Established, Current & Emerging Concepts of

SPINE



Conceptual Orthopedics

The Learning Never Ends

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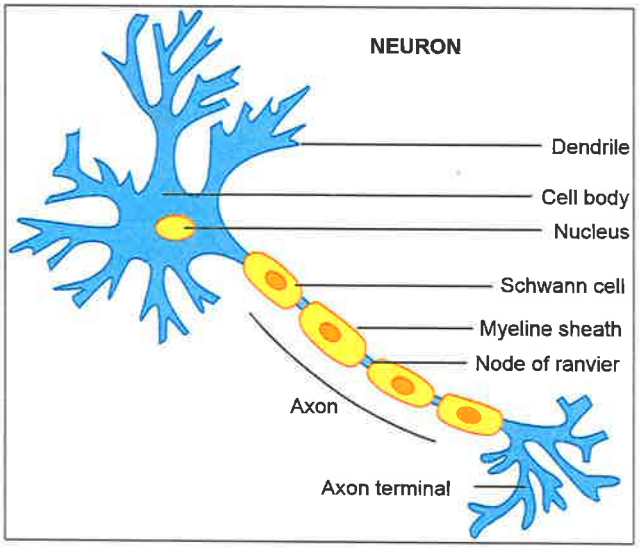
Section 1
General Concepts of Spine

CHAPTER 1.1

Spine Neural Anatomy

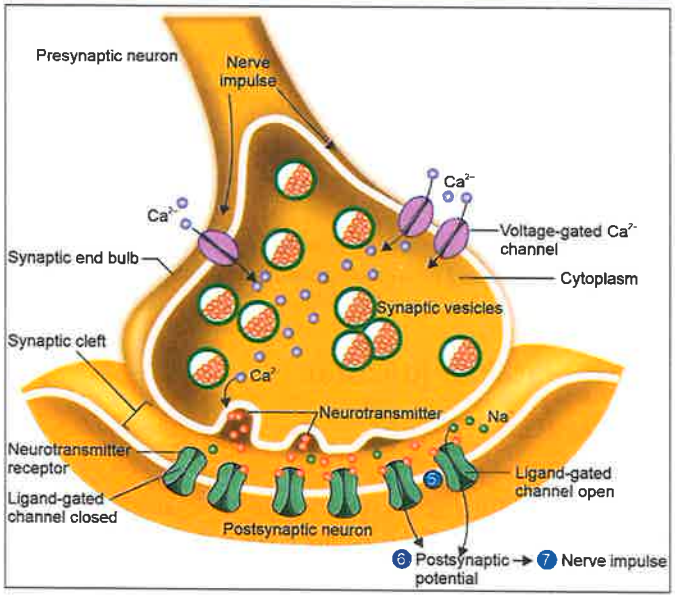
Neuron Anatomy

Basic components



Components	Function
Dendrites	Receive signals from other neuron for transfer towards body
Cell body	Contain cell nucleus. Protein and ATP production
Axon hillock	Site for action potential summation
Axon	Carries action potential from cell body to terminal branches
Myelin sheath	Insulating layer around axon, facilitates action potential through saltatory conduction Oligodendrocytes - myelinate central nervous system. Schwann's cells- myelinate neurons of peripheral nervous system
Nodes of Ranvier	Interruptions in myelin sheath . contain high density voltage gated channels.
Terminal branches	Site for neurotransmitter release into synaptic cleft. Often known as presynaptic terminal

Mechanism of basic chemical synapses



Pre and post synaptic complex

Depolarization, or action potential, reaches the presynaptic neuron's terminal branch.

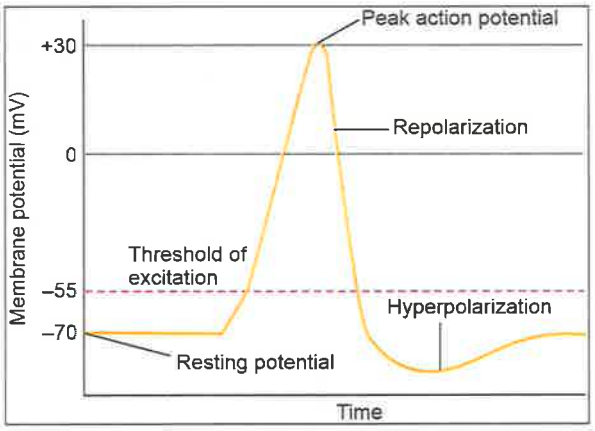
1. Ca2+ influx causes N-type Ca2+ channels to open.
   - (this related pathology: myasthenic syndrome associated with Lambert-Eaton).
2. Neurotransmitter released into the synaptic cleft is facilitated by Ca2+ during vesicle docking.
   - Related pathologies: tetanus (lockjaw), botulism.
3. Postsynaptic neurons, or neurotransmitter receptors, are bound by neurotransmitters.
   - Pathologies associated with it: myasthenia gravis.
4. The neurotransmitter receptor generates an inhibitory postsynaptic potential (IPSP) or an excitatory postsynaptic potential (EPSP) based on its function.

By depolarizing the postsynaptic neuron, EPSPs raise the

likelihood that an action potential will develop.

IPSPs reduce the likelihood of action potential production by either resisting or hyperpolarizing the postsynaptic neuron.

1. The cell body and axon hillock integrate the potentials from all dendrites to determine whether an action potential will fire in the postsynaptic neuron.
2. To stop the postsynaptic stimulation, a number of processes, including as enzymatic breakdown (acetylcholine) and presynaptic reuptake (serotonin), remove neurotransmitters from the synaptic cleft.

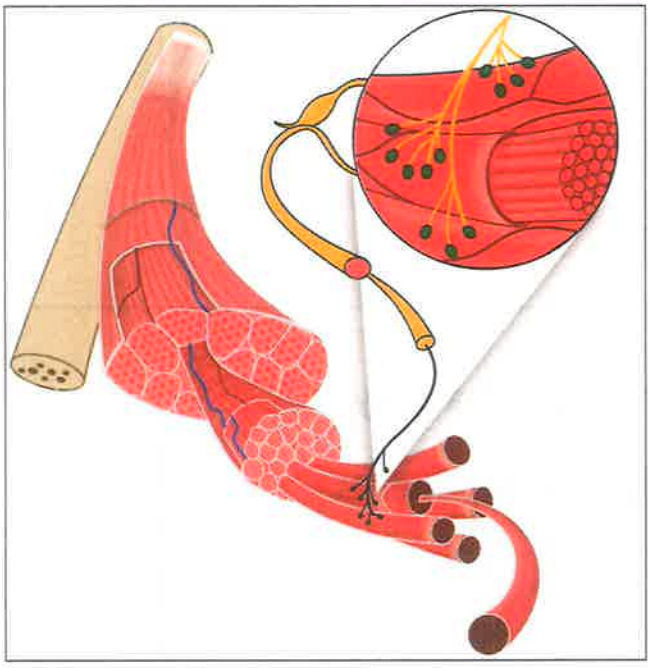


A neuronal action potential. The dashed line represents the threshold voltage. The action potential could be either EPSP or IPSP

Neuromuscular junction:

Specialized chemical synapse connecting the muscle fiber and motor neuron.

Nicotinic acetylcholine receptors make up the majority of the cholinergic synapses. Muscle fiber contraction is the outcome of a nerve impulse.



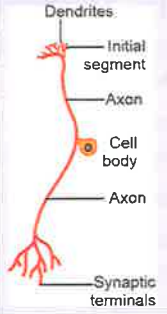
Motor unit:

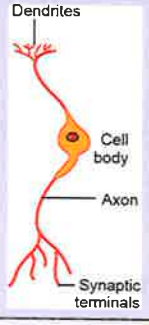
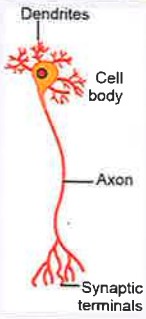
One motor neuron and every muscle fiber it innervates make up the motor unit.

A tiny motor unit governs fine-motor control muscles and consists of three to six muscle fibers.

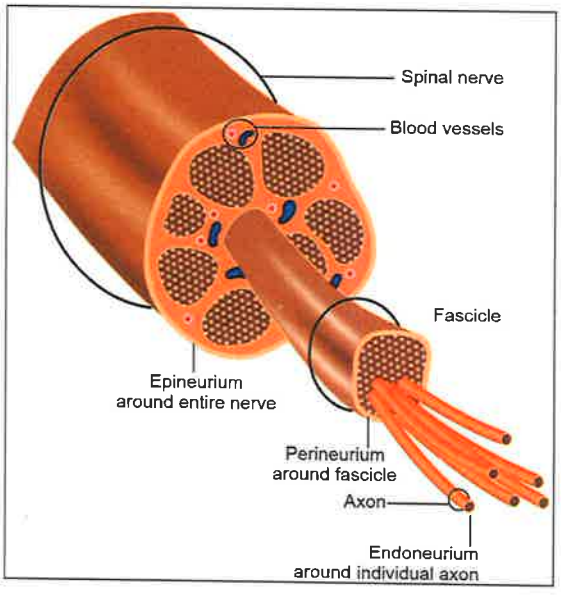
100–1,000 muscle fibers make up a big motor unit, which regulates muscles with basic strength and control (e.g., quadriceps, biceps). A single motor unit's muscle fibers are all of the same type (types 1, 2a, and 2b).

Neuron types

Type	Image	Description	Examples
Pseudounipolar		A single axon split into two branches with an adjacent cell body: • Peripheral branch: Periphery to cell body (contains dendrites) • Central branch: Cell body to spinal cord (contains synaptic terminals) Transmits sensory information from the periphery to the CNS	• Sensory neurons of dorsal root ganglia • Sensory ganglia or cranial nerves V, VII, IX and X

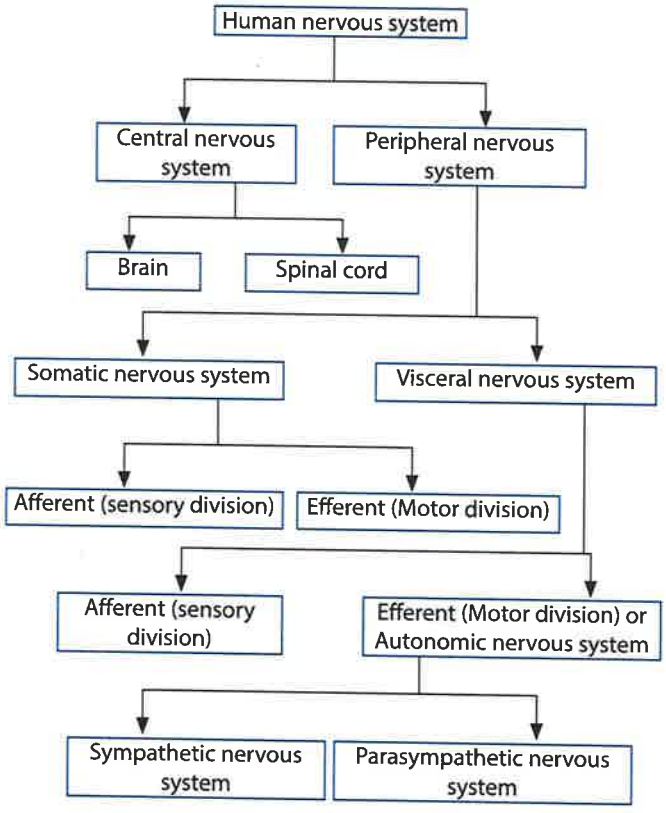
Bipolar		Cell body centrally located between a: • Dendrite: transmits signals toward cell body • Axon: Transmits signals away from cell body Specialized sensory neurons for the transmission of special senses (i.e., vision, hearing)	• Bipolar cells, ganglion cells, horizontal cells, and amacrine cells of the retina • Cochlear and vestibular ganglia of the inner ear
Multipolar		Cell body contains multiple dendrites and a single axon able to receive and integrate abundant nerve impulses	• Motor neurons (ventral horn of spinal cord) • Interneurons (spinal cord gray matter) • Purkinje's cell (cerebellum) • Pyramidal cells (cerebral cortex)

Nerve fiber organization



COMPONENT	COVERING
Axon	Endoneurium
Fascicle	Perineurium
Nerve	Epineurium

Nervous system organization



Afferent and efferent nerves

Dorsal roots allow afferent nerve fibers—which transmit sensory data—to reach the spinal cord.

Through ventral roots, efferent nerve fibers leave the spinal cord with motor information.

Type	Root	Cell body location	Information conveyed
Afferent:	Dorsal	Dorsal root ganglion	Sensory
General somatic afferent (GSA)			Skin, Muscles, tendons, Joints
General visceral afferent (GVA)			Visceral organs
Efferent:	Ventral	Spinal cord gray matter	Motor
General somatic efferent (GSE)		Ventral horn	Skeletal muscle
General visceral efferent (GVE)		Lateral horn	Smooth and cardiac muscle, glands

Efferent motor neurons

A. Upper motor neurons (UMNs): The primary motor cortex or brainstem nuclei are the source of the cell bodies of UMINs.

- Communicate motor information through synapsing with spinal cord or brainstem lower motor neurons (LMNs, also known as interneurons).

B. ower motor neurons

- Brainstem nuclei or the ventral horn of spinal cord gray matter are the places where cell bodies begin.
- Transmit motor information from UMNs by using neuromuscular connections to generate synapses with peripheral skeletal muscle.

Afferent sensory receptors

Receptor type	Modality	Adaption rate	Fiber class
Cutaneous mechanoreceptors			
Meissner's corpuscle	Touch (superficial)	Rapid	II
Merkel's cell	Touch (superficial)	Slow	II
Hair follicle receptor	Touch, vibration	Rapid and slow	II
Pacinian corpuscle	Touch (deep), Vibration	Rapid	II
Ruffini's ending	Touch (deep), stretch, Proprioception	Very slow	II
Stretch receptors			
Muscle spindle			
Nuclear bag fibers	Proprioception (muscle stretch)	Slow	I
Nuclear chain fibers	Proprioception (muscle tone)	Slow	II
Golgi's tendon organ	Proprioception (muscle tension)	Slow	I
Pain and temperature recetors			
Free nerve endings	Nociception (fast)	-	III
	Nociception (slow)	-	IV
	Temperature (cool)	-	III
	Temperature (warm)	-	IV

Afferent sensory neurons

Sensory fiber type	Myelinated	Sensory modality	Free nerve endings Sensory receptor
A-α^a	Yes	Proprioception	Muscle spindle Golgi tendon organ
A-β	Yes	Proprioception superficial touch Touch, vibration Deep touch, vibration Deep touch, stretch	Muscle spindle Meissner's corpuscle Merkel's cell Hair follicle receptor Pacinian corpuscle Ruffini's ending
A-δ	Yes	Nociception (fast) Temperature (cool)	Free nerve endings Free nerve endings
C^b	No	Nociception(slow) Temperature (warm)	Free nerve endings Free nerve endings

Reflex arcs

Reflex arcs are brain pathways that control reflex actions.

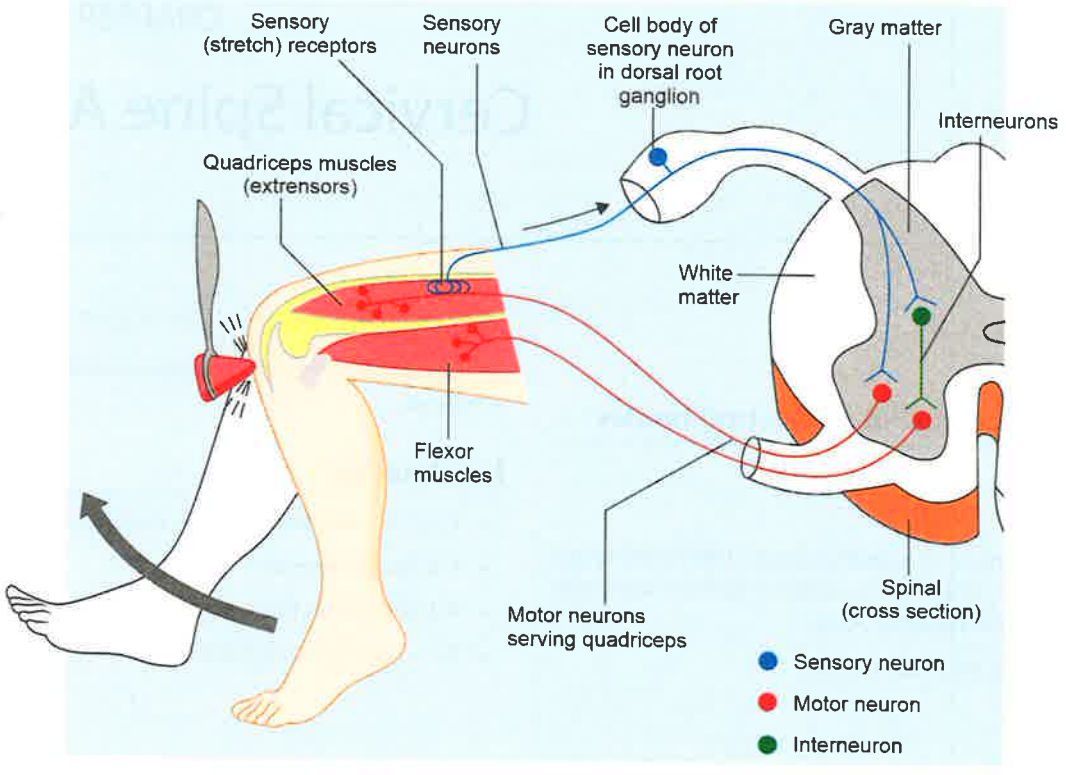
It only affects the spinal cord, allowing for quick, subconscious responses.

The brain processes sensory information once the reflex occurs.

Types:

1. Monosynaptic: consists of two neurons (sensory and motor) connected by a single chemical synapse. Examples include the patellar and Achilles reflex.
2. Polysynaptic: includes one or more interneurons that connect a sensory neuron to a motor neuron.
   - This represents the bulk of reflex arcs.
   - Enables higher order processing and control.
   - That is the pain withdrawal reaction.
3. Somatic: affects the skeletal muscles.
4. Autonomic: influences the internal viscera.

Components of mono synaptic reflex arc



Signs of upper motor neuron and lower motor neuron injury

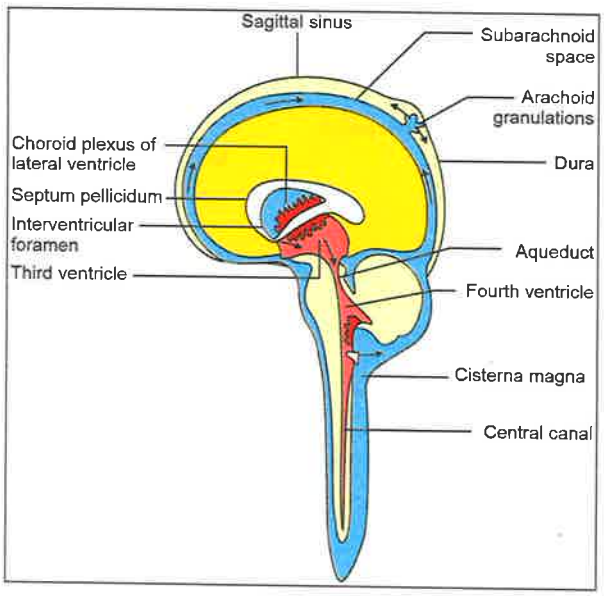
CLINICAL SIGNS	UMN (ACUTE)	UMN (CHRONIC)	LMN
WEAKNESS	Yes	Yes	Yes
ATROPHY	No	Some	Severe
TONE	Flaccid	Spastic	Decreased
FASICULATIONS	No	No	Yes
REFLEXES	Decreased	Increased	Decreased
BABINSKI SIGN	No	Yes	No

Spinal cord anatomy

Cord extends from brainstem to inferior border of L1 vertebra

1. Conus medullaris - terminal portion of spinal cord
2. Filum terminale - residual fibres of spinal cord extending from conus to sacrum
3. Thecal sac - dural matter surrounding spinal cord. Contains CSF
4. Cauda equina - nerve roots along with filum terminale that extends from spinal cord.

Cerebral spinal fluid



Ultra filterate of blood plasma from choriod plexus.

Colourless fluid within the subarachnoid space surrounding brain, spinal cord. It provides mechanical and immunological protection to brain, spinal cord.

Production of CSF is produced by the choroid plexus in the third and fourth and lateral ventricle.

Total CSF volume at one point of time is around 150 ml

Production is at 500ml per day with turn over rate of 3-4 times per day.

CHAPTER **1.2**

Cervical Spine Anatomy

OSTEOLOGY

Cervical spine consist of 7 vertebral bodies

1. C1 (ATLAS)
2. C2(AXIS)
3. C3–C7 also termed as subaxial spine. The cerval spinal motion segment where the majority of flexion/ extension of neck and lateral bending occur

Maximal flexion at C4/C5 and C5/C6.

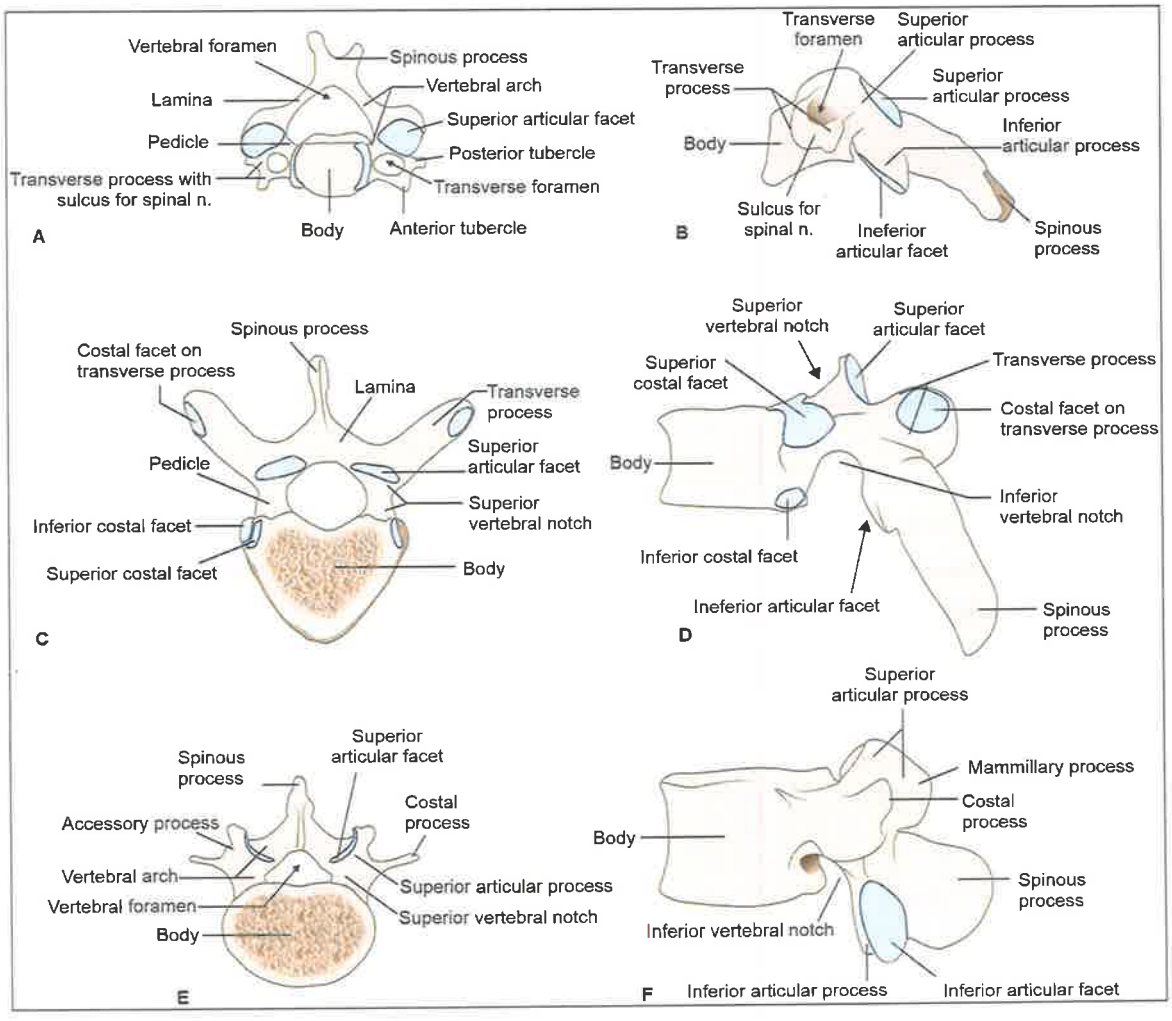
Maximal lateral bending at C2/C3, C3/C4, and C4/C5.

ALIGNMENT: primary Lordotic curvature: 10 to 25 degrees is normal.

Landmarks:

- C2/C3: lower border of the mandible.
- C3: hyoid bone level.
- C4: thyroid cartilage level.
- C6: cricoid cartilage level.

Bony Anatomy



Vertebral body

Concave superiorly.

Convex inferiorly.

Uncinate process

Directly interacts with the adjacent vertebral body above.

Contain articular surfaces.

Pedicle

Angled medially and superiorly.

Pedicles smaller than those in the thoracic and lumbar spine.

Transverse process:

- **All** cervical vertebrae have transverse foramen.
- Anterior to nerve root groove.
- Allow for passage of vertebral artery.

C6 transverse process (Chassaignac's tubercle) is palpable.

Lamina:

A bridge between lateral masses and spinous process.

Lateral mass

Lateral to the junction between the pedicle and lamina.

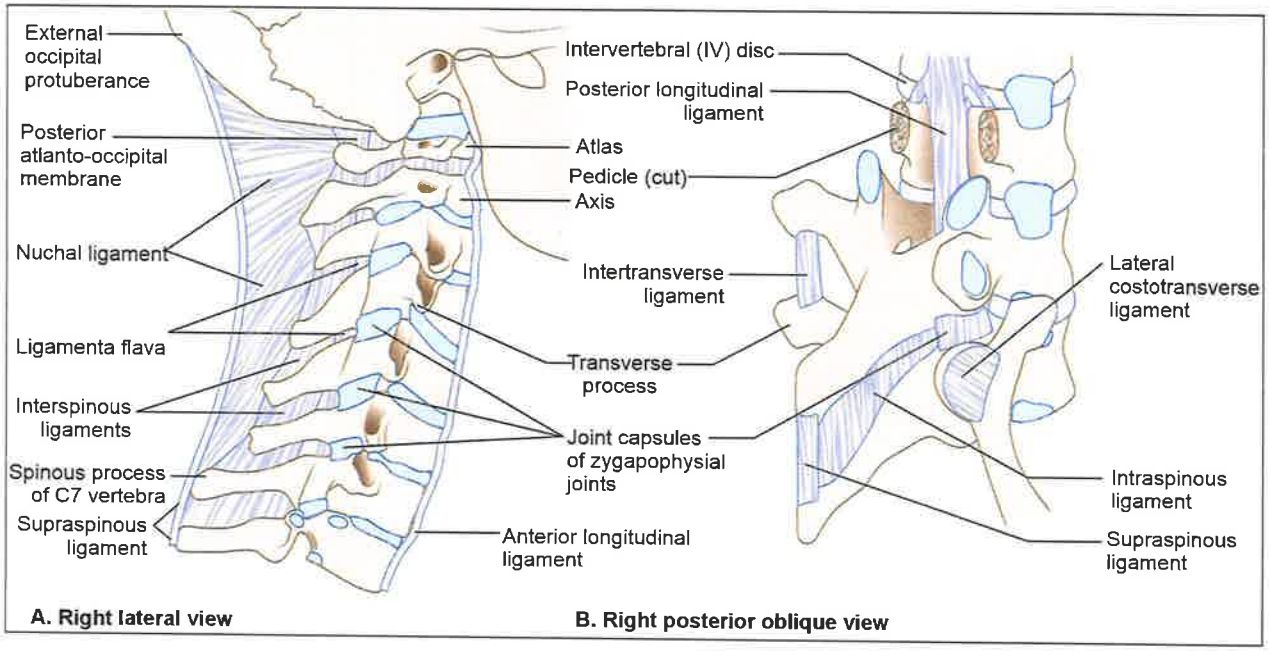
Contains the superior and inferior articular processes

Spinous process:

Bifid from C3 to C5.

C7 exhibits the largest spinous process.

Ligamentous Anatomy



Anterior ligamentous complex:

1 Anterior longitudinal ligament (ALL):

Travel along the anterior surface of vertebral bodies.

Resists extension.

2 Annulus fibrosis of the intervertebral disk.

Middle ligamentous complex:

1. Posterior longitudinal ligament (PLL):

Travel along the posterior surface of vertebral bodies.

Resists flexion.

2. Annulus fibrosis.

Posterior ligamentous complex:

1. Facet capsules:

Assist the facet joint at the neighboring vertebral articulation and fend against distracting forces.

2. Interspinous and supraspinous ligament:

Traverse between spinous processes.

Consist of midline avascular plane. Continuous with ligamentous nuchae above C7

3. Ligamentum flavum

Deepest structure posteriorly

Connects the laminas of adjacent vertebrae.

Muscular anatomy

Fascial layers

1. Platysma

   Superficial muscle.

2. Superficial layer of deep cervical fascia:

   Contains anterior neck muscles (except longus colli) and trapezius posteriorly.

3. Prevertebral layer of deep cervical fascia:

   Contains all posterior neck muscles deep to trapezius.

   Covers ALL and longus colli.

4. Pretracheal fascia

   Contains thyroid and trachea.

5. Carotid sheath

   Contains carotid artery, internal jugular vein, and vagus nerve

Muscular layers

Anterior neck muscle

Divided into two regions: anterior neck and anterior cervical triangle

Table 1. Anteior neck

Muscle	Origin	Insertion	Action	Innervation
Platysma	Deltoid and pectoralis major	Mandible	Lower jaw	Cranial nerve VII
Sternocleidomastoid (SCM)	Manubrium of sternum and clavicle	Mastoid process of skull	Turn head (left SCM turns head to the right)	Cranial nerve XI

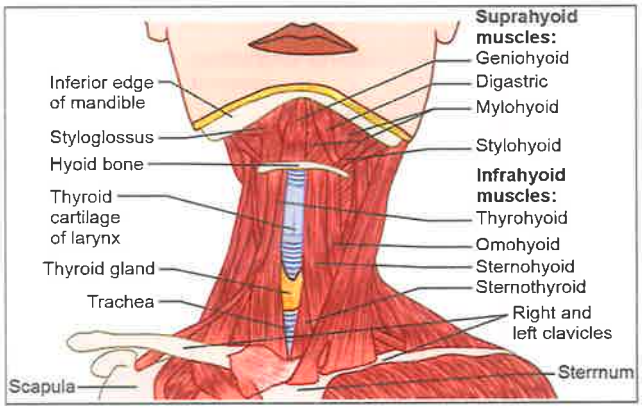


Table 2. Anterior cervical triangle

Muscle	Origin	Insertion	Action	Innervation
Suprahyoid				
Digastric	Mandible (anterior belly); Mastoid notch of temporal bone (posterior belly)	Hyoid bone	Depresses mandible and elevates larynx	Cranial nerve V (anterior belly); Cranial nerve VII (Posterior belly)
Mylohyoid	Mandible	Hyoid bone	Depresses mandible, elevated hyoid	Cranial nerve V
Stylohyoid	Styloid process	Hyoid bone	Elevate hyoid	Cranial nerve VIi
Geniohyoid	Mandible	Hyoid bone	Elevate hyoid	C1
Infrahyoid (superficial)				
Sternohyoid	Manubrium and clavicle	Hyoid bone	Depress hyoid	Ansa cervicalis (C1-C3)
Omohyoid	Suprascapular notch	Hyoid bone	Depress hyoid	Ansa cervicalis
Infrahyoid (deep)				
Thyrohyoid	Thyroid cartilage	Hyoid bone	Depress hyoid	C1
Sternothyroid	Manubrius of sternum	Hyoid bone	Depress hyoid and larynx	Ansa cervicalis

Posterior neck muscles:

Divided into three regions: posterior neck, occipital triangle, and suboccipital triangle

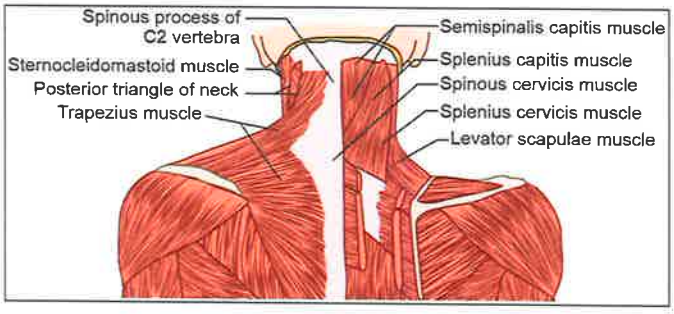


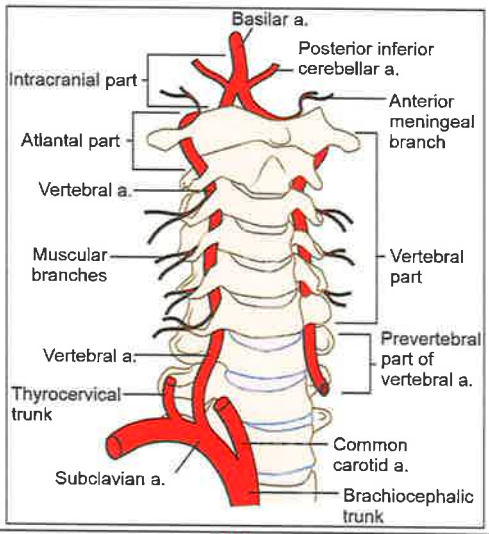
Table 3. Posterior neck

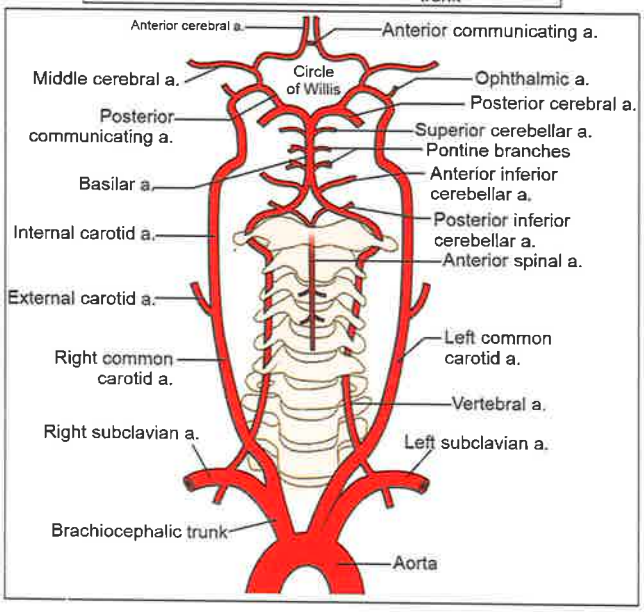
Muscle	Origin	Insertion	Action	Innervation
Superficial (extrinsic)				
Trapezius	Spinous processes of C7-T12	Clavicle and scapula	Rotate and raise scapula	Cranial nerve XI
Superficial (intrinsic)				
Splenius capitis	Ligamentum nuchae	Mastoid and nuchal line	Laterally flex and rotate neck	Dorsal rami of C4, C5, C6
Deep (intrinsic)				
Semispinalis capitis	Transverse process T1-T6	Nuchal ridge	Extend head	Dorsal rami

Table 4. Occipital triangle

Muscle	Origin	Insertion	Action	Innervation
Anterior scalene	Transverse process C3-C6	First rib	Laterally flexes neck and raises first rib	C5-C8 nerve roots
Middle scalene	Transverse process C2-C7	First rib	Laterally flexes neck and ralses first rib	C5-C8 nerve roots
Posterior scalene	Transverse process C4-C6	Second rib	Laterally flexes neck and raises first rib	C5-C8 nerve roots

Vascular anatomy





The main blood supply to the spinal cord

Anterior spinal artery (ASA).

Posterior spinal arteries (PSA).

The vertebral arteries, which begin at the first segment of the subclavian artery, combine to produce the anterior spinal artery. The basilar artery is formed by the vertebral arteries passing via the transverse foramen of C1 through C6 and the foramen magnum.

Neural anatomy

- The cranial diameter of the cervical spinal cord diminishes as we proceed caudally

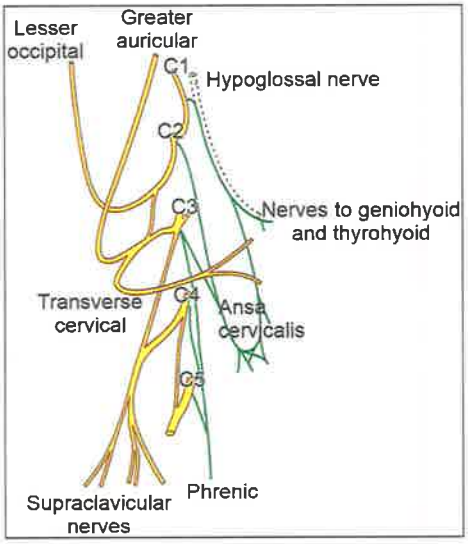
Anterolateral exit of the nerve roots leads to the superior facet.

- The C3–C7 nerve roots emerge above each vertebral pedicle.

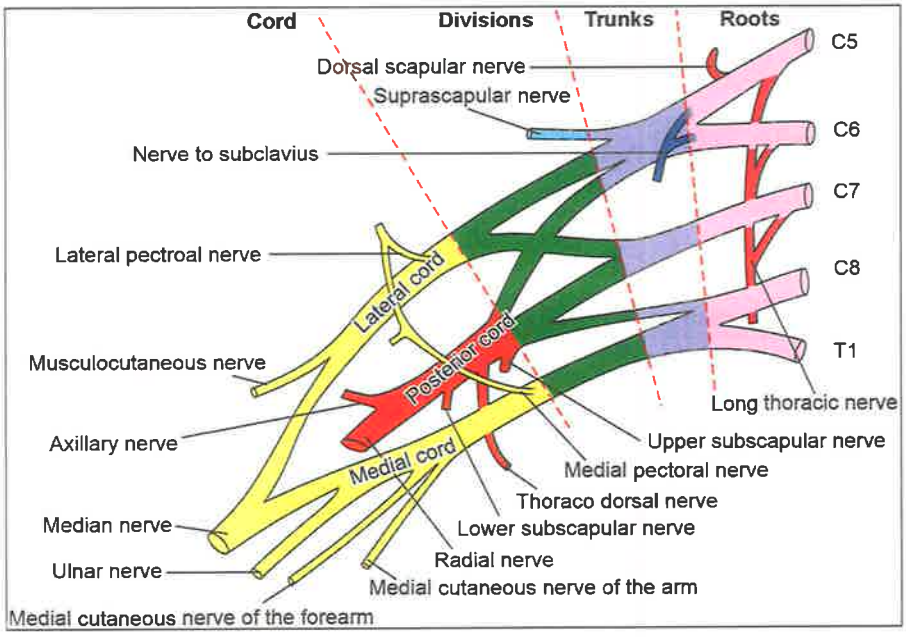
- C8 exits above the T1 pedicle, below the C7 vertebra.

The majority of the posterior neck and head are sensed by dorsal (posterior) rami.

Two nerve plexuses are formed by the ventral (anterior) rami: the cervical plexus. the brachial plexus, too.



Cervical plexus



Brachial plexus

CHAPTER 1.3

Thoracic Spine Anatomy

General Information

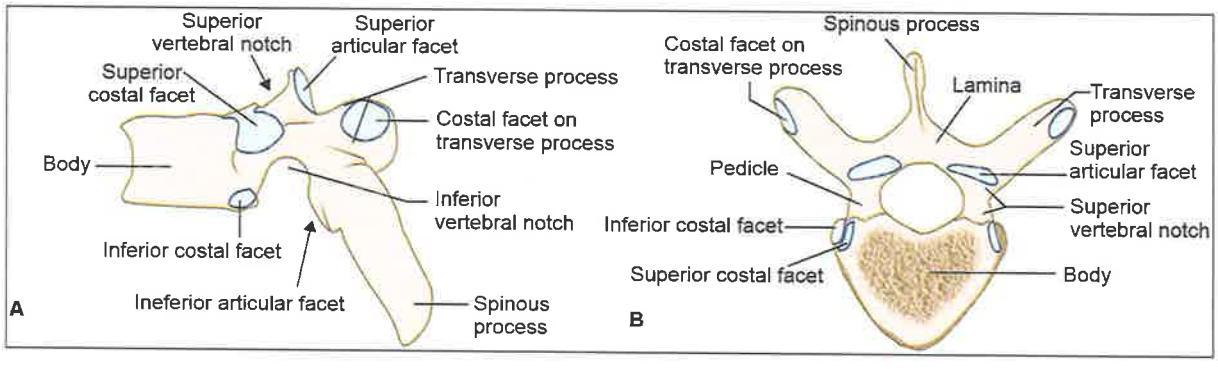
- Thoracic vertebrae consist of T1- T12
- Kyphotic curvature of around 20-40 degrees is normal kyphosis.
- Apex of kyphosis at T7-T8

All vertebrae articulate with corresponding ribs along with facet joint, leading to a limited range of motion

- Flexion–extension minimal at T1–T2; maximum T12–L1.
- Axial rotation is minimal at the thoracolumbar junction; and maximum at T12.

The shape of thoracic vertebrae is wedge-shaped with anteriorly shorter height and long posterior height.

Bony Anatomy



Vertebral body:

Large wedge shaped vertebra, articulates with ribs corresponding.

Each rib articulates with two vertebral bodies.

Superior costal demifacet (costal facet):

The superoposterior edge of the vertebral body Articulates with corresponding ribs of same number.

Exceptions

A. Superior costal facet of T1 is not a demifacet

The first rib only articulates with T1.

B. T10 has one pair of complete costal facets located between the vertebral body and pedicle.

C.T11 and T12 have one pair of complete costal facets located on the pedicles.

Inferior costal demifacet (costal facet):

- Inferoposterior edge of vertebral body.
- Articulates with the head of the rib below.

Pedicle:

- Height of pedicle is double that of the width.
- Inferior notch is superior border of intervertebral foramen.
- Superior notch is inferior border of intervertebral foramen.
- Pedicle diameter is maximal at T1 and minimal at T6:
- The diameter gradually increases again from T6.

Superior articular process:

- Faces posterolaterally.
- Articulates with the inferior articular process of adjacent superior vertebrae.

Inferior articular process:

- Faces anteromedially.

- Articulates with the superior articular process of adjacent inferior vertebrae

Lamina.

Posterior border of vertebral foramen.

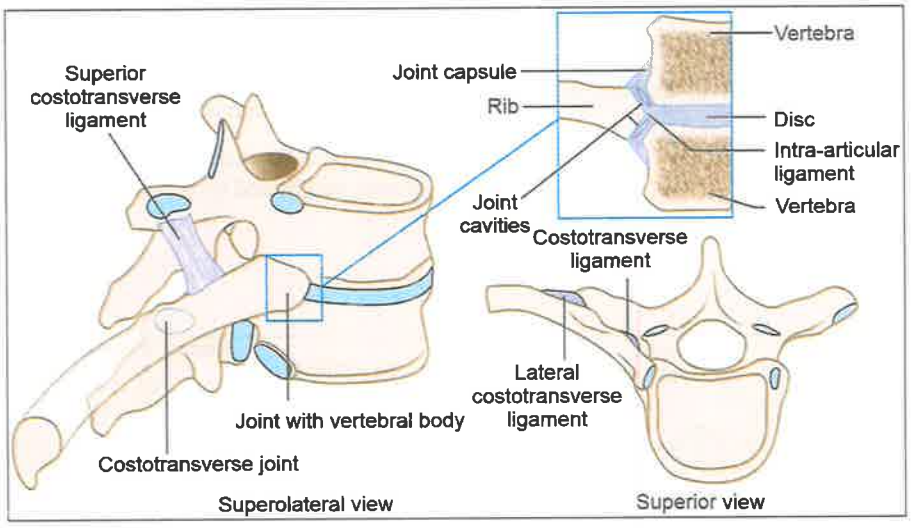
Transverse process:

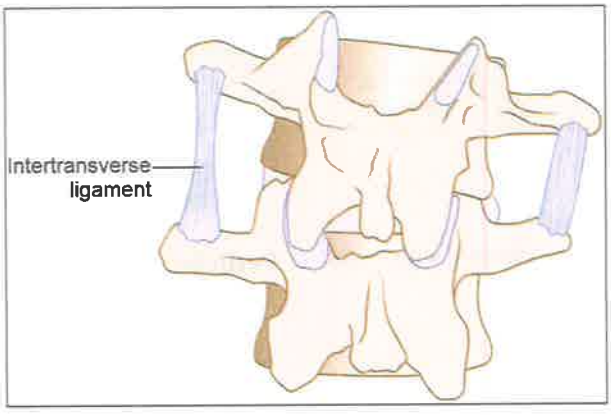
- Forms the costotransverse joint.
- T1–T10 have a costal facet on transverse process that articulates with tubercle of rib.

Spinous process:

- Long, points downward.
- Becomes level with body of vertebrae below.

Ligaments Anatomy





Radiate ligament:

- Attaches head of rib to bodies and disk.
- Reinforces costovertebral joint anteriorly.

1. Costotransverse ligament

Transverse process to neck of rib attachment

2. Superior costotransverse ligament:

Attaches rib to the transverse process of superior vertebrae.

3. Intratransverse ligament:

Fibrous strands that mix in the nearby back muscles and connect neighboring thoracic vertebrae.

4. Lateral costotransverse ligament:

Attaches transverse process to the tubercle of the rib.

Muscular anatomy

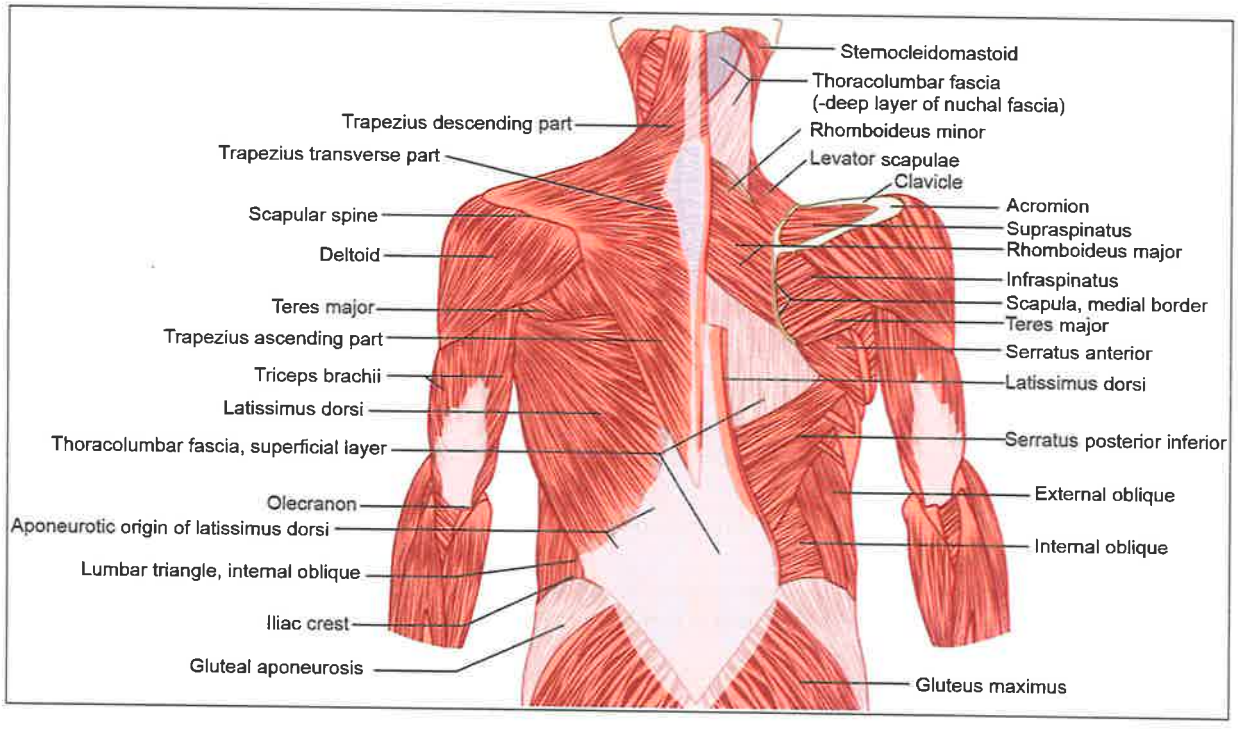


Table 1. Superficial layers of the back

Muscle	Origin	Insertion	Action	Innervation
Trapezius (upper, middle, and lower divisions)	Upper division: Medial one-third of superior nucahl line, external occipital protuberance, ligamentum nuchae, spinous processes of C7 Middle division: Spinous process of T1-T5 Lower division: Spinous process of T6-T12	Upper division: lateral one-third of clavicle and acromion process of scapula Middle division: superior border of spine of scapula Lower division: medial one-third of spine of scapula	Upper division: upward rotation of scapula and elevatio n of scapula Middle division: retraction of scapula Lower division: Upward rotation of scapula and depression of scapula	Cranial nerve XI C3-C4 dorsal rami (for proprioception)
Lattissimus dorsi	Spinous processes of T7-L5, lower three or four ribs, posterior one-third of iliac crest	Floor of intertubercular groove	Extension and internal (medial) rotation of arm	Thoracodorsal nerve (C7-C8)
Rhomboid major	Spinous processes of T2-T5	Medial border of scapula (inferior to spine of scapula)	Retraction, elevation, and rotation of scapula	Dorsla scapular nerve (C5)
Rhomboid minor	Inferior end of ligamentum nuchae, spinous processes of C7-T1	Medial border of scapula	Retraction, elevation, and rotation of scapula	Dorsal scapular nerve (C5)

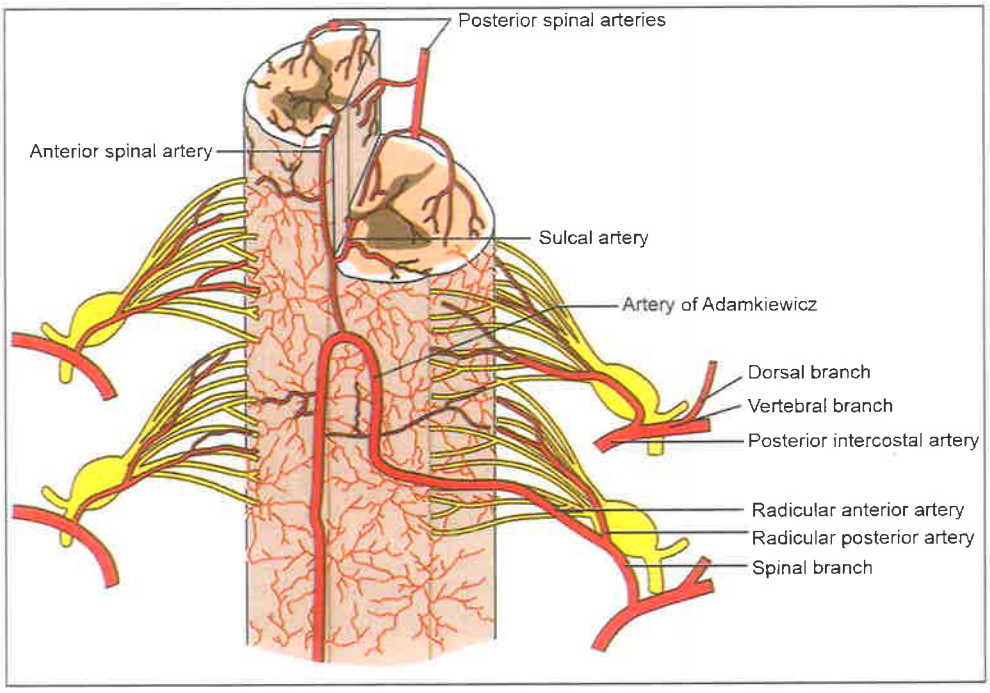
Table 2. Intermediate layers of the back

Muscle	Origin	Insertion	Action	Innervation
Serratus posterior superior	Ligamenum nucahe, spinous processes of C7-T3	Ribs 2-5 (lateral to angle of rib)	Elevation of upper libs	T1-T4 ventral rami
Serratus posterioinferior	Thoracolumbar fascia, spinous processes of T11-L2	Ribs 9-12 (lateral to the angle of rib)	Depression of lower ribs	T9-T12 ventral rami
Iliocostalis thoracis (erector spinae)	Superior borders of the angles of the lower six ribs	Angles of upper six or seven ribs and transverse process of C7	Extension and lateral flexion of trunk and neck	C4-S5 dorsal rami

Muscle	Origin	Insertion	Action	Innervation
Longissimus thoracis (erector spinae)	Transverse process and spinous process of lumbar vertebrae, sacrum, and iliac crest	Transverse process of T1-T12	Extension and lateral flexion of trunk and neck	C1-S1 dorsal rami
Spinalis thoracis (erector spinae)	Spinous process of T11-L3	Spinous processes of T3-T8	Extension and lateral flexion of trunk and neck	C2-L3 dorsal rami

Table 3. Deep layers of the back

Muscle	Origin	Insertion	Action	Innervation
Semispinalis thoracis	Transverse process of C7-T12	Semispinalis capitis: back of skull between nuchal lines; semispinalis cervicis and thoracis: spinous processes of four to six vertebrae above origin	Extension lateral flexion, and contralateral rotation of trunk	C1-T12 dorsal rami
Thoracic interspinales	Transverse process of vertebrae	Adajacent spinous process	Extension of spine	Dorsal rami of spinal nerves of region
Thoracic intertransversaarii	Transverse process of vertebrae	Adjacent transverse process	Assist with lateral flexion of spine	Dorsal rami of spinal nerves of region
Multifidus	Sacrum, ilium transverse procss of T1-T12, and articular processes of C4-C7	Spinous processes of superior vertebrae, spanning two to four segments	Stabilize vertebral column	Dorsal rami of spinal nerves of region



1. Anterior spinal artery:
   - Provides the thoracic cord's ventral two-thirds.
   - Comes from the area of the medulla oblongata where the vertebral artery arised

The anterior spinal artery continues below T4 as the anterior medial spinal artery.

2. Posterolateral spinal arteries:
   - Come from the arteries in the spine.
   - In the direction of the upper thoracic and lower cervical regions.

3. Posterior spinal arteries:

The posterolateral arterial plexus is made up of paired arteries that split off from the vertebral arteries at different levels. Provide the posterior third of the cord (the posterior part of the dorsal gray columns and the dorsal white columns).

5. Radicular arteries:

Originate at the level of the costotransverse joint from the