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Chapter 3

The Sound Structure of Mawu Words: A Case Study in the Cognitive Science of Speech

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3.1 Introduction

The most intimate and habitual things in life are sometimes hard to see objectively. For instance, it seems natural and inevitable for human communication to depend on spoken words, even though this requires tens of thousands of arbitrary connections between noises and concepts. It seems natural and inevitable for human children to learn these connections over the course of a decade or so, even though this requires analyzing the behavior of adults emitting concatenations of noises referring to logically structured combinations of (often very abstract) properties of experiences. These facts are so obvious and familiar that it is not easy for us to appreciate what a strange and wonderful achievement they represent, and how far from obvious it is that this is how a system for communication among intelligent creatures should be designed.

Human vocal communication has some characteristics that are not logically necessary and are nonetheless remarkable for being so ordinary that they are hardly ever noticed.

1. Each language includes a large number of distinct words whose sound and meaning are not genetically given and therefore must be learned.
2. The number of words that are learned (estimated by Nagy and Herman (1987) to be at least forty thousand for modern American high school graduates), and the number of years available for learning them, imply that about ten words must be learned every day, on average, over a period of ten to fifteen years.
3. Most words are learned simply by observation of their use, rather than from explicit instruction, and the number of observations on which word learning is based is often small.
4. In using this large word stock, people maintain an extraordinary degree of agreement about what words were said, despite large

> individual, geographic, and social differences in pronunciation: in an experiment reported by Doddington and Hydrick (1978), isolated words, selected at random from a set of forty thousand, each pronounced by a different and unknown speaker, were recognized by consensus of a panel of judges with an error rate of only about 2 percent.

This situation might have been different. For instance, Cheney and Seyfarth (1990) indicate that the vervet monkey's repertory of meaningful cries is genetically fixed to a substantial degree, although the number of different classes of cries identified in this case is only about ten. Some philosophers of language have argued that there is a fixed stock of basic human concepts, and so our species might have saved us all from international communications barriers—not to speak of language requirements—by expanding a system like the vervet monkey's. We might have tried to get along with a few hundred such built-in vocal symbols, using our ability to combine words into phrases whose meaning is determinable from the meaning of their parts, and our skill in pointing, making air pictures with our hands, and so on.

This is not, however, the path that human evolution has taken. Instead, each human language develops its own rather large set of essentially arbitrary vocal signs, roughly what we normally call "words." Exactly how large this set is depends on how you define its members: we do not need to count *cats* if we already have *cat*, but does *building* add to the count if *build* is already counted? What about *red herring* if we already have *red* and *herring*? The size of this set may also depend on the language (or perhaps the culture) examined. Nevertheless, if we define "word" as a piece of language whose conventional form and meaning cannot be predicted by composing smaller units contained in it, then it seems likely that normal speakers know something in the range of 10,000 to 100,000 words of their native language. The cognitive (and social!) problem of establishing such a large number of essentially arbitrary sound-meaning correspondences, and ensuring that individual children learn them in such a way as to end up able to communicate with one another across groups as well as within family groups, is a daunting one.

How do we do it?

Well, some might say that we do not. Perhaps human lexical accomplishments have been exaggerated a bit. After all, most talk is on some identifiable topic or another, restricting the likely vocabulary to a few thousand words. Within and across topics, we often use highly stereotyped word sequences; thus, the actual average uncertainty about what the next word will be is typically under a thousand and may often be under a hundred. Even so, we suffer plenty of mishearings and other communication failures.

Although these caveats have some validity, they do not change the earlier estimates of vocabulary size, learning rate, and accuracy in word transmission under good conditions. The difficulty and interest of the problem is increased by the fact that much more than words goes into the noises someone makes when talking. Speech sounds are modulated in a way that also communicates who you are, how you feel, what kind of impression you want to make, the structure of your message, and the process by which you compose it. Furthermore, what your addressee hears will be considerably changed by where you are talking (a shower stall, an office, a cathedral), by noises around you (running water, other voices, traffic, music), and perhaps by various unnatural means of transmission such as a telephone or public address system.

Somehow, listeners usually manage to hear the words that were spoken despite (or more precisely, in addition to) all these other things, both the extralexical modulations added by the speakers and the distortions imposed by the environment. This ability further emphasizes the nontrivial character of the central question: How do humans efficiently learn, remember, and use such a large number of distinct equivalence-classes of vocal noises, which we call *words*?

The answer is *phonology*—or more precisely, the linguistic sound structures that phonology studies. The rest of this paper is devoted to explaining what these sound structures are like.

The basic principle of phonology is that the notion "possible word of language X," from the point of view of pronunciation, is defined in terms of structured combinations of a small number of basic meaningless elements. Phonologists have developed a variety of theories about what these elements and structures are. The simplest idea is to suppose that the basic phonological elements are like the letters of an alphabet, each of which represents a type of vocal gesture or sound. Then phonological structures are simply strings of such letters (usually called *phonemes*), with sequence in the string representing succession in time. In fact, there is a special alphabet, known as the International Phonetic Alphabet (IPA), which aims to provide enough symbols to represent all the crucial distinctions in all the languages of the world (even though the sounds associated with an IPA symbol typically vary somewhat from language to language).

This alphabetic approach is enough to provide a basic description of the phonological system of any given language. It is possible to provide an inventory of phonemic symbols for that language so that all its words can have the distinctive aspects of their sound defined in terms of strings of those symbols; it is also possible to provide an account of the articulatory and acoustic meaning of such strings of symbols. Traditionally, the study of the distribution of phonemic symbols is the domain of the field of phonology, while the physical interpretation of those symbols is the domain of the field of phonetics.

This simple theory is enough to clarify how humans can learn, remember, and use such a large number of different words. Words are not arbitrarily distinct classes of vocal noises. Instead, a word's claims on sound are spelled out in terms of the phonological system of some particular language. This splits the problem, conceptually speaking, into two parts. Learning a given language requires figuring out what its phonological system as a whole is and how structures of phonological elements are related to vocal noises, independent of any consideration of particular words. Learning the sound of any particular word, then, requires only figuring out how to spell it phonologically. This phonological spelling is a relatively small amount of information, which might be inferred from a couple of hearings. A phonological spelling nevertheless suffices to predict the wide range of ways in which the word might be spoken by different speakers on different occasions in different contexts, because it is the phonological system as a whole that is anchored to sound. Learners' knowledge of the physical grounding of a phonological system is therefore based on every bit of experience they have ever had in talking, or listening to, the language in question, and all this experience can be brought to bear in processing any particular word.

Careful consideration of the facts of individual languages suggests that it is more insightful—scientifically more interesting—to decompose phonemic letters into smaller pieces (called *features*), organized into simple phonological structures of which syllables are the most familiar example. In this view, phonemic segments—as represented by the letters of the IPA—are actually just convenient names for pieces of these phonological structures. Hypotheses about this type of phonological organization arise naturally out of efforts to define the sound structure of words in particular languages and to model the phonetic interpretation of these structures. Such investigations indicate that the theory of phonemic letters, taken literally, is not a very good model for any particular phonological system; also, it tends to make the phonology of different languages look much more variable than it really is. When we replace a rigidly alphabetic theory of phonology with one based on structured combinations of phonological features, we get a more insightful analysis of individual languages, and we also find that the same sorts of phonological features and structures arise in the analysis of widely separated and apparently unrelated languages.

The human species has not evolved a fixed set of words. We have not even evolved a fixed set of phonemes or syllables out of which to make words. What we have evolved, it seems, is a set of basic phonological features and structures capable of specifying a wide variety of phonological systems, each of which in turn is capable of specifying the sound patterns of a set of words. This amounts to a sort of parts inventory and tool kit for designing and building the pronunciation systems of languages.

When a group of humans use this tool kit to set up a phonological system and to define the sound of a set of words in terms of it, they are ordinarily not at all aware of what they are doing, despite the considerable complexity of the problem. Doing phonology, in this practical sense, is something that just comes naturally. Each of us participates especially actively in this process during the first few years of our life; indeed, most of us are unable to achieve fully native abilities in a phonological system that we encounter later in life, no matter how carefully we study and how much we practice.

Of course, the process of creating a phonological system is never really carried out starting from nothing. Instead, an existing system is learned again by each individual, while new words are constantly added, old words die out or change their nature, and the phonological system as a whole is gradually redefined in an evolutionary process. Throughout this process of constant renewal and change, the sound system as a whole remains relatively consistent across the speech community; it retains its coherence as a system for each individual, despite the fact that speech communities throughout human history have not had official bodies such as the Académie Française to act as language police. Phonological systems remain lawful because the cognitive architecture of the human species requires them to do so.

3.2 Words in Mawu

The best way to make these basic ideas clear is to work through a concrete example in a certain amount of detail. From this perspective all human languages that have ever been studied exhibit the same basic patterns, even though their particular phonological alphabets and syllabic arrangements vary widely. As a characteristic example, we will take a look at *Mawu*, which is spoken by about 100,000 people in the Ivory Coast and Guinea. *Mawu*[1] is the name of a region, *Mawuka* is what the people who live there call themselves, and *Mawukakan* is what they call the language that they speak. Mawu is a Manding language, closely related to other languages such as Bambara and Mandinka that are spoken by millions of people in West Africa. The information and insights about Mawu in this chapter come primarily from the work of Moussa Bamba, especially Bamba (1991), and his help and advice are gratefully acknowledged. Remaining errors of fact or interpretation are the fault of the author of this chapter.

At first inspection Mawu has some unusual characteristics, such as three different kinds of nasalized vowels and a system of lexical tone with complicated rules for determining the tonal patterns of compound words

1. Also spelled "Mau," or "Mahou" in French orthography.

and phrases. The themes and concepts that emerge from a careful analysis of Mawu are, however, essentially the same ones that would emerge from a careful consideration of the phonology of any language. In fact, the things about Mawu phonology that are superficially most peculiar will turn out, when properly analyzed, to be strikingly similar to the comparable aspects of much more familiar languages such as French and Japanese. This abstract similarity points us toward the basic cognitive architecture underlying human speech.

It will be clearest to start with a conventional phonemic analysis, resulting in a set of phonological "letters" that can be arranged to specify the sound patterns of Mawu words. This will prepare the ground for a more insightful analysis in terms of structured combinations of phonological features.

Mawu has a simple syllable structure, compared with English, with all words aside from pronouns being made up of syllables consisting of a single consonant and a following vowel (like /ko/ "to say"), a single consonant and a following double or long vowel (like /koo/ "bone, pit, seed"), or a single consonant, one of the two *glides* symbolized in English by the letters *w* and *y* and a single following vowel (like /kwo/ "tail"). We simply need to specify what the set of consonant and vowel "letters" can be to fill out these patterns completely.

In this approach, Mawu has twenty-four consonant phonemes and twenty vowel phonemes. The nature of these "letters" of the Mawu lexical alphabet is indicated in tables 3.1 and 3.2, which are arranged in rows and columns to help indicate the nature of the corresponding mouth gestures. These tables (and also the Mawu examples that we provide) use a selection from a special set of letters called the *International Phonetic Alphabet*, or IPA, which forms a sort of universal standard for representing speech sounds. In this chapter IPA characters are used to write down Mawu examples (although a few liberties are taken with the IPA standard with respect to the notation of the second and third types of nasalized vowels).

Mawu is also a tone language, in the sense that words are distinguished according to their pitch patterns. Thus /kawa/ said with high pitch means "stone," /kawa/ said with low pitch means "cloud," and /kawa/ said with rising pitch means "shoulder." Tonal phenomena will be disregarded until the basic nontonal aspects of Mawu phonology have been presented.

The tour of Mawu phonemes begins with the seven oral vowels and the first two types of nasal vowels.

The seven oral vowels in the left-most panel of table 3.1 refer roughly to the standard American English sounds /i/ as in "beet," /e/ as in "bait," /ɛ/ as in "bet," /a/ as in "bott," /ɔ/ as in "bought," /o/ as in "boat," /u/ as in "boot." The top-to-bottom dimension in the panel represents *vowel height* or *openness*, with higher positions on the page corresponding to a higher position of the tongue and thus also to a more closed, less open

Table 3.1
Seventeen basic Mawu vowels.

Oral vowels	Nasal vowels I	Nasal vowels II
i u	ĩ ũ	
e o	ẽ õ	
ɛ ɔ	ɛ̃ ɔ̃	ɛ̰ ɔ̰
a	ã	a̰

vocal tract. The left-to-right dimension in each panel of the chart very roughly divides the vowels according to front-to-back position of the tongue in the mouth, so that the tongue is raised farthest forward for /i/ and raised farthest back for /u/. Finally, the three vowels closest to the right (that is, back and high) corner of the panel—/ɔ/, /o/, /u/—are *rounded,* which is to say that they are made with rounded and protruded lips, while the other four vowels are *unrounded.*

The seven corresponding nasal vowels, in the middle panel labeled "nasal vowels I," are pronounced with just the same positions of tongue and lips, but with the *velum* (the back part of the soft palate) lowered, as it would be in American English for /ĩ/ in "mean," /ẽ/ in "main," /ɛ̃/ in "men," /ã/ in "mom," /ɔ̃/ in "dawn," /õ/ in "moan," /ũ/ in "moon."

If the nature of the nasal vowels is not clear to you, try comparing the oral vowel in (for instance) "bee" with its nasal counterpart produced by saying "bean" without actually pronouncing the final /n/. After a little practice you should be able to sense your velum going up and down while you keep your tongue and lips in the same place, to make oral and nasal versions of each vowel. If you can do that, then you are making the distinction between the Mawu words /bi/ meaning "bag" and /bĩ/ meaning "grass." Similarly /cɛ̃/ (pronounced somewhat like the name "Chen" without the final /n/) means "animal fat," while /cɛ/ (pronounced like the name "Chet" without the final /t/) means "man."

For speakers of Mawu, the seven nasal vowels are first-class phonological elements, familiar from the cradle, and not just the indirect consequence of a vowel adjacent to nasal consonants, as in English. In fact, Mawu speakers learn to distinguish two additional kinds of nasal vowels.

The nasal vowels that we have labeled type "I" are by far the most common, which is why we have given them the first roman numeral. The three vowels in the rightmost panel, labeled "nasal vowels II," are very similar in pronunciation to the type I nasal vowels. Thus, it is not always easy to tell the difference between /cɛ̃/ "animal fat," which has a nasal vowel of type I, and /cɛ̰/ "sand," which has a nasal vowel of type II.[2]

2. We are again disregarding tone here—the word for "animal fat" has high tone while the word for "sand" has low tone.

There are, nevertheless, several differences showing clearly that a phonological distinction exists in such pairs of words—a difference in the time course of nasality, a difference in effect on the beginning of following words, and a shift in vowel quality.

1. In very slow and careful speech, the nasal vowels of type I start out nonnasal, becoming increasingly nasal toward the end, whereas the nasal vowels of type II are fully nasal from the beginning.
2. Nasal vowels of type I cause characteristic changes in following consonants, while nasal vowels of type II (usually) do not. Thus when the word /lɑɑ/ meaning "jar" is combined with the words for "sand" and "animal fat," the initial /l/ changes to /n/ following the type I vowel but not the type II vowel: /cɛ̃ nɑɑ/ "jar of lard," but /cɛ̰ lɑɑ/ "jar of sand."
3. Especially in the case of the vowel we are writing /ɑ/, type II nasality causes a shift in vowel quality. The vowel /ɑ/, which is normally similar in sound to the vowel in standard American English "father," has as its closest type II equivalent a nasalized version of a vowel that in IPA is written [ə] and pronounced somewhat like the vowel in American English "cut." Thus, the type II nasal vowel in /sɑ̰/ meaning "snake" is something like American English "sunk" before the final consonants, while the type I nasal vowel in /sɑ̃/ meaning "rain" retains the basic /ɑ/ quality, with added nasality as might be heard in American English "psalm" before the final consonant.

In notating this second series of nasal vowels, the standard IPA notation is being abused a bit, since the IPA provides only one way to mark vowel nasality, and we have just shown that Mawukakan seems to need two. The notation used here for the second type of vowel nasality borrows the symbol (underdrawn tilde) specified by the IPA for vowels with "creaky voice," since Mawu does not use creaky voice distinctively.

Type II vowel nasality divides Mawu vowels into two groups: /ɑ/, /ɛ/ and /ɔ/, which have type II nasal versions, and /i/, /e/, /o/ and /u/, which do not. A corresponding distinction among vowels is frequently seen to play a role in the phonology of the world's languages. This distinction is especially salient in some of the other languages of West Africa, where words are ordinarily made up of vowels drawn from only one class or the other. As a result, the nature of the vocal tract gestures involved in this distinction has been carefully studied using X-rays and other methods, with the conclusion that in the vowels of the /i/ /e/ /o/ /u/ class, the root of the tongue is drawn forward, expanding the throat (or *pharynx*) cavity, while in the vowels of the /ɑ/ /ɛ/ /ɔ/ class, the root of the tongue is back, resulting in a narrower pharynx. The gesture involved in the first set of vowels is called Advanced Tongue Root, abbreviated ATR, and phonologists use this convenient abbreviation as a description for the gesture and for the corresponding class of vowels. We can say that Mawu type II nasality only occurs in non-ATR vowels.

In fact, the nasal vowel situation in Mawu is even more complex, at least superficially, than has been indicated so far. There are some words containing non-ATR vowels that share characteristics of both kinds of nasalized vowels. For example /ka̰ã̰/ "love" and /mjã̰/ "antelope" have the shift in vowel quality characteristic of type II nasal vowels and also are fully nasalized throughout slow and careful pronunciation like type II nasal vowels; but at the same time they have the effects on following consonants typical of type I nasal vowels.

Since we have not run out of roman numerals, even though we have run out of IPA symbols, we can call vowels of this last class "type III nasalized vowels." Since they exhibit simultaneously characteristics of type I and type II, we can symbolize them in a phonemic notation by combining the diacritic mark for type I (a tilde above) with the diacritic mark for type II (a tilde below).

The existence of three distinctive types of vowel nasality is unusual—which is why the IPA does not provide for it—and might be seen as an example of the endless variability of human speech patterns. However, a consideration of the distribution of phonological features (including nasality) in Mawu syllables and words will suggest a simple reanalysis based on elements and structures that are familiar to phonologists from the analysis of many other languages. This analysis will simultaneously clarify the nature of Mawukakan and the nature of human phonological systems in general, providing a nice example of the limitations of the alphabetic metaphor, as well as a motivation for the kinds of structured combinations of features that modern phonologists postulate to explain the sound patterns of words.

First, some additional information about the phonological inventory of Mawu is needed. The set of possible consonants in Mawu is given in table 3.2.

The column labels in table 3.2 specify the *place of articulation* of the Mawu consonants. Consonants involve closing off the vocal tract, partially or completely, while in vowels the vocal tract is basically open. The closure for a Mawu consonant can occur at five different places: at the lips (a "labial" consonant such as /p/ or /b/), at the *alveolar ridge* just in back of the upper incisors (an "alveolar" consonant such as /t/ or /d/), on the hard palate a little further into the mouth (a "palatal" consonant made in roughly the same place as the consonant in English "chew"), on the soft palate still futher back in the mouth (a "velar" consonant such as /k/ or /g/), or in the larynx or "voice box" (a "glottal" consonant such as /h/

Table 3.2
Twenty-four Mawukakan consonants.

			Labial	Alveolar	Palatal	Velar	Labiovelar	Glottal
obstruents	stops	voiceless	p	t	c	k	k͡p	
		voiced	b	d	ɟ	g	g͡b	
	fricatives	voiceless	f	s				
		voiced	v	z				
implosives			ɓ	ɗ				
sonorants	nasals		m	n	ɲ			
	approximants			l	j	ɯ	w	h

or the consonantal sound in English *unh-unh* meaning "no"). Mawu also has "labiovelar" consonants, in which both labial and velar closures are made at the same time, sort of like saying /k/ and /p/ or /g/ and /b/ simultaneously.

The rows in table 3.2 specify the *manner of articulation* of the Mawu consonants. Thus, a consonant whose *place of articulation* is *alveolar*—that is, whose constriction is made with the tip or blade of the tongue pressing against the alveolar ridge, just behind the top front teeth—can be of six different kinds, according to how the constriction is made, and what is happening elsewhere in the vocal tract. There are three distinct kinds of constriction in Mawu: a complete constriction (producing a *stop*); a nearly complete constriction with a turbulent flow of air through a narrow opening (producing a *fricative*), and an incomplete, relaxed constriction (producing an *approximant*). These possibilities are further distinguished by *voicing* and *nasality*. In *voiced* consonants the vocal cords (two muscular folds of tissue in the larynx) are kept together; thus, the buzzing sound typical of vowels is continued through the consonant closure, whereas in *voiceless* consonants the vocal cords are spread apart; thus, the laryngeal buzz stops during the closure and for a short time after. In *nasal* consonants, just as in nasalized vowels, the velum is lowered so that the sound is affected by the resonances of the nasal cavity.

Finally, Mawu has *implosive* consonants, in which the vocal folds are kept closed and vibrating, as in voiced consonants. The larynx is lowered during the consonant closure, so that when the closure is released, air actually flows briefly into the mouth instead of out of it. It is not clear whether to consider this special laryngeal maneuver as a different kind of voicing, or as a different kind of constriction. For convenience of tabular display, implosives are laid out in tables 3.2 and 3.3 as if they involved a different kind of constriction.

There are then sixteen logically possible combinations of the three features of constriction type, voicing, and nasality: 4 × 2 × 2. Mawu makes distinctive use of only seven of these, as table 3.3 indicates.

Table 3.3
Combinations of consonant features for alveolar place.

	Velum closed (nonnasal)		Velum open (nasal)	
	Voiced	Voiceless	Voiced	Voiceless
Stop	d	t	n	
Fricative	z	s		
Implosive	ɗ			
Approximant	l			

This kind of partial cross-classification is typical of the sound systems of the world's languages. Voiceless nasal consonants do exist (for example, in Burmese), but they are quite rare. It is similarly rare for distinctive nasality to apply to fricatives and approximants. These restrictions are natural, given the physical characteristics of the articulations and sounds involved. For instance, it is difficult to maintain sufficient oral air flow for a fricative if the nasal passages are open; similarly, the basic gesture producing an implosion supposes that the vocal folds are brought together as in voiced speech, that the nasal passages are shut off, and that the oral constriction is complete.

Since these features do not interact orthogonally (that is, not all logically possible combinations in fact occur in Mawukakan phonemes), it is initially tempting to regard them as an analytic artifact, imposed because an analysis of articulatory mechanisms is most easily framed in terms of such a decomposition, but playing no real role in the cognitive structure of Mawu (or English) speech. Further investigation, though, will show that this kind of featural decomposition is essential to understanding the larger-scale sound structure of words, the variations in word pronunciation according to context, and the way that word pronunciations change over time.

In fact, a much greater degree of nonorthogonality arises in the way that basic phonological elements combine into words. These basic elements have just been described for Mawu as a set of phonemic letters in terms of which Mawu spells its words. This phonological alphabet is not actually a writing system, except insofar as a few linguists have used something like it—the Mawuka do not use their language in writing. Rather, it is a sort of theory about the cognitive structure of Mawu speech, just as similar phonological alphabets represent theories about the speech patterns of speakers of every other human spoken language. There is, however, much more to the cognitive structure of speech, among the Mawuka as among any other people, than such a phonological alphabet alone.

Mawu words are not composed of just any sequence of such phonemic segments. Among the types of sequences that do not occur are some that we may plausibly consider unpronounceable: /ptpkt/ or /mksbpi/. Some sequences that seem quite natural to English speakers are impossible in Mawu: /let/ (which would be pronounced like English "late"), /stej/ (like English "stay"), /ɑjl/ (like English "aisle"), and so on. On the other hand, Mawukakan has word structures that English speakers find difficult: /g͡bɛ/ (meaning "palm wine"), /k͡pako/ (meaning "coconut").

These sequence restrictions, in Mawu or in English, are based on a sort of phonological syntax, in which syllables are a typical constituent type. In discussing the internal structure of syllables, it is convenient to notate consonants with capital C and vowels with capital V. In table 3.4, capital G

Table 3.4
Mawu syllable types.

CV	/ɓa/ "goat"	/so/ "horse"	/ku/ "yam"	/je/ "squash"
CVV	/ɓaa/ "poison"	/saa/ "pistachio"	/kuu/ "bump, hill"	/joo/ "wing, feather"
CGV	/ɓja/ "loincloth" /fwo/ "to greet"	/ɓwɛ/ "medicine"	/swa/ "monkey"	/sja/ "road"

is also used to mean one of the glides /w/ or /j/ (as in the beginning of English "wash" and "yes"). Leaving aside pronouns, Mawu words are made up of syllables of the three types shown in table 3.4: consonant-vowel, consonant-vowel-vowel, and consonant-glide-vowel.[3]

Mawu words can be made up of several such syllables in a row, even in the case of simple (or *monomorphemic*) words that do not contain other words or identifiable pieces of words within them. Thus, we have

CVCV	/sama/	"elephant"
CVCGV	/ɲakwa̰/	"cat"
CVVCV	/fɛɛla/	"orphan"
CGVCVV	/ɗjemuu/	"citrus fruit"
CVCVV	/manɔɔ/	"kind of fish"
CVVCVV	/ɲɔɔmɛɛ/	"camel"
CVCVCV	/jabibi/	"pineapple"

Phoneme sequences that cannot be constructed by concatenating the three basic types are systematically absent from Mawu. For instance, there are no words with the form. *CVC, *CVVV, *CGVV, *CCV, *VCV (where the asterisk is used, as in syntactic examples, to mean that the form in question is not grammatically possible). This is the first reason to postulate syllablelike structures in Mawu: it enables us to give a simple account of the possible phoneme sequences in Mawu words. From what we have seen so far, Mawu words are just concatenations of the three basic syllable types. When we take a look at the distribution of the two types of vowel nasality, the evidence will become more complex; but the conclusion will stand: Mawu words are concatenations of Mawu syllables.

In the permitted CVV syllable type, the two vowels are always the same. Sequences like /toi/ or /kɛa/ are not found in Mawu. Thus, we might consider treating CVV syllables as containing long vowels—the IPA provides a symbol for this, /ː/, so that we could write the word meaning "hill" as /kuː/ instead of /kuu/. This notation certainly expresses

3. A small number of Mawu words borrowed from Arabic begin with a vowel, such as /ala/ "God". In most other cases, borrowed words that ought to begin with a vowel are borrowed as consonant-initial, such as /mobili/ "automobile," /burama/ "Abraham."

something true about Mawu; namely, that a syllable can have only one specification of vowel quality, even if it has two vowel segments in it. At this point the notion of a phonemic alphabet is beginning to lose its coherence, since we are either introducing a symbol that just means "repeat the previous vowel" or stating that a specification of vowel quality is shared by two adjacent symbols.

One piece is missing from the discussion so far: a demonstration that /kuu/ "hill" ends in two segments of the same type that /ku/ "yam" ends in one of. Granting that /kuu/ has the same vowel quality as /ku/ and that (allowing for speech rate, emphasis, and other sorts of timing modulation) /kuu/ is longer than /ku/, perhaps we should model vowel length as a feature, like consonant voicing, that can be present or absent in a single vowel segment. This hypothesis would simply double the number of Mawu vowel symbols by introducing a new series of long vowel phonemes, just as we introduced two (or even three) series of nasalized vowel phonemes.

Strong evidence against this length-as-a-feature analysis is provided by a Mawu language game called /ŋgoɓooɓo/. This game is similar in spirit to games familiar to English-speaking children, such as pig latin—children use it as a way to disguise their speech from those unfortunates who don't understand the rules or who are not practiced enough to decode rapidly. In /ŋgoɓooɓo/, the basic rule is to replace every vowel V with the sequence /VɓV/, where the second V is a copy of the original. Thus /ku/ "yam" becomes /kuɓu/, and /bisɑ/ "whip" becomes /biɓisɑɓɑ/.

What about /kuu/ "hill"? If this word contained a single long vowel, we would expect the /ŋgoɓooɓo/ version to be /kuːɓuː/. Such a form, however, would provoke any Mawuka child to laughter. The correct outcome for /kuu/ is /kuɓuuɓu/, which is exactly what should happen if each of two separate vowels in /kuu/ is given its own /ŋgoɓooɓo/ expansion.

There is one apparent exception to the Mawu rule that the two vowels in a CVV syllable must be the same. This exception provides one more distinction between type I and type II nasalization. Remember that type I nasalization nasalizes only the end of its vowel, at least in sufficiently slow and careful speech, and spreads to the initial consonant of the following syllable in all kinds of speech, whereas type II nasalization nasalizes all of its vowel, does not spread to following consonants, and produces a change in vowel quality in /ɑ/. Since this change in vowel quality is a useful signpost, our initial discussion of the distribution of Mawu vowel nasality will focus on /ɑ/.

Type II nasalization acts like any other vowel feature with respect to VV sequences: If one of the adjacent vowel segments has type II nasalization, then both must. Thus, there are words such as /dɑ̰ɑ̰/ "curse," /sɑ̰ɑ̰/ "funeral," /fɑ̰ɑ̰/ "power," in which two adjacent identical vowels also share type II nasalization. There are no words containing sequences such as /ɑɑ̰/ or /ɑ̰ɑ/, in which two adjacent vowels differ in type II nasalization.

The distribution of type I nasalization in CVV syllables is, however, completely different. There are many CVV words in which the first vowel is not nasalized at all, while the second vowel has type I nasalization: thus /cɑɑ̃/ "peanut," /ɓɑɑ̃/ "dike," /kɑɑ̃/ "to sew." There are no words containing VV sequences such as /ɑ̃ɑ/ or /ɑ̃ɑ̃/.

Type I nasalization, unlike all other vowel features, is thus limited to the very end of such syllables. It cannot apply to the first of a pair of non-ATR vowels, unlike all other vowel features, which must be shared by both vowels in such a case. Even in a CV syllable, it only affects the end of the vowel, at least if speech is slow enough to permit such a contour of nasality to be distinguished. Furthermore, it readily spreads to influence the initial consonant of a following syllable in a systematic pattern according to which voiceless consonants become voiced; voiced stops and fricatives become prenasalized (that is, they acquire a short nasal segment at their beginning); and glides, liquids, and implosives all become the corresponding nasal consonants. Nasal consonants are not affected. Examples of these outcomes are given in table 3.5 for the labial and alveolar consonants. These examples have been constructed using the word /jɑ̃/, meaning "here"; in combination with a following noun X, it means something like "X of this place," or "local X."

The pattern exemplified in table 3.5 has certain well-defined structural limits. For instance, it does not apply between the end of one syntactic clause and the beginning of the next, or even between a verb and a following adverbial. These limits provide some interesting clues of a

Table 3.5
Mawu nasal assimilation.

Consonant	Result	Example
p	mb	/jɑ̃/ + /pinɛ ⇒ [jɑ̃mbinɛ] "local wheel"
b	mb	/jɑ̃/ + /bɑ/ ⇒ [jɑ̃mbɑ] "local river"
f	mv	/jɑ̃/ + /fyɛ/ ⇒ [jɑ̃mvyɛ] "local plantation"
v	mv	/jɑ̃/ + vũ/ ⇒ [jɑ̃mvũ] "local basket"
ɓ	m	/jɑ̃/ + /ɓɑ/ ⇒ [jɑ̃ma] "local goat"
t	nd	/jɑ̃/ + /tuu/ ⇒ [jɑ̃nduu] "local oil"
d	nd	/jɑ̃/ + /di/ ⇒ [jɑ̃ndi] "local honey"
s	nz	/jɑ̃/ + /so/ ⇒ [jɑ̃nzo] "local horse"
z	nz	/jɑ̃/ + /zoolo/ ⇒ [jɑ̃nzoolo] "local zoolo-worm"
ɗ	n	/jɑ̃/ + /ɗyemuu/ ⇒ [jɑ̃nyemuu] "local citrus fruit"
l	n	/jɑ̃/ + /lɔɔ/ ⇒ [jɑ̃nɔɔ] "local firewood"

purely phonological character to the constituent structure of Mawu sentences. However, within constituents of the appropriate type—including words, compound words, and combinations of nouns with adjectives, verbs and auxiliary verbs, and so forth—this pattern of influence of the type I nasal feature on a following initial consonant is entirely automatic and exceptionless. It does not matter what the words are. If a type I nasal is followed by an initial consonant that is not already a nasal, that consonant will change according to the pattern in table 3.5.

The effect shown in table 3.5 clearly involves the spread of nasality from type I nasals to following consonants. Such effects are called *assimilation* by phonologists. Assimilation effects clearly involve the influence of an articulatory gesture on its neighbor—here the velum is staying down a little longer. This effect cannot, though, be treated purely as a matter of articulatory laziness. For one thing, this assimilatory effect does not occur with type II nasal vowels, which have a lowered velum, just as type I vowels do. For another thing, the affected consonant articulations are changing in other ways besides a lowered velum. Approximants are becoming regular nasal consonants with full oral closure, voiceless consonants are becoming voiced as well as prenasalized, and so forth. Mawu nasal assimilation is thus being mediated by the phonological system, both in the definition of when it happens and in the results when it does happen.

The assimilation effect shown in table 3.5 gives us a reliable test for the presence of type I nasality in a syllable-final vowel, just as the shift in quality of a type II nasal /ɑ/ (roughly from the vowel of "non" to the vowel of "nun") gives us a reliable indication of the presence of type II nasality in any vowel. There is a third test that tells us whether a vowel has any sort of nasality at all. Table 3.6 shows that in the language game ŋgoɓooɓo, a nasal vowel of whatever type is doubled according to the pattern VmV rather than VɓV.

Table 3.6
ŋgoɓooɓo with nasal vowels.

Word	Gloss	ŋgoɓooɓo
sɑ̃	rain	sɑmɑ
sɑ̰	snake	sama
g͡bɑ̰̃	celibate	g͡bɑmɑ
kɔ̰ɔ̰	hunger	kɔmɔɔmɔ
dɑ̰ɑ̰̃	clock	dɑmɑɑmɑ
kɑɑ̃	to sew	kɑɓɑɑmɑ

The shift to /m/ from /ɓ/ is the expected consequence of nasalization caused by a type I nasal vowel, as shown earlier in table 3.5. In ŋgoɓooɓo, the nasal aspect of any sort of nasalized vowel has this same effect, thus underlining the point that we are really dealing with the same nasal feature in different disguises. Furthermore, all vowels in ŋgoɓooɓo wind up being oral. Their nasality, if they had any, is transferred to the /ɓ/, turning it into /m/. The result is to "uncover" the basic identity of the type II and III nasal vowels with the type I nasal vowels and with nonnasalized vowels; they all become one set of seven vowels; phonemic nasality and any consequent quality changes are removed. This underlines the point that we are really dealing with the same nonnasal vowel features, with the basic seven vowels of Mawu transformed into twenty superficial vowel phonemes by various sorts of interaction with nasality.

Table 3.7 summarizes what we know about the permitted interactions of the various effects of nasality in Mawu CVV syllables whose vowel is /ɑ/. The first five columns represent questions that we can ask about a form. Columns 1 and 2 ask "does the first (or second) vowel shift in quality to schwa?" as type II nasal /ɑ/ does. Columns 3 and 4 ask "does the first (or second) vowel replicate with mV in ŋgoɓooɓo?" as all nasal vowels do. Column 5 asks "does the first consonant of a following word undergo nasal assimilation?" as consonants do following type I nasal vowels. Column 6 presents the phoneme sequence that corresponds to the answer to these questions.

The four rows in table 3.7 are the only possible configurations of answers to these questions, and also the only four nasal vowel sequences, that Mawu allows. One simple way to summarize what table 3.7 tells us is that CVV syllables, like CV syllables, permit exactly four types of vowels: nonnasal, nasal type I, nasal type II, and nasal type III. If there really were four basic types of vowel letters freely co-occurring, we would expect CVV syllables to have $4 \times 4 = 16$ possibilities of nasality type, not just four.

Table 3.7
Possible distributions of nasality in Mawu ɑɑ sequences.

1 V1 ə	2 V2 ə	3 V1 ŋg m	4 V2 ŋg m	5 C assimilation	6 phoneme sequence
no	no	no	no	no	ɑɑ
no	no	no	yes	yes	ɑɑ̃
yes	yes	yes	yes	no	ɑ̰ɑ̰
yes	yes	yes	yes	yes	ɑ̰ɑ̰̃

Table 3.8
Impossible distributions of nasality in Mawu ɑɑ sequences.

1 V1 ə	2 V2 ə	3 V1 ŋg m	4 V2 ŋg m	5 C assimilation	6 phoneme sequence
no	no	yes	no	no	ɑ̃ɑ
no	yes	no	yes	no	ɑɑ̰
yes	no	yes	no	no	ɑ̰ɑ
yes	no	yes	yes	yes	ɑ̰ɑ̃
no	yes	yes	yes	no	ɑ̃ɑ̰
no	yes	yes	yes	yes	ɑ̃ɑ̰̃

Table 3.8 gives examples of configurations of answers that seem plausible in the abstract, and are predicted by free combination of vowel phonemes, but are not in fact possible in Mawu for the vowel /ɑ/.

The situation for the other six vowels is similar. The vowels /ɔ/ and /ɛ/ (with roughly the sound of the vowels in American English "awe" and "Ed") are just like /ɑ/, except that the clear vowel quality shift caused by type II nasalization in /ɑ/ does not occur. We can thus disregard the first two columns, and ask about the pattern of answers in the third through fifth columns. Here, as in the case of /ɑ/, only four of the eight logically possible combinations can be found, and the four possibilities are exactly as they are for /ɑ/.

The vowels /i/, /e/, /u/, /o/ have a still simpler pattern. For these vowels there are only two rows in a table giving the possible constellation of answers to these questions for two-vowel sequences. These two rows represent an oral pattern, where there is no vowel nasality of any sort at all in the syllable and the answer to all questions is "no" and a nasal pattern. The nasal pattern (for these four vowels) always produces nasal assimilation in following consonants, and it always produces ŋgoɓooɓo nasality in the second vowel of a two-vowel sequence. As for the ŋgoɓooɓo treatment of the first vowel in two-vowel sequences whose second element is nasal, it is always oral for /e/ and /o/, and always nasal for /i/ and /u/. Thus, in none of the four vowels is there any option for the treatment of the first of a VV sequence in case the second is nasal, and so there is only one kind of nasalized-vowel syllable, whether its shape is CV or CVV.

Many readers will by now have recognized that the apparent complexity of the Mawu system of vowel nasality is just a consequence of our misapplication of the alphabetic metaphor. Aiming to represent Mawu words as sequences of letters, each representing a distinctive class of speech sounds, we ended up with a system of twenty vowel phonemes interacting with one another and with adjacent consonants in a complex way.

There is a much simpler way to look at things. Type I nasal vowels, as noted before, are mainly a phenomenon of the syllable margin: They usually occur only in the second of a VV pair, and they affect the initial consonants of following syllables; in slow pronunciations only the end of a type I nasal vowel is nasalized.

Suppose we represent type I nasality as an optional element at the end of the syllable, symbolized X. Now Mawu syllable types become CV, CVX, CVV, CVVX, CGV, and CGVX. The type I nasal vowel phonemes vanish from the analysis—they are just the phonetic interpretation of VX sequences, X causing preceding vowels to assimilate in nasality just as it causes such assimilation in following consonants. The three type II nasal vowels remain—they are intrinsically nasalized vowels. The type III nasal vowel phonemes also vanish from the analysis—they are just concatenations of the type II nasal vowels with the element X. Mawu is left with a system of seven oral and three (intrinsically) nasal vowels, a state of affairs that is quite similar to the vowel inventories of many other and more well-known languages, such as French.

The complex distribution of the various types of Mawu vowel nasality, laid out in tables 3.7 and 3.8 and the subsequent discussion, now follows from two simple principles: VV sequences must be repetitions of the same vowel (nasal or otherwise), and X is an optional syllable-final element, occurring freely after all possible syllables. There are now guaranteed to be a maximum of four types of syllable with respect to vowel nasality for the non-ATR vowels, whether the syllable shape is CV or CVV or CGV:

1. no nasality at all;
2. nasality due to element X following the syllable;
3. intrinsic nasality of the vowel(s) in the syllable;
4. both intrinsic vowel nasality and element X following the syllable.

In the case of the ATR vowels, intrinsic vowel nasality cannot occur, since the Mawu inventory of vowels includes nasalized versions only of the non-ATR cases /ɑ/, /ɔ/, /ɛ/, and not the ATR cases /i/, /e/, /u/, /o/. As a result, the only choice for the ATR vowels is whether or not element X is present at the end of the syllable or not. Thus, there is just one type of nasalized-vowel possibility for syllables containing these four vowels, whether the syllable contains a single vowel or a VV sequence, and this nasality is always of the type that spreads to following consonants. In the case of the high vowels /i/ and /u/, there is one extra wrinkle: the nasality produced by element X at the end spreads to the first vowel of a VV sequence, so that the ŋgoɓooɓo output of the first vowel as well as the second has /m/ rather than /ɓ/ in these cases.

What is this element X? Well, it is certainly nasal in character; however, it is not a vowel. If it were, it should add an extra VɓV sequence in ŋgoɓooɓo, which it does not, and it would also violate the general Mawu constraint against CVVV syllables. Neither is it a consonant, in the normal sense—there is no associated constriction in the vocal tract, just the lowering of the velum to produce nasality. Thus X seems to be a pure floating nasal feature, free of any other content. In what follows, we will therefore write it as a floating IPA nasal diacritic / ˜ /.

This whole situation is a familiar story to those who have looked at the sound systems of even a small sample of the world's languages. It is normal for syllable structure to play a strong role in the permitted distribution of phonological features. ATR and nasality are common, almost ubiquitous as distinctive features in the phonological systems of the world. Syllable types CV and CVV are among the most common and natural of phonological structures. CVN (where N is a nasal consonant of some sort) is almost as simple and natural a syllable structure as CV is, and it is quite common for languages to allow only such a nasal as a syllable-final element. It is normal for such syllable-final nasals to produce assimilatory effects in the preceding vowel and to assimilate in place of articulation to a following consonant. When the syllable-final nasal does not assimilate in place to a following consonant, its closure often becomes very weak (as in Japanese) or vanishes, leaving bare nasality behind (as in French and often in Mandarin Chinese).

The basic phonological building blocks of the Mawu nasal vowel situation are, then, widespread and natural ones. Mawu assembles these routine building blocks in a slightly unusual way, permitting intrinsically nasalized vowels to co-occur freely with syllable-final nasal elements, never treating the syllable-final nasal elements as an independent consonantal constriction. As a result, its phonological system seems to have a peculiar, unheard-of characteristic—three distinct kinds of nasalized vowels—requiring us to add to the already-unwieldy IPA standard and to recognize yet another odd quirk of human linguistic culture. However, this apparent peculiarity is only the result of superficial misanalysis, and a more careful examination yields an empirically more accurate description of Mawu, which also reaffirms the abstract unity of human phonological systems.

One characteristic of this analysis deserves special note. In isolation, or in final position in an utterance, there is apparently no articulatory or acoustic difference at all between what we originally called type II and type III nasal vowels, that is, between an intrinsically nasal vowel, and an intrinsically nasal vowel followed by a floating nasal element. The intrinsically nasal vowel already causes the velum to be fully lowered, and there is no extra duration or other sign of the floating nasal element, whose existence is purely potential in this case. This potential is actualized only when another word follows whose initial consonant is not already nasal, since the floating nasal will spread, whereas the "bound" nasal feature instrinsic to the nasalized vowel will not. The spreading nasal feature is easy enough to hear, changing for instance /l/ to /n/. Thus /swɑ̰/ "odor" and /swɑ̰~/ "dish of pounded yam" are both identically [swɑ̰] in isolation, or if followed by a word beginning with a nasal consonant; but they will be clearly distinguished if followed by an element of another type, such as the plural element /lu/: [swɑ̰lu] vs. [swɑ̰nu].

In such cases phonological representation of Mawu words may contain an element that cannot be heard or spoken in even the most careful isolated citation-form pronunciation, but which comes out in a clear and systematic way through its effect on a following word, if one is present. We will soon see that a similar state of affairs applies in an even more thoroughgoing way in the case of Mawu tone. Such cases underline the abstract coherence of the phonological system, which finds little difficulty in establishing and preserving such distinctions because they are simple expressions of its basic combinatoric nature.

Mawu makes one additional use of bare nasality that is worthy of comment. There is one word—namely, the first person singular pronoun "I"—that consists solely of a bare nasal feature. Mawu pronouns in general conspicuously flout the normal syllable structure restrictions of the language, which require syllables (and thus words) to start with a consonant.

~	"I"	H
i	"you"	H
ɑ	"he, she, it"	L
ɑ̃	"we"	H(L)
ɑ	"you-all"	H
i	"they"	L

The last column gives the tone—Mawu is a tone language, remember? We will learn what the tonal categories mean shortly. Except for "I," the pronouns are all single vowels. The "I" pronoun behaves as if it were a floating nasal feature: it produces assimilatory changes in following consonants similar to those we presented earlier.

This allows us to explain where the language-game name ŋgoɓooɓo comes from. Sharp-eyed readers may have noticed that the first syllable of this word is an exception to the generalizations about Mawu syllable structure that we have been claiming. In fact, this word comes from the phrase /~ko o/, in which /~/ means "I," /ko/ is a verb meaning "say," and /o/ is a mark of emphasis, so that the whole phrase means something like "I say!" With nasal assimilation this becomes /ŋgoo/, which in turn is subjected to the normal rule of the language game to produce /ŋgoɓooɓo/.

Many languages, including some that are quite closely related to Mawu, have an independent series of prenasalized stops. In Mawu, however, these segments are always derived from the sequence of a floating nasal feature with a voiced stop or fricative, and so there is no reason to set them up as an independent choice to be made in specifying the sound pattern of words.

Although phonological features are not usually seen in such a transparently unbound state as Mawu floating nasality, many aspects of language sound structures argue in favor of representing words as structured combinations of features rather than simply as strings of phonemic symbols. We have already seen examples of three of these motivations:

1. *Phonological inventories.* In specifying the distinctive sound elements of a language, it is natural to use featural concepts such as "place of articulation," " voicing," "nasality" and so on.
2. *Combinatory constraints.* In specifying the combinations and sequences of distinctive sound elements that can be used to define the sound of words, it is natural to use concepts such as "consonant," "vowel," "syllable" and so forth, which provide a kind of structural framework on which distinctive features can be arranged.
3. *Contextual variation.* In specifying how word pronunciation changes depending on adjacent words, it is natural to refer to effects such as the assimilation of features in a structural setting.

Treating Mawu nasality in terms of the distribution of a nasal feature in syllabic structures produces a description that is simple and quasi-universal in character, rather than complex and highly particular to Mawu. Such successful analyses show that language sound patterns instantiate simple, effective, but rather abstract cognitive structures that recur across languages.

There is a fourth kind of motivation for thinking of a phonological representation as a structured combination of features instead of as a sequence of phonemic letters. In some cases different phonological features seem to operate on completely different scales of time and space. Phonologists call these different strands of featural activity *tiers,* and Mawu tone provides a good example. Mawu words can be distinguished by their pitch patterns, and these distinctive pitch patterns are naturally modeled as simple sequences of distinctive high (H) and low (L) tones rather than as arbitrary melodies. This aspect of Mawu phonology has a curious characteristic: All words, regardless of their length, exhibit one of exactly four possible tone patterns.

Table 3.9 shows a sample of monosyllabic Mawu words that differ minimally in tone. In these cases the way that the speaker modulates the pitch of his or her voice makes the difference between words. The CV

Table 3.9
Mawu tone patterns.

L	LH(L)	H	H(L)
si "life"		si "seed"	si "fly"
	so "horse"	so "village"	
g͡ba "kitchen"			g͡ba "hut"
saa "sheep"	saa "salary"	saa "squash seed"	saa "charm"

syllable /so/ said with pitch rising from low to high means "horse," while /so/ said with pitch starting high and remaining high means "village." Table 3.9 shows that monosyllabic Mawu nouns, even if only a single vowel is present, can have four distinctive pitch patterns: low tone, which is written L; rising tone, which is written LH(L); and two kinds of high tone, which we write as H and H(L).

In isolation, patterns H and H(L) sound exactly alike; thus, /si/ "seed" and /si/ "fly" are pronounced identically if said in isolation. The difference comes out only in combination forms. For instance, the Mawuka indicate plurality with an element /lu/ that occurs following the noun phrase to be pluralized. The plural element /lu/ has no distinctive tone of its own—its tone is always predictable from context. When added directly to a noun with the H tone pattern, /lu/ also has a high tone, so that /si/ H "seed" + /lu/ is /silu/ HH "seeds," with a high tone on both syllables. When added to a noun with the H(L) tone pattern, /lu/ has a low tone, so that /si/ H(L) "fly" + /lu/ is /silu/ HL "flies," said with a falling tone pattern.

The parenthesized low tone in the H(L) pattern is similar in character to the floating nasal element when it follows an intrinsically nasalized vowel, such as in the word /swa̰~/ "starch dish." This floating nasal element makes no difference pronounced in isolation, since the preceding vowel is already nasal, but emerges when a following nonnasal consonant is available to be nasalized. Similarly, the floating L tone is not pronounced in isolation; it takes effect only when a following syllable gives it space to dock.

The final floating low tone in words like /si/ H(L) "fly" differs from the final floating nasal in words like /ka~/ "neck," where the preceding vowel is not intrinsically nasal, and therefore is partly nasalized by the floating nasal feature. Logically, a final floating low tone should be able to affect the pitch pattern of the preceding vowel in /si/ H(L), producing a falling tone. This, however, does not happen. A similar state of affairs applies in the case of rising-tone words such as /so/ LH(L) "horse." Such words start low and end high; but, following a rising-tone word, a determiner element such as /lu/ will get a low tone.

For the purposes of the present discussion, the main point is that every Mawu word has one of the four tone patterns L, LH(L), H, H(L). This is true for the monosyllabic words shown in table 3.9, and it is equally true for longer words, including borrowed words.

L	/namaa/"paralytic"	/safɛɛni -/ "donkey"
LH(L)	/sukuu/ "kind of dance"	/falati/ "provocation"
H	/namaa/ "trouble"	/ɲamakuu -/ "ginger"
H(L)	/ɲɔɔmɛɛ/ "camel"	/bɔlɔsi/ "brush"

The patterns L, H, and H(L) assign a uniform phonological tone to the whole word, either low or high. The pattern LH(L) requires a transition from low tone to high tone somewhere in the word. If tone were freely contrastive on vowels or syllables in Mawu, we might expect to see words differing only where this rise takes place. Instead, the location of the rise is predictable from the rest of the phonological spelling of the word. The final high tone is associated with the last vowel of the word, and the initial low tone is associated with the first vowel of the word. If the word has only one or two vowels, there is nothing more to say. If there are three or more vowels, then the initial low tone spreads as long as it encounters only vowels or approximant consonant. The first sufficiently strong consonant will form the boundary between the low tone region and the high tone region. For example, the three vowels of /salaba/ LH "lamp wick" will have the tone pattern LLH, while the three vowels of /ja-galo/ LH "sickness" will have the tone pattern LHH.

The only tonal choice that can thus be made for a Mawu word is to pick one of the four tonal patterns. The four options are the same whether the word has one vowel in it or six vowels. This is a clear example of the way in which phonological features sometimes operate on distinct strands, or *tiers.* In Mawu the phonological spelling of a word on the tonal tier is decoupled from its spelling in terms of consonants and vowels or even syllables. If we had to describe Mawu tone in terms of high- and low-pitched varieties of vowel phonemes, we would have to use schematic descriptions of sequences of these classes of vowels to describe the set of possible tonal categories. It is much simpler just to talk about whole words having tone patterns like L or H or LH(L).

Such independence of the tonal tier is commonly found, but in other tone languages the tonal choices available in constructing a word may be more closely linked to the rest of its phonological spelling. In Yoruba each vowel may be given one of the three phonologically distinct tone levels (low, mid, or high); and in Mandarin Chinese each syllable may have one of four tone patterns that may be described as high, rising, low, or falling.

In the case of Mawu, there is good evidence that the limitation of words to four basic tonal patterns is part of what every speaker understands implicitly about the language. For instance, the limitation is maintained in a systematic way for compound words, even newly minted ones. Mawu has a productive system for making new words out of old ones—nouns, verbs, adjectives, and adverbs can all be made this way. One aspect of this derivational system is the combination of two words into a compound word, just as with English compounds such as "phonebook," "horsehair," and "oxcart."

When a Mawu compound is made in this way, its tone pattern is predictable on the basis of the tone patterns of its constituent parts. Not only is the output predictable, but the predicted output in each case is also one of the four basic tonal patterns. Table 3.10 shows the outcome for each of the sixteen possible inputs.

Thus, /jɛɛ/ H "fish" combines with /ku~/ L "head" to make /jɛɛku~/ H "fish head"; /ku~/ L "head" combines with /sye/ H(L) "hair" to make LH(L) "head hair," /caa~/ L "peanut" combines with /fyɛ/ H "farm" to make /caa~fyɛ/ L "peanut farm"; /lɑ/ H "mouth, door" combines with /kuu/ L "hill, bump" to make /lɑkuu/ H "chin."

Table 3.10
Tone of Mawu compound words.

Tone of word 1	Tone of word 2	Tone of resulting compound
L	L	L
L	LH(L)	LH(L)
L	H	L
L	H(L)	LH(L)
LH(L)	L	L
LH(L)	LH(L)	LH(L)
LH(L)	H	L
LH(L)	H(L)	LH(L)
H	L	H
H	LH(L)	H(L)
H	H	H
H	H(L)	H(L)
H(L)	L	H
H(L)	LH(L)	H(L)
H(L)	H	H
H(L)	H(L)	H(L)

As these examples suggest, such compounds can sometimes be somewhat idiosyncratic in the way that their meaning is related to the meanings of their parts, but they can also be formed in quite a regular way. For instance, /faa/ L "skin, rind" can be combined with the word for any animal, fruit, or vegetable to make a compound word to refer to its skin or rind, and all such compounds will follow the tonal relationships laid out in table 3.10.

Of course, it is also possible to make various sorts of phrases out of the same words—somewhat like the difference between English "banana peel" and "peel of a banana"—and the tone pattern of such phrasal combinations will not necessarily remain among the lexically possible patterns. Thus /gɔɔ/ H "banana" combines with /faa/ L "skin' by the principles of table 3.10 to make /gɔɔfaa/ H "banana peel," but the combination /gɔɔfaa/ H(L) "skin of a banana" is also possible.

The principles in table 3.10 can apply recursively to create compound words of three or more elements, such as /kawacelwa/ H "quarry," made from /kawa/ H "rock," /ce/ L "to break by striking," /lwa/ H "place." Such examples also stay within the lexical pattern of four possible tone patterns, which is a durable characteristic of the notion "possible word of Mawu."

The situation as we have described it seems complex enough. Imagine how difficult it would be to encompass it at all in a purely alphabetic theory, in which tonal categories might be expressed as varieties of vowels, whose co-occurrences at the level of simple and compound words would have to be restricted so as to be consistent with the patterns so far described. By treating tonal phenomena as a separate strand or tier of activity, at least the basic tonal facts of Mawu can be laid out in a straightforward fashion.

As in the case of the three types of nasal vowels, however, the reader ought again to be restless and suspicious. What could be the real meaning of these rather odd constraints? Why limit tone patterns to four, and why limit them to this particular, somewhat odd, set of four patterns, two of which have floating tones that are hidden except when a toneless particle follows? Having decided on such a limitation, why maintain it in compound words through the particular pattern of combination rules expressed in table 3.10?

As with the matter of three types of nasal vowels, we might simply shrug and mention the boundless variability of the human imagination. In fact, the description given here has only begun to scratch the surface of the complex tonal phonology of Mawu. As in the nasal vowel case, though, a more careful consideration of a wider variety of facts suggests a simple and rational account, although a slightly more abstract one, according to which Mawu looks very much like many other languages. Such an account has been proposed in Bamba (1991). We can see the essence of his proposal—the presentation here is superficially a bit different—by considering an analogy to the facts of Japanese.

The Tokyo dialect of Japanese is usually described (Haraguchi 1977; Poser 1984; Pierrehumbert and Beckman 1988) as having lexically distinctive accent. Any syllable in a word may be accented, or none may be. Thus, *hashi* with initial-syllable accent means "chopsticks," *hashi* with final-syllable accent means "bridge," and *hashi* with no accent at all means "edge." All words typically begin on a low pitch, rising immediately if the first syllable is long,[4] or just after the first syllable if it is short. An accent is realized as a fall in pitch just after the accented syllable, while an accentless word stays high to the end. It is therefore said that the final-syllable accent and the accentless case are usually pronounced in the same way; however, when a particle such as the subject marker *-ga* follows, a final-accented word expresses its latent pitch fall with a low tone on the following particle, while the particle remains high following an accentless word.

In the Osaka dialect an additional degree of tonal differentiation is possible. Whether the word is accented or accentless, it may begin with a low tone or a high tone. Thus, in Osaka Japanese, there are four types of words from the point of view of tone and accent:

1. low beginning, accentless;
2. low beginning, accented;
3. high beginning, accentless;
4. high beginning, accented.

These are essentially the same as the four tonal types of Mawu. The Mawu tone patterns H(L) and LH(L) are like final-accented words in Tokyo Japanese, with the final floating L tone only emerging if a particle is added so as to give it a place to dock. The Mawu tone patterns L and LH(L) are like the low-beginning words of Osaka Japanese, accentless and accented respectively, while the tone patterns H and H(L) are like the corresponding high-beginning words.

The similarity is disguised by a few differences. In Osaka Japanese an accent can be on any vowel, except that high-beginning words cannot be final-accented, and low-beginning words cannot be initial-accented. In Mawu, on the other hand, an accent, if present, can only be on the final vowel, regardless of whether the word begins high or low; but high and low beginnings can freely combine with presence or absence of accent even in monosyllables. Thus, Osaka Japanese cannot exhibit the full range of four categories on monosyllabic words, as Mawu does; on the other

4. Long syllables in Japanese contain two vowels, or a vowel and a syllable-final consonant.

hand, Mawu cannot exhibit the range of options for accent placement in polysyllabic words that Japanese does.

In Osaka Japanese, because we can place an accent almost anywhere in polysyllabic words, we tend to think of the facts primarily in terms of variable stress or accent, although they clearly have a tonal dimension as well. In Mawu, the four tonal patterns remain available in words with only one vowel, and the options for accentuation are only final-syllable accent or absence of accent, without any variation in accent location. We therefore tend to think of the facts primarily in terms of tone, although they have an accentual dimension that comes out more clearly as a wider range of phenomena are examined.

As a further demonstration of the fundamental similarity, consider the treatment of compound nouns in Osaka Japanese. Such compounds remain within the basic scheme of the language; they may begin high or low, and they may be accented or accentless. Whether or not the compound is accented depends on the second member, whereas whether or not the compound has a high beginning or a low beginning depends on the first member.

The basic relationship is given in table 3.11. We can ignore whether or not the first word is accented, and likewise whether or not the second word starts low or high, because these questions will have no impact on the starting tone or the accentuation of the compound. Each cell in the table shows the outcome for the whole compound, as a function of whether the first word starts low or high, and whether the second word is accented or accentless.

Table 3.11, representing the compounding facts for Osaka Japanese, is exactly a schematic form of table 3.10, which presented the compounding facts for Mawu! The abstract ingredients in both cases are the same—the formation of compound words in a phonological system whose words can be high or low at their beginning and may also be either accented or not. In both cases the basic outcome is the same: Compound words remain within the system, exhibiting the same range of tonal/accentual behaviors as simple words do, with the initial-tone specification of the compound taken from its initial word and the accentuation of the compound determined by the final word. In the two languages both simple and compound

Table 3.11
Compound nouns in Osaka Japanese.

	Word 2 is accented	Word 2 is accentless
Word 1 begins L	Result begins L, is accented	Result begins L, is accentless
Word 1 begins H	Result begins H, is accented	Result begins H, is accentless

words remain limited to the four basic patterns because the elements of the patterns are defined phonologically at the level of the word and not at the level of the individual vowel or even syllable.

It is clear that a single theory of tone and accent should be able to encompass both the Mawu and the Japanese systems, since the facts, in a slightly abstracted form, are essentially the same in both cases. A careful consideration of the distributional peculiarities in each language leads us to an analysis that makes otherwise odd and complex phenomena seem sensible and simple. Curiously, the analysis is nearly the same for (this aspect of) two languages spoken at opposite ends of the world by peoples who have surely been separated for a long time. This similarity cannot be due to cultural influence or to inheritance of a shared feature from a common parent language. Instead, it can only mean that both peoples happen to have picked up the same pieces from the phonological tool kit that is the common property of humanity.

3.3 Conclusion

This discussion has omitted many complex and interesting aspects of the Mawu phonological system; for instance, a striking range of tonal phenomena arise when words are combined into phrases. Also omitted have been many fascinating phenomena from other languages of the world: clicks, voice quality variation, vowel harmony, introduction and deletion of features and segments to achieve proper syllable structure, and so on.

The point, however, has not been to present a complete description of any one language, nor has it been to list schematically the components of the universal phonological parts inventory and tool kit. Instead, a detailed analysis of two apparently peculiar facts of Mawu word-level phonology—the three classes of nasal vowels and the restriction to four word-level tonal patterns—has aimed to show that these apparent oddities arise naturally out of the interaction of simple elements and structures that are also part of the phonological systems of much more familiar languages. This demonstration exemplifies concretely what phonological analysis is like and why it tells us something important about the cognitive structures that underlie human speech.

Suggestions for Further Reading

The efforts of phonologists and phoneticians to define the notion *possible word of such-and-such a language,* carried out in careful detail across many languages, has led to a general picture of the phonological parts bin and tool box out of which the world's languages form their phonological systems. Although these systems exhibit a fascinating and perhaps even endless variety of superficial differences, just as biological forms of other other sorts do, careful analysis always shows us deeper similarities, reflecting the fact that these systems are all built out of the same sort of stuff by the same sorts of processes. An excellent introduction to modern phonology, presented in breadth and also in considerable depth, can be found in Kenstowicz 1993.

Theories of phonology have improved a great deal over the past thirty years, with the result that a trained phonologist begins to work on a new language with a set of analytic tools producing insightful analyses of many of its phonological phenomena. This process of improvement continues, as new ways of thinking shed light on old problems and as new analyses strengthen or undermine existing theories. For examples of how a fresh perspective can improve on familiar analyses while offering a convincing account of new phenomena, see Prince and Smolensky, 1995 or McCarthy and Prince, 1995.

Problems

3.1 *An alien language.* Imagine an intelligent race of creatures in another galaxy whose system of communication includes nothing at all analogous to a human phonological system. In particular, they have no culturally specific combinatory system of meaningless elements out of which basic meaningful ones are made. If their communications system has an inventory of basic meaningful elements, it can be genetically given, or culturally variable, as you please, as long as it is not built on top of anything like a phonology.

Describe how this alien communications system works. Try to be specific and to avoid concepts like direct transfer of thoughts, unless you have a concrete and physically plausible idea about how this might occur.

Why might a species evolve in the direction of your system? What would be the advantages and disadvantages compared with the human system of spoken language?

3.2 *How many possible words are there in Mawu?* Keeping in mind the number of consonants and vowels, the set of possible syllable structures, the distribution of final nasal elements, and the tonal system, how many monosyllabic words could there be in Mawu? How many two-syllable words? How many words of three syllables? (Assume that seventeen initial consonant-glide sequences are possible and that there are no other constraints on feature co-occurrences beyond those mentioned in this chapter.)

3.3 *Comparison of Mawu and Bambara nasality.* The table below compares certain Mawu words with their cognates in Bambara, a related Manding language. The Bambara words are given in their standard spelling, in which a syllable-final nasal indicates a preceding nasalized vowel.

Bambara	Mawu	gloss
so	so	"horse"
ba	bɑ	"river"
fin	fi~	"black"
basa	bɑsɑ	"lizard"
faga	fɑɑ	"to kill"
fara	fɑɑ	"skin, rind"
kolo	koo	"bone"
kelen	kee~	"one"
sula	swɑ	"monkey"

Bambara	Mawu	gloss
todi	twe	"toad"
fila	fjɑ	"two"
kɔŋɔ	kɔ̰ɔ̰	"hunger"
kuna	kwɑ̰	"bitter"
suma	swɑ̰	"slow"
sunan	swɑ̰~	"millet"
wari	wɛɛ	"money"
sali	sɛɛ	"to pray"

Based on the information in this table, predict the Mawu equivalents of the Bambara words /furu/ "stomach," /togo/ "hut," /fali/ "donkey," /mina/ "to catch," /falin/ "to germinate," /kɔnɔn/ "pearl."

Now can you predict the Bambara equivalents of the Mawu words /muu/ "flour," /wuu/ "dog," /sɑɑ/ "sheep," /sɑɑ/ "to pay"?

Do you think it is harder for Bambara speakers to understand Mawu or for Mawu speakers to undertand Bambara?

References

Bailleul, C. (1981). *Petit dictionaire bambara-francias francias-bambara.* Avebury, England.

Bamba, M. (1991). *De l'interaction entre tons et accent.* Ph.D. thesis, Université du Québec à Montréal.

Cheney, D. L., and R. M. Seyfarth (1990). *How monkeys see the world: Inside the mind of another species.* Chicago: University of Chicago Press.

Doddington, G. R., and B. M. Hydrick (1978). High performance speaker-independent word recognition. *J. Acoust. Soc. Am.*, 64S1: S182.

Haraguchi, S. (1977). *The tone pattern of Japanese.* Tokyo: Kaitakusha.

Kenstowicz, M. (1993). *Phonology in generative grammar.* Oxford: Blackwell.

McCarthy, J. J., and A. S. Prince (1995). *Prosodic morphology.* Cambridge, MA: MIT Press.

Nagy, W. E., and P. A. Herman (1987). Breadth and depth of vocabulary acquisition: Implications for acquisition and instruction. In M. G. McKeown and M. E. Curtis, eds., *The nature of vocabulary acquisition.* Hillsdale, N.J.: Erlbaum. 19–35.

Pierrehumbert, J. B., and M. E. Beckman (1988). *Japanese tone structure.* Cambridge, MA: MIT Press.

Poser, W. J. (1984). *The phonetics and phonology of tone and intonation in Japanese.* Ph.D. thesis, Massachusetts Institute of Technology.

Prince, A., and P. Smolensky (1995). *Optimality theory: Constraint interaction in generative grammar.* Cambridge, MA: MIT Press.