1. The resonances of a tube closed at both ends are: $f_n = \frac{nc}{2L}$

2. The resonances of a tube closed at one end and open at the other are: $f_n = \frac{(2n-1)c}{4L}$

3. The natural resonant frequency of a Helmholtz resonator is: $f = \frac{c}{2\pi}\sqrt{\frac{A_n}{A_b l_b l_n}}$,

where *n* refers to the neck of the resonator and *b* refers to the body of the resonator.

4. The speed of sound in warm, moist air (c) is 35,000 cm/sec.

5. The velocity nodes and antinodes of the first four standing waves of the vocal tract are shown in the following figure:

1. Phonetic Transcription. Write the following sentences in normal English orthography.

wʌnts ðəˠ wz ə jʌŋ ræʔ hu ˈkʊdn̩ meɪk ʌp hɪz maɪn. wənˈɛvəˠ ðɪ ˈʌðəˠ ˈræts ʔæst ɪm ɪf hi wʊd laɪk tə kʌm aʊt wɪð əm hi wəd ˈantsəˠ aɪ də noʊ

2. Gestures. In the utterances transcribed above there are serveral instances of words that are not pronounced in their typical "dictionary" pronunciation. For example, "rat" is pronounced with a final glottal stop in place of [t]. Pick one such example, give the name of the phonological process, and describe the pattern of gestural interaction produced the variant found in the transcription.

3. IPA symbols. Circle the correct symbols.

a. Circle the uvular consonants: k ɦ χ ʁ ʔ ŋ ʟ

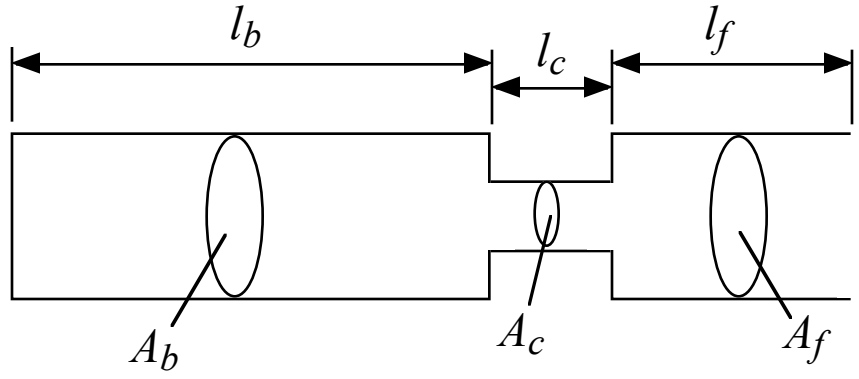
b. Circle the dental consonants: n ɹ t̪ θ ɽ ʒ ð

c. Circle the fricatives: ɤ ʂ c j ɟ ɸ v ɣ

d. Circle the central vowels: i u a ɐ ə ʌ ɨ

e. Circle the implosives: k’ ɡ ɠ t’ d ɗ p’ b ɓ

4. Vocal tract resonant frequencies. Assume that the vocal tract model below has the following dimensions: l_b = 10 cm, l_c = 2 cm, l_f = 4 cm, A_b= 3 cm^2, and A_c = 0.2 cm^2.



(a) What are the first three formants of this vocal tract? Show your work.

(b) What IPA symbol would you give to this vocal tract? Why?

(c) Show how to predict the F2 frequency of this vocal tract using pertubation theory. Compare the second formant frequency that you calculated in (a) with the second formant for this vocal tract that you would predict using perturbation theory.

5. Phonological analysis. The following words of Japanese illustrate some of the consonant and vowel sounds in the language.

[gomɯ]	'rubber'	[gamɯ]	'gum'
[gɯɴ]	'army'	[gʲeːmɯ]	'game'
[gɯntai]	'troops'	[gʲiɴ]	'silver'
[kʲʰiɴ]	'gold'	[gʲiɴkoː]	'bank'
[kʲʰi̥ta]	'north'	[kʲʰiːta]	'heard'
[kʲeɴ]	'prefecture'	[kʲenɾitsɯ]	'prefectural'
[kokʰɯɾitsɯ]	'national'	[kokʰɯ̥sai]	'international'
[koɴ]	'current ...'	[kondo]	'this time'
[koŋgʲetsɯ]	'this month'	[kombaɴ]	'tonight'
[kotsɯ]	'knack'	[koːtsɯː]	'traffic'
[koʃi]	'waist'	[kado]	'corner'
[kʲʰi̥sɯ]	'kiss'	[kaːdo]	'cards'
[kʰɯ̥sa]	'grass'	[kasa]	'umbrella'
[kʰɯma]	'bear'	[kama]	'rice kettle'
[koma]	'top (the toy)'	[kana]	'syllabic writing system'
[tama]	'ball'	[tomo]	'friend'
[teːma]	'theme'	[tsɯma]	'wife'
[tʃiːmɯ]	'team'	[tʃizɯ]	'map'
[tsɯgʲi]	'next'	[tʃiːzɯ]	'cheese'
[sɯgʲi]	'Japanese cedar'	[tsɯ̥kʲʰi]	'moon'
[sɯgokʰɯ]	'very'	[sɯːgakʰɯ]	'mathematics'
[sato]	'village'	[ʃi̥ta]	'tongue'
[sɯ̥poːtsɯ]	'sports'	[sɯ̥to]	'strike'
[sekʲʰi]	'seat'	[seːkʲʰi]	'century'
[dame]	'useless'	[damɯ]	'dam'
[daɾe]	'who'	[doɾo]	'dirt'
[demo]	'demonstration'	[doːɾo]	'road, street'
[dzɯɾe]	'gap, lag'	[dʒiɾeɾɯ]	'fret, fuss'

Examine the words carefully, and then answer the following questions. If you are positing that two or more sounds or sound classes contrast, justify your analysis by citing word pairs or larger

sets of words that support your analysis. If you are positing that they do not contrast, state the distributions of the sounds (the conditioning environment) in a phonological rule.

a. Is vowel length contrastive?

b. Is vowel voicing contrastive?

c. Does labial [m] contrast with dental [n]?

d. Does velar [ŋ] contrast with uvular [ɴ]?

e. Do the palatalized velarized stops [kʲʰ], [kʲ] and [gʲ] contrast with the plain velar stops [kʰ], [k] and [g]?

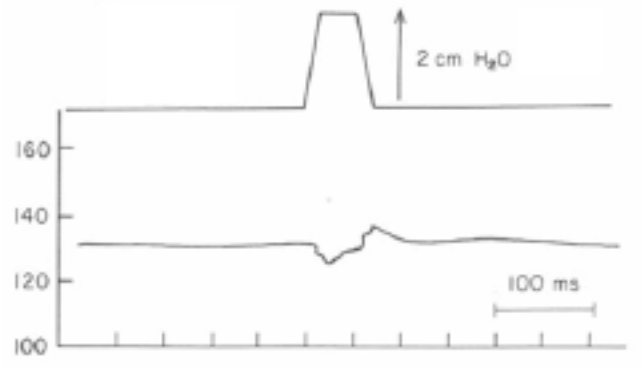
f. Does [ʃ] contrast with [s]?

g. Do aspirated [kʲʰ] and [kʰ] contrast with their unaspirated counterparts [kʲ] and [k]?

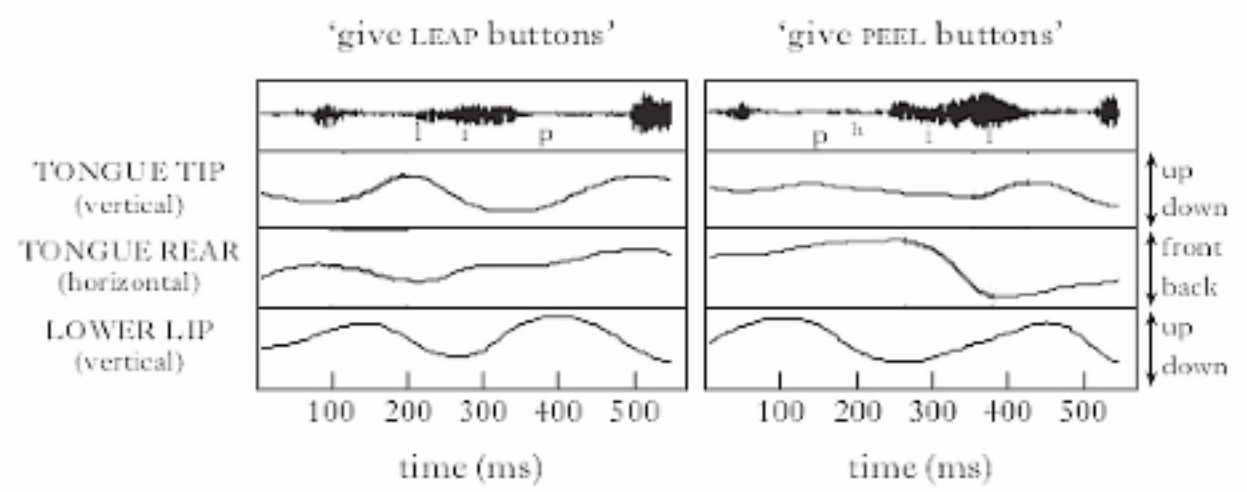
h. Do the voiceless affricates [tʃ] and [ts] contrast with [t]?

i. Do the voiced affricates [dʒ] and [dz] contrast with [d]?

6. Aerodynamics. The traces below show the voice fundamental frequency during sustained vowel productions [ɑɑɑɑɑɑɑ:]. The step function shows a 2 cm H^2O pressure change that was introduced into a mask that the speaker was talking into. That is, during the vowel the intra-oral pressure was suddenly increased by 2 cm H^2O and then decreased back to normal. What happened to the vocal fold vibration as a result of the pressure change and why did it happen?



7. Articulation. The graphs below (from Gick 1999) show acoustic signals of the words "*leap*" and "*peel*" uttered in the phrase "*give* ____ *buttons*." In addition, three movement trajectories show up-down or front-back motions of the tongue tip, tongue dorsum, and lower lip during these utterances.

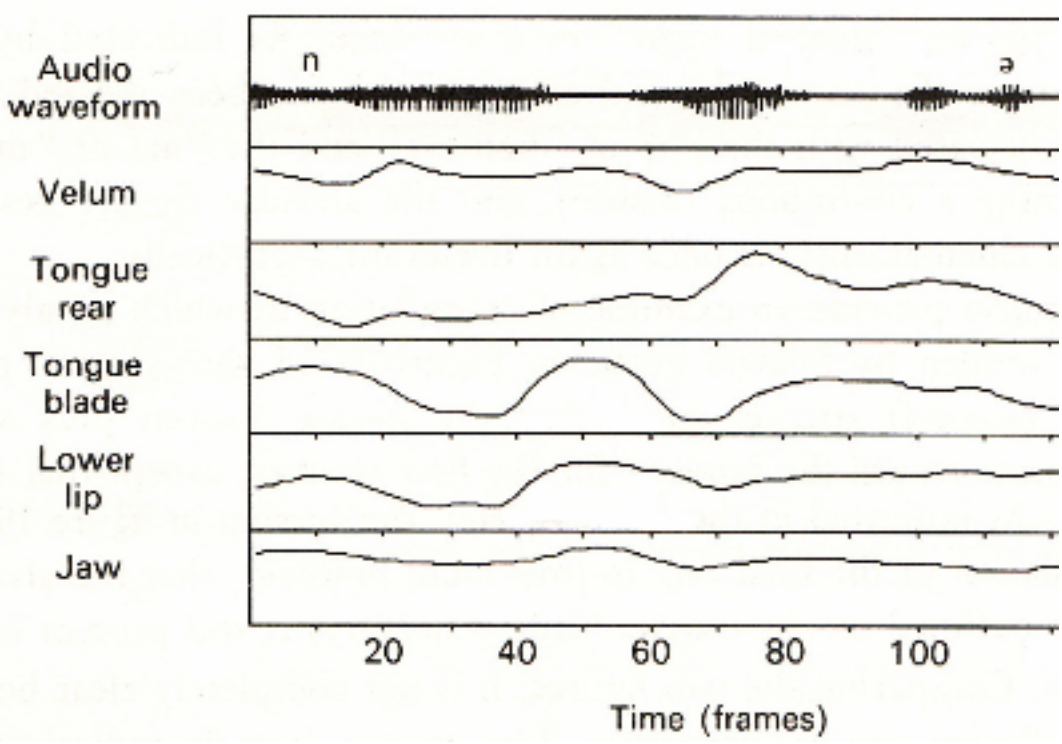


(a) Look at the lower lip movement during the word "peel". After the [p] closure is released, when does the lower lip begin to raise again? Provide two possible reasons why the lower lip raises here:

(b) For onset /l/ in "leap" and the coda /l/ in "peel," the tongue tip goes up and the tongue rear goes back. What is different about the relative timing of these gestures in the onset and coda articulations?

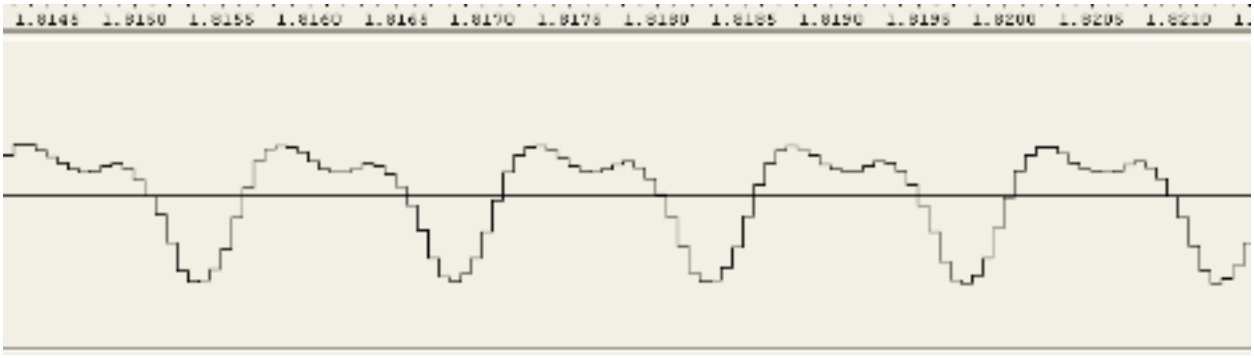
(c) One of these two /l/'s is velarized more than the other. Which one is it and which movement trace indicates velarization?

8. Articulation. The graph below (from Browman & Goldstein 1990) shows an acoustic waveform of the phrase "*nabbed most of the*," and shows corresponding kinematic signals obtained using X-ray microbeam. All of the traces in this graph are of the vertical movement of the articulator.



(a) Paying careful attention to waveform and the vertical movements of the tongue blade and lower lip, provide a phonetic transcription of what you would expect to hear if you listened to this utterance:

9. Speculative acoustics. Archeologists uncover an ancient burial of a pre homo sapien hominid, *homo johnnydamonensis*. The hominid is buried with a clay pot that has a waveform-like image etched into it, complete with a time axis. It makes for a lovely design, claim the archeaologists, but you, a bright young linguist on the team, recognize what you are seeing: the earliest audio recording.



(a) What is the fundamental frequency in the clay pot waveform?

(b) *Homo johnnydamonensis's* body was dismembered in the burial; the cultural anthropologist on the team assures us this is traditional in many cultures. The oral cavity and the trachea have been separated; they are 4 cm and 2 cm, respectively. Put *homo johnnydamonensis* back together and provide the first and second formant frequencies of its vocal tract.

(c) Given the length of the fosil vocal tract and the fundamental frequency of the clay pot wave form, is it plausible to suppose that the waveform of speech produced by *homo johnnydamonensis*?

(d) A physical anthropologist on the research team discovers that *homo johnnydamonensis* had muscles around its nostrils much like our obicularis oris. How might having a voluntarily controllable muscle in this region of the vocal tract affect the inventory of sounds in the hominid's language?