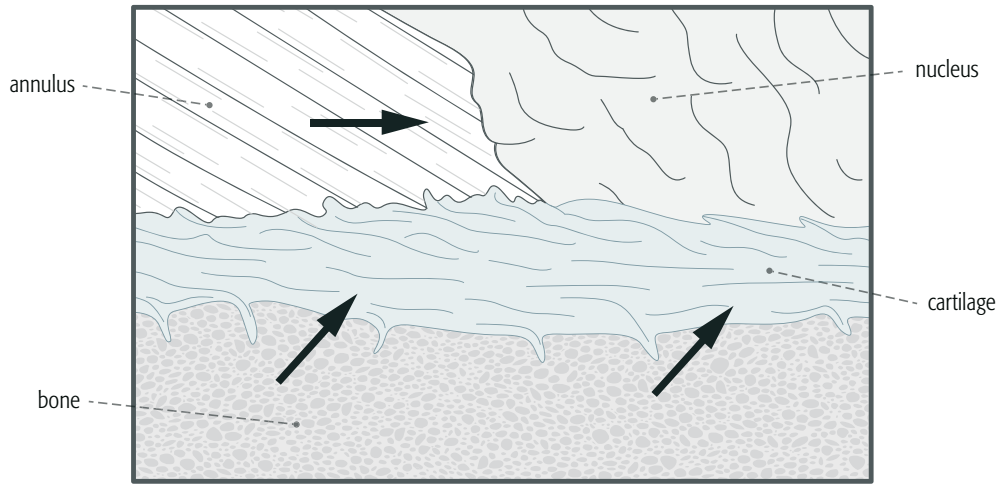
The particular characteristic of the uncovertebral joints on the laterals of the bodies, described previously, are found at the cervical level.

The discs are formed from three components:

Annulus fibrosus	A hard fibrous ring located around each disc, surrounding the nucleus pulposus and limiting its expansion. It is composed of several concentric layers of fibrocartilage. These fibers extend from one vertebral body to another, following an oblique alignment that varies from one concentric layer to another, providing the disc with greater resistance to the constant movements it endures. The following ligaments are attached to the annulus fibrosus: ▪ anteriorly, the anterior longitudinal ligament; and ▪ posteriorly, the posterior longitudinal ligament.
Nucleus pulposus	A soft, gelatinous substance, with a consistency similar to toothpaste, formed from a proteoglycan gel. It does not occupy a perfectly central position but is actually closer to the posterior margin of the disc. Its color and consistency change over the years, starting as off-white and highly hydrated in childhood and becoming yellowish, opaque and dehydrated in older adults. Discs are avascular from the age of 10 years onwards, after this point they receive nutrients via diffusion from neighboring structures, primarily the vertebral endplates.
Vertebral endplates	Endplates can be considered as a transition between vertebral bodies and intervertebral discs since they are strongly attached to both structures. Their function is to prevent migration of the nucleus toward the cancellous bone and to distribute loads evenly. The cartilage is in direct contact with the cancellous bone of the vertebral body, without any cortical bone, unlike the majority of the body's articular surfaces. They are vital for the nourishment of the annulus fibrosus and the nucleus pulposus; by functioning as a semipermeable interface, they permit water and salts to pass through but prevent the loss of large proteoglycan molecules.



Components of an intervertebral disc (Williams, 1998)



Close relationship of the annulus fibrosus, nucleus pulposus and endplates (Williams, 1998)

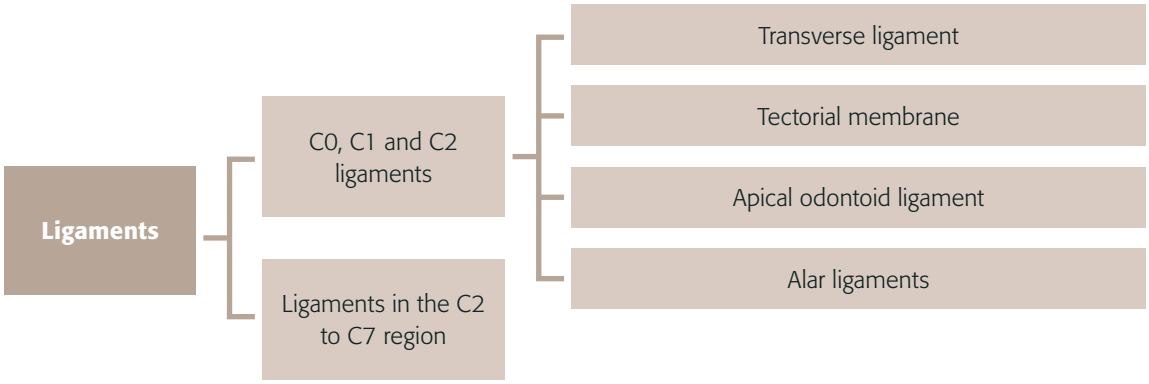
Intervertebral facet joints

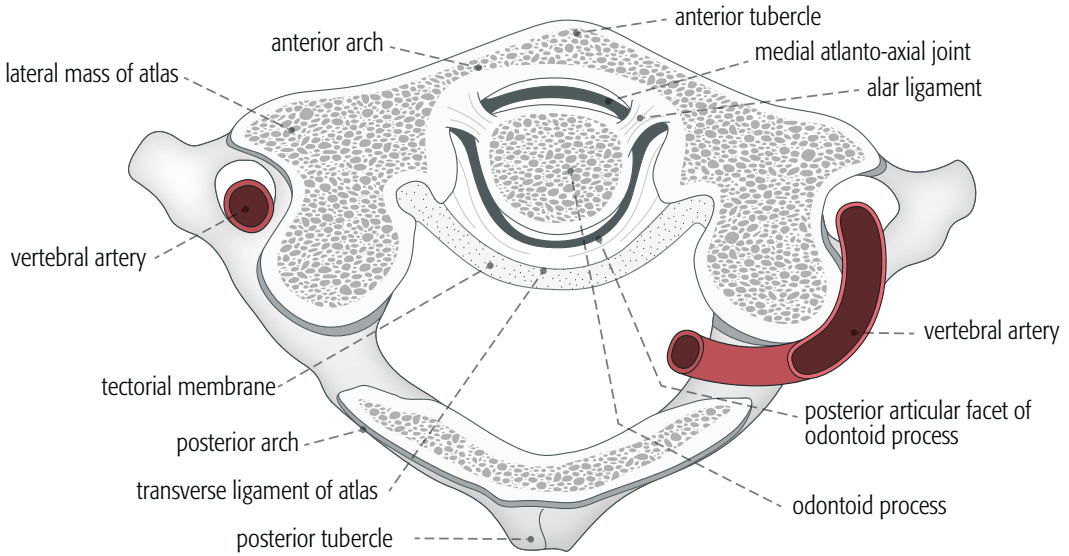
These are synovial joints. They possess a thin, lax joint capsule which affords stability to the articular surfaces.

Articular surfaces, known as articular facets, are covered with a thin layer of cartilage. Articular processes are cylindrical with oblique cuts, the superior facets face backwards and upwards, while the inferior facets face forwards and downwards.

4. LIGAMENTS

The ligaments connect different elements of the vertebrae and are the main short-range stabilizers.





Axial section of the atlanto-odontoid joint

Transverse ligament (Latarjet and Ruiz Liard, 2005)

C0, C1 and C2 ligaments

A complex system of ligaments reinforces the joints between the occipital, atlas and axis bones.

On one hand, this system includes ligaments common to the whole spine, such as the anterior and posterior longitudinal ligaments, while on the other, C0, C1 and C2 have their own particular ligaments, which are described below.

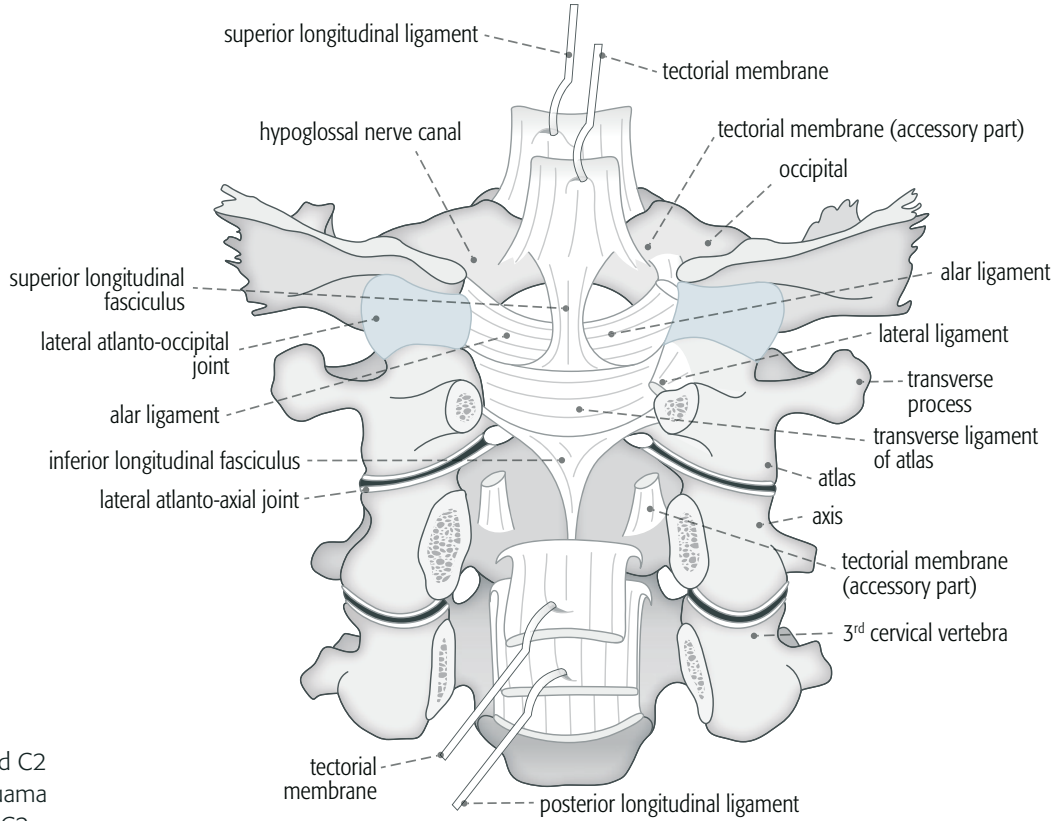
Transverse ligament (cruciform ligament)

A short, very strong, band-like ligament that extends in a slight forward arch from one lateral mass to the other, more specifically it attaches where the lateral masses join with the posterior aspect of the anterior arch of the atlas.

The transverse ligament is located behind the posterior aspect of the odontoid process and in front of the tectorial membrane.
Two fascicles extend from the middle of the ligament:

- the upper fascicle, called crus superius or superior longitudinal fasciculus, which is attached to the anterior margin of the FM; and
- the lower fascicle, called crus inferius or inferior longitudinal fasciculus, which is secured to the posterior aspect of the body of the axis.

Collectively, the transverse ligament and the two fascicles take the form of a cross, which is why the group is known as the cruciform ligament of the atlas.



Posterior view of C0, C1 and C2 joints, with the occipital squama and posterior arches of C1, C2 and C3 removed.

Cruciform and alar ligaments plus the tectorial membrane (Latarjet and Ruiz Liard, 2005)

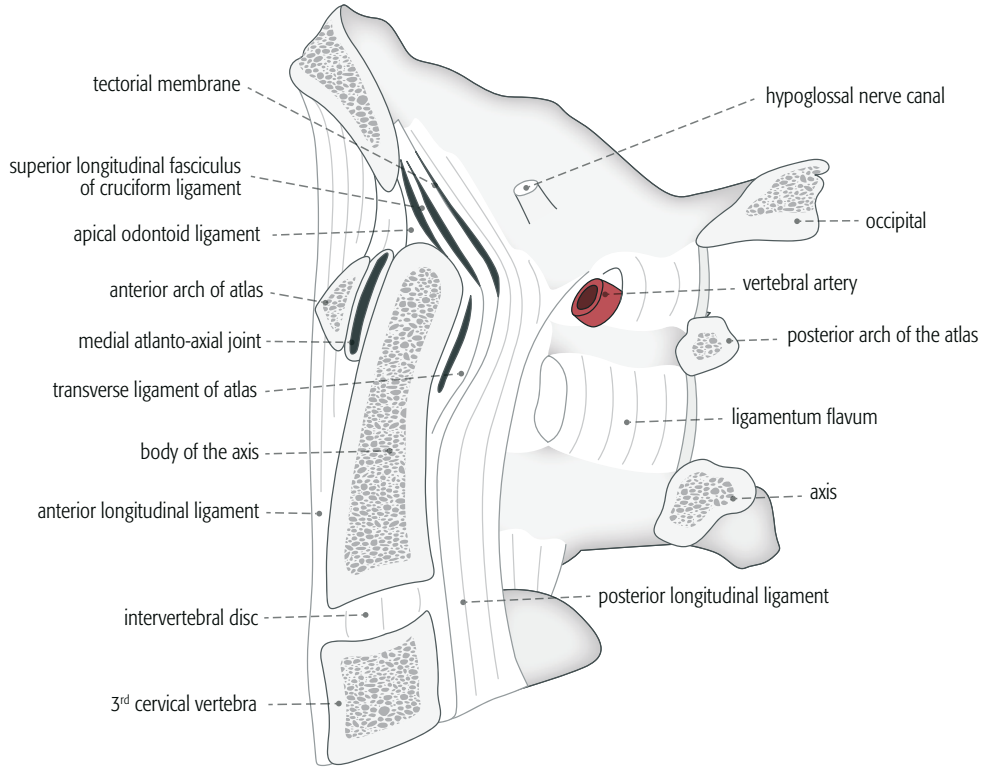
Tectorial membrane

The tectorial membrane extends from the anterior margin of the FM to the posterior aspect of the body of the axis, located immediately behind the cruciform ligament of the atlas.

It is a strong membrane consisting of three fascicles, one medial and two lateral.

Apical odontoid ligament

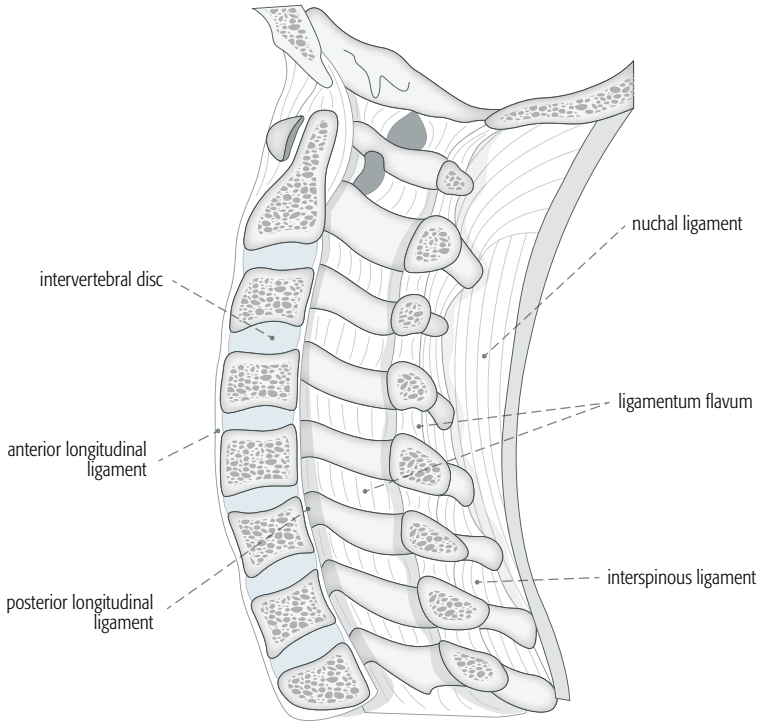
The apical ligament of the odontoid process, also known as the suspensory or apical ligament of dens, is a short ligament running from the anterior margin of the FM to the apex of the odontoid process.



Midsagittal section of the occipital, C1 and C2 region (Latarjet and Ruiz Liard, 2005)

Ligaments moving caudally from C2

- Anterior longitudinal
- Posterior longitudinal
- Supraspinous
- Interspinous
- Ligamentum flavum



Sagittal section of the intervertebral discs and ligaments (Louis, 1982)

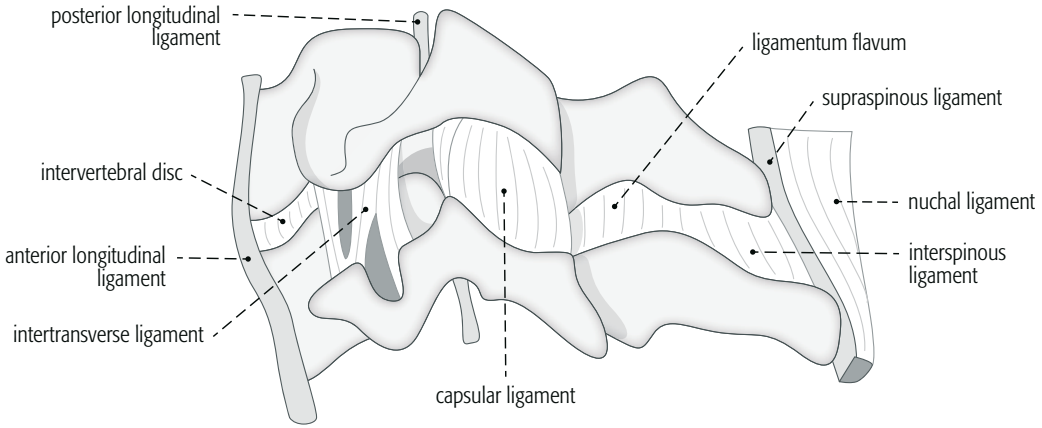


Diagram of the ligament structures of a mobile segment (Louis, 1982)

4

Alar ligaments

The alar ligaments are a pair (left and right) of short, strong ligaments which run from the anterior portion of the medial side of the occipital condyles to the sides of the upper portion of the odontoid process.

Ligaments in the C2 to C7 region

Described below is a series of ligaments that are common to all vertebral regions moving caudally from C2. Anterior longitudinal ligament

This ligament descends down the anterior aspect of the spine, from the exocranial surface of the basilar portion of the occipital bone to the anterior aspect of the second sacral vertebra.

It is a strong ligament of varying width, narrow at the upper cervical level. It gradually widens until it reaches its maximum width at the thoracic level and then narrows through the lumbar level down to just a small strip in the sacral region.

The ligament is strongly attached to the anterior aspects of both the discs and the vertebral bodies (primarily in areas which are close to the discs).

Posterior longitudinal ligament

This ligament runs from the endocranial surface of the basilar process of the occipital down to the coccyx.

It runs along the posterior aspect of the vertebral bodies, located on the anterior margin of the spinal canal.

The ligament presents a scalloped shape because it is wider at the level of the discs than it is near the bodies.

As with the anterior longitudinal ligament, it is strongly attached to both the discs and vertebral bodies, at points close to the discs.

Supraspinous ligament

The supraspinous ligament is a fibrous cord extending behind the interspinous ligaments along the length of the whole spine, anchoring to the apices of the spinous processes.

At the cervical level, it is continuous with the nuchal ligament and continues dorsally to form an intermuscular septum that extends to the superficial fascia.

4

Interspinous ligament

This ligament differs from the previous ligaments because it has a segmented distribution, there is no continuity with the ligaments in the levels above or below.

It occupies the space between the spinous processes of a mobile segment, situated on the processes' inferior and superior margins.

The anterior surface contacts the ligamentum flavum, while the posterior surface merges with the supraspinous ligament.

Ligamentum flavum

The ligamentum flavum is formed by a left-right pair of short, thick, strong and highly elastic ligaments that occupy the space between the laminae of a mobile segment. Each ligament in the pair extends horizontally from either side of the articular process to the median line where they contact with the contralateral.

The size of the ligamentum flava depend on the level of the spine. Typically, their width, that is, their medial to lateral extension, decreases from the cervical to lumbar spine, while their height and thickness increase.

The superior margin is inserted on the anterior surface of the overlying lamina, the point of insertion gets closer to the inferior margin of the overlying lamina while moving down the vertebrae towards the sacrum. The inferior border is attached to the superior margin of the underlying lamina.

5. BASIC ANATOMY

Posterior region

The recognized limits of this region are: cranially, the external occipital protuberance; laterally, the superior nuchal line; and caudally, a line from the spinous process of the seventh cervical vertebra to the acromial end of the clavicle.

In the superior section, the skin is thick and has hair follicles. In lean individuals, a fossa produced by the protrusion of the trapezius and, on each side, the semispinalis capitis muscles can be discerned at the median line beneath the external occipital protuberance. In obese people, skin at the nape of the neck can present in one or two horizontal folds produced by the subcutaneous adiposity.

Found within the subcutaneous tissue, of variable size depending on whether the patient is lean or obese, located in relation to the occipital bone and to the sides of the median line, is the terminal branch of the occipital artery and the greater occipital nerve.

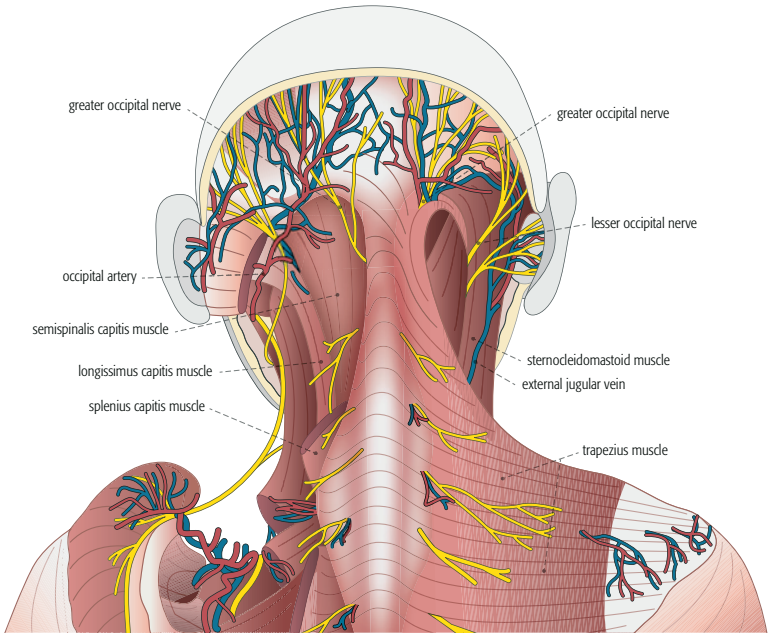
The cervical fascia is located just below the subcutaneous level (aponeurosis that covers the trapezius). The nuchal ligament attaches to the middle of this fascia and runs down to the spinous processes of the cervical vertebrae where it merges with the supraspinous ligament.

Since the nuchal ligament spans from the cervical fascia to the supraspinous ligaments, it is of utmost importance from a surgical point of view because it is an avascular plane that can be used during muscle dissection in posterior approaches to the cervical spine and occipitocervical junction.

Beneath the cervical fascia, the muscles divide into four planes.

First plane, superficial

This plane is comprised of the trapezius and sternocleidomastoid muscles.



Superficial plane of muscles at the back of the neck (Sobotta, 1985)

Trapezius

The trapezius muscle is inserted in different structures along the median line:

- the external occipital protuberance;
- the medial third of the superior nuchal line;
- the posterior margin of the nuchal ligament; and
- the spinous processes of the seven cervical vertebrae and of the first ten thoracic vertebrae.

The muscle fibers of all of these insertions run towards the shoulder, where they converge and end at the clavicle, the acromion and the spine of the scapula.

Sternocleidomastoid

Some authors call the sternocleidomastoid muscle the sternocleido-occipitomastoid, clearly referring to its insertions.

It is inserted by two fascicles:

- the sternal fascicle attaches to the anterior surface of the manubrium sterni; and
- the clavicular fascicle inserts in the superior surface of the medial third of the clavicle.

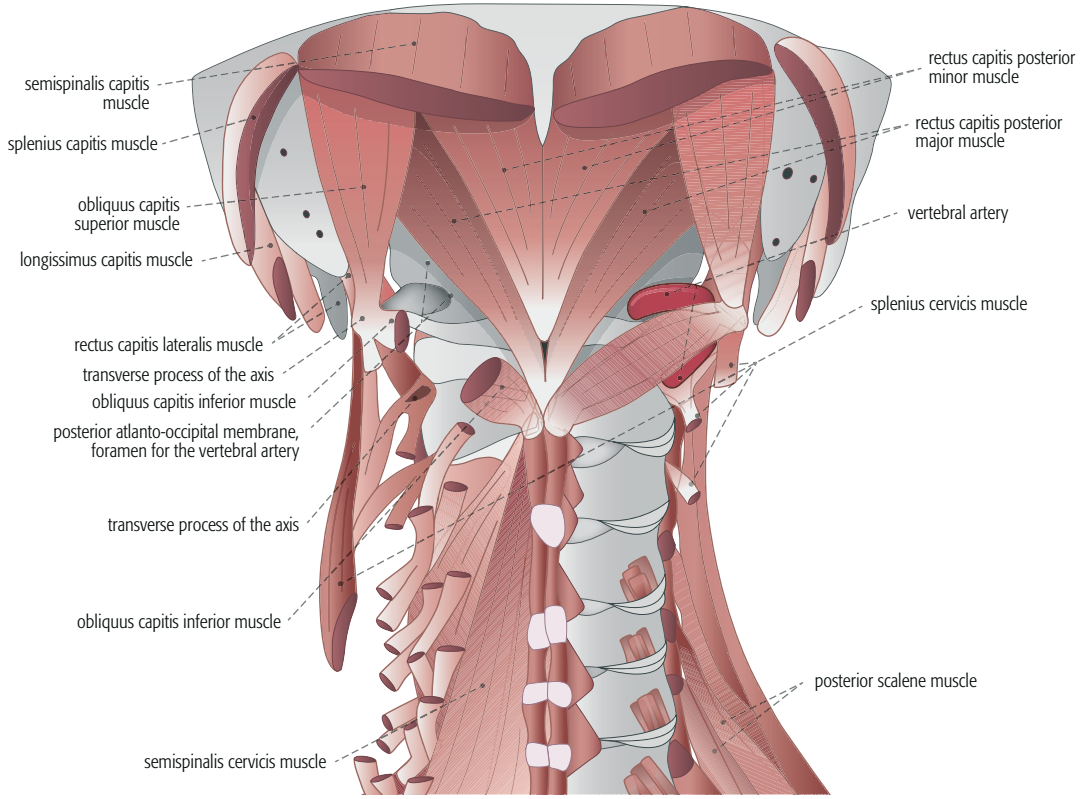
These fascicles join to form a muscular mass that directs upwards, outwards and backwards, before again dividing into two fascicles:

- the mastoid fascicle, which ends at the lateral aspect, the posterior margin and the apex of the mastoid process; and
- the occipital fascicle, ending in the lateral portion of the superior nuchal line.

Second plane, intermediate

This plane comprises the splenius capitis muscle and splenius cervicis.

Caudally, it arises collectively in the spinous processes of C7 and T1-T5, and in the interspinous ligaments found in between them.



Intermediate and deep plane of muscles at the back of the neck (Sobotta, 1985)

Splenius capitis	Splenius cervicis muscle
The splenius capitis is inserted proximally on the superior nuchal line and on the mastoid process.	The splenius cervicis has insertions in the transverse processes of the atlas, axis and C3.

Third plane, intermediate

This plane is composed medially by the semispinalis capitis muscle and laterally by the longissimus capitis muscle.

Semispinalis capitis

The semispinalis capitis, formerly known as complexus major, is a broad, thick muscle located to the sides of the median line, occupying the neck and superior dorsal portion of the thorax.

Inferiorly, it inserts in the transverse processes of the last five cervical and first five thoracic vertebrae.

Its cranial insertion is between the superior and inferior nuchal lines.

Longissimus capitis

The longissimus capitis, formerly known as complexus minor, is located laterally on the neck, to the sides of the semispinalis capitis muscle.

Cranially, it inserts into the apex and posterior margin of the mastoid process, descending to its inferior insertion in the transverse processes of the last four cervical vertebrae.

Fourth plane, deep

This plane comprises the following muscles:

Semispinalis cervicis

The semispinalis cervicis muscle corresponds to the transversospinal muscles found in the rest of the spine.

It arises in the transverse processes of T1 to T5, and ends in the spinous processes of C3 to C7.

Rectus capitis posterior minor

The rectus capitis posterior minor muscle connects the atlas to the occipital bone.

It lies to the sides of the median line. It arises from the posterior tubercle of the atlas, ascending straight up to its insertion at the inferior nuchal line.

This muscle covers the atlanto-occipital membrane.

Rectus capitis posterior major

The rectus capitis posterior major muscle connects the axis to the occipital, arising from the spinous process of the axis, running laterally and upwards where it inserts in the external portion of the inferior nuchal line, outside the point of insertion of the rectus capitis posterior minor.

Obliquus capitis inferior

The obliquus capitis inferior is a large muscle.

It connects the axis and atlas, originating at the spinous process of the axis, running laterally and slightly upwards where it inserts in the transverse process of the atlas.

Obliquus capitis superior

The obliquus capitis superior muscle joins the atlas to the occipital bone.

It is inserted in the transverse process of the atlas, passing upwardly and slightly inwardly to end in the lateral portion of the inferior nuchal line, above the insertion of the rectus capitis posterior major.

5

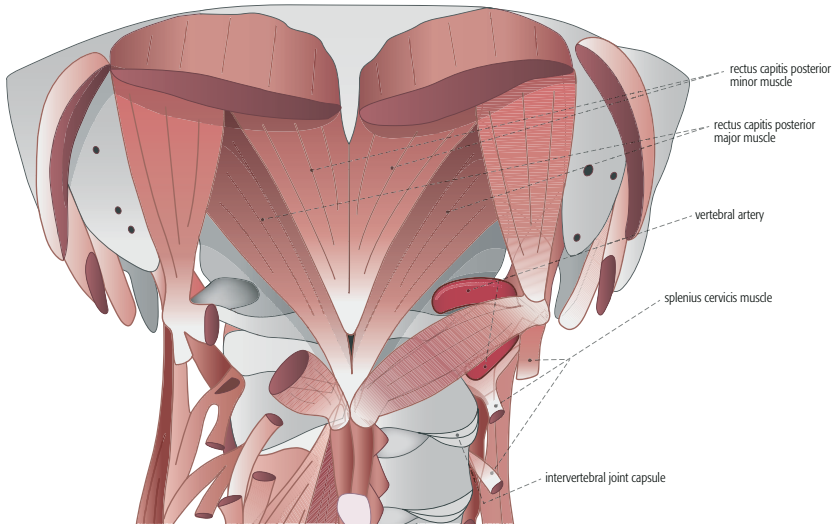
The suboccipital triangle is delimited by the rectus capitis posterior major (medially), the obliquus capitis superior (laterally and above), and the obliquus capitis inferior (laterally and below) muscles.

This triangle contains the vertebral artery and posterior branch of the first cervical nerve, in the sector running along the superior aspect of the posterior arch of the atlas.

Beneath the muscle plane, on the median line, are the spinous processes of the cervical vertebrae, covered by the supraspinous and interspinous ligaments.

Whenever performing a laminectomy with repositioning or a laminoplasty, it is essential to identify and preserve the supraspinous and interspinous ligaments as they are vital to spinal dynamics, particularly to prevent postoperative cervical kyphosis.

As with the rest of the spine, to the sides of the spinous processes are the broad laminae running laterally from the median line, connected together by the ligamentum flava. Laterally outside the laminae, the articular processes are covered by their joint capsules.



Details of the suboccipital triangle (Sobotta, 1985)

Anterior and lateral regions

The anatomy of the anterolateral cervical region is complex because various structures pass through it:

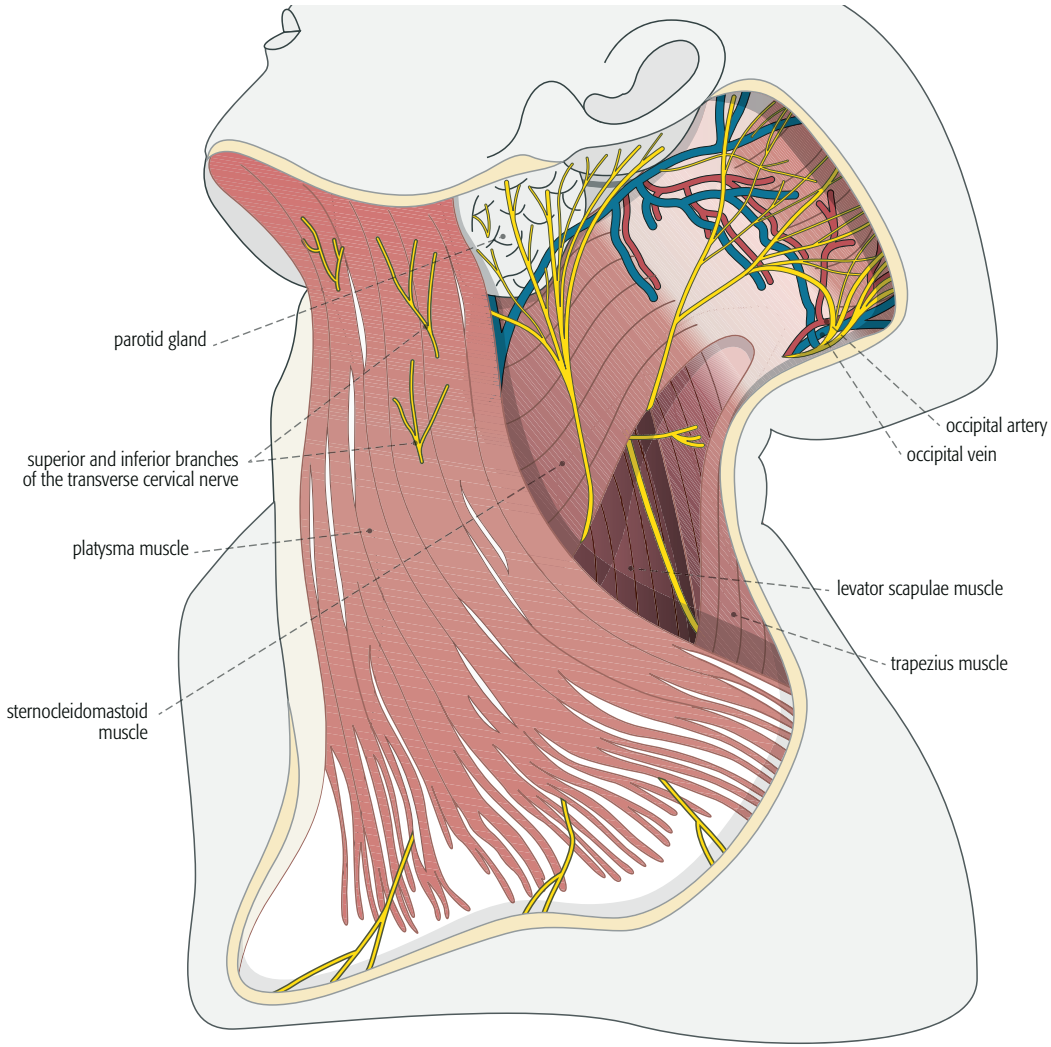
- components of the digestive system;
- elements of the respiratory apparatus, including speech organs; and
- vessels ascending to and descending from the head.

All of these structures, in addition to those of the neck itself, create a multitude of relationships within a small space of which surgeons must be familiar. The following limits can be identified:

- superiorly, projection of the hyoid bone located tangentially to the inferior border of the mandible; and
- inferiorly, jugular notch of the sternum and superior margin of the clavicles.

5

The skin is lean and thin, it usually presents two or more horizontal folds.



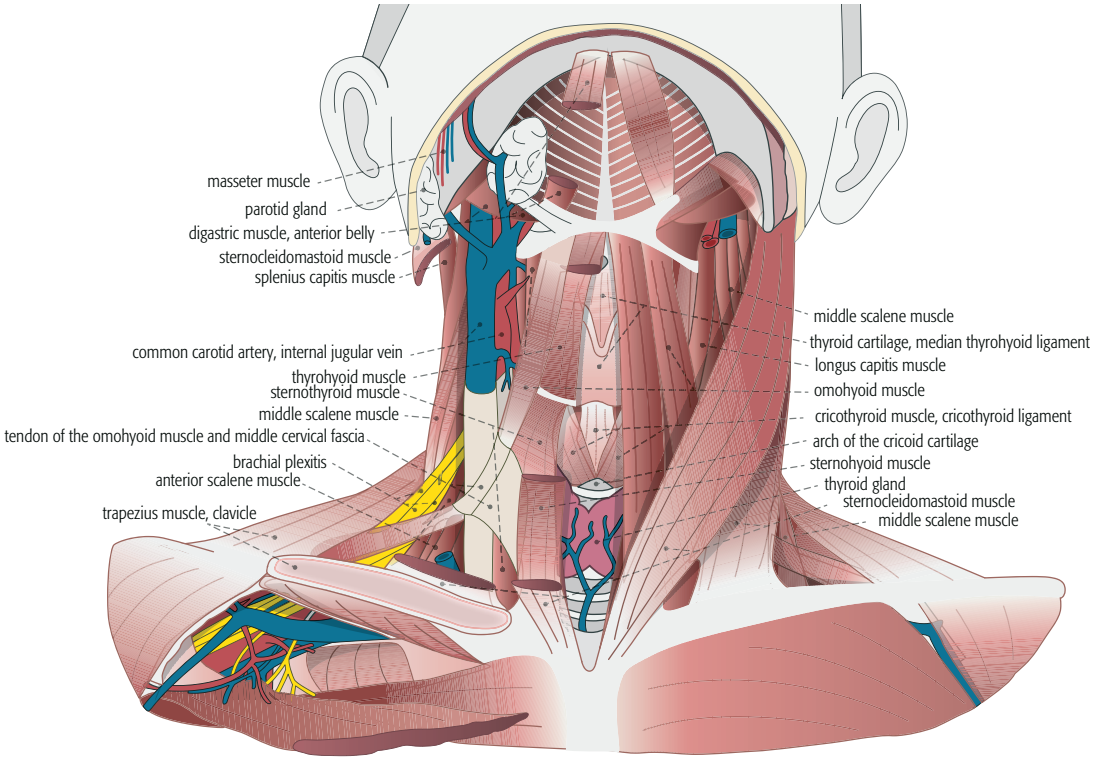
Superficial plane of muscles in the anterior and lateral regions of the neck (Sobotta, 1985)

Immediately beneath the skin is firstly the plane of superficial fascia and then the platysma muscle. This is a thin, broad muscle with a caudal insertion in the subcutaneous tissue of the infraclavicular region, it ascends and crosses the neck to reach the face, where it inserts into the mandible, the mentum and just beneath the mouth's opening.

Underneath this muscle one finds the anterior jugular medially, while the external jugular, of greater diameter, is located laterally. Immediately after comes the superficial layer of the cervical fascia. The anterior cervical region is located medially and the sternocleidomastoid region is situated laterally.

Medial region (anterior cervical)

The medial anterior region comprises the infrahyoid muscles divided into two planes.



Anterior view of the anterolateral and anterior muscle groups of the neck (Sobotta, 1985)

First plane

This plane is comprised of the sternohyoid and the superior belly of the omohyoid.

Sternohyoid	Omohyoid
The sternohyoid is inserted into the medial third of the clavicle's posterior border, the posterior surface of the manubrium sterni and into the first costal cartilage, before ascending where it attaches to the inferior aspect of the body of the hyoid bone.	The omohyoid is a digastric muscle, meaning it has two muscular masses ("bellies") connected by an intermediate tendon. It originates on the upper border of the scapula, firstly running medially and slightly upwards, before ascending almost vertically where it attaches to the lower border of the body of the hyoid bone.

Second plane

This plane is formed by the sternothyroid and thyrohyoid muscles.

Sternothyroid

The sternothyroid muscle inserts into the posterior surface of the manubrium sterni and the cartilage of the first rib before ascending to attach to the thyroid cartilage.

Its path is covered by that of the sternohyoid muscle.

Thyrohyoid

The thyrohyoid is a short muscle that appears to be a continuation of the sternothyroid since it travels upwards from its inferior insertion into the thyroid to attach to the inferior aspect of the body of the hyoid.

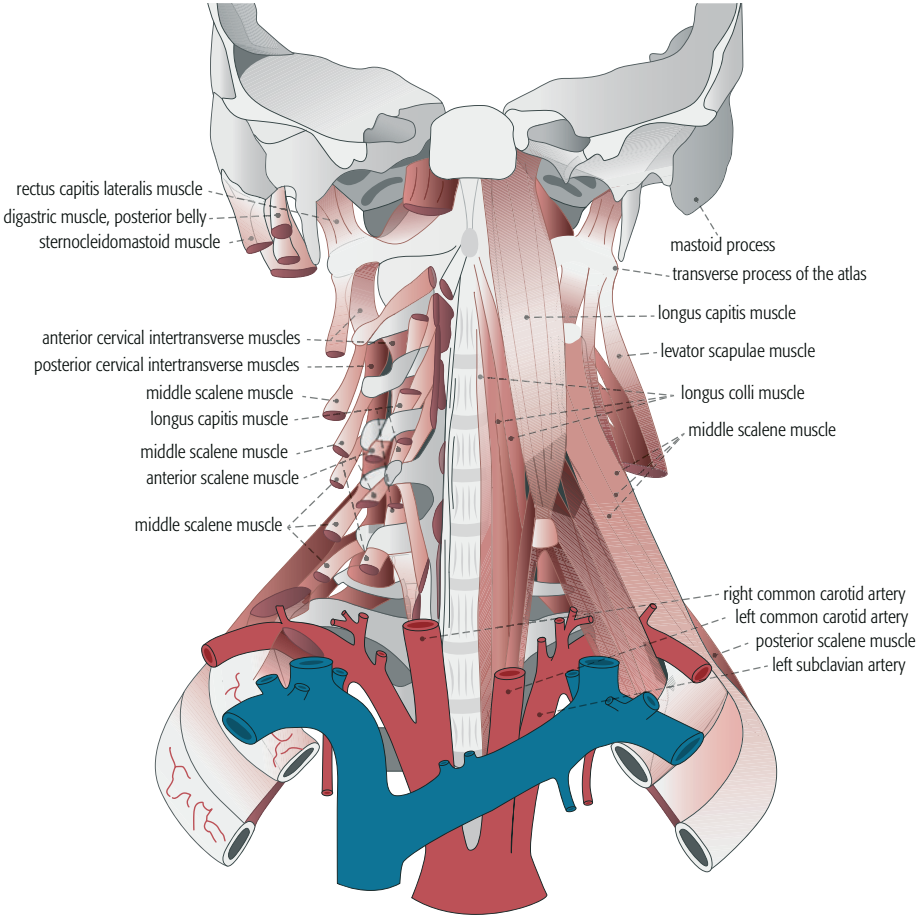
As with the sternothyroid muscle, it is covered by the sternohyoid.

Beneath this muscle plane is located the pretracheal layer of the cervical fascia which medially envelops the laryngotracheal canal and inferiorly the thyroid gland in front of the trachea.

Laterally and posteriorly, the pretracheal layer covers, from top to bottom, the laryngeal artery and nerve, as well as the superior and inferior thyroid neurovascular bundles.

Behind the laryngotracheal canal is the pharynx, cranially, and the esophagus, caudally. Both structures are enclosed by the visceral sheath of the cervical aponeurosis.

Finally, the prevertebral muscles and the cervical spine are enclosed by the prevertebral layer of the cervical fascia.



Anterior view of the prevertebral muscles of the neck (Sobotta, 1985)

5

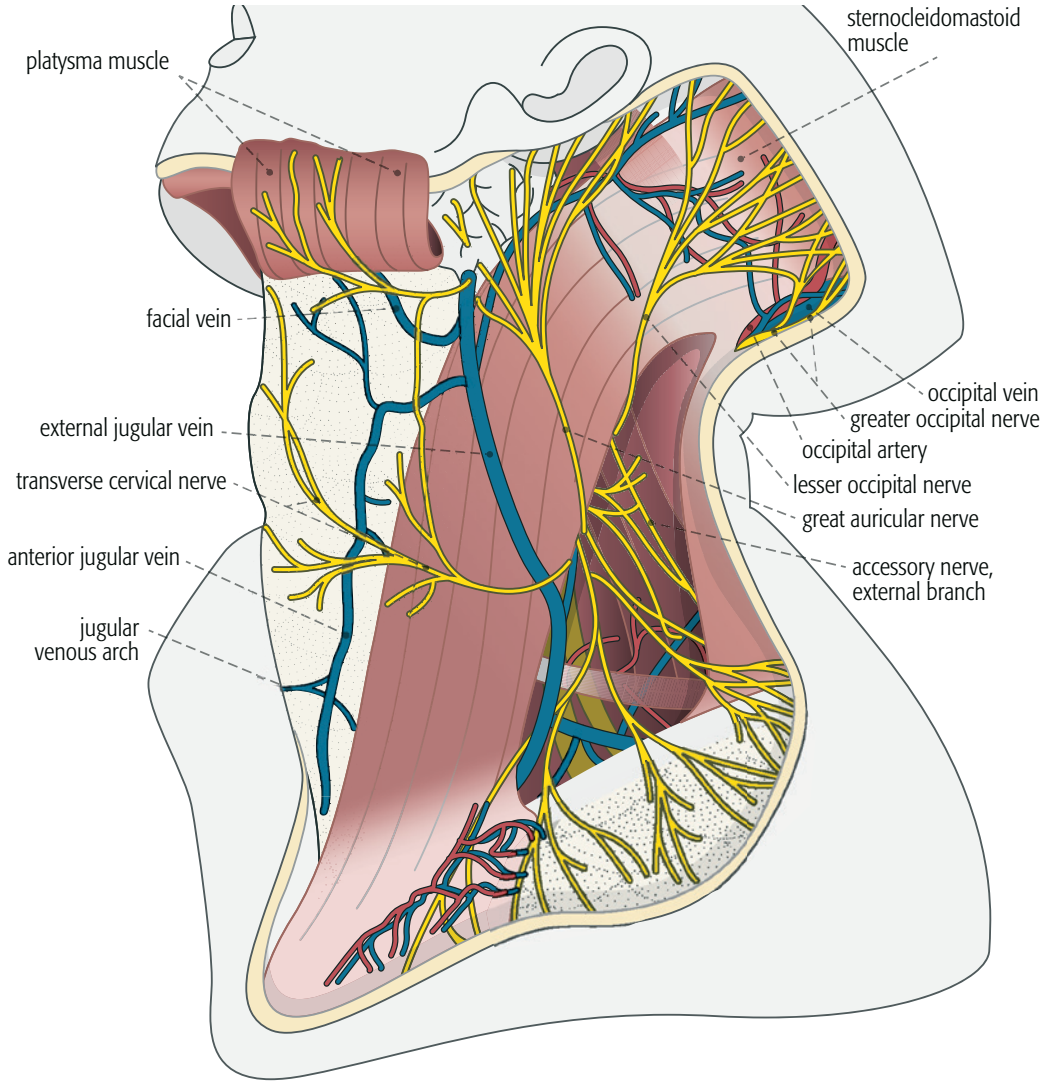
The prevertebral muscles are in direct contact with the anterior border of the spinal column.

Longus capitis	The longus capitis is the most superficial muscle. It arises caudally from the anterior tubercles of the C3 to C6 transverse processes, running upwards and slightly medially where it inserts in the basilar portion of the occipital.
Rectus capitis anterior	The rectus capitis anterior is a short muscle joining the atlas with the base of the cranium. It originates from the anterior aspect of the lateral mass of the atlas and of the transverse processes, inserting into the base of the cranium at the occipital and temporal bones.
Longus colli	The longus colli is the deepest muscle. It is a complex muscle with three portions: ■ vertical; ■ superior oblique; and ■ inferior oblique. It inserts into the bodies of the first three thoracic vertebrae and the anterior tubercles of the C3 to C6 transverse processes.

A lax space exists behind the pharynx and esophagus and in front of the cervical spine and prevertebral muscles, known as the retrovisceral space. This space allows the esophagus to be separated in order to expose the spinal column.

Lateral region (sternocleidomastoid)

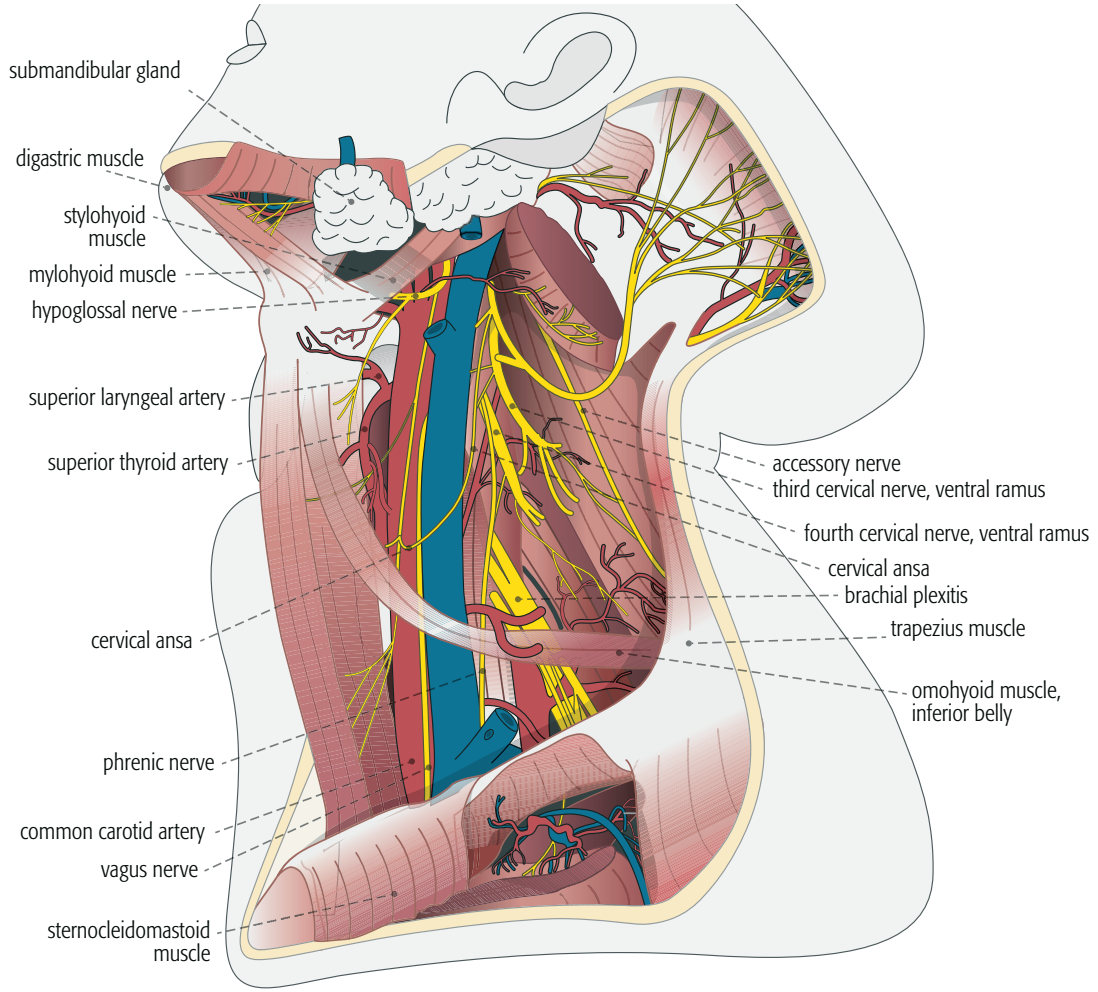
The sternocleidomastoid muscle is covered by the superficial layer of the aponeurosis.



Lateral region (sternocleidomastoid) of the neck, superficial (Sobotta, 1985)

The superficial surface of this muscle relates to the platysma muscle and the skin in contact with the external jugular vein and superficial sensory branches of the cervical plexus.

The internal surface relates with the neurovascular bundle of the neck, which is formed by the carotid arteries (common carotid below and the internal and external above), the internal jugular vein, the vagus nerve and the ganglia.



Lateral region of the neck, sternocleidomastoid muscle removed (Sobotta, 1985)

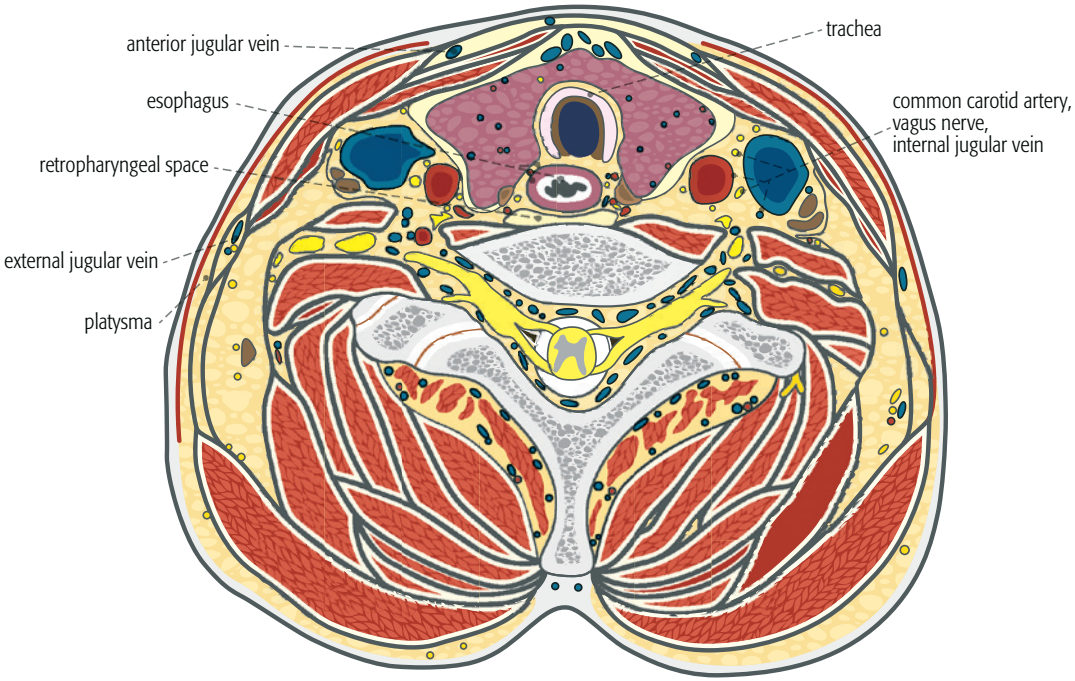
Beneath the muscle is the cellulo-adipose layer which is crossed, at the lower portion of the region, by the inferior belly of the omohyoid muscle, with an oblique path running laterally outwards and downwards.

This plane also contains the vascular elements that run from and to the neurovascular bundle of the neck, for example, the thyrolinguofacial trunk and superior thyroid artery, as well as numerous chains of cervical ganglia and neural elements belonging to the cervical plexus.

Elements within the bundle always have the same distribution:

- the artery is found medially and anteriorly;
- the vein, laterally and anteriorly; and
- the nerve is located posteriorly, between the artery and vein.

The bundle is located in front of the spine, in the lateral portion of its anterior aspect, with the artery (the bundle's most medial element) in front of the transverse processes. It relates laterally with the trachea, esophagus, pharynx and larynx, and anteriorly with the lobes of the thyroid gland, the omohyoid and the sternocleidomastoid.



Axial section of the neck at C7 level (Sobotta, 1985)

Behind the bundle, and before reaching the prevertebral muscles, is the sympathetic lateroverteb chain. Lying deeply and laterally are the scalene and intertransverse muscles of the neck.

The scalenes are a group of three muscles (anterior, middle and posterior) with superior insertion into the anterior tubercles of the transverse processes of the cervical vertebrae and inferior insertion into the first and second ribs. Resting on the first rib, passing between the anterior and middle scalene muscles, is the subclavian artery and above this the nerve trunks corresponding to the brachial plexus. The phrenic nerve descends down to the thorax along the anterior surface of the anterior scalene muscle.

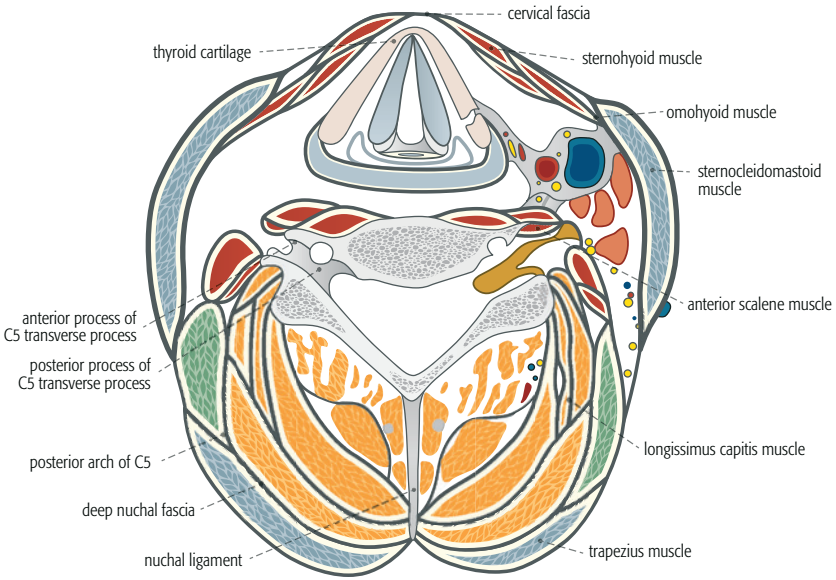
There is one intertransverse neck muscle located anterior and another posterior to each intertransverse space. They insert into the inferior border of the overlying vertebra's transverse process and the superior border of the underlying vertebra's transverse process, one in the anterior lip and the other in the posterior. The vertebral artery ascends in front of the posterior and behind the anterior intertransverse muscles as it passes through the transverse foramina.

From the above descriptions, after dissecting the platysma muscle, one encounters an avascular plane of fasciae that help to separate the following structures:

- medially:
  - trachea;
  - larynx;
  - esophagus; and
  - pharynx;
- laterally:
  - sternocleidomastoid muscle; and
  - neurovascular bundle.

Thus, the anterior aspect of the cervical spine, covered by its envelope of prevertebral muscles, can be exposed.

This trajectory is crossed, primarily, from superficial to deep, by the superior belly of the omohyoid muscle (at the level of C5 and C6, approximately). Secondly, it is crossed cranially by the thyrolinguofacial trunk (or its variations) and caudally by the inferior thyroid vessels.



Axial section of the neck at C5 level (Pernkopf, 1963)

Anatomical projections

The occipital bone, the cervical vertebrae and the first thoracic vertebrae present a projection over the structures of the face and neck that, while they do not replace localization of elements with X-ray imaging, provide guidance when planning a surgical approach.

VERTEBRAL PROJECTIONS

AAto: floor of the nasal cavities

C1: lower part of the medulla oblangata and upper pole of the superior cervical ganglion of the sympathetic trunk

C1/C2: soft palate and palatine tonsil

C2: buccal opening

C3: angle of the mandible, lower pole of the superior cervical ganglion of the sympathetic trunk and superior external border of the epiglottis

C4: hyoid bone, submandibular gland and carotid bifurcation

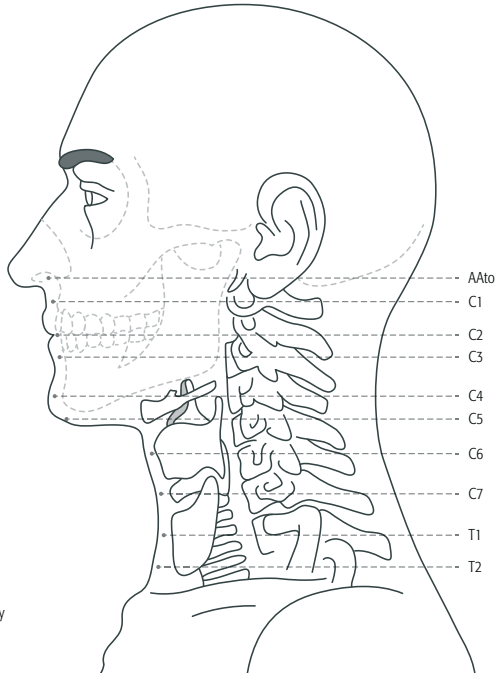
C5: superior border of the thyroid cartilage

C6: laryngeal ventricle and middle cervical ganglion of the sympathetic trunk

C7: cricoid cartilage and the start of the trachea and esophagus

T1: cervicothoracic ganglion

T2: superior border of the first rib and subclavian artery



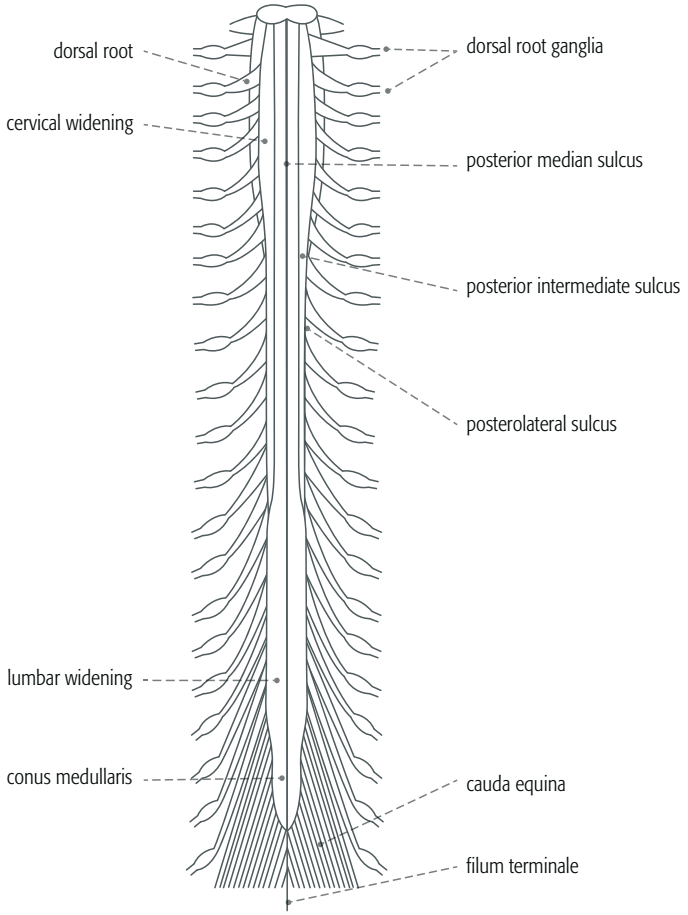
Anatomical projections on the face and neck (Rouviére and Delmas, 2005)

6. THE SPINAL CORD AND SPINAL NERVES

Overview

The spinal cord is contained within the spinal canal. The cord and nerve roots are protected by the following elements:

- cerebrospinal fluid (CSF);
- the meningeal membranes:
  - dura mater;
  - arachnoid; and
  - pia mater.



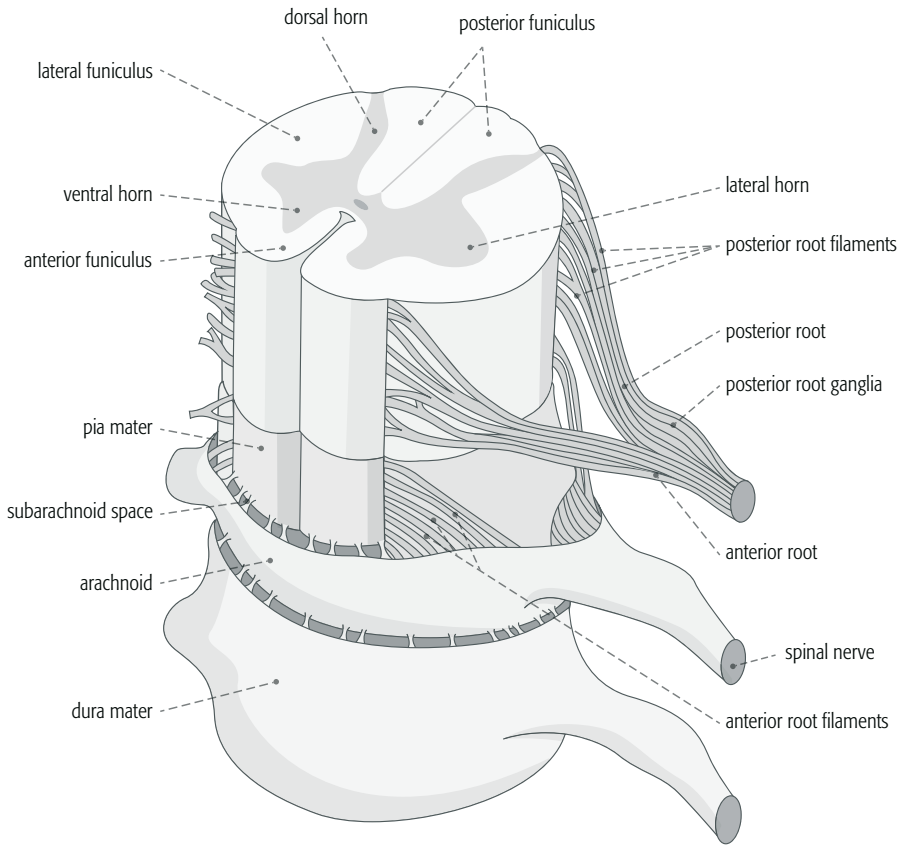
Anterior view of the spinal cord and nerve roots

The cord starts in the pyramidal decussation (where the pyramidal tracts cross), which occurs approximately at the height of the atlanto-occipital joint, continuing cranially with the medulla oblangata.

The actual cord ends between the first and second lumbar vertebrae, at which point it continues by means of a fibrous extension known as the filum terminale that finally inserts into the sacral-coccygeal region.

At the end of the cord is the horse's tail, or cauda equina, formed by the motor and sensory roots of the L3 to coccygeal spinal nerves which pass through their corresponding intervertebral foramen.

Inspecting the surface of the cord from an anterior view presents, on the median line, a wide, shallow sulcus; the anterior median fissure, which runs as deep as the white commissure.



The distribution of the gray and white matter inside the cord is shown.

Spinal cord with the meninges partially removed

The anterior roots of the spinal nerves emerge on each side of the median line, and as they overlap they form another sulcus; the anterolateral sulcus.

The anterior column of white matter is located between the two sulci (anterior median fissure and anterolateral).

Toward the back, the posterior roots of the spinal nerves enter into the cord. These roots, overlapped, conform another sulcus; the posterolateral sulcus.

The anterolateral and posterolateral sulci delimit the lateral column of white matter.

Observed from a posterior view, on the median line, the cord presents a narrow and very deep sulcus; the posterior median sulcus, which runs as deep into the cord as the posterior gray commissure. This sulcus is really a septum since, unlike the anterior sulcus, it constitutes a virtual space.

The posterior column of white matter is located between the posterolateral and posterior median sulci.

The spinal nerves form from the conjunction of the anterior root (motor), which exits via the anterolateral sulcus, and the posterior root (sensory), which enters at the posterolateral sulcus.

Because there is a nerve on each side they are known as spinal nerve pairs. The anterior root of the spinal nerve consists of 5 or 6 rootlets and the posterior has 7 or 8. The posterior root also broadens at its trunk; the spinal ganglion.

6

There are 31 spinal nerve pairs in total, distributed through the different regions of the spine:

- 8 cervical pairs;
- 12 thoracic pairs;
- 5 lumbar pairs;
- 5 sacral pairs; and
- 1 coccygeal pair.

Cord characteristics at the occipitocervical level

As described above, the cord starts at approximately the level of the foramen magnum.

The cervical section of the cord has the largest diameter for two reasons:

- it contains the greatest amount of white matter, as all of the ascending and descending information coming from and going to each of the more caudal sectors must pass through this section; and
- there is a marked increase in gray matter, due to the presence of cells that form the spinal nerves of the brachial plexus, known as cervical widening or brachial plexus widening.

It is, therefore, easy to understand why there is a high incidence of cervical compression in cases involving narrowing of the cervical canal (cervical spinal canal stenosis).

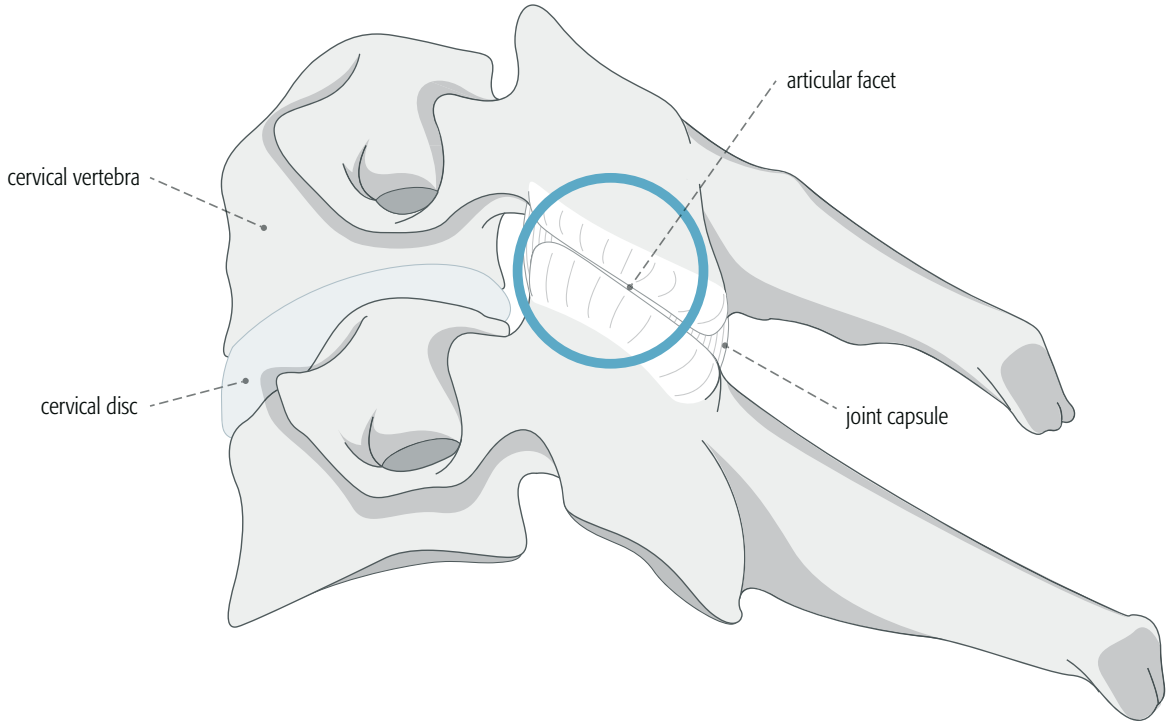
The nerves emerge from the spinal canal via an orifice delimited by the vertebrae, called the intervertebral foramen.

Spinal nerve characteristics at the occipitocervical level

There are eight pairs of cervical spinal nerves. The first nerve pair ascends intradurally (the only one which does), while the second pair runs almost horizontally, and from then on each pair has a progressively more descending trajectory.

Cervical nerve pairs take the name of the underlying vertebra, corresponding to the intervertebral foramen from which they exit the spinal canal, e.g., the fourth cervical nerve emerges between C3 and C4.

The first cervical pair does not leave the column via an intervertebral foramen, but rather at the level of the atlanto-occipital joint, just behind the joint, between the condyle and glenoid cavity of the atlas, passing below the vertebral artery and above the posterior arch of the atlas. The second spinal nerve pair also emerges from an atypical intervertebral foramen, as the atlas (the overlying vertebra) does not have a pedicle.



Intervertebral foramen at cervical level

The borders of the intervertebral foramen are clinically and surgically very important:

- superiorly, the inferior margin of the pedicle of the overlying vertebra;
- inferiorly, the superior margin of the pedicle of the underlying vertebra;
- anteriorly, the intervertebral disc and the uncovertebral joints; and
- posteriorly, the ligamentum flavum and the capsule of the articular processes.

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