SWALLOWING PHYSIOLOGY

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Aula Magna - Università degli Studi di Milano
Via Festa del Perdono, 7 - Milano

Società Italiana di Deglutologia
SID
già G.I.S.D.

Corso di Aggiornamento S.I.D. 2024
LA GESTIONE DEL PASTO NELLA PERSONA CON DISFAGIA: dalla nascita ai 100 anni

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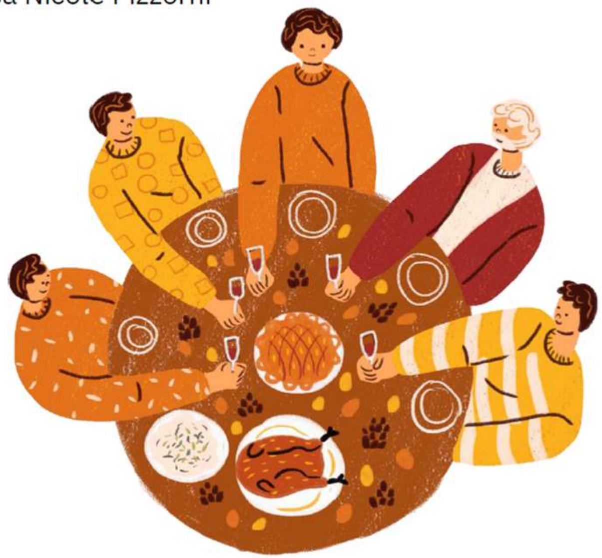

Per informazioni e iscrizioni **www.sid2024.it**

Quali sono i bisogni di cura dei pazienti con disfagia al pasto a casa e fuori casa?

LEARNING OBJECTIVES

At the end of the lesson the student will know:

- The difference between swallowing, nutrition and eating
- The characteristics of the oral phase
- The characteristics of the pharyngeal phase
- The characteristic of the esophpageal phase
- The neural circuites underlying swallowing
- Swallowing physiology in the elderly

OUTLINE

- Swallowing and body functions
- The oral phase
- The pharyngeal phase
- The esophageal phase
- The neural circuites underlying swallowing
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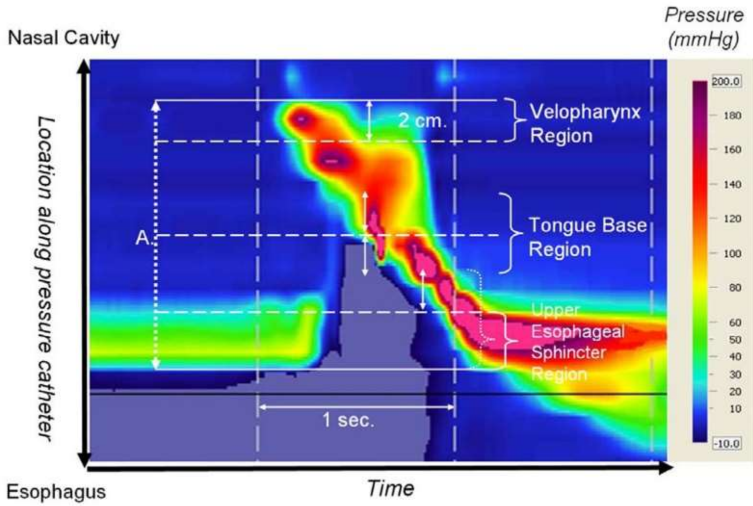
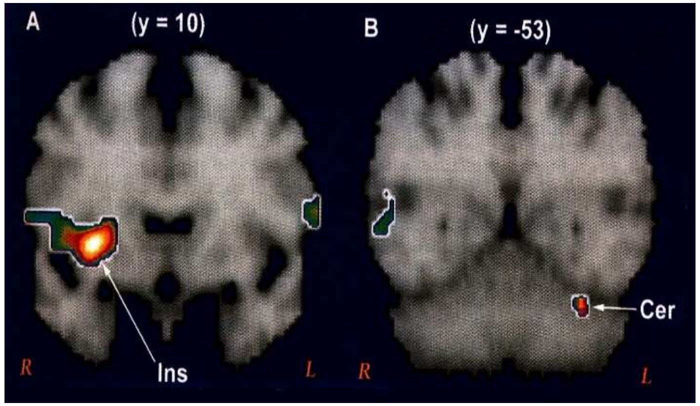
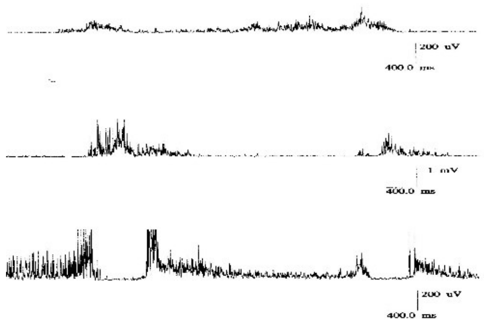
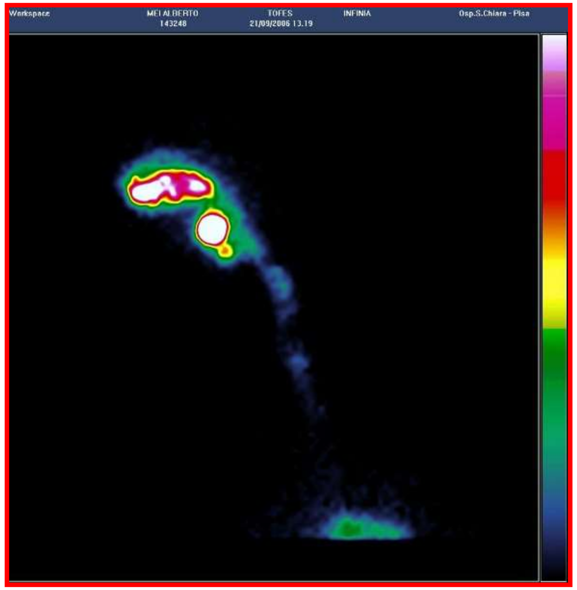
SWALLOWING:
How can we study it?



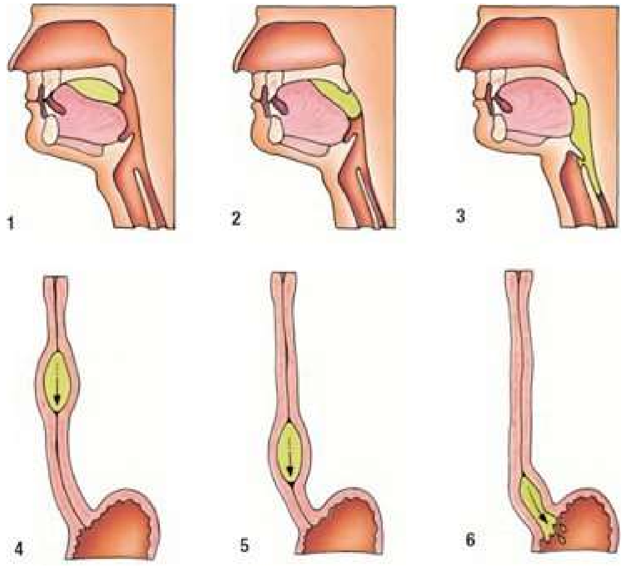






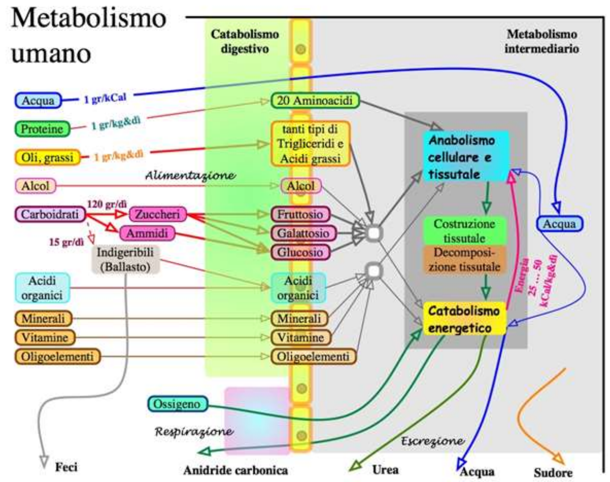
DEGLUTITION vs

Motor function of driving bolus into the stomach



NUTRITION vs

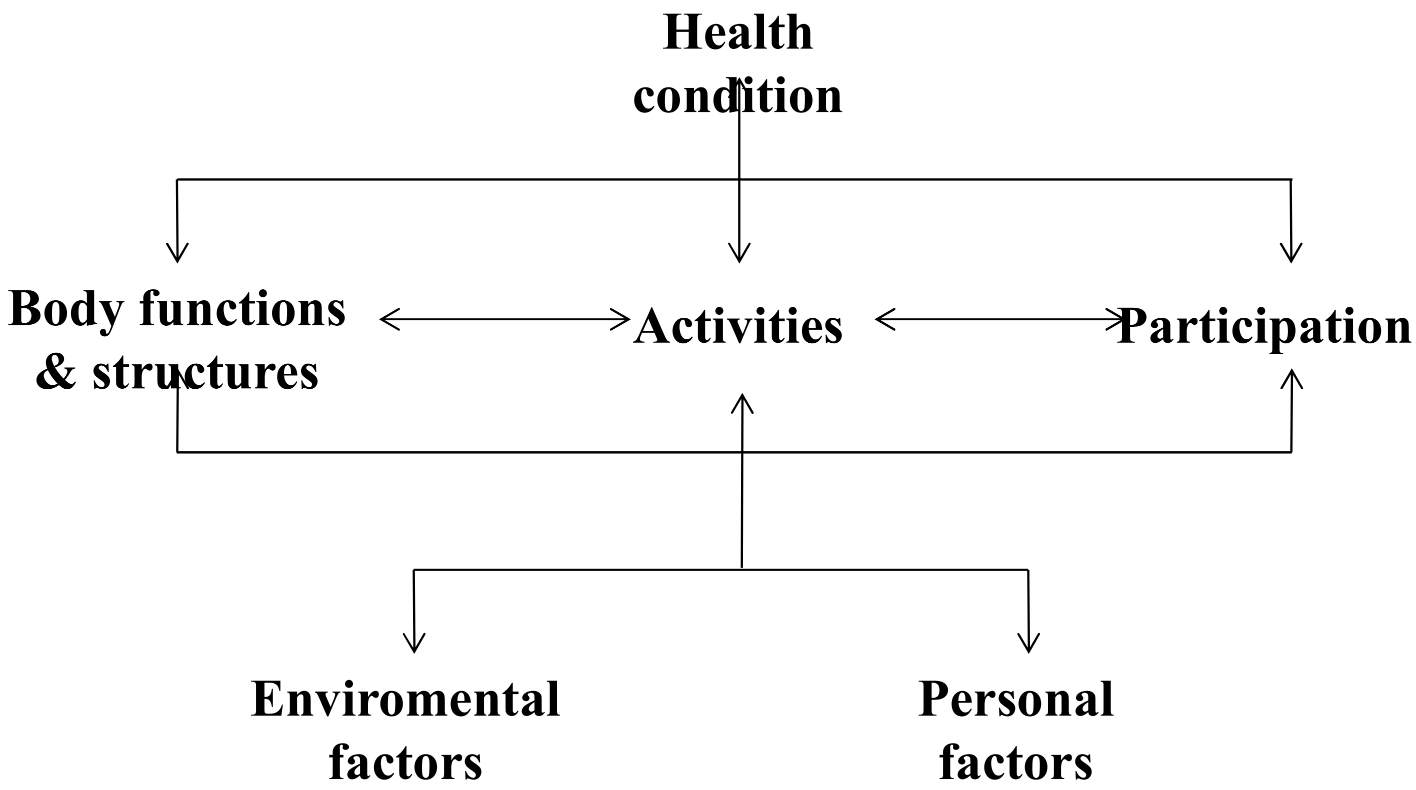
Metabolic activity



EATING

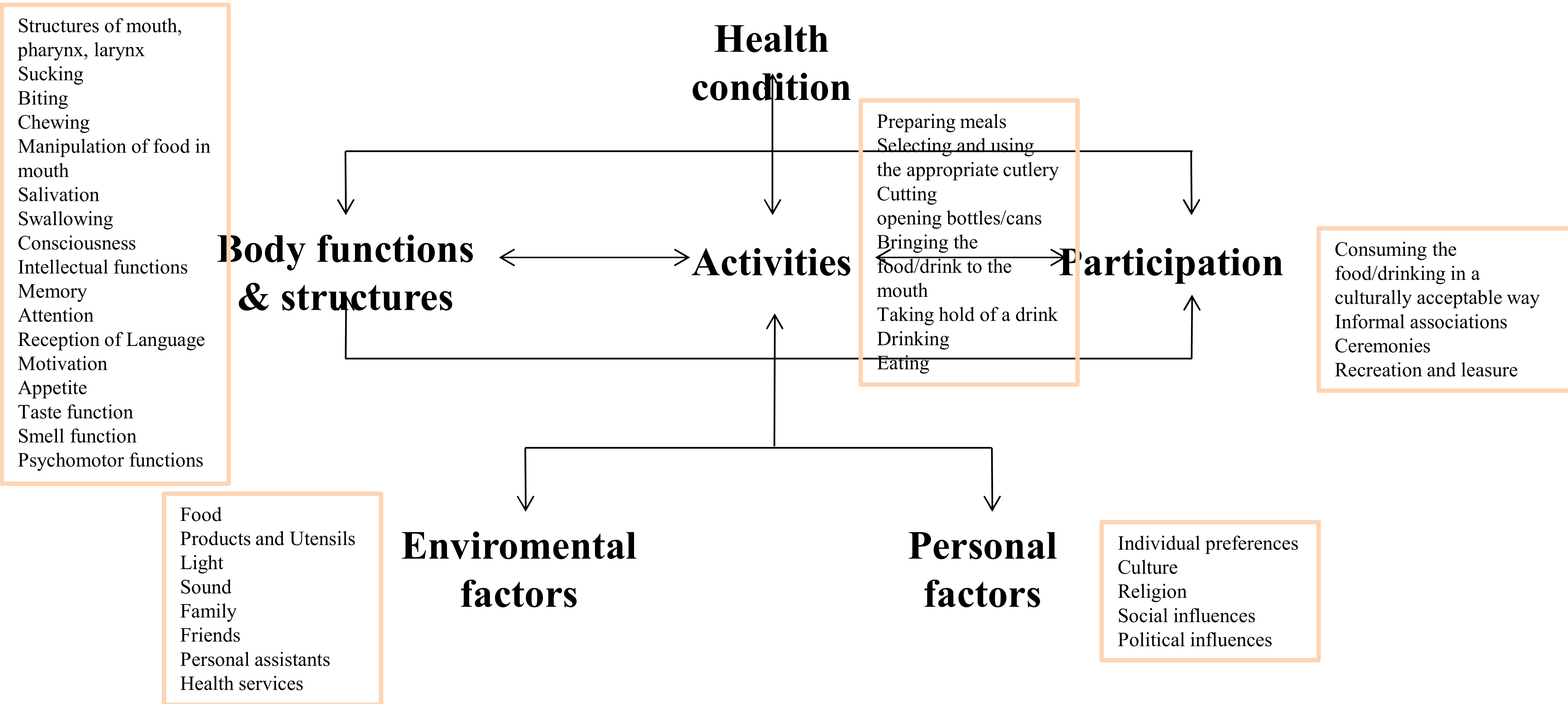
Activity of daily living

ICF



International Classification of Functioning, Disability and Health (ICF, WHO, 2001)

Swallowing and meals



What do we swallow?

a. **<u>Substances coming from outside</u>**

- Food
- Liquids
- Drugs
- Foreign body

b. **<u>Substances coming from inside the oral cavity and pharynx</u>**

- Saliva
- Mucus

c. **<u>Substances coming from the stomach</u>**

- Food and stomach liquids

SWALLOWING:
numbers to remember

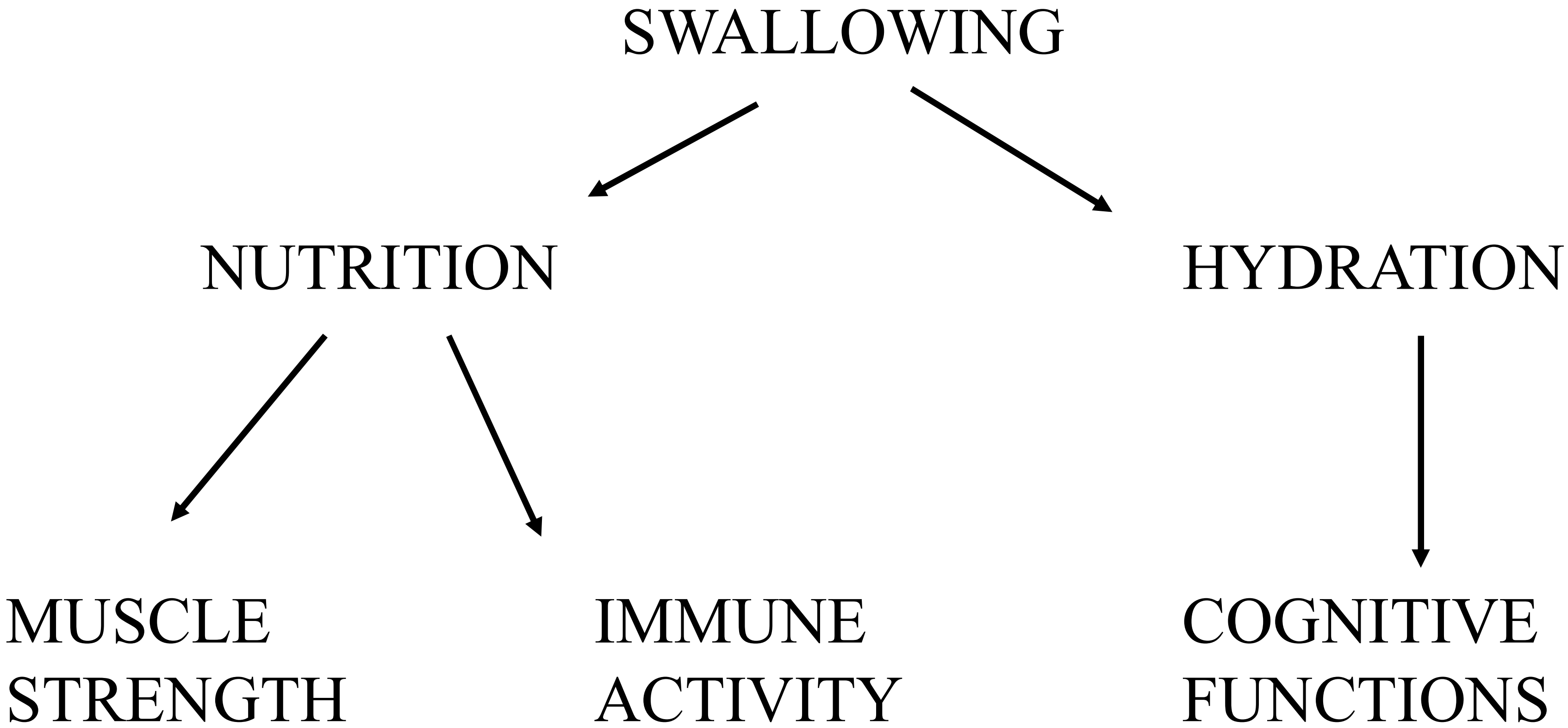
1000-15000 ml of saliva are swallowed every day

On average 1 swallow/minute→ 1200-1400 swallows every day

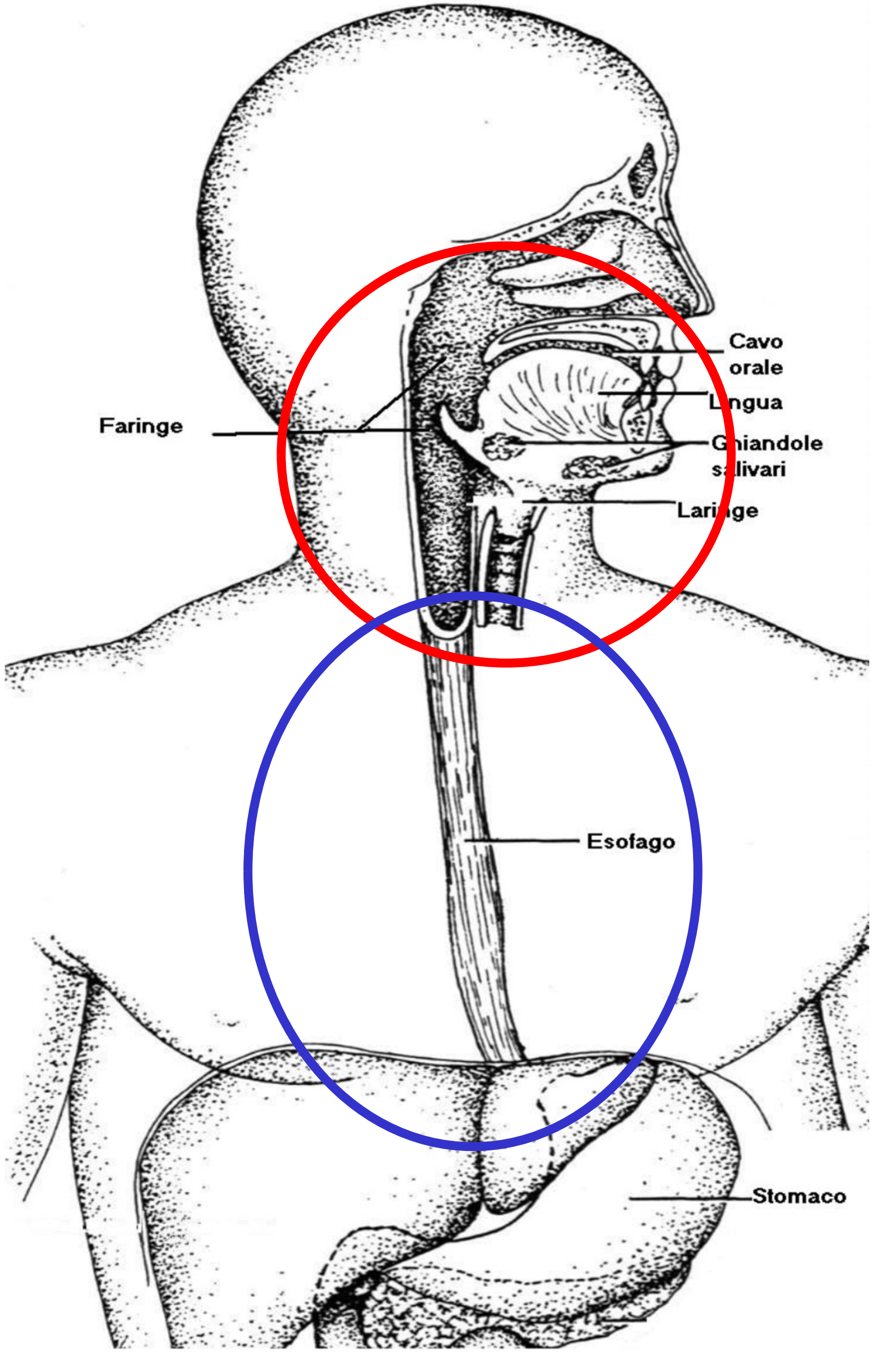
Swallowing strarts at birth and ends when we die

Swallowing is a key body function for survival

SWALLOWING AND BODY FUNCTIONS



Oropharyngeal swallowing



Esophageal swallowing

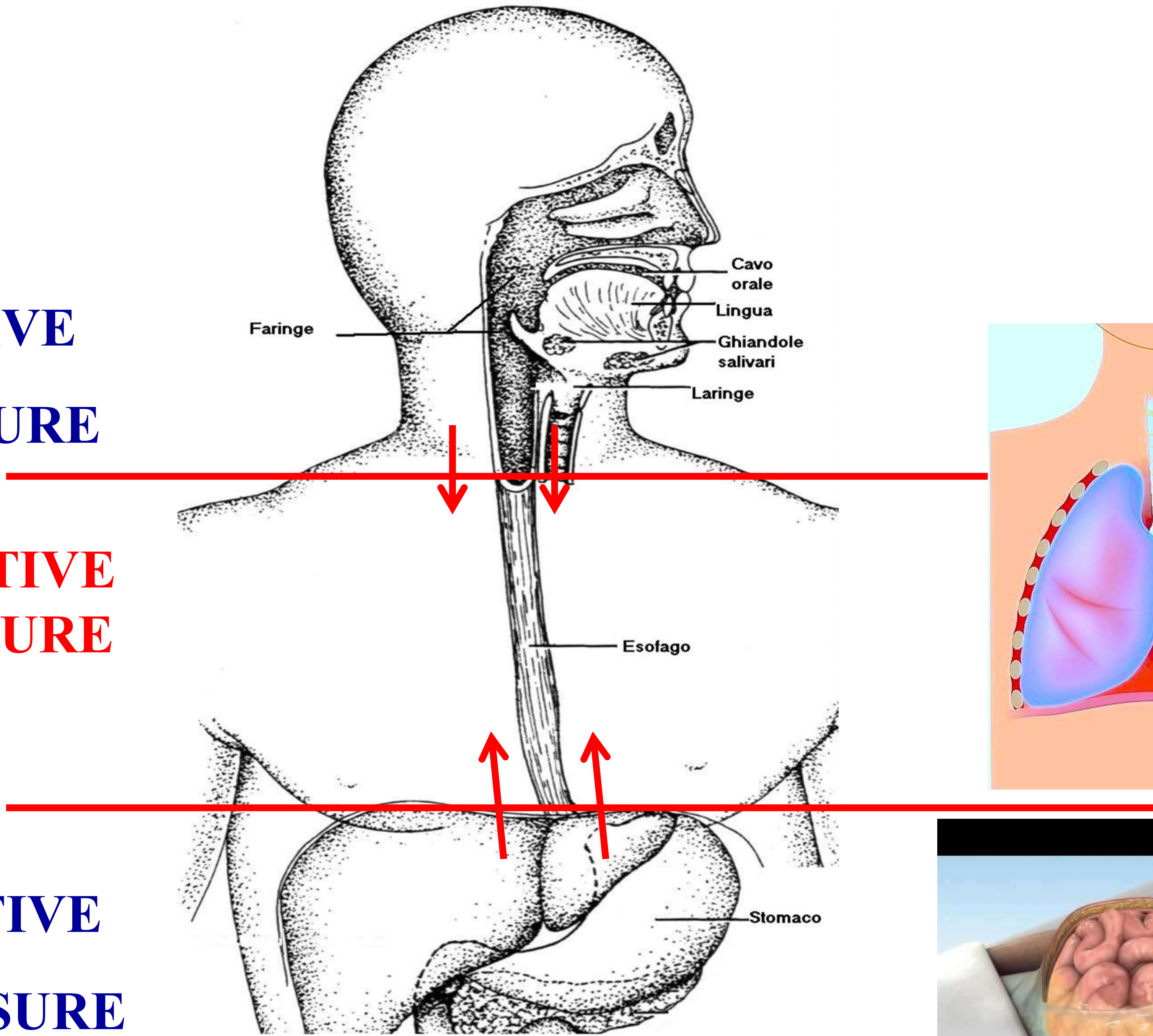
POSITIVE

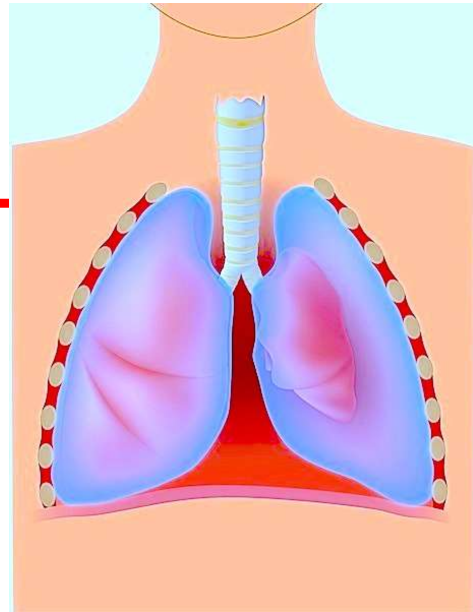
PRESSURE

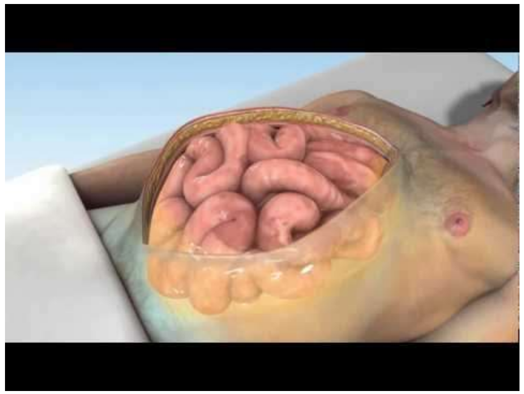
NEGATIVE
PRESSURE

POSITIVE

PRESSURE







DEGLUTIZIONE

- > 25 paia di muscoli
- 6 nervi cranici
- < 2 sec

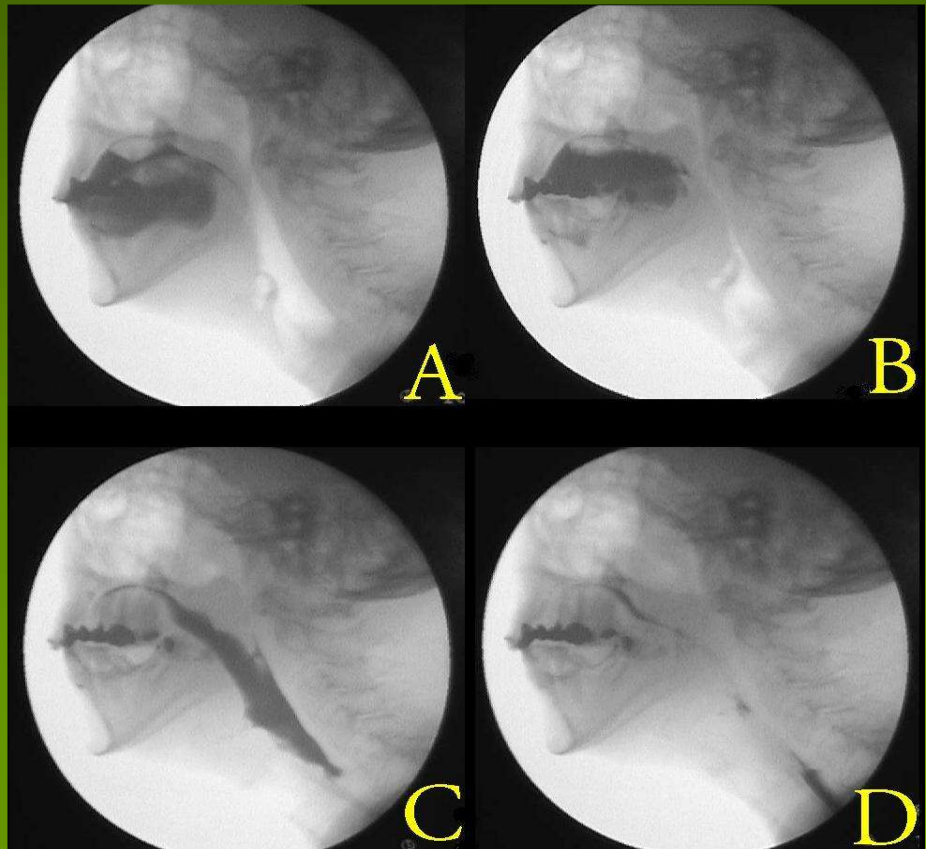
SWALLOWING PHENOMENOLOGY

Three major phase are described:

Oral phase (stage I, II)

Pharyngeal phase

Esophageal phase



OUTLINE

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- The oral phase
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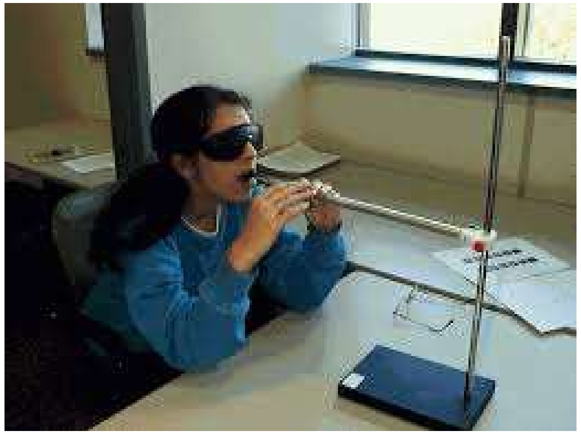
ANTICIPATORY PHASE

Although the anticipatory phase happens before swallowing, it can severly impact on swallowing
It is related primarily to smell, taste and memory of previous experience

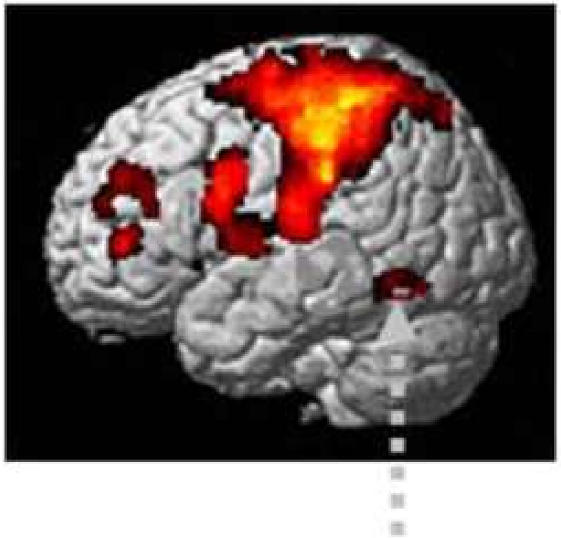
ORAL PHASE

The oral phase is the most complex sensori-motor activity in deglutition and it includes: biting, sucking, chewing

ORAL PHASE – oral stereognosis

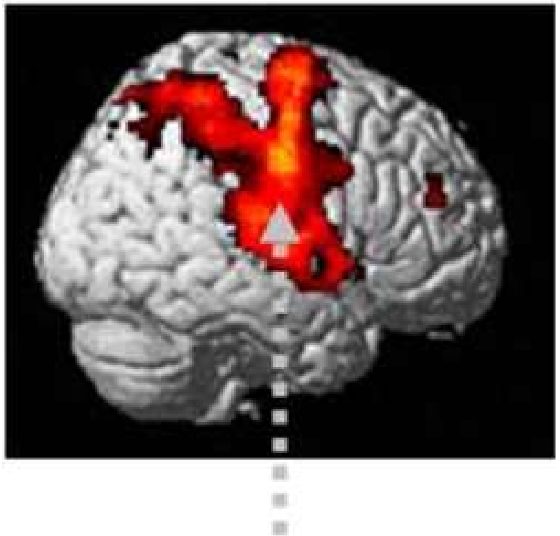


Manual stereognosis



Visual association cortex

Oral stereognosis

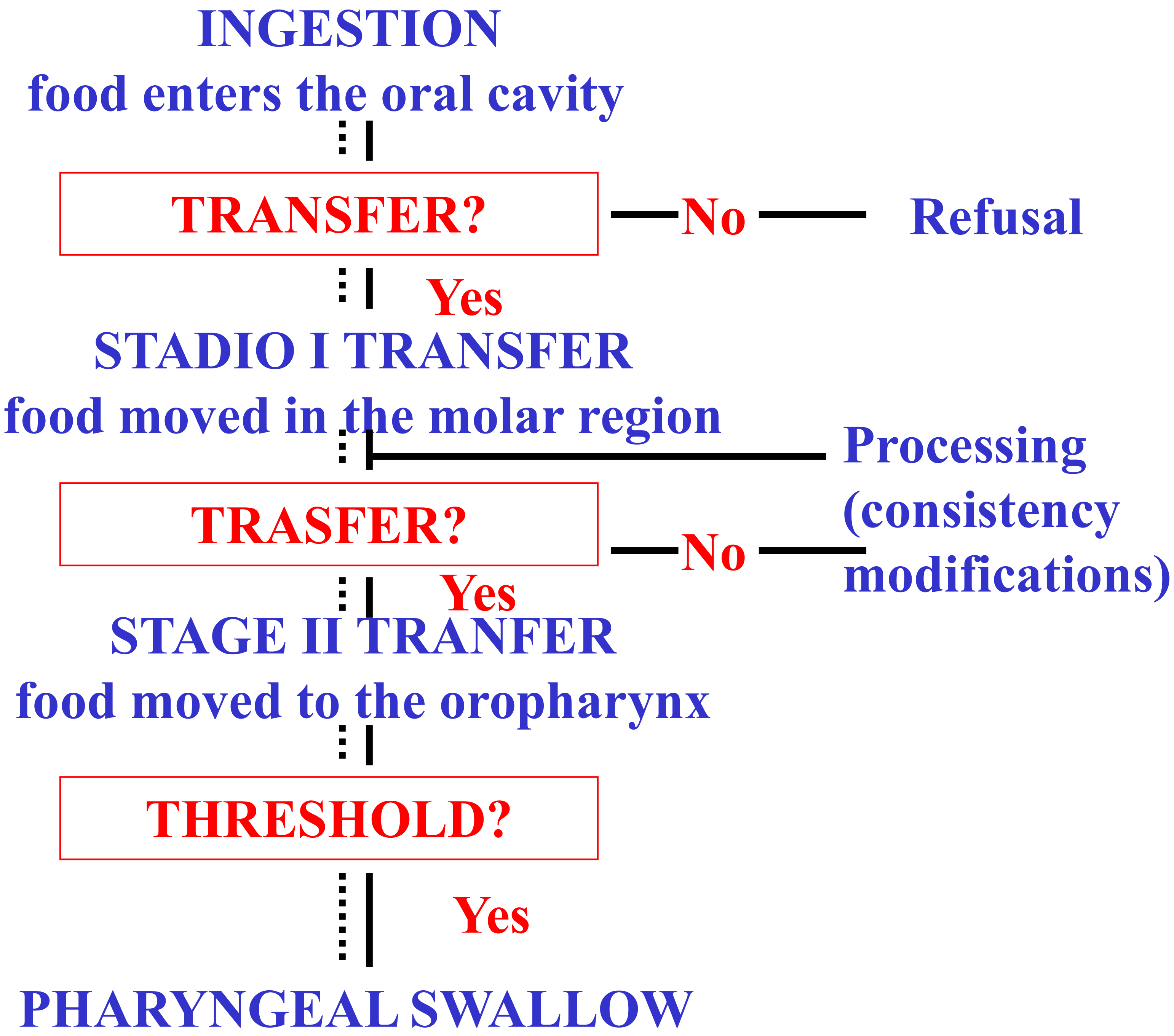


Insular, lies deep in the floor of lateral fissure.

ORAL PHASE: ingestion

Different ways exist to introduce food/liquids into the oral cavity

- nippling
- biting
- spoon
- fork
- cup/glass


INGESTION
food enters the oral cavity
TRANSFER?
No
Refusal
Yes
STADIO I TRANSFER
food moved in the molar region
Processing
(consistency
modifications)
TRASFER?
No
Yes
STAGE II TRANFER
food moved to the oropharynx
THRESHOLD?
Yes
PHARYNGEAL SWALLOW

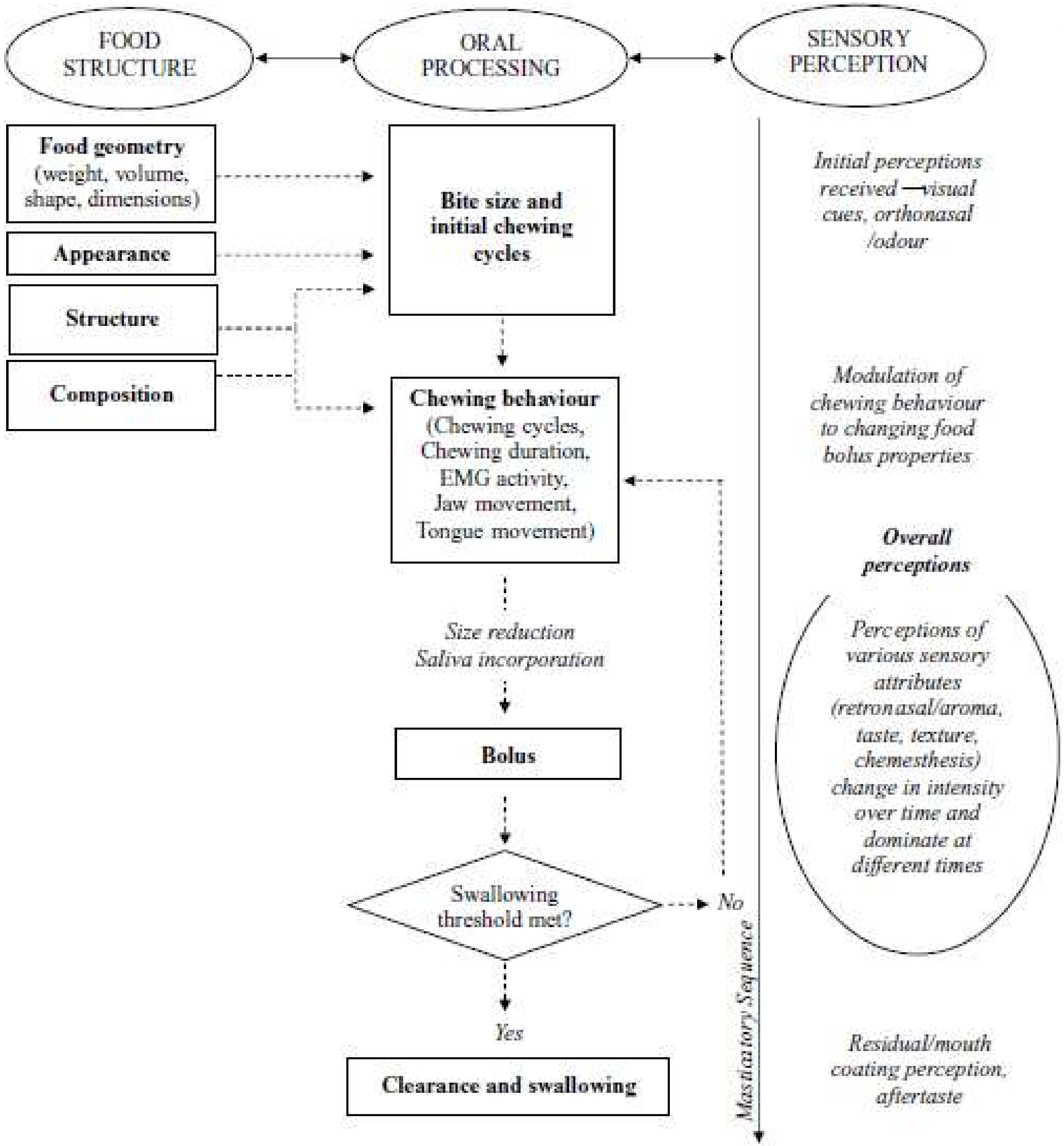
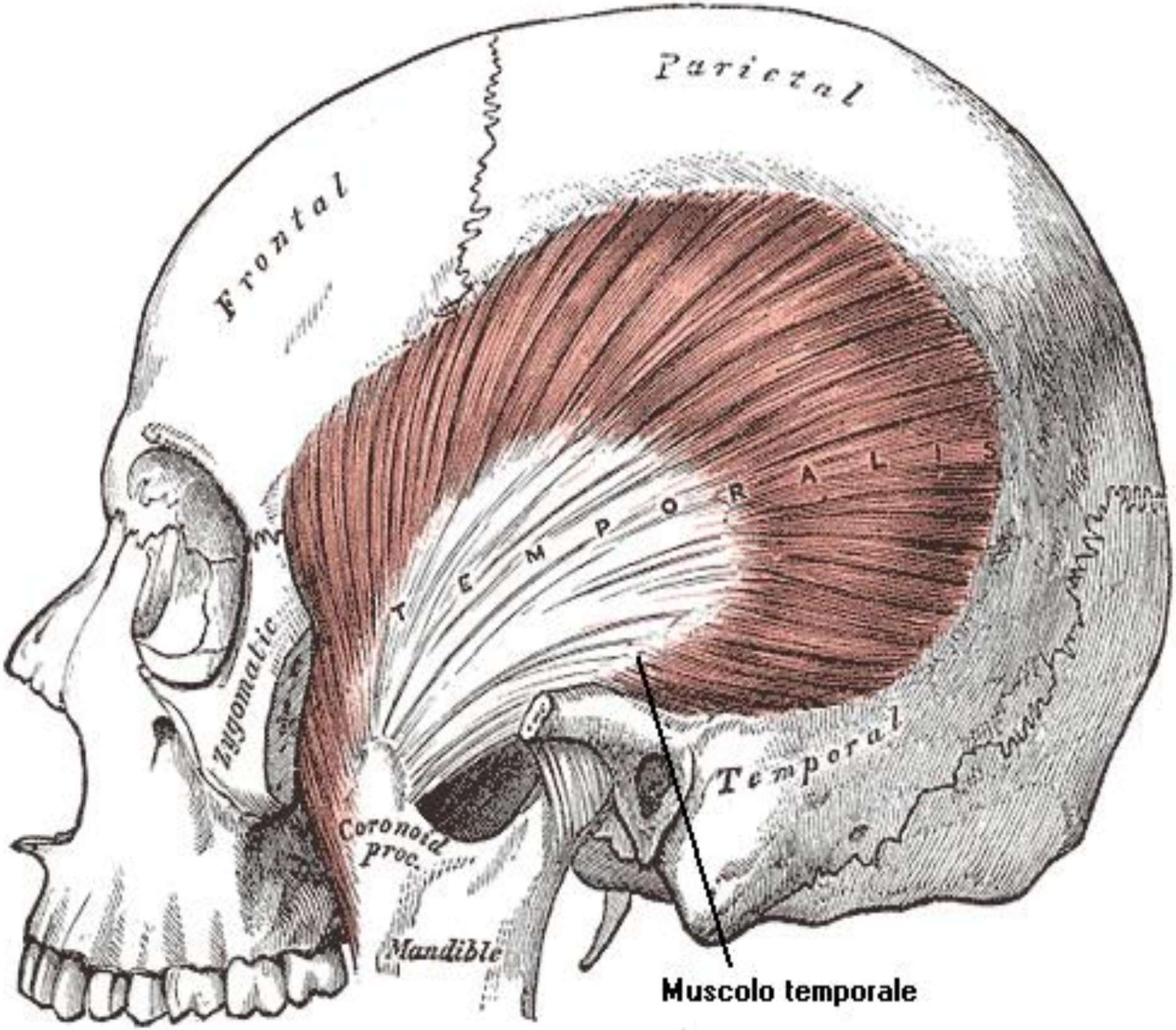


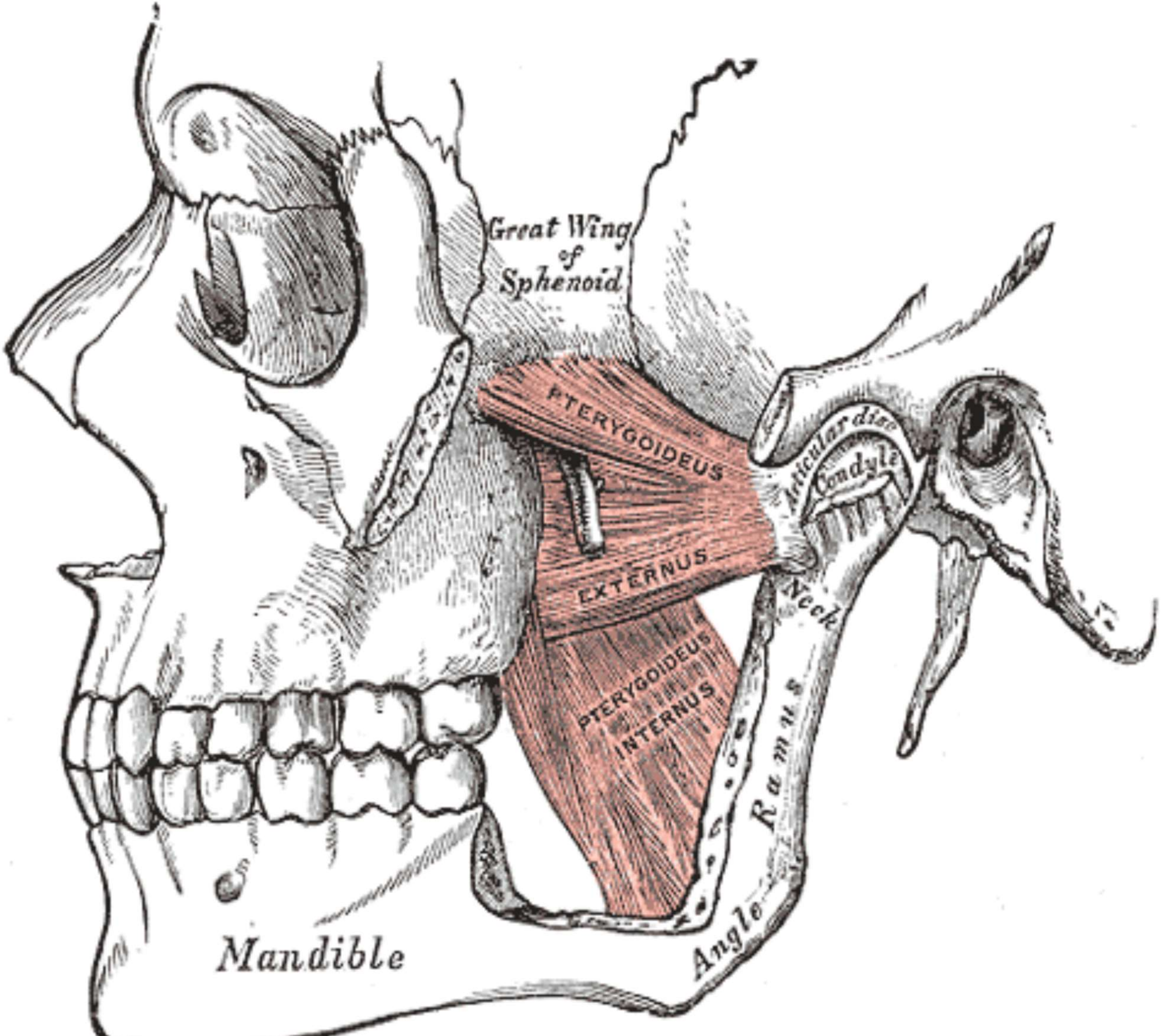
Figure 1–Overview of interactions among food properties, oral processing, and sensory perception.

ORAL PHASE

Oral phase sequence for liquids:
Oral preparatory stage – oral propulsive stage – pharyngeal stage

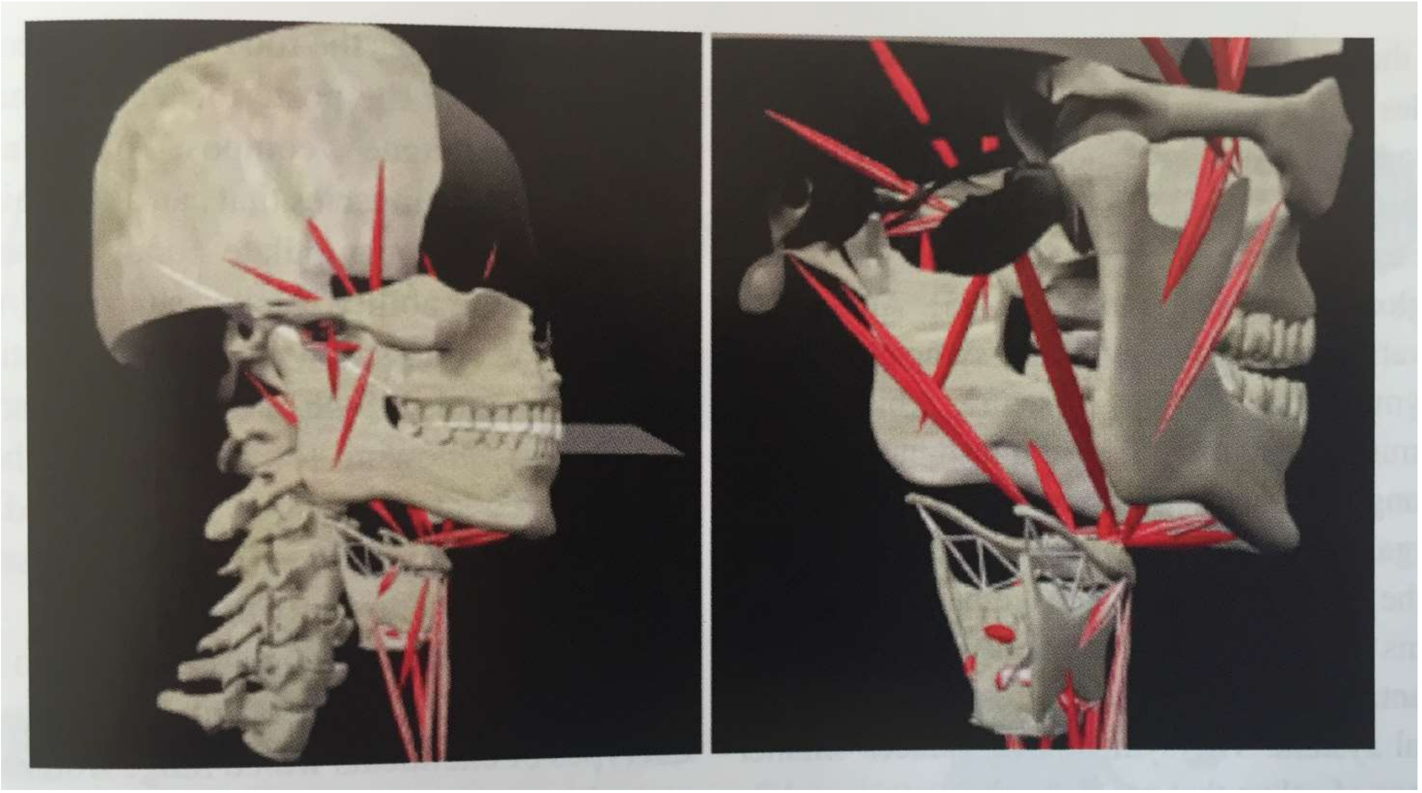
Oral phase sequence for solids:
Transport to molar region – food processing – oral propulsive stage – pharyngeal stage


Parietal
Frontal
TEMPORALIS
Zygomatic
Temporal
Coronoid proc.
Mandible
Muscolo temporale

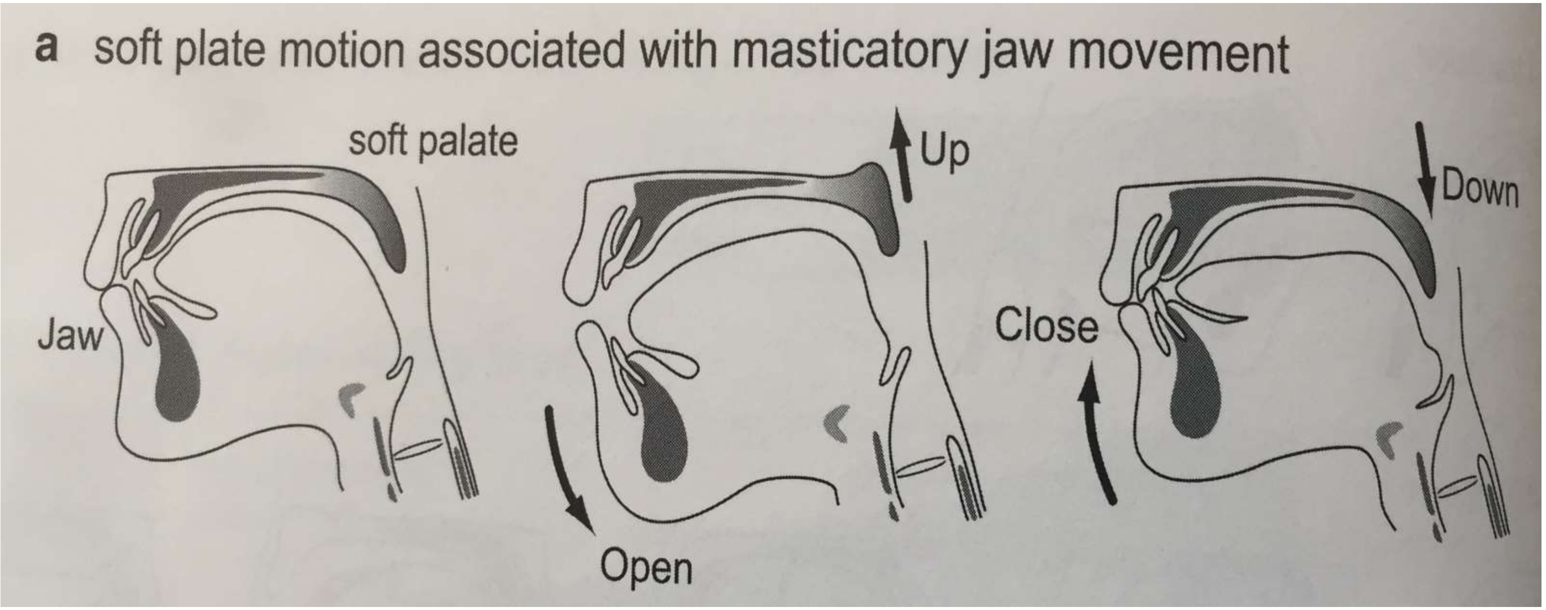


Great Wing
of
Sphenoid
PTERYGOIDEUS
EXTERNUS
PTERYGOIDEUS
INTERNUS
Articular disc
Condyle
Neck
Ramus
Angle
Mandible

MUSCLES INVOLVED IN MANDIBULE MOVEMENTS

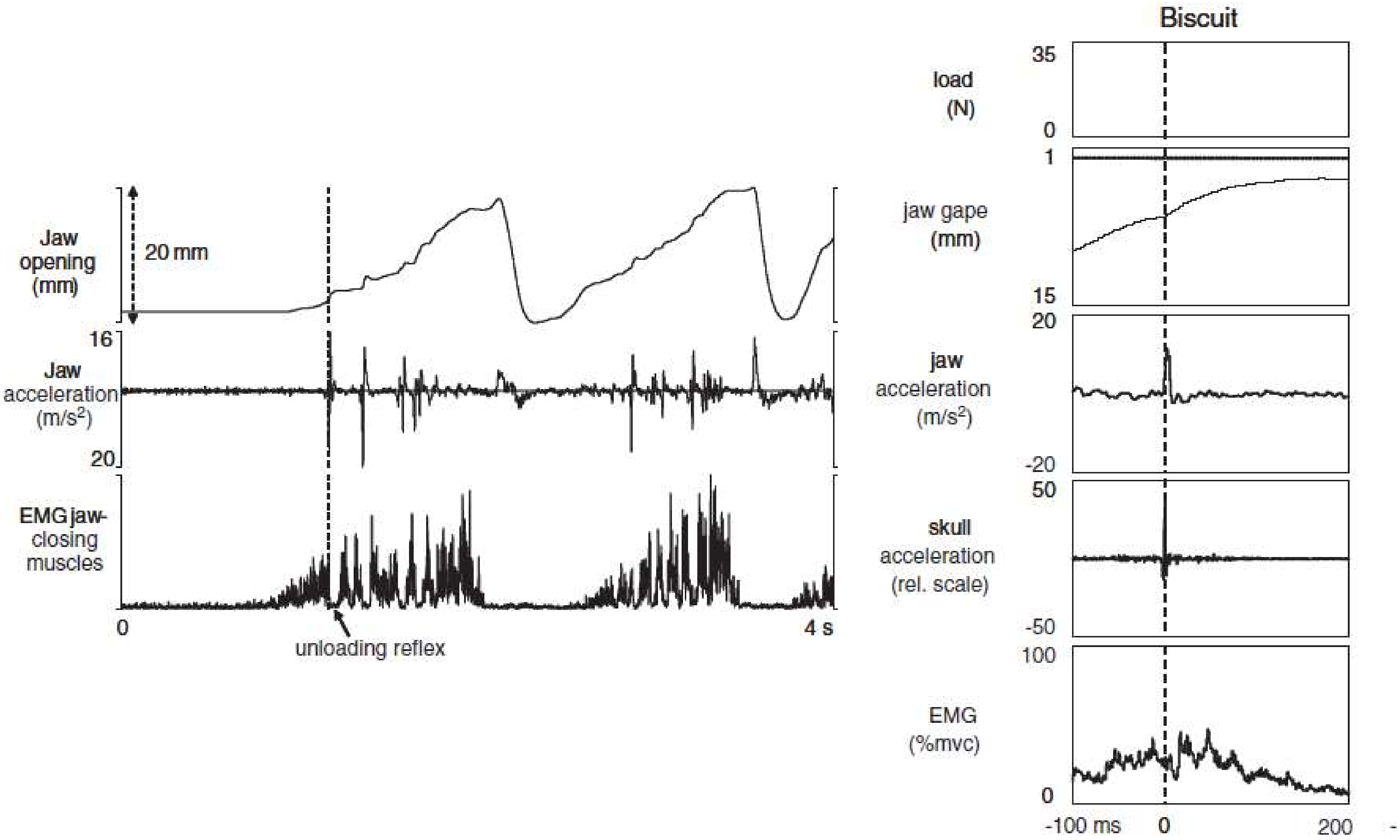


ORAL PHASE AND SOFT PALATE MOVEMENTS

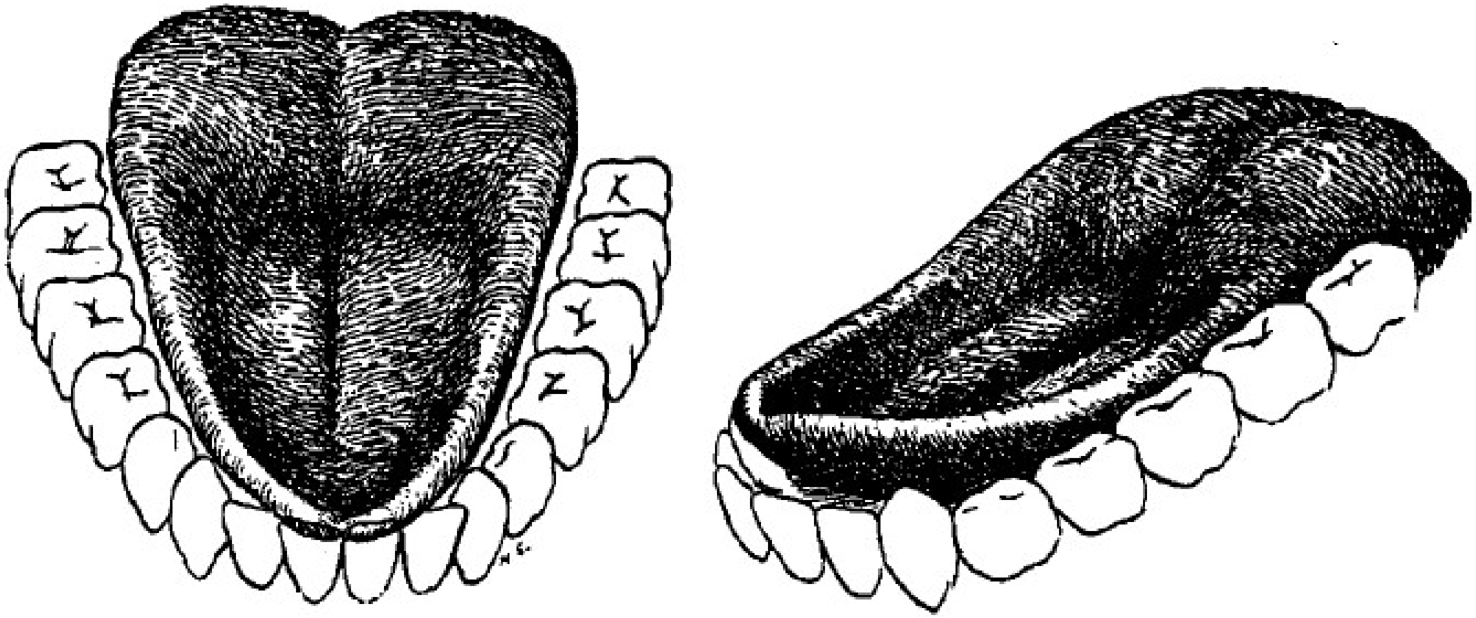


During jaw closure volume of the oral cavity decreases and air is pumped into the nasal cavity

MASTICATION

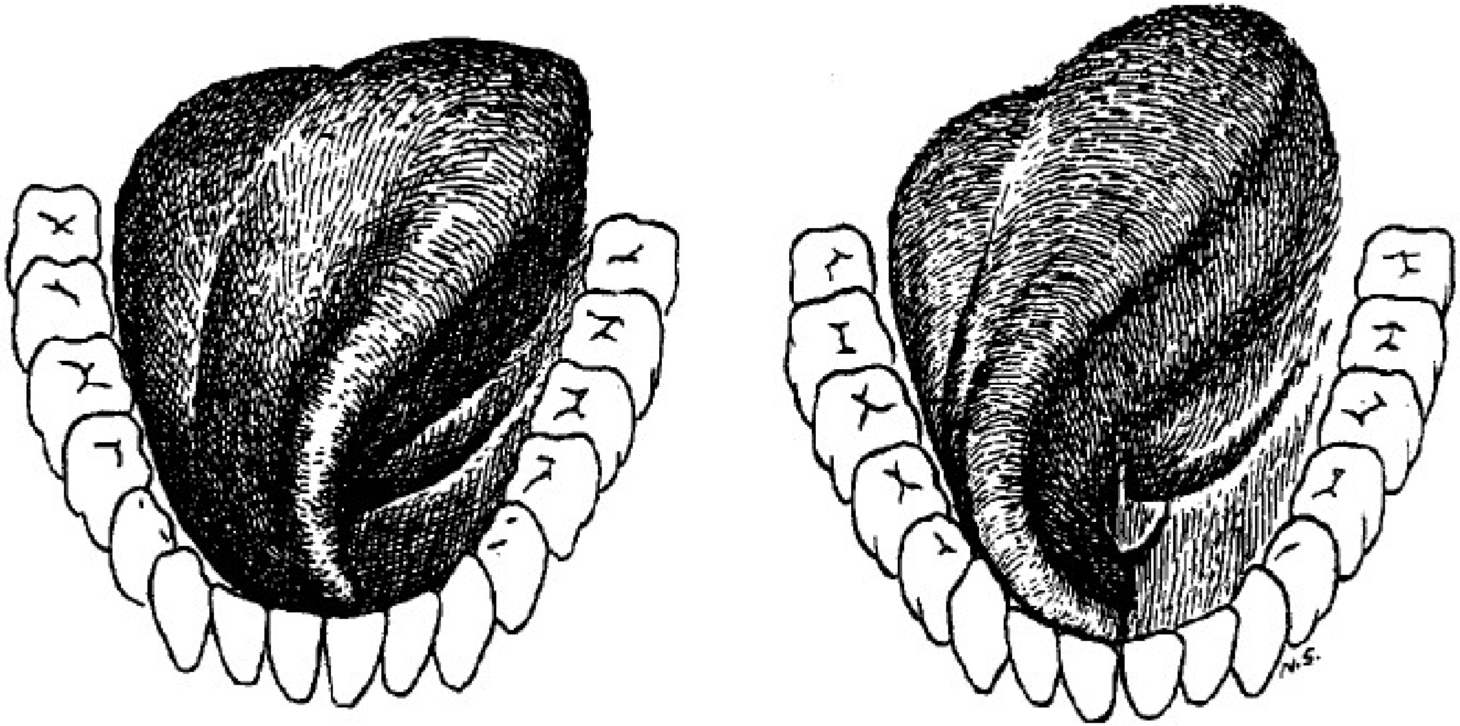


TONGUE POSTURE

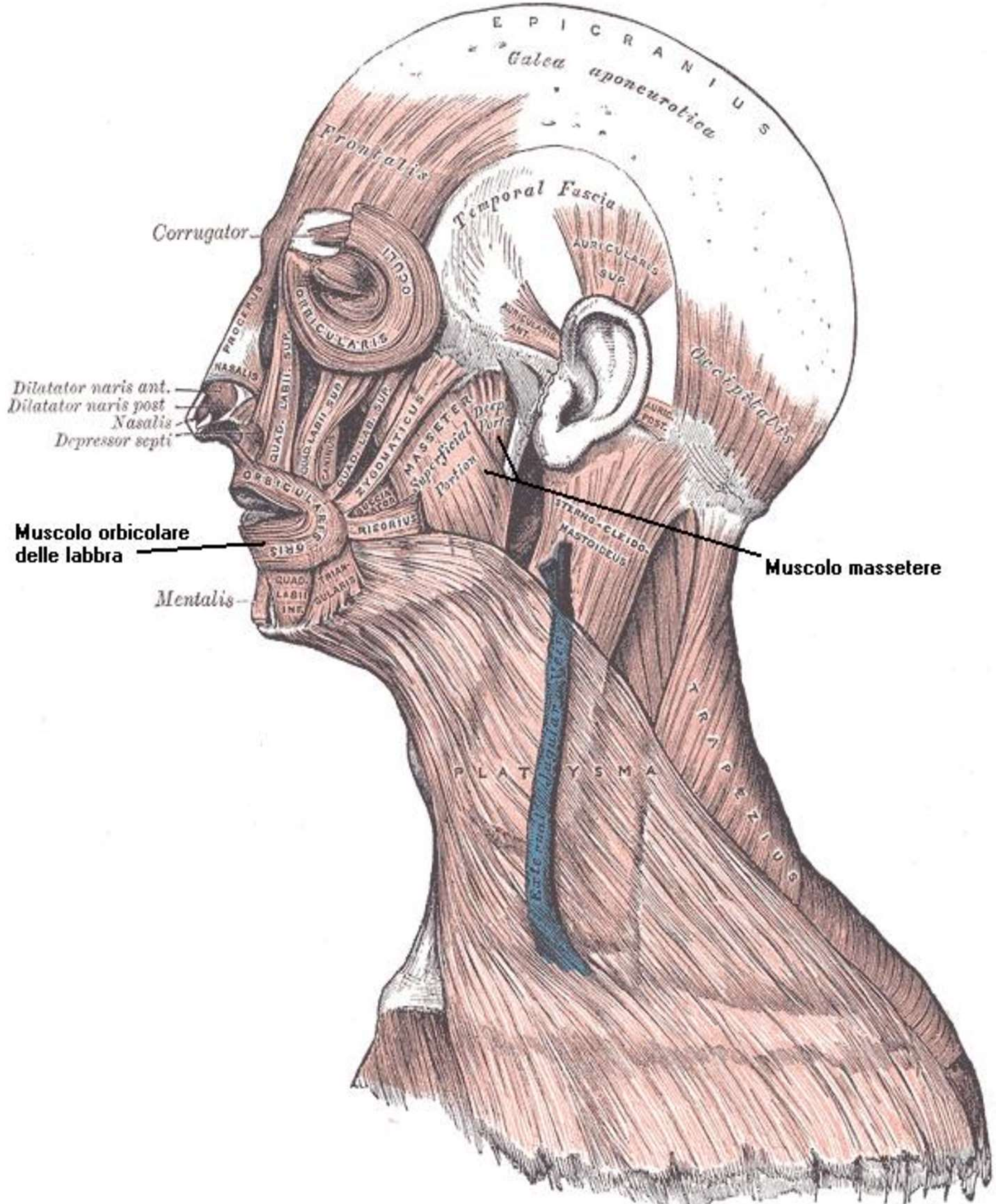


Tongue posture as food is placed in the oral cavity and at the beginning of transport to the oropharynx

TONGUE & MASTICATION



Tongue posture in order to move and remove the food to/from the molar region



EPICRANIUS
Galea aponeurotica
Frontalis
Temporal Fascia
AURICULARIS SUP.
AURICULARIS ANT.
Occipitalis
Corrugator
ORBICULARIS OCULI
PROCERUS
NASALIS
Dilatator naris ant.
Dilatator naris post
Nasalis
Depressor septi
QUAD. LABII SUP.
ZYGOMATICUS
MASSETER
Superficial Portion
ORBICULARIS ORIS
RISORIUS
Muscolo orbicolare
delle labbra
Muscolo massetere
STERNO-CLEIDO-MASTOIDEUS
Mentalis
TRIANGULARIS
PLATYSMA
TRAPEZIUS

Acta Odontologica Scandinavica, 2006; 64: 193–201

Taylor & Francis
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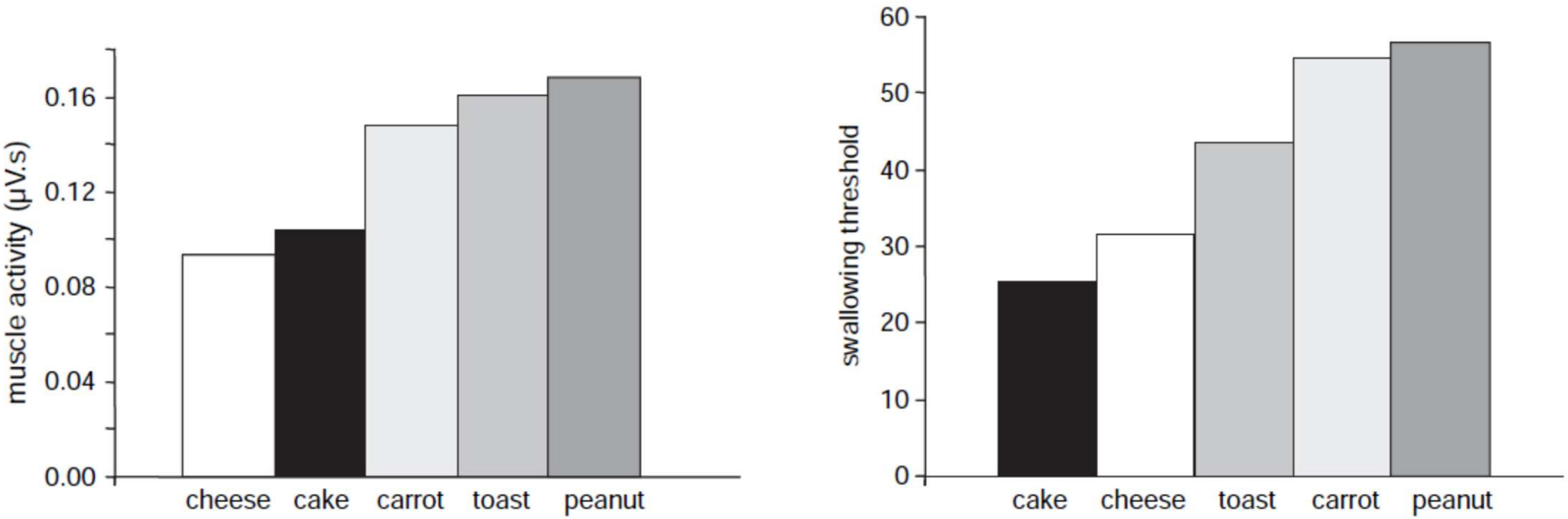
REVIEW

Influence of oral characteristics and food products on masticatory function

LUCIANO JOSE PEREIRA[1], MARIA BEATRIZ DUARTE GAVIAO[2] & ANDRIES VAN DER BILT[3]



Physiology & Behavior 194 (2018) 456–465

Contents lists available at ScienceDirect

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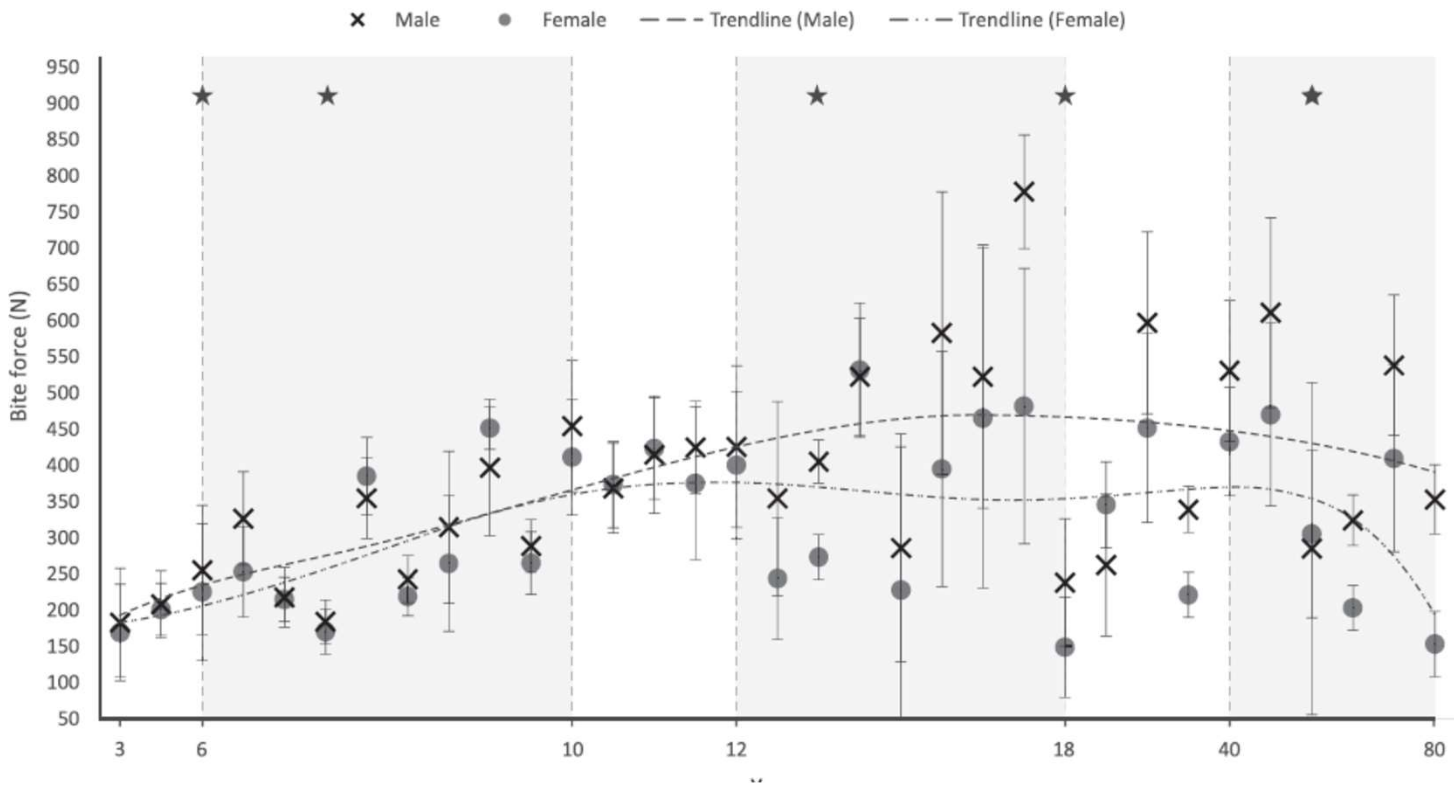
Review

Development of the jaw sensorimotor control and chewing - a systematic review

N. Almotairy[a,b,c,*], A. Kumar[a,b], M. Trulsson[a,b], A. Grigoriadis[a,b]



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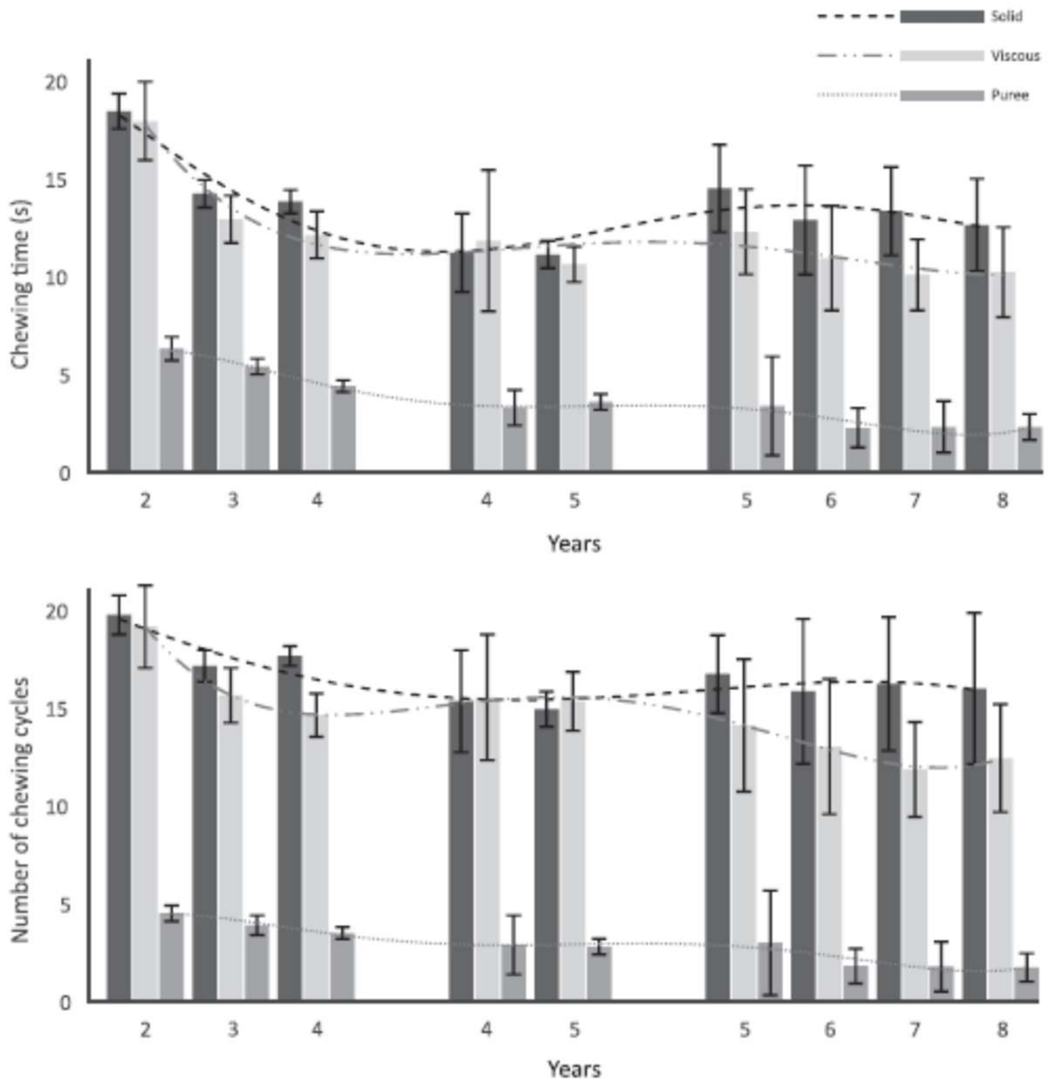


Crecker
Raisin
Apple juice

ELSEVIER

Physiology & Behavior 89 (2006) 28 – 35

PHYSIOLOGY & BEHAVIOR

Adaptation of healthy mastication to factors pertaining to the individual or to the food

A. Woda [a,*], K. Foster [a,b], A. Mishellany [a], M.A. Peyron [c]

		Number of cycles	Sequence duration	EMG activity /sequence	EMG activity /cycle	Masticatory frequency	Vertical amplitude	Lateral amplitude	Closing velocity
Extrinsic factors	Hardness (from soft to hard)	↗ 10, 65, 66, 79, 81, 83	↗ 10, 25, 79, 83, 100	↗ 10, 65, 79, 83	↗ 10, 65, 78, 83	= 10, 79, 80, 83	→ 9, 10, 69, 79, 83, 84	→ 10, 81, 98	↘ 10, 32
	Physical properties (from elastic to plastic)	= 83	= 83	= 83	= 83	↘ 83	↗ 83	↗ 83	↗ 83
	Sample size	↗ 6, 84–86	↗ 6	↗ 82, 85, 88			↗ 6, 71, 85, 89	→ 85, 89	↗ 6, 87, 89
Intrinsic factors	Age	↗ 39, 44, 49	↗ 39, 44, 49	↗ 39, 49	Depends on food 39, 49	= 39	= 39	= 39, 50	
	Gender (from female to male)	= 36–39	= 39	↗ 39	= 38, 39	→ 36, 38, 39, 94	↗ 36–39	↗ 36	↗ 36,37
	Tooth loss (edentate)	↗ 48, 101	↗ 48	↗ 48	Depends on food 48, 56, 99	↘ * 48, 56, 101, 102			↘ 101

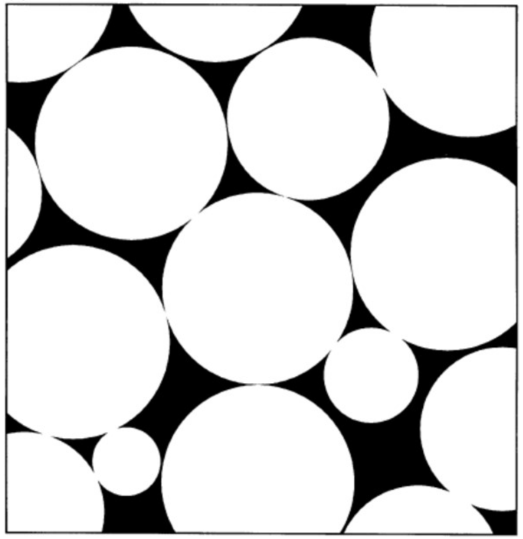
An optimization model for mastication and swallowing in mammals

JON F. PRINZ*† AND PETER W. LUCAS
Department of Anatomy, The University of Hong Kong, Li Shu Fan Building, 5 Sassoon Road, Hong Kong

Both comminution and lubrication take place during mastication

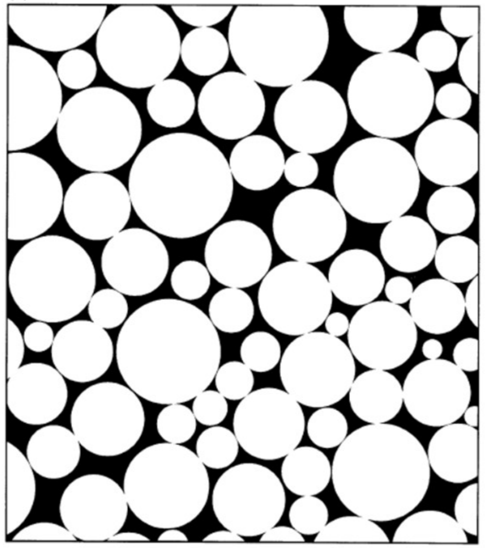
Chewing cause particle size reduction, while salivation fills the gradually reducing spacies between particles

(a)



Early mastication

(b)



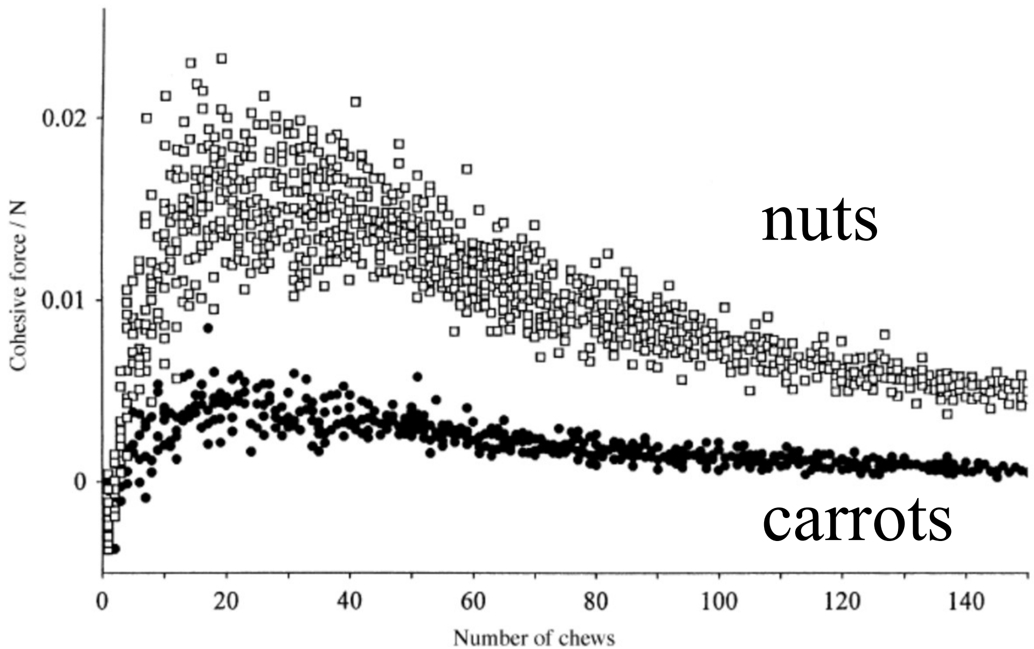
Late mastication

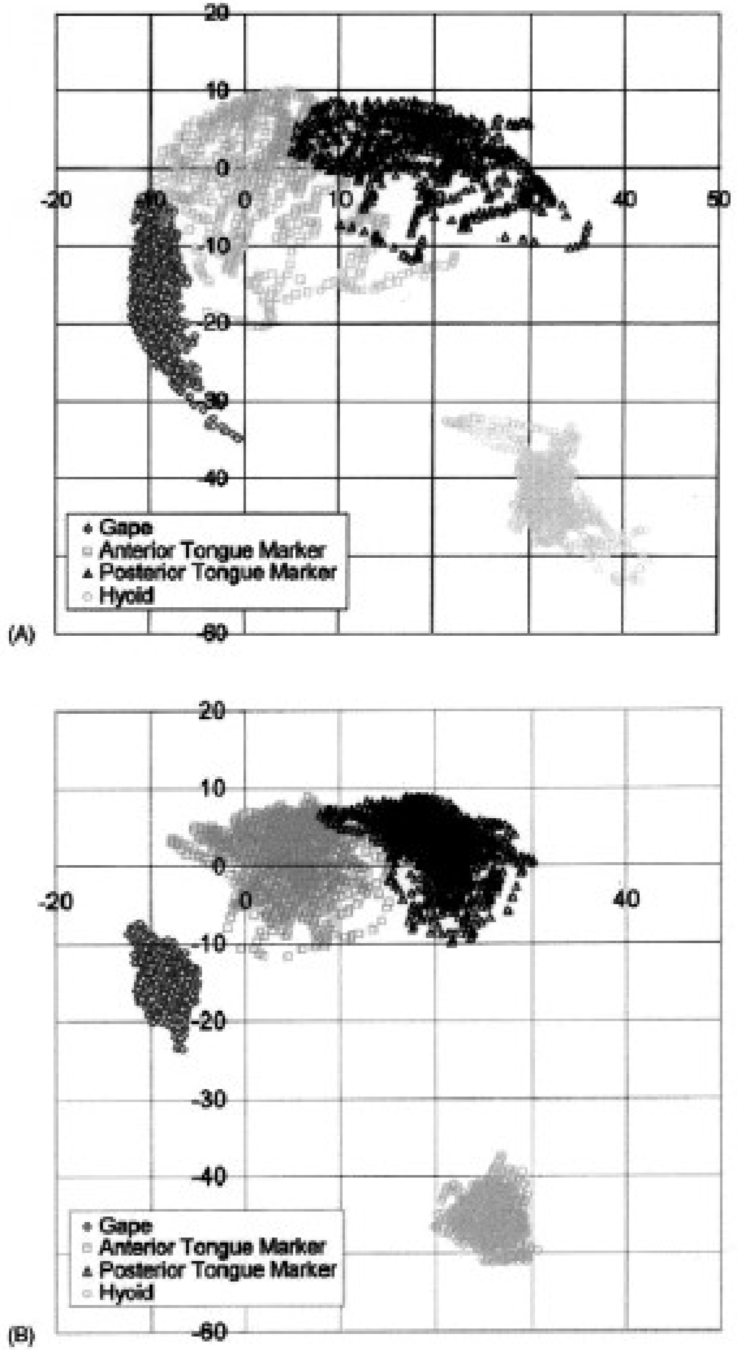
An optimization model for mastication and swallowing in mammals

JON F. PRINZ*† AND PETER W. LUCAS

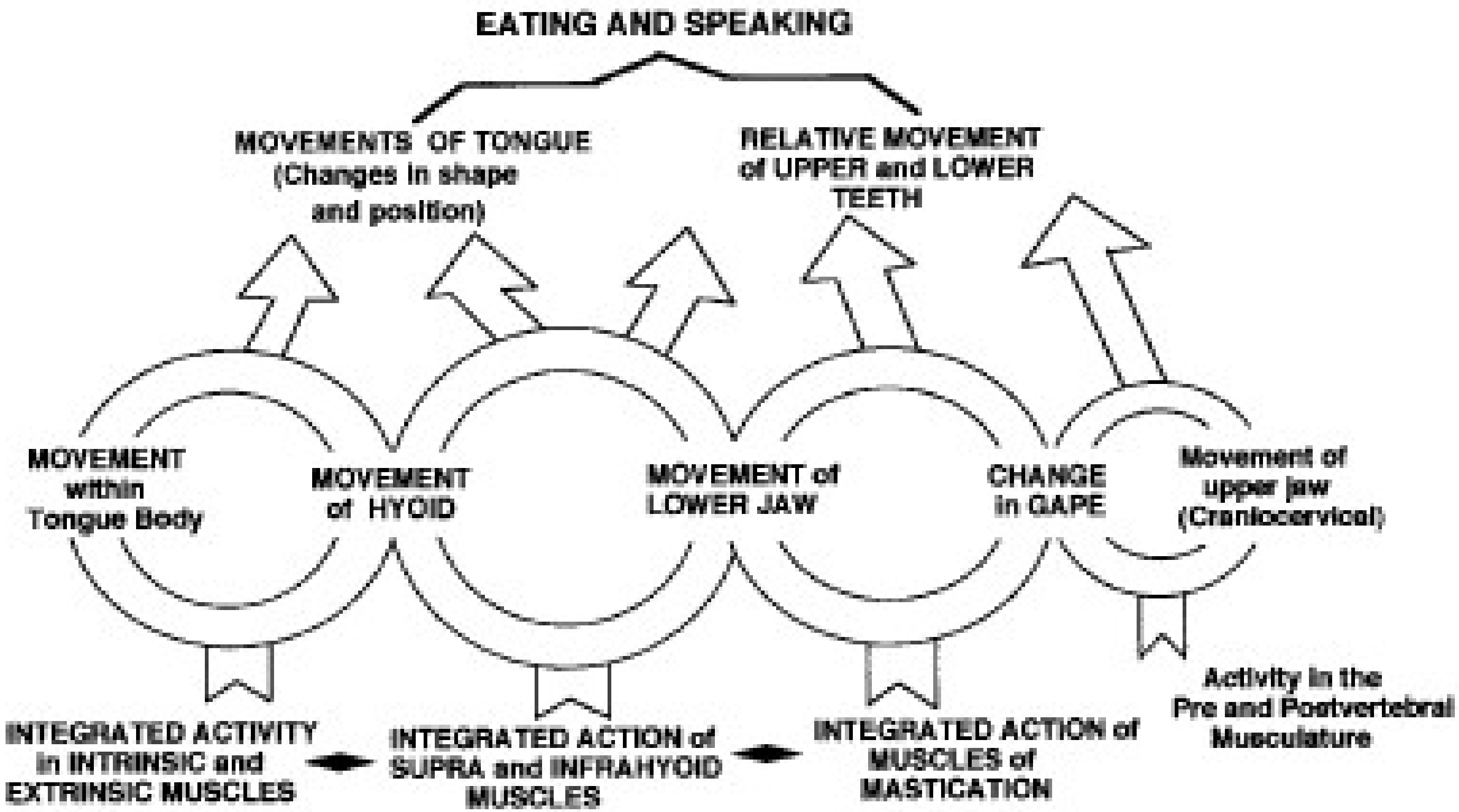
Department of Anatomy, The University of Hong Kong, Li Shu Fan Building, 5 Sassoon Road, Hong Kong

Optimal time to trigger swallow is when there is a peak in cohesive forces (saliva related)

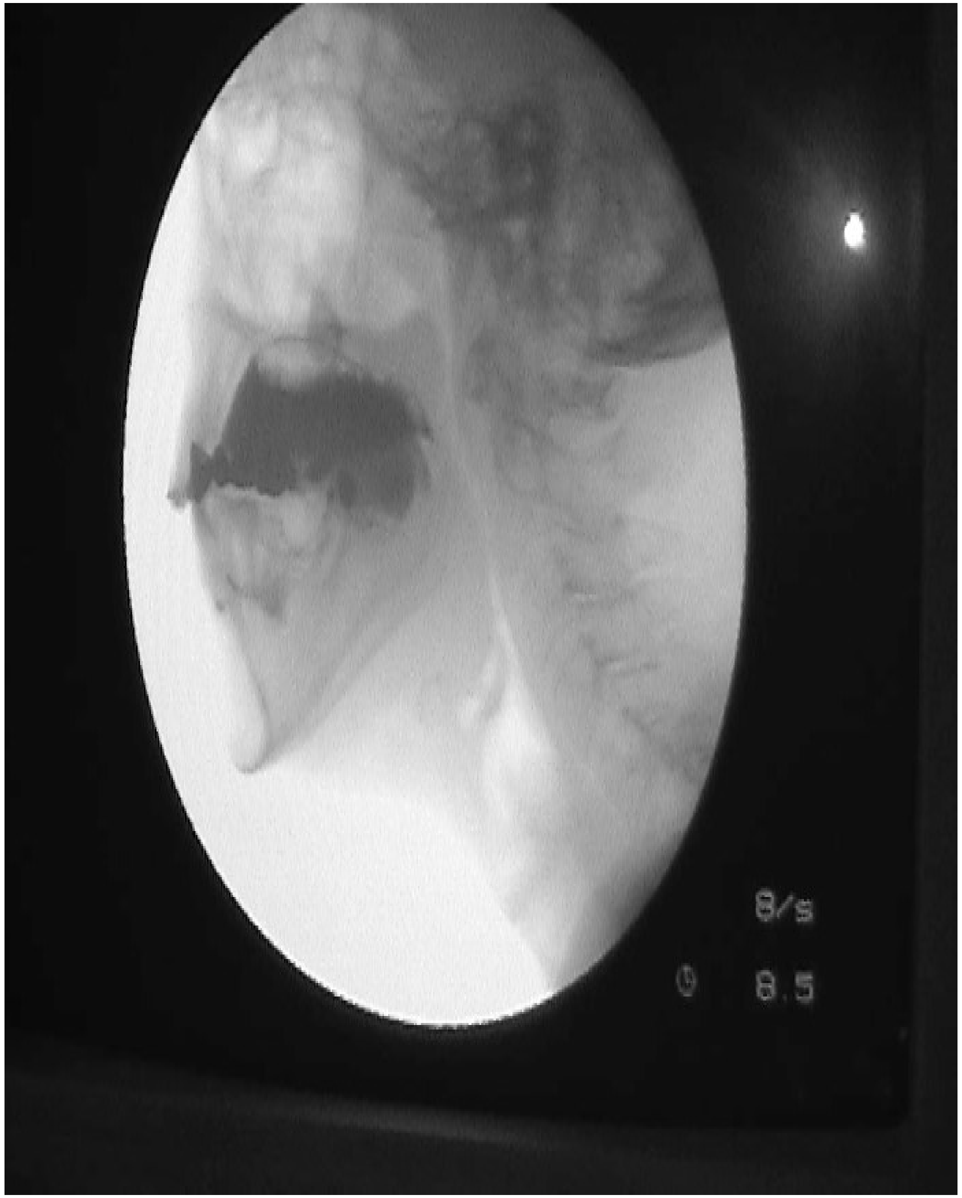




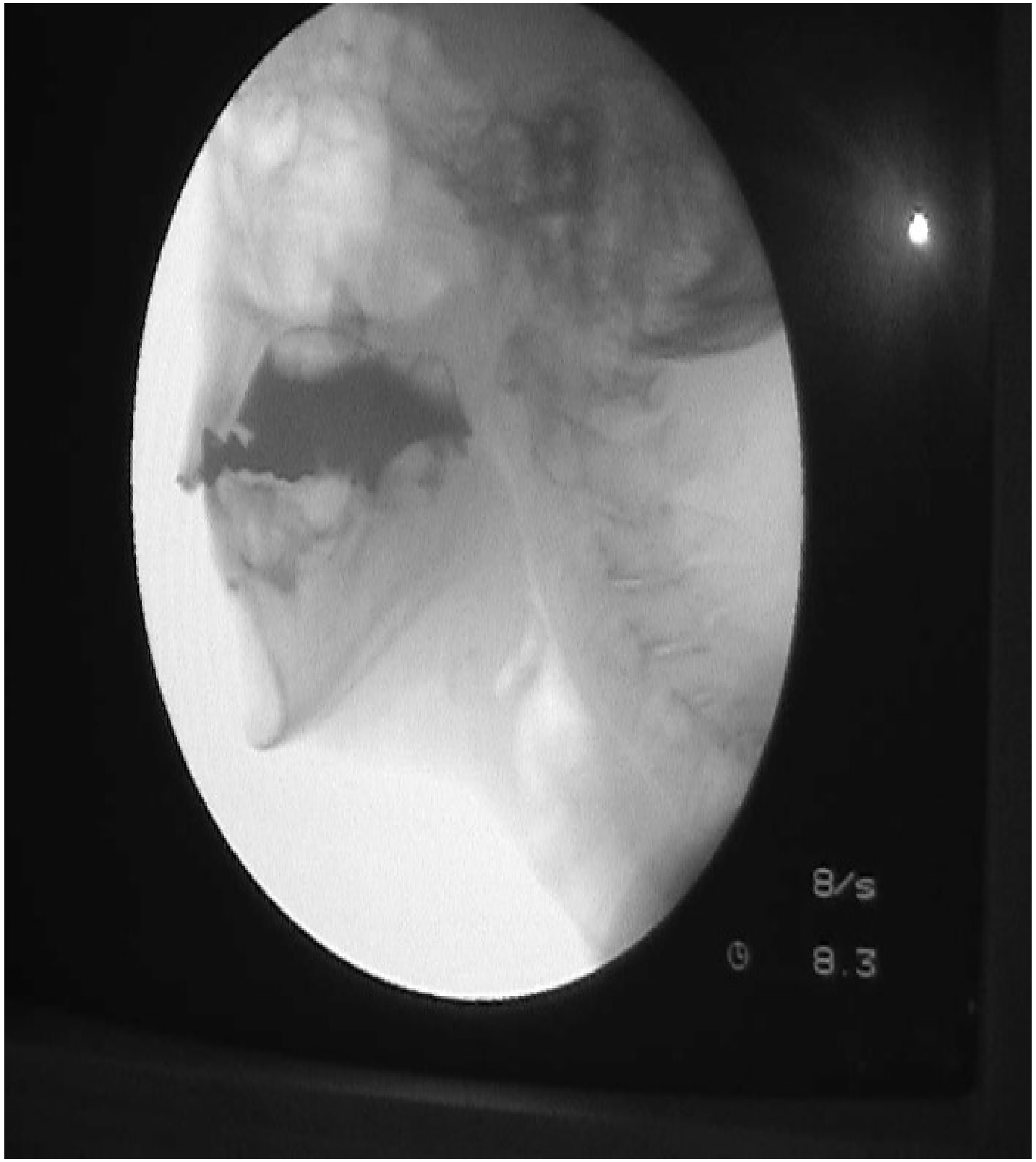
TONGUE IN SWALLOWING AND SPEAKING

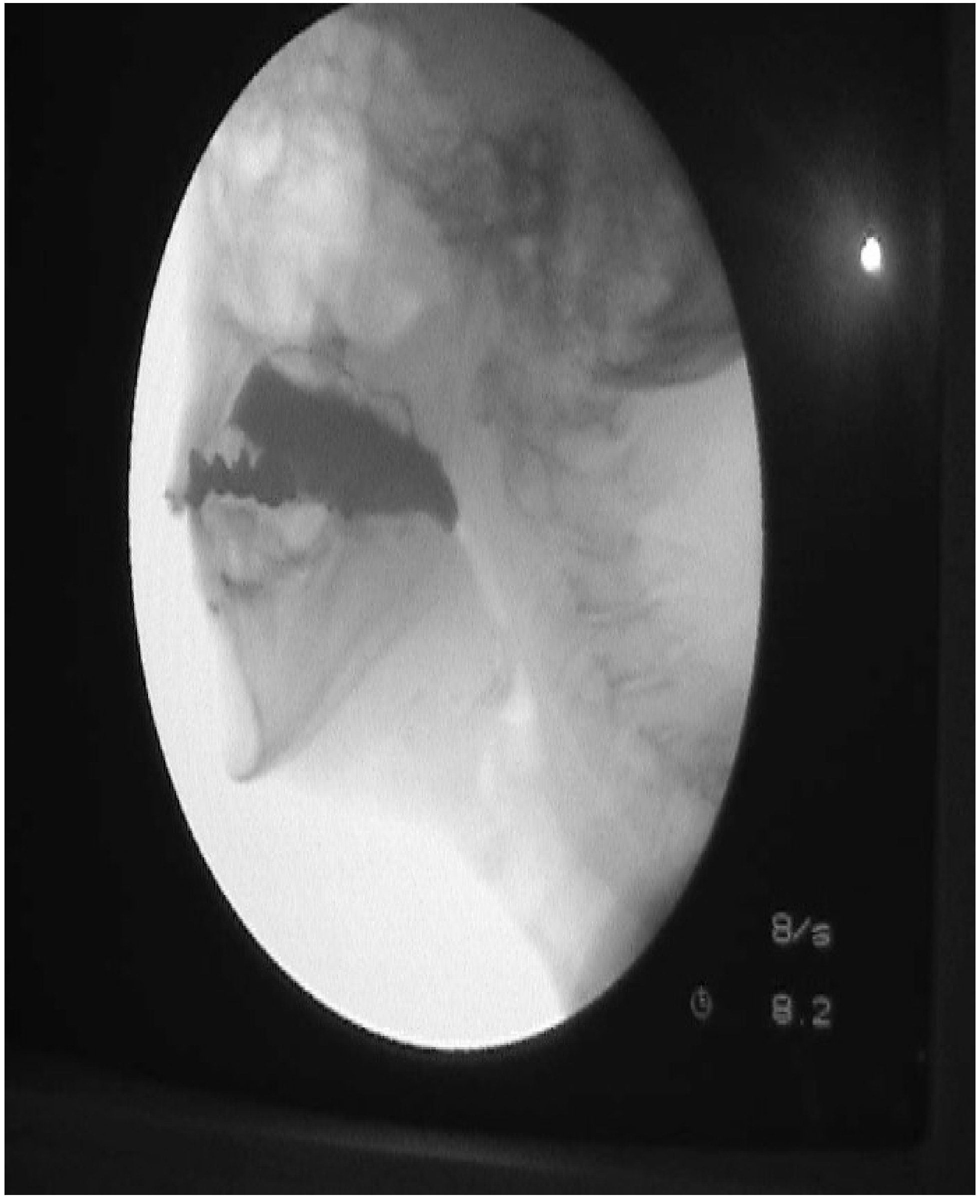

EATING AND SPEAKING
MOVEMENTS OF TONGUE
(Changes in shape
and position)
RELATIVE MOVEMENT
of UPPER and LOWER
TEETH
MOVEMENT
within
Tongue Body
MOVEMENT
of HYOID
MOVEMENT of
LOWER JAW
CHANGE
in GAPE
Movement of
upper jaw
(Craniocervical)
Activity in the
Pre and Postvertebral
Musculature
INTEGRATED ACTIVITY
in INTRINSIC and
EXTRINSIC MUSCLES
INTEGRATED ACTION of
SUPRA and INFRAHYOID
MUSCLES
INTEGRATED ACTION of
MUSCLES of
MASTICATION

ORAL PHASE



ORAL – PHARINGEAL PHASE





TAKE HOME MESSAGE

The oral phase is the most complex sensory-motor action of deglutition

Nonetheless, it is usually not difficult to understand and remember as it is higly conscious

The tongue action is of key importance in both bolus transport and bolus maintenance within the oral cavity

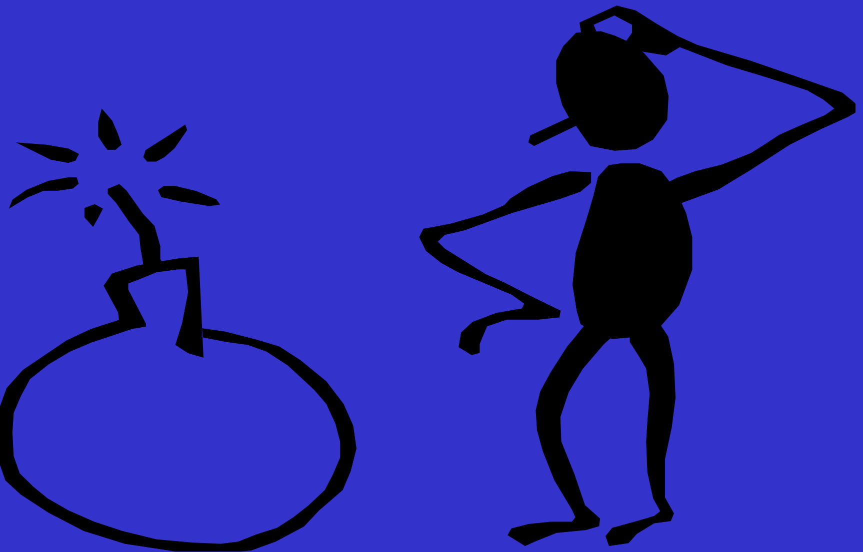
OUTLINE

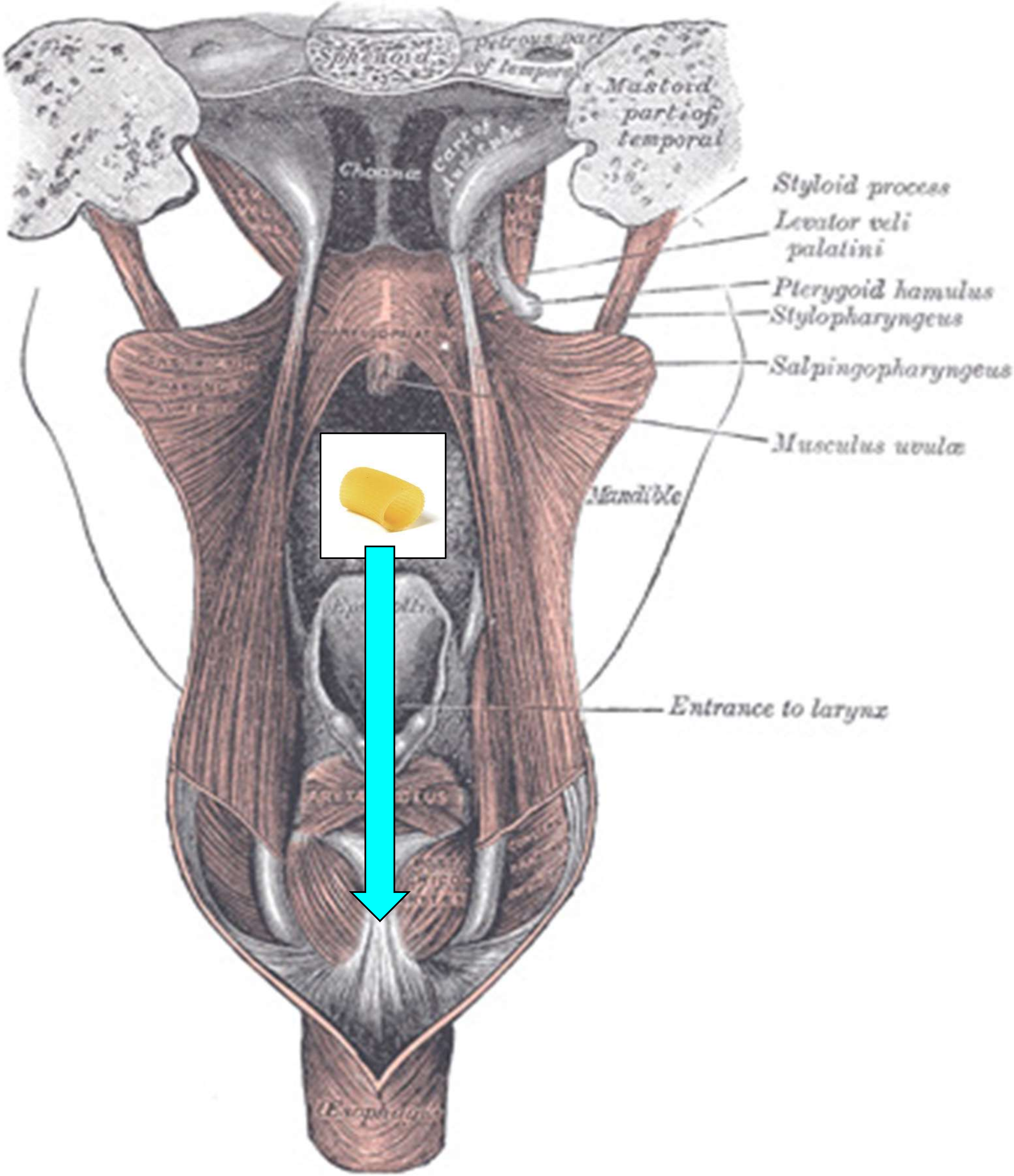
- Swallowing and body functions
- The oral phase
- The pharyngeal phase
- The esophageal phase
- The neural circuites underlying swallowing
- Swallowing physiology in the elderly

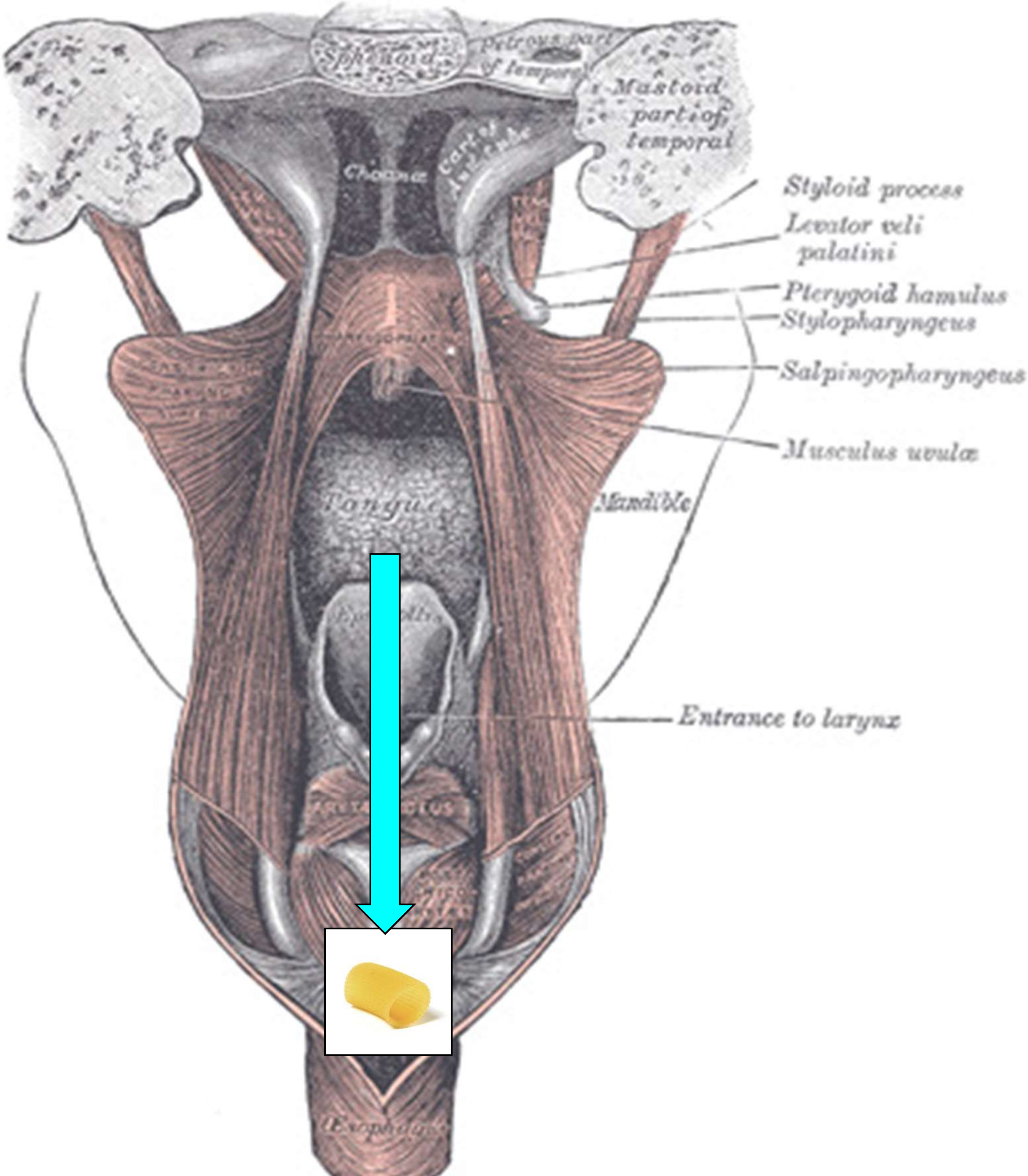
PHARYNGEAL PHASE

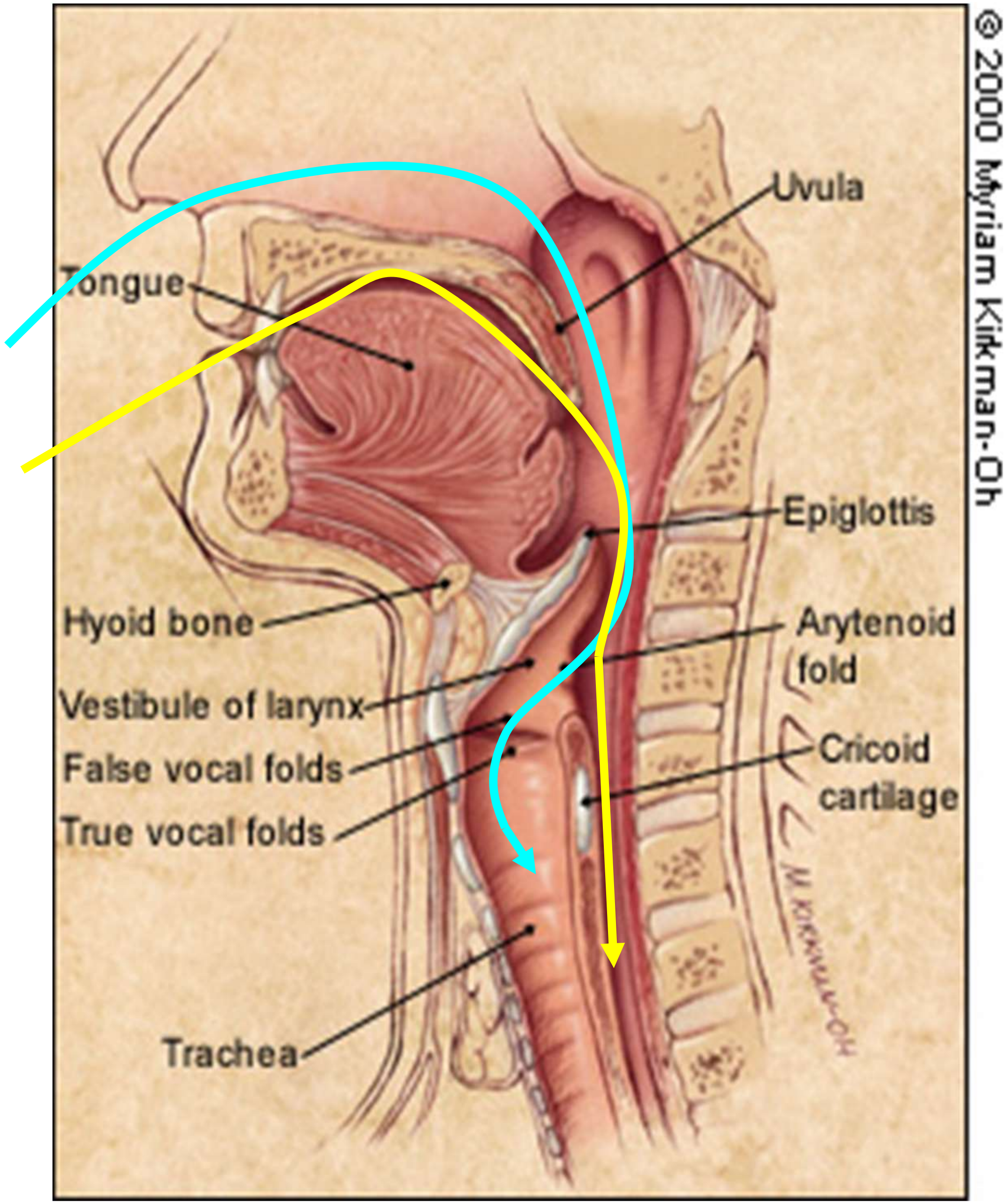
The bolus moves from the oral cavity into the esophagus

The bolus passes the aero-digestive cross




Sphenoid
Petrous part of temporal
Mastoid part of temporal
Choanæ
Styloid process
Levator veli palatini
Pterygoid hamulus
Stylopharyngeus
Salpingopharyngeus
Musculus uvulæ
Mandible
Epiglottis
Entrance to larynx
Œsophagus


Sphenoid
Petrous part of temporal
Mastoid part of temporal
Choanæ
Tongue
Mandible
Styloid process
Levator veli palatini
Pterygoid hamulus
Stylopharyngeus
Salpingopharyngeus
Musculus uvulæ
Entrance to larynx

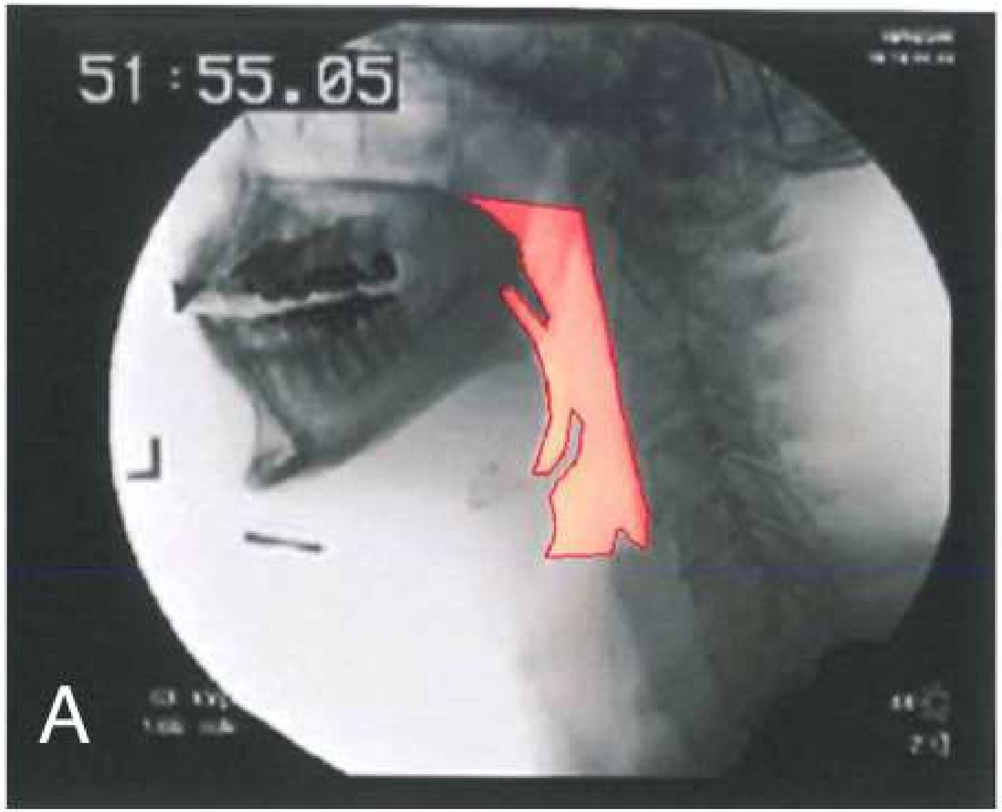


AIRWAY

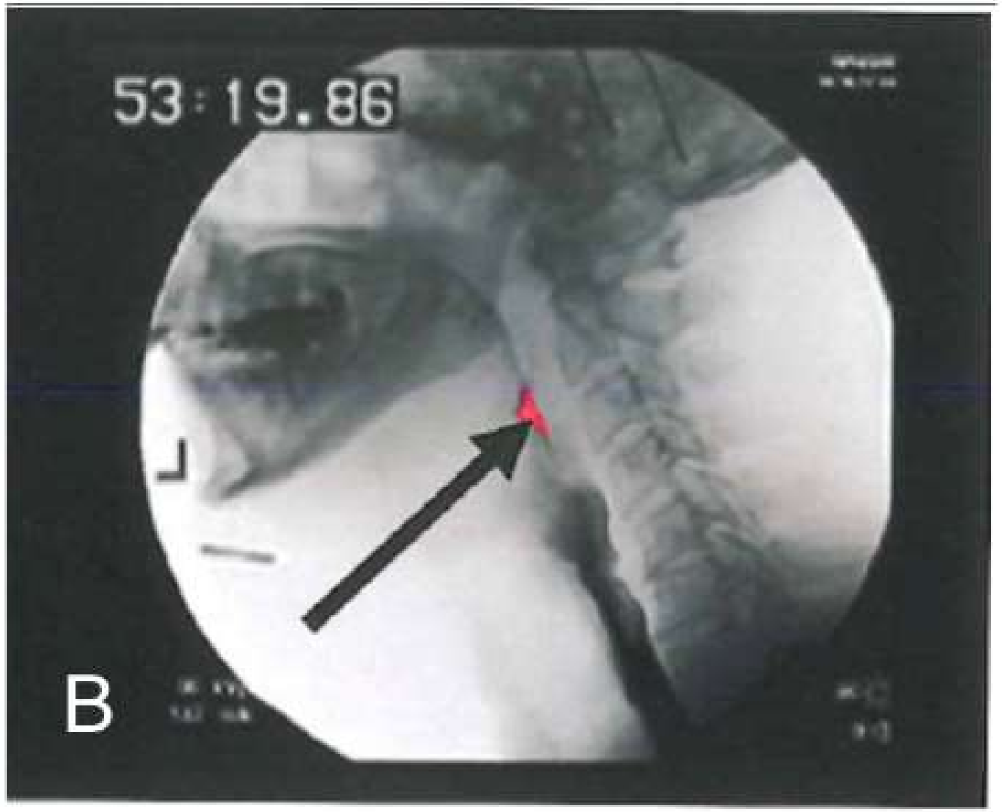
FOOD WAY

CHANGE IN PHARYNGEAL CONFIGURATION

Respiratory configuration



Swallowing configuration



Dysphagia (2019) 34:192–200
https://doi.org/10.1007/s00455-018-9961-0

ORIGINAL ARTICLE

Effect of Age, Sex, Bolus Volume, and Bolus Consistency on Whiteout Duration in Healthy Subjects During FEES

Francesco Mozzanica[1,2] · Rosaria Lorusso[2] · Carlo Robotti[2] · Tania Zambon[2] · Pietro Corti[2] · Nicole Pizzorni[2] · Jan Vanderwegen[3] · Antonio Schindler[2]

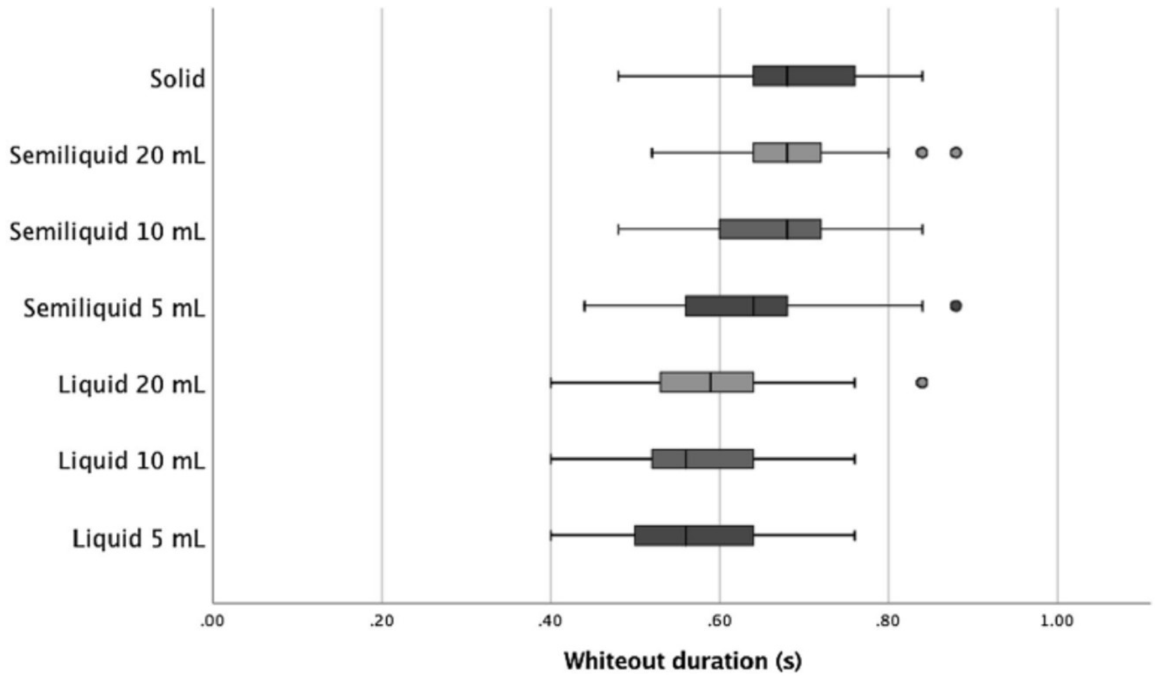


Table 2 Intrarater and interrater reliability obtained using the two-way random Intraclass Correlation Coefficient (ICC). Interquartile ranges are reported in brackets

Interrater	Intrarater		
Rater 1 test–retest	Rater 1 versus rater 2	Rater 1 versus rater 3	Rater 2 versus rater 3
0.985 (0.98–0.987)	0.982 (0.980–0.984)	0.992 (0.990–0.993)	0.961 (0.951–0.971)

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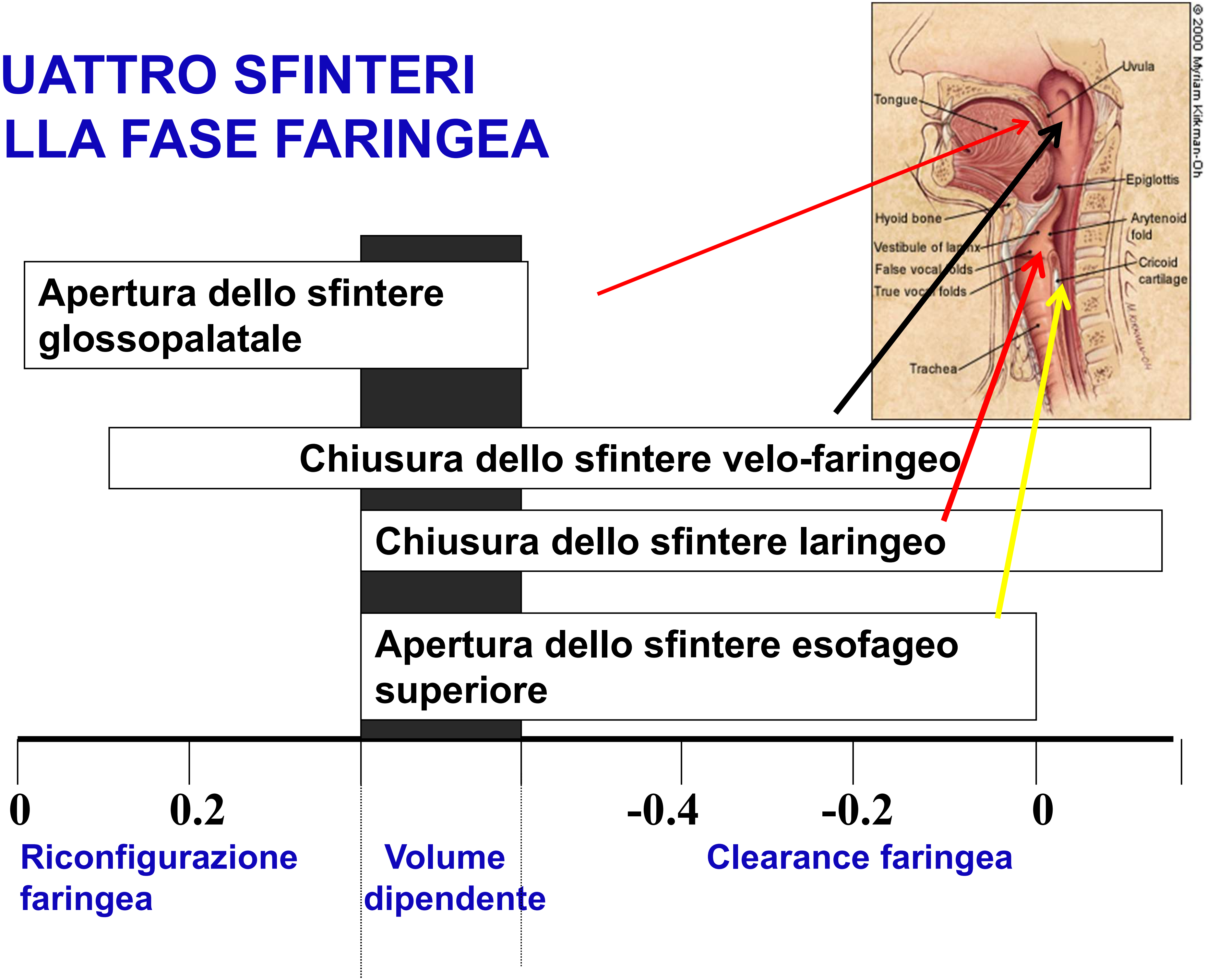
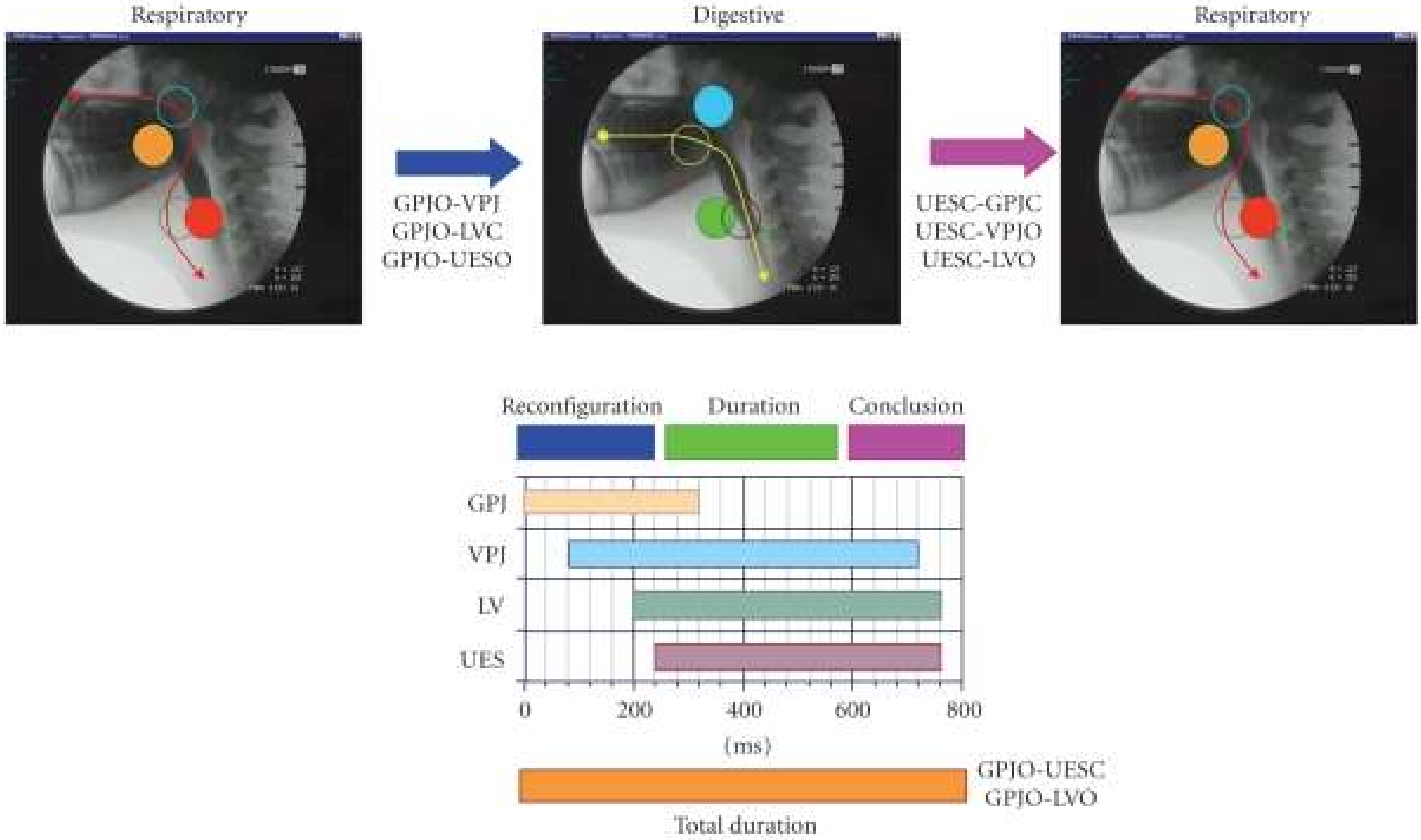
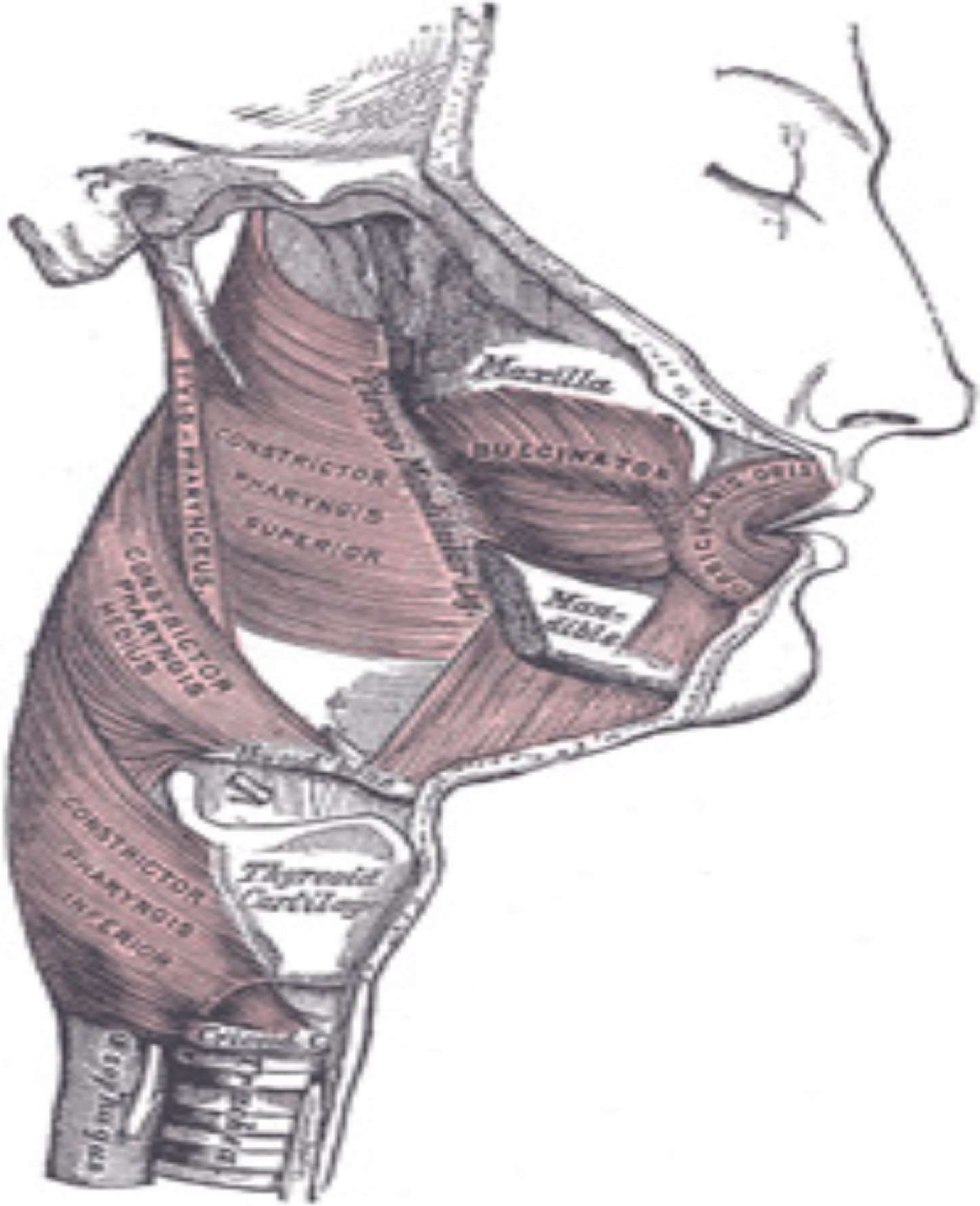


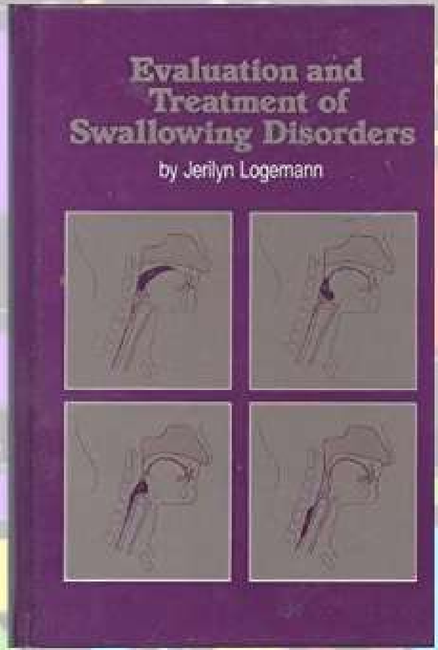


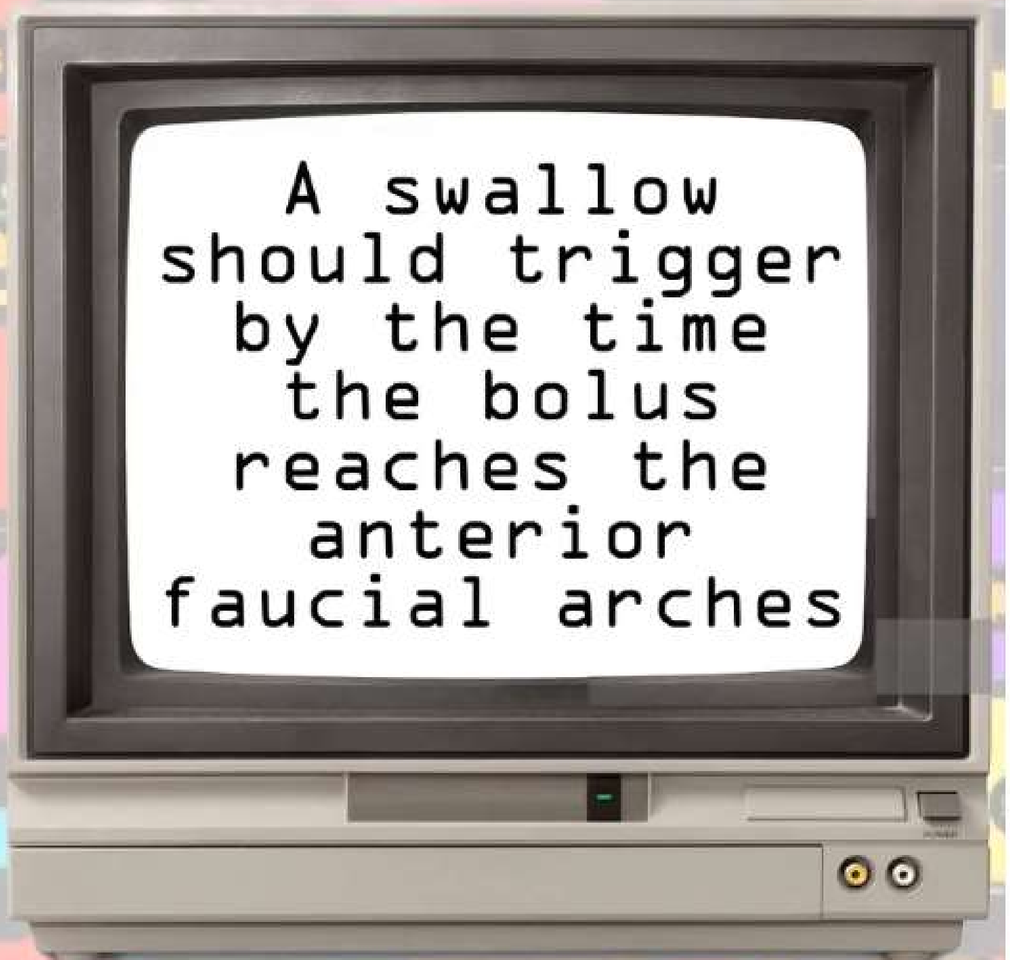
Respiratory
Digestive
Respiratory
GPJO-VPJ
GPJO-LVC
GPJO-UESO
UESC-GPJC
UESC-VPJO
UESC-LVO
Reconfiguration
Duration
Conclusion
GPJ
VPJ
LV
UES
0
200
400
600
800
(ms)
GPJO-UESC
GPJO-LVO
Total duration



Maxilla
BUCCINATOR
ORBICULARIS ORIS
CONSTRICTOR PHARYNGIS SUPERIOR
STYLO-PHARYNGEUS
CONSTRICTOR PHARYNGIS MEDIUS
Man-dible
Thyroid Cartilage
CONSTRICTOR PHARYNGIS INFERIOR

1983


Evaluation and Treatment of Swallowing Disorders
by Jerilyn Logemann


A swallow should trigger by the time the bolus reaches the anterior faucial arches

Triggering of the Pharyngeal Swallow

1998

As the tongue movement propels the bolus posteriorly, sensory receptors in the oropharynx and tongue itself (particularly deep proprioceptive receptors) are stimulated, sending sensory information to the cortex and brainstem. It is hypothesized that a sensory recognition center in the lower brainstem (medulla) in the nucleus tractus solitarus decodes the incoming sensory information and identifies the swallow stimulus, sending this information to the nucleus ambiguous, which initiates the pharyngeal swallow motor pattern (Doty, Richmond, & Storey, 1967; Miller, 1972). When the leading edge of the bolus, or the "bolus head," passes any point between the anterior faucial arches and the point where the tongue base crosses the lower rim of the mandible (see Figure 2.14), the oral stage of the swallow is terminated and the pharyngeal swallow should be triggered. If the pharyngeal stage is not triggered by that time, the pharyngeal swallow is said to be delayed. In the first edition of this book, the trigger point for the pharyngeal swallow was defined as the anterior faucial arch. This was based on studies of young and middle-aged adults. The point of triggering of the pharyngeal swallow has been lowered in response to more recent observations of older normal swallowers whose pharyngeal swallow triggers when the bolus head has reached the lower level (Robbins, Hamilton, Lof, & Kempster, 1992; Tracy et al., 1989). Individuals of all ages should trigger the pharyngeal swallow by the time the bolus head reaches the point where the mandible crosses the tongue base, as seen radiographically.

In younger, normal individuals, the triggering of the pharyngeal swallow occurs at the anterior faucial arch, and timing is such that posterior movement of the bolus is not interrupted (Jean & Car, 1979; Lederman, 1977; Tracy et al., 1989). There is no pause in bolus movement while the pharyngeal swallow triggers. Pommerenke (1928) and others have established the base of the anterior faucial pillars as the most sensitive place for elicitation of the pharyngeal swallow. Hollshwandner, Brenman, and Friedman (1975) and Storey (1976) postulated receptors in the tongue, epiglottis, and larynx as additional centers for elicitation of the pharyngeal swallow. Older (over age 60) normal individuals are not seen to trigger the pharyngeal swallow until the bolus head reaches approximately the middle of the tongue base (Robbins et al., 1992; Tracy et al., 1989). Observations of neurologically impaired patients corroborate these vari-

2007

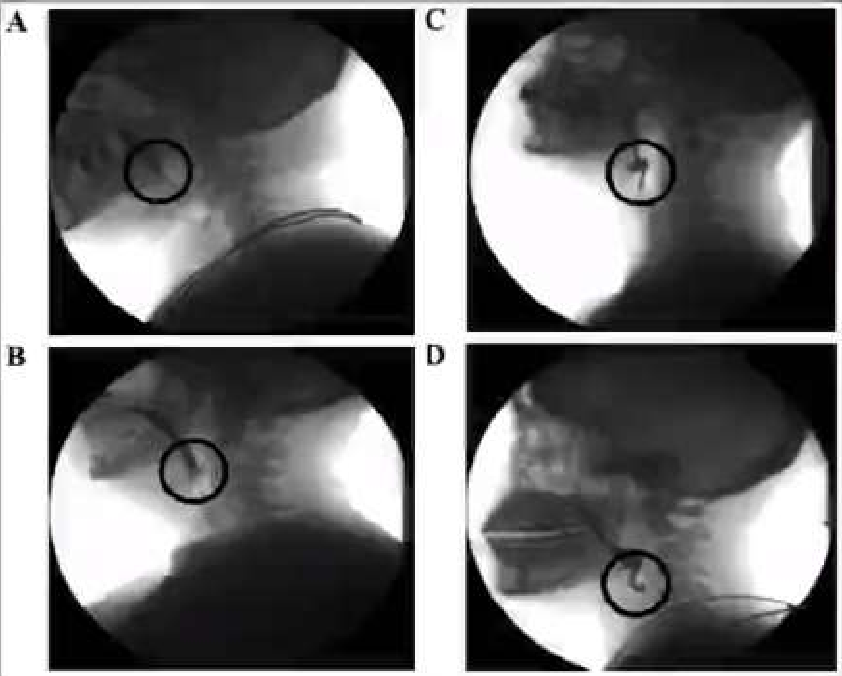
Delayed Initiation of the Pharyngeal Swallow: Normal Variability in Adult Swallows

Bonnie Martin-Harris
Medical University of South Carolina

Martin B. Brodsky
Medical University of South Carolina and University of Pittsburgh

Yvonne Michel
Fu-Shing Lee
Bobby Walters
Medical University of South Carolina

Purpose: The purpose of this investigation was to determine bolus head timing and location relations with the onset of hyoid movement at the initiation of the pharyngeal swallow and at the onset of swallow-related apnea.
Method: Bolus head timing and location and the timing of swallow-related apnea were recorded from frame-by-frame analyses of 5 ml single liquid swallows using dual-modality videofluoroscopy and nasal airflow recordings in 82 consecutive, healthy volunteers. The presence, depth, and response to airway entry were also recorded and related to the bolus head location and the onset of hyoid movement.
Results: The majority of participants—80% on at least 1 trial—produced the onset of hyoid movement at pharyngeal swallow initiation after the bolus head passed the



1998

Triggering of the Pharyngeal Swallow

As the tongue movement propels the bolus posteriorly, sensory receptors in the oropharynx and tongue itself (particularly deep proprioceptive receptors) are stimulated, sending sensory information to the cortex and brainstem. It is hypothesized that a sensory recognition center in the lower brainstem (medulla) in the nucleus tractus solitarus decodes the incoming sensory information and identifies the swallow stimulus, sending this information to the nucleus ambiguous, which initiates the pharyngeal swallow motor pattern (Doty, Richmond, & Storey, 1967; Miller, 1972). When the leading edge of the bolus, or the "bolus head," passes any point between the anterior faucial arches and the point where the tongue base crosses the lower rim of the mandible (see Figure 2.14), the oral stage of the swallow is terminated and the pharyngeal swallow should be triggered. If the pharyngeal stage is not triggered by that time, the pharyngeal swallow is said to be delayed. In the first edition of this book, the trigger point for the pharyngeal swallow was defined as the anterior faucial arch. This was based on studies of young and middle-aged adults. The point of triggering of the pharyngeal swallow has been lowered in response to more recent observations of older normal swallowers whose pharyngeal swallow triggers when the bolus head has reached the lower level (Robbins, Hamilton, Lof, & Kempster, 1992; Tracy et al., 1989). Individuals of all ages should trigger the pharyngeal swallow by the time the bolus head reaches the point where the mandible crosses the tongue base, as seen radiographically.

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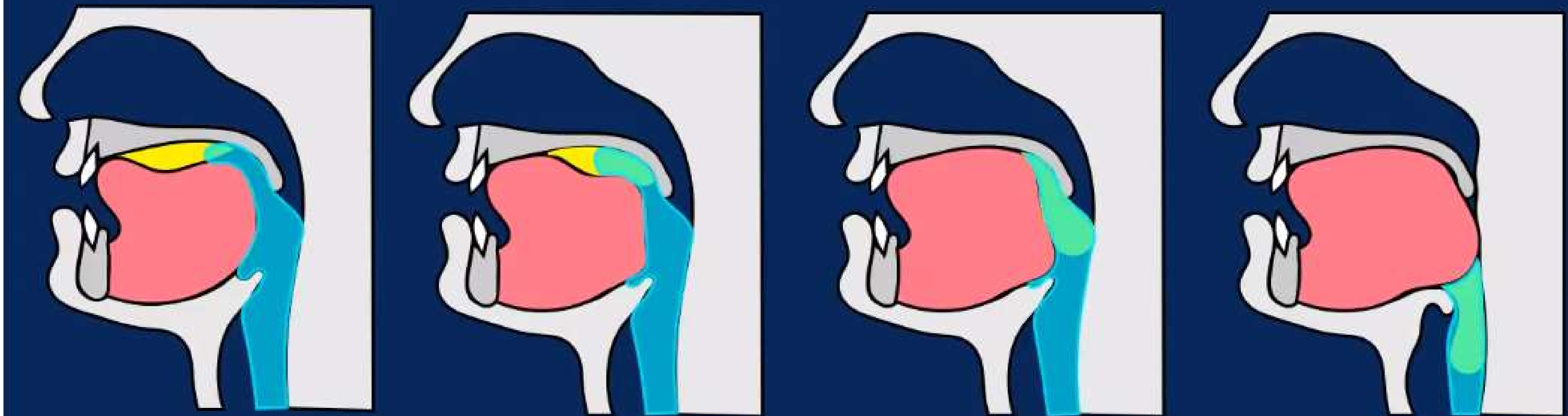
Normal Swallowing Events
Swallow Trigger

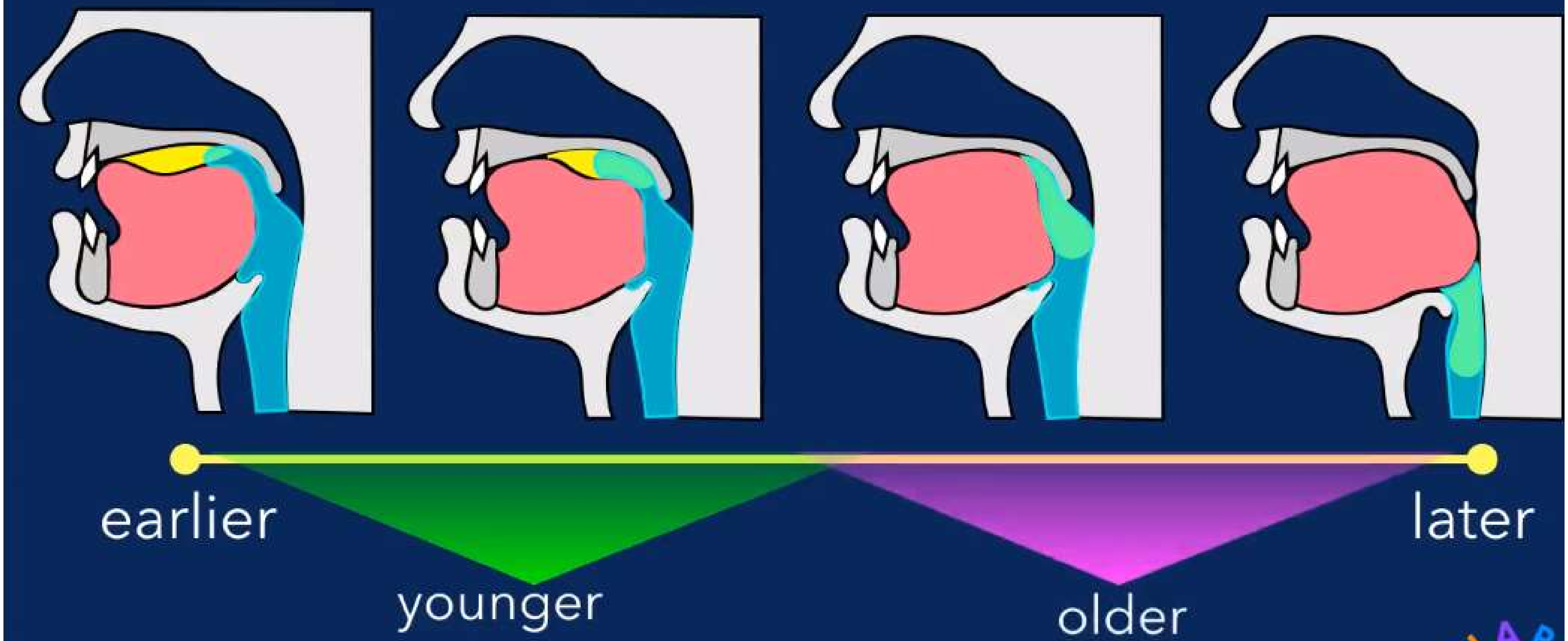


Sensory input via the bolus can trigger a swallow at any point as it travels through the oropharynx.

*Normal Variability

SNAPS

Normal Swallowing Events
Swallow Trigger



FACTORS INFLUENCING PHARYNGEAL PHASE INITIATION

Cued swallow: cued swallow reduceds the likelihood of bolus leading edge in the hypopharynx

Viscosity: high viscosity delay swallow initiation

Taste: sour taste facilitate swallow initiation

Chemestesis: menthos and capsaicin facilitate swallow initiation

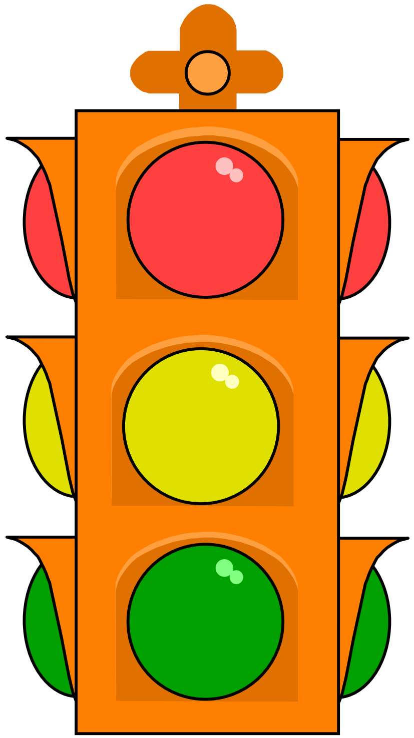
Sequential drinking: bolus leading edge is usually in the vallecule or hypopharynx before swallow initiation

Solid food: bolus leading edge is usually in the vallecule or oropharynx before swallow initiation

Mixed consistency: bolus leading edge is usually in the hypopharynx before swallow initiation

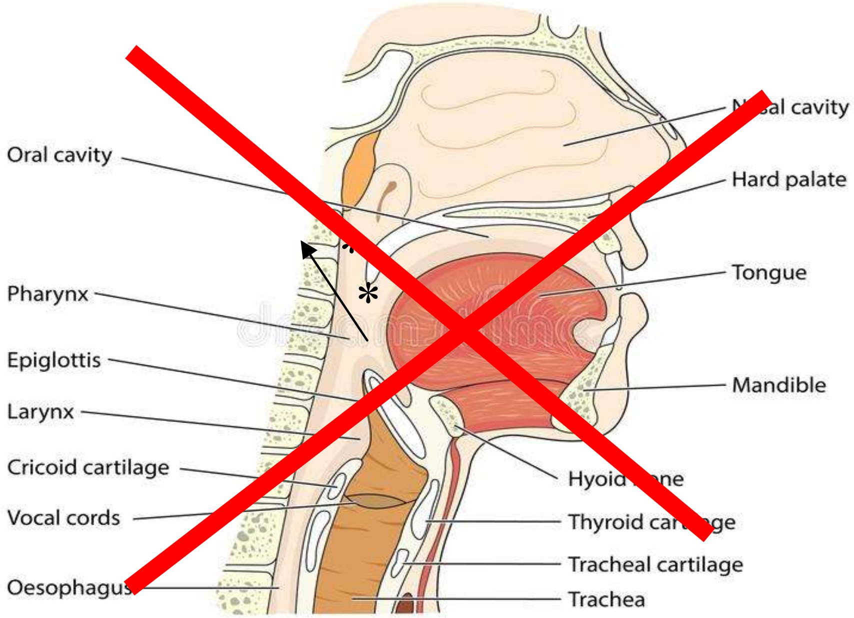
PHARYNGEAL PHASE BIOMECHANICS

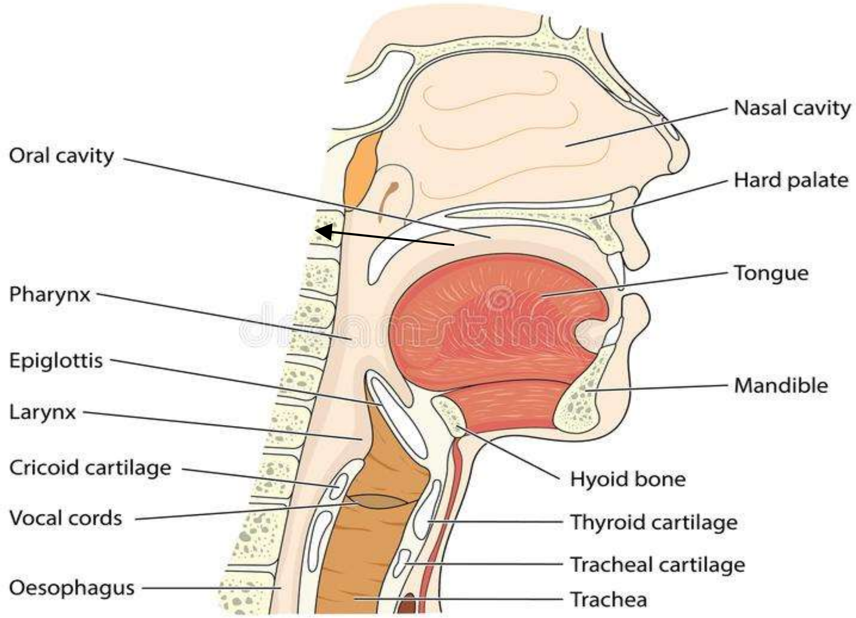
- Velopharyngeal closure
- UES opening
- Laryngeal sphincter closure
- Tongue base back-ward movement
- Pharyngeal clearance



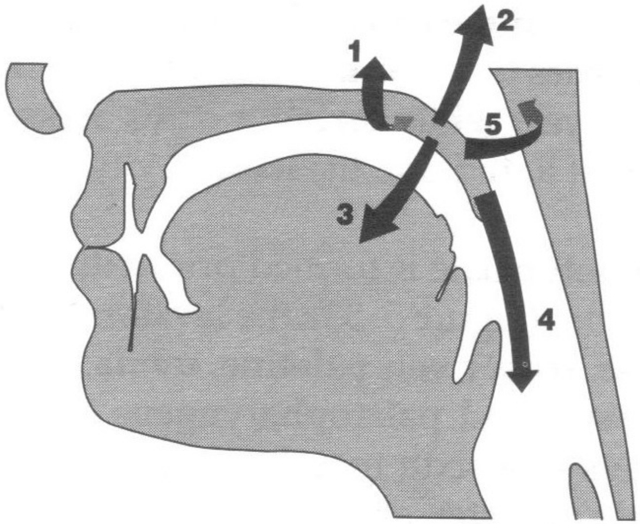
VELOPHARYNGEAL CLOSURE

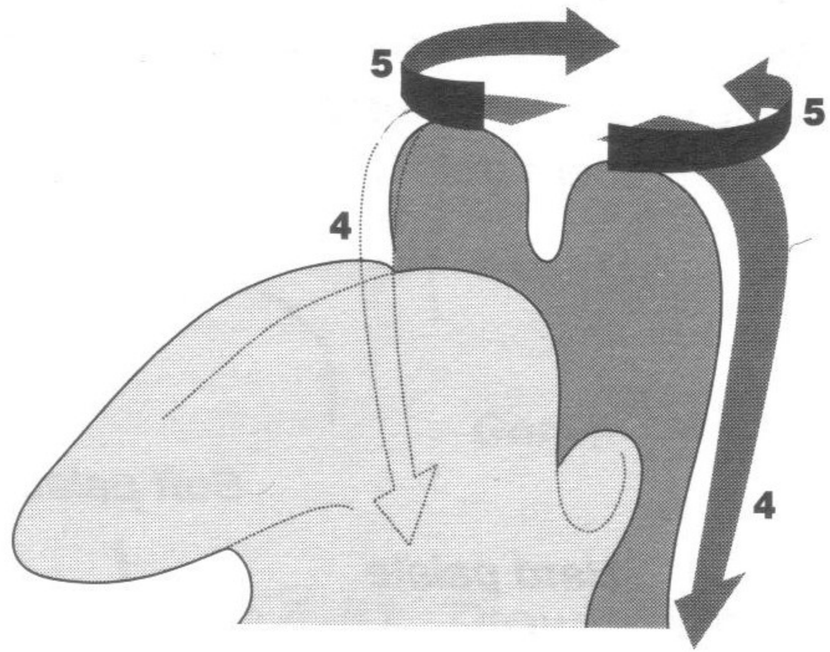
VELOPHARYNGEAL CLOSURE

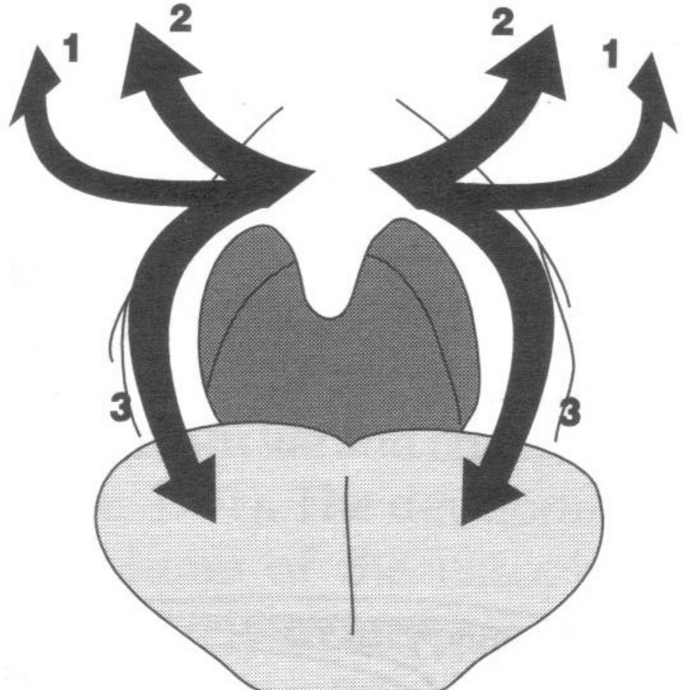




VELOPHARYNGEAL CLOSURE



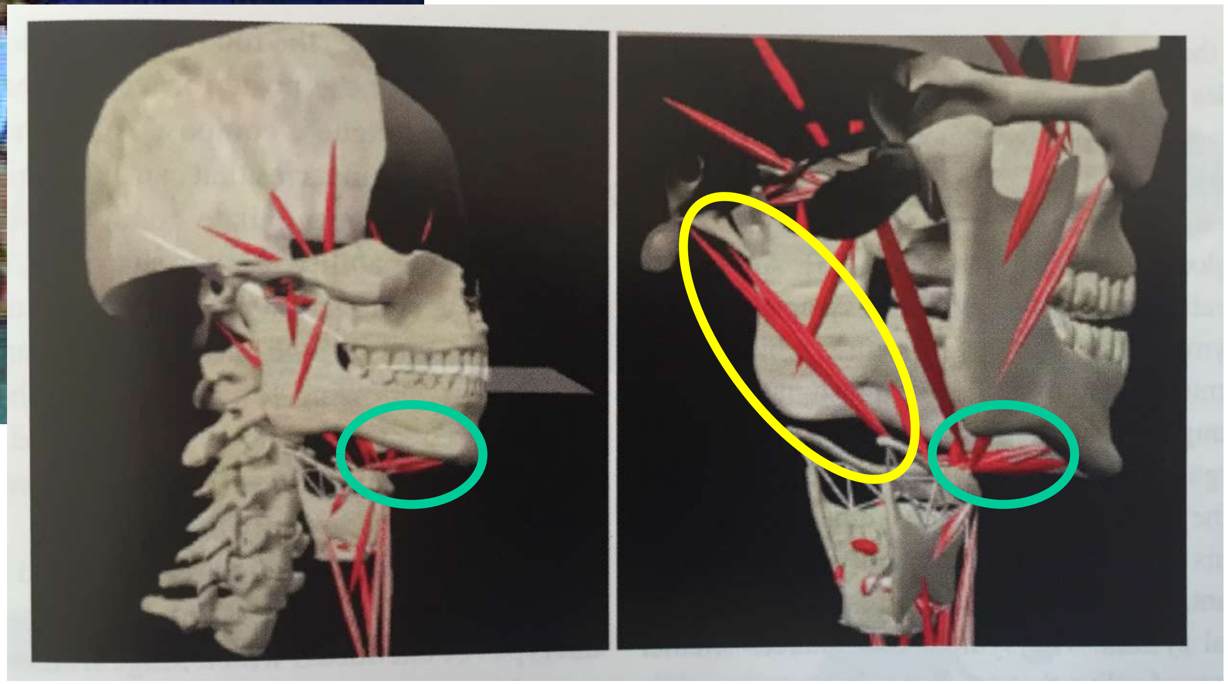




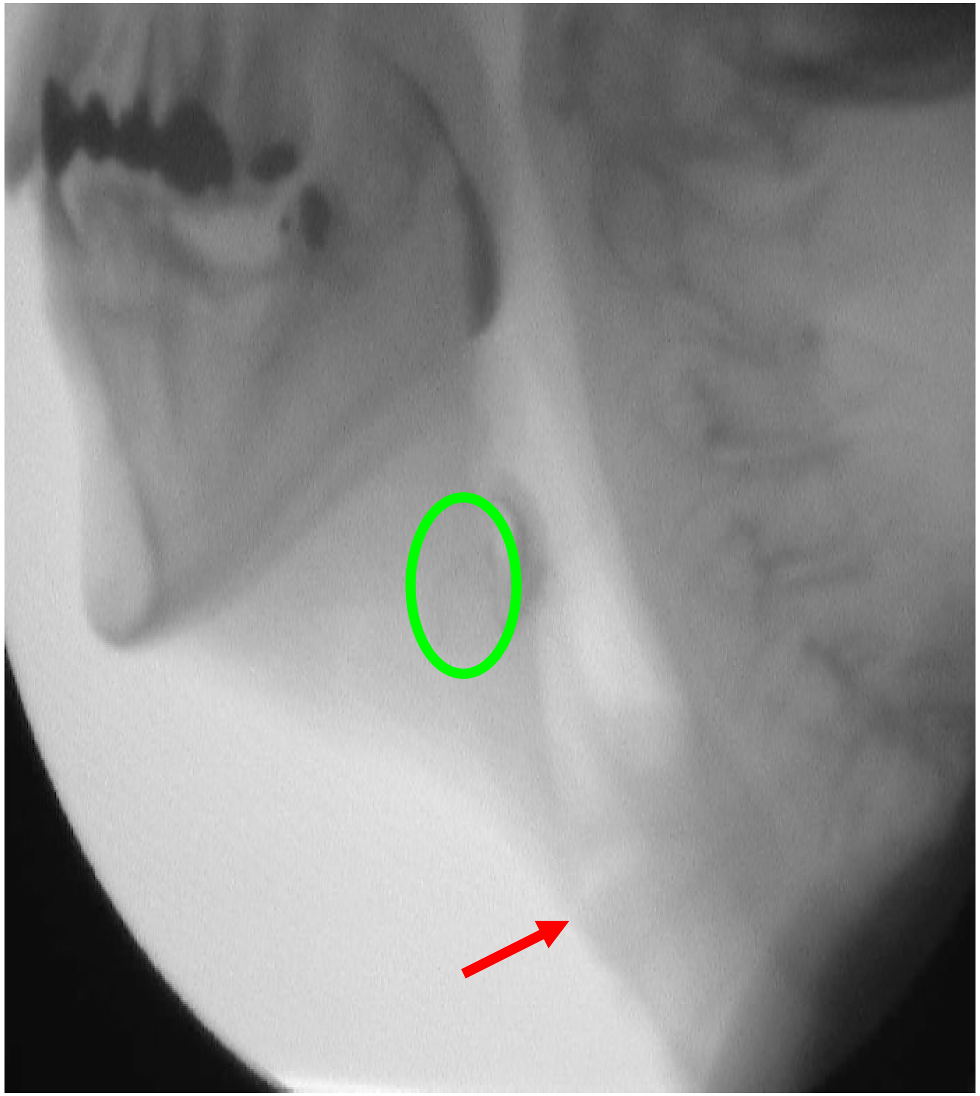
1. m. tensor of the velum (n. mandibolaris V)
2. M. elevator velum
3. M. palatoglossus
4. M. palatofaringeus
5. M. superior pharyngeal constrictor

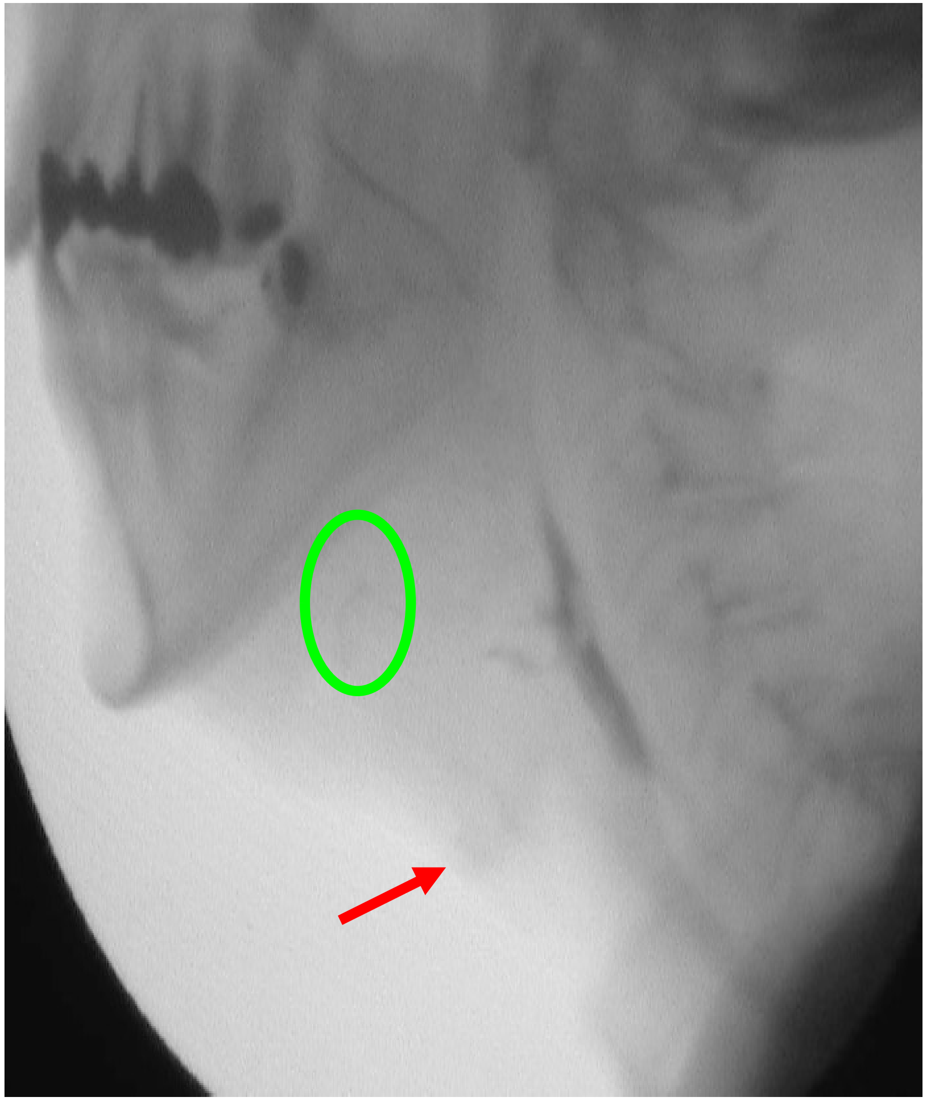
} plesso faringeo (VII, IX, X)

LARYNGEAL ELEVATION



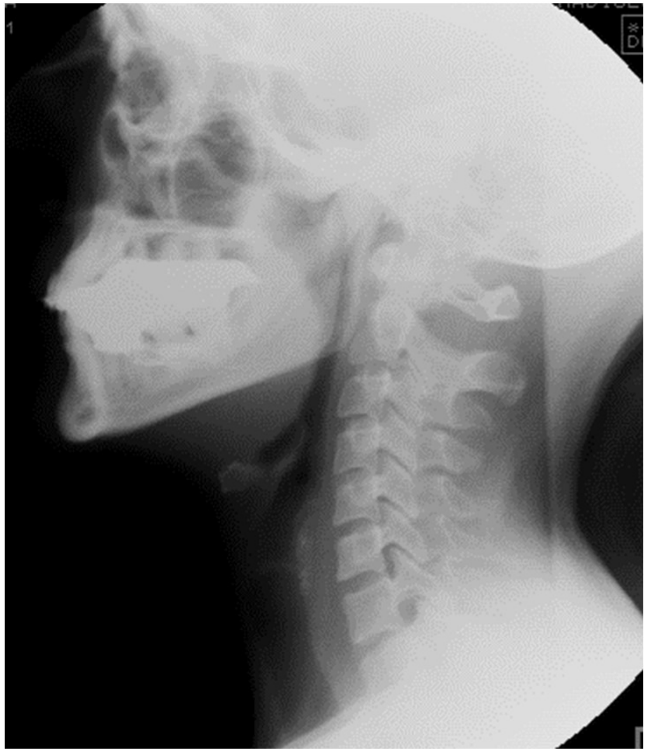
LARYNGEAL ELEVATION





WHAT ARE THE IMPLICATIONS OF LARYNGEAL ELEVATION?

1: PROTECT THE AIRWAYS

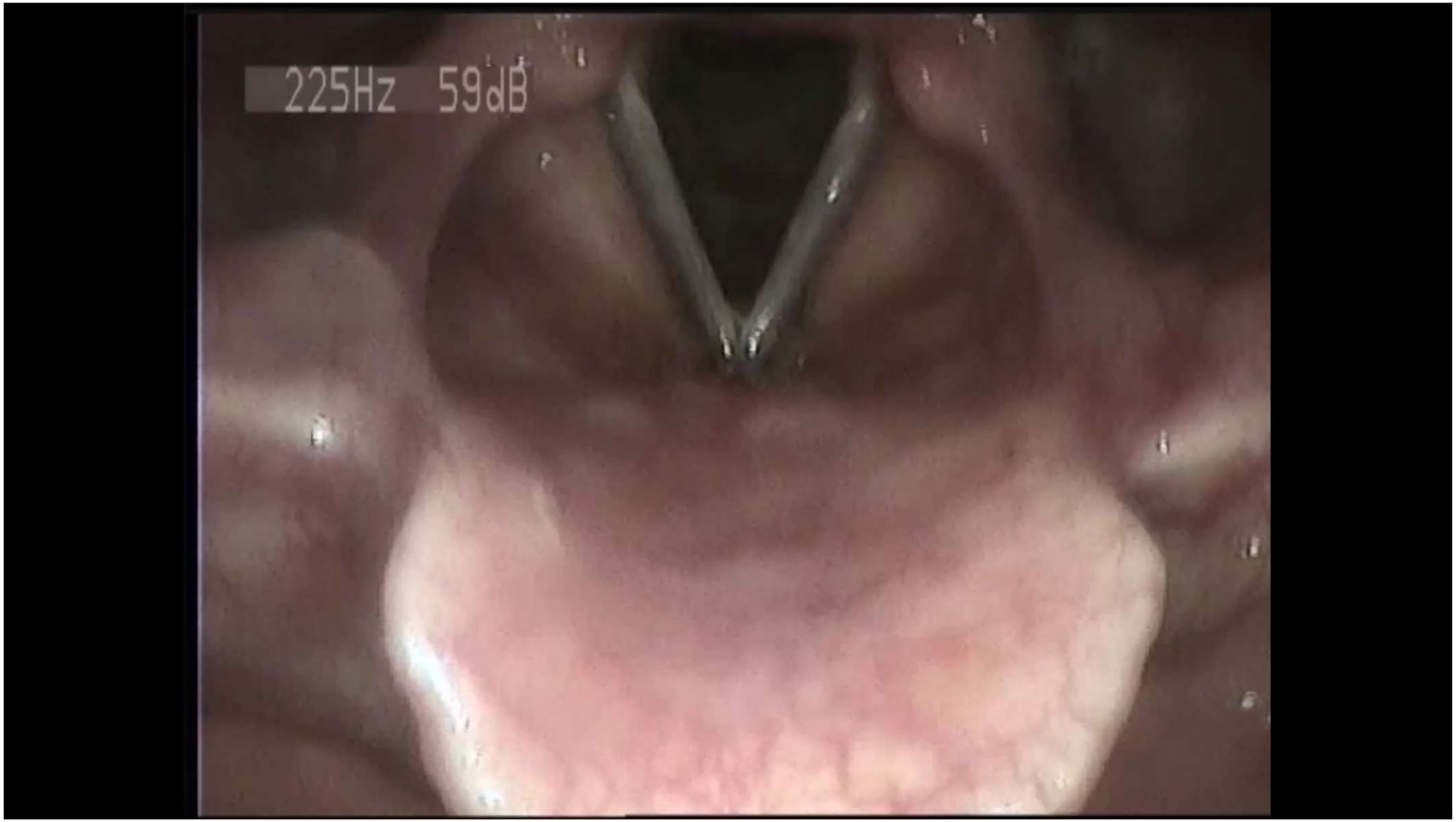


LARYNGEAL CLOSURE



LARYNGEAL CLOSURE: ADDUCTION

LARYNGEAL CLOSURE: VESTIBULAR CLOSURE



TILT OF THE EPIGLOTTIS

During swallowing the free margin of the epiglottis reaches the postcricoid region

Tilt of the epiglottis is the results of

1. Laryngeal elevation
2. Tongue base retraction
3. Bolus weight

TILT OF THE EPIGLOTTIS

Dysphagia (2023) 38:1497–1510
https://doi.org/10.1007/s00455-023-10576-z

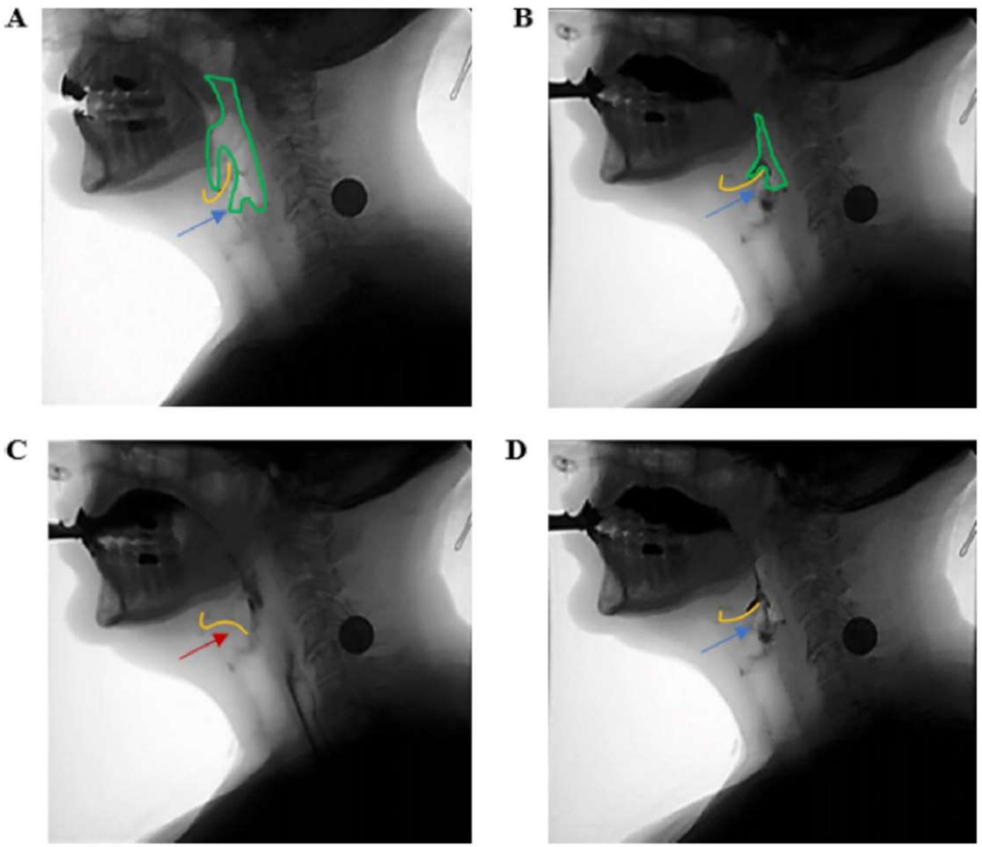
ORIGINAL ARTICLE

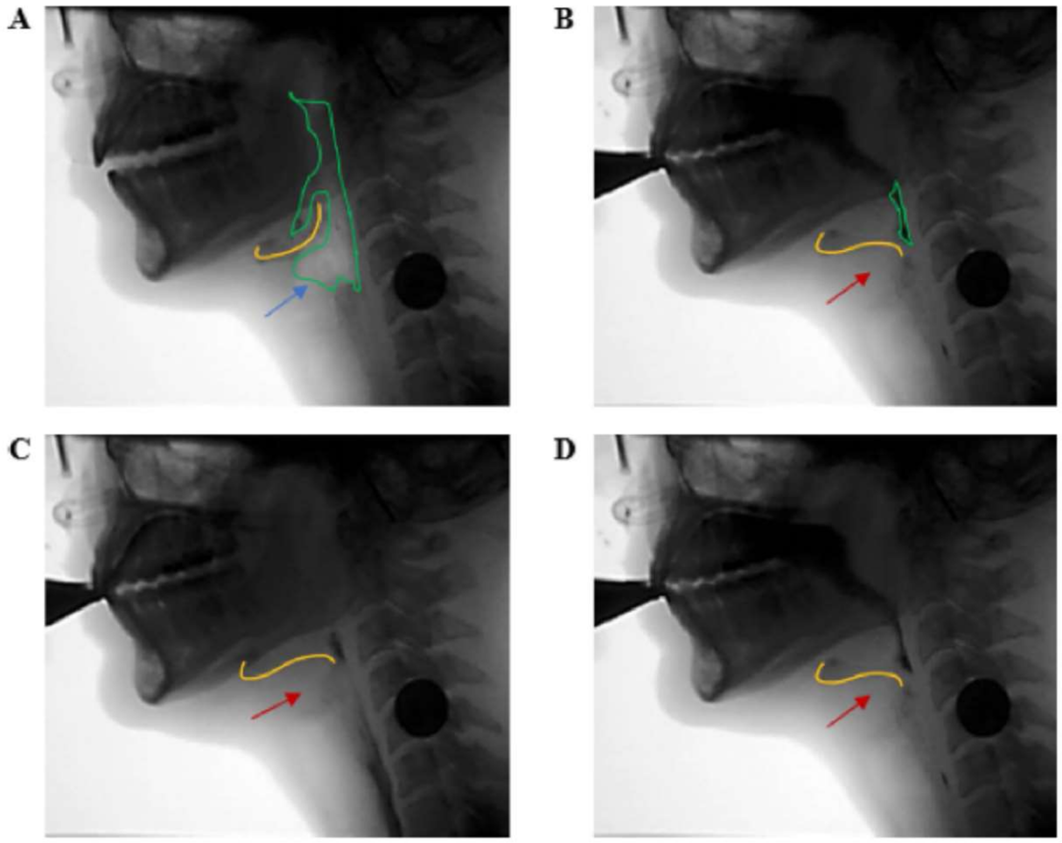
Defining Normal Sequential Swallowing Biomechanics

Kevin Renz Ambrocio[1] · Anna Miles[2] · Ankita M. Bhutada[3] · Dahye Choi[3] · Kendrea L. Garand[1]

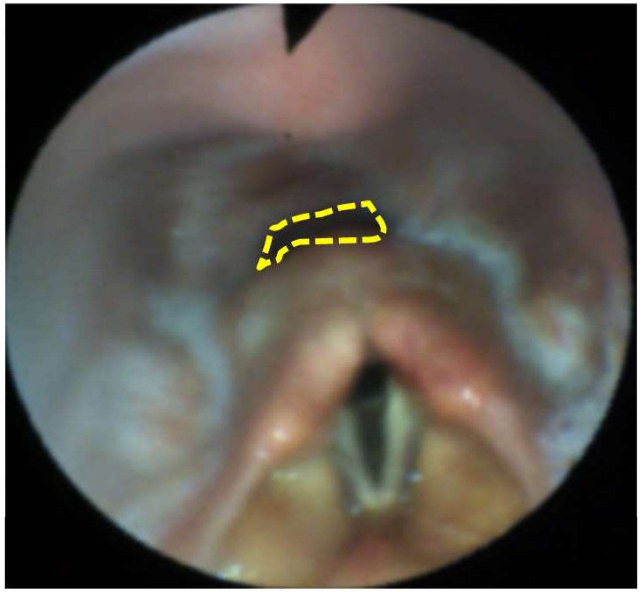
Table 1 Defining characteristics of HLC types

Type	Definition
I	The HLC partially lowers, resulting in the epiglottis returning to or approximating its baseline position, opening of the laryngeal vestibule, and incomplete pharyngeal patency
II	The HLC remains relatively elevated (slight recoil may occur), resulting in sustained epiglottic inversion and laryngeal vestibule closure, and incomplete pharyngeal patency
III	Mixed characteristics of Types I and II are present





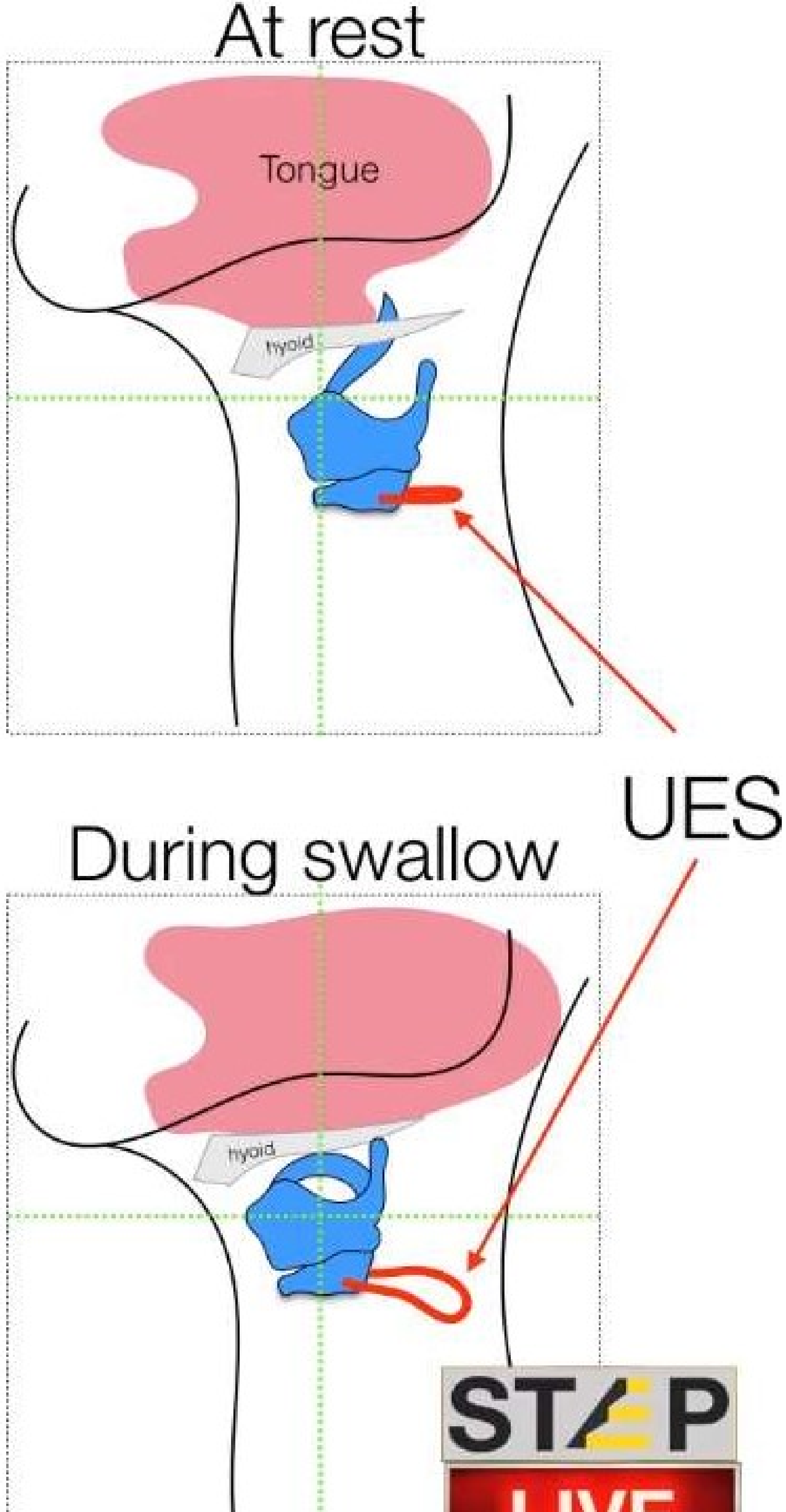
Larynx/UES relationship

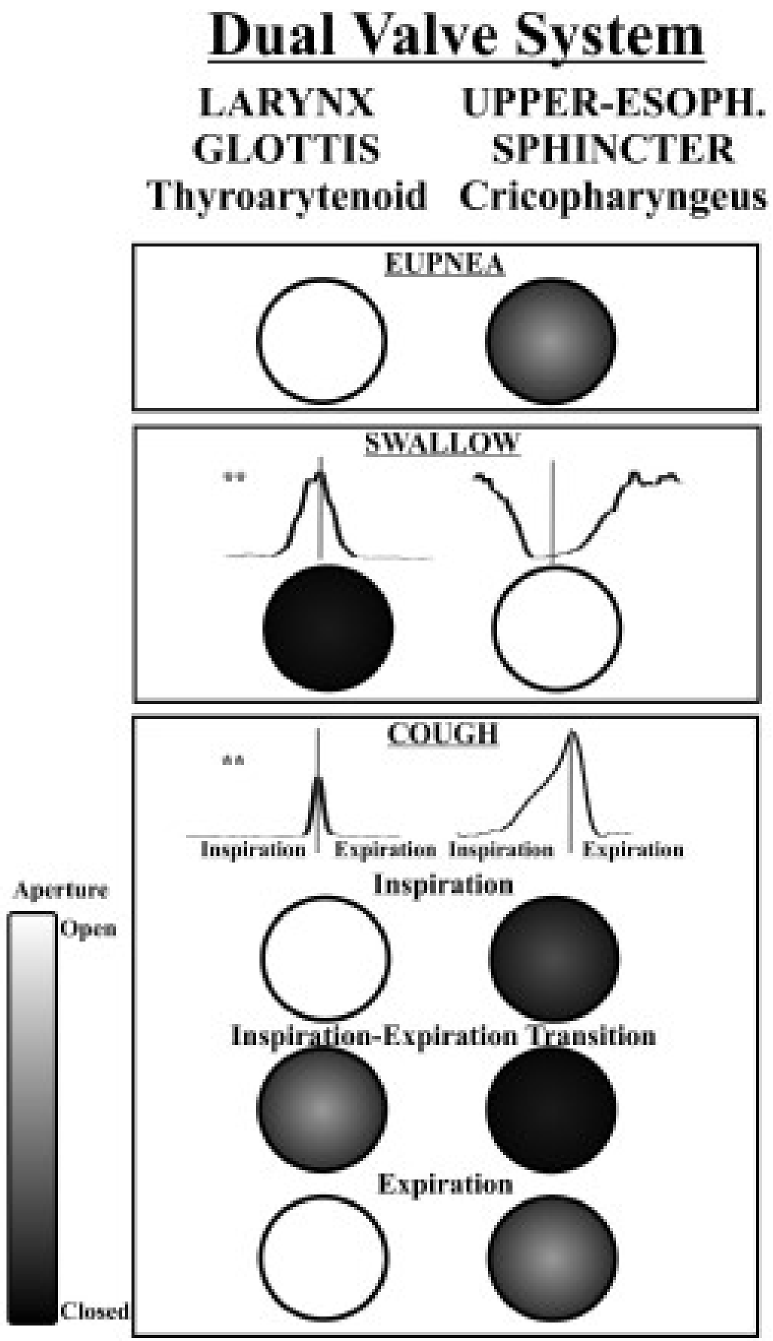


Laryngeal Vestibule Closure

Hyo-laryngeal excursion

Traction on UES to stretch it open



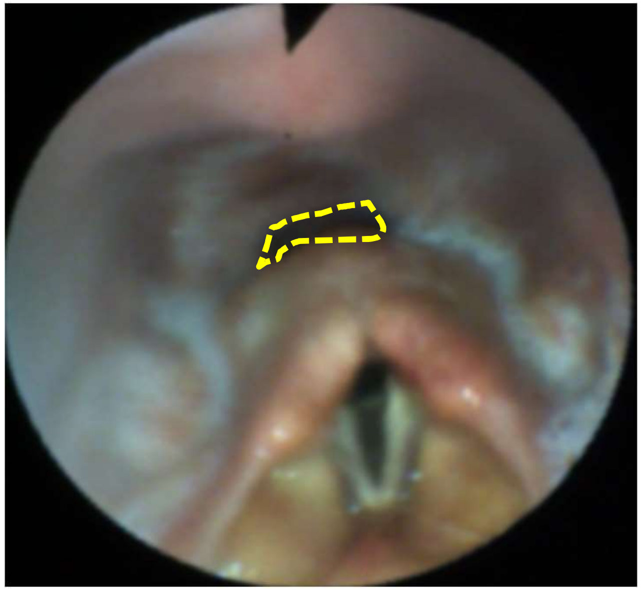


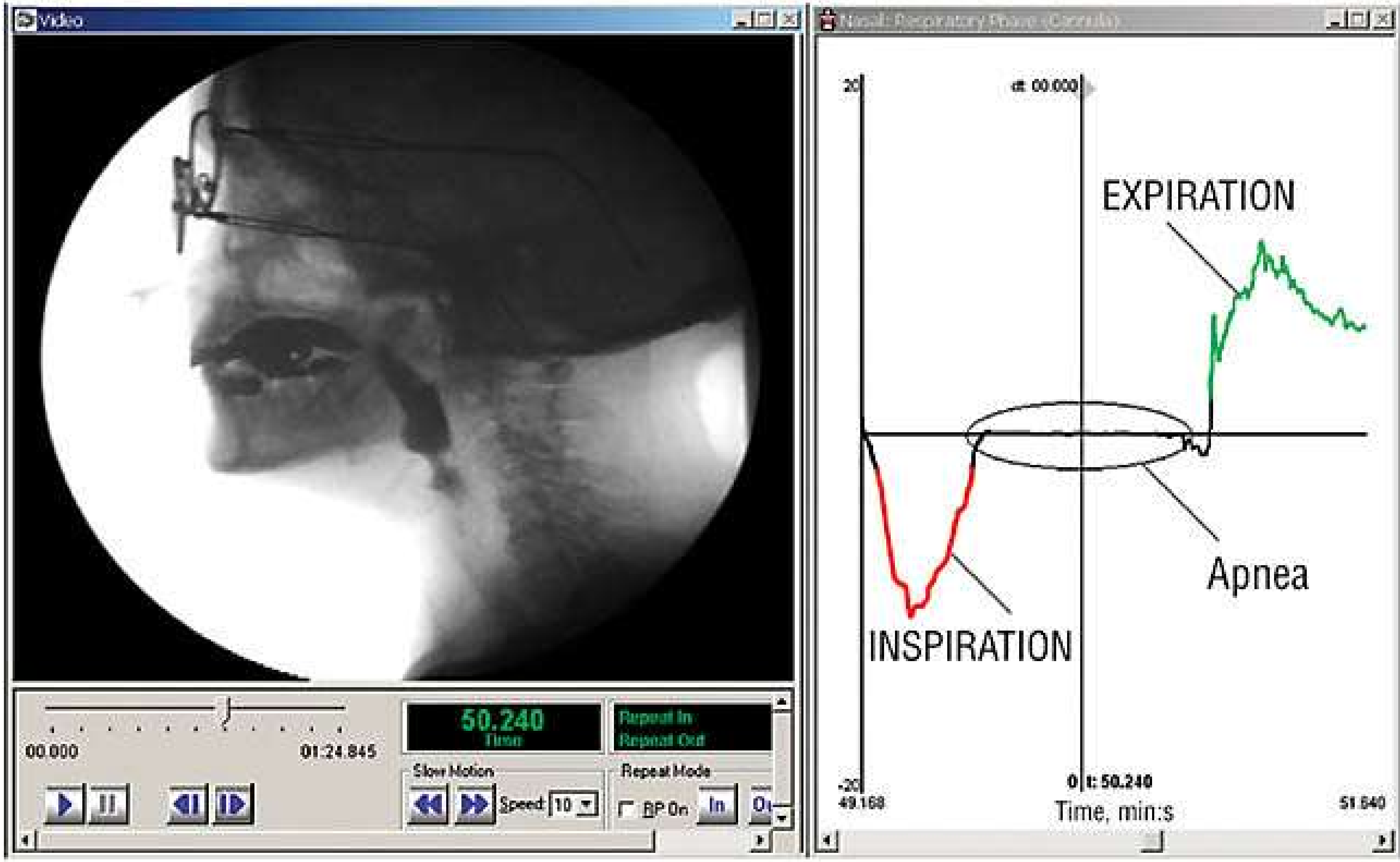
Dual Valve System
LARYNX
GLOTTIS
Thyroarytenoid
UPPER-ESOPH.
SPHINCTER
Cricopharyngeus
EUPNEA
SWALLOW
**
COUGH
**
Inspiration
Expiration
Inspiration
Expiration
Inspiration
Inspiration-Expiration Transition
Expiration
Aperture
Open
Closed

UES opening

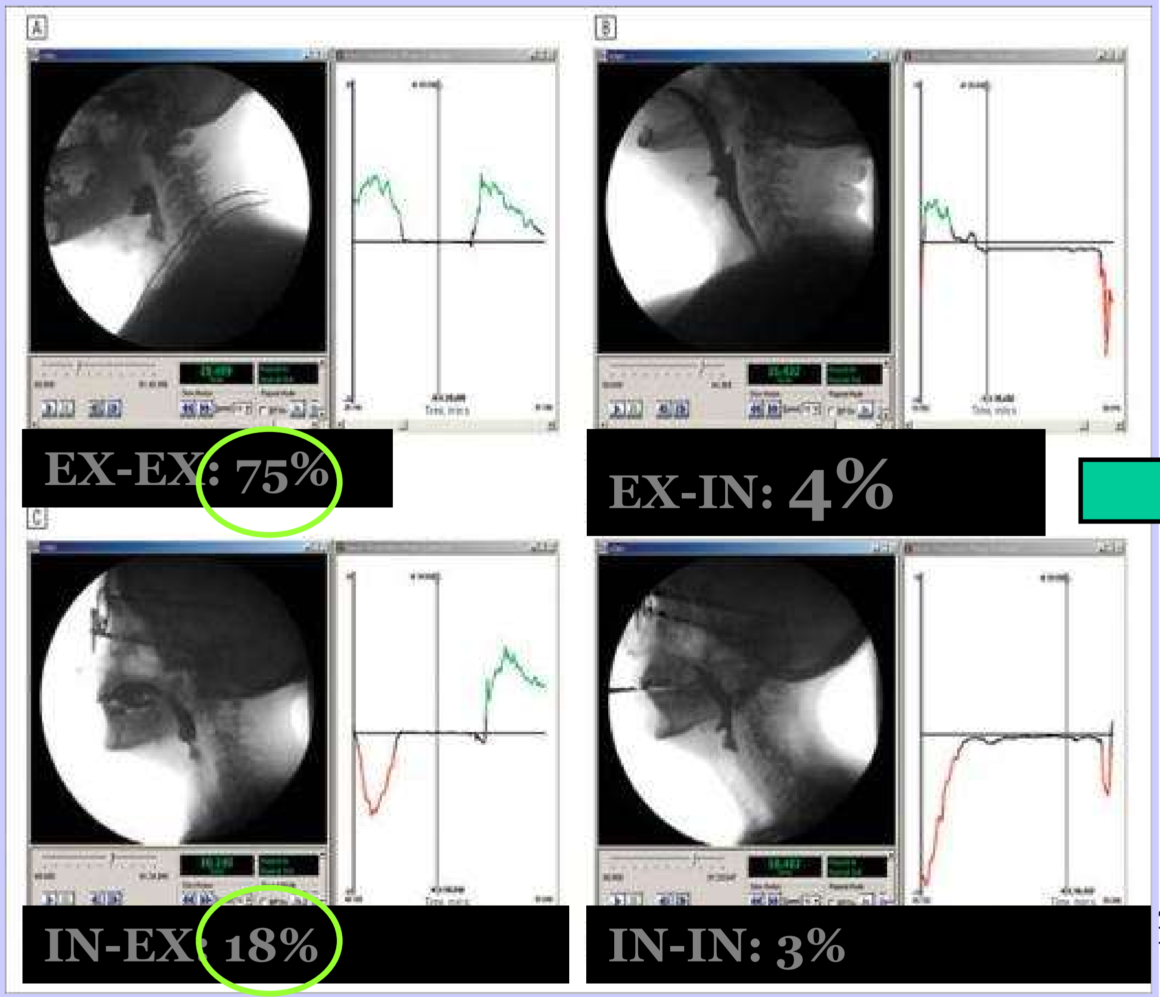
4 main factors contribute to UES elevation:

- Laryngeal anteriorization (and elevation)
- UES compliance
- UES relaxation
- Bolus weigth





Video
50.240
Time
Repeat In
Repeat Out
00.000
01:24.845
Slow Motion
Speed 10
Repeat Mode
RP On
In
20
dt: 00.000
EXPIRATION
Apnea
INSPIRATION
-20
49.168
0
t: 50.240
Time, min:s
51.640

- 

Espirazione post-deglutitoria nel **93%** delle deglutizioni

- La durata dell' **apnea deglutitoria** si colloca tra **1.0 e 1.5** sec. durante l' assunzione dei liquidi.

(Hiss et al; 2001)

translational physiology

J Appl Physiol 95: 2211–2217, 2003.
First published August 8, 2003; 10.1152/japplphysiol.00316.2003.

Lung volume effects on pharyngeal swallowing physiology

Table 1. *Mean, SD, SE, and number of subjects for the three lung conditions (TLC, FRC, RV)*

	Mean	SD	SE	*n*
	EMG amplitude, mV			
TLC	5.37	4.36	1.17	14
FRC	5.30	4.03	1.08	14
RV	5.11	4.00	1.07	14
	EMG duration, ms			
TLC	952.00	118.00	31.50	14
FRC	902.00	166.00	44.50	14
RV	1,000.00	126.00	33.70	14
	Bolus transit time, ms			
TLC	521.00	81.40	17.40	22
FRC	527.20	55.70	11.90	22
RV	520.00	72.40	15.40	22
	Pharyngeal activity duration, ms			
TLC	690.00	112.00	24.00	22
FRC	694.00	122.00	26.00	22
RV	719.50	105.00	22.30	22

n, No. of subjects. EMG, electromyography; TLC, total lung capacity; FRC, functional residual capacity; RV, residual volume.

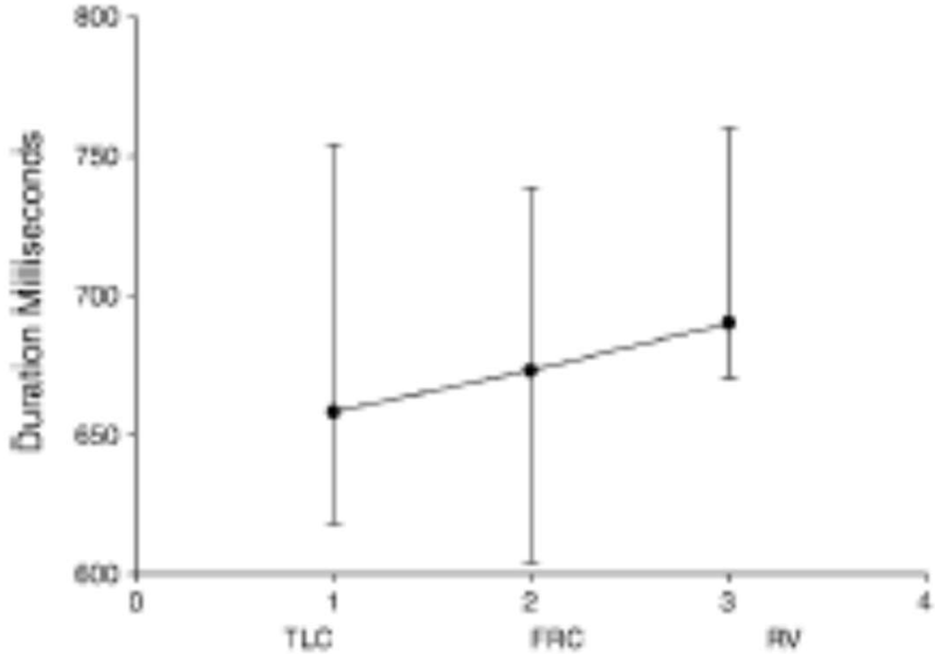


Fig. 1. Pharyngeal activity duration (PAD). Median, 25th, and 75th quartiles are shown. TLC, total lung capacity; FRC, functional residual capacity; RV, residual volume.

The Laryngoscope
Lippincott Williams & Wilkins, Inc.

Direct Measurement of Subglottic Air Pressure While Swallowing

Roxann Diez Gross, PhD; Kimberly M. Steinhauer, PhD; David J. Zajac, PhD; Mark C. Weissler, MD

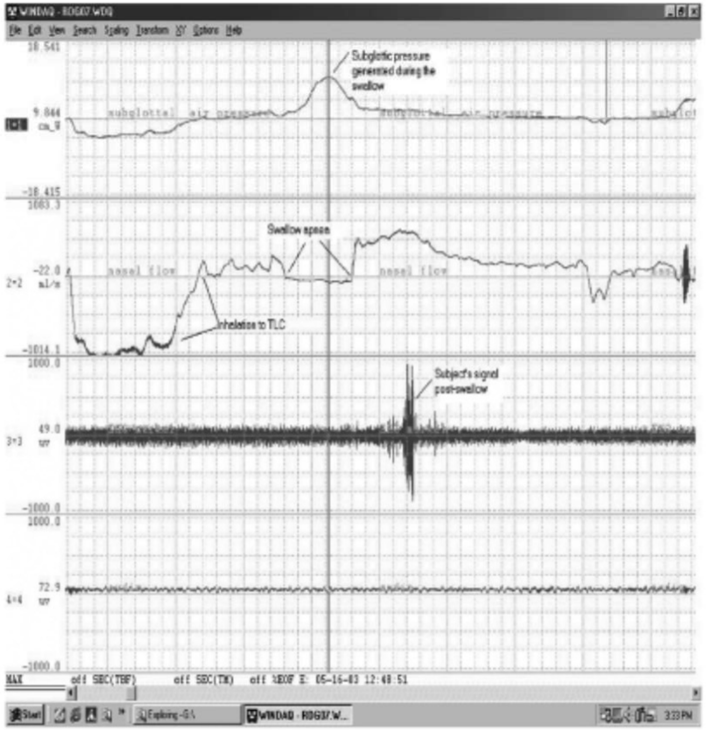


TABLE I.
Subglottic Air Pressures Measured While Swallowing at Different Lung Volumes.

Lung Volume	cm H_2O	cm H_2O	cm H_2O	cm H_2O
Total lung capacity	7.37	9.84	10.76	7.54
Tidal volume	2.03	2.56	1.97	2.04
Functional residual capacity	1.41	0.20	0.95	1.34
Residual volume	−4.14	−4.12	−4.39	−4.48

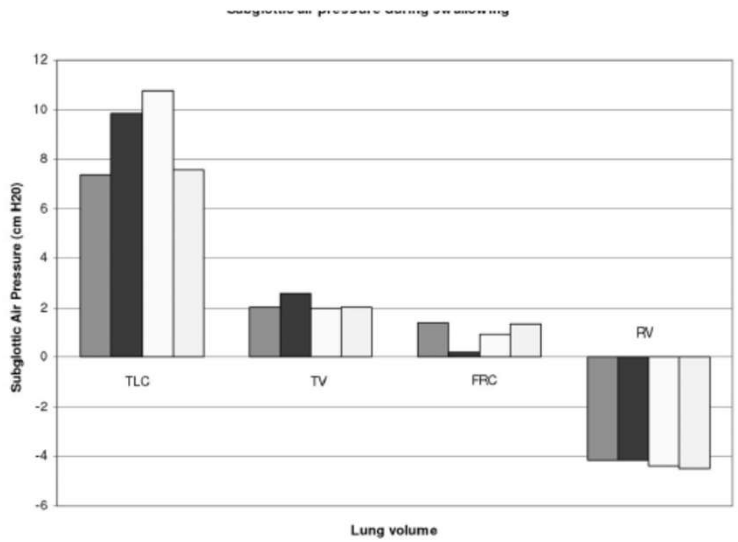


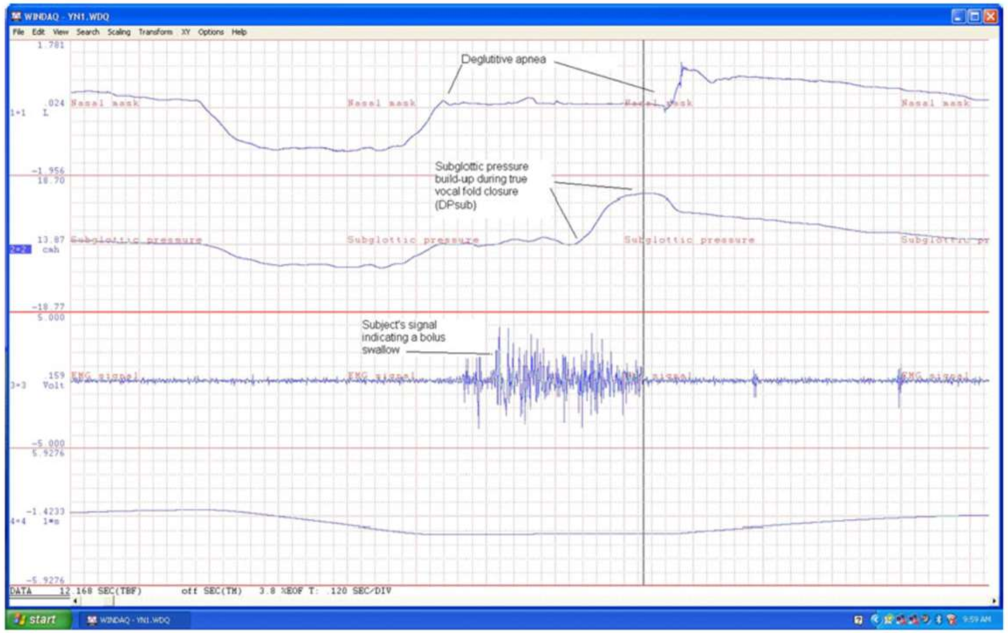
Fig. 1. TLC = total lung capacity; TV = tidal volume; FRC = functional residual capacity; RV = residual volume. Each shaded bar represents a swallow.

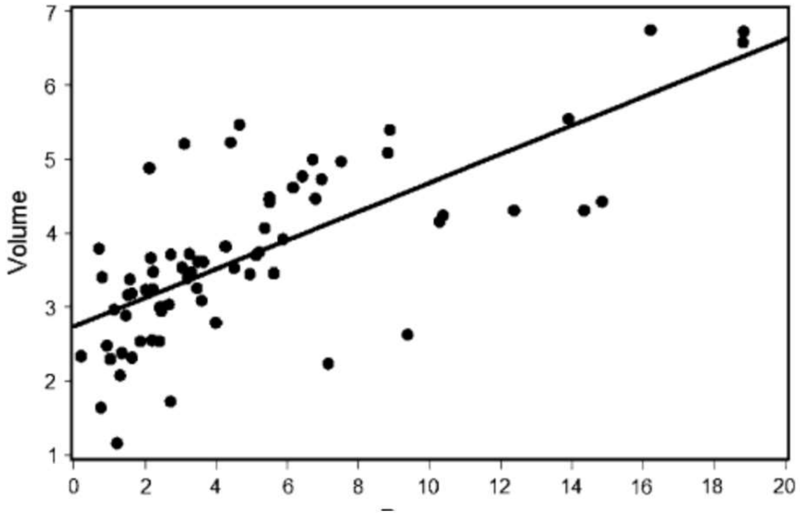
Dysphagia (2012) 27:452–459
DOI 10.1007/s00455-011-9389-2

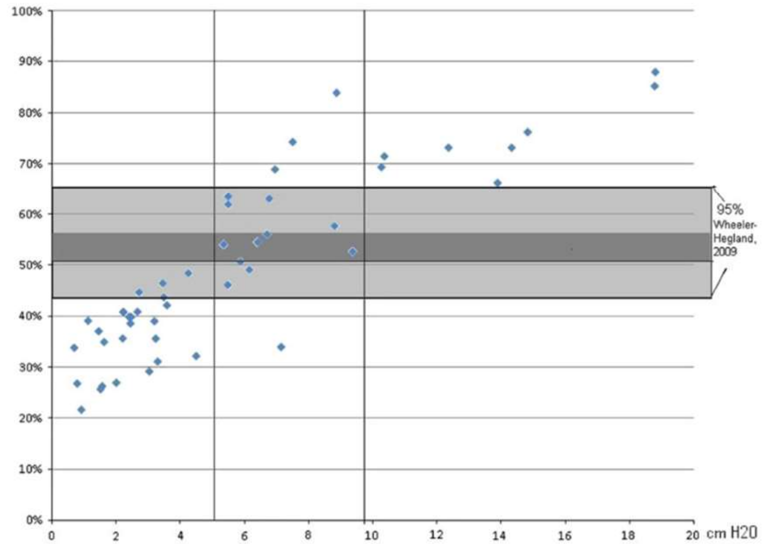
ORIGINAL ARTICLE

Deglutitive Subglottic Air Pressure and Respiratory System Recoil

Roxann Diez Gross · Ricardo L. Carrau ·
William A. Slivka · Ronit G. Gisser ·
Libby J. Smith · David J. Zajac · Frank C. Sciurba

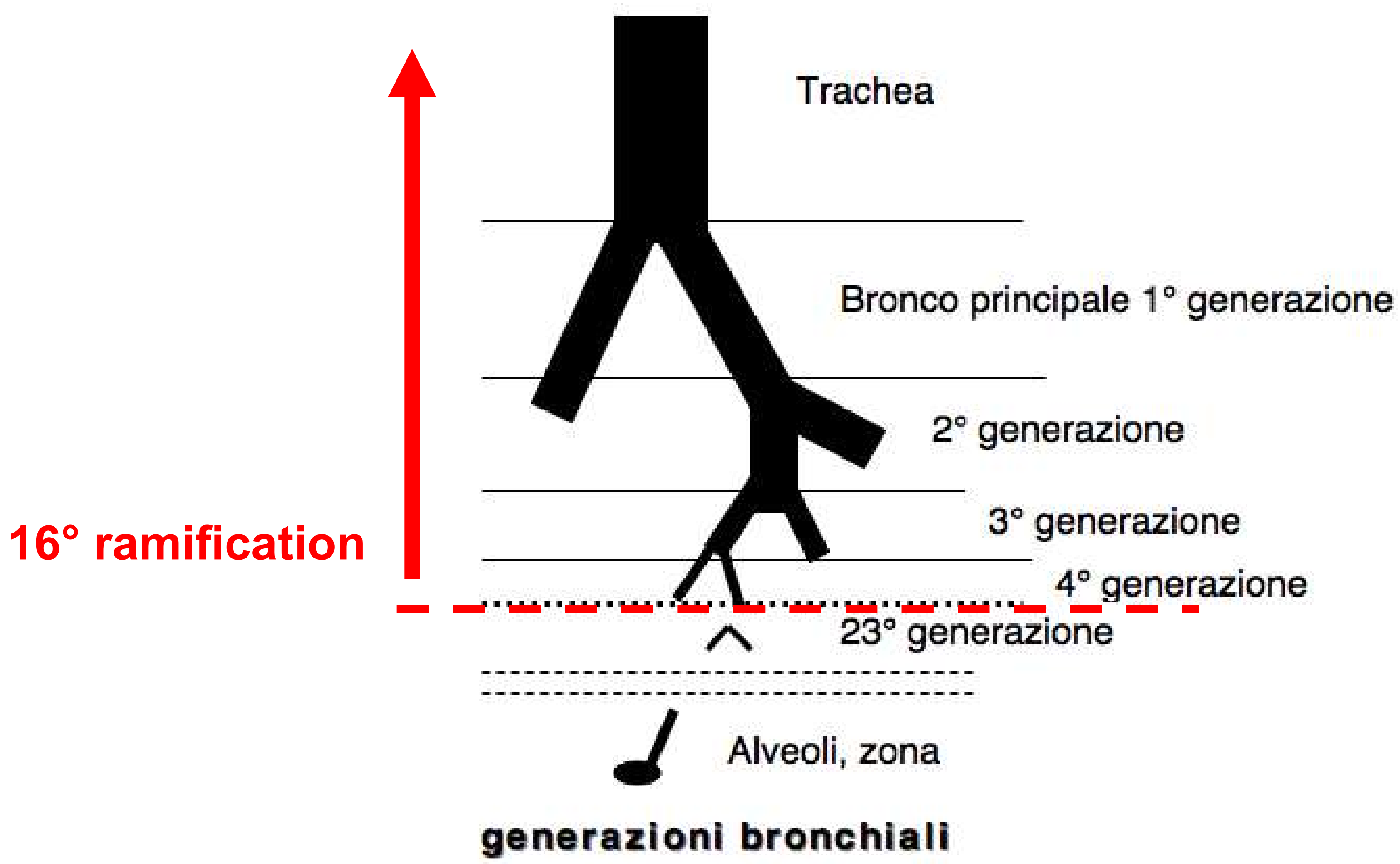






MUCOCILIARY ACTION and COUGH

When do they come in to action?



COUGH

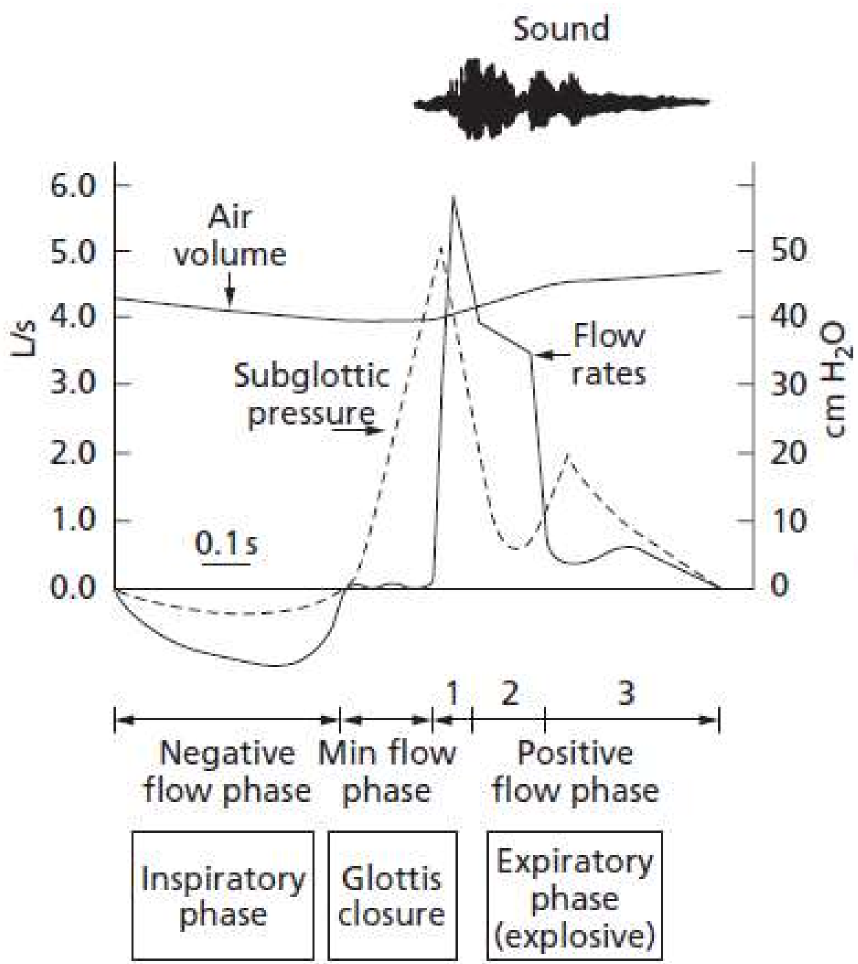
Cough is a mechanism used to clear lower airways

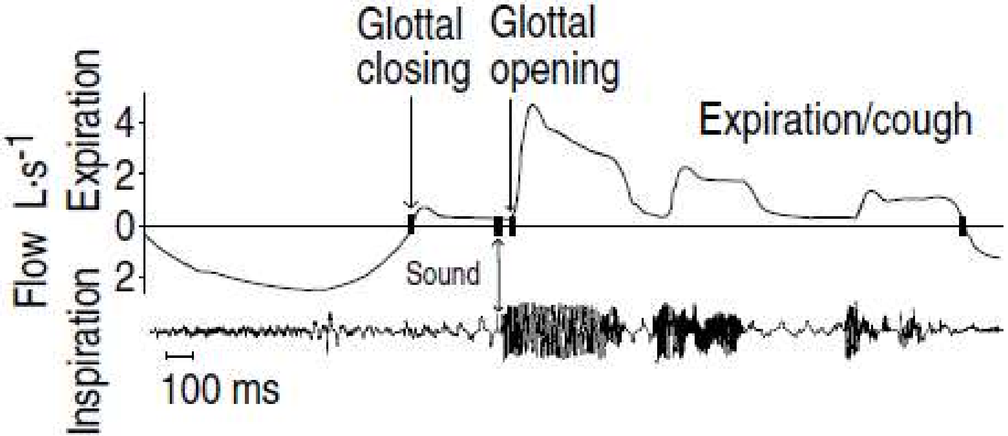
Reflexive cough is more important than voluntary cough

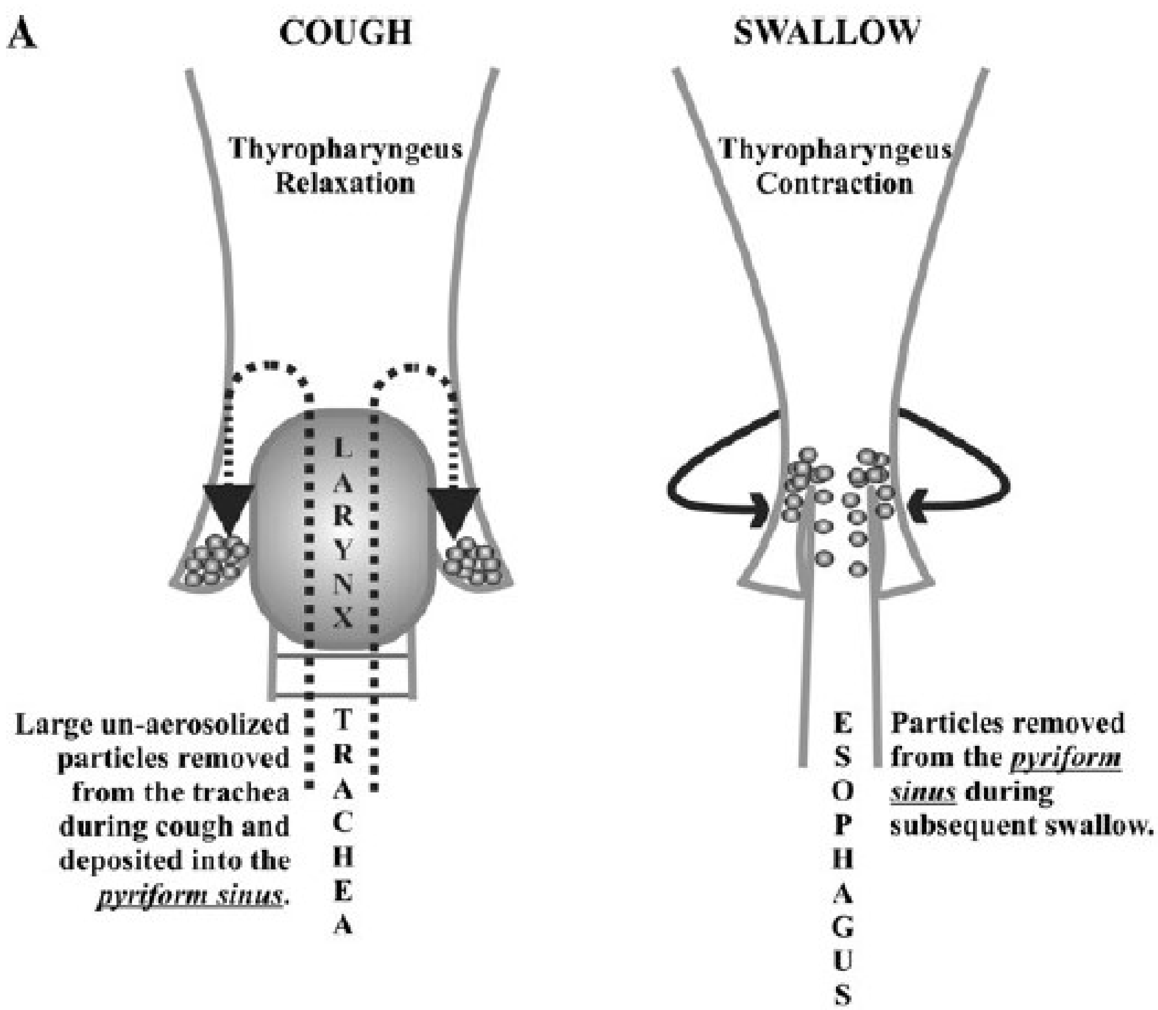
However

Expulsive phase rise time of voluntary cough significantly correlates with aspiration status (in stroke patients)

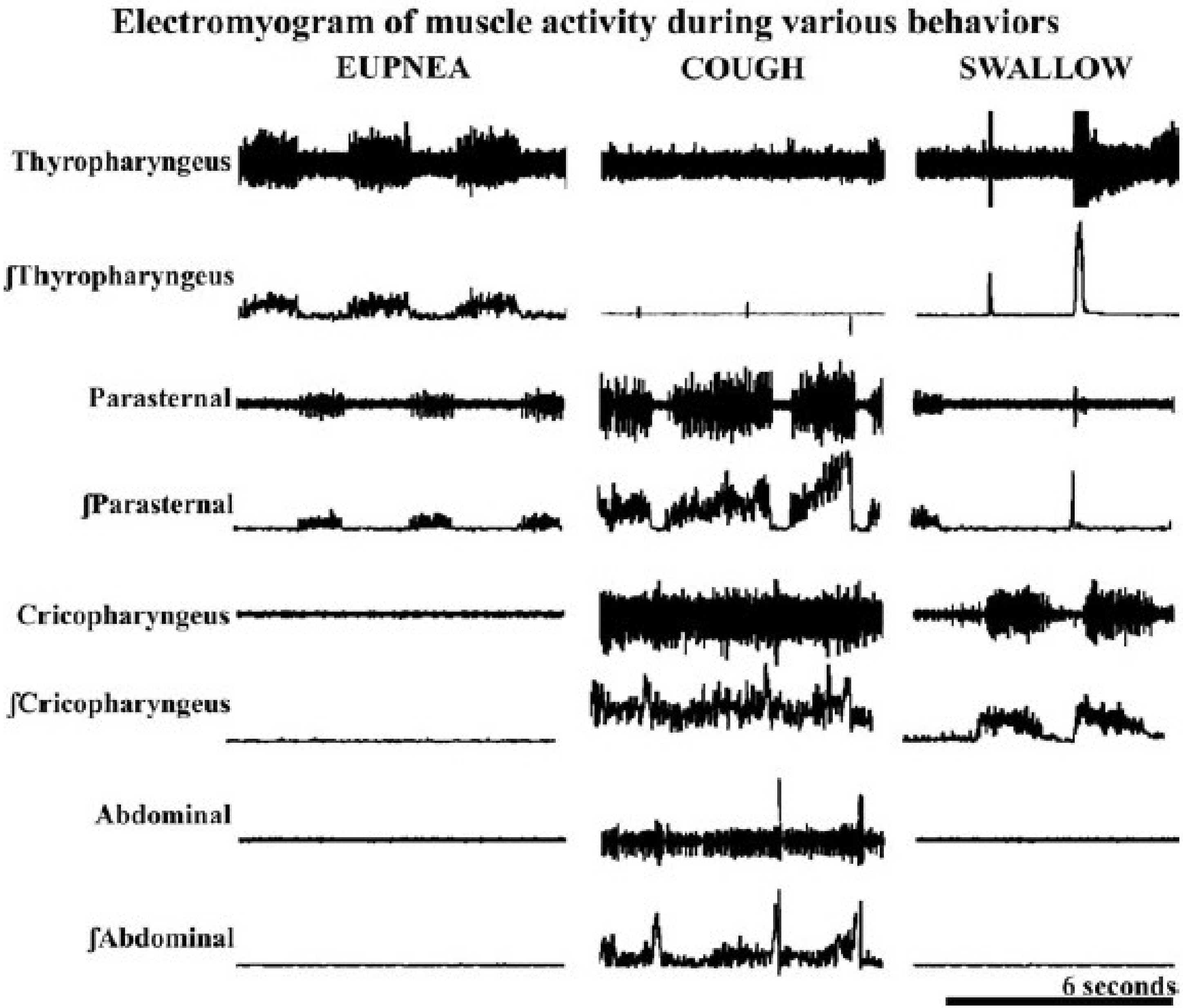
(Hammond & Goldstein 2006; Chest 129: 154S-168S)

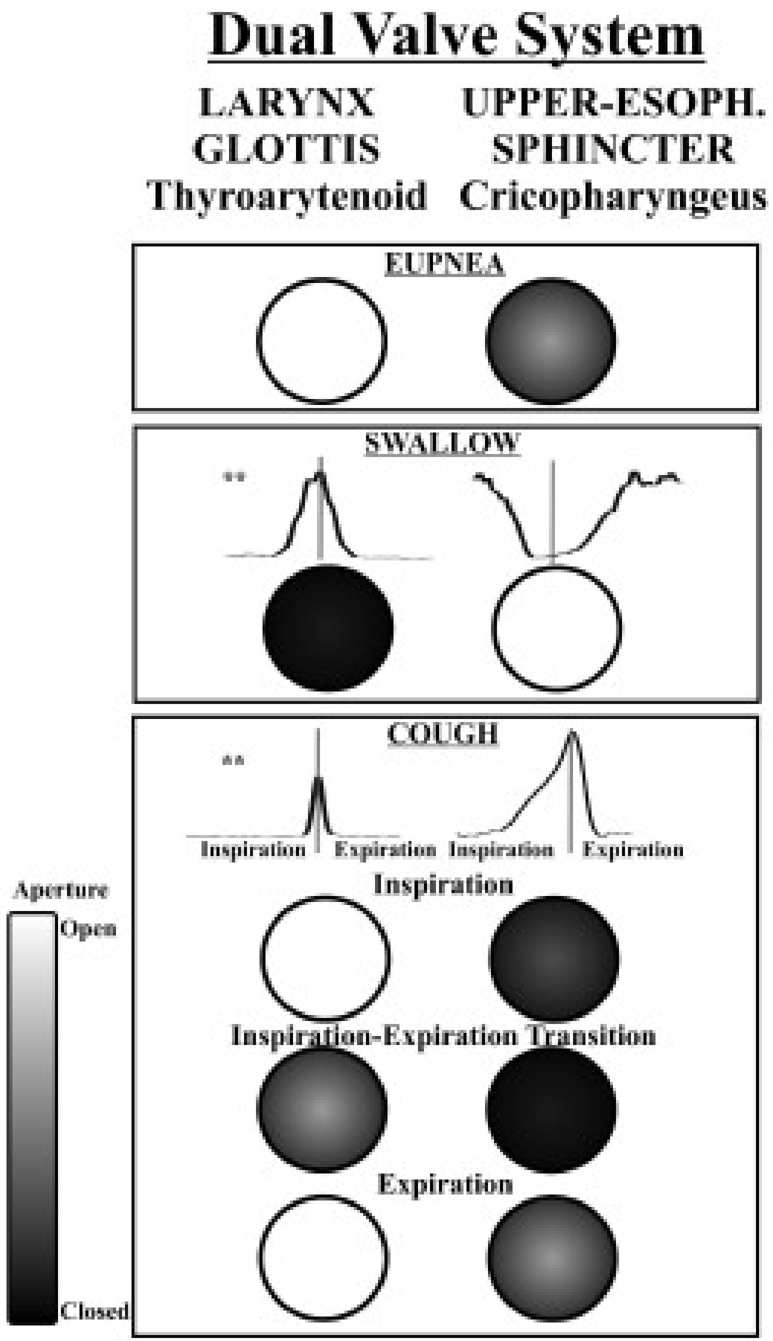

Sound
6.0
5.0
4.0
3.0
2.0
1.0
0.0
L/s
Air volume
Subglottic pressure
Flow rates
0.1 s
50
40
30
20
10
0
cm H_2O
1
2
3
Negative flow phase
Min flow phase
Positive flow phase
Inspiratory phase
Glottis closure
Expiratory phase (explosive)


Glottal closing
Glottal opening
Expiration/cough
Flow L·s-1
Expiration
Inspiration
4
2
0
2
Sound
100 ms



A
COUGH
SWALLOW
Thyropharyngeus
Relaxation
Thyropharyngeus
Contraction
LARYNX
TRACHEA
ESOPHAGUS
Large un-aerosolized particles removed from the trachea during cough and deposited into the pyriform sinus.
Particles removed from the pyriform sinus during subsequent swallow.


Electromyogram of muscle activity during various behaviors
EUPNEA
COUGH
SWALLOW
Thyropharyngeus
∫Thyropharyngeus
Parasternal
∫Parasternal
Cricopharyngeus
∫Cricopharyngeus
Abdominal
∫Abdominal
6 seconds


Dual Valve System
LARYNX
GLOTTIS
Thyroarytenoid
UPPER-ESOPH.
SPHINCTER
Cricopharyngeus
EUPNEA
SWALLOW
**
COUGH
**
Inspiration
Expiration
Inspiration
Expiration
Inspiration
Inspiration-Expiration Transition
Expiration
Aperture
Open
Closed

COUGH (1)

Reflexive cough has not been study thouroughlly

Reflexive cough arise following laryngeal vestibule receptors stimulation

LYMPHATIC CLEARANCE

Clearing of lung liquids: 400-700 ml/day!

Factors limiting lymphatic clearance: ↓

- decreased osmotic gradient (serum albumin concentration: cirrhosis, nephrotic syndrome)
- high hydrostatic pressure (congestive heart failure)

Consequences of decreased lymphatic clearance:

- pleural effusion
- lung stuff with fluid

ALVEOLAR MACROPHAGE

1-2 macrophage/alveolus

↓

phagocitosis

↓

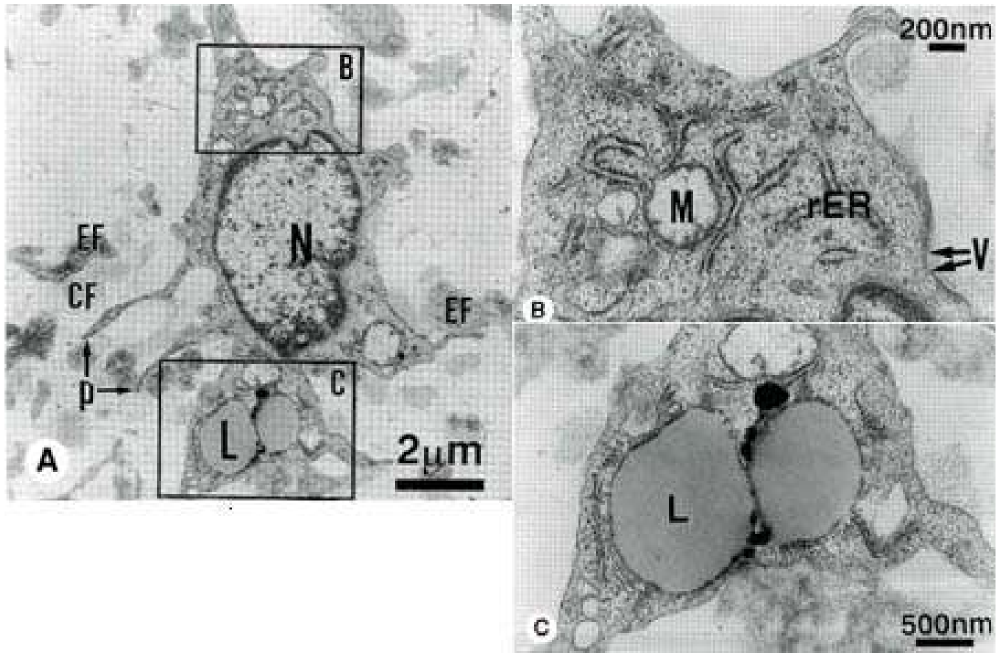
lymph node

↓

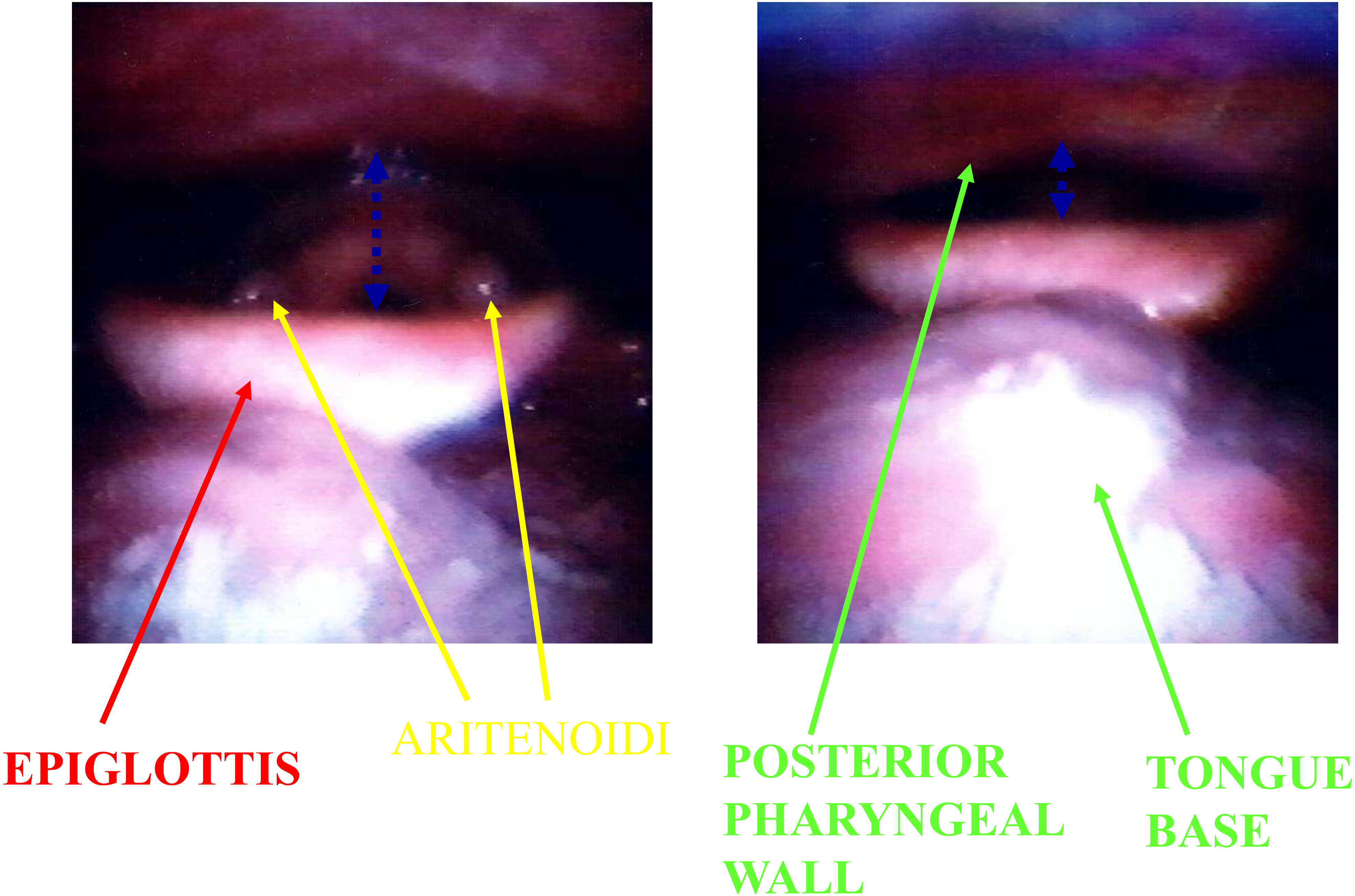
immune response

LYMPHOCYTES

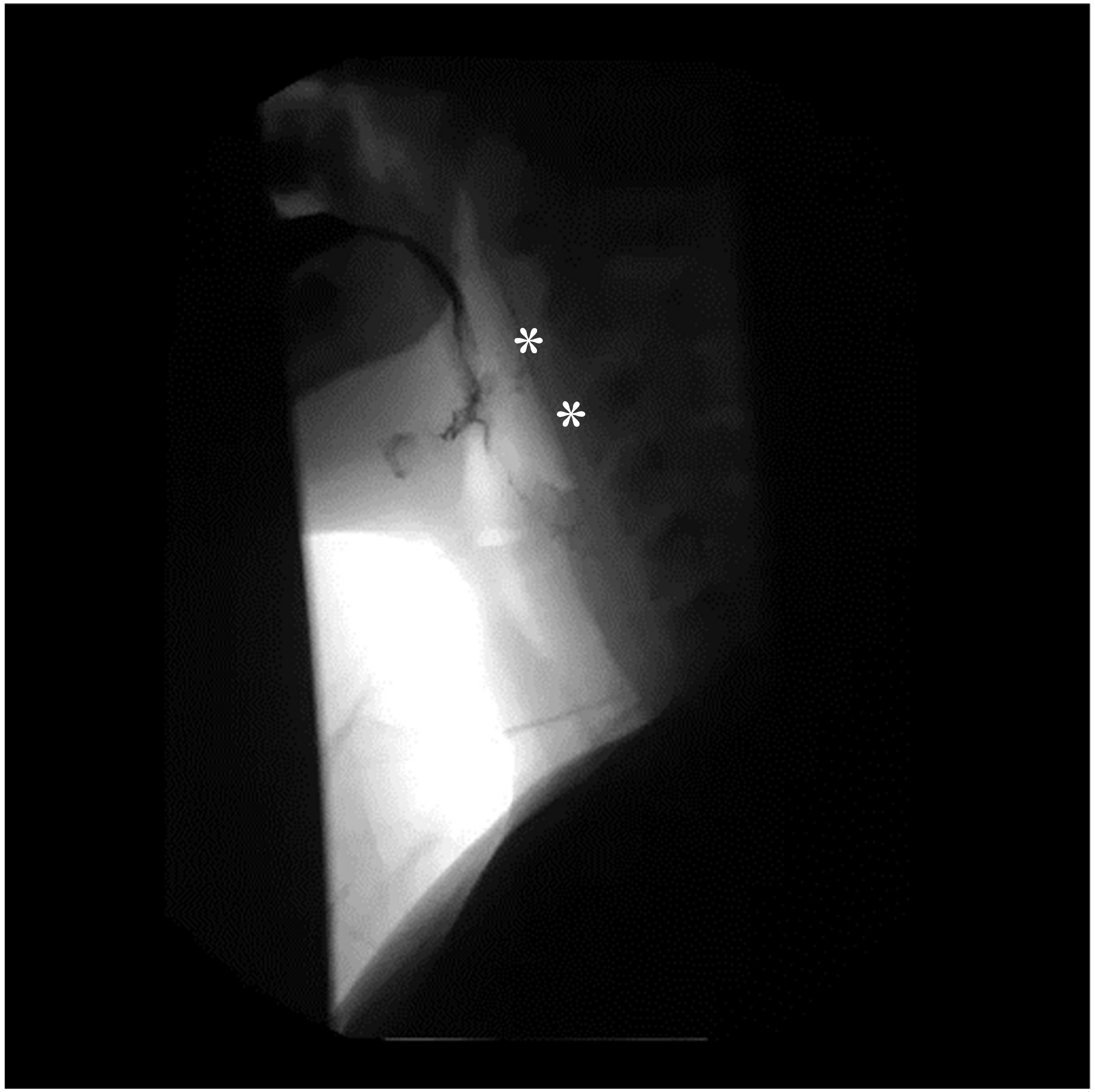
NEUTROPHILS



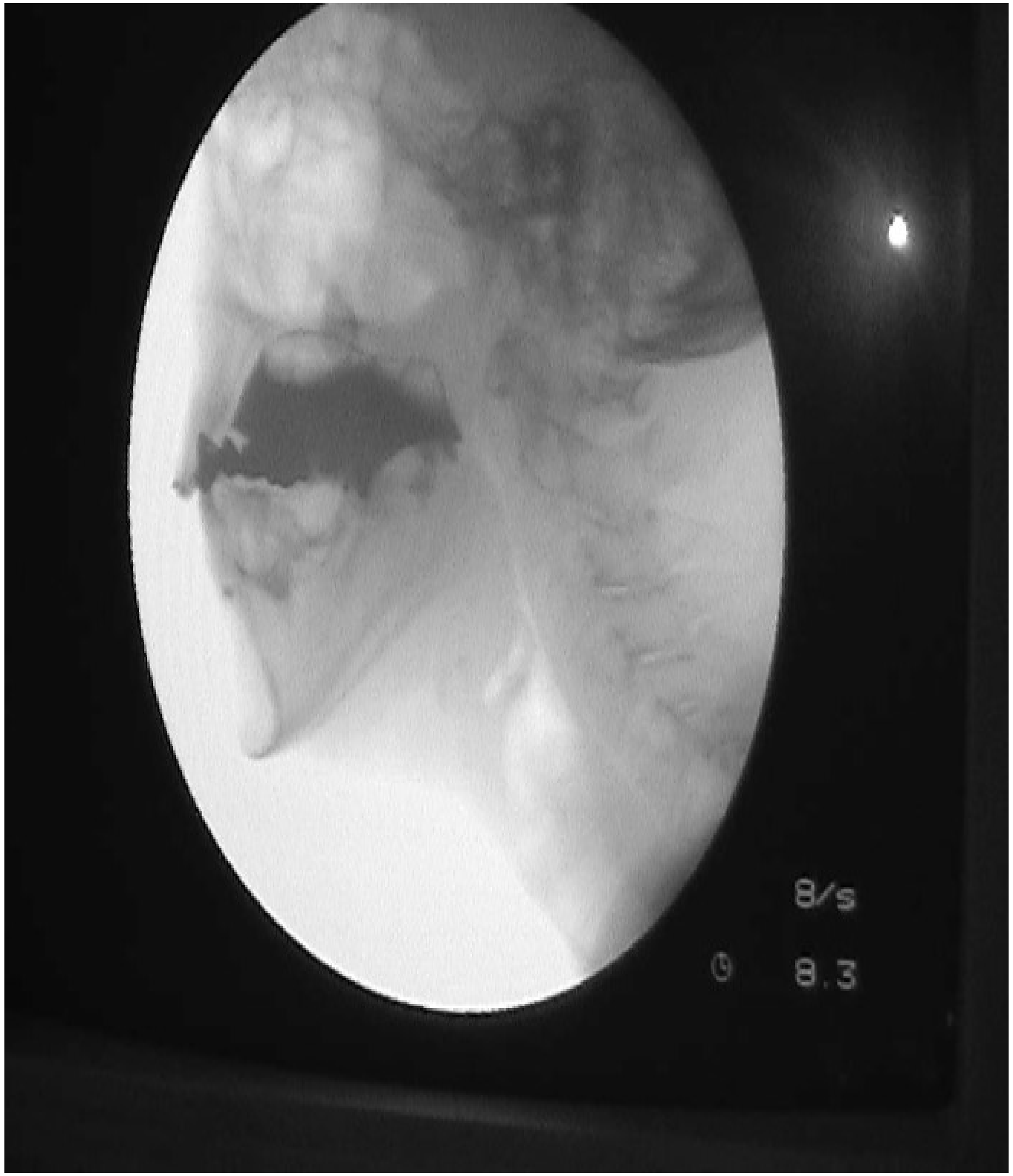
TONGUE BASE BACKWARD MOVEMENT



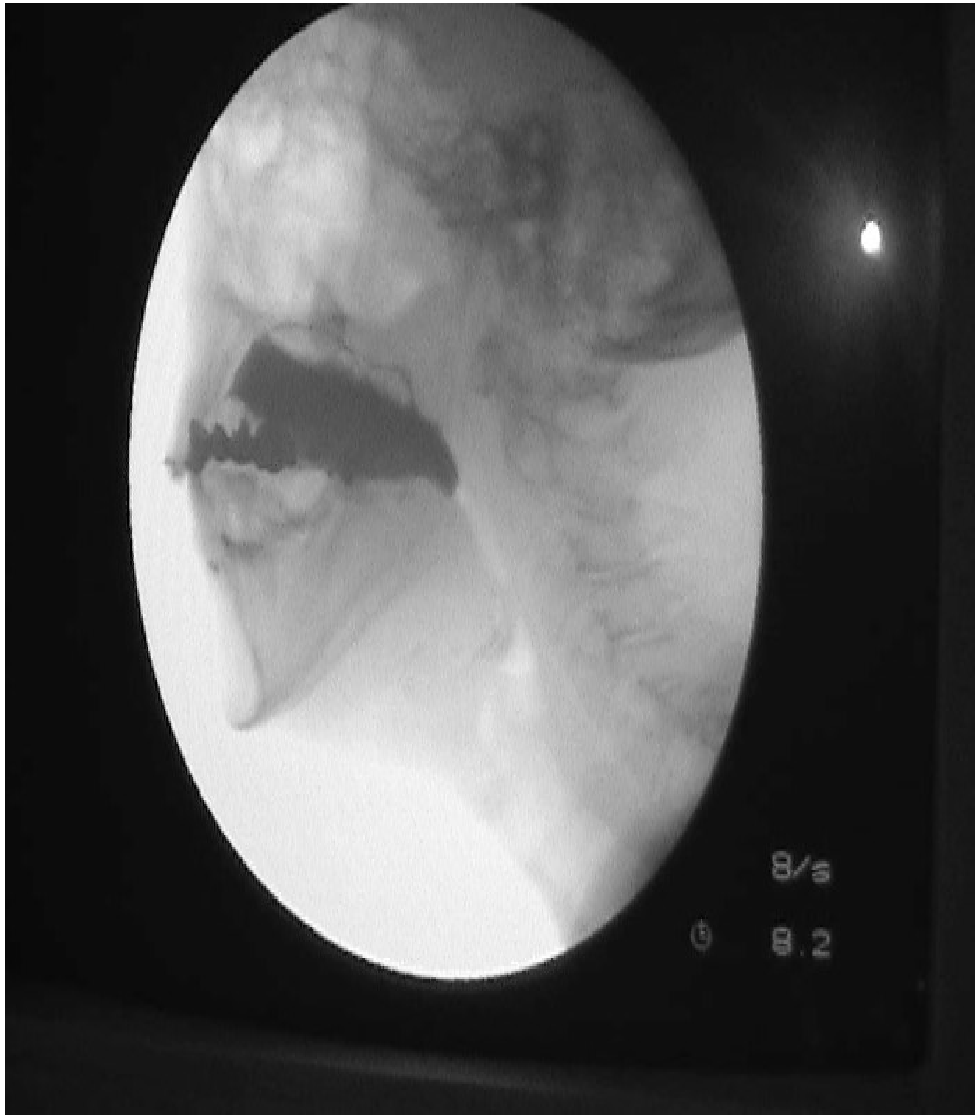
STRIPPING WAVE



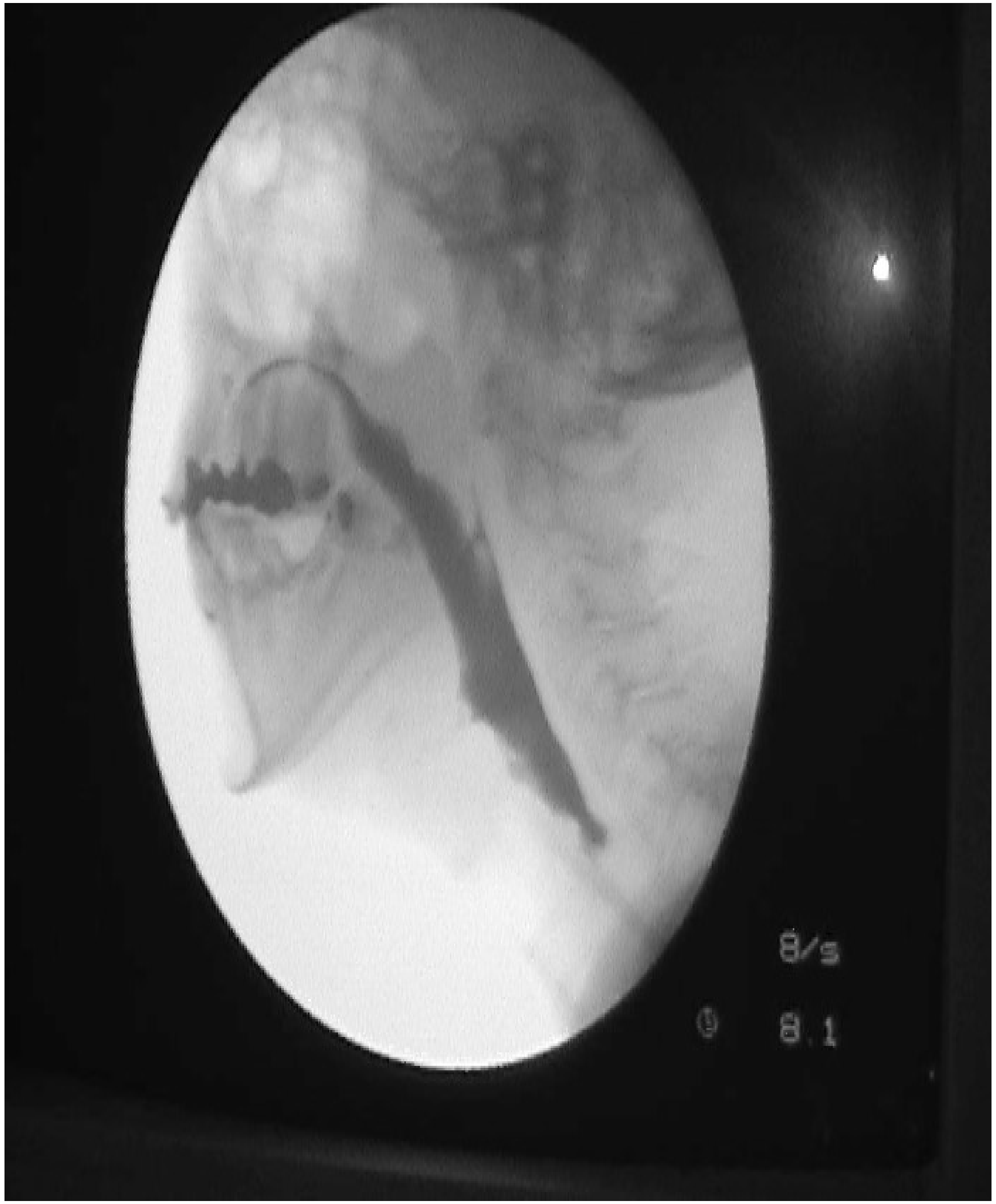
PHARINGEAL PHASE



PHARINGEAL PHASE



PHARINGEAL PHASE



Reference Values for Healthy Swallowing Across the Range From Thin to Extremely Thick Liquids

Catriona M. Steele,[a,b] Melanie Peladeau-Pigeon,[a] Carly A. E. Barbon,[a,b] Brittany T. Guida,[a] Ashwini M. Namasivayam-MacDonald,[a,b,c] Weslania V. Nascimento,[a,d] Sana Smaoui,[a,b] Melanie S. Tapson,[a,b] Teresa J. Valenzano,[a,b] Ashley A. Waito,[a,b] and Talia S. Wolkin[a]

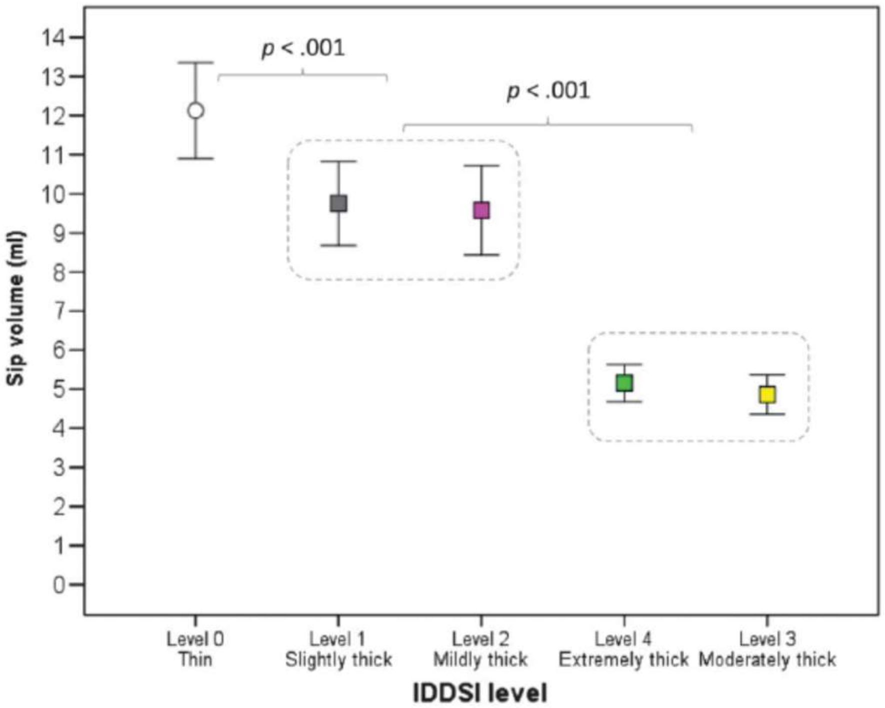


Table 1. Descriptive statistics for sip volume (milliliters) by consistency, for thin and xanthan gum–thickened barium stimuli (20% w/v).

Consistency	*M*	*SD*	95% confidence interval Lower bound	95% confidence interval Upper bound
Thin	12.13	6.68	10.90	13.36
Slightly thick	9.75	5.87	8.68	10.83
Mildly thick	9.58	6.23	8.44	10.72
Moderately thick	4.86	2.76	4.36	5.37
Extremely thick	5.15	2.59	4.68	5.63

Timing measure	Consistency	Event latency in frames			
				95% confidence interval	
		M	*SD*	Lower bound	Upper bound
Swallow Reaction Time (i.e., bolus passing the mandible to hyoid burst onset)	Thin	3.25	5.32	2.06	4.44
	Slightly thick	5.32	8.07	3.71	6.93
	Mildly thick	5.95	8.33	4.29	7.61
	Moderately thick	9.22	12.05	6.79	11.65
	Extremely thick	10.41	14.11	7.55	13.26
Hyoid burst onset to UES opening	Thin	3.48	1.45	3.16	3.81
	Slightly thick	3.70	1.82	3.33	4.06
	Mildly thick	3.83	1.74	3.48	4.18
	Moderately thick	4.55	1.65	4.21	4.88
	Extremely thick	4.65	1.52	4.34	4.95
UES opening duration	Thin	13.72	1.88	13.30	14.14
	Slightly thick	13.18	1.89	12.81	13.56
	Mildly thick	13.26	2.26	12.81	13.71
	Moderately thick	12.31	2.09	11.89	12.73
	Extremely thick	12.05	2.02	11.64	12.46
LVC Reaction Time (i.e., hyoid burst onset to LVC)	Thin	5.38	3.00	4.71	6.05
	Slightly thick	5.33	2.70	4.79	5.87
	Mildly thick	4.82	2.36	4.35	5.29
	Moderately thick	4.55	1.88	4.17	4.93
	Extremely thick	4.30	1.63	3.97	4.63
LVC duration	Thin	13.06	3.24	12.34	13.79
	Slightly thick	12.36	2.69	11.83	12.90
	Mildly thick	12.96	2.99	12.36	13.56
	Moderately thick	13.01	2.71	12.46	13.56
	Extremely thick	13.08	2.50	12.58	13.59

Note. UES = upper esophageal sphincter; LVC = laryngeal vestibule closure.

Reference Values for Healthy Swallowing Across the Range From Thin to Extremely Thick Liquids

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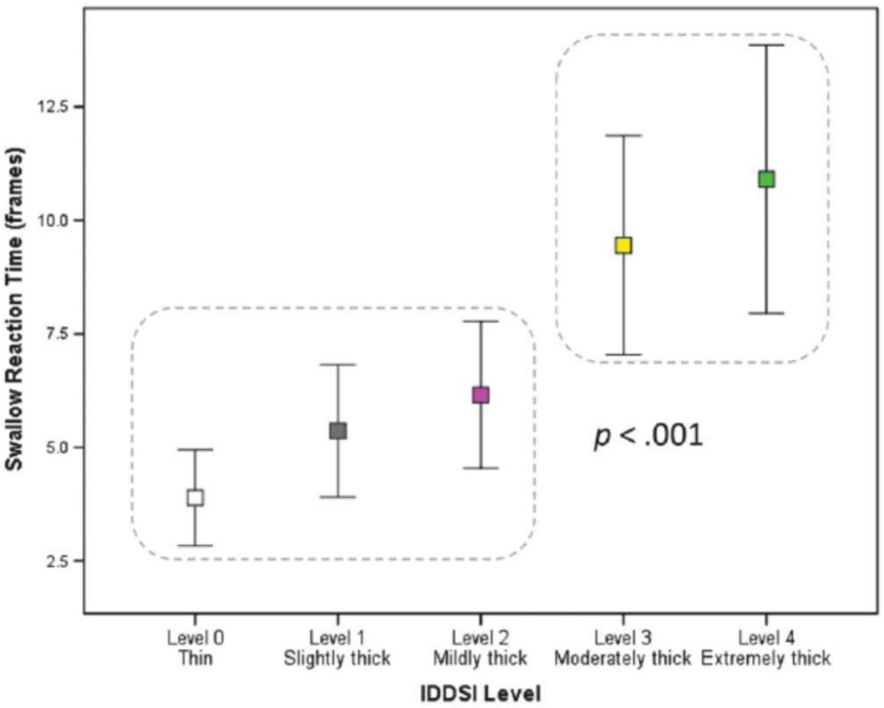

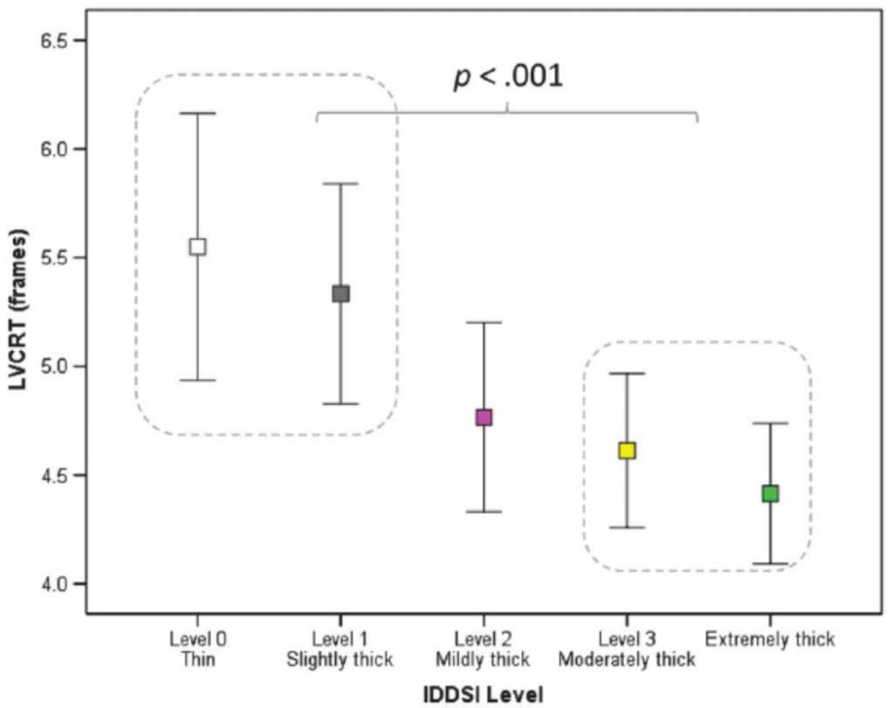

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Table 3. Descriptive statistics for the timing of maximum pharyngeal constriction, expressed as a percentage of upper esophageal sphincter opening duration.

Consistency	*M*	*SD*	95% confidence interval	
			Lower bound	Upper bound
Thin	49.5	12.1	46.6	52.4
Slightly thick	48.8	11.0	46.1	51.5
Mildly thick	48.9	11.5	46.2	51.5
Moderately thick	44.3	10.1	41.5	47.1
Extremely thick	44.1	10.2	41.3	46.8

Reference Values for Healthy Swallowing Across the Range From Thin to Extremely Thick Liquids

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Table 7. Descriptive statistics for maximum diameter of upper esophageal sphincter opening, expressed as percentage of the C2–C4 reference scalar.

Consistency	*M*	*SD*	95% confidence interval	
			Lower bound	Upper bound
Thin	20.6	6.6	19.3	21.8
Slightly thick	18.7	5.8	17.7	19.8
Mildly thick	18.3	5.1	17.4	19.3
Moderately thick	15.6	5.3	14.7	16.6
Extremely thick	16.9	4.7	16.0	17.7

TAKE HOME MESSAGE

Pharyngeal phase of swallowing is a very rapid phenomenon

Timing in biomechanical events is crucial

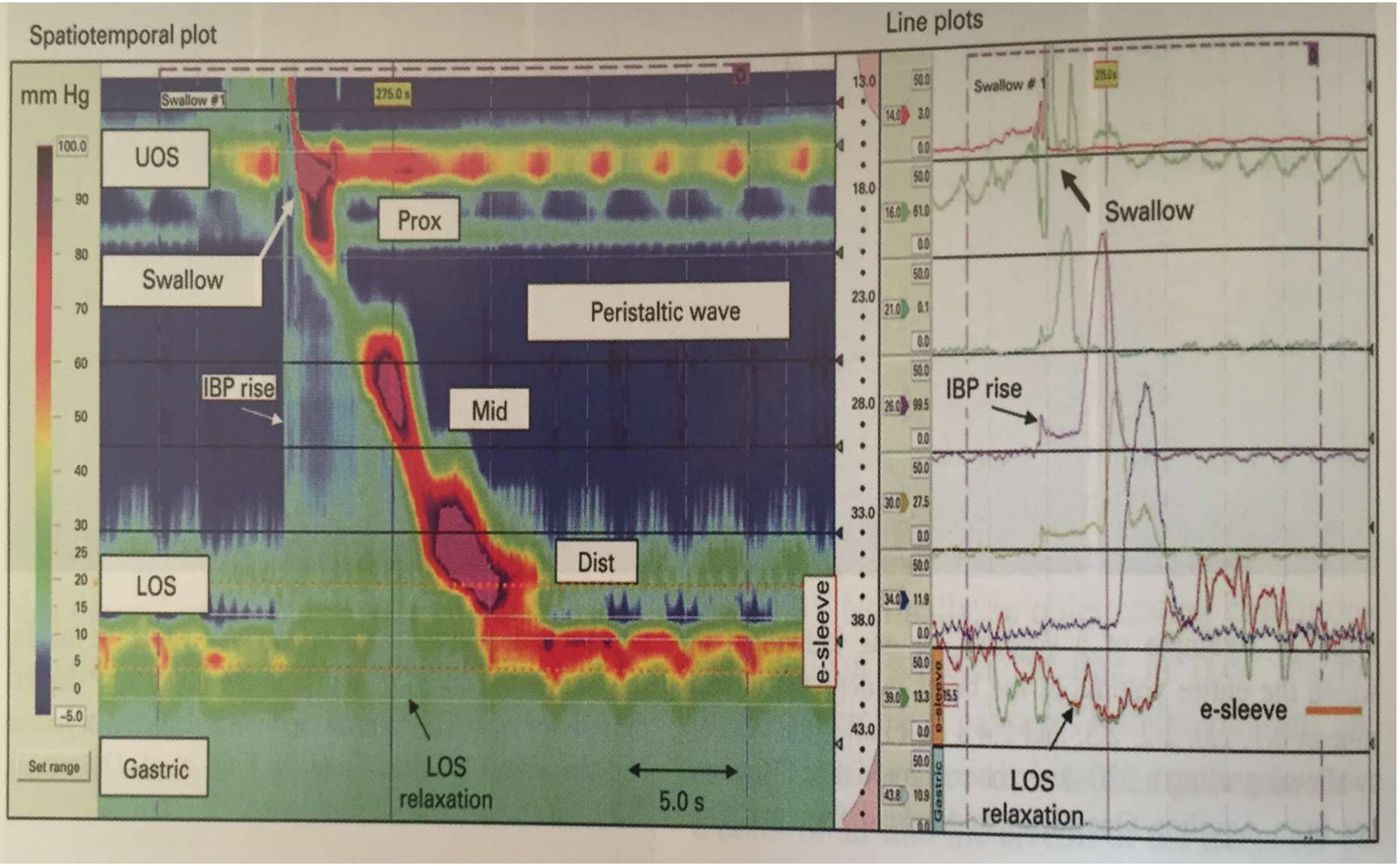
Other key factors are:

- Tongue strength to move the bolus
- Laryngeal elevation to open the UES

OUTLINE

- Swallowing and body functions
- The oral phase
- The pharyngeal phase
- The esophpgeal phase
- The neural circuites underlying swallowing
- Swallowing physiology in the elderly

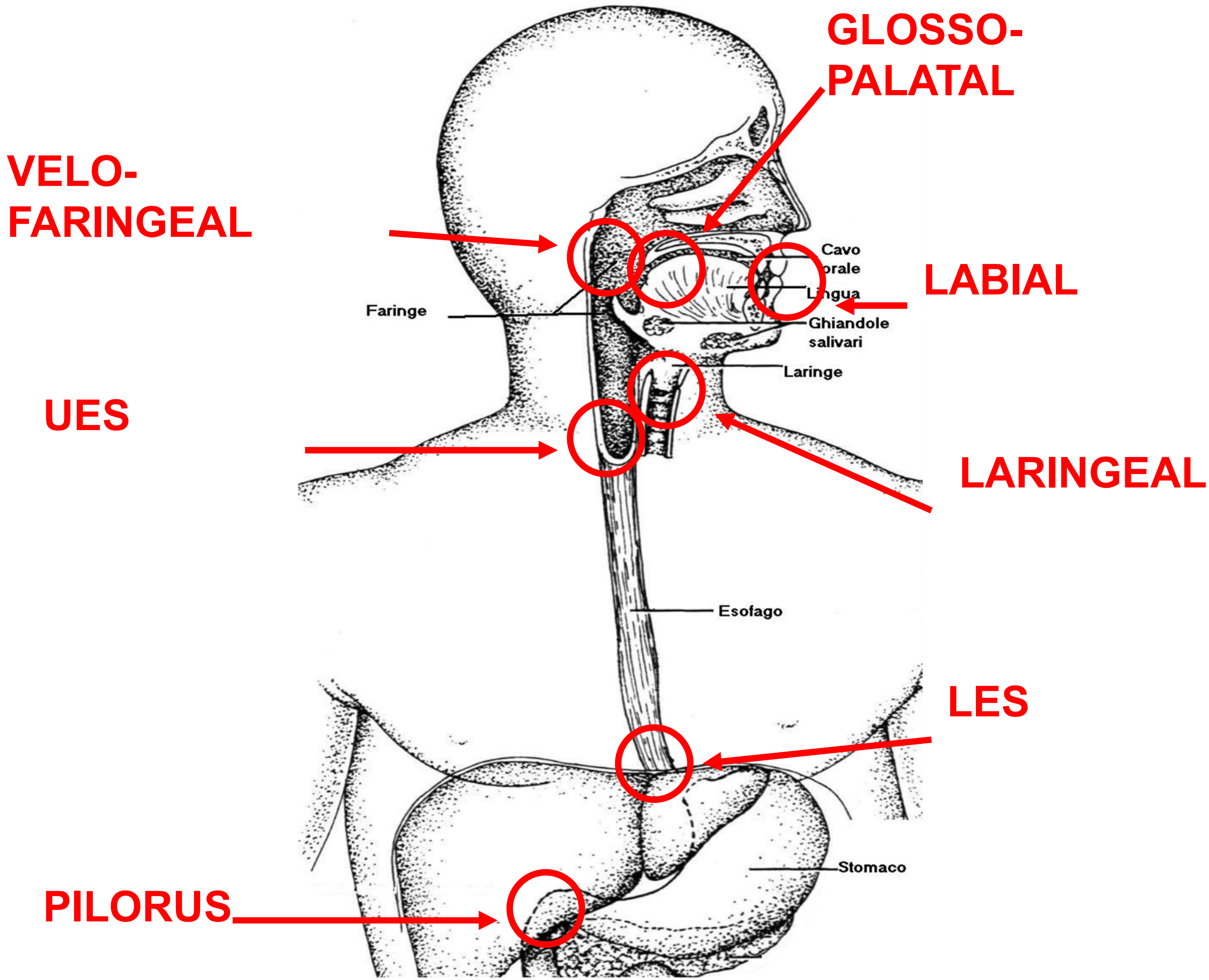

ISTITUT
RADI



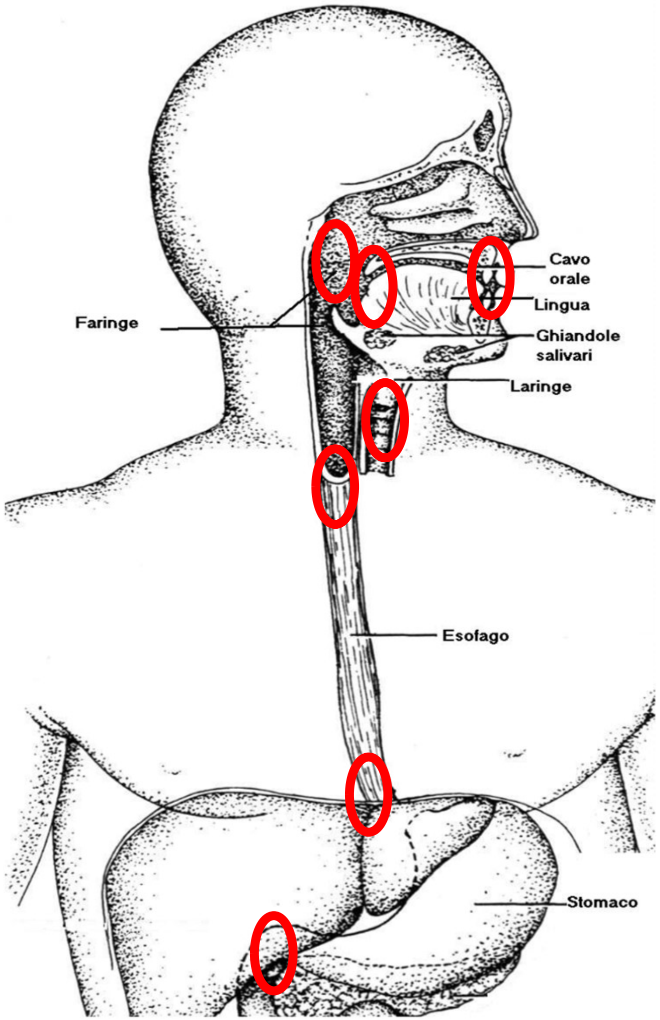
Spatiotemporal plot
mm Hg
UOS
Prox
Swallow
Peristaltic wave
IBP rise
Mid
Dist
LOS
Gastric
LOS relaxation
5.0 s
e-sleeve
Set range
Line plots
Swallow
IBP rise
e-sleeve
LOS relaxation

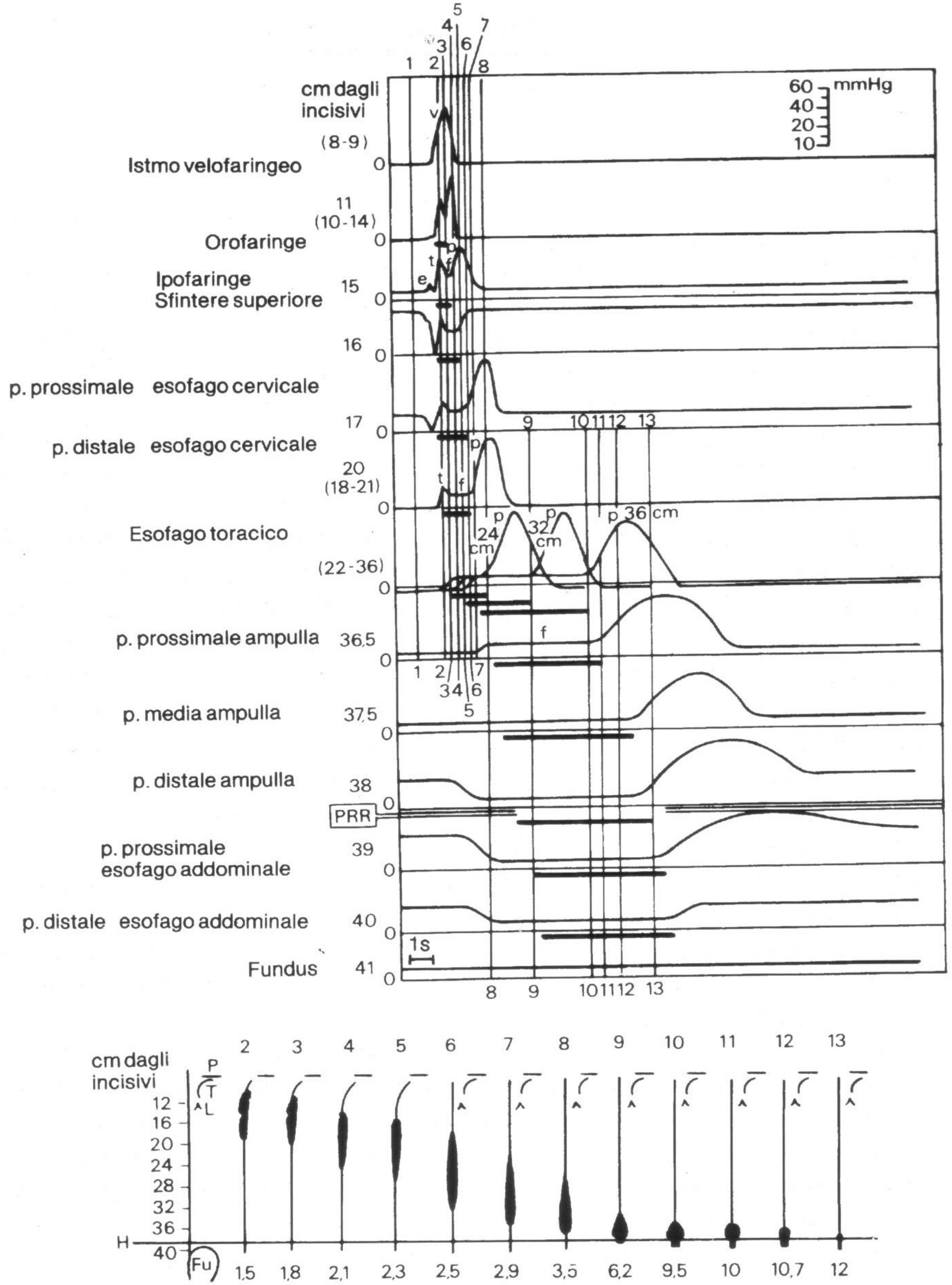
FASE GASTRICA

E' il punto finale della deglutizione.
Anche questa fase è governata dal funzionamento di una muscolatura liscia compresa fra due sfinteri (il cardias e il piloro)



GLOSSO-
PALATAL
VELO-
FARINGEAL
Cavo
orale
Lingua
LABIAL
Faringe
Ghiandole
salivari
Laringe
UES
LARINGEAL
Esofago
LES
Stomaco
PILORUS

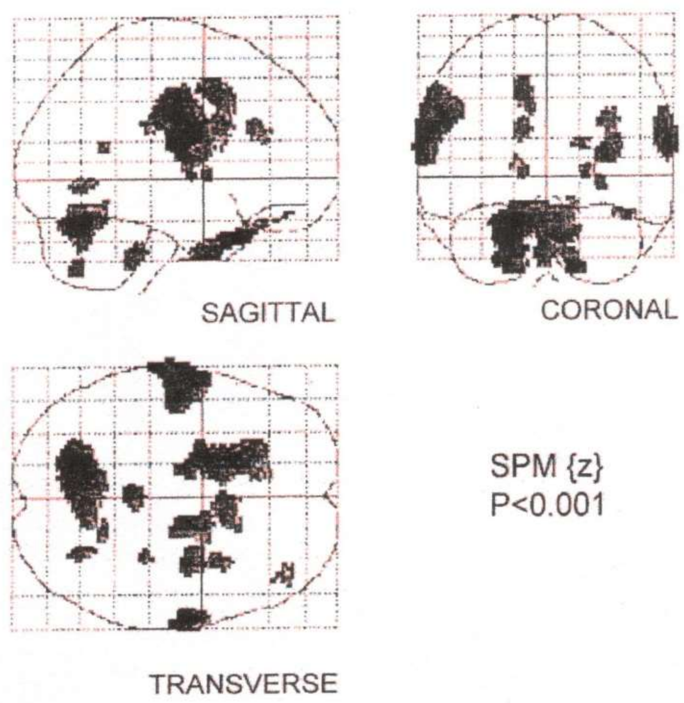

Cavo
orale
Lingua
Faringe
Ghiandole
salivari
Laringe
Esofago
Stomaco

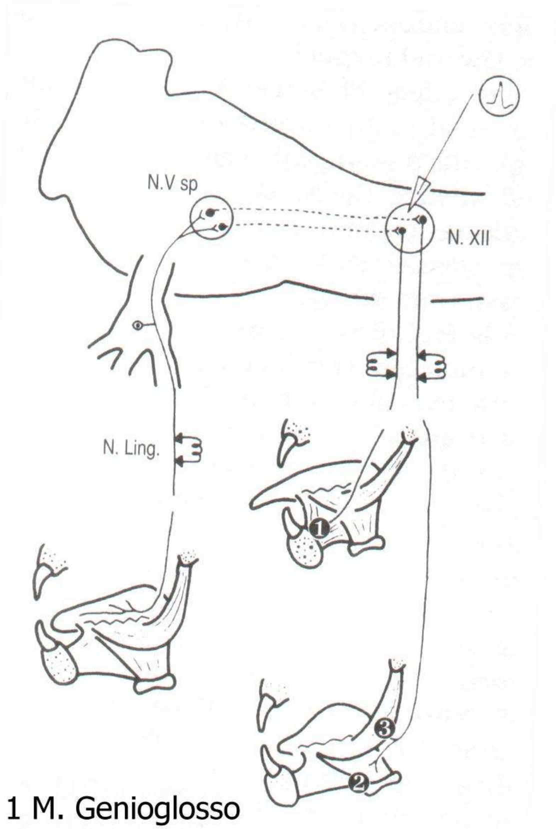

cm dagli
incisivi
60 mmHg
40
20
10
Istmo velofaringeo
(8-9)
11
(10-14)
Orofaringe
Ipofaringe
Sfintere superiore
15
16
p. prossimale esofago cervicale
17
p. distale esofago cervicale
20
(18-21)
Esofago toracico
(22-36)
24 cm
32 cm
36 cm
p. prossimale ampulla
36,5
p. media ampulla
37,5
p. distale ampulla
38
PRR
p. prossimale
esofago addominale
39
p. distale esofago addominale
40
1s
Fundus
41
cm dagli
incisivi
Fu
1,5
1,8
2,1
2,3
2,5
2,9
3,5
6,2
9,5
10
10,7
12

OUTLINE

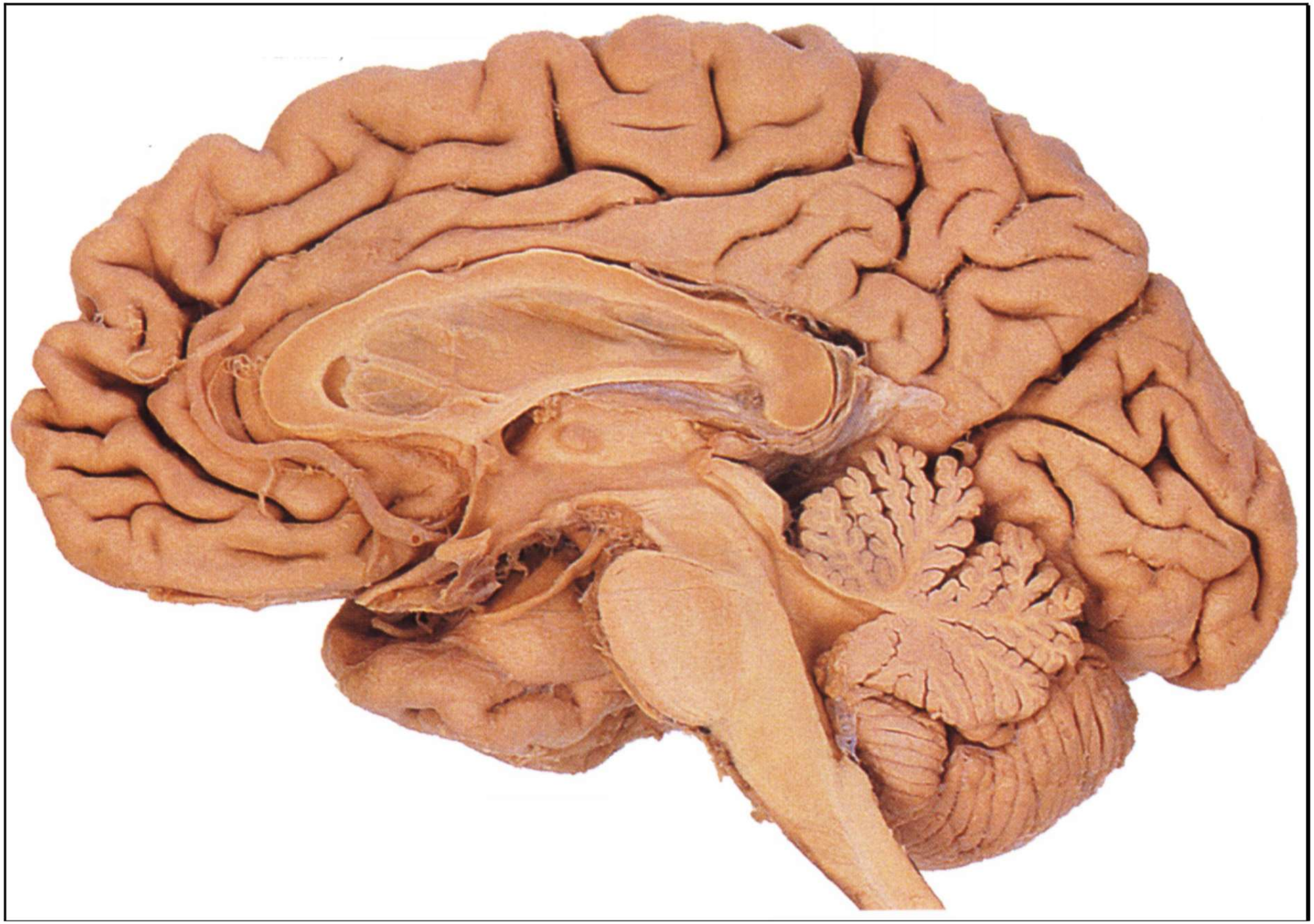
- Swallowing and body functions
- The oral phase
- The pharyngeal phase
- The esophpageal phase
- The neural circuites underlying swallowing
- Swallowing physiology in the elderly

MECCANISMI NEURALI

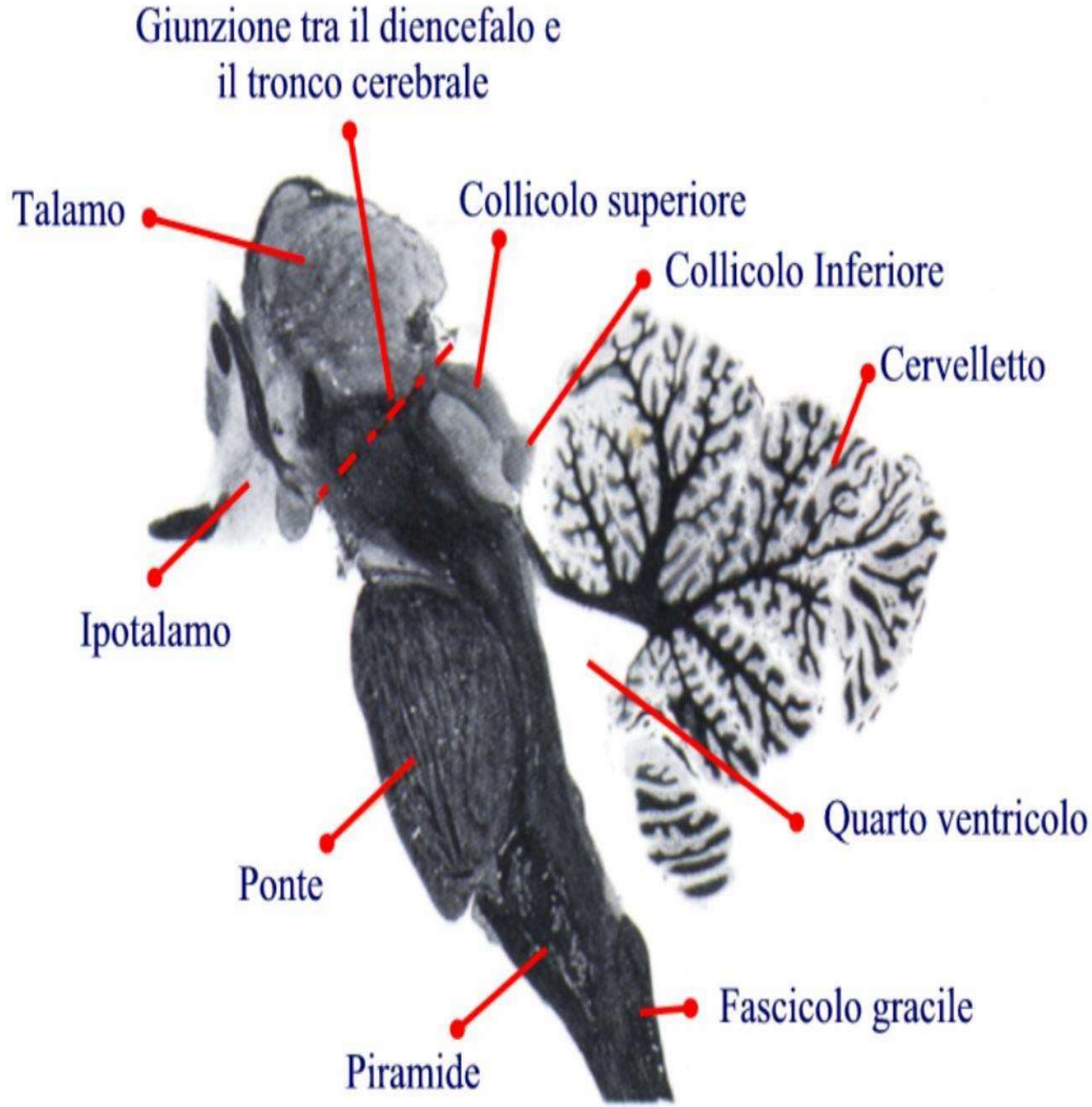


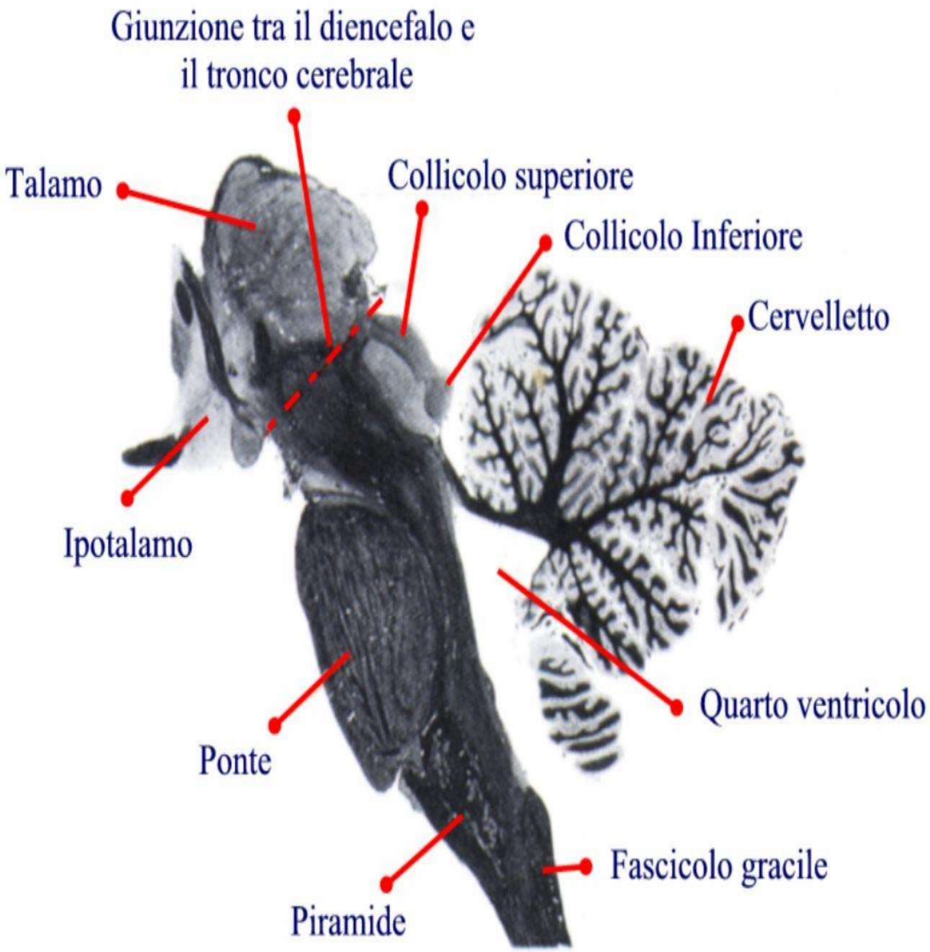


1 M. Genioglosso
2 M. Ioglosso
3 M. Stiloglosso

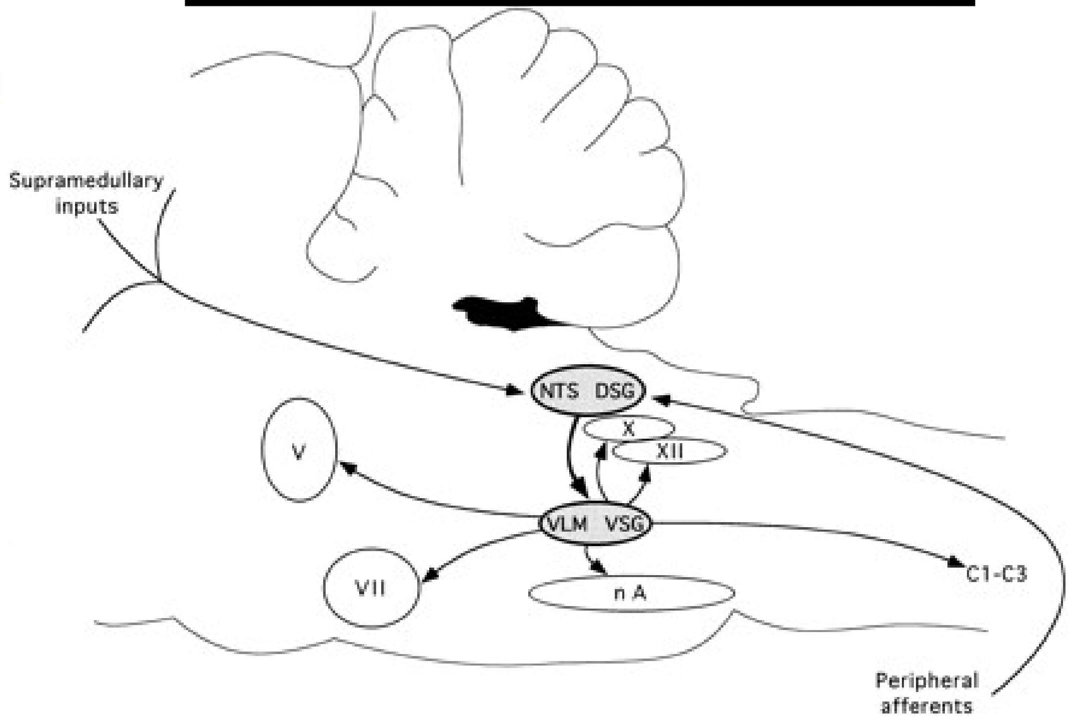


TRONCO DELL'ENCEFALO: INPUT-OUPUT



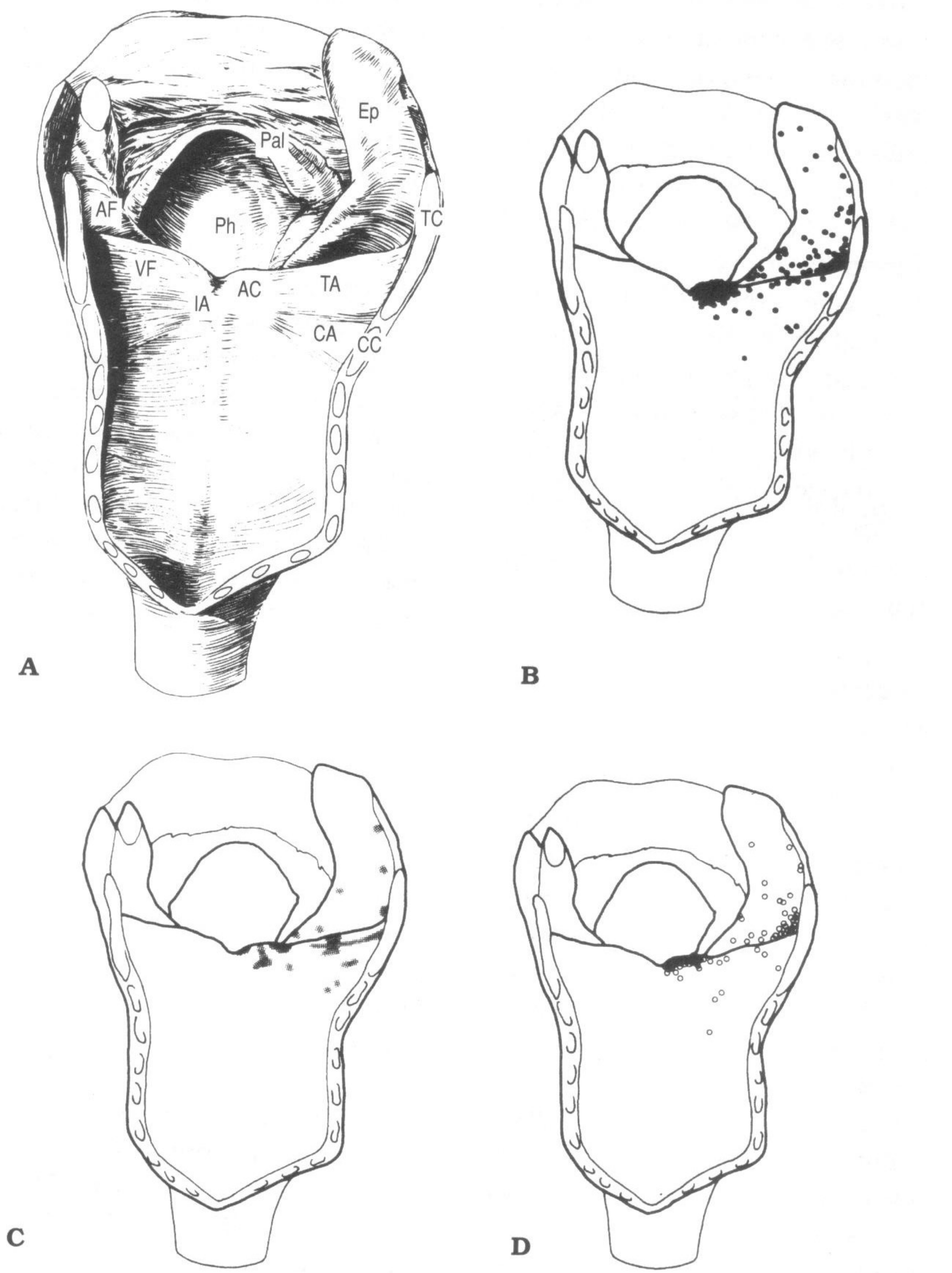


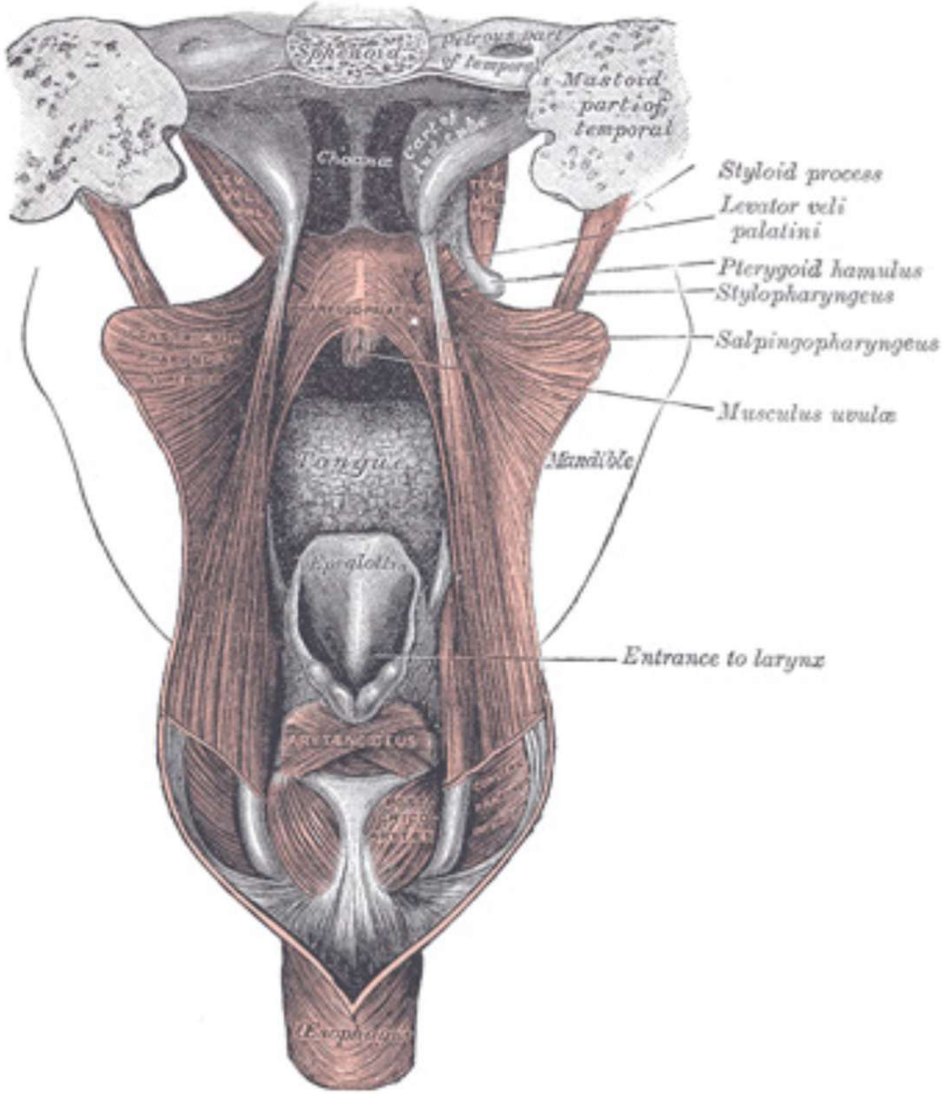
Giunzione tra il diencefalo e
il tronco cerebrale
Talamo
Collicolo superiore
Collicolo Inferiore
Cervelletto
Ipotalamo
Quarto ventricolo
Ponte
Fascicolo gracile
Piramide

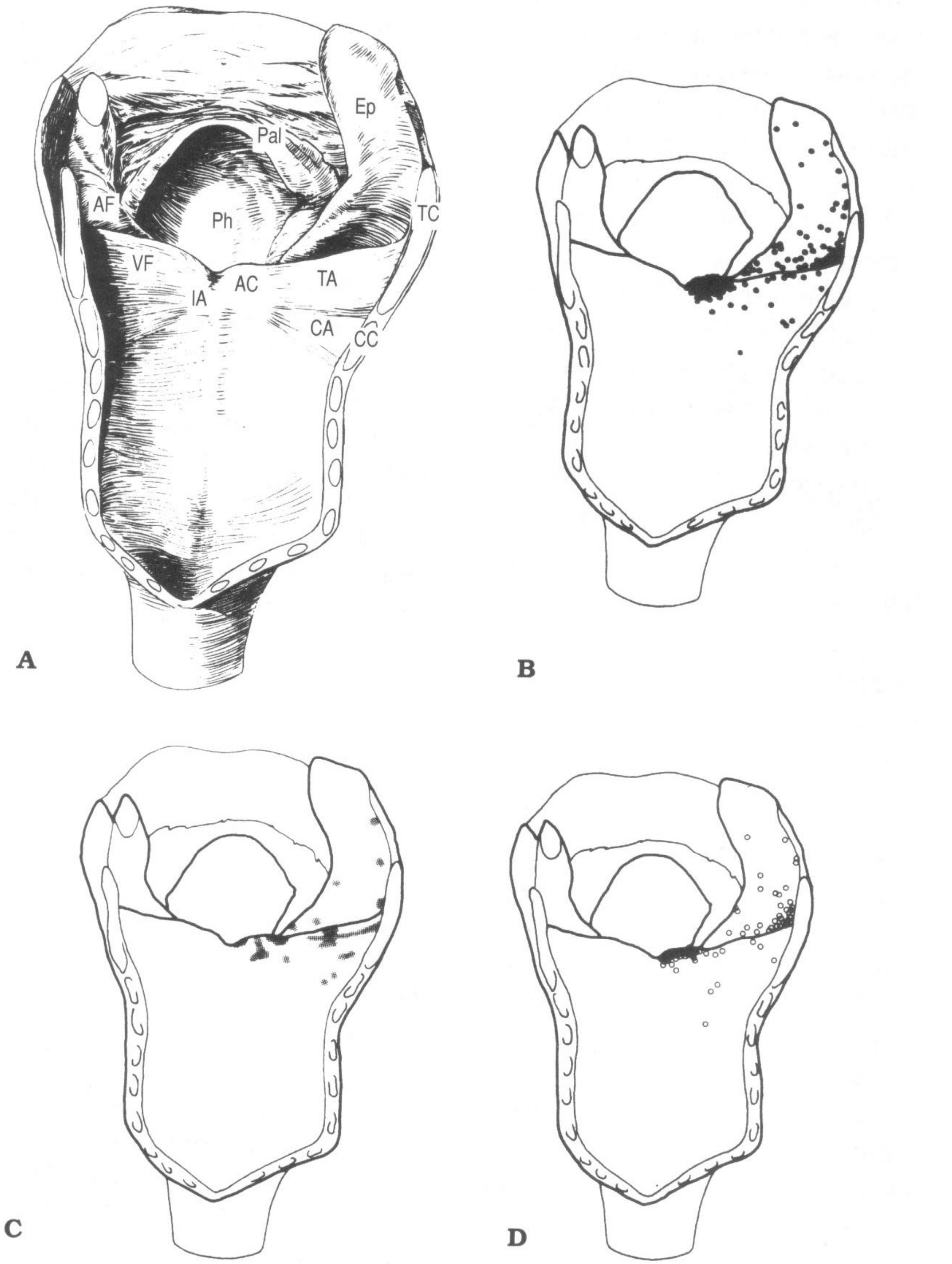


Supramedullary
inputs
NTS DSG
X
XII
V
VLM VSG
VII
n A
C1-C3
Peripheral
afferents

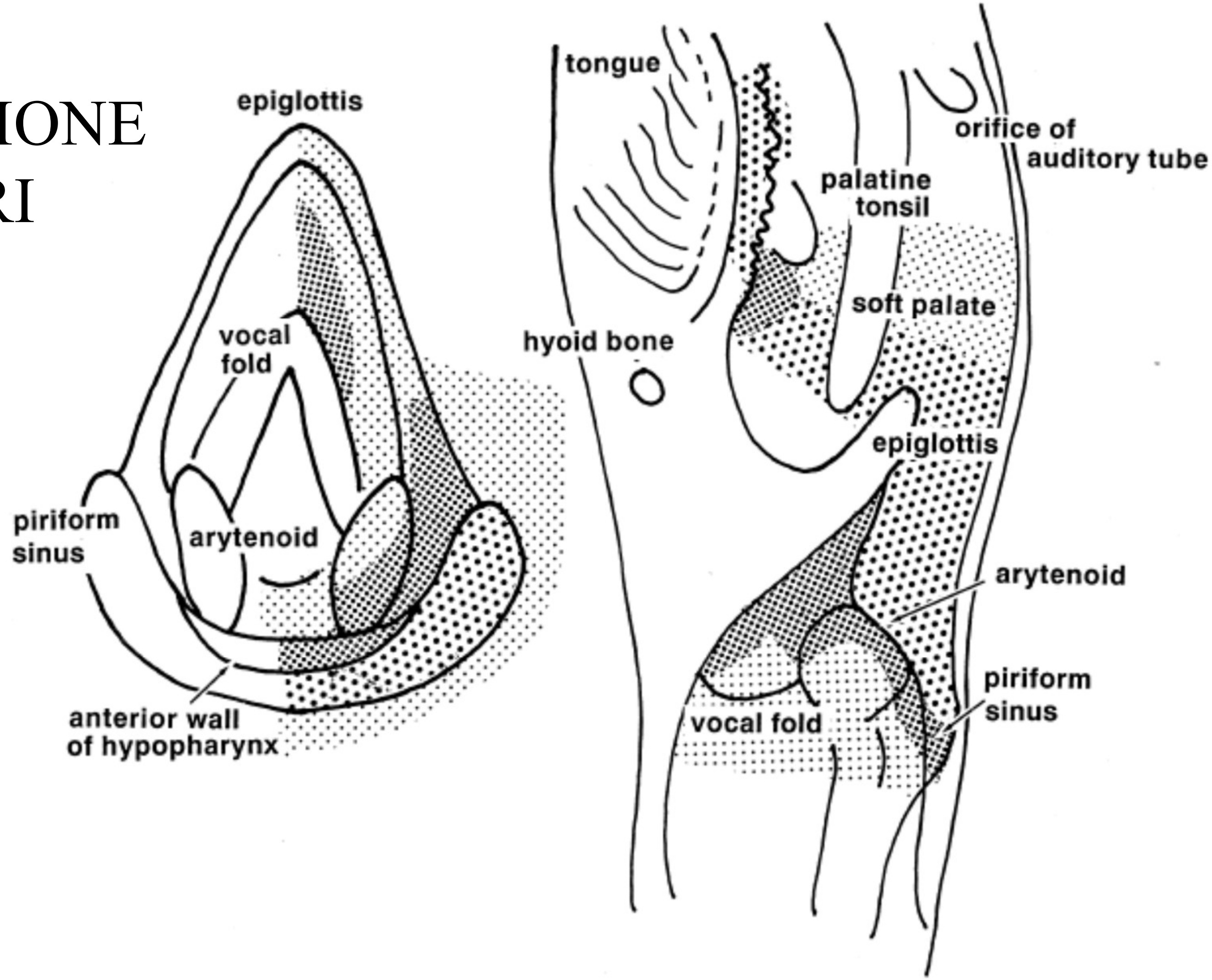
RECETTORI
- visivi (II NC)
- olfattivi (I NC)
- tattili (V/IX/X NC)
- termici (V/IX/X NC)
- dolorifici (V/IX/X NC)
- osteomuscolari (V/IX/X NC)
- articolari (V/IX/X NC)
- gustativi (VII/IX/X NC)



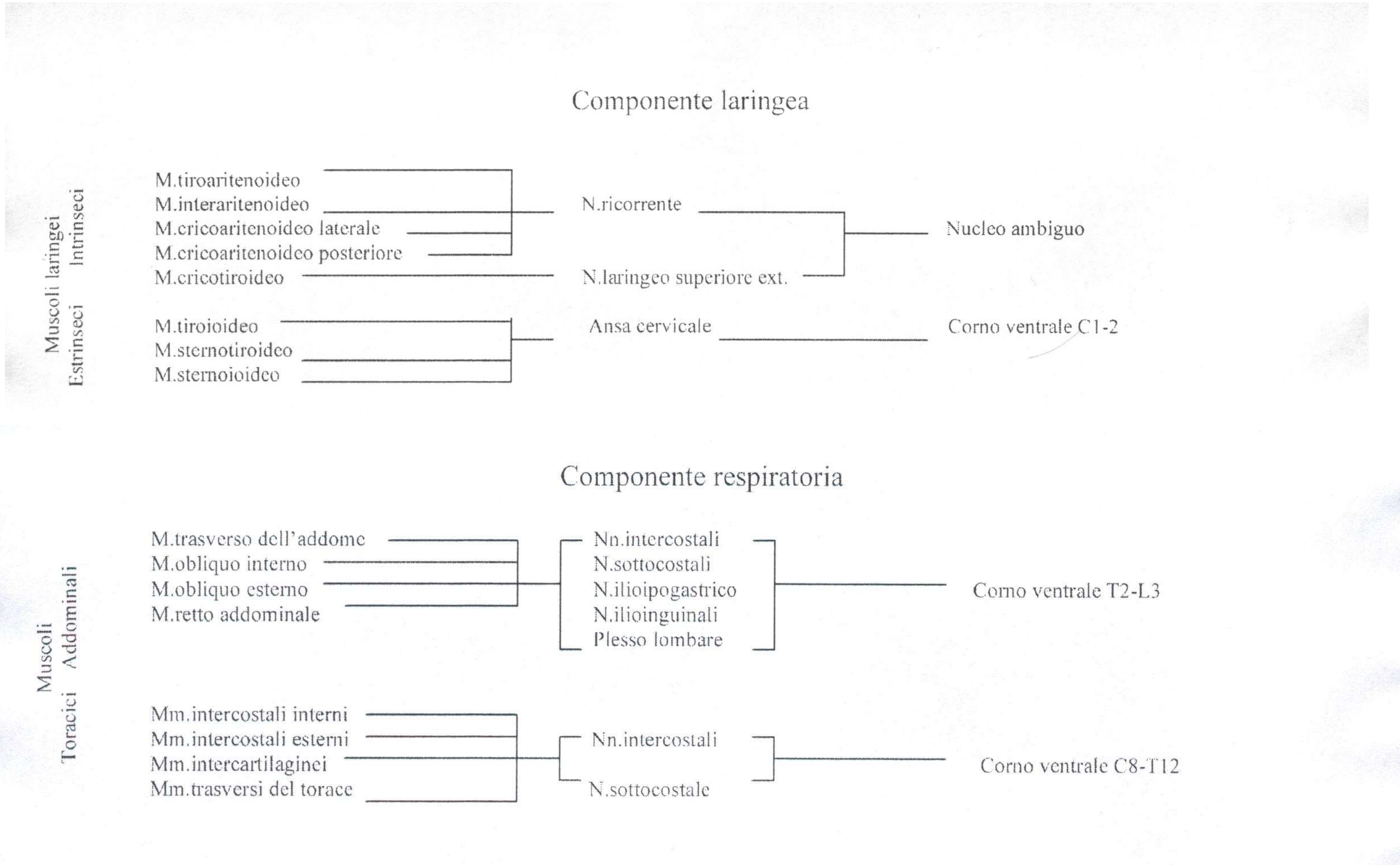

Sphenoid
Petrous part of temporal
Mastoid part of temporal
Choanæ
Styloid process
Levator veli palatini
Pterygoid hamulus
Stylopharyngeus
Salpingopharyngeus
Musculus uvulæ
Mandible
Tongue
Epiglottis
Entrance to larynx
Arytænoideus
Œsophagus


Ep
Pal
AF
Ph
TC
VF
IA
AC
TA
CA
CC
A
B
C
D

CONCENTRAZIONE DEI RECETTORI



MUSCOLI, NERVI, NUCLEI NERVOSI



Componente sovralaringea

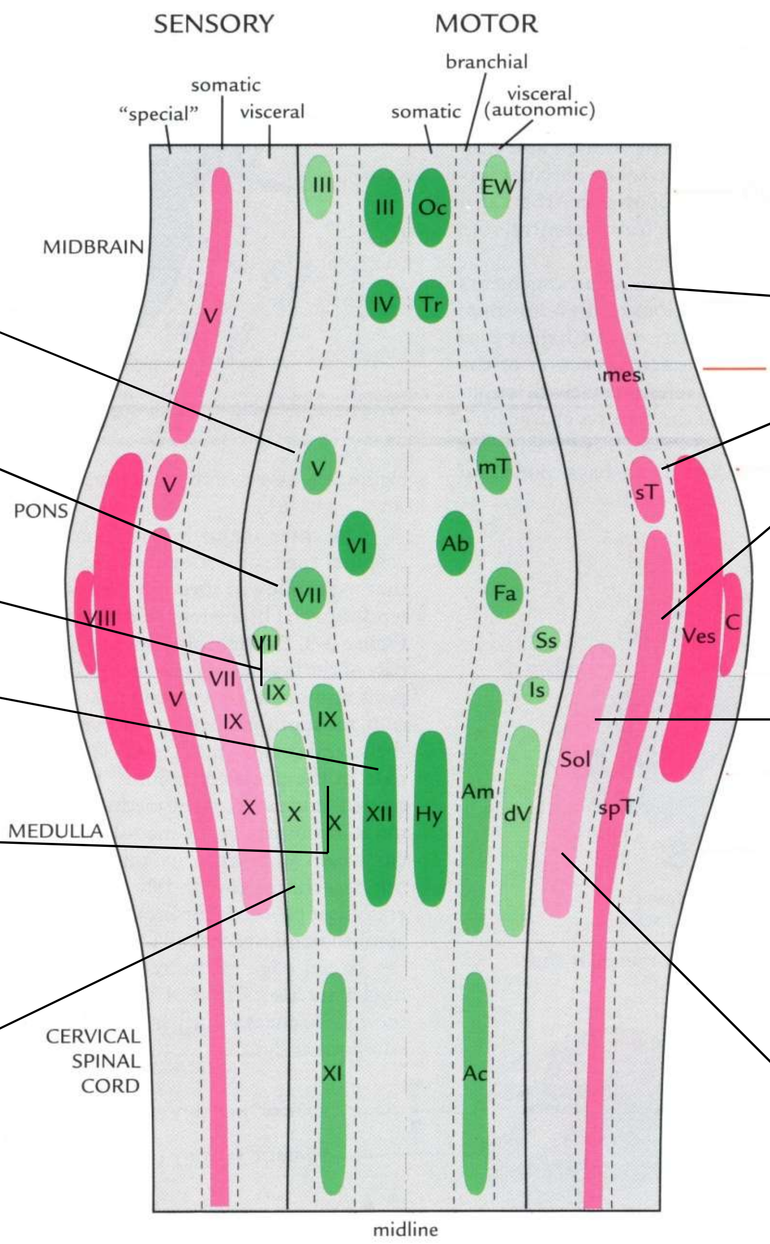
Muscoli labiali	M.orbicolare della bocca	N. facciale	Nucleo del facciale
	M.zigomatico		
	M.buccinatore		
	M.elevatore labiale superiore		
	M.depressore labiale inferiore		
	M.depressore angolo bocca		
	M.elevatore angolo della bocca		
	M.mentale		
Muscoli Chiusura Bocca	M.digastrico	N.facciale	Nucleo del facciale
	M.miloioideo	N.mandibolare	Nucleo motore del trigemino
	M.pterigoideo esterno		
	M.genioioideo	N.ipoglosso	Nucleo ventrale corno C1-2
Apertura	M.temporale	N.mandibolare	Nucleo motore del trigemino
	M.massetere		
	M.pterigoideo interno		
Velo palatino	M.elevatore del velo del palato	Plesso faringeo	Nucleo ambiguo
	M.tensore del velo del palato	N.mandibolare	Nucleo motore del trigemino
Muscolatura lingua Intrinseca	M.longitudinale superiore lingua	N.ipoglosso	Nucleo dell' ipoglosso
	M.longitudinale inferiore lingua		
	M.traverso della lingua		
	M.verticale della lingua		
Estrinseca	M.ioglosso		
	M.genioglosso		
	M.stiloglosso		

mm. Masticatori
mm. Mimici

Salivazione
mm. Linguali

Mm. Laringei
mm. Faringei

Attività
parasimpatica del
vago

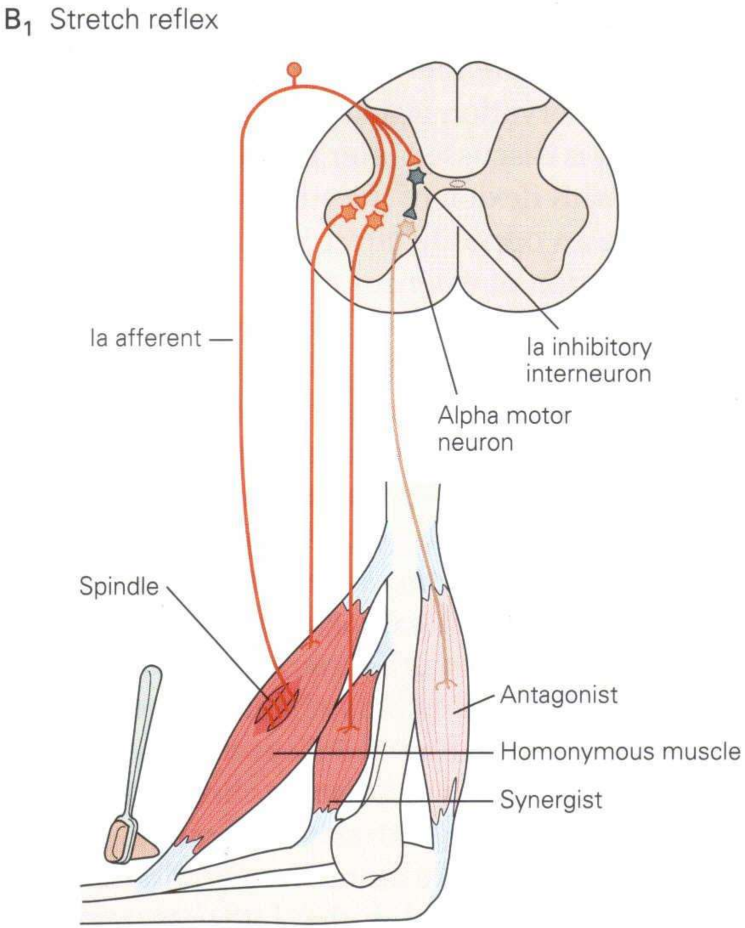


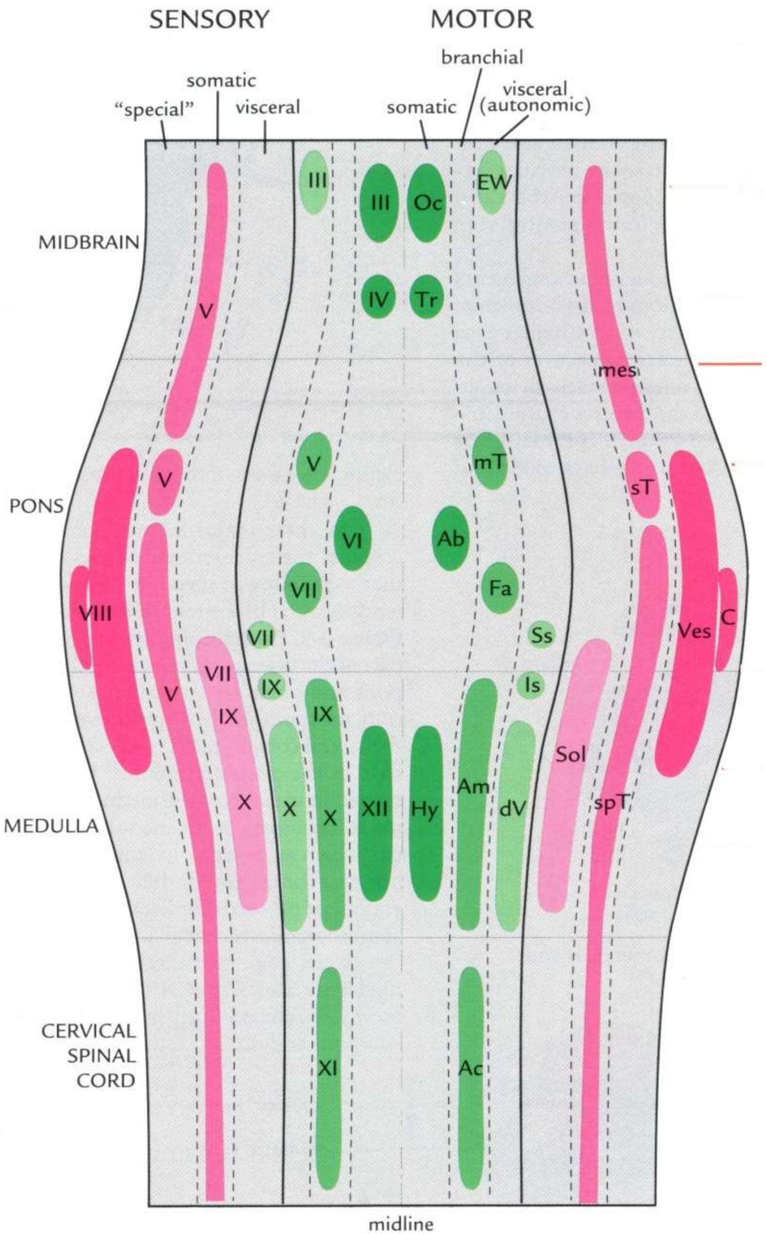
Sensibilità tattile,
termica, dolorifica,
cinestesica del volto
e della bocca

Sensibilità gustativa

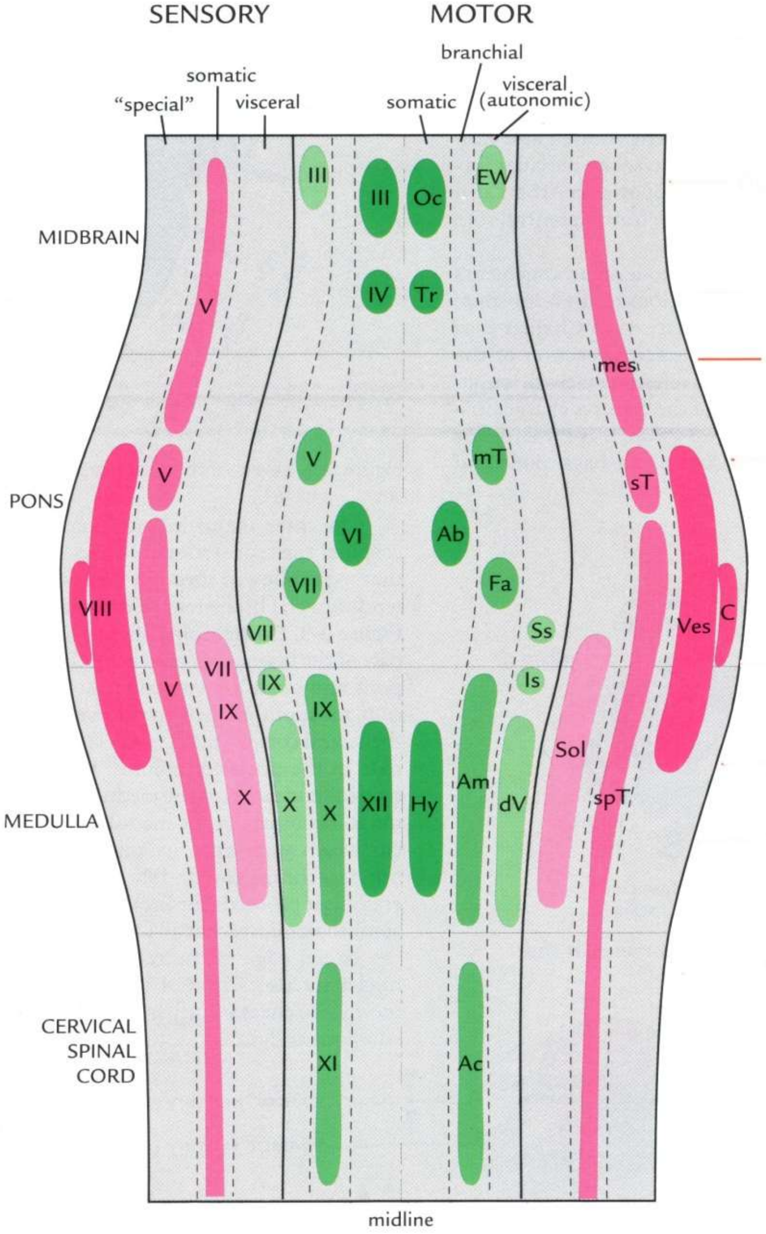
Sensibilità tattile,
termica, dolorifica,
cinestesica della
faringe e della
laringe

IL RIFLESSO DA STIRAMENTO INPUT-OUTPUT

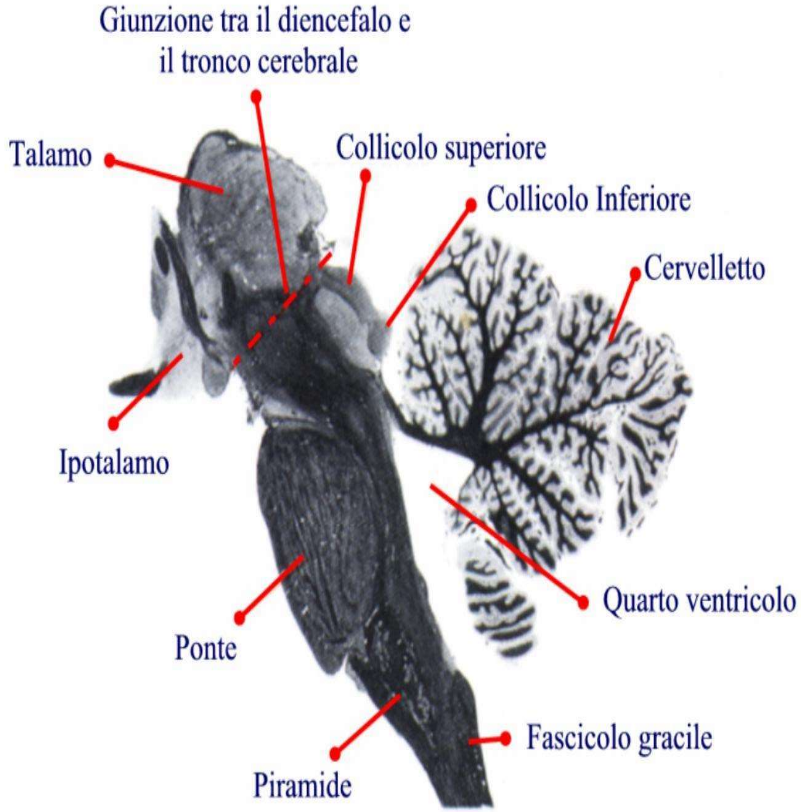




SENSORY
MOTOR
branchial
somatic
visceral
(autonomic)
"special"
somatic
visceral
MIDBRAIN
PONS
MEDULLA
CERVICAL
SPINAL
CORD
III
III
Oc
EW
V
IV
Tr
mes
V
mT
V
sT
VI
Ab
VIII
VII
Fa
Ves
C
VII
Ss
VII
V
IX
Is
IX
IX
Sol
Am
X
X
X
XII
Hy
dV
spT
XI
Ac
midline



SENSORY
MOTOR
"special"
somatic
visceral
somatic
branchial
visceral (autonomic)
MIDBRAIN
PONS
MEDULLA
CERVICAL SPINAL CORD
III
Oc
EW
IV
Tr
V
mes
mT
sT
VI
Ab
VII
Fa
VIII
Ves
C
Ss
Is
IX
X
XII
Hy
Am
dV
Sol
spT
XI
Ac
midline



Giunzione tra il diencefalo e il tronco cerebrale
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Collicolo superiore
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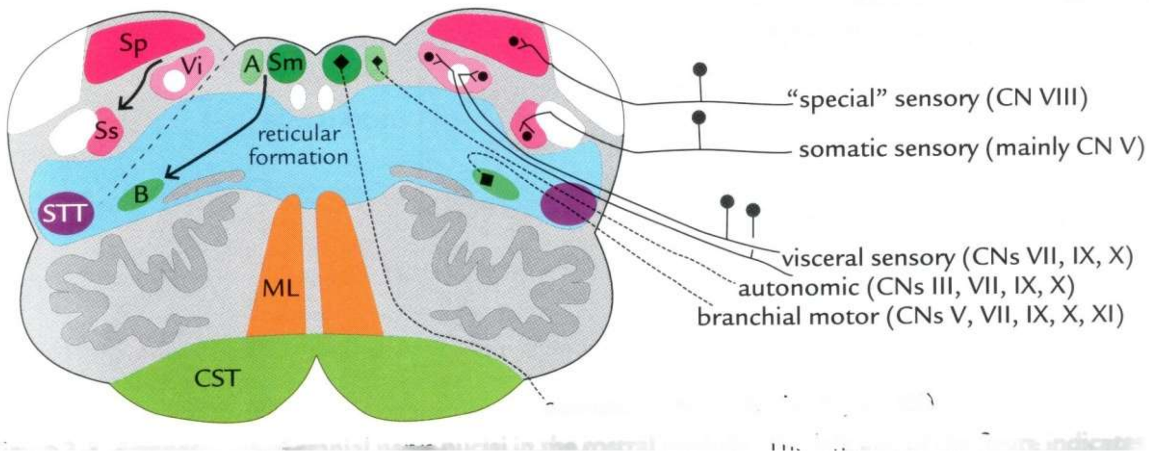
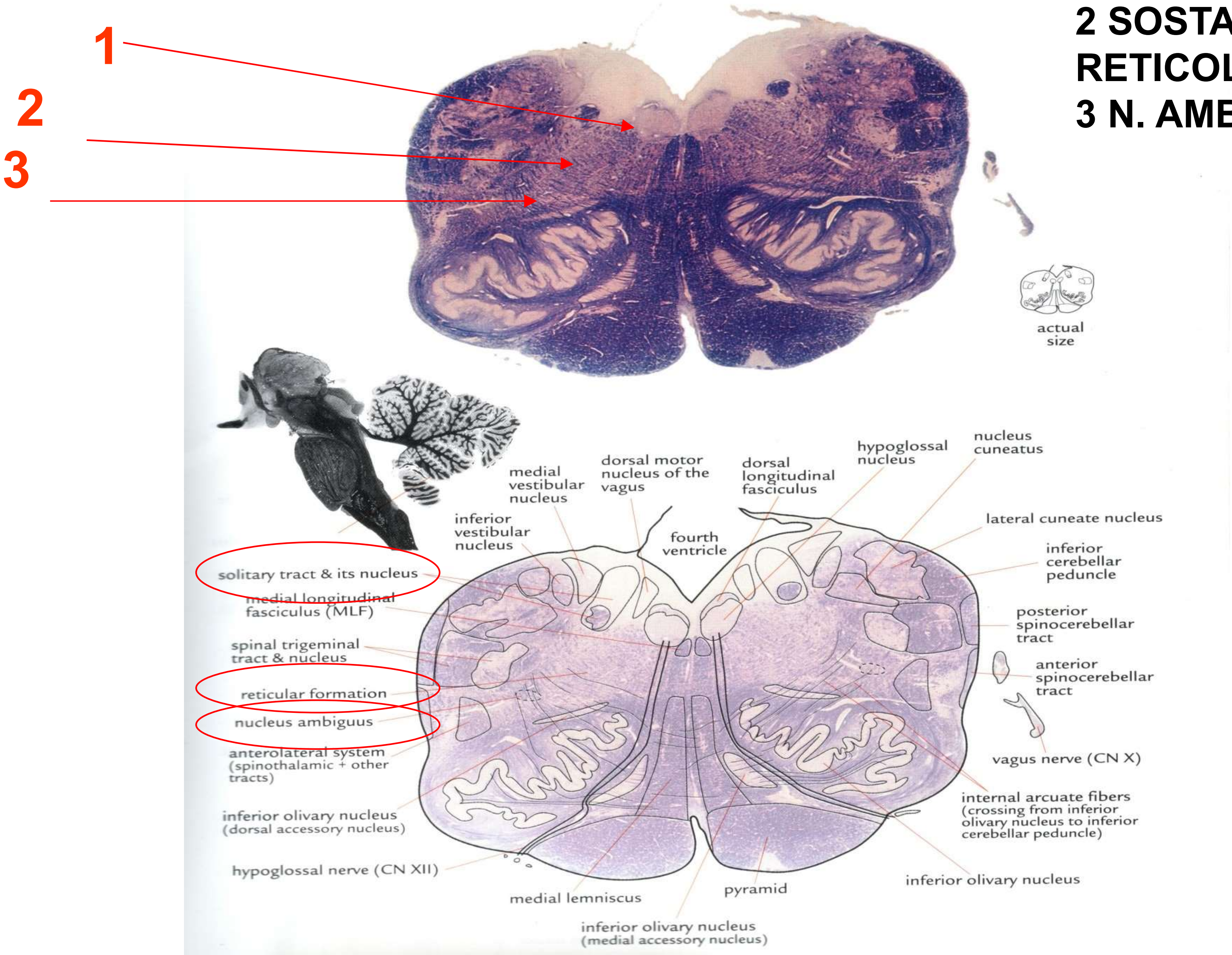
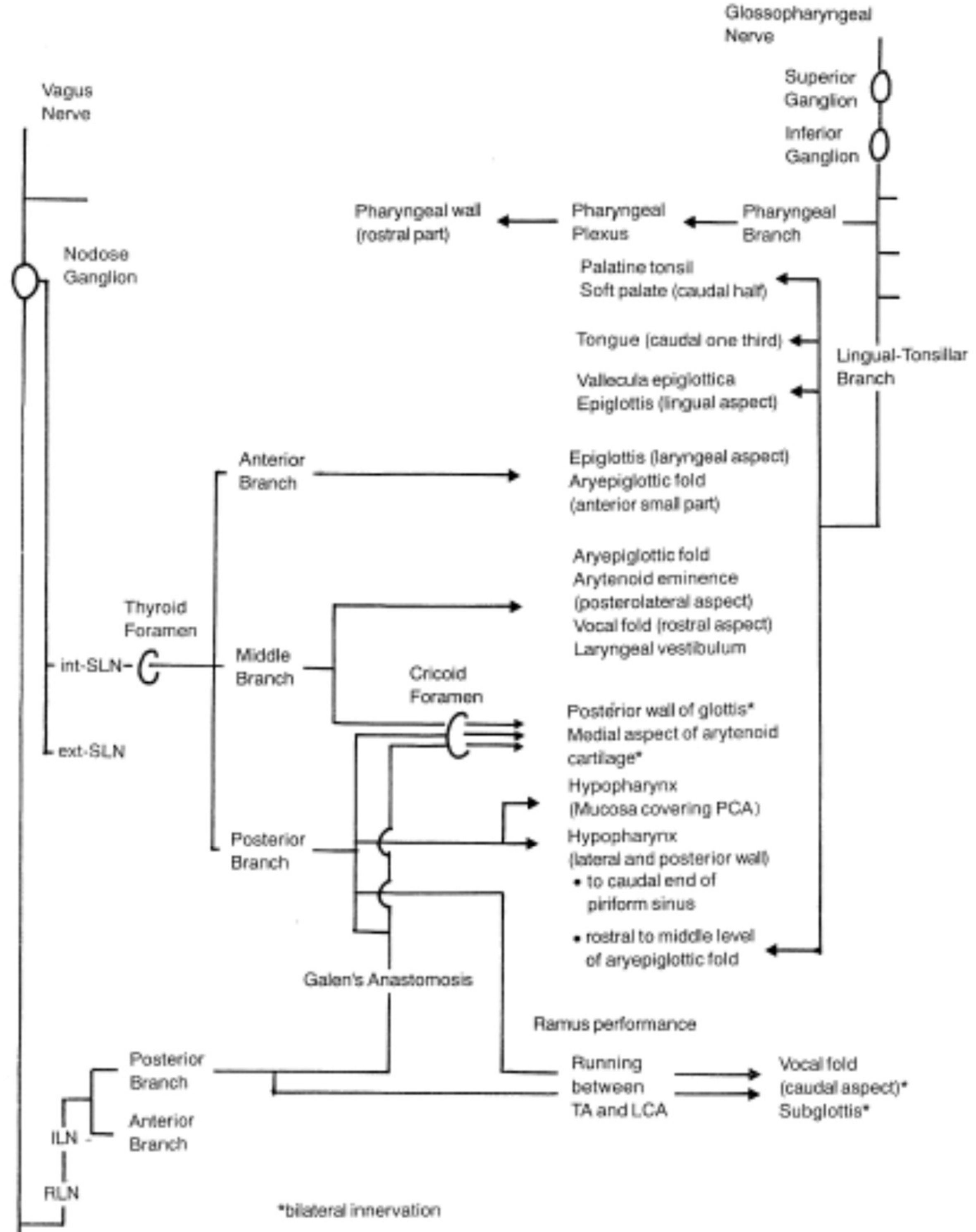


Sp
Vi
A
Sm
Ss
reticular formation
B
STT
ML
CST
"special" sensory (CN VIII)
somatic sensory (mainly CN V)
visceral sensory (CNs VII, IX, X)
autonomic (CNs III, VII, IX, X)
branchial motor (CNs V, VII, IX, X, XI)

1 N. TRATTO SOLITARIO
2 SOSTANZA RETICOLARE
3 N. AMBIGUO



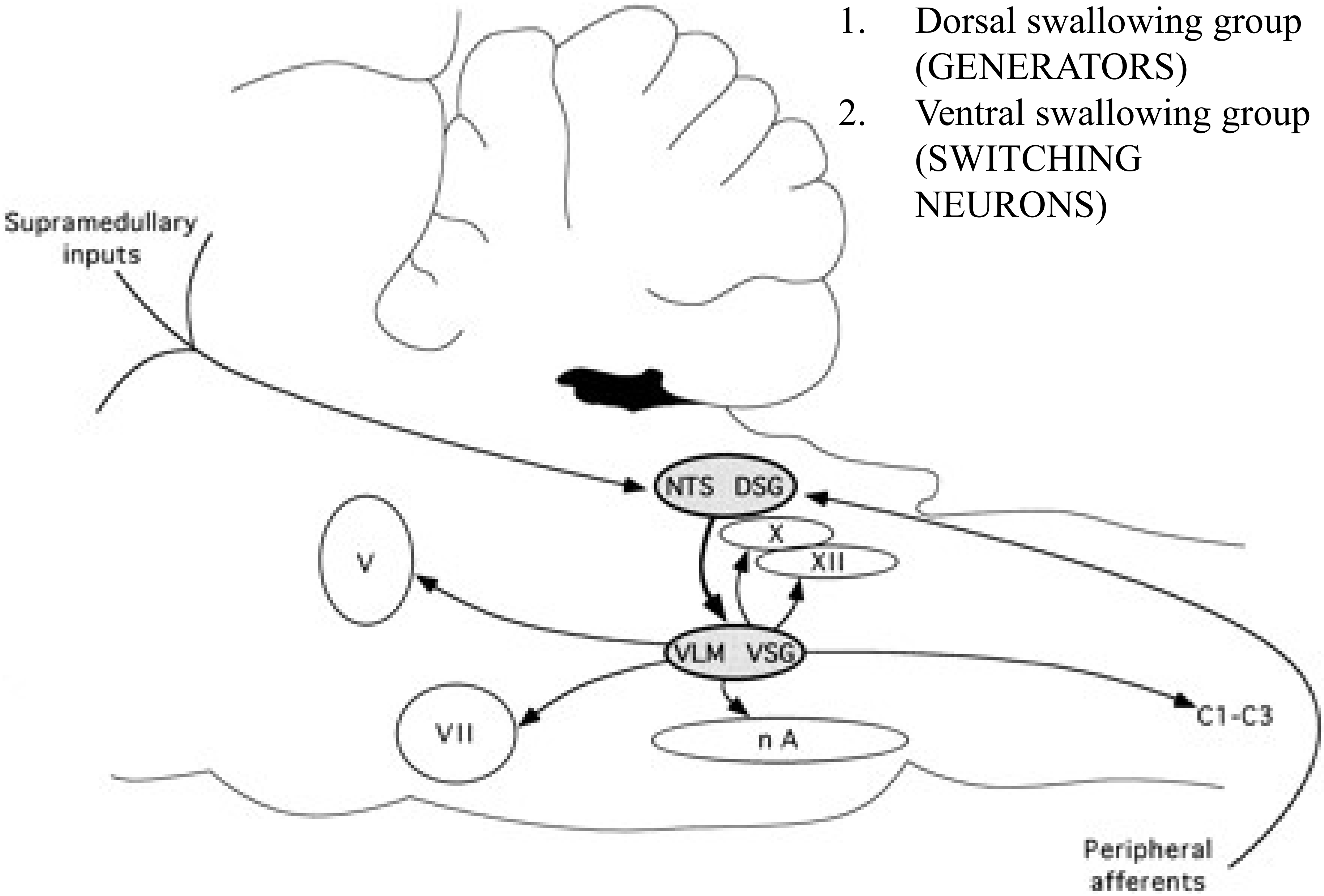


Yoshida et al;
Am J Med 2000;
108(4A): 51S-61S

IL CENTRAL PATTERN GENERATOR

Il CPG è formato da:

1. Dorsal swallowing group (GENERATORS)
2. Ventral swallowing group (SWITCHING NEURONS)



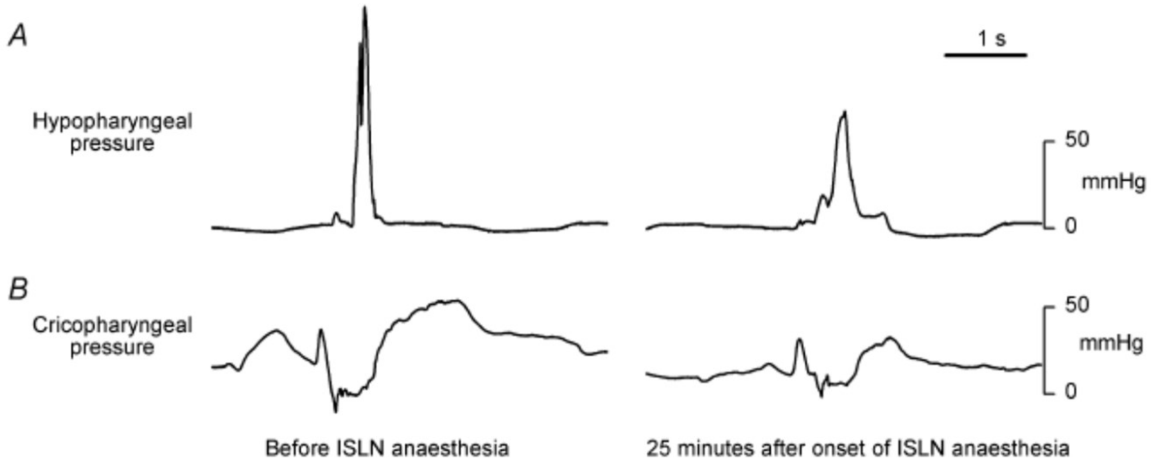
Fase faringea: regolazione nervosa

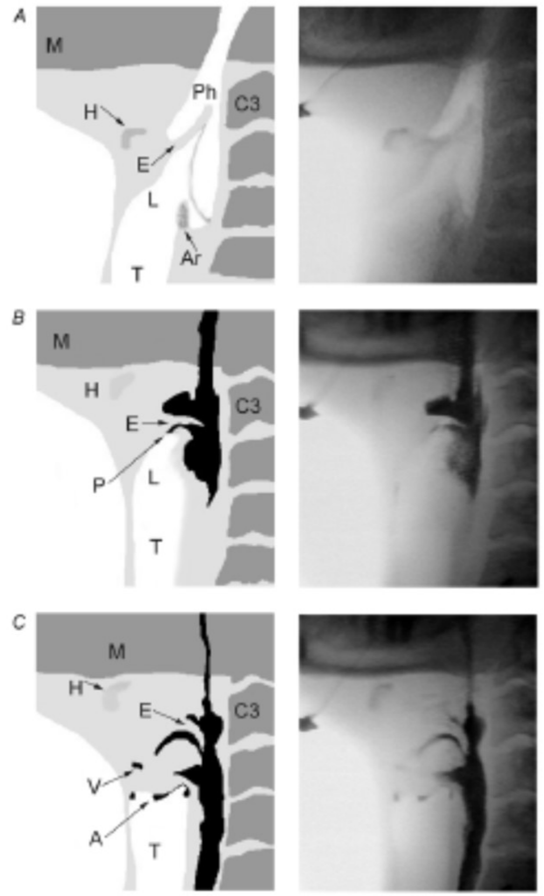
J Physiol (2003), 550.1, pp. 287–304
© The Physiological Society 2003
DOI: 10.1113/jphysiol.2003.039966
www.jphysiol.org

Sensory regulation of swallowing and airway protection: a role for the internal superior laryngeal nerve in humans

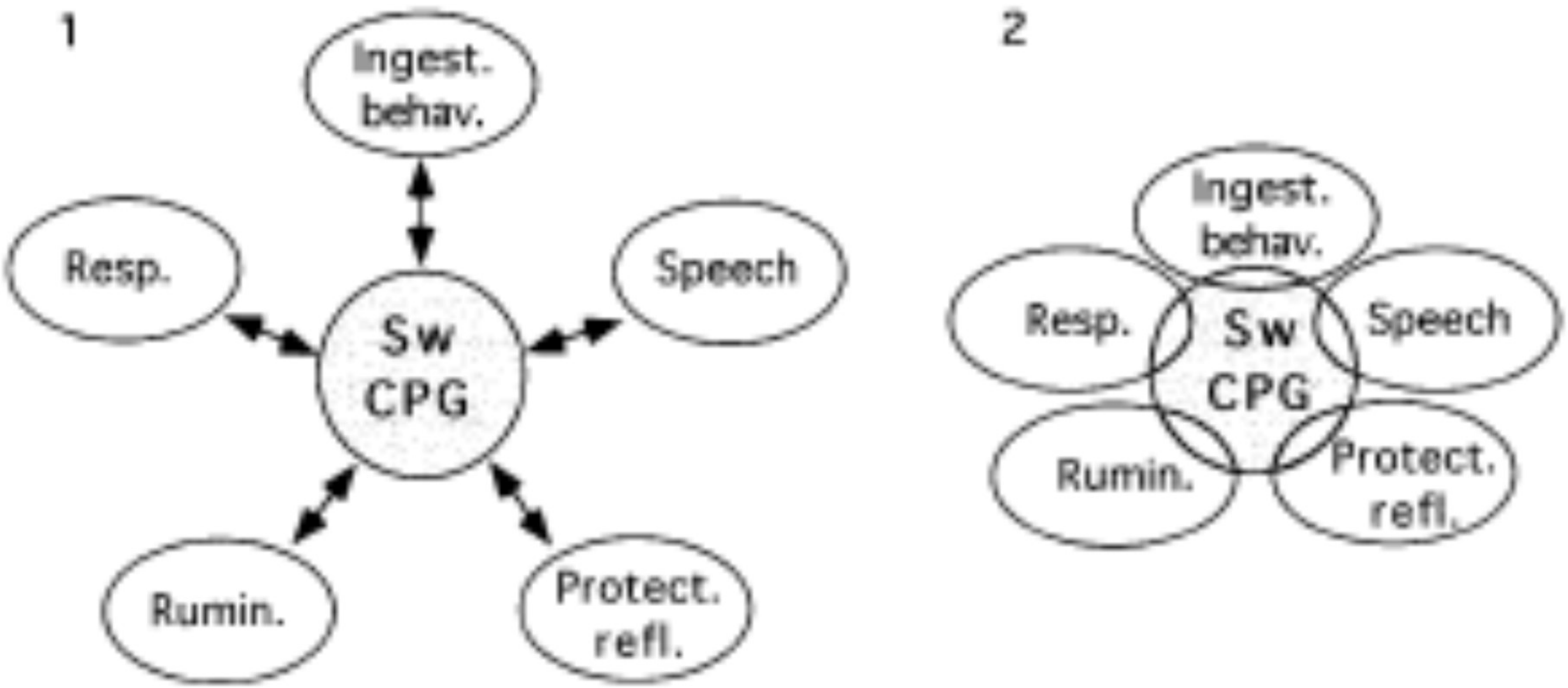
Samah Jafari*, Rebecca A. Prince*, Daniel Y. Kim† and David Paydarfar*‡

*Departments of *Neurology, †Otolaryngology and ‡Physiology, University of Massachusetts Medical School, Worcester, MA 01655, USA*

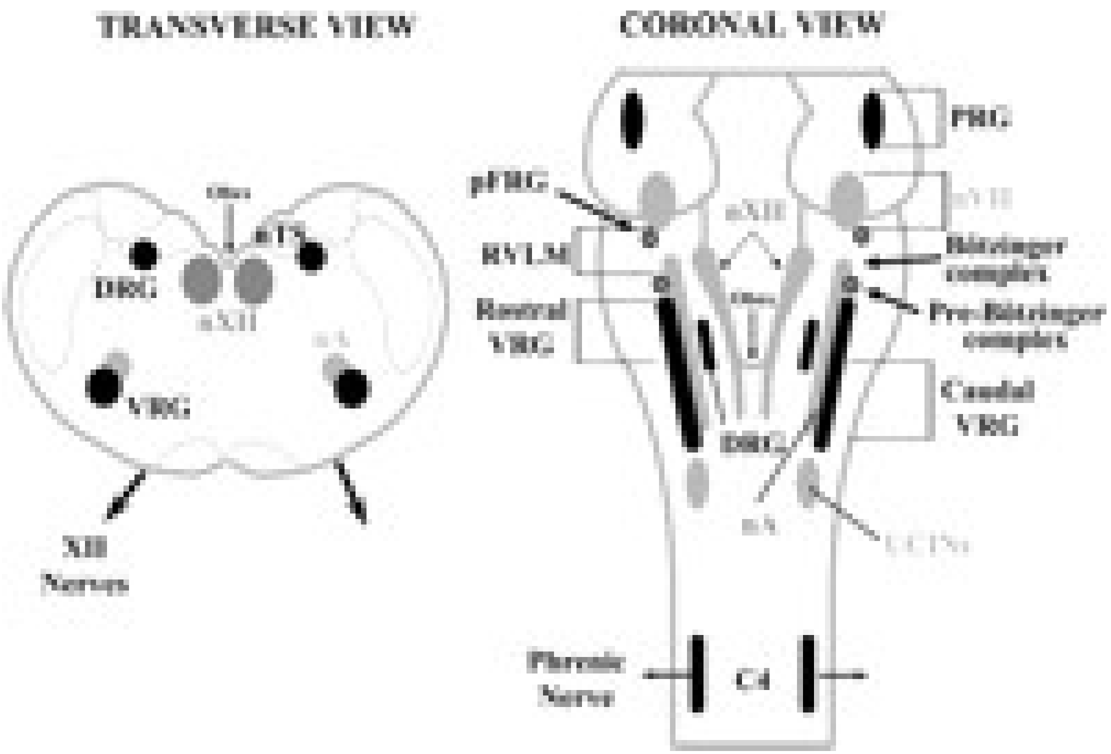




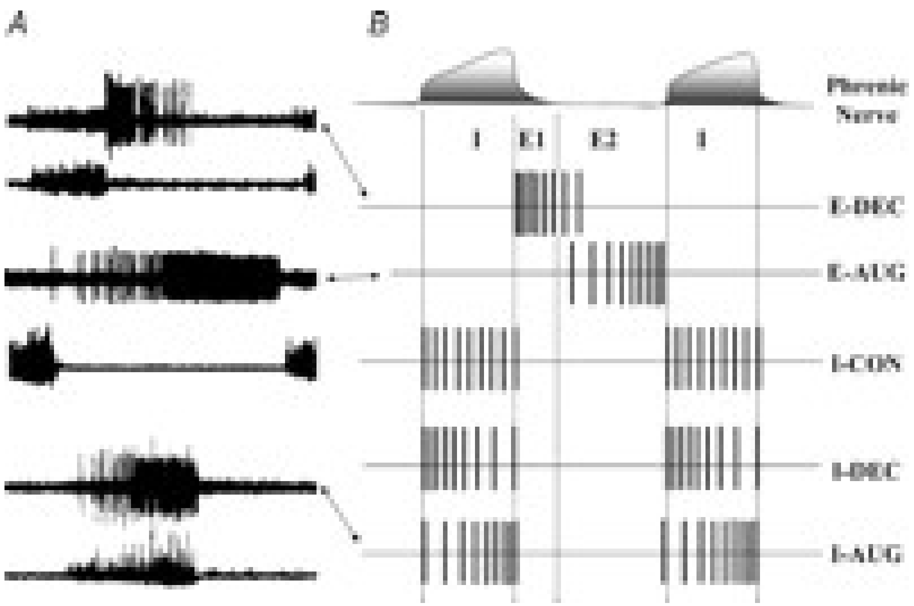
LA NATURA DEL CENTRAL PATTERN GENERATOR

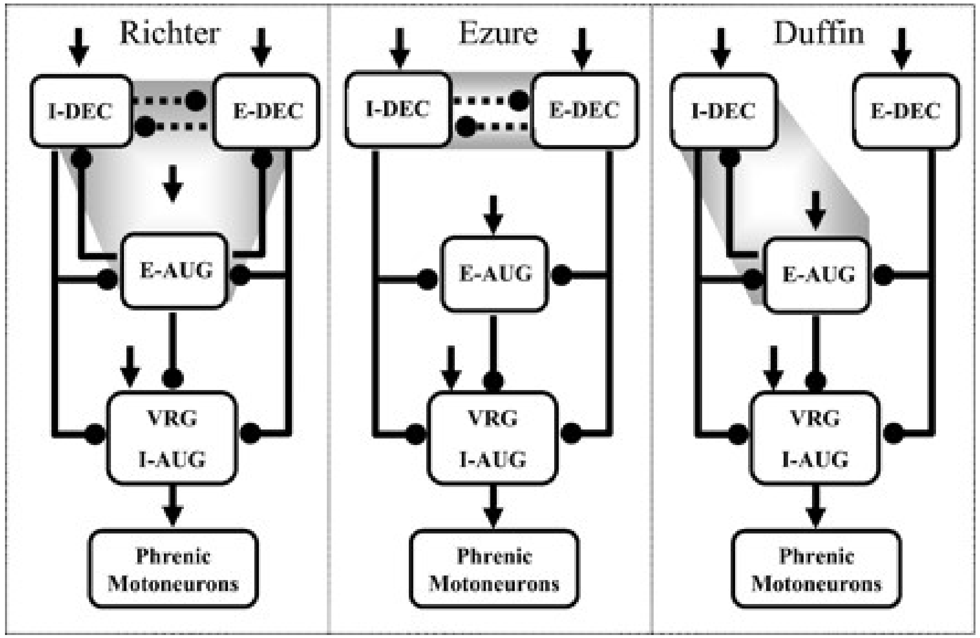


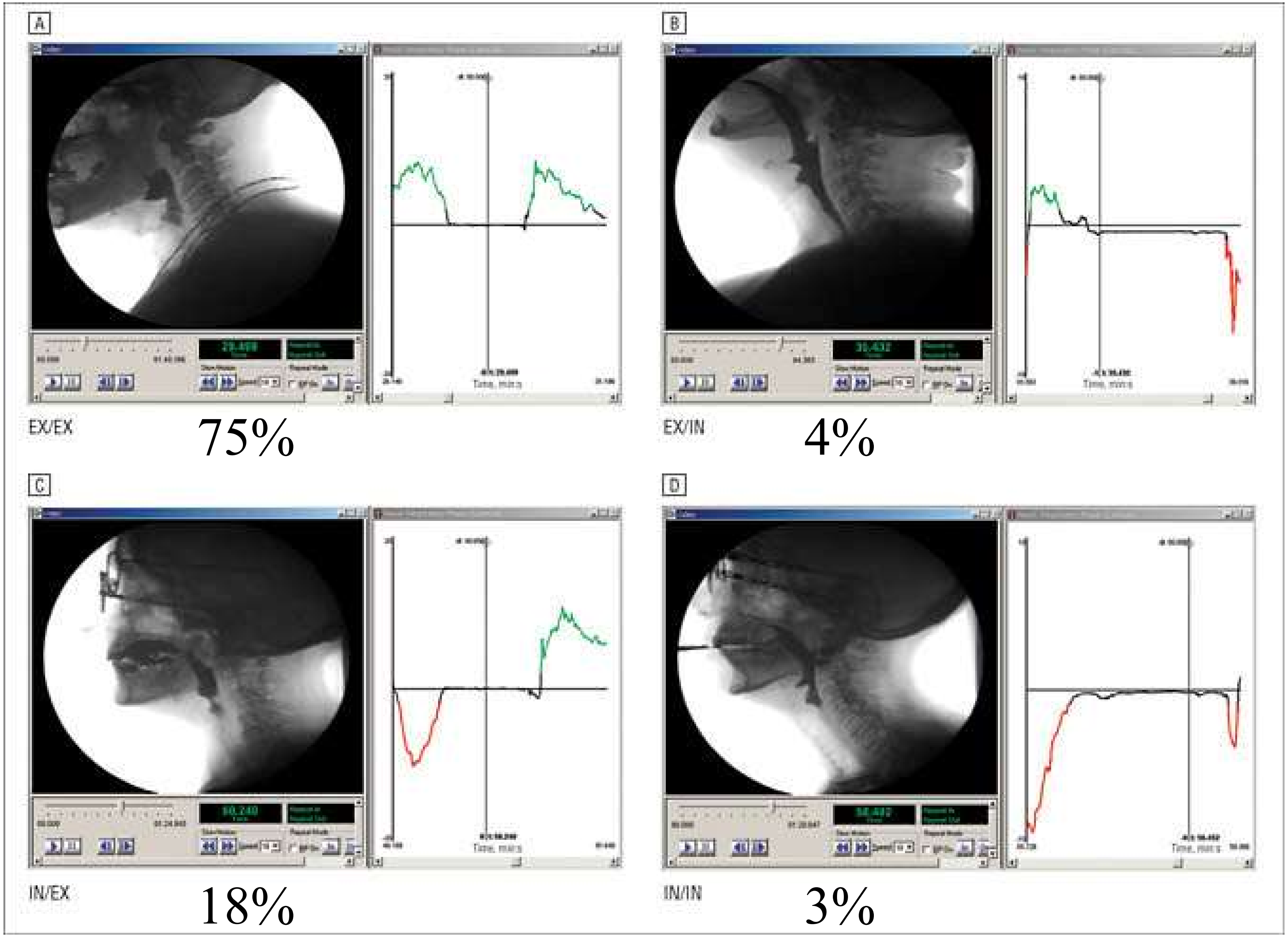
PATTERN GENERATOR RESPIRATORIO



PATTERN GENERATOR RESPIRATORIO







A
EX/EX
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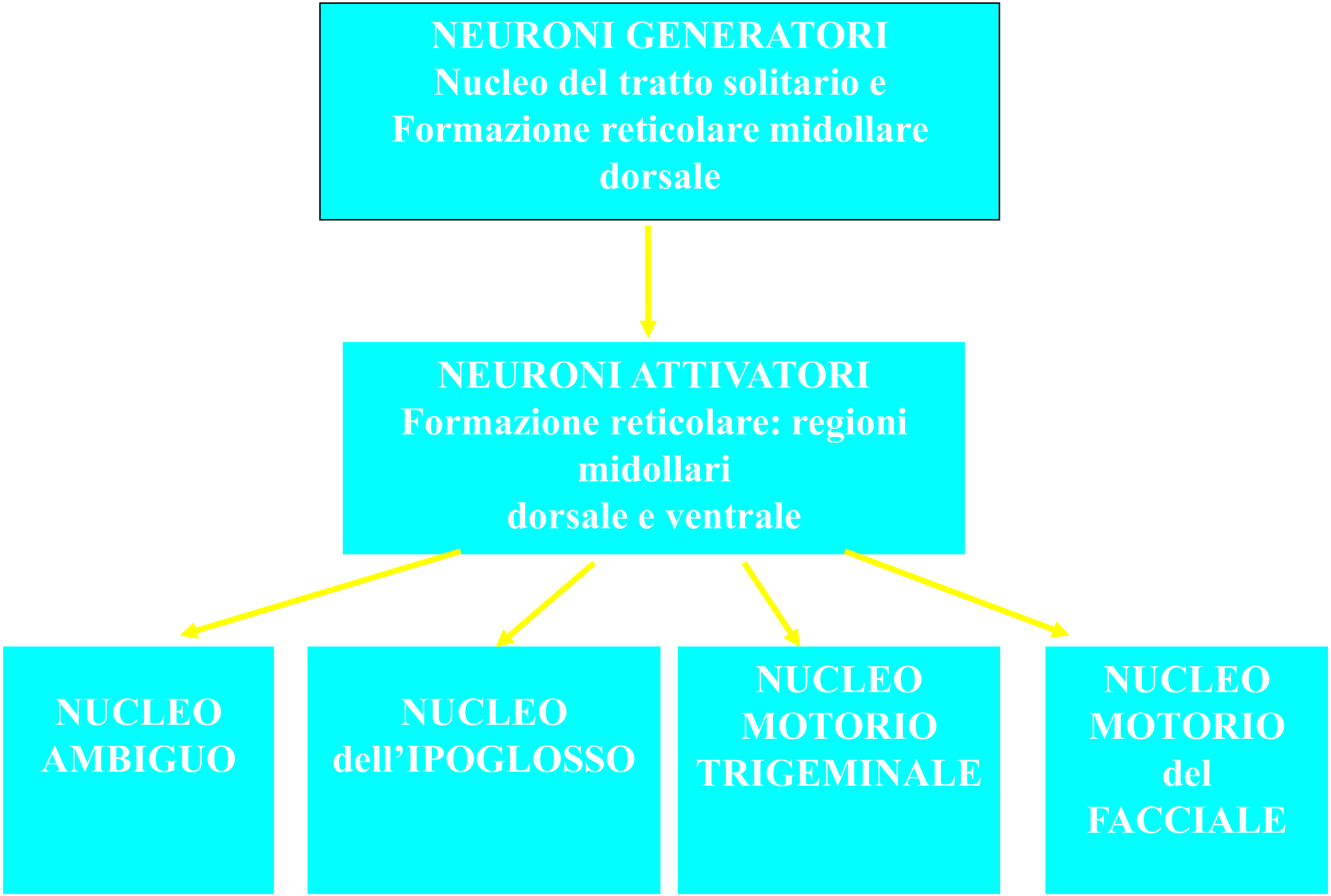
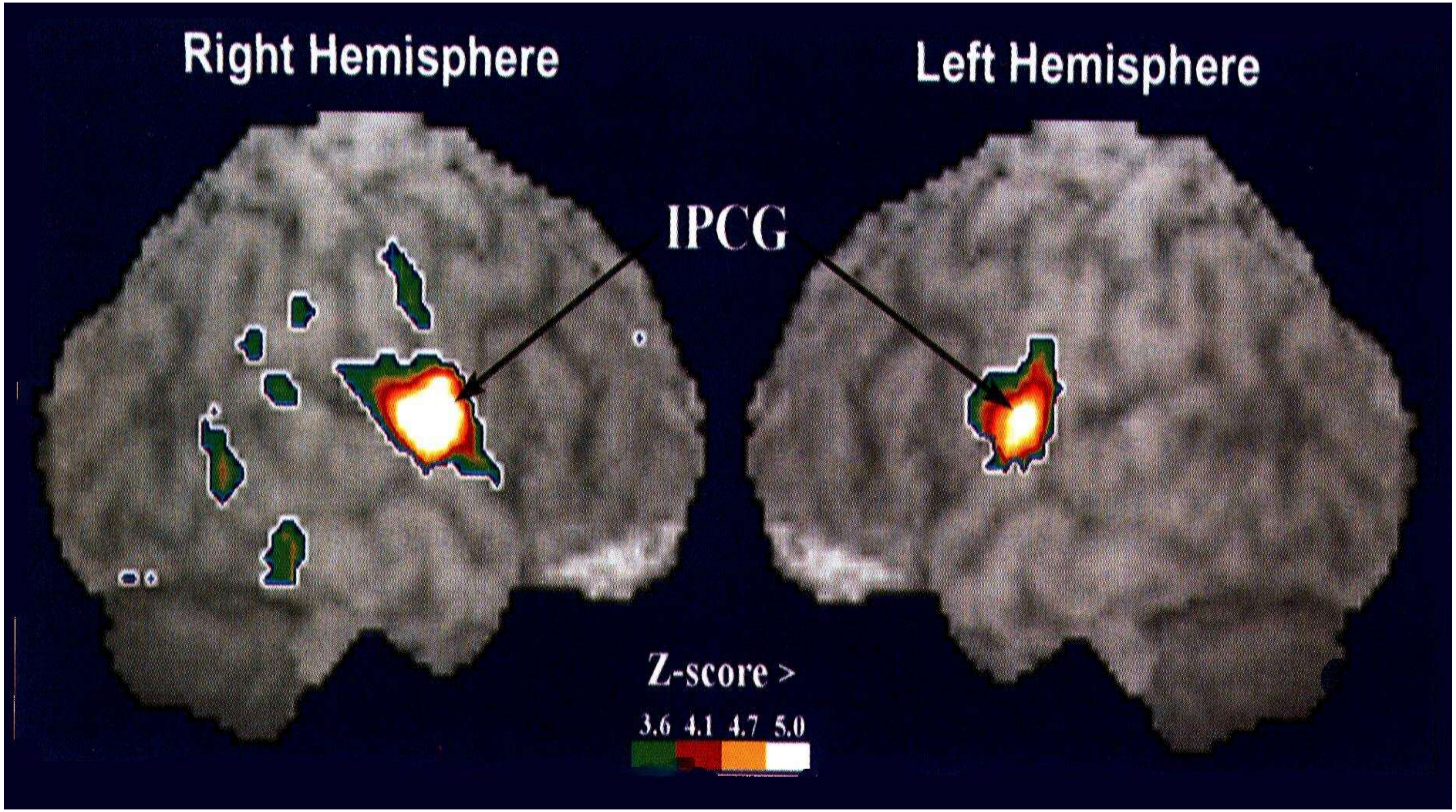

NEURONI GENERATORI
Nucleo del tratto solitario e
Formazione reticolare midollare
dorsale
NEURONI ATTIVATORI
Formazione reticolare: regioni
midollari
dorsale e ventrale
NUCLEO
AMBIGUO
NUCLEO
dell'IPOGLOSSO
NUCLEO
MOTORIO
TRIGEMINALE
NUCLEO
MOTORIO
del
FACCIALE

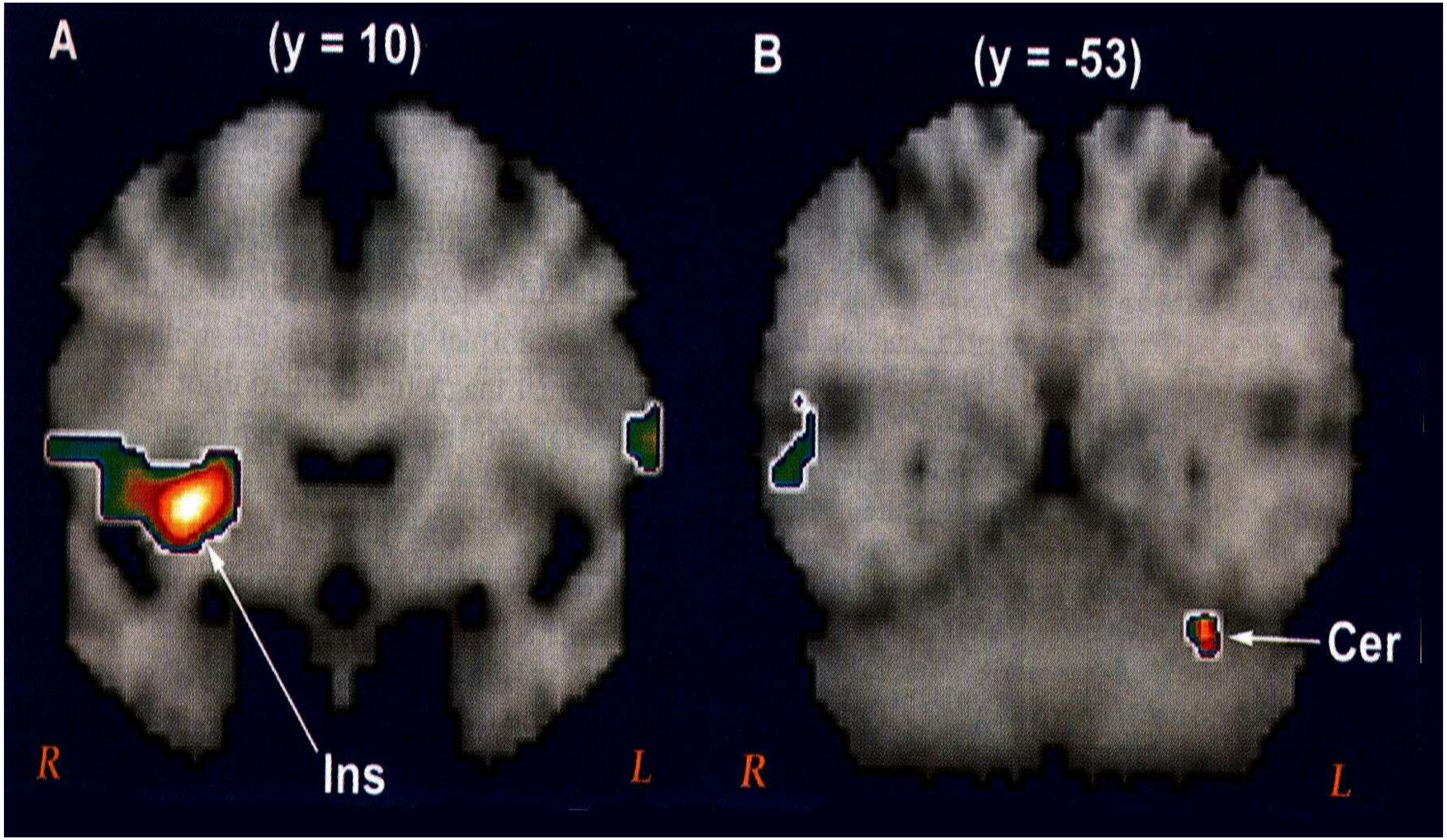
DEGLUTIZIONE VOLONTARIA: PET

La deglutizione volontaria, confrontata con movimenti linguali volontari, determina l'attivazione del giro prefrontale bilateralmente ***(Zald & Pardo, 1999)***



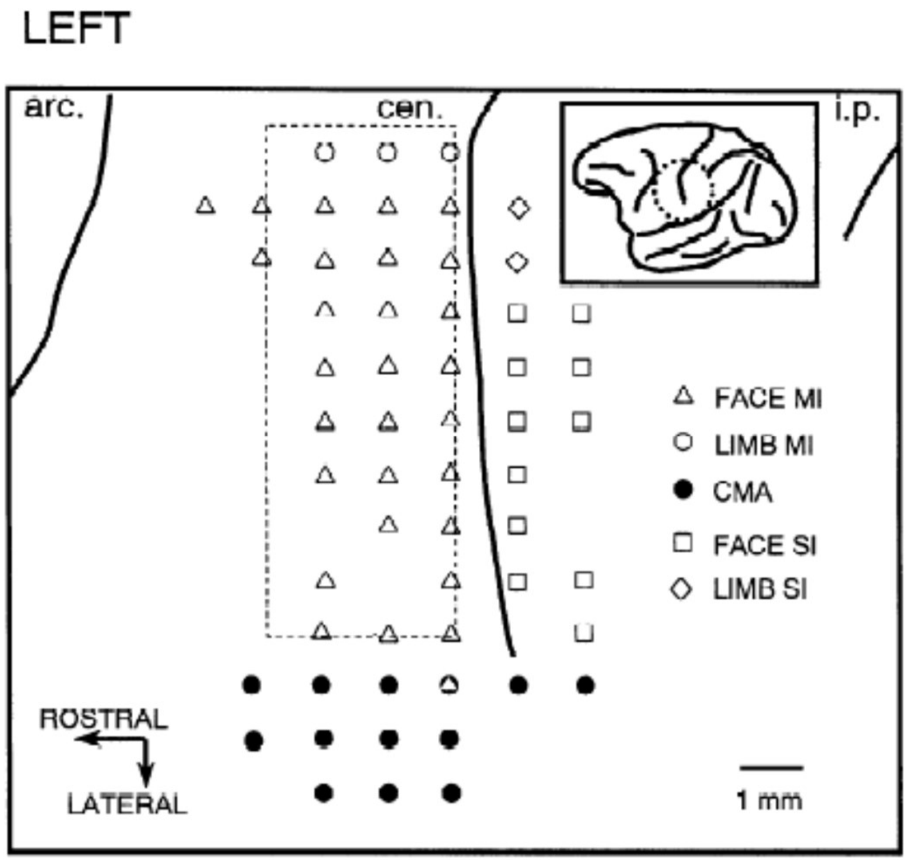
DEGLUTIZIONE VOLONTARIA: PET

La deglutizione volontaria, confrontata con movimenti linguali volontari, determina l'attivazione dell'insula anteriore e del claustrum destri, del lobo cerebellare sinistro ***(Zald & Pardo, 1999)***



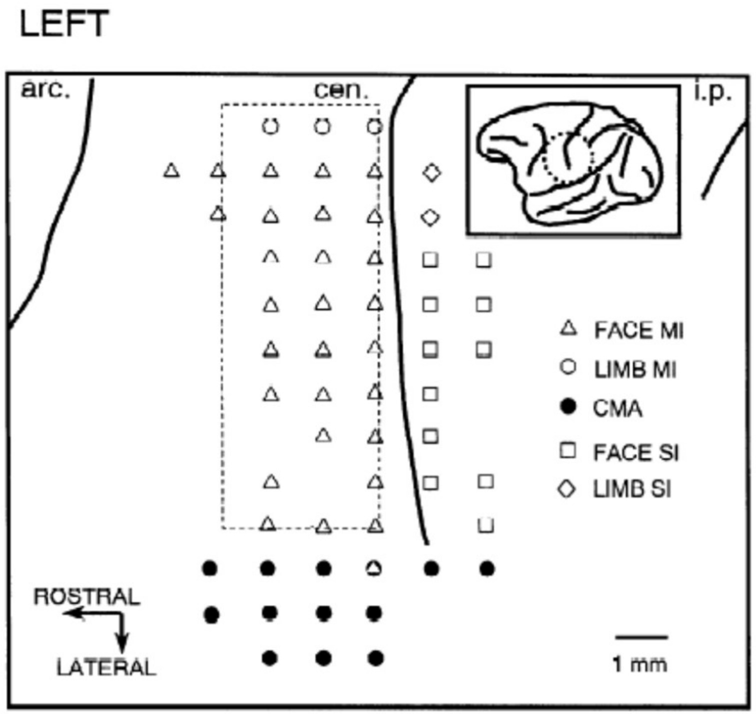
NEURONAL STIMULATION IN ANIMAL MODELS

In the sheep the stimulation of the chewing area, within the fronto-orbital cortex, inhibit the CPG and suppress the muscular activity of the pharynx and of the oesophagus.



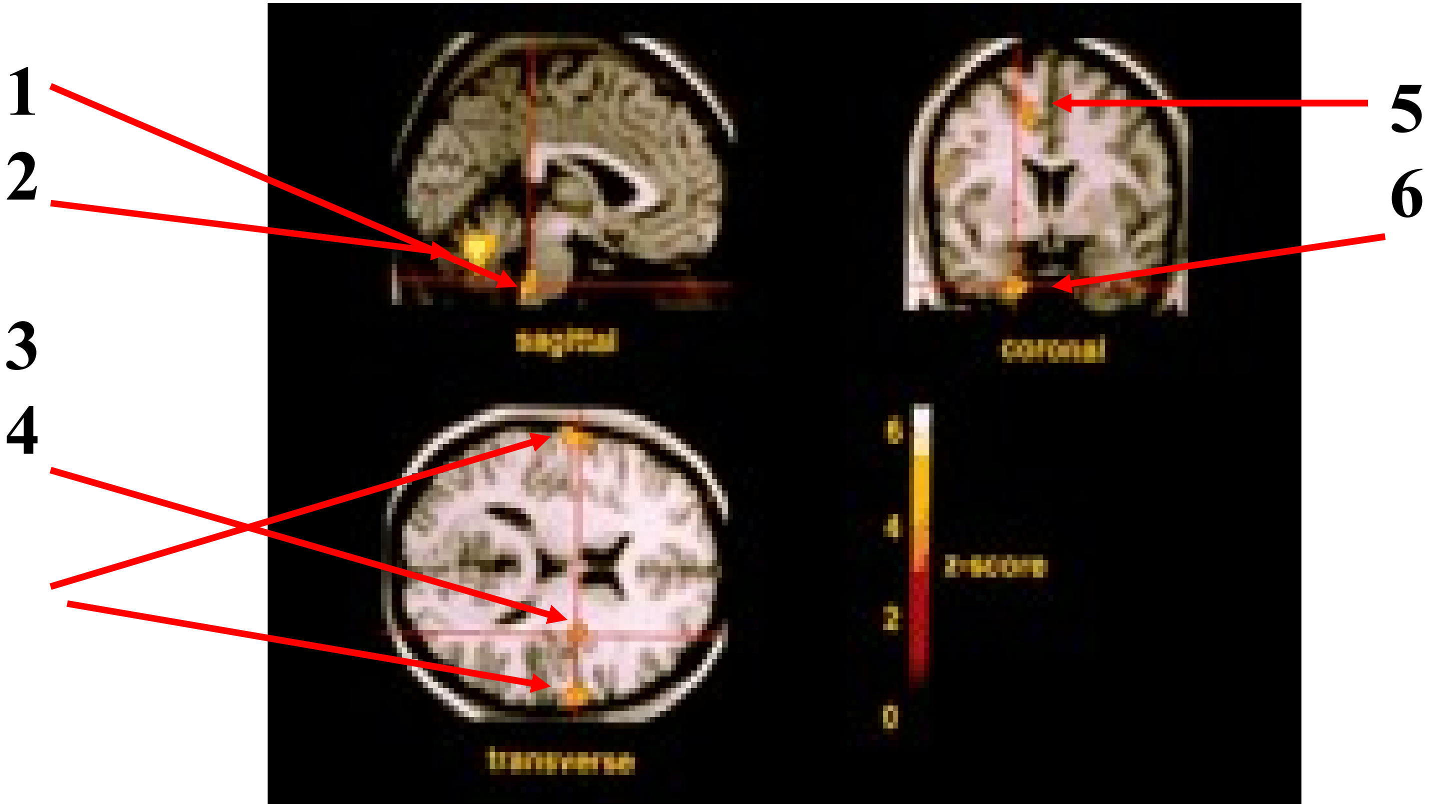
In the monkey brain cortical stimulation found the regions that trigger swallowing: the face motor cortex, the primary somatosensory cortex, the cortical masticatory area (CMA) and the white matter underlying the CMA and frontal operculum.
In most of the areas, the electrophysiological stimulation induced not only swallowing, but also other oro-facial responses.

Cortical inactivation through cold block showed that while blocking the CMA markedly affected the ability to carry out swallowing, inactivation of the somatosensory cortex as well as of the primary motor cortex, preserve swallowing.



DEGLUTIZIONE VOLONTARIA: PET

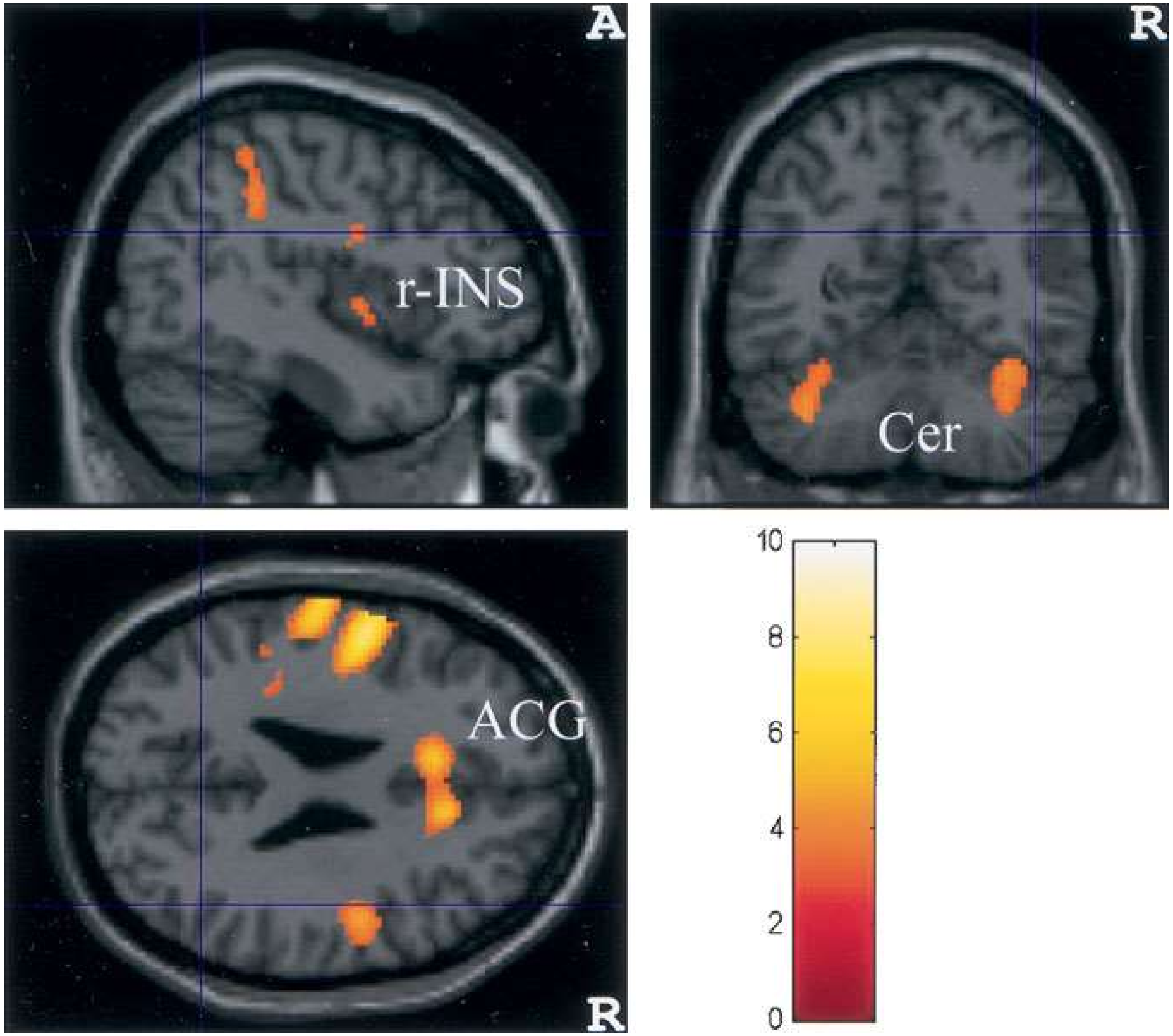
La deglutizione volontaria determina l'attivazione della parte posteriore del tronco (1), del cervelletto sn (2), dell'insula anteriore destra (3), della corteccia sensomotoria bilateralmente (4), del giro del cingolo sinistro (5) e dell'amigdala sinistra (6) ***(Hamdy et al, 1999)***



DEGLUTIZIONE VOLONTARIA E INVOLONTARIA

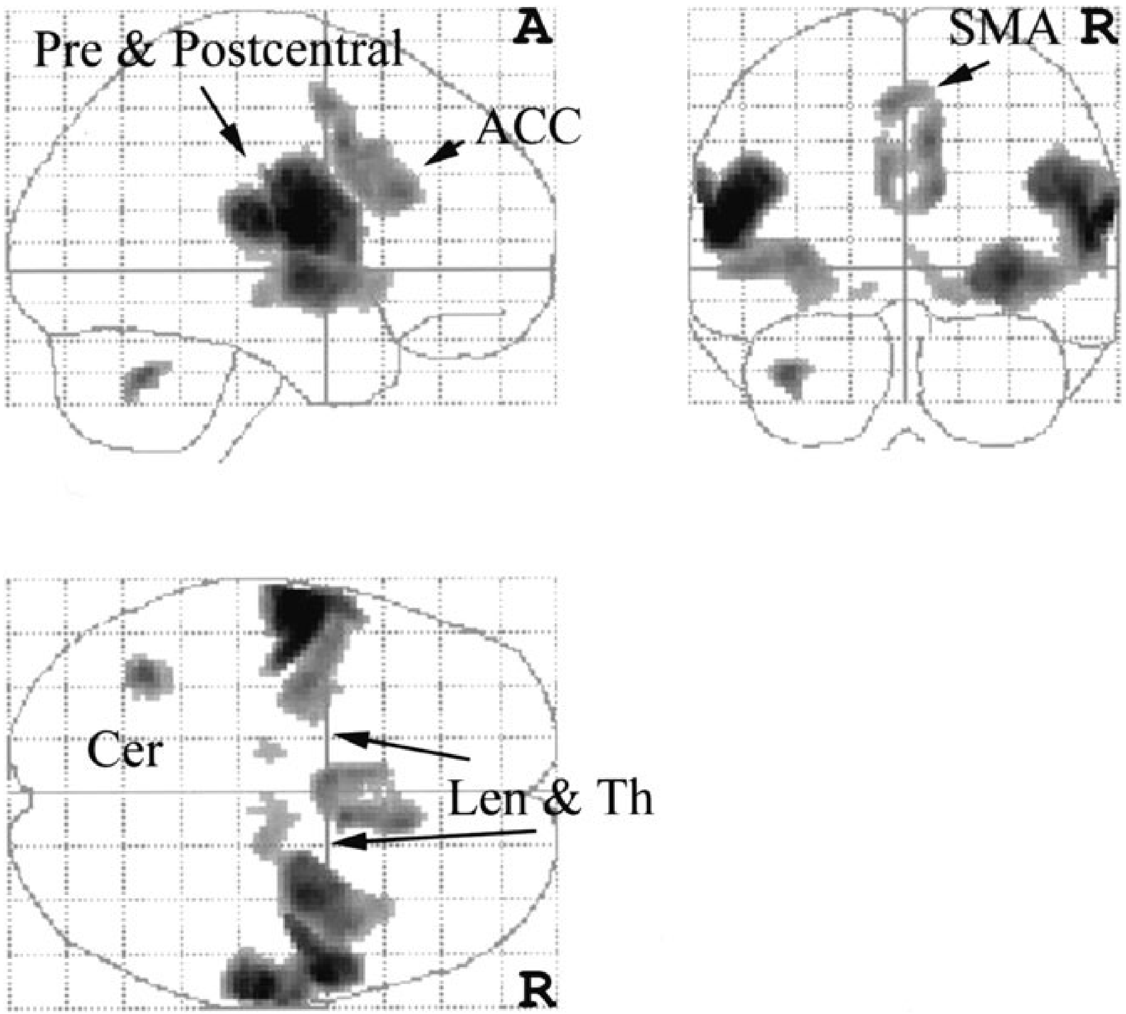
L'attivazione cerebrale in compiti di deglutizione volontaria e involontaria è diversa; in entrambe i casi si assiste al coinvolgimento delle aree senso-motorie, ma nella deglutizione volontaria regioni corticali parieto-occipito-frontali sono coinvolte (intenzione e programmazione?) ***(Kern et al, 2001)***
L'attivazione corticale in compiti deglutitori e in altri compiti del vocal tract (protrusione labiale, movimenti mandibolari, movimenti linguali) non sono significativamente diversi: le regioni evidenziate potrebbero attivarsi non per la funzione deglutitoria per sé ***(Kern et al, 2001)***

fMRI: ATTIVAZIONE CORTICALE E SOTTOCORTICALE



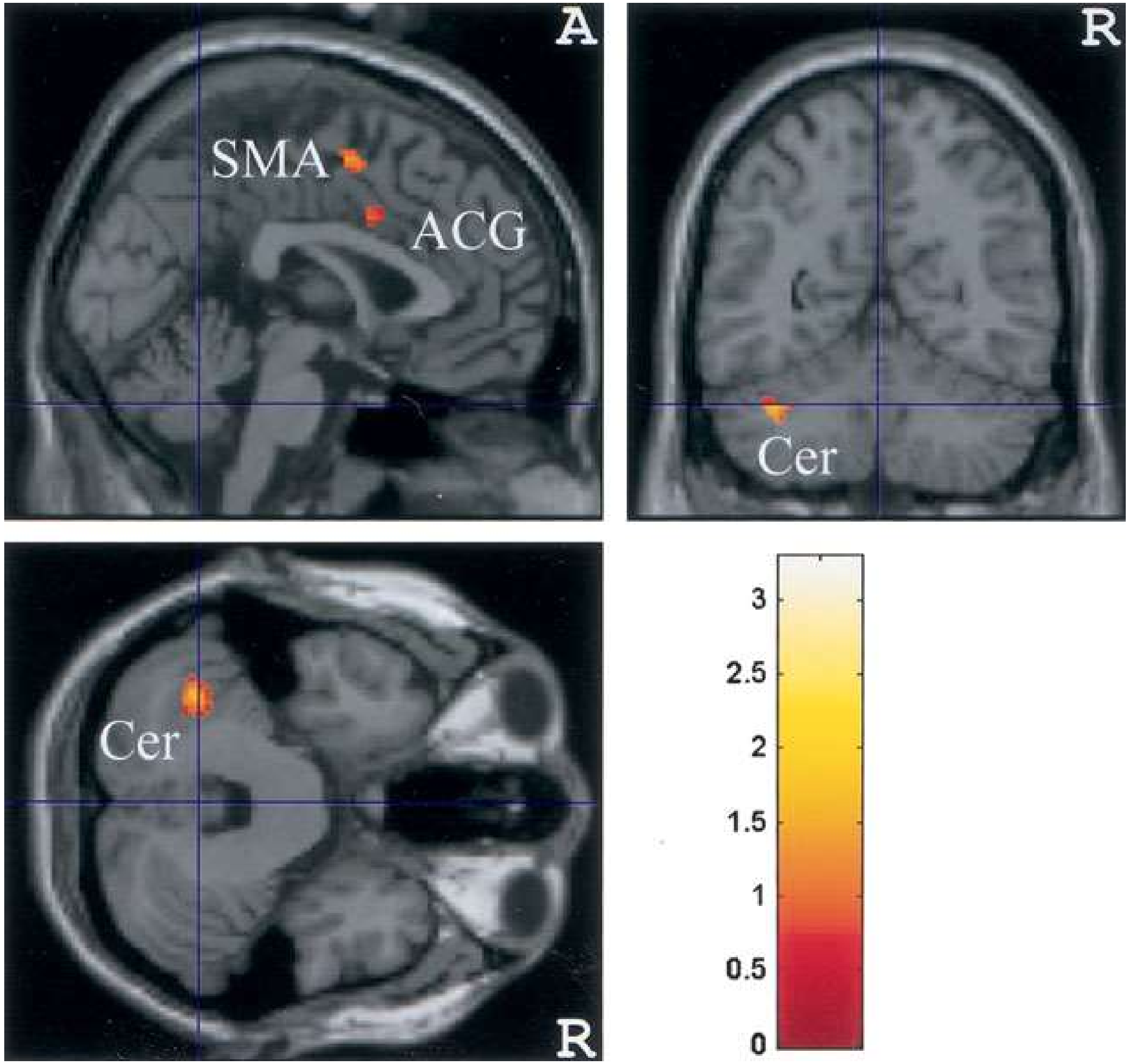
Suzuki et al, 2003

fMRI: ATTIVAZIONE CORTICALE E SOTTOCORTICALE



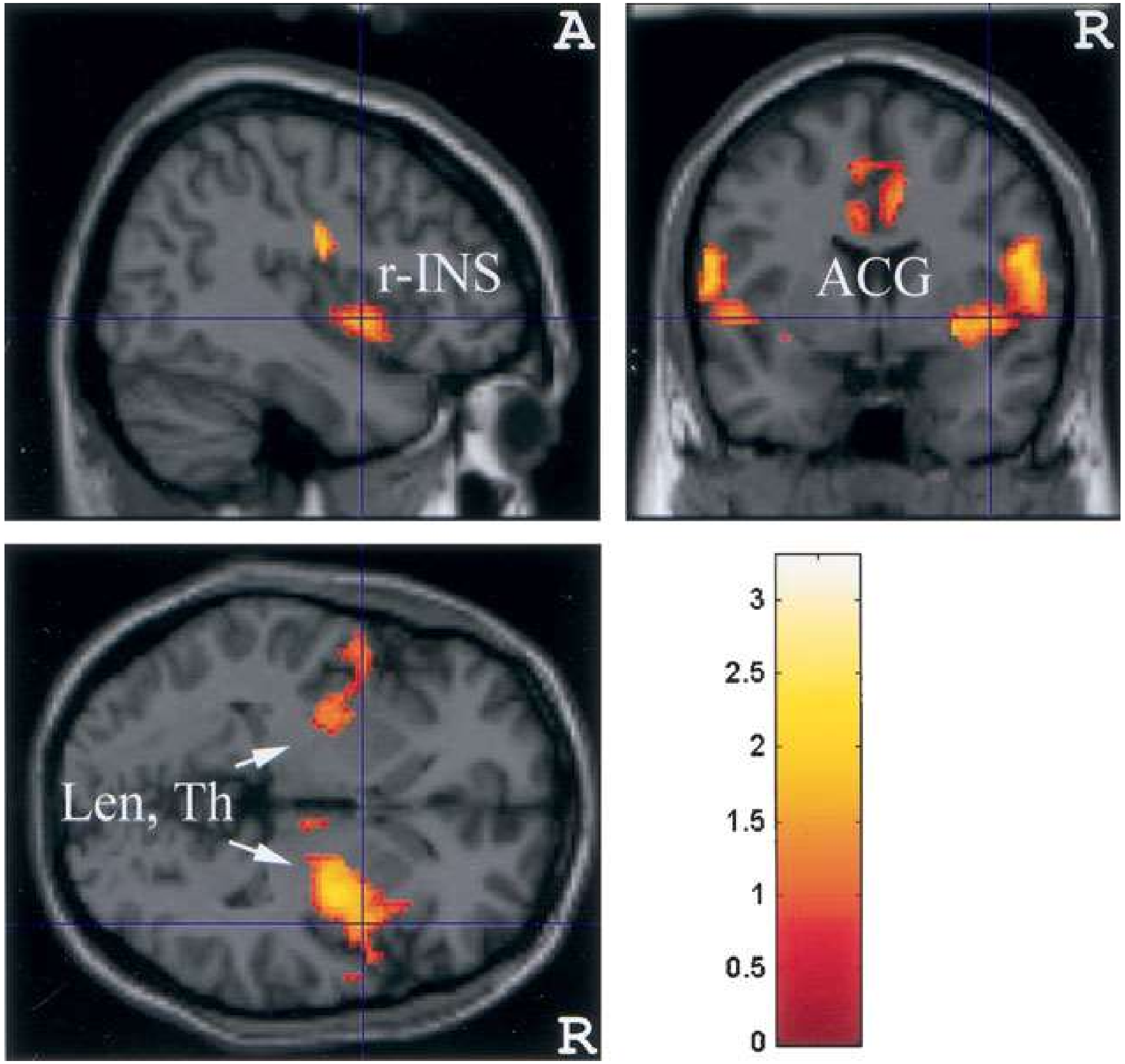
Suzuki et al, 2003

fMRI: ATTIVAZIONE CORTICALE E SOTTOCORTICALE



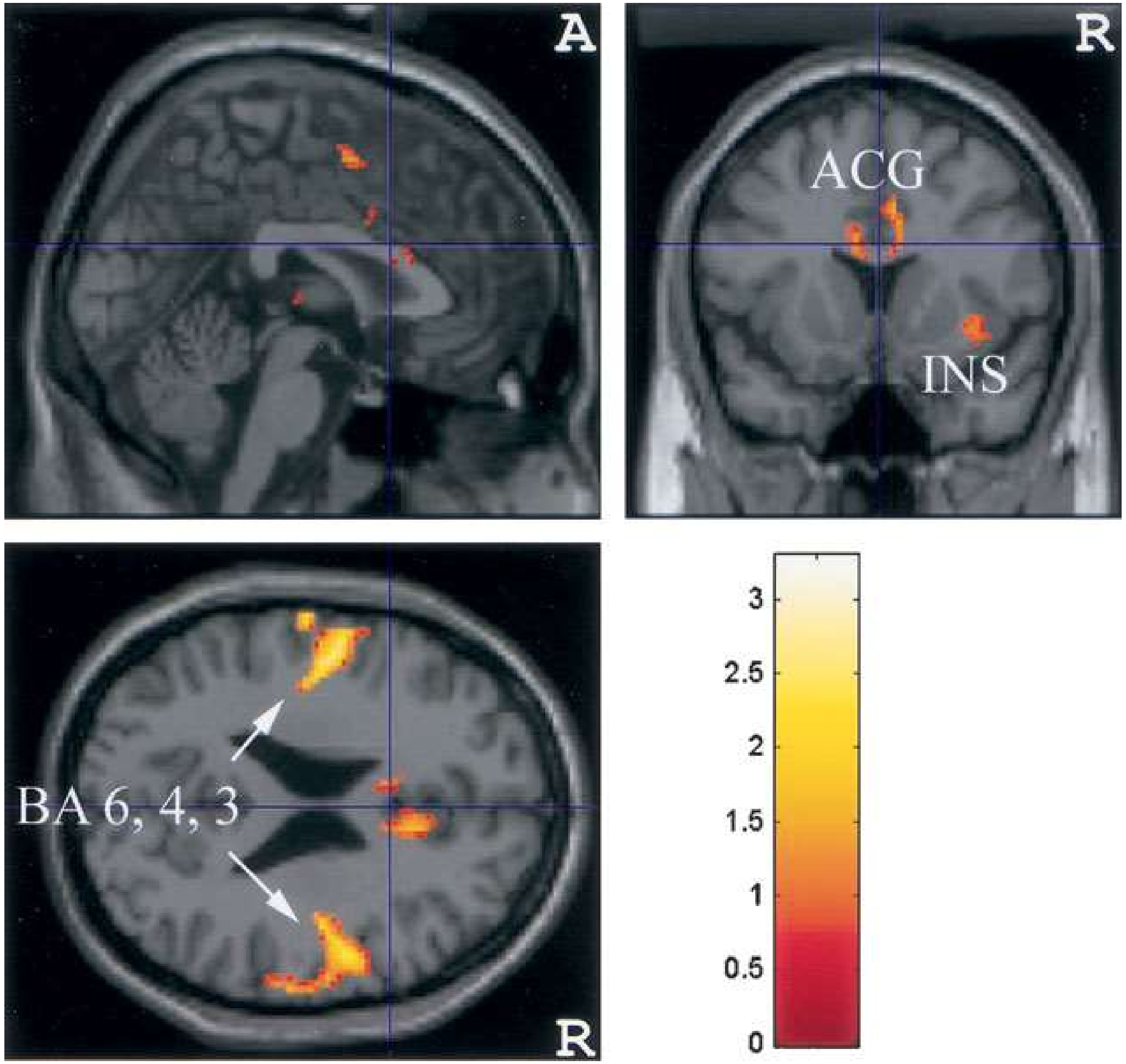
Suzuki et al, 2003

fMRI: ATTIVAZIONE CORTICALE E SOTTOCORTICALE



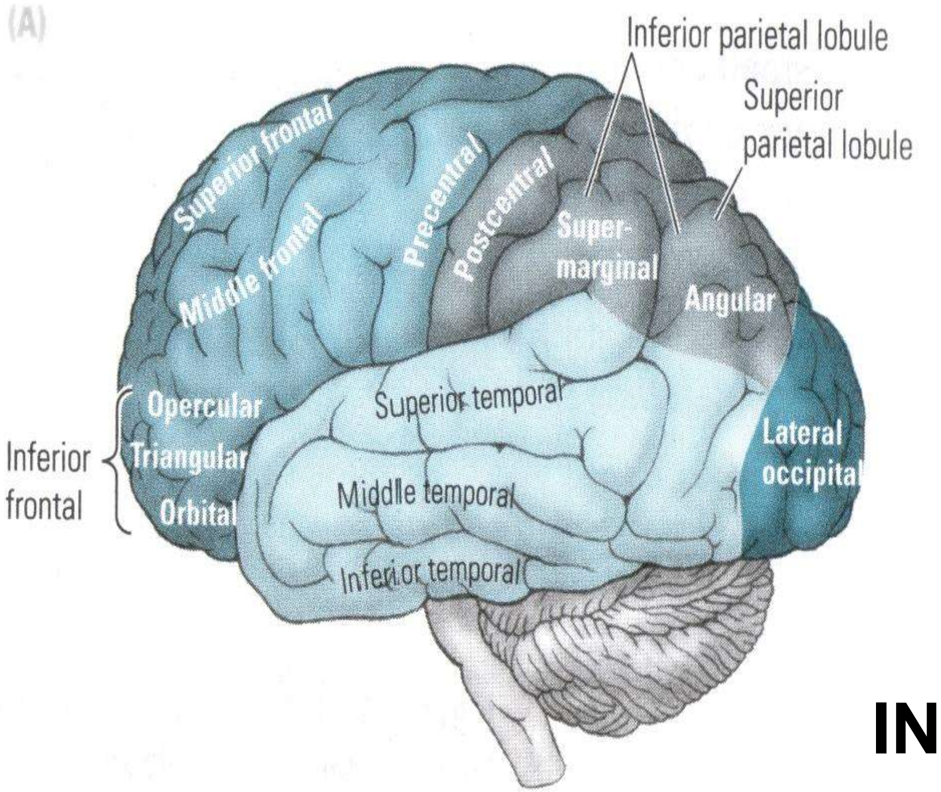
Suzuki et al, 2003

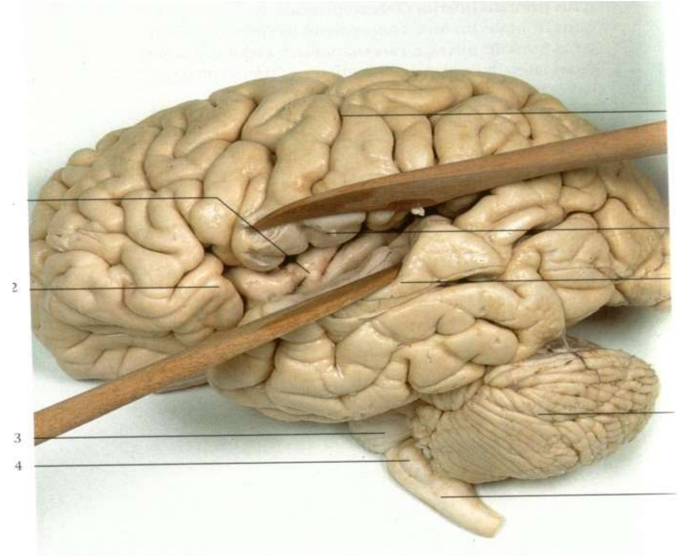
fMRI: ATTIVAZIONE CORTICALE E SOTTOCORTICALE

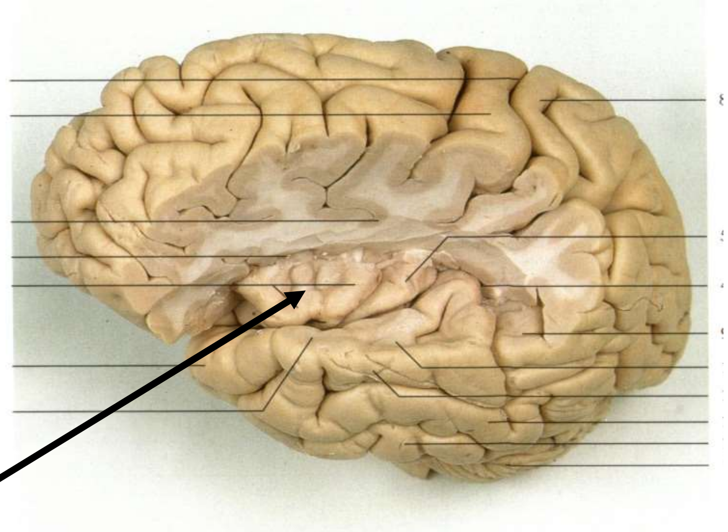


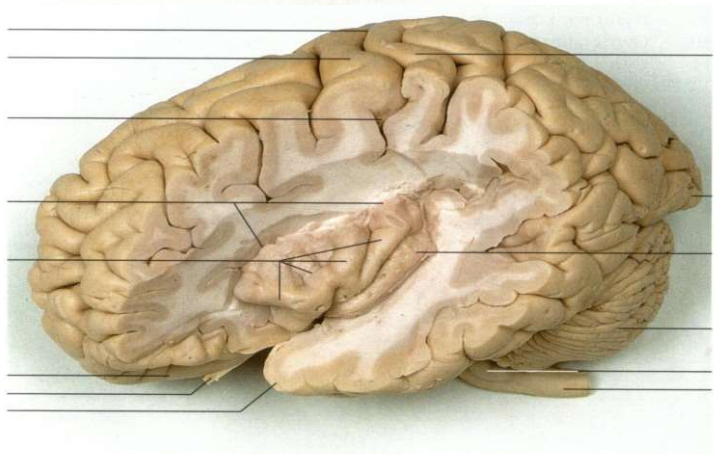
Suzuki et al, 2003

CORTECCIA



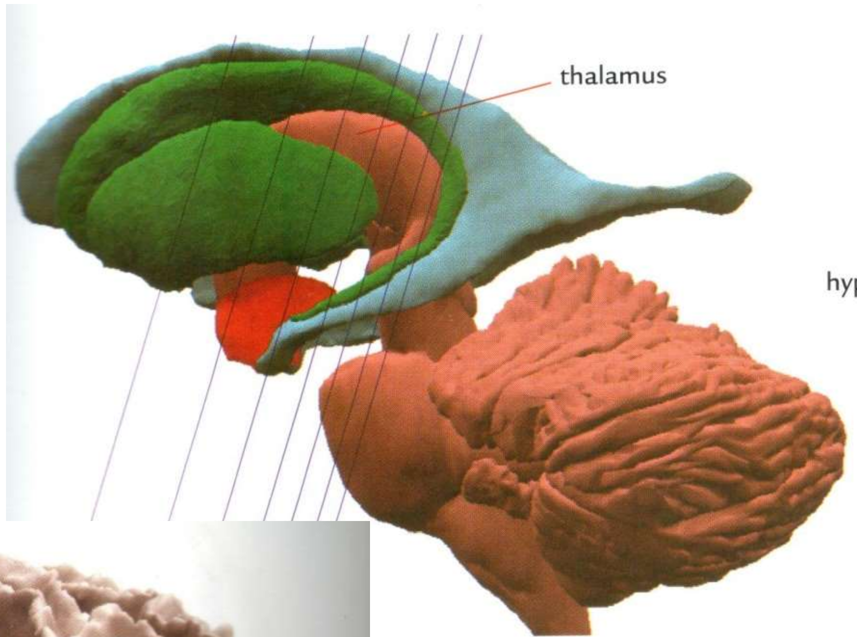


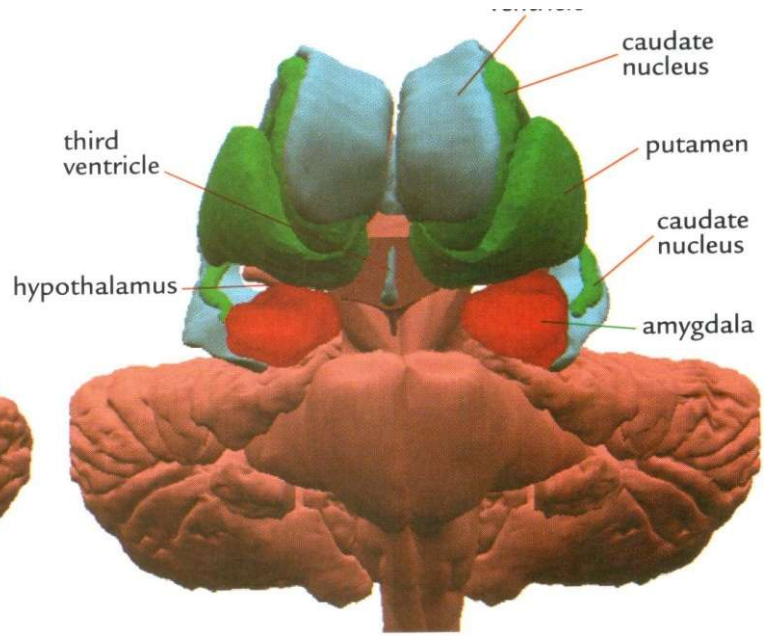


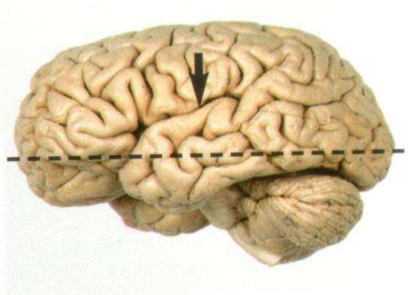


INSULA

CORTECCIA MA NON SOLO







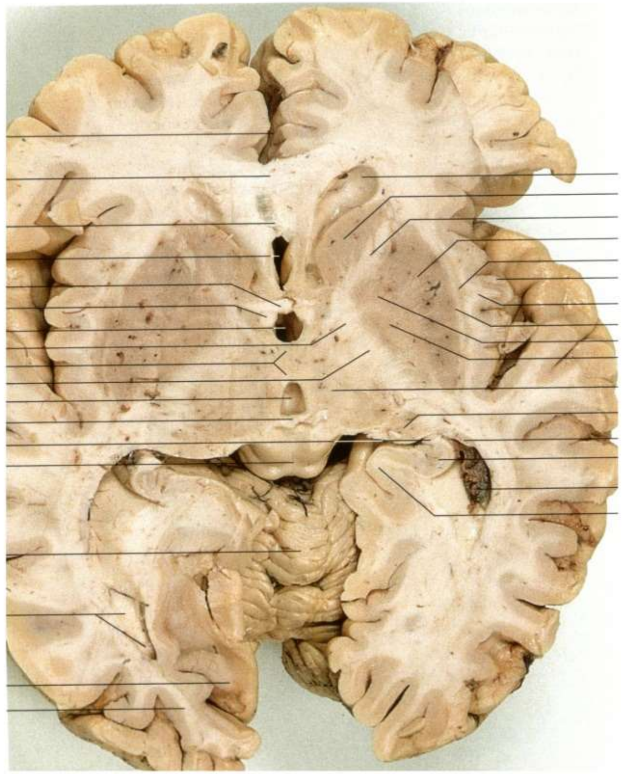
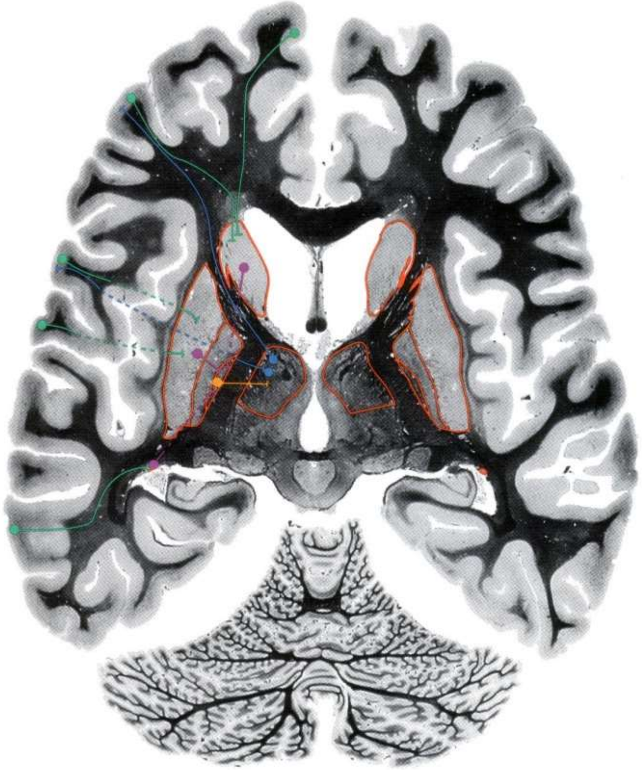
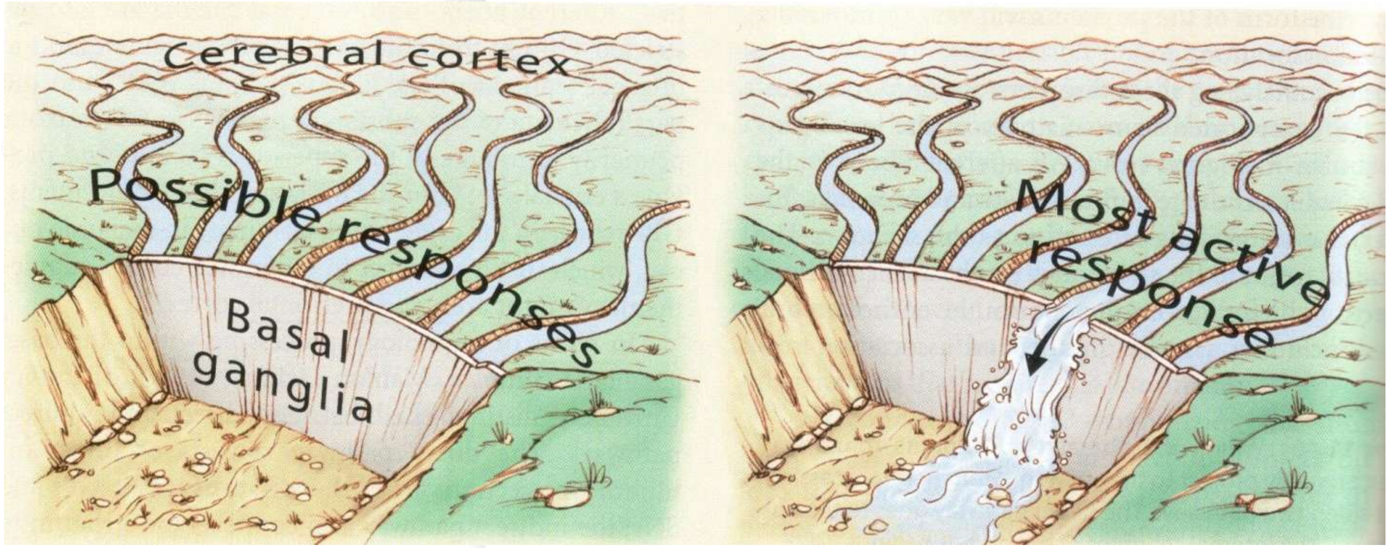
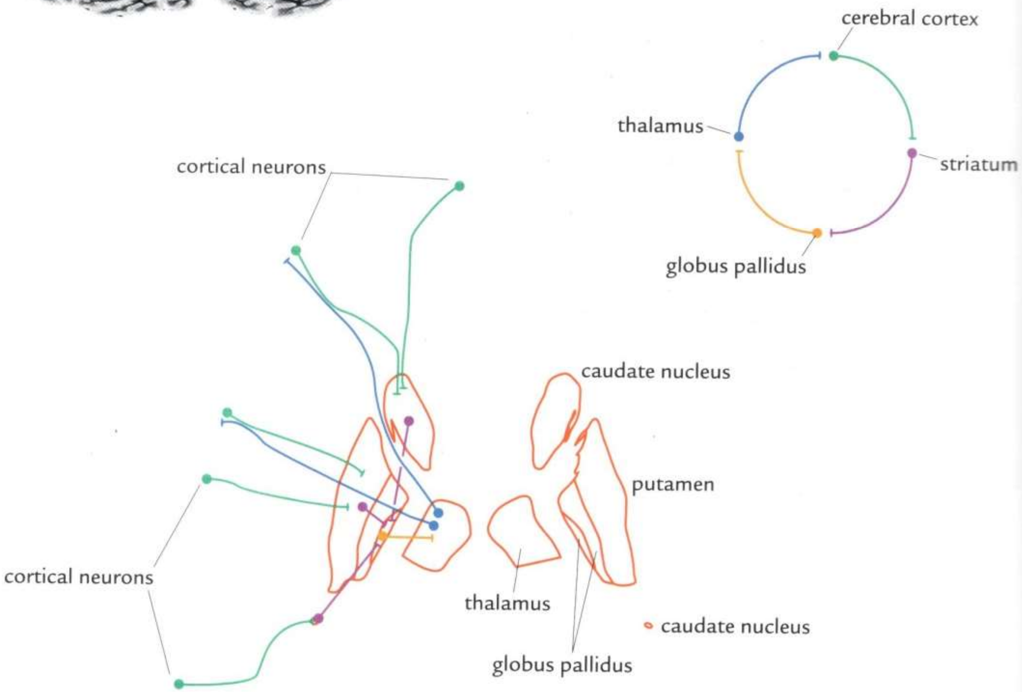


Figure 8-11. The principal circuit of the basal ganglia.

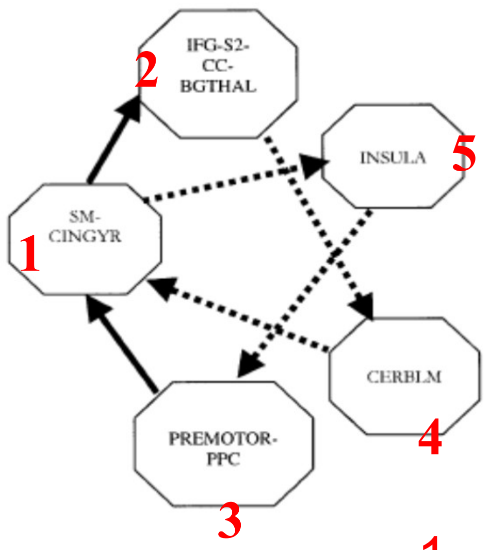






GANGLI DELLA BASE

NEUROIMAGING AND ELECTROPHYSIOLOGICAL STUDIES IN HUMAN SUBJECTS



Five functional modules have been suggested:

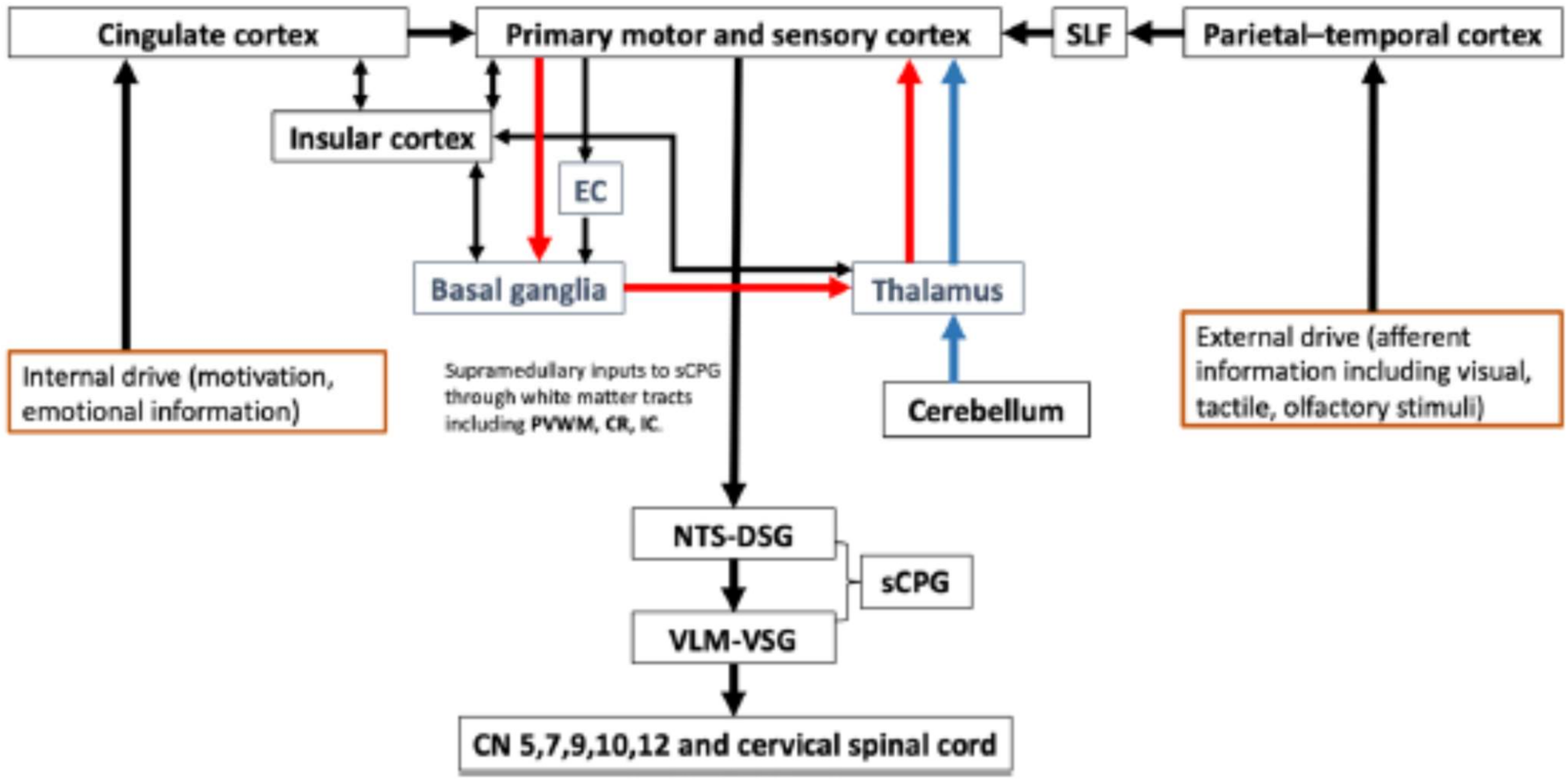
1. sensorimotor areas and cingulated cortex, establishing a sensorimotor output for which other areas converge;
2. inferior frontal gyrus, corpus callosum, basal ganglia and thalamus, involved in movement planning and implementation to other voluntary motor behaviours;
3. premotor cortex and posterior parietal cortex, serving to integrate sensory information about the bolus with the internal representation of swallowing movements;
4. cerebellum, whose role is to facilitate modulation of the internal representation for swallowing and coordination among the multiple effectors and effectors states during swallowing;
5. insula, recruited for synchronizing the kinematics of the movements

Dysphagia (2024) 39:177–197
https://doi.org/10.1007/s00455-023-10613-x

REVIEW

The Cortical and Subcortical Neural Control of Swallowing: A Narrative Review

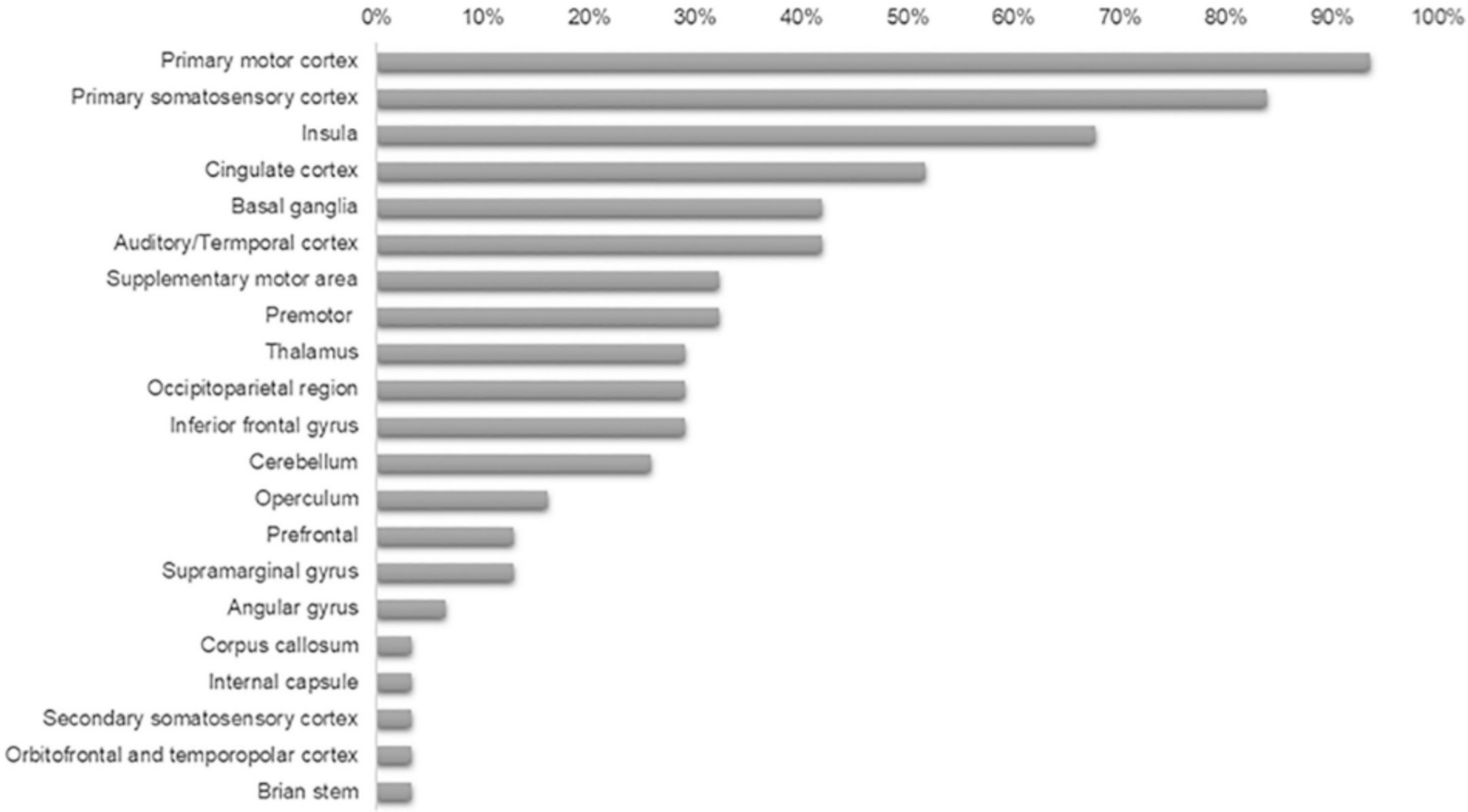
Kuo-Chang Wei[2,3] · Tyng-Guey Wang[1,2] · Ming-Yen Hsiao[1,2]



Review Article

Cerebral control of swallowing: An update on neurobehavioral evidence

Ivy Cheng [a,*], Kazutaka Takahashi [b], Arthur Miller [c], Shaheen Hamdy [a]



OUTLINE

- Swallowing and body functions
- The oral phase
- The pharyngeal phase
- The esophpageal phase
- The neural circuites underlying swallowing
- Swallowing physiology in the elderly

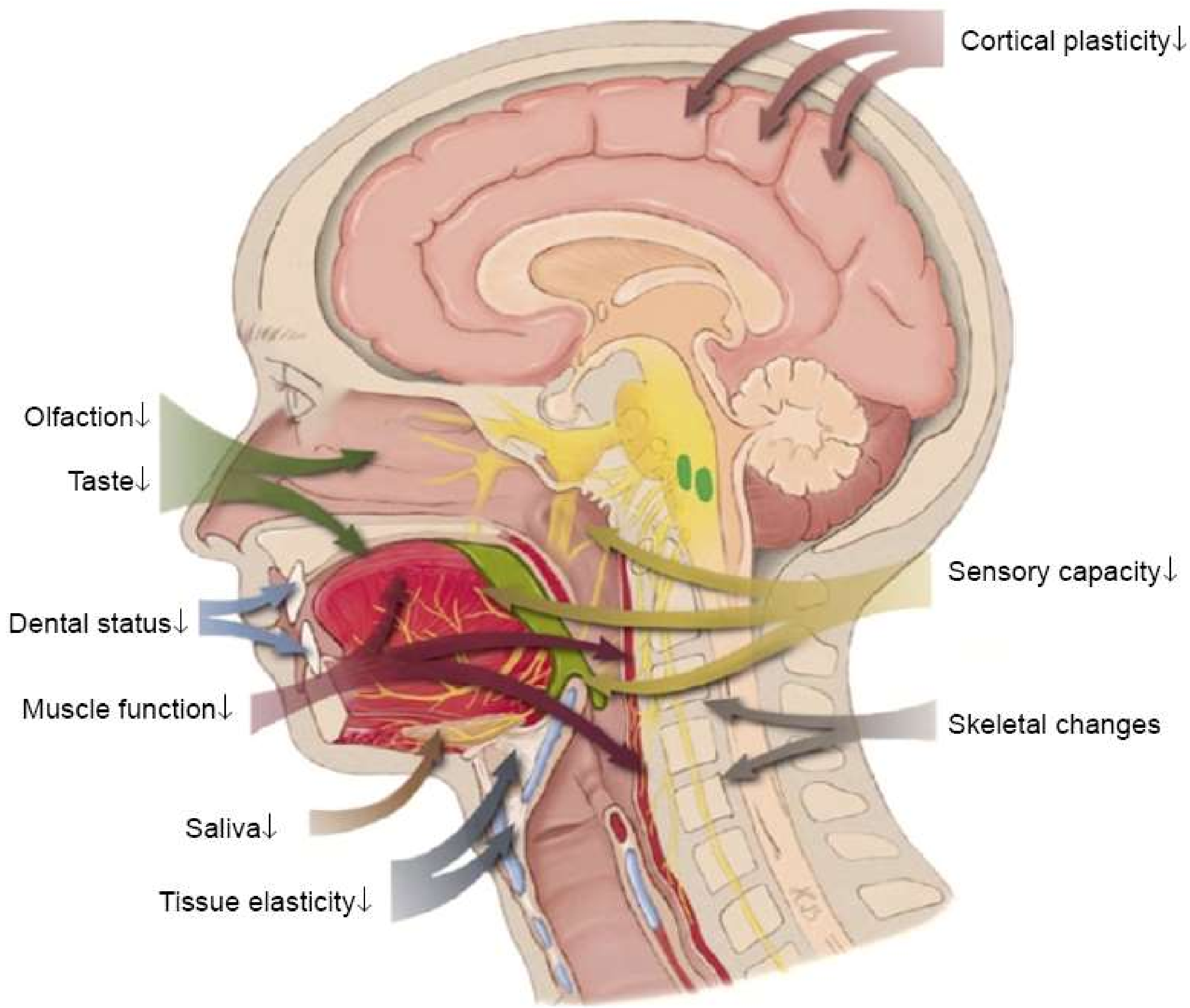
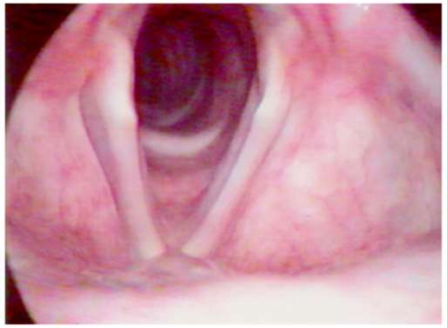


Figure 1 Factors associated with dysphagia in older persons.
Note: ↓ Indicates decreased function. Modified from Muhle P, Wirth R, Glahn J, Dziewas R. [Age-related changes in swallowing. Physiology and pathophysiology]. *Nervenarzt*. 2015;86(4):440–451.[29]

ANATOMIC AND PHYSIOLOG CHANGES DURING AGING

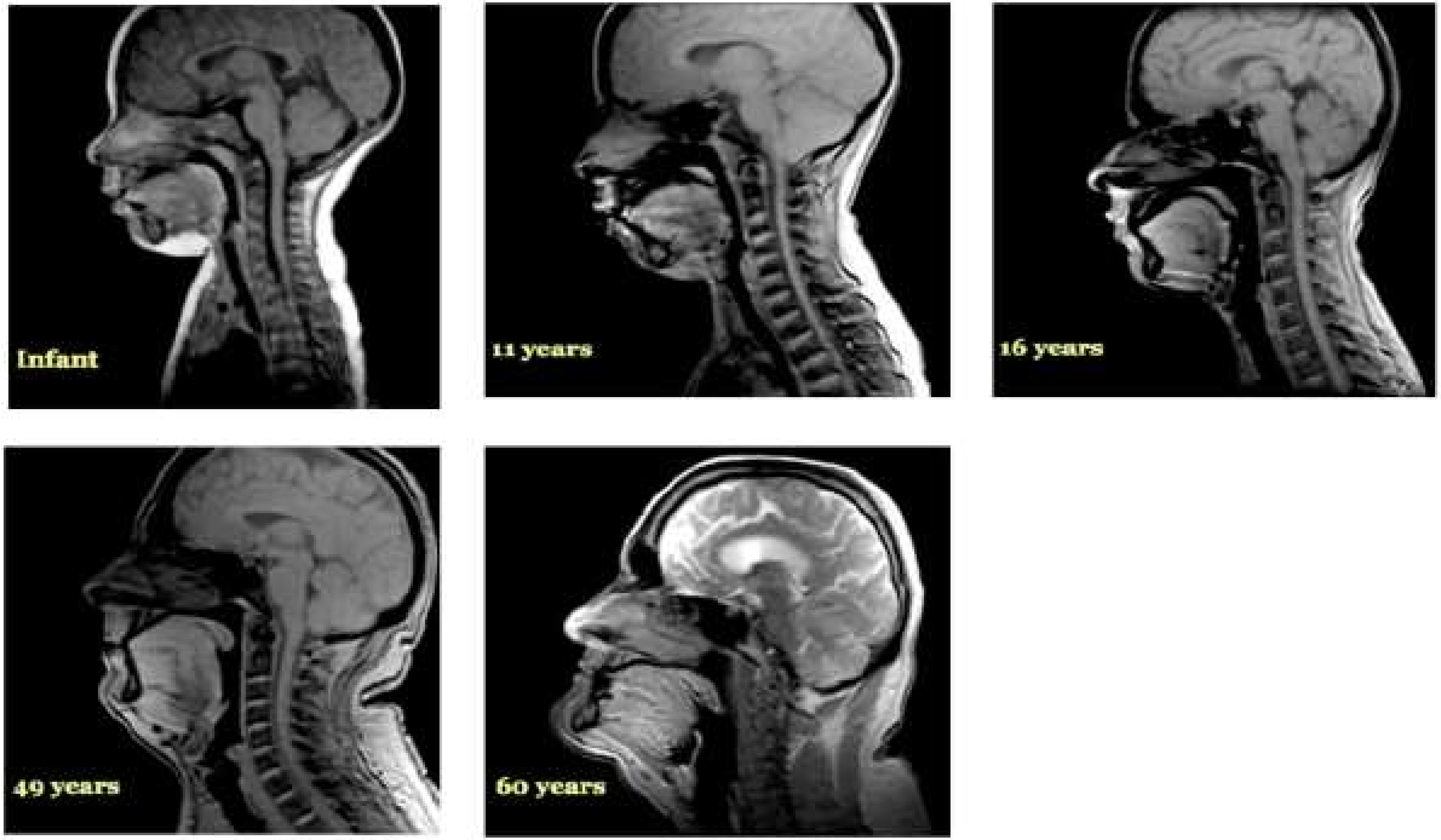
1. Teeth loss
2. Tongue weaknes
3. Laryngeal weakness
4. Olfaction reduction
5. Oral sensibility reduction
6. Laryngeal sensibility reduction



Head Neck. 2011 October ; 33(0 1): S30–S36. doi:10.1002/hed.21902.

Upper Aerodigestive Tract Neurofunctional Mechanisms: Lifelong Evolution and Exercise

JoAnne Robbins, Ph.D.[1,2]

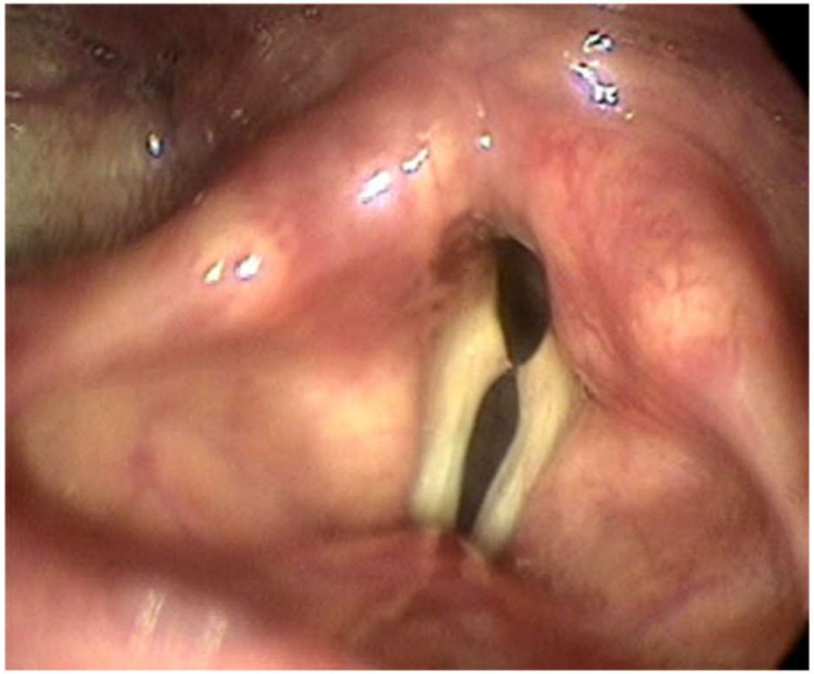


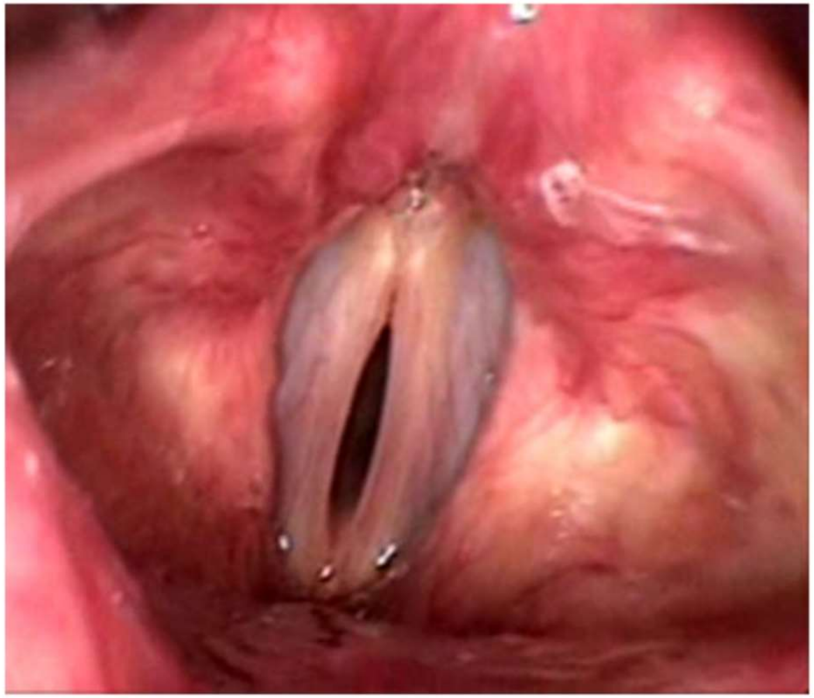
Aging Clin Exp Res (2014) 26:1–5
DOI 10.1007/s40520-013-0143-5

REVIEW

Aging voice: presbyphonia

Regina Helena Garcia Martins · Tatiana Maria Gonçalvez · Adriana Bueno Benito Pessin · Anete Branco





The Laryngoscope

Aging Voice and the Laryngeal Muscle Atrophy

Regina Helena Garcia Martins, MD, PhD; Adriana Bueno Benito Pessin, PhD; Douglas Jorge Nassib;
Anete Branco, PhD; Sergio Augusto Rodrigues, PhD; Selma Maria Michelim Matheus, PhD

TABLE I.
Measure of the Muscle Fiber Diameter (Mean ± SD, μm) in Both Genders and Age Groups.

	Gender		
Age Groups (years)	Male	Female	Total
30–50	17.214 μm ± 1.139	15.565 μm ± 1.899	16.389 μm ± 1.713
60–75	14.354 μm ± 0.627	14.471 μm ± 0.699	14.412 μm ± 0.617*
76–90	14.309 μm ± 0.452	14.016 μm ± 0.921	14.162 μm ± 0.701*
Total	15.292 μm ± 1.595	14.684 μm ± 1.365	14.988 μm ± 1.486

Statistical analysis: $P = 0.174$ between groups × gender; $P = 0.131$ between genders; $P < 0.01$ between age groups (*).
SD = standard deviation.

Hyaluronic Acid Behavior in the Lamina Propria of the Larynx with Advancing Age

Anete Branco[1], Sergio Augusto Rodrigues[2],
Alexandre Todorovic Fabro, MD, PhD[3],
Carlos Eduardo Fonseca-Alves[4], and
Regina Helena Garcia Martins, MD, PhD[5]

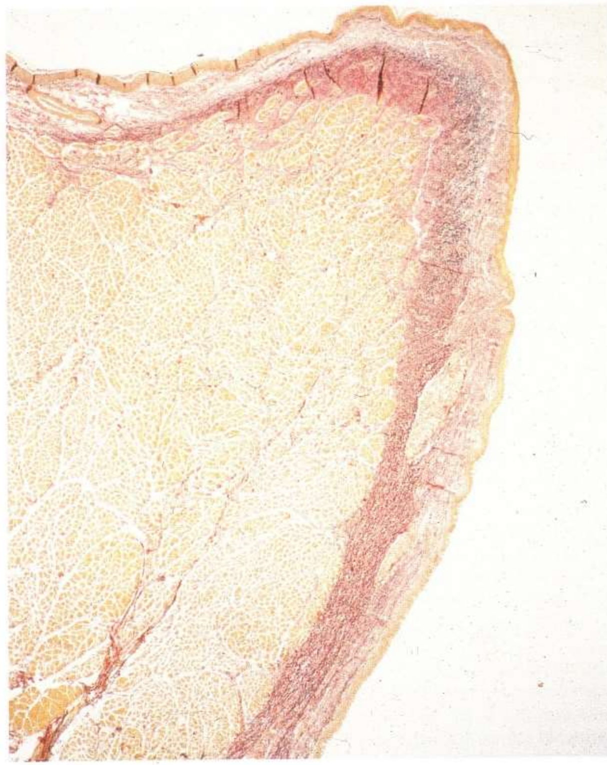


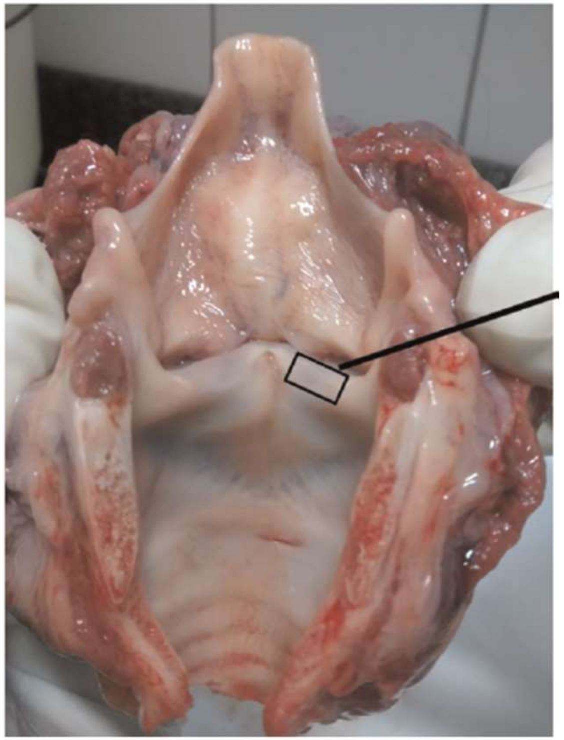
Table 1. Mean and Standard Deviation (SD) of Hyaluronic Acid (HA) Density, as Area Percentage (%), According to the Age Range and the Lamina Propria Layers.[a]

	Mean and SD	
Age Range (years)	Superficial Layer	Deep Layer
30-50	41.6 (10.8)[B]	38.5 (10.1)[B]
60-75	26.7 (6.1)[A]	24.6 (4.1)[A]
>76	21.8 (5.7)[A]	24.1(4.6)[A]

[a]Two frequencies followed by the same letter do not differ concerning to the respective age groups (lines) ($p > .05$). Two frequencies followed by the same letter do not differ concerning to the layers (columns) ($p > .05$), Goodman test.

Scanning Electron Microscopy of the Presbylarynx

Tatiana Maria Gonçalves, MD[1], Daniela Carvalho dos Santos, PhD[2], Adriana Bueno Benito Pessin, PhD[1], and Regina Helena Garcia Martins, MD, PhD[1]



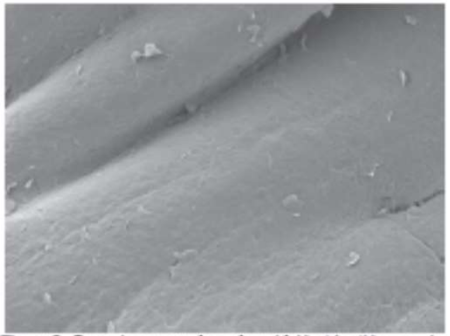


Figure 2. Control group: surface of vocal fold with mild mucosal undulation and some desquamation cells. Scanning electron microscopy, magnification 300×.

Figure 4. Control group: epithelial surface of vocal fold highlighting the microfolds and protruding intercellular junctions. Scanning electron microscopy, magnification 4000×.

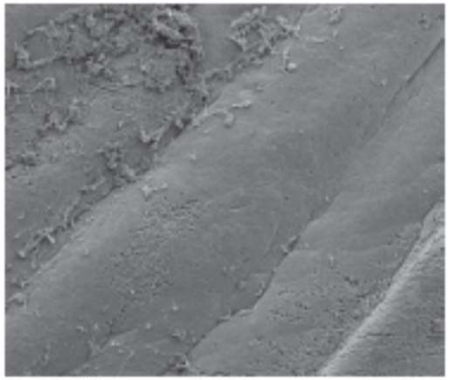


Figure 3. Elderly group: surface of the covering mucosa of the vocal folds more folded and with more desquamation cells. Scanning electron microscopy, magnification 300×.

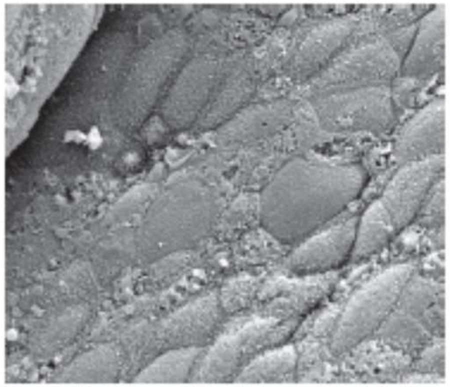


Figure 5. Elderly group: epithelium with well-demarcated cells, separated by deep sulci. Scanning electron microscopy, magnification 4000×.

had soft undulation and few desquamation cells (Figure 2).

BIOMECHANIC MODIFICATIONS

1. Reduced ISOMETRIC tongue strength (unchanged swallowing strenght) → reduced functional reserve
2. Prolonged oral phase
3. Delayed swallowing reflex
4. Reduced opening times oof the UES
5. Reduced pharyngeal peristalsis
6. Reduced laryngeal elevation

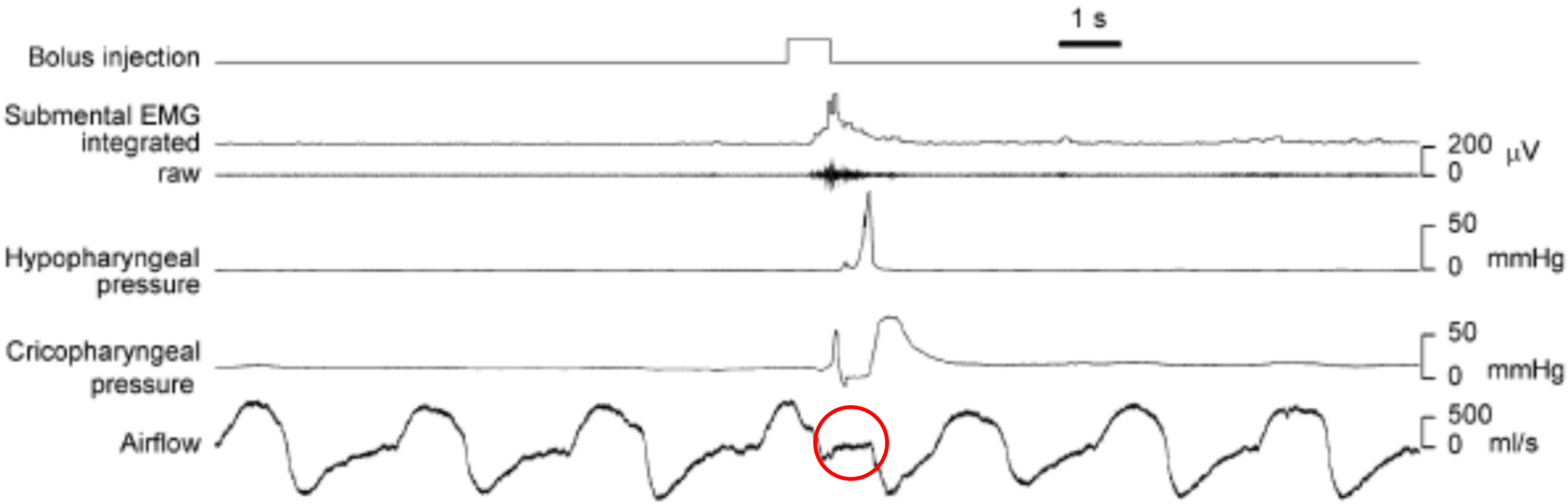
→ INCREASED RESIDUE

INCREASED RISK OF PENETRATION/ ASPIRATION

(Schindler et al; in Deglutologia II ed, 2011)

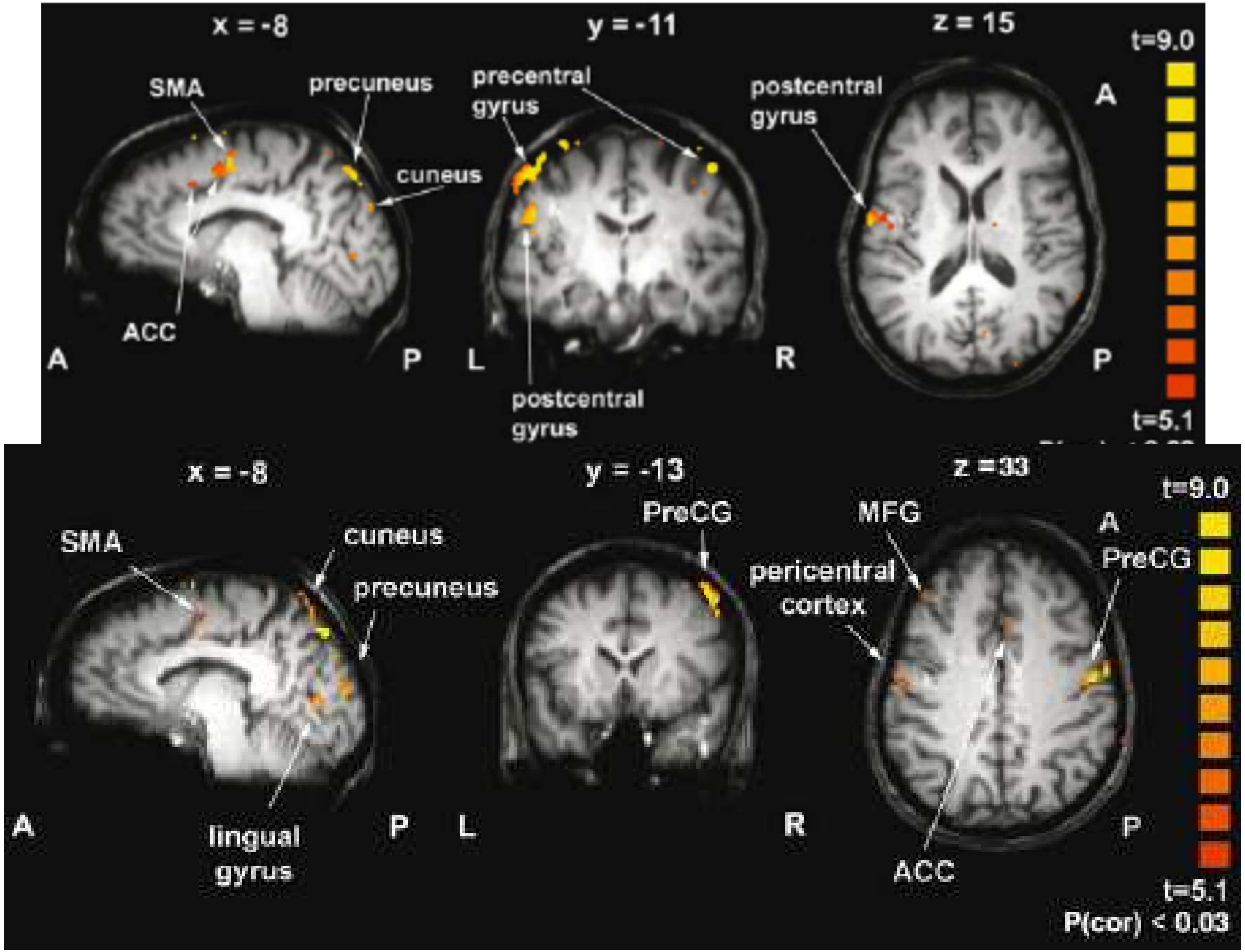
SWALLOWING-BREATHING COHORDINATION

In the elderly swallowing apnea duration increases, respiratory frequency increases, oxygen saturation decreases



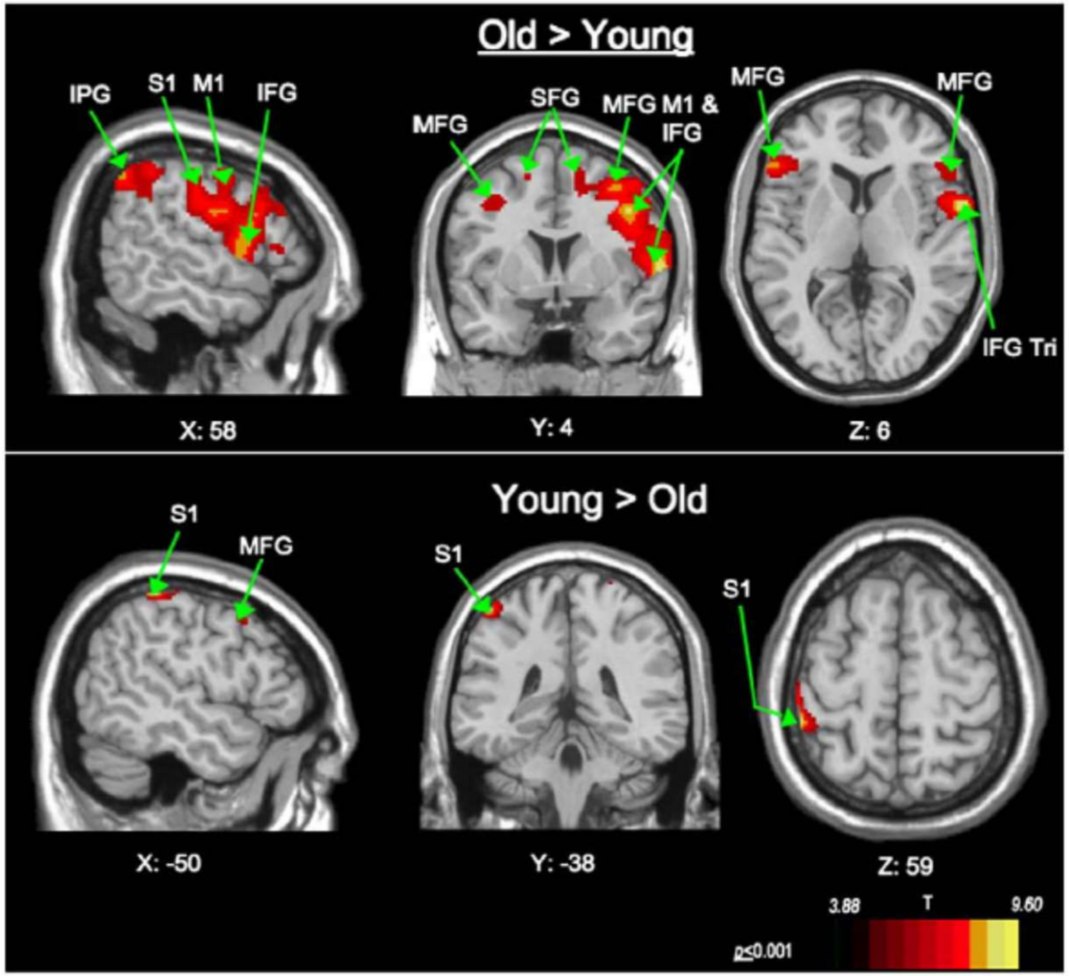
Hirst et al; Dysphagia 2002; 17: 152-161

BRAIN ACTIVITY IN THE ELDERLY



Brain activation in voluntary swallowing of water: increased activation compared to saliva swallowing

INCREASED BRAIN ACTIVITY IN THE ELDERLY



Older subjects recruite significantly larger regions of the supratentorial brain

(Humbert et al; Neuroimage 2009; 44: 982-991)

REDUCED FUNCTIONAL RESERVE