- **Nasals (nasal stops)**
- **Approximants**

Background reading:

- *V&C Ch 6, sec 6.4, "Nasals"*
- *AAP Ch 9, sec 9.1 "Bandwidth"; 9.2, "Nasal stops"*
- *V&C Ch 6, sec 6.3, "Approximants"*
- *AAP Ch 9, sec 9.3, "Laterals"*
- *Review AAP Ch 6, pp 140-141 on the filter for [ɹ]*

0. Today's objectives

After today's class, you should be able to:

- Explain the **articulation** of **nasal stops** & **laterals**
- Describe the source and filter of a **uvular nasal** [ɴ], and use the s/f model to **predict** its acoustics
- Understand the role of a **side tube** in the s/f model
    - Predict the acoustics of **other nasals**
    - Predict the acoustics of an **alveolar lateral** [l]
- *Prep for next time:* Use perturbation theory to predict acoustics of **central approximants** [ɹ j w]

0. For more experience with nasals, liquids

- Try looking at sound files in Praat
  - The *V&C* IPA chart with audio examples
  - The consonants of English (*V&C*)
  - Nasals in Malayalam (*V&C*) — many places of articulation
  - Synthetic speech demos of [ɹ] (F3), and of nasals and [l] (according to *AAP*) (Elliott Moreton, UNC-CH)

1. Nasal stops: Articulation and typology

- What **nasal stop** phonemes (contrastive sound categories) do we have in English?
  - What **places of articulation** are represented?

1. Nasal stops: Articulation and typology

- What **nasal stop** phonemes (contrastive sound categories) do we have in English?

labial	alveolar	velar
m	n	ŋ

- Nasal stops found in other languages include:

retroflex	palatal	uvular
ɳ	ɲ	ɴ

- The palatal nasal has a tail like a “j”, the palatal glide
- All retroflex consonant symbols have a right hook

1. Nasal stops: Articulation and typology

- How common are nasals in the languages of the world?
  - WALS map: Languages that lack nasals (in red)
  - WALS map: Languages that have (dark and light blue) vs. lack (white) a *velar* nasal

1. Nasal stops: Articulation and typology

- What are the **articulatory characteristics** of a (voiced) nasal stop?
  - **voiced**:
  - **nasal**:
  - **stop**:

- How can we model this **acoustically**?
  - What is the **sound source**?
  - What is the **filter**?

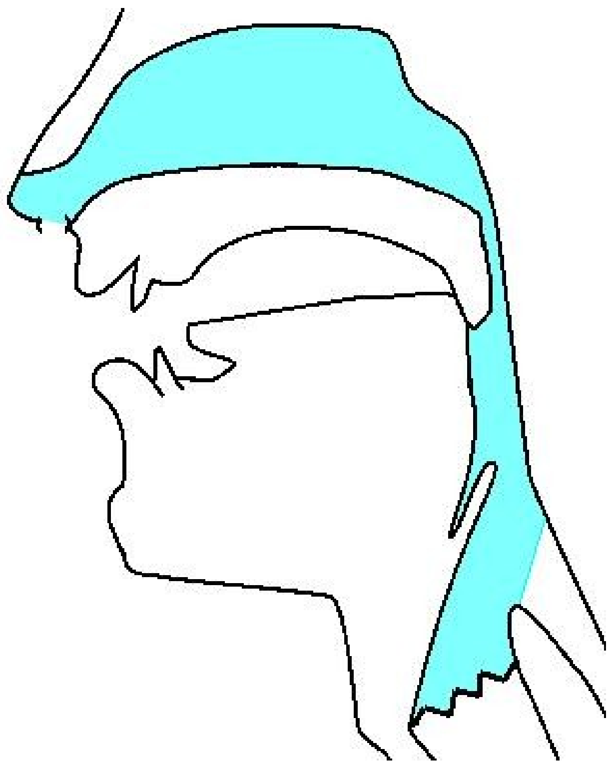
1. Nasal stops: Articulation and typology

- What are the **articulatory characteristics** of a (voiced) nasal stop?
  - **voiced**: vocal-fold **vibration**
  - **nasal**: velar port is open; **nasal airflow**
  - **stop**: oral tract has a **complete constriction**

- How can we model this **acoustically**?
  - What is the **sound source**? | voicing — the glottal-source wave
  - What is the **filter**? | we'll look at this now

2. The vocal-tract filter for nasal stops

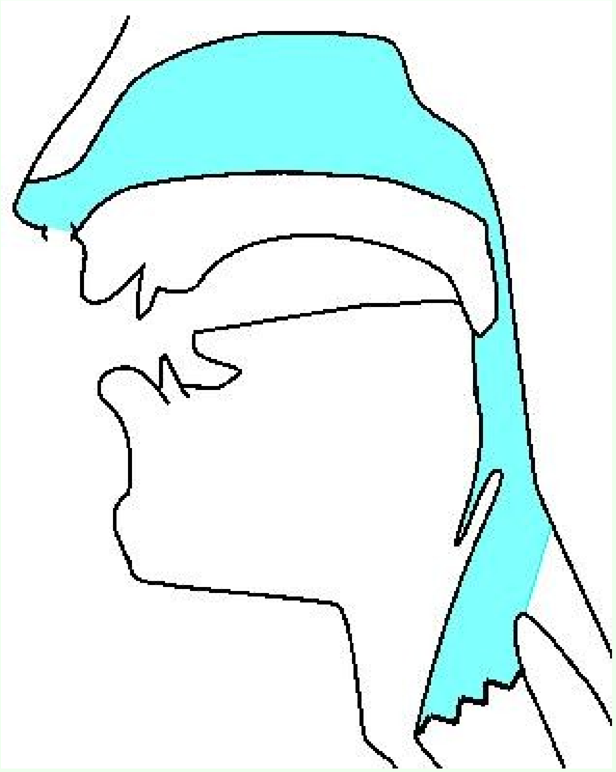
- Consider a **uvular nasal** [ɴ]
  (images adapted from Daniel Currie Hall's Interactive Sagittal Section)



- The oral tract is blocked off by the constriction at the uvula
- The pharynx and the nasal cavity essentially form a single tube
- While this is not strictly speaking a uniform tube, we can treat it as *approximately* uniform in order to model its formants

2. The vocal-tract filter for nasal stops

- How do we predict that the **formant frequencies** of a uvular nasal should differ from those of schwa?



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  - The tube is longer in [ɴ] than in schwa
  - The nose has what *AAP* calls “permanent ‘lip’ rounding” (the nostrils are narrow)

- What **effect** should these factors have on formant frequencies?

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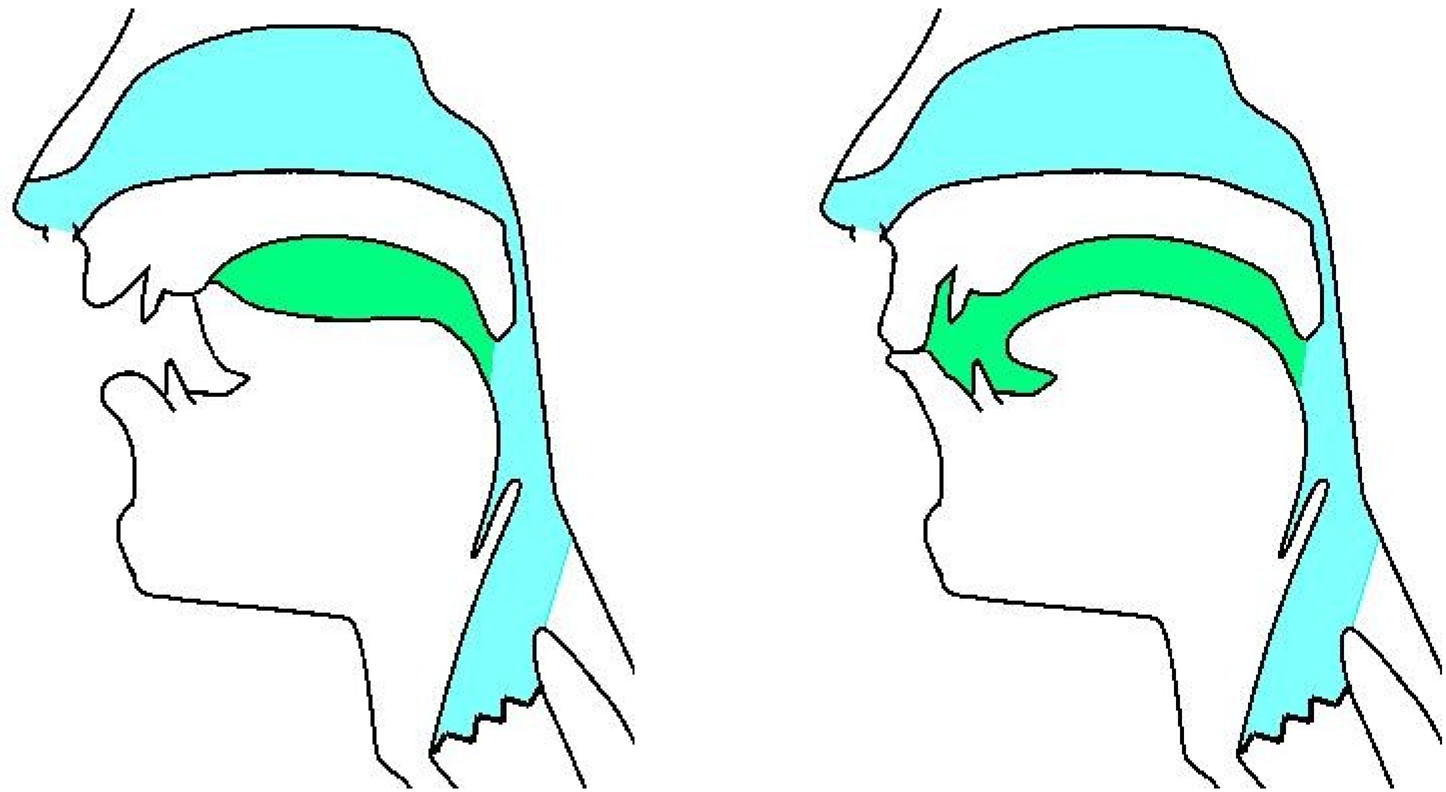
  - The tube is longer in [ɴ] than in schwa
  - The nose has what AAP calls “permanent 'lip' rounding” (the nostrils are narrow)
- What **effect** should these factors have on formant frequencies?
  - [ɴ] formants should be lower (closer together) than those of schwa
  - Note: still evenly-ish spaced (“uniform” tube)

3. Side tubes in the source/filter model

- What nasals are pictured here, and how does their filter differ from that of a uvular nasal?



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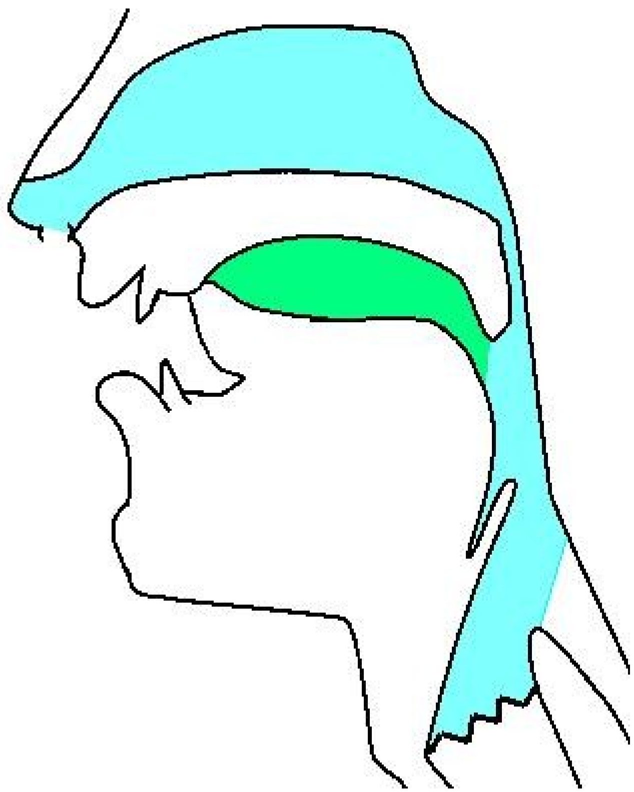
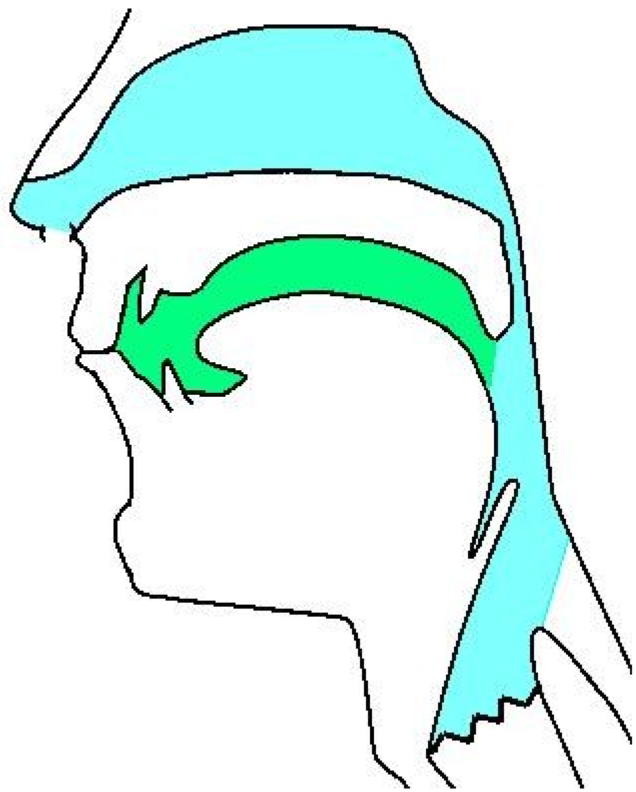


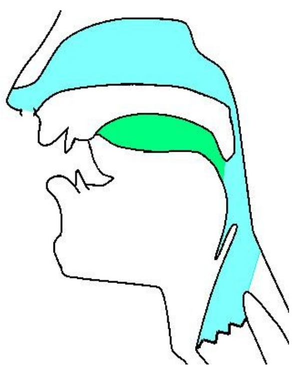
alveolar: [n]



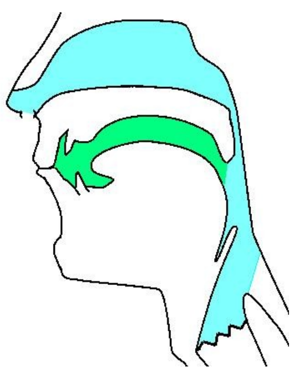
bilabial: [m]

3. Side tubes in the source/filter model

- Nasals other than uvular [ɴ] have **side tubes**
  - **Main tube** is glottis to nares (as in [ɴ])
  - **Side tube** extends from uvula (where the tubes split) to the place of articulation



[n] side tube: uvula → alveolar ridge



[m] side tube: uvula → lips

3. Side tubes in the source/filter model

- The main tube has **formants** (the **same** as for [ɴ])
- The side tube creates **antiformants**
  - Antiformants are regions of very **low** amplitude in the spectrum — sound energy is “missing”
  - These occur at the **resonance frequencies** of the **side tubes**
  - Essentially, sound energy at these frequencies is resonating in the side tube and is not heard from outside the vocal tract
  - In practice, antiformants can be **hard to see** on a spectrogram, especially if there is background noise

4. Modeling nasal acoustics

- **For discussion next time:** Try modeling some nasal filters, assuming these vocal-tract distances

Measurements from an X-ray study by Fant (1960), as reported in *AAP* (Johnson 2012)

  - Glottis to uvula - 9cm
  - Uvula to nares (nostrils) - 12.5cm
  - Uvula to lips - 8cm
  - Uvula to alveolar ridge - 5.5cm

- What is the **main tube** for [m]? For [n]? What are the **side tubes**? What **formants** and **antiformants** are predicted?

5. Other acoustic characteristics of nasal stops

- Nasals typically have **lower amplitude** than vowels
  - Nostril openings are smaller than mouth → less energy gets out
  - Some sound energy is absorbed by the soft tissues in the nasal tract
    - This factor also contributes to the fact that nasal formants (especially F1) have a **wider bandwith** than vowel formants — the spectral peaks span a wider interval on the frequency range

5. Other acoustic characteristics of nasal stops

- Nasals, being stops, have _________________________ just like those of the corresponding oral stops

5. Other acoustic characteristics of nasal stops

- Nasals, being stops, have **formant transitions** just like those of the corresponding oral stops (why?)
  - Both antiformants and formant transitions provide information about the **place of articulation** of a nasal
  - Antiformants are actually less perceptually robust than formant transitions — they can be obscured by background noise, for example
    - Given conflicting cues from antiformants and formant transitions (in an experiment), listeners pay more attention to the formant transitions

6. Approximant basics

- What is the (articulatory) definition of an **approximant**? (from *V&C*)

- Sub-types of approximants:
  - **Laterals** (“l”-type sounds; lateral airflow)
  - **Rhotics** (“r”-type sounds)
    - [ɹ] — as in American English
    - Flaps, taps, trills — we may discuss these later
  - **Glides**, also called **semi-vowels**

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  Consonant with unrestricted airflow

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  - **Glides**, also called **semi-vowels**

6. Approximant basics

- Different ways of classifying approximant sub-types
  - **Articulatory** classes — as seen on IPA chart
    - **lateral approximants** (laterals)
    - **central approximants** (rhotics, glides)
  - **Phonological** classes — based on cognitively relevant sound patterning
    - **liquids** (laterals, rhotics)
    - **glides**

7. Laterals: Acoustics of [l]

- A **lateral** consonant is one where:

- Some examples:

7. Laterals: Acoustics of [l]

- A **lateral** consonant is one where:
  oral airflow is blocked in center but not sides

- Some examples:
  - English [l] — where is airflow blocked?
  - The voiceless alveolar lateral fricative [ɬ]
  - The Spanish palatal lateral [ʎ]
    (found in some Sp. varieties)

- WALS map: Lateral consonants

7. Laterals: Acoustics of [l]

- The only lateral consonant that Johnson models in *AAP* is alveolar (~dental) **[l]**, so this is the only one we will try to model explicitly

- Source-filter model of [l] — we need to consider:
  - What is the **source**?
  - What is the **filter**?

7. Laterals: Acoustics of [l]

- The only lateral consonant that Johnson models in *AAP* is alveolar (~dental) **[l]**, so this is the only one we will try to model explicitly

- Source-filter model of [l] — we need to consider:
  - What is the **source**? | voicing / glottal wave
  - What is the **filter**? | main tube + side tube
    - This model of the filter for [l] is drastically simplified (although it sounds fairly convincing — see demo)
    - *AAP* is an introductory text; Johnson is trying to show how far we can go with a few simple models

7. Laterals: Acoustics of [l]

- What is the **main tube** in [l]?
    - Glottis to lips (oral vocal tract)
- What is the **side tube** in [l]?
    - The pocket of air over the tongue, from the uvula to the place of articulation (alveolar ridge)
    - This side tube takes away space from the main tube → main tube is narrower at this end
- How do the **formant frequencies** of (this simplified version of) [l] compare to those of schwa?

7. Laterals: Acoustics of [l]

- How do the **formant frequencies** of (this simplified version of) [l] compare to those of schwa?
  - Length of main tube?
  - But: Main tube is narrower at front (because of side tube) — effect on **F1**?

  - Observationally, **F3 tends to be high** in [l] (possibly due to an interaction with the first antiformant)
    - *AAP* does not model this directly

7. Laterals: Acoustics of [l]

- How do the **formant frequencies** of (this simplified version of) [l] compare to those of schwa?
  - Length of main tube? | **same** as schwa
  - But: Main tube is narrower at front (because of side tube) — effect on F1? | **F1 low** in [l]

  - Observationally, **F3 tends to be high** in [l] (possibly due to an interaction with the first antiformant)
    - *AAP* does not model this directly

7. Laterals: Acoustics of [l]

- What determines the frequencies of the **antiformants** in [l]? → **Prep for next time**
  - Antiformants are resonance frequencies of the side tube
  - Side tube here is uvula → alveolar ridge

- Synthesized [l], based on Johnson's simplified model (by Elliott Moreton, UNC-CH) | look/listen in Praat
  - It’s not too bad, despite the simplification

~ Try the rest on your own ~

- The rest of the slides will be the basis for **discussion** next time
  - Try to do the discussion questions for practice!

8. The central ("retroflex"?) approximant [ɹ]

- Much like vowels, this sound is acoustically defined; its articulations can be quite variable
    - Some speakers have a true retroflex articulation, with the tongue tip turned up and approximating the postalveolar region
    - Other speakers are “tongue bunchers”, using the body of the tongue to articulate [ɹ]

- What is the primary **acoustic characteristic** of [ɹ] that distinguishes it from other approximants?
    - See *V&C* reading, and *AAP* Ch 6, pp 140-141

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- What is the primary **acoustic characteristic** of [ɹ] that distinguishes it from other approximants?
  - See *V&C* reading, and *AAP* Ch 6, pp 140-141
  - [ɹ] has a **very low F3**

8. The central ("retroflex"?) approximant [ɹ]

- A demonstration of the importance of the low F3
  - Synthesized speech: a continuum from schwa to [ɹ] in which only F3 is changing (by Elliott Moreton, UNC-CH) | look/listen in Praat

8. The central ("retroflex"?) approximant [ɹ]

- To consider: What kinds of articulations will lead to a **lowered F3**, according to perturbation theory?
  - FYI: A paper showing diagrams of productions of AmEng [ɹ] — “retroflex” vs. “bunched”
    (Zhou, Xinhui, et al. 2008. A magnetic resonance imaging-based articulatory and acoustic study of ‘retroflex’ and ‘bunched’ American English /r/. *JASA* 123(6): 4466-4481.)

9. Glides

- **Glides** are very, very similar to **vowels**
  - **Duration** and **position** (within the syllable) are the main differences
    - Glides are shorter than vowels
    - Vowels form the ‘nucleus’ of a syllable; glides do not

9. Glides

- Glides on a spectrogram: “very short vowels” (usually next to a “real” vowel)

- Where is the vocal-tract perturbed in glides?
  - [j] — **palatal** constriction
    - like a high front V
  - [w] — **labial** and **velar** constrictions
    - like a high back round V

- So what should formants look like in [w] and [j] compared to schwa? → **Be ready to discuss!**