REVIEW QUESTIONS

1. What are the three main cavities of the vocal tract? Which of these play a role in the production of speech?
2. Describe the way in which the vocal folds vibrate.
3. Describe the role of the vocal folds in producing an "h" sound.
4. The spectrum envelope of speech sound can be thought of as the product of what three components?
5. Describe the spectrum of the glottal source function.
6. Give examples of the following types of consonants: fricative, nasal, liquid, semivowel.
7. Give examples of voiced and unvoiced consonants.
8. Sketch simple two-tube models of the vocal tract configuration for the vowels /ɑ/ and /ɪ/.
9. What voiced and unvoiced consonants are formed with the lips?
10. What voiced and unvoiced consonants are formed with the soft palate?
11. Describe the role of the vocal tract in whistling.
12. What are prosodic features of speech? Give two examples.
13. What are typical vocal fold vibration frequencies in male and female speakers?
14. How is it possible to observe the motion of the vocal folds?
15. How is it possible to observe the shape of the vocal tract for different vowel sounds?
16. How does the glottal waveform change when one speaks louder?

QUESTIONS FOR THOUGHT AND DISCUSSION

1. Discuss the function of each of the principal parts of the vocal tract.
2. If a person partially fills his or her lungs with helium and then speaks, the speech sounds distorted (it is sometimes described as sounding like Donald Duck). Explain this on the basis of formants (the information in Table 3.1 may be helpful). (This type of distortion will be discussed in Chapter 16.)
3. Discuss the acoustics of
   - **(a)** a "hoarse" throat;
   - **(b)** a stuffed nose;
   - **(c)** swollen tonsils.
4. Although the vibrations of the vocal folds are similar to the vibrations of a trumpeter's lips, the control of frequency by the air column through feedback is all but missing in the case of the vocal folds. Can you explain why? (Consider the mass of the vibrating members, the sharpness of the air resonances, and damping in each case.)

EXERCISES

1. Calculate the first three resonances of a tube 11 cm long (the approximate length of a child's vocal tract) open at one end and closed at the other. Compare these to the formant frequencies for /ϵ/ given in Table 15.3.
2. Make a graph of the second formant frequency (vertical axis) versus the first formant frequency (horizontal axis) for the ten vowel sounds given in Table 15.3. Do this for either the average male or female voice. Select a scale for each axis that is appropriate for the data you intend to graph.
3. Take a simple sentence (e.g., "You always give the right answers") and attempt to give it several meanings by changing prosodic features. For each different way of speaking the sentence, indicate the pattern of pitch and loudness used.
4. Express in newtons/meter^2 the maximum and minimum lung pressures used in speech (4 cm and 20 cm of water). Atmospheric pressure (10^5 N/m^2) corresponds to a manometer pressure of about 34 ft of water.
5. Calculate the frequencies of resonance for a tube 16 cm long closed at one end and open at the other, and show that they correspond to F_{10}, F_{20}, F_{30}, in Fig. 15.15.
6. Determine whether there is a "scaling factor" relating male and female vowel formants by the following calculations. Determine the ratios of the female-to-male for-

mant frequencies for the vowels given in Table 15.3. Find the average ratio. Could recording male speech and playing it back 16% faster make it resemble female speech?

7. Suppose a vocal tract 17 cm long were filled with helium ($v = 970$ m/s). What formant frequencies would occur in a neutral tract?

8. Estimate relative male and female vocal tract lengths by:

- **(a)** Averaging the ratios of a male and female formant frequencies for several vowels;
- **(b)** Assuming they have about the same ratio as male and female heights.

9. The resonance frequency of a Helmholz resonator (Section 2.3) is

$$f = \frac{v}{2\pi}\sqrt{\frac{A}{lV}},$$

where v is the velocity of sound, A and l are the cross-sectional area and length of the neck, and V is the volume of the resonator. For the model in Fig. 15.14, assume a neck area of 0.6 cm^2, a length of 3 cm, a volume V of 20 cm^3, and a sound velocity of 344 m/s, and calculate the resonance frequency. Compare this to F_{10}, calculated in Problem 5.

EXPERIMENTS FOR HOME, LABORATORY, AND CLASSROOM DEMONSTRATION

Home and Classroom Demonstration

1. *Formant tube* The experiment illustrated in Fig. 15.10 can be expanded to simulate other vocal tract resonances, as shown in Fig. 15.19. A pure tone is varied over the frequency range of 200–4000 Hz, and the resonances of the tube are observed. Listening to a sawtooth waveform with a fundamental frequency of 100–150 Hz should suggest vowellike sounds as the constriction is moved (b) or tubes of different diameters and lengths are joined together (c).

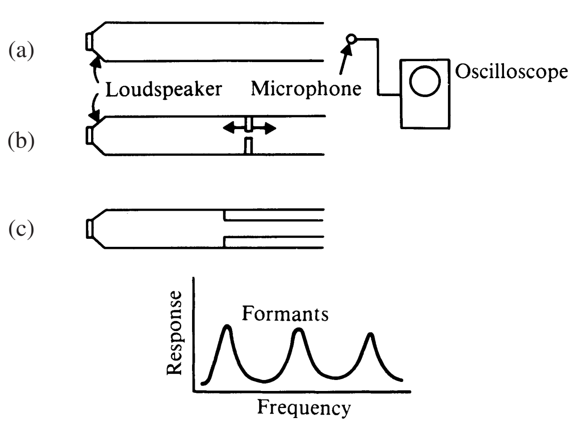

FIGURE 15.19 Formant tube, which can be used to demonstrate resonances of the vocal tract.

2. *Movable constriction* The effect of constricting the air flow at different places in the vocal tract can be simulated by inserting a small nozzle into a short length of pipe, as shown in Fig. 15.20. As the constriction moves up and down the pipe, the sound changes in character, growing louder when the source reaches the position of a pressure maximum for one of the pipe resonances.

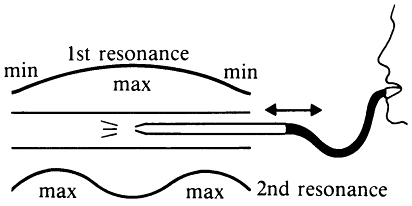

FIGURE 15.20 Demonstration to show the effect of moving a constriction up and down the vocal tract.

3. *Whispered vowels* During a whisper, the vocal folds produce broadband (“white”) noise, which contains a wide range of frequencies and virtually no sensation of pitch. Whispering vowel sounds, however, shapes the vocal tract so that bands of noise near the formant frequencies are emphasized. A rather faint sense of pitch develops, which usually corresponds to the second formant frequency (Thomas 1969).