palate well behind the alveolar ridge but without touching or causing friction at any point, and a channel is left in the center of the tongue well visible at the tip in a V-formation." Emeneau offers good evidence for all these 15 vowels being phonologically contrastive. Emeneau's fieldwork was conducted in the 1930s, and it seems that the form of Badaga he investigated is no longer spoken. We have made recordings of a large number of Badaga speakers, going from one end of their dialect region to another. Our speakers included the son of Emeneau's informant and others from the same district. We found only a few speakers from very conservative groups who maintained a three-way contrast, and then it was in only one or at the most two vowels. However, two speakers did reliably distinguish the words shown in table 9.12.

Fricative vowels

The next added vowel feature to be discussed is frication. Fricative vowels can usually be thought of as syllabic fricatives that are allophones of vowels. The best known examples are the allophones of i that occur after retroflex (flat post-alveolar) and alveolar fricatives and affricates respectively in Standard Chinese. These vowels are made with the tongue in essentially the same position as in the corresponding fricatives. Because of the articulation used in the alveolar case, these vowels have sometimes been referred to as 'apical' vowels. This term is not appropriate for the so-called retroflex cases. In addition, in Liangshang Yi there are fricative vowels which are syllabic variants of a labial fricative (Maddieson and Hess 1986) and in Czech a laminal r can occur as a fricative vowel (Ladefoged 1971, and see chapter 7). These non-Chinese cases indicate that the more general term fricative vowel is preferable. Fricative vowels are reconstructable for Proto-Bantu (they are usually referred to by Bantuists as 'superclose' vowels, written u, i). The fricative vowel pronunciation is retained in some languages in the northwestern part of the Bantu area, but has often resulted in frication of a preceding consonant elsewhere. In both Yi and Czech the fricative vowels may be not only fricated but also trilled. In the case of the Yi labial vowel, it is the lips that are trilled.

indian languages of the Plains and the Rockies. In some of these languages they appear to be phonologically contrastive. For example. Miller and Davis (1963) reconstruct voiceless vowels for Proto-Keresan. In other languages, such as Acoma (Miller 1966), they are not underlying phonemes; in yet others, such as Comanche, their status is problematic (Armagost 1986). Voiceless vowels also occur in the Bantu languages of the Congo basin and the Indo-Iranian languages in the Indic/Iranian border region; but here they are simply surface phonetic phenomena. Voiceless vowels occur as allophones of regularly voiced vowels in many languages, including English (e.g. in the first syllables of 'peculiar' and 'particular'). In Japanese there is a contrast between the voiceless allophones of i and u between voiceless obstruents, as in kip 'shore' and kufi 'comb'.

Many languages have phonemic contrasts involving other kinds of phonation. Some languages exploit a breathy voice quality which some linguists call 'murmur' (Ladefoged 1971, Pandit 1957), but which in this book we are calling breathy voice. As shown in table 9.13, Gujarati has developed surface phonetic contrasts between plain and breathy voiced vowels, in addition to the more common Indo-Aryan contrasts between plain and breathy voiced stops, discused in chapter 3. !X66 contrasts involving breathy voice have already been illustrated in table 9.11.

Another type of vowel is produced with the body of the vocal folds, the vocalis muscle, stiffened, forming what we are here calling stiff voice. A good example occurs in Mpi, a language with six tones, each of which may occur with a plain or a laryngealized vowel, so that the same articulatory sequence,

Table 9.13 Words illustrating contrasts between voiced and breathy voiced vowels in Gujarati. (For further comparison, contrasts between voiceless aspirated, voiced aspirated, voiceless, and voiced consonants are also shown)

	Voiced initial		Voiceless initial	
Plain vowel	bar	'twelve'	por	'last year'
Breathy vowel	bar	'outside'	par	'early morning'
Aspirated consonant	b"ar	'burden'	p^adz	'army'

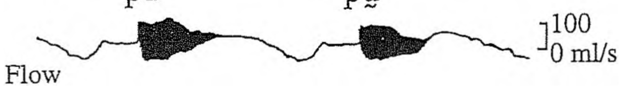

Figure 9.29 Airflow and intra-oral pressure records of two pairs of words with stiff and slack voicing in Parauk (retraced from the original recordings).

Table 9.14 Contrastingphonation types and tones occurring on the segments si in Mpi. The 12 glosses are appropriate for the segments si with the tones and phonation types as shown

	Tone	Modal voice	Stiff voice
1	low rising	'to be putrid'	'to be dried up'
2	low	'blood'	'seven'
3	mid rising	'to roll'	'to smoke'
4	mid	(a color)	(classifier)
5	high rising	'to die'	(man's name)
6	high	'four'	(man's name)

si, has 12 different meanings depending on accompanying tone and phonation type, as shown in table 9.14.

Often the contrast is not so much between regular voicing and stiff voicing, but instead is between a slightly breathy and slightly stiff type of phonation. Parauk (Wa), a Mon-Khmer language, uses two such contrasting phonation types, neither of which is as breathy or as creaky as the contrasting phonation types in the other languages we have been considering in this chapter; both are much closer to modal voice. The small differences in Parauk vowels are illustrated in the aerodynamic records of two pairs of words shown in figure 9.29 (from Maddieson and Ladefoged 1985). There are insignificant variations in the pressure, due to various factors such as the sequence in which the words were read. However, for a given pressure, there is always a higher mean flow for the slack vowels, which, accordingly, must have been produced with a less constricted glottis.

A more extreme type of laryngealization, creaky voice, occurs in some languages, such as Jalapa Mazatec, an Otomanguean language spoken in Mexico (Kirk, Ladefoged and Ladefoged 1993). As we noted in the case of stop consonants, the distinction drawn between creaky voice and stiff voice is somewhat arbitrary. We have, ourselves, referred to the voice quality in Mpi as creaky (Ladefoged 1982), although, in comparison with the Jalapa Mazatec vowels, Mpi vowels definitely have a less constricted glottis. Jalapa Mazatec is exceptional in that it has a three way contrast between creaky (laryngealized), breathy (murmured) and modal (plain) vowels, as illustrated in table 9.15, and the vowel contrasts are therefore worth examining in some detail.

The acoustic cues distinguishing vowels with different phonation types have been described at length by Ladefoged, Maddieson and Jackson (1988). As a general rule, vowels with stiff voice or creaky voice have more energy in the harmonics in the region of the first and second formants than those with modal voice. Conversely, vowels with slack or breathy voice have comparatively more energy in the fundamental frequency. There is also a tendency (though not in all languages) for vowels with creaky voice to have a more irregular vocal cord pulse rate (more jitter), and for breathy voice vowels to have more random energy (a larger noise component) in the higher frequencies. These points can be seen in the narrow band power spectra of the creaky, modal and breathy vowels of five speakers of Jalapa Mazatec, shown in figure 9.30.

Figure 9.31 shows the difference between the amplitude of the fundamental and that of the first formant in each of these spectra. It thus illustrates the way in which some of these differences can be expressed quantitatively. Data for each of the five speakers is shown separately, followed by the mean for all five. The lowest set of three bars shows that the mean difference in amplitude between the fundamental and the first formant for creaky voice (black bar) is -17 dB, i.e. the fundamental has 17 dB less amplitude than the first formant, which is thus considerably stronger. The mean for modal voice (shaded bar) is -7 dB, and that for breathy voice (white bar) is +5 dB (i.e. for breathy voice there is a comparatively large amount of energy in the fundamental rather than in the first formant). There is considerable variation from speaker to speaker in the value for each of the three phonation types, but for all speakers the value for breathy voice is higher than that for modal voice for any speaker. Creaky

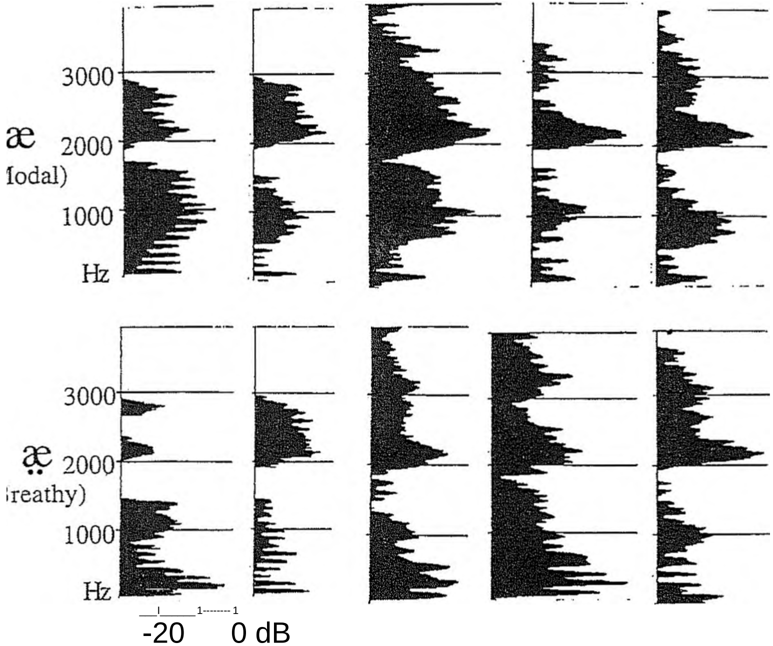

Figure 9.30 Narrow band power spectra of the creaky, modal and breathy vowels of five speakers of Jalapa Mazatec, taken during the middle of the vowels in the last row of table 9.15.

voice and modal voice show some overlap of values, but it is still true that for every speaker creaky voice has a relatively lower value than modal voice.

Some of the differences between the three phonation types can also be seen in records of the waveforms of these vowels. Figure 9.32 shows the three vowels as produced by one speaker. The creaky vowel has more irregular pulses and a comparatively undamped waveform corresponding to the narrow

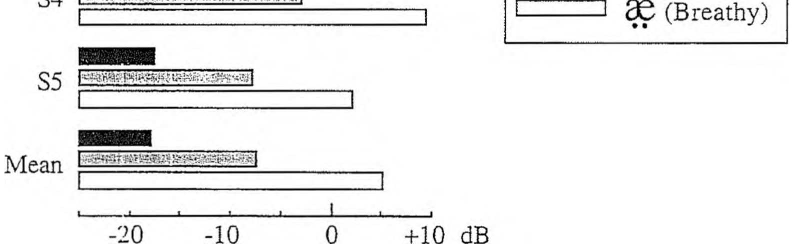

Figure 9.31 Relative amplitude of the fundamental and the first formant in Jalapa Mazatec vowels for five speakers and the mean of all five.

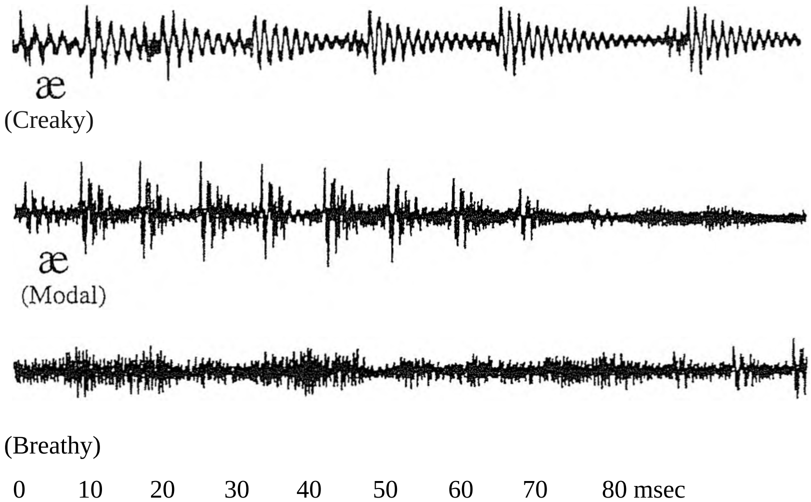

Figure 9.32 Waveforms of the three vowels in the first row of table 9.15 as spoken by one speaker.

Numerous languages distinguish long and short vowels. Occasionally, as in Estonian, there are three contrasting vowel lengths. In this language, however, as has been pointed out by Lehiste (1970), the significant differences in quantity are not simply lexical, but are related to the structure of the word. The only language that we know of that has persuasively been shown to use three degrees of length to contrast lexical items is Mixe (Hoogshagen 1959). Lehiste (1970), commenting on Hoogshagen's description of this language, concludes that "vowel quantity in Mixe is segmental, i.e., does not depend on syllable structure or on word patterns as was the case in Estonian." Our reading of Hoogshagen's data leads to the same conclusions; Hoogshagen provides numerous examples, mainly monosyllabic words, showing that there are three degrees of contrastive vowel length, independent of the syllable pattern, the vowel quality, the preceding or following consonants, the stress, the pitch and the intonation. Examples are given in table 9.16. Yavapai also has distinctions between vowels of three different lengths which seem to be lexical (Thomas and Shaterian 1990).

Larger numbers of length differences have been observed in some languages, but these are associated with the distinction between vowels that are contained in one syllable versus those which form more than one syllable. Whiteley and Muli (1962) suggested that KiKamba has four degrees of length. Although they pointed out that the very long vowels have cognate forms in neighboring languages with an intervening consonant within the vowel

Table 9.16 Words illustrating the three contrastive vowel lengths in Mixe (data from Hoogshagen 1959)

pof	'guava'	pet	'climb (n)'	pif	'flea'
poj	'spider'	pe't	'broom'	pi’J’	'marigold'
Pt>:J	'knot'	pe:t	'Peter'	tjllt	'cat'

consisting of more than one syllable. Roberts-Kohno (1995) has clarified the situation: there is a four-way distinction between vowel lengths because there are two independent factors. There are long and short vowels, and identical vowels may have a syllable boundary (or 'hiatus') between them. This yields the difference V, V:, V.V, and V.V: (neither V:.V nor Vi.V: occurs). Examples of each type are given in table 9.17. In the case of hiatus, non-identical vowel sequences also occur, as in ko.uma 'to curse'. Two identical short vowels in hiatus are much longer than a long vowel; Roberts-Kohno measured the mean duration of the bisyllabic vowel sequence in koto. 6m e<5ja 'to cause to bite us' as 232 ms, but the long vowel in kotoomeSja 'to dry us' as only 127 ms.

Diphthongs

If we consider phonetic descriptions of vowels to be equivalent to statements about the targets of vocalic gestures, then we can consider diphthongs to be vowels that have two separate targets. There is a problem with this definition, in that it does not distinguish between diphthongs and long vowels, which may well be considered to be vowels that have two identical targets. Accordingly we must stipulate that diphthongs must have two different targets. Lindau, Norlin and Svantesson (1985) have calculated that diphthongs occur in about a third of the world's languages. They also note that diphthongs of the ai-type occur in 75 percent of these languages, and of the au-type in 65 percent of these languages.

As with all sounds with two targets, the time-course of the movement from one target to the next has to be specified. Lindau, Norlin and Svantesson (1985) examined diphthongs in Arabic, Hausa, Standard Chinese, and English, and showed that there are differences in the way that the diphthong targets are joined. For some of the diphthongs in these languages certain general principles seemed to apply. For example, for the ai diphthong in English, and for the upward moving diphthongs in Chinese it was true that "the further to go, the longer it takes." But for other Chinese diphthongs, and for English au diphthongs, this was not true. In addition Hausa and Arabic had significantly

9.3 Vowel-like Consonants

Traditional phonetic classification has often set up a category of sounds known as semi-vowels. These are vowel-like segments that function as consonants, such as w and j. These sounds have also been termed 'glides', based on the idea that they involve a quick movement from a high vowel position to a lower vowel. This term, and this characterization of the nature of these sounds is inappropriate; as with other consonants they can occur geminated, for example in Marshallese, Sierra Miwok and Tashlhiyt.

Vowel-like segments that function as consonants are common in the world's languages. Of the world's languages 85 percent have the palatal approximant j and 76 percent the labial-velar approximant w (Maddieson 1984a). Other semivowels are far less common, occurring in less than 2 percent of languages. Table 9.18 illustrates the contrasts between the labial-palatal approximant q and the two more familiar semivowels j, w in French. The (unrounded) velar approximant tq is even less common. It occurs in Axininca where it contrasts with "a bilabial approximant [EPA g] which has no simultaneous velar ... articulation as w would," (Payne 1981) as well as with the palatal approximant j.

There has been a great deal of discussion about the relationship between vowels and semivowels. It is clear that there is a contrast between English words such as *east* and *yeast* and between words such as *woos* and ooze. But Jakobson, Fant and Halle (1952) suggested that this does not necessitate setting up a category of semivowels. In their view, there is only an allophonic difference between semivowels and vowels. Thus Jakobson, Fant and Halle transcribed the words *woo* and *ye* as uuu and iii, instead of wuw and yiy as was the

Table 9.IS Words illustrating contrasting semivowels in French

mjet	'crumb'	mqet	'mute' (f.)	mwet	'sea gull'
Ue	'tied'	Iqi	'him'	Iwi	'Louis'
J0	'eyes'	qit	'eight'	wi	'yes'

'r' and are more appropriately considered in chapter 7, which is concerned with all forms of rhotics. But we should note here that, for many speakers of American English, the approximant j at the beginning of the word 'red' bears the same relationship to the vowel a- in 'bird' as the approximant j in 'yes' does to the vowel i in 'heed'. Similarly, the Danish 'r' sound in words such as 'raad' (council) is not a uvular approximant as some textbooks (Bredsdorf 1958) describe it, but a pharyngeal approximant with an articulatory position similar to that in a low back vowel.

We should also consider whether there are semivowels corresponding to mid-vowels in a language. A possibility of this sort can be seen by considering the resyllabifications of vowel elisions that occur in Nepali, shown in table 9.19. In this language there are several possible sequences of vowels that occur in a slow, formal style of speech. In normal, colloquial speech one or other of two adjacent vowels becomes non-syllabic. The examples cited in the tables sound like two syllables in slow speech, but like single syllables in normal speech, both to us and to the Nepali linguist B.M. Dahal, who suggested them to us. Sometimes it is the first of the two vowels that is affected, and sometimes the second. The six vowels of the language may be described in terms of three vowel heights: i, u; e, o; a, a. Kelkar (personal communication) has pointed out that when a sequence includes a high or mid-vowel, and a vowel of a lower height, the higher vowel in the sequence becomes non-syllabic, irrespective of whether it is the first or second vowel in the sequence. The high vowels become the semivowels j, w; and, when a mid-vowel occurs with a low vowel, the mid-vowels become the non-high semivowels, e, o. When high or mid-vowels of equal height occur in sequence, either of them may become non-syllabic, so that either of the possible semivowels is produced. Only when two low vowels alone occur in sequence (i.e. in a sequence without a mid- or high vowel), is the first of the two elided. Facts such as these not only indicate the possibility of non-high semivowels, but also support the notion of vowel heights forming a multi-valued ordered set that cannot be expressed in binary terms.

While not actually semivowels, we will also consider here the bilabial approximant § and the labiodental approximant u. Hindi is a good example of a language in which there is no v or w, but instead the most common allophone