The Initial State and Verbal Stems in Arabic

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Abstract

Semitic verbs exhibit a well-known prohibition against forms with initial gemination, *ssam, or with an initial sequence of two identical consonants, *sasam, alongside an abundance of forms with final gemination or final identity such as samm, samam (Greenberg 1950). This asymmetry has received considerable attention in the phonological literature. Past explanations crucially rely on restrictions imposed on the inventory of lexical inputs. In this paper, properties of the Semitic lexicon such as the asymmetry *ssam versus samm and other well-known alternations in the shape of the verb such as the doubled verb alternation are considered in the context of the inflectional paradigm. This makes it possible to derive the asymmetries in the lexical inventory and the previously puzzling alternations in the verb by employing three independently motivated factors: basic phonotactics, intra-paradigmatic identity constraints, and a language-independent learnability assumption about the initial state of the grammar (Smolensky 1996, Tesar and Smolensky 1998, McCarthy 1998). Implications of the proposal are then developed for the issue of root- versus stem-based morphology, and the issue of the phonological prerequisites for non-concatenative morphology.

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1. Introduction

Arabic[1] verbs exhibit a well-known prohibition against forms with initial gemination, *ssam, or with an initial sequence of two identical consonants, *sasam, alongside an abundance of forms with final gemination or final identity such as samm, samam (Greenberg 1950). This asymmetry has received considerable attention in the literature. Past explanations crucially rely on restrictions imposed on the inventory of lexical inputs, thereby raising a learnability challenge for linguistic theory.

In this paper, properties of the Arabic lexicon, such as the asymmetry *ssam versus samm, and other well-known alternations in the shape of the verb, such as the doubled verb alternation, are considered in the context of the inflectional paradigm. This makes it possible to derive the asymmetries in the lexicon and the previously puzzling alternations in the doubled verb by employing three independently motivated factors: basic phonotactics, intra-paradigmatic identity constraints, and a language-independent learnability assumption about the initial state of the grammar (Smolensky 1996, Tesar and Smolensky 1998, McCarthy 1998). The basic idea in the core of the proposed model of (im)possible stems in Arabic is this: the phonology of Arabic is such that when stems with initial gemination or initial repetition are put in the context of the paradigm, they undergo substantial alternation. This alternation renders the relevant phonological properties (of initial gemination and identity) of these stems unrecoverable. By a formal application of a language-independent learnability argument, such stems are shown to be unlearnable and hence impossible in Arabic. Implications of the main proposal are then developed for the issue of root- versus stem-based morphology, and the issue of the phonological prerequisites for non-concatenative morphology.

This paper is organized as follows. Section 2 defines terms and introduces the formal means employed in the rest of the paper by pursuing an account of the [CCVC] shape of the triliteral verb which crucially relies on the paradigmatic context. The next two sections present the main proposals. Section 3 is devoted to the phonology of doubled verbs. Its main point is that a careful look at doubled verbs requires reference to stems with final geminates. In short, the form underlying the alternation between [samm] ~ [samam] is /samm/, and not /samam/ or a biliteral root |sm| as in past accounts. This proposal departs from past work on Arabic in several respects. Thus, a substantial part of this paper is devoted to formulating this proposal about doubled verbs precisely and testing it by pursuing its predictions beyond the domain of doubled verbs. This proves to be a crucial task, because section 4 on Greenberg's asymmetry shows that the facts about impossible stems are intimately related to the phonology uncovered in section 3. Section 5 draws implications for the debate between root- versus stem-based morphology and the issue of the phonological prerequisites for non-concatenative morphology. Section 6 concludes with a summary of the main points. The appendix, considers doubled verbs in those Forms which do not undergo the alternation, and shows how the core analysis in section 3 readily extends to these Forms as well.

2. Putting the verb in context

Arabic, like other languages with rich inflectional morphology, organizes words in *paradigms*. These can be described as sets of words built from combinations of stems with inflectional markers, the latter designating various morphosyntactic categories. As an example, consider a fragment of the Arabic verbal paradigm in (1). The Arabic verb is described as having two sets of forms or 'Tense/Aspect'

[1] In this paper, unless the term Arabic is otherwise qualified, it refers to Classical Arabic. However, since the paper's focus (on doubled verbs and Greenberg's asymmetry) is on aspects of the Classical language that have been preserved in modern standard Arabic (the official language of over a 100 million people today), the forthcoming analysis and its consequences apply to the modern language as well.

categories known as the imperfect and the perfect. The words in (1) illustrate the indicative mood of the imperfect aspect of the lexeme ‘to write’. Fully inflected words are formed by placing /ktub/ in the context of the appropriate prefix—suffix pair. These pairs consist of {ya—u, ta—u, ta—u, ta—iina, ʔa—u, ya—uuna, ya—na, ta—uuna, ta—na, na—u, ya—aani, ta—aani, ta—aani, ta—aani}, the markers of the morphosyntactic categories of Mood (Indicative), Person (First, Second, Third), Number (Singular, Plural, Dual) and Gender (Masculine, Feminine). Henceforth, I refer to the set of phonological forms made out of the exponents of the morphosyntactic categories of some paradigm as the *inflectional context* of that paradigm.

1. Imperfect, Indicative[2]

		Singular	*Plural*	*Dual*
3	*m*	ya-ktub-u	ya-ktub-uuna	ya-ktub-aani
	f	ta-ktub-u	ya-ktub-na	ta-ktub-aani
2	*m*	ta-ktub-u	ta-ktub-uuna	ta-ktub-aani
	f	ta-ktub-iina	ta-ktub-na	ta-ktub-aani
1		ʔa-ktub-u	na-ktub-u	

I refer to the form /ktub/ as the verbal *stem*. To avoid ambiguity, this term is used here in the sense of Aronoff (1992), who writes: “While a lexeme consists of form, meaning, and the usually arbitrary association between them, I will reserve the term *stem* for only the form part of this trinity. A stem, in my use of this term, is a form. In particular, it is the domain of a realization rule, that form of a lexeme to which a given affix is attached” (1992, p. 14). This sense of stem is essentially the same as that assumed in other modern lexeme-based theories of morphology such as that of Matthews (1972), Anderson (1992) and Zwicky (1985).

Given the inflectional context of a paradigm π and a stem ς, an important point is that in principle each of these has the potential of shaping the other through phonological interaction. It is the role of this interaction that I emphasize in this paper because it turns out to provide a powerful source of conditions on what constitutes a viable stem within paradigm π. In this section, I develop this idea by focusing on a prominent characteristic of the predominant class of verbs in the Semitic lexicon, the so-called ‘strong’ or triliteral verbs. These appear with the invariant shape [-CCVC-]. The present goal is to show how the inflectional context of the paradigm coupled with the simple phonotactics of the language dictates this shape of the triliteral stem.

All basic verbal moods, the indicative, the subjunctive, the jussive, and the imperative, are based on the imperfect form [-CCvC-]. The indicative was shown in (1). The subjunctive differs from the Indicative in substituting the suffix vowel /a/ for /u/, and in the absence of the /na/ from the feminine singular, dual, and masculine plural suffixes, e.g. indicative [ta-ktub-iina] ‘write.2fs’, subjunctive [ta-ktub-ii] ‘write.2fs’. I will therefore not give the subjunctive forms here as these differences do not affect the ensuing discussion in any way. The jussive and the imperative are in (2) and (3), respectively.[3] As

[2] Throughout this paper, the following notational conventions are employed. The numbers ‘1’, ‘2’, ‘3’ stand for first, second, and third person; ‘m’, ‘s’ stand for masculine, feminine; ‘s’, ‘p’ stand for singular, plural; and ‘impf, ‘perf’ stand for imperfect, perfect. Capital letters in transcriptions denote pharyngealization.

[3] There is also a rare variant of the Jussive, called the Energicus (Schramm 1962, p. 364). The phonological make-up of the affixes in this mood is in all relevant respects similar to the other moods, that is, all prefixes are vowel-initial and suffixes are vowel- or consonant-initial. The forthcoming results readily extend to this mood as well.

with the indicative, a verbal form in these moods is constructed on the imperfect stem placed in the context of a set of prefixes and suffixes, the markers of Person, Gender, and Number.

2. Imperfect, Jussive

		Singular	*Plural*	*Dual*
3	*m*	ya-ktub	ya-ktub-uu	ya-ktub-aa
	f	ta-ktub	ta-ktub-aa	ya-ktub-na
2	*m*	ta-ktub	ta-ktub-uu	ta-ktub-aa
	f	ta-ktub-ii	ta-ktub-na	ta-ktub-aa
1		ʔa-ktub	na-ktub	

3. Imperfect, Imperative

		Singular	*Plural*	*Dual*
2	*m*	ʔu-ktub	ʔu-ktub-uu	ʔu-ktub-aa
2	*f*	ʔu-ktub-ii	ʔu-ktub-na	ʔu-ktub-aa

The vowel of the verbal stem must be lexically specified: [ya-ktub-u] ‘he writes’, [ya-lbas-u] ‘he dresses’, [ya-Drib-u] ‘he hits’. There are also a few minimal pairs of stems distinguished solely on the basis of this vowel: [ya-smar-u] ‘be brown’ versus [ya-smur-u] ‘spend the night conversing’, and [ya-Hzun-u] ‘sadden’ versus [ya-Hzan-u] ‘be sad’. Given these facts, a number of researchers have proposed that the verbal morphology of triliterals builds on the stem /ktub/ (Schramm 1962, 1992, p. 1403, Kuryłowicz 1972, pp. 34, 43, McOmber 1995, p. 179, Ratcliffe 1998, p. 33, Benmamoun 1999, p. 176, among others). Thus, Kuryłowicz (1972) writes that “The fundamental form of the Sem. conjugation, the so-called “imperfect(ive)” yaqtul(u) shows a characteristic vowel after (R2) which is unpredictable, i.e. independent of any grammatical rule, hence basic. Therefore the verbal root is not a consonantal skeleton (q-t-l), but contains an essential vocalic component (u of qtul)”(p. 43).

Put in modern terms, Kuryłowicz’s view consists of the claim that the verbal morphology is stem-based. This may be a plausible hypothesis, but it raises an important question which has not been addressed by the proponents of a stem-based morphology. Observe that there is no surface contrast between [ya-ktub-u] and [ya-kutb-u]. Both [ya-ktub-u] and hypothetical [ya-kutb-u] are phonologically well-formed, but only the former is attested.[4] Whence this [CCVC] shape invariance of the triliteral verb? One account of this lack of surface contrast is to restrict the inventory of underlying stems to include only /ktub/, not /kutb/. Since there is no underlying /kutb/ stem, it follows that no [ya-kutb-u] surface form can exist. This account derives a systematic property of the surface patterns by imposing a restriction on the set of admissible inputs or a ‘Morpheme Structure Constraint’ (MSC) in the terms of Chomsky and Halle (1968). However, as in other cases of apparent restrictions on inputs (Kisseberth 1970, Kenstowicz and Kisseberth 1979), the absence of /CVCC/ stems will be shown to derive from properties that must be stated independently in the grammar of Arabic. Moreover, from the theoretical perspective of Optimality Theory (Prince and Smolensky 1993), the model of grammar assumed in this paper, henceforth OT, the only locus of explanation for systematic patterns is the constraint-based

[4] McCarthy and Prince (1990a, pp. 251-260; 1990b, pp. 17-23) have argued convincingly that Arabic stems are subject to a minimality requirement of two moras. Both /ktub/ and /kutb/ would satisfy this requirement. In [ya-ktub-u], /u/ and /k/ are both moraic (the /k/ is moraic due its coda status). In [ya-kutb-u], /u/ and /t/ are moraic. Thus, the minimality requirement does not exclude any of the two stems.

grammar. In OT, restrictions on inputs are expressly disallowed, a basic methodological assumption known as *Richness of the Base* (Prince and Smolensky 1993, p. 191, Smolensky 1996).

Let us turn to the task of deriving the absence of /kutb/ stems from the grammar. I begin by setting a slightly different goal first, namely, to identify the grammatical statement of the fact that there are can be no surface [kutb] forms for triliteral verbs (§2.1). Once this goal is achieved, I employ a language-independent learnability assumption for lexical inputs to show that the grammar responsible for the absence of surface [kutb] forms also derives the absence of /kutb/ stems from the lexicon (§2.2). The formal tools introduced in this section also derive other well-known systematic properties of the Semitic lexicon such as the absence of stems with initial geminates or the absence of stems with initial identity. The ensuing analysis builds significantly on McCarthy's (1998) proposals on paradigm-level optimization.

2.1 Absence of [kutb] surface forms

Three crucial factors 'conspire' to account for the absence of surface [kutb] in Arabic: the inflectional context supplied by the affixes in the verbal paradigm, the phonotactics of the language, and identity requirements between related forms within the paradigm. I consider each of these factors in turn.

Let us entertain the fate of a hypothetical stem /kutb/ in the context of the paradigm. Observe that there is an asymmetry in the inflectional context of the paradigm built on this stem. For all verbal moods, indicative, subjunctive, jussive, and imperative, as shown in (1)-(3) above, prefixes are always vowel-final, but some suffixes begin with a consonant or have no overt marking. This asymmetry provides the key phonotactic motivation for avoiding [-kutb-] surface forms. Before a consonant-initial or null suffix, [-kutb-C] or [-kutb-#] would induce a phonotactic violation. Arabic does not permit CCC clusters or CC margins (see Angoujard 1990, Broselow 1980, 1992, Itô 1986, Farwaneh 1995, Broselow, Chen, and Huffman 1997 for syllabification in Arabic). The sequence *[ya-kutb-na] contains a sequence of three consonants which may be syllabified as [(kut)$^{\sigma}$(bna)$^{\sigma}$] with a complex onset, or as [(kutb)$^{\sigma}$(na)$^{\sigma}$] with a complex coda word-medially. Both of these syllabic sequences are disallowed. I will use *COMPLEX for the constraint that disallows such clusters, defined in (4) (Prince and Smolensky 1993).[5]

4. Phonotactic constraint
   *COMPLEX: Complex syllable margins are prohibited ('complex': more than one segment)

Given this constraint, /ya, ktub, na/ cannot surface as *[ya-kutb-na]. The phonotactic problem created at the stem-suffix boundary could be resolved by metathesis from /ya-kutb-na/ to [ya-ktub-na]. Metathesis results in a violation of an identity requirement between the form of the stem /kutb/ and its surface realization [ktub]. Within OT, identity constraints between related forms are referred to as Faithfulness constraints, and they are the subject matter of McCarthy and Prince's Correspondence Theory of Faithfulness (McCarthy and Prince 1995b). The relevant constraint is LINEARITY, defined below. The specific dimension over which input /kutb/ and output [-ktub-] differ is the linear ordering of segments. The version of the constraint holding between input and output is denoted as IO-

[5] The so-called 'super-heavy' CVCC and CVVC syllables do occur in the limited context before a pause (Wright 1896, p. 15). For example, pre-pausally [katab-tu] 'write-past-1sg' and [kitaab-in] 'book-gen-indef' appear as [katab-t] and [kitaab] (see Hoberman 1995). It is reasonable to assume that the output of the truncation morphology escapes prosodic limitations on syllable weight, as proposed in McCarthy and Prince (1990b, pp. 19, 50). Another instance where CVVC syllables occur is discussed in the appendix.

LINEARITY or IO-LIN.

5. LINEARITY: S_1 is consistent with the precedence structure of S_2, and vice versa.

By standard OT reasoning, hypothetical /kutb/ stems would surface as [kutb] as a result of the grammatical statement *COMPLEX >> IO-LIN. This is illustrated in tableau (6). Intuitively, this tableau expresses the fact that the phonotactics of the language (*COMPLEX) take priority over identity between input and output (IO-LIN), a typical case of phonological action in OT. The tableau is the same for a null suffix such as the 3ms Jussive /ya, ktub/ → [ya-ktub].

6. Fate of hypothetical stem /kutb/: /ya, kutb, na/ → [ya-ktub-na]; *COMPLEX >> IO-LIN

/ya, kutb, na/	*COMPLEX	IO-LIN
a. ya-kutb-na	*!	
b. ☞ ya-ktub-na		*

Metathesis, then, repairs the local phonotactic violation of *COMPLEX in the case of consonant-initial or null suffixes. However, metathesis creates allomorphy in the verbal paradigm, since as shown in (7) the stem surfaces with two distinct forms [-ktub-], [-kutb-].

7. Consequence of hypothetical stem /kutb/: non-uniform realization

3ms: /ya, kutb, u/ → [ya-kutb-u]

↘

[-ktub-] ≠ [-kutb-]

↗

3fp: /ya, kutb, na/ → [ya-ktub-na]

Non-uniformity in stem realization is the final crucial factor involved in explaining the absence of [kutb] forms. Formally, this factor enters the grammar via intra-paradigmatic identity constraints. Here, I rely on a body of research which converges on the hypothesis that identity constraints between related linguistic forms hold not only between an input and an output but also between pairs of related output forms (see, among others, Benua 1995, Burzio 1993, 1994, 1998, Buckley 1999, Kenstowicz 1997, McCarthy 2000, Steriade, to appear; for earlier explorations of the idea see Kiparsky 1971, 1972 and Harris 1973). Such constraints are called Output-Output Faithfulness constraints. In our example, the Output-Output version of the constraint LINEARITY, OO-LIN, penalizes the disparity between the two forms [ya-kutb-u] and [ya-ktub-na].[6]

To review, when /kutb/ stems are considered within the inflectional context of the paradigm, they

[6] The notion of OO-Faith implicated here can be instantiated with either one of the two basic versions of OO-Faith constraints in the literature. The first version is expressed with the constraint UNIFORMITY requiring that 'A lexical item (here, stem) has the same realization for property P (here, linear order) in its various contexts of occurrence' (Kenstowicz 1997, Buckley 1999, Steriade, to appear). The other version of OO-LIN requires pairwise identity between every surface realization S of stem ς within a paradigm and some *specific* realization S_i within the same paradigm, where S_i is the 'base' of the paradigm (see the rest of the references in the text). If this latter version of OO-LIN is assumed, then it can be shown that independent of the choice of the base (an S_i before a vowel-initial or an S_i before a consonant-initial suffix), the only possible realization of stem /kutb/ is [ya-ktub-u, ya-ktub-na]. In sum, uniform realization of the stem can be achieved under any of the two notions of OO-Faith.

raise a local phonotactic problem: before a consonant-initial or null suffix, such stems would result in a violation of *COMPLEX. The problem can be resolved by metathesis, but this has the global consequence of introducing allomorphy. The fact that such allomorphy is not attested in Arabic is a consequence of a high-ranked OO-LIN. The grammar expressing this idea formally is shown in the 'paradigm tableau' below (the term is due to Tesar and Smolensky 1998, p. 41). A paradigm tableau computes the surface realizations of a hypothetical stem ς in all contexts of some paradigm π. Thus, given a stem ς = /kutb/, the tableau below assesses the performance of its various candidate realizations, given the ranking of the constraints *COMPLEX, OO-LIN and IO-LIN. The candidate realizations are not individual surface forms, but rather sets of surface forms. Henceforth, I refer to any such set as the *realization set* of stem ς within paradigm π, or in short π(ς). For space reasons, however, I do not show all fourteen forms in each candidate realization set (of a stem within the imperfect, indicative paradigm) but rather only two representative surface forms, one with a vowel-initial suffix, the 3ms /ya-, -u/, and the other with a consonant-initial suffix, the 3fp /ya-, -na/. These are representative in the sense that, within each candidate set, the surface forms not shown do not violate any constraints other than those violated by the forms shown. Thus, candidate (8a) [ya-kutb-u, ya-kutb-na] incurs a fatal violation of *COMPLEX. Candidate (8b) is the non-uniform set [ya-kutb-u, ya-ktub-na] with a fatal violation of OO-LIN. Candidate (8c) avoids the OO-LIN violation by leveling to [ktub] in all contexts. This violates the low-ranked IO-LIN twice, once for each of the mappings /kutb/ → [ya-ktub-u] and /kutb/ → [ya-ktub-na]. Comparing (8b,c), we see that the crucial ranking relation is OO-LIN >> IO-LIN. The dominant OO-LIN requires the same linear order [ktub] throughout the realization set, that is, both before a consonant- and a vowel-initial suffix.

8. Uniform realization: /kutb/ → [ya-ktub-u, ya-ktub-na]; *COMPLEX, OO-LIN >> IO-LIN

π(/kutb/) = ?		*COMPLEX	OO-LIN	IO-LIN
a.	ya-kutb-u, ya-kutb-na	*!		
b.	ya-kutb-u, ya-ktub-na		*!	*
c. ☞	ya-ktub-u, ya-ktub-na			**

Overall, then, *COMPLEX, OO-LIN >> IO-LIN is the grammatical statement of the fact that allomorphy, as in [ya-kutb-u, ya-ktub-na], is not attested in Arabic.

In sum, a stem ς is realized in the inflectional context of some paradigm π, which induces local phonotactic pressures on the realization of ς. These pressures have global consequences when intra-paradigmatic identity is dominant. Specifically, it is the phonotactic pressures in the context before a consonant, [-kutb-na], which demand alternation to [-ktub-na]. With OO-LIN being dominant, the effect of the local phonotactic (here, metathesis) is transmitted to the rest of the forms in the paradigm, namely, to the contexts where the stem occurs before a vowel-initial suffix, hence [-ktub-u], not *[-kutb-u]. This is why surface *[-kutb-u] is not attested in Arabic. The reasoning here generalizes to any phonotactic constraint which targets some phonological configuration in some morphosyntactic context, and any faithfulness constraint which is forced to violation in that local context where the phonotactic pressure is met. Indeed, as we will see, this reasoning also allows us to derive the absence of stem realizations with the properties of initial gemination or initial identity, where different phonotactic and faithfulness constraints are involved.

To return to our task, it takes one more step to show that the effects of the paradigmatic context on

stem realization have consequences for the inventory of viable stems.

2.2 Absence of /kutb/ stems

Our goal now is to derive the absence of /kutb/ stems from the lexical inventory of the language. Recall that the grammar, that is, the ranking SYLL, OO-LIN >> IO-LIN, is responsible for the absence of [kutb] surface forms. This grammar is such that both stems /kutb/ and /ktub/ map to the same set of surface forms, [ya-ktub-u, ya-ktub-na]. Which stem is the learner to choose as the one underlying the surface facts? A general answer to this question is obtained by the following logic, originally due to Stampe (1972). Given that there are no surface [kutb] forms in the data, the learner will not set up a stem /kutb/. Even though both /kutb/ and /ktub/ derive the surface forms, the learner will choose /ktub/ because this stem is 'closer' to the observed surface facts.

In OT, the logic of 'Stampean occultation' is expressed formally by *Lexicon Optimization* (Prince and Smolensky 1993, Inkelas 1995, Tesar and Smolensky 1996, 1998, Itô, Mester, and Padgett 1996, Yip 1997, McCarthy 1998). Lexicon Optimization evaluates the relative harmony of the two mappings, /kutb/ → [ya-ktub-u, ya-ktub-na] and /ktub/ → [ya-ktub-u, ya-ktub-na], as shown in (9). The shaded parts of (9) show non-optimal realization sets, emphasizing the fact that both stems here map to the same realization set [ya-ktub-u, ya-ktub-na]. Evaluation proceeds in the standard way as defined by the Optimality theoretic function *H-Eval*, that is, the learner selects the stem which supplies the least violations of the most important constraints. Here, stem /kutb/ surfaces as [ya-ktub-u, ya-ktub-na] with two violations of IO-LIN, but /ktub/ does not violate any constraint. Hence, /ktub/ provides the most harmonic mapping or, equivalently, *H-Eval* determines the harmonic ordering /ktub/ ≻ /kutb/ ('α ≻ β' stands for 'α is more harmonic than β').

9. Lexicon Optimization: /ktub/ ≻ /kutb/

Candidate Stems	Surface set	*COMPL	OO-LIN	IO-LIN
a. /kutb/	ya-kutb-u, ya-kutb-na	*!		
	ya-kutb-u, ya-ktub-na		*!	*
	☞ ya-ktub-u, ya-ktub-na			**
b. ☞ /ktub/	ya-kutb-u, ya-kutb-na	*!	*	
	ya-kutb-u, ya-ktub-na		*!	*
	☞ ya-ktub-u, ya-ktub-na			

We see, then, that Lexicon Optimization projects the effects of the grammar from the surface forms back to their inputs. This is how we can derive the absence of /kutb/ stems without stipulating a ban on such stems from the lexical inventory of the language. The latter statement would be equivalent to a Morpheme Structure Constraint against */CVCC/ stems in Arabic. Lexicon Optimization obviates such

stipulations about the set of admissible inputs (on a reevaluation of MSCs from an OT perspective see Myers 1997 and McCarthy 1998). Indeed, surface properties of the language, here the segmental make-up of the affixes in the paradigm coupled with intra-paradigmatic identity constraints are responsible for the absence of /kutb/ stems from the lexical inventory.

Let us state this result in the most general and explicit form. Assume a language L with grammar G, and a paradigm π. Let $[\![\Phi]\!]$ be the realization set of some lexeme V in π. We are interested in identifying the stem which underlies the surface data in $[\![\Phi]\!]$. To do so, *H-eval* determines the relative harmony of all stems ς in the set $\{\varsigma \mid \varsigma \rightarrow [\![\Phi]\!]\}$, that is, the set of all forms that can generate the realization set $[\![\Phi]\!]$. We then say that *lexeme V has stem* ς iff $\varsigma = H\text{-}max\{\varsigma \mid \varsigma \rightarrow [\![\Phi]\!]\}$, where *H-max* returns the ς with the most harmonic mapping to $[\![\Phi]\!]$. To illustrate with our example, *H-eval* compares the relative harmony of the forms /ktub/ and /kutb/, the two forms which generate the set $[\![\Phi]\!]$ = [ya-ktub-u, ya-ktub-na] under grammar G. *H-max* returns the most harmonic form, here the stem /ktub/. We may now also define the notion of an *impossible* stem to be any ς_i in the set $\{\varsigma \mid \varsigma \rightarrow [\![\Phi]\!]\}$ such that $\varsigma_i \prec H\text{-}max\{\varsigma \mid \varsigma \rightarrow [\![\Phi]\!]\}$.

Consider now the fact that our result rests on establishing a particular ranking of the constraints, namely, *COMPLEX, OO-LIN >> IO-LIN. This ranking is inferred from the *absence* of the paradigm [ya-kutb-u, ya-ktub-na] in the primary data. This means that this ranking is unlearnable, and hence it must be stipulated as such in our analysis. But then why is this analysis an improvement over the alternative which places an explicit ban on /kutb/ stems from the lexical inventory? The reason is that the crucial ranking relation *COMPLEX, OO-LIN >> IO-LIN of the present analysis finds *independent* motivation from work on learnability and child language acquisition in OT. This work converges on the hypothesis in (10) that the two crucial ranking relations in *COMPLEX, OO-LIN >> IO-LIN are necessary subrankings of the initial constraint hierarchy, called the *Initial State* or H_0 of the grammar.

10. Learnability hypothesis about the Initial State

(a) MARKEDNESS >> IO-FAITH (required for learnability of languages with unmarked inventories)

(b) OO-FAITH >> IO-FAITH (required for learnability of languages with uniform paradigms)

The ranking *COMPLEX >> IO-LIN and more generally the ranking schema MARKEDNESS >> IO-FAITH in (10a) is part of the initial state as argued in Smolensky (1996) and Tesar and Smolensky (1998). To briefly sketch that argument, consider the implicational universal that consonant inventories with geminates imply the existence of single, non-geminate consonants in those inventories (but not vice versa). We thus assume the existence of a markedness constraint $*C^{GEM}$ which bans gemination in consonants. A language with no geminates requires the ranking $*C^{GEM}$ >> IO-$FAITH^{LENGTH}$. This is the ranking ensuring that a geminate contrast could never arise, always being neutralized by the dominating markedness constraint. A learner exposed to a language with geminate consonants has overt evidence which contradicts this ranking. Given this, the learner can switch the ranking of the two constraints, IO-$FAITH^{LENGTH}$ >> $*C^{GEM}$, which is the correct target grammar for the ambient language. However, a learner exposed to a language with the unmarked inventory of no geminate consonants has no overt evidence for the target grammar of that language, that is, $*C^{GEM}$ >> IO-$FAITH^{LENGTH}$. This is because there are no geminates in the overt data. It follows that, unless the learner starts with the ranking $*C^{GEM}$ >> IO-$FAITH^{LENGTH}$, the unmarked inventory would be unlearnable. This argument can be generalized to any pair of conflicting markedness and faithfulness constraints. Moreover, (10a) is

consistent with a significant body of independent work on child phonology (see Tesar and Smolensky 1998 for further discussion).

A learnability argument for (10b), OO-FAITH >> IO-FAITH, is developed in McCarthy (1998) who extends the initial state ranking to a grammar model with OO-FAITH constraints. The logic of McCarthy's argument is essentially the same as that for MARKEDNESS >> IO-FAITH. The 'unmarked' inventories here correspond to uniform paradigms which are learnable only under the assumption that learners start with OO-FAITH >> IO-FAITH in the initial state. An instance of McCarthy's argument was illustrated above with the ranking COMPLEX, OO-LIN >> IO-LIN. See also Hayes, *to appear,* on how McCarthy's proposal may be integrated in a learning algorithm and for some independent evidence for that assumption from acquisition.

The present stem-in-context approach extends to provide an account for the shape invariance of triliteral nouns. Briefly, triliteral nouns appear consistently as CVCC: [nafs-un] 'soul', [baħr-un] 'sea', [qufl-un] 'lock', [burd-un] 'robe', [ħiml-un] 'load', [qidħ-un] 'arrow' and so on. There exists thus a basic surface asymmetry between the noun and the verb: CVCC shape for the former, but CCVC shape for the latter. To understand this asymmetry, we must consider again properties of the inflectional context in which verbal and nominal stems are realized. For nouns, crucially this context consists of vowel-initial suffixes, [*stem*-un] for the indefinite and [ʔal-*stem*-u] for the definite form. The paradigm is shown below, built on Case, Gender and Number.

11. Noun	*Masc. Sing.*	*Masc. Pl.*	*Fem. Sing.*	*Fem. Pl.*
Nominative	-un	-uuna	-atun	-aatun
Genitive	-in	-iina	-atin	-aatin
Accusative	-an	-iina	-atan	-aatin

The inflectional context of this paradigm contrasts with the verbal one, where all prefixes are vowel-final and crucially some suffixes are consonant-initial or null. It is now easy to see why the CC cluster in the noun appears at the right edge, [CVCC], not *[CCVC] as for the verb. The inflectional context of the nominal paradigm coupled with the basic syllabification constraint *COMPLEX dictates [CVCC-V] as the only possible realization of a triliteral noun. The alternative [CCVC-V] is avoided because of the initial complex onset. The ranking *COMPLEX >> IO-LIN ensures that independent of the linear order of the segments of the input, a triliteral noun surfaces as [CVCC-V]. Lexicon Optimization would then determine /CVCC/ to be the stem, since this form provides the most optimal mapping to the surface data.

The only previous attempt known to me for an account of the [CCVC] shape of verbs versus the [CVCC] shape of nouns is found in Ratcliffe (1998, pp. 51-2). Ratcliffe proposes that the underlying stem for both nominal and verbal stems is the same, /CVCC/. He derives the deviant [CCVC] surface realization of the verbal stem via a requirement for 'Maximal Syllabification' said to operate in a left-to-right mode. This requirement prefers [ya-ktub-u] over [ya-kutb-u] because in the former syllabification builds the maximally possible syllable [(yak)(t...] at the left edge. The present analysis obviates such assumptions about the input, which are pre-theoretically undesirable and, in fact, impossible in a theory like OT. The present analysis also obviates the language-particular assumption about the directionality of syllabification. The paradigmatic context in conjunction with the basic syllabification constraint *COMPLEX and intra-paradigmatic identity constraints suffice to explain the asymmetry in the realization between nominal, verbal forms and their underlying stems.

To sum up, I have provided formal content to a particular mode of interaction between inflectional

contexts and stems. The inflectional context of a paradigm π coupled with phonotactic constraints sets limits on the theoretically possible diversity of stem realizations within that context. Effectively, the paradigm 'molds' the shape of verbal stems to 'fit' the inflectional context supplied by π. Later sections show how other systematic properties of the Semitic lexicon derive from the same kind of interaction between contexts and stems.

2.3 The perfect

The perfect forms of the verb takes the shape [CaCvC-] and generally refer to past time.[7] Fully inflected words based on the perfect appear with suffixes, marking person, gender, and number. In contrast to the imperfect, there are no prefixes in the perfect paradigm. This fact is crucial in understanding the absence of consonant gemination and repetition at the left edge of the Semitic stem, the topic of section 4. In this section, I address the issue of the relation between perfect and imperfect.

12. *Perfect*		*Singular*	*Plural*	*Dual*
3	*m*	katab-a	katab-uu	katab-aa
	f	katab-at	katab-na	katab-ataa
2	*m*	katab-ta	katab-tum	katab-tumaa
	f	katab-ti	katab-tunna	katab-tumaa
1		katab-tu	katab-naa	

In addressing this issue, we must first review the complex facts of vowel alternations in Form I verbs. As we have seen, the vowel of the imperfect form [ktub] is an arbitrary property of the verb 'to write'. In the perfect, putting aside the first /a/ in [katab] – a marker of Active Voice – the second vowel is a counterpart of the /u/ in the imperfect [ktub]. Additional examples of this vowel alternation are shown in (13). The counts are from McCarthy (1994), derived from Wehr (1971). With possible exceptions to be discussed below, neither the vowel quality nor the presence of the alternation itself seems predictable. As Guerssel and Lowenstamm (1996) point out, in [krub, xrib, drab] all vowels /u, i, a/ are found in the imperfect, even though the consonantal contexts are highly similar. The same is true with the vocalism of the perfect, [qarub-, ʃarib-, harab-].

13. *Vowel alternation*		*Perfect*	*Imperfect*	*Gloss*	*Frequency*
1	$a^{Perf} \sim u^{Impf}$	karab-	-krub-	'come near'	1029
		harab-	-hrub-	'flee'	
2	$a^{Perf} \sim i^{Impf}$	xarab-	-xrib-	'devastate'	842
		Darab-	-Drib-	'hit'	
3	$i^{Perf} \sim a^{Impf}$	darib-	-drab-	'be experienced'	518
		ʃarib-	-ʃrab-	'drink'	
4	$a^{Perf} \sim a^{Impf}$	faʕal-	-fʕal-	'do'	436
		radaʕ-	-rdaʕ-	'prevent'	
5	$u^{Perf} \sim u^{Impf}$	qarub-	-qrub-	'be close to'	191
		kabur-	-kbur-	'be great'	

[7] But not always; see Al-Karouri (1996, chapter 4) for discussion of the long-standing issue of Tense/Aspect in the Arabic verb and for uses of the perfect to refer to future time.

Classes 4 and 5 illustrate some dimensions of predictability. Class 4 is said to be an exception to the phonologically arbitrary character of the alternation, since in the verbs of this class it is the presence of a guttural consonant, either before or after the vowel, which conditions the quality of the stem vowel /a/ (but as McCarthy 1994 has shown, there about 25, out of 436, verbs which surface with an invariant /a/ but do not have a pharyngeal consonant adjacent to the vowel). Class 5 illustrates another dimension of predictability, since all verbs in that class are stative. Finally, there are a few verbs whose vocalism does not fit any of the above classes, e.g. [watiq-], [-(w)tiq-] 'to rely on', and these are treated as 'exceptions' to the system of classes given above.

The proper statement of these complex facts was and continues to be an important open problem for Semitic scholars (Kuryłowicz 1972, McCarthy 1979, pp. 290-3, 1994, McOmber 1995, Guerssel and Lowenstamm 1996). This paper does not address this problem. Rather, the paper aims to establish certain claims about the phonological properties that can be specified in the lexical entries of verbal stems. It is therefore important to ensure that those claims stand independently of the vowel alternation facts in (13). Indeed, previous research suggests that, assuming some account of these alternations, that account does not preclude the specification of lexical vowels as parts of stems. The various proposals on the alternations in (13) build on the fact that given one of the vowels, either that of the perfect or the imperfect, it is generally possible to predict the other vowel with varying degrees of success. Thus, one unavoidable, shared conclusion here is that the information specified in the lexical entry of a verb must consist of at least the consonantal sequence *plus a vowel*. Beyond this, there is little consensus. Specifically, the details of how exactly this minimal information is to be specified differ from one proposal to the other. According to the proposals following the root-based tradition, the consonants are to be listed separately from the lexical vowel, as in /Drb, a^{PERF}/ (Guerssel and Lowenstamm 1996, Chekayri and Scheer 1996). According to others, the listed form is a unitary vowelled-stem, e.g. /Drib/$^{\text{IMPF}}$ (Kuryłowicz 1972, Schramm 1991, McOmber 1995). The important point is that the different choices here are motivated by assumptions that are independent of the vowel alternation facts. In other words, the facts of vowel alternations are compatible with a number of different choices about the form of the lexical entry for the verb. Consequently, to address the issue of the representations, we must first (re)consider properties of the verbal morphology beyond the vocalic alternations. This is the topic of the sections in the rest of this paper.

The second issue of the perfect, imperfect relation is the issue of directionality. From (13), it is not trivial to establish which is the basic and which is the derived form in the perfect, imperfect pairs.[8] Given two distinct but phonetically similar variants of a lexeme, the phonologist is tempted to devise a system that derives one of the forms from the other. This is the approach to the data in (13) favored in the literature, though there is no consensus on the directionality of the derivation. Thus, Schramm (1962, 1991), Brame (1970), Ratcliffe (1988), McOmber (1995), and Benmamoun (1999) favor the imperfect as the basic stem, whereas McCarthy (1981) and Guerssel & Lowenstamm (1996) favor the perfect as the basic form (as in the traditional view expressed, for example, in Wright 1896, p. 27).

As Matthews (1974) and Aronoff (1994) have cogently discussed, however, it is not clear whether a 'basicness' distinction should be made beyond simply recognizing the presence of two stems for each verb. The basic problem lies in that, no matter which form is assumed to be basic, at least some of the vowel alternations in (13) cannot be motivated via independent phonological considerations. Therefore, to avoid the problem of setting up spurious derivational relations, I will assume that there is simply no

[8] Note that the representational issue (vowelled-stems versus segregated consonantism plus vowel) is orthogonal to the issue of directionality.

directionality in the perfect-imperfect relation. That is, I do not assume that one form is derived from the other. To further justify this view, we must first recall a well-established fact about morphology. Lexemes can have more than one stem, the choice of each stem being determined by the morphosyntactic properties of the word for which the stem is being chosen (Aronoff 1994). In the case of Arabic, we will say that Form I verbal lexemes have two stems, an *imperfect stem* and a *perfect stem*. Thus, the verb 'to write' has imperfect stem /ktub/ and perfect stem /ktab/, the verb 'to drink' has imperfect stem /ʃrab/ and perfect stem /ʃrib/, and so on (see Aronoff 1994 for a similar proposal on Hebrew). My use of the terms 'perfect / imperfect stem' coincides with Carstairs' (1987) notion of *realization stem*: "If P is some morphosyntactic property, we typically speak of X' as the P-stem of some word X when all and only the forms of X which share the property P use X' as a basis for further inflexion" (p. 208). So, to say that /ktub/ is the imperfect stem of the lexeme 'to write' is to say that all (and only) the forms of this lexeme specified for [+impf] employ /ktub/ as the form on which various inflectional markers are attached.

Finally, to spell out the phonological side of this non-directional view of perfect-imperfect morphology, I will rely crucially on the notion of correspondence (McCarthy and Prince 1995b). Specifically, to say that stems ς, ς' are the [+perf], [+impf] stems for a lexeme V is to say that there exists a correspondence relation between these two forms requiring their identity. Because of its attendant identity constraints, this relation imposes limits on allomorphy across the two non-overlapping sets of words specified for [+perf], [+impf]. As the following sections show, the phonological consequences of this non-directional perfect-imperfect relation are manifest in the allomorphy of doubled verbs (section 3) and in Greenberg's asymmetry (section 4).

3. Doubled verbs

The so-called 'doubled verbs' in Arabic are those verbs which show an alternation between what is allegedly a 'canonical' form [samam] and a 'contracted' form [samm], with a final geminate. Departing from a long-standing tradition of treating this alternation as phonologically arbitrary, this section argues that phonology does not only determine the distribution of the two allomorphs, but also the nature of the relation between the two. The analysis supporting this argument is the main theme of sections 3.1 and 3.2, which deal with the alternation in the perfect and the imperfect, respectively. Section 3.3 establishes connections to other verbs as well as to non-verbal morphology, arguing that the formal statement of the doubled verb alternation makes predictions beyond the data set of doubled verbs and that these predictions are borne out. Section 3.4 discusses alternative analysis of the alternation, and section 3.5 discusses the alternation in the other Forms of the verb.

3.1 Allomorphy in the perfect

In the perfect, doubled verbs show two forms, [madd] and [madad], e.g. 3ms [madd-a], 1s [madad-tu], as shown below.

14. *Perfect*

		Singular	*Plural*	*Dual*
3	*m*	madd-a	madd-uu	madd-aa
	f	madd-at	madad-na	madd-ataa
2	*m*	madad-ta	madad-tum	madad-tumaa
	f	madad-ti	madad-tunna	madad-tumaa
1		madad-tu	madad-naa	

Henceforth, [madd] is referred to as the *geminate* allomorph and [madad] as the *strong* alllomorph of the doubled verb ('strong' due to its resembling the strong verb [katab]). Which one of these two allomorphs shall we take as the one underlying the surface alternation between [madd] and [madad]? One answer to this question is suggested by the following observation. The shape of /madad/ is the shape of the non-alternating triliteral verbs: [katab-a] 'he wrote', [katab-tu] 'I wrote'. Traditionally, triliterals are assumed to be the 'canonical' verbs in Arabic, and by extension their prosodic shapes are assumed to be the canonical shapes for verbs. This assumption has been inherited in all analyses of these facts known to me (Wright 1896, pp. 68-71; Cantineau 1946, p. 133; Brame 1970, p. 119; McCarthy 1979, pp. 265-267). This suggests that [madd] is derived from the 'canonical' /madad/, which would be the form underlying the alternation.

However, there is an alternative proposal: the basic form is /madd/, and [madad] is a surface variant of /madd/ before a consonant-initial suffix. This alternative has not been considered yet. Standard methodology in generative grammar (Kenstowicz and Kisseberth 1979), however, dictates that given the alternation between [madd] and [madad], we must consider at least the two hypotheses outlined above, and contemplate their consequences for the rest of the grammar of the language. In what follows, I will develop this alternative proposal, and then I will compare it to the traditional view as well as to other views of the alternation.

Let us begin by observing that, as with the vowel of strong verbs, the stem vowel of doubled verbs changes between the perfect and the imperfect. Thus, the imperfect stem of 'to stretch' in (14) contains the vowel /u/, whereas its perfect stem contains /a/ in the second vowel position of [madad]. As discussed below, the first /a/ in [madad] as well as the /a/ in [madd] are inflectional markers. Additional examples of such vowel alternations for doubled verbs are shown below (from Wright 1896, pp. 68-9).[9]

15. *Imperfect*	*Perfect+V*	*Perfect+C*	
ya-mudd-u	madd-a	madad-tu	'stretch'
ya-ʃuqq-u	ʃaqq-a	ʃaqaq-tu	'split, cleave'
ya-Hibb-u	Habb-a	Habab-tu	'love'
ya-jill-u	jall-a	jalal-tu	'be lofty'
ya-mall-u	mall-a	malil-tu	'be weary'
ya-mass-a	mass-a	masis-tu	'touch'
ya-ʃamm-a	ʃamm-a	ʃamim-tu	'smell'
ya-lubb-u	labb-a	labub-tu	'become wise'
ya-Hubb-u	Habb-a	Habub-tu	'become dear'

In the perfects of (15), observe that all stem vowel contrasts are neutralized in the prevocalic form which always surfaces with /a/, [CaC^{x}C^{x}-], irrespective of the stem vowel of the perfect, e.g. [Hab**a**b-tu,

[9] As is the case with the strong verbs, the stem vowel of doubled verbs can be the only source of contrast between two verbs, e.g. [ya-Sabb-u] 'to love passionately' versus [ya-Subb-u] 'to pour (liquid)'. These examples are from Cantineau (1946, p. 133) who presents them as illustrations of the lexical status of the vowel inserted to repair the phonotactic violation under the standard analysis of the doubled verb alternation. In Cantineau's words "Il a déjá été dit que l'arabe classique n'admettait pas de groupes de plus de deux consonnes; quand un group de trois consonnes risque de se produire, une voyelle s'insère entre les deux premières consonnes du groupe: yamdudu > yamddu > yamuddu; cette voyelle n'est pas purement phonétique, puisqu'elle peut jouer un rôle différenciatif: yaSubbu 'il versera (un liquide)' — yaSabbu 'il aimera ardemment'" (p. 133).

mal**i**l-tu, lab**u**b-tu].[10] The situation is shown more explicitly below, with examples from a strong verb and a doubled verb. The perfect stems shown in the first column are /ktab/ and /mill/. That is, as with strong verbs, I assume that the perfect stem of a doubled verb includes its characteristic vocalism, here /i/. Affixed to the stem are the perfect active voice marker /a/, henceforth /a^{PAV}/, and the appropriate person, number, gender suffix. The vowel of the stem /ktab/ surfaces in the second vowel position of the perfect output. For the doubled verb /mill/, however, the lexical vowel /i/ surfaces only before a consonant-initial suffix, [malil-naa].

16. *Stem*		*Stem-suffix*		*Morphological parse*
/kt**a**b/	→	kat**a**b-a	3ms	k-a^{PAV}-t**a**b-a
/kt**a**b/	→	kat**a**b-naa	1p	k-a^{PAV}-t**a**b-naa
/m**i**ll/	→	mall-a	3ms	m-a^{PAV}-ll-a
/m**i**ll/	→	mal**i**l-naa	1p	m-a^{PAV}-l**i**l-naa

Consider the fact that the lexical vowel of the perfect stem /mill/ is left unrealized before a vowel-initial suffix. The /a/ in the surface form [mall-] is the marker of perfect active voice, /a^{PAV}/. This means that the requirement for morphological expression of the perfect active voice is dominant and suppresses the vowel of the stem. This is shown in tableau (17). MAX is a basic constraint of correspondence theory which dictates that "Input segments must have output correspondents" (McCarthy and Prince 1995b). Individual morphemes come with different MAX requirements. Here, IO-MAX^{PAV} dictates that /a^{PAV}/ must have a correspondent in the output, and IO-MAX^{V} dictates that the stem vowel must have a correspondent in the output. Since the constraints are in conflict and (17a) is the actual output, we infer that IO-MAX^{PAV} >> IO-MAX^{V}.

17. Stem vowel is replaced: priority to expression of aspect, voice

/a^{PAV}, mill, +a/	IO-MAX^{PAV}	IO-MAX^{V}
a. mill-a	*!	
b. ☞ ma^{PAV}ll-a		*

The ranking inferred from this tableau is in apparent contradiction with the schema "Root-Faith >> Affix-Faith" which has been proposed by McCarthy and Prince (1995b, p. 364) to hold between Roots or Stems and Affixes, in general. Vocalic melodies in Semitic, however, offer good reasons to believe that this ranking needs to be refined by making reference to different kinds of morphological realization. The /a/ of PAV is a marker of inflectional class. All Form I verbs show this invariant vowel in the active voice of the perfect. We know independently that the definitional characteristic of inflection is that it is obligatory. Because of this reason, then, the vowel /a/ must be expressed, even when there is only one vowel position in the surface realization of the stem.[11]

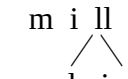
[10] I thank Robert Hoberman for pointing out this crucial fact to me.

[11] This is true of some modern Arabic dialects as well. Thus, in Egyptian Arabic, there is no vowel contrast in the perfect: all perfect forms are [CaCC], as in [ħabb] 'to love, like', [dall] 'to indicate'; but in the imperfect, a contrast is possible, thus [biyħibb] versus [biydull] (Abdel-Massih 1975, pp. 135-137). Similarly, in Iraqi Arabic, all doubled verbs have [a] in their perfect as in [dazz] 'to send', [gaSS] 'to cut', but in the imperfect we have [ydizz] vs. [yguss] (Erwin 1969,

One way to avoid replacement of the lexical vowel is to employ the strong allomorph of the doubled verb [malil] also in the prevocalic context, [malil-a]. In this form, both /a^{PAV}/ and the stem vowel /i/ surface. This also satisfies the templatic requirement, TEMPL= CVCVC, on the shape of the perfect.[12] The crucial point is that [malil-a] violates another basic constraint of correspondence theory called INTEGRITY, defined below. INTEGRITY penalizes relations between a form S_1 (here, the stem) and another related form S_2 (here, the perfect), where a segment in S_1 has more than one correspondent in S_2. Note that the two lines in the example relation /mill/, [malil] below portray pairs of correspondent segments, so that the segment /ll/ in the stem /mill/ enters into two (hence the INTEGRITY violation) correspondent pairs, (ll, l) and (ll, l). These lines do not denote spreading of a consonant to two C positions (see section 5.2 regarding such spreading).

18. INTEGRITY: No segment of S_1 has multiple correspondents in S_2

IO-INTEGRITY violation:



Stem (= S_1), /mill/

Perfect (= S_2), [malil]

Since the stem geminate does not separate as in /mill/ → [malil] to satisfy TEMPL=CVCVC, it follows that IO-INT >> TEMPL. Tableau (19) compares the two relevant candidates. From this tableau, it also evident that IO-INT >> IO-MAX^V. In other words, maintaining the integrity of the geminate takes priority over satisfying the template and parsing the stem vowel.

19. No integrity violation before V-initial suffixes: /a^{PAV}, mill, +a/ → [mall-a]

/a^{PAV}, mill, +a/	IO-INT	TEMPL	IO-MAX^V
a. malil-a	*!		
b. ☞ mall-a		*	*

As seen above, the templatic requirement for the perfect is suppressed in favor of maintaining faithfulness to the stem, /mill/ → [mall-a], *[malil-a]. However, as we now turn to see, when the stem cannot surface as such due to phonotactics, the template does come into play. In particular, when doubled verb stems are combined with C-initial suffixes, as in /a^{PAV}, mill, +tu/, a phonotactic problem arises. Arabic does not allow sequences of a geminate followed by another consonant as in *[mill-tu] or *[mall-tu]. Such sequences, we assume, are excluded via a constraint disallowing geminates as syllable codas, *VC$_x$C$_x$]$^\sigma$. [13]

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p. 240).

[12] In assuming the presence of this templatic requirement for the perfect, the analysis follows McCarthy (1979, p. 248) and subsequent work. As a large body of research within Prosodic Morphology shows, the notion of template is orthogonal to the issue of root- versus stem-based morphology (see McCarthy and Prince 1995a for a review). Thus, also non-root based approaches to Arabic morphology assume this template for the perfect (for instance, Ratcliffe 1997, p. 157).

[13] This may ultimately be seen a reflex of a general upper bound on syllabic weight (e.g. see Broselow, Chen, Huffman 1997, p. 65, for a proposal on a bound of two moras). For present purposes it suffices to formulate it as given. Moreover, as discussed in the appendix, there is some independent evidence that *VC$_x$C$_x$]$^\sigma$ rhymes are treated differently from their moraic equivalent *VVC]$^\sigma$ rhymes in the grammar of Arabic.

20. *$VC_xC_x]^{\sigma}$: Geminates are not allowed as syllable codas

The actual output from /a^{PAV}, mill, +tu/ is [malil-tu]. The phonotactic problem met by simple concatenation as in *[mill-tu] is resolved by violating IO-INT. Therefore, the markedness constraint *$VC_xC_x]^{\sigma}$ dominates IO-INT.[14] Moreover, *COMPLEX dominates IO-INT, because [(mil)(l-tu)], with a complex onset, is not an option either. Using the cover name SYLL for the two syllable structure constraints *$VC_xC_x]^{\sigma}$ and *COMPLEX, then, from (21), we can infer the new ranking relation SYLL >> IO-INT.

21. Integrity violation before C-initial suffixes: /a^{PAV}, mill, +tu/ → [malil-tu]; SYLL >> IO-INT

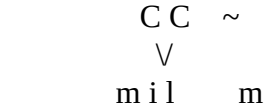
/a^{PAV}, mill, +tu/	SYLL	IO-INT	TEMPL
a. mall-tu	*!		*
b. ☞ malil-tu		*	

An alternative repair to the phonotactic problem met by simple concatenation of the stem and the suffix in /a^{PAV}, mill, +tu/ is to shorten the geminate as in [mal-tu]. This candidate, compared to the actual output in (21), violates TEMPL and IO-MAX^{V}. But since these are dominated by IO-INT as shown in (19), their violation cannot be the reason for the suboptimality of [mal-tu]. Rather, the constraint ruling out this candidate is the constraint $IDENT^{Q}$ in (22), which requires that the skeletal quantity of segments in the stem must be preserved or 'transfered' in the surface form (Dell and Elmedlaoui 1992, Gafos and Bazar 2001). Specifically, in /mill/ → [mal-tu], the geminate /ll/ in the stem /mill/ is linked to two skeletal C slots, but the correspondent of /ll/ in [mal-tu] is the segment /l/ linked to only one C slot. This mismatch is penalized by $IDENT^{Q}$. No such mismatch exists in the relation between /ll/ in /mill/ and its two correspondent /l/ in [malil-tu]. As shown in (22a), the /ll/ in /mill/ is linked to two C slots, the same number of slots as those linked to the two correspondents of /ll/ in [malil], one C slot for each /l/. Another example of a relation illustrating the evaluation of $IDENT^{Q}$ is shown in (22b). The stem is /Sal/ 'to arrive' and its hypothetical realization is [Salal]: the /l/ of the stem is linked to one C slot, whereas its two correspondents in [Salal] are linked to two C slots, a violation of $IDENT^{Q}$ (the actual output of /Sal/ is [waSal], as discussed in section 3.3).

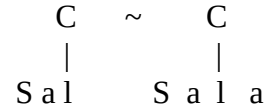
22. $IDENT^{Q}$

A segment in S_1 and its *correspondent set* in S_2 have identical quantities (here, no. of C slots)

a. S_1 = /mill/ 'be weary', S_2 = [malil]



b. S_1 = /Sal/ 'to arrive', S_2 = [Salal]



[14] The markedness of a geminate consonant in coda position cannot be subsumed under the general markedness constraint against complex margins, *COMPLEX, introduced in §2.1. This can be illustrated by the dialect of Palestinian Arabic described in Abu-Salim (1980). In this dialect, geminates are permitted at the ends of syllables so that, for example, [ʔimm-na] 'our mother' contrasts with [ʔim-na] 'we removed'. Triconsonantal clusters must be broken by epenthesis, hence /ʔakl/ 'food', [ʔakl-i] 'my food', [ʔakil-na] 'our food', [ʔakil-kum] 'your food', with an epenthetic /i/ in the last two forms. Hence, a constraint specifically targeting geminates in coda position is necessary, our $VC_xC_x]^{\sigma}$, and must be independent from *COMPLEX.

Tableau (23) summarizes the discussion by comparing [mal-tu] to the attested output [malil-tu]. From this tableau, we can infer the new ranking relation IO-IDENT^{Q} >> IO-INT.

23. Integrity violation before C-initial suffixes: /a^{PAV}, mill, +tu/ → [malil-tu]

/a^{PAV}, mill, +tu/	IO-IDENT^{Q}	IO-INT	TEMPL
a. mal-tu	*!		*
b. ☞ malil-tu		*	

The formal statement of skeletal preservation in IDENT^{Q} employs the notion of the 'correspondent set' of a segment which is defined as follows. Given two forms S_1, S_2, and a correspondence relation $\Re$ between the two, the correspondent set of any segment x in S_1 is defined as the set of all segments y in S_2 that are correspondents of x. This is the set {y: x$\Re$y}, that is, the set of all $y \in S_2$ such that $x \in S_1$ corresponds to y. This set may be empty, as in the case where x does not have a correspondent in S_2 (deletion), or it may consist of one or more elements. In our example, the correspondent set of the final consonant of /mill/ in [malil-tu] consists of two segments, the two /l/. The correspondent set of the final consonant of /mill/ in [mal-tu] consists of one segment, the /l/. Let the quantity of a segment be the set of skeletal slots associated with that segment. The quantity of a geminate is {C, C}, whereas the quantity of a single consonant is just {C}. In general, given a correspondent set of segments S = {y_1, y_2, … , y_n}, let the quantity of the set to be the union of the quantities of its elements. IDENT^{Q} requires preservation of quantity between any given segment in some form and its correspondent set in a related form. Thus, a geminate in an input stem must have a correspondent set in the output whose quantity is exactly two C slots. This extension of correspondence constraints to evaluate identity between segments and *sets of segments* is unavoidable in applying correspondence theory to templatic morphology, where one input segment may have multiple output correspondents.[15]

A notable aspect of this analysis is the violation of geminate integrity in /a^{PAV}, mill, +tu/ → [malil-tu]. This violation seems unusual given the often-made assumption that geminates do not split in word-formation (Kenstowicz and Pyle 1973, Guerssel 1977, 1978, Steriade 1982, Hayes 1986, Schein and Steriade 1986). Crucially, however, the evidence supporting this generalization derives from cases of concatenative or *affixal* word-formation. The Arabic case in /a^{PAV}, mill, +tu/ → [malil-tu] involves a case of *templatic* word-formation. The behavior of geminates in templatic word formation has been much less explored. The reason for this is a historical coincidence. The well-studied languages with templatic word formation like Arabic are also languages for which research is typically carried in the root-based tradition. Roots are assumed to be devoid of prosodic properties like consonantal length. Consequently, given this assumption, there can be no instance of geminate integrity in templatic word-

[15] A precursor of IDENT^{Q} in the context of non-templatic morphology is found in the study of syllable weight by Broselow, Chen and Huffman (1997). Their relevant constraint is called MORAFAITH and "is violated when there is a mismatch between the number of moras linked to the input segment and the number of moras linked to the corresponding output segment" (p. 65). There are two differences between our constraint and MORAFAITH. First, MORAFAITH requires identity in moras whereas IDENT^{Q} requires identity in skeletal slots. It is conceivable that IDENT^{Q} can also be formulated in terms of moras. Our choice of skeletal slots is motivated by the fact that IDENT^{Q} is applicable to languages where no crucial evidence exists for the role of weight (e.g. Moroccan Colloquial Arabic, about which more later). The second difference is in terms of the notion of correspondent set that is part of IDENT^{Q} but not of MORAFAITH. This difference stems from the fact that the empirical domain of Broselow, Chen and Huffman (1997) does not include cases of multiple correspondence, which are the norm in templatic morphology.

formation because there are no geminates at any prefinal stages of the derivation. We may illustrate this by reviewing the well-known analysis of [malil-tu] in a root-and-template approach (as in McCarthy 1981). The output [malil] derives by left-to-right mapping of the consonants in the root |ml| onto the CVCVC template. There is no issue of geminate integrity here because there is no geminate in the input.

Past work strongly indicates that the assumption that all languages with templatic morphology also employ root-based derivation cannot be maintained as a general claim. It thus becomes possible to assess the issue of geminate (in-)separability in templatic word formation, by turning to languages with templates and lexically-specified gemination. One example is provided in an insightful study of the Tashlhiyt Berber dialect spoken in Imdlawn, Morocco, by Dell and Elmedlaoui (1992) who argue that consonantal gemination must be a lexically-specified property of Berber stems. Closer to our interests, in a meticulous study of Moroccan Colloquial Arabic (MCA), Heath (1987) argues that both templatic and affixational word-formation in MCA builds on stems containing vowels and consonants, which can be geminate or single, and that segregation of vowels and consonants in different tiers is not necessary (e.g. see pp. 7, 339, 188-9, 222; the latter point concurs with the independent proposals in Gafos 1996, 1998). Representative examples of templatic word-formation in MCA are given in (24) (/ŭ/ denotes a round, short vowel; page numbers refer to Heath 1987).

24. Geminate separability in templatic word-formation
    a. Professional noun (‘dealer in *Noun*’), p. 140
        sʷkkaR ‘sugar’ → skakR-i
        sbbən ‘wash clothes’ → sbabn-i (some professional nouns are deverbative)
    b. Plural, p. 103
        fddan ‘field’ → fdadᵊn
        mŭxx ‘brain’ → mʷxax
    c. Diminutive, p. 114
        mŭxx ‘brain’ → mʷxiyᵊx
        dllaH ‘watermelon’ → dliliH-a, dlilH-a
    d. Passive participle, p. 92
        kŭbb ‘pour’ → m-kbub
        Həll ‘open’ → m-Hlul

The examples in (24) illustrate relations between a basic form with a geminate consonant and its derived form with two non-adjacent, identical consonants. This is precisely the same relation between /mill/ and [malil] seen in the doubled verb alternation. The full argument that these examples illustrate genuine cases of geminate separability involves showing that alternative analyses in terms of roots and autosegmental spreading are not viable. Though this argument cannot be given here in its entire form, I provide one of its core points. Consider an example from (24a), /sbbən/ → [sbabn-i]. It appears that the relation between stem and derived form can be recast in an alternative form which bypasses the issue of geminate separability. Suppose the root |sbn| is ‘extracted’ from the stem /sbbən/. To form the derived word, root |sbn| maps to the template /CCaCC-i/ in the edge-in mode of association (Yip 1988, Hoberman 1988, 1992, Buckley 1990), which results in precisely the pattern of medial duplication seen in these examples, [sbabn-i]. Consider, however, a simple triliteral stem /nšət/ ‘be lively’ and its derived professional noun [nšayt-i] ‘livery stable’, with an epenthetic glide. Root extraction from /nšət/ results in |nšt| which should give, through edge-in mapping, *[nšašt-i] rather than the attested [nšayt-i]. The contrast between /sbbən/ → [sbabn-i] and /nšət/ → [nšayt-i] is systematic: gemination in the base has

a differential effect on the form of the derived word (more on this later). However, by assumption, roots do not preserve gemination. It follows that this attempt to bypass geminate separability cannot be maintained.[16] I therefore assume from now on that geminates *can* establish relations of multiple correspondence in templatic word-formation, where a geminate in a stem corresponds to two separate consonants in the derived word, as in /mill/ ~ [malil] of the doubled verb alternation. Geminate inseparability or integrity stands as a true generalization in the domain of non-templatic or affixal word-formation.

To return to the Arabic facts, we have by now identified a phonotactic motivation for the alternation between [mall-a] and [malil-tu]. The presence of alternation, however, implies a violation of the Output-Output version of INTEGRITY, because the geminate in [mall-a] corresponds to two separate consonants in [malil-tu] (the domain of OO-INT is the set of forms specified for [+perf]). The situation is depicted in (25) which evaluates various realizations of /mill/ within the perfect paradigm. The candidate in (25a) remains faithful to the stem, with respect to maintaining its geminate, but violates the dominant SYLL and it is thereby excluded. The informative comparison is that between (25b), (25c). The candidate in (25b), where the stem surfaces invariantly as [malil-], avoids the violation of OO-INT at the cost of violating IO-INT twice, once for each of /mill/ → [malil-a], /mill/ → [malil-tu]. In (25c), [malil-tu] incurs only one violation of IO-INT, and a violation of OO-INT. Since the attested paradigm is (25c), it follows that IO-INT >> OO-INT.

25. /mill/ → [mall-a, malil-tu], SYLL >> IO-INT >> OO-INT

π(/mill/) = ?		SYLL	IO-INT	OO-INT
a.	mall-a, mall-tu	*!		
b.	malil-a, malil-tu		*!*	
c. ☞	mall-a, malil-tu		*	*

If, instead, OO-INT dominated IO-INT, then uniformity of stem realization would be required (see 25b). An example of this case was met in the account of the absence of [ktub] ~ [kutb] alternation in strong verbs in section 2. Note also that the ranking responsible for the doubled verb alternation, SYLL >> IO-INT >> OO-INT, can be inferred from the surface data. Given the mapping /mill, tu/ → [malil-tu], a learner must demote the faithfulness constraint IO-INT below the markedness constraint SYLL. Furthermore, in the presence of the surface alternation [mall, mill], the learner must also demote OO-INT below IO-INT.

Finally, consider alternative resolutions to the phonotactic problem created between a geminate-final stem and a consonant-initial suffix, /a^{PAV}, mill, +tu/, such as deletion of the entire geminate as in *[ma-tu], vowel epenthesis as in *[mall□-tu], or metathesis as in *[mall**i**-tu]. These options violate independently motivated constraints which we thus assume to be undominated. For example, deletion as in *[ma-tu] violates IO-MAX^{C} which states that every consonant in the stem must be parsed in the output, a well-established constraint in Semitic morphology (McCarthy 1979, Yip 1988). Deletion also violates the bimoraic minimality requirement for Semitic stems, which has been argued for in McCarthy

[16] The full argument is provided in Gafos (in press). Note, also, that the argument in the text is not against edge-in association *in general*. Rather, this argument concerns the proper account of the specific pattern discussed here. A first typological assessment of geminates in templatic word-formation is under way in Gafos & Bazar (2001).

and Prince (1990a,b). Epenthesis as in [mall□-tu] violates IO-DEP^{V} and also the requirement of proper suffixation, since the epenthetic vowel is inserted in the seams between stem and affix (formally, this latter requirement can be expressed by an alignment constraint, as in McCarthy and Prince 1993). This latter constraint is also violated by the candidate which employs metathesis as in *[mall**i**-tu], with the lexical vowel surfacing between the geminate and the suffix. The form *[mall**i**-tu] also violates what McCarthy and Prince (1990b) argue to be a general canon for Arabic stems, namely, a constraint that all stems end in a consonant, known as Final Consonantality (see also McCarthy 1993, Gafos 1996, 1998, Rose 1997).

This completes the core analysis of doubled verbs in the perfect. To review, the doubled verb allomorphy between [mall] and [malil] is *phonologically-determined*, if we assume that the verbal stem is /mill/. In saying that an alternation is phonologically-determined, I mean that the alternation can be formulated explicitly in the form of a grammar, that is, a set of generally accepted constraints along with their language-particular prioritization. Indeed, as we have seen, the alternation between the two allomorphs can be expressed by the grammar SYLL, IO-IDENT^{Q} >> IO-INT >> OO-INT, TEMPL along with MAX^{PAV} >> MAX^{V}. These rankings express formally the phonotactic motivation for the alternation and the particular form that this alternation takes. Specifically, the phonotactic motivation is expressed by SYLL: the alternation of stem /mill/ in the context before a C-initial suffix, [malil-tu], takes place because Arabic does not permit clusters of a geminate followed by another consonant as in *[mall-tu] or *[mill-tu]. The particular form that this alternation takes is expressed formally by the sub-ranking IO-IDENT^{Q} >> IO-INT >> OO-INT, TEMPL (no geminate shortening, but geminate splitting).

3.2 Allomorphy in the imperfect

As with the perfect, in the imperfect, doubled verbs exhibit allomorphy between [ya-mudd-u], 3ms, indicative, and [ya-mdud-na], 3fp, indicative. The conditioning of the two allomorphs is identical to that of the perfect: the geminate allomorph occurs before vowels, the strong allomorph elsewhere. Given this, I will not give the entire paradigm for the doubled verb here. That paradigm was shown for a strong verb in (1, 2, 3), and the inflectional markers are the same for doubled verbs. A sample of imperfect forms is given in (26). If we assume that /mudd/ is the stem, the alternation follows the same phonotactic pattern as in the perfect. Specifically, when a V-initial suffix attaches to the stem /mudd/ the result is straightforward, [ya-mudd-u]. When a C-initial suffix attaches to the stem, /ya, mudd, na/, a violation of the constraint *VC$_x$C$_x$]$^{\sigma}$, disallowing geminates as syllable codas, would result. The same constraint is in effect for the case of null suffixes such as the 3ms, jussive /ya, mudd/. Thus, the phonotactic *VC$_x$C$_x$]$^{\sigma}$ enforces the alternation to the surface form [ya-mdud(-na)].

26.	*Perfect*	*Imperfect, Indicative*	*Imperfect, Jussive*
3ms	madd-a	ya-mudd-u	ya-mdud
3fp	madad-na	ya-mdud-na	ta-mudd-a

We now turn to the formal aspects of this analysis. In (27a), [ya-mudd-na] violates SYLL, our cover name for *COMPLEX and *VC$_x$C$_x$]$^{\sigma}$. In particular, *COMPLEX is violated in [(ya)-(mud)(d-na)] and *VC$_x$C$_x$]$^{\sigma}$ is violated in [(ya)-(mudd)-(na)]. Moreover, the stem cannot surface as in (27b), [ya-mud-na]. This candidate violates IO-IDENT^{Q}, requiring preservation of the skeletal structure of stem segments. The geminate in /mudd/ is linked to two C slots but its correspondent in [ya-mud-na] is linked to only one slot. The actual surface alternant is [ya-mdud-na], with the stem geminate separated, as in (27c). The alternation to [mdud] incurs a violation of IO-INT but avoids the violation of the higher ranked

constraints SYLL and IO-IDENT^{Q}. The tableau is the same in all relevant respects for a null suffix such as the 3ms, Jussive /ya, mudd/ → [ya-mdud].

27. Alternation before C-initial suffixes: /ya, mudd, na/ → [ya-mdud-na]

/ya, mudd, na/	SYLL	IO-IDENT^{Q}	IO-INT
a. ya-mudd-na	*!		
b. ya-mud-na		*!	
c. ☞ ya-mdud-na			*

Recall now that imperfect morphology is purely affixal, consisting of the addition of a prefix, suffix pair to the stem /mudd/. As discussed earlier, the assumption that geminates do not separate in word-formation does seem to be true for affixal word-formation. If the analysis above is correct, then it seems to illustrate a genuine case of a geminate integrity violation in /ya, mudd, na/ → [ya-mdud-na]. We seem to have reached a contradiction. However, the crucial point here is that in the case of Arabic we have a combination of templatic (perfect) and affixal (imperfect) morphology. As I turn to show now, under the presence of OO Faithfulness in the grammar, this combination of templatic and affixal morphology leads to the apparent violation of geminate integrity in the imperfect.

In the imperfect, before a consonant-initial suffix, the final geminate in /mudd/ must be avoided and it cannot be avoided by shortening that geminate due to IO-IDENT^{Q}. Therefore, some other form that resolves the phonotactic problem must be employed. Given the presence of OO-Faith in the grammar, the needed allomorph must resemble some surface variant of the same verb. In the templatic perfect, there exists a surface variant of the verb with the strong (triliteral) allomorph as in 1s [madad-tu], 2ms [madad-ta], 2fs [madad-ti] and so on. This alternant contains three separate consonants 'm-d-d' and is therefore phonotactically appropriate in the imperfect context before a consonant. It is this strong allomorph which is chosen in the imperfect context. It will be recalled that the difference in the vocalism between perfect [madad-tu] and imperfect [ya-mdud-u] is a matter of the constraints regulating these vocalic qualities in the distinct morphosyntantic contexts, and which override total identity between imperfect and perfect forms. Putting aside this difference in vocalism, however, imperfect [mdud] consists of the same three stem consonants as perfect [madad]. In sum, geminate separability is motivated in the templatic perfect, i.e. /madd/ → [madad]. This strong allomorph of the verbal stem in the perfect is transferred to the non-templatic imperfect through OO Faithfulness, applying across the perfect-imperfect contexts. Hence, the apparent violation of geminate integrity in the concatenative morphology of /ya, mudd, na/ → [ya-mdud-na].

The notion of OO-Faith across the perfect-imperfect contexts is different from the OO-Faith employed thus far. Specifically, so far we have employed an OO-Faith constraint whose domain of application is the set of forms specified for the features of [+perf] or [+impf]. This OO-Faith requires identity among all forms specified for the same morphosyntactic feature. This is different from the OO-Faith constraint between perfect and imperfect forms. We thus need to justify the assumption about the presence of a faithfulness relation between perfect and imperfect forms. By definition, correspondence relations hold between pairs of 'related forms'. The perfect and imperfect forms of a verb are forms of the same lexeme. It is by virtue of this fact that a correspondence relation must exist between perfect and imperfect forms. At a more intuitive level, the perfect-imperfect correspondence relation maintains paradigm coherence across the two distinct morphosyntactic contexts. Further consequences of this

correspondence relation are illustrated in section 4.

We must also specify the perfect-imperfect forms that stand in correspondence and are evaluated by attendant faithfulness constraints. One reasonable hypothesis is that the imperfect-perfect pairs are determined by the morphosyntactic features of person, number, and gender (henceforth, PNG). That is, for example, the 3ms perfect stem realization must be identical to the 3ms imperfect stem realization (see Gafos and Ralli, *in press*, for the proposal that OO identity in inflectional paradigms is projected on the basis of shared morphosyntactic features). However, as shown in (26), there are imperfect forms with the strong allomorph, such as the jussive 3ms [ya-mdud] or 3fs [ta-mdud], whose perfect counterparts (same PNG features) employ the geminate allomorph, e.g. 3ms [madd-a], 3fs [madd-at]. The existence of such pairs shows that imperfect forms may employ perfect allomorphs with which they do not necessarily share the same PNG features. Thus, for example, the imperfect 3ms jussive [ya-mdud] employs the strong allomorph of the perfect stem, [madad-], which does not appear in the 3ms perfect context. In that context, the perfect employs the geminate allomorph [madd-].

Definition (28) expresses formally the notion of faithfulness between the perfect and imperfect. Let FAITH be any faithfulness constraint, and let π^1, π^2 be two paradigms of some lexeme ℓ. We will say that π^1, π^2 satisfy FAITH, iff for each S_i in π^1 there exists some S_j in π^2 such that $S_i \mathfrak{R} S_j$ satisfies FAITH, and for each S_i in π^2 there exists some S_j in π^1 such that $S_i \mathfrak{R} S_j$ satisfies FAITH. All S_i, S_j refer to surface realizations of the stem of lexeme ℓ within the paradigms. As indicated by the conjunction, faithfulness constraints that hold over the perfect-imperfect correspondence relation require bidirectional identity: that is, each imperfect form must be identical to some perfect form, and vice versa (i.e., each perfect form must be identical to some imperfect form.) This bidirectionality is a consequence of our assumption (from section 2) that there is no derivational relation between the perfect and the imperfect forms of a lexeme.

28. Definition of FAITH(π^1, π^2)
$\forall S_i \in \pi^1, \exists S_j \in \pi^2$ s.t. $S_i \mathfrak{R} S_j$ satisfies constraint FAITH $\wedge$
$\forall S_i \in \pi^2, \exists S_j \in \pi^1$ s.t. $S_i \mathfrak{R} S_j$ satisfies constraint FAITH
(For every realization S_i of stem ς within paradigm π^1, there exists some realization S_j of ς within π^2, such that the correspondence relation $\mathfrak{R}$ between S_i, S_j satisfies FAITH; and vice versa.)

Let us illustrate the definition with the constraint INTEGRITY applying across π^1 = imperfect and π^2 = perfect. The two actual realization sets are the imperfect [mdud, mudd] and the perfect [madd, madad]. The correspondence relation between these two sets satisfies PI-INTEGRITY ('PI' for Perfect, Imperfect). For each S_i in the imperfect, there exists S_j in the perfect such that no segment of S_i has multiple correspondents in S_j (for imperfect [mdud], that perfect form is [madad]; for imperfect [mudd] it is [madd]); and for each S_i in the perfect, there exists S_j in the imperfect such that no segment of S_i has multiple correspondents in S_j (for perfect [madad], that imperfect form is [mdud]; for perfect [madd] it is [mudd]). Let us also see an example of two hypothetical realization sets that violate PI-INTEGRITY. Consider the pair perfect [mamad], imperfect [mmud] or [mud]. Here, all perfect realizations take the form [mamad] and all imperfect realizations take the form [mmud]/ [mud]. These realization sets illustrate an ideal situation with respect to uniformity *within* the perfect or the imperfect sets, since no allomorphy is observed set-internally. Across the two sets, however, PI-INTEGRITY is violated: the first segment of imperfect [mmud]/[mud] has two correspondent segments in perfect [mamad].

Before completing the analysis, we must also specify the relative ranking of the different OO Faith constraints involved. First, we consider PI-Faith. Since there is no allomorphy across the two distinct

sets of forms, there is no evidence for a specific ranking of PI-Faith with respect to the rest of the constraints. Any ranking of PI-Faith with respect to these constraints will give the same results. However, following McCarthy (1998) and Tesar & Smolensky (1998), I assume that PI Faithfulness is top-ranked in accordance with the initial state M, OO-F >> IO-F. Starting with this hierarchy, OO-Faithfulness constraints would be demoted only under the presence of positive evidence to that effect, one instance of which is illustrated immediately below for a different faithfulness constraint. In the case of PI-Faith, such positive evidence would consist of allomorphy across the perfect-imperfect sets of forms. Since such allomorphy is not found, the ranking M, PI-F >> IO-F persists as such in adult grammars.

Consider also the OO-Faith constraint applying within the imperfect set, that is, all forms specified for [+impf]. In this set, there is alternation between [ya-mudd-u] and [ya-mdud-na]. As discussed in detail in the previous section, this implies that OO-INT must be low ranked, specifically that SYLL >> IO-INT >> OO-INT. The only expected difference is that the perfect OO-INT enforces identity within the set of [+perf] forms.

To sum up, for the doubled verb allomorphy in the imperfect, the stem /mudd/ underlies the surface set [ya-mudd-u, ya-mdud-na]. The alternation between [mudd] and [mdud] is phonologically-determined as with the perfect. Specifically, the alternation is triggered by phonotactics, in the sense that the independently necessary syllabification canons of Arabic disallow the combination of a geminate-final stem with a consonant-initial or null suffix, *[mudd-na], *[mudd]. The choice of the allomorph [mdud] is determined by identity requirements in stem realization across the imperfect, perfect contexts.[17]

3.3 Interim predictions

We have by now a sufficiently developed hypothesis about doubled verbs which states that their allomorphy is determined by phonological principles, that is, principles characteristic of the phonology of the language as a whole. Consequently, as we turn to see now, that hypothesis makes predictions that go beyond the doubled verb data. These predictions provide a crucial test for the validity of our hypothesis.

We begin by pursuing some limitations on stem allomorphy predicted by the presence of the two key faithfulness constraints, IO-INT and IO-IDENT^{Q}, in our grammar. One such prediction concerns the fate of a hypothetical biliteral stem /C^{1}VC^2/. Such a stem cannot surface as [C^{1}VC^{2}VC^2], in analogy to the pattern of final identity in doubled verbs as in [madad]. This is so because IO-INT and IDENT^{Q} dominate TEMPL, and hence multiple correspondence cannot be employed in order to satisfy the perfect's /CVCVC/ template. This prediction is borne out as can be seen by considering a class of verbs that have only two consonants in the imperfect, in (29). The stems of these verbs are biliterals, attested as such in the imperfect context, e.g. [ya-Sil-u] 'he arrives'. In the perfect, such /CVC/ stems would fall short of the templatic requirement /CVCVC/. These stems apparently conform to the template by epenthesis of /w/, e.g. imperfect [ya-Sil-u], perfect [waSal-a] 'to arrive'.[18] In accordance with the

[17] The appendix extends the basic proposal to the so-called 'exceptional' Forms. In those Forms, the doubled verb alternation is not observed.

[18] See Chekayri and Scheer (1996, pp. 74-75) and Ratcliffe (1997, p. 157; 1998, p. 45) for similar proposal about these verbs. It should also be noted that an alternative view of the phonology of the epenthetic /w/ in the perfect is that it is the result of spreading from its tautosyllabic /a/. Since this proposal is consistent with the main claim being made here, namely, that the /w/ is epenthetic as opposed to lexical, I will not pursue it further.

prediction of our analysis, then, such stems do not extend to the template as in *[Salal-a] or *[SaSal-a].

29. Verbs 'rejecting /w/' in the imperfect (Wright 1896, pp. 78-79)

Imperfect	*Perfect*		*Imperfect*	*Perfect*	
ya-lid-u	walad-a	'bear children'	ya-riθ-u	wariθ-a	'to inherit'
ya-ʃid-u	waʃad-a	'promise'	ya-zar-u	wazar-a	'let alone'
ya-zin-u	wazan-a	'weigh'	ya-Daʃ-u	waDaʃ-a	'put'
ya-θiq-u	waθiq-a	'trust, confide'	ya-saʃ-u	wasaʃ-a	'be wide/spacious'
ya-rim-u	warim-a	'swell'	ya-qaʃ-u	waqaʃ-a	'fall'

The proposed view of these verbs diverges from past descriptions which take the perfect form, [waSal-a], as basic and posit a morphologically-conditioned process of /w/-deletion in the imperfect, [ya-Sil-u] (Wright 1896, p. 78, McCarthy and Prince 1990a, p. 255). However, this description and its concomitant /w/-deletion are an artifact of the conventional assumption that the basic verbal form is the citation form, that is, the perfect.[19] If we do not make this assumption, we can interpret the data in novel terms without the arbitrary /w/-deletion. This is the description that will guide the formal analysis of this data.

Before we get to that analysis, however, I consider converging evidence for the claim that the stems of these verbs do not contain /w/. This evidence derives from further facts related to the behavior of these verbs, and from facts of nominal and adjectival morphology. If, as claimed here, the /w/ in [waSal-a] is supplied to satisfy the perfect's template, rather than being a part of the lexical entry of the verb (deleted in [ya-Sil-u]), we expect to find non-alternating /w/-initial stems, that is, stems beginning with /w/ in both the perfect and the imperfect. These stems *would* have /w/ as part of the verbal stem. Examples are shown below. Whereas these are perfectly regular under our proposal, they must be stipulated as exceptions to the arbitrary process of /w/-deletion in the standard analysis (for 'be afraid', Wright also lists root |wjr|).

30. Invariantly /w/-initial stems (Wright 1896, pp. 78-79, Haywood & Nahmad, p. 219)

Imperfect	*Perfect*		*Imperfect*	*Perfect*	
ya-wjal-u	wajil-a	'be afraid'	ya-wjaʃ-u	wajiʃ-a	'be in pain'
ya-wHal-u	waHil-a	'stick in the mud'	ya-wDuw-u	waDuw-a	'be clean and fair'
ya-wbul-u	wabul-a	'be unwholesome'	ya-wadd-u	wadd-a	'love'

A second argument for the non-lexical status of /w/ in verbs that show the alternation between [ya-Sil-u], [waSal-a] derives from the fact that /w/-epenthesis is attested independently in the phonology of Arabic. In the nominal plural and diminutive, /w/ is employed systematically as the default consonant filling in onset positions in the iambic foot that is required at the left edge of the derived form; e.g. /xaatam/ 'signet-ring', plural [xa**w**aatim], diminutive [xu**w**aytim], /jaamuus/ 'buffalo', plural [ja**w**aamiis], diminutive [ju**w**aymiis] (hence the 'Consonantal Default Rule: 0 → /w/' in the classic analysis of these facts in McCarthy and Prince 1990a, pp. 247-9).

Epenthesis is also employed in adjectival morphology as the mechanism of extension in stems that

[19] "By the citation-form of a lexeme is meant the form of the lexeme that is conventionally employed to refer to it in standard dictionaries and grammars of the language" (from Aronoff 1994, citing Lyons 1977, p. 19).

fall short of minimality requirements. Consider in this respect the denominal adjective or *nisba* of an underived biliteral noun like /ʔab/ 'father' which takes the form [ʔaba**w**-iy] 'paternal'. McCarthy and Prince (1990a, p. 256) have argued convincingly that this /w/ is inserted to satisfy the requirement that the base of /-iy/ suffixation be minimally bimoraic. Derived nouns from the biliteral verbs in (29) show the same phenomenon. For example, the deverbal noun of [ya-ʕid-u], [waʕad-a] 'to promise' is built on the imperfect stem, hence [ʕid-at] 'promise'. Its denominal adjective is [ʕida**w**-iy] 'promissory', with the epenthetic /w/ appearing again before the suffixal boundary. Thus, whether extension of a stem is due to mapping to a template as in the verbal perfect or the nominal plural and diminutive, or due to satisfying a minimality requirement as in the denominal adjective, epenthesis of a default consonant is systematically employed to fill in syllabic positions required by the (template's) prosody.

I now return to the verbal facts in order to obtain a formally explicit statement of the descriptions up to now. This is a crucial goal, because this formal statement will enable us to test further the validity of the proposed verbal phonology, a major theme in section 4. Tableau (31) considers a representative set of candidate realizations for a biliteral stem like /Sal/ 'to arrive' in the perfect. Candidates (31a) *[Salal-a] and (31b) *[SaSal-a] are excluded due to their violation of IO-INT and the quantity preservation constraint IO-IDENT^{Q}. Comparing (31c) and (31d), we can infer the new ranking relation TEMPL >> IO-DEP^{C}, expressing the fact that the templatic requirement is satisfied by epenthesis. The situation is the same before consonant-initial suffixes, and will not be discussed here.

31. Epenthesis to satisfy template: /a^{PAV}, Sal, +a/ → [waSal-a] 'to arrive'; TEMPL >> IO-DEP^{C}

/a^{PAV}, Sal, +a/	IO-IDENT^{Q}	IO-INT	TEMPL	IO-DEP^{C}
a. Salal-a	*!	*!		
b. SaSal-a	*!	*!		
c. Sal-a			*	
d. ☞ waSal-a				*

We have thus seen that multiple correspondence is not an option in forming the perfect of biliterals verbs, /Sal/ → [waSal-], *[SaSal-]. Conversely, epenthesis is not an option for doubled verbs as (32) shows. The candidates with epenthesis in (32a,b) violate the high ranked constraints IO-IDENT^{Q}, SYLL. The constraint IO-DEP^{C} violated in (32a,b) is not shown; it is irrelevant in this context because it is ranked below IO-INT, the constraint violated in the actual output. Candidate (32c), [malil-tu], avoids the violation of the violation of SYLL and IO-IDENT^{Q} by maintaining the quantity of the stem geminate. Alternative candidates such as [mall-tu], [mal-tu] are excluded because they violate SYLL, IO-IDENT^{Q}, respectively; and [mamil-tu] is excluded due to its IO-IDENT^{Q} violation.

32. Integrity violation, rather than epenthesis, before C-initial suffixes:/a^{PAV}, mill, +tu/ → [malil-tu]

/a^{PAV}, mill, +tu/	IO-IDENT^{Q}	SYLL	IO-INT	TEMPL
a. wamil-tu	*!			
b. wamill-tu		*!		*
c. ☞ malil-tu			*	

I summarize the overall picture from (31) and (32) in (33) to emphasize the fact that lexically-specified consonantal length in verbal stems has a differential effect on the form of the derived perfect. Specifically, in doubled verbs, the templatic constraint (of the perfect) is satisfied via multiple correspondence, /madd/ → [madad-tu], but in biliteral verbs the template is satisfied via epenthesis, /Sal/ → [waSal-tu], not *[SaSal-tu] or *[Salal-tu]. I refer to this observation about the potential of geminates but not single consonants in establishing multiple correspondence as the *length-distinction effect*.

33. Length-distinction effect (LDE) in templatic morphology
    - Stems with single consonants extend via epenthesis, /Sal/ → [waSal-], *[Salal-]
    - Stems with geminate consonants extend via multiple correspondence, /madd/ → [madad-]

The crucial fact here is that the same effect is also observed in the nominal morphology of the language. In an extensive study of plural formation, Ratcliffe (1998) observes that in Arabic "there is a clear distinction between true biconsonantal stems ... and geminate stems which are phonologically triconsonantal forms" (p. 232). Biconsonantal noun stems with a geminate show extension by splitting of the geminate in the plural. Biconsonantals noun stems without a geminate show extension by an epenthetic consonant. In (34), compare [ħam-un] vs. [liss-un], and [dam-un] vs. [samm-un].[20]

34. *Singular*	*Plural*		*Singular*	*Plural*	
ħam-un	ʔa-ħmaaʔ-un	'father in law'	dam-un	dimaaʔ-un	'blood'
liSS-un	ʔa-lSaaS-un	'thief'	samm-un	sumuum-un, simaam-un	'poison'

The LDE is not a peculiarity of this small set of biconsonantal noun stems. The same effect has been observed with nouns that contain more than two consonants (Hammond 1988, McCarthy and Prince 1990a). Thus, in the broken plural and diminutive, an epenthetic consonant appears in the /CvCvv/ (plural) or /CvCay/ (diminutive) part of the output as in (35a,b,c), except when the base contains a geminate in which case template satisfaction is by multiple correspondence between the base geminate and two non-contiguous consonants in the derived forms, as in (35d,e,f). The fact that gemination, a surface property of the singular noun (rather than the root), systematically conditions the form of the corresponding plural has served as an argument for a stem-based rather than root-based morphology in the noun (McCarthy and Prince 1990a, pp. 218, 248).

35.	Singular	Plural	Diminutive
a.	jaamuus	ja**w**aamiis	ju**w**aymiis
b.	faakih-at	fa**w**aakih	fa**w**aykih

[20] Note that the epenthetic (final) consonant in the plurals [dimaaʔ-un], [ʔa-ħmaaʔ-un] is not /w/ but /ʔ/. In McCarthy and Prince's (1990a) analysis, this /ʔ/ is assumed to be a phonologically conditioned variant of /w/ after /aa/ and before /u/ (see pp. 255, 247, 249, 255). In a more extensive survey of the plural in various Semitic languages, Ratcliffe (1998) reports that this consonant can be any of /w, ʔ, y, h/ or a consonant that is usually part of an affix such as /t/ and rarely /m, n/ (pp. 81, 91, 93). It seems safe to conclude that the factors determining the identity of this consonant have not been studied in any detail. Nevertheless, the length-distinction effect stands out as a clear generalization.

c. xaatam	xa**w**aatim	xu**w**aytim
d. kuttaab	ka**t**aa**t**iib	ku**t**ay**t**iib
e. nuwwaar	nu**w**aa**w**iir	nu**w**ay**w**iir
f. tinniin	ta**n**aa**n**iin	tu**n**ay**n**iin

The LDE is observed in other languages as well. For present purposes, the two representative cases below will suffice. The first case in (36a) comes from the professional noun of Moroccan Colloquial Arabic. The template for the derived noun is /CCaCC-i/. The examples illustrate the relevant contrast between geminate triliterals like /s^{w}kkaR/ 'sugar' and simple triliterals like /skər/ 'get drunk'.The former extend on the template by consonant repetition, whereas the later employ glide epenthesis. The same generalization is illustrated in (36b) with data from the Imdlawn dialect of Tashlhiyt Berber (ITB).[21]

36. The LDE in two other languages

a. MCA, Professional noun (Heath 1987, p. 140)

s^{w}kkaR 'sugar'	→	skakR-i	Sbbən 'wash clothes'	→	Sbabn-i
skər 'get drunk'	→	skayr-i	nšəT 'be lively'	→	nšayT-i

b. Imdlawn Tashlhiyt Berber, "ABNAKLIY" template (Dell and Elmedlaoui 1992, pp. 108-9)

a-zrg '(mill)stone mender'	→	a-zrayg-iy	i-fsk 'medicinal plants'	→	a-fsayk-iy
l-brrad 'teapot'	→	a-brard-iy	a-qššb 'smock'	→	a-qšašb-iy

To review, we have seen that a phonologically-determined analysis of the doubled verb alternation is possible if one assumes that gemination can be a lexically-specified property of verbal stems, /madd/ versus /Sal/. As we see now, these stems pattern just like other stems in the templatic morphology of Arabic and other languages: the stems with geminate consonants consistently expand by multiple correspondence, whereas the stems with single consonants expand by epenthesis. The crucial point here is that verbal and nominal morphology show striking similarities in the phonological patterns of word-formation. These similarities would have to be treated as accidental if one were to take at face value the long-standing dichotomy in Arabic between root-based versus stem-based morphology along the verbal versus nominal divide.

It is appropriate at this point to compare the proposed view of the doubled verb alternation with its precursor. In taking /madd/ to be the basic form of doubled verbs, the present view departs from a long-standing tradition of treating [madd] as derived from an allegedly canonical /madad/ (Wright 1896, Cantineau 1946, Brame 1970, McCarthy 1979, Farley 1987, Ratcliffe 1998, Moore 1990). This traditional view necessitates an analysis where the basic form /madad/ is converted to the other allomorph before a vowel-initial suffix via a process of syncope as in /madad+V/ → [maddV], and in some cases metathesis as in /ya+mdud+V/ → [yamuddV]. As McCarthy (1986, pp. 247-8) notes, however, this analysis treats the alternation as 'morpholexical' in character. There does not seem to be

[21] Detailed discussion of these and other examples of the LDE from Berber, Syrian Arabic, Nigerian Arabic, and Moroccan Arabic is pursued in Gafos and Bazar (2001).

any reason why /madad/ should reduce to [madd] or why /ya-mdud-/ should reduce to [ya-mudd-]. If this alternation was phonological, we would expect it apply to triliterals as well so that /katab-/ would alter to [katb-] and /ya-ktub/ would alter to [ya-kutb-] before a vowel. We thus see that the doubled verb alternation, as formulated in the syncope / metathesis rule, is portrayed as arbitrary in the sense that there is no phonological motivation for the particular form that this alternation takes.[22] In principle, there is nothing wrong with true morpholexical alternations. It is a basic fact about morphology that languages may employ allomorphs whose phonological relation is arbitrary (see Carstairs 1998, 1990). However, as I have argued, the doubled verb allomorphy *is* phonological nature. But to see this, we must abandon the long-standing assumption of treating /madad/ as the 'canonical' form of doubled verbs (because of its resembling the triliteral verb).

In short, doubled verbs have their own stems with lexically-specified final gemination. This, in turn, raises the question: if gemination can be a lexically-specified property of stems, why are stems with *initial* gemination, e.g. /ssam/, absent from the Arabic lexicon? This is one of the topics addressed in section 4.

3.4 Optimality of the geminate stem

The question addressed in this section is how does the learner of the language converge to the geminate allomorph /mudd/ as the stem underlying the alternation [mudd, mdud].

We can sharpen the question at hand by making explicit the assumptions that have informally guided the analysis up to now. Following standard practice in generative grammar, we have *assumed* that the surface forms [mudd, mdud] of a doubled verb derive from a unique underlying stem. The surface realization of that hypothesized stem is a function of the grammatical context, usually what follows or precedes the stem in the intended utterance. The goal is to discover the degree to which the various realizations of the hypothesized stem are determined by generally accepted laws in a theory of language. In our case, we have seen that, if we assume that the stem is /mudd/, then the realization set [mudd, mdud] can be accounted for by the grammar with the subranking SYLL >> IO-INT >> OO-INT in its core (which highlights the phonotactic motivation for the alternation, SYLL, and the form that the alternation takes, SYLL >> IO-INT). Given the surface data [mudd, mdud], however, another plausible underlying stem would be /mdud/, a form which is phonetically identical to the second surface variant. Yet another option is to interpret the final consonantism of [mudd] not as a geminate but as two abutting consonants. This leads to another hypothetical stem /mud^{1}d^{2}/. This section shows that these alternative stems cannot underlie the surface set [mudd, mdud]. In fact, we show that there exists no stem that can derive the realization forms of the doubled verb better than the stem /mudd/.

Consider first the hypothesis that /md^{1}ud^{2}/ underlies the set [ya-mudd-u, ya-mdud-na]. This is to say that input /md^{1}ud^{2}/ is realized as [ya-mud^{1}d^{2}-u] before a vowel and as [ya-md^{1}ud^{2}-na] before a consonant. In [ya-mud^{1}d^{2}-u], the two separate /d/s of the hypothetical stem /md^{1}ud^{2}/ are adjacent. This

[22] In an analysis of the doubled verb allomorphy, Rose (2000) views syncope (in /madad-a/ → [madd-a]) as driven by phonotactic pressures, proposing that [madad-a] violates a long-distance re-formulation of the OCP which disallows identical consonants across a vowel (see Hudson 1986 for a precursor). The crucial difference between the present analysis and that in Rose (2000) is that the latter analysis shares with all past accounts the assumption that /madad-/ is the 'canonical' form. This assumption forces one to treat the length-distinction effect (this section) and Greenberg's asymmetry (section 4), as orthogonal to the issue of the doubled verb alternation (in fact, given that assumption, it is not possible to even state the length-distinction effect). However, as I argue in this paper, these generalizations are intimately related to the doubled verb alternation: the same grammatical principles that underlie the doubled verb alternation also derive the length-distinction effect and Greenberg's asymmetry. As far as I know, no analysis has established these connections before.

is a violation of the Obligatory Contour Principle (Leben 1973, Goldsmith 1976, McCarthy 1979, 1986), defined in (37). In OT, the Obligatory Contour Principle has the status of a constraint which applies on surface representation just like any other markedness constraint (see Myers 1997).

37. OCP: Adjacent identical elements are prohibited (here, 'elements' stands for segments)

Moreover, in the mapping /md^{1}ud^2/ → [ya-mud^{1}d^2-u, ya-md^{1}ud^2-na], the LINEARITY constraints are also violated. OO-LIN is violated because of the disparity in the linear order between the two surface forms and IO-LIN is violated in /md^{1}ud^2/ → [ya-mud^{1}d^2-u]. These violations are shown in (38a) below. In this tableau, OCP is shown to dominate IO-LIN. This ranking is not crucial for our purposes, as I argue below. The specific ranking shown is assumed because it is consistent with independent work from the acquisition literature which converges on the conclusion that markedness constraints dominate IO-faithfulness constraints in the initial state of the grammar (Smolensky 1996, Tesar and Smolensky 1998). In Arabic, given that the surface facts present no instances of two adjacent, identical consonants (a violation of the OCP), it follows that the ranking relation OCP >> IO-LIN persists into adult grammars. The other ranking OO-LIN >> IO-LIN was inferred in §2.

38. Fate of stem /md^{1}ud^2/

/md^{1}ud^2/	OCP	OO-LIN	IO-LIN
a. ya-mud^{1}d^2-u, ya-md^{1}ud^2-na	*	*	*
b. ☞ ya-md^{1}ud^2-u, ya-md^{1}ud^2-na			

Another possible realization of stem /md^{1}ud^2/ that is phonetically identical to [ya-mudd-u] is via fusion of the two input /d/ consonants to a geminate [dd]. This realization would incur a violation of some constraint against fusion (McCarthy and Prince 1995b, Lamontagne and Rice 1995). Once again, the point is that /md^{1}ud^2/ → [ya-mudd-u, ya-mdud-na] violates *some* constraint. This suffices to show that /md^{1}ud^2/ cannot underlie the surface set [ya-mudd-u, ya-mdud-na], because the mapping /md^{1}ud^2/ → [ya-md^{1}ud^2-u, ya-md^{1}ud^2-na] does not violate *any* constraint. The best realization of /md^{1}ud^2/ is (38b), where no constraint violations are involved. In fact, this result holds true independent of the ranking of the constraints, that is, independent of the grammar G. In other words, under any ranking of the constraints, [ya-md^{1}ud^2-u, ya-md^{1}ud^2-na] is the most harmonic realization of stem /md^{1}ud^2/, since it incurs no constraint violations. It thus follows that stem /md^{1}ud^2/ cannot underlie the surface forms [ya-mdud-na, ya-mudd-u].

The learner would be faced with a choice between the stems /mudd/ and /mdud/, if both could underlie the observed surface forms. A concrete example of this situation was the case of /kutb/ and /ktub/, both mapping to the surface form [ktub]. However, in the present case, our hypothetical stem /md^{1}ud^2/ gives rise to the set [ya-md^{1}ud^2-u, ya-md^{1}ud^2-na], a different set from [ya-mudd-u, ya-mdud-na]. Consequently, the set of possible stems that can derive the surface set [ya-mudd-u, ya-mdud-na] does not include /md^{1}ud^2/. This conclusion confirms the earlier point that if /md^{1}ud^2/ is the basic form from which [mudd] is to be derived, then the doubled verb facts cannot be accounted for in phonological terms. As noted in the previous section, a morpho-lexical rule must be set up to change /md^{1}ud^2/ to [mudd].

It is important to observe that the analysis above does not show that /md^{1}ud^2/ is an impossible stem. It only shows that if such a stem is 'fed' to the grammar, it would surface as [md^{1}ud^2] in all

contexts. Just like a triliteral stem, the surface realization of /md^{1}ud^2/ would show no alternation. This is another testable prediction of our analysis that is borne out. Wright (1896)'s grammar lists more than a dozen verbs showing precisely this invariable shape. Hence we find, in their perfect forms, [šarur-a] 'he was bad' but not *[šarr-a], [damum-a] 'he was ugly' but not *[damm-a], [laHiH-a] 'he was sore (of the eye)' but not *[laHH-a], [Sakik-a] 'he was knock-kneed (or weak in the hocks)' but not *[Sakk-a], [fakuk-a] 'he was silly' but not *[fakk-a], [labub-a] 'to be wise or intelligent' but not *[labb-a], [qaTaT-a] 'he was curly' but not *[qaTT-a], [ʕazuz-a] 'he had narrow orifices of the teats' but not *[ʕazz-a], and [Dabib-a] 'he abounded in lizards' but not *[Dabb-a] (Wright 1896, p. 69). These verbs do not undergo the alternation seen in doubled verbs. Consequently, they have to be treated as exceptions in all previous accounts known to me (cf. O'Leary 1969, p. 264, who calls them 'regular' precisely because they behave like the strong verbs in not showing the alternation). The absence of alternation for these verbs is readily explained by proposing that their stems are /šrur/ for [šarur-a] 'to be bad', /dmum/ for [damum-a] 'to be ugly', and so on. These stems differ crucially from the geminate-final stems of doubled verbs, /madd/. Thus, the phonotactic pressures for alternation do not apply to stems like /šrur/, just as they do not apply to strong stems like /ktab/.[23]

Consider now another potential stem for the doubled verbs, namely, the form /mud^{1}d^2/ with two abutting, identical consonants. Can this stem give rise to the surface set [ya-mudd-u, ya-mdud-na]? If these surface forms are realizations of /mud^{1}d^2/, then as shown in (39a) the following constraints are violated: OCP due to [ya-mud^{1}d^2-u], OO-LIN due to the disparity in the linear order of stem segments between [ya-mud^{1}d^2-u, ya-md^{1}ud^2-na], and IO-LIN due to the disparity between /mud^{1}d^2/ and [ya-md^{1}ud^2-na]. Avoiding the violations of OO-LIN and IO-LIN, as in (39b), incurs an additional violation of the OCP and a SYLL violation because of the geminate coda. The predicted optimal realization of /mud^{1}d^2/ is shown in (39c).

39. Fate of stem /mud^{1}d^2/

/mud^{1}d^2/		OCP	SYLL	OO-LIN	IO-LIN
a.	ya-mud^{1}d^2-u, ya-md^{1}ud^2-na	*		*	*
b.	ya-mud^{1}d^2-u, ya-mud^{1}d^2-na	**	*		
c. ☞	ya-md^{1}ud^2-u, ya-md^{1}ud^2-na				**

Hence, /mud^{1}d^2/ does not underlie the set [ya-mudd-u, ya-mdud-na]. Rather, stem /mud^{1}d^2/ underlies the set [ya-mdud-u, ya-mdud-na], just like the previous stem /md^{1}ud^2/. Following §2, one can

[23] Note that we do not explain the relative rarity of stems like /Skak/ in Arabic as compared to doubled verb stems. The job of a grammar and also the goal of this paper is to define a mapping between inputs and their various realizations in different contexts of occurrence. This is a different goal from that of accounting for the (in)frequency of particular stem forms. See the discussion of section 4.4 for some work that may be relevant to this point. Having clarified this, I note that in modern Arabic dialects and other branches of Semitic stems with two final, identical consonants abound. See Heath (1987) on Moroccan Arabic, Borg (1985) on Cypriot Arabic, and Bat-El (1989) on Hebrew. Moreover, at least for Arabic dialects, two identical consonants in underived verbal and nominal stems like /Skik/ behave as two independent consonants for all purposes (see Heath 1987, pp. 7, 231-4).

proceed to show that /mud^{1}d^2/ is less harmonic than /md^{1}ud^2/, and is therefore effectively banned from the inventory of possible stems. The situation is fully parallel to that of stem /kutb/ in relation to /ktub/ and will not be discussed further.

There exists one difference between stem /md^{1}ud^2/ and /mud^{1}d^2/ which should be addressed before the issue is settled. For /md^{1}ud^2/, its optimal realization is [ya-mdud-u, ya-mdud-na] under any ranking of the constraints (see 38b). But for /mud^{1}d^2/, the same realization in (39c) is optimal only under a particular (partial) ranking of the constraints. If the ranking was instead IO-LIN >> OCP, OO-LIN then (39a) would be optimal, and /mud^{1}d^2/ would be a true rival to /mudd/ since both stems would give rise to [ya-mudd-u, ya-mdud-na]. However, the prerequisite ranking relations cannot be true for the language at hand. The strong verbs facts in §2 independently argue for the crucial ranking OO-LIN >> IO-LIN, which suffices to establish the suboptimality of (39a). Furthemore, as discussed above, there is independent evidence for the ranking OCP >> IO-LIN.

To sum up, doubled verbs show two allomorphs [mudd, mdud]. We have seen that hypothetical stems /md^{1}ud^2/ or /mud^{1}d^2/ cannot underlie the realizational forms of doubled verbs. This result can now be generalized by showing that the stem /mudd/ supplies the optimal mapping to the realization set [mudd, mdud]. That is, the goal is to show that there exists no ς' ≠ /mudd/ such that ς' → [mudd, mdud] is more harmonic than /mudd/ → [mudd, mdud]. To see this, let us assume the contrary to our hypothesis. Any such ς' must either incur a subset of the violations incurred by /mudd/ → [mudd, mdud], or it must incur violations of some other constraint(s) lower-ranked than the highest ranked constraint violated in /mudd/ → [mudd, mdud], that is, IO-INT. In /mudd/ → [mudd, mdud], there is a violation of IO-INT, due to /mudd/ → [mdud], and OO-INT, due to allomorphy. The violation of IO-INT could be avoided by a stem like /mdud/, with two separate, identical consonants. But then, as shown above, the realization set would consist of just [mdud]; no alternation. Similarly, avoiding the OO-INT violation also implies no alternation, by definition of OO-INT. We see then that contrary to our assumption, the hypothesized ς' cannot underlie the realizational forms [mudd, mdud]. It follows that there exist no such ς' ≠ /mudd/, with ς' → [mudd, mdud] more harmonic than /mudd/ → [mudd, mdud].

Finally, we must consider yet another alternative analysis of the facts. Suppose that for each verb showing the [mudd, mdud] alternation, we list two stem allomorphs {/mudd/, /mdud/}. The choice of each allomorph would be conditioned phonologically, the geminate allomorph appearing before vowels and the strong allomorph before consonants.[24] If unpredictability or arbitrariness is the defining property of listed allomorphs, then listing two allomorphs for every doubled verb cannot be right. The substance of the alternation is precisely the same across different lexemes: in all cases, [madd] ~ [madad], [samm] ~ [samam], [mall] ~ [malil] and so on, there is a relation between a form with a geminate and another form with the two 'halves' of the geminate separated. Moreover, this relation pervades the morphological system of the language. It is seen in the nominal morphology of plurals and diminutives and, as I show in the next section, in other Forms of the Arabic verb (IX, XI, QIV). This recurrence of the same pattern, under exactly the same conditions, is the hallmark of a systematic relation between the two forms. It also falsifies the listing hypothesis which admits no systematicity. Moreover, as we have seen, the systematic relation between the two allomorphs can be captured only if the language learner posits /mudd/ as the underlying form. The other form, /mdud/, cannot underlie the observed surface realizations of the doubled verb.

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[24] For a recent analysis of some stem alternations in these terms in Polish see Rubach and Booij (2001), and for a recent proposal on the phonological conditioning of listed allomorphs see Kager, to appear.

3.5 Stems in other Forms

The pattern of final repetition seen in the [madad] alternant of the doubled verb is found not only in Form I verbs but also in verbs of Form IX ktabab, Form XI ktaabab, and also those of the quadriconsonantal Form QIV FξaʕalaI. The proposed analysis of final repetition readily extends to the verbs of these other Forms as well. In what follows, I focus on Form IX which is representative of the other two Forms.

Traditionally grammars identify Form IX with the pattern ktabab (Wright 1896, p. 43). All subsequent work in the generative tradition known to me has assumed that ktabab is the canonical form of a verb in IX (McCarthy 1981 *et seq*). However, actual stems in IX surface as ktabab only before consonant-initial suffixes for familiar reasons by now. As shown in (40), verbs in Form IX derive from corresponding adjectives of color and bodily defect by gemination of the final consonant.[25] Formally, the verbal stem is derived by the addition of a suffixal mora to the adjectival stem: /Sfar-/$^{\text{Adj-stem}}$ + μ → /Sfarr-/$^{\text{Verb-stem}}$. Once the verbal stem is placed in the context of its inflectional paradigm, it is clear that what is involved in the allomorphy between [ʔi-Sfarr-a] and [ʔi-Sfarar-tu] 'he/I became yellow' is the familiar by now phonologically-determined alternation.

40. Adjectives			Derived verb in Form IX (perfect)		
ʔa-ħmar-u	'red'	→	ʔi-ħmarr-a	ʔi-ħmarar-tu	'he/I blushed'
ʔa-Sfar-u	'yellow'	→	ʔi-Sfarr-a	ʔi-Sfarar-tu	'he/I became yellow'
ʔa-qbal-u	'cross-eyed'	→	ʔi-qball-a	ʔi-qbalal-tu	'he/I became cross-eyed'
Cf. Verbs			Form I (perfect)		
/radd/	'to return'	→	radd-a	radad-tu	'he/I returned'

The same alternation applies to quadriliteral verbs in Form QIV, [ʔi-šmaʕall-a] 'he hastened', [ʔi-šmaʕlal-tu] 'I hastened' and [ʔi-TmaʔannI-a] 'he was tranquil', [ʔi-TmaʔnanI-tu] 'I was tranquil'. These examples are all perfect forms. In the imperfect, we find the same alternation, e.g. [ya-Tmaʔinn-u] and [ya-TmaʔnIn-na] 'he/they (f) are tranquil' (Schramm 1962, p. 362). The conditions for the alternation and the form that this alternation takes are identical throughout.

We see, then, that the allegedly canonical form of verbs in IX, ktabab is a phonologically-determined surface variant of a stem with a final geminate. Traditionally, Semitic grammars enumerate verbal forms in terms of 'canonical' patterns so that, for example, [madad] and [ħmarar] are described as manifesting the orthodox realization of their respective Forms I and IX (with provisos for the non-orthodox realizations [madd], [ħmarr]). Generative phonology has inherited this preoccupation with canonical patterns from descriptive grammars. But as I have emphasized throughout, shifting some of the focus from the allegedly 'canonical' patterns to actual stems makes it possible to recognize genuine phonology applying across the different Forms of the Arabic verb (see also Cowell 1962, pp. 41, 47-8, for concerns with this preoccupation with patterns).

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[25] For an illustration of exactly this morphology in a modern dialect, consider the following examples of Form IX verbs from Syrian Arabic (dialect of Damascus, Cowell 1962): /ʔaHmar/ 'red' → [Hmarr] 'to become red, to blush', /ʔaSfar/ 'yellow' → [Sfarr] 'to become yellow, turn pale', /ʔaswad/ 'black' → [swadd] 'to become black', and so on (Cowell 1962, pp. 250, 294). The derived verbal form is realized in the context of the (im)perfect paradigm, e.g. [Hmarr] 'to blush.Perfect.3ms', [byə-Hmarr] 'to blush.Imperfect.Indicative.3ms', [byə-Hmarr-u] 'to blush.Imperfect.Indicative.3p' (for the full paradigm see Cowell 1962, p. 101).

Moreover, as a consequence of the proposal that the observed alternations across different Forms are phonologically-determined, there is no need for setting up parameters dedicated to individual Forms. I illustrate this by underscoring an important difference between the present analysis and past analyses which assume left-to-right spreading in deriving the duplication pattern of [madad] in doubled verbs of Form I or Form IX (McCarthy 1981). In the present analysis, the left-to-right spreading in doubled verbs of Form I and verbs in Form IX is *epiphenomenal*. The left-to-right setting of the directionality parameter was meant to capture the pattern of final, not initial, repetition in Form I [madad-], not *[mamad-], and in Form IX [Sfarar-], not *[SSafar-]. In our analysis, there is no parameter dedicated to this aspect of the verbal morphology. Rather, final repetition derives from the fact that the verbal stems are geminate-final, and the fact that some suffixes are consonant-initial. In short, the present analysis derives the effect of the directionality parameter.

The same improvement is seen when we compare the present approach to the analysis in Gafos (1996, 1998a). For doubled verbs, Gafos (1996, 1998) argues that the duplication of the consonant /d/ in the form [madad] is effected by segmental copy (as in reduplication) rather than by spreading. In that analysis too, the reduplicant inducing copying of the final root consonant must be a suffix. No such assumption is necessary once we carefully consider the interaction between stem and inflectional context. Moreover, the assumption of reduplicative morphology is also unnecessary in deriving [madad]. The form [madad] is a surface variant of stem /madd/ in the context before a consonant-initial or null suffix. The crucial point is that the relation between the two forms, /madd/ and [madad], is phonological in nature; no reduplicative affix is involved.

4. Greenberg's asymmetry

Section 3 formulated a hypothesis about the phonology of the verb in Arabic, and presented some evidence that this hypothesis makes correct predictions beyond the data set it was originally devised for. In this section, I test further the validity of that hypothesis by exploring the potential of its underlying grammatical principles in deriving a fundamental asymmetry of the Arabic lexicon. Recall that doubled verbs surface in two forms [mVdd, m(a)dVd]. The first variant has a *final* geminate, and the second has a *final* sequence of two identical consonants separated by a vowel. In Arabic, there are no verbal forms with *initial* gemination, *[mmVd], or with an *initial* sequence of two identical consonants, *[mamVd] (Greenberg 1950). I refer to these facts as Greenberg's asymmetry. Though the facts were well-known to Arab grammarians (see Cantineau 1946 for discussion), Greenberg's study was the first systematic investigation of these asymmetries in the Semitic lexicon. In modern phonology, this celebrated property of the Semitic lexicon has been accounted for by making reference to Morpheme Structure Constraints on inputs as in the well-known analysis of *[mamVd] in McCarthy (1979). This section shows that these lexical asymmetries are lawful consequences of the inflectional context in the verbal paradigm, the presence of intra-paradigmatic identity constraints, and the independently necessary phonotactics of the language. Specifically, the next two subsections demonstrate that stems with initial gemination (§4.1) and stems with initial repetition (§4.2) are impossible stems in the sense of the term introduced in section 2.

4.1 Impossibility of initial gemination

There exists no stem with an initial geminate in Arabic. In the core of all past accounts for the absence of such stems is an axiom about the admissible inputs to the lexicon: root consonants are devoid of any prosodic properties such as length. It is apparently assumed that *all* instances of such properties are to be derived as a byproduct of mapping to template and associated morpho-phonological processes as in

the syncope rule in /mdVd-a/ → [mVdd-a] discussed earlier. In particular, /mmVd/ stems would be impossible because, by assumption, gemination is ostracized from the lexicon. As we now turn to see, no assumption to that effect is necessary, because the absence of stems with initial gemination is derivable by the independently necessary phonotactics of the language, the phonological context created by the inflectional affixes, and identity requirements in stem realization across the perfect-imperfect context.

Crucial to the absence of /mmVd/ stems is the fact that the verbal paradigm of the perfect is prefixless. More accurately, the perfect paradigm does not have prefixes that end in vowels. Lack of such prefixes would expose the initial geminate of a hypothetical stem /mmVd/ to word-initial position. In Arabic, as in other languages with long consonants like Italian or Japanese, length is neutralized at the edges of words (Ladefoged and Maddieson 1996, p. 92). We assume that this is due to a markedness constraint which disallows geminates in edge positions, *EDGE-GEM "Edge geminates are not allowed." Hence, were /mmVd/ to surface as [mmad] in the perfect, it would result in a violation of *EDGE-GEM.

Given this phonotactic problem, various alternative realizations of the stem /mmVd/ are imaginable. For example, the stem could surface by loss of gemination as in [mad] or by loss of gemination plus epenthesis as in [wamad], with the latter choice improving over [mad] by satisfying the templatic /CVCVC/ requirement of the perfect. Yet another option is to split the geminate as in [mamad]. Recall, however, that the stem /mmVd/ must also be realized in the context of the imperfect paradigm. Faithfulness between the realization of the stem in the different morphosyntactic contexts, the perfect and the imperfect, imposes limits on how different these realizations can be. In fact, assuming the default ranking M, OO-F >> IO-F, from the initial state, the high-ranked status of OO-F demands that the effects of the local pressure against the initial geminate in the perfect must be transmitted to the rest of the forms in the imperfect paradigm. We may therefore begin to see why geminate-initial stems cannot surface as such in Arabic. Local pressures within the perfect paradigm ban initial geminates. OO-Faithfulness imposes this ban to the rest of the verbal forms.

I now turn to the formal demonstration of this logic. Tableaux (41), (42) consider various possible realizations of a hypothetical stem /mmVd/ in the perfect, imperfect contexts. The top row of (41) underscores the global form of the constraint hierarchy: M, OO-F >> IO-F^{+}, where M stands for the markedness constraint against initial geminates, and OO-F stands for the faithfulness constraints holding between the perfect and the imperfect, here PI-IDENT^{Q} and PI-INT. The markedness constraint along with output-output faithfulness constraints, here PI-F, dominate IO-F constraints. The '$^{+}$' in IO-F^{+} is a mnemonic for the fact that the IO-F sub-hierarchy also includes the constraint TEMPL, which is not of the IO-F type but is ranked between two IO-F constraints as demonstrated earlier. In (41), we explore various candidates with PI-F violations. In (42), comparison will narrow down to the two crucial candidates which evade violations of PI-F.

Let us consider each tableau in turn. The general point illustrated in (41) is that any attempt to maintain the stem-initial gemination is bound to M or PI-F violations. Specifically, (41a) illustrates the case of fully faithful realization of the stem in both the perfect and the imperfect contexts. Consequently, in the perfect, the geminate-initial form incurs a fatal violation of *EDGE-GEM. Candidate (41b) exemplifies the case where the perfect realization of /mmVd/ is [mad-], with loss of initial gemination. Recall that the imperfect context supplies a set of (consistently) vowel-final prefixes. Hence, stem /mmVd/ could in principle surface as [ya-mmVd-u] in the imperfect as the vowel-final prefix would protect the geminate from exposure to word-initial position. The resulting set would then be [mVd-u, ya-mmVd-na], a non-uniform set with respect to consonantal gemination. This violates PI-IDENT^{Q}, the OO faithfulness constraint requiring identity of consonantal quantity between correspondent

consonants in the perfect and the imperfect. PI-IDENT^{Q} disallows length alternations between the perfect and imperfect stem. In effect, PI-IDENT^{Q} suppresses the length contrast also in the context where the constraint against edge geminates is not in effect, that is in the imperfect paradigm. Throughout (41) PI-F, IO-F^{+} violations are indicated by the usual '*" followed by the constraint being violated. I have also shaded the IO-F^{+} block since these lower ranked constraints are not relevant to the present discussion.

41. Fate of geminate-initial stems ('PI-F': faithfulness across the perfect-imperfect context)

	M	PI-F	IO-F^{+}
/mmvd/	*E-GEM	PI-IDENT^{Q} PI-INT	IO-IDENT^{Q} >> IO-INT >> TEMP >> IO-DEP^{C}
a. mmad-a ya-mmvd-u	*		* TEMP
b. mad-a ya-mmvd-u		* PI-IDENT^{Q}	* IO-IDENT^{Q} * TEMP
c. mamad-a ya-mmvd-u		* PI-INT	* IO-INT
d. wamad-a ya-mmvd-u		* PI-IDENT^{Q}	* IO-IDENT^{Q} * IO-DEP^{C}
e. mamad-a ya-mvd-u		* PI-INT * PI-IDENT^{Q}	* IO-IDENT^{Q} * IO-INT

In (41c), [mamad-a, ya-mmvd-u], the phonotactic problem in the perfect is resolved by splitting the geminate; all perfect forms surface as [mamad-]. This also satisfies the templatic requirement of the perfect. In the imperfect, the stem surfaces faithfully with a geminate throughout. However, the set [mamad-a, ya-mmvd-u] violates PI-INT since the geminate consonant in the imperfect [ya-mmvd-u] is in correspondence with two consonants in the perfect [mamad-].

In (41d), [wamad-a, ya-mmvd-u] the stem is realized in the perfect as [wamad], with loss of gemination and epenthesis. The imperfect realization remains faithful to the stem, [ya-mmvd]. The perfect realization incurs violations of IO-IDENT^{Q}, due to the loss of gemination, and IO-DEP^{C}, due to

epenthesis. Because of the mismatch is consonantal quantity between the perfect and imperfect, PI-IDENT^{Q} is violated.

Candidate (41e), [mamad-a, ya-mVd-u], incurs violations of IO-IDENT^{Q} due to the imperfect [ya-mVd-u], and IO-INT due to the perfect [mamad-a]. Moreover, the perfect, imperfect correspondence relation violates PI-INT because the /m/ of the imperfect corresponds to two consonants in the perfect, and PI-IDENT^{Q} because the quantity of /m/ in [ya-mVd-u] is {C}, but the quantity of that /m/'s correspondent set in the perfect is {C,C}.

All candidates in (41) violate M or some aspect of PI-F. They are therefore excluded because of the top-ranked status of the M, PI-F constraints. The next tableau in (42) turns to the crucial comparison between candidates that avoid these violations. Because of the irrelevance of M, PI-F in this context, the top row in (42) unfolds the IO-F^{+} subhierarchy. Candidate (42a), [mad-a, ya-mVd-u], avoids the violations of PI-IDENT^{Q} and PI-INT of all candidates in (41) by shortening the geminate throughout. However, IO-IDENT^{Q} and TEMP are violated. TEMP is violated because [mad-a] falls short of the templatic requirement for a /CVCVC-/ output in the perfect. This violation crucially renders (42a) less harmonic than (42b). This latter candidate does violate IO-IDENT^{Q} just as (42a) does, since /mm/ is realized with loss of gemination throughout, but trades the violation of TEMP in (42a) for a violation of the lower ranked constraint against epenthesis, IO-DEP^{C}. Candidate (42b), with loss of gemination and epenthesis in the templatic perfect, is therefore the predicted output.

42. Fate of geminate-initial stems

/mmVd/	IO-IDENT^{Q}	IO-INT	TEMPL	IO-DEP^{C}
a. mad-a ya-mVd-u	**		*!	
b. ☞ wamad-a ya-mVd-u	**			*

The crucial relation in (42) is TEMPL >> IO-DEP^{C}. This was a relation inferred as part of the verbal phonology of Arabic (in section 3). Tableau (42) then illustrates the seamless connection that can be established between the phonology of Arabic and Greenberg's asymmetry. We see that the grammar is such that a stem with initial gemination /mmVd/ surfaces as [wamad-a, ya-mVd-u]. The absence of stem-initial gemination exemplifies another global consequence of local phonotactics. The phonotactic *EDGE-GEM effects a local change in the realization of the stem in the perfect paradigm. Due to the dominant OO-F, this local effect is imparted to the realizations of the stem in all contexts, that is, also in the imperfect where the local phonotactic pressure is not present. In short, the underlying contrast between /mVd/ and /mmVd/ is neutralized to [mVd] on the surface.

This neutralizing property of the grammar also provides the answer to the impossibility of geminate-initial stems in Arabic. Learners would never posit such stems because, once put in the context of the paradigm, their crucial phonological characteristic of initial gemination is unrecoverable. Stems with initial gemination are 'hidden' behind stems without gemination whose mapping to the surface set is most transparent. This can be illustrated formally with the paradigm tableau in (43), which compares the two rival stems /mmVd/ and /mVd/. Both of these are realized as [wamad-tu, ya-mVd-na]. However, /mmVd/ in (43a) incurs violations of three different constraints from IO-F^{+}, whereas /mVd/ in (43b) incurs a subset of these violations and hence provides the most harmonic mapping to the surface set. That is, /mVd/ → [wamad-a, ya-mVd-u] ≻ /mmVd/ → [wamad-a, ya-mVd-u].

43. Demonstration of /mVd/ ≻ /mmVd/

Stems	Surface set	*E-GEM	PI-F	IO-F^{+}
a. /mmVd/	wamad-a ya-mVd-u			** IO-IDENT^{Q} * IO-DEP^{C} * TEMP
b. ☞ /mVd/	wamad-a ya-mVd-u			* IO-DEP^{C}

In sum, optimization at the level of the verbal paradigm derives the absence of /mmVd/ stems without stipulating a ban on such stems from the inventory of inputs in this language. The absence of V-final prefixes in the perfect, the independently necessary phonotactic *EDGE-GEM, and intra-paradigmatic identity constraints 'conspire', in the spirit of Kisseberth (1970), for the absence of /mmVd/ stems from the lexical inventory of the language.

4.2 Impossibility of initial repetition

Consider now a stem /m^{1}m^{2}Vd/, a triliteral with two identical consonants at the left edge of the stem. In the perfect, this stem would surface as [m^{1}am^{2}Vd-], a phonotactically unproblematic form. In the imperfect, however, stem /m^{1}m^{2}Vd/ is bound to phonotactic problems. If the stem is realized faithfully, as [m^{1}m^{2}Vd], then OCP is violated. This is shown in (44a) below. To avoid the OCP violation(s), the two identical consonants may be shifted apart by relocating the vowel as in [ya-m^{1}Vm^{2}d-a] of (44b). This shifted /m^{2}/, however, is bound to meet other phonotactic strictures imposed by SYLL, because some imperfect suffixes are consonant-initial or null. Alternatively, the stem may be realized as [m^{1}Vm^{2}d] before a vowel and as [m^{1}m^{2}Vd] before a consonant as in (44c). The point here is that, in any case, violations of the OCP or SYLL are unavoidable. Moreover, as (45) shows, the same phonotactic problems arise with a variant of /m^{1}m^{2}Vd/, the stem /m^{1}Vm^{2}d/. Once again, in the imperfect, that stem leads to a violation of either the OCP or SYLL.

44. Fate of /m^{1}m^{2}Vd/ in the imperfect: Violations of OCP, SYLL

/m^{1}m^{2}Vd/	OCP	SYLL	OO-LIN	IO-LIN
a. ya-m^{1}m^{2}Vd-a, ya-m^{1}m^{2}Vd-na	**			
b ya-m^{1}Vm^{2}d-a, ya-m^{1}Vm^{2}d-na		*		**
c. ya-m^{1}Vm^{2}d-a, ya-m^{1}m^{2}Vd-na	*		*	*

45. Fate of /m^{1}Vm^{2}d/ in the imperfect: Violations of OCP, SYLL

/m^{1}Vm^{2}d/	OCP	SYLL	OO-LIN	IO-LIN
a. ya-m^{1}Vm^{2}d-a, ya-m^{1}Vm^{2}d-na		*		

b. ya-m^{1}Vm^{2}d-a, ya-m^{1}m^{2}Vd-na	*		*	*
c. ya-m^{1}m^{2}Vd-a, ya-m^{1}m^{2}Vd-na	**			**

The situation here is fully parallel to that of geminate-initial, /mmVd/, stems. The only difference is in the local context where the phonotactic violations are met and in the nature of the relevant phonotactic. For /mmVd/ stems, the phonotactic is one against edge geminates, and its violation is met in the prefix-less perfect. For /m^{1}m^{2}Vd/, the phonotactics are the OCP and SYLL, and their violation is met in the imperfect.

Thus, irrespective of the linear order between the consonants and the stem vowel, /m^{1}m^{2}Vd/, /m^{1}Vm^{2}d/ lead to violations of a markedness constraint, either OCP or SYLL.[26] Violations of these constraints are never attested in the surface forms of Arabic. The grammatical statement of this fact is a ranking between these markedness constraints and some faithfulness constraint that favors the preservation of the segmental make-up of hypothetical inputs that would lead to such markedness violations. Specifically, that ranking must be OCP, SYLL >> IO-MAX, where IO-MAX is the faithfulness constraint requiring that all stem segments be realized. This ranking is an instance of the general schema M >> IO-FAITH which is independently argued to be part of the initial state. The tableau below illustrates the specific ranking for stem /m^{1}m^{2}Vd/. Candidate (46b) also violates IO-LIN which, however, is ranked below SYLL.

46. Impossibility of initial repetition in the imperfect (stem is /m^{1}m^{2}Vd/)

/m^{1}m^{2}Vd/	OCP	SYLL	IO-MAX
a. ya-m^{1}m^{2}Vd-na	*!		
b. ya-m^{1}Vm^{2}d-na		*!	
c. ☞ ya-mVd-na			*

Given these strictures of the imperfect, consider now the fate of /m^{1}m^{2}Vd/ in the perfect context, in (47). In the perfect, stem /m^{1}m^{2}Vd/ could surface as [m^{1}am^{2}Vd-a] without violating the OCP. However, as (47b) illustrates, PI-MAX prevents this by requiring that the perfect, imperfect stem realizations must consist of the same set of segments. Candidate (47a) avoids the PI-MAX violations but violates OCP, a top-ranked constraint. Candidate (47c) is the only available option. It avoids the violations of OCP, PI-MAX at the expense of IO-FAITH constraints (it will be recalled that /w/-epenthesis in the perfect is due to TEMP >> IO-DEP^C inferred earlier).

[26] The following discussion applies equally to /m^{1}Vm^{2}d/ stems which I will therefore not discuss further.

47. Fate of stems with initial identity: leveling of the absence of initial identity through PI-F

	M	OO-F	IO-F
/m^1m^2vd/	OCP	PI-MAX	IO-MAX IO-DEP^C
a. m^1am^2vd-a ya-m^1m^2vd-u	*!		
b. m^1am^2vd-a ya-m^2vd-u		*!	* IO-MAX
c. ☞ wam^2ad-a ya-m^2vd-u			** IO-MAX * IO-DEP^C

The crucial ranking in (47) is an instance of the general schema M, OO-FAITH >> IO-FAITH, assumed to be part of the initial state of the grammar. Due to this ranking, stem /m^1m^2vd/ is realized as [wamad-a, ya-mvd-a], the same set as that supplied by stem /mvd/. Consequently, via a familiar by now logic, learners would not posit /m^1m^2vd/ stems. Put in the context of the paradigm, such stems are subject to substantial alternation which effectively renders them unrecoverable. Formally, as (48) shows, the rival stem /mvd/ supplies the same realization set as that of /m^1m^2vd/ stems in the most transparent way. The mapping /m^1m^2vd/ → [wam^2ad-a, ya-m^2vd-u] violates the IO-F constraints IO-MAX and IO-DEP, a superset of the violations incurred by /mvd/ → [wamad-a, ya-mvd-u].

48. Demonstration of /mvd/ ≻ /m^1m^2vd/

Stems	Surface set	OCP	PI-F	IO-F
a. /m^1m^2vd/	wam^2ad-a ya-m^2vd-u			** IO-MAX * IO-DEP
b. ☞ /mvd/	wamad-a ya-mvd-u			* IO-DEP

As in the case of stems with initial gemination, stems with initial identity /m^1m^2vd/, /m^1vm^2d/ are excluded in past analyses by stating restrictions on what can be a possible *input*: a triliteral root |m^1m^2d| is banned by the OCP applying at the level of the input (McCarthy 1979 *et seq*). In this account, the absence of verbal forms with initial identity is the direct consequence of there being no inputs with that property. Once again, no such assumption about inputs is necessary (or available in the theory adopted in this paper). The *|m^1m^2d| gap is a consequence of the independently necessary phonotactics (no surface violations of OCP) and identity constraints between the perfect and imperfect forms. Specifically, the absence of stems with initial identity is a consequence of the ranking OCP, PI-F >> IO-F, an instance of an independently supported hypothesis about the initial state of the grammar.

4.3 Recapitulation

In this section, I have pursued the predictions of two hypotheses: the first consists of the grammar underlying the phonology of doubled verbs developed in section 3, and the second is the language-independent learnability hypothesis about the initial state of the grammar M, OO-FAITH >> IO-FAITH (Smolensky 1996, Tesar and Smolensky 1998, McCarthy 1998). The coupling of these two hypotheses

makes precise predictions about the inventory of (im)possible stems in Arabic. Specifically, it predicts that stems with initial gemination and stems with initial repetition are impossible. As seen here, these predictions are borne out in the facts of Greenberg's asymmetry. This result, in turn, provides further converging evidence for the correctness of the two hypotheses.

Let us review the reason why stems with initial gemination or initial repetition are not possible stems in Arabic. The phonotactic pressures from the paradigmatic context result in substantial alternations in their realization. These alternations effectively hide these stems behind other stems whose mapping to that realization is more transparent. Consequently, a learner would never posit these unrecoverable stems. Pursuing the logic of this language-independent argument obviates the language-particular assumptions previously thought necessary in accounting for Greenberg's asymmetry ('roots with initial geminates are not allowed', 'roots with two identical consonants are not allowed', 'the direction of mapping root consonants to template positions is left-to-right').

4.4 OCP Place effects

Greenberg's asymmetry discussed above concerns *impossible* stems. Another well-known fact about the Semitic lexicon concerns a class of *possible* but under-represented stems. Specifically, stems with non-identical, homorganic consonants, such as /dtVf/, /kbVm/, /stVm/, are statistically under-represented in the Semitic lexicon (Cantineau 1946, Greenberg 1950). This generalization stands in sharp contrast to the fact that [madad] forms, with two identical consonants, are well attested. Given that identical consonants are also homorganic, if homorganic consonants are avoided then identical consonants should be avoided too. As Greenberg (1950) characteristically writes, "The geminate type is thus clearly an anomaly in terms of the overall patterning of Semitic verbal roots [*author*: in Greenberg's usage the term 'geminate type' refers to the madad allomorph of doubled verbs]" (p. 162). The results of the present paper allows us to rationalize this apparently contradictory state of affairs, once we recognize that the facts related to homorganicity and identity are the domain of two different systems.

Research on the homorganic avoidance facts, also known as 'OCP-place' effects, has provided refined quantitative measures of that avoidance by showing that not only place but also manner and voicing features as well as the distance between the two consonants contribute to the strength of the under-representation of 'similar' consonants (McCarthy 1986, 1988, 1994, Pierrehumbert 1993, Frisch, Broe and Pierrehumbert 1997). The relevant notion of similarity contributing to that under-representation is addressed in detail in Frisch, Broe and Pierrehumbert (1997). The authors of that article propose a quantitative model with a gradient constraint on similarity avoidance, defined in formal terms. The model is quantitative in that it aims to match the observed probabilities of occurrence for the various roots based on the gradient similarity avoidance constraint. In fact, through regression analyses, the authors argue that their similarity avoidance model provides a better fit to the facts than (a quantitative interpretation of) McCarthy's (1994) account and also Pierrehumbert's (1993) account.

One important issue in this line work concerns the nature of the constraints underlying the OCP-place effects and Greenberg's asymmetry. On the one hand, the model in McCarthy (1994) consists of two categorical OCP constraints, one targeting identical consonants, the other targeting non-identical, homorganic consonants (McCarthy 1994, pp. 205, 206 respectively). The two different constraints seem motivated by the fact that Greenberg's asymmetry concerns absolutely ill-formed (impossible) stems, whereas the homorganic avoidance effect concerns under-represented but not impossible stems. On the other hand, Frisch, Broe and Pierrehumbert (1997) argue that an adequate account of the OCP-Place effects necessitates a quantitative model. The core argument for this consists in showing that a

categorical constraint is not well-suited to the task of capturing the fine-grained variations characteristic of the OCP-place effects, which vary depending on degree of similarity and distance. In addition, however, the authors suggest that the OCP-total effects, which concern absolutely ill-formed stems, can be subsumed as the limit case of a gradient similarity avoidance constraint. This, in turn, raises the question of the relation between the results obtained with the model of this paper and that of Frisch, Broe and Pierrehumbert (1997).

The present paper and the work on similarity avoidance are complementary but not incompatible. They are complementary because they address different generalizations. The similarity model provides an account of the statistical under-representation (not the impossibility) of stems with non-identical, homorganic consonants, that is, the OCP-Place effects. These gradient effects are not addressed in the categorical model of grammar responsible for the impossibility of initial gemination and identity, as derived in this paper. Conversely, the similarity model does not address the fact that initial gemination is impossible. There are no gradient effects here that would invite accounts with gradient constraints. Stems with initial gemination are simply not attested. This fact about absolutely ill-formed stems derives from the standard conception of an OT grammar as a set of prioritized categorical constraints.

Another reason why the model presented in this paper and that of similarity avoidance are complementary is met with the well-attested pattern of final identity in [madad]. Frisch, Broe and Pierrehumbert (1997) exclude this pattern from the responsibility of their model, because it is exceptional with respect to the overall patterning of similarity avoidance (under their suggestion that similarity subsumes identity). This is done by embracing McCarthy's (1986) analysis which holds that [madad] derives from a biliteral root |md| (see 1997, p. 8 and fn. 4). But then, on this particular point, the similarity model falls back on the (total) OCP. This is because, in McCarthy's analysis, the only motivation for internalizing [madad] forms as biliteral roots is the OCP. Consequently, in the case of the final identity pattern, the similarity model appears to assume rather than subsume the OCP for identical consonants. However, as argued in this paper, the final identity pattern in [madad] does not require reference to the OCP. A careful look at doubled verbs shows that forms like [madad] are the surface variants of geminate-final stems such as /madd/ which are forced to alternation in the context of the paradigm. The similarity model is strengthened by this result because it does not have to exclude [madad] forms from the very facts it aspires to account for. At the same time, recall that the explanation offered here for [madad] involves a grammar that captures the systematic relation between the two allomorphs of every doubled verb, [madd] and [madad]. This allomorphy is not statistical in nature and it involves a set of interacting categorical constraints on phonotactics and templatic shape. This kind of explanation of possible allomorphs, rooted in constraint interaction, seems at present beyond the scope of the similarity model which studies the effects of a single gradient constraint in capturing gradient patterns in the data.

We are left with the pattern of initial identity. The model presented here and that of Frisch, Broe and Pierrehumbert (1997) make overlapping predictions on this point. However, as I discussed above, the latter model does not generalize to the case of initial gemination, the other impossible structure at the left edge of stems. Both absolutely ill-formed structures derive from a grammar of categorical constraints in the model of this paper.[27]

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[27] Note that the distribution of identical consonants is the jurisdiction of a categorical grammar only when the consonants are adjacent or are forced to adjacency by the paradigmatic context (see 3.2). This is because the OCP applies between adjacent consonants (by definition), and thus the grammar remains silent for non-adjacent, identical consonants. This predicts that stems with identical, non-adjacent consonants exist. Indeed, Greenberg (1950) reports that there are about 20 such stems. However, such stems are under-represented and this seems to invite an account along the lines of Frisch, Broe

Overall, at present, an account of Greenberg's asymmetry and the OCP-place facts seems to require a hybrid model, that is, a model which is neither uniformly categorical as in McCarthy (1994), nor uniformly probabilistic as in Frisch, Broe and Pierrehumbert (1997), but instead combines elements from both views. This hybrid model is composed of a categorical component as developed in this paper, that is, a grammar of categorical constraints responsible for the fact that stems with initial gemination and initial identity are impossible. The model also includes a probabilistic component which accounts for why stems with similar consonants are statistically under-represented but not impossible.[28]

5. Implications

In this section, I discuss implications of the main proposal of this paper.

5.1 Root-based versus stem-based morphology

I have argued that core aspects of the verbal morphology of Arabic require that verb lexemes have stems which specify properties such as vocalism and consonantal length: /madd/ 'to stretch', /mill/ 'to be weary', /Sal/ 'to arrive'. This claim is relevant to some recent proposals on morphology in Arabic. On the one hand, some well-known studies of Arabic morphology have established that a stem, a unit which includes consonants and vowels, and not just the bare consonantal root, is the base on which morphology operates (e.g. noun broken plurals, Hammond 1988, McCarthy and Prince 1990a, Ratcliffe 1998). These studies have shown that surface properties of the singular noun stem such as vocalic and consonantal length condition in crucial ways the form of the corresponding plural stem.

On the other hand, traditionally in verbal morphology derivation operates on the consonantal root (Cantineau 1950, Fleisch 1956, McCarthy 1979, Yip 1988, Hoberman 1988, Farwaneh 1990, Moore 1990, Goldenberg 1994, Chekayri and Scheer 1996, among others). More recently, however, work by various authors suggests that the stem-based view of verbal morphology in Arabic is worth exploring (McCarthy 1993, McOmber 1995, Ratcliffe 1998, Benmamoun 1999). A pressing problem for all such proposals was the set of facts related to doubled verbs and Greenberg's asymmetry, whose explanation has continued to rely on root-based derivation. Consider, for instance, McCarthy's (1993) reanalysis of verb morphology in which verbal Forms are derived by affixation rather than root-based derivation with one crucial exception. The characteristic pattern of final duplication in /madad/ is still derived from a biliteral root /md/ mapped onto the /CVCVC/ template (as in McCarthy 1979, 1981). This root-based core of verbal morphology has apparently remained as such even in stem-oriented proposals of Semitic morphology.

A careful analysis of doubled verbs resolves the inconsistency in the current state of knowledge about root- versus stem-based morphology. As we have seen, there is no need for getting from the root /md/ to /madad/ in a first step, treating that as an intermediate form, and then reducing it to /madd/ whenever necessary. Rather, the basic stem of doubled verbs is /madd/ with the form [madad] surfacing before consonant-initial or null suffixes as a result of a phonologically-determined alternation. In other words, an adequate account of the doubled verb allomorphy requires reference to underlying forms specified for vocalism and consonantal-length. As soon as doubled verbs are properly understood, they cease to provide crucial evidence for root-based derivation, and thus for the view admitting two distinctly different modes of word-formation in the same language, root-based derivation for verbs and

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and Pierrehumbert (1997). In the case of long-distance identity then, identity avoidance could be subsumed by the gradient similarity avoidance constraint.

[28] See Berent and Shimron (2001) for an argument from Hebrew that identity is treated differently from similarity.

stem-based derivation for nouns.[29] In short, doubled verbs constitute an argument for stem-based morphology.

Converging evidence for the validity of this conclusion derives from two other considerations. The first concerns the length-distinction effect, namely, the generalization that consonantal length has a differential effect on the form of the derived output. Specifically, in the templatic word-formation of Arabic, stems with single consonants extend via epenthesis, whereas stems with geminate consonants extend via multiple correspondence. Representative examples are given in (49). The stem-based grammar underlying the doubled verb alternation derives the LDE without the unmotivated postulate of verbs 'rejecting /w/' (section 3.3) or directionality parameters dedicated to the final duplication pattern in [ma**d**a**d**-] (section 3.5).

49. The length-distinction effect (LDE) across the verbal, nominal divide

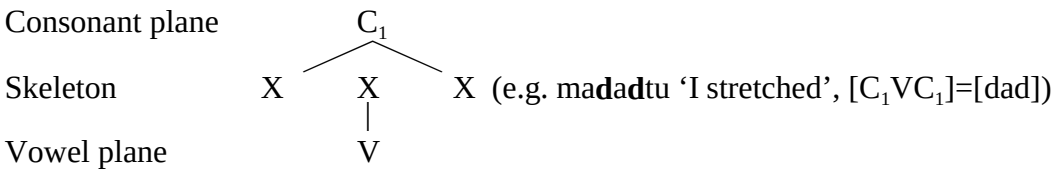
	Verbs		*Nouns*		
Simple biliteral stems	/Sal/	→ [waSal-], *[Sa**l**a**l**-]	/ħam/	→	[-ħmaaʔ-], *[-ħmaam-]
'Geminate' stems	/ma**dd**/	→ [ma**d**a**d**-]	/ku**tt**aab/	→	[ka**t**aa**t**iib]

The crucial point here is the overarching generalization that stands out in (49), namely, that the LDE applies across the verbal-nominal divide. This generalization would be inexpressible if verbal morphology were root-based. Moreover, coupling a language-independent learnability assumption with the stem-based grammar underlying the doubled verb alternation derives Greenberg's asymmetry without Morpheme Structure Conditions on admissible inputs (section 4). In sum, coherence emerges in the data if we assume that verbal morphology also builds on stems, just as has been argued to be the case with nominal morphology.

5.2 No special phonology

One goal of linguistic theory is to minimize to the extent possible apparent theoretical distinctions in the analysis of facts across descriptively distinct sets of data. Nonconcatenative morphology was originally argued to require special phonological representations, where consonants and vowels occupy distinct planes and spreading of consonants can apply across a vowels (see McCarthy 1981, 1986, Yip 1988, among others).

50. V/C planar segregation and spreading



Recent work has argued that core phonological distinctions between concatenative and non-concatenative morphology, like the segregation of vowels and consonants on different planes and

[29] See Bat-El (1994, pp. 591-594) and Ussishkin (1999) for critiques of roots in Hebrew and alternatives.

consonant spreading across vowels, are unnecessary (Gafos 1996, 1998). The main claim of that work is that, as far as the phonology is concerned, concatenative and non-concatenative morphology rely on the *same phonological representations*. The patterns of consonant-vowel interleaving, characteristic of non-concatenative morphology, derive from independently necessary means such as segmental copy, as opposed to autosegmenal spreading, and by the requirements of prosody, best expressed by the formal notion of template in the theory of Prosodic Morphology (McCarthy and Prince 1995a).[30] See also McCarthy (1995 [2000]) for a critique of V/C planar segregation and Rose (1997, 2000), Kenstowicz and Banksira (1999), and Berent, Everett and Shimron (2001) for related analysis of spreading as segmental copy.

The present paper provides further evidence for the main claim of that earlier work, namely, that the phonological prerequisites for non-concatenative morphology are not distinct from those of concatenative morphology. As I have argued, no special phonology is involved in the account of doubled verb allomorphy or Greenberg's asymmetry in Arabic.

5.3 Processing: External evidence for roots

The view of Semitic morphology which has gained some impetus in recent years and which finds support in this paper is that the grammar, as a system of lawful relations between words, must have access to more richly specified representations than allowed by consonantal roots. Typically, the arguments given in this line of research and in particular in this paper aim to establish claims about linguistic morphology and phonology. In the terms of Kenstowicz and Kisseberth (1979), then, these arguments constitute *internal* sources of evidence for the necessity of more articulated representations, specifying properties such as consonantal length and vocalism.

External evidence on Semitic morphology, however, suggests that consonantal roots are conspicuous processing domains. For example, roots seem to facilitate lexical decision and naming tasks (Frost, Deutsch, and Froster 1997). Roots also seem to play an important role in how Semitic words are processed in aphasia and speech games (e.g. Barkai 1980, Safi-Stagni 1995, and Prunet, Béland, and Idrissi 2000 for a review and some new evidence).

These two apparently opposing lines of evidence derive from different domains, grammar and lexical processing. Phonology and morphology are components of the grammar. Lexical processing is the grammar in use. The relation between grammar and processing is complex or at least indirect (Chomsky 1965). The information structures implicated in processing are related to the units of morphology, but that does not mean that they must be identical to those units. The arguments in this paper do not exclude consonantal roots as units of processing. Conversely, as Prunet, Béland, and Idrissi (2000, pp. 642-3) are careful to point out, the *external* evidence from processing does not preclude that morphology may operate on units not identical to consonantal roots (see Davis and Zawaydeh 2001 for some relevant discussion).

The issue, then, is how to put together the external evidence for roots with the internal evidence for more articulated representations from the side of the grammar. Though this issue cannot be addressed in this paper, I note that the two apparently opposing lines of evidence are not incompatible.

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[30] This proposal is neutral to the issue of stems versus roots. As discussed in Gafos (1998, pp. 272-3), a morphological distinction between vowels and consonants does not logically entail the specific geometric depiction of that distinction as portrayed by V/C planar segregation (which, as argued therein, is problematic for phonological reasons). For instance, an alternative representation in terms of two distinct linear sequences, a vowel sequence and a consonant sequence, is fully adequate. Such sequences can be 'intercalated' by the forces of prosody (i.e. the independently needed notion of template). See also Bat-El (1989) for this proposal on Hebrew.

Assuming there is something essentially correct about both views, the key to their compatibility is likely to be found in the *relation* between grammar and processing. Consider in this respect the role of vowels in Semitic morphology. A crucial fact here is that vowels are employed as the inflectional markers of the aspect and voice system. As a prototypical example, compare the perfect active forms in (51), where stem vowels are in bold, with their corresponding passives. In the passives, the stem vowels are replaced by the vocalism /u, i/, the marker of passive voice in the perfect aspect. The same applies to the imperfect active and passive pairs in (51).

51. Stem vowel replacement:	'write'	'drink'	'be brown'
Perf. Active	kat**a**b-a	ʃar**i**b-a	sam**u**r-a
Perf. Passive	kutib-a	ʃurib-a	sumir-a
Impf. Active	ya-kt**u**b-u	ya-ʃr**a**b-u	ya-sm**u**r-u
Impf. Passive	yu-ktab-u	yu-ʃrab-u	yu-smar-u

Given the obligatoriness of inflectional morphology, stem vowels must be suppressed. Another example is the prevocalic perfect of doubled verbs, where stem vowel contrasts are neutralized to /a/, the marker of the active voice. Thus, in a non-prevocalic context we find [mad**a**d-] 'stretch', [mal**i**l-] 'be weary', [Hab**u**b-] 'become dear', but prevocalically these contrasts are systematically suppressed, [madd], [mall], [Habb].

Ordinarily, then, stem vowels are masked by the inflectional markers attached to the stem. In terms of the grammar, this means that stem vowels have *low faithfulness* requirements (section 3). This fact about the grammar leads to a non-representational view of the salience of consonants in Semitic morphology. It seems reasonable to propose that the low faithfulness of stem vowels renders these vowels transparent, or at least less salient that stem consonants, to the process of lexical access. Consequently, stem consonants or roots are emergent from the grammatical system as salient units of lexical processing.

In short, it is not that the grammar is built on roots, rather, that roots are derived from the grammar in use. Accordingly, the two views of Semitic morphology, stem-based from the side of the grammar and root-based from the side of processing, are not incompatible. As the evidence from Semitic and elsewhere suggests, it seems reasonable and promising to maintain a distinction between grammar and processing, and seek the key to apparent incompatibilities in the relation between these two domains.[31]

6. Conclusion

Schramm (1991) writes that "the conventional statement of Semitic morphological typology for the last thousand years or so has always reflected the view that all verbs and most nouns are to be derived by a process of interdigitating discontinuous consonantal root morphemes, expressing lexical content, and vocalic pattern morphemes which express grammatical content." (p. 1402). This is the standard view in the background of all past and current work. For reviews see Goldenberg (1994) and Hoberman (1995).

This paper re-examines a number of well-known issues in the morphology and phonology of the

[31] Cowell (1962), in his Syrian Arabic grammar which is exceptional in placing emphasis on relations between words rather than roots and 'canonical' patterns, expresses a similar view. Cowell describes Semitic morphology as "the system of interrelationships among members of a word family. A root, as conceived here, is neither parental nor ancestral to those members, but is merely their family resemblance" (Cowell 1962, p. 47). In the text, I have attempted to identify a crucial aspect of these "interrelationships" among words in Semitic that makes consonantal roots particularly salient.

Arabic strong and doubled verb which were thought to provide crucial support for consonantal roots. Parting with tradition, these issues are examined by considering verbal forms not in isolation but in the context of the inflectional paradigm in which they are realized. This perspective allows us to explore the extent to which systematic patterns in the behavior of the verb as well as systematic patterns of the lexicon are lawful consequences of independent properties of the language as opposed to consequences of morpheme structure constraints applying on roots. Explanation of the systematic patterns discussed here is based on stems and generally accepted constraints on phonological forms built on these stems. We find no evidence for constraints applying exclusively at the level of the root. In fact, we argue that the stem-based analysis consistently results in a better solution to the problems discussed in this paper. A summary of these problems and the specific results obtained follows.

First, we have asked why should the form of the triliteral verb be /CCVC/, as posited Kuryłowicz (1972) and others. We have seen that the /CCVC/ form arises as a consequence of the inflectional context of the verbal paradigm. That context effectively 'molds' the shape of the stem to 'fit' into the context of the paradigm. This idea is expressed formally using standard OT resources: a grammar constructed from a set of constraints requiring preservation of lexically-specified properties (IO-Faithfulness), constraints requiring identity between related forms within the paradigm (OO-Faithfulness), and markedness constraints that express well-formedness conditions on phonological forms (e.g. OCP, no edge geminates, syllabification).

Second, in all respects relevant to morphology and phonology, Arabic doubled verbs have stems with lexically-specified vocalism and consonantal length, e.g. 'to stretch' has perfect stem /madd/ and imperfect stem /mudd/. This allows us to make sense of the behavior of doubled verbs in ways that have not been possible before. Specifically, the stem-based view of doubled verbs developed in this paper allows us to explain why the alternation between [madd] and [madad] takes place using the independently necessary phonotactics of the language. This proposal also obviates language-particular parameters dedicated to the pattern of final duplication in [madad], and resolves a long-standing inconsistency between stem-based morphology for nouns and root-based morphology for verbs, with respect to this aspect of verbal morphology.

Finally, the well-known property of the Arabic lexicon, the absence of *ssam, *sasam forms versus the presence of samm, samam, is derived as another consequence of independently necessary factors. It is shown that the systematic absence of *ssam, *sasam emerges from the interaction of the inflectional context of the paradigm coupled with the phonotactics of the language and identity constraints between related forms in the paradigm.

Appendix: The 'exceptional' Forms

Forms II and III are characterized as exceptional because doubled verbs in these Forms do not show the alternations discussed earlier (Wright 1896, Schramm 1962, Yousmanov1961 [1938]). The same applies to Forms V (5) and VI (6) which are derived from II, III respectively by prefixation of /ta-/. Here I argue that the 'exceptionality' of these Forms does not need to be stipulated, but in fact derives from the interaction of constraints on syllabic well-formedness and morphological expression, as in the core analyses of this paper. We focus on II and III here. The analysis readily extends to their respective derived conjugations.

Our task is complicated by the fact that verbs in Form III sometimes do undergo alternation. As Schramm (1962) writes, "the second and fifth conjugations pattern exactly as do those of strong verbs" in that they do not show any alternation. But the "third and sixth conjugations show variants which resemble the strong verb, while parallel forms resemble the geminate stems in other conjugations" (p. 365) (see also Yushmanov 1961, p. 56). Schramm also writes that the contracted and uncontracted forms in III, VI "are in free variation" (p. 365), whereas Wright (1896, p. 71) says that the uncontracted forms appear "not infrequently" (Wright 1896, p. 71). In any case, it seems safe to assume that there is variability in Form III, VI. To sum up the facts in need of an account then, for Form II we have [maddad-a], *[madd-a], [maddad-tu], and for Form III, we have [maadad-a] or [maadd-a] before vowel-initial suffixes and only [maadad-tu] before consonant-initial or null suffixes (examples drawn from Wright 1896, pp. 70, 304).

We begin with Form III. The invariant property of Form III is the presence of a long vowel in the first syllable of the stem. There are different ways to express this property in the grammar. One is by a templatic requirement, say TEMPL=Hσ or TEMPL=CVVCVC , which dictates that the first syllable in a bisyllabic sequence must be heavy (McCarthy 1981). Alternatively we may assume that the morphology of Form III is affixational, adding a moraic affix to a base, along the lines of McCarthy (1993). The precise shape of that affix depends on our assumption about the base. If the base is the perfect stem /ktab/, then a long vowel would be affixed, /+aa, ktab/ → [kaatab]. Alternatively, if the base is the derived perfect form [k-a^{PAV}-tab], then a short vowel or a mora would be affixed, /+a, katab/ → [kaatab] (see McCarthy and Prince 1995a, p. 330).

For doubled verbs in Form III and their derivatives in VI, the sources report variation in the output form between [maadd-a] and [maadad-a], e.g. [ħaajj-a], [ħaajaj-a] 'he argued'. Again, note that it is only before vowel-initial suffixes that the form with the final geminate may occur. When that happens the form surfaces with a non-final CVVC syllable. This is the key to why [ħaajj-a] is avoided. In Arabic, such superheavy syllables are marked, usually found in word-final position, before a pause only (Wright 1896, p. 15). Hence, let us assume a constraint penalizing such syllables, *VVC]$^{\sigma}$. The variation between [maad**a**d-a] (stem vowel in bold) and [maadd-a] can now be expressed by the relative ranking of *VVC]$^{\sigma}$ and IO-INT(EGRITY), as in (52). When syllable phonotactics dominate, that is when *VVC]$^{\sigma}$ >> IO-INT, splitting of the geminate is enforced. The optimal form then is [maadad-a]. When IO-INT dominates, instead, we get [maadd-a], with the marked syllable structure. Templatic requirements, if any, and lexical vowel parsing requirements are assumed to be ranked lower than IO-INT (as already inferred in section 3 for Form I verbs).[32]

[32] Recall the constraint penalizing geminates in coda, *VC$_x$C$_x$]$^{\sigma}$, which is responsible for the doubled verb alternation. This constraint is similar to *VVC]$^{\sigma}$ in that it also penalizes tri-moraic syllables. However, as seen in section 3.1, *VC$_x$C$_x$]$^{\sigma}$ dominates IO-INT. If our interpretation of variation in Form III in terms of variable ranking is correct, then the two constraints *VC$_x$C$_x$]$^{\sigma}$ and *VVC]$^{\sigma}$ should not be unified as a single constraint in the grammar of Arabic.

52. Variation through variable ranking *VVC]$^{\sigma}$ >?> IO-INTEGRITY

{+aa^{III}, m**a**dd, -a^{Infl}}	*VVC]$^{\sigma}$	IO-INT
a. maad**a**d-a		*
b. maadd-a	*	

Hence, assuming that the base is /madd/, the behavior of Form III can be expressed by the interaction of the faithfulness constraint IO-INT, and syllabification, *VVC]$^{\sigma}$, exactly as is the case with the basic analysis of the alternation in Form I. This analysis, of course, does not explain why there is variation and no analysis known to me does that. Perhaps the reasons for this variation are to be sought in the relatively limited instances where evidence for a ranking between *VVC]$^{\sigma}$ and IO-INT could be obtained (i.e., number of verbs in Form I which have derivatives in Forms III, VI). I know of one more instance where marked CVVC syllables are generated. In participles one finds [yadullu, daallun] vs. [yaktubu, kaatibun].

Turning to Form II, we assume that the morphology of II consists of the affixation of a mora to the basic verbal stem /madd/, and that this mora must be realized by medial gemination (see McCarthy and Prince 1990b, pp. 45-47). Assuming that the stem for a doubled verb is /madd/, some representative candidates are shown in (53) below. In (53a), the affixal mora is left unrealized, a violation of the constraint on morphological realization we call REALIZEMORPH (Samek-Lodovici 1993). In (53b), the affixal mora is attached to the coda of the first syllable. This creates an usyllabifiable sequence /ddd/, violating SYLL. In the optimal form, (53c), the affixal mora finds its realization as the moraic part of the medial geminate /dd/. The input geminate has two output correspondents in the non-contiguous sequence /dad/, where the first /d/ is the second part of the medial geminate. We infer from (53a,c) that the constraint on the morphological expression of Form II, REALMORPH, takes priority over IO-INT. The other relation, SYLL >> IO-INT, was inferred in section 3.

53. Form II, Ranking argument: REALMORPH >> INTEGRITY^{IO}

{μ^{Affix}, m**a**dd, -a^{Infl}}	SYLL	REALIZEMORPH	IO-INTEGRITY
a. m**a**dd-a		*!	
b. m**a**Cdd-na | μ^{Affix}	*!		
input ~dd~ / \ c. ☞ m**a**ddad-na / μ^{Affix}			*

There is one interpretation of (53a) above, [madd-a], that deserves special attention. We may interpret [madd-a] as realizing the affix mora by gemination. But then it must be that the mora of the input geminate has been deleted and its place given to the affix mora (which is filled by spreading of the /d/). Equivalently, in this interpretation of [madd] the input geminate shortens. Doubled verbs in

all their surface forms never appear with an ungeminated consonant. The constraint responsible for this fact is IO-IDENT^{Q}, requiring preservation of distinctive length. This is the constraint excluding the interpretation of [madd-a] discussed here.

Note that the constraints which interact in deciding the fate of (53a,c) above are crucially different from those that decide the outcome of the vascillating Form III. In Form III the constraints in conflict are a syllable well-formedness constraint *VVC]$^{\sigma}$ and the constraint IO-INT. Sometimes *VVC]$^{\sigma}$ gives in to satisfy IO-INT, but other times the syllable markedness constraint takes priority, and geminate separability obtains. In Form II, instead, the conflict is between IO-INT, the faithfulness constraint, and a constraint on the morphological expression of the conjugation, the definitional characteristic of Form II. Since morphological expression of conjugation class is at stake, it is not surprising that allomorphy (violation of faithfulness) is admitted in this case. In other words, IO-INT is violated to satisfy the expression of Form II.[33]

To conclude, the 'exceptionality' of Forms II, V and Forms III, VI derives from the interaction of independently necessary constraints on phonotactics and morphological expression of the corresponding Forms. The present analysis obviates elaborations of the Syncope/ Metathesis rule of the standard analysis whose effect is to make that rule applicable only to the Forms where the alternation is present.

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[33] The absence of variation in Form II can also be interpreted as an argument that Form II in Arabic is the result of affixation of a mora as opposed to a templatic requirement that dictates gemination in some way. This is the same position as that taken in McCarthy and Prince (1990b, p. 45) and McCarthy (1993). If the morphology consisted of a templatic requirement for a heavy syllable in the form of a geminate, then *[madd-a] would be a legitimate output. Thus, we must assume that the morphology is affixational, consisting of the addition of a mora to the input stem. This does not mean that all cases of stem-internal gemination in Semitic should be derived by affixation. See Buckley (1997), for instance, for an argument that, in Tigrinya, gemination in the Imperfect of a class of verbs, the so-called class A, is the result of a templatic requirement that the first syllable of the stem be heavy. See also Hudson (1991, 1995) for relevant discussion of the interesting issue of medial gemination in Ethiopian languages.

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