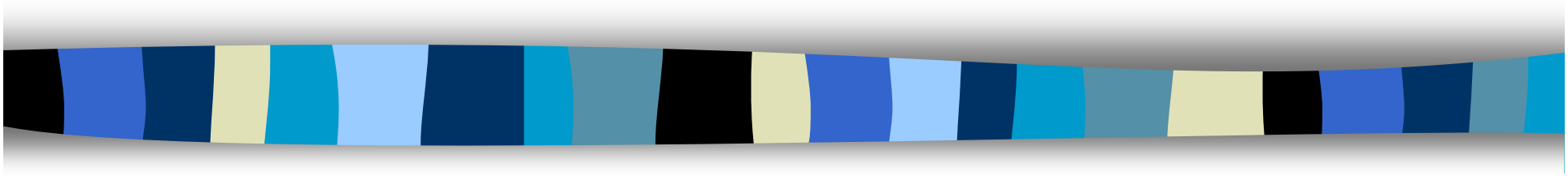
Neurological Representation of Swallowing



Patti Bailey

April 2004

Swallowing

- Complex sensorimotor activity
- Involving organized interactions between cortical, cerebellar, bulbar, and peripheral systems

Research

- Several types:
  - Electrical muscle/neuron stimulation
  - Functional imaging studies (fMRI, PET)
  - Lesion studies

Objectives:

- Review cranial nerves important for mechanical swallow
- Cranial nerve nuclei & pathways
- Brainstem
- Cortex
- Cerebellum

Cranial Nerves

(Highlighted nerves involved in mechanical swallow)

I – Olfactory	**VII - Facial**
II – Optic	VIII - Auditoryvestibular
III – Oculomotor	**IX - Glossopharyngeal**
IV - Trochlear	**X - Vagus**
V - Trigeminal	**XI – Spinal Accessory**
VI -Abducens	**XII - Hypoglossal**

Cranial Nerves – Peripheral Nervous System

- Can be motor (lower motor neurons), sensory, or both
- Can also contain special sensory (i.e., taste) or special motor components (i.e., salivary glands)
- Sensory nerves provide information on :
  - Touch
  - Temperature
  - Pain
  - Proprioception

V – Trigeminal Nerve

- Motor + Sensory
- Innervates muscles of mastication
- Sensory nerve of the face and neck

V - Trigeminal Nerve

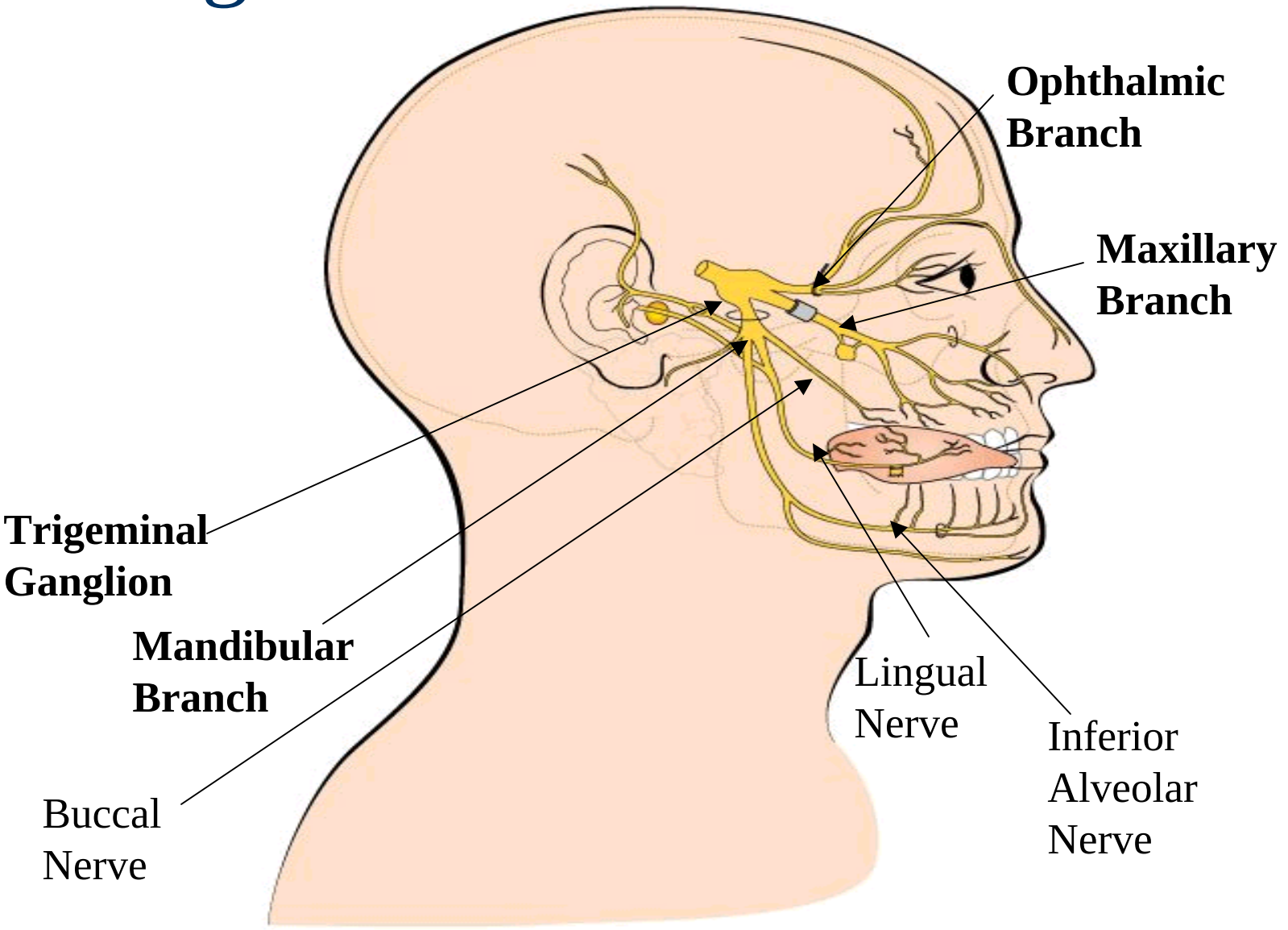
- 3 Branches
  - Ophthalmic (sensory): not involved in swallow
  - Maxillary (sensory): upper lip, maxillary teeth and palate, small area of pharynx
  - Mandibular (sensory + motor)

Note: Several other CN branches hitchhike along V, including parts of VII (visceral motor nerves including salivary glands) and IX

V- Mandibular Branch

- Sensory:
  - Anterior 2/3 of tongue (but not taste)
  - Mucous membranes of mouth & buccal walls,
  - Gums and mandibular teeth
  - Temporomandibular joint
- Motor:
  - Mastication muscles: temporalis, masseter, pterygoids
  - Tensor muscles: tensor veli palatini (velar tensor)
  - Suprahyoid muscles– mylohyoid & anterior belly of digastric muscle

V - Trigeminal Nerve



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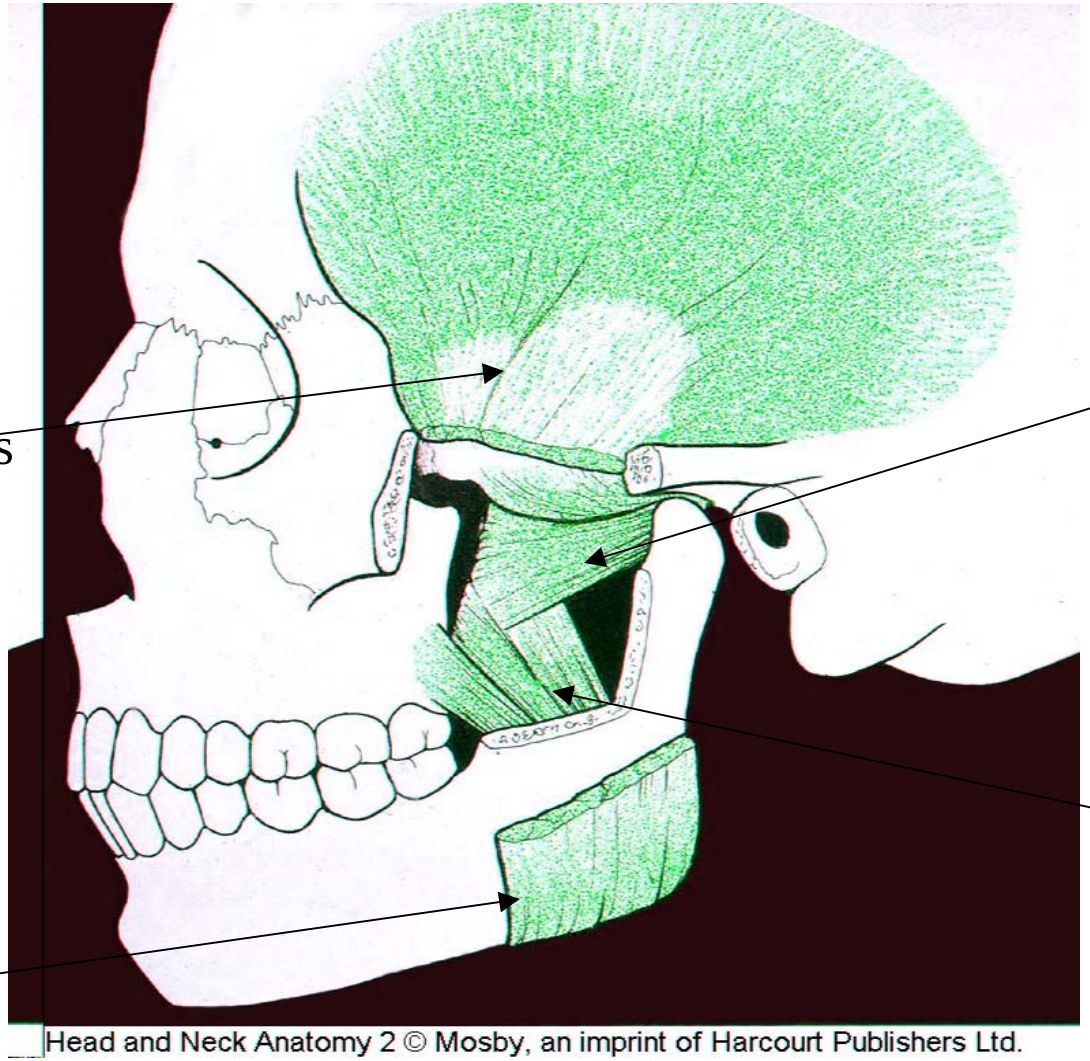
Mastication Muscles



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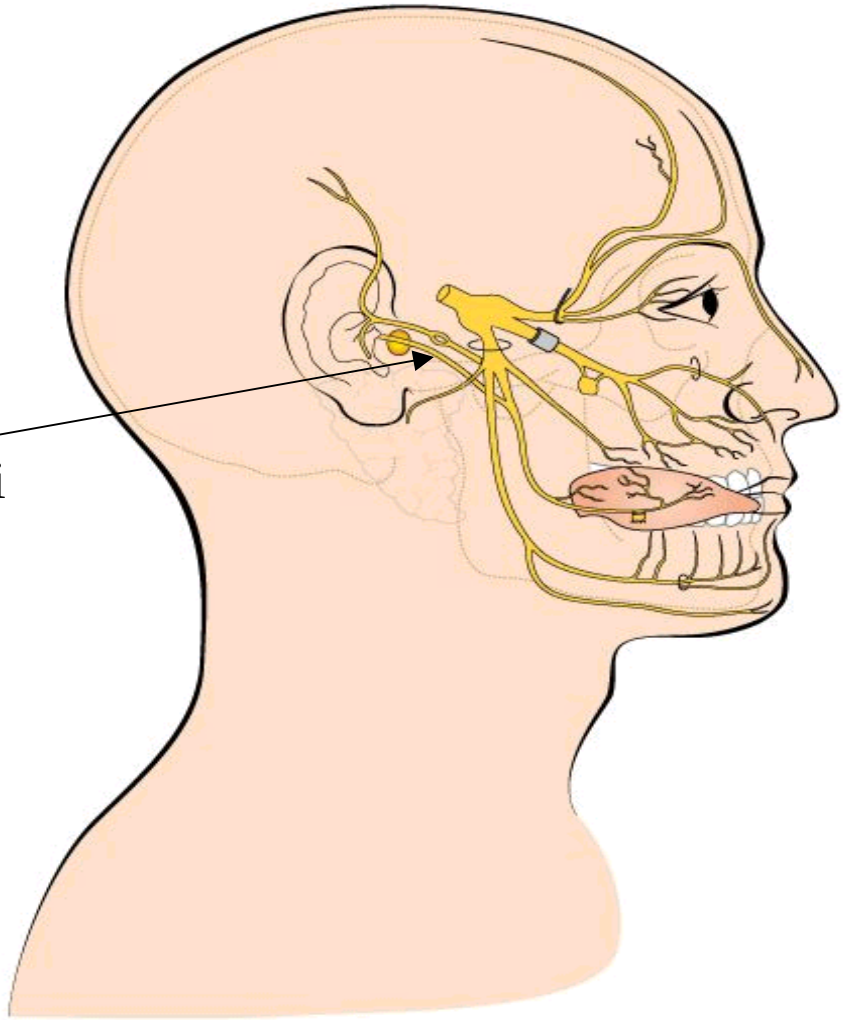
VII – Facial Nerve

- Whereas V is the sensory nerve of the face and neck, VII is the motor nerve of the face and neck.
- Sensory + Motor Components
- Innervates superficial face and neck muscles
- Contains special sensory and visceral motor components

VII – Facial Nerve Sensory Branches

- Special Sensory
  - Chorda Tympani: taste for anterior 2/3 of tongue & other sensory for hard/soft palate
- General Sensory:
  - not involved in swallow

VII – Facial Nerve Sensory Branches



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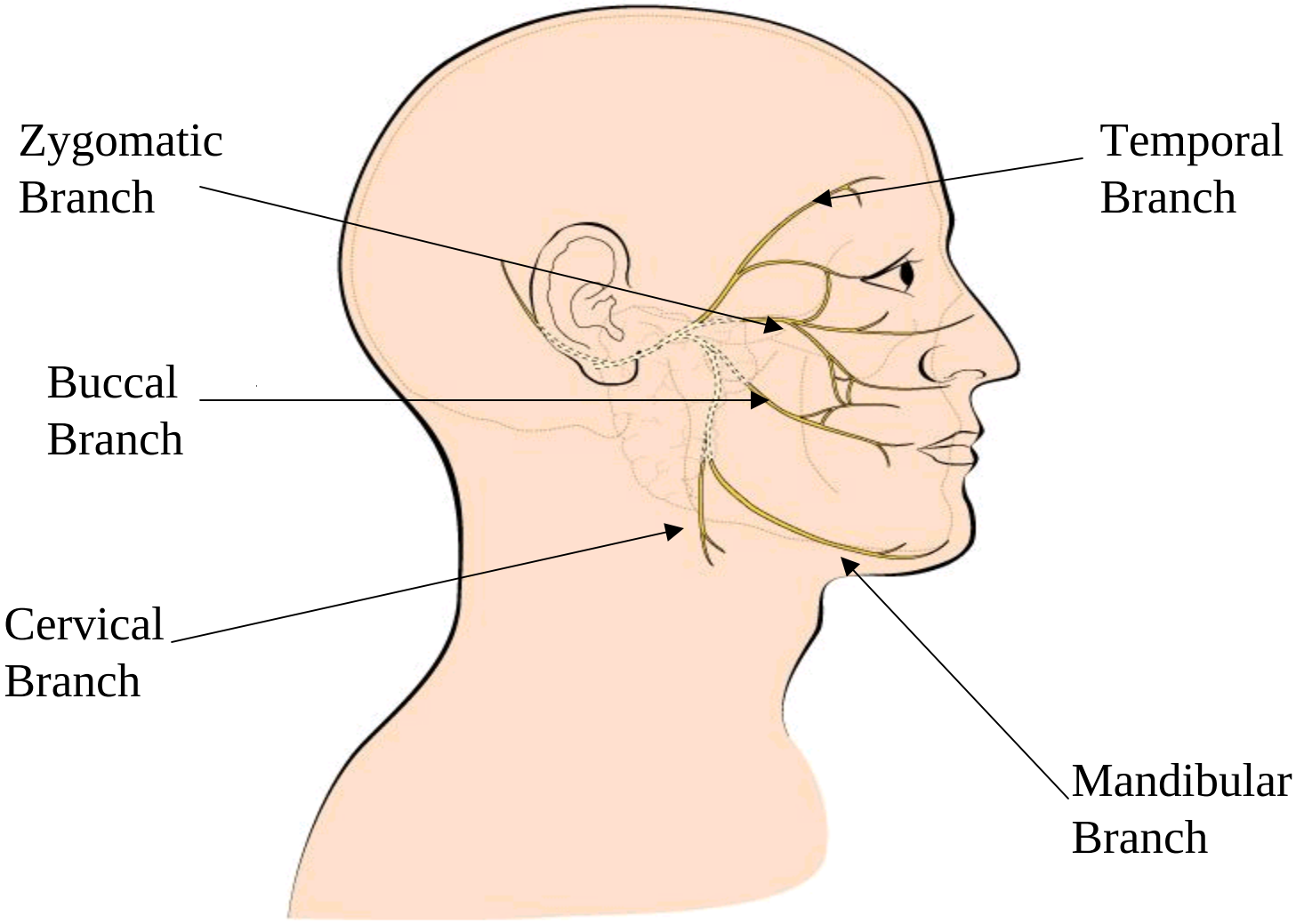
VII - Facial Nerve Motor Branches

- General Motor – 5 branches
  - Temporal – not involved in swallow
  - Zygomatic - not involved in swallow
  - Buccal – orbicularis oris, buccinator (masticator), risorius (lip retractor)
  - Mandibular – orbicularis oris, mentalis (lip protruder)
  - Cervical – platysma (mandibular depressor)
- Visceral Motor
  - Salivary glands (hitchhike with CN V)
  - Palatal & nasal mucosal membranes

VII – Facial Nerve Motor Branches



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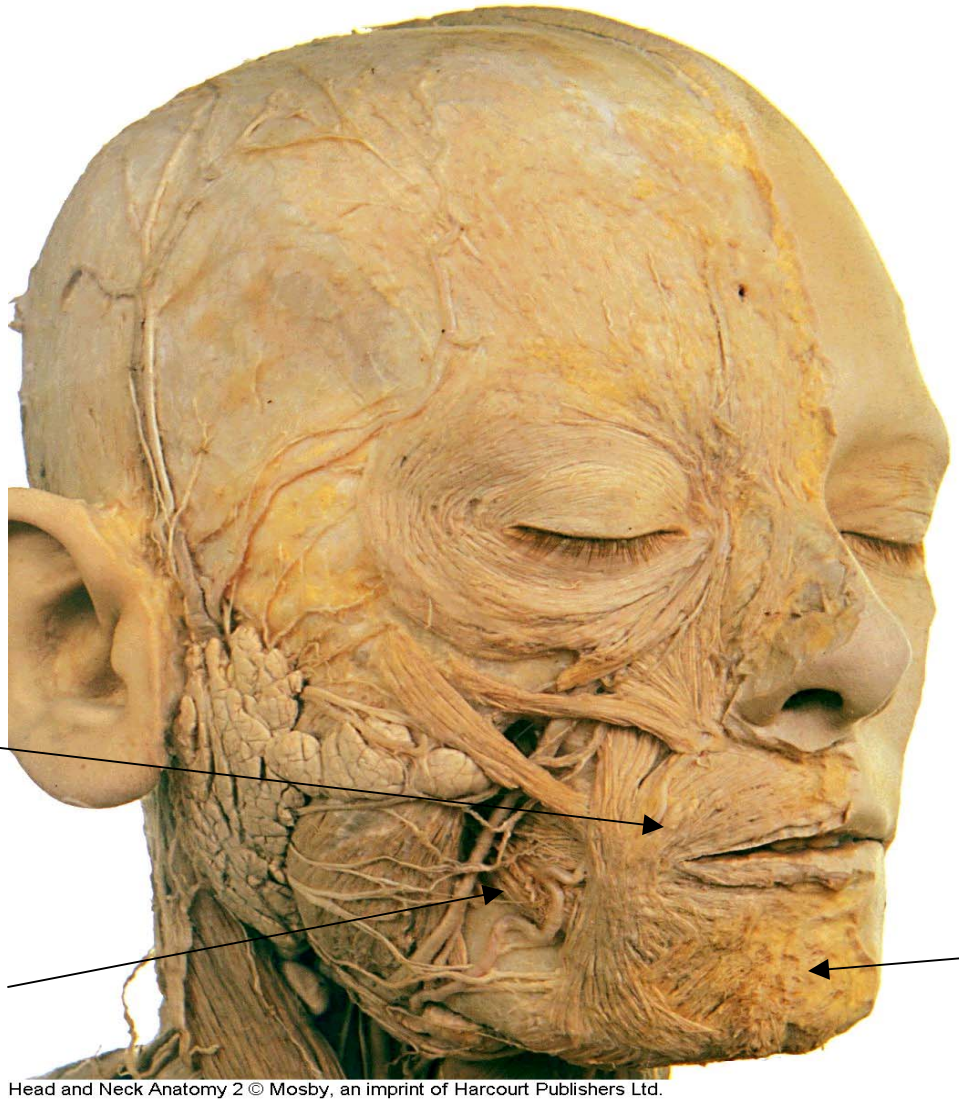
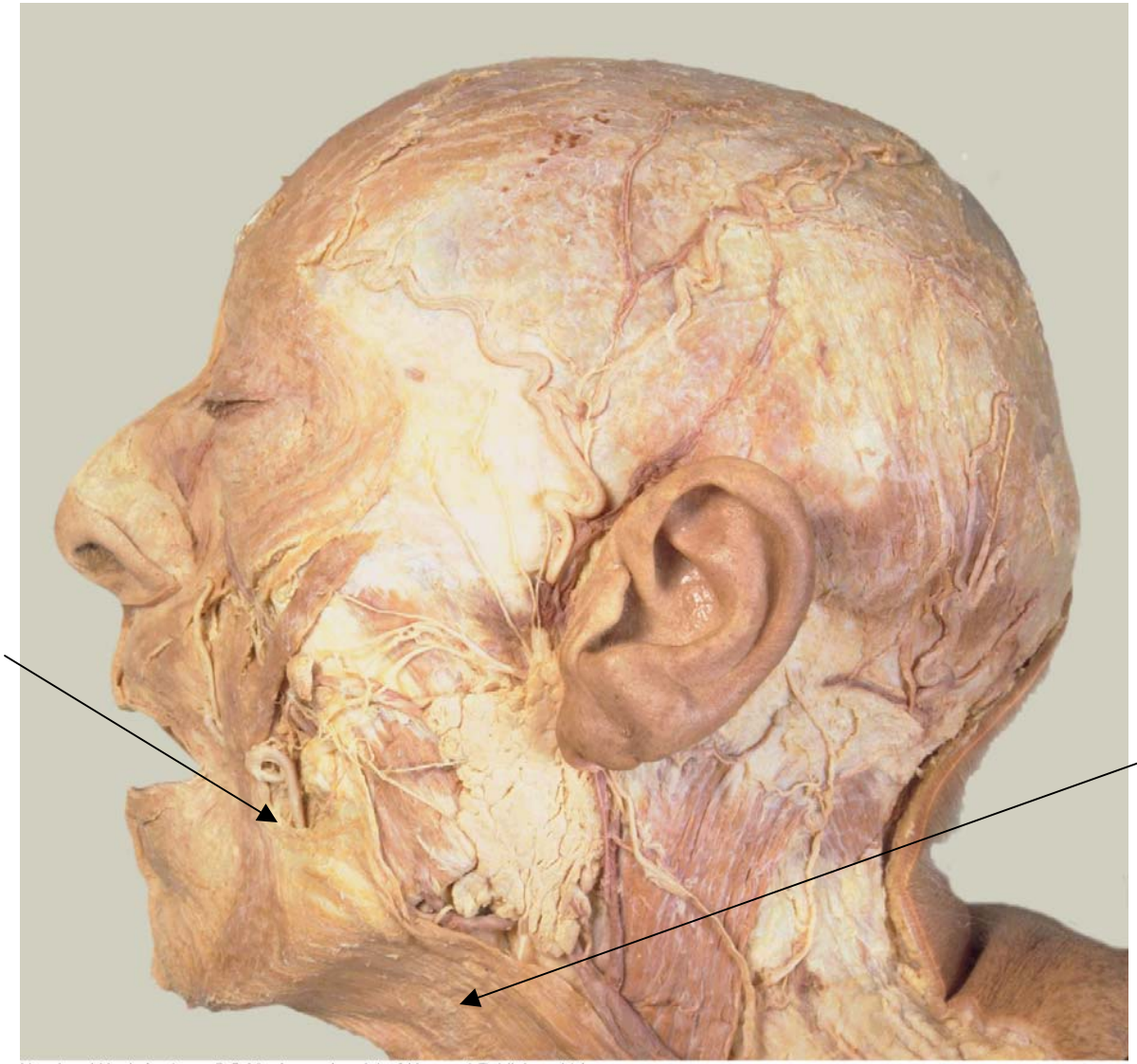
Facial Muscles
Important for Swallow



More Facial Muscles…



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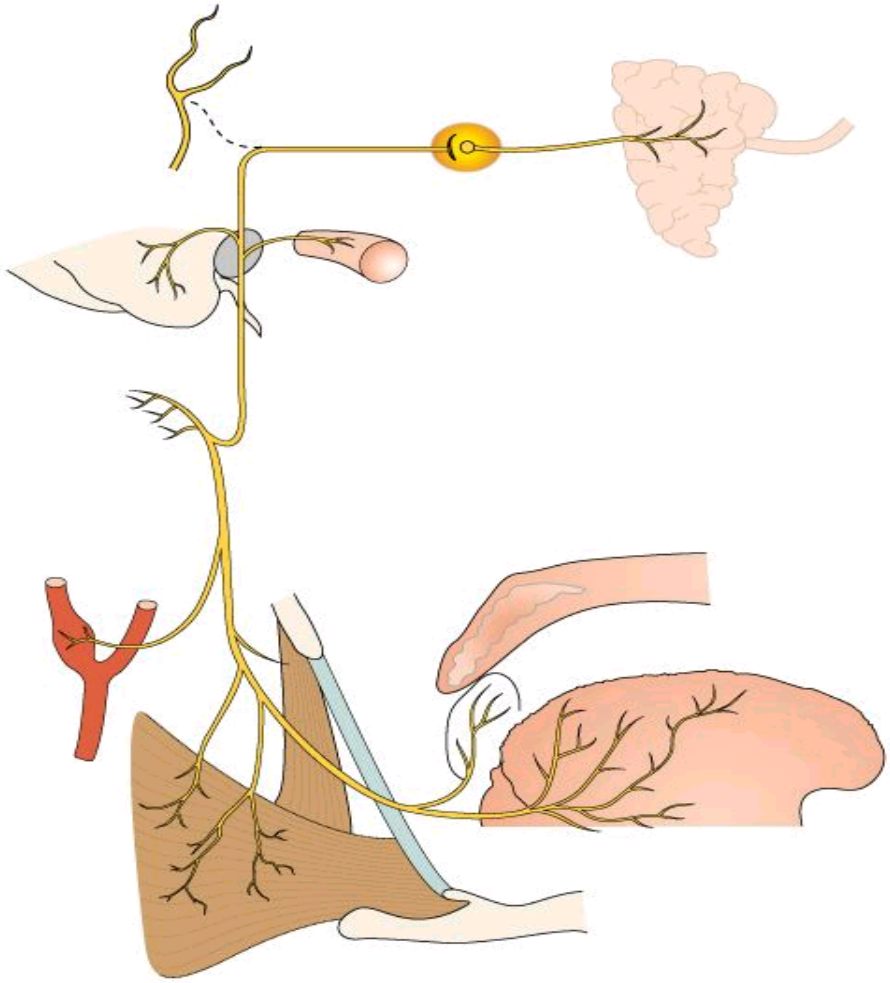
IX – Glossopharyngeal Nerve

- Sensory + Motor Components
  - Special visceral efferent supplies the stylopharyngeus muscle
- Contains special sensory components
  - visceral afferent supplies the mucous membranes of part of the tongue, tonsil, upper pharynx
  - visceral afferent provides taste sensation from the posterior third of the tongue
- “Cooperative innervation” with CN X
  - Damage to IX may result in absent gag, though typically absent gag is considered vagal

IX – Glossopharyngeal Nerve



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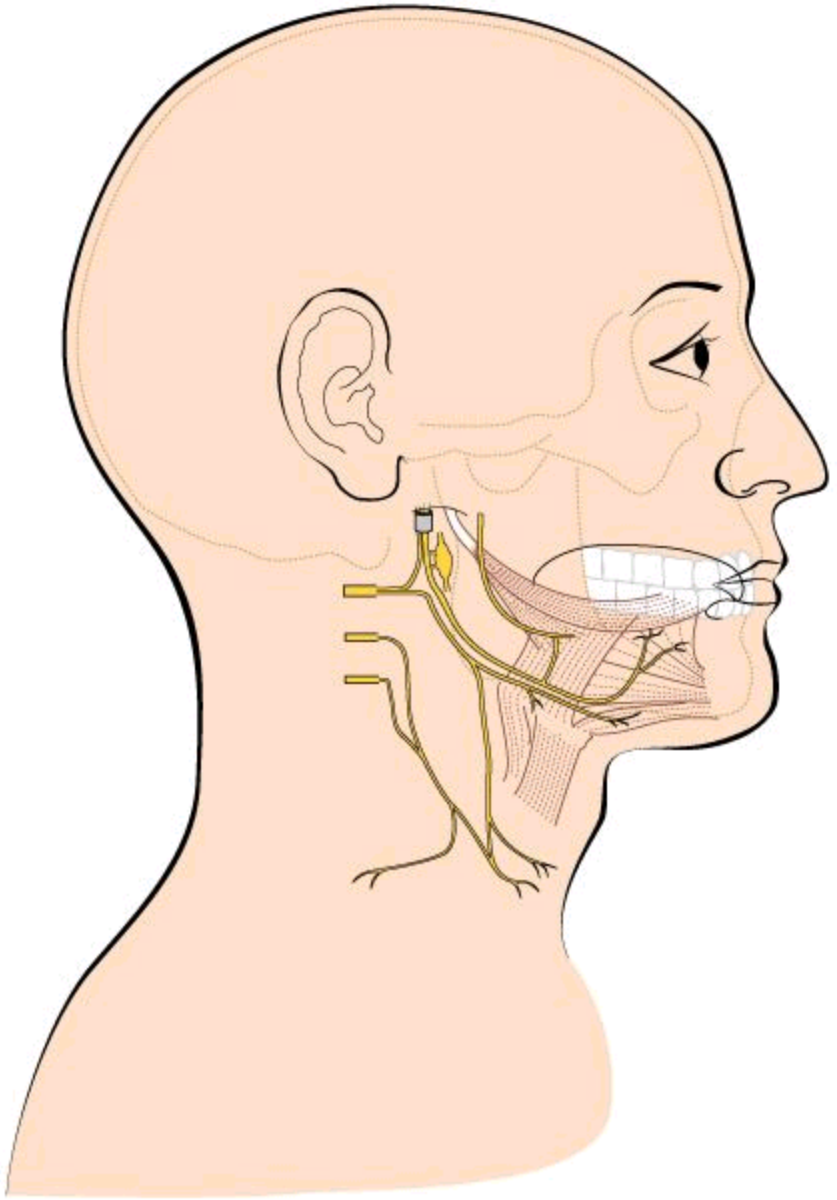
X – Vagus Nerve

X – V



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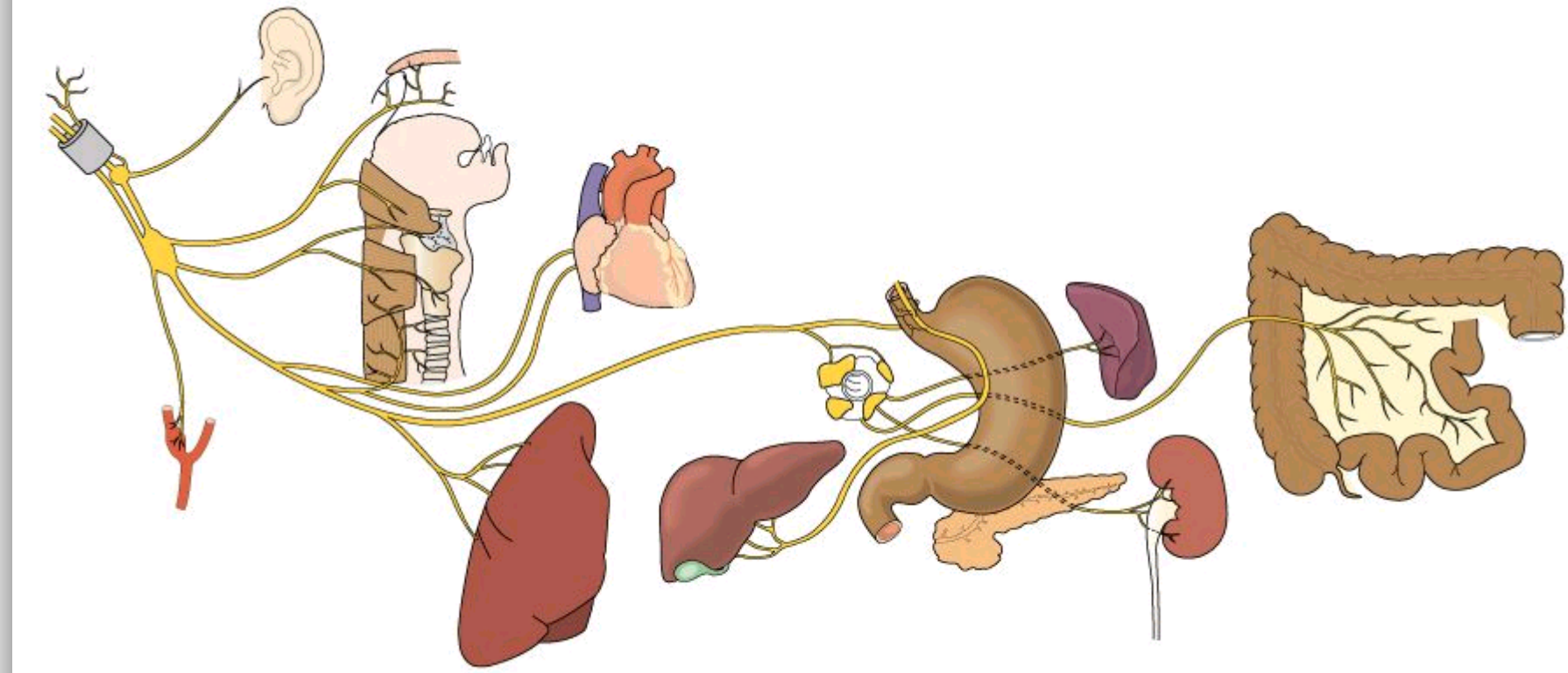

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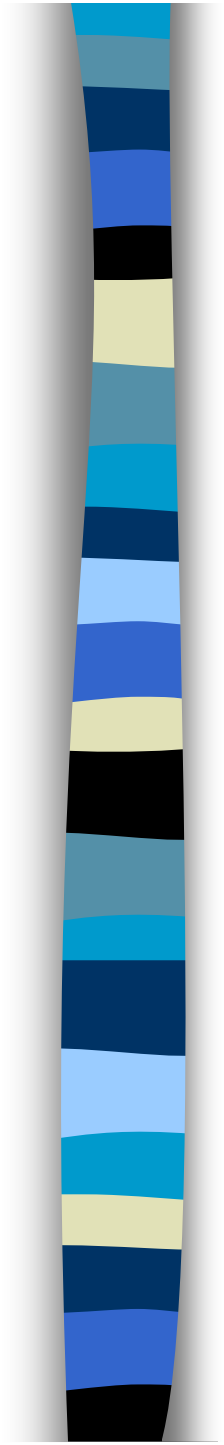
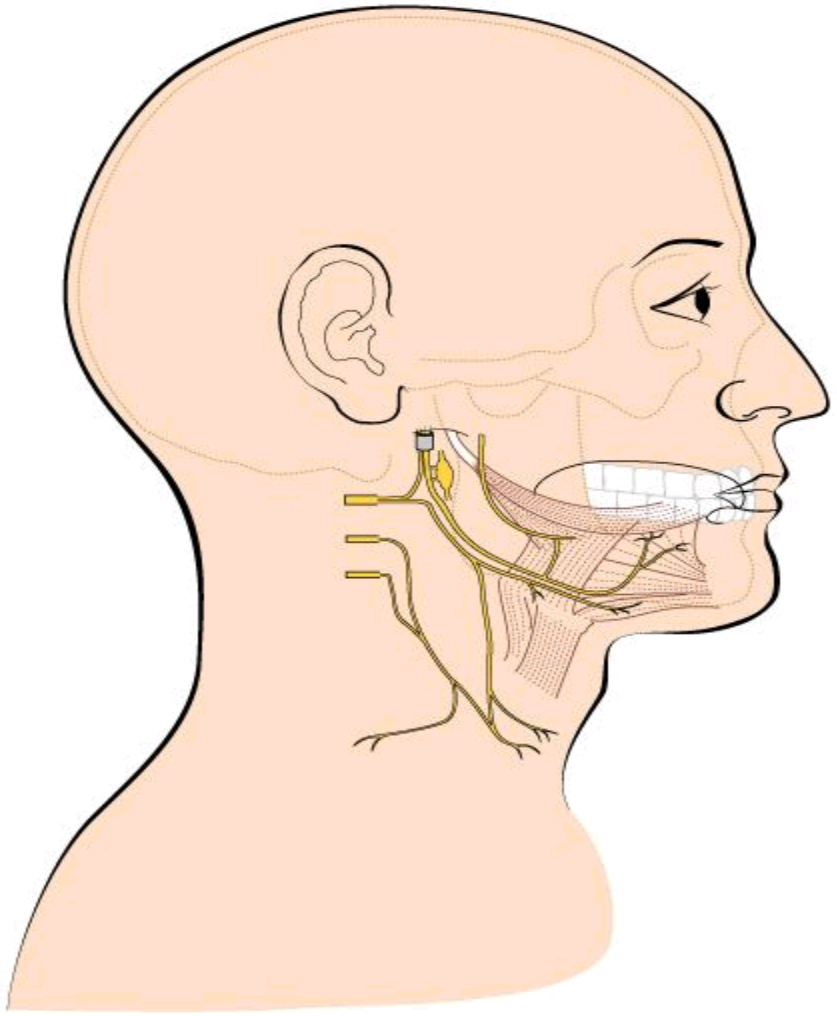
XI – Spinal Accessory Nerve



XII – Hypoglossal Nerve



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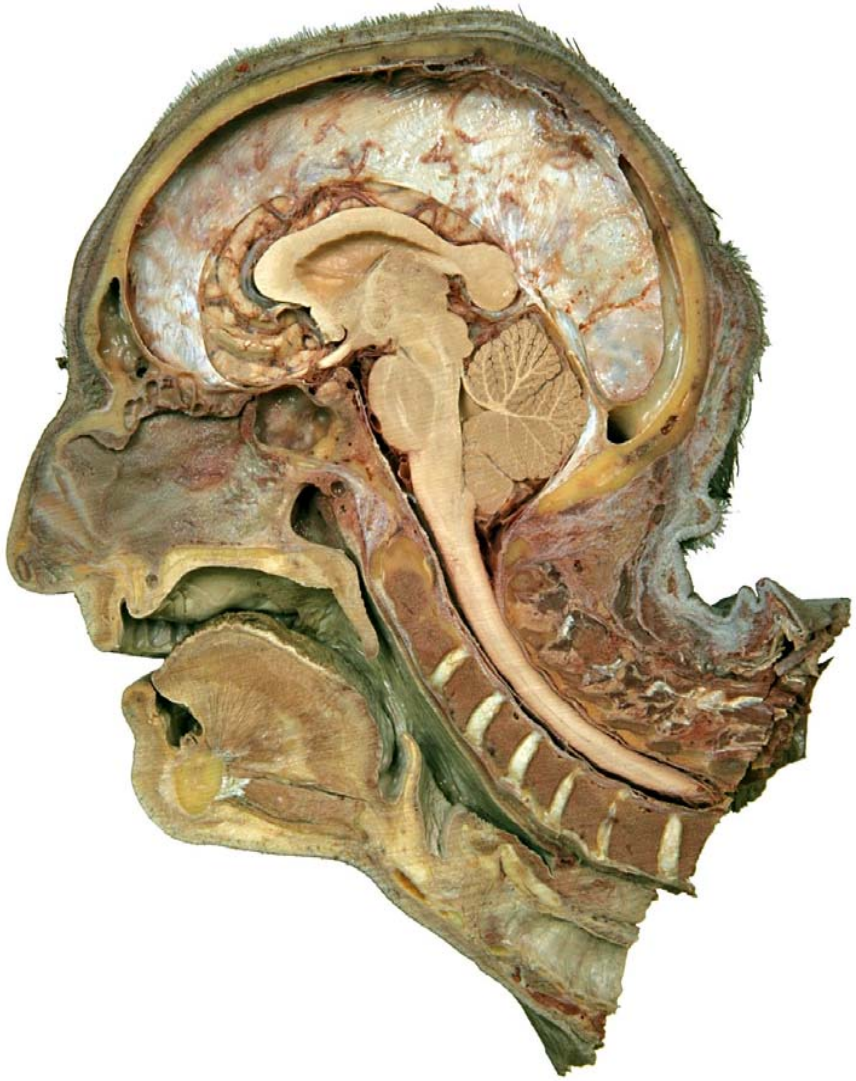
Brainstem + Spinal Cord



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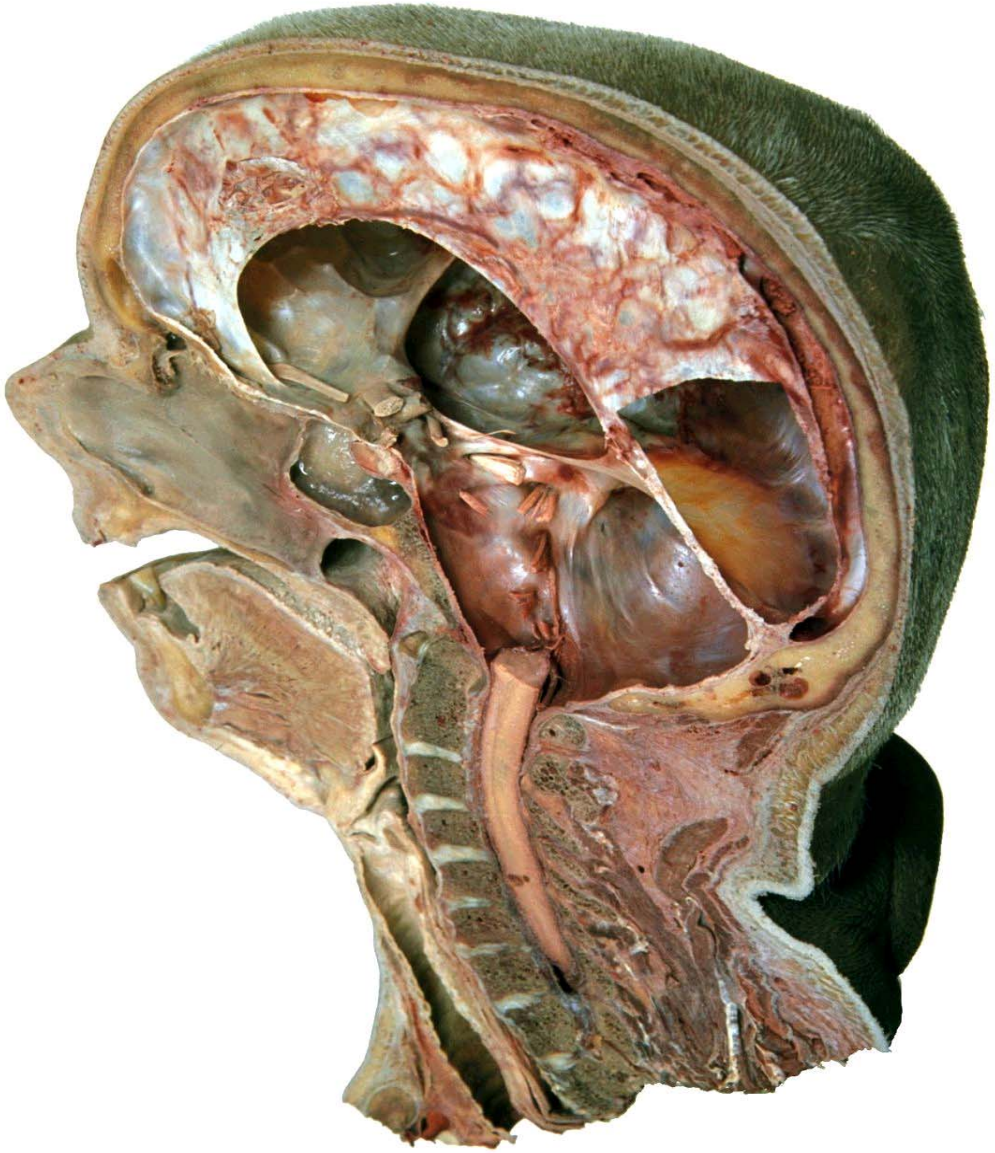
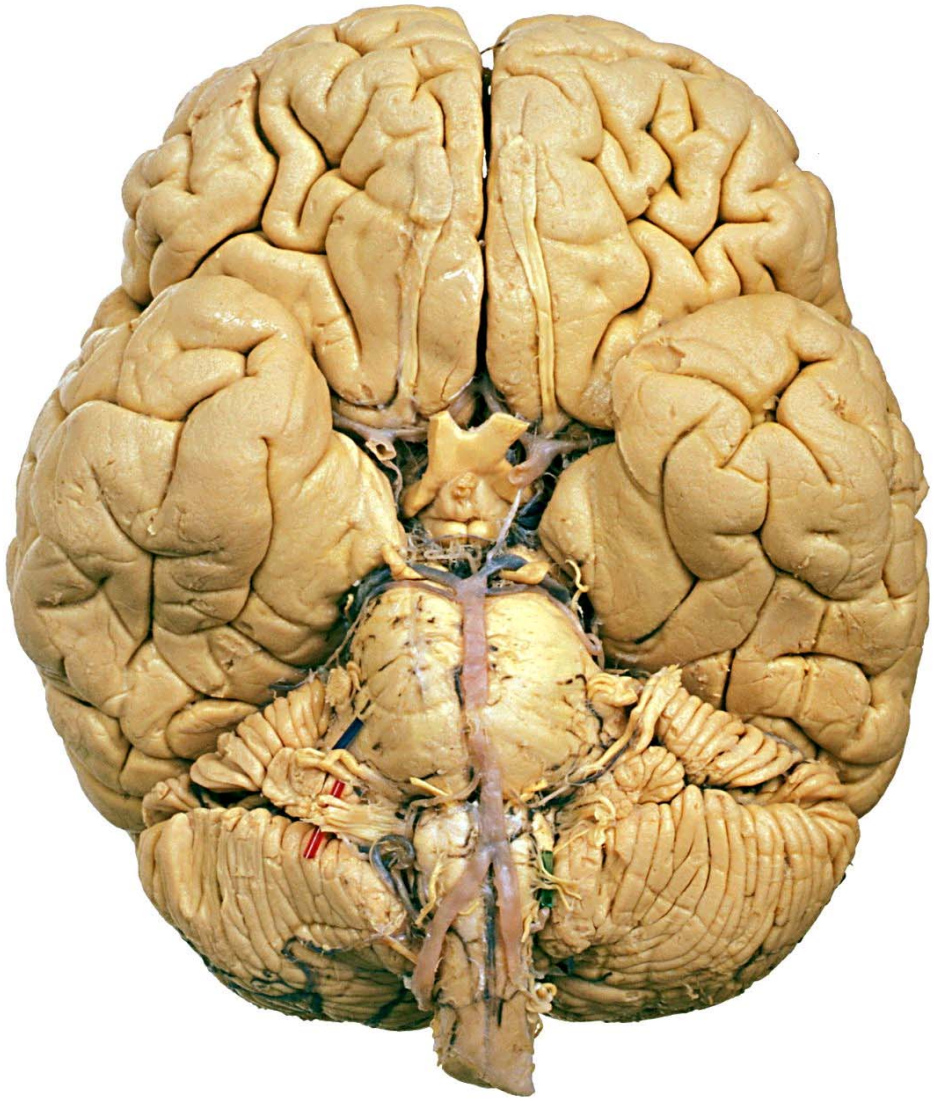
Cranial Nerve Nuclei





Brainstem – Medulla "Central Pattern Generator"

- Brainstem is the home of all sensory & motor cranial nerve nucleii
- Bilateral innervation
- Controls sequential muscle activity of swallow
- Interneurons for both respiration (swallow apnea) and vomiting
- Modulated, not controlled by higher regions

Note: Pons does contain nucleus for CN V & reticular formation, but info is "processed" in medulla nucleii

Brainstem Nucleii - Medulla

- Sensory CN - Nucleus Tractus Solitarius(NTS)
- Motor CN - Nucleus Ambiguous

  (sends motor messages to oral, pharyngeal, & esophageal muscles of swallow)
- Sensory info (bolus on faucial arches, PPW, base of tongue, etc) sent via CN to NTS. Interneurons in dorsal medulla relay info to NA & surrounding reticular formation (ventral medulla) which sends efferent messages to CN pathways.

2 types of swallows

- Volitional (voluntary initiation by positioning bolus within oral cavity followed by reflexive “pharyngeal” swallow)
- Involuntary/Reflexive (as in secretion management, stim to faucial pillars)

Voluntary Swallow Pathways

- Corticobulbar – pyramidal pathway
- Corticofugal pathway mediates cortical initiated swallows & the afferent pathway mediating the reflex phase of swallow may share interneuron in the bulbar center

Reflexive Swallow Pathways

- Reflexive pathways from bulbar center (particularly when laryngeal elevation begins – early event of reflexive swallow)

Cortical Involvement in Swallow

- Involved with the anticipatory, oral, and “triggering phases” of the volitional swallow
- Most research indicates: No direct involvement in the reflexive part of the swallow (initiation & execution)

Cortex

- Controls initiation of volitional swallow
- Controls activity/attention level for volitional swallow (I.e.,drowsy… reduced cortical input results in difficulty accommodating different boluses)
- Specifically controls duration and intensity of tongue muscles, hyoid elevations, vocal fold adduction, UES contraction – corticobulbar pathway through internal capsule
- Frontal lobe anterior to sensorimotor cortex & suppl. motor strip, bilateral anterolateral in frontal of precentral cortex

Strongest Activation Areas in Cortex

- Inferior precentral gyrus – bilaterally
- Primary somatosensory area (BA 43)
- Right Premotor cortex
- Right Precentral Gyrus
- Right Anterior Insula
- Left cerebellum
- Basal ganglia, Thalamus, right temporal gyri, right inferior parietal lobe
    - Zald & Pardo, 1999

Reflexive vs. Volitional

- Reflexive: bilateral activation of primary motor and primary somatosensory cortex; left hemisphere dominance observed
- Volitional: bilateral activation of above & bilateral insula, prefrontal cortex (arousal, intent, planning, urge), anterior cingulate (emotional processing of stimuli), precuneus, cuneus, & parieto-occipital regions, right hemisphere dominance
  - » Kern et al (2001)

Reflexive vs. Volitional

- All swallows activated:
  - Primary & pre-motor cortex (BA 4, 6), primary somatosensory cortex (3/2/1, 43), right insula
  - Less prominent & consistent: superior temporal gyrus (BA 42/41, 22), middle & inferior frontal gyri, and frontal operculum
- Volitional Swallow also activated:
  - Anterior cingulate
    - Processor of sensory, motor, cognitive info
    - Movement regulation, autonomic functions, attention, response selection

Primary Cortical Areas

- Primary Motor Cortex (4)
- Premotor Cortex (6)
- Both involved in volitional swallow
- Cortical – brainstem pathways
  - Corticobulbar
  - Corticofugal

Bilateral Asymmetric Cortical Representation

- Muscles of speech and oral swallow are symmetrically represented
- Muscles of pharyngeal and esophageal swallow appear to be asymmetric with a dominant side

Bilateral Asymmetric Cortical Representation

- Pts. with pharyngeal dysphagia are those with lesions on the in the dominant “swallow” hemisphere

  Hamdy et al (1997)

- Improved pharyngeal swallow associated with plasticity of non-lesioned hemisphere

  Hamdy et al (1998)

Left vs. Right

- Left frontal & parietal operculum lesions associated with “swallow apraxia”
- Intact reflexive swallow

Left vs. Right

- Robbins & Levine (1989)
  - Left CVA – decreased oral prep & delayed pharyngeal swallow
  - Right CVA – decreased pharyngeal response & increased aspiration
- Mosier et al (1999)
  - All cortical areas (frontal, parietal, temporal) bilaterally innervated, but left hemisphere appeared to be dominant hemisphere for @ 63%

Left vs. Right

- Zald & Pardo (1999)
  - Bilateral innervation of inferior precentral gyrus, primary somatosensory (BA 43), & inferior pre-motor cortex
  - Right dominance observed in anterior insula
- Hamdy et al (1999)
  - Bilateral innervation, but increased dominance seen in pre-motor, insular, & frontal operculum (Left vs right??)

Insula

- Located beneath the juncture of frontal, temporal, and parietal lobes
- Coordinates/orchestrates interaction of oral musculature & gustation & alimentary tract
- Connects with primary and supplementary motor cortex, thalamus, NTS

Right Anterior Insula

- Lesions reduce magnitude of sensory input resulting in delayed swallow
- Increasing sensory input – taste, volume, temperature
- Receives afferent info, mediates sensory & motor aspects of swallow and alimentary tract, including voluntary oral movements (& motor speech)

» Daniels & Foundas (1997)

Cerebellum

- Minimal research
- Connectivity between primary motor & supplemental motor cortex, as well as brainstem & thalamus

Left Cerebellum

- Plays role in pharyngeal & esophageal swallow
  - Coordination, sequencing, & timing of swallow
  - Integrates proprioceptive, vestibular, & motor planning to create smooth movements
  - Lesions: delayed swallow, incoordination, drooling

  (Zald & Pardo, 1999)

Basal Ganglia

- Left basal ganglia lesions result in mild oral-pharyngeal dysphagia
- Slow transit times
- Decreased efficiency of swallow

Thalamus/Hypothalamus

- Thalamus acts as relay for info from hypothalamus to premotor and motor cortex
- Hunger & thirst control

So what does this all mean?

- Neurologically, swallowing is a highly complex, integrated activity
- With differences between volitional & reflexive swallows
- Sensory based activity (requires sensory info to stimulate swallow)
- Little research on pediatric population
- Expect recovery of function secondary to tissue healing, but also plasticity
- Benefit to boosting sensory messages (temperature, taste, amount)