Towards a computer model of the historical phonology and morphology of Latin.

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Abstract

Research projects in Optimality Theory tend to take a synchronic view of a particular generalisation, and set their standards for rigour in typological terms (see for example Suzuki 1998 on dissimilation, Crosswhite 2001 on vowel reduction). The goal of this thesis is to use Stratal OT to take a diachronic view of multiple generalisations within the morpho-phonology of one language, namely Latin, with the principal empirical aim of producing an analysis that is demonstrably true to all the attested facts of the generalisations in question.

To that end, I have written PyOT, a computer program implementing the OT calculus and a theory of phonological representations, which I use in this work to model the histories of Lachmann's Law, rhotacism and the phonologically conditioned allomorphy of the *-alis/aris-* suffix as active generalisations within the phonological component of the grammar. Appendix A gives the results of the computer model applied to a dataset consisting of 185 attested Latin forms, which suffice to illustrate the exact conditions of the generalisations in question.

I show that producing a complete analysis of the three generalisations I have chosen to model entails analysis of other generalisations that interact with them, including the treatment of the Indo-European voiced aspirates in Latin (which interacts with rhotacism), and reduplication in forming perfect stems (which interacts with Lachmann's Law). Constraint rankings sufficient to model these interactions, and consistent with the general conditions of the interacting generalisations have been included in the model.

The intention is for this work to illustrate both the utility of formal phonological theory in advancing hypotheses within historical-comparative linguistics, and the potential of PyOT as a tool for producing Optimality-Theoretic models of (eventually) a language's entire phonology.

Acknowledgments

As I am not a parent, I have no strong feelings on exactly what it takes to raise a child. Some argue for the sufficiency of a single parent, others for the necessity of a mother and a father, still others claim (in the words of a bestseller) that it takes a village: I would not presume to judge until I've walked a mile in their shoes. Experience does, however, qualify me in saying that there are definite advantages to being able to say *Ich stamm' aus einer traditionellen Doktorfamilie.* Any grad student would be lucky to have Andreas Willi as a *Doktorvater*, or Aditi Lahiri as a *Doktormutter*, but their areas of expertise and attitudes to the student-supervisor relationship so positively and exactly complement one another that to be supervised by both, as I have, is to approach about as nearly as may be the Platonic ideal of support. I really have no excuse for any failings in the result.

If a good academic is married to his work, then I owe a very great debt to the following, who collectively introduced me to my spouse: Philomen Probert introduced me to the problem of Lachmann's Law, and encouraged me to choose it as a topic for my MPhil thesis, which now appears (in modified form) as Chapter 3 of the present work. While I was an undergraduate at the University of Manchester, David Langslow and Ricardo Bermúdez-Otero introduced me to comparative philology and Stratal Optimality Theory respectively, and proved, in so doing, the old adage of the Jesuits: *give me the child until the age of seven* (or twenty-one, as the case may be)...

Audiences at Oxford's own Comparative Philology Seminar, OnLI-II, LSA-2011, 19mfm and LAGB-2011 were very patient with me as I inflicted presentations of various parts of this work on them, and repaid me handsomely with insightful questions and comments. Certain amendments to manuscripts suggested by anonymous reviewers for *LI* and the *Transactions of PhilSoc* have also made their way into the text of this thesis, for which I am grateful.

Finally, I only wish I had realised sooner how necessary it is to have a group of peers around you who are going or have gone through the same things you are, and how sterling such a bunch can be found in the Language and Brain Lab. So, in no particular order, Eedoo, Ninjara, Catsaddles, Bruv, Hippie Jackie O, Pennyfarthing, Flygirl, Big Daddy and Ellie (otherwise Nora), you are all wonderful human beings, and I thank you from the bottom of my heart for keeping me, well, not exactly sane (a lost cause), but at least the most productive kind of mad.

Contents

Chapter 1

Introduction

1.1 Goals

This thesis seeks to demonstrate some of the ways in which modern phonological theory and traditional historical-comparative reconstruction can complement each other. It is my belief that theoretical abstractions from phonology, properly employed, can be used as a kind of "scaffolding", from which it becomes possible to advance more ambitious hypotheses about the sound and sound development of dead languages than could otherwise be sustained without sacrificing empirical rigour. Conversely, bringing to bear philological techniques of recovering as much phonetic substance as possible from orthographic representations can provide a valuable raft of data against which to test theories of phonology, helping us to do as much as possible with the material we have on hand.

The danger in any analysis that crosses the lines between sub-disciplines is that the grey area between the two will be used for nothing more than reasonable doubt: that the author will hide the parts of the analysis that are questionable from the point of view of one discipline in the technical argot of the other, and hope that those literate enough in the one to spot the problem will not notice it due to their relative unfamiliarity with the other. I have, I believe, avoided all temptations toward this strategy; instead, I intend this work to stand as an example of linguistic philology and theoretical phonology reinforcing one another while meeting their best and most exacting standards of scientific rigour.

1.1.1 On rigour

Comparative philology

The Neogrammarian hypothesis entails a standard of rigour that is well understood in the practice of comparative reconstruction. "Economy" is the watchword: sound changes must be regular, and not multiplied to meet the needs of a theory without corroborating evidence. Unfortunately, economy is to a certain extent in the eye of the beholder: for example, Bammesberger (1989) apparently felt it was important to economise on the number of phonemes reconstructed for PIE, and so attempted to argue that the evidence of Greek supported the reconstruction of only one laryngeal; most philologists, however, took issue with his methodology, particularly his assertion that the distribution of vocalic reflexes of his single laryngeal was random (see Swiggers 1989 in the same volume, and the review article by Garrett 1991).

Though they may disagree on the proper application of the standard, however, comparative philologists are united in taking a dim view of analyses which multiply grammatical entities of any kind in a manner that does not seem plausible from what is otherwise known about the language being studied (see e.g. the desiderata for an ideal theory listed in Willi 2010: 6–7).

It is into this niche, that of "what is known about the language being studied" that I propose to fit insights from theoretical phonology. In this respect, I am in one sense doing nothing new: There has been an ongoing dialogue between the generative tradition and historical linguistics since at least the late sixties, with the publication of Kiparsky (1965); Chomsky & Halle (1968) and King (1969)[1]. What I believe has changed is that best practice in theoretical phonology, particularly but not exclusively within Optimality Theory, has now achieved parity in terms of empirical rigour with best practice in comparative philology.

Theoretical phonology

The potential for empirical rigour in Optimality Theory arises from its fundamental axiom that the constraint set (Con) is universal: instead of arguing that observable patterns in the sound of a language are somehow present in the mind of themselves (*à la* SPE), OT models a phonological generalisation as an emergent property of the interaction between basic violable constraints on the form of utterances produced by any speaker. These constraints are either available to the child learning language as part of an innate faculty of Universal Grammar (as assumed by Prince & Smolensky 1993), or can be relied upon to be discovered by the learner as she monitors her own process of acquiring language by mimesis of her elders (see Bermúdez-Otero & Börjars 2006).

Regardless of how constraints make themselves available to the speaker, there are explicit conditions on what constitutes a plausible constraint as proposed by a

[1]See e.g. Reis (1970); Wetzels & Jacobs (1988); Dresher & Lahiri (1991); Lahiri & Dresher (1999) and the summary of the history of the field offered by Adamson & Ayres-Bennett (2011)

linguist. For one, a well-formed markedness constraint should mirror an observable implicational universal: the structure it penalises as marked should only be tolerated alongside a corresponding structure it does not penalise (see e.g. Kager 1999: 93–4). For another, it is promising to be able to observe that children acquire the structure penalised by a proposed constraint later than the minimally different one that is not (Kager 1999: 336). In general, a new constraint is much more expensive to propose than a new rule, as it constitutes a hypothesis about the nature of the phonology of all languages, and must be evaluated as such. This consideration is made explicit by McCarthy (2002: 39–42), who observes that the gold standard of practice for an OT analysis that introduces new constraints is factorial typology: a formal examination of the behaviours predicted by the new constraint in every possible permutation of rankings with respect to those constraints that already exist. Best practice in OT, then, consists in offering a factorial typology for any constraint that you propose *de novo*, and in general using only those constraints to which the techniques of factorial typology have been applied.

If the approach I have just laid out constitutes best practice, then it must be conceded that customary practice in the field is often less than optimal. Quite apart from the fact that it is not uncommon for OT constraints to be defined *ad hoc* for the purpose of analysing a specific phenomenon, OT makes no particular claims about the theory of phonological representations it manipulates. This is welcome in one sense, as it allows for OT to be tested as a possible solution to any linguistic problem, or indeed to any problem which seems to call for a heuristic function. However, the result is that OT phonologists tend to assume the theories of representations most favourable to their own analyses, and the result is fragmentation, with different communities of researchers producing OT analyses that rely on mutually incompatible assumptions about the nature of phonological representations.

This in itself is no insurmountable hardship; we can simply let the competing theories of representation stand or fall based on the accuracy of the predictions they make with respect to attested data. Unfortunately, some theories of representation are less formally rigorous than others, and their lack of formal rigour vitiates the otherwise impeccable formal rigour of any OT analysis built on them.

In commenting on the lack of formal specification of linguistic analyses, Pullum (1989: 138) proposes the following "non-negotiable [...] statements of intent, for formal theories of grammar":

(1)
a. "The notion 'structural representation' must be effective. That is, there must be an algorithm for determining whether some arbitrary string, graph, or diagram counts as a structural representation according to the theory.
b. "The notion of 'rule' (or 'principle' or 'law' or 'condition' or 'constraint' or 'filter' or whatever) must be effective. That is, there must be an algorithm for determining whether some arbitrary string, graph, or diagram is a rule (or 'principle' or 'law'...) according to the theory.
c. "The notion 'generates' (or 'admits' or 'licenses' or whatever) must be effective. That is, there must be an algorithm for determining whether some arbitrary structural representation is generated (or admitted or licensed...) by a given set of rules (or 'principles' or 'laws'...)."

If we know nothing about the theory of representations, OT only clearly fulfils criterion (1c), in that the EVAL function provides a formally specified means of selecting the optimal candidate, and thus the output, for a given input based on the ranking of constraints. However, even this satisfaction of the condition is incomplete: EVAL requires a set of candidates to compare, which is provided by the Gen function, a function which may in principle generate every possible representation as a candidate. The definition of "every possible representation", of course, depends on the theory of representations satisfying criterion (1a). Then, too, constraints, whose formal rigour is required by criterion (1b) must be defined in terms of the theory of representations: a markedness constraint assesses violations when particular representational structures appear in a candidate, and a faithfulness constraint assesses violations when the input and the candidate differ in some respect specified in terms of their structure. Clearly, therefore, the analytical rigour of an OT analysis stands or falls according to the rigour with which its theory of representations is defined.

A theory must satisfy the criteria in (1) *a fortiori* if that theory has been implemented as a computer program. This fact forms a part of my rationale for performing my analyses of historical phenomena using a computer program. The exact nature of the theory of representations and OT calculus I have implemented is described in §1.2.

Modelling phonological change

As I have said above (p. 7), I believe phonological theory has usefulness in comparative reconstruction in answering the question "Is this sound change I have proposed a possible one, given the facts of the language in which it takes place?" Answering this question in OT terms requires us to complete three tasks:

(2) a. Gather pairs of forms, either attested or reconstructed, which represent the state of the language before and after the change took place.

b. Propose constraint rankings and inputs that generate the correct outputs for each of the proposed diachronic stages, before the change and after.

c. Compare the "before" and "after" grammars and lexica, assessing the changes necessary to move from one to the other for plausibility of acquisition from one generation to the next. In particular, can the outputs of the "before" stage plausibly prompt a generation of learners to acquire the inputs of the "after" stage?

The proper approach to data gathering will be discussed below (p. 15). For the present, it suffices to point out that a comprehensive set of data is necessary to produce a maximally rigorous account of a given change. Ideally, we should gather not only every available example of the change, but also every apparent exception to the rule (if any), and at least a representative set of forms we do not expect to show the change whose phonological representations are minimally distinct from the forms that do show it.

Identifying the outputs we expect to find is usually straightforward: unless the forms concerned are affected by other sound changes we are not attempting to model, the output will simply be identical to the attested form. Even in this case, however, we must remember that the attested forms themselves are orthographic, and our hypothetical output must be specified in phonological terms. This necessitates hypotheses about the phonology of the language under study, which must be made and tested before the analysis can begin.

There are two possible dimensions along which the "before" and "after" grammars may differ: the constraint ranking may change, and/or the input may change.

Jacobs (1995) points out that these possibilities map neatly onto the two classic possibilities for language change with phonological consequences: regular, Neogrammarian-style sound change and lexical analogy.

To assess the plausibility of a constraint re-ranking, there are two possible indices. One is theory-internal: how great is the difference between the two rankings? Is the change simply a matter of swapping the places of two adjacent constraints in the ranking, or moving one constraint from one ranking "slot" to another, or some other change that can be considered to be a quantum leap? The other index is perhaps more compelling: can the "after" ranking plausibly be acquired by learners given the output of the "before" ranking as a stimulus?

This index may be the more plausible because it can potentially be evaluated by a formal algorithm: Tesar & Smolensky (1998) provide a formal model of how an OT grammar can be acquired: by applying their Error-Driven Constraint Demotion algorithm to the output of the "before" stage, it is possible to evaluate the likelihood that the "after" generation might acquire a given constraint ranking.

One factor we have thus far not taken into account is the interaction between phonology and morphology. It has repeatedly been observed that phonological generalisations often behave in unexpected ways when morpheme boundaries intervene in their environments, and furthermore it has often been observed that, taking a diachronic view, the longer a generalisation has been part of a phonology, the more likely it is to underapply at morpheme boundaries (Bermúdez-Otero 2011). We will deal with this life cycle of phonological processes in full in chapter 2, in which I illustrate that the diachronic progress of Latin rhotacism is exactly that which we would expect given the theory of the life cycle. In the meantime, I should note here that my analyses will employ Stratal Optimality Theory, a version of OT that makes the life cycle an explicit part of its architecture.

Stratal Optimality Theory (Stratal OT: Kiparsky 2000b) retains the basic theoretical architecture proposed by Prince & Smolensky (1993): the phonology maps an input onto an output by evaluating an exhaustive candidate set against a transitively ranked hierarchy of constraints, and selecting as output the candidate whose violations are least expensive. Where Stratal OT and Classic OT differ is in their approach to opacity and the morphology-phonology interface.

Stratal OT accounts for the fact that some phonological processes are sensitive to boundaries by re-introducing a very limited degree of serialism into the generation of outputs. The derivation of an output from an input, in Stratal OT, involves three, and only three, Optimality-Theoretic co-phonologies: the stem-level, the word-level and the phrase-level. If a given input contains a stem-level domain (which is defined idiosyncratically from language to language), the material in the stem-level domain is passed as input to the stem-level co-phonology; the material in the prosodic word is then concatenated with the output from the stem-level, and passed through the word-level co-phonology, and finally the outputs from the word-level co-phonology for each prosodic word are concatenated together and passed as input to the phrase-level co-phonology, which produces the whole utterance as its output.

Like its predecessor, Lexical Phonology (Kiparsky 1982b,c), Stratal OT incorporates the life cycle of phonological generalisations into its basic architecture: as analogy causes the domain of a phonological process to shrink, generations of learners acquire constraint rankings at progressively higher strata of the grammar (Bermúdez-Otero 2003). We may therefore have to reckon with not one but three constraint rankings in any given generation's phonological grammar, and we should consider it a plausible change for a generation to acquire the same constraint ranking as its elders, but at a higher level of the grammar.

In assessing the plausibility of an input restructuring, that is to say of an analogy, we are faced with the same question as for a constraint ranking: given the output of the "before" grammar as a stimulus, how plausible is it that the "after" generation will acquire the input hypothesised? In general we expect that the output of the "before" grammar will be adopted as the input of the "after" grammar, however, another input may be acquired if it would be a better fit for patterns in the underlying representations (see Tesar & Smolensky 1996: 41, Kiparsky 2000a: 15). We shall see practical examples of this in the final stage of the life cycle of Latin rhotacism and in the case of liquid dissimilation (chapter 2).

Choice of phenomena

The standard aim for an OT analysis with respect to empirical rigour is typological: it is common for an OT research project to focus on one kind of phonological generalisation, and show that a given constraint set is capable of modelling every variant of it that is found to be attested (see, for example, Suzuki (1998)'s typology of dissimilation phenomena, or Crosswhite (2001)'s study of vowel reduction). The emphasis on factorial typology and the universality of Con within OT makes this a natural focus for research within the theoretical paradigm, but concentrating on typological studies of specific phenomena to the exclusion of all else causes an important question to go relatively unaddressed: to what extent is OT capable of serving as the theoretical basis for a model of an entire grammar?

In order to address this question within the constraints of time and scope imposed by the nature of this project, I have chosen three phonological generalisations from the history of Latin: the first is rhotacism, the tendency for intervocalic *s* to become *r*; the second is the phonologically-conditioned allomorphy of the suffix -*ālis/āris*-, which interacts with rhotacism in forms like *flōrālis* 'floral', *plūrālis* 'plural'. The third is Lachmann's Law, which never directly interacts with the other two, but whose history, I will argue, must overlap with them to a certain degree. In the ensuing chapters, I will demonstrate and explore the unforeseen consequences that can arise when the attempt is made to account for the full extent and history of each of these generalisations within the same model.

Doing full justice to the generalisations I have chosen requires gathering a relatively large amount of data, representing every condition on the environment of the generalisation as it progresses through the life cycle. The size of the data set almost demands an automated analysis if exhaustive candidate sets are to be generated and evaluated for each datum, so I have couched my theoretical analyses in terms of a computer model.

Data gathering

Recent developments in the availability and power of information technology resources in linguistics have led to a qualitatively significant increase in the potential for empirical rigour. Keynote speakers at the annual meetings both of the Linguistic Society of America and the Linguistic Association of Great Britain in 2011 have remarked on this. In his valedictory address as President of the LSA, David Lightfoot spoke of a "unique moment in the history of science" precipitated by the ready availability of "cyberinfrastructure"[2]. In his Henry Sweet Lecture at the

[2]January 9th, 2011; slides available at `http://www.lsadc.org/info/documents/2011/annual-meeting/lightfoot.ppt`, last accessed 15th February 2012

2011 LAGB meeting, Mark Liberman spoke of "the coming golden age of speech and language science", and averred that "new analysis techniques and inexpensive computation, constitute an extraordinary new scientific instrument, a modern equivalent of the 17th-century invention of the telescope and microscope."[3]

The practical consequence of these observations for present purposes has been that quantitative data, be it derived from experiments or corpus studies, is now a *sine qua non* of empirical credibility in linguistics.

There has been another consequence for the proposal of theoretical analyses, one that gains particular point in OT: sufficient computing power to generate and evaluate candidates can now be found on almost every linguist's desk, and high-level interpreted programming languages make it possible for one to be a linguist by the majority of one's training, and learn enough about programming to test one's theories computationally almost in one's spare time.

I have endeavoured to take full advantage of the opportunities the availability of computing technology affords: as I mentioned above (p. 9), a theory must have formal rigour of definition if a computer can be programmed to implement it. I have therefore written a computer program that implements a theory of phonological representations, and applies the OT calculus to them. This has proven necessary because the enhanced standard of rigour that is called for by the wide availability of corpora almost demands a way of automating the analysis of the data gathered from them.

In studying language change using written data from ancient languages, experimental methods are of course inapplicable, but the other pre-requisite for "golden

[3]An abstract of a similar lecture can be found at `http://ling.umd.edu/events/archive/125/`.

age" rigour, data gathered from corpora, still applies. We will see in chapter 2 that a corpus study has already shown that the facts of Latin liquid dissimilation are more nuanced than those that appear in the handbooks (Cser 2010), with the effect that an OT analysis relying on the textbook descriptive accounts that has already been proposed (Suzuki 1998) must in fact be wrong.

In the analysis of the mini-corpus I have built, which contains 185 examples of the phonological generalisations I have chosen to address, each of which must be evaluated against multiple iterations of the OT algorithm, the need for an automated analysis makes itself felt. To conduct this analysis, I have designed a computational OT machine with a fully-specified theory of phonological representations, which I will now describe.

1.2 Method — computational phonology

PyOT, my implementation of OT, is so named because it is written in Python, a widely available interpreted programming language. The choice to use Python was based on a number of considerations:

In the first place, Python is regarded as being comparatively easy to learn, which has made it possible for me to develop PyOT in it rapidly and, I hope, will make it possible for other linguists who are so minded to learn Python and help develop PyOT to encompass more analyses in the future.

In the second place, Python programs are cross-platform: a program written in Python under MacOS, for example, will run equally well under Windows or Linux, without modification.

Finally, Python, like many other languages, implements the object-oriented programming model (OOP). OOP is a framework that encourages the programmer to model the memory state of his/her program in terms of objects—of abstract constructs with which particular pieces of information that the program stores are associated. This metaphor is a useful one for computational phonology: phonologists are accustomed to thinking of syllables, feet, and other units of prosodic structure as abstract objects, so PyOT's theory of representations builds on that mode of thinking.

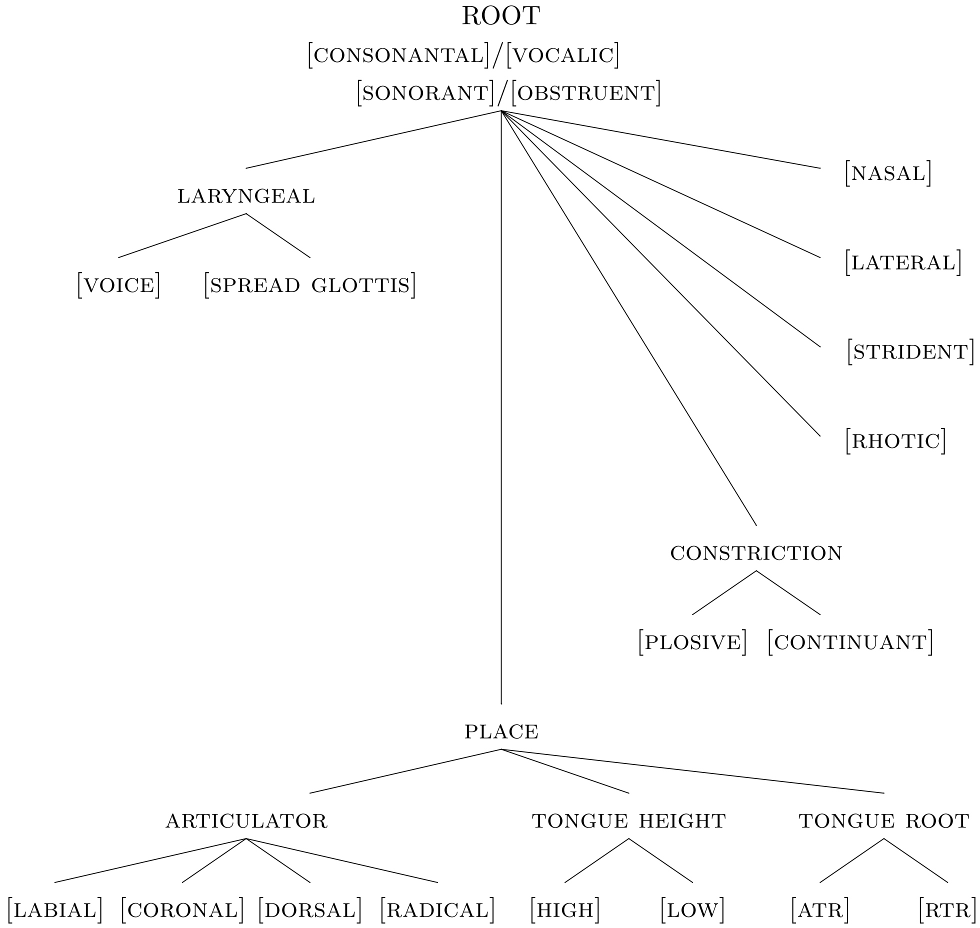
The source code of PyOT and programs to demonstrate it are provided as part of the accompanying software. When I make explicit reference to a Python function or object in the source code, I will use `typewriter-style type`.

1.2.1 Theory of representations

Distinctive features

The inventory of features that PyOT's theory of representations employs is taken from the Featurally Underspecified Lexicon (FUL) model (Lahiri & Reetz 2010). The geometry of features in FUL is as follows:

(3) Feature geometry in FUL:



(Lahiri & Reetz 2010: 46)

The pairs [CONSONANTAL]/[VOCALIC] and [SONORANT]/[OBSTRUENT] are mutually exclusive and obligatorily specified: to be well-formed, a segment must be specified as either [CONS] or [VOC], not both (and not neither). This makes these feature pairs equivalent to e.g. [±cons] and [±obs] in SPE, as SPE segments are assumed to be specified + or − for every distinctive feature (Chomsky & Halle 1968: 64–69). All other features in FUL are privative: either a segment is specified for a given feature or it is not. The pairs ([ATR], [RTR]) and ([HIGH], [LOW]) are also mutually exclusive; a segment cannot be specified for both members of either pair. Unlike [CONSONANTAL]/[VOCALIC] and [SONORANT]/[OBSTRUENT], however, a legal segment can be specified as bearing neither feature.

It should be noted at this point that this is not an attempt to implement the Featurally Underspecified Lexicon itself: we will not be assuming in our model that segments are underspecified for default features such as [CORONAL] (cf. Lahiri & Reetz 2002, 2010). Rather, I have chosen to employ the FUL system of distinctive features because it represents a deliberate attempt on the part of its authors to apply Occam's Razor to feature theory as fully as possible. In the first place, the inventory of features is explicitly kept as small as possible while remaining powerful enough to encode constrasts between phonemes in any language in the world (Lahiri & Reetz 2010: 46). The fact that features are privative also limits multiplication of entities, as there are only two possible settings for any given feature, rather than the settings +, − and (not specified) that a binary system potentially allows for. This choice of distinctive feature systems is made so that the model will test, among other things, the claims of economy that the feature system makes, without attempting to implement the broader theoretical claims of FUL.

`Segment` objects in `OT.representations` inherit from the built-in datatype that Python provides to model sets. They are defined as sets of strings corresponding to the features the segment is specified for. There is also a function `OT.representations.possibleSegment`, which takes a `Segment` object as its argument, and checks it for well-formedness according to the conditions in FUL described above: illicit specifications with respect to the feature pairs ([CONS], [VOC]), ([OBS, SON]), ([HIGH], [LOW]) and ([ATR], [RTR]) cause the function to return `False`, indicating that the segment is impossible according to FUL. `False` is also returned if any of the strings in the `Segment` does not correspond to a feature in the FUL inventory.

The `possibleSegment` function is provided so that the GEN function can rule out ill-formed candidate segments before attempting to build any higher-order prosodic structures on them[4]. The function is kept separate from the definition of the `Segment` class, however, so that other distinctive feature systems can be modelled. From the point of view of the `Segment` object, and of the functions that encode constraints in PyOT, the members of a `Segment` set are simply strings, to be compared with one another and manipulated using Python's normal functions. As a result, changing the inventory of features, or modifying the well-formedness conditions on segments arising from feature geometry, requires only minimal changes to the program.

`Segment` objects also have an `indices` property, which is used for computing violations of correspondence constraints. For example, when evaluating an input/candidate pair with respect to IDENT-[RHOTIC], the function `Ident` looks for pairs of segments in the input and output that have the same value for `indices['IO']`, and assigns a violation if they have different specifications for the feature [RHOTIC].

For the purposes of general syllabification, as well as for the evaluation of constraints enforcing sonority sequencing, it is necessary for the theory of representations to be able to assess the sonority of a `Segment` object. The approach I have taken is to add a function `gradeSonority` to the module. `gradeSonority` assigns a numerical score to a given `Segment` object based on its FUL features, according to the following formula:

[4] We will discuss methods of filtering the output of `Gen` further below (p. 40)

(4) Sonority scoring algorithm for PyOT with FUL features:

a. Start with a base score of 4.

b. For each of the following features, if it is present in the segment, deduct 1 from the score: [CONSONANTAL, OBSTRUENT, LATERAL, RHOTIC, HIGH]

c. If the segment has the feature [VOCALIC] add 1 to the score. If it also has the feature [LOW], add 1 again.

d. If the segment has the feature [SONORANT], add 2 to the score.

e. If the segment has the feature [PLOSIVE], deduct 2 from the score.

This results in the following mapping of feature complexes to sonority scores:

(5) Sonority scores assessed by PyOT, listed by segment class:

Segment class	Features	Score
plosive	[CONS, OBS, PLOS]	0
fricative	[CONS, OBS, CONT]	2
nasal	[CONS, SON, PLOS, NAS]	3
liquid	[CONS, SON, LAT]	4
	[CONS, SON, RHO]	4
semivowel	[CONS, SON]	5
high vowel	[VOC, HIGH]	6
mid vowel	[VOC]	7
low vowel	[VOC, LOW]	8

Contrastively long segments (geminate consonants and long vowels) are modelled as sequences of two identical `Segment` objects, which have the same `indices` property. This allows for long segments to be treated as equivalent to any other pair of segments when the situation calls for it (e.g. when computing syllable weight, or dealing with heterosyllabic geminate clusters), or treated as a single, inalterable segment when that is necessary (e.g. when changing the featural specification of the segment in order to generate a violation of IDENT).

Syllables

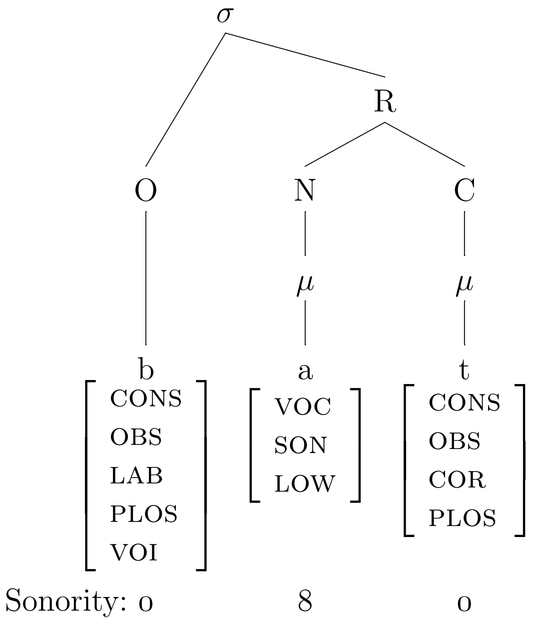
All prosodic categories in `OT.representations` inherit from Python's built-in `list` datatype, a type that serves as an all-purpose container for ordered sequences of objects. A `Syllable` object representing a syllable such as [$_\sigma$bat], then, is from the computer program's point of view a sequence of three `Segment` objects representing /b/, /a/ and /t/ respectively. `Syllable` objects also have considerable internal structure, however.

To begin with, there are three attributes `Syllable.ons`, `Syllable.nuc` and `Syllable.cod`, which are lists representing, as their names suggest, the onset, nucleus and coda of the object respectively. The object also provides a `hierarchize` function, which assigns the segments within it to the `ons`, `nuc` and `cod`, depending on their sonority. It proceeds by looking for the leftmost `Segment` object in the syllable that has a sonority score of 5 or above (i.e. is a vowel). This `Segment` is assigned to the `nuc` attribute, as are `Segment`s following it until one is found whose sonority drops below 5. Thereafter, `Segment`s are assigned to the `cod` attribute. All `Segment`s preceding the first vowel are placed in the `ons`.

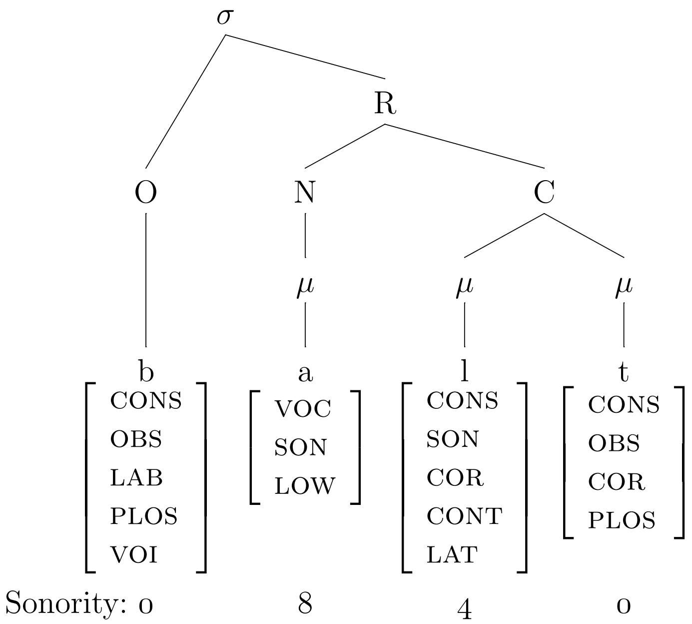
If no `Segment` with a sonority score above 5 is found, `hierarchize` looks for the leftmost pair of two sequential `Segment`s in the `Syllable` object such that the second `Segment` has a lower sonority score than the first. The `cod` is then taken to begin with the second `Segment`, and the first is assigned to the `nuc`, as are `Segment`s immediately preceding it that are of equal sonority, if any.

This function gives the following results in the cases of the syllables [$_{\sigma}$bat], [$_{\sigma}$balt], [$_{\sigma}$bait] and [$_{\sigma}$bl̩t]:

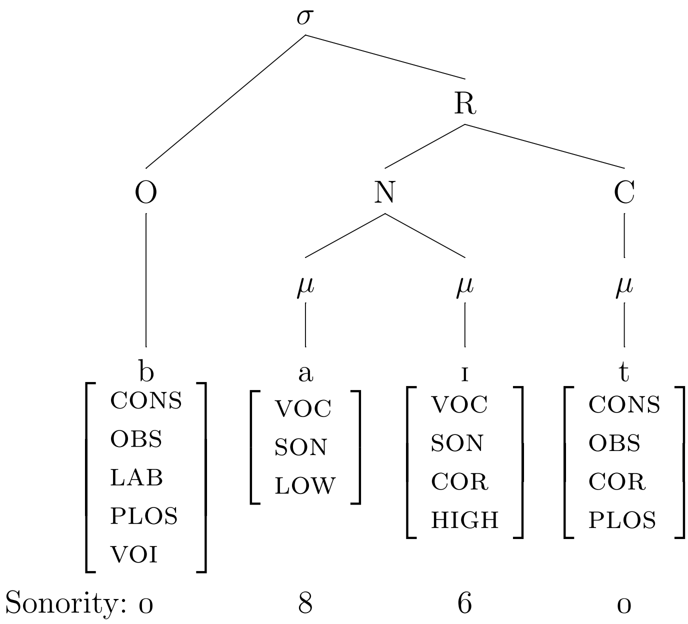
(6) Schematic of the object `OT.Syllable('bat')`:



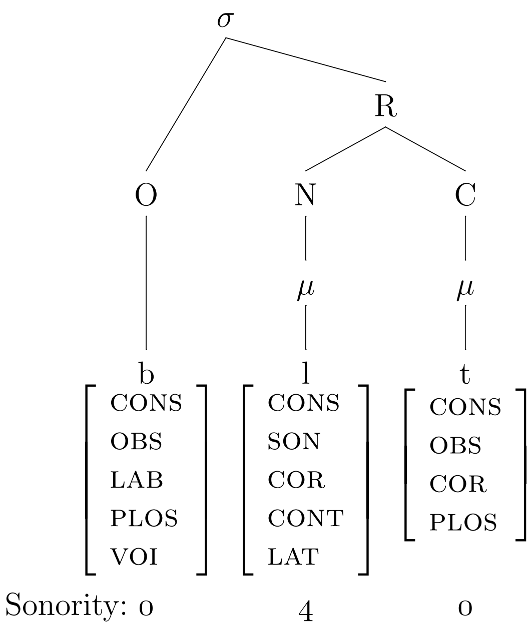
(7) Schematic of the object `OT.Syllable('balt')`:



(8) Schematic of the object `OT.Syllable('bait')`:



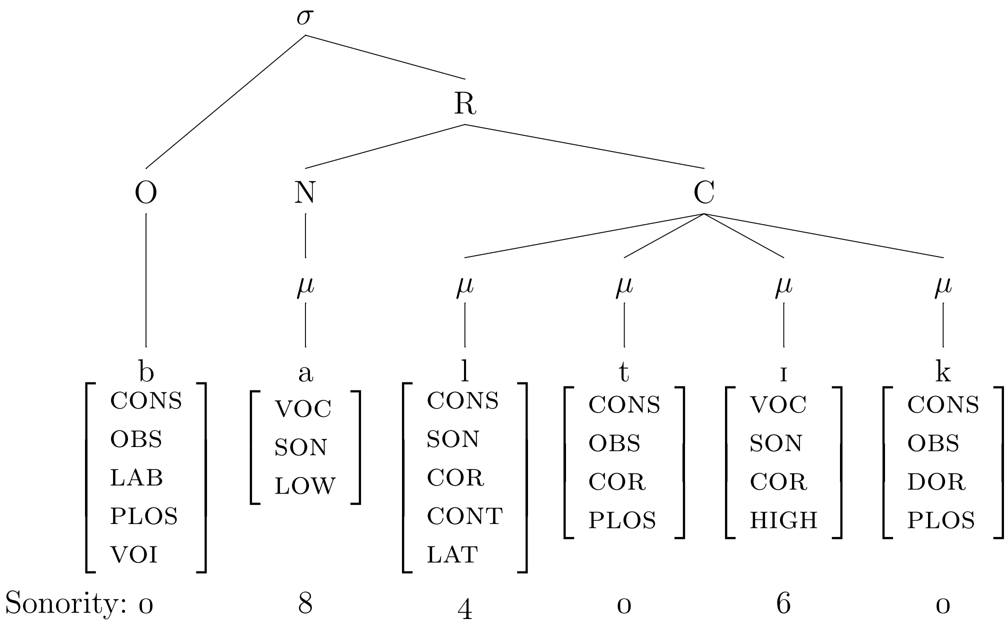
(9) Schematic of the object `OT.Syllable('blt')`:



In this way, `hierarchize` captures the facts about sonority sequencing that seem to be genuinely universal, namely that a vowel will always be in the nucleus of a syllable in which it appears, and that absent a vowel, the highest-sonority segment occupies the nucleus, as best it can without altering the contents of the syllable to which it is applied. Further, more nuanced, restrictions on the sonority of syllables are assumed to be part of the individual language's phonotactics, and so are implemented by the ranking of sonority sequencing constraints.

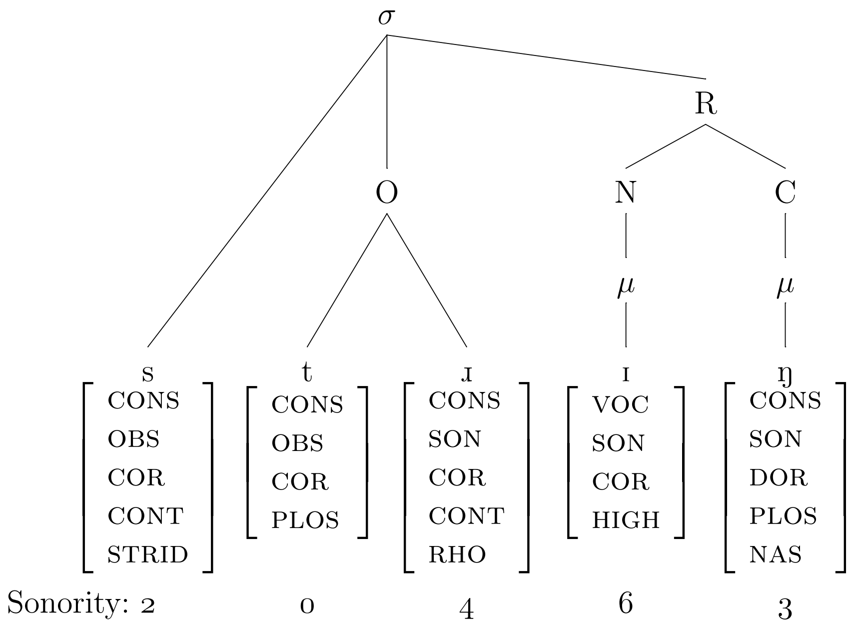
In cases where there are multiple vowels in the syllable, `hierarchize` will always select the leftmost one to be the syllabic nucleus, regardless of the sonority score of any `Segment` following it:

(10) Schematic of the object `OT.Syllable('baltik')`:



The module also makes provision for a `Segment` to be in a `Syllable` object, but not in the syllable's `ons`, `nuc`, or `cod` attributes. This is used to account for cases in which certain segments are apparently exempt from sonority sequencing, as with English coronal fricatives in e.g. /stɹɪŋ/, /sɪksθs/ etc. (see Cruttenden 2001: 240ff.). A `Syllable` object representing the word *string* in PyOT looks like this:

(11) Schematic of the object `OT.Syllable('strɪŋ')`:



This approach to modelling edgemost segments of this kind has the side-effect that non-parsed coda segments also do not "make position", that is that a segment has to be parsed into the `cod` of a `Syllable` whose nucleus consists of a light vowel for the `Syllable` to count as heavy. This is because the weight of a `Syllable` is computed by the `getMoraCount` function, which simply returns the sum of the number of segments in the `nuc` and the number of segments in the `cod`.

Feet and higher categories

Like `Syllable` objects, the `Foot`, `ProsodicWord` and `ProsodicPhrase` objects in PyOT's theory of representations are subclasses of the built-in `list` datatype, that is to say that they represent ordered sequences of the objects contained within them. They also have an optional `head` attribute, which may be set to the index of the most prominent member of the object. So, in the `Foot` object representing the sequence (ˈko.la), the `head` attribute will be 0, as indices in Python are counted from zero, so the 0th element of the object is the syllable [$_\sigma$ko], which is the head of the foot. In the right-headed equivalent, (ko.ˈla), the `head` attribute would be 1.

By the same token, the distinction between primary and secondary stress is captured by the assigment of the `head` attribute of the `ProsodicWord`. The representation of [$_\omega$(ˌko.la)(ˈbet)], for example, consists of a `ProsodicWord` object containing two `Foot` objects. The `head` of each of the `Foot` objects is 0, as the first syllable is prominent in each. The `head` of the `ProsodicWord` object is 1, as it is the second (counting from zero) of the two `Foot` objects that is the more prominent.

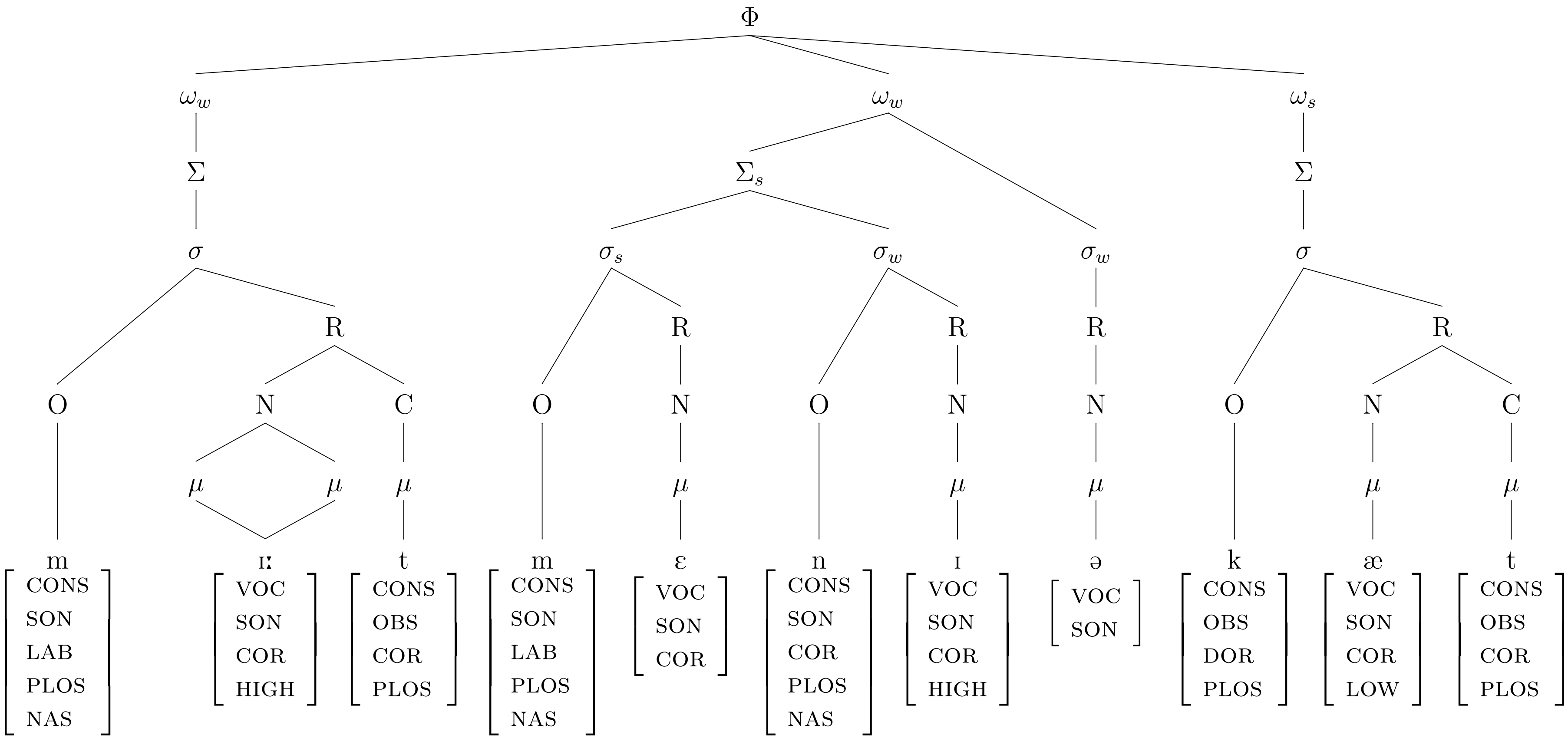
No explicit checks are performed by the `representations` module itself on the kinds of objects that are put inside any of the objects representing prosodic categories. It would be possible, for example, to construct a `ProsodicWord` that contained a `ProsodicPhrase` that contained a `ProsodicWord`, an illegal structure from the point of view of phonological theory. This is prevented from happening by the implementation of Gen in the `OT.gen` module, which is so designed as to build only valid prosodic structures (see page 40). The convenience functions used to construct inputs from transcriptions entered by the user are also specified so as to output only well-formed structures (see page 32).

This creates the potential for the model to be extended: if it is found necessary for a new type of object to be dominated by a `ProsodicWord`, for example, it will be necessary only to define the datatype for the new object, and add to the `gen` module so that Gen generates objects of the new type in the appropriate position. The goal is for extension of the model to be possible with a minimum of modifications to the existing code.

This design choice allows syllables that are not parsed into feet to be modelled without further ado: `Syllable` objects can appear within a `Foot`, or within a `ProsodicWord`, or within any other object. The code within the `gen` module that generates foot structure is designed to generate candidates such that any given `Syllable` may appear within a `Foot` or a `ProsodicWord`, representing parsed and unparsed syllables respectively.

To illustrate these objects in use, the following is the structure PyOT builds for the sentence *meet many a cat* /$[_{\Phi}[_{\omega}$(ˈmiːt)$][_{\omega}$(ˈmɛ.ni)ə$][_{\omega}$(ˈkæt)$]]$/, in which sentence stress is assumed to fall on the word *cat*:

(12) Schematic of the object `OT.Utterance(u"(miːt)|('mɛ.ni)ə|('kæt)‖")`



One final datatype that needs to be mentioned is that of `Utterance` objects. This type also subclasses `list`, and is designed to contain objects of all the other types described in this section, and serve as the basic type for inputs and outputs of the OT machine. It offers various convenience functions for inspecting the structure of the utterance it represents, and for specifying its constituent structure based on a transcription input by the user.

Convenience functions

As we have seen in the preceding section, a phonological representation appears to PyOT as a kind of sequence, containing other sequences which may themselves contain either other sequences of similar kinds, or sets of features corresponding to segments. The "native" form of such an object, from Python's point of view, looks like this:

(13) Output of the statement `print OT.Utterance(u"(mi:t)|('mɛ.ni)ə|('kat)||")`:

```
[[[[[Segment([u'nas', u'cons', u'lab', u'plos', u'son']),
     Segment([u'high', u'son', u'cor', u'voi', u'voc']),
     Segment([u'high', u'son', u'cor', u'voi', u'voc']),
     Segment([u'cons', u'obs', u'plos', u'cor'])
  ]]],
  [[[Segment([u'nas', u'cons', u'lab', u'plos', u'son']),
     Segment([u'voi', u'son', u'cor', u'voc'])
    ],
    [Segment([u'nas', u'cons', u'cor', u'plos', u'son']),
```

```
      Segment([u'high', u'son', u'cor', u'voi', u'voc'])
    ]],
    [Segment([u'voc'])
    ]],
   [[[Segment([u'dor', u'cons', u'obs', u'plos']),
      Segment([u'dor', u'son', u'low', u'voi', u'voc']),
      Segment([u'cons', u'obs', u'plos', u'cor'])
 ]]]]]
```

Representations like the one in (13) (to which indentation and carriage returns have been added manually) are not particularly convenient for the user either to specify as OT inputs or to parse by eye when presented by PyOT as candidates. To avoid this necessity, PyOT's `representations` module provides methods for parsing phonemic transcriptions into `Utterance` objects, and rendering representations of objects in a variety of formats.

For this to be possible, the program needs to be aware of the symbols that can be used in transcription to represent specific segments. As the assignment of features to segments in FUL is language-specific (Lahiri & Reetz 2002: 638ff), PyOT includes files containing mappings of feature sets to IPA, X-SAMPA and TIPA[5] transcriptions. The program expects to find one of each of these files for any given language, and also has a fallback set which it uses to match `Segment`s to transcriptions when no language has been specified. The feature mapping for Latin segments is as follows:

[5]IPA being the International Phonetic Alphabet (see The International Phonetic Association 1999), X-SAMPA being the Extended SAM (Speech Assessment Methods) Phonetic Alphabet (Wells 1997), and TIPA being the encoding used to render phonetic symbols in LaTeX (Rei 1996)

(14) FUL features for Latin segments (generated based on the file `latin.tipa`):

Feature complex	Transcription
[CONS, OBS, PLOS, LAB]	p
[CONS, OBS, PLOS, COR]	t
[CONS, OBS, PLOS, DOR]	k
[CONS, OBS, PLOS, DOR, LAB]	k^w
[CONS, OBS, VOI, PLOS, LAB]	b
[CONS, OBS, VOI, PLOS, COR]	d
[CONS, OBS, VOI, PLOS, DOR]	g
[CONS, OBS, VOI, PLOS, DOR, LAB]	g^w
[CONS, OBS, SPRGL, PLOS, LAB]	p^h
[CONS, OBS, SPRGL, PLOS, COR]	t^h
[CONS, OBS, SPRGL, PLOS, DOR]	k^h
[CONS, SON, NAS, LAB]	m
[CONS, SON, NAS, COR]	n
[CONS, SON, NAS, DOR]	ŋ
[CONS, OBS, CONT, LAB]	ɸ
[CONS, OBS, STRID, CONT, LAB]	f
[CONS, OBS, STRID, CONT, COR]	s
[CONS, OBS, CONT, COR]	θ
[CONS, OBS, CONT, DOR]	x
[CONS, OBS, CONT, DOR, LAB]	x^w
[CONS, OBS, CONT, RAD]	h

[CONS, OBS, CONT, LAB, VOI]	β
[CONS, OBS, STRID, CONT, LAB, VOI]	v
[CONS, OBS, CONT, COR, VOI]	ð
[CONS, OBS, CONT, DOR, VOI]	ɣ
[CONS, OBS, CONT, DOR, LAB, VOI]	ɣʷ
[CONS, SON, RHO, COR]	r
[CONS, SON, LAT, COR]	l
[CONS, SON, HIGH, DOR, LAB]	w
[CONS, SON, HIGH, COR]	j
[VOC, SON, RTR, COR]	ɪ
[VOC, SON, RTR, COR, HIGH]	ɪ̞
[VOC, SON, RTR, DOR, HIGH, LAB]	ʊ̞
[VOC, SON, HIGH, COR]	i
[VOC, SON, COR]	e
[VOC, SON, LOW, DOR]	a
[VOC, SON, DOR, LAB]	o
[VOC, SON, HIGH, DOR, LAB]	u

This is not intended to represent the segment inventory of any one diachronic stage of the language's development (cf. the inventory of segments for the classical language discussed by Allen 1978: 11–63, Meiser 1998: 52). Rather, it represents transcriptions for every segment that appears at any level of representation at any diachronic stage in our model. It therefore includes, for example, series of voiced and voiceless non-strident fricatives [ɸ, β, θ, ð, x, ɣ, xʷ, ɣʷ] to represent the reflexes of the Indo-European voiced aspirates in the prehistoric language (which are analysed in §2.2.1). Long vowels do not appear separately, because they are represented in PyOT as sequences of two identical `Segment` objects.

The transcription file provides a definition in terms of features for every segment we expect to find as an output from a PyOT analysis of Latin. It follows from this that a well-composed set of transcription files can also serve as an output segment inventory. The use of transcription sets in this way to filter the output of `Gen` is documented below (p. 44).

These transcription sets are used by the function `prettyPrint` to produce human-readable representations of the objects documented in this section. Boundaries between prosodic constitutents are represented in transcriptions in a fairly conventional way, as seen below:

(15) Output of the statement `print`

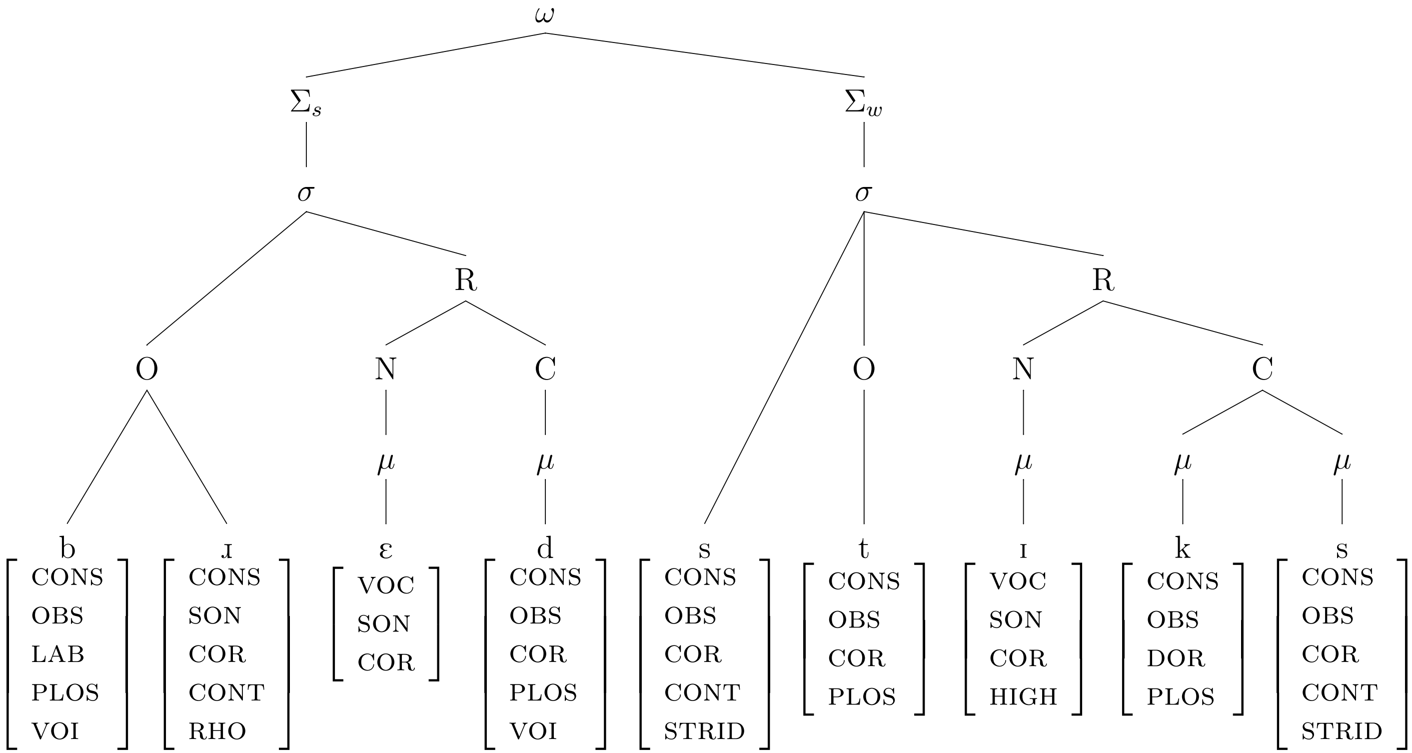
```
OT.Utterance(u"(mi:t)|('mE.ni)@|('kæt)||Im('pæ.rIs)").prettyPrint('tipa'):
```

(ˈmɪːt) | (ˈmɛ.nɪ)ə | (ˈkæt) ‖ ɪm(ˈpæ.ɹɪs)

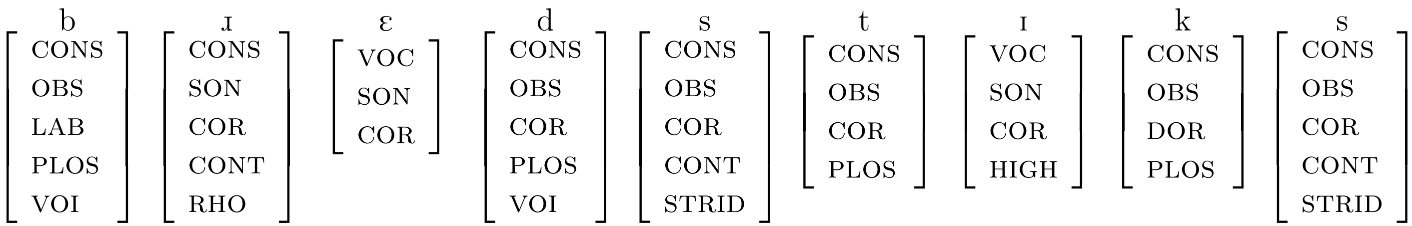
Syllable boundaries are marked with a `.` character, feet are bounded with parentheses `()`, prosodic word boundaries are marked with single vertical lines (|), and prosodic phrase boundaries are marked with double vertical lines (‖). These conventions are respected both for displaying transcriptions and for parsing transcriptions specified by the user (e.g. as input to the OT machine).

Another convenience method provided by the `representations` module is the `flatten` function. This function is used to disregard all prosodic structure in a given `Utterance` object up to a specific level, so that, for instance, if we are only interested in the segments contained within a given `Utterance`, we can apply `flatten` and obtain an `Utterance` object with no higher-order structure:

(16) Schematic of the object `OT.Utterance('''('brEd)("stIks)''')`



(17) Schematic of the object `OT.flatten(OT.Utterance('''('brEd)("stIks)'''), OT.Segment))`



This function is useful for the user when inspecting `Utterance` objects (s)he has created, but mainly its purpose is to facilitate writing functions to encode OT constraints, as constraints typically assign violations based on the candidate's structure at a single tier of the prosodic hierarchy. As we shall see in the next section, PyOT makes use of the ability to flatten a representation not only when evaluating constraints, but also when generating candidates.

1.2.2 OT calculus

My goal in implementing the heuristic function specified by OT is not to mimic the functioning of the human brain directly. Instead, I take it as an assumption that OT constitutes an accurate model of human linguistic cognition, and confine myself to attempting to implement the OT calculus in whatever way best takes advantage of the computer's resources.

The most exacting design question in implementing OT is how to minimize the amount of time it takes to search the space of possible representations for the optimal candidate. Freedom of Analysis dictates that every possible form in the theory of representations is evaluated as a candidate for any given input. Whether or not this theoretical candidate set is finite or infinite depends on the nature of the theory of representations. In either case, however, it is certainly intractably large for a computational analysis. I shall now proceed to discuss the ways in which I and others have set about constraining the space of candidates to be searched, while still generating enough candidates to be sure that the ranking is subjected to a fully rigorous test.

Gen function

Frank & Satta (1998) have demonstrated, with a mathematical proof, that any OT constraint can be computed by a finite-state automaton, provided that there is an upper bound on the number of violations the constraint can assess. Building on this result, Karttunen (1998) presents an algorithm for generating and evaluating all candidates that are not harmonically bounded, by using a finite-state transducer that is the product of finite-state machines representing all constraints in the ranking. A similar algorithm has been implemented by Riggle (2004b,a), and released as part of the PyPhon package, another computational OT machine written in Python. Citing the argument of Karttunen (1993) that generative phonology can be modelled as a finite-state process, Frank and Satta argue for a restriction on the form of OT constraints as follows:

> Constraints should be limited in the number of distinctions they can make in levels of violation. We suspect that following this regimen will necessitate a shift in the type of optimization which is carried out in OT, from global optimization over arbitrarily large representations to local optimization over structural domains of bounded complexity (where only a bounded number of violations can possible occur).

Frank & Satta (1998: 8)

Even granting that the empirical predictions of Karttunen (1993)'s argument have yet to be falsified, this prescription seems methodologically suspect. I tend to agree with Asudeh & Toivonen (2006: 677) "that the theory should constrain the formalism and not the other way around." Therefore, I have not attempted to implement constraints as necessarily being finite-state machines; rather, they are defined as Python functions, and may potentially be evaluated with reference to any amount of context. It should be noted, however, that every constraint I have implemented so far could be modelled as a finite-state automaton, though in some cases there is no theoretical upper bound on the number of violations. Since I do not implement constraints explicitly according to the prescription of Frank & Satta (1998), I am, of course, unable to simultaneously generate and evaluate candidates according to the nature of the constraint ranking in the way that Karttunen (1998) does.

Instead, the approach I have taken has been to restrict the output of PyOT's Gen based on the faithfulness constraints that appear in the ranking passed to the `Grammar` object. I take this approach in reflection of a common practice employed when generating candidates "by hand"—that is, using the unaided imagination to devise candidates for tableaux: it is customary to treat faithfulness constraints not included in the ranking under test as though they were placed in an undominated ranking stratum above all constraints explicitly mentioned, like so:

(18) A representative tableau, generated by PyOT based on tableau (9b) from Lombardi (1999: 274):

/gut/	OnsIdent-[voi]	VOP	Ident-[voi]
1. kut	*!		*
2. kud	*!	*	**
3. ☞ gut		*	
4. gud		**!	*

(19) Tableau illustrating ranking of faithfulness constraints implicit in (18)

/gut/	Max	Dep	Ident-[lab]	OnsIdent-[voi]	VOP	Ident-[voi]
1. kut				*!		*
2. ☞ gut					*	
3. kud				*!	*	**
4. gud					**!	*
5. ut	*!					
6. e.gut		*!			*	
7. gɯt			*!		*	

Candidates (19:5,6,7) were no doubt not included in the original tableau because they were not germane to the point at issue: they instantiated other phonological repair strategies than Lombardi (1999) was attempting to model. Regardless of the practical reason for omitting them, however, in theoretical terms the equivalent behaviour consists of assigning faithfulness constraints that penalise other repair strategies to an undominated stratum. PyOT's `Gen` function restricts the candidate space it explores by the same means, and so approximates conventional OT practice, while still performing an exhaustive search, and so ensuring that all potentially relevant candidates are found.

To generate the candidates for the input and ranking in tableau (18), PyOT's `Gen` proceeds as follows:

(20) Input to the `Grammar` object that generates tableau (18):

$$\overset{\text{g}}{\begin{bmatrix}\text{CONS}\\\text{OBS}\\\text{DOR}\\\text{PLOS}\\\text{VOI}\end{bmatrix}}\quad\overset{\text{u}}{\begin{bmatrix}\text{VOC}\\\text{SON}\\\text{LAB}\\\text{DOR}\\\text{HIGH}\\\text{VOI}\end{bmatrix}}\quad\overset{\text{t}}{\begin{bmatrix}\text{CONS}\\\text{OBS}\\\text{COR}\\\text{PLOS}\end{bmatrix}}$$

(21) Constraint ranking: OnsIdent-[voi] $\gg$ VOP $\gg$ Ident-[voi]

(22) Procedure of the `Gen` function:

a. `Gen` begins by using the `flatten` function to discard all structure from the input of a level higher than that of the `Segment`. In this case, (20) has no such structure, but for any input, `Gen` would proceed to work with a representation that consists only of a linear sequence of `Segment` objects.

Working state: [gut]

b. `Gen` then examines the constraint ranking, and generates every possible permutation of violations of the faithfulness constraints that it finds. In this case, it finds only Ident-[voi], and so generates candidates with every possible permutation of specifications with respect to the feature [voice].

Working state: [gud, gut, kud, kut, gu̥d, gu̥t, ku̥d, ku̥t]

c. Finally, `Gen` builds prosodic structure on top of the segmental variants it has already generated, up to the level specified by the user. In this case, we are only interested in the syllabic structure, so `Gen` yields every possible syllabification of every possible segmental variant we have already generated.

Final state: [k̩.ut, k̩.u.t̩, gut, g̩.ut, gu.t̩, g̩.u.t̩, k̩.ud, k̩.u.d̩, gud, g̩.ud, gu.d̩, g̩.u.d̩, kut, ku.t̩, kud, ku.d̩]

In order to restrict `Gen` to producing only those candidates seen in tableau (18), I have generalised the principle of restricting the candidate space by implicitly assigning constraints to an undominated stratum: `Gen` can be provided with a `filter`, consisting of a sequence of constraints that must not be violated by any candidate `Gen` yields. This allows `Gen` to discard a candidate that violates a filter constraint as soon as it has generated enough structure for the filter constraint to apply: in the case of the constraint FtBin, for example, which penalises outputs in which feet are not binary, `Gen` will not attempt to build `ProsodicWord` or `ProsodicPhrase` structure on top of any candidate which contains a foot that violates FtBin, if FtBin appears in the filter.

There exists a special function `inventoryFilter` in the `gen` module, which can be included in the filter to restrict the candidate space for Ident violations still further. If this function is found in the filter, `Gen` will generate candidates violating Ident containing only `Segments` for which there exists a transcription in the `representations` module's set for that particular language.

This requires that the transcription set for the language being studied contain a robust inventory of all possible segments in the language. In principle, the composition of the segment inventory of a language should be a function of its constraint ranking, so that restricting the output to contain only segments from the inventory could be done with regular filter constraints. However, when the composition of the segment inventory is not the main object of the analysis, using the transcription set in this way can be a useful shortcut, if the transcription set is carefully composed.

Unless otherwise indicated, all tableaux in this thesis have been generated by PyOT, and, in addition to the input and constraint ranking, I will indicate the filter constraints and maximum level of prosodic structure specified to the program, like so:

(23) A representative tableau, generated by PyOT based on tableau (9b) from Lombardi (1999: 274):

Maximum level of structure: `Syllable`

Filter constraints:

*C̩: Assess a violation for every consonant in the output that is dominated by a syllabic nucleus.

*V̥: Assess a violation for every vowel in the output that lacks the feature [VOICE].

/gut/	OnsIdent-[voi]	VOP	Ident-[voi]
1. kut	*!		*
2. kud	*!	*	**
3. ☞ gut		*	
4. gud		**!	*

Definition of constraints

As mentioned above (p. 40), constraints in PyOT are implemented as Python functions, with one function for each constraint schema. Constraints have a uniform interface, giving the function access to the input, the candidate and an arbitrary number of arguments. To illustrate this in practice, the following is the source code for the Ident constraint schema:

(24)
```
def Ident(inp, outp, *args):
    out = 0

    for seg in flatten(outp):
```

```
5           if inp.unitByIndex(seg.index):
6               if ((args[0] in seg) !=
7                   (args[0] in inp.unitByIndex(seg.index))):
8                   out += 1
9
10      return out
```

Line 1 defines the function according to the standard interface, such that it expects parameters `inp`, which should be an `Utterance` object representing the input, `outp`, an `Utterance` representing the candidate being evaluated, and a sequence of arguments `args`. In this case, `Ident` expects that `args` will contain one object representing the feature under test, such as e.g. the string `'voi'`, representing the [voice] feature.

Line 4 uses the `flatten` function to treat the candidate `outp` as a sequence of segments, through which it iterates. Line 5 tests whether the input `inp` has a segment that corresponds to the segment under test, and if it does, lines 6 and 7 test whether the corresponding segments are different with respect to the feature passed to the function as the first member of `args`. If indeed they are different, line 8 increments the number of violations assessed by 1.

Finally, line 10 causes the function to return a value equal to the number of violations of the constraint found in the candidate `outp`.

Particular instances of a given constraint schema are defined as sequences consisting of the function representing the schema, followed by any arguments that need to be passed. So, the PyOT representation of the constraint Ident-[voi] looks like this: `(OT.constraints.Ident, 'voi')`.

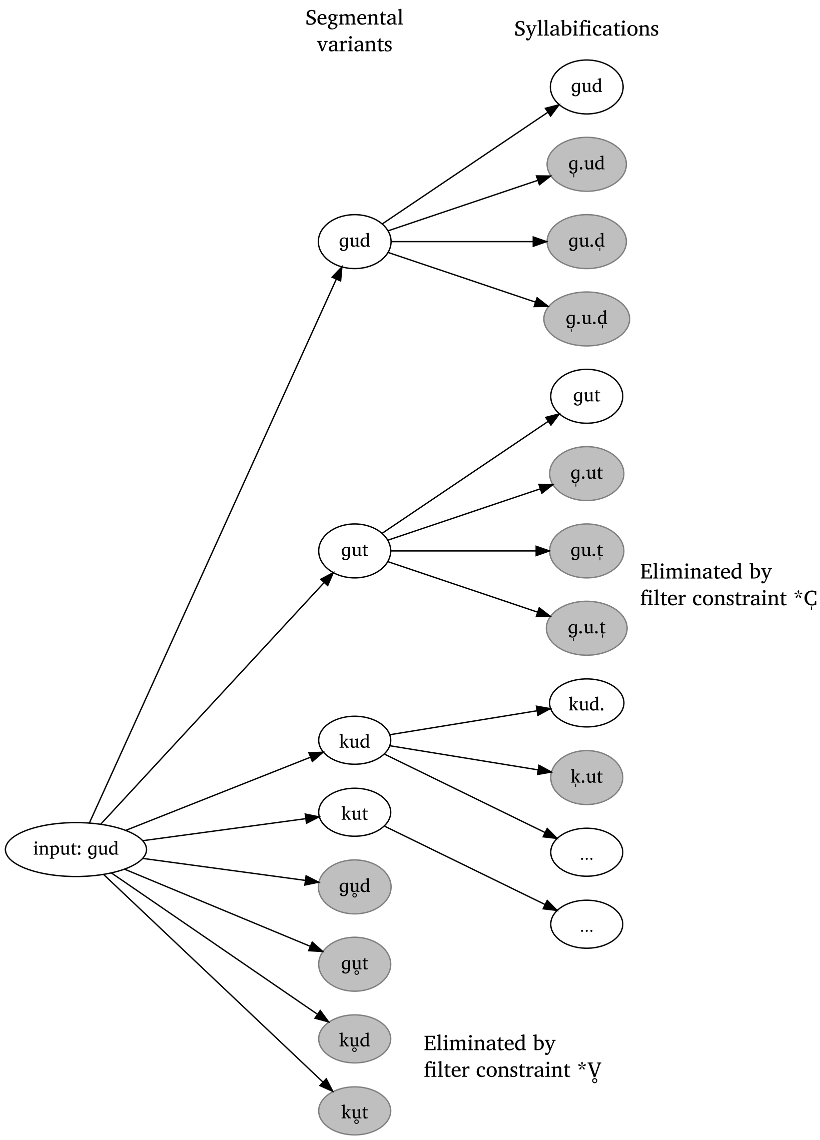
If a candidate passed as the `outp` parameter to a constraint function does not have enough prosodic structure to be meaningfully evaluated—that is, if a candidate that consists only of `Segment`s is passed to `Onset` constraint, for example—the function returns 0, i.e. no violations, so that when filtering outputs, `Gen` will not discard a candidate before it has enough structure to be meaningfully evaluated.

Every constraint function defines the `inp` and `args` parameters, though some do not use them: the function `Onset`, for example, can compute violations simply by iterating through the `Syllable`s in `outp`, and assessing a violation whenever it finds one with an empty `ons` attribute. Constraint functions all define the same parameters, however, so that `Eval` can use the same methods to call them with respect to a given candidate.

Evaluation

The Gen procedure described above defines a candidate space that may be visualised in terms of a tree, like so:

(25) Schematic of candidate space for PyOT's Gen procedure:

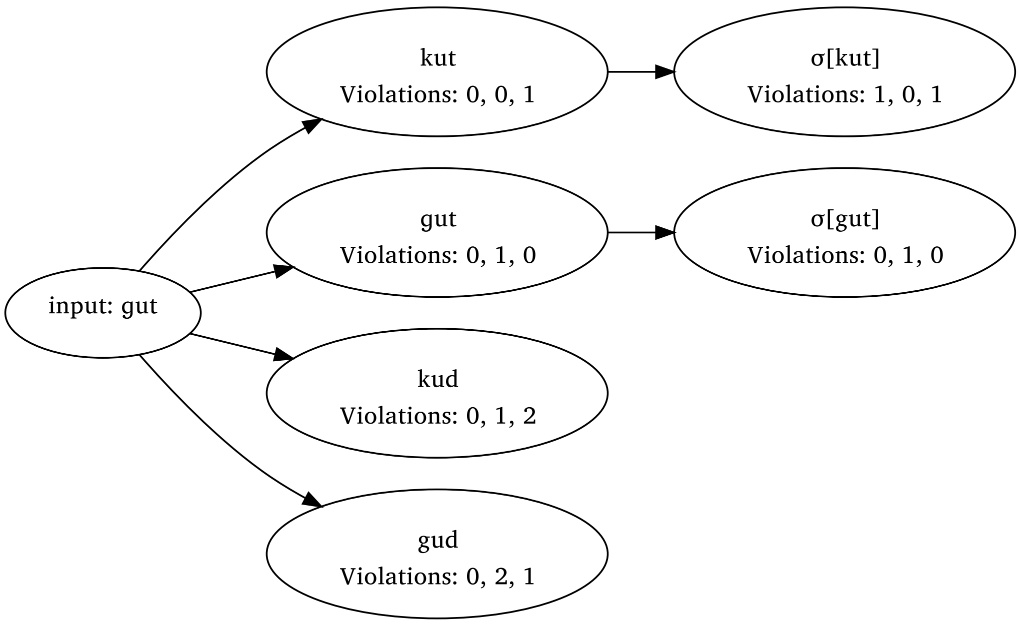


Some candidates are excluded by filter constraints, as the diagram indicates, but even so, searching the entire tree for the most harmonic candidate takes exponentially longer as the input gets longer and as the number of different faithfulness constraints included in the ranking rises.

To optimize the search time, therefore, PyOT's `Eval` function makes use of the principle mentioned above, that a constraint will assess no violations if the candidate has insufficient structure to evaluate it. It is a consequence of this principle that a given candidate can only get less harmonic as more structure is built on it.

So, PyOT's `Eval` function begins by taking the segmental variants output by `Gen` (with the filter constraints applied) and sorting them in order of harmonicity. Segmental variants are then syllabified, beginning with the most harmonic, until the most harmonic syllabification is more harmonic than the next segmental variant in the queue to be syllabified, like so:

(26) Schematic of state for function `OT.Grammar.smartGenEval`:



Once the segmental variants have been evaluated, the function syllabifies [kut], the most harmonic segmental variant. The only syllabification that the filter constraints permit is monosyllabic [kut], which has a violation of the top-ranked constraint OnsIdent-[voi]. The syllabified [kut] is less harmonic than [gut], the next most harmonic segmental variant, so the syllabified candidate [gut] is built.

Syllabified [gut] is more harmonic than [kud], the next segmental variant in the queue, and therefore more harmonic than any other segmental variant that has not already been syllabified. Building structure on top of the remaining segmental variants can only make them less harmonic, therefore [gut] will necessarily be more harmonic than any syllabification that `Gen` could generate, so the `Eval` function stops at this point and declares [gut] the winner.

If more structure is called for, `Eval` proceeds on similar lines: as each new batch of candidates, parsed into feet, prosodic words etc. is generated, the most harmonic in the batch is compared with all candidates that have not been parsed up to the same level. That is to say, for example, that the most harmonic candidate parsed into prosodic words is compared with the most harmonic segmental variant not yet parsed, the most harmonic syllabification not yet parsed, and the most harmonic footing not yet parsed. `Eval` ceases to call for more candidates once the most harmonic candidate with the level of structure called for by the user emerges as more harmonic in these comparisons,

PyOT has been designed throughout with an eye to extensibility. It has been my intention to make it as easy as possible for future linguists and programmers to use it to produce analyses of phenomena I never considered when writing it, and even to use parts of it in completely different theoretical paradigms. To that end, there is no tighter coupling between the theory of representations and the OT machine than OT itself calls for: `Gen` and the constraints are written in terms of the theory of representations, and so would have to be modified or replaced if another theory of representations were used, but the `Eval` function could be used unmodified with a different set of constraints that implemented the same interface. Conversely, the theory of representations itself contains no OT-specific components, and could in principle be used to implement any other theory of phonology.

1.2.3 Structure of the thesis

To illustrate the potential of computational methods in modelling historical phonology, and particularly of phonological change, we shall address the phenomena I have chosen to model one by one, incorporating them cumulatively into the overall model.

Chapter 2 will address the factors affecting the distribution of [r] and [l], including rhotacism and its progress through the life cycle of phonological generalisations, as well as the phonologically conditioned allomorphy of the suffix.

In chapter 3, we consider Lachmann's Law, and I will attempt to provide a principled answer to the questions it raises about the division of labour between morphology and phonology, and between the grammar and the lexicon, while demonstrating where it fits into the same diachronic stages and synchronic grammars already proposed.

Finally, in chapter 4, I will review the factors that must be taken into consideration to produce a fully rigorous account of multiple phonological generalisations within the history of same language. We will see how OT allows us to build a model of these generalisations that is expressed in terms of independently proposed constraints, and how having a computer model of OT available allows us to test the model against a comprehensive collection of attested examples.

Chapter 2

Rhotacism and liquid dissimilation.

2.1 The data

2.1.1 Rhotacism

Rhotacism in Latin is a well-known phonological generalisation which, in its paradigm cases, can be stated simply as "intervocalic /s/ is realized as [r]", or, in the Neogrammarian tradition, "*s* becomes *r* between vowels." It is possible, however, to cite a number of exceptions to the basic rule:

(27) a. Geminate *ss* is regularly exempt from rhotacism, examples include *gessī* 'I undertook', *missum* 'sent'. Following a long vowel or diphthong, in a process we shall revisit later on (§3.2.1), the *ss* regularly degeminated to *s*, which created a class of apparent exceptions to rhotacism, e.g. *suāsum* 'persuaded', *uīsus* 'seen', *causa*

'cause'. (Leumann 1977: §182)

b. Certain identifiable loanwords show intervocalic ⟨s⟩, such as *basis* 'pedestal' (from Greek), *cisium* 'cabriolet' (from Gaulish), *mense Flusare* 'in the month of Flora' (from Oscan, on which form see below). The earliest attestations of these loans are generally late, so it has been argued that they were borrowed after rhotacism ceased to be an active part of the phonology (Leumann 1977: §180, q.v. for all remaining exceptions)

c. In transparently morphologically complex words exceptions to rhotacism are regularly found at morpheme boundaries: *dē-siliō* 'I jump down' (cf. *saliō* 'I jump'), *ni-sī* 'unless' (cf. *sī* 'if')

d. Rhotacism appears to be blocked when the *s* co-occurs with an *r* in an adjacent syllable: for example, in *miser* 'wretched' (for which we might expect **mirer*, cf. the verb *maereō*, *maestus* 'lament'), and in *caesariēs* 'luxuriant hair' (cf. Skt. *kēsara-* 'mane'). However, there are apparent counterexamples where one *r* is the product of rhotacism, including *soror* 'sister' < **swesor* (cf. German *Schwester*), *uror* 'I am burnt' (cf. the supine *ustum*).

e. Finally, there is the much discussed apparent overapplication of rhotacism in nouns of the type *honor*, *honōris* 'honour' (formerly *honōs*, *honōris*). In the comparative tradition this is treated as a case of paradigm levelling and four-part analogy combined, given the extant pattern of nouns declining in *-or, -ōris* (like *soror*, *uxor* 'wife' and agent nouns in *-tor*, but other analyses, drawing on e.g.

output-output correspondence have been proposed (see Kiparsky 1982a; Kenstowicz 1996; Albright 2005: and references therein).

If one attempts to model rhotacism as a synchronic process in Classical Latin, the over- and under-generations listed in (27) amount, in some cases, to outright paradoxes. For example, the dissimilatory blocking of rhotacism in *miser* and *caesariēs* is absent from forms like *soror* and *ūror*. Then again, the qualifier 'transparently' is present in (27c) with good reason: we have on the one hand forms where rhotacism appears to be sensitive to morpheme boundaries, and on the other forms where it is apparently not, such as *dir-imō* 'I take apart' and *dir-(h)ibeō* 'I lay apart' (Baldi 1994: 209–10). For a counterexample with the same *dis-* prefix, see *disertus* 'discussed', which is discussed by Leumann (1969, 1977: 179).

The notion that a diachronic awareness is necessary to produce a complete descriptive account of rhotacism is not a new one: Touratier (1975) proposes an account in which there are two synchronic stages. In the first, rhotacism is a purely phonological process, then in the second the rule becomes sensitive to morphological structure. Baldi (1994) notes that rhotacism did not begin to affect what were historically geminates after they simplified to *s*: we do not have e.g. **caura* for *causa* (formerly *caussa*), and concludes that rhotacism in Classical Latin is the lexical residue of a phonological rule that is no longer active. The same position is more or less a prerequisite of the arguments of e.g. Kiparsky (1982a) and Albright (2005), who argue, in generative terms, for the extension of *r* to the nominative in nouns of the *honōs*, *honōris* type as analogical input restructuring.

In this chapter I intend to demonstrate that all these accounts are essentially correct, for different stages of the language, and that they should be expected to be correct, given what has been observed about the life cycle of phonological generalisations.

2.1.2 Liquid dissimilation

Latin has a denominal adjective-forming suffix *-āli-*, visible in e.g. *nāuālis* 'naval', *flōrālis* 'floral'. A functionally identical suffix *-āri-* appears when the nearest liquid preceding the suffix in the word is /l/, e.g. *cōnsulāris* 'having the rank of consul', *mīlitāris* 'military'. The handbooks tell us that it is the nearest liquid left of the suffix, and only the nearest liquid left of the suffix, that determines the quality of the liquid in the suffix: so we have ***l**ībe**r**ā**l**is* 'liberal' and ***r**ēticu**l**ā**r**is* 'net-like' (Leumann 1977: 231, Meiser 1998: 127).

As Cser (2010) points out, however, there are certain conditions on the dissimilation that many handbooks make insufficiently clear: firstly, the dissimilation is restricted to specific morphological environments, namely the suffixes *-āli/āri-*, the related noun-forming suffix *-al/ar*, and in the noun-forming suffixes *-bulum/-brum* and *-culum/crum* (e.g. in *simulācrum* 'likeness' vs. *perīculum* 'danger'; *lauābrum* 'bathtub' vs. *pabulum* 'fodder', see Meiser 1998: 127). In general, though there are certain co-occurrence restrictions on liquids in Latin, they are not satisfied by the kind of dissimilation we see in the suffixes.

Secondly, the dissimilation in the suffix *-āri/āli-* is blocked by an intervening non-coronal consonant, as in ***loc**ā**l**is*, *g**lob**ā**l**is*, ***lēg**ā**l**is*. By contrast, the dissimilation in the noun-forming suffix *-al/ar* is not blocked by any consonant, and depends solely on the nature of the nearest adjacent liquid: so we have *anima**l*** 'animal' and *quad**r**anta**l*** (a liquid measure), but ***l**acūna**r*** 'panelled ceiling' (not ****lac**ūna**l***, with the dissimilation blocked by the dorsal represented by ⟨c⟩) (Cser 2010: 37).

2.1.3 Interaction

Watkins (1970a) observed that the dissimilation of this suffix interacts with Latin rhotacism in a way that is unexpected given the diachronic facts and a rule-based approach to morphophonology. Liquid dissimilation is clearly old. There is no point in the attested history of Latin where we can observe the beginning of liquid dissimilation: the earliest inscriptions either have it, or do not include the relevant words. Furthermore, liquid dissimilation is attested in the Sabellian languages as well as in Latin: Watkins cites Oscan *fert-ali-s* 'consisting of sacrificial cakes' and Umbrian *tefr-ali* 'pertaining to Tefer [a god]' against Oscan *luis-ari-fs* and Umbrian *stafl-are-m*, which are adjectives formed on nouns whose meanings are more or less unclear[1].

Whether there existed such a language as Common Italic, the ancestor that Latin, Sabellian *et al.* share with one another but not with the other Indo-European languages, is debatable and debated, but for Watkins, the Sabellian evidence is enough to prove that the *-āri/āli-* dissimilation is an inheritance from one of Latin's precursors, rather than an innovation. Those who disbelieve in Common Italic would either have to argue that the dissimilation existed in PIE, but was lost

[1]It is apparent from context that *luis-ari-fs*, is a month name, but the meaning of the root *lois-* is unclear. See Untermann (2000: 436), and p. 693 for *staflarem.* Set against the examples cited, we have Oscan *dekkviarím* and Paelignian *casnar*, which appear to show the *-āri-* allomorph. Von Planta (1892: vol. 2, pp. 47–48) attributes this to a secondary spread of the *-āri-* variant. As we shall see (p. 124), the domains of the allomorphs also shift in Latin over time.

outside of Italy, and that its preservation in the Italic branch is due to language contact, or that one or more of the Italic languages innovated the process, and those that did not acquired it by language contact. In any case, we have no stage of either Latin or Sabellian attested which categorically lacks it, so we must accept that the dissimilation is old.

Rhotacism, by contrast, is very obviously new. The earliest Latin inscriptions lack it: the first word of the *duenos*-inscription, the earliest extant Latin inscription that is generally considered to be genuine, is IOVESAT, which we read as equivalent with Classical *iūrat* 'he swears' (Gordon 1975: 60). On epigraphic grounds, and based on the accounts of Roman authors, we can establish a *terminus ante quem* for the onset of rhotacism in the first half of the 4th century B.C.E (Leumann 1977: 178)[2]. Liquid dissimilation, then, was a part of the grammar of Latin from the beginning, whereas rhotacism did not enter the grammar until later.

Watkins' observation was that, treating dissimilation and rhotacism as rules in a serial derivation, their ordering is the opposite of the chronological one. To derive the attested *flōrālis* 'floral' from an underlying /floːs-aːli-s/, one must apply rhotacism first, then liquid dissimilation afterwards, like so:

(28)	UR	floːsaːlis
	s → r / V__V	floːraːlis
	aːli → aːri / l...__	——
	SR	floːraːlis

[2]A *terminus post quem* would of course be more to the point for our purposes, but it is in the nature of the phenomenon that we cannot divine one. For any given date, it could be argued that rhotacism was an active part of the grammar at the time, but that any inscriptions of that date lacking it do so out of archaism.

Applying the rules in chronological order gives the unwanted result **flōrāris*:

(29) UR flo:sa:lis

a:li → a:ri / l...__ flo:sa:ris

s → r / V__V flo:ra:ris

SR *flo:ra:ris

Watkins argued that rhotacism had to be inserted into the derivation such that it preceded liquid dissimilation, rather than adding the new rule to the end of the derivation, as might be expected in early generative morpho-phonology, in order to account for the attested facts. This involves a purely stipulative theoretical characterisation of the nature of the change to the grammar that introduced rhotacism.

The model I intend to argue for in this chapter, by contrast, treats the advent of rhotacism as a natural response to phonetic conditions that have been independently argued for, and its diachronic progress through the levels of Stratal OT as the expected one given observations about the life cycle of phonological generalisations. It will be shown that the observed interaction between rhotacism and liquid dissimilation on this model is exactly what we expect to find given the architecture of the theory.

2.2 Modelling rhotacism

Trying to construct an OT model of rhotacism that takes account of all the exceptions listed in (27) above raises two apparent paradoxes, if we assume that we must generate all forms with the same synchronic grammar.

The first paradox is one that will confront any attempt to produce an account of Latin rhotacism. It is mentioned in (27d): why do we find rhotacism blocked by dissimilation in *miser*, but not in *soror*?

The second paradox is, to a certain extent, imposed on us by our decision to use Stratal OT as our theoretical formalism. On the one hand, we have forms such as *de-siliō* and *ni-sī*, which appear to indicate that rhotacism is sensitive to morphological boundaries within the word. Our natural impulse might then be to argue that rhotacism is the product of a stem-level constraint ranking. In Chapter 3, however, we will claim that the domain of Latin's stem-level phonology encompasses everything but the inflectional ending. Rhotacism is visible in the *ā*-stem genitive plural ending *-ārum* < *-āsom* (see Meiser 1998: 132), therefore we must either re-examine our assumptions with respect to the extent of the stem-level domain in Latin, or reckon with rhotacism as having been, at least at some stage in its history, a word-level generalisation.

Introducing an awareness of diachrony, and particularly of the life cycle of phonological processes, into our analysis allows for a principled resolution to each of these dilemmas.

2.2.1 The life cycle of rhotacism

Wherever records allow us to observe multiple generations' implementations of a phonological process, it has been observed repeatedly since Baudouin de Courtenay (1895) that the domain of the generalisation tends to shrink over time. Rules that begin by obeying the Neogrammarian prescription and being exceptionless become increasingly sensitive to the morpho-syntactic structure of their environment, typically by ceasing to apply when a boundary intervenes in the relevant context. Finally, when the morpho-syntactic conditioning obscures the phonological conditioning sufficiently, the rule can become systematised as a set of lexical exceptions. In formalisms such as Lexical Phonology and Stratal OT, this is modelled in terms of a rule/constraint ranking ascending from the phrase- to the word-level, then from the word- to the stem-level.

Bermúdez-Otero (1999, 2007, 2011) provides a classification of the life cycle into discrete stages, as follows:-

(30) **Stage 0 — gradient phonetic rules.** Co-articulatory pressures create a tendency towards a different realisation of a segment in a particular phonetic environment.

Stage 1 — categorical postlexical rules. The phonetic tendency is stabilised into a categorical rule, involving modification of a feature or other item in the output representation. The rule continues to apply in its specified environment irrespective of word- or morpheme-boundaries.

Stage 2 — word-level rules. The rule ceases to apply across word-boundaries. Within words, the rule is enforced productively: i.e. loan-words will show adaptation, paradigmatic alternants that create the rule's environment will cause the rule to apply.

Stage 3 — stem-level rules. The rule is sensitive to morpheme boundaries, and applies only if its entire environment falls within the stem-level domain.

Stage L — lexical listing. The environment of the rule is opaque due to boundary conditions. The rule has become a systematic set of lexical exceptions, and is no longer productive.

(Adapted from Bermúdez-Otero 2011: §3)

If we construct an account of the development of rhotacism that assumes a standard progression through the stages of the life cycle, we arrive at an analysis which predicts the exceptions in (27) and has the potential to resolve the paradoxes arising from them.

Stage 0 — a phonetic tendency.

The Stage 0 for rhotacism has effectively already been proposed: it is uncontroversially assumed that rhotacism began with a tendency for intervocalic /s/ to be realised with voicing, i.e. as [z] (Leumann 1977: §180, Allen 1978: 35, Meiser 1998: 95). This tendency may be part of a more general pressure on the phonetics of pre-historic Latin. A tendency for fricatives to become voiced between vowels has been appealed to as part of accounts of the development of the Indo-European voiced aspirates in the Italic languages, most influentially by Ascoli (1868), Rix (1957) and Stuart-Smith (2004), of which last see pp. 19–29 for more extensive references. Each of these accounts posits a slightly different sequence of changes, but they all claim for some stage in the history of the language a complementary distribution of voiceless fricatives word-initially and voiced fricative word-internally and particularly intervocalically.

This kind of phonetic tendency—for the inherent vocal-fold vibration of segments to bleed into their neighbours, has been observed in a number of phonetic studies (Lisker 1957; Keating 1980; Westbury & Keating 1986). It has also been observed that this tendency can be codified into the phonology in a number of different ways: in the *distinción* dialects of Peninsular Spanish, for example, /θ/ is realised as [ð] when it precedes a sonorant (Hammond 2001: 231); in Old English, fricatives were realised as voiced between vowels and when adjacent to sonorants (Lass 1971); for more examples, see Cho (1990). I propose that rhotacism and the sound changes affecting the reflexes of the IE voiced aspirates were both consequences of the same set of phonological changes, which arose out of this phonetic tendency.

A measure of the gradient nature of the phonetic tendency we are dealing with can be observed in the extent to which we find the tendency affecting not only voiceless obstruents between vowels, but also voiceless obstruents between pairs of sonorants. In the case of the medial stops reflecting IE voiced aspirates, this voicing is exceptionless, e.g. in *umbō* 'shield-boss' < **omb*^{h}*-ōn* (cf. Gk. *ὀμφαλός*, German *Nabel* 'navel'), *mingō* 'I urinate', *ninguit* 'it is snowing' (on which see page 71 below). These sounds, however, are reconstructed as having been fricatives at the relevant period, and no such universal generalisation can be made concerning voicing assimilation from sonorants to the other fricatives of the sound inventory: for example, we have *mānsiō* 'dwelling'; *tōnsum* 'shaven'; *ānser* 'goose' and *īnferus* 'lower'. Then again, there are examples of voiceless stops becoming voiced when adjacent to sonorants, though these are by no means thoroughgoing: for example, we have *pandō* 'I unfold' from **patanō*, syncopated and metathesised, but not **uingo* for *uinco* 'I conquer'. Derivatives of *quattuor* 'four' in *quadr-* are often found, such as *quadrāre* 'to make square', but note also the form *quadrantal* 'a liquid measure', which does not become **quadrandal*.

One purpose of this section is to argue that apparent counterexamples to rhotacism, which begins with a tendency towards voicing of [s] between vowels, are artefacts of its progress through the life cycle, and that they will disappear once situated in their appropriate diachronic context. I do not believe that this can be said for the tendency towards voicing of obstruents when adjacent to sonorant consonants. Therefore, I claim that the phonetic tendency at Stage 0 was codified into the phonology such that it affected only intervocalic oral fricatives, and that any voicing of fricatives or other obstruents in wider environments is due to direct lexicalisation of a phonetic misparse.

Stage 1 — phrase-level phonology.

Phonetic tendencies at stage 0 are gradient, they apply to different degrees to different segments and in different contexts. I claim that the tendency for fricatives to be voiced word medially was formalised in the phrase-level phonology by the ranking over faithfulness of a constraint penalising voiceless oral fricatives between vowels. This constraint is defined formally as follows:

(31) **Name:** IORALFRICV

PyOT representation: `(IOralFricV,)`

Definition : Assess a violation for every segment in the output that:

a. stands between two segments, each having the feature [VOCALIC], *and*

b. has one or more of the features [LABIAL, CORONAL, DORSAL], *and*

c. has all of the features [CONSONANTAL, OBSTRUENT, CONTINUANT], *and*

d. lacks the feature [VOICE]

Ranking this constraint over IDENT-[VOI] gives the pattern that most authors on the subject of the reflexes of the PIE voiced aspirates in Latin agree in reconstructing for some precursor of the attested language. For some authors, this stage is dated to Proto-Italic, while others assume it goes back only as far as Latino-Faliscan (see Meiser 1998: §74, Stuart-Smith 2004: 19–29 and references therein). At any rate, we are not alone in proposing it for pre-historic Latin. Given the ranking IORALFRICV ≫ IDENT-[VOI], then, /s/ surfaces as [z] between vowels, so that e.g. */ruːsis/ → *[ruːzis], which will eventually become *rūris* by rhotacism:

(32) Tableau illustrating phrase-level intervocalic voicing of /s/

Maximum level of structure: `Segment`

Filter constraints: None

/ruːsis/	IORALFRICV	IDENT-[VOI]
☞ 1. ruːzis	0	1
∼ 2. ruːziz	$_0$—	$_2$W
∼ 3. ruːsis	$_1$W	$_0$L
∼ 4. ruːsiz	$_1$W	$_1$—

Likewise, the non-strident fricatives that reflect the IE voiced aspirates are voiced intervocalically, so **neb^h^elā* > */neɸelaː/ → *[neβelaː] > *nebula* 'cloud' (cf. Gk. *νεφέλη*, Gothic *nibul*):

(33) Tableau illustrating phrase-level intervocalic voicing of /ɸ/

Maximum level of structure: `Segment`

Filter constraints: None

/neɸelaː/	IORALFRICV	IDENT-[VOI]
☞ 1. neβelaː	0	1
∼ 2. neɸelaː	$_1$W	$_0$L

Likewise, PIE *$h\underset{\frown}{u}id^{h}e\underset{\frown}{u}ah_2$ (for which form cf. Gk. *ἠ(Ϝ)ίθεος* 'bachelor', Skt. *vidhā́va* 'widow') becomes */wi.θu.aː/ → *[wi.ðu.aː], whence eventually Latin *uidua* 'widow'. Likewise, *$\underset{\frown}{u}\acute{e}g^{h}eti$ (cf. Skt. *váhati* 'travels') > */wexit/ → *[weɣit] > *uehit* 'conveys', and the root *$sneig^{wh}$ (cf. English *snow*, Gk. *νείφει* 'snow-3SG.PRES') gives */nixʷis/ → *[niɣʷis] > *niuis* 'snow-GEN.SG'. (For full synchronic and diachronic derivations of all Latin forms mentioned in this thesis, taking account of every change the thesis sets out to model, see appendix A, and the tableaux in the accompanying software archive.)

As this is a phrase-level constraint ranking, the hypothesis also predicts that, for example, a word-initial fricative followed by a vowel would be voiced following a word that ended in a vowel. As this stage of the language predates anything we have attested, the only way in which we might expect to evaluate this prediction against the attested data is if we found, let us say, a word for which we reconstruct an initial voiced aspirate in IE, that frequently occurs following a word ending in a vowel (perhaps in an idiomatic expression), and which shows the regular word-medial reflex of the voiced aspirate. So, if we found that in a description of a ritual, for example, it was common to write **si dumus erubescet* for *sī fūmus ērubēscet* 'if the smoke reddens', that would vindicate the prediction.

The lack of such evidence, however, should not be taken to falsify the prediction outright, as the phonological generalisation I am arguing for at this stage is of the kind that speakers are least likely to be aware of and to record in writing. The voicing process does not neutralise any phonemic contrasts, either partially or fully, and it also results in a sound for which the writing system lacks a distinct representational strategy. Furthermore, as a phrase-level process, it makes the complementary distribution of the allophones it produces in theory completely exceptionless, and therefore children acquiring the language are most likely to draw the inference that they represent a single series of underlying phonemes.

A parallel would be Pre-Fortis Clipping in English, the tendency of vowels to be realised as shorter before voiceless consonants than before voiced ones, without neutralising the distinction between short and long vowels (see Wells 1990). Pre-Fortis Clipping is phrase-level, it manipulates a parameter that is not directly represented in the orthography (there is no common written form for a "half-long" vowel), it does not neutralize phonemic contrasts, and indeed it is only known through studies of recordings of English speakers; most native speakers are unaware that it is part of their phonology.

If we assume that the voicing of medial fricatives reflecting IE voiced aspirates was part of the same process that voiced /s/ as a prelude to rhotacism, then the parallel with Verner's Law in Germanic seems irresistible: by Verner's Law, the Common Germanic fricatives, which were the reflexes of the voiceless stops of Indo-European, plus inherited /s/, became voiced word-medially when not preceded by an original stressed syllable (Verner 1877: see Wright 1908: 112ff. for a concise summary of the evidence and Ringe 2006: 102–5 for discussion of the subsequent literature).

The sequel to Verner's Law is particularly instructive in comparison: the voiced fricatives merged with voiced stops (in favour of a fricative realisation, as opposed to the plosives of Latin), with the exception of [z], **which became [r] in the Verner's Law environment** in North and West Germanic (cf. OE *cēosan* 'to choose' and *coren* 'chosen' (Campbell 1959: §404))

In sum, the reflexes of the PIE sounds in the relevant environments are as follows:

(34)

PIE	*bʰ	*dʰ	*s	*gʰ	*gʷʰ		*p	*t	*s	*k	*kʷ
PItal.	*β	*ð	*z	*ɣ	*ɣʷ	PGmc.	*β	*ð	*z	*ɣ	*ɣʷ
Latin	b	d (b)	r	h	w	OE	v	ð	r	g	g (w)

It is clear that this first, phrase-level process of fricative voicing in Latin is most directly comparable with Verner's Law in Germanic. It has been argued that the sequels to the two processes have more in common than the attested data seem to suggest: in particular, it has been claimed that the voiced stops of Latin had fricative allophones word-medially, and that that is why the reflexes of the voiced aspirates merged with them (Stuart-Smith 2004: 205). However, I believe this is a stipulation that need not be made. Instead, I claim that both rhotacism and the treatment of the IE voiced aspirates in Latin were the result of learners of the language attempting to square their misparsing of the sounds perceived from their elders speech with universal constraints on the structure of phonological segment inventories. This reanalysis took place at the word level.

Stage 2 — word-level phonology.

(35) Inventory of fricatives hypothesised for Latin at Stage 1:

Features	[LABIAL]	[CORONAL]	[LAB, DOR]	[DORSAL]
[VOICE]	β	ð	ɣʷ	ɣ
—	ɸ	θ	xʷ	x
[STRIDENT]		s		
[STRID, VOI]		z		

(36) Oral consonant inventory of Classical Latin, with changes of segments in (35) indicated.

Features	[LABIAL]	[CORONAL]	[LAB, DOR]	[DORSAL]	[RADICAL]
[PLOSIVE]	p	t	k^w	k	
[PLOS, VOI]	b	d	g^w	g	
[OBS, CONT, VOI]	*β	*ð	*$ɣ^w$	*ɣ	
[OBS, CONT]	*ɸ	*θ	*x^w	*x	h
[STRID]	f	s			
[STRID, VOI]		*z			
[SON]		r	w		

The phonological change we are concerned with modelling at this stage appears to have as its goal the elimination of two natural classes from the segment inventory: that of non-strident fricatives (characterised by the features [CONS, OBS, CONT] but lacking the feature [STRID]) and that of voiced fricatives (marked as [CONS, OBS, CONT, VOI], whether [STRID] or not). In this section I will attempt to demonstrate that this is a natural, if not *the* natural response of the phonology to the phonetic tendencies argued for by Stuart-Smith (2004: ch. 6).

Stuart-Smith offers detailed, phonetically motivated arguments to explain the treatment of the fricatives reconstructed for this stage. Of these, I believe the most crucial are those that concern [θ, ð] from PIE *d^h. She proposes that these sounds changed to [f] and [v] respectively, citing various studies to the effect that these pairs of sounds have strikingly similar acoustic properties (Ohala 1989; Borden & Harris 1980), and that similar changes are directly attested, the most common parallel being that of Cockney English (Stuart-Smith 2004: 207). The change of [θ] to [f] seems to have occurred everywhere there was no adjacent segment offering a robust indicator of coronal place (as in **aid*^{h}*-tus* > *[aiθ.tus] > *aestus* 'heat'), whereas the change of [ð] to [v] occurs under specific co-articulatory influences that involve lip-rounding, whether intended to be present in the signal by the speaker (as with the [u] in *ruber* < *h_1*rud*^{h}*ro-*), or perceived by the hearer due to lowering of the second and third formants (as with the [r] in *uerbum* < **u̯erd*^{h}*om*) (see Stuart-Smith 2004: 213ff.).

I argued above (62) that the voicing of the sounds reflecting IE voiced aspirates when they are adjacent to sonorants is the result of a lexicalisation of a phonetic misparse, on the basis that a similar voicing is found in stops adjacent to sonorants, but not regularly. This requires an explanation of why the voicing of non-strident fricatives under these circumstances was so thoroughgoing, given that a misparse of this kind should be phonetically gradient. I believe the answer lies in two factors: firstly, the non-strident fricatives at Diachronic Stage 1 lack contrastively voiced counterparts, therefore we can reasonably infer that listeners at Stage 1 would readily have been able to parse a surface [β], for example, as a token of underlying /ɸ/, so that a wider variation of voice onset times could be expected for non-strident fricatives than for stops, where there is a contrast in the lexicon between voiced and voiceless. By contrast, the learners of Diachronic Stage 2 have, to begin with, no preconceptions with respect to whether or not the voicing pattern of fricatives they are hearing is contrastive, and, as we shall see presently, the misparse they are making of [θ] to [f] casts the status of the entire system of fricatives they are attempting to acquire into doubt. Under these circumstances, where, due to misparses, a segment inventory consistent with the composition of the constraint set cannot be built up, they will import every distinctive feature recoverable from the signal into the underlying representation, even including a

[VOICE] feature their elders never intended to produce. For this reason, the model I am proposing has e.g. [nɪŋxʷɪt] as the output for *ninguit* 'snows' at Diachronic Stage 1 (representing the sounds the speakers at Stage 1 intended to be recovered from the signal), but has /nɪŋɣʷɪt/ as the input to Diachronic Stage 2 (representing the features the learners recovered, including a hypocorrected [VOICE]).

Another class of phonetic tendency that must be mentioned is that which causes certain intervocalic voiced fricatives to be realised in a manner that is difficult to distinguish from a near-homorganic sonorant. This includes the corollary that must necessarily be made to the general assumption that intervocalic /s/ became [z], if this assumption is to be used to account for rhotacism. The corollary is best expressed by Catford (2001: 179):

> It is generally assumed that the fact that intervocalic -z- (< -s-) came to be reinterpreted as an r implies that the /r/ of the language at that time must have been a fricative or approximant ɹ, or at least that such an r must have been an acceptable pronunciation of /r/.

In other words, rhotacism came about not because [s] became [r], but because [s] became [z], and the language already possessed an [r] which was similar enough to [z] that a token of [z] in the speech signal could be misperceived as a token of [r] by learners.

In a similar fashion, due to the aperture necessary to pronounce the vowels, the velar constriction in [ɣʷ] is weakened, creating a tendency for intervocalic [ɣʷ] to be realised as [w] (Stuart-Smith 2004: 210).

Stuart-Smith (2004) offers similar phonetic argumentation to explain the sound changes affecting the other fricatives, but I believe that in formulating a theory of the sound changes we wish to argue for, it is sufficient to consider a state of affairs in which only the phonetic tendencies I have cited so far are in play.

I agree with the arguments in chapter 1 of Stuart-Smith (2004), and those of Ohala (1973, 1989, 1992, 1993); Blevins (2004, 2006), that sound change is actuated when learners misperceive noise as signal or signal as noise in speech, and that we can therefore study even historically remote sound changes by replicating their conditions as best we can in the lab, and testing whether or not the misparses we believe to have been involved are plausible. However, I also agree with Kiparsky (2008), that the effect of a learner's phonetic misparse on the phonology is constrained by phonological universals; in OT terms, by the composition of the constraint set. With this in mind, I believe I can demonstrate that the tendencies for [θ] to be misparsed as [f], and for the distinction between [z] and [r] to be collapsed prompted learners to acquire rhotacism, and the mergers affecting the reflexes of the PIE voiced aspirates, as a side-effect of their attempt to rank constraints so as to generate the segment inventory they so mis-perceived from their elders' speech.

In order to make the hypotheses this involves clear, an added piece of notation is needed: I will use the harpoon sign ($\rightharpoonup$) to stand for 'is misperceived as' alongside the arrow ($\rightarrow$) for 'is realised as' and the greater-than sign ($>$) for 'becomes by regular sound change'.

The changes I am arguing for at this stage, then, are as follows:

(37) Sound changes affecting Latin fricatives at stage 2

$*b^h > *$ɸ $\rightarrow$ f / #__ (e.g. in *frāter* 'brother', cf. Gothic *broþar*, Gk. *φρᾱ́τηρ*)

$*b^h > *$β $\rightarrow$ b (e.g. in *nebula* 'mist', cf. Gk. *νεφέλη*, Hittite *nepis*)

*d^h > *θ ⇀ f → f / #___ (e.g. in *fūmus* 'smoke', cf. Gk. *θῡμός*, Skt. *dhumaḥ*)

*d^h > *θ / ___C (e.g. in *aestus* 'heat', cf. Gk. *αἴθω* 'burn', Skt. *indh* 'kindle')

*d^h > *ð ⇀ v → b / u___ (e.g. in *ruber* 'red', cf. Gk. *ἐρυθρός*, U. **rufru**)

*d^h > *ð ⇀ v → b / r,l___ (e.g. in *uerbum* 'word', cf. Gothic *waurd*, U. *uerfale*)

*d^h > *ð → d (e.g. in *medius*, cf. Skt. *madhyaḥ*, Homeric Greek *μέσσος*)

*g^{wh} > *x^w → f / #___ (e.g. in *formus* 'warm', cf. Gk. *θερμος*, Armenian *ǰerm*)

*g^{wh} > *x^w → k / ___C (e.g. in *nix* 'snow', cf. Gothic *snaiws*)

*g^{wh} > *ɣ^w ⇀ w / V___V (e.g. in *niuis* 'snow-GEN.SG', cf. Gk. *νείφει*)

*g^{wh} > *x^w ⇀ *ɣ^w → g^w / n___ (e.g. in *ninguit* 'snow-3SG.PRES', cf. Old Irish *snigid*)

*s > *z → r / V___V (e.g. in *iūrat* 'swears', cf. earlier *iouesat*)

*s > *s → r / r___ (e.g. in *terret* 'frightens', cf. Umbrian **tursitu**)

*s > *s → l / l___ (e.g. in *uelle* 'to wish' < **uel-se*, cf. *es-se* 'to be')

*g^h > *x → h (e.g. in *holus* 'green vegetable', cf. Gk. *χλωρός* 'yellow-green', German *Gold* 'gold')

*g^h > *ɣ → g / ___r,l (e.g. in *grāmen* 'grass', cf. Gothic *gras*)

*g^h > *ɣ → h / V___V (e.g. in *uehit* 'transports', cf. Skt. *vahati*, Lithuanian *vežù*)

*g^h > *ɣ → g / n___ (e.g. in *mingit* 'urinates', cf. Gk. *ὀμείχω*, Skt. *méhati*)

*g^h > *x → k / ___C (e.g. in *mictus* 'urinated', cf. Gk. *ὀμείχω*)

To see how such changes might be provoked by the phonetic misparses listed, let us compare the fricative inventory so mis-perceived with the one speakers intended to produce:

(35, repeated) Inventory of fricatives hypothesised for Latin at Stage 1:

Features	[LABIAL]	[CORONAL]	[LAB, DOR]	[DORSAL]
[VOICE]	β	ð	$ɣ^w$	ɣ
—	ɸ	θ	x^w	x
[STRIDENT]		s		
[STRID, VOI]		z		

(38) Inventory of fricatives perceived by learners of Stage 2:

Features	[LABIAL]	[CORONAL]	[LAB, DOR]	[DORSAL]
[VOICE]	β	ð	$ɣ^w$	ɣ
—	ɸ		x^w	x
[STRIDENT]	f	s		
[STRID, VOI]	v			

This assumes that the misparse [θ] ⇀ [f] was, if not exceptionless, sufficiently thoroughgoing as to cause [θ] to be considered an exceptional realisation of an underlying /f/. This contrasts with the misparse [ð] ⇀ [v], which occurs only when adjacent segments provide lip-rounding to provoke the misperception (see page 68 above). It should be stressed at this point that [θ] and [ð] are hypothesised to be in complementary distribution: [θ] occurs word-initially, [ð] word-medially. In word-medial position, and particularly intervocalic position, there will be more tokens of [ð] with consistent coronal-pattern formant transitions from the preceding vowel to indicate the place of articulation. The less thoroughgoing nature of the [ð] ⇀

[v] misparse, I argue, is due to the fact that [ð] occurs in a different environment, in which place of articulation cues are likely to be more robust.

If the acquisition of a phonology were a matter of possibly imperfect mimesis, that is to say if a child learning to speak a language simply internalised whatever patterns she, correctly or incorrectly, perceived her elders to be producing, then we would need to assume a phonetic misparse for every sound change listed in (37). This would be to argue, as Stuart-Smith (2004) and Ohala (1989) implicitly do, that phonology plays no role in sound change, and ultimately to deny all of the generalisations that phonology sets out to identify and explain.

I contend, however, with Tesar & Smolensky (1998) and Kiparsky (2008), that the acquisition of phonology is in fact a process whereby the learner finds patterns in the language as she (mis-)perceives it, but those patterns are selected from an independently-derived set, namely the inventory of OT constraints, and expressed in terms of their ranking. I contend also that if we examine the inventory in (38) and attempt to make sense of it in terms of constraints that can be argued for independently based on the typology of segment inventories in the languages of the world, we will arrive at a ranking that predicts the sound changes in (37) without needing to assume any more phonetic misparses than we already have.

This theory of sound change actuated by phonetic misparses and sustained by the ranking of constraints has within it the potential to falsify the Neogrammarian hypothesis, inasmuch as the phonological form of the linguistic sign is fundamentally arbitrary. The theory must admit the possibility of the form of sound change argued for by Ohala (1989) etc.: the form whereby, in generative terms, a phonetic misparse is construed immediately as a property of the lexicon, without reference to phonological generalisations, in effect going straight from Stage 0 (phonetic tendency) of the life cycle to Stage L (lexical listing). Such a change need not be exceptionless with respect to its environment in the sense claimed for all sound changes by the Neogrammarians. The behaviour of the misparses *[θ] ⇀ [f] and *[ð] ⇀ */v/ → [b] constitutes, I argue, two changes of this form.

Fortunately for regular sound change, however, we can expect changes of this form to be rare, and in some cases to be practically indistinguishable from changes that involve a phonological generalisation even where they occur. Single-lexeme changes of this form are apt to be construed as outright errors by speakers who have the older form in their lexica, and corrected accordingly[3]. Then again, when a misparse applies more broadly, it is likely to align sufficiently well with a phonological or morpho-phonological category as to be acquired as a morpho-phonological generalisation (see p. 240). Nevertheless, the mechanism must exist for the domain of a phonological segment to be considered simply an arbitrary property of the lexicon, if only so that generations of learners can acquire generalisations that have reached Stage L of the life cycle.

Even where this occurs, it is likely that it will be possible to identify a descriptively accurate phonological environment for the change, and so satisfy the Neogrammarian hypothesis, without the environment ever being synchronically enforced, because phonetic tendencies conditioning misparses are likely to line up, if imperfectly, with phonological representations. It is arguable that the behaviour of *[ð], in particular, constitutes exactly this state of affairs, given the difficulties inherent in defining the environment in which this sound is misparsed as */v/ → [b]. The textbook account, as retailed by e.g. Stuart-Smith (2004: 207) and

[3]Where a misparse shifts a percept from matching one lexeme to another, however, a single-lexeme change of this form can be more persistent: witness English misparses such as *the girl next store* for *the girl next door* and, perhaps more compellingly, *hone in* for *home in*.

Meiser (1998: 104) is that *d^h becomes *b* after *u*, before or after *r*, or before *l*. This is accurate as a descriptive generalisation, but given that the number of tokens of $d <$ *d^h and of $b <$ *d^h is relatively small, other divisions of labour between the essential and the contingent have been proposed: Serbat (1968), for example, argues that *b* is the regular outcome, and *d* conditioned by preceding nasals (as in *condō* from the root *$d^h eh_1$) or adjacent *i* (as in *uidua*). In either case, it is difficult to see how the environment argued for can be encompassed in terms of a phonological generalisation. The position of the conditioning segment relative to the *[ð] is different in each case, and the conditioning segments do not constitute a natural class in featural terms. When theory and data conflict, it is of course theory that must bend, but I contend that theories of phonological representations have reached a point of sufficient maturity that I am justified in arguing that this change is better modelled in the terms of phonetic theory, as a misparse, than in terms of a phonological generalisation.

The absence of [θ] from the perceived inventory is crucial to the ranking arguments this will involve. It has been demonstrated convincingly that coronal is the least marked place of articulation (see Paradis & Prunet 1991, supported by the experimental findings of Friedrich et al. 2006, 2008). This generalisation is codified into phonological theories in various ways: in OT the standard assumption, after Prince & Smolensky (1993), is an inviolable ranking of all other oral place features such that they dominate *[COR] (see the discussion in Lombardi 2002). In other theories it is common to assume that the feature [CORONAL] is underspecified, and added to segments only in default of other place features (see Steriade 1987; Lahiri

& Reetz 2010)[4]. Voiceless obstruents are similarly unmarked: Maddieson (1984) notes that while the pronunciation of sonorants outside specific environments characterised by a lack of vocal fold vibration tends to involve voicing, the presence of a voiced series of obstruents in a segment inventory entails the presence of a corresponding voiceless series. With these universals in mind, it becomes unlikely that a series of obstruents such as the non-strident fricatives in (38), with every place of articulation and specification with respect to voicing attested except the voiceless coronal, could be acquired given any ranking of constraints typology justifies us in proposing. In my view, the acquisition of a phonology consists of the child learner perceiving a stimulus in her elders' speech (correctly or incorrectly) and re-ranking constraints in her grammar until the language she produces is, not necessarily identical to the stimulus, but intelligible to the elders providing it. What I claim does not happen is that the child should reject the stimulus if and when she finds that no ranking of constraints is capable of replicating it, because intelligibility to other speakers is the goal, not mimesis of them.

I believe that the closest an OT grammar can come, using constraints justifiable from implicational universals over segment inventories, to producing the fricative inventory in (38) is to rank the constraint OralFricStrid above faithfulness so that there are no non-strident oral fricatives at all. OralFricStrid is defined as follows.

(39) **Name:** OralFricStrid

PyOT representation: `(OralFricStrid,)`

Definition : Assess a violation for every segment in the output that:

[4]Inkelas (1995) attempts to re-import this reasoning into OT, by arguing that the relative harmony of [coronal] arises because constraints penalising it are simply not present in Con

a. has all of the features [CONSONANTAL, OBSTRUENT, CONTINUANT], *and*

b. has one or more of the features [LABIAL, CORONAL, DORSAL], *and*

c. lacks the feature [STRIDENT]

This constraint is readily justifiable on typological grounds. WALS lists forty languages with "th-sounds", each of which constrasts them with an otherwise homorganic strident sound (Maddieson 2011, see also Lombardi 2003, who deals with an ad-hoc constraint *θ, but notes that a broader constraint schema is needed).

The distribution of voiced vs. voiceless fricatives is still apparent, so IORALFRICV continues to dominate faithfulness, but the ranking of faithfulness constraints changes, like so:

(40) Partial ranking of constraints at Stage 2:

ORALFRICSTRID, IORALFRICV, ORALFRICVOICELESS ≫ MAX-[CONT], MAX-[DOR], DEP-[PLOS], DEP-[RAD] ≫ MAX-[OBS], DEP-[SON], DEP-[RHO] ≫ IDENT-[STRID]

In the top ranking stratum, we have three markedness constraints: ORALFRICSTRID and ORALFRICVOICELESS, as their names suggest, call for all oral fricatives to have the feature [STRID] and lack the feature [VOICE] respectively. That these constraints should be undominated in Latin will come as no surprise, since the inventory of fricatives in the attested language consists solely of {[s, f, h]}: there are no voiced fricatives, and the oral fricatives [s] and [f] are both strident.

The remaining constraint, IORALFRICV, is undominated as at Stage 1, but it is no longer ranked over IDENT-[VOICE]; instead, the faithfulness constraints are ranked so as to generate the following repair strategies, in descending order of harmonicity:

The least expensive repair strategy in terms of constraint rankings, as Ident-[strid] is bottom-ranked, is to realise a non-strident fricative as strident: /ɸ/ → /f/, /θ/ → [s]. This is the repair strategy we find in e.g. *frater*, *aestus*:

(41) Tableau for /ɸraːter/ > *frāter* ‘brother’ at Stage 2

/ɸraːter/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. fraːter	0	0	0	0	0	0	0	0	0	0	1
∼ 2. praːter	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L
∼ 3. ɸraːter	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L

(42) Tableau for /aɪθtus/ > *aestus* ‘heat’ at Stage 2

/aɪθtus/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. aɪstus	0	0	0	0	0	0	0	0	0	0	1
∼ 2. aɪrtus	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_1$W	$_1$W	$_1$W	$_0$L
∼ 3. aɪtːus	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L
∼ 4. aɪθtus	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L

The constraints Dep-[rho], Max-[obs], Dep-[son] and Max-[cont] rank above Ident-[strid], so the next repair strategy in order of harmonicity is to realise a fricative as the nearest homorganic sonorant, adding the feature [RHOTIC] if necessary. This repair strategy gives /s/ → [r], i.e. rhotacism:

(43) Tableau for /jousaːt/ > *iūrat* ‘swears’ at Stage 2

/jousaːt/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. jouraːt	0	0	0	1	0	0	0	1	1	1	1
∼ 2. joutaːt	$_0$—	$_0$—	$_0$—	$_1$—	$_0$—	$_1$W	$_0$—	$_0$L	$_0$L	$_0$L	$_1$—
∼ 3. jousaːt	$_0$—	$_1$W	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L

Next, we have the option to realise a labiovelar fricative as a labial. This can combine with a violation of the bottom-ranked IDENT-[STRID] to give /xʷ/ → [f].

(44) Tableau for /xʷormos/ > *formus* ‘warm’ at Stage 2

/xʷormos/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. formos	0	0	0	0	1	0	0	0	0	0	1
∼ 2. kʷormos	$_0$—	$_0$—	$_0$—	$_1$W	$_0$L	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L
∼ 3. xʷormos	$_1$W	$_0$—	$_0$—	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L

Finally, if it will produce a candidate that is more harmonic with respect to the markedness constraints in the top stratum, there is a choice of two repair strategies that are equally dispreferred compared to the others:

- Realise a fricative as a homorganic stop: /β/ → [b], /ɣ/ → [g]:

(45) Tableau for /neβela/ > *nebula* 'cloud' at Stage 2

/neβela/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. nebela	0	0	0	1	0	1	0	0	0	0	0
∼ 2. nevela	$_{0}$—	$_{0}$—	$_{1}$W	$_{0}$L	$_{0}$—	$_{0}$L	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{1}$W
∼ 3. neβela	$_{1}$W	$_{0}$—	$_{1}$W	$_{0}$L	$_{0}$—	$_{0}$L	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—

(46) Tableau for /meðios/ > *medius* 'middle' at Stage 2

/meðios/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. medios	0	0	0	1	0	1	0	0	0	0	0
∼ 2. mezios	$_{0}$—	$_{0}$—	$_{1}$W	$_{0}$L	$_{0}$—	$_{0}$L	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{1}$W
∼ 3. meðios	$_{1}$W	$_{0}$—	$_{1}$W	$_{0}$L	$_{0}$—	$_{0}$L	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—

This also affects word-medial [ð] that is misparsed as [v], as in *ruber*:

(47) Tableau for [ruðer] ⇀ /ruver/ > *ruber* 'red' at Stage 2

/ruver/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. ruber	0	0	0	1	0	1	0	0	0	0	1
∼ 2. ruver	$_0$—	$_0$—	$_1$W	$_0$L	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L

- Debuccalise a dorsal segment: /ɣ/ → [ɦ], /x/ → /h/

(48) Tableau for /xolus/ > *holus* 'green vegetable' at Stage 2

/xolos/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. holos	0	0	0	0	1	0	1	0	0	0	0
∼ 2. kolos	$_0$—	$_0$—	$_0$—	$_1$W	$_0$L	$_1$W	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—
∼ 3. xolos	$_1$W	$_0$—	$_0$—	$_0$—	$_0$L	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—

(49) Tableau for /weɣit/ > *uehit* 'travels' at Stage 2

/weɣit/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. weɦit	0	0	0	0	1	0	1	0	0	0	0
∼ 2. wegit	$_0$—	$_0$—	$_0$—	$_1$W	$_0$L	$_1$W	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—
∼ 3. weɣit	$_1$W	$_0$—	$_1$W	$_0$—	$_0$L	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—

In other cases, segments in the output from speakers at Diachronic Stage 1 are phonetically misparsed as discussed above, and the misparse is reproduced faithfully at Diachronic Stage 2:

(50) Tableau for [θuːmos] ⇀ /fuːmos/ > *fūmus* 'smoke' at Stage 2

/fuːmos/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. fuːmos	0	0	0	0	0	0	0	0	0	0	0

(51) Tableau for /niɣʷis/ ⇀ /niwis/ > *niuis* 'snow-GEN.SG' at Stage 2

/niwis/	OralFricStrid	IOralFricV	OralFricVoiceless	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. niwis	0	0	0	0	0	0	0	0	0	0	0

There remains to account for the behaviour of fricatives that are word-medial, but adjacent to a consonant, including the assimilation of [s] to an adjacent liquid, as in *terret*, *uelle*, and the behaviour of non-strident fricatives in e.g. *uerbum*, *nix*, *ninguit*, *mingo* and *mictus*. To model these changes, we must augment our ranking to include the following constraints:

(52) **Name:** [CONS]-AGREE-[RAD]

PyOT representation: `(CondAgree, 'cons', 'rad')`

Definition : Assess a violation for every pair of consecutive consonants in the output that are differently specified with respect to the feature [RADICAL].

(53) **Name:** [CONS]-AGREE-[DOR]

PyOT representation: `(CondAgree, 'cons', 'dor')`

Definition : Assess a violation for every pair of consecutive consonants in the output that are differently specified with respect to the feature [DORSAL].

(54) **Name:** [CONS]-AGREE-[LAT]

PyOT representation: `(CondAgree, 'cons', 'lat')`

Definition : Assess a violation for every pair of consecutive consonants in the output that are differently specified with respect to the feature [LATERAL].

(55) **Name:** [CONS]-AGREE-[RHO]

PyOT representation: `(CondAgree, 'cons', 'rho')`

Definition : Assess a violation for every pair of consecutive consonants in the output that are differently specified with respect to the feature [RHOTIC].

(56) Partial ranking of constraints at Stage 2:

[CONS]-AGREE-[LAT] ≫ DEP-[LAT] ≫ MAX-[RHO] ≫ ORALFRICSTRID, ORALFRICVOICELESS, IORALFRICV, [CONS]-AGREE-[RAD], [CONS]-AGREE-[DOR], [CONS]-AGREE-[RHO] ≫ MAX-[CONT], MAX-[DOR], Dep-[plos], Dep-[rad] $\gg$ Max-[obs], Dep-[son], Dep-[rho] $\gg$ Dep-[strid],

The crucial ranking conditions here are [cons]-Agree-[lat] $\gg$ Dep-[lat], Max-[obs], Dep-[son], so that a cluster /ls/ surfaces as [ll], but Dep-[lat] dominates all other markedness constraints, so that [l] is never the most harmonic realisation for a fricative anywhere else:

(57) Tableau for /welse/ > *uelle* 'to wish' at Stage 2

/welse/	[CONS]-AGREE-[LAT]	DEP-[LAT]	MAX-[RHO]	ORALFRICSTRID	ORALFRICVOICELESS	ONSET	IORALFRICV	[CONS]-AGREE-[RAD]	[CONS]-AGREE-[DOR]	[CONS]-AGREE-[RHO]	CODACOND-[CONT]	MAX-[CONT]	MAX-[DOR]	DEP-[PLOS]	DEP-[RAD]	MAX-[OBS]	DEP-[SON]	DEP-[RHO]	IDENT-[STRID]
☞ 1. welːe	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1
~ 2. welse	$_1$W	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$L	$_0$L	$_0$—	$_0$L

Similarly, [CONS]-AGREE-[RHO] dominates DEP-[RHO] MAX-[OBS] and DEP-[SON] so that /rs/ surfaces as [rr]:

(58) Tableau for /terseːt/ > *terret* 'frightens' at Stage 2

/terseːt/	[CONS]-AGREE-[LAT]	DEP-[LAT]	MAX-[RHO]	ORALFRICSTRID	ORALFRICVOICELESS	ONSET	IORALFRICV	[CONS]-AGREE-[RAD]	[CONS]-AGREE-[DOR]	[CONS]-AGREE-[RHO]	CODACOND-[CONT]	MAX-[CONT]	MAX-[DOR]	DEP-[PLOS]	DEP-[RAD]	MAX-[OBS]	DEP-[SON]	DEP-[RHO]	IDENT-[STRID]
☞ 1. terːeːt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1
~ 2. terseːt	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L
~ 3. telːeːt	$_0$—	$_2$W	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_1$—	$_0$—	$_0$—	$_0$—	$_1$—	$_1$—	$_0$L	$_1$—
~ 4. telseːt	$_1$W	$_1$W	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L

Because [cons]-Agree-[lat] dominates both Dep-[lat] and Max-[rho] this ranking also generates place assimilation of liquid clusters in favour of the lateral, as in *stēlla* < **$h_2$stēr-lah$_2$* (Meiser 1998: 123). Max-[lat], the constraint that would penalise the repair strategy /rl/ → [rr], is not included in the ranking, therefore PyOT takes it to be undominated, and does not generate any candidate in which a lateral surfaces as non-lateral:

(59) Tableau for /steːrlaː/ > *stēlla* 'star' at Stage 2

/steːrlaː/	[cons]-Agree-[lat]	Dep-[lat]	Max-[rho]	OralFricStrid	OralFricVoiceless	Onset	IOralFricV	[cons]-Agree-[rad]	[cons]-Agree-[dor]	[cons]-Agree-[rho]	CodaCond-[cont]	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. steːlːaː	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
~ 2. steːrlaː	$_1$W	$_0$L	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—

Finally, because [cons]-Agree-[rad] and [cons]-Agree-[dor] dominate the relevant faithfulness constraints, a dorsal fricative is never debuccalised when adjacent to a dorsal nasal:

(60) Tableau for [werðom] ⇀ /wervom/ > *uerbum* ‘word’ at Stage 2

/wervom/	[cons]-Agree-[lat]	Dep-[lat]	Max-[rho]	OralFricStrid	OralFricVoiceless	Onset	IOralFricV	[cons]-Agree-[rad]	[cons]-Agree-[dor]	[cons]-Agree-[rho]	CodaCond-[cont]	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. werbom	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1
∼ 2. wervom	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_1$—	$_0$—	$_0$L	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L
∼ 3. welbom	$_1$W	$_1$W	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$—	$_1$—	$_0$—	$_1$—	$_0$—	$_0$—	$_0$—	$_0$—	$_1$—
∼ 4. welvom	$_1$W	$_1$W	$_1$W	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$—	$_0$L	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L

(61) Tableau for /nixʷs/ > *nix* 'snow' at Stage 2

/nixs/	[CONS]-AGREE-[LAT]	DEP-[LAT]	MAX-[RHO]	ORALFRICSTRID	ORALFRICVOICELESS	ONSET	IORALFRICV	[CONS]-AGREE-[RAD]	[CONS]-AGREE-[DOR]	[CONS]-AGREE-[RHO]	CODACOND-[CONT]	MAX-[CONT]	MAX-[DOR]	DEP-[PLOS]	DEP-[RAD]	MAX-[OBS]	DEP-[SON]	DEP-[RHO]	IDENT-[STRID]
☞ 1. niks	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0
~ 2. nihs	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$L	$_0$—	$_0$—	$_0$L	$_1$W	$_0$L	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—
~ 3. nixs	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_1$—	$_0$—	$_0$—	$_0$L	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—

(62) Tableau for /niŋɣʷit/ > *ninguit* 'snows' at Stage 2

/niŋɣʷit/	[CONS]-AGREE-[LAT]	DEP-[LAT]	MAX-[RHO]	ORALFRICSTRID	ORALFRICVOICELESS	ONSET	IORALFRICV	[CONS]-AGREE-[RAD]	[CONS]-AGREE-[DOR]	[CONS]-AGREE-[RHO]	CODACOND-[CONT]	MAX-[CONT]	MAX-[DOR]	DEP-[PLOS]	DEP-[RAD]	MAX-[OBS]	DEP-[SON]	DEP-[RHO]	IDENT-[STRID]
☞ 1. niŋgʷit	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
~ 2. niŋvit	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$L	$_1$W	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W
~ 3. niŋɣʷit	$_0$—	$_0$—	$_0$—	$_1$W	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—

(63) Tableau for /miŋɣoː/ > *mingō* ‘urinate-1SG.PRES’ at Stage 2

/miŋɣoː/	[cons]-Agree-[lat]	Dep-[lat]	Max-[rho]	OralFricStrid	OralFricVoiceless	Onset	IOralFricV	[cons]-Agree-[rad]	[cons]-Agree-[dor]	[cons]-Agree-[rho]	CodaCond-[cont]	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. miŋgoː	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
∼ 2. miŋɦoː	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_1$W	$_0$—	$_0$—	$_0$L	$_1$W	$_0$L	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—
∼ 3. miŋɣoː	$_0$—	$_0$—	$_0$—	$_1$W	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—

(64) Tableau for /mixtos/ > *mictus* ‘urinate-PTCP.PERF’ at Stage 2

/mixtos/	[cons]-Agree-[lat]	Dep-[lat]	Max-[rho]	OralFricStrid	OralFricVoiceless	Onset	IOralFricV	[cons]-Agree-[rad]	[cons]-Agree-[dor]	[cons]-Agree-[rho]	CodaCond-[cont]	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. miktos	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0
∼ 2. mihtos	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$L	$_0$—	$_0$—	$_0$L	$_1$W	$_0$L	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—
∼ 3. mixtos	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_1$—	$_0$—	$_0$—	$_0$L	$_0$—	$_0$L	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—

(65) Tableau for [ɣraːmen] > *grāmen* ‘grass’ at Stage 2

/ɣraːmen/	[cons]-Agree-[lat]	Dep-[lat]	Max-[rho]	OralFricStrid	OralFricVoiceless	Onset	IOralFricV	[cons]-Agree-[rad]	[cons]-Agree-[dor]	[cons]-Agree-[rho]	CodaCond-[cont]	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]
☞ 1. graːmen	0	0	0	0	0	0	0	0	1	1	0	1	0	1	0	0	0	0	0
∼ 2. firaːmen	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{1}$W	$_{0}$L	$_{1}$—	$_{0}$—	$_{0}$L	$_{1}$W	$_{0}$L	$_{1}$W	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—
∼ 3. ɣraːmen	$_{0}$—	$_{0}$—	$_{0}$—	$_{1}$W	$_{1}$W	$_{0}$—	$_{0}$—	$_{0}$—	$_{1}$—	$_{1}$—	$_{0}$—	$_{0}$L	$_{0}$—	$_{0}$L	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—
∼ 4. glaːmen	$_{1}$W	$_{1}$W	$_{1}$W	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{1}$—	$_{0}$L	$_{0}$—	$_{1}$—	$_{0}$—	$_{1}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—
∼ 5. filaːmen	$_{1}$W	$_{1}$W	$_{1}$W	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{1}$W	$_{0}$L	$_{0}$L	$_{0}$—	$_{0}$L	$_{1}$W	$_{0}$L	$_{1}$W	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—
∼ 6. ɣlaːmen	$_{1}$W	$_{1}$W	$_{1}$W	$_{1}$W	$_{1}$W	$_{0}$—	$_{0}$—	$_{0}$—	$_{1}$—	$_{0}$L	$_{0}$—	$_{0}$L	$_{0}$—	$_{0}$L	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{0}$—

This constraint ranking represents an attempt by learners to produce the inventory of fricatives they are misperceiving in the speech of the generation at Stage 1, which is given in (35) and repeated here for reference:

(35) Inventory of fricatives perceived by learners of Stage 2:

Features	[LABIAL]	[CORONAL]	[LAB, DOR]	[DORSAL]
[VOICE]	β	ð	ɣʷ	ɣ
—	ɸ		xʷ	x
[STRIDENT]	f	s		
[STRID, VOI]	v			

As I argued above (p. 73), learners are incapable of acquiring this inventory, as the patterns it calls for are inconsistent with phonological universals as represented mentally by the constraint set. Instead, they acquire the ranking in (56) as the approximation of the patterns in (35) most intelligible to speakers of the language at Stage 1.

The acquisition of the ranking in (56), however, depends on learners (mis-)perceiving the sounds in (38) in the stimulus from which they acquire their phonology. In other words, it depends on learners hearing the output of Stage 1, with the phonetic misparses to which it is liable ([θ] ⇀ [f], [ɣʷ] ⇀ [w], [z] ⇀ [r] etc.). Therefore, once there arises a generation of learners who have no opportunity to hear the output of Stage 1, they may draw different inferences when only the output of Stage 2 is available as a stimulus.

In particular, they will be expected to draw different inferences about which sound is the underlying representation of an output [r]. In the output of this stage, an intervocalic [r] can in principle reflect an underlying /r/ or an underlying /s/.

This situation, and the response to it we expect the learner to display, is described in Tesar & Smolensky (1996: 41) and Kiparsky (2000a: 15): an output [A] that can reflect either /A/ or /B/ is parsed as /B/ when paradigmatic alternations make the underlying /B/ apparent, otherwise as /A/. This means that the underlying /s/ of rhotacism will only be acquired by learners after Stage 2 when there is an alternation to make it apparent, as in *rūs*, *rūris* or *fūneris*, *fūnestus*.

The other sound changes generated by the Stage 2 ranking are not apparent from the output: as OralFricStrid is undominated, non-strident fricatives are entirely absent from the output. Therefore, the next generation of learners has no opportunity to learn the ranking of faithfulness constraints in (56); they learn that oral fricatives must be strident, but not what to do about it if one happens to occur in the input. The only alternation that remains apparent on the basis of the Stage 2 output is that of rhotacism, and because the underlying /s/ is only apparent in alternating environments, rhotacism comes to be associated with morphologically complex forms, and the generation at Stage 3 acquires the ranking that produces it at the stem level.

2.2.2 Stage 3 — stem-level phonology

In this stage, morphological boundaries that obscure the environment of rhotacism keep it from applying, so we have *s* in *ni-sī* and *dē-siliō*. This presupposes an analysis in which the prefix does not form part of the stem-level domain: the UR of, for example, *de-siliō* would be /$[_{\omega}$de$[_{\text{stem}}$sali]o]/[5]. This accords with the hypothesis we will explore in chapter 3 that, for regular forms, the phonological stem in Latin excludes the prefix, but otherwise includes all material up to, but

[5]This assumes that vowel weakening occurs on the word level; see §4.2.4.

not including the inflectional ending. Therefore, the input to the stem-level cophonology is /sali/, in which the /s/ is not between vowels, therefore no violation of IOralFricV is provoked.

Given that endings do not form part of the stem-level domain, we might expect that genitive plural endings like -*ārum* and regular infinitives in -*āre*, *ēre*, etc., in which the *r* is the product of rhotacism, would revert to being *-*āsom* and *-*āse* and so on, once the constraint ranking giving rise to rhotacism reached the stem level. The reason why they did not is that the intervocalic environment in these forms is contained entirely within the ending. Because the [r] of the genitive plural and regular infinitive endings is always intervocalic, no alternation exists from which the learning generation can deduce that it reflects underlying /s/. This will cause them to parse the [r] as a token of /r/, by the principle of parsimony that Prince & Smolensky (1993) term lexicon optimisation. For *de-siliō*, by contrast, the alternation with the un-prefixed verb *saliō* suffices, at the word level, to make the underlying /s/ apparent, so that when the grammar reaches the stem level, the /s/ is no longer intervocalic, and is realised as [s].

It should be noted at this point that although there are alternations which might be expected to make the underlying /s/ of the general infinitive ending -*se* apparent, such as the irregular infinitive *esse* 'to be' and the perfect infinitive in -*sse* (**regese* 'to rule' > *regere* ∼ *rēxisse* 'to have ruled'), the formation of infinitives must necessarily have been opaque to speakers of Classical Latin. We have already seen that at Diachronic Stage 2 an *s* assimilated completely to an adjacent liquid: this created the irregular infinitive */welse/ > *uelle* 'to wish'. After Stage 2, however, the /s/ resurfaced whenever a morpheme boundary interfered, just as in *desiliō*: we regularly find *pulsus* 'driven'; *morsus* 'bitten' etc., but *uelle* was not remade to **uelse*. This suggests that despite the extant parallels, *-se* was no longer considered to be a general infinitive suffix: instead, *uelle* and *esse* were lexicalised as irregular forms, and the regular endings were likewise taken to be those apparent on the surface: *-āre*, *-ēre*, *-ere*, *-īre*.

Because the class of non-strident fricatives produced by the speakers of Stage 1 is not part of the input from which learners of Stage 3 acquire their phonology, the ranking of faithfulness constraints in (56), with the preference hierarchy of repair strategies it predicts, is no longer in effect. The only generalisation that can be induced from the output of Stage 2 is rhotacism, so the ranking is as follows:

(66) Partial stem-level ranking of constraints at Stage 3:

OralFricStrid, IOralFricV ≫ Max-[obs], Dep-[son], Dep-[rho], Max-[strid], Max-[cont]

Under this ranking, sequences of VsV that are entirely stem-internal continue to undergo rhotacism regularly:

(67) Tableau for /[$_{stem}$juːsaː]t/ > *iūra-t* 'swear-3sg.pres' at Stage 3, stem level.

/juːsaː/	*[rho]-μ-[rho]	OralFricStrid	IOralFricV	Max-[obs]	Dep-[son]	Dep-[rho]	Max-[strid]	Max-[cont]
☞ 1. juːraː	0	0	0	1	1	1	1	1
∼ 2. juːsaː	$_0$—	$_0$—	$_1$W	$_0$L	$_0$L	$_0$L	$_0$L	$_0$L
∼ 3. juːθaː	$_0$—	$_1$W	$_1$W	$_0$L	$_0$L	$_0$L	$_1$—	$_0$L

An /r/ from *s that has been elevated to the lexicon as described above, due to the lack of a morphologically related form with [s] making the alternation apparent, such as the regular GEN.PL endings in e.g. *ārārum* 'altar-GEN.PL', surfaces unaltered:

(68) Tableau for /[$_{stem}$aːraː]rom/ > *ārārum* 'altar-GEN.PL' at Stage 3, stem level.

/aːraːrom/	*[RHO]-μ-[RHO]	ORALFRICSTRID	IORALFRICV	MAX-[OBS]	DEP-[SON]	DEP-[RHO]	MAX-[STRID]	MAX-[CONT]
☞ 1. aːraːrom	0	0	0	0	0	0	0	0

It is also now "safe" for forms with intervocalic /f/ to be borrowed, such as the name *Rūfus* from Sabellian, as there is no sonorant that can appear as its surface exponent without violating faithfulness constraints not mentioned in (66):

(69) Tableau for /[$_{stem}$ruːfo]s/ > *rūfus* (name) at Stage 3, stem level.

/ruːfo/	*[RHO]-μ-[RHO]	ORALFRICSTRID	IORALFRICV	MAX-[OBS]	DEP-[SON]	DEP-[RHO]	MAX-[STRID]	MAX-[CONT]
☞ 1. ruːfo	0	0	1	0	0	0	0	0
∼ 2. ruːɸo	$_0$—	$_1$W	$_1$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—

In a similar vein, it is at this stage that the dissimilatory blocking of rhotacism in e.g. *caesariēs* makes itself felt. This process occurs in deference to a markedness constraint that applies across the entire vocabulary of Latin. Cser (2010: 42–3) points out that a sequence rV̆r is only found to occur in final syllables, and that all instances of final rV̆r reflect an earlier rV̄r, being the products of the shortening of vowels in closed word-final syllables that occurred circa 200 B.C.E. (Meiser 1998: 77). I claim in §2.2.3 below that at the time when the final shortening occurred, rhotacism had already entered Stage L of the life cycle, therefore I argue that at the period in the history of the language when rhotacism was a word-level process, the prohibition of rV̆r was exceptionless, and also a part of the word-level phonology.

This co-occurrence restriction is by no means typologically surprising: compare the case of Yimas discussed by Suzuki (1998: 84–7), the English word *pilgrim* from Late Latin *pelegrīnus* < *peregrīnus*, and the dissimilation in colloquial Spanish, whereby canonical *glándula* is realised as *grándula* (Lloret 1997: 125). I therefore adopt a constraint formulated according to Suzuki's Generalised OCP schema to model it:

(70) **Name:** *[RHOTIC]-μ-[RHOTIC]

PyOT representation: `(GOCP, 'rho', 1)`

Definition : Assess a violation for every sequence of two segments in the output with the feature [RHOTIC] separated by material amounting to no more than one mora.

If we insert this constraint into our ranking so that it dominates IOralFricV, the grammar generates *caesariēs* correctly:

(71) Tableau for /[$_{stem}$kaesarieː]s/ > *caesariēs* 'luxuriant hair' at Stage 3

/kaesarieː/	*[RHO]-μ-[RHO]	OralFricStrid	IOralFricV	Max-[obs]	Dep-[son]	Dep-[rho]	Max-[strid]	Max-[cont]
☞ 1. kaesarieː	0	0	1	0	0	0	0	0
∼ 2. kaerarieː	$_1$W	$_0$—	$_0$L	$_1$W	$_1$W	$_1$W	$_1$W	$_1$W

Besides the final syllable examples such as *error* 'error-NOM.SG', *feror* 'carry-1SG.PASS', Cser (2010: 47) notes that there are surface exceptions to the generalisation that rV̆r sequences are prohibited occurring at morpheme boundaries: such as in certain passive forms of verbs with stems in *-r*, e.g. *quaerĕ-rētur* 'seek-3SG.IMPF.PASS.SUBJ', *mor-ĕris* 'die-2SG'. To these we may properly add the infinitive *gerĕ-re* 'to bear/wear' and the non-nominative forms of the name of the goddess Ceres: ACC *Cerĕr-em*, GEN *Cerĕr-is* etc. In every case but that of *Cereris*, a morpheme boundary occurs within the rV̆r sequence. So, to explain a form such as *gerĕ-re*, I argue first that the surface [r] of the ending *-re* is underlying at Diachronic Stage 3, having been lexicalised as set out above (p. 94), and the underlying form of the stem is /gese/. No rV̆r sequence is visible to the stem-level phonology, so the /s/ surfaces as [r]:

(72) Tableau for /[$_{stem}$gese]re/ > *gerere* 'to bear/wear' at Stage 3, stem level

/gese/	*[RHO]-μ-[RHO]	OralFricStrid	IOralFricV	Max-[obs]	Dep-[son]	Dep-[rho]	Max-[strid]	Max-[cont]
☞ 1. gere	0	0	0	1	1	1	1	1
∼ 2. gese	$_0$—	$_0$—	$_1$W	$_0$L	$_0$L	$_0$L	$_0$L	$_0$L

This leaves *Cereris*. The phonological stem here ought, etymologically, to be /keres/ (see de Vaan 2008: 109), which ought to surface as *[keres], in obedience to *[RHO]-μ-[RHO].

The nominative *Cerēs* shows a long vowel. The alternation betwen nominative long vowel and oblique short vowel is generally taken to be old, reflecting the hysterokinetic nature of the PIE stem (see Weiss 2009: 261). Therefore, since synchronically the alternation must be handled as a lexical exception anyway, the inference does not necessarily hold that the /s/ of the nominative is part of the underlier of the oblique stem. In plain terms, since a speaker is not generating the oblique forms from the same stem as the nominative (or else we would expect **Cerēris*, **Cerērem* etc.), she might list /kerer/ as the underlying oblique stem just as well as /keres/. This would not be unnatural, since the constraint against rV̆r only comes into play at Diachronic Stage 3, so that the first learners at DS3 would be hearing [ke.re.rɪs] in the language of their elders who speak the language of Diachronic Stage 2. This would constitute a premature advance for this particular stem from Stage 2 direct to Stage L of the life cycle of rhotacism, exactly as for the endings (see p. 94).

The literature on the life cycle states that a generalisation makes the transition from stage 3 to stage L, becoming a systematic property of the lexicon, when its sensitivity to morpheme boundaries creates enough apparent counterexamples that its environment is no longer recoverable (Bermúdez-Otero 2011: §3). Ideally, we should like to be able to point to an identifiable change in the grammar that would give rise to such counterexamples in the case of rhotacism, and precipitate the transition from stage 3 to stage L. This would require a theoretical stipulation that allows VsV sequences to surface elsewhere than at morpheme boundaries while rhotacism is still a part of the stem-level phonology.

This might be possible in the case of loanwords[6] such as *basis* and *cisium* if we stipulate that, as loanwords, their morphological structure was not apparent and they therefore did not form stem-level domains. If such forms are possible, then stage 3 rhotacism becomes essentially a derived environment effect. This would, however, require a departure from our hypothesis that the stem-level input excludes the inflectional ending, since if we take the hypothesis as read, it is difficult to see how a loanword with regular inflection like *cisium* can be any less of a derived environment than any other inflected form.

I should prefer to say that the stage 3 state of affairs—in which both [s] and [r] appear on the surface and both /s/ and /r/ occur in underlying representations, but surface [r] is sometimes the exponent of underlying [s], is inherently unstable: as a phonological process becomes more sensitive to morphological structure, there will be more apparent exceptions to it on the surface, and it becomes more and more likely that learners will assume that the surface form always reflects the underlying representation unmodified. In this case, that involves a generation of

[6] It is, however, not possible in the case of the degemination of *ss*; see note 8 below.

learners treating every surface [r] as reflecting an underlying /r/, so that rhotacism becomes a property of the lexicon and the morphology rather than of the phonological component of the grammar.

2.2.3 Stage L — lexical listing

The extension of the *r* to the nominative in forms of the *honor*, *honōris* type is the latest exception to rhotacism, and I assign it to this, the latest stage in the life cycle. Some authors (Kenstowicz 1996; Benua 1997; Steriade 2000) have attempted to account for this overapplication of rhotacism within the constraint ranking, by means of Uniform Exponence or output-output correspondence constraints. The principal objection to this approach is that it would predict that the change from the -*ōs*, -*ōris* pattern to the -*or*, -*ōris* pattern would be lexically abrupt, that is, that it would affect all the relevant nouns at the same time. This is not the case. In fact *honor*, the most commonly cited example, only begins to occur relatively late: Cicero, for example, uses *honōs*, but *arbor* 'tree'. In fact, the spread of the -*or*, -*ōris* pattern follows the standard progression of an analogy: it is phonetically abrupt, but lexically gradient (Bermúdez-Otero 2007: §21.3.1). Therefore, I argue that it is a matter of input restructuring, which is the Optmality-Theoretic mechanism by which analogy is modelled. Similar claims, with a computational model of the analogy in question, are advanced by Albright (2005).

Despite the levelling in polysyllabic nouns of the -*ōs*, -*ōris* type, it must remain the case that the -*ōs*, -*ōris* pattern remained a viable model on which to build a paradigm, since, in monosyllables such as *mōs*, *mōris* 'custom', and indeed *rūs*, *rūris* 'countryside', we never find levelling: **mōr* for 'custom-NOM.SG' is never attested, for example. Baldi (1994: 214) provides an example of this -*ōs*, -*ōris* alternation being enforced where it is etymologically unexpected, in the form *iānitōs* 'doorkeeper' (the more common form *iānitor* reflects the original agent noun in -*tor*). The morphological productivity of the -*ōs*, -*ōris* pattern in monosyllables can also be seen in the way paradigms are built for loans from Greek, such as *tūs*, *tūris* 'incense' (from Greek *ϑύος*), and *glōs*, *glōris* 'sister-in-law' (from */gloː-s/ reanalyzed as /gloːs/, or perhaps from Greek *γάλως*).

2.2.4 Interim conclusion.

Our Stratal OT model of the progression of rhotacism through the life cycle presently looks like this:

Stage 0 — phonetic tendency. Co-articulatory pressures cause intervocalic voiceless consonants to tend to be realised as voiced.[7]

Stage 1 — phrase-level phonology. The phonetic tendency of stage 0 is phonologised as a pattern of non-neutralising intervocalic obstruent voicing, with the result that [z] becomes the regular allophone of /s/ between vowels.

Stage 2 — word-level phonology. The repair strategy by which intervocalic [s] is avoided changes: underlying /s/ is realised as [r] between vowels. Unless there are paradigmatic alternants with [s], subsequent generations interpret intervocalic [r] as a token of /r/, by lexicon optimisation.

Stage 3 — stem-level phonology. Rhotacism is productive under the same conditions as at the word level, unless this would create a sequence rV̆r,

[7] As noted above (§2.2.1), this phonetic tendency is extremely general, and can be phonologised in many different ways: cf. Spanish *vida* from Latin *uīta* 'life'.

which would violate the crucially undominated *[RHOTIC]-μ-[RHOTIC] constraint, and only if the /s/ and the vowels around it are all contained within the phonological stem.

Stage L — lexical listing. Rhotacism is a systematic property of the lexicon, subject to extension by analogy. It is no longer productive over new VsV sequences, such as in loans or those created by the degemination of *ss*.

This model demonstrates that by adopting Stratal OT, a formalism which includes observations of the life cycle of phonological processes in its basic architecture, we can construct an account of the diachronic development of rhotacism which explains all the apparent inconsistencies and exceptions to it listed in (27):

(73) a. For the geminates, I argued that they are representationally equivalent to consonant clusters, and therefore not intervocalic in the sense penalised by IORALFRICV. We know from ancient sources that the degemination in e.g. *causa* did not occur until after the time of Cicero (see Quintilian, *Institutio Oratoria* I, 7, 20–1), so rhotacism did not affect the new examples of intervocalic *s* because it was already at Stage L, and no longer a productive part of the phonology.[8]

[8] A reviewer suggests modelling the interaction between rhotacism and degemination as a synchronic chain shift, either by means of contrast-preservation constraints, or by positing a ranking giving rise to degemination at a later stage in the derivation than that which gives rise to rhotacism. This would be desirable insofar as it would provide a motivation for rhotacism to make the transition from stage 3 to stage L, as a generation of learners is confronted with a raft of forms with a new intervocalic [s], such as *causa*, *religiōsae* (from *caussa* and *religiōssae*, respectively; see Baldi 1994: 214; for *religiōssae*, see CIL I^2 580 = ILS 6086), and so must assume that [r] always represents underlying /r/, no matter the consequences for the morphology. Unfortunately, however, considerations of relative chronology preclude it. As the extension of [r] to the nominative in nouns of the *honōs* type was already underway at the time of Cicero (see §2.2.3), rhotacism must have entered stage L before then, and we know from Quintilian's witness that the degemination did not occur until after the time of Vergil. Therefore, at the time when

b. Similarly, the loanwords, such as *basis* and *cisium*, were borrowed at a stage when rhotacism was a property of the Latin lexicon, and not of the phonology.

c. The blindness of rhotacism to its intervocalic context, where a morpheme boundary intervenes, as in *de-siliō* and *ni-sī*, reflects the fact that at the most recent stage when rhotacism was part of the phonology, it was specifically part of the stem-level phonology, and therefore blind to phonological structure outside the stem-level domain. Examples of rhotacism in endings, such as *-ārum* and *-ere*, are relics of the word-level stage, preserved by lexicon optimisation.

d. The dissimilatory blocking of rhotacism in forms like *miser* and *caesariēs* is regular, in obedience to a crucially undominated constraint penalising occurrences of r$\breve{V}$r. Apparent counterexamples, like *soror* and *ūror*, are confined to final syllables, and the product of a sound change that took place after rhotacism had already entered stage L.

e. Finally, the analogical extension of rhotacism to nominatives of the *honor* type is modelled as input restructuring, the spread of an idiosyncratic set of lexical exceptions that has its roots in what was formerly a productive phonological process.

We will now proceed to devise constraint rankings to account for the liquid dissimilation in the *-āli/āri-* suffix, and to integrate those rankings into the model we already have.

degemination became a part of the phonology, rhotacism was already part of the lexicon: every surface [r] reflected underlying /r/

2.3 Modelling liquid dissimilation

The dissimilation of *-āri/āli-* has attracted notice in the generative tradition, not just in Watkins (1970a), but also in e.g. Steriade (1987) and Cohn (1992). An OT analysis is offered by Suzuki (1998). Like many of the standard grammars of Latin, however, these analyses do not take account of the fact that the dissimilation is blocked by non-coronals between the conditioning liquid and the suffix. Furthermore, Suzuki (1998) is apparently unaware that the dissimilation is restricted to particular morphological environments.

2.3.1 Emergence of the unmarked.

Suzuki proposes to model liquid dissimilation by means of a Generalized OCP family of constraints, for which the schema is as follows:

(74) Generalized OCP:

X. . . X: A sequence of two X's is prohibited

Where: X ∈ {PCat, GCat}

. . . is intervening material

Suzuki (1998: 42)

This makes it possible to follow the intuition that dissimilation is an OCP effect (which is not uncommon, see for example Cohn 1992) while still keeping our account distinct from those that employ the already-existing family of OCP markedness constraints in OT, which are defined as applying strictly to adjacent entities in the theory of representations.

Suzuki's account assumes that the UR of the suffix is simply /-ali-/, and that the dissimilation is enforced by the local conjunction (Smolensky 1993; Kager 1999: 392–400) of the following two GOCP constraints:

(75) *[LIQUID]∼[LIQUID] (*[LIQ]∼[LIQ]):

Sequential segments must be differently specified for features within the class [LIQUID][9]

(76) *[lateral]. . . [lateral] (*[lat]. . . [lat]):

Sequential segments must be differently specified for the feature [±lateral]

He then defines the constraint governing liquid dissimilation, per local conjunction, as one that is violated iff both *[LIQUID]∼[LIQUID] and *[lateral]. . . [lateral] are violated. This allows him to retrodict the blocking effect of the intervening [r] in e.g. *flōrālis* by ranking the conjoined constraint (*[LIQ]∼[LIQ] & *[lat]. . . [lat]) over Faith, like so:

(77)

sol-alis	(*[LIQ]∼[LIQ] & *[lat]. . . [lat])	Faithfulness
1. so$\underbrace{\text{l-a}}_{x}$lis	*[LIQ]∼[LIQ] ⊠ *! *[lat]. . . [lat] ⊠	
2. ☞ so$\underbrace{\text{l-a}}_{x}$ris	*[LIQ]∼[LIQ] ⊠ *[lat]. . . [lat] □	*

flor-alis	(*[LIQ]∼[LIQ] & *[lat]. . . [lat])	Faithfulness
1. ☞ f$\overbrace{\underbrace{\text{lo}}_{x}\underbrace{\text{r-a}}_{y}}^{z}$lis	*[LIQ]∼[LIQ] ⊠ ⊠ □ *[lat]. . . [lat] □ □ ⊠	
2. f$\overbrace{\underbrace{\text{lo}}_{x}\underbrace{\text{r-a}}_{y}}^{z}$ris	*[LIQ]∼[LIQ] ⊠ ⊠ □ *[lat]. . . [lat] □ □ □	*!

[9] I am following the feature system and geometry of the original work. See Suzuki (1998: 103) for full elucidation.

(Suzuki 1998: 104)

Leaving aside, for the moment, the fact that non-coronals, as well as [r], block liquid dissimilation, leaving FAITHFULNESS crucially dominated fails to capture the morphological particularity of the process. Suzuki's ranking generates not only /floːraːlis/ → [floːraːlis], but also, for example, the undesirable /liːlium/ 'lily' → *[liːrium] or *[rːilium]:

(78)

liːlium	(*[LIQ]∼[LIQ] & *[lat]. . . [lat])	FAITHFULNESS
1. ☹ liːlium	*[LIQ]∼[LIQ] ⊠ *! *[lat]. . . [lat] ⊠	
2. ☺ liːrium	*[LIQ]∼[LIQ] ⊠ *[lat]. . . [lat] ☐	*
3. ☺ riːlium	*[LIQ]∼[LIQ] ⊠ *[lat]. . . [lat] ☐	*

Liquid dissimilation in Latin is an example of phonologically conditioned allomorphy, akin to the distribution of *a/an* in English or the example of the Dyirbal ergative discussed by Mascaró (1996); Wolf (to appear) and others, which is marked by [-ŋku] on disyllabic vowel-final noun stems, and [-ku] on longer vowel-final stems. In each case, an alternation is conditioned entirely by phonological conditions, but affects one particular morpheme.

We may partially rescue Suzuki's analysis by following their approach, and treating liquid dissimilation as an example of the emergence of the unmarked (TETU). To retrodict accurately, we must rank FAITHFULNESS above (*[LIQ]∼[LIQ] & *[lat]. . . [lat]), and posit a distinct underlying representation for the *-āri/-āli-* suffix, one for which either allomorph: [aːri] or [aːli], is a faithful parse. We will notate this underlier as /aːRi/. If neither allomorph violates FAITHFULNESS, (*[LIQ]∼[LIQ] & *[lat]. . . [lat]) will be allowed to decide between the two:

(79)

liːlium	FAITH	(*[LIQ]∼[LIQ] & *[lat]... [lat])
1. ☞ liːlium (x)		*[LIQ]∼[LIQ] ☒ *! *[lat]... [lat] ☒
2. liːrium (x)	*!	*[LIQ]∼[LIQ] ☒ *[lat]... [lat] ☐
3. riːlium (x)	*!	*[LIQ]∼[LIQ] ☒ *[lat]... [lat] ☐

(80)

soːl-aːRis	FAITH	(*[LIQ]∼[LIQ] & *[lat]... [lat])
1. soːl-aːlis (x)		*[LIQ]∼[LIQ] ☒ *! *[lat]... [lat] ☒
2. ☞ soːl-aːris (x)		*[LIQ]∼[LIQ] ☒ *[lat]... [lat] ☐

To this extent, the analysis can be modified to retrodict the attested data. However, the account is predicated on the assumption that non-liquids cannot block liquid dissimilation (Suzuki 1998: 103), and, as we know, this assumption is empirically falsified. Latin liquid dissimilation is blocked by non-coronal consonants between the liquid and the suffix, therefore to model it we need a new genus of analysis. In the next section, I will propose one based on CC-correspondence theory.

2.3.2 CC-correspondence and anti-faithfulness.

CC-correspondence theory, as articulated by Rose & Walker (2004), is designed to account for long-distance consonant *assimilations*. It achieves this by means of a family of constraints that require segments of sufficient featural similarity to enter into a correspondence relation. The schema for this constraint family is as follows:

(81) CORR-C↔C

> Let S be an output string of segments and let C_i, C_j be segments that share a specified set of features F. If C_i, $C_j \in S$, then C_i is in a relation with C_j; that is, C_i and C_j are correspondents of one another.
>
> (Rose & Walker 2004: 491)

CC-correspondence theory also includes a family of faithfulness constraints that enforce similarity between segments coerced into correspondence by Corr-C↔C constraints. The theory can be extended to account for dissimilation by assuming that there is also a family of anti-faithfulness constraints (as defined in Alderete 1999, 2001) enforcing dissimilarity between segments in CC-correspondence.

Constructing an account of Latin liquid dissimilation in terms of CC-correspondence theory depends crucially on two observations. Firstly, because the dissimilation is a TETU effect, the entire ranking that generates it must perforce be dominated by IO-Faithfulness. This leaves two possible repair strategies for violations of CC-antifaithfulness:

(82) a. Selection of a different allomorph of -aːRi-

b. Ejection of one or more segments from the CC-correspondence relationship, at the expense of the Corr-C↔C constraints.

The second observation is that, since we are working with a privative feature system, there is no difference between the non-laterality of Latin [r] and the non-laterality of e.g. Latin [g]. That is to say, we are *not* working in a system where [r] is contrastively [−lateral] and [g] is not specified for [±lateral] at all. With these facts in mind, we can make some telling observations about our data that will allow us to formulate an account of liquid dissimilation in CC-correspondence theory.

Let us assume that each of the operative segments (the surface exponent of the /R/ in -aːRi-, and the segments that either condition or block its dissimilation) is in a CC-correspondence relation. Examining these segments' specifications with respect to the feature [LATERAL] and to the features under the ARTICULATOR node will allow us to draw the inferences necessary to construct a constraint ranking. We will begin with *lēgālis*:

(83)

	l_i	e	g_i	aː	l_i	i	s
[LATERAL]	+				+		
ARTICULATOR	COR		DOR		COR		

It is important to note at this point that CC-faithfulness and -antifaithfulness constraints are evaluated pairwise with respect to consecutive pairs of CC-corresponding segments. That is, violations will be assessed for the candidate in (83) with respect to the first [l] and the [g], then with respect to the [g] and the second [l], and *not* with respect to the two [l]s. Hansson (2007: 402–403) has demonstrated that any other mode of evaluation leads to "bizarre typological predictions".

With that in mind, we can observe that the CC-corresponding segments in (83) respect a perfect anti-faithfulness contour with respect both to [LATERAL] and to the features under the ARTICULATOR node: that is to say that each consecutive pair of CC-corresponding segments is differently specified with respect to both. This should lead us to posit the following two constraints:

(84) ¬IDENT-CC-[LAT]

Assess a violation for every pair of segments in a CC-correspondence relation that are identically specified for the feature [LATERAL]

(85) ¬Ident-CC-articulator

Assess a violation for every pair of segments in a CC-correspondence relation that each have the same feature under the articulator node.

To determine their relative ranking, and which constraints enforce the CC-correspondence relation between the segments, we must examine more data:

(86)

	l_i	uː	n	aː	r_i	i	s
[lateral]	+						
articulator	cor				cor		

Here, the suffix dissimilates to the [l], therefore we are obliged to posit that the [l] enters into the correspondence relation, despite the violation of ¬Ident-CC-art that that entails, as the [l] and the [r] are both coronal. The liquid in the suffix does not dissimilate to the [n], else we would expect *[luːnaːlis]. This leads us to infer that non-coronal consonants enter into the correspondence relation, but coronal non-liquids do not. We can model this inference as an example of repair strategy (82.2): ¬Ident-CC-art is being satisfied by the ejection of [n] from the correspondence relation, at the expense of the Corr-C↔C constraint that wants it to enter into the relation (and succeeds in coercing the [g] of *lēgālis* into the relation, because no violation of ¬Ident-CC-art is thus provoked). These observations, that liquids enter into the correspondence relation at the expense of ¬Ident-CC-art, but other consonants do not, require the following constraints and ranking:

(87) CC-Corr-[cons]

For every pair of segments [... α ... β ...], assess a violation if α and β both have the feature [CONSONANTAL] and are not in a CC-correspondence relation.

(88) CC-CORR-{[LAT], [RHO]}

For every pair of segments [... α ... β ...], assess a violation if α and β both have the feature [LATERAL] or [RHOTIC] and are not in a CC-correspondence relation.

(89) CC-CORR-{[LAT], [RHO]} ≫ ¬IDENT-CC-ART ≫ CC-CORR-[CONS]

There remains only to determine the ranking of ¬IDENT-CC-[LAT]. Based on the fact that dissimilation takes place wherever the undominated IO-faithfulness allows, we may propose the following ranking:

(90) ¬IDENT-CC-[LAT] ≫ CC-CORR-{[LAT], [RHO]} ≫ ¬IDENT-CC-ART ≫ CC-CORR-[CONS]

This ranking effectively sets up a state of affairs in the grammar such that a dissimilatory pair of consonants must be found: it is preferred for a pair to dissimilate with respect to place of articulation (as in *lo**c**ā**l**is*), but, if all consonants in the output are coronal, a dissimilation with respect to [LATERAL] will be enforced on suffixes that offer the *l/r* allomorphy (as in ***l**ūnā**r**is*). The blocking effect of non-coronals arises out of the fact that [l] and [r] are themselves marked for [CORONAL] in the output.

The following tableaux exemplify this ranking in action:

(91)

/miːlitaːRis/	¬Ident-CC-[lat]	CC-Corr-[lat]	CC-Corr-[rho]	¬Ident-CC-art	CC-Corr-[cons]
☞ 1. m$_i$iːl$_i$itaːr$_i$is	0	0	0	1	2
∼ 2. m$_i$iːl$_i$it$_i$aːl$_i$is	$_0$—	$_0$—	$_0$—	$_2$W	$_1$L
∼ 3. m$_i$iːl$_i$it$_i$aːl$_i$is$_i$	$_0$—	$_0$—	$_0$—	$_3$W	$_0$L
∼ 4. m$_i$iːl$_i$itaːris	$_0$—	$_0$—	$_1$W	$_0$L	$_3$W
∼ 5. m$_i$iːl$_i$itaːlis	$_0$—	$_1$W	$_0$—	$_0$L	$_3$W
∼ 6. m$_i$iːlitaːl$_i$is	$_0$—	$_1$W	$_0$—	$_0$L	$_3$W

(92)

/naːwaːRis/	¬Ident-CC-[lat]	CC-Corr-[lat]	CC-Corr-[rho]	¬Ident-CC-art	CC-Corr-[cons]
☞ 1. naːw$_i$aːl$_i$is	0	0	0	0	2
∼ 2. naːw$_i$aːl$_i$is$_i$	$_0$—	$_0$—	$_0$—	$_1$W	$_1$L
∼ 3. n$_i$aːw$_i$aːl$_i$is	$_1$W	$_0$—	$_0$—	$_0$—	$_1$L
∼ 4. n$_i$aːw$_i$aːl$_i$is$_i$	$_1$W	$_0$—	$_0$—	$_1$W	$_0$L

(93)

/leːgaːRis/	¬Ident-CC-[lat]	CC-Corr-[lat]	CC-Corr-[rho]	¬Ident-CC-art	CC-Corr-[cons]
☞ 1. l$_i$eːg$_i$aːl$_i$is	0	0	0	0	1
∼ 2. l$_i$eːg$_i$aːl$_i$is$_i$	$_0$—	$_0$—	$_0$—	$_1$W	$_0$L

(94)

/floːraːRis/	¬Ident-CC-[lat]	CC-Corr-[lat]	CC-Corr-[rho]	¬Ident-CC-art	CC-Corr-[cons]
☞ 1. f$_i$l$_i$oːr$_i$aːl$_i$is	0	0	0	2	1
∼ 2. f$_i$l$_i$oːr$_i$aːl$_i$is$_i$	$_0$—	$_0$—	$_0$—	$_3$W	$_0$L
∼ 3. f$_i$l$_i$oːr$_i$aːris	$_0$—	$_0$—	$_1$W	$_1$L	$_2$W
∼ 4. f$_i$l$_i$oːraːr$_i$is	$_0$—	$_0$—	$_1$W	$_1$L	$_2$W
∼ 5. f$_i$l$_i$oːraːris	$_0$—	$_0$—	$_2$W	$_0$L	$_3$W
∼ 6. f$_i$l$_i$oːr$_i$aːlis	$_0$—	$_1$W	$_0$—	$_1$L	$_2$W
∼ 7. f$_i$l$_i$oːraːlis	$_0$—	$_1$W	$_1$W	$_0$L	$_3$W
∼ 8. f$_i$loːraːl$_i$is	$_0$—	$_1$W	$_1$W	$_0$L	$_3$W
∼ 9. f$_i$loːr$_i$aːlis	$_1$W	$_2$W	$_0$—	$_0$L	$_3$W

The inference we drew from (86) above, that the importance with respect to CC-CORR-ART of having liquids in the correspondence relation is greater than the importance of placing any consonant in the correspondence relation, is an important and decisive one for the purposes of a theoretical debate in CC-correspondence theory. The Latin data attest a pattern predicted, but not exemplified by Hansson (2007), which he refers to as "conditional blocking"[10].

Based on the lack of examples of conditional blocking, McCarthy (2010) argues that the constraint schema in (81) is redundant, since the similarity requirements on segments in a correspondence relation can be enforced by IDENT-CC constraints, with the exception of the conditional blocking pattern. In the place of the CORR-C↔C constraint family, he proposes the following single constraint:

(95) MAX-CC:

Assign a violation mark for every consonant that is not in the domain of the CC correspondence relation.

However, our CC-correspondence account of liquid dissimilation requires the constraints CC-CORR-[LAT] and CC-CORR-[RHO] in addition to the constraint we have notated CC-CORR-[CONS], which is functionally identical to MAX-CC. In the absence of these constraints, the ranking of constraints to generate the attested forms as desired optima is intractable:

[10] In strict form, we should say that they attest the dissimilatory counterpart of Hansson's conditional blocking pattern, since the specific pattern he predicted was one of blocking of long-distance *assimilation*. The conclusion it invites us to draw, however: that separate CORR-C↔C constraints, enforcing correspondence relations between different degrees of similarity between segments, are needed, remains valid.

(96)

/miːlit-aːRi-s/	Ident-CC-[son]	Max-CC	¬Ident-CC-art
☞ m_iiːl$_i$itaːr$_i$is	0	2	1
1. ∼ m_iiːl$_i$it$_i$aːr$_i$is$_i$	$_2$ W	$_0$ L	$_3$ W
2. ∼ miːlitalis	$_0$ –	$_5$ W	$_0$ L

(97)

/loc-aːRi-s/	Ident-CC-[son]	Max-CC	¬Ident-CC-art
☹ l$_i$oc$_i$aːl$_i$is	1	2	0
1. ∼ l$_i$ocaːr$_i$is	$_0$ L	$_3$ W	$_1$ W

Therefore, either our CC-correspondence- and antifaithfulness-based account of liquid dissimilation is in error, or it demonstrates the need for separate Corr-C↔C constraints in Con.

2.3.3 Diachronic considerations

Our account of liquid dissimilation as phonologically conditioned allomorphy is sufficient to account for the textbook cases applying to the *-āli/āri-* suffix, but there are other considerations which need to be taken into account:

a. The dissimilation in the related noun-forming suffix *-al/ar*, which is not blocked by an intervening non-coronal (e.g. in *calcar*), remains to be accounted for.

b. Certain forms with *-āri/āli-* show a liquid other than that predicted by the model above, or show variation, such as *lētālis* 'deadly' (regularly with [l]) or *Latiālis/Latiāris* 'of Latium' (both are attested, but the expected *Latiaris* is attested on the order of ten times as frequently) (Cser 2010: 39)

c. Finally, there are theoretical ramifications to consider: we must take a principled stand on the question of which stratum the dissimilation takes place in (is it a phrase-level, a word-level or a stem-level generalisation?), and determine to what extent it can be seen to observe the life cycle.

To model the dissimilation of *-al/ar*, which is not blocked by non-coronals, using a CC-correspondence account along the same lines as that used for *-āri/āli-*, is in itself straightforward. We simply propose the following constraint ranking:

(98) CC-Corr-[rho], CC-Corr-[lat] ≫ Ident-CC-[nas], Ident-CC-[high], Ident-CC-[son], ¬Ident-CC-[lat] ≫ CC-Corr-[cons],

The two top-ranked constraints ensure that all liquids (segments marked for one of the features [rhotic, lateral] enter into the correspondence relation in the winning candidate. The three Ident-CC constraints in the next ranking stratum ensure that where there is more than one liquid in the winner, no other consonant that may stand between the two of them is permitted to enter into the correspondence relation, while the bottom-ranked CC-Corr-[cons] ensures that where the only liquid available is the liquid in the suffix, some other consonant will be found in the input for it to dissimilate to. The constraint ¬Ident-CC-[lat], of course, enforces the dissimilation pattern itself.

This ranking predicts the attested data, giving [l] when there is no preceding liquid to condition the allomorphy:

(99) Tableau illustrating liquid dissimilation in *animal* 'animal'

Filter constraints: Ident-CC-[cons]

Maximum level of structure: `Segment`

/animaR/	CC-Corr-[rho]	CC-Corr-[lat]	Ident-CC-[nas]	Ident-CC-[high]	Ident-CC-[son]	¬Ident-CC-[lat]	CC-Corr-[cons]
☞ 1. an$_i$imal$_i$	0	0	1	0	0	0	1
☞ 2. anim$_i$al$_i$	0	0	1	0	0	0	1
∼ 3. an$_i$im$_i$al$_i$	$_0$—	$_0$—	$_1$—	$_0$—	$_0$—	$_1$W	$_0$L
∼ 4. an$_i$imar$_i$	$_0$—	$_0$—	$_1$—	$_0$—	$_0$—	$_1$W	$_1$—
∼ 5. anim$_i$ar$_i$	$_0$—	$_0$—	$_1$—	$_0$—	$_0$—	$_1$W	$_1$—
∼ 6. an$_i$im$_i$ar$_i$	$_0$—	$_0$—	$_1$—	$_0$—	$_0$—	$_2$W	$_0$L
∼ 7. an$_i$im$_i$al	$_0$—	$_1$W	$_0$L	$_0$—	$_0$—	$_1$W	$_1$—
∼ 8. an$_i$im$_i$ar	$_1$W	$_0$—	$_0$L	$_0$—	$_0$—	$_1$W	$_1$—

Giving [l] when an [r] precedes the suffix in the word:

(100) Tableau illustrating liquid dissimilation in *quadrantal* (a liquid measure)

Filter constraints: Ident-CC-[cons]

Maximum level of structure: `Segment`

/k^{w}adrantaR/	CC-Corr-[rho]	CC-Corr-[lat]	Ident-CC-[nas]	Ident-CC-[high]	Ident-CC-[son]	¬Ident-CC-[lat]	CC-Corr-[cons]
☞ 1. k^{w}adr$_i$antal$_i$	0	0	0	0	0	0	4
∼ 2. k$^{w}{}_i$adr$_i$antal$_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_1$W	$_3$L
∼ 3. k^{w}ad$_i$r$_i$antal$_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_1$W	$_3$L
∼ 4. k$^{w}{}_i$ad$_i$r$_i$antal$_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_2$W	$_2$L
∼ 5. k$^{w}{}_i$ad$_i$r$_i$ant$_i$al$_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_3$W	$_3$W	$_1$L
∼ 6. k^{w}adr$_i$an$_i$tal$_i$	$_0$—	$_0$—	$_2$W	$_0$—	$_0$—	$_1$W	$_3$L
∼ 7. k$^{w}{}_i$ad$_i$r$_i$an$_i$tal$_i$	$_0$—	$_0$—	$_2$W	$_0$—	$_1$W	$_3$W	$_1$L
∼ 8. k$^{w}{}_i$ad$_i$r$_i$an$_i$t$_i$al$_i$	$_0$—	$_0$—	$_2$W	$_0$—	$_3$W	$_4$W	$_0$L
∼ 9. k$^{w}{}_i$ad$_i$rant$_i$al	$_1$W	$_1$W	$_0$—	$_0$—	$_0$—	$_2$W	$_3$L
∼ 10. k$^{w}{}_i$ad$_i$rant$_i$ar	$_2$W	$_0$—	$_0$—	$_0$—	$_0$—	$_2$W	$_3$L

And giving [r] when the suffix is preceded by [l], regardless of whether or not a non-coronal intervenes:

(101) Tableau illustrating liquid dissimilation in *nubilar* ‘barn’

Filter constraints: Ident-CC-[cons]

Maximum level of structure: `Segment`

/nuːbilaR/	CC-Corr-[rho]	CC-Corr-[lat]	Ident-CC-[nas]	Ident-CC-[high]	Ident-CC-[son]	¬Ident-CC-[lat]	CC-Corr-[cons]
☞ 1. nuːbil$_i$ar$_i$	0	0	0	0	0	0	2
∼ 2. nuːbil$_i$al$_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_2$—
∼ 3. nuːb$_i$il$_i$ar$_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_1$L
∼ 4. nuːb$_i$il$_i$al$_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_1$W	$_1$L
∼ 5. n$_i$uːbil$_i$ar$_i$	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_1$L
∼ 6. n$_i$uːbil$_i$al$_i$	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_1$L
∼ 7. n$_i$uːb$_i$il$_i$ar$_i$	$_0$—	$_0$—	$_1$W	$_0$—	$_2$W	$_1$W	$_0$L
∼ 8. n$_i$uːb$_i$il$_i$al$_i$	$_0$—	$_0$—	$_1$W	$_0$—	$_2$W	$_2$W	$_0$L
∼ 9. nuːb$_i$il$_i$al	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_0$—	$_2$—
∼ 10. nuːb$_i$ilal$_i$	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_0$—	$_2$—
∼ 11. nuːb$_i$ilar$_i$	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_1$W	$_2$—
∼ 12. n$_i$uːbil$_i$al	$_0$—	$_1$W	$_1$W	$_0$—	$_0$—	$_0$—	$_2$—
∼ 13. n$_i$uːbilal$_i$	$_0$—	$_1$W	$_1$W	$_0$—	$_0$—	$_0$—	$_2$—
∼ 14. n$_i$uːbilar$_i$	$_0$—	$_1$W	$_1$W	$_0$—	$_0$—	$_1$W	$_2$—
∼ 15. n$_i$uːb$_i$il$_i$al	$_0$—	$_1$W	$_1$W	$_0$—	$_2$W	$_1$W	$_1$L
∼ 16. n$_i$uːb$_i$ilal$_i$	$_0$—	$_1$W	$_1$W	$_0$—	$_2$W	$_1$W	$_1$L
∼ 17. n$_i$uːb$_i$ilar$_i$	$_0$—	$_1$W	$_1$W	$_0$—	$_2$W	$_2$W	$_1$L
∼ 18. n$_i$uːb$_i$ilal	$_0$—	$_2$W	$_1$W	$_0$—	$_1$W	$_1$W	$_2$—
∼ 19. nuːb$_i$il$_i$ar	$_1$W	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_2$—
∼ 20. n$_i$uːbil$_i$ar	$_1$W	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_2$—
∼ 21. n$_i$uːb$_i$il$_i$ar	$_1$W	$_0$—	$_1$W	$_0$—	$_2$W	$_1$W	$_1$L
∼ 22. n$_i$uːb$_i$ilar	$_1$W	$_1$W	$_1$W	$_0$—	$_1$W	$_1$W	$_2$—

(102) Tableau illustrating liquid dissimilation in *calcar* ‘spur’

Filter constraints: Ident-CC-[cons]

Maximum level of structure: `Segment`

/kalkaR/	CC-Corr-[rho]	CC-Corr-[lat]	Ident-CC-[nas]	Ident-CC-[high]	Ident-CC-[son]	¬Ident-CC-[lat]	CC-Corr-[cons]
☞ 1. $kal_i kar_i$	0	0	0	0	0	0	2
∼ 2. $kal_i kal_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_2$—
∼ 3. $k_i al_i kar_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_1$L
∼ 4. $k_i al_i kal_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_1$W	$_1$L
∼ 5. $kal_i k_i al_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_2$W	$_0$—	$_1$L
∼ 6. $kal_i k_i ar_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_2$W	$_1$W	$_1$L
∼ 7. $k_i al_i k_i al_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_3$W	$_0$—	$_0$L
∼ 8. $k_i al_i k_i ar_i$	$_0$—	$_0$—	$_0$—	$_0$—	$_3$W	$_1$W	$_0$L
∼ 9. $k_i al_i kal$	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_0$—	$_2$—
∼ 10. $kal_i k_i al$	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_0$—	$_2$—
∼ 11. $k_i alkal_i$	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_0$—	$_2$—
∼ 12. $kalk_i al_i$	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_0$—	$_2$—
∼ 13. $k_i alk_i al_i$	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_1$W	$_1$L
∼ 14. $k_i alkar_i$	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_1$W	$_2$—
∼ 15. $kalk_i ar_i$	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_1$W	$_2$—
∼ 16. $k_i alk_i ar_i$	$_0$—	$_1$W	$_0$—	$_0$—	$_1$W	$_2$W	$_1$L
∼ 17. $k_i al_i k_i al$	$_0$—	$_1$W	$_0$—	$_0$—	$_2$W	$_0$—	$_1$L
∼ 18. $k_i alk_i al$	$_0$—	$_2$W	$_0$—	$_0$—	$_0$—	$_1$W	$_2$—
∼ 19. $k_i al_i kar$	$_1$W	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_2$—
∼ 20. $kal_i k_i ar$	$_1$W	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_2$—
∼ 21. $k_i al_i k_i ar$	$_1$W	$_0$—	$_0$—	$_0$—	$_2$W	$_0$—	$_1$L
∼ 22. $k_i alk_i ar$	$_1$W	$_1$W	$_0$—	$_0$—	$_0$—	$_1$W	$_2$—

The ranking in (98), however, is inconsistent with the ranking for *-āri/āli-* in (90). It is impossible to model the behaviour of both affixes within the same synchronic grammar using CC-correspondence. Rather, I claim that the dissimilation pattern in *-al/ar* represents the lexicalised residue of an older pattern of dissimilation, which entered Stage L of its life cycle before the attested period.

Evaluating the plausibility of this claim, and addressing the remaining points requires proposing a diachronic account of exactly how the allomorphy came to be. Unfortunately, given that liquid dissimilation is an entirely archaic feature of Latin that may go back to a Common Italic ancestor or even further, we may lack sufficient documentation to pronounce meaningfully upon its genesis. It should be noted at this point that Watkins (1970a)'s informal rule *-āli-* → *-āri-* / (. . .)*l* (. . .)___ is equally stipulative, but could not be expected to be otherwise, given the architectural lack of explanatory adequacy in rule-based morphophonology.

Although we lack attestations of a stage of the language diachronically prior to liquid dissimilation, it is possible to make tentative statements about the nature of the change that precipitated it on first principles. On the same principles of internal reconstruction that we employ as part of our reasoning to posit e.g. a pre-rhotacism **fūnesis* for Classical *fūneris*, comparing forms like *fūnus* and *fūnestus*, we can hypothesise proto-forms such as **mīlitalis*, proposing that of the *-āl(i)-* and *-ār(i)-* allomorphs, only *-āl(i)-* is old. The reasoning is exactly parallel: given a paradigm like *fūnus*, *fūneris*, which shows *s* in some of its members, and *r* in the corresponding position in others, we note that the *r* is restricted to a certain phonological environment, viz. between vowels. We therefore propose that the *r* is the product of change, and that the paradigm originally showed the "elsewhere" form *s* everywhere. In the same fashion I propose that the *l* of *-āli-* is default and therefore original.

With this hypothesis in hand, we have, as it were, "before" and "after" snapshots of the theoretical grammar: a simple underlier /-aːli-/, faithfully parsed, before the change, and /-aːRi-/, parsed according to the preference of ¬IDENT-CC-[LAT], after it. We can now evaluate the plausibility of such a change in light of the first principles of change in OT grammars.

The first observation we can make is that, in OT terms, this change has more in common with an analogy, like the change in the formation of plurals that gives us Modern English *cows* instead of the earlier *kine*, than with a regular sound change like rhotacism. Sound change, as we have already seen (§1.1.1) is matter of constraint re-ranking, whereas this change takes place in the input.

This finding may come as a surprise, in that the motivation for the change is phonological: the only factors that are necessary and sufficient to decide the set of nouns which will show *-āri-* deal in phonological segments (i.e. the presence or absence of an /l/) or features thereof (blocking of dissimilation by segments with non-coronal place). This contrasts with cases like *kine* > *cows*, which can be motivated in terms of the productivity of the *-s* form expanding at the expense of older mechanisms for marking plural. This requires us to ask the following question: does our theory of language acquisition and the genesis of sound change allow for an entirely phonologically-motivated change to consist of what is essentially an analogy?

Taking the standard OT model of error-driven constraint demotion, where the grammar changes as children learning language misperceive the utterances of their elders (Tesar & Smolensky 1998; Bermúdez-Otero 2003), the answer is almost certainly "yes". Consider the following thought experiment: a child learning language regularly mishears the sequence /l. . . l/ as [l. . . r], (a not unlikely proposition, cf. the /l. . . l/ → [r. . . l] process in colloquial Spanish: canonical *glándula* → *grándula* (Lloret 1997: 128)) and in all such sequences the elders produce during her crucial language-formative phase, the second *l* happens to be part of the suffix *-ali-*. At this point the child has a choice in her linguistic competence: she can consider the first criterion, the presence of a preceding /l/, to be necessary, and the second, the fact that the form being dissimilated is the suffix *-āli-*, contingent, or she can conclude that both criteria are necessary for the dissimilation to take place. If she does the former, she will rank ¬IDENT-CC-[LATERAL] above FAITH-IO, and the result will be a regular sound change: liquids in her speech will all dissimilate. Because the words she is exposed to are morphologically complex, however, she is given the option of drawing the latter conclusion, that she is hearing a morpheme /-aR(i)-/ with two allomorphs.

There is marginal evidence that some learners may have made the alternate decision, choosing to leave ¬IDENT-CC-[LAT] top-ranked, and therefore showing an alternation of liquids throughout their idiolects: Leumann (1977: 231) cites attestations of a number of dissimilated forms whose best-attested versions have identical liquids in sequence: e.g. *pelegrīnus* for *peregrīnus* (cf. English *pilgrim*), *fragellum* for *flagellum* (the diminutive of *flagrum*). This may suggest that there existed a sociolinguistic variable as to whether the language tolerated successive identical liquids.

This piece of inductive reasoning allows us to reach the stage where there is a single dissimilation affecting both *-ar/-al* and *-āri/āli-*, with the misparse interpreted as being a phonologically-conditioned allomorphy of a single morpheme. In the case of a non-morphologically delimited phonological generalisation, this would be codified into the phonology at the phrase level (Stage 1 of the life cycle). In the case of a phonological generalisation that is interpreted as pertaining to a specific affix, however, it is by its very nature specific at least to the word, if not to the stem, and so will enter the phonology directly at either the stem or the word level. It will only change from word-level to stem-level or vice versa, furthermore, if the affix it pertains to changes its phonological affiliation from one to the other.

What I propose, therefore, is a truncated progress through the life cycle for this particular generalisation: in the first stage, the dissimilation applies equally to *-āri/āli-* and to *-ar/al*, without blocking by intervening non-coronals. In the second stage, the variation in the application of the dissimilation to the more productive *-āri/āli-* morpheme (as witness *Latiāris* vs. *Latiālis*) is re-interpreted such that the dissimilation is blocked by intervening non-coronals. It is at this stage that the dissimilation without blocking in *-ar/al*, and in *-brum/b(u)lum*, *crum/c(u)lum* is preserved, and systematised into the lexicon. In the model we are developing, this takes place between Diachronic Stages 1 and 2, but this need not mean that it takes place at exactly the same time that, for example, the non-strident fricatives are lost, only that it follows an (only vestigially attested) stage in which all dissimilations follow the same pattern (see page 239). In particular, as this is a matter of lexicalisation, the pattern need not be imposed on all members of the category in lockstep: it may be that for some speakers, the phonologically conditioned allomorphy remained active in those *-ar/al* nouns which were semantically minimally distinct from the adjective longer than for the more individuated examples. In support of this view, it is a suggestive fact that forms such as *animāle*, *nūbilāre*, which may be read as neuter adjectives, and are taken to represent the origin of the nouns in *-ar/al*, exemplify the nouns which are minimally distinct from their parent adjectives (we may gloss *animāl(e)* equally well as 'animal' or 'living thing', for example; contrast *fēminal* as a term specifically for the female pudenda—**fēmināle* is not attested). It is also the case that every *-al/ar* noun that is attested in a form retaining the final *e* is one for which we would predict the same liquid in the suffix regardless of whether the blocking or non-blocking dissimilation pattern is applied. In order to explain the attested facts, I claim that a core group of *-ar/al* nouns were considered sufficiently distinct from the *-āris/ālis* adjectives to constitute a separate category, so that the *-āris/ālis* forms could be treated separately from them, and from the *-brum/bulum* and *-crum/culum* nouns, within the grammar (see page 240 below).

The dissimilation with blocking in *-āri/āli* remains an active part of the phonology throughout the history of Latin, and may indeed be part of the phonology of languages influenced by it, including English, for as Cser (2010: n. 3) points out, the productive *-ar/al* allomorphy in e.g. *labial, global, subliminal* observes the same pattern.

The fact that both *Latiāris* and *Latiālis* are attested suggests that there was variation between speakers as to which allomorph of the suffix was used in which forms. As Cser (2010: 39) notes, this is unsurprising, and in particular we should not be surprised to find two specific kinds of exception to the generalisations that can be made over the majority of the data:

a. Extension of *-ālis*, as the most frequent allomorph, to forms where we might expect *-āris*. This represents the language of speakers who have not acquired the generalisation of dissimilation blocked by non-coronals, and instead treat forms in *-āris* as exceptional, and use *-ālis* as the productive allomorph of the suffix. This is the pattern we find in *lētālis*, *Latiālis*, *aquilōnālis* and *Palātuālis*.

b. Preservation of the older dissimilation pattern that is not blocked by non-coronals, and that is found regularly in nouns in *-al/ar*. This includes *palmāris*, *uulgāris* and *līmināris*.

The only really difficult form this leaves is *coquīnāris* 'of kitchen'. All that can be said about this form is that there are only two attestations of it, one of which has certain difficulties of textual transmission (Cser 2010: 39). In our model, it is treated as a lexically-specified exception; i.e. the underlying representation is simply taken to be /kok^{w}iːnaːris/, as are the other problematic forms. The model should be taken to represent the grammar of a speaker who uses the dissimilating allomorphy as the productive form of the suffix, and treats exceptions to the generalisation as lexically specified.

2.4 The story so far

We are now in a position to combine the two analyses proposed in this chapter into a model of the historical development of Latin phonology that correctly captures the facts of rhotacism and liquid dissimilation in their entirety, including their separate progress through the life cycle of phonological processes. This model necessitates that we distinguish four separate diachronic stages, each of which may in principle have a stem-level, a word-level and a phrase-level constraint ranking. These stages are as follows:

Diachronic stage 1; pre-historic (7th century B.C.E and before)		
Word level:	liquid dissimilation	/kalkaR/ → *calcar*
	(without blocking)	/animaR/ → *animal*
Phrase level:	fricatives voiced / V__V	/ruːsis/ → *[ruːzis] > *rūris*
		/neɸula/ → *[neβula] > *nebula*

Diachronic stage 2; pre-literary (6th – 2nd century B.C.E)		
Word level:	rhotacism	/ruːsis/ → *rūris*
	liquid dissimilation	/lokaːRis/ → *locālis*
	(with blocking)	/floːsaːRis/ → *flōrālis*
	non-strident fricatives lost	/neβula/ → *nebula*
		/ɸiðem/ → *fidem*
		/ruver/ → *ruber*
		/xʷormos/ → *formus*
		etc.

Diachronic stage 3; early literary (2nd century B.C.E)		
Stem level:	rhotacism	/[$_{stem}$ruːsi]s/ → *rūris*
		/nː[$_{stem}$siː]/ → *nisī*
Word level:	liquid dissimilation	/lokaːRis/ → *locālis*
	(with blocking)	/floːsaːRis/ → *flōrālis*

Diachronic stage 4; classical (1st century B.C.E)		
Word level:	liquid dissimilation	/lokaːRis/ → *locālis*
	(with blocking)	/flōraːRis/ → *flōrālis*

(103)

To model the generalisations listed above, we have proposed the following constraint rankings:

(104) Constraint ranking for liquid dissimilation not blocked by non-coronals:

CC-Corr-[rho] ≫ CC-Corr-[lat] ≫ Ident-CC-[nas] ≫ Ident-CC-[high] ≫ Ident-CC-[son] ≫ ¬Ident-CC-[lat] ≫ CC-Corr-[cons]

(105) Constraint ranking for liquid dissimilation blocked by non-coronals:

¬Ident-CC-[lat] ≫ CC-Corr-[lat] ≫ CC-Corr-[rho] ≫ ¬Ident-CC-art ≫ CC-Corr-[cons]

(106) Constraint ranking for rhotacism:

*[rho]-μ-[rho] ≫ OralFricStrid ≫ IOralFricV ≫ Max-[obs] ≫ Dep-[son] ≫ Dep-[rho] ≫ Max-[strid] ≫ Max-[cont]

(107) Constraint ranking for loss of non-strident fricatives:

[cons]-Agree-[lat] ≫ Dep-[lat] ≫ Max-[rho] ≫ OralFricStrid ≫ OralFricVoiceless ≫ Onset ≫ IOralFricV ≫ [cons]-Agree-[rad] ≫ [cons]-Agree-[dor] ≫ [cons]-Agree-[rho] ≫ CodaCond-[cont] ≫ Max-[cont] ≫ Max-[dor] ≫ Dep-[plos] ≫ Dep-[rad] ≫ Max-[obs] ≫ Dep-[son] ≫ Dep-[rho] ≫ Ident-[strid]

(108) Constraint ranking for voicing of intervocalic oral fricatives:

IOralFricV ≫ Ident-[voi]

Synthesising these rankings together, we arrive at the following Stratal OT hypothesis for part of the history of Latin phonology:

(109) **Diachronic Stage 1; Word-level ranking** CC-Corr-[rho] ≫ CC-Corr-[lat] ≫ Ident-CC-[nas] ≫ Ident-CC-[high] ≫ Ident-CC-[son] ≫ ¬Ident-CC-[lat] ≫ CC-Corr-[cons]

Phrase-level ranking IOralFricV ≫ Ident-[voi]

Diachronic Stage 2; Word-level ranking [cons]-Agree-[lat] ≫ Dep-[lat] ≫ Max-[rho] ≫ OralFricStrid ≫

ORALFRICVOICELESS ≫ ONSET ≫ IORALFRICV ≫ [CONS]-AGREE-[RAD] ≫ [CONS]-AGREE-[DOR] ≫ [CONS]-AGREE-[RHO] ≫ CODACOND-[CONT] ≫ MAX-[CONT] ≫ MAX-[DOR] ≫ DEP-[PLOS] ≫ DEP-[RAD] ≫ MAX-[OBS] ≫ DEP-[SON] ≫ DEP-[RHO] ≫ IDENT-[STRID] ≫ ¬IDENT-CC-[LAT] ≫ CC-CORR-[LAT] ≫ CC-CORR-[RHO] ≫ ¬IDENT-CC-ART ≫ CC-CORR-[CONS]

Diachronic Stage 3; Stem-level ranking *[RHO]-μ-[RHO] ≫ ORALFRICSTRID ≫ IORALFRICV ≫ MAX-[OBS] ≫ DEP-[SON] ≫ DEP-[RHO] ≫ MAX-[STRID] ≫ MAX-[CONT]

Word-level ranking ¬IDENT-CC-[LAT] ≫ CC-CORR-[LAT] ≫ CC-CORR-[RHO] ≫ ¬IDENT-CC-ART ≫ CC-CORR-[CONS]

Diachronic Stage 4; Word-level ranking ¬IDENT-CC-[LAT] ≫ CC-CORR-[LAT] ≫ CC-CORR-[RHO] ≫ ¬IDENT-CC-ART ≫ CC-CORR-[CONS]

This hypothesis predicts the correct transparent interaction between rhotacism and liquid dissimilation in e.g. *flōrālis*:

(110) Tableau illustrating liquid dissimilation in *flōrālis* 'floral'

Filter constraints: Ident-CC-[cons]

Maximum level of structure: `Segment`

/floːsaːRis/	[cons]-Agree-[lat]	Dep-[lat]	Max-[rho]	OralFricStrid	OralFricVoiceless	Onset	IOralFricV	[cons]-Agree-[rad]	[cons]-Agree-[dor]	[cons]-Agree-[rho]	CodaCond-[cont]	Max-[cont]	Max-[dor]	Dep-[plos]	Dep-[rad]	Max-[obs]	Dep-[son]	Dep-[rho]	Ident-[strid]	¬Ident-CC-[lat]	CC-Corr-[lat]	CC-Corr-[rho]	¬Ident-CC-art	CC-Corr-[cons]
☞ 1. f$_i$l$_i$oːr$_i$aːl$_i$is	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	0	0	0	2	1
~ 2. f$_i$l$_i$oːr$_i$aːl$_i$is$_i$	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{3}$W	${}_{0}$L
~ 3. f$_i$l$_i$oːr$_i$aːris	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{1}$W	${}_{1}$L	${}_{2}$W
~ 4. f$_i$l$_i$oːraːr$_i$is	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{1}$W	${}_{1}$L	${}_{2}$W
~ 5. f$_i$l$_i$oːraːris	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{2}$W	${}_{0}$L	${}_{3}$W
~ 6. f$_i$l$_i$oːr$_i$aːlis	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{0}$—	${}_{1}$W	${}_{0}$—	${}_{1}$L	${}_{2}$W
~ 7. f$_i$l$_i$oːraːlis	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{0}$—	${}_{1}$W	${}_{1}$W	${}_{0}$L	${}_{3}$W
~ 8. f$_i$loːraːl$_i$is	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{0}$—	${}_{1}$W	${}_{1}$W	${}_{0}$L	${}_{3}$W
~ 9. f$_i$loːr$_i$aːlis	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{1}$—	${}_{1}$W	${}_{2}$W	${}_{0}$—	${}_{0}$L	${}_{3}$W
~ 10. floːtaːris	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{1}$W	${}_{0}$—	${}_{0}$L	${}_{0}$L	${}_{0}$L	${}_{1}$—	${}_{0}$—	${}_{1}$W	${}_{1}$W	${}_{0}$L	${}_{5}$W
~ 11. floːtaːlis	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{1}$W	${}_{0}$—	${}_{0}$L	${}_{0}$L	${}_{0}$L	${}_{1}$—	${}_{0}$—	${}_{2}$W	${}_{0}$—	${}_{0}$L	${}_{5}$W
~ 12. floːsaːris	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$W	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$L	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$L	${}_{0}$L	${}_{0}$L	${}_{0}$L	${}_{0}$—	${}_{1}$W	${}_{1}$W	${}_{0}$L	${}_{5}$W
~ 13. floːsaːlis	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$W	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$L	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$L	${}_{0}$L	${}_{0}$L	${}_{0}$L	${}_{0}$—	${}_{2}$W	${}_{0}$—	${}_{0}$L	${}_{5}$W
~ 14. floːlaːris	${}_{1}$—	${}_{1}$W	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{1}$—	${}_{0}$L	${}_{1}$—	${}_{0}$—	${}_{2}$W	${}_{1}$W	${}_{0}$L	${}_{5}$W
~ 15. floːlaːlis	${}_{1}$—	${}_{1}$W	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{0}$—	${}_{0}$—	${}_{0}$—	${}_{1}$—	${}_{1}$—	${}_{0}$L	${}_{1}$—	${}_{0}$—	${}_{3}$W	${}_{0}$—	${}_{0}$L	${}_{5}$W

Appendix A shows the results when inputs representing the forms discussed in this chapter, as well as others showing the effects of the same sound changes, are fed to PyOT with the constraint rankings above in the order specified above. As the appendix shows, the attested forms are predicted in each case. The rankings in (109), however, are only a subset of those against which PyOT evaluated inputs in order to produce Appendix A. This is because the full model of phonological change in Latin which we are in the process of building also includes rankings to model Lachmann's Law, which we will now discuss.

Chapter 3

Lachmann's Law

3.1 The data.

Lachmann's Law is a peculiarity of the grammar of Latin whereby the past participles (and some other morphologically complex forms) of certain verbal roots show an etymologically unexpected long vowel. So, for example, we find *uīsus* alongside *uĭdeo*, *ēsus* alongside *ĕdo*, *āctus* alongside *ăgo* and *tūsus* alongside *tŭndo*.

The most important fact from the point of view of any phonological analysis of Lachmann's Law is that, as a lengthening process, it is **not surface-true**, which is to say that there is no featural statement of a surface environment which will suffice to capture every instance where lengthening is attested, while including none in which it is not. If, for example, we take as our environment __*Cto* (or subsequent reflex thereof, as in e.g. *cāsus* from **kad-tos*), then we have successfully accounted for the fourteen forms that appear to show lengthening by Lachmann's Law, but we have also included a greater number of forms that show no such lengthening, viz:

(111)

With lengthening			Without lengthening		
āctus	∼	*ăgō*	*făctus*	∼	*făciō*
frāctus	∼	*frăngō*	*iăctus*	∼	*iăciō*
tāctus	∼	*tăngō*	*uĭctus*	∼	*uĭncō*
pāctus	∼	*păngō*	*dŏctus*	∼	*dŏceō*
rēctus	∼	*rĕgō*	*strĭctus*	∼	*strĭngō*
tēctus	∼	*tĕgō*	*fĭssus*	∼	*fĭndō*
lēctus	∼	*lĕgō*	*scĭssus*	∼	*scĭndō*
ēmptus	∼	*ĕmō*	*trăctus*	∼	*trăhō*
tūsus	∼	*tŭndō*	*pĭctus*	∼	*pĭngō*
fūsus	∼	*fŭndō*	*fŏssus*	∼	*fŏdiō*
cāsus	∼	*cădō*	(*sĕssum*)[2]	∼	*sĕdeō*
ēsus	∼	*ĕdō*	*păssus*	∼	*păndō*
ōsus	∼	(*ŏdium*)[1]	*uĕctus*	∼	*uĕhō*
uīsus	∼	*uĭdeō*	*iŭssus*	∼	*iŭbeō*

The forms in the "with lengthening" column of the table above are those generally accepted as being affected by Lachmann's Law (e.g. by Sommer 1914; Kent 1928; Collinge 1985; Jasanoff 2004: etc.). The list should also be taken to include all compounds of the verbs present, e.g. *compactus* ∼ *pactus*, *redactus* ∼ *actus* *neglectus* ∼ *lectus* and so on. Indeed, as we shall see below (p. 136), the behaviour of the vowels in compound forms is an important source of the evidence which

[1]The verb *ōdi* has perfect forms but present function, the earliest texts attest no present tense alongside it, and the form *ŏdio* is a back-formation of Imperial date (Ernout & Meillet 1959: 458). The noun *ŏdium* is cited here in order to show that the root of *ōsus* had a short vowel

[2]The verb *sedeō*, being intransitive, lacks a past particple. Compounds such as *obsideō*, *possideō* have participles in -*sĕssus*, however, and the form of *sedeō* cited here, the supine *sĕssum*, likewise has a short vowel.

leads us to ascribe these forms to the list in the first place.

3.2 The evidence.

3.2.1 Sources.

The syllables containing the vowels we are concerned with are necessarily closed, since they precede a cluster comprised of the final consonant of the verbal root and the *t* of the suffix *-tos*. Therefore, what is normally the most useful metric of vowel length available to us from the attested material, scansion of the syllables when they appear in verse, offers no evidence in this case, since the syllables will always be long "by position", regardless of the length of the vowel. There are, however, other indicators of vowel length which suffice to give us the data for our analyses.

The apex.

Quintilian tells us (*Inst* I, 7, 2–3):

> *ut longis syllabis omnibus adponere apicem ineptissimum est, quia plurimae natura ipsa verbi quod scribitur patent, sed interim necessarium, cum eadem littera alium atque alium intellectum, prout correpta vel producta est, facit: (III.) ut "malus" arborem significet an hominem non bonum apice distinguitur, "palus" aliud priore syllaba longa, aliud sequenti significat, et cum eadem littera nominativo casu brevis, ablativo longa est, utrum sequamur plerumque hac nota monendi sumus.*

> "To place an apex on every long syllable is most absurd..., because most are obvious by the very nature of the word which is written, but from time to time, when the same letter is understood in one way or another, accordingly as it is long or short, it makes it necessary: whether *malus* means a plant or a man who is not good can be discerned from the apex, *palus* means one thing when the first syllable is long, and another when the second is, and when the same letter is short in the nominative case and long in the ablative, in many cases we are advised which sense to follow by this notation."

Quintilian speaks of long and short syllables, rather than vowels, and indeed some uses of the apex mark short vowels in long syllables (see, for example *pássa* at CIL VI 22251, *cautíssimus* at Dessau 1892: 56), but the majority of the evidence indicates that the apex is primarily a marker specifically of vowel length, rather than syllable weight (Rolfe 1922). Oliver (1966: 135) suggests that "The use of the apex in inscriptions makes it obvious that, from the very first, the function of the apex was to show the correct pronunciation of words that, presumably, were sometimes mispronounced in current speech." This would include the sort of disambiguation for which the apex is prescribed by Quintilian, but Oliver is at pains to point out that the majority of the attested instances of the apex do not in fact conform to Quintilian's rule, and therefore that some other principle must have originally governed its use. Since the Lachmann forms comprise a minority of past participles, it is not unreasonable to imagine that they would be prime targets for apex-marking according to Oliver's principle, and indeed we do find apices on many of the attested inscriptional examples of the Lachmann verbs.

It bears mentioning, however, that some scribes evidently intended their uses of the apex to mark syllable weight, rather than vowel length, and furthermore that there are uses of the apex which must be regarded as sheer mistakes, since they mark what we know from scansion or morphology are neither long vowels nor long syllables (e.g. *Germaníco* at Dessau (1892: 538), *Caesarís* at Dessau (1892: 391), *tectorúm* at CIL XIV 2922). This being so, we should take it as a principle that an apex alone is not sufficient to confirm vowel length definitively.

Regular sound changes.

Some sound changes within the history of Latin affect long vowels differently from short ones. Vowel weakening, for example, does not affect long vowels at all. Being conditioned by the pre-historic initial stress accent, vowel weakening only affects medial and final syllables, so to identify a participle as falling subject to Lachmann's Law, we look for a lack of qualitative alternation between the participles of a simplex verb and its compounds. For example, we know that the *ā* of *āctus* is long because the participles of compounds like *redactus*, *adactus* retain their *a*: if it were short, it would have weakened to *e*, as in *perfectus* ∼ *făctus*. Vowel weakening in general only affects *a* and *o* (Meiser 1998: 70), and so can only provide testimony as to Lachmann's Law for verbs which a) have compounds and b) show *a* or *o* in the participle of the base form.

A related phenomenon is the contraction of vowels when adjacent to one another. Sequences of short vowel + long vowel only regularly contract together when in final syllables: e.g. *laudēs* < **lau̯daēs* (Meiser 1998: 88), whereas sequences of short vowel + short vowel or long vowel + short vowel always contract: e.g. *cōgō* < *cō-agō* (Meiser 1998: 88), *lātrīna* < *lau̯atrīna*, with regular loss of intervocalic u̯ (Meiser 1998: 87). So, when a verb without a stem-initial consonant is compounded with a prefix that ends in a vowel, we know the verb is subject to Lachmann's Law if the vowels do not contract together. An example of this is the past participle of the aforementioned *cōgō*: *coāctus*.

Romance reflexes.

An extension of this principle, of querying the effect of sound changes on the vowels whose quantity is in question, is to examine the reflexes of the forms we are concerned with in the Romance languages. For example, the regular French reflex of Latin *ē* (outside particular environments conditioning other changes) is ⟨oi⟩, while the reflex of *ĕ* is ⟨i⟩. So, since *tectum* yields French *toit*, we can surmise that the *e* of *tectum* is long.

It should be noted that in some cases the evidence from Romance is equivocal: Abbruzzese Italian, for example, has *pettá*, which points to the attested Latin **pĭct-*, but standard Italian has *pittura*, which appears to reflect *pīctūra*, with an otherwise unevinced long vowel.

Degemination of -*ss*.

Indo-European -*tt*- or -*dt*- regularly yields Latin -*ss*- (Meiser 1998: 124). However, following a long vowel or diphthong, this sequence, which is generally believed to represent a long consonant, underwent a change which simplified it to *s* c. 100 BC., e.g. in *mīsit* < *mīssit* (attested at CIL I^2 1216) (Meiser 1998: 125). This change was formalised in the orthography somewhat later than it actually occurred (see the quote from Quintilian and discussion on page 174 below), but nonetheless in participles from roots ending in a dental, a single *s* (as in *ōsus* and *ēsus*) suffices to show that the vowel of the stem is long.

Transcription into Greek.

Where Latin is written in the Greek alphabet, it becomes possible to distinguish some vowel quantities, since there are separate letters in the Greek alphabet for marking long *ē* and *ō*. The useful examples for our purposes are Dio Cassius' rendering of *Aemilio Recto* as *Αἰμιλίῳ... Ῥήκτῳ*, and the rendering of *redempta* as *ϱεδημπτα* at CIG 9811. There are, however, counterexamples, as discussed by Osthoff (1884: 113), including one of Dio writing *Ἔκλεκτος* (LXXII, 4, 6) and an example of *Ῥεκτός* from a fragment of Plutarch. Osthoff presents two hypotheses for why the choice of Greek letters may not represent the correct Latin vowel quantity: firstly, if the author is a native speaker of Latin, he may be unused to making a written distinction between long and short vowels, and so use epsilon where he would naturally use *e* and omicron where he would use *o*. Conversely, if the author is a Greek, he may be influenced by the presence of similar-sounding words in his native language (e.g. *λεκτός* 'speakable') which, even if they are cognate, would of course not undergo Lachmann's Law, which is Latin-specific.

In any case, as with the apex, prudence dictates that we should not regard transcription into Greek alone as definitive evidence of vowel quality.

Testimony of contemporary authors.

The most straightforward evidence for Lachmann's Law, as we shall see, is that occasionally a grammarian or scholiast will comment directly on the length of a particular form.

We will now examine in detail the evidence which prompts us to claim that Lachmann's Law affects each individual form.

3.2.2 Forms.

āctus

Probably our best evidence for the length of the *ā* of *āctus* comes from the testimony of Aulus Gellius, who writes (IX, 6, 3):

(112) *quoniam frequentatiua ferme omnia eodem modo in prima syllaba dicuntur, quo participia praeteriti temporis ex his uerbis, unde ea profecta sunt, in eadem syllaba pronuntiantur, sicuti 'lego, lectus' facit 'lectito'; 'ungo, unctus' 'unctito'; 'scribo, scriptus' 'scriptito; 'moueo, motus' 'motito'; 'pendeo, pensus' 'pensito'; 'edo, esus' 'esito'; 'dico' autem 'dictus' 'dictito' facit; 'gero, gestus' 'gestito'; 'ueho, uectus' 'uectito'; 'rapio, raptus' 'raptito'; 'capio, captus' 'captito'; 'facio, factus' 'factito'. sic igitur 'actito' producte in prima syllaba pronuntiandum, quoniam ex eo fit, quod est 'ago' et 'actus'.*

"For nearly all frequentatives are pronounced in the same way in the first syllable, as the past participles of those verbs, from which they are derived, are pronounced in the same syllable, thus '*lego*, *lēctus*' makes '*lēctito*'; '*ungo*, *ūnctus*', '*ūnctito*'; '*scrībo*, *scrīptus*' '*scrīptito*'; '*moueo*, *mōtus*' '*mōtito*'; '*pendeo*, *pēnsus*' '*pēnsito*'; '*edo*, *ēsus*' '*ēsito*'; but '*dico*, *dictus*' makes '*dĭctito*'; '*gero*, *gestus*' '*gestito*'; '*ueho*, *uectus*' '*uectito*'; '*rapio*, *raptus*'

> '*raptito*'; '*capio*, *captus*' '*captito*'; '*facio*, *factus*' '*factito*'. So therefore '*āctito*' is to be pronounced long in the first syllable, because it comes from *ago* and *āctus*."

Note that in this passage Gellius is arguing for a four-part analogy, on the proportion *dĭctus : dĭctito :: āctus : X*, in an attempt to persuade the reader to adopt the frequentative *āctito*, instead of the *ăctito* he has heard from '*non sane indoctos viros*'. This implies that the length of the *ā* of *āctus* is a well-established part of the contemporary grammar, or else Gellius could not expect it to be persuasive in an analogy.

Further corroborating evidence becomes visible when the *ā* of *āctus* occurs in environments where, if short, it would be subject to vowel weakening or contraction. Thus we find *adāctus*, with a word-medial *a* in a closed syllable, which we would expect, if short, to weaken to *e*, cf. *perfectus* < **per-făctus* (Meiser 1998: 70). Similarly, if the *a* of *coāctus* were short, we would expect it to contract with the preceding *o*, cf. *cōgō* < **co-ăgō* (Meiser 1998: 88).

There are three attestations of *āctus* with apex: *áctum* CIL XI, 3805; *exáctus* CIL XIII, 1668; *redácta* CIL VI, 701.

frāctus

The only evidence for the length of the *ā* of *frāctus* is the lack of vowel weakening in the prefixed form *effrāctus*.

tāctus

Likewise for *tāctus*, the only evidence is the lack of weakening in *contāctus*.

pāctus

Again in *pāctus*, we are reliant on the lack of vowel weakening in *compāctus* to evince the length of the vowel.

rēctus

Strong evidence for the *ē* of *rēctus* is provided by French *droit* < *dīrēctum*, with ⟨oi⟩ as the regular reflex of Lat. *ē* (cf. *loi* < *lēgem*, *roi* < *rēgem*).

There is a corroborating apex on *réctorem* at CIL XII 4333. Cf. also Dio Cassius LVII, 10, 5 *Αἰμιλίῳ… Ῥήκτῳ*.

tēctus

The nature of the evidence for *tēctus* is almost identical with that of the evidence for *rēctus*: we have a French ⟨oi⟩ in *toit* < *tēctum* and an apex on *téctor* at CIL VI 5205.

lēctus

The length of the vowel in *lēctus* is directly attested to by Gellius in the passage quoted at (112), and the apex of *léctus* at CIL XI, 1826 agrees.

There is also evidence for a long *ē* in *lēctor*, viz. the apex of *léctor* at CIL VI, 9447 and the following passage Aulus Gellius XII, 3, 4

(113) *si quis autem est, qui propterea putat probabilius esse, quod Tiro dixit, quoniam prima syllaba in 'lictore', sicuti in 'licio', producta est in eo verbo, quod est 'ligo', correpta est, nihil ad rem istuc pertinet. nam sicut a 'ligando' 'lictor', et a 'legendo' 'lector'*

> *et a 'uiendo' 'uitor' et 'tuendo' 'tutor' et 'struendo' 'structor' productis, quae corripiebantur, vocalibus dicta sunt.*
>
> "But if there is anyone who thinks that what Tiro says is more likely because the first syllable in '*līctor*' is long just as that in '*līcio*', but in the word '*ligō*' is short, that is not relevant to the discussion. For likewise in '*līctor*' from '*ligando*', '*lēctor*' from '*legendo*', '*uītor*' from '*uiendo*', '*tūtor*' from '*tuendo*', and '*strūctor*' from '*struendo*', the vowels, which were short, are pronounced long."

Furthermore, in his commentary on Horace, *Serm.* I, 6, 122, Porphyrio tells us that *lecto producta priore syllaba enuntiare debemus, quia frequentatiuum est ab eo, quod est: lego* "we should pronounce the first syllable of *lecto* as long, because it is the the frequentative of *legō*."

ēmptus

The evidence for the length of the vowel in *ēmptus* is probably the weakest in the Lachmannian dataset. We have an apex on *redémpta* at CIL VI 22251, and the same form is spelt *ϱεδημπτα* at CIG 9811.

For the participles of verbs with roots ending in dentals: ***tūsus***, ***fūsus***, ***cāsus***, ***ēsus***, ***ōsus***, ***uīsus***, we are mainly reliant on the simplification of *-ss-* to *-s-* to show us that the vowels in question are long. Even leaving aside the proposal that this degemination is conditioned by the presence of a preceding long vowel, once the degemination has taken place, the preceding syllable is open, and so we can observe the quantity of the vowel directly in e.g. verse scansion.

3.3 Previous analyses.

The major division between accounts of how Lachmann's Law came to be is between the two traditional mechanisms by which philologists have characterised changes between the proto-language and its attested children, viz. regular sound change and analogy.

3.3.1 Lachmann's Law as regular sound change.

Lachmann (1850) himself, in first noting the rule, envisaged it as a sound change affecting past participles of roots '*ubi in praesenti media est*' (which is taken to refer to roots ending in a voiced stop). As it stands, Lachmann's 23-word statement of the rule is more problematic than explanatory, since it offers no attempt to explain why such a phonological change should be restricted to the morphological domain of the past participle. Furthermore, it does not attempt to address the apparent exceptions to the rule, as enumerated above, and it ignores the fact that the required environment is not surface-true and likely was not so at any stage of the history of Latin.

Two developments towards the end of the nineteenth century created the basic 'engine' of Lachmann's Law as sound change. First, and most important, was the contribution of de Saussure (1889). In investigating the development of consonant clusters from Proto-Indo-European into the various attested daughter languages, de Saussure (1889: 256) almost tangentially advances the hypothesis that the Lachmann participles were analogically re-made on the model of their respective paradigms at some point in the early history of Latin.

We have good comparative evidence for voicing assimilation of stop clusters across Indo-European: for example we have Greek *λεκτός* from the root *leg-*, cognate with Lachmannian *lēctus*, and likewise in Sanskrit we have *vēt-tha* from the root *uid-*, the same root found in Lachmannian *uīsus* (King 1969: 43). This suggests that the assimilated forms are inherited from the proto-language. However, if this is so, then Latin must have inherited **ak-tos* as past participle for *ago*, and **fak-tos* as past participle for *facio*. If Lachmann's Law is a regular sound change, then something must have occurred within the history of Latin to make the environment in the inherited **ak-tos* different from that in **fak-tos*. That something, Saussure suggested, was the analogical reintroduction of a voiced stop into the past participles of verbs which had them elsewhere in the paradigm. So **ak-tos*, **lek-tos*, **et-tos* (> *ēsus*) etc. were re-made to **ag-tos*, **leg-tos*, **ed-tos* and so on. Then the sound change hinted at by Lachmann occurred:

(114) $\mathrm{V} > \bar{\mathrm{V}}$ / __DC, where D represents a voiced stop.

Subsequent to this, a second voicing assimilation took place, and assibilation of the dental stop clusters[1], giving the attested *āctus*, *lēctus*, *ēsus* etc.

Kuryłowicz (1968b) and Kiparsky (1965), in presenting their own individual alternative explanations of Lachmann's Law, both dismissed Saussure's hypothesis in no uncertain terms. Kuryłowicz (1968b: 295) flatly states that "Nowhere and at no period has *gt* been a possible combination in I.E. languages opposing voiced *g d* to voiceless *k t*." He also points out the existence of exceptions like the adjective *lăssus* < **lad-tos* and the noun *tŭssis* < **tud-tis*, in order to advance his argument that Lachmann's Law is not a sound change at all, but an analogy. Kiparsky (1965: 21), for his part, presents an objection based on the evidence of the process

[1]The change of *o* to *u* in word final closed syllables is much later, within the attested history of Latin.

of assibilation which gives us (inter alia) *ēsus* from **ed-tos* and *cāsus* from **kad-tos*. Clusters of dental + dental which are formed within the history of Latin, Kiparsky points out, assimilate in voicing but do not undergo assibilation (see, for example, *attero* from **ad-tero*). So, if the inherited **kat-tos*, for example, had been analogically remade to **kad-tos* within the history of Latin, and then had its vowel lengthened by (114), we would expect **cāttus* or **cātus*, rather than the attested *cāsus*.

Jasanoff (2004: 411ff.) defends against these objections on behalf of the Neogrammarians. He neatly rebuts Kuryłowicz's statement about the impossibility of *gt* or other voiced-voiceless combinations by pointing out examples from English like *ragtime, magpie, tadpole* etc., and meets Kiparsky's objection by suggesting that the Lachmann participles from roots ending in dental stops were remade in *-sos* rather than *-tos*, so **kadsos*, **edsos*, **tudsos*, **odsos* for *cāsus*, *ēsus*, *tūsus*, *ōsus* etc. As for *tussis* and *lassus*, Jasanoff borrows Kiparsky (1965: 21)'s explanation for their exemption from Lachmann's Law: their derivation from PIE roots was synchronically opaque at the time Lachmann's Law operated (the root **lad* is otherwise unattested in Latin, and the verb *tundo* had already come to mean 'bruise', so that its link to *tussis* 'cough' was not apparent), so there was no model on which to remake them to **lad-sos* and **tud-sis*, as one might otherwise have expected. Jasanoff (2004: 412–413) is also able to offer an attested example of an analogy exactly like Saussure's, from Ukrainian, in which the inherited infinitive *vesti* 'to convey' (attested in other East Slavic languages) is remade to *vezty* under the influence of forms in the paradigm like 1sg. *vezu*. Jasanoff (2004: 412) freely acknowledges, however, that none of this constitutes proof that Saussure's analogical reformation of the participles really took place, it only rebuts the contentions of Kuryłowicz and Kiparsky that such a reformation would have been impossible. Furthermore, his evidence that (114) really took place is not as ironclad as he makes it sound. He cites the irregular superlative *maximus*, and states that "we know that the -*a*- of this form is long" (Jasanoff 2004: 411). He proposes, following Cowgill (1970), a development of original **mag-is-m̥mo-s* by syncope to **magsm̥mos* or **magsamos*, which, by (114), voicing assimilation and vowel weakening, gave *māximus*. This is quite plausible, but Jasanoff overstates the quality of the evidence for the length of the *a*: the length is attested to only by an apex in a single inscription (CIL vi. 2080, 17), and, as we saw above (p. 135), the use of the apex is not, on its own, a reliable indicator of vowel length. We will discuss the evidence of *maximus* and other possible examples of Lachmann's Law outside participles below (p. 210)

The second contribution, which obviated a central difficulty of Lachmann's formulation, was that of Pedersen (1896), who first made explicit the restriction of the operation of Lachmann's Law to roots whose final voiced stop is original, i.e. not the reflex of a voiced aspirate. This dates the period of productivity of Lachmann's Law to before the word-medial merger of the prehistoric Latin reflexes of the voiced aspirates with the voiced stops—in our terms, before Diachronic Stage 2 (see §2.2.1). Thereafter, up until the publication of Kuryłowicz (1968b), the textbooks generally took de Saussure (1889) and Pedersen (1896)'s observations as the core of their accounts of Lachmann's Law, differing only in their characterisations of the scope of the lengthening process, and therefore which subset of the Lachmann forms they viewed as directly subject to the change, and which, for the sake of accounting for the exceptions, they viewed as secondary.

The first such attempt was that of Sommer (1914: 122–123), who suggests that the main participles for which lengthening is predicted on the Saussure-Pedersen model, but which do not show it, namely *fĭssus*, *scĭssus* and *strĭctus* escaped Lachmann's Law because the presence of a nasal infix in their present stems made the voiced quality of the relevant consonant less clear. However, Sommer offers no account of why the nasal infix had no such effect on e.g. *pāctus* ∼ *pangō*, *tāctus* ∼ *tangō* and *frāctus* ∼ *frangō*.

Elsewhere, however, (Sommer 1914: 38), he repeats a different account, due to Meillet (1908): that high vowels were regularly exempt from lengthening processes. On this account, *fĭssus*, *scĭssus* and *strĭctus* are regular, whereas *uīsus* and *fūsus* (and, presumably, also *tūsus*) were formed by a less thoroughgoing version of the Osthoff-Kent analogy we will discuss below (p. 166), taking over the long vowel of their respective perfect stems. This notion of high vowels being exempt from lengthening processes is a recurring theme in accounts of Lachmann's Law and in phonetics generally, and indeed we shall be making mention of it in the next chapter (p. 213).

The phonetic story — Niedermann (1953)

Niedermann (1953: 69–71), unlike Meillet (1908), is happy to argue that this exemption from lengthening processes can apply solely to [i], rather than universally to the high vowels. This exception is built into his detailed phonetic account of the mechanism of Lachmann's Law: he begins with the Saussure-remodelled form [ag.tos], and argues that lengthening of the vowel was a concomitant of the second devoicing of the restored voiced stop. His position may be put in terms of the misparsing model of sound change proposed by Ohala (1989): the speakers of the generation that restored the voiced stops to the Lachmann participles signalled the voicing of the stop in the usual way, by continuing vocal fold vibration longer into the closure phase of the stop than for a voiceless one; listeners of the succeeding generation, having acquired the generalisation that consonant clusters assimilate in voicing, interpreted this extended period of voicing as a cue to the length of the preceding vowel, rather than the voice feature of the stop. The length of [i] was left unchanged because of [i]'s special phonetic status: it is measurably the shortest of all the vowels, and the closest in articulatory position to the consonants. Therefore, the transition phase from [i] to a following consonant is shorter, and the available time within which to make the distinction between [i] and [iː] is less. Vocal fold vibration would be transferred from the stop to the vowel in the same way as for the forms featuring other vowels, but the difference made by this added duration was not enough to cause the listener to perceive the phoneme /iː/ rather than /i/.

This reasoning closely foreshadows the "compensatory listening" argumentation retailed, *inter alia* by Gussenhoven (2004). Where Niedermann's argumentation becomes markedly weaker is in his account of the exceptions. The least controversial account of such is his answer to the evidence of *uīsus*. He echoes what would later come to be known as the Osthoff-Kent hypothesis (for which see p 166ff.), that the etymologically unexpected long vowel of the participle was taken over on the analogy of the long vowel of the perfect stem. *uīsus*, because of its exceptional nature, vexes even those who wish to claim that the Osthoff-Kent analogy is the basis for the entirety of Lachmann's Law, so for detailed argumentation on the special nature of *uīsus* some of the best sources are analogists (see Watkins 1970b: 62, Strunk 1976: 49 and references therein). We will discuss *uīsus* further below.

Rather less convincing is Niedermann (1953: 71)'s account of the *-sĕssus* exception. He argues that "*peut-être*" the compound *obsĕssus* acquired its characteristic vowel length on the analogy of its synonym *prĕssus*. No doubt because of the tentative nature of the hypothesis, Niedermann leaves us to infer many of its details. One must suppose that once *obsessus* had undergone the analogy Niederman suggests, the other compounds in *-sessus*: *possessus*, *praesessus* etc., followed suit.

One may have to assume further that Niedermann means to claim that the supine *sessum* from the base verb *sedere* followed the vocalism of *obsessus*. It would seem that if this series of analogies did take place, they all had full and thoroughgoing effect before the attested period, since examples of the expected *-*sēsum* are wanting. It is difficult to see how this can be so, since Niedermann's theory is based on the synonymy of *pressus* and *obsessus* in very specific sub-senses of each verb, viz. that of "besiege, blockade". This being so, we might expect to find evidence that the analogy Niedermann posits began specifically in the military sociolect, and eventually spread to the Latin speech community as a whole, then spread to the other forms of *-sessus*. If evidence for this exists, it has escaped the notice of both modern and ancient scholars.

Finally, it should be pointed out that Niedermann (1953) entirely omits the question of *ēmptus*. With some knowledge of phonetics, we might conclude that the arguments with respect to vocal fold vibration being reinterpreted as a continuation of a preceding vowel apply equally well to nasal stops as to (voiced) oral ones, but that would leave us with the task of explaining the lack of lengthening in forms with other-than-labial nasals: in *căntus*, for example. Conversely, since nasals in Latin are not contrastively voiced, we might suppose that the deliberate cue to voicing which, on Niedermann's theory, was misparsed as vowel length, was absent from participles formed on roots ending in nasals, and so account for *căntus*, but require an explanation for *ēmptus*. As we shall see, other scholars have essayed accounts that address these difficulties to variously convincing extents, but Niedermann offers none.

Maniet's account - only *g*?

A different approach, which also takes the Saussure-Pedersen hypothesis as its starting point, is that of Maniet (1956, 1957). Maniet (1957: 113) states the basic rubric of his hypothesis as follows: "Une voyelle, sauf *i*, s'est allongée par suite de l'assourdissement d'un *g* suivant dans les mots offrant un rapport clair avec les formes connexes en *g*" "A vowel, excepting *i*, is lengthened as a result of the devoicing of a following *g* in words which show a clear connection with related forms showing *g*." For the exception of [i], Maniet (1957: 114) uses the same phonetically-based reasoning as Niedermann (1953): [i] was lengthened, but not to the extent of being parsed as the phoneme /iː/. The rider stipulating the requirement of a clear connection with forms retaining *g* is essentially a restatement of the condition of the Saussure hypothesis that the etymological voiced stop must be recoverable from the synchronic facts of the rest of the paradigm. Maniet (1957: 115) regards this as necessary to explain the lack of lengthening in *ăxis* "axle" < **ag-sis*, which is a kindred example to *tussis* and *lăssus* (see p. 145).

Restricting the domain of Lachmann's Law, as he envisions it, to verbs from roots ending in *g* explains the following forms without further ado:

(115)

participle	1sg. perf.
rēctus	*rēxī*
tēctus	*tēxī*
lēctus	*lēgī*
āctus	*ēgī*
frāctus	*frēgī*
tāctus	*tetigī*
pāctus	*pepigī*

However, it requires Maniet to find alternate explanations for the following forms:

(116)

participle	1sg. perf.
fūsus	*fūdī*
ēsus	*ēdī*
ōsus	*ōdī*
ēmptus	*ēmī*
uīsus	*uīdī*
tūsus	*tutudī*
cāsus	*cecidī*

Like Niedermann before him, Maniet makes no mention of *ēmptus*. For the other forms, all of which come from roots ending in **d*, he proposes that the length was taken over analogically from a putative full-grade supine, after the merger of *o* with *u* in closed word-final syllables made the majority of supines and (ACC.SG) past participles identical. Maniet (1956: 232) points to the participle *genitus* 'begotten', which shows full-grade treatment of the PIE root **gen*. The expected participle, according to the rubric zero-grade + *to*, is **gn̥$h_1$tos* > *gnātus* > *natus* 'born'. Given that it is possible for a full-grade supine to be used as an analogical model for a participle, Maniet argues, why not posit a pre-historical supine **kād-tum*, on which the attested participle *cāsus* could be built, and likewise **ēd-tum* for *ēsus*, **u̯eid-tum* for *uīsus* and so on Maniet (1956: 232–233)?

Maniet's account, however, ignores the fact that there is a specific motivation for the full-grade supine **genh̥$_1$tum* > *genitum* to influence the shape of the participle: the IE root **gen* yields *two* verbs in Latin: *(g)nāscor* 'I am born' and *gignō* 'I beget'. It is the need to disambiguate between these two verbs that caused *gignō* to take over its participle from the full-grade supine (if indeed, that is the source of *genitus*, since it should be stressed that Maniet's supines are entirely hypothetical creatures, at least as far as the Latin evidence goes). Maniet's argumentation smacks of *ad hoc* reasoning: he offers no independent reason why it should be specifically the participles listed in (116) which take over their ablaut grades from the supine. This, combined with the fact that there is no direct evidence for the necessary supines, prompts Schrijver (1991: 137–138) to argue that the full grades — if it is an analogical importation of ablaut grades we are dealing with, rather than a sound change — are taken from elsewhere in the paradigm.

Maniet (1956: 236)'s stated reason for restricting his sound change to verbs from roots ending in *g*, and seeking full-grade supines to explain the forms in *d*, is the lack of lengthening in *passus*, past participle of *pandō*. Maniet notes the similarity in meaning between *pateō* 'I am open' and *pandō* 'I open' (transitive), but opines that the etymological link between the two is too unclear to judge definitively that *pandō* reflects **pantō* and so that *passus* reflects **pat-tos*, as opposed to **pad-tos*. The prevailing opinion has moved on since the publication of Maniet

(1956), and textbooks (Meiser 1998: 122, Sihler 1995: 209) now present it as uncontroversial that *pandō* reflects **patane/o-*, with syncope and a metathesis of the resulting sequence **tn* (this hypothesis is originally due to Thurneysen 1883). On this basis, we can assume that at the time Lachmann's Law operated, the neutralisation of voicing contrasts after the nasal meant that the connection of *passus* to a form showing *d* was insufficiently strong, to co-opt Maniet's terminology, for a *d* to be reintroduced by the Saussure process. We may suppose that the semantic connection with *pateō*, coupled with the irregular nature of *pandō* (it forms a so-called "simple" perfect stem *pand-* (e.g. in *pandī*), which is a formation preferred by a relatively small minority of third conjugation verbs) was enough to make it clear to the synchronic grammar that the participle was (or reflected) **pat-tos*. If this is found plausible, then, in conjunction with the objections to the full-grade supine hypothesis presented by Schrijver (1991), Maniet's entire justification for restricting Lachmann's Law to forms in *g* is called into question.

Glottalic Theory

Kortlandt (1989) claims that adopting the glottalic theory allows one to posit a phonetic account of Lachmann's Law analogous to that of Niedermann (1953) and Maniet (1956), but without the need for any Saussurean analogical reintroduction of voiced (or glottalic) stops into the forms in question. Kortlandt's contention is that the stops that conditioned Lachmann's Law were inherited by Latin as being contrastively glottalic, so that e.g. *lēctus* began its post-PIE life as /lek'.tos/. For Kortlandt (1978, 1989), as for many other glottalicists (cf. the other papers in Vennemann 1989), the attested phonation series in the IE languages result from reanalysis of contrastive features of the original PIE phonemes as contingent or phonetic, and of their contingent features as essential or contrastive. In this particular case, Kortlandt argues (obliquely; for criticism of the vagueness of Kortlandt's argumentation see Garrett 1991: 800–801) that voicing was reanalysed as the contrastive feature of the glottalic stops: where the stop is not adjacent to a voiceless one, we surmise, it was phonetically voiced before the change, and contrastively voiced after it, and the glottalic feature disappeared without trace. Where it was followed by a plain voiceless stop (as in a *-to-* participle), it was phonetically voiceless by assimilation, and so became contrastively voiceless after the change. The glottalic feature, however, left a trace in this environment in that as it disappeared it lengthened the preceding vowel, presumably by a similar phonetic mis-parsing as that described by Niedermann (1953: 69–71) (see above p. 147).

The brief and condensed nature of Kortlandt's essays into accounting for Lachmann's Law (Kortlandt 1978: 117, Kortlandt 1989, Kortlandt 1999) has caused them to attract a certain degree of opprobrium (see *inter alia* Collinge 1985: 265 Garrett 1991: 800-801, Jasanoff 2004: p. 410 n. 10), but the shrift their detractors have given them may perhaps be too short. This is certainly the view of Schrijver (1991: 134–138) and Baldi (1991), whose views of Lachmann's Law are based in glottalic theory and partly echo those of Kortlandt. Jasanoff (2004)'s objection, for example, is valid but overstates the case: he says "Kortlandt['s]... interpretation, which effectively denies the merger of *-*gt*- and *-*kt*- in the parent language, is unacceptable". Jasanoff is right to point out that there is an implicit challenge to our assumptions in Kortlandt's arguments: we have taken it as read that assimilation of stop clusters took place in PIE because of the good comparative evidence that suggests as much (for which see p. 143), but claiming that the contrast between clusters survived into Latin in spite of it is not necessarily an untenable position.

Wherever we observe a correspondence, there is always the possibility that equivalent forms have developed independently in related languages, by virtue of an inherited typological propensity towards the development or sheer chance. A good example of this principle is Grassmann's Law: despite the fact that Greek and Sanskrit share it, as novice Indo-Europeanists are regularly warned, we cannot reconstruct Grassmann's Law for PIE, and claim that every language but Greek and Sanskrit lost it, since Greek has to have inherited *$b^h e\underaccent{\frown}{u} d^h$-, for example, to give *πευϑ-* by Grassmann's Law. If Greek had inherited a "pre-Grassmanized" *$be\underaccent{\frown}{u}d^h$-, the reflex would be **βευϑ-*. Therefore the standard Neogrammarian theory leaves us no alternative but to claim that Sanskrit and Greek developed their respective instantiations of Grassmann's Law independently[2]. Kortlandt (1978: 117) (which, to be scrupulously fair, it must be pointed out that Jasanoff does not cite) explicitly argues along the same lines, claiming that the evidence of Winter's Law, Bartholomae's Law and Lachmann's Law argues for the retention of the glottalic feature into Balto-Slavic, Indo-Iranian and Latin respectively, even in environments subject to assimilation, and therefore that regressive voicing assimilation should be considered an independent development in each of the IE languages. This would not be unsurprising on typological grounds, since assimilation is one of the most widely found phonological processes (Cho 1990). On the other hand, Jasanoff is right to point out that Kortlandt's analysis implies this account of IE assimilation, and a more explicit mention of this entailment is an unfortunate casualty of the notorious (Garrett 1991: 801) brevity of Kortlandt (1989, 1999)'s presentation.

[2]I leave aside the not unconvincing generative account which claims that Grassmann's Law was active for PIE but did not alter underlying representations until the dialectal period (for which see Kiparsky 1973). Jasanoff's arguments are Neogrammarian, so I meet them on Neogrammarian terms.

In addition from criticising the slimness of Kortlandt (1989) as a product of excessive "chutzpah", Garrett (1991: 801) raises a more trenchant exception to Kortlandt's arguments. Since Kortlandt (1989: 103) claims that Saussure's analogical reintroduction of voiced stops is unneccessary, he does not gain the benefit of being able to restrict the operation of Lachmann's Law to participles which alternate with inflected forms in which the voiced (or glottalic) forms is still visible. Kortlandt claims that the glottalic stops which conditioned the Law as he formulates it were present by simple inheritance, having yet to be assimilated away by the foundational shift in the stop system from PIE to Latin. Therefore, he is obligated to explain the lack of lengthening in forms which Kiparsky (1965) and Maniet (1956) considered synchronically opaque and thus immune to Saussure's analogy (see p. 145). These forms include *lăssus* 'tired', *tŭssis* 'cough' and *ăxis* 'axle', and are presumed to come from **lad-tos* (cf. Gk. *ληδειν*), **tud-tis* and **ag-sis* respectively. Kortlandt (1989: 104) rather unsatisfactorily dismisses the etymologies of *axis* and *tussis* as "too uncertain to serve as an argument". He engages more closely with *lassus*, and accounts for it by arguing for a sound change HT' > HT, so that **lh$_1$t'-tos* > **lat-tos* > *lassus*, without going through the intermediate stages **lat'-tos* > **lad-tos* which would subject it to Lachmann's Law. If this sound change is not intended to be subject to any environmental restriction, and Kortlandt does not mention one in either of the places where he invokes it (Kortlandt 1989: 104, Kortlandt 1999: 247), then, as Garrett (1991: 801) rightly points out, it predicts more widespread effects which fail to be attested: we might expect **tēns* < **h$_1$dn̥t* for *dēns* "tooth" or **suātuis* < **su̯ah$_2$d-u̯-ih$_2$-s* for *suāuis* "sweet". This last example is particularly damning, since the **d* (or **t'*, as the glottalic theory demands we reconstruct it) is tautosyllabic with the preceding laryngeal, exactly as in *lh_1t'-*tos* > *lassus*, and so serves as a counterexample to what might otherwise be a sensible reformulation of Kortlandt's sound change.

Kortlandt (1989: 104)'s account of the exceptions in [i] is likewise problematic. He claims that the glottalic *t we might expect in the antecedents of *fissus*, *scissus*, *strictus* etc. is absent because the contrast between obstruent series in the present stem is neutralised after the nasal infix: as the **pand-* of *pandō* comes from **patane-*, Kortlandt argues, the present stems **find-*, **scind-* and **string-* of *findō scindō* and *stringō*, with their glottalisation feature neutralised in the post-nasal environment, caused the analogical creation of new participles **fit-tos*, **scit-tos* and **strik-tos*, giving the attested *fĭssus*, *scĭssus* and *strĭctus*. In an omission that must be regarded as fatal to the credibility of this argument, Kortlandt (1989, 1999) offers no account of why the same analogy was not extended to the other Lachmann verbs with nasal infixes in the present, giving e.g. **tŭssus* from *tundō* or **păctus* from *pangō*.

Kortlandt (1989: 104) argues that *-sessus* is to be accounted for by virtue of the fact that it shows an *e*-grade. In general terms, participles in PIE are formed on the rubric ⟨∅-grade of root⟩+ -tos. For the IE root **sed*, this would predict participle **sdtos*, which would not square with Latin phonotactics. Kortlandt argues that in order to avoid the infelicitous zero-grade, the grammar innovated an *e*-grade participle for the compounds of *sedeō after the operation of Lachmann's Law*, so that the environment of Lachmannian lengthening was not present in the participle at the time the Law took effect. In view of the fact that *sedeō* itself has no past participle, it is intuitive to suppose that its compounds might have developed an *e*-grade in their participles later than verbs built on other CeC roots (and indeed Watkins (1970b) advances a hypothesis that shares this notion, that the participles in *-sessus* were formed too late to be affected by Lachmann's Law, as we shall see in the next section). It must be pointed out that the adoption of *e*-grades for the participles of verbs from CeC roots in general must have been earlier than for *-sessus*, if Kortlandt's theories are correct, since there are Lachmann participles from CeC roots, like *ēsus* (root *h_1*ed*) and *lēctus* (root **leĝ*). Kortlandt might have benefited from stipulating that his principle of zero-grade for CeRC roots and *e*-grade for CeC-roots was generally instantiated before Lachmann's Law, and the compounds of *-sessus* followed it analogically after Lachmann's Law, but such reasoning is more or less implicit in his argumentation.

Because Kortlandt follows Strunk (1976) (whose arguments are discussed in the section on analogists) in claiming that *cāsus* was not subject to Lachmann's Law proper, and follows Maniet (1956) in linking Plautine *cassō* 'I waver' with *cadō* 'I fall', Kortlandt is obliged to claim that for CeHC roots, both zero- and *e*-grade participles are possible, and that *cāsus* reflects a full grade, and the presumed **cassos* (on which Maniet 1956: 233 claims *cassō*, *cassāre* is built) reflects a zero-grade. However, Schrijver (1991: 136) argues that the evidence for **cassos* is much slimmer than it appears. Since *cassō* is found in the meaning 'I waver' only in Plautus, who predates the degemination of *ss* after long vowel, his writing *cass-* cannot be proven not to represent **cāss-*. Schrijver also points out that the semantic connection between *cassō* and *cadō* is not conclusive, and that *casso* may be related instead to *quassō* 'I shake'. Kortlandt's analysis would be considerably tidier if we simply consider *cāsus* to be a Lachmann form and so argue that CeHC roots produce zero-grade participles in Latin, just like (other) CeRC roots.

Kortlandt (1989: 104) and Schrijver (1991: 136) both use the same evidence to dismiss *maximus* and *pessimus* as irrelevant that Jasanoff (2004: 412) uses to adduce them, namely Cowgill (1970: 125)'s reconstruction of them as coming from **magism̥mos* and **pedism̥mos* respectively. Schrijver and Kortlandt fail to explore the implication of this reconstruction, that syncope must have created the forms **mags-* and **peds-* at some point within the history of Latin, since the devoicing (or deglottalisation) of the **g* and **d* cannot have occurred before they were brought into assimilatory contact with the following *s*, and we are left to infer that they believe that this point came after the operation of Lachmann's Law. It is certainly more convenient to dismiss the single apex that supports the reading of length in *māximus* as unreliable than to assume that Lachmann's Law must have affected both forms, since Jasanoff (2004: 412) has to claim that the synchronically regular superlative form *-ssimus* was re-imported into his putative **pēsimus*, whereupon the *e* was shortened by the *littera*-rule[3].

Given the above empirical and implementational difficulties with the ideas laid out in Kortlandt (1978, 1989, 1999), we may pass lightly over the theoretical objections; it is enough to note that Kortlandt's equation of Bartholomae's Law, Lachmann's Law and Winter's Law under the rubric of epiphenomena of the preservation of glottalics has been called into question (difficulties summarised neatly in Collinge 1985: 226) and to mention that the glottalic account of Winter's Law, with which Kortlandt most strongly equates Lachmann's Law, competes with, among others, accounts that ascribe its characteristic lengthening to the presence of laryngeals (Collinge 1985: 225–227). To do full justice to these theoretical debates would require a more lengthy investigation of the relevant data from Indo-

[3]Kortlandt (1989: 104) deals with the other Lachmann-embarrassing reflex of the root **ped*, namely the supine *pessum* 'to the ground', by citing Collinge (1975: 475)'s suggestion that the vowel was shortened to avoid homophony with forms of the verb *pēdō* 'break wind'. This hypothesis is essentially unprovable.

Aryan and Balto-Slavic than the soundness of Kortlandt's argumentation on the subject of Lachmann's Law and the space available to us warrant.

A different analogy.

Drinka (1991) discards the Saussure-Pedersen engine of Lachmann's Law and offers an entirely novel account. Like Saussure, she obviates the difficulty that Lachmann's Law is not surface-true by arguing that the environment which conditioned it was introduced analogically and lost again after the change took place, but unlike the followers of Saussure and Pedersen, she relies on a sound change which has already been posited for Latin on independent grounds, namely the following:

(117) V > $\bar{\text{V}}$ / __n{s,f,c}

So *cōnsul*, *īnferī*, *sānctus*, *quīntus* (< *quinctus*)

The analogy that Drinka claims created the environment for this change to take place in the Lachmann verbs was the importation of the *n*-infix of the present into the past participle, as well as a present-forming suffix *-de/o-* in some cases. Drinka (1991: 60ff.) envisages this as a staged process, with the jumping-off point being forms such as *spondeō*: *spopondī*: *spōnsus* 'pledge oneself', *tondeō*: *totondī*: *tōnsus* 'shear' etc. Drinka points out that alongside Lachmannian *tūsus*, we also have attested *tunsus*. She argues that all the Lachmann forms with nasal infixes in the present, so *frāctus*, *pāctus*, *tāctus*, *tūsus fūsus* imported the nasal infix of their present stems into their participles on the model of verbs with nasals in the root like *spondeō*: *spōnsus*, then lost the nasal with compensatory lengthening and nasalisation of the vowel. Drinka (1991: 62) adduces parallels from Oscan and

Umbrian, viz. O. *saahtúm* and U. *sahatam* to *sānctum* and U. *šihitu* to *cīnctus* in an attempt to show that the loss of the nasal with compensatory lengthening was the regular Italic treatment, and that the presence of the nasal in some Latin forms like *sānctus* and *cīnctus* was secondary and analogical.

One difficulty that Drinka (1991: 65–66) forthrightly acknowledges is the fact that Lachmann's Law does not seem to apply to participles in *i*, with the exception of *uīsus*. (117), by contrast, seems to have no difficulty in lengthening *i* (cf. *quīntus*). For this she presents the essentially *ad hoc* explanation that the analogy spreading the nasal infix to the participle did not affect verbs in *i* until the secondary stage, whereupon it produced *uīnctus*, *cīnctus* and *extīnctus*.

Finally, Drinka (1991: 68–69) proposes another secondary innovation (which may be contemporaneous with the first one) which spread the lengthening to the Lachmann forms without nasal infixes in the present, so *lēctus*, *tēctus*, *ēsus*, *ōsus* etc. In particular, she claims that the model of *frēgi, frāctus* was the source of the *ē* of *ēgi* as well as of the *ā* of *āctus*, in contrast to accounts which claim that *ēgī* was the model for *frēgī* (e.g. Meiser 1998: 211). In any case, Drinka offers no account of where the *ē* of *frēgī* comes from.

Although the title of Drinka (1991) bills it as "a phonological solution", Drinka exploits the fact that analogy creates the environment for the sound change in a way reminiscent of the manoeuverings of the analogists. She relies on the fact that analogy, unlike sound change, is not inherently regular to avoid explaining why the analogy that gives us *lingō*: *līnctus* and *cingō*: *cīnctus* does not also give us *stringō*: **strīctus* or *mingō*: **mīctus*, for example. Furthermore, she elides the issues of *uīsus* and *sessum*: if, as we might suppose, the final process, which gave us *lēctus* from *legō* on the model of *pactus* from *pangō* etc. was also enough to give us *uīsus* from *uideō*, why did it not also give *-*sēsus* from -*sideo* (< *sedeō*)? Conversely, if the final analogy did not affect presents in -*eo*, whence *uīsus*?

Drinka (1991: 70) also attempts to claim it as an advantage of her theory that "it does not seek to account for every datum at one synchronic level". However, absent evidence from the attested language that one change actually preceded another, the way that she envisages the analogies and subsequent sound changes occurring by stages must be viewed as an *ad hoc* hypothesis, and can hardly be claimed as an advantage.

Like the analogists (p. 166ff.), Drinka abandons the descriptive criterion that Lachmann's Law affects verbs whose IE roots ended in voiced stops, and attempts to replace it with morphological conditioning. Even accepting the fact that the descriptive criterion does not hold entirely (given the exceptions of *uīsus* and *sessum*), and is difficult to make accessible to the synchronic grammar (requiring an analogy like that of de Saussure (1889), or a generative account like that of Kiparsky (1965), which we will look at next), it is nonetheless my contention that Drinka's alternative fails as satisfactorily to answer the question "Why these verbs and not any others?"

Generative sound change.

The last account of Lachmann's Law we shall mention that envisages it as a sound change is that of Kiparsky (1965: 19–24). Kiparsky took it as an axiom of his approach, as we do, that Neogrammarian sound changes are the observable artefacts of changes in the structure of the phonological component of the grammar. Therefore, rather than try to characterise Lachmann's Law as a regular sound change directly, he posited a change in the phonology of Latin that cast Lachmann's Law as a case of rule insertion.

The generative theory of the time (best exemplified in Chomsky & Halle 1968) cast phonology as a series of language specific, extrinsically ordered rewrite rules: an "assembly line", to use the metaphor of Hayes (1999), which converted underlying phonological representations into surface utterances by applying atomic processes one after another. On this model, the standard way to model a Neogrammarian-style sound change was simply to turn the > into a →, as it were, and add the rule to the end of the derivation.

Kiparsky (1965: 19)'s suggestion was that it might be possible to add rules to the derivation in places other than the very end. He proposed the following rules for the grammar of Latin:

(118) $$V \rightarrow [+\text{long}] \quad / \quad \underline{\quad\quad} \begin{bmatrix} +\text{obstruent} \\ +\text{voice} \end{bmatrix} \begin{bmatrix} +\text{obstruent} \\ -\text{voice} \end{bmatrix}$$

(119) $$[+\text{obstruent}] \rightarrow [\alpha \text{ voice}] \quad / \quad \underline{\quad\quad} \begin{bmatrix} + & \text{obstruent} \\ \alpha & \text{voice} \end{bmatrix}$$

(Kiparsky 1965: 19)

On this account, (119), which predicts voicing assimilation of adjacent stops would have been inherited from Proto-Indo-European, squaring with our observation that such assimilation can be found across the Indo-European languages (see page 143), but (118), which gives rise to the Lachmannian lengthening proper, would be a Latin innovation. This removes the need for Saussure's analogical reintroduction of voiced stops into participles, since the necessary voiced stops, Kiparsky argued, were present in the underlying representations of the Lachmann participles already. All that was needed was to take the sound change (114) proposed by Saussure and his followers, and add it to the phonology where it could "see" the voiced stops that conditioned it, i.e. before (119) could assimilate them away. This is an example of counterbleeding, an opaque interaction between rules like that which was posited as giving rise to e.g. the misapplication of Canadian diphthong raising in Chomsky & Halle (1968: 342–343).

Kiparsky appears to have been unaware of the exceptions to Lachmann's Law that we have discussed. In particular, in discussing certain non-participles which one might expect to undergo the Law, he shows that he expects words from IE roots ending in voiced aspirates to undergo Lachmannian lengthening as well. We have already mentioned (p. 145) the exceptions *tussis* and *lassus*, from **tud-tis* and **lad-tos* respectively, which Kiparsky (1965: 21) explains by arguing that the etymological voiced stops were no longer present in the underlying representations of the words in question, as their connection to verbal paradigms in which the stops were visible was no longer apparent. The revealing fact, however, is that Kiparsky includes *lĕctus* 'bed' with *tussis* and *lassus* as another example of word whose vowel would have lengthened if its UR had reflected its etymology at the time Lachmann's Law operated. *lĕctus*, however, is reconstructed as being built on an IE root **leg^h* (cf. Gk. *λεχος*) (Kiparsky 1965: 21). No doubt Kiparsky was forced to this conclusion by his belief that Lachmann's Law is "a relatively late Latin innovation", which would entail that it occurred after the merger of the voiced aspirates with the voiced stops (in the positions we are concerned with). Nonetheless, however, this would require an explanation of why the Law did not affect participles from roots with voiced aspirates, like *fossus* from **b^{h}od^h*. I can only conclude that Kiparsky was unaware that this was the case. This omission need not be fatal to the proposal, however, since (118) can still be hypothesised to be a Latin-specific rule. We must simply argue that it was inserted into the grammar before the voiced aspirates were merged away, and remained there long enough to change the underlying representations of the Lachmann participles to include their characteristic long vowels. This step is necessary because (118) cannot have remained in the grammar after the merger of the voiced aspirates. If it had, it would have produced **fōsus* etc. If we were merely refurbishing Kiparsky's rule-based account, we would have to leave that as a stipulation. As we shall see, however, elaborating Kiparsky's account in the terms of the model we are building will allow us to explain the short half-life of (118) in independently-derived terms (see p. 210).

The above objection to Kiparsky's account does not necessitate a change in the rules (118) and (119), only a stipulation as to chronology. The other main respect in which Kiparsky's analysis is false to the facts, however, does. His general statement: "In Latin, vowels become lengthened before clusters of the form 'voiced obstruent + voiceless obstruent' by Lachmann's Law" (Kiparsky 1965: 19) is of course an overstatement of the case. Where the vowel in question is *i*, as we have seen, the lengthening generally does not occur (as in *scĭssus*, *pĭctus*, *fĭctus*), with the apparent exception of *uīsus*. Furthermore, there is the exception of the compounds in *-sessus* to the rule as applied to *e*. There is also the lengthening before *m* in *ēmptus*.

The fact that Kiparsky offers no account of these empirical objections to his hypothesis made it all the more easy for others to abandon it when faced with a theoretical objection. The form of change which Kiparsky argued that Lachmann's Law exemplified, non-chronological rule insertion, was new, and as Kiparsky (1965:

19) himself acknowledges, hard to concretely exemplify. The validity of Kiparsky's approach, and of rule addition in general, was hotly debated on the squib pages of LI (Watkins 1970a; Perini 1978; Joseph 1979; Klausenburger 1979; Stephens 1979), but the hypothesis never truly recovered from the dramatic recantation of King (1973). King had repeated Kiparsky's account of Lachmann's Law in his textbook King (1969: 43–44) as an example of rule insertion, but by 1973 he had searched in vain for parallels, and decided on the basis of their absence that rule insertion did not exist. The field moved on, and Kiparsky's account of Lachmann's Law fell out of fashion. I believe that this was unfortunate, since the basic engine of Kiparsky's analysis seems to me to be the most sound of those that have been offered so far. In the next section I hope to show, by setting them in the empirical framework of PyOT, and in the partial model of Latin historical phonology we are in the process of developing, how Kiparsky's arguments can be refurbished and updated to take full account of the facts of Lachmann's Law as we understand them.

3.3.2 Lachmann's Law as analogy.

As early as 1884, the difficulties inherent in treating Lachmann's Law as a regular sound change were sufficiently well recognised for Osthoff (1884: 113) to abandon the idea entirely, and to propose in its stead the hypothesis that the vowels of Lachmann's past participles were lengthened by analogy with the long vowels of their respective verbs' perfect stems. This hypothesis is enthusiastically taken up by Kent (1928), but it is acknowledged by both Osthoff and Kent that it only goes so far, i.e. it only accounts for those verbs which have a long vowel perfect, as follows:

(120)

participle	**1sg. perf.**
Accounted for by Osthoff-Kent	
rēctus	*rēxī*
tēctus	*tēxī*
lēctus	*lēgī*[4]
fūsus	*fūdī*
ēsus	*ēdī*
ōsus	*ōdī*
ēmptus	*ēmī*
uīsus	*uīdī*
Arguably accounted for by Osthoff-Kent	
āctus	*ēgī*
frāctus	*frēgī*
Unaccounted for by Osthoff-Kent	
tāctus	*tetigī*
pāctus	*pepigī*
tūsus	*tutudī*
cāsus	*cecidī*

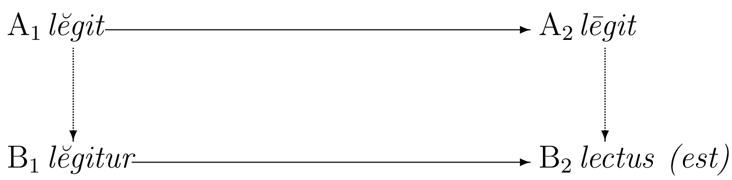
As we can see, the difficulties with the Osthoff-Kent hypothesis fall into two broad categories: there are those words in which the analogy seems to be incomplete, insofar as the length of the vowel has been extended from the perfect active to the participle, but not the vowel quality (*āctus* ∼ *ēgi* and *frāctus* ∼ *frēgi*), and, more seriously and numerously, there are those Lachmann verbs which have no long vowel in the perfect active to be imported into the perfect passive, e.g. *tutudī* ∼ *tūsus*, *pepigī* ∼ *pāctus*. These problems have been subject to multiple attempts at solution: Kuryłowicz (1968a,b) offered a comprehensive account which Jasanoff (2004) described as a "counterattack" to Kiparsky (1965)'s phonological account.

[4] A perfect in *-lēxī* is attested for certain compounds of *legō*, viz. *intellēxī*, *dīlēxī* and *neglēxī*.

Watkins (1970b) supplemented and amended it to the extent that Collinge (1985) refers to the analogical account of Lachmann's Law in general as the "Osthoff-Kent-Kuryłowicz-Watkins formulation", and the latest complete account is offered by Strunk (1976). We shall treat these accounts in chronological order.

The fact that there seems to be a gradient scale of difficulties with the Osthoff-Kent hypothesis, from the forms where the perfect stem has a long vowel, but does not otherwise perfectly match the shape of the present stem: e.g. *rēxī* ∼ *regō*, to those where the perfect stem has no long vowel for the participle to appropriate, such as *tetigī* ∼ *tegō*, might suggest to the well-trained analogist that the attested facts are the result of a successive series of analogical processes. This is exactly the way Kuryłowicz (1968a,b) formulates his account. He begins by casting the original observation of Osthoff and Kent in the form of the following diagram (Kuryłowicz 1968a: 326, Kuryłowicz 1968b: 296):

(121)



On this account, the *fons et origo* of Lachmann's Law is a paradigm levelling: informally "if the active and passive present stems match, then the active and passive perfect stems should too!" According to Kuryłowicz, however, it affected only those forms where the A_1 and A_2 stems were identical in shape save only for the length of the vowel ("subgroup (a)"). Thus he accounts for *lēctus*, *ēsus*, *uīsus*, *ēmptus* and *ōsus*. Kuryłowicz (1968b: 298) stipulates that this process took place at a stage when the medial reflexes of the PIE voiced aspirates were still voiced fricatives, and stipulates that the analogy covers only forms whose paradigms match the prescription of (121), and whose perfect stems end in -*d*, -*g* or -*m*, hence the lack of lengthening in *fŏssus*: *fōdī* and *trăctus*: *trāhī* (or, at the time: */foθ.tos/: */foː.ðiː/ and */trax.tos/: */traːɣ.iː/ or similar.)

The first extension of this process is subject to certain phonological restrictions: as with the initial analogy, the root must end in -*d*, -*g* or -*m* (hence the lack of lengthening in *factus*, *missus*), and, though the A_2 (perfect) stem does not have to have the same shape as the B_2 (participial) stem, the shape of the B_2 stem must match that of the A_1 (present) stem (i.e. the present must not have a nasal infix, hence the short vowel of *fissus* from *findō*, *strictus* from *stringo*). Thus Kuryłowicz accounts for *rēctus*: *regere*, *tēctus*: *tegere*, *āctus*: *agere* and *cāsus*: *cadere* ("subgroup (b)").

Kuryłowicz divides the remaining four Lachmann participles, which do not fulfil any of the conditions of (121) (neither the present nor the perfect stem has the same shape as the participal stem): *fūsus*, *tūsus*, *tāctus* and *frāctus* into two groups, based on the vowel that is lengthened, but each is accounted for more or less individually. The opposition *fundere*: *fūsus* is described as arising analogically on the model of *ēsus*, and *tūsus* in turn on the model of *fūsus*, under further pressure from the also-attested *tūnsus*, which shows the regular lengthening of vowel before -*ns* (cf. *cōnsul*).

Kuryłowicz (1968a: 328) adduces the parallel of Gk. *ἐπάγην*: *πηκτός* to demonstrate that the long vowel of *pāctus* is inherited. He posits (Kuryłowicz 1968b: 299) that the length of the vowel in *frāctus* may be analogical on the inherited *pāctus*, and states that although we have a Greek parallel in *τεταγών* for *tetigī*, it is impossible to state which of the two possible ætiologies for *tāctus*, inheritance from PIE *à la pāctus*, or analogy on *pāctus à la frāctus*, is more likely.

Chief among the perceived weaknesses of the account exposited in Kuryłowicz (1968a,b) is that it delimits the environment of Lachmann's Law by both phonological and morphological criteria — all of Kuryłowicz's processes are restricted to roots ending in an original voiced stop (or *m*), and the process is explicitly limited to past participles. To obviate this difficulty, Watkins (1970b) discards all but Kuryłowicz's initial process (121), and sets himself the task of either explaining how the forms that do not appear to meet the conditions of (121) (i.e. a present stem that has the same shape as the perfect stem save for the length of the vowel, which is short in the present and long in the perfect), in fact do meet the conditions, or why their lengthening is not to be considered a part of Lachmann's law at all.

With the parameters of the question so defined, Watkins can and does accept Kuryłowicz's account of the lengthening in *lēctus*, *ēmptus*, *ēsus* and, assuming the existence of an appropriate present stem at the time the process operated, though none such is attested, *ōsus*. He might also accept the first process as applying to *uīsus*, but instead rightly points out that the IE perfect for this root had an *i*-diphthong (cf. Gk. *oĩδα*, Skt. *veda*), which had probably not yet changed to *ī* at that point in the history of Latin. He nonetheless argues that *uīsus* took over the vocalism of the perfect *uīdī*, but argues that the process must be seen as distinct from the rest of Lachmann's Law, since its effect was diphthongisation rather than lengthening of a monophthong. For a parallel, he cites the development in Germanic which gives Gothic *un-weis* and English *wise* (Watkins 1970b: 62).

Watkins' most uncontroversial contribution to the development of the Harvard account is to refer the reader to Watkins (1962: 32–35), where, in order to support his contention that the IE sigmatic aorist did not ordinarily show a lengthened grade of ablaut, he dismisses *rēxī* as a Latin innovation by citing Festus (422–423) to the effect that Livius Andronicus regularly employed a perfect *surēgit*. This places *rēctus* within the domain of (121), since the perfect stem *rēg* matches the present stem *rĕg*, save only for the length of the vowel, as with *lĕgō* ∼ *lēgī*, *ĕdō* ∼ *ēdī* etc.

Watkins (1962: 33) wishes to extend the same argumentation to include *tēctus* in the domain of (121). The requisite perfect stem **tēg-* is not attested, but Watkins points out that neither the sigmatic *tēxit* nor any other perfect of *tegō* is attested until Lucretius, and that the attested paradigms of the three verbs with rhyming stems in -*ē̆g*-: *regō*, *tegō*, *legō*, otherwise match in every detail (once we have accepted Festus' evidence for *rēgī* as the original perfect of *regō*), even to the point that *rēgula* and *tēgula*, forms ostensibly derived from the perfect stems of *regō* and *tegō*, are alike. If we accept the arguments of Watkins (1962) to the effect that the lengthened grade was not characteristic of the IE sigmatic aorist, then *tēxī* cannot be inherited, and since the paradigms of *tegō*, *regō* and *legō* are otherwise so alike, it is difficult to imagine that *tēxī* would have been innovated significantly earlier than *rēxī* or *(intel)lēxī*. Thus it seems plausible to include *tēctus* with the other Lachmann participles accounted for by (121).

Watkins (1970b: 62) accounts similarly for *ēgī* ∼ *āctus*, by taking a stand on the issue of exactly what the source of *ēgī* is. The alternation between *ă* in the present stem and *ē* in the perfect stem arises originally as the regular behaviour of Latin verbs which meet the following conditions:

(122) a. The IE root from which the verb is derived ends in a laryngeal.

b. The present stem of the verb in Latin is formed by one of the IE derivational processes which indicates a zero-grade of the root: e.g. *-ie/o*-suffixation.

c. The perfect stem of the verb is formed on a full-grade IE aorist, e.g. the root aorist.

An example of a Latin verb that meets these conditions is *faciō* ∼ *fēcī*: the IE root in question is $*d^h eh_1$ (cf. Gk. *τι-ϑη-μι*) (Mayrhofer 1986a: 95); the present is formed by *-ie/o*-suffixation of the root aorist: *faciō* < $*d^h \underset{\circ}{h}^1$*-k-i̯ṓ* (Meiser 1998: 196); and the perfect stem is formed on the IE root aorist: *fēcī* < $*d^h eh_1$*-k-* (cf. *ἔ-ϑη-κᾱ*) (Meiser 1998: 212).

agō, by contrast, does not meet the conditions set out in (122). It derives from an IE root $*h_2 eg$. This has led certain scholars, most notably Benveniste (1949), to assume that *ēgī* cannot be original, and must therefore be analogical on the verbs which acquire the *ă/ē* alternation by regular sound change, e.g. *faciō* ∼ *fēcī*, *iaciō* ∼ *iēcī* etc. Benveniste (1949: 17) accounts for the long vowels of the Latin perfects that are attested from similar IE laryngeal-initial roots by reduplication, as follows:

(123) $*h_1 e\text{-}h_1 p\text{-}ai$ > Lat. *ēpī*
$h_1 e\text{-}h_1 d\text{-}ai$ > Lat. *ēdī*
$h_3 e\text{-}h_3 d\text{-}ai$ > Lat. *ōdī*

On this account, we would expect $*h_2 e\text{-}h_2 g\text{-}ai$ > ***āgī* for *āgō*, and Benveniste (1949: 17) cites Old Norse *ōk* < **āga* as comparative support for his hypothesis that Latin showed exactly such a form, before it was replaced by the *ēgī* which he views as analogical.

Kent (1928: 186) anticipated Benveniste in citing *ōk* as a parallel for a hypothetical Latin **āgī* in his attempt to explain the inclusion of *āctus* in Lachmann's Law, and Watkins (1970b: 62) cites Benveniste as vindicating Kent's views on this point, but it should be noted that Benveniste's is not the only account of the genesis of *ēgī*. Sihler (1995: 581), for example, accounts for *ēgī* as the product of reduplication. On this account **e-ag-ai* > *ēgī* by contraction without ever passing through the intermediate stage **āgī* necessary to bring *āctus* within the purview of (121). Chronology, at least, is on Sihler's side here, since reduplication appears to have remained a productive part of the Latin grammar well after the laryngeals were lost from it[5], but the majority of scholars accept the account of Benveniste (1949).

Having thus folded *rēctus*, *tēctus* and *āctus* into Kuryłowicz's original analogy (121), Watkins (1970b: 62ff.) is left with the following Lachmann participles to account for:

(124)	*cadō*	*cecidī*	*cāsus*
	frangō	*frēgī*	*frāctus*
	fundō	*fūdī*	*fūsus*
	pangō	*pepigī*	*pāctus*
	tangō	*tetigī*	*tāctus*
	tundō	*tutudī*	*tūsus*

Watkins (1970b: 63) adds further support to Kuryłowicz (1968b: 297)'s assertion that the lengthening in *tūsus* is late, and analogical on the regular lengthening of its competitor form *tūnsus* by citing a possible example of Kuryłowicz's

[5] As we shall see, Watkins (1970b) himself relies on reduplication being an active part of the morphological component of the grammar.

hypothesised older *tŭssus* from Plautus: *Pseud.* 369 has *pertussum*. On its own, however, the double ⟨ss⟩ of Plautus' *pertussum* does not guarantee that the *u* in question was short, even if we accept that it is not the result of an error in the transmission of the text. The point is made aptly in the following passage of Quintilian (*Institutio Oratoria* I, 7, 20–21)

(125) *quid quod Ciceronis temporibus paulumque infra, fere quotiens s littera media vocalium longarum vel subiecta longis esset, geminabatur, ut caussae, cassus, divissiones? quomodo et ipsum et Vergilium quoque scripsisse manus eorum docent.*

atqui paulum superiores etiam illud, quod nos gemina dicimus iussi, una dixerunt

For was it not in the time of Cicero and a little later, that in nearly all cases an *s* between long vowels or after a long vowel, was doubled, as in *caussae*, *cassus*, *diuissiones*? That he himself, and also Vergil wrote in this way is shown by [manuscripts in] their own hands.

Yet a little before that, that *iussī* which we write with a double *s*, they spelled with one.

Quintilian speaks only of the time of Cicero and later, not of that of Plautus, but nonetheless the implication is clear: it was not until after Cicero that the convention of writing ⟨-ss-⟩ after a short vowel and ⟨-s-⟩ after a long was entrenched, and even then the vagaries of spelling convention are such that we should not rely solely on it as an indicator of the length of the preceding vowel.

Watkins also notes that *fundō* may not originally have had a participle in root + *-tos.* He cites the gloss in Paulus ex Festo 59 of *exfuti* as *effusi.* This, when taken with Gk. *χυτός* seems to make it relatively certain that we have to reckon with an IE past participle *g^h*utós* or similar. However, this seems only to defer, not to answer the question of why Latin, when it chose to innovate a participle for *fundō*, innovated *fūsus* as opposed to anything else. In fact, as we shall see, Watkins tacitly re-formulates (121) to ignore nasal infixes in the A_1 form, so it seems to be an unnecessary multiplication of difficulties to call *fūsus* a "late creation" — one could simply argue that *fundō* had its inherited past participle (*futus*, according to Festus' gloss) replaced on the principle of (121) at the same time as *regō*, *legō* etc.

To account for *cāsus*, *frāctus*, *pāctus* and *tāctus*, Watkins (1970b: 62) appeals to a pattern in the distribution of methods of Latin perfect marking which is noted by Ernout & Meillet (1959: 94) viz. that with the functional merger into Latin of the IE stative and aorist, the domain of reduplication as a perfect marker shrank to cover only those roots where apophonic marking of the perfect would be impossible (i.e. roots with *a*-vocalism). On this account, reduplicated and long-vowel perfects are to be seen as equivalent for the purposes of (121), hence *cāsus* from *cadō*: *cecidī*. Watkins (1970b: 63) also abandons Kuryłowicz (1968a)'s strictures regarding the lack of nasal infix, hence successfully deriving *pāctus* from *pango*: **pepagai* (> *pepigī*), *tāctus* from *tango*: **tetagai* (> *tetigī*) and *frāctus* from *frango*: **fefragai* (which form is reconstructed on the basis of the Old Irish parallel *bebraig* 'broke wind').

This proposal is difficult entirely to square with our understanding of Latin grammar: certainly the long-vowel and reduplicated forms are functionally equivalent, in that they are allomorphs of the same notional PERFECT morpheme, but Watkins seems to suggest that they have a closer equivalence with each other which they do not share with the simple, sigmatic and *u*-perfects, or else we should expect e.g. **pāsus* from *pandō*: *pandī*.

Without direct experimental access to the intuitions of native speakers, there is little to be gained by further debating the theoretical merits of this hypothesis. Its empirical implications, however, do admit of further test. Having eliminated phonological conditions entirely from the domain of (121), Watkins is forced to concede that Lachmannian lengthening ought to extend to any verb that has a short vowel in the present stem (with or without nasal infix) and a long-vowel or reduplicated perfect, which leaves him the task of explaining the lack of lengthening in participles from roots ending in other than an original voiced stop.

Watkins (1970b: 63) proposes to account for the lack of lengthening in *canō*: *cecinī*: *căntus* and other roots ending in a sonorant by appealing to Osthoff's Law, which states that long vowels are not permitted before a sequence of sonorant plus stop (Meiser 1998: 75). The difficulty with this suggestion is obvious — if Osthoff's Law applied after (or simultaneously with) Lachmann's Law, why did it not reverse the lengthening of *ēmptus* as well? Watkins (1970b: 60) redefines Osthoff's Law to apply only to *n, l, r*. This squares with the attested evidence, since certain examples of Osthoff's Law applying before *m* in Latin are wanting. A non-Lachmannian example of Latin -$\bar{V}mT$- would be valuable for the purposes of evaluating Watkins' views, but in its absence there is no evidence on which to discount the hypothesis.

A more serious objection can be raised to the reasoning in Watkins (1970b: 63–64)'s account of why there should be no lengthening in *fŏssus*. His statement

"If *fōdī* had existed ... it would have produced **fōsus*. The implication is clear: *fōdī* did not exist at the time of the operation of the rule" is shockingly circular in its reasoning. The implication would in fact be "*either fōdī* did not exist at the time of the operation of the rule *or Watkins has fundamentally mischaracterised the rule itself.*"

Watkins is on firmer ground when he points out that there is no comparative evidence to suggest that *fōdī* is inherited, Meiser (1998: 212), for example, agrees with him in accounting for *fōdī* as analogical, though they disagree in the proportion. Watkins (1970b: 64) adduces *ōdī* as the analogical model for *fōdī*, though it is difficult to see on what proportion such an analogy could be founded, given that *ōdī* lacks present-tense forms: a proportion *ōsus*: *ōdī* :: *fossus* : ??? would be unfortunate for obvious reasons. Meiser (1998: 212). however, derives *fōdī* on the proportion *ueniō* : *uēnī* :: *fodiō* : *fōdī*, which is generally satisfactory. He likewise derives *scābī* (∼ *scabō*) from *lēgī*. Positioning these analogies chronologically after the operation of (121) would be sufficient to explain their lack of susceptibility to Lachmann's Law as Watkins formulates it.

By way of explaining the lack of lengthening in *-sessus* (*obsessus*, *possessus*), Watkins (1970b: 64–65) makes the important point that Lachmann's Law, however it is formulated, applied in the first instance only to past participles, and *not* to supines. He does so by invoking the supine *pessum* 'to perdition', which comes from a well-paralleled IE verbal root **ped-* (cf. Skt. *padati*, OCS *pado*, OE *fetan*) (Watkins 1970b: 64). Watkins chooses to infer from this datum that Lachmann's Law cannot be a purely phonological change of the order posited by Saussure, Maniet, Kiparsky etc., since *pessum* must derive from **ped-tu*, which displays the consonant cluster characteristic of phonological accounts of the Law, and therefore that the identity of vowel length between the Lachmannian participles and the supines of the same verbs must be the result of a separate analogy conditioned by the widespread identity of supine and perfect participle in most other Latin verbs.

Watkins uses this evidence as the starting point for his account of the lack of lengthening in participles in *-sessus*, which runs as follows: at the time of the operation of (121), *sedere* had neither a perfect participle (for semantic reasons: there was no function for the perfect participle passive of an intransitive verb of this kind to serve) *nor yet any compounds*. It had a supine *sessum*, attestations of which Watkins (1970b: 64) cites from both Plautus and Cicero, but as *pessum* demonstrates, supines lacking a corresponding past participle went unaffected by Lachmann's Law. Subsequently, and after (121) ceased to be a productive analogy, new verbs were derived from *sedeō* by compounding, verbs for which the semantic function served by the past participle was not empty as it is for the base verb. To innovate the necessary participles, the grammar turned to the form which most closely resembles the past participle, namely the supine, as an analogical model, hence *-*sessus*.

The most recent account that accepts the OKKW engine of Lachmann's Law undiluted — which is to say without translating it into generative morphophonemic rule-notation or otherwise re-characterising it as anything but a pure analogy — is that of Strunk (1976). Strunk accepts and further develops Watkins (1970b)'s proposal of a synchronic equivalence between reduplicated and long-vowel perfects, and between thematic root presents with and without nasal infix, that is stronger than the simple allomorphic equivalence they share with other forms serving the same grammatical function.

Like Watkins (1970b), Strunk (1976) begins by taking (121) as the basic analogy driving Lachmann's Law, and rejecting the phonological conditions Kuryłowicz (1968b) originally imposed on it. This leaves him with a starting point as follows:

(126) *lĕgitur*: *lēgī*: *lēctus*
ĕmitur: *ēmī*: *ēmptus*
uĭditur: *uīdī*: *uīsus*
ĕditur: *ēdī*: *ēsus*
(*ŏdium*): *ōdī*: *ōsus*

Strunk endeavours to get the right result by delimiting the scope of (121) in new ways. He sets out the following three conditions:

(127) Reduplicated perfects are equivalent to long-vowel perfects for the purposes of the analogy. Sigmatic, simple and *u*-perfects are not.

(128) Presents with nasal infix are equivalent to root presents for the purposes of the analogy. Derived presents (e.g. in -*i̯e/o*-) are not.

(129) There must be two differences between the active perfect and the passive perfect before the analogy will take effect.

Each of these claims is essentially *ad hoc*: it is hard to see any reason independent of the Lachmann data to make them. Indeed, from the point of view of Latin grammar generally, there are positive difficulties with them, many of which are pointed out by Morpurgo Davies (1979). Firstly, though Strunk (1976: 36ff.) relies heavily on the notion of an equivalence of reduplicated and long-vowel perfect stems, he does not present an account of how this equivalence operates. The question in Morpurgo Davies (1979: 260) deserves repeating: "is it something which can be stated by a morphophonemic rule?" In other words, if Watkins (1970b) and Ernout & Meillet (1959) are right, and the domain of reduplication can be described as "verbs with (Latin) root vowel /a/ which would otherwise form long-vowel perfects", then we need a synchronic account of how the grammar selects which method of forming the perfect to use. We might say that for the third conjugation (into which all the Lachmann-susceptible verbs fall), long-vowel/reduplicated perfects are the default, and simple or sigmatic perfects are lexically-specified exceptions. This would raise questions such as "why do we have reduplicated *tutudi* for *tundo*, but long-vowel *fūdi* for *fundo*?" Before we can accept grand statements about the workings of Latin morphology such as Strunk's, answers to these and other questions, answers which make empirical predictions that we can test, need to be provided. What Strunk does offer, namely the idea that the two short vowels of the reduplicated forms are metrically equivalent to the single long vowel of perfects like *lēgi*, on principles familiar from the scansion of Latin verse, is problematic. Morpurgo Davies (1979: 260) points out that in verse, quantitative equivalence holds not between vowels, but between *syllables*, and the syllables of the Lachmann participles are already long "by position", that is, because they are closed and therefore bimoraic.

Similar objections can be made to Strunk's other claims: the assertion that nasal infixes are invisible to the analogy, but suffixes deriving present stems are not, is even less well-motivated than the claims about reduplicated vs. long-vowel perfects. In the case of the perfects, there are the distributional regularities noted by Ernout & Meillet (1959), but for the presents there are none such. Without an independently motivated theory of how one process can be invisible to the analogy, but another can be visible enough to prevent it from occurring, the generalisation in (128) must be considered unacceptably *ad hoc*.

Strunk (1976: 60)'s third assertion, that the analogy only operated when there was more than one difference between the perfect stem and the stem of the participle, may be intuitively pleasing, since it squares with the cross-linguistic tendency of analogies to obviate some, but not all of the irregularity in language, but like Strunk's other contentions, its lack of corroborating evidence raises questions. Morpurgo Davies (1979: 260) cuts to the chase once again: "if we want to think in terms of a two-feature contrast, why does Latin preserve *pēs*[6], *pedis*?" In other words, why is it only in the alternation between perfect verb stem and past participle that Strunk's dictum seems to hold? As it is an analogy, it would be fallacious to expect his process to be as exceptionless as a Neogrammarian sound change, but nonetheless Strunk does implicitly claim a degree of regularity for his analogy, and Morpurgo Davies (1979) is right to point out that that claim is ill-supported by evidence that is not part of the Lachmann dataset.

Furthermore, the analogy is false to the attested facts even under these constraints. *scăptus* meets all the necessary conditions to fall subject to Strunk's analogy: its present stem is not derived, being simply *scabō*, *scabit* etc., it forms a long-vowel perfect (*scābī*, *scābit* etc.), and it has exactly the same differences between active and passive perfect as any of the Lachmann forms: if we do not take the inheritance of voiced aspirates to be significant, then *lēgit*: *lēctus* is an exact parallel for *scābit*: !*scăptus*, yet Strunk's generalisations predict ***scāptus*.

[6] As we shall see later on (p. 210), *pēs* is an interesting datum for Lachmann's Law considered as a sound change.

Strunk (1976) does make general statements about the nature of the analogy that, in his view, produced Lachmann's Law, but since they are not independently motivated, and fall down when confronted with evidence that Strunk's work is silent on, the allegation of Jasanoff (2004: 410) that "Strunk's theory is little more than a *post hoc*, case-by-case justification of why each form turned out the way it did" would not seem unmerited.

3.4 The analysis.

The debate around Lachmann's Law has historically been concerned primarily with settling the question of which of its properties is essential and which contingent: the analogists argued that the essential property was its restriction to a morphologically-defined domain, viz. the past participle, and the phonologists argued that the essential property was its primarily phonological effect (vowel lengthening) and the phonological criterion by which the verbs to which it applies are selected (presence of a final voiced stop in the verbal root, whether underlyingly or by Saussure's analogical reintroduction). This frame has largely been forced onto the question by the necessity of choosing between one of two classically understood mechanisms of linguistic change: Neogrammarian-style sound change or analogy. The nature of the problem means that deciding one way or the other will cause the resultant analysis to be a poor fit to the data, as the morphological and phonological properties of Lachmann's Law seem about equally essential to it. The model we are developing has significant potential to produce an account of the Law that takes its morphological and phonological conditions equally into account, given that PyOT as written uses Stratal Optimality Theory as its phonological engine: Stratal OT is a model not only of phonology, but of the interface between morphology and phonology.

3.4.1 Assumptions.

It is as well to list all the assumptions and stipulations that the analysis entails in one place and at the outset. They fall broadly into two categories: the chronological, where I set out exactly at what period in the history of Latin I am claiming the changes in the grammar I describe in this chapter take place, and the morphological, where I describe the synchronic state of affairs that I assume to obtain as concerns the formation of Latin stems and words.

Chronology: voiced aspirates.

Accepting that Pedersen (1896)'s observation, that Lachmann's Law does not affect verbs from roots ending in an IE voiced aspirate, is accurate and reflects an essential component of the restriction of the operation of the Law requires that we model our phonological changes as taking place while the voiced aspirates (or their Latin reflexes) were still distinct from the voiced stops in word-medial position. This same assumption is more or less explicitly made by, and in any case required of any phonological account of the Law (Sommer 1914; Niedermann 1953; Maniet 1956), but its implications deserve to be explored.

We have already modelled the sound changes affecting the voiced aspirates in chapter 2. Given that Lachmann's Law treats verbs containing reflexes of voiced aspirates differently than those containing reflexes of voiced stops, the assumption must be that pre-historic Latin retained the distinction between medial reflexes of voiced aspirates and medial reflexes of voiced stops long enough for a generation to acquire the phonological change giving rise to Lachmann's Law, and for a subsequent generation to acquire a grammar in which that change was no longer productive. In terms of the model we are developing, this places Lachmann's Law in Diachronic Stage 1, contemporaneous with Stage 1 of the life cycle of rhotacism, or earlier.

Chronology: laryngeals.

Throughout this work, except when specifically referring to the PIE forms, I have referred to e.g. **ag-tos* > *āctus* and **od-tos* > **ōsus*, rather than *h_2*eg-tos* and *h_3*ed-tos*. This convention is not haphazard: I am assuming that we have to do with a Latin that postdates the loss of the laryngeals, because of the implications that that assumption has for the synchronic working of Latin morphology. Fortunately, the chronological ordering that this entails: loss of laryngeals, then word-medial merger of voiced aspirates with voiced stops, is implied if we assume that Latin and Sabellian share a common ancestor in Proto-Italic, by the way that Latin and Sabellian treat the IE laryngeals. Latin and Sabellian share the following general rules with regard to laryngeals:

(130) If the laryngeal is between consonants of lower sonority than itself (i.e. if it is syllabic), its Italic reflex is *a*, e.g. in *factus*, *status*, *datus*, cf. Gk. *θετός, στατός, δοτός*.

(131) Otherwise, if the laryngeal is word-initial and precedes a vowel, the vowel is coloured as appropriate and the laryngeal itself is lost, e.g. *est* < *h_1*esti*, *ago* from a root *h_2*eg*, *onus* < *h_3*enos* (Schrijver 1991: 50) etc.

(132) All other consonantal laryngeals are lost entirely, with compensatory lengthening in certain post-vocalic environments (see Schrijver 1991; Ringe 1988).

This suggests that the sound changes which eliminated the laryngeals from the Italic segment inventory occurred in Proto-Italic, which necessarily entails that it preceded the Latin-specific changes affecting the voiced aspirates.

However, this analysis is only logically entailed if we believe that Proto-Italic genuinely existed, a question that is still open and subject to debate (Jones 1950; Beeler 1966; Rix 1994; Clackson 2008). If we do not believe in Proto-Italic, and so claim that the sound changes of Latin are independent of those that give rise to Sabellian, this ordering that we have established: loss of laryngeals followed by medial merger of voiced aspirates with voiced stops, must be regarded as a stipulation. It is, nonetheless a necessary one, since the assumptions which I make about the workings of Latin morphology (see below) often require the laryngeals to have already been lost. Many features of the familiar Latin system of conjugations and declensions are the result of the analogical spread of a feature that has its genesis in the reflex of a form containing a laryngeal. For example, the characteristic *ā* of the first conjugation comes, in most cases, originally from a laryngeal, as in *nat* 'swims' < **sneh*$_2$*-si* (cf. Skt. *snā́-ti* 'bathes') or *tonāre* 'thunder' from **tonh*$_2$*-ei̯e-* (cf. Skt. *stanáya-* 'thunder') Meiser (1998: 186–188). Crucially, I am assuming that the IE rubric for forming past participles, namely ⟨ROOT⟩+ -tos, still applies, but that synchronically, the notion of "root" has been redefined in the first, second and fourth conjugations to include those conjugations' characteristic vowels, so that the stem-level underlying representation of e.g. *amātus* was at the time already /amaː-to-/, and the environment conditioning Lachmann's Law was not present. Since in many cases the analogical models on which the general principles of Latin synchronic morphology were built arose due to loss of laryngeals, it is necessary to assume that that loss has already occurred.

Morphology

The inflected forms of Latin verbs are built on one of two basic stems: the present stem and the perfect stem. My assumptions with regard to the formation of these stems are as follows:

The present stem.

If we were dealing solely with the synchronic facts of Latin as it is attested, we might wish to argue that the present-tense endings of the third conjugation are *o, is, it* etc., and so that the present stem is simply the verbal root, i.e. that 3rd conjugation forms built on the present stem analyse as e.g. *reg-it*, *ag-ē-bātis*, etc. This assumption may well be adequate to the description of Classical Latin, but the examination of the comparative evidence for the source of the third conjugation verbs indicates a different analysis.

Meiser (1998: §126) gives a concise summary of the sources of the present stems of third conjugation verbs. The simplest source is PIE presents built with a thematic vowel: this is what we find in e.g. *agit* 'drives' < **$h_2$eg-e-ti*; *coquit* < **pek^w-e-ti*. However, the PIE thematic/athematic distinction is obscured in that athematic root presents built on roots ending in laryngeals also enter the third conjugation; see e.g. *uomit* 'vomits' < **u̯ema-ti* < **u̯emh$_1$-ti*, *sonit* 'sounds' < **su̯ena-ti* < **su̯enh$_2$-ti*. The third conjugation also includes verbs formed in vowel-final suffixes such as *-*sk̂e/o*- (e.g. *poscit* 'demands' < **porske-ti* < **pr̥k̂-sk̂e-ti*, from the same root **prek̂*- found in the noun *precēs* 'prayers' and the verb *precor* 'I pray'.) and *-*i̯e/o*- (as in *fugit* 'flees' from **b^h^ug-i̯e-ti*). This being so, it seems uncontroversial to assume that the present stem of the third conjugation was characterised at the time by a short vowel. Given that we have already stipulated that the basic Latin system of conjugations was already in effect, the present stems of the other conjugations would of course have been characterised by *ā*, *ē*, or *ī* as appropriate.

The perfect stem.

The prototypical source for the long-vowel perfect stems of Latin is a PIE root aorist in the *e*-grade, from a root containing a glide or laryngeal (so *fūdī* < **ĝ^h^eu̯d*- (cf. Goth. *giutan*) ∼ *fundō*, *līquī* < **lei̯k^w^*- (cf. Ved. *rik-thās*) ∼ *lĭnquō*, *fēcī* < **d^h^eh₁-k-ai* (cf. Gk. *ἔ-ϑη-κα*) (Sihler 1995: 582)). We may assume that the grammar includes a morphological process for which some verbs are flagged in the lexicon that says, informally "to form the perfect stem, take the vowel of the root and lengthen it". So the stem-level underlying representation for a long-vowel perfect stem like the *lēg* of *lēgī* will be /leːg/.

Similar diachronic reasoning tells us that the stem for a reduplicated perfect like *tutudī* must be /tu.tud/ *vel sim.* As we shall see, accounting for the lack of lengthening in reduplicated perfects of Lachmann verbs entails the assumption that reduplication is still a productive part of the Latin grammar, and so, instead of /tu.tud/, I am going to follow the standard Optimality-Theoretic approach to reduplication (see McCarthy & Prince 1999, Kager 1999: Chapter 5), and assume that the reduplicated element of the stem is generated by an underlying morpheme

RED. So, the underlying representation of *tutud* in *tutudī* is assumed to be /RED-tud/. This assumption will become particularly important later on (§3.5.3).

Roots.

I am assuming that, outside obvious cases of suppletion (as in *ferō*, *ferre*, *tulī*, *lātum*), the stems of any given verb are all built by modifying the same root, so that the stem-level underlying representation of e.g. *lĕgit* was /le.ge/, built from the root *leg* + stem-vowel *e*, the perfect stem /leːg/ was built by a non-concatenative morphological operation lengthening the vowel of the root, and the participle stem (underlying) /leg.to/ is built by the morphological operation of root *leg* + *to*.

In making this proposal, I am assuming that, for the purposes of morphophonology, the stem of the Latin of the period was maximal; that is, that it encompassed everything except the inflectional ending. So the input to the ranking in 136 was, to take *āctus* as an example, /ag.to/. This stipulation is supported by the observation which has been imported into Stratal OT from the LPM tradition, namely that roots are phonologically inert (Kiparsky 1982c: 32–33, Inkelas 1990: 48–55, Bermúdez-Otero 2006, Bermúdez-Otero 2012: §3.3.3). This principle, which is supported by observations from a number of languages, has useful implications for our present analysis, as we shall see below (p 191).

This assumption entails that where a vowel is long throughout the paradigm, eg. in *scrībō*, *scrīpsī*, *scrīptus*, the synchronic root will likewise contain the long vowel, and so such forms do not need to be explained by our account of Lachmann's Law.

3.4.2 Objectives.

I said above, at the end of §3.3.1, that my intention in this chapter is to update and extend Kiparsky (1965)'s generative account of Lachmann's Law. The core of Kiparsky's analysis was the rules I cited above as examples (118) and (119). I shall repeat them here for ease of reference:

(118) $$V \rightarrow [+\text{long}] \quad / \quad \_\_\_\_ \begin{bmatrix} +\text{obstruent} \\ +\text{voice} \end{bmatrix} \begin{bmatrix} +\text{obstruent} \\ -\text{voice} \end{bmatrix}$$

(119) $$[+\text{obstruent}] \rightarrow [\alpha\ \text{voice}] \quad / \quad \_\_\_\_ \begin{bmatrix} + & \text{obstruent} \\ \alpha & \text{voice} \end{bmatrix}$$

(Kiparsky 1965: 19)

We have already seen that there is one minimal modification that could make this model more persuasive. Adopting a cyclic theory of phonology such as Stratal OT, and arguing that the rule in (118) is stem-level, explains the restriction of its effects to particular morphological domains, and the fact that it appears to have been inserted into the grammar above (119) (which we have independent reason to believe is word-level, see p 194 below). We will now go further, and make an account of Lachmann's Law part of our model of Latin historical morphophonology.

3.4.3 A new constraint.

To model (118), we will need to propose the addition of a new constraint to Con. Adding a new constraint in OT is permissible insofar as Con as it stands does not account for all human grammars, but the addition of a constraint to Con has empirical consequences in terms of the grammars we predict to be possible. The way the new constraint interacts with the other constraints in the set will predict the existence of certain grammars; we will examine the typological implications of our new constraint below.

The constraint I propose to add is as follows:

(133) **Name:** $*V_\mu D\ldots_\sigma]$

PyOT representation: `(PVL,)`

Definition : Assess a violation for every sequence in the output of a vowel followed by a tautosyllabic voiced stop where the vowel is dominated by only one mora.

A proposed new constraint like $*V_\mu D\ldots_\sigma]$ must pass a factorial typology before it can be accepted as a member of Con as we model it, and indeed I put $*V_\mu D\ldots_\sigma]$ through this process below (§3.4.4), but there is also a rule-of-thumb which may be considered the first hurdle a constraint has to leap: it must capture an observable cross-linguistic tendency (McCarthy 2002: §3.1.5). In the case of $*V_\mu D\ldots_\sigma]$, the tendency is the frequently-observed one that the relative duration of a preceding vowel is one of the cues to the specification of the [voice] feature for consonants (Delattre 1962; Klatt 1976; Jongman et al. 1992). This phenomenon, termed Pre-Fortis Clipping by Wells (1990) and others, is not generally considered to be a part of the phonology, but it should be noted that a closely related phenomenon must be. Moreton (2004) found that the off-glides of diphthongs were higher before voiceless consonants than before voiced ones: this may well have been the genesis of the well-known phonological process of Canadian Dipththong Raising, whereby diphthongs are raised before voiceless stops. So, *ride* is pronounced as [ɹɑɪd], but *write* is pronounced [ɹəɪt]. Crucially, however, Canadian raising must be a part of the phonology, not simply a phonetic observation, since it occurs before underlying voiceless stops that are turned into flaps by a process occurring later in the derivation: *rider* is pronounced [ɹɑɪɾɚɹ], but *writer* is pronounced [ɹəɪɾɚɹ] (Chomsky & Halle 1968: 342). This would seem to be good *prima facie* evidence for the plausibility of $*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}]$

Modelling (118) will also require us to admit the following previously-defined constraints:

(134) **Name:** $*\sigma_{\mu\mu\mu}$

PyOT representation: `(StarTriMora,)`

Definition : Assess a violation for every syllable in the output that dominates three or more morae.

(135) **Name:** Dep-μ

PyOT representation: `(DepMora,)`

Definition : Assess a violation for every mora in the output that lacks a correspondent in the input.

My hypothesis is that, at Diachronic Stage 1, the period we fixed for Lachmann's Law above (§3.4.1), a generation of learners of prehistoric Latin acquired the following constraint ranking at the stem level:

(136) $*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}] \gg$ Dep-μ, $*\sigma_{\mu\mu\mu}$

where Faith-IO is a cover term for all constraints that militate against other potential repair strategies for $*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}]$. I further propose that, at the time in question, the stem of the participle was the only one that regularly contained the structure penalised by $*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}]$ in its underlying representation. It is at this point that the assumption mentioned above (p. 188) about the phonological inertness of roots becomes important: if it were untrue, and roots formed active phonological domains, the first iteration of the stem-level co-phonology over a Lachmann form like *āctus* would operate on an input /ag/ for all forms in the paradigm. This would, of course, violate $*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}]$, and so we should expect lengthening in all forms of the verb, so a 1SG.PRES **āgō*, a 3PL.IMPF **āgebant* etc. However, it is a well-settled principle that roots do not form stem-level domains until a stem is derived from them (see Inkelas 1990: §3.5 and references therein for empirical support for this claim). Since we have already established it as a reasonable assumption that the present and perfect stems, on which the other forms of the Latin verb are built, regularly ended in vowels (§3.4.1), the structure targeted by $*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}]$ will not occur in those stems even if the root ends in a voiced stop.

So, my claim is that for a Lachmann participle like *lēctus*, the underlying representation is /$[_{stem}$leg.to]s/, the bracketed section being the stem-level domain. The input to the first stage in the derivation is therefore /leg.to/, and the calculus looks like this:

(137) Tableau illustrating lengthening of vowels before tautosyllabic voiced stops.

Maximum level of structure: `Syllable`

Filter constraints: MINNUCSON-6, DIPHHIGH, LENLIMIT-Onset-2, LENLIMIT-Nuc-2, LENLIMIT-Coda-2, ONSETSONORITY-2 CODASONORITY-1

/legto/	*$V_\mu D\ldots_\sigma$]	DEP-μ	*$\sigma_{\mu\mu\mu}$
☞ 1. leːg.to	0	1	1
∼ 2. leːg.toː	$_0$—	$_2$W	$_1$—
∼ 3. leg.to	$_1$W	$_0$L	$_0$L
∼ 4. leg.toː	$_1$W	$_1$—	$_0$L

Assimilation.

To model the rule in (119), the OT literature offers multiple approaches that we could take. For present purposes, I will follow the account given in Lombardi (1999), and assume the following constraints and ranking:

(138) **Name:** [OBS]-AGREE-[VOI]

PyOT representation: `(CondAgree, 'obs', 'voi')`

Definition : Assess a violation for every pair of consecutive segments with the feature [OBSTRUENT] in the output that are differently specified with respect to the feature [VOICE].

(139) **Name:** IDENT-[VOI]

PyOT representation: `(Ident, 'voi')`

Definition : Assess a violation for every pair of segments i, i' in the output such that:

- i is a segment in the input
- i' is the correspondent of i in the output
- i and i' are differently specified with respect to the feature [VOICE]

(140) **Name:** ONSIDENT-[VOI]

PyOT representation: `(OnsIdent, 'voi')`

Definition : Assess a violation for every pair of segments i, i' in the output such that:

- i is a segment in the input *and*
- i' is the correspondent of i in the output *and*
- i' is dominated by the Onset node of a syllable *and*
- i and i' are differently specified with respect to the feature [VOICE]

(141) ONSIDENT-[VOI] ≫ AGREE-[VOI] ≫ IDENT-[VOI]

If voicing assimilation of stops in Latin applies across word boundaries, the evidence for this is masked by the writing system. However, there is evidence that assimilation applies across morpheme boundaries, such as that between a prefix and a verb stem: we have *appareo* attested alongside *adpareo* 'I appear'[7]. This implies that the level on which assimilation operates cannot be higher than the word level. Since we are going to place the constraint ranking that models (118) on the stem level, we can in principle place the ranking in (141) on either the word or the phrase level and still attain the required counterbleeding effect. We will assume for present purposes that (141) is in effect on the word level.

To continue our example derivation of *lēctus*, then, recall that the stem-level ranking has already given us /leːg.to/; on the word level, we add the ending to form the input /leːg.tos/, and present it to the word-level constraint ranking:

(142) Tableau illustrating lengthening of vowels before tautosyllabic voiced stops.

Maximum level of structure: `Syllable`

[7] Allen (1978: 22) argues that even an analogically reintroduced form such as *adpareo* would have been pronounced, if it is not just a written form, with voicing assimilation (i.e. as *a*[t]*pareo*).

Filter constraints: MinNucSon-6, DiphHigh, LenLimit-Onset-2, LenLimit-Nuc-2, LenLimit-Coda-2 OnsetSonority-2 CodaSonority-1

/leːgtos/	OnsIdent-[voi]	[obs]-Agree-[voi]	Ident-[voi]
☞ 1. leːk.tos	0	0	1
∼ 2. leːk.toz	$_0$—	$_0$—	$_2$W
∼ 3. leːg.tos	$_0$—	$_1$W	$_0$L
∼ 4. leːg.toz	$_0$—	$_1$W	$_1$—
∼ 5. leːg.dos	$_1$W	$_0$—	$_1$—
∼ 6. leːg.doz	$_1$W	$_0$—	$_2$W
∼ 7. leːk.dos	$_1$W	$_1$W	$_2$W
∼ 8. leːk.doz	$_1$W	$_1$W	$_3$W

This produces the attested output: [leːk.tos] > *lēctus*.

3.4.4 Typological implications of *$V_\mu D\ldots_\sigma]$.

One of the axioms of Optimality Theory is that constraints specify targets, not repair strategies: NoCoda, for example, does not say "If a syllable has a coda, delete it", merely "Syllables should not have codas." How a crucially undominated constraint is satisfied depends on the ranking of other constraints. A further desideratum for a proposed markedness constraint is that it show robust rerankability: a constraint which is envisaged as being top-ranked in some languages, and bottom-ranked in others, so that it behaves like a parameter in more traditional generative phonology (Booij 1983; Kenstowicz 2006) is presumed to be ill-thought-out until proven otherwise (McCarthy 2002: §3.1.5). Therefore, we will now examine the interaction of *$V_\mu D\ldots_\sigma]$ with other constraints that have been proposed for Con, and list the typological generalisations that are entailed by it. The method by which this is accomplished is known as factorial typology.

Repair strategies.

On a purely *a priori* basis, using only our knowledge of how $*V_\mu D\ldots_\sigma]$ is formulated, we can surmise in advance what we expect the repair strategies to be. Violation of $*V_\mu D\ldots_\sigma]$ depends on the conjunction of three requirements, viz.:

(143) The vowel in question must be short.

(144) The consonant in question must be voiced.

(145) Vowel and consonant must be adjacent to one another within the same syllable.

Therefore, $*V_\mu D\ldots_\sigma]$ can in principle be satisfied by any repair strategy that causes any of the conditions above not to be true. Lachmann's Law satisfies $*V_\mu D\ldots_\sigma]$ by making the vowel long, and so falsifying (143), but we might instead devoice the consonant, and so falsify (144). If we wish to deny (145), we might delete either the vowel or the consonant, or we might insert a segment, either between vowel and consonant, so they are no longer adjacent, or such that resyllabification is triggered, so that vowel and consonant are adjacent but heterosyllabic.

Another, more subtle means of falsifying (145) may be at our disposal. If our grammar ordinarily does not tolerate branching onsets, so that e.g. /pakri/ is syllabified as [pak.ri], we may breach that restriction in order to satisfy $*V_\mu D\ldots_\sigma]$, so that the input /pagri/, for example, produces the output [pa.gri]. In cases like these, there will always be inputs for which resyllabification is not a possible repair strategy, e.g. when the offending syllable is input-final, as in /fad/. So it follows that in any case where resyllabification is the grammar's preferred strategy, it will select one of the others to handle violations for inputs where resyllabification is not possible.

Finally, since we know that $*V_\mu D\ldots_\sigma]$ is violable, we have to reckon with the possibility that it will be bottom-ranked, so that /fad/ surfaces as [fad], and /adri/ as [ad.ri]. This is the situation familiar from English and most European languages. In cases like these, there will always be inputs for which resyllabification is not a possible repair strategy, e.g. when the offending syllable is input-final, as in /fad/. So it follows that in any case where resyllabification is the grammar's preferred strategy, it will select one of the others to handle violations for inputs where resyllabification is not possible.

On this reasoning we expect the factorial typology of $*V_\mu D\ldots_\sigma]$ to predict that the following behaviours of a grammar are possible:

(146) Resyllabification possible?

No	Yes		
no change	no change	/fad/ → [fad],	/adri/ → [ad.ri]
devoice C	devoice C	/fad/ → [fat],	/adri/ → [at.ri]
lengthen V	lengthen V	/fad/ → [faːd],	/adri/ → [aːd.ri]
delete	delete	/fad/ → [fa],	/adri/ → [a.ri]
insert	insert	/fad/ → [fa.də],	/adri/ → [a.də.ri]
no change	resyllabify	/fad/ → [fad],	/adri/ → [a.dri]
devoice C	resyllabify	/fad/ → [fat],	/adri/ → [a.dri]
lengthen V	resyllabify	/fad/ → [faːd],	/adri/ → [a.dri]
delete	resyllabify	/fad/ → [fa],	/adri/ → [a.dri]
insert	resyllabify	/fad/ → [fa.də],	/adri/ → [a.dri]

Constraints.

The constraints which penalise or otherwise control these repair strategies, and so are relevant to the factorial typology of $*V_{\mu}D\ldots_{\sigma}]$, are as follows:

(147) **Name:** $*\sigma_{\mu\mu\mu}$

PyOT representation: `(StarTriMora,)`

Definition : Syllables should dominate no more than two morae.

(148) **Name:** IDENT-[VOI]

PyOT representation: `(Ident, 'voi')`

Definition : Corresponding segments in the input and output should be identically specified for the feature [VOICE].

(149) **Name:** MAX-seg

PyOT representation: N/A

Definition : Segments in the input should have correspondents in the output.

(150) **Name:** DEP-seg

PyOT representation: N/A

Definition : Segments in the output should have correspondents in the input.

(151) **Name:** DEP-μ

PyOT representation: `DepMora`

Definition : Morae in the output should have correspondents in the input.

(152) **Name:** *ComplexOnset

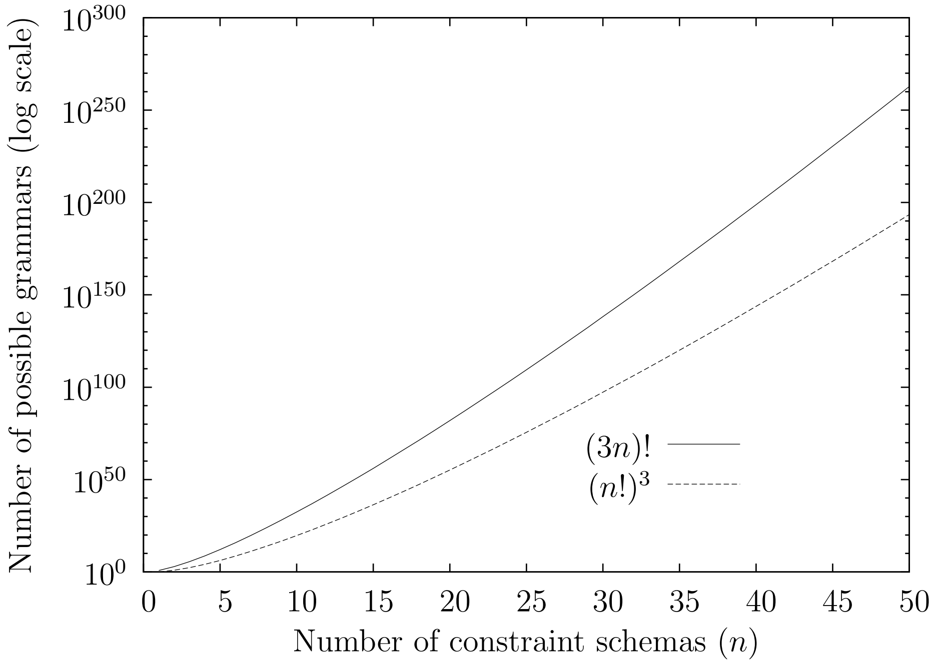
PyOT representation: `(LenLimit, 'ons', 1)`

Definition : Onset nodes should dominate no more than one segment.

Factorial typology.

Factorial typology is so-named because, in Classic OT, the maximum number of possible grammars is predicted to be $n!$, where n is the cardinality of Con, the universal constraint set, as there will be $x!$ possible rankings of the constraints in Con. For Stratal OT, the theoretical maximum is higher. We expect it to be $(n!)^3$, as there are three co-phonologies. It should be pointed out, however, that the theoretical maximum for an OT grammar that includes the constraint schemas necessary to model paradigm effects and opacity without employing multiple strata, such as sympathy and output-output correspondence constraints (McCarthy 1999; Benua 1997), is also greater than for Classic OT. Each theory proposes its own series of faithfulness constraints, which has a multiplicative effect on the size of Con: every new IO-Faithfulness constraint is presumed to have a sympathy-theoretic and an OO-counterpart. The factorial series grows faster than the cubic series, such that $(pn)! > (n!)^p$. So, provided that accounting for opacity without assuming multiple strata involves at least trebling the number of constraints, we have the following relationships between the number of constraint schemas and the number of possible grammars:

(153) Graph of the number of possible grammars under different approaches to opacity in OT:



Furthermore, there are two facts that limit the number of grammars that we expect to find attested under Stratal OT in practice, and minimise the potential difficulties that this theoretical observation poses with respect to the task of factorial typology.

Firstly, although there is nothing implicit in the architecture of the theory that constrains the extent to which rankings at different levels of a Stratal OT phonology can differ, we have already observed in examples of the life cycle of phonological processes including rhotacism in Latin, that there is an observable diachronic tendency for the domains of phonological processes to shrink over time. This has been formalised in hypotheses of the acquisition of Stratal OT phonology, to the extent that one can state in general terms that the stem-level phonology originates on the word level, and the word-level phonology on the phrase level (Bermúdez-Otero 2007). Therefore, although there is no formal link between the constraint rankings at the different levels, we can expect that out of the $(x!)^3$ grammars that are theoretically possible, we are most likely to find those in which the stem level's ranking is similar to an older grammar's word-level ranking, and the word level's ranking is similar to an older phrase-level ranking, and so on.

Secondly, and more importantly for our purposes, the predictions of a Classic-OT style factorial typology will be a proper subset of the predictions of what we might call a "factorial-cubed typology" in Stratal OT. For generalisations that apply globally, either over the entire phrase or over the entire word, we can temporarily forget about the existence of strata and perform our analyses in Classic-OT terms. It is in the exceptional situations, i.e. where we observe opacity, or a restriction in the domain of a phonological process, that we must remember the strata again. Put more concretely, even though there may be $(|\textsc{Con}|!)^3$ possible SOT grammars, each of those grammars must instantiate one of only $|\textsc{Con}|!$ rankings at the phrase level, and the generalisations called for by that ranking must hold as exceptionlessly as those called for by a ranking in Classic OT.

Therefore, we must stipulate for present purposes that this factorial typology is a typology of phrase-level generalisations, and when we look for examples to vindicate it we keep in mind that there may be opaque interactions that complicate the assessment of any given phonology.

Since we have seven constraints to deal with, the six in (147) through (152) plus $*\mathrm{V}_{\mu}\mathrm{D}\ldots{}_{\sigma}]$, that gives $7! = 5040$ possible rankings. I will now go through each of the repair strategies in (146), list the crucial rankings that give rise to them, and show that these crucial rankings account exhaustively for all 5040 possible rankings of the constraints in consideration.

To yield **lengthening in all environments**, the repair strategy we posit for the stem level to give Lachmann's Law, requires the following ranking:

(154) *V$_\mu$D. . . $_\sigma$], IDENT-[VOI], MAX-seg, DEP-seg, *COMPLEXONSET ≫ *$\sigma_{\mu\mu\mu}$ DEP-μ

The following tableau shows this ranking in action:

(155)

/fad/	*COMPLEX	*V$_\mu$D. . . $_\sigma$]	ID-[VOI]	MAX-seg	DEP-seg	*$\sigma_{\mu\mu\mu}$	DEP-μ
1. fad		*!					
2. ☞ faːd						*	*
3. fat			*!				
4. fa.də					*!		
5. fa				*!			

There are 5! × 2! = 120 × 2 = 240 possible rankings that conform to the specification of (154), leaving us with 4800 rankings still to account for.

The crucial ranking condition that predicts each of the remaining repair strategies is that of which constraint is bottom-ranked, with the proviso that so long as one of *$\sigma_{\mu\mu\mu}$ and DEP-μ is not bottom-ranked, the ranking of the other is immaterial.

So, for example, to yield **no change in any environment**, the behaviour we posit for the word and phrase levels of Latin so that /is.tud/ surfaces as the attested *istŭd*, requires either of the following rankings:

(156) IDENT-[voice], *COMPLEXONSET, *$\sigma_{\mu\mu\mu}$, MAX-seg, DEP-seg ≫*V$_\mu$D. . . $_\sigma$]

(157) IDENT-[voice], *COMPLEXONSET, DEP-μ, MAX-seg, DEP-seg ≫*V$_\mu$D. . . $_\sigma$]

Given that in each of the rankings above, either $*\sigma_{\mu\mu\mu}$ or DEP-μ dominates $*\text{V}_\mu\text{D}\ldots_\sigma]$, it will always be more expensive in terms of violations to lengthen a vowel, and violate both $*\sigma_{\mu\mu\mu}$ and DEP-μ, than to leave the vowel unaltered and so violate $*\text{V}_\mu\text{D}\ldots_\sigma]$.

The same reasoning holds for each repair strategy, with the exception of resyllabification: there are 888 rankings that meet one (or both) of the conditions above, i.e. where the constraint that militates against the repair strategy is dominated by at least one constraint that militates against every other repair strategy. 888 rankings for each of insertion, deletion and devoicing, plus the "null" repair strategy, where $*\text{V}_\mu\text{D}\ldots_\sigma]$ is crucially dominated, accounts for $888 \times 4 = 3552$ rankings. 5040 rankings total, minus 240 rankings that generate lengthening, minus 3552 rankings that generate repair strategies other than lengthening and resyllabification, leaves 1248 rankings still to account for.

Because resyllabification is not possible for all inputs (as some instances of the structure $*\text{V}_\mu\text{D}\ldots_\sigma]$ penalises may be word-final, for example), it is necessary to distinguish between rankings based on the "second-choice" repair strategy that they predict. This is determined by the next-lowest-ranked constraint after *COMPLEXONSET.

To predict **Resyllabification where possible, otherwise lengthening**, a ranking must meet at least one of the following specifications:

(158) $*\text{V}_\mu\text{D}\ldots_\sigma]$, DEP-seg, MAX-seg, IDENT-[voice] $\gg$ $*\sigma_{\mu\mu\mu}$, DEP-μ $\gg$ *COMPLEXONSET

(159) $*\text{V}_\mu\text{D}\ldots_\sigma]$, DEP-seg, MAX-seg, IDENT-[voice] $\gg$ $*\sigma_{\mu\mu\mu}$ $\gg$ *COMPLEXONSET $\gg$ DEP-μ

(160) $*V_{\mu}D\ldots_{\sigma}]$, DEP-seg, MAX-seg, IDENT-[voice] ≫ DEP-μ ≫ *COMPLEXONSET

Once again, the fact that either $*\sigma_{\mu\mu\mu}$ or DEP-μ can inhibit lengthening imposes complicated conditions on what constitutes a ranking that generates this repair strategy:

a. One of $*\sigma_{\mu\mu\mu}$ or DEP-μ must dominate *COMPLEXONSET

b. The other constraints must dominate both $*\sigma_{\mu\mu\mu}$ and DEP-μ.

The following tableaux illustrate these principles in action:

(161)

/fad/	MAX-seg	DEP-seg	$*V_{\mu}D\ldots_{\sigma}]$	ID-[voi]	$*\sigma_{\mu\mu\mu}$	*COMPLEX	DEP-μ
1. fad			*!				
2. ☞ faːd					*		*
3. fat				*!			
4. fa.də		*!					
5. fa	*!						

(162)

/adri/	MAX-seg	DEP-seg	$*V_{\mu}D\ldots_{\sigma}]$	ID-[voi]	$*\sigma_{\mu\mu\mu}$	*COMPLEX	DEP-μ
1. ad.ri			*!				
2. aːd.ri					*!		*
3. at.ri				*!			
4. a.də.ri		*!					
5. a.ri	*!						
6. ☞ a.dri						*	

4 possible rankings of $*\sigma_{\mu\mu\mu}$, *COMPLEXONSET and DEP-μ multiplied by 4! possible rankings of the other constraints equals $24 \times 4 = 96$ rankings down, 1152 to go.

The crucial rankings that give rise to **Resyllabification where possible, otherwise no change** are similarly convoluted:

(163) MAX-seg, DEP-seg, IDENT-[voi], $*\sigma_{\mu\mu\mu} \gg *\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}] \gg$ *COMPLEXONSET

(164) MAX-seg, DEP-seg, IDENT-[voi], DEP-$\mu \gg *\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}] \gg$ *COMPLEXONSET

They may be stated in words as:

- $*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}]$ must dominate *COMPLEXONSET
- One of $*\sigma_{\mu\mu\mu}$ and DEP-μ must dominate $*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}]$
- All other constraints must also dominate $*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}]$

These principles are illustrated by the following tableaux:

(165)

/fad/	MAX-seg	DEP-seg	$*\sigma_{\mu\mu\mu}$	ID-[voi]	$*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}]$	*COMPLEX	DEP-μ
1. ☞ fad					*		
2. faːd			*!				*
3. fat				*!			
4. fa.də		*!					
5. fa	*!						

(166)

/adri/	MAX-seg	DEP-seg	$*\sigma_{\mu\mu\mu}$	ID-[voi]	$*\mathrm{V}_{\mu}\mathrm{D}\ldots_{\sigma}]$	*COMPLEX	DEP-μ
1. ad.ri					*!		
2. aːd.ri			*!				*
3. at.ri				*!			
4. a.də.ri		*!					
5. a.ri	*!						
6. ☞ a.dri						*	

There are 288 rankings that meet these criteria, therefore we have 864 rankings left to cover.

Similar principles to those in (3.4.4) govern the remaining repair strategies. To predict **Resyllabification where possible, otherwise epenthesis** requires the following crucial rankings:

(167) $*V_\mu D\ldots_\sigma]$ MAX-seg, IDENT-[voi], $*\sigma_{\mu\mu\mu} \gg$ DEP-seg $\gg$
*COMPLEXONSET

(168) $*V_\mu D\ldots_\sigma]$ MAX-seg, IDENT-[voi], DEP-$\mu \gg$ DEP-seg $\gg$
*COMPLEXONSET

This accounts for 288 rankings, and leaves 576 still to go.

Likewise, to predict **Resyllabification where possible, otherwise deletion** takes the following crucial rankings:

(169) $*V_\mu D\ldots_\sigma]$ MAX-seg, IDENT-[voi], $*\sigma_{\mu\mu\mu} \gg$ DEP-seg $\gg$
*COMPLEXONSET

(170) $*V_\mu D\ldots_\sigma]$ MAX-seg, IDENT-[voi], DEP-$\mu \gg$ DEP-seg $\gg$
*COMPLEXONSET

288 rankings are consistent with this specification, and 288 are left over. It will come as no surprise to the reader to learn that the remaining 288 are those which meet the following specification, and predict **Resyllabification where possible, otherwise devoicing**:

(171) $*V_\mu D\ldots_\sigma]$, MAX-seg, DEP-seg, $*\sigma_{\mu\mu\mu} \gg$ IDENT-[voi] $\gg$
*COMPLEXONSET

(172) $*V_\mu D\ldots_\sigma]$, Max-seg, Dep-seg, Dep-μ $\gg$ Ident-[voi] $\gg$ *ComplexOnset

It should be noted that this factorial typology only covers grammars in which the effects of $*V_\mu D\ldots_\sigma]$'s ranking are visible. For example, it does not predict phonologies which do not tolerate voiced obstruents at all. In such a language, VOP (Voiced Obstruent Prohibition) dominates Ident-[voi], and so output candidates that contain the structure $*V_\mu D\ldots_\sigma]$ penalises can never be considered harmonic by Eval. Our factorial typology assumes that, in searching for examples to vindicate it, we will ignore languages in which $*V_\mu D\ldots_\sigma]$'s ranking is never the crucial factor in selecting the winning candidate.

It should likewise be noted that other constraints not included in the typology will predict exactly how certain repair strategies are instantiated. For example, where Max-seg is dominated, and so structures targeted by $*V_\mu D\ldots_\sigma]$ are repaired by deletion, other constraints will control which segment is deleted, according to the relative markedness of the candidates violating Max-seg. Similarly, sonority sequencing constraints will control which inputs cause $*V_\mu D\ldots_\sigma]$ to be satisfied by resyllabification, and which by another repair strategy, in those cases where *ComplexOnset is bottom-ranked. Then again, depending on the exact environment, more complicated repair strategies may be possible: for example, in the cases where $*V_\mu D\ldots_\sigma]$ can be satisfied by resyllabification, it may also be satisfied by metathesis: /adri/ may become [ar.di]. We might amend our factorial typology in light of this to include the constraint Linearity, but I hope it has become apparent by this point that in a properly thoroughgoing OT analysis, everything depends to a certain extent on everything else, and as such an attempt to construct a factorial typology for a given new constraint quickly becomes the intractably large task of constructing a factorial typology for the entire constraint set as we have so far modelled it. The usefulness of such an endeavour becomes particularly suspect when we consider that, for all that targets are axiomatically decoupled from repair strategies in OT, hypotheses about what counts as marked tend to travel in company with specific repair strategies.

This observation has been made by Steriade (2009), who proposes to account for it formally by adding a module to the OT calculus known as the P-map, which projects the ranking of faithfulness constraints with respect to a given markedness constraint based on the relative perceptibility of the repair strategies they call for.

I believe that Steriade has identified a very real difficulty with OT and factorial typology in what she calls the "Too-Many-Solutions problem" (Steriade 2009: 154), which is the very difficulty we are faced with in the factorial typology of $*V_{\mu}D\ldots_{\sigma}]$: our typology predicts many more repair strategies for the new constraint than we would ever expect to find attested.

I disagree, however, with Steriade's approach to solving the Too-Many-Solutions problem. Rather than re-introduce a coupling between targets and repair strategies into OT, as the P-map does, I believe that the coupling can be found in the nature of phonological acquisition. As I have said in the previous chapter (p. 71), I believe that the acquisition of a phonology consists of learners attempting to find the constraint ranking that most intelligibly matches the patterns of sounds they perceive or misperceive in the speech of their elders, and I believe that sound change is often actuated by a misperception of the speech signal that learners are using as a stimulus. These misperceptions are under no such stricture as OT with respect to the separation of targets from repair strategies, and so it is in them that we find the link between the two.

The practical consequence of this is that we cannot necessarily expect to find every repair strategy called for by a factorial typology attested in the languages of the world. We must, therefore, reduce our standard of proof for a new constraint to demand simply that the markedness hypothesis entailed by the constraint holds not only for the language it is intended to model, but also for at least one other.

With respect to $*V_{\mu}D\ldots_{\sigma}]$, I believe that that condition is satisfied by the fact that the structure $*V_{\mu}D\ldots_{\sigma}]$ penalises as marked is entirely absent from underlying representations in modern German[8]; an observation made by (Lahiri & Dresher 1999: 688). That is to say that there are no words in German that are like [taːk], [taːgə] 'day', with an alternation between final voiceless and medial voiced stop that we routinely analyse as pointing to an underlying voiced stop, but with a short vowel; forms like [tag] → *[tak] are unattested. Richness of the Base dictates that for this generalisation over underlying representations to remain stable, it must be the result of lexicon optimization based on the constraint ranking (Prince & Smolensky 1993: 209). We might hypothesize that $*V_{\mu}D\ldots_{\sigma}]$ is crucially undominated at a level of the grammar of German higher than that on which final devoicing takes place, and so the neutralization of length contrasts counterbleeds final devoicing in the same way that Kiparsky (1965) suggested that Lachmannian vowel lengthening counterbleeds voicing assimilation in Latin.

[8]Hagège & Haudricourt (1978: 85) make a similar observation with respect to the phonology of the French spoken in the Alsace region. Very probably this is under the influence of the local Alemannic dialect.

3.5 Refinements to the model.

So far, we have hewn closely to Kiparsky (1965)'s account, merely translating it into Optimality-Theoretic terms and deriving the advantages associated with that framework. However, Kiparsky's account is demonstrably false to the facts of Lachmann's Law: it does not account for the lengthening of *ēmptus*, nor predict the lack of lengthening in *strĭctus*, *fĭctus* and *-sĕssus*. We will now attempt to modify our analyses to take in the exceptions to the general rule proposed by Kiparsky and adapted above.

3.5.1 Life cycle effects.

The constraint ranking (136), which generates the characteristic lengthening of Lachmann's Law, is posited for the stem level of Diachronic Stage 1. Diachronic Stage 1, the earliest stage in our model, represents a stage of the language older than anything we have attested: it should be considered as the stage representing the earliest phonology of prehistoric Latin that we have enough data to reconstruct. Given the standard assumptions about the life cycle of phonological processes that have been made throughout this work, we should expect to find evidence that Lachmann's Law had been a phrase-level and then a word-level generalisation before Diachronic Stage 1, and became a property of the lexicon after Stage 1.

There is insufficient data to reliably reconstruct the earlier stages of the life cycle of Lachmann's Law, but there are marginalia within the attested language that are consistent with, if not probative of the hypothesis that the Law was once a word- or phrase-level generalisation:

Schrijver (1991: 135) adduces the example of *pēs* 'foot'. If the stem of this noun is underlyingly /ped/ (and the existence of alternating forms in the paradigm such as ACC.SG *pedem*, GEN.SG *pedis* would require us to suggest that it is, by the same reasoning that leads us to suppose a stem /agto/ for āctus on the basis of *āctus*, *āctum* etc.), then our conception of Lachmann's Law would require us to assume that it was lengthened to /peːd/ as the input to the word level. This explains the vocalism of the NOM.SG *pēs* (which is unexpected in IE terms: Latin should have inherited **pōd-s*, cf. Gk. *πούς*, English *foot*), but is embarrassing with respect to the rest of the paradigm, which has *pĕdem*, *pĕdis* etc. If the lengthening in *pēs* occurs in order to avoid violating $*V_{\mu}D\ldots_{\sigma}]$, then it may be a vestige of a word-level instance of the constraint ranking in (136). A similar pattern is in evidence in the irregular paradigm of the verb *edere* 'eat': which runs *edō, ēs, ēst, edimus, ēstis, edunt*. The long vowels in the 2SG, 3SG and 2PL are usually taken to represent lengthened grades of ablaut (see e.g. Meiser 1998: 223), but they could also be the product of a word-level Lachmann's Law, with *h_1*ed-si* > /eds/ → [eːs], for example, but not /edont/ → *[eː.dont], as the [d] is not tautosyllabic with the vowel. These forms do not constitute sufficient evidence to say definitively that Lachmann's Law underwent a word-level stage; I only cite them as data that are consistent with the expectation that the theory of the life cycle creates that it should have.

Consonant stem nouns of the third declension are a problem in general for our conception of Lachmann's Law, if we assume that they contain a stem-level domain encompassing everything up to and including the inflectional ending: we would expect nominatives in -V̆D*s* to become -V̄D*s*. The evidence is clear that they do not, and, more compellingly, a contrast between short and long root vowels is preserved in consonant-stem nominatives: *grex*, *gregis* 'herd' is kept quantitatively distinct from *rēx*, *rēgis* ‘king’, etc. (see Kennedy 1962: §37). This suggests that if at any point these forms were subject to a stem-level Lachmann’s Law, so that we had nominatives **grēx*, **uās*, **pecūs* etc., the short vowel must subsequently have been restored on the analogical model of the oblique cases (leaving *pēs* ∼ *pedem* and *Cerēs* ∼ *Cereris* untouched, for whatever reason).

An alternative would be to modify our hypothesis with respect to what constitutes a phonological stem (as articulated on page 188), such that a phonological stem is formed iff there is a stem vowel. On this hypothesis, a consonant-stem nominative such as *grex* has no phonological stem, and so is never subject to lengthening by Lachmann’s Law as I have modelled it.

Neither of these two possibilities is independently corroborated, so I leave it to the reader to decide which is more plausible.

As for the later stage, in which Lachmann’s Law is a property of the lexicon, the fact that the Law is considered to be a property specifically of past participles and forms like frequentatives that are built on the same stem (as witness Gellius, see page 139), constitutes effective evidence that, in the attested language, Lachmann’s Law has already entered Stage L of the life cycle, and become a part of the lexicon.

Since we have argued that the characteristic lengthening of Lachmann’s Law is a stem-level phonological process, not a strictly morphological one, it follows that the particular restriction to past participles must be an accidental one: that is, that any Latin form that has a stem-level domain in its underlying representation could potentially show Lachmannian lengthening. Particularly, we must consider nouns and other substantives that may contain the Lachmann environment. We have already considered the claims of *pēs*, which leaves one other notable pair of examples, for which the evidence is precisely equivocal: on the one hand, there is one piece of evidence that leads us to read *maximus* 'greatest-NOM.SG.M' as being in fact *māximus*, namely the apex discussed by (Jasanoff 2004: 411) (see page 3.3.1). On the other hand, there is one piece of evidence that leads us to read the antonym *pessimus* as having a definitely short *ĕ*, namely the lack of visible degemination of the *ss*. For Jasanoff, who claims that Lachmann's Law is a regular sound change occurring within the attested history of Latin, after the expected **mag-is-m̥mo-s* and **ped-is-m̥mo-s* have undergone syncope and become **magsamos* and **pedsamos* respectively, *pessimus* is the inconvenient form, and to explain it he suggests an analogy, which restored the *-ss-* on the model of the regular superlative, and shortened the vowel by the *littera*-rule.

Our model, however, assumes that Lachmann's Law takes place before the attested history of the language, and therefore before vowel weakening and syncope, so that we would not expect a regular lengthening in *maximus*, since in Diachronic Stage 1 it would still be underlyingly /magismmos/ *vel sim.* For us, then, *pessimus*, without lengthening, is the expected form, and the apparent *ā* in *maximus* is something to be explained away. As we have already established (p. 135), the exact guiding principle behind the use of the apex is not clear enough to justify us in relying on it without corroborating evidence, so the needs of the model force us to claim that the apex on *máximus* at CIL VI 2080 17 marks something other than vowel length.

3.5.2 Front vowels.

Many of the apparent counterexamples to Lachmann's Law contain front vowels: to the lack of lengthening in the compounds of *-sessus* may be added the example of *pessum* 'to perdition', and against them we may set the participles *lēctus, rēctus, tēctus, ēsus*, which are well-behaved from the point of view of the Law. With the high vowel *i*, we have one example which seems to observe Lachmann's Law: *uīsus*, and at least three that do not: *strictus*, *fissus*, *scissus*. Simply by counting the relevant forms, we may draw the conclusion that Lachmannian lengthening is regular for *e*, but exempts *i*, provided that we can find a satisfactory explanation for why *-sessus* and *pessum* should not show lengthening, and for why lengthening should be found in *uīsus*.

For *uīsus*, Watkins (1970b: 62) argues for an independent analogy that built a new participle **u̯eid-to-* on the model of the perfect stem with original diphthong (cf. Gk. *οἶδα*, Skt. *veda*). I would add as a possible reason for the reformation the comparatively pronounced difference in meaning between the active forms of the IE root **u̯id* and the stative forms, which are reflected by the Latin perfect. It seems reasonable to infer that in Proto-Indo-European the stative of **u̯id* 'see' became specialised in the meaning 'know': cf. Irish *fios* 'knowledge', Gk. *οἶδα* 'I know', English *wit* etc. (Vanhove 2008: 341) Therefore, the participle **wid-tos* may have acquired the meaning 'known (having been seen)', necessitating the formation of a new one to mean 'seen' without this sub-sense.

This brings us to the question of the forms with *e* that lack lengthening: are we to adopt Watkins (1970b: 64–65)'s reasoning, and suppose on the basis of *sessum* and *pessum* that supines as a whole were exempt from the workings of Lachmann's Law itself, and that where they are found to match a Lachmann participle, this is due to analogy (see page 177)? Since we have assumed a strict definition of the term "stem" for our present purposes — that is, anything to which inflectional endings are appended is a stem — we might be justified in arguing that supines, which do not inflect, do not form stem-level domains, so that the stem-level ranking which precipitated Lachmannian lengthening did not apply to them. If this is not palatable, we must assume that the supines underwent Lachmann's Law along with the participles, and find reasons why *pessum* and *sessum* were excluded from the general development. Perhaps the analogical change from **pēsimus* to *pessimus* spread to *pessum* as well, or perhaps the link from *pessum* to a root in **ped-* was unclear, so that at the time *pessum* was underlyingly /pet.tum/. If necessary, we might revive Collinge (1975: 475)'s suggestion that the vowel was shortened to avoid homophony with forms of the verb *pēdō* 'break wind', but as I noted above, this hypothesis is essentially unprovable.

I can offer no better account of the exceptional nature of the compounds in *-sessus* or of *uīsus* than those given by Watkins (1970b). I shall merely note that our OT account is compatible with his arguments, and offer some extra indications in support of them.

For *-sessus*, Watkins (1970b: 64–65) argues that the basic verb *sedeō*, being intransitive, originally had no past participle, and so that when its (transitive) compounds came to form past participles, they relied on the nearest available model: the Lachmann-exempt supine *sessum*.

Our hypothesis also includes a provision for supines to be exempt from lengthening, though it is a stipulative one, so it is compatible on that score. As to the plausibility of the compounds' using the supine as a model, I can only echo Kortlandt (1989)'s observation that they may have been given extra incentive to do so by the fact that if *sedeō* had a past participle, we would expect it to reflect the rather unlikely **sdtos*.

Assuming that we are justified in our reasoning for excluding short *e* and long *ī* from our analyses, this will leave us needing to account for Lachmann's Law as lengthening all vowels except /i/. Niedermann (1911) was already able to cite "neuere experimentalphonetische Untersuchungen" in support of his phonetic account of the Law, which held that the lengthening imposed on [i] was insufficient to cross the perceptual boundary between the phonemes /i/ and /iː/. Phonetic analyses in the intervening years have only confirmed Niedermann's observations, and provided more complete theoretical accounts of why they should be so. For example, Gussenhoven (2004: 18) and Catford (1977) agree in the finding that high vowels are inherently shorter than low vowels. Tellingly, Gussenhoven (2004) also finds that listeners tend to compensate for this inherent difference in duration by subtracting from the perceived length of a vowel in inverse proportion to its height as part of their computation of perceived length. That is, a listener hearing [ɑ] tacitly knows that, since it is a low vowel, the speaker will involuntarily take more time to say it. This means that perceived duration of vowels is positively correlated with vowel height. Since [i], on Gussenhoven (2004)'s theory, is compensatorily perceived as longer, it follows that it will be less likely to be analysed as phonologically long when phonetic circumstances lengthen it.

This finding is supported by the study by Hillenbrand et al. (2000), who tested the extent to which the distinction between pairs of English vowels was controlled by duration. They found that markedly fewer experimental subjects identified an artificially lengthened /ɪ/ as /i/ or a shortened /i/ as /ɪ/ than identified lengthened /ɛ/ as /æ/ or shortened /æ/ as /ɛ/. These results are English-specific, and it might be argued that, although the phonological difference between English /i/ and /ɪ/ is primarily one of quantity, the pattern in the resuts of Hillenbrand et al. (2000)'s tests has more to do with their phonetic qualitative difference. This may very well be so, and if it is it is small wonder that Latin should show evidence of a similar tendency, since a tense/lax distinction between short and long high vowels very much like that of English is proposed for Latin on the basis of the eventual merger of Latin short *i* with long *ē* and short *u* with long *ō* (Allen 1978: 47, Sturtevant 1940: 107ff.).

The late Latin developments provide evidence only for a tense/lax distinction between long and short high vowels, so including /u/ as well as /i/. Given that Lachmann's Law affects *tūsus* and *fūsus* also, we should best prefer to find evidence of a greater opposition between long and short *i* than between any other quantitatively opposed pair of vowels. There is some independent evidence from the vocalism of reduplicant vowels that short *ĭ* was treated separately from the other vowels. Another asymmetry can be found in the fact that the off-glide of the diphthong *ai* appears to be lowered, as it begins to be spelled *ae* early in the 2nd century B.C.E (Allen 1978: 60), but no such lowering takes place in the high back vowel: *au* does not become **ao*. The fact that the early Latin orthography has a separate strategy for marking length in *i* than in the other vowels, namely the *i longa* (Rolfe 1922; Meiser 1998: 49), is also suggestive. None of these facts—the exemption of *i* from Lachmann's Law, the separate treatment of *i* in reduplication and as an off-glide to diphthongs, and the *i longa*—is dispositive on its own, but taken together, I believe they constitute a preponderance of evidence in favour of a qualitative distinction between long and short /i/ at Diachronic Stage 1 that is not shared by any other quantitatively opposed pair of vowels. The FUL system uses the feature [RTR] to encode the qualitative distinction between long and short vowels in German (Lahiri & Reetz 2002), so I will use [RTR] for the short *i*, which I will transcribe [ɪ]. I will rely on this featural distinction to account for all the indications in the data that seem to point to it: the exemption of [ɪ] from Lachmann's Law will be modelled presently, the vocalism of reduplication in the section that follows (§3.5.3), and the lowering of *i*-diphthongs in the next chapter (§4.3.1).

With this featural stipulation added to the theory of representations, the stem-level ranking that generates Lachmann's Law can be modified so as not to predict lengthening of *i* by adding the following constraint:

(173) **Name:** *Seg([rtr]):

PyOT representation: `(StarLongFeat, 'rtr')`

Definition : Assess a violation for every long segment in the output that has the feature [rtr]

To inhibit the lengthening of [ɪ], we add *Seg([rtr]): to the ranking such that it dominates $*\sigma_{\mu\mu\mu}$ and Dep-μ:

(174) *Seg([rtr]): $\gg$ $*V_{\mu}D\ldots_{\sigma}]$, $*\sigma_{\mu\mu\mu}$, Dep-μ

This predicts the attested lack of lengthening in e.g. *scissus*, provided that the input is taken to be /$[_{stem}$skɪd]tos/:

(175) Tableau illustrating exemption of [ɪ] from Lachmann's Law

Maximum level of structure: `Syllable`

Filter constraints: MinNucSon-6, DiphHigh, LenLimit-Onset-2, LenLimit-Nuc-2, LenLimit-Coda-2, OnsetSonority-2 CodaSonority-1

/skɪdto/	*Seg([rtr])ː	*$V_{\mu}D\ldots{}_{\sigma}]$	Dep-μ	*$\sigma_{\mu\mu\mu}$
☞ 1. skɪ.dto	0	0	0	0
☞ 2. skɪ.dto	0	0	0	0
∼ 3. skɪ.dtoː	$_0$—	$_0$—	$_1$W	$_0$—
∼ 4. skɪ.dtoː	$_0$—	$_0$—	$_1$W	$_0$—
∼ 5. skɪd.to	$_0$—	$_1$W	$_0$—	$_0$—
∼ 6. skɪd.to	$_0$—	$_1$W	$_0$—	$_0$—
∼ 7. skɪdto̯	$_0$—	$_1$W	$_0$—	$_1$W
∼ 8. skɪdto̯	$_0$—	$_1$W	$_0$—	$_1$W
∼ 9. skɪdt.o	$_0$—	$_1$W	$_0$—	$_1$W
∼ 10. skɪdt.o	$_0$—	$_1$W	$_0$—	$_1$W
∼ 11. skɪd.toː	$_0$—	$_1$W	$_1$W	$_0$—
∼ 12. skɪd.toː	$_0$—	$_1$W	$_1$W	$_0$—
∼ 13. skɪdt.oː	$_0$—	$_1$W	$_1$W	$_1$W
∼ 14. skɪdt.oː	$_0$—	$_1$W	$_1$W	$_1$W
∼ 15. skɪː.dto	$_1$W	$_0$—	$_1$W	$_0$—
∼ 16. skɪː.dto	$_1$W	$_0$—	$_1$W	$_0$—
∼ 17. skɪːdto̯	$_1$W	$_0$—	$_1$W	$_1$W
∼ 18. skɪːdto̯	$_1$W	$_0$—	$_1$W	$_1$W
∼ 19. skɪːd.to	$_1$W	$_0$—	$_1$W	$_1$W
∼ 20. skɪːd.to	$_1$W	$_0$—	$_1$W	$_1$W
∼ 21. skɪːdt.o	$_1$W	$_0$—	$_1$W	$_1$W
∼ 22. skɪːdt.o	$_1$W	$_0$—	$_1$W	$_1$W
∼ 23. skɪː.dtoː	$_1$W	$_0$—	$_2$W	$_0$—
∼ 24. skɪː.dtoː	$_1$W	$_0$—	$_2$W	$_0$—
∼ 25. skɪːd.toː	$_1$W	$_0$—	$_2$W	$_1$W
∼ 26. skɪːd.toː	$_1$W	$_0$—	$_2$W	$_1$W
∼ 27. skɪːdt.oː	$_1$W	$_0$—	$_2$W	$_1$W
∼ 28. skɪːdt.oː	$_1$W	$_0$—	$_2$W	$_1$W

3.5.3 Reduplicated perfects.

We have taken it as an assumption (§3.4.1) that the underlying representation of a reduplicated perfect stem like the *tutud* of *tutudī* is /red.tud/. Since *$V_{\mu}D\ldots{}_{\sigma}]$ targets vowels which are tautosyllabic with voiced stops, rather than vowels preceding stop clusters as in Kiparsky (1965), we might expect Lachmannian lengthening to give us [tu.tuːd] as input to the word level, producing a perfect in **tutūdī*. The systematic exemption of reduplicated stems from the stem-level lengthening process arises naturally from the way reduplication is traditionally modelled in OT. The textbook account (e.g. Kager 1999: Chapter 5) is to assume that the underlying representation of a reduplicated form contains the morpheme RED, giving us our stem /RED.tud/, and to go on to propose that CON includes faithfulness constraints that, instead of penalising differences between input and output, penalise differences between base and reduplicant (Kager 1999: 201ff.). Within this framework, the account of the underapplication of our lengthening process in Latin is parallel with the account of the behaviour of Tonkawa analysed by Gouskova (2007). Latin is like Tonkawa in that it appears that the reduplicant adheres to a specific template: namely, the reduplicant must be a single CV̆-syllable. Gouskova (2007: 375) captures this restriction by proposing the following constraint:

(176) RED=σ_μ

The reduplicative morpheme is a light syllable

As Gouskova goes on to explain, this constraint is in fact a cover term for three separate markedness constraints affecting the reduplicant specifically. These are:

(177) NoCoda$_{\text{RED}}$

Syllables in the reduplicant do not have codas.

(178) NoLongV$_{\text{RED}}$

No long vowels in the reduplicant.

(179) Affix$\leq \sigma$

The phonological exponent of an affix is no longer than a syllable.

Gouskova (2007: 378)

The following constraints and constraint schema have been added to PyOT to implement models of reduplication along these lines:

(180) **Name:** *$\bar{\text{V}}$-BR

PyOT representation: `(LenLimit, 'nuc', 1, 'BR')`

Definition : Assess a violation for every long vowel in the output that is part of a reduplicant.

(181) **Name:** MAX-C-BR

PyOT representation: `(Max_C, 'BR')`

Definition : Assess a violation for every consonant in the base that lacks a correspondent in the reduplicant.

(182) **Name:** REDLENGTH-*obj*-*n*

PyOT representation: `(RedLength, obj, n)`

Definition : Assess a violation for every reduplicant in the output that contains more than *n* elements of type *obj*.

For example:

(183) **Name:** REDLENGTH-σ-1

PyOT representation: `(RedLength, Syllable, 1)`

Definition : Assess a violation for every reduplicant in the output that contains more than 1 syllable.

The constraint against reduplicant syllables having codas is treated as an emergence of the unmarked effect: the context-free constraint NoCoda is ranked such that it is dominated by all IO-faithfulness constraints, and dominates Max-C-BR.

The crucial ranking that predicts a Latin- and Tonkawa-style restriction of reduplicants to C$\breve{V}$-shape is as follows:

(184) RedLength-σ-1, *$\bar{V}$-BR, NoCoda $\gg$ Max-C-BR

This ranking restricts the reduplicant to a single light syllable, and permits deletion of consonants to keep the reduplicant to that template, but it predicts that the reduplicant will match the base in every other respect. So, a stem /REDtud/ will surface as [tu.tud], and a stem /REDmord/ will surface as [mo.mord], but a stem /REDkad/ will also surface as *[ka.kad], which is not what we find in Latin (cf. *cadō* ~ *cecidī*). The ranking needs to be adjusted to predict the correct vocalism for the reduplicant syllable.

Aulus Gellius (*Noctes Atticae*, 6, 9) tells us that, although Classical Latin has *momordī* 'bite-1SG.PRF' and *pupugī* 'pierce-1SG.PRF', earlier authors had *e* as the vowel of the reduplicant for every base vowel except *i*: so *mordeō* alternated with *memordī*, and *pungō* with *pepugī*, as well as *cadō* with **cecadī* > *cecidī* and *teneō* with **tetenī* > *tetinī*. *scindō*, however, does not alternate with **scecidī* but with *scicidī*.

Gellius' statement is sufficiently well corroborated as to make it into the handbooks (Leumann 1977: 586, Sihler 1995: 580 Meiser 1998: 210), so we must reckon with the reduplication pattern he describes as being the one extant at Diachronic Stage 1.

The pattern Gellius describes, in which roots characterised by the vowels [a], [o] and [u] have reduplicants in [e], can be modelled as an emergence of the unmarked, with a constraint against back vowels ranked below all IO-Faithfulness constraints, but above BR-IDENT constraints on place features, like so:

(185) **Name:** *SEG[VOC ∧ DOR]

PyOT representation: `(StarFeats, 'dor', 'voc')`

Definition : Assess a violation for every segment in the output with the features [VOCALIC] and [DORSAL]

(186) **Name:** IDENT-*feat*-BR

PyOT representation: `(Ident, feat, BR)`

Definition : Assess a violation for every pair of segments i, i' in the output such that:

- i is a segment in the base
- i' is the correspondent of i in the reduplicant
- i and i' are differently specified with respect to the feature *feat*

(187) *SEG[DOR ∧ VOC] ≫ IDENT-[RTR]-BR, IDENT-[HIGH]-BR, IDENT-[DOR]-BR, IDENT-[COR]-BR, IDENT-[LOW]-BR, IDENT-[LAB]-BR

Adding the ranking in (184) that calls for the reduplicant to be a single syllable of the form CV, and the constraint ranking that predicts Lachmannian lengthening gives us the following overall ranking for the stem level of Diachronic Stage 1:

(188) *SEG([RTR])ː, REDLENGTH-σ-1, *$\bar{\text{V}}$-BR, ≫

$*V_\mu D\ldots_\sigma] \gg$

DEP-$\mu \gg$

*SEG[DOR ∧ VOC], *GEMINATE, NOCODA $\gg$

MAX-C-BR, IDENT-[RTR]-BR, IDENT-[HIGH]-BR, IDENT-[DOR]-BR,

IDENT-[COR]-BR, IDENT-[LOW]-BR, IDENT-[LAB]-BR,

The ranking generates *[te.tu.dit], in accordance with Gellius's rule, for the perfect stem from /RED-tud/ as follows[9]:

[9]This analysis is of course incompatible with the account of reduplication in Stratal OT proposed by Kiparsky (2010), and necessarily so, since it entails "back-copying" of the short vowel from the reduplicant to the base, and Kiparsky argues that back-copying is in fact unattested.

(189) Tableau illustrating reduplication in the forerunner of *tutudit* 'bruise-3SG.PRF' at Diachronic Stage 1.

Maximum level of structure: `Syllable`

Filter constraints: MinNucSon-6, DiphHigh, LenLimit-Onset-2, LenLimit-Nuc-2, LenLimit-Coda-2, OnsetSonority-2 CodaSonority-1

/REDtud/	[voc ∧ high ∧ cor] ⊃ [rtr]	RedLength-σ-1	*V̄-BR	*Seg[voc ∧ dor]	*Seg([rtr])	*Geminate	NoCoda	Max-C-BR	Ident-[rtr]-BR	Ident-[high]-BR	Ident-[dor]-BR	Ident-[cor]-BR	Ident-[low]-BR	Ident-[lab]-BR	*ComplexCoda
☞ 1. te.tud	0	0	0	1	0	0	1	1	0	1	1	1	0	1	0
~ 2. ted.tud	$_0$—	$_0$—	$_0$—	$_1$—	$_0$—	$_0$—	$_2$W	$_0$L	$_0$—	$_1$—	$_1$—	$_1$—	$_0$—	$_1$—	$_0$—
~ 3. tu.tud	$_0$—	$_0$—	$_0$—	$_2$W	$_0$—	$_0$—	$_1$—	$_1$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$—	$_0$L	$_0$—
~ 4. tud.tud	$_0$—	$_0$—	$_0$—	$_2$W	$_0$—	$_0$—	$_2$W	$_0$L	$_0$—	$_0$L	$_0$L	$_0$L	$_0$—	$_0$L	$_0$—
~ 5. te.dtud	$_0$—	$_1$W	$_0$—	$_1$—	$_0$—	$_0$—	$_1$—	$_0$L	$_0$—	$_1$—	$_1$—	$_1$—	$_0$—	$_1$—	$_0$—
~ 6. tu.dtud	$_0$—	$_1$W	$_0$—	$_2$W	$_0$—	$_0$—	$_1$—	$_0$L	$_0$—	$_0$L	$_0$L	$_0$L	$_0$—	$_0$L	$_0$—
~ 7. ti.tud	$_1$W	$_0$—	$_0$—	$_1$—	$_0$—	$_0$—	$_1$—	$_1$—	$_0$—	$_0$L	$_1$—	$_1$—	$_0$—	$_1$—	$_0$—
~ 8. tid.tud	$_1$W	$_0$—	$_0$—	$_1$—	$_0$—	$_0$—	$_2$W	$_0$L	$_0$—	$_0$L	$_1$—	$_1$—	$_0$—	$_1$—	$_0$—
~ 9. ti.dtud	$_1$W	$_1$W	$_0$—	$_1$—	$_0$—	$_0$—	$_1$—	$_0$L	$_0$—	$_0$L	$_1$—	$_1$—	$_0$—	$_1$—	$_0$—

Since $*\bar{\text{V}}$-BR is top-ranked, it is impossible for a candidate to win where the reduplicant is anything other than /t$\breve{\text{V}}$/. Base-reduplicant faithfulness, in turn selects the candidate in which the base is minimally different from the reduplicant, at the expense of $*\text{V}_\mu\text{D}\ldots_\sigma$], without violating (MAX-C,)-IO (that is, we cannot delete from the base to give the output /te.tu/). Our lengthening process underapplies in reduplicated environments in Latin in the same way that syncope underapplies in reduplicated environments in Tonkawa (Gouskova 2007).

In Diachronic Stage 2, the ranking must change to predict the pattern of reduplicant vowels that is attested in the Classical language. In this pattern, vowels in the reduplicant match the vowels in the base, except that an [a] in the base calls for an [e] in the reduplicant. This pattern can be modelled by ranking *[LOW], instead of *SEG[DOR ∧ VOC], over BR-faithfulness, as follows:

(190) REDLENGTH-σ-1 $*\bar{\text{V}}$-BR *[LOW], NOCODA ≫ MAX-C-BR
IDENT-[DOR]-BR IDENT-[COR]-BR IDENT-[LOW]-BR

Under this ranking, reduplicants for any vowel except /a/ will match the base, so e.g. the stem /REDtud/ surfaces as [tu.tud], as attested in *tutudit*:

(191) Tableau illustrating reduplication in *tutudit* 'bruise-3SG.PRF' at Diachronic Stage 2.

Maximum level of structure: `Syllable`

Filter constraints: MINNUCSON-6, DIPHHIGH, LENLIMIT-Onset-2, LENLIMIT-Nuc-2, LENLIMIT-Coda-2, ONSETSONORITY-2 CODASONORITY-1

/REDtud/	RedLength-σ-1	*V̄-BR	*[low]	*Geminate	NoCoda	Max-C-BR	Ident-[dor]-BR	Ident-[cor]-BR	Ident-[low]-BR
☞ 1. tu.tud	0	0	0	0	1	1	0	0	0
∼ 2. tud.tud	0—	0—	0—	0—	2W	0L	0—	0—	0—
∼ 3. tudt.ud	0—	0—	0—	0—	2W	0L	0—	0—	0—
∼ 4. tu.dtud	1W	0—	0—	0—	1—	0L	0—	0—	0—

Where the root contains /a/, however, the vowel of the reduplicant is [e], as in *[ke.ka.dit] > *cecidit*:

(192) Tableau illustrating reduplication in the forerunner of *cecidit* 'fall-3SG.PRF' at Diachronic Stage 2.

Maximum level of structure: `Syllable`

Filter constraints: MinNucSon-6, DiphHigh, LenLimit-Onset-2, LenLimit-Nuc-2, LenLimit-Coda-2, OnsetSonority-2 CodaSonority-1

/REDkad/	OnsetSonority-2	RedLength-σ-1	*Geminate	*V̄-BR	Ident-[high]-BR	Ident-[lab]-BR	*[low]	*Seg([rtr]):	NoCoda	Max-C-BR	Ident-[dor]-BR	Ident-[cor]-BR	Ident-[low]-BR	*ComplexCoda	*[dor]
☞ 1. ke.kad	0	0	0	0	0	0	1	0	1	1	1	1	1	0	3
~ 2. te.kad	0—	0—	0—	0—	0—	0—	1—	0—	1—	1—	2W	2W	1—	0—	2L
~ 3. e.kad	0—	0—	0—	0—	0—	0—	1—	0—	1—	2W	1—	1—	1—	0—	2L
~ 4. ked.kad	0—	0—	0—	0—	0—	0—	1—	0—	2W	0L	1—	1—	1—	0—	3—
~ 5. ted.kad	0—	0—	0—	0—	0—	0—	1—	0—	2W	0L	2W	2W	1—	0—	2L
~ 6. ed.kad	0—	0—	0—	0—	0—	0—	1—	0—	2W	1—	1—	1—	1—	0—	2L
~ 7. ka.kad	0—	0—	0—	0—	0—	0—	2W	0—	1—	1—	0L	0L	0L	0—	4W
~ 8. ta.kad	0—	0—	0—	0—	0—	0—	2W	0—	1—	1—	1—	1—	0L	0—	3—
~ 9. a.kad	0—	0—	0—	0—	0—	0—	2W	0—	1—	2W	0L	0L	0L	0—	3—
~ 10. kad.kad	0—	0—	0—	0—	0—	0—	2W	0—	2W	0L	0L	0L	0L	0—	4W
~ 11. tad.kad	0—	0—	0—	0—	0—	0—	2W	0—	2W	0L	1—	1—	0L	0—	3—
~ 12. ad.kad	0—	0—	0—	0—	0—	0—	2W	0—	2W	1—	0L	0L	0L	0—	3—
~ 13. ko.kad	0—	0—	0—	0—	0—	1W	1—	0—	1—	1—	0L	0L	1—	0—	4W
~ 14. pe.kad	0—	0—	0—	0—	0—	1W	1—	0—	1—	1—	2W	1—	1—	0—	2L
~ 15. o.kad	0—	0—	0—	0—	0—	1W	1—	0—	1—	2W	0L	0L	1—	0—	3—
~ 16. kod.kad	0—	0—	0—	0—	0—	1W	1—	0—	2W	0L	0L	0L	1—	0—	4W
~ 17. ped.kad	0—	0—	0—	0—	0—	1W	1—	0—	2W	0L	2W	1—	1—	0—	2L
~ 18. od.kad	0—	0—	0—	0—	0—	1W	1—	0—	2W	1—	0L	0L	1—	0—	3—
~ 19. pa.kad	0—	0—	0—	0—	0—	1W	2W	0—	1—	1—	1—	0L	0L	0—	3—
~ 20. pad.kad	0—	0—	0—	0—	0—	1W	2W	0—	2W	0L	1—	0L	0L	0—	3—
~ 21. po.kad	0—	0—	0—	0—	0—	2W	1—	0—	1—	1—	1—	0L	1—	0—	3—
~ 22. pod.kad	0—	0—	0—	0—	0—	2W	1—	0—	2W	0L	1—	0L	1—	0—	3—
~ 23. ke.dkad	1W	1W	0—	0—	0—	0—	1—	0—	1—	0L	1—	1—	1—	0—	3—
~ 24. te.dkad	1W	1W	0—	0—	0—	0—	1—	0—	1—	0L	2W	2W	1—	0—	2L
~ 25. e.dkad	1W	1W	0—	0—	0—	0—	1—	0—	1—	1—	1—	1—	1—	0—	2L
~ 26. ka.dkad	1W	1W	0—	0—	0—	0—	2W	0—	1—	0L	0L	0L	0L	0—	4W
~ 27. ta.dkad	1W	1W	0—	0—	0—	0—	2W	0—	1—	0L	1—	1—	0L	0—	3—
~ 28. a.dkad	1W	1W	0—	0—	0—	0—	2W	0—	1—	1—	0L	0L	0L	0—	3—
~ 29. ko.dkad	1W	1W	0—	0—	0—	1W	1—	0—	1—	0L	0L	0L	1—	0—	4W
~ 30. pe.dkad	1W	1W	0—	0—	0—	1W	1—	0—	1—	0L	2W	1—	1—	0—	2L
~ 31. o.dkad	1W	1W	0—	0—	0—	1W	1—	0—	1—	1—	0L	0L	1—	0—	3—
~ 32. pa.dkad	1W	1W	0—	0—	0—	1W	2W	0—	1—	0L	1—	0L	0L	0—	3—
~ 33. po.dkad	1W	1W	0—	0—	0—	2W	1—	0—	1—	0L	1—	0L	1—	0—	3—

It might be argued that prefixed forms of Lachmann verbs which form their perfect stems argue against stem-level lengthening being blocked by reduplication, because they appear to show a prefix instead of a reduplicant, as in *contudit* 'grind-3SG.PRF' ∼ *tutudit* 'bruise-3SG.PRF', *dīscidit* 'cut up-3SG.PRF' ∼ *scicidit* 'cut-3SG.PRF'. However, there is evidence elsewhere in the language that prefixed forms of reduplicated perfect stems are derived from a form that includes a reduplicant by syncope or haplology, as in *rettulit* 'bring back-3SG.PRF' < **retetul-eit* (cf. *tetulit* 'bring-3SG.PRF')[10](Meiser 1998: 210). As Diachronic Stage 1 predates syncope, I reconstruct an underlying representation /komREDtud/ for the stem which eventually becomes *contud-it*. There is no analogue of the geminate in *rettulit*—the form is not *conttudit*—because the post-consonantal geminate has been simplified[11]; sequences of the form $C_1C_2.C_2$ are unattested in the classical language.

After Diachronic Stage 2, vowel weakening has taken place, but reduplication still behaves as though the vocalism of the root were unchanged (Leumann 1977: 586, (Meiser 1998: 210)). Therefore, the model assumes that reduplication has become lexicalised after Diachronic Stage 2, so that the underlying representation of e.g. *tutudit* is /tutudit/, with no RED object (for more on vowel weakening, see §4.2.4 below).

[10]This is the general pattern where the perfect stem has not clearly been remodelled, as in *compēgit* 'join-3SG.PRF' ∼ *pepigit* 'fix-3SG.PRF', which appears to have been analogically reformed on the model of *agō* ∼ *ēgī*, *frangō* ∼ *frēgī* etc.

[11]This degemination is included in the model at Diachronic Stage 4. The actual phonological generalisation is likely dated somewhat earlier, but is confined to DS4 in the model in order to optimise computation time (see page 239).

3.5.4 Lengthening before nasals?

$*V_\mu D\ldots_\sigma]$ only penalises short vowels before tautosyllabic voiced stops, not other obstruents or nasals, therefore our model does not account for the lengthening in *ēmptus*. I believe that lengthening before nasals is not a part of Lachmann's Law, but rather arises due to a misparse of the frequent production of sequences of vowel + nasal as a long, nasalised vowel. The evidence from the spelling of e.g. *consul* as *cosol* (or abbreviated *cos.*), the development into Romance and the witness of contemporary grammarians (see Velius Longus, K., 7, 79) suggests that this production was, if not universal, at least widespread (see Allen 1978: 28–29). Furthermore, the evidence of the etymologically unexpected [p] in **em-tos* > *ēmptus* suggests that the /m/ was realised as nasalisation of the vowel, plus a bilabial gesture, so as something which may be transcribed [ẽːp.tos].

I contend that wherever the consonant cluster in a sequence VNC^+ is heterorganic, so in underlying /em.tos/, where the nasal is labial and the stop coronal, or in /kʷiŋkʷtos/ → *quīntus*, /konjuŋks/ → *coniūnx* (Allen 1978: 66–67), where the nasal is followed by a cluster of a dorsal plus a coronal, the extra time necessary to form the first of the two place gestures tends to be misparsed as a token of contrastive vowel length.

Where the consonant cluster is homorganic, as in *căntus*, the [ãː] is successfully parsed as a token of short vowel + nasal.

3.6 Interim conclusion

At the end of chapter 2, we saw that the attested facts of rhotacism and the -*aris/alis*-allomorphy call for a model distinguishing four diachronic stages, each with the possibility of applying generalisations on the stem-, the word- or the phrase-level. We also found that modelling rhotacism in full necessitates modelling the sound changes affecting the reflexes of the PIE voiced aspirates. Specifically, the data call for the assignment of generalisations to synchronic and diachronic strata given in (103) (repeated here):

(103) Generalisations the model must include to account for rhotacism and liquid dissimilation, ordered by stage and stratum:

Diachronic stage 1; pre-historic (7th century B.C.E and before)		
Word level:	liquid dissimilation	/kalkaR/ → *calcar*
	(without blocking)	/animaR/ → *animal*
Phrase level:	fricatives voiced / V__V	/ruːsis/ → *[ruːzis] > *rūris*
		/neɸula/ → *[neβula] > *nebula*

Diachronic stage 2; pre-literary (6th – 2nd century B.C.E)		
Word level:	rhotacism	/ruːsis/ → *rūris*
	liquid dissimilation	/lokaːRis/ → *locālis*
	(with blocking)	/floːsaːRis/ → *flōrālis*
	non-strident fricatives lost	/neβula/ → *nebula*
		/ɸiðem/ → *fidem*
		/ruver/ → *ruber*
		/xʷormos/ → *formus*
		etc.

Diachronic stage 3; early literary (2nd century B.C.E)		
Stem level:	rhotacism	/[$_{stem}$ruːsi]s/ → *rūris*
		/ni[$_{stem}$siː]/ → *nisī*
Word level:	liquid dissimilation	/lokaːRis/ → *locālis*
	(with blocking)	/floːsaːRis/ → *flōrālis*

Diachronic stage 4; classical (1st century B.C.E)		
Word level:	liquid dissimilation	/lokaːRis/ → *locālis*
	(with blocking)	/floːraːRis/ → *flōrālis*

In this chapter, we have determined that Lachmann's Law must (a) be a stem-level generalisation and (b) take place before Diachronic Stage 2 (as it does not affect verbs from IE roots ending in voiced aspirates, such as *fossus*). We have proposed a word-level constraint ranking to generate the voicing assimilation in /ag-tus/ → [aktus], and we have seen that modelling Lachmann's Law in full requires modelling reduplication, so we have proposed constraint rankings to generate both the older pattern of reduplication attested to by Aulus Gellius, and the more familiar classical pattern. This augments the requirements on our model as follows:

(193) Generalisations the model must take account of to generate rhotacism, liquid dissimilation and Lachmann's Law.

Diachronic stage 1; pre-historic (7th century B.C.E and before)		
Stem level:	Lachmann's Law	/[$_{stem}$agto]s/ → [aːg] (*āctus*)
		/[$_{stem}$ɸoθto]s/ → [ɸoθ] (*fossus*)
	reduplication according	/[$_{stem}$REDpug]ai/ → [pepug] (*pupugī*)
	to Gellius	/[$_{stem}$REDkad]ai/ → [kekad] (*cecidī*)
Word level:	voicing assimilation	/aːgtos/ → *āctus*
	liquid dissimilation	/kalkaR/ → *calcar*
	(without blocking)	/animaR/ → *animal*
Phrase level:	fricatives voiced / V__V	/ruːsis/ → *[ruːzis] > *rūris*
		/neɸula/ → *[neβula] > *nebula*

Diachronic stage 2; pre-literary (6th – 2nd century B.C.E)		
Stem level:	reduplication	/[$_{stem}$REDpug]ai/ → *pupugī*
	(Classical pattern)	/[$_{stem}$REDkekad]ai/ → *cecidī*
Word level:	voicing assimilation	/aːgtos/ → *āctus*
	rhotacism	/ruːsis/ → *rūris*
	liquid dissimilation	/lokaːRis/ → *locālis*
	(with blocking)	/floːsaːRis/ → *flōrālis*
	non-strident fricatives lost	/neβula/ → *nebula*
		/ɸiðem/ → *fidem*
		/ruver/ → *ruber*
		/xʷormos/ → *formus*

etc.

Diachronic stage 3; early literary (2nd century B.C.E)		
Stem level:	rhotacism	/[$_{stem}$ruːsi]s/ → *rūris*
		/ni[$_{stem}$siː]/ → *nīsī*
Word level:	voicing assimilation	/aːgtus/ → *āctus*
	liquid dissimilation	/lokaːRis/ → *locālis*
	(with blocking)	/floːsaːRis/ → *flōrālis*

Diachronic stage 4; classical (1st century B.C.E)		
Word level:	voicing assimilation	/aːgtus/ → *āctus*
	liquid dissimilation	/lokaːRis/ → *locālis*
	(with blocking)	/floraːRis/ → *florālis*

The constraint rankings proposed in this chapter are as follows:

(174) Constraint ranking generating lengthening by Lachmann's Law (repeated from p. 218):

*Seg([rtr])ː ≫ *V$_\mu$D. . . $_\sigma$] ≫ Dep-μ, *$\sigma_{\mu\mu\mu}$

(141) Constraint ranking generating voicing assimilation (repeated from p. 194):

OnsIdent-[voi] ≫ Agree-[voi] ≫ Ident-[voi]

(194) Constraint ranking generating reduplication according to Gellius' rule:

RedLength-σ-1, *V̄-BR, ≫

*Seg[dor ∧ voc], *Geminate, NoCoda ≫

Max-C-BR, Ident-[rtr]-BR, Ident-[high]-BR, Ident-[dor]-BR,

Ident-[cor]-BR, Ident-[low]-BR, Ident-[lab]-BR,

(190) Constraint ranking generating reduplication in the Classical language (repeated from p. 226):

RedLength-σ-1, *V̄-BR, ≫

*Seg[dor ∧ voc], *Geminate, NoCoda ≫

Max-C-BR, Ident-[rtr]-BR, Ident-[high]-BR, Ident-[dor]-BR,

Ident-[cor]-BR, Ident-[low]-BR, Ident-[lab]-BR,

If we combine these rankings with those already laid down in §109 we arrive at the following ranking hypotheses for our model[12]:

(195) Constraint rankings for a model of rhotacism, liquid dissimilation and Lachmann's Law

Diachronic Stage 1 Stem level	
Constraint	Generalisation
*Seg([rtr]):	Lachmann's Law
RedLength-σ-1	Reduplication according to Gellius
*V̄-BR,	"
*V_μD. . . $_\sigma$]	Lachmann's Law
Dep-μ	"
*Seg[dor ∧ voc]	Reduplication according to Gellius
*Geminate	"
NoCoda	"
Max-C-BR	"
Ident-[rtr]-BR	"
Ident-[high]-BR	"
Ident-[dor]-BR	"
Ident-[cor]-BR	"
Ident-[low]-BR	"
Ident-[lab]-BR	"
Word level	
Constraint	Generalisation
OnsIdent-[voi]	Voicing assimilation
[obs]-Agree-[voi]	"
Ident-[voi]	"

[12]Note that as PyOT is not programmed to recognise that constraints may be in the same ranking stratum, the rankings in (195) should be taken to be strictly transitive, so for Diachronic Stage 1, stem level *Seg([rtr]): ≫ RedLength-σ-1 ≫ *V̄-BR etc.

CC-CORR-[RHO]	Liquid dissimilation (without blocking)
CC-CORR-[LAT]	”
IDENT-CC-[NAS]	”
IDENT-CC-[HIGH]	”
IDENT-CC-[SON]	”
¬IDENT-CC-[LAT]	”
CC-CORR-[CONS]	”
Phrase level	
Constraint	Generalisation
IORALFRICV	Intervocalic fricative voicing
IDENT-[VOI]	”
Diachronic Stage 2	
Stem level	
Constraint	Generalisation
REDLENGTH-σ-1	Reduplication (Classical pattern)
*GEMINATE	”
*V̄-BR	”
IDENT-[HIGH]-BR	”
IDENT-[LAB]-BR	”
*[LOW]	”
*SEG([RTR]):	”
NOCODA	”
MAX-C-BR	”
IDENT-[DOR]-BR	”
IDENT-[COR]-BR	”
IDENT-[LOW]-BR	”
*[DOR]	”
Word level	
Constraint	Generalisation
[CONS]-AGREE-[LAT]	Assimilation of liquids
DEP-[LAT]	”
MAX-[RHO]	”
ONSIDENT-[VOI]	Voicing assimilation
[OBS]-AGREE-[VOI]	”
IDENT-[VOI]	”
[CONS]-AGREE-[LAT]	Changes affecting fricatives
DEP-[LAT]	(including rhotacism)
MAX-[RHO]	”
ORALFRICSTRID	”
ORALFRICVOICELESS	”

Onset	”
IOralFricV	”
[cons]-Agree-[rad]	”
[cons]-Agree-[dor]	”
[cons]-Agree-[rho]	”
CodaCond-[cont]	”
Max-[cont]	”
Max-[dor]	”
Dep-[plos]	”
Dep-[rad]	”
Max-[obs]	”
Dep-[son]	”
Dep-[rho]	”
Ident-[strid]	”
¬Ident-CC-[lat]	Liquid dissimilation (with blocking)
CC-Corr-[lat]	”
CC-Corr-[rho]	”
¬Ident-CC-art	”
CC-Corr-[cons]	”
Diachronic Stage 3	
Stem level	
Constraint	Generalisation
*[rho]-μ-[rho]	Rhotacism
OralFricStrid	”
IOralFricV	”
Max-[obs]	”
Dep-[son]	”
Dep-[rho]	”
Max-[strid]	”
Max-[cont]	”
Word level	
Constraint	Generalisation
OnsIdent-[voi]	Voicing assimilation
[obs]-Agree-[voi]	”
Ident-[voi]	”
¬Ident-CC-[lat]	Liquid dissimilation (with blocking)
CC-Corr-[lat]	”
CC-Corr-[rho]	”
¬Ident-CC-art	”
CC-Corr-[cons]	”

Diachronic Stage 4 Word level	
Constraint	Generalisation
OnsIdent-[voi]	Voicing assimilation
[obs]-Agree-[voi]	”
Ident-[voi]	”
¬Ident-CC-[lat]	Liquid dissimilation (with blocking)
CC-Corr-[lat]	”
CC-Corr-[rho]	”
¬Ident-CC-art	”
CC-Corr-[cons]	”

In the next and concluding chapter, I will indicate what needs to be done to build these ranking hypotheses into a model that can be tested against a set of 185 inputs corresponding to word-forms that fully exemplify each of the three generalisations under analysis, and takes at least some account of every other generalisation to which the inputs fall subject.

Chapter 4

Completing the model

4.1 Principles and limits

We have seen repeatedly in the previous chapters that producing a complete analysis within our model of any given morphophonological generalisation necessarily involves producing an analysis of every generalisation with which it interacts. In §2.2.1, for example, I demonstrated that it is impossible to extricate rhotacism from the more general pattern of treatment of fricatives in pre-historic Latin. Then again, in §3.5.3, we saw that it is necessary to produce a model of reduplication in the formation of perfect-tense stems to complete our analysis of Lachmann's Law.

If I were to adopt the same standard of rigour in analysing these additional phenomena my chosen generalisations interact with as I have for rhotacism, liquid dissimilation and Lachmann's Law themselves, I have no doubt that it would swiftly become apparent that they depend in their turn on other phenomena, that their dependencies have their own dependencies and so on. The scope of the project would come to encompass the entire history of the language, and the scope of the effort required might well come to encompass an entire lifetime's work or more. Some consistent principle is needed on which to restrict the goals of the model, without vitiating its rigour as an account of the three generalisations I have explicitly set out to address.

4.1.1 Dating of Diachronic Stages

The dates attached to the Diachronic Stages in the model should be taken as approximate guides only. Furthermore, the hypothesis they represent about the synchronic grammars that were present in the minds of native speakers of the language is only a subset of the actual situation. Besides the fact that Latin phonology must have included many more generalisations than I have set out to model here, the exact progress of the generalisations that are included through the life cycle is not tied to the four diachronic stages listed here. The definite statements of the model with respect to the grammar of Latin are as follows:

(196) Firstly, that any generalisation modelled in Diachronic Stage 1 took place at a stage before the attested history of the language

(197) Secondly, that generalisations included in any given Diachronic Stage were all part of the same synchronic grammar at some point during the rough time-span indicated for that Diachronic Stage in e.g. (193).

(198) Thirdly, that generalisations that interact with one another diachronically; that is, generalisations that occur in different Diachronic Stages, and affect the same word-forms, were not part of the same synchronic grammar at any stage.

Most importantly, no particular relationship should be inferred between generalisations that do not interact with one another either synchronically or diachronically. For example, I am not arguing that phrase-level intervocalic fricative voicing ceased to be an active component of the grammar at exactly the same time that the vocalism in reduplicated of perfect stems changed from the pattern commented on by Aulus Gellius to the pattern generally observable in the attested language.

It should be noted in particular that the Diachronic Stages in the model have been proposed mainly to model Stages 1, 2, 3 and L of the life cycle of rhotacism. Generalisations which have been included because they interact either synchronically or diachronically with rhotacism, liquid dissimilation or Lachmann's Law have been fitted in as best as may be within the principles laid down in (196)–(198). The level of diachronic detail the model includes is, I hope, that which is necessary and sufficient to accurately encompass the generalisations I have set out to model.

4.1.2 On lexicalisation — fault lines in the grammar

Wherever the domain of a phonological generalisation overlaps to a significant extent with an unrelated category, the potential exists for language learners to re-interpret the category as the domain of the generalisation. This principle is the driving force behind the progress of generalisations through the life cycle: a generalisation moves from Stage 0 to Stage 1 when a contingent phonetic fact about the speech signal happens to be true to a sufficient degree of a specific environment that it becomes associated with it, as we saw with intervocalic fricative voicing in §2.2.1. Once they have entered the grammar at the phrase level, generalisations often move quickly to the word level, as their conditioning environment is more likely to be found consistently word-medially, as with the intervocalic environment of rhotacism.

Later stages of the life cycle are more complicated, as they involve the architecture of the lexicon to a significant degree. For a generalisation to move from Stage 2 to Stage 3, i.e. to be acquired at the stem level, for example, the learner has to decide on a set of categories to which stem-level domains apply—in plain terms, the stem level is whatever the language learner needs it to be, provided that it is defined in terms of some morphological category. This may be synchronically arbitrary with respect to the lexicon, as with Class I and Class II suffixes in English (see Kiparsky 1979, 1982c). On the other hand, it may appeal to some overriding morphological condition, such as our hypothesis that the phonological stem is whatever you add an ending to (see page 188), or the possibility that you build a phonological stem wherever you have a stem vowel (see page 210).

The transition into Stage L is the most involved from the point of view of categorical re-analysis, as it is most likely to invoke morphological fault-lines as conditions. We have seen examples of this in e.g. the assumption that the regular infinitive ending is underlyingly *-re* rather than *-se*, and that genitives in *-ārum*, *-ōrum*, *-ērum* have /r/ in the underlying representation (see page 94), or in the hypothesis that the *-ālis/āris* category becomes semantically and formally distinct from the nouns in *-ar/al*, and so is considered to be the domain of liquid dissimilation blocked by non-coronals (see page 124).

The acquisition of a language is fundamentally an exercise in pattern-finding, and the lexicalisation of a phonological process occurs when a contingent overlap between a morphological or other lexical category and the domain of a phonological generalisation is re-interpreted as being essential.

4.1.3 Two kinds of dependency

I have already identified two classes of generalisation that are of relevance to the model, and must perforce be analysed relatively completely in it: the first is that of the three generalisations that I have explicitly set out to analyse, namely rhotacism, liquid dissimilation and Lachmann's Law. I shall refer to these as PRIMARY GENERALISATIONS or PRIMARIES. The second class consists of those generalisations that are inextricably bound up with the PRIMARIES, as they interact either synchronically or diachronically with them, such that identifying the form we expect to find for a given etymon depends on having a full understanding of the PRIMARIES and of these generalisations of the second class, which I shall call INTERACTORS.

There is, however, a third class of generalisation which we must take account of, and that is the class of generalisations that do not directly interact with the PRIMARIES, but whose effects can be observed in some or all of the same forms that the effects of the PRIMARIES are observable in. For example, in Chapter 3, I have described a model that produces outputs in *-tos* for the past participles affected by Lachmann's Law, despite the fact that the attested forms regularly have ⟨tus⟩, as in /[$_{stem}$agto]s/ → *[aːk.tos] > *āctus*. This is because the raising of [o] to [u] in closed word-final syllables is entirely orthogonal to Lachmann's Law: it does not take place in the same diachronic stratum, and it never obscures the observable conditions of Lachmann's Law. I will refer to dependencies of this kind as ORTHOGONALS.

4.1.4 Standards of proof

In Appendix A, I have gathered a representative set of 185 Latin words, with hypothesised inputs to the grammar for each Diachronic Stage in the model, and given the stem-, word- and phrase-level outputs the model yields for each input. In this section, I indicate the standards I have used to decide what constitutes a "representative set" with respect to the different classes of generalisation.

For the PRIMARIES, I have given examples of every class of input that falls subject to them, and every class that systematically fails to fall subject to them, as well as examples of special cases that illustrate what must be done to accommodate them. In some cases, this means giving every identifiable word that fits the conditions, as with liquid dissimilation, where I have included every form cited in the corpus study of Cser (2010). In others, specific examples stand for larger categories, as with the treatment of fricatives, where I have added one example for each fricative in each kind of environment where it is found: intervocalic, word-initial, word-final, after nasal, before consonant etc.

For the INTERACTORS, I have included examples of every case in which the effect of an INTERACTOR determines the application or non-application of a PRIMARY. For example, I have included the reduplicated 3SG perfects *tutudit* 'bruised', *pepigit* 'fixed', and *cecidit* 'fell' with the data exemplifying Lachmann's Law, as our account of reduplication is crucial to explaining why there is no vowel lengthening in these forms (see §3.5.3). I have not, however, included examples of reduplication, or any other INTERACTOR simply for the sake of illustrating that the model's account of the INTERACTOR is complete.

The application of these standards determines which generalisations must be considered ORTHOGONALS, as the set of ORTHOGONALS is simply the set which must be taken account of for the model to yield the correct outputs for the data gathered to illustrate its handling of the PRIMARIES and INTERACTORS. I have not added any forms to the data set to make the analysis of ORTHOGONALS more complete, and in cases where an ORTHOGONAL affects no more than one or two forms in the data set, I have made no attempt to model it within the constraint ranking, but rather altered the input to take it as read at the relevant diachronic stage. So, for example, as *soror* < **swesōr* (Meiser 1998: 82) is the only form in the dataset that undergoes the change of **we* > **wo* > *o*, I have specifed /swesoːr/ as the input to Diachronic Stage 1, but /sosoːr/ as the input to Diachronic Stage 2, without explicitly modelling the sound change that gives rise to it. Cases where I have adopted this approach to an ORTHOGONAL in order to account for a specific form are listed in §4.3.3 below.

Some ORTHOGONALS, such as vowel weakening, affect the forms in the dataset more widely and more systematically. These generalisations have been incorporated into the constraint ranking, and are discussed in §4.3. To the best of my knowledge, none of the hypotheses I have advanced to account for these ORTHOGONALS, or for the INTERACTORS is false to the attested facts, however, the query against the dataset illustrated in Appendix A is only intended to serve as evidence that I have produced a complete and internally consistent model of the PRIMARIES.

4.2 Interactors

4.2.1 Syllable structure

The `gen` module of PyOT syllabifies candidates simply by treating every pair of consecutive `Segment` objects as falling one on each side of a possible syllable boundary: that is to say that given an input /CVC/, the `Gen` function will yield not only [[$_{\sigma}$CVC]], with all segments parsed into one syllable with the vowel as its peak, but also [C̩.VC], [CV.C̩] and [C̩.V.C̩]. As individual languages vary as to the class of segments they will tolerate in syllabic nuclei, restrictions of this kind are left to the constraint ranking.

Lachmann's law is a syllable-level generalisation, therefore the model generates candidates specified up to the level of the syllable. The tableaux in Chapter 3 are generated based on filter constraints which control the sonority sequencing and internal structure of syllables in Latin. These constraints are as follows:

(199) MinNucSon-6

Assess a violation for every segment in the candidate that is dominated by a syllable nucleus and has a sonority score less than 6.

(200) OnsetSonority-2

Consecutive segments in syllable onsets should rise in sonority score by at least 2.

(201) CodaSonority-1

Consecutive segments in syllable codas should fall in sonority score by at least 1

(202) NucSonority-0

Consecutive segments in syllable nuclei should not rise in sonority score.

(203) LenLimit-Onset-2

Assess a violation for every syllable onset in the candidate that dominates more than two segments.

(204) LenLimit-Nuc-2

Assess a violation for every syllable nucleus in the candidate that dominates more than two segments.

(205) LenLimit-Coda-2

Assess a violation for every syllable coda in the candidate that dominates more than two segments.

As this is a filter (see page 44), PyOT is guaranteed not to generate any candidates that violate any of the above constraints. So, the LenLimit constraints guarantee that onsets, nuclei or codas will never be more than binary branching. MinNucSon-6 guarantees that syllable peaks will always be vowels, and the other sonority constraints enforce the pattern of sonority sequencing that we find attested.

The algorithm for computing sonority scores is given on page 22, and the mapping of segment classes to sonority scores is given in (5) (repeated here for ease of reference).

(5)

Segment class	Features	Score
plosive	[CONS, OBS, PLOS]	0
fricative	[CONS, OBS, CONT]	2
nasal	[CONS, SON, PLOS, NAS]	3
liquid	[CONS, SON, LAT]	4
	[CONS, SON, RHO]	4
semivowel	[CONS, SON]	5
high vowel	[VOC, HIGH]	6
mid vowel	[VOC]	7
low vowel	[VOC, LOW]	8

The constraint NUCSONORITY-0 demands that the off-glides of dipththongs not be lower (i.e. have a higher sonority score) than the vowels that precede them. So, the low vowel [a] can have either [e] or [ɪ] as an off-glide (allowing for the stages before and after the lowering of the diphthong *ai* to *ae*), or be followed by itself (i.e. be a long [aː]).

The constraint ONSETSONORITY-2 allows for an onset in, for example, fricative plus liquid (as in *frangit* 'breaks'), but not nasal plus liquid: **nra* is not a valid syllable. ONSETSONORITY-2 would not penalise an onset of plosive + fricative, so that we might expect to find that **tse* was permitted. In fact, such an onset would be ruled out by the constraints that predict assibilation, as we shall see in the next section.

The final sonority constraint, CODASONORITY-1, demands that codas fall in sonority by at least 1. So a sequence [pl] would not be a valid coda, nor would a sequence of segments of the same sonority, such as [fs].

In some cases, the phonological stems of forms in the model contain sequences of segments that cannot be parsed into well-formed syllables within the limits established by this filter. The form *exemplar* 'copy', for example, is modelled as being underlyingly /[$_{stem}$eksempl]aR/, with the final sequence [mpl] that is not a valid coda, as it violates both LenLimit-Coda-2 and CodaSonority-1. On the word level, of course, the [l] is syllabified into the onset of the following syllable. The filter on stem-level grammars, therefore, contains the relaxed length limit constraint LenLimit-Coda-3, and no CodaSonority constraints at all.

Certain other tendencies in syllable structure are identifiable, but not exceptionless, and so cannot be assigned to the filter. Onset-maximal syllabification for example, the tendency for, all other things being equal, a sequence /VCV/ to be parsed [V.CV], is identifiable in Latin—note that the last two feet of the first line of the *Aeneid*, for example, are scanned *prīmŭs ăb* | *ōrīs*, suggesting that the phrase-level syllabification must be the onset-maximal [priː.mu.sa.boː.ris]. This tendency is captured in OT by the presence in Con of the constraints Onset and NoCoda (Prince & Smolensky 1993). These constraints cannot be used as part of the filter, however, as some syllables in Latin lack onsets (such as *agit* 'drives', *doc[u.i]t* 'taught'), and many syllables in Latin have codas (for example, any inflected form with a consonantal ending: *rēgem* 'king-ACC.SG', *edit* 'eat-3SG', *flōris* 'flower-GEN.SG' etc.)

Instead, these constraints are placed in what I refer to as the tie-breaker: a collection of constraints that the program assigns to the lowest ranking stratum if they do not already appear in the ranking specified, so that if all other constraints are satisfied they select the candidate they prefer

The segment [s] is permitted to appear in a syllable but not to be parsed into the onset or coda, as discussed on page 27, as an [s] at the very edge of a syllable appears to be exempt from sonority sequencing, as in *stringō* or *rēx*. The constraints that militate against this behaviour are ParseSeg-ons and ParseSeg-cod, and they appear in the tie-breaker so that an [s] will only be left out of the syllable's constituents if higher-ranked constraints demand it.

As syllabification is an interactor, these constraints are not intended to represent every phonotactic restriction on syllables in Latin, merely the subset of restrictions on syllables which is sufficient to cause the model to syllabify the inputs that illustrate the primaries correctly.

4.2.2 Assibilation

The assibilation of clusters of dental + dental that is visible in the Lachmann participles from roots ending in /d/, such as *cāsus*, *ēsus*, *ōsus*, *tūsus* etc. is the result of a phonological process whose early stages are reconstructed for Proto-Indo-European (Leumann 1977: §198; Mayrhofer 1986b: §4.10.1; Meiser 1998: §87; Fortson 2004: §3.36). Mayrhofer in particular articulates certain fairly abstract morpho-phonological conditions on the generalisation, suggesting that for the assibilation to apply, not only a syllable boundary but also a morpheme boundary had to intervene between the first and second dental of the cluster. This sensitivity to morphological structure suggests that the process was relatively advanced through the life cycle already in PIE. If this is so, it must still have been phonologically active, that is to say that it must not yet have reached Stage L of the life cycle and become a property of the lexicon, as the reflexes of the assibilated clusters are different in the individual daughter languages.

Be that as it may, it is certainly true that secondary clusters of dental stop + dental stop in Latin do not undergo assibilation: *ad+tango* becomes *attingo*, not **assingo* (Kiparsky 1965: 32; Leumann 1977: 193). Furthermore, the [ss] clusters that reflect the IE assibilation in Latin are all found at morpheme boundaries, including the supines (e.g. *sessum*) and agent nouns in *-sor* < *-tor* (e.g. *messor* 'reaper'). I therefore assume that by Diachronic Stage 1 of our model the IE assibilation has entered the lexicon, creating separate allomorphs in *s* of each of the suffixes in question (a similar assumption is made by Jasanoff (2004: 411) in his Neogrammarian account of Lachmann's Law). The underlying representation in the model for *cāsus* at Diachronic Stage 1, therefore, is /[$_{stem}$kad]sos/, and similar inputs are assumed for every form in the dataset that shows the effects of the IE assibilation.

The place assimilation that creates the *ss* clusters we find as reflexes of PIE *[t^st] in Latin takes place in Diachronic Stages 1 and 2 of the model. In Stage 1, [t] and [d] assimilate to the following [s] in manner of articulation in the same way that voiced stops assimilate to the [t] of the suffix in voicing. To achieve this effect, we take the Stage 1 ranking that generates voicing assimilation of obstruents (141, repeated here):

(141) Ranking of constraints generating voicing assimilation

OnsIdent-[voi] ≫ [obs]-Agree-[voi] ≫ Ident-[voi]

And augment it to also include constraints calling for assimilation in respect of stridency:

(206) Partial ranking of constraints at Diachronic Stage 1, word level:

OnsIdent-[voi], OnsIdent-[strid] ≫ [obs]-Agree-[strid], [obs]-Agree-[voi] ≫ Ident-[voi], Max-[plos], Dep-[cont], Dep-[strid],

This generates the [ss] clusters in *missum* 'sent-ACC' and **cāssus* > *cāsus*:

(207) Tableau illustrating assibilation in *missum*, Diachronic Stage 1, word level

/mitsom/	OnsIdent-[voi]	OnsIdent-[strid]	[obs]-Agree-[strid]	[obs]-Agree-[voi]	Ident-[voi]	Max-[plos]	Dep-[cont]	Dep-[strid]	NoCoda	*ComplexCoda
☞ 1. mis.som	0	0	0	0	0	1	1	1	2	0
∼ 2. mizːom	$_0$—	$_0$—	$_0$—	$_0$—	$_2$W	$_1$—	$_1$—	$_1$—	$_0$L	$_0$—
∼ 3. miszom	$_0$—	$_0$—	$_0$—	$_1$W	$_1$W	$_1$—	$_1$—	$_1$—	$_0$L	$_0$—
∼ 4. mizsom	$_0$—	$_0$—	$_0$—	$_1$W	$_1$W	$_1$—	$_1$—	$_1$—	$_0$L	$_0$—
∼ 5. mitsom	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L	$_0$—

(208) Tableau illustrating assibilation in *cāsus*, Diachronic Stage 1, word level

/kaːdsos/	OnsIdent-[voi]	OnsIdent-[strid]	[obs]-Agree-[strid]	[obs]-Agree-[voi]	Ident-[voi]	Max-[plos]	Dep-[cont]	Dep-[strid]	NoCoda	*ComplexCoda
☞ 1. kaːs.sos	0	0	0	0	1	1	1	1	2	0
∼ 2. xaːsːos	$_0$—	$_0$—	$_0$—	$_0$—	$_1$—	$_2$W	$_2$W	$_1$—	$_0$L	$_0$—
∼ 3. xaːzːos	$_0$—	$_0$—	$_0$—	$_0$—	$_1$—	$_2$W	$_2$W	$_1$—	$_0$L	$_0$—
∼ 4. gaːsːos	$_0$—	$_0$—	$_0$—	$_0$—	$_2$W	$_1$—	$_1$—	$_1$—	$_0$L	$_0$—
∼ 5. gaːzːos	$_0$—	$_0$—	$_0$—	$_0$—	$_2$W	$_1$—	$_1$—	$_1$—	$_0$L	$_0$—
∼ 6. kaːsːoz	$_0$—	$_0$—	$_0$—	$_0$—	$_2$W	$_1$—	$_1$—	$_1$—	$_0$L	$_0$—
∼ 7. kaːzːoz	$_0$—	$_0$—	$_0$—	$_0$—	$_2$W	$_1$—	$_1$—	$_1$—	$_0$L	$_0$—
∼ 8. kaːzsos	$_0$—	$_0$—	$_0$—	$_1$W	$_0$L	$_1$—	$_1$—	$_1$—	$_0$L	$_0$—
∼ 9. kaːdzos	$_0$—	$_0$—	$_1$W	$_0$—	$_1$—	$_0$L	$_0$L	$_0$L	$_0$L	$_0$—
∼ 10. kaːtsos	$_0$—	$_0$—	$_1$W	$_0$—	$_1$—	$_0$L	$_0$L	$_0$L	$_0$L	$_0$—
∼ 11. kaːdsos	$_0$—	$_0$—	$_1$W	$_1$W	$_0$L	$_0$L	$_0$L	$_0$L	$_0$L	$_0$—

After Stage 1, the first [s] of the cluster is lexicalised as part of the past participle stem, just as the characteristic vowel length of Lachmann's Law is, and for the same reason: owing to the fact that the conditioning environment is found much more often in specific morphological contexts, the morphological condition comes to be reanalysed as an essential condition of the generalisation. Furthermore, as it is not possible to generate the assibilated forms from the same underlying suffix (as by now compounds such as *attingo* are demonstrating that [ss] is not the regular outcome of underlying /tt/ or /dt/). Therefore, the alternation is simply made lexical: the morphology is altered so that underlying /[$_{stem}$kadɪ]t/ for *cadit* 'falls' alternates with underlying /[$_{stem}$kaːs]sos/ > cāsus. This creates, in effect, an allomorph *-sus* of the participle forming suffix *-tus*, which is productive outside of the original environment, as Jasanoff (2004: 411) notes, citing verbs to which it has been extended, such as *lābor* ∼ *lāpsus* 'glide', *mulceo* ∼ *mulsus* 'stroke', *spargo* ∼ *sparsus* 'strew'.

One class of participles to which I have assumed that the *-sus* suffix must have been extended is that of participles such as *iussus* 'ordered', where the root ends in a *[θ] from PIE *d^h. If one assumes that the participial ending is underlyingly /sos/ already at Diachronic Stage 2, then the [ss] cluster is the expected output, and underlying sequences of /θt/ surface as [st], as in *aestus* (see page 79)[1]. After Diachronic Stage 2, however, the [s] from /θ/ must also be lexicalised, as there is no longer a [θ] in the output to be recovered as an underlier (also, it is difficult to see what common stem could possibly be inferred for *iubeō* ∼ *iussus*, given that [ss] is certainly not the regular output for /bs/—cf. *lābor* ∼ *lāpsus* 'glide').

4.2.3 Degemination

Later on in the history of the language, the [ss] clusters we have just analysed are degeminated when they close a syllable headed by a long vowel or diphthong, as in *cāsus*, *uīsus*, *causa*, but not in *fŏssus*, *păssus* or *gĕssī*. This generalisation is a diachronic INTERACTOR with both Lachmann's Law and rhotacism, as it obscures

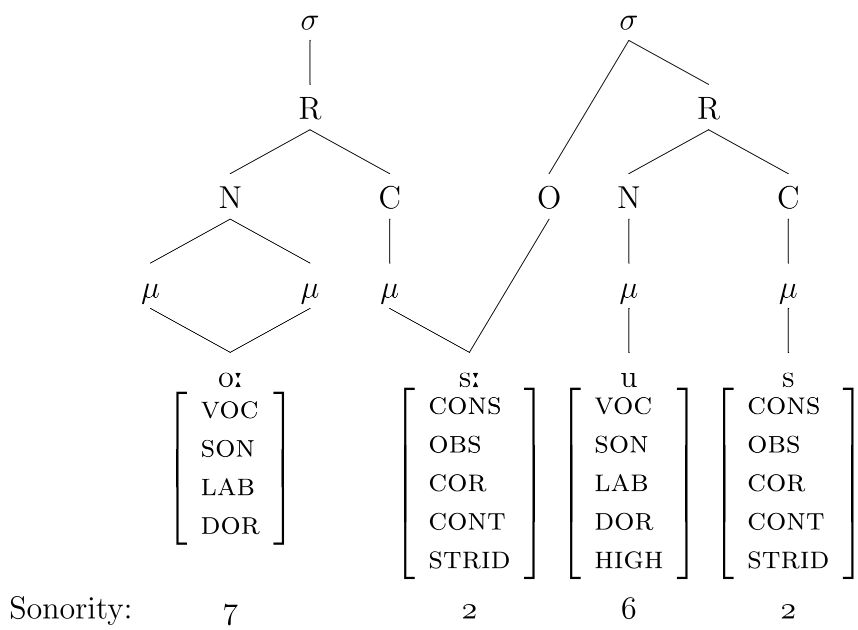
[1]De Vaan (2008) makes the opposite assumption, claiming that *-ss-* in *iussus*, *fossus* is the regular outcome for *-d^ht-, and that isolated *aestus* is analogical, with its *-*tu* suffix re-applied after the change that would otherwise have given **aessus*. Given that we must reckon with a *-sus* allomorph for participles anyway in order to explain *casus*, *sparsus* etc., I believe the most economical model is to assume that *aestus* shows the phonologically regular treatment, despite the fact that it is outnumbered by *iussus*, *fossus*, etc.

the conditions of Lachmann's Law (given that the underlying stem-final /d/ that we hypothesise for forms like *cāsus* is by no means apparent on the surface once the assibilation and degemination have taken place). It also creates an apparent exception to rhotacism, as the degeminated [s] appears between vowels. Baldi (1994) points this out, and uses it as the basis of a claim that rhotacism is not an active phonological rule in Classical Latin. I follow Baldi's reasoning, and so assign the following constraint ranking to the word level of Diachronic Stage 4:

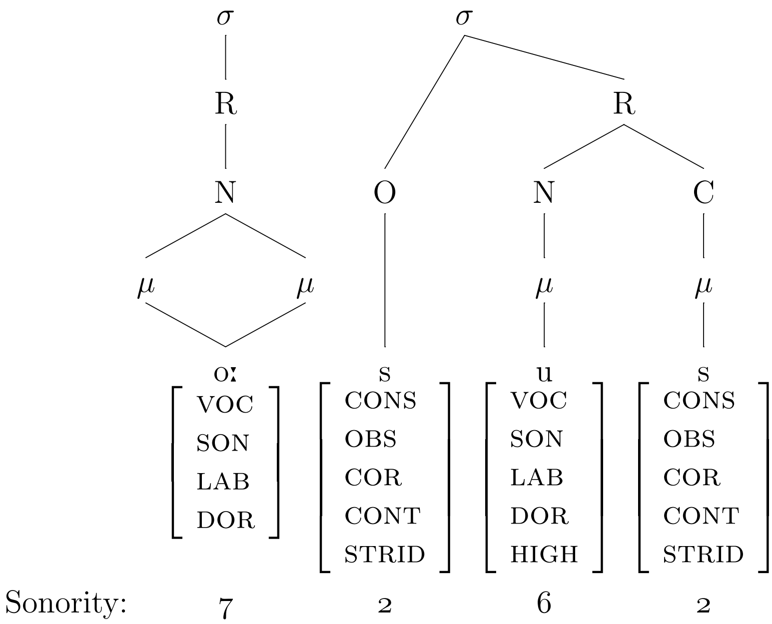
(209) MAX-C $\gg$ $*\sigma_{\mu\mu\mu}$ $\gg$ PARSESEG-cod PARSESEG-ons $\gg$ MAX-μ,

The operative markedness constraint is $*\sigma_{\mu\mu\mu}$, a constraint which penalises superheavy syllables (that is, syllables whose rhyme node dominates three or more morae). $*\sigma_{\mu\mu\mu}$ is ranked over MAX-μ but below MAX-C. This has the result that segments like the [ss] in *ōsus* will be shortened, as their representation is as follows:

(210) PyOT's representation of the utterance /oːs.sus/ (input to the word-level grammar at Diachronic Stage 4 for *ōsus* 'hated':



(211) PyOT's representation of the utterance [oː.sus]:



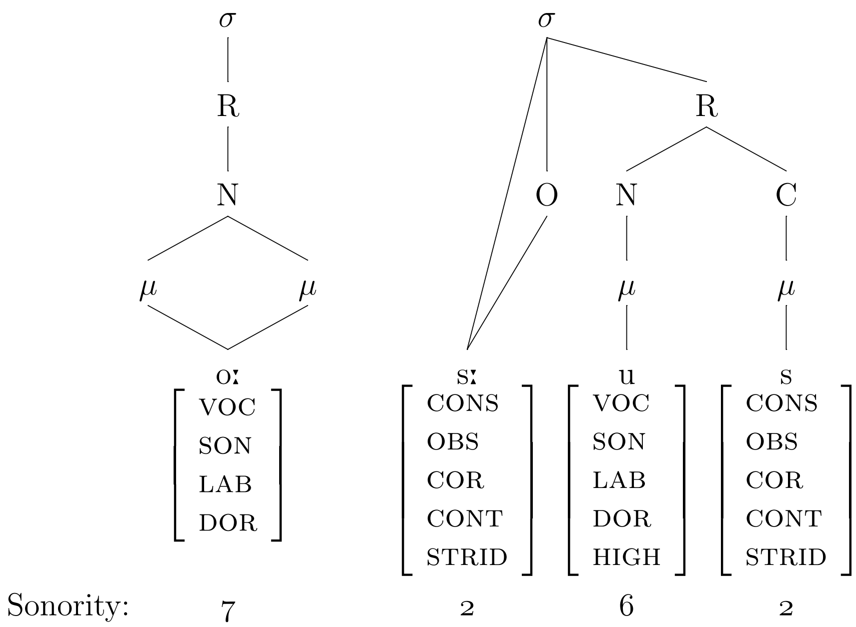
In the output tree (211), the coda of the first syllable in (210), with its mora that dominates the [s] has been deleted, so a violation of MAX-μ is provoked. The [s] itself, however, is still present, so MAX-C is not violated:

(212)

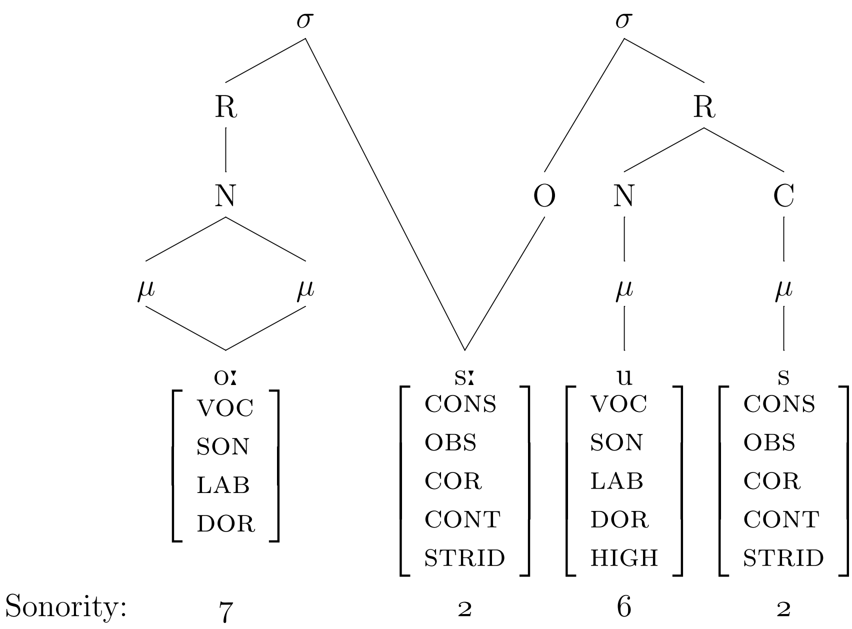
/oːsːus/	MAX-C	$*\sigma_{\mu\mu\mu}$	PARSESEG-COD	PARSESEG-ONS	MAX-μ
☞ 1. oː.sus	0	0	0	0	1
∼ 2. oː.ssus	$_0$—	$_0$—	$_0$—	$_1$W	$_0$L
∼ 3. oːs.sus	$_0$—	$_0$—	$_1$W	$_0$—	$_0$L
∼ 4. oːsːu	$_1$W	$_0$—	$_0$—	$_0$—	$_0$L
∼ 5. oːsu	$_1$W	$_0$—	$_0$—	$_0$—	$_1$—
∼ 6. oːus	$_2$W	$_0$—	$_0$—	$_0$—	$_0$L
∼ 7. oːu	$_3$W	$_0$—	$_0$—	$_0$—	$_0$L

Candidates 4 through 7 are the segmental variants that PyOT does not build syllable structure on as the violate the top-ranked constraint MAX-C, and there are other segmental variants that do not. Candidates 2 and 3 are ruled out by the constraints ParseSeg-ons and ParseSeg-cod, respectively, as they contain instances of [s] that are outside the syllable constituents. In candidate 3 in particular, placing the [s] outside the coda is a viable repair strategy for $*\sigma_{\mu\mu\mu}$, as non-parsed segments of this kind do not make position (see page 27). The constituent structure of candidates 2 and 3 is as follows:

(213) PyOT's representation of candidate 2 in tableau (212)



(214) PyOT's representation of candidate 3 in tableau (212)



4.2.4 Vowel weakening and syncope

Our dataset includes many examples of Latin vowel weakening, both in medial syllables (as in *[ke.ka.dit] > *cecidit*) and in final syllables (past participles in *-tos* becoming *-tus*). There are also some examples of syncope, as in *miser* < **miseros*, *pandit* < **patanet* (for which see Meiser 1998: 122).

Simply describing the conditions on vowel weakening and syncope in Latin occupies twenty pages of Leumann (1977: 79–99) and nine pages of Meiser (1998: 66-74), some of which are given over to simply stating that there is no hard and fast rule (this is particularly so in the case of which forms should be expected to show syncope, and which vowel weakening, as in some cases both are attested, e.g. *culmen* vs. *columen*; *ualde* vs. *ualide*.)

Neither vowel weakening nor syncope can be classed as an INTERACTOR with any of our PRIMARY generalisations: far from obscuring the conditions of Lachmann's Law, for example, the presence or absence of vowel weakening is one of the indicators we look for in discerning which verbs fall subject to it (see p. 136). Rhotacism and liquid dissimilation, of course, affect only consonants, and take no account of the quality of vowels.

Vowel weakening does, however, interact diachronically with reduplication, as reduplication must cease to be a productive part of the morpho-phonology either before, or at the same time as vowel weakening begins (see §3.5.3).

Given that weakening and syncope are not full INTERACTORS, but rather INTERACTORS with an INTERACTOR, producing a full analysis of them in all their vagaries is beyond the scope I have defined for this project. However, in order to take some account of them, I have added constraint re-rankings to the model that capture the change from the early Latin system of initial stress-accent to the familiar Classical penultima rule.

An analysis of Classical Latin stress in terms of the metrical parameters of Hayes (1995) is offered by Lahiri (2001: 1356), as follows:

(215) Metrical Phonology parameters for the Latin penultima rule (example (29) in Lahiri (2001)):

Syllable weight:	Long vowels and closed syllables are heavy
Extrametricality:	Final syllable
Direction of parsing:	Right to Left
Main stress:	End Rule Right

(	X	)	(	X	)	(X		)	(X		)
	(x)		(x)	(x)		(x	.)		(x)		
μ	$\mu\mu$		$\mu\mu$	$\mu\mu$	$\mu\mu$	μ	μ	$\mu\mu$	$\mu\mu$	μ	$\mu\mu$
re	féc	⟨tus⟩	dē	léc	⟨tat⟩	vó	lu	⟨cres⟩	múr	mu	⟨ris⟩

The effects parameter settings may be duplicated in OT on the principles laid down by Prince & Smolensky (1993); McCarthy & Prince (1993) by the following constraints and ranking (cf. the OT account of Latin stress in Jacobs 2000, 2003):

(216) **Name:** FtBin

PyOT representation: `(FtBin,)`

Definition : Assess a violation for every foot in the output that is not binary under either a syllabic or moraic analysis.

(217) **Name:** Weight-To-Stress

PyOT representation: `(WeightToStress)`

Definition : Assess a violation for every heavy syllable in the output that is not a foot head.

(218) **Name:** Alignσ_s, L; Σ, L

PyOT representation: `(FtTypeT,)`

Definition : Assess a violation for every foot in the output whose head syllable is not left-aligned within it.

(219) **Name:** Align-[Σ, R; ω, R]

PyOT representation: `(AlignFoot, 'R')`

Definition : For every foot in the output, assess a number of violations equal to the number of syllables between it and the leftmost edge o the prosodic word that dominates it.

(220) **Name:** Align-[Σ_s, R; ω, R]

PyOT representation: `(AlignHeadFootInWord, 'R')`

Definition : Assess a violation for every prosodic word in the output whose head foot is not left-aligned within it.

(221) **Name:** NONFINALITY

PyOT representation: `(NonFinParse,)`

Definition : Assess a violation for every prosodic word in the output that ends with a syllable that heads a foot.

(222) **Name:** PARSE-σ

PyOT representation: PARSE-σ

Definition : Assess a violation for every syllable in the output that is not dominated by a foot.

(223) Ranking of constraints to generate the Classical Latin stress pattern:

FTBIN, WEIGHT-TO-STRESS, ALIGNσ_s, L; Σ, L $\gg$

NONFINALITY $\gg$

PARSE-σ $\gg$

ALIGN-[Σ, R; ω, R], ALIGN-[Σ_s, R; ω, R],

Within the model the top ranking stratum is assigned to the filter, and, as none of the PRIMARY generalisations depends on metrical structure, the other constraints are placed in the tie breaker. In conjunction with the constraints already in the filter and tie breaker, this generates the penultima rule according to the footing pattern argued for by Lahiri (2001):

(224)

Tableau illustrating footing according to the penultima rule in *refectus*

Filter constraints: MinNucSon-6, LenLimit-Onset-2, LenLimit-Nuc-2, LenLimit-Coda-2, OnsetSonority-2, CodaSonority-1, NucSonority-0, FtBin, Weight-To-Stress, Alignσ_s, L; Σ, L

/refektus/	NoCoda	*ComplexCoda	Onset	NonFinality	Weight-To-Stress	Parse-σ	Align-[Σ, R; ω, R]	Align-[Σ_s, R; ω, R]
☞ 1. re(ˈfek)tus	2	0	0	0	1	2	1	1
∼ 2. (ˈre.fek)tus	$_2$—	$_0$—	$_0$—	$_0$—	$_2$W	$_1$L	$_1$—	$_1$—
∼ 3. re(ˌfek)(ˈtus)	$_2$—	$_0$—	$_0$—	$_1$W	$_0$L	$_1$L	$_1$—	$_0$L
∼ 4. (ˌre.fek)(ˈtus)	$_2$—	$_0$—	$_0$—	$_1$W	$_1$—	$_0$L	$_1$—	$_0$L
∼ 5. re(ˈfek.tus)	$_2$—	$_0$—	$_0$—	$_1$W	$_1$—	$_1$L	$_0$L	$_0$L
∼ 6. (ˌref)(ˈek)tus	$_3$W	$_0$—	$_1$W	$_0$—	$_1$—	$_1$L	$_3$W	$_1$—
∼ 7. (ˌref)(ˌek)(ˈtus)	$_3$W	$_0$—	$_1$W	$_1$W	$_0$L	$_0$L	$_3$W	$_0$L

(225) Tableau illustrating footing according to the penultima rule in *dēlectat*

/deːlektat/	NoCoda	*ComplexCoda	Onset	NonFinality	Weight-To-Stress	Parse-σ	Align-[Σ, R; ω, R]	Align-[Σ_s, R; ω, R]
☞ 1. (ˌdeː)(ˈlek)tat	2	0	0	0	1	1	3	1
∼ 2. (ˈdeː.lek)tat	$_2$—	$_0$—	$_0$—	$_0$—	$_2$W	$_1$—	$_1$L	$_1$—
∼ 3. (ˌdeː)(ˌlek)(ˈtat)	$_2$—	$_0$—	$_0$—	$_1$W	$_0$L	$_0$L	$_3$—	$_0$L
∼ 4. (ˌdeː.lek)(ˈtat)	$_2$—	$_0$—	$_0$—	$_1$W	$_1$—	$_0$L	$_1$L	$_0$L
∼ 5. deː(ˈlek.tat)	$_2$—	$_0$—	$_0$—	$_1$W	$_2$W	$_1$—	$_0$L	$_0$L

(226) Tableau illustrating footing according to the penultima rule in *uolucrēs*

/volukres/	NoCoda	*ComplexCoda	Onset	NonFinality	Weight-To-Stress	Parse-σ	Align-[Σ, R; ω, R]	Align-[Σ_s, R; ω, R]
☞ 1. (ˈvo.lu)kres	1	0	0	0	1	1	1	1
∼ 2. (ˌvo.lu)(ˈkres)	$_1$—	$_0$—	$_0$—	$_1$W	$_0$L	$_0$L	$_1$—	$_0$L
∼ 3. vo.lu(ˈkres)	$_1$—	$_0$—	$_0$—	$_1$W	$_0$L	$_2$W	$_0$L	$_0$L
∼ 4. vo(ˈlu.kres)	$_1$—	$_0$—	$_0$—	$_1$W	$_1$—	$_1$—	$_0$L	$_0$L

(227) Tableau illustrating footing according to the penultima rule in *murmuris*

/murmuris/	NoCoda	*ComplexCoda	Onset	NonFinality	Weight-To-Stress	Parse-σ	Align-[Σ, R; ω, R]	Align-[Σ_s, R; ω, R]
☞ 1. (ˈmur.mu)ris	2	0	0	0	1	1	1	1
∼ 2. (ˌmur.mu)(ˈris)	${}_2$—	${}_0$—	${}_0$—	${}_1$W	${}_0$L	${}_0$L	${}_1$—	${}_0$L
∼ 3. mur.mu(ˈris)	${}_2$—	${}_0$—	${}_0$—	${}_1$W	${}_1$—	${}_2$W	${}_0$L	${}_0$L
∼ 4. mur(ˈmu.ris)	${}_2$—	${}_0$—	${}_0$—	${}_1$W	${}_2$W	${}_1$—	${}_0$L	${}_0$L

To generate an initial-stress pattern which leaves unstressed every syllable in the dataset that appears to undergo vowel weakening or syncope requires the following constraint ranking (cf. the analyses of syncope in Jacobs 2004 andSen 2012):

(228) Ranking of constraints to generate the Old Latin initial stress pattern:

FtBin, Alignσ_s, L; Σ, L $\gg$

Align-[Σ_s, L; ω, L], $\gg$

NonFinality Weight-To-Stress, Parse-σ $\gg$

Align-[Σ, L; ω, L],

The differences between the ranking above and the ranking in (223) are minimal, involving only re-ranking of the alignment constraints on feet and on primary stresses. In the Old Latin ranking, Align-[Σ_s, L; ω, L] is assigned to the top ranking stratum so that stress is initial even in words with an LH syllable weight pattern, such as *ăgit* ‘drives’:

(229) Tableau illustrating the Old Latin stress pattern in *ăgit* ‘drives’

/agit/	ALIGN-[Σ_s, L; ω, L]	NOCODA	*COMPLEXCODA	ONSET	NONFINALITY	WEIGHT-TO-STRESS	PARSE-σ	ALIGN-[Σ, L; ω, L]	ALIGN-[Σ_s, L; ω, L]
☞ 1. (ˈa.git)	0	1	0	1	1	1	0	0	0
∼ 2. (ˈag)it	$_0$—	$_2$W	$_0$—	$_2$W	$_0$L	$_1$—	$_1$W	$_0$—	$_0$—
∼ 3. (ˈag)(ˌit)	$_0$—	$_2$W	$_0$—	$_2$W	$_1$—	$_0$L	$_0$—	$_1$W	$_0$—
∼ 4. a(ˈgit)	$_1$W	$_1$—	$_0$—	$_1$—	$_1$—	$_0$L	$_1$W	$_1$W	$_1$W

The change from one system to another is also minimal in respect of the output patterns; note that there is a significant constituency of outputs in which the only change is from End-Rule-L to End-Rule-R, and some in which the stress pattern does not change at all[2]:

(230) Tableau illustrating the Old Latin stress pattern in *dēlectat*

[2]cf. the observations about the pertinacity of stress patterns in the history of English made by Fikkert et al. (2006); Dresher & Lahiri (1991).

/deːlektat/	ALIGN-[Σ_s, L; ω, L]	NOCODA	*COMPLEXCODA	ONSET	NONFINALITY	WEIGHT-TO-STRESS	PARSE-σ	ALIGN-[Σ, L; ω, L]	ALIGN-[Σ_s, L; ω, L]
☞ 1. (ˈdeː)(ˌlek)tat	0	2	0	0	0	1	1	1	0
∼ 2. (ˈdeː.lek)tat	$_{0}$—	$_{2}$—	$_{0}$—	$_{0}$—	$_{0}$—	$_{2}$W	$_{1}$—	$_{0}$L	$_{0}$—
∼ 3. (ˈdeː)(ˌlek)(ˌtat)	$_{0}$—	$_{2}$—	$_{0}$—	$_{0}$—	$_{1}$W	$_{0}$L	$_{0}$L	$_{3}$W	$_{0}$—
∼ 4. (ˈdeː)(ˌlek.tat)	$_{0}$—	$_{2}$—	$_{0}$—	$_{0}$—	$_{1}$W	$_{1}$—	$_{0}$L	$_{1}$—	$_{0}$—

(231) Tableau illustrating the Old Latin stress pattern in *uolucres*

/volukres/	ALIGN-[Σ_s, L; ω, L]	NOCODA	*COMPLEXCODA	ONSET	NONFINALITY	WEIGHT-TO-STRESS	PARSE-σ	ALIGN-[Σ, L; ω, L]	ALIGN-[Σ_s, L; ω, L]
☞ 1. (ˈvo.lu)kres	0	0	0	0	0	0	1	0	0
∼ 2. (ˈvo.lu)(ˌkres)	$_{0}$—	$_{1}$W	$_{0}$—	$_{0}$—	$_{1}$W	$_{0}$—	$_{0}$L	$_{2}$W	$_{0}$—
∼ 3. (ˈvol)(ˌu.kres)	$_{0}$—	$_{1}$W	$_{0}$—	$_{1}$W	$_{1}$W	$_{0}$—	$_{0}$L	$_{1}$W	$_{0}$—

As I said above, producing a model that yields the right resulting vowel in the case of weakening and no vowel in the appropriate environment in the case of syncope is beyond the scope of the present model, given that weakening and syncope do not interact correctly with any of our PRIMARY generalisations. I have therefore confined myself to adding the ranking in (228) to the word level of Diachronic

Stages 1 and 2, to generate the old initial-stress pattern, and the ranking in (223) to the word level of Stages 3 and 4, to generate footing according to the penultima rule. I have proceeded to amend the inputs to Diachronic Stages 3 and 4 to take vowel weakening as read, having shown that the ranking in (228) predicts that every syllable at Diachronic Stage 2 is unstressed in which a vowel that ultimately undergoes weakening is found, and that the ranking in (223) generates the correct primary stress for the Classical language at Stages 3 and 4.

4.3 Orthogonals

4.3.1 Shift of diphthongs in [ɪ]

The sound change of *ei* > *ẹ̄* > *ī* never interacts directly with any of the PRIMARIES, but the solution I am about to offer to it does depend on the assumptions I have made about the quality of short vs. long *i* (see page 217 above). I have therefore added constraint rankings and feature specifications to the model to account for it.

Recall that in Chapter 3, I argued that at Diachronic Stage 1, the vowel *ĭ* was unique among the short vowels in that it was distinguished from its long counterpart not only by being linked to only one mora, but also by being specified as having the feature [RTR]. I based this claim on a preponderance of indications, including the fact that *i* is never lengthened by Lachmann's Law, the fact that it the glide of the diphthong *ai* lowers to *ae*, but the vowel of *au* does not lower to **ao*, and also the fact that in the pre-Classical reduplication pattern attested to by Aulus Gellius, roots in *u* reduplicate not as their fellow high vowel *i*, but with an *e* in the reduplicant syllable.

This assumption can be employed to help model the develoment of *ei* provided that it includes the stipulation that, at Diachronic Stages 1 and 2, the short counterpart of Latin [iː], transcribed [ɪ], has the following featural specification: [VOC, SON, COR, RTR]. That is to say that in the archaic and pre-historic language Latin short *i* was not, featurally speaking, a [HIGH] vowel.

If this assumption is admitted, the change from a dipththong *ai* (presumed to be [aɪ]) to *ae*, and from *ei* to the close-mid long vowel Allen (1978: 53) and Meiser (1998: 58) notate as *ẹ̄* can be modelled by assuming the following ranking of constraints, hypothesised for the word level of Diachronic Stage 2:

(232) **Name:** NODEAGREE-[RTR]

PyOT representation: `(NodeAgree, 'rtr')`

Definition : Assess a violation for every pair of adjacent segments within the same syllabic node (onset, nucleus or coda) that are not identically specified with respect to the feature [RTR].

(233) **Name:** MAX-[RTR]

PyOT representation: `(MaxFeat, 'rtr')`

Definition : Assess a violation for every segment *i* in the input that has a correspondent *i′* in the output, iff *i* has the feature [RTR] and *i′* does not.

(234) **Name:** DEP-[RTR]

PyOT representation: `(DepFeat, 'rtr')`

Definition : Assess a violation for every segment *i* in the input that has a correspondent *i′* in the output, iff *i* does not have the feature [RTR] and *i′* does.

(235) Ranking of constraints calling for shift of dipththongs in I

NODEAGREE-[RTR] ≫ MAX-[RTR] ≫ DEP-[RTR]

As DEP-[RTR], the ranking in (235) is most harmonically satisfied by adding the feature [RTR] to a vowel. As [e] is defined as [VOC, SON, COR], an input /e/ can employ this repair strategy by turning into [[ɪ]], which we define as [VOC, SON, COR, RTR]. Therefore, /eɪ/ surfaces as [ɪː] in, for example, */weɪdeɪt/ > *uīdit* 'see-3SG.PRF':

(236) Tableau illustrating shift of dipththongs in Latin *uīdit* 'see-3SG.PRF':

/weɪdeɪt/	NODEAGREE-[RTR]	MAX-[RTR]	DEP-[RTR]
☞ 1. wɪɪ.dɪɪt	0	0	2
∼ 2. wɪɪ.deet	$_0$—	$_1$W	$_1$L
∼ 3. wee.dɪɪt	$_0$—	$_1$W	$_1$L
∼ 4. wee.deet	$_0$—	$_2$W	$_0$L
∼ 5. wɪɪ.deɪt	$_1$W	$_0$—	$_1$L
∼ 6. weɪ.dɪɪt	$_1$W	$_0$—	$_1$L
∼ 7. weɪ.deet	$_1$W	$_1$W	$_0$L
∼ 8. wee.deɪt	$_1$W	$_1$W	$_0$L
∼ 9. weɪ.deɪt	$_2$W	$_0$—	$_0$L

The [ɪɪ] of the output here is equivalent to the *ẹ̄* of Allen (1978: 53) and Meiser (1998: 58)

The other repair strategy, which is more expensive in terms of constraint violations, is to turn an input [ɪ] into an [e]. This is the repair strategy that gives the diphthong *ae* from earlier *ai*, as there is no counterpart of [a] with the [RTR] feature in the segment inventory, or else we should expect an output *[a̙ɪ]:

(237) Tableau illustrating shift of dipththongs in Latin *praes* 'bondsman':

/praɪs/	NodeAgree-[RTR]	Max-[RTR]	Dep-[RTR]
☞ 1. praes	0	1	0
∼ 2. praɪs	$_{1}$W	$_{0}$L	$_{0}$—

At some point after Diachronic Stage 1 the grammar must make the transition to the system Allen (1978: 47) describes, in which there is a qualitative as well as a quantitative distinction between both long and short *i* and long and short *u*. I believe the watershed of the switch to the newer system was vowel weakening. The evidence for this is what Sturtevant (1940: 119ff.) calls 'the alleged "intermediate" vowel' (see also Meiser 1998: 68). The fact that we find weakened vowels in some contexts spelled either as ⟨i⟩ or as ⟨u⟩ (e.g. in OPTUMUM for *optimum* 'best', *aurufex/aurifex* 'goldsmith'), suggests at least that learners of the language after the period of vowel weakening treated short *i* and *u* the same, and given that we generally suppose the quality of the vowel of weakening to have been [ə] (Meiser 1998: 66), a lax realisation similar to that of English [ɪ] and [ʊ] seems most probable.

I therefore assume that after vowel weakening, in Diachronic Stages 3 and 4, short *i* and *u* are to be represented by segments with the features ['VOC', 'SON', 'COR', 'HIGH', 'RTR'] and ['VOC', 'SON', 'DOR', 'LAB', 'HIGH', 'RTR'], transcribed as [ɪ̙] and [ʊ̙], respectively (this marking ̙ does not necessarily indicate any change in phonetic realisation, only that, unlike the older [ɪ], these segments do have the feature [HIGH]). The qualitative opposition between the relatively tense and therefore non-[RTR] high vowels on the one hand and [ɪ̩] and [ʊ̩] is enforced by the following ranking of constraints:

(238) **Name:** *SEG([RTR])ː

PyOT representation: `(StarLongFeat, 'rtr')`

Definition : Assess a violation for every long segment in the output that has the feature [RTR]

(239) **Name:** [VOC ∧ HIGH] ⊃ [RTR]

PyOT representation: `(EntailsFeats, ('voc', 'high'), ('rtr',))`

Definition : Assess a violation for every segment in the output that has the features [VOCALIC] and [HIGH], but lacks the feature [RTR]

(240) **Name:** IDENT-[RTR]

PyOT representation: `(Ident, 'rtr')`

Definition : Assess a violation for every segment i in the input that has a correspondent i' in the output, iff i and i' are differently specified with respect to the feature [RTR].

(241) Ranking of constraints enforcing qualitative opposition between long and short high vowels:

*SEG([RTR])ː ≫ [VOC ∧ HIGH] ⊃ [RTR] ≫ IDENT-[RTR]

This entails the assumption that the [ɪ], including the long [ɪː] from /eɪ/ in the output of Stage 2 was taken into the input Stage 3 as [ɪ̩ː]. This need not involve any misperception of the phonetic quality of the Stage 2 [ɪ], only the interpretation of it as representing a sound with a [HIGH] feature the speakers of Stage 2 never intended. In other words, this misparse is a CHOICE in the terminology of Blevins (2004).

This ranking causes the merger of long [ɪː] from [eɪ] that we find in e.g. *uīdit*:

(242) Tableau illustrating merger of [ɪː] with [iː] in *uidit* 'see-3SG.PRF':

/wɪ̝ːdɪ̝ːt/	*SEG([RTR])ː	[VOC ∧ HIGH] ⊃ [RTR]	IDENT-[RTR]
☞ 1. wiː.diːt	0	2	4
∼ 2. wɪ̝ː.diːt	$_1$W	$_1$L	$_2$L
∼ 3. wiː.dɪ̝ːt	$_1$W	$_1$L	$_2$L
∼ 4. wɪ̝ː.dɪ̝ːt	$_2$W	$_0$L	$_0$L

The 3SG.PRF ending **ei̯t* > [eɪt] > [ɪɪt] > [iːt] shortens to *ĭt* at Diachronic Stage 4 (see Meiser 1998: 217). As we shall see, this shortening can be modelled by an augmentation of the same constraint ranking we have already used to model degemination of *ss*.

4.3.2 Final syllable shortening

In final syllables of polysyllabic words closed by *-r, -l, -m* or *-t*, a long vowel is regularly shortened (Meiser 1998: 77). This affects two major classes of words in our dataset: nouns in *-al/ar* are shortened from earlier *-āl/ār* (cf. the long vowel in *-ālis/āris*), and the 3SG perfects in *-it* < [-iːt] < [-ɪːt] < [-eɪt] that I have cited from the verbs used to exemplify Lachmann's Law.

The fact that this shortening affects specifically closed syllables suggests that, just as for degemination of *ss*, the markedness constraint being satisfied is $*\sigma_{\mu\mu\mu}$.

Furthermore, the fact that the shortening only occurs in final syllables of polysyllabic words suggests that it is restricted to syllables that are not foot-heads. Given the assumptions about Latin stress detailed at p. 260ff. above, we should expect that the only circumstance in which a heavy syllable would not be the head of a foot would be if it is final in a polysyllabic word, and therefore extrametrical:

(243) **kalkār* > *calcar* [(ˈkal)⟨kar⟩] 'spur'

(244) **ēgīt* > *ēgit* [(ˈeː)⟨gɪ̠t⟩] 'drive-3SG.PRF'

(245) *fūr* > *fūr* [(ˈfuːr)] 'thief' (not **fŭr*)

In (245), a stress-pattern cannot be assigned to the word while observing extrametricality (as there is only one syllable available), so NonFinality is violated and the syllable becomes a foot-head, and no shortening occurs.

We can therefore capture the facts of final syllable shortening by adding the positional faithfulness constraint in (246) to the constraint rankings we have already proposed for Diachronic Stage 4[3] to model degemination and the penultima rule (see pp. 253, 260), arriving at the ranking in (247):

(246) **Name:** Max-μ-σ_s

PyOT representation: `(StressMaxMora,)`

Definition : For every segment o in the output that is entirely dominated by a stressed syllable and has a correspondent o' in the input, assess a

[3]Since final syllable shortening takes place c. 200 B.C.E. (Meiser 1998: 77), Diachronic Stage 4 might seem too late, given the approximate date assigned to it. However, vowel shortening must follow the change of [eɪ] > [ɪː], and of [ɪː] > [iː], both of which occur within the attested history of the language. I therefore assign the first two generalisations to Diachronic Stages 2 and 3, and final shortening to Diachronic Stage 4, according to the principles laid down in §4.1.1

violation for every mora linked to o' which lacks a correspondent linked to o.

(247) NonFinality, Max-μ-σ_s ≫ $*\sigma_{\mu\mu\mu}$ ≫ ParseSeg-cod, ParseSeg-ons ≫ Max-μ ≫ Weight-To-Stress ≫ Parse-σ ≫ Align-[Σ, R; ω, R], Align-[Σ_s, R; ω, R]

The only difference between this ranking and the rankings already in place at Diachronic Stage 4 is that Max-μ-σ_s has been inserted such that it dominates $*\sigma_{\mu\mu\mu}$, and so inhibits vowel shortening in syllables that are foot-heads.

Degemination, e.g. in /eːssus/ → *ēsus* 'eaten', still takes place, because the degeminated *s* is no longer dominated by the stressed syllable, so no violation of Max-μ-σ_s is provoked:

(248) Tableau illustrating degemination in *ēsus* 'eaten', Diachronic Stage 4, word level.

/eːsːus/	Max-C	Max-V	NonFinality	Max-μ-σ_s	$*\sigma_{\mu\mu\mu}$	ParseSeg-cod	ParseSeg-ons	Max-μ	Weight-To-Stress	Parse-σ	Align-[Σ, R; ω, R]	Align-[Σ_s, R; ω, R]
☞ 1. (ˈeː)sus	0	0	0	0	0	0	0	1	1	1	1	1
~ 2. (ˌeː)(ˈsus)	0—	0—	1W	0—	0—	0—	0—	1—	0L	0L	1—	0L
~ 3. (ˈeː)(ˌsus)	0—	0—	1W	0—	0—	0—	0—	1—	0L	0L	1—	1—
~ 4. (ˈeː.sus)	0—	0—	1W	0—	0—	0—	0—	1—	1—	0L	0L	0L
~ 5. eː(ˈsus)	0—	0—	1W	0—	0—	0—	0—	1—	1—	1—	0L	0L
~ 6. es(ˈsus)	0—	0—	1W	0—	0—	0—	0—	1—	1—	1—	0L	0L
~ 7. e.(ˈsus)	0—	0—	0—	0—	0—	0—	0—	2W	0L	0L	0L	0L

Vowel shortening takes place in the extrametrical syllables at the end of words, as in /kalkaːr/ → *calcăr* ‘spur’:

(249) Tableau illustrating vowel shortening in *calcar* ‘spur’, Diachronic Stage 4, word level.

/kalkaːr/	MAX-C	MAX-V	NONFINALITY	MAX-μ-σ_s	*$\sigma_{\mu\mu\mu}$	PARSESEG-COD	PARSESEG-ONS	MAX-μ	WEIGHT-TO-STRESS	PARSE-σ	ALIGN-[Σ, R; ω, R]	ALIGN-[Σ_s, R; ω, R]
☞ 1. (ˈkal)kar	0	0	0	0	0	0	0	1	1	1	1	1
☞ 2. (ˈkal)kar	0	0	0	0	0	0	0	1	1	1	1	1
∼ 3. (ˈkal.kar)	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_1$—	$_1$—	$_0$L	$_0$L	$_0$L
∼ 4. (ˈkal.kar)	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_1$—	$_1$—	$_0$L	$_0$L	$_0$L
∼ 5. kal.(ˈkaːr)	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L	$_0$L
∼ 6. (ˈkal.kaːr)	$_0$—	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L	$_0$L
∼ 7. kal.(ˈkar)	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_1$—	$_0$L	$_0$L	$_0$L	$_0$L
∼ 8. kal.(ˈkar)	$_0$—	$_0$—	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_1$—	$_0$L	$_0$L	$_0$L	$_0$L
∼ 9. klkaːr	$_0$—	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L	$_0$L
∼ 10. kalkaː	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L	$_0$L
∼ 11. kalaːr	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L	$_0$L
∼ 12. kakaːr	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L	$_0$L
∼ 13. alkaːr	$_1$W	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L	$_0$L

No shortening, however, is found in stressed super-heavy syllables, such as those in the Lachmann participles (e.g. /reːk.tu̥s/ → *rēctus* ‘ruled’):

(250) Tableau illustrating lack of vowel shortening in *rēctus* ‘ruled’, Diachronic Stage 4, word level.

/reːktʊ̯s/	Max-C	Max-V	NonFinality	Max-μ-σ_s	$*\sigma_{\mu\mu\mu}$	ParseSeg-cod	ParseSeg-ons	Max-μ	Weight-To-Stress	Parse-σ	Align-[Σ, R; ω, R]	Align-[Σ_s, R; ω, R]
☞ 1. (ˈreːk)tʊ̯s	0	0	0	0	1	0	0	0	1	1	1	1
~ 2. rek(ˈtʊ̯s)	$_0$—	$_0$—	$_1$W	$_0$—	$_0$L	$_0$—	$_0$—	$_1$W	$_1$—	$_1$—	$_0$L	$_0$L
~ 3. rek(ˈtʊ̯s)	$_0$—	$_0$—	$_1$W	$_0$—	$_0$L	$_0$—	$_0$—	$_1$W	$_1$—	$_1$—	$_0$L	$_0$L
~ 4. (ˌreːk)(ˈtʊ̯s)	$_0$—	$_0$—	$_1$W	$_0$—	$_1$—	$_0$—	$_0$—	$_0$—	$_0$L	$_0$L	$_1$—	$_0$L
~ 5. (ˈreːk.tʊ̯s)	$_0$—	$_0$—	$_1$W	$_0$—	$_1$—	$_0$—	$_0$—	$_0$—	$_1$—	$_0$L	$_0$L	$_0$L
~ 6. (ˈreːk.tʊ̯s)	$_0$—	$_0$—	$_0$—	$_0$—	$_1$—	$_1$W	$_0$—	$_0$—	$_0$L	$_0$L	$_0$L	$_0$L
~ 7. (ˈrek.tʊ̯s)	$_0$—	$_0$—	$_0$—	$_1$W	$_0$L	$_0$—	$_0$—	$_1$W	$_0$L	$_0$L	$_0$L	$_0$L
~ 8. (ˈrek.tʊ̯s)	$_0$—	$_0$—	$_0$—	$_1$W	$_0$L	$_0$—	$_0$—	$_1$W	$_0$L	$_0$L	$_0$L	$_0$L

Nominative singular *-*s*

PIE is reconstructed as having a regular ending *-*s* for the NOM.SG. In Latin, some of these endings are still in evidence, as in the second declension *-us* from thematic *-*o*- + NOM.SG *-*s*. (Leumann 1977: 423) or third declension consonant stems such as **rēg-s* > *rēx* 'king'. In others, however, the *-*s* has been systematically discarded in favour of what is effectively a zero ending, most notably for our purposes in second declension substantives from stems (not counting the thematic vowel) in *r* (such as *miser* and *frāter*), and in the entire class of nouns in *-al/ar*.

It is not always clear whether this is a matter of loss of final *-s* by regular sound change (perhaps in deference to the ranking of [CONS]-Agree-[LAT] and [CONS]-Agree-[RHO] at Diachronic Stage 2), or if the change of endings represents a reanalysis of declension patterns (which is always a possibility, given the presence of the first declension, with stem vowel -*ā*, and NOM.SG in -*ă̆*, therefore effectively a zero ending in the NOM.SG).

Given that the change from *-*rs* to -*r* often depends on syncope creating the *-*rs* in question (as in *miser* < **misers* < **miseros*: see Leumann 1977: §179), and syncope is not explicitly incorporated into the model, the change, be it phonological or morphological, is taken as read, and inputs appear with their attested (lack of a) nominative singular ending.

4.3.3 Notes on specific forms

fulminālis

Owing to its clear semantic connection with *fulgur*, the root of this form is usually traced to an etymon **fulg-men* (see e.g. Ernout & Meillet 1959). I have not included constraint rankings to account for this cluster reduction in the model, but simply amended the input to take the change as read.

glēbālis

This form has no clear etymology, so it is impossible to say whether the *b* comes from IE *b, *b^h or *d^h. I have used /b/ as the input.

hiemālis

I assume that the vowel hiatus in this form was pronounced with a tense but short [i], rather than the [ɪ] I have assumed to represent short *i* everywhere else, in order to maximise the qualitative difference between the two vowels (cf. English [ri.ækt], not *[rɪ.ækt]). This assumption is necessary as without it, the model incorrectly generates *[hɪː.maː.lɪs], given the constraint ranking proposed above for the monopthongisation of *ei*.

trahere

The etymology of this form is obscure. Despite the semantic similarity, a connection with English *drag*, German *tragen*, Greek *τρέχω* etc. is generally considered to be out of court (see Ernout & Meillet 1959; Rix & Kümmel 2001; de Vaan 2008: s.v.), as the Germanic cognates, in particular, point to a PIE root with two voiced aspirates: **dʰreǵʰ vel sim.*, for which we might expect the Latin reflex **frahere*, with *f* as the regular initial reflex of **dʰ* (cf. *frētus* 'relying on'; de Vaan 2008: s.v.). If, however, we may be permitted to posit that the phonetic misparse that gives [f] from [θ] at Diachronic Stage 2 did not affect the [θ] of *trahere* for whatever reason (cf. /aiθtus/ > *aestus*, p. 68), then it should be noted that an input /θraːɣit/ at Diachronic Stage 2 would give the output [trafiit], provided that a constraint penalising syllable-initial clusters in [sr] is added to the filter constraints on syllable structure discussed in §4.2.1 above.

The hierarchy of repair strategies for input /θr/ at Diachronic Stage 2, as set out above (p. 79ff.) is as follows:

(251)
- Best preferred: realise non-strident fricative as strident: /θr/ → [sr]. This must be ruled out by syllable structure constraints, as syllables in the native vocabulary of Latin are not permitted to begin with a sequence of [s] + liquid.
- Next best: realise fricative as liquid: /θr/ → [rː]. This is ruled out by sonority sequencing constraints, as consecutive segments within a

syllable onset must rise in sonority.

- Next best: realise fricative as stop: /θr/ → [tr]. This is the most expensive repair strategy in terms of faithfulness constraint violations, but the only one that produces a clearly viable syllable onset.

There are difficulties with this hypothesis, however. In the first place, we are required to stipulate that the sound change that gives **sr* > *fr* in *frīgus* 'cold' (see Meiser 1998: 112) must take place before Diachronic Stage 2, as otherwise /sr/ would also give [tr], and we would expect **trīgus*.

Furthermore, it is difficult to see how an initial */θ/ could escape being misparsed as [f] in an onset */θr/, given that it is precisely the presence of an adjacent [r] that is argued to prompt the misparse of */ð/ as *[v] in e.g. *uerbum* and *glaber* (Meiser 1998: 104–5; Stuart-Smith 2004: 213)

Given the difficulties with the etymology, I have left the input to the forms from *trahere* in the model as beginning with /t/. Let the record reflect, however, that the model will produce the attested outputs given inputs beginning with /θ/.

umbilīcālis

This form attests the regular raising of *o* to *u* before nasals besides the plain coronal [n] (cf. Greek *ὀμφαλός*, and see Meiser 1998: 83). As this change is entirely ORTHOGONAL, I have taken it as read in the input to Diachronic Stage 3.

Vulcānālis

This form shows raising of *o* to *u* before tautosyllabic and non-geminate (therefore presumably dark) *l*. Once again, this is an ORTHOGONAL, so it is taken as read in the input to Stage 3.

uulgāris

This form attests the same vowel raising before *l* as *Vulcānālis*.

4.4 Conclusion

4.4.1 The model reviewed

Generalisations

We have now examined every phonological generalisation that must be taken into account in order to fully analyse every word-form in the dataset. Not counting ORTHOGONALS affecting only one or two word-forms, which are listed in the previous section, these generalisations are as follows:

(252) Generalisations accounted for by the model:

Generalisation	Class
Lachmann's Law	PRIMARY
Liquid dissimilation	PRIMARY
Rhotacism	PRIMARY
Reduplication	INTERACTOR
Loss of non-strident fricatives	INTERACTOR
Assibilation	INTERACTOR
Degemination of *ss*	INTERACTOR
Foot structure constraints (for vowel weakening)	INTERACTOR

Generalisation	Class
Syllable structure constraints	INTERACTOR
Shift of dipththongs in [ɪ]	ORTHOGONAL
Final syllable shortening	ORTHOGONAL
Short high vowels [RTR]	ORTHOGONAL

Assigning these generalisations to their proper diachronic strata, we arrive at the following desiderata for our model, in terms of the generalisations it must predict:

(253) Generalisations accounted for by the model, arranged by stages and strata:

Diachronic stage 1; pre-historic (7th century B.C.E and before)		
Stem level:	Lachmann's Law	/[$_{stem}$agto]s/ → [aːg] (*āctus*)
		/[$_{stem}$ɸoθto]s/ → [ɸoθ] (*fossus*)
	reduplication according	/[$_{stem}$REDpug]ai/ → [pepug] (*pupugī*)
	to Gellius	/[$_{stem}$REDkad]ai/ → [kekad] (*cecidī*)
Word level:	voicing assimilation	/aːgtos/ → *āctus*
	assibilation	/[$_{stem}$kad]sos/ → *cāsus*
	initial stress pattern	/agit/ → [(ˈa.git)]
		/leːgaːlis/ → [(ˈleː)(ˌgaː)lis]
	liquid dissimilation	/kalkaR/ → *calcar*
	(without blocking)	/anamaR/ → *animal*
Phrase level:	fricatives voiced / V__V	/ruːsis/ → *[ruːzis] > *rūris*
		/neɸula/ → *[neβula] > *nebula*

Diachronic stage 2; pre-literary (6th – 2nd century B.C.E)		
Stem level:	reduplication	/[$_{stem}$REDpug]ai/ → *pupugī*
	(Classical pattern)	/[$_{stem}$REDkekad]ai/ → *cecidī*
Word level:	voicing assimilation	/aːgtos/ → *āctus*
	rhotacism	/rusis/ → *rūris*
	change of *ei* to *ẹ̄*	/weɪdeɪt/ → [wɪːdɪːt] (*uīdit*)
	change of *ai* to *ae*	/praɪs/ → *praes*
	liquid dissimilation	/lokaːRis/ → *locālis*
	initial stress pattern	/agit/ → [(ˈa.git)]

		/leːgaːlis/ → [(ˈleː)(ˌgaː)lis]
	(with blocking)	/floːsaːRis/ → *flōrālis*
	non-strident fricatives lost	/neβula/ → *nebula*
		/ɸiðem/ → *fidem*
		/ruver/ → *ruber*
		/xʷormos/ → *formus*
		etc.

Diachronic stage 3; early literary (2nd century B.C.E)		
Stem level:	rhotacism	/[$_{stem}$ruːsi]s/ → *rūris*
		/ni[$_{stem}$siː]/ → *nīsī*
Word level:	voicing assimilation	/aːgtus/ → *āctus*
	short high vowels [RTR]	/aːgtus/ → [aːk.tʊ̙s] (*āctus*)
	[ɪː] merges with [iː]	/wɪːdɪːt/ → [wiːdiːt] (*uīdit*)
	penultima rule	/agit/ → [(ˈa.git)]
		/leːgaːlis/ → [(ˌleː)(ˈgaː)lis]

Diachronic stage 4; classical (1st century B.C.E)		
Word level:	voicing assimilation	/aːgtus/ → *āctus*
	liquid dissimilation	/lokaːRis/ → *locālis*
	(with blocking)	/floraːRis/ → *florālis*
	degemination	/kaːssus/ → *cāsus*
	final shortening	/kalkaːr/ → *calcar*
	penultima rule	/agit/ → [(ˈa.git)]
		/leːgaːlis/ → [(ˌleː)(ˈgaː)lis]

At all periods		
Syllable structure	*stāre* but	not **ftāre*
	[ho.noː.ris]	not *[hon.oːr.is]
		not *[hono̯ː.ris]
		not *[h̩.o.noː.ris]

These generalisations can be predicted accurately using the filters, constraint rankings and tie breakers we will now examine.

Constraint rankings

Every input fed to the model is evaluated against twelve successive constraint rankings, representing each of the three synchronic strata at each of the Diachronic Stages. Every constraint ranking is composed of a filter, a unique element, and a tie breaker.

The filter, as discussed in §1.2.2 consists of those constraints which no candidate is allowed to violate. It is used for syllable structure constraints as detailed in §4.2.1 above so as to restrict the candidate space searched by PyOT's Gen function and so reduce the amount of time taken by each evaluation. Slightly different filters are used depending on the synchronic stratum, as follows:

(254) Filter constraints at the stem level:

MinNucSon-6, LenLimit-Onset-2, LenLimit-Nuc-2, LenLimit-Coda-3, OnsetSonority-2, NucSonority-0,

(255) Filter constraints at the word level:

MinNucSon-6, LenLimit-Onset-2, LenLimit-Nuc-2, LenLimit-Coda-2, OnsetSonority-2, CodaSonority-1, NucSonority-0, FtBin, Align[σ_s, L; Σ, L]

(256) Filter constraints at the phrase level:

MinNucSon-6, LenLimit-Onset-2, LenLimit-Nuc-2, LenLimit-Coda-2, OnsetSonority-2, CodaSonority-1, NucSonority-0,

As discussed above (p. 247), the restrictions on syllable codas are relaxed at the stem level, because phonological stems are not required to end in licit syllable codas (e.g. underlying /[$_{stem}$eksempl]aR/ for *exemplar*).

The foot-structure constraints FtBin and Align[σ_s, L; Σ, L] are included only at the word level because we are only concerned with predicting lexical stress, and there are no identifiable cyclicity effects in the assignment of Latin stress, so the model only builds foot structure at the word level.

Certain other constraints are included in the filter depending on the Diachronic Stage. At Stages 1 and 2, for which we do not reconstruct the segments [ɪ̞] and [ʊ̞], we add the constraint *Seg[high ∧ rtr] to the filter so that candidates including them are never generated. Conversely, in Diachronic Stages 3 and 4, the non-[high] segment [ɪ] is excluded from the inventory by a filter constraint [rtr] ⊃ [high]. Also at Stages 3 and 4, where diphthong off-glides are uniformly of lower sonority than their on-glides, the constraint NucSonority-1 appears in the filter to save the model from evaluating candidates that do not observe this restriction.

The remaining restrictions on syllable and foot structure are enforced by the tie breaker, a set of constraints that are automatically added to the bottom of the ranking if they do not already appear in it. The tie-breakers are as follows:

(257) Tie-breaker for Diachronic Stages 1 and 2:

Align-[Σ_s, L; ω, L], ParseSeg-ons, NoCoda, *ComplexCoda, Onset, ParseSeg-cod, NonFinality Parse-σ Weight-To-Stress Align-[Σ, L; ω, L]

(258) Tie-breaker for Diachronic Stages 3 and 4:

ParseSeg-ons, NoCoda, *ComplexCoda, Onset, ParseSeg-cod, NonFinality Parse-σ Weight-To-Stress Align-[Σ, R; ω, R] Align-[Σ_s, R; ω, R], These constraints enforce the syllable- and foot-structure patterns described in §4.2.1 and §4.2.4.

Within this ranking frame of FILTER $\gg x \gg$ TIE-BREAKER come the individual rankings for each Diachronic Stage and stratum, which predict the generalisations in (253) as follows:

(259) Constraint rankings for the complete model:

Diachronic Stage 1 Stem level			
Constraint	Primary	Interactor	Orthogonal
*Seg([rtr])ː	Lachmann's Law		
LenLimit-Coda-2		Syllable structure	
CodaSonority-1		”	
RedLength-σ-1		Reduplication	
*$\bar{\text{V}}$-BR		”	
*$\text{V}_{\mu}\text{D}\ldots{}_{\sigma}]$	Lachmann's Law		
Dep-μ	”		
*Seg[dor ∧ voc]		Reduplication	
*Geminate		”	
NoCoda		”	
*ComplexCoda		”	
Max-C-BR		”	
Ident-[rtr]-BR		”	
Ident-[high]-BR		”	
Max-[dor]		”	
Dep-[cor]		”	
Max-[low]		”	
Max-[lab]		”	
Word level			
Constraint	Generalisation		
OnsIdent-[voi]	Voicing assimilation		
OnsIdent-[strid]		Assibilation	
ParseSeg-ons		”	
ParseSeg-cod		”	
[obs]-Agree-[strid]		”	

[obs]-Agree-[voi]	Voicing assimilation	
Ident-[voi]	”	
Max-[plos]		Assibilation
Dep-[cont]		Assibilation
Dep-[strid]		Assibilation
Onset		Syllable structure
CC-Corr-[rho]	Liquid dissimilation	
CC-Corr-[lat]	”	
Ident-CC-[nas]	”	
Ident-CC-[high]	”	
Ident-CC-[son]	”	
¬Ident-CC-[lat]	”	
CC-Corr-[cons]	”	
Phrase level		
Constraint	Generalisation	
IOralFricV	Intervocalic fricative voicing	
Ident-[voi]	”	
Diachronic Stage 2 **Stem level**		
Constraint	Generalisation	
RedLength-σ-1	Reduplication	
*Geminate	”	
*$\bar{\text{V}}$-BR	”	
Ident-[high]-BR	”	
Ident-[lab]-BR	”	
*[low]	”	
*Seg([rtr]):	”	
NoCoda	”	
Max-C-BR	”	
Ident-[dor]-BR	”	

Ident-[cor]-BR	”
Ident-[low]-BR	”
*[dor]	”
Word level	
Constraint	Generalisation
[cons]-Agree-[lat]	Assimilation of liquids
Dep-[lat]	”
Max-[rho]	”
OnsIdent-[voi]	Voicing assimilation
[obs]-Agree-[voi]	”
Ident-[voi]	”
[cons]-Agree-[lat]	Changes affecting fricatives
Dep-[lat]	(including rhotacism)
Max-[rho]	”
OralFricStrid	”
OralFricVoiceless	”
Onset	”
IOralFricV	”
[cons]-Agree-[rad]	”
[cons]-Agree-[dor]	”
[cons]-Agree-[rho]	”
CodaCond-[cont]	”
Max-[cont]	”
Max-[dor]	”
Dep-[plos]	”
Dep-[rad]	”
Max-[obs]	”
Dep-[son]	”
Dep-[rho]	”
Ident-[strid]	”

¬IDENT-CC-[LAT]	Liquid dissimilation (with blocking)
CC-CORR-[LAT]	”
CC-CORR-[RHO]	”
¬IDENT-CC-ART	”
CC-CORR-[CONS]	”
NODEAGREE-[RTR]	Diphthongs in [ɪ]
MAX-[RTR]	”
DEP-[RTR]	”
Diachronic Stage 3	
Stem level	
Constraint	Generalisation
*[RHO]-μ-[RHO]	Rhotacism
ORALFRICSTRID	”
IORALFRICV	”
MAX-[OBS]	”
DEP-[SON]	”
DEP-[RHO]	”
MAX-[STRID]	”
MAX-[CONT]	”
Word level	
Constraint	Generalisation
*SEG([RTR])ː	Short high vowels [RTR]
[VOC ∧ HIGH] ⊃ [RTR]	”
IDENT-[RTR]	”
ONSIDENT-[VOI]	Voicing assimilation
[OBS]-AGREE-[VOI]	”
IDENT-[VOI]	”
NOCODA	Syllable structure
Diachronic Stage 4	

Word level			
Constraint	Generalisation		
OnsIdent-[voi]	Voicing assimilation		
*Seg([rtr]):			Short high vowels [rtr]
[obs]-Agree-[voi]	Voicing assimilation		
Ident-[voi]	”		
NonFinality		Foot structure	
Parse-σ		”	
Max-μ-σ_s			Final syllable shortening
Onset		Syllable structure	
*$\sigma_{\mu\mu\mu}$			Degemination
ParseSeg-ons		Syllable structure	
Max-μ			Degemination & final shortening
ParseSeg-cod		Syllable structure	
NoCoda		”	

These constraint rankings constitute half of the hypothesis about the history of Latin morphophonology it is the purpose of this thesis to present. The other half of the hypothesis consists of the assumptions on which the inputs to the model are based. The inputs the model evaluates itself against are read directly from the LaTeX source code for Appendix A, the format of which I will now describe.

Reading the report

Entries for particular word-forms in Appendix A take the following form:

(260) Sample output from the model's query report:

Attested form: *funestus* [fuː.ˈnes.tus] 'funereal.NOM.SG.M'				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$θuːnes]tos/ →	[θuː.nes]	[(ˈθuː.nes)tos]	[θuː.nes.tos]
D. stage 2:	/[$_{stem}$fuːnes]tos/ →	[fuː.nes]	[(ˈfuː.nes)tos]	[fuː.nes.tos]
D. stage 3:	/[$_{stem}$fuːnes]tus/ →	[fuː.nes]	[(ˌfuː)(ˈnes)tʊ̞s]	[fuː.nes.tʊ̞s]
D. stage 4:	/[$_{stem}$fuːnes]tʊ̞s/ →	[fuː.nes]	[(ˌfuː)(ˈnes)tʊ̞s]	[fuː.nes.tʊ̞s]

In the top row, we have the attested orthographic form, and a phonetic transcription representing what I take to be the pronunciation of the form in question. This represents what may be considered to be the first metric of success with respect to the model: as Diachronic Stage 4 is hypothesised to represent the state of the Classical language, we should expect the output of stage 4 to match the transcription in the top line.

The inputs, in angled brackets, are those I have specified as being what we expect to find at each stage. After the → sign on each line we have the stem-level, word-level and phrase-level outputs for that line's inputs. This gives the second metric for evaluating the hypothesis: we should expect that the output of any given stage can plausibly be parsed as representing the input to the following line, whether by a phonetic misparse (as in the Stage 1 output [θuːnestos] being misparsed as /fuːnestus/ at Stage 2 (for which see page 71), or by an ORTHOGONAL generalisation not modelled in the constraint ranking (as where the unstressed [o] in the output of Stage 2 is parsed, by vowel weakening, as an [u] in the input to Stage 3).

The whole of Appendix A, then, represents several claims. Firstly, that the inputs in the dataset are based on accurate assumptions about the lexicon of Latin at the relevant diachronic stages. Secondly, that the constraint rankings in (259) collectively constitute a hypothesis about the workings of Latin phonology that is consistent with the attested facts. Thirdly, that the outputs of the constraint rankings at each stage can plausibly be parsed as the inputs to the next stage, and finally that the fact that PyOT outputs what it does given the inputs and rankings specified is a sufficient condition to vindicate the hypothesis with respect to the PRIMARY generalisations I have set out to model.

4.4.2 Remarks

The perfect computer model of a human language would be one that accepted a thought as its input and emitted as output an utterance expressing it that was indistinguishable from one produced by a native speaker. The model I have presented in this thesis is, of course, more modest in its goals, but it is nevertheless worth keeping the archetype in mind when assessing the extent to which this work reaches the goals I have established for it, and in particular the compatibility of these goals with those of historical-comparative linguistics.

The principal challenge of comparative philology is that we have, by definition, no access to the intuitions of native speakers of the language we are reconstructing, and in Indo-European comparative philology, our reconstructions depend greatly, more often than not, on ancient languages, so that we have no access to native-speaker intuitions for those either. Viewed in this light, the utility of formal models of language competence for historical linguistics becomes obvious; it is essentially the uniformitarian principle taken to extremes: we wish to test our hypotheses about the history and prehistory of an ancient language, but we have no access to authentic native speakers; let us therefore use what we know about how language works to construct, as it were, a synthetic native speaker, expose it to the stimuli our hypotheses call for, and see if the result is as we predict.

If we keep in mind that our goal is to create the most accurate possible model of a native speaker's competence, firstly I hope that it will be agreed that the model I have designed represents a step towards that goal, but I also believe that it suggests certain potential avenues of further research.

One possibility I have already mentioned at the beginning of this chapter: treating the three PRIMARY generalisations in full requires modelling those that interact with them, so that one could very naturally extend the analysis proposed here to encompass more and more INTERACTORS, and treat the ORTHOGONALS more fully until, ultimately, one has the goal of modelling an entire (morpho-) phonology.

As we can broaden the analysis to encompass more of the landscape of phonology, so too could we deepen it, coupling it, for example, with formal models of morphology so as to produce end-to-end formal accounts of phenomena in which morphology and phonology interact. The most immediate example would be to attempt to integrate the model of the life cycle of rhotacism presented here with the formal model of the analogical change from *honos* to *honor* proposed by Albright (2005). Or, to go in the other direction along the same axis, one could extend the model to include a more formal phonetic implementation model than is conceived of within Optimality Theory as I have modelled it here, and so demonstrate the viability of phonetic misparses in more formal terms than I have contented myself with here (cf. the work of Boersma & Hamann 2009; Boersma 2011, 2012).

Illustrating the utility of PyOT as a model of phonology, and its potential to be extended as I have just described, is only one of two goals I have set for myself in this thesis. The other, of course, is to advance certain hypotheses about the historical morphophonology of Latin. We have seen that treating Latin rhotacism in its entirety requires an awareness of its life cycle as a phonological generalisation, and of its inextricable interaction with the fate of the Proto-Indo-European voiced aspirates. We have seen that the interaction between rhotacism and liquid dissimilation is not a matter of rule insertion, *pace* Watkins (1970a), but rather of the expected, transparent interaction between constraint interactions within the same stratum. We have seen that Lachmann's Law can be accounted for within a formal phonological framework if it is situated in the correct diachronic and synchronic context, and if appropriate attention is paid to the generalisations with which it interacts. We have also identified certain indications that it may, during stages of the prehistoric language that are too remote for us to reconstruct more than tentatively, have undergone its own progression through the life cycle of phonological processes. Above all we have seen that to treat any one phonological generalisation in isolation, without a fully-elaborated statement of exactly how it interacts with the rest of the phonology, necessarily gives one an incomplete picture even of the generalisation itself. If this is borne in mind, it is possible to get a picture of a generalisation that is sufficiently complete to serve a particular purpose (e.g. to model how it interacts with another), but to treat a generalisation in full requires that we identify and allow for its dependencies, and develop a clear and specific statement of exactly where it fits into the language's phonology as a whole.

Bibliography

Adamson, Sylvia & Ayres-Bennett, Wendy, 2011. 'Linguistics and philology in the twenty-first century: introduction'. *Transactions of the Philological Society* 109:201–206.

Albright, Adam, 2005. 'The morphological basis of paradigm leveling'. In Laura Downing, Tracy Alan Hall & Renate Raffelsiefen (eds.), *Paradigms in phonological theory*, 17–43, Oxford: OUP.

Alderete, John, 1999. *Morphologically Governed Accent in Optimality Theory*. Ph.D. thesis, University of Massachusetts, Amherst, available from the Rutgers Optimality Archive as ROA-309.
URL `http://roa.rutgers.edu/view.php3?roa=309`

Alderete, John, 2001. 'Dominance effects as transderivational anti-faithfulness'. *Phonology* 18:201–253.

Allen, W. Sidney, 1978. *Vox latina: a guide to the pronunciation of Classical Latin*. 2nd edition, Cambridge: Cambridge University Press.

Ascoli, Graziadio I., 1868. 'Zur lateinischen Vertretung der indogermanischen Aspiraten'. *Zeitschrift für vergleichende Sprachforschung* 17:241–81.

Asudeh, Ash & Toivonen, Ida, 2006. 'Response to David Adger's "Remarks on minimalist feature theory and Move"'. *Journal of Linguistics* 42:675–686.

Baldi, Philip, 1991. 'Lachmann's Law in the light of the glottalic theory of PIE consonantism'. In Robert Coleman (ed.), *New studies in Latin linguistics*, 3–22, Amsterdam/Philadelphia: John Benjamins.

Baldi, Philip, 1994. 'Some thoughts on Latin rhotacism'. *General Linguistics* 34:209–216.

Bammesberger, Alfred, 1989. 'The laryngeal theory and the phonology of prehistoric Greek'. In Theo Vennemann (ed.), *The New Sound of Indo-European*, 35–41, Mouton de Gruyter.

Baudouin de Courtenay, Jan N. I., 1895. *Versuch einer Theorie phonetischer Alternationen: ein Kapitel aus der Psychophonetik*. Strasbourg: Trübner.

Beckman, Jill N., 1998. *Positional Faithfulness*. Ph.D. thesis, University of Massachusetts, Amherst, available from the Rutgers Optimality Archive as ROA-234.
URL http://roa.rutgers.edu/view.php3?roa=234

Beeler, Madison S., 1966. 'Interrelationships within Italic'. In Henrik Birnbaum & Jaan Puhvel (eds.), *Ancient Indo-European dialects*, 51–58, Berkeley, CA: University of California Press.

Benua, Laura, 1997. *Transderivational identity: phonological relations between words.* Ph.D. thesis, University of Massachusetts, Amherst.
URL http://roa.rutgers.edu/view.php3?id=271

Benveniste, Émile, 1949. 'Sur quelques développements du parfait indo-européen'. *Archivum Linguisticum* 1:16–22.

Bermúdez-Otero, Ricardo, 1999. *Constraint interaction in language change: quantity in English and Germanic*. Ph.D. thesis, University of Manchester & Universidad de Santiago de Compostela.

Bermúdez-Otero, Ricardo, 2003. 'The acquisition of phonological opacity'. In Jennifer Spenader, Anders Eriksson & Östen Dahl (eds.), *Variation within Optimality Theory: Proceedings of the Stockholm Workshop on 'Variation within Optimality Theory'*, Stockholm University, longer version available from the Rutgers Optimality Archive as ROA-593.
URL http://roa.rutgers.edu/view.php3?roa=503

Bermúdez-Otero, Ricardo, 2006. 'Morphological structure and phonological domains in Spanish denominal derivation'. In Fernando Martínez-Gil & Sonia Colina (ed.), *Optimality-theoretic studies in Spanish phonology*, 278–311, Amsterdam: John Benjamins.
URL http://www.bermudez-otero.com/Spanish.pdf

Bermúdez-Otero, Ricardo, 2007. 'Diachronic phonology'. In Paul de Lacy (ed.), *The Cambridge Handbook of Phonology*, 497–517, Cambridge University Press.

Bermúdez-Otero, Ricardo, 2011. 'Cyclicity'. In Marc van Oostendorp, Colin Ewen, Elizabeth Hume & Keren Rice (eds.), *The Blackwell companion to phonology*, 2019–2048, Malden, MA: Wiley-Blackwell.

Bermúdez-Otero, Ricardo, 2012. 'The architecture of grammar and the division of labour in exponence'. In Jochen Trommer (ed.), *The morphology and phonology of exponence*, number 41 in Oxford Studies in Theoretical Linguistics, 8–83, Oxford: OUP.
URL http://ling.auf.net/lingBuzz/001153

Bermúdez-Otero, Ricardo & Börjars, Kersti, 2006. 'Markedness in phonology and in syntax: the problem of grounding'. In Patrick Honeybone & Ricardo Bermúdez-Otero (eds.), *Linguistic knowledge: perspectives from phonology and from syntax*, 710–756, Special Issue of *Lingua*, 116(5).

Blevins, Juliette, 2004. *Evolutionary Phonology: the Emergence of Sound Patterns.* Cambridge: CUP.

Blevins, Juliette, 2006. 'A theoretical synopsis of Evolutionary Phonology'. *Theoretical Linguistics* 32:117–116.

Boersma, Paul, 2011. 'A programme for bidirectional phonology and phonetics and their acquisition and evolution'. In *Bidirectional Optimality Theory*, Amsterdam: John Benjamins.

Boersma, Paul, 2012. 'Modelling phonological category learning'. In Abigail C Cohn, Cecile Fougeron & Marie K. Huffman (eds.), *The Oxford handbook of laboratory phonology*, OUP.

Boersma, Paul & Hamann, Silke (eds.), 2009. *Phonology in Perception.* Berlin: Mouton de Gruyter.

Booij, Geert, 1983. 'Principles and parameters in prosodic phonology'. *Linguistics* 21:249–280.

Borden, G. & Harris, K., 1980. *Speech Science Primer.* 2nd edition, Baltimore: Williams & Wilkins.

Campbell, Alistair, 1959. *Old English Grammar.* Oxford: Oxford University Press.

Catford, John C., 1977. *Fundamental problems in phonetics.* Edinburgh University Press.

Catford, John C., 2001. 'On Rs, rhotacism and paleophony'. *Journal of the International Phonetic Association* 31:171–186.

Cho, Young-mee Yu, 1990. 'A typology of voicing assimilation'. In Aaron L Halpern (ed.), *The Proceedings of the Ninth West Coast Conference on Formal Linguistics.*

Chomsky, Noam & Halle, Morris, 1968. *The sound pattern of English.* New York: Harper and Row.

Clackson, James, 2008. 'Italic: an Indo-European subgroup?' Paper presented at a meeting of the Philological Society, 19th January 2008.

Cohn, Abigail, 1992. 'The consequences of dissimilation in Sundanese'. *Phonology* 9:199–220.

Collinge, Neville E, 1975. 'Lachmann's Law revisited'. *Folia Linguistica* 8:223–253.

Collinge, Neville E, 1985. *The Laws of Indo-European.* Amsterdam: John Benjamins.

Cowgill, Warren, 1970. 'Italic and Celtic superlatives and the dialects of Indo-European'. In George Cardona, Henry M Hoenigswald & Alfred Senn (eds.), *Indo-European and Indo-Europeans*, Philadelphia: University of Pennsylvania Press.

Crosswhite, Katherine, 2001. *Vowel reduction in Optimality Theory.* Outstanding dissertations in linguistics, New York: Garland, originally presented as a PhD dissertation at UCLA in 1999.

Cruttenden, Alan (ed.), 2001. *Gimson's pronunciation of English.* Sixth edition, Arnold.

Cser, András, 2010. 'The *-alis/aris-* allomorphy revisited'. In Franz Rainer, Wolfgang U. Dressler, Dieter Kastovsky & Hans Christian Luschützky (eds.), *Variation and change in morphology: selected papers from the 13th international morphology meeting, Vienna, February 2008*, 33–51, Amsterdam/Philadelphia: John Benjamins.

de Saussure, Ferdinand, 1889. 'Sur un point de la phonétique des consonnes en indo-européen'. *Mémoires de la Société de linguistique de Paris* 6:246–257.

de Vaan, Michiel, 2008. *Etymological Dictionary of Latin and the other Italic Languages.* Leiden: Brill.

Delattre, Pierre, 1962. 'Some factors of vowel duration and their cross-linguistic validity'. *Journal of the Acoustical Society of America* 34:1141–1143.

Dessau, Hermann, 1892. *Inscriptiones latinae selectae.* Berlin: Weidmann.

Dresher, B Elan & Lahiri, Aditi, 1991. 'The Germanic foot: metrical coherence in Old English.' *Linguistic Inquiry* 22:251–286.

Drinka, Bridget, 1991. 'Lachmann's Law: A phonological solution'. *Indogermanische Forschungen* 96:52–74.

Ernout, Alfred & Meillet, Antoine, 1959. *Dictionnaire étymologique de la langue latine.* 4th edition, Paris: Klincksieck.

Fikkert, Paula, Dresher, B. Elan & Lahiri, Aditi, 2006. 'Prosodic preferences: From old english to early modern english.' In *The Handbook of the History of English*, Oxford: Blackwell.

Fortson, Benjamin W., 2004. *Indo-European language and culture: an introduction.* Blackwell.

FRANK, ROBERT & SATTA, GIORGIO, 1998. 'Optimality theory and the generative complexity of constraint violability'. *Computational Linguistics* 24:307–315.

FRIEDRICH, CLAUDIA K., EULITZ, CARSTEN & LAHIRI, ADITI, 2006. 'Not every pseudoword disrupts word recognition: an ERP study.' *Behavioral and Brain Functions* 2:1–36.

FRIEDRICH, CLAUDIA K., LAHIRI, ADITI & EULITZ, CARSTEN, 2008. 'Neurophysiological evidence for underspecified lexical representations: Asymmetries with word initial variations.' *Journal of Experimental Psychology* 34:1545–1559.

FUKAZAWA, HARUKA, 1999. *Theoretical Implications of OCP Effects on Features in Optimality Theory*. Ph.D. thesis, University of Maryland at College Park, available from the Rutgers Optimality Archive as ROA-307.
URL `http://roa.rutgers.edu/view.php3?roa=307`

GARRETT, ANDREW, 1991. 'Review article: Indo-European reconstruction and historical methodologies'. *Language* 67:790–804.

GORDON, ARTHUR E., 1975. 'Notes on the Duenos-vase inscription in Berlin'. *California Studies in Classical Antiquity* 8:153–72.

GOUSKOVA, MARIA, 2007. 'The reduplicative template in Tonkawa'. *Phonology* 24:367–396.

GUSSENHOVEN, CARLOS, 2004. 'A vowel height split explained: compensatory listening and speaker control.' Paper presented at the 9th conference on laboratory phonetics.
URL `http://ling.cornell.edu/events/labphon9gussenhoven.pdf`

HAGÈGE, CLAUDE & HAUDRICOURT, ANDRÉ, 1978. *La phonologie panchronique : comment les sons changent les langues*. Presses Universitaires de France.

HAMMOND, ROBERT M., 2001. *The sounds of Spanish: analysis and application*. Somerville, MA: Cascadilla Press.

HANSSON, GUNNAR ÓLAFUR, 2007. 'Blocking effects in agreement by correspondence'. *Linguistic Inquiry* 38:395–409.

HAYES, BRUCE, 1995. *Metrical stress theory: principles and case studies*. University of Chicago Press.

HAYES, BRUCE, 1999. 'Phonetically driven phonology: the role of Optimality Theory and inductive grounding'. In M. Darnell, E. Moravcsik, F. Newmeyer, M. Noonan & K. Wheatley (eds.), *Functionalism and Formalism in Linguistics*, 243–285, Amsterdam: John Benjamins.
URL `http://roa.rutgers.edu/view.php3?id=170`

Hillenbrand, James, Clark, Michael A & Houde, Robert A, 2000. 'Some effects of duration on vowel recognition'. *Journal of the Acoustical Society of America* 108:3013–3022.

Hung, Henrietta, 1994. *The rhythmic and prosodic organisation of edge constituents*. Ph.D. thesis, Brandeis University, available from the Rutgers Optimality Archive as ROA-24.

Inkelas, Sharon, 1990. *Prosodic Constituency in the Lexicon*. New York/London: Garland.

Inkelas, Sharon, 1995. 'The consequences of optimization for underspecification'. In E. Buckley & S. Iatridou (eds.), *Proceedings of the Twenty-Fifth Northeastern Linguistics Society.*, 287–302, Amherst, MA: GLSA.

Jacobs, Haike, 1995. 'Optimality Theory and sound change'. In *Proceedings of NELS*, volume 25, available from the Rutgers Optimality Archive as ROA-129.
URL `http://roa.rutgers.edu/view.php3?roa=129`

Jacobs, Haike, 2000. 'The revenge of the uneven trochee: Latin main stress, metrical constituency, stress-related phenomena and OT'. In Aditi Lahiri (ed.), *Analogy, levelling, markedness*, 333–352, Berlin: Mouton de Gruyter.

Jacobs, Haike, 2003. 'Why preantepenultimate stress in Latin requires an OT-account'. In Paula Fikkert & Haike Jacobs (eds.), *Development in Prosodic Systems*, 395–418, Berlin: Mouton de Gruyter.

Jacobs, Haike, 2004. 'Rhythmic vowel deletion in OT: syncope in Latin'. *Probus* 16:63–89.

Jasanoff, J H, 2004. '*Plus ça change. . .*: Lachmann's Law in Latin'. In John H W Penney (ed.), *Indo-European perspectives — studies in honour of Anna Morpurgo Davies*, 405–416, OUP.

Jones, D M, 1950. 'The relation of Latin to Osco-Umbrian'. *Transactions of the Philological Society* 1950:60–87.

Jongman, Allard, Sereno, Joan A, Raaijmakers, Marianne & Lahiri, Aditi, 1992. 'The phonological representation of [voice] in speech perception'. *Language and Speech* 35:137–152.

Joseph, B, 1979. 'Lachmann's law once again'. *Linguistic Inquiry* 10:363–5.

Kager, René, 1999. *Optimality Theory*. Cambridge Textbooks in Linguistics, Cambridge University Press.

Karttunen, Lauri, 1993. 'Finite-state constraints'. In John A Goldsmith (ed.), *The last phonological rule*, 173–194, Chicago University Press.

Karttunen, Lauri, 1998. 'The proper treatment of optimality theory in computational phonology.' In Lauri Karttunen & Kemal Oflazer (eds.), *FSMNLP '98: Proceedings of the International Workshop on Finite-State Methods in Natural Language Processing*, 1–14.

Keating, Patricia A., 1980. *A Phonetic Study of a Voicing Contrast in Polish*. Ph.D. thesis, Brown University.
URL `http://www.linguistics.ucla.edu/people/keating/keating.htm`

Kennedy, Benjamin H., 1962. *The Revised Latin Primer*. Longman.

Kenstowicz, Michael, 2006. 'Generative phonology'. In Keith Brown (ed.), *The encyclopedia of language and linguistics*, Elsevier.

Kenstowicz, Michael J., 1996. 'Base-identity and Uniform Exponence: alternatives to cyclicity'. In Jacques Durand & Bernard Laks (eds.), *Current trends in phonology: models and methods*, ESRI, University of Salford, available from the Rutgers Optimality Archive as ROA-103.
URL `http://roa.rutgers.edu/view.php3?roa=103`

Kent, Roland G, 1928. 'Lachmann's Law of vowel lengthening'. *Language* 4:181–190.

King, Robert D, 1969. *Historical Linguistics and Generative Grammar*. Englewood Cliffs, N J: Prentice Hall.

King, Robert D, 1973. 'Rule insertion'. *Language* 49:551–78.

Kiparsky, Paul, 1965. *Phonological Change*. Ph.D. thesis, MIT, Cambridge, MA, reproduced as a publication of the Indiana University Linguistics Club, 1971.

Kiparsky, Paul, 1973. 'On comparative linguistics: The case of Grassmann's Law'. In *Diachronic, Areal and Typological Linguistics*, *Current Trends in Linguistics*, volume 11, 115–134, The Hague/Paris: Mouton.

Kiparsky, Paul, 1979. 'Metrical structure assignment is cyclic'. *Linguistic Inquiry* 10:421–441.

Kiparsky, Paul, 1982a. *Explanation in phonology*. Dordrecht: Foris.

Kiparsky, Paul, 1982b. 'From Cyclic Phonology to Lexical Phonology'. In Harry van der Hulst & Norval Smith (eds.), *The structure of phonological representations*, Dordrecht: Foris Publications.

Kiparsky, Paul, 1982c. 'Lexical phonology and morphology'. In The Linguistic Society of Korea (ed.), *Linguistics in the morning calm*, 3–91, Seoul: Hanshin.

KIPARSKY, PAUL, 2000a. 'Analogy as optimization: 'exceptions' to Sievers' Law in Gothic'. In Aditi Lahiri (ed.), *Analogy, levelling, markedness*, Berlin: Mouton de Gruyter.

KIPARSKY, PAUL, 2000b. 'Opacity and cyclicity'. *The Linguistic Review* 17:351–365.

KIPARSKY, PAUL, 2008. 'Universals constrain change; change results in typological generalizations.' In Jeff Good (ed.), *Language Universals and Language Change.*, Oxford: OUP, accessed 13th December 2012.

KIPARSKY, PAUL, 2010. 'Reduplication in Stratal OT'. In Linda Uyechi & Lian Hee Wee (eds.), *Reality Exploration and Discovery: Pattern Interaction in Language & Life*, Stanford, CA: CSLI.

KLATT, DENNIS H, 1976. 'Linguistic uses of segmental duration in English: Acoustic and perceptual evidence'. *Journal of the Acoustical Society of America* 59:1208–1221.

KLAUSENBURGER, J, 1979. 'Is Lachmann's law a rule?' *Linguistic Inquiry* 10:362–3.

KORTLANDT, FREDERIK, 1978. 'Proto-Indo-European obstruents'. *Indogermanische Forschungen* 83:107–118.

KORTLANDT, FREDERIK, 1989. 'Lachmann's Law'. In Theo Vennemann (ed.), *The new sound of Indo-European: essays in phonological reconstruction*, Mouton de Gruyter.

KORTLANDT, FREDERIK, 1999. 'Lachmann's Law again'. In *Language Change and Typological Variation: In Honour of Winfred P. Lehmann on the Occasion of His 83rd Birthday*, 30, 246–248, Washington, D.C.: Journal of Indo-European Studies Monograph.

KURYŁOWICZ, JERZY, 1968a. *Indogermanische Grammatik*, volume II. Carl Winter.

KURYŁOWICZ, JERZY, 1968b. 'A remark on Lachmann's Law'. *Harvard Studies in Classical Philology* 72:295–299.

LACHMANN, K, 1850. *T. Lucreti Cari de rerum natura*. Berlin: G. Reimer.

LAHIRI, ADITI, 2001. 'Metrical patterns'. In Martin Haspelmath, Ekkehard König, Wulf Oesterreicher & Wolfgang Raible (eds.), *Language Typology and Language Universals*, volume 2, 1347–1367, Berlin/New York: Walter de Gruyter.

LAHIRI, ADITI & DRESHER, B. ELAN, 1999. 'Open syllable lengthening in West Germanic'. *Language* 75:678–719.

LAHIRI, ADITI & REETZ, HENNING, 2002. 'Underspecified recognition.' In Carlos Gussenhoven & Natasha Warner (eds.), *Laboratory Phonology 7*, 637–676, Berlin: Mouton de Gruyter.

LAHIRI, ADITI & REETZ, HENNING, 2010. 'Distinctive features: Phonological underspecification in representation and processing'. *Journal of Phonetics* 38:44–59.

LAMONTAGNE, GREG & RICE, KEREN, 1995. 'A correspondence account of coalescence'. In Jill N Beckman, Susanne Urbanczyk & Laura Walsh Dickey (eds.), *Papers in Optimality Theory*, *University of Massachusetts Occasional Papers in Linguistics*, volume 18, University of Massachusetts, available from the Rutgers Optimality Archive as ROA-60.
URL `http://roa.rutgers.edu/view.php3?roa=60`

LASS, ROGER, 1971. 'Boundaries as obstruents: Old english voicing assimilation and universal strength hierarchies'. *Journal of Linguistics* 7:15–30.

LEUMANN, MANU, 1969. 'Lat. *disertus*'. In Jacqueline Bibauw (ed.), *Hommages à Marcel Renard*, volume 1, 547–550, Brussels: Latomus.

LEUMANN, MANU, 1977. *Lateinische Laut- und Formenlehre*. 5th edition, Munich: Beck.

LISKER, LEIGH, 1957. 'Closure duration and the intervocalic voiced-voiceless distinction in English'. *Language* 33:42–49.

LLORET, MARIA-ROSA, 1997. 'Sonorant dissimilation in the Iberian languages'. In Fernando Martínez-Gil & Alfonso Morales-Front (eds.), *Issues in the phonology and morphology of the major Iberian languages*, Washington, D.C.: Georgetown University Press.

LOMBARDI, LINDA, 1999. 'Positional faithfulness and voicing assimilation in Optimality Theory'. *Natural Language and Linguistic Theory* 17:267–302.

LOMBARDI, LINDA, 2002. 'Coronal epenthesis and markedness'. *Phonology* 19:219–251.

LOMBARDI, LINDA, 2003. 'Second language data and constraints on manner: explaining substitutions for the English interdentals'. *Second Language Research* 19:225–250.

MADDIESON, IAN, 1984. *Patterns of sounds*. Cambridge University Press.

MADDIESON, IAN, 2011. 'Presence of uncommon consonants'. In Matthew S. Dryer & Martin Haspelmath (eds.), *The World Atlas of Language Structures Online*, Munich: Max Planck Digital Library.
URL `http://wals.info/chapter/19`

MANIET, ALBERT, 1956. 'La "loi de Lachmann" et les antinomies de l'allongement compensatoire'. In *Hommages à Max Niedermann*, number 23 in Collection Latomus, Brussels: Berchem.

MANIET, ALBERT, 1957. *L'évolution phonétique et les sons du latin ancien dans le cadre des langues indo-européennes*. 3rd edition, Louvain/Paris: Nauwelaerts.

MASCARÓ, JOAN, 1996. 'External allomorphy as emergence of the unmarked'. In Jacques Durand & Bernard Laks (eds.), *Current trends in phonology: models and methods*, 76–86, ESRI, University of Salford.

MAYRHOFER, MANFRED, 1986a. 'Die Vertretung der indogermanischen Laryngale im Lateinischen'. *Zeitschrift für vergleichende Sprachforschung* 100:86–108.

MAYRHOFER, MANFRED, 1986b. *Segmentale Phonologie des Indogermanischen*, *Indogermanische Grammatik*, volume I, chapter 2, 73–186. Carl Winter.

MCCARTHY, JOHN J, 1999. 'Sympathy and phonological opacity'. *Phonology* 16:331–399.

MCCARTHY, JOHN J, 2002. *A thematic guide to Optimality Theory*. Cambridge: CUP.

MCCARTHY, JOHN J, 2010. 'Agreement by correspondence without CORR constraints'. The Selected Works of John McCarthy.
URL `http://works.bepress.com/john_j_mccarthy/106/`

MCCARTHY, JOHN J & PRINCE, ALAN, 1993. 'Generalized alignment'. In Geert Booij & Jaap van Marle (eds.), *Yearbook of Morphology*, 79–153, Dordrecht: Kluwer, available from the Rutgers Optimality Archive as ROA-7.
URL `http://roa.rutgers.edu/view.php3?roa=7`

MCCARTHY, JOHN J. & PRINCE, ALAN, 1995. 'Faithfulness and reduplicative identity'. In Jill N Beckman, Susanne Urbanczyk & Laura Walsh Dickey (eds.), *Papers in Optimality Theory*, *University of Massachusetts Occasional Papers in Linguistics*, volume 18, 249–384, University of Massachusetts, available from the Rutgers Optimality Archive as ROA-60.
URL `http://roa.rutgers.edu/view.php3?roa=60`

MCCARTHY, JOHN J & PRINCE, ALAN, 1999. 'Faithfulness and identity in prosodic morphology'. In René Kager, Harry van der Hulst & Wim Zonneveld (eds.), *The prosody-morphology interface*, 218–309, Cambridge: CUP.
URL `http://roa.rutgers.edu/view.php3?id=216`

MEILLET, ANTOINE, 1908. 'Sur la quantité des voyelles fermées'. *Mémoires de la Société de linguistique de Paris* 15:265–272.

MEISER, GERHARD, 1998. *Historische Laut- und Formenlehre der lateinischen Sprache*. Darmstadt: Wissenschaftliche Buchgesellschaft.

MORETON, ELLIOT, 2004. 'Realization of English postvocalic [voice] contrast in F1 and F2'. *Journal of Phonetics* 32:1–33.

MORPURGO DAVIES, ANNA, 1979. 'Review of Strunk (1976)'. *Classical Review* 29:259–260.

Niedermann, Max, 1911. *Historische Lautlehre des Lateinischen.* 2nd edition, Heidelberg: Winter.

Niedermann, Max, 1953. *Précis de phonétique historique du latin.* 3rd edition, Paris: Klincksieck.

Ohala, John J, 1973. 'Experimental historical phonology'. In John M Anderson & Charles Jones (eds.), *Historical linguistics: proceedings of the first International Conference on Historical Linguistics, Edinburgh, 2nd-7th September 1973*, volume 2, 353–387, Amsterdam: North-Holland.

Ohala, John J., 1989. 'Sound change is drawn from a pool of synchronic variation'. In L. E. Breivik & E. H. Jahr (eds.), *Language Change: Contributions to the study of its causes.*, Mouton de Gruyter.

Ohala, John J., 1992. 'What's cognitive, what's not, in sound change.' In Günter Kellerman & Michael D. Morrissey (eds.), *Diachrony within synchrony: Language history and cognition.*, Peter Lang Verlag.

Ohala, John J, 1993. 'The phonetics of sound change'. In Charles Jones (ed.), *Historical Linguistics: problems and perspectives*, 237–278, London: Longman.

Oliver, Revilo P., 1966. 'Apex and sicilicus'. *The American Journal of Philology* 87:129–170.

Osthoff, Herman, 1884. *Zur Geschichte des Perfects im Indogermanischen.* Trübner.

Paradis, Carole & Prunet, François, 1991. *The special status of coronals: internal and external evidence.* Academic Press.

Pedersen, Holger, 1896. 'Bartholomaes aspirativlov og lachmanns tydning af gellius ix 6 og xii 3'. *Nordisk Tidskrift for Filologi* 5:28–38.

Perini, Mário A, 1978. 'The latest note on Lachmann's Law'. *Linguistic Inquiry* 9:144–146.

Prince, Alan & Smolensky, Paul, 1993. 'Optimality Theory: constraint interaction in generative grammar.', Rutgers University Center for Cognitive Science technical report 2, version of 8/2002. Available from the Rutgers Optimality Archive as ROA-537.
URL `http://roa.rutgers.edu/view.php3?roa=537`

Pullum, Geoffrey K, 1989. 'Formal linguistics meets the boojum'. *Natural Language and Linguistic Theory* 7:137–143.

Rei, Fukui, 1996. 'TIPA: a system for processing phonetic symbols in LaTeX'. *TUGboat* 17:102–114.
URL `http://www.tug.org/TUGboat/tb17-2/tb51rei.pdf`

REIS, MARGA, 1970. *Lauttheorie und Lautgeschichte. Untersuchungen am Beispiel der Dehnungs- und Kürzungsvorgänge im Deutschen.* Ph.D. thesis, LMU Munich.

RIGGLE, JASON, 2004a. 'Contenders and learning'. In Benjamin Schmeiser, Vineeta Chand, Ann Kelleher & Angelo Rodriguez (eds.), *WCCFL 23: Proceedings of the 23rd West Coast Conference on Formal Linguistics*, 101–114, Somerville, MA: Cascadilla Press.

RIGGLE, JASON, 2004b. *Generation Recognition and Learning in Finite State Optimality Theory.* Ph.D. thesis, University of California, Los Angeles. URL `http://www.linguistics.ucla.edu/research/55-ucla-phd-dissertations.html`

RINGE, DONALD A., 1988. 'Laryngeal isoglosses in the western Indo-European languages'. In Alfred Bammesberger (ed.), *Die Laryngaltheorie und die Rekonstruktion des indogermanischen Laut- und Formensystems*, Carl Winter.

RINGE, DONALD A., 2006. *From Proto-Indo-European to Proto-Germanic.* Oxford: OUP.

RIX, HELMUT, 1957. 'Sabini. Sabelli. Samnium: ein Beitrag zur Lautgeschichte der Sprachen Altitaliens.' *Beiträge zur Namenforschung* 8:127–43.

RIX, HELMUT, 1994. 'Latein und Sabellisch. Stammbaum und/oder Sprachbund?' *Incontri linguistici* 17:13–29.

RIX, HELMUT & KÜMMEL, MARTIN, 2001. *Lexikon der indogermanischen Verben: die Wurzeln und ihre Primärstammbildungen.* Wiesbaden: Ludwig Reichert.

ROLFE, JOHN C., 1922. 'The use of devices for indicating vowel length in Latin'. *Proceedings of the American Philosophical Society* 61:80–98.

ROSE, SHARON & WALKER, RACHEL, 2004. 'A typology of consonant agreement as correspondence'. *Language* 80:475–531.

SCHRIJVER, PETER, 1991. *The reflexes of the Proto-Indo-European laryngeals in Latin.* Leiden Studies in Indo-European, Rodopi.

SEN, RANJAN, 2012. 'Exon's law and the latin syncopes'. In Philomen Probert & Andreas Willi (eds.), *Laws and Rules in Indo-European*, Oxford: OUP.

SERBAT, GUY, 1968. 'Indo-européen *-*dh*-, latin *-b-/-d- (stabulum, aedes)*'. *Revue de philologie, de littérature et d'histoire anciennes* 42:78–90.

SIHLER, ANDREW L, 1995. *New comparative grammar of Greek and Latin.* Oxford University Press.

SMOLENSKY, PAUL, 1993. 'Harmony, markedness & phonological activity', handout from Rutgers Optimality Workshop 1. Available from the Rutgers Optimality Archive as ROA-87.
URL `http://roa.rutgers.edu/view.php3?roa=87`

SOMMER, FERDINAND, 1914. *Handbuch der lateinischen Laut- und Formenlehre: eine Einführung in das sprachwissenschaftliche Studium des Lateins*. 2nd edition, Heidelberg: Winter.

STEPHENS, L, 1979. 'Once again Lachmann's Law'. *Linguistic Inquiry* 10:365–9.

STERIADE, DONCA, 1987. 'Redundant values'. In Barbara Need, Eric Schiller & Anna Bosch (eds.), *CLS 23: papers from the 23rd Annual Regional Meeting of the Chicago Linguistic Society / Chicago Linguistic Society*, 339–362, Chicago Linguistic Society.

STERIADE, DONCA, 2000. 'Paradigm uniformity and the phonetics/phonology boundary'. In Janet Pierrehumbert & M Broe (eds.), *Papers in Laboratory Phonology, vol. 6*, Cambridge: Cambridge University Press.

STERIADE, DONCA, 2009. 'The phonology of perceptibility effects: The P-map and its consequences for constraint organization'. In Kristin Hanson & Sharon Inkelas (eds.), *The Nature of the Word: Studies in Honor of Paul Kiparsky*, 151–181, Cambridge, Massachusetts and London: MIT Press.

STRUNK, KLAUS, 1976. *Lachmanns Regel für das Lateinische: eine Revision*. Number 26 in Ergänzungshefte zur Zeitschrift für vergleichende Sprachforschung, Göttingen: Vandenhoeck & Ruprecht.

STUART-SMITH, JANE, 2004. *Phonetics and philology: sound change in Italic*. Oxford: OUP.

STURTEVANT, EDGAR H., 1940. *The Pronunciation of Greek and Latin*. William Dwight Witney Linguistic Series, 2nd edition, Philadelphia: The Linguistic Society of America.

SUZUKI, KEIICHIRO, 1998. *A typological investigation of dissimilation*. Ph.D. thesis, University of Arizona, available from the Rutgers Optimality Archive as ROA-281.
URL `http://roa.rutgers.edu/view.php?roa=281`

SWIGGERS, PIERRE, 1989. '(the nature of) the Indo-European laryngeals: review.' In Theo Vennemann (ed.), *The new sound of Indo-European: essays in typological reconstruction.*, Mouton de Gruyter.

TESAR, BRUCE & SMOLENSKY, PAUL, 1996. 'Learnability in Optimality Theory'. Technical Report JHU-CogSci-96-3, Rutgers University Centre for Cognitive Science, available from the Rutgers Optimality Archive as ROA-156.
URL `http://roa.rutgers.edu/view.php3?roa=156`

TESAR, BRUCE & SMOLENSKY, PAUL, 1998. 'Learnability in Optimality Theory'. *Linguistic Inquiry* 29:229–268.

THE INTERNATIONAL PHONETIC ASSOCIATION, 1999. *Handbook of the International Phonetic Association*. Cambridge University Press.

THURNEYSEN, RUDOLF, 1883. 'Urspr. *dn tn cn* im lateinischen'. *Zeitschrift für vergleichende Sprachforschung* 26:301–314.

TOURATIER, CHRISTIAN, 1975. 'Rhotacisme Synchronique du latin classique et Rhotacisme diachronique'. *Glotta* 53:246–281.

TSIAPERA, MÁRIA (ed.), 1971. *Generative studies in historical linguistics*. Linguistic Research.

UNTERMANN, JÜRGEN, 2000. *Wörterbuch des Oskisch-Umbrischen*, *Handbuch der Italischen Dialekte*, volume 3. Heidelberg: Carl Winter.

VANHOVE, MARTINE, 2008. *From polysemy to semantic change: towards a typology of lexical semantic associations*. Number 106 in Studies in language companion series, Amsterdam/Philadelphia: John Benjamins.

VENNEMANN, THEO (ed.), 1989. *The new sound of Indo-European: essays in phonological reconstruction.*, *Trends in Linguistics: Studies and Monographs*, volume 41. Mouton de Gruyter.

VERNER, KARL, 1877. 'Eine Ausnahme der ersten Lautverschiebung'. *Zeitschrift für vergleichende Sprachforschung* 23:97–130.

VON PLANTA, ROBERT, 1892. *Grammatik der oskisch-umbrischen Dialekte*. Strasbourg: K. J. Trübner.

WATKINS, CALVERT, 1962. *Indo-European origins of the Celtic verb*. Dublin University Press.

WATKINS, CALVERT, 1970a. 'A case of non-chronological rule insertion'. *Linguistic Inquiry* 1:525–527.

WATKINS, CALVERT, 1970b. 'A further remark on Lachmann's Law'. *Harvard Studies in Classical Philology* 74:55–65, also reprinted in Tsiapera (1971: pp. 73–87).

WEISS, MICHAEL, 2009. *Outline of the Historical and Comparative Grammar of Latin*. Ann Arbor/New York: Beech Stave Press.

WELLS, JOHN C., 1990. 'Syllabification and allophony'. In *Studies in the pronunciation of English*, 76–86, New York/London: Routledge.
URL `http://phon.ucl.ac.uk/home/wells/syllabif.htm`

WELLS, JOHN C., 1997. 'SAMPA computer readable phonetic alphabet'. In Dafydd Gibbon, Roger Moore & Richard Winski (eds.), *Handbook of Standards and Resources for Spoken Language Systems*, Berlin: Mouton de Gruyter, part IV, Section B.
URL `www.phon.ucl.ac.uk/home/sampa`

WESTBURY, JOHN R. & KEATING, PATRICIA A., 1986. 'On the naturalness of stop consonant voicing'. *Journal of Linguistics* 22:145–166.

WETZELS, W LEO & JACOBS, HAIKE, 1988. 'Early french lenition. a formal account of an integrated sound change'. In Harry van der Hulst & Norval Smith (eds.), *Feature Specification and Segmental Structure*, 105–129, Dordrecht: Foris.

WILLI, ANDREAS, 2010. 'The Umbrian perfect in **-nç-**/*-nś̀-*'. *Transactions of the Philological Society* 108:1–14.

WOLF, MATTHEW, to appear. 'Lexical insertion occurs in the phonological component'. In Bernard Tranel (ed.), *Understanding Allomorphy: Perspectives from Optimality Theory*, Sheffield: Equinox, available from the Rutgers Optimality Archive as ROA-912.
URL `http://roa.rutgers.edu/`

WRIGHT, JOSEPH, 1908. *Old English Grammar*. London: Oxford University Press.

Towards a computer model of the historical phonology and morphology of Latin.

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Appendices

Appendix A

Latin sound changes query report

Lachmann's Law

Forms with lengthening

Attested form: *agit* [ˈa.gɪ̞t] 'drive-3SG.PRES'

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$agɪ]t/ →	[a.gɪ]	[(ˈa.gɪt)]	[a.gɪt]
D. stage 2:	/[$_{stem}$agɪ]t/ →	[a.gɪ]	[(ˈa.gɪt)]	[a.gɪt]
D. stage 3:	/[$_{stem}$agɪ̞]t/ →	[a.gɪ̞]	[(ˈa.gɪ̞t)]	[a.gɪ̞t]
D. stage 4:	/[$_{stem}$agɪ̞]t/ →	[a.gɪ̞]	[(ˈa.gɪ̞t)]	[a.gɪ̞t]

Attested form: *egit* [ˈeː.gɪ̞t] 'drive-3SG.PRF'

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$eːg]eɪt/ →	[eːg]	[(ˈeː)geɪt]	[eː.geɪt]
D. stage 2:	/[$_{stem}$eːg]eɪt/ →	[eːg]	[(ˈeː)gɪːt]	[eː.gɪːt]
D. stage 3:	/[$_{stem}$eːg]ɪ̞ːt/ →	[eːg]	[(ˈeː)giːt]	[eː.giːt]
D. stage 4:	/[$_{stem}$eːg]iːt/ →	[eːg]	[(ˈeː)gɪ̞t]	[eː.gɪ̞t]

Attested form: *actus* [ˈaːk.tʊ̞s] 'drive-PRF.PTCP-NOM.SG.M'

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$agto]s/ →	[aːg.to]	[(ˈaːk)tos]	[aːk.tos]
D. stage 2:	/[$_{stem}$aːgto]s/ →	[aːg.to]	[(ˈaːk)tos]	[aːk.tos]
D. stage 3:	/[$_{stem}$aːgtʊ̞]s/ →	[aːg.tʊ̞]	[(ˈaːk)tʊ̞s]	[aːk.tʊ̞s]
D. stage 4:	/[$_{stem}$aːgtʊ̞]s/ →	[aːg.tʊ̞]	[(ˈaːk)tʊ̞s]	[aːk.tʊ̞s]

Attested form: *frangit* [ˈfraŋ.gɪ̞t] 'break-3SG.PRES'

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸraŋgɪ]t/ →	[ɸraŋ.gɪ]	[(ˈɸraŋ)gɪt]	[ɸraŋ.gɪt]
D. stage 2:	/[$_{stem}$ɸraŋgɪ]t/ →	[ɸraŋ.gɪ]	[(ˈfraŋ)gɪt]	[fraŋ.gɪt]
D. stage 3:	/[$_{stem}$fraŋgɪ̞]t/ →	[fraŋ.gɪ̞]	[(ˈfraŋ)gɪ̞t]	[fraŋ.gɪ̞t]
D. stage 4:	/[$_{stem}$fraŋgɪ̞]t/ →	[fraŋ.gɪ̞]	[(ˈfraŋ)gɪ̞t]	[fraŋ.gɪ̞t]

Attested form: *fregit* [ˈfreː.gɪ̞t] 'break-3SG.PRF'

	Input	Stem Level	Word Level	Phrase Level

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸreːg]eɪt/ →	[ɸreːg]	[(ˈɸreː)geɪt]	[ɸreː.geɪt]
D. stage 2:	/[$_{stem}$ɸreːg]eɪt/ →	[ɸreːg]	[(ˈfreː)gɪːt]	[freː.gɪːt]
D. stage 3:	/[$_{stem}$freːg]ɪ̞ːt/ →	[freːg]	[(ˈfreː)giːt]	[freː.giːt]
D. stage 4:	/[$_{stem}$freːg]iːt/ →	[freːg]	[(ˈfreː)gɪ̞t]	[freː.gɪ̞t]

Attested form: *fractus* [ˈfraːk.tʊ̞s] ‘break-PRF.PTCP-NOM.SG.M’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸragto]s/ →	[ɸraːg.to]	[(ˈɸraːk)tos]	[ɸraːk.tos]
D. stage 2:	/[$_{stem}$ɸraːgto]s/ →	[ɸraːg.to]	[(ˈfraːk)tos]	[fraːk.tos]
D. stage 3:	/[$_{stem}$fraːgtʊ̞]s/ →	[fraːg.tʊ̞]	[(ˈfraːk)tʊ̞s]	[fraːk.tʊ̞s]
D. stage 4:	/[$_{stem}$fraːgtʊ̞]s/ →	[fraːg.tʊ̞]	[(ˈfraːk)tʊ̞s]	[fraːk.tʊ̞s]

Attested form: *tangit* [ˈtaŋ.gɪ̞t] ‘touch-3SG.PRES’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$taŋgɪ]t/ →	[taŋ.gɪ]	[(ˈtaŋ)gɪt]	[taŋ.gɪt]
D. stage 2:	/[$_{stem}$taŋgɪ]t/ →	[taŋ.gɪ]	[(ˈtaŋ)gɪt]	[taŋ.gɪt]
D. stage 3:	/[$_{stem}$taŋgɪ̞]t/ →	[taŋ.gɪ̞]	[(ˈtaŋ)gɪ̞t]	[taŋ.gɪ̞t]
D. stage 4:	/[$_{stem}$taŋgɪ̞]t/ →	[taŋ.gɪ̞]	[(ˈtaŋ)gɪ̞t]	[taŋ.gɪ̞t]

Attested form: *tetigit* [ˈte.tɪ̞.gɪ̞t] ‘touch-3SG.PRF’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$REDtag]eɪt/ →	[te.tag]	[(ˈte.ta)geɪt]	[te.ta.geɪt]
D. stage 2:	/[$_{stem}$REDtag]eɪt/ →	[te.tag]	[(ˈte.ta)gɪːt]	[te.ta.gɪːt]
D. stage 3:	/[$_{stem}$te.tɪ̞g]ɪ̞ːt/ →	[te.tɪ̞g]	[(ˈte.tɪ̞)giːt]	[te.tɪ̞.giːt]
D. stage 4:	/[$_{stem}$te.tɪ̞g]iːt/ →	[te.tɪ̞g]	[(ˈte.tɪ̞)gɪ̞t]	[te.tɪ̞.gɪ̞t]

Attested form: *contigit* [ˈkon.tɪ̞.gɪ̞t] ‘reach-3SG.PRF’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/kom[$_{stem}$REDtag]eɪt/ →	[te.tag]	[(ˈkom)(ˌte.ta)geɪt]	[kom.te.ta.geɪt]
D. stage 2:	/kon[$_{stem}$REDtag]eɪt/ →	[te.tag]	[(ˈkon)(ˌte.ta)gɪːt]	[kon.te.ta.gɪːt]
D. stage 3:	/kon[$_{stem}$ttɪ̞g]ɪ̞ːt/ →	[tːɪ̞g]	[(ˈkont.tɪ̞)giːt]	[kont.tɪ̞.giːt]
D. stage 4:	/kon[$_{stem}$ttɪ̞g]iːt/ →	[tːɪ̞g]	[(ˈkon.tɪ̞)gɪ̞t]	[kon.tɪ̞.gɪ̞t]

Attested form: *tactus* [ˈtaːk.tʊ̞s] ‘touch-PRF.PTCP-NOM.SG.M’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$tagto]s/ →	[taːg.to]	[(ˈtaːk)tos]	[taːk.tos]
D. stage 2:	/[$_{stem}$taːgto]s/ →	[taːg.to]	[(ˈtaːk)tos]	[taːk.tos]
D. stage 3:	/[$_{stem}$taːgtʊ̞]s/ →	[taːg.tʊ̞]	[(ˈtaːk)tʊ̞s]	[taːk.tʊ̞s]
D. stage 4:	/[$_{stem}$taːgtʊ̞]s/ →	[taːg.tʊ̞]	[(ˈtaːk)tʊ̞s]	[taːk.tʊ̞s]

Attested form: *pangit* [ˈpaŋ.gɪ̞t] ‘fix-3SG.PRES’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$paŋgɪ]t/ →	[paŋ.gɪ]	[(ˈpaŋ)gɪt]	[paŋ.gɪt]
D. stage 2:	/[$_{stem}$paŋgɪ]t/ →	[paŋ.gɪ]	[(ˈpaŋ)gɪt]	[paŋ.gɪt]
D. stage 3:	/[$_{stem}$paŋgɪ̞]t/ →	[paŋ.gɪ̞]	[(ˈpaŋ)gɪ̞t]	[paŋ.gɪ̞t]
D. stage 4:	/[$_{stem}$paŋgɪ̞]t/ →	[paŋ.gɪ̞]	[(ˈpaŋ)gɪ̞t]	[paŋ.gɪ̞t]

Attested form: *pepigit* [ˈpe.pɪ̞.gɪ̞t] ‘fix-3SG.PRF’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$REDpag]eɪt/ →	[pe.pag]	[(ˈpe.pa)geɪt]	[pe.pa.geɪt]
D. stage 2:	/[$_{stem}$REDpag]eɪt/ →	[pe.pag]	[(ˈpe.pa)gɪːt]	[pe.pa.gɪːt]
D. stage 3:	/[$_{stem}$pe.pɪ̝g]ɪ̝ːt/ →	[pe.pɪ̝g]	[(ˈpe.pɪ̝)giːt]	[pe.pɪ̝.giːt]
D. stage 4:	/[$_{stem}$pe.pɪ̝g]iːt/ →	[pe.pɪ̝g]	[(ˈpe.pɪ̝)gɪ̝t]	[pe.pɪ̝.gɪ̝t]

Attested form: *compegit* [ˌkom.ˈpeː.git] ‘join-3SG.PRF’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/kom[$_{stem}$REDpag]eɪt/ →	[pe.pag]	[(ˈkom)(ˌpe.pa)geɪt]	[kom.pe.pa.geɪt]
D. stage 2:	/kom[$_{stem}$REDpag]eɪt/ →	[pe.pag]	[(ˈkom)(ˌpe.pa)gɪːt]	[kom.pe.pa.gɪːt]
D. stage 3:	/kom[$_{stem}$peːg]ɪ̝ːt/ →	[peːg]	[(ˌkom)(ˈpeː)giːt]	[kom.peː.giːt]
D. stage 4:	/kom[$_{stem}$peːg]iːt/ →	[peːg]	[(ˌkom)(ˈpeː)gɪ̝t]	[kom.peː.gɪ̝t]

Attested form: *pactus* [ˈpaːk.tʊ̝s] ‘fix-PRF.PTCP-NOM.SG.M’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$pagto]s/ →	[paːg.to]	[(ˈpaːk)tos]	[paːk.tos]
D. stage 2:	/[$_{stem}$paːgto]s/ →	[paːg.to]	[(ˈpaːk)tos]	[paːk.tos]
D. stage 3:	/[$_{stem}$paːgtʊ̝]s/ →	[paːg.tʊ̝]	[(ˈpaːk)tʊ̝s]	[paːk.tʊ̝s]
D. stage 4:	/[$_{stem}$paːgtʊ̝]s/ →	[paːg.tʊ̝]	[(ˈpaːk)tʊ̝s]	[paːk.tʊ̝s]

Attested form: *regit* [ˈre.gɪ̝t] ‘rule-3SG.PRES’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$regɪ]t/ →	[re.gɪ]	[(ˈre.gɪt)]	[re.gɪt]
D. stage 2:	/[$_{stem}$regɪ]t/ →	[re.gɪ]	[(ˈre.gɪt)]	[re.gɪt]
D. stage 3:	/[$_{stem}$regɪ̝]t/ →	[re.gɪ̝]	[(ˈre.gɪ̝t)]	[re.gɪ̝t]
D. stage 4:	/[$_{stem}$regɪ̝]t/ →	[re.gɪ̝]	[(ˈre.gɪ̝t)]	[re.gɪ̝t]

Attested form: *rexit* [ˈreːk.sɪ̝t] ‘rule-3SG.PRF’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$reːgs]eɪt/ →	[reːgs]	[(ˈreːk)seɪt]	[reːk.seɪt]
D. stage 2:	/[$_{stem}$reːgs]eɪt/ →	[reːgs]	[(ˈreːk)sɪːt]	[reːk.sɪːt]
D. stage 3:	/[$_{stem}$reːgs]ɪ̝ːt/ →	[reːgs]	[(ˈreːk)siːt]	[reːk.siːt]
D. stage 4:	/[$_{stem}$reːgs]ɪ̝ːt/ →	[reːgs]	[(ˈreːk)sɪ̝t]	[reːk.sɪ̝t]

Attested form: *rectus* [ˈreːk.tʊ̝s] ‘rule-PRF.PTCP-NOM.SG.M’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$regto]s/ →	[reːg.to]	[(ˈreːk)tos]	[reːk.tos]
D. stage 2:	/[$_{stem}$reːgto]s/ →	[reːg.to]	[(ˈreːk)tos]	[reːk.tos]
D. stage 3:	/[$_{stem}$reːgtʊ̝]s/ →	[reːg.tʊ̝]	[(ˈreːk)tʊ̝s]	[reːk.tʊ̝s]
D. stage 4:	/[$_{stem}$reːgtʊ̝]s/ →	[reːg.tʊ̝]	[(ˈreːk)tʊ̝s]	[reːk.tʊ̝s]

Attested form: *tegit* [te.gɪ̝t] ‘cover-3SG.PRES’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$tegɪ]t/ →	[te.gɪ]	[(ˈte.gɪt)]	[te.gɪt]
D. stage 2:	/[$_{stem}$tegɪ]t/ →	[te.gɪ]	[(ˈte.gɪt)]	[te.gɪt]
D. stage 3:	/[$_{stem}$tegɪ̝]t/ →	[te.gɪ̝]	[(ˈte.gɪ̝t)]	[te.gɪ̝t]
D. stage 4:	/[$_{stem}$tegɪ̝]t/ →	[te.gɪ̝]	[(ˈte.gɪ̝t)]	[te.gɪ̝t]

Attested form: *texit* [ˈteːk.sɪ̯t] ‘cover-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$teːgs]eɪt/ →	[teːgs]	[(ˈteːk)seɪt]	[teːk.seɪt]
D. stage 2:	/[$_{stem}$teːgs]eɪt/ →	[teːgs]	[(ˈteːk)sɪːt]	[teːk.sɪːt]
D. stage 3:	/[$_{stem}$teːgs]ɪ̯ːt/ →	[teːgs]	[(ˈteːk)siːt]	[teːk.siːt]
D. stage 4:	/[$_{stem}$teːgs]iːt/ →	[teːgs]	[(ˈteːk)sɪ̯t]	[teːk.sɪ̯t]

Attested form: *tectus* [ˈteːk.tʊ̯s] ‘cover-PRF.PTCP-NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$tegto]s/ →	[teːg.to]	[(ˈteːk)tos]	[teːk.tos]
D. stage 2:	/[$_{stem}$teːgto]s/ →	[teːg.to]	[(ˈteːk)tos]	[teːk.tos]
D. stage 3:	/[$_{stem}$teːgtʊ̯]s/ →	[teːg.tʊ̯]	[(ˈteːk)tʊ̯s]	[teːk.tʊ̯s]
D. stage 4:	/[$_{stem}$teːgtʊ̯]s/ →	[teːg.tʊ̯]	[(ˈteːk)tʊ̯s]	[teːk.tʊ̯s]

Attested form: *legit* [ˈle.gɪ̯t] ‘read-3SG.PRES’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$legɪ]t/ →	[le.gɪ]	[(ˈle.gɪt)]	[le.gɪt]
D. stage 2:	/[$_{stem}$legɪ]t/ →	[le.gɪ]	[(ˈle.gɪt)]	[le.gɪt]
D. stage 3:	/[$_{stem}$legɪ̯]t/ →	[le.gɪ̯]	[(ˈle.gɪ̯t)]	[le.gɪ̯t]
D. stage 4:	/[$_{stem}$legɪ̯]t/ →	[le.gɪ̯]	[(ˈle.gɪ̯t)]	[le.gɪ̯t]

Attested form: *legit* [ˈleː.gɪ̯t] ‘read-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$leːg]eɪt/ →	[leːg]	[(ˈleː)geɪt]	[leː.geɪt]
D. stage 2:	/[$_{stem}$leːg]eɪt/ →	[leːg]	[(ˈleː)gɪːt]	[leː.gɪːt]
D. stage 3:	/[$_{stem}$leːg]ɪ̯ːt/ →	[leːg]	[(ˈleː)giːt]	[leː.giːt]
D. stage 4:	/[$_{stem}$leːg]iːt/ →	[leːg]	[(ˈleː)gɪ̯t]	[leː.gɪ̯t]

Attested form: *lectus* [ˈleːk.tʊ̯s] ‘read-PRF.PTCP-NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$legto]s/ →	[leːg.to]	[(ˈleːk)tos]	[leːk.tos]
D. stage 2:	/[$_{stem}$leːgto]s/ →	[leːg.to]	[(ˈleːk)tos]	[leːk.tos]
D. stage 3:	/[$_{stem}$leːgtʊ̯]s/ →	[leːg.tʊ̯]	[(ˈleːk)tʊ̯s]	[leːk.tʊ̯s]
D. stage 4:	/[$_{stem}$leːgtʊ̯]s/ →	[leːg.tʊ̯]	[(ˈleːk)tʊ̯s]	[leːk.tʊ̯s]

Attested form: *tundit* [ˈtʊ̯n.dit] ‘bruise-3SG.PRES’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$tundɪ]t/ →	[tun.dɪ]	[(ˈtun)dɪt]	[tun.dɪt]
D. stage 2:	/[$_{stem}$tundɪ]t/ →	[tun.dɪ]	[(ˈtun)dɪt]	[tun.dɪt]
D. stage 3:	/[$_{stem}$tundɪ̯]t/ →	[tun.dɪ̯]	[(ˈtʊ̯n)dɪ̯t]	[tʊ̯n.dɪ̯t]
D. stage 4:	/[$_{stem}$tʊ̯ndɪ̯]t/ →	[tʊ̯n.dɪ̯]	[(ˈtʊ̯n)dɪ̯t]	[tʊ̯n.dɪ̯t]

Attested form: *tutudit* [ˈtʊ̯.tʊ̯.dɪ̯t] ‘bruise-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$REDtud]eɪt/ →	[te.tud]	[(ˈte.tu)deɪt]	[te.tu.deɪt]
D. stage 2:	/[$_{stem}$REDtud]eɪt/ →	[tu.tud]	[(ˈtu.tu)dɪːt]	[tu.tu.dɪːt]
D. stage 3:	/[$_{stem}$tʊ̯.tʊ̯d]ɪ̯ːt/ →	[tʊ̯.tʊ̯d]	[(ˈtʊ̯.tʊ̯)diːt]	[tʊ̯.tʊ̯.diːt]

D. stage 4:	/[$_{stem}$tʊ̝.tʊ̝d]iːt/ →	[tʊ̝.tʊ̝d]	[(ˈtʊ̝.tʊ̝)dɪ̝t]	[tʊ̝.tʊ̝.dɪ̝t]

Attested form: *contudit* [ˈkon.tʊ̝.dɪ̝t] ‘pound-3SG.PRF’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/kom[$_{stem}$REDtud]eɪt/ →	[te.tud]	[(ˈkom)(ˌte.tu)deɪt]	[kom.te.tu.deɪt]
D. stage 2:	/kon[$_{stem}$REDtud]eɪt/ →	[tu.tud]	[(ˈkon)(ˌtu.tu)dɪːt]	[kon.tu.tu.dɪːt]
D. stage 3:	/kon[$_{stem}$ttʊ̝d]ɪ̝ːt/ →	[tːʊ̝d]	[(ˈkont.tʊ̝)diːt]	[kont.tʊ̝.diːt]
D. stage 4:	/kon[$_{stem}$ttʊ̝d]iːt/ →	[tːʊ̝d]	[(ˈkon.tʊ̝)dɪ̝t]	[kon.tʊ̝.dɪ̝t]

Attested form: *tusus* [ˈtuː.sʊ̝s] ‘bruise-PRF.PTCP-NOM.SG.M’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$tudso]s/ →	[tuːd.so]	[(ˈtuːs)sos]	[tuːs.sos]
D. stage 2:	/[$_{stem}$tuːsso]s/ →	[tuːs.so]	[(ˈtuːs)sos]	[tuːs.sos]
D. stage 3:	/[$_{stem}$tuːssʊ̝]s/ →	[tuːs.sʊ̝]	[(ˈtuːs)sʊ̝s]	[tuːs.sʊ̝s]
D. stage 4:	/[$_{stem}$tuːssʊ̝]s/ →	[tuːs.sʊ̝]	[(ˈtuːs)sʊ̝s]	[tuːs.sʊ̝s]

Attested form: *fundit* [ˈfʊ̝n.dit] ‘pour-3SG.PRES’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$fundɪ]t/ →	[fun.dɪ]	[(ˈfun)dɪt]	[fun.dɪt]
D. stage 2:	/[$_{stem}$fundɪ]t/ →	[fun.dɪ]	[(ˈfun)dɪt]	[fun.dɪt]
D. stage 3:	/[$_{stem}$fʊ̝ndɪ̝]t/ →	[fʊ̝n.dɪ̝]	[(ˈfʊ̝n)dɪ̝t]	[fʊ̝n.dɪ̝t]
D. stage 4:	/[$_{stem}$fʊ̝ndɪ̝]t/ →	[fʊ̝n.dɪ̝]	[(ˈfʊ̝n)dɪ̝t]	[fʊ̝n.dɪ̝t]

Attested form: *fudit* [ˈfuː.dɪ̝t] ‘pour-3SG.PRF’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$fuːd]eɪt/ →	[fuːd]	[(ˈfuː)deɪt]	[fuː.deɪt]
D. stage 2:	/[$_{stem}$fuːd]eɪt/ →	[fuːd]	[(ˈfuː)dɪːt]	[fuː.dɪːt]
D. stage 3:	/[$_{stem}$fuːd]ɪ̝ːt/ →	[fuːd]	[(ˈfuː)diːt]	[fuː.diːt]
D. stage 4:	/[$_{stem}$fuːd]iːt/ →	[fuːd]	[(ˈfuː)dɪ̝t]	[fuː.dɪ̝t]

Attested form: *fusus* [ˈfuː.sʊ̝s] ‘pour-PRF.PTCP-NOM.SG.M’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$fudso]s/ →	[fuːd.so]	[(ˈfuːs)sos]	[fuːs.sos]
D. stage 2:	/[$_{stem}$fuːsso]s/ →	[fuːs.so]	[(ˈfuːs)sos]	[fuːs.sos]
D. stage 3:	/[$_{stem}$fuːssʊ̝]s/ →	[fuːs.sʊ̝]	[(ˈfuːs)sʊ̝s]	[fuːs.sʊ̝s]
D. stage 4:	/[$_{stem}$fuːssʊ̝]s/ →	[fuːs.sʊ̝]	[(ˈfuːs)sʊ̝s]	[fuːs.sʊ̝s]

Attested form: *cadit* [ˈka.dɪ̝t] ‘fall-3SG.PRES’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$kadɪ]t/ →	[ka.dɪ]	[(ˈka.dɪt)]	[ka.dɪt]
D. stage 2:	/[$_{stem}$kadɪ]t/ →	[ka.dɪ]	[(ˈka.dɪt)]	[ka.dɪt]
D. stage 3:	/[$_{stem}$kadɪ̝]t/ →	[ka.dɪ̝]	[(ˈka.dɪ̝t)]	[ka.dɪ̝t]
D. stage 4:	/[$_{stem}$kadɪ̝]t/ →	[ka.dɪ̝]	[(ˈka.dɪ̝t)]	[ka.dɪ̝t]

Attested form: *cecidit* [ˈke.kɪ̝.dɪ̝t] ‘fall-3SG.PRF’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$REDkad]eɪt/ →	[ke.kad]	[(ˈke.ka)deɪt]	[ke.ka.deɪt]
D. stage 2:	/[$_{stem}$REDkad]eɪt/ →	[ke.kad]	[(ˈke.ka)dɪːt]	[ke.ka.dɪːt]

D. stage 3:	/[$_{stem}$ke.kɪ̝d]ɪ̝ːt/ →	[ke.kɪ̝d]	[(ˈke.kɪ̝)diːt]	[ke.kɪ̝.diːt]
D. stage 4:	/[$_{stem}$ke.kɪ̝d]iːt/ →	[ke.kɪ̝d]	[(ˈke.kɪ̝)dɪ̝t]	[ke.kɪ̝.dɪ̝t]
Attested form: *incidit* [ˈiŋ.kɪ̝.dɪ̝t] ‘fall into-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/in[$_{stem}$REDkad]eɪt/ →	[ke.kad]	[(ˈin)(ˌke.ka)deɪt]	[in.ke.ka.deɪt]
D. stage 2:	/iŋ[$_{stem}$REDkad]eɪt/ →	[ke.kad]	[(ˈiŋ)(ˌke.ka)dɪːt]	[iŋ.ke.ka.dɪːt]
D. stage 3:	/iŋ[$_{stem}$kkɪ̝d]ɪ̝ːt/ →	[kːɪ̝d]	[(ˈɪ̝ŋk.kɪ̝)diːt]	[ɪ̝ŋk.kɪ̝.diːt]
D. stage 4:	/iŋ[$_{stem}$kkɪ̝d]iːt/ →	[kːɪ̝d]	[(ˈɪ̝ŋ.kɪ̝)dɪ̝t]	[ɪ̝ŋ.kɪ̝.dɪ̝t]
Attested form: *casus* [ˈkaː.sʊ̝s] ‘fall-PRF.PTCP-NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$kadso]s/ →	[kaːd.so]	[(ˈkaːs)sos]	[kaːs.sos]
D. stage 2:	/[$_{stem}$kaːsso]s/ →	[kaːs.so]	[(ˈkaːs)sos]	[kaːs.sos]
D. stage 3:	/[$_{stem}$kaːssʊ̝]s/ →	[kaːs.sʊ̝]	[(ˈkaːs)sʊ̝s]	[kaːs.sʊ̝s]
D. stage 4:	/[$_{stem}$kaːssʊ̝]s/ →	[kaːs.sʊ̝]	[(ˈkaːs)sʊ̝s]	[kaːs.sʊ̝s]
Attested form: *edit* [ˈe.dɪ̝t] ‘eat-3SG.PRES’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$edɪ]t/ →	[e.dɪ]	[(ˈe.dɪt)]	[e.dɪt]
D. stage 2:	/[$_{stem}$edɪ]t/ →	[e.dɪ]	[(ˈe.dɪt)]	[e.dɪt]
D. stage 3:	/[$_{stem}$edɪ̝]t/ →	[e.dɪ̝]	[(ˈe.dɪ̝t)]	[e.dɪ̝t]
D. stage 4:	/[$_{stem}$edɪ̝]t/ →	[e.dɪ̝]	[(ˈe.dɪ̝t)]	[e.dɪ̝t]
Attested form: *edit* [ˈeː.dɪ̝t] ‘eat-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$eːd]eɪt/ →	[eːd]	[(ˈeː)deɪt]	[eː.deɪt]
D. stage 2:	/[$_{stem}$eːd]eɪt/ →	[eːd]	[(ˈeː)dɪːt]	[eː.dɪːt]
D. stage 3:	/[$_{stem}$eːd]ɪ̝ːt/ →	[eːd]	[(ˈeː)diːt]	[eː.diːt]
D. stage 4:	/[$_{stem}$eːd]iːt/ →	[eːd]	[(ˈeː)dɪ̝t]	[eː.dɪ̝t]
Attested form: *esus* [ˈeː.sʊ̝s] ‘eat-PRF.PTCP-NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$edso]s/ →	[eːd.so]	[(ˈeːs)sos]	[eːs.sos]
D. stage 2:	/[$_{stem}$eːsso]s/ →	[eːs.so]	[(ˈeːs)sos]	[eːs.sos]
D. stage 3:	/[$_{stem}$eːssʊ̝]s/ →	[eːs.sʊ̝]	[(ˈeːs)sʊ̝s]	[eːs.sʊ̝s]
D. stage 4:	/[$_{stem}$eːssʊ̝]s/ →	[eːs.sʊ̝]	[(ˈeːs)sʊ̝s]	[eːs.sʊ̝s]
Attested form: *odium* [ˈo.dɪ̝.ʊ̝m] ‘hatred’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$odio]m/ →	[o.di.o]	[(ˈo.di)om]	[o.di.om]
D. stage 2:	/[$_{stem}$odio]m/ →	[o.di.o]	[(ˈo.di)om]	[o.di.om]
D. stage 3:	/[$_{stem}$odɪ̝ʊ̝]m/ →	[o.dɪ̝.ʊ̝]	[(ˈo.dɪ̝)ʊ̝m]	[o.dɪ̝.ʊ̝m]
D. stage 4:	/[$_{stem}$odɪ̝ʊ̝]m/ →	[o.dɪ̝.ʊ̝]	[(ˈo.dɪ̝)ʊ̝m]	[o.dɪ̝.ʊ̝m]
Attested form: *odit* [ˈoː.dɪ̝t] ‘hate-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$oːd]eɪt/ →	[oːd]	[(ˈoː)deɪt]	[oː.deɪt]

D. stage 2:	/[$_{stem}$oːd]eɪt/ →	[oːd]	[(ˈoː)dɪːt]	[oː.dɪːt]
D. stage 3:	/[$_{stem}$oːd]ɪ̞ːt/ →	[oːd]	[(ˈoː)diːt]	[oː.diːt]
D. stage 4:	/[$_{stem}$oːd]iːt/ →	[oːd]	[(ˈoː)dɪ̞t]	[oː.dɪ̞t]

Attested form: *osus* [ˈoː.sʊ̞s] ‘hate-prf.ptcp-nom.sg.m’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$odso]s/ →	[oːd.so]	[(ˈoːs)sos]	[oːs.sos]
D. stage 2:	/[$_{stem}$oːsso]s/ →	[oːs.so]	[(ˈoːs)sos]	[oːs.sos]
D. stage 3:	/[$_{stem}$oːssʊ̞]s/ →	[oːs.sʊ̞]	[(ˈoːs)sʊ̞s]	[oːs.sʊ̞s]
D. stage 4:	/[$_{stem}$oːssʊ̞]s/ →	[oːs.sʊ̞]	[(ˈoːs)sʊ̞s]	[oːs.sʊ̞s]

Attested form: *uidet* [ˈwɪ̞.det] ‘see-3sg.pres’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$wɪdeː]t/ →	[wɪ.deː]	[(ˈwɪ.deːt)]	[wɪ.deːt]
D. stage 2:	/[$_{stem}$wɪdeː]t/ →	[wɪ.deː]	[(ˈwɪ.deːt)]	[wɪ.deːt]
D. stage 3:	/[$_{stem}$wɪ̞deː]t/ →	[wɪ̞.deː]	[(ˈwɪ̞.deːt)]	[wɪ̞.deːt]
D. stage 4:	/[$_{stem}$wɪ̞deː]t/ →	[wɪ̞.deː]	[(ˈwɪ̞.det)]	[wɪ̞.det]

Attested form: *uidit* [ˈwiː.dɪ̞t] ‘see-3sg.prf’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$weɪd]eɪt/ →	[weɪd]	[(ˈweɪ)deɪt]	[weɪ.deɪt]
D. stage 2:	/[$_{stem}$weɪd]eɪt/ →	[weɪd]	[(ˈwɪː)dɪːt]	[wɪː.dɪːt]
D. stage 3:	/[$_{stem}$wɪ̞ːd]ɪ̞ːt/ →	[wɪ̞ːd]	[(ˈwiː)diːt]	[wiː.diːt]
D. stage 4:	/[$_{stem}$wiːd]iːt/ →	[wiːd]	[(ˈwiː)dɪ̞t]	[wiː.dɪ̞t]

Attested form: *uisus* [ˈwiː.sʊ̞s] ‘see-prf.ptcp-nom.sg.m’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$weɪdso]s/ →	[weɪd.so]	[(ˈweɪs)sos]	[weɪs.sos]
D. stage 2:	/[$_{stem}$weɪsso]s/ →	[weɪs.so]	[(ˈwɪːs)sos]	[wɪːs.sos]
D. stage 3:	/[$_{stem}$wɪ̞ːssʊ̞]s/ →	[wɪ̞ːs.sʊ̞]	[(ˈwiːs)sʊ̞s]	[wiːs.sʊ̞s]
D. stage 4:	/[$_{stem}$wiːssʊ̞]s/ →	[wiːs.sʊ̞]	[(ˈwiːs)sʊ̞s]	[wiːs.sʊ̞s]

Forms with no stem-final voiced stop

Attested form: *facit* [ˈfa.kɪ̞t] ‘make-3sg.pres’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$θakɪ]t/ →	[θa.kɪ]	[(ˈθa.kɪt)]	[θa.kɪt]
D. stage 2:	/[$_{stem}$fakɪ]t/ →	[fa.kɪ]	[(ˈfa.kɪt)]	[fa.kɪt]
D. stage 3:	/[$_{stem}$fakɪ̞]t/ →	[fa.kɪ̞]	[(ˈfa.kɪ̞t)]	[fa.kɪ̞t]
D. stage 4:	/[$_{stem}$fakɪ̞]t/ →	[fa.kɪ̞]	[(ˈfa.kɪ̞t)]	[fa.kɪ̞t]

Attested form: *fecit* [ˈfeː.kɪ̞t] ‘make-3sg.prf’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$θeːk]eɪt/ →	[θeːk]	[(ˈθeː)keɪt]	[θeː.keɪt]
D. stage 2:	/[$_{stem}$feːk]eɪt/ →	[feːk]	[(ˈfeː)kɪːt]	[feː.kɪːt]
D. stage 3:	/[$_{stem}$feːk]ɪ̞ːt/ →	[feːk]	[(ˈfeː)kiːt]	[feː.kiːt]
D. stage 4:	/[$_{stem}$feːk]iːt/ →	[feːk]	[(ˈfeː)kɪ̞t]	[feː.kɪ̞t]

Attested form: *factus* [ˈfak.tʊ̞s] ‘make-prf.ptcp-nom.sg.m’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$θakto]s/ →	[θak.to]	[(ˈθak)tos]	[θak.tos]
D. stage 2:	/[$_{stem}$fakto]s/ →	[fak.to]	[(ˈfak)tos]	[fak.tos]
D. stage 3:	/[$_{stem}$faktʊ̝]s/ →	[fak.tʊ̝]	[(ˈfak)tʊ̝s]	[fak.tʊ̝s]
D. stage 4:	/[$_{stem}$faktʊ̝]s/ →	[fak.tʊ̝]	[(ˈfak)tʊ̝s]	[fak.tʊ̝s]
Attested form: *iacit* [ˈja.kɪ̝t] ‘throw-3SG.PRES’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$jakɪ]t/ →	[ja.kɪ]	[(ˈja.kɪt)]	[ja.kɪt]
D. stage 2:	/[$_{stem}$jakɪ]t/ →	[ja.kɪ]	[(ˈja.kɪt)]	[ja.kɪt]
D. stage 3:	/[$_{stem}$jakɪ̝]t/ →	[ja.kɪ̝]	[(ˈja.kɪ̝t)]	[ja.kɪ̝t]
D. stage 4:	/[$_{stem}$jakɪ̝]t/ →	[ja.kɪ̝]	[(ˈja.kɪ̝t)]	[ja.kɪ̝t]
Attested form: *iecit* [ˈjeː.kɪ̝t] ‘throw-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$jeːk]eɪt/ →	[jeːk]	[(ˈjeː)keɪt]	[jeː.keɪt]
D. stage 2:	/[$_{stem}$jeːk]eɪt/ →	[jeːk]	[(ˈjeː)kɪːt]	[jeː.kɪːt]
D. stage 3:	/[$_{stem}$jeːk]ɪ̝ːt/ →	[jeːk]	[(ˈjeː)kiːt]	[jeː.kiːt]
D. stage 4:	/[$_{stem}$jeːk]iːt/ →	[jeːk]	[(ˈjeː)kɪ̝t]	[jeː.kɪ̝t]
Attested form: *iactus* [ˈjak.tʊ̝s] ‘throw-PRF.PTCP-NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$jakto]s/ →	[jak.to]	[(ˈjak)tos]	[jak.tos]
D. stage 2:	/[$_{stem}$jakto]s/ →	[jak.to]	[(ˈjak)tos]	[jak.tos]
D. stage 3:	/[$_{stem}$jaktʊ̝]s/ →	[jak.tʊ̝]	[(ˈjak)tʊ̝s]	[jak.tʊ̝s]
D. stage 4:	/[$_{stem}$jaktʊ̝]s/ →	[jak.tʊ̝]	[(ˈjak)tʊ̝s]	[jak.tʊ̝s]
Attested form: *uincit* [ˈwɪ̝ŋ.kɪ̝t] ‘defeat-3SG.PRES’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$wɪnkɪ]t/ →	[wɪn.kɪ]	[(ˈwɪn)kɪt]	[wɪn.kɪt]
D. stage 2:	/[$_{stem}$wɪŋkɪ]t/ →	[wɪŋ.kɪ]	[(ˈwɪŋ)kɪt]	[wɪŋ.kɪt]
D. stage 3:	/[$_{stem}$wɪ̝ŋkɪ̝]t/ →	[wɪ̝ŋ.kɪ̝]	[(ˈwɪ̝ŋ)kɪ̝t]	[wɪ̝ŋ.kɪ̝t]
D. stage 4:	/[$_{stem}$wɪ̝ŋkɪ̝]t/ →	[wɪ̝ŋ.kɪ̝]	[(ˈwɪ̝ŋ)kɪ̝t]	[wɪ̝ŋ.kɪ̝t]
Attested form: *uicit* [ˈwiː.kɪ̝t] ‘defeat-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$wiːk]eɪt/ →	[wiːk]	[(ˈwiː)keɪt]	[wiː.keɪt]
D. stage 2:	/[$_{stem}$wiːk]eɪt/ →	[wiːk]	[(ˈwiː)kɪːt]	[wiː.kɪːt]
D. stage 3:	/[$_{stem}$wiːk]ɪ̝ːt/ →	[wiːk]	[(ˈwiː)kiːt]	[wiː.kiːt]
D. stage 4:	/[$_{stem}$wiːk]iːt/ →	[wiːk]	[(ˈwiː)kɪ̝t]	[wiː.kɪ̝t]
Attested form: *uictus* [ˈwɪ̝k.tʊ̝s] ‘defeat-PRF.PTCP-NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$wɪkto]s/ →	[wɪk.to]	[(ˈwɪk)tos]	[wɪk.tos]
D. stage 2:	/[$_{stem}$wɪkto]s/ →	[wɪk.to]	[(ˈwɪk)tos]	[wɪk.tos]
D. stage 3:	/[$_{stem}$wɪ̝ktʊ̝]s/ →	[wɪ̝k.tʊ̝]	[(ˈwɪ̝k)tʊ̝s]	[wɪ̝k.tʊ̝s]
D. stage 4:	/[$_{stem}$wɪ̝ktʊ̝]s/ →	[wɪ̝k.tʊ̝]	[(ˈwɪ̝k)tʊ̝s]	[wɪ̝k.tʊ̝s]

Attested form: *docet* [ˈdo.ket] ‘teach-3SG.PRES’	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$doke:]t/ →	[do.keː]	[(ˈdo.keːt)]	[do.keːt]
D. stage 2:	/[$_{stem}$doke:]t/ →	[do.keː]	[(ˈdo.keːt)]	[do.keːt]
D. stage 3:	/[$_{stem}$doke:]t/ →	[do.keː]	[(ˈdo.keːt)]	[do.keːt]
D. stage 4:	/[$_{stem}$doke:]t/ →	[do.keː]	[(ˈdo.ket)]	[do.ket]

Attested form: *docuit* [ˈdo.kʊ̞.ɪ̞t] ‘teach-3SG.PRF’	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$doku]eɪt/ →	[do.ku]	[(ˈdo.ku)eɪt]	[do.ku.eɪt]
D. stage 2:	/[$_{stem}$doku]eɪt/ →	[do.ku]	[(ˈdo.ku)ɪːt]	[do.ku.ɪːt]
D. stage 3:	/[$_{stem}$dokʊ̞]ɪːt/ →	[do.kʊ̞]	[(ˈdo.kʊ̞)iːt]	[do.kʊ̞.iːt]
D. stage 4:	/[$_{stem}$dokʊ̞]iːt/ →	[do.kʊ̞]	[(ˈdo.kʊ̞)ɪ̞t]	[do.kʊ̞.ɪ̞t]

Attested form: *doctus* [ˈdok.tʊ̞s] ‘teach-PRF.PTCP-NOM.SG.M’	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$dokto]s/ →	[dok.to]	[(ˈdok)tos]	[dok.tos]
D. stage 2:	/[$_{stem}$dokto]s/ →	[dok.to]	[(ˈdok)tos]	[dok.tos]
D. stage 3:	/[$_{stem}$dok]tʊ̞s/ →	[dok]	[(ˈdok)tʊ̞s]	[dok.tʊ̞s]
D. stage 4:	/[$_{stem}$dok]tʊ̞s/ →	[dok]	[(ˈdok)tʊ̞s]	[dok.tʊ̞s]

Forms with [ɪ] in the stem

Attested form: *findit* [ˈfɪ̞n.dɪ̞t] ‘split-3SG.PRES’	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸɪndɪ]t/ →	[ɸɪn.dɪ]	[(ˈɸɪn)dɪt]	[ɸɪn.dɪt]
D. stage 2:	/[$_{stem}$ɸɪndɪ]t/ →	[ɸɪn.dɪ]	[(ˈfɪn)dɪt]	[fɪn.dɪt]
D. stage 3:	/[$_{stem}$fɪ̞ndɪ̞]t/ →	[fɪ̞n.dɪ̞]	[(ˈfɪ̞n)dɪ̞t]	[fɪ̞n.dɪ̞t]
D. stage 4:	/[$_{stem}$fɪ̞ndɪ̞]t/ →	[fɪ̞n.dɪ̞]	[(ˈfɪ̞n)dɪ̞t]	[fɪ̞n.dɪ̞t]

Attested form: *fidit* [ˈfɪ̞.dɪ̞t] ‘split-3SG.PRF’	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸɪd]eɪt/ →	[ɸɪd]	[(ˈɸɪ.deɪt)]	[ɸɪ.deɪt]
D. stage 2:	/[$_{stem}$ɸɪd]eɪt/ →	[ɸɪd]	[(ˈfɪ.dɪːt)]	[fɪ.dɪːt]
D. stage 3:	/[$_{stem}$fɪ̞d]ɪːt/ →	[fɪ̞d]	[(ˈfɪ̞.diːt)]	[fɪ̞.diːt]
D. stage 4:	/[$_{stem}$fɪ̞d]iːt/ →	[fɪ̞d]	[(ˈfɪ̞.dɪ̞t)]	[fɪ̞.dɪ̞t]

Attested form: *fissus* [ˈfɪ̞s.sʊ̞s] ‘split-PRF.PTCP-NOM.SG.M’	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸɪdso]s/ →	[ɸɪd.so]	[(ˈɸɪs)sos]	[ɸɪs.sos]
D. stage 2:	/[$_{stem}$ɸɪsso]s/ →	[ɸɪs.so]	[(ˈfɪs.sos)]	[fɪs.sos]
D. stage 3:	/[$_{stem}$fɪ̞ssʊ̞]s/ →	[fɪ̞s.sʊ̞]	[(ˈfɪ̞s)sʊ̞s]	[fɪ̞s.sʊ̞s]
D. stage 4:	/[$_{stem}$fɪ̞ssʊ̞]s/ →	[fɪ̞s.sʊ̞]	[(ˈfɪ̞s)sʊ̞s]	[fɪ̞s.sʊ̞s]

Attested form: *scindit* [ˈskɪ̞n.dɪ̞t] ‘cut-3SG.PRES’	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$skɪndɪ]t/ →	[skɪn.dɪ]	[(ˈskɪn)dɪt]	[skɪn.dɪt]
D. stage 2:	/[$_{stem}$skɪndɪ]t/ →	[skɪn.dɪ]	[(ˈskɪn)dɪt]	[skɪn.dɪt]

	Input	Stem Level	Word Level	Phrase Level
D. stage 3:	/[$_{stem}$skɪ̞ndɪ̞]t/ →	[skɪ̞n.dɪ̞]	[(ˈskɪ̞n)dɪ̞t]	[skɪ̞n.dɪ̞t]
D. stage 4:	/[$_{stem}$skɪ̞ndɪ̞]t/ →	[skɪ̞n.dɪ̞]	[(ˈskɪ̞n)dɪ̞t]	[skɪ̞n.dɪ̞t]

Attested form: *scicidit* [ˈskɪ̞.kɪ̞.dɪ̞t] 'cut-3SG.PRF'				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$SREDkɪd]eɪt/ →	[skɪ.kɪd]	[(ˈskɪ.kɪ)deɪt]	[skɪ.kɪ.deɪt]
D. stage 2:	/[$_{stem}$SREDkɪd]eɪt/ →	[skɪ.kɪd]	[(ˈskɪ.kɪ)dɪːt]	[skɪ.kɪ.dɪːt]
D. stage 3:	/[$_{stem}$skɪ̞kɪ̞d]ɪːt/ →	[skɪ̞.kɪ̞d]	[(ˈskɪ̞.kɪ̞)diːt]	[skɪ̞.kɪ̞.diːt]
D. stage 4:	/[$_{stem}$skɪ̞kɪ̞d]iːt/ →	[skɪ̞.kɪ̞d]	[(ˈskɪ̞.kɪ̞)dɪ̞t]	[skɪ̞.kɪ̞.dɪ̞t]

Attested form: *discidit* [ˈdiː.skɪ̞.dɪ̞t] 'cut apart-3SG.PRF'				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/diː[$_{stem}$SREDkɪd]eɪt/ →	[skɪ.kɪd]	[(ˈdiːs)(ˌkɪ.kɪ)deɪt]	[diːs.kɪ.kɪ.deɪt]
D. stage 2:	/diː[$_{stem}$SREDkɪd]eɪt/ →	[skɪ.kɪd]	[(ˈdiːs)(ˌkɪ.kɪ)dɪːt]	[diːs.kɪ.kɪ.dɪːt]
D. stage 3:	/diː[$_{stem}$skkɪ̞d]ɪːt/ →	[skːɪ̞d]	[(ˈdiːsk.kɪ̞)diːt]	[diːsk.kɪ̞.diːt]
D. stage 4:	/diː[$_{stem}$skkɪ̞d]iːt/ →	[skːɪ̞d]	[(ˈdiːs.kɪ̞)dɪ̞t]	[diːs.kɪ̞.dɪ̞t]

Attested form: *scissus* [ˈskɪ̞s.sʊ̞s] 'cut-PRF.PTCP-NOM.SG.M'				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$skɪdso]s/ →	[skɪd.so]	[(ˈskɪs)sos]	[skɪs.sos]
D. stage 2:	/[$_{stem}$skɪsso]s/ →	[skɪs.so]	[(ˈskɪs.sos)]	[skɪs.sos]
D. stage 3:	/[$_{stem}$skɪ̞ssu]s/ →	[skɪ̞s.su]	[(ˈskɪ̞s)sʊ̞s]	[skɪ̞s.sʊ̞s]
D. stage 4:	/[$_{stem}$skɪ̞ssʊ̞]s/ →	[skɪ̞s.sʊ̞]	[(ˈskɪ̞s)sʊ̞s]	[skɪ̞s.sʊ̞s]

Forms from IE roots ending in voiced aspirates				
Attested form: *trahit* [ˈtra.hɪ̞t] 'drag-3SG.PRES'				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$traxɪ]t/ →	[tra.xɪ]	[(ˈtra.xɪt)]	[tra.ɣɪt]
D. stage 2:	/[$_{stem}$traɣɪ]t/ →	[tra.ɣɪ]	[(ˈtra.ɦɪt)]	[tra.ɦɪt]
D. stage 3:	/[$_{stem}$trahɪ̞]t/ →	[tra.hɪ̞]	[(ˈtra.hɪ̞t)]	[tra.hɪ̞t]
D. stage 4:	/[$_{stem}$trahɪ̞]t/ →	[tra.hɪ̞]	[(ˈtra.hɪ̞t)]	[tra.hɪ̞t]

Attested form: *traxit* [ˈtrak.sɪ̞t] 'drag-3SG.PRF'				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$traxs]eɪt/ →	[traxs]	[(ˈtrax)seɪt]	[trax.seɪt]
D. stage 2:	/[$_{stem}$traxs]eɪt/ →	[traxs]	[(ˈtrak)sɪːt]	[trak.sɪːt]
D. stage 3:	/[$_{stem}$traks]ɪːt/ →	[traks]	[(ˈtrak)siːt]	[trak.siːt]
D. stage 4:	/[$_{stem}$traks]iːt/ →	[traks]	[(ˈtrak)sɪ̞t]	[trak.sɪ̞t]

Attested form: *tractus* [ˈtrak.tʊ̞s] 'drag-PRF.PTCP-NOM.SG.M'				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$traxto]s/ →	[trax.to]	[(ˈtrax)tos]	[trax.tos]
D. stage 2:	/[$_{stem}$traxto]s/ →	[trax.to]	[(ˈtrak)tos]	[trak.tos]
D. stage 3:	/[$_{stem}$traktʊ̞]s/ →	[trak.tʊ̞]	[(ˈtrak)tʊ̞s]	[trak.tʊ̞s]
D. stage 4:	/[$_{stem}$traktʊ̞]s/ →	[trak.tʊ̞]	[(ˈtrak)tʊ̞s]	[trak.tʊ̞s]

Attested form: *scabit* [ˈska.bɪ̞t] 'scratch-3SG.PRES'				
	Input	Stem Level	Word Level	Phrase Level

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$skaɸɪ]t/ →	[ska.ɸɪ]	[(ˈska.ɸɪt)]	[ska.βɪt]
D. stage 2:	/[$_{stem}$skaβɪ]t/ →	[ska.βɪ]	[(ˈska.bɪt)]	[ska.bɪt]
D. stage 3:	/[$_{stem}$skabɪ̞]t/ →	[ska.bɪ̞]	[(ˈska.bɪ̞t)]	[ska.bɪ̞t]
D. stage 4:	/[$_{stem}$skabɪ̞]t/ →	[ska.bɪ̞]	[(ˈska.bɪ̞t)]	[ska.bɪ̞t]
Attested form: *scabit* [ˈskaː.bɪ̞t] ‘scratch-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$skaːɸ]eɪt/ →	[skaːɸ]	[(ˈskaː)ɸeɪt]	[skaː.βeɪt]
D. stage 2:	/[$_{stem}$skaːβ]eɪt/ →	[skaːβ]	[(ˈskaː)bɪːt]	[skaː.bɪːt]
D. stage 3:	/[$_{stem}$skaːb]ɪːt/ →	[skaːb]	[(ˈskaː)biːt]	[skaː.biːt]
D. stage 4:	/[$_{stem}$skaːb]iːt/ →	[skaːb]	[(ˈskaː)bɪ̞t]	[skaː.bɪ̞t]
Attested form: *scaptus* [ˈskap.tʊ̞s] ‘scratch-PRF.PTCP-NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$skaɸto]s/ →	[skaɸ.to]	[(ˈskaɸ)tos]	[skaɸ.tos]
D. stage 2:	/[$_{stem}$skaɸto]s/ →	[skaɸ.to]	[(ˈskap)tos]	[skap.tos]
D. stage 3:	/[$_{stem}$skabtʊ̞]s/ →	[skab.tʊ̞]	[(ˈskap)tʊ̞s]	[skap.tʊ̞s]
D. stage 4:	/[$_{stem}$skabtʊ̞]s/ →	[skab.tʊ̞]	[(ˈskap)tʊ̞s]	[skap.tʊ̞s]
Attested form: *fodit* [ˈfo.dɪ̞t] ‘dig-3SG.PRES’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸoθɪ]t/ →	[ɸo.θɪ]	[(ˈɸo.θɪt)]	[ɸo.ðɪt]
D. stage 2:	/[$_{stem}$ɸoðɪ]t/ →	[ɸo.ðɪ]	[(ˈfo.dɪt)]	[fo.dɪt]
D. stage 3:	/[$_{stem}$fodɪ̞]t/ →	[fo.dɪ̞]	[(ˈfo.dɪ̞t)]	[fo.dɪ̞t]
D. stage 4:	/[$_{stem}$fodɪ̞]t/ →	[fo.dɪ̞]	[(ˈfo.dɪ̞t)]	[fo.dɪ̞t]
Attested form: *fodit* [ˈfoː.dɪ̞t] ‘dig-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸoːθ]eɪt/ →	[ɸoːθ]	[(ˈɸoː)θeɪt]	[ɸoː.ðeɪt]
D. stage 2:	/[$_{stem}$ɸoːð]eɪt/ →	[ɸoːð]	[(ˈfoː)dɪːt]	[foː.dɪːt]
D. stage 3:	/[$_{stem}$foːd]ɪːt/ →	[foːd]	[(ˈfoː)diːt]	[foː.diːt]
D. stage 4:	/[$_{stem}$foːd]iːt/ →	[foːd]	[(ˈfoː)dɪ̞t]	[foː.dɪ̞t]
Attested form: *fossus* [ˈfos.sʊ̞s] ‘dig-PRF.PTCP-NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸoθso]s/ →	[ɸoθ.so]	[(ˈɸos)sos]	[ɸos.sos]
D. stage 2:	/[$_{stem}$ɸoθso]s/ →	[ɸoθ.so]	[(ˈfos.sos)]	[fos.sos]
D. stage 3:	/[$_{stem}$fossʊ̞]s/ →	[fos.sʊ̞]	[(ˈfos)sʊ̞s]	[fos.sʊ̞s]
D. stage 4:	/[$_{stem}$fossʊ̞]s/ →	[fos.sʊ̞]	[(ˈfos)sʊ̞s]	[fos.sʊ̞s]
Attested form: *iubet* [ˈjʊ̞.bet] ‘order-3SG.PRES’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$juθeː]t/ →	[ju.θeː]	[(ˈju.θeːt)]	[ju.ðeːt]
D. stage 2:	/[$_{stem}$juveː]t/ →	[ju.veː]	[(ˈju.beːt)]	[ju.beːt]
D. stage 3:	/[$_{stem}$jubeː]t/ →	[ju.beː]	[(ˈjʊ̞.beːt)]	[jʊ̞.beːt]
D. stage 4:	/[$_{stem}$jʊ̞beː]t/ →	[jʊ̞.beː]	[(ˈjʊ̞.bet)]	[jʊ̞.bet]
Attested form: *iussit* [ˈjʊ̞s.sɪ̞t] ‘order-3SG.PRF’				

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$juθs]eɪt/ →	[juθs]	[(ˈjus)seɪt]	[jus.seɪt]
D. stage 2:	/[$_{stem}$juθs]eɪt/ →	[juθs]	[(ˈjus.sɪːt)]	[jus.sɪːt]
D. stage 3:	/[$_{stem}$juss]ɪ̞ːt/ →	[jusː]	[(ˈjʊ̞s)siːt]	[jʊ̞s.siːt]
D. stage 4:	/[$_{stem}$jʊ̞ss]iːt/ →	[jʊ̞sː]	[(ˈjʊ̞s)sɪ̞t]	[jʊ̞s.sɪ̞t]

Attested form: *iussus* [ˈjʊ̞s.sʊ̞s] ‘order-PRF.PTCP-NOM.SG.M’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$juθso]s/ →	[juθ.so]	[(ˈjus)sos]	[jus.sos]
D. stage 2:	/[$_{stem}$juθso]s/ →	[juθ.so]	[(ˈjus.sos)]	[jus.sos]
D. stage 3:	/[$_{stem}$jussʊ̞]s/ →	[jus.sʊ̞]	[(ˈjʊ̞s)sʊ̞s]	[jʊ̞s.sʊ̞s]
D. stage 4:	/[$_{stem}$jʊ̞ssʊ̞]s/ →	[jʊ̞s.sʊ̞]	[(ˈjʊ̞s)sʊ̞s]	[jʊ̞s.sʊ̞s]

Miscellaneous

Attested form: *pandit* [ˈpan.dɪ̞t] ‘unfold-3SG.PRES’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$patane]t/ →	[pa.ta.ne]	[(ˈpa.ta)net]	[pa.ta.net]
D. stage 2:	/[$_{stem}$patane]t/ →	[pa.ta.ne]	[(ˈpa.ta)net]	[pa.ta.net]
D. stage 3:	/[$_{stem}$pandɪ̞]t/ →	[pan.dɪ̞]	[(ˈpan)dɪ̞t]	[pan.dɪ̞t]
D. stage 4:	/[$_{stem}$pandɪ̞]t/ →	[pan.dɪ̞]	[(ˈpan)dɪ̞t]	[pan.dɪ̞t]

Attested form: *pandit* [ˈpan.dɪ̞t] ‘unfold-3SG.PRF’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$pand]eɪt/ →	[pand]	[(ˈpan)deɪt]	[pan.deɪt]
D. stage 2:	/[$_{stem}$pand]eɪt/ →	[pand]	[(ˈpan)dɪːt]	[pan.dɪːt]
D. stage 3:	/[$_{stem}$pand]ɪ̞ːt/ →	[pand]	[(ˈpan)diːt]	[pan.diːt]
D. stage 4:	/[$_{stem}$pand]iːt/ →	[pand]	[(ˈpan)dɪ̞t]	[pan.dɪ̞t]

Attested form: *passus* [ˈpas.sʊ̞s] ‘unfold-PRF.PTCP-NOM.SG.M’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$patso]s/ →	[pat.so]	[(ˈpas)sos]	[pas.sos]
D. stage 2:	/[$_{stem}$passo]s/ →	[pas.so]	[(ˈpas.sos)]	[pas.sos]
D. stage 3:	/[$_{stem}$passʊ̞]s/ →	[pas.sʊ̞]	[(ˈpas)sʊ̞s]	[pas.sʊ̞s]
D. stage 4:	/[$_{stem}$passʊ̞]s/ →	[pas.sʊ̞]	[(ˈpas)sʊ̞s]	[pas.sʊ̞s]

Attested form: *sedet* [ˈse.det] ‘sit-3SG.PRES’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$sedeː]t/ →	[se.deː]	[(ˈse.deːt)]	[se.deːt]
D. stage 2:	/[$_{stem}$sedeː]t/ →	[se.deː]	[(ˈse.deːt)]	[se.deːt]
D. stage 3:	/[$_{stem}$sedeː]t/ →	[se.deː]	[(ˈse.deːt)]	[se.deːt]
D. stage 4:	/[$_{stem}$sedeː]t/ →	[se.deː]	[(ˈse.det)]	[se.det]

Attested form: *sedit* [ˈseː.dɪ̞t] ‘sit-3SG.PRF’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$seːd]eɪt/ →	[seːd]	[(ˈseː)deɪt]	[seː.deɪt]
D. stage 2:	/[$_{stem}$seːd]eɪt/ →	[seːd]	[(ˈseː)dɪːt]	[seː.dɪːt]
D. stage 3:	/[$_{stem}$seːd]ɪ̞ːt/ →	[seːd]	[(ˈseː)diːt]	[seː.diːt]
D. stage 4:	/[$_{stem}$seːd]iːt/ →	[seːd]	[(ˈseː)dɪ̞t]	[seː.dɪ̞t]

Attested form: *sessum* [ˈses.sʊ̝m] ‘sit-SUPINE’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/sedsum/ →		[(ˈses)sum]	[ses.sum]
D. stage 2:	/sessum/ →		[(ˈses.sum)]	[ses.sum]
D. stage 3:	/sessʊ̝m/ →		[(ˈses)sʊ̝m]	[ses.sʊ̝m]
D. stage 4:	/sessʊ̝m/ →		[(ˈses)sʊ̝m]	[ses.sʊ̝m]

Attested form: *emit* [ˈe.mɪ̝t] ‘buy-3SG.PRES’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$emɪ]t/ →	[e.mɪ]	[(ˈe.mɪt)]	[e.mɪt]
D. stage 2:	/[$_{stem}$emɪ]t/ →	[e.mɪ]	[(ˈe.mɪt)]	[e.mɪt]
D. stage 3:	/[$_{stem}$emɪ̝]t/ →	[e.mɪ̝]	[(ˈe.mɪ̝t)]	[e.mɪ̝t]
D. stage 4:	/[$_{stem}$emɪ̝]t/ →	[e.mɪ̝]	[(ˈe.mɪ̝t)]	[e.mɪ̝t]

Attested form: *emit* [ˈeː.mɪ̝t] ‘buy-3SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$eːm]eɪt/ →	[eːm]	[(ˈeː)meɪt]	[eː.meɪt]
D. stage 2:	/[$_{stem}$eːm]eɪt/ →	[eːm]	[(ˈeː)mɪːt]	[eː.mɪːt]
D. stage 3:	/[$_{stem}$eːm]ɪ̝ːt/ →	[eːm]	[(ˈeː)miːt]	[eː.miːt]
D. stage 4:	/[$_{stem}$eːm]iːt/ →	[eːm]	[(ˈeː)mɪ̝t]	[eː.mɪ̝t]

Attested form: *emptus* [ˈeːm.tʊ̝s] ‘buy-PRF.PTCP-NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$emto]s/ →	[em.to]	[(ˈem)tos]	[em.tos]
D. stage 2:	/[$_{stem}$eːmto]s/ →	[eːm.to]	[(ˈeːm)tos]	[eːm.tos]
D. stage 3:	/[$_{stem}$eːmtʊ̝]s/ →	[eːm.tʊ̝]	[(ˈeːm)tʊ̝s]	[eːm.tʊ̝s]
D. stage 4:	/[$_{stem}$eːmtʊ̝]s/ →	[eːm.tʊ̝]	[(ˈeːm)tʊ̝s]	[eːm.tʊ̝s]

Liquid dissimilation

Nouns in *-al*

Attested form: *animal* [ˈa.nɪ̝.mal] ‘animal’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$anam]aːR/ →	[a.nam]	[(ˈa.na)maːl]	[a.na.maːl]
D. stage 2:	/[$_{stem}$anam]aːl/ →	[a.nam]	[(ˈa.na)maːl]	[a.na.maːl]
D. stage 3:	/[$_{stem}$anɪ̝m]aːl/ →	[a.nɪ̝m]	[(ˈa.nɪ̝)maːl]	[a.nɪ̝.maːl]
D. stage 4:	/[$_{stem}$anɪ̝m]aːl/ →	[a.nɪ̝m]	[(ˈa.nɪ̝)mal]	[a.nɪ̝.mal]

Attested form: *uectigal* [wek.ˈtiː.gal] ‘toll’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$wektiːg]aːR/ →	[wek.tiːg]	[(ˈwek)(ˌtiː)gaːl]	[wek.tiː.gaːl]
D. stage 2:	/[$_{stem}$wektiːg]aːl/ →	[wek.tiːg]	[(ˈwek)(ˌtiː)gaːl]	[wek.tiː.gaːl]
D. stage 3:	/[$_{stem}$wektiːg]aːl/ →	[wek.tiːg]	[(ˌwek)(ˈtiː)gaːl]	[wek.tiː.gaːl]
D. stage 4:	/[$_{stem}$wektiːg]aːl/ →	[wek.tiːg]	[(ˌwek)(ˈtiː)gal]	[wek.tiː.gal]

Attested form: *tribunal* [tri.ˈbuː.nal] ‘judgment-seat’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$trɪɸuːn]aːR/ →	[trɪ.ɸuːn]	[(ˈtrɪ.ɸuː)naːl]	[trɪ.βuː.naːl]

	Input	Stem Level	Word Level	Phrase Level
D. stage 2:	/[$_{stem}$trɪβuːn]aːl/ →	[trɪ.βuːn]	[(ˈtrɪ.buː)naːl]	[trɪ.buː.naːl]
D. stage 3:	/[$_{stem}$trɪ̞buːn]aːl/ →	[trɪ̞.buːn]	[trɪ̞(ˈbuː)naːl]	[trɪ̞.buː.naːl]
D. stage 4:	/[$_{stem}$trɪ̞buːn]aːl/ →	[trɪ̞.buːn]	[trɪ̞(ˈbuː)nal]	[trɪ̞.buː.nal]
Attested form: *capital* [ˈka.pɪ̞.tal] ‘headdress’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$kaput]aːR/ →	[ka.put]	[(ˈka.pu)taːl]	[ka.pu.taːl]
D. stage 2:	/[$_{stem}$kaput]aːl/ →	[ka.put]	[(ˈka.pu)taːl]	[ka.pu.taːl]
D. stage 3:	/[$_{stem}$kapɪ̞t]aːl/ →	[ka.pɪ̞t]	[(ˈka.pɪ̞)taːl]	[ka.pɪ̞.taːl]
D. stage 4:	/[$_{stem}$kapɪ̞t]al/ →	[ka.pɪ̞t]	[(ˈka.pɪ̞)tal]	[ka.pɪ̞.tal]
Attested form: *cubital* [ˈku.bɪ̞.tal] ‘cushion’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$kubɪt]aːR/ →	[ku.bɪt]	[(ˈku.bɪ)taːl]	[ku.bɪ.taːl]
D. stage 2:	/[$_{stem}$kubɪt]aːl/ →	[ku.bɪt]	[(ˈku.bɪ)taːl]	[ku.bɪ.taːl]
D. stage 3:	/[$_{stem}$kubɪ̞t]aːl/ →	[ku.bɪ̞t]	[(ˈkʊ̞.bɪ̞)taːl]	[kʊ̞.bɪ̞.taːl]
D. stage 4:	/[$_{stem}$kʊ̞bɪ̞t]aːl/ →	[kʊ̞.bɪ̞t]	[(ˈkʊ̞.bɪ̞)tal]	[kʊ̞.bɪ̞.tal]
Attested form: *feminal* [ˈfeː.mɪ̞.nal] ‘*pudendum muliebre*’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$θeːmen]aːR/ →	[θeː.men]	[(ˈθeː.me)naːl]	[θeː.me.naːl]
D. stage 2:	/[$_{stem}$feːmen]aːl/ →	[feː.men]	[(ˈfeː.me)naːl]	[feː.me.naːl]
D. stage 3:	/[$_{stem}$feːmɪ̞n]aːl/ →	[feː.mɪ̞n]	[(ˈfeː.mɪ̞)naːl]	[feː.mɪ̞.naːl]
D. stage 4:	/[$_{stem}$feːmɪ̞n]aːl/ →	[feː.mɪ̞n]	[(ˈfeː.mɪ̞)nal]	[feː.mɪ̞.nal]
Attested form: *quadrantal* [kʷa.ˈdran.tal] ‘(a liquid measure)’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$kʷadrant]aːR/ →	[kʷa.drant]	[(ˈkʷa.dran)taːl]	[kʷa.dran.taːl]
D. stage 2:	/[$_{stem}$kʷadrant]aːl/ →	[kʷa.drant]	[(ˈkʷa.dran)taːl]	[kʷa.dran.taːl]
D. stage 3:	/[$_{stem}$kʷadrant]aːl/ →	[kʷa.drant]	[kʷa(ˈdran)taːl]	[kʷa.dran.taːl]
D. stage 4:	/[$_{stem}$kʷadrant]aːl/ →	[kʷa.drant]	[(ˌkʷad)(ˈran)tal]	[kʷa.dran.tal]
Nouns in *-ar*				
Attested form: *puluinar* [pʊ̞l.ˈwiː.nar] ‘cushion’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$pulwiːn]aːR/ →	[pul.wiːn]	[(ˈpul)(ˌwiː)naːr]	[pul.wiː.naːr]
D. stage 2:	/[$_{stem}$pulwiːn]aːr/ →	[pul.wiːn]	[(ˈpul)(ˌwiː)naːr]	[pul.wiː.naːr]
D. stage 3:	/[$_{stem}$pulwiːn]aːr/ →	[pul.wiːn]	[(ˌpʊ̞l)(ˈwiː)naːr]	[pʊ̞l.wiː.naːr]
D. stage 4:	/[$_{stem}$pʊ̞lwiːn]aːr/ →	[pʊ̞l.wiːn]	[(ˌpʊ̞l)(ˈwiː)nar]	[pʊ̞l.wiː.nar]
Attested form: *calcar* [ˈkal.kar] ‘spur’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$kalk]aːR/ →	[kalk]	[(ˈkal)kaːr]	[kal.kaːr]
D. stage 2:	/[$_{stem}$kalk]aːr/ →	[kalk]	[(ˈkal)kaːr]	[kal.kaːr]
D. stage 3:	/[$_{stem}$kalk]aːr/ →	[kalk]	[(ˈkal)kaːr]	[kal.kaːr]
D. stage 4:	/[$_{stem}$kalk]aːr/ →	[kalk]	[(ˈkal)kar]	[kal.kar]
Attested form: *exemplar* [ek.ˈsem.plar] ‘copy’				

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$eksempl]aːR/ →	[ek.sempl]	[(ˈek)(ˌsem)plaːr]	[ek.sem.plaːr]
D. stage 2:	/[$_{stem}$eksempl]aːr/ →	[ek.sempl]	[(ˈek)(ˌsem)plaːr]	[ek.sem.plaːr]
D. stage 3:	/[$_{stem}$eksempl]aːr/ →	[ek.sempl]	[(ˌek)(ˈsem)plaːr]	[ek.sem.plaːr]
D. stage 4:	/[$_{stem}$eksempl]aːr/ →	[ek.sempl]	[(ˌek)(ˈsem)plar]	[ek.sem.plar]
Attested form: *torcular* [ˈtor.kʊ̞.lar] ‘winepress’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$torkul]aːR/ →	[tor.kul]	[(ˈtor.ku)laːr]	[tor.ku.laːr]
D. stage 2:	/[$_{stem}$torkul]aːr/ →	[tor.kul]	[(ˈtor.ku)laːr]	[tor.ku.laːr]
D. stage 3:	/[$_{stem}$torkʊ̞l]aːr/ →	[tor.kʊ̞l]	[(ˈtor.kʊ̞)laːr]	[tor.kʊ̞.laːr]
D. stage 4:	/[$_{stem}$torkʊ̞l]aːr/ →	[tor.kʊ̞l]	[(ˈtor.kʊ̞)lar]	[tor.kʊ̞.lar]
Attested form: *lacunar* [la.ˈkuː.nar] ‘panelled ceiling’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$lakuːn]aːR/ →	[la.kuːn]	[(ˈla.kuː)naːr]	[la.kuː.naːr]
D. stage 2:	/[$_{stem}$lakuːn]aːr/ →	[la.kuːn]	[(ˈla.kuː)naːr]	[la.kuː.naːr]
D. stage 3:	/[$_{stem}$lakuːn]aːr/ →	[la.kuːn]	[la(ˈkuː)naːr]	[la.kuː.naːr]
D. stage 4:	/[$_{stem}$lakuːn]aːr/ →	[la.kuːn]	[la(ˈkuː)nar]	[la.kuː.nar]
Attested form: *laquear* [ˈla.kʷe.ar] ‘panelled ceiling’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$lakʷe]aːR/ →	[la.kʷe]	[(ˈla.kʷe)aːr]	[la.kʷe.aːr]
D. stage 2:	/[$_{stem}$lakʷe]aːr/ →	[la.kʷe]	[(ˈla.kʷe)aːr]	[la.kʷe.aːr]
D. stage 3:	/[$_{stem}$lakʷe]aːr/ →	[la.kʷe]	[(ˈla.kʷe)aːr]	[la.kʷe.aːr]
D. stage 4:	/[$_{stem}$lakʷe]aːr/ →	[la.kʷe]	[(ˈla.kʷe)ar]	[la.kʷe.ar]
Attested form: *lupanar* [lu.ˈpaː.nar] ‘brothel’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$lupaːn]aːR/ →	[lu.paːn]	[(ˈlu.paː)naːr]	[lu.paː.naːr]
D. stage 2:	/[$_{stem}$lupaːn]aːr/ →	[lu.paːn]	[(ˈlu.paː)naːr]	[lu.paː.naːr]
D. stage 3:	/[$_{stem}$lupaːn]aːr/ →	[lu.paːn]	[lʊ̞(ˈpaː)naːr]	[lʊ̞.paː.naːr]
D. stage 4:	/[$_{stem}$lʊ̞paːn]aːr/ →	[lʊ̞.paːn]	[lʊ̞(ˈpaː)nar]	[lʊ̞.paː.nar]
Attested form: *nubilar* [ˈnuː.bɪ̞.lar] ‘barn’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$nuːbɪl]aːR/ →	[nuː.bɪl]	[(ˈnuː.bɪ)laːr]	[nuː.bɪ.laːr]
D. stage 2:	/[$_{stem}$nuːbɪl]aːr/ →	[nuː.bɪl]	[(ˈnuː.bɪ)laːr]	[nuː.bɪ.laːr]
D. stage 3:	/[$_{stem}$nuːbɪ̞l]aːr/ →	[nuː.bɪ̞l]	[(ˈnuː.bɪ̞)laːr]	[nuː.bɪ̞.laːr]
D. stage 4:	/[$_{stem}$nuːbɪ̞l]aːr/ →	[nuː.bɪ̞l]	[(ˈnuː.bɪ̞)lar]	[nuː.bɪ̞.lar]
Adjectives in *-alis* — no earlier [l]				
Attested form: *naualis* [naː.ˈwaː.lɪ̞s] ‘naval’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$naːw]aːRɪs/ →	[naːw]	[(ˈnaː)(ˌwaː)lɪs]	[naː.waː.lɪs]
D. stage 2:	/[$_{stem}$naːw]aːRɪs/ →	[naːw]	[(ˈnaː)(ˌwaː)lɪs]	[naː.waː.lɪs]
D. stage 3:	/[$_{stem}$naːw]aːlɪ̞s/ →	[naːw]	[(ˌnaː)(ˈwaː)lɪ̞s]	[naː.waː.lɪ̞s]
D. stage 4:	/[$_{stem}$naːw]aːlɪ̞s/ →	[naːw]	[(ˌnaː)(ˈwaː)lɪ̞s]	[naː.waː.lɪ̞s]

Attested form: *regalis* [reː.ˈgaː.lɪ̝s] ‘royal’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$reːg]aːRɪs/ →	[reːg]	[(ˈreː)(ˌgaː)lɪs]	[reː.gaː.lɪs]
D. stage 2:	/[$_{stem}$reːg]aːRɪs/ →	[reːg]	[(ˈreː)(ˌgaː)lɪs]	[reː.gaː.lɪs]
D. stage 3:	/[$_{stem}$reːg]aːlɪ̝s/ →	[reːg]	[(ˌreː)(ˈgaː)lɪ̝s]	[reː.gaː.lɪ̝s]
D. stage 4:	/[$_{stem}$reːg]aːlɪ̝s/ →	[reːg]	[(ˌreː)(ˈgaː)lɪ̝s]	[reː.gaː.lɪ̝s]

Attested form: *hiemalis* [hɪ̝.e.ˈmaː.lɪ̝s] ‘of winter’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$hiem]aːRɪs/ →	[hi.em]	[(ˈhi.e)(ˌmaː)lɪs]	[hi.e.maː.lɪs]
D. stage 2:	/[$_{stem}$hiem]aːRɪs/ →	[hi.em]	[(ˈhi.e)(ˌmaː)lɪs]	[hi.e.maː.lɪs]
D. stage 3:	/[$_{stem}$hiem]aːlɪ̝s/ →	[hi.em]	[(ˌhɪ̝.e)(ˈmaː)lɪ̝s]	[hɪ̝.e.maː.lɪ̝s]
D. stage 4:	/[$_{stem}$hɪ̝em]aːlɪ̝s/ →	[hɪ̝.em]	[(ˌhɪ̝.e)(ˈmaː)lɪ̝s]	[hɪ̝.e.maː.lɪ̝s]

Attested form: *autumnalis* [aʊ̝.tʊ̝m.ˈnaː.lɪ̝s] ‘of autumn’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$autumn]aːRɪs/ →	[au.tumn]	[(ˈau)(ˌtum)(ˌnaː)lɪs]	[au.tum.naː.lɪs]
D. stage 2:	/[$_{stem}$autumn]aːRɪs/ →	[au.tumn]	[(ˈau)(ˌtum)(ˌnaː)lɪs]	[au.tum.naː.lɪs]
D. stage 3:	/[$_{stem}$autumn]aːlɪ̝s/ →	[au.tumn]	[(ˌaʊ̝)(ˌtʊ̝m)(ˈnaː)lɪ̝s]	[aʊ̝.tʊ̝m.naː.lɪ̝s]
D. stage 4:	/[$_{stem}$aʊ̝tʊ̝mn]aːlɪ̝s/ →	[aʊ̝.tʊ̝mn]	[(ˌaʊ̝)(ˌtʊ̝m)(ˈnaː)lɪ̝s]	[aʊ̝.tʊ̝m.naː.lɪ̝s]

Attested form: *Augustalis* [aʊ̝.gʊ̝s.ˈtaː.lɪ̝s] ‘rel. to Augustus’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$august]aːRɪs/ →	[au.gust]	[(ˈau)(ˌgus)(ˌtaː)lɪs]	[au.gus.taː.lɪs]
D. stage 2:	/[$_{stem}$august]aːRɪs/ →	[au.gust]	[(ˈau.gus)(ˌtaː)lɪs]	[au.gus.taː.lɪs]
D. stage 3:	/[$_{stem}$august]aːlɪ̝s/ →	[au.gust]	[(ˌaʊ̝)(ˌgʊ̝s)(ˈtaː)lɪ̝s]	[aʊ̝.gʊ̝s.taː.lɪ̝s]
D. stage 4:	/[$_{stem}$aʊ̝gʊ̝st]aːlɪ̝s/ →	[aʊ̝.gʊ̝st]	[(ˌaʊ̝)(ˌgʊ̝s)(ˈtaː)lɪ̝s]	[aʊ̝.gʊ̝s.taː.lɪ̝s]

Adjectives in *-alis* — intervening [r]

Attested form: *litoralis* [liː.to.ˈraː.lɪ̝s] ‘littoral’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$liːtos]aːRɪs/ →	[liː.tos]	[(ˈliː.to)(ˌsaː)rɪs]	[liː.to.zaː.rɪs]
D. stage 2:	/[$_{stem}$liːtos]aːRɪs/ →	[liː.tos]	[(ˈliː.to)(ˌraː)lɪs]	[liː.to.raː.lɪs]
D. stage 3:	/[$_{stem}$liːtor]aːlɪ̝s/ →	[liː.tor]	[(ˌliː.to)(ˈraː)lɪ̝s]	[liː.to.raː.lɪ̝s]
D. stage 4:	/[$_{stem}$liːtor]aːlɪ̝s/ →	[liː.tor]	[(ˌliː.to)(ˈraː)lɪ̝s]	[liː.to.raː.lɪ̝s]

Attested form: *lateralis* [la.te.ˈraː.lɪ̝s] ‘lateral’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$lates]aːRɪs/ →	[la.tes]	[(ˈla.te)(ˌsaː)rɪs]	[la.te.zaː.rɪs]
D. stage 2:	/[$_{stem}$lates]aːRɪs/ →	[la.tes]	[(ˈla.te)(ˌraː)lɪs]	[la.te.raː.lɪs]
D. stage 3:	/[$_{stem}$later]aːlɪ̝s/ →	[la.ter]	[(ˌla.te)(ˈraː)lɪ̝s]	[la.te.raː.lɪ̝s]
D. stage 4:	/[$_{stem}$later]aːlɪ̝s/ →	[la.ter]	[(ˌla.te)(ˈraː)lɪ̝s]	[la.te.raː.lɪ̝s]

Attested form: *floralis* [floː.ˈraː.lɪ̝s] ‘floral’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸloːs]aːRɪs/ →	[ɸloːs]	[(ˈɸloː)(ˌsaː)rɪs]	[ɸloː.zaː.rɪs]
D. stage 2:	/[$_{stem}$ɸloːs]aːRɪs/ →	[ɸloːs]	[(ˈfloː)(ˌraː)lɪs]	[floː.raː.lɪs]

	Input	Stem Level	Word Level	Phrase Level
D. stage 3:	/[$_{stem}$floːr]aːlɪ̝s/ →	[floːr]	[(ˌfloː)(ˈraː)lɪ̝s]	[floː.raː.lɪ̝s]
D. stage 4:	/[$_{stem}$floːr]aːlɪ̝s/ →	[floːr]	[(ˌfloː)(ˈraː)lɪ̝s]	[floː.raː.lɪ̝s]

Attested form: *pluralis* [pluː.ˈraː.lɪ̝s] ‘manifold’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$pluːs]aːRɪs/ →	[pluːs]	[(ˈpluː)(ˌsaː)rɪs]	[pluː.zaː.rɪs]
D. stage 2:	/[$_{stem}$pluːs]aːRɪs/ →	[pluːs]	[(ˈpluː)(ˌraː)lɪs]	[pluː.raː.lɪs]
D. stage 3:	/[$_{stem}$pluːr]aːlɪ̝s/ →	[pluːr]	[(ˌpluː)(ˈraː)lɪ̝s]	[pluː.raː.lɪ̝s]
D. stage 4:	/[$_{stem}$pluːr]aːlɪ̝s/ →	[pluːr]	[(ˌpluː)(ˈraː)lɪ̝s]	[pluː.raː.lɪ̝s]

Adjectives in *-alis* — intervening non-coronal

Attested form: *legalis* [leː.ˈgaː.lɪ̝s] ‘legal’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$leːg]aːRɪs/ →	[leːg]	[(ˈleː)(ˌgaː)rɪs]	[leː.gaː.rɪs]
D. stage 2:	/[$_{stem}$leːg]aːRɪs/ →	[leːg]	[(ˈleː)(ˌgaː)lɪs]	[leː.gaː.lɪs]
D. stage 3:	/[$_{stem}$leːg]aːlɪ̝s/ →	[leːg]	[(ˌleː)(ˈgaː)lɪ̝s]	[leː.gaː.lɪ̝s]
D. stage 4:	/[$_{stem}$leːg]aːlɪ̝s/ →	[leːg]	[(ˌleː)(ˈgaː)lɪ̝s]	[leː.gaː.lɪ̝s]

Attested form: *fluuialis* [flʊ̝.wɪ̝.ˈaː.lɪ̝s] ‘riverine’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸluwɪ]aːRɪs/ →	[ɸlu.wɪ]	[(ˈɸlu.wɪ)(ˌaː)rɪs]	[ɸlu.wɪ.aː.rɪs]
D. stage 2:	/[$_{stem}$ɸluwɪ]aːRɪs/ →	[ɸlu.wɪ]	[(ˈflu.wɪ)(ˌaː)lɪs]	[flu.wɪ.aː.lɪs]
D. stage 3:	/[$_{stem}$fluwɪ̝]aːlɪ̝s/ →	[flu.wɪ̝]	[(ˌflʊ̝.wɪ̝)(ˈaː)lɪ̝s]	[flʊ̝.wɪ̝.aː.lɪ̝s]
D. stage 4:	/[$_{stem}$flʊ̝wɪ̝]aːlɪ̝s/ →	[flʊ̝.wɪ̝]	[(ˌflʊ̝.wɪ̝)(ˈaː)lɪ̝s]	[flʊ̝.wɪ̝.aː.lɪ̝s]

Attested form: *pluuialis* [plʊ̝.wɪ̝.ˈaː.lɪ̝s] ‘rainy’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$plu.wɪ]aːRɪs/ →	[plu.wɪ]	[(ˈplu.wɪ)(ˌaː)rɪs]	[plu.wɪ.aː.rɪs]
D. stage 2:	/[$_{stem}$plu.wɪ]aːRɪs/ →	[plu.wɪ]	[(ˈplu.wɪ)(ˌaː)lɪs]	[plu.wɪ.aː.lɪs]
D. stage 3:	/[$_{stem}$plu.wɪ̝]aːlɪ̝s/ →	[plu.wɪ̝]	[(ˌplʊ̝.wɪ̝)(ˈaː)lɪ̝s]	[plʊ̝.wɪ̝.aː.lɪ̝s]
D. stage 4:	/[$_{stem}$plʊ̝.wɪ̝]aːlɪ̝s/ →	[plʊ̝.wɪ̝]	[(ˌplʊ̝.wɪ̝)(ˈaː)lɪ̝s]	[plʊ̝.wɪ̝.aː.lɪ̝s]

Attested form: *glacialis* [gla.kɪ̝.ˈaː.lɪ̝s] ‘icy’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$gla.kɪ]aːRɪs/ →	[gla.kɪ]	[(ˈgla.kɪ)(ˌaː)rɪs]	[gla.kɪ.aː.rɪs]
D. stage 2:	/[$_{stem}$gla.kɪ]aːRɪs/ →	[gla.kɪ]	[(ˈgla.kɪ)(ˌaː)lɪs]	[gla.kɪ.aː.lɪs]
D. stage 3:	/[$_{stem}$gla.kɪ̝]aːlɪ̝s/ →	[gla.kɪ̝]	[(ˌgla.kɪ̝)(ˈaː)lɪ̝s]	[gla.kɪ̝.aː.lɪ̝s]
D. stage 4:	/[$_{stem}$gla.kɪ̝]aːlɪ̝s/ →	[gla.kɪ̝]	[(ˌgla.kɪ̝)(ˈaː)lɪ̝s]	[gla.kɪ̝.aː.lɪ̝s]

Attested form: *umbilicalis* [ʊ̝m.bɪ̝.liː.ˈkaː.lɪ̝s] ‘umbilical’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$omɸaliːk]aːRɪs/ →	[om.ɸa.liːk]	[(ˈom.ɸa)(ˌliː)(ˌkaː)rɪs]	[om.ɸa.liː.kaː.rɪs]
D. stage 2:	/[$_{stem}$omβaliːk]aːRɪs/ →	[om.βa.liːk]	[(ˈom.ba)(ˌliː)(ˌkaː)lɪs]	[om.ba.liː.kaː.lɪs]
D. stage 3:	/[$_{stem}$umbɪ̝liːk]aːlɪ̝s/ →	[um.bɪ̝.liːk]	[(ˌʊ̝m.bɪ̝)(ˌliː)(ˈkaː)lɪ̝s]	[ʊ̝m.bɪ̝.liː.kaː.lɪ̝s]
D. stage 4:	/[$_{stem}$ʊ̝mbɪ̝liːk]aːlɪ̝s/ →	[ʊ̝m.bɪ̝.liːk]	[(ˌʊ̝m.bɪ̝)(ˌliː)(ˈkaː)lɪ̝s]	[ʊ̝m.bɪ̝.liː.kaː.lɪ̝s]

Attested form: *Vulcanalis* [wʊ̝l.kaː.ˈnaː.lɪ̝s] ‘of Vulcan’

	Input	Stem Level	Word Level	Phrase Level

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$wolkaːn]aːʀɪs/ →	[wol.kaːn]	[(ˈwol)(ˌkaː)(ˌnaː)rɪs]	[wol.kaː.naː.rɪs]
D. stage 2:	/[$_{stem}$wolkaːn]aːʀɪs/ →	[wol.kaːn]	[(ˈwol)(ˌkaː)(ˌnaː)lɪs]	[wol.kaː.naː.lɪs]
D. stage 3:	/[$_{stem}$wulkaːn]aːlɪ̞s/ →	[wul.kaːn]	[(ˌwʊ̞l)(ˌkaː)(ˈnaː)lɪ̞s]	[wʊ̞l.kaː.naː.lɪ̞s]
D. stage 4:	/[$_{stem}$wʊ̞lkaːn]aːlɪ̞s/ →	[wʊ̞l.kaːn]	[(ˌwʊ̞l)(ˌkaː)(ˈnaː)lɪ̞s]	[wʊ̞l.kaː.naː.lɪ̞s]
Attested form: *cloacalis* [klo.aː.ˈkaː.lɪ̞s] ‘of sewer’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$kloːaːk]aːʀɪs/ →	[kloː.aːk]	[(ˈkloː)(ˌaː)(ˌkaː)rɪs]	[kloː.aː.kaː.rɪs]
D. stage 2:	/[$_{stem}$kloːaːk]aːʀɪs/ →	[kloː.aːk]	[(ˈkloː)(ˌaː)(ˌkaː)lɪs]	[kloː.aː.kaː.lɪs]
D. stage 3:	/[$_{stem}$kloaːk]aːlɪ̞s/ →	[klo.aːk]	[klo(ˌaː)(ˈkaː)lɪ̞s]	[klo.aː.kaː.lɪ̞s]
D. stage 4:	/[$_{stem}$kloaːk]aːlɪ̞s/ →	[klo.aːk]	[klo(ˌaː)(ˈkaː)lɪ̞s]	[klo.aː.kaː.lɪ̞s]
Attested form: *Flauialis* [flaː.wɪ̞.ˈaː.lɪ̞s] ‘of Flavian priests’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸlaːwɪ]aːʀɪs/ →	[ɸlaː.wɪ]	[(ˈɸlaː.wɪ)(ˌaː)rɪs]	[ɸlaː.wɪ.aː.rɪs]
D. stage 2:	/[$_{stem}$ɸlaːwɪ]aːʀɪs/ →	[ɸlaː.wɪ]	[(ˈflaː.wɪ)(ˌaː)lɪs]	[flaː.wɪ.aː.lɪs]
D. stage 3:	/[$_{stem}$flaːwɪ̞]aːlɪ̞s/ →	[flaː.wɪ̞]	[(ˌflaː.wɪ̞)(ˈaː)lɪ̞s]	[flaː.wɪ̞.aː.lɪ̞s]
D. stage 4:	/[$_{stem}$flaːwɪ̞]aːlɪ̞s/ →	[flaː.wɪ̞]	[(ˌflaː.wɪ̞)(ˈaː)lɪ̞s]	[flaː.wɪ̞.aː.lɪ̞s]
Attested form: *glebalis* [gleː.ˈbaː.lɪ̞s] ‘of clods’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$gleːb]aːʀɪs/ →	[gleːb]	[(ˈgleː)(ˌbaː)rɪs]	[gleː.baː.rɪs]
D. stage 2:	/[$_{stem}$gleːb]aːʀɪs/ →	[gleːb]	[(ˈgleː)(ˌbaː)lɪs]	[gleː.baː.lɪs]
D. stage 3:	/[$_{stem}$gleːb]aːlɪ̞s/ →	[gleːb]	[(ˌgleː)(ˈbaː)lɪ̞s]	[gleː.baː.lɪ̞s]
D. stage 4:	/[$_{stem}$gleːb]aːlɪ̞s/ →	[gleːb]	[(ˌgleː)(ˈbaː)lɪ̞s]	[gleː.baː.lɪ̞s]
Attested form: *localis* [lo.ˈkaː.lɪ̞s] ‘local’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$lok]aːʀɪs/ →	[lok]	[(ˈlo.kaː)rɪs]	[lo.kaː.rɪs]
D. stage 2:	/[$_{stem}$lok]aːʀɪs/ →	[lok]	[(ˈlo.kaː)lɪs]	[lo.kaː.lɪs]
D. stage 3:	/[$_{stem}$lok]aːlɪ̞s/ →	[lok]	[lo(ˈkaː)lɪ̞s]	[lo.kaː.lɪ̞s]
D. stage 4:	/[$_{stem}$lok]aːlɪ̞s/ →	[lok]	[lo(ˈkaː)lɪ̞s]	[lo.kaː.lɪ̞s]
Attested form: *fulminalis* [fʊ̞l.mɪ̞.ˈnaː.lɪ̞s] ‘projectile’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸulgmen]aːʀɪs/ →	[ɸul.gmen]	[(ˈɸul.gme)(ˌnaː)rɪs]	[ɸul.gme.naː.rɪs]
D. stage 2:	/[$_{stem}$ɸulmen]aːʀɪs/ →	[ɸul.men]	[(ˈful.me)(ˌnaː)lɪs]	[ful.me.naː.lɪs]
D. stage 3:	/[$_{stem}$fulmɪ̞n]aːlɪ̞s/ →	[ful.mɪ̞n]	[(ˌfʊ̞l.mɪ̞)(ˈnaː)lɪ̞s]	[fʊ̞l.mɪ̞.naː.lɪ̞s]
D. stage 4:	/[$_{stem}$fʊ̞lmɪ̞n]aːlɪ̞s/ →	[fʊ̞l.mɪ̞n]	[(ˌfʊ̞l.mɪ̞)(ˈnaː)lɪ̞s]	[fʊ̞l.mɪ̞.naː.lɪ̞s]
Adjectives in *-alis* — intervening [r] and non-coronal				
Attested form: *liberalis* [lɪ̞.be.ˈraː.lɪ̞s] ‘gentlemanly’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$leɪθer]aːʀɪs/ →	[leɪ.θer]	[(ˈleɪ.θe)(ˌraː)lɪs]	[leɪ.ðe.raː.lɪs]
D. stage 2:	/[$_{stem}$leɪver]aːʀɪs/ →	[leɪ.ver]	[(ˈlɪː.be)(ˌraː)lɪs]	[lɪː.be.raː.lɪs]
D. stage 3:	/[$_{stem}$lɪ̞ːber]aːlɪ̞s/ →	[lɪ̞ː.ber]	[(ˌliː.be)(ˈraː)lɪ̞s]	[liː.be.raː.lɪ̞s]
D. stage 4:	/[$_{stem}$liːber]aːlɪ̞s/ →	[liː.ber]	[(ˌliː.be)(ˈraː)lɪ̞s]	[liː.be.raː.lɪ̞s]

Attested form: *larualis* [laːr.ˈwaː.lɪ̞s] ‘ghostly’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$laːrw]aːRɪs/ →	[laːrw]	[(ˈlaːr)(ˌwaː)lɪs]	[laːr.waː.lɪs]
D. stage 2:	/[$_{stem}$laːrw]aːRɪs/ →	[laːrw]	[(ˈlaːr)(ˌwaː)lɪs]	[laːr.waː.lɪs]
D. stage 3:	/[$_{stem}$laːrw]aːlɪ̞s/ →	[laːrw]	[(ˌlaːr)(ˈwaː)lɪ̞s]	[laːr.waː.lɪ̞s]
D. stage 4:	/[$_{stem}$laːrw]aːlɪ̞s/ →	[laːrw]	[lar(ˈwaː)lɪ̞s]	[lar.waː.lɪ̞s]

Attested form: *latrocinalis* [la.troː.kɪ̞.ˈnaː.lɪ̞s] ‘of thieves’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$latroːkɪn]aːRɪs/ →	[la.troː.kɪn]	[(ˈla.troː)kɪ(ˌnaː)lɪs]	[la.troː.kɪ.naː.lɪs]
D. stage 2:	/[$_{stem}$latroːkɪn]aːRɪs/ →	[la.troː.kɪn]	[(ˈla.troː)kɪ(ˌnaː)lɪs]	[la.troː.kɪ.naː.lɪs]
D. stage 3:	/[$_{stem}$latroːkɪ̞n]aːlɪ̞s/ →	[la.troː.kɪ̞n]	[la(ˌtroː.kɪ̞)(ˈnaː)lɪ̞s]	[la.troː.kɪ̞.naː.lɪ̞s]
D. stage 4:	/[$_{stem}$latroːkɪ̞n]aːlɪ̞s/ →	[la.troː.kɪ̞n]	[(ˌlat)(ˌroː.kɪ̞)(ˈnaː)lɪ̞s]	[la.troː.kɪ̞.naː.lɪ̞s]

Attested form: *sepulcralis* [se.pʊ̞l.ˈkraː.lɪ̞s] ‘sepulchral’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$sepulkr]aːRɪs/ →	[se.pulkr]	[(ˈse.pul)(ˌkraː)lɪs]	[se.pul.kraː.lɪs]
D. stage 2:	/[$_{stem}$sepulkr]aːRɪs/ →	[se.pulkr]	[(ˈse.pul)(ˌkraː)lɪs]	[se.pul.kraː.lɪs]
D. stage 3:	/[$_{stem}$sepulkr]aːlɪ̞s/ →	[se.pulkr]	[se(ˌpʊ̞l)(ˈkraː)lɪ̞s]	[se.pʊ̞l.kraː.lɪ̞s]
D. stage 4:	/[$_{stem}$sepʊ̞lkr]aːlɪ̞s/ →	[se.pʊ̞lkr]	[se(ˌpʊ̞l)(ˈkraː)lɪ̞s]	[se.pʊ̞l.kraː.lɪ̞s]

Attested form: *fulguralis* [fʊ̞l.gʊ̞.ˈraː.lɪ̞s] ‘of lightning’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸulgur]aːRɪs/ →	[ɸul.gur]	[(ˈɸul.gu)(ˌraː)lɪs]	[ɸul.gu.raː.lɪs]
D. stage 2:	/[$_{stem}$ɸulgur]aːRɪs/ →	[ɸul.gur]	[(ˈful.gu)(ˌraː)lɪs]	[ful.gu.raː.lɪs]
D. stage 3:	/[$_{stem}$fulgʊ̞r]aːlɪ̞s/ →	[ful.gʊ̞r]	[(ˌfʊ̞l.gʊ̞)(ˈraː)lɪ̞s]	[fʊ̞l.gʊ̞.raː.lɪ̞s]
D. stage 4:	/[$_{stem}$fʊ̞lgʊ̞r]aːlɪ̞s/ →	[fʊ̞l.gʊ̞r]	[(ˌfʊ̞l.gʊ̞)(ˈraː)lɪ̞s]	[fʊ̞l.gʊ̞.raː.lɪ̞s]

Adjectives in *-aris* — intervening [r] and non-coronal

Attested form: *consularis* [kon.sʊ̞.ˈlaː.rɪ̞s] ‘consular’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$konsol]aːRɪs/ →	[kon.sol]	[(ˈkon.so)(ˌlaː)rɪs]	[kon.so.laː.rɪs]
D. stage 2:	/[$_{stem}$konsol]aːRɪs/ →	[kon.sol]	[(ˈkon.so)(ˌlaː)rɪs]	[kon.so.laː.rɪs]
D. stage 3:	/[$_{stem}$konsʊ̞l]aːrɪ̞s/ →	[kon.sʊ̞l]	[(ˌkon.sʊ̞)(ˈlaː)rɪ̞s]	[kon.sʊ̞.laː.rɪ̞s]
D. stage 4:	/[$_{stem}$konsʊ̞l]aːrɪ̞s/ →	[kon.sʊ̞l]	[(ˌkon.sʊ̞)(ˈlaː)rɪ̞s]	[kon.sʊ̞.laː.rɪ̞s]

Attested form: *popularis* [po.pʊ̞.ˈlaː.rɪ̞s] ‘popular’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$popol]aːRɪs/ →	[po.pol]	[(ˈpo.po)(ˌlaː)rɪs]	[po.po.laː.rɪs]
D. stage 2:	/[$_{stem}$popol]aːRɪs/ →	[po.pol]	[(ˈpo.po)(ˌlaː)rɪs]	[po.po.laː.rɪs]
D. stage 3:	/[$_{stem}$popʊ̞l]aːrɪ̞s/ →	[po.pʊ̞l]	[(ˌpo.pʊ̞)(ˈlaː)rɪ̞s]	[po.pʊ̞.laː.rɪ̞s]
D. stage 4:	/[$_{stem}$popʊ̞l]aːrɪ̞s/ →	[po.pʊ̞l]	[(ˌpo.pʊ̞)(ˈlaː)rɪ̞s]	[po.pʊ̞.laː.rɪ̞s]

Attested form: *militaris* [mɪ̞.lɪ̞.ˈtaː.rɪ̞s] ‘military’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$mɪlet]aːRɪs/ →	[mɪ.let]	[(ˈmɪ.le)(ˌtaː)rɪs]	[mɪ.le.taː.rɪs]
D. stage 2:	/[$_{stem}$mɪlet]aːRɪs/ →	[mɪ.let]	[(ˈmɪ.le)(ˌtaː)rɪs]	[mɪ.le.taː.rɪs]
D. stage 3:	/[$_{stem}$mɪ̞lɪ̞t]aːrɪ̞s/ →	[mɪ̞.lɪ̞t]	[(ˌmɪ̞.lɪ̞)(ˈtaː)rɪ̞s]	[mɪ̞.lɪ̞.taː.rɪ̞s]

	Input	Stem Level	Word Level	Phrase Level
D. stage 4:	/[$_{stem}$mɪ̞lɪ̞t]aːrɪ̞s/ →	[mɪ̞.lɪ̞t]	[(ˌmɪ̞.lɪ̞)(ˈtaː)rɪ̞s]	[mɪ̞.lɪ̞.taː.rɪ̞s]

Attested form: *lunaris* [luː.ˈnaː.rɪ̞s] ‘lunar’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$luːn]aːRɪs/ →	[luːn]	[(ˈluː)(ˌnaː)rɪs]	[luː.naː.rɪs]
D. stage 2:	/[$_{stem}$luːn]aːRɪs/ →	[luːn]	[(ˈluː)(ˌnaː)rɪs]	[luː.naː.rɪs]
D. stage 3:	/[$_{stem}$luːn]aːrɪ̞s/ →	[luːn]	[(ˌluː)(ˈnaː)rɪ̞s]	[luː.naː.rɪ̞s]
D. stage 4:	/[$_{stem}$luːn]aːrɪ̞s/ →	[luːn]	[(ˌluː)(ˈnaː)rɪ̞s]	[luː.naː.rɪ̞s]

Attested form: *stellaris* [stel.ˈlaː.rɪ̞s] ‘stellar’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$sterl]aːRɪs/ →	[sterl]	[(ˈster)(ˌlaː)rɪs]	[ster.laː.rɪs]
D. stage 2:	/[$_{stem}$sterl]aːRɪs/ →	[sterl]	[(ˈstel)(ˌlaː)rɪs]	[stel.laː.rɪs]
D. stage 3:	/[$_{stem}$stell]aːrɪ̞s/ →	[stelː]	[(ˌstel)(ˈlaː)rɪ̞s]	[stel.laː.rɪ̞s]
D. stage 4:	/[$_{stem}$stell]aːrɪ̞s/ →	[stelː]	[(ˌstel)(ˈlaː)rɪ̞s]	[stel.laː.rɪ̞s]

Attested form: *Saliaris* [sa.lɪ̞.ˈaː.rɪ̞s] ‘of Salian priests’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$salɪ]aːRɪs/ →	[sa.lɪ]	[(ˈsa.lɪ)(ˌaː)rɪs]	[sa.lɪ.aː.rɪs]
D. stage 2:	/[$_{stem}$salɪ]aːRɪs/ →	[sa.lɪ]	[(ˈsa.lɪ)(ˌaː)rɪs]	[sa.lɪ.aː.rɪs]
D. stage 3:	/[$_{stem}$salɪ̞]aːrɪ̞s/ →	[sa.lɪ̞]	[(ˌsa.lɪ̞)(ˈaː)rɪ̞s]	[sa.lɪ̞.aː.rɪ̞s]
D. stage 4:	/[$_{stem}$salɪ̞]aːrɪ̞s/ →	[sa.lɪ̞]	[(ˌsa.lɪ̞)(ˈaː)rɪ̞s]	[sa.lɪ̞.aː.rɪ̞s]

Problematic forms				
Attested form: *palmaris* [pal.ˈmaː.rɪ̞s] ‘of palms’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$palm]aːRɪs/ →	[palm]	[(ˈpal)(ˌmaː)rɪs]	[pal.maː.rɪs]
D. stage 2:	/[$_{stem}$palm]aːrɪs/ →	[palm]	[(ˈpal)(ˌmaː)rɪs]	[pal.maː.rɪs]
D. stage 3:	/[$_{stem}$palm]aːrɪ̞s/ →	[palm]	[(ˌpal)(ˈmaː)rɪ̞s]	[pal.maː.rɪ̞s]
D. stage 4:	/[$_{stem}$palm]aːrɪ̞s/ →	[palm]	[(ˌpal)(ˈmaː)rɪ̞s]	[pal.maː.rɪ̞s]

Attested form: *uulgaris* [wul.ˈgaː.rɪ̞s] ‘vulgar’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$wulg]aːRɪs/ →	[wulg]	[(ˈwul)(ˌgaː)rɪs]	[wul.gaː.rɪs]
D. stage 2:	/[$_{stem}$wulg]aːrɪs/ →	[wulg]	[(ˈwul)(ˌgaː)rɪs]	[wul.gaː.rɪs]
D. stage 3:	/[$_{stem}$wulg]aːrɪ̞s/ →	[wulg]	[(ˌwʊ̞l)(ˈgaː)rɪ̞s]	[wʊ̞l.gaː.rɪ̞s]
D. stage 4:	/[$_{stem}$wʊ̞lg]aːrɪ̞s/ →	[wʊ̞lg]	[(ˌwʊ̞l)(ˈgaː)rɪ̞s]	[wʊ̞l.gaː.rɪ̞s]

Attested form: *aquilonalis* [a.kʷɪ̞.loː.ˈnaː.lɪ̞s] ‘northern’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$akʷɪloːn]aːlɪs/ →	[a.kʷɪ.loːn]	[(ˈa.kʷɪ)(ˌloː)(ˌnaː)lɪs]	[a.kʷɪ.loː.naː.lɪs]
D. stage 2:	/[$_{stem}$akʷɪloːn]aːlɪs/ →	[a.kʷɪ.loːn]	[(ˈa.kʷɪ)(ˌloː)(ˌnaː)lɪs]	[a.kʷɪ.loː.naː.lɪs]
D. stage 3:	/[$_{stem}$akʷɪ̞loːn]aːlɪ̞s/ →	[a.kʷɪ̞.loːn]	[(ˌa.kʷɪ̞)(ˌloː)(ˈnaː)lɪ̞s]	[a.kʷɪ̞.loː.naː.lɪ̞s]
D. stage 4:	/[$_{stem}$akʷɪ̞loːn]aːlɪ̞s/ →	[a.kʷɪ̞.loːn]	[(ˌa.kʷɪ̞)(ˌloː)(ˈnaː)lɪ̞s]	[a.kʷɪ̞.loː.naː.lɪ̞s]

Attested form: *liminaris* [liː.mɪ̞.ˈnaː.rɪ̞s] ‘of lintel’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$liːmen]aːRɪs/ →	[liː.men]	[(ˈliː.me)(ˌnaː)rɪs]	[liː.me.naː.rɪs]

D. stage 2:	/[$_{stem}$liːmen]aːrɪs/ →	[liː.men]	[(ˈliː.me)(ˌnaː)rɪs]	[liː.me.naː.rɪs]
D. stage 3:	/[$_{stem}$liːmɪ̝n]aːrɪ̝s/ →	[liː.mɪ̝n]	[(ˌliː.mɪ̝)(ˈnaː)rɪ̝s]	[liː.mɪ̝.naː.rɪ̝s]
D. stage 4:	/[$_{stem}$liːmɪ̝n]aːrɪ̝s/ →	[liː.mɪ̝n]	[(ˌliː.mɪ̝)(ˈnaː)rɪ̝s]	[liː.mɪ̝.naː.rɪ̝s]

Attested form: *coquinaris* [ko.kʷiː.ˈnaː.rɪ̝s] ‘of kitchen’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$kokʷiːn]aːrɪs/ →	[ko.kʷiːn]	[(ˈko.kʷiː)(ˌnaː)rɪs]	[ko.kʷiː.naː.rɪs]
D. stage 2:	/[$_{stem}$kokʷiːn]aːrɪs/ →	[ko.kʷiːn]	[(ˈko.kʷiː)(ˌnaː)rɪs]	[ko.kʷiː.naː.rɪs]
D. stage 3:	/[$_{stem}$kokʷiːn]aːrɪ̝s/ →	[ko.kʷiːn]	[ko(ˌkʷiː)(ˈnaː)rɪ̝s]	[ko.kʷiː.naː.rɪ̝s]
D. stage 4:	/[$_{stem}$kokʷiːn]aːrɪ̝s/ →	[ko.kʷiːn]	[ko(ˌkʷiː)(ˈnaː)rɪ̝s]	[ko.kʷiː.naː.rɪ̝s]

Attested form: *Palatualis* [pa.laː.tʊ̝.ˈaː.lɪ̝s] ‘(a feast)’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$palaːtu]aːlɪs/ →	[pa.laː.tu]	[(ˈpa.laː)tu(ˌaː)lɪs]	[pa.laː.tu.aː.lɪs]
D. stage 2:	/[$_{stem}$palaːtu]aːlɪs/ →	[pa.laː.tu]	[(ˈpa.laː)tu(ˌaː)lɪs]	[pa.laː.tu.aː.lɪs]
D. stage 3:	/[$_{stem}$palaːtu]aːlɪ̝s/ →	[pa.laː.tu]	[pa(ˌlaː.tʊ̝)(ˈaː)lɪ̝s]	[pa.laː.tʊ̝.aː.lɪ̝s]
D. stage 4:	/[$_{stem}$palaːtʊ̝]aːlɪ̝s/ →	[pa.laː.tʊ̝]	[pa(ˌlaː.tʊ̝)(ˈaː)lɪ̝s]	[pa.laː.tʊ̝.aː.lɪ̝s]

Attested form: *letalis* [leː.ˈtaː.lɪ̝s] ‘lethal’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$leːt]aːlɪs/ →	[leːt]	[(ˈleː)(ˌtaː)lɪs]	[leː.taː.lɪs]
D. stage 2:	/[$_{stem}$leːt]aːlɪs/ →	[leːt]	[(ˈleː)(ˌtaː)lɪs]	[leː.taː.lɪs]
D. stage 3:	/[$_{stem}$leːt]aːlɪ̝s/ →	[leːt]	[(ˌleː)(ˈtaː)lɪ̝s]	[leː.taː.lɪ̝s]
D. stage 4:	/[$_{stem}$leːt]aːlɪ̝s/ →	[leːt]	[(ˌleː)(ˈtaː)lɪ̝s]	[leː.taː.lɪ̝s]

Attested form: *Latialis* [la.tɪ̝.ˈaː.lɪ̝s] ‘of Latium’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$la.tɪ]aːlɪs/ →	[la.tɪ]	[(ˈla.tɪ)(ˌaː)lɪs]	[la.tɪ.aː.lɪs]
D. stage 2:	/[$_{stem}$la.tɪ]aːlɪs/ →	[la.tɪ]	[(ˈla.tɪ)(ˌaː)lɪs]	[la.tɪ.aː.lɪs]
D. stage 3:	/[$_{stem}$la.tɪ̝]aːlɪ̝s/ →	[la.tɪ̝]	[(ˌla.tɪ̝)(ˈaː)lɪ̝s]	[la.tɪ̝.aː.lɪ̝s]
D. stage 4:	/[$_{stem}$la.tɪ̝]aːlɪ̝s/ →	[la.tɪ̝]	[(ˌla.tɪ̝)(ˈaː)lɪ̝s]	[la.tɪ̝.aː.lɪ̝s]

Attested form: *Latiaris* [la.tɪ̝.ˈaː.rɪ̝s] ‘of Latium’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$la.tɪ]aːRɪs/ →	[la.tɪ]	[(ˈla.tɪ)(ˌaː)rɪs]	[la.tɪ.aː.rɪs]
D. stage 2:	/[$_{stem}$la.tɪ]aːRɪs/ →	[la.tɪ]	[(ˈla.tɪ)(ˌaː)rɪs]	[la.tɪ.aː.rɪs]
D. stage 3:	/[$_{stem}$la.tɪ̝]aːrɪ̝s/ →	[la.tɪ̝]	[(ˌla.tɪ̝)(ˈaː)rɪ̝s]	[la.tɪ̝.aː.rɪ̝s]
D. stage 4:	/[$_{stem}$la.tɪ̝]aːrɪ̝s/ →	[la.tɪ̝]	[(ˌla.tɪ̝)(ˈaː)rɪ̝s]	[la.tɪ̝.aː.rɪ̝s]

Rhotacism

Attested form: *soror* [ˈso.ror] ‘sister.NOM.SG’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$swe.soːr]/ →	[swe.soːr]	[(ˈswe.soːr)]	[swe.zoːr]
D. stage 2:	/[$_{stem}$so.soːr]/ →	[so.soːr]	[(ˈso.roːr)]	[so.roːr]
D. stage 3:	/[$_{stem}$so.soːr]/ →	[so.roːr]	[(ˈso.roːr)]	[so.roːr]
D. stage 4:	/[$_{stem}$so.roːr]/ →	[so.roːr]	[(ˈso.ror)]	[so.ror]

Attested form: *flos* [ˈfloːs] ‘flower.NOM.SG’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸloːs]/ →	[ɸloːs]	[(ˈɸloːs)]	[ɸloːs]
D. stage 2:	/[$_{stem}$ɸloːs]/ →	[ɸloːs]	[(ˈfloːs)]	[floːs]
D. stage 3:	/[$_{stem}$floːs]/ →	[floːs]	[(ˈfloːs)]	[floːs]
D. stage 4:	/[$_{stem}$floːs]/ →	[floːs]	[(ˈfloːs)]	[floːs]

Attested form: *floris* [ˈfloː.rɪ̞s] ‘flower.GEN.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸloːsɪ]s/ →	[ɸloː.sɪ]	[(ˈɸloː)sɪs]	[ɸloː.zɪs]
D. stage 2:	/[$_{stem}$ɸloːsɪ]s/ →	[ɸloː.sɪ]	[(ˈfloː)rɪs]	[floː.rɪs]
D. stage 3:	/[$_{stem}$floːsɪ̞]s/ →	[floː.rɪ̞]	[(ˈfloː)rɪ̞s]	[floː.rɪ̞s]
D. stage 4:	/[$_{stem}$floːrɪ̞]s/ →	[floː.rɪ̞]	[(ˈfloː)rɪ̞s]	[floː.rɪ̞s]

Attested form: *rus* [ˈruːs] ‘countryside.NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ruːs]/ →	[ruːs]	[(ˈruːs)]	[ruːs]
D. stage 2:	/[$_{stem}$ruːs]/ →	[ruːs]	[(ˈruːs)]	[ruːs]
D. stage 3:	/[$_{stem}$ruːs]/ →	[ruːs]	[(ˈruːs)]	[ruːs]
D. stage 4:	/[$_{stem}$ruːs]/ →	[ruːs]	[(ˈruːs)]	[ruːs]

Attested form: *ruris* [ˈruː.rɪ̞s] ‘countryside.GEN.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ruːsɪ]s/ →	[ruː.sɪ]	[(ˈruː)sɪs]	[ruː.zɪs]
D. stage 2:	/[$_{stem}$ruːsɪ]s/ →	[ruː.sɪ]	[(ˈruː)rɪs]	[ruː.rɪs]
D. stage 3:	/[$_{stem}$ruːsɪ̞]s/ →	[ruː.rɪ̞]	[(ˈruː)rɪ̞s]	[ruː.rɪ̞s]
D. stage 4:	/[$_{stem}$ruːrɪ̞]s/ →	[ruː.rɪ̞]	[(ˈruː)rɪ̞s]	[ruː.rɪ̞s]

Attested form: *funeris* [ˈfuː.ne.rɪ̞s] ‘funeral.GEN.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$θuːnesɪ]s/ →	[θuː.ne.sɪ]	[(ˈθuː.ne)sɪs]	[θuː.ne.zɪs]
D. stage 2:	/[$_{stem}$fuːnesɪ]s/ →	[fuː.ne.sɪ]	[(ˈfuː.ne)rɪs]	[fuː.ne.rɪs]
D. stage 3:	/[$_{stem}$fuːnerɪ̞]s/ →	[fuː.ne.rɪ̞]	[(ˈfuː.ne)rɪ̞s]	[fuː.ne.rɪ̞s]
D. stage 4:	/[$_{stem}$fuːnerɪ̞]s/ →	[fuː.ne.rɪ̞]	[(ˈfuː.ne)rɪ̞s]	[fuː.ne.rɪ̞s]

Attested form: *funestus* [fuː.ˈnes.tus] ‘funereal.NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$θuːnesto]s/ →	[θuː.nes.to]	[(ˈθuː)(ˌnes)tos]	[θuː.nes.tos]
D. stage 2:	/[$_{stem}$fuːnesto]s/ →	[fuː.nes.to]	[(ˈfuː.nes)tos]	[fuː.nes.tos]
D. stage 3:	/[$_{stem}$fuːnestʊ̞]s/ →	[fuː.nes.tʊ̞]	[(ˌfuː)(ˈnes)tʊ̞s]	[fuː.nes.tʊ̞s]
D. stage 4:	/[$_{stem}$fuːnestʊ̞]s/ →	[fuː.nes.tʊ̞]	[(ˌfuː)(ˈnes)tʊ̞s]	[fuː.nes.tʊ̞s]

Attested form: *gessi* [ˈges.siː] ‘undertake.1SG.PRF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$gess]iː/ →	[gesː]	[(ˈges)siː]	[ges.siː]
D. stage 2:	/[$_{stem}$gess]iː/ →	[gesː]	[(ˈges.siː)]	[ges.siː]
D. stage 3:	/[$_{stem}$gess]iː/ →	[gesː]	[(ˈges)siː]	[ges.siː]
D. stage 4:	/[$_{stem}$gess]iː/ →	[gesː]	[(ˈges)siː]	[ges.siː]

Attested form: *missum* [ˈmis.sum] ‘send-PRF.PTCP.M.ACC’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$mɪtso]m/ →	[mɪt.so]	[(ˈmɪs)som]	[mɪs.som]
D. stage 2:	/[$_{stem}$mɪsso]m/ →	[mɪs.so]	[(ˈmɪs.som)]	[mɪs.som]
D. stage 3:	/[$_{stem}$mɪ̯ssu]m/ →	[mɪ̯s.su]	[(ˈmɪ̯s)sʊ̯m]	[mɪ̯s.sʊ̯m]
D. stage 4:	/[$_{stem}$mɪ̯ssʊ̯]m/ →	[mɪ̯s.sʊ̯]	[(ˈmɪ̯s)sʊ̯m]	[mɪ̯s.sʊ̯m]

Attested form: *causa* [ˈcau.sa] ‘cause-NOM-ACC.F’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$kaussa]/ →	[kaus.sa]	[(ˈkaus)sa]	[kaus.sa]
D. stage 2:	/[$_{stem}$kaussa]/ →	[kaus.sa]	[(ˈkaus)sa]	[kaus.sa]
D. stage 3:	/[$_{stem}$kaussa]/ →	[kaus.sa]	[(ˈkaʊ̯s)sa]	[kaʊ̯s.sa]
D. stage 4:	/[$_{stem}$kaussa]/ →	[kaus.sa]	[(ˈkaʊ̯s)sa]	[kaʊ̯s.sa]

Attested form: *desilio* [de.ˈsɪ̯.lɪ̯.oː] ‘jump down-.1SG.PRES’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/de[$_{stem}$salɪ]oː/ →	[sa.lɪ]	[(ˈde.sa)lɪ.oː]	[de.za.lɪ.oː]
D. stage 2:	/de[$_{stem}$salɪ]oː/ →	[sa.lɪ]	[(ˈde.ra)lɪ.oː]	[de.ra.lɪ.oː]
D. stage 3:	/de[$_{stem}$sɪ̯lɪ̯]oː/ →	[sɪ̯.lɪ̯]	[de(ˈsɪ̯.lɪ̯)oː]	[de.sɪ̯.lɪ̯.oː]
D. stage 4:	/de[$_{stem}$sɪ̯lɪ̯]oː/ →	[sɪ̯.lɪ̯]	[de(ˈsɪ̯.lɪ̯)oː]	[de.sɪ̯.lɪ̯.oː]

Attested form: *nisi* [ˈni.siː] ‘unless’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/nɪ[$_{stem}$siː]/ →	[siː]	[(ˈnɪ.siː)]	[nɪ.ziː]
D. stage 2:	/nɪ[$_{stem}$siː]/ →	[siː]	[(ˈnɪ.riː)]	[nɪ.riː]
D. stage 3:	/nɪ̯[$_{stem}$siː]/ →	[siː]	[(ˈnɪ̯.siː)]	[nɪ̯.siː]
D. stage 4:	/nɪ̯[$_{stem}$siː]/ →	[siː]	[(ˈnɪ̯.siː)]	[nɪ̯.siː]

Attested form: *dirimo* [ˈdɪ̯.rɪ̯.moː] ‘take apart’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/dɪs[$_{stem}$em]oː/ →	[em]	[(ˈdɪ.se)moː]	[dɪ.ze.moː]
D. stage 2:	/dɪs[$_{stem}$em]oː/ →	[em]	[(ˈdɪ.re)moː]	[dɪ.re.moː]
D. stage 3:	/dɪ̯r[$_{stem}$ɪ̯m]oː/ →	[ɪ̯m]	[(ˈdɪ̯.rɪ̯)moː]	[dɪ̯.rɪ̯.moː]
D. stage 4:	/dɪ̯r[$_{stem}$ɪ̯m]oː/ →	[ɪ̯m]	[(ˈdɪ̯.rɪ̯)moː]	[dɪ̯.rɪ̯.moː]

Attested form: *miser* [ˈmɪ̯.ser] ‘wretched’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$mɪsero]s/ →	[mɪ.se.ro]	[(ˈmɪ.se)ros]	[mɪ.ze.ros]
D. stage 2:	/[$_{stem}$mɪsero]s/ →	[mɪ.se.ro]	[(ˈmɪ.re)ros]	[mɪ.re.ros]
D. stage 3:	/[$_{stem}$mɪ̯ser]/ →	[mɪ̯.ser]	[(ˈmɪ̯.ser)]	[mɪ̯.ser]
D. stage 4:	/[$_{stem}$mɪ̯ser]/ →	[mɪ̯.ser]	[(ˈmɪ̯.ser)]	[mɪ̯.ser]

Attested form: *basis* [ˈba.sɪ̯s] ‘pedestal’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:				
D. stage 2:				
D. stage 3:				

D. stage 4:	/[$_{stem}$basɪ̝]s/ →	[ba.sɪ̝]	[(ˈba.sɪ̝s)]	[ba.sɪ̝s]

Attested form: *cisium* [ˈkɪ̝.sɪ̝.ʊ̝m] ‘cabriolet’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:				
D. stage 2:				
D. stage 3:				
D. stage 4:	/[$_{stem}$kɪ̝sɪ̝ʊ̝]m/ →	[kɪ̝.sɪ̝.ʊ̝]	[(ˈkɪ̝.sɪ̝)ʊ̝m]	[kɪ̝.sɪ̝.ʊ̝m]

Attested form: *caesaries* [kae.ˈsa.rɪ̝.eːs] ‘luxuriant hair’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$kaɪsarɪeː]s/ →	[kaɪ.sa.rɪ.eː]	[(ˈkaɪ)(ˌsa.rɪ)eːs]	[kaɪ.za.rɪ.eːs]
D. stage 2:	/[$_{stem}$kaesarɪeː]s/ →	[kae.sa.rɪ.eː]	[(ˈkae)(ˌra.rɪ)eːs]	[kae.ra.rɪ.eːs]
D. stage 3:	/[$_{stem}$kaesarɪ̝eː]s/ →	[kae.sa.rɪ̝.eː]	[(ˌkae)(ˈsa.rɪ̝)eːs]	[kae.sa.rɪ̝.eːs]
D. stage 4:	/[$_{stem}$kaesarɪ̝eː]s/ →	[kae.sa.rɪ̝.eː]	[(ˌkae)(ˈsa.rɪ̝)eːs]	[kae.sa.rɪ̝.eːs]

Attested form: *honos* [ˈho.noːs] ‘honour-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$honoːs]/ →	[ho.noːs]	[(ˈho.noːs)]	[ho.noːs]
D. stage 2:	/[$_{stem}$honoːs]/ →	[ho.noːs]	[(ˈho.noːs)]	[ho.noːs]
D. stage 3:	/[$_{stem}$honoːs]/ →	[ho.noːs]	[(ˈho.noːs)]	[ho.noːs]
D. stage 4:	/[$_{stem}$honoːs]/ →	[ho.noːs]	[(ˈho.noːs)]	[ho.noːs]

Attested form: *honor* [ˈho.nor] ‘honour-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$honoːs]/ →	[ho.noːs]	[(ˈho.noːs)]	[ho.noːs]
D. stage 2:	/[$_{stem}$honoːs]/ →	[ho.noːs]	[(ˈho.noːs)]	[ho.noːs]
D. stage 3:	/[$_{stem}$honoːs]/ →	[ho.noːs]	[(ˈho.noːs)]	[ho.noːs]
D. stage 4:	/[$_{stem}$honor]/ →	[ho.nor]	[(ˈho.nor)]	[ho.nor]

Attested form: *honoris* [ho.ˈnoː.rɪ̝s] ‘honour-GEN.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$honoːsɪ]s/ →	[ho.noː.sɪ]	[(ˈho.noː)sɪs]	[ho.noː.zɪs]
D. stage 2:	/[$_{stem}$honoːsɪ]s/ →	[ho.noː.sɪ]	[(ˈho.noː)rɪs]	[ho.noː.rɪs]
D. stage 3:	/[$_{stem}$honoːsɪ̝]s/ →	[ho.noː.rɪ̝]	[ho(ˈnoː)rɪ̝s]	[ho.noː.rɪ̝s]
D. stage 4:	/[$_{stem}$honoːrɪ̝]s/ →	[ho.noː.rɪ̝]	[ho(ˈnoː)rɪ̝s]	[ho.noː.rɪ̝s]

Attested form: *labos* [ˈla.boːs] ‘work-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$laɸoːs]/ →	[la.ɸoːs]	[(ˈla.ɸoːs)]	[la.βoːs]
D. stage 2:	/[$_{stem}$laβoːs]/ →	[la.βoːs]	[(ˈla.boːs)]	[la.boːs]
D. stage 3:	/[$_{stem}$laboːs]/ →	[la.boːs]	[(ˈla.boːs)]	[la.boːs]
D. stage 4:	/[$_{stem}$laboːs]/ →	[la.boːs]	[(ˈla.boːs)]	[la.boːs]

Attested form: *labor* [ˈla.bor] ‘work-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$laɸoːs]/ →	[la.ɸoːs]	[(ˈla.ɸoːs)]	[la.βoːs]
D. stage 2:	/[$_{stem}$laβoːs]/ →	[la.βoːs]	[(ˈla.boːs)]	[la.boːs]

D. stage 3:	/[$_{stem}$laboːs]/ →	[la.boːs]	[(ˈla.boːs)]	[la.boːs]
D. stage 4:	/[$_{stem}$laboːr]/ →	[la.boːr]	[(ˈla.bor)]	[la.bor]

Attested form: *laboris* [la.ˈboː.rɪ̞s] ‘work-GEN.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$laɸoːsɪ]s/ →	[la.ɸoː.sɪ]	[(ˈla.ɸoː)sɪs]	[la.βoː.zɪs]
D. stage 2:	/[$_{stem}$laβoːsɪ]s/ →	[la.βoː.sɪ]	[(ˈla.boː)rɪs]	[la.boː.rɪs]
D. stage 3:	/[$_{stem}$laboːsɪ̞]s/ →	[la.boː.rɪ̞]	[la(ˈboː)rɪ̞s]	[la.boː.rɪ̞s]
D. stage 4:	/[$_{stem}$laboːrɪ̞]s/ →	[la.boː.rɪ̞]	[la(ˈboː)rɪ̞s]	[la.boː.rɪ̞s]

Attested form: *laborare* [la.bo.ˈraː.re] ‘work-INF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$laɸosaː]se/ →	[la.ɸo.saː]	[(ˈla.ɸo)(ˌsaː)se]	[la.βo.zaː.ze]
D. stage 2:	/[$_{stem}$laβosaː]se/ →	[la.βo.saː]	[(ˈla.bo)(ˌraː)re]	[la.bo.raː.re]
D. stage 3:	/[$_{stem}$labosaː]re/ →	[la.bo.raː]	[(ˌla.bo)(ˈraː)re]	[la.bo.raː.re]
D. stage 4:	/[$_{stem}$laboraː]re/ →	[la.bo.raː]	[(ˌla.bo)(ˈraː)re]	[la.bo.raː.re]

Attested form: *flere* [ˈfleː.re] ‘weep-INF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$fleː]se/ →	[fleː]	[(ˈfleː)se]	[fleː.ze]
D. stage 2:	/[$_{stem}$fleː]se/ →	[fleː]	[(ˈfleː)re]	[fleː.re]
D. stage 3:	/[$_{stem}$fleː]re/ →	[fleː]	[(ˈfleː)re]	[fleː.re]
D. stage 4:	/[$_{stem}$fleː]re/ →	[fleː]	[(ˈfleː)re]	[fleː.re]

Attested form: *uenire* [we.ˈniː.re] ‘come-INF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$weniː]se/ →	[we.niː]	[(ˈwe.niː)se]	[we.niː.ze]
D. stage 2:	/[$_{stem}$weniː]se/ →	[we.niː]	[(ˈwe.niː)re]	[we.niː.re]
D. stage 3:	/[$_{stem}$weniː]re/ →	[we.niː]	[we(ˈniː)re]	[we.niː.re]
D. stage 4:	/[$_{stem}$weniː]re/ →	[we.niː]	[we(ˈniː)re]	[we.niː.re]

Attested form: *esse* [ˈes.se] ‘come-INF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$es]se/ →	[es]	[(ˈes)se]	[es.se]
D. stage 2:	/[$_{stem}$es]se/ →	[es]	[(ˈes.se)]	[es.se]
D. stage 3:	/[$_{stem}$es]se/ →	[es]	[(ˈes)se]	[es.se]
D. stage 4:	/[$_{stem}$es]se/ →	[es]	[(ˈes)se]	[es.se]

Attested form: *uelle* [ˈuel.le] ‘wish-INF’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$wel]se/ →	[wel]	[(ˈwel)se]	[wel.se]
D. stage 2:	/[$_{stem}$wel]se/ →	[wel]	[(ˈwel)le]	[wel.le]
D. stage 3:	/[$_{stem}$wel]le/ →	[wel]	[(ˈwel)le]	[wel.le]
D. stage 4:	/[$_{stem}$wel]le/ →	[wel]	[(ˈwel)le]	[wel.le]

Attested form: *ararum* [aː.ˈraː.rum] ‘altar-GEN.PL’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$aːsaː]som/ →	[aː.saː]	[(ˈaː)(ˌsaː)som]	[aː.zaː.zom]

D. stage 2:	/[$_{stem}$aːsaː]som/ →	[aː.saː]	[(ˈaː)(ˌraː)rom]	[aː.raː.rom]
D. stage 3:	/[$_{stem}$aːraː]rʊ̯m/ →	[aː.raː]	[(ˌaː)(ˈraː)rʊ̯m]	[aː.raː.rʊ̯m]
D. stage 4:	/[$_{stem}$aːraː]rʊ̯m/ →	[aː.raː]	[(ˌaː)(ˈraː)rʊ̯m]	[aː.raː.rʊ̯m]

Attested form: *annorum* [an.ˈnoː.rum] ‘year-GEN.PL’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$anno]om/ →	[an.no]	[(ˈan)noːm]	[an.noːm]
D. stage 2:	/[$_{stem}$anno]om/ →	[an.no]	[(ˈan)noːm]	[an.noːm]
D. stage 3:	/[$_{stem}$annoː]rʊ̯m/ →	[an.noː]	[(ˌan)(ˈnoː)rʊ̯m]	[an.noː.rʊ̯m]
D. stage 4:	/[$_{stem}$annoː]rʊ̯m/ →	[an.noː]	[(ˌan)(ˈnoː)rʊ̯m]	[an.noː.rʊ̯m]

Attested form: *rerum* ˈreː.rum] ‘matter-GEN.PL’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$reː]som/ →	[reː]	[(ˈreː)som]	[reː.zom]
D. stage 2:	/[$_{stem}$reː]som/ →	[reː]	[(ˈreː)rom]	[reː.rom]
D. stage 3:	/[$_{stem}$reː]rʊ̯m/ →	[reː]	[(ˈreː)rʊ̯m]	[reː.rʊ̯m]
D. stage 4:	/[$_{stem}$reː]rʊ̯m/ →	[reː]	[(ˈreː)rʊ̯m]	[reː.rʊ̯m]

IE voiced aspirates

Attested form: *frater* [ˈfraː.ter] ‘brother-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ɸraːter]/ →	[ɸraː.ter]	[(ˈɸraː)ter]	[ɸraː.ter]
D. stage 2:	/[$_{stem}$ɸraːter]/ →	[ɸraː.ter]	[(ˈfraː)ter]	[fraː.ter]
D. stage 3:	/[$_{stem}$fraːter]/ →	[fraː.ter]	[(ˈfraː)ter]	[fraː.ter]
D. stage 4:	/[$_{stem}$fraːter]/ →	[fraː.ter]	[(ˈfraː)ter]	[fraː.ter]

Attested form: *fumus* [ˈfuː.mʊ̯s] ‘smoke-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$θuːmo]s/ →	[θuː.mo]	[(ˈθuː)mos]	[θuː.mos]
D. stage 2:	/[$_{stem}$fuːmo]s/ →	[fuː.mo]	[(ˈfuː)mos]	[fuː.mos]
D. stage 3:	/[$_{stem}$fuːmʊ̯]s/ →	[fuː.mʊ̯]	[(ˈfuː)mʊ̯s]	[fuː.mʊ̯s]
D. stage 4:	/[$_{stem}$fuːmʊ̯]s/ →	[fuː.mʊ̯]	[(ˈfuː)mʊ̯s]	[fuː.mʊ̯s]

Attested form: *formus* [ˈfor.mʊ̯s] ‘warm-NOM.SG.M’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$xʷormo]s/ →	[xʷor.mo]	[(ˈxʷor)mos]	[xʷor.mos]
D. stage 2:	/[$_{stem}$xʷormo]s/ →	[xʷor.mo]	[(ˈfor)mos]	[for.mos]
D. stage 3:	/[$_{stem}$formʊ̯]s/ →	[for.mʊ̯]	[(ˈfor)mʊ̯s]	[for.mʊ̯s]
D. stage 4:	/[$_{stem}$formʊ̯]s/ →	[for.mʊ̯]	[(ˈfor)mʊ̯s]	[for.mʊ̯s]

Attested form: *gramen* [ˈgraː.men] ‘grass-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$xraːmen]/ →	[xraː.men]	[(ˈxraː)men]	[xraː.men]
D. stage 2:	/[$_{stem}$ɣraːmen]/ →	[ɣraː.men]	[(ˈgraː)men]	[graː.men]
D. stage 3:	/[$_{stem}$graːmen]/ →	[graː.men]	[(ˈgraː)men]	[graː.men]
D. stage 4:	/[$_{stem}$graːmen]/ →	[graː.men]	[(ˈgraː)men]	[graː.men]

Attested form: *holus* [ˈho.lus] ‘green vegetable-NOM.SG’

	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$xelo]s/ →	[xe.lo]	[(ˈxe.los)]	[xe.los]
D. stage 2:	/[$_{stem}$xolo]s/ →	[xo.lo]	[(ˈho.los)]	[ho.los]
D. stage 3:	/[$_{stem}$holʊ̞]s/ →	[ho.lʊ̞]	[(ˈho.lʊ̞s)]	[ho.lʊ̞s]
D. stage 4:	/[$_{stem}$holʊ̞]s/ →	[ho.lʊ̞]	[(ˈho.lʊ̞s)]	[ho.lʊ̞s]
Attested form: *nebula* [ˈne.bʊ̞.laː] ‘cloud-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$neɸel]a/ →	[ne.ɸel]	[(ˈne.ɸe)la]	[ne.βe.la]
D. stage 2:	/[$_{stem}$neβel]a/ →	[ne.βel]	[(ˈne.be)la]	[ne.be.la]
D. stage 3:	/[$_{stem}$nebʊ̞l]a/ →	[ne.bʊ̞l]	[(ˈne.bʊ̞)la]	[ne.bʊ̞.la]
D. stage 4:	/[$_{stem}$nebʊ̞l]a/ →	[ne.bʊ̞l]	[(ˈne.bʊ̞)la]	[ne.bʊ̞.la]
Attested form: *uidua* [ˈwi.dʊ̞.aː] ‘widow-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$wɪθu]a/ →	[wɪ.θu]	[(ˈwɪ.θu)a]	[wɪ.ðu.a]
D. stage 2:	/[$_{stem}$wɪðu]a/ →	[wɪ.ðu]	[(ˈwɪ.du)a]	[wɪ.du.a]
D. stage 3:	/[$_{stem}$wɪ̞dʊ̞]a/ →	[wɪ̞.dʊ̞]	[(ˈwɪ̞.dʊ̞)a]	[wɪ̞.dʊ̞.a]
D. stage 4:	/[$_{stem}$wɪ̞dʊ̞]a/ →	[wɪ̞.dʊ̞]	[(ˈwɪ̞.dʊ̞)a]	[wɪ̞.dʊ̞.a]
Attested form: *ruber* [ˈrʊ̞.ber] ‘red-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$ruθro]s/ →	[ru.θro]	[(ˈru.θros)]	[ru.θros]
D. stage 2:	/[$_{stem}$ruver]/ →	[ru.ver]	[(ˈru.ber)]	[ru.ber]
D. stage 3:	/[$_{stem}$ruber]/ →	[ru.ber]	[(ˈrʊ̞.ber)]	[rʊ̞.ber]
D. stage 4:	/[$_{stem}$rʊ̞ber]/ →	[rʊ̞.ber]	[(ˈrʊ̞.ber)]	[rʊ̞.ber]
Attested form: *uerbum* [ˈwer.bʊ̞m] ‘word-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$werθo]m/ →	[wer.θo]	[(ˈwer)θom]	[wer.θom]
D. stage 2:	/[$_{stem}$wervo]m/ →	[wer.vo]	[(ˈwer)bom]	[wer.bom]
D. stage 3:	/[$_{stem}$werbʊ̞]m/ →	[wer.bʊ̞]	[(ˈwer)bʊ̞m]	[wer.bʊ̞m]
D. stage 4:	/[$_{stem}$werbʊ̞]m/ →	[wer.bʊ̞]	[(ˈwer)bʊ̞m]	[wer.bʊ̞m]
Attested form: *aestus* [ˈaɪs.tus] ‘heat-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$aɪθtu]s/ →	[aɪθ.tu]	[(ˈaɪθ)tus]	[aɪθ.tus]
D. stage 2:	/[$_{stem}$aeθtu]s/ →	[aeθ.tu]	[(ˈaes)tus]	[aes.tus]
D. stage 3:	/[$_{stem}$aestu]s/ →	[aes.tu]	[(ˈaes)tʊ̞s]	[aes.tʊ̞s]
D. stage 4:	/[$_{stem}$aestu]s/ →	[aes.tu]	[(ˈaes)tʊ̞s]	[aes.tʊ̞s]
Attested form: *nix* [ˈniks] ‘snow-NOM.SG’				
	Input	Stem Level	Word Level	Phrase Level
D. stage 1:	/[$_{stem}$nɪx^{w}]s/ →	[nɪx^{w}]	[(ˈnɪx^{w}s)]	[nɪx^{w}s]
D. stage 2:	/[$_{stem}$nɪx]s/ →	[nɪx]	[(ˈnɪks)]	[nɪks]
D. stage 3:	/[$_{stem}$nɪ̞k]s/ →	[nɪ̞k]	[(ˈnɪ̞ks)]	[nɪ̞ks]
D. stage 4:	/[$_{stem}$nɪ̞k]s/ →	[nɪ̞k]	[(ˈnɪ̞ks)]	[nɪ̞ks]

	Input	Stem Level	Word Level	Phrase Level
Attested form: *niuis* [ˈnɪ̝.wɪ̝s] ‘snow-GEN.SG’				
D. stage 1:	/[$_{stem}$nɪxʷɪ]s/ →	[nɪ.xʷɪ]	[(ˈnɪ.xʷɪs)]	[nɪ.ɣʷɪs]
D. stage 2:	/[$_{stem}$nɪwɪ]s/ →	[nɪ.wɪ]	[(ˈnɪ.wɪs)]	[nɪ.wɪs]
D. stage 3:	/[$_{stem}$nɪ̝wɪ̝]s/ →	[nɪ̝.wɪ̝]	[(ˈnɪ̝.wɪ̝s)]	[nɪ̝.wɪ̝s]
D. stage 4:	/[$_{stem}$nɪ̝wɪ̝]s/ →	[nɪ̝.wɪ̝]	[(ˈnɪ̝.wɪ̝s)]	[nɪ̝.wɪ̝s]
Attested form: *ninguit* [ˈnɪ̝ŋ.gʷɪ̝t] ‘snow-3SG.PRES’				
D. stage 1:	/[$_{stem}$nɪŋxʷ]ɪt/ →	[nɪŋxʷ]	[(ˈnɪŋ)xʷɪt]	[nɪŋ.xʷɪt]
D. stage 2:	/[$_{stem}$nɪŋɣʷ]ɪt/ →	[nɪŋɣʷ]	[(ˈnɪŋ)gʷɪt]	[nɪŋ.gʷɪt]
D. stage 3:	/[$_{stem}$nɪ̝ŋgʷ]ɪ̝t/ →	[nɪ̝ŋgʷ]	[(ˈnɪ̝ŋ)gʷɪ̝t]	[nɪ̝ŋ.gʷɪ̝t]
D. stage 4:	/[$_{stem}$nɪ̝ŋgʷ]ɪ̝t/ →	[nɪ̝ŋgʷ]	[(ˈnɪ̝ŋ)gʷɪ̝t]	[nɪ̝ŋ.gʷɪ̝t]
Attested form: *mingit* [ˈmɪ̝ŋ.gɪ̝t] ‘urinate-3SG.PRES’				
D. stage 1:	/[$_{stem}$mɪŋx]ɪt/ →	[mɪŋx]	[(ˈmɪŋ)xɪt]	[mɪŋ.xɪt]
D. stage 2:	/[$_{stem}$mɪŋɣ]ɪt/ →	[mɪŋɣ]	[(ˈmɪŋ)gɪt]	[mɪŋ.gɪt]
D. stage 3:	/[$_{stem}$mɪ̝ŋg]ɪ̝t/ →	[mɪ̝ŋg]	[(ˈmɪ̝ŋ)gɪ̝t]	[mɪ̝ŋ.gɪ̝t]
D. stage 4:	/[$_{stem}$mɪ̝ŋg]ɪ̝t/ →	[mɪ̝ŋg]	[(ˈmɪ̝ŋ)gɪ̝t]	[mɪ̝ŋ.gɪ̝t]
Attested form: *mictus* [ˈmɪ̝k.tʊ̝s] ‘urinate-PRF.PTCP-NOM.SG.M’				
D. stage 1:	/[$_{stem}$mɪxto]s/ →	[mɪx.to]	[(ˈmɪx)tos]	[mɪx.tos]
D. stage 2:	/[$_{stem}$mɪxto]s/ →	[mɪx.to]	[(ˈmɪk)tos]	[mɪk.tos]
D. stage 3:	/[$_{stem}$mɪ̝ktʊ̝]s/ →	[mɪ̝k.tʊ̝]	[(ˈmɪ̝k)tʊ̝s]	[mɪ̝k.tʊ̝s]
D. stage 4:	/[$_{stem}$mɪ̝ktʊ̝]s/ →	[mɪ̝k.tʊ̝]	[(ˈmɪ̝k)tʊ̝s]	[mɪ̝k.tʊ̝s]
Attested form: *uehit* [ˈwe.hɪ̝t] ‘convey-3SG.PRES’				
D. stage 1:	/[$_{stem}$wexɪ]t/ →	[we.xɪ]	[(ˈwe.xɪt)]	[we.ɣɪt]
D. stage 2:	/[$_{stem}$weɣɪ]t/ →	[we.ɣɪ]	[(ˈwe.ɦɪt)]	[we.ɦɪt]
D. stage 3:	/[$_{stem}$wehɪ̝]t/ →	[we.hɪ̝]	[(ˈwe.hɪ̝t)]	[we.hɪ̝t]
D. stage 4:	/[$_{stem}$wehɪ̝]t/ →	[we.hɪ̝]	[(ˈwe.hɪ̝t)]	[we.hɪ̝t]

Appendix B

Index of constraints

Name: *[lateral]. . . [lateral] 106–108

*[lat]. . . [lat]

PyOT representation: N/A

Definition : Sequential segments must be differently specified for the feature [±lateral]

References : Suzuki (1998)

Name: AGREE-[VOI] 194, 233

AGREE-[VOI]

PyOT representation: `(Agree, 'voi')`

Definition : Adjacent segments should be identically specified with respect to [VOICE]

References : Lombardi (1999)

Name: ALIGN-[Σ, L; ω, L] 263–265, 283

ALIGN-[Σ, L; ω, L]

PyOT representation: `(AlignFoot, 'L')`

Definition : Every foot should be left-aligned within the prosodic word that dominates it.

References : McCarthy & Prince (1993)

Name: ALIGN-[Σ, R; ω, R] 259–263, 273–275, 283

ALIGN-[Σ, R; ω, R]

PyOT representation: `(AlignFoot, 'R')`

Definition : Every foot should be right-aligned within the prosodic word that dominates it.

References : McCarthy & Prince (1993)

Name: ALIGN-[Σ_s, L; ω, L] 263–265, 283

ALIGN-[Σ_s, L; ω, L]

PyOT representation: `(AlignHeadFootInWord, 'L')`

Definition : Every foot that is the head of the prosodic word that dominates it should be right-aligned within the prosodic word.

References : McCarthy & Prince (1993)

Name: ALIGN[σ_s, L; Σ, L] 259–261, 263, 282–283

ALIGN[σ_s, L; Σ, L]

PyOT representation: `(FtTypeT,)`

Definition : Stressed syllables should be left-aligned in the feet that dominate them.

References : McCarthy & Prince (1993)

Name: ALIGN-[Σ_s, R; ω, R] 259–263, 273–275, 283

ALIGN-[Σ_s, R; ω, R]

PyOT representation: `(AlignHeadFootInWord, 'R')`

Definition : Every foot that is the head of the prosodic word that dominates it should be right-aligned within the prosodic word.

References : McCarthy & Prince (1993)

Name: CC-CORR 108–109, 114–115

CC-CORR

PyOT representation: `(CC_Corr,)`

Definition : Segments in the output should be CC-coindexed.

References : Rose & Walker (2004); McCarthy (2010)

Name: CC-CORR-ART 114

PyOT representation: `(CC_Corr, 'cor', 'dor', 'lab', 'rad')` CC-CORR-ART

Definition : Segments with any articulatory place feature should be CC-coindexed.

References : Rose & Walker (2004)

Name: CC-CORR-[CONS] 111–114, 116–120, 127–130, 235–237, 286, 288

PyOT representation: `(CC_Corr, 'cons')` CC-CORR-[CONS]

Definition : Consonants should be CC-coindexed.

References : Rose & Walker (2004)

Name: CC-CORR-[LAT] 112–114, 116–120, 127–130, 235–237, 286, 288

PyOT representation: `(CC_Corr, 'lat')` CC-CORR-[LAT]

Definition : Segments with the feature [LATERAL] must be CC-coindexed.

References : Rose & Walker (2004)

Name: CC-CORR-[RHO] 113–114, 116–120, 127–130, 235–237, 286, 288

PyOT representation: `(CC_Corr, 'rho')` CC-CORR-[RHO]

Definition : Segments with the feature [RHOTIC] should be CC-coindexed.

References : Rose & Walker (2004)

Name: CODACOND-[CONT] 86–91, 128–130, 236, 287

PyOT representation: `(CodaCond, 'cont')` CODACOND-[CONT]

Definition : Output segments dominated by syllable codas should not have the feature [eatcontinuant]

Name: CodaSonority-1 192, 195, 218, 225–227, 245, 247–248, 261, 282, 285

CodaSon-1

PyOT representation: `(CodaSonority, 1)`

Definition : For each pair of segments in the coda, the second segment should have a sonority score less than the first by at least 1.

Name: CodaSonority 248

CodaSon

PyOT representation: `(CodaSonority,)`

Definition : Constraint schema for specifying the required sonority cline of a syllable coda.

Name: *ComplexCoda 225, 228, 251–252, 261–265, 283, 285

*Complex-Coda

PyOT representation: `(LenLimit, 'cod', 1)`

Definition : Syllables in the output should not have branching codas.

References : Kager (1999: 97)

Name: *ComplexOnset 199, 202–203

*Complex-Ons

PyOT representation: `(LenLimit, 'ons', 1)`

Definition : Syllables in the output should not have branching onsets.

References : Kager (1999: 97)

Name: [cons]-Agree-[dor] 84, 86–91, 128–130, 236, 287

[cons]-Agree-[dor]

PyOT representation: `(CondAgree, 'cons', 'dor')`

Definition : Adjacent pairs of segments with the feature [CONSONANTAL] should be specified identically for the feature [DORSAL]

References : Lombardi (1999: 272)

Name: [CONS]-AGREE-[LAT] 84–91, 128, 130, 235, 275, 287

[CONS]-AGREE-[LAT]

PyOT representation: `(CondAgree, 'cons', 'lat')`

Definition : Adjacent pairs of segments with the feature [CONSONANTAL] should be specified identically for the feature [LATERAL]

References : Lombardi (1999: 272)

Name: [CONS]-AGREE-[RAD] 83–84, 86–91, 128–130, 236, 287

[CONS]-AGREE-[RAD]

PyOT representation: `(CondAgree, 'cons', 'rad')`

Definition : Adjacent pairs of segments with the feature [CONSONANT] should be specified identically for the feature [RADICAL]

References : Lombardi (1999: 272)

Name: [CONS]-AGREE-[RHO] 84, 86–91, 128–130, 236, 275, 287

[CONS]-AGREE-[RHO]

PyOT representation: `(CondAgree, 'cons', 'rho')`

Definition : Adjacent pairs of segments with the feature [CONSONANTAL] should be specified identically for the feature [RHOTIC]

References : Lombardi (1999: 272)

Name: DEPENDENCE 42

DEP

PyOT representation: N/A

Definition : Elements in the output should have correspondents in the input.

References : McCarthy & Prince (1995, 1999)

Name: DEP-[CONT] 251–252, 286

DEP-[CONT]

PyOT representation: `(DepFeat, 'cont')`

Definition : The output correspondent of a constraint that lacks the feature [CONTINUANT] must also lack the feature [CONTINUANT]

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: DEP-[COR] 285

DEP-[COR]

PyOT representation: `(DepFeat, 'cor', 'BR')`

Definition : If a segment in the base has the feature [CORONAL], its correspondent in the reduplicant should also.

References : McCarthy & Prince (1995); Lamontagne & Rice (1995)

Name: DEP-[LAT] 84–91, 128, 130, 235, 287

DEP-[LAT]

PyOT representation: `(DepFeat, 'lat')`

Definition : The output correspondent of a constraint that lacks the feature [LATERAL] must also lack the feature [CONTINUANT]

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: DEP-[PLOS] 78–83, 85–91, 128–130, 236, 287

DEP-[PLOS]

PyOT representation: `(DepFeat, 'plos')`

Definition : The output correspondent of a constraint that lacks the feature [PLOSIVE] must also lack the feature [PLOSIVE]

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: DEP-[RAD] 78–83, 85–91, 128–130, 236, 287

DEP-[RAD]

PyOT representation: `(DepFeat, 'rad')`

Definition : The output correspondent of a constraint that lacks the feature [RADICAL] must also lack the feature [RADICAL]

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: DEP-[RHO] 78–83, 85–91, 95–96, 98–99, 128–130, 236, 287–288

DEP-[RHO]

PyOT representation: `(DepFeat, 'rho')`

Definition : The output correspondent of a constraint that lacks the feature [RHOTIC] must also lack the feature [RHOTIC]

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: DEP-[RHO] 86

DEP-[RHO]

PyOT representation: `(Dep, 'rho')`

Definition : The output correspondent of a constraint that lacks the feature [RHOTIC] must also lack the feature [RHOTIC]

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: DEP-[RTR] 267–269, 288

DEP-[RTR]

PyOT representation: `(DepFeat, 'rtr')`

Definition : The output correspondent of a constraint that lacks the feature [RTR] must also lack the feature [RTR]

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: DEP-[SON] 78–83, 85–91, 95–96, 98–99, 128–130, 236, 287–288

DEP-[SON]

PyOT representation: `(DepFeat, 'son')`

Definition : The output correspondent of a constraint that lacks the feature [SONORANT] must also lack the feature [SONORANT]

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: Dep-[strid] 85, 251–252, 286

Dep-[strid]

PyOT representation: `(DepFeat, 'strid')`

Definition : The output correspondent of a constraint that lacks the feature [strident] must also lack the feature [strident].

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: Dep-μ 191, 193, 198, 202–203, 218–219, 224, 233–234, 285

Dep-μ

PyOT representation: `(DepMora,)`

Definition : Morae in the output should have correspondents in the input.

References : Kager (1999: 156)

Name: Dep-seg 202

Dep-seg

PyOT representation: N/A

Definition : A segment in the output should have a correspondent in the input.

Name: DiphHigh 192, 195, 218, 225–227

DiphHigh

PyOT representation: `(DiphHigh,)`

Definition : The off-glide of a diphthong should have the feature [high].

Name: ¬Ident-CC-art 110–112

¬Ident-CC-art

PyOT representation: `(notIdentCC, 'cor', 'dor', 'lab', 'rad')`

Definition : A CC-coindexed segment should be differently specified with respect to place features than the next CC-coindexed segment in the candidate.

Name: ¬IDENT-CC-ART 113, 115, 128–130, 236–237, 288

¬IDENT-CC-ART

PyOT representation: `(notIdentCC, 'lab', 'cor', 'dor', 'rad')`

Definition : A CC-coindexed segment should be differently specified with respect to articulatory place features than the next CC-coindexed segment in the candidate.

References : Rose & Walker (2004)

Name: ¬IDENT-CC-[LAT] 110, 112–113, 116–120, 122–123, 127–130, 235–237, 286, 288

¬IDENT-CC-[LAT]

PyOT representation: `(notIdentCC, 'lat')`

Definition : A CC-coindexed segment should be differently specified with respect to the feature [LATERAL] than the next CC-coindexed segment in the candidate.

Name: $*\sigma_{\mu\mu\mu}$ 191, 193, 198, 202–203, 218–219, 233, 254–256, 271, 273–275, 289

$*\sigma_{\mu\mu\mu}$

PyOT representation: `(StarTriMora,)`

Definition : A syllable should dominate no more than two morae.

Name: FAITHFULNESS 106–109, 123

FAITH

PyOT representation: N/A

Definition : Cover term for all input-output correspondence constraints.

References : McCarthy & Prince (1995, 1999)

Name: *[COR] 76

*[COR]

PyOT representation: `(StarFeats, 'cor')`

Definition : Segments should not have the feature [CORONAL]

Name: *[DOR] 228, 235, 287

*[DOR]

PyOT representation: `(StarFeats, 'dor')`

Definition : Segments should not have the feature [DORSAL]

Name: *[LOW] 226–228, 235, 286

*[LOW]

PyOT representation: `(StarFeats, 'low')`

Definition : Segments should not have the feature [LOW]

Name: *[RHO]-μ-[RHO] 95–99, 128–129, 236, 288

*[RHO]-μ-[RHO]

PyOT representation: `(GOCP, 'rho', 1)`

Definition : Sequences of segments with the feature [RHOTIC] separated by material amounting to no more than one mora are marked.

References : Suzuki (1998)

Name: [RTR] $\supset$ [HIGH] 283

[RTR] $\supset$ [HIGH]

PyOT representation: `(EntailsFeats, 'rtr', 'high')`

Definition : A segment with the feature [RTR] must also have the feature [HIGH].

Name: [VOC $\wedge$ HIGH] $\supset$ [RTR] 270–271, 288

[VOC $\wedge$ HIGH] $\supset$ [RTR]

PyOT representation: `(EntailsFeats, ('voc', 'high'), ('rtr',))`

Definition : A segment with the features [VOC, HIGH] must also have the feature [RTR].

Name: [VOC $\wedge$ HIGH $\wedge$ COR] $\supset$ [RTR] 225

[VOC $\wedge$ HIGH $\wedge$ COR] $\supset$ [RTR]

PyOT representation: `(EntailsFeats, ('voc', 'high', 'cor'), ('rtr',))`

Definition : A segment with the features [VOC, HIGH, COR] must also have the feature [RTR].

Name: FTBIN 44, 259–261, 263, 282–283

FTBIN

PyOT representation: `(FtBin,)`

Definition : Feet should be binary under a syllabic or moraic analysis.

References : Kager (1999: 156)

Name: *GEMINATE 224–225, 227–228, 233–235, 285–286

*GEMINATE

PyOT representation: `(StarGeminate,)`

Definition : Consonants in the output should not be long.

Name: IDENT 23, 44–45

IDENT

PyOT representation: `(Ident,)`

Definition : Constraint schema enforcing featural identity between segments (equivalent to the co-ranking of extscMax-feat and extscDep-feat.

References : McCarthy & Prince (1995); Lamontagne & Rice (1995)

Name: IDENT-BR 223

IDENT-BR

PyOT representation: `(Ident, 'BR')`

Definition : Corresponding pairs of segments in the input and output must be identically specified with respect to featyres

References : McCarthy & Prince (1995)

Name: IDENT-CC 114, 116

IDENT-CC

PyOT representation: `(IdentCC,)`

Definition : A CC-coindexed segment must be identically specified with the next CC-coindexed segment in the candidate.

References : Rose & Walker (2004); Hansson (2007)

Name: IDENT-CC-[CONS] 116–119, 130

IDENT-CC-[CONS]

PyOT representation: `(IdentCC, 'cons')`

Definition : A CC-coindexed segment must be identically specified for the feature [CONSONANTAL] with the next CC-coindexed segment in the candidate.

References : Rose & Walker (2004); Hansson (2007)

Name: IDENT-CC-[HIGH] 116–120, 127–128, 235, 286

IDENT-CC-[HIGH]

PyOT representation: `(IdentCC, 'high')`

Definition : A CC-coindexed segment must be identically specified for the feature [CONSONANTAL] with the next CC-coindexed segment in the candidate.

References : Rose & Walker (2004); Hansson (2007)

Name: IDENT-CC-[NAS] 116–120, 127–128, 235, 286

IDENT-CC-[NAS]

PyOT representation: `(IdentCC, 'nas')`

Definition : A CC-coindexed segment must be identically specified for the feature [NASAL] with the next CC-coindexed segment in the candidate.

References : Rose & Walker (2004); Hansson (2007)

Name: IDENT-CC-[SON] 115–120, 127–128, 235, 286

IDENT-CC-[SON]

PyOT representation: `(IdentCC, 'son')`

Definition : A CC-coindexed segment must be identically specified for the feature [SONORANT] with the next CC-coindexed segment in the candidate.

References : Rose & Walker (2004); Hansson (2007)

Name: IDENT-[COR]-BR 223–228, 233–235, 287

IDENT-[COR]-BR

PyOT representation: `(Ident, 'cor', 'BR')`

Definition : Corresponding pairs of segments in the base and reduplicant must be identically specified with respect to [CORONAL].

References : McCarthy & Prince (1995)

Name: IDENT-[DOR]-BR 223–228, 233–235, 286

IDENT-[DOR]-BR

PyOT representation: `(Ident, 'dor', 'BR')`

Definition : Corresponding pairs of segments in the base and reduplicant must be identically specified with respect to [DORSAL].

References : McCarthy & Prince (1995)

Name: IDENT-[HIGH]-BR 223–225, 228, 233–235, 285–286

IDENT-[HIGH]-BR

PyOT representation: `(Ident, 'high', 'BR')`

Definition : Corresponding pairs of segments in the base and reduplicant must be identically specified with respect to [HIGH].

References : McCarthy & Prince (1995)

Name: IDENT-[LAB] 42

IDENT-[LAB]

PyOT representation: `(Ident, 'lab')`

Definition : Corresponding pairs of segments in the input and output must be identically specified with respect to [LABIAL].

References : McCarthy & Prince (1995, 1999)

Name: IDENT-[LAB]-BR 223–225, 228, 233–235, 286

IDENT-[LAB]-BR

PyOT representation: `(Ident, 'lab', 'BR')`

Definition : Corresponding pairs of segments in the base and reduplicant must be identically specified with respect to [LABIAL].

References : McCarthy & Prince (1995)

Name: IDENT-[LOW]-BR 223–228, 233–235, 287

IDENT-[LOW]-BR

PyOT representation: `(Ident, 'low', 'BR')`

Definition : Corresponding pairs of segments in the base and reduplicant must be identically specified with respect to [LOW].

References : McCarthy & Prince (1995)

Name: IDENT-[RHO] 21

IDENT-[RHO]

PyOT representation: `(Ident, 'rho')`

Definition : Corresponding pairs of segments in the input and output must be identically specified with respect to [RHOTIC].

References : McCarthy & Prince (1995, 1999)

Name: IDENT-[RTR] 270–271, 288

IDENT-[RTR]

PyOT representation: `(Ident, 'rtr')`

Definition : Corresponding pairs of segments in the input and output must be identically specified with respect to [RTR].

References : McCarthy & Prince (1995, 1999)

Name: IDENT-[RTR]-BR 223–225, 233–234, 285

IDENT-[RTR]-BR

PyOT representation: `(Ident, 'rtr', 'BR')`

Definition : Corresponding pairs of segments in the base and reduplicant must be identically specified with respect to [RTR].

References : McCarthy & Prince (1995)

Name: IDENT-[STRID] 78–83, 86–91, 128–130, 236, 287

IDENT-[STRID]

PyOT representation: `(Ident, 'strid')`

Definition : Corresponding pairs of segments in the input and output must be identically specified with respect to [STRIDENT].

References : McCarthy & Prince (1995, 1999)

Name: IDENT-[VOI] 41–43, 45–46, 64, 78, 128, 193–195, 198, 202, 207, 233–237, 250–252, 286–289

IDENT-[VOI]

PyOT representation: `(Ident, 'voi')`

Definition : Corresponding pairs of segments in the input and output must be identically specified with respect to [VOICE].

References : McCarthy & Prince (1995, 1999)

Name: IORALFRICV 63–64, 78–84, 86–91, 94–99, 103, 128–130, 235–236, 286–288

IORALFRICV

PyOT representation: `(IOralFricV,)`

Definition : Fricatives bearing any of the oral place features [LABIAL, CORONAL, DORSAL] should be voiced if they are intervocalic.

Name: LENLIMIT 246

LENLIMIT

PyOT representation: N/A

Definition : Constraint schema for specifying length limits on syllable nodes.

Name: LENLIMIT-Coda-2 192, 195, 218, 225–227, 246, 248, 261, 282, 285

LENLIMIT-Coda-2

PyOT representation: `(LenLimit, 'cod', 2)`

Definition : Syllable codas should be no more than binary branching.

Name: LenLimit-Coda-3 248, 282

LenLimit-Coda-3

PyOT representation: `(LenLimit, 'cod', 3)`

Definition : Syllable codas should dominate no more than 3 segments.

Name: LenLimit-Nuc-2 192, 195, 218, 225–227, 246, 261, 282

LenLimit-Nuc-2

PyOT representation: `(LenLimit, 'nuc', 2)`

Definition : Syllable nuclei should not dominate more than two segments.

Name: LenLimit-Onset-2 192, 195, 218, 225–227, 246, 261, 282

LenLimit-Onset-2

PyOT representation: `(LenLimit, 'ons', 2)`

Definition : Syllable onsets should be no more than binary-branching.

Name: Linearity 207

Lin

PyOT representation: N/A

Definition : The order of segments in the input should be the same as in the output.

Name: *[liquid]∼[liquid] 106–108

*[liq] ∼ [liq]

PyOT representation: N/A

Definition : Sequential segments must be differently specified for features within the class [liquid]

References : Suzuki (1998)

Name: (*[LIQUID]~[LIQUID] & *[lateral]...[lateral]) 106–108

(*[LIQ]~[LIQ] & *[lat]...[lat])

PyOT representation: N/A

Definition : Local Conjunction of *[LIQUID]~[LIQUID] and *[lateral]...[lateral] (q.v.).

References : Suzuki (1998: 103); Smolensky (1993); Kager (1999: 392–400)

Name: MAX-C 226, 254–255, 273–275

MAX-C

PyOT representation: `(Max_C,)`

Definition : Consonants in the input should have correspondents in the output.

References : McCarthy & Prince (1995, 1999)

Name: MAX-C-BR 221–222, 224–228, 233–235, 285–286

MAX-C-BR

PyOT representation: `(Max_C, 'BR')`

Definition : Consonants in the base should have correspondents in the reduplicant.

References : McCarthy & Prince (1993)

Name: MAX-CC 114–115

MAX-CC

PyOT representation: N/A

Definition : Segments in the output should be CC-coindexed.

References : Rose & Walker (2004); McCarthy (2010)

Name: MAX-μ-σ_s 272–275, 289

MAX-μ-σ_s

PyOT representation: `(StressMaxMora,)`

Definition : Long segments in the input, whose correspondents in the output are exhaustively dominated by a stressed syllable should not be shortened in the output.

Name: MAX-[CONT] 78–84, 86–91, 95–96, 98–99, 128–130, 236, 287–288

MAX-[CONT]

PyOT representation: `(MaxFeat, 'cont')`

Definition : The output correspondent of a constraint that has the feature [CONTINUANT] must also have the feature [CONTINUANT]

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: MAX-[DOR] 78–84, 86–91, 128–130, 236, 287

MAX-[DOR]

PyOT representation: `(MaxFeat, 'dor')`

Definition : The output correspondent of a constraint that has the feature [DORSAL] must also have the feature [DORSAL].

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: MAX-[DOR] 285

MAX-[DOR]

PyOT representation: `(MaxFeat, 'dor', 'BR')`

Definition : If a segment in the base has the feature [DORSAL], its correspondent in the reduplicant should also.

References : McCarthy & Prince (1995); Lamontagne & Rice (1995)

Name: MAX-[LAB] 285

MAX-[LAB]

PyOT representation: `(MaxFeat, 'lab', 'BR')`

Definition : If a segment in the base has the feature [DORSAL], its correspondent in the reduplicant should also.

Name: MAX-[LAT] 87

MAX-[LAT]

PyOT representation: `(MaxFeat, 'lat')`

Definition : The output correspondent of a constraint that has the feature [LATERAL] must also have the feature [LATERAL].

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: MAX-[LOW] 285

MAX-[LOW]

PyOT representation: `(MaxFeat, 'low', 'BR')`

Definition : If a segment in the base has the feature [DORSAL], its correspondent in the reduplicant should also.

Name: MAX-[OBS] 78–83, 85–91, 95–96, 98–99, 128–130, 236, 287–288

MAX-[OBS]

PyOT representation: `(MaxFeat, 'obs')`

Definition : The output correspondent of a constraint that has the feature [OBSTRUENT] must also have the feature [OBSTRUENT].

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: MAX-[PLOS] 251–252, 286

MAX-[PLOS]

PyOT representation: `(MaxFeat, 'plos')`

Definition : The output correspondent of a constraint that has the feature [PLOSIVE] must also have the feature [PLOSIVE].

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: MAX-[RHO] 84, 86–91, 128, 130, 235, 287

MAX-[RHO]

PyOT representation: `(MaxFeat, 'rho')`

Definition : The output correspondent of a constraint that has the feature [RHOTIC] must also have the feature [RHOTIC]

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: Max-[rtr] 267–269, 288

Max-[rtr]

PyOT representation: `(MaxFeat, 'rtr')`

Definition : The output correspondent of a constraint that has the feature [rtr] must also have the feature [rtr].

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: Max-[strid] 95–96, 98–99, 128–129, 236, 288

Max-[strid]

PyOT representation: `(MaxFeat, 'strid')`

Definition : The output correspondent of a constraint that has the feature [strident] must also have the feature [strident].

References : Lamontagne & Rice (1995); Fukazawa (1999)

Name: Maximality 42

Max

PyOT representation: N/A

Definition : Elements in the input should have correspondents in the output.

References : McCarthy & Prince (1995); McCarthy (1999)

Name: Max-μ 254–255, 273–275, 289

Max-μ

PyOT representation: `(MaxMora,)`

Definition : Morae in the input should have correspondents in the output.

Name: Max-seg 198, 202

Max-seg

PyOT representation: N/A

Definition : Segments in the input should have correspondents in the output.

References : McCarthy & Prince (1995, 1999)

Name: MAX-V 273–275

MAX-V

PyOT representation: `(Max_V,)`

Definition : Vowels in the input should have correspondents in the output.

Name: MINNUCSON-6 192, 195, 218, 225–227, 245–246, 261, 282

MINNUCSON-6

PyOT representation: `(MinNucSon, 6)`

Definition : Segments in a syllabic nucleus must have a minimum sonority score of 6.

Name: NOCODA 222, 224–228, 233–235, 248, 251–252, 261–265, 283, 285–286, 288–289

NOCODA

PyOT representation: `(LenLimit, 'cod', 0)`

Definition : Syllables should not have codas.

References : Prince & Smolensky (1993)

Name: NODEAGREE-[RTR] 267–269, 288

NODEAGREE-[RTR]

PyOT representation: `(NodeAgree, 'rtr')`

Definition : Adjacent pairs of segments within the same node of a syllable (onset, nucleus or coda) should be identically specified with respect to the feature [RTR]

References : Lombardi (1999: 272); Beckman (1998)

Name: NONFINALITY 260–265, 272–275, 283, 289

NONFINALITY

PyOT representation: `(NonFinParse,)`

Definition : A syllable that is final in a prosodic word should not be dominated by a foot.

References : Prince & Smolensky (1993); Hung (1994)

Name: NucSonority-1 246, 283

NucSon-1

PyOT representation: `(NucSonority, 1)`

Definition : For each pair of segments in the nucleus, the second segment should have a sonority score less than the first by 1.

Name: NucSonority-0 247, 261, 282

NucSon-0

PyOT representation: `(NucSonority, 0)`

Definition : Consecutive pairs of segments in output syllable nuclei should not rise in sonority.

Name: [obs]-Agree-[strid] 251–252, 285

[obs]-Agree-[strid]

PyOT representation: `(CondAgree, 'obs', 'strid')`

Definition : Adjacent pairs of segments with the feature [obstruent] should be specified identically for the feature [strident]

Name: [obs]-Agree-[voi] 193, 195, 234–237, 250–252, 286–289

[obs]-Agree-[voi]

PyOT representation: `(CondAgree, 'obs', 'voi')`

Definition : Adjacent pairs of segments with the feature [obstruent] should be specified identically for the feature [voice]

References : Lombardi (1999: 272)

Name: Onset 86–91, 128–130, 236, 248, 261–265, 283, 286–287, 289

Onset

PyOT representation: `(Onset,)`

Definition : Syllables should have onsets.

References : Prince & Smolensky (1993)

Name: ONSETSONORITY-2 192, 195, 218, 225–228, 245, 247, 261, 282

NUCSON-2

PyOT representation: `(OnsetSonority, 2)`

Definition : For each pair of segments in the coda, the second segment should have a sonority score greater than the first by 2.

Name: ONSIDENT 42

ONSIDENT

PyOT representation: `(OnsIdent,)`

Definition : Corresponding pairs of segments in the input and output must be identically specified, if the output correspondent is dominated by a syllable onset.

References : Beckman (1998)

Name: ONSIDENT-[STRID] 251–252, 285

ONSIDENT-[STRID]

PyOT representation: `(OnsIdent, 'strid')`

Definition : Corresponding pairs of segments in the input and output must be identically specified with respect to [STRIDENT], if the output correspondent is dominated by a syllable onset.

References : Beckman (1998)

Name: ONSIDENT-[VOI] 41–42, 45, 50, 193–195, 233–237, 250–252, 285, 287–289

ONSIDENT-[VOI]

PyOT representation: `(OnsIdent, 'voi')`

Definition : Corresponding pairs of segments in the input and output must be identically specified with respect to [VOICE], if the output correspondent is dominated by a syllable onset.

References : Beckman (1998)

Name: ORALFRICSTRID 77–84, 86–91, 93, 95–96, 98–99, 128–130, 235–236, 287–288

ORAL-FRIC-STRID

PyOT representation: `(OralFricStrid,)`

Definition : Fricatives bearing any of the features [LAB, COR, DOR] should also have the feature [STRID]

References : Lombardi (2003)

Name: ORALFRICVOICELESS 78–84, 86–91, 128–130, 235, 287

ORALFRIC-VOICELESS

PyOT representation: `(OralFricVoiceless,)`

Definition : Fricatives bearing any of the features [LAB, COR, DOR] should not have the feature [VOICE]

Name: PARSESEG-cod 249, 254–256, 273–275, 283, 285, 289

PARSESEG-cod

PyOT representation: `(ParseSeg, 'cod')`

Definition : Segments following the nucleus within a syllable should be dominated by the syllable coda.

Name: PARSESEG-ons 249, 254–256, 273–275, 283, 285, 289

PARSESEG-ons

PyOT representation: `(ParseSeg, 'ons')`

Definition : A segment preceding the onset of a syllable should be dominated by the syllable onset.

Name: PARSE-σ 260–265, 273–275, 283, 289

PARSE-σ

PyOT representation: `(ParseSyll,)`

Definition : A syllable should be dominated by a foot.

Name: REDLENGTH 221

REDLENGTH

PyOT representation: `(RedLength,)`

Definition : Constraint schema for specifying limits on the length of the output exponent of a `Reduplicant` object.

Name: RedLength-σ-1 221–223, 225–228, 233–235, 285–286

RedLength-σ-1

PyOT representation: `(RedLength, Syllable, 1)`

Definition : The output exponent of a reduplicant object should be no longer than one syllable.

References : Gouskova (2007)

Name: *Seg[dor ∧ voc] 223–224, 226, 233–234, 285

*Seg[dor ∧ voc]

PyOT representation: `(StarFeats, 'dor', 'voc')`

Definition : Segments in the output should not have the features [
eatdor, voc]

Name: *Seg[high ∧ rtr] 283

*Seg[high ∧ rtr]

PyOT representation: `(StarFeats, 'high', 'rtr')`

Definition : A segment in the output should not have the features
eat[high] and
eat[rtr]

Name: *Seg([rtr]): 218–219, 223, 225, 228, 233–235, 270–271, 285–286, 288–289

*Seg([rtr]):

PyOT representation: `(StarLongFeat, 'rtr')`

Definition : Long vowels should not have the feature [rtr]

Name: *Seg[voc ∧ dor] 225

*Seg[voc ∧ dor]

PyOT representation: `(StarFeats, 'voc', 'dor')`

Definition : Segments should not have the features [VOCALIC, DORSAL] (no back vowels).

Name: *V̥ 45

*V̥

PyOT representation: `(StarVoicelessV,)`

Definition : Vowels in the output must have the feature [VOICE]

Name: *C̩ 45

*C̩

PyOT representation: `(StarSyllC,)`

Definition : Consonants must not appear in syllable nuclei.

Name: *V̄-BR 221–223, 225–228, 233–235, 285–286

*V̄-BR

PyOT representation: `(LenLimit, 'nuc', 1, 'BR')`

Definition : No long vowels in the reduplicant.

References : Gouskova (2007)

Name: *$V_\mu D\ldots_\sigma$] 190–193, 195–198, 201–209, 211, 218–219, 224, 226, 230, 233–234, 285

*$V_\mu D\ldots_\sigma$]

PyOT representation: `(PVL,)`

Definition : A short vowel should not be followed by a tautosyllabic voiced stop.

Name: VOP 41–42, 45, 207

VOP

PyOT representation: `(VOP,)`

Definition : Obstruents should not be voiced.

References : Lombardi (1999)

Name: WEIGHT-TO-STRESS 259–265, 273–275, 283

WEIGHT-TO-STRESS

PyOT representation: `(WeightToStress,)`

Definition : Heavy syllables in the output should be heads of feet.

References : McCarthy & Prince (1993)

Index of Latin forms cited