THE PERIPHERAL NERVOUS SYSTEM

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Part I. Overview of the Peripheral Nervous System

The peripheral nervous system consists of the sensory, motor, and autonomic neural elements outside of the brain and spinal cord.

The cell bodies for the **motor** components are in the anterior horn cells. Axons from the motor neurons in the spinal cord anterior horn traverse the nerve roots into peripheral nerves. The motor nerve communicates with the muscle at the neuromuscular junction, using acetylcholine (nicotinic receptor) as the neurotransmitter.

Sensory nerves are derived from neurons located within the dorsal root ganglion, just outside the neural foramina. Sensory receptors in the periphery include muscle spindles, Golgi tendon organs, Pacinian corpuscles, and Meissner's corpuscles.

There are eight pairs of cervical roots, twelve pairs of thoracic roots, five pairs of lumbar roots, five pairs of sacral roots and one coccygeal root. Cervical roots exit above the corresponding numbered vertebral body, whereas the thoracic, lumbar and sacral nerve roots exit below the corresponding numbered vertebral body.

Dorsal and ventral rootlets exit the cord and form dorsal and ventral roots, respectively. Roots traverse the intervertebral foramen and fuse just distal to the dorsal root ganglion to form the spinal nerves. The posterior primary rami, which innervate the skin and muscles of the dorsal aspect of the trunk, exit first. The remaining fibers continue as anterior primary rami.

The anterior primary rami from C5, C6, C7, C8, and T1 fuse to form the upper, middle, and lower trunks of the brachial plexus. The trunks in turn, divide into three anterior and three posterior divisions, which fuse to form the lateral, posterior and medial cords. Finally, the cords terminate in peripheral nerves, including the musculocutaneous, median, ulnar, radial, and axillary nerves, among others.

The lumbosacral plexus provides sensorimotor innervation to the lower extremity. It arises from the L1, L2, L3, L4, L5, S1, S2, S3, and S4 roots. This plexus is located in the retroperitoneum posterior to the psoas muscle. The anterior and posterior divisions of the L2, L3 and L4 roots form the obturator and femoral nerves, while the lower portions of the plexus contribute to the sciatic nerve. Around the popliteal fossa, the sciatic branches further into the common peroneal (fibular) nerve, the tibial nerve, and the sural nerve.

The *cauda equina* refers to the dorsal and ventral lumbar and sacral nerve roots that arise from the most caudal portion of the spinal cord. These paired radicular nerves descend in a bundle and branch off to exit through their appropriate foramen to provide motor and sensory innervation to the pelvis and lower extremities.

Each root corresponds to a myotome (muscle fibers subserved by the corresponding root) and a dermatome (the area of skin where sensation is subserved by the corresponding root).

The autonomic nervous system includes sympathetic and parasympathetic preganglionic axons, the ganglion cells, and postganglionic axons. The preganglionic **sympathetic** cell bodies are located in the intermediolateral cell column of the spinal cord between T1 and L2, and use acetylcholine (nicotinic receptor) as the neurotransmitter. The post-ganglionic sympathetic cell bodies are in the sympathetic chain ganglia outside the spinal cord, and attach to spinal nerves. These use norepinephrine as a neurotransmitter.

Outside of the brainstem, the preganglionic **parasympathetic** cell bodies are located in the intermediate gray of spinal cord segments S2-4. Acetylcholine (nicotinic receptor) is the neurotransmitter for preganglionic axons. The post-ganglionic cell bodies are located in the target organs, and use acetylcholine (muscarinic receptor) as the neurotransmitter.

Part 2: ~~All~~ Most of the Lesions

UPPER EXTREMITY ROOTS

Structure	**Principal Muscles Involved**	**Sensory distribution**	**Diminished Reflexes**
C5 Root	Rhomboids Supraspinatus Infraspinatus Deltoid Brachioradialis *Biceps*	Lateral upper arm	Biceps Brachioradialis
C6 Root	*Supraspinatus* *Infraspinatus* *Deltoid* Brachioradialis *Triceps* Flexor carpi radialis Extensor carpi radialis Pronator teres	Lateral forearm and hand, first two digits	Biceps Brachioradialis
C7 Root	Triceps Flexor carpi radialis Extensor carpi radialis Pronator teres Extensor digitorum Flexor digitorum Flexor pollicis longus	Middle forearm and third digit	Triceps
C8 Root	*Triceps* Extensor indicis Flexor pollicis longus Abductor pollicis brevis Interossei	Fourth and fifth digit and medial hand	*None*
T1 Root	Abductor pollicis brevis Interossei	Medial forearm	*None*

UPPER EXTREMITY PLEXUS

Structure	Principal Muscles Involved	Sensory distribution	Diminished Reflexes
Upper trunk	Supraspinatus Infraspinatus Deltoid Brachioradialis Biceps *Triceps* *Pronator teres* *Extensor carpi radialis* *Flexor carpi radialis*	Lateral upper arm and forearm, and first 1-2 digits.	Biceps Brachioradialis
Lower trunk	*Triceps* Extensor digitorum Extensor indicis Flexor digitorum Flexor pollicis longus Abductor pollicis brevis Interossei	Medial forearm and hand, fourth and fifth digits.	*None*
Lateral cord	Biceps Pronator teres Flexor carpi radialis Flexor digitorum Flexor pollicis longus	Lateral forearm, palmar hand and first three digits.	Biceps
Medial cord	Flexor digitorum Flexor pollicis longus Abductor pollicis brevis Interossei	Medial forearm and hand, fourth and fifth digits.	*None*
Posterior cord	Deltoid Brachioradialis Triceps Extensor carpi radialis Extensor digitorum Extensor indicis	Dorsal aspect of upper arm, forearm, lateral hand and the first three digits.	Triceps Brachioradialis

UPPER EXTREMITY NERVES

Structure	Principal Muscles Involved	Sensory distribution	Diminished Reflexes
Dorsal scapular	Rhomboids	*None*	*None*
Suprascapular	Supraspinatus Infraspinatus	*None*	*None*
Musculocutaneous	Biceps	Lateral forearm	Biceps
Axillary	Deltoid	Lateral shoulder	*None*
Radial Superficial sensory nerve at the wrist	*None*	Dorsal hand and first three digits.	*None*
Radial Posterior interosseous	Extensor digitorum Extensor indicis	*None*	*None*
Radial At the spiral groove	Brachioradialis Extensor carpi radialis Extensor digitorum Extensor indicis	Dorsal hand and first three digits.	Brachioradialis
Radial At the axilla	Triceps Brachioradialis Extensor carpi radialis Extensor digitorum Extensor indicis	Dorsal aspect of upper arm, forearm, lateral hand and the first three digits	Brachioradialis Triceps
Median Anterior interosseous	Flexor pollicis longus Flexor dig profund 1-2	*None*	*None*
Median At the carpal tunnel	Abductor pollicis brevis	Palmar digits 1-3	*None*
Median At the elbow	Pronator teres Flexor carpi radialis Flexor pollicis longus Flexor dig profund 1-2 Abductor pollicis brevis	Palmar hand and digits 1-3	*None*
Ulnar At the wrist	Interossei	Palmar aspect of fourth and fifth digits	*None*
Ulnar At the elbow	Interossei Flexor digit.profund 4-5	Medial hand, fourth and fifth digits	*None*

LOWER EXTREMITY ROOTS

Structure	Principal Muscles Involved	Sensory distribution	Diminished Reflexes
L2 Root	Iliopsoas Adductor longus	Anterior thigh	*None*
L3 Root	Iliopsoas Quadriceps Adductor longus	Medial thigh, knee	*None*
L4 Root	Quadriceps Adductor longus *Tibialis anterior*	Medial foreleg	Patellar
L5 Root	Gluteus medius *Hamstrings* Tibialis anterior Extensor digitorum Peroneus longus Tibialis posterior	Lateral foreleg, dorsal foot	*None*
S1 Root	Gluteus maximus Hamstrings Gastrocnemius *Peroneus longus* *Extensor digitorum* *Tibialis posterior*	Posteriori/lateral foreleg, plantar aspect of foot.	Ankle

LOWER EXTREMITY PLEXUS

Structure	Principal Muscles Involved	Sensory distribution	Diminished Reflexes
Lumbar plexus	Iliopsoas Quadriceps Adductor longus	Anterior thigh, medial and lateral thigh, medial foreleg	Patellar
Lower lumbosacral plexus	Gluteus medius Gluteus maximus Hamstrings Tibialis anterior Extensor digitorum Peroneus longus Tibialis posterior Gastrocnemius	Posterior thigh, lateral foreleg, all of foot	Ankle

LOWER EXTREMITY NERVES

Structure	Principal Muscles Involved	Sensory distribution	Diminished Reflexes
Femoral Above inguinal ligament	Iliopsoas Quadriceps	Medial thigh and foreleg	Patellar
Femoral Below inguinal ligament	Quadriceps	Medial thigh and foreleg	Patellar
Obturator	Adductor longus	Medial thigh	*None*
Sciatic	Hamstrings Tibialis anterior Extensor digitorum Peroneus longus Tibialis posterior Gastrocnemius	Lateral foreleg, all of foot	Ankle
Peroneal Deep	Tibialis anterior Extensor digitorum	First dorsal webspace	*None*
Peroneal Superficial	Peroneus longus	Lateral foreleg, dorsal aspect of foot	*None*
Peroneal Common	Tibialis anterior Extensor digitorum Peroneus longus	Lateral foreleg, dorsal aspect of foot	*None*
Tibial	Tibialis posterior Gastrocnemius	Plantar aspect of foot	Ankle

Part 3a:
Using the Motor Exam to Localize

Muscle	Action	When to test
Deltoid	Shoulder abduction	Screening exam
Biceps	Elbow flexion, palm up	Screening exam
Triceps	Elbow extension	Screening exam
Wrist extension	Extensor carpi radialis	Screening exam
Flexor carpi radialis	Wrist flexion	Screening exam
Extensor digitorum	Finger extension	Screening exam
Dorsal interossei	Finger abduction	Screening exam
Abductor pollicis brevis	Thumb abduction	Screening exam
Iliopsoas	Hip flexion	Screening exam
Quadriceps	Knee extension	Screening exam
Hamstrings	Knee extension	Screening exam
Tibialis anterior	Ankle dorsiflexion	Screening exam
Gastrocnemius	Ankle plantarflexion	Screening exam
Extensor hallucis longus	Great toe extension	Screening exam

Muscle	Action	Test when you suspect a lesion of what structure?
Rhomboids	Pressing the palm backwards from the small of the back	C5
Serratus anterior	Scapular fixation (look for scapular winging)	Long thoracic nerve (or FSH dystrophy)
Infraspinatus	Shoulder external rotation	C5, C6, upper trunk, suprascapular nerve
Brachioradialis	Elbow flexion with thumb up	Radial nerve
Pronator teres	Forearm pronation	C6, C7
Extensor indicis	Index finger extension	C8 or lower trunk
Flexor pollicis longus	Thumb flexion	Anterior interosseous nerve, proximal median nerve
Flexor digitorum profundus digits 4&5	Flexion of finger at DIP joint	Ulnar nerve (or inclusion body myositis)
Flexor digitorum profundus digits 2&3	Flexion of finger at DIP joint	Anterior interosseous nerve, proximal median nerve (or inclusion body myositis)
Gluteus medius	Hip abduction	L5, lumbosacral plexus
Adductor longus, magnus, gracilis	Hip adduction	L3, L4, lumbar plexus
Tibialis posterior	Ankle inversion	L5, lumbosacral plexus, sciatic nerve
Peroneus longus and brevis	Ankle eversion	L5, lumbosacral plexus, peroneal nerve

Part 3b:
Motor Testing in Common Clinical Scenarios

Finger drop

Weakness of finger extension could be caused by a posterior interosseous mononeuropathy, radial mononeuropathy at the spiral groove, radial neuropathy at the axilla, posterior cord plexopathy, or C7 radiculopathy. Testing three additional muscles can help distinguish among the possible localizations.

	Extensor digitorum	Brachioradialis	Triceps	Deltoid
Posterior interosseous	Weak			
Radial (spiral groove)	Weak	Weak		
Radial (Axilla)	Weak	Weak	Weak	
Posterior cord	Weak	Weak	Weak	Weak
C7	Weak		Weak	

Foot drop

Dorsiflexion weakness could suggest a deep peroneal mononeuropathy, common peroneal mononeuropathy, sciatic mononeuropathy, lumbosacral plexopathy, or L5 radiculopathy. Testing four additional muscles can help distinguish among the possible localizations.

	Tibialis anterior	Peroneus longus	Tibialis posterior	Gastrocnemius	Gluteus medius
Deep peroneal	Weak				
Common peroneal	Weak	Weak			
Sciatic nerve	Weak	Weak	Weak	Weak	
Lumbosacral plexus	Weak	Weak	Weak	Weak	Weak
L5 root	Weak	Weak	Weak		Weak

Interosseous Weakness
Weakness of finger abduction could suggest an ulnar mononeuropathy, medial cord plexopathy, lower trunk plexopathy, C8 radiculopathy, or T1 radiculopathy. Testing thumb abduction and index finger extension can narrow down the possible localizations significantly. There is no limb muscle that can be used to conclusively distinguish a lower trunk plexopathy from a C8 or T1 radiculopathy.

	Interossei	Abductor pollicis brevis	Extensor indicis
Ulnar (elbow)	Weak		
Medial cord plexus	Weak	Weak	
Lower trunk plexus	Weak	Weak	Weak
C8 or T1 root	Weak	Weak	Weak

Thumb weakness
Testing both thumb abduction and thumb flexion can be very helpful in localizing a lesion to the median nerve at the carpal tunnel, the anterior interosseous nerve, the proximal median nerve, or the C8 root. Including the interossei in the examination can help localize the lesion further.

	Abductor pollicis brevis	Flexor pollicis longus	Interossei
Median (carpal tunnel)	Weak		
Anterior interosseous		Weak	
Median (elbow)	Weak	Weak	
C8 root	Weak	Weak	Weak

Quadriceps weakness
Weakness of knee extension can be the result of several focal peripheral lesions, including a femoral mononeuropathy below or above the inguinal ligament, a lumbar plexopathy, an L3 radiculopathy, or an L4 radiculopathy. Testing hip flexion and adduction can narrow down this differential significantly. There is no limb muscle that can be used to conclusively distinguish an L3 radiculopathy from a lumbar plexopathy.

	Quadriceps	Iliopsoas	Adductor longus
Femoral (below inguinal ligament)	Weak		
Femoral (above inguinal ligament)	Weak	Weak	
Lumbar plexus	Weak	Weak	Weak
L3 Root	Weak	Weak	Weak
L4 Root	Weak		Weak