

Introduction to Linguistic Phonetics

Physiology and Aerodynamics

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Reflection

- Spend ~3 minutes reviewing your notes from last lecture and from R&J ch. 2.
- Look for questions you have or clarifications you need.

The International Phonetic Alphabet

- A transcription system with the goal of describing the sounds found in all the world's languages
- While the human vocal tract can produce an amazing array of sounds, the ones used in languages are more limited (200)
- Any individual language has a much smaller number of sounds in its inventory (all the speech sounds used in that language)
 - Rotokas (11)
 - !Xóõ (122)

The IPA Chart

THE INTERNATIONAL PHONETIC ALPHABET (revised to 2020)

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	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Vocal	Uvular	Pharyngeal	Glossal
Plosive	p b		t d	t̪ d̪	c j	k g	q q̪		?		
Nasal	m	n̪	n	n̪	ŋ	ŋ̪		N			
Trill	B		r					R			
Tap or Flap		v̪	t̪		t̪						
Fricative	f̪ β̪	f v̪	θ̪ ð̪	s z̪	ʃ̪ ʒ̪	ʂ̪ ʐ̪	ç̪ ɟ̪	x ɣ̪	χ̪ ʁ̪	h ʕ̪	h̪ fi̪
Lateral				l̪	ɿ̪						
Approximant		U		t̪̫	j̪̫	w̪̫					
Lateral approximant			I	ɬ̪̫	ɻ̪̫	L̪̫					

Symbols to the right in a cell are voiced, to the left are voiceless. Shaded areas denote articulations judged impossible.

CONSONANTS (NON-PULMONIC)

Clicks	Voiceless implosives	Ejectives
ʘ Bilabial	ʘ Bilabial	ʘ Example:
ǀ Dental	ǀ Dental	ǀ Bilabial
ǃ Postalveolar	ǃ Palatal	ǃ Dental/Postalveolar
ǂ Palato-alveolar	ǂ Velar	ǂ Velar
ǁ Alveolar lateral	ǁ Uvular	ǁ Alveolar/ejective

OTHER SYMBOLS

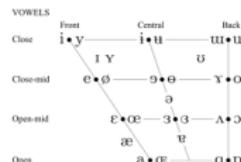
ʍ Voiced labio-velar fricative	ç ʐ Alveolo-palatal fricatives
w Voiced labio-velar approximant	ɿ̪ Voiced alveolar lateral flap
ɥ Voiced labial palatal approximant	ɻ̪ Simultaneous ɿ̪ and X
h Voiced eephtal fricative	Affricates and double articulations can be represented by two symbols joined by a tie bar if necessary.
χ Voiced eephtal fricative	ts kp
ɸ Ejective plosive	

DIACRITICS

‿ Voiceless	n̪ d̪	‿ Breathy voiced	b̪ a̪	Dental	t̪ d̪
~ Voiced	s̪ t̪	~ Croaky voiced	b̪ a̪	Apical	t̪ d̪
h Aspirated	th̪ dh̪	~ Lingualized	t̪ d̪	Laminal	t̪ d̪
ɔ More rounded	ɔ̪	~ Labilized	t̪ w̪ d̪ w̪	Naлизed	ɛ̪
ɔ̄ Less rounded	ɔ̪̄	ɔ̄ Palatalized	t̪̪ d̪̪	No nasal release	d̪̪
ū Advanced	ū̪	ū Velarized	t̪̪ d̪̪	Lateral release	d̪̪
~ Retracted	ē̪	~ Pharyngalized	t̪̪ d̪̪	~ No audible release	d̪̪
~ Centralized	ɛ̪̄	~ Velarized or pharyngalized	ɬ̪		
~ Mid-centralized	ɛ̪̄	~ Raising	ç̪	(ç̪ = voiced alveolar fricative)	
~ Syllabic	n̪̪	~ Lowering	ç̪̪	(ç̪̪ = voiced bilabial approximant)	
~ Non-syllabic	ɛ̪̄	~ Advanced Tongue Root	ɛ̪̄		
~ Rhymotic	ə̪̄	~ Retracted Tongue Root	ə̪̄		

Some diacritics may be placed above a symbol with a descender, e.g. ɬ̪̫

Transliteration: Double-barred letters, non-syllabic vowels (circled),



Where symbols appear in pairs, the one to the right represents a rounded vowel.

SUPRASEGMENTALS

↑ Primary stress *foʊndən̪ tʃɪfən̪*

↓ Secondary stress *eɪt̪̪*

— Long *eː*

— Half-long *eː*

— Extra-short *ɛ̪*

— Minor (foot) group

— Major (intonation) group

— Syllable break *zi‿ækt̪*

— Linking (absence of a break)

TONES AND WORD ACCENTS

LEVEL CONTOUR

ē = ↗ Extra high ē = ↘ Rising

ē = ↗ High ē = ↘ Falling

ē = ↗ Mid ē = ↘ Middle

ē = ↗ Low ē = ↘ Low

ē = ↗ Extra low ē = ↘ Extra low

ē = ↗ Downstep ↗ Global rise

ē = ↗ Upstep ↘ Global fall

Speech articulators

- Most of these body parts have other essential functions—primarily breathing and eating
- They have been co-opted and adapted to speech through evolutionary processes
- In this class we're mostly talking about **descriptive articulation** (i.e., only a minimal examination of physiology and motor control)

Chimpanzee (*Pan troglodytes*) vs. Human Vocal Tracts

(A)

Nasal cavity
Soft palate
Hard palate
Tongue
Epiglottis
Vocal fold
Oesophagus

(B)

Nasal cavity
Hard palate
Tongue
Pharynx
Hyoid bone
Larynx (voice box)
Trachea
Soft palate
Epiglottis
Vocal fold
Oesophagus

Human development

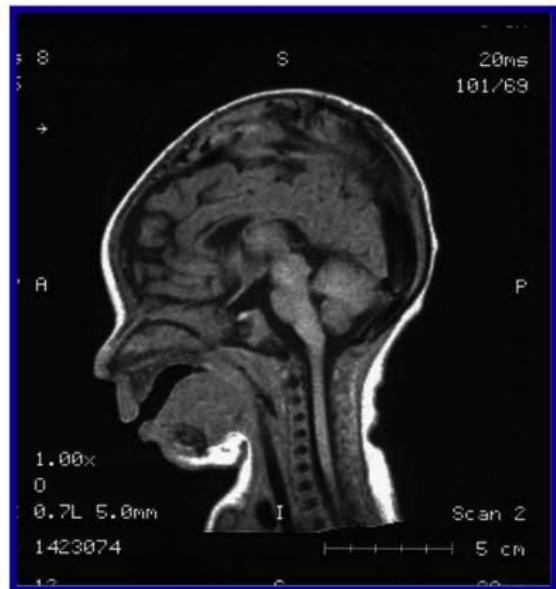


Figure 1. Male 2 week old infant MRI



Figure 2. Adult male MRI

What does speech look like?

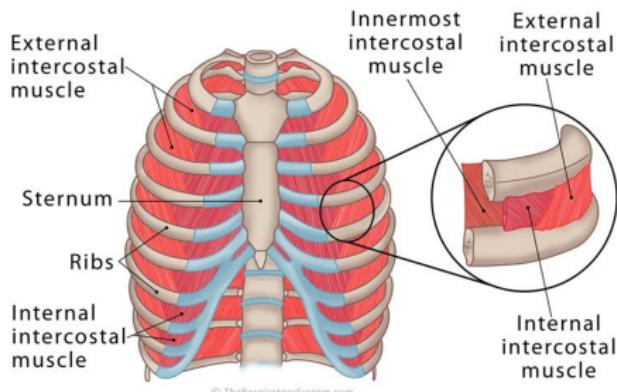
- To begin, we need to understand the basic articulators for speech
- Ken Steven's X-ray
- Vocal tract MRI during speech

Breathing apparatus

- The basic source of power in speech is the respiratory system pushing air out of the lungs
- In most instances, we superimpose speech on an outgoing breath
- Humans have considerable control over breathing, especially compared to other primates

Breathing

Intercostal Muscles



- **Inhalation:** the ribs are pulled up by the external intercostal muscles
- **Exhalation:** rib cage is deflated by pulling the ribs down by the internal intercostals
- Exhalation is a more passive activity in during **tidal breathing**—elastic tension on the ribs naturally compresses them

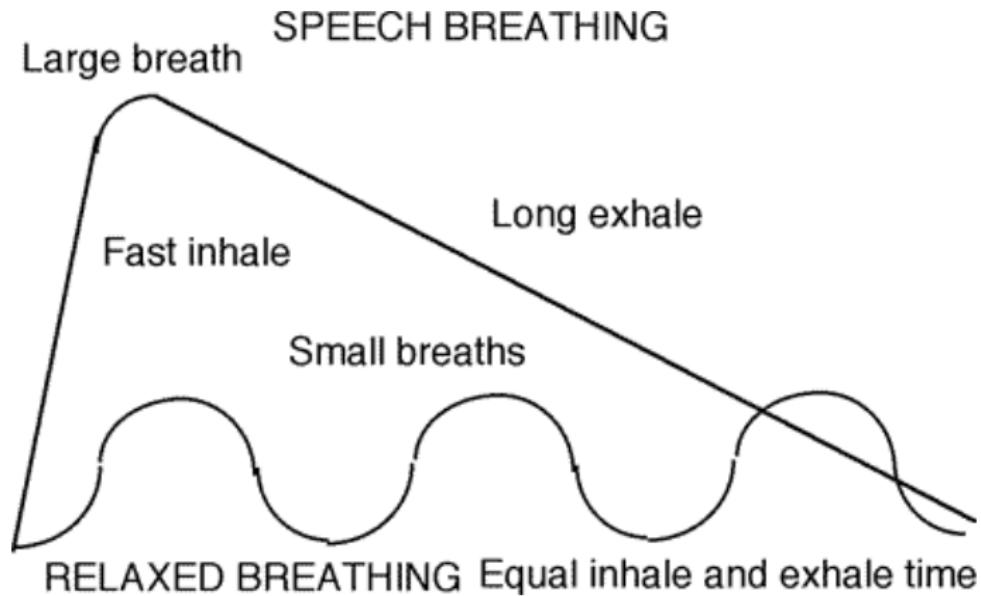
Breathing for staying alive vs. speech

- Both an active and passive process
- **Respiration** is breathing to stay alive. It's mostly unconscious, controlled by the brainstem—regulated primarily by blood pH
- **Speech breathing** is a very different story

Speech breathing

- Higher level motor control regions interact with the brainstem to control breathing
- Inhalations timed for major phrasal/sentence boundaries depending on overall utterance length
- Depth of inhalation and speed of exhalation controlled to utter the desired amount of speech per breath cycle
- A learned behavior—notice that children and very excited people often get out of breath while talking

Speech breathing



A small note

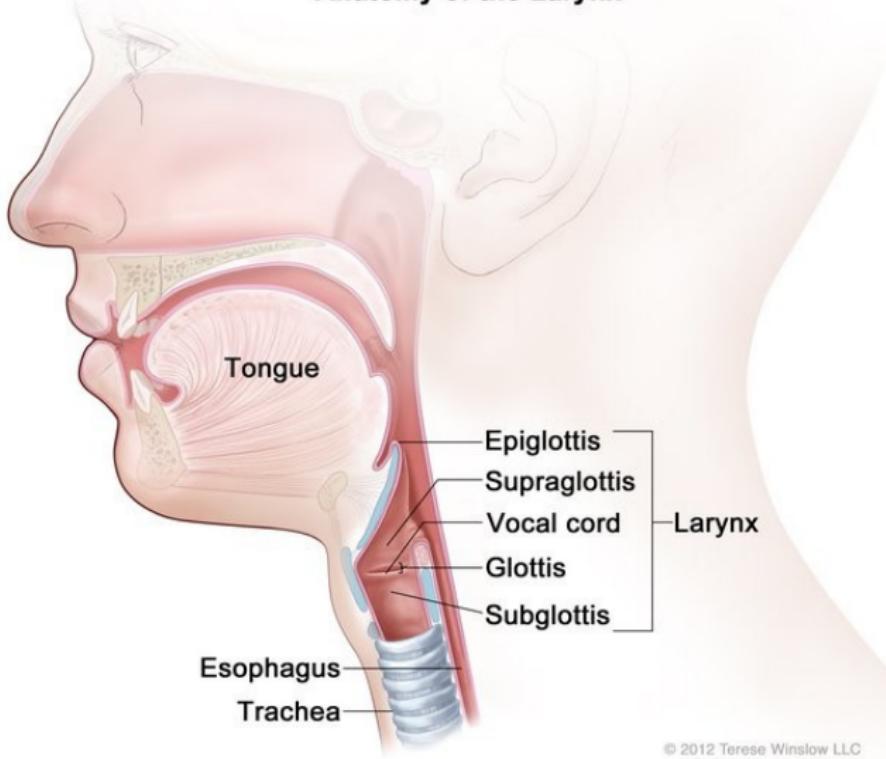
- We will be coming back to the physics in a few weeks.

The larynx and glottis

- Reminder: the **larynx** is the entire structure that holds the vocal folds (plural is larynges)
 - Can also move up and down as a kind of articulator (e.g., ejective and implosive consonants)
 - Consonants made here are **laryngeal**
- Consonants articulated by opening and closing the vocal folds are **glottal**
 - Only if the opening or closing of the glottis the primary articulation (e.g., not just voicing)
- There's lots of confusion in the field between the terms

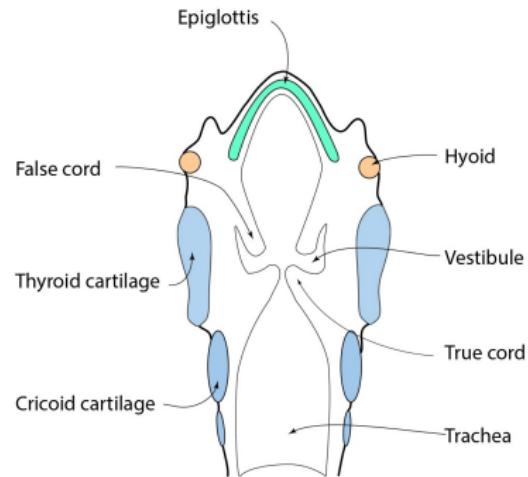
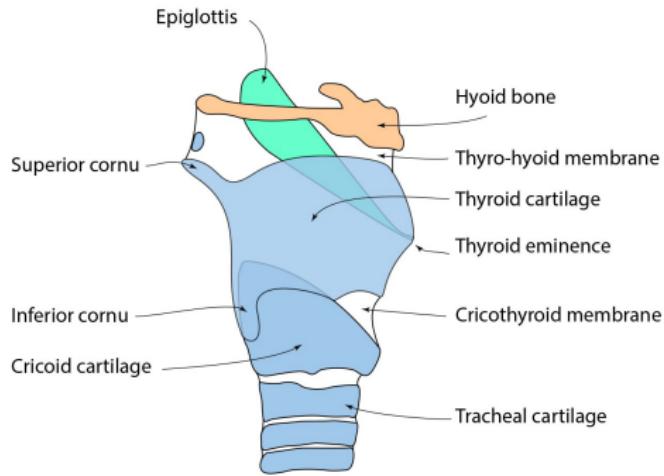
The Larynx

Anatomy of the Larynx



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Major structures of the larynx

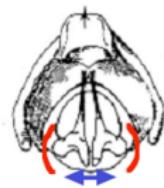


How the larynx works

- The triangular-shaped **arytenoid cartilages** sit on the upper back of the **cricoid cartilage**
- They **rotate** and **slide** to *abduct* (move apart) and *adduct* (bring together) the vocal folds



View of the larynx
from the back



View of the larynx
from the top

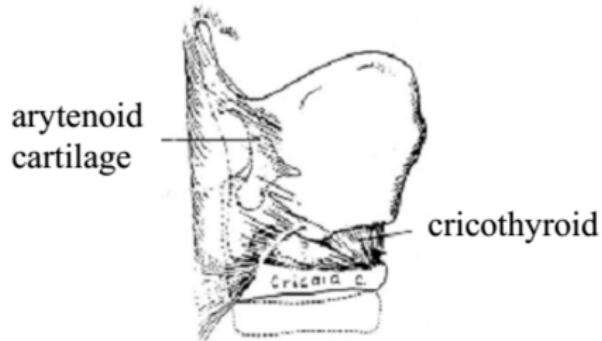
How the larynx works

- The length of the vocal folds is correlated with the angle between the thyroid cartilage and the cricoid cartilage
- When the thyroid is tilted **forward** the vocal folds are longer and thinner
- When the thyroid is tilted **back** the vocal folds are shorter and thus thicker and vibrate at a lower rate



Muscle in the larynx

- The main muscle in the larynx that controls the pitch of the voice is the **cricothyroid muscle**



The vocal folds

- Tissue folds crucial to voicing
- Hormone changes at puberty stimulate enlarging in adolescents (roughly, more testosterone \rightarrow larger vocal folds)
 - Range from 12.5mm to 25mm in length, 3-5mm thick
 - The larynx also lowers for all people, with more lowering corresponding to (roughly) more testosterone
- More massive folds result in slower vibration (= lower pitch, on average)
- Most research has been with *WEIRD*¹ societies, so take a lot of this with grain of salt (maybe even a pound *shrug*)

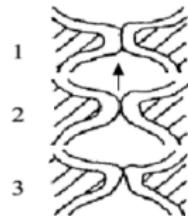
¹Term coined in 2010 by Henrich, Heine, and Norenzayn to describe how 96% of psychological samples come from Western, Educated, Industrialized, Rich, and Democratic societies.

Vocal folds during speech

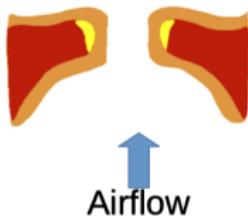
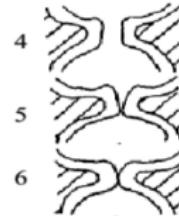
- Higher pressure air resulting from lung compression flows to the lower pressure (usually atmospheric) in the oral cavity
- We think of “pushing” air through the vocal tract, but it’s better to think about air flowing from higher to lower pressure (i.e., the Bernoulli effect)
- The lungs create pressure greater than atmospheric pressure when they compress
- Airflow passing through the adducted (= pulled together) vocal folds results in *voicing*

The vocal folds during speech

Air pressure below the glottis forces the vocal folds open



Muscle elasticity and the Bernoulli force close the vocal folds



- **Phonation:** setting the vocal folds into vibration
- Broader definition: any active modification of airflow by the larynx (This make my research really difficult)
- Also called: **voice, voicing**
- Videos:
 - Movies of vocal folds in action
 - Synthesis
 - Mucosal wave

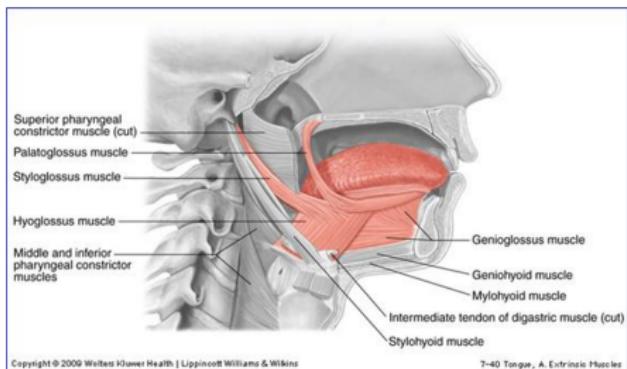
Break Time!

10 minute break
(stretch, grab a drink, etc.)

Articulators

- All articulators come in two flavors:
 - **Active articulators** move to produce a sound
 - **Passive articulators** are static landmarks
- Active articulators always move towards passive ones
- **Constrictions** pretty much all sounds are made by constrictions — two articulators actively narrowing some point (or points) of the vocal tract
 - This means that we could potentially just use the physics of tubes to explain what occurs acoustically.
 - More to come in a few weeks

The tongue



- The most widely used articulator
- Active for all vowels and most consonants
- A muscle anchored to the jaw (by the hyoid bone)
- Capable of considerable freedom of movement—especially the anterior (front) part

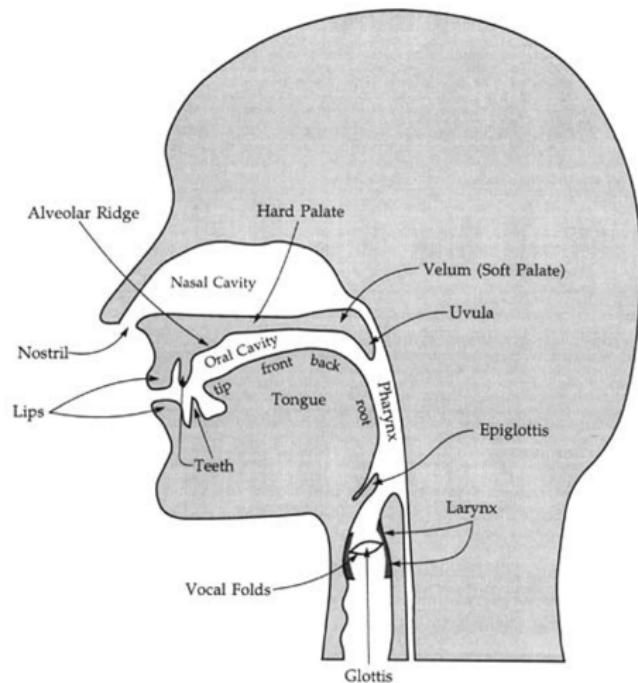
Major parts of the tongue

- **Corona (Front)** – if you stuck your tongue out and put a little paper crown on it, the crown would sit on the coronal parts of the tongue
 - Tip / apex
 - Blade – the part near the front immediately behind the tip
- **Dorsum (Rear)** – think dorsal fin on a dolphin's back
 - Center
 - Back
- **Root / radix**

Passive articulators

- If the tongue is the active articulator for most sounds, what are the passive articulators?

Passive articulators



The lips

- Sounds made with the lips are called **labial**
- Sounds where the lower lip touches the upper teeth are **labio-dental**
- Minor point: sounds made with the outer, external part of the lips are exo-labial, those with the inner lip are endo-labial

Lip Movements

- **Rounding** – the lips compress at the corners and squeeze inward
- **Spreading** – the lips straighten and the corners spread (like a smile)
- **Constricting** – the lips block airflow, either somewhat or completely

The teeth

- Incisors and canines are the primary articulators
 - Obligatory passive articulators
 - Only the upper teeth are considered articulators
- Sounds made at the teeth are **dental**
- Have acoustic consequences for certain sounds made at other places (especially the sibilant fricatives, we'll talk about this in a few weeks)

The alveolar ridge

- Ridge between the upper teeth and the hard palate
- The location of the sockets (alveoli) for the roots of the upper teeth
- Not everyone has a clearly defined ridge; some don't and still talk fine!
- Sounds made here are **alveolar**
- Very important place of articulation—the most flexible, nimble part of the tongue can easily make contact here

The palate

- Hard, bony structure; the “roof of the mouth”
- Some people have a relatively domed palate, others flatter
- Sounds made here are **palatals**

The velum

- Soft tissue (aka the **soft palate**)
- As an active articulator:
 - Controls the opening of the velo-pharyngeal port (the connection between the oro-pharynx and the nasal cavity)
 - Allows airflow through the nose for **nasal** sounds
- As a passive articulator:
 - Holds still while constriction is actively made by the tongue dorsum
 - Consonants produced this way are called **velar**

The uvula

- A fleshy conical extension of the soft palate
 - Can be seen if you open your mouth wide and look in a mirror
 - Fun fact: uvula is Latin for “little grape”
- Mainly a passive articulator
 - The tongue back moves up and back
 - Sounds made here are called **uvular**
- As a quasi-active articulator, airflow can be used to vibrate it (uvular trill)

The pharynx

- The part of the vocal tract below the uvula and above the epi(glottis)
 - **Oral cavity:** cavity between the lips and uvula
 - **Oropharynx / buccal cavity:** oral cavity + pharynx
 - **Nasopharynx:** pharynx + posterior part of the nasal cavity
 - **Throat:** pharynx + glottis + esophagus + trachea
- The tongue root can move back towards the pharynx
- Sounds made here are **pharyngeal**

Summary of articulators and adjectives

<i>Articulator Name</i>	<i>Adjective</i>
Lips	Labial
Teeth	Dental
Alveolar Ridge	Alveolar
Palate	Palatal
Velum	Velar
Uvula	Uvular
Pharynx	Pharyngeal
Tongue Tip	Apical
Tongue Blade	Laminal
Tongue Center	Dorsal
Tongue Back	Dorsal
Tongue Root	Radical
Epiglottis	Epiglottal
Glottis/Larynx	Glottal/Laryngeal

To Do:

- Complete the exit ticket for today on Canvas by 12:30pm.
- Complete Homework 2 by Tuesday at 8:30am.