- **Fricatives: Source(s) and filter**

Follow-up reading (review before Lab #07):

- *V&C* Ch 6, sec 6.5 (“Fricatives”)
- *AAP* Ch 1, sec 1.3.3 (“Aperiodic waves”)
- *AAP* Ch 7, sec 7.1 (“Turbulence”)
- *AAP* Ch 7, sec 7.2 (“Place of articulation…”)

0. Today's plan

- Fricatives: Overview and articulation
- Voiceless fricatives: Source
- Voiceless fricatives: Filter
- Voiced fricatives
- Some special fricatives

1. Fricatives: Overview and articulation

- What **fricative** phonemes (contrastive sound categories) do we have in English?
  - What **places of articulation** are represented?
  - What **other property** distinguishes classes of fricatives in English?

1. Fricatives: Overview and articulation

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

	labiodental	dental	alveolar	post-alveolar	glottal
voiceless	f	θ	s	ʃ	h
voiced	v	ð	z	ʒ	

1. Fricatives: Overview and articulation

- Are fricatives in general **common** or **uncommon** cross-linguistically?
  - WALS map:
    Languages with no fricatives (red symbols)

- Are languages likely to make use of both **voiced** and **voiceless** fricatives?
  - WALS map:
    Languages with a contrast between voiceless and voiced fricatives (blue symbols)

2. Voiceless fricatives: Source

- What is the **source** of the sound energy in a voiceless fricative?
  - **Turbulent airflow** at the location of the **fricative constriction** in the vocal tract

- Turbulent airflow involves random fluctuations in air pressure: this produces **aperiodic noise**
  - What are aperiodic waveforms and spectra like?
    - See the file "FricSource-Johnson2012Figure7_1.wav" on Sakai (*Resources* > *Sound files* > *Fricatives*)
    - See also *AAP* sec 1.3.3 on aperiodic waves

2. Voiceless fricatives: Source

- Some factors that contribute to **higher amplitude** in turbulent airflow
  - **Particle velocity** of the air molecules
  - **Narrowness** of the channel
  - Presence of an **obstacle** in the channel
    - This may be nearly parallel to airflow (“wall”)
    - Or nearly perpendicular to airflow → **loudest**

- Which **loud** fricatives have perpendicular obstacle turbulence? What term is typically used for these?

2. Voiceless fricatives: Source

- Some factors that contribute to **higher amplitude** in turbulent airflow
  - Higher **particle velocity** of the air molecules
  - **Narrowness** of the channel
  - Presence of an **obstacle** in the channel
- Which **loud** fricatives have perpendicular obstacle turbulence? What term is typically used for these?
  - Notable in alveolar or denti-alveolar [s], palato-alveolar [ʃ], alveolopalatal [ɕ], retroflex [ʂ]
  - Called **sibilants** or **stridents**

2. Voiceless fricatives: Source

- **No** vocal-fold vibration in the production of **voiceless** consonants (including fricatives)
  - They have only an **aperiodic** source
  - **By definition**, they have **no fundamental frequency**

- **Acoustic** consequences of this fact
  - **No glottal pulses** or "**voice bar**" are visible on a wide-band spectrogram
  - **No glottal harmonics** are visible on a narrow-band spectrogram (or spectrum)

3. Voiceless fricatives: Filter

- The aperiodic sound wave travels from the fricative **constriction** to the **end** of the vocal tract (the lips)
- We can model this as a **tube** that is **closed** at the fricative constriction (because the opening is so small) and **open** at the lips
  (See below on labial fricatives, where the constriction is *at* the lips)
  - Are we working with a half-wavelength or quarter-wavelength system here?
  - What does the length of this tube depend on?

3. Voiceless fricatives: Filter

- As usual, this filter will amplify any sound energy near its **resonance frequencies**

- Note that fricative resonance frequencies, strictly speaking, are **not formants** (except in [h] — why [h]?)

  → The term **formant** refers to a resonance frequency of the **whole** vocal-tract (oral-tract or nasal-tract) tube

3. Voiceless fricatives: Filter

- What will the spectrum of a voiceless fricative, combining the effects of the source and of the filter, look like?
  - What does the source look like?
  - What effect will the filter have?

3. Voiceless fricatives: Filter

- What will the spectrum of a voiceless fricative, combining the effects of the source and of the filter, look like?
  - What does the source look like?

    Aperiodic — like white noise (random spectrum)

    But amplitude decreases as frequency increases
  - What effect will the filter have?

    Boost amplitude of components near **resonance frequencies**
    - See the file "FricGliss.wav" on Sakai (*Resources* > *Sound files* > *Fricatives*)

3. Voiceless fricatives: Filter

- Typically it's the high-energy region of the spectrum corresponding to the **first resonance frequency** that helps us distinguish among most fricatives
  - Voiceless fricatives do not have f_0 (why not?)
  - But their aperiodic noise is **centered** (i.e., has the highest-amplitude components) around a particular frequency on the spectrum
- Reminder:
  - The tube resonance frequencies for fricatives are conceptually the same as vowel formants
  - But the term "formant" is generally reserved for resonance fequencies of the vocal tract as a whole

4. Voiced fricatives

- Voiced fricatives have **two** sound sources
  -
  -
- Should we expect a voiced fricative to have…
  - Glottal harmonics?
  - Random components?

4. Voiced fricatives

- Voiced fricatives have **two** sound sources
  - Turbulent airflow at the fricative constriction
  - Vocal-fold vibration
- Should we expect a voiced fricative to have…
  - Glottal harmonics? | yes!
  - Random components? | yes!
- On a wide-band spectrogram, you can see aperiodic noise *and* glottal pulses

4. Voiced fricatives

- Voiced fricatives are relatively **rare** (WALS map)
  - And even when they exist, they are often produced as approximants/glides (no turbulence)

- Voiced fricatives are **difficult to produce** — why?
  - **High volume velocity** is needed for high-amplitude turbulence
  - How is this affected by voicing?

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- Voiced fricatives are **difficult to produce** — why?
  - **High volume velocity** is needed for high-amplitude turbulence
  - How is this affected by voicing?
    - Vocal folds are closed about half the time
    - This restricts airflow → *lower* volume velocity

5. Some special fricatives

- In the **voiceless glottal fricative [h]**, the aperiodic sound source is at the glottis, so the whole oral tract is the filter — just like vowels
  - [h] often has visible vowel-like formants
  - One way of thinking about [h] is that it is similar to a voiceless vowel
    - In fact, [h] often takes on the same formants as a following vowel — the articulators anticipate the vocal-tract shape of the upcoming vowel

5. Some special fricatives

- In a **bilabial or labiodental fricative** — and even in an **interdental fricative** — there is essentially no filter, so there is generally no particular high-amplitude region in the spectrum
    - See the file "V&C_EngFric.wav" on Sakai, an excerpt from Table 6.1 in *V&C*
      (*Resources* > *Sound files* > *Fricatives*)