12. Doubling the subglottal pressure produces about how much change in the sound level?
13. What is the approximate range of air flow during singing?
14. Describe the vocal folds when singing in *chest* voice.
15. What is vocal fry? For what type of singing is it employed?
16. How does glottal closure rate change as the phonation level increases?
17. What are two differences in the male singing voice in solo and choir singing?
18. What are two differences in the female singing voice in solo and choir singing?
19. What is *belting*?
20. Describe the technique used by a Tibetan monk to sing what sounds like a chord.

QUESTIONS FOR THOUGHT AND DISCUSSION

1. Try to sing as many notes as possible in both chest and head registers. Can you sing in both registers? How much overlap is there in your voice?
2. Is a stress of 10^6 N/m^2 (See Fig. 17.15) a large stress? What is the breaking stress of a piece of cotton cord? nylon thread?
3. Normal speaking is done in chest voice. Is it possible to speak in a head voice? Is speech intelligibility affected?
4. Place either a cardboard tube, a length of pipe, or your cupped hands around your lips to extend the vocal tract and lower the formant frequencies. Describe the tone produced. What is often called a dark, or covered, tone is produced by extending the vocal tract at the lower end. Is this equivalent to what you have done?

EXERCISES

1. Find the frequencies that correspond to the three singing registers designated in Fig. 17.14.
2. What harmonics of G_2 ($f = 98$ Hz) are enhanced by the formants of /i/? of /u/?
3. Compare the first three formant frequencies in Fig. 17.4 to those in Table 17.1 for the sung vowels /u/, /ɑ/, and /i/.
4. Find the lengths of closed pipes that would resonate at 2500 and at 3000 Hz. Are these reasonable lengths for the cavity formed by the (closed) glottis and the (open) pharynx?
5. The power (in watts) used to move air in or out of the lungs is equal to the pressure (in N/m^2) multiplied by the flow rate (in m^3/s). Find the power for:
   - **(a)** Quiet breathing ($p = 100$ N/m^2, flow rate $=$ 100 cm^3/s);
   - **(b)** Soft singing ($p = 1000$ N/m^2, flow rate $=$ 100 cm^3/s);
   - **(c)** Loud singing ($p = 4000$ N/m^2, flow rate $=$ 400 cm^3/s).
6. According to Fig. 17.13, a pressure of 4000 N/m^2 will produce a sound level of about 120 dB.
   - **(a)** Find the intensity and sound pressure that correspond to this sound level (see Chapter 6).
   - **(b)** Compare the sound pressure at the mouth to the steady subglottal air pressure.
   - **(c)** Assuming a mouth opening of 20 cm^2, calculate the total radiated sound power.
   - **(d)** What portion of the total power calculated in Exercise 5 is converted into sound? (*Answer:* About 0.1%.)

EXPERIMENTS FOR HOME, LABORATORY, AND CLASSROOM DEMONSTRATION

Home and Classroom Demonstration

1. *Waveforms of vowel sounds* By connecting a microphone to an oscilloscope, display the waveforms for different vowel sounds. A male voice singing "oo" in falsetto at E_4 (near the first formant frequency) produces nearly a sine wave with few overtones, for example. Singing "ee" at the same frequency adds small wiggles due to the upper harmonics (mainly the sixth and seventh), which are near the second formant. Finally singing "ah" in a normal chest voice at about