THE BACK

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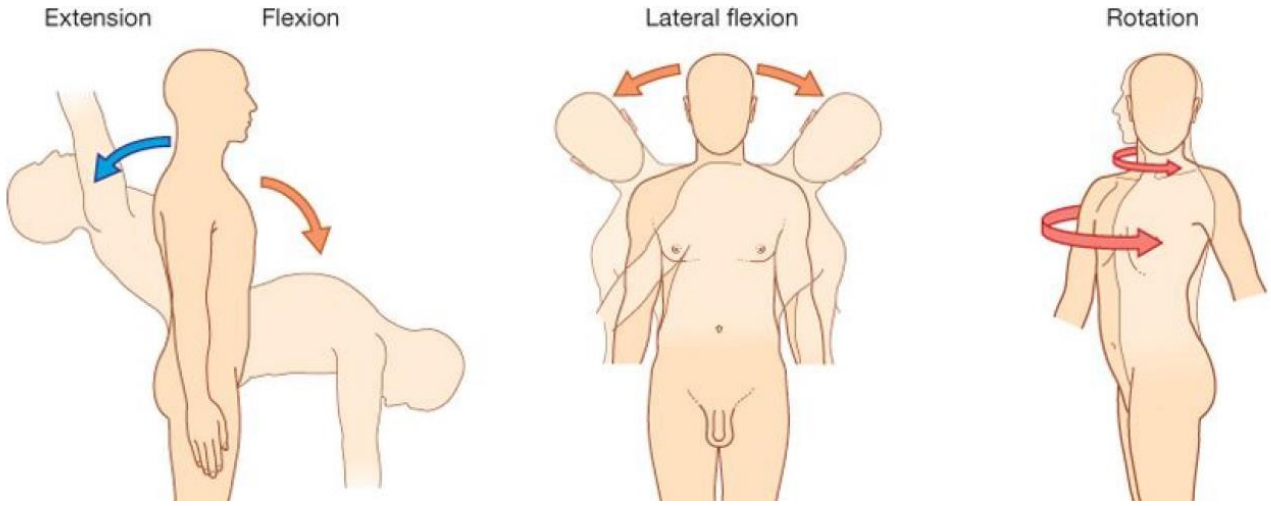
Definition & overview:

The back is the posterior aspect of the body, from the base of the skull to the buttocks. Anatomically, it consists of bones, muscles, & the neurovascular structures associated with them. The back serves the following functions:

- Support: the back, represented by the vertebral column & its surrounding muscles, supports the head & trunk weight, & transmits forces from the head & upper limbs to the ground through the pelvis & legs.
- Movement: the vertebral column facilitates the movements of the head & trunk, through its capability of flexion (anterior bending), extension (posterior bending), lateral flexion (lateral bending), & rotation.
- Protection: the bony vertebral column protects the soft spinal cord & proximal parts of the spinal nerves, which are situated in the spinal canal.



Bones of the back:

The principle bony structure of the back is the vertebral column. Bones from other parts of the body also contribute to the back due to their close position & shared attached muscles. These include: the occipital bone of the skull, the scapulae, the posterior parts of the ribs, & the iliac bones. The vertebral column will be detailed below.

The vertebral column (= the spine, the back bone) is the centrally-located pillar that holds the skull, ribs, & pelvis together, & is indirectly connected to the upper & lower limbs. The vertebral column is made of 33 small irregular bones (vertebrae) that align above each other like a chain. Note the following:

- Regional vertebrae: 7 cervical, 12 thoracic (dorsal), 5 lumbar, 5 sacral, & 3-4 coccygeal vertebrae.
- Curvatures: the vertebral column looks straight from the A-P aspect. However, from the lateral aspect, it looks like a sneak, having 4 curvatures: the cervical & lumbar regions are concave posteriorly, while the thoracic & sacro-coccygeal regions are concave anteriorly.
- Fused parts: the 5 sacral vertebrae are fused together forming one bone (the sacrum), also, the coccygeal vertebrae are fused to form the coccyx. There is a fibrous joint between the lower tip of the sacrum & the upper end of the coccyx, which allows a minimal A-P movement in young age & usually fuses with aging.
- Articulations: the vertebral column articulates with the skull (occipital bone) superiorly via C1 vertebra, with the iliac bones inferiorly via the lateral portion of the sacrum, & with the 12 pairs of ribs via the thoracic vertebrae. All these joints are synovial.
- Shape of the vertebra: generally, the vertebra consists of a short cylindrical body anteriorly, & an arch (that has many processes) posteriorly, with a rounded foramen in between.
- Shape of the vertebral column: the anterior part of the vertebral column resembles a long curvy cylinder that is made by the vertebral bodies with the intervertebral discs between them. Posteriorly, the vertebral arches (surrounding the vertebral foramina) arrange above each other form the vertebral canal inside them. The posterior part of the column is characterized by lateral & posterior bony projections emerging from the vertebral arches.

- Movement: The vertebral column movement is the summation of the tiny movements of its individual vertebrae over each other. The cervical part has the greatest movement range, followed by the lumbar part. The thoracic part has a limited mobility, while the sacral & coccygeal vertebrae are fused (zero movement).

The Typical Vertebra:

A typical vertebra consists of a vertebral body and a vertebral arch, with the vertebral foramen in between.

The vertebral body resembles a short cylinder, with the upper & lower surfaces slightly concave & attached to the intervertebral discs. Vertebral body is the main weight-carrying part of the vertebra. The vertebral arch is attached to the (upper half) of the posterior surface of the vertebral body. The lateral parts of the arch are the short "pedicles", & the posterolateral parts are the thin "laminae". Note the following:

- The 2 laminae of each vertebra meet in the midline posteriorly. Here, a singe bony process project posteriorly, the "spine" of the vertebra.
- From the region where the pedicle meets the lamina, 3 processes form on each side:
  - The transverse process (laterally)
  - The superior articular process (superiorly)
  - The inferior articular process (inferiorly)
- Superior articular processes of one vertebra articulate with the inferior articular processes of the vertebra above, by 2 flat synovial "facet joints".
- The superior surface of the pedicle forms the shallow "superior vertebral notch"
- The inferior surface of the pedicle (with the adjacent parts of the vertebral body & lamina) forms the deep "inferior vertebral notch".
- Superior vertebral notch of a vertebra, inferior vertebral notch of the vertebra above, & the intervertebral disc between them, form the "intervertebral foramen". This foramen is traversed by the spinal nerve, & blood & lymphatic vessels supplying structures in the vertebral canal.

The above features apply only to the cervical, thoracic, & lumbar vertebrae, with minor variations from region to region. However, there are unique features for different vertebral regions, like the presence of foramina transversaria in the cervical vertebrae & the attachment of ribs in the thoracic vertebrae.

Cervical Vertebrae:

- Seven vertebrae (C1 – C7)
- The first cervical vertebra (C1: the Atlas) is atypical. It is a ring-shaped bone (described further below)
- The second cervical vertebra (C2: the Axis) is also atypical (described further below)
- C3-7 are typical cervical vertebrae, they have:
  - Small, oval or kidney-shaped body
  - Large triangular foramen
  - Large vertebral arch, large vertebral canal
  - Short transverse process, containing a foramen for the passage of vertebral vessels (foramen transversarium), anterior & posterior tubercles (for muscle attachment)
  - Bifid spinous processes
  - Superior articular facets directed posterosuperiorly, inferior articular facets directed anteroinferiorly.
  - Uncinate processes: 2 triangular processes project superiorly from the lateral parts of the body of cervical vertebrae. They articulate with the lower sides of the vertebral body above forming 2 shallow synovial joints (the uncovertebral joints), that maximize cervical vertebral movement.
- Atlas vertebra (C1): this vertebra is modified to accommodate the head movement. It is made of 2 lateral masses, connected anteriorly by the short "anterior arch" & posteriorly by the longer "posterior arch". Note the following:
  - In the midline, the anterior arch has a tubercle anteriorly & an articular facet for the dens of axis (C2) vertebra posteriorly to form the "median atlanto-axial joint" (mediating the right-left rotation of the head on the neck).
  - The posterior arch has the posterior tubercle posteriorly

    - Laterally, the lateral mass has the transverse process projecting laterally & also contains a foramen transversarium
    - Medially, the lateral mass has a small tubercle for attachment of the transverse ligament of atlas
    - Superiorly, the lateral mass has the "superior articular facet", for articulation with the occipital condyles to form the "atlanto-occipital joints" (mediating the flexion-extension of the head on the neck).
    - Inferiorly, the lateral mass has the "inferior articular facet", for articulation with the superior articular facet of the axis (C2) vertebra to form the "lateral atlanto-axial joints" (mediating the right-left rotation of the head on the neck).
    - The atlas vertebra has the largest vertebral foramen among all vertebrae.
- Axis vertebra (C2): also modified to accommodate head movement. It has a very small body & a large triangular vertebral arch. Note the following:
    - From the body, a thump-like process, the "odontoid process (= dens)" projects up, with an articular facet anteriorly, to form the median atlato-axial joint with the anterior arch of atlas.
    - Just lateral to the body, the vertebral arch is large & has the superior articular facet, inferior articular facet, & the transverse process that also contains a foramen.
    - Posteriorly, C2 vertebra has a bifid spinous process.
    - There is no intervertebral disc between atlas & axis vertebrae.

Thoracic Vertebrae:

- Twelve vertebrae (T1 – T12)
- Vertebral body: heart-shaped, larger than that of cervical vertebrae, & contains articular facets for articulation with the heads of the ribs (costal demifacets).
- Vertebral foramen: rounded, smaller than that of cervical vertebrae.
- Transverse processes: long (but length decreases from T1 to T12), directed posterolaterally, & have articular facets for articulation with the tubercles of the ribs (costal facets), except T11 & T12.
- Superior articular facets directed posteriorly and slightly laterally; inferior articular facets directed anteriorly and slightly medially.
- Spines are directed posteroinferiorly.
- Articulation of thoracic vertebrae with ribs: note the following:
    - Each rib articulates by its head with the bodies of thoracic vertebrae (costovertebral joints), & by its tubercle with the transverse process of its vertebra (costotransverse joints). The last 2 ribs (11^{th} & 12^{th}) have only costovertebral joints.
    - For ribs 2^{nd} – 9^{th}, the head articulates with the body of its own vertebra (the large superior costal demifacet), & with the body of the vertebra above (the smaller inferior costal demifacet), & with the intervertebral disc between them (via the intra-articular ligament).
    - For ribs 1^{st}, 10^{th}, 11^{th}, & 12^{th}, the head articulates only with the body of its own vertebra (the costal facet).
    - Ribs 1^{st} – 10^{th} have costotransverse joints, ribs 11^{th} & 12^{th} don't.
    - All of these joints are synovial.

Lumbar vertebrae:

- Five vertebrae (L1 – L5), larger than thoracic vertebrae.
- Body: large, kidney-shaped.
- Vertebral foramen: triangular; larger than in thoracic vertebrae and smaller than in cervical vertebrae.
- Transverse process: long & slender.
- Superior articular facets directed posteromedially (or medially); inferior articular facets directed anterolaterally (or laterally). The joints are curved.
- Spinous process: Short, thick, broad, and rectangular.

Sacral Vertebrae:

- Fused to form one bone (the sacrum), shaped like inverted triangle, concave anteriorly, with smooth anterior surface & rough posterior surface.

- The sacrum consists of a central mass (= vertebral bodies) & 2 lateral parts (alae) that fuse with each other posteriorly to surround the vertebral (sacral) canal.
- The sacrum has 2 superior articular processes (to articulate with the 2 inferior articular processes of L5 vertebra), 2 large articular facets laterally (to articulate with the iliac bones forming the sacro-iliac joints), & the lower tip that articulates with the coccyx.
- On each side, the sacral canal is connected to 4 anterior sacral foramina (transmitting the anterior rami of the 4 sacral spinal nerves) & 4 posterior sacral foramina (transmitting the posterior rami of the 4 sacral spinal nerves).
- The sacral canal ends inferiorly by an opening (the sacral hiatus) that transmits the 5^{th} sacral spinal nerves & the coccygeal nerves.
- The spinous processes of the first 4 sacral vertebrae are fused to form the median sacral crest.

Joints of the Vertebral Column:

Atlanto-occipital joints:

2 synovial joints, formed between the kidney-shaped convex occipital condyles & the shallow superior articular facets of the atlas vertebra. Each joint is surrounded by a strong fibrous capsule. These joints mediate anteroposterior (nodding) movement of the head over the neck (as in saying "yes").

Median atlanto-axial joint:

A special midline synovial joint that forms between the back of the anterior arch of atlas & the front of the odontoid process (dens) of axis vertebra. The dens is firmly held in position against the anterior arch of atlas by the strong transverse ligament of atlas. Due to its critical position, the dens of axis is supported by the following ligaments:

- The apical ligament of dens: a small ligament extending from the tip of dens to the anterior border of the foramen magnum of occipital bone.
- The alar ligaments of dens: 2 oblique bands extending from the sides of the dens to the lateral borders of the foramen magnum of occipital bone.
- The cruciform ligament: cross-shaped ligament supporting the posterior surface of dens, consisting of:
  - The transverse ligament of atlas: very strong, extending between the lateral masses of atlas
  - The superior longitudinal band: from the mid-portion of the transverse ligament to the basilar part of occipital bone (inside the cranial cavity).
  - The inferior longitudinal band: from the mid-portion of the transverse ligament to the posterior surface of the body of axis.
- Tectorial membrane (upper part of posterior longitudinal ligament): posterior to the cruciform ligament, attached superiorly to the basilar part of occipital bone (inside the cranial cavity).

Lateral atlanto-axial joints:

2 flat synovial joints formed between the inferior articular facets of the atlas & the superior articular facets of the axis. Those joints, together with the median atlanto-axial joint, mediate the horizontal rotation of the head on the neck (moving the head left-right, as in saying "no").

Zygapophysial joints:

These are the small synovial joints formed between the superior & inferior articular processes of adjacent vertebrae. They occur in all regions of the vertebral column except the sacral & coccygeal bones. Note the following:

- In the cervical region, these joints are flat, with almost horizontal plane (the superior articular facet directed mainly superiorly)
- In the thoracic region, these joints are slightly curved, with almost vertical plane (the superior articular facet directed mainly posteriorly)
- In the lumbar region, these joints are curved, with almost vertical plane (the superior articular facet directed mainly medially)

- Those joints allow a minimal sliding movement between the 2 adjacent vertebrae. However, the summation of all the small movements produces a considerable range of movement of the vertebral column as a whole.

Uncovertebral joints:

Small curved synovial joints formed between the bodies of cervical vertebrae (C2 – C7). The articulation occurs between the uncinate process of a typical cervical vertebra & the inferolateral surface of the vertebral body above it. These joints increase the range of lateral flexion of the cervical spine.

Intervertebral discs:

Between the 2 adjacent vertebral bodies, there is a special type of fibrous joints, represented by the "intervertebral disc". The superior & inferior surfaces of the vertebral body are covered by a thin layer of hyaline cartilage. Then, the space between the bodies is filled by the disc. The disc consists of an external, strong, compressible, multi-layered region of fibrous cartilage (the annulus fibrosus), & a central gelatinous mobile core (the nucleus pulposus). The disc allows compression-decompression movement of the 2 vertebral bodies in all directions. Importantly, when the disc is compressed anteriorly, the nucleus moves posteriorly; when the disc is compressed on the left, the nucleus moves to the right, & so on.

Costovertebral joints, costotransverse joints, & sacroiliac joints: outside the scope of this lecture.

Ligaments of the Vertebral Column:

I- Vertebral bodies ligaments:
   a. Anterior longitudinal ligament: a long strong wide band located along the anterior aspect of the vertebral column. It is attached superiorly to the occipital bone just anterior to the foramen magnum, & inferiorly to the anterior surface of the coccyx.
   b. Posterior longitudinal ligament: a long strong narrow band located along the posterior aspect of the vertebral bodies. It is attached superiorly to the intracranial surface of occipital bone anterior to the foramen magnum (as the tentorial membrane), & inferiorly to the posterior surface of the coccyx.
   c. Anterior atlanto-occipital membrane: fibrous layer closing the space between the occipital bone & atlas vertebra anteriorly. It extends from the capsule of one atlanto-occipital joint to the other, & is strengthened in the middle by the anterior longitudinal ligament.
   d. Anterior atlanto-axial membrane: fibrous layer closing the space between the atlas & axis vertebrae anteriorly. It extends from the capsule of one lateral atlanto-axial joint to the other, & is strengthened in the middle by the anterior longitudinal ligament.

II- Vertebral arches ligaments:
   a. Posterior atlanto-occipital membrane: fibrous layer closing the space between the occipital bone & atlas vertebra posteriorly. It extends from the capsule of one atlanto-occipital joint to the other. It is perforated on both sides by the vertebral arteries.
   b. Posterior atlanto-axial membrane: fibrous layer closing the space between the atlas & axis vertebrae posteriorly. It extends from the capsule of one lateral atlanto-axial joint to the other.
   c. Ligamentum flavum (pl. ligamenta flava): a thin fibrous layer extending between the laminae of the adjacent vertebrae, closing the gap between them.
   d. Interspinous ligaments: short ligaments connecting the spinous processes of adjacent vertebrae.
   e. Supraspinous ligament: a long midline fibrous band that starts from the sacral hiatus, bridging the tips of the spinous processes of vertebrae. At C7, this ligament continues as the ligamentum nuchae.
   f. Ligamentum nuchae: a strong, broad, midline ligament that extends from the tips of the spines of cervical vertebrae to the external occipital crest & protuberance. It represents an important site of muscle attachment.
   g. Other ligaments: ligaments of the costovertebral joints, ligaments of the sacroiliac joints, etc.

   Note: there are no ligaments connecting the pedicles of adjacent vertebrae (why?)

Intervertebral Foramina: these are the openings leading to the vertebral canal. Each foramen is formed between 2 successive vertebrae, oval in shape, being vertically placed.

Boundaries: Superiorly: inferior vertebral notch. Inferiorly: superior vertebral notch. Posteriorly: zygapophyseal joint. Anteriorly: lower part of vertebral body & the intervertebral disc

Contents: Spinal nerve, recurrent meningeal branches of the spinal nerve, segmental spinal arteries & veins.

Clinical Applications

Herniation of intervertebral discs:

A tear can occur within the anulus fibrosus of intervertebral disc, through which the material of the nucleus pulposus can emerge (herniate). After a period of time, this material may track into the vertebral canal or into the intervertebral foramen to impinge on neural structures. This is a common cause of back pain. A disc may protrude posteriorly to directly impinge on the cord or the roots of the lumbar nerves, depending on the level, or, more commonly, may protrude posterolaterally adjacent to the pedicle and impinge on the descending root. In cervical regions of the vertebral column, cervical disc protrusions often become ossified and are termed disc osteophyte bars.

The vertebrae and cancer:
The vertebrae are common sites for metastatic disease (secondary spread of cancer cells). When cancer cells grow within the vertebral bodies and the posterior elements, they destroy the mechanical properties of the bone. A minor injury may therefore lead to vertebral collapse. Importantly, vertebrae that contain extensive metastatic disease may extrude fragments of tumor into
the vertebral canal, so compressing nerves and the spinal cord.

Scoliosis
Scoliosis is an abnormal lateral curvature of the vertebral column. This tends to occur in either the
infantile, juvenile, or adolescent age groups due to poorly understood mechanism. The vertebral bodies and posterior elements (pedicles and laminae) are normal in these patients. When a scoliosis is present from birth (congenital scoliosis) it is usually associated with other developmental abnormalities.

Kyphosis
Kyphosis is abnormal curvature of the vertebral column in the thoracic region, producing a "hunchback" deformity. This condition occurs in certain disease states, the most dramatic of which is usually secondary to tuberculosis
infection of a thoracic vertebral body, where the kyphosis becomes angulated at the site of the lesion.

Lordosis
Lordosis is abnormal curvature of the vertebral column in the lumbar region, producing a swayback deformity.

Variation in vertebral numbers:
There are usually seven cervical vertebrae, although in certain diseases these may be fused at different levels (eg: fusion of vertebrae C1 and C2 or C5 and C6, etc). Variations in the number of thoracic vertebrae are well described. One of the commonest abnormalities in the lumbar vertebrae is a partial fusion of vertebra L5 with the sacrum (sacralization of the lumbar vertebra). Partial separation of vertebra S1 from the sacrum (lumbarization of first sacral vertebra) may also occur.
No definite correlation exists between the number of vertebrae and back pain, although the two cannot be dissociated. Surgeons, radiologists, and other physicians must be able to accurately define vertebral levels to prevent errors. A hemivertebra occurs when a vertebra develops only on one side.

Spina bifida
Spina bifida is a disorder in which the two sides of vertebral arches, usually in lower vertebrae, fail to fuse during development, resulting in an "open" vertebral canal. There are two types of spina bifida.

- *The commonest type is spina bifida occulta, in which there is a defect in the vertebral arch of L5 or S1. This defect occurs in as many as 10% of individuals and results in failure of the posterior arch to fuse in the midline. Clinically, the patient is asymptomatic.*
- *The more severe form of spina bifida involves complete failure of fusion of the posterior arch at the lumbosacral junction with a large outpouching of the meninges. This may contain cerebrospinal fluid (a meningocele) or a portion of the spinal cord (a myelomeningocele). These abnormalities may result in a variety of neurological deficits, including problems with walking and bladder function.*

Muscles of the Back:

The muscles of the back are classified into 3 groups:

I- Superficial group (extrinsic): this layer includes trapezius, latissimus dorsi, levator scapulae, rhomboid minor & rhomboid major muscles. Those muscles originate from the skull & vertebral column & are inserted into the scapula & humerus, & supplied by the anterior rami of spinal nerves (mostly via the brachial plexus). They function to move the upper limb.

II- Intermediate group (extrinsic): this layer includes serratus posterior superior & serratus posterior inferior muscles. They originate from the vertebral column & are inserted into the ribs. They are supplied by anterior rami of spinal nerves, & considered as accessory respiratory muscles. See the table for details.

III- Deep group (intrinsic): this is the deepest group, they are located around the posterior part of vertebral column as tough bundles of muscles, from the skull base to the pelvis, & are innervated by the posterior rami of spinal nerves. This group is subdivided into:

a. Rotators / extensors of the head & neck: Splenius capitis & splenius cervices. They originate from the spinous processes of lower cervical & upper cervical vertebrae, & inserted into the transverse processes of upper cervical vertebrae (& lateral part of occipital bone). Therefore, this group is called "spinotransvesales muscles". See the table for details.

b. Rotators / extensors of the vertebral column: erector spinae muscles, & transversospinales muscles:

i. Erector spinae: the largest group of intrinsic back muscles. The muscles lie posterolaterally to the vertebral column between the spinous processes medially and the angles of the ribs laterally. They are covered in the thoracic and lumbar regions by thoracolumbar fascia. The mass arises from a broad, thick tendon attached to the sacrum, spinous processes of the lumbar and lower thoracic vertebrae, and the iliac crest. It divides in the upper lumbar region into three vertical columns of muscle, each of which is further subdivided regionally (lumborum, thoracis, cervicis, and capitis), depending on where the muscles attach superiorly.

1. Iliocostalis: the most laterally placed column, which passes from the common tendon of origin to the angles of the ribs and the transverse processes of the lower cervical vertebrae.
2. Longissimus: the intermediate & largest column of erector spinae. It passes from the common origin to the base of the skull.
3. Spinalis: the most medially placed & smallest column. It originates from- & inserts into- the spinous processes of vertebrae. It is most prominent in the thoracic region & almost absent in the cervical region.

ii. Transversospinalis muscles: those are muscles that originate from the transverse processes of vertebrae, & inserted into the occipital bone (semispinalis capitis), the spines of cervical vertebrae (semispinalis cervices), or the spines of upper thoracic vertebrae (semispinalis thoracis). Other muscles in this group include multifidus & the rotators (lumborum, thoracis, & cervicis).

c. Short segmental muscles: these are called "segmental" because they originate from one segment of vertebral column & are inserted into the next segment of the column. They include 3 sets of muscles:

i. Levators costarum: from transverse processes to the ribs below.
ii. Interspinales: between adjacent spinous processes.
iii. Intertransversarii: between adjacent transverse processes.

Suboccipital Region (triangle):

A small group of deep muscles in the upper cervical region at the base of the occipital bone move the head. They connect vertebra CI (the atlas) to vertebra CII (the axis) and connect both vertebrae to the base of the skull. Because of their location they are sometimes referred to as suboccipital muscles. They include, on each side:

- rectus capitis posterior major;
- rectus capitis posterior minor;
- obliquus capitis inferior; and
- obliquus capitis superior.

Contraction of the suboccipital muscles extends the head at the atlanto-axial joint. See the table for details.

The suboccipital muscles are innervated by the posterior ramus of the first cervical nerve (C1), which enters the area between the vertebral artery and the posterior arch of the atlas. The vascular supply to the muscles in this area is from branches of the vertebral and occipital arteries.

The suboccipital muscles form the boundaries of the **suboccipital triangle**, as follows:

- rectus capitis posterior major forms the medial border of the triangle;
- obliquus capitis superior forms the lateral border;
- obliquus capitis inferior muscle forms the inferior border.

The suboccipital muscles & triangle are covered posteriorly by the large semispinalis capitis & the trapezius muscles. The contents of the triangle are: the posterior ramus of C1, the posterior arch of atlas, the vertebral artery, and associated veins. The posterior ramus of C2 spinal nerve is large, it emerges from the inferior border of obiquus capitis inferior muscle, turns up to cross the suboccipital triangle, then pierces semispinalis capitis & trapezium muscles to enter the scalp as the greater occipital nerve, the sensory supply of the posterior half of the scalp. Similarly, a smaller branch from the posterior ramus of C3 runs parallel & medial to the great occipital nerve, to emerge as the third occipital nerve.

Clinical Applications

Nerve injuries affecting superficial back muscles:

Weakness in the trapezius, caused by an interruption of the accessory nerve [XI], may appear as drooping of the shoulder, inability to raise the arm above the head because of impaired rotation of the scapula, or weakness in attempting to raise the shoulder (i.e., shrug the shoulder against resistance).

A weakness in the latissimus dorsi, resulting from an injury to the thoracodorsal nerve, diminishes the capacity to pull the body upward while climbing or doing a pull-up.

An injury to the dorsal scapular nerve, which innervates the rhomboids, may result in a lateral shift in the position of the scapula on the affected side.

Back muscles spasm:

The muscles of the back are prone to spasm due to over-exertion, long duration of fixed posture, etc. The most affected muscles are those in the back of the neck & the lumbar region. Spasm causes pain, movement limitation, & can result in temporary loss of normal curvature of the vertebral column (seen in x-ray as straight cervical or lumbar region of the vertebral column = loss of normal lordosis).