



RU RMT 16 · NEUROLOGY 2

Neuroanatomy & Pathophysiology 2

Lecture 8

Cerebral Functional Organization & Somatic Sensation

Ruhani College of Massage Therapy

Massage Therapy Diploma Program · Prepared to CMTCA competency standards



Learning Objectives

On completion of this lecture, the student will be able to:

- Describe the functional organization of the cerebral cortex — sensory, motor, and association areas.
- Locate the primary somatosensory and primary motor cortices and explain the sensory and motor homunculus.
- Outline the four steps of sensation formation and the role of the first-order neuron.
- Classify sensory receptors by microscopic structure, location, and function.
- Differentiate rapidly and slowly adapting receptors and explain the clinical significance for treatment.
- Describe cutaneous (tactile), thermal, pain, and proprioceptive sensation and their receptors.
- Apply proprioceptor physiology (muscle spindle, Golgi tendon organ) to therapeutic technique.
- Relate pain physiology — fibre types, referred pain, threshold and tolerance — to assessment and scope of practice.

Cerebral Functional Organization

The cortex is organized into three broad categories of functional areas:

1

Sensory Areas

Receive sensory information from receptors and turn sensation into conscious perception.

2

Motor Areas

Control the execution of voluntary movement of specific muscles and muscle groups.

3

Association Areas

Perform complex integrative functions — complex movement, memory, emotion, and language.

- **Motor areas lie anterior** to the central sulcus (frontal lobe).
- **Sensory & association areas lie posterior** to it (parietal, occipital, temporal lobes).



Sensory Areas: Primary vs. Association

- **Primary sensory areas** are activated directly by sensory receptors in the periphery.
- **Sensory association areas** integrate and interpret those inputs into perception, recognition, and awareness.

General Sensory

- **Somatic:** everyday touch, pressure, vibration, heat/cold, pain, and proprioception (skin and muscle).
- **Visceral:** sensation from internal organs — mostly perceived as pain.

Special Sensory

- Vision
- Hearing and balance
- Taste (gustation)
- Smell (olfaction)

Primary Somatosensory Cortex

- **Location:** the postcentral gyrus of the parietal lobe (posterior to the central sulcus).
- **Function:** receives general sensations — touch, pressure, vibration, pain, and proprioception.
- **Contralateral & somatotopic:** each region maps to a specific body part (the sensory homunculus).
- **Cortical area reflects receptor density,** not body size — lips, tongue, hands, and fingertips occupy the most cortex.

MESSAGE THERAPY RELEVANCE

The hands and fingertips have the highest receptor density and the largest cortical representation — a physiological reason they are the therapist's most sensitive palpation tools, and why clients register touch most acutely there. Expect sensitivity to vary widely from region to region.



Somatosensory Association Area

- **Location:** situated posterior to the primary somatosensory area.
- **Input:** receives information from the primary somatosensory cortex and the thalamus.
- **Function:** interprets somatosensory stimuli — texture, shape, size, and orientation — and relates them to stored memory of past sensations (stereognosis).

MASSAGE THERAPY RELEVANCE

Integration here lets a client identify the quality and location of pressure and recognize objects by touch. When this area is damaged, a person may still feel touch but be unable to interpret it (astereognosis) — a useful distinction when a client reports that sensation "feels wrong" rather than absent.



Primary Motor Cortex

- **Location:** the precentral gyrus of the frontal lobe (anterior to the central sulcus).
- **Function:** each region controls voluntary contraction of specific muscles or muscle groups.
- **Contralateral & somatotopic:** organized as a motor homunculus.
- **More cortex is devoted** to muscles used in skilled, complex, or delicate movement — hands, face, tongue.

MASSAGE THERAPY RELEVANCE

Because motor control is contralateral, a lesion such as a stroke produces weakness or paralysis on the opposite side of the body. Understanding somatotopy helps the RMT interpret patterns of motor loss during assessment and set realistic, safe treatment goals.



Motor Association Areas

Premotor area

Immediately anterior to the primary motor cortex; governs learned motor activities of a complex and sequential nature (skilled movement patterns).

Broca's area

Left frontal lobe; controls the articulation (motor production) of speech, connecting to the primary motor areas for the larynx, pharynx, mouth, and respiration.

Frontal eye field

Controls voluntary scanning movements of the eyes.



General Association Area

- **Prefrontal cortex:** situated in the anterior portion of the frontal lobe.
- **Responsible for personality** — decision-making, problem-solving, judgment, planning, and emotional regulation.
- **Association tracts** of sub-cortical white matter connect association areas to each other and to the primary sensory and motor areas.

MASSAGE THERAPY RELEVANCE

Rapport, informed consent, and reliable feedback all depend on prefrontal function. After a frontal-lobe injury, changes in personality, judgment, or impulse control can affect a client's ability to participate in and consent to treatment — the RMT should adapt communication and confirm comfort throughout.

Speech Areas & Aphasia

Broca's area — Production

Left frontal lobe. Non-fluent ("Broca's") aphasia: the person understands speech and knows what they want to say, but cannot form words — speech is effortful and halting, both spoken and written.

Wernicke's area — Comprehension

Left temporal and parietal lobes; interprets the meaning of speech by recognizing spoken and written words. Fluent ("Wernicke's") aphasia: words are produced easily but do not make sense; comprehension is impaired.

MASSAGE THERAPY RELEVANCE

With post-stroke clients, adapt communication to the type of aphasia: allow extra time, use simple questions, confirm consent and comfort non-verbally (gestures, thumbs up/down, pointing to a pain scale), and never assume that difficulty with language equals reduced intelligence or cognitive decline.

Hemispheric Lateralization

- **Language is lateralized:** both Broca's and Wernicke's areas are in the left hemisphere in most people.
- **Largely symmetrical:** most of the brain is symmetrical, with some subtle differences between hemispheres.
- **Dominance:** generally both hemispheres perform most tasks, but one hemisphere can be "dominant" for a given function.

MASSAGE THERAPY RELEVANCE

Lateralization explains the pattern of deficits after a one-sided lesion. A left-hemisphere stroke, for example, tends to produce right-sided motor and sensory changes together with language difficulty — recognizing these patterns supports safe assessment and appropriate referral.



Brain Waves (EEG)

The electrical impulses of the brain can be measured with an electroencephalogram (EEG).

Wave	State
Beta	Alert; increased activity of the nervous system
Alpha	Awake but relaxed / at rest — normal resting rhythm
Theta	Drowsy
Delta	Deep sleep; when abnormal, may signify brain damage

MESSAGE THERAPY RELEVANCE

The relaxation response commonly reported during massage is associated with a shift toward calmer, alpha-type activity and increased parasympathetic tone. This provides physiological support for stress-reduction and relaxation as legitimate, measurable treatment outcomes.



Sensation, Perception & Modalities

- **Sensation:** conscious or subconscious awareness of changes in the external or internal environment; may be processed at the spinal cord, brainstem, or cerebral cortex.
- **Perception:** the conscious awareness and interpretation of sensations — primarily a function of the cerebral cortex.
- **Sensory modality:** each unique type of sensation. A given receptor is almost always tuned to a single modality.

Somatic modalities covered in this lecture:

- **Tactile** — touch, pressure, vibration, itch, tickle
- **Thermal** — hot and cold
- **Pain** — somatic and visceral
- **Proprioception** — position and movement of body parts in space

Sensation Formation: Four Steps

1

Stimulation of the sensory receptor

An adequate stimulus is applied within the receptive field, usually at the dendrites of the receptor.

2

Transduction of the stimulus

The stimulus is converted into an electrical graded potential.

3

Generation of a nerve impulse

The graded potential reaches threshold and triggers action potentials that propagate toward the CNS along the first-order neuron.

4

Integration of sensory input

The appropriate part of the CNS receives the information and interprets it.



Classification by Microscopic Structure

Free nerve endings

Bare dendrites NOT covered by any connective tissue. Include receptors for pain, temperature, and some touch, itch, and tickle sensations.

Encapsulated receptors

The dendrites are enclosed in connective-tissue capsules. Different capsules change the sensitivity or specificity of the receptor — e.g., for pressure and vibration.

MASSAGE THERAPY RELEVANCE

Because different strokes engage different receptors, technique can be selected for a purpose: light effleurage and gentle contact for superficial free-nerve and touch receptors; deep, gliding, or vibratory work and tapotement for encapsulated pressure and vibration receptors.

Classification by Location

Exteroceptors

At or near the external body surface.
Provide information about the external environment: touch, pressure, vibration, temperature, pain, and the special senses.

Interoceptors

"Visceroceptors" in blood vessels and organs; monitor the internal environment. Usually not consciously perceived, but strong stimuli are felt as pain or pressure.

Proprioceptors

In muscles, tendons, joints, and the inner ear. Provide information about body position, muscle length and tension, and joint position and movement.

Massage works primarily through exteroceptors of the skin and proprioceptors of muscle, tendon, and joint.



Classification by Function (Stimulus)

- **Mechanoreceptors** — respond to deformation, stretch, or bending: touch, pressure, vibration, proprioception, hearing and equilibrium; also monitor stretch of blood vessels and organs.
- **Thermoreceptors** — detect changes in temperature.
- **Nociceptors** — respond to painful stimuli when tissue is damaged physically or chemically.
- **Photoreceptors** — detect light hitting the retina.
- **Chemoreceptors** — detect chemicals in the mouth (taste), nose (smell), and body fluids (e.g., blood).
- **Osmoreceptors** — detect the osmotic pressure of body fluids.

MASSAGE THERAPY RELEVANCE

Manual therapy acts mainly on mechanoreceptors; hydrotherapy adds thermoreceptor input (hot/cold); and both can modulate nociceptor activity — the three receptor classes most relevant to massage practice.



Sensory Adaptation

- **Adaptation:** the response of a receptor decreases during a sustained, constant stimulation.

Rapidly adapting

Quickly reduce firing to a constant stimulus. Related to pressure, touch, and smell (e.g., Meissner and Pacinian corpuscles).

Slowly adapting

Reduce firing slowly and keep firing as long as the stimulus is present. Monitor sustained pressure, stretch, pain, and blood chemistry (e.g., Merkel, Ruffini, nociceptors).

MASSAGE THERAPY RELEVANCE

Rapidly adapting receptors explain why a static hold seems to "fade" and why clients acclimate to a given pressure. The therapist maintains sensory input by varying depth, rhythm, and direction of movement; a sustained, unchanging hold, by contrast, is used deliberately to let tissue and receptors settle so deeper work is tolerated.



Cutaneous (Tactile) Receptors

Receptor	Location	Senses	Adaptation
Meissner's corpuscle	Dermis of hairless (glabrous) skin — fingertips, palms, lips, tongue tip	Light touch	Rapid
Merkel disc	Base of epidermis / dermis — hands, fingertips, lips	Sustained touch, edges, texture	Slow
Ruffini ending	Deep in the dermis (encapsulated)	Skin stretch and pressure	Very slow
Pacinian corpuscle	Deep dermis / subcutaneous — fingertips	Deep pressure and vibration	Rapid

MASSAGE THERAPY RELEVANCE

Matching technique to receptor helps target the intended response: light gliding strokes recruit Meissner and Merkel receptors; sustained skin/fascial stretch engages Ruffini endings; deep pressure and vibration or tapotement activate Pacinian corpuscles. The dense receptor supply of the hands also makes them the therapist's primary assessment instrument.



Primary Afferent Nerve Fibre Types

Type	Diameter	Myelin	Speed	Carries
A-alpha (A α)	13–20 μ m	Myelinated	80–120 m/s	Proprioception, motor
A-beta (A β)	6–12 μ m	Myelinated	35–75 m/s	Touch, pressure, vibration
A-delta (A δ)	1–5 μ m	Thinly myelinated	5–35 m/s	Fast, sharp pain; cold
C	0.2–1.5 μ m	Unmyelinated	0.5–2 m/s	Slow, aching pain; warmth

MASSAGE THERAPY RELEVANCE

Gate control theory: input from large, fast touch and pressure fibres (A β) can inhibit slow pain signals carried by C fibres at the dorsal horn of the spinal cord. This is a key physiological rationale for why massaging, rubbing, or applying pressure to a painful area can reduce the perception of pain.



Thermal Sensation

- **Thermoreceptors are free nerve endings.**
- **Cold receptors:** located in the epidermis; related to medium- and small-diameter fibres; more numerous than warm receptors.
- **Warm receptors:** located in the dermis; related to small, unmyelinated C fibres; less abundant.
- **Temperature extremes** — below $\sim 10^{\circ}\text{C}$ and above $\sim 48^{\circ}\text{C}$ — stimulate pain receptors (nociceptors).

MASSAGE THERAPY RELEVANCE

Thermal physiology underpins hydrotherapy. Hot and cold applications drive thermoreceptor input to influence circulation, tone, and pain. Because thermoreceptors adapt, re-check the client's comfort during an application, and stay clear of temperature extremes that would cross into nociceptor (pain and tissue-damage) territory.



Pain Sensation: Nociceptors

- **Vital and protective:** signals the presence of dangerous conditions or damaged/dying tissue in the body.

Fast pain

Perceived very rapidly — within about 0.1 second of the stimulus, travelling on myelinated A δ fibres. Pain is sharp, well localized, and acute.

Slow pain

Perceived more slowly — within about 1 second, on unmyelinated C fibres. Pain is aching, diffuse, throbbing, and chronic.

MASSAGE THERAPY RELEVANCE

The client's own words often map onto these fibre types: sharp, localized pain (fast, A δ) versus dull, diffuse, aching pain (slow, C). Chronic aching pain — a common presentation in practice — is typically C-fibre in nature. Listening for these descriptors helps characterize and document a client's pain.



Referred Pain

- **Definition:** visceral pain perceived as somatic pain — felt in the skin or region surrounding, or distant from, the affected organ.
- **Mechanism:** the organ and the skin region share neural supply from the same spinal cord segment (convergence).

Common referral patterns:

- **Heart** → left arm, jaw, chest
- **Lung / diaphragm** → neck and shoulder region
- **Liver / gallbladder** → right shoulder and scapula
- **Kidney / ureter** → flank and low back

MASSAGE THERAPY RELEVANCE

Pain location is not always the source. Recognizing red-flag referral patterns is essential: it guides assessment and, critically, tells the RMT when symptoms may be non-musculoskeletal and require referral to a physician — a core scope-of-practice and duty-to-refer responsibility.



Pain Threshold, Tolerance & Analgesia

- **Pain threshold:** the smallest stimulus at which a person perceives pain — very similar across all people.
- **Pain tolerance:** the greatest intensity of pain a person can endure — varies widely, influenced by factors such as sex and social support (not fully understood).
- **Analgesia:** blocks the perception of pain without removing its cause. Lidocaine, for example, blocks ion channels on nociceptors so they cannot produce action potentials.

MASSAGE THERAPY RELEVANCE

Work within the client's tolerance — not to a fixed number — because tolerance is individual and subjective. A "no pain, no gain" approach is inappropriate and unsafe. Use ongoing client feedback and pain scales to guide pressure and depth, and document the client's reported pain rather than the therapist's assumption.



Proprioceptors

Provide the location of the body in space and judge object weight and the muscular effort a task requires.

Muscle spindles

In the belly of skeletal muscle; detect changes in muscle length (stretch). Drive the stretch reflex and help maintain muscle tone.

Golgi tendon organs (GTO)

In tendons next to the muscle belly; monitor tension in the tendon and muscle. Trigger the GTO reflex — autogenic inhibition, in which the muscle relaxes.

Joint kinesthetic receptors

Around the capsule of synovial joints; respond to acceleration and deceleration of the joint during movement.

MASSAGE THERAPY RELEVANCE

Proprioceptors underpin stretching technique. Slow, gradual stretch avoids triggering the muscle-spindle stretch reflex, while sustained tension recruits the GTO to produce autogenic inhibition — the basis of muscle energy technique (MET), PNF, and static stretching used to reduce tone. Massage also supports proprioceptive and postural retraining.

Phantom Limb

- **After amputation**, a person may still perceive that the limb is in its normal place — attached and moving.
- **They may experience** itch, pain, pressure, or tingling as if the limb were still present.
- **Mechanism:** the cortical representation of the limb (in the homunculus) persists and reorganizes after the limb is gone.
- **Mirror therapy** can sometimes help relieve phantom limb pain.

MASSAGE THERAPY RELEVANCE

Validate the client's experience — phantom sensations are real and neurologically based, not imagined. Awareness of residual-limb care and mirror-based approaches supports compassionate, informed treatment and appropriate collaboration with the client's healthcare team.



Clinical Integration for RMT Practice

- **Somatotopy (homunculus)** — interpret patterns of sensory and motor loss during assessment.
- **Receptor variety** — match the stroke (light, deep, vibration, stretch) to the intended receptor and response.
- **Adaptation** — vary pressure and rhythm to sustain input; use deliberate sustained holds to settle tissue.
- **Fibre types & gate control** — touch and pressure can modulate pain ($A\beta$ inhibits C-fibre pain).
- **Proprioceptors** — the foundation of stretching technique — spindle stretch reflex vs. GTO inhibition.
- **Referred pain & red flags** — assess the true source; refer out when symptoms suggest non-musculoskeletal origin.
- **Communication & consent** — adapt for aphasia; respect the client's subjective pain and individual tolerance.



Review Questions

- Name the gyrus and lobe of the primary somatosensory cortex, and list the general sensations it receives.
- Why do the hands and lips occupy such large areas on the sensory and motor homunculus?
- List the four steps of sensation formation in order.
- Differentiate rapidly and slowly adapting receptors, and give one implication for treatment.
- Match Meissner, Merkel, Ruffini, and Pacinian receptors to their modality and rate of adaptation.
- Explain the Golgi tendon organ reflex and how it underlies muscle energy technique.
- Define referred pain and give one red-flag example relevant to RMT scope of practice.
- Differentiate pain threshold from pain tolerance.