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# Introducing **Phonology**

David Odden

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# Introducing Phonology

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# About this book

This is an introductory textbook on phonological analysis, and does not assume any prior exposure to phonological concepts. The core of the book is intended to be used in a first course in phonology, and the chapters which focus specifically on analysis can easily be covered during a ten-week quarter. Insofar as it is a textbook in phonology, it is not a textbook in phonetics (though it does include the minimum coverage of phonetics required to do basic phonology), and if used in a combined phonetics and phonology course, a supplement to cover more details of acoustics, anatomy and articulation should be sought: Ladefoged 2001a would be an appropriate phonetics companion in such a course.

The main emphasis of this book is developing the foundational skills needed to analyze phonological data, especially systems of phonological alternations. For this reason, there is sig-

nificantly less emphasis on presenting the various theoretical positions which phonologists have taken over the years. Theory cannot be entirely avoided, indeed it is impossible to state generalizations about a particular language without a theory which gives you a basis for postulating general rules. The very question of what the raw data are must be interpreted in the context of a theory, thus analysis needs theory. Equally, theories are formal models which impose structure on data – theories are theories *about* data – so theories need data, hence analysis. The theoretical issues that are discussed herein are chosen because they represent issues which have come up many times in phonology, because they are fundamental issues, and especially because they allow exploration of the deeper philosophical issues involved in theory construction and testing.

# Acknowledgments

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Finally, I would like to acknowledge my debt to authors of various source books, in particular Whitley 1978, Halle and Clements 1983, and especially Kenstowicz and Kisseberth 1979.

# A note on languages

The languages which provided data for this book are listed below. The name of the language is given, followed by the genetic affiliation and location of the language, finally the source of the data ("FN" indicates that the data come from my own field notes). Genetic affiliation typically gives the lowest level of the language tree which is likely to be widely known, so Bantu languages will be cited as "Bantu," and Tiv will be cited as "Benue-Congo," even though "Bantu" is a part of Benue-Congo and "Tiv" is a specific language in the Tivoid group of the Southern languages in Bantoid. Locations will generally list one country but sometimes more; since language boundaries rarely respect national boundaries, it is to be understood that the listed country (or countries) is the primary location where the language is spoken, especially the particular dialect used; or this may be the country the language historically originates from (the Yiddish-speaking population of the US appears to be larger than that of any one country in Eastern Europe, due to recent population movements).

- Akan [Volta-Congo; Ghana]: Dolphyne 1988; Charles Marfo p.c.  
Amharic [Semitic; Ethiopia]: Whitley 1978; Grover Hudson p.c.  
Angas [Chadic; Nigeria]: FN.  
Arabela [Zaparoan; Peru]: Rich 1963.  
Aramaic (Azerbaijani) [Semitic; Azerbaijan]: Hoberman 1988.  
Araucanian [Araucanian; Argentina, Chile]: Echeverría and Contreras 1965; Hayes 1995.  
Armenian [Indo-European; Armenia, Iran, Turkey]: Vaux 1998 and p.c.  
Axininca Campa [Arawakan; Peru]: Payne 1981 and p.c.  
Bedouin Hijazi Arabic [Semitic; Saudi Arabia]: Al-Mozainy 1981 and p.c.  
Bukusu [Bantu; Kenya]: Nasiombe Mutonyi p.c.  
Catalan [Romance; Spain]: Lleo 1970, Kenstowicz and Kisseberth 1979; Wheeler 1979; Hualde 1992.  
Chamorro [Austronesian; Guam]: Topping 1968; Topping and Dungca 1973; Kenstowicz and Kisseberth 1979; Chung 1983.  
Chukchi [Chukotko-Kamchatkan; Russia]: Krauss 1981.  
Digo [Bantu; Kenya and Tanzania]: Kisseberth 1984.  
Efik [Benue-Congo; Nigeria]: FN.  
Eggon [Benue-Congo; Nigeria]: Ladefoged and Maddieson 1996.  
Evenki [Tungusic; Russia]: Konstantinova 1964; Nedjalkov 1997; Bulatova and Grenoble 1999.  
Ewe (Anlo) [Volta-Congo; Benin]: Clements 1978.  
Farsi [Indo-European; Iran]: Obolensky, Panah and Nouri 1963; Cowan and Rakušan 1998.  
Finnish. [Uralic; Finland, Russia]: Whitney 1956; Lehtinen 1963; Anders Holmberg p.c.  
Fula [West Atlantic; West Africa]: Paradis 1992.  
Gã [Volta-Congo; Ghana]: FN in collaboration with Mary Paster.  
Luganda [Bantu; Uganda]: Cole 1967; Snoxall 1967.  
Gen [Kwa; Togo]: FN.  
Greek [Indo-European; Greece]: Georgios Tserdanelis p.c.  
Hebrew [Semitic; Israel]: Kenstowicz and Kisseberth 1979.  
Hehe [Bantu; Tanzania]: FN in collaboration with Mary Odden.  
Holoholo [Bantu; Congo]: Coupez 1955.  
Hungarian [Uralic; Hungary]: Vago 1980, Kenesei, Vago and Fenyesi 1998, 2000.  
Icelandic [Germanic; Iceland]: Einarsson 1945; Jónsson 1966; Oresnik 1985.  
Japanese [Japanese; Japan]: Martin 1975.  
Jita [Bantu; Tanzania]: Downing 1996.  
Kamba [Bantu; Kenya]: FN in collaboration with Ruth Roberts-Kohno.

- Karok [Hokan; USA]: Bright 1957, Kenstowicz and Kisseberth 1979.
- Keley-i [Austronesian; Philippines]: Kenstowicz and Kisseberth 1979; Lou Hohulin p.c.
- Kenyang [Bantu; Cameroun]: FN.
- Kera [Chadic; Chad]: Ebert 1975; Kenstowicz and Kisseberth 1979.
- Kerewe [Bantu; Tanzania]: FN.
- Kikuyu [Bantu; Kenya]: Clements 1984.
- Kimatuumbi [Bantu; Tanzania]: FN.
- Kipsigis [Nilotic; Kenya]: FN.
- Klamath [Penutian; USA]: Barker 1963, 1964.
- Koasati [Muskogean; Louisiana]: Kimball 1991.
- Kolami [Dravidian; India]: Emeneau 1961.
- Korean [Korean; Korea]: Martin 1992; Younghee Chung, Noju Kim and Misun Seo p.c.
- Koromfe [Gur; Bourkina Fasso]: Rennison 1997.
- Kotoko [Chadic; Cameroun]: FN.
- Krachi [Kwa; Ghana]: Snider 1990.
- Kuria [Bantu; Kenya]: FN.
- Lamba [Bantu; Zambia]: Doke 1938, Kenstowicz and Kisseberth 1979.
- Lardil [Pama-Nyungan; Australia]: Klokeid 1976.
- Latin [Indo-European; Italy]: Allen and Greenough 1983; Hale and Buck 1966.
- Lithuanian [Indo-European; Lithuania]: Dambriunas et al. 1966; Ambrazas 1997; Mathiassen 1996.
- Lomongo [Bantu; Congo]: Hulstaert 1961.
- Lulubo [Nilo-Saharan; Sudan]: Andersen 1987.
- Makonde [Bantu; Mozambique]: Marcelino Liphola p.c.
- Maltese [Semitic; Malta]: Aquilina 1965; Borg and Azzopardi-Alexandre 1997; Brame 1972; Hume 1996.
- Manipuri [Sino-Tibetan; India, Myanmar, Bangladesh]: Bhat and Ningomba 1997.
- Maranungku [Australian: Australia]: Tryon 1970; Hayes 1995.
- Margyi [Chadic; Nigeria]: Hoffmann 1963.
- Mende [Mande; Liberia, Sierra Leone]: Leben 1978.
- Mixtec [Mixtecan; Mexico]: Pike 1948; Goldsmith 1990.
- Mohawk [Hokan; USA]: Postal 1968; Beatty 1974; Michelson 1988 and p.c.
- Mongolian [Altaic; Mongolia]: Hangin 1968.
- Nkore [Bantu; Uganda]: FN in collaboration with Robert Poletto.
- Norwegian [Germanic; Norway]: Ove Lorentz p.c.
- Osage [Siouan; Oklahoma]: Gleason 1955.
- Ossetic [Indo-European; Georgia, Russia]: Abaev 1964; Whitley 1978.
- Palauan [Austronesian; Palau]: Josephs 1975; Flora 1974.
- Polish [Slavic; Poland]: Kenstowicz and Kisseberth 1979.
- Quechua (Cuzco) [Quechua; Peru]: Bills et al. 1969; Cusihuamán 1976, 1978.
- Saami [Uralic; Sápmi (Norway, Sweden, Finland, Russia)]: FN in collaboration with Curt Rice and Berit Anne Bals.
- Sakha (Yakhut) [Altaic; Russia]: Krueger 1962; Nadezhda Vinokurova p.c.
- Samoan [Austronesian; Samoa]: Milner 1966.
- Serbo-Croatian [Slavic; Yugoslavia] Kenstowicz and Kisseberth 1979; Wayles Browne, Svetlana Godjevac and Andrea Sims p.c.
- Setswana [Bantu; Botswana]: Cole 1955, Snyman, Shole and Le Roux 1990.
- Shambaa [Bantu; Tanzania]: FN.
- Shona [Bantu; Zimbabwe]: FN.
- Swati [Bantu; Swaziland]: FN.
- Slave [Athapaskan; Canada]. Rice 1989.
- Slovak [Slavic; Slovakia]: Kenstowicz 1972; Rubach 1993.
- Somali [Cushitic; Somalia]: Andrzejewski 1964; Kenstowicz 1994; Saeed 1993, 1999
- Sundanese [Austronesian; Indonesia]: FN.
- Syrian Arabic [Semitic; Syria]: Cowell 1964.
- Tera [Chadic; Nigeria]: Newman.
- Thai [Daic; Thailand]: Halle and Clements 1983.
- Tibetan [Sino-Tibetan; Tibet]: FN.
- Tiv [Benue-Congo; Nigeria]: Arnott 1964; Goldsmith 1976.
- Tohono 'O'odham (Papago) [Uto-Aztecan; USA]: Saxton 1963, Saxton and Saxton 1969, Whitley 1978.
- Tonkawa [Coahuiltecan; USA]: Hoijer 1933.
- Turkish [Altaic; Turkey] Lees 1961, Foster 1969, Halle and Clements 1983.
- Ukrainian (Sadžava, Standard) [Slavic; Ukraine]: Carlton 1971; Kenstowicz and Kisseberth 1979; Press and Pugh 1994 (Standard); Popova 1972 (Sadžava).

- 
- Vata [Kru; Côte d'Ivoire]: Kaye 1982.  
Votic [Uralic; Russia]: Ariste 1968.  
Warao [Warao; Venezuela] Osborn 1966, Hayes 1995.  
Weri [Goilalan: New Guinea]: Boxwell and Boxwell 1966; Hayes 1995.  
Wintu [Penutian; USA]: Pitkin 1984.  
Woleaian [Austronesia; Micronesia]: Sohn 1975.  
Yawelmani [Penutian; USA]: Newman 1944; Kenstowicz and Kisseberth 1979.  
Yekhee (Etsako) [Edoid; Nigeria]: Elimelech 1978.  
Yiddish [Germanic; Eastern Europe]: Neil Jacobs p.c.  
Yoruba [Kwa; Nigeria]: Akinlabi 1984.

# Abbreviations

abl	ablative	masc	masculine
acc	accusative	ms(c)	millisecond
ant	anterior	nas	nasal
ATR	advanced tongue root	neut	neuter
bk	back	nom	nominative
c.g.	constricted glottis	obj	object
cl	class	pl	plural
cons	consonantal	poss	possessive
cont	continuant	pres	present
cor	coronal	rd	round
dat	dative	sg, sing	singular
dB	decibel	s.g.	spread glottis
del.rel	delayed release	son	sonorant
dim	diminutive	sp	species
distr	distributed	strid	strident
e.o.	each other	syl	syllabic
fem	feminine	tns	tense
gen	genitive	tr	transitive
hi	high	vcd	voiced
Hz	Hertz	vcls	voiceless
imp	imperative	voi	voice
intr	intransitive	1	first person
lat	lateral	2	second person
lo	low	3	third person
loc	locative		



# 1 What is phonology?

## PREVIEW

### KEY TERMS

*sound*  
*symbol*  
*transcription*  
*grammar*  
*continuous*  
*nature of*  
*speech*  
*accuracy*

This chapter introduces phonology, the study of the sound systems of language. Its key objective is to:

- ◆ introduce the notion of phonological rule
- ◆ explain the nature of sound as a physical phenomenon
- ◆ highlight the tradeoff between accuracy and usefulness in representing sound
- ◆ distinguish between phonetics and phonology
- ◆ contrast the continuous and discrete aspects of linguistic sounds
- ◆ introduce the notion of “sound as cognitive symbol”

Phonology is one of the core fields that composes the discipline of linguistics, which is defined as the scientific study of language structure. One way to understand what the subject matter of phonology is, is to contrast it with other fields within linguistics. A very brief explanation is that phonology is the study of sound structure in language, which is different from the study of sentence structure (syntax) or word structure (morphology), or how languages change over time (historical linguistics). This definition is very simple, and also inadequate. An important feature of the structure of a sentence is how it is pronounced – its sound structure. The pronunciation of a given word is also a fundamental part of the structure of the word. And certainly the principles of pronunciation in a language are subject to change over time. So the study of phonology eventually touches on other domains of linguistics.

An important question is how phonology differs from the closely related discipline of phonetics. Making a principled separation between phonetics and phonology is difficult – just as it is difficult to make a principled separation between physics and chemistry, or sociology and anthropology. A common characterization of the difference between phonetics and phonology is that phonetics deals with “actual” physical sounds as they are manifested in human speech, and concentrates on acoustic waveforms, formant values, measurements of duration measured in milliseconds, of amplitude and frequency, or in the physical principles underlying the production of sounds, which involves the study of resonances and the study of the muscles and other articulatory structures used to produce physical sounds. On the other hand, phonology, it is said, is an abstract cognitive system dealing with rules in a mental grammar: principles of subconscious “thought” as they relate to language sound. Yet once we look into the central questions of phonology in greater depth, we will find that the boundaries between the disciplines of phonetics and phonology are not entirely clear-cut. As research in both of these fields has progressed, it has become apparent that a better understanding of many issues in phonology requires that you bring phonetics into consideration, just as a phonological analysis is a prerequisite for any phonetic study of language.

## 1.1 Concerns of phonology

As a step towards understanding what phonology is, and especially how it differs from phonetics, we will consider some specific aspects of sound structure that would be part of a phonological analysis. The point which is most important to appreciate at this moment is that the “sounds” which phonology is concerned with are symbolic sounds – they are cognitive abstractions, which represent but are not the same as physical sounds.

**The sounds of a language.** One aspect of phonology considers what the “sounds” of a language are. We would want to take note in a description

of the phonology of English that we lack a particular vowel that exists in German in words like *schön* ‘beautiful,’ a vowel which is also found in French (spelled *eu*, as in *jeune* ‘young’), or Norwegian (*øl* ‘beer’). Similarly, the consonant spelled *th* in English *thing*, *path* does exist in English (as well as in Icelandic where it is spelled with the letter *þ*, or Modern Greek where it is spelled with *θ*, or Saami where it is spelled *ʈ*), but this sound does not occur in German or French, and it is not used in Latin American Spanish, although it does occur in Continental Spanish in words such as *cerveza* ‘beer,’ where by the spelling conventions of Spanish, the letters *c* and *z* represent the same sound as the one spelled *θ* (in Greek) or *th* (in English).

**Rules for combining sounds.** Another aspect of language sound which a phonological analysis would take account of is that in any given language, certain combinations of sounds are allowed, but other combinations are systematically impossible. The fact that English has the words *brick*, *break*, *bridge*, *bread* is a clear indication that there is no restriction against having words begin with the consonant sequence *br*; besides these words, one can think of many more words beginning with *br* such as *bribe*, *brow* and so on. Similarly, there are many words which begin with *bl*, such as *blue*, *blatant*, *blast*, *blend*, *blink*, showing that there is no rule against words beginning with *bl*. It is also a fact that there is no word *\*blick*<sup>1</sup> in English, even though the similar words *blink*, *brick* do exist. The question is, why is there no word *\*blick* in English? The best explanation for the nonexistence of this word is simply that it is an accidental gap – not every logically possible combination of sounds which follows the rules of English phonology is found as an actual word of the language.

Native speakers of English have the intuition that while *blink* is not actually a word of English, it is a theoretically possible word of English, and such a word might easily enter the language, for example via the introduction of a new brand of detergent. Fifty years ago the English language did not have any word pronounced *bick*, but based on the existence of words like *big* and *pick*, that word would certainly have been included in the set of nonexistent but theoretically allowed words of English. Contemporary English, of course, actually does contain that word – spelled *Bic* – which is a type of pen.

While the nonexistence of *blink* in English is accidental, the exclusion from English of many other imaginable but nonexistent words is based on a principled restriction of the language. While there are words that begin with *sn* like *snake*, *snip* and *snort*, there are no words beginning with *bn*, and thus *\*bnick*, *\*bnark*, *\*bniddle* are not words of English. There simply are no words in English which begin with *bn*. Moreover, native speakers of English have a clear intuition that hypothetical *\*bnick*, *\*bnark*, *\*bniddle* could not be words of English. Similarly, there are no words in English which are pronounced with *pn* at the beginning, a fact which is not only demonstrated by the systematic lack of words such as *\*pnark*, *\*pnig*, *\*pnilge*,

1 The asterisk is used to indicate that a given word is non-existent or wrong.

but also by the fact that the word spelled *pneumonia* which derives from Ancient Greek (a language which does allow such consonant combinations) is pronounced without *p*. A description of the phonology of English would then provide a basis for characterizing such restrictions on sequences of sounds.

**Variations in pronunciation.** In addition to providing an account of possible versus impossible words in a language, a phonological analysis will explain other general patterns in the pronunciation of words. For example, there is a very general rule of English phonology which dictates that the plural suffix on nouns will be pronounced as [ɪz], represented in spelling as *es*, when the preceding consonant is one of a certain set of consonants including [ʃ] (spelled *sh*) as in *bushes*, [tʃ] (spelled as *ch*) as in *churches*, and [dʒ] (spelled *j*, *ge*, *dge*) as in *cages*, *bridges*. This pattern of pronunciation is not limited to the plural, so despite the difference in spelling, the possessive suffix *s*<sup>2</sup> is also subject to the same rules of pronunciation: thus, plural *bushes* is pronounced the same as the possessive *bush's*, and plural *churches* is pronounced the same as possessive *church's*.

This is the sense in which phonology is about the sounds of language. From the phonological perspective, a “sound” is a specific unit which combines with other such specific units, and which represent physical sounds.

## 1.2 Phonetics – what is physical sound?

Phonetics, on the other hand, is about the concrete, instrumentally measurable physical properties and production of these cognitive speech sounds. That being the case, we must ask a very basic question about phonetics (one which we also raise about phonology). Given that phonetics and phonology both study “sound” in language, what *are* sounds, and how does one *represent* the sounds of languages? The question of the physical reality of an object, and how to represent the object, is central in any science. If we have no understanding of the physical reality, we have no way of talking meaningfully about it. Before deciding *how* to represent a sound, we need to first consider *what* a sound is. To answer this question, we will look at two basic aspects of speech sounds as they are studied in phonetics, namely **acoustics** which is the study of the properties of the physical sound wave that we hear, and **articulation**, which is the study of how to modify the shape of the vocal tract, thereby producing a certain acoustic output (sound).

### 1.2.1 Acoustics

A “sound” is a complex pattern of rapid variations in air pressure, traveling from a sound source and striking the ear, which causes a series of neural signals to be received in the brain: this is true of speech, music and random noises.

2 This is the “apostrophe *s*” suffix found in *The child's shoe*, meaning ‘the shoe owned by the child.’

**Waveforms.** A concrete way to visually represent a sound is with an acoustic **waveform**. A number of computer programs allow one to record sound into a file and display the result on the screen. This means one can visually inspect a representation of the physical pattern of the variation in air pressure. Figure 1 gives the waveforms of a particular instance of the English words *seed* and *Sid*.

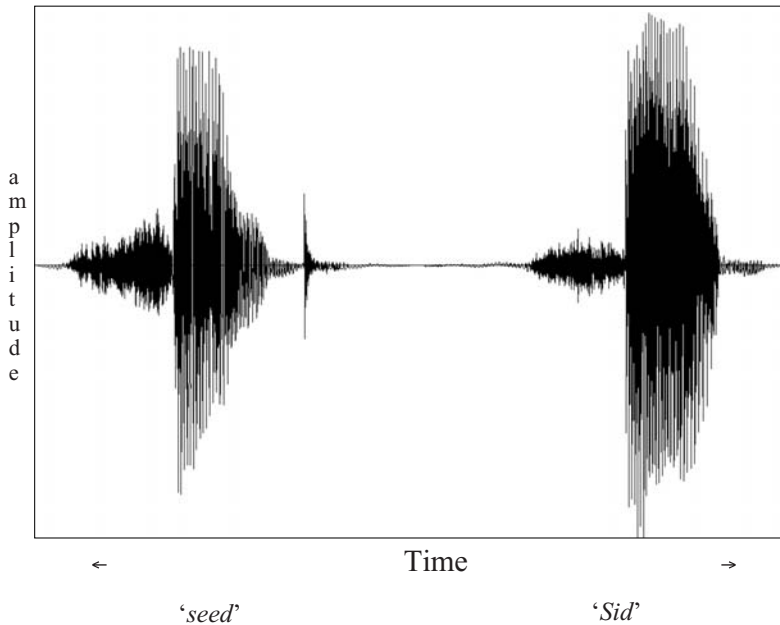


FIGURE 1  
Waveforms of speech

The horizontal axis represents time, with the beginning of each word at the left and the end of the word at the right. The vertical axis represents displacement of air particles and correlates with the variations in atmospheric pressure that affect the ear. Positions with little variation from the vertical center of the graph represent smaller displacements of air particles, such as the portion that almost seems to be a straight horizontal line at the right side of each graph. Such minimal displacements from the center correspond to lower amplitude sounds. The portion in the middle where there is much greater vertical movement in the graph indicates that the sound at that point in time has higher amplitude. While such a direct representation of sounds is extremely accurate, it is also fairly uninformative.

The difference between these words lies in their vowels (*ee* versus *i*), which is the part in the middle where the fluctuations in the graph are greatest. It is difficult to see a consistent difference just looking at these pictures – though since these two vowels *are* systematically distinguished in English, it cannot be impossible. It is also very difficult to see similarities looking at actual waveforms. Consider figure 2 which gives different repetitions of these same words by the same speaker.

Absolute accuracy is impossible, both in recording and measurement. Scientific instruments discard information: microphones have limits on what they can capture, as do recording or digitizing devices. Any representation of a sound is a measurement, which is an idealization about an actual physical event.

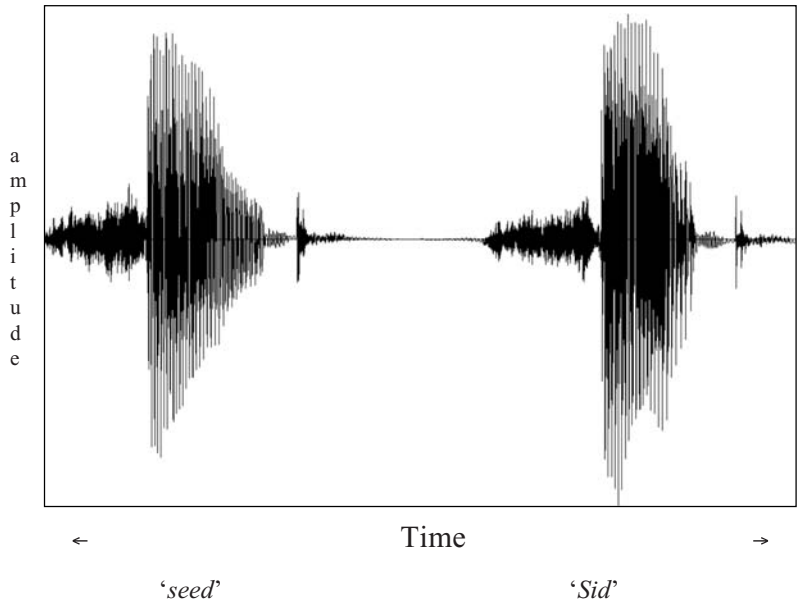


FIGURE 2  
Different repetitions of  
words

Visual inspection gives you no reason to think that these sets of graphs are the same words said on different occasions. The problem is that while a physical waveform is a very accurate representation of a word, it provides so much information that we cannot tell what is important and what is not.

Since we are interested in the part which makes these two words sound different, we might get a clearer picture of the physical difference by expanding the scale and looking just at a part of the vowel. Vowels are **periodic**, which means that the pattern of their waveform repeats over time. The display in figure 3 gives a portion of the

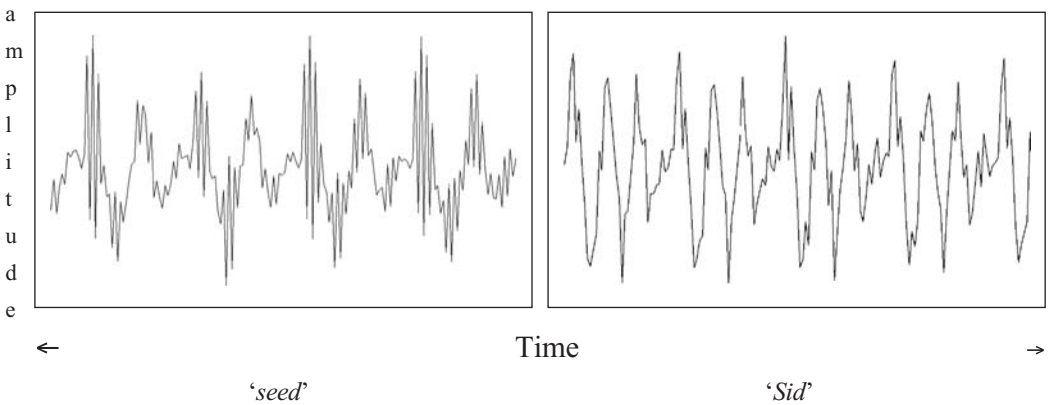


FIGURE 3  
Closeup waveform of vowels of *seed*, *Sid*

vowels from the middle of the words *seed* and *Sid*, involving around 30 milliseconds (ms) of each of the words (the entire word in each of these two examples actually lasts approximately 600 ms, so this is a small part of the entire word). We can indeed see that there is a pattern which is repeated (although successive repetitions are not perfect reproductions).

Though there are visible differences between the waveforms, the basis for distinguishing these vowels remains unclear.

**Sound spectra.** We need a better analytical technique than just looking at raw sound, to be able to talk precisely about properties of these sounds. We therefore need to understand some basic properties of physical sounds. All sound waves are definable in terms of three properties that characterize a **sine wave** familiar from trigonometry, namely **frequency** measured in cycles per second also known as Hertz (Hz), **amplitude** measured in decibels (dB), and **phase** measured in the angular measure radians. These characteristics suffice to define any sine wave, which is the analytic basis of sounds. The property phase, which describes how far into the infinite cycle of repetition a particular sine wave is, turns out to be unimportant for the study of speech sounds, so it can be ignored. Simple sine waves (termed “pure tones” when speaking of sounds) made up of a single frequency are not commonly encountered in the real world, but can be created by a tuning fork or by electronic equipment.

Speech sounds (indeed all sounds) are complex waveforms which are virtually impossible to describe with intuitive descriptions of what they “look like.” Fortunately, a complex waveform can be mathematically related to a series of simple waves which have different amplitudes at different frequencies, so that we can say that a complex waveform is “built from” a set of simple waves. Figure 4 shows a complex wave on the left which is constructed mathematically by just adding together the three simple waveforms of different frequencies and amplitudes that you see on the right.

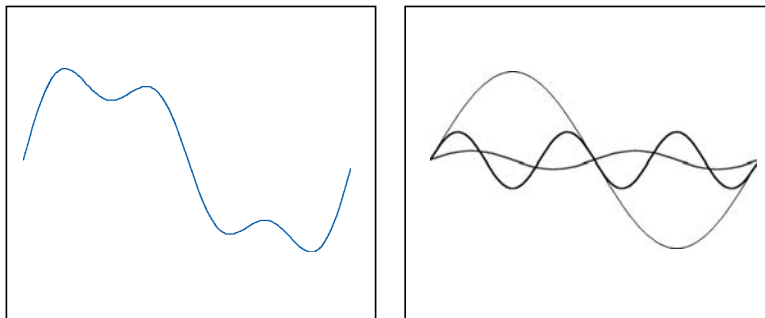


FIGURE 4  
Complex wave and the  
component simple waves  
defining it

The complex wave on the left is made from simple sine waves at 100, 200, and 300Hz, and the individual components defining the complex wave are graphed on the right. The most prominent component (the one



with the highest amplitude) is the one at 100 Hz, the thinnest line which makes one cycle in the chart: it has an amplitude of 60 dB. By comparison, the component at 200 Hz (graphed with a medium-weight line, which makes two cycles in the chart on the right) has the lowest amplitude, 40 dB. The 300 Hz component, graphed with the thickest line, has an intermediate amplitude of 50 dB. It is the amplitudes of the individual components which determine the overall shape of the resulting complex wave.

Now we will see what happens when we change this artificial sound to make the 200 Hz component be the most prominent component and the 100 Hz one be less prominent – if we simply switch the amplitudes of the 100 Hz and 200 Hz components, we get the wave shown in figure 5.

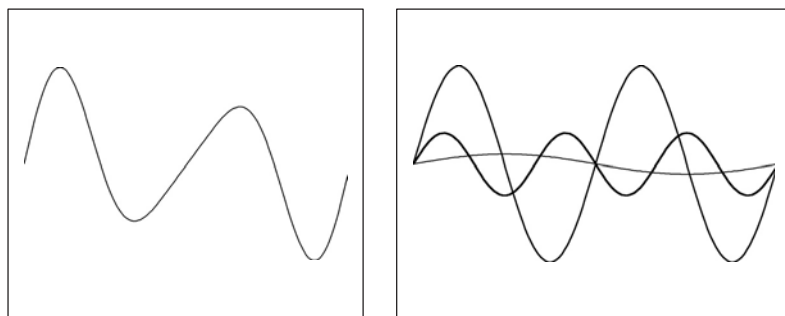


FIGURE 5  
Effect of changing  
component amplitude

Changing the amplitude of one such component changes the overall character of the waveform. A complex wave is mathematically equivalent to a corresponding series of sine wave components, so describing a complex wave directly is equivalent to describing the individual components. If we see two differently shaped complex waves and we can't describe their differences directly in terms of the complex waves, we can instead focus on the equivalent series of sine wave components, and describe the differences in terms of very simple information about component frequency and amplitude.

Just as a single complex waveform can be constructed from a series of simple waves at different frequencies and amplitudes, a single complex waveform can also be mathematically broken down into a series of components which have different frequencies and amplitudes. Rather than graph the full shape of each specific sine wave component – which becomes very hard to understand if there are more than a handful of components – we can simply graph the two important values for each of the component sine waves, the amplitude and frequency. This is known as a **spectrum**: it is the defining frequency and amplitude components of a complex waveform, over a fixed period of time. The spectrum of the waveform in figure 4 is plotted in figure 6, where the horizontal axis corresponds to frequency from 0 to 7,000 Hz and the vertical axis corresponds to amplitude from 0 to 60 dB. Note that in this display, time is not represented: the spectrum simply describes amplitude and frequency, and information about how long a particular complex waveform lasts would have to be represented somewhere else.



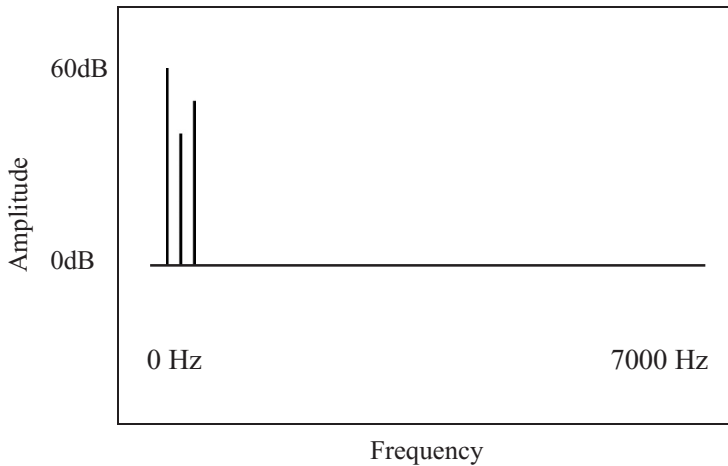


FIGURE 6  
Spectrum

This is a very simple spectrum, representing an artificially constructed sound containing only three components. Naturally occurring sounds have many more components than this.

Since complex sounds can be mathematically broken down into a series of simple components, we can use this very useful tool to look at the vowel sounds of *seed* and *Sid*: we look at the physical properties of the component frequencies that define the two vowels that we were interested in. Figure 7 provides the spectrum of the portion from the middle of the vowels of *Sid* and *seed* which we looked at in figure 3. The horizontal axis again represents frequency, ranging from 0 to 7000 Hz, and the vertical axis represents amplitude in decibels. Here, the spectrum is represented as a continuous set of amplitude values for all frequencies in this frequency range, and not just three discrete frequencies as seen in the constructed sound of figure 6.

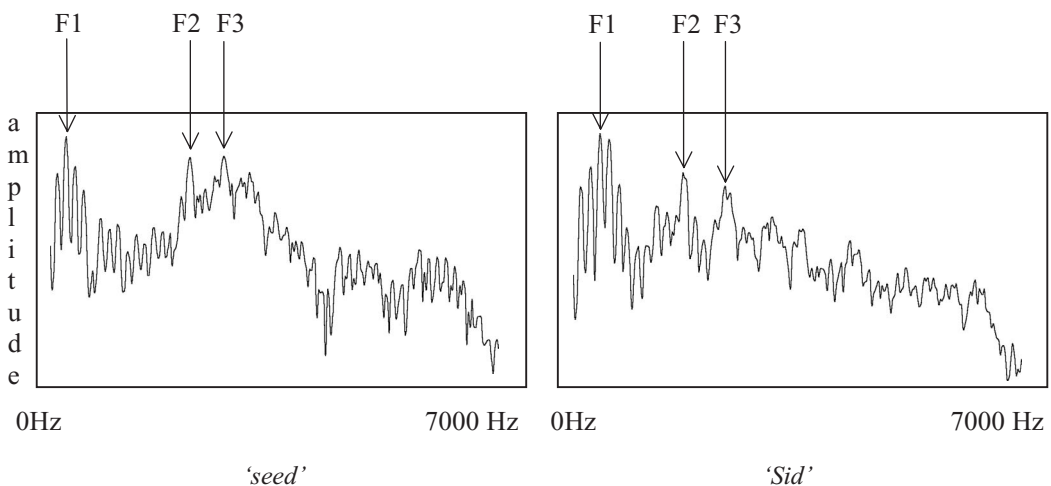


FIGURE 7  
Spectrum of the vowels of *seed*, *Sid*

Inaccuracy in spectral data has three main sources. Half of the information in the original signal, phase, has been discarded. Frequency information is only approximate and is related to how much speech is analyzed. Finally, a spectrum assumes that sound properties are constant during the period being analyzed. If too large a piece of speech is taken for analysis, a misrepresentative blending of a continuously changing signal results.

In these spectra, certain frequency regions are more prominent than others, due to **resonances** in the vocal tract. Resonances are frequency regions where sound amplitude is enhanced. These frequencies are perceptually more prominent than other lower-amplitude frequencies. The frequencies at which these resonances occur are related to the length of various parts of the vocal tract (ultimately related to the position of the tongue and lips as specific sounds are made). The relation between size and frequency is simple and familiar: a large bottle has a low-resonance frequency and a small bottle has a higher-resonance frequency. The first three of these prominent frequency regions, called **formants**, are indicated with pointed vertical lines in the graphs. You can see that in the spectrum for *seed* on the left, the first formant (F1) occurs at a lower frequency than the first formant of the vowel in *Sid*. However, the second and third formants (F2, F3) of *seed* occur at somewhat higher frequencies than F2 and F3 of *Sid*. By comparing the frequencies at which these formants occur, one can begin to systematically describe the physical properties of the vowels in *seed* and *Sid*. One of the most important properties which allows a listener to distinguish speech sounds, such as the vowels of *seed* versus *Sid*, is the frequencies of these formants.

Viewing the waveform versus the spectrum of a sound involves a trade-off between accuracy and usefulness. While the spectrum is more informative since it allows us to focus on certain specific properties (formant frequencies), it is a less accurate representation of reality than the original waveform. Another very significant limitation of this type of spectral display is that it only characterizes a single brief moment in the utterance: speech is made up of more than just little 30 millisecond bits of steady sound. We need to include information about changes over time in a sound.

A spectrogram can be made by a mechanical spectrograph, which uses an adjustable filter to select different frequency ranges and display the changes in amplitude at each frequency range; or, it can be created by a computer program, which uses Fourier analysis to determine these component amplitudes.

**Spectrograms.** Another display, the **spectrogram**, shows both frequency and amplitude properties as they change over time, by adding a third dimension of information to the display. Figure 8 provides spectrograms of the entirety of the two words *seed* and *Sid*. In this display, the horizontal axis represents the time dimension: the utterance begins at the left and ends at the right. The vertical axis represents frequency information, lower frequencies appearing at the bottom and higher frequencies at the top. Amplitude is represented as darkness: higher amplitudes are darker and lower amplitudes are lighter.

The initial portion of the spectrogram between the arrows represents the consonant *s*, and the second portion with the series of minute vertical striations represents the vowel (the consonant *d* is visible as the light horizontal band at the bottom of the graph, beginning at around 500 ms). The formants which characterize the vowels of *seed* and *Sid* are represented as dark bands, the first formant being the darker lower band and the second and third formants being the two somewhat lighter bands appearing approximately one-third of the way up the display.

Looking at these spectrograms, we learn two other things about these vowels that we would not have suspected from looking at the spectrum in

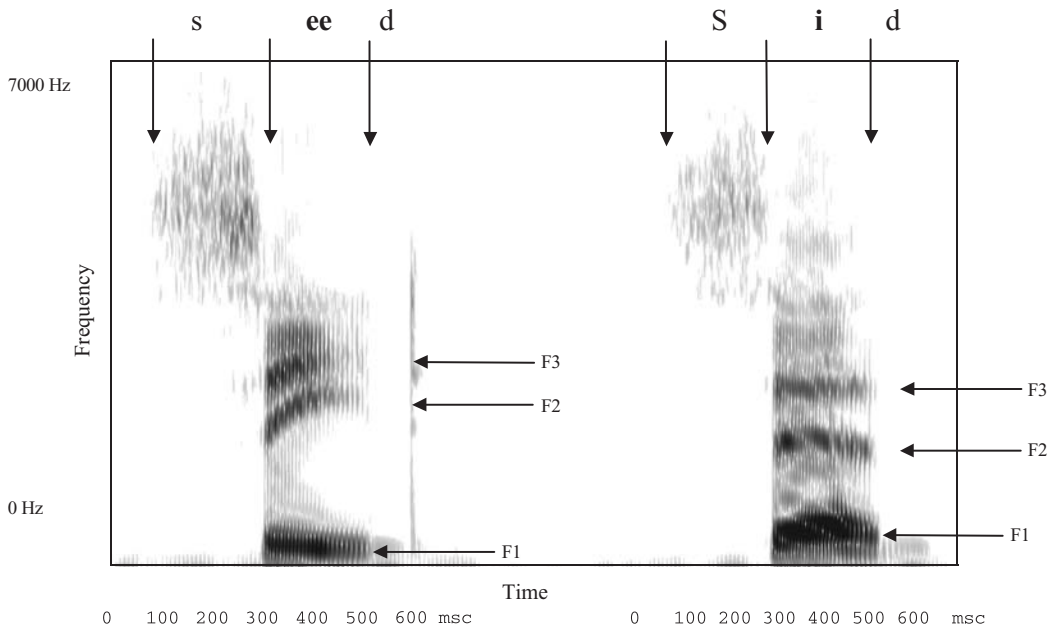


FIGURE 8  
Spectrograms

figure 7 taken from a single point in time. First, notice that the vowel portion of *seed* is longer than in *Sid*. Second, the frequencies of the formants change over time, so in *seed* the first two formants start out much closer together than they do in *Sid*, and then in *seed* the second formant rises over the first half of the vowel whereas in *Sid* the second formant falls.

A spectrogram is a reasonably informative and accurate display of properties of sound. It is less accurate than the spectrum at a single point, such as figure 7. A spectrogram is nothing more than a series of such spectra, where the more detailed amplitude information represented on the vertical axis in figure 7 is simplified to a less detailed and less reliable visual difference in darkness. It is also inefficient as a representation of the sound in two ways. First, as represented on a computer, it is bulky in comparison to a waveform, so that the above spectrogram is around eight times the size of the original waveform. Second, it is still difficult to interpret. While you can learn how to read a spectrogram of a word in a familiar language, and be fairly certain from inspecting certain properties of the display what word the spectrogram represents, even the most skilled of spectrogram readers require tens of seconds to interpret the display; the average person who has learned the basics of spectrogram reading would require a number of minutes and may not be able to correctly identify the utterance at all. Spectrograms are created either by special machinery or specialized computer programs, which are not always available. It is therefore quite impractical and also unnecessary to base the scientific study of language sound systems exclusively on spectrograms.

### 1.2.2 Articulation

Another way to analyze speech sounds is in terms of the arrangement of **articulators** – the lips, tongue and other organs of the vocal tract required to produce a particular speech sound. By appropriate positioning of articulators, the shape of the vocal tract can be changed, and consequently the sound which emerges from the vocal tract can be changed (much as different sized bottles produce different tones when you blow across the top). For the purpose of studying the production of speech, the most important articulators are the lips, teeth, tongue, palate, velum, pharynx and larynx.

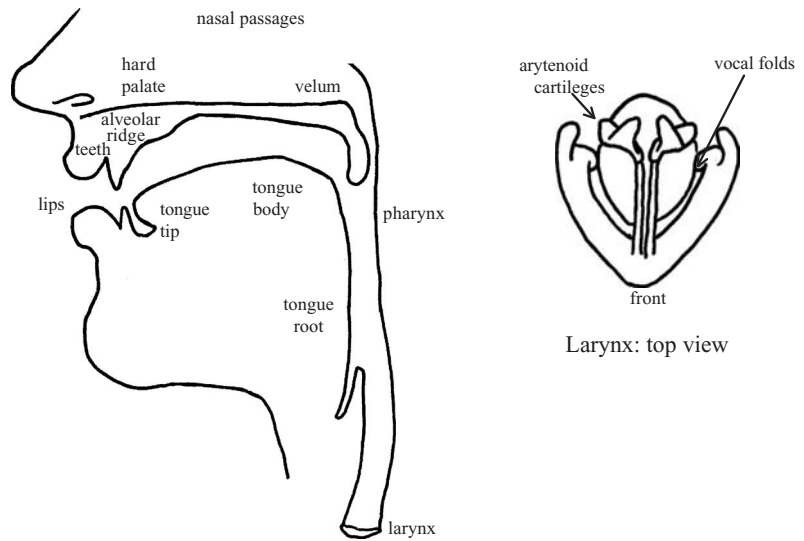


FIGURE 9  
Speech anatomy

Figure 9 illustrates the anatomical landmarks which are most important for the study of speech production.

Because sound production involves the manipulation of airflow, production of speech generally begins with the lungs which drive the air coming out of our mouths. Air is forced out of the lungs through the vocal folds, which act as a valve that goes through a repeated cycle of blocking and allowing air to pass from the lungs to the vocal tract. This repeated movement of air would produce a waveform that looks something like figure 10, which represents airflow through the vocal folds when a voiced sound (such as a vowel) is produced.

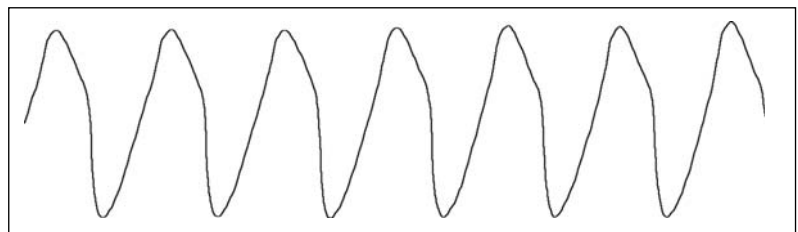


FIGURE 10  
Airflow through glottis

This wave is further shaped by the geometry of the vocal tract, which emphasizes certain frequencies and suppresses others. Thus the particular tongue shape that is characteristic of the vowel in *seed* – a higher and fronter position of the tongue – is responsible for the acoustic difference between that vowel and the vowel of *Sid*.

It is a fact of physics that a longer tube has a lower resonance frequency than a shorter one. The vocal tract can be treated as a series of tubes, where the resonance frequencies of different tubes correspond to different frequencies of formants. By placing the tongue in various positions or by protruding the lips, sections of the vocal tract are lengthened or shortened, and thus their resonances – formant frequencies – are lowered or raised. For example, the length of the vocal tract in front of the constriction formed with the tongue determines the frequency of the second formant. When the tongue is advanced as it is for the vowel in *seed*, the portion of the vocal tract in front of the tongue is rather short, and therefore this front part of the vocal tract has a high resonance frequency: and thus the vowel has a high value for F2. On the other hand, the vowel in *pool* is produced with the tongue positioned further back, which means that the part of the vocal tract in front of the tongue is relatively long – it is made even longer because when [u] is produced, the lips are also protruded, which lengthens the entire vocal tract. The effect of lengthening the front part of the vocal tract is that the resonance frequency is lowered, and thus the vowel in *pool* has a very low value of F2.

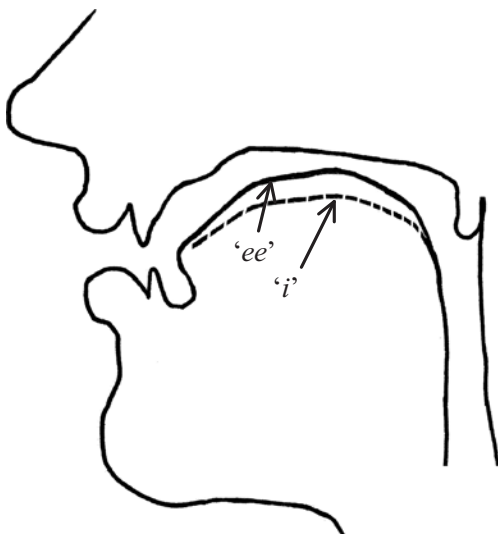


FIGURE 11  
Tongue position differences between *ee* and *i*

How vocal tract shape determines the acoustic output is the domain of phonetics. While the acoustic and articulatory properties of speech are important in understanding phonology, indeed constitute the foundation on which phonology is built, it is just that – the foundation. Phonology

looks at how these physical aspects of manifested speech are represented as part of the mental entity “language.”

### 1.3 The symbolic representation of speech

The English word *ground* is composed of six letters, and by happy coincidence, six distinct phonological sounds or, as they are called by phonologists, **segments**. But an inspection of what we can measure objectively in the acoustic signal, such as found in a spectrogram, shows no physical boundaries in the stream of sound pointing to exactly six distinct sound events. Instead, we find a continuously changing sound pattern, with the amplitude of the signal being stronger at a given time at certain frequencies than at others – corresponding to formant frequencies – where the frequencies of these peaks are constantly changing. For example, looking at the spectrogram in figure 12, one can see a sliver of a darker area in the lower quarter at the very left edge of the spectrogram, which is followed by a light area, and then a pattern of closely spaced vertical striations. Below the spectrogram, you can see points that provide approximate indications where each segment begins and ends, and this initial dark sliver followed by a light sliver constitutes the acoustic energy of the initial consonant [g]. While there seems to be a relatively clear break between the initial [g] and the following [r], the same cannot be said for any of the other adjacent sounds in this word.

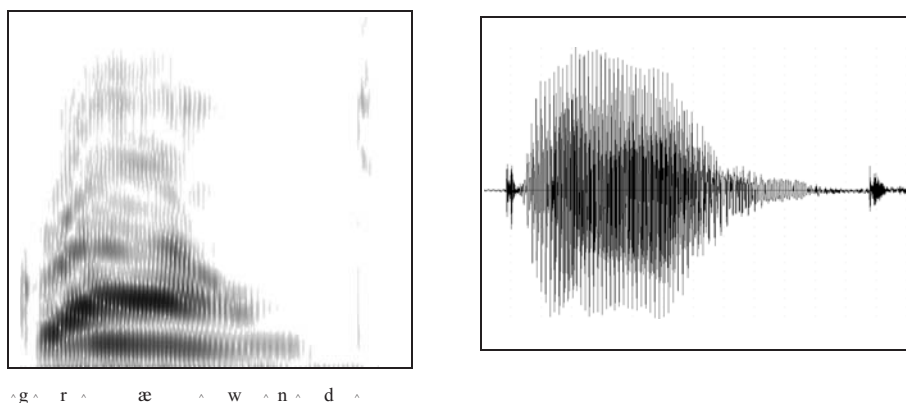


FIGURE 12  
Spectrogram

acoustic waveform

This points to one of the most basic properties of phonology, and clarifies another essential difference between phonetics and phonology. Phonetics studies language sound as a continuous property. A phonological analysis relies on an important idealization of language sound, that the continuous speech signal can be analyzed as a series of discrete

segments with constant properties. It is evident, looking at the portion of the spectrogram corresponding to *r*, that the physical properties of the *r* change continuously over time – this is true of the entire spectrogram. Yet the transcription simply indicated a single unit *r*, implying a clear beginning and end, and not suggesting that there is time-varying structure within *r*.

Both phonetics and phonology involve representations of sound. A phonetic representation can be given as a series of numbers, representing the three acoustic essentials – amplitude, frequency and time – or as an analogous description of the complex and continuously changing internal geometry of the vocal tract. Such a representation would be highly accurate, and is appropriate if the goal is to understand the fine-grained details of speech sounds as physical entities. For the purposes of grammar, physical sound contains way too much information to allow us to make meaningful and general statements about language sound, and we require a way to represent just the essentials of language sounds. A phonological representation of an utterance reduces this great mass of phonetic information to a cognitively based minimum, a sequence of discrete segments.

The basic tool behind this conversion of the continuous stream of speech sound into units is the phonetic transcription. The philosophy behind a transcription is that one can adequately represent all of the linguistically important details of an utterance by symbols whose interpretation is predefined. Phonology then can be defined as the study of higher-level patterns of language sound, conceived in terms of discrete mental symbols, whereas phonetics can be defined as the study of how those mental symbols are manifested as continuous muscular contractions and acoustic waveforms.

By way of introduction to the nature of a symbolic transcription, let us take the case of the word *ground* given above. The spelling *ground* is a poor representation of the pronunciation of the word, for scientific purposes. If you were to follow rules for pronunciation in other languages such as Portuguese, Spanish or Italian, you might think that the word spelled *ground* would be pronounced like *groaned*. The problem with spelling is that the letter sequence *ou* is pronounced one way in Portuguese, another way in French (the word would be pronounced more like *grooned* if French pronunciation rules were followed), and a third way according to English rules. We need a system for representing sounds, one which is neutral with respect to the choice of language being studied – a system which could be used to discuss not only languages with a long written history like Greek or Chinese, but also languages like Ekoti (a Bantu language spoken in Mozambique) which remains to this day largely unwritten.

In addition, English spelling is imprecise in many cases. The consonant in the middle of *ether* is not the same as the one in the middle of the word *either* (if it were, these words would be pronounced the same, and they are not). English has two distinct kinds of *th* sound, but both are represented the same way in spelling. Linguists adopt special symbols which are better suited to accurately representing speech in an objective manner, so

that anyone who knows the pronunciation of the symbols could pronounce a word of English (or Portuguese, Chinese, or Ekoti) written with those symbols with a high degree of accuracy. Thus, we would represent the word *ground* (as spoken by this author) as [græwnd], where [æ] represents the vowel found in *hat*.

The goal of phonology is not to provide accurate symbolic representations of speech. Rather, the goal is to understand the linguistic rules which operate on sounds mentally represented as symbols, and the transcription is our means of representing the data which we discuss. As it happens, the transcription [græwnd] does not really tell the scientist everything they need to know, in order to pronounce this word the same way as in figure 12. A transcription is, essentially, a measurement of a physical phenomenon, and like all measurements can be made with greater or less precision. This particular transcription is quite sufficient for most purposes (such as a phonetic dictionary of English, where knowledge of the systematic principles of the language's sound system might be taken for granted). A more precise transcription such as [kɹ<sup>w</sup>æ:wnd] could be required for another purpose, such as conveying information about pronunciation that is independent of general knowledge of rules of phonetic realization that exist in English.

The very idea of trying to render a highly information-rich structure such as an acoustic waveform in terms of a rather small repertoire of discrete symbols is based on a very important assumption, one which has proven to have immeasurable utility in phonological research, namely that there are systematic limits on what constitutes a possible speech sound in human language. Some such limitations may be explained in terms of physical limits on the vocal tract, so humans are not physically capable of producing the sound emitted by a dentist's high-speed drill, nor can humans produce the sound of a ton of dynamite exploding, but even restricting our attention to sounds which can be produced by the human vocal tract, there are very many sounds which humans can produce which are nevertheless not part of language. The basis for this limitation on speech sounds will be taken up in more detail in later chapters.

Interestingly, humans (especially standup comics) are capable of producing sounds which we understand as representing non-human sounds, even though they are not the actual sounds themselves. Even such sounds-representing-sounds are not part of the set of human speech sounds.

## Summary

Phonetics and phonology both study language sound. Phonology examines language sound as a mental unit, encapsulated symbolically for example as [æ] or [g], and focuses on how these units function in grammars. Phonetics examines how symbolic sound is manifested as a continuous physical object. The conversion from physically continuous event to symbolic representation requires focusing on the information that is important, which is possible because not all physical properties of speech sounds are cognitively important. One of the goals of phonology is then to discover exactly what these cognitively important properties are, and how they function in expressing regularities about languages.



## Exercises

These exercises are intended to be a framework for discussion of the points made in this chapter, rather than being a test of knowledge and technical skills.

1. Examine the following true statements and decide if each best falls into the realm of phonetics or phonology.
  - a. The sounds in the word *frame* change continuously.
  - b. The word *frame* is composed of four segments.
  - c. Towards the end of the word *frame*, the velum is lowered.
  - d. The last consonant in the word *frame* is a bilabial nasal.
2. Explain what a "symbol" is; how is a symbol different from a letter?
3. Give four rules of the phonological system of English, other than the ones already discussed in this chapter. Important: these should be rules about segments in English and not about spelling rules.
4. How many segments (not letters) are there in the following words (in actual pronunciation)?

sit	trap	fish
bite	ball	up
ox	through	often

5. Why would it be undesirable to use the most accurate representation of a spoken word that can be created under current technology in discussing rules of phonology?

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### Further reading

Fry 1979; Johnson 1997; Kelly and Local 1989; Ladefoged 2001; Levelt 1989; Liberman 1983; Stevens 1998; Zemlin 1981.



# 2 Phonetic transcriptions

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## PREVIEW

### KEY TERMS

*transcription*  
*vowels*  
*consonants*  
*place and*  
*manner of*  
*articulation*

This chapter gives an overview of phonetic transcriptions. It:

- ◆ gives the important transcriptional symbols
- ◆ introduces the two major schemes of phonetic transcriptions
- ◆ presents the main articulatory classifications of sounds
- ◆ surveys the main variations in phonetic properties exploited by languages
- ◆ further develops the relevance of phonetics for the study of phonology

Angled brackets, e.g. <sh>, represent spelling and square brackets, e.g. [ʃɪp], are for phonetic representation. Underlying forms, found in later chapters, are placed in slanted brackets, e.g. /ʃɪp/.

In phonetic transcription, speech is represented by a small set of symbols with a standard interpretation. This chapter looks at the different systems for phonetic transcription. There are two major schemes, the informal American scheme used especially in North America, sometimes known as APA (American Phonetic Alphabet), and the IPA (International Phonetic Alphabet), promulgated by the International Phonetic Association. The primary difference between these systems is that in certain cases the American scheme uses a regular letter plus a diacritic where IPA tends to use separate special characters. Thus the sound spelled <sh> at the beginning of *ship* would be transcribed as [ʃ] in the American system, but with the separate letter [ʃ] in IPA. There are relatively few differences between the two systems, and you should become familiar with both systems (actively with one and passively with the other). This text uses APA: the distinctly IPA symbols are given in section 2.3. In this chapter, we will aim for a general overview of transcription and articulation. The goal is not to have a complete account of these topics, but rather to mention the important phonetic symbols, so that the student has a working knowledge of basic transcription, as well as an introduction to the articulatory basis for speech sounds which will be referred to in discussing phonological processes.

## 2.1 Vowels: their symbols and properties

Conventionally, the first division in speech sounds is made between vowels and consonants. Symbols for vowels will be considered first, because there are fewer vowels than consonants. American English has a fairly rich vowel inventory, so we can illustrate most of the vowel symbols with English words.

(1)	Symbol	English equivalent
	i	beat [biyt]
	ɪ or I	bit [bɪt]
	e	bait [beyt]
	ɛ	bet [bɛt]
	æ	bat [bæt]
	a	cot [kat]
	ɔ	caught [kɔt]
	o	coat [kowt]
	ʊ or U	could [kud]
	u	cooed [kuwd]
	ʌ	cud [kʌd]
	ə	(unstressed vowel in) 'array' [əréy]

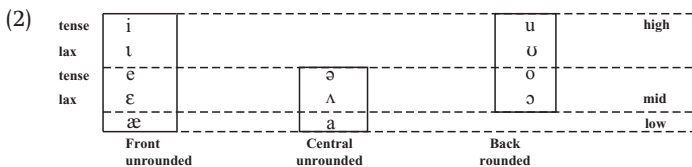
The glides *y* and *w* in the transcription of tense vowels in English reflect the phonetic diphthongal quality of these vowels, which is especially evident when one compares the pronunciation of English *say* and Spanish *se*. There are different ways of transcribing that vowel, e.g. [se], [se:], [sei], [sei], [se<sup>l</sup>] and [sey]. Transcriptions like [se] or [se:] are much broader, that is,

reveal less of the phonetic details of English because they suppress the information that this is phonetically a **diphthong** – which can be predicted by a rule – whereas [sei], [seɪ], [seʔ] and [sey] report this phonetic property. There is little scientific basis for picking a specific one of these latter four transcriptions as a representation of how the word is pronounced, and you are likely to encounter all of them in one source or another.

Some dialects of English make no distinction in the pronunciation of the words *cot* and *caught*; even among speakers who distinguish the pronunciation of *cot* and *caught*, the precise pronunciation of the two vowels differs considerably. An important point developed in this book is that transcriptional symbols are approximations representing a range of similar values, and that symbols do not always have absolute universal phonetic values.

A diphthong is a sequence of vowel-like elements – vowels and glides – in one syllable.

**Tongue and lip position in vowels.** Values of phonetic symbols are defined in terms of a variety of primarily articulatorily defined phonetic dimensions as in (2).



The three most important properties for defining vowels are **height**, **backness**, and **roundness**. The height of a vowel refers to the fact that the tongue is higher when producing the vowel [i] than when producing [e] (which is higher than that used for [æ]), and the same holds for the relation between [u], [o] and [a].

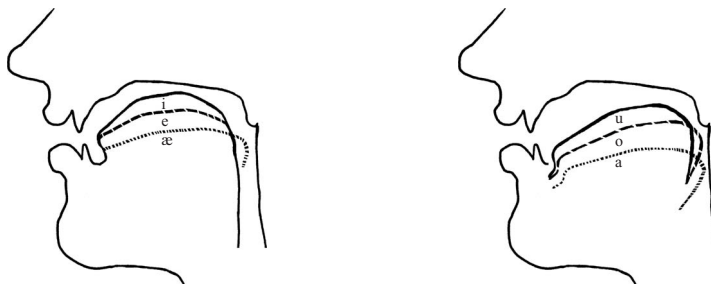


FIGURE 13  
Tongue position of vowels

Three primary heights are generally recognized, namely **high**, **mid** and **low**, with secondary distinctions introduced either under the name **tense** ~ **lax** or **close** ~ **open** to distinguish vowel pairs such as [i] (*seed*) vs. [ɪ] (*Sid*), [e] (*late*) vs. [ɛ] (*let*) or [u] (*food*) vs. [ʊ] (*foot*), where [ieu] are tense (close) and [ɛʊ] are lax (open). Tense vowels are higher and often less centralized compared to their lax counterparts.