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The Vertebral column

Bones

The vertebral column (also known as the backbone or the spine), is a column of approximately 33 small bones, called vertebrae. The column runs from the cranium down to the apex of the coccyx, on the posterior aspect of the body. Its functions are:

- **Protection**: it encloses the spinal cord, shielding it from damage
- **Support**: it carries the weight of the body above the pelvis (below the pelvis, the lower limbs take over)
- **Axis**: the vertebral column forms the central axis of the body.
- **Movement**: it has roles in both posture and movement

The vertebral column is composed of a series of 31 separate bones known as vertebrae. There are:

- 7 cervical or neck vertebrae
- 12 thoracic vertebrae
- 5 lumbar vertebrae
- The sacrum is composed of five fused vertebrae
- 3 - 5 coccygeal vertebrae which are sometimes fused

![Figure 1 Vertebral column](image)

The bones are numbered from the top down.

Each vertebra is composed of a body (anteriorly), which consists of a large anterior middle portion called the centrum, and a vertebral, or, neural, arch (posteriorly). The body is composed of cancellous bone, which is the spongy type of osseous tissue, covered by a thin coating of cortical bone (or compact bone), the hard and dense type of osseous tissue. The upper and lower surfaces of the body of the vertebra are flattened and rough in order to give attachment to the intervertebral discs. These surfaces are the vertebral endplates which are in direct contact with the intervertebral discs and form the joint. The endplates are formed from a thickened layer of the cancellous bone of the vertebral body, the top layer being denser. The endplates function to contain the adjacent discs, to evenly spread the applied loads, and to provide anchorage for the collagen fibres of the disc. They also act as a semi-permeable interface for the exchange of water and solutes.
The vertebral arch is made up of thicker coverings of cortical bone and has named bony components.

Protruding from the back and sides of the neural arch are the processes:

- **The spinous process** - from the back
- **The transverse processes** from the sides

These are present for muscle attachments for the spinal muscles.

The neural arch is formed by the pieces of bone between the processes:

- **The pedicles** - between the vertebral body and transverse process
- **The laminae**
  - Between the transverse processes and spinous process
  - The upper surfaces of the laminae are rough to give attachment to the ligamentum flavum (Pl. Ligamenta flava)

Also at the point of where the pedicles and laminae meet are the articular processes.

These are the components parts of the facet joints between the vertebrae.
These facets joints, or zygapophyseal joints, are synovial joints (gliding) and define what type of movement occurs between the bones - see later. These facets are joined by a thin portion of the neural arch called the **pars interarticularis**.

Above and below the pedicles are shallow depressions called vertebral notches (**superior** and **inferior**). When the vertebrae articulate the notches align with those on adjacent vertebrae and these form the openings of the vertebral foramina. The foramina allow the entry and exit of the spinal nerves from each vertebra, together with associated blood vessels from the vertebral canal.

Now this only describes the common factors of a ‘typical vertebra’. There are differences in the shape of the vertebrae along its length. The thirty-three vertebrae in the human vertebral column are named after the regions they occupy.
The Occiput, Atlas and Axis

The occiput is a bone that forms the base of the head. It has two articular facets at its base; the occipital condyles. The occiput sits on top of the atlas, C1, and shares a joint with it; the occipito-atlantal joint. Considering the attachments of these structures, it is difficult to regard them separately.

The atlas and axis: C1 and C2

Note here that C1 (the atlas) has no vertebral body or spinous process but has a tubercle posteriorly

C2 (the axis) does have a vertebral body and, in addition to this, a bony process protruding straight up and into the arch of C1 where the body of C1 'should' be. This process it called the Dens, or the Odontoid Process.

The occiput, atlas and axis are different from the rest of the vertebral column in that they do not have any intervertebral discs. Between these joints are only synovial joints.
Joints and Movements

Figure 8 C1 and C2 together

Figure 9 Occipito-atlantal joint

Ligaments of O/A Region
The occipito-atlantal joint is a condylar joint and functions essentially like a hinge, so there are ligaments present to stabilise it to prevent erroneous movements.

Figure 10 Apical and Alar Ligaments
For details of the functions of these ligaments, see below

Compiled by Laurence Hattersley 2017
Structures that stabilise the occiput with the atlas and axis are:

- **The apical ligament**
  - From the top of the dens up to the front margin of the foramen magnum
  - It secures the dens of C2 to the occiput

- **The alar ligaments**
  - These are from the top sides of the dens, moving up and laterally, to the front margins of the foramen magnum
  - They are the primary restraints to rotation of the upper cervical motion unit
  - Together with the tectorial membrane the alar ligaments limit flexion
  - They limit the side-bending of the occiput on the atlas, via tightening of the contralateral alar ligament, focussing movement below C1/2 and the rest of the cervical spine
  - At midposition of the head they are slack. By turning the head in one direction, the alar ligament contralateral to the direction of rotation tightens, while the ipsilateral ligament slackens

- **The transverse ligament**
  - This is a band that passes across the shaft of the dens, holding it against the articular facet on anterior margin of C1
  - It ensures that rotation is the only movement that occurs at C1/2
  - It also stabilises the dens, preventing compression of the spinal cord

- **The anterior and posterior longitudinal ligaments**
  - At the level of the occipitoatlantal joint, it called the tectorial membrane. It also limits flexion and distraction

**Movements of O/A joint**

The joint between the occiput and the atlas is the occipito-atlantal (O/A) joint. It is a synovial joint of a condylar type; it has two articular facets, permitting movement in one plane.

*Figure 11 Occipitoatlantal joint showing flexion and extension*

The joint plane of the O/A is largely in the transverse plane (across the neck). It only allows flexion/extension (nod if you understand). With this flexion and extension, though, the details of the plane of the joints should be taken into consideration.

- The occipital condyles face down, are convex and are angles laterally
- The superior facets of the atlas face up, are concave and are angled medially

Hence with extension, the condyles of the occiput are compressed medially.
Figure 12 Occipitoatlantal joint from front

It is best to see the O/A joint and C1/2 as a unit. This diagram shows attempted side-bending at the O/A joint. Note the movement is entirely denied by the presence of the dens (see below).

The movement that occurs at C1/2 is entirely rotation.

Figure 13 Rotation at C1/2

Note that the axis of movement at C1/2 is the dens itself; the atlas rotates around it. Hence this configuration of joints and the fact that it is synovial, creates a situation allowing a great deal of rotation.
The Cervical Spine
The cervical spine consists of 7 bones. The top two are the atlas and axis and have been covered already.

The cervical vertebrae all share certain characteristics:

- The spinous process is bifid - it is 'Y' shaped, except C7
  - The concavity of the bifid process contains the Ligamentum Nuchae
- The transverse processes are also bifid
  - For muscle attachments
- There is a hole in the transverse processes
  - For the vertebral artery
- The vertebral body is relatively small
- The vertebral canal is relatively large and is triangular in shape
The Vertebral Artery

The vertebral artery is an artery that runs up in the foraminae in the transverse processes of the cervical spine, as seen in the diagram of Fig 16.

Figure 16 Vertebral artery

The two branches pass up through the foraminae, to and through C1. Then the two branches fuse in the midline to form the basilar artery and enters the foramen magnum. There it supplies the brain stem before merging with the arterial circle of Willis.

In addition to the characteristics listed above, the vertebral bodies of C3 to C7 have a different shape to elsewhere in the spinal column. The vertebral body has a 'lip' at its lateral edge; an uncus, or uncinate process.

Figure 17 Cervical vertebra seen from the front, showing the uncus

This bony part prevents a vertebra from sliding backwards off the vertebra below it (i.e. it prevents posterior linear translation movements of the vertebral bodies) and limits lateral flexion (side-bending). Luschka’s joints involve the vertebral uncinate processes.
Joints, ligaments and movements
All movement between the vertebrae are entirely dependent upon the distance of their separation. This separation is created by the intervertebral disc, but is also facilitated by the uncinate processes.

An intervertebral disc (symphysis) consists of:

- The **Annulus Fibrosus**
  - The outmost rings of the disc
  - These are attached to the vertebral bodies either side and hold them together

- The **Nucleus pulposus**
  - The central, gelatinous, region, which keeps the two vertebrae apart

The elements of this symphysis put together create a narrow flexible region of relatively limited movement. In principle, it acts like a ball between two boards; it allows movement in any direction (these are covered again in the Lumbar spine section).

What type of movement that occurs at any level of the spine depends upon the **zygapophyseal joints**, aka facets joints. These are small, synovial, facets joints of the gliding type. Here the direction of the face of the facet defines the direction of movement.
The uncinate processes on the vertebral bodies create a unique shape in the cervical spine, giving it a saddle shape. The upper surface of the vertebral body is concave in the transverse plane and convex in the sagittal plane. This complementary shape of apposite bodies facilitates flexion/extension and side-bending.

**Figure 19 Cervical spine - shape of bodies**

**Facet joints in the cervical spine**
This diagram shows the zygapophyseal (facet) joints of the cervical spine. Note that the plane of the facets is about 45° to the horizontal. Hence the disc space, along with the horizontal plane of the O/A and the C1/2 joint, allows a great deal of movement, especially rotation, in the neck.

**Figure 21 Facet joint alignment in the cervical spine**
Figure 22 Gross movement of the neck

This is gross movement. However, the type of movement that occurs between each bone changes down the spine. This is due to the centre of axis of the spine at that level.

Figure 23 Axis of rotation in cervical spine

Fig 23 shows the planes of motion in the cervical spine

I. Is the axis of flexion/extension
II. Is the axis of rotation. It is a modified axis and is perpendicular to the zygapophyseal joints
III. Is perpendicular to II, but no motion can occur along this axis
**Figure 24 Axes of rotation of cervical spine**

Fig. 24 is a diagram of an idealised schematic showing the axes of centres of movement (rotation) in the cervical spine.

As was stated above, the axis of rotation of C1/2 is the dens itself. This diagram shows how the axis of rotation tends to shift forwards down the neck.

This will a point to consider later when we see the type of movement in the thoracic and lumbar spines.

The direction of the plane of the facets defines what type of movement occurs at each level.

**Figure 25 Plane of facets of C-Spine**

Hence, broadly speaking, there are three axes of movement at every level of the spine:

**Figure 26 Movements that occur at the intervertebral joints**

So, considering the alignment of the facets, the usual movement that takes place towards greatest ease is side bending a rotation in contralateral directions, e.g. rotation left with side-bending right. This generality can vary with degrees of flexion and extension.
Seeing the cervical spine from the side, via x-ray:

![Cervical spine X-ray from side](image)

**Figure 27 Cervical spine X-ray from side**

- O/A joint
- Anterior aspect of C1
- Dens, posterior to anterior margin of C1
- C1/2 joint
- Tubercle of C1
- C2 spinous process
- C4 body
- Intervertebral disc space
- Facet joint
- C7 spinous process (prominens)

**Ligaments of the spine**

There are several ligaments that are along the length of the spine. The general function of these is to limit its movement and hence provide stability. The ligaments at the base of the head have already been covered above.

Let us list these ligaments from posterior to anterior

![Ligamentum nuchae](image)

**Figure 28 Ligamentum nuchae**

- **Ligamentum Nuchae**
  - This runs down the posterior of the cervical spine from the external occipital protuberance of the skull to the spinous process of C7 (prominens)
  - The ligamentum nuchae continues as the supraspinous ligament
  - Its function is to limit flexion of the neck and to assist in maintaining the cervical lordosis (holding the head up)
- **Supraspinous ligament**
  - The connects the ends of all the spinous processes down the spine to S1
  - It limits flexion of the spine

![Supraspinous Ligament](image1)

- **Interspinous ligament**
  - The interspinous ligament is situated between the spinous processes
  - It limits flexion of the spine

![Interspinous ligament](image2)

- **Ligamentum flavum**
  - This is situated between the laminae of the vertebrae
  - Even though it is defined as a ligament, it has an elastic component
  - It limits flexion of the spine

![Ligamentum flavum](image3)
• **Posterior longitudinal ligament**
  - This ligament runs along the entire length of the spine, along the posterior surfaces of the vertebral bodies and intervertebral discs
  - Its function is to limit flexion and to reinforce the posterior annulus fibrosus of the disc

• **Anterior longitudinal ligament**
  - This is situated along the entire length of the vertebral column on its anterior aspect
  - It limits extension of the spine

*Figure 32 Anterior longitudinal ligament*
The Thoracic Spine

Bones

The thoracic spine consists of 12 bones, the vertebrae of which also share a typical shape, but there are differences along its length. The bodies get bigger going down along its length. The upper four thoracic vertebrae are like cervical vertebrae in some respects, having posteriorly directed spinous processes. The lower four contain some lumbar characteristics, like large bodies and robust transverse and spinous processes.

Characteristics thoracic vertebrae share:

- Vertebral body is more heart shaped
- Transverse processes are longer and point posterolateral
- Spinous process are longer and point more posteroinferior
- In addition to the zygapophyseal facet joints, there are facets for the ribs on the vertebral bodies

Joints and movements

The disc space between the thoracic vertebrae are narrower than the cervical and lumbar spine, so there is less movement between the vertebrae overall.

The direction of the plane of the facets define the type of movement that occurs there.
This alignment of facets allows certain types of movement. With regard to rotation the centre of axis of movement is anterior to the facets, just anterior to the vertebral foramen. Here, though, rotation would be inherently limited with the presence of the ribs.

![Thoracic spine facets and axis of movement](image)

**Figure 35 Thoracic spine facets and axis of movement**

In addition to the discs and facets joints there are also the ribs. There are 12 pairs of ribs. Collectively they form the thoracic cage and facilitate the protection and function of the heart and lungs.

**Sternum and ribs**
Ribs 1 - 10 articulate directly or indirectly with the sternum

![The Sternum](image)

**Figure 36 the Sternum**

The sternum is a flat bone at the front of the chest. It consists of three sections:

- The manubrium
- The body
- The xiphoid process
The clavicles and 7 pairs of ribs articulate directly with the sternum.

There is a (not well developed) symphysis between the manubrium and the body, allowing limited movement.

**Figure 37 Side view of the rib cage**
- There are 7 true ribs - these articulate directly with the sternum
- Ribs 8 - 10 are false ribs - they do not articulate directly with the sternum, but with the costal cartilages, a bar of cartilage that extends up to the sternum
- Ribs 11 and 12 are floating ribs - they have no anterior articulation
- The top 7 ribs articulate with the sternum via a bar a of cartilage; a synchondrosis

**Ribs - Structure**

Each rib has:
- A head
- Two articular facets
  - At the **head** - for the vertebral body
  - At the **tubercle** - for the transverse process
- An angle, the most posterior part of the rib, where the rib direction changes and angles forwards
  - Except rib 1, which does not have an angle, only a tubercle
- A groove on its underside for the intercostal blood vessels and nerves
The First Rib

Rib 1 (seen here as the left first rib) has:

- A head that articulates with the vertebral body
- A tubercle, which forms the posterior aspect of the costotransverse joint
- A groove on its superior side formed by the pressure of the subclavian vein
- The anterior end of the rib articulates with the superior end of the sternum immediately under the clavicle at the sternoclavicular joint

Joints of the Ribs

The sternoclavicular joint is a synovial joint of the saddle type. In addition to its own joint ligaments, it also has the supraclavicular ligament, running across the top of the sternum and joints, but also ligaments between the clavicle and the first rib.

Each rib also has:

- A body - the shaft
- All the ribs each have an articulation with the thoracic vertebral body: **Costovertebral Joint**
  - Rib 1 articulates directly with the body of T1
Rib 2 - 9 have a 'V' shaped head, which has an articulation between the vertebral bodies, each having a hemifacet on each adjacent vertebra.

Ribs 10 - 12 have a direct articulation with their respective vertebral body.

- From the head, each rib is directed backwards. Then there being a small length of rib, the neck, between the costovertebral joint and the next joint along its length. This joint between the rib and the transverse process - Costotransverse joint.

The summation of all these structures forms a cage - the rib cage, seen from above on the next page.
This complex of joint structures, both posterior and anterior, allow for movement. The joints with the spine are all synovial gliding, allowing limited movement. However, as the rib has some length, there is an amplification effect along its length and the anterior end moves some distance. Hence the ribs can move up and down, giving us inhalation and exhalation.

The figure here shows rib movement. The ribs can move in two ways:

- **Pump handle**
  - Here the ribs move up and down at the front end, moving the sternum with them

- **Bucket handle**
  - Here the ribs move up and down at their most lateral points, with the joints at the anterior and posterior ends of the rib allowing this

This also demonstrates a reciprocal relationship between the thoracic spine and the ribs. If one is restricted, the other will be also.
Lumbar Spine

Bones
The five vertebrae in the lower back are the lumbar spine. The lumbar vertebrae are even larger than those in the thoracic region having more weight to bear, however, it is more flexible due to the increased disc space and the lack of ribs there. All the weight of the upper body bears down on the lumbar vertebrae and this may contribute to the problems experienced there. The pedicles are strong as are the laminae and the spinous process is thick and broad.

The vertebrae in the lumbar spine are numbered L1 through L5. These vertebrae (vertebral bodies) are the largest in the spine and support the head and trunk. For example, the L5 vertebra transfers upper body weight through the sacrum and pelvis into the legs. The sacrum consists of 5 vertebrae that are naturally fused and provides a stable platform for the spinal column. Although the bones of sacrum are fused, they are numbered S1 through S5. The pelvis is often referred to as the hip (though strictly speaking the hip is a joint).

![Lumbar Vertebra](image)

Figure 46 Typical lumbar Vertebra

Each lumbar vertebra shares a basic structure:

- **A vertebral body**
  - Largest in the spine
  - A large, kidney shaped, when viewed from above

- **Facet joints**
  - Aligned in the vertical and sagittal planes

- **Intervertebral disc**
  - Allowing the widest separation of vertebrae anywhere in the spine

Bones and Joints of the lumbar spine

Anatomy of the lumbar spine
The lumbar spine is made up of 5 vertebrae, separated by intervertebral discs, and the sacrum, which consists of 5 bones fused together.
Each lumbar vertebra has a structure sharing common factors
- Body (bearing the weight)
- Pedicles
- Laminae
- Transverse processes
- Spinous process
- Superior and inferior articular processes

The pedicles and laminae form an arch, the neural arch, and the vertebral foramen. When all the vertebrae are aligned, this foramen forms the spinal canal and forms a body corridor for the spinal cord and the spinal nerves of the cauda equina.

**Intervertebral Disc**
It is said that the primary joint of the spine is the intervertebral disc
The intervertebral disc consists of the annulus fibrosus, which consists of 10 - 20 concentric rings on the outside. These are known as lamellae and their fibres are arranged at right angles to each other. These are firmly attached to the adjacent vertebrae and have the function of holding the two vertebrae together.

The annular fibres are directly attached to the vertebral bodies on each side of the intervertebral disc. The endplates of the discs are not as well attached as the annular fibres.

These endplates act mainly like a semipermeable membrane, allowing diffusion of nutrition and waste products. The nature of the endplate does not allow the movement of larger molecules, like the proteoglycans that maintain the nucleus pulposus. As the nucleus pulposus is avascular, it must get its nutrition via the blood supply through the segmental vertebral blood supply. Only the outer third of the annulus receives a blood supply and the endplate receives it from the vertebral body.
The centre of the disc is a jelly-like, almost liquid, substance called the nucleus pulposus, which acts to hold the two vertebrae apart and to permit movement between the two bones.

The discs of the lumbar spine are taller, as compared to the cervical and thoracic. They contain 65% proteoglycans which have a great affinity for water (its water content can be about 80%).

Behind the disc are the zygapophyseal (facet) joints. The superior and inferior articular processes are bony projections that form these facets joints above and below. These are synovial joints, and the alignment of the facets defines what types of movement will be permitted at that level of the spine. In the lumbar spine, they are in the vertical plane on an antero-posterior alignment, allowing flexion/extension and sidebending, but very little rotation. The discs are cartilaginous and are mainly avascular and, like other cartilaginous tissues, are slow healing if damaged.

**Zygapophyseal (Facet) Joints**
The facet joint alignment defines the axis of movement in the lumbar spine
The Articular facets in the lumbar spine are aligned largely in the sagittal plane
In addition to this, the bones of the spine are shaped such that, where they normally aligned, there are holes for the mixed spinal nerves to emerge from the spinal canal – the intervertebral foraminae. This foramen enclosed the exiting nerve root and the delicate dorsal root ganglion (DRG). The DRG contains all the sensory nerve cell bodies. Anatomical variations show that the DRG can be inside or outside the intervertebral foramen.
Even though the joints are small and gliding, the superior facets are mildly concave, so the alignment here allows some rotation movement, with the axis of rotation now posterior to the vertebra.
The facet alignment (in the sagittal plane) and significant disc space allows a great deal of flexion and extension in the lumbar spine, this complementing the movement in the hips for picking objects up.

Figure 57 Range of movement in the lumbar spine
Sacrum and Coccyx

Bones

The sacrum is made up of five bones fused together

It is described as an upside down triangle, with the apex pointing inferiorly. On the lateral walls of the sacrum (S1-S3) are facets, for articulation with the pelvis at the sacro-iliac joints. The coccyx is a small bone of 3-5 bones fused together, which articulates with the apex of the sacrum and is recognised by its lack of vertebral arches. The sacrum has a vertebral canal, though the vertebral arches are fused as one, it ending at its inferior end as a hiatus (an opening). With the coccyx, though, there is no vertebral canal, so does not transmit the spinal cord.

If you want more information on the sacrum, sacroiliac joints and the pelvis, see the section on The Pelvis

Joints and movements

The facets at the top of the sacrum are aligned in the transverse plane, the primary reason for this is to stabilise the lumbar spine on top of the sacrum and prevent any anterior shift of L5 on top of S1. This because of the sacral angle; the angle of inclination of the top surface of the sacrum, which is normally 30°.

The transverse (coronal) alignment of the lumbosacral facets are present to prevent the fifth lumbar sliding forward off the upper surface of the sacrum.
Curvatures of the Spine

In the normal adult there are four curvatures in the vertebral column in the anteroposterior (A/P) plane. These serve to align the head with a vertical line through the pelvis.

- A curvature concave anterior is a kyphosis
- A curvature concave posterior is a lordosis

The function of these curvatures is help create and maintain a physiologic efficient posture.

In an ideal anatomically efficient posture the centre of gravity fall through certain points:

- Through the occipital base
- Through the dens
- Through the anterior edge of the body of C7
- Through the body of L1
- Through the anterior edge of S1 (sacral promontory)
- Through the hip
- Through the knee
- Through the ankle

This format of spine is only the ‘finished item’, as it were. It wasn’t born like this, though, the curves grew and developed.
In foetal life the whole of the spine was in a kyphosis. Then we learned to hold our head upright and the first secondary curvature developed; this is a reverse curvature, a lordosis - here in the cervical spine. Then we learned to walk on our hind limbs and our second secondary curvature, the lumbar lordosis, developed. Hence the normal kyphosis remains in the thoracic and sacral spines.

Deviations away from this physiologically efficient posture are usually defined in the adjective:

- **Kyphotic** - an exaggerated curvature concave anteriorly
  - If this is of significance it can create a hunchback deformity
- **Lordotic** - An exaggerated curvature concave posteriorly
  - If this is of significance it can manifest as a swayback deformity

Exaggerated kyphosis or lordosis can occur under some normal conditions (e.g. increased lumbar lordosis in pregnancy).

**Scoliosis**
Any curvature of the vertebral column laterally away from the midline can occur normally or pathologically and is known as a *scoliosis*. A scoliosis can be both functional and organic.

**Functional scoliosis**
A functional scoliosis is a normal aberration of the curvature of the spine away from the line of centre of gravity. If you were walking along a bank, or even just stood on one foot, the centre of gravity would shift. The head would want to stay over the pelvis, so a curvature would appear in the spine to achieve this. If there is side-bending in the normal spine, there will be contralateral rotation (to the opposite side). However, all the curvatures will normalise when both feet are returned to a level surface.

*Figure 63 Functional scoliosis*

**Organic Scoliosis**
An organic scoliosis is a curvature that develops during the growth process. Theories on causative factors vary, but it can be seen as persistent tension patterns within the fascia along, and even within, the axis of the spine. Such tension patterns will define how the bones (vertebrae, ribs and pelvis) grow.

*Figure 64 Organic Scoliosis*

Note the curvature of the spine and ribs. This can cause compression of internal visceral organs with their consequent dysfunction.
Rotation of the spine, particularly in the thoracic region, can have ‘knock on’ effects in attachments and adnexae in that region. With reference to the ribs the tension patterns that define how the spine develop and grow also effect the growth and development of the attached ribs.

**Figure 65 Scoliosis and ribs**

Fig 56 here shows a level of the thoracic spine with its associated ribs.

![Diagram of scoliosis and ribs](image)

**Note:**
- The rotation of the vertebral body.
- The difference in the angles of the ribs. Here the rib on the right of the diagram has a more acute angle compared with the rib on the left.
- Note that the spinous process is also being pulled over to the concave side, which also supports the concept of tension patterns of **pulling**.
- The bony configuration can affect the structure and function of the organs and viscera adjacent to the ribs.
Any organic scoliosis defines how each level of the spine grows and develops. Hence the facet joints grow and develop in response to this persistent, on-going, tension pattern and the facets do not have a normal configuration and alignment. Every vertebrae will have an aberrant movement compared to normal.

Figure 66 Scoliotic spine and ribs

Muscles moving the spine
The muscles moving the spine are numerous and complex. They can be simplified by grouping them into three groups:

- Vertical muscles
  - Spinalis
  - Longissimus
  - Iliocostalis
- Oblique muscles
  - Semispinalis
  - Multifidus
  - Rotatores
- Deepest muscles
  - Interspinales
  - Intertransversarii

These are long muscles, but in addition to these are:
- Suboccipital muscles
- Covering muscles
There are always more - but later. Taking these in groups:

**Vertical Muscles**
- **Spinalis**
- **Iliocostalis**
- **Longissimus**

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinalis Thoracis, a medial continuation of the sacrospinalis</td>
<td>Spinal processes of T10-L2</td>
<td>Spinal processes of upper thoracic vertebrae</td>
<td>Unilaterally: Side-bends the head and neck to same side</td>
<td>Posterior primary division of spinal nerve</td>
</tr>
<tr>
<td>Cervicis</td>
<td>Lower end of ligamentum nuchae, spinous process of C7, and T1 and T2</td>
<td>Spinal process of C2</td>
<td>Bilaterally: Extends the vertebral column</td>
<td></td>
</tr>
<tr>
<td>Capitis</td>
<td>Usually inseparably connected to Semispinalis Capitis (see obliques)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Iliocostalis**

Iliocostalis is a band of muscle connecting the sacrum to the ribs to the neck.

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iliocostalis</td>
<td>Angles of ribs 3, 4, 5, 6</td>
<td>Posterior tubercles of transverse processes of C4, 5, 6</td>
<td>Unilaterally: Side-bends the head to the same side</td>
<td>Posterior primary division of spinal nerve</td>
</tr>
<tr>
<td><strong>Cervicis</strong></td>
<td>From upper borders of angles of lower 6 ribs</td>
<td>Posterior tubercles of transverse processes of C4, 5, 6</td>
<td>Bilaterally: Extends vertebral column</td>
<td></td>
</tr>
<tr>
<td><strong>Thoracis (dorsi)</strong></td>
<td>Iliac crest and thoracolumbar fascia</td>
<td>Inferior borders of angles of lower 6 or 7 ribs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 68 Spinalis*
Longissimus extends from the sacrum up either side of the spine, to both the vertebrae and the ribs and on right up to the head

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longissimus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thoracis</td>
<td>Arises from the whole of the posterior surfaces of the transverse processes of the lumbar vertebrae and the thoracolumbar fascia</td>
<td>The tips of the transverse processes of all the thoracic vertebrae, and to the lower 9 or 10 ribs between their tubercles and angles</td>
<td>Unilaterally: Flex the head and neck to the same side. Bilaterally: Extend the vertebral column.</td>
<td>Posterior primary division of spinal nerve</td>
</tr>
<tr>
<td>Cervicis</td>
<td>Tops of the transverse processes</td>
<td>The posterior tubercles of the transverse processes of</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
of the upper four or five thoracic vertebrae
the cervical vertebrae from the second to the sixth inclusive

| Capitis   | The transverse processes of the upper four or five thoracic vertebrae, and the articular processes of the lower three or four cervical vertebrae | The posterior margin of the mastoid process |

There are three muscles in this group:

- **Semispinalis**
- **Multifidus**
- **Rotatores**

This group of muscles are deep to the vertical muscles. In the main, they pass from the transverse processes up obliquely to the spinous processes, only passing up one or two vertebrae. Their function is to rotate the spine contralaterally; to the opposite side.

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semispinalis</td>
<td>Transverse processes T6-10</td>
<td>Spinous processes C6-7, T1-4</td>
<td>Rotates spine Contralaterally</td>
<td>Posterior primary division of spinal nerve</td>
</tr>
</tbody>
</table>

Figure 70 Longissimus
### Multifidus

Multifidus is a very thin muscle, filling the groove either side of the spinous processes from the sacrum to the axis. Its fibres originate from the transverse processes. They pass up obliquely, crossing 2 or 3 vertebral segments before inserting onto the spinous processes.

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multifidus</td>
<td>Sacrum</td>
<td>Posterior sacrum Aponeurosis with sacrospinalis Medial surface of the PSIS Posterior S/I ligaments</td>
<td>Fibres pass up and insert onto spinous process</td>
<td>Rotates spine contralaterally Stabilises spine in local movements</td>
</tr>
</tbody>
</table>
Lumbar | Mamillary processes of vertebrae above
---|---
Thoracic | All the transverse processes
Cervical | Articular processes C4-7

Figure 72 Multifidus: whole and in close up

Rotatores
These muscles present as a band of muscles on either side of the spine, deep to Multifidus, and are most prominent in the thoracic region.

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotatores</td>
<td>The transverse processes From their posterior and Superior aspects</td>
<td>The lower border and lateral surface of the laminae, extending as far as the spinous processes</td>
<td>They rotate the spine contralaterally and stabilise the spine in local movements</td>
<td>Posterior roots of spinal nerves</td>
</tr>
<tr>
<td>They have a high number of proprioceptors and have been implicated in postural control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Deepest muscles
These are the deepest of all the spinal muscles. They are tiny muscles, passing between individual vertebrae. They are attached to the processes of the vertebrae and only occur in the cervical and lumbar spines, with a little overlap. They are:

- Interspinales
- Intertransversarii

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interspinales</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical</td>
<td>Spinous processes C3-7</td>
<td>Spinous process of next vertebra above</td>
<td>Extends vertebral column</td>
<td>Posterior roots spinal nerves</td>
</tr>
<tr>
<td>Thoracic</td>
<td>Spinous processes T2-12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumbar</td>
<td>Spinous processes L2-5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 74 Interspinales as a whole and in close up

Spinous Process
Spinales
Intertransversarii
## Intertransversarii

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cervical</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anteriores</td>
<td>Anterior tubercle Transverse process T1 – C2</td>
<td>Anterior tubercle Next vertebra up</td>
<td>Side-bends spine Ipsilaterally</td>
<td>Anterior primary division spinal nerves</td>
</tr>
<tr>
<td>Posteriore</td>
<td>Posterior tubercle Transverse process T1 – C2</td>
<td>Posterior tubercle Next vertebra up</td>
<td>Side-bends spine Ipsilaterally</td>
<td></td>
</tr>
<tr>
<td><strong>Thoracic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thoracic</td>
<td>Transverse processes T11-L1</td>
<td>Transverse process next vertebra up</td>
<td>Side-bends spine Ipsilaterally</td>
<td></td>
</tr>
<tr>
<td><strong>Lumbar</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laterales</td>
<td>Transverse processes Lumbar vertebrae</td>
<td>Transverse process Next vertebra up</td>
<td>Side-bends spine Ipsilaterally</td>
<td>Posterior primary division spinal nerves</td>
</tr>
<tr>
<td>Mediales</td>
<td>Mamillary process Lumbar vertebrae</td>
<td>Accessory process of next vertebra up</td>
<td>Side-bends spine Ipsilaterally</td>
<td>Anterior primary division spinal nerves</td>
</tr>
</tbody>
</table>

Figure 75 Intertransversarii
Suboccipital Muscles
All the muscles described so far extend the length of the spine, but the majority stop at C2.

All the muscles that attach onto the spine up as far as C2 rotate the spine contralaterally (to the opposite side). All the muscles above C2 and that attach directly onto the occiput rotate the head and neck ipsilaterally (to the same side). These muscles include:

- The Suboccipital muscles
- The Splenius muscles

The Suboccipital muscles (posterior)

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus Capitis Posterior Major</td>
<td>Spinous process C2</td>
<td>Lateral end Inferior nuchal line of occiput</td>
<td>Extends and rotates head ipsilaterally</td>
<td>Suboccipital C1</td>
</tr>
<tr>
<td>Rectus Capitis Posterior Minor</td>
<td>Posterior arch of C1</td>
<td>Medial end Inferior nuchal line of occiput</td>
<td>Extends head</td>
<td>Suboccipital C1</td>
</tr>
<tr>
<td>Obliquus Capitis Inferior</td>
<td>Spinous process of C2</td>
<td>Transverse process of C1</td>
<td>Rotates C1 ipsilaterally</td>
<td>Suboccipital C1</td>
</tr>
<tr>
<td>Obliquus Capitis Superior</td>
<td>Transverse process of C1</td>
<td>Between superior and inferior nuchal lines of occiput</td>
<td>Extends and side-bends head</td>
<td>Suboccipital C1</td>
</tr>
</tbody>
</table>

Figure 76 Suboccipital muscles – posterior
The anterior Suboccipital muscles number only two:

- **Rectus Capitis Anterior**
- **Rectus Capitis Lateralis**

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus Capitis Anterior</td>
<td>Anterior base of transverse processes of C1</td>
<td>Occiput anterior to foramen magnum</td>
<td>Flexes head</td>
<td>C2-3</td>
</tr>
<tr>
<td>Rectus Capitis Lateralis</td>
<td>Transverse process of C1</td>
<td>Jugular process of occiput</td>
<td>Side-bends O/A</td>
<td>C2-3</td>
</tr>
</tbody>
</table>

*Figure 77 Rectus Capitis Anterior and Rectus Capitis Lateralis*
The Splenius Muscles

The word ‘splenius’ derives from the Greek, meaning ‘bandage’. These muscles are therefore seen as the most superficial of the posterior neck muscles.

There are two:

- Splenius Capitis
- Splenius Cervicis

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splenius Capitis</td>
<td>Lower end ligamentum nuchae</td>
<td>Mastoid Process of temporal</td>
<td>Extends and ipsilaterally rotates head</td>
<td>Lateral branches of dorsal primary rami C3-4</td>
</tr>
<tr>
<td></td>
<td>Spinous process of C7, T1-4</td>
<td>Lateral end superior nuchal line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Splenius Cervicis</td>
<td>Spinous process of T3-6</td>
<td>Transverse processes of C1-3</td>
<td>Extends and ipsilaterally rotates head</td>
<td>Lateral branches of dorsal primary rami of middle and lower cervical nerves</td>
</tr>
</tbody>
</table>

Figure 78 Splenius Capitis and Splenius Cervicis
Anterior and lateral neck muscles
Most muscles charts only show the superficial muscles of the spine, rarely the lateral and never the muscles on the anterior aspect of the cervical spine.

Anterior Cervical Muscles

There are two key ones here:

- Longus Capitis
- Longus Colli
  - This is seen as one muscle, but is subdivided into three parts

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longus Capitis</td>
<td>Transverse processes C3-6</td>
<td>Occiput anterior to foramen magnum</td>
<td>Flexes head</td>
<td>C1-3</td>
</tr>
<tr>
<td>Longus Colli</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior oblique part</td>
<td>Transverse processes of C3-5</td>
<td>Anterior arch of C1</td>
<td>Flexes cervical spine</td>
<td>C2-7</td>
</tr>
<tr>
<td>Inferior oblique part</td>
<td>Anterior surfaces of C1-3</td>
<td>Transverse processes of C5-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical part</td>
<td>Anterior surfaces of bodies of C1-3 and C5-7</td>
<td>Anterior surfaces of C2-4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 79 Longus Capitis and Longus Colli
The Scalene Muscles

The Scalenes are a group of muscles that pass between the side of the cervical spine and the upper two ribs. There are three:

- **Anterior scalene**
- **Medial scalene**
- **Posterior scalene**

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Scalene</td>
<td>Transverse processes of C3-6</td>
<td>Inner border of Rib 1 (scalene tubercle)</td>
<td>Elevates Rib 1 (inspiration) Flexes and rotates neck contralaterally</td>
<td>Ventral rami of cervical nerves</td>
</tr>
<tr>
<td>Medial Scalene</td>
<td>Transverse processes C2-7</td>
<td>Upper surface of rib 1</td>
<td>Elevates rib 1 (inspiration) Flexes and rotates neck contralaterally</td>
<td>Ventral rami of cervical nerves</td>
</tr>
<tr>
<td>Posterior scalene</td>
<td>Transverse processes of C5-7</td>
<td>Outer surface of Rib 2</td>
<td>Elevates rib 2 (inspiration) Flexes and rotates neck contralaterally</td>
<td>Ventral rami of lower cervical nerves</td>
</tr>
</tbody>
</table>

Figure 80: Scalenes: Anterior, Medial and Posterior

Figure 80: Scalenes: Anterior
Muscles of Respiration
Other muscles that attach onto ribs. These include the primary and secondary muscles of respiration.

Primary muscles of respiration:
- Diaphragm
- External Intercostal Muscles
- Internal Intercostal Muscles
- Transversus Abdomis

Diaphragm

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sternal</td>
<td>Inner part of xiphoid process</td>
<td>Central tendon</td>
<td>Draws tendon down, increasing volume of thoracic cavity</td>
<td>Phrenic nerve C3-5</td>
</tr>
<tr>
<td>Costal</td>
<td>Inner surfaces of lower 6 ribs and costal cartilages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumbar (crura)</td>
<td>L1-3 lumbar vertebrae and medial lumbocostal arches</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 81 Diaphragm
## Intercostals

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>External intercostal</td>
<td>Lower margin of upper eleven ribs&lt;br&gt; Fibres run down and forwards</td>
<td>Superior border of rib below</td>
<td>Elevates anterior part of ribs&lt;br&gt; Increases chest volume - inhalation</td>
<td>Intercostal nerve</td>
</tr>
</tbody>
</table>

Figure 82 External intercostals
## Intercostals

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal intercostal</td>
<td>From cartilages to angles of upper eleven ribs&lt;br&gt;&lt;i&gt;Fibres run up and forwards&lt;/i&gt;</td>
<td>Superior border of rib below</td>
<td>Pulls anterior part of ribs down&lt;br&gt;Decreases volume of chest cavity - exhalation</td>
<td>Intercostal nerve</td>
</tr>
</tbody>
</table>

![Figure 83 Internal Intercostals](image)
Accessory Muscles of Respiration

Any muscle that attaches onto a rib potentially becomes a muscle of respiration, so this section cannot be complete without the others.

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcostales</td>
<td>Inner surface of each rib at its angle <em>Fibres pass down and medially</em></td>
<td>Inners surface of rib one or two below</td>
<td>Draws anterior part of rib down Decreases chest volume (exhalation)</td>
<td>Intercostal</td>
</tr>
</tbody>
</table>

Figure 84 Subcostales
## Transversus Thoracis

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transversus Thoracis</td>
<td>Inner surface of lower end sternum and adjacent costal cartilages</td>
<td>Inner surface of costal cartilages of ribs 2-6</td>
<td>Pulls down anterior end ribs, reducing chest volume exhalation</td>
<td>Intercostal</td>
</tr>
</tbody>
</table>

Figure 85 Transversus Thoracis
## Levator Costae

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levator Costae</td>
<td>Transverse processes of C7 – T11</td>
<td>Outer surface of next lower rib</td>
<td>Elevates ribs, Extends, Side-bends and contralaterally rotates spine</td>
<td>Intercostal</td>
</tr>
<tr>
<td></td>
<td><em>Fibres pass down and laterally</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 86 Levator Costae
## Serratus Posterior Superior

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serratus Posterior</td>
<td>Ligamentum nuchae Spinous processes of C7 and T1-3</td>
<td>Upper borders of upper edges of ribs 2-5 Lateral to angles</td>
<td>Raises ribs in inspiration</td>
<td>T1-4</td>
</tr>
</tbody>
</table>

Figure 87 Serratus Posterior Inferior
# Serratus Posterior Inferior

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serratus Posterior</td>
<td>Spinous processes of T11-12, L1-3</td>
<td>Lower borders of Ribs 9-12</td>
<td>Pulls ribs down, resisting pull of diaphragm</td>
<td>T9-12</td>
</tr>
</tbody>
</table>

![Figure 88 Serratus Posterior Inferior](image)
Pectoralis Minor
Pectoralis minor is actually a muscles of the shoulder. It is included here as a muscle of respiration

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pectoralis Minor</td>
<td>Outer surfaces of Ribs 3-5</td>
<td>Coracoid process of scapula</td>
<td>Draws scapula forward and down (depresses shoulder) Raises ribs in forced inspiration</td>
<td>Medial pectoral nerve C8, T1</td>
</tr>
</tbody>
</table>

Figure 89 Pectoralis Minor
**Quadratus Lumborum**
Quadratus is really a muscle of the low back, but it also can function as a muscle of respiration

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadratus Lumborum</td>
<td>Iliolumbar ligament</td>
<td>Rib 12</td>
<td>Side-bends lumbar spine</td>
<td>T12, L1</td>
</tr>
<tr>
<td></td>
<td>Iliac crest</td>
<td>Transverse processes of L1-4</td>
<td>Fixes ribs for forced expiration</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 90 Quadratus Lumborum*
**Abdominal Muscles**

The primary function of these is to hold and compress the abdominal contents, but as they also attach onto ribs, they can also function as accessory muscles of respiration.

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rectus Abdominis</strong></td>
<td>Crest of pubis Symphysis pubis</td>
<td>Cartilages of ribs 5-7 Xiphoid process</td>
<td>Flexes vertebral column Compresses abdominal contents Forces expiration</td>
<td>7-12 intercostal nerves</td>
</tr>
</tbody>
</table>

Figure 91 Rectus Abdominis
## External Obliques

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External</strong></td>
<td>Lower 8 ribs</td>
<td>Anterior part of iliac crest Abdominal aponeurosis to linea alba</td>
<td>Compresses abdominal contents; Side-bends ipsilaterally Rotates contralaterally</td>
<td>Intercostals 8-12 Iliohypogastric Ilioinguinal</td>
</tr>
<tr>
<td><strong>Obliques</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Internal</strong></td>
<td>Lateral half inguinal ligament; iliac crest, thoracolumbar fascia</td>
<td>Cartilage of ribs 9-12, abdominal aponeurosis to linea alba</td>
<td>Compresses abdominal contents; ipsilaterally side-bends and rotates spine</td>
<td>Intercostals 8-12 Iliohypogastric Ilioinguinal</td>
</tr>
<tr>
<td><strong>Obliques</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transversus</strong></td>
<td>Lateral part inguinal ligament; iliac crest; thoracolumbar fascia; cartilage ribs 6-12</td>
<td>Abdominal aponeurosis to linea alba</td>
<td>Compresses abdomen</td>
<td>Intercostals 7-12 Iliohypogastric Ilioinguinal</td>
</tr>
<tr>
<td><strong>Abdomis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Figure 92 External Oblique, Internal Oblique, Transversus Abdominis](image_url)
## Hip and Low Back Flexors

<table>
<thead>
<tr>
<th>Name</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Psoas Major</strong></td>
<td>Bases of transverse processes of all lumbar vertebrae</td>
<td>Lesser trochanter of femur</td>
<td>Flexes hip and lumbar spine</td>
<td>Branches of lumbar plexus L2-3 (and L1-4)</td>
</tr>
<tr>
<td><strong>Psoas Minor</strong></td>
<td>Sides of T12 and L1</td>
<td>Arcuate line to iliopectineal eminence</td>
<td>Flexes lumbar spine</td>
<td>First lumbar nerve from Lumbar plexus</td>
</tr>
<tr>
<td><strong>Iliacus</strong></td>
<td>Upper 2/3 of iliac fossa; ala of sacrum and adjacent ligaments; anterior inferior iliac spine</td>
<td>Onto tendon of psoas major</td>
<td>Flexes hip</td>
<td>Femoral nerve L2-3</td>
</tr>
</tbody>
</table>

![Figure 93 Psoas Major and Minor](image1.png)

![Figure 94 Iliacus](image2.png)
Spinal cord within the vertebral canal

The vertebral canal encloses the thecal sac (aka dura mater) which, in turn, houses the spinal cord and spinal nerves. This extends from the base of the brain stem (the foramen magnum) down to the level of L1.

Along the length of the spinal cord are ‘expansions’.

These expansions are in the cervical and the lumbar regions, these reflecting the greater activity and demand through those regions to the upper and lower extremities.

One thing that needs to be addressed in the cervical spine is the numbering of the nerve roots emerging from it.

All the nerve roots along the length of the spine emerge from below the numbered vertebrae. In the cervical spine, the numbered nerve root emerges from above the numbered vertebra. The nerve root of C1 is purely motor; it does has not sensory root.

All the remaining nerve roots have both a sensory and motor roots.

This also means that a nerve root emerges from below C7, which is called C8.
Within the spinal canal, the vertebral canal is lined with the dura mater, which is a waterproof sac enveloping the brain, spinal cord and spinal nerves. The arachnoid mater is on the inside of the dura and held out against it by the presence of CSF in the subarachnoid space. The pia mater is on the outside of the spinal cord and follows all its convolutions. Even though the dura is a robust structure enveloping all this, there are specializations of the pia mater that penetrate the dura appearing as 21 pairs of denticulate ligaments. These acts to help anchor the spinal cord in the spinal canal.

**Spinal nerves**

The spinal nerves originate as a confluence of rootlets emerging from the spinal cord. These rootlets emerge from both the anterior and posterior aspects of the cord, the anterior roots are motor and the posterior are sensory. These anterior and posterior rootlets converge forming the anterior and posterior roots. The roots then form a mixed spinal nerve of both sensory and motor fibres. This mixed spinal nerve then emerges from the spinal canal, piercing the theca at about half a lumbar vertebra above that level.
The spinal cord proper ends at the level of L1, at the conus medullaris. The remainder of the spinal canal is occupied by the spinal nerves, these continuing caudad to their level of exit from the spinal canal.

The dura ends at S2, with its other points of fixation at the foramen magnum and C2. The pia pierces the dura and continues to its final attachment at the coccyx. The cord proper ends at the conus medullaris at the level of L1. Below that the spinal nerves continue down to their level of exit as the cauda equina.

During the embryological period, the spinal cord filled the vertebral canal entirely. However, as the foetus grew, the body, here the vertebral column, grew faster than the spinal cord. This resulted in the nerve roots being ‘dragged down’ away from the spinal cord, down to their level of exit from the vertebral canal. This angle gets increasing more acute the further down the vertebral canal.
The picture to the left here, shows the angle of the nerve roots emerging from the cervical spinal cord.

The nerve roots emerging from the spinal cord have grown increasingly more acute in the thoracic spine.
In the lumbar spine, the nerve roots are almost vertical.

As has been mentioned already, the spinal cord proper ends at the level of L1. Below this level, even though it is still inside the vertebral canal, there are only nerve roots. These continue down from the point of origin from the spinal cord, down to their level of exit from the vertebral canal.

This lease of nerves is called the cauda equina (horse’s tail).

Below L1 there are four roots that are going to exit the thecal sac at each level of the lumbar spine, and these are referred to as traversing nerve roots.

This suggests that they cross the posterior of the next caudad disc en route to their level of exit, whilst still inside the thecal sac.
The nerve roots emerge from the spinal cord sequentially. However, the S1 root is an exception to this general format. Oddly enough, it emerges from the thecal sac more cephalad than the other nerve roots (fig. 107), therefore is already in nerve root form at it crosses the posterior aspect of the L5 disc. As the roots emerge from the spinal canal, the dura mater changes into the epineurium around the peripheral nerves.

The mixed spinal nerve, on emergence, immediately divides into a ventral (anterior) ramus that supplies motor and sensory function to the lower extremities, and dorsal (posterior) ramus that supplies the muscles and skin over the lower back and buttocks.

Nerves from the ventral rami from the lumbar and lumbosacral plexus form the femoral, obturator and sciatic nerves, supplying the thigh and the leg.

**Nerves supplying the disc**

All the nerves referred to thus far have been somatic nerves. These are nerves that supply the skeletal muscles, for movement, and provide sensory supply to skin, ligaments, tendons and joints (for conscious and proprioceptive sense).
The other nerves that emerge from the spinal cord, between levels of T1 down to L2 are the roots that supply the sympathetic trunk.

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**Figure 108 Sympathetic Trunk**

The ventral ramus also gives off a small branch that helps form the **sinuvertebral nerve**, which carries pain signals from the posterior aspect of the disc and gives off another branch, the grey ramus communicans, connecting to the sympathetic trunk of the autonomic nervous system. The dorsal ramus also gives off the medial branch of the dorsal ramus giving sensory supply to the facet joints.
The sympathetic trunk nerve pathway also innervates each region of the disc; a phenomenon that occurs in no other structure in the body.

- The posterior and posterolateral regions of the disc are innervated by the **sinuvertebral nerve**
- The lateral disc by the **grey ramus communicans** (a sympathetic nerve of the autonomic system)
- The anterior disc by the **sympathetic branches of the sympathetic trunk** or ganglion

The meningeal branches of the spinal nerves (also known as **recurrent meningeal nerves**, **sinuvertebral nerves**, or **recurrent nerves of Luschka**) are several small nerves that branch from the spinal nerve near the origin of the anterior and posterior rami, but before the rami communicantes branch.
They then re-enter the intervertebral foramen, and innervate the facet joints, the outer third of the anulus fibrosus of the intervertebral disc, and the ligaments and periosteum of the spinal canal, carrying pain sensation. The nucleus pulposus of the intervertebral disk has no pain innervation, it being both avascular and aneural.

The true pain sensors of the disc (the free nerve endings of the nociceptors) are shown as yellow dots, and have a greater concentration in the posterior and posterolateral aspects of the annulus of the disc, as compared to the lateral and anterior regions. This suggests that the posterior and posterolateral regions of the disc are more sensitive to pain and possibly to the development of chronic back pain.

The sinuvertebral nerve has a bilateral origin and looks like a wishbone, for it arises from both the ventral ramus (a somatic nerve) and the grey ramus communicans of the sympathetic ganglion (an autonomic nerve).

This nerve not only innervates the posterior outer third of the disc at the same level, but also the same areas of the disc of the level above, e.g. the L4 sinuvertebral nerve innervates the posterior annulus of both L3 and L4. Other opinions claim that one nerve can innervate three levels.

This shared nerve supply and overlap suggests that there can be a distribution of pain with disc pathology. Hence, sensation can enter the cord at one or more levels (myelomeres). From here the nerves decussates and thence travels up to the thalamus and on to the sensory cortex.

Despite extensive research, the precise pathway of the pain signals from the sinuvertebral nerves is uncertain. (This is frustrating to the orthodox medical world and its endeavours in injectable pain reduction). Any sensory input from the disc would have to enter the spinal cord, not through the posterior horn and the dorsal root ganglion, like all conscious input, but via the same route of supply; a more convoluted route.

Using L4 as an example:

- The sinuvertebral nerve goes to the grey ramus communicans (GRC)
- The GRC to the sympathetic ganglion of L4
- The sympathetic ganglion of L4 up to the sympathetic ganglion of L1 or L2
- Across the white ramus communicans (WRC) (which are only present at L1 and L2)
- The WRC to the same level ventral root of the spinal nerve of L1 or L2 to the DRG of L1 or L2
- The DRG of L1 or L2 to the spinal cord at the L1 or L2 myelomere
- The spinal cord to the sensory cortex.

This will be expanded upon more in the disorders section of the vertebral column.