# Acoustic Phonetics

Lesson 1

Busà 2018-19

## Introduction to Experimental Phonetics

Introduction

- What is experimental phonetics?
- Uses and methods in experimental phonetics
- Phonetics and linguistic systems
- Sound articulation
  - vowels
  - consonants

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## Phonology and Phonetics

Phonology:

- the study of the linguistic system of a language.
  - Linguistic phonemes (vowels and consonants with a distinctive function in the language)
  - the phonotactics of the language (combinatory rules in the language, i.e., what sounds can combine),
  - language-specific rules (for ex., vowel reduction, deletion, assimiliation, co-articulation, etc.).



## Phonetics and Phonology

Phonetics:

- the study of the physical properties of sounds (i.e., physiological, acoustic, aerodynamic and articulatory factors affecting sound production, perception and co-occurrence).

## Areas of Phonetic Analysis

Articulatory

studies the movements of the articulatory organs in the production of sounds and aims to reconstruct the cerebral commands that controls them

Acoustic:

studies the linguistic signal (sound waves) and reconstructs the articulatory movements from the sound wave

Auditory-perceptual:

studies how the acoustic signal (sound waves) is perceived and decoded linguistically



## Aims of experimental phonetics

- Linguistic data are physical data and as such they can be collected and analysed
  - Graphic visualization
  - Strict metodological procedure
  - Numeric/quantitative studies
  - Scientific results

## Charatteristics of experimental phonetic studies

- Based on experimental method
  - Ipotheses
  - Experiment with data collection and analysis
  - Testing and Verification
- Testing hypotheses requires the use of appropriate instrumentation
- Knowledge and methods from other disciplines may be needed (interdisciplinariety)
  - Ex. acoustics, psycology, statistics…



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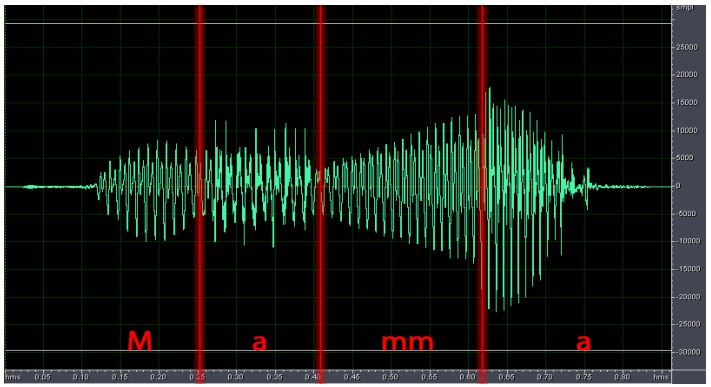
## Some examples of methods used in experimental phonetics

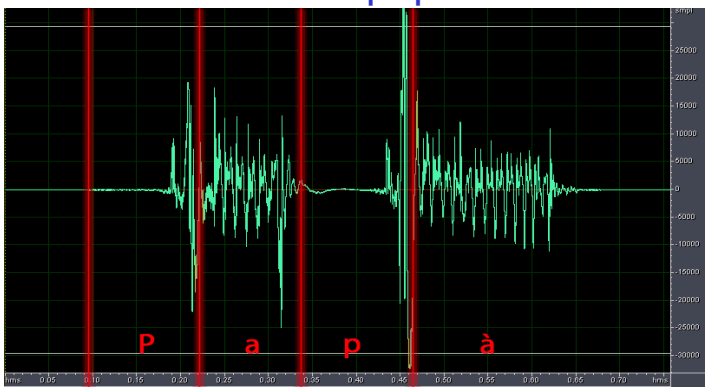


## Acoustic Analysis : wave form of the word ‘mamma’




source: I colori della voce: http://www.scuolaer.it/pages.asp?IDCategoria=129&IDSezione=380&ID=42363

## Acoustic Analysis : wave form of the word ‘papà’




Source: I colori della voce: http://www.scuolaer.it/pagg.asp?IDCategoria=129&IDSezione=380&ID=42363



## X-ray analysis of the production of a vowel sound (no longer used)

https://www.youtube.com/watch?v=DcNMCB-Gsn8

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https://www.youtube.com/watch?v=b9URTdEe_Ko

For a text, read: Gick, 2002, The Use of Ultrasound for Linguistic Phonetic Fieldwork, JIPA Fall 2002

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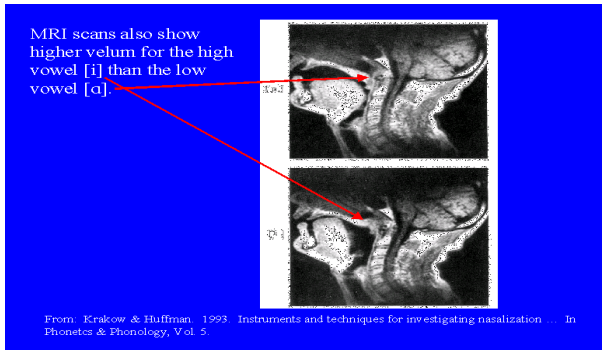
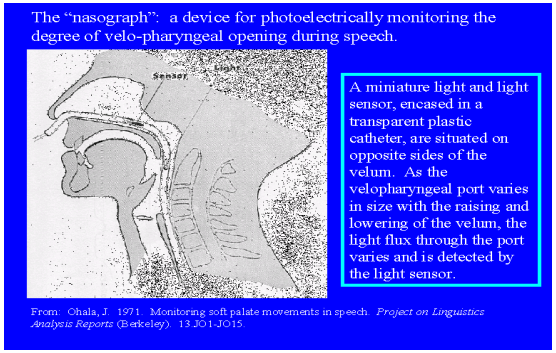
## Magnetic Electroresonance



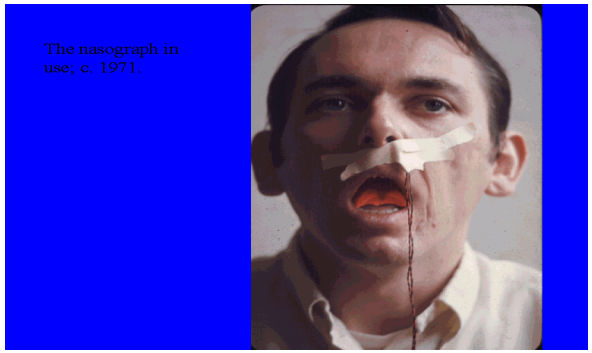

http://trill.linguistics.berkeley.edu/PhonLab/classes/ling110/lecturesslides_2003.html

## Nasograph (1)



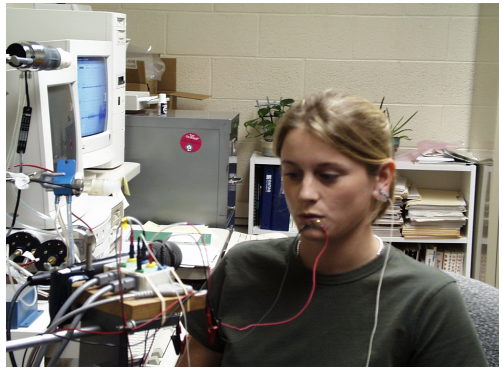

http://trill.linguistics.berkeley.edu/PhonLab/classes/ling110/lecturesslides_2003.html

## Nasograph (2)




http://trill.linguistics.berkeley.edu/PhonLab/classes/ling110/lecturesslides_2003.html

## Electromyography



http://www.unc.edu/~dzajac/lab.htm

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## Electromyography

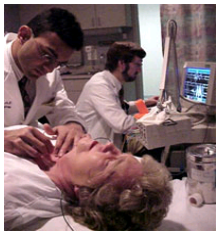


Figure 1: Example of a Laryngal Electromyography procedure.
The speech specialist places the electrodes, the neurologist operates the machines and reads the traces on the monitor.. Both specialists interpret the results.

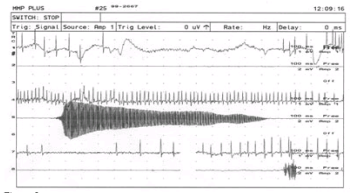
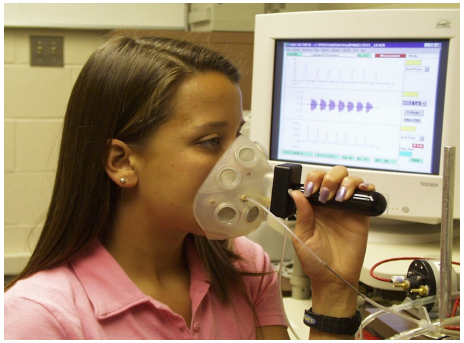


Figure 2: Example of a trace produced with a laryngal elctromyography. The traces are interpreted to give an idea of what muscles move during certain movements or articulations.

Fonte: http://www.med.nyu.edu/voicecenter/services/voice/laryn_electro.html



## Aerodynamic Studies



http://www.unc.edu/~dzajac/lab.htm



A mask is used that is partitioned in a way that oral and nasal flow can be collected separately. The mask is partitioned into nasal and oral chambers. Each chamber has fine mesh, wire screens that serve as flow-resistive pneumotachographs. Catheters (not visible in photograph) are inserted into each chamber to detect pressure variations associated with airflow. A microphone (also not visible in photograph) is positioned outside of the mask to record the audio signal. Integration of the airflow signals is done to determine lung volumes associated with speech utterances. An additional catheter (visible in the photograph) is inserted through the oral chamber and positioned in the mouth to detect oral air pressure. Software is used to display and analyze the aerodynamic and acoustic data.

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## Phonetics and Phonology

- The knowledge of phonetic mechanisms is of fundamental importance for phonology
- Phonetics cannot give answers to its questions if it does not take the phonology of languages into account

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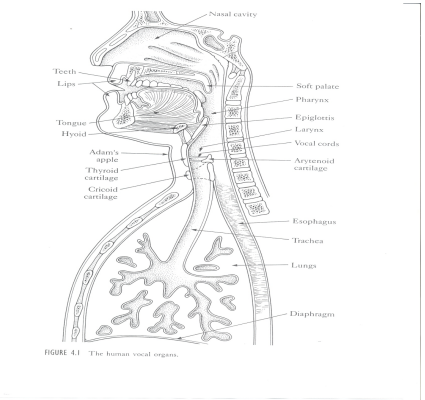
## About linguistic systems

- The organs for speech production are the organs of the articulatory, or phonatory, apparatus and are used also for breathing and eating.
- Languages differ in the number and types of sounds that are used **linguistically** (**phonemes**)



## The phonatory organs




Fonte: P. Denes & E. Pinson, The Speech Chain, New York, W.H. Freeman Company

## Sound production

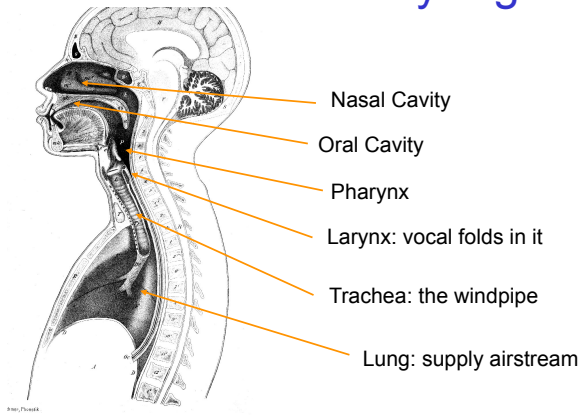
- Sounds are produced by the air that comes out of the lungs, goes through the larynx, the nose and the mouth
- The air stream coming from the lungs is modified by the different shapes of the vocal tract, due to the different movements of the articulatory organs
- The modifications of the vocal tract cause the air particles to move in different ways



## Speech Production Mechanism

- Airstream process (Respiration): the lungs push air out or suck it in during speech. Source of energy for speech.
- Phonation process: the vocal folds convert the energy into audible sound.
- Articulatory process: the movements of the tongue and the lips interacting with the roof of the mouth and the pharynx. Convert sound into intelligible speech.

## The Phonatory organs




Sagittal section of the vocal tract (Techmer 1880)
[From: Dan Jurafsky slide]



## The lungs

- Give rise to Phonation
- Phonation takes place during espiration
  - Expansion of the thoracic cavity by expanding the rib cage (raising the ribs) increases lung volume,
  - Decrease the air pressure in the lungs
  - Air is drawn in from the from the outside to equalise pressure.
  - Contraction of the thoracic cavity by contracting the rib cage (lowering the ribs) decreases lung volume and increases air pressure in the lungs
  - Air is expelled from the lungs to equalise pressure with the outside air.

## Larynx and vocal folds

- The Larynx (voice box):
  - A structure made of cartilage and muscle
  - Located above the trachea (windpipe) and below the pharynx
  - Contains the vocal folds
- Vocal Folds (vocal cords)
  - Two bands of muscle and tissue in the larynx
  - Sounds produced when the vocal folds are vibrating are said to be voiced, those produced when the vocal folds are apart are voiceless

Adapted from: LING 520 Introduction to Phonetics I, Liberman & Yuan

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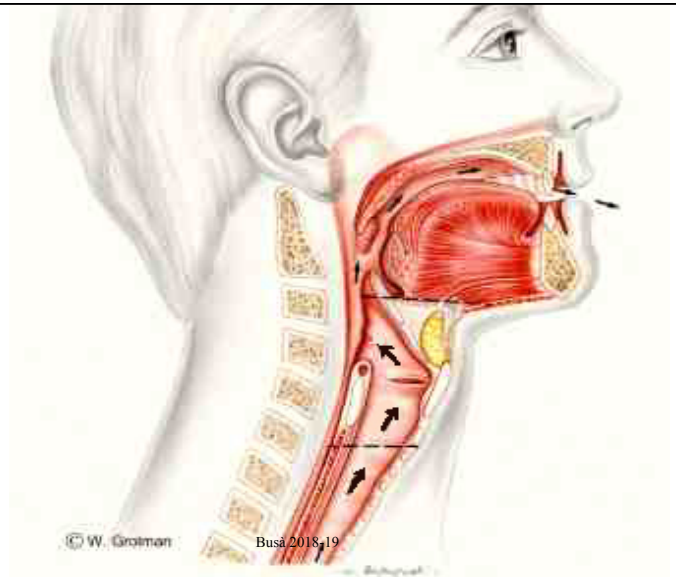


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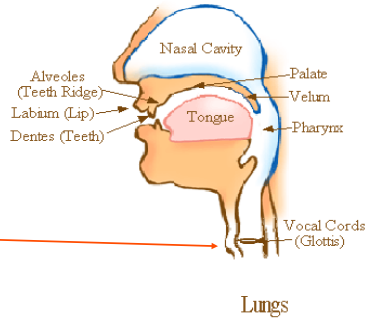
## The Larynx

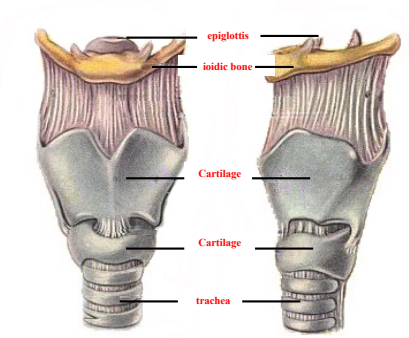
- The air coming out of the lungs goes through the trachea and comes into the larynx




Source: http://home.hib.no/al/engelsk/seksjon/SOFF-MASTER/Organs.htm

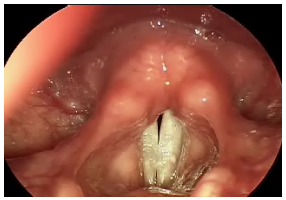


## larynx




**anterior** **lateral**

## The vocal folds



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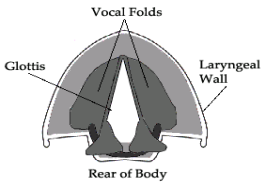
## Vocal Chords (folds) and Glottis

- Two bands of muscle and tissue in the larynx
- The internal part of the larynx is called glottis

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## What happens in the larynx

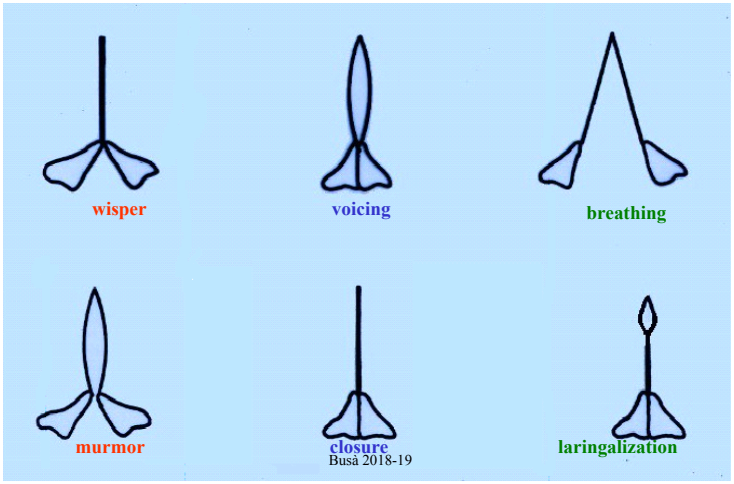
- High air pressure below closed vocal folds (sub-glottal pressure) forces the vocal folds to open
- Elastic and aerodynamic forces force the vocal folds to spring back closed
- pressure builds up again, the vocal folds open again, etc.
- This continuous periodic process is known as phonation and produces a "voiced" sound source.



## What happens in the larynx

- Different configurations of vocal folds vibrations result in different voice qualities, some of which are important linguistically in some languages.

## Positions of the glottis

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## Movement of the vocal folds

https://www.youtube.com/watch?v=9TIpkdq8a8c

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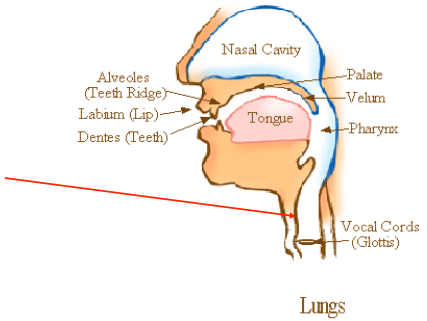
## Pharynx

- extends from the larynx to the nasal cavity, it is about 15 cm long.

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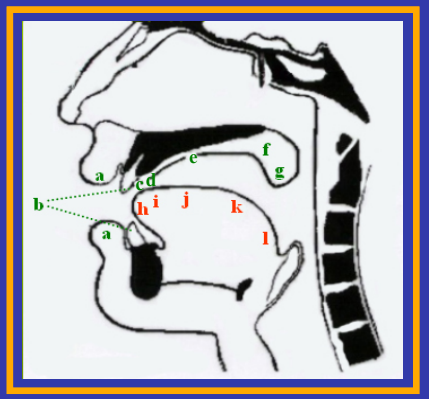
## Oral cavity

a) lips
b) teeth
c) alveolars
d) postalveolars
e) Hard palate
f) Soft palate
g) uvola
h) tip punta
i) blade
k) postdorsum
l) root

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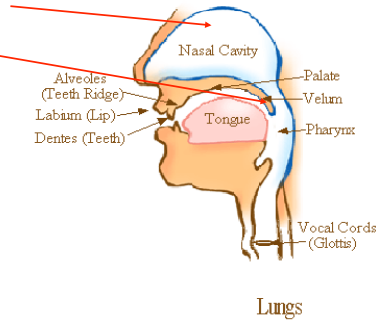
## Nasal Cavities

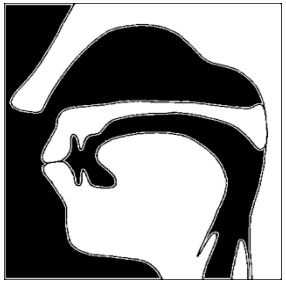
- Extend from the velum (uvula) to the nasal fossae






## Nasal Cavities

- During phonation can be excluded by raising or pushing the velum against the pharynx (**oral phones**).



fonte: http://www.ling.mq.edu.au/ling/units/ling210-901/phonetics/consonants/oral_stops.html

## Nasal Cavities

- If, in phonation, the velum is lowered, the channel is open and the air can go out of the nasal cavities (**nasal fones**).

fonte: http://www.ling.mq.edu.au/ling/units/ling210-901/phonetics/consonants/nasal_stops.html



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## Speech sounds

- Vowels and approximants
- Consonants



## What is the difference between a vowel and a consonant?

- Vowels: when we produce a vowel, the air coming out of the mouth is not impeded or blocked in any way.
- Consonants: when we produce a consonant, the air coming out of the mouth meets some impedance or blockage in one or more regions of the vocal tract

## Vowels

- In the production of a vowel the tongue raises and approaches (but never comes in contact with!) the palate. The lips may be spread flat or rounded. The uvula may be up or down.
- Different vowel sounds are the result of the position of the tongue, lips and uvula during their production.



## Visualization

- X-Ray Vowel Production
- Note:
  - Position of the tongue
  - Position of the lips
  - The uvula is raised against the pharynx, the vowels are oral, not nasalized.

[i]

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[i]

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## [æ]


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## [a]


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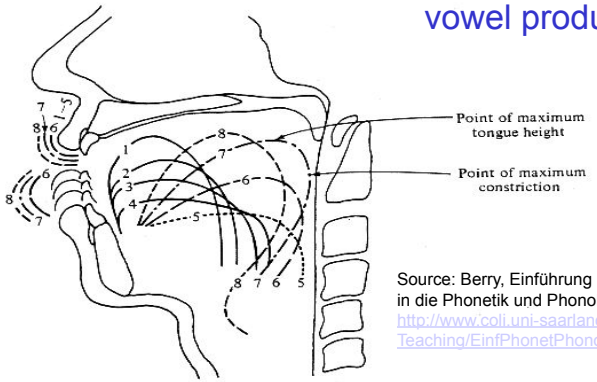
# [u]




## Tongue and lip positions in vowel production



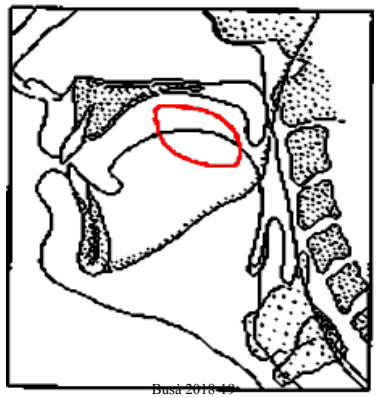

Source: Berry, Einführung in die Phonetik und Phonologie, 2003
http://www.coli.uni-saarland.de/~wbarry/Teaching/EinfPhonetPhonol.html

Tongue and lip positions for the vowels

(1) [i] (5) [a]
(2) [e] (6) [ɔ]
(3) [ɛ] (7) [o]
(4) [æ] (8) [u]

(a)

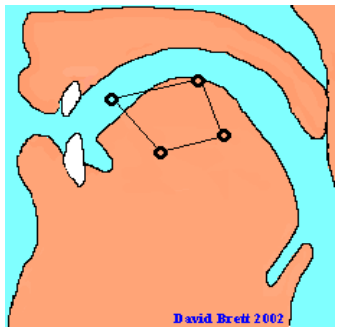
## Area of production of vowels



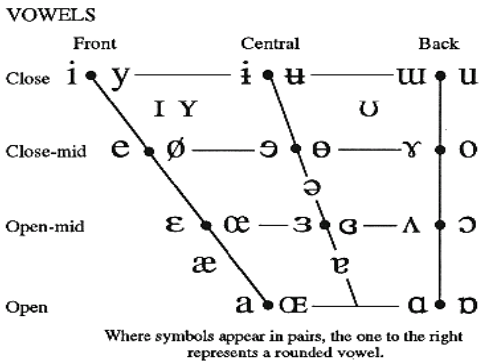


## Stylisation of this area for vowel production has been called the *Vowel Quadrilateral*

This quadrilateral is used for plotting all the vowel sounds that the human voice can produce



## Vowel diagram with Cardinal Vowels and IPA symbols

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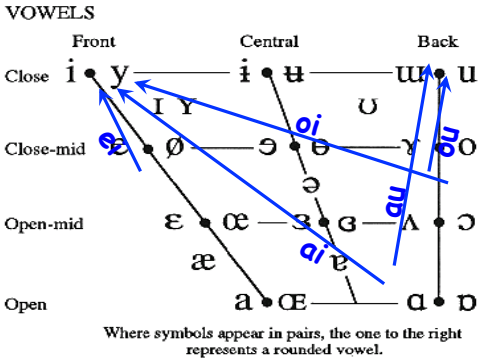
http://www.phonetics.ucla.edu/course/chapter1/vowels.html

## Vowel diphthongs

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## Consonant Production

- The particular configuration of the vocal tract and mouth will give rise to perturbations of the air coming out of the mouth and so determine the kind of consonant produced



## Consonant Production

- Look at the following clip
- http://www.phonetics.ucla.edu/course/chapter1/linkschapter1.htm

## Parameters used to distinguish sounds

- Direction of airflow
  - egressive (or espiratory) or ingressive (o inspiratory)
- Production of initial energy
  - lungs, larynx, tongue
- Position of glottis
  - sonority, breathing, murmor, etc.
- Position of the velum (lowered or raised)
  - determines oral or nasal sounds
- Manner and place of articulation
  - determines modifications of the air in the oral cavity

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## Voiced and voiceless sounds

Voiced:

The cartilages are close to one another. The air passing through causes the vocal folds to vibrate and create turbolence. Periodic opening and closing movement of the glottis

Voiceless:

the vocal folds are apart and the air passing through does not cause them to vibrate or produce turbolence.

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## Voicing

- Placing your fingers on the external part of your glottis you can feel the difference in vibrations of the vocal folds
  - Try saying:
    - [ffffvvvvffffvvvv]
    - [sssszzzzsssszzzz]

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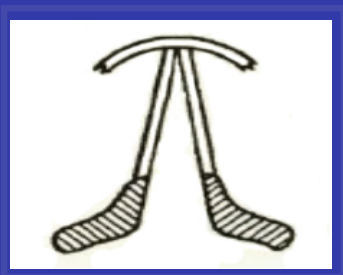
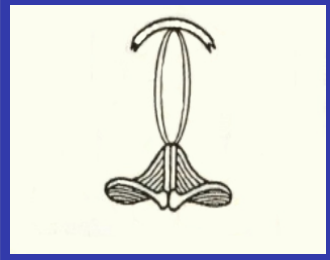
## Positions of the glottis





voiceless

Voiced

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## Position of the vocal folds during voiced and voiceless sounds

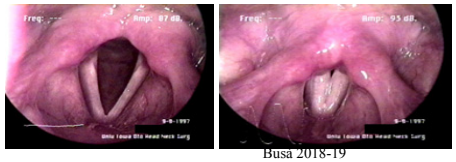
Voiced Voiceless

Source: http://www.let.uu.nl/~Rene.Kager/personal/TV1/Pho_2_10.htm

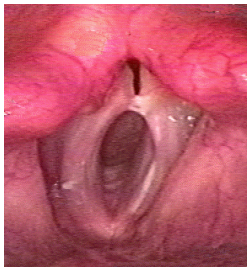


## Vocal folds

Open and closed clottis during the production of a voicelss and voiced sound



## Other configurations of the glottis



murmur

laryngalization

http://hctv.humnet.ucla.edu/departments/linguistics/VowelsandConsonants/vowels/chapter12/chapter12.html

## Position of the velum

- In sound production, the velum (uvula) can be lowered or raised
- If the velum is lowered, the passing air can go out through the nose and the mouth, giving rise to a **nasal sound**
- If the velum is raised and touches the back of the pharynx, the passing air can go out through the mouth only, giving rise to an **oral sound**

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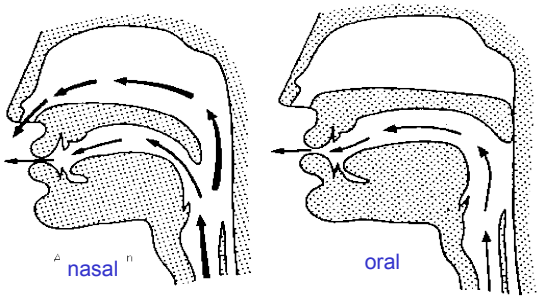
## Production of nasal and oral sounds






## Manner of articulation

- Consonants are also classified by the *manner* in which they are articulated for their production.
- The MANNER of an articulation specifies the DEGREE of STRICTURE (or constriction), i.e. the narrowing of the oral tract, which is required to produce a particular sound.

## Manner of articulation

- Depending on the degree of constriction of the oral tract, consonants can be divided into :
  - Stops
  - Affricates
  - Fricatives
  - Approximants



## Oral Stop Consonants

- Production of oral stops:

  - the active and passive articulators are narrowed to form a complete closure of the oral tract;
  - the air behind the closure is withheld, with an increase in the air pressure;
  - the air is released rapidly, causing an explosion or puff of air.

## Release phase in oral stop production

- The air release can be:
  - with explosion: takes place when the release of the articulators is abrupt. Ex. [p, t, k] in ital.
  - unexploded: the release is not abrup. Typical English word final stops: ex. [kip']
  - with aspiration: the release is accompanied by a puff of air. Typical of English stops [pʰɛn]
  - delayed: the release takes place slowly, and the explosion ends in friction. These sounds are also classified as *affricates* [pf, ts, ks, ecc.]



## Nasal Stop Consonants

- Nasal stops are produced with :
  - the active articulator approaches the place of articulation causes a complete closure of the oral tracta;
  - the velum is lowered and so the air can go out freely from the nose; this prevents the pressure build-up that characterises oral stops → the air release does not cause the explosion that characterises oral stops
  - examples: [m, n]

## Consonant classification by degree of stricture of the articulators

| Stricture | Definition | Class |
|---|---|---|
| Complete Closure | Active & passive articulators touching: no air can escape through the oral tract | Stops |
| Close Approximation | Articulators close enough to produce audible friction in the airstream, but air can escape orally | Fricatives |
| Open Approximation | Articulators not close enough to produce audible friction | Approximants |

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## Fricative Consonants

- Fricative sounds are produced when the articulators are brought so closely together that the air passing through the mouth produces audible friction
- The velum is raised to prevent air from escaping through the nose, which would lower the pressure build-up and reduce the frication noise
- Ex. [f, v, s, z]

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## Approximants

- are produced by narrowing but not blocking the vocal tract, as by placing an articulator, such as the tongue, near another part of the vocal tract. This produces an audible turbolence, but no frication.
- All approximants are voiced
- Since they are produced with a relatively open vocal tract, they resemble vowels and, in their production, the articulatory organs anticipate the position of the following vowel



## Degree and mode of approximation

- Trills
  - The air goes through the active and passive articulator intermittently. The active articulator vibrates against the passive articulator [r]
- Flaps and taps
  - The active articulator hits the passive articulator only one time (Ex. American pronunciation of the word 'city')

## Degree and manner of approximation

- **Partiale Closure**
  - There may be a contact in the central area of the vocal tract, but the air can go out freely from the sides
  - Ex. [l]
- **Open Approximation**
  - The articulators are close but there is enough space for the air to go out with no turbolence.
  - Ex. Semivowels [j, w] in ieri, uovo

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## Place of articulation

- Consonants are also classified by the *place* in which the constriction for their production occurs.
- The PLACE of articulation is defined as the *place* in which the *active* (or mobile) articulator, which is raised to form the stricture, touches/ approaches the *passive* (or fix) articulator.

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## Places of articulation

**Bilabial** : The point of maximum constriction is made by the coming together of the two lips.

**Labiodental** The lower lip articulates with the upper teeth.

**Dental** The tip of the tongue articulates with the back or bottom of the top teeth.

**Alveolar** The tip or the blade of the tongue articulates with the forward part of the alveolar ridge. A sound made with the tip of the tongue here is an apico-alveolar sound; one made with the blade, a lamino-alveolar.


http://www.phon.ox.ac.uk/jcoleman/PLACE.htm

## Places of articulation

**Postalveolar** The tip or the blade of the tongue articulates with the *back* area of the alveolar ridge.

**Palatal** The front of the tongue articulates with the domed part of the hard palate.

**Velar** The back of the tongue articulates with the soft palate.

**Uvular** The back of the tongue articulates with the very back of the soft palate, including the uvula.


http://www.phon.ox.ac.uk/jcoleman/PLACE.htm

## Places of articulation

**Pharyngeal** The pharynx is constricted by the faucal pillars moving together (lateral compression) and, possibly, by the larynx being raised. "It is largely a sphincteric semi-closure of the oro-pharynx, and it can be learned by tickling the back of the throat, provoking retching" (Catford 1978:163).

**Glottal** The vocal folds are brought together; in some cases, the function of the vocal folds can be part of articulation as well as phonation, as in the case of [?] and [h] in many languages.

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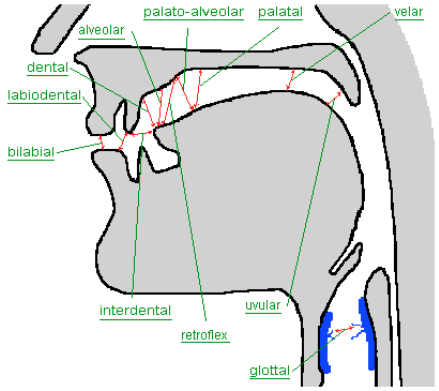
http://www.phon.ox.ac.uk/jcoleman/PLACE.htm

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www.vocal.com

## An interactive model

http://smu-facweb.smu.ca/~s0949176/sammy/



## Question…

- For a second language speaker is it easier to learn to produce correctly the L2 vowels or consonants?

## Answer…

- Consonants are easier to learn to produce correctly than vowels
  - In the production of vowels, there is very little contact between the articulators:
  - There are no real instructions that can be taught (or learned) to produce vowels correctly
  - Training your ears to hear the differences is often the only way to learn how to produce vowels