The respiratory system

- Respiratory cycles: airflow in and out of the chest
- Sound production and airflow
  - Pulmonic airstream mechanism: speech created by the pushing out of air from the lungs
  - Other airstream mechanisms … to be continued
- Exercise: try talking while breathing in, contrast with normal talking while breathing out

Respiratory system: chest (=thorax)

- Enclosure: the chest is enclosed in the rib cage at the sides and top, and the diaphragm on the bottom
- Lungs: made of tiny sacs of air, called alveoli, that empty out into the bronchial tube and the tracheae
- Tracheae (=windpipe): tube that connects the lungs to the vocal tract
- Larynx: set of muscle structures that act like a valve between the tracheae and the vocal tract.

Respiratory system: Sounds superimposed on our breath

- Source of air: respiratory cycles are caused by the expansion and retraction of the chest, lifting upwards and outwards of ribcage and lowering of diaphragm causes expansion
- Source of sounds: actions in the larynx, e.g., vocal fold vibration and also adjustment of muscle structures surrounding the larynx
- Sound filter: subtle differences in sounds caused by small changes in the throat and the mouth; these changes filter the sound source in a way that is detectable by listeners

The larynx: principal structures

- Vocal folds (=vocal ligaments): a pair of muscular flaps that can be controlled in different ways
- Arytenoids (or arytenoid cartilages): posterior structures that can be tilted back to produce tension on the vocal folds
- Glottis: the space between the vocal folds
The larynx, cont’ d

- Valve-like function of the larynx:
  - Tension can be applied to the vocal folds, with the result of sealing off the lungs or causing specific states in the glottis used in speech
  - Non-speech laryngeal action: in swallowing, larynx shuts automatically to prevent food and drink from entering the lungs
  - Exercise: hold your breath; you are using the larynx to seal off the air in the lungs

- The larynx in speech:
  - Actions in the larynx produce the sound sources in many speech sounds.
    - Exercise: produce [fffvvvvffffvvvv]; this illustrates the distinction between voiceless and voiced sounds; the voicing in the production of [vvvv] is caused by applying tension on the vocal folds in a way that causes them to vibrate as air passes through the glottis
  - The larynx is also used as an articulator, or an anatomical structure that comes together in speech production.
    - Exercise: the sound in the middle of the word uh-oh is called a glottal stop, a very important sound in many languages. It is caused by the opening and closing of the glottis.

The vocal tract

- Cavities in the vocal tract:
  - Oral tract: the mouth and the pharynx (AKA, the throat; area behind the back of the tongue and below the nasal tract)
  - Nasal tract: the cavity within the nose

- Sound-filtering effect of the vocal tract
  - The vocal tract acts like a tube through which air flows and sound waves propagate. Changing the structure of the tube through different articulations causes air to flow differently and sound waves to propagate differently, which makes possible different sound contrasts

- Articulators
  - Active articulators: anatomical structures that move to cause some kind of constriction
  - Passive articulators: immobile anatomical structures that are involved in a constriction
Exercise: consider the difference between words like row/wrong, rack/rang, till/tin

Observation: Many consonants involve airflow through the oral tract, but some allow air to flow out the nasal tract.

Oro-nasal process: the raising and lowering of the velum (=soft palate) to open or close the opening to the nasal tract.

Raised = closed ('velic closure') = oral sound
Lowered = open = nasal sound

Place of articulation

Constrictions: all consonants involve a constriction or obstruction somewhere in the vocal tract or glottis; describing constrictions involves pin-pointing articulators.

Primary articulations in consonant constrictions
- Labial: involving the lips
- Coronal: involving the tongue tip or blade
- Dorsal: involving the back of the tongue
- Glottal: involving the glottis

Further refinements: many subtypes within these primary articulations, e.g., alveolar /s/ sip vs. post-alveolar /ʃ/ ship; refinements used in most phonetic descriptions
Place of articulation, refinements

- **Bilabial**: two lips
- **Labiodental**: lower lip and upper front teeth
- **Dental**: tongue tip and upper front teeth
  - Note: some speakers differ between dental (tip right behind upper teeth) and interdental (tip protruding between the teeth)
- **Alveolar**: tongue tip or blade and alveolar ridge
  - Exercise: what is the difference in the last consonants in *tent* vs. *tenth*

- **Retroflex**: tongue tip and back of the alveolar ridge
  - Exercise: some English dialects have slightly trilled retroflex /r/’s in words like *rye, row, ray*; also Hindi has many retroflex sounds, and it is evident in Hindi-accented English; Mandarin has many retroflex sounds
- **Post-alveolar**: tongue blade and back of the alveolar ridge (also ‘palato-alveolar’)
- **Palatal**: front of tongue and hard palate
- **Velar**: back of tongue and hard palate
- **Glottal**: vocal folds

Place cont’d: mid-sagittal profiles

- Two dimensional drawings of a cross-section of the vocal tract are a great way to illustrate place, as well as other aspects of an articulation

Manner of articulation

- **Observation**: the degree and nature of the constriction can signal differences among consonants
- **Oral stop**: complete closure of the articulators in the mouth, with raised velum (=velic closure); characterized by a stop closure, followed by a release
- **Nasal stop**: complete closure of articulators, without velic closure; air flows out the nasal tract
  - N.b.: ‘stop’ technically refers to both oral and nasal stops, but in practice is often meant as an oral stop
Manner of articulation, cont’d

- **Fricative**: close constriction of two articulators so that the airstream is partially obstructed and a turbulent airflow is produced
  - N.b.: fricatives differ from stops in that they can be sustained (no complete closure)
- **Approximant**: a constriction of two articulators without the vocal tract being so narrow that it produces a turbulent airflow.
- **Lateral** (approximant): constriction along the center of the oral tract with an incomplete closure between one or both sides of the tongue and the roof of the mouth.

Additional phonetic vocabulary

- **Sibilant**: a fricative with a high-pitched hiss.
- **Tap/flap**: a single alveolar stop with a very short duration for the closure
- **Trill**: a sequence of taps in rapid succession, e.g., Spanish /r/ in *perro* ‘dog’, cf. *pero* ‘but’, Scottish dialects
- **Affricate**: stop with a release that constitutes a fricative
- **Liquids**: /r/ and /l/ sounds, a cover term for a set of sounds that often pattern together

Consonants: summary

- **Five principal factors in classifying consonants**
  - Place of articulation: bilabial, dental, alveolar, palato-alveolar, palatal, velar, glottal
  - Manner of articulation: oral stop, nasal stop, fricative, (affricate), approximant
  - States of glottis: voiced, voiceless, etc.
  - Velic closure: raised (=oral), lowered (=nasal)
  - Airstream: pulmonic (and other mechanisms, given later)
  - Also: Direction of airflow: central, lateral
- **Objective**: have a working toolbox for uniquely identifying speech sounds, and also seeing natural groupings (‘natural classes’) based on phonetic similarities

Exercise: mid-sagittal profiles

- **Task**: learn the phonetic factors for consonants by drawing their productions.
- **Sounds to draw**: /f b m ð r j w h ŋ t ñ p v s d n l ʒ k z ɴ dʒ/
Vowel articulations

Observation: vowels are different from consonants in that the articulators are not very close, and air flows in an unobstructed way. This is one of the limitations on articulatory phonetics for vowels (requires acoustics too).

Articulatory factors for vowels:
- **Tongue height**: high, mid (mid-high, mid-low), low
- **Tongue advancement**: front, central, back
- **Lip rounding**: rounded, unrounded
- **Also**: ‘tense’ vs. ‘lax’ vowels, cf. peripherality

Vowels: tongue height and advancement

<table>
<thead>
<tr>
<th>Front</th>
<th>Back</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. heed</td>
<td>7. food</td>
</tr>
<tr>
<td>2. hid</td>
<td>6. good</td>
</tr>
<tr>
<td>3. head</td>
<td></td>
</tr>
<tr>
<td>4. had</td>
<td>5. father</td>
</tr>
</tbody>
</table>

Vowels: rounding

Exercise: consider lip position with [i] in heed vs. [u] in who ’d. This differs in lip rounding, and the length of the cavity for the vowel sounds to resonate in the mouth.

Exercise: consider French high vowels
- /li/ ‘read (pres.sg) (front, unrounded vowel)
- /ly/ ‘read (past.participle) (front, rounded vowel)
- /lu/ ‘rent’ (back, rounded vowel)

Observation: lip rounding is independent of tongue advancement

Sound waves

- **Acoustics**: mathematics of sound waves rather than articulations involved in making sounds
- **Speech in acoustic terms**: sound waves are variations in air pressure caused by the sound source in the human vocal tract, e.g., larynx
- **Sound propagation**: sound waves propagate through the air, like ripples in a pond, and are heard by listeners
- **Properties of sounds based on how they are heard**:
  - **Pitch**: a high/low scale that relates to fundamental frequency (exemplified in tone and intonation)
  - **Loudness**: a high/low scale that relates to intensity
  - **Quality**: a multi-dimensional scale that relates to vowel formant structure
Air pressure waveforms

- **Waveform:**
  - Vertical: air pressure (amplitude)
  - Horizontal: time

- **Questions:**
  - Which sounds have regular cycles from vibrating vocal cords?
  - Which sounds have greater amplitude (~louder)?