Underlying Representations

Martin Krämer

KEY TOPICS IN PHONOLOGY

CAMBRIDGE

Underlying Representations

At the heart of generative phonology lies the assumption that the sounds of every language have abstract underlying representations, which undergo various changes in order to generate the ‘surface’ representations; that is, the sounds we actually pronounce. The existence, status and form of underlying representations have been hotly debated in phonological research since the introduction of the phoneme in the nineteenth century. This book provides a comprehensive overview of theories of the mental representation of the sounds of language. How does the mind store and process phonological representations? Krämer surveys the development of the concept of underlying representation over the last 100 years or so within the field of generative phonology. He considers phonological patterns, psycholinguistic experiments, statistical generalizations over data corpora and phenomena such as hypercorrection. The book offers a new understanding of contrastive features and proposes a modification of the optimality-theoretic approach to the generation of underlying representations.

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MARTIN KRÄMER

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Acknowledgements

The topic of this book is quite wide, even though I tried to narrow it down to keep it within moderate limits, that is, around 300 pages rather than the length of a novel by Dan Brown. This cutting-down process led to the omission of several aspects of underlying representations and the discussions around them, which will be sketched in the first chapter. More sadly, trimming the subject matter led to the necessity of simply ignoring the work of some authors. Some omissions, I admit, are surely the result of my ignorance. However, the nature of underlying representations is a central issue in phonological theorizing and the numbers of those doing research on the topic are legion; there is also many a good insight to be found about the nature of underlying representations in books and articles that do not primarily set out to contribute to this discussion but are focusing on some other issue. Furthermore, my task here was to provide an overview of a central topic in phonological theorizing but give it my own slant. Since I was asked for it I wrote a book that is biased. And because of all this I feel the need to start with an apology, an apology to all those excellent and hardworking scholars whose work didn't get acknowledged here. Sorry! If I ever get to write volume 2, I will try to make up for it.

My heartfelt apologies also go to the students who will read this book as part of a course in phonology. Some passages are quite challenging, even though I have tried to explain complex issues as clearly as possible.

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All errors and shortcomings of this book are my own.

Abbreviations

AP	Articulatory Phonology
ASL	American Sign Language
C	consonant
CM	Comparative Markedness
CON	constraint set
ET	Exemplar Theory
EVAL	Evaluation function
FFC	Fully Faithful Candidate
fMRI	functional Magnetic Resonance Imaging
FUL	featurally underspecified lexicon
GP	Government Phonology
KISS	'Keep it simple, stupid!'
L1	first/native language
L2	second language
LO	Lexicon Optimization
LP / LPM	Lexical Phonology and Morphology
MEG	Magnetoencephalography
MMN	mismatch negativity
OCP	Obligatory Contour Principle
OT	Optimality Theory
PR	phonetic representation
RotB	Richness of the Base
RROC	Redundancy Rule-Ordering Constraint
SDA	Successive Division Algorithm
SCC	Strict Cycle Condition
SPE	*The Sound Pattern of English* (Chomsky & Halle 1968)
SR	surface representation
UG	Universal Grammar
UR	underlying representation
V	vowel
VOT	voice onset time
$	syllable

1 Getting started

> It is the holy grail of phonology to be sure of what the underlying form is.
>
> (William Labov, 21 May 2010, Manchester Phonology Meeting)

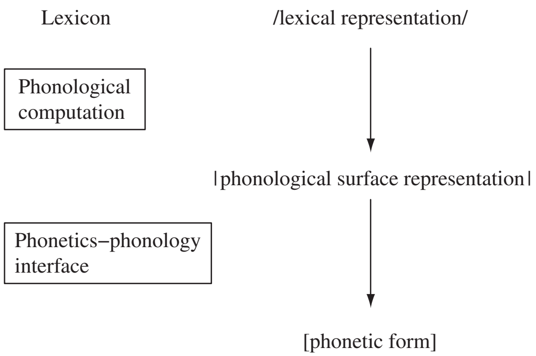
1.1 WHAT THIS BOOK IS ABOUT

This book surveys the development of the concept of underlying representation or underlying form over the last 100 years or so within the field of generative phonology and its predecessors. We will consider phonological patterns and phenomena such as hypercorrection, linguistic experiments, statistical generalizations made over data corpora as well as theoretical arguments that have been used as arguments for underlying representations, their form and degree of (under) specification or the absence of such abstract entities. We will necessarily also look at the theoretical background that shaped our understanding of underlying representations at different times. Finally, a view of underlying representations will be converged on that sees two principles of economy as central in the determination of underlying representations: the avoidance of unnecessary information and the (over)generalization of alternation-inducing patterns to non-alternating forms as a strategy to achieve this goal of lexical parsimony. These principles, designed to maximize different aspects of lexical economy, actually stand in conflict with each other. It will be shown that these conflicts lead in some instances to underlying representations that defy common intuitions on economic lexical representations.

One cannot think about underlying representations without considering what their basic building blocks are. Accordingly, this book will also discuss this aspect of underlying representations. Originally, the smallest unit of phonology was thought to be the phoneme. As in physics, it turned out very soon that the atomic unit consisted of smaller elements or particles, the contrastive features. The nature of these features and their contents are pragmatically defined as relating them to their articulation or to the corresponding acoustic signal, though we will see that there is considerable dissent when it comes to the details. On the basis of economy considerations, we will end up with a theory of features that connects the smallest building blocks of phonological representations with concepts from other domains of cognition, but especially with other modules of the language faculty.

Underlying representations are at the heart of modern phonological theorizing. Most contemporary, especially generative, phonological theories are mechanisms that map assumed more or less abstract underlying representations to much less abstract phonological representations, which are either regarded as instructions to the articulators or translated into such in a phonology–phonetics interface component.

(1) From the phonological lexicon to the phonetics[1]



While abstract phonemic representations were a mere theoretical construct in structuralist phonology, underlying representations received a more challenging status in generative phonology and even more so in psycholinguistic research. The criterion of psychological reality was imposed on the postulation/deduction of underlying representations such that present-day phonological research is trying to pin-point how the signifying part of atomic linguistic units is stored in the human mind.

The terms lexical representation and underlying representation are used in various ways in the literature. Some authors use the former term to refer to some intermediate representation that is created from the lexically stored form or underlying representation, while for other authors the underlying form is derived from a more abstract form. In this book I will try to avoid this terminological pitfall and use both terms, *underlying* and *lexical*, as referring to the state of phonological units before any computation to prepare them for production has applied, i.e., the representation stored in the (mental) lexicon.

Reasoning about underlying representations in phonology has been guided and shaped to a considerable degree by two ideas. Ockham's razor, or the *lex parsimoniae*,[2] is a general principle determining theory formation not only in linguistics; it holds that if more than one explanation is available, the one making fewer assumptions has to be preferred. The other guiding idea is the belief that the human capacity for storage of memories is limited. To be able to store as much information as possible, this information has to be stored in the most economic way.

In our context this can be broken down into four dimensions of lexical economy.

(2) Lexical economy (Yip 1996: 766)

a. economy of individual lexical entries
b. economy of phoneme inventory
c. economy of phonotactic combinations
d. economy of paradigms

If individual lexical entries are stored in the most economic way, to leave room for as many of them as possible, they should contain as little information as necessary to be distinguished from one another. If the goal of mental storage is maximal accuracy, individual lexical entries should contain all information on every single rendition of every word or morpheme a language user has ever perceived or produced or even thought of and might even store linguistically irrelevant information about the context in which the realization happened, such as the weather, the hairstyle of the speaker, the shoes of an accidental passer-by in the situation, etc.

The same standard of information-saving measures holds for the economy of the phoneme inventory. According to Saussure, all that matters in language is contrast. Quite a few of the sounds we use in each language are not contrastive segments but predictable positional variants. In addition, not all phonetic/physical aspects of every contrastive segment are necessary to distinguish it from all other such segments. In the optimal case we can distil a small set of relatively abstract contrastive features for each language that are sufficient to account for the contrasts. If only these are stored in underlying representations, this also reduces the load of every lexical entry. According to Ockham's razor, the analysis with the smallest set of features wins. Extending this beyond the analysis of single languages one can hope to find the smallest set of features necessary to describe all contrasts in all languages, with every language using a principled subset. Again, the simplicity metric prefers this theory to one that postulates different contrastive features for different languages.

In all languages we are aware of, sounds cannot be combined randomly inside words. They are (probably) organized in syllables and other prosodic units. Usually this kind of structure can be generated automatically and doesn't have to be memorized. Many languages allow only sequences of consonant–vowel–consonant–vowel . . . (CVCV . . .), rather than random combinations of Cs and Vs, in which case one could even go as far as to claim that a competent user of such a language doesn't even have to memorize whether a sound is a consonant or vowel since that is determined by its position in the string.

Finally, in most languages, words often consist of several morphemes. These morphemes can be recombined to form new words, just as words are constantly recombined to form new phrases, sentences and utterances. So if we are dealing with paradigms, it is more economic to just store the individual morphemes rather than every form in every paradigm. To take an example, an ordinary Italian verb has around 57 different forms, including participles and the infinitive, and the past participle alone is used in an additional 42 forms together with 42 different forms of auxiliary verbs. Simplicity and the observation of productivity or linguistic creativity suggest breaking these forms down into a verb stem and definitely less than 57 affixes. Since this army of verb forms is inflected for tense/mood/aspect as well as person and number we can break down every form into a stem or root and several affixes, which recur in the paradigm. If we assume that an average Italian knows roughly 8,000 verbs we reduce the number of lexical entries from (8,000 × 57 =) 456,000 to around 8,020.[3]

A question to ask: but why should our mind be so obsessed with economy when it comes to storage? We have plenty of memory space. The human brain contains an estimated 100 billion nerve cells.

Question 1: How economic are underlying forms?
Question 2: What do these forms consist of? Are there features?

If the answer to question 2 is yes, which features are these? What is in a feature? How many are there? Are they universal, i.e., already present at birth by genetic endowment, or learned? Are they language-specific?

One can add two more technically minded subquestions then: how do we arrive at underspecification (i.e., what is the best algorithm)? What are the boundaries of phonological data compression? Learnability might set a natural boundary in limiting the abstractness of such underlying representations, but also other factors, such as efficiency of computation and retrieval. After all, once a thought has turned up in our mind followed by the desire to dress this thought in language, we want to be fast and efficient in finding the necessary morphemes and words to express it and excessive abstractness might hamper this ambitious task. One can also assume that any listener wants to keep the job of interpreting a sound stream as efficient and fast as possible and the presence of more phonetic detail in lexical entries could help identify the right lexical entries.

The degree of abstractness, as well as the primitives of phonological representations in general and in particular of underlying representations, have been subject to a long debate starting with the introduction of underlying representations into modern linguistics by Bloomfield (1933). Before this, the Prague school, based on Saussure's work, introduced a revolutionary degree of abstractness with the archiphoneme (Jakobson 1939, Trubetzkoy [1939]1971).

While American structuralism focused on the identification of phonemes and their allophones based on the Bloomfieldian view of underlying form, generative phonology, especially from the publication of Chomsky & Halle's (1968) *The Sound Pattern of English* (*SPE*), concentrated more on phonological processes, i.e., the computational aspect of phonology. This led to a much more abstract view of underlying forms.

With the observation that on the one hand there are substantial restrictions on the form of underlying representations, i.e., the lexicon (morpheme structure rules; Halle 1959), and that on the other hand very often similar rules had to be assumed for the grammar mapping underlying forms to surface representations, the duplication problem arose (Kenstowicz & Kisseberth 1977).

While already early on in generative phonology predictable or redundant features were assumed to be filled in by feature filling or redundancy rules, a type of rule to be distinguished from actual phonological rules, the degree of abstractness, was furthered in the 1980s and early 1990s with the emergence of theories of underspecification, e.g., Radical Underspecification (Archangeli 1984, 1988, Archangeli & Pulleyblank 1989) and Contrastive Underspecification (Steriade 1987, 1995).

However, since the main objective of generative linguistics is to define the space of grammar, i.e., develop a theory of what is a possible natural language and what is not, the conclusion that underlying representations are highly abstract is not ineluctable. That underlying representations are much richer than had been concluded in the above-mentioned studies was argued for by Mohanan (1991) and Vaux (2003) among others.

In the 1990s, the introduction of Optimality Theory (OT; Prince & Smolensky 1993/2004) gave rise to a complete overhaul of the view of underlying representations. First of all, the basic idea behind the framework explicitly doesn't allow for restrictions on underlying representations, which solves the duplication problem via hypothesis. The question then is whether the theory has anything to say about underlying representations at all. While, in general, generative work assumes certain principles of economy applying in the determination of underlying forms (for example, every aspect of representation that is predictable is stripped off and taken care of by the grammar, such as syllable structure or redundant non-contrastive features), OT provides a fully automatic way to determine underlying representations: Lexicon Optimization (LO; Prince & Smolensky 1993/2004, Inkelas 1994, Itô, Mester & Padgett 1995 and others). Lexicon Optimization reverses the usual mechanism of candidate evaluation central to OT by evaluating competing underlying representations that are compatible with a given output form (i.e., that, if assumed as the input, would lead to an evaluation of this output candidate as the winner). The nature of the set of constraints, especially Faithfulness constraints, determines the underlying representation that is most like the corresponding output as the winning candidate.

Prince & Smolensky (1993/2004) already raise doubts on whether identity of underlying and surface forms is the desired outcome and entertain the option that other grammatical mechanisms besides candidate evaluation against the constraint hierarchy could be involved in the determination of underlying forms.

More recently, Lexicon Optimization has come under attack in two respects. On the one side it was doubted that Lexicon Optimization actually makes the predictions posited in earlier work, since the definitions of constraints as well as the theory of representation (Feature Geometry, *SPE*-style binary features, etc.) are actually crucial factors (see, e.g., McCarthy 2003; Krämer 2006a, b), as are productive patterns resulting in alternations (Harrison & Kaun 2000). A more radical criticism challenges the notion of LO altogether (Nevins & Vaux 2007). In a similar vein as the latter faction, McCarthy (2005) introduces an OT-compatible reformulation of the free ride principle that leads to a higher degree of abstractness/underspecification in some underlying forms.

Some researchers in the realm of OT have abandoned the idea of underlying representations altogether and instead assume that the only representations grammar has access to are surface forms (e.g., Burzio 1996 *et seq.*). In such approaches correspondence relations are established between morphologically related output forms, mostly to explain phenomena within paradigms, such as paradigm levelling, paradigm uniformity, etc.

While all the former agree on the nature of (underlying) representations as composed of discrete categorical primitives (for an exception to this within OT, see, e.g., the work of Boersma), Exemplar Theory (e.g., Pierrehumbert 2001) departs from this common ground and regards words, morphemes or even individual phonemes as stored clouds of memories of actual realizations with all phonetic detail (linguistic or not), just like a box of high-resolution photographs (and just like with high-resolution photographs printed on low-quality paper or with cheap ink, the details fade away over time). This position is based on frequency effects found in the application of phonological processes. Roughly speaking, more frequent lexical items have been found to be more susceptible to neutralization than less frequent items. From this, advocates of Exemplar Theory conclude that the greater number of stored exemplars that come with higher frequency results in more variation in the stored signal and therefore higher flexibility in production, i.e., lower cost to neutralization.

Thus, generative phonology moves from underlying forms of extreme abstractness and extreme underspecification to underlying forms of a very low degree of abstractness, with full specification of all phonological features, to the rejection of underlying forms altogether and to a phonetically detailed view of underlying forms.

The great challenge in this field is that the nature and details of underlying representations cannot be observed directly, unlike surface patterns. We will see that the predictions of theories regarding underlying representations are far from unambiguous. One could likewise start with assumptions about underlying representations that then shape the theory, though priority has to be given to indirect observation through data collection and experimentation. However, there is often more than one conclusion to be drawn from naturally occurring linguistic patterns, statistical observations and the like, as has also been indicated in this short summary of the ongoing discussion on underlying representations in phonology.

1.2 WHERE YOU FIND WHAT

The book covers the following ground. Chapter 2 goes back to the early twentieth century, discussing Saussure and Trubetzkoy in particular and their ideas of contrast and phonemes as well as the relevance of categorical contrast in phonology. We will also look at Trubetzkoy's methodology to diagnose contrastive segments and touch on his ideas about contrastive segments as a system. I hope to elucidate to the reader the foundations of modern theorizing and research on underlying representations in phonology in this way.

Chapter 3 is concerned with the abstractness of underlying representations. This increased as a by-product of the development of a more sophisticated theory of transformation from the representation assumed to be phonologically relevant to the form that is passed on to the phonetics, which consists of non-categorical physical events. Saussure and Trubetzkoy prepared the ground for what was later termed underspecification and Jakobson's and Halle's work moved further in this direction. Generative phonology of the 1950s was based on these scholars' work until the idea of underspecification of redundant or predictable segmental information was challenged and by and large abandoned for at least a decade.

Chapter 4 reviews the arguments to reconsider theories of underspecification and how these developed from the 1980s on. In this chapter we also have a look at more systematic ways to derive different degrees of underspecification, before we turn to an argument against systematic underspecification and the use of blanks (underspecification) in analyses of lexical exceptions.

Chapter 5 is dedicated to the opposite extreme view. Usage-based phonology, or Exemplar Theory, holds that language computation runs statistics over huge corpora of experienced and memorized linguistic data and that linguistic patterns and language change can be explained this way. At the end of this chapter we try to reconcile these opposing views.

Chapter 6 reviews studies, mostly from the 1990s and the first decade of the twenty-first century, that provide insight into whether the human brain operates with abstract categorical units and whether phonological features are ever underspecified.

The content of phonological features is the subject of Chapter 7. In Chapters 2–6 standard phonological features are used, which are defined mostly in articulatory and partially acoustic terms. Chapter 7 looks at the motivation of feature definitions and concludes that there is an alternative way of defining phonological features on a broader cognitive basis.

While *The Sound Pattern of English* (*SPE*) and its successor, *Lexical Phonology*, provide the background for most of the discussion in Chapters 3 and 4, Chapter 8 is dedicated to the issue of underlying representations in Optimality Theory. The chapter starts with a sketch of the basics of the theory and then discusses its mechanism of Lexicon Optimization (LO). LO will be shown not only to make false predictions (compared with some of the results of Chapter 6) but also to be based on a misunderstanding. The last part of the chapter develops a revised version of LO that generates underlying forms more in line with Chapter 6.

Finally, in Chapter 9 we will look back to see if we have learned anything from the preceding 210 pages.

1.3 WHAT YOU WON'T FIND HERE

There are quite a few aspects of phonological research that one could imagine including in a book with this title that you won't find in here. The issue of feature values is discussed in many places in the book, though a discussion of whether contrastive features should be binary, privative or multivalued is not really undertaken.

The internal structure of segments is not discussed either. If, for example, the trees of Feature Geometry are universal we (by simplicity) only need features, which we then can organize into the universal tree when needed in the computation to explain feature interaction and class behaviour. If some aspects of phonological contrast can be represented in the tree, as indicated (but not discussed) in Chapter 7, then this bears on the quest for the nature and form of underlying representations.

We will merely touch upon whether prosodic structure, such as syllables, syllable constituents, stress and feet and the like, has to be part of the mental representation of morphemes. Section 4.5, where this is taken up, only brushes over underlying syllable structure in a very cursory way, though there is extensive literature on the representation of lexical stress and foot structure.

The nature of tones and tonal contrasts is not covered at all. The lexical properties that underlie allomorphy and allomorph selection are potentially illuminating pieces of the puzzle and would have deserved a separate chapter if not a separate volume.

Finally, speech errors, language acquisition and language change potentially provide insight into the nature of the mental representation of the phonological side of linguistic units. These sources of evidence are referred to in many places in the book, but not discussed separately or thoroughly.

Thus, there is plenty of material left for a second volume.

1.4 HOW TO USE THIS BOOK

The description of the series this book is published in suggests that one of the ways this book is going to be used is as a textbook for advanced undergraduate or graduate students. In Norway, or at least at the University of Tromsø, where I have been teaching for the last six years, a course usually consists of thirteen weeks of lectures, interrupted by the occasional reading week. So, why doesn't this book have thirteen chapters then? I personally like the number thirteen, since it is a prime number, and it would not have been any problem to write another four chapters about different aspects of underlying representations. However, prime numbers are difficult to divide into teaching blocks of equal weight. Besides, at most universities, courses last for about ten to twelve weeks. There is another, more important issue with numbers here. Whenever I use a textbook in one of my courses that has eleven or twelve chapters, we either don't make it through all the chapters (and, remember, I have thirteen weeks to get through them), because we need more time for one or several topics, or I have to cut one or two chapters because there are some issues that are not covered in the book and I think they should have been. In the optimal case you won't have either reason to skip a chapter of this book, since there are only nine of them. The reading suggestions at the end of each chapter are of two types, they can either be used to cover the topic of the chapter or an aspect of it in more depth or to go beyond the scope of the chapter and explore a related topic. In this way every unit can be expanded and dwelled on for more than one session.

Since the topic of the book is rather broad, though it actually only covers a subset of the theoretical issues and relevant empirical areas, there is ample room to add topics according to the lecturer's and the students' interests. The bearing of different types of allomorphy or of prosodic morphology on our understanding of underlying representations, for example, is not touched on here at all. The question of whether syllable structure is ever stored lexically is only dealt with briefly (in Section 4.5 and by the prediction of the absence of syllable structure in Section 8.3.3), as is a discussion of potential options for the representation of lexical stress.

The chapters are by and large ordered chronologically, showing how research on underlying representations evolved over time and how it was influenced by or led to shifting theoretical paradigms. Accordingly, working through the chapters in the order they are presented in here is recommended.

Besides the suggestions for further reading, you will find discussion points at the end of each chapter. These serve three functions: they are meant to stimulate discussion of a central issue and to further understanding by applying a theoretical/analytical tool introduced in the respective chapter, or they are intended to encourage the readers to go beyond the coverage of the chapter and expand on a related issue.

They might, of course, also be used as a base to distil topics for course papers.

Of course, you don't have to be involved in a course on underlying representations in phonology to be interested in the topic or aspects thereof. For the individual student/researcher the individual chapters should be autonomous enough to be studied in isolation and cross-referenced well enough to lead to the relevant other parts where necessary.

2 Arbitrariness and opposition

> Dans la langue il n'y a que des différences.
>
> (Saussure 1975: 166)[1]

2.1 OVERVIEW

Contrastive features are considered the basic building blocks of phonological representations today. This was not always the case. Originally the phoneme was considered the smallest unit distinguishing the meaning of a morpheme. This shift can be considered parallel to the shift from regarding atoms as the smallest units of physics to the research on particles, such as quarks or the Higgs boson in modern physics. Also our understanding of which features there are, how they are defined and how much of this information is present in underlying representations has changed considerably over the last 100 years. In this chapter we go back to the foundations of modern phonological theorizing on underlying forms and their elemental parts, and how these ideas developed up to the introduction of generative phonology. We will look at the arguments that led to increasing abstractness in structuralist theories and also get a grasp of the methodology to detect contrastive segments and dimensions of contrast developed by Trubetzkoy, which is more or less still standard – at least in many introductory courses to phonology – today.

In the first section you will meet Ferdinand de Saussure's ideas that language is divided into *langue* and *parole*, roughly, grammar and speech, that every morpheme has two parts – its meaning/grammatical function and its form – and that the relation between the meaning of a word and its form are arbitrary. The second section zooms in on the idea that contrast is the only thing that matters phonologically for the form part of morphemes, and on what kinds of phonological contrast we find in language. The following sections are occupied with the development of definitions of these categories of contrast and their formalization as binary features.

2.2 SAUSSURE'S CAT

The idea of the phoneme goes back to Pāṇini and his work on Sanskrit grammar. Nevertheless we start with Saussure, who is generally regarded as the father of modern structuralism and, for his distinction between *langue* and *parole*, of modern linguistics in general.

The primordial substantive distinction Saussure (1916) taught was that between *signifié* and *signifiant*, the concept referred to in a linguistic expression and the sign used to express this concept. According to Saussure, and generally endorsed by linguists since, there is no direct relation between concept and sign, that is, there is no inherent semantics in speech sounds or the linguistically relevant parts of them and the meaning they are used to express in a certain lexical item.

To illustrate this point I list the words for *table* in some random languages I happen to be more or less familiar with.

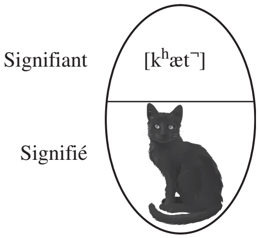
(1) Some Indo-European tables

English:	table	/tebl/
German:	Tisch	/tɪʃ/
Norwegian:	bord	/bur/
Italian:	tavola	/tavola/
Spanish:	mesa	/mesa/
Russian:	стол	/stol/

While there is a striking similarity between some of the examples in (1), which points to a common history of the languages or borrowing between them, especially Norwegian, Spanish and Russian stick out in that the sounds used in these words have not much to do with the sounds employed to express the concept 'table' in the other languages. Apart from the lack of a common phonetic element in these examples it is also difficult to imagine what aspect any sound should have that would a priori make it more suitable to express any semantic aspect of the concept 'table'.

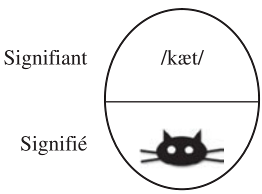
Even for words that express sound emission, such as 'to sing' (compare Italian *cantare*) or 'to whistle' (German *pfeifen*, Italian *fischiare*) cross-linguistic comparison reveals that the sounds used to express these don't have much in common (apart from a preference for sibilants and high vowels in the latter case). Especially the latter can be regarded as sound-symbolic, iconic or onomatopoetic in that the sound structure seems to imitate the sound emission referred to in some way. However, it is also obvious that the choice of sounds to express that relation is subject to considerable cross-linguistic variation. Putting aside the small number of sound-symbolic words present in most, if not all, languages, for the moment we can say that the relation between sign and meaning is arbitrary.[2] This presupposes that we can divide up any linguistic expression into these two components, i.e., *signifiant* and *signifié*, a dichotomy that goes back at least to Plato's Kratylos.

(2) Saussure's cat: lexical representation I



Furthermore, Saussure established the importance of contrast. According to Saussure, the most important property of a sign (either side of it, the sound as well as the meaning) is its difference from the other signs, i.e., to be something the other signs are not. This conception of lexical information renders a lot of detail redundant. First of all, one has to extract the essence of each linguistically used sound to be able to identify it independently of the speaker who produces it. Furthermore, any aspect of a sound we can predict because of the position the sound is found in and the sound class the sound belongs to etc. can be stripped off, since it doesn't make the sound different from other sounds, though this detail often helps to identify sounds as different from others. In our *cat* example we can strip off the aspiration of the initial stop, since in English aspiration of voiceless obstruents is usually found only in restricted environments, such as the beginning of a stressed syllable.[3] The lack of a release burst at the end of the word indicated in (2) is also expected. Taking these parts of the signal away one gets a leaner phonological representation, as given in (3), now kept between forward slashes rather than square brackets to indicate its abstract nature.

(3) Saussure's cat: lexical representation II



Difference or contrast is the core idea that was developed further most prominently by Trubetzkoy and Jakobson. Since Saussure saw the contrastive function as the most important one, it was only a step to reduce the linguistic content of contrastive segments to those aspects of their phonetics that are relevant and identify these.

2.3 THE PRAGUE SCHOOL

Interestingly, Trubetzkoy was one of the first to discuss a set of features for systems of contrasts but didn't make the crucial step of considering the contrastive properties as the basic building blocks of phonology. On the one hand he decomposed the phoneme into its smallest parts. 'One can say that the phoneme is the collectivity/totality of the phonologically relevant properties of a sound structure' ([1939] 1971: 35; my translation).[4] But then Trubetzkoy still regarded the phoneme, and with this the segment, as the smallest unit of language when he maintains 'that the phoneme is an element of such an opposition that cannot be decomposed into smaller distinctive units' ([1939] 1971: 39; my translation).[5]

Nevertheless, he argued for an abstract view of underlying contrastive segments and was the first to devise a universal set of distinctive features or contrastive properties of sounds, explicitly arguing against an all-inclusive view of mental storage of sounds.

In this context he emphasizes the categorical and classificatory nature of perception by making an analogy to encyclopaedic concepts, e.g., 'dog'. Under the concept 'dog' we have room for quite a lot of very different animals, but we don't think of them all when we think 'dog', nor do we think of some statistical nightmare dog that consists of the averaged out properties of all the dogs we know, but rather we have some core concept of *dog*-ness that leaves room for all this variation but doesn't include it.

At the end of the day even people who don't care about dogs can identify a creature as a dog or something different even if they haven't ever seen the particular breed at hand before. Excluding the little furry animals that wag their tail when they are annoyed rather than when they are happy (i.e., cats) from classification as dogs could be done in a statistical approach, that takes into account huge amounts of data from memories of perceived or experienced dogs, cats, squirrels, wolves and other animals by including a maximum deviation from the statistically average dog, and this statistical method is what he contrasts his approach with.

Trubetzkoy discusses in this context various phonetic characteristics of segments like German [k], such as its rounding, fronting, etc. according to the phonetic environment, as I illustrate in (4), and the fact that even in individual words the same speaker produces different renditions on different occasions.

(4) A few German /k/s

Küche	[ʷk̹ʏçə]	'kitchen'
Kirche	[k̟ɪɐçə]	'church'
Kuchen	[ʷk̠uːxən]	'cake'
Kachel	[kaχl]	'tile'

He stresses that 'However, the norm speakers refer to is "*k* as such", and this cannot be tracked down by measurements and calculations' ([1939] 1971: 11; my translation).[6] At least since Liberman *et al.* (1957) we have experimental evidence on categorical perception, i.e., that listeners identify all the different *k*'s in (4) as '*k* überhaupt' up to a cut-off point on the continuum of place of articulation, where the perceived category shifts to '*t* an sich'.

Trubetzkoy went further than just discarding all the non-contrastive information by introducing the archiphoneme. An archiphoneme is the shared information of two contrastive segments in a neutralization position minus the neutralized feature. For example, English *p* and *b* are contrastive for voicing or aspiration in most positions. In non-initial position in a syllable onset this contrast is neutralized, as in a word like *sponge*. Here Trubetzkoy would assume the archiphoneme, /P/, is devoid of information on voicing or aspiration.

Trubetzkoy introduced an elaborate methodology for finding phonemes and stripping them down to their contrastive content. We will have a short run through this methodology now to understand what he means by phonological relevance and the three different types of feature values used by him.

2.3.1 Trubetzkoy's rules for finding phonemes

CONTRAST AND RECOGNIZABILITY: if two sounds occur in the same environment and cannot be substituted for each other without a change in meaning or the word becoming unrecognizable, they are phonetic realizations of two distinct phonemes.

(5) German

[k]anne – [pf]anne – [f]anne	'pitcher' – 'pan' – 'pan'
[k]eil – [pf]eil – [f]eil	'chock' – 'arrow' – 'arrow'/'for sale'
hü[pf]te – Hü[f]te	'jumped' – 'hip (body part)'

In the examples in (5), [k] and [pf] are identified as distinct phonemes in the first and second row, while [pf] and [f] can be substituted without dramatic consequences, though in the second row substitution of [f] for [pf] results in ambiguity. In the third row [pf] and [f] cannot be exchanged. If one did this, it would result in a change in meaning, i.e., a different word, qualifying [pf] and [f] as distinct phonemes.

Variation: if two sounds occur in the same phonetic environment and can be substituted without a change in meaning, they are facultative variants of the same phoneme. The variation referred to here covers not only the variation found in all speakers (*allgemeingültige*) but also the variation from one speaker to another (*individuelle*). The latter also covers variation across dialects, such as the different ways of pronouncing /r/ in the different regional varieties of German.

Complementary distribution: if two articulatorily or acoustically related sounds never occur in the same phonetic environment, they are regarded as two allophones of the same phoneme.

Subcase A: if there is a whole class of sounds *a’*, *a’’*, *a’’’* etc., that occur in a certain environment *e* and one *a* that doesn’t, only the sound in environment *e* that is acoustically/articulatorily closest to sound *a* is a realization of the same phoneme that *a* is.

In Korean, [s] and [r] are not found in syllable-final position, while [l] is. [l] on the other hand is not found in syllable-initial position. The criterion of phonetic similarity then leads to an analysis of [l] and [r] as allophones of one phoneme, since they are in complementary distribution and phonetically more similar to each other than [l] and [s] are.

(6) Korean

*s, *r /__)$_{\sigma}$
*l /$_{\sigma}$(__

Subcase B: *a’*, *a’’*, *a’’’* etc. occur in environment *e* and *b’*, *b’’*, *b’’’* occur in environment ¬*e*. Only the most acoustically/articulatorily related sounds from *a* and *b* are variants of the same phoneme.

The difference between subcases A and B lies in whether we are dealing with a one-to-many or a many-to-many relation. In Japanese, neither [t] nor [h] occurs before [u], where we find [ts] and [f], which we don’t find anywhere else. Via phonetic similarity we can establish [t] and [ts] as two allophones of one phoneme and [h] and [f] as two allophones of another phoneme.

(7) Japanese

*t, *h /__[u]
*ts, *f elsewhere

Subcase C: only one sound occurs exclusively in an environment and one exclusively does not occur in this environment. These can only be variants of one phoneme if they don't stand in indirect phonological opposition.

German [h] and [ŋ] are candidates for allophones of one phoneme, but stand in indirect opposition. An indirect opposition can be detected by comparing pairs of minimal pairs and thus establishing a chain of contrast. In German, [h] and [ŋ] are in complementary distribution, with [h] only occurring at the beginning of syllables and [ŋ] only occurring syllable-finally or before schwa (where [h] is not found). Each of them directly contrasts with [p]. Thus, we can establish an indirect contrast between the two via their relation to /p/.

(8) German [h] and [ŋ] in indirect opposition

a. hacken 'to hack' – packen 'to pack'
b. Ringe 'rings' – Rippe 'rib'

On the other hand, Japanese [g] and [ŋ] also occur in mutually exclusive environments. Since there is no third phoneme with which they constitute an indirect contrast, they do qualify as variants of one phoneme.

ADJACENCY: two sounds that satisfy the previous criterion still cannot be variants of a phoneme if they can stand next to each other, like English *r* and schwa.

(9) English *r* and schwa

r / __V
*schwa /__V

With this rule Trubetzkoy paves the ground for structuralism's biuniqueness condition, the problematic assumption that an allophone in a certain environment can only be an allophone of one phoneme. Schwa could be an allophone of *r* and emerge from other sources as well, e.g., epenthesis or vowel reduction.

Once we have the criteria at hand to identify phonemes we can move on to identify the relevant oppositions in a language or the contrastive features.

2.3.2 Trubetzkoy's division of phonemic oppositions

A phoneme's content has to be unspecific enough to include all its phonetic variants but specific enough to distinguish it from all other sounds it contrasts with.

Here we can come back to German /k/: it can't be 'velar' because of its fronted variants before front vowels. Thus, /k/ has to be dorsal. This is not specified enough though, since /g/ and /ç/ are dorsal too. To distinguish /k/ from each of the latter it has to be a tensed non-nasal dorsal occlusive, with tenseness contrasting it with /g/ and occlusiveness separating it from /ç/.

Thus, in the specification of phonemes there is a certain balance to be struck that clarifies the relations between a phoneme and its allophones on the one hand and between this and other phonemes (and their allophones) on the other. Accordingly, the specification of any phoneme in a given language can only be determined under consideration of the rest of the inventory of this language. In the following paragraphs we look at this systemic aspect of contrast and then move on to another important way in which phonemes relate, namely, the nature of a given contrast as separating out elements on a scale or continuum or two opposing poles, i.e., the distinction between scalar, n-ary and binary oppositions, which will become the foundations of the Jakobsonian feature values that will be discussed later in this chapter.

Contrast in relation to the system

'The content of phonemes can differ from language to language or dialect, since the systems of phonological oppositions are different in different languages and dialects. This difference in content can also have repercussions for the realization of a phoneme' (Trubetzkoy [1939] 1971: 65; my translation).[7]

This is a consequence of the contrastive method: if a segment is phonologically specified only to (minimally) express contrast with other segments in the system, a different phonological specification of the same phone can be expected in different systems, i.e., languages.

Trubetzkoy divides systematic contrast into equations involving contrasting pairs to identify features (or dimensions of contrast) that hold for several phonemes, as illustrated for place of articulation in German in (10).

(10) German equations

a. b–d=p–t=m–n
b. u–o=ü–ö=i–e

This shows the simple observation that the contrast between *b* and *d* is the same as that between *p* and *t* and *m* and *n*, i.e., one between labial and coronal place of articulation. A contrast, once established, is reused in the system and not just there to differentiate two phonemes.

In the next step we can build chains of phonemes, showing the internal relations in the system. The idea is to be able to establish a chain between two contrastive segments that differ in more than one feature, with each successive link in the chain differing from the previous one by only one feature. In the first chain in (11a), the second member differs from the first in backness and from the third member in roundness. Thus, /u/ and /i/ are not in direct contrast, they differ in two features. The chains in (11b) and (11c) follow the same principle.

(11) Chains of homogenous multidimensional oppositions (German again)

a. u–ü–i
b. u–e : u–o, o–ö, ö–e => u–o–ö–e
c. x–ŋ : x–k, k–g, g–ŋ => x–k–g–ŋ

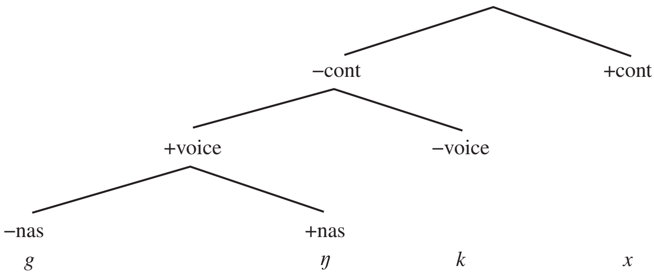
From such a methodology one can derive a stepwise mechanism to build up phoneme inventories. The first split in (11c) involves the feature [±stop] or [±continuant], dividing *x* from *k*, *g* and ŋ. The next cut divides the voiceless segments (x, k) from the voiced (g, ŋ). The last division then divides the voiced segments into oral and nasal. Thus inventories are built up in a step-wise fashion, as shown in (12).

(12) Incremental system formation

x–k : continuancy (e.g., [±stop])
k–g : already [+stop] also need [±voice]
g–ŋ : already [+voice] also need [±nasal]

Incremental splitting of sound systems can be expressed in a division tree (compare the discussion of Dresher and colleagues in Chapter 4 below).

(13) A division tree



One interesting result of this technique is that the dorsal fricative is underspecified for voicing. It is also not contrastive in this dimension, since there is no [ʒ] in German (it occurs only marginally in some loanwords, such as *Gara[ʒ]e* 'garage'). If we allow that, besides negative and positive specification, features can be left blank for a value, as the fricative is for voicing, we can get even more blanks, i.e., underspecification, since the feature specifications in (13) are still slightly redundant because nasals don't contrast in voicing and oral stops don't need a specification for nasality. Likewise one might underspecify the voiceless oral stop for voicing as well. Trubetzkoy didn't go down this road; I am anticipating later developments and discussions which we will take up here in later sections and more seriously in Chapters 3 and 4.

However, the tree metaphor just gets us so far. If we consider place as well, we end up with a matrix in Trubetzkoy's model.

(14) System matrix for German

			v	*z*	
		x	*f*	*s*	*ʃ*
p	*t*	*k*	*pf*	*ts*	
b	*d*	*g*			
m	*n*	*ŋ*			

It is no accident that the two liquids are missing in the matrix. *r* in German is in mono-dimensional contrast only to *l* and accordingly heavily underspecified. 'Its phonological content is very poor, in a sense purely negative' (Trubetzkoy [1939]1971: 65; my translation).[8] Trubetzkoy sees this supported by the observation that the rhotic varies across speakers (alveolar, uvular, guttural; trill or spirant in different varieties) and across positions (trill in syllable onsets, fricative in complex onsets, non-syllabic nondescript vowel in the coda, imperfect guttural). Thus, Trubetzkoy assumes that the absence of contrast equates the absence of a feature and the absence of features results in an imprecise articulatory target. However, he is not very explicit about these issues.

It remains unclear, for example, whether he saw the contextual allophones as the result of contextual feature filling. Unfortunately, he didn't say much about the lateral either. Since *l* is also only in a direct contrast with *r* it should be underspecified in the same way and show the same or similar variation.

Instead, he compares German *r* with the Czech *r*. Czech *r* contrasts with ř and *l* and shows much less variation.

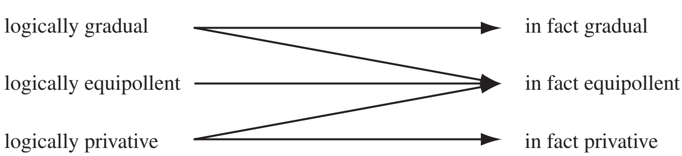
This method of establishing chains and matrices of contrasts also enables us to find out more about the nature of a certain contrast, and Trubetzkoy uses this to determine the types of values for his contrastive features.

Contrast and the relation between the members of an opposition

To determine the nature of a certain opposition we can consider how many elements are in a contrasting chain (two or more) and what the acoustic properties or articulatory properties of the contrast are. Regarding the physical properties, there might be two options (e.g., nasal or oral) or several (e.g., from spread lips over neutral, slightly rounded, etc. to heavily protruded lips). That is, contrasts can be binary or scalar in nature. However, this is also a language-specific choice: at least a scalar contrast can be used in a binary way in a given language, which could just abdicate from using all the potential options on the scale in a contrastive way, and instead allow for greater allophonic variation or simply never realize some of the potential segments on the scale.

Trubetzkoy acknowledges three types of features, their nature depending on the system. I will run us through these below in (15).

(15) Contrasts and feature values



An example of a gradual contrast is vowel height. Vowel height systems can distinguish five degrees of height (as in *i*-ɪ-*e*-ɛ-*a*); some might be analysed as distinguishing six levels of height (see (18)), which is difficult to formalize as a binary or privative opposition and thus regarded as gradual.

Place of articulation as well as continuancy, as in the oppositions *p*–*t* and *p*–*f*, respectively, is equipollent, since none of the segments in opposition can be regarded as marked or unmarked with respect to the other.

Nasality is logically privative. It is either present or absent, and with a markedness difference, since we are dealing with the presence of nasalization in the acoustic signal as opposed to its absence (in nasal versus oral vowels, for example).

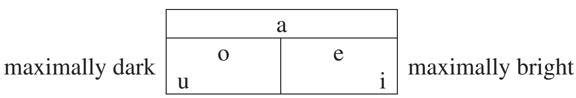
However, Trubetzkoy observes a few mismatches between the logical nature of a contrast and its phonological implementation that actually would justify an additional arrow in the diagram reproduced in (15).

While vowel height is gradual in nature (as in German), it can also be used in a privative manner (as in Turkish) depending on the number of height positions used in the system. Voicing is also gradual in its (phonetic) nature and is nevertheless usually used privatively.

We now move on to have a look at which features Trubetzkoy envisages to be used in these ways. He tries to define features mostly via their acoustic properties. Since at that time technology for acoustic analysis wasn't as developed as it is today, his feature labels are quite impressionistic at times. Also he doesn't entirely follow through with the acoustic grounding and still employs some articulatory descriptors.

Vowel place is defined by sound-quality impression as a basic distinction between bright and dark sounds, and the problem with many small vowel systems is that neither rounding nor backness can be identified as contrastive.

(16) Vowel place



In Russian, which has (more or less) a five-vowel system, backness depends on the preceding consonant, i.e., whether that consonant is palatalized or velarized. Rounding stays constant and is thus phonologically relevant (contrastive), whereas backness isn't, since it varies according to the environment.

Vowel height, one of the logically gradual contrasts, is broken down into two two-way distinctions in the case of languages that distinguish four levels of height.

(17) Ibo (Trubetzkoy [1939] 1971: 101)

broad	open	ɔ	a	4th	degree of opening
	closed	o	ɛ	3rd	
narrow	open	ʊ	e	2nd	
	closed	u	i	1st	

The language used as an example in (17) displays Advanced Tongue Root (ATR) harmony. In Trubetzkoy's system the active restriction then has to be that in a word all vowels have to be closed or all vowels have to be open.[9]

Surprisingly, in his analysis of Gweabo he uses different features, this time referring to sound quality rather than jaw opening for what might be analysed as a distinction between open and closed as well, as shown in (18).

(18) Gweabo

broad	'bright'	A	6th	degree of opening
	'muffled'	O E	5th	
medium	'bright'	ɔ ɛ	4th	
	'muffled'	o e	3rd	
narrow	'bright'	o̲ e̲	2nd	
	'muffled'	u i	1st	

Even though Trubetzkoy is aware of the interaction between consonantal place of articulation and vowel place in Russian, he develops an independent and entirely articulator-based set of consonant place of articulation, differentiating a base series of places that stand in heterogeneous multidimensional oppositions and can be used to distinguish three or up to six places, since each of the basic features can be used in an equipollent opposition with another feature that isn't part of the basic set labial, apical and guttural. The base series furthermore separates sibilants from apicals as a distinct localization series.

(19) Consonants: localization properties

a. Base series
guttural (dorsal) – apical (dental) – labial

b. Side series
labial: labial ≠ labiodental (e.g., Shona *p, b, β – p̌, b̯, v*)
apical: apical ≠ retroflex
guttural: anterior ≠ posterior

These additional features are referred to as 'side job series' (*Nebenarbeitsreihen*) and encode retroflexion, palatalization/velarization/labialization and clicks (*Schnalzkorrelation*).

Manner of articulation (or First-degree *Überwindungseigenschaften* 'transcendence properties') is divided into five correlations or contrastive distinctions. On the basis of Tamil data, Trubetzkoy argues the distinction between obstruents and sonants to be the most basic one.

Tamil has quite a big surface consonant inventory. Most consonants, though, can be identified as positionally determined, as indicated in (20). Aspirated stops are found in word-initial onsets where they only contrast with the sonorants in the bottom row, which apparently can occur everywhere (there is also a series of nasals in Tamil, but Trubetzkoy doesn't mention it). Fricatives and voiced stops occur only in well-defined positions, where we otherwise find son(or)ants. Trubetzkoy concludes that in Tamil aspiration, voicing and continuancy are phonologically irrelevant, i.e., not contrastive.

(20) Tamil consonants–sonant correlation (Trubetzkoy [1939] 1971: 135)

pʰ	tʰ	ʈʰ	cʰ	kʰ	Onset
β	ð	ʂ	ʃ	x	V__
b	d	ɖ	ɟ	g	N__
p	t	ʈ	c	k	r__
w	l	ɭ	j	ɹ	
					r

(21) Manner of articulation distinctions

Distinction a:	obstruent – sonant
Distinction b:	stop – continuant
Distinction c:	stop – fricative
Distinction d:	fricative – sonorant
Distinction e:	stop – sonorant

To cover the remaining contrasts among consonants found in the world's languages Trubetzkoy divides up the second-degree transcendence properties which cover basically laryngeal distinctions, geminates and the non-pulmonic obstruents.

(22) Second-degree transcendence properties

Correlation	Strong member of opposition	Weak member
Tenseness correlation:	fortis	lenis
Intensity correlation:	heavy	light
Voicing correlation:	voiceless	voiced
Aspiration correlation:	aspirated	unaspirated
Recursion correlation:	infraglottal	recursive
Resolution correlation:	explosive	injective

Whether the strong or weak member of such oppositions is the marked one is a matter that can only be decided on a language-specific basis. 'Whether the "strong" or the "weak" member of a second-degree transcendence correlation is the unmarked can only be concluded from the way in which the respective phonological system works' (Trubetzkoy [1939]1971: 141; my translation).[10] On the other hand he notes that in each of these oppositions one member is naturally marked by the presence of an articulatory gesture or acoustic property that the other one lacks. Thus, in a tenseness correlation the fortis consonant is the marked one, in an aspiration correlation the aspirated member is the marked one and for the voicing correlation the voiced member is marked. Accordingly, the division into strong and weak members doesn't correspond to marked versus unmarked.

For nasality, the articulatory criterion holds to determine the marked value since no cross-linguistic variation in markedness is observed.

Now that we have a set of features that can be used in the ways shown on the right side in (15) a side remark on the archiphoneme is in order. The archiphoneme, as said earlier, is assumed to be a third type of segment in a neutralizing position, consisting of all the remaining shared properties of two phonemes that contrast elsewhere with respect to the neutralized feature, such as /P/ in coda position as the archiphoneme of German /p/ and /b/. On the one hand Trubetzkoy argues that only phonemes in bilateral oppositions can have a common archiphoneme, on the other he says, as noted above, that in bilateral distinctions such as voicing the contrastive feature is used in a privative way, with a marked and an unmarked member of the correlation. For trilateral or multilateral oppositions an archiphoneme is an option, as for the place of articulation of nasals that share the place of assimilation with a following consonant but elsewhere are contrastively labial, apical, etc. (see, e.g., Anderson 1985 for a discussion).

Setting such details aside, the proposal of the archiphoneme shows nicely that Trubetzkoy actually distinguishes not only a phonemic and a phonetic level of representation but altogether three levels. Since the archiphoneme emerges in positions of contrast and some morphemes alternate in their surface form depending on the presence of other morphemes in the syntagm, the archiphoneme must be located at an intermediate level of representation, and not necessarily in the lexicon. Of course, in lexemes that never change, such as the example of English *sponge* /sPɔnd͡ʒ/, the archiphoneme /P/ can be present at the lexical level. However, in morphemes that display alternations, the situation is more complex. In morpheme-final voiced obstruents in languages with final-devoicing we have an alternation and contrasting stops such as German [ʀaːt – ʀɛːtə] ('councillor – councillors') versus [ʀaːt -ʀɛːdɐ] ('wheel – wheels'), which should be in a voicing correlation despite the neutralized archiphoneme in the singular forms. Thus, the model must have looked like (23).

(23) Trubetzkoyan levels of representation

Lexical	/Ra:d/	/Ra:t/
(Archi-)Phonemic	|Ra:T|	|Ra:T|
Phonetic	[ʀa:t]	[ʀa:t]

In summary, Trubetzkoy, identified contrast as the only phonologically relevant function, whereas variation and positional neutralization are used as criteria to diagnose underspecification. Trubetzkoy develops a large set of distinctive features and furthermore leaves their use as equipollent or privative in principle open as a language-specific choice. He develops a theory of markedness that distinguishes two criteria for markedness, the role of a segment class in a phoneme system and its articulatory properties compared to the other member of the opposition. Oppositions can be a relation between two segments or multidimensional, i.e., connecting several sound classes to a system of contrasts. Starting from the view of an inventory as a system, he also proposes an algorithm for the partly language-specific, partly universally parallel determination of contrastive relations and accordingly features for every language, a division algorithm. Thus, the structure of a phoneme and its phonetic realizations emerge from the nature of the system at hand.

2.4 THE JAKOBSON–HALLE PROGRAMME

Roman Jakobson and his associates (Jakobson 1939, 1941; Jakobson, Fant & Halle 1952, Jakobson & Halle 1956) continued Trubetzkoy's work by mainly focusing on three goals: first, tightening the definitions of contrastive features, boiling them down to a coherent set of articulatory, acoustic and perceptual definitions; second, reducing the set of contrastive features; and, third, reducing the values of features to binary choices.

The programme to develop an acoustic, perceptual and articulatory definition for each feature was driven by the insight that the same acoustic effect can often be achieved in several ways of articulation and, vice versa, the same articulation can result in different acoustic signals. On the other hand, language was seen as primarily a spoken medium, i.e., transmitted via sound, and the sound signal is the part both hearer and listener share in communication. If communication is intended to work, the speaker must be listener-oriented, i.e., take care that s/he produces a signal that the listener can map to the right phonemes and identify the intended morphemes. Thus, phonological features have to be grounded in the physical side of language.

The reduction of the number of features, however, also led to a higher degree of abstractness, since Jakobson achieved this through, among other things, unifying features for vowels and consonants. He argued that vowels and consonants are produced with the same articulators and should therefore also have the same features (the 'one-mouth principle'). This is an elegant move since it potentially explained the interactions between consonants and vowels in processes such as palatalization or pharyngeal harmony, in which consonantal (secondary) place of articulation depends on an adjacent vowel or vice versa. Higher abstractness furthermore results in that now the same feature could be used to express quite different types of contrast. For example, the feature [±flat], acoustically defined as 'exhibiting weakening or downward shift of the upper frequencies in the spectrum', is used to distinguish labial/rounded vowels from the other vowels as well as pharyngeals and retroflex sounds. In the end, Jakobson managed to reduce Trubetzkoy's set of over forty features to around a dozen binary features.

The concentration on binarity was based on the insight that the brain works in an on/off fashion. Neurons fire or they don't. Furthermore, Jakobson was enthusiastic about information theory, in which binarity and economy were central to achieve maximum compression of information.

We will come back to the issue of abstractness and the typological implications later on. For the moment, we start off with a look at the reduction of place features besides the introduction of [±flat].

As seen a few pages ago, Trubetzkoy had divided consonantal place of articulation into three major places (labial, apical, guttural), each of which divided into two subclasses with a different feature for each subcontrast (labiodental, retroflex and anterior vs posterior, respectively). Furthermore, vowels had their own place features, i.e., 'dark' and 'bright'. This is an impressive set and some of the features are defined articulatorily while others are defined perceptually/acoustically.

In the Jakobson–Halle system, labials and velars are separated from alveolars by the features [±grave] and [±acute], with [+grave] for labials and velars. [+grave] is defined as a concentration of energy in the lower frequencies of the spectrum, while [+acute] segments are characterized by a concentration of energy in the upper frequencies. Labials and velars were first distinguished by the articulatory features [±anterior] and [±posterior] and then by the acoustic features [±diffuse] and [±compact]. For the feature [+compact] the front of the resonating cavity has to be relatively large to create high energy in the middle of the spectrum, which can be achieved by raising the back of the tongue towards the velum, while [+diffuse] sounds have energy spread throughout the spectrum.

(24) A few Jakobson–Halle features

a. V-rounding: [±flat]
(also used for retroflexion, velarization, pharyngealization)
V-height: [±compact] (low), [±diffuse] (high)
b. Place: [grave] *p,k*; back vowels vs [acute] *t*; front vowels
p [grave, anterior/diffuse]
k [grave, posterior/compact]
t [acute, anterior/diffuse]

If we put this system into a chart we see that the three corner vowels *i, a, u* have exactly the same specifications as the three basic stops *t, k, p*, respectively, and one can arrange the stops in a triangle as is commonly done with the vowels.

(25) Jakobson–Halle feature chart for basic places of articulation

	p	t	k	i	a	u
[grave]	+	–	+	–	+	+
[acute]	–	+	–	+	–	–
[diffuse]	+	+	–	+	–	+
[compact]	–	–	+	–	+	–

Apart from the shared spectral characteristics, Jakobson distinguished the velar and the labial as one class from the coronal, because of some historical changes such as the Romanian change of /k/ to /p/ before /t/ and /s/, as in *direct* -> *drept*. This is analysed as /k/ swapping [posterior] for [anterior] and keeping [grave].

In palatalization before front vowels, /k/ trades [grave] for [acute] and keeps [diffuse].

Further place distinctions are made via [strident] (noisy release). [strident] distinguishes labials from labiodentals, dentals from alveolars and velars from uvulars.

Jakobson didn't have a theory on how to link the abstract lexical, the archiphonemic and the surface representations. In Trubetzkoy's model, alternations were to some extent already built into the representation with the archiphoneme (recall final devoicing and the use of the archiphoneme to represent those morpheme-final obstruents that are voiceless when in final position on the surface but voiced when followed by a vowel). Jakobson captures, especially, non-structure-preserving neutralization by defining features relatively. Danish, for example, displays a chain-shift, in which the voiceless aspirated stops are realized as voiced in final position, while the voiced series is realized as a voiced fricative or approximant.[11] For Jakobson, part of the definition of the features [tense] and [lax] was the specification of their respective realizations in different positions, as indicated in (26).

(26) Relatively defined features in Danish

Initial	Final	relatively
[t]	[d]	[tense]
[d]	[ð]	[lax]

Despite the acoustic definitions of features, representations are thus quite abstract, since the same phoneme can be phonetically realized in different ways in different positions, the same surface phone doesn't have to be the same phoneme in two languages that display it and the same feature can be used for different types of oppositions in different languages (see the multifarious use of the feature [±flat]).

Jakobson developed the theory of phonological representations considerably. The changes he introduced can be summarized as follows:

- Articulatory, acoustic and perceptual grounding of features
- Result: acoustic descriptors as feature labels

- Reduction of feature inventory from below forty to around twelve
- Unified features for vowels and consonants
- Reduction of feature value types to one: binarity
- Inclusion of variation/alternation in representations

On a different note, Jakobson criticizes Saussure's strict separation of synchrony and diachrony. This (among other things) leads to excessive abstractness in Jakobson's successors' works (Halle and his associates), which we will discuss in the next section and in Chapter 3.

Jakobson's theory was criticized for several reasons. On the one hand, the high level of abstractness of features and the many ways in which some can be realized remove the contrastive features not only very far from the signal, they also make predictions about the co-occurrence of contrasts within languages that aren't necessarily borne out. The assumption of the feature [±flat] predicts that retroflexion and pharyngealization cannot occur in one language and if a language has one of these contrasts plus an allophonic rule that creates retroflexed or pharyngealized vowels in the respective context, it can't have a series of contrastively rounded vowels. Actually, such patterns and contrast coexist very rarely if at all and the typological situation still needs further examination. The features only determine contrastive characteristics of segments and do this in a very abstract way, which means that a lot of phonetic information that is present on the surface and that needs to be specified at this level, since its properties are not universally automatic, has to be added somehow and the theory doesn't provide a means to do this, such as feature-filling rules/redundancy rules. Writing positional variants and alternations into every lexical entry is redundant if one can capture that in a mechanism that links phonemic and surface representations, such as transformational rules. With an apparatus that provides the mapping, fills in redundant features and determines positional variants one can dispense with the archiphonemic level of representation and just assume a lexical representation and the surface phonetic representation (or the surface phonological representation that can be phonetically interpreted). Finally, Jakobson simply went beyond the goal in reducing the set of features to its absolutely necessary primes. The set of features that distinguishes places of articulation captures the systems of most known languages, but some languages have elaborate contrasts that cannot be analysed with the available features (see Anderson

1985: 124 for a very illuminating and concise discussion of the challenges to Jakobson and Halle's theory).

2.5 THE SPE FEATURES

The theory of features received a major overhaul with Chomsky & Halle's *The Sound Pattern of English* (*SPE*) and most of the features proposed there are still accepted and used in mainstream phonology at the time of writing. A major motivation behind the changes in theory was that Jakobson's system, with its impoverished set of features, didn't capture enough contrasts, it didn't predict the correct relations between contrasts and didn't make the right predictions about class behaviour, about consonant–vowel interactions.

SPE features were mostly defined in articulatory terms, though some are acoustic or aerodynamic. While Chomsky & Halle claim at one point that this shift towards articulation is a matter of convenience rather than an active decision against acoustic/perceptual definitions, they also point out that, in the Jakobsonian framework with relational features defined acoustically relative to the phonetic environment, it is difficult to actually determine an acoustic parameter for each feature.

To illustrate the shift we will have a brief look at place features. Recall the place features [grave/acute] and [compact/diffuse] from the previous section. With these features it is difficult to analyse languages with more complex distinctions in place of articulation and it is hard to explain why usually the coronal zone is split up into several contrasting places of articulation (e.g., dental, alveolar, retroflex, palato-alveolar).

Chomsky & Halle return to Sievers' (1901) features referring to the active articulator. Among place features this affects most dramatically the feature [grave] which is replaced by [coronal]. Every segment that was [+grave] is now [−coronal] and vice versa. However, this change only affects the analysis of place of articulation systems in combination with the other features. The feature [diffuse] is replaced by [anterior]. The big difference in classification comes in with the tongue body features [high], [low] and [back] and the further place features [posterior] and [distributed].

Apart from their obvious function in the distinction of vowels, the tongue body features are used to analyse secondary articulations, palatalization, pharyngealization and velarization, respectively, in coronal consonants.

While [posterior] is antagonistic to [anterior], [+distributed] refers to the distribution of the actively involved articulator along the passive articulator and [–distributed] to a punctual approximation of the passive articulator. The only active articulator that can execute such a distinction is the tongue and especially the blade of the tongue, the corona.

(27) Basic places of articulation in *SPE* features

	anterior	coronal	distributed
velar	–	–	–
labial	+	–	–
alveolar	+	+	–
dental	+	+	+
retroflex	–	+	–
palato-alveolar	–	+	+

In practice the system allows palato-alveolars to be analysed as given at the bottom of the table in (27). However, Chomsky & Halle don't use the feature [distributed] to distinguish palato-alveolars from the other coronals. Since they are often the result of palatalization processes they are distinguished by [+high], which is the feature used to describe secondary palatalization as well. The other two vocalic place features are additionally used to distinguish the places of articulation in the back of the oral tract, i.e., velar, uvular and pharyngeal, as indicated in the first rows of the table in (28).

The table in (28) shows the places of articulation as captured in feature values. Secondary articulations are only illustrated for labials here, though the respective tongue body feature values can be combined with the non-anterior segments as well.

(28) *SPE* place system

	anterior	coronal	distributed	high	low	back
pharyngeal	–	–	–	–	+	+
uvular	–	–	–	–	–	+
velar	–	–	–	–	–	–

(*continued*)

	anterior	coronal	distributed	high	low	back
labial	+	–	–	–	–	–
palatalized labial	+	–	–	+	–	–
(?) uvularized labial	+	–	–	–	–	+
pharyngealized labial	+	–	–	–	+	+
alveolar	+	+	–	–	–	–
dental	+	+	+	–	–	–
retroflex	–	+	–	–	–	–
palato-alveolar	–	+	–	+	–	–

As in Jakobsonian feature theory, all phonological features are binary because of their classificatory or categorial function. A segment either belongs to a class of segments or it doesn't (Chomsky & Halle 1968: 297). The contrastive features of phonology work in the same way as the categorizing features of syntax, which also only encode oppositions, such as [±verb] and [±nominal], which distinguish all major syntactic categories, or [±plural], [±past tense], etc. Chomsky & Halle draw a strict line between binary phonological features and scalar phonetic features (e.g., degrees of aspiration). Thus, at the phonology–phonetics interface all features have to be 'translated' into their scalar phonetic counterparts.

2.6 CONCLUDING SUMMARY

In this chapter we took a first look at the atomic building blocks of underlying representations and phonological segments in general. We have seen how the distinction between underlying phonological representations and surface representations developed and reviewed the arguments for the increasing abstractness of phonological features.

The arguments for abstractness and underspecification in underlying forms are twofold. Phonological features have two major functions, the distinction of phonological primes, i.e., contrast, and the ordering of segments into (natural) sound classes. As far as the contrastive function is concerned, a central observation was that contrasting segments have a tendency to group into opposing pairs (such as nasal and oral, voiced and voiceless, etc.).

Some contrasts are not binary oppositions at first sight, such as places of articulation, which seem more like cut-off points on a scale or line. However, in the formalization of contrast the categorizing function (member of a group or not) and parsimony dictate that in an optimally economic theory all features are binary oppositions. In these early theories binarity was formalized as positive and negative values for each feature. Trubetzkoy already envisaged a different way to encode such two-way distinctions, namely by privative features, which are either present or absent in a segment. In Chapter 7 we will come across feature theories that exploit this type of feature to the fullest, assuming privativity rather than binarity for all features. However, since the aim of this chapter was not to provide an overview of theories of phonological features but rather develop the notions of contrast and underspecification, introduction of additional theories of phonological features has to wait until we are in a position to come back to the contents and definitions of features again in Chapter 7. Structuralist and taxonomic phonemic theories of contrast will not be discussed here. The interested reader may consult some of the suggestions for further reading given below.

For the moment, it is sufficient to note that, given the primary functions of contrast and categorization, features could in principle be abstract arbitrary labels. Imagine you use colours to get some order into the folders and files of your desktop. Any colour does the job and the different basic colours divide the files and folders into major groups (e.g., work, friends, food, money); subdivisions in the folders can be marked by shades of the same colour or unrelated arbitrary symbols, like triangles versus squares versus circles. The latter could be reused in every colour category, etc. The scholars we have discussed so far did not go down that route for good reasons. Most fervently Jakobson emphasized what he thought was the primary function of language in connection with the issue of the definition of contrastive features: we speak to be heard and the medium of speech is sound produced with our respiratory and mastication organs, which happen to overlap physically. Purely abstract arbitrary features need a complex transduction device, in the frame of rule-based generative phonology, which we will discuss in the next chapter. This can be captured in rules that map meaningless symbols to physical correlates. It is thus more parsimonious to define features by their physiological correlates directly (rather than invent a completely new and meaningless set). This is by and large the reasoning for departing from Saussure's assumption of radical arbitrariness at least in this aspect of language.

In generative phonology, which we will discuss in the next chapter, more attention is paid to morphophonological alternations than was the case in structuralist approaches, since generative phonology has a more explicit means of capturing generalizations about alternation-inducing processes and linking underlying and surface representations. We have seen above that such alternations, such as the word- or syllable-final lenition of obstruents in Danish, lead to very abstract and relational definitions of features in Jakobson's framework. Accordingly, Chomsky & Halle could readjust definitions of features to be related more directly to the phonetics and abandon the phonemic or archiphonemic level, following Halle (1959). This issue will be discussed in more detail in the following chapter.

If all that is needed in the storage of words and morphemes are the contrastive features that distinguish segments and, accordingly, also morphemes from each other and classify segments into sound classes (which can be turned into realization instructions for the articulators), all the remaining detail of the phonetic signal can be discarded. Thus, in principle, underlying representations can be much leaner than surface representations. Even some of the contrastive features are dependent on other contrastive features and can accordingly be discarded in abstract representations. However, to do so a theory is needed that connects the different levels of representation and fills in the missing feature values. This will be the focus of attention in the next chapter. The issue of abstractness will be discussed from a completely different angle in Chapter 5 in which we consider the option to deny the existence of abstract categorial features. Evidence for categorial features and underspecification will be presented in Chapter 6. Chapter 7 comes back to the question of the nature and definitions, i.e., the contents of features.

DISCUSSION POINTS

- Discuss the pros and cons of categorial features.
- Should the determination of the contrastive features of a language rely exclusively on minimal pairs? Which other evidence or criteria could be relevant?
- Which alternatives to binarity are there? Discuss options.
- Why should features be defined in articulatory, perceptual, acoustic terms? Can you imagine alternatives?

SUGGESTIONS FOR FURTHER READING

Anderson, Stephen R. (1985). *Phonology in the Twentieth Century*. University of Chicago Press. Chs. 6–11.

Dresher, B. Elan (2011). The phoneme. In Marc van Oostendorp, Colin J. Ewen, Elizabeth Hume & Keren Rice (eds.), *The Blackwell Companion to Phonology*. Oxford: Wiley-Blackwell.

Jones, Daniel (1967). *The Phoneme: Its Nature and Use*, 3rd edn. Cambridge: W. Heffer & Sons.

3 Derivation and abstractness

3.1 INTRODUCTION

In the development of generative phonology from structuralism the most dramatic shift in paradigm was the focus on a transformational component that turned underlying highly abstract representations into surface representations with all feature values present. As noted in the previous chapter, morphophonological alternations were built into the representations in earlier models, which caused the representations to become somewhat complex, while generalizations got lost and the distinctive features became increasingly abstract since their phonetic derivatives had to be defined in relation to phonetic context. Moreover, structuralism distinguished the lexical representation from a phonemic or archiphonemic level, the one that includes the alternation space of a phoneme, i.e., its allophones. Furthermore, the biuniqueness condition was proven to be an inappropriate condition on the relation between allophones and phonemes. It was these two theoretical assumptions, the archiphonemic level and biuniqueness, that were challenged by early generative studies and replaced by an apparatus of ordered rules that freely transform a phoneme into its contextual allophones.

The transformational component also took over some changes of a historical nature. Saussure's strict separation of diachrony and synchrony, already criticized by Jakobson, got even more blurred. Accordingly, the machinery was used to establish underlying representations that were far removed from surface structures and linked to them by an intricate system of transformational rules. In this chapter we examine the development of this rule component and the effect these rules had on what was believed about underlying representations. These rules were basically of two types, proper phonological rules, which capture phonological alternations in morphological paradigms and which are expected to be of maximal generality, and redundancy rules, which capture static patterns, speaker intuitions on well-formedness that cannot be boiled down to proper phonological rules, and which supply feature values for predictable features or unmarked values.

3.2 LINKING LEVELS OF REPRESENTATION

With the development of a formalism for the statement of phonological processes and generalizations as rules, the attention shifted from the contrastive function of phonology to a discussion of the dynamic aspects of phonological systems. Morphophonemic alternations, an area barely touched upon for example in Trubetzkoy's work, from now on to a large extent determined the development of phonological theory. However, the shifting focus and the tools for analysing phonological patterns also had consequences for the determination of underlying representations and the assumptions made about them.

Halle's (1959) killer argument for generative phonology circled around voicing alternations in Russian and the archiphoneme and the biuniqueness condition.

With a simple phonological rule, as given in (1), it is possible to state the assimilation of the voicing value of obstruents to the adjacent following obstruent in one go, identifying it as one phonological process.

(1) Voicing assimilation rule

$$[+\text{obstruent}] \rightarrow [+\text{voice}] / \_\_ \begin{bmatrix} +\text{obstruent} \\ +\text{voice} \end{bmatrix}$$

Voiceless clusters emerge automatically as a result of the final devoicing rule, which also applies in Russian.

Such an analysis is more parsimonious than the earlier structuralist analysis of the same pattern in two ways. We have seen before that Trubetzkoy would have assumed an archiphoneme at some level for a segment which gets neutralized with respect to a contrastive feature in a certain context and Jakobson also would have built the alternation into the representation of the morpheme's phonemic structure, as structuralism in the 1950s would have done. Now, if a phonological process doesn't only neutralize a contrastive feature in a certain context but also creates segments that are not contrastive, the process has to be decomposed into two separate parts in structuralist or phonematic approaches. Halle's crucial example is given in (2). While the alternants [k] and [g] in (2a) are also two contrastive segments in

Russian, i.e., the contrast between voiced and voiceless stops is neutralized in the assimilation context, the voiced and voiceless palatal affricates in (2b) are not contrastive elsewhere and can thus be analysed as two allophones of one phoneme.

(2) Halle's Russian example

a.	[m'okl'i]	'was (he) getting wet?'
	[m'ogbɨ]	'were (he) getting wet'
b.	[ʒ'et͡ʃl'i]	'should one burn?'
	[ʒ'ed͡ʒbɨ]	'were one to burn'

The development of a sophisticated theory connecting the different levels of representation has repercussions for our understanding of underlying representations. While previously contrast was the most important aspect of representations, now the determination of underlying forms is subordinated to the goal of finding the most elegant and most parsimonious analysis of the observed patterns and processes, formalized as transformational rules. Analyses in such a formalism can be evaluated according to evaluation metrics for theory construction (e.g., one can count the number of symbols used in a rule or assess the generality of a rule or compare grammars and determine their relative complexity).

At first sight this looks as if underlying representations become less abstract in consequence. The phonematic or archiphonemic level between the underlying or lexical representation and the surface or phonetic representation can be abandoned and features don't have to be defined relatively anymore either, i.e., in relation to their phonetic realization in different positions, as in the Danish example discussed in connection with Jakobson's contribution. The underlying obstruents in Danish now can be assumed to have a feature in their underlying form that is changed by a rule sensitive to the lenition context.

3.3 THE ABSTRACTNESS DEBATE

There are, however, two aspects of the theory that eventually led to much more abstract representations and to a debate about abstractness in phonology. First, a grammar is a set of rules that transform an underlying representation into a surface representation. Accordingly, rules can interact and feed each other, i.e., the output of one rule provides or destroys the context for the next rule to apply. A rule that applies later in the derivation can also create or destroy the context of a rule that has already applied earlier on in the derivation. Accordingly, phonological generalizations don't have to be surface-true, they might hold just at some abstract point in a derivation. This opens the door to a rule-based analysis of a lot of patterns that apply inconsistently. Second, a rule applies automatically whenever the context for the rule is given. This statement needs further qualification: A rule only applies if its context is present in a representation at the point in the derivation at which the rule is expected to be operative. Some rules, though, can be specified such that they reapply several times during a derivation. In some versions of generative rule-based phonology the derivation is divided into levels or cycles and rules can differ in whether they are present in only one of these compartments or in all of them. Given such a stratification, rules can also be regarded as unordered and simultaneously apply within a stratum/level.

The automaticity of application raises the option that forms take free rides on rules. A rule is assumed on the basis of an observed alternation in a paradigm. Once the rule is there all non-alternating forms that look like the output of this rule can be assumed to have undergone the change the rule brings about, and thus the underlying form of these morphemes is assumed to deviate from the surface form even though this morpheme never shows its underlying form on the surface. To illustrate what I mean by a free ride, we will have a short look at trisyllabic shortening in English. This process causes an alternation between a diphthong and a short lax vowel, as in (3a). (We will come to the other examples shortly.)

(3) English trisyllabic shortening

a.	sublime	– sublimity	/sVbli:m/	→ [səbláim] – [səblɪ́mɪti]
	opaque	– opacity		
	table	– tabulate		
b.	slime	*sl[ɪ]mulate	?/sli:m/	→ [slaim]
c.	ivory	*[ɪ]*vory*	?/i:vorj/	→ [aivəri]
	nightingale	*n[ɪ]ghtingale	?/nixtVngael/	→ [naitɪŋgeil]

Now one could argue that the underlying diphthong is contracted to a high lax vowel or, vice versa, an underlying high lax vowel is expanded to a diphthong. A historically and typologically informed analysis draws on the fact that historically the words in question had a long tense high vowel, which we still find in other Germanic languages today, that didn't go through the same vowel shifts as English did in its history. This points to another issue that led to increasing abstractness of underlying forms: the analyst's knowledge of the subject language's past states. For an alternating morpheme such as that in (3a), we can thus postulate an underlying /iː/, which is realized either as a diphthong or a lax high vowel, depending on how many syllables follow (broadly speaking). These realizations are determined by rules that apply in the respective prosodic contexts. The rule that creates [ai] in *sublime* now can be assumed to have applied to all surface appearances of [ai] in the same prosodic environment (the free ride). Accordingly the [ai] in words like *slime* that always surfaces with a diphthong can be assumed to be underlying /iː/. The analysis has a domino effect: some of these forms need further amendments to their underlying representation, because now that they have an underlying /iː/ one expects them to undergo the same changes as all the others, but some of them don't, such as the surface [ai] in *nightingale*, which escapes trisyllabic laxing. In addition, all surface appearances of long /iː/ in the same context (as in *squeeze* or *beat*) have to be derived from another underlying vowel, since rules apply automatically and therefore apply to every underlying /iː/. As you can see in (3b,c), this leads to underlying representations that are quite remote from the surface form.

At this point we can split up abstractness into two aspects. Excessive interactions of rules (i.e., long derivations) are more abstract than derivations in which only few rules apply between an input and the output of a grammar. Apart from this kind of distance between input and output, the structural differences between an input and an output can be used to evaluate abstractness.[1] The latter cannot only arise by analyses of neutralization rules, but also through the application of economy principles, which justify the elimination of redundant feature values. Since there has been general agreement since the 1950s that surface representations are fully specified for all features, these missing values had to be filled in by some mechanism, redundancy or morpheme structure rules. We will discuss this latter aspect of underspecification later in this chapter.

The excessive abstractness, which can be quantified by the structural difference between surface and underlying representation and brought about by the automatic application of neutralization rules, was subject to intensive discussion already in the late 1960s and 1970s and several principles were introduced to rein in abstractness of phonological analyses. Most prominently featured was the Alternation Condition and its various revisions (Kiparsky 1968/1973a), which is closely related to the Strict Cycle Condition.[2]

(4) Revised Alternation Condition

Obligatory neutralization rules apply only in derived environments.

The Alternation Condition separates the examples in (3a) from those in (3b,c) by stating that such neutralizing rules only apply to derived forms. You might have noted already that the right-hand forms in (3a), the ones that have undergone trisyllabic shortening, are all morphologically derived from the forms to their left while we have no such relations in (3b,c). Without such a principle one would have had to either assume dramatically different underlying representations or mark the exceptional items with an arbitrary tag that indicates that they are exempt from the shortening rule.

Kenstowicz & Kisseberth (1977) discuss a set of principles according to which one could restrict the abstractness of underlying representations, which in a way recapitulates the discussion at that time, and end up with one that keeps underlying representations relatively close to the surface form (at least compared to the competing underlying representations they discuss – we will see much more phonetics-heavy proposals in Chapter 5). Their arguments rely, first, on the assumption that phonological features are phonetic in nature (like the Jakobsonian and *SPE* features) and, second, on phonological alternations observed in morphemes when brought into different morphosyntactic contexts and by this also into different phonological contexts. Their conclusion is that the content of the underlying representation of a morpheme has to be present in surface forms even if the bits are spread across different realizations of the morpheme.[3] These principles are intended as hard constraints and are supposed to be valid on underlying representations cross-linguistically. They all embrace the basic assumption that phonological segments are specified only for idiosyncratic properties, i.e., contrastive features, and all predictable information is stripped off. We cannot go through all the potential constraints they discuss here, but it is instructive to have a look at the major ones.

(A) The UR of a morpheme consists of all and only the invariant phonetic properties of a morpheme.

This statement about underlying representations has several unwanted consequences. First of all, it requires that redundant phonetic information, such as the voicing of sonorants, is stored as well. Second, it leads to something very similar to archiphonemic underspecification. In a language with a voicing contrast and final devoicing, the morpheme-final obstruents that show an alternation in different case forms, such as Russian 'bread' *xlep* (nom.sg.) – *xlebu* (dat.sg.) – *xleba* (nom.pl.), have to be underspecified for [voice], because they are not invariant across forms, while in a word like 'skull' *tʃerep* – *tʃerepu* – *tʃerepa* the final obstruent is specified as [–voice]. With these underlying representations one needs a grammar that fills in the right voicing specifications in morphemes like 'bread' and doesn't change them in 'skull'-type words. If one assumes underlying /xleb/ and /tʃerep/ one only needs a rule that changes word- or syllable-final voiced stops to voiceless.

(B) The UR of a morpheme includes those variant (alternating) and invariant phonetic properties that are idiosyncratic (unpredictable). But it may include only those variant properties that occur in the PR that appears in isolation (or as close to isolation as the grammar of the language permits).

There is a good argument for taking the morphologically least complex form as the basic form. It is usually morphosemantically simpler as well. Moreover, the blocking of phonological processes occurs in paradigms often to maintain closer identity of derived forms with some base form. However, as a dogma to determine underlying representations this restriction produces odd results. For our Russian 'bread' we get the same counterintuitive underlying representation as with principle (A). The morphologically simplest form is the nominative singular, which is the one with final devoicing. Accordingly, one has to assume a rule of intervocalic voicing to derive the voiced [b] in affixed forms and lexically mark either all morphemes that show a voicing alternation or all morphemes that have a consistently voiceless final stop for exceptional application of the rule or exceptional blocking of the rule. Thus, with this constraint on underlying representations we need arbitrary non-phonological information in the underlying representations.

A common method for determining the underlying form or basic phone of two allophones is to select the one that occurs in most contexts. Here, context refers to phonetic/phonological context. Kenstowicz & Kisseberth discuss a twisted version of this, reminiscent of methodologies relying on frequency of occurrence. Although here it is not the most frequent form that is selected, but the one that occurs more often in the paradigm.

(B') The UR of a morpheme includes those variant and invariant phonetic properties that are idiosyncratic. But it may include only those variant properties that occur in the greatest number of 'contexts'.

For our Russian example we get the right result. The voiced stop [b] occurs in all forms of 'bread' inflected for case or number. The devoiced [p] occurs only in the nominative singular. However, we get a problem with some other Russian nouns. Russian displays vowel neutralization in unstressed syllables. The vowels *o* and *a* only contrast when stressed. In unstressed position they merge into [a]. In many nominal forms inflected for case the stress shifts from the root vowel in the nominative to the affix vowel, as shown for the words *stol* 'table' and *vrak* 'enemy' below.

(5) Russian vowel reduction and case marking

a.		singular	plural	b.	singular	plural
	Nominative	stól	stal-ý		vrák	vrag'-í
	Genitive	stal-á	stal-óf		vrag-á	vrag-óf
	Dative	stal-ú	stal-ám		vrag-ú	vrag-ám
	Accusative	stól	stal-ý		vrag-á	vrag-óf
	Instrumental	stal-óm	stal-ám'i		vrag-óm	vrag-ám'i
	Locative	stal'-é	stal-áx		vrag'-é	vrag-áx

The majority of the surface forms of 'table' contain an *a*. Accordingly, we pick /stal/ as the underlying form and assume a rule that turns this /a/ into an [o] if it is stressed. Now either words with an *a* in stressed position (such as example b) or the morphemes showing the alternation have to be indexed for the blocking or application of the rule, respectively. Again, we need arbitrary non-phonological information in the underlying form.

If one can't determine the underlying form by 'majority vote' one needs another constraint to find it. One could at least expect to be able to pick out one surface form as the underlying form. This hope is reflected in the next candidate for principled determination of underlying representations.

(C) The UR of a morpheme includes those variant and invariant phonetic properties that are idiosyncratic. But all of the variant properties assigned to the UR must occur together in at least one phonetic manifestation of the morpheme. This manifestation can be referred to as the *basic alternant*.

This restriction becomes interesting in cases where we have several phonological processes at work in the same morpheme. Usually these different processes apply in different forms, though. In our Russian examples, final devoicing applies in the singular. Stress shift and accompanying vowel reduction apply in other case forms. Accordingly, we expect cases where we see the underlying consonant on the surface but not the underlying vowel and vice versa. The question is whether we always get one form in which we observe both on the surface. Words like those in (6) are problematic, because the idiosyncratic /o/ and /e/, in the respective words, only surface in the nominative singular, which has a derived voiceless final obstruent. In the forms in which the obstruent surfaces as voiced, stress is on the suffix and the (second) vowel in the stem is neutralized.

(6) More Russian vowel reduction, stress shift and final devoicing

pirók	pirag-á	'pie' (nom.sg./gen.sg.)
sapók	sapag-á	'boot' (nom.sg./gen.sg.)
b^jét	b^jidá	'woe' (gen.pl./nom.sg.)
b^jék	b^jigóm	'run' (nom.sg./instr.sg.)

Thus, to have the right vowel in the underlying representation one would use the form in the left column as the base form and to have the right final consonant in the underlying representation one would select the form in the column to the right. However, there is no form in the paradigm that shows the underlying vowel *and* the underlying consonant.

Since condition (C) is too strong, Kenstowicz & Kisseberth relax it to a statement that requires all the underlying feature specifications of a morpheme to be realized somewhere in the paradigm, but not necessarily all in the same form.[4]

(D) The UR of a morpheme includes those variant and invariant phonetic properties that are idiosyncratic. Given a morpheme with the underlying shape $/P/_i$, $/P/_j$,…$/P/_n$, there must be a $[P]_j$ (where $[P]_j$ is one of the phonetic realizations of $/P/_j$) such that $[P]_j$ contains all of the feature specifications of $/P/_j$.

The data that can prove this constraint inappropriate/too restrictive are cases in which a segment can be shown to be present underlyingly in some morphemes in a language but never surfaces. Yawelmani (Newman 1944, nowadays usually referred to as Yowlumne) provides just such a scenario. Yowlumne has a process of height-dependent backness harmony. Suffix vowels only change their backness specification in accordance with the preceding stem vowel if that vowel is of the same height as the suffix vowel.

Yowlumne has five vowels that distinguish two heights, high (*i* and *u*) and non-high (*e, o, a*). It also has a length distinction, but the high vowels are always short. Since some stems with long *e* and with long *o* don't trigger harmony in following affixes with low vowels, these long vowels are suspected to be the missing underlyingly high long vowels that get lowered after vowel harmony has applied. (7a) exemplifies the harmony pattern with short vowels in the stem. The vowel in the affix can have a backness specification that doesn't match the backness of the preceding stem vowel if the two vowels are different in height. In (7b) we see two stems with a long *o*. However, they do not behave in the same way. The first one causes assimilation in the low vowel in the dubitative suffix and has no effect on the high vowel in the passive suffix, just like the short *o*. The second long *o* causes the high vowel in the passive suffix to materialize as a back vowel, in violation of the height condition on harmony, and has no effect on the low vowel in the dubitative suffix even though they are both low.

(7) Yowlumne vowel harmony

	non-future passive	dubitative	
a.	xat-it	xat-al	'eat'
	xil- it	xil-al	'tangle'
	bok'-it	bok'-ol	'find'
	dub-ut	dub-al	'lead by hand'
b.	do:s-it	do:s-ol	'report'
	c'o:m-ut	c'o:m-al	'destroy'

Either the morpheme for 'destroy' gets an arbitrary lexical mark that triggers harmony in affixes of opposing height and blocks harmony in affixes of the same height, or the forms are stored wholly as they are, or 'destroy' has an underlying high vowel. This high vowel causes harmony in suffixes with a high vowel and then the vowel in the stem is lowered. When the stem vowel turns into a low vowel the dubitative morpheme has already been added and harmony didn't apply because at the point at which harmony should have applied the two vowels were of different height.

(8) Yowlumne underlying long high vowels and serial rule application

Input	/do:s -it/	/do:s -al/	/c'u:m -it/	/c'u:m -al/
harmony	n.a.	do:s-ol	c'u:m-ut	n.a.
lowering	n.a.	n.a.	c'o:m-ut	c'o:m-al
Output	do:sit	do:sol	c'o:mut	c'o:mal

Kenstowicz & Kisseberth champion this analysis in which there is a vowel in the Yowlumne system that never surfaces. Thus there is no surface form of the morphemes with underlying high vowels and accordingly principle (D) has to be rejected as too strict.

There are plenty of less dramatic cases (not discussed by Kenstowicz & Kisseberth), involving contrastive segments that are part of the surface inventory but which never surface in certain morphemes in which they are generally assumed to be present underlyingly. Take for example morpheme-final voiceless alveolar stops in some varieties of English. These stops never surface. In word-final position they surface as glottal stops or glottalized/ejective alveolar stops, as in *hit* [hɪʔ]/[hɪt̚]/[hɪˀt̚]. If followed by a suffix they are realized as flaps, as in *hitting* [hɪɾɪn], or, in faster speech, as glottal stops if the following vowel is elided [hɪʔn], in parallel with the pattern in words like *button* [bʌʔn]. Thus, while /t/ surfaces as an aspirated or unaspirated voiceless alveolar stop in other positions in other morphemes, such as the initial *t* in *toad* or *stout*, in the morphemes in which it is in final position the /t/ doesn't surface at all. However, the flap is not contrastive in these varieties and derives only from underlying *t* and *d*. The glottal stop is not part of the set of contrastive segments either. All glottal stops can be predicted as epenthetic or the result of debuccalization. The voiced alveolar doesn't glottalize in final position. Furthermore, rules that turn an underlying flap into a glottal stop or vice versa aren't very plausible, while a change from /t/ to a surface flap as well as the change from /t/ to surface glottal stop are independent natural changes in the respective contexts. So, if the final segment in *hit* shouldn't be stored as a glottal stop, to keep these out of the English lexicon, it can only be a /t/ underlyingly. This results in quite a few morphemes in the English lexicon with a final /t/ that never surfaces. To (a) capture the generalization and (b) keep glottal stops and flaps and other predictable structure out of the lexicon, one can set up a set of rules that turn intersonorant coronal stops into flaps (as in *ride–riding* [ɹaɪd–ɹaɪɾɪn]) and word-final and pre-nasal voiceless stops into glottal stops. Under the assumption that rules apply automatically, i.e., they are used whenever their context is met, these rules can be extended to apply to non-alternating forms such as *button* [bʌʔn] and *bottom* [bɑːɾm] as well, yielding underlying /bʌtn/ and /bɑːtm/.

Applying principle (D) to the *hit–hitting* alternation, we would have to either choose the glottal stop, the glottalized coronal or the flap as the final underlying consonant. Either way one would have to set up at least one unnatural rule that isn't independently attested elsewhere (flapping of intervocalic glottal stops or glottalization of word-final flaps).

Since (D) is too restrictive, Kenstowicz & Kisseberth provide a more abstract version of (D), reproduced here in (E).

(E) The UR of a morpheme includes those variant and invariant phonetic properties that are idiosyncratic. Furthermore, given a morpheme with the UR $/P/_i$, $/P/_j$,. . .$/P/_n$, for all $/P/_j$, it must be the case that each feature value of $/P/_j$ occurs in a $[P]_j$ (though not all of the feature values are required to occur together in the same $[P]_j$).

If we return to Yowlumne and its long high vowels we see that the feature [+high] doesn't surface in a single form in the data we have looked at so far. However, these vowels do surface as high in shortened form. Yowlumne long vowels are shortened when followed by more than one consonant. Thus, if the root /c'u:m/ is combined with an affix that starts in a consonant, such as the nonfuture *-hin* the stem vowel triggers harmony, gets lowered and is then shortened, resulting in the form *c'omhun*. Another form in which the vowel is shortened is the extension to a bisyllabic stem, as in *c'umo-hno:l-* 'place of x's being destroyed'. Here we see the high vowel surface. Thus, in the last form we get the feature [+high], while in other forms we get the length, and now we can put them all together into an abstract high long vowel.

Similarly the *hit*–*hitting* alternants are not really a problem anymore, since the glottal(ized) stop displays [−voice] and the flap shows [coronal] place of articulation (and maybe both can be characterized as [−continuant]). However, we boldly extended the analysis to forms that display glottal stops or flaps that never change (*bottom* and *button*). For the latter one can't make use of principle (E) unless they include the flap or glottal stop, respectively, in their underlying representation.

Kenstowicz & Kisseberth discuss another aspect of Yowlumne for which this principle turns out to be too strong. Yowlumne has a suffix, which is realized either as *-en* or *-on*. However, it does so with the wrong hosts and shows harmony only with high stem vowels and with the derived low vowels (the underlyingly high long vowels). Accordingly, Kenstowicz & Kisseberth conclude that the underlying form of the suffix is /-i:n/ or /-u:n/, containing a high long vowel. Since the suffix ends in a consonant, the vowel is always in a closed syllable and shortened according to the general shortening rule. Before that, but after the application of vowel harmony, it is lowered according to the rule lowering the high long vowels. This morpheme's vowel never displays length but has to be assumed to be underlyingly high and long since otherwise one has to introduce arbitrary lexical markings to explain its erratic behaviour in the harmony pattern.

As with the previous constraints, Kenstowicz & Kisseberth go through several examples that all show internal evidence for the postulation of underlying feature specifications that only show their presence indirectly at the surface level. We skip these here and move on to the next option, which abandons the restrictiveness of the previous attempts, as they all turned out to face problems with internal evidence for underlying contrastive features that either never surface or never surface together in one form.

(F) Given a morpheme with the UR $/P/_i$, $/P/_j$,. . ./P/$_n$, for all $/P/_j$, at least one of the features of $/P/_j$ must occur in a corresponding $[P]_j$ of at least one PR of that morpheme.

In this context Kenstowicz & Kisseberth discuss postnasal *g*-deletion in English. The velar nasal in English only occurs in postvocalic or more accurately in preconsonantal and absolute final position. In preconsonantal position the velar nasal is found only before *k* and can be derived as the result of place assimilation. This is supported by alternations in morphologically complex forms. Accordingly, the velar place of the nasal is never assumed to be underlyingly present. Furthermore, there are many morphemes with a final velar nasal and none with a velar nasal followed by the voiced velar stop *g*. (The same holds for final labial nasals and *b*.) Morpheme-internally the velar nasal is (almost) always followed by a *g* or *k*. Furthermore, some morphemes show an alternation in which a *g* is present in some surface forms but not in others (9e). Whether the *g*/∅-alternation is found or not depends on the suffix (compare (9e,f)). Labial nasals show this point even better, as can be seen by comparing *bom~~b~~* – *bom~~b~~ing* – *bombard*. The progressive marker doesn't facilitate realization of underlying *b* but the derivational suffix -*ard* does.

(9) English velar nasals and *g*-deletion

a.	*ŋæp		d.	æŋgɚ	'anger'
b.	rɪŋ	'ring'		æŋkɚ	'anchor'
	ɪŋk	'ink'	e.	lɒŋ	'long'
c.	*ɪŋg			lɒŋgɚ	'long-er'
			f.	rɪŋɪŋ, rɪŋɚ	'ring-ing, ring-er'
				*rɪŋgɪŋ, *rɪŋgɚ	

The problem, according to Kenstowicz & Kisseberth, is that the *g* that can be postulated as underlyingly present in morphemes like *ring* never shows up on the surface. It only makes its presence felt by causing assimilation of place of articulation of the preceding nasal before it is deleted. Thus there is never a segment $[P]_j$, corresponding to $/P/_j$, i.e., /g/, that shows at least one of the features of underlying /g/. The place feature is the only one that is realized, but is realized on a different segment.

The point stands and falls with our analysis of final *g*-deletion. If we analyse this as coalescence rather than deletion, the underlying /g/ is realized together with the preceding nasal. The nasal and oral stop are realized as one segment, specified as [+nasal], [–continuant], [+voice], [–coronal, –anterior]. All features bar the first are supplied by underlying /g/.

In these examples from English we can clearly determine the segment that never surfaces as a /g/. Things can get more abstract, though. An example Kenstowicz & Kisseberth discuss is French *h aspiré*. Despite the fact that it is called *h aspiré* and many words that show the phenomenon had an initial *h* historically, for speakers of modern French the identity of this segment is not recoverable. *h aspiré* shows its presence only in the blocking of liaison. Liaison is the seemingly unexpected emergence of consonants between vowels. Many adjectives and the plural determiner end in a vowel when followed by a noun starting in a consonant, but show a final consonant when followed by a vowel-initial noun, as in (10a) versus (10b). Some vowel-initial words, usually written with an initial *h*, do not trigger appearance of the *z*, as illustrated in (10c). Unlike regular vowel-initial nouns they also don't cause deletion of the vowel in the singular determiners; see. (10d) vs (10e).

(10) French *h aspiré* and liaison

a.	[levwatyr]	les voitures	'the cars'
b.	[lezami]	les amis	'the friends'
c.	[leero]	les héros	'the heroes'
d.	[lami]	l'ami(e)	'the friend'
e.	[laaʃ]	la hache	'the axe'
	[ləero]	le héro	'the hero'

Assuming that these exceptional words have an underlying consonant that never surfaces makes sense because this explains in a very natural way why they behave as if they started in a consonant, causing deletion of the final consonant in preceding articles and blocking vowel deletion in preceding articles. However, there are no alternations that support the assumption of an underlying laryngeal fricative at the beginning of these words, the laryngeal fricative never occurs in French. Furthermore, from a synchronic perspective there is no independent reason to assume a rule of word-initial consonant deletion. However, this rule helps explain the exceptionality of these forms as regular rule application. Since there is no evidence in favour of underlying /h/ and all other consonants found in French are excluded because they don't delete in word-initial position, this underlying initial consonant could be a highly underspecified root node with the sole feature [+consonantal] (Schane 1985).

The data are slightly more complex than laid out here, though for the current discussion this suffices to reveal that there are patterns which support the assumption of 'ghost' segments that have to be present in underlying representations but are never realized and which make their presence felt only indirectly. Since there is not a single surface segment showing at least one feature of the underlying segment condition, (F), the most liberal constraint so far, has to be discarded as too restrictive.

However, even though Kenstowicz & Kisseberth don't manage to develop any principled constraint on underlying representations they do apply a set of principles and criticize earlier generative analyses, specifically for their excessive abstractness. Excessive abstractness arises whenever the history of a language is taken into consideration in a synchronic analysis. To take a modest case, that the irregular French words discussed earlier have an underlying initial /h/ is a conclusion that cannot be reached by any speaker or learner of French. Native learners are illiterate and cannot use orthographic conventions as internal data in the construction of their native grammar. Despite the fact that the French word for 'hero' is written with an initial <h>, there is no evidence for this morpheme to actually have an underlying /h/. What a learner can deduct from the primary linguistic data s/he is exposed to is that there is 'something' at the beginning of 'hero' that causes the preceding morphemes to behave as if the word started with a consonant rather than the vowel they can hear. The only other thing about this initial consonant a learner can find out is that it can't be any of the consonants that are found at the beginning of other morphemes. Accordingly, it should be specified for as few features as possible. Thus Kenstowicz & Kisseberth assume that the grammar and the lexicon of a language have to be learnable on exposure to the language. A French toddler doesn't know anything about the state of French several hundred years before her/his birth. They furthermore assume that contrastive features are phonetically grounded, like the Prague-school features, the Jakobson-Halleian features and the features of *SPE*. Phonological processes or rules should be natural at least to some degree, comprising of the assimilation, dissimilation and neutralization of these phonetic contrasts.

3.4 MORPHEME STRUCTURE CONDITIONS AND REDUNDANCY RULES

A further issue arises in the determination of underlying representations when we look at language-specific inventories: every language makes use only of a subset of all contrasts attested cross-linguistically. Accordingly, every language uses only a subset of the contrastive features in its lexicon. It has almost unanimously been assumed that surface representations are fully specified for all phonological features. If this holds true every language also only uses in its underlying representations a subset of the features it has in surface representations. And if the assumption is warranted that only contrastive unpredictable features are specified in underlying representations there has to be a mechanism that fills in the missing features to derive the surface forms. At this point it is helpful to recall that in early generative phonology features were generally assumed to be binary in their specification. At the surface level every feature has a positive or a negative value. Underspecification is the absence of such a value. We are thus dealing with a three-way choice for underlying features, commonly labelled as [0F], [-F] or [+F].[5]

As shown in the previous paragraphs, apart from contrasting minimal pairs and language-specific systemic considerations, large parts of underlying phonological representations of individual morphemes are determined on the basis of surface alternations. In addition, there are in every language static patterns that lead analysts to conclude that there are additional restrictions on both the surface representations and underlying forms. Further evidence for such additional restrictions comes from loanword adaptation and speaker intuitions about possible new words. Of the words in (11) only two are actually attested in the English lexicon, those with the thumbs-up symbol are acceptable for native speakers of English, they might be English words the speakers just don't happen to know, while those with a star are unacceptable/impossible.

(11) English (im)possible onset clusters

✓brick	👍trin
👍blick	*tlin
*bnick	*tnin
✓spick	👍stin
*θpick	*θtin

A generative grammar that consists of rules which transform underlying forms into surface representations doesn't have anything to say about such grammaticality judgements. Furthermore, there seem to be 'hidden rules' which only apply when speakers are confronted with words (e.g., loanwords) that don't conform to the patterns in their language. These rules then turn these new words into surface representations that conform to the phonotactics and segment inventory of the language of the speaker. Such phenomena were generally attributed to rules or constraints on underlying representations. Hence, rules can be divided into two types: phonological rules, which cause alternations of (mostly) contrastive features in specified phonological and morphological environments that can be determined usually only after morphemes have been accessed in the lexicon and concatenated, and morpheme-structure rules (or constraints), which on the one hand fill in the missing redundant non-contrastive features and on the other constrain the lexicon.

The morpheme-structure rules can be further subdivided into context-free and context-specific insertion rules, since some non-contrastive features receive a value according to the (surface) context. Vowels, for example, are voiced in all languages and thus not contrastively specified for the feature [±voice] at the lexical or underlying level. In some languages, e.g., Japanese or the Chawchila variety of Yokuts, voiceless vowels surface in some contexts. In Chawchila, phrase-final vowels (i.e., vowels before a pause) are optionally realized as voiceless.

From this example we can learn three things. First, the default value to be filled in for an underspecified feature doesn't always have to be the negative value. For all sonorants, the positive (i.e., otherwise 'marked') value has to be supplied by the feature-filling rule.[6] Second, there are positional feature-filling rules that supply the opposite value in a specified context; and third, if these rules are defined as exclusively feature-filling and not feature-changing, the more specific rule has to apply first, since otherwise it wouldn't find the conditions for application anymore.

Furthermore, since we have this device of feature-filling rules at our hands, we can also use them to strip unmarked values off of contrastive segments. To stick to our example, [±voice], in languages that have a voicing contrast, this is usually only a matter of obstruents, sometimes only stops are contrastively voiced or voiceless. From an articulatory as well as acoustic/perceptual perspective the unmarked state for a stop is to be voiceless (it is simply more difficult to maintain vocal fold vibration if you bring the outgoing air stream to a halt at the same time). Accordingly, we can postulate the rule in (12d) and all obstruents with underlying [–voice] can now be considered underspecified for this feature, i.e., [0voice]. Thus, with this device at hand it is not only redundant non-contrastive features that can be regarded as underspecified in lexical representations. We will discuss the potential options that arise from this technology in more detail in Chapter 4.

(12) Typical redundancy rule(s)[7]

a.	Context-free:	[0voice] → [+voice]
b.	Context-sensitive:	[0voice] → [–voice]/__#
c.	Ordering:	b › a
d.	Class-specific:	[–continuant] → [–voice]

It is important to note that a feature-filling rule can supply either value, depending on the class of segments and features referred to and, in context-sensitive rules, the context referred to. In some cases such feature-filling rules can be used to simplify phonological rules. Reconsider the rule of regressive voicing assimilation in Russian, given in (1). Sonorants don't participate in this pattern in Russian (as in most languages with voicing assimilation). Sonorants can be assumed to be underspecified for voicing and get the positive value by redundancy rule. If this rule is ordered after the assimilation rule, the latter can be simplified to refer to the voicing feature only and not the class feature [+obstruent] or [–sonorant]. Still, voiceless obstruents can be underspecified and the value supplied by a redundancy rule, which has to apply before the assimilation rule. All the rules are given in their order of application in (13).

(13) More Russian rules

a.	r-rule (feature-filling):	[–sonorant, Øvoice] → [–voice]
b.	p-rule (feature-changing):	[+voice] → [–voice]/__#
c.	p-rule (feature-changing):	[–voice] → [+voice]/__[+voice]
d.	r-rule (feature-filling):	[+sonorant, Øvoice] → [+voice]

Stanley (1967) criticized this use of blanks and redundancy rules to simplify phonological rules as a 'misuse of blanks'.

A further, slightly more complex, example of a misuse of blanks in Stanley's sense is the arbitrariness of choice when it comes to underspecification of interdependent features. Consider vowel features. In a language like Yowlumne, which has a four-vowel system (*i, e, u, o*), all front vowels are unrounded and all back vowels are rounded. Since rounding is not contrastive, for it is entirely predictable from the specification of the backness feature, it might as well be left unspecified in underlying representations. However, in order for the articulation apparatus to receive the appropriate commands such that the back vowels are not realized as [ɯ] and [ɤ] and the front vowels don't accidentally surface as [y] and [ø], we need a feature-filling rule. In this case it first looks as if we actually need two, one supplying [−round] for the front vowels and one filling in [+round] in the back vowels. If we allow feature values to be replaced by variables we can collapse the two rules into one.

(14) Redundancy rules to capture the backness-rounding correlation

a. [–back] → [–round]
b. [+back] → [+round]
c. [αback] → [αround]

In the discussions above I referred to the Yowlumne harmony pattern as backness harmony, and this is in line with underspecification of [±round] and contrastiveness of backness. However, in such a case the relation between the two features might just be the reverse. In their discussion of Yowlumne, Kenstowicz & Kisseberth refer to the pattern as rounding harmony and accordingly would have the redundancy rules fill in values for the feature [0back] dependent on underlying roundness specifications (i.e., [αround] → [αback]). Such seemingly arbitrary choices were criticized as exactly that: arbitrary.

Furthermore, as already mentioned, the use of a positive value, a negative value and a blank constitutes a ternary contrast. Since at the surface all features have to be specified as either positively or negatively valued, one might think that the contrasts are still binary. However, since the filling in of a value in many rules depends on the specification of another feature, and since phonological behaviour in morphophonological patterns can crucially depend on the presence or absence of a value at a certain stage in the derivation, Stanley argues, the blanks do establish ternary contrasts. If we have three lexical options for a feature A and redundancy rules that fill in the values of features B and C on the basis of the (non-)specification of feature A, this can result in three different (contrasting) segments on the surface.

(15) Ternary contrast through the backdoor

i. a. [–A] → [+B]
   b. [+A] → [+C]
   c. [0B] → [–B]
   d. [0C] → [–C]
   e. [0A] → [–A]

ii. /X/[–A, 0B, 0C] → [–A, +B, –C]
    /Y/[+A, 0B, 0C] → [+A, –B, +C]
    /Z/[0A, 0B, 0C] → [–A, –B, –C]

The result is basically the same as we have seen in the Russian voicing assimilation pattern. We have two contrastive sets and one that isn't and three different types of behaviour in the assimilation pattern. The suspicion is not unjustified that we are dealing with a misanalysis here since contrast doesn't really lie in feature A, even though the system allows this result.[8]

We also find static positional neutralization of contrastive features. And if the value of a feature can be deduced by knowing the environment, it can be underspecified too. For example, the laryngeal contrast in English stops is suspended in word-/syllable-initial position if the stop is preceded by /s/, as in, e.g., *spill* (recall the discussion of *sponge* and the archiphoneme in Chapter 2). There is no minimal pair **spill/sbill* in the English lexicon. Even though represented by a *p* in English orthography, phonetically, the *p* in *spill* is more similar to the *b* in *bill* than the *p* in *pill*, because of the lack of aspiration. Since this suspension of contrast doesn't cause any alternations, it can be captured as a morpheme-structure condition.

The line between contrastive and non-contrastive features is thus a bit more difficult to draw than one might initially have thought. On the one hand, we can distinguish between the features that are contrastive in language L1 but not in language L2. These features still need to be inserted in the segments in L2 on their way from the lexicon to the surface. Among the features contrastive in L2 we can further distinguish between those contrastive in segment class A but not in segment class B. For the features contrastive in a given class a distinction has to be made according to contexts. Feature F is contrastive in segment class X everywhere except in context C.

To fill these distinctions with real examples: lip rounding is contrastive in vowels in French but not in Italian. Nevertheless, lip rounding can or has to be supplied via morpheme structure rule or feature insertion rule in both languages. In both languages, lip rounding occurs non-contrastively and predictably in back (non-low) vowels, where it can be inserted by rule. Italian front vowels are never [+round], while the feature is unpredictable in French front vowels. The feature [±voice] is a good example of a feature that is contrastive only for a certain class, obstruents but not sonorants. However, some members of this class occur in contexts (prevocalically after /s/) where the contrast is suspended and the default value can be inserted automatically and doesn't have to be stored in every morpheme that has an obstruent in this environment.

In the last chapter of *The Sound Pattern of English* Chomsky & Halle point out a fundamental problem with the features and rules they had proposed in the previous chapters: the whole machinery can in principle be used in an arbitrary way to describe languages that are not attested and not expected to exist either. With their sketch of a solution to this problem they also solve the issues outlined above, the arbitrariness of choice in underspecification and the potential for ternary contrast through zero specification. Chomsky & Halle replace the zero specification by markedness values, which are intended to not actually constitute feature values. Thus, apart from the binary values + and –, features can be prespecified as having a marked or unmarked value, [*u*F] or [*m*F], but not [0F]. A series of universal marking conventions determines whether the individual *u*'s and *m*'s in underlying feature matrices get substituted by a positive or negative value.

The feature [±high], for example, is assumed to have the unmarked value [+high] in vowels, unless the feature [±low] is specified as [+low]. The relevant marking conventions are given in (16).

(16) Some marking conventions for vowel height

a. [*u* high] → [+high]
b. [+low] → [–high]
c. [+high] → [–low]

Whether a segment receives the mark *u* or *m* for a feature depends on the specification of other features of this segment and the environment, i.e., feature specifications of neighbouring segments in the string. This can be illustrated with the major class features. The unmarked state of a segment in string-initial position is assumed to be consonantal. Thus in a segment marked as [*u* consonantal, *u* vocalic], the conventions fill in the former with a positive value and the latter with a negative value, resulting in [+consonantal, –vocalic]. Vowels then have to be the reverse: [*m* consonantal, *m* vocalic] or at least partially specified. After a consonant these conventions are reversed: [*u* consonantal, *u* vocalic] gets filled in as [−consonantal, +vocalic].

With *u*'s and *m*'s instead of blanks, all features are specified in all segments at all times now and the conventions determine the positive and negative values *u* and *m* stand for in the individual cases. So why not make the theory even simpler and just specify every feature at every level with a positive or negative value? There are three benefits to this way of marking features. First, the marking conventions are universal unlike the morpheme structure rules/constraints they are intended to replace. Thus these conventions don't add to the complexity of individual grammars, since they are present in all grammars anyway. Universality has the even more important 'side-effect' that a mechanism that determines a certain value for a feature as the unmarked value (such as [–voice] in obstruents and [+voice] in sonorants) is no longer a language-specific accident but rather part (and parcel) of a universal theory of markedness. Second, according to Chomsky & Halle, the parasitic use of blanks and the derivation of ternary contrasts mentioned earlier are no longer possible. Third, with the distinction between markedness values and feature specification it is possible to build a complexity metric into the theory that allows for the ranking of sound inventories according to their complexity and markedness. With this tool one can explain why sound systems expand or contract cross-linguistically in the way typologists observe.

In their illustration of the latter issue Chomsky & Halle start with three-vowel systems and show how a system with the three corner vowels, *i*, *u*, *a*, has lower complexity than systems with more or, more importantly, other vowels. If *u*-marked features don't add to complexity, but *m*-marked and positively or negatively specified features add one point to the complexity count and if we make maximal use of the marking conventions, we get the matrix and relative markedness values for vowels given in (17).

(17) Feature specifications for vowels according to universal marking conventions

	a	i	u	æ	ɔ	e	o	y	ɨ	œ	ø	ʌ
low	*u*	*u*	*u*	*m*	*m*	*u*	*u*	*u*	*u*	*m*	*u*	*u*
high	*u*	*u*	*u*	*u*	*u*	m	m	*u*	*u*	*u*	*m*	*m*
back	*u*	–	+	m	*u*	–	+	–	+	*m*	–	+
round	*u*	*u*	u	*u*	*m*	*u*	*u*	*m*	*m*	*m*	*m*	*m*
complexity	0	1	1	2	2	2	2	2	2	3	3	3

The complexity or markedness of vowel systems can now be quantified by adding up the complexity measures of their component vowels. The lower the resulting number, the more likely it is for such a system to be attested. The unattested three-vowel system /œ, ø, ʌ/ has a complexity value of 9 (=3+3+3), while the very common system /a, i, u/ has a complexity value of 2 (=0+1+1). Needless to say, this works if we compare vowel systems of the same size and not vowel systems in general. After all, the odd three-vowel system just mentioned is unattested, while systems with twelve or so vowels are quite familiar even though they have a much higher complexity measure. Thus, one might want to add to Chomsky & Halle's formula that the sum of complexity values should be divided by the number of vowels in the system. Though this latter modification then gives us no way of explaining why systems with three or five vowels are more common than systems with 10 or more vowels cross-linguistically.

It is also worth noting that Chomsky & Halle specify only [back]. At this time students still thought in hierarchies of contrasts, such as that in the Trubetzkoyan tree in (15) in Chapter 2. It isn't evident why in such a procedure in general the feature [back] should be specified first. This would predict that languages with only two vowels have a tendency to have the inventory /e, ɤ/ or, admitting phonetic enhancement, /e, o/. Usually languages with this minimal vowel system distinguish vowels in height rather than backness, as do children in the course of language acquisition (Jakobson 1941). Children most often start with a low vowel and then distinguish a high or non-low vowel. We would thus expect them to make use of the feature [±low] or [±high] first.[9] Accordingly, marking conventions have to be restated (or reordered – which is problematic since the conventions and their order of application are assumed to be universal) and potentially result in different *u*- and *m*-assignments. However, this is not a major issue to be discussed here.

The critique of blanks and Chomsky & Halle's theory of markedness and its replacement of zeroes by *u*- and *m*-prespecifications resulted in almost total abandonment of underspecification in generative phonology for more than a decade. While there was still widespread consent that all predictable information should be derived by rules, the full power of feature-filling rules was not used anymore.

While Chomsky & Halle's theory of markedness solves many of the problems indicated above and many more, it doesn't deal with another undesirable effect of the division of rules into phonological rules proper and redundancy or morpheme structure rules/constraints: the duplication of generalizations.

3.5 THE DUPLICATION PROBLEM

The Morpheme Structure Rules apply to morphemes in isolation, while the phonological rules apply to segments in morphemes within a string of other morphemes, since the latter are usually sensitive to the phonological context, which is usually created by the concatenation of morphemes (either in words or in phrases in the syntax). Accordingly, one would intuitively say that the Morpheme Structure Rules apply before the phonological rules proper. Stanley (1967), Harms (1968) and Kenstowicz & Kisseberth (1977) most clearly point out that this leads to a loss of generality, the duplication problem, as they termed the issue. The problem is that with this division of labour some phonological phenomena have to be explained twice in one and the same grammar and the generalization that both phenomena are closely related, often an effect of the same condition, is lost. The assumption that two seemingly unrelated rules in the analysis of a language apparently have the same effect was also labelled a conspiracy in the literature.

Recall the Yowlumne vowel inventory and harmony pattern. Above I said that Yowlumne vowels don't need the feature [±round], because it is predictable by a vowel's backness. Accordingly every vowel can be assigned the value for [round] when it is lifted out of the lexicon. Earlier on we discussed the Yowlumne vowel harmony patterns. By and large, suffix vowels surface with the same backness feature as the preceding vowel. If the vowel harmony rule is restricted to the feature backness, which we assume for reasons of parsimony, an input like /c'u:m -it/ would result in surface *[c'o:mɯt], containing a back unrounded vowel that never occurs in Yowlumne. Thus, we need a repair rule following the harmony rule that turns any accidentally generated front rounded and back unrounded vowels into front unrounded and back rounded vowels respectively. The two rules, though, do exactly the same thing: they make sure that no back unrounded and front rounded vowels are found in Yowlumne (or many other languages). They differ slightly, since one fills in a feature and one changes a feature. A solution to the problem is to just assume the feature-filling rule and order it after the phonological rule. Ordering the morpheme-structure rules en bloc after the phonological rules also solves another potential problem: if redundant features are filled in too early they can interfere in unwanted ways in phonological processes. Voicing assimilation (as found in Russian, see above, and many other languages) is a process that affects obstruent consonants but not sonorants. Sonorants usually don't cause voicing of preceding obstruents. If the process is seen as assimilation to [+voice] and sonorants are underspecified for [voice] at the time this rule applies, they won't wreak havoc on preceding stops and fricatives. Once the assimilation rule is done, the feature-filling rule that supplies vowels and all other sonorant segments with the feature that will be interpreted as vocal fold vibration in phonetic implementation can do its job.

However, there are problems with the ordering solution. First of all it seems unlikely that all morpheme-structure rules can be ordered after all (morpho)phonological (or morphophonemic) rules en bloc. Kenstowicz & Kisseberth discuss several scenarios in which both rule types have to be interspersed. Since in some cases of duplication the morpheme-structure rule and the morphophonemic rule can be conflated, the distinction that morpheme-structure rules are feature-filling and phonological rules feature-changing cannot be upheld. If the two rule types cannot be kept in separate compartments of the grammar and they cannot be formalized in different ways, the whole distinction between the two types of rules is no longer valid and the generalizations holding over the lexicon get lost.

Also, even though in some cases of duplication the morpheme-structure rule and the morphophonemic rule can be conflated, resulting in greater parsimony of the grammar, this is not always the case. The duplication problem is, at the end of the day, part of a more general problem of rule-based phonology, the observation that very often several rules conspire to achieve the same effect, i.e., avoid a certain marked structure.

3.6 RECAP

Generative phonology states generalizations about co-occurrences of segments and features within segments in terms of phonological rules. These rules are ordered and used as transformation instructions to turn an abstract underlying representation into a surface phonological or phonetic representation. Phonological rules achieve higher generality than the archiphonemic representations and relationally defined features of structuralist phonology. The rule technology had an impact on the understanding of underlying representations. Rules are not only used to formalize productive alternation-inducing processes but also unproductive alternations and static patterns, anything generalizable. The excessive use of this technique led to highly abstract representations, which, as for example in *SPE*, incorporated a good deal of the language history. Such abstract underlying representations were criticized for not matching psychological reality. It was argued that such systems and representations are unlearnable and in the absence of an alternation it is unlikely that a learner departs significantly from the surface representation (as in the *SPE* analysis /ni:xtingael/ – [naitɪŋgeil]).

By stipulation it was generally believed throughout the 1950s to the 1970s that surface representations were fully specified and generative phonology inherits from earlier theories the principle of lexical economy/minimality, i.e., the assumption that at the abstract level only the information that is absolutely necessary is specified. To change abstract underspecified underlying representations into fully specified surface representations such rules, morpheme-structure rules or constraints, can then also be used to fill in the non-contrastive feature values, or, more radically, all redundant feature values. To separate the two notions, non-contrastive and redundant, consider voicing. The feature [+voice] is non-contrastive (and redundant) in sonorants. Thus it can be left out of a segment's representation that contains the feature [+sonorant] if one assumes a rule that fills in [+voice] in sonorants at some point. In obstruents (in Russian, for example) the feature [±voice] is contrastive. Though [–voice] is contrastive in obstruents it is redundant, since it can be considered the default value for this segment class.

The role of lexical minimality (economy – the most powerful argument for underspecification) has been questioned on the grounds that underspecification in connection with free ordering of rules can lead to arbitrary and undesired results.

Thus, while generative phonology replaced an undesired type of abstractness in representations and started a quest for more explanatory adequacy in analysis, it introduced another type of excessive abstractness, which was soon criticized, leading the field in its first steps towards appreciation of the criterion of psychological reality, i.e., learnability of grammars and recoverability of underlying forms.

Chomsky & Halle's marking conventions can be said to be a starting point for a theory of phonological markedness. The criticism of the unnecessary power of rule ordering sparked a research programme that looked into constraints on rule ordering, which in its turn, led to a revival of underspecification, as we will see in Chapter 4.

DISCUSSION POINTS

- Reconsider the abstract representations that reflected earlier stages of the language under analysis. What is it that a generative grammar of a language or pattern in a language describes?
- Consider the pros and cons of abstract representations and of fully specified underlying forms.
- Recall Stanley's calculations that result in ternary contrasts if features can be unspecified, i.e., [0F]. Discuss why Chomsky & Halle's theory of markedness does not make this prediction. Consult the marking conventions of *SPE* chapter 9 and do the calculations.

SUGGESTIONS FOR FURTHER READING

Chomsky, Noam & Morris Halle (1968). *The Sound Pattern of English*. Ch. 9.

Clayton, Mary L. (1976). The redundance of underlying morpheme-structure conditions. *Language* **52**: 295–313.

Kaye, Jonathan (1981). Recoverability, abstractness and phonotactic constraints. In Didier L. Goyvaerts (ed.), *Phonology in the 1980's*. Ghent: E. Story-Scientia. 469–81.

Kiparsky, Paul (1968). *How Abstract Is Phonology?* Distributed by Indiana University Linguistics Club, Bloomington. Reprinted in Paul Kiparsky (1982). *Explanation in Phonology*. Dordrecht: Foris.

(1973). Phonological representations. In Osamu Fujimura, (ed.), *Three Dimensions of Linguistic Theory*. Tokyo: TEC. 3–136. Chapter 1 'How abstract is phonology?' (First distributed 1968 by the Indiana Linguistics Club.)

Paradis, Carole (1993). On the validity of morpheme structure constraints. *Canadian Journal of Linguistics/Revue canadienne de linguistique* **38**: 235–56.

4 Underspecification returns

4.1 INTRODUCTION

In Chapter 3 we found that the omission of feature values in underlying representations became discredited by the end of the 1960s. Underspecification in the form of zeroes or blanks (rather than *u* and *m* markings) had a revival in the 1980s, which came in two flavours: Contrastive Underspecification (Steriade 1987, 1995, Clements 1988) and Radical Underspecification (Kiparsky 1982, Archangeli 1984, 1985, 1988, Pulleyblank 1986). The main point of disagreement between the two approaches lay in the question of how to determine feature values and whether this could be done on a language-specific basis or had to follow universal principles, i.e., make use of universally valid feature-filling rules and constraints. A third approach to underspecification, the deduction of feature specifications (and lack thereof) on the basis of a Contrastive Hierarchy, reappeared in the late 1990s and the following decade with the work of Dresher and his associates (Dresher 2003, 2008, 2009, 2010 and references there). We have seen such a hierarchy or division tree in the discussion of Trubetzkoy in Chapter 2 and it had been a common tool in generative phonology in the 1950s, e.g., in Halle (1959).

The 1980s also saw a renewed interest in unary or privative features, which we also have met in passing in the section on Trubetzkoy's work (Section 2.3). A privative feature is either present or absent rather than taking a value. Thus, zero is one of two options rather than one of three and the adoption of privative features renders large parts of the discussion around underspecification obsolete. However, the issue does not vanish completely. If we take, for instance, the feature [voice], which has been argued to be privative by Lombardi (1991) and others, we see that underspecification is still an option. While in a language contrasting /p,t,k/ with /b,d,g/ the voiceless series is now necessarily underspecified, the sonorants in the same language, which are redundantly voiced at the surface, could be specified as [voice] underlyingly for the sake of completeness or lack this feature because it is redundant.[1]

Before we have a look at the arguments for and mechanics of radical underspecification, contrastive underspecification and the contrastive hierarchy, respectively, it is necessary to ask why people returned to underspecification after Stanley's devastating criticism (1967; see Section 3.4).

The first observation that cast doubt on the assumption of full specification in the lexicon was of a methodological nature, questioning the soundness of Stanley's argument (Ringen 1975). Stanley argued that underspecification can result in undesired ternary contrasts on the following assumptions: first, rules can be extrinsically (or freely) ordered. Second, the rules he proposes are possible rules of natural languages. Third, phonological representations contain unspecified features. As mentioned in the previous chapter, the general reaction was to question the third point.

Ringen (1975) questions the first premise, i.e., that rules can be extrinsically ordered. If rules are subject to universal principles of rule ordering and if these principles exhaustively determine relations between rules, languages cannot differ in whether rule A applies before rule B or after, but only in whether it has rules A and B, just one of them, or none. This challenge sparked a research programme to find the intrinsic orderings and ordering principles for rules, pushed forward most rigorously in the works of Ringen, Archangeli and Kiparsky. One widely discussed constraint on rule ordering is Archangeli's (1984) Redundancy Rule-Ordering Constraint (RROC), which stipulates that any redundancy rule has to apply before a phonological rule referring to the same feature. This constraint will be discussed further below. Another example for a rule-ordering constraint is Kiparsky's (1973b *et seq.*) Elsewhere Condition. The Elsewhere Condition demands that of two rules with overlapping arguments the more specific one applies before the more general one.

More important for the current purposes are Kiparsky's idea of Structure Preservation and his development of Marking Conventions. With Lexical Phonology's (Mohanan 1982, Kiparsky 1982a,b, 1985) division of the phonological and morphological module of grammar into a lexical and a postlexical domain, it is possible to distinguish phonological processes by two criteria which Kiparsky argued to be related: the domain of application and the potential restriction of the output of a rule to the set of contrastive segments of a given language or to a larger set of segments. Kiparsky argued that the output of the lexical phonology is restricted to segments from the set of contrastive segments, while postlexical phonological processes can create other segments as well. Rules operative at the early level(s) of phonology can only refer to contrastive features, since all other features are assumed to be absent as an effect of marking constraints.

(1) Structure Preservation (Kiparsky 1985: 87)

> Structure Preservation is the result of constraints formulated over the entire lexicon. For example, if a feature is non-distinctive in a language we shall say that it may not be specified in the lexicon. This means that it may not figure in non-derived lexical items, nor be introduced by any lexical rule, and therefore may not play any role at all in the lexical phonology.[2]

An example of a postlexical process that creates a non-contrastive segment is American English flapping. Flapping applies to intervocalic coronal stops at the phrasal domain (as in the phrase *split apples*). English voicing assimilation does not cross word boundaries and doesn't create non-contrastive segments.[3] Russian voicing assimilation, on the other hand, does create segments that are not found in minimal pairs or unpredictable contexts, as discussed in the previous chapter, and it applies across words, for example in compounds.

We will come back to Kiparsky's marking conventions and redundancy rules in the next section.

A further premise of the argument against underspecification is that there are phonological rules at all. This premise has been questioned repeatedly and resulted in diverse phonological theories, which explain phonological patterns by constraints (e.g., Harmonic Phonology or Optimality Theory) or by principles and parameters (as Government Phonology does; see, e.g., Kaye, Lowenstamm & Vergnaud 1985 *et seq*., or, for a recent retrospective and more references, Scheer 2004).

Moreover, the premise that phonological features are binary-valued and can be left blank is not uncontroversial either. Privative features were an inevitable development following from the introduction of autosegmental phonology, which formalizes changes in segmental features as the insertion of an association line between a feature and an additional segment (assimilation) or removal of an association line linking a feature with a segment or root node, aka delinking (neutralization).

This rigid and restrictive theory of possible phonological operations forcefully advances the grounding of features in concepts of markedness. So, if voicelessness is the unmarked state of obstruents in coda position, because this is the result of neutralization and neutralization is the delinking of the marked feature, then voicelessness is best described as the absence of the laryngeal feature.

Similarly to Russian (which was discussed earlier), Thai neutralizes the contrast between aspirated, unaspirated plain and voiced stops in final position, displaying only plain stops there. Thus [spread glottis] and [voice] must be the marked configurations, the delinking of which results in plain stops. A similar approach to features was developed in Element Theory and Dependency Theory (Anderson & Ewen 1987). In these frameworks contrastive features are radicals that are linked to a segment position and stand in head-dependent relations. Such radicals are either present or absent, but don't have values (see Chapter 7 for further discussion of elements).

In summary, the structure of the argument against underspecification was challenged on several fronts. It doesn't have to be taken for granted that phonological grammars contain rules; if there are phonological rules, they might be subject to universal principles or constraints that place restrictions on rule ordering, and, last but not least, features are not necessarily binary, i.e., ±-valued.

Steriade (1979) also argues for underspecification on empirical grounds. She observes that certain distributional patterns can only, or best, be explained by recourse to underspecification in some positions of neutralization. The distribution of round vowels in Khalkha Mongolian is such a case. Mongolian has both back and front rounded vowels. A vowel harmony process causes all non-initial vowels to agree in backness. A second harmony process applies only between non-high vowels and assimilates all non-initial non-high vowels to the [±round] specification of the initial non-high vowel. If there is a high vowel (round or not) in the first syllable all following vowels surface as non-round. Thus all non-initial vowels, apart from the high vowels, are systematically non-round. A grammar that doesn't have the means to determine all these vowels as underspecified for roundness, Steriade argues, wrongly predicts that in environments in which harmony is dispensed, they can surface with any specification for this feature.

A further blow to full specification in the lexicon comes from phonetic studies, which reveal that there is reason to believe that surface representations are not fully specified either (e.g., Keating 1985, 1988). Take, for example, the English word *tool*. The coronal stop at the beginning of this word is articulated with lip rounding, unlike the /t/ in *team*.

This rounding is a phonological feature on the following vowel, but hardly anybody would seriously assume that the /t/ is specified as [+round] at any phonological level. /h/ is a more dramatic case: as a laryngeal fricative, /h/ has no oral place features. An /h/ in intervocalic position is usually used for the transition of the articulatory settings of the previous vowel to the following one (Keating 1988). Steriade (1995) discusses Chumash sibilant harmony under the aspect of permanent underspecification of stops. In Chumash, the anterior and the posterior fricative do not occur together; they are subject to regressive assimilation. Chumash stops don't show a contrast between an anterior and a posterior place of articulation and don't trigger or undergo assimilation in anteriority as the fricatives do. Steriade (1987) assumes the stops to be underspecified for the feature. Dart (1990) shows that the anterior stop [t] displays a great deal of variation in the realization of its place of articulation in languages that don't contrast finer distinctions among coronal stops. This suggests that these stops are not specified on the surface for features such as [±anterior], [±laminal] or [±distributed]. If they are not specified at this level there is no reason to assume that they have the feature specification at some more abstract level either.

In the following three sections we will go through the mechanics of Radical Underspecification, Contrastive Underspecification and the feature division algorithm, respectively. This will give a more detailed insight into the way phonological information at the segmental level is assumed to be stored in these approaches.

In Section 4.5 we briefly consider arguments for the underlying specification of syllable structure, which I take as a major argument against economy of representation in the lexicon and accordingly against underspecification. In most of the phonological literature there is and was broad consent on the absence of predictable prosodic structure in the lexicon. Syllable structure has never been convincingly shown to be contrastive or unpredictable in any language. I regard Vaux' (2003) study as the most convincing of the works that have argued against large-scale underspecification, since he argues on the basis of empirical observation rather than invoking theoretical arguments, as will be discussed further in Chapter 8.

Section 4.6 shows exemplary studies, in which underspecification is used to account for lexical exceptions. Such studies ultimately have to be related to Stanley's argument, since they seem to provide the evidence for (derived) ternary contrast that is not manifest in the phonetic realization of the segments in question, but in their behaviour in different phonological environments.

4.2 RADICAL UNDERSPECIFICATION

Radical Underspecification (Kiparsky 1982a,b; Archangeli 1984, 1988; Pulleyblank 1986) regards lexical economy as the most important force determining the shape of underlying representations of segments. Segments are stripped of all non-contrastive features. This is referred to as trivial underspecification. These features are supplied when forms leave the lexical component of phonology, since they can be phonologically active in postlexical processes. In addition, default values of contrastive features are supplied by rule. Kiparsky (1982a,b, 1985) distinguishes two mechanisms that determine underspecification. On the one hand, he makes use of rules that fill in default values of contrastive features. On the other hand, he assumes there are filters that keep non-contrastive feature specifications out of the lexicon, such as the condition on sonorants, given in (2).

(2) $*\begin{bmatrix} \alpha\,\text{voiced} \\ +\,\text{son} \end{bmatrix}$

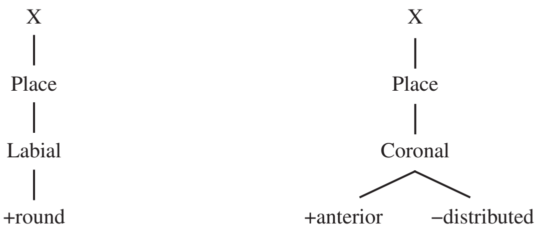
Such conditions explain the inactivity of segments in phonological processes that manipulate features which are not contrastive in these segment classes, such as the non-participation of sonorants in Russian voicing assimilation.

Unlike default feature-filling rules, these filters are not universal. A language that doesn't have a voicing contrast in obstruents either, such as Finnish, is assumed to have a condition that bans specifications of this feature from all segments in the lexicon, *[α voiced].

The differentiation of conventions and feature-filling rules shows a principled distinction between two types of underspecification. Archangeli labels underspecification of features which are not contrastive in a segment class *inherent underspecification*, while Steriade uses the term *trivial underspecification*. Voicing in sonorants or a place feature, such as [laminal] in segments that don't show a contrast, say, labials or coronal stops in a language that only has one coronal stop, which contrasts with /p/ and /k/, is assumed to be inherently or trivially underspecified.

This type of underspecification can best be understood in terms of autosegmental representations. In feature geometric approaches to segmental structure, contrastive features are dominated by a mother node. These mother or class nodes are part and parcel of the hierarchical organisation of segments. In Sagey's (1986) Feature Geometry the features [anterior] and [distributed] are dominated by the coronal node. A segment that is specified with a labial node lacks a coronal node. Trivially, it also lacks any specifications of features that are dependents of the missing node.

(3) Trivial underspecification as a result of hierarchical organization



As mentioned in the introduction to this chapter, there are reasons to assume that at least some features are not binary (such as Labial and Coronal in the above tree). Privative or unary features contribute another type of inherent underspecification. If the feature [nasal] does not have values, contrast is marked by the presence or absence of the feature, the latter being another trivial underspecification.

In Radical Underspecification, features are assumed to be underspecified beyond the trivial. While one could assume that binary contrastive features are always specified in segments that participate in the contrast, Kiparsky, much in the spirit of underspecification in the 1950s and 1960s, assumes that there are default values, such as [–voice] in obstruents, which can be underspecified and filled in by rule. Thus, an English /p/ is lexically unspecified for the feature [±voice], while an English /b/ is [+voice]. However, if the function of features is reduced to contrast, one can omit further specifications from segments, leaving only those specifications that are needed to differentiate every segment from the rest of the inventory and are unpredictable. Archangeli (1984, 1985, 1988) goes a step further than Kiparsky by assuming that not only universally unmarked and therefore predictable feature values can be left blank, but that any feature value that can be filled in by rule is left unspecified. If feature-filling rules can be postulated on a language-specific basis, the choice of which features to specify becomes a matter of deduction from language-specific contrasts and patterns of phonological activity.

Evidence for such a view comes from vowel epenthesis. Languages with an identical vowel system vary quite a lot as to the choice of epenthetic vowel. Among languages with the five-vowel system /i, e, a, o, u/ some choose [i] as the epenthetic vowel, some use [e] and Japanese employs [u] (Matthews 2010, Labrune 2012). Yet others use [a] or non-contrastive schwa, but we focus on the first three options here. If one assumes further that the epenthetic vowel is the least marked vowel in a system, i.e., the one whose feature specifications can be filled in automatically, these languages have to have different feature-filling rules.

(4) gives a fully specified five-vowel inventory with the three features that are minimally necessary to contrast these vowels.

(4) Full specification

	i	e	a	o	u
high	+	–	–	–	+
low	–	–	+	–	–
back	–	–	+	+	+

Now we want to derive Radical Underspecification with [e] as the completely underspecified vowel in the system. [e] has only negative feature values. If we take these out, we have to postulate the rules given to the right in (5).

(5) Unmarked *e*

	i	e	a	o	u
high	+		–	–	+
low	–		+	–	–
back	–		+	+	+

[ ] → [–high]
[ ] → [–low]
[ ] → [–back]

Since these rules are present in the grammar, every negative feature can be removed, since it will be filled in by our three rules.

(6) More underspecification

	i	e	a	o	u
high	+				+
low			+		
back			+	+	+

[ ] → [–high]
[ ] → [–low]
[ ] → [–back]

There is only one low vowel in the system. Since this vowel is sufficiently specified if it only has the feature [+low], its [+back]-specification can be removed and a rule added to avoid filling in the wrong backness specification for the low vowel. Accordingly, this rule has to precede the rule that fills in the default backness value.

(7) Radical underspecification with unmarked *e*

	i	e	a	o	u
high	+				+
low			+		
back				+	+

[+low] → [+back]
[ ] → [−high]
[ ] → [−low]
[ ] → [−back]

The same exercise can be repeated with any other vowel as the unmarked or maximally underspecified one. So, to derive the Japanese system, with [u] as the epenthetic vowel,[4] we need the following rules, which give us the feature profiles in (8). The first rule can be assumed to be universal. The features [+low] and [+high] are assumed to be incompatible for articulatory reasons and thus a rule fills in the opposite value for one feature if the other is positively specified.

(8) Radically Japanese

	i	e	a	o	u
high		−		−	
low			+		
back	−	−			

[+low] → [−high]
[ ] → [+high]
[ ] → [−low]
[ ] → [+back]

Now we run into a problem with phonological activity (Dresher 2009): Japanese has a palatalization process that requires /i/ and /u/ to have some common marked feature that can spread to coronal obstruents, such as [+high]. This, however, is dealt with by the Redundancy Rule-Ordering Constraint (RROC). Any underspecified feature has to be specified before a proper phonological rule can apply.

(9) RROC (Archangeli 1984/1988: 73)

> A redundancy rule assigning ‘α’ to F, where ‘α’ is ‘+’ or ‘–’, is automatically ordered prior to the first rule referring to [αF] in structural description.

As Steriade (1995) and Dresher (2009) point out, the RROC ensures that most features are filled in very early in the derivation and this makes the theory relatively immune to any empirical effects. This type of underspecification has hardly any application to explain surface phonological behaviour.

Since palatalization in Japanese refers to the feature [+high], height feature specifications have to be filled in before this rule applies. This can also be seen in Yowlumne (Archangeli 1984). Yowlumne has a roundness harmony rule (or backness harmony; see the discussion in Chapter 3), which is dependent on the height specification of the participating vowels. The harmony rule has to apply before a lowering rule, which obfuscates the height dependency of the harmony rule. Hence, height features have to be filled in very early in Yowlumne and have no bearing on the explanation of phonological patterns. While Steriade and Dresher criticize this, one can actually regard it as a result. With this theoretical architecture, the analyst is not allowed to rely on arbitrarily chosen underlying representations to explain surface patterns. Hence, the grammar has to be more restrictive.

This early application is in strong contrast to earlier arguments on redundancy rules, which then were assumed to apply as late as possible, in order to explain exceptional behaviour in phonological processes (see Chapter 3). Apart from economy, a driving force behind underspecification was the simplification of phonological rules. Reconsider the case of Russian (or most other cases of) voicing assimilation: if the predictably voiced sonorants are underspecified for the feature [voice] the Russian assimilation rule can be stated as voiceless segments becoming voiced before a voiced segment, i.e., without reference to the affected segment class [−sonorant] in its structural description. If sonorants have the same feature [+voice] on the surface as obstruents (though see Rice 1993 for arguments to assume two distinct features causing vocal fold vibration in sonorants and obstruents, respectively), the assimilation rule has to be formulated such that it excludes sonorants from triggering assimilation, since this would result in the complete absence of voiceless segments from the language. Alternatively, the RROC has to be able to distinguish between underspecified contrastive features and trivially underspecified features and not apply to the latter.

A further criticism, which is also admitted by Archangeli (1988), is that since redundancy rules are language-specific, learning underlying representations in a language becomes quite a challenge.

It is more desirable to find universal redundancy rules, like the back/round correlation, which by default inserts a negative value for roundness in front vowels and a positive value in non-low back vowels, or, vice versa, specifies round vowels as back, and that can be overridden with contrast on a language-specific basis.

4.3 CONTRASTIVE UNDERSPECIFICATION

This theory of underspecification (Clements 1988; Steriade 1987, 1995) deals with the final issue of the preceding section by only allowing universal redundancy rules by hypothesis.

(10) The hypothesis of contrastive underspecification (Steriade 1995: 142)

a. Feature values predictable on the basis of universal co-occurrence conditions or on the basis of neutralization statements can be omitted from underlying representations.
b. No other features may be underspecified.

As above with Radical Underspecification, we first ignore phonological processes here and concentrate on the inventory as a system, applied to vowel systems. To find out whether a feature specification in a vowel is predictable by rule or contrastive a learner first has to know the whole system and have specified every feature in every vowel (Archangeli 1984). Archangeli (1984: 192) gives the following algorithm to determine which feature specification can be left out in a given system.

(11) A recipe for contrastive feature specification

i. Fully specify all segments.
ii. Isolate pairs.
iii. Isolate all pairs that differ only by one feature and mark this as contrastive.
iv. Remove all features that are not marked as contrastive.

Following step (i) provides us with the following set of representations for a five-vowel system (e.g., Spanish, Japanese).

(12) i. Full specification

	i	e	a	o	u
high	+	–	–	–	+
low	–	–	+	–	–
back	–	–	+	+	+

Now we have to identify minimal pairs, that is, pairs which differ in exactly one feature. /a/ and /i/ for example differ in value in three features. There is no principled reason to pick one of them and discard the others. Thus, such pairs are ignored.

(13) ii. and iii. Identifying contrastive pairs

	i	e
high	+	–
low	–	–
back	–	–

o	u
–	+
–	–
+	+

i	u
+	+
–	–
–	+

a	o
–	–
+	–
+	+

e	o
–	–
–	–
–	+

(14) iv. Contrastive specification

	i	e	a	o	u
high	+	–		–	+
low			+	–	
back	–	–		+	+

The rules needed to fill in the missing features are the following.

(15) Feature-filling rules for contrastive specification

a. [ ] → [–low]
b. [ ] → [–high]
c. [+low] → [+back]

If we strictly follow Steriade's hypothesis and apply the rules in (15) 'backwards' we actually end up with a different, more economic, set of specifications. Part (a) of the Contrastive Underspecification Hypothesis gives the option to omit all specifications that are predictable by universal rules. The three rules we have here look like suspiciously good candidates for universal fill-in rules.

(16) Contrastive specification with automatic rule application

	i	e	a	o	u
high	+				+
low			+		
back	–	–		+	+

On the other hand, rules (a) and (b) are, strictly speaking, not co-occurrence restrictions, since they refer to only one feature. If we interpret the hypothesis narrowly we can apply only one rule, rule (c), which gives us the representations in (17).

(17) Contrastive specification

	i	e	a	o	u
high	+	–	–	–	+
low	–	–	+	–	–
back	–	–		+	+

This comes very close to full specification. However, it only does so if we restrict ourselves to considering only the minimal set of distinctive features. If features are available universally there are quite a few features that have not been taken into account here. The question of which features are used to mark contrasts in a given inventory is still an issue. While tenseness, or ATR, obviously doesn't play a role in such systems, the choice is less trivial with regard to other features, especially those that are in co-occurrence relations with another feature. This has been discussed already with respect to the features [round] and [back] in Chapter 3. Whether values for [round] depend on the values for [back] among non-low vowels or vice versa is a seemingly arbitrary choice. The feature [round] could be substituted for the feature [back] in all the analyses above (including those in the previous section) without any consequence. This thought can be extended to the height features. It seems odd to use two height features in such a system if they don't play a role in phonological patterns. Thus one could analyse the same set of vowels with the features in (18). Like the above feature set, these leave room for underspecification by co-occurrence rules or default rules. This analysis also reflects markedness differentials in many languages very nicely, if not better than the above set, except when analysing Japanese.

(18) Arbitrary choice of features

a.		i	e	a	o	u		b.		i	e	a	o	u
	high	+	–	–	–	+			high	+	–	–	–	+
	round	–	–	–	+	+			round	–	–	–	+	+
	back	–	–	+	+	+			ATR	+	+	–	+	+

Language-specific choices of markedness, or markedness reversals, are also a problem if we don't allow for language-specific choices regarding the feature-filling rules or, alternatively, the features used to encode contrasts. There is no way one can define a vowel such as [u] as the least marked one on a language-specific basis as we have done with /e/ and /a/ in (18), i.e., by selecting features which have negative values for the respective vowel.[5] Thus, if one subscribes to Contrastive Underspecification, the quality of the inserted segment has to be defined in the epenthesis rule.

Dresher (2008) shows that the condition in the algorithm in (11) to start with full specification leads to undesired results if the relevant contrastive features are not selected beforehand. Since a language learner doesn't know a priori which features his/her target language uses, all features have to be specified at the start. (19) shows Dresher's choice of features for the exercise, which is not exhaustive.

(19) Full specification with too many features

	i	e	a	o	u
high	+	–	–	–	+
low	–	–	+	–	–
back	–	–	+	+	+
round	–	–	–	+	+

We can isolate /i/ and /e/ as a minimal pair, contrasting [±high] and no other feature, as well as /o/ and /u/, which contrast in the same feature. All other possible pairs differ in more than one feature specification and are therefore ignored according to Dresher's interpretation of the algorithm. The result is displayed in the next table.

(20) Contrastive Underspecification wreaking havoc

	i	e	a	o	u
high	+	–		–	+
low					
back					
round					

But does this comply with the contrastive hypothesis? The restriction on contrastivity has the clause that every feature omitted has to be insertable by a universal co-occurrence condition. /a/ doesn't have any features left to start with. Thus, we cannot find a rule of the type [αF]→[+G]. If we allow for universal feature-filling rules, we have rule (15a) that gives us a starting point, though the wrong one for /a/, since it inserts [–low] while an /a/ needs [+low].

While the Contrastive Underspecification Hypothesis leaves very little room for underspecification in the cases we have considered so far and in which we have only taken into account co-occurrence restrictions, the other condition under which underspecification results, predictability through neutralization statements, is more interesting. Steriade (1995) cites a study on Australian languages by Hamilton (1993) to strengthen her case. The Gaagudju and Gooniyandi data she presents do not only lend support for this type of underspecification but can also be regarded as evidence for the claim that phonological representations are not fully specified at the surface level either.

Australian languages are known for the multiple contrasts among coronal segments, distinguishing alveolar and retroflex or more places, which can be analysed with the features [±laminal] and [±anterior] subordinated to the coronal place feature. Gaagudju has a word-internal contrast between these two places, which is neutralized in word-initial position. In this position we don't find retroflex coronals unless there is a retroflex following. This can be analysed as a long-distance regressive assimilation process. This process does not apply word-internally. Steriade concludes that the string-internal coronals are specified for anteriority while the word-initial coronals are not. The assimilation rule is a structure-building rule, which affects under-specified segments only. Gooniyandi has a similar pattern. The curious difference between Gooniyandi and Gaagudju is that in the former the initial coronals, which are not followed by a trigger that determines their anteriority, are variably realized as alveolar or retroflex.

(21) Gooniyandi initial coronals (Steriade 1995: 143)

a.	ɖiɻipindi	*diɻipindi	'he entered'
b.	dili	*ɖili	'flame, light'
c.	duwu /	ɖuwu	'cave'
	laɲgija /	ɭaɲgija	'midday'

Steriade concludes that these initial coronals are passed on to the phonetics without a specification of the place feature associated to coronal and the phonetic module is free to interpret the underspecified structure. The assimilation rule applies to underspecified segments. If it doesn't apply, for lack of a trigger, the target segment stays underspecified. One might object of course that this is a case of complete neutralization. Thus, since a neutralization rule or constraint that eliminates the surface contrast is required anyway, these data do not prove that the word-initial segments are underspecified underlyingly – they only show that the segments are underspecified at the surface. To show a potential underlying feature specification one would need a pattern or morphophonological operation in which the initial coronals are brought into a position of contrast. Interestingly, Steriade (1995) discusses just such a case: harmonizing affixes in Hungarian.

Hungarian has stem-controlled backness harmony. Thus, the front/back realization of vowels in suffixes depends on the quality of the last vowel in the root. If the last vowel is a neutral vowel, i.e., [i], affix vowels have the backness value of the vowel preceding the neutral vowel. Affixes to roots with a neutral vowel only are usually front. With some roots containing a neutral vowel only, affixes are realized with a back vowel. Thus, affix vowels are always in a position of neutralization, even if preceded by a neutral vowel (very much like in the Khalkha Mongolian pattern briefly mentioned above). There are two noted exceptions to this, the two case markers *nal* and *töl*. (22) shows that the vowels in these two morphemes are subject to backness harmony when they are used as suffixes (a, b) and that they act as triggers, displaying an idiosyncratic backness specification, when used as a stem (c).

(22) Hungarian harmony

a.	ház-nal	'at the house'
	ház-tol	'from the house'
b.	kép-nel	'at the picture'
	kép-töl	'from the picture'
c.	nal-am	'at me'
	töl-em	'from me'

Steriade concludes that an analysis of such patterns cannot rely on morpheme-structure constraints that enforce underspecification in suffixes. However, as she also points out, the backness specification of most other suffix vowels is simply unlearnable. The same extends to the Australian initial coronals and all other examples of segments in contrast-neutralizing environments (e.g., English stops preceded by tautosyllabic [s] which we discussed earlier). However, what choices are there if a specification is not learnable? If lexical minimality or lexical economy plays any role at all, indeterminable features are surely left unspecified. Otherwise a learner might as well store any such feature with its least marked value. In this case there is a choice between the least marked value for this feature in general: its least marked value for the segment class it is associated with or its least marked value in the neutralization position. A third alternative, at least for alternating segments, is to store the value that occurs with highest frequency. This option has two sub-choices, we can opt either for type frequency or for the number of environments in which a certain feature specification occurs. For the moment we have to leave this as an open question.

A further possible conclusion one can draw in the face of the Australian data, which is not necessarily compatible with Steriade's approach, focuses on the fact that we find variation in the neutralization position in Gooniyandi but not in Gaagudju. This can be explained if one assumes that feature-filling rules are language-specific and not universal. In Gaagudju a feature-filling rule applies, in Gooniyandi it doesn't. In such an analysis a neutralization rule removes whatever specification the initial coronals have underlyingly, and then a feature-filling rule inserts the default value (Gooniyandi) or it doesn't (Gaagudju).

If Archangeli's observation is correct that Contrastive Underspecification requires full specification of all features first in order to be able to determine the contrastive features and then remove everything else, this has repercussions for our understanding of language acquisition. Language acquisition has to be 'forgetting' rather than learning in the usual sense: the learner first has to use all the features available and can only then start with pairwise comparisons to extract contrastive features and 'forget' the redundant feature values (a similar proposal is argued for by Hale & Reiss 2008).

This is an interesting position, since it excludes the option that features are acquired or mature during language acquisition. They must be hard-wired (i.e., part of Universal Grammar) and available from early on. It is also slightly problematic in that the learner has to have an overview of the system as a whole, while still expanding his/her vocabulary and discovering new segments.

Another potential problem, with both approaches, Radical and Contrastive Underspecification, is posed by the choice of contrastive features. The set of features is not exhaustively used in any language. In the last two sections we have mainly looked at vowel systems and concluded that whether one analyses a five-vowel system with the features in (17) or (18) or another set is an arbitrary choice.

4.4 THE CONTRASTIVE HIERARCHY

Especially the two last-mentioned issues, namely that the underspecification algorithm requires full specification first and that neither Radical nor Contrastive Underspecification account for an adequate choice of contrastive features, are tackled with Dresher's (2003, 2008, 2009, 2010) resurrection of the contrastive hierarchy and the feature division algorithm. The idea goes back to Trubetzkoy, who analysed phoneme systems as division trees, but also as matrices (see Section 2.3). Dresher focuses on the division tree, which is generated on principled grounds by the Successive Division Algorithm (SDA; Dresher, Piggott & Rice 1994; Dresher 2003 *et seq.*).

Languages do not arbitrarily use a random set of features for contrasts. Since Jakobson (1941) we have known that there are implicational relations between contrasts. Languages with affricates usually have stops; the presence of fricatives in a language implies the presence of sonorants and stops; if a language has front rounded vowels it also has back rounded vowels, but not vice versa, etc. Usually languages with a minimal vowel system of just two contrastive vowels distinguish these in height rather than backness or roundness, as do children at the start of language acquisition (Jakobson 1941).

By and large, Jakobson (1941) showed that there are amazing parallels between implicational relations between segment classes in typology, language acquisition and language loss (e.g., in aphasia). Children most often start with a low vowel and then distinguish a high or non-low vowel. We would thus expect that they make use of the feature [±low] or [±high] first. Thus, to account for the vowel system series in (23) one would want to first specify [±low], then use [±back] and then add a second height feature and only then make use of [±round]. Many languages distinguish more levels of height rather than exploiting lip rounding as a distinctive feature.

(23) Common vowel systems (ignoring length)

/a, ɨ/, /a, ə/ ‹ /a, ə, ɨ /, /a, i, u/ ‹ /a, i, u, e, o/ etc.
Margi, Ubykh ‹ Kabardian, Ainu ‹ Spanish

However, (23) is oversimplifying, since languages can make other splits in the inventory. Turkish and other Turkic languages, for example, distinguish only two phonological vowel heights but contrast front rounded and unrounded vowels as well as back rounded and unrounded vowels.

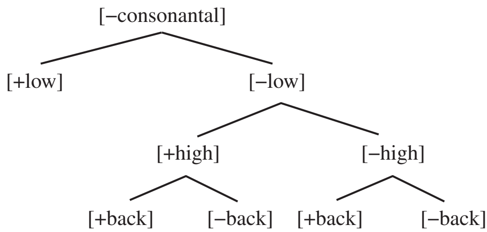
Among the languages with very small vowel inventories we don't find any that distinguish front and back vowels or front and central or central and back vowels, or any language which uses only the presence versus absence of lip rounding to contrast vowels.

(24) Unknown vowel systems

/e, ə/, /e, ɤ/, /e, o/, /i, u/, /i, ɪ/ ‹ /e, ə, o/, /i, ʉ, u/, /a, ɨ, ɑ/ ‹ /e, o, u, ɯ/, /i, ɪ, u, ʊ/ etc.

Thus, on the basis of typological observations it should be possible to establish a division order, at least to some degree, i.e., a universally preferred order in which features are used to encode phonological contrasts.

(25) A vowel feature division tree



The same sequencing of contrastive splits should hold for the acquisition of contrasts by children learning their first language. This was first explicitly proposed by Jakobson & Halle (1956), who claim that children learn the contrastive system of their native language by making binary splits, separating first labial from dental consonants. After this split they separate low and high vowels. After that they separate palatal and velar vowels as well as the velopalatal from the labial and dental consonants.

Nevertheless, one could expect that languages diverge in how they split up their contrastive inventory. The result is a divergence in the underlying specification of features. A possible source of evidence for such differences in specifications can be found in different phonological patterns. Accordingly, minimal pairs or unpredictability aren't the only criteria for regarding a feature as contrastive. Phonological activity (in assimilation or neutralization processes, etc.) is another important diagnostic for considering a feature specified. In an assimilation process, such as vowel harmony, at least the triggering segments have to have a specified feature at some stage. In the autosegmental understanding of such processes, features spread by the addition of association lines to additional segments. This generalization on phonological activity is enshrined in the Contrastivist Hypothesis.

(26) The Contrastivist Hypothesis (Hall 2007: 20)

> The phonological component of a language L operates only on those features which are necessary to distinguish the phonemes of L from one another.

By hypothesis, then, phonological processes that are generally assumed to be non-structure preserving (such as English flapping) should not create segments containing features additional to those needed to distinguish the contrastive segments of a language and should instead consist of feature combinations that are not in use in the lexicon.

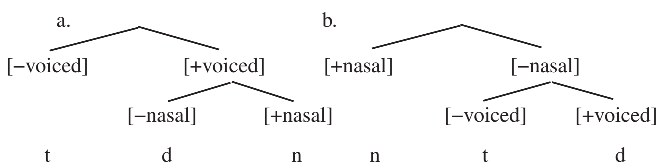
Before we have a look at phonological activity as a factor in determining contrastive features it is essential to know the Successive Division Algorithm (Dresher, Piggott & Rice 1994; Dresher 2003 *et seq.*), which selects contrastive features to encode contrasts.

(27) Successive Division Algorithm (SDA) (Dresher 2003 *et seq.*)

a. In the initial state, all tokens in inventory I are assumed to be variants of a single member. Set I = S, the set of all members.
b. i. If S is found to have more than one member, proceed to (c).
   ii. Otherwise, stop. If a member, M, has not been designated contrastive with respect to a feature, G, then G is redundant for M.
c. Select a new *n*-ary feature, F, from the set of distinctive features. F splits members of the input set, S, into n sets, $F_1 - F_n$, depending on what value of F is true of each member of S.
d. i. If all but one of $F_1 - F_n$ is empty, then loop back to (c).
   ii. Otherwise, F is contrastive for all members of S.
e. For each set F_i, loop back to (b), replacing S by F_i.

Dresher discusses Trubetzkoy's and Martinet's (1964) analyses of the French dental obstruents and nasal in several publications. The options at stake are whether the nasal is underspecified for [+voiced] or the voiceless stop is underspecified for [–nasal]. These options arise from different ways of splitting this set of consonants.

(28) Splitting French dental consonants (e.g., Dresher 2008: 21)



(29) French dental consonants: resulting specifications

	n	t	d	n	t	d
nasal	+		–	+	–	–
voiced	+	–	+		–	+

With such a division mechanism feature specifications are not particularly economic. A more economic specification (following Radical

Underspecification) had additionally left all the negative values out of the table to the right in (29).

(30) Radically underspecified French dental consonants

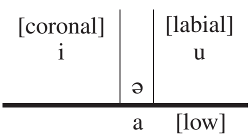
	n	t	d
nasal	+		
voiced			+

Specification of these consonants according to (28a) or (28b) should optimally have observable effects. One could imagine that a nasal, which is specified for voicing, triggers voicing assimilation in following obstruents at an early level, while an underspecified nasal doesn't.

An instructive example relating to the issue of phonological activity that also shows the stance taken on abstractness is discussed by Dresher (2009). The Yupik and Inuit/Inupiaq varieties of Eskimo-Aleut have very small vowel inventories. Proto-Eskimo is assumed to have had four vowels, [i, u, ə, a]. Many modern varieties have only three vowels, [i, u, a]. The languages differ, however, in the phonological activity of the vowel [i]. In some modern varieties, some /i/'s cause palatalization of following coronals. The varieties that display palatalization have either four vowels and palatalization applies before all instances of /i/, or they have only three surface vowels and palatalization applies only after those high front vowels that correspond to high front vowels in varieties with four vowels but not after high front vowels that are a schwa in cognates in varieties with four vowels.

To explain this micro-typology, Dresher develops the following analysis, based on unary features.[6] In Proto-Eskimo and all varieties with four contrastive vowels, the feature [low] separates /a/ from the rest of the inventory. [labial] splits /u/ off from /i/ and schwa and finally [coronal] separates schwa and /i/.

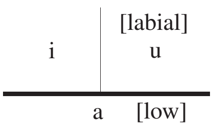
(31) Splitting Proto-Eskimo vowels



This division sets each vowel off from all others and keeps schwa as the literally unmarked vowel. Furthermore, /i/ can cause palatalization by spreading the vowel place feature [coronal] and schwa cannot cause any assimilation since it doesn't have any features. The varieties that have replaced schwa with [i] all still have this system, separating four vowels. The realization of the unmarked vowel as [i] is regarded as a phonetic implementation difference. This explains why the [i] vowels that were historically schwa don't spread.

This leaves the last group of varieties to be analysed, those that have only three vowels and have given up on palatalization. In these varieties, schwa and /i/ merged by /i/ losing its feature. That is, these varieties have a phonological three-vowel system, while the others phonologically still have four vowels and only show a merger in the phonetics.

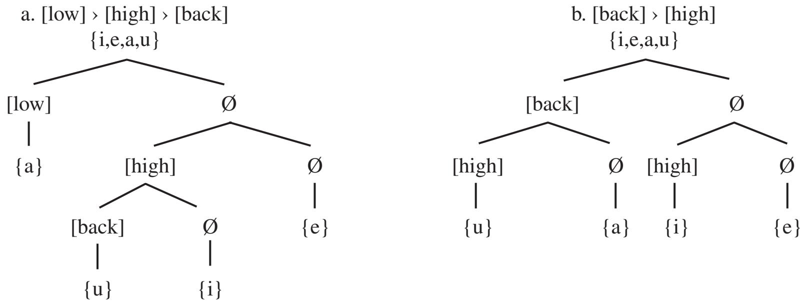
(32) Phonological three-vowel system



The order of division doesn't really matter in this example and in principle the SDA doesn't determine any order. However, Dresher (2009) maintains that the historical loss of the feature [coronal] rather than loss of [low] or [labial] follows from division order. Thus, the Eskimo-Aleut vowel systems are split by [low] first, then by [labial] and last by [coronal]. The expected, or more commonly applied, order of the latter two features is reversed, i.e., the feature [coronal] divides the inventory before [labial] is used. The lowest feature in the hierarchy, in this case [coronal], is also the first that can get lost. A new generation of learners simply doesn't bother to do the last split.

Hall (2007) illustrates the effects of splitting inventories in different ways with hypothetical four-vowel systems, consisting of /i, e, a, u/. In such systems the feature [low] can precede [high], which precedes [back], or [back] is used first and then only [high] is needed to contrast all vowels.

(33) Splitting inventories



To summarize, we see that the SDA is a relatively liberal device that does not a priori determine which features are more basic in general and leaves phonetically identical systems open for more than one analysis. Even though the generated underspecification is not as extensive as in Radical Underspecification, especially if privative features are assumed, the degree of underspecification is considerable. Unlike in Radical Underspecification, though, lexical minimality is not a driving force behind the theory at all, since it is designed to detect contrastive features and account for phonological (in)activity by assuming features to be present/absent in segment classes. 'It is not a question of what memories are stored in the brain, but of how phonology is organized' (Dresher 2009: 169).

4.5 SCEPTICS AND SYLLABLES

Criticism of underspecification comes from two main directions. The extreme position holds that every word, every morpheme and every segment is stored in the lexicon with all phonetic detail or, if phonological representations are still accepted, underlying representations are assumed to be identical to surface representations. These two full specification stances will be discussed in Chapters 5 and 8, respectively. In this section we look at a moderate position that doesn't deny underspecification and lexical economy entirely but argues that at least some predictable information has to be stored underlyingly.

Halle *et al.* (2000), for example, hold that underspecification is not only unnecessary but also misguided. At least contrastive features are fully specified, though only for the features that are contrastive in a given language. Clements (2001) argues for non-contrastive features to be specified if they are active in the phonology. This clashes with the

Contrastivist Hypothesis, since features that can be shown to be phonologically active should be contrastive as well.

Syllable structure is a rewarding topic since there is a relatively broad consent that syllabification is generally predictable and never contrastive and therefore should be derived by an algorithm, if it exists at all. CV-phonology flatly denies the existence of syllables. Furthermore, it has proved difficult, if not impossible, to extract any reliable physical correlates to syllable boundaries. Among those that do not share the scepticism regarding the existence of the syllable as a linguistic unit, the non-contrastive nature and absence of syllable structure in underlying representations is, however, not entirely undisputed.

A potential example of contrastive syllabification could be the English pair *patrol* vs *petrol*, i.e., [pə.ˈtɹəʊl] vs [ˈpet.ɹəl]. Underlying syllabification of the medial obstruent as either the coda of the first or onset of the second syllable determines stress placement, which determines vowel reduction. This contrast can likewise be analysed as a minimal pair for lexical stress, with one of the two words carrying lexical stress and the other derived by default. Scottish Gaelic is reported to have a contrast between monosyllabic and bisyllabic words, as illustrated in Clements (1986), Bosch (1998) and Ladefoged *et al.* (1998).

(34) Scottish Gaelic contrastive syllabification

tu.an	'hook'
tuan	'song'
pal^{ɣ}.ak	'skull'
pal^{ɣ}ak	'belly'

Vaux (2003) shows in a study of Armenian allomorphy that syllabification is at least partially lexically stored in this language, since, he argues, it determines the selection of allomorphs.

Golston & van der Hulst (1999) dispense with segments as basic units in phonological representations and replace them by syllable constituents.

That prosodic structure is part of mental representations is also assumed in psycholinguistic studies to explain tip-of-the-tongue (TOT) phenomena and some types of speech errors (e.g., articles in Fromkin 1973, 1985; Brown 2004).

In TOT phenomena, subjects usually recall the initial onset as well as the number of syllables of a word and the location of stress, which suggests that syllable structure is somehow present in lexical storage (Brown & McNeill 1966). Similarly, in lexical access errors, i.e., word substitutions, the substitute and target word usually have the same number of syllables and the same stress pattern, as in the famous example *white Anglo-Saxon prostitute* (target: *protestant*) (Fay & Cutler 1977). Although, the syllable structure (regarding complexity of onsets and codas, presence of codas) does not necessarily match (compare *prostitute* and *protestant*).

4.6 LEXICAL EXCEPTIONS AND UNDERSPECIFICATION

'One of the reasons for postulating segments that are underlyingly unspecified for some feature F, is that these segments, and only they, are targeted by assimilation rules that spread F' (Steriade 1995: 164). This statement comes as a bit of a surprise after the discussion of the connection between underspecification and contrast in the previous chapter and Section 4.4.

In the context of the SDA (Section 4.4), analyses crucially assumed that segments which (unexpectedly) do not cause assimilation in an adjacent target are underspecified for the spreading feature.

Underspecification of non-contrastive features, such as [±voice] in sonorants, had been argued for to simplify the formal statement of a rule on voicing assimilation between adjacent obstruents; it then explains why certain segment classes do not participate in a phonological process. If sonorants are systematically underspecified for the feature [±voice], a voicing assimilation rule can be stated as in (35a) or (35b).

(35)

a. [αvoice] → [βvoice]/__ [βvoice]
b. [–voice] → [+voice]/__ [+voice]

The underspecified sonorants don't have any value for [voice], i.e., no – or +, which α is a place holder for, and are accordingly neither a target nor a trigger for these rules. If they are fully specified already in the lexicon for all features that have a phonetic correlate in the surface form, these rules will cause devoicing of pre-obstruent sonorants and voicing of obstruents followed by any sonorant. The latter process is actually observed, as in Italian voicing of /s/ before nasals and liquids (as in co[zm]o 'universe' or O[zl]o 'Oslo'), but it is usually not a side effect of an assimilation rule on obstruents. Postnasal or postsonorant voicing is a widespread phenomenon. However, such voicing patterns are usually not related to voicing assimilation in obstruents.

It was mentioned earlier in this chapter that the RROC poses a problem for this type of (trivial) underspecification, since the feature-filling rule has to apply before the phonological rule, which then has to be stated in a less economic way, specifying the segment class to which it applies.

(36) [–sonorant, αvoice] → [βvoice]/__ [–sonorant, βvoice]

If the segment class is stated in a rule, the affected feature can be avoided in the description of the target of the rule and rules can be formulated in such a way that they affect only segments that are underspecified for the feature subjected to change by the rule.

If we ignore the RROC, rule (36) can apply to systematically underspecified segments (i.e., those which have the unmarked feature value either for the segment class in general or according to their environment) or one assumes generally full specification of contrastive features but idiosyncratic underspecification. The latter is a variation on what was labelled opportunistic or diacritic use of underspecification. It explains exceptional application of a rule and basically derives ternary contrasts.

Inkelas, Orgun & Zoll (1997) propose a pre-specification account of lexical exceptions. Krämer's (2000) analysis of Breton patterns showing a ternary voicing contrast through underspecification, as well as his (2001) account of Yucatec Maya morpheme-specific vowel alternations, uses the same technique: idiosyncratic underspecification as an explanation for exceptional phonological behaviour.

Turkish has a voicing contrast among obstruents, which is neutralized in syllable codas, as shown in (37a,b). However, some words do not undergo final devoicing, see (37c).

(37) Turkish final devoicing with exceptions (Inkelas *et al.* 1997: 395)

a.	kanat	‘wing’
	kanatlar	‘wing-plural’
	kanadɯ	‘wing-accusative’
b.	devlet	‘state’
	devletler	‘state-plural’
	devleti	‘state-accusative’
c.	etyd	‘study’
	etydler	‘study-plural’
	katalog	‘catalogue’
	katalogdan	‘catalogue-ablative’

Inkelas *et al.* suggest an analysis that uses underspecification for the alternating segments, i.e., [∅voice], while the non-alternating voiceless set is marked as [–voice] and the non-alternating voiced series as

[+voice]. The alternating obstruents are realized as voiced in intervocalic position as an effect of a passive-voicing process (intervocalic or prevocalic voicing), which is structure filling rather than structure changing.

A reasonable criticism of this approach notes that all the forms that don't undergo final devoicing are recent loanwords. In many languages loanwords tend to be subject to less strict constraints than the native vocabulary. Itô & Mester (1995a,b, 1999, 2009) provide an insightful account of loanword phonology with their onion model of lexical strata. According to Itô & Mester, the core, or native, vocabulary of a language is subject to the most restrictive constraints on phonological structure and loanwords can be placed in successive, less restrictive layers of the lexicon outside this core lexicon. Inkelas *et al.* (1997) object that such a model of grammar causes learnability problems.

The same case, i.e., for idiosyncratic underspecification and full specification elsewhere, is made for the same feature in a different language, the variety of Breton spoken on Île de Groix, by Krämer (2000). Breton displays final devoicing, like Turkish. In addition, there is an assimilation pattern that is operative at the phrasal level. Voicing assimilation is usually regressive, as you can see in (38a). Some word-initial consonants, though, undergo progressive devoicing, such as those in (38b-d).

(38) Île de Groix Breton (Ternes 1970; Krämer 2000: 651f.)

a.	unačypaš	+	ba:k	→	unačypa**žb**a:k
	'a crew'		'boat'		'a boat crew'
	urve:ryš	+	goux	→	urve:ry**žg**oux
	'a jacket'		'old'		'an old jacket'
b.	unačypaš	+	bənak	→	unačypa**šp**ənak
	'crew'		'any'		'any crew'
c.	urmi:s	+	bənak	→	urmi:**sp**ənak
	'a month'		'any'		'any month'
d.	peamzek	+	daj	→	peamze**kt**aj
	'fifteen'		'day'		'fifteen days'

It is instructive to briefly compare this with Dutch. Dutch displays a very similar pattern of a combination of final devoicing, regressive voicing assimilation and a reversal of the directionality of the latter process in some environments (see, e.g., Grijzenhout & Krämer 2000). However, Dutch assimilation turns out to be progressive devoicing when the second member of the cluster is a fricative. In Breton, such a phonological generalization is not possible.

Krämer (2000) resorts to the same solution that Inkelas *et al.* propose for Turkish final consonants, i.e., to underspecify the alternating initial consonants, while non-alternating morpheme-initial obstruents are specified as either [–voice] or [+voice]. In absolute final position potential underspecification can't have any effect in Breton, since final devoicing is assumed to be structure changing (unlike in Inkelas *et al.*'s account of Turkish final devoicing). The voicing of the underspecified obstruents, which is realized when they are in phrase-initial position, is explained by a voicing process, that also causes alternations in other contexts in Breton (resyllabification of a final obstruent across a word boundary).

Both languages, Turkish and Breton, display considerable aspiration of their voiceless series. However, an analysis that regards the voiceless consonants as specified for [spread glottis], some of the voiced consonants as specified for [voice] and the alternating consonants as underspecified for these unary features is not desirable either. Such an analysis postulates a three-way contrast that should have a surface reflex in positions of contrast. However, what we find here is a three-way contrast that only shows in positions of neutralization. It manifests itself only indirectly, through the segments' behaviour in the assimilation pattern.

To illustrate the idiosyncratic use of blanks further we consider one last example, coming from Yucatec Maya. Similar cases are easily found. Yucatec has a typical five-vowel system (Like Spanish, alluded to earlier). Some of the mood and aspect affixes show complete harmony (or copying) of the preceding root vowel, as you can see in (39a,b), while others display stable quality, as exemplified in (39c,d). If the alternating affixes are separated from the last root vowel by more than one consonant, vowel harmony is blocked and the affix vowel surfaces as [a], as shown in (39e). However, (39d) shows that there are other underlying low vowels that don't undergo harmony in the relevant context.

(39) Yucatec Maya harmony

a.	ʔah-al	'wake.up-IMPF'	b.	ʔah-ak	'wake.up-SUBJ'
	ʔok-ol	'enter-IMPF'		ʔok-ok	'enter-SUBJ'
	lub'-ul	'fall-IMPF'		lub'-uk	'fall-SUBJ'
	wen-el	'sleep-IMPF'		wen-ek	'sleep-SUBJ'
	kíim-il	'die-IMPF'		kíim-ik	'die-SUBJ'
c.	yil-ik	'see-IMPF'	d.	yil-ah	'see-PERF'
	tsol-ik	'explain-IMPF'		tsol-ah	'explain-PERF'
	putʃ-ik	'hit-IMPF'		putʃ-ah	'hit-PERF'
e.	t'otʃ-b'-al	'harden(glue)-PASS-IMPF'			
	ts'íib'-n-ak	'write-voice-SUBJ'			

An underspecification account of these data posits complete underspecification for the alternating vowels in the imperfective morpheme in (39a), /-Vl/ and (39b), /-Vk/. The assimilation process is a mere structure-filling rule and does not affect affix vowels with underlying feature specifications. In the blocking context the underspecified vowels surface with default feature specifications. However, other vowels with these specifications, i.e., other /a/'s, have to have the features specified underlyingly, since they would otherwise be expected to undergo harmonization.

The alternations in (39a,b) could be analysed in (at least) three alternative ways. First, this could be epenthesis with parasitic feature-filling. In this case the imperfective marker in (39a) and the subjunctive marker in (39b) don't have a vowel underlyingly, they are /-l/ and /-k/, respectively, and the vowel preceding the consonant in the surface forms is epenthesized to avoid a consonant cluster. Rather than inserting default values for all features, the epenthetic vowel is supplied with the feature specifications of the vowel to its left. In another alternative, these affixes are reduplicative morphemes with a fixed segment (the consonant). The third approach doesn't have anything to say about underspecification and assumes that individual morphemes contain indexical lexical information that can trigger or block phonological rules.

Even in an epenthesis analysis, however, one has to wonder why features spread/are copied to the epenthetic vowel but not to any other vowel. Moreover, it seems suspicious that this is an all-or-nothing choice between specification and underspecification. Why are there no vowels with underspecification of height only, or backness? Such underspecification accounts also don't capture the substantially different nature of the Turkish and Yucatec patterns. While in Turkish, application of final devoicing is the regular pattern and the stems that don't undergo the rule can be regarded as the exception, this is the reverse in Yucatec, where the application of harmony is the exception.

Yucatec Maya displays other morpheme-specific patterns that give evidence to doubt all the above analyses sketched for Yucatec harmony and instead assume that individual morphemes can trigger the application of a rule, i.e., a rule can be exclusively linked to one morpheme or a class of morphemes. There are at least two suffixes with a vowel that dissimilates with the preceding vowel. One of them, the suffix deriving denominal and deadjectival verbs, is shown below.

(40) Yucatec Maya dissimilating suffix

a.	uts-kiin-t-ik good-D-TR-IMPF	'enhance/repair sthg.'
b.	haw-kuun-t-ik lie.down.face.up-D-TR-PERF	'lay sthg. down face up'
c.	sáasil-kuun-s le k'oʔob'en-oʔ light.up-D-CAUS DET kitchen-DEM	'Light up the/that kitchen!'

If the vowel preceding the suffix is from the set *i, e, a*, the suffix surfaces as *kuun*, if the vowel to the left is *o* or *u* the suffix surfaces as *kiin*. We can thus assume that the suffix vowel is specified for height and shows the opposite value for [±round] as the adjacent root vowel.

Yet another affix, that links base and reduplicant in the formation of participles of positional verbs, dissimilates in a more complex way, surfacing as *un* when attached to stems containing *a* or *e* and as *en* when attached to stems with *i*, *o* or *u* (Krämer 2001: 206). Apart from roundness (or backness) this vowel also changes height. The two allomorphs divide the vowel set in different ways and they dissimilate in different ways. Rounding does not seem to be of importance in the latter pattern. Thus, just (under)specifying the vowels in the latter two suffixes for different features and assuming that they are targeted by the same process doesn't give a satisfactory explanation. Assigning each of the three affixes to a different stratum of grammar in which three different rules apply is not a good solution either,[7] since we add strata and general rules exclusively on the basis of these few affixes.

The issue of exceptionality is much broader than indicated so far. Individual morphemes do not only idiosyncratically trigger phonological processes, they also block otherwise regular processes. Such processes do not only affect segmental features but also segment deletion and insertion or stress placement. There is a long and ongoing discussion on how to handle such idiosyncratic behaviour. Apart from underspecification, which handles only a subset of attested exceptional behaviour, approaches fall broadly speaking into two types. One possibility is to posit specific subgrammars or co-phonologies for individual morphemes or morpheme classes, which seems to be an intuitive solution for loanwords, for example. However, even with loanwords there is a problem in that if several morphemes from different co-phonologies are concatenated, it is impossible to choose the correct co-phonology for the resulting word. If, for example, loanwords are combined with affixes from the native vocabulary, such a situation arises. In languages with vowel harmony, such as Turkish or Hungarian, loanwords often contain vowels that don't conform to the requirements of vowel harmony in the respective language. Nevertheless, suffixes added to disharmonic loans follow the usual assimilation pattern. Thus, each morpheme adheres to its own phonology. The alternative to co-phonologies invokes diacritic marking. Arbitrary diacritic marks, which are not phonetically motivated contrastive features, are added to the underlying representations of morphemes and these diacritics activate or block one or several phonological processes (see, e.g., Pater 2009b for an OT implementation of the latter approach as well as for an overview of the discussion and further references).

4.7 DISCUSSION

Underspecification of phonological features had its renaissance in the 1980s. The theories developed in this era made significant progress in systematically differentiating between trivial or inherent underspecification and non-trivial underspecification and in developing algorithms to determine underlying specifications resulting in different degrees of (under)specification. This development was possible for three reasons. First, the argument against underspecification was decomposed and its premises laid bare, and it was shown that the latter did not necessarily have to be taken for granted, such as, for example, the assumption that rules can be ordered freely. Second, phonetic research also raised doubts about the dogma of surface full specification. It has been observed that languages that don't use certain contrasts show segments that are articulatorily and acoustically located somewhere between those that are used in languages in which the relevant features are contrastive, especially place of articulation. (For example, English and French /t/ are vacillating somewhere in between dental and alveolar, while Italian or Spanish /t/ is dental. Unlike English and French, Italian and Spanish have a series of palatal consonants crowding the lingual articulation space.) Third, further examination of phonological patterns (such as the distribution of vowels in Mongolian) was regarded as evidence that segments are systematically underspecified for certain features.

However, just as the discovery of surface underspecification suggests that underlying representations are most likely not fully specified either, observations on the mental status of syllable structure contribute to the conclusion that lexical economy isn't as important a principle as assumed in theories of underspecification. The pendulum swings further away from underspecified lexical representations with analyses of lexical exceptions in terms of idiosyncratic under- and pre-specification. Thus, by the turn of the century we have almost gone full circle.

Of course, there is no consent on the matter, as can be seen by the range of positions sketched above that stem from the early 2000s, ranging from Toronto-style (Dresher and associates) systematic contrastive underspecification to Inkelas' and others' pre-specification account of exceptions.

In the next chapter we will look at the opposite extreme to Radical Underspecification, Exemplar Theory, a school that emerged in the 1990s and is gaining ground.

DISCUSSION POINTS

- Why should one consider leaving out any information in lexical/mental storage at all? Doesn't detailed information make it easier to identify and retrieve lexical items?
- In footnote 5 I mention some possible features, i.e., [±spread lips], [±front] [±low] and [±mid]. Discuss these features and why some of them are bad choices.
- Discuss alternatives to underspecification to explain exceptional phonological behaviour (either exceptional blocking or exceptional application of a process).

SUGGESTIONS FOR FURTHER READING

Underspecification and economy

Clements, G. N. (2003). Feature economy in sound systems. *Phonology* **20**: 287–333.

Hall, Daniel Currie (2007). The role and representation of contrast in phonological theory. PhD dissertation, University of Toronto.

Vaux, Bert (2003). Syllabification in Armenian, Universal Grammar, and the lexicon. *Linguistic Inquiry* **34**: 91–124.

Lexical exceptions

(Readers not familiar with Optimality Theory should consult Section 8.1 before reading these articles.)

Becker, Michael (2009). Phonological trends in the lexicon: the role of constraints. PhD dissertation, University of Massachusetts, Amherst.

Kager, René (2008). Lexical irregularity and the typology of contrast. In Kristin Hanson & Sharon Inkelas (eds.), *The Nature of the Word: Essays in Honor of Paul Kiparsky*. Cambridge, MA: MIT Press. 397–432.

Pater, Joe (2009). Morpheme-specific phonology: constraint indexation and inconsistency resolution. In Steve Parker (ed.), *Phonological Argumentation: Essays on Evidence and Motivation*. London: Equinox. 123–54.

More on allomorphy

Bye, Patrik (2007). Allomorphy – selection, not optimization. In Sylvia Blaho, Patrick Bye & Martin Krämer (eds.), *Freedom of Analysis?* Berlin: Mouton. 63–91.

5 The devil is in the detail: usage-based phonology

5.1 INTRODUCTION

In the previous chapters we had a look at theories of underspecification and the issue of abstractness in underlying representations in phonological theories. While from a theoretical perspective underspecification is desirable, this doesn't necessarily have to correspond with psychological reality. Mental representations could be rich and detailed, like high-resolution photographs or like other memories we store in our minds, like the flavour of a particular cheese or an event we have experienced. In this chapter we consider such an approach to underlying representations.

The idea that statistical calculations play an important role in the shaping of language patterns and consequently in lexical storage goes back quite a bit (for a young discipline such as linguistics). Zwirner (1936) held the belief that we cannot properly understand language and language change without statistical methods.

> The passage from research into norms for the articulation of speech sounds to the investigation of speech includes the passage from the investigation of language history to a tailored survey of the variation found in language, since these handed down norms for the articulation of speech sounds cannot be met in exactly the same way twice. (Zwirner 1936: 77; my translation)[1]

At the time, scholars such as Saussure, Trubetzkoy and Jakobson brought forth forceful arguments in favour of categorical contrasts, as outlined in Chapter 2. Around sixty years later the use of statistical methods, or better, explanations of linguistic patterns through their statistical properties have gained ground again.

In the following section the basic ideas of Exemplar Theory will be laid out. In Section 5.3 we will have a closer look at the role of frequency, since the assumption that lexical representations consist of detailed memories of actual productions of surface forms heavily relies on the belief that statistical aspects of experienced speech shape grammar and consequently underlying representations. In Section 5.4 we will discuss how compatible the two approaches, formal categorical on the one hand and statistical on the other, are. It turns out that in the best of all worlds they complement each other. The exemplar approach will be over-critically evaluated in Section 5.5. I will point out examples of abuse of statistics and some of the problems that emerge in the work with linguistic corpora. Section 5.6 summarizes the previous discussions and concludes the chapter.

5.2 THE BASIC IDEA

In usage-based phonology phonological items are not stored as abstract units composed of categorical features. It is assumed that speakers store the signal as it is, with all the redundant information and all the background noise. Thus, over time a speaker/learner acquires a huge stock of such items for each word or form. These memorized exemplars of the same token, for example all the renditions of the word *dog* ever heard and produced by a user, are connected with each other, as are different morphological combinations (i.e., inflected forms, derived forms etc.; e.g., *dogs*, *doggish*, *doggie*…). Furthermore, all perceived instances of every segment in a language are connected among all lexical items that contain them. That is, all the exemplars of [d] when realized as the first sound in the word *dog* are connected to all exemplars of [d] in *dirk*, in *dad*, in *bud*, in *abdomen*, in *adorable* etc.

If one accepts this idea of storage in its most radical form, there doesn't seem to be any need for abstract categorical features or for a phonological grammar containing mechanisms that generate the results of phonological generalizations. To start with a more trivial matter, Coleman (2002) points out that any generalization regarding the targets and the context of a phonological process can be stated in acoustic phonetic terms as well (which is not particularly surprising since usually the phonologist starts this way, i.e., stating a generalization in phonetic (usually articulatory) terms to then move on to a formalization of the finding). He discusses in particular Halle's (1997) claims about the distribution of genitive /s/ (as opposed to /z/ or /ɪz/) in English and gives the following phonemic (a) and featural (b) summary.

(1) English genitive /s/ in phonological terms

a. Phonemic version
If the last phoneme of the word is a member of the set [/p/, /t/, /k/, /tʃ/, /f/, /θ/], the genitive allomorph is /s/.
b. Featural version
If the last segment of the word bears the features [+consonantal, –vocalic, –sonorant, –voice] (and if also [+continuant, +coronal] then [–strident]), the genitive allomorph is [+consonantal, –vocalic, –sonorant, +continuant, +coro-onal, +strident, –voice].

He then translates the generalization into phonetic terms.

(2) English genitive /s/ in phonetic terms (Coleman 2002: 115f.)

a. Articulatory version
If at the end of the word there is an obstruction within the vocal tract, but the vocal cords are not vibrating (and if furthermore there is a critical constriction between the tongue tip and the alveolar ridge, but the teeth are covered so that any turbulence is generated along the walls of the vocal tract rather than at the teeth), the genitive is formed by a critical constriction between the tongue tip and the alveolar ridge with the teeth uncovered so that turbulence is caused at the teeth, the vocal cords continuing not to vibrate.
b. Acoustic version
If at the end of the word there is an interval of relatively low amplitude, either silence or with aperiodic excitation, and if in the latter case higher frequencies predominate in the spectrum and the lower limit of the frequency distribution is relatively high, but with comparatively low amplitude relative to other aperiodic intervals and a stronger resonant structure),[2] the genitive is formed by aperiodic excitation with higher frequencies predominating in the spectrum, the lower limit of the frequency distribution being relatively high, comparatively high amplitude and a weak or indiscernible resonant structure.

Furthermore, and more importantly, a language user can run statistics over this immense data corpus s/he has stored in his/her mind and extrapolate any category and any pattern as emergent from these statistical calculations via frequencies, averages, standard deviations etc.

The issue here, however, is not so much in which way we understand morphological patterns or phonological ones, but what consequences such a view has for underlying representations. Johnson (2006) outlines the exemplar theoretic view on underlying forms as follows.

> [T]he key idea of the exemplar-based approach is that people remember, as the core of the cognitive representation of language, linguistic episodes not linguistic descriptions. We operate from mental

> images – detailed memories of specific linguistic experiences – rather than from impoverished descriptions of such experiences. (Johnson 2006: 492)

In this quote, Johnson differentiates declarative from recognition knowledge (in the above quote the impoverished descriptions and the episodes, respectively). In declarative knowledge we have an abstract representation, such as the mental picture we have of a historical person we have never met (like Julius Caesar, for example), while recognition knowledge is the knowledge of something or someone we have personal experiences of, e.g., a present-day politician (say, Barack Obama) or even more so a close friend, of whom we remember the way they move, body posture, ticks, hair style, the way they speak and dress etc. Johnson (1997, 2006) developed Exemplar Theory, however, to explain extralinguistic phenomena, such as gender differences in vowel articulation (2006), and extends the scope of explanation to phonology. Regarding the gender differences in vowel formants, Johnson observed that in international comparisons there is no clear correlation between acoustic differences and physical differences between members of the two sexes, such that one cannot straightforwardly conclude that the acoustic differences are due to a difference in body height, which implies longer vocal tracts for one gender as the explanation. Thus such differences have to be conventionalized on a language-specific basis.

One of the key pieces of evidence Johnson (2006) puts forth for the exemplar view are Strand's (2000) word-naming experiments. In these experiments subjects were presented with auditory stimuli of monosyllabic words and had to repeat each word after presentation. The variable controlled for encoding a gender cue was the third formant of the vowel. It turned out that subjects have faster reaction times if stimuli are presented with a stereotypical (either male or female) acoustic realization than when they are produced with a non-typical realization of the third formant of the vowel. Thus, listeners have extralinguistic expectations concerning the gender allocation of speech. If these expectations are not met this hinders linguistic processing.

Johnson (2006) simulates the results of Strand's experiments by feeding a computer with spectrograms of the exemplars that were used in Strand's experiment as well as with the renditions of Strand's subjects as additional exemplars. The exemplar that is tested for is then taken out of the exemplar cloud available to the model for matching. The table in (3) shows the results for recognition of the word *case*.

(3) Percentage of words correct and gender correct in Johnson's simulations of Strand's experiment

Talker	% words correct	% gender correct
F5 – stereotypical female	79	75
F7 – non-stereotypical female	75	17
M5 – stereotypical male	71	54
M8 – non-stereotypical male	50	79

It is difficult to compare reaction times with the percentage of correct identifications. We can, though, assume that Strand's human subjects were much better at identifying the four different types of renditions, it just took them longer to identify them. The algorithm, however, almost replicates the same trends. Stereotypical female forms are identified correctly more often than non-stereotypical female forms (though one could wonder whether a 4 percent difference is statistically significant) and the latter are identified correctly less often than the former. As far as the male forms are concerned, the simulation deviated from the expected result in gender identification but replicated the correct results for word identification.

Since the algorithm shows a tendency towards categorical identification in the face of fuzzy data, Johnson concludes that it should also be possible to analyse phonological categories as emergent in this way.

Bybee (2001) discusses English flapping and concludes that users store flaps as they store all phonetic detail of every rendition of every morpheme or word they are ever exposed to: according to Bybee (2001), for non-alternating forms like *butter* and *ladder*, the generative phonologist is faced with the problem of which segment to posit as underlying, /t/ or /d/. With phonetic representations this conundrum doesn't arise since both words are stored with a flap. Nevertheless, they are connected to flaps in other words, some of which do alternate with stops. The words that show alternation are stored with both phones. Since all the phonetic (and probably even visual) detail of every form of every morpheme and all its occurrences are assumed to be stored, this is not surprising. However, the different realizations of individual morphemes are connected such that morphological/lexical identity can be established. The reasoning then has to be that flapping as a mostly exceptionless pattern is established via the connection between the different forms of the alternating morphemes, and the connections of so many flaps with coronal stops through these alternating forms. Thus phonological alternation is not really conceived as one and the same thing (i.e., the /t/ in the morpheme /hɪt/ surfacing in different guises as the effect of the application of a rule or as the response to the pressure of markedness constraints) but as a relation, based on semantic and phonetic similarity.

One question that wants to be answered in this context is how one defines phonetic similarity: if a German morpheme-final /g/ sometimes surfaces as [g] and other times as [x] or even [ç], this criterion is slightly problematic, as it is for the classic method of allophone allocation to a common phoneme (see the discussion of Trubetzkoy in Chapter 2). In the latter case voicing, manner and place have changed. But, since such forms are also connected via their semantics, the relation between [g], [x] and [ç] can be based on the observation that some of their exemplars come with the same semantics and the same or extremely similar phonetic material preceding them.

The 'mainstream generative phonologist' would assume that non-alternating morphemes and by extension non-alternating phones, as in our *butter* and *ladder* examples, do take free rides on alternating phones (see as well Chapters 2, 3 and 8) to reduce the information load on the lexicon. Needless to say, the answer provided by exemplar theorists is that this does not happen. Storing surface forms as they are and instead connecting them to similar forms saves the language user from making a decision on an underlying form where it is impossible to make, i.e., when the phonological process is neutralizing, as in the case of English flapping.

Since speakers are able to determine a fitness value for different renditions of the same phonological category and since speakers are also able to take all sorts of information into consideration, i.e. phonetic context, pragmatic information, a speaker's state of health etc., and since they can even identify other speakers by their voices, many researchers assume that speakers have access to this information (Miller 1994; Rosch 1978; Johnson 1997 amongst others).

There are two models that were proposed to account for this. Rosch (1978) assumes that language users store prototypes, which are the best-fit or summary exemplar one can derive after running statistics over the percepts one has been exposed to. A problem with such an approach is, of course, that all the information about possible maximal and standard deviation from a prototype gets lost. Furthermore, we are constantly exposed to new exemplars, since every realization of a sound even by the same speaker differs from the same speaker's previous renditions by minute detail (reflecting state of health, mental state, whether the speaker has chewing gum in the mouth or a peg between the lips or is lifting a box, inaccuracies in fine motor control, air pressure variation etc.), and we constantly talk and listen to new people who produce additional renditions for our mental database. Furthermore, the listener's mind isn't always in the same state; we have variation in attention according to our physical state (just woken up, tired, excited, annoyed etc.), which influences how much detail we store of the speech stream we are exposed to. If we want to keep our prototypes up-to-date we have to do the statistics again and again. Thus one might conclude that there is a need to store all percepts or exemplars, which is the solution proposed by Johnson (1997).

In Exemplar Theory (Johnson 1997, 2006; Bybee 2001; Pierrehumbert 2001) exemplars that are identical, i.e., occur more often than others or are extremely similar, are stored together and get thus strengthened, while exemplars that don't occur often weaken and start to fade until they disappear. (Just like other memories: try to remember the face of the flight attendant that served you a coffee on a short flight a year ago and compare that to the ease with which you probably remember the face of the person who usually prepares your fancy Italian-style coffee in your favourite café around the corner.)

Apart from that strengthening and fading property, exemplars are connected in various ways. An exemplar can be an exemplar of a morpheme, of an inflected form or of a phoneme in a certain context and of the phoneme in question as such or of the realization of a certain phonological feature (if we still believe in those) and so forth. Accordingly, exemplars are connected in all these dimensions as well as with exemplars with semantic similarity. This results in an impressive network or overlapping and interwoven clouds of exemplars.

In a nutshell, word recognition works as follows. The incoming acoustic signal of a word, say, *cloud*, is compared to the exemplars of memories of *cloud* and other (similar) words (*loud, clod, clad, clout, plough, ploughed*…) and mapped to the most similar exemplars (i.e., those of *cloud*). There will not be any complete match, since every realization of the same morpheme even by the same speaker is phonetically unique in its phonetic details, but one or several close ones. Simultaneously, the listener compares the signal's acoustic aspects that identify the speaker's gender with all sorts of exemplars that are stored as having been produced by female and male speakers, respectively. That is, the stored realizations of *cloud* are not only part of the cloud of the sound-meaning pair *cloud* but also of other clouds, such as the cloud of *k* sounds, *l* sounds, the cloud of female voices, the cloud of voices of males with freckles etc. To complete the picture there are clouds for all sorts of linguistic categories, not only for contrastive segments, i.e., noun, verb, present tense, past tense…, as well as all sorts of non-linguistic information in addition to the gender mapping, such as age groups, peer groups, dialect, state of health, mood etc.

There are quite a few phenomena that one could expect such a theory to handle better than rigid stripped-down abstract phonological systems and their computation through an also inflexible formal system. It has been observed that language change often doesn't happen in one fell swoop, but that a change slowly creeps through the lexicon, for example as a phonological rule that first optionally applies to items that are used very often, then gets applied to these with increasing frequency and then contaminates other less frequent lexical items until it has infected the whole lexicon and is a compulsory process or completed change. Furthermore, some types of sociolinguistic variation, the use of dialectal traits to various degrees even by the same speakers in different situations, seem to require access to a rich reservoir of phonetic detail. As far as statistical mining of such a big corpus in memory is concerned, consider for example the variable application of *r*-dropping by speakers of New York English as examined in the famous studies by Labov (1972). The rate of *r*-dropping depends on all sorts of non-linguistic factors, not just the social class of the speaker but also the social aspirations of the speaker, the environment, expectations the speaker has about the social class of the listener etc. All this information has no place in a formal generative system and a generative phonologist would classify much of this type of variation as a matter of performance rather than competence.

The exact phonetic realization of sounds varies from language to language and dialect to dialect, and much of this is not necessarily categorically phonological in nature. How far back or how fronted English /u/ is realized in different varieties of English is a matter that is not necessarily attributable to differences in contrastive feature specifications but rather a matter of social convention, and the exact way of realizing a certain sound in a specific variety can only be learned via exposure and by using the data the learner gets through this. As far as English /u/ is concerned, the phonological fact that English doesn't have a front high rounded vowel (i.e., /y/) surely opens the door for relative fronting of /u/ in some varieties, but whether this happens and which articulatory/acoustic range is acceptable in a certain variety for the realization of /u/ is largely a phenomenon that lends itself to an analysis that has access to the cache of the language users' experience. Similarly, foreign accents of L2 speakers and the observation that the later someone starts learning a second language the thicker his/her foreign accent will be/stay could be attributed to the effects of exemplars from the native language suppressing felicitous realizations of the targeted L2 phonetic forms. While some foreign-accent phenomena have a systemic explanation – For example, native Italian speakers have notorious problems with lax high vowels in English because the high lax vowels and the contrast between tense and lax high vowels are absent from Italian – others don't. For instance, the observation that the same Italian speakers produce the English high vowels /i/ and /u/ much closer to cardinal vowels 1 and 8, respectively, than most native speakers of English do is difficult to explain with a feature theory but easily understood as an effect of stored exemplars. Another example is the difference in realization of the high vowels /i/, /ɪ/, /u/ and /ʊ/ in English and German. Even though both languages have the same phonological contrast here, all the high vowels have a lower articulation/acoustic target in English than they have in German.

Lastly, it has been observed that the idiolects of individual speakers change over their life spans (most famously reported for the phonetics of Queen Elizabeth II; Harrington 2006).

5.3 FREQUENCY

One of the central exemplar-theoretic claims is that frequency matters. For example, whether a phonological or morphological process is productive or not depends on its frequency. Bybee (2001) illustrates this with strong and weak verbs in English. The question is whether the productive pattern of past tense and participle formation is *-ed* affixation, as in *need* – *needed* – *needed* or *excavate* – *excavated* – *excavated* or whether it is ablaut, as in *drink* – *drank* – *drunk* or *dig* – *dug* – *dug*. There is also a third group with suppletive forms that don't follow any pattern, as in *go* – *went* – *gone* or *be* – *was* – *been*.[3] The verbs that follow the former pattern are much more numerous than those that follow the second pattern, that is they show a higher type frequency. Furthermore, every single verb in the latter group is used more often than the individual verbs in the former group, i.e., we use the form *drunk* and the form *gone* more often than the form *needed*. This is higher token frequency. The type frequency results in the emergent productivity of *-ed* affixation,i.e., when we come across a verb we don't have a past tense exemplar for yet, but we want to produce one, we follow the pattern with the higher type frequency.

Exemplar Theory is argued to explain especially the distribution of application of non-obligatory phonological processes (that are seen as historical change in progress). Coleman (2002: 119) shows this very nicely with the example of palatalization in English, which historically caused alternations such as *face* – *facial* ([s] – [ʃ]) and is synchronically showing alternations at word boundaries (e.g., *miss* + *you* ->*mi*[ʃ]*ou*). This, though, only happens in high-frequency phrases, but not in those with low frequency (e.g., *Miss Eunice*).[4] On the one hand, it is claimed that high-frequency items undergo change faster and, on the other, that they are most likely to resist change. This sounds contradictory at first, but we are dealing with two types of change. While high-frequency items are more prone to undergo phonological changes and phonetic reduction processes, they resist regularization, for example in morphological paradigms.

Bybee (2002) discusses the erratic application of past tense *t*-dropping in the LA corpus. In her corpus the doubly marked past tense form with the highest frequency (the verb *told*) shows the highest rate of final *t*-dropping, 68 percent, while the verb with the lowest frequency, for example *found* doesn't show any *t*-dropping.

A phonological change that introduces a historical change, such as lenition, will affect such high-frequency items earlier and more thoroughly than low-frequency items. Bybee (2001) discusses English *æ*-tensing in this context. In all accents of English we find slightly longer vowels before voiced consonants than before voiceless ones. In some varieties this length difference is as substantial as contrastive length differences in other languages and accompanied by a change in quality especially where the vowel *æ* is concerned. Bybee's claim is that the contextually determined length of vowels is stored in the lexicon and that in varieties with *æ*-tensing, high-frequency words lead the change.

It has been observed that the length difference between vowels preceding voiced and voiceless stops, respectively, is bigger in English than in other languages that show a similar effect, and that words with high frequency are affected by this more thoroughly than low-frequency words.

If we take, for instance, the high-frequency word *bad* and use the internet search engine Google as our database (740,000,000 Google hits on 24 June 2010),[5] there is a huge cloud of exemplars for this word in every speaker's memory, which also must be assumed to grow at a fast rate, i.e., with every new exemplar that is added. The lower-frequency word *glad* (147,000,000 hits, same day) has an accordingly smaller exemplar cloud, which we can also assume to grow at a slower rate. Any historical change, such as *æ*-tensing, should affect *bad* first.

Since the two clouds are connected as one cloud of an [æ]-ish vowel followed by a [d]-ish consonant, everything that happens to *æ* in *bad* also affects *æ* in *glad* after a while.

Why should anything have happened to the *æ* in *bad* then? The ever growing clouds of exemplars should suppress any deviant (i.e., lengthened) rendition of *bad*, since it has only one exemplar to start with, which is hugely outnumbered by the already present exemplars, the statistic middle of which serves as the role model for any new rendition.

To account for the initiation and propagation of change Pierrehumbert (2001) assumes, following Lindblom (1984), a production bias. This can be seen as an articulatorily motivated drive to produce something in a different way from how it has been realized for the last several hundred years.

We stipulate now that at a certain point in history speakers of English felt that they had to overdo the vowel length in vowels preceding voiced stops. Thus they added an articulatory target (= 'veeery long vowel') or production bias to their production machinery. The exemplar cloud of words like *bad* now keeps the speaker from just producing *bad* with a long vowel the next time s/he uses it. Instead, every new exemplar is moved a little bit closer to the target.

In a word that receives more new exemplars than other words because of its high frequency, this articulatory target is met faster than in low-frequency words, because every new exemplar moves a bit towards the target and with mass production of new exemplars the target has to be reached faster. Thus, high-frequency items are at the forefront of language change.

The items with lower frequency are then dragged along, influenced by their own new exemplars but more importantly by the mass of high frequency word exemplars. Since the *æ*'s in the exemplars of *bad* are connected to all the *æ*'s in words of lower frequency, the latter could slow down propagation towards the new target in high-frequency words. But since the new articulation target holds for these *æ*'s as well, this influence should be negligible. Since the articulation target doesn't hold for *æ*'s that aren't in the specified phonetic context, i.e., those that are not followed by a voiced or continuant consonant, the cloud of *æ*'s will split into two clouds according to the two contexts, resulting in the exemplar-theoretic equivalent of a length distinction.

To apply this theory to our concern, underlying representations, I discuss Pierrehumbert's (2001) analysis of category recognition now and will then turn to Ernestus & Baayen's (2003) nonce-word study of Dutch final devoicing.

If we focus on one acoustic cue for a vowel now rather than keeping track of all the information a hearer gets with the speech signal and concentrate on the second formant, F2, value that distinguishes height, one can see how a perceived vowel lands within the exemplar clouds and gets associated with one of them. English distinguishes between /ɛ/ and /ɪ/, as in *bet* and *bit*. The articulation of any of the realizations of any of the vowels in each of these two classes varies considerably. With respect to F2, some realizations of *bit* words and some realizations of *bet* words overlap. However, the majority of *bit* words have a clearly higher F2 than the majority of *bet* words. Exemplars that have identical or nearly identical F2 values merge and get strengthened. We can assume that the exemplars at the centre of the F2 range of a vowel are not only more numerous than those at the fringes, they are also stronger. If a speaker hears a word that has an F2 somewhere in the middle between the F2 values of the cores of these two exemplar clouds, category assignment is difficult. To allocate an incoming new exemplar to one of the two categories the listener scans a certain range around the F2 value of the perceived exemplar and calculates which type of exemplar has more tokens and stronger tokens and adds the new exemplar to this group, thus strengthening it further. In the case at hand – is the listener hearing an /ɪ/ (with a very low F2) or an /ɛ/ (with a very high F2)? – the yet unidentified object will be assigned to the phoneme /ɪ/ if the neighbourhood of its F2 is populated by more and stronger exemplars of /ɪ/ than by exemplars of /ɛ/. If its F2 is just a little bit lower, it will be identified with /ɛ/. In the first case the cloud of /ɪ/ grows and shifts a tiny bit towards the /ɛ/ cloud if this happens a few times. Of course, the /ɛ/ cloud can also grow in the direction of the /ɪ/ cloud if incoming forms with a relatively high F2 get identified with /ɛ/ for other reasons than F2.

This analysis makes use of abstract categorical contrasts and the question is, of course, whether such vowel classes are necessary at all, whether it isn't enough to identify a perceived item with a cloud that is linked to the right semantic concept for the listener to understand the speaker. If phonological categories are still necessary in the lexicon, the question arises whether these are emergent from the topographic organization of exemplars within clouds or have to be assumed a priori for the clouds to form at all. These issues will be addressed in the next section.

Ernestus & Baayen (2003) find a correlation between lexical statistics and assignment of underlying voicing specifications in a nonce-word experiment with speakers of Dutch. Dutch shows final devoicing as well as voicing assimilation (very much like Russian or Turkish, which are familiar from previous chapters). Participants in Ernestus & Baayen's study were presented with non-existing words ending in an obstruent, used as the first-person singular present tense verb form in the stimulus. Word-finally, the underlying specification for the feature [voice] cannot be retrieved due to final neutralization. The subjects were then asked to produce the past tense form. Dutch regular past tenses are formed by adding either the suffix *-de* or *-te* to the verb stem. Choice of the former or the latter depends on the underlying specification for [voice] in the stem-final obstruent. Even though the participants heard only voiceless stimuli, they realized about 24 percent of past tense forms with the suffix *-de*, indicating that they had assigned the stem-final obstruent an underlying voice feature in these cases. Furthermore, the probability for *-de* to emerge in this experiment depends on context, that is, the segment preceding the stem-final obstruent and whether the final obstruent is a stop or a fricative. Ernestus & Baayen compare their results with the percentage of underlying stem-final voiced obstruents in the CELEX corpus of Dutch and find a strong correlation. The frequencies of voiced past tense preceding different stops and fricatives in their experiment by and large match the frequencies of voiced obstruents of these subgroups in the CELEX corpus.

Ernestus & Baayen conclude that the subjects try to match their own lexico-statistical expectations. A segment type that is represented with more tokens in the lexicon is more likely to be added when a new form with ambiguous surface information is encountered. The alternative strategies subjects could have used are the following. The subjects could just have mapped the stimulus to the lexicon, i.e., stored what they hear. This map is favoured by two strategies, avoidance of disparity between surface and underlying form and avoidance of marked structure whenever possible. If the subjects had considered the process of final devoicing and 'undone' its effect categorically, they would have overgeneralized all final obstruents in the stimuli to correspond to underlyingly voiced segments, which they only heard as voiceless as an effect of final devoicing. The first two strategies would have resulted in the choice of voiceless *-te* in all past tenses, while the overgeneralization of final devoicing would have resulted in all past tenses with the affix *-de*. A fourth strategy could have led to yet another result, an approximate 50/50 split between the two choices for past tense formation. This would have been the expected result if speakers randomly picked one voicing specification or the other.

This experiment doesn't tell us whether language users rely on stored exemplars of individual lexical elements or whether they underspecify features or not. It rather shows how (adult) language users hypothesize underlying representations when confronted with new words. When a phonological neutralization pattern, such as final devoicing, masks a contrastive feature, the proper underlying value for such a feature can only be stored once the learner encounters the segment in question in a phonological position in which it can show its contrastive value, in this case the infinitive or past tense form of the verb, for example.

Most lexical representations, however, are not acquired and stored by adults but by infants, children learning their native language. Several authors (e.g., Hudson Kam & Newport 2005; Wonnacott & Newport 2005; Walter in press) have pointed out that children, unlike adults, deal with inconsistencies (exceptions to a pattern) in the input by overgeneralizing grammatical (phonological) regularities. While adults usually simply learn inconsistent forms when learning an artificial language in a laboratory setting, children regularize these inconsistent forms (Hudson Kam & Newport 2005). Adults have been found to regularize as well. According to Hudson Kam & Newport (2005), adults regularize an inconsistent form if it is in variation with a consistent form and there is a frequency bias towards the consistent form. Thus we can conclude that L1 learners ignore statistical information and (relatively) rigorously apply the grammatical rules they have generalized, while L2 learners (aka grown-ups) can more easily ignore grammatical restrictions and instead rely more on statistical distribution, as also shown in Ernestus & Baayen's study.

In this section we have seen how information about lexical statistics and surface frequency is argued to determine representations. There are some core claims here that have been looked at. First of all, whether an item is of high or low frequency determines its lexical status.

Frequency also determines which processes are regular and which are not. If an item is used very often it has accordingly many exemplars and its lexical representation is very strong, while for a low-frequency item the low number of exemplars and their tendency to fade away mean that the lexical entry is not only smaller but also weaker. Despite the alleged strength of high-frequency items, they are subjected to phonological patterns (such as lenition or segment deletion) more often than low-frequency items. Eventually they drag low-frequency items along, resulting in the regularization of a pattern and the emergence of categorical phonological rules. Such new processes are established through production biases. Otherwise the already existing exemplars would suppress any historical change. We have also seen that such a conception of the lexicon and grammar is not unproblematic. In the last section we will discuss this in more detail.

5.4 HOW COMPATIBLE ARE EXEMPLAR THEORIES AND GENERATIVE PHONOLOGY?

Above it was said that our mental representations of linguistic objects are extremely rich in detail and, in particular, identical to surface phonetic forms. While some proponents of the theory try to eliminate abstract representations and the categorical computation (aka grammar), some exercise more caution.

Pierrehumbert (2006) points out that Exemplar Theory and generative phonology explain complementary aspects of the sound patterns of language. While Exemplar Theory is designed to account for probabilities of variation, aspects of lexical exceptions and slow lexically idiosyncratic sound change (lexical diffusion) and the like, i.e., exactly those aspects of phonetics and phonology that generative theories do not have much to say about, generative phonology with its categorical representations and deterministic algorithms explains categorical perception of contrast, facultative rule application and much more where Exemplar Theory is at a loss.

The use of abstract contrastive categories and the categorical boundaries drawn in extremely similar ways cross-linguistically are especially troublesome for Exemplar Theory. Consider the two contrastive vowels /ɪ/ and /ɛ/ again. From an exemplar perspective it should be fully sufficient if a listener can distinguish, e.g., *bit* from *bet* somehow, but it is not necessary that the vowel in either of these words is identifiable as 'the same vowel as in *chicken*' or 'the same vowel as in *dress*', respectively. The phonetic profile of the word as a whole should be sufficient for identification against all other words in the lexicon and categorization is not necessary. The clustering of one group of words around the higher F2 value and the clustering of another group of words around the significantly lower F2 is surprising. Also surprising is the shift in categorization that speakers make if presented with stimuli that vary along this dimension when stimuli cross a threshold on that scale, i.e., categorical perception.Why should segments group into classes if individual words are stored in meticulous detail and can easily be retrieved from the lexicon?

If we can distinguish three, five or even seven degrees of voicing in stops by the perceivable differences in VOT, we expect this difference to be exploited in some language in a contrastive way.[6] So, if hypothetical [**B**] is a stop with voicing throughout the closure phase, [B] is a stop that has a very short VOT, [b] has a slightly longer VOT, [p] has an even longer VOT, [P] is almost completely voiceless and [**P**] is entirely voiceless through out the closure and release phase and maybe slightly devoices the initiation phase of the next segment. If we can perceive these differences or if we can be trained to perceive them reliably, then we would expect that some language has a set of words that differ only in this respect, i.e., the language uses this distinction as contrastive.

However, languages just use voicing in a digital way: phonologically a segment is contrastively either voiced or it is not. If a language has a three-way laryngeal contrast, other phonetic cues, such as aspiration or glottalization, are employed. Given the existence of these other cues and the fact that languages sometimes even combine them to some degree, resulting in voiced aspirated or breathy voiced segments, for example, we could imagine a language that maybe doesn't have any distinction among obstruents regarding place of articulation, but has twelve or more series of consonants which differ contrastively in their laryngeal configuration. The majority of languages that have laryngeal contrast distinguish between two series (plain versus ejective or glottalized; plain versus voiced; plain versus aspirated; e.g., Yucatec Maya, French and Norwegian, respectively). A few have a three-way contrast (e.g., Korean). And some go up to four (e.g., Sanskrit; Kehrein 2002). Languages that exploit the possibilities of a more fine-grained division of differences in VOT, pre- and postaspiration or even degrees of aspiration etc., to express contrast are simply not attested. Moreover, in languages with a two-way contrast (and presumably in languages with more distinctions too) language users exploit all sorts of acoustic cues to encode/decode the voicing contrast besides vocal fold vibration, such as the length of the preceding vowel, length of the obstruent itself, the abruptness of transition from and to a flanking sonorant, intensity of release burst, fundamental frequency of flanking sonorants (with lower F0 for voiced than for voiceless obstruents), height of the first formant etc. (see Hawkins 2010 for a discussion). This is surprising since we can perceive such cues and could use this potential of our auditory apparatus to make lexical distinctions, but usually we don't.[7]

We can extend this kind of reasoning even further. We are not only capable of identifying speakers by their voice or timbre, some of us even manage to imitate other people's voices. With a little bit of faith in human kind we can believe that in principle everyone could be trained to be a reasonably mediocre voice imitator, especially if we start training them early enough (as usually happens in natural language acquisition). Given all this, one would actually expect to find a language somewhere in which voice quality is contrastive in some discrete and linguistic way. Languages use Fundamental Frequency (i.e., have tonal contrasts) and they use difference in speed with which we let the vocal cords vibrate to a limited extent (in the distinction between voiced and creaky voiced segments), they use the possible differences in height of the first three formants (in vowels and sonorants), but no language uses the higher formants beyond F3 in a linguistically relevant, i.e., contrastive, way. The radical branch of Exemplar Theory or any theory that wants to include excessive phonetic detail in the linguistic representations humans store in their lexicon (i.e., the linguistically relevant part of long-term memory) and deny the existence of more abstract representations cannot give satisfying answers to such questions or explain such observations.

Accordingly, Pierrehumbert (2001, 2006) and Hawkins (2010) advocate a hybrid approach that combines categorical contrastive features and storage of phonetic detail. In a similar vein Hay, Pierrehumbert & Beckman (2004) conclude that their results support parsing models in which phonological analyses for a phonetic signal compete. They carried out a nonce-word experiment in which it turned out that phonotactics of the stimulus led subjects to analyse words as either morphologically simplex or complex depending on the segment combinations (nasal place assimilation, the pattern under investigation, is obligatory morpheme-internally in English and happens only in very restricted environments across morpheme and word boundaries). Hay *et al.* envisage connectionist or Hidden Markov models when pointing out the competitive nature of phonological analysis. Generative models that are designed to deal with variation and probabilistic optimization can also be found among the close relatives of Optimality Theory[8] (OT; Prince & Smolensky 1993/2004) in Stochastic OT (Boersma 1997, 1998, 2000) and Harmonic Grammar (Legendre *et al.* 1990; Pater 2009a; Coetzee & Pater 2011).

The basic OT idea of the selection of an optimal surface analysis from a candidate pool by the candidates' evaluation against a set of ranked conflicting violable constraints already has an approach to variation and probability built in. Constraints not ranked with respect to each other that prefer different candidates can be ranked differently in every evaluation and thus drive the grammar to select varying outputs, as proposed by Anttila (2002). If constraints A and B are unranked and constraint A prefers candidate α, while constraint B prefers candidate β, (4), this results in a 50 percent chance for each of the two candidates to be selected as the optimal surface form, as shown in (5) and (6).

(4) A tie in OT

	Constraint A	Constraint B
candidate α		*
candidate β	*	

(5) Temporary ranking I

	Constraint A	Constraint B
candidate α		*
candidate β	*!	

(6) Temporary ranking II

	Constraint B	Constraint A
candidate α	*!	
candidate β		*

If a third constraint C also prefers candidate α and is also unranked with respect to constraints A and B, the chances for candidate α to be selected as optimal rise to 66.6 percent, since there are six rankings that can occur randomly of which four prefer candidate α.

(7) Three unranked constraints

	Constraint A	Constraint B	Constraint C
candidate α		*	
candidate β	*		*

(8) Temporary ranking α.I

	Constraint A	Constraint B	Constraint C
candidate α		*	
candidate β	*!		*

(9) Temporary ranking α.II

	Constraint A	Constraint C	Constraint B
candidate α			*
candidate β	*!	*	

(10) Temporary ranking α.III

	Constraint A	Constraint B	Constraint C
candidate α		*	
candidate β	*		*

(11) Temporary ranking α.IV

	Constraint C	Constraint B	Constraint A
candidate α		*	
candidate β	*!		*

(12) Temporary ranking β.I

	Constraint B	Constraint A	Constraint C
candidate α	*!		
candidate β		*	*

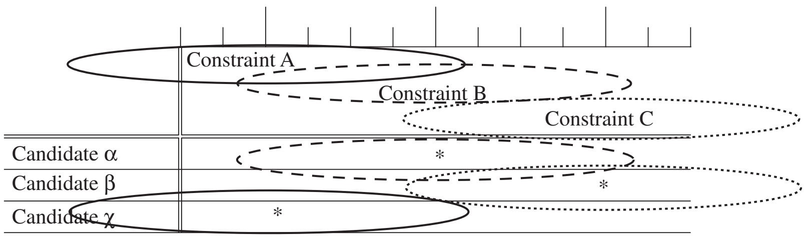
(13) Temporary ranking β.II

	Constraint B	Constraint C	Constraint A
candidate α	*!		
candidate β		*	*

In Stochastic OT, constraints are not ranked in an absolute way but occupy a space on a scale along which constraints are ordered. Constraint spaces can overlap and each constraint can assume any position randomly within its limited space of movement on the scale. This also results in constantly shifting rankings, which, accordingly, can describe the probabilities of surface forms in free variation.

The tableau in (14) illustrates this property of Stochastic OT schematically. The general positioning of the constraints indicates their ranking. The leftmost constraint is most important and the rightmost constraint is least important for the evaluation of candidates; that is, a violation of constraint A is quite likely to be fatal for a candidate, while a candidate that violates constraint B but not A has a very good chance to be selected as optimal. This absolute ranking is relativized by the ranges in the hierarchy within which the constraints 'float'. The circles indicate the range within which the respective constraint can randomly assume a position indicated by the vertical strokes on the line above the constraints. Constraints are expected to be in the centre of their span more often than at the margins. However, given the overlapping zones of the constraints, sometimes it happens that a violation of constraint C is regarded as more important than violations of the other two constraints, though the probability of this ranking and thus frequency of this form is very low. However, in such a case it can happen that candidate β, which at first sight looks like a safe bet, as well as candidate α can lose out to candidate χ, which at first sight looks like a hopeless case. Thus, this grammar produces a kind of variation in which form α is realized much more often than form β, which is observed more often than the rarely attested form χ.

(14) Stochastic ranking produces probabilistics of variation



Furthermore, Stochastic OT defines constraints as referring to acoustic phonetic details rather than categorical phonological features, which sets the approach in a position to model fine-grained phonetic variation.

Harmonic grammar assigns a weight to every constraint in addition to ranking them, which can also result in fluctuating rankings within the same grammar that can potentially describe frequency patterns.

Such grammars, however, have nothing to say about sociolinguistically driven variation of the kind observed in Labov's famous fourth-floor experiment (see the comment on *r*-dropping in New York above).

There have recently also been attempts to integrate extralinguistic information into OT-style candidate evaluations, as in Kostakis' (2010) proposal in which constraints are coindexed with information on gender, style, class, social standing etc. of speaker and listener, and activation rates of constraints are calculated according to these factors which influence candidate selection.

Such approaches, on the one hand, have the potential to be fruitfully combined with Exemplar Theory. On the other hand, if the effect of exemplar clouds is built into the constraint rankings, as just described, these theories can describe some of the frequency effects without exemplar clouds.

However, it is not clear at all how the correlation between the frequency of an item and the frequency of application of optional phonological processes could be accounted for in these systems.

Thus, since the loci of explanation of Exemplar Theory and generative phonology, though overlapping, do not completely coincide, we could attenuate Pierrehumbert's observation on the different explanatory scopes of either approach by saying that Exemplar Theory explains speakers' performance, while generative phonology and abstract categorical representations account for speakers' competence.

5.5 DISCUSSION

Even though the more cautious authors argue for hybrid models that acknowledge both the necessity of abstract phonological features and a phonological computation system, on the one hand, as well as access to detailed memories, on the other, given the observation of gradience in production and frequency effects and the convincing modelling of these in Exemplar Theory, one can still wonder if the former theoretical assumptions are necessary. There is a huge body of evidence from word games, spelling errors, psycho- and neurolinguistic experiments that suggests that language users make use of such abstract features. We will review such studies in more detail in Chapter 6. Here we have a short preview to put the usage-based account into a larger empirical perspective. After this I will go through some cases that have been put forward as empirical evidence in favour of usage-based phonology, but which apparently turn out problematic and show a more general issue in the methodology.

Hypercorrections, as reported, for example, by Nevins & Vaux (2007), suggest that speakers store non-alternating allophones, such as the flap in English in words such as *butter*, as one of the contrastive segments they are potentially related to, contrary to Bybee's analysis of the problem. Nevins & Vaux discuss speakers of American English who produce words with non-alternating flaps, such as *enchilada*, with a [t] on occasion. Such hypercorrections suggest two things: A. non-alternating forms do take free rides on alternating forms and B. in cases where a process is neutralizing, the less marked member of a contrasting pair is chosen when the dilemma of irretrievability of underlying specification, as discussed earlier on, arises. Thus, for items like *butter* and *ladder*, a naive speaker will assume an underlying /t/. This state of affairs can only be changed through knowledge of orthography, but this educated correction doesn't necessarily happen, as common spelling errors, such as the sporadic spelling of *sporadic* as *sporatic*, suggests. This is particularly troublesome for an account relying on surface phonetics, since [d] is phonetically much more similar to [ɾ] than [t$^{(h)}$].

Another aspect of the proposed theory that deserves further scrutiny is of a methodological nature and relates to the use of large corpora and the extraction of statistically significant generalizations from such data.

The correlation between frequency and the application of phonological processes introduced above is a disputable claim, since corpora that can be used to extract frequency calculations can't necessarily be trusted to correspond to any language user's real experience.

Earlier on I mentioned Bybee's (2002) discussion of the erratic application of past tense *t*-dropping in doubly marked past tense forms in the LA corpus. To illustrate her point, she gives the data reproduced in (Table 5.1).

Bybee (2002: 218) comments on these data: '[a] striking confirmation of the role of frequency is that, even within the semi-weak verbs, the high-frequency verbs undergo deletion much more than the low-frequency verbs, as shown in Table 10'.

Table 5.1 *Semi-weak past tense forms from the LA corpus ordered by frequency, with ties ordered by Francis & Kučera frequency*

Total tokens	Verb	Tokens with deletions
32	told	22 (68%)
9	felt	5(55%)
8	left	2(25%)
6	kept	4(66%)
4	sent	1(25%)
4	built	0(0%)
3	held	0(0%)
3	heard	0(0%)
2	slept	1(50%)
2	lent	0(0%)
1	found	0(0%)
1	lost	0(0%)
1	meant	0(0%)

Spearman rank order correlation: $p = 0696$, significant at the .01 level (two-tailed or one-tailed)

While the item with the highest frequency (*told*) clearly has the highest *t*-deletion rate (68 percent), there are some items that also show a pretty high chance of deletion which have a much lower frequency in the corpus. If we have to establish a threshold between high and low frequency on a scale from 32 to 1, where would we put this intuitively? Here we would have to conclude that only items that occur less than two times in our corpus are of low frequency. Of course, we could draw the line somewhere in the middle and end up with a lower likelihood for *t*-deletion in low-frequency items if we compare the average percentage of deletion of the twelve members of the group with the 'average' of the one-member group of high-frequency verbs. Bybee draws the line between six and four occurrences.

Apart from the difficulty of finding the line between high and low frequency, it is an academic question to ask what the statistics would have looked like if the LA corpus had been 1,000 times larger. The items that occur only once and show 0 percent *t*-deletion could still show 0 percent *t*-deletion. They could, if there were only 32 of them, which then probably still would qualify them as low frequency and also show 68 percent deletion – or 97 percent. We can't tell.

If we use another, larger, corpus, e.g., the World Wide Web, and check for the frequency of *told*, *kept*, *slept*, *lost* and *found*, we arrive at a very different picture, as shown in Table 5.2. The numbers in brackets are repeated from Table 5.1; they are the numbers of tokens of these words found in the LA corpus and the percentage of observed deletion.

Unfortunately, it is impossible to track *t*-deletion with Google, but, still, where do we draw the line between frequent and not frequent? And if a form is frequent in one corpus and less frequent in another, does that mean that this has an effect on the application of phonological rules regarding this lexical item in the respective corpus? Or was Bybee just misguided in this particular case and the generalization is that *t*-deletion is more likely to apply to low-frequency rather than high-frequency items? The generalization, though, was more general than that. Phonological processes/changes apply to high-frequency items earlier and faster and more often.

Table 5.2 *Google hits of some semi-weak past tense forms (on 7 Sept. 2010)*[9]

lost	1,310,000,000	(1; 0%)
found	967,000,000	(1; 0%)
told	420,000,000	(32; 68%)
kept	140,000,000	(6; 66%)
slept	17,100,000	(2; 50%)

Table 5.3 *Token frequency – Google hits on 9 July 2010*

	Token	Hits
a.	needed	361,000,000
	failed	203,000,000
	passed	159,000,000
b.	went	357,000,000
	gone	254,000,000
d.	wrote	280,000,000
	written	390,000,000
c.	drank	20,100,000
	drunk	78,700,000
	swam	4,920,000
	swum	350,000
	beaten	38,600,000
e.	read	1,480,000,000

The orthogonal claim that exceptions are of high token frequency and regular forms are of low token frequency but of high type frequency deserves a short discussion since this bears on the overall argument of which role statistical data play in grammar and consequently in the determination of underlying forms.

In a little ad hoc data collection I searched for a few past tense forms and participles in the largest corpus of written English available, the World Wide Web, using the search engine www.google.com. The results are given in Table 5.3.

Category (a) exemplifies regular past tense/past participle, i.e., the past as formed with most verbs, while (b) exemplifies suppletive forms, (c) ablaut verbs and (d) and (e) exemplify irregular verbs whose frequency could be affected by the medium in which we searched (the internet by and large depends on written text so far and mass media have a tendency to be self-referential).[10] As can be seen from the hit rates, there are regular verbs that outnumber irregular forms, even the suppletive forms, by token frequency. Furthermore, the unproductive pattern of ablaut shows extremely low token frequency.

To make sure this wasn't an accidental distribution I googled more weak and strong verbs in their past tense and past participle forms. The strong verbs have distinct forms. Thus, the number of googled forms doesn't equal the number of googled verbs. Since we are dealing with exemplars, I keep the past tense and participle forms separate for those verbs that have separate forms.

Altogether, the number of strong verbs in the English lexicon amounts to about 300 or 400, which is a very small number compared with the potentially infinite number of weak verbs. Nevertheless, more than half of the forms included in the corpus are forms of strong or irregular verbs (35 out of 64 forms of 23 irregular and 29 regular verbs).[11]

Table 5.4 *Frequency of irregular forms in the Google corpus*

(35/64 = irregular/strong)		
Most frequent	(top 10)	0.6
Frequent	(top 20)	0.3
Mid fielders	(21.-40.)	0.6
Low frequency	(bottom 20)	0.8
Least frequent	(bottom 10)	0.8

Despite the relative overrepresentation of irregular items in the corpus, the individual irregular verbs do not turn out to be more frequent than the regular forms. Instead, a clustering of irregular forms can be observed at the lower end of the frequency band, as shown in Table 5.4.

The token frequency of these irregular forms is actually way below average, if we take this ad hoc corpus as the measure (see Table 5.5). An individual regular form occurs on average above 134,000,000 times. Irregular forms occur around 76,000,000 times and 27 of the 35 irregular forms, i.e., 77 percent, are below this modest number of hits. On the other hand, only 6 irregular forms are above the general average of 96,806,687 hits per form.

This informal data collection reveals that, on the one hand, token frequency and irregularity are not necessarily correlated. On the other hand, it shows that, even though the irregular forms are overrepresented in number of lexical items included in this study, the regular forms by far outnumber them, i.e., there is a strong positive correlation between regularity and type frequency.

To connect this discussion of frequency more directly to phonology we have a look at the role of frequency in a phonological pattern for which it is difficult to say whether it is productive or exceptional. The decision speakers make here has a direct impact on underlying representations since either the alternating forms have to be stored separately or the non-alternating forms do (if we keep aside the exemplar view for a second and instead subscribe to a dual-route access theory that has forms composed by productive affixation not stored in the lexicon).

Italian has a process of velar palatalization (see Krämer 2009b and references there), which is exemplified in (15). Some stem-final /k/ and /g/ are realized as a postalveolar affricate if the front high vowel /i/ follows, (a). For some nouns and adjectives the process is completely blocked, (c), while others vacillate, (d).

Table 5.5 *Sixty-four verb forms – Google hits on 9 July 2010 – in decreasing frequency*

started	472,000,000	looked	196,000,000	searched	108,000,000
wanted	412,000,000	delivered	186,000,000	loaded	98,800,000
needed	361,000,000	printed	161,000,000	founded	89,800,000
went	357,000,000	passed	159,000,000	grown	89,400,000
sold	356,000,000	ordered	159,000,000	deleted	81,300,000
charged	349,000,000	lived	147,000,000	shaped	78,900,000
told	305,000,000	helped	144,000,000	drunk	78,700,000
gone	254,000,000	ended	132,000,000	stolen	75,200,000
bought	225,000,000	killed	127,000,000	frozen	73,800,000
brought	217,000,000	forced	110,000,000	taught	66,500,000
grew	65,000,000	rode	26,800,000	spoiled	12,200,000
sang	56,000,000	booked	26,000,000	climbed	12,200,000
dressed	49,800,000	crashed	25,400,000	ridden	10,200,000
struck	45,700,000	blew	22,100,000	shaken	9,100,000
blown	42,500,000	pissed	21,000,000	spilled	6,840,000
sung	41,500,000	shook	20,400,000	froze	5,450,000
dealt	31,300,000	drank	20,100,000	forsaken	5,190,000
ruled	30,900,000	dug	17,100,000	swam	4,920,000
cried	28,500,000	sank	15,100,000	crept	3,620,000
stole	28,300,000	sunk	13,600,000	wept	3,580,000
stung	3,480,000				
fumbled	1,180,000				
forsook	418,000				
swum	350,000				

(15) Italian velar palatalization – idiosyncratic/optional in nouns

a.	aˈmiːko, aˈmiːtʃi, aˈmiːke	'friend/pl./fem.pl.'
b.	ˈbrontʃo, ˈbrontʃi	'sad face/pl.'
c.	ˈkwɔːko, ˈkwɔːki	'cook$_N$/pl.'
d.	ˈmaniko, ˈmanitʃi / ˈmaniki	'door handle/pl.'

Krämer (2009b) reports the results of a Google data collection and a nonce-word experiment. Luckily, whether palatalization applies or not is indicated in the Italian orthography, which makes its application detectable in written texts. When the letters *c* and *g*, which represent the consonants /k/ and /g/, are followed by an *i* or *e*, which usually represent /i/ and /e/ respectively, they are realized as affricates. If they are not supposed to be realized as such an *h* has to be placed between the consonant and the vowel.

Table 5.6 *Frequencies of non-vacillating forms in the Italian Web*

Item	Hits	%
amici	3,140,000	99.68%
*amichi	9,970	0.32%
total	3,149,970	
*amice	12,700	0.6%
amiche	2,120,000	99.4%
total	2,132,700	
greci	2,060,000	96.27%
*grechi	79,800	3.73%
total	2,139,800	

Table 5.7 *Occurrences of vacillating nouns in the Italian Web*[12]

item	hits	%	item	hits	%
fármaci	2,220,000	99.97%	**mónaci**	982,000	98.86%
farmachi	548	0.03%	monachi	11,300	1.14%
total	2,220,548		total	993,300	
chirúrghi	1,900,000	97.98%	**mánici**	225,000	99.76%
chirurgi	39,100	2.02%	manichi	546	0.24%
total	1,939,100		total	225,546	
sarcófagi	65,400	80.54%	**stómaci**	49,400	98.16%
sarcofaghi	15,800	19.46%	stomachi	925	1.84%
total	81,200		total	50,325	

For palatalizing nouns that don't vacillate, a Google search, which scanned only pages in Italian domains, revealed the unsurprising results given in Table 5.6. The misspelled forms **amichi*, **amice* and **grechi* occur with a probability of >.04.

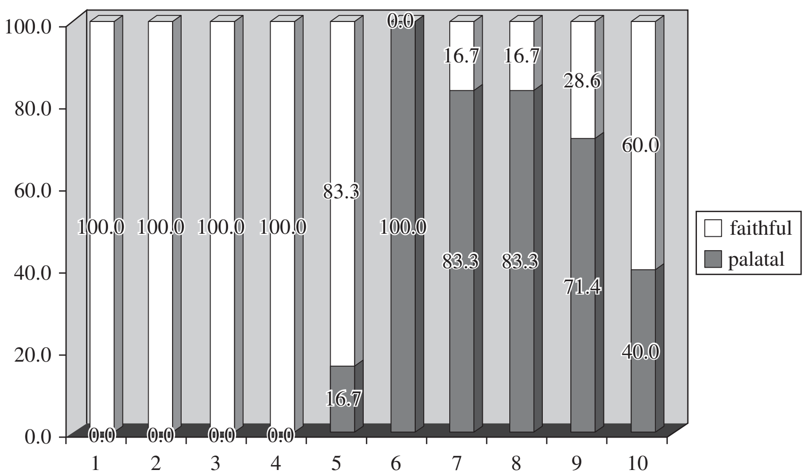
For the so-called vacillating nouns a Google search showed that each of them has a favourite form and that the other occurs at the same ratio as a typo (compare the less frequent forms in Table 5.7 with the starred forms in Table 5.6).

Furthermore, for most of these few words the form with palatalization is the preferred one. Also, the non-vacillating forms accessed all occur around 2–3 million times, while some of the vacillating words have a much lower frequency. So, if low token frequency is associated with productivity, palatalization should be productive and the words that block palatalization have to be stored separately rather than produced online. If the grammar doesn't determine whether palatalization or lack of alternation is preferred, the low-frequency items could show an even variation.

Now, a problem for an exemplar-based explanation is that most adjectives and nouns in Italian are of the *cuoco* type, i.e., they don't palatalize. Thus, the palatalization of low-frequency words can't be brought about by the high type frequency of the alternation.

When native speakers of Italian were confronted with non-words, which they had to read from a list giving the singular and then had to produce in a carrier sentence requiring the plural form (i.e., replacing the final *o* with an *i*), half the subjects palatalized almost all forms and the other half of the group did not (Krämer 2009), as shown in (16).[13] The last column shows the behaviour of the whole group.

(16) Palatalization in plural forms of nonce-words in percentage by subject



Thus, in Italian it is a personal decision whether velar palatalization is productive or not. This is surprising, given that the majority of lexical items behave like *cuoco* (*cuochi*) and only very few lexical items behave like *amico* (*amici*). This result would, of course, also have been surprising if the imbalance had been skewed the other way round. Since all speakers can be expected to be subject to by and large the same exemplars, we would expect a more uniform behaviour.

5.6 HOW FAR DO SPEAKERS MAKE USE OF PHONETIC DETAIL IN THE GRAMMAR?

In this chapter we have reviewed studies that show that language users store detailed information on the precise phonetics of every individual lexical item. Furthermore, it was claimed that such detail is stored for every experience of every form, i.e., every exemplar. Exemplars are connected in various dimensions, as exemplars of lexical items, exemplars of female or male speech, of speech of young or old, rich or undereducated people, nervous or overtired or happy people or as exemplars of phonemes and maybe even exemplars of contrastive features. Among the many things that this approach sets out to explain are sociolinguistic variation and competence, token variation, sound change and frequency effects (faster lexical access to high-frequency lexical items, higher likelihood of application of reductive phonological processes such as lenition or deletion or contraction).

The question is not so much whether language users have access to fine-grained phonetic information, but rather whether this information is linguistically relevant and whether it is sufficient.

That anecdotal memory is not entirely sufficient and that abstract phonological representations are indispensable has recently been argued for also by proponents of Exemplar Theory (Pierrehumbert 2006, Hawkins, in press).

Linguistic relevance can be understood to mean that some perceivable difference between sounds is used either to contrast two (or more) segments or in a systematic phonological process. The miracle of human speech perception is not that we have such fine ears, such a well-developed auditory cortex and an amazingly good memory that we can identify speakers' voices and even their mood and so on, but that we extract all this information out of a pretty blurred signal with lots of useless noise and, as far as we are concerned here, that the human mind manages to identify which parts of the signal are linguistically relevant.

Thus, one conclusion we can draw from this chapter is that our mental representations of linguistic items are, on the one hand, very detailed and, on the other, they are very abstract and discrete. Representations are very detailed since we have some kind of extralinguistic memories of individual words and of speakers and their voices. They are very abstract because we do feature extraction and discrete categorization of sound classes.

DISCUSSION POINTS

- Could one say that analyses of productive linguistic patterns that try to explain these by frequency of occurrence are circular?
- Why is the correlation between frequency of use and phonological change problematic for generative theories?
- Google the following forms and compare the numbers with their real past participle forms. Use the data to figure out the relative likelihood of individual verbs in this group to be regularized. Discuss your findings with regard to the hypothesis that low frequency makes forms more amenable to historical change.

  selled, telled, teached, dealed, stinged, weeped

  (Don't use *creeped* – 'creeped out' is an all too popular expression.)

SUGGESTIONS FOR FURTHER READING

Burzio, Luigi (2010). Lexicon and grammar: unequal but inseparable. MS, Johns Hopkins University.

Coleman, John (2002). Phonetic representations in the mental lexicon. In Jacques Durand & Bernard Laks (eds.), *Phonology, Phonetics, and Cognition*. Oxford University Press. 96–130.

Hawkins, S. (in press) Lexical representations. In A. Cohn, C. Fougeron & M. Huffman (eds.), *Handbook of Laboratory Phonology*. Oxford University Press.

Hay, Jennifer, Janet Pierrehumbert & Mary Beckman (2004). Speech perception, well-formedness, and the statistics of the lexicon. *Papers in Laboratory Phonology VI*. Cambridge University Press. 58–74.

Keating, Patricia (1988). Underspecification in phonetics. *Phonology* **5**: 275–92.

Pierrehumbert, Janet B. (2001). Exemplar dynamics: word frequency, lenition and contrast. Joan Bybee & P. Hooper (eds.), *Frequency and the Emergence of Linguistic Structure*. Amsterdam: Benjamins. 137–57.

Laboratory Phonology 1 (2), (2010). Special issue: Phonetic detail in the lexicon: Papers from the Eleventh Conference on Laboratory Phonology.

6 Psycho- and neurolinguistic evidence

6.1 INTRODUCTION

Traditionally underlying representations were determined on the basis of contrast and of generalizations that can be made about the surface patterns found in a language, as well as on the basis of assumptions about lexical economy. The last two decades, though, have seen a surge of experimental work that tries to reveal the form of underlying representations by subjecting speakers to word games or nonce-word tests. With these techniques forms can be elicited that reveal activity of otherwise static or unobservable patterns and the corresponding generalizations about restrictions on the surface as well as in the lexicon. Other recent studies show aspects of phonological representations by measuring brain activity or reaction times in listening, judgement or lexical decision tasks.

In the following we will look at a few exemplary studies that produce evidence for the form of underlying representations. We will be considering the following aspects of underlying representations: segments that never alternate could be specified differently from their surface form in the redundant features but also in contrastive features. Such divergences can be based on several grounds, either pure lexical economy, a notion that has been challenged repeatedly (see Chapters 3, 5 and 8), or because the contrastive feature is not contrastive in a given environment, or because the contrastive feature is predictable through a process that is operative elsewhere.

Furthermore, it has to be shown whether underlying representations are composed of abstract features or whether they are more like an imprint of the physical signal itself.

We can establish a hierarchy of likelihood of mismatch between underlying form and surface form on the foundations laid in the previous chapters.

(1) Likelihood of mismatch between underlying and surface form

Mismatch expected	Type	Example
most	Feature not contrastive in language x	nasality on English vowels (e.g., [sæ̃nd]); Tenseness or length on English vowels
	non-contrastive segment	glottal stop in German, English...; Flap in English
	redundant feature	voicing in sonorants; roundness on back non-low vowels
	unmarked value in two-way contrast	[–voice] in obstruents, [–round] in front vowels, [+back] in languages with assimilation to front vowels...
	contrastive feature in neutralisation position	[–voice] in coda in languages with final devoicing; Spanish word-initial rhotic
least	contrastive feature in position of contrast	coronality in stops; [–voice] in obstruents

In mismatch-negativity (MMN) measurements Näätänen *et al.* (1997) showed that speakers make a difference between segments that do occur in their language and those that don't. In an oddball experiment they played sequences of vowels to Finnish and to Estonian speakers. All speakers heard the vowels /e/, /ö/, /õ/ (a central vowel between /ö/ and /o/) and /o/. While the vowel /õ/ is contrastive in Estonian, it doesn't occur in Finnish at all. Finnish subjects showed stronger MMN effects to deviant /ö/ and /o/ than to /õ/, while the Estonians showed the same MMN effect for all these vowels.

Näätänen *et al.* conclude that speakers treat potential linguistic stimuli differently depending on whether they are part of the language-specific sound or phoneme system or not.

Such a study alone, though, does not prove the existence of a category phoneme or of contrastive features. It does, however, show that the brain does not simply access the phonetic information. The brain differentiates between auditory or speech stimuli that are part of the subjects' language and those that are not. Since Näätänen *et al.* made sure that the difference between stimuli was a difference in the F2 value, we would expect that interrupting a sequence of prototypical [e] vowels with an [ø] or [o] or the other mid vowel causes the same neural reaction or one that correlates with relative distance from the base stimulus, and that it does so equally in both languages (unless we grant the Finnish subjects some additional surprise on encountering a stimulus they don't have any stored memories or prototype of). The study also doesn't show how vowels are stored in the mental lexicon, since the study didn't use any lexical items, but rather operated on simple vowels as stimuli. Further below in this chapter we will see how such experiments that do not tap existing words or morphemes can still show us something about the structure of segments in underlying representations.

In the following sections we will get closer to the actual details of representations and to the issues discussed in previous chapters such as whether underlying representations of non-alternating morphemes are influenced by alternating morphemes, whether non-contrastive segments are stored as they are, whether non-contrastive features are stored and whether contrastive features can be underspecified.

6.2 REDUNDANT FEATURES

We begin with a more anecdotal case of hypercorrection that shows that segments that are not contrastive are not necessarily stored as such in underlying forms. The segment in question is the flap in American English.

Alternations show that the two coronal stops *t* and *d* are not allowed to surface in intervocalic position. Instead they are realized as a flap, as in *write* versus *writing* or *ride* versus *riding*, respectively. In the same environment we find flaps that never alternate with *t* or *d*, but which are represented as *t*, *tt* or *d* in the orthography, as in *mitre*, *clutter* or *cider*.

Nevins & Vaux (2007) report that the wife of one of the authors systematically produces forms such as *enchila*[t^h]*a* for *enchilada* , *che*[t^h]*ar* for *cheddar cheese*, *somebo*[t^h]*y* for *somebody* in careful pronunciation or what they label 'baby talk' register. They confirmed this tendency with a Google search on misspellings of analogous forms and found, for example, 25,000 hits for *sporatic*.

I repeated this search on 21 August 2010 (www.google.com) and received 57,400 hits (for control, the search for correctly spelled *sporadic* generated 16,900,000 hits; *enchilata* = 7,660; *enchilada* = 6,970,000).

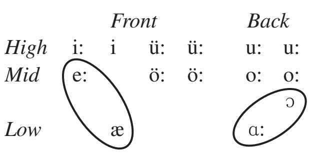
Nevins & Vaux conclude that such hypercorrections reveal the underlying form of the segments in question. Thus, the non-alternating flaps take a free ride on the pattern causing alternations involving flaps in other morphemes. Nevins & Vaux also note that by choosing /t/ rather than /d/ the underlying form of flaps is more different than necessary, since /t/ and [ɾ] additionally differ in voicing.

There are two potential explanations for this divergence. The flap is the phonetic realization of the central liquid or rhotic in other languages and other varieties of English (e.g., Scottish English), and phonotactically behaves like a sonorant there. In sonorants, voicing is redundant and is therefore a good candidate for underspecification, as we have seen in Chapter 3. Accordingly, the representation of /t/ is closer to the representation of a flap – if both lack a voicing specification and /d/ is specified. The other explanation bears on markedness and the ongoing discussion on which laryngeal feature is contrastive in English. If the feature is [voice], English *d* is marked, i.e., it has a laryngeal specification in its underlying (and surface) representation, while *t* is unmarked, lacking a laryngeal feature, and we can conclude that in the morphemes with a flap that don't show alternation, speakers store the less marked member of the contrast pair, the one without the specification. If the contrastive feature is [spread glottis], as argued by Iverson & Salmons (1995) and many others thereafter, we have to conclude that speakers choose the marked member of the pair if in doubt. At the end of this chapter I will report on an experiment by Hwang *et al.* (2010) that suggests the analysis assuming privative [voice] is preferable. Pre-empting this here, the conclusion gains ground that speakers store non-alternating non-contrastive segments as the unmarked member of a set of potentially corresponding contrastive segments.

Now we move on one step and consider evidence that was presented to reveal the status of features that are not contrastive in the segment class under investigation but contrastive in other sound classes in the language at hand.

Harrison & Kaun (2001) draw on a pattern from Hungarian to argue that predictable features might not necessarily be underspecified. Hungarian has a length contrast in vowels. For the low vowels in the system the length difference is accompanied by a difference in quality. These pairs are circled in (2) below.

(2) Hungarian vowel system



Note that one of the phonetic differences between the two low back vowels, rounding, is contrastive among the non-low front vowels, while the increased jaw opening that is characteristic for the short non-high unrounded front vowel in comparison to its long companion is not contrastive in front vowels, which only show a two-way height distinction. The back vowels, though, differentiate three levels of height. Thus, each of the two redundant features is contrastive in the system but not in the respective vowels. From the perspective of Radical or Contrastive Underspecification there is good reason to assume that the front low vowels do not carry any height feature and the two back low vowels are not specified for the feature [labial] or [±round].

Some monosyllabic stems that have a long vowel in the unaffixed form undergo shortening when a suffix is added, while some retain the long vowel. Some stem-final vowels are short when in word-final position and lengthen when certain affixes are added. In these length alternations the low vowels show an expected alternation also in quality. A third group meets the conditions for shortening or lengthening but is immune to the processes.

(3) Hungarian shortening, lengthening and resistance

a.	u:r	‘master’	urɔk	‘master-pl.’
			urɔ	‘master-3’
	e:r	‘vein’	æræk	‘vein-pl.’
			æræi	‘vein-3’
b.	kæfæ	‘brush’	kæfe:k	‘brush-pl.’
	fɔ	‘tree’	fɑ:k	‘tree-pl.’
c.	ke:p	‘picture’	ke:pæk *kæpæk	‘picture-pl.’
	hɑ:z	‘house’	hɑ:zɔk *hɔzɔk	‘house-pl.’
	kært	‘garden’	kærtæk	‘garden-pl.’

One is tempted to conclude two things: the vowels that alternate in length are underspecified for length and the low vowels that alternate in quality as well are at least underspecified for these non-contrastive features, as indicated above.

Harrison & Kaun (2001) discuss the Hungarian word game Veve to determine whether the latter is the case. In Veve, the sequence -Vv- is inserted before the rhyme of each syllable in a word. The inserted vowel, V, is a copy of the vowel in the syllable the infix is breaking up. Furthermore, this vowel is always short. For bases with long low vowels Harrison & Kaun expect the inserted vowel to adapt to the phonotactics and change quality if the base vowel is underspecified for the non-contrastive features. They observe no change in quality. The game produces otherwise unattested vowels, i.e., short [e] and [ɑ].

(4) Hungarian Veve game

a.	itt	ivitt	‘here’
	ti:z	tivi:z	‘ten’
	sæm	sævæm	‘eye’

b.	eːr	eveːr*æveːr	'vein'
	ɑːr	ɑvɑːr *ɔvɑːr	'price'
	neːvmɑːʃ	neveːvmɑvɑːʃ *næveːvmɔvɑːʃ	'pronoun'

Harrison & Kaun also report on a variety of the game in which length is neutralized in the base vowel as well. In this version quality doesn't change according to the general Hungarian pattern either. Harrison & Kaun conclude that the lack of alternation shows that these vowels are underlyingly specified for the redundant features. An option they don't consider, though, is that the game (either version) operates with the surface form as the base (or the output of the lexicon in Lexical Phonology; see Chapter 2; Mohanan & Mohanan 1984). Thus, Harrison & Kaun's evidence that predictable features are specified in underlying representations is at best inconclusive.

In Section 6.4 we will see some further evidence for underspecification of a non-contrastive feature, nasality in English vowels. The experiment in which underspecification of nasality in English nasal vowels is revealed is part of an experiment that also sheds light on predictable nasality in a language that has a nasality contrast among vowels, Bengali. The latter is what we now turn to: the underlying status of contrastive features in neutralization contexts.

6.3 CONTRASTIVE FEATURES IN A NEUTRALIZATION CONTEXT

The same authors, Harrison & Kaun, show with another language game that features in non-alternating segments, which are predictable via a pattern that causes alternation in other segments of the same type, are underspecified, i.e., that such segments take a free ride on a process that applies elsewhere (as with the English flap above). To show this they taught speakers of Turkish a word game that is known to some speakers of Tuvan but not to Turkish speakers. Both languages display the same type of vowel harmony, stem-controlled backness and roundness assimilation. They also have the same vowel inventory.

(5) Tuvan vowels

	Front		Back	
High	i	ü	ɨ	u
	e	ö	a	o

The Tuvan game involves reduplication of the whole stem or root and replacement of the first vowel in the reduplicant by a dummy vowel. The original vowel is substituted by the dummy vowel *a*, unless it is an *a*. In this case the dummy vowel is *u*.

(6) Tuvan reduplication of monosyllables (Harrison & Kaun 2001: 225)

a.	nom	nom-nam	'book'
	er	er-ar	'male'
	se:k	se:k-sa:k	'mosquito'
	is	is-as	'footprint'
	ög	ög-ag	'yurt'
	süt	süt-sat	'milk'
	qis	qis-qas	'girl'
	xol	xol-xal	'hand'
b.	at	at-ut	'name'
	a:r	a:r-u:r	'heavy'

Polysyllabic roots with vowels that conform to the general harmony pattern, i.e., that agree in backness (and roundness if the target is high), show reharmonization of the second vowel in the reduplicant.

(7) Tuvan reduplication with harmonic polysyllabic bases (Harrison & Kaun 2001: 226)

a.	idik	idik-adik	*adik	'boot'
	fi:dik	fi:dik-fa:dik	*fa:dik	'video cassette'
b.	teve	teve-tava	*tave	'camel'
	tevelerim	tevelerim-tavalarim	*tavalarim	'my camels'

This is not the case with disharmonic roots. In these forms the second vowel in the reduplicant does not change with respect to its correspondent in the base if it is in disagreement with the preceding replacement vowel.

(8) Tuvan reduplication of disharmonic polysyllabic bases (Harrison & Kaun 2001: 226)

maʃina	maʃina-muʃina	*muʃuna	'car'
ajbek	ajbek-ujbek	*ujbak	'Aibek' (name)
ʒiguli	ʒiguli-ʒaguli	*ʒagili	'Zhiguli' (car)
a:l=ʒe	a:l=ʒe-u:l=ʒe	*u:l=ʒa	'yurt' (= ALL)

Speakers who are new to the game produce the same results. Turkish speakers introduced to the pattern produce the same results too.

Harrison & Kaun conclude that the harmonic vowels in the second syllable of the base are underspecified for the harmony feature and the process fills in the feature on the surface as it does in affix vowels, while the disharmonic vowels in the second syllable of loanwords are specified for the feature in the underlying form and thus don't alternate in the game. Their insight, in general terms, is that predictable non-alternating material is underspecified, or, in OT terms, Lexicon Optimization is pattern-responsive (see Chapter 8 for further discussion of Lexicon Optimization).[1]

As part of an argument against Optimality Theory's Lexicon Optimization, Nevins & Vaux (2007) list a few cases in which we have evidence from word games, misspellings and overgeneralizations that speakers use other means than the identity map to create underlying representations. To argue for the role of lexicostatistics they discuss a Spanish word game, very similar to French Verlan, that reveals an interesting alternation in rhotics. In Spanish, the coronal flap and trill are contrastive word-internally but not word-initially. In addition, they cite Harris (2001) giving the lexical frequency of the two contrasting *r*-sounds. The contrast is neutralized at the beginning of words. Here, only the trill occurs.

(9) Spanish rhotics

pero	'but'	(flap)	80%
perro	'dog'	(trill)	20%
rosa	'rose'	(trill)	100%

(statistics according to Harris 2001)

The word game inverts the order of syllables. Thus, *casa* 'house' is realized as *saca* etc. Word- or stem-initial trills are realized as flaps when transposed into the middle of the word in this game.[2]

(10)

casa → saca
gato → toga
[r]osa → sa[ɾ]o (trill turns to flap)

Since the trill is allowed in intervocalic position the lexically stem-initial trills could just have stayed faithful when brought into an intervocalic environment.

Nevins & Vaux conclude that lexical frequency in the contrastive position (i.e., intervocalic) causes storage of initial trills as underlying flaps and the grammar turns them all into trills.

Spanish doesn't have any process that changes trills into flaps or vice versa. (We could imagine, for example, that stem-final rhotics exist which are turned into flaps when a vowel-initial suffix is added.) Thus, the initial trills can't parasitically benefit from an alternation and be stored as flaps in analogy to this, i.e. they cannot take a free ride (see above and Chapter 8). The chances that there is a rule that operates exclusively in this word game are extremely low. Word games of this type are not reported to have additional segmental rules. Thus the initial rhotics have to be stored as flaps in underlying representations and they are changed into trills at the surface to comply with phonotactic constraints (i.e., flaps are not tolerated word-initially).

It is, however, not an inescapable conclusion that this unfaithful storage is brought about by lexicostatistics. Articulatorily a trill is more complex than a flap. This might indicate that it is also more marked phonologically, either being represented by an additional feature or a marked feature value that is unmarked in the flap. Thus, this could be an effect of either lexical economy (it is not necessary to store a feature for a segment that is always in a position where it can't have a deviant specification) or markedness (a marked feature value can be left underspecified if the grammar enforces its realization in a certain position anyway).

Thus, storage of the less marked category in a neutralization context, even one that prefers the opposing category, can be explained without recourse to lexicostatistics. We will come back to this case in Section 8.3.3.

6.4 COMPARING CONTRASTIVE AND NON-CONTRASTIVE FEATURES IN A NEUTRALIZATION CONTEXT

We will now have a look at whether there is a difference in speakers' minds between contrastive and non-contrastive features. Lahiri & Marslen-Wilson (1991) report the results of a lexical decision task involving nasal and oral vowels. In Bengali, nasality on vowels is contrastive. In addition to this, the language has a nasalization process in which vowels that precede a nasal consonant are nasalized. The same process can be found in English, in which nasality is not contrastive on vowels. The patterns of the two languages are illustrated below.

(11) Bengali

a.	[bãn]	'flood'	b.	/pan/ → [pãn]	'betel leaf'
	[bãd]	'dam'		/pa+n/ → [pãn]	'you (honorific) get'
	[bad]	'difference'		/pa+ʃ/ → [paʃ]	'you (familiar) get'

(12) English

a.	[bæ̃n]	'ban'
b.	[bæd]	'bad'
c.	*[bæ̃d]	

Lahiri & Marslen-Wilson presented words with nasal and with oral vowels of which the final consonant had been removed to speakers of either language and asked them to list all the words this initial sound sequence could result in.

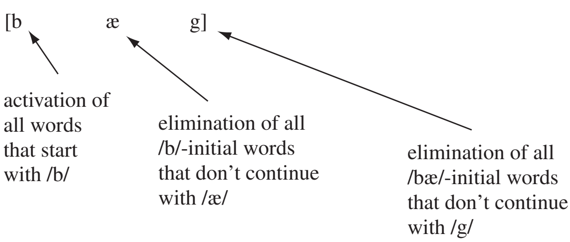
(13) Options

a.		Patterns		
	Bengali:	CVC	CṼN	CṼC
	English:	CVC	CṼN	*CṼC
b.		Stimuli		
		CV(C)	CṼ(C)	

Words were divided into gates after the offset of the first C, 'chopping up' the stimuli in successively longer tokens. For better comparability they also included a group of Bengali stimuli, which have nasal vowels and no words in the lexicon that start with the same segment combination and end in an oral consonant.

The experimental design is based on the cohort model of word recognition in which it is assumed that exposure to a word activates first all words in the lexicon that start with the same segment as that of the stimulus and successively excludes words from this candidate pool as more segments become available, finally converging on only the candidates with the same segmental make-up at the offset of the word (Marslen-Wilson 1984, 1987; Marslen-Wilson & Welsh 1978).

(14) The cohort model of word recognition



Lahiri & Marslen-Wilson compare the predictions of a full specification model, or a model that assumes storage of words in all their phonetic detail, with a model assuming underspecification of predictable features.

(15) Predictions:

a. Full phonetic specification:
- Encounter of nasal V excludes oral V candidates
- Encounter of oral V excludes all nasal V candidates

b. Underspecification:
- Encounter of nasal V keeps all candidates
- Encounter of oral V keeps candidates with oral and nasalized Vs and excludes distinctively nasal Vs

Bengali speakers keep their options open when encountering surface nasal vowels, even giving words with oral vowels that are not followed by a nasal (33.2 per cent CVC responses to CṼC stimuli and 23.5 per cent CVC to CṼN stimuli). Strikingly, when confronted with nasal vowels they hardly give any words in which the vowel is nasalized because it is followed by a nasal consonant even for the stimuli in which such a nasal consonant was removed (5.2 per cent CVN responses with CṼC and 7.9 per cent with CṼN stimuli). When the stimulus contains an oral vowel the majority of words given by the subjects have an oral vowel too, but 13.4 per cent of words given have a nasalized vowel even though there was no nasalization in the stimulus.

Similarly, English subjects ignore the nasalization in the signal to a large extent and give words with oral vowels when confronted with a nasal vowel stimulus (59.3 per cent CVC responses to CṼN stimuli).

Lahiri & Marslen-Wilson regard the high percentage of CVC responses to CVN stimuli in both subject groups troubling for full specification approaches and conclude that what these speakers access are potential underlying representations which differ significantly from the surface signal. If vowels that are predictably nasalized on the surface are stored as oral vowels, this explains why English subjects give more words ending in an oral consonant after hearing a word onset with a nasal vowel, but also why they provide some words ending in a nasal consonant when they hear a word with an oral vowel. For the Bengali speakers, unlike speakers of English, nasality is contrastive and thus if they hear an oral vowel this cannot be underlyingly nasal, while if they hear a nasal vowel, this nasality can be a lexical feature or something that has to be stripped off before scanning the lexicon (thus the high percentage of oral V responses to CṼX stimuli).

So far we can claim with some confidence that underlying representations differ from surface representations and that features predictable through an alternation-inducing process (Bengali) or even a static pattern (English) are absent from underlying forms.

6.5 CONTRASTIVE FEATURES

In the previous sections evidence was accumulated that supports the position that individual phonological features are underspecified in underlying representations, the reason being that they alternate when brought into a phonetic context in which they are realized in a way that would have been unexpected if all their articulatory or acoustic details had been stored or because they primed phonetically different words in word completion tasks. To look at whether contrastive features can be underspecified we need to pick features that show more than a binary opposition as well as a markedness hierarchy.

Features with a binary opposition are features that traditionally have a positive and a negative value and many of these are nowadays regarded as unary or privative, such as nasality. While *SPE* had a feature [±nasal], most phonologists today would regard this feature as one that is either present as [nasal] on a segment or it is absent. Place contrasts, on the other hand, show at least a three-way contrast in most languages, contrasting labial versus coronal versus dorsal segments, most commonly among stops. Among these one can observe a cross-linguistic asymmetry in that assimilation processes often target the coronal series which assimilates to labials and dorsals, and neutralization processes also often focus on the coronals, which are realized as glottals in syllable- or word-final position or deleted. According to general assumptions about markedness (see the overview in Rice 2007), coronals are prime candidates for the least marked of the three major places of articulation. According to the logic that turns binary features into unary features as well as Feature Geometry's way of dealing with assimilation and neutralization, the least marked state is the one to be regarded as underspecified. If, for example, coronal segments don't have a place feature specified in underlying forms, this feature has to be filled in before the segment can be realized and place assimilation rules that target coronals can only be regarded as structure-filling rather than structure-changing.

The literature on the question of whether coronal segments are underspecified for place of articulation is quite extensive. In addition to the vast literature discussing conventional phonological data, Lahiri and her associates have carried out a range of psycho- and neurolinguistic experiments, which they argue show that coronal segments, obstruents and vowels alike, are underspecified for place of articulation. The programme has a wider scope, since they advocate a specific theory of the lexicon, the featurally underspecified lexicon (FUL) in tandem with a theory of lexical access in perception (Lahiri &

Reetz 2002, 2010, Marslen-Wilson 1984, 1987). Here we recapitulate some of the most revealing experiments.

Lahiri & Reetz (2002) introduce the ternary distinction of *match*, *mismatch*, *no-mismatch* for recognition of phonological features. If (some) contrastive features are underspecified in the lexicon, there should be three possible reactions in feature recognition according to how the signal and the primed lexical representations match. If signal and underlying form are identical they match, while if they are incompatible they mismatch. If one of the two is underspecified, we have a no-mismatch situation, since even though the two representations aren't identical they are also not incompatible because a lexically underspecified feature can be filled on the surface with anything according to context (via assimilation or according to markedness).

(16) Examples of *match*, *mismatch* and *no-mismatch* (Lahiri & Reetz 2002: 641)

Signal	Matching	Lexicon
[high]	mismatch	[low]
[coronal]	mismatch	[dorsal]
[dorsal]	no-mismatch	[underspecified]
[dorsal]	match	[dorsal]

If coronal segments are underspecified for place of articulation, substituting a coronal segment in a stimulus by a labial or dorsal one should trigger different reactions in test subjects than the replacement of a labial with a coronal or dorsal, since in the first case the change leads to a no-mismatch while the second substitution leads to a mismatch between lexically specified and surface place of articulation.

So, if German test persons are primed with the word *Bahn* 'railway/train' and then have to recognize the word *Zug* 'train', substitution of the final nasal by a labial nasal should not lead to an increased reaction time for *Zug*. If the word *Krach* 'noise' is primed by modified *Lärn* instead of existing *Lärm* 'noise', reaction times should be longer than for the *Bahm*–*Zug* test. Lahiri & Reetz (2002) report that in such experiments reaction times for *Krach* primed by *Lärn* are twice as long as those for *Zug* primed by *Bahm*.

In a lexical recognition task, Weeldon & Waksler (2004) confronted subjects with sentences containing adjectives with a final coronal (e.g., *wicked*), on the one hand, and with final labials and dorsals, on the other (e.g., *frantic*). In some stimuli the final consonant was manipulated in accordance with the place of articulation of the following consonant at the beginning of the next word (e.g., *wickeb prince* and *frantip moments*, respectively). In others the final consonant was inappropriately changed (*wickeb ghost* and *frantip days*). Subject reactions indicate that expected alternations (e.g., *wickeb prince*) are treated differently from unexpected alternations. That is, alternation of the coronal to labial is expected according to an optional phrasal assimilation process in English, while a change from a dorsal to a labial is not.

If we put this study together with Marslen-Wilson, Nix & Gaskell's (1995) finding that a stimulus like *lake* primes *lake* as well as *late* (as in *late cruise/lake cruise* which can both be realized as *lake cruise*), while the stimulus *late* only primes *late*, but not *lake*, we observe an asymmetry between places of articulation that can be attributed to a difference in representation.

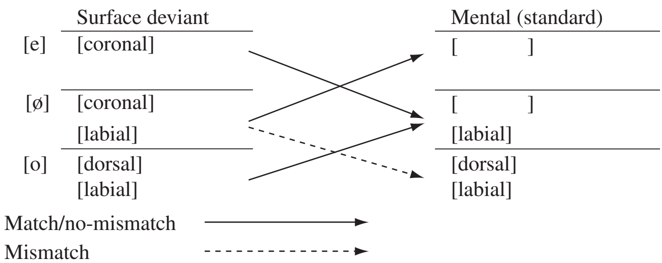
While these studies test the coronal asymmetry in word-final position, a parallel asymmetry between the places of articulation of English initial stops was revealed by a magnetoencephalographic (MEG) study by Walter & Hacquard (2004), who presented subjects with the sequences [ma ma ma ma na], [ba ba ba ba da] and the reverse odd-one-out series.

Friedrich, Lahiri & Eulitz (2008) test the same effect in word-initial position with German subjects showing different responses to pairs such as *Grenze* 'border' – *Drenze* (non-word) versus *Drachen* 'dragon' – *Brachen* (non-word). While the non-words with an initial non-coronal (*Brachen*) activate real words with an initial coronal (*Drachen*), the non-words with initial coronals (*Drenze*) do not as successfully activate the real words with initial non-coronals (*Grenze*). Thus, the surface labial does not constitute a mismatch with the underlying underspecified segment, while the surface coronal constitutes a mismatch with the underlying dorsal.

Eulitz & Lahiri (2004) present an oddball EEG experiment with vowels in which deviation of different vowels results in asymmetric MMN effects. They argue that such an asymmetry wouldn't be expected in a theory assuming full specification, since all acoustic differences should result in the same reaction of the brain. Accordingly, one of the tested vowels has to be underspecified for place of articulation. They presented subjects with repetitions of the vowel [o] that were interrupted by deviant [ø] and the reverse row, repetitions of [ø] with a deviant [o].

The reasoning being that the acoustic distances are the same, thus, if we are sensitive to all phonetic detail the reaction should be the same for either row. If one of the two vowels is underspecified for the feature distinguishing the two, say, [coronal], a mismatch is created in the [o, o, o, o, ø] series, in which [dorsal] is expected, while no mismatch is created in the [ø, ø, ø, ø, o] series, in which a surface [coronal] vowel is primed, which is underspecified underlyingly, and a [dorsal] vowel doesn't cause a mismatch, but rather just a no-mismatch reaction. In the former series underlying [dorsal] is incompatible with surface [coronal] and in the latter series there is no underlying feature with which the surface feature [dorsal] could cause an incompatibility clash. To make sure they measured the right aspect of phonological representations they included series with the vowel [e] in the experiment. In the pair [e, ø] both vowels are coronal and the authors didn't expect the same asymmetry in MMN with the two reversed oddball series. The diagram in (17) shows matching expectations for the tested series, i.e., standard [e] with deviant [ø], standard [ø] with deviant [e], standard [ø] with deviant [o] and standard [o] with deviant [ø].

(17) Stimulus-to-representation mapping in [ø]$_{[e]}$, [e]$_{[ø]}$, [o]$_{[ø]}$, [ø]$_{[o]}$ series



The MMN effects measured in this experiment singled out the [o]$_{[ø]}$ and [o]$_{[e]}$ series, which have a delayed peak latency as well as a reduced amplitude, especially compared with the reverse conditions, [ø]$_{[o]}$ and [o]$_{[e]}$, respectively.

(18) Mean peak latencies and amplitudes of MMN (Eulitz & Lahiri 2004: 580)

Experimental condition	Peak latency ±SEM (msec)	Mean Fz amplitude ±SEM (μV)	Mean rms amplitude ±SEM (μV)
[e]$_{/ø/}$	157.5 ± 3.3	−1.83 ± 0.30	0.75 ± 0.09
[ø]$_{/e/}$	158.2 ± 2.4	−1.95 ± 0.27	0.83 ± 0.11
[ø]$_{/o/}$	148.2 ± 2.7	−2.80 ± 0.31	1.17 ± 0.13
[o]$_{/ø/}$	164.0 ± 2.4	−1.77 ± 0.18	0.72 ± 0.07
[e]$_{/o/}$	149.2 ±3.9	−2.94 ± 0.21	1.22 ± 009
[o]$_{/e/}$	167.0 ± 3.6	−2.66 ± 0.37	1.01 ± 0.14

Since [ø] is typologically less frequent than [o] (Ladefoged & Maddieson 1996) and, probably, in a language that has both vowels the former is less frequent than the latter, there is reason to believe that switching from [ø] to [o] has a different effect than switching from [o] to [ø]. However, for the switch between [o] and [e] and vice versa Eulitz & Lahiri report the same asymmetry. In languages that have both [e] and [o], [e] is very likely to be more frequent. Even though the frequency expectations[3] are reversed in the two pairings, the MMN effect is observed in the same direction. Thus, these data support the hypothesis of abstract representations, and in particular lexical underspecification of the feature [coronal].

So far we have focused on place features. The laryngeal distinction on obstruents is also a hotly debated contrast. The feature [±voice], as indicated here, is traditionally, like most features, regarded as a binary feature. However, Lombardi (1991, 1995), for example, argues for a privative feature [voice]. Thus, an obstruent either has a feature or it doesn't. Likewise, one might assume that voiceless stops are underspecified for the binary feature, since the negative specification is the default value for this segment class and can be filled in by a feature-filling rule. For English it was claimed that the laryngeal contrast makes use of the feature [spread glottis] rather than [voice] (Iverson & Salmons 1995, Avery & Idsardi 2001). Durvasula, Hestvik, Bradley & Bradley (2008) tested this theory in an oddball experiment and observe a marked MMN effect for deviant [d]. They conclude that this supports the (now standard) analysis of English /d/ as underspecified and /t/ as marked for [spread glottis]. According to the logics applied above in the match/mismatch/no-mismatch paradigm, a marked MMN effect should be observed for a surface representation that is a mismatch to the primed abstract form. So, if we have a stimulus of repetitions of [t] and an interrupting [d] shows an effect, while in a series of [d]'s an interrupting [t] shows a weaker effect or none at all, one has to conclude that surface [d] is incompatible with abstract /t/. Thus, underlying /t/ is specified and only compatible with surface [t] while underlying /d/ is underspecified and an unexpected [t] with [spread glottis] doesn't constitute a mismatch with the underspecified underlying /d/.

Hwang, Monahan & Idsardi (2010) also tested whether there is a measurable difference in recognition between voiced and voiceless obstruents in English-speaking subjects, as some of the above studies have noted for underspecified [coronal] opposed to specified [dorsal] and [labial]. They presented subjects with nonce-words of the forms [uts, utz, uds, udz]. Speakers had to decide whether they heard a final [s] or [z] by pressing a button. Hwang *et al.* measured both reaction time and the number of correct responses for each stimulus. They carried out the experiment with forms containing stops with all three major places of articulation (i.e., [ubz], [ukz] etc.).

Their subjects, who were all native speakers of American English, needed significantly longer to decide on the sequences of a voiced stop followed by a voiceless fricative than on any other sequence. The percentage of correct responses was also much lower for this set of forms. These results were confirmed across all three places of articulation in two experiments. A comparison of the different cluster types shows a significantly lower percentage of correct responses to clusters of a voiced stop followed by a voiceless fricative.

Hwang *et al.* conclude that their results support a theory that assumes an asymmetric specification of the laryngeal feature. If the voiced stop is specified as [voice] it raises the expectation that the following approximant is voiced as well. An unspecified voiceless stop, on the other hand, doesn't prime any expectations for the following fricative, since there is nothing present in the representation that could cause such an expectation.

Since they used non-words they do not claim that they directly tested for underlying specifications. However, they maintain that if a feature is underspecified at the surface it is also underspecified at the lexical level. They adopt Keating's (1988) trichotomy of lexical, phonological and phonetic levels of representation. There is an implicational relation between these levels, as indicated in (19) (Hwang *et al.* 2010: 220).

(19) Possibilities of underspecification in voicing among levels of representation

	A	B	C	D
lexical	✓	∅	∅	∅
phonological	✓	✓	∅	∅
phonetic	✓	✓	✓	∅

✓ means that [−voice] is specified; ∅ that it isn't.

If a voiceless obstruent is not specified at the lexical level there are three options for the other two levels. It might be specified on both the other two levels (B), it might be specified on the phonetic level only (C) or nowhere (D). If a voiceless obstruent is not specified as [−voice] at the phonetic level, there is only one choice: it is also unspecified at the lexical level (D). And since voiceless obstruents do not cue any expectations on the following segment, while voiced obstruents do, the former have to be underspecified at the phonetic level and at the lexical level as well.

Hwang *et al.* note that the cluster that causes most difficulty, [ds], is actually one that is encountered in American English in fast natural speech very often, since final /z/ often gets devoiced in fast speech, as observed by Ohala (1983) and Smith (1997). Accordingly, any theory that relies on distributional statistics, such as type frequency, would have difficulties explaining why it wasn't the virtually non-existent [tz] clusters that show the longest reaction times and highest error rate.

Hwang *et al.* propose an interpretation according to Lahiri & Reetz's terms, assuming that inputs are matched with potential phonological representations. The encounter of a voiceless fricative after a voiced, i.e., specified, stop corresponds to a mismatch, causing prolonged reaction time, while anything (voiced or voiceless) after a voiceless, i.e., unspecified, stop amounts to a no-mismatch.

Thus, the result of the study is that [voice] is a unary feature and in English the voiceless series is the unmarked series, at both the phonetic and the lexical levels. This experiment (if the conclusions are valid) not only falsifies the theory that regards voice as a binary feature but also the [spread glottis] analysis of the contrastive laryngeal feature in English (e.g., Iverson & Salmons 1995). In the latter analysis, the voiceless series aspiration of these stops doesn't need explanation in terms of rules that add aspiration in certain positions. More interestingly in this context, the voiceless series is the marked one, carrying [spread glottis] while the voiced stops are unmarked. To confirm this analysis, Hwang *et al.* would have expected a mismatch evidenced by delayed reaction time for the [tz] stimuli rather than [ds].

Since Hwang *et al.* conclude that their results support an analysis of English as contrasting obstruents with the feature [voice], they contradict Durvasula *et al.*'s results, which support the [spread glottis] analysis.

In Durvasula *et al.*'s experiment the voiced deviant causes a mismatch, while in Hwang *et al.*'s experiment it is the combination of a voiced stop with a voiceless fricative that shows delayed reaction time whereas the combination of a voiceless stop followed by a voiced fricative doesn't cause a delay. As with the studies on place of articulation reviewed above, there is an asymmetry. Such an asymmetry cannot be explained with binary features or the change in the acoustic signal. Whether one of the two studies on the laryngeal contrast can be reinterpreted in such a way that the results are in line with the other one, thus enabling the question of the contrastive laryngeal feature in English to be answered conclusively, is a project that needs further investigation of the methodologies used and further, more refined experiments.

In this section we have reviewed studies that show that different contrastive categories are treated in asymmetric ways that wouldn't be expected if speakers/listeners were just processing the phonetic signal and calculating probabilities on the basis of their perceptual experience. In both three-way (place of articulation) as well as two-way contrasts (obstruent voicing) one set causes different reactions compared to the other(s) in reaction time and error rate in judgemental tasks, as well as in electromagnetic brain activity. The conclusions the authors of the discussed studies draw are the following. First, as just said, subjects access more abstract categories than just the acoustic properties of the signal, i.e., contrastive features. Second, in a three-way contrast the least marked member of the contrasting set is underspecified for the contrastive feature since the corresponding representation is compatible with the other stimuli but there is no compatibility the other way round, i.e., of a marked feature with a divergent signal. Third, in a two-way contrast, the situation is basically the same. While the marked or specified category evokes a mismatch with a divergent signal, the unspecified/unmarked category yields a no-mismatch, a reaction that is identical with a match. Accordingly, such a feature should be regarded as unary rather than binary.

6.6 SUMMARY AND DISCUSSION

Are there such things as phonemes which can be considered as the abstract smallest units in phonology? If not, are the smallest units of phonology even more abstract and even smaller than segments? If they are abstract, how much of the information from the incoming signal is stripped off for linguistic computation and storage? Or do language users not need these abstract categorical elements because they base recognition and production on large-scale calculations over a huge and ever growing database of detailed phonetic memories? These are among the key questions in this book. In this chapter we reviewed research from the last two decades that by and large approaches the problem with experimental methods. As far as the results of such experimental work are concerned, this chapter heels considerably. Beginning with what I regarded as the most likely candidates for deviation from the phonetic signal, non-contrastive segments and features, going over to contrastive features in neutralization position and finishing with the least likely candidates for underspecification, contrastive sounds in positions of contrast, we have seen evidence that all indicates a considerable level of abstractness in underlying representations.

While there is good reason to believe that non-contrastive segments are not stored in their surface form (e.g., English flaps and nasalized vowels), the phoneme, as a contrastive unit, didn't seem to play any detectable role. Instead, subjects show sensitivity to contrastive features. In several of the studies reviewed above, individual features could be identified as the information extracted by subjects (place features and voicing in obstruents).

Apart from sensitivity to contrastive features, some of the studies also strongly suggest that the featural content of underlying segments is stripped down to a bare minimum, since not only are predictable non-contrastive features eliminated but so also are the least marked states in dimensions of contrast (for example, the place feature [coronal] or the negative specification of [voice]). Some of the data we have discussed also contradict the view that we make use of all the rich and detailed phonetic information we receive in the linguistic signal, such as the asymmetry in MMN effects in the oddball studies on front and back vowels.

It would take a little more than a twenty-page chapter to inspect the experimental results to decide which of the algorithms and accordingly theories of underspecification reviewed in Chapter 4 is the most appropriate one. In many of the studies reviewed in this chapter the authors took their results as evidence supporting the FUL model (Featurally Underspecified Lexicon) developed by Lahiri and her colleagues. While the model champions a high degree of abstractness and underspecification, it isn't very explicit on the detailed nature of the degree of underspecification and how a learner arrives there, unlike Dresher (2010), for example, who advocates the successive division algorithm.

DISCUSSION POINTS

- Consider word games you know that involve substitution or permutation operations and discuss whether they are relevant for a discussion of phonological representations and to what extent.
- What is the problem with nonce-word experiments in the context of a discussion of underlying representations? How can such experiments cast light on underlying forms?
- Why do asymmetries in perceptive reaction to phonological primes pose a problem for full specification/exemplarist approaches?
- Do the experiments discussed in this chapter give evidence supporting one or other theories of underspecification discussed in Chapter 4?

- For readers familiar with Optimality Theory: could mismatch negativity or reaction time effects that show activation asymmetries between different places of articulation be explained in terms of OT constraint rankings and constraint violation rather than underspecification?

SUGGESTIONS FOR FURTHER READING

Lahiri, Aditi & Henning Reetz (2010). Distinctive features: phonological underspecification in representation and processing. *Journal of Phonetics* **38**: 44–59.

7 On the form and contents of contrastive features

> [W]e have no right to attribute to the sound some value which would disagree with its nature.
>
> (Grammont 1901: 321)

7.1 INTRODUCTION

In the previous chapters it has been established that underlying representations can be fairly abstract. First, it was shown that language users make use of discrete contrastive features rather than the whole phonetic signal. Second, psycho- and neurolinguistic experiments have shown that features are underspecified in underlying representations if they are the unmarked value of a contrast or if they are redundant. In this chapter we will have a look at what is inside contrastive features. The question is whether they contain information on or instructions for their articulation or information on the acoustic/perceptual properties of segments. Alternatively, features could be abstract labels that mark segments as different from others and group them into classes.

In most contemporary feature theories the features are defined by acoustic properties of the targeted sound or by the involved articulators or articulation. Halle (1995) distinguishes articulator-bound features and articulator-free features. Among the former we find features such as [round] (lip rounding) or [labial] (involvement of/constriction of the air stream channel with the lips), the additional place features [coronal] (constriction via the corona or front part of the tongue) and [dorsal] (constriction by the back of the tongue), [ATR]/[tense] (raising or lowering of the tongue root and consequential tenseness or laxness of the tongue body) and [nasal] (air flow through the nasal cavity). Examples of the latter are [±continuant], referring to continuant or interrupted air stream, which can be interrupted at (almost) any point in the vocal tract, [±sonorant], which refers more or less to intensity and [±strident], which is defined by turbulence in the air stream, high energy at high frequencies.

Jakobson set out to define each distinctive feature in acoustic terms and this work culminated in Jakobson, Fant & Halle (1963). The reasoning behind this choice was by and large that since humans use sound as the medium to transmit language and the listener has to be able to retrieve the contrastive features from the speech signal, each feature has to have a unique acoustic signature.The acoustic signal is the part of language both participants share, the signal the listener gets and the signal the speaker has to monitor in order to get his/her message across to the listener. This approach found its continuation in Harris & Lindsey's (1995) attempt to define each radical of Element Theory as a core spectral characteristic, which we will have a look at in the next section.

However, at the same time that Jakobson worked on acoustic definitions, Cooper *et al.* (1952) developed the diametral theory that defined every feature as instructions to the articulators. From the perspective of speech synthesis or speech production one needs features that result in distinctive productions rather than identification (as is necessary from the perspective of the listener). Also cognitively it makes more sense if the representations of segments incorporate instructions for their realization, i.e., motoric instructions, which is a good argument to define, for example, place of articulation via the active articulator, i.e., the lips or the tongue or the glottis, with which the speaker produces an obstruction to the air stream, rather than the passive articulator, which can be targeted, but not moved. Therefore the features [coronal] (the corona of the tongue) and [dorsal] (the back of the tongue), which refer to the body part that should move, make more sense than [alveolar] and [velar], which refer to body parts that can't be moved, i.e., passive articulators.

Chomsky & Halle (1968) already incorporated both acoustically defined as well as articulatorily defined features in their set of contrastive features, as do today's Revised Articulator Theory (Halle, Vaux & Wolfe 2000) and Feature Geometry (Clements & Hume 1995). The articulatory programme found its continuation in Articulatory Phonology (Browman & Goldstein 1986, 1992 *et seq.*), which will be introduced in Section 6.3.

Under functional considerations the choice between acoustic and articulatory definitions of features is a dead-end. Features defined by articulatory properties are closer to the gesture to be executed and thus more efficient for the speaker since they don't have to be 'translated', whereas a listener receives the acoustic signal, has to decode this into the articulatory actions necessary to produce the signal, decompose these into the respective features and can then scan the lexicon for the lexical entries. Acoustic features are, however, more efficient from the listener's perspective since the acoustic signal can be directly mapped to features as stored in the lexicon and accordingly lexical access in parsing is speeded up.

(1) The transduction catch-22

a. articulation-based features (less transduction for the speaker)

Speaker | *Listener*

lexicon → phonology → sound → articulation → phonology → lexicon

b. acoustics-based features (less transduction for the hearer)

Speaker | *Listener*

lexicon → phonology → articulation → sound → phonology → lexicon

The problem that what is considered as one contrast isn't necessarily always realized with the same acoustic cues nor with the same articulatory gestures was pointed out by Fudge (1967). He noted also that there is not necessarily a one-to-one correlation between articulatory gesture and acoustic effect, since the same effect can be obtained in different ways. Fudge (1967) concluded that phonological features should be completely abstract labels that just define segments with, say, label A as different from those without it and further can be used to organize segments into classes. The downside of such a maximally abstract proposal is that it requires a much more elaborate mapping procedure or phonetics–phonology interface than any of the phonetically grounded proposals, as is obvious if one has a look at the set of rules he proposes that establish correlations between his abstract features and acoustic and articulatory substance (Fudge 1967: 11ff.).

At the time of writing there seems to be general agreement that the extraction of defining acoustic properties for contrastive features is a hopeless task. Among other things this is because of the insight that listeners even understand heavily distorted speech (produced by speakers while eating or speakers with oral cavity abnormalities etc.) and more importantly that individual features usually have several acoustic cues, which vary across and within languages and which can, moreover, be dislocated from the segment they are associated with, i.e., anticipated in a preceding segment or ranging into neighbouring segments (acoustic cues for place of articulation of stops are located in the formants or turbulence of the offset or initiation phase of neighbouring segments, an acoustic cue for a voicing contrast in obstruents can be the duration of the preceding vowel etc.). Furthermore, speakers tend to express individual features with several acoustic cues (e.g., Stevens & Keyser's (1989) phonetic enhancement) and any of them can be removed from the signal without impeding identification (Hawkins 2010, see here Chapter 5).

Regarding these two choices for the content or definition of contrastive features, Clements & Hallé (2010: 4) conclude that 'neither approach seems likely to be entirely correct'.

As mentioned, the two positions had already found a compromise in *SPE*. Chomsky & Halle's (1968) set of features is a mix of articulatory and acoustically defined features, most of which are still in use today (see Hall 2007 for an overview of the most commonly used features). Similarly, Stevens & Keyser's Quantal Theory (see Stevens & Keyser 2010 and references there) defines the transitions between feature values as acoustic and articulatory parameters.

The enterprise of phonetic grounding received criticism from two more directions. On the one hand, researchers familiar with sign languages maintain that sign language has phonology too. '[P]honology is the level of linguistic structure that organizes the medium through which language is transmitted' (Sandler & Lillo-Martin 2006: 114).

This perspective challenges the idea of the phonetic grounding of contrastive features, since sign languages use contrastive features too and if phonological features are innate they cannot be defined in acoustic terms, because then they are useless for sign language. Reference to specific articulators or acoustic properties renders features modality-specific and if they are innate, phonology should make use of the same features independent of the modality of a language. Consequently, they have to be much more abstract than the current theories define them as being (Morén 2003, 2004, 2006, 2007, 2009).

There is also the possibility that sign language is primary and that spoken language evolved from signed language historically (see, e.g., Corballis 2009 for an overview of the discussion). If this turns out to be true, contrastive features are certainly not defined by their acoustic or audio-articulatory properties, but more general gestures.

Another attack comes from a purely theoretical perspective that sees human cognition as organized in modules (as commonly accepted among generative phonologists). Hale & Reiss (2008: 22) articulate the theoretically driven unease with the commonly used feature definitions most straightforwardly:

> [I]f we take seriously (and *we* [emphasis in the original] do) the generative notion that grammar, including its phonological component, is a property of individual minds, and the modern cognitive science conception of the mind as a set of computational devices (or 'modules'), then phonology will involve computation over abstract mental entities. Since these entities will not have the

> properties of tongues, lips, and vocal folds, phonology will not be grounded in the facts of articulatory practice; and since the entities over which phonological computation takes place are not acoustic waves, or not the body's physiological response to such waves, phonology will not be grounded in the facts of human perception.

If we follow these two lines of argumentation to their conclusion it seems we have to take Saussure seriously when he says 'Dans la langue il n'y a que des différences' (Saussure 1975: 166; 'In language there are only differences'). Accordingly, distinctive features are maximally abstract, maybe completely void of content and just there to differentiate or label segments. Such an approach, though, only shifts the burden of explanation to another module or to the interface with the sensory and/or articulatory organs of the respective transmission channel in which each feature has to receive some physical correlate. And here the same problem arises as in all other attempts to define features.

If contrastive features are completely empty and just serve to mark contrasts and group segments into classes, the theory can explain discreteness of categories, but it can't explain why we only find certain types of contrasts cross-linguistically, as already indicated in Section 4.4; or, to give another example, some segments and some gestures are physically possible but never used in language, such as an ingressive nasal (which humans produce when snoring) (see as well the discussion in Kang 2009).

Morén's (2003) Parallel Structures Model shows a first attempt to define features in a transmission-channel neutral way, such that they hold for spoken as well as signed language. Krämer (2009c, 2010) continues this line of research, proposing a set of features that results by and large in the same segment classes as the features of Feature Geometry but basing features on concepts used in other modules of grammar, recycling the basic categories of aspect, of deixis, of spatial adpositions and other syntactic and semantic features. These features define events of articulation which can be executed either in the vocal tract as audio signs or with the upper body as visible gestures. We will have a look at this way of defining features in Section 7.4.

To summarize the structure of this chapter, we will have a look at three different ways of defining categories of contrast. The way in which these categories are defined directly impacts what we can assume to be 'inside' a feature apart from its function as a label that discriminates one entity from another. Section 7.2 will sketch the acoustic approach to the content of features, Section 7.3 gives a brief discussion of an audio-articulatory centred view of the mental units of contrast, while in Section 7.4 we will go through a proposal that tries to define contrastive features in a cognitively economic and modality-independent way. Finally, in Section 7.5, we will briefly consider whether sound symbolism and synaesthetic phenomena might have something to tell us about the form and content of phonological features in underlying representation.

7.2 ACOUSTIC DEFINITIONS IN ELEMENT THEORY – BACK TO JAKOBSONIAN IDEA(L)S

While in *SPE* and other feature theories a feature is just a building block of the segment which consists of a set of features uniform across all segments just varying in their underlying and surface specifications and features thus cannot be realized alone, in Element Theory (Anderson & Jones 1974, 1977) features or elements are monovalent and individually phonetically interpretable. An element like |U| stands for labiality and if spelled out is realized as the cardinal vowel [u]. Accordingly there are no feature fill-in rules in Element Theory, just as in Jakobson's feature theory.

Another trait of Element Theory that would have delighted Jakobson is the extremely economic number of features assumed to analyse the contrasts found cross-linguistically, which is down to around ten elements.

'[E]lements are internally represented pattern templates by reference to which listeners decode auditory input and speakers orchestrate and monitor their articulations' (Harris & Lindsey 1995). The interesting question for us in this chapter is of course what these pattern templates consist of, i.e., what kind of information they provide to warrant identification of abstract segments from an acoustic input. Harris & Lindsey (1995) define these templates as resonance characteristics (see as well Ingleby & Brockhaus 2002 for acoustic signatures of phonological elements).

Before we go into this matter a short introduction is necessary. Here we will concentrate on the vowel and place features, the basic primes |I|, |U| and |A|, which specify the vowel triangle, as in languages with only three vowels, exemplified in (2a). All other vowels are complex and consist of combinations of these three primes. The mid vowels in a five-vowel system are specified as |I,A| for /e/ and |I,U| for /o/, respectively, as shown in (2b). Further height differentiation is formalized as two combined primes of which one is assigned head status, indicated by underlining in (2c), and the other is the head's dependent.

(2) Elemental example: vowel features

a.	/i/		/u/	I		U
		/a/			A	
b.	/i/		/u/	I		U
	/e/		/o/	I,A		U,A
		/a/			A	
c.	/i/		/u/	I		U
	/e/		/o/	$\underline{\text{I}}$,A		$\underline{\text{U}}$,A
	/æ/		/ɐ/	I,$\underline{\text{A}}$		U,$\underline{\text{A}}$
		/a/			A	

The same elements are used to specify place of articulation in consonants. For example, the three basic stops, /p/, /t/, /k/, are represented as a stop element, |ʔ| that on its own represents the glottal stop, plus either |U|, |I| or |A|, respectively.

Central vowels, in particular schwa or schwa-like vowels, are represented by the element |ə|, which doesn't stand for anything in particular, unlike the other three. Further distinctions in vowel height, such as an ATR contrast, are a matter of dispute. One way of representing this additional contrast makes use of |ə| and the notion of headedness. In such a system all vowels are specified as |ə| plus some other element, or two (in the case of mid vowels). In the vowels with retracted tongue root |ə| is specified as the head.

Harris & Lindsey (1995a,b) identify the central acoustic footprint of every element in the system. The difficult issue here is of course finding such a core correlate in elements that are used in many different ways. |U|, for example, is present in back vowels as well as rounded vowels in general and in labial consonants, so actually it looks more like it is intended to specify articulator involvement. |ə| stands for the absence of the characteristics of any of the other elements. Despite |ə|'s emptiness schwa-like vowels do of course have formant structure. Accordingly, the acoustic footprint of the elements is not defined quantitatively by determining typical formant frequencies or the like but more indirectly as increased or reduced spectral energy in certain frequency regions.

The characteristic spectral properties of the three basic elements are defined as higher amplitude/intensity located somewhere within the frequency range used by humans for language, i.e., 0–3000 Hertz. |A| shows a spectral energy mass in the middle of this zone. In low vowels, formants 1 and 2 are relatively close together in the middle of the frequency spectrum, since F1 is relatively high. |I| is characterized by a low first formant and relatively high F2 and F3, which are very close together, resulting in high spectral energy at the lower and the upper ends of the spectrum and low spectral energy in the middle. |U| shows a concentration of F1 and F2 in the low range of the overall frequency span.

Compound segments that have more than one radical, such as the mid vowels in (2b), are characterized acoustically by a blend of the two elements' spectral footprints. In complex segments with a head dependency asymmetry between the two elements, the acoustic signal has a predominance of the element specified as head.

Representation of the segments of a language in terms of elements implies by definition specification according to their spectral properties. Thus sounds/segments do not enter contrastive relations. In vowel systems such as those in (2), one cannot identify vowel pairs, as was done in Chapter 4, that are minimally contrastive with respect to the value of one feature.

In Element Theory, it seems, segments cannot be completely underspecified, just consisting of a root node. For example, underspecification of the closest correlate to the feature [coronal], i.e., |R|, in stops or fricatives, results in a representation as |ʔ| for stops and |h| for fricatives which are realized as [ʔ] or [h], respectively, since there are no feature-filling rules. Accordingly, even the glottal stop can't be an unmarked segment, since interpretation of an empty skeletal position is unclear.[1] Similarly, the vowel [e], which is the least marked and also the epenthetic vowel in many vowel systems, has to be specified as |I,A| and can't be void of features or feature values, contrary to what was assumed in other feature theories to acknowledge its place and role in the system.

Assimilation patterns, however, are treated in Element Theory in a similar way to Autosegmental Phonology, i.e., assimilation can be represented as element spreading via establishment of an association line between an element and an additional segment position. For material that is predictable by its environment through assimilation, whether alternating or not, and especially if it is not alternating, such as morpheme-internal preconsonantal nasals in English, the discussion of underspecification does make sense. In English, the place of articulation of morpheme-internal nasals, as in *pump*, *punk*, *punt*, is predictable by the place of articulation of the following consonant. This is assumed to be regressive rather than progressive assimilation, since some final nasals do show alternations, as in [sæmbɒks] 'sand box' or the much discussed negating prefix *iN-* (*intolerant* vs *impossible*), while postnasal oral consonants haven't yet been observed changing place of articulation. Accordingly, the morpheme-internal nasals are regarded as underspecified for place of articulation in most accounts.

Furthermore, at morphological junctures it is only the coronal nasals that undergo assimilation, as in [sæmbɒks], [hæmbʊk] 'handbook', while others only do that in extremely fast speech, i.e., *[hæŋgəlɔɹ] 'ham galore' *[rɪmpɔl] 'ring Paul'. Consequently, the lexical (under) specification of coronal place in nasals, which are specified with an element indicating nasality, is an issue.

In the light of the discussion on cross-modality compatibility started in the introduction, a more serious problem for acoustic definitions is that they are not easily transferable to the visual domain, i.e. the analysis of sign language. The recipient in audio-transmitted language has a clear advantage if features are acoustically/perceptually defined, while the sender or speaker has the transduction problem of finding the optimal articulatory gestures corresponding to the production of the acoustic cues of each feature.

7.3 THE ARTICULATORY SIDE

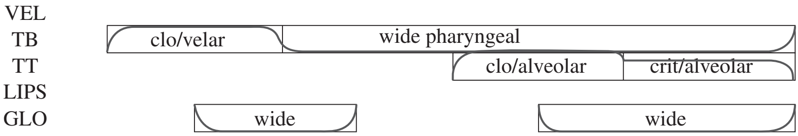
In Articulatory Phonology (Browman & Goldstein 1986, 1992 *et seq.*) segments and features don't exist. Speech production is seen as physical events consisting of gestures.

Gestures are a local constriction involving specification of constriction degree, a tract variable set and extension in time of the gesture. The vocal tract is divided into tract variables, which by and large correspond to the place of articulation or execution of a gesture. Tract variables are the Lips, Tongue Tip (TT), Tongue Body (TB), VELum, GLOTtis. At these points various degrees of expansion or contraction can be performed (wide, critical or closed).

Such a gesture can stretch over a whole morpheme and in connected speech probably over a whole utterance. Usually several gestures happen simultaneously during one event. Since every gesture has its own inherent duration, which can be extended, these gestures do not only happen simultaneously but can overlap in various ways as well. For the event of an aspirated obstruent a TT (tongue tip) gesture with closure has to be executed as well as a widening in the GLO (glottis). These two gestures, though, cannot be executed perfectly simultaneously since otherwise the glottal widening would be covered completely by the alveolar closure. Accordingly, glottal widening is slightly delayed.

Contrast is the presence or absence of a gesture or a difference of a gesture in temporal extension. Since the speech event is only present via one or several gestures, these gestures cover the function of both the segment (or root node) and the feature. The scheme in (3) exhibits the English word *cats* seen as articulatory events. On the vertical axis we see the tiers for the event locations. The horizontal axis represents time expanding from left to right. The boxes indicate which temporal extension a gesture happens with on which tract tier. The degree of opening/constriction is indicated by the grey lines as well as the labels 'wide/crit/clo'. The lines show a short transition phase from rest to target position and then a steady state and at the end a short transition phase back to rest position. These lines are just there to better illustrate the idea of overlapping gestures and the nature of gestures as articulators assuming a state different from their rest position. The whole representation is of course highly idealized. As we can see, the presence or absence of a traditional segment can depend on the presence or absence of a single gesture and gestures extend temporally independently of segments.

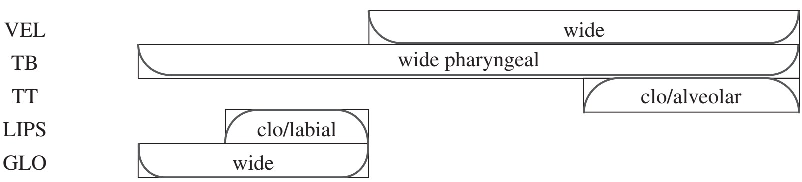
(3) AP *cats*[kʰæts]



Phonotactic patterns as well as assimilation are matters of timing of gestures. Nasalization of vowels preceding nasal consonants, for example, is an early onset of the gesture of velum lowering during the articulation of the vowel, i.e., long before the characteristic oral closure gesture is initiated, as illustrated in (4).

Like any theory of representation, Articulatory Phonology needs principles that organize events appropriately. The mere assumption of gestures that can have extensions in time of varying length as well as different kinds of temporal overlap and alignment can be used to model unattested contrasts. A representation such as that in (4), that has glottal widening preceding the labial closure gesture of the word-initial stop, can easily be stored in the lexicon and processed by the production system, resulting in an unattested contrast between pre- and postaspiration.

(4) [ʰpan]: contrastive preaspiration



Even though aspiration contrasts are widespread, languages that use the difference between preaspiration and postaspiration contrastively have not been found yet (Kehrein 2002). If languages show pre- as well as postaspiration these are usually in complementary distribution. The prediction of such contrasts is avoided in Autosegmental Phonology by the assumption of root nodes and that either root nodes or separate slots on a timing tier refer to chronological extension but features usually don't. A feature such as [spread glottis] is associated to a segment but the phonology can't determine whether it is realized as pre- or postaspiration. Similarly, fine-grained timing of gestures is not part of the phonology and since features are discrete, i.e., determine either one state or the other, they cannot model fine scalar differences such as slight, medium and excessive aspiration of obstruents or different degrees of nasalization in vowels.

Articulatory Phonology provides a model for production and speech synthesis. The representations are still quite abstract, since for a cognitive articulatory model of phonological contrasts one could imagine one with detailed instructions for the muscles involved in speech production.

7.4 A CHANNEL-NEUTRAL APPROACH TO THE CATEGORIES OF CONTRAST

As discussed in the introduction to this chapter, approaches such as Element Theory or Articulatory Phonology can be criticized for being channel-specific and therefore not theories of contrastive phonological features but of contrastive features for spoken language. Features could be articulatory or sign-relevant but so generally formulated that the modality doesn't matter. The proposal we consider now tries to reuse features from other areas of grammar. As with the other two approaches I will only discuss some central features.

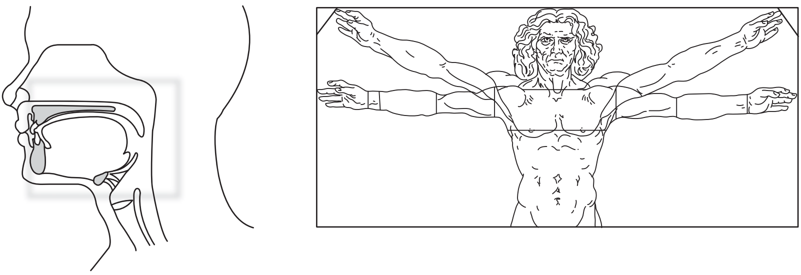
The idea is the following: if the articulatory tract is predefined for a language as either the vocal tract or the upper body, features that characterize fundamental properties of the segment that is specified for them do not have to refer to the involved articulators, such as [dorsal].

The proposal we are going to look at now is based on the Parallel Structures Model (Morén 2003). The goal of the Parallel Structures Model is to not only have the same features for vowels and consonants (as in Trubetzkoy's feature theory, Feature Geometry and Element Theory), but also for spoken and signed language. Krämer's (2010) approach develops the latter idea and advances the additional idea that features are parallel in the independent linguistic modules. To do this the Articulatory Phonology notion of speech as an event, or segments as events, is central. The difference is that in the new approach events aren't as specific as in Articulatory Phonology.

General spatial and temporal concepts can be relatively directly interpreted as instructions to unspecified articulators if the articulation zone is defined a priori.

(5) Articulatory spaces for spoken and signed language

a. Spoken – vocal tract b. Signed – front of upper body and head



Within the articulatory zone for each modality we can easily identify the front area and the back area as well as point to where up and where down are. Once we define a zone we can define a spatial relation between two participants, the active and the passive articulator. Moreover, we can define events that can be modelled with the active articulators in the respective tract. The most basic event categories that are used most often in the languages of the world are those that drive the distinction between perfective and imperfective aspect, changes of state and states. Let's go through all these options and how they can be used to define contrastive phonological features that (a) serve the function of contrast, (b) divide segments into the right classes and (c) contain instructions for physical implementation/signal identification.

Adpositions and especially spatial adpositions usually have two arguments, which were termed figure and ground by Talmy (1983). Adpositions like *on*, *in*, *in front of* etc. specify the location of a figure with respect to a ground (*figure* on the *ground*). This is illustrated in (6).

(6) Figure and ground (Talmy 1983)

There was pizza (figure) *all over the sofa* (ground)
The ball (figure) *is rolling along the canal* (ground)

The figure is usually understood as an object that can move or be moved more or less freely. (Even though in a phrase like *the house in front of my bicycle* the figure is immobile while the ground can be moved.) For phonological purposes the active articulator is analogous to the figure and the passive articulator is the ground (as in *the tip of the tongue touches the alveolar ridge*). In a feature specification like [coronal] the figure is specified, the front of the tongue, but the ground is not, unless we add [anterior], which specifies the anterior region of the roof of the mouth, the alveolar ridge (and upper teeth).

(7) Figure and ground in phonology

Figure = active articulator (lips, tongue; arms, hands, fingers . . .)
Ground = passive articulator (palate, velum; tummy, chest, nose, earlobe . . .)

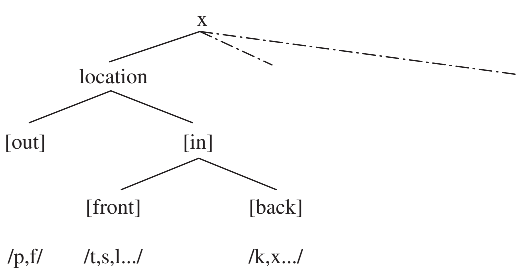
One of the most basic concepts of relation between objects encoded in language either lexically or functionally (i.e., either via lexical words or via functional elements, such as adpositions) is location (Talmy 1983, Levinson *et al.* 2003).

(8) Cross-linguistically popular adpositions

in(side) versus *out(side)* x,
in front of or *behind* x,
on top of/above x or *below/under (and beside)* x

With these ingredients at hand and the articulatory area determined, place of articulation can be formalized without direct reference to the articulators. Just as in discourse, once the location and the actants are set we don't need to refer to them explicitly anymore and we can use pronouns, a proper definition of where a phonological event (segment) happens saves us from specifying which body parts are involved.

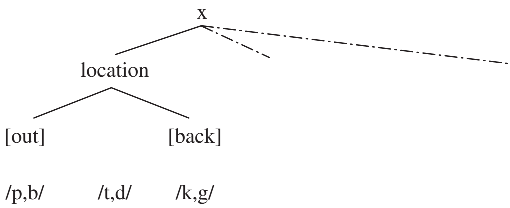
(9) Place of articulation and spatial relations of unspecified articulators[2, 3]



For the vocal tract the division between [out] and [in] corresponds to that between [labial] (outside) and the other places of articulation. Dividing the inside of the vocal tract into a [front] and [back] area corresponds to the distinction between [coronal] and [dorsal]. Neurolinguistic experiments by Obleser *et al.* (2004) showed that front or coronal vowel stimuli result in brain activity in a more anterior region in the auditory cortex than back or dorsal vowels in direct comparison, while labials when contrasted with coronals or dorsals do not fit into this line. Obleser *et al.* (2006) reproduced the same results for consonants.

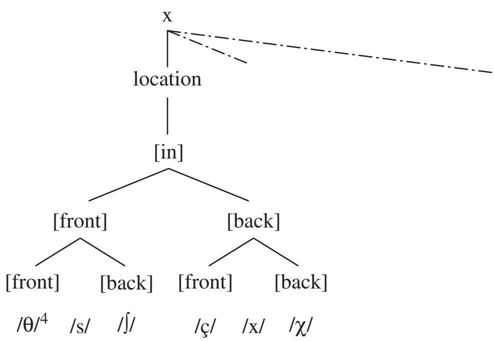
Languages like English and German that have been shown to have the coronal stops underspecified for place underlyingly (see Chapter 6 and references there) are potentially analysed as just specifying the features [out] and [back] underlyingly in obstruents.

(10) Underlying place of articulation in English and German stops



Further potential divisions can be introduced by recursively dividing the [front] and [back] areas into a [front] and [back] subarea, i.e., specifying locations as more front in the front or more back in the front (dental and postalveolar) and more front in the back and more back in the back (palatal and uvular).

(11) Further subdivisions and recursion of place of articulation



The most basic distinction in manner of articulation between stops and other segments (continuants, more or less) is understood as that between different event types. Philosophers and semanticists distinguish the event types in (12).

(12) Event types / verb classes

a. punctual/change of state/perfective/telic
   i. *to explode*, *choke*, *jump*
   ii. *start*, *stop*, *die*, *fall, leave, arrive, cure*

b. continuous/states/activities/imperfective/atelic
   to live, sleep, *run*, *hammer, treat*

There are quite a few classifications that show slight variation in how many classes are assumed, but they all agree on the distinction between telic and atelic events. This dichotomy determines morphological class affiliation of verbs (conjugation classes) in many languages and also determines syntactic behaviour (such as case assignment, e.g., in split-ergative or active/inactive languages). Last but not least, many languages mark the distinction of perfective and imperfective aspect morphologically on verbs (for an outstanding example have a look at Russian).

(13) The Vendler/Kenny/Mourelatos classification of verb phrases

Achievements *find* Accomplishments *run-a-mile*	performances	telic
Activities *run* States *love*	processes	atelic

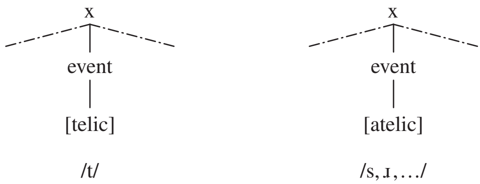
If we 'slice up' such events in the time dimension we get nothing meaningful in the case of performances, but we get a smaller/shorter version of the same event with processes. If we subdivide phonological segments in the time dimension we get nothing useful in the case of stops but short versions of the same segment with all others. That is, if we take a recording of a stop and just use some randomly sliced-out 5 milliseconds or so we are most likely to get silence or part of a transition or part of the release burst, but not a stop. If we do this with a fricative or a vowel we get a very short fricative or vowel, respectively.

(14) Manner of articulation as event type

Stops	≈	performances, climactic/telic events
Continuants	≈	processes, atelic events

To formalize this we use the features [telic] and [atelic] to stand for the two event types.[5]

(15) Manner of articulation I



Recall Trubetzkoy's discussion of Tamil in Chapter 2. In this theory, Tamil only uses the feature [telic] contrastively (for the stop series). The consonants that are not specified for event type receive specification on the surface according to position.

Languages that have further distinctions of manner of articulation need additional features. Despite the distinction between stops and other manners, manner of articulation has been seen as a matter of degree of aperture or closure (as in Steriade's (1993, 1994) Aperture Theory or as implied in the terminology used by the IPA in the classification of vowel height). In the current model a fricative is characterized by an active articulator that is very close to the passive articulator, while an approximant is characterized by a slightly bigger distance of the active articulator from the passive articulator. A concept that does this and which is used in most languages is deixis. (16) shows some deictic particles.

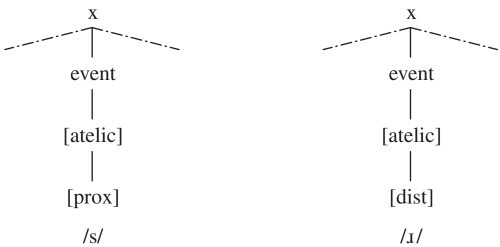
(16) Cross-linguistically popular deictic categories: near and far

English:	here – there; this – that
German:	hier – da; dies – das/jenes
Italian:	qui – qua; questo – quello
Yucatec Maya:	te'la' – te'lo'

Deixis indicates whether a referent is close to the speaker or comparably distant. In terms of the Figure–Ground/Active–Passive Articulator relation, the active articulator is interpreted as being either near to the passive articulator or at a distance from it. Interestingly, many languages display sound symbolism in their deictic particles: the particles indicating proximity often contain a high vowel while the particles indicating distance often contain a low vowel. In high vowels the jaw is relatively closed with the tongue body near to the roof of the mouth, while in low vowels the jaw is lowered to the maximum and the tongue body is far away from the roof of the mouth.

The proximity/distance distinction can be formalized with two unary features as well, [proximal] and [distal], that can be dependents of the event feature [atelic], as shown in (17).

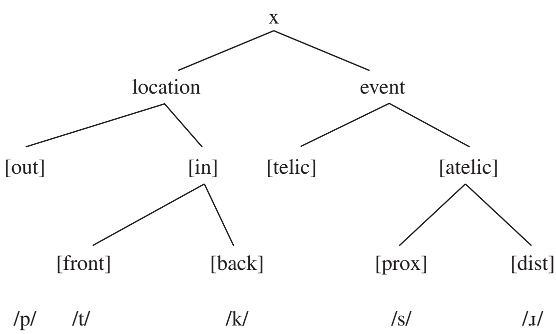
(17) Manner of articulation II



For both feature pairs the question arises of whether we need each feature or just one of them. This depends on how many manners of articulation a language distinguishes. Furthermore, if we recycle the deictic features for vowel height (as indicated in the comment on sound symbolism in deictic particles above) we need both [prox] and [dist] to capture a three-way height distinction. /i,u/ are [prox], /a/ is [dist] and /e,o/ can be left blank.

With the features discussed so far we have assembled the following segment structure.

(18) A parasitic Feature Geometry



With recursion of features more distinctions in place and manner can be captured. Additionally, there are still many dimensions of contrast we haven't discussed, such as laryngeal distinctions or tones. Since this approach ‘recycles’ distinctions from other grammatical domains for phonological contrast there is quite a big reservoir of potential phonological features available. Most other morphologically and syntactically expressed distinctions, though, such as case or gender, do not lend themselves easily to an articulatory interpretation and are for this reason (articulatory uninterpretability) excluded.

Instead of discussing more options and details of the system, we will have a very brief look at possible uses of the same features in signed languages. As illustrated in (19), the distinction between some gestures can be understood as parallel to a height distinction in vowels.

(19) Height in sign language (Fox 2008; photographs © Ivan Farkas)

a

SUMMER

b

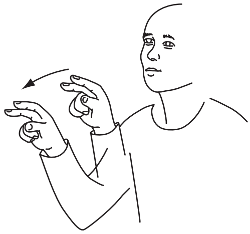
UGLY

c

DRY

While height in spoken language is analysed with the proximal/distal distinction, this same distinction can be used in a much more obvious way in signed languages, for example to distinguish signs that point away from the body/speaker, as the one for ‘look at’ in ASL (American Sign Language) in (20) in contrast to signs like those above in (19) or those in (21b) that do not involve movement of the active articulator away from the speaker.

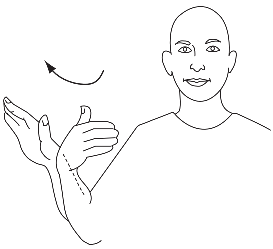
(20) ‘to look at’ in ASL



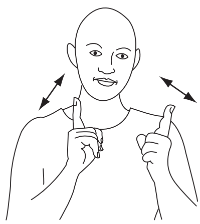
The data from American Sign Language in (21) illustrate another distinction, that between body-anchored and non-body-anchored signs (see, e.g., Pfau & Steinbach 2005 on this distinction in German Sign Language). In the feature system proposed above such a gesture corresponds to the [in]–[out] dichotomy, with the body-anchored signs inside the articulatory tract/zone and the non-body-anchored signs outside.

(21) Body anchoring in ASL

a. non-body-anchored/outside



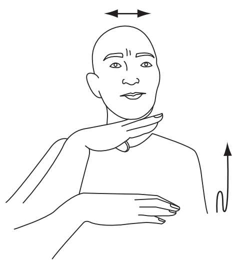
‘away’



‘talk’

b. body-anchored/inside

‘sick’

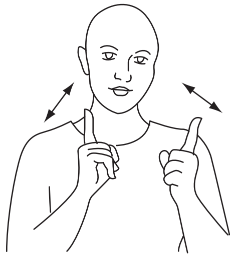


‘fed up’

The aspectual distinction between [telic] and [atelic] very often displays a close sign–meaning correlation in sign language. For example, change-of-state verbs often involve a stop gesture. In (22) we see the verb ‘arrive’ with a telic gesture and the verb ‘talk’ with an atelic gesture.

(22) Telic and atelic gestures in ASL

a. Telic: ‘arrive’



b. Atelic: ‘talk’

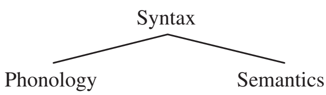
The marking of perfective and continuative aspect in ASL also involves corresponding gestures, i.e., perfective aspect is expressed by adding a stop or hold at the end of a gesture. Interestingly, some spoken languages show similar close correlations between a grammatical feature and the phonological sign used to indicate it. Most Germanic languages, such as English, German, Norwegian etc., use a coronal stop to indicate what is often analysed as past tense and sometimes as perfective aspect. In the feature theory proposed in this section this would be regarded as a close match between *signifiant* and *signifié*. Though in this particular case it might, of course, just be an accident. We will discuss arbitrariness and iconicity in the next section.

It is, of course, less than surprising that semantics, morphology and syntax supply a set of concepts that can be used as contrastive features in phonological representations. After all, we are able to talk about the articulatory and acoustic/visual properties of linguistic segments. What is more surprising is that most phonologists restrain themselves and propose features that only make sense in one dimension or modality. For the earlier proposals this is understandable since sign language was long assumed to be mostly iconic and was considered somehow not to be a real language type because of this. Nowadays the status of sign languages as languages in their own right with syntax, semantics, morphology and phonology is fully acknowledged, as is the fact that sign languages have the same tendency as spoken languages to be arbitrary in sign–meaning correlations.

The special appeal of phonological features defined in the way just laid out lies in the parallelism between sound and sign language in the abstract apparatus used to indicate contrast and, at the same time the use of contrastive features as ‘instructions’ for their realization in both dimensions, neither of which is possible if features are defined via a perceptual correlate or by the active articulator involved in production. As mentioned above, there are certainly concepts and features in use in the other modules of grammar that do not lend themselves to use as contrastive phonological features because there is no articulatory or acoustic/visual correspondence. Similarly, it is obvious that both modalities have different means to express things. With gestures one has more dimensions and articulators available than with vocalization. Since the two modalities are very different, it cannot be expected that they use exactly the same feature set, but rather that there is a big overlap in the features used.

As a welcome side effect, this theory directly explains at least some cases of iconicity. This is, though, also a potential problem. If the same concepts are used for phonological encoding as in semantics, the interpretation of utterances might get messed up if phonological form and logical form are not kept strictly separate. Most (generative) linguists and cognitive scientists assume that cognition is organized in separate modules.

(23) Modularity: the Y model (Chomsky 1995)



One might argue that one defining aspect of modularity is that the different modules compute different alphabets, i.e., manipulate different sets of symbols (which is the standard assumption). However, it is not cogent to assume different sets of signs for each module. Syntax and phonology, for example, two modules particularly relevant for our discussion here, are also substantially different in the hierarchical organization of signs and in the operations performed on them (see, e.g., Neeleman & van de Koot 2006). A syntactic tree looks very different from a tree in feature geometry and the rules and constraints of phonology are substantially different from the operations in syntax, such as Merge. Similarly, semantic structures, at least those cast in logic calculus in formal semantics, consist of propositions, predicates and their argument variables, manipulated via quantifiers and other logical operators. As noted in footnote 5, concepts used as features in phonology, that is, basically as labels that classify entities, such as the telic–atelic distinction, take on a very different form and are distinguished in a structurally very different way in semantics.

If semantics, syntax and phonology are separate modules, and their internal organization is not the same, theoretical parsimony suggests that the set of features is shared across modules. Phonological features with a very general semantic content don't mess up the actual semantics/interpretation. Though sometimes they do support interpretation, for example in iconic words or in particularly evocative uses of language, such as in poetry.

7.5 ICONICITY

In the previous section we have already seen a few cases of sound symbolism, i.e., the use of high vowels in particles indicating proximity and low vowels in particles indicating distance, the use of a stop consonant or stop gesture to indicate perfective aspect, telicity or past tense. For the purpose of this chapter, sound symbolism is interesting since we are trying to figure out what underlying representations, and here, especially, contrastive features, are or 'look like'.

Despite such frequently observed connections between sound and meaning, this relation has been regarded as arbitrary since Saussure (1916). And indeed in most words and morphemes there is no correlation between the sounds and the meaning or concept they are used to express, as can be seen from the examples in (24) and example (1) in Chapter 2.

(24) Arbitrariness

English: *mist, missed*
German: *Mist* 'manure; bullshit'

Thus it is generally accepted that the job of phonological features is to distinguish signs that differ in meaning, and that there is no inherent meaning in a phonological segment or feature.

That some words have a more intimate relation between signans and signatum was observed long ago, starting at least with the discussion in Plato's *Kratylos*. Saussure's claim of arbitrariness was, for example, criticized by Jespersen in several publications (1922a, b, 1933 among others). Similarly, Jakobson was fascinated by sound symbolism and dedicated several studies to the topic after a brief start in 1941.

To start with, there is an intuitive colour affiliation of vowels. For many people front vowels are somehow light and back vowels are perceived as dark. In German, the adjective and noun for 'light' *hell* and *Licht*, respectively, have a front, i.e., light vowel, while the adjective and noun for 'dark(ness)' *dunkel* has a back, i.e., dark vowel. As Jakobson notes, in Russian the word for 'day' has a front vowel and the word for 'night' has a back vowel. In French, though, this is reversed, with a dark vowel in the word for 'day' and a light vowel in the word for 'night'. Jakobson refers to the French poet Mallarmé who complains that in French the natural connection between signifier and signified has been reversed in these words. This relation gets more extreme in onomatopoetically sensitive people who associate vowels with colours: the front high vowel *i* is usually perceived as yellow or white, the high back vowel *u* is mostly blue and the low vowel *a* evokes dark red. Mid vowels are blends of the colours of the corner vowels: *e* is orange (mixing red and yellow) and *o* is purple (mixing blue and red). This colour association finds its expression in Element Theory, in which the three corner vowels are the basic elements or colours and all other vowels are represented as blends of these elements or 'colours'.

It remains to be shown, though, how far the characteristic acoustic spectral properties of the three radicals correspond to the optical spectral properties of the basic colours. While the colour red has a comparatively low frequency range (*c.* 430–480THz), low vowels and the element |A| are characterized by a concentration of spectral energy in the middle of the frequency range for speech. The colour blue has a very high frequency range (610–670THz), while the corresponding back high vowels and element |U| have an energy concentration in the lower zone of the frequency band. Yellow is right in between red and blue with respect to its frequency range (510–540THz), while the front high vowels have a high-frequency energy concentration. If we consider the colours' wavelength, blue is at ~470nm, yellow at ~570nm and red around ~650nm. It is to be suspected that we are considering the wrong parameters.

Another very frequent type of sound symbolism connects vowels (and consonants) with size. The vowel *i* is a cross-linguistic favourite in diminutive suffixes, while *u* and *o* occur often in augmentatives. Compare Italian *gatto* 'cat' – *gattino* 'cat-diminutive' – *gattone* 'cat-augmentative'. Italian shows the same iconic relation in the respective adjectives *p**i**ccolo* 'small' and *gr**a**nde* 'big'. As the English glosses show, such size symbolism is an option, not facultative.

Ohala (1997) points out that this iconicism correlates with the acoustic properties of these sounds. While the vowels used for diminutives have a characteristic concentration of energy in the higher frequencies of the spectrum (i.e., the Jakobsonian feature [–grave] or elemental |I|), the vowels used in augmentatives show a concentration in the lower frequencies ([+grave] or |A|). Large resonance bodies result in low frequencies, while small resonance bodies result in high frequencies. Accordingly, we expect small people and animals (e.g., mice) to emit higher-pitched sounds than large humans or animals (e.g., cows – elephants and whales are not good examples here). Ohala also notes that animals use the same iconicism in conflict situations. The aggressor emits low-pitched sounds and uses all possible resources to appear as big as possible (raising back hair, ears and tail, if available), while the submissive animal emits high-pitched sounds and tries to appear as small as possible (imagine the sound emission and body language of dogs in the respective roles). The size-evoking quality of high and low frequency is also employed in intonation. Cross-linguistically question intonation has an overall higher pitch and rising intonation, while statements, especially answers, are produced on a lower pitch and very often with final falling pitch. Ohala suggests that the asker puts himself in a submissive role since he needs cooperation of, i.e., an answer from, the listener. The answerer underlines his authority by low and falling pitch, simulating bigness.[6] With this explanation, size sound symbolism falls into the same category as other symbolic uses of sound that directly mimic a sound, such as the words for whistling in many languages, with their abundance of fricatives and especially labial and coronal ones, and other verbs for sound emissions, like *shriek*, *sing*, *growl*, *howl*, *whisper* etc. in English.

Further types of sound symbolism show how certain sound classes evoke or enforce the event type of a verbal expression or of the structure, form, texture etc. of objects referred to, albeit in slightly more subtle ways than observed with the English past tense marker above (e.g., *gurgle, bubble, chuckle, glow, gleam, glitter, stick, stitch, stand* …). The examples in brackets show another property of iconic words. Gathering phonetically similar words of this type into groups and networks according to their onsets and into others according to their rimes, one can attempt to establish semantic fields and eventually isolate sememes, sounds or sound combinations and their alleged inherent meaning.

It is an open question, though, whether we perceive such sound–meaning correlations because of the sounds' surface articulatory and/or acoustic characteristics or because of their phonological properties. It might as well be that sound symbolism and especially synaesthesia arise because of the topology of the brain, i.e., low vowels activate regions in the brain that are close to the regions that are activated during the perception of the colour red, and the association with low vowels and the colour red is some kind of neural activation spill-over effect. After all, synaesthetically gifted people even associate speech sounds and flavours. One might attribute this to different tastes being perceived by specialized taste buds located in different zones in the oral tract (more specifically, on the tongue), which coincide with the points of articulation of respective sounds. However, the widely held belief that the different tastes, sour, sweet, bitter, salty and umami, correspond to specialized separate zones of the tongue seems to be a myth.

Recent experimental findings, however, suggest that the link between meaning and segmental make-up of a morpheme/word is more subtle than the arbitrariness hypothesis leads us to expect (see, e.g., Martino & Marks 2001; Ramachandran & Hubbard 2001, Nygaard, Cook & Namy 2009 and references to earlier studies cited there). Nygaard *et al.* (2009) presented monolingual English-speaking subjects with Japanese word-learning tasks. It turned out that subjects fared much better in learning Japanese words when these were paired with their real English gloss or with their English antonym (with lower performance in the second condition) than when they were paired with some arbitrary (i.e., simply wrong) English translation.

This indicates that the phonology actually carries at least some semantics in a more systematic way than investigations concentrating on sound symbolism and synaesthesia let us think, or the arbitrariness hypothesis allows, since the sound structure of unsuspicious words seems to aid lexical access and storage.

This discussion of sound symbolism/iconicity and synaesthesia did not give an exhaustive overview of these phenomena. The interested reader may consult, e.g., Hinton, Nichols & Ohala (1994).

7.6 CONCLUDING REMARKS

In this chapter we discussed the content of phonological features in underlying representations. The primary objective of phonological features is to serve the purpose of contrast. They distinguish items, i.e., segments, from others such that words or morphemes can be distinguished. For this purpose, completely empty labels that sort segments into classes would be sufficient. From the beginning of feature theories, features have been defined by characteristic articulatory and acoustic properties. This serves three purposes. First, features defined in such ways group segments into natural as opposed to arbitrary classes, paying tribute to the observation that segments behave in classes in phonological processes. Second, acoustically or perceptually defined features also help identification of the feature bearer and thereby lexical access, since the listener is confronted with an acoustic signal rather than with the features themselves. Third, articulatorily defined features help the speaker select the right gestures to execute the realization of every feature. The latter two tasks can be done in a more indirect way, in each case relying on the opposite information on the perception–production divide. That is, lexical access can be achieved as well with articulatory features if the listener mentally simulates the production of the perceived stimulus, identifies the features and then moves on to lexical access. Conversely, the speaker can mentally try out gestures that result in emission of the segment specified with acoustically defined features and then move on to actual production. Thus, one doesn't have to assume a separate production lexicon and a perception lexicon with different representations (i.e., articulatory in the former and perceptual/acoustic in the latter). Acoustic definitions are motivated in the observation that the acoustic signal is everything the listener and the speaker share. However, one might as well counter that both participants also share a common physiology, that is, organs for articulation.

We looked at three different ways of defining features and the respective resulting feature theories, acoustic definitions, articulator-based definitions and, third, more abstract articulatory definitions. The former two approaches can be criticized for being too audio-centric by focusing exclusively on spoken language and completely ignoring sign language. This criticism was at least in principle avoided in the last approach, since with its articulator-neutral definitions the same features can potentially be used in both modalities.

Finally, apart from detecting contrasts, investigating phonological patterns and studying the physical production and perception of the signal, an additional potential source of information can be suspected in iconicity phenomena, the subject of the last section. It turns out, though, that it is quite likely that most sound symbolism arises due to surface properties of sounds and sound combinations rather than their abstract phonological representations (especially in sound imitating iconicity). However, the whole research area is characterized by a high degree of speculative musing; serious experimental studies have been conducted only recently and they are very few and far between. Also synaesthesia is not necessarily the effect of structural parallels at an abstract level, but could be a side effect of the localization of different perception centres in the brain.

DISCUSSION POINTS

- Why should contrastive features contain information on the realization of the contrast?
- Why are there no contrastive pairs in Element Theory?
- Discuss the modality issue: what are the differences between spoken and signed language? Which do you think emerged first? What potential consequences does this have for our understanding of features?

SUGGESTIONS FOR FURTHER READING

On features in phonology

Fudge, Eric C. (1967). The nature of phonological primes. *Journal of Linguistics* **3**: 1–176.

Hall, T. A. (2007). Segmental features. In Paul de Lacy (ed.), *The Cambridge Handbook of Phonology*. Cambridge University Press. 311–34.

Harris, John (2007). Representation. In Paul de Lacy (ed.), *The Cambridge Handbook of Phonology*. Cambridge University Press. 119–37.

Mielke, Jeff (2008). *The Emergence of Distinctive Features*. Oxford University Press.

Schane, Sandford (1985). The fundamentals of Particle Phonology. *Phonology Yearbook* **1**: 129–55.

Uffmann, Christian (in prep.). *Distinctive Features*. Cambridge University Press.

On sound symbolism/iconicity/synaesthesia

Cuypere, Ludovic de (2008). *Limiting the Iconic*. Amsterdam: John Benjamins.

Hinton, Leanne, Johanna Nichols & John J. Ohala (1994). *Sound Symbolism*. Cambridge University Press.

8 Underlying representations in Optimality Theory

Optimality Theory is a theory that is claimed to make predictions about the form of underlying representations. Thus, after we have seen neuro- and psycholinguistic evidence for some aspects of underlying forms, we might think we are now in a position to test whether the theory is appropriate in its predictions. However, we will also see that, since OT is a theory of computation rather than of representation and many aspects of the computation system (in particular the definition of constraints) depend on the feature theory used, there is not one set of predictions but several. After that, we make a U-turn and discuss the options for trimming the theory, such that it gives us some of the results that are confirmed by experimental or other evidence, and what insights we can gain from this exercise.

The first section of this chapter provides the basic architecture of OT. Readers familiar with the framework are warmly recommended to skip this section. The second section discusses OT's mechanism of Lexicon Optimization and shows that this optimization is far from optimal when evaluated against the principles of lexical economy identified in previous chapters and against the neuro- and psycholinguistic evidence. In Section 8.3, we will consider some potential modifications to Lexicon Optimization and whether we can arrive at more appropriate results or have to abandon this way of generating underlying forms altogether.

8.1 INTRODUCTION TO OPTIMALITY THEORY

In Optimality Theory surface representations are evaluated according to how well they do with respect to a set of universal violable conflicting constraints that are placed in a language-specific hierarchy of relative importance. The language-specific constraint ranking determines the inventory of surface forms. Thus, the typological observation that, for example, Hawaiian does not have any consonant clusters while, for example, German can have up to four consonants in a row in monomorphemic forms (as in [hɛʀpst] 'autumn') is attributed to differences in constraint ranking, as is made explicit in the Richness of the Base Hypothesis.

(1) Richness of the Base Hypothesis (RotB; Smolensky 1996:3)

> The source of all systematic cross-linguistic variation is constraint reranking. In particular, the set of inputs to the grammars of all languages is the same. The grammatical inventories of a language are the outputs which emerge from the grammar when it is fed the universal set of all possible inputs.

The notion of input as used in the statement of RotB in (1) deserves a comment. 'Input' here is not referring to a representation stored in the lexicon. The input is a hypothetical construct, which serves the linguist to test an analysis. The grammar developed by the analyst should optimally produce all and only those patterns that are attested in the language under scrutiny or that are judged as grammatical by the speakers of the language. To test how far this goal has been achieved we can use all sorts of inputs, feed them into the proposed grammar and see which form the grammar generates on this basis (e.g., we take the German word for 'autumn' as the input for a grammar of Hawaiian). OT makes no claims about what a possible surface representation or a possible input looks like, since it is not a theory of representation, but one of computation. Thus, the 'universal set of possible inputs' referred to in (1) is determined by the theory of representation.

The other assumption implied in the RotB which is important for our purposes is that there are only constraints on surface forms (and faithfulness constraints that check the mapping between underlying and surface form) but no constraints on input forms.[1] Constraints on input forms sneak in, of course, through the theory of representations that has to be added to OT. However, such a theory contains constraints on the well-formedness of representations in general, but no specific constraints on underlying forms which could, via rankings, result in language-specific restrictions on possible underlying forms.

This assumption (i.e., 'No constraints on the lexicon!') has consequences for OT's capacity to generate underlying forms as well, as we will see shortly.

Before we proceed I will give a summary of the main components of OT. An optimality-theoretic grammar consists of the following parts.

(2) The building blocks of OT

CON: The set of universal constraints on surface representations (Markedness constraints) and input-output mapping (Faithfulness constraints) (Richness of the Base Hypothesis: 'No constraints on the lexicon!')
CAND: The candidate set: a potentially infinite set of surface representations[2]
GEN / The Generator: A function generating output candidates
The lexicon: A set of underlying representations, which have to be acquired for each language, but consist of a universal 'alphabet'.
A language-specific ranking or hierarchy of CON, the constraint set
EVAL: The function that evaluates the optimal output from the set of candidates according to their harmony with the constraints in their language-specific ranking.

An OT grammar selects the form that is optimal under a given constraint ranking from a potentially infinite set of possible forms.

If we just consider a few ways of realizing the word *writer* in different varieties of English we get an idea of what this means and how it deals with typologies.

(3) English *writer*

a. US/Canada etc. [ɹaɪɾɚ]
b. UK/BBC [ɹaɪtə]
c. UK/London etc. [ɹaɪʔə]
d. ScottishE [raɪʔɚ]

For the moment, we will just consider an input that has a medial /t/ underlyingly. For some varieties we can say there is one because it surfaces in the unaffixed form, i.e., *write*; for other varieties the situation is a bit more complex since they display additional final glottalization.

For simplicity's sake we assume that intervocalic flapping of *t* and *d* is caused by a markedness constraint against intervocalic coronal stops, *VTV. This constraint interacts with other constraints and different rankings of these constraints yield the different surface forms we find across the spectral slice of language called English.

Since in English the coronal stops generally contrast in manner and place of articulation as well as voicing (or aspiration), we know that the markedness constraint against *t* and *d*, let us call it *T, has to be outranked by some faithfulness constraints that make sure that an underlying /d/ surfaces as a [d] and an underlying /t/ surfaces as a [t].

We also know that both [ʔ] and [ɾ] only occur in very restricted environments in the varieties of English we are dealing with. Since they are fully predictable, the markedness constraints against them have to be ranked higher than faithfulness, but lower than the markedness constraints that cause their emergence, such as *VTV. This gives us the basic ranking for varieties with intervocalic flapping or glottalization.

The tableau in (4) shows the most important constraints to the left and the least important constraint to the right. Constraints separated by an interrupted line are not ranked with respect to each other and thus their violations count equally. The input is given in the usual slashes and the relevant output candidates are listed below the input. The winning candidate, i.e., the form this grammar will produce, is marked with a pointing finger. Constraint violations that lead to the exclusion of a candidate are marked with an asterisk.

(4) First OT sketch of English intervocalic coronal neutralization[3]

/ɹaɪt-ə/	*VTV	*ɾ	*ʔ	FAITH	*T
☞ a. ɹaɪtə	*				*
b. ɹaɪʔə			*	*!	
c. ɹaɪɾə		*		*!	

In (4) the three highest-ranked constraints are actually irrelevant since they cancel out each other's effects. With every candidate violating one of the highest constraints and all three constraints being equally important, the decision is passed on to the next lower ranked constraint, in this case FAITH, which is violated by any deviation from the input. Once we rank the three highest-ranked constraints with respect to each other we get a different result.

(5) OT sketch of English intervocalic coronal glottalization

/ɹaɪt-ə/	*VTV	*ɾ	*ʔ	FAITH	*T
a. ɹaɪtə	*!				*
☞ b. ɹaɪʔə			*	*	
c. ɹaɪɾə		*!		*	

A minimal change in the ranking of these three constraints yields the flapping pattern.

(6) OT sketch of English intervocalic coronal flapping

/ɹaɪt-ə/	*VTV	*ʔ	*ɾ	FAITH	*T
a. ɹaɪtə	*!				*
b. ɹaɪʔə		*!		*	
☞ c. ɹaɪɾə			*	*	

As we can see, minimal permutations of the constraints result in different surface forms of the same input. In this way OT explains cross-linguistic differences in surface patterns by constraint interaction.

With this background we can turn to the discussion of underlying representations in OT.

8.2 LEXICON OPTIMIZATION

In the project report laying the foundations for OT, Prince & Smolensky (1993/2004) already discuss the possibility of using the evaluation mechanism that chooses the optimal output among the candidate set to determine underlying representations rather than output forms. Once a grammar, i.e., ranking has been found that adheres to the RotB and maps any conceivable input to a form that is well-formed in a given language, it is possible to determine the set of input forms that will map to one and the same surface form and use the language-specific constraint hierarchy to determine the most harmonic underlying representation from these input candidates.

They also observe the problem that arises from the set of faithfulness constraints: a non-alternating surface form will always be mapped to an identical underlying form, since any deviation from the surface representation will in principle result in a faithfulness violation that classifies the respective candidate as less harmonic than a competitor that is closer to the output. They also note that this is a fundamental problem since it conflicts with generally held assumptions about economy in the lexicon within generative phonology. As we have seen earlier, redundant (i.e., non-contrastive) features and features that are in some way predictable were assumed to be underspecified and filled in during the derivation. On the other hand, Exemplar Theory claims that (not only) in non-alternating forms the fully predictable aspects of a segment are stored as they are on the surface. Taking an English word with a predictable but never alternating flap, we can see the dilemma of OT. Since *butter* doesn't have a morphological base *butt* (with a stop rather than a flap) a learner/user will have no direct evidence for an underlying medial segment other than the flap. The grammar determines the output regardless of the input because of the RotB.

(7) English intervocalic coronal flapping in a non-alternating form

	*VTV	*ʔ	*ɾ	FAITH	*T
a. bʌtə	*!			?	*
b. bʌʔə		*!		?	
☞ c. bʌɾə			*	?	

Once the ranking has been established such that the grammar determines candidate (c) as optimal regardless of whether the input has a /t/ or a glottal stop or a flap, it can be used to select one of the candidates as the underlying form. Prince & Smolensky propose the following mechanism to do this.

(8) Lexicon Optimization (Prince & Smolensky 1993/2004)

Suppose that several different inputs $I_1, I_2, \ldots, I_n$ when parsed by a grammar G lead to corresponding outputs $O_1, O_2, \ldots, O_n$, all of which are realised as the same phonetic form Φ – these inputs are all phonetically equivalent with respect to G. Now one of these outputs must be the most harmonic, by virtue of incurring the least significant violation marks: suppose this optimal one is labelled O_k. Then the learner should choose, as the underlying form for Φ, the input I_k.

(9) Lexicon Optimization

	Constraint A	B	C	D
a. $I_1 \sim O_1$	*!		*	
b. $I_2 \sim O_2$		*!	*	
c. $I_3 \sim O_3$			*!	
☞d. $I_k \sim O_k$				*

For any pattern that is by standard assumptions believed to be non-structure-preserving OT thus predicts storage of the predictable structures. The only structure that is exempt is syllable structure since there are no faithfulness constraints on syllable constituents. Epenthetic material predictable from syllable well-formedness constraints is stored in the lexicon.

(10) Prince & Smolensky's prediction

Potential Input /CCC/ -> [CVCVCV] -> /CVCVCV/ UR
Potential Input/VVV/ -> [CVCVCV] -> /CVCVCV/ UR
in insertion grammar

Consider a hypothetical language that doesn't show alternations. All syllables are CV(C). The absence of onsetless syllables leads to the ranking of Onset above Parse and Fill.[4] In addition, we observe that the obstruent inventory in syllable-initial position consists of *p, t, k,* ʔ, while in syllable-final position we only find *p, t, k*. The 'average phonologist' would conclude that ʔ is not contrastive in the language and just serves as the epenthetic consonant that helps out when a syllable onset is needed. A language that uses consonant epenthesis to supply otherwise vowel-initial syllables with an onset can be formally described in OT, as in the following tableau.

(11) A CV language

/a/	ONSET	PARSE	FILL
a. .a.	*!		
☞b. .ʔa.			*
c. <a>		*!	

Prince & Smolensky's mechanism of Lexicon Optimization yields the following result.

(12) Lexicon Optimization in languages without alternations

LO	ONSET	PARSE	FILL
a. /a/ – .ʔa.			*!
☞b. /ʔa/ – .ʔa.			

Similar results are obtained in languages with alternations. Reconsider English flapping.

(13) English flapping

a.	hi[t]	hi[ɾ]er
b.	-/-	bu[ɾ]er

Irrespective of what happens in (a)-type paradigms, the (b) words have no chance of being stored without a flap.

In our specific case and in every other parallel case (such as non-alternating alleged epenthetic segments, as discussed by Prince & Smolensky) the result is maximal identity.

(14) English intervocalic coronal flapping in a non-alternating form

	*VTV	*ʔ	*ɾ	FAITH	*T
a. /bʌtə/ - [bʌɾə]			*	*!	*
b. /bʌʔə/ - [bʌɾə]			*	*!	
☞ c. /bʌɾə/ - [bʌɾə]			*		

The point has been reiterated by quite a few scholars and is now standard belief.

> [I]f no alternations occur in a morpheme's shape, the learner will never postulate an input deviating from the actual observable output form. Due to *Lexicon Optimization*, the input simply equals the output unless there is reason to deviate. (Kager 1999: 414)

> [R]edundant features will be specified in optimal lexical representations. (Beckman & Ringen 2004: 101)

However, few have drawn such radical conclusions from this effect of faithfulness constraints as Burzio.

> It is easy to see that … the actual input *equals* the actual output. The reason is that any input different from the output … would only add violations of IO-F without ever avoiding any other violation in return … Now the claim illustrated for P&S … appears to be non-distinct from the … claim that there is only surface representation and no UR. (Burzio 2000: 55; see also Szentgyörgyi 2004)

The situation is more serious than that. OT does not only predict fully specified underlying representations for non-alternating monomorphemic forms, it predicts that a learner will store every form in a paradigm instead of decomposing them into their component morphemes.

(15) LO discourages a learner from any morphological analysis

LO			*VTV	FAITH(F)
a.	/hɪt (-r)/	- hi[t] - hi[ɾ]er		*
☞b.	/hɪt/ /hɪɾr/	- hi[t] - hi[ɾ]er		

This multiplies the number of lexical entries and poses a real challenge to the learner when it comes to making generalizations. Prince & Smolensky (1993/2004: 228) speculate: One simple way of formulating such a global lexicon optimization would be in terms of minimizing the totality of underlying material contained in the lexicon. To achieve this they propose the following constraint.

(16) *SPEC: Underlying material must be absent.

This constraint has two serious problems. On the one hand, it is the only constraint on underlying representations and undermines the hypothesis that there are no constraints on the lexicon. On the other hand, it is a rankable constraint, as Prince & Smolensky immediately note. If it is ranked too low, and in any language that has a lexicon (that is, in every language) it can't be top-ranked, it doesn't have any effect: once it is ranked below a substantial number of faithfulness constraints the original problem re-emerges – the grammar generates fully specified underlying representations to avoid violations of faithfulness constraints.

Inkelas (1994) discusses this problem and proposes a restatement of Lexicon Optimization to cater for alternating morphemes.

(17) Inkelas' (1994) alternation-sensitive restatement of LO:

Given a set S = [S_1, S_2, …, S_i] of surface phonetic forms for a morpheme M, suppose that there is a set of inputs I = [I_1, I_2, …, I_j], each of whose members has a set of surface realizations equivalent to S. There is some $I_i \in I$ such that the mapping between I_i and members of S is the most harmonic, i.e. incurring the fewest marks in grammar for the highest ranked constraints. The learners should choose that I_i as the underlying representation for M.

(18) Schematic tableau for alternation-sensitive Lexicon Optimization

			Constraint A	B	C	D
a.	I_1 ~	S_1	*!		*	
		S_2		*		*
b.	I_2 ~	S_1		*!	*	*
		S_2				
c.	I_3 ~	S_1			*!	*
		S_2				
☞d.	I_4 ~	S_1				*
		S_2				

With this mechanism in place, her conclusion is that all underlying representations are fully specified except for predictably alternating structures.

(19) OT/LO view on lexical representation (Inkelas 1994):

	Predictable	Unpredictable
Alternating	underspecified	specified
Nonalternating	specified	specified

The more common view, as it emerged from structuralism and *SPE* (see preceding chapters) is schematized in (20).

(20) Very common view

	Predictable	Unpredictable
Alternating	underspecified	specified
Nonalternating	underspecified	specified

Inkelas argues for another option that hadn't been seriously considered before: almost-contrastive ternarity (her take on the archiphoneme). In such a view of contrastive features a feature can be positively or negatively valued or have no value at all. She illustrates this with Turkish voicing patterns (among other examples).

Turkish shows a two-way voicing contrast on the surface, which is neutralized in word-final position. However, some morpheme-final voiced stops that emerge as such in intervocalic position are exempt from word-final devoicing (see also the discussion in Section 4.6).

(21) Turkish devoicing

a.	[t~d]	kanat	'wing'	kanat-lar	'wings'	kanad-ɨ	'wing-acc'
b.	[t]	sanat	'art'	sanat-lar	'arts'	sanat-ɨ	'art-acc'
c.	[d]	etüd	'étude'	etüd-ler	'études'	etüd-y	'étude-acc'

Inkelas proposes the following underlying forms and a grammar that allows only the underspecified obstruents to receive their voicing specification according to the context in the surface form.

(22) Underlying

/kanaD/	Ø
/sanat/	[−voice]
/etüd/	[+voice]

Thus, the grammar is assumed to show effects of a markedness constraint causing intervocalic voicing as well as one militating against word-final voiced obstruents.[5]

For non-alternating predictable structure Inkelas (1994) gives the following OT analysis, perpetuating Prince & Smolensky's observation. In (23), capital letters in input candidates indicate underspecification of the segment.

(23) Inkelas on predictable non-alternating structure

LO		Insert[c-place]	Insert[voice]	Insert[v-place]
☞a.	/ti/ ti			
b.	/Ti/ ti	*	*	
c.	/TI/ ti	*	*	*

The aspect of this tableau that immediately leaps to the eye is that the constraints are all labelled Insert and are violated whenever a surface form has a feature that is missing in the input. This observation raises at least the following two questions. To what extent do the theory of faithfulness and the formulation of faithfulness constraints influence the outcome of Lexicon Optimization? What happens if we bring other constraints than just 'anti-insertion' constraints into the game? Inkelas' article was published before Correspondence Theory was introduced. At that time OT still ran on the Containment model of faithfulness which doesn't allow any difference between underlying and surface representation anyway (though this was skilfully ignored by many scholars at the time). The currently most widely used theory of input–output relations in OT is Correspondence Theory, as introduced by McCarthy & Prince (1995, 1999). In the following we will have a brief look at which influences the definition of faithfulness constraints has on Lexicon Optimization. Later, in Section 8.3.3, we will investigate the role of markedness constraints more seriously.

Correspondence between input and output or a base and a derived form (as in paradigms or in reduplication) is defined as in (24). Such correspondence relations are guarded by the faithfulness constraints listed in (25) among others (we ignore constraints on linearization of segments and other aspects of faithfulness here since we are only concerned with epenthesis and faithfulness to segmental features).

(24) Correspondence (McCarthy & Prince 1995)

Given two related strings S_1 and S_2. Correspondence is a relation $\Re$ from the elements of S_1 to those of S_2. An element $\alpha \in S_1$ and any element $\beta \in S_2$ are referred to as correspondents of one another when $\alpha \Re \beta$.

(25) Correspondence constraints (McCarthy & Prince 1995: 264)

a. MAX-IO: Every segment in S_1 has a correspondent in S_2. ('No deletion!')
b. DEP-IO: Every segment in S_2 has a correspondent in S_1. ('No insertion!')
c. IDENT(F): Let α be a segment in S_1 and β be any correspondent of α in S_2.
If α is [γF] then β is [γF].
('Correspondent segments are identical in feature F.')

We will first consider phonological features and the relevant correspondence constraint group IDENT(Feature) and turn to epenthesis afterwards. If the segment to which a feature is associated is present in both representations under scrutiny, the following two interpretations of these constraints are possible.

(26) Potential interpretations for IDENT[F]: violations are registered…

a. …for all changes of γ. (From Ø, +, – to something else).
b. …only if γ has a value [±] in each corresponding representation and these values differ.

Under the first reading, Inkelas-style underspecification results in IDENTITY violations in Lexicon Optimization, thus favouring full specification, while under the interpretation in (b), underspecification in the input and insertion of a default value in the output is gratuitous. However, that underspecification comes for free is not a reason to opt for it in OT; it only means that the grammar can't decide between the two options.

(27) Interpretations of IDENT in LO

LO		IDENT[voice](26)a	IDENT[voice](26)b
a.	/t…/ t…		
b.	/T…/ t…	*	
c.	/d…/ t…	*	*

Another trait of the definition of IDENTITY constraints is that the presence of the segment bearing the feature is a precondition for violations to be calculated. The feature and its value are an attribute of the segment rather than an entity in its own right. If an underlying segment is not present in the output or vice versa IDENTITY constraints are vacuously satisfied.

A further aspect that has to be noted is that the definition explicitly mentions a value of the respective feature. Unary or privative features don't have values, they are either present or absent. One could conceive a feature like [coronal] as a value of the place node though.

These two aspects are different if faithfulness to features is defined in terms of MAX(feature) and DEP(feature) constraints, as given in (28).

(28) MAX/DEP(F)

a. MAX(F): Every feature in S_1 has a correspondent in S_2.
b. DEP(F): Every feature in S_2 has a correspondent in S_1.

Here we can again envisage two interpretations, this time depending on whether we are dealing with binary or privative features. In the case of binary features, one can imagine a multiplication of constraints, with MAX(+F) and MAX(−F) etc. for each feature, or the MAX (F) constraints scan the feature including its value, registering a violation if the feature is gone or the value switched and vice versa for DEP (F). For Lexicon Optimization the relevant constraint that stands in the way of lexical economy is DEP(F).

(29) Evaluation with DEP(F) constraints and binary features

	DEP [high]	DEP [back]	DEP [low]	*[+back] *[+high] *[+low]	*[−back] *[−high] *[−low]
a. /V/ ~ [e]	*	*	*		***
☞ b. /e/ ~ [e]					***

If we assume unary features, a vowel that is the unmarked member of a system in a given language doesn't have any (marked) features in the input or in the output, and there is no point in the whole exercise since it is underspecified in both representations. The situation is less trivial for redundant marked features. If in a language all back vowels are [labial], DEP[labial] (or DEP[round]) will cause the redundant feature to be stored in underlying forms even though its presence in surface forms is accounted for by a markedness constraint enforcing rounding of back vowels on the surface. It doesn't matter whether the feature is contrastive, i.e., unpredictable for front vowels, as in French, or not, as in Spanish for example. However, as we have seen in earlier chapters, some theories as well as the results of neurolinguistic experiments suggest that such redundant features are unspecified.

(30) Redundant [labial] in back vowels

	DEP [labial]	If[back]then[labial]
a. /ɯ/ ~ [u]	*!	
☞ b. /u/ ~ [u]		

The standard OT claim that constraints are universal has another unwelcome consequence, though. We have just seen that it doesn't matter for Lexicon Optimization whether a feature is contrastive or not. As we have seen in Chapter 4, features that aren't contrastive in a language are normally left out. Some non-contrastive features are then filled in by default rules or left out entirely. Thus, an *e* in a language that only has this one front mid unrounded vowel doesn't need a specification for Advanced Tongue Root at either level, since ATR or tenseness doesn't play any role in the grammar (while *e* has to have a value at both levels in a language with a contrast between /e/ and /ɛ/, as in Italian, and it has to have an ATR specification at least in surface representations in a language in which [e] and [ɛ] are in complementary distribution, as in Spanish). If DEP(ATR) and *ATR are universal, one could conclude that representations are the same universally as well, that is, *e* has the same feature profile as the Italian or Spanish *e*'s, at least on the surface. Adopting unary features, we now end up in a situation where the unmarked vowel in the system is specified underlyingly for one marked feature only, which is a feature that is not contrastive in the language.

(31) The Dependency dilemma with universally uniform representations

	Markedness	Dep[ATR]	Max[ATR]
a. /V/ ~ [e]		*!	
☞ b. /e/ ~ [e]			

For a language like Spanish we end up with a situation that is as odd as with the rounding of back vowels: the allophones of the front mid vowel are stored with all their allophonic detail that is predictable from the context in the surface form.

According to D'Introno, del Teso & Weston (1995), Spanish has a tense *e* in stressed open syllables and in syllables closed by a dental, *s* or a nasal, while the lax allophone occurs in syllables closed by all other consonants. In unstressed syllables they observe reduction to schwa. The case parallels the English flapping pattern: all non-alternating allophones are stored in the underlying form.

In conclusion, we can say that with binary features and Identity constraints the learner has a choice, since the LO evaluation doesn't distinguish between specified and underspecified values, while with binary features and Max/Dep there is no choice, since any underspecification results in insertion which is punished by Dep (as with Inkelas' insert constraints, see (23) again). On the other hand, unary features are by definition underspecified if unmarked.

As we have seen in Chapter 6, there is some evidence that underspecification is more common than some OT practitioners would have us believe.

As for epenthesis, the Max/Dep model of correspondence generates the same results as the Parse/Fill model of faithfulness. Dep-IO punishes all candidates for underlying representations that have less material than the surface form. For alternating forms the consequence is that the OT grammar needs to account for deletion of glottal stops or any other default segment rather than, or as well as, their epenthesis.

Considering the German epenthesis pattern, there are paradigms in which the base form has a glottal stop, while the derived form doesn't have one and vice versa. Glottal stop occurs in German at the beginning of a word (32a) and word-internally at the beginning of a stress foot (32b) if no other consonant is present and is thus fully predictable. Hiatus in other positions is either tolerated or avoided by glide formation if the first vowel in hiatus is a high vowel (32c). An analysis of glottal stop as epenthetic receives further support by alternations of glottal stop and zero when stress shifts, as shown in the forms in (32d), which are morphologically related to the respective forms in (32b).

(32) Glottal stop in German

a.	[ˈʔeːkl]	Ekel	'disgust'	c.	[ˈzaːən]	sahen	'see' (past, -2, pl.)
	[ʔiˈdjoːt]	Idiot	'idiot'		[ˈbaʊwən]	bauen	'build'
b.	[ʔa'ʔiːda]	Aida	'Aida'				
	[kaˈʔoːtɪʃ]	chaotisch	'chaotic'	d.	[ˈkaɔs]	Chaos	'chaos'
	[teˈʔaːta]	Theater	'theatre'		[teaˈtraːlɪʃ]	theatralisch	'showily'

The usual conclusion is that glottal stop is the least marked consonant in the language and is therefore chosen as the epenthetic segment to provide an onset to word- and foot-initial syllables (see Alber 2001 and references there).

(33) Epenthesis in German

/teaːta/	MAX-IO	ONSET$_{/\text{PWD,FT}}$	DEP-IO
☞a. [teˈʔaːta]			*
b. [teˈaːta]		*!	

However, since all occurrences of the segment are fully predictable, it is not contrastive and should according to standard procedure be kept out of the lexicon.

A learner would probably first store the German noun *Chaos* without a glottal stop and the word *Theater* with a glottal stop. And this is what LO predicts as well.

(34) LO of alleged epenthesis in German

	ONSET$_{/\text{PWD,FT}}$	DEP-IO
a. /teaːta/ – [teˈʔaːta]		*!
☞b. /teʔaːta/ – [teˈʔaːta]		

For the former, the grammar has to establish an insertion-generating ranking once the derived form is analysed and for the latter a deletion-generating ranking has to be established as soon as the derived form is encountered and identified as such.

How do we build economy of inventories into the OT grammar then?

8.3 ADD-ONS TO OT THAT HELP DETERMINE UNDERLYING REPRESENTATIONS

In this section we will look at extensions/modifications to Optimality Theory that change the results of Lexicon Optimization. Two of these proposals, Comparative Markedness and the free ride mechanism, were developed by McCarthy (2003, 2005, respectively) to solve completely different problems. The third proposal, which can be labelled literal mirror-image evaluation, is a novel take on Lexicon Optimization. The latter two, the free ride and mirror-image evaluation, can be combined to yield results that are closer to the understanding of underlying representations as developed in structuralism and generative phonology and supported by neurolinguistic experiments.

8.3.1 Comparative Markedness (CM)

McCarthy (2003) proposes CM to account for a subset of opacity effects, especially grandfather effects. A grandfather effect, in a sense, is the opposite of structure preservation: a feature is contrastive in a language but its marked value is not allowed to emerge as the result of a phonological process. In structure preservation (Kiparsky 1985) a non-contrastive feature or structure is allowed to emerge as the result of a postlexical rule but not allowed as the output of a rule in the lexicon. In Mekkan Arabic, for example, voiced obstruents never surface as the result of voicing assimilation even though some obstruents are contrastively voiced, and thus voiced obstruents are part of both the underlying and the surface inventory.

In CM, Markedness is divided into two sets of constraints. Old Markedness ($_{O}$M) constraints punish structure that is present in the surface candidate and is part of the input form as well, while New Markedness ($_{N}$M) constraints are violated by structure in the output candidate that is not present in the input.

Krämer (2006) uses CM to account for non-structure-preserving phonology; in particular, he shows how a CM analysis of glottal stop epenthesis also keeps these predictable non-contrastive segments out of the lexicon.

In OT, this results in a ranking paradox. The first line of reasoning results in the ranking of the markedness constraint against this segment at the bottom of the hierarchy, as in (35a). Since the glottal stop is found to be more suitable as an epenthetic consonant than labial, coronal or dorsal stops, the markedness constraint against laryngeal constriction has to be dominated by the markedness constraints against the other place features. The second argument places the same constraint at the top of the hierarchy, as in (35b). Labial, coronal and dorsal are contrastive places of articulation. Thus the markedness constraints against these places have to be dominated by a faithfulness constraint. The glottal stop is not contrastive and hence the markedness constraint against the corresponding feature has to dominate the respective faithfulness constraint. Since we are dealing with one and the same language we have to reconcile the two ranking arguments, which is impossible, (35c).

(35)

a. FAITH(Place) ›› *Labial, *Dorsal ›› *Coronal ›› *Laryngeal
b. *Laryngeal ›› FAITH(Place) ›› *Labial, *Dorsal ›› *Coronal
c. c. a + b = *Laryngeal ›› Ident(place) ›› *Lab/dors, *Cor ›› (circular)

The conundrum is resolved by CM's division of markedness constraints into those that militate against surface structures present in the input ($_{O}$M) and those markedness constraints against surface structures not present in the input ($_{N}$M).[6]

(36) Old and New Markedness

a. $_{O}$*PLACE	Assign a violation mark for each consonantal place of articulation in the output that is present in the fully faithful candidate (FFC).
b. $_{N}$*PLACE	Assign a violation mark for each consonantal place of articulation in the output that is *not* present in the FFC.

The tableau in (37) illustrates how violations of the two faces of the same markedness constraint are calculated. The place-holder constraint *Place is violated by any consonant that has a place of articulation (within the articulatory tract, that is, not by a glottal stop).

(37) Comparative markedness constraint satisfaction and violation

	/p/ FFC: p	$_{O}$*PLACE	$_{N}$*PLACE
a.	p	*	
b.	k		*
c.	Ø		

If the glottal stop is not contrastive in German, $^{*}_{\text{OLD}}$LARYNGEAL has to outrank Faithfulness. With such a ranking any /ʔ/ will be mapped to something else, as shown in tableau (38).

(38) Hypothetical input

	/ʃʔRoːʔ/	O*LAR	MAXIO	IDENT(PLACE)	N*LAR
a.	ʃʔRoːʔ	*!*			
☞ b.	ʃtRoːt			**	
☞ c.	ʃRoː		**		

To allow [ʔ] to emerge as a response to the requirement to have an onset $^{*}_{\text{NEW}}$LARYNGEAL has to be ranked very low in the hierarchy. Epenthetic glottal stops vacuously satisfy $^{*}_{\text{OLD}}$LARYNGEAL because they don't have a correspondent in the input.

(39) Epenthesis

	/ekl/	O*LAR	ONSET	IDENT(PLACE)	N*LAR
a.	ˈeːkl		*!		
☞ b.	ˈʔeːkl				*

With this differentiation of markedness constraints, the constraints against glottal stop can be ranked with respect to markedness constraints against consonants with other places of articulation to explain both the relative unmarkedness of the glottal stop with respect to these other obstruents, i.e., the fact that it is chosen as the epenthetic consonant, and its relative markedness, i.e., its absence from the contrastive inventory, as shown in (40).

(40) Choosing the right epenthetic consonant

	/ekl/	ONSET	O*LAR	IDENT(PLACE)	*LAB/DORS/COR (OLD and NEW)	N*LAR
a.	ˈeːkl	*!			**	
b.	ˈteːkl				***!	
c.	ˈpeːkl				***!	
d.	ˈkeːkl				***!	
☞ e.	ˈʔeːkl				**	*

With this grammar, a learner can't store a non-alternating form containing a glottal stop, such as the one in (39) and (40), with a glottal stop in the lexicon, since this would be mapped to something else, as shown by the tableau in (38). Even if we allow the glottal stop in a candidate for an underlying representation, Lexicon Optimization would reject it in favour of the candidate that doesn't violate $_{\text{OLD}}$*LAR.

(41) LO with Comparative Markedness

		O*LAR	ONSET	N*LAR
a.	/ʔekl/ – [ˈʔeːkl]	*!		
☞ b.	/ekl/ – [ˈʔeːkl]			*

However, the same results can be obtained if the learner constructs the right analysis of alternating glottal stops (insertion, not deletion) and has the non-alternating forms take a free ride on the alternating forms. The Free Ride mechanism will be discussed in the next section.

8.3.2 Taking a free ride in morphophonemic learning

Even though McCarthy (2005) borrowed the term from Zwicky (1970), the concepts they use the term for are very different. In McCarthy's sense of the term we are dealing with a free ride if in the course of language acquisition the underlying representation of a non-alternating form is adjusted according to the pattern observed in a morpheme that shows an alternation. This is common practice in phonological analysis (i.e., among phonologists looking at their data, see Chapters 2, 3 and 4) but hitherto had no formal theoretical status. We have also seen in Chapter 5 that children tend to extend generalizations to irregular lexical items (Hudson Kam & Newport 2005). The advantages the learner gains from this strategy are a smaller inventory in the lexicon and a more restrictive ranking of constraints. The latter is seen by McCarthy as the ultimate drive behind the strategy, while the former is seen as a welcome by-product.

McCarthy's example of a free ride is the Sanskrit vowel system. Sanskrit has a five-vowel system with a length distinction, but there are no short mid vowels. Furthermore, the language has no diphthongs. If a morpheme ending in a low vowel is followed by one starting in a high vowel they are realized as a long mid vowel, /…a – i…/ is realized as […eː…] and /…a – u…/ is realized as […oː…].

(42) Sanskrit coalescence

/tava indra/	tave:ndra	'for you, Indra (voc.)'
/hita upadaiʃah/	hito:pade:ʃah	'friendly advice'

The obvious conclusion is that Sanskrit has a three-vowel system and that all the non-alternating long mid vowels are derived from underlying sequences of a low and a high vowel, as proposed by, e.g., Gnanadesikan (1997). According to the RotB, an OT analysis has to map any mid vowels in hypothetical inputs, including long mid vowels, to something else.

(43) Gnanadesikan (1997): chain shift

/e:/ → a: or i:
/ai/ → e:

(44) Sanskrit

i. /be(:)/	*MID	IDENT(VH)[7]
☞a. bi(:) or ba(:)		*
b. be(:)	*!	

ii. /va-i/	*DIPH	UNIFORMITY	IDENT(VH)
☞ a. ve:		*	**
b. vai	*!		

iii. /va-i/	ID-ADJ(VH)[8]	*MID
a. ve:		*
b. vi: or va:	*!	

Before morphological analysis, learners take emergent mid vowels as underlying. The problem now is that the grammar is already too liberal, since it admits a structure to both levels of representation, and its faithful mapping from one to the other, that actually shouldn't exist in the lexicon. The reason is that in order to map an input (in this case input = what the learner hears from the more advanced speakers) *e:* or *o:* to a surface *e:* or *o:*, respectively, the learner had to demote the markedness constraint against mid vowels, *MID, below the relevant faithfulness constraint.

(45) Sanskrit after phonotactic learning

		*DIPH	IDENT(VH)	*MID	ID-ADJ(VH)	UNIFORMITY
/ba/	☞ ba					
	bi		W		W	
	be		W	W		
/bi/	☞ bi					
	ba		W		W	
	be		W	W		
/be:/	☞ be:			L		
	bi:		W			
	ba:		W			

Once a learner realizes that the long *e* in *tave:ndra* (42) corresponds to underlying *a+i*, the grammar has to be altered to account for this process.

(46) Sanskrit after morphological analysis and additional learning

		*DIPH	ID-ADJ(VH)	IDENT(VH)	*MID	UNIFORMITY
/ba/	☞ba					
	bi		W	W		
	be			W	W	
/bi/	☞bi					
	ba		W	W		
	be			W	W	
/be:/	☞be:				L	
	bi:			W		
	ba:			W		
/va-i/	☞ve:			L	L	L
	vai:	W				
	vi: or va:		W	*		

At this point in the learning process the learner wonders if not all long mid vowels are derived from sequences of low and high vowels.

(47)

> **The free ride** (very informally stated): once *some* instances of surface *x* are detected as derived from /yz/, *all* instances of surface *x* are assumed to be derived from /yz/. All URs are changed. Learning goes through another stage of constraint demotion operations.

Once all underlying correspondents of surface long mid vowels are changed to diphthongs, the learner has new material for a new round of constraint demotion.

(48) Sanskrit after morphological analysis and a free ride

		*Diph	Id-Adj(VH)	Ident(VH)	*Mid	Uniformity
	☞ba					
/ba/	bi		W	W		
	be			W	W	
	☞bi					
/bi/	ba		W	W		
	be			W	W	
	☞be:			L	L	L
/bai/	bai	W		W		
	bi:		W			
	ba:		W			
	☞ve:			L	L	L
/va-i/	vai	W				
	vi: or va:		W	*		

The ranking between Ident(VH) and *Mid can be reversed, such that *Mid dominates Ident(VH) again, as it did in the beginning, at the initial stage. The net gain is a more restrictive grammar.

Since in standard OT, the constraints are universal, all grammars are equally complex (unlike rule-based grammars, which differ in complexity by the number of rules they contain). An evaluation metric for comparing grammars is to determine their restrictiveness. The restrictiveness of OT grammars can be measured by counting for every faithfulness constraint how many markedness constraints dominate it. The higher the number, the more restrictive the grammar.

(49) R-measure (Tesar & Smolensky 2004)

> The r-measure for a constraint hierarchy is determined by adding, for each faithfulness constraint in the hierarchy, the number of markedness constraints that dominate the faithfulness constraint.

(50) Sanskrit after morphological analysis, a free ride and reranking

		*Diph	Id-Adj(VH)	*Mid	Ident(VH)	Uniformity
	☞ba					
/ba/	bi		W		W	
	be			W	W	
	☞bi					
/bi/	ba		W		W	
	be			W	W	
	☞be:			L	L	L
/bai/	bai	W			W	
	bi:		W			
	ba:		W			
	☞ve:			L	L	L
/va-i/	vai	W				
	vi: or va:		W		*	

The procedure gives surprising but explanatory results when applied to hyperrhoticity, as found in some varieties of English.

Especially American varieties of English that were originally non-rhotic and had linking as well as intrusive *r* and which recently changed to rhoticity, i.e., the realization of preconsonantal and phrase-final *r*, succumbing to the pressure from General American, display hyperrhoticity, the realization of postvocalic *r* in non-etymological contexts (52), (53).

(51) English *r* neutralization, linking and intrusive *r* (Eastern Mass. and BBC/RP)[9]

a. [sɔː]	'soar'	f. [sɔːɹɪŋ]	'soaring'
b. [sɔː]	'saw'	g. [sɔːɹɪŋ]	'sawing'
c. [kɑː]	'car'	h. [kɑːɹɔːbaɪk]	'car or bike'
d. [tuːnə]	'tuner'	i. [tuːnəɹɪnɔɪl]	'tuner in oil'
e. [tuːnə]	'tuna'	j. [tuːnəɹɪnɔɪl]	'tuna in oil'

(52) Hyperrhoticity in Massachusetts and New York (Wells 1982, Gordon 2004)

a. [aɪdɪəɹ]	'idea'
b. [wɒɹʃɪŋtən]	'Washington'
c. [klɒɹθ]	'cloth'

(53) New York English (Gordon 2004)

a. Non-rhotic		b. Hyperrhotic	
[stɒət]	'start'	[vɜɹs]	'voice/verse'
[kɑət]	'cart'	[tɜɹlət]	'toilet'
[noəθ]	'north'		
[nɜɪs]	'nurse'		

Wells (1982) formulates an insertion rule (54), while Gordon (2004) observes that, because of the intrusive *r*, it was actually impossible for these non-rhotic speakers to learn which morphemes have a postvocalic *r* and which don't. Thus, minimal pairs collapse to one of the two options in (55).

(54) *r* insertion rule: Ø → r / $V_{[\text{-high}]}$ __

(55) Lexical merger in intrusion accents

a. /tunə/ → /tunɹ/ ← /tunɹ/

b. /tunə/ → /tunə/ ← /tunɹ/ 'tuna' 'tuner'

In OT, the formulation of such a rule is out of the question and the introduction of a new constraint for the specific purpose of explaining one single pattern is not an option either. With the inventory of markedness constraints available, though, the insertion of an approximant creating a syllable coda or making an already present coda complex cannot be modelled. The point is that OT markedness constraints object to marked structure, while hyperrhoticity creates new marked structures without any apparent motivation.

(56) OT: Markedness constraints object to marked structure.

*CODA:Syllables do not have a coda.
*COMPLEX:Syllables do not have a complex onset or a complex coda.
ONSET:Syllables have an onset.

If phonological processes create marked structures this happens usually in avoidance of a different kind of markedness. For example, vowel deletion creates complex onsets and codas in some languages, as in English [glæktɪk] as a rendition of *galactic*, but it does so in optimization of higher-level prosodic structure, here, avoiding an unfooted syllable (i.e., a violation of the constraint that wants to see every syllable in a foot).

Similarly, intrusive *r* creates an onset in a position in which we would otherwise find a vowel hiatus. Hyperrhotic *r* insertion doesn't give any structural benefit. Krämer (2008, 2009a) argues that the explanation for hyperrhoticity lies outside grammar proper. This kind of hypercorrection is a side effect of L1 lexicon acquisition by non-rhotic speakers. When storing lexical entries for items with alternating *r* they overgeneralize to items without the alternation possibility. Thus, the non-alternating forms take a free ride, in McCarthy's sense, on the alternating forms, inserting an *r* after non-high vowels in underlying representations. The advantage is that apart from testing a grammar that produces intervocalic *r* as insertion, the grammar also analyses the process as deletion of underlying *r* in coda position, in adherence to the RotB.

Once these speakers switch to rhoticity (L2), all underlying *r*'s are realized, which is a superset of the *r*'s emerging in originally rhotic speakers.

I leave out the technical details of the analysis here, since they are not important for our purposes. The case serves as additional evidence for the free ride strategy in acquisition, as well as to show that mechanisms that are set in place to achieve increased economy (economy of lexical inventory) can result in a detrimental effect, that is, structure in underlying forms which never surfaces.

According to this line of reasoning, learners of intrusion varieties have underlying *r*'s after all non-tense vowels at least until they become aware of the contrast when they acquire reading and writing skills and learn that there is a difference between *tuna* and *tuner* etc. The analysis is additionally supported by the high rate of hypercorrect *r*'s in spelling errors made by British English speakers with low literacy levels (misspellings such as *idearl* or *clorth*).

As discussed in Chapters 5 and 6, Nevins & Vaux (2007) report an interesting hypercorrection in the context of flapping that can be understood in the same way. Speakers of American English realize some words with a non-alternating flap hypercorrectly with an intervocalic *t* in exaggerated careful pronunciation, such as *enchila*[t]*a*. This shows that these speakers let the non-alternating forms with a flap take a free ride on the alternating forms, changing the flap to an underlying /t/ (though Nevins & Vaux draw different conclusions). The speakers actually have two choices, storing the surface flaps as either /t/ or /d/, since both coronals are realized as flaps intervocalically. The hypercorrect forms suggest that they prefer the unmarked member of the contrastive pair (see Section 6.3). This preference can be explained neither by Lexicon Optimization nor by the free ride mechanism, which brings us to the next and final fix to Lexicon Optimization to be discussed here.

8.3.3 LO as mirror-image evaluation – LO 2.0

In LO, markedness constraints don't play any role. They are statements on output or surface structures. Since in LO different candidates for the underlying representation are always paired with the same surface representation, the markedness violation profile of every competing input–output pair is the same. Thus, what this putative Lexicon Optimization computes is actually not an optimization of lexical representations, it rather trivially just measures the distance between different potential underlying representations and the surface representation. The more faithfulness violations a /UR/–[SR] pair incurs the more distant is the underlying from the surface representation. (Needless to reiterate: the pair with the smallest distance wins.)

In this context we have to be cautious with the terminology. The representation that is usually referred to as the input is actually the surface representation in an LO tableau, while the output of an LO evaluation is the underlying form which usually serves as the input. In other words, in the usual OT tableau candidates for surface representations are evaluated and the output of the tableau is a surface form, while the input is either an underlying form or a hypothesized underlying form (for example, an unlikely one, that is chosen to test if the analysis conforms to the RotB). In LO, on the other hand, the candidates under evaluation are candidates for underlying representation and the output of the evaluation is an underlying representation while the input here is a surface form.

(57) Mapping of representations

	Input		Output
Production	/underlying form/	——>	[surface form]
Recognition[10]	[surface form]	——>	/underlying form/
Lexicon Optimization	[surface form]	——>	/underlying form/

The table in (57) summarizes the mapping situation. In a production grammar, the starting representation, i.e., input, is the lexical representation and the surface representation is the output, i.e., the form that is evaluated. In perception, the situation is reversed: the listener hears a phonetic signal, maps this first to a surface phonological form and then has to find the right underlying representation that corresponds to this surface form, thus the output of the computation is the lexical or underlying representation. Lexicon Optimization does by and large the same job as perception: for a given surface representation, an underlying representation has to be found. In this case the representation can be chosen from the subset of the potentially infinite pool of linguistically possible representations that would map to the given surface representation if taken as the input and fed into the given constraint hierarchy.[11]

If we seriously evaluate potential underlying forms and these are the output of the computation, it makes sense to evaluate these candidates according to their markedness. Markedness can be effectively measured by counting violations of markedness constraints. The only change one has to make is to define markedness constraints as constraints on output representations rather than surface representations.

(58)

Markedness constraints apply to the candidate *output* representations of an evaluation, be that UR(I) → SR(O), Base(I) → SR(O) or SR(I) → UR(O) or any other mapping.
*X: 'x is not allowed in the output of evaluation.'

If we now go back to Inkelas' example of the evaluation of non-alternating unmarked *ti*, we see the different results obtained. In the tableau in (59), the markedness constraints are violated by the candidates under evaluation that show the condition defined as unwanted by the respective constraint.

The ranking of markedness constraints on different places of articulation makes sure that coronal is the least marked place of articulation in the language at hand. However, the candidates that are not specified at all incur fewer violations of markedness constraints than the ones with the feature [coronal].

(59) Non-alternating unmarked structure re-evaluated

LO [ti]	*Laryngeal	MAX (lab/dors/cor)	*Labial/ *Dorsal	*Coronal	DEP (cor)	IDENT (cor)
a. /ti/				**!		
b. /Ti/				*!	*	*
☞c. /TI/					**	**

If underspecification is the goal for such cases of least marked structure, this has consequences for our theory of faithfulness. If contrastive features are monitored by IDENT(F) constraints only, rather than MAX(F) and DEP(F), mirror-image evaluation doesn't achieve the desired results either. In this theory Ident(cor) as the only relevant faithfulness constraint would have to outrank *Coronal and the winning candidate would be the fully specified one.[12]

Furthermore, if we completely reverse the evaluation and the surface form is the input and the underlying form the output and these are the levels of representation referred to in constraint definitions, the constraint Max(F) should be violated once by candidate (b) and twice by candidate (c). I assume that, unlike markedness constraints, the definitions of Max(F) and Dep(F) maintain the distinction between surface and underlying representation.

(60) Mirror-blind faithfulness

a. US-Max(F): 'Every F in the underlying representation is present in the surface representation.'
~~IO-Max(F): 'Every F in the input representation is present in the output representation.'~~

b. US-Dep(F): 'Every F in the surface representation is present in the underlying representation.'
~~IO-Dep(F): 'Every F in the output representation is present in the input representation.'~~

Moreover, it is important in tableau (59) that Dep(F) and Ident(F) constraints are ranked below markedness to achieve any underspecification effect at all.

Is the form of underlying representations then still a matter of Faithfulness definitions and ranking again? Not entirely. The results of learnability studies and acquisition studies suggest that, universally, language learners (that is, children acquiring their native language) start with the ranking in (61).

(61) Initial state: H_0 = M ›› F

In the course of acquisition, this hierarchy of two strata is unfolded into a multistratal hierarchy and in the ideal case an exhaustive ranking by conservative demotion, that is, downward movement of constraints. This keeps the grammar as restrictive as possible and thus avoids the subset problem. A learner needs a good reason to demote *F below Dep(F). As long as s/he doesn't do this underspecification is the result of LO. If s/he does demote *F that far down it is probably already too late anyway.

This mirror-image evaluation also yields plausible results for noncontrastive segments. Recall English flapping and Nevins & Vaux' observation on hypercorrection in American English. To ban flaps from being contrastive the markedness constraint against flaps, say, *Flap, remains higher in the hierarchy than Faithfulness, while the constraint against coronal stops, *T, has to be demoted below Faithfulness. The contextual markedness constraint against coronal stops in intervocalic position remains at the top of the hierarchy. If a learner has established this ranking and learns a new word with a non-alternating flap, such as *enchilada*, mirror-image evaluation takes its course.

(62) Shrinking an inventory: English flapping with mirror-image LO

[enʃilærə]	$*V^{t}{}_{d}V$	*Flap	Faith(F)	*[cor]
a. /enʃilætə/	*!		*	*
b. /enʃilædə/				*!
c. /enʃilærə/		*!		
☞d. /enʃilæC[stop]ə/				

Harrison & Kaun (2000, 2001) labelled this kind of underspecification Pattern-Responsive Underspecification. Their word game data were discussed in Chapter 6 and we can pick them up again here. Recall the Tuvan reduplication game: in the reduplicant the first vowel of the stem was replaced with a dummy vowel. In reduplicants derived from harmonic roots the second root vowel harmonized according to the backness feature of the dummy vowel, while this did not happen in reduplicants derived from disharmonic roots.

(63) Tuvan reduplication of harmonic polysyllabic bases (Harrison & Kaun 2001: 226)

a.	idik	idik-adik	*adik	'boot'
	fi:dik	fi:dik-fa:dik	*fa:dik	'video cassette'
b.	teve	teve-tava	*tave	'camel'
	tevelerim	tevelerim-tavalarim	*tavalarim	'my camels'

(64) Tuvan reduplication of disharmonic polysyllabic bases (Harrison&Kaun 2001: 226)

maʃina	maʃina-muʃina	*muʃuna	'car'
ajbek	ajbek-ujbek	*ujbak	'Aibek' (name)
ʒiguli	ʒiguli-ʒaguli	*ʒagili	'Zhiguli' (car)
a:l=ʒe	a:l=ʒe-u:l=ʒe	*u:l=ʒa	'yurt' (=ALL)

With our current LO mechanism underspecification of the second vowel in the underlying form can be generated easily.

(65) Tuvan with mirror-imaging technology:

LO [idik]	Ident$1(cor)	Max(F)$_{stem}$	*[cor]	Ident(cor)
a. /idik/			**!	
☞b. /idIk/			*	*
c. /IdIk/	*!			*

Now we can also return to Nevins & Vaux' example of the surprising alternation between a trill and a flap in a Spanish word game. The emergence of a flap in intervocalic position in the word game that is in correspondence with a word-initial trill in the base form was attributed to lexicostatistics by Nevins & Vaux. While 100 per cent of word-initial rhotics are trills, 80 per cent of intervocalic rhotics are flaps. In Chapter 6 I hinted at an alternative solution: markedness. The trill has an additional feature or marked feature value compared to the flap, but this is not needed word-initially. And for this reason it doesn't get stored in the UR.

An OT grammar first has to account for the distributional facts, i.e., neutralization word-initially. It also has to account for the contrast between trills and flaps in other than word-initial position. Furthermore it can reflect the observation that generally trills are more marked than flaps.

(66) Ranking for distribution of trills and flaps in Spanish[13]
$*_{PWd}${Flap ›› Max(trill) ›› *Trill ›› *Flap

The tableau in (67) shows how this grammar bans systematically unattested forms on the surface and accounts for the word-internal contrast.

(67) Tableau evaluating surface forms with hypothetic input:

	$*_{PWd}${Flap	Max(trill)	*Trill	*Flap
i.a. /ɾosa/- ɾosa	*!			*
☞i.b. /ɾosa/- rosa			*	
ii.a. /rosa/- ɾosa	*!	*		*
☞ii.b. /rosa/- rosa			*	
☞iii.a. /peɾo/ - peɾo				*
iii.b. /peɾo/ - pero			*!	
iv.a. /pero/ - peɾo		*!	*	
☞iv.b. /pero/ - pero				*

Mirror-image LO works here only if the positional markedness constraint refers to a category/position that is present only in the surface candidates but not in the candidates for URs (for example, the left edge of the Prosodic Word, as indicated above in the constraint *{$_{\text{PWd}}$Flap 'Flaps are not allowed at the left edge of the prosodic word').

(68) LO 2.0 tableau for Spanish rhotics

[rosa]	*$_{\text{PWd}}${Flap	MAX(trill)	*Trill	*Flap
☞a. /ɾosa/				*
b. /rosa/			*!	

Since the markedness constraints are now turned on the UR candidates, the positional markedness constraint banning flaps from the left edge of the Prosodic Word is vacuous, because URs don't have PWd edges. In the absence of this filter and with a MAX(F) rather than an IDENT(F) constraint guarding contrast, the two markedness constraints decide the matter in favour of the flap.

Thus, LO 2.0 doesn't only yield the right result here, it also tells us something about the organization of constraints beyond the evidence supplied by surface patterns alone, in this case the ranking of two low-ranked markedness constraints with respect to each other.

This grammar determines all word-initial trills as underlying flaps. In cases where these are brought in an intervocalic position, in which the constraint *{$_{\text{PWd}}$Flap doesn't apply, as in the word game (*rosa* → *saro*), these flaps can surface faithfully.

A more instructive case is the nasalization of vowels before nasals in English, as discussed in Chapter 6. According to Ladefoged (2001: 84), nasalization happens only in tautosyllabic vowel-nasal sequences.

(69)

[bənæːnə] 'banana'
[bæ̃ːn] 'ban'

The markedness constraint that causes nazalization is sensitive to syllable structure and can be informally stated as in (70).

(70)

*VN)$_{\$}$: oral vowels are not allowed before nasals within a syllable.

The tableau in (71) shows how a ranking of this special constraint with respect to a context-free constraint against nasality in vowels and a lowranked faithfulness constraint account for the distributional pattern at the surface.

(71) Only predictably nasal vowels surface in English

	*VN)$_\$$	*V$^{[nas]}$	MAX(nas)	*Nasal
☞a. [.bæ̃n.]		*	?	**
b. [.bæn.]	*!		?	*
c. /bæ̃d/ – [.bæ̃d.]		*!		
☞d. /bæ̃d/ – [.bæd.]			*	

Since nasality is not contrastive in vowels and since we have seen evidence in Chapter 6 that nasality is very likely to be absent from the abstract form of superficially nasal vowels in English, the desired result of LO eliminates nasality from vowels. Crucially, the markedness constraint *VN)$_\$$ is sensitive to syllable structure. As we will see shortly, this version of LO systematically avoids specification of syllable structure in the lexicon. Hence, the markedness constraint is vacuously satisfied in any LO evaluation, as can be seen in the tableau in (72).

(72) Keeping underlying nasal vowels out of the English lexicon

[.bæ̃n.]	*VN)$_\$$	*V$^{[nas]}$	MAX(nas)	*Nasal
☞a. /bæn/				
b. /bæ̃n/		*!		*

The analysis suggests that many contextual markedness constraints are sensitive to prosodic structure. If they are not, their effect cannot be neutralized in LO in favour of more general markedness constraints that determine the unmarked state of a feature for a segment class rather than for a phonological context.

The avoidance of diphthongs in Sanskrit, discussed above in the context of the free ride strategy, cannot be accounted for with this kind of LO. The non-contrastive mid vowels cannot be excluded from the non-alternating underlying forms even though the case is apparently completely parallel to English flapping.

(73) Sanskrit mid vowels still need an additional mechanism

[be:]	*DIPH	ID-ADJ(VH)	*MID	IDENT(VH)	UNIFORMITY
☞a. /be:/			*		
b. /bai/	*!			**	*

Thus, the free ride mechanism has to be considered as an additional strategy for L1 learners to detect URs by using generalizations extracted from regular sound patterns.

The family of faithfulness constraints as proposed in Prince & Smolensky 1993/2004) and McCarthy & Prince (1995, 1999 etc.) does not contain any constraints that refer to syllable structure. However, there is no reason in the system to strip off syllable structure when determining the underlying representation in correspondence with a surface form. Thus, the learner is free to keep it or leave it out.

The mechanism of LO proposed here generates underlying forms bare of syllable structure since in many cases the presence of syllable structure violates some markedness constraint, such as ONSET, *CODA, *COMPLEX or the sonority-related markedness constraints determining the optimal segment in a specific syllable constituent (such as *Stop/Nucleus ›› *Fric/Nuc ›› *Son/Nuc … and orthogonally *V/Onset ›› *Liquid/Ons ›› *Nas/Ons…).

(74) Disappearing syllable structure

i. [.æpt.]	MAX-IO	DEP-IO	ONSET	*CODA	*COMPLEX
a. /.æpt./			*!	*	*
☞ b. /æpt/					

ii. [.si:.]	FAITH-IO	*COMPLEX NUCLEUS	*FRIC/ONS	*HIGHV/NUC
a. /.si:./		*	*	*
☞ b. /si:/				

Syllable structure is generally assumed to be absent from underlying forms because it hasn't convincingly been shown to be contrastive in any language (though see the discussion in Section 4.5) and, as we have just seen, it is also predicted to be absent by Lexicon Optimization 2.0.

Insertions and changes in response to well-formedness constraints on syllable structure are, at first sight, still expected to be stored in underlying forms, since the omission of a suspect epenthetic consonant from the underlying form results in a DEP-IO violation.

Any constraint causing insertion, such as e.g., ONSET, doesn't apply to the input candidates or is vacuously satisfied by the input candidates since they are stripped off syllable structure.

(75) Epenthesis reconsidered (German *Idee* 'idea')

[.ʔiˈde:.]	MAX-IO	ONSET	DEP-IO
☞a. [.ʔi.ˈde:.] - /ʔide:/			
b. [.ʔi.ˈde:.] - /ide:/			*!

However, if we assume that every structure violates some markedness constraint, as we just did, even the least marked/unmarked segment in a position, the candidate with the 'unmarked' segment in the above tableau, candidate (a), violates a constraint that isn't violated by candidate (b). This markedness constraint has to outrank the faithfulness constraint violated by the other candidate. Again learning theory favours this ranking. Since in the initial state all markedness constraints outrank all faithfulness constraints, a learner doesn't have any motivation to demote the markedness constraint violated by the epenthetic segment below the faithfulness constraint violated by the candidate that stores this segment in the underlying form.

(76) Epenthesis rereconsidered

[.ʔi'de:.]	Max-IO	Onset	*Laryngeal	Dep-IO
a. [.ʔi.'de:.] – /ʔide:/			*!	
☞b. [.ʔi.'de:.] – /ide:/				*

Mirror-Image LO is a principled solution to rein in OT's proliferation of redundancy in the lexicon: it weeds out redundant features from underlying representations, keeps the lexicon free from non-contrastive segments and features and strips predictable prosodic structure off representations.

However, it doesn't take care of non-contrastive segments across the board and this suggests that the free ride principle is indispensable. It is to be suspected that some form of a free ride algorithm is also needed to encourage decomposition of morphologically complex forms, which is not favoured by LO.

8.4 LAST WORDS

In this chapter we have looked at Optimality Theory's predictions for underlying representations. It turned out that the widespread belief that OT's mechanism of Lexicon Optimization predicts fully specified underlying representations stands on shaky ground. Per se OT doesn't make any straightforward predictions. There are, however, several additions to OT, Comparative Markedness and the free ride, that do have an impact on the generation of underlying representations and this is more in conformity with what has been shown in previous chapters to be the most likely aspects of underlying forms. They are determined by economy criteria. The free ride, though, has been shown here to sometimes have a detrimental, anti-economic, effect, as with the storage of non-etymological *r*'s by learners of intrusion varieties of English. Finally, we have seen that LO delivers much more interesting results if we take it more seriously and turn the effect of markedness constraints on outputs of evaluations rather than on surface representations only.

There are some interesting offshoots of OT-internal developments that haven't found appropriate discussion in this chapter. As mentioned in the introduction, Burzio (1996, 2000b, 2002, 2005) concluded that there are no underlying representations at all and develops a theory according to which related surface forms attract and repel each other depending among other things on the constraints involved as well as the frequency of forms, moving towards a view in which the boundary between representations and constraints becomes increasingly blurred. The full leap in the direction of equating representations and constraints was taken by Golston (1996), who still makes use of features but argues that underlying representations are not stored as strings of segments with features, but in the form of constraint violations. He explores the side effect of evaluation that every morpheme has its own unique profile of constraint violations, which is reminiscent of Kiparsky's (1973a) proposal that underlying representations are (identity) rules. Surprisingly, Golston's theory has not sparked much discussion.

DISCUSSION POINTS

- Are the pairs of terms 'input – output' and 'underlying form – surface form' interchangeable terminological variants?
- Put together the results on the underlying place feature of German /t/ from Chapter 6 with an LO analysis. After that, try to combine this grammar with the grammar for glottal stop epenthesis from Section 8.3.3. If you run into trouble, you will find the solution in this chapter as well.

SUGGESTIONS FOR FURTHER READING

Optimality Theory (and contrast)

Kager, René (1999). *Optimality Theory*. Cambridge University Press.

Dresher, B. Elan (2009). *The Contrastive Hierarchy in Phonology*. Cambridge University Press. Chapter 6 'Contrast in Optimality Theory', pp. 138–61.

Lexicon Optimization

Inkelas, Sharon (1994). The consequences of optimization for underspecification. In *Proceedings of the Twenty-Fifth Annual Meeting of the North East Linguistic Society (NELS 25)*, Amherst, MA: GLSA Publications. 287–302.

Yip, Moira (1996). Lexicon Optimization in languages without alternations. In Jacques Durand & Bernard Laks (eds.), *Current Trends in Phonology: Models and Methods*. Vol. 2. European Studies Research Institute (ESRI), University of Salford Publications. 757–88.

Krämer, Martin (2006). Optimal underlying representations. In Leah Bateman & Cherlon Ussery (eds.), *Proceedings of the Thirty-Fifth Annual Meeting of the North East Linguistic Society (NELS 35)*. Amherst, MA: GLSA Publications. 351–65.

Nevins, Andrew & Bert Vaux (2007). Underlying representations that do not minimize grammatical violations. In Sylvia Blaho, Patrik Bye & Martin Krämer (eds.), *Freedom of Analysis?* Berlin and New York: Mouton de Gruyter. 35–62.

Alternative views of underlying forms/the lexicon in OT

Burzio, Luigi (1996). Surface constraints versus underlying representation. In Jacques Durand & Bernard Laks (eds.), *Current Trends in Phonology: Models and Methods*, vol 1. European Studies Research Institute (ESRI), University of Salford Publications. 97–122.

(2000). Segmental contrast meets output-to-output faithfulness. *The Linguistic Review* **17**: 368–84.

(2005). Lexicon and grammar: unequal but inseparable. MS, Johns Hopkins University.

Golston, Chris (1996). Direct Optimality Theory: representation as pure markedness. *Language* **72**: 713–48.

9 Preliminary results

> There is some correct answer to the question of how lexical items are represented[.]
>
> (Chomsky & Halle 1968: 296)

9.1 IN SEARCH OF THE HOLY GRAIL?

At the end of this book it is time to take stock of what we know about underlying representations. The first and most fundamental question, after looking at all these studies and arguments, is of course the same one we can ask about the holy grail alluded to in the quote by Labov at the beginning of Chapter 1. Do underlying representations exist?

One might counter that this is a stupid question, since to be competent speakers of a language we have to have memorized linguistic units in one way or another in our minds. However, the question is more about whether they exist as specifically linguistic entities and not as memories as in general cognition, such as the memory of eating pizza at the Italian restaurant around the corner three weeks ago or the memory of pizza as such (as differentiated from kebab or pine trees or our mental representation of having a headache).

The answer is: both. We have seen language-internal as well as external evidence for categorization and abstract features, but we have also seen that statistics of linguistic experience and phonetic detail play a role in the shaping of phonological patterns and thus have to be present in the minds of speakers in some form.

If frequency data play a major role in shaping generalizations and productivity of processes, one could conclude that phonological categories are emergent as generalizations over the mass of details a user or learner is exposed to. Such a conclusion, though, might be a bit premature: while adults, who by and large have completed the process of language acquisition and with it the acquisition of (most) underlying representations, use frequency data and adapt their behaviour, when for example faced with tasks such as learning an artificial language or using or judging nonce-words, children deal with language in a different way from adults. Children make generalizations and over-apply them (as adults tend to do with regard to people), while adults are sensitive to statistical distributional information. It is the children learning their first language who have to build the lexicon from scratch, and due to lack of exposure they don't have a huge database to tinker with (unlike adults) and identify categories etc. emerging from statistical calculations.

One might also conclude that the use of frequency patterns by adults is a compensation strategy. It is established knowledge that children are particularly fast and efficient and little perfectionists when it comes to learning a language and that most humans lose the capability of learning a language perfectly (i.e., up to native-speaker competence) when they pass through puberty.[1] However, this efficiency of infants does not necessarily prove that categorical features and other categories are inborn. They still might be learnable.

Overgeneralization also points towards another tendency in memorization: the omission of information – but how much information can be stripped off? And what kind of information?

The universality issue leads to the next question: how specific are mental phonological categories? Are they language-specific? Phonology-specific? Medium-specific? Speaker-specific? Or are they general concepts humans use to spatially organize the world and to categorize and understand events? Specificity, in the sense of phonology-specific, opens up another issue. Should a theory of phonological computation generate lexical representations – and even such representations that correspond to psychological reality – or should this task be left to extra-grammatical mechanisms?

9.2 ECONOMY

At least since Saussure many phonologists have believed that all there is in language is contrast. However, the insight that only contrastive information is linguistically relevant does not necessarily imply that contrastive information is all there is in lexical representations. Even if the phonological underlying form of a morpheme contains only contrastive information, it is not quite clear how much and what information this is.

If a segment is contrastive for a feature X it could carry a value of this binary feature or it could be characterized by the feature's presence or absence. If we consider binary features it is not necessary for every segment to be specified either positively or negatively for that feature. Every feature has an unmarked value, which can be filled in by default rules. For many features we can also identify class-specific or position-specific unmarked values. While voicing is unmarked for most segments, it is the marked state for obstruents or at least stops, and for the latter it seems to be less marked to be voiced if flanked by vowels or sonorants. The unmarked values, general, class-specific or position-specific, can be determined automatically, i.e., by rules or constraints. Anything that can be determined automatically can be left out. The additional benefit is that the grammar contains a statement that determines the unmarked value of feature X. Without this explicit statement one has to list the corresponding value in every segment that should have it on the surface and a generalization is lost.

Focus on generalizations was one of the factors that led to the postulation of very abstract highly underspecified underlying representations. The explanatory scope of a grammar should be as wide as possible, covering by rules optimally all generalizations that can be made.

The more general motivation for the assumption of underlying representations stripped of as many features and their values as possible or, for example, the omission of syllable structure from underlying forms, lies in the general idea of economy or simplicity that guides modern theory formation and goes back to the fourteenth-century philosopher William of Ockham. His famous maxim, Ockham's razor, holds that concepts or entities should not be assumed unless they are necessary.

There are three concerns regarding extremely abstract and economic underlying representations. The first is the technical problem of finding an algorithm that derives underlying forms in an unambiguous deterministic way. A crucial question is which feature-filling rules or morpheme-structure constraints we can assume and how they are allowed to interact with each other and with other parts of phonology (i.e., p-rules). These rules can be language-specific or universal and they could be freely ordered with respect to other rules or there might be restrictions on their ordering. An observation that brought this type of analysis into rough waters was that often it is an arbitrary choice which of two dependent features is underspecified and even which features are contrastive in a system. Another challenge to language-specific restrictions on lexical representations is learnability. Such rules have to be inferable from surface patterns.

There might be stipulations as well on which features can be underspecified, such as the restriction in Contrastive Underspecification Theory that features that are contrastive in a segment class have to be specified because of their contrastive status. However, such a restriction doesn't solve the more basic riddle of which feature is contrastive in a given segment class in a language and which feature is not.

The second concern regards functional motivation. A major (practical) task that can be achieved with the help of phonological representations is the retrieval of lexical items in processing. A hearer has to isolate individual lexical items from a stream of sound to be able to interpret what s/he is hearing. This lexical recognition and look-up has to be fast so that a listener can react fast and take her/his turn. And this look-up is very efficient and fast, as lexical decision tasks or sentence completion experiments show. Listeners are usually able to complete another person's sentence without much delay (as you might have experienced yourself in conversations whenever some obnoxious or helpful conversation partner finished your sentence for you or answered your question before you had completed it).

If underlying representations are impoverished one might conclude that listeners also have very few cues to rely on to identify contrastive segments and with them morphemes in the lexicon. Though if we assume maximally economical lexical representations with very abstract features that each map to several phonetic cues, we get a rich input, rich in the sense that for the identification of each contrastive feature we have several cues, if one or more of these cues get lost (bad hearing, it is windy, a truck is passing by, the speaker whispers, is hoarse, drunk, eating, missing some teeth etc.) the category is usually still identifiable. In the lexicon, then, only a few crucial criteria (the idiosyncratic i.e. contrastive features) have to be checked, which speeds up access. If one had to check many details this would simply take longer and be more error-prone. If every bit of phonetic detail is stored this can impede category recognition, since many a phonetic detail is common to a number of segments or not linguistically relevant at all, and therefore not relevant to lexical access on the listener's side. A possible conclusion is that, to help the communication process, the signal should be extremely redundant and rich, while stored representation should be as simple as possible. In this case very abstract features should correspond to several phonetic cues each, none of which is central for the recognition of the feature.

The evidence that has been brought to bear on the discussion unfortunately points in opposite directions. On the one hand, we have seen that language-internal data lend support to the assumption of contrastive features and of systematic underspecification. On the other hand, the analysis of some patterns and the behaviour of some morphemes in some languages seem to require full specification and idiosyncratic underspecification.

We have also seen that (at least) adults make use of phonetic detail and frequency in their use of language. Otherwise it is difficult to understand the distribution of variably applying phonological processes and some aspects of language change. On the other hand, we have seen the results of psycho-/neurolinguistic experiments that support categorical features and large-scale underspecification of unmarked and of predictable categories.

9.3 THE QUARKS OF PHONOLOGY

Originally the smallest unit of phonology was thought to be the phoneme, i.e., the segment. That, however, changed pretty fast and the distinctive feature was considered the smallest unit, just as in physics the atom had to pass its status as the smallest unit on to particles, especially the quark.

Features fulfil three different functions, contrast, class membership and instruction for realization.

The first function is to differentiate or contrast every segment in a language from every other segment. This is a task achieved by all features of a segment together, since what ultimately differentiates segments is their feature profile, when seen in the system as a whole. Systems of contrastive segments, though, have a tendency to be economic in that, when it comes to individual segments within a class, one always finds segments that differ only by one feature and not only do such minimal pairs exist for every feature, but every feature is used to distinguish a maximal number of segments. There are some systematic exceptions to the latter, when, for example, in a language a voicing contrast is used exhaustively to distinguish two series of stops but not two series of fricatives. Similarly, place of articulation is often used exhaustively in stops, but the same language distinguishes fewer places of articulation in other segment classes. This kind of economic systemic use of features, though, was not so much in the focus of discussion in the preceding chapters.

Features also do the opposite job, they mark membership in a class. Class membership determines a segment's phonotactic positioning (vowels can be syllabic nuclei, stressed, etc, consonants can be syllable margins and only combined in certain sequences in these positions etc.) and its behaviour with respect to its neighbourhood, i.e., phonological activity in syntagmatic processes (e.g., in many languages, nasals are undergoers of place assimilation, stops are triggers of place assimilation in nasals, while most other segments are not involved in the process, only behaving as blockers if situated between a nasal and a stop).

The third task of features is to serve as a link between a lexical unit and its realization, optimally both in production (resulting in instructions for the positioning of the relevant articulators and modulation of air stream) and in recognition (extraction from the signal).

If it were only for the first two tasks, features could be arbitrary, highly abstract labels without any intrinsic content, such as the letters of an alphabet. Such abstract features, however, require an elaborate interface component that translates them into motor commands or maps them to specific components of sound or gesture. For such an interface one then has to determine how it is structured, how it works and whether it is a language-specific or universal mechanism. A general tendency seems to be to avoid not only the issue of this interface but keep it small by defining features by some characteristic articulatory component/gesture and/or acoustic or perceptual cue. A problem that has been observed with this practice is that many linguistically relevant sound effects can be achieved by several articulatory actions and often the same articulatory setting can be used to produce more than one distinct acoustic effect. This is a problem for the definition of features for spoken language. If we consider signed languages as well, cross-modality economy should be a guiding principle as economy is in theory formation in general. This excludes feature definitions based on acoustic and perceptual properties of segments, since they are irrelevant for the visual channel of signed language (unless we find perceptual categories that are modality-neutral).

Most current theories of phonological features accurately describe the dimensions of contrast, define by and large the phonological classes that can be observed in segmental class behaviour (though see Mielke 2008) and appropriately encode markedness relations in most respects. Attempts at defining these features, i.e., ultimately determining their content, are notoriously difficult because of the variable options for mapping acoustic signal and articulatory gesture and because of the fact that language is not only used in one modality.

Features could be universal and innate, or universal and emergent, or language-specific and emergent. Economy suggests they are universal or emergent (rather than language-specific and inborn – a position that is refuted by cross-linguistic comparison and the observation that the genetic heritage of a child does not make a difference for the child in learning whichever language is spoken around it). Current feature theories agree that all languages, at least spoken languages, make use of a language-specific subset of the same set of universally available features.

Most theories of features also agree that features are specific to the phonological module. Only the last approach we discussed in Chapter 7 holds that this is not a necessary conclusion, but that this assumption together with the acoustic and/or articulator-dependent definition of features are uneconomic assumptions, regarding economy of categories across modalities as well as modules. The features proposed in Chapter 7 are articulation instructions based on broad linguistic (maybe general cognitive?) concepts that are relevant in determining grammatical classes, syntactic and morphological behaviour and semantic interpretation, i.e., central to other linguistic modules. Such a 'parasitic' approach to features, however, has to reject the idea that different linguistic modules are structurally (syntactically – in the broader sense of the word) parallel and operate on different alphabets or sets of features. Instead, the different modules of linguistics have to differ in their syntax and organizing principles, rather than the primes (features, alphabets) they operate on. This stance is supported by the long and unsuccessful search for recursivity in phonological representations, a hallmark of syntactic structure (Hauser, Chomsky & Fitch 2002) and other arguments brought forward which support the claim that phonological and syntactic representations are organized and computed in different ways (Bromberger & Halle 1989, Neeleman & van de Koot 2006).

9.4 GENERATING UNDERLYING FORMS

Interestingly enough, the predominant orientation in phonological research is to devise a theory that correctly generates surface structures and patterns. In Optimality Theory this surface orientation has been taken to the extreme to demand grammars to generate only attested or grammatical patterns for a given language regardless of what is taken as the input to the computation. This output orientation is interesting, since for linguistics, understood as part of the cognitive sciences, it is as important a goal to describe and understand output patterns as it is to unveil the cognitive mechanisms underlying language and the structures stored in mental representation.

Early morpheme-structure rules were often actually not statements about underlying representations, but rather feature-filling rules of the type '$\emptyset \rightarrow [\alpha F](/\_\_Y)$'. Such rules could then be 'undone' or applied backwards. Underspecification of a certain feature was in many cases assumed because one could state such a rule, not because there was any evidence for underspecification beyond the predictability of a feature value. In general, morpheme-structure constraints functioned as a filter that excluded inputs from the computation (i.e., from the application of p-rules) that would lead to ungrammatical output representations. However, it turned out that these restrictions on the lexicon often overlapped in their goals (avoidance of certain structures) with other rules, labelled the duplication problem.

Optimality Theory's stance on the (ir)relevance of the input was a response to the duplication problem and should in part actually be regarded as an evaluation metric for theory formation. The Richness of the Base Hypothesis demands that there are no restrictions on underlying form. The input–output mapping mechanism alone has to be restrictive enough to allow all and only those forms considered grammatical in the language under investigation.

A side effect of the Richness of the Base Hypothesis, however, was that many researchers regarded underlying representations as no longer of interest or concluded that they are not different from surface forms and thus don't exist as such. OT constraints hold only on surface representations or on the mapping between input and output of the computation. It should be possible, then, to use the computational device bi-directionally. It should not only generate the correct output forms, but also a unique underlying representation for every surface form (disregarding the issue of homophony for the sake of simplicity here). The way in which Lexicon Optimization was understood and used unfortunately led many then to the belief that surface and underlying representations should be maximally identical, since disparity between input and output correlates with violation of faithfulness.

In Chapter 8 we looked at a different way of using LO. The crucial difference lay in the interpretation of markedness constraints as referring to the output of evaluation rather than to surface representations. In this way the mechanism can converge on underlying representations that are in line with the results of the studies presented in Chapter 6, i.e., underspecification of unmarked contrastive features and of predictable feature values. Since it is the markedness constraints that restrict the inventory of surface forms that are used to restrict the underlying inventory, the duplication of restrictions (constraints) is avoided in this version of LO too.

However, we have seen in the previous chapters that other factors play a role in the determination of underlying representations as well, that lie outside OT's evaluation function, such as children's strategy of giving non-alternating forms free rides on alternations observed in other morphemes, their general tendency of overgeneralization, and, for more educated language users, the influence of orthography. It is also extremely likely that adults adjust or update lexical representations, but follow different strategies when doing so than children in L1 acquisition.

9.5 SUMMARY

We have seen that there is still some way to go until we know the correct answer to what lexical representations look like. There is some evidence suggesting that there is not only one correct answer. Different speakers of the same variety of a language may come to different conclusions on what the active processes in the grammar and what the lexical exceptions are, as the nonce-word experiment on Italian palatalization briefly discussed in Chapter 5 showed. However, the central issue is what the building blocks of lexical representations are and how these can be combined. At the moment consent seems to be emerging that we store a lot of very detailed information but also categorial representations. There are at least three established theories of phonological primes, i.e., distinctive features, Articulatory Phonology, Element Theory, and the theories that developed from the *SPE* feature theory, such as Revised Articulator Theory and Feature Geometry.

The internal evidence leaves room for discussion on how far these phonological representations are determined by principles of lexical economy. Experimental evidence supports both categorial features as well as some degree of underspecification of these.

Unfortunately, we have to be cautious even with respect to the results of studies using up-to-date brain scanning technology, such as fMRI or MEG, since interpretations of such data within a given theoretical framework do not necessarily correspond to what is going on in the brain. After all, such technology, as of today, just gives a relatively superficial picture of the activity of the brain in response to stimuli. Results are not always replicable (Bennett & Miller 2010) and similar studies may show conflicting results, depending on factors we are not aware of yet and that have not or could not be controlled for (as we have seen when comparing studies on the laryngeal contrast in English in Chapter 6). For such psycho- and neurolinguistic studies, as for studies of data corpora in which statistical methods have to be applied, such as data filtering, averaging and significance tests, the general problem of data interpretation should not be underestimated, e.g., there is the question of where to draw the line between frequent and infrequent items or statistically significant or insignificant.

Trying to understand something that cannot be directly observed is a challenging task and we haven't succeeded in finding the holy grail of phonology yet. We have merely seen it twinkle in the dark and can look forward to more discoveries and insights on underlying representations in the future.

SUGGESTIONS FOR FURTHER READING

Cole, Jennifer & José I. Hualde (2011). Underlying representations. In Marc van Oostendorp, Colin J. Ewen, Elisabeth Hume & Keren Rice (eds.), *The Blackwell Companion to Phonology*. Oxford: Blackwell.

Glossary

Entries marked with an asterisk * are from Trask (1996). In certain cases Trask's definition is shortened here, as indicated by [...]. The interested reader is invited to consult the source for more information.

Entries marked [*OED*] are taken from the *Oxford English Dictionary* online.

absolute neutralization An analysis which posits an underlying contrast which is never realized phonetically on the surface. Such analyses have most often been invoked to account for an observation that some single segment exhibits two distinct conflicting types of behaviour. [...] Absolute neutralizations were an important if highly controversial feature of classical generative phonology, but were generally prohibited in Natural Generative Phonology and its successors by the **Alternation Condition**. [...]*

acute In the Jakobson–Halle feature system, a **distinctive feature** defined as 'exhibiting a concentration of energy in the upper frequencies of the spectrum', interpreted as representing a non-peripheral (dental, alveolar, palato-alveolar, palatal) articulation. The specification [acute] corresponds approximately to the *SPE* specifications [+coronal] for consonants and [–back] for vowels.*

allomorph One of two or several surface forms which are assumed by a **morpheme** in varying circumstances.*

allophone One of two or more phonetically distinct segments which can realize a single **phoneme** in varying circumstances.*

Alternation Condition The principle that obligatory neutralization rules may not apply to all occurrences of a morpheme [...]. It was succeeded by the **Revised Alternation Condition**.*

arbitrariness The general property of human languages by which there is no necessary, predictable, a priori relation between a particular meaning and the phonological form used to represent that meaning in a particular language. Thus English *dog*, French *chien*, German *Hund*, Basque *txakur*, Turkish *köpek*, Arabic *kalb* all express approximately the same meaning, while English *mean*, Welsh *min* 'edge', Basque *min* 'pain', French *mine* '(coal) mine', Arabic *min* 'from', all with roughly the same pronunciation, have quite unrelated meanings. Instances of iconicity, such as onomatopoeia, constitute partial exceptions to arbitrariness.

archiphoneme In Prague school phonology, the name given to a segment which represents the **neutralization** of two or more phonemes in a specified environment, often conventionally represented by a capital letter.*

autosegment In Autosegmental Phonology, any one of more-or-less independent elements recognized as existing on any of the various parallel tiers posited in that framework, though usually excluding the ordinary **segments** occurring on the segmental tier, when such a tier is recognized. […]*

binary feature n. A distinctive feature which can assume one of only two possible values; most typically, though not necessarily, the two values are represented as + and –, indicating that the feature in question is present or absent, respectively. […]*

biuniqueness (condition/principle) […] a given phone in a given environment must be an allophone of one and only one phoneme. […] First advanced by Bloch (1941), this principle was named by Harris (1944), and it formed a cornerstone of the phonology of American structuralists. […]*

compact In the Jakobson–Halle feature system, a distinctive feature defined as 'exhibiting a concentration of energy in the central area of the spectrum', interpreted as representing an articulation in which the front resonating cavity in the mouth is large compared to the rear cavity, and associated with low vowels and with palatal and velar consonants. The feature [compact] corresponds very roughly to [+low] in vowels and to [–anterior] for consonants in the *SPE* feature system. […]*

complementary distribution The relation which holds in a given speech variety between two **phones** which never occur in the same environment. For example, in the English of England, clear *l* occurs only before a vowel, while dark *l* never occurs before a vowel; in many varieties of English, [h] occurs only before a stressed vowel, while [ŋ] never occurs before a stressed vowel. In each of these cases, the phones are therefore in complementary distribution. Providing additional criteria are satisfied, most notably **phonetic similarity**, such segments can be assigned to a single **phoneme**. Clear and dark *l* are accordingly assigned to a single phoneme /l/, while [h] and [ŋ] are not. Complementary distribution is a fundamental notion in classical phonology, especially in American structuralism.*

CON The set of violable constraints on surface representations assumed in Optimality Theory.

conspiracy The phenomenon in which the phonology of a language exhibits several independently motivated and formally quite distinct rules whose combined effect is to produce a surface generalization which is expressed in none of the rules in question, most often a phonotactic one. […] The identification of such conspiracies by the proponents of generative phonology has often been interpreted by critics as a fundamental weakness in such a process-oriented approach and as an argument for approaches to phonology in which surface phonotactic constraints can be stated directly.*

constraint Any statement, in some particular framework or description, which prohibits some derivation, process, structure or combination of elements which would otherwise be allowed.*

continuant 1. Any segment during whose articulation there is no complete closure in the mouth. 2. In the Jakobson–Halle feature system, a distinctive feature defined as 'lacking any interruption or abrupt transition in the spectrum' and interpreted as representing the absence of any rapid closure and opening of the vocal tract. […] 3. In the *SPE* feature system, a distinctive feature defined as 'involving a primary constriction which is not narrowed to the point where the airflow past the constriction is blocked'.*

contrast 1. (also opposition) The paradigmatic relation between two or more segments which can occur in the same environment to produce different meanings. Such segments must be assigned to different **phoneme**s. […] Labov (1994: 351) proposes the following account of contrast: two types are in contrast when (a) there is at least one environment where the difference between them is the only difference between two utterances that differ in meaning; (b) the distribution of the two types is not predictable by any general rule; (c) native speakers are sensitive to the difference between the two types, at some level of behaviour, but not the differences between tokens of the same types. 2. The syntagmatic relation between consecutive syllables which differ in stress, pitch or tone.

Contrastive Underspecification A version of underspecification theory which assumes that only features contrastive in a segment are specified.

coronal 1. adj. (of an articulation) Articulated with the tip or blade of the tongue. 2. n. A segment so articulated, such as [t], [n] or [s]. 3. adj. (cor) In the *SPE* feature system, a **distinctive feature** defined as 'produced with the blade of the tongue raised from its neutral position'.*

debuccalization/deoralization Any phonological process in which a consonant segment loses its oral articulation. For example, non-prevocalic [s] is deoralized to [h] in many varieties of Spanish: *mismos* 'same' (plural) [mihmoh].*

diffuse In the Jakobson–Halle feature system, a **distinctive feature** defined as 'exhibiting a spread of energy throughout all frequencies of the spectrum' and interpreted as representing high vowels and front consonants. The specification [diffuse] corresponds roughly in the *SPE* system to [+high] for vowels and to [+anterior] for consonants.*

distinctive feature One of a specified set of phonological primes defined in such a way that every **segment** in a language, at least at the phonological level, can be exhaustively characterized as some permitted combination, or 'bundle', of features, each with an associated value. There have been various approaches to defining systems of features. […]*

Distinctness Condition A principle that defines the notion of contrast in a way that exclusively relies on feature values rather than structural differences or underspecification: 'Segment-type {A} will be said to be different from segment-type {B}, if and only if at least one feature which is phonemic in both, has a different value in {A} than in {B}; i.e., plus in the former and minus in the latter, or vice versa' (Halle 1959: 32).

dorsal 1. Pertaining to the back (dorsum) of the tongue. 2. Pertaining to the body of the tongue, both front and back. 3. (of a segment) Articulated with the back of the tongue involved in the primary constriction, as in the dorso-velar consonants [k], [g], [x] and [ŋ]. 4. (of a segment) Articulated with either the front or the back of the tongue involved in the primary constriction. 5. An occasional synonym for velar (senses 2 and 3). 6. In some versions of **Feature Geometry**, a superordinate class node taking the features high, low and back as dependents.*

Duplication problem Refers to the observation that morpheme-structure constraints and phonological rules often have overlapping or the same effect(s).

element In Element Theory, a radical or phonological prime, more or less equivalent to a feature, with the function to distinguish contrastive segments. See also phonological **prime**.

Elsewhere Condition A fundamental, and putatively universal, constraint on the applicability of rules. It says: two rules of the form (i) A → B/P__Q, and (ii) C → D/R__S are disjunctively ordered iff (a) the set of strings that match PQ is a subset of the strings that match RCS, and (b) the structural changes of the two rules are identical or incompatible. In other words, wherever (i) can apply, it does so and (ii) does not; (ii) applies only 'elsewhere'. Similar, but not identical, to Proper Inclusion Precedence, this condition is designed to minimize extrinsic ordering. […] (Kiparsky 1973[b]).*

equipollent opposition adj. In Prague school phonology, a contrast between two segments which are distinguished neither by the presence or absence of a single feature (as in a privative opposition) nor by variation in degree along a single dimension (as in a gradual opposition); instead, the two segments differ in respect of multiple phonetic characteristics and must be regarded as logically equivalent: for example, the /p/–/t/ contrast or the /f/–/k/ contrast in English.*

EVAL (evaluation) A function in Optimality Theory that selects an output from a candidate set according to the individual candidates' performance with regard to a hierarchy of constraints.

exemplar In Exemplar Theory, an accurate and detailed memory of a speech event, connected to other exemplars of the same phrase/word/morpheme/segment/etc. in a cloud of exemplars.

f-rule (feature-filling rule), also redundancy rule or morpheme-structure constraint/rule. In Underspecification Theory, a rule that fills in feature values that are assumed to be underspecified or blanks.

feature See distinctive feature.

Feature Geometry A theory of **distinctive features** in which features, contrary to the traditional view, are not combined into structureless bundles, but are organized in such a way that some features are grouped together within superordinate nodes called gestures. […]*

flat In the Jakobson–Halle feature system, a distinctive feature defined as 'exhibiting weakening or downward shift of the upper frequencies in the spectrum' and interpreted as representing any of lip rounding, pharyngealization or retroflexion. The use of this feature implies the interesting and controversial claim that no language contrastively employs more than one of these three phenomena. In the *SPE* system, a number of features are used to cover the same ground: [+round] for lip rounding, [+low, +back] for pharyngealization and [–anterior, –distributed] for retroflexion. […]*

free ride 1. In a derivational theory of phonology, the phenomenon in which rules posited to account for certain data automatically produce the correct result for other significantly different data for which they were not originally posited; these other data are said to receive a 'free ride'. The statement that maximization of such free rides is desirable is called the free ride principle. (Zwicky 1970)* 2. A principle according to which the underlying representation of non-alternating morphemes is altered in accordance with an alternation observed in other morphemes that show the non-alternating structure of the former as the result of the application of a regular phonological process. (McCarthy 2005)

Fully Faithful Candidate (FFC) An abstract representation, assumed in Comparative Markedness theory, that is identical to the underlying representation or input except for prosodic structure, which is assumed to be absent in the input while the FFC is fully prosodified. (McCarthy 2003)

GEN (Generator) A function assumed in Optimality Theory that produces candidate representations from a universal alphabet of phonological representational primes for evaluation (**EVAL**) by a constraint hierarchy.

grandfather effect A phonological process is blocked if it creates a marked structure, even though this structure is contrastive and therefore present in the language. (McCarthy 2003)

grave 1. In the Jakobson–Halle feature system, a distinctive feature defined as 'exhibiting a concentration of energy in the lower frequencies of the spectrum', interpreted as representing a peripheral (labial, velar, uvular) articulation. The specification [grave] corresponds approximately to the *SPE* specifications [–coronal] for consonants and [+back] for vowels. […] 2. In the Ladefoged and Williamson feature systems, a similar binary feature, invoked largely to account for such acoustically based historical developments as that of English [x] to [f] in *laugh*. […]*

inherent underspecification In Underspecification theories, the absence of features or feature values which are not contrastive or the underspecification of features which are dependent on another feature in segments which lack this feature. To illustrate the latter, think of the feature [open] in the Clements & Hume (1995) version of Feature Geometry. This feature is inherently or trivially absent in consonants since they lack the node *vocalic* and its dependent *aperture* to which [open] is linked.

input A representation that is fed into a grammar for computation.

invariance condition (also, informally, 'once a phoneme, always a phoneme') A proposed criterion for phonological analysis. Two versions of it have been advocated. Under 'strong' or 'absolute' invariance (also called the non-intersection condition), all occurrences of a single phone in a language must be assigned to the same single phoneme – that is, two different phonemes may not overlap at all in their phonetic realizations. This version was adopted by some of the American structuralists (explicitly by Hockett 1942), but it is untenable; see Sommerstein (1977: 25) for a demonstration. Under 'weak' or 'relative' invariance, all occurrences of a single phone in a given environment must be assigned to a single phoneme, but identical phones in different environments may be assigned to different phonemes. This version thus permits partial overlapping of phonemes. Weak invariance was adopted by Jakobson and by some other American structuralists, but all versions of invariance were rejected by Chomsky (1964); the proponents of generative phonology preferred to admit analyses involving complete overlapping, ruled out even by weak invariance.*

KISS Acronym for 'Keep it simple, stupid!' see **Ockham's razor**

labial 1. Pertaining to the lips. 2. (of a segment) Articulated with the lips. 3. A segment so articulated, such as [p], [m] or [f]. 4. A **distinctive feature** invoked to distinguish labial segments ([+lab]) from all other segments ([–lab]). […] 5. A different distinctive feature invoked to separate labial consonants and rounded vowels and glides (all [+lab]) from all other segments ([–lab]). 6. In some versions of **Feature Geometry**, a superordinate feature taking [round] as its dependent. […]*

laminal 1. adj. Pertaining to the blade of the tongue. 2. adj. (of a segment) Articulated with the blade of the tongue forming the primary stricture. 3. n. A segment so articulated, such as English [t] and [n] for most speakers. […]*

lexical representation The form in which a lexical item is represented in the lexicon.* According to the theoretical framework this is either the representation before the application of any rules or, as in Lexical Phonology, after the application of lexical rules.

lexicon That part of the complete grammar of a language which contains at least the lexical and grammatical morphemes, including any peculiarities which these may exhibit, and which in some frameworks may also contain additional material, such as lexical rules.*

Lexicon Optimization The evaluation function of Optimality Theory is used to generate underlying representations from output forms on the basis of the constraint ranking that generates these output forms adhering to the **Richness of the Base Hypothesis**.

liquid 1. A conventional label for any non-nasal sonorant. The class of liquids includes lateral approximants and most rhotics, especially alveolar and postalveolar taps, trills and approximants but occasionally certain others. Informally, this is the class of '*l*-sounds' and '*r*-sounds', and membership in doubtful cases is determined chiefly by phonological patterning. In the *SPE* feature system, liquids are

[+consonantal, +vocalic]. 2. In Lass (1984), any member of a somewhat larger class including the traditional liquids plus the glides.*

markedness rule A rule which declares the unmarked value of a feature or segment, such as the rule which asserts that a non-high vowel has the same value for [round] as it has for [back].*[1]

markedness theory Any of several approaches which attempt to establish a systematic, principled and (usually) universal distinction between marked and unmarked forms. The best-known attempt is that in the last chapter of Chomsky & Halle (1968), which argues that, for every feature in every possible environment, one value will be unmarked. […]* See Rice (2007) on markedness in phonology.

marking convention A markedness rule, often particularly expressed in the framework of Chomsky & Halle (1968), such as the following (*u* = 'unmarked'):

$$[\text{u voice}] \rightarrow [\text{+voice}] \;/\; \left(\begin{array}{c}\underline{\quad\quad} \\ \text{+son}\end{array}\right) \qquad *$$

mismatch negativity (MMN) MMN is an event-related potential (ERP), that can be shown in electroencephalographic (EEG) experiments, a significant change in electrical activity in the brain in response to a stimulus. MMN effects are most easily observed in oddball sequences, in which a repetition of the same stimulus is interrupted by a deviant stimulus.

morpheme The minimal grammatical unit; the smallest unit which plays any part in morphology and which cannot be further decomposed except in phonological terms. A morpheme is an abstract unit which may or may not be realized by a fairly consistent stretch of phonological material. Morphemes may be classified as free or bound.*

morpheme structure rule (also morpheme structure condition, lexical redundancy rule, morphophonotactic rule) A phonotactic constraint which is stated for single morphemes, rather than for entire words. For example, English has the constraint C → [+cor] / ɑʊ___ for morphemes, but not for words: endowment, cowboy. Halle (1959).* See also **f-rule**, **redundancy rule**.

neutralization The disappearance, in a particular position, of a **contrast** between two or more segments which is maintained in other positions. The single segment which appears in the position of neutralization may be phonetically similar to one or other of the neutralized segments; it may be phonetically intermediate; or it may have a distinctive phonetic form. […] Most versions of classical phonology attempt to identify the segment in the position of neutralization with one of the segments contrasting elsewhere, but the Prague school treats it as a distinct type of segment, the **archiphoneme**. […]*

obstruent 1. Any segment whose articulation involves an obstruction in the vocal tract at least radical enough to produce friction noise: a plosive, an affricate or a fricative. Note that nasal stops are not classed as obstruents. […] 2. (obstr) A **distinctive feature** sometimes used to distinguish obstruents [+obstr] from all other segments [–obstr]. […]*

Ockham's razor (also Occam's razor) The principle that in explaining anything no more assumptions should be made than are necessary. (*OED*)

opacity The over- or underapplication of a phonological process, in derivational theories attributed to the creation or destruction, respectively, of the environment of the previous phonological process by another process, which applies after the former. In overapplication (counter-bleeding), rule A applies in its regular context and then rule B destroys that context. In underapplication (counter-feeding), rule A does not apply because at the stage when it should apply the context for its application is not present in the representation. Rule C creates this context afterwards. (Kiparsky 1973a)

opposition see **contrast**

output A representation produced or chosen by a grammar, on the basis of an **input**.

p-rule A phonological rule (assimilation rule, neutralization rule etc.), as opposed to **f-rule**.

phonaestheme A phoneme or cluster in a particular language which recurs repeatedly in words of related meanings, such as English /sl-/ in *slip, slick, slide, slop, slush* etc. (Firth 1930)*

phone A single phonetic segment, viewed in terms of its phonetic character and without regard to its possible phonological status.*

phoneme In many theories of phonology, a fundamental (often the fundamental) unit of phonological structure, an abstract segment, which is one of a set of such segments in the phonological system of a particular language or speech variety, often defined as 'the smallest unit which can make a difference in meaning'. First recognized in the late nineteenth century, the phoneme occupied a more or less central position in every theory of phonology promulgated in the twentieth century, with the sole exception of Prosodic Analysis, until the development of non-linear approaches in the 1980s; often regarded as the most conspicuous characteristic of classical phonology, the phoneme was also important in all earlier versions of generative phonology. Two points need to be stressed: (1) the most important property of a phoneme is that it contrasts with the other phonemes in the system, and hence (2) we can only speak of phonemes of some particular speech variety (a particular accent of a particular language). […] Several views of the phoneme have been advanced, chiefly differing first as to whether the phoneme is regarded as a phonological prime not capable of further decomposition or as a cluster of more primitive elements, second in the degree of abstractness imputed to it, and finally whether the phoneme is regarded as a mental reality, a physical unit or merely a convenient analytical fiction. Both the British school and the American structuralists regard the phoneme as indivisible and as minimally abstract, a conception often labelled the autonomous (or classical) phoneme. In this view the phoneme is essentially a structureless object which nonetheless has identifiable phonetic characteristics; it may be realized in speech by phonetically different **phones** in different environments (its **allophones**), and the allophones of a phoneme are united within it by their shared phonetic similarity and by their complementary distribution. The view of the Prague school differs somewhat in regarding the phonetic characteristics of a phoneme as fundamental, and hence stressing the way in which phonemes tend to occur in phonetically identifiable patterns. A very different conception, the systematic phoneme, was put forward by the early generative phonologists. The systematic phoneme is explicitly regarded, not as a primitive, but as a mere bundle of the real primitives, the **distinctive features**. More importantly, the systematic phoneme is in general a highly abstract object, closely resembling the morphophoneme of the American structuralists; as a result of the application of a long series of ordered rules, a single phoneme may reach the surface in a form which is phonetically utterly different from its canonical form; it may merge with another phoneme into a single segment; it may even disappear altogether. The non-linear approaches which have dominated the field since the 1980s have dispensed with the phoneme altogether, though the term 'phoneme' is still sometimes applied to an autosegment on the segmental tier in those versions of Autosegmental Phonology which recognize such a tier. […]*

phonetic form (also phonetic representation) The phonetically more-or-less fully specified representation of a word or a longer sequence, often especially when this is contrasted with its **phonological (underlying) form**.*

phonetic similarity An important but elusive criterion for phonological analysis. The idea is that two phones in **complementary distribution** can be assigned to a single **phoneme** if they are 'phonetically similar', but this notion is difficult to make explicit. One approach is to demand that such segments should share more phonetic features with each other than either does with any other segment. In English, for example, unaspirated [p=] is in complementary distribution with each of [p^h], [t^h] and [k^h] (which themselves contrast), but [p=] clearly shares more features with [p^h] than either does with any of the others, and so [p=] and [p^h] can be assigned to a single phoneme /p/. On the other hand, English [h] and [ŋ] are in complementary distribution, but they share no features at all, beyond [–syllabic], which they also share with all other English consonants, and hence they should not be assigned to a single phoneme. […]*

phonological form (PF) In some theory or analysis, a representation of a linguistic object (a word, a phrase, etc.) in terms of the phonological elements recognized in that framework. The term is particularly associated with early versions of generative phonology, where it is applied to a rather abstract level of representation which has not yet been converted by rules to its corresponding **phonetic form**.*

prime, phonological (also phonological primitive, atom) In a given theory of phonology, any one of the minimal phonological elements in terms of which the theory operates and which can in no way be decomposed into simpler elements. Most versions of classical phonology took the **phonemes** as primes; the Prague school (arguably) and classical generative phonology (certainly) took the **distinctive features** as primes. Many contemporary theories of phonology take as their primes components or autosegments which are rather similar to unary features. See Fudge (1967).*

privative opposition n. In Prague school phonology, a contrast between two segments one of which (the marked member) is characterized by the presence of a property which is absent from the other (the unmarked member). An example is the /p/–/b/ contrast in English, in which /b/ is marked by the presence of voice, absent from /p/, there being no other differences between the two. Privative oppositions are fundamental in a number of current theories of phonology, such as Particle Phonology, Dependency Phonology and Government Phonology* (as well as the Parallel Structures Model).

quark Each of a group of subatomic particles regarded (with leptons) as basic constituents of matter, and postulated never to occur in the free state but to be combined in pairs to form mesons and in triplets to form baryons, and to have fractional electric charges (+⅔ and −⅓ that of the proton). (*OED*)

radical see **element**

Radical Underspecification Underspecification theory which assumes that all feature values in a segment that can be derived by a feature-filling rule are underspecified.

redundancy rule Any rule which states that some feature or behaviour is entirely predictable from the presence of something else. […]* See also **f-rule**, **marking convention**.

Redundancy Rule-Ordering Constraint (RROC) A constraint on the sequencing of rules, that demands that any feature-filling rule is applied before a phonological rule referring to the same feature applies. The constraint was introduced as one of two principles that govern underspecification in underlying representations and as part of an effort to restrict arbitrary extrinsic rule ordering. 'A redundancy rule assigning "a" to F, where "a" is "+" or "–", is automatically ordered prior to the first rule referring to [a F] in structural description' (Archangeli 1984/1988: 73).

representation 1. Any conventional rendering of a piece of speech with a set of symbols or linguistic objects appropriate to some particular level of analysis. […] 2. One of the planes (sense 1) of phonology, the one handling the purely linguistic content of expressions: phonology in the ordinary sense. 3. In some American structuralist work, the relation which holds between certain linguistic elements: morphemes are represented by morphs and morphophonemes are represented by phonemes. […] Sense 3: Hockett (1961).* See **lexical representation**, **surface representation**, **underlying representation**

Revised Alternation Condition A principle formulated to constrain abstract analyses and specifically to prohibit the use of **absolute neutralization**. It says: an obligatory neutralization rule may apply only in a derived environment. A reformulation of the earlier

Alternation Condition, this principle helped pave the way for Lexical Phonology. […] (Kiparsky 1973b)*

Richness of the Base (RotB) Hypothesis One of the assumptions Optimality Theory operates on. It says basically that constraints on underlying representations don't exist and that all surface patterns and typological variation have to be explained through the permutation of rankings of universal constraints on surface structures. The OT grammar of a given language has to produce grammatical results regardless of the input fed into it. (Prince & Smolensky 2004/1993)

segment 1. A single speech sound; any one of the minimal units of which an utterance may be regarded as a linear sequence, at either the phonetic or the phonological level, such as [a], [s], [k] or [m]. The segment is broadly conceived of as a period of speech during which the organs of articulation are more or less unmoving; however, since the speech organs are actually in constant and largely independent motion during speech, phoneticians have long stressed that the segment is (phonetically, at least) a fiction, but it is none the less a very convenient fiction, and such varied evidence as alphabetic writing and slips of the tongue show that the segment is linguistically real. 2. A bundle of **distinctive features** which is fully specified and hence capable of receiving phonetic interpretation in a particular language. 3. (seg) In the *SPE* feature system, a distinctive feature invoked to distinguish segments ([+seg]) from boundaries ([–seg]). 4. In **Autosegmental Phonology**, a frequent shorthand for **autosegment**. […]*

sonorant 1. (also resonant) A consonant which is not an obstruent – that is, a liquid, a nasal or an approximant. 2. In the *SPE* feature system, a distinctive feature defined as 'produced with a configuration of the vocal tract cavity in which spontaneous vocal cord vibration is possible'. Obstruents are [–son]; all other segments are [+son], including [ʔ] and [h] and all vowels. This definition in terms of 'spontaneous voicing' has been shown to be unworkable. Many analysts have preferred to rename this feature obstruent, with exactly the opposite specifications, though many now prefer to regard [h] and [ʔ] as [+obstr]. 3. In the Ladefoged system, a distinctive feature defined as 'possessing a high amount of acoustic energy' and specifically designed to pick out segments which are capable of being syllabic. Hence vowels, nasals and liquids are [+son], while obstruents and glides are [–son]. Note these definitions are not equivalent.*

Strict Cycle Condition/Strict Cyclicity Condition Especially in Lexical Phonology, a proposed constraint upon cyclic rules. It says: cyclic rules may apply in derived environments only. In other words, a cyclic rule can only effect a change in an input which has been created within the current cycle. This condition does essentially the same work as the **Revised Alternation Condition** and the Derived Environment Constraint. (Mascaró 1976; Kaisse & Shaw 1985)*

structure-changing rule (see also **p-rule**) A rule that changes or overwrites structure that is already specified in a representation, for example the value of a feature.

structure-filling rule A rule that only affects unspecified structure, e.g., unspecified feature values.

structure preservation In Lexical Phonology, a constraint upon lexical rules. It says: lexical rules do not introduce distinctions not present in lexical entries. […] (Kiparsky 1985)*

Successive Division Algorithm (SDA) A method to divide a set of segments step by step into smaller sets until every contrastive segment has a unique feature profile.
SDA definition (Dresher 2003 *et seq.*):

a. In the initial state, all tokens in inventory I are assumed to be variants of a single member. Set I = S, the set of all members.
b. i. If S is found to have more than one member, proceed to (c).
   ii. Otherwise, stop. If a member, M, has not been designated contrastive with respect to a feature, G, then G is redundant for M.
c. Select a new *n*-ary feature, F, from the set of distinctive features. F splits members of the input set, S, into n sets, $F_1 - F_n$, depending on what value of F is true of each member of S.
d. i. If all but one of $F_1 - F_n$ is empty, then loop back to (c).
   ii. Otherwise, F is contrastive for all members of S.
e. For each set F_i, loop back to (b), replacing S by F_i.

surface representation see **phonetic form**.* Surface representations in most phonological theories are not to be confused with the phonetic output, the acoustic signal or its IPA transcription. A surface representation is a phonological structure consisting of segments, which consist of features (organized in a hierarchy or not) and which are organized into prosodic units (in *SPE* and most derivational generative theories and in most versions of OT).

transduction Conversion of an alternation in one medium to a corresponding alternation in another medium (for example, mapping sound waves to equivalent alternations in electrical current).

trivial underspecification see **inherent underspecification**

underlying representation (also underlying form, underlyer) see **phonological form**. A more or less abstract phonological representation of a segment, a morpheme, a word or a phrase which is posited by an analyst and from which corresponding surface forms, including any variant realizations, are derived by the application of rules. Underlying forms may be more or less abstract, depending upon the theoretical preferences of the analyst. Note: Though the ancient Indian grammarians made extensive use of underlying forms, both the concept and the term were introduced into modern linguistics by Bloomfield (1933). American structuralists generally rejected the idea, though Swadesh, Pike, Nida and Hockett all made use of it. With the rise of generative phonology, underlying forms became central to phonological analysis.*

Notes

1 Getting started

1 Phonological surface representation and phonetic form are distinguished by vertical slashes and square brackets, respectively, in (1). In the rest of the book, this distinction is not made, unless indicated. For a more complex exposition that acknowledges the different roles of production and perception/recognition in the picture see, e.g., Boersma (1998).
2 Among twenty-first-century nerds more commonly referred to as the KISS principle: 'Keep it simple, stupid!' (with or without the comma).
3 This oversimplifies matters slightly. There are a considerable number of irregular verbs which cannot be decomposed straightforwardly. Furthermore, irregular verbs can be divided into subgroups of which some show subregularities and one can argue whether these are morphologically decomposed or not. Thus, we might end up with a higher number of lexically stored morphemes, which might approach 20,000, but not 400,000.

2 Arbitrariness and opposition

1 'In language there are only differences.'
2 We will come back to the issue of sound–meaning correlations in Chapter 6, where the arbitrariness hypothesis will be relativized. The hypothesis was also criticized by Jakobson (1941, 1973; Jakobson & Waugh 1979), who undertook considerable research into sound symbolism.
3 This is an issue that will be taken up repeatedly later on: is it the aspiration that is predictable in English obstruents or the absence or presence of vocal fold vibration?
4 'Man darf sagen, daß das Phonem die Gesamtheit der phonologisch relevanten Eigenschaften des Lautgebildes ist.'
5 'daß das Phonem ein in noch kleinere distinktive ("phonologische") Einheiten *nicht* [my italic] weiter zerlegbares Glied einer solchen Opposition ist.'
6 '[d]ie Norm auf die sich die Sprecher beziehen, ist aber "*k* überhaupt", und dieses kann nicht durch Messungen und Berechnungen ermittelt werden.'
7 'Da die Systeme der phonologischen Oppositionen je nach der Sprache und je nach dem Dialekt verschieden sind, so ist auch der phonologische Gehalt der Phoneme je nach der Sprache und dem Dialekt verschieden. Der Unterschied kann sich auch in der Realisation der Phoneme auswirken.'
8 'Sein phonologischer Gehalt ist sehr arm, eigentlich rein negativ.'
9 Note that current IPA conventions use the same terminology (open vs closed) in a different way, referring to the absolute degree of openness rather than a relative degree dependent on a superordinate one.
10 'Ob das "starke" oder das "schwache" Oppositionsglied einer Überwindungskorrelation zweiten Grades das merkmallose ist, das kann ja letzten Endes nur aus dem Funktionieren des betreffenden phonologischen Systems objektiv erschlossen werden.'

11 See Hart (2010) for an up-to-date discussion of analyses of Danish lenition as well as a more accurate description of the data.

3 Derivation and abstractness

1 A third aspect of abstractness is determined by the definitions of features. Phonetically motivated features are of course less abstract than features that don't have any content and function only as labels to assign segments to sets and separate segments from other segments, i.e., to categorize them, whereas storage as the perceptual and articulatory experience with all details can be said to be the least abstract representation. These issues will be discussed in following chapters.

2 See, e.g., Cole (1995) for an enlightening discussion of these constructs.

3 This excludes allomorphs, i.e., those morphemes that are regarded as unrelated surface forms of the same lexical entry because they cannot be connected to one underlying phonological form with phonological rules explaining the differences between them, as in substitution, e.g., English irregular verbs, such as *go* – *went* – *gone*, or the plural markers in *oxen* vs *cats*. These cannot be phonologically derived from a joint base form in any reasonable analysis, or allomorphs that can be predicted by phonological context, but the alternation still can't be explained this way, such as the German nominalizers *-heit* and *-keit*, as opposed to the different realizations of the default plural marking, *-s*, *-z*, *-ɪz*, that can be accounted for with a phonological analysis, or the paradigm *keep* – *kept*, which could be explained with a phonological analysis involving vowel shortening and lowering before final consonant clusters to avoid syllables with more than three positions in the rime. In the text I refer to the latter, broader use of allomorphs.

4 In my reading, statement (D) doesn't actually say this, but from the discussion surrounding the statement one can infer this to be Kenstowicz & Kisseberth's intended interpretation of (D), i.e., that there must be some surface form for each underlying feature specification.

5 Which is an odd development, considering that Jakobson developed the binarity of features based on binarity in information theory, and feature binarity is often considered to correspond to neural activity as a firing or inactive state. Binarity in informatics/mathematics is usually expressed through '0' and '1', but no third choice.

6 The marked and unmarked value depends on the way features are defined. Voicing is contrastive in obstruents and rarely so in sonorants. For obstruents, most notably stops, articulatorily and cross-linguistically the unmarked state is voicelessness. Since the markedness situation is such, some scholars proposed alternative solutions. In Articulatory Phonology the unmarked state for speech sounds is assumed to include vocal fold vibration. Rice (1993) proposes a separate feature, SV (Sonorant Voicing or Spontaneous Voicing), for sonorants that is filled in surface representations where it then can cause post-sonorant voicing for example. More recently, Blaho (2008) proposed the feature [voiceless].

7 The underspecified feature [0voice] is given for expository purposes and doesn't actually need to be there. Kenstowicz & Kisseberth (1977) give the same rules using the feature [+syllabic] to define the class to which it applies and leave out the underspecified feature.

8 Inkelas (1994, 2000), Inkelas, Orgun & Zoll (1997) and Krämer (2000, 2001) among others argue for ternary contrasts, but these show in a substantially different way than those discussed here. Ternarity in Inkelas' and Krämer's conception of ternarity shows in the different behaviour of segments. Those segments with a specified value for feature F don't alternate, while the underspecified features show alternation according to context. For example, in a typical root-controlled

vowel harmony pattern (e.g., Turkish backness harmony), the (disharmonic) root vowels are specified and the alternating harmonic vowels are underspecified. Krämer (2001) uses idiosyncratic underspecification to account for morpheme-specific processes. See Section 4.6.

9 We will discuss hierarchies of contrast and their relation to typology and acquisition in more detail in Chapter 4.

4 Underspecification returns

1 One might also ask whether the feature correctly matches markedness relations. If vocal cord vibration is the 'norm' among speech sounds, i.e., redundantly present in vowels, approximants, nasals and trills, one would expect that the stops and fricatives which lack this property are in a sense the marked classes, since they are the odd ones out. Consequently, they should be literally marked with the presence of a feature, e.g., [voiceless] or [glottal width]. The situation, however, is a bit more complex. For stops, the articulatory and aerodynamic characteristics suggest that being voiced is the more difficult state, while the same criteria suggest the reverse for most other sound classes. Furthermore, languages differ in the phonetic implementation of laryngeal contrast (in English, for instance, the phonetic cues for laryngeal contrast are much more intricate than just vocal cord vibration and in parts displaced on neighbouring segments; see the discussion in Chapter 5) and phonological patterns give evidence that a binary laryngeal contrast is best analysed with a feature [voice] in some languages but with, e.g., [spread glottis] in others. The nature of features will be discussed in more detail in Chapter 7.

2 The generalization that structure preservation is a characteristic of the lexical phonology was shown to be too strong a claim by Harris (1990).

3 Kiparsky (1985) splits up English voicing assimilation into two separate processes, one applying lexically and one that applies postlexically. The former doesn't cross word boundaries, as evidenced in compounds, such as *club soda* [… b#s …] *[p.s / b.z] or phrases, such as *kiss Berta* [… s#b …]. The latter affects inflectional affixes, such as past tense *-d*, plural, genitive, verbal *-s* and the final fricative in auxiliaries such as *has* and *is*.

4 Archangeli (1984) thought the least marked vowel in Japanese was [i]. We follow more recent research here since, for the argument at hand, the choice is irrelevant. After all, the theory allows any vowel to be chosen as unmarked (which could, actually, be regarded as a problem).

5 An option would be to assume different features, such as [±spread lips], [±front] [±low] and [±mid].

6 In the following discussions I follow Dresher's practice and use the features that are used in the respective source, regardless of label or whether binary or unary.

7 For example, derivational *-kuun* could be added in an early stratum in which rounding dissimilation applies in a feature-filling way. On the next stratum the participle-forming affix *-en-* is inserted between base and reduplicant and the *-en*-specific rule applies. Finally, perfective and subjunctive marking is located in stratum 3, at which a feature-filling rule of complete assimilation applies.

5 The devil is in the detail: usage-based phonology

1 'Da solche für die Bildung von Sprechlauten überlieferten Normen nicht zweimal in genau derselben Weise durch die Sprechorgane erfüllt werden können, schließt der Übergang von der Erforschung dieser Normen zur Erforschung des Sprechens den Übergang von Sprachgeschichte zu einer auf sie abgestellten statistischen Erfassung der Variation des Sprechens in sich.'

2 Opening bracket missing in the original.
3 The system of English verb classes is slightly more complex than indicated here since there are additional subclasses, but for the current concern this classification is fully sufficient.
4 Given the selected examples, one might speculate whether the second unit involved has to be a functional item rather than attributing the matter to frequency.
5 The sequence of letters *bad* is a word in other languages as well (for instance in Norwegian and German *bad/Bad* mean 'bathroom/baths'). Even if one uses Google's filters it doesn't reliably filter out pages in other languages.
6 For this little thought experiment we ignore the fact that a voicing contrast can have other cues than just vocal cord vibration (see further down though).
7 Though in some cases the overuse of certain cues can lead to a reanalysis, i.e., historical change, from a voicing contrast to a tonal contrast or from a length to a voicing contrast etc.
8 Readers unfamiliar with OT might want to consult the brief introduction to the theory in Section 7.1.
9 As mentioned earlier, using the internet as a corpus has its drawbacks: *Lost* for example is also a very popular TV series, which increases its hit rate considerably. Furthermore, the numbers constantly change. On 1 October 2010 we got the following results:

lost	458,000,000
found	1,010,000,000
told	413,000,000
kept	143,000,000
slept	16,700,000

The same disclaimer holds for all other Google data presented: handle with care!
10 The low frequency of *swim*-related items might also be due to a medium-specific bias owing to the sociocultural profile of significant parts of the user population. The extremely high frequency of *read* is due to the syncretism between not only past and participle but also most present tense forms.
11 The irregular forms *had* and *was* are not included here since they are used as auxiliary verbs and can therefore be expected to have hit rates far above any other verb, as they in fact do, with 1,320,000,000 and 2,900,000,000 hits, respectively.
12 In two previous runs in which I accessed all pages the search engine identified as written in Italian ('pagine in italiano'; 7 April 2006 /9 April 2006) I found a reverse correlation of vacillation with frequency. In the plurals with the lowest frequency (e.g., *stomac(h)i*) the hits for the dispreferred form approached 20 percent. I suspect that this has to do with the presence of Web documents written by L2 speakers (like me). This factor was minimized by searching only sites in Italian in the Italian Web.
13 Giavazzi (2009) conducts a similar study and produces different results. Thus, a third study seems to be necessary.

6 Psycho- and neurolinguistic evidence

1 An alternative analysis could regard the vowel harmony process as structure-changing rather than structure-filling (as Harrison & Kaun seem to assume). The disharmonic loanwords would have to be marked with a diacritic (e.g., [+loanword]) as exempt from this process. Parsimony favours the underspecification account, since it doesn't need an additional feature, i.e., the diacritic. However,

the whole discussion about the psycholinguistic reality of the effect of economy principles on underlying forms only arises if we challenge the imperative of parsimony.

2 Not a single one of the Spanish speakers I asked to play the game realized the inverted form of *rosa* with a flap. Nevins & Vaux apparently refer to a variety that wasn't represented among my consultants.

3 Somebody should really work out the numbers: (a) is there typologically an implicational relation between [ø] and [o]; (b) is there a frequency difference between the two that holds across all languages that have both; do all languages that have [o] also have [e] and/or vice versa; and (c) in languages that have [o] and [e], is one of the two more frequent?

7 On the form and contents of contrastive features

1 In my understanding of the associated Government Phonology, which provides the segmental skeleton of strings as well as a set of principles and parameters that regulate cohabitation of elements in a string, an empty position is either phonetically empty, i.e., not realized, if in a position in the string where this is licensed or it is filled with elemental material from neighbouring positions by spreading as in Feature Geometry.

2 The tree not only differs from standard Feature Geometry in the labels. The feature [in] is here used as an intermediate node between the location class node and the front/back features, reminiscent of the relation between place, [coronal] and [anterior]/[distributed]. However, as it is given, it corresponds more to a lingual node (Keyser & Stevens 1994). The in/out distinction could also be a privative split with a feature [out] and the features [front] and [back] directly linked to the location node.

3 The interrupted lines indicate other features of the segment, which will be discussed shortly.

4 Dentals could likewise be specified as [location[out][in]]. This representation would explain why they are replaced with labials in child English (and some English dialects), rather than with alveolars.

5 In formal semantics the two event types are actually distinguished by their complexity rather than by a feature slapped on to them.

6 In this article Ohala even explains why we smile. The interested reader is invited to consult the paper.

8 Underlying representations in Optimality Theory

1 Prince & Smolensky (1993/2004: 225) regard Kisseberth's reduplication problem (see Chapter 3) as solved by simply stipulating that there are no constraints on the lexicon or the input. As we will see shortly, this doesn't solve the problem since OT's mechanism of Lexicon Optimization doesn't restrict storage of phonological information appropriately and Prince & Smolensky relativize their strong claim five pages later with the half-hearted proposal of a very general markedness constraint on underlying forms or alternatively the application of several economy principles.

2 It has been noted that anything could be subject to evaluation in an OT grammar (e.g., Hale & Reiss 2008). Thus, even a banana could be an output candidate, or part of one. If we consider this argument in the light of RotB, we have to consider whether a banana could be in the input. There are two objections to this kind of reasoning: (i) OT is a linguistic theory, which, by definition, attempts to explain language patterns – and bananas are not language, they are fruit. Thus a linguistic theory evaluates linguistic objects and not just any object. (Similarly, one could ask how phonological rules are applied if a banana is entered into the derivation

of a rule-based theory. Since the contextual rules don't find the relevant contexts they won't apply and the redundancy rules will fill in default values – or maybe not, since they need basic categories like consonants and vowels. So, the banana will exit the speaker's mouth unchanged.) (ii) Bananas, the real objects, are difficult to get into any speaker's mind as such. The only banana that can end up there is the concept of 'banana' or the memories of specific bananas the speaker has come across.

3 Disclaimer: this sketch is intended to give a basic understanding of OT and therefore ignores quite a few aspects of the patterns under consideration and is thus a highly idealized analysis of these data.

4 Onset: 'Every syllable starts with a consonant.' Parse and Fill are faithfulness constraints in the Containment model of faithfulness, which holds that nothing can be added or literally deleted. Presence of segments in the output that are not assumed in the input is a violation of Fill, which demands that every syllable position be filled with lexical material, while deletion of segments is regarded as underparsing, i.e., an underlyingly present segment is not associated with syllable structure in the output and therefore receives no phonetic realization, which is registered in the grammar as a Parse violation.

5 As noted in Section 4.6, the analysis crucially misses the point that the morphemes that don't undergo final devoicing are all relatively recent loanwords. Thus we might be dealing with lexical classes here rather than a representational difference at the contrastive segmental level.

6 The definition in (36) refers to the FFC, the Fully Faithful Candidate. Since most of prosodic structure is generally assumed to be absent in underlying forms there has to be an intermediate form, the FFC, that is identical to the underlying form, with the only difference being that it is fully prosodified. In this way also markedness constraints that refer to prosodic structure, such as *VoicedCoda, can be meaningfully split into Old and New Markedness.

7 Ident(VH): identity in vowel height.

8 Id-Adj(VH): identity-adjacent vowel height: 'A change of one step on a three-step vowel height scale is allowed but two steps are not.' /a/ -> [e], /i/ -> [e]; */a/ -> [i], */i/ -> [a].

9 In these data, transcription is very broad to focus on the features of interest in both varieties.

10 The issue of recognition/perception has to be taken with caution. The actual perception of linguistic signals has the acoustic signal or its electromagnetic signal as it is transmitted from the ear to the brain as its input and the output of this process should be the surface phonological form or forms that correspond to a set of phonetic cues. The listener then has to retrieve the underlying form or lexical representation that matches best with this (these) surface form(s). I ignore the phonetics–phonology mapping in this table and 'recognition' refers to the recognition of a lexical form corresponding to a given surface phonological form. For an elaborate model of representations and mapping relations between phonetics and lexicon see, e.g., Boersma (1998, 2000).

11 Boersma (1998 *et seq.*) as well as Broselow (2004, 2009) propose perception-specific OT grammars, which contain perception-specific markedness constraints, which determine which underlying form can be retrieved for a given surface form or created in relation to it. The null hypothesis should be that learners of a language have to acquire only one ranking and that this can be used in either direction, which is the avenue pursued here.

12 This discussion assumes that a feature like [coronal] is regarded as a 'value' of the place feature/node and Ident(F) is violated by any change in value.

13 This grammar oversimplifies matters, since the situation is more interesting than indicated, but the additional details to the patterns of liquids are not of immediate concern to the current discussion. Word-initial position is not the only locus of neutralization of the trill and the flap. The flap surfaces to the exclusion of the trill in complex onsets and in the coda. If a preceding consonant is not in the same syllable as the rhotic, the latter surfaces as a trill. In word-final position we find variably the trill and the flap. There is more or less free variation (Barrutia & Schwegler 1982). In coda position we find the same variation as word-finally and in the latter context the trill is realized if the following word starts with a vowel (Proctor 2009). In addition, the distribution of flaps and trills in neutralization contexts varies from speaker to speaker, among dialects and registers (Proctor 2009).

9 Preliminary results

1 For illustration, consider this personal anecdote. When the author moved to Norway his son was seven years old. After less than a year of immersion in Norwegian the boy couldn't be distinguished from the local kids anymore, while the parent, even after six years, still gets identified as a foreigner by his accent.

Glossary

1 Trask probably intended 'non-low' rather than 'non-high'.

References

Alber, Birgit (2001). Regional variation and edges: glottal stop epenthesis and dissimilation in standard and southern varieties of German. *Zeitschrift für Sprachwissenschaft* **20**: 3–41.

Alderete, John D. (2001a). Dominance effects as transderivational anti-faithfulness. *Phonology* **18**: 201–53.

(2001b). *Morphologically Governed Accent in Optimality Theory*. New York and London: Routledge.

Anderson, John M. & Colin J. Ewen (1987). *Principles of Dependency Phonology*. Cambridge University Press.

Anderson, John M. & Charles Jones (1974). Three theses concerning phonological representations. *Journal of Linguistics* **10**: 1–26.

(1977). *Phonological Structure and the History of English*. Amsterdam: North-Holland.

Anderson, Stephen R. (1985). *Phonology in the Twentieth Century*. University of Chicago Press.

Anttila, Arto (2002). Variation and phonological theory. In Jack Chambers, Peter Trudgill & Natalie Schilling-Estes (eds.), *Handbook of Language Variation and Change*. Oxford: Blackwell. 206–43.

Archangeli, Diana (1984/1988). *Underspecification in Yawelmani Phonology and Morphology*. PhD dissertation, MIT. Published 1988, New York: Garland.

(1985). Underspecification in underlying representation. In G. Youmans (ed.) *In Memory of Roman Jakobson: Papers from the 1984 Mid-America Linguistics Conference*. Columbia, MO: Linguistic Area Program. 3–15.

(1988). Aspects of underspecification theory. *Phonology* **5**: 183–207.

Archangeli, Diana & Douglas Pulleyblank (1989). Yoruba vowel harmony. *Linguistic Inquiry* **20**: 173–217.

Aronoff, Mark (1976). *Word Formation in Generative Grammar*. Cambridge, Mass.: MIT Press.

Avery, Peter & William J. Idsardi (2001). Laryngeal dimensions, completion and enhancement. In T. A. Hall (ed.), *Distinctive Feature Theory*. Berlin: Walter de Gruyter. 41–70.

Baković, Eric (2000). Harmony, Dominance and Control. PhD dissertation, Rutgers University, New Brunswick.

Barrutia, Richard & Armin Schwegler (1982). *Fonética y fonologia españolas: teoría y práctica*. New York: Wiley.

Becker, Michael (2009). Phonological trends in the lexicon: the role of constraints. PhD dissertation, University of Massachusetts, Amherst.

Beckman, Jill N. (1997). Positional faithfulness, positional neutralization and Shona vowel harmony. *Phonology* **14**: 1–46.

Beckman, Jill N. & Catherine O. Ringen (2004). Contrast and Redundancy in OT. In *Proceedings of the West Coast Conference on Formal Linguistics* 23. Somerville, MA: Cascadilla Press. 101–14.

Bennett, Craig M. & Michael B. Miller (2010). How reliable are the results from functional magnetic resonance imaging? *Annals of the New York Academy of Sciences* **1191**: 133–55.

Benua, Laura (1995). Identity effects in morphological truncation. In *UMOP* **18**. University of Massachusetts, Amherst. 77–136.

Blaho, Sylvia (2008). The syntax of phonology: a radically substance-free approach. PhD dissertation, University of Tromsø.

Bloch, Bernard (1941). Phonemic overlapping. *American Speech* **16**: 278–84. Reprinted in Martin Joos (ed.) (1957), *Readings in Linguistics I*. Chicago University Press. 93–96. Also reprinted in V. B. Makkai (ed.) (1972), *Phonological Theory: Evolution and current practice*. New York: Holt, Rinehart & Winston. 66–70.

Bloomfield, Leonard (1933). *Language*. New York: Holt, Rinehart & Winston.

Boersma, Paul (1997). How we learn variation, optionality, and probability. *IFA Proceedings* **21**: 43–58.

(1998). Functional phonology: formalizing the interactions between articulatory and perceptual drives. PhD dissertation, University of Amsterdam.

(2000). Learning a grammar in functional phonology. In Joost Dekkers, Frank van der Leeuw & Jeroen van de Weijer (eds.), *Optimality Theory: Phonology, Syntax, and Acquisition*. Oxford University Press. 465–523.

(2009). Cue constraints and their interaction in phonological perception and production. In Paul Boersma & Silke Hamann (eds.), *Phonology in Perception*. Berlin: Mouton de Gruyter. 55–108.

Boersma, Paul & Silke Hamann (2009). Loanword adaptation as first-language phonological perception. In Andrea Calabrese & W. Leo Wetzels (eds.), *Loanword Phonology*. Amsterdam: John Benjamins. 11–58.

Bosch, Anna (1998). The syllable in Scottish dialect studies. *Scottish Gaelic Studies* **18**: 1–22.

Bromberger, Sylvain & Morris Halle (1989). Why phonology is different. *Linguistic Inquiry* **20**: 51–70.

Broselow, Ellen (2004). Language contact phonology: richness of the stimulus, poverty of the base. *NELS* **34**: 1–22.

(2009). Stress adaptation in loanword phonology: perception and learnability. In P. Boersma & S. Hamann (eds.), *Phonology in Perception*. Berlin: Mouton. 191–234.

Browman, Catherine P. & Louis Goldstein (1986). Towards an articulatory phonology. In C. Ewen & J. Anderson (eds.), *Phonology Yearbook* 3. Cambridge University Press. 219–52.

(1992). Articulatory phonology: an overview. *Phonetica* **49**: 155–80.

Brown, Jason C. (2004). Eliminating the segment tier: evidence from speech errors. *Journal of Psycholinguistic Research* **33**: 97–101.

Brown, Roger & David McNeill (1966). The 'tip of the tongue' phenomenon. *Journal of Verbal Learning and Verbal Behaviour* **5**: 325–37.

Burzio, Luigi (1996). Surface constraints versus underlying representations. In Jacques Durand & Bernard Laks (eds.), *Current Trends in Phonology: Models and Methods*, vol. 1. European Studies Research Institute (ESRI), University of Salford Publications. 123–41.

(2000a). Cycles, non-derived-environment blocking, and correspondence. In Joost Dekkers, Frank van der Leeuw & Jeroen van de Weijer (eds.), *Optimality Theory. Phonology, Syntax, and Acquisition*. Oxford University Press. 47–87.

(2000b). Segmental contrast meets output-to-output faithfulness. *The Linguistic Review* **17**: 368–84.

(2002). Surface-to-surface morphology: when your representations turn into constraints. In P. Boucher (ed.), *Many Morphologies*. Somerville, MA: Cascadilla Press. 142–77.

(2005) Sources of paradigm uniformity. In Laura J. Downing, T. A. Hall & Renate Raffelsiefen (eds.), *Paradigms in Phonological Theory*. Oxford University Press. 65–106.

(2010). Lexicon and grammar: unequal but inseparable. MS, Johns Hopkins University.

Bybee, Joan (2001). *Phonology and Language Use*. Cambridge University Press.

(2002). Word frequency and context of use in the lexical diffusion of phonetically conditioned sound change. *Language Variation and Change* **14**: 261–90.

Bybee, Joan & Paul J. Hopper (eds.) 2001. *Frequency and the Emergence of Linguistic Structure*. Amsterdam: John Benjamins.

Bye, Patrik (2007). Allomorphy – selection, not optimization. In Sylvia Blaho, Patrick Bye & Martin Krämer (eds.), *Freedom of Analysis?* Berlin: Mouton. 63–91.

Carey, Susan (2009). *Origins of Concepts*. Oxford University Press.

Chomsky, Noam (1964). *Current Issues in Linguistic Theory*. The Hague: Mouton.

(1995). *The Minimalist Program*. Cambridge, MA: MIT Press.

Chomsky, Noam & Morris Halle (1968). *The Sound Pattern of English*. New York: Harper & Row.

Clayton, Mary L. (1976). The redundance of underlying morpheme-structure conditions. *Language* **52**: 295–313.

Clements, George N. (1986). Syllabification and epenthesis in the Barra dialect of Gaelic. In Koen Bogers, Harry van der Hulst & Maarten Mous (eds.), *The Phonological Representation of Suprasegmentals*. Dordrecht: Foris. 317–36.

(1988). Towards a substantive theory of feature specification. *Proceedings of the Annual Meeting of the North East Linguistic Society (NELS)* **18**: 79–93.

(2001). Representational economy in constraint-based phonology. In T. A. Hall (ed.), *Distinctive Feature Theory*. Berlin: Mouton. 71–146.

(2003). Feature economy in sound systems. *Phonology* **20**: 287–333.

(2009). The role of features in phonological inventories. In Eric Raimy & Charles Cairns (eds.), *Contemporary Views on Architecture and Representations in Phonological Theory*. Cambridge, MA: MIT Press. 19–68.

Clements, George N. & P. A. Hallé (2010). 'Phonetic bases of distinctive features': introduction. *Journal of Phonetics* **38**: 3–9.

Clements, George N. & Elisabeth Hume (1995). The internal organization of speech sounds. In J. Goldsmith (ed.), *Handbook of Phonological Theory*. Oxford: Basil Blackwell. 245–306.

Clements, George N. & Engin Sezer (1982). Vowel and consonant disharmony in Turkish. In Harry van der Hulst & Norval Smith (eds.), *The Structure of Phonological Representations*, vol. 2. Dordrecht: Foris. 213–55.

Coetzee, Andries & Joe Pater (2011). The place of variation in phonological theory. To appear in John Goldsmith, Jason Riggle & Alan Yu (eds.), *The Handbook of Phonological Theory*, 2nd edn. Oxford: Blackwell. 401–34.

Cole, Jennifer (1995). The cycle in phonology. In John A. Goldsmith (ed.), *The Handbook of Phonological Theory*. Malden, MA: Blackwell. 70–113.

Cole, Jennifer & José I. Hualde (2011). Underlying representations. In Marc van Oostendorp, Colin J. Ewen, Elisabeth Hume & Keren Rice (eds.), *The Blackwell Companion to Phonology*. Oxford: Wiley-Blackwell. 1–26.

Coleman, John (2002). Phonetic representations in the mental lexicon. In Jacques Durand & Bernard Laks (eds.), *Phonology, Phonetics, and Cognition*. Oxford University Press. 96–130.

Cooper, F. S., Delattre, P. C., Liberman, A. M., Borst, J. M. & Gerstman, L. J. (1952). Some experiments on the perception of synthetic speech sounds. *Journal of the Acoustical Society of America* **24**: 597–606.

Corballis, Michael C. (2009). The gestural origins of language. *WIREs Cognitive Science* **1**: 2–6.

Corbett, Greville G. (2000). *Number*. Cambridge University Press.

Cuypere, Ludovic de (2008). *Limiting the Iconic*. Amsterdam: John Benjamins.

Dart, Sarah N. (1990). Articulatory and acoustic properties of apical and laminal articulations. PhD dissertation, UCLA. UCLA Working Papers in Linguistics, vol. 79.

D'Introno, Francesco, Enrique del Teso & Rosemary Weston (1995). *Fonética y fonología actual del Español*. Madrid: Cátedra.

Dowty, David (1990). Thematic proto-roles and argument selection. *Language* **67**: 547–619.

Dresher, B. Elan (2003). Contrast and asymmetries in inventories. In Anna-Maria di Sciullo (ed.), *Asymmetries in Grammar,* vol. 2: *Morphology, Phonology, Acquisition*. Amsterdam: John Benjamins. 239–57.

(2008). The contrastive hierarchy in phonology. In Peter Avery, B. Elan Dresher & Keren Rice (eds.), *Contrast in Phonology: Theory, Perception, Acquisition*. Berlin: Mouton de Gruyter. 11–33.

(2009). *The Contrastive Hierarchy in Phonology*. Cambridge University Press.

(2010). Feature hierarchies and contrast in phonology. In Anna Kibort & Greville G. Corbett (eds.), *Features: Perspectives on a Key Notion in Linguistics*. Oxford University Press. 37–63.

(2011). The phoneme. In Marc van Oostendorp, Colin J. Ewen, Elizabeth Hume & Keren Rice (eds.), *The Blackwell Companion to Phonology*. Oxford: Wiley-Blackwell. 241–66.

Dresher, B. Elan, Glyne L. Piggott & Keren D. Rice (1994). Contrast in phonology: overview. *Toronto Working Papers in Linguistics* **13**: iii–xvii.

Durvasula, Karthik, Arild Hestvik, Evan Bradley & Catherine Bradley (2008). ERP-evidence for laryngeal underspecification in English: a mismatch negativity study. Handout distributed at the Western Conference on Linguistics 2008 (WECOL 2008), Davis, CA.

Ellison, T. Mark (1995). Phonological derivation in Optimality Theory. Unpublished ms, University of Edinburgh.

Ernestus, Mirjam & Harald Baayen (2003). Predicting the Unpredictable: Interpreting Neutralized Segments in Dutch. *Language* **79**: 5–38.

Eulitz, Carsten & Aditi Lahiri (2004). Neurobiological evidence for abstract phonological representations in the mental lexicon during speech recognition. *Journal of Cognitive Neuroscience* **16**: 577–83.

Fay, David & Ann Cutler (1977). Malapropisms and the structure of the mental lexicon. *Linguistic Inquiry* **8**: 505–520.

Firth, J. R. (1930). *Speech*. London: Ernest Benn.

Fox, Margalit (2008). *Talking Hands*. New York: Simon & Schuster.

Friedrich, Claudia K., Aditi Lahiri & Carsten Eulitz (2008). Neurophysiological evidence for underspecified lexical representations: asymmetries with word initial variations. *Journal of Experimental Psychology: Human Perception and Performance* **34**: 1545–59.

Fromkin, Victoria A. (ed.) (1973). *Speech Errors as Linguistic Evidence*. The Hague: Mouton.

(1985). Evidence in Linguistics. In *Linguistics and Linguistic Evidence. The LAGB Silver Jubilee Lectures 1984*. Newcastle: Grevatt & Grevatt. 18–38.

Fudge, Eric C. (1967). The nature of phonological primes. *Journal of Linguistics* **3**: 1–176.

Giavazzi, Maria (2009). On the application of velar palatalization in Italian. Poster presented at the 17th *Manchester Phonology Meeting*.

Gnanadesikan, Amalia (1997). Phonology with ternary scales. PhD dissertation, University of Massachusetts, Amherst. [Available on Rutgers Optimality Archive #195, http://roa.rutgers.edu/.]

Golston, Chris (1996). Direct Optimality Theory: representation as pure markedness. *Language* **72**: 713–48.

Golston, Chris & Harry van der Hulst (1999). Stricture is structure. In Ben Hermans & Marc van Oostendorp (eds.), *The Derivational Residue in Phonological Optimality Theory*. Dordrecht: Reidel. 153–74.

Gordon, Matthew J. (2004). New York, Philadelphia, and other northern cities: phonology. In Edgar W. Schneider *et al.* (eds.), *A Handbook of Varieties of English*, vol. 1: *Phonology*. Berlin, New York: Mouton de Gruyter. 282–99.

Grammont, M. (1901). Onomatopées et mots expressifs. In *Trentenaire de la Société pour l'Étude des Langues Romanes*. Montpellier. 261–332.

Grijzenhout, Janet & Martin Krämer (2000). Final devoicing and voicing assimilation in Dutch derivation and cliticization. In Barbara Stiebels & Dieter Wunderlich (eds.), *Lexicon in Focus*. Berlin: Akademie Verlag. 55–82.

Hale, Mark & Charles Reiss (2008). *The Phonological Enterprise*. Oxford University Press.

Hall, Daniel Currie (2007). The role and representation of contrast in phonological theory. PhD dissertation, University of Toronto.

(2008). The voicing system of Île de Groix Breton. Paper presented at the Workshop on Phonological Variation in Voicing, Universiteit Leiden, September 2008.

Hall, T. A. (ed.) (2001). *Distinctive Feature Theory*. Berlin: Mouton.

(2007). Segmental features. In Paul de Lacy (ed.), *The Cambridge Handbook of Phonology*. Cambridge University Press. 311–34.

Halle, Morris (1959). *The Sound Pattern of Russian*. The Hague: Mouton & Co.

(1995). Feature Geometry and Feature Spreading. *Linguistic Inquiry* **26**: 1–46.

(1997). Some consequences of the representation of words in memory. *Lingua* **100**: 91–100.

Halle, Morris & Alec Marantz (1994). Some key features of Distributed Morphology. *MIT Working Papers in Linguistics* **21**: 275–88.

Halle, Morris, Bert Vaux & Andrew Wolfe (2000). On feature spreading and the representation of place of articulation. *Linguistic Inquiry* **31**: 387–444.

Hamilton, Philip (1993). On the internal structure of the coronal node: evidence from Australian languages. MS, University of Toronto.

Harms, Robert T. (1968). *Introduction to Phonological Theory*. Englewood Cliffs, NJ: Prentice-Hall.

Harrington, J. (2006). An acoustic analysis of 'happy-tensing' in the Queen's Christmas broadcasts. *Journal of Phonetics* **34**: 439–57.

Harris, James (2001). Flaps, trills, and syllable structure in Spanish. *MIT Working Papers in Linguistics* 42. Cambridge, MA: MITWPL.

Harris, John (1990). Derived phonological contrasts. In Susan Ramsaran (ed.), *Studies in the Pronunciation of English: A Commemorative Volume in Honour of A. C. Gimson*. London: Routledge. 87–105.

(2007). Representation. In Paul de Lacy (ed.), *The Cambridge Handbook of Phonology*. Cambridge University Press. 119–37.

Harris, John & Geoff Lindsey (1995a). Segmental decomposition and the signal. In Wolfgang U. Dressler, Martin Prinzhorn & John R. Rennison (eds.), *Phonologica 1992: Proceedings of the 7th International Phonology Meeting*. Turin: Rosenberg & Sellier. 97–106.

(1995b). The elements of phonological representation. In Jacques Durand & Francis Katamba (eds.), *Frontiers of Phonology: Atoms, Structures, Derivations*. Harlow, Essex: Longman. 34–79.

Harris, Zellig S. (1944). Simultaneous components in phonology. *Language* **20**: 181–205.

Harrison, K. David & Abigail Kaun (2000). Pattern responsive lexicon optimization. *North East Linguistics Society* **30**: 327–40.

(2001). Patterns, pervasive patterns and feature specification. In T. Alan Hall (ed.), *Distinctive Feature Theory*. Berlin Mouton de Gruyter. 211–36.

Hart, Margot Sue (2010). *Consonant lenition in Danish*. Masters dissertation, University of Tromsø. (Available online through UiT)

Hauser, Marc D., Noam Chomsky & W. Tecumseh Fitch (2002). The faculty of language: What is it, who has it, and how did it evolve? *Science* **298**: 1569–79.

Hawkins, Sarah (2010). Phonological features, auditory objects, and illusions. *Journal of Phonetics* **38**: 60–89.

(in press). Phonetic variation as communicative system: Perception of the particular and the abstract. In C. Fougeron, M. D'Imperio, B. Kühnert & N. Vallée (eds.), *Papers in Laboratory Phonology* X. Berlin: Mouton de Gruyter.

(to appear). Lexical representations. In A. Cohn, C. Fougeron & M. Huffman (eds.), *Handbook of Laboratory Phonology*. Oxford University Press.

Hay, Jennifer, Janet Pierrehumbert & Mary Beckman (2004). Speech perception, well-Formedness, and the statistics of the lexicon. In John Local, Richard Ogden & Rosalind Temple (eds.), *Papers in Laboratory Phonology* VI. Cambridge University Press. 58–74.

Hayes, B., R. Kirchner & D. Steriade (2004). *Phonetically Based Phonology*. Cambridge University Press.

Hinton, Leanne, Johanna Nichols & John J. Ohala (1994). *Sound Symbolism*. Cambridge University Press.

Hockett, Charles F. (1942). A system of descriptive phonology. *Language* **18**: 3–21.

(1961). Linguistic elements and their relations. *Language* **37**: 29–53.

Hudson Kam, Carla L. & Elissa L. Newport (2005). Regularizing unpredictable variation: the roles of adult and child learners in language formation and change. *Language Learning and Development* **1**: 151–95.

Hwang, So-One K., Philip J. Monahan & William J. Idsardi (2010). Underspecification and voicing asymmetries in speech perception. *Phonology* **27**: 205–24.

Ingleby, Michael & Wiebke Brockhaus (2002). Phonological primes: cues and acoustic signatures. In Jacques Durand & Bernard Laks (eds.), *Phonology, Phonetics, and Cognition*. Oxford University Press. 131–50.

Inkelas, Sharon (1994). The consequences of optimization for underspecification. In *Proceedings of the Twenty-Fifth Annual Meeting of the North East Linguistic Society (NELS 25)*. Amherst, MA: GLSA Publications. 287–302.

(2000). Phonotactic blocking through structural immunity. In Barbara Stiebels & Dieter Wunderlich (eds.), *Lexicon in Focus*. Berlin: Akademie Verlag. 7–40.

Inkelas, Sharon, Cemil Orhan Orgun & Cheryl Zoll (1997). Implications of lexical exceptions for the nature of grammar. In Iggy Roca (ed.), *Derivations and Constraints in Phonology*. Oxford: Clarendon Press. 393–418.

Itô, Junko & Armin Mester (1995a). Japanese phonology. In John Goldsmith (ed.), *The Handbook of Phonological Theory*. Oxford: Blackwell. 817–38.

(1995b). The core-periphery structure of the lexicon and constraints on reranking. In Jill Beckman, Suzanne Urbanczyk & Laura Walsh (eds.), *University of Massachusetts Occasional Papers in Linguistics* (*UMOP*) vol. 18: *Papers in Optimality Theory*. Amherst, MA: GLSA publications. 181–209.

(1999). The structure of the phonological lexicon. In Natsuko Tsujimura, (ed.), *The Handbook of Japanese Linguistics*. Malden, MA, and Oxford: Blackwell. 62–100.

(2003). On the sources of opacity in OT: coda processes in German. In Caroline Féry & Ruben van de Vijver (eds.), *The Syllable in Optimality Theory*. Cambridge University Press. 271–303.

(2009). Lexical classes in phonology. In Shigeru Miyagawa & Mamoru Saito (eds.), *The Oxford Handbook of Japanese Linguistics*. Oxford University Press. 84–106.

Itô, J., A. Mester & J. Padgett (1995). Licensing and underspecification in optimality theory. *Linguistic Inquiry*, **26**: 571–613.

Iverson, G. K. & J. C. Salmons (1995). Aspiration and laryngeal representation in Germanic. *Phonology* **12**: 369–96.

Jakobson, Roman (1939). Observations sur le classement phonologique des consonnes. In Edgard Blancquaert & Willem Pée (eds.), *Proceedings of the Third International Congress of Phonetic Sciences*. Ghent: Laboratory of phonetics of the University. 34–41.

(1941). *Kindersprache, Aphasie und allgemeine Lautgesetze*. Uppsala: Almquist & Wiksells.

(1973). *Essais de linguistique générale: rapports internes et externes du langage: Arguments*. Paris: Minuit.

Jakobson, Roman, Gunnar Fant & Morris Halle (1952). *Preliminaries to Speech Analysis*. Cambridge, MA: MIT Press.

Jakobson, Roman & Morris Halle (1956). *Fundamentals of Language*. The Hague: Mouton.

Jakobson, Roman & Linda Waugh (1979). *The Sound Shape of Language*. Bloomington: Indiana University Press.

Jespersen, Otto (1922a). Lydsymbolik. *Nordisk Tidskrift for Vetenskap, Kunst og Industri* **2**: 122–31.

(1922b). *Language – Its nature, Development and Origin*. London: Allen & Unwin.

([1922] 1933). Symbolic value of the vowel *i*. In his *Linguistica: Selected Papers in English, French and German*. Copenhagen: Levin & Munksgaard. 283–303.

Johnson, Keith (1997). Speech perception without speaker normalization. In Keith Johnson & John W. Mullennix (eds.), *Talker Variability in Speech Processing*. San Diego, CA: Academic Press. 145–65.

(2006). Resonance in an exemplar-based lexicon: the emergence of social identity and phonology. *Journal of Phonetics* **34**: 485–99.

Jurgec, Peter & Bruce Morén Duolljá (2008). When representational economy yields cross-linguistic results. Talk given at the Substance-free Workshop, 5 June 2008, University of Tromsø.

Kager, René (1999). *Optimality Theory*. Cambridge University Press.

(2008). Lexical irregularity and the typology of contrast. In Kristin Hanson & Sharon Inkelas (eds.), *The Nature of the Word: Essays in Honor of Paul Kiparsky*. Cambridge, MA: MIT Press. 397–432.

Kaisse, Ellen & Patricia Shaw (1985). On the theory of lexical phonology. *Phonology Yearbook* **2**: 1–30.

Kang, Yoonjung (2009). A brief remark on the role of phonetics in phonology. *Toronto Working Papers in Linguistics* **30**: 131–47.

Kaye, Jonathan (1981). Recoverability, abstractness and phonotactic constraints. In Didier L. Goyvaerts (ed.), *Phonology in the 1980s*. Ghent: E. Story-Scientia. 469–81.

Kaye, Jonathan, Jean Lowenstamm & Jean-Roger Vergnaud (1985). The internal structure of phonological elements: a theory of charm and government. *Phonology* **2**: 305–28.

(1990). Constituent structure and government in phonology. *Phonology Yearbook* **7**: 193–231.

Keating, Patricia (1985). *Universal Phonetics and the Organization of Grammars*. In Victoria A. Fromkin (ed.), *Phonetic Linguistics: Essays in Honor of Peter Ladefoged*. New York: Academic Press. 115–32.

(1988). Underspecification in phonetics. *Phonology* **5**: 275–92.

Kehrein, Wolfgang (2002). *Phonological Representation and Phonetic Phasing. Affricates and Laryngeals*. Tübingen: Niemeyer.

Kenstowicz, Michael & Charles Kisseberth (1977). *Topics in Phonological Theory*. New York: Academic Press.

Keyser, Samuel J. & Kenneth N. Stevens (1994). Feature Geometry and the vocal tract. *Phonology* **11**: 207–36.

Kiparsky, Paul (1973a). Phonological representations. In Osamu Fujimura (ed.), *Three Dimensions of Linguistic Theory*. Tokyo: TEC. 3–136. (Chapter 1 'How abstract is phonology?' first distributed 1968 by the Indiana Linguistics Club.)

(1973b). 'Elsewhere' in phonology. In S. Anderson & P. Kiparsky (eds.), *A Festschrift for Morris Halle*. New York: Holt, Rinehart & Winston. 93–106.

(1982a). From cyclic phonology to lexical phonology. In Harry van der Hulst & Norval Smith (eds.), *The Structure of Phonological Representations*. Dordrecht: Foris. 131–75.

(1982b). Lexical phonology and morphology. In I. S. Yang (ed.), *Linguistics in the Morning Calm*. Seoul: Hanshin. 3–91.

(1985). Some consequences of lexical phonology. In *Phonology Yearbook* **2**: 85–135.

Kirchner, Robert (1993). Turkish vowel harmony and disharmony: an optimality theoretic account. Paper presented at Rutgers Optimality Workshop I (ROW I), 22 October.

Kisseberth, Charles (1970). On the functional unity of phonological rules. *Linguistic Inquiry* **1**: 291–306.

Kostakis, Andrew (2010). Vestige theory: sociolinguistic evidence for output–output constraints. *Lingua* **120**: 2476–96.

Krämer, Martin (2000). Voicing alternations and underlying representations: the case of Breton. *Lingua* **110**: 639–63.

(2001). Yucatec Maya vowel alternations: harmony as syntagmatic identity. *Zeitschrift für Sprachwissenschaft* **20**: 175–217.

(2003). *Vowel Harmony and Correspondence Theory*. Berlin and New York: Mouton de Gruyter.

(2006a). The emergence of the comparatively unmarked. In Donald Baumer, David Montero & Michael Scanlon (eds.), *Proceedings of the 25th West Coast Conference on Formal Linguistics*. Somerville, MA: Cascadilla Press. 236–44.

(2006b). Optimal underlying representations. In Leah Bateman & Cherlon Ussery (eds.), *Proceedings of the Thirty-Fifth Annual Meeting of the North East Linguistic Society*. Amherst, MA: GLSA Publications. 351–65.

(2008). Taking a free ride can cau[r]se severe hyperrhoticity. Talk presented at the 16th Manchester Phonology Meeting, 22–24 May 2008, Manchester.

(2009a). Hypercorrection and underlying representation. Talk given at the GLOW 32 Workshop 'The Lexicon – if any', Nantes, 15 April 2009.

(2009b). *The Phonology of Italian*. Oxford University Press.

(2009c). The stuff of features. Talk given at the Toronto–Tromsø Phonology Workshop, University of Toronto, 9–11 October 2009.

(2010). The semantics of phonological features. Talk given at the 18th Manchester Phonology Meeting, Manchester, 20–22 May 2010.

Labov, William (1972). The social stratification of (r) in New York City department stores. In W. Labov (ed.), *Sociolinguistic Patterns*. Philadelphia: University of Pennsylvania Press, 43–69.

(1994). *Principles of Linguistic Change,* vol. 1: *Internal Factors*. Oxford: Blackwell.

Labrune, Laurence (2012). *The Phonology of Japanese*. Oxford University Press.

Ladefoged, Peter (2001). *A Course in Phonetics*, 4th edn. Fort Worth: Harcourt College.

Ladefoged, Peter, Jenny Ladefoged, Alice Turk, Kevin Hind & St John Skilton (1998). Phonetic structures of Scottish Gaelic. *Journal of the International Phonetic Association* **28**: 1–42.

Ladefoged, Peter & Ian Maddieson (1996). *The Sounds of the World's Languages*. Oxford: Blackwell.

Lahiri, Aditi & William Marslen-Wilson (1991). The mental representation of lexical form: a phonological approach to the recognition lexicon. *Cognition* **38**: 245–94.

Lahiri, Aditi & Henning Reetz (2002). Underspecified recognition. In Carlos Gussenhoven & Natasha Warner (eds.), *Laboratory Phonology 7*. Berlin and New York: Mouton de Gruyter. 637–75.

(2010). Distinctive features: phonological underspecification in representation and processing. *Journal of Phonetics* **38**: 44–59.

Lamontagne, Greg & Keren Rice (1995). A correspondence account of coalescence. In Jill N. Beckman, Laura Walsh Dickey & Suzanne Urbanczyk (eds.), *University of Massachusetts Occasional Papers in Linguistics* 18. University of Massachusetts, Amherst. 211–24.

Lass, Roger (1984). *Phonology: An Introduction to Basic Concepts*. Cambridge University Press.

Legendre, Géraldine, Yoshiro Miyata & Paul Smolensky (1990). Harmonic grammar: a formal multi-level connectionist theory of linguistic well-formedness: theoretical foundations. In *Proceedings of the Twelfth Annual Conference of the Cognitive Science Society*. Hillsdale, NJ: Erlbaum. 388–95.

Levinson, Stephen, Sérgio Meira & the Language and Cognition Group (2003). 'Natural concepts' in the spatial topological domain-adpositional meanings in crosslinguistic perspective: an exercise in semantic typology. *Language* **79**: 485–516.

Liberman, A. M., K. S. Harris, H. S. Hoffman & B. C. Griffith (1957). The discrimination of speech sounds within and across phoneme boundaries. *Journal of Experimental Psychology* **54**: 358–68.

Liberman, Nira & Yaacov Trope (2008). The psychology of transcending the here and now. *Science* **322**: 1201–5.

Lindblom, B. (1984). Can the models of evolutionary biology be applied to phonetic problems? In M. P. R. van den Broecke & A. Cohen (eds.), *Proceedings of the 10th International Congress of Phonetic Sciences*. Dordrecht: Foris. 67–81.

Lombardi, Linda (1991). Laryngeal features and laryngeal neutralization. PhD dissertation, University of Massachusetts, Amherst.

(1995). Dahl's law and privative [voice]. *Linguistic Inquiry* **26**: 365–72.

Marslen-Wilson, W. D. (1984). Function and process in spoken word recognition. In H. Bouma & D. G. Bouwhuis (eds.), *Attention and Performance X: Control of Language Processes*. Hillsdale, NJ: Erlbaum.

(1987). Functional parallelism in spoken word-recognition. In U. Frauenfelder & L. K. Tyler (eds.), *Spoken Word Recognition*. Cambridge, MA: MIT Press.

Marslen-Wilson, W. D., A. Nix & M. G. Gaskell (1995). Phonological variation in lexical access: abstractness, inference and English place assimilation. *Language and Cognitive Processes* **10**: 285–308.

Marslen-Wilson, W. D. & A. Welsh (1978). Processing interactions during word-recognition in continuous speech. *Cognitive Psychology* **10**: 29–63.

Martinet, André (1964). *Elements of General Linguistics*. With a foreword by L. R. Palmer. Translated by Elisabeth Palmer. University of Chicago Press.

Martino, G. & L. E. Marks (2001). Synesthesia: strong and weak. *Current Directions in Psychological Science* **10**: 61–5.

Mascaró, Joan (1976). *Catalan Phonology and the Phonological Cycle*. Bloomington: Indiana University Linguistics Club.

Matthews, John (2010). Progress in L2 proficiency and regress in L2 speech. *Chuo University Working Papers in Linguistics*. Tokyo. 93–115.

McCarthy, John J. (2003). Comparative markedness. *Theoretical Linguistics* **29**: 1–51.

(2005). Taking a free ride in morphophonemic learning. *Catalan Journal of Linguistics* **4**: 19–55.

McCarthy, John & Alan Prince (1995). Faithfulness and reduplicative identity. *University of Massachusetts Occasional Papers in Linguistics (UMOP)* **18**: 249–384.

(1999). Faithfulness and identity in prosodic morphology. In René Kager, Harry van der Hulst & Wim Zonneveld (eds.), *The Prosody–Morphology Interface*. Cambridge University Press. 218–309.

Mielke, Jeff (2008). *The Emergence of Distinctive Features*. Oxford University Press.

Miller, Joane (1994). On the internal structure of phonetic categories: a progress report. *Cognition* **50**: 271–85.

Mohanan, K. P. (1982). *Lexical Phonology*. Bloomington: University of Indiana Linguistics Club.

Mohanan, K. P. (1991). On the bases of radical underspecification. *Natural Language & Linguistic Theory* **9**: 285–325.

Mohanan, K. P. & Tara Mohanan (1984). Lexical phonology of the consonant system of Malayalam. *Linguistic Inquiry* **15**: 575–602.

Morén, Bruce (2003). The parallel structures model of feature geometry. *Working Papers of the Cornell Phonetics Laboratory* **15**: 194–270.

(2004). *Unifying and economizing phonological features and representations: bridging the gap between consonants and vowels*. Talk given at the CASTL/Reykjavík Workshop, 4 June 2004, University of Reykjavík.

(2006). Toward constructing a minimalist phonological feature theory. Talk at CASTL Colloquium, 7 December 2006, University of Tromsø.

(2007). Phonological segment inventories and their phonetic variation: a substance-free approach. Talk at GLOW XXX–Segment Inventories Workshop, 11 April 2007, University of Tromsø.

Morén-Duolljá, Bruce Timothy (2009). Minimalist phonological feature theory: a beginning. Talk at the Toronto–Tromsø Phonology Workshop, Toronto, 9 October 2009, University of Toronto.

Mourelatos, Alexander P. (1978). Events, processes, and states. *Linguistics and Philosophy* **2**: 415–34.

Näätänen, Risto, Anne Lehtokosky, Mietta Lennes, Marie Cheour, Minna Huotilainen, Antti Iivonen, Martti Vainio, Paavo Alku, Risto J. Ilmoniemi, Aavo Luuk, Jüri Allik, Janne Sinkkonen & Kimmo Alho (1997). Language-specific phoneme representations revealed by electric and magnetic brain responses. *Nature* **385**: 432–4.

Neeleman, Ad & Hans van de Koot (2006). On syntactic and phonological representations. *Lingua* **116**: 1524–52.

Nevins, Andrew & Bert Vaux (2007). Underlying representations that do not minimize grammatical violations. In Sylvia Blaho, Patrik Bye & Martin Krämer (eds.), *Freedom of Analysis?* Berlin and New York: Mouton de Gruyter. 35–61.

Newman, Stanley (1944). *Yokuts Language of California*. Viking Fund Publications in Anthropology 2. New York: Viking Fund.

Nygaard, Lynne C., Allison E. Cook & Laura L. Namy (2009). Sound to meaning correspondences facilitate word learning. *Cognition* **112**: 181–6.

Obleser, J., A. Lahiri & C. Eulitz (2004). Magnetic brain response mirrors extraction of phonological features from spoken vowels. *Journal of Cognitive Neuroscience* **16**: 31–9.

Obleser, J., S. K. Scott & C. Eulitz (2006). Now you hear it, now you don't: transient traces of consonants and their unintelligible analogues in the human brain. *Cerebral Cortex* **16**: 1069–76.

Ohala, John J. (1983). The origin of sound patterns in vocal tract constraints. In Peter F. MacNeilage (ed.), *The Production of Speech*. New York: Springer. 189–216.

(1997). Sound symbolism. *Proceedings of the 4th Seoul International Conference on Linguistics [SICOL] 11–15 Aug 1997*. 98–103.

Ortmann, Albert (2004). A factorial typology of number marking. In Gereon Müller, Lutz Gunkel & Gisela Zifonun (eds.), *Explorations in Nominal Inflection*. Berlin: Mouton de Gruyter. 229–67.

Paradis, Carole (1993). On the validity of morpheme structure Constraints. *Canadian Journal of Linguistics/Revue canadienne de linguistique* **38**: 235–56.

Pater, Joe (2009a). Weighted Constraints in Generative Linguistics. *Cognitive Science* **33**: 999–1035.
(2009b). Morpheme-specific phonology: constraint indexation and inconsistency resolution. In Steve Parker (ed.), *Phonological Argumentation: Essays on Evidence and Motivation*. London: Equinox. 123–54.
Pfau, Roland & Markus Steinbach (2005). Plural formation in German Sign Language: constraints and strategies. In H. Leuninger & D. Happ (eds.), *Gebärdensprachen: Struktur, Erwerb, Verwendung* (*Linguistische Berichte* Special Issue 13). Opladen: Westdeutscher Verlag. 111–44.
Pierrehumbert, Janet B. (2001). Exemplar dynamics: word frequency, lenition and contrast. In Joan Bybee & P. Hopper (eds.), *Frequency and the Emergence of Linguistic Structure*. Amsterdam: Benjamins. 137–57.
(2006). The next toolkit. *Journal of Phonetics* **34**: 516–30.
Pinker, Steven (2008). *The Stuff of Thought: Language as a Window into Human Nature*. London: Penguin.
Prince, Alan & Paul Smolensky (2004). *Optimality Theory: Constraint Interaction in Generative Grammar*. Oxford: Blackwell. (First circulated in 1993 as a technical report. Rutgers University and University of Colorado.)
Prince, Alan & Bruce Tesar (2004). Learning phonotactic distributions. In René Kager, Joe Pater & Wim Zonneveld (eds.), *Constraints in Phonological Acquisition*. Cambridge University Press. 245–91.
Proctor, Michael (2009). Gestural characterization of a phonological class: the liquids. PhD dissertation, Yale University.
Pulleyblank, Douglas (1986). Underspecification and low vowel harmony in Okpe. *Studies in African Linguistics* **17**: 119–53.
Ramachandran, V. S. & E. M. Hubbard (2001). Synaesthesia – a window into perception, thought and language. *Journal of Consciousness Studies* **8**(12): 3–34.
Ramchand, Gillian Catriona (2008). *Verb Meaning and the Lexicon: A First-Phase Syntax*. Cambridge University Press.
Rappaport Hovav, Malka & Beth Levin (2000). Classifying single argument verbs. In M. Everaert, P. Coopmans & J. Grimshaw (eds.), *Lexical Specification and Insertion*. Amsterdam: John Benjamins. 269–304.
Rice, Keren (1993). A reexamination of the feature [sonorant]: the status of ‘sonorant obstruents’. *Language* **69**: 308–44.
(2007). Markedness in phonology. In Paul de Lacy (ed.), *The Cambridge Handbook of Phonology*. Cambridge University Press. 79–97.
Ringen, Catherine (1975). Vowel harmony: theoretical implications. PhD dissertation, Indiana University.
Rosch, Eleanor (1978). Principles of Categorization. In Eleanor Rosch & Barbara B. Lloyd (eds.), *Cognition and Categorization*. Hillsdale, NJ: Erlbaum. 27–47.
Sagey, E. (1986). The representation of features and relations in non-linear phonology. PhD dissertation, MIT.

Sandler, Wendy (1989). *Phonological Representation of the Sign*. Berlin: Walter de Gruyter.

(2000). One phonology or two? Sign language and phonological theory. In L. Cheng & R. Sybesma (eds.), *The First Glot International State-of-the-Article Book: the Latest in Linguistics*. Berlin: Mouton de Gruyter, 349–83.

Sandler, Wendy & Diane Lillo-Martin (2006). *Sign Languages and Linguistic Universals*. Cambridge University Press.

Saussure, Ferdinand de (1916). *Cours de linguistique générale*. Paris: Payot.

(1975). *Eléments de linguistique générale*. Paris: Payot.

Schane, Sandford (1985). The fundamentals of Particle Phonology. *Phonology Yearbook* **1**: 129–55.

Scheer, Tobias (2004). *A Lateral Theory of Phonology,* vol. 1*: What is CVCV, and Why Should It Be?* Berlin: Mouton de Gruyter.

Sievers E. (1901). *Grundzüge der Phonetik*. Leipzig: Breitkopf und Härtel.

Smith, Caroline L. (1997). The devoicing of /z/ in American English: effects of local and prosodic context. *Journal of Phonetics* **25**: 471–500.

Smolensky, Paul (1993). Harmony, markedness, and phonological activity. Paper presented at Rutgers Optimality Workshop-1 at Rutgers University: New Brunswick, NJ, October 1993.

(1996). *The Initial State and 'Richness of the Base' in Optimality Theory*. Technical Report, Johns Hopkins University, Baltimore.

Sommerstein, Alan (1977). *Modern Phonology*. London: Edward Arnold.

Stanley, Richard (1967). Redundancy rules in phonology. *Language* **43**: 393–436.

Steriade, Donca (1979). Vowel harmony in Khalka Mongolian, including as an appendix: the input representations to Waripiri's vowel assimilation rules. In K. Safir (ed.), *Papers on Syllable Structure, Metrical Structure, and Harmony Processes*. MIT Working Papers in Linguistics. Cambridge, MA: MIT Dept of Linguistics.

(1987). Redundant values. In A. Bosch, B. Need & E. Schiller (eds.), *Papers from the Parasession on Autosegmental and Metrical Phonology*. Chicago Linguistic Society. 339–62.

(1993). Closure, release, and nasal contours. In M. K. Huffman & R. A. Krakow (eds.), *Nasals, Nasalization, and the Velum*. San Diego: Academic Press. 401—70.

(1994). Complex onsets as single segments: the Mazateco pattern. In J. Cole & C. Kisseberth (eds.), *Perspectives in Phonology*. Stanford, CA: CSLI Publications. 203–91.

(1995). Underspecification and markedness. In John Goldsmith (ed.), *Handbook of Phonological Theory*. Oxford: Blackwell. 114–74.

(2007). Contrast. In Paul de Lacy (ed.), *The Cambridge Handbook of Phonology*. Cambridge University Press. 139–57.

Stevens, Kenneth N. (2005). Features in speech perception and lexical access. In David B. Pisoni & Robert E. Remez (eds.), *Handbook of Speech Perception*. Malden, MA: Blackwell.

Stevens, Kenneth N., & Samuel J. Keyser (1989). Primary features and their enhancement in consonants. *Language* **65**: 81–106.

(2010). Quantal Theory, enhancement and overlap. *Journal of Phonetics* **36**: 10–19.

Strand, Elizabeth A. (2000). Gender stereotype effects in speech processing. PhD dissertation, Ohio State University.

Supalla, Ted & Elissa Newport (1978). How many seats in a chair? The derivation of nouns and verbs in American Sign Language. In P. Siple (ed.), *Understanding Language through Sign Language Research*. New York: Academic Press. 91–132.

Svenonius, Peter (2004). Adpositions, particles, and the arguments they introduce. MS CASTL, University of Tromsø.

Szentgyörgyi, Szilárd (2004). Richness of the base, lexicon optimization and underlying representations in OT. Paper presented at the 12th Manchester Phonology Meeting, 20–22 May 2004, Manchester.

Talmy, L. (1983). How language structures space. In H. Pick & L. Acredolo (eds.), *Spatial Orientation: Theory, Research and Application*. New York: Plenum. 225–82.

(1988). Force dynamics in language and cognition. *Cognitive Science* **12**: 49–100.

Ternes, Elmar (1970). *Grammaire structurale du Breton de l'Île de Groix (dialecte occidental)*. Heidelberg: Carl Winter Universitätsverlag.

Tesar, Bruce & Paul Smolensky (2004). Learning phonotactic distributions. In René Kager, Joe Pater & Wim Zonneveld (eds.), *Constraints in Phonological Acquisition*. Cambridge University Press. 245–91.

Trask, R. L. (1996). *A Dictionary of Phonetics and Phonology*. London: Routledge.

Trigo, L. (1987). On the phonological derivation and behavior of nasal glides. PhD dissertation, MIT.

Trubetzkoy, Nikolai S. ([1939]1971). *Grundzüge der Phonologie*. Göttingen: Vandenhoeck & Ruprecht.

Vaux, Bert (2003). Syllabification in Armenian, Universal Grammar, and the lexicon. *Linguistic Inquiry* **34**: 91–124.

Vendler, Zeno (1957). Verbs and times. *Philosophical Review* **56**: 143–60.

Walter, Mary Ann (in press). Probability matching in Arabic and Romance morphology. In *Perspectives on Arabic Linguistics XXII*. Amsterdam: Benjamins.

Walter, Mary Ann & Valentine Hacquard (2004). MEG evidence for phonological underspecification. In Eric Halgten, Seppo Ahlfors, Matti Hëmäläinen & David Cohen (eds.), *Proceedings of BioMag 2004*. 292–3.

Wells, J. C. (1982). *Accents of English*, 3 vols. Cambridge University Press.

Wheeldon, Linda & Rachelle Waksler (2004). Phonological underspecification and mapping mechanisms in the speech recognition lexicon. *Brain and Language* **90**: 401–12.

Wiese, Richard (1996/2000). *The Phonology of German*. Oxford University Press.

Wonnacott, Elizabeth & Elissa L. Newport (2005). Novelty and regularization: the effect of novel instances on rule formation. In A. Brugos, M. R. Clark-Cotton & S. Ha (eds.), *BUCLD 29: Proceedings of the 29th Annual Boston University Conference on Language Development*. Somerville, MA: Cascadilla Press.

Yip, Moira (1996). Lexicon optimization in languages without alternations. In Jacques Durand & Bernard Laks (eds.), *Current Trends in Phonology: Models and Methods*, vol. 2. European Studies Research Institute (ESRI), University of Salford Publications. 757–88.

Youssef, Islam (2006). Vocalic feature assimilation in Cairene Arabic and Buchan Scots. MPhil thesis, University of Tromsø.

Zoll, Cheryl (1996). Parsing below the segment in a constraint based framework. PhD dissertation, University of California, Berkeley.

Zwicky, Arnold M. (1970). The free-ride principle and two rules of complete assimilation in English. In M. A. Campbell *et al.* (eds.), *Papers from the Sixth Regional Meeting of the Chicago Linguistic Society*. Chicago Linguistic Society. 579–88.

Zwirner, E. (1936). Aufgaben und Methoden der Sprachvergleichung durch Maß und Zahl, Phonometrie. *Zeitschrift für Mundartforschung* **12**.2: 65–82.

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