

RU RMT 16 — NEUROLOGY 2

Lecture 9

Neuroanatomy & Pathophysiology 2

Somatic Sensory & Somatic Motor Pathways

Ruhani College of Massage Therapy

Registered Massage Therapy Program



Learning Objectives

Aligned to CMTCA entry-to-practice competencies for safe, evidence-informed care

- Trace the three-neuron organization of the somatic sensory pathways and identify where each crosses the midline (decussation).
- Differentiate the dorsal column–medial lemniscus, spinothalamic, and trigeminothalamic pathways by the sensations they carry.
- Distinguish upper motor neurons (UMNs) from lower motor neurons (LMNs) and the direct vs. indirect motor pathways.
- Recognize the clinical signs of UMN vs. LMN lesions, including flaccid vs. spastic paralysis.
- Relate common neurological conditions (ALS, Parkinson's, Huntington's, Tourette) to their motor-pathway origins.
- **Apply this knowledge to massage assessment, treatment adaptation, contraindications, and appropriate referral within RMT scope of practice.**

Agenda

Part A — Somatic Sensory Pathways

- The three-neuron chain & decussation
- Dorsal column–medial lemniscus pathway
- Spinothalamic (anterolateral) pathway
- Trigeminothalamic pathway (face)
- Somatosensory mapping (homunculus)
- Spinocerebellar tracts (proprioception)
- Clinical application in RMT practice

Part B — Somatic Motor Pathways

- UMNs, LMNs & the four motor circuits
- Direct (pyramidal) pathways
- Indirect (extrapyramidal) pathways
- Motor mapping (homunculus)
- Paralysis: flaccid vs. spastic
- ALS & the basal nuclei disorders
- Parkinson, Huntington, Tourette
- RMT red flags & referral

PART A

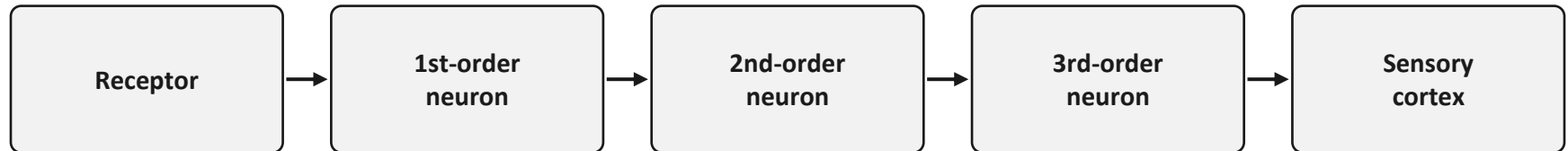
Somatic Sensory Pathways

From receptor → spinal cord / brainstem → thalamus → cerebral cortex



Somatic Sensory Pathways: The 3-Neuron Chain

Each pathway carries information from a sensory receptor to the cerebral cortex, most commonly across three neurons



- First-order neuron: carries the impulse from the receptor into the spinal cord or brainstem. Cell body sits in the dorsal root ganglion (body) or a cranial sensory ganglion (face).
- Second-order neuron: travels from the cord/brainstem to the thalamus. This is the neuron that decussates (crosses the midline) — so most left-body input reaches the right thalamus and vice-versa.
- Third-order neuron: relays from the thalamus to the primary somatosensory cortex on the same (ipsilateral) side as that thalamus.

Massage Therapy Relevance

- Because sensory input crosses over, a lesion above the crossover produces sensory changes on the opposite side of the body — a key idea when reasoning about stroke or spinal-cord findings a client reports.



First, Second & Third-Order Neurons

Neuron	Runs from → to	Cell body / key point
First-order	Receptor → spinal cord or brainstem	Dorsal root ganglion (spinal nerves) or cranial nerve ganglion (face, mouth, teeth, eyes)
Second-order	Spinal cord / brainstem → thalamus	Decussates to the contralateral side
Third-order	Thalamus → primary somatosensory cortex	Projects to the ipsilateral cortex

- Sensory input from the neck, trunk, limbs, and back of the head enters through spinal nerves.
- Sensory input from the face, mouth, teeth, and eyes enters through cranial nerves.

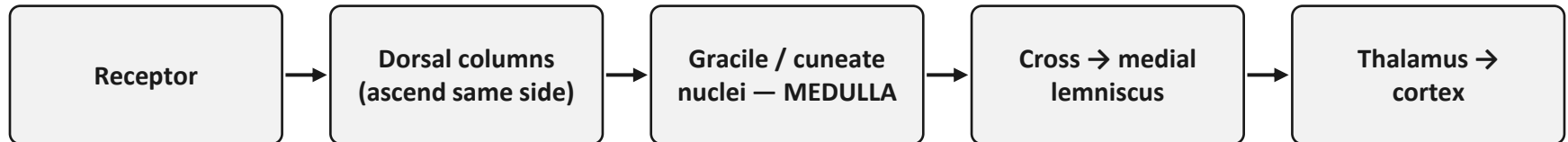
Massage Therapy Relevance

- Knowing which nerve type carries a region's sensation helps an RMT interpret altered sensation reported during assessment and decide whether it fits a peripheral nerve, a nerve root, or a central pattern.



Dorsal Column – Medial Lemniscus Pathway

Fine touch, pressure, vibration & conscious proprioception from the limbs, trunk & back of head



- First-order neurons ascend the dorsal (posterior) columns on the same side and synapse in the medulla.
- Gracile nucleus receives the lower limbs and lower trunk; cuneate nucleus receives the upper limbs, upper trunk, neck, and back of the head.
- Second-order axons form the medial lemniscus and cross to the opposite side within the medulla before reaching the thalamus.
- Third-order neurons carry the signal from the thalamus to the primary somatosensory cortex.

Massage Therapy Relevance

- This is the pathway for the proprioception and vibration sense an RMT relies on when assessing joint position, balance, and coordination. Loss here can mean unsteadiness with eyes closed — relevant to positioning and fall prevention.



Spinothalamic (Anterolateral) Pathway

Pain, temperature, itch & tickle from everywhere except the face



- First-order neurons (cell bodies in the dorsal root ganglia) enter the spinal cord and synapse onto second-order neurons.
- Second-order neurons cross to the contralateral side within the spinal cord, then ascend all the way to the thalamus.
- Third-order neurons carry the information from the thalamus to the cortex.
- **Key contrast: this pathway crosses in the spinal cord, whereas the dorsal-column pathway crosses in the medulla.**

Massage Therapy Relevance

- This carries the pain and temperature information central to massage: it explains why a client may feel heat or discomfort. Reduced pain/temperature perception is a safety concern for hydrotherapy and heat application.

A high-yield distinction for interpreting sensory findings

Feature	Dorsal Column–Medial Lemniscus	Spinothalamic (Anterolateral)
Sensations	Fine touch, pressure, vibration, proprioception	Pain, temperature, itch, tickle
Where it crosses	In the medulla	In the spinal cord (near entry)
Course in cord	Ascends the posterior (dorsal) columns	Ascends the anterolateral columns
Relay	Thalamus → sensory cortex	Thalamus → sensory cortex

Massage Therapy Relevance

- Because the two pathways cross at different levels, a cord lesion can knock out pain/temperature on one side while touch/proprioception is affected on the other. Any client describing patchy or side-specific numbness, tingling, or loss of temperature sense warrants documentation and referral rather than treatment alone.



Trigeminothalamic Pathway (The Face)

The trigeminal nerve (CN V) carries all somatic sensation from the face, oral cavity, nasal cavity & teeth



- First-order neurons carry touch, pain, temperature and related sensation to cell bodies in the trigeminal ganglion.
- Their axons run to the pons and descend to the medulla, where they synapse on second-order neurons.
- Second-order neurons decussate in the medulla, ascend, and synapse on third-order neurons in the thalamus.
- Third-order neurons reach the somatosensory cortex in the hemisphere opposite the stimulus.

Massage Therapy Relevance

- Facial or head/neck massage engages CN V territory. Altered facial sensation, facial pain, or numbness is a clinically significant finding — assess carefully and refer, as it can reflect trigeminal or central involvement.



Somatosensory Mapping (Homunculus)

The primary somatosensory cortex is organized by body region

- Specific areas of cortex receive input from specific body parts, forming an orderly “map” of the body.
- More cortex devoted to a region = greater sensitivity. Hands, lips, and face occupy disproportionately large areas.
- Each somatosensory cortex receives input from the contralateral (opposite) side of the body.

Massage Therapy Relevance

- The dense representation of the hands and face explains why these areas are highly sensitive to touch, pressure, and temperature — pressure that feels moderate on the back may feel intense on the hands or face.
- Highly innervated regions give clearer feedback during palpation but also require more careful pressure grading and communication.
- Contralateral organization means a client with cortical injury on one side may show sensory changes on the opposite side of the body.



Sensory Pathways to the Cerebellum

Proprioceptive information that never reaches consciousness

- Two spinocerebellar tracts — anterior and posterior — carry proprioceptive information from muscles and tendons (e.g., Golgi tendon organs) up to the cerebellum.
- We do not consciously perceive this information; the cerebellum uses it in the background to coordinate balance, posture, and complex movement.

Massage Therapy Relevance

- This unconscious proprioceptive stream underlies the coordination and balance an RMT observes during gait and postural assessment.
- Massage that stimulates muscle and tendon receptors feeds this system; techniques affecting proprioception may influence a client's sense of body position and muscle tone.
- Poor coordination or balance may signal cerebellar or proprioceptive-pathway involvement — note it, adapt positioning, and refer where appropriate.



Sensory Pathways in RMT Practice

Why sensory anatomy matters at the treatment table

Pathway	Carries	Practical implication
Dorsal column	Touch, vibration, proprioception	Balance & joint-position awareness; fall/positioning safety
Spinothalamic	Pain & temperature	Reduced sensation → caution with heat/hydrotherapy; check skin
Trigeminothalamic	Face & head sensation	Facial numbness/pain is a red flag — refer

- RMTs assess sensation and function; they do not diagnose. Document changes objectively and refer when findings are new, progressive, or unexplained.

PART B

Somatic Motor Pathways

From the cortex → lower motor neuron → skeletal muscle



Upper vs. Lower Motor Neurons

The two-neuron organization that delivers every voluntary command to muscle

	Upper Motor Neuron (UMN)	Lower Motor Neuron (LMN)
Location	Primary motor cortex (precentral gyrus)	Ventral grey horn of spinal cord; brainstem nuclei for cranial nerves
Connects to	Lower motor neurons only — stays within the CNS	Effector organs (e.g., skeletal muscle) — exits the CNS
Role	Sends excitatory & inhibitory signals that regulate LMN firing, tone, balance, posture	Directly triggers muscle contraction

- Brainstem LMNs drive cranial-nerve muscles of the face, tongue, eyes, and head; spinal LMNs drive the limbs and trunk.



Four Circuits that Command the LMNs

Motor output is shaped by four interacting systems before it reaches muscle

1. Local circuit neurons

Interneurons near the LMNs in cord/brainstem. Receive sensory input (nociceptors, proprioceptors) to fine-tune and coordinate muscle activity — the basis of reflexes.

2. Upper motor neurons

In the primary motor cortex; send signals down to LMNs. Regulate voluntary movement, muscle tone, balance, and posture.

3. Basal nuclei (ganglia)

Give input to UMNs: help initiate & terminate movement, suppress unwanted movement, and set muscle tone.

4. Cerebellum

Aids/alters UMN output; key for accurate movement (error reduction) and for coordinating normal posture and balance.



Direct (Pyramidal) Pathways

UMN axons that synapse directly onto LMNs — named for the pyramidal cells of the motor cortex

- Direct and indirect pathways work together at all times to control skeletal muscle.
- **The three direct (pyramidal) pathways are:**
 - Lateral corticospinal tract
 - Anterior corticospinal tract
 - Corticobulbar tract
- Corticospinal axons form bulges called the pyramids on the medulla. About 90% of fibres decussate just below the pyramids (the “decussation of the pyramids”).
- **After crossing, axons synapse on LMNs in the spinal cord and control the contralateral side — e.g., the right motor cortex controls the left limbs and trunk.**



Lateral vs. Anterior Corticospinal Tracts

Feature	Lateral corticospinal	Anterior corticospinal
Where it crosses	Decussates in the medulla, then descends in the lateral cord	Descends uncrossed in the anterior cord, then crosses at the target spinal level
Synapses	Interneurons / LMNs in the ventral grey horn	Interneurons / LMNs in the ventral grey horn
Controls	Distal limbs — precise, agile, highly skilled movement	Trunk & proximal limbs

Massage Therapy Relevance

- The lateral tract governs fine hand and distal-limb control an RMT observes in grip and dexterity; the anterior tract governs the trunk and proximal stability that underlies posture. Loss of fine distal control vs. proximal/postural control points to different levels of involvement.



Corticobulbar Pathway (Muscles of the Head)

UMN axons from the motor cortex to the cranial-nerve motor nuclei in the brainstem

Cranial nerve	Motor function
Oculomotor (III), Trochlear (IV), Abducens (VI)	Eye movement
Trigeminal (V)	Mastication (chewing)
Facial (VII)	Facial movement, salivation
Glossopharyngeal (IX)	Swallowing, salivation
Vagus (X)	Speech, swallowing, lifting the palate
Accessory (XI)	Neck movement (trapezius, SCM)
Hypoglossal (XII)	Tongue movement



Indirect (Extrapyramidal) Pathways

All motor tracts other than the corticospinal & corticobulbar; UMN cell bodies sit in the brainstem

Tract	Origin	Main role
Rubrospinal	Red nucleus (midbrain)	Influences flexor muscle tone / movement of the upper limbs
Tectospinal	Tectum (midbrain)	Eye & head (postural) movements in response to visual stimuli
Vestibulospinal	Vestibular nuclei (brainstem)	Balance and posture
Reticulospinal	Reticular formation (brainstem)	Wakefulness; balance & posture to a lesser extent

Massage Therapy Relevance

- These pathways set the postural tone and balance an RMT works with constantly. They help explain baseline muscle tone and the automatic postural adjustments seen during treatment and gait.



Mapping the Motor Area

The primary motor cortex is organized like the sensory cortex

- The precentral gyrus (primary motor cortex) initiates all voluntary movement.
- The premotor area is an association area for more complex movement patterns, understanding movement, and integrative planning.
- **The more cortex dedicated to a body part, the finer the control of that part — hands and face have the largest motor representation, allowing complex, delicate movements.**

Massage Therapy Relevance

- The large motor representation of the hands mirrors the fine control clients need for daily tasks; deficits here are functionally significant.
- Because motor control is contralateral, one-sided weakness of the face, arm, or leg is an important pattern to recognize and refer (e.g., possible stroke).



Paralysis: Flaccid vs. Spastic

Loss of muscle function, sometimes with sensory loss — the pattern tells you where the lesion is

	Flaccid paralysis	Spastic paralysis
Cause	Damage/disease of LMNs	Damage to UMNs (loss of inhibitory signal to LMNs)
Muscle tone	Decreased or lost — muscle is limp/flaccid	Increased — hypertonic, stiff
Reflexes	Decreased or absent	Heightened; may show a positive Babinski sign
Movement	Reduced or lost voluntary movement	Weak, poorly controlled, hyperreflexic

Massage Therapy Relevance

- Flaccid (LMN) presentations benefit from massage that supports circulation and helps prevent contracture; spastic (UMN) presentations may benefit from tone-management approaches — but heightened reflexes and a positive Babinski sign are referral-level findings.



UMN vs. LMN Signs: RMT Assessment

Recognizing the pattern guides safe treatment and timely referral

Sign	UMN lesion	LMN lesion
Tone	Increased (spasticity)	Decreased (flaccid)
Reflexes	Hyperreflexia; positive Babinski	Hyporeflexia / absent
Muscle bulk	Preserved (disuse only)	Atrophy
Strength	Weakness, impaired fine control	Weakness, limpness

Referral / Red Flags

- Refer (do not treat in isolation) when you note: new or progressive weakness, spreading numbness, a positive Babinski sign, sudden one-sided facial/limb weakness, or loss of bowel/bladder control. RMTs assess and refer — they do not diagnose.



Amyotrophic Lateral Sclerosis (ALS)

Progressive degeneration of motor neurons — UMNs, LMNs, and brainstem motor nuclei

- Progressive degeneration of: LMNs of the ventral grey horn, UMNs of the cerebrum, and motor nuclei in the brainstem.
- **Because both UMNs and LMNs are affected, presentations vary and often mix signs:**
 - UMN component: muscle weakness, spasticity, hyperreflexia, impaired fine motor control.
 - LMN component: muscle weakness, limpness, atrophy, hyporeflexia.
- Most commonly begins in a single limb and spreads; becomes life-threatening when it reaches the muscles of respiration or the cranial nerves.
- There is currently no cure, and the cause is not fully understood.

Massage Therapy Relevance

- Massage is supportive/palliative: comfort, circulation, relief of muscle tension, and reduced anxiety. Avoid fatiguing the client, adapt for weakness and respiratory involvement, and coordinate with the healthcare team.



Basal Nuclei (Basal Ganglia)

Grey-matter structures deep within the cerebrum that shape UMN output

- Functions include: helping initiate and terminate movement, suppressing unwanted movement, and influencing muscle tone (usually decreasing it).
- Also involved in attention, memory, and planning.
- Key components include the caudate nucleus, putamen, globus pallidus, and (in the midbrain) the substantia nigra.
- **Damage or disorders of the basal ganglia can have large effects on movement, cognition, and behaviour.**
Examples:
 - Parkinson's disease
 - Huntington's disease
 - Tourette syndrome



Parkinson's Disease

Progressive degeneration of the basal ganglia — chiefly the dopamine-producing substantia nigra

- Less available dopamine leads to resting tremor (oscillating flexion/extension of joints) that eases during movement and sleep; tremor usually starts unilaterally and becomes bilateral.
- Bradykinesia: slowness initiating and carrying out movements, plus difficulty stopping — makes walking and daily activities difficult.
- Rigidity, forward-tilted posture, reduced arm swing, and a shuffling gait with short steps.
- Reduced facial/emotional movement (mask-like face); can progress to cognitive and sleep problems, and to psychiatric issues and dementia.

Massage Therapy Relevance

- Massage may help reduce rigidity, ease muscle tension, improve comfort and ROM, and lower anxiety. Adapt for a stooped posture and fall risk, allow time for slow transfers, watch for postural (orthostatic) hypotension when changing positions, and remember the mask-like face can hide discomfort — check in verbally.



Huntington's Disease

A hereditary disorder of basal-ganglia neurons that modulate motor output

- Characterized by chronic progressive chorea (abnormal, involuntary movements), psychological changes, and dementia.
- Normally the basal ganglia suppress unwanted movement; when these neurons degenerate, that suppression is lost — producing the choreic movements.
- Can also lead to depression and antisocial behaviours.

Massage Therapy Relevance

- Massage can provide comfort and relaxation and ease muscle soreness that results from constant involuntary movement.
- Ensure safe, supported positioning given unpredictable movements; adapt pace and pressure to tolerance.
- Approach with sensitivity to mood and cognitive changes, and coordinate care with the client's healthcare team.



Tourette Syndrome

A basal-ganglia–related tic disorder

- Characterized by involuntary movements (motor tics) and involuntary sounds or words (vocal tics).
- Thought to arise from dysfunction of neural circuits between the basal ganglia and the prefrontal cortex.

Massage Therapy Relevance

- Stress and anxiety can worsen tics, so a calm, unhurried, non-judgmental environment matters.
- Massage may support general relaxation and stress reduction, which some clients find helpful.
- Do not draw attention to tics; adapt positioning and pacing so the client remains comfortable and in control throughout the session.



Key Takeaways for RMT Practice

- Sensory pathways are three-neuron chains; they decussate, so problems above the crossover show on the opposite side of the body.
- Dorsal columns = touch/vibration/proprioception (cross in medulla); spinothalamic = pain/temperature (cross in the cord). Reduced pain/temperature sense means extra caution with heat and hydrotherapy.
- Motor commands travel UMN → LMN. UMN lesions cause spastic paralysis with hyperreflexia (and Babinski); LMN lesions cause flaccid paralysis with atrophy and hyporeflexia.
- Basal-ganglia disorders (Parkinson's, Huntington's, Tourette) and ALS each change movement and tone in ways that require individualized, adapted treatment.
- **Within CMTCA scope: assess and document objectively, adapt treatment to the presentation, and refer for new, progressive, or red-flag neurological findings. RMTs do not diagnose.**



Review & References

- **Review questions:**

- Where does each of the three body sensory pathways cross the midline?
- Contrast the signs of a UMN lesion with those of an LMN lesion.
- Which basal-ganglia disorder involves the substantia nigra and dopamine? Which involves chorea?
- Name three neurological red flags that would prompt referral.

Suggested references

- Tortora & Derrickson, Principles of Anatomy & Physiology (nervous-system chapters).
- Marieb & Hoehn, Human Anatomy & Physiology.
- CMTCA / provincial college competency and scope-of-practice standards for RMTs.