Emergent phonology

Diana Archangeli

Douglas Pulleyblank

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1 What motivates Emergent Grammar?

There is a striking dichotomy in the way that oral languages make use of sound. Many of the properties of a language's sounds are idiosyncratic, such as which sounds are associated with a particular meaning. At the same time, sounds are combined in highly regulated ways – certain sounds are permitted while others are not (English allows [s] but not [x]); certain sounds cooccur in sequences while others do not (English allows initial [tr] as in *treat*, but not initial **tl*), etc. And some patterns are both regular and idiosyncratic, such as the regularity of nasal place assimilation in English, coupled with the idiosyncrasy that there are invariant nasal-final prefixes, immune to the regularity. The issue at the core of this monograph is the nature, source, and representation of phonological and morphophonological knowledge – the deep and pervasive regular patterns, the various idiosyncratic forms, and their interaction.

What is the source of this knowledge? At some level, these principles must emerge from the human learner's consideration of the data. The way in which this is achieved is determined by the nature of the learner's mental capacities that drive the acquisition of phonology. At one end of the spectrum, phonological acquisition might result from cognitive capacities of a specifically linguistic nature, with general phonological principles encoded as a necessary part of natural language grammar. Under this view, an innate language faculty (*Universal Grammar*) enables the language learner to cope with learning an ambient language by restricting the realm of possible grammars (Chomsky & Halle 1968).

We explore an alternative towards the other end of the spectrum, that general human cognition enables the learner to characterise patterns appropriate for the data concerned – there are no, or perhaps few, *a priori* regulatory principles specific to language sounds. Under this view, phonological knowledge is acquired by domain-general mechanisms, the *Emergent Grammar* hypothesis: general cognitive principles are the driving force behind the acquisition and form of morphophonological grammars, rather than cognitive principles that have evolved specifically for language sound patterns (Lindblom 1999).[1] Under this research

[1]In this, our starting point is similar to that of Construction Grammar, e.g., "what is central here is the conviction that language is on a par with all other human cognitive faculties, by whatever manner they are acquired." Välimaa-Blum (2011: 1). At this point, there is little work on phonological systems under Construction Grammar; Välimaa-Blum (2011), Höder (2014), Van der Spuy (2017) are notable exceptions.

program, principles specific to an innate "language" module would be posited only if general cognitive principles are inadequate. In all our work within Emergence to date, we have yet to find convincing evidence of the inadequacy of the Emergence hypothesis.

Box 1.1: The Emergent Grammar Hypothesis

General human cognition provides much, if not all, of the necessary scaffolding for the acquisition of morphophonology, allowing construction of a phonological grammar of the ambient language.

Our motivation for this exploration begins with the realisation that, if one were to argue strongly in favour of innate regulatory principles that were inherently linguistic, it would be important methodologically to eliminate the possibility of adopting comparable principles that were rooted in general, nonlinguistic capabilities.[2] In other words, if we wish to strongly argue in favour of innately-encoded linguistic principles, we need to demonstrate that it is impossible to learn the grammar (or a specific aspect of it) using only general cognition. As we demonstrate with our case studies here, accounting for patterns with minimal – or no – recourse to linguistically-specific principles is not only feasible, but in many cases the resulting system is far less complex than the one resulting from an innatist approach.

To begin laying out our proposal, it is important to be clear about what we mean by *grammar*. Grammar is a set of regulatory principles governing a wide array of patterns in some human language; our focus is on the patterns involving sounds. The grammar of a language characterises the recurrent linguistic sounds of that language (the language's "segmental inventory") and generalisations about those sounds. The language's grammar determines what sorts of sequences of sounds constitute well-formed meaningful strings of sounds (*phonotactics*), strings such as morphs and words. Additionally, the combination of meaningful sound strings into larger units is also subject to regulatory principles (*morpho-phonotactics*, cases where well-formedness statements about sounds are mediated by morphological categories). There are also regularities concerning

[2] As demonstrated for example in Mielke (2008), from its inception, Generative Grammar has typically assumed innate phonological principles rather than providing arguments for such innate principles.

productive relations between morphs, that is, regularities whereby one morph is perceived as related to another morph in terms of its meaning or syntax, even though the sounds of the forms differ (*Morph Set Relations*, *Morph set Conditions*). The grammar that we are concerned about, then, is the mental encoding of phonological and morphophonological regularities such that speakers are able to understand novel forms as well as generate novel forms that are perceived as acceptable in the language (Berko 1958, etc.).[3]

In pursuing this Emergentist approach we follow a large literature, including Hopper (1987), Lacerda (1995), Deacon (1997), Bybee (1998), Hopper (1998), Lacerda (1998), Bybee (1999), Lindblom (1999), MacWhinney (1999), Lindblom (2000), Frisch et al. (2001), Kochetov (2002), Lacerda (2003), Harrison & Raimy (2007), O'Grady (2008), Beckner et al. (2009), Cole (2009), Pater (2012), Hopper (2015), McCauley et al. (2015), Rácz et al. (2015), van de Weijer (2017), Haspelmath (2020a), inter alia, as well as extending our own work on the topic (Mohanan et al. 2010, Archangeli et al. 2011, Archangeli & Pulleyblank 2012, Archangeli et al. 2012a,b, Archangeli & Pulleyblank 2013, 2014a,b, 2015a,b,c,d, 2016, 2017, Anghelescu et al. 2017, Gambarage & Pulleyblank 2017, Archangeli & Pulleyblank 2018a, submitted).

In this monograph, we build on such work, aiming to develop our understanding of how human cognition serves to construct a grammar, addressing patterns involving inventories, phonotactics, morpho-phonotactics and relations within morph sets. In the next chapter, we illustrate these grammatical components through the lens of a single language. But before we turn to that exemplification, we address briefly how general cognitive properties might give rise to the sorts of phonological patterns just alluded to.[4]

Relevant cognitive properties include uncontroversial abilities such as the ability to attend to language (Peña et al. 2003), to remember (Meltzoff 1988), to identify similarities (Goldstone 1994), to process sequences (Conway & Christiansen 2001), to attend to frequency (Tenenbaum & Griffiths 2001, Thiessen & Erickson 2015), to form categories (Ashby & Maddox 2005, 2011), to generalise, and to gen-

[3]Properties of inventories have been given considerable attention in the Emergence literature, for example, in the early work of Lindblom (1999) and subsequently in work such as Mielke (2008), Cohn (2011). How combinatorial patterns emerge and what their nature is has been explored in work such as Cole (2009). This is an important aspect of the emergence of a grammar, but not the one that we focus on in this work.

[4]See van de Weijer (2009, 2012, 2014, 2017, 2019) for a similar research program, couched within Optimality Theory.

eralise over generalisations (Deacon 1997, Gómez & Gerken 2000, Saffran et al. 2007).[5]

(1) Human cognition primitives (a non-exhaustive list)
  a. Attention
  b. Memory
  c. Similarity
  d. Sequential processing
  e. Frequency
  f. Categories
  g. Generalising (& generalising over generalisations)

Building such cognitive scaffolding into an account of phonological patterns is rampantly "bottom-up" – especially at the outset. However, as forms are acquired and hypotheses are formed, the nascent grammar also informs continued acquisition: grammar construction is not only bottom-up, it is also "top-down".[6] This is consistent with language acquisition research: as knowledge is acquired, the learner not only adds new knowledge, but also builds generalisations upon existing generalisations (Martin et al. 2013, Curtin & Zamuner 2014).

In order to learn the phonological system of a language, there are certain necessities. The learner must experience the language being learned auditorily and/or visually and remember (some of) what is perceived.[7] Early learning involves breaking up strings of segments. This might be through mechanisms such as tracking transitional probabilities between units (Saffran et al. 1996), or it might be by identifying chunks within the speech stream (Perruchet & Vinter 1998;

[5]Perhaps some abilities involve some degree of language-specificity. For example, the neonate attending to linguistic input over other types of input might suggest a preference for speech that is innate (Peña et al. 2003), a surmise that is contested in Lacerda (2003). Even if there were such a preference, it does not take us far along the spectrum of properties needed for a full characterisation of an adult phonological grammar. Similarly, there is evidence that infants in nonhuman species attend preferentially to the sounds of their own species, e.g. pygmy marmosets (Snowdon & Pola 1978), birds (Whaling 2000), and Japanese macaques (Adachi et al. 2006), as well as subspecies (birds again, Nelson 2000).

[6]See Rose (2009), Rose & Brittain (2011), Rose (2014) for arguments in favour of acquisition involving multiple factors, both bottom-up and top-down.

[7]In the acquisition of oral language, both audition and vision are relevant (McGurk & MacDonald 1976, Rosenblum et al. 1997, Burnham & Dodd 2004) from a very early age (Coulon et al. 2013, Weikum et al. 2007). In this work, we focus on spoken language and auditory perception. This is a simplifying strategy. We also assume that the essence of the proposals we are making here for spoken languages is similarly relevant for signed languages, *mutatis mutandis.*

for discussion of these two possibilities, see Black 2018). The remembered fragments may begin as individual, unanalysed entities, but eventually the learner recognises that some of these fragments are highly similar in some way (due to density in the representational space), and so posits groups based on that similarity. The higher the density of some property defined by similarity of any type, the greater the likelihood of that property being encoded in the grammar.[8]

Thus, early learning identifies sound chunks and similarities among those chunks. Learners keep track of chunks they have heard: highly frequent sound chunks take on greater significance as categories, established as the contrastive sounds of the language encountered. Constellations of highly frequent properties lead to generalisations about sounds and about patterns. The earliest generalisations identify the sound segments and categories of the ambient language.[9] As learning progresses, longer sequences are committed to memory. This allows for frequency observations with respect to position and with respect to substantive properties of the strings encountered, leading to new generalisations. Phonotactics, both sequential and positional, are identified.[10]

At the point when sound-meaning correspondences begin, the earliest items acquired are individual vocabulary items (perhaps not corresponding exactly to the adult items); as more items are acquired, those with similar properties are grouped together leading to new generalisations which serve to identify the morphs of the language, to group morphs together, to identify phonological relations among morphs in a set, and so on (see Seidl & Buckley 2005, Gerken & Bollt 2008, Gerken et al. 2015). When multiple morphs are identified with the same set of morphosyntactic features, the learner is faced with the challenge of selecting among the morphs when building words – an assessment which relies on phonological and/or morphological *well-formedness conditions.*

[8]Thanks to Ben Martin for helpful discussion of this point.

[9]For similarities and sound chunks, see Newell (1990), Saffran & Thiessen (2003), Christiansen et al. (2009), Graf Estes et al. (2011), Martin et al. (2013). On frequency of chunks and categorisation, see Rosch et al. (1976), Plunkett & Marchman (1991), Saffran et al. (1996), Aslin et al. (1998), Zacks & Tversky (2001), Maye et al. (2002), Saffran (2003), Newport & Aslin (2004), Newport et al. (2004), Zacks et al. (2006), Diessel (2007), Pelucchi et al. (2009), Seger & Miller (2010), Ellis et al. (2015), Thiessen & Erickson (2015). And on generalising, see Eimas et al. (1971), Werker et al. (1981), Werker & Tees (1984), Jusczyk et al. (1994), Polka & Werker (1994), Pegg & Werker (1997), Stager & Werker (1997), Werker & Tees (2002), White et al. (2008).

[10]On committing sounds and strings to memory, see Cristia & Peperkamp (2012), Peperkamp et al. (2006); for sequence learning and frequency, see Marcus et al. (1999), Saffran & Thiessen (2003). For further generalisation, see Kuhl et al. (1992), Jusczyk et al. (1993, 1994, 1999), Gómez (2002), Martin et al. (2013).

Box 1.2: Acquisition of phonological, morphological, and sociolinguistic conditions

A more complete proposal would consider the acquisition of sociolinguistic conditions, pragmatic conditions, and so on, considering how and when such conditions are acquired relative to more purely phonological conditions, how children's acquisition of phonology, morphology and sociolinguistic conditions is synchronised or sequential, at what point forms identified as polymorphic for an adult come to be identified as such by the child, and so on. For example, Roberts (1994, 1997) compares the alternation between [t]/[d] and ∅ among 3 and 4 year olds in South Philadelphia to that of their care givers. Her work finds differences in the extent to which children of this age group reflect adult patterns depending on whether the verbal patterns under investigation are regular or irregular (the weak verbs). The asymmetric pattern she identifies indicates that, while adults treat the semi-weak verbs as they treat polymorphic words, children treat the semi-weak as they treat monomorphemic items. This suggests a stage in acquisition where the child has yet to generalise a polymorphic pattern for the semi-weak verbs.

While such work about phonological usage is important, we do not build it into our discussion here. However, we suspect that the Emergent framework extends readily to usage domains (van de Weijer 2012): a case in point is the Emergent analysis of diglossia in Faifi (Alfaifi 2020a,b).

To make concrete what such considerations would mean for acquiring a phonological grammar within an Emergentist framework, we sketch what appears to take place during the acquisition of the phonological grammar of a specific language. Our goal is twofold. On the one hand, we build on the points sketched briefly above, aiming to elucidate how a phonological grammar might emerge. On the other hand, we do so concretely as well as abstractly, showing that the model we are developing allows us to address phonological problems of intricacy and complexity. The phonological literature has established numerous patterns both within and across languages that demand explanation. Within an Emergentist framework, we attempt here to build a model that allows us to address such patterns. One could in principle use almost any language for illustration since the types of phenomena illustrated are familiar across languages: in the next two chapters, we explore the nature of phonological and morphophonological analysis from the Emergentist point of view, using the distribution of vowels in Yangben.

2 Conceptualising Emergence

In this chapter, we walk through multiple aspects of acquiring an adult phonology from the infant learner's perspective. We begin with the challenge of identifying the segments of the language being learned, then turn to its discrete vowel categories and how those categories are cross-classified. The distribution of Yangben vowels raises issues of phonetic concreteness and the role of phonological patterns in establishing segment classes (addressed in §2.1), two issues that play a central role in our discussion. Yangben ([jàŋbɛ̀n]), also referred to as Kalong ([kàlɔ̀ŋ]), is a member of the Mbam group of Bantu languages spoken in Cameroon, classified as Bantu A62 by Guthrie (1967–1971), glottocode yang1293. Our analysis builds on earlier investigations by Paulian (1986) and Hyman (2003), but depends primarily on Boyd (2015).

There is something of a back story to our choice of Yangben for this basic demonstration of the Emergent framework – fundamentally this demonstration could be made with any language. Our initial interest in Yangben stemmed from the work of Paulian (1986) and Hyman (2003). What was intriguing was their argument that the language would require the postulation of abstract vowels to determine phonological patterns of importance where the relevant vowels were not distinguished phonetically. As it turns out, however, Boyd (2015) demonstrates that the "abstract" vowels of Yangben are actually phonetically motivated. Boyd's description and analysis differ importantly from the earlier literature in that she identifies high retracted vowels, [ɪ, ʊ], vowels whose existence had been expected for phonological reasons and which she documents both phonologically and phonetically. Hence Boyd proposes a nine-vowel system in contrast to earlier analyses of Yangben with a seven-vowel system. For our purposes, this means that Yangben moves from being an example of required abstractness to relatively mundane concreteness.

In addition, vowel distribution in Yangben illustrates issues involved in building words by compiling smaller parts, or morphs, addressed in Chapter 3. Together, the discussion in these two chapters demonstrates both that it is possible to develop a grammar without significant recourse to universal innate principles, and that such a grammar can resolve complex challenges to classical innateness-based phonological analysis.

Our initial focus is identifying the nine contrastive vowels in Yangben and their relevant classification. We show here that some of the motivation for their classification is phonetic (§2.1), how this classification is represented in grammatical categories (§2.2), and, finally, that some of the motivation for such categories is phonological (§2.3).

2.1 Acquiring discrete sound categories

We sketch here in an idealised fashion how hearing and remembering, identifying similarities and generalising over what is stored can lead to a phonological grammar of a vowel system. For a language to be learnable at all, the data must be sufficient for each learner to acquire knowledge of the particular segments and patterns encountered: what a learner hears must ultimately include sufficient information for phonological acquisition. We demonstrate here the viability of our claim, that an adequate, predictive adult phonological grammar is possible to be acquired without appeal to innate linguistic principles.[1]

The symbols in Table 2.1 represent the vowel qualities of Yangben that the Yangben learner must acquire; these are the symbols used in Boyd (2015), representing the nine vowel qualities cross-cut by two lengths and two tones.

Table 2.1: Yangben vowels

	front		central	back/round	
advanced	i̇́/i̇́ː/i̇̀/i̇̀ː	é/éː/è/èː		ó/óː/ò/òː	ú/úː/ù/ùː
retracted	ı́/ı́ː/ı̀/ı̀ː	ɛ́/ɛ́ː/ ɛ̀/ɛ̀ː	á/áː/à/àː	ɔ́/ɔ́ː/ɔ̀/ɔ̀ː	ʊ́/ʊ́ː/ʊ̀/ʊ̀ː

An early challenge for the language learner is to perceive and identify these 36 distinct vocalic categories, a necessary stage in acquisition regardless of whether or not there are innate linguistic principles. For our discussion, we assume that the learner's pool of knowledge has grown to approach an amount sufficient to at least begin to identify acoustically distinct, sometimes contrastive, vowels.

[1] See van de Weijer (2017) for a similar demonstration, looking into the acquisition of a constraint against complex onsets in English.

Box 2.1: Are language sound categories evidence of linguistic human cognition?

As has been known since the 1970s, there is agreement between humans and some other animals for at least some sound categories. Kuhl & Miller (1975) and Kuhl & Padden (1982) show that chinchillas and macaques categorise a /ba/-/pa/ continuum in the same way as very young infants (1 and 4 month-olds), Eimas et al. (1971). Kluender et al. (1987) show Japanese quail have a sophisticated categorisation of [t] and [d] regardless of phonetic effects of following vowels. Acquiring sound categories of particular types may be part of human cognition, but it is not exclusive to humans, and so is not necessarily evidence of human cognition specific to language.

Our suppositions in this domain are reminiscent of both exemplar models (Lacerda 1995, 1998, Pierrehumbert 2001, Johnson 2007, Cole 2009; see also van de Weijer 2009, 2012 on coupling Optimality Theory and Exemplar Theory) and self-organising systems (de Boer 2000, Lin 2005, Wedel 2007). We assume that a Yangben learner hears and remembers parts of the ambient speech. To "hear and remember" requires the learner to identify at least a chunk of an utterance and mentally store that chunk. In the earliest learning, only small chunks of language sound may be remembered. Some of these will correspond neatly to vowels, while other chunks may correspond to consonants, or to transitions, chunks that span both part of a vowel and part of a consonant. For example, a Yangben learner hearing [nìpàná] 'c5-foot' may perceive and retain (some of) the vowel chunks [ì], [à], and [á], and (some of) the consonant chunks [n] and [p].[2] But the learner may also retain chunks that span C-V transitions, getting units like [nì], or [ìp], or [pá], or some subpart thereof.

There are numerous differences among the items that are acquired: each token is physically distinct from all other tokens (uttered at different times, by different people, at different volumes, etc., as well as the possibility of being phonologically different). At the same time, there are some tokens bearing similarities. As shown in Lindblom (2000), incidences of physical properties cluster in some areas and are sparse in others, urging identification of certain similarities due to density in the observational space. Thus, as more items are acquired, the frequency of chunks corresponding most closely to single vowels are highly likely

[2]Yangben, as is typical of Bantu languages, exhibits noun classes; 'c5' refers to noun class 5.

to exceed the frequency of certain other types of chunks, due to the nature of the input. As a point of reference, consider the F1/F2 chart in Figure 2.1, from Boyd (2015). The vowels represented here also vary along dimensions that are not shown in this figure – whether the vowel is long or short, and whether the vowel is high-toned or low-toned. The challenge for the learner is to sort out this multidimensional space. We simplify the discussion here by focussing only on F1 and F2, only two of the multiple relevant dimensions, the two shown in Figure 2.1.

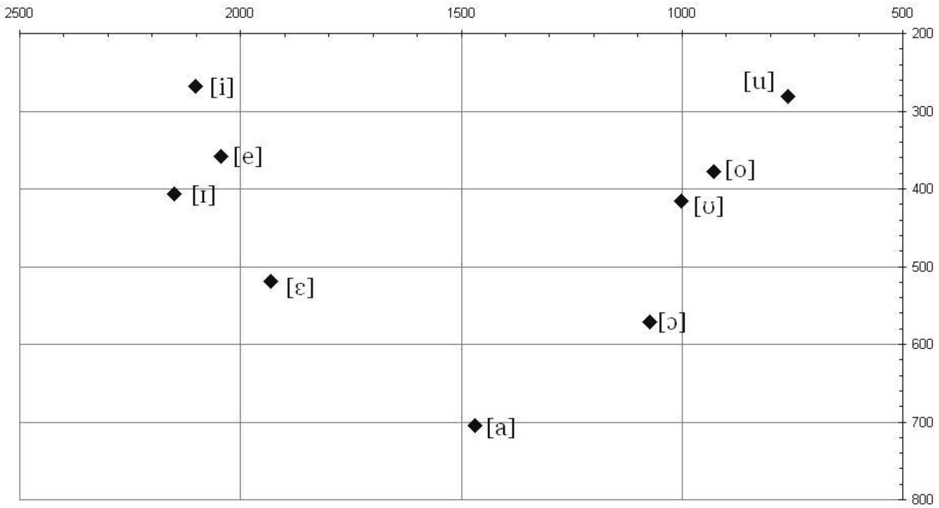


Figure 2.1: Acoustics of Yangben vowels, from Boyd (2015: 238)

Each vowel "point" on the chart in Figure 2.1 corresponds to a cloud of observations, with large gaps where tokens are non-existent or rare. Lacerda (2003) shows that the search space is enormous, so that clusters of similar sounds really stand out. Gerken et al. (2015) demonstrates that learning can be accomplished based even on a single surprising input. Putting these two together, here the surprise is finding more than one token in a particular area of the search space. The stage is set for the human drive to find and generalise over similarities: the learner creates categories of similar items based on acoustic properties, resulting in vowel categories.[3] To summarise, by remembering and storing, learners

[3]There are fewer vowel qualities than consonant types in most if not all languages (Ladefoged & Maddieson 1996) and syllables typically have at least one vowel, so tokens of individual vowels occur with higher frequency than do tokens of individual consonants, correctly predicting that learners will generally hone in on vowels first (Kuhl et al. 1992, Polka & Werker 1994).

acquire dense clusters of chunks, primitive vowel categories. Recognising that the chunks in each cluster are similar to each other and generalising over that similarity leads to the initial abstract representation of each vowel category.[4]

Box 2.2: Generalising and attention to detail

Assuming a role for some version of Exemplar Theory, we hypothesise that a great deal of phonetic detail is recorded in the relevant memory traces that make up each cloud. Categorisation over multiple distinct tokens focusses on shared similarities; by grouping units sharing properties, the fine detail defining particular exemplars comes to hold less importance. Similarities may define cross-cutting categories for a single set of forms. For example, [ì, ì:, í, í:] might form an "i" category, while [ì, í, ì, í, è, é, ...] might form the category of short vowels, and so on. Categories could be established by sharing advanced or retracted tongue root, high or low tone, particular F1 values, etc. Categorisation, however, does not mean loss of observed detail; rather, categorisation simply provides a means of grouping individual units based on shared properties.

To ground this with Yangben data, suppose the learner acquires the forms in (1). This set contains all nine vowel qualities found in Yangben, though they occur with different frequencies: there are six H-toned [á], ten L-toned [à], three L-toned [ʊ̀], one H-toned [ʊ́], etc. (Note that (1) has been deliberately simplified by only including words that have short vowels.)

(1) Yangben words (Boyd 2015: 160–162)

[kʊ̀fát]	'carve, sharpen'	[m̀b^{w}à]	'c9-dog'
[nìpàná]	'c5-foot'	[m̀bàlpálɛ̀]	'c9-pain'
[ŋ̀ilí]	'c9-path'	[nʊ̀kál]	'c11-language/speech'
[ŋál]	'c9-argument'	[kìsɔ́^{m}b̥]	'c7-row for planting'
[kʊ̀kʊ́tà]	'fasten, bind'	[ìp^{w}àp^{w}à]	'c19-puppy'
[àmbàŋɔ́]	'c3-crying'	[àmbàná]	'c6ᴀ-feet'
[ŋèt^{j}è]	'c9-plan'	[pùkòlí]	'c14-vine (specific)'

[4]We assume that learning consonants is similar to learning vowels as discussed here, with the added complexity of determining place from transitions to adjacent vowels. As with vowels, snippets of consonant sounds which include pieces of multiple consonants will have low frequency and so will lack reinforcement as a relevant unit.

Were these data representative of vowel distribution in the forms a learner is acquiring, the vowels [á] and [à] would be readily learned as identifiable categories for three reasons: (i) each vowel sounds different from the other vowels because each has formant properties quite unlike any other vowel in the language (see Figure 2.1); (ii) the two sounds differ from each other due to their different pitches; and (iii) there are multiple examples of each, six tokens of [á] and ten of [à], rendering each a well-supported category, the set of instances of [á], $\{á_1, á_2, ..., á_6\}_{á}$, and of [à], $\{à_1, à_2, ..., à_{10}\}_{à}$.

Ultimately, there will be sufficient tokens of [á] and [à] for the learner to determine that they occupy the same dimensions in formant space, despite occupying different dimensions in tonal space. Taken together, these observations enable the learner to posit not only the specific sets $\{[á]\}_{á}$, $\{[à]\}_{à}$ but also the more general set $\{[á], [à]\}_{a}$, containing both [á] and [à].

Box 2.3: Sets

Two elements {X}, {Y} are members of a single set $\{...\}_{\alpha}$ iff ∃ property α, where α is a property of both {X} and {Y}.

Sets used in language can be motivated by single properties or by groups of properties. These properties may be syntactic or semantic, such as NOUN, VERB, PARASOL, THWART, as well as phonetic or phonological, e.g. HIGH-F1 or ATR.

Similarly, [ɛ́], [ɛ̀], [ɔ́], and [ɔ̀] occupy two distinct vowel formant spaces (recall Figure 2.1) and so might be identifiable as discrete sets even from a very small number of tokens due to the clustered tokens within the large search space. As more tokens are identified, and the frequency of similar sounds increases, the three vowel categories [a], [ɛ], and [ɔ] would be increasingly established as acoustically distinct categories in the Yangben inventory, along the lines of exemplar-based models (Lacerda 1998, Lindblom 2000, Pierrehumbert 2001, Bybee 2001, 2010).

On the other hand, the formants of the other six vowels are relatively tightly clustered, falling into two general sets – a higher front nonround class represented by the symbols [i], [ɪ], [e], and a higher back rounded set, represented by [u], [ʊ], [o].[5]

Initially, learners might distinguish these in terms of only two formant-based categories ([i-ɪ-e] vs. [u-ʊ-o]) due to the crowded vowel space and the low frequency of these vowels in the data recorded. As more items are learned, the distinctions are teased apart. We could imagine that some Yangben learners might pass through a phase of not distinguishing [ɪ̀] from [è], and/or not distinguishing [ʊ́] from [ó], etc., but ultimately all typical learners make the necessary distinctions. In fact, the high retracted and the mid advanced vowels are not distinguished in Paulian (1986) nor in Hyman (2003), giving rise to their seven-vowel analyses. Evidence from early acquisition suggests that human learners are extremely good at sorting out this kind of problem (Werker & Tees 1999, 2002), and there is evidence that infants are better at sorting out F1 differences than they are at F2 differences, suggesting greater ease with the categories distinguished by F1 values (Lacerda 1993, Curtin et al. 2009); our expectation would be that by 6-8 months, a child learning Yangben would have correctly identified the nine categories of vowels indicated in Figure 2.1.

Nonetheless, such identification would be insufficient for developing an understanding of the vowel class relations that form part of the Yangben phonological system. Consider, for example, the vowels symbolised by Boyd as [ɪ], [e], [o] and [ʊ]. *A priori*, the interpretation of [ɪ] and [ʊ] as "high" vowels would lead us to expect lower F1 values than for [e] and [o], two "mid" vowels. In fact, however, Boyd has chosen to use the symbols [ɪ], [e], [o] and [ʊ] in a manner exactly opposite to these expectations; see Figure 2.1. Boyd's reason is the phonological behaviour of Yangben vowels, as we shall see shortly. However, the best the learner can do before phonological patterns are identified is to determine that there are up to nine distinct vowel segments in the language and to categorise those vowels based on some combination of acoustics and articulation.

[5] Given the limited number of vowels in (1), there are some types for which no token appears. For example, there are two examples of [ɔ́], but none of [ɔ̀]; conversely, there is one example of [ɛ̀], but none of [ɛ́]. Such gaps are to be expected, particularly at very early stages of acquisition. While it is almost certain that every Yangben learner would hear [ɔ̀] and [ɛ́] in the first year of life, gaps do occur. Gaps may be relatively infrequent at the level of the inventory of consonants and vowels, but they may be more common in the morphology, particularly for a language with rich inflection. In such cases, gaps may be interpreted by the learner as accidental – filled in easily and even productively – or as systematic, encoded into the grammar as a formal "gap".

Box 2.4: Acquiring a vowel inventory: UG principles vs. Emergence principles

Frameworks with innate linguistic principles, such as universal distinctive features, require the step of identifying the relevant segments of the language – otherwise there is nothing to assign distinctive features to. On this score, Emergence and Innatist views are essentially the same.

Once a segment is identified in either framework, there remains the challenge of identifying the relevant properties for the segment. This is not something that can be done based on acoustics and articulation alone. What a linguist classifies as "[high]", for instance, varies acoustically across languages. In this regard, see the discussion of inventories with contrasts in tongue root features in Ladefoged & Maddieson (1996): it is impossible, for example, to decide whether a vowel is [high] or not *directly from F1 values*; it is also impossible to determine if a vowel is advanced or retracted *from relative F1 values* – Yangben vowels are a case in point. Hence to establish "highness" (and ultimately "[±high]" (UG) or a "[high]" category (Emergence)), some consideration of phonological patterning is critical. We return to this issue in §2.3.

For a theory with pre-determined features, this mapping problem has not received a great deal of attention, yet it plays a critical role in acquisition. For discussion of this issue, see box 2.12, p. 27.

Under Emergence, on the other hand, one task for the learner is to identify sets of segments with shared properties. If we refer to some such set as "[high]", it is as a convenience to the linguist.

2.2 (Natural) classes: Vowel categories and phonetic properties

Relations among vowels are motivated by different types of similarity. Consider the example of similarity based on acoustics, already appealed to in the above discussion.[6] Imagine that we were to divide the nine vowels of Yangben into just

[6] We appeal to acoustics in the absence of auditory perception data about Yangben, let alone of perception during the acquisition of Yangben.

two sets based on acoustic properties. Setting aside length, one might imagine a variety of possible partitionings; a few are shown in (2).

Box 2.5: Partitions

A partition of a set S is a set of non-empty subsets, where every element of S appears in one and only one of the subsets. We use the noun *partition* to refer to one of these subsets, as well as to refer to the full partitioning of a set. Where context does not disambiguate, we will be more explicit. A set may be partitioned in more than one way; see for example the partitions in (2).

Conservatively, we assume that each simple partition is accomplished by a single criterion, thereby deriving *binarity* in our classifications. The basis for establishing partitions includes phonetic, phonological, and morphological criteria. While it would be possible to assume complex partitions (e.g., along the dimension of F1, vowels could be divided into three subsets: (i) <500Hz; (ii) >500Hz & <600Hz; (iii) >600Hz), the null hypothesis seems to be using singleton criteria as primitives: creating a complex partitioning implies the ability to create a simple partitioning. We therefore assume that all complex partitions result from the combined effect of multiple simple partitions, deriving an effect comparable to that of binary features (Chomsky & Halle 1968).

When a set is partitioned, it is not necessarily the case that both partitions will be equally amenable to definition. For example, if the set of segments included oral and nasal vowels, along with oral and nasal consonants, then a partition based on segments produced with exclusively nasal airflow would separate nasal plosives from the three other segment types. Nasal plosives as a class could be defined phonetically but the complement class could not be. See relevant discussion in §5.2, especially the box 5.2, p. 97.

(2) Possible partitions for Yangben vowels

		meet criterion	*do not meet criterion*
a.	*low F1* F1< 500Hz	i̇́, i̇̀, é, è, ɪ́, ɪ̀, ʊ́, ʊ̀, ó, ò, ú, ù	ɛ́, ɛ̀, á, à, ɔ́, ɔ̀
b.	*lower F1* F1<400Hz	i̇́, i̇̀, é, è, ó, ò, ú, ù	ɪ́, ɪ̀, ɛ́, ɛ̀, ɔ́, ɔ̀, ʊ́, ʊ̀, á, à
c.	*low F2* F2 <1250Hz	ɔ́, ɔ̀, ʊ́, ʊ̀, ó, ò, ú, ù	i̇́, i̇̀, é, è, ɪ́, ɪ̀, ɛ́, ɛ̀, á, à
d.	*close F1 & F2* F2–F1<1000Hz	á, à, ɔ́, ɔ̀, ʊ́, ʊ̀, ó, ò, ú, ù	i̇́, i̇̀, é, è, ɪ́, ɪ̀, ɛ́, ɛ̀
e.	*high F1* F1>650Hz	á, à	i̇́, i̇̀, é, è, ɪ́, ɪ̀, ɛ́, ɛ̀, ɔ́, ɔ̀, ʊ́, ʊ̀, ó, ò, ú, ù
f.	*high F0* relatively high pitch	i̇́, ɪ́, é, ɛ́, á, ɔ́, ó, ʊ́, ú	i̇̀, ɪ̀, è, ɛ̀, à, ɔ̀, ò, ʊ̀, ù
	and so on...		

As noted in (2), various principles might be invoked to guide each such partitioning, with different effects. For example, considering F1 values alone, we can see the line between partitions could be drawn in different places. In (2a), for example, a distinction is made around 500 Hz; in (2b), the partition divides vowels at around 400 Hz. Similarly, F1 or F2 values would favour sets like (2a, b, c) while F1/F2 spacing would favour (2d) – partitioning which results in sets of more or less equal size. Similarly, pitch separates half the vowels from the other half in (2f). On the other hand, having a high F1 value, used in the partitioning shown in (2e), results in quite unequal sizes of sets. In addition, other sorts of properties, for example, phonation differences, might interact with the fundamental frequency and formant properties referred to here. In many cases, the partitions correspond to the *natural classes* made familiar in various theories of universal distinctive features – natural because they correspond to phonetic properties. However, exact mapping between the two is not a necessary – nor a desired – consequence: as demonstrated in Mielke (2008), theories of universal distinctive features do not always map well to the ways that sounds pattern in languages.

As the learner takes other factors into consideration, such as articulatory properties (by integrating visual information (Rosenblum et al. 1997, Teinonen et al. 2008, Coulon et al. 2013)), and later by developing the capacity to produce the perceived speech sounds (DePaolis et al. 2011, Tenenbaum et al. 2013, Yeung & Werker 2013), these other factors will reinforce some partitions, weaken some, and suggest other divisions. A very interesting and important result of this aspect of language acquisition is discovering the most robustly supported sets, the ones most likely to be part of the representation of the sounds of the language.

Box 2.6: Labelling sound sets

Sets are labelled (or indexed). We use familiar distinctive feature terms to label many of our sets as a mnemonic convenience and a recognition that such sets are well-established robust categories. But they are not necessary categories. Under Emergence, the true test is how each set is motivated in a particular language, both phonetically and phonologically. While the class of segments that is labelled [high] or [sonorant] or [voiced] in one language might be related to a similarly-labelled class in another language, there would be no reason to expect that the perceptual or articulatory properties shared by the members of similar sets would be identical, nor would it be expected that the precise segments in the set be identical, nor would it be expected that the phonological motivation would be exactly the same. (See box 5.1 on p. 92 for a case in point.)

Box 2.7: Robust evidence & sets of sounds

The robustness of the property (or properties) identifying a set ought to correlate with the robustness of the set, and in reverse fashion, a set that has at best tenuous similarities, or no identifying property, ought not to be a robust set. We assume that robustness would correlate positively with learnability, with diachronic stability, with frequency of occurrence in the patterns in a specific language, with recurrence in multiple diverse languages, and so on. Note, however, that robustness depends on more than just phonetic properties. Frequency of a pattern in the lexicon, morphological transparency, types of lexical items illustrating a pattern, and so on, all contribute to robustness.

Many such robust sets have already been identified in linguistic research, sets identified by particular distinctive feature values (Jakobson et al.

1954, Chomsky & Halle 1968, Clements & Hume 1995, among others). For example, the set in (2e), by invoking reference to F_1: {i, e, ɪ, ɛ, ɔ, ʊ, o, u}$_{F1>650Hz}$ vs. {a}$_{F1>650Hz}$, corresponds to the "feature" values that we generally refer to as [−low] and [+low], respectively. Rather than proposing that segments are composed of features, we propose atomistic segments that are categorised by properties that are relevant in the language. Of course, frequently such properties will be relevant cross-linguistically.

Because Emergence does not assume innate feature categories, there is no expectation that there is some small set of features that can account for the phonological patterns found in every language, consistent with results presented in Mielke (2008).

2.3 Distributional evidence for partitions

Acoustic and articulatory properties give rise to a wide range of ways to classify vowels because there are myriad physical properties and each is gradient. Yet in the course of acquiring a language, the learner amasses evidence in support of some partitions, thereby reinforcing those partitions. Other partitions receive little or no support, and so may atrophy. Both phonological and morphophonological distribution provide evidence that supports certain phonetic categories and not others, which provides critical evidence in determining the classification of the phonological system of a specific language. Purely phonological distribution does not require morphological analysis and so will be acquired earlier; in turn, it can be used to help identify morphological structure. Here we examine two types of phonological distribution in Yangben, sequential distribution and positional distribution.

2.3.1 Sequential evidence for a partition

Our first example involves a phonotactic restriction governing vowel cooccurrence patterns. As noted in Boyd (2015: 161), inspection of words in Yangben (such as those in Table 2.2) shows that words fall into two classes defined by the sets of vowels that cooccur. The eight vowels {í, ì, ú, ù, é, è, ó, ò} cooccur in words with each other, and vowels of the set {ɪ́, ɪ̀, ʊ́, ʊ̀, ɛ́, ɛ̀, ɔ́, ɔ̀, á, à} cooccur in words with each other, but there are no words with vowels from both sets together. (We continue to simplify the discussion by considering only forms that contain short vowels.)

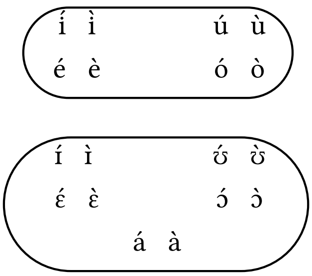
Table 2.2: Yangben: Two word classes (Boyd 2015: 160–164, 172–173)

{í, ì, ú, ù, é, è, ó, ò}		{ɪ́, ɪ̀, ʊ́, ʊ̀, ɛ́, ɛ̀, ɔ́, ɔ̀ á, à}	
[kùtùnè]	‘back up (rear first)’	[kɪ̀sɔ́ᵐb̥]	‘c7-row for planting’
[ŋètʲè]	‘c9-plan’	[kʊ̀kʊ́tà]	‘fasten, bind’
[pùkòlí]	‘c14-vine (specific)’	[àmbàŋɔ́]	‘c3-crying’
[òŋòlí]	‘c3-vine (generic)’	[kɪ̀tɛ̀kʊ́]	‘c7-gift of forgiveness’
[èŋìní]	‘chicken flea’[a]	[kʊ̀kɔ̀t]	‘fasten, bind’
[kìfòŋó]	‘c7-bottomless pit’	[nɪ̀pàná]	‘c5-foot’
[kùkètì]	‘measure, weigh (v)’	[nʊ̀kál]	‘c11-language/speech’
[pùkìlí]	‘c14-path’	[m̀bàlpálɛ̀]	‘c9-pain’
[òndé]	‘c3-grass sp.’	[mɔ̀fɔ̀ᵐʲfɛ̀]	‘c6-marrow’
[kùpíkòf]	‘devour’	[kɪ̀ᵐbɪ̀lɔ̀]	‘c7-tadpole’

[a] Class information is missing for [èŋìní] ‘chicken flea’ in Boyd (2015); class information is reconstructed for several nouns beginning with [kì] or [kɪ̀], since only the class 7 prefix has this form.

This pattern reinforces the partition given in (2b) and depicted visually in (3), a partition that separates vowels based on F$_1$ height (recall Figure 2.1).

(3) Yangben vowel sets based on the cooccurrence patterns in Table 2.2



Observing such cooccurrence patterns with specific tokens of vowels has four consequences for the grammar (4).

(4) Consequences of a cooccurrence pattern

i. The partition supports classifying [é] as distinct from [ɪ́], and classifying [è] as distinct from [ɪ̀] – though acoustically very similar, the vowel set {é, è}$_{\text{e}}$ functions differently than set {ɪ́, ɪ̀}$_{\text{ɪ}}$.

ii. The partition supports classifying [ó] as distinct from [ʊ́], and classifying [ò] as distinct from [ʊ̀] – though acoustically very similar, the vowel set {ó, ò}$_{\text{o}}$ functions differently from {ʊ́, ʊ̀}$_{\text{ʊ}}$.

iii. The Yangben vowel partition from (2b), [í, ì, é, è, ó, ò, ú, ù] and [ɪ́, ɪ̀, ɛ́, ɛ̀, á, à, ɔ́, ɔ̀, ʊ́, ʊ̀], is reinforced as salient in the language.

iv. The pattern supports a word phonotactic requiring vowels in a word to be from the set {í, ì, é, è, ó, ò, ú, ù}$_{\text{[F1<400Hz]}}$ or from {ɪ́, ɪ̀, ɛ́, ɛ̀, á, à, ɔ́, ɔ̀, ʊ́, ʊ̀}$_{\text{[F1>400Hz]}}$, but not from both sets within a single word.

Boyd (2015) suggests that tongue root position, advanced or retracted, is the relevant phonetic property for distinguishing these two classes of vowels in Yangben.[7] We accept this, designating the set {i, e, o, u} as [atr] and the set {ɪ, ɛ, a, ɔ, ʊ} as [rtr]; the issue is interesting, however, and we return to it briefly in §2.3.1.1.[8]

Box 2.8: Labelling convention

When labelling sound categories, we use where possible terms that are relatively familiar in the distinctive feature literature (Jakobson et al. 1954, Chomsky & Halle 1968, etc.) precisely because they are familiar and descriptive. However, we eschew the "+" and "−" values, using [atr] and [rtr] instead of [+ATR] and [−ATR], [low] and [nonlow] instead of [+low] and [−low], etc. to emphasise that these terms identify classes of sounds that a learner might reasonably posit, not classes of sounds defined by innate universal distinctive features. (When referring to traditional analyses, we use the terms in the sources, as with Boyd 2015 in footnote 7.) See also box 2.6 on page 19.

[7] Boyd (2015) classifies the set {i, e, o, u} as [+ATR] and the set {ɪ, ɛ, a, ɔ, ʊ} as [−ATR].

[8] Tongue root position is an articulatory property with variable acoustic effects; see Warren (2014) for a review. We expect that the learner may successfully identify the [atr]/[rtr] partition before being able to control the articulators sufficiently to produce the distinction. However, Yangben F1 values may be adequate for relating the distributional partition to a physical property based on the formant values shown in Figure 2.1, so the distributional evidence enhances a partition motivated perceptually and perhaps articulatorily as well. On the robustness of sets, see box 2.7 on p. 19.

The [atr] and [rtr] vowel classes are identified in part due to their distribution, a pattern which is generalised as a phonotactic requiring sequences of identical tongue root values. A learner may begin by positing generalisations that are quite narrow – for example, they might be specific to particular sequences of segments: there are [i…i] sequences and there are no [ɛ…i] sequences, etc. As more such segment-specific generalisations are formed, such generalisations can – and, we propose, will – constitute the basis for further generalisation if possible: "there are [i…i], [e…i], [o…i] sequences" leads to "there are [i/e/o…i] sequences; "there are no [ɛ…i], [ɔ…i], [ɪ…i] sequences" leads to "there are no [ɛ/ɔ/ɪ…i] sequences". This in turn leads to generalisations based on categories such as "there are no sequences of rtr…high-atr" until the broadest generalisation possible for the data is obtained: in the case of Yangben, the language allows only sequences of vowels that are in the set as defined by tongue root position (5). (The similarity to Optimality Theoretic constraints is intentional, though the source of conditions in a language is quite different.)

(5) Yangben tongue root phonotactics

a. *[rtr][atr], $\mathcal{F}$: vowels, $\mathcal{D}$: morph, word
With a focus on vowels, assign a violation to a word or a morph for each sequence of a retracted vowel followed by an advanced vowel.

b. *[atr][rtr], $\mathcal{F}$: vowels, $\mathcal{D}$: morph, word
With a focus on vowels, assign a violation to a word or a morph for each sequence of an advanced vowel followed by a retracted vowel.

Box 2.9: Focus $\mathcal{F}$ and Domain $\mathcal{D}$

In some cases, phonotactics are relevant only to particular segment-types, indicated by $\mathcal{F}$ in the formulation of a phonotactic, $\mathcal{F}$ for *focus*. The concept is elucidated further in box 3.4 on page 37.

Syntactic, morphological, and phonological information together can converge on recurring units, such as *word* or *stem* or *morph*. These units may serve to delimit the *domain* of particular phonotactics, indicated by "$\mathcal{D}$" in (5) and elsewhere, as well as play other roles in a grammar.

Box 2.10: What is the role of phonotactics in lexicon-building?

Phonotactics, such as those in (5), play various roles in acquisition. First, such phonotactics provide a hypothesis when perception is incomplete. That is, a grammatically encoded phonotactic condition sets the learner's expectation for new lexical items in favour of sequences defined as well-formed by the phonotactic (Moore-Cantwell 2016); the strength of this effect correlates with the strength of the phonotactic (based on factors such as the number of relevant forms and the frequency of lexical exceptions; see also Yang 2016). In the Yangben case, if a vowel is perceived imperfectly, it may not be obvious whether it is [atr] or [rtr]; the phonotactic provides the learner with a hypothesis. Additionally, word-based phonotactics guide the learner in identifying word edges: here, a change from [atr] to [rtr] or vice versa signals a word-boundary change, since words do not contain both [atr] and [rtr] vowels.

The effect of (5) is that both [atr]…[rtr] and [rtr]…[atr] are penalised, but that neither [atr]…[atr] nor [rtr]…[rtr] is penalised; rather, when all vowels in a word are in the same tongue root set, the word is well-formed. Following Hayes & Wilson (2008), we assume that such phonotactics can be generated by a mechanism such as maximum entropy and we formalise them, again following Hayes & Wilson, as well-formedness conditions prohibiting a particular sequence involving either particular classes of segments or the complement of a class of segments. Complement classes (designated as [^X] – the complement class of [X]) are discussed in §5.2. (See (15) in Chapter 3 for a schematisation of syntagmatic phonotactic well-formedness conditions.)

The skewed distribution of vowels in Yangben words provides the learner with evidence confirming a particular partitioning of the Yangben vowels. Additionally, this same distribution supports positing a word-level condition, requiring that tongue root values within a word are all the same. The evidence for the tongue root partitioning is robust.

2.3.1.1 Aside: Converging properties

It is evident that the nine Yangben vowels are divided into two harmonic sets; the distribution of vowels supports this partition. However, the evidence in Boyd (2015) for the specific labels [atr] and [rtr] is fundamentally distributional. While the proposed analysis appears plausible, no articulatory evidence has been presented to suggest that there is a shared articulatory property, such as tongue root advancement/retraction or pharyngeal expansion/constriction (Lindau et al. 1972, Lindau 1978), that would give independent support to the [atr]/[rtr] labels. In short, using [atr] and [rtr] to characterise the Yangben pattern reflects an as yet unsubstantiated hypothesis that a particular articulatory correlate applies to a partition which is independently needed to account for the phonological distribution. In fact, despite the plausibility of Boyd's analysis, there is an alternative analysis, in terms of a category of tongue body height.

Under the alternative analysis, the vowels transcribed in Boyd (2015) as "e" and "o" would be classified as "high" vowels, corresponding to their lower F1, {ɪ, ʊ}. Conversely, the vowels transcribed as "ɪ" and "ʊ" by Boyd would be classified as "mid" vowels, {e, o}, corresponding to their higher F1. According to this [high]/[nonhigh] analysis, words such as 'plan' and 'vine (generic)' (Table 2.2) (transcribed as [ŋètʲè] and [òŋòlɪ́] in Boyd) would be transcribed [ŋɪ̀tʲɪ̀] and [ʊ̀ŋʊ̀lí]; words such as 'gift of forgiveness' and 'language, speech' (transcribed in Boyd as [kɪ̀tɛ̀kʊ́] and [nʊ̀kál]), would be transcribed as [kètɛ̀kó] and [nòkál], so that the symbols used correspond directly to the hypothesised vowel categories. Under this view, harmony is of shared height, [high] vs. [nonhigh], rather than shared tongue root, [atr] vs. [rtr]. This is consistent with an analysis of height harmony as has been done with some other vowel harmony systems in the region, e.g. Esimbi (Hyman 1988) and Mmala (Boyd 2015).

Though something of a puzzle if one has started thinking in terms of a tongue root distinction, this reanalysis is equivalent to the analysis assuming a tongue root distinction, *mutatis mutandis*: vowels within a word must share the same feature, a feature that characterises the two classes that we have shown in (3) and (6). This is true of Yangben whether we call the two classes [high]/[nonhigh] or [atr]/[rtr].

Box 2.11: Mutually-intelligible but distinct grammars

Could one Yangben speaker adopt a tongue root characterisation of the fundamentally phonological vowel partitioning seen in Table 2.2 while another speaker adopts a tongue body characterisation? Would this be a problem? We suggest that this might occur and that it would be neither problematic, nor perhaps, even very noticeable. Consider, for example, the realisation of "r" in English as bunched or retroflex, along with interesting inter-speaker variation in the sorts of articulatory patterns observed (Archangeli et al. 2011, Mielke et al. 2016). What is crucial is that the learners identify the same partitions among the sounds of their language. Realising the partitioned segments in slightly different ways would only be problematic if the realisations were different enough to produce confusion. Simply having slightly different articulatory mechanisms, as in these cases, does not raise the concern of mutually unintelligible grammars: the grammars agree in their partitioning of segments and adopt articulatory mechanisms for producing a perceptually similar effect.

At the same time, the Emergent framework predicts each learner will have a unique grammar, a response on the part of the learner to the data to which they are exposed. We expect – for language to be understandable – that there will be a high degree of overlap with the grammars of different speakers of the same language. The differences between the grammars of individuals characterise idiolectal and dialectal properties; there will also be differences between an individual's grammar at different points in their life, due to maturation and to the impact of continually acquiring language knowledge.

(6) Yangben vowel sets under [high]/[nonhigh] analysis

í	ì	ú	ù
ɪ́	ɪ̀	ʊ́	ʊ̀

é	è	ó	ò
ɛ́	ɛ̀	ɔ́	ɔ̀
	á	à	

The representations in (3) and (6) are functionally the same though the labelling differs: they designate the same number and arrangement of vowel categories. What is critical is that the categories posited allow for straightforward characterisations of the vowel cooccurrence pattern seen in Table 2.2. The vowel generalisations discussed in Boyd (2015) can be expressed in either system, simply by varying the roles of [high] and [nonhigh], [atr] and [rtr]. The difference between the two analyses is the claim made about the phonetic substance, specifically the articulatory correlates, of the partitions motivated by vowel cooccurrence patterns.

The crucial point is that the phonological characterisation of the set is compatible with both phonetic characterisations of the partition – as involving the tongue root or as involving the tongue dorsum. Either would serve to partition the vowels into sets relevant for expressing the distributional patterns in the language. For our discussion here, given the absence of articulatory evidence one way or the other, we use symbols and features consistent with Boyd (2015), for ease of cross-referencing with our primary source.

Box 2.12: The Mapping Problem & assigning feature labels

Under Emergence, segments are assigned category membership based on their behaviour, both phonetic and phonological. In this way, the critical categories for the segments of a language emerge. Compare this to the learning trajectory in some version of UG where it is necessary to map a set of universal, innate distinctive features to the segments of a language: the learner must identify segments, how they are articulated, and how they are phonologically and morphologically categorised. But there is another step: the learner must identify which innate distinctive features best map to these categories. In the Yangben case, this is a challenge because of the two possible analyses. Depending on the way the set is articulated, the learner might correctly identify the feature, but they might make a mistake. The learning challenge would be to correctly identify the articulation that aligns with an ambiguous acoustic pattern.

With emergent distinctive features, the final “mapping to innate distinctive features” is irrelevant. Identifying and labelling the categories is all that is necessary. The Emergent model of Yangben has no need to distinguish between the [atr]/[rtr] analysis and the [high]/[nonhigh] analysis: what is needed is some segment category contrast [α]/[β] such that the [α] set (the [atr] or the [high] set in the analyses above) contrasts with the [β] set (the [rtr] or [nonhigh] set in the above). What is critical is to identify the categories necessary to account for the distributional patterns. To the extent that the articulatory properties are unambiguous, of course, learners would adopt consistent articulations to realise what is a robustly motivated partition phonologically. Again, for mnemonic ease, we use familiar terms like [high] and [atr] rather than abstract ones like [α] and [β].

See box 2.4 on p. 16 and Pulleyblank (2006b), Blaho (2008), Mohanan et al. (2010), Archangeli & Pulleyblank (2015a, 2018a) for further discussion of the mapping problem.

2.3.2 Positional evidence for a partition

Phonotactics may involve properties other than feature class. For example, learners will acquire constituents like *word* and *stem*, as noted in box 2.9 on page 23. Phonotactics may be limited to a particular domain; phonotactics may also occur only at some domain edge. An example from Yangben involves a restriction whereby low-toned high vowels, and only such vowels, are voiceless word-finally. (Boyd 2015 does not include noun classes for the items in Table 2.3.)

Table 2.3: Yangben word-final vowels & [voice] (Boyd 2015: 163–164)

[voiceless]		[voiced]			
V is low-toned & high		*V is low-toned & nonhigh*		*V is high but high-toned*	
[kɪ̀↓tólɪ̥̀]	‘ant’	[kɪ̀kújè]	‘plant, sp.’	[kɪ̀tòlɪ́]	‘musical form’
[kʲàⁿsɪ̥̀]	‘house’	[kɪ̀tɛ̀lɛ̀]	‘palm bamboo’	[kʲàⁿsɪ́]	‘challenge’
[kɪ̀tékù̥]	‘navel’	[ɪ̀tópò]	‘flank (body)’		
[kìkáːⁿdʊ̥̀]	‘woman’	[àsànà]	‘shrimp’		

The class of vowels would need to be expanded to include {ɪ̥̀, ù̥, ì̥, ʊ̥̀} with a phonotactic requiring that low-toned high vowels be voiceless word-finally.

(7) Yangben word-final phonotactic

$$*\begin{bmatrix}\text{voice}\\ \text{high}\\ \text{low-tone}\end{bmatrix}\#,\ \mathcal{F}\text{: segments},\ \mathcal{D}\text{: word}$$

For all segments, assign a violation to a word containing a final low-toned voiced high vowel.

We use the symbol # to indicate an edge; the word domain requirement establishes that this phonotactic is relevant at word edges, not at all morph edges.[9]

2.4 Conclusion

These two examples from Yangben illustrate that the segmental classes relevant for a language are not necessarily based on any one type of evidence, yet the necessary classes are nonetheless derived from the input (see also Flemming 2005, Sylak-Glassman 2014 on deriving "natural" classes). Here we see a partition between [atr] and [rtr] vowels that is supported both acoustically and by a syntagmatic vowel cooccurrence pattern. The partitions between [voiced] and [voiceless] and between [high] and [nonhigh] vowels are similarly motivated by both the phonetics of articulation and perception alongside phonological considerations of word position. The more types of evidence in support of a class, the more robust that class will be in that language.

Partitions in the sweet spot – those that are supported simultaneously by acoustics, articulation, and phonological patterns – will be the most robust, hence predicted to be more easily learnable and more stable in a language. Consequently, we expect most partitions used in phonological patterns to have a phonetic basis in spite of no requirement that all classes have such a phonetic characterisation (Mielke 2008). Particularly where the phonetic basis for a class is weak, we would expect the stability of the class to correlate with the amount of data motivating the pattern. That phonetically motivated classes recur in phonological systems is precisely what is expected in a stable system that is readily transmitted from one generation to the next (Blevins 2004). Due to the similarity of human physiology, driving both articulation and perception, we expect acoustic and articulatory pressure to be largely similar across languages, leading to the impression of innate, universal distinctive features. It is this kind of consideration that provides the motivation for the sorts of substantive proposals made in the literature on feature geometry (Mohanan 1983, Clements 1985, Sagey 1986, McCarthy 1988, Clements & Hume 1995), with the tight (but cross-linguistically variable) relation between feature structure and phonetic properties of human articulation and perception.

[9] A logical extension of our framework is that the language learner acquires the notions of *word* and of *morph* from observing the data, not because these are innate categories, and so the nature of the categories might vary somewhat from language to language. See Haspelmath (2007, 2011) for arguments in favour of learners extracting morphosyntactic categories from data to which they are exposed, including some notion of *word*.

Note also that this framework predicts that learners may construct phonetic partitions that have no independent role in the phonological system; conversely, it is also possible to construct phonological partitions that have no basis in the phonetic properties of the sounds (Anderson 1981, Mielke 2008). In either case, the evidence is weaker, and is less likely to be canonised in the grammar. Encoding such conditions in a diachronically stable fashion will depend on factors such as the number of members in a class: a class that occurs with high frequency is more likely to be maintained than one that is highly restricted, with both type and token frequency relevant. Partitions that are identified but serve no grammatical purpose will not be reinforced; partitions that are erroneously established will never be used by the grammar and so, with a frequency of close to zero, these partitions would atrophy and disappear.

This chapter has explored how different types of categories relevant to a language emerge from the data that the learner is exposed to. We turn now to the emergence of more complex categories – sets of related morphs – and their roles in the emerging grammar.

3 Building a phonological grammar

Hearing, remembering, noting similarities and frequencies, creating categories, generalising, and re-generalising serve not only to identify distinctive sounds (as laid out in Chapter 2) but also help the learner identify words and morphs within words. As morphemic structure is acquired, the learner must recognise that there can be multiple morphs with the same meaning, that there are systematic ways of combining morphs to generate new words, that forming well-formed words involves selecting among possible morphs with related meanings, and that the class of observed morphs can be expanded to enable use of as-yet-unheard morphs.

Concreteness continues to guide us. Learners encounter surface forms that are meaningful; they therefore posit representations corresponding to pairing such forms with their meanings. Learners encounter instances where phonologically distinct forms have the same meaning; they therefore posit representations corresponding to such cases. Learners also encounter instances where a single phonological form has more than one meaning; again, the learner posits representations that transparently correspond to such occurrences. The fundamental notion is one where sound strings are meaningful, and where the sound-meaning correspondences are represented in the grammar. Meaningful (surface) morphs are grouped into sets according to their meaning.

In this chapter, we therefore focus on morph sets and their interactions, beginning with characterising related morphs as sets (§3.1). When morphs from different sets are compiled to create words, some means is needed to select among the possible compilations. In large part, this is a consequence of the well-formedness conditions already identified in order to understand the relevant categories in the language (§3.2). We close with a discussion of systematic phonological relations among members of morph sets and how to determine which combination of morphs is appropriate to represent a given set of morphosyntactic features (§3.3).

3.1 Cataloguing the data: Morph sets

We hypothesise a learning trajectory along the following lines. As the learner becomes aware of and stores longer sequences, recurring longer chunks get high frequency counts; those sequences become the learner's proto-words (Martin et al. 2013). Refinement occurs over time as more items are acquired, and stored words become increasingly adult-like. The learner recognises that certain sound strings cooccur with particular meanings. We define morphs along the lines of traditional definitions of the "morpheme" (Bloomfield 1933, etc.; see discussion in §4.2): a *morph* is a string of sounds associated with a meaning and/or grammatical function: {[sound string]}$_{\text{MEANING/FUNCTION}}$.[1] In addition, as we discuss below, there are many instances where more than one string of sounds corresponds to the same meaning. We refer to sets of morphs which share a label as *morph sets* where a morph set could include a single morph or multiple morphs: {[sound string]$_1$, [sound string]$_2$, ...}$_{\text{MEANING/FUNCTION}}$.

Box 3.1: Morph Sets

Morph sets are defined by morphosyntactic features. A morph set may have as few as one member, but is not restricted to only one. Where there are multiple members, the different morphs in a set may be systematically related to each other, although this is not necessary. Systematic relations are captured by *Morph Set Relations* (3.3.1); productive relations are expressed with *Morph Set Conditions* (3.3.2). Additionally, there may be well-formedness conditions that restrict a class of morphs; such conditions may be distinct from the well-formedness conditions which play a role in selecting between morph compilations that make up words.

Morphs and morph sets are identified through their similarity – initially, similarity of both the phonological string and the semantic and syntactic functions – and their frequency of occurrence. A Yangben learner might begin identifying words (due to phonotactics) such as [kùtı̀m] 'dig.INF' and [kùtùn] 'back up (rear first).INF', alongside [kʊ̀nɛ̀ːn] 'abandon, let fall.INF' and [kʊ̀jɛ̀k] 'rot.INF'. Without knowing the syntactic function of these sequences, the learner might still note the similarity of how the words begin, and identify two classes, the [kù...] class and the [kʊ̀...] class. (In (1), the component words in the glosses are separated by "." to denote that the learner has yet to identify independent meanings for subparts of the word; data are from Boyd 2015: 162.)

[1] This use of the term *morph* is consistent with our earlier work (such as Archangeli & Pulleyblank 2015a, 2018a,b). See also Haspelmath (2020b: 117): "A morph is a minimal linguistic form".

(1) Early morph acquisition: two word classes, [kù...]-words and [kʊ̀...]-words

a. [kù...]-words
[kùtìm] 'to.dig'
[kùtùn] 'to.back.up.(rear.first)'

b. [kʊ̀...]-words
[kʊ̀nɛ̀ːn] 'to.abandon, to.let.fall'
[kʊ̀jɛ̀k] 'to.rot'

Note that these classes must be distinct if the learner has established the difference between [u] and [ʊ] prior to the onset of vocabulary development; see §2.1.

As syntactic functions are identified, the learner establishes that these two classes each have a particular syntactic function, INFINITIVE. Now the two classes can be labelled more precisely, the $[\text{kù...}]_{\text{INF}}$ class and the $[\text{kʊ̀...}]_{\text{INF}}$ class, leading to the generalisation that "INFINITIVE begins with [kù] or [kʊ̀]".

(2) Mid morph acquisition: two classes of INFINITIVES

[kù...]-INFINITIVES	[kʊ̀...]-INFINITIVES
[kùtìm] 'dig-INF'	[kʊ̀nɛ̀ːn] 'abandon-INF, let.fall-INF'
[kùtùn] 'back.up.(rear.first)-INF'	[kʊ̀jɛ̀k] 'rot-INF'

Similarity of the initial sound sequence in each class leads to separating those initial sequences into units that are independent of the rest of the word.

(3) Mid morph acquisition: two INFINITIVE morphs: $\{\text{kù}\}_{\text{INF}}$, $\{\text{kʊ̀}\}_{\text{INF}}$

[kù...]-INFINITIVES	[kʊ̀]...-INFINITIVES
[kù-tìm] 'dig-INF'	[kʊ̀-nɛ̀ːn] 'abandon-INF, let.fall-INF'
[kù-tùn] 'back.up.(rear.first)-INF'	[kʊ̀-jɛ̀k] 'rot-INF'

Once this step is reached, the learner is in position to hypothesise both $\{\text{kù}\}_{\text{INF}}$ and $\{\text{kʊ̀}\}_{\text{INF}}$, and, by the union of these two INFINITIVE forms, the morph set $\{\text{kù, kʊ̀}\}_{\text{INF}}$. This hypothesis is supported by identifying the remainder of the forms as a verb morph, which in turn is supported by learned forms containing the same sound-meaning pairing.

(4) Late morph acquisition: an INFINITIVE morph set, plus verb morphs

$\{\text{kù, kʊ̀}\}_{\text{INFINITIVE}}$

$\{\text{tìm}\}_{\text{DIG}}$	$\{\text{nɛ̀ːn}\}_{\text{ABANDON, LET.FALL}}$
$\{\text{tùn}\}_{\text{BACK.UP.(REAR.FIRST)}}$	$\{\text{jɛ̀k}\}_{\text{ROT}}$

As more infinitives are learned, the hypothesis is repeatedly supported: infinitive forms begin with either [kù] or [kʊ̀], (5). The stronger the evidence, the more entrenched the hypothesis becomes in the grammar.[2]

(5) Yangben infinitives (Boyd 2015: 162)

a. [atr] roots

	INF-verb-CONT	INF-verb	gloss
[i]	kù-tím-è	kù-tìm	‘dig’
	kù-tíːn-è	kù-tîːn	‘flee in fear’
[e]	kù-sèl-èn	kù-sèl	‘descend’
	kù-téːɲ-ì	kù-têːn	‘(make) drip’
[o]	kù-pí-kóf-ò	kù-pí-kòf	‘devour’
	kù-fóːk-òn	kù-fôːk	‘advance, go ahead’
[u]	kù-tùn-è	kù-tùn	‘back up (rear first)’
	kù-túːn-è	kù-tûːn	‘crush’

b. [rtr] roots

	INF-verb-CONT	INF-verb	gloss
[ɪ/ɛ]	kʊ̀-jɪ̀k-à	kʊ̀-jɛ̀k	‘rot’
	kʊ̀-jɪ́ːl-à	kʊ̀-jɛ̂ːl	‘(be) slimy (food)’
[ɛ]	kʊ̀-fɛ̀k-ɛ̀	kʊ̀-fɛ̀k	‘measure’
	kʊ̀-nɛ̀ːn-ɛ̀n	kʊ̀-nɛ̀ːn	‘abandon, let fall’
[a]	kʊ̀-fát-à	kʊ̀-fàt	‘husk (corn); shell’
	kʊ̀-fáːt-à	kʊ̀-fâːt	‘carve, sharpen’
[ɔ]	kù-sɔ́k-ɔ̀	kʊ̀-sɔ̀k	‘extract’
	kʊ̀-sɔ́ːk-ɔ̀	kʊ̀-sɔ̂ːk	‘grow (of plants)’
[ʊ/ɔ]	kù-kʊ́t-à	kʊ̀-kɔ̀t	‘fasten, bind’
	kʊ̀-pʊ́ːk-à	kʊ̀-pɔ̂ːk	‘cook meat (wrapped in leaves)’

To achieve a maximal degree of generalisation, the learner moves towards definitions of morph sets that group together all morphs with the same syntactic or semantic properties, and that provide sets which cannot be further broken down in terms of the syntactic or semantic components – minimal morph sets.

[2] In (5), the final suffix is the CONTINUOUS, except for one form that involves the causative, [kù-téːɲ-ì] ‘drip-CAUSATIVE’. We do not address suffix-related alternations here, such as the alternations in root vowels when in the context of different suffixes.

Box 3.2: Minimal Morph Sets

While morph sets are defined as the set of morphs sharing any set of morphosyntactic features, we use the term *minimal morph set* for a set bearing a simple semantic label.

Examples of minimal morph sets include sets with single members, such as $\{\text{dɑg}\}_{\text{DOG, NOUN}}$, and sets with multiple members, such as $\{\text{hɪt, hɪɾ}\}_{\text{HIT, VERB}}$, $\{\text{naɪf, naɪv}\}_{\text{KNIFE, NOUN}}$, and $\{\text{mæn, mɛn}_{\text{PL}}\}_{\text{MAN}}$.

Fundamentally, the learner is concerned with chunking the speech stream and identifying strings of sounds with a particular meaning or syntax. In many instances, such chunking will result in sets that are non-minimal. As described in Bybee (1999), "[i]n network models, internal structure is emergent – it is based on the network of connections built up among stored units. The stored units are pronounceable linguistic forms – words or phrases stored as clusters of surface variants organised into clusters of related words." In our terms, a chunk like $\{\text{hæpinəs}\}_{\text{HAPPINESS, NOUN}}$ would belong with $\{\text{dɑg}\}_{\text{DOG, NOUN}}$ in a non-minimal set labelled NOUN – all nouns in the language would be included in that set. Another type of non-minimal morph set is a semantically random set of items linked only by their behaviour, such as the various sets making up the noun classes in Yangben, linked by the affixes they appear with, or the set of morphs which behave disharmonically (see box 3.10 on p. 52 and the surrounding discussion).

In general, we refer to *morph sets*, reserving the term *minimal morph set* for contexts where the distinction is critical.

3.2 Selection among multiple morphs: Well-formedness conditions

During production, speakers identify meanings that they wish to express. For the meaning α–β, this involves bringing together morph sets $\{...\}_{\alpha}$ and $\{...\}_{\beta}$. When morph sets are combined, the consequence may bring together singleton morph sets ($\{X\}_{\alpha}$+$\{A\}_{\beta}$), or morph sets with multiple members ($\{X, Y, ...\}_{\alpha}$+$\{A, B, ...\}_{\beta}$), or some combination of singleton and multiple morph sets. For instance, Yangben INFINITIVE-BACK.UP identifies the morph sets {kù, kʊ̀}$_{\text{INF}}$ and {tùn}$_{\text{BACK.UP}}$ while INFINITIVE-ROT identifies {kù, kʊ̀}$_{\text{INF}}$, and {jìk, jɛ̀k}$_{\text{ROT}}$.[3] Where morph sets contain multiple members, as in these examples, multiple potential words are created by compiling the morphs in the logically possible ways.

Box 3.3: Morph Compilation

The *morph compilation* for two morph sets, {...}$_{\alpha}$ and {...}$_{\beta}$, is created by combining each member of {...}$_{\alpha}$ with each member of {...}$_{\beta}$.

If there are more than two morph sets to be compiled, the morph compilation is built in the same way, resulting in all possible combinations of the individual morphs from the participant morph sets. (Assessment selects one member from each morph compilation; in assessments, we consider only compilations with the correct order of morphs.)

Morph sets	{{kù, kʊ̀}$_{\text{INF}}$ + {tùn}$_{\text{BACK.UP}}$}$_{\text{INFINITIVE-BACK.UP}}$
Morph compilation	kù-tùn, kʊ̀-tùn
Output of assessment	{kù-tùn}$_{\text{INF-BACK.UP}}$

Morph sets	{{kù, kʊ̀}$_{\text{INF}}$ + {jìk, jɛ̀k}$_{\text{ROT}}$}$_{\text{INFINITIVE-ROT}}$
Morph compilation	kù-jìk, kù-jɛ̀k, kʊ̀-jìk, kʊ̀-jɛ̀k
Output of assessment	{kʊ̀-jɛ̀k}$_{\text{INFINITIVE-ROT}}$

Part of the task of the speaker is to identify which morph combination to use in cases where there are multiple options, an uncertain situation. In this section, we have two goals. First, we consider ways in which such uncertainties are resolved, focussing on *syntagmatic* and *paradigmatic* well-formedness conditions guided by frequency. Second, we provide the formal framework for the kinds of *well-formedness conditions* that we motivate throughout this monograph.

[3] The set {jìk, jɛ̀k}$_{\text{ROT}}$ may be a truncated morph set. We provide evidence in §3.3 for there being additional morphs involving tongue root alternations, and there may also be tonal variation (which we do not discuss), e.g. {sɔ́:k, sɔ̂:k, só:k}$_{\text{GROW}}$.

3.2.1 Syntagmatic conditions

We have already introduced the key component in choosing between alternative members of a morph set, well-formedness conditions of different types ((5) and (7) in Chapter 2). Syntagmatic phonotactics of the type schematised in (6) play a central role in this kind of choice. (See (15) for the final version of this schema.)

(6) Preliminary syntagmatic phonotactic schema

*[X][Y] Assign a violation to a form for each sequence of [X] followed by [Y], where [X], [Y] are phonological properties.

Phonological properties are the labels assigned to partitioned sets; these may be simple, referring to sets with a single label ([low]); they may also be complex, referring to the intersection of two sets ([high, atr]); they may also be a complement class (^[coronal]).

Box 3.4: How close must two elements in a phonotactic be to each other?

While there is no question that well-formedness conditions frequently hold of segments, X and Y, that are string-adjacent, there are also cases where the interacting segments are separated by some number of segments. This can be seen in cases of vowel harmony, consonant harmony, consonant and vowel dissimilation, and so on. At issue is whether well-formedness conditions must be allowed to include potentially unbounded non-participating classes of segments (W in *XWY) or whether simple well-formedness conditions hold of "tiers" or "projections" of some kind (*XY, W excluded from consideration). Under the tier/projection approach, for example, if we specifically focus on the class of vowels, excluding consonants, then vowel harmony is governed by a *local* condition governing vowel sequences. See, for example, Jardine (2016), Jardine & Heinz (2016), Gouskova & Gallagher (2020) for recent approaches to how nonlocal conditions might be learned in such an approach. We assume some version of such a tier/projection model here, designating the class of segments constituting the *focus* of a well-formedness condition by $\mathcal{F}$ in the formal expression of a condition.

We assume that local effects will be easier to observe and therefore both more frequent and more learnable (Finley 2011, 2012, McMullin 2016); such local effects could also be due to coarticulatory effects that would be observable locally but not nonlocally. This, likely in combination with properties of the learner (Hayes & Wilson 2008, Gouskova & Gallagher 2020), can derive the claim that more proximal patterns are more likely (Suzuki 1998, Pulleyblank 2002, Rose & Walker 2004, Hansson 2010). We expect that the salience of a not-strictly-local class is crucial in differentiating the focus segments from the segments that are excluded by some well-formedness condition, with more salient classes being more likely to serve as the focus of some well-formedness condition. For example, vowels share salient features acoustically that consonants as a class do not; certain sub-classes of consonants are distinctively salient, however, such as the class of sibilants.

To illustrate with Yangben, the harmony conditions given in (5) in Chapter 2, *[rtr][atr] and *[atr][rtr], determine whether [atr] or [rtr] variants of class prefixes are chosen from the relevant prefixal morph sets. Consider the example of [kù-sèl]$_{\text{DESCEND}}$ from (5a). Here, while the prefix has the two morphs, {kù, kʊ̀}, the verb stem has only one morph, {sèl}$_{\text{DESCEND}}$. Since the Yangben harmony conditions prohibit words that mix tongue root specifications, the only well-formed prefix option in this case is advanced [kù], shown by the *assessment table* in (7).

Box 3.5: Assessment tables

The role of an *assessment table* is to demonstrate that a proposed grammar serves to capture an observed phonological distribution. Each table demonstrates whether a proposed ranking of specific well-formedness conditions appropriately identifies an attested morph compilation corresponding to the desired semantic, syntactic, and morphological properties.

Assessment tables intentionally follow the organisation of the tableaux in Optimality Theory (Prince & Smolensky 1993), with certain crucial differences. In an assessment table, the upper left-hand cell identifies the morph sets to be compiled, either by the morph sets themselves, as in (7), or by the morphosyntactic features, as in (9). In either case, we include the morph sets being compiled in each example above the related assessment table, to be clear about what is being compiled.

The left-hand column lists the members of the morph compilation – the logically possible combinations of the morphs in the relevant morph sets; this is a finite set. Phonotactics and other well-formedness conditions motivated for the language are arrayed across the top row of the table. The "*" marks where a well-formedness condition is violated by the form; "*!" marks a fatal violation. In (7), the infinitive has two morphs and the verbs each have one, so there are only two possible forms to assess.

Following the Optimality Theory convention, a solid line between two conditions indicates that the well-formedness condition on the left has priority over the condition on the right. Dashed lines between conditions indicates that the ranking of those conditions is not crucial. While we assume strict domination in our presentation throughout, the adequacy of strict domination may be an artifact of the examples we discuss. We do not discuss alternatives such as weighted conditions (see, for example, Pater 2009, van de Weijer 2012), leaving for further investigation the nature of the interaction among conditions.

(7) Assessment for [kù-sèl]$_{\text{INFINITIVE-DESCEND}}$
morph sets: {kù, kʊ̀}$_{\text{INFINITIVE}}$; {sèl}$_{\text{DESCEND}}$

{kù, kʊ̀}$_{\text{INFINITIVE}}$-{sèl}$_{\text{DESCEND}}$	*[rtr][atr]	*[atr][rtr]
a. kʊ̀-sèl	*!	
☞ b. kù-sèl		

In parallel fashion, if the root is [rtr] (e.g. [kʊ̀-fàt] 'husk (corn); shell') then the only well-formed prefix option would be the [rtr] morph.

In such cases, the phonotactics posited as the result of observations about words are reinforced in the grammar by their role in assessing morph compilations. The skewed distribution within Yangben vowel sequences is that advanced vowels occur more frequently with adjacent advanced vowels while retracted vowels occur more frequently with adjacent retracted vowels. This is encoded as a purely phonological well-formedness condition on sequences.

Box 3.6: Emergence is not Optimality Theory in disguise

While assessments owe an obvious debt to the tableaux of Optimality Theory, Emergent Phonology is quite different from Optimality Theory. Four key differences are noted here.

1. *Richness of the Base*: There is no Richness of the Base in Emergence. Inputs are morph sets which are based on observed forms – either directly observed or generated from an observed form based on a (deduced) general pattern.

2. *Gen*: There is no infinite candidate set in Emergence; instead there is morph compilation (see box 3.3 on p. 36). That is, the forms to be assessed are the result of compiling morphs from the relevant morph sets, a finite number of compiled forms. Since there is only one morph for {tùn}$_{\text{BACK.UP}}$, all forms with BACK.UP in their compilation include this morph. An imaginable form with a retracted verb root vowel, such as *[kʊ̀-tʊ̀n], cannot result from compiling the relevant morphs (since [tʊ̀n] is not a member of the set labelled BACK.UP) so such a form is simply not an option.

3. *Faithfulness*: There is no role for Faithfulness conditions in Emergence. The forms to be assessed are composed from morphs that correspond to surface forms.

4. *Universality*: There is no "universal constraint set" in Emergence. The phonotactics and other well-formedness conditions used for assessing the possible compilations are exactly those motivated for the language. (We reserve the term *constraint* for universal prohibitions as in Optimality Theory; we use *(well-formedness) conditions* when referring to the learned prohibitions within the Emergent framework.)

3.2.2 Prohibitions of types

While sequential phonotactics are often sufficient to determine the choice between possible compilations, there are also instances where additional well-formedness conditions are required. In Yangben, this can be illustrated by the root alternations observed when forms with two suffixes, CAUSATIVE and AGENTIVE, are compared with the familiar infinitive forms.

(8) Yangben root alternations, CAUSATIVE & AGENTIVE (Boyd 2015: 177)

a.

	INF-verb		INF-verb-CAUSATIVE	
[u]	kù-sùk	‘miss, stop’	kù-súk-ì	‘cause to stop’
[ʊ, u]	kʊ̀-fʊ́l-à	‘flow’	kù-fúl-ì	‘cause to flow’
[ɔ, o]	kʊ̀-sɔ́ːk-ɔ̀	‘grow’	kù-sóːk-ì	‘germinate’
[a, e]	kʊ̀-pàl	‘uproot’	kù-pèl-ì	‘cause to uproot’
[ɛ, e]	kʊ̀-kɛ́t-ɪ̀k	‘blink’	kù-két-ìk-èɲ-ì	‘cause to blink’
[ɪ, i]	kʊ̀-jɪ̀k-à	‘boil’	kù-jìk-ì	‘boil over’

b.

	INF-verb		INF-verb-AGENTIVE	
[e]	kʷ-ěp-è	‘steal’	èŋ-ép-ì	‘robber’
[ʊ, u]	kʊ̀-sʊ̀l-à	‘drink (spoon)’	è-sùl-ì	‘drinker’
[ɔ, o]	kʊ̀-lɔ́k-ɔ̀	‘fish’	ò-lók-ì	‘fisherman’
[a, e]	kʊ̀-tát-à	‘do sorcery’	è-tét-ì	‘sorcerer/ess’
[ɛ, e]	kʊ̀-fɛ́ːf-ɛ̀	‘watch’	è-féːf-ì	‘sentry’

As shown by the first line in each of (8a) and (8b), when the root in the infinitive is advanced, such a root appears unchanged in the causative and agentive forms (e.g., [kù-sùk] ‘miss, stop’ vs. [kù-súk-ì] ‘cause to stop’). In contrast, when the root is retracted in the infinitive, it appears as advanced in both the causative and the agentive (e.g., [kʊ̀-pàl] ‘uproot’ vs. [kù-pèl-ì] ‘cause to uproot’). The motivation for the consistently advanced forms seen in the causative and agentive is straightforward. The morphs for causative and agentive are nonalternating and advanced: {ì}$_{\text{CAUSATIVE}}$ and {ì}$_{\text{AGENTIVE}}$; when followed by such suffixes, only the [atr] morph satisfies the tongue root phonotactics (Chapter 2, (5)).

There are three types of morph sets observed in these forms. First, we have the familiar prefix sets involving [atr] and [rtr] pairs, {kù, kʊ̀}$_{\text{INFINITIVE}}$. Second, we have comparable [atr]/[rtr] morph sets involving roots, e.g. {pàl, pèl}$_{\text{UPROOT}}$. Third, we have instances where morph sets include a single member, roots such as {sùk}$_{\text{MISS, STOP}}$[4] and suffixes such as {ì}$_{\text{CAUSATIVE}}$ and {ì}$_{\text{AGENTIVE}}$.[5]

[4] We abstract away from the tonal alternations seen in some cases.

[5] It is not accidental that the nonalternating forms are [atr]; see §3.3.1.

In the words involving a nonalternating suffix, both root and prefix forms are unambiguously determined by the tongue root phonotactics. Consider a case such as [kù-pèl-ì] 'cause to uproot' (INFINITIVE-UPROOT-CAUSATIVE):

(9) Assessment for [kù-pèl-ì]$_{\text{INFINITIVE-UPROOT-CAUSATIVE}}$
morph sets: {kù, kʊ̀}$_{\text{INFINITIVE}}$; {pàl, pèl}$_{\text{UPROOT}}$; {ì}$_{\text{CAUSATIVE}}$

INFINITIVE-UPROOT-CAUSATIVE			*[rtr][atr]	*[atr][rtr]
	a.	kʊ̀-pàl-ì	*!	
	b.	kʊ̀-pèl-ì	*!	
	c.	kù-pàl-ì	*!	*!
☞	d.	kù-pèl-ì		

There is only one morph in the causative morph set and it is [atr], while all other morph sets have both advanced and retracted morphs. The tongue root phonotactics are satisfied only by selection of advanced morphs throughout.

Consider, however, the result of combining the infinitive and root morph sets without the causative, that is, combining {kù, kʊ̀}$_{\text{INFINITIVE}}$ and {pàl, pèl}$_{\text{UPROOT}}$. In this case, there are two possible compilations that would respect the tongue root phonotactics.

(10) Preliminary assessment for [kʊ̀-pàl]$_{\text{INFINITIVE-UPROOT}}$
morph sets: {kù, kʊ̀}$_{\text{INFINITIVE}}$; {pàl, pèl}$_{\text{UPROOT}}$

INFINITIVE-UPROOT			*[rtr][atr]	*[atr][rtr]
?	a.	kʊ̀-pàl		
	b.	kʊ̀-pèl	*!	
	c.	kù-pàl		*!
?	d.	kù-pèl		

Given an absence of relevant phonotactics, we would expect the speaker to select the most commonly observed morph – in essence, the prediction of exemplar theory (Bybee 2001, Pierrehumbert 2001, 2003, Johnson 2007, Wedel 2007, van de Weijer 2012). This can be straightforwardly formalised by imposing a penalty on any morph in a morph set that is not the most frequently occurring one, a lexically-based generalisation.

(11) Penalty on less frequent morphs
*{$morph_{\beta}$}, Assign a violation to each $morph_{\beta}$ which is not the most frequently occurring morph in its morph set

Box 3.7: Frequency

The issues relating to *frequency* are multiple and complex; we only touch on them here. The frequency effect in (11) might be better expressed as, "given a choice between two morphs from the same morph set, choose the one that is more frequent". This would mean that if the most frequent morph was ruled out for some reason, there would be a preference for the next most frequent morph. We adopt the simple statement in (11) since it is adequate for the cases we consider.

See Yang (2016) for a review and for modeling of ranked frequency in language acquisition and word recognition. How learners deal with patterns of varying frequency is important, whether they reproduce frequency distributions observed in the data or whether they impose regularity, creating a grammar that is consistent even in the face of inconsistent data (Hudson Kam & Newport 2005, 2009).

Consistent with the overall framework we are proposing, phonological generalisations will be distilled out of sets of such lexically-based generalisations. For example, in the Yangben case, where root alternations involve retracted forms in all instances other than when followed by the agentive and causative suffixes, there will be a recurrence of prohibitions of the less frequent forms: *{pèl}$_{\text{UPROOT}}$, *{só:k}$_{\text{GROW}}$, *{jìk}$_{\text{BOIL}}$, etc. The penalised morphs share a recurrent property and so are regularised to a phonological condition: they are all advanced. From the Yangben lexically-specific conditions, a general prohibition on a particular type can be extracted, prohibiting [atr].[6]

(12) Yangben tongue root phonotactic
*[atr], $\mathcal{F}$: vowels, $\mathcal{D}$: word
With a focus on vowels, assign a violation to a word for each advanced vowel.

[6] The discussion here reframes the concept of *default* introduced in our earlier work on Emergence, e.g. Archangeli & Pulleyblank (2016, 2018a) and builds on the proposal of *priority* in Mascaró (2007), Bonet et al. (2007), and, by generalising, goes beyond the role of *frequency* used in van de Weijer (2012). The concept here is quite different from the role for "default" in underspecification theory (Archangeli 1984, 1988, Pulleyblank 1986). Another use of "default" is found in Construction Grammar phonology for constructions which place no requirements on the form of the morpheme being used (Välimaa-Blum 2011: 142–143).

Given (12), an [rtr] form will be chosen from a morph set unless some other well-formedness condition overrides that choice. In Yangben, the tongue root phonotactic conditions do just that. Note that the harmonic conditions must outrank *[atr] to prevent a form like *[kʊ̀-pàl-ì] from surfacing in (9). (The dashed and solid lines in (13) show unranked and ranked well-formedness conditions respectively; see box 3.5 on p. 38.)

(13) Final assessment for [kʊ̀-pàl]$_{\text{INFINITIVE-UPROOT}}$
morph sets: {kù, kʊ̀}$_{\text{INFINITIVE}}$; {pàl, pèl}$_{\text{UPROOT}}$

INFINITIVE-UPROOT			*[rtr][atr]	*[atr][rtr]	*[atr]
☞	a.	kʊ̀-pàl			
	b.	kʊ̀-pèl	*!		*
	c.	kù-pàl		*!	*
	d.	kù-pèl			*!*

3.2.3 Schemas for well-formedness conditions

The prohibition *[atr] is a condition penalising a *type* of representation.[7]

(14) Type condition schema: [X] is a property
*[X] Assign a violation to a form for each [X], where [X] may be either morphological or phonological.

(Morphological properties include both labels on morphological sets as well as edges of morphological categories. See discussion of (6) on phonological properties.)

In any representation containing at least one instance of [X], one violation is assessed for every instance of [X]. As seen in §3.2.2, the element [X] can be of (at least) two types: (i) [X] can be a morph (11); (ii) [X] can be a featural property (12). That is, [X] may be morphological or phonological. The type condition in (12) is an example where a phonological property is penalised, *[atr] in Yangben.

Using morphological units in (14) leads to considering morphological units as an option in the syntagmatic schema, introduced in (6) and revised here.

[7]When specific well-formedness conditions are presented, as in (12), we specify the relevant focus ($\mathcal{F}$) and domain ($\mathcal{D}$); see box 2.9 on page 23. The schemas presented in this section show the conventions we use to formulate the three different kinds of prohibitions independently of focus and domain.

(15) Syntagmatic schema

*[X][Y] Assign a violation to a form for each sequence of [X] followed by [Y], where [X], [Y] may be either morphological or phonological.

We have seen cases where [X] and [Y] are phonologically defined in (5) and (7) in Chapter 2 and have seen an example of the role they play in §3.2.1. In §3.2.5 we discuss a Yangben case where one of the factors in a syntagmatic condition is morphological.

Box 3.8: Formally unlimited syntagmatic well-formedness conditions

We formulate syntagmatic prohibitions as involving two elements. Clearly this is the simplest type of syntagmatic prohibition, and therefore, we assume, the easiest to learn and consequently the most common. We do not rule out more complex well-formedness conditions, e.g. ones involving a sequence of three elements, though we consider that they would be harder to learn and therefore less common due to their added complexity. The basic schema in (15) would simply be extended to account for such cases; an example is found in our discussion in Chapter 5 of Polish (36).

The third and final schema is for paradigmatic conditions, well-formedness conditions that prohibit overlapping properties.

(16) Paradigmatic schema

$^*\begin{bmatrix} \text{X} \\ \text{Y} \end{bmatrix}$ Assign a violation to a form for each combination of [X] and [Y], where [X], [Y] may be either morphological or phonological.

We illustrate a paradigmatic condition involving phonological properties, in §3.2.4.

3.2.4 Paradigmatic featural prohibition

One of our central contentions is that human learners are highly sensitive to skewed distributions and that, where such distributions involve language, the learner encodes them into a grammar. Consider again the vowel inventory given in Chapter 2, Table 2.1, repeated here.

Table 3.1: Yangben vowels

	front		central	back/round	
advanced	í/íː/ì/ìː	é/éː/è/èː		ó/óː/ò/òː	ú/úː/ù/ùː
retracted	ɪ́/ɪ́ː/ɪ̀/ɪ̀ː	ɛ́/ɛ́ː/ ɛ̀/ɛ̀ː	á/áː/à/àː	ɔ́/ɔ́ː/ɔ̀/ɔ̀ː	ʊ́/ʊ́ː/ʊ̀/ʊ̀ː

By the kinds of considerations discussed in §2.1 and §2.3, these vowels can be categorised into long and short vowels, high-toned and low-toned vowels, front and back vowels, advanced and retracted vowels, and so on. While some of these properties are quite symmetrical, there is a marked skewing in terms of the way tongue root advancement/retraction treats vowels of different heights. While high and mid vowels all exhibit pairs of [atr] and [rtr] vowels, low vowels are consistently [rtr] – there are no low advanced vowels. To encode this unexpected gap – an extreme instance of a skewed distribution – a paradigmatic condition prohibiting the combination of [low] and [atr] is motivated, a paradigmatic condition of the sort given in (16).

(17) Tongue root redundancy in Yangben low vowels

$*\begin{bmatrix}\text{atr}\\ \text{low}\end{bmatrix}$, $\mathcal{F}$: segments, $\mathcal{D}$: morph, word

With a focus on segments, assign a violation to a morph or word for each low advanced segment.

This well-formedness condition holds of words in Yangben, so is very easy for the learner to identify. It also governs well-formed lexical entries. It reflects a close to 0% probability of encountering an advanced low vowel, a 0% frequency of occurrence – an extreme skewing in terms of feature combinations. In essence, it means that the intersection of the [atr] partition and the [low] partition is null. As a condition on the well-formedness of morphs, this condition means that a putative morph combining [atr] and [low] would be ill-formed in Yangben, but that morphs with nonlow vowels, advanced or retracted, are well-formed as are morphs whose vowels are all retracted.

3.2.5 Syntagmatic conditions combining morphology and phonology

In many instances, skewed distributions depend on a combination of morphological and phonological factors, cases where X and Y in the schemas in (15) involve a mixture of morphology and phonology. A commonly attested case of this type is one where specific morphs or morph sets require particular phonological properties in the phonological strings found before or after them.[8] Our proposals here build on “subcategorisation” models argued for in work such as Lieber (1980), Yu (2007), Paster (2009, 2015); we differ from such work in folding *subcategorisation* into a general class of sequential prohibitions, where the units that legitimately occur in a sequence happen to involve both phonological and morphological elements.

In keeping with our use of a single language for illustration throughout this introduction, we continue with an illustration from Yangben. We first show that Yangben has a further harmonic pattern, one of round harmony, motivating syntagmatic conditions governing sequences involving round vowels. We then turn to instances where a morph surfaces that is not the one preferred by the general harmonic conditions. Such lexically-conditioned cases require morpho-phonotactics, conditions which supersede the more general requirements of harmony.

Consider the words that involve Class 3 and Class 6 prefixes in Table 3.2.[9]

Table 3.2: Class prefixes (Boyd 2015: 173–175 except as noted)

Vowels	Class 3		Class 6	
[ɛ]	ɛ̀m-bɛ̀sɛ̀	‘maize’	mɛ̀-pɛ́ːnɛ̀	‘milk’
[e]	è-mèkú	‘flesh, muscle’	mè-kút	‘fat, oil’
[ɔ]	ɔ̀-ɔ̀pì	‘green mamba’ p. 179	mɔ̀-fɔ̀ᵐfɛ̀	‘marrow’
[o]	ò-ŋòlí	‘vine (generic)’ p. 161	mò-ɲǒː	‘cemetery’

Two harmonic properties are important in Table 3.2: (i) the tongue root value of the prefix vowel matches the tongue root value of the root vowel; (ii) the prefix has a rounded back vowel if the first vowel of the root is a mid rounded back vowel; otherwise the prefix vowel is mid, front, and nonround.

The observation concerning tongue root agreement falls out from the phonotactics already discussed, *[rtr][atr] and *[atr][rtr]. The observation concerning

[8]While different in execution, the discussion of interactions of morphology and phonology owes a debt to Ford & Singh (1983). This section develops and modifies the concept of *selection*, introduced in our earlier work, e.g. Archangeli & Pulleyblank (2018a).

[9]We consider a subpart of the overall pattern here, setting aside forms that involve low-vowel variants of the prefixes, e.g., [àm-bàŋ-ɔ́] ‘c3-crying’ (Boyd 2015: 160). The forms with low vowels require an additional morph in the relevant morph sets, with a phonotactic requiring agreement in lowness. These effects are not problematic but are orthogonal to the issue of morpho-phonotactics under discussion.

the rounded vs. nonround forms requires two properties. First, we assume that all else being equal, the preferred morphs for Class 3[10] and Class 6 are nonround; we attribute this to a type penalty on rounded vowels, *[round], formalised in (19) (following the schema in (14)). Second, we posit a syntagmatic condition governing round harmony (20).

(18) Class 3 & Class 6

Morph sets: $\{$è, ɛ̀, ò, ɔ̀$\}_{\text{CLASS.3}}$
$\{$mè, mɛ̀, mò, mɔ̀$\}_{\text{CLASS.6}}$

(19) Nonround condition

*[round], $\mathcal{F}$: vowels, $\mathcal{D}$: word

With a focus on vowels, assign a violation to a word for each round vowel.

(20) Round phonotactic

$*\begin{bmatrix}\text{nonrd}\\ \text{mid}\end{bmatrix}\begin{bmatrix}\text{rd}\\ \text{mid}\end{bmatrix}$, $\mathcal{F}$: vowels, $\mathcal{D}$: morph, word

With a focus on vowels, assign a violation to a morph or a word for each sequence of a mid unrounded vowel followed by a mid rounded vowel.

Two Class 6 examples with [round] stem vowels illustrate how these phonotactics interact, shown in the assessments in (21) and (22).[11] In (21), the vowel is high so the round phonotactic (20) is irrelevant. The choice between rounded and nonround options falls to *[round] (19).

Box 3.9: Acquisition and type conditions

There are different considerations with regard to how type conditions like *[round] might be learned, and exactly what is learned.

First, it is possible that *[round] might be acquired along the lines of the acquisition of *[atr], (11). A learner might identify the need for *[round] with respect to a specific morph set first, then later do the same

[10] Class 3 prefixes include morphs with and without a final nasal consonant; we do not address this pattern here.

[11] In both cases, the conditions governing tongue root harmony also play a role; since only *[rtr][atr] is relevant with an [atr] root vowel, *[atr][rtr] is omitted for expositional simplicity.

for another morph set, leading to a generalisation over generalisations because multiple morph sets share the same restriction. However, there are only a few instances in Yangben where *[round] plays a deciding role – only with the small number of morph sets containing both [round] and [nonround] morphs, while *[atr] is significant for virtually every verb stem. And whether or not the learner extends this morph-based generalisation more broadly to a generic *[round], there would be no impact on functionality of the grammar and communication (though it might result in differences in, e.g., nonce word studies).

Turning to frequency, we note that in terms of vowel types, there are more nonround vowels in the inventory than rounded vowels. In addition, although we do not have the numbers, we think it is likely that token frequency would show a similar skewing, perhaps even more dramatically. For example, low vowels – a member of the nonround class – are very frequent in a number of Bantu languages (Archangeli et al. 2012b).

Hence, while acknowledging that our frequency motivation for the condition given in (19) is speculative at this point, we think it a plausible hypothesis for Yangben.

(21) Assessment for [mè-kùt]$_{\text{CLASS.6-FAT, OIL}}$
morph sets: {mè, mɛ̀, mò, mɔ̀}$_{\text{CLASS.6}}$; {kùt}$_{\text{FAT, OIL}}$

C6-FAT, OIL			*[rtr][atr]	*$\begin{bmatrix}\text{nonrd}\\ \text{mid}\end{bmatrix}\begin{bmatrix}\text{rd}\\ \text{mid}\end{bmatrix}$	*[round]	*[atr]
☞	a.	mè-kùt			*	**
	b.	mɛ̀-kùt	*!		*	*
	c.	mò-kùt			**!	**
	d.	mɔ̀-kùt	*!		**	*

In the second case, (22), the stem vowel is mid, making the round phonotactic critical in deciding which morph to choose from the morph compilation: both (22a, b) are eliminated due to the round disharmony.

(22) Assessment for [mò-ɲòː]$_{\text{CLASS.6-CEMETERY}}$
morph sets: {mè, mɛ̀, mò, mɔ̀}$_{\text{CLASS.6}}$ {ɲòː}$_{\text{CEMETERY}}$

C6-CEMETERY		*[rtr][atr]	*[nonrd mid][rd mid]	*[round]	*[atr]
	a. mè-ɲòː		*!	*	**
	b. mɛ̀-ɲòː	*!	*!	*	*
☞	c. mò-ɲòː			**	**
	d. mɔ̀-ɲòː	*!		**	*

So far, these examples constitute additional illustrations of type conditions in conjunction with syntagmatic conditions. However, a sporadic set of stems shows an interesting interaction between phonology and morphology; examples are in (23). In these cases, certain stems appear with an unexpected form of the class prefix, either [round] where [nonround] is expected or [nonround] where [round] is expected. For each example, the unattested (but expected) forms are given in the rightmost column.[12]

(23) Atypical prefix-root pairings in Yangben (Boyd 2015: 172)

a. [è] is expected but does not appear

attested		expected
òn-dé	‘c3-grass.sp.’	*èn-dé

b. [ɛ̀] is expected but does not appear

attested		expected
ɔ̀-kɛ́l	‘c3-mountain’	*ɛ̀-kɛ́l
ɔ̀-kɛ̀n	‘c3-tail’	*ɛ̀-kɛ̀n
ɔ̀-mì^{n}dɛ́	‘c3-fence’	*ɛ̀-mì^{n}dɛ́
ɔ̀m-bɛ́l	‘c3-hole’	*ɛ̀m-bɛ́l

c. [ɔ̀] is expected but does not appear

attested		expected
ɛ̀-tɔ̀	‘c3-head’	*ɔ̀-tɔ̀
ɛ̀-sɔ̌	‘c3-penis’	*ɔ̀-sɔ̌

[12] Where patterns are not completely regular, we have assumed that there is a threshold determining whether a pattern is analysed as a generalisation with exceptions or simply as a list of exceptions (Archangeli et al. 2012a,b), perhaps along the lines of the Tolerance Principle (Yang 2016). Thanks to Beau Peterson and Ryan Smith for help in understanding the math used in the Tolerance Principle.

In each of these cases, the only way to know that an atypical prefix morph is required is to hear and learn the correct form. Such cases represent a skewing in the data that is parallel to the skewings that motivate phonotactics, but in this kind of case, we are dealing with a skewing that is specific to a particular morphological environment – in fact, in this particular case, the skewing is specific to particular morphs. For example, given the morph set for Class 3, $\{è, ὲ, ò, ɔ̀\}_{\text{CLASS.3}}$ (18), a lexical item like HEAD must assign a penalty to the prefix form that ought to be selected. Similar penalties would be required for all of the atypical stems shown in (23).

(24) Morph-conditioned penalties

a. *[nonround] $\{dé\}_{\text{GRASS.SP.}}$; $\mathcal{F}$: vowels; $\mathcal{D}$: word
   *[nonround] $\{kέl\}_{\text{MOUNTAIN}}$; $\mathcal{F}$: vowels; $\mathcal{D}$: word
   *[nonround] $\{kὲn\}_{\text{TAIL}}$; $\mathcal{F}$: vowels; $\mathcal{D}$: word
   *[nonround] $\{mì^{n}dέ\}_{\text{FENCE}}$; $\mathcal{F}$: vowels; $\mathcal{D}$: word
   *[nonround] $\{bέl\}_{\text{HOLE}}$; $\mathcal{F}$: vowels; $\mathcal{D}$: word

b. *[round] $\{tɔ̀\}_{\text{HEAD}}$; $\mathcal{F}$: vowels; $\mathcal{D}$: word
   *[round] $\{sɔ̌\}_{\text{PENIS}}$; $\mathcal{F}$: vowels; $\mathcal{D}$: word

Formally, these instances of lexically-imposed penalties constitute instances of the syntagmatic schema in (15) where the first element is phonological and the second is morphological, expressed in terms of a morphological set of stems in (25).[13]

(25) Lexically conditioned penalties

a. *[nonround] $\{\ \}_{\alpha}$, where $\{\ \}_{\alpha} \in$ {GRASS.SP., MOUNTAIN, ...}
   $\mathcal{F}$: vowels; $\mathcal{D}$: word

b. *[round] $\{\ \}_{\beta}$, where $\{\ \}_{\beta} \in$ {HEAD, PENIS, ...}
   $\mathcal{F}$: vowels; $\mathcal{D}$: word

Since the class of stems prohibiting a nonround prefix is phonologically and morphologically arbitrary, and similarly for the class prohibiting round prefixes, these penalties can only be expressed in terms of arbitrary sets, which we label here with α and β.

[13]Since the set of conditions penalising [nonround] has [nonround] vowels (24a) while the set penalising [round] has [round] vowels (24b), it might be possible to achieve further generalisation, uniting these two penalties as a single prohibition (still lexically conditioned): *[α round] $\{\alpha \text{ round}\}_{\beta}$, where $\{...\}_{\beta} \in$ {GRASS.SP., MOUNTAIN, HEAD, PENIS, ...}; $\mathcal{F}$: vowels; $\mathcal{D}$: word. This further generalisation requires treating [round] and [nonround] formally as a binary feature and then invoking SPE-style variable reference (Chomsky & Halle 1968). Since we do not need reference to binarity elsewhere, and since this case involves a small number of lexically specific exceptions, we do not introduce binarity here.

Box 3.10: Phonologically and morphologically arbitrary classes

Arbitrary sets are identified by distribution alone: there is no independent unifying phonological or morphological property. Once the set is identified, its label is available for reference, comparable at this point to a phonological label like [high] or [voiceless] or a morphological label like VERB or CLASS.3.

In previous work (e.g. Archangeli & Pulleyblank 2015a,c, 2018a), we labelled these sorts of sets as *selectors*; using that terminology, these morphs would be called the "[round] selectors" ([rd]_) and "[nonround] selectors" ([nonrd]_) respectively.

Assessment of the morph compilation proceeds as shown in (26), where the morph-specific conditions (morpho-phonotactics) must outrank the round phonotactic, *[nonrd, mid] [rd, mid]. The morpho-phonotactic is violated in (26c,d), since the morph {tɔ̀}$_{\text{HEAD.}\beta}$, a member of the arbitrary class β, is preceded by a [round] vowel, not a [nonround] vowel.

(26) Assessment for [ɛ̀-tɔ̀$_{\beta}$]$_{\text{CLASS.3-HEAD}}$
morph sets: {è, ɛ̀, ò, ɔ̀}$_{\text{CLASS.3}}$; {tɔ̀}$_{\text{HEAD}\beta}$

C3-HEAD$_{\beta}$	*[rd]{…}$_{\beta}$	*[atr][rtr]	*[nonrd mid][rd mid]	*[round]	*[atr]
a. è-tɔ̀$_{\beta}$		*!	*	*	*
☞ b. ɛ̀-tɔ̀$_{\beta}$			*	*	
c. ò-tɔ̀$_{\beta}$	*!	*		**	*
d. ɔ̀-tɔ̀$_{\beta}$	*!			**	

3.2.6 Summary

In this section, we have addressed the issue of how to select among multiple members of a morph compilation. In general, the most frequently occurring morph would be expected to be used (the formal result of *type* conditions penalising less frequent morphs (14)) except in instances where such selection would violate some condition. We have presented the three kinds of conditions, *type* (14), *syntagmatic* (15), and *paradigmatic* (16), that we assume throughout this work, illustrated in this chapter with examples from Yangben. These conditions may make reference to phonologically and morphologically defined sets, the former constituting generalisations over the latter. The learner's high sensitivity to skewings in the data encountered means that learning may either begin with the identification of purely phonological asymmetries – pure phonotactics – or it may begin by noting certain morph-specific properties, encoding them, and then generalising to sets exhibiting comparable behaviour.

3.3 Expanding morph sets: Morph Set Relations & Conditions

When words are created by compiling morph sets with multiple members, the resulting morph compilations are assessed to identify the preferred form in accordance with the conditions relevant for the language. Such word-level compilations are created by the addition of derivational or inflectional morphology, by compounding, by reduplication, and so on (Aronoff 1976, Kiparsky 1982, Lieber 1992, among many, many others); these word-formation operations are one source of productivity in the lexicon.

In this section, we address a second source of productivity in the lexicon, one that is widely recognised as part of the grammar, but that is often conceptualised in a way that excludes it from the domain of lexical productivity: productivity that results when the phonological system creates previously unencountered morphs. In the framework we are presenting here, word formation in the sense of affixation, compounding, and so on, occurs when morph sets are compiled; we have little to say about such word-formation here though we assume some appropriate mechanism throughout. The second type is the result of mechanisms that expand morph set membership. It is frequently the case – and a hallmark of paradigms – that the existence of one morph implies the existence of another – phonologically-related – morph. In such cases, the lexicon exhibits productivity, so that the learner may generate a large class of lexical items after exposure to a small subset of relevant forms. Such productivity in the lexicon is the topic of this section.

Consider, for example, the Yangben morph sets introduced above: many of these morph sets contain two members, differing only by tongue root values, [atr] and [rtr]. For example, the infinitive prefix has two forms: $\{$kʊ̀, kù$\}_{\textsc{infinitive}}$ (5), and verb roots may alternate in their tongue root values, seen by comparing plain infinitives with causatives and agentives: {fɔ̋l, fúl}$_{\text{FLOW}}$ (8). Are such alternations evidence of lexical productivity? In the case of some affixes, there may be no particular reason for productively generating alternative morphs since in many cases the relevant sets are both finite and small. We could plausibly assume that the learner simply incorporates morphs into sets as they are encountered. With verbs, on the other hand, such an assumption would be highly implausible. Verbs constitute a large, potentially unlimited set. It is extremely unlikely that the learner will encounter all of the relevant forms of the verbal lexemes that are learned – some generative predictive power is necessary in the grammar (cf. Ford & Singh 1983). We account for the observed regularities with *Morph Set Relations* – which define the systematic relations between related morphs – and *Morph Set Conditions* – which identify sub-optimal morph sets. Together, Morph Set Relations and Morph Set Conditions bring about productivity in the appropriate cases. In Yangben, then, both prefixes and verb roots show evidence of the same Morph Set Relation; this relation is necessarily productive in verb roots, perhaps productive in affixes as well.

Box 3.11: Top-down learning

When the morph compilation contains more than one member, there is uncertainty: which is the appropriate form to use in a given case? We hypothesise that this uncertainty is commonly resolved in favour of the most frequent morph.

In cases where there are multiple morphs in a set and the learner observes that the morph used is *not* the most frequently occurring morph, selection based on frequency would result in an error. Hence the uncertainty motivates seeking out a resolution, a case of top-down learning. At this point, the learning can be quite focussed: the properties of the competing morph combinations direct the learner's attention to the types of conditions that might be relevant.

Similarly, the existence of a syntagmatic condition can lead the learner to expect multiple members of a morph set differing by properties in that condition, guiding the identification of relevant Morph Set Relations.

3.3.1 Morph Set Relations (MSRs)

We begin our discussion by identifying an issue that arises when the learner establishes a morph set. In general, learners show evidence of a principle of *contrast* (Clark 1987) or *mutual exclusivity* (Markman & Wachtel 1988): an object has a single label.[14] Hence when introduced to a novel word, the learner assumes that the word refers to something not already labelled. This general principle has been formulated in a number of ways with somewhat different implications, accounting for a range of effects discussed in a large literature (Slobin 1973, Wexler & Culicover 1980, Pinker 1984, Clark 1987, Markman & Wachtel 1988, Markman 1989, 1992, Musolino 1999, Markman et al. 2003, *inter alia*).[15] Important with respect to Emergence, there is suggestive work indicating that the effect may not be specific to word learning (Markman & Wachtel 1988, Markman 1989, Markson & Bloom 1997, Childers & Tomasello 2003, Moher et al. 2010, Orena & Werker 2020) or even perhaps to humans (Kaminski et al. 2004, Markman & Abelev 2004, Fischer et al. 2004).

The willingness of a learner to postulate multiple morphs in a minimal morph set, $\{X, Y, ...\}_{\alpha}$,[16] seems to directly contradict this principle, whether or not a learner exhibits a stage where different meanings are attributed to the distinct morphs $\{X\}_{\alpha\text{-}i}$, $\{Y\}_{\alpha\text{-}j}$ that ultimately are grouped into a single set $\{X, Y\}_{\alpha}$. Yet there is evidence suggesting that systematicity among morphs competing for the same meaning – i.e. in the same minimal morph set – facilitates an override of mutual exclusivity.

Work such as Byers-Heinlein & Werker (2009), Kandhadai et al. (2017) presents evidence that bilingual children do not exhibit mutual exclusivity the way that monolingual children do; Clark (1987) speculates that such behaviour might emerge when bilingual children begin to systematically distinguish phonologically between the languages they are exposed to. As both Markman & Wachtel (1988) and Markman (1989) observe, it is not that mutual exclusivity cannot be overridden, it is rather that the learner is biased towards respecting it and will only override the principle when presented with sufficient evidence. The evidence cited above suggests that systematic phonological differences between two labels for one object is sufficient evidence, such as the systematic differences that arise due to learning distinct phonological systems. For our purposes, we hypothesise that the evidence of systematic phonological relations between morphs

[14]Thanks to Janet F. Werker for pointing us in the direction of this literature.

[15]In the literature on morphology, Clark (1987) suggests the effect derives "blocking", where the presence of one form *blocks* the formation of a morphologically related form that would have the same meaning (see, for example, Aronoff 1976, Kiparsky 1982).

[16]For the definition of minimal morph sets, see box 3.2 on p. 35.

constitutes sufficient evidence for the child to override mutual exclusivity in such cases, allowing the learner to assign multiple morphs to a single minimal morph set.

(27) The Systematicity hypothesis
Systematic phonological differences between morphs with the same label constitute sufficient evidence to override mutual exclusivity.

By hypothesis, systematicity is the key to exempting related sets of morphs from the mutual exclusivity requirement, the general expectation that morphs in a morph set will be identical except for those systematic divergences, formalised here as the Identity Principle (28).[17]

(28) The Identity Principle
Morphs in a minimal set are identical except in systematically identified ways.

Let us see how *Systematicity* and *Identity* play out in acquiring Yangben. Consider the impact of learning forms like those in (29).

(29) Yangben root patterns (Boyd 2015: 177)

a. nonalternating with respect to tongue root values

{ép, ěp}$_{\text{STEAL}}$	kʷ-ěp-è	‘steal’	èŋ-ép-ì̀	‘robber’
{sùk, súk}$_{\text{MISS, STOP}}$	kù-sùk	‘miss, stop’	kù-súk-ì̀	‘cause to stop’

b. alternating with respect to tongue root values

{fɛ́ːf, féːf}$_{\text{WATCH}}$	kʊ̀-fɛ́ːf-ɛ̀	‘watch’	è-féːf-ì̀	‘sentry’
{fʊ́l, fúl}$_{\text{FLOW}}$	kʊ̀-fʊ́l-à	‘flow’	kù-fúl-ì̀	‘cause to flow’

There are a variety of observations to encode, even when abstracting away from tonal alternations (as we do here, though we continue to mark tone and encode tonally distinct morphs as separate morphs in a morph set). One observation of importance is the existence of prefixes and suffixes, allowing the learner to isolate verb stems as well. In some cases, such as {ép, ěp}$_{\text{STEAL}}$ and {sùk, súk}$_{\text{MISS, STOP}}$, tongue root values are consistent. The morphological decomposition also reveals that meanings such as WATCH can be associated with two different sound strings

[17]A corollary is that, while idiosyncratic differences are penalised, in the event that there is considerable positive evidence, minimal morph sets may contain distinct and disparate morphs, as is the case with, for example, the English morph sets for HAVE {hæv, hæz, hæd}$_{\text{HAVE}}$, and for BE and {æm, ɪz, ɑɹ, wʌz, wəɹ, biː, bɪn}$_{\text{BE}}$.

differing solely by tongue root features, [fɛ́ːf] and [féːf], just as FLOW is associated with both [fʊ́l] and [fúl]. When sufficient such pairs are identified, a systematic relation emerges between morphs with retracted vowels and those with advanced vowels. Were there to be no systematic relation between the pairs of morphs with the same meanings, putting a pair into a single morph set would be in direct contradiction to mutual exclusivity and its derivative, the Identity Principle.

To the extent that such pairs are systematically related, the learner must override mutual exclusivity. There is such evidence in Yangben.

In the adult language, morph sets are of three types: (i) both noun and verb morph sets where all morphs are [atr], Table 3.3a; (ii) noun morph sets where all morphs are [rtr], Table 3.3b; and (iii) verb morph sets where morphs are related, in [atr]~[rtr] pairs, Table 3.3c. It is type (iii), the verb morph sets with two members, that is our focus.[18]

Table 3.3: Three types of minimal morph sets in Yangben

	Nouns		Verbs	
a.	[atr] morphs			
	{tèŋé}	'waterhole'	{ép, ěp}	'steal'
	{kújè}	'plant sp., fan'	{sùk, súk}	'miss, stop'
	{nòní}	'bird'		
b.	[rtr] morphs			
	{pɛ́ːsɛ̀}	'twins'	–	
	{kɔ́tɔ́}	'pipe'		
	{tɛ̀nʊ́}	'shame'		
c.	[atr] and [rtr] morphs			
	–		{fɛ́ːf, féːf}	'watch'
			{fʊ́l, fúl}	'flow'

In the earliest stages of learning, we hypothesise that the learner posits single-morph sets, even for morphs like those in Table 3.3, in accordance with mutual exclusivity. However, as learning progresses, evidence begins to accrue that, alongside the morph sets with only [atr] vowels and those with only [rtr] vowels, there

[18]The verbs in Table 3.3 are from (29); the full forms of the nouns in Table 3.3 are: [kì-tèŋé] 'waterhole'; [kì-kújè] 'plant sp., fan'; [ì-nòní] 'bird'; [kì-pɛ́ːsɛ̀] 'twins'; [ì-kɔ́tɔ́] 'pipe'; [ɛ̀-tɛ̀nʊ́] 'shame' (Boyd 2015: 165). Since morph sets, not words, are represented in Table 3.3, the nouns have been stripped of their class prefixes.

is sufficient evidence with some verbs to posit minimal morph sets with both [atr] and [rtr] morphs. Of course, learners do not directly encounter morph sets with multiple members: the words actually encountered by the learner will have either one form or the other. To put two distinct morphs together into one morph set requires sufficient evidence that the two forms have the same meaning and function. Importantly for our point here, the resistance brought by mutual exclusivity decreases as the similarity between the two morphs increases. In the case of Yangben, the related morphs under discussion are completely identical except for the tongue root position.

Since learners are rampant generalisers, as learners identify two distinct morphs as members of the same morph set, they identify patterns (here, that the morphs are identical except for tongue root). As additional such sets are acquired, the same pattern emerges repeatedly, leading to the generalisation that if a morph set has two morphs in it, the morphs are identical except for tongue root position. In the Yangben case, such sets have a second similarity: the pattern is found in verb stems, not noun stems.

Given the nature of the Yangben data, this is a robust generalisation, leading the learner to posit a relation along the lines of (30). Such relations are to be interpreted non-exhaustively: the claim is that morphs of the type described are attested, not that such pairs are necessarily the only morphs encountered within the relevant set. For example, there might be morphs with different tones, and so on.

(30) Yangben Morph Set Relation$_{[\mathrm{TR}]}$
In a minimal verb morph set, there is a systematic relation between morphs with nonlow advanced vowels and morphs with retracted vowels.

examples {sɔ́:k, só:k}$_{\mathrm{GROW,\ VERB}}$
{pàl, pèl}$_{\mathrm{UPROOT,\ VERB}}$

MSR$_{[\mathrm{TR}]}$: $\{\mathcal{M}_i, \mathcal{M}_j\}_{\mathrm{VERB}}$ $\mathcal{M}_i$: [atr] $\wedge\ {}^{*}\begin{bmatrix}\text{atr}\\ \text{low}\end{bmatrix}$
$\mathcal{M}_j$: [rtr]

For completeness, the Yangben MSR$_{[\mathrm{TR}]}$ includes a further criterion, that of respecting the paradigmatic prohibition on combining [atr] and [low] (17) because of pairs like {pàl, pèl}$_{\mathrm{UPROOT}}$ and {tát, tét}$_{\mathrm{DO.SORCERY}}$: while there are no low advanced vowels, low vowels do have advanced counterparts – which are non-low.[19]

MSRs characterise properties of minimal morph sets with more than one member. The relation between two such morphs is not only as defined in an MSR, but also as restricted by the Identity Principle. Given the Identity Principle, the assumption is that morphs in a set are identical; the MSR characterises only the differing properties of the related morphs, both the stipulated differences and differences that hold when specific phonotactics are invoked.

The final point to be addressed is the role of MSRs in expanding the learner's inventory of morph sets, that is, whether the relation characterised by an MSR is productive.

Box 3.12: Morph Set Relation format

In general, we formulate a Morph Set Relation (MSR) as in (31). In expressing such relations, we assume the Identity Principle (28). Hence morphs are assumed to be identical to each other in all aspects not either (a) explicitly designated in the expressed relation, or (b) the result of explicitly conjoined well-formedness conditions.

(31) Morph Set Relation
In a minimal morph set, there is a systematic relation between morphs with α (subject to $\mathcal{C}_m$) and morphs with β (subject to $\mathcal{C}_n$).

MSR: $\{\mathcal{M}_i, \mathcal{M}_j\}$ $\mathcal{M}_i$: α ($\wedge\ \mathcal{C}_m$)
$\mathcal{M}_j$: β ($\wedge\ \mathcal{C}_n$)

[19]In a language like Yangben (where *[atr, low] (17) is part of the grammar), were there no conjunction with this condition, then we assume that morphs with low vowels would have no advanced counterpart. This is the case in languages like Fula (Paradis 1992) and Yorùbá (Archangeli & Pulleyblank 1989), whose vowel inventories are similar to that of Yangben, and which have morph sets with advanced and retracted pairs – except for morph sets with low vowels because (i) there are no low advanced vowels in these languages and (ii) there is no other advanced counterpart for the low vowels (unlike in Yangben).

For expository convenience, we label specific MSRs – for example, $MSR_{[TR]}$ in (30), "[TR]" for "tongue root". To assist in interpreting the formal statements, when giving a specific MSR for a language, we include examples illustrating the relation, as seen in (30).

A Morph Set Relation simply constitutes the expression of a relation holding between the observed morphs within a morph set. If an MSR does not define a counterpart for some segment, our assumption is that an applicable Morph Set Condition (MSC) (see §3.3.2) would simply fail to produce an expanded set. For example, if the tongue root MSR simply related [rtr] and [atr] vowels, without reference to respecting *[atr, low] then the MSC would have no effect on a morph set containing a low vowel morph: there is no segment that only differs from a low retracted vowel (in Yangben) solely with reference to tongue root values. We crucially do *not* assume that the expansion of morph sets has the effect of creating unobserved segment types.

In many instances, there may be multiple such relations holding; for example, a morph set could exhibit independent regularities concerning both tongue root values and tone. If there is some systematic relation between the morphs within a morph set, then there is a Morph Set Relation. Whether such relations result in the augmentation of a morph set – that is, whether they productively result in new forms – depends on Morph Set Conditions, discussed in §3.3.2.

3.3.2 Morph Set Conditions (MSCs) and productivity

Having recognised that morphs of different shapes can have the same meaning – giving rise to morph sets – the learner can form generalisations about these derived structures: generalisations over generalisations. We propose therefore that productivity is triggered by a skewed distribution favouring morph sets whose members are consistent with some MSR; if morph sets with a morph of type α typically also have a morph of type β, then a morph set with both types of morphs is favoured over a morph set with only one type. Such skewed distribution leads to conditions about the structure of morph sets: the rare or non-occurring type of morph set is identified as ill-formed, or sub-optimal. A learner, on acquiring a morph which alone constitutes an ill-formed morph set, regains equilibrium in the grammar by generating the missing morph(s) in accordance with both the MSR and the Identity Principle; the result is an augmented, now well-formed, morph set.

Consider how this plays out in the case of Yangben harmony. As learning progresses beyond the point of identifying Yangben's $\text{MSR}_{[\text{TR}]}$, the learner discovers that, among verb roots, the number of verb morph sets with singleton [rtr] morphs diminishes as observation adds an [atr] morph to such sets. Consequently, there is a preponderance of only two types of sets, not three, along the tongue root dimension; those with [atr] morphs and those with corresponding [atr] and [rtr] morphs, expressed in (32). The skewed distribution of the (well-formed) [atr]-only sets and [atr]-and-[rtr] sets vs. the (ill-formed) [rtr]-only sets becomes increasingly apparent as additional verbs are encountered.

(32) Generalisations about verb root patterns

a. *nonalternating roots*: consistently [atr]

b. *alternating roots*: correspondents systematically related by $\text{MSR}_{[\text{TR}]}$

Relating these observations to Yangben's $\text{MSR}_{[\text{TR}]}$, the learner finds morph sets with only advanced morphs, $\{\mathcal{M}_{[\text{atr}]}\}$, and morph sets with corresponding advanced and retracted morphs, $\{\mathcal{M}_{[\text{atr}]}, \mathcal{M}_{[\text{rtr}]}\}$. On the other hand, morph sets of the type $\{\mathcal{M}_{[\text{rtr}]}\}$, while possible for nouns, are rare if not non-existent for verbs. This gap, we propose, is codified in the Yangben grammar by a Morph Set Condition, or MSC. The Yangben $\text{MSC}_{[\text{TR}]}$ penalises morph sets that contain an [rtr] morph but no [atr] morph, $\mathcal{M}_j$ and $\mathcal{M}_i$ respectively in (30).

On acquiring a new [rtr] morph, the logical thing for a learner to do is to posit a morph set $\{\mathcal{M}_{[\text{rtr}]}\}$ – a set that is perfectly well-formed in the nominal system, but that is ill-formed if it is a verb, due to (33): a $\{\mathcal{M}_{[\text{rtr}]}\}$ verb morph set is ill-formed. This creates tension in the grammar. The learner has essentially two choices to rectify the situation, either (i) disregard the evidence of having heard the retracted morph, or (ii) accept the evidence and posit that the morph set contains another morph. The latter strategy is intrinsically limited: the Identity Principle ensures that the rectifying morph is minimally different from the observed one, while the related MSR precisely defines that minimal difference – in the Yangben case, the result is the emergence of a corresponding morph with an advanced, nonlow vowel, conforming to $\text{MSR}_{[\text{TR}]}$.

(33) Yangben Morph Set Condition$_{[\text{TR}]}$ (MSC$_{[\text{TR}]}$)
With respect to MSR$_{[\text{TR}]}$, a minimal morph set is ill-formed if there is a morph with a retracted vowel and there is no corresponding morph with a nonlow advanced vowel.

examples	*observed*	*repaired*
	*{lɔ́k}$_{\text{FISH; VERB}}$	{lɔ́k, lók}$_{\text{FISH; VERB}}$
	*{tát}$_{\text{DO.SORCERY; VERB}}$	{tát, tét}$_{\text{DO.SORCERY; VERB}}$

MSC$_{[\text{TR}]}$ For $\mathcal{M}_i$, $\mathcal{M}_j$ of MSR$_{[\text{TR}]}$, $^*\{\mathcal{M}_j, \neg\mathcal{M}_i\}$

Concrete expression: $^*\{\ldots[\text{rtr}]\ldots, \neg\ldots\begin{bmatrix}\text{atr}\\ \text{nonlow}\end{bmatrix}\ldots\}$

Schematic examples: *{...ɛ..., ¬...e...}, *{...ʊ..., ¬...u...}, etc.

The * in the *observed* column means that a morph set is ill-formed, not that the morph itself is unattested.

Box 3.13: Interpreting a Morph Set Condition

$\mathcal{M}_i$, $\mathcal{M}_j$ in a Morph Set Condition are interpreted in terms of the paired Morph Set Relation; the indices on morphs in the MSC correspond to the requirements identified in the MSR. For expository reference, we label a specific MSC with a label identical to that of the corresponding MSR. Thus, MSC$_{[\text{TR}]}$ corresponds to MSR$_{[\text{TR}]}$. As an expository device, we also provide a concrete expression of the MSC in terms of the relevant categories (here features), and schematic examples.

By provoking morph set expansion, MSCs are key to productivity: MSCs define certain morph sets as ill-formed with respect to a particular MSR; ill-formed morph sets posited on the basis of observed forms are repaired to satisfy MSC(s) in accordance with the relevant MSR(s) and the Identity Principle. The critical grammatical element is the Morph Set Condition; productivity is the consequence.

Before moving on, we turn briefly to a general formalisation of MSCs. Since each MSC is interpreted with respect to an MSR, we begin there. Schematically, as established in §3.3.1, an MSR is motivated by observing a systematic relation between morphs within a morph set $\{\mathcal{M}_i, \mathcal{M}_j\}$. There are four logically possible types of languages with a particular MSR, as shown in Table 3.4, depending on whether singleton morph sets, $\{\mathcal{M}_i\}$ or $\{\mathcal{M}_j\}$, occur in conjunction with a directly observed polymorph set containing $\{\mathcal{M}_i, \mathcal{M}_j\}$ (the existence of which motivates the MSR in question).

Table 3.4: Well-formed minimal morph sets including $\{\mathcal{M}_i, \mathcal{M}_j\}$

	$\{\mathcal{M}_i\}$	$\{\mathcal{M}_j\}$	$\{\mathcal{M}_i, \mathcal{M}_j\}$
a. neither singleton set is well-formed	–	–	observed
b. one singleton set is well-formed	observed	–	observed
c. the other singleton set is well-formed	–	observed	observed
d. both singleton sets are well-formed	observed	observed	observed

While the MSR is simply a statement of a relation between $\mathcal{M}_i$ and $\mathcal{M}_j$, the relevance of each MSR in a language varies depending on which singleton sets are – or are not – common. An MSC requires a particular morph to have a correspondent morph, as defined by some MSR. Requiring that $\mathcal{M}_i$ have a correspondent is consistent with Table 3.4a,c, where $\{\mathcal{M}_i\}$ is rare or unattested; requiring that $\mathcal{M}_j$ have a correspondent is consistent with Table 3.4a,b, where $\{\mathcal{M}_j\}$ is rare or unattested. Put together, three types of MSC effects are derived: *no singletons* (Table 3.4a) is the result of requiring that both $\mathcal{M}_i$ and $\mathcal{M}_j$ have correspondent morphs (as defined by the relevant MSR); *one singleton* (Table 3.4b,c) is the result of requiring that either $\mathcal{M}_i$ or $\mathcal{M}_j$ have a correspondent, but not the other. The fourth case, *two singletons* (Table 3.4d), is the result of no related MSC, so there is no requirement that the morph set contain corresponding morphs (as defined by the relevant MSR). Thus, formally speaking there are two possible versions of a given MSC because the underrepresentation of $\{\mathcal{M}_i\}$ and of $\{\mathcal{M}_j\}$ can be independent of each other. These possibilities are all attested. The symmetric type where no singletons are allowed, Table 3.4a, is found in Warembori (§5.1). Yangben, as discussed in this section, is an example of the asymmetric type, Table 3.4b,c, while Mayak (§5.3) and Polish (§5.5) are examples of the fully differentiated type, Table 3.4d.

As presented here, neither Morph Set Relations nor Morph Set Conditions prohibit particular types of morphs. Rather, the MSR characterises relations among morphs within polymorph sets, while the MSC defines certain morph sets as ill-formed as characterised by the relevant Morph Set Relation. The consequence of having both MSR and MSC in a grammar is that the grammar is able to automatically generate the morphs necessary to have only well-formed morph sets.

Box 3.14: The two Morph Set Conditions

Morph Set Conditions determine whether the morph sets of a language are ill-formed with respect to a particular Morph Set Relation, MSR_{γ}. A language may impose no conditions, a single condition, or both conditions.

(34) Morph Set Conditions

a. With respect to MSR_{γ}, a minimal morph set is ill-formed if there is an $\mathcal{M}_i$ and there is no corresponding $\mathcal{M}_j$.

MSC_{γ}: For $\mathcal{M}_i$, $\mathcal{M}_j$ of MSR_{γ}, *$\{\mathcal{M}_i, \neg\mathcal{M}_j\}$

b. With respect to MSR_{γ}, a minimal morph set is ill-formed if there is an $\mathcal{M}_j$ and there is no corresponding $\mathcal{M}_i$.

MSC_{γ}: For $\mathcal{M}_i$, $\mathcal{M}_j$ of MSR_{γ}, *$\{\neg\mathcal{M}_i, \mathcal{M}_j\}$

(35) Morph Set Relation (repeated from (31))
In a minimal morph set, there is a systematic relation between morphs with α (subject to $\mathcal{C}_m$) and morphs with β (subject to $\mathcal{C}_n$).

MSR: $\{\mathcal{M}_i, \mathcal{M}_j\}$ $\mathcal{M}_i$: α ($\wedge\ \mathcal{C}_m$)
$\mathcal{M}_j$: β ($\wedge\ \mathcal{C}_n$)

In general, we label MSCs with the same label as the corresponding MSR ($MSR_γ$ and $MSC_γ$) regardless of which schema(s) are part of the grammar, (34a), (34b), or both.

Just as more than one relation (MSR) may hold of a morph set, a morph set may be ill-formed along more than one dimension. For example, a morph set might lack morphs both with respect to tongue root values and with respect to tone. In such instances of multiple relevant MSCs, a morph set would be augmented in all of the appropriate ways.

3.3.3 Productivity

The very important role of MSCs in a grammar is to expand the lexicon. To see how this works, consider the "toy lexicon" in (36), simulating a stage in Yangben acquisition that precedes identification of the $MSR_{[TR]}$. (Boundaries between morphs are left in as a convenience to the reader; the learner may still be figuring some of these out.)

(36) Pre-MSR Yangben toy lexicon 1: random lexical items (Boyd 2015: 177)

kù-sùk	'INF-miss, stop'	kù-súk-ì̀	'cause to stop'
kʊ̀-sɔ́ːk-ɔ̀	'INF-grow'	kù-fúl-ì̀	'cause to flow'
kʊ̀-kɛ́t-ìk	'INF-blink'	kù-sóːk-ì̀	'germinate'
kʊ̀-pàl	'INF-uproot'	kù-pèl-ì̀	'cause to uproot'
kʊ̀-jìk-à	'INF-boil'	èŋ-ép-ì̀	'robber'
kʷ-ěp-è	'INF-steal'	è-sùl-ì̀	'drinker'
kʊ̀-lɔ́k-ɔ̀	'INF-fish'	ò-lók-ì̀	'fisherman'
kʊ̀-tát-à	'INF-do sorcery'	è-tét-ì̀	'sorcerer/ess'
kʊ̀-fɛ́ːf-ɛ̀	'INF-watch'		

The learner identifies semantic connections among some of these lexical entries, creating morph sets with multiple members; we consider only those sets involving roots here. (We include the tonally distinct morphs for $\{$sùk, súk$\}_{\text{MISS, STOP}}$ and $\{$ěp, ép$\}_{\text{STEAL}}$ for completeness; we do not explore the Yangben tonal alternations.)

(37) Pre-MSR Yangben toy lexicon 2: preliminary morph sets

a. *Sets with morphs differing by tongue root*

{sɔ́ːk, sóːk}	kʊ̀-sɔ́ːk-ɔ̀	‘inf-grow’	kù-sóːk-ì̀	‘germinate’
{lɔ́k, lók}	kʊ̀-lɔ́k-ɔ̀	‘inf-fish’	ò-lók-ì̀	‘fisherman’

b. *Sets with only [atr] morphs*

{ěp, ép}	kʷ-ěp-è	‘inf-steal’	èŋ-ép-ì̀	‘robber’
{sùk, súk}	kù-sùk	‘inf-miss, stop’	kù-súk-ì̀	‘cause to stop’
{fúl}	kù-fúl-ì̀	‘cause to flow’		
{sùl}	è-sùl-ì̀	‘drinker’		

c. *Sets with only [rtr] morphs*

{kɛ́t}	kʊ̀-kɛ́t-ìk	‘inf-blink’
{jìk}	kʊ̀-jìk-à	‘inf-boil’
{pàl}	kʊ̀-pàl	‘inf-uproot’
{fɛ́ːf}	kʊ̀-fɛ́ːf-ɛ̀	‘inf-watch’
{tát}	kʊ̀-tát-à	‘inf-do sorcery’

When enough entries are acquired (Gerken & Bollt 2008) to recognise the pattern relating morphs, the learner posits the Morph Set Relation involving tongue root values, MSR$_{[\text{TR}]}$. As morph set acquisition continues, the learner observes that {[rtr]} morph sets merge with {[atr]} morph sets, but that many of the {[atr]} morph sets do not match up with a corresponding {[rtr]}. This leads to the generalisation that {[rtr]} – a morph set with only retracted morphs – is ill-formed because there is no advanced counterpart to the retracted morph, formalised as MSC$_{[\text{TR}]}$. As a consequence of this MSR/MSC pair, the learner/speaker is now able to generate some of the missing forms in the lexicon, stage 3.

(38) Post-MSC$_{[\text{TR}]}$ Yangben toy lexicon 3: filling in missing morphs via MSR$_{[\text{TR}]}$ and MSC$_{[\text{TR}]}$

a. *Direct evidence for both [atr] and [rtr] morphs*

{sɔ́ːk, sóːk}	kʊ̀-sɔ́ːk-ɔ̀	‘inf-grow’	kù-sóːk-ì̀	‘germinate’
{lɔ́k, lók}	kʊ̀-lɔ́k-ɔ̀	‘inf-fish’	ò-lók-ì̀	‘fisherman’

b. *Indirect evidence for [rtr] morphs; MSC$_{[TR]}$ adds [atr] morph*

{kɛ́t, két}	kʊ̀-kɛ́t-ìk	‘inf-blink’
{jìk, jì̀k}	kʊ̀-jìk-à	‘inf-boil’
{pàl, pèl}	kʊ̀-pàl	‘inf-uproot’
{fɛ́ːf, féːf}	kʊ̀-fɛ́ːf-ɛ̀	‘inf-watch’
{tát, tét}	kʊ̀-tát-à	‘inf-do sorcery’

c. *Direct evidence for [atr] morphs (MSC$_{[TR]}$ does not generate [rtr] morphs)*

{sùk, súk}	kù-sùk	‘INF-miss, stop’	kù-súk-ȉ	‘cause to stop’
{fúl}	kù-fúl-ȉ	‘cause to flow’		
{sùl}	è-sùl-ȉ	‘drinker’		
{ĕp, ép}	kʷ-ĕp-è	‘INF-steal’	èŋ-ép-ȉ	‘robber’

The consequence of having MSRs coupled with MSCs in a grammar is that the learner is able to hypothesise “missing” morphs to fill out incomplete morph sets. As new lexical items are acquired throughout the speaker’s life, MSCs allow the speaker/learner to expand morph sets beyond the forms actually heard: the learner is able to generate other morph set members rather than waiting to actually hear those items.[20] At the same time, it is important to realise that the only morph sets that get expanded are those that are deemed ill-formed by the MSC. In Yangben for example, on hearing only a causative or agentive, the learner establishes a morph set that contains an [atr] morph, because an [atr] morph was heard. There is no MSC identifying such morph sets as ill-formed, so no further morph is generated. From an advanced morph alone it cannot be predicted whether there will be a corresponding retracted form or not. For such items, it is necessary to learn some form that does not have an advanced suffix, such as the infinitive, to determine whether the morph set is complete or whether there is also a retracted morph.

When multiple morphs exist in a morph set, whether as the result of direct observation or as the the result of an MSC such as (33), a tension exists in the grammar due to uncertainty: once two morphs are posited for a given morph set, when is each morph to be used? Interestingly, MSRs explicitly identify dimensions along which uncertainty can be resolved. Thus, the learner has the potential to build on existing generalisations in a top-down fashion. In Yangben, MSR$_{[TR]}$ (30) identifies systematicity in corresponding [rtr]/[atr] values in verb roots. The tension created here can be resolved by a phonotactic that addresses the distribution of tongue root position in words. (See §2.3.1 for discussion of the relevant phonotactics.) However, if the learner were to generalise over multi-member morph sets before identifying the relevant phonotactic, the nature of the MSR$_{[TR]}$ and MSC$_{[TR]}$ creates tension specifically around the distribution of tongue root features in words. This tension can only be resolved by a phonotactic governing the distribution of [atr] and [rtr] morphs in words, thereby giving focus to the learning process.

[20]Though quite different in their effects, MSCs bear a relation to the productive power of the structural change of a rule in classic generative phonology (Chomsky & Halle 1968, Kenstowicz & Kisseberth 1979) and the role of Gen in Optimality Theory (Prince & Smolensky 1993): each of these mechanisms enables the language user to produce forms that have yet to be heard.

3.4 Conclusion

This extended discussion of some properties of the Yangben morphophonological system has served to illustrate different aspects of phonological knowledge under Emergence. We have couched much of our discussion in terms of language acquisition because, in order for a grammar to exist it must be acquired. Only learnable grammars become adult grammars. In this way, Emergence is learner-focussed. The learner isolates chunks in the speech stream, committing sequences to memory where particular sound strings are surmised to have identifiable meanings. The chunks will be of varying sizes, with minimal chunks (*morphs*) being combined into larger chunks including *words* (which we consider) and *phrases* (which we do not). In some cases, more than one morph can be identified for the same meaning, resulting in *morph sets* with multiple members.

Morphs and words are subject to a variety of conditions. The key property of a well-formedness condition is that it encodes a skewing in the observed data. Initial acquisition is bottom-up while later stages of acquisition may also be driven by top-down considerations, using what is known (conditions on segments and sequences, existing morph sets, Morph Set Relations, and Morph Set Conditions) to explicitly guide and focus learning. The consequence is that complex patterns emerge from the interaction of phonological and lexical generalisations.

The framework builds on a learner's ability to assess frequency distributions, noting asymmetries in the distribution of phonological elements and of morphological elements. Sequences of phonological and morphological elements that are infrequently encountered are penalised, while the morphological forms observed the most frequently are preferred when all else is equal. Hence grammar construction is limited by the general cognitive abilities of the learner to assess frequency and similarity, and to generalise. Such generalisation results in a symbolic system, a grammar.

A central element of the Emergent model proposed here is the morph set, eradicating the commonly postulated device of a single underlying representation for each lexical item. The next chapter argues that despite underlying representations (inputs) being entrenched in phonological modelling since the structuralists, there is no conceptual evidence in support of the concept (Chapter 4). A consequence of this approach, discussed in Chapter 5, is complete, simple, and concise analyses of data which, if underlying representations are adopted, involve a significant and frequently undesirable degree of abstraction.

4 What happened to underlying representations?

This chapter examines in more detail the concept of morph sets, sets that are composed of distinct surface morphs sharing some syntactic and semantic features. Such morphs are directly related to the data encountered by a learner. We propose that sets of morphs are the formal instantiation of the phonological forms corresponding to a particular set of morphosyntactic features, instead of invoking the more common unique underlying representation (UR). The issue of URs is significant to an Emergent framework because we do not see a plausible way to derive them directly from the input. Thus, if we were to conclude that URs are essential to accounting for phonological patterns, we would have evidence of at least one innate linguistic principle governing phonological systems. In this chapter, we argue that there is no conceptual necessity for underlying representations; in Chapter 5, we present our empirical argument against the concept, providing Emergent analyses to demonstrate how a wide range of phonological patterns are explained under Emergence, without recourse to underlying representations.

Throughout our discussion, and especially in this chapter, we use the term *morpheme* strictly to reference the structuralist concept (as defined in this chapter), which forms the basis of both the generativist's underlying representation and the optimality theorist's input. We use the term *underlying representation* to refer to the hypothesis that there is a single mental representation for each (regular) "morpheme", whether it is the underlying representation of generative phonology or the input of Optimality Theory.

4.1 Relating sound to meaning: Schematising the relations

We begin our discussion by returning to a point of central importance that was raised in Chapter 1, namely that the core of establishing a morph set – vocabulary learning – involves a great deal of memorisation. For a learner to identify the phonetic forms of morphs, the learner must encounter them. These forms must occur in the ambient language, and must occur in a salient enough fashion to be committed to memory. Whether or not the occurring surface morphs are grouped into sets related by meaning in the adult grammar or exhibit other systematic redundancies that must be encoded grammatically, the beginning of any such learning involves encountering the relevant phonetic forms and committing some sort of information to memory.

This early learning is central to the Emergent hypothesis: adult grammars have the shape they do because those shapes can be acquired by children (Deacon 1997). Thus, we begin with acquisition, starting with the straightforward case where a learner encounters no phonologically significant variation in the realisation of a lexical item. In the absence of any such variation in the form of the lexical item (see §2.1), the most straightforward representation of the lexical item would be as it is: what you hear is what you get.[1] In early stages, a generalisation over the observed exemplar cloud might be conceived of as the representation of the lexical item. Yet acquisition involves more than such holistic learning. At some point in the acquisition of a lexical item, the learner connects the holistic lexical item with a temporally arranged sequence of individual sound units (Bybee 1999), providing another type of symbolic representation for the lexical item in development. If the symbolic sound units making up this lexical item are invariant, then there would be no reason to postulate anything other than that observed string as the representation of the lexical item under consideration.

To make this concrete, consider a learner who is exposed to an English form like [dɑɡ]$_{\text{DOG}}$ on multiple occasions. The word may be produced with varying amplitudes, it may be produced with a fully released [ɡ] or with an unreleased [ɡ], on various pitches, and so on – productions which fall within the range of phonetic realisations encountered for those three segments. In this scenario, a plausible representation for [dɑɡ]$_{\text{DOG}}$ would simply be {dɑɡ}$_{\text{DOG}}$.

Box 4.1: The abstract and concrete morph

The proposed lexical representation of a morph is already a considerable abstraction because the production of any lexical item will vary according to all manner of factors, including (but not limited to) speaker, speech rate, and social context. We conceive of each morph as a single unimodal exem-

[1] For signed languages, the straightforward representation would be based directly on what is seen. The fact that language is readily learned in either an auditory or a visual modality is consistent with our position that much of the learning of the sound system of a language makes use of cognition that is not specific to language.

plar cloud of sound sequences where there is no systematic variation in the phones making up the lexical item, nor in stress, nor in tone – in short, no systematic “higher level” linguistic variation at all (see van de Weijer 2012). The *morph* is a label for that cloud; labelling a cloud gives access both to the undifferentiated cloud (via the label; in this way a morph is abstract, though in a way directly controlled by the content of the cloud) and to the individual tokens making up the cloud (in this way the morph is concrete). See relevant discussion in §2.1.

Now consider a somewhat more complex case: the learner encounters two different phonetic realisations corresponding to the same meaning. Phonetically, the realisations might be quite similar to each other, for example, [nʌɪf]$_{\text{KNIFE}}$ vs. [naɪv]$_{\text{KNIFE}}$ (the latter encountered in plurals), both as encountered by some speaker of “Canadian” English. In this case, there are two differences: the vowel quality and the quality of the final consonant. At an early stage the learner might consider [ʌɪ] and [aɪ] to be variant realisations of a single sound, just like the released or unreleased [ɡ] of [dɑɡ]$_{\text{DOG}}$. However, even at quite an early stage the final consonants are likely to be categorised as distinct: knowledge of the contrast between forms like [fɛɹi]$_{\text{FERRY}}$ vs. [vɛɹi]$_{\text{VERY}}$, [weɪfəɹ]$_{\text{WAFER}}$ vs. [weɪvəɹ]$_{\text{WAVER}}$, [seɪf]$_{\text{SAFE}}$ vs. [seɪv]$_{\text{SAVE}}$, and so on, would show the learner that [f] and [v] are different and so neither [nʌɪf] nor [naɪv] would be considered an expected phonetic variant of the other as far as the final consonant is concerned.

Such regular patterns have formed the focus of a great deal of attention for decades. While we might naïvely conceive of such pairs as belonging to the schema in (1a), the generative approach has been to adopt the schema in (1b) wherever possible, where the lines linking /Z/ to [X] and [Y] represent phonologically predictable relations. The schema in (1a) is typically reserved for cases where the relations between the morphs are not predictable, as in Tranel (1996), Bonet (2004), Bonet et al. (2007), Mascaró (2007), Nevins (2011).

(1) Conceptions of the relationship between morphs

a. {[X], [Y]}$_{\text{MEANING-}\alpha}$

b. [X] [Y]
 \ /
 /Z/ MEANING-α

The schemas in (1) represent cases of various types, with the most heavy restrictions placed on the type in (1b). In (1b), /Z/ is related to both [X] and [Y] by phonological rules/constraints (e.g., in English, /z/$_{\text{PLURAL}}$ relates to [z], [s], [əz]). In a case where /Z/ is altered in some context but surfaces without change in others, one of [X] or [Y] is related by phonological identity to /Z/. Such phonological identity is not a necessary property of the relation, however, since in some cases all instances of underlying /Z/ will undergo phonological change before surfacing (this is illustrated in §5.1 and §5.4). Since both [X] and [Y] are phonologically related to /Z/, it follows that [X] and [Y] must be phonologically related to each other. Crucial to note, however, is that this relation of phonological similarity is instantiated *indirectly* in theories with an underlying representation, via the underlying representation itself: the relation is indirect, through /Z/; there is no direct formal relation between [X] and [Y].

Three properties are important in understanding these schemas, listed in (2). The first involves *derivability*: can the relationship between /Z/ and each of [X], [Y] be defined in terms of phonological properties? The second property involves *productivity*: are the patterns relating /Z/ to [X] and [Y] observed systematically in the language or are they idiosyncratic patterns? The third property is *optimisation*: is the choice between [X] and [Y] in a given context determined by phonological properties?[2] For the ensuing discussion, we use the terms as defined in (2), so that we have a means of referring to each concept independently. (In (2), α stands for morphological, syntactic, and semantic properties.)

(2) Criteria for /Z/$_\alpha$ given [X]$_\alpha$, [Y]$_\alpha$

a. Derivable: The relations between /Z/$_\alpha$ and [X]$_\alpha$ and between /Z/$_\alpha$ and [Y]$_\alpha$ are defined phonologically.

[2] We use *optimisation* and *optimisable* as defined in (2c) (phonologically determined by context, as opposed to being in a phonologically definable relation, i.e. *derivable* (2a)); this is different from the use of these terms in Optimality Theory where "optimisation" refers to satisfying universal markedness and faithfulness constraints. The two uses are slightly different: for example, choosing a V-initial morph after a consonant and a C-initial morph after a vowel is phonologically determined and satisfies syllabic markedness constraints; choosing a V-initial morph after a vowel and a C-initial morph after a consonant is again phonologically determined, but counter to syllabic markedness constraints. As the pressures for choosing a particular morph will tend to be phonetically/phonologically motivated, we collapse both possibilities in the discussion here. Note that there has been considerable controversy over whether non-productive relations among morphs are optimising in the optimality theoretic sense (Kager 1996, Rubach & Booij 2001, McCarthy 2002) or not (Paster 2005, 2006, Bye 2007). Productive cases of the type in (1b) are generally assumed to be optimising in the optimality theoretic sense (though see Ford & Singh 1983); these are the core cases addressed by phonological analysis.

b. Productive: The relations between $/Z/_\alpha$ and $[X]_\alpha$ and between $/Z/_\alpha$ and $[Y]_\alpha$ are found sytematically in the language.
c. Optimisable: The choice between $[X]_\alpha$ and $[Y]_\alpha$ is determined by phonological properties.

The concepts are familiar, but are not always differentiated in the literature – which is unfortunate, since these properties do not always correlate. For example, the two suffixal morphs indicating nominative in Korean, $\{\text{i, ka}\}_{\text{NOMINATIVE}}$, are not similar enough to be phonologically related to a single underlying form; they are not derivable, yet the choice between the two is phonologically optimising, with [i] chosen after a consonant and [ka] after a vowel (Sung 2005). The English indefinite article, $\{\text{ə, ən}\}_{\text{INDEFINITE}}$, is similar in that it is also phonologically optimising ([ə] pre-consonantal, [ən] pre-vocalic) but – unlike Korean – the two morphs could be related to a phonologically similar underlying representation, a relation that is not productive.

In generative phonology, the schema in (1b) is generally reserved for cases that satisfy all three criteria: they are phonologically relatable, productive, and optimising. If any of the three properties is missing, then the different forms are simply listed (1a).[3] Note that while both listed and derived forms may be phonologically optimising, both rule-based and constraint-based accounts treat them as formally distinct objects, either listed morphs (Mascaró 2007, Nevins 2011) or unitary underlying representations (Chomsky & Halle 1968, Prince & Smolensky 1993).[4]

There is no argument from derivability, nor from productivity, nor from being optimising that unambiguously selects (1b) over (1a). Derivability does not require underlying representations: it is possible to phonologically relate [X] and [Y], directly by means of Morph Set Relations (MSRs), rather than relying on indirect encoding mediated by an abstract representation, /Z/. Encoding productivity does not require the postulation of unitary underlying representations: these relations may be highly productive or may be relevant for some (possibly quite small) subset of the lexicon, representing different degrees of productivity. Finally, being optimising does not motivate (1b): it is possible to use quite standard conditions to choose the optimal member of a set in a given context, whether that set is listed – as in Emergence – or generated – as in Optimality Theory. In Emergence, derivability is expressed by Morph Set Relations, introduced in §3.3.1, productivity by Morph Set Conditions, §3.3.2, and optimisation

[3]In some cases, unproductive forms may be treated by rule but their lack of productivity presents problems. See §5.2 and §5.3.

[4]Things are a bit more complex in Optimality Theory. See discussion of the rich base in §5.1.

by well-formedness conditions, §3.2. On these concepts, see also Archangeli & Pulleyblank (2012, 2015a,c,d, 2016, 2017, 2018a). Hence to motivate the construct "/Z/", the underlying representation, requires some sort of evidence that does not depend on phonological relatedness, productivity, or optimisation.

Box 4.2: Predictable vs. idiosyncratic information

The criterion behind underlying representations is whether some aspect of the sounds of a form is predictable or not: "[t]he underlying representation (UR) … contain[s] all of the idiosyncratic information about the pronunciation of the constituent morphemes of the utterance, and the phonetic representation (PR) … contains the idiosyncratic information plus the predictable information about the pronunciation of the utterance." (Kenstowicz & Kisseberth 1979: 32; see also Archangeli 1984, Cole & Hualde 2011).

In the generative framework, the predictable information was added by rule. Under Optimality Theory, the predictable information is determined by a comparison between the input and the output of Evaluation. With the Emergent framework, predictable and idiosyncratic is more nuanced. Morph Set Relations express systematic relations between morphs within a set; productivity (characterised by Morph Set Conditions) may be unrestricted or may be a property of a subset of the lexicon. Well-formedness conditions determine the overall shape of a unit within a particular domain, whether a morph or a polymorphic constituent.

4.2 Where did the concept of /Z/ come from?

Since phonological reasons for positing underlying representations fall short, as shown in §4.1, we are left wondering why phonologists have relied on the concept. To answer this, and to determine whether the historical record provides motivation for the notion, we review why a construct like an *underlying representation* was ever posited in the first place: what motivated the postulation of /Z/ in (1b)?

It is uncontroversial that learning the sound string associated with a given meaning involves memorising the appropriate string and assigning it to the appropriate meaning. The learner of English must learn that the notion DOG is encoded by the sounds [dɑg], while the learner of Japanese encodes (at least roughly) the same notion by [inɯ], the learner of French by [ʃjɛ̃], and the learner of Yorùbá by [āɟá]. Whether a theory in some general sense tilts the scale towards the nature end or the nurture end, there is agreement that learning lexical items involves committing to memory sound strings paired arbitrarily with semantic and morphosyntactic information; that is, learning lexical items involves a large component of nurture. Our first question then is whether there is something in acquisition that drives the learner towards postulating some abstract /Z/ when exposed to [X] and [Y].

4.2.1 Does acquisition require /Z/?

When we consider the various morphs a language learner acquires, we see wide variety in the types of items that must be learned and related to each other. In some instances the formatives corresponding to a particular meaning may be phonologically unrelated to each other, as in English [biː]$_{\text{BE}}$, [ɪz]$_{\text{BE.3SG.PRES}}$, [ɑɹ]$_{\text{BE.3PL.PRES}}$, [wʌz]$_{\text{BE.3SG.PAST}}$, and [wəɹ]$_{\text{BE.3PL.PAST}}$ all encoding (in part) the semantic notion of BE. Here the relation between the various formatives is just as arbitrary as the relation between form and meaning in a unit like [dɑg] = DOG (de Saussure et al. 1916). Related forms may be natural – phonologically optimising – even if not fully productive, as in the English prefix {ɪn, ɪm, ɪ, …}$_{\text{NEG}}$: [ɪn] (*ineffective*), [ɪm] (*imperfect*), [ɪ] (*irregular*); cf. the invariant prefix {ʌn}$_{\text{NEG}}$ (*unafraid*, *unpleasant*, *unresolved*).[5] Still other sound strings may be related in a highly productive, regular fashion. For example, English verbs ending in [t] or [d] have related forms ending in a tap, as illustrated by [sɪt]$_{\text{SIT}}$:[sɪɾ-ɪŋ]$_{\text{SIT-PROG}}$, [weɪd]$_{\text{WADE}}$:[weɪɾ-ɪŋ]$_{\text{WADE-PROG}}$, and so on.

Box 4.3: How dissimilar can morphs in the same set be?

The absence of innate linguistic predispositions governing the phonological properties of language predicts a wide spectrum of possibilities in morph set membership, from single forms to multiple forms corresponding to the same meaning, from phonetically similar to phonetically dissimilar forms. Items like [dɑg]$_{\text{DOG}}$ illustrate the single morph end of the spectrum while {nʌɪf, naɪv}$_{\text{KNIFE}}$ and {sɪt, sɪɾ}$_{\text{SIT}}$, etc., have multiple forms with a fair amount of phonetic similarity. Standard cases of suppletion are

[5] See §5.2 for discussion of this English case.

characterised by multiple morphs with high dissimilarity, such as $[\text{goʊ}]_{\text{GO}}$ vs. $[\text{wɛnt}]_{\text{GO.PAST}}$ ($\{\text{goʊ}, \text{wɛnt}_{\text{PAST}}\}_{\text{GO}}$), and the various forms of BE just discussed. The Identity Principle (28) applies pressure for similarity among morphs in a morph set, but this is not an absolute law.

Crucially, we see that semantically or syntactically related forms occur on a scale of phonological relatedness (Hockett 1958: 279–281), from no significant variation {[P]} (Table 4.1a), to forms that bear a phonological relation $\{[P_i], [P_j]\}$ (Table 4.1b), whether the relation is productive or not, to forms that are phonologically unrelated {[P], [Q]} (Table 4.1c).

Table 4.1: Hockett's scale of phonological relatedness

	variation?	relation?	schematic	example
a.	no	–	$\{[P]\}_{\text{MEANING-}\alpha}$	$\{\text{dɑg}\}_{\text{DOG}}$
b.	yes	yes	$\{[P_i], [P_j]\}_{\text{MEANING-}\beta}$	$\{\text{sɪt}, \text{sɪɾ}\}_{\text{SIT}}$
c.	yes	no	$\{[P], [Q]\}_{\text{MEANING-}\gamma}$	$\{\text{goʊ}, \text{wɛnt}_{\text{PAST}}\}_{\text{GO}}$

Of these three logical possibilities, only Table 4.1b meets the criteria in (2) for having an underlying representation that is distinct from at least one of its surface realisations. Yet, it seems unavoidable that part of learning a language is learning when different strings of sounds correspond to the same meaning, whether or not those strings are phonologically related. Prior to recognising correspondences, learned items are represented as simple invariant pairings between some sound sequence and a meaning, Table 4.1a. As the learner recognises that some meanings have more than one set of sounds, but before phonological productivity has been established, these would presumably be represented as members of the class with unrelated variation, Table 4.1c. It is only on recognising phonological relations among some of the varied sets that a learner can shift some instances of the type in Table 4.1c into the type in Table 4.1b. Underlying representation models claim that the learner would establish a unique underlying phonological form of the type schematised in (1b), but would do so *only* for those sets where the observed surface forms are not only phonologically related but related in a productive way. The postulation of such a unique form – a unit that has achieved remarkable currency – cannot be motivated by simple observation since nonuniqueness is the norm in terms of actual observations. Prima facie, this assumption leads to a curious phase of language acquisition, where learners reconfigure their lexicons to include underlying representations for some lexical entries – precisely those where the relation is productive and completely phonological (that is, it is both derivable and optimisable). In trying to understand whether this hypothesis can make sense as a model of learner behaviour, we explore the factors that led linguists to the postulation of this theoretical unit.

4.2.2 "Morphemes", syntax, and underlying representations

Crucial to an understanding of this postulated unit, the underlying representation, is the structuralist notion that linguistic structures are composed of various kinds of building blocks that are assembled to produce linguistic expressions. In the structuralist view, sentences are composed of words, words are composed of morphemes – "[t]he grammar … of a language is (i) the morphemes used in the language, and (ii) the arrangements in which these morphemes occur relative to each other in utterances" (Hockett 1958: 129) – and morphemes are composed of phonemes. Foreshadowing current work in theoretical syntax based on features rather than formatives (with specific phonological shapes), Hockett (1958: 147) observes that "[i]n grammatical study we are concerned with morphemes and their arrangements, but not, save in an ancillary way, with the phonemic shapes which represent morphemes." Hockett (1958: 271) illustrates this by examples such as the English words *bought, went, paid, sold, sang* which are all analysed as containing two such morphemes (a verb stem and the past tense marker), despite the lack of obvious phonological compositionality in most of the cases he cited. Where most current syntactic theories approach this issue by positing semantic/syntactic features that are not necessarily distinctly spelled out for a phonological form (see, e.g. Pollock 1989), the structuralist approach was to posit morphemes linking sound, syntax and semantics, with a phonological representation that abstracts away from the kind of surface variation that is routinely observed in natural language.

The move of interest to us is the argument that grouping the surface-occurring morphs into a single abstract morpheme "simplifies our general picture of linguistic structure, i.e. of what relations can be discovered between the elements of linguistic expressions" (Harris 1942: 179). "Instead of listing both members of each unit, we now list only one representative of each unit with a general statement of the difference which applies to all of them" (Harris 1942: 173). This was in essence the move from {[X], [Y]}$_{\text{MEANING-}\alpha}$ to /Z/$_{\text{MEANING-}\alpha}$.[6]

Box 4.4: The morpheme – the smallest individually meaningful element...

The fundamental idea of the *morpheme* led to a large body of work aimed at establishing what the properties of these postulated units were, work defining the morpheme and then going on to consider implications that these definitions have for sound systems, e.g. Bloomfield (1933, 1939), Swadesh & Voegelin (1939), Harris (1942), Wells (1949), Hockett (1958), etc. Bloomfield (1933: 161) described a simple form, or morpheme, as "[a] linguistic form which bears no partial phonetic-semantic resemblance to any other form." There was a great deal of discussion of such definitions in the subsequent structuralist literature but the fundamental idea of the morpheme was maintained. Harris (1942: 170), for example, states that "[w]e divide each expression in the given language into the smallest sequences of phonemes which have what we consider the same meaning when they occur in other expressions, or which are left over when all other parts of the expression have been divided off", leading to the much quoted claim that "[m]orphemes are the smallest individually meaningful elements in the utterances of a language." (Hockett 1958: 123).

For structuralists, morphology produces the building blocks referred to by the syntax. Since surface variation in phonological form does not translate into syntactic differences, the structuralist approach was to abstract away from such variation, associating a "unique" phonological form with any given morpheme, along the lines of sememes (the meaning of a morpheme, Bloomfield 1926: 155): "[t]he sememes, on the other hand, *which stand in one-to-one correspondence with the morphemes*, cannot be further analyzed by linguistic methods." (Bloomfield 1926: 159) [emphasis added – da/dp].

[6]Current work continues to explore the two general approaches. For dual mechanism analyses, where regular verbs are treated as compositional and irregular verbs are treated as whole words, see Pinker & Prince (1988), Pinker (1991). For single mechanism compositional analyses for both regular and irregular verbs, see McClelland & Patterson (2002a,b), Stockall & Marantz (2006). See Albright & Hayes (2003) and Fruchter et al. (2013) for experimental evidence supporting a single mechanism analysis.

Fundamentally, the structuralist approach to defining the minimal grammatical building blocks of language involved linking a particular minimal sequence of phonemes with a particular meaning. Yet, when that meaning is actually linked with multiple different sequences of sounds, which of those different sequences – which morph – is the correct one to be linked with that particular meaning when defining the morpheme? There were three parts to answering this question. First, if the syntax operated on units corresponding to morphemes, and if observed surface variation in the phonological forms of morphemes was the responsibility of some other component of the grammar, then the syntax is agnostic about the phonological properties of morphemes. Second, examination led to the observation that in many cases the surface alternants, or allomorphs, of a morpheme can be phonologically related to each other in a systematic fashion. Third, it was argued that these observed surface alternants were not all of equal status: "[s]trictly speaking, we should say that the morpheme [...in cases of alternation...] has two (or, sometimes, more) different phonetic forms...and that each of these *alternants* appears under certain conditions. In our examples, however, one of the alternants has a much wider range than the other and, accordingly, is a *basic alternant*." Bloomfield (1933: 164); the non-basic alternant is described as "a phonetically modified form". Hockett (1958: 277) states that if one surface alternant cannot be predicted from one or more other alternants, then the form that cannot be predicted is the "base form", giving the relationship in either (3a) or (3b) where the base form, /X/ or /Y/, matches one of the surface forms [X] or [Y] respectively, and "α" indicates the syntactic/semantic unit.

(3) The "base form"

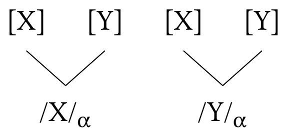
a. [X] [Y] → $/X/_{\alpha}$

b. [X] [Y] → $/Y/_{\alpha}$

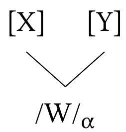
The three notions – that syntax needed no phonetic detail, that surface alternants were systematically related on phonological grounds, and that there was a "base form" among those alternants – came together, and the unitary abstract representation was born. However, once a basic alternant was posited, it quickly became apparent that surface alternants and the "base form" do not necessarily align. "[T]he base form in some instances is considerably rarer than its replacements. Indeed, in some instances the most conveniently recognised base form never actually occurs; under these conditions we call it a *theoretical base form*" (Hockett 1958: 282). The upshot was that not only were unique underlying representations posited, these representations could be different from any surface manifestation: in short, underlying representations could be abstract – (4b) which has no phonetically occurring [W] corresponding to the abstract /W/ – alongside the relatively concrete representations in (4a).[7]

(4) Concrete and abstract "base forms"

a. Concrete underlying form



b. Abstract underlying form (W *distinct from* X, Y)



4.2.3 But syntax doesn't need URs, abstract or not

The groundwork for the ubiquitous "underlying form" was laid. Morphemes were considered to pair a unique sound string with a particular meaning, even though multiple, nonunique sound strings actually occur in many, perhaps most, instances. In effect, the underlying form was a mechanism for asserting the irrelevance for syntax of such phonological alternations. As a consequence, the *underlying phonological representation* was postulated as a core part of every morpheme, with morphemes constituting the building blocks for syntax.

Viewed from the perspective of contemporary syntax, however, this role for underlying representations seems entirely unmotivated. Syntax and morphology manipulate elements; depending on the theory of syntax and morphology, there are different views of what these elements are and how they are structured, but it is generally agreed that the relevant features are morphosyntactic, not phonological. For instance, Network Morphology (Corbett & Fraser 1993, Brown et al.

[7]Note that our use of /W/ here differs from our use of /Z/ in (1) and the preceding discussion. Both are underlying representations corresponding to the surface forms [X], [Y], but /W/ is specifically restricted to be distinct from both [X] and [Y]. On the other hand, /Z/ above is unrestricted, referring to an underlying representation that matches one of the surface forms (either /X/ or /Y/), or to a representation which does not match any surface form (/W/).

1996, Fraser & Corbett 1997, Brown & Hippisley 2012) holds that there is an independent grammatical module that creates words, interfacing with syntax, semantics, and phonology. In Distributed Morphology (Halle & Marantz 1993, Harley & Noyer 1999, Embick & Noyer 2007, Siddiqi 2009, Matushansky & Marantz 2013), the syntax operates on sets of morphosyntactic features which are spelled out into chunks which may or may not correspond to units comparable to traditional morphemes. In both types of theories, the lexical and functional elements available for manipulation by the syntax and/or morphology are strictly nonphonological, and it is these morphosyntactic features that are referred to in spell-out or word formation.

In terms of the schemas in (1), the relevant unit for syntax is MEANING-α where α is whatever syntactic properties are appropriate, information that is accessible whether we adopt the flat set structure of (1a) or the hierachical set with an underlying form as in (1b). Thus syntax has access to the features it needs, regardless of whether there is a unique underlying form or not. There is no argument from syntax to support the unique underlying form.

4.3 Conclusion

Neither syntax nor phonology supports the concept of underlying representations, at least conceptually. Our conclusions agree with Burzio (1996: 123) about the concept of a unique phonological underlying representation: It "is neither conceptually necessary nor empirically supported, and should be dispensed with." While relations between surface morphs must be accounted for, we concur with Burzio that the null hypothesis consists of a more direct encoding of such relations, unmediated by abstract underlying representations (see also van de Weijer 2012). We hypothesise *morph sets*, each morph set being a collection of occurring morphs that share some syntactic or semantic label, whether or not there are productive, derivable, and/or optimising relations among those morphs.

As a framework which does not mandate unique underlying representations, Emergence is a surface-to-surface model. We develop a model where a morph set contains one or more surface-based representations. However, morph sets with multiple members are not all created equal. At the phonologically regular and general end of the scale, the phonological differences between members of a morph set are encoded by a Morph Set Relation and the productivity of the pattern is encoded by a Morph Set Condition. The relation between coronal stops and flaps in English falls into this category; which variant is used in a given context is the domain of well-formedness conditions. Phonologically regular but non-productive patterns are characterised by a Morph Set Relation with no accompanying Morph Set Condition; this situation is found with English morph-final voiceless/voiced pairs like {nʌɪf, naɪv}$_{\text{KNIFE}}$ (but {bɹiːf}$_{\text{BRIEF}}$ not *{bɹiːf, bɹiːv}$_{\text{BRIEF}}$, and {weɪv}$_{\text{WAVE}}$, not *{weɪv, weɪf}$_{\text{WAVE}}$) as well as with the Polish stem-final CVC and CC alternation (see §5.5). In each case, the relation between morphs within the set can be characterised phonologically, and so can enhance acquisition and recognition, but the patterns are not productive. Note that a lack of productivity, encoded as the absence of a Morph Set Condition, would not prevent a creative speaker from the sporadic generalisation of an unproductive Morph Set Relation. Finally, truly suppletive morph sets, such as English {æm, ɪz, wʌz, wəɹ, bɪn}$_{\text{BE}}$, must simply be memorised, with no generalisation to be found. The consequence is that Emergence identifies a continuum between "regular phonology" and "suppletive allomorphy" – including phonologically regular but lexically idiosyncratic sets – while maintaining surface-oriented representations. The role of MSRs and MSCs is to express regularities among members of a morph set, answering, in part, the charge to "capture generalizations…[and] capture the speakers' knowledge" (Hyman 2018: 221).

The remainder of the generalisations and knowledge is represented by the language's well-formedness conditions which serve to select among possible morph compilations. And, similar to morph set membership, well-formedness conditions range from fully phonological to highly morphological (and logically extend to syntactic domains as well, though our examples do not include such data). Bermúdez-Otero (2018) and Hyman (2018) raise a variety of issues for a framework which abandons underlying representations in favour of surface morphs. The surface-morph model considered in those works appears to have no mechanism for representing productive relations among morphs nor for selection among the multiple possibilities, that is, no counterpart to our network of MSRs, MSCs, and well-formedness conditions. At issue therefore is which of the types of generalisations possible with underlying-to-surface relations vs. surface-to-surface relations more closely corresponds to what we observe in natural language.

Box 4.5: Construction Grammar

The Construction Grammar model of phonology laid out in Välimaa-Blum (2011) is also a surface-to-surface model. Fully systematic phonological patterns are characterised by listing the *co-allophones* of each *phoneme* along with statements about their distribution. Morphophonological patterns are treated quite differently: morphemes are represented as sets of *co-allomorphs*, and certain morphological constructions select a morph with a particular sound property. There is nothing in the model to characterise phonological sub-regularities in terms of the sounds themselves. Thus, co-allomorphs like {nʌɪf, naɪv}$_{\text{KNIFE}}$ are on a par with co-allomorphs like {æm, ɪz, wʌz, wəɹ, bɪn}$_{\text{BE}}$, despite the clear phonological relation between [f] and [v] and lack thereof with the BE morphs.

We turn in Chapter 5 to a series of case studies which demonstrate that morph sets allow for concrete, straightforward analyses consistent with the Emergent hypothesis, rather than the kind of abstract analyses often required by frameworks positing single underlying representations.

5 Consequences

In this chapter, we explore certain consequences of the Emergent Hypothesis, through five case studies. We show that productive, derivable, optimising patterns are captured under the Emergent morph-based framework (Warembori, §5.1). Our second case involves a pattern that is not productive; we show that the Emergent Hypothesis seamlessly accounts for unproductive patterns that are nonetheless phonologically related (derivable) and phonologically predictable (optimising) (English, §5.2). We then turn to three examples which are traditionally analysed by appealing to abstract underlying representations – ternary distribution (Mayak, §5.3), tone shift (Kinande, §5.4), and absolute neutralisation (Polish §5.5).

5.1 Derivable, productive and optimising: Complementary distribution in Warembori

Underlying representations are key to the standard analysis of complementary distribution, namely to motivate assigning *allophones* to a single abstract unit, the *phoneme*. Schematically, complementary distribution involves at least two sounds, [p_1] and [p_2], where [p_1] occurs in contexts where [p_2] does not occur and, conversely, [p_2] occurs in contexts where [p_1] is not found – that is, the contexts for the sounds are complementary, the quintessential pattern driving the criteria for underlying representations (laid out in Chapter 4, (2)). Rather than encode each sound in its appropriate contexts when such sounds are phonetically similar, generative phonology follows the structuralist analysis of "phonemes" and "allophones" (Bloomfield 1926, Sapir 1933/1944, Twaddell 1935, Bloch 1948; see Chapter 4): a single underlying phoneme is related to its surface manifestations by rules or constraints. The analysis might involve the relation seen in (4a) of Chapter 4, selecting one sound as corresponding directly to the underlying form and letting the grammar convert the underlying form into surface forms in the appropriate contexts. Alternatively, the analysis might involve the relation seen in (4b), Chapter 4, where the underlying form is unlike any surface form in the language; one such strategy is to represent the underlying form as impoverished in some way (e.g. an underspecified segment, Archangeli 1984, 1988, Pulleyblank 1986): because the values for the alternating features are predictable, these are provided by the grammar, and not included as part of the underlying representation.

Virtually any language could be used to illustrate the phenomenon: complementary distribution of sounds is ubiquitous. To illustrate the concrete Emergent analysis of sounds in complementary distribution, we choose an example from Warembori (glottocode ware1253), a Lower Mamberamo language of the Papua region of Indonesia, relying on Donohue (1999).

5.1.1 The Warembori puzzle

Donohue (1999: 6) provides a phonemic inventory of Warembori consonants; adding in the phonetically occurring but "non-contrastive" segments [β] and [r], we make the classifications in Table 5.1. Consistent with the discussion in §2.2 and §2.3, we partition the consonants based on a combination of phonetic and phonological criteria. For reasons of simplicity, we place both [β] and [r] in the class labelled *obstruent*. This classification is sufficient for our purposes and distinguishes the consonants from each other. We return to this partitioning in our discussion in §5.1.4.[1]

As shown by (1a, b, c) respectively, the voiced stop [b] is found word-initially and after nasals; the continuant [β] occurs after a vowel. The form in (1d) shows both initial and post-vocalic labials in the same form. The same distribution is

[1]The Warembori series of stops marked by ˈ (oral and nasal) are referred to as *heavy consonants* in Donohue (1999: 8). Generally, a syllable beginning with a heavy consonant is stressed (using V́ to show stress, to reserve ˈ for heaviness): [ˈbóro] 'thorn-IND', *[ˈboró], cf. [boró] 'fruit-IND' where stress is predictably final in the absence of heavy consonants; a post-nasal heavy consonant is preceded by a lengthened nasal: [nuamːˈboro] 'coconut.thorn.IND' vs. [nuamboro] 'coconut.fruit.IND', and heavy nasals involve a slight glottal onset when not followed by an oral stop: [aˈʔnːéro] 'jungle-IND', cf. [anéro] 'crocodile-IND'. Relevant to our discussion here, heavy consonants do not alternate with continuants in intervocalic position: [ayoˈboro], *[ayoβoro] 'tree thorn'. The phonetic correlates distinguishing the heavy consonants are not well understood, but they clearly have a distinct phonological behaviour, indicating that they are in a class distinct from the alternating consonants under discussion here. If closer analysis were to reveal that they do not have phonetic properties distinct from those of the stops that alternate with continuants, then Warembori would present an example of the independence of morph sets from each other, like the English example discussed in §5.2 and the Mayak example considered in §5.3.

Table 5.1: Warembori consonants

	labial	coronal	dorsal	
voiceless	p	t	k	
voiced	b	d		
heavy	ˈb	ˈd		
voiceless continuant		s		
voiced continuant	β	r		obstruent
nasal	m	n		sonorant
nasal-heavy	ˈm	ˈn		
approximant	w	y		

found for [d] and [r] in (1e-i). Numbers in the final column identify the appropriate page in Donohue (1999).[2]

(1) Warembori Indicative (‘It is…’)

a.	bo-ro	‘mouth-IND’	59
b.	warɛm-bo-ro	‘river-mouth-IND’	6
c.	kɛ-βo-o-ro	‘1PL.IN.POSS-mouth-tooth-IND’	9
d.	bava-ro (baβa-ro)	‘stone-IND’	37
e.	doro-ro	‘rain-IND’	62
f.	dan-do	‘water-IND’	25
g.	doro-ran-do	‘rain-water-IND’	6
h.	daran-do	‘ear-IND’	63
i.	ke-raran-do	‘1.PL.INCL.POSS-ear-IND’	54

Items such as those in (1) demonstrate that a morph may exhibit both the stop and the continuant forms, for example, {bo, βo}$_{\text{MOUTH}}$, {do, ro}$_{\text{INDICATIVE}}$, and {dan, ran}$_{\text{WATER}}$. Both these pairings and the selection between the alternants is perfectly regular. Of special interest, however, are forms with no alternation, seen

[2]We have faithfully followed representations in Donohue (1999); Donohue uses the symbol “v” for [β] once the pattern has been explained, hence the parenthesised *baβa-ro* in (1d). Another consequence is the apparent difference between [kɛ] and [ke] in (1c, i). This is only apparent: Donohue (1999: 6) notes that “the vowels require little comment; they show remarkably little allophony, appearing with their expected phonetic value”. Where Donohue uses IPA, we find [ɛ]; when he stops using IPA, we find “e”. Vowel quality is not at issue in our discussion.

with the stem-medial consonants in [baβa-ro] 'stone-IND' and [daran-ro] 'ear-IND'. In words such as these, the roots contain intervocalic voiced continuants, [baβa], *[baba] and [daran], *[dadan]. Nevertheless, the discussion in Donohue (1999) follows standard analysis of such patterns, positing stops underlyingly as in (2), under the assumption that the stop is the basic form. For roots like 'stone' and 'ear', intervocalic stops are standardly posited underlyingly, /baba/ and /dadan/, even though such forms are never observed.

(2) Analysis positing underlying representations: alternating voiced consonants in Warembori with two "phonemes", /b/ & /d/

a.	/baba/	'stone'	c.	/dadan/	'ear'
b.	/bo/	'mouth'	d.	/do/	INDICATIVE

This kind of analysis is so widely adopted for cases of complementary distribution that it almost seems as though positing intervocalic stops is unquestionably plausible – and yet the forms that a learner would actually encounter are [...baβa...]/[...βaβa...] and [...daran...]/[...raran...]. To posit an underlying stop in forms where only a continuant is ever observed requires that the learner establish an alternation pattern and then use it to work backwards and establish an underlying form (/baba/, /dadan/, etc.), despite the medial consonants never being realised as stops on the surface.[3]

Why would such a move be taken by a learner? The first reason could be that the theory requiring such a basic form is preferable for some reason, an argument we rejected in §4.2. The second reason might be to capture the phonological generalisation that the distribution of stops and continuants is predictable. Let us consider that latter point here. The relevant generalisations are given in (3).

(3) Generalisations

   a. voiced stops only occur word-initially and after a consonant/nasal
   b. voiced continuants only occur after a vowel

In the following section, we show that an Emergent account explains these generalisations – and does so without requiring abstract underlying representations.

[3]This issue has received considerable attention in the literature on the alternation condition, strict cycle condition, and elsewhere condition, e.g., Kiparsky 1968, 1973b, 1982, Mascaró 1976. See van de Weijer (2012) on the irrelevance of the alternation condition if we assume strictly surface representations.

5.1.2 Emergence and complementary distribution

Under Emergence, the forms recorded in the lexicon simply mirror what is observed on the surface: $\{\text{baβa, βaβa}\}_{\text{STONE}}$, $\{\text{dan, ran}\}_{\text{WATER}}$, $\{\text{daran, raran}\}_{\text{EAR}}$, $\{\text{do, ro}\}_{\text{IND}}$, and so on. The fact that morphs which begin with a voiced consonant have both stop-initial and continuant-initial counterparts is captured in a Morph Set Relation, (4).[4]

(4) Warembori stop/continuant Morph Set Relation, $\text{MSR}_{[\text{d}]\sim[\text{r}]}$
In a minimal morph set, there is a systematic relation between morphs with an initial voiced obstruent stop and morphs with an initial voiced obstruent continuant.

examples $\{\text{baβa, βaβa}\}_{\text{STONE}}$
$\{\text{dan, ran}\}_{\text{WATER}}$
$\{\text{ro, do}\}_{\text{IND}}$

$$\text{MSR}_{[\text{d}]\sim[\text{r}]}:\quad \{\mathcal{M}_i, \mathcal{M}_j\}\quad \mathcal{M}_i:\ \#\begin{bmatrix}\text{stop}\\ \text{voice}\\ \text{obstruent}\end{bmatrix}$$
$$\mathcal{M}_j:\ \#\begin{bmatrix}\text{continuant}\\ \text{voice}\\ \text{obstruent}\end{bmatrix}$$

The Warembori stop/continuant Morph Set Relation is a symmetric relation that gives rise to the Morph Set Condition (MSC) in (5); it holds of morph sets with initial voiced obstruents, whether stops or continuants.

While the presence of both continuant and stop variants in a morph set is achieved by the MSC (or by direct observation if both forms happen to be encountered), the choice between the variants within a morph set is achieved by the well-formedness conditions in (6).

[4]Even though this pattern obtains only with labials and coronals, place need not be mentioned in the Warembori Morph Set Relation (4) because voiced velar obstruents do not occur in the language (neither [g] nor [ɣ]), as shown in the consonant chart in Table 5.1. Note, however, that Donohue (1999: 9) notes that velar stops are "written as *g*" after a nasal suggesting that velar stops may be voiced in that one context.

(5) Warembori Morph Set Conditions, $\text{MSC}_{[d]\sim[r]}$

a. With respect to $\text{MSR}_{[d]\sim[r]}$, a minimal morph set is ill-formed if there is a morph with an initial voiced obstruent stop and no corresponding morph with an initial voiced obstruent continuant.

b. With respect to $\text{MSR}_{[d]\sim[r]}$, a minimal morph set is ill-formed if there is a morph with an initial voiced obstruent continuant and no corresponding morph with an initial voiced obstruent stop.

$\text{MSC}_{[d]\sim[r]}$: For $\mathcal{M}_i$, $\mathcal{M}_j$ of $\text{MSR}_{[d]\sim[r]}$, $*\{\mathcal{M}_i, \neg\mathcal{M}_j\}$, $*\{\neg\mathcal{M}_i, \mathcal{M}_j\}$

Schematic: *{d…, ¬r…}, *{¬d…, r…}
*{b…, ¬β…}, *{¬b…, β…}

One condition penalises voiced obstruent continuants generally (6a); we assume this is reflected in the frequency of their occurrence. A second condition penalises a voiced obstruent stop specifically after a vowel. Since only morph-initial voiced obstruent stops exhibit alternation, as expressed in $\text{MSR}_{[d]\sim[r]}$, it might be possible to express the phonotactic condition more generally than in (6b).

(6) Conditions for Warembori

a. $*\begin{bmatrix}\text{cont}\\ \text{voice}\\ \text{obstruent}\end{bmatrix}$, $\mathcal{F}$: segments, $\mathcal{D}$: word

For all segments, assign a violation to a word for each voiced obstruent continuant.

b. $*\text{V}\begin{bmatrix}\text{stop}\\ \text{voice}\\ \text{obstruent}\end{bmatrix}$, $\mathcal{F}$: segments, $\mathcal{D}$: morph, word

For all segments, assign a violation to a morph or a word for each post-vocalic voiced obstruent stop.

With a domain setting for both morphs and words, (6b) holds broadly in the language; in fact, Donohue (1999) implies that there are no counter-examples. As a morph condition, (6b) guides acquisition of new morphs; as a word condition, (6b) selects among different compilations. Illustrating with $\{\text{do, ro}\}_{\text{INDICATIVE}}$ in (7), the continuant-initial morph is chosen when following a vowel, due to

(6b) militating against stops in this context. The compilations in (7a, c) are eliminated by (6b); selection devolves to (6a), which eliminates the continuant-rich *[βaβaro] of (7d).

(7) Assessment for [βaβaro]$_{\text{STONE-INDICATIVE}}$
morph sets: {baβa, βaβa}$_{\text{STONE}}$; {do, ro}$_{\text{INDICATIVE}}$

STONE-INDICATIVE			*V [stop, voice, obstruent]	*[cont, voice, obstruent]
	a.	baβado	*!	*
☞	b.	baβaro		**
	c.	βaβado	*!	**
	d.	βaβaro		***!

Compilations with no V-C sequence are resolved solely by the cost assigned to voiced obstruent continuants (6a), whether due to the alternating segment being word-initial or post-consonantal; both contexts are illustrated in (8). The form with no such continuants, (8a), is selected; *V [stop] plays no role.

(8) Assessment for [dando]$_{\text{WATER-INDICATIVE}}$
morph sets: {dan, ran}$_{\text{WATER}}$; {do, ro}$_{\text{INDICATIVE}}$

WATER-INDICATIVE			*V [stop, voice, obstruent]	*[cont, voice, obstruent]
☞	a.	dando		
	b.	danro		*!
	c.	rando		*!
	d.	ranro		*!*

Complementary distribution involves a phonological distribution of X and Y such that they occur in complementary contexts throughout a language – in both underived and derived contexts. Such patterns are derivable, productive, and optimising (see Chapter 4, (2)). The Emergent analysis expresses these properties with (i) an MSR that relates morphs in a morph set (derivable); (ii) the related MSC (productive), and (iii) a phonological well-formedness condition (optimising). Because this condition is relevant in both morph and word domains, it both selects between morphs (word domain) and governs acquisition of new morphs (morph domain). Each of these elements is necessary independently of complementary distribution; when they cooccur, complementary distribution is the result. The phonological generalisations are expressed using morph sets, not unique underlying representations.

Box 5.1: The category [β, r]

Partitions based on voicing, stop/continuant, and what we have called "obstruent/sonorant" are critical to a phonological analysis of the Warembori facts. The first two are phonetically unambiguous. We address here our classification of [r] as an obstruent, alongside other obstruent segments like [b], [d], and [β], a classification supported by the Warembori phonological pattern.

In terms of an obstruent~sonorant distinction, we can quite unambiguously separate [p, t, k, b, d, ˈb, ˈd, s] from [m, n, ˈm, ˈn, w, y], for which we use the familiar terms "obstruent" and "sonorant" respectively. This is less clear for [β, r] where standard assumptions might suggest the assignment of [β] to the obstruent class and [r] to the sonorant class. Based on the phonetics only, the assignments are not completely clear, however. A learner might classify [β] with the sonorants, particularly if it has only weak friction; a learner might classify [r] as an obstruent based on its differences with the unambiguous members of the sonorant class. The phonetics are plausible either way: [β, r] are the only voiced nonvocalic continuants and so we might expect ambiguity in their classification (Mielke 2008). With respect to the phonology, the situation is simple. As long as [β] and [r] are members of the same class, their relation to [b, d] can be characterised in a uniform fashion: [b, d] are stops; [β, r] are continuants. As seen above, this allows for a simple analysis.

If features are assigned in a more phonetically rigid manner, with [β] analysed as an obstruent and [r] as a sonorant, the analysis becomes more complicated hence the pattern less expected. From a rule-based perspective, the stops /b, d/ must become continuants with their values for [sonorant] dependent on place: labials become continuant (obstruents) while coronals become continuant sonorants. The shift in [sonorant] is arbitrary and unexplained. In a constraint-based framework, the constraints can be analogous to those of (6), with the post-vocalic prohibition on voiced obstruent stops and the context-free prohibition on voiced continuant consonantal segments. The problem is that general considerations of faithfulness would favour repairs involving only [continuant]. Since the constraints can be satisfied without a change of [sonorant], there would be no reason for such a shift – short of positing an additional constraint with no independent motivation to penalise voiced coronal continuant obstruents. Both labial and coronal stops would be expected to alternate with labial and coronal continuants, with the same value for sonorant. In short, if feature specifications are universally specified, there is rigidity in their utilisation. However, if featural classifications are established on the basis of experience, as proposed in Chapter 2, then this issue does not arise.

5.1.3 Analyses with underlying representations

Complementary distribution is a phenomenon that satisfies the three criteria for underlying representations given in Chapter 4, (2); every framework of phonology has some kind of analysis for these patterns. As noted in the introduction to this section, the standard analysis, exemplified by that in Donohue (1999), is to assume that one type of underlying segment (voiced stops in Warembori) are converted by rule to another class (here, continuants), requiring reverse engineering during acquisition to posit the underlying segment even in contexts where only a different sound appears (e.g. the medial continuants in Warembori morphs like [doro] 'rain').

In contrast, Optimality Theory does not impose restrictions on the underlying forms (richness of the base; Prince & Smolensky 1993). Consequently, inputs may contain both stops /b, d/ and continuants /β, r/ without positional restrictions. Gen creates the corresponding possible outputs, and the constraint hierarchy evaluates input-output pairings to eliminate forms with stops or continuants "in the wrong place": a constraint penalising post-vocalic [voiced, obstruent, stop] would outrank a general constraint against [voiced, obstruent, continuant]; both must outrank faithfulness to [continuant] and to [stop] in voiced obstruents. The upshot is that if either /β/ or /r/ were posited in an underlying representation then it would only surface unaltered if it happened to be post-vocalic on the surface; in any other context, it would be better to have [b] or [d]. Similarly, if /b/ or /d/ were posited underlyingly, then each would surface unaltered only when *not* post-vocalic. If the input for a form like [baβa-ro] was /baba-do/, or /baba-ro/, or /baβa-ro/, or indeed, /βaba-do/, the surface output would be the same. In fact, since Warembori has a very limited consonant inventory, the possible underlying representations could be quite varied, e.g. /βava-d̪o/ involving somewhat gratuitous adjustments of place of articulation. In such cases of complementary distribution, much of the specific input representation is immaterial. The crucial aspect of the OT analysis is the constraint set, with markedness outranking faithfulness – a ranking that is comparable in a sense to the approach taken here in terms of the importance of markedness constraints. Indeed, if OT invokes an interpretation of lexicon optimisation where inputs should be maximally harmonic with surface forms (Prince & Smolensky 1993), then even the inputs postulated by OT would be largely comparable to the forms obtained by direct observation. This is a necessary result of the Emergent framework but a possible stipulated property in OT.

5.1.4 Conclusion

Patterns that are both productive and phonological (both in the optimising and the derivable senses) provide the quintessential argument for the unique underlying representation. In a rule-based generative analysis, complementary distribution requires the postulation of a unique underlying form since the "conditioned variants" must be prevented from appearing in contexts where the rule would not apply: a generative analysis of such cases always pairs a particular postulated form for the underlying representation with a particular form of the required rule. In some cases, the choice of underlying form is determined by the ease of characterising the contexts for each sound; in some cases, the contexts are equally expressible (e.g. vowel harmony contexts) and an arbitrary (or underspecified) representation is posited.

In a constraint-based approach, this need for a unique underlying form disappears since conditions govern all variants. The motivation for an underlying representation is therefore lost. Since Emergent Grammar as we model it is a condition-based approach, unique, abstract underlying forms are completely unmotivated.

The representations required under the Emergent account are neither unique nor abstract, consisting of morph sets containing all and only morphs that are directly related to surface forms. In this case, complementary distribution results from the confluence of three properties (each of which is independently necessary for cases not involving complementarity). (i) A word- and morph-domain condition ensures that the pattern holds both in words and morphs (derived and underived contexts); word-domain conditions express optimisation. (ii) A phonological Morph Set Relation characterises derivable patterns by relating morphs directly to each other. (iii) The paired Morph Set Conditions determine which morph sets are incomplete and so ill-formed; rectifying this ill-formedness results in productivity.

We turn now to an example where the pattern is derivable and optimisable but not productive, the distribution of preconsonantal nasals in English.

5.2 Phonological but unproductive: Limited place assimilation in English

Every morph set involves some degree of learning. At a minimum, each morph set involves the sort of learning involved in mapping some arbitrary set of sounds onto a set of semantic and syntactic markers, whether or not there is additional regularity to acquire. While it is common cross-linguistically for morphs within a morph set to bear a systematic and productive relation to each other (characterised by Morph Set Relations and Morph Set Conditions, §3.3) there is no necessity for such relations to be productive within a language, even within morph sets that bear significant similarities to each other. Each morph set is an entity unto itself. While certain properties in a morph set involve productive regularity (expressed by MSRs and the related MSCs), there are also patterns within morph sets that are *not* productive – for example, when the multiple forms in a morph set simply reflect an earlier stage in the language's history when a pattern was productive (Blevins 2004). The English nasal place assimilation example presented here illustrates the kind of case where morph choice is phonologically optimising, but the pattern observed is not productive (English: glottocode nort3314).

Our focus is the negative prefixes, *in-* as in *inattentive*, *un-* as in *unaccented*, and *non-* as in *nonacademic*: each ends with [n] when prevocalic. The situation changes with consonant-initial stems: the *in-* morph set has multiple members, while the morph sets for *un-* and *non-* have only one each. Consequently, one morph set shows alternation (because there are multiple related members) but the other morph sets show no alternation (having only one member on the relevant dimension). There is no systematic pattern governing all nasal-final prefixes in English. Thus, although morph choice is phonologically optimising, the pattern itself is not productive. We begin by reviewing the data.

5.2.1 A non-productive pattern

English exhibits a pattern seen in many languages where nasals share place of articulation with a following consonant, within an appropriate domain. In English this pattern is restricted morphologically: some morph sets participate in the pattern while others do not (Allen 1978). Examples showing participation are given in (9).

(9) English nasal place assimilation

a. within morphs

[bʌmp]	'bump'
[tɛnt]	'tent'
[bænd]	'band'
[bæləns]	'balance'
[lɛnz]	'lens'
[bæŋk]	'bank'
[mɪŋks]	'minx'

b. between morphs

[ɪmbæləns]	'imbalance'
[ɪntɹænsɪʤənt]	'intransigent'
[ɪŋkənsɪdəɹət]	'inconsiderate'
[ɪnæptɪtud]	'inaptitude'

The nasal place assimilation pattern holds within morphs as shown in (9a), suggesting a morph-domain syntagmatic condition preferring NC sequences which share place of articulation. In some instances, this condition also holds between morphs, illustrated in (9b): as shown, the prefix in (9b) has at least three morphs, {ɪn, ɪm, ɪŋ}NEGATIVE.[5] The appropriate polymorphic form is selected by a phonotactic preferring nasal-obstruent sequences with the same place of articulation. Thus, as the forms in (9) illustrate, the domain for this phonotactic is both morph and word, (10).

(10) English nasal place assimilation phonotactic

$\begin{bmatrix}\text{nasal}\\ \text{\^{}place}_i\end{bmatrix}\begin{bmatrix}\text{obstruent}\\ \text{place}_i\end{bmatrix}$, $\mathcal{F}$: segments, $\mathcal{D}$: morph, word

For all segments, assign a violation to a morph or a word for each nasal-obstruent sequence where the nasal's place is in the complement class of the place of the obstruent.

[5] The discussion is simplified by omitting details such as that the {ɪn} morph also occurs before vowels, that there is an {ɪ} morph which occurs before sonorants, an {ɪɱ} morph which occurs before labiodentals, and so on.

Box 5.2: Complement class

The notion of complement class (Hayes & Wilson 2008), introduced in §2.2, is relevant for two types of situations. In one, the complement class is characterised by some specifiable property (e.g., the complement class [^nasal] can also be characterised by [oral]); in the other, the complement class cannot be expressed by a single property or set of properties shared by all members. In the first, the specifiable property cases, we adopt the convention of representing the complement class by the relevant specification (e.g. [oral], not [^nasal]). We reserve the notion of *complement class* for cases where the complement class is not amenable to independent specification. Such reference follows from the notion of partitioning introduced in §2.2 and box 2.5, p. 17. As noted there, it does not follow that every phonetic partitioning will result in all subsets of the partition being characterisable in terms of phonetic properties.

English nasal place assimilation makes critical use of the notion of complement class. The complement class notation allows generalisation over several separate phonotactics, each prohibiting a nasal-obstruent sequence where place features do not match:

$$*\begin{bmatrix}\text{nasal}\\ \text{labial}\end{bmatrix}\begin{bmatrix}\text{obstruent}\\ \text{coronal}\end{bmatrix}, *\begin{bmatrix}\text{nasal}\\ \text{labial}\end{bmatrix}\begin{bmatrix}\text{obstruent}\\ \text{dorsal}\end{bmatrix}, \text{etc.}$$

The series of separate phonotactics misses the general observation that nasal-obstruent sequences are disallowed if their place features are distinct from each other.

An alternative to the complement class concept would be some other type of convention, such as defining both identity (F_i, F_j, where $F_i = F_j$) and non-identity (F_i, F_j, where $F_i \neq F_j$) relations (represented through reference to subscripts), so that the nasal place phonotactic could be defined as shown below:

$$*\begin{bmatrix}\text{nasal}\\ \text{place}_i\end{bmatrix}\begin{bmatrix}\text{obstruent}\\ \text{place}_j\end{bmatrix}, \text{where } [\text{place}_i] \neq [\text{place}_j]$$

> Given that the simple notion of partitioning establishes both sets and their complements, we adopt that device here rather than invoke some additional convention.

In English, nasal place assimilation is not required between members of a compound (*fan-boy*, **fa[m]-boy*; *fa[n]-girl*, **fa[ŋ]-girl*),[6] and crucial for our purposes here, there are also nasal-final prefixes which do not exhibit place assimilation, illustrated in (11).

(11) English non-alternating nasal-final prefixes

	a. {ʌn}$_{\text{NEGATIVE}}$		b. {nɑn}$_{\text{NEGATIVE}}$	
	[ʌnpɹɑbləmætɪk]	‘unproblematic’	[nɑnpeɪpəl]	‘nonpapal’
	[ʌnbælənst]	‘unbalanced’	[nɑnbəlif]	‘nonbelief’
	[ʌntʌʧt]	‘untouched’	[nɑntɑksɪk]	‘nontoxic’
	[ʌndɪsəplənd]	‘undisciplined’	[nɑndɛɹi]	‘nondairy’
	[ʌnkaɪnd]	‘unkind’	[nɑnkɹɛdɪt]	‘noncredit’
	[ʌnglud]	‘unglued’	[nɑnglɛɹ]	‘nonglare’

The problem is clearly stated by Allen (1978: 2): “[s]ome property of the prefix in-, other than its segmental composition, must be proposed in order for a rule of Nasal Assimilation to operate in forms prefixed by in-, but not in forms prefixed by un- or non-. At this point, there is no reason to rule out the possibility that the necessary ‘property’ is simply a statement of the relevant facts”.

5.2.2 The Emergent analysis

Our suggestion, under an Emergent analysis, is that we do indeed want to simply provide “a statement of the relevant facts”. There is only one morph per morph set for the two prefixes in (11), {ʌn}$_{\text{NEGATIVE}}$ in (11a) and {nɑn}$_{\text{NEGATIVE}}$ in (11b). The learner perceives one form of the prefix, acquires the morph set, and has no uncertainty when producing forms, nonce or otherwise. In contrast, for the *in-* prefix in (9b), there are multiple surface forms observed and the nasal place phonotactic – motivated morph-internally – determines which form to use in any given case, again without uncertainty. Allen’s arguments against such a transparent analysis are essentially of two types. First, the prefix *in-* attaches to various non-words (e.g., *inert*, *implacable*, *intrepid*, *insipid*, *immaculate*) but fails to attach to certain

[6] See Mohanan (1993) for discussion of some of the variables involved in causing nasal place assimilation to apply differently in different domains.

productively derived words (e.g. **inselfish*, **inthoughtful*, **infreckled*, **inchildlike*, **infriendly*). Second, the semantics of *in-* derivatives is less compositional than with either *un-* or *non-* (whose differences she also discusses). Overall, we interpret Allen's observations as evidence for a lack of productivity with the prefix *in-*. Allen concludes that if *in-* prefixation is lexically restricted, and if this is the sole nasal-final prefix exhibiting place assimilation, then the need for a general rule of nasal assimilation is weakened. The Emergent analysis given here captures the essential properties, (i) it is unpredictable whether a nasal-final prefix will alternate and that is encoded appropriately in the morph sets; (ii) if it does alternate, the pattern is phonologically predictable due to the nasal place assimilation phonotactic condition (10); (iii) the nasal place assimilation phonotactic holds of underived forms (morphs) as well. The division of labour between morph sets and conditions results in exactly the patterns observed.

Assessments comparing {ɪn, ɪm, ɪŋ}$_{\text{NEGATIVE}}$ and {ʌn}$_{\text{NEGATIVE}}$ are given in (12) and (13) respectively. When there are multiple morphs in the morph set, as in (12), the nasal place assimilation phonotactic selects among the available compilations.

(12) Assessment for [ɪmbæləns]$_{\text{NEGATIVE-BALANCE}}$
morph sets: {ɪn, ɪm, ɪŋ}$_{\text{NEGATIVE}}$; {bæləns}$_{\text{BALANCE}}$

NEGATIVE-BALANCE			$*\begin{bmatrix}\text{nasal}\\ {}^\wedge\text{place}_i\end{bmatrix}\begin{bmatrix}\text{obstruent}\\ \text{place}_i\end{bmatrix}$
☞	a.	ɪm-bæləns	
	b.	ɪn-bæləns	*!
	c.	ɪŋ-bæləns	*!

When there is only one prefix morph, as in (13), there is no selection to be made.[7]

(13) Assessment for [ʌn-bæləns-t]$_{\text{NEGATIVE-BALANCE-ADJECTIVE}}$
morph sets: {ʌn}$_{\text{NEGATIVE}}$; {bæləns}$_{\text{BALANCE}}$; {d, t, əd}$_{\text{ADJECTIVE}}$

NEGATIVE-BALANCE-ADJECTIVE			$*\begin{bmatrix}\text{nasal}\\ {}^\wedge\text{place}_i\end{bmatrix}\begin{bmatrix}\text{obstruent}\\ \text{place}_i\end{bmatrix}$
☞	a.	ʌn-bæləns-t	*

[7]We do not represent the choice of suffix morphs in the table here, including only the compilation that shows the correct morph, [t]. We also do not give an account of the selection of the prefixal [ɪn] morph when prevocalic: presumably there is a type condition against non-coronal place features (comparable in its effect to the condition against voiced continuants in Warembori (6a)).

5.2.3 Non-productive patterns and URs

The standard generative analysis of these three prefixes is not so straightforward. The invariant prefixes in (11) are [n]-final in all instances, so it is logical to assume that these prefixes are /n/-final in their underlying representations. However, an underlying representation for the prefix in (9b) would also be arguably /n/-final because it surfaces as [ɪn-] when pre-vocalic (where the nasal cannot acquire place features from a following consonant). This creates a conundrum for both generative and Optimality Theoretic frameworks: how are the assimilating and the non-assimilating instances of /n/ to be distinguished in English underlying representations, where the relation among morphs is derivable and optimisable but not productive? Recognising the phonological properties of the alternations, linguists have attempted to bypass the productivity criterion either by positing enriched representations (for example, the alternating /n/ might be underspecified, simply [+nasal], while each nonalternating /n/ has place specifications, Archangeli 1984) or enriched grammar structures (for example the different strata of Lexical Phonology, Kiparsky 1982).

A different kind of problem arises in Optimality Theory. Whatever the input, Gen ought to produce candidate outputs where the nasal of the prefix agrees in place with a following consonant. The problem is to distinguish between cases of the *in-* input – where place agreement is optimal, more important than remaining faithful to some input form – and the *un-* and *non-* inputs – where faithfulness to input [n] is more important than place agreement.

5.2.4 Conclusion

These problems stand in sharp contrast to the Emergent approach, where an asymmetric distribution of morphs across morph sets is not unexpected, because there is no requirement that featural patterns within morph sets will always be equivalent across morph sets. In particular, because there is no recurrent pattern of nasal-final morphs exhibiting multiple places of articulation, there is no motivation in English for a general Morph Set Condition deriving multi-member nasal-final morph sets: the English pattern is not productive – morph sets differ in either having (i) invariant final [n], or (ii) having a final nasal differentiated across place features. However, inspection of members of the alternating morph set reveals that the individual members are phonologically related to each other (derivable – and expressible as a Morph Set Relation for this morph set), and that selection among morphs is achieved by a phonologically defined condition (optimising).

5.3 Ternary contrasts: Mayak low vowels

In this section, we consider a pattern involving similarly unproductive morph sets, a case where morph sets differ in terms of a single feature. The example we consider involves Mayak tongue root harmony. We show that morph sets can differ in terms of the tongue root specification(s) within a morph set – retracted, advanced, or both. We demonstrate that ternary behaviour arises from the way tongue root features are distributed across morph sets.

Given the human capacity for learning both highly regular and highly idiosyncratic properties, we expect to find cases where morph sets share some, but not all, properties. Mayak (glottocode buru1301) is a Western Nilotic language spoken predominantly in South Sudan, a Northern Burun language which, together with Southern Burun, forms "one of the three branches of Western Nilotic in …[the] internal subgrouping of the Nilotic language, the other two being the Nuer-Dinka languages and the Luo languages" (Andersen 1999b: 1, following Köhler 1955). Mayak provides a particularly interesting case where the phonotactics are transparent, while the behaviour of particular morph sets is determined by idiosyncratic properties of those sets. Hence phonological regularity is clear as far as the phonotactics are concerned, but not in the morph sets, illustrating a case that is derivable and optimising but not productive. Noteworthy in terms of the general conception of the Emergent framework, morph sets with minimal membership may result in words which violate conditions simply because there is no completely well-formed compilation available. As we show, the case is problematic for models with underlying representations, whether using rules or optimality theoretic constraints and Gen.

Mayak exhibits a wide variety of alternations: morphologically-conditioned vowel raising (Andersen 1999b, Trommer 2016), rounding harmony (Andersen 1999b, McCollum 2017), vowel length alternations (Andersen 1999b), and interestingly complex tongue root harmony alternations (Andersen 1999b, 2000, Finley 2007, Ozburn 2019), as well as a rich and regular system of stem-final consonant alternations (Andersen 1999a). In this discussion we limit our attention to a select part of tongue root harmony, those patterns involving low-vowelled suffixes.

5.3.1 Mayak harmony patterns

Mayak has a symmetrical ten-vowel system, breaking along a cross-height contrast, as shown in Table 5.2. Following Andersen (1999b), we characterise this contrast in terms of tongue root position.

Table 5.2: Mayak vowels (Andersen 1999b: 3)

	[rtr]				[atr]			
high	ɪ			ʊ	i			u
mid		ɛ	ɔ			e	o	
low			a				ʌ	

Of interest here are low vowel suffixes which either harmonise or fail to harmonise with the root vowel, depending on the suffix and the specific vowel that precedes. To situate this discussion, we sketch very briefly the general properties of progressive tongue root harmony in Mayak.

As shown in Andersen (1999b), there are two contexts which exhibit progressive harmony. We illustrate both with high vowels, turning subsequently to the analysis of low vowels.[8] First, when a root vowel is high advanced, we observe advanced suffixes.[9] (In (14a, b), the suffix [k] marks PLURAL.)

(14) Mayak progressive harmony I: {ɪ, i}$_{\text{1.SG.POSS}}$ (Andersen 1999b: 10)

	noun	{ɪ, i}$_{\text{1.SG.POSS}}$	gloss
a.	ŋɪn	ŋɪŋ-ɪ-k	‘eyes’
b.	lɛk	lɛk-ɪ-k	‘teeth’
c.	pal	pal-ɪ	‘navel’
d.	wɔŋ	wɔŋ-ɪ	‘eye’
e.	t̪ʊk	t̪ʊɣ-ɪ	‘outer mouth’
f.	ʔʌm	ʔʌm-ɪ	‘thigh’
g.	ʔid	ʔid-i	‘ear’
h.	ʔuŋ	ʔuŋ-i	‘knee’

As seen in (14a-e), the first person singular possessive suffix is retracted ([ɪ]) when the root is retracted; similarly, when the root is low advanced (14f), the suffix is retracted. When the root is high advanced, however, the suffix vowel is advanced as well (14g, h). This pattern can be derived by positing both advanced and retracted variants in the morph set for the suffix ({ɪ, i}$_{\text{1.SG.POSS}}$) in combination with two conditions.

[8] Mid vowels have a restricted distribution that we do not consider here. See Andersen (1999b).

[9] We follow the transcription used in Andersen (1999b) with one exception: Andersen (1999b) notes that the language has [t, t̪, d, d̪] but chooses to represent [t, d] with [ƭ, ɗ] to emphasise the visual difference – [ƭ, ɗ] vs. [t̪, d̪] rather than [t, d] vs.[t̪, d̪]. We use standard IPA symbols here.

(15) Mayak *[atr, high][rtr] phonotactic condition

$*\begin{bmatrix}\text{atr}\\ \text{high}\end{bmatrix}$ [rtr], $\mathcal{F}$: vowels, $\mathcal{D}$: morph, word

With a focus on vowels, assign a violation to a word or a morph for each sequence of a high advanced vowel followed by a retracted vowel.

(16) Mayak *[atr] type condition

*[atr], $\mathcal{F}$: vowels, $\mathcal{D}$: word

With a focus on vowels, assign a violation to a word for each advanced vowel.

The *[atr, high][rtr] condition ensures that the suffix is advanced after a high atr root vowel; the *[atr] condition prefers retracted morphs.

Second, when a suffix is back, we see an additional instance of harmony.[10]

(17) Mayak progressive harmony II: {ʊk, uk}$_{\text{PLURAL}}$ (Andersen 1999b: 13)

	singular	plural	gloss
a.	mɛɛk	mɪɣ-ʊk	‘spider’
b.	gɔɔc	gʊj-ʊk	‘bowl’
c.	cɪɪma	cim-uk	‘knife’[11]
d.	bul	bul-uk	‘stomach’
e.	jaaŋ	jʌŋ-uk	‘crocodile’

With a retracted root, the plural suffix is retracted (17a,b); with a high advanced root, the plural suffix is advanced (17c,d). These tongue root values are entirely analogous to those seen in (14) and would be accounted for by the conditions in (15) and (16).

Of particular interest is the comparison between the harmonic [jʌŋ-uk] ‘crocodile-PL’ (17e) vs. the disharmonic [ʔʌm-ɪ] ‘thigh-1.SG.POSS’ (14f). We see that an advanced low vowel in a root does not cause a front vowel to be advanced in a suffix, but it does induce advancement on a back vowel, motivating the condition in (18).

[10] Andersen (1999b) analyses the difference between suffixes with [i] and with [u] as resulting from the former being specified for [−ATR] and the latter being underlyingly unspecified (along with [a]). We reanalyse this through reference to the backness distinction between [ɪ, i] on the one hand and [ʊ, u, a] on the other. See Ozburn (2019). Finally, we ignore the vowel length alternations as well as the height alternations in the roots in (17).

[11] Andersen (1999b: 13) notes that certain roots in the plural exhibit “grammatically conditioned root vowel alternation”. This accounts for the difference in tongue root values between the singular and plural root forms for ‘knife’. As Andersen notes, however, the behaviour of the suffix is phonologically regular.

(18) Mayak *[atr, back][rtr, back] phonotactic condition

$*\begin{bmatrix}\text{atr}\\ \text{back}\end{bmatrix}\begin{bmatrix}\text{rtr}\\ \text{back}\end{bmatrix}$, $\mathcal{F}$: vowels, $\mathcal{D}$: morph, word

With a focus on vowels, assign a violation to a word or a morph for each sequence of a back advanced vowel followed by a back retracted vowel.

To conclude this brief introduction to progressive harmony, we have shown that Mayak patterns respond to two pressures. First, all else being equal, retracted vowels are preferred. Second, this general preference is overridden in two contexts: advanced vowels are preferred in suffixes after a high advanced vowel; back advanced vowels are preferred in suffixes after a back advanced vowel.

Box 5.3: Mayak regressive harmony

In addition to the progressive harmony that is of direct relevance to our discussion, Mayak also exhibits regressive harmony, cases where root vowels alternate as a result of a particular suffix (see Andersen 1999b for discussion; examples in this box are from p. 7). Verbs with subject suffixes illustrate the pattern:

retracted suffix	[gɛb-ɛr]	‘beat-3s’	[gʊd̪-ɛr]	‘untie-3s’
high advanced suffix	[geb-ir]	‘beat-2s’	[gud̪-ir]	‘untie-2s’

Accounting for such cases involves the interaction of three things. First, appropriately defined morph sets for roots must include both retracted and advanced forms, for this case, {gɛb, geb}$_{\text{BEAT}}$ and {gʊd̪, gud̪}$_{\text{UNTIE}}$. The relevant Morph Set Relation ensures appropriate two-member morph sets, relating a retracted, nonlow $\mathcal{M}_i$ and an advanced $\mathcal{M}_j$. This MSR is asymmetrically productive: retracted nonlow vowels have advanced counterparts, but [atr] vowels need not have retracted counterparts. Thus, two classes of roots show no alternations, those with low vowels, {ʔam}$_{\text{EAT}}$: [ʔam-b-ɛr] ‘eat-3s’, [ʔam-b-ir] ‘eat-2s’, and those with advanced vowels, {ʔib}$_{\text{SHOOT}}$ ([ʔib-ɛr] ‘shoot-3s’, [ʔib-ir] ‘shoot-2s’; {pʌd̪}$_{\text{UNTIE}}$, [pʌd̪-ɛr] ‘untie-3s’, [pʌd̪-ir] ‘untie-2s’.

The next relevant factor is the type condition in (16), *[atr], causes morphs with retracted vowels to be preferred, all else being equal.

The final element is a syntagmatic condition that causes the advanced form to be preferred before a high, advanced suffix: *[rtr][atr, hi]; $\mathcal{F}$: vowels; $\mathcal{D}$: morph, word. (With a focus on vowels, assign a violation to a morph or a word for any sequence of a retracted vowel followed by a high advanced vowel.)

The phonotactic *[rtr][atr, hi], responsible for regressive harmony, requires that the second vowel be high. When alternating roots like {gɛb, geb}$_{\text{BEAT}}$ and {gʊd̪, gud̪}$_{\text{UNTIE}}$ are followed by a low advanced vowel, the harmony phonotactic does not override the general preference for retracted vowels: [gɛb-ʌr] 'beat-1s', [gʊd̪-ʌr] 'untie-1s'. (Low vowel retracted roots are similarly unaffected by a low advanced suffix, [ʔam-b-ʌr] 'eat-1s'. This is doubly expected since such roots have no advanced forms and the low advanced suffix is exempt from the regressive harmony condition.)

5.3.2 Three patterns for suffixes with low vowels

We now turn to the focus of this section, the behaviour of low vowel suffixes in the progressive harmony contexts outlined above. As seen in Table 5.3 and Table 5.4, low vowel suffixes exhibit three distinct harmonic patterns.[12]

Table 5.3: Low vowel suffixes: alternating behaviour (Andersen 1999b)

	{at̪, ʌt̪}, p. 13		
	SG	PL	*gloss*
[ɪ]	rɪm-at̪	rɪm	'blood'
[a]	daal-at̪	daal	'flower"
[ʊ]	kʊm-at̪	kʊm	'egg"
[i]	ʔin-ʌt̪	ʔin	'intestine"
[u]	ruuj-ʌt̪	ruuc	'worm"
[ʌ]	ʔʌʌw-ʌt̪	ʔʌʌp	'bone"

The singular suffix {at̪, ʌt̪}$_{\text{SINGULAR}}$ has both retracted and advanced forms, alternating as a function of the harmonic context. This alternation contrasts with

[12]For additional data, including examples with mid vowels, see Andersen (1999b, 2000).

both the plural suffix {ak}$_{\text{PLURAL}}$, which is invariably retracted without regard for its harmonic context, and with the first singular subject suffix, which is similarly invariant, but advanced rather than retracted, {ʌr}$_{\text{1.SINGULAR}}$. These differences are summarised in (19) – given what a learner encounters, these are the morph sets that will be acquired. We also include a fourth suffix {ʌn}$_{\text{SINGULAR}}$, given in Andersen (2000), which has an invariant advanced low vowel.

Table 5.4: Low vowel suffixes: invariant behaviour (Andersen 1999b)

	{ak}, p. 12			{ʌr}, p. 8		
	SG	PL	gloss	3SG	1SG	*gloss*
[ɪ]	bɪl	bɪl-ak	'iron'	d̪ɪɪm-b-ɛr	d̪ɪɪm-b-ʌr	'weed'
[a]	kac	kaj-ak	'leopard'	caab-ɛr	caab-ʌr	'cook'
[ʊ]	kʊr	kʊr-ak	'boat'	ɟʊʊɟ-ɛr	ɟʊʊɟ-ʌr	'find'
[i]	kic	kij-ak	'bee'	wiin-d-ɛr	wiin-d-ʌr	'cook'
[u]	kut	kud-ak	'nest'	puur-d̪-ɛr	puur-d̪-ʌr	'hoe'
[ʌ]	kʌm	kʌm-ak	'elbow'	ʔʌʌb-ɛr	ʔʌʌb-ʌr	'catch in the air'

(19) Three types of suffixes with initial low vowels in Mayak

a. alternating [rtr]~[atr] {at̪, ʌt̪}$_{\text{SINGULAR}}$
b. invariant [rtr] {ak}$_{\text{PLURAL}}$
c. invariant [atr] {ʌr}$_{\text{1.SINGULAR}}$
{ʌn}$_{\text{SINGULAR}}$[13]

In terms of the criteria discussed in Chapter 4, (2), for relating morphs, we see first that the only case with multiple morphs is {at̪, ʌt̪}$_{\text{SINGULAR}}$. Regarding *derivability*, these two morphs are certainly related to each other phonologically: one is retracted, the other is advanced; all other features are the same. Similarly, as we

[13] Andersen (2000) lists an invariant suffix [-ʌnit̪] 'singular' but notes that it is "probably morphologically complex, consisting of the suffixes /-ʌn/ and /-it̪/" Andersen 2000: 34; both are glossed as SINGULAR). Phonologically, both [-ʌn] and [-it̪] are invariant, as would be the putative [-ʌnit̪]. We adopt Andersen's proposal that [-ʌnit̪] is bimorphemic ([-ʌn-it̪]), and interpret his examples accordingly. Since these morphs are harmonically invariant, regardless of whether [-ʌnit̪] is compositional, the proposals made here are not affected other than in the postulation or non-postulation of a harmonically invariant {ʌnit̪}$_{\text{SINGULAR}}$ in addition to the harmonically invariant {ʌn}$_{\text{SINGULAR}}$ and {it̪}$_{\text{SINGULAR}}$. Note that interpreting [-ʌnit̪] as bimorphemic creates a form that is doubly-marked for SINGULAR, assuming the adequacy of the gloss for the morph's syntactic and semantic properties.

are about to show, the choice between the two is phonologically *optimising*, determined by the dictates of tongue root harmony. Like English nasal place assimilation (§5.2), however, there is no *productivity* in the observed variation. Because of the small number of such suffixes and their relatively even distribution across the three categories (alternating, invariably retracted, invariably advanced), each morph set must be learned through exposure to the morphs themselves. It seems unlikely that a single pair is sufficient to establish a Morph Set Relation governing advanced and retracted morphs in the low vowel morph sets in Mayak; however, even if such a relation were established, there is no recurring pattern in the observed morph sets to motivate a productive Morph Set Condition. Once the learner has identified suffix morph set membership (through observation), assessment of the morph compilation follows directly from the proposed conditions on sequences of vowels, (15) and (18), and on vowel types, (16), where the syntagmatic conditions take precedence over the type condition.

We provide sample assessments with each of the three types of low-vowelled suffixes in turn. The crucial point is that given the structure of each morph set, selection follows straightforwardly. There is no need to treat one suffix type as the "normal" pattern and the other two as "exceptional".

5.3.2.1 The alternating low suffix

We turn first to the case where the learner has acquired a suffix with an alternating [low] vowel, {at̪, ʌt̪}$_{\text{SINGULAR}}$: the retracted morph appears after retracted roots and the advanced morph appears after advanced roots.

With a high advanced noun, the choice between the advanced and retracted suffix options is illustrated in (20). The prohibition against [atr, high][rtr] sequences eliminates the retracted form of the suffix, *[ʔin-at̪], thereby selecting the fully harmonic form, [ʔin-ʌt̪].

(20) Assessment for [ʔin-ʌt̪]$_{\text{INTESTINE-1.SINGULAR}}$
morph sets: {ʔin}$_{\text{INTESTINE}}$; {at̪, ʌt̪}$_{\text{SINGULAR}}$

INTESTINE-SG	*[atr high][rtr]	*[atr back][rtr back]	*[atr]
a. ʔin-at̪	*!		*
☞ b. ʔin-ʌt̪			**

With a low advanced root, harmony is again predicted since low vowels are [back].

(21) Assessment for [ʔʌʌw-ʌt̪]$_{\text{BONE-1.SINGULAR}}$
morph sets: {ʔʌʌw}$_{\text{BONE}}$; {at̪, ʌt̪}$_{\text{SINGULAR}}$

BONE-SG			*[atr, high][rtr]	*[atr, back][rtr, back]	*[atr]
	a.	ʔʌʌw-at̪		*!	*
☞	b.	ʔʌʌw-ʌt̪			**

Hence the alternating low vowel suffix follows precisely the pattern established above for high vowels: the low vowel is advanced if the root is [atr, high] (20), advanced if the root is [atr, back] (21), and retracted otherwise – where we illustrate the retracted case in (22). (In our assessment of [rɪm-at̪] 'blood-SINGULAR', we include both [rtr] and [atr] morphs for the root for 'blood'. This is because regressive harmony (see box 5.3, p. 104) motivates the possibility of an advanced morph for such a root. This is immaterial in general, since the retracted form will be preferred due to *[atr] – only in contexts forcing regressive harmony will such a root be chosen. We include the advanced morph in the morph set here for two reasons: (i) completeness, (ii) to show that positing such a form, as required for regressive harmony, results in no difficulties for the analysis).

(22) Assessment of [rɪm-at̪]$_{\text{BLOOD-SINGULAR}}$
morph sets: {rɪm, rim}$_{\text{BLOOD}}$; {at̪, ʌt̪}$_{\text{SINGULAR}}$

BLOOD-SG			*[atr, high][rtr]	*[atr, back][rtr, back]	*[atr]
☞	a.	rɪm-at̪			
	b.	rɪm-ʌt̪			*!
	c.	rim-at̪	*!		*
	d.	rim-ʌt̪			*!*

A case like (22) might make it appear that the harmony conditions play a crucial role in selecting the surface form with {at̪, ʌt̪}$_{\text{SINGULAR}}$. Careful consideration of such forms, however, shows that there is invariably some other condition that would be sufficient to determine the attested form. In (22), for example, *[atr] is crucial (necessary to avoid indeterminacy) and would independently eliminate the form (22c) that also violates a harmonic condition: [rɪm-at̪] (22a) is incidentally harmonic and the harmony phonotactics play no crucial role.

We turn now to suffixes with low vowels that do not alternate. As seen in (19), there are three suffixes with invariant low vowels: one with retracted [a] and two with advanced [ʌ]. We begin with the retracted case: {ak}$_{\text{PLURAL}}$ invariably surfaces as retracted, regardless of root vowel.

5.3.2.2 Nonalternating low retracted suffix

When an affix is invariant, the learner acquires a morph set with exactly one morph, in this case, $\{\text{ak}\}_{\text{PL}}$. If there is also only one morph in the stem morph set, compilation gives only one option. That one option is the surface form, regardless of violations. The assessment in (23) illustrates the point.[14]

(23) Assessment for $[\text{kij-ak}]_{\text{BEE-PL}}$
morph sets: $\{\text{kij}\}_{\text{BEE}}$; $\{\text{ak}\}_{\text{PL}}$

BEE-PL	*[atr, high][rtr]	*[atr, back][rtr, back]	*[atr]
☞ a. kij-ak	*		*

Such a word violates harmony since the advanced stem vowel is followed by a retracted suffix, but there are no options in the morph sets that would avoid this violation. In addition, there is an [atr] vowel and again no way to avoid a violation of *[atr].

5.3.2.3 Nonalternating low advanced suffixes

We turn now to the two suffixes with invariant [ʌ], where, regardless of the quality of the root vowel, the suffixes surface with the vowel [ʌ].

Like $\{\text{ak}\}_{\text{PLURAL}}$, the morph sets of these suffixes have exactly one morph, i.e. $\{\text{ʌn}\}_{\text{SINGULAR}}$, and $\{\text{ʌr}\}_{\text{1.SINGULAR}}$. Consequently, when these suffixes are attached to a non-alternating stem, i.e. a stem with only one advanced morph, the result is harmonic, simply because both stem and suffix are advanced. This is because, as with $\{\text{ak}\}_{\text{PLURAL}}$, when there is also only one morph in the stem morph set, morph compilation gives only one option – and with only one option, that is the surface form. The assessment in (24) illustrates the point.

(24) Assessment for $[\text{ʔin-ʌn-it̪}]_{\text{INTESTINE-SINGULAR}}$
morph sets: $\{\text{ʔin}\}_{\text{INTESTINE}}$; $\{\text{ʌn}\}_{\text{SINGULAR}}$; $\{\text{it̪}\}_{\text{SINGULAR}}$

INTESTINE-SG	*[atr, high][rtr]	*[atr, back][rtr, back]	*[atr]
☞ a. ʔin-ʌn-it̪			***

[14] This same strategy is adopted in Construction Grammar: Välimaa-Blum (2011: 27) observes "[s]hould a lexical morpheme only have one sound shape in the lexicon, the schemas would consequently use this one form in all derivation."

The same result obtains with an alternating root, as illustrated in (25). While the harmonic prohibitions discussed here prohibit particular sequences where the second vowel is retracted, in this case the suffix vowel is advanced. Hence neither of the harmony conditions is relevant. The motivation for such alternating roots, as noted in box 5.3 on p. 104, is their behaviour before high advanced suffixes (*[rtr][atr, high]; $\mathcal{F}$: vowels; $\mathcal{D}$: morph, word). Low vowels do not trigger regressive harmony so the presence of a low advanced suffix does not override the general preference for retracted vowels in the root (*[atr]).

(25) Assessment for [ɟʊʊɟ-ʌr]$_{\text{FIND-1SG}}$
morph sets: {ɟʊʊɟ, ɟuuɟ}$_{\text{FIND}}$; {ʌr}$_{\text{1.SINGULAR}}$

HAIR-SG	*[atr, high][rtr]	*[atr, back][rtr, back]	*[atr]
☞ a. ɟʊʊɟ-ʌr			*
b. ɟuuɟ-ʌr			**!

5.3.3 A three-way contrast without enriched representations

The three types of low vowel suffixes are summarised in Table 5.5.

Table 5.5: Summary of low vowel morph set types

Morph set		Harmony role	Preference for retracted vowels
alternating	{at̪, ʌt̪}$_{\text{SG}}$	crucial	plays a role, all else being equal
nonalternating	{ak}$_{\text{PL}}$	not crucial	plays a role, all else being equal
nonalternating	{ʌn}$_{\text{SG}}$	not crucial	plays a role, all else being equal
	{ʌr}$_{\text{1.SG}}$		

As demonstrated, morph sets including low vowels do not exhibit a consistent pattern. When the learner encounters an advanced low vowel, for example, it is impossible to predict whether that vowel would have a retracted counterpart in another context or not – the same unpredictability is found with a retracted low vowel and a possible advanced counterpart. Each morph set must simply be learned through exposure to appropriately affixed words. There is no productive Morph Set Condition.

5.3.4 Discussion and conclusion: Ternary distinctions

The cases from English (§5.2) and Mayak (§5.3) highlight a problem that derives directly from the postulation of underlying representations. Consider again the Mayak case. As just seen in Table 5.5, low vowel suffixes are of three types: (i) alternating, [atr] or [rtr], (ii) nonalternating [rtr], (iii) nonalternating [atr]. Assuming underlying representations, it might seem straightforward to assume that the nonalternating [rtr] forms are underlyingly retracted and that the nonalternating [atr] forms are underlyingly advanced.

(26) Putative underlying representations for Mayak

	surface form	*underlying representation*
a.	[rtr]	/rtr/
b.	[atr]	/atr/

The problem is what then to do with the alternating forms. The expected options would be that underlying /atr/ becomes surface [rtr] in some context (a harmonic context in this case) or that underlying /rtr/ becomes surface [atr] in some context (again, a harmonic context). A core aspect of the underlying representation hypothesis is that once an underlying form is postulated, there is no "look-ahead" access to the eventual surface form. Hence if /rtr/ is posited, then one cannot look ahead to see that the underlying representation in question will become [atr] in appropriate contexts. The result therefore is that a postulated /rtr/ for an alternating form becomes indistinguishable from the /rtr/ of (26a), just as a postulated /atr/ for an alternating form would be indistinguishable from the /atr/ of (26b). A third type of representation, not directly motivated by the values of the feature in question, becomes necessary.

An entirely comparable problem arises in the English case. Since the negative prefix [ɪ, ɪn, ɪm, ɪŋ] appears prevocalically as [ɪn] (*inelegant*) while the preconsonantal environment conditions the appearance of different morphs, the plausible underlying representation for the prefix would be /ɪn-/ (Allen 1978). This means that however the rule or condition causing assimilation is formulated, it needs to target coronal nasals. A problem analogous to that of Mayak now arises. If the underlying nasal at the end of /ɪn-/ is blind to the fact that it ultimately surfaces in a variety of ways ([ɪ, ɪn, ɪm, ɪŋ]), then it is indistinguishable from the underlying – but nonalternating – nasal of *non-* and *un-*.

These cases do not appear to be isolated or unusual. In Margi (Hoffmann 1963, Pulleyblank 1986, Archangeli & Pulleyblank 2018a), the morphs in a morph set may bear a consistently low tone, a consistently high tone, or may alternate between low and high. In Polish (Bethin 1978, Sanders 2003), morph set members may exhibit a back vowel that is consistently mid, a back vowel that is consistently high, or may exhibit back vowels that alternate between mid and high. In Nuu-chah-nulth (Davidson 2002, Stonham 1990, Kim 2003, Archangeli & Pulleyblank 2018b), barring the effect of certain "shortening" or "lengthening" suffixes, morph sets may have vowels which are consistently short, consistently long, or that alternate between short and long. In Barrow Inupiaq (Kaplan 1981, Archangeli & Pulleyblank 1994) and Kashaya (Buckley 1994), certain apparently phonetically identical segments diverge behaviourally, where one set acts as a target and not a trigger and the other as a trigger and not as a target. And this list goes on: in §5.5, we discuss another three-way alternation, the Polish *yer* pattern.

Since postulating underlying representations is the source of the difficulty, any theory assuming such representations must seek a solution that involves either enrichment of the theory's representations or enrichment of the theory's architecture. Both have been proposed. For example, underspecification has been proposed as a solution to cases such as those seen in Mayak and Margi. For Margi, Pulleyblank (1986) suggests that the consistently low morphemes in Margi have a lexical L, the consistently high morphemes have a lexical H, and the alternating morphemes have no lexical tone; the surface tone of an alternating morpheme is determined contextually or by default.[15] For Mayak, Andersen (1999b) proposes that the alternating low vowel suffixes are unspecified for the tongue root feature, whereas the nonalternating suffixes are underlyingly specified, and for Barrow Inupiaq, Archangeli & Pulleyblank (1994) argues for an unspecified vowel contrasting with a (partially) specified /i/, both surfacing as [i] in most environments. In a prosodic case such as Nuu-chah-nulth length, representational enrichments have been proposed for syllable structure: Stonham (1990) proposes two types of long vowels, distinguished by reference to a syllable nucleus and a syllable rhyme; Kim (2003) proposes a distinction between two types of long vowels underlyingly, one prelinked to two moras and one that is only partially linked. Architecturally, cases such as the English one have been proposed to involve multiple lexical strata (Kiparsky 1982, Mohanan 1986). If the rule of place assimilation is assigned to a stratum where /ɪn-/ is attached but not to a stratum where /nɑn-/ and /ʌn-/ are attached, then the differences in behaviour can be accounted for morphologically.

These enrichments are necessary in rule-based as well as constraint-based frameworks. In a rule-based framework, the enrichment is to ensure that the

[15] We use the term "morpheme" advisedly here, referring to earlier analyses. An Emergent account would represent the distribution in terms of morph sets with only low-toned morphs, only high-toned morphs, or both low- and high-toned morphs respectively.

relevant rule applies to only a subset of the cases that appear to match the rule's structural description. In a constraint-based framework such as Optimality Theory, something is needed to ensure that the combination of Gen plus markedness constraints results in one form being optimal in one type of case but some other form being optimal in a different class of cases. For example, faithfulness to one type of structural input (e.g., unspecified) works differently from faithfulness to a different type of structural input (e.g., specified). Rule-based and constraint-based frameworks are comparable in this regard.

Strikingly, in the Emergent Grammar approach, there is no comparable problem. At all levels, the creation of higher level structure does not entail destruction of lower level structure. This has been amply motivated in the exemplar literature (Pierrehumbert 2001, 2003, etc.). In the current context, when the learner establishes the relation between [at̪] and [ʌt̪] in Mayak, for example, this does not erase the actual words in which [at̪] and [ʌt̪] occur, nor does the postulation of a morph set {at̪, ʌt̪} erase in some way the information that this form involves two possible surface forms.

At issue in the Emergent approach are two questions:

(i) Is there a relation between the members of a morph set?
(ii) If so, does the relation define productive augmentations of morph sets?

The answer to (i) is that if there are multiple members in a morph set, the Identity Principle predicts a high degree of similarity among those members. The human's predilection for generalisation leads us to expect a high degree of systematic variation: relations of a systematic nature are expected between the members of a morph set, our Morph Set Relations; nonsystematic differences are expected to be less common and more difficult to acquire. In cases like the Yangben vowels discussed in §3.3 and the Warembori voiced obstruents examined in §5.1, large numbers of morph pairs are related in this kind of systematic manner, warranting the grammaticisation of Morph Set Relations.

Stability in a phonological system is predicted when the pressures of phonotactics engage smoothly with systematic options made available by morph sets. When morph sets productively provide precisely the options in morphs needed to satisfy word-domain conditions, the grammar is able to maximally satisfy the phonotactic conditions that it imposes. Compare, for example, (22) with (23); by having both advanced and retracted morphs in its morph set, the polymorph sg suffix in (22) allows the harmony phonotactics to be satisfied in a way that the monomorph pl suffix in (23) cannot. In response to (ii), therefore, we would expect Morph Set Relations to tend to define productive augmentation of morph sets: the absence of a paired morph may render it impossible to satisfy some word-level phonotactic. Hence where an unpaired morph is dispreferred, Morph

Set Conditions are imposed to penalise non-compliant (“singleton”) morph sets. In Warembori, stop-initial morphs are systematically paired with fricative-initial morphs (4); neither stop-initial nor fricative-initial morphs are allowed as singletons, captured in the symmetric Warembori MSC (5); in Yangben, advanced morphs are paired with retracted morphs ($MSR_{[TR]}$, (30), Chapter 3); pairing is asymmetrically imposed, with singleton [rtr] morphs penalised by the Yangben $MSC_{[TR]}$ but with singleton [atr] morphs allowed. It is also possible for both pairs and singletons to be well-formed. In Polish, discussed in §5.5, there is a systematic relation observed between many pairs of morphs (enough to establish MSR_{yer}), yet both the sets of paired morphs and the two types of singleton morph sets occur. That is, in Polish, there is an MSR but no corresponding MSC.

There is no expectation that such distinctions in the structure of morph sets should be limited to any particular type of feature. That distinctions occur for tongue root (Mayak), place features (English), tone (Margi), length (Nuu-chah-nulth), and so on is unproblematic. The prediction for the Emergent framework is that any property that can give rise to lexical distinctions could give rise to the sort of three-way distinctions that we have observed in this section.

Moreover, the theory predicts a maximum differentiation of three: for any contrast involving *P* and *^P*, the complement class of *P*, the set of options includes maximally the morph sets including {P}, {^P}, {P, ^P}. Whether the restriction to a maximally three-way possibility holds or doesn’t hold of an approach invoking abstract underlying representations depends on the specific nature of the representation or architectural enrichment invoked.

5.4 Contrast (re)location: Kinande tone shift

In the next two sections, we address examples which illustrate another key difference between the concepts of morph set and of underlying representation: while members of morph sets are concrete and directly related to observable forms, underlying representations may be abstract, only indirectly related to observable forms – Hockett’s “theoretical base form”. The difference is illustrated by schemas in (27), which show possible lexical representations for an observed form [X] under the different frameworks. Given $[X]_{\alpha}$, the one-member morph set in (27a) is the only possible corresponding morph set under Emergence. With underlying representations there are two types of representations: (i) a concrete representation, depicted in (27b), where underlying /X/ corresponds directly to surface [X], and (ii) an abstract representation, depicted in (27c), where underlying /Z/ corresponds indirectly to surface [X]. (Again, “α” indicates the syntactic/semantic unit.)

(27) Lexical representations given $[X]_{\alpha}$

a. Emergence:	b. Concrete UR	c. Abstract UR
$\{X\}_{\alpha}$	[X]	[X]
	|	|
	$/X/_{\alpha}$	$/Z/_{\alpha}$

In the abstract case, (27c), the observed form is not postulated at the abstract level (as /X/) and the abstract form is not realised (as [Z]) on the surface.

We illustrate the abstract schema of (27c) with discussion of tonal distribution in Kinande.[16] Kinande, or Nande, (glottocode nand1264), is a Narrow Bantu language, D42 in Guthrie's classification (Guthrie 1967), spoken in the Democratic Republic of the Congo by around 900,000 in 1991 (Simons & Fennig 2019). Data are primarily taken from Mutaka (1994) and Akinlabi & Mutaka (2001).[17]

5.4.1 The Kinande tone puzzle

The two core observations about Kinande tone are that (i) in most cases the prefix tone, high (H) or low (L), is determined by the root that the prefix is attached to, not by the prefix itself, and (ii) verb roots are typically L on the surface, while noun roots are either L or H-L (Hyman & Valinande 1985, Mutaka 1994, Akinlabi & Mutaka 2001). Both points are illustrated in (28).[18] In (28a, b), the prefixes immediately to the left of the root surface as L, while in (28c, d) the immediately pre-root prefixes surface as H – the difference results from the root to which the prefixes are attached.[19]

[16] A similar example in a different featural domain is found in Esimbi, where prefix vowel height is determined largely by the root to which a prefix is attached. See Hyman (1988) for a standard account of Esimbi, and Archangeli & Pulleyblank (2015a) for an EG account.

[17] Big thanks to Philip Ngessimo Mutaka for thought-provoking discussion of this section. Data from Mutaka (1994) are indicated with M; from Akinlabi & Mutaka (2001) by AM. A few forms were provided by Philip Ngessimo Mutaka (personal communication), indicated by Mpc.

[18] In our transcriptions, vowel quality is represented in IPA, rather than with the orthographic conventions used in Mutaka (1994); tongue root values are indicated and all tones, both L and H, are marked. We do not address tongue root harmony here, but present all data in a way that is consistent with the correct surface forms; a more complete treatment of Kinande would include both advanced and retracted morphs in the appropriate morph sets. Roots are indicated by square brackets. Noun classes are indicated by "C" followed by the number of the class.

[19] We restrict our discussion here to the tonal forms that occur in non-phrase-final position; in phrase-final position, an additional penultimate H tone is present in many forms (Hyman & Valinande 1985, Mutaka 1994). Our analysis here follows that of Archangeli & Pulleyblank (2015c); see that work for a more complete discussion of the Kinande basic tone pattern and see Archangeli & Pulleyblank (submitted) for extension to a class of more complex verbal tone patterns.

(28) Kinande phrase-medial verbs & nouns

a. *Verbs: L prefixes*

ɛ̀-rì-[hʊ̀m]-à màgʊ́ːlʊ̀	'to hit Magulu'	AM336
ɛ̀-rì-nà-[hʊ̀m]-ìr-à màgʊ́ːlʊ̀	'to just hit for Magulu'	AM336

b. *Nouns: L prefixes*

ɔ̀-kʊ̀-[gʊ̀lʊ̀] kù-líːtɔ̀	'heavy leg' (C15)	M155
à-kà-[gɔ́ngɔ̀] kà-lwɛ́ːrɛ̀	'the back is sick' (C12)	M158

c. *Verbs: H prefixes*

ɛ̀-rí-[tʊ̀m]-à màgʊ́ːlʊ̀	'to send Magulu'	AM338
ɛ̀-rì-ná-[tʊ̀m]-ìr-à màgʊ́ːlʊ̀	'to just send for Magulu'	AM338

d. *Nouns: H prefixes*

ɔ̀-kʊ́-[bɔ̀kɔ̀] kù-líːtɔ̀	'heavy arm' (C15)	M155
à-ká-[hʊ́kà] kà-lwɛ́ːrɛ̀	'the insect is sick' (C12)	M158

A standard autosegmental analysis of this kind of distribution postulates an underlying feature on the root that spreads onto the affix, and then delinks from its original position. Mutaka (1994) does exactly that for Kinande, positing an underlying high tone on the stem that surfaces one mora to the left of its underlying location via a derivation illustrated in Figure 5.1. Noniterative Association causes the H tone to associate to a preceding mora, while Delink Rightmost removes the association between the H tone and its underlying host. L tones are assigned to all unspecified vowels by default (Pulleyblank 1986). We illustrate this with the examples ɔ̀-kʊ̀-[gʊ̀lʊ̀]... (28b) and ɔ̀-kʊ́-[bɔ̀kɔ̀]... (28d).[20]

A comparable analysis is proposed in an optimality theoretic account in Akinlabi & Mutaka (2001): a H tone is introduced as in Mutaka's autosegmental account, but prevented from being realised in that position by an anti-faithfulness "AvoidSponsor" constraint. What is remarkable about such analyses of Kinande is that the underlyingly postulated H tones never surface attached to the vowel they start with. Rather, they attach to a neighbour and detach from the underlying vowel host. This gives rise to the kinds of input/output relations shown in Figure 5.2 for sample morphs from (28).

As seen by comparing the underlying representations and surface forms in Figure 5.2, there is no direct relation between any of the tones of the underlying morphemes and the tones observed in the surface forms. A vowel that is underlyingly toneless does not surface as toneless; however, it can surface in multiple ways tonally – as variably L or H (Figure 5.2a), as invariably L (Figure 5.2b), or as

[20] In Figure 5.2, we give the hypothesised underlying representations for the noun and verb roots found in (28), including the cases illustrated in Figure 5.1. The roots with H tones undergo Noniterative Association and Delink Rightmost to derive the surface tones.

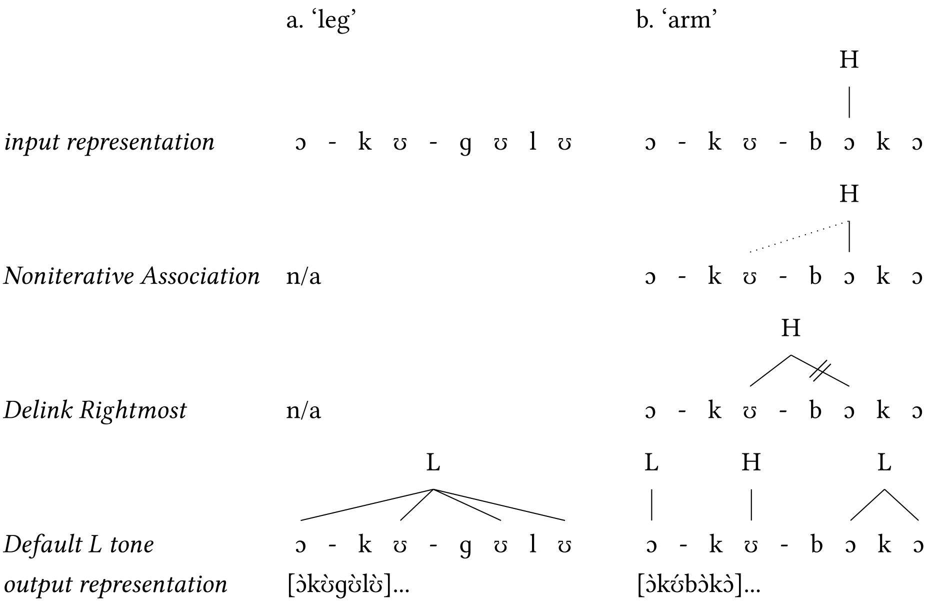


Figure 5.1: Kinande root-tone based derivations

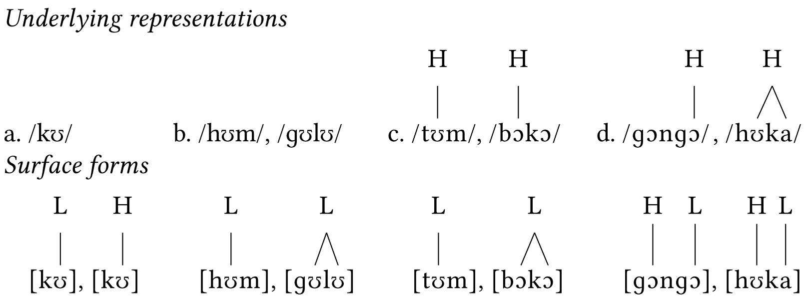


Figure 5.2: Types of input/output relations in spreading account of Kinande

invariably H (Figure 5.2d). In contrast, a vowel that is underlyingly H surfaces invariably as L, Figure 5.2c, d, never as H. Representations of the type in Figure 5.2d show a toneless-H sequence paired with a H-L sequence, due to the shifting H tone. In this tone-shift approach, underlying representations have moved away from the structuralist notion of building blocks. Rather, underlying representations are worked out by the reverse engineering of rules: here, prefixal H tone is assumed to result from the tone of the following morpheme and this is accomplished by spreading, ergo the following (L-toned) vowel must be underlyingly H. As seen in Kinande, this means that underlying representations must be highly abstract entities – the underlying H tones are in locations where they are not observed on the surface, abstractness of the type schematised in (27c).

5.4.2 The Emergent analysis: Lexical classes in Kinande

In a framework like Emergence, where representations reflect observed forms directly, such an analysis is not possible. How, then, is the Kinande tone "shift" to be understood? Abstracting away from vowel quality changes due to tongue root harmony, observation establishes that the relevant prefixes have two forms, $\{$mʊ̀, mʊ́$\}_{\text{C3}}$, $\{$kà, ká$\}_{\text{C12}}$, $\{$kʊ̀, kʊ́$\}_{\text{C15}}$, $\{$rì, rí$\}_{\text{INFINITIVE}}$ and $\{$nà, ná$\}_{\text{JUST}}$; in contrast, roots typically have one form, e.g. $\{$gʊ̀lʊ̀$\}_{\text{LEG}}$, $\{$bɔ̀kɔ̀$\}_{\text{ARM}}$ and $\{$hʊ́kà$\}_{\text{INSECT}}$, etc. The emergent morph sets correspond directly to the surface forms of (27). Yet there is still a difference to capture since there are two classes of roots – a class whose prefix bears H tone – $\{$bɔ̀kɔ̀$\}_{\text{ARM}}$, $\{$hʊ́kà$\}_{\text{INSECT}}$, etc. – and a class whose prefix bears L tone – $\{$gʊ̀lʊ̀$\}_{\text{LEG}}$, $\{$gɔ́ngɔ̀$\}_{\text{BACK}}$, etc. The distribution of H tone cannot be predicted from any observable phonological property of the roots concerned – it is phonologically arbitrary. We use the label α for the class whose prefixes typically have H tone. Lexical items like $\{$bɔ̀kɔ̀$\}_{\text{ARM}}$ would be members of the α class, $\{$bɔ̀kɔ̀$\}_{\text{ARM}, \alpha}$.[21]

Reviewing the distribution of H tone in Kinande, we see that in general Kinande vowels have L tone (Pulleyblank 1986, Mutaka 1994), leading to positing a general prohibition on high tones, *[H] (29a). Nonetheless, in the variable Kinande prefix morph sets, the H-toned morph does surface with roots of class α, achieved by a condition stating that α roots must not occur with a preceding L tone: *[L]$\{...\}_{\alpha}$, given in (29b).[22] (The general formalism for type conditions like

[21] See box 3.10, p. 52 for discussion of arbitrary lexical classes (like the α class) and their interaction with conditions in the grammar.

[22] Since surface moras in Kinande have either a H or L tone, this condition could equivalently be expressed positively, by a condition requiring H tones before the α class, H$\{...\}_{\alpha}$. This was how the condition was expressed in Archangeli & Pulleyblank (2015c). However, as laid out in (4), (5), and (6) in Chapter 6, we are assuming all conditions are expressed as prohibitions, hence this, too, is expressed negatively.

(29a) and syntagmatic conditions like (29b) are introduced in §3.2; the schemas are summarised in Chapter 6, in (4) and (5) respectively.) Both conditions are given a word domain: (29a) is not true generally of individual morphs and (29b) requires two morphs so must hold of a domain larger than the morph.

(29) Kinande tone conditions

a. *[H], $\mathcal{F}$: vowels, $\mathcal{D}$: word
With a focus on vowels, assign a violation to a word for each high-toned vowel.

b. *[L]{...}$_\alpha$, $\mathcal{F}$: vowels, $\mathcal{D}$: word
With a focus on vowels, assign a violation to a word for each sequence of a low-toned vowel preceding a member of the α class.

Assessment is illustrated in (30). With (30a), there is no α class noun stem, so *[L]{...}$_\alpha$ is irrelevant. In this case, *[H] is the decider, selecting the L-toned prefix morph. In (30b), the noun stem is a member of the α class, so *[L]{...}$_\alpha$ is relevant: the H-toned prefix morph wins out over the L-toned prefix morph.

(30) Kinande noun assessments (vowel alternations not represented in morph sets)

a. ɔ̀-kʊ̀-[gʊ̀lʊ̀]...
morph sets: {ɔ̀}$_{\text{DET}}$, {kʊ́, kʊ̀}$_{\text{C15}}$, {gʊ̀lʊ̀}$_{\text{LEG}}$

		DET-C15-LEG	*[L]{...}$_\alpha$	*H
☞	a.	ɔ̀-kʊ̀-[gʊ̀lʊ̀]...		
	b.	ɔ̀-kʊ́-[gʊ̀lʊ̀]...		*!

b. ɔ̀-kʊ́-[bɔ̀kɔ̀$_\alpha$]...
morph sets: {ɔ̀}$_{\text{DET}}$, {kʊ́, kʊ̀}$_{\text{C15}}$, {bɔ̀kɔ̀}$_{\text{ARM}.\alpha}$

		DET-C15-ARM$_\alpha$	*[L]{...}$_\alpha$	*H
	c.	ɔ̀-kʊ̀-[bɔ̀kɔ̀$_\alpha$]...	*!	
☞	d.	ɔ̀-kʊ́-[bɔ̀kɔ̀$_\alpha$]...		*

5.4.3 Consequences

There are three desirable consequences of this analysis. First, we have already seen morph sets with a single L-toned morph and morph sets with both H- and L-toned morphs. There is the logical possibility of a morph set with a single H-toned morph, a morph which surfaces as H-toned regardless of the context. In fact, such prefixes exist, for example {ká}$_{\text{CONTINUOUS}}$, illustrated in (31) where the continuous is compared with infinitives for the same verb (repeated from (28)).[23]

(31) Invariant H tones in Kinande (M219)

{ká}$_{\text{CONTINUOUS}}$

tʊ̀-ká-[hʊ̀m-à] vàlìnáːndɛ̀	'we are hitting Valinande'
tʊ̀-ká-[tʊ̀m-à] vàlìnáːndɛ̀	'we are sending Valinande'

{rì, rí}$_{\text{INFINITIVE}}$

ɛ́-rì-[hʊ̀m-à]…	'to hit…'
ɛ̀-rì-[hʊ̀m-à]…	'to hit…'
ɛ́-rí-[tʊ̀m-à]…	'to send…'
ɛ̀-rí-[tʊ̀m-à]…	'to send…'

Under the Emergent analysis, there is simply a single morph in this morph set, {ká}$_{\text{CONTINUOUS}}$. Since there are no other options, a H tone is realised regardless of the type of verb it attaches to. In contrast, an analysis with abstract underlying representations is challenged because these H tones cannot arise from the morpheme to which they are attached: {hʊ̀m}$_{\text{HIT}}$ does not typically appear with a preceding H; see (28a). Nor do these H tones shift to the preceding morpheme, unlike other H tones. This state of affairs is expected under Emergence. An affix with only a H-toned morph is a logical possibility; given such a morph set, compilations are assessed normally. The apparent "lack of tone shift" follows under Emergence because the affix is not of class-α, so does not require a preceding H; selection of a preceding tone is made by *H.

Second, extending this line of thought further, the EG analysis predicts four types of morphs based on tone type and whether or not the morph is a member of the α-class: L, not α-class; H, not α-class; L, α-class; H, α-class. All four types are found in Kinande.

We have already seen examples of the L and H morphs that are not members of the α class, that is, that do not condition a H tone to their left. Both roots ({gʊ̀lʊ̀}, {gɔ́ngɔ̀}, (28b))[24] and affixes ({rì, rí}, {nà, ná}, (28a, c)) with this behaviour can be observed. Moreover, as just noted, the prefix {ká}$_{\text{CONTINUOUS}}$ is invariably H and does not condition a preceding H (31).

As for morphs of the α-class, we have already seen roots in (28c, d). Affixes too may be members of the α-class, as seen in (32).

[23] As noted in Mutaka (2001), the marker *ka* exhibits different tonal behaviour in tenses other than the present. We do not address these tenses here.

[24] As observed above, only noun roots may belong to the "H" class, with a H on the initial vowel.

(32) Kinande prefixes of the α-class

a. {tà$_{\alpha}$} è-rí-tà-[hʊ̀m]-à màgʊ́ːlʊ̀ M36/Mpc
'to merely hit Magulu'
{tá$_{\alpha}$} è-rí-tá-[tʊ̀m]-à màgʊ́ːlʊ̀ Mpc
'to merely send Magulu'

b. {mʊ̀} è-rì-mʊ̀-[hʊ̀m]-ìr-à màgʊ́ːlʊ̀ AM336
'to hit him for Magulu'
{mʊ̀} è-rì-nà-mʊ̀-[hʊ̀m]-ìr-à màgʊ́ːlʊ̀ AM336
'to just hit him for Magulu'
{mʊ́$_{\alpha}$} è-rí-mʊ́-[tʊ̀m]-ìr-à màgʊ́ːlʊ̀ AM338
'to send him for Magulu'
{mʊ́$_{\alpha}$} è-rì-ná-mʊ́-[tʊ̀m]-ìr-à màgʊ́ːlʊ̀ AM338
'to just send him for Magulu'

As seen in (32), some morphs must be assessed individually, not by morph set, for whether they are members of class α, requiring the presence of a preceding H. For 'merely', both L and H morphs belong to class α (32a); for the object marker (32b), the L-toned morph does not condition a preceding H while the H-toned morph does.

These patterns are striking – and they are problematic for a rule-based approach. 'Merely' has two morphs: {tà$_{\alpha}$, tá$_{\alpha}$}$_{\text{MERELY}}$. Both morphs require a preceding H; the choice between the two morphs depends on the verb root that follows. Similarly, the object marker has two morphs: {mʊ̀, mʊ́$_{\alpha}$}$_{\text{3.SG.OBJ}}$. Again, the choice between the two morphs is determined by the verb root that follows. But there is a crucial difference: in {mʊ̀, mʊ́$_{\alpha}$}$_{\text{3.SG.OBJ}}$, only the H morph requires a preceding H tone. This double-H effect seen with the object marker required special treatment in a spreading account. Mutaka (1994) proposed a special architecture for the object marker so that the object marker triggered a special cycle of rule application, one where spreading would apply twice (once to the object marker from a "H-toned" root and a second time from the object marker to the preceding prefix), but delinking would apply only once. In their optimality theoretic account, Akinlabi & Mutaka (2001) proposed an interaction between two tonal alignment constraints and the constraint mentioned above, AvoidSponsor, which prevents a H from being realised on the vowel it is lexically a part of. Note the problem for such an analysis of the continuous forms where {ká}$_{\text{CONTINUOUS}}$ is consistently H, regardless of what follows. According to the analysis presented here, we propose that the H-toned morph for a third person object is a member of the α-class while the corresponding L-toned morph is not: {mʊ̀, mʊ́$_{\alpha}$}$_{\text{3.SG.OBJ}}$. As such the L-toned morph imposes no requirements on a preceding morph while the H-toned morph is subject to *[L]{...}$_{\alpha}$.

Finally, the Emergent analysis of Kinande tone is unlike other analyses of Kinande in that it makes no appeal to a tone spreading rule, iterative or noniterative. This is significant because the traditional Kinande spreading analysis crucially requires that tone not only spreads, but that it does so only to the next vowel over – a rare instance of noniterative spreading. Distinguishing between iterative and noniterative spread poses a variety of problems, problems that disappear under the EG analysis since it has no "spread", iterative or not. In general, we would expect a phonotactic to constitute pressure for iterativity since *XY would be violated in domino fashion by changes in a sequence involving multiple potential targets: XXXXY → XXXYY → XXYYY → XYYYY → YYYYY. In contrast, a morpho-phonotactic condition constitutes pressure only on the targeted element adjacent to the relevant morph: $*X\{\,\}_\alpha$ is satisfied by $XXXY\{\,\}_\alpha$ hence there is no pressure to become $YYYY\{\,\}_\alpha$.[25]

5.4.4 Discussion: Diacritics vs. representations

In Kinande, a morph's phonological properties cannot be predicted from the phonological make-up of the morph in question: the tone pattern is non-derivable. The effect of a root on the prefix tone cannot in any way be predicted from phonological properties of the root: the pattern is not optimising. Only through observation do we know that a root must cooccur with a H-toned prefix, by observing the H tone on the prefix and tracking which root the H-toned prefix happens to have occurred with: the pattern is unproductive. Despite meeting none of the criteria for an underlying representation, generativists have attempted a phonological analysis requiring abstract underlying representations and special non-iterative rules. Essentially, the traditional analysis observes the H on the prefix and then "explains" its presence and its location by positing an otherwise unmotivated underlying H on a different morpheme. This is circularity, not an explanation: the H is a diacritic masquerading as phonological motivation for the observed effect.[26]

We propose instead a lexical class α and a morpho-phonotactic condition (i.e. a condition referring to both phonological and morphological content) referring to that class. The morpho-phonotactic condition outranks the general *H type condition. This, along with representations involving H tones and L tones, accounts for the basic patterns of tone distribution in Kinande. There is of course

[25] See Kaplan (2008) on issues involving noniterativity. For additional discussion of Kinande tone in an Emergent framework, see Archangeli & Pulleyblank (2015c, submitted); for an alternative take on Kinande within a non-emergentist framework, see Jones (2014).

[26] See Hyman (2018) for an analysis of tone "displacement" in Mijikenda, for another example of this type of analysis.

much remaining to be examined for a full account of Kinande tone; see, for example, Hyman & Valinande (1985), Mutaka (1994, 2001), Jones (2014), Archangeli & Pulleyblank (submitted).

5.5 Abstract segments: Polish yers

The final issue we address in this chapter involves another three-way distinction: Slavic languages are known for having a three-way contrast among lexical items involving *yer* vowels. The yer shows a V/∅ alternation; analyses typically posit a highly abstract underlying representation for the yer since the V/∅ alternation contrasts with both non-alternating V and non-alternating CC. This leads to surface opacity of two types, (i) alternations that occur despite there being no surface trigger for the alternation (*overapplication*), and (ii) alternations that do not occur despite the presence of a trigger (*underapplication*). As we show here, under Emergence, opacity is an expected consequence of the way that conditions assess compilations of morph sets with a three-way difference along a particular dimension. Opacity, rather than motivating novel representations (Gussmann 1980, Rubach 1984, Spencer 1986, Rubach 1986, Kenstowicz & Rubach 1987, Piotrowski et al. 1992, Szpyra 1992), unnatural rule-ordering (Kiparsky 1971, 1973a, Baković 2011) or challenging the architecture of the theory itself (Anttila 1997, 2002, Jarosz 2005a, Gouskova 2012, Iwan 2015), is simply business as usual in the Emergent framework.

We illustrate our analysis of opacity with the distribution of yers in Polish (Indo-European, Slavic; glottocode poli1260).

5.5.1 The yer phenomenon

A comparison of stem-final sequences in Polish contrasts alternating roots with roots that do not alternate along the same dimension. As seen in Table 5.6a, there can be an alternation between a root-final *CεC* sequence and a root-final consonant cluster. Yet this alternation is not necessary: we also find roots that invariably end in *CεC*, Table 5.6b and roots that invariably end in a consonant cluster, Table 5.6c. Stems are indicated with square brackets in Table 5.6.[27]

The alternating yer vowel is illustrated in Table 5.6a, where stems in the NOM.SG form end with a CεC sequence, e.g. [sfεtε̲r] (where the yer is underlined),

[27] As argued in Szpyra (1992) the alternation cannot be triggered by syllable structure since all combinations of sonorants and obstruents are found with each of the three types of roots (alternating, CVC#, and CC#).

Table 5.6: Stem-final variation in Polish (Jarosz 2005b: 181)

	a. yer (alternating vowel)		b. final CVC	c. final cluster
nom.sg	[sfɛtɛr]	*[sfɛtr]	[rovɛr]	[pʲotr]
gen.sg	[sfɛtr]a	*[sfɛtɛr]a	[rovɛr]a	[pʲotr]u
instr.pl	[sfɛtr]ami	*[sfɛtɛr]ami	[rovɛr]ami	[pʲotr]ami
	‘sweater’		‘bicycle’	‘Peter’

while in both the gen.sg and the instr.pl, the stem ends with a CC sequence, e.g. [sfɛtr]a (where the stem-final CC is underlined). Forms with yers contrast with forms which invariably end with a CɛC sequence, as in [rovɛr], [rovɛr]a, *[rovr]a, Table 5.6b, as well as with those which invariably end with a consonant cluster, as in [pʲotr], [pʲotr]a, *[pʲotɛr], Table 5.6c.

Analyses of this pattern typically invoke both a representational component and a relational component. For the former, the yer must have an abstract underlying representation since, as seen, the yer contrasts both with invariant *CɛC* and with invariant *CC*. Relationally, there must be a means of expressing when the yer surfaces and when it does not; the typical analysis involves some version of Havlík’s Law, which states that yers surface when there is a following yer, but delete otherwise. Havlík’s Law is shown in Table 5.7b; an obligatory neutralisation rule, Table 5.7c, removes all yers that have not been converted to [ɛ].

Table 5.7: Schematic derivational analysis

		i. sweater-nom.sg	ii. sweater-gen.sg
a.	URs	/sfɛt(V)r + (V)/	/sfɛt(V)r + a/
b.	(V) → [ɛ] / __C$_{\varnothing}$(V)	sfɛtɛr + (V)	—
c.	(V) → ∅	sfɛtɛr	sfɛtr + a
d.	SR	[sfɛtɛr]	[sfɛtra]

In Table 5.7i, ii, the UR /sfɛt(V)r/ has a yer, depicted here by “(V)”. When a yer-containing suffix such as /(V)/ ‘nom.sg’ is attached as in Table 5.7i, the first of the two yers surfaces according to Havlík’s Law. The nom.sg, being a final suffix, can never be followed by a yer; the consequence is that it never surfaces, since it is composed solely of a yer. Similarly, when /a/ ‘gen.sg’ is attached as in Table 5.7ii, there is only one yer vowel in the word, the yer in /sfɛt(V)r/, which cannot surface since there is no following yer.

5.5.2 The Emergent analysis

Under Emergence, the analysis is concrete: morphs are constructed from material observed phonetically; there can be no "(V)" representation. Rather, the three-way contrast of Table 5.6 is represented directly, by three distinct types of morph sets, as in (33): one has two morphs differing by the presence/absence of the vowel [ɛ] (33a), while the other two have single morphs, showing no variation along this dimension (33b, c).

(33) Examples of three types of morph sets in Polish

a. $\{$sfɛtɛr, sfɛtr$\}_{\text{SWEATER}}$

b. $\{$rovɛr$\}_{\text{BICYCLE}}$

c. $\{$pʲotr$\}_{\text{PETER}}$

These morphs sets are established based on observed forms. While there is a systematic relation between the morphs in a yer set, captured with a Morph Set Relation (34), this is not a productive relation. Whether a morph set has two members can only be learned through observation. (This step is true also for frameworks which propose an abstract representation for yers, the typical solution when assuming underlying representations. However, positing an abstract representation requires an additional stage of learning – after identifying that there are two forms corresponding to the same meaning and the phonological relation between the two forms, the learner would then also devise a third, abstract, representation corresponding to the two surface variants.)

Under the Emergent framework, the learner posits morph sets with one or two morphs in them, depending on what has been observed. In the case of the polymorph sets, there is a consistent relationship between the morphs – the presence or absence of [ɛ] near the end of the morph. Systematic relationships are expressed in MSRs. MSR_{yer}, (34), captures the two consistent and generalisable phonological properties of yers, namely the quality and location of the vowel in the alternating class: the vowel [ɛ] is found between the last two stem consonants (Piotrowski et al. 1992: 30, Jarosz 2005b: 184–185).[28]

[28] Rubach (2013: 1140) notes that there is a smattering of alternating [ɔ] words, again with the vowel between the final two consonants: $[\text{kɔtɕɔł}]_{\text{NOM.SG}}$, $[\text{kɔtła}]_{\text{GEN-PL}}$ 'cauldron', $[\text{ɔɕɔł}]_{\text{NOM-SG}}$, $[\text{ɔsła}]_{\text{GEN-PL}}$ 'donkey', $[\text{kɔʑɔł}]_{\text{NOM-SG}}$, $[\text{kɔzła}]_{\text{GEN-PL}}$ 'goat'. This is not unexpected under Emergence; class membership is arbitrary and must be learned.

(34) Polish yer MSR

In a minimal morph set, there is a systematic relation between morphs with a final CɛC sequence and morphs with a final CC sequence.

example {sfɛtr, sfɛtɛr}$_{\text{SWEATER}}$
{marxɛv, marxv}$_{\text{CARROT}}$[29]

MSR$_{yer}$: $\{\mathcal{M}_i, \mathcal{M}_j\}$ $\mathcal{M}_i$: CC#
$\mathcal{M}_j$: CɛC#

The pattern is not productive because of the numerous invariant stems ending with either CC# or with CɛC#, (33b, c) respectively. Consequently, there is no related MSC.

Box 5.4: What counts towards *identity*?

In an MSR such as (34), we do not specify in the relation of ...CC# with ...CɛC# that the first C of ...CC# must correspond with the first C of ...CɛC#, and the same with the second C of both – although we do assume that such correspondence holds. That is, we do not stipulate something like:

MSR$_{yer}$: $\{\mathcal{M}_i, \mathcal{M}_j\}$ $\mathcal{M}_i$: C_pC_q#
$\mathcal{M}_j$: C_pɛC_q#

Such specification is unnecessary, though assumed, due to a combination of *The Identity Principle* (28) (Chapter 3) with our assumptions about the substance of phonological representations. *Identity* holds both of the featural make-up of segments and of properties of precedence and adjacency. A pair of morphs such as {sfɛtr, sfɛtɛr}$_{\text{SWEATER}}$ satisfies featural identity (except for the presence/absence of [ɛ]) and satisfies precedence since [t] precedes [r] in both morphs. Adjacency is not identical in both due to the presence/absence of [ɛ] and is stipulated in the MSR.

[29] The example for CARROT is from Jarosz (2005b: 185).

The above provides the Emergent analysis of the representations necessary for the yers in Polish. We turn now to determining when to use which morph: Havlík's Law is not an option because there is no abstract yer in any representation. Three contexts must be considered: the word-final context seen with the NOM.SG, where the yer is preferred, and two types of pre-suffix contexts, one which prefers the yer and the other which does not, illustrated by representative forms in Table 5.8. Again, the stem is bracketed for clarity.

Table 5.8: Vowel & no-vowel contexts in Polish

		word-final	suffix 1	suffix 2	
		NOM.SG	NOM.SG-DIM	GEN.SG	
a.	'staple'	[skɔbɛl]	[skɔbɛl]ɛk	[skɔbl]a	Rubach (2013: 1141)
b.	'sweater'	[sfɛtɛr]	[sfɛtɛr]ɛk	[sfɛtr]a	Jarosz (2005b: 186)

Inspection of the forms in Table 5.8 reveals that the [ɛ]-form surfaces when the morph is word-final (*word-final* column). Before suffixes, the choice of root forms is phonologically arbitrary, simply depending on the suffix which is added. Table 5.8 illustrates this with two vowel-initial suffixes, where type 1 requires the *...CɛC* form of the root (*suffix 1* column) and type 2 requires the *...CC* form (*suffix 2* column). Were the phonological shape of the suffixes to drive the selection between morphs, we would expect the same result with both types of suffixes, yet they differ. We take the general pattern to be the *...CɛC* pattern, derived by the condition *CC, a prohibition on consonant clusters.[30] Since CC clusters abound within morphs, this can only be a prohibition at the word domain.

(35) Polish CC condition
*CC, $\mathcal{F}$: segments, $\mathcal{D}$: word
With a focus on segments, assign a violation to a word for each sequence of two consonants.

Despite the preference to avoid CC clusters, certain suffixes like $\{a\}_{\text{GEN.SG}}$ or $\{ami\}_{\text{INSTR.PL}}$ require the CC-final form – $[\text{sfɛtra}]_{\text{SWEATER-GEN.SG}}$, *[sfɛtɛra]. We propose that this class of suffixes avoids a particular phonological shape in the sequence immediately preceding the suffix, namely a preceding VC sequence, with

[30] Whether the *...CC* pattern or the *...CɛC* pattern is generally preferred shapes the nature of the analysis. Taking the *...CC* pattern as the more general pattern would require a prohibition on open syllables to penalise, e.g., *[skɔbɛla] and *[sfɛtɛra]. We present only the *CC analysis here.

the result that the otherwise nonoptimal CC sequence results. There is no way to predict whether or not a suffix imposes the *VC{...}$_{\alpha}$ condition: this condition is imposed by a lexically arbitrary class, hence reference to this arbitrary "α-class" must be built into the condition. As with the CC condition, it holds at the word domain since it requires a combination of morphs to meet its conditions.

(36) Polish VC condition
*VC{...}$_{\alpha}$, $\mathcal{F}$: segments, $\mathcal{D}$: word
With a focus on segments, assign a violation to a word for each VC sequence preceding a member of the α class.

Selection of relevant forms is illustrated by assessments. In (37), the NOM.SG is a null affix; there are only two compilations and *CC is the deciding factor. For comparison, (38) shows the assessment for {pʲotr}$_{\text{PETER.NOM.SG}}$: since this is a root with a single form, there is only one compilation to consider hence no competition for selection.

(37) Assessment for [sfɛtɛr]$_{\text{SWEATER-NOM.SG}}$
morph sets: {sfɛtɛr, sfɛtr}$_{\text{SWEATER}}$; {∅}$_{\text{NOM.SG}}$

SWEATER-NOM.SG	*VC{...}$_{\alpha}$	*CC
☞ a. sfɛtɛr		*
b. sfɛtr		**!

(38) Assessment for [pʲotr]$_{\text{PETER-NOM.SG}}$
morph sets: {pʲotr}$_{\text{PETER}}$; {∅}$_{\text{NOM.SG}}$

PETER-NOM.SG	*VC{...}$_{\alpha}$	*CC
☞ a. pʲotr		*

The assessments in (39) and (40) illustrate the effect of adding an α-class suffix. In the case of {sfɛtɛr, sfɛtr}$_{\text{SWEATER}}$, there is a CC-final option ({sfɛtr}); [sfɛtr-a] is selected over [sfɛtɛr-a].

(39) Assessment for [sfɛtɛra]$_{\text{SWEATER-GEN.SG}}$
morph sets: {sfɛtɛr, sfɛtr}$_{\text{SWEATER}}$; {a}$_{\text{GEN.SG}, \alpha}$

SWEATER-GEN.SG$_{\alpha}$	*VC{...}$_{\alpha}$	*CC
a. sfɛtɛr-a$_{\alpha}$	*!	*
☞ b. sfɛtr-a$_{\alpha}$		**

With a single-morph set, like {rovɛr}$_{\text{BICYCLE}}$ in (40), there is only one compilation so there is no competition; [rovɛra] is selected despite the *VC{...}$_{\alpha}$ violation.

(40) Assessment for [rovɛra]$_{\text{BICYCLE-GEN.SG}}$
morph sets: {rovɛr}$_{\text{BICYCLE}}$; {a}$_{\text{GEN.SG}, \alpha}$

BICYCLE-GEN.SG$_{\alpha}$	*VC{...}$_{\alpha}$	*CC
☞ a. rovɛr-a$_{\alpha}$	*	

5.5.3 Stacking up alternating suffixes

A striking property of the Polish pattern is that it is possible to concatenate sequences of morph sets containing multiple alternating vowels, illustrated in (41). As established in Table 5.8 and repeated in (41a), [skɔbɛl]$_{\text{STAPLE}}$ patterns like [sfɛtɛr]$_{\text{SWEATER}}$, having a final CɛC with NOM.SG but a final CC-cluster with GEN.SG. When the diminutive suffix is added in (41b), we see a V/∅ alternation in the diminutive suffix itself, {ɛk, k, ɛʧ, ʧ}$_{\text{DIM}}$, depending on the following suffix, as well as in the noun stem. Polish also has a double diminutive construction, shown in (41c).

(41) Multiple alternating vowels (data from Rubach 2013: 1141)

		MASC.NOM.SG	GEN.SG
a.	'staple'	skɔbɛl	skɔbla
b.	'staple-DIM'	skɔbɛlɛk	skɔbɛlka
c.	double DIM	skɔbɛlɛʧɛk	skɔbɛlɛʧka

Since the diminutive attaches to [skɔbɛl] and not [skɔbl], we conclude that it does not belong to class α. Adding the morph set {ɛk, k, ɛʧ, ʧ}$_{\text{DIM}}$ is all that is needed to account for the patterns seen in (41), shown by the assessments in (42) and (43).

(42) Assessment for [skɔbɛlɛk]$_{\text{STAPLE-DIM-NOM.SG}}$
morph sets: {skɔbɛl, skɔbl}$_{\text{STAPLE}}$; {ɛk, k, ɛʧ, ʧ}$_{\text{DIM}}$; {∅}$_{\text{NOM.SG}}$

STAPLE-DIM-NOM.SG	*VC{...}$_{\alpha}$	*CC
☞ a. skɔbɛl-ɛk		*
b. skɔbɛl-k		**!
c. skɔbl-ɛk		**!
d. skɔbl-k		**!*

In (42), the *CC phonotactic makes the crucial determination, while (43) relies on $^*\mathrm{VC}\{...\}_\alpha$ to eliminate combinations where the suffix $\{a\}_{\text{GEN.SG},\,\alpha}$ follows a VC sequence.[31]

(43) Assessment for $[\text{skɔbɛlka}]_{\text{STAPLE-DIM-GEN.SG}}$
morph sets: $\{\text{skɔbɛl, skɔbl}\}_{\text{STAPLE}}$; $\{\text{ɛk, k, ɛʧ, ʧ}\}_{\text{DIM}}$; $\{\text{a}\}_{\text{GEN.SG},\,\alpha}$

STAPLE-DIM-GEN.SG$_\alpha$			$^*\mathrm{VC}\{...\}_\alpha$	*CC
	a.	skɔbɛl-ɛk-a$_\alpha$	*!	*
☞	b.	skɔbɛl-k-a$_\alpha$		**
	c.	skɔbl-ɛk-a$_\alpha$	*!	**
	d.	skɔbl-k-a$_\alpha$		***!

When two diminutive suffixes are added, again the phonotactic *CC is the deciding factor when there are no α-class suffixes to make the selection, shown in (44). (See footnote 31 on the simplified morph compilations in (44), (45).)

(44) Assessment for $[\text{skɔbɛlɛʧɛk}]_{\text{STAPLE-DIM-DIM-NOM.SG}}$
morph sets: $\{\text{skɔbɛl, skɔbl}\}_{\text{STAPLE}}$; $\{\text{ɛk, k, ɛʧ, ʧ}\}_{\text{DIM}}$; $\{\varnothing\}_{\text{NOM.SG}}$

STAPLE-DIM-DIM-NOM.SG			$^*\mathrm{VC}\{...\}_\alpha$	*CC
☞	a.	skɔbɛl-ɛʧ-ɛk		*
	b.	skɔbɛl-ɛʧ-k		**!
	c.	skɔbɛl-ʧ-ɛk		**!
	d.	skɔbɛl-ʧ-k		**!*
	e.	skɔbl-ɛʧ-ɛk		**!
	f.	skɔbl-ɛʧ-k		**!*
	g.	skɔbl-ʧ-ɛk		**!*
	h.	skɔbl-ʧ-k		**!**

With a morph compilation involving a class α suffix, such as $\{a\}_{\text{GEN.SG},\,\alpha}$, the condition $^*\mathrm{VC}\{...\}_\alpha$ prevents the immediately preceding suffix from surfacing

[31] The distribution of palatal consonants in Polish reveals intriguing alternations, including those that give rise to the four morphs in the DIM morph set. We do not explore the puzzle of Polish palatalisation here; those facts suggest, among other things, that there may be two distinct diminutive suffixes, differing by their interaction with palatalisation. See Łubowicz (2016) and Czaplicki (2014) for discussion of palatalisation and Polish diminutives; see Manova & Winternitz (2011) for discussion of multiple diminutives. See also Mihajlović (2020) for an Emergent analysis of palatalisation in Bosnian/Croatian/Serbian. In assessments, we simplify the surface possibilities by including only those forms that have the appropriate morphs in terms of palatalisation, leaving for future work the conditions which select among the different consonantal possibilities.

with a vowel, here the rightmost of the two diminutive suffixes. That is, ...CC-{a}$_{\alpha}$ is preferred to ...VC-{a}$_{\alpha}$. The form in (45b) is therefore selected, with a CC cluster only before the suffix {a}$_{\text{GEN.SG},\ \alpha}$.

(45) Assessment for [skɔbɛlɛʧka]$_{\text{STAPLE-DIM-DIM-GEN.SG}}$
morph sets: {skɔbɛl, skɔbl}$_{\text{STAPLE}}$; {ɛk, k, ɛʧ, ʧ}$_{\text{DIM}}$; {a}$_{\text{GEN.SG},\ \alpha}$

STAPLE-DIM-DIM-GEN.SG$_{\alpha}$			*VC{...}$_{\alpha}$	*CC
	a.	skɔbɛl-ɛʧ-ɛk-a$_{\alpha}$	*!	*
☞	b.	skɔbɛl-ɛʧ-k-a$_{\alpha}$		**
	c.	skɔbɛl-ʧ-ɛk-a$_{\alpha}$	*!	**
	d.	skɔbɛl-ʧ-k-a$_{\alpha}$		***!
	e.	skɔbl-ɛʧ-ɛk-a$_{\alpha}$	*!	**
	f.	skɔbl-ɛʧ-k-a$_{\alpha}$		***!
	g.	skɔbl-ʧ-ɛk-a$_{\alpha}$	*!	***
	h.	skɔbl-ʧ-k-a$_{\alpha}$		***!*

5.5.4 The position and quality of yers

Under the Emergent account, the morph set representations directly correspond to the surface forms: the alternating effect is represented by morph sets with multiple members, e.g. {sfɛtɛr, sfɛtr}$_{\text{SWEATER}}$ while the lack of alternation is represented by morph sets with single members, {rovɛr}$_{\text{BICYCLE}}$, {p^{j}otr}$_{\text{PETER}}$. There are no abstract representations of the Slavic yer. Selection of the appropriate morph is achieved by a general prohibition on CC sequences mediated by a prohibition on a preceding VC sequence before certain suffixes.

One consequence of this analysis is that it explains both the location and the quality of the yer vowels, issues raised in Jarosz (2005b):

> "All word-final yer vocalization follows the template XCC-Y ~ XCɛC-∅, where Y is any overt inflection, and X, any vowel or consonant....In contrast, alternations of the type CCC-Y ~ CɛCC-∅, where a yer vocalizes between the first and second consonant of the triple, are conspicuously absent." Jarosz (2005b: 184–5)

Given the Emergent analysis, these patterns are explained. Formally, the vowel quality and the location are encoded in the Morph Set Relation (34). Analytically, if a morph set were posited with the alternating vowel in a different location, e.g. {...CɛCC, ...CCC}, the final CCC would never surface: in the special environment where class-α morphs avoid a preceding VC, both morphs would be equivalent with respect to the *VC{...}$_{\alpha}$ well-formedness condition since neither ends in a VC; the choice between the two would default to *CC which would select ...CεCC (one violation) over ...CCC (two violations). In contexts where the class-α condition is not relevant, the ...CεCC morph would continue to incur fewer violations than the ...CCC morph. In other words, the ...CCC morph would never be chosen. The result is that only morph pairs differing by ...CC vs. ...CεC at the right edge could result in different surface forms. Functionally, this analysis ensures that the relevant suffixes avoid sequences of light open syllables, satisfying *VC{...}$_{\alpha}$.

Box 5.5: Syllables

Throughout this work, we have been deliberately agnostic as to the necessity for syllables as a constituent, how they might be structured and how they might be acquired. We note in this regard though that both phonetic and distributional cues may lead to such a constituent (Maddieson 1985, Turk 1994); the acquisition literature shows that patterns of learning support acquisition of such a constituent (Carter 1999, Carter & Gerken 2004); further, as pointed out in van de Weijer (2012), the tip-of-the-tongue phenomenon suggests some concept of "syllable" in mental representations.

If syllables are indeed motivated, it remains to be seen whether the *syllable* is best characterised in terms of the distribution of phonetic cues or by a more abstract construct; we are noncommittal at this point in our research. As a simplifying move, we have therefore omitted morph set members that might be distinguished by syllabically correlated phonetic cues. For example, we use {CVC}, not making a distinction between {CVC, CV.C}, even when there is evidence that the final consonant is syllabified as a coda in some words (CVC) and as an onset in others (CV.C).

5.5.5 Discussion: Opacity

The crux of the Polish case is that while there are two phonological shapes in play (CεC#, CC#), there are three lexical classes (alternating final CεC/CC, non-alternating final CεC, non-alternating final CC). This three-way contrast leads to the issue of opacity, a phenomenon that raises analytic challenges unique to the underlying representation hypothesis. Two types of opacity, overapplication opacity and underapplication opacity, can be identified (Kager 1999, McCarthy 1999, Idsardi 2000).[32]

(46) Opacity

"An opaque generalization is a generalization that does crucial work in the analysis, but which does not hold of the output form." (Idsardi 2000: 338)

	type	*environment*	*generalisation*
a.	overapplication	not surface-apparent	holds anyway
b.	underapplication	surface-apparent	does not always hold

Overapplication opacity is relevant for Polish because there is no surface-apparent context triggering the appearance of the yers, yet in some contexts the yer surfaces.

We also see cases of underapplication opacity: even if a context were clear for the appearance of the yer, there are both vowels that always surface, even where the yer does not (compare [rovɛra] 'bicycle-gen.sg' and [sfɛtra] 'sweater-gen.sg'), and there are final CC sequences that are never interrupted by a vowel, in contrast to where the yer surfaces (compare [p^jotr] 'Peter-nom.sg' and [sfɛtɛr] 'sweater-nom.sg').

Opacity in general presents a challenge to both rule-based and constraint-based frameworks: rules that insert vowels should apply in forms like /p^jotr/, yet do not; at the same time, rules that delete vowels should apply in /rovɛr-a/, yet do not. Optimality Theory is challenged by opacity as well due to the role of Gen: constraints that eliminate *[sfɛtɛra] in favour of [sfɛtra] would erroneously eliminate [rovɛra] in favour of *[rovra]; constraints that eliminate *[sfɛtr] in favour of [sfɛtɛr] would erroneously eliminate [p^jotr] in favour of *[p^jotɛr].

The concrete Emergent analysis contrasts sharply with the abstraction forced by unique underlying representations: under the assumption of unique underlying representations, Polish yers rely on a vowel with an abstract representation (to distinguish it from other vowels, including /ɛ/, which do not alternate with ∅). Due to the reliance on Havlík's Law, the nom.sg is represented underlyingly as a yer despite the fact that there is no surface reflex of this suffix. Exactly how a specific analysis plays out varies. Derivational proposals include analyses relying on

[32] For more on opacity, see Kiparsky (1971, 1973a, 1979, 2000), McCarthy (1996), Baković (2011), among others.

abstract vowels with absolute neutralisation (Gussmann 1980, Rubach 1984), featureless skeletal slots (Spencer 1986), floating features (Rubach 1986, Kenstowicz & Rubach 1987), epenthesis (Czaykowska-Higgins 1988, after unpublished work by Alicja Gorecka),[33] lexical syllabic consonants (Piotrowski et al. 1992), and underspecification (Szpyra 1992). Optimality theoretic analyses also propose abstract vowels (Yearley 1995); additionally, such analyses involve partial ordering (Jarosz 2005a; see also Anttila 1997, 2002 on partial ordering), morpheme exceptionality (Gouskova 2012), and intermediate levels of representation (Iwan 2015). These accounts involve segments that do not surface in the language and so require absolute neutralisation; such representational approaches are not available – or necessary – under EG.[34]

To conclude, at least in Polish, opacity – whether of underapplication or of overapplication – is a non-issue under Emergence. There is no call for abstract segments, special orderings, more complex formal systems, etc. The apparent opacity effect arises due to the presence of MSR_{yer} and the absence of a corresponding MSC: this results in a three-way distinction in Polish morph sets, (i) those which always end with a CC, (ii) those which always end with a CεC, and (iii) those with two morphs, one ending with CC and the other ending with CεC; choices among morph compilation members are adjudicated by two conditions, $*VC\{...\}_\alpha$ and *CC.

5.6 Conclusion: Dispensing with abstract representations

The examples in this chapter all share the property of seemingly "requiring" abstract underlying representations; we have provided analyses using concrete representations in accordance with Emergence. Derivable, productive, and optimisable, the three criteria (defined in Chapter 4, (2)) that are often taken as indicative of underlying representations, are expressed under Emergence without appeal to that mechanism. Additionally, in our examples in this chapter, we see cases where a phonological pattern is not derivable, not productive, and/or not optimisable, summarised in Table 5.9.

[33] An advantage of epenthesis would be that there is no need for the abstract vowels, and syllabification places the epenthetic vowel in exactly the right position; Szpyra (1992) argues strongly against epenthesis.

[34] There are a small number of alternative assumptions about yers, for example, Jarosz (2005a), Gouskova (2012). There are also prefixes/proclitics which have been argued to contain yers; Pajak & Baković (2010) argue that there is no yer in these forms. Our analysis, as shown in this section, is that some morph sets have one member; others have two members, and well-formedness conditions assess morph compilations appropriately.

Table 5.9: Summary of examples

Language	Phenomenon	Derivable	Productive	Optimisable
a. Warembori	stop/fricative	yes	yes	yes
b. English	nasal place assimilation	possible	no	yes
c. Mayak	3 low V suffix types	possible	no	yes
d. Kinande	“tone shift”	possible	no	no
e. Polish	yers	yes	no	no

Whether a relation is derivable is expressed in Emergence by whether or not there is evidence for a Morph Set Relation. In Warembori, the pattern is pervasive, and in Polish, the alternation is seen in about a third of the possible cases; there is sufficient reason for a learner to posit MSRs in both these cases. For the other three languages, the alternations are observed in a limited number of affixes; once the alternants have been observed, there may be no further generalisation so there is no need for an MSR. However, a learner might posit a relation with very limited use, hence “possible” in the *derivable* column in Table 5.9; no significant generalisation is missed if there is no relevant MSR in these cases nor is communication impacted.

Productivity, characterised by an MSC, is found only in Warembori; in the other four languages, whether or not a morph set exhibits an alternation is learned on a case-by-case basis. Finally, in three of the languages, the distribution of morphs is optimisable, characterised by phonological conditions. In the other two languages, Kinande and Polish, the distribution of morphs is not optimisable. In Kinande, the appearance of a H tone on a prefix is made based on conditions that refer to an arbitrary lexical class rather than to phonological properties. In Polish, while a CɛC sequence is preferred phonologically to a CC sequence, the occurrence of a CC sequence in cases of alternation occurs only when required by a class that is lexically arbitrary.[35]

To analyse each of these cases in terms of single underlying representations requires the introduction of otherwise-unmotivated representations, changes to the theory of relations among representations, or both. In contrast, an analysis in Emergent theoretic terms requires three independently motivated mechanisms, the Morph Set Relation (MSR), the Morph Set Condition (MSC), and word-domain well-formedness conditions. Each of these devices serves to characterise

[35] A very interesting analysis of Irish initial consonant mutation, McCullough (2020, 2021), provides an example of a derivable and productive pattern that is not optimisable.

observations about surface forms in the language; together, they represent the alternations found under morphological concatenation.

These cases collectively demonstrate that underlying representations have been posited in cases where the three criteria are not simultaneously satisfied, despite these being the criteria used to motivate underlying representations. But the examples go further: in each case, we provide explanatory analyses under Emergence, with surface-based representations, not unique underlying representations, solving long-standing challenges like ternarity, abstractness, and opacity without additional mechanisms. Representations are concrete, phonotactics express general properties, and morpho-phonotactics pinpoint exactly where subpatterns occur. The formal mechanisms used are Morph Set Relations, to codify differences among members of a morph set, Morph Set Conditions, to codify the productivity of an MSR, and word-domain well-formedness conditions, to select among competing compilations.

6 Conclusion

The starting point for our exploration in this monograph was the Emergent Grammar Hypothesis, that there are no – or minimal – innate language-specific principles driving the shape of the adult morphophonological grammar.

(1) The Emergent Grammar Hypothesis (Repeated from box 1.1 on p. 2)
General human cognition provides much, if not all, of the necessary scaffolding for the acquisition of morphophonology, allowing construction of a phonological grammar of the ambient language.

As outlined in Chapter 1, Emergence assumes that the critical elements for acquiring a phonology are aspects of cognition that humans use in their general interactions with the world, not simply with respect to language – attention, memory, similarity, sequential processing, frequency, categories, generalising (including generalising over generalisations), and identity. Chapter 2 provided an extensive example from Yangben of how these general principles of cognition might result in the language learner acquiring categories like "segment", "feature", "morph", and "word". In examining phonological patterns from this perspective, as is done in Chapter 3, we proposed two general mechanisms for representing phonological patterns – morph sets and well-formedness conditions. We summarise the role of each, repeating figures from Chapter 3 for convenience.

Systematicity within minimal morph sets is expressed with *Morph Set Relations* (MSRs) and *Morph Set Conditions* (MSCs). MSRs encode systematic relations between morphs in minimal morph sets, while MSCs, which govern when a minimal morph set is well-formed, result in the productive expansion of morph sets.

(2) Morph Set Relation (Chapter 3, (31))
In a minimal morph set, there is a systematic relation between morphs with α (subject to $\mathcal{C}_m$) and morphs with β (subject to $\mathcal{C}_n$).
MSR: $\{\mathcal{M}_i, \mathcal{M}_j\}$ $\mathcal{M}_i$: α ($\wedge\, \mathcal{C}_m$)
$\mathcal{M}_j$: β ($\wedge\, \mathcal{C}_n$)

(3) Morph Set Conditions (Chapter 3, (34))

a. With respect to MSR_γ, a minimal morph set is ill-formed if there is an $\mathcal{M}_i$ and there is no corresponding $\mathcal{M}_j$.

MSC_γ: For $\mathcal{M}_i$, $\mathcal{M}_j$ of MSR_γ, $*\{\mathcal{M}_i, \neg\mathcal{M}_j\}$

b. With respect to MSR_γ, a minimal morph set is ill-formed if there is an $\mathcal{M}_j$ and there is no corresponding $\mathcal{M}_i$.

MSC_γ: For $\mathcal{M}_i$, $\mathcal{M}_j$ of MSR_γ, $*\{\neg\mathcal{M}_i, \mathcal{M}_j\}$

Well-formedness is characterised by three classes of conditions, *type* conditions, *syntagmatic* conditions, and *paradigmatic* conditions. Where observed properties occur with varying frequencies, type conditions penalise the infrequent properties.

(4) Type condition schema (Chapter 3, (14))

*[X] Assign a violation to a form for each [X], where [X] may be either morphological or phonological.

Syntagmatic conditions, conditions governing sequences of properties, characterise unattested/underattested sequential patterns of occurrence.

(5) Syntagmatic schema (Chapter 3, (15))

*[X][Y] Assign a violation to a form for each sequence of [X] followed by [Y], where [X], [Y] may be either morphological or phonological.

Finally, asymmetries in the cooccurrence of observed properties motivate paradigmatic conditions.

(6) Paradigmatic schema (Chapter 3, (16))

$*\begin{bmatrix} X \\ Y \end{bmatrix}$ Assign a violation to a form for each combination of [X] and [Y], where [X], [Y] may be either morphological or phonological.

These mechanisms are a formal means of representing the logical result of acquiring a phonological grammar under Emergence; they are not additional language-specific innate cognitive mechanisms.

A further logical result, examined in Chapter 4 and tested against complex patterns in five languages in Chapter 5, is that there is no motivation or evidence for unique underlying forms/inputs, despite what is assumed in most phonological theories. We found no evidence for the kind of abstract "underlying" representations that are commonly assumed, finding instead that such underlying forms introduce analytic difficulties and raise significant conceptual challenges.

It is from observed surface variety that structuralist frameworks, traditional generative phonology and Optimality Theory construct *underlying forms* and from which Emergent Phonology constructs *morph sets*. An argument for a unique underlying form might be that it provides an account of the systematicity in the relations observed between multiple surface forms. This argument, however, proves to be illusory. While accounting for the observed systematicity is important, we have shown that the systematicity can be expressed through a network of surface-based relations (Morph Set Relations and Morph Set Conditions) and phonological and morpho-phonological well-formedness conditions.

In concluding this work, we highlight briefly a number of additional implications of Emergence for phonological systems, broadly construed. In some cases, the implications seem consistent with the predictions of Emergence while in others they may pose challenges.

6.1 Phonological phenomena

The examples discussed in this monograph merely skim the surface of the rich and diverse patterns of sounds in the world's languages. These patterns have led researchers to posit constructs such as directional spread, iterative and non-iterative application, radical underspecification, and a stratal organisation for the lexicon, targeting phenomena such as complex harmony patterns, disharmony, chain shifts, and so on. Here we sketch briefly how Emergence might approach some of these phenomena.

6.1.1 Directionality

Numerous phonological patterns exhibit apparent directional effects where it seems on the surface to make a difference whether the "target" of some process is to the left or right of the process's trigger. Many cases of this type have been discussed. In some cases, only targets on one side of a trigger are affected (for example, in Fula (Paradis 1992, Archangeli & Pulleyblank 1994; see Archangeli & Pulleyblank forthcoming for an Emergent account) mid vowels to the left of a high vowel are advanced while those to the right are unaffected), in some cases targets on both sides of a trigger are affected (e.g. bidirectional harmony in Akan, Clements 1985), while in other cases potential targets are treated differently on one side or the other of a trigger (e.g., in Maasai, a low vowel to the left of a trigger blocks harmony while a low vowel to the right undergoes harmony, shifting to a mid vowel, Levergood 1984).

To a certain extent, the directionality issue in an Emergent framework is comparable to much work in Optimality Theory. If the source of harmony is an intrinsically nondirectional syntagmatic condition, as assumed here, then all directional effects should be derivative (Baković 2000). Unlike a contextually unconditioned "Agree" constraint though, directional effects can be achieved by syntagmatic conditions or by regularities within morph sets. For example, a condition prohibiting mid retracted vowels before high vowels will cause mid vowels to be advanced before a high vowel in Fula ([ɓet-ir-dɛ] 'to weigh'), but not after a high vowel (*[ɓet-ir-de]) (Paradis 1992: 87). In addition, it is possible that certain morph sets and not others exhibit related pairs of morphs. We have seen idiosyncratic differences in our discussion of Mayak (§5.3) but it is also possible to see systematic differences. For example, if all suffixes had harmonic pairs in their morph sets whereas prefixes were systematically singletons, then harmony would apply to suffixes but not to prefixes. Warlpiri (Nash 1980, Simpson 1983) is a particularly interesting test case since nouns and verbs appear to motivate quite different patterns of harmony. In Archangeli & Pulleyblank (in preparation), we show that these differences can be derived by having the same phonotactics governing both nouns and verbs, but with different Morph Set Relations for the two categories.

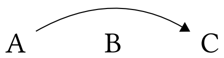
6.1.2 Noniterativity

We have argued in §5.4 that the standard "noniterative spread" analysis of Kinande High tones is better seen as a type of morphologically induced "selection": a lexically arbitrary class of morphs requires a preceding morph that ends on a High tone. Not all cases of apparent noniterativity involve such blatant morphological conditioning, however. In Lango (Woock & Noonan 1979, Noonan 1992), for example, apparent noniterative tongue root harmony is triggered by a vowel bearing the harmonic value: [bɔ̀ŋó-wú] 'your dress' vs. [bɔ̀ŋɔ́] 'dress' (Woock & Noonan 1979: 22), with the appropriate morph selected from the morph set {bɔ̀ŋɔ́, bɔ̀ŋó}$_{\text{DRESS}}$. Consistent with Kaplan (2008), we consider that such cases of apparent noniterativity require something other than a simple harmony phonotactic. Our working hypothesis is that apparent noniterative patterns result either from limited options in the relevant morph sets (for example, Lango might systematically have morph sets like {bɔ̀ŋɔ́, bɔ̀ŋó}, not {bɔ̀ŋɔ́, bòŋó}), or there might be a morphological condition on the phonotactic such that harmony would only be enforced at a morph boundary.

6.1.3 Saltation and chain shifts

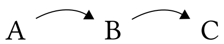
Two recurrent problems for ranked constraint-based systems are saltation (Hayes & White 2015) and chain shifts (Kirchner 1996). The problem appears to be similar for both patterns. With saltation, we see cases where instances of A alternate with C, but where an intermediate category B does not alternate, (7). If C is "better" than A by some constraint hierarchy, then C should be better than B as well, so both /A/ and /B/ should be realised as [C]. For example, in German, spirantisation of voiced velars (Ito & Mester 2003) results in voiced [g] alternating with voiceless [x] or [ç] while voiceless [k] does not alternate.

(7) Saltation



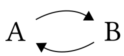
In chain shifts, we can distinguish between two types of cases. In the first, the situation is very similar to that seen for saltation, except that A shifts to B and B shifts to C. (The English "Great Vowel Shift" (Chomsky & Halle 1968) is an instance of a chain shift.)

(8) Chain shifts 1



In an extreme case, the chain can bite its tail, so to speak, creating a circle. C could shift to A in (8), or, in a circle involving only A and B, A shifts to B and B shifts to A. Such chains raise two problems: in (8), if C is "better" than B, then why would A shift to B and not continue to C? In (9), if B is "better" than A along some dimension – motivating the shift from A to B – then how do we motivate a shift from B to A? (A classic case is the Taiwanese tone circle; for an Emergent analysis see Archangeli & Pulleyblank 2016.)

(9) Chain shifts 2



In the Emergent framework that we have sketched here, these cases require analyses that are quite different from either rule-based analyses or optimising constraint-based analyses. For saltation (7), since A alternates with C, there must be a morph set {A, C}. Conversely, since B does not alternate, it is in a singleton morph set, {B}. There is no inherent contradiction in having morph sets containing {A, C} – productively related by a Morph Set Condition – and also having morph sets containing {B}. Phonological optimisation is the domain of a different component, namely the well-formedness conditions. We may choose {C} in some context due to phonological optimisation, and yet, with another morph set, choose {B} in that same context simply because B has no counterpart that would be "better" along the scale in question. The situation is similar for the sequential chain shift in (8): morph sets contain either {A, B} or {B, C}; no morph set contains *{A, B, C}. Optimisation does the best that it can, choosing C over B in one case and B over A in the other, depending on the context and the conditions governing it.

On the other hand, the circular chain shifts involve morph sets containing both A and B, {A, B}. Again, the domain of operation of MSRs and MSCs is to create morph sets of a particular structure, in this case {A, B} morph sets. However, in this instance, where set $\{A, B\}_\alpha$ has A, morph set $\{A, B\}_\beta$ has B, and vice versa. Selection cannot be purely phonological with circular chain shifts: the prediction is that these patterns must involve some morphotactic or syntactic element to characterise the pattern followed by each morph set (as is indeed the case in the classic Taiwanese case, for example).

6.1.4 Opacity

Finally, a different kind of challenge occurs in certain cases of opacity (McCarthy 1999, 2007, Idsardi 2000), already touched on in §5.5. To recall, opacity refers to an analysis where some critical element for the analysis is not observed at the surface. For example, Standard Yorùbá exhibits a robust pattern of tongue root harmony (Bamgboṣe 1967, Awobuluyi 1967, Archangeli & Pulleyblank 1989). Mid vowels within native vocabulary consistently show the same tongue root position as a following nonhigh vowel: [ēkpō] 'oil', [ɔ̄bɛ̀] 'soup', *[eCɛ], *[oCa], etc. (Archangeli & Pulleyblank 1989: 177). Derived mid-mid sequences, however, do not invariably harmonise. For example, when we see [r]-deletion and the resulting application of adjacent vowel assimilation, the results can be disharmonic: [ērùkpɛ̀] ~ [ēèkpɛ̀] 'earth', *[ɛ̄ɛ̀kpɛ̀] (Archangeli & Pulleyblank 1989: 187). Just as in the saltation and chain shift cases, the answer in an Emergent framework lies in the distinction between regularities within morph sets and the optimisation determined by phonotactic well-formedness conditions (rather than in a set of ordered rules perhaps recapitulating the historical development of the pattern, the standard analysis of the Polish yers discussed in §5.5). In the Standard Yorùbá example, complexities in the formulation of the MSR with and without the encoding of harmony lead to the simplest MSR being one that derives [ēèkpɛ̀], and not *[ɛ̄ɛ̀kpɛ̀] (see Archangeli & Pulleyblank 2015d for discussion). The result violates the harmony phonotactic, but the phonotactics do not directly drive patterns of alternation.

6.1.5 Summary

There are numerous other sorts of cases to be considered where an Emergent framework either provides a different way of viewing phenomena or forces an analysis to move in a particular direction. Such cases routinely involve underspecified lexical entries in harmony systems, long-distance effects in consonant harmony, and so on. Phonological interactions with other modules of grammar, such as morphology, are by their nature quite different from standard approaches. See, for example, Kwak (2020) on a preliminary Emergent alternative to level-ordering in Tsilhqot'in.

A recurring theme in our brief discussion of extensions of Emergence is the separation of responsibility between MSRs, MSCs, and well-formedness conditions. MSRs characterise relationships within morph sets and MSCs ensure productivity of these relationships, while well-formedness conditions penalise ill-formed morphs and morph compilations. Despite their formal simplicity, interactions among these components are consistent with the diverse patterns observed in natural language.

6.2 Prosody

There is a range of prosodic phenomena that have not been discussed at all in this work, phenomena including the encoding of length, determining whether and how to include syllables, how to represent templatic phenomena, reduplication, and so on. The challenge in considering such phenomena is to determine both whether the sorts of structures that have been proposed are required in an Emergent framework and if so, how to derive them. It is important to consider two different types of properties. Some properties are "concrete", in the sense that they are directly encoded phonetically. For example, long vowels and consonants, tone, the actual manifestation of stress and intonation are present in the phonetic string encountered by a learner. In contrast, constituency – syllables, feet, prosodic words, etc. – are not directly encoded, but are postulated to explain a variety of patterns that are directly encoded: we don't "hear" syllables or feet, but such constituents appear to determine whether a reduplicative form is well-formed or not, whether a consonant is released or not, flapped, voiced, and so on – properties that are directly observable.

6.2.1 Syllables

Consider syllable structure, which we carefully set aside in box 5.5 on p. 132. We know that segments may be realised very differently in "onset" and "coda" positions. Consider two tendencies identified in Gick et al. (2006: 69): "(1) postvocalic liquids always have a measurable dorsal constriction; (2) patterns of gestural timing and magnitude in liquids are almost always different (asymmetrical) in pre- vs. postvocalic positions". We could imagine a relatively abstract approach to such phenomena (Kahn 1980, Clements & Keyser 1983, Levin 1985; etc.) where phonological representations abstract away from the phonetic details, building representations that include syllable constituents that condition the phonetic realisation of such segments. The alternative is to build the phonetically different segments into our phonological representations, representing "syllabically different" segments in morph sets, establishing MSRs to relate them, and so on. This approach would relate more directly to work such as that of Steriade (1999). We might assume, for example, that liaison in French involves morph sets pairing a form without a consonant., e.g. {tʁo} 'too much' with a form where the final consonant is marked as being obligatorily pre-vocalic, {tʁop^{V}}. Syllabic structure involves a large number of interacting issues and patterns and we will not begin to address them here, noting only that the Emergent hypothesis might lead one to explore those hypotheses that have depended on encoding more segmental properties than constituency-based properties.

But does this mean that Emergence leads us away from constituency? What about templatic morphology, minimal word considerations, reduplication, and so on? What about the role of constituency in patterns of rhythmic prominence?

6.2.2 Stress, etc.

There has been a great deal of attention in the literature on stress about whether constituency should factor into phonological analyses, for example, Prince (1983) for a grid-only approach, versus Halle & Vergnaud (1987) and Hayes (1995) for approaches incorporating constituency. Of particular importance, from the Emergentist perspective is work such as that incorporating the iambic-trochaic law (Hayes 1985, Yiu 2018). As Hayes points out, research in experimental psychology motivates trochaic groupings based on intensity and iambic groupings based on duration. Similar evidence can be found in music. So while it seems relatively uncontroversial that constituency plays a role in phonology, it seems much less clear that such constituency is specifically linguistic. This issue deserves much closer attention paid to it than we can do in these closing remarks. To be more comprehensive, an Emergent framework must address these issues of constituency in stress systems, in syllable structure and then in a wide array of templatic patterns, including reduplication. We will not engage in that discussion here but see this as an area ripe for future research.

6.3 Beyond adult phonology

Emergence has implications for a wide range of phonological phenomena, beyond characterising adult grammars. For example, the discussion of language acquisition in this monograph, particularly in Chapters 2 and 3, is highly speculative, based on our understanding of the acquisition literature and on the logic of the Emergent hypothesis. In this section, we touch on implications for a few such areas – language change, multilingualism, perception and frequency in production.

6.3.1 Language change

Because an Emergent grammar is built firmly on the basis of observed forms, Emergence is consistent with an Evolutionary understanding of language change (Blevins 2004, Wedel 2006). Emergence adds to the Evolutionary framework by providing a formalism for analyses of earlier and later stages of a grammar, allowing the researcher to pinpoint with some precision the nature of the change and the forces leading to a particular change.

An Emergent phonology characterises alternations in terms of MSRs (productive or not) and well-formedness conditions. In the event that one component is general and phonological but the other is bound to specific morphs, we expect to see change with the morph-bound component, but not directly with the general component. A case in point is initial consonant mutation in Irish (McCullough 2020), where the phonologically regular mutation occurs in idiosyncratic morphosyntactic contexts; the modern-day usage involves a solid grasp of the phonological forms, but inconsistency in the form selected for a given morphosyntactic category. McCullough (2020) provides an Emergent analysis of the pattern and discussion of the changes in progress.

There are other imaginable implications for language change. For instance, the Emergent framework predicts that different speakers may have divergent formal representations of the same patterns, yet there may be no functional distinction between the two. This raises the possibility of a language change which has an effect on a subpart of the population of speakers, due to the different formal representations possible for the language.

6.3.2 Multilingualism

Most of the world's population is multilingual. How are multiple languages represented in the speaker's mind, how are they kept separate, and how do they interact? Alfaifi (2020b) offers a very interesting study of diglossia in the Faifi region of southern Saudi Arabia where the local language, Faifi, is used at home and in informal settings while a version of Modern Standard Arabic is used in schools and in formal settings. Alfaifi (2020b) argues that much of the phonology, lexicon, and morphology is shared between the two, but there are both sounds and morphs – stems, affixes, and templates – that are specific to one language and cannot be used in the other. Alfaifi's Emergent analysis characterises these patterns in terms of morph sets with single members, such as $\{\text{dawla}\}_{\text{COUNTRY}}$, unrelated members, such as $\{\text{daʕdaʕa}_{\text{LOW}}, \text{kala:m}_{\text{HIGH}}\}_{\text{TALK}}$, as well as morph sets with systematically related members, such as $\{\text{t}^{\text{h}}\text{alb, kalb}\}_{\text{DOG}}$. Alfaifi proposes Morph Set Relations which assign a context-marker HIGH or LOW (following terms familiar in the diglossia literature) to morphs containing specific sounds ([t^{h}] is a LOW sound, not a HIGH sound), as well as MSRs which relate morphs: for instance, there is an MSR relating LOW [t^{h}] and HIGH [k], hence, $\{\text{t}^{\text{h}}\text{alb}_{\text{LOW}}, \text{kalb}_{\text{HIGH}}\}_{\text{DOG}}$. The large number of morph sets whose members are unrelated show that such relations are not productive, arguing against MSCs connected with the MSRs. Alfaifi also draws on well-formedness conditions which penalise disagreement among context-markers within a word. This prohibits LOW morphology combined with HIGH stems and the converse, HIGH morphology with LOW stems, where LOW and HIGH are read off the labels and the labels themselves are in some cases arbitrary and in other cases systematic. In addition to sorting out the complexities of Faifi diglossia, Alfaifi (2020b) provides a roadmap for exploring multilingualism under Emergence.

6.3.3 No "reverse engineering"

There is an important difference between a theory that records surface representations in morph sets and a theory which posits abstract underlying representations. With morph sets, what is observed on the surface is directly represented in the structure of a morph set: each phonologically distinct surface form is directly represented in the morph set. In contrast, a theory of underlying representations involves reverse engineering. Based on the observed surface forms, and based on the rules and/or constraints, a unique underlying representation is postulated that will give the correct surface results. Essentially, the effect of the rules/constraints is undone to see what sort of form can be postulated from which the observed surface forms can be derived. Crucially, once posited, the derivation of surface forms from this abstract underlying representation is proposed to be blind to the results. That is, when applying rules or constraints to some underlying representation, the computation has no look-ahead knowledge of what the results should be. What is odd about this failure to use "look-ahead" knowledge is that the (hypothetically inaccessible) "look-ahead" forms are precisely those that the learner has actually encountered and has used to create the underlying representation.

The absence of look-ahead knowledge creates problems when phonologically identical underlying representations behave differently with respect to rules/constraints: knowledge of the surface form is needed to determine the appropriate computation for a given underlying form, yet that requires access to the result of the computation, not blindness. As seen in the examples in Chapter 5, lexical items may differ in idiosyncratic ways that are easily identifiable on the surface, but that do not straightforwardly allow derivation from a single phonological representation. For example, in Mayak we saw that low vowel affixes may be consistently advanced, consistently retracted, or alternate between advanced and retracted forms – behaviour that is trivially represented in surface-oriented morph sets but requires some enrichment of the theory when attempting to postulate unique underlying representations for the three types of morphemes with low vowels. A general pattern of tongue root harmony is apparent in the language, but whether it affects a particular form depends on whether any of the contributing morph sets contain both advanced and retracted vowels. The phonotactic is independent of morph set structure; underlying representation models do not make this separation and so must create novel representations, whether rule-based or constraint-based.

Finally, we return to learning, pointing to cases where reverse engineering results in forms which would seem to constitute significant problems, languages exhibiting a wide variety of instances where there is no observed form from which all surface forms could be derived (e.g. Kinande, Mayak, Polish), leading in turn to the postulation of forms of considerable abstractness. In Kinande, for example, the adoption of rules of H tone spreading and delinking means that identifying a H tone on the surface requires reverse engineering in order to ascertain which vowels must be considered underlyingly high toned (even though they are never high toned on the surface), while other vowels are reverse engineered to have no underlying high tone (even though they are high toned on the surface). In terms of learning, observations about surface tonal representations must lead to particular rules/constraints; based on these rules/constraints, underlying representations must be constructed not because they ever occur for the morpheme in question, but because the postulation of such a morpheme shape allows it to interact with the rule/constraint set and produce forms that are indeed attested. The requirements for learning are complex, and largely unaddressed; the same issues arise in modeling the perceptual processing of a phonetic string (Boersma 2011).

6.3.4 Frequency in production and perception

We have assumed that learners track the frequency of occurrence of different items. Highly frequent polymorphic forms may even be represented as part of a stem's morph set: {lʊk, lʊkt$_{\text{PAST}}$}$_{\text{LOOK}}$. In such cases, when producing LOOK-PAST, the speaker would have both [lʊkt]$_{\text{LOOK.PAST}}$ and [lʊk-t]$_{\text{LOOK-PAST}}$, giving two routes for identifying the appropriate form. This may lead to a difference in production patterns – or conversely in recognising lexical items – based on the more frequent forms having multiple means for accessing the item.

6.4 Concluding remarks

In setting out on this (ad)venture, our goal was to understand what innate principles are absolutely necessary in order to represent adult phonological systems. Our explorations, dating from Pulleyblank (2006a,b), Mohanan et al. (2010), have yet to reveal any compelling phonology-specific innate mechanisms. To the extent that our analyses integrate morphology, there too we have yet to discover the need for innate mechanisms specific to language. As we hope this monograph has shown, apparently complex data receive straightforward, transparent analysis within the Emergent framework. This chapter has sketched ways that Emergence might be extended to other types of phonological patterns, as well as to other domains of linguistic research. Because the general approach assumes a minimal role for an innate linguistic faculty, the expectation is that there is no "phonological component", no "morphological component", etc.; the appearance of such silos must be epiphenomenal, a consequence of analysing each language on its own terms, rather than resulting from separate innate cognitive constructs. We are left wondering in what ways Emergence is relevant to the whole of language, syntax and semantics, perception and production, usage and change, along with morphology and phonology.

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Emergent phonology

To what extent do complex phonological patterns require the postulation of universal mechanisms specific to language? In this volume, we explore the Emergent Hypothesis, that the innate language-specific faculty driving the shape of adult grammars is minimal, with grammar development relying instead on cognitive capacities of a general nature. Generalisations about sounds, and about the way sounds are organised into meaningful units, are constructed in a bottom-up fashion: As such, phonology is emergent.

We present arguments for considering the Emergent Hypothesis, both conceptually and by working through an extended example in order to demonstrate how an adult grammar might emerge from the input encountered by a learner. Developing a concrete, data-driven approach, we argue that the conventional, abstract notion of unique underlying representations is unmotivated; such underlying representations would require some innate principle to ensure their postulation by a learner. We review the history of the concept and show that such postulated forms result in undesirable phonological consequences. We work through several case studies to illustrate how various types of phonological patterns might be accounted for in the proposed framework. The case studies illustrate patterns of allophony, of productive and unproductive patterns of alternation, and cases where the surface manifestation of a feature does not seem to correspond to its morphological source. We consider cases where a phonetic distinction that is binary seems to manifest itself in a way that is morphologically ternary, and we consider cases where underlying representations of considerable abstractness have been posited in previous frameworks. We also consider cases of opacity, where observed phonological properties do not neatly map onto the phonological generalisations governing patterns of alternation.

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