Templatic morphology as an emergent property: Roots and functional heads in Hebrew*

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Abstract

Modern Hebrew exhibits a non-concatenative morphology of consonantal "roots" and melodic "templates" that is typical of Semitic languages. Even though this kind of non-concatenative morphology is well known, it is only partly understood. In particular, theories differ in what counts as a morpheme: the root, the template, both, or neither. Accordingly, theories differ as to what representations learners must posit and what processes generate the eventual surface forms. In this paper I present a theory of morphology and allomorphy that combines lexical roots with syntactic functional heads, improving on previous analysis of root-and-pattern morphology. Verbal templates are here argued to emerge from the combination of syntactic elements, constrained by the general phonology of the language, rather than from some inherent difference between Semitic morphology and that of other languages. This way of generating morphological structure fleshes out a theory of morphophonological alternations that are non-adjacent on the surface but are local underlyingly; with these tools it is possible to identify where lexical exceptionality shows its effects and how it is reigned in by the grammar. The Semitic root is thus analogous to lexical roots in other languages, storing idiosyncratic phonological and semantic information but obeying the syntactic structure in which it is embedded.

1 Introduction

Morphological and phonological systems are often conceived of in linear terms: the concatenation of one morpheme to another, or the assimilation of a feature from one segment to an adjacent one, play a central role in describing the structures generated by the grammar of a language. Against this backdrop, cases of non-concatenative morphology in Semitic languages make notable reference to non-adjacent interactions. A common approach in the analysis of these languages is to revise basic assumptions of what morphemes are like, introducing non-linear morphophonological elements. The current paper argues that such a revision is not necessary, once the correct structural and lexical specifications are defined. A novel analysis of the verbal system of Modern Hebrew demonstrates that correctly combining lexical roots and syntactic heads is able to derive the non-concatenative effects of the language, making accurate predictions about allomorphic interactions within the phonological word. The result is a theory

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of morphosyntax and morphophonology that is as applicable to concatenative languages as it is to non-concatenative ones.

According to the traditional view of Central Semitic non-concatenative morphology, a word such as Arabic *takattab* 'got written' is made up of the consonantal "root" $\sqrt{\text{ktb}}$ and a melodic verbal "template" (alternatively called Pattern, Measure, Form, *wazn* or *binyan*). This idea was famously formalized by McCarthy (1979, 1981), who divided the Semitic verb into three "planes" or "tiers": the CV skeleton (slots for consonant and vowels), the root (consonants) and the melody (individual vowels and inflectional information). For example, *takattab* was analyzed as in (1a), with a default verbal vowel *-a-* (McCarthy 1981:392). By including the vocalism on a separate tier, McCarthy's theory allowed vowels to be manipulated independently of the roots or the skeleton. In (1b), the melody *u-a-i* was taken to derive the active participle (McCarthy 1981:401). This theory allowed for an elegant separation of three morphological elements on three phonological tiers. In contrast, the term "template" is used in the current paper in a descriptive sense, referring to morphophonological patterns such as "CaCaCCaC" without treating them as morphological primitives.

(1) a. *takattab*: b. *mutakaatib*:

Yet the nature of the CV skeleton and the melody has never been fully understood. The differences between templates are not purely phonological; rather, each template is associated with certain semantics – alternations in argument structure. McCarthy's work, as well as work inspired by it, leaves us in prime position to ask what the morphosyntax behind the different forms is, and how it translates into templatic *effects*.

My answers to these questions lead me to make different assumptions than McCarthy. Like in his theory, I too believe that the consonantal root lies at the core of the Semitic lexicon. Unlike in his theory, I do not postulate independent CV skeletons and do not accord the prosody morphemic status. The skeletons are a by-product of how functional heads are pronounced and regulated by the phonology of the language. There is no skeleton CVCVCCVC yielding *takattab* as in (1a), for example: there would be a prefix *ta-*, a number of vowels spelling out Voice, gemination spelling out an additional head, and the organization of these segments will proceed in a way that satisfies the phonology without making reference to prosodic primitives.

The data in this paper are drawn from the seven verbal templates of Modern Hebrew, allowing us to make a direct comparison with a competing theory of non-concatenative morphology. According to what I call the *stem-based approach*, there is no morphemic consonantal root at the base of the derivation (Bat-El 1994; Ussishkin 2005). Instead, forms are derived from one another via output-output correspondence, with markedness regulating the phonological system as a whole. On that view the consonantal root is epiphenomenal, a "residue".

Support for my own view is given by going beyond citation forms, considering all parts of the morphological system across tenses, agreement features, templates and root classes. The current analysis also predicts where syncretism arises, as certain structural configurations do not allow for allomorphic interactions between elements. Previous accounts overgenerate forms across different tense features and are not able to account for the syntactic and semantic characteristics of different templates. In terms of competing hypotheses, this paper claims that neither the tier-based proposal nor the stem-based approach are correct. The proper treatment of Semitic morphology requires recourse to a morphemic root and a number of functional heads, whose composition with the root derives the templatic effects both in the syntax-semantics and in the phonology.

As a consequence of this approach, Semitic differs from other language families not in the design of what morphemes are like (there are no independent syntactic-semantic-phonological templates) but in generalizations about what the morphophonology of individual elements is like: a root is triconsonantal, for example, and a functional head might be spelled out as a prefix and an infix. In terms of appeal beyond Semitic, the current study thus demonstrates that a cyclic, syntax-based approach to morphology with rigid locality constraints is well suited not only to languages with concatenative morphology but to templatic morphology of the Semitic kind as well. Under this view, the syntax is rigid but lexical roots provide the locus of exceptionality, both in the semantics and in the phonology. The emerging picture is one in which the syntax generates structure which is then interpreted at the interfaces as long as it satisfies idiosyncratic requirements of individual roots.

The paper is organized as follows. Section 2 introduces the basics of the Hebrew verbal system, outlining what is constant and what varies from root to root and from template to template. Section 3 develops a theory of the Hebrew verb in Distributed Morphology (Halle and Marantz 1993). Here the templatic effects will emerge as the result of spelling out functional heads which themselves are necessary for the syntactic work done by each template. Section 4 tests the predictions made by this theory for cases of syncretism between affixes. Sections 5 and 6 compare this account with the stem-based approach and with a recent root-based approach. Section 7 concludes with a number of topics for further research, including surface forms, underlying representations, and how these might be learned.

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2 Roots, templates and alternations

Modern Hebrew makes use of seven distinct morphophonological verbal forms in which a given root may or may not be instantiated. The argument structure alternations can be straightforward, as in (2), or more opaque, as in (3). Not all roots instantiate all seven templates; I begin here with a subset of four verbal templates out of the seven. X, Y and Z are placeholders for the root consonants. The non-syllabic diacritic Y̯ marks a consonant which does not spirantize, an issue that is explored further in Sect. 3.3. The template *heXYiZ* usually appears in the literature as *hi̱XYiZ*, with the first vowel an /i/, reflecting older usage; nothing hinges on this distinction.

(2) Some forms for $\sqrt{\text{ktb}}$, generally associated with writing.

	Template	Verb	Gloss	Note
a.	*XaYaZ*	katav	'wrote'	unmarked/transitive
b.	*niXYaZ*	nixtav	'was written'	anticausative of *XaYaZ* (2a)
c.	*heXYiZ*	hextiv	'dictated'	causative of *XaYaZ* (2a)
d.	*huXYaZ*	huxtav	'was dictated'	passive of *heXYiZ* (2c)

(3) Some forms for $\sqrt{\text{pk̯d}}$, generally associated with surveying or commanding.

	Template	Verb	Gloss	Note
a.	*XaYaZ*	pakad	'ordered'	
b.	*niXYaZ*	nifkad	'was absent'	not an anticausative of *XaYaZ* (3a)
c.	*heXYiZ*	hefkid	'deposited'	not a causative of *XaYaZ* (3a)
d.	*huXYaZ*	hufkad	'was deposited'	

It can already be seen that there are some regularities and some irregularities to the system. Roots usually have one overarching semantic field but the relation between forms is not necessarily transparent: *writing* and *dictating* are similar, but *ordering* and *depositing* much less so. Similarly with respect to the templates, some participate in predictable argument structure alternations (*huXYaZ* is always a passivized version of *heXYiZ*) but at other times the semantic contribution of a given template is much harder to pin down (Doron 2003; Arad 2005).

In order to understand how these forms are generated we will need to distinguish between what is lexically specified (crucially depends on the root) and what must be the same across the paradigm (underspecified and can be filled in by the grammar). I begin by examining the Hebrew data more closely.

2.1 Hebrew preliminaries

The consonantal inventory of Modern Hebrew is given in Table 1, where the highlighted segments are those that undergo spirantization to their fricative counterparts. Segments in parentheses are either limited to loanwords (ʧ, ʤ, ʒ) or are slowly disappearing (ʔ, h).[1] I transcribe /ɡ/ as "g", /χ/ as "x" and /ʁ/ as "r". Syncopated vowels are marked in this paper with angled brackets, *hal<a>xá* [halxá]. Acute accents are used to mark stress.

	Labial	Dental	Alveolar	Palato-alveolar	Palatal	Velar	Uvular	Glottal
Stop	p b	t d				k		(ʔ)
Nasal	m	n						
Fricative	f v		s z	ʃ (ʒ)			χ ʁ	(h)
Affricate			ts	(ʧ) (ʤ)				
Approximant	w		l		j	w		

Table 1: The consonantal inventory of Modern Hebrew. Spirantizing segments are highlighted, marginal segmentes are in parentheses.

A process of spirantization causes the stops /p/, /b/ and /k/ to undergo lenition to [f], [v] and [x] following a vowel. The examples in (4a–c) show a few regular verbs in *XaYaZ* and their future forms. The examples in (4d–f) demonstrate a number of roots with spirantizing stops. Underlying /k̯/ never spirantizes to [x], unlike /k/.

(4) Spirantization and tense alternations:

	Root		Past 3SG.M	Future 3SG.M
a.	'light'	√dlk̯	dalak	ji-dlok (*ji-zlok)
b.	'steal'	√gnv	ganav	ji-gnov (*ji-ɣnov)
c.	'pull'	√mʃx	maʃax	ji-mʃox (*ji-vʃox)
d.	'cancel'	√**b**tl	**b**itel	je-**v**atel
e.	'meet'	√**p**gʃ	**p**agaʃ	ji-**f**goʃ
f.	'write'	√**k**t**b**	**k**ata**v**	ji-**x**to**v**

This process will be returned to in Sect. 3.3. We will now see how the standard picture in (4) is marred by the rest of the language: first roots, then templates.

2.2 Lexical exceptionality in root classes

The verbal morphophonology of Hebrew is fairly uniform once a template is specified: most roots enter into a predictable alternation in a given template. For example, the "simple" template *XaYaZ* forms past tense 3SG.M verbs as *XaYaZ* and future ones as *jiXYoZ*. Some examples were seen in (4a–c) and a few more are given in (5).

[1] The /h/ is still pronounced by some older speakers and certain sociolinguistic groups, especially marginalized ones (Schwarzwald 1981; Gafter 2014).

(5) Some regular roots in *XaYaZ*:

Root			Past 3SG.M *XaYaZ*	Future 3SG.M *jiXYoZ*
a.	‘write’	√ktb	katav	jixtov
b.	‘wash’	√ʃtf	ʃataf	jiʃtof
c.	‘break’	√ʃbr	ʃavar	jiʃbor

This section discusses lexical exceptions: roots which disrupt the regularity of paradigms like (5). Semitic roots are traditionally classified into different classes defined by their hypothesized underlying consonantal representations: /j/-final √XYj, /ʔ/-final √XYʔ, /n/-initial √nYZ, geminated/spread √XYY, and so on. In this sense, root classes are similar to the conjugation classes of many European languages. In each class, the forms of verbs in some tenses may be different than in regular roots such as those in (5). Within a given template and tense, these differences mostly include changes to the *stem vowels* which slot between and around the root consonants. A recent formalization of the division to classes can be found in Faust (2016).

(6) Some irregular roots in *XaYaZ* by root class with predictable alternations:

Class	Root			Past 3SG.M		Future 3SG.M	
/j/-final √XYj	a.	‘happen’	√k̭rj	kara̲	(*karaj̲)	jikre̲	(*jikroj)
	b.	‘want’	√rtsj	ratsa̲	(*ratsaj̲)	jirtse̲	(*jirtsoj)
	c.	‘buy’	√k̭nj	kana̲	(*kanaj̲)	jikne̲	(*jiknoj)
/ʔ/-final √XYʔ	d.	‘freeze’	√k̭pʔ	kafa̲	(*kafaʔ̲)	jikpa̲	(*jikpoʔ)
	e.	‘read’	√k̭rʔ	kara̲	(*karaʔ̲)	jikra̲	(*jikroʔ)
/w/-medial √XwZ	f.	‘reside’	√g̭wr	gar	(*gaw̲ar)	jagu̲r	(*jigwor)
	g.	‘get up’	√k̭wm	kam	(*kaw̲am)	jaku̲m	(*jikwom)

Later on, in Sect. 7.1, I will revisit the question of whether it is accurate to speak of underlying consonants or whether we should only discuss surface forms. For the meantime, certain underlying consonants can be seen in other forms. For example, the action nominal of *XaYaZ* is in the pattern *XYiZa*. The root-final /j/ of √k̭nj from (6c) and the /ʔ/ of √k̭pʔ from (6d) do not surface in the past or future but do surface in the action nominal, (7). Modern usage often omits the glottal stop, as noted earlier.

(7) Hypothesized root consonants appear in other forms instantiating the same root:

	Root	Past 3SG.M	Action nominal
a.	√ʃbr̲	ʃavar̲	ʃvir̲a ‘breaking’
b.	√k̭nj̲	kana	knij̲a ‘buying’
c.	√k̭pʔ̲	kafa	kfiʔ̲a ‘freezing’

Some classes do not show predictable alternations like those in (6), as can be seen from the idiosyncratic forms in (8). There are also root-specific exceptions, (9).

(8) Some /n/-initial roots in *XaYaZ*, √nYZ, without predictable alternations:

Class	Root			Past 3SG.M	Future 3SG.M	
/n/-initial √nYZ	a.	‘fall’	√npl	nafal	jip̲ol	(*jinpol)
	b.	‘give’	√ntn	natan	jit̲en	(*jinton)
	c.	‘avenge’	√nk̭m	nakam	jinkom	
	b.	‘drip’	√nzl	nazal	jiz̲ol/jinzol/jizal̲	

(9) Other idiosyncratic exceptions in *XaYaZ*:

Class		Root		Past 3SG.M	Future 3SG.M	
Various exceptions	a.	'lie down'	√ʃkb	ʃaxav	jiʃkav	(*jiʃkov)
	b.	'wear'	√lbʃ	lavaʃ	jilbaʃ	(*jilboʃ)
	c.	'learn'	√lmd	lamad	jilmad	(*jilmod)
	d.	'whisper'	√lxʃ	laxaʃ	jilxaʃ	(*jilxoʃ)
	e.	'take'	√lk̯x	lakax	jikax	(*jilkox)
	f.	'travel'	√nsa	nasa	jisa, jinsa	(*jinso)
	g.	'ride'	√rkb	raxav	jirkav	(*jirkov)

It is difficult to estimate what proportion verbs such as those in (6)–(9) make up out of the entire language since the existing corpora do not have the fine-grained annotation which would make such a search immediately straightforward. Yet these forms are frequent and at least some root classes show productive alternations in nonce words (Moore-Cantwell 2013; Asherov and Bat-El 2016).

Similar effects arise in other templates, for instance in *XiY̯eZ*.

(10) A regular and irregular root in *XiY̯eZ*:

Class		Root		Past 3SG.M	Future 3SG.M
Regular √XYZ	a.	'complicate'	√sbx	sibex	jesabex
Doubled √XYY	b.	'spin'	√svv	sovev	jesovev

In all these cases, the alternations are due to idiosyncratic requirements of specific lexical items (roots) and are not the result of predictable, phonologically-conditioned processes (Faust 2012). For example, future *jikre* 'will happen' is derived from √kr̯j in *XaYaZ*, as can be gleaned from nominal forms such as *karjan* 'news anchor'. The regular form would have been **jikroj*, (6a–c). The process giving *jikre* instead is relativized to √XYj, not a general rule which turns /oj/ into [e].

(11) No general rule of Hebrew */oj/ → [e]:

a.	/ojev/	'enemy'	→	[o.jev]	(*eev)
b.	/avoj/	'woe! (interjection)'	→	[a.voj]	(*ave)
c.	/oj/	'oi! (interjection)'	→	[oj]	(*e)

To summarize the first set of examples, Hebrew roots can alter the vowels of the verbal stem and even elide segments in ways which are often systematic, but not entirely so. One question is to what extent lexical exceptionality is maintained across templates and when do templates ignore lexical idiosyncrasies. In order to approach this topic we will need a theory of how the verbal forms are derived.

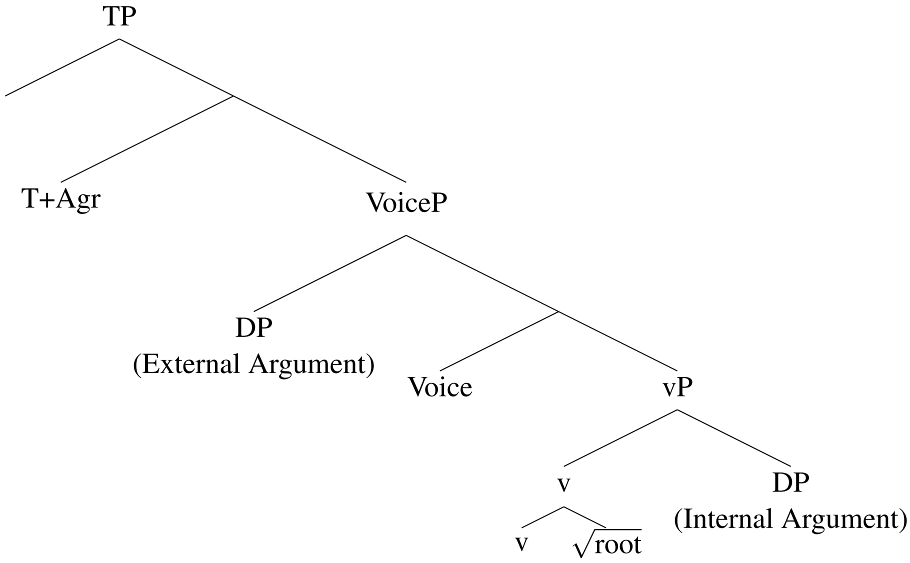
2.3 Alternations by template

This paper implements a version of Distributed Morphology (Halle and Marantz 1993) in which abstract roots and functional syntactic heads are part of the syntactic derivation; there is no separate morphological component to the grammar (Embick 2015). The syntactic structure is derived as is commonly assumed, phase by phase (Chomsky 1995, 2001), and sent off for interpretation at the interfaces with the phonology and the semantics. Upon interpretation in the phonological component (Spell-Out), abstract morphemes are replaced with phonologically contentful Vocabulary Items via a process of Vocabulary Insertion.

We are interested in the difference between roots and functional morphemes as a way of getting at the loci of idiosyncrasy and systematicity in the grammar. The root is an acategorial morpheme: the verb *walk*, for example, consists under these assumptions of a root √WALK adjoined to a verbalizing categorizer, little v. There are three such categorizers: a, n, and v, which serve to categorize roots as adjectives, nouns or verbs (Marantz 2001; Arad 2003, 2005; Wood and Marantz To appear). I make no distinction between the Semitic consonantal root and the abstract root of Distributed Morphology since I take the two to be one and the same. This is a main point of contention in the debate between the syntactic, root-based approach and the lexicalist, stem-based approach of Sect. 5 (Aronoff 1994; Bat-El 1994; Ussishkin 2005): on the stem-based approach there are no roots, be they abstract or consonantal.

The functional head v introduces an event variable and categorizes a root as a verb. The internal argument (object) is the complement of v. A higher functional head, Voice, introduces the external argument (Kratzer 1996; Pylkkänen 2008; Marantz 2013b). T is the locus of tense and agreement features, postsyntactically yielding two exponents, T and Agr. A basic structure is given in (12).

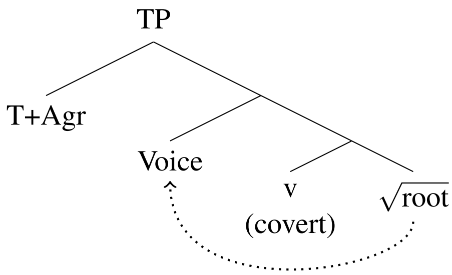
(12) Basic structure of a TP:



In order to derive the full range of templates in Hebrew, a few variants of these heads are also necessary. In general, morphemes affecting transitivity are variants of Voice (Alexiadou and Doron 2012; Doron 2013). Functional heads in Hebrew will be introduced as we proceed; each is meant to capture specific syntactic-semantic behavior. An explicit discussion of their syntax and semantics is given in Kastner (2016a).

Let us see how this works by analyzing an alternation such as *katav* 'wrote' ∼ *jixtov* 'will write' in *XaYaZ*. A simplified structure is given in (13), leaving out the internal and external arguments. To recap, little v is a categorizing head, verbalizing an acategorial root. Voice is the standard head that introduces an external argument. The dotted arrow should be read as "conditions allomorphy on".

(13) Simplified structure of a TP:



On my analysis, little v is phonologically null in Hebrew (by hypothesis). Hebrew stem vowels originate on Voice. Contextual allomorphy of Voice is conditioned by the identity of the root. The two, Voice and the root, are in a local relationship after Spell-Out since v is silent: the sequence is linearized as Voice-v-$\sqrt{\text{root}}$, at which point silent elements like v are removed ("Pruning", Embick 2010). Since Voice and $\sqrt{\text{root}}$ are now linearly adjacent, the latter can condition allomorphy on the former. In Sect. 4 I explain further how this theory of allomorphy requires linear adjacency between the allomorphic trigger and target.

Following ideas first made explicit by McCarthy (1981), I assume that the stem vowels are spelled out as unmarked *a-á* in the past tense of *XaYaZ*. In the future only one vowel is inserted, *ó*. Vocabulary Insertion proceeds "inside-out" from the most deeply embedded element, typically the root (Bobaljik 2000, 2012; Marantz 2013a). Vocabulary Items (lexical entries) are given in (14). Past and future forms are derived from the root. The stem-based approach contrasted in Sect. 5 would generate these verbs differently, deriving the future form from the past tense form.

(14) Vocabulary Items for:
$\sqrt{\text{XYZ}}$ *katav* 'wrote' ∼ *jixtov* 'will write'
$\sqrt{\text{XYj}}$ *kara* 'happened' ∼ *jikre* 'will happen'
$\sqrt{\text{XYʔ}}$ *kafa* 'froze' ∼ *jikpa* 'will freeze'.

a. $\sqrt{\text{XYZ}} \leftrightarrow$ *XYZ*

b. $\sqrt{\text{XYj}} \leftrightarrow$ *XYe* / T[Fut] ___

c. $\sqrt{\text{XYʔ}} \leftrightarrow$ *XYa* / T[Fut] ___

d. v ↔ (silent)

e. $$\text{Voice} \leftrightarrow \begin{cases} \textit{a,á} & \text{/ T[Past] \_\_\_} \\ \textit{-ó-} & \text{/ T[Fut] \_\_\_} \\ \text{(silent)} & \text{/ T[Fut] \_\_\_ } \sqrt{\text{XYj}} \\ \text{(silent)} & \text{/ T[Fut] \_\_\_ } \sqrt{\text{XYʔ}} \\ \ldots & \end{cases}$$

f. T[Fut] ↔ *ji-* / ___ Voice

This analysis does not attempt to give a reason for why there are two vowels in the past tense and only one in the future tense. I also assume that affixes may bear stress underlyingly; for in-depth discussions of the intricacies of Hebrew stress, especially in the nominal domain, see Graf and Ussishkin (2002), Becker (2003), Bat-El (1993, 2008) and Ussishkin (2005).

In what follows I combine these kinds of Vocabulary Items in an Optimality Theoretic grammar (Prince and Smolensky 1993/2004). Table 2 summarizes the contribution of the different morphemes that will be used in this paper. Empty cells are underspecified and "EA" stands for obligatory external argument. For full justification see Kastner (2016a); the seven templates can be seen under the column marked "Phonology".

Heads			Syntax	Semantics	Phonology	Sect.
	Voice				*XaYaZ*	3
	Voice	$\sqrt{\text{ACTION}}$		**Agentive**	*XiY̯eZ*	3.3.2
Pass	Voice	$\sqrt{\text{ACTION}}$	*Passive*	**Agentive**	*XuY̯aZ*	4.3
	Voice$_{\{D\}}$		EA		*he-XYiZ*	3.1.2
Pass	Voice$_{\{D\}}$		*Passive*		*hu-XYaZ*	4.3
	Voice$_{\varnothing}$		No EA		*ni-XYaZ*	4.5
	Voice$_{\varnothing}$	$\sqrt{\text{ACTION}}$	No EA	**Agentive**	*hit-XaY̯eZ*	4.5

Table 2: The requirements of functional heads in the Hebrew verb.

In essence, the stem vowels are treated as contextually conditioned segments hosted on the Voice head. That is to say, the vowels can be seen either as a spell-out of Voice or as a spell-out of a Theme head adjoined to Voice post-syntactically, as in Oltra Massuet (1999) and Embick (2010). At this point I see no difference emerging between the two possibilities and will treat the vowels as exponents of Voice for simplicity. The upshot of this configuration is that the root can determine the choice of theme vowels. I next explain how tense and agreement information interact with the root, deriving the templatic effects explicitly.

3 Deriving the morphophonological alternations

Let us see a simple case of spirantization in action before we begin inflecting our verbs for tense and agreement. The linearized structure is T[Past]-Voice-v-$\sqrt{\text{spr}}$.

(15) *safár* 'counted':

a. Voice ↔ *a,á* / T[Past] ___

b. v ↔ (silent)

c. $\sqrt{\text{spr}}$ ↔ *spr*

For the phonological component of the grammar, a subset of the constraints used by Temkin Martínez (2010) in her treatment of Hebrew will be adopted:

(16) a. ***V-STOP**: Postvocalic stops are prohibited.
Assign a violation mark for every stop preceded by a vowel.

b. **IDENT(CONT)**: Input-output correspondents are identical in [cont].
Assign a violation mark for every segment in the input whose output correspondent differs in its value for [cont].

To these I add:

(17) a. ***COMPLEX** (Prince and Smolensky 1993/2004): No complex coda clusters.
Assign a violation mark for every consonant followed by another consonant syllable-finally, $*\text{CC}]_\sigma$.

b. **STRESS-TO-WEIGHT PRINCIPLE (SWP)** (Prince 1990:358): If stressed, then heavy.
Assign a violation mark for every monomoraic stressed syllable, $*\text{C}\acute{\text{V}}]_\sigma$.

c. **IDENT(FORTIS)**: Input-output correspondents are identical in [cont] for input segments marked by the diacritic C̯.
Assign a violation mark for every segment in the input with the diacritic C̯ whose output correspondent differs in its value for [cont].

Lexical items are concatenated according to the structure: outer elements are linearized to the left. The tableau in (18) shows two processes applying at once: postvocalic spirantization, (18b–c), and insertion of the stem vowels. The overall rarity of coda clusters in Hebrew is accounted for by *COMPLEX, here ruling out (18a); I set aside clusters licensed by sonority rises. The ranking ID(FORTIS) ≫ *V-STOP will account for the difference between roots that spirantize and those that do not when these are returned to in Sect. 3.3.2.

(18) [T[Past] [Voice [v $\sqrt{\text{spr}}$]]] 'counted':

a,á-$\sqrt{\text{spr}}$	*COMPLEX	ID(FORTIS)	*V-STOP	SWP	ID(CONT)
a. aáspr	*!				
☞ b. safár					*
c. sapár			*!		
d. safrá				*!	*

Next, in Section 3.1 I go beyond the citation form (3rd person masculine singular past tense) and show how agreement morphology is captured in this system, extending the discussion to additional templates. Section 3.2 reintroduces root exceptionality, deriving the correct forms across roots, tenses, templates and agreement features. Section 3.3 reintroduces spirantization.

3.1 Tense and agreement

This section fleshes out how in the same template, different combinations of stem vowels arise depending on tense and agreement. In anticipation of some confounding issues, I will first of all explain the cyclic "inside-out" derivation and the process of syncope.

3.1.1 Affixes and syncope

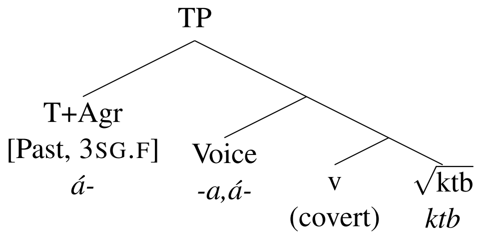
Some affixes bear underlying stress; when they attach to the stem, its previously stressed vowel syncopates. See the 3SG.F, 3PL.M and 3PL.F forms in (19).

(19) Past tense *a,á* for *katáv* 'wrote':

	XaYaZ $\sqrt{\text{ktb}}$	
	SG	PL
1	katáv-ti	katáv-nu
2M	katáv-ta	katáv-tem
2F	katáv-t	katáv-tem
3M	katáv	kat<á>v-ú
3F	kat<á>v-á	kat<á>v-ú

The structure for *katvá* 'she wrote' is as in (20). Vocabulary Insertion and phonological calculation apply incrementally.

(20) *katvá* 'she wrote':



Spell-out proceeds cyclically (Bobaljik 2000; McCarthy 2007, 2008a,b; Wolf 2008): first Voice and v combine with $\sqrt{\text{ktb}}$ to give *katáv*, then the agreement suffix attaches. Phonologically silent v is ignored: T[Past, 3SG.F]-Voice-$\sqrt{\text{ktb}}$, *katvá* 'she wrote'.

(21) a. $\sqrt{\text{ktb}}$ ↔ *ktb*

b. Voice ↔ *a,á* / T[Past] ___

c. *a,á-ktb*

d. At this point the phonology would yield:
⇒ *katáv*. See (18) for a similar derivation.

e. T[Past, 3SG.F]-*katáv*

f. 3SG.F ↔ *á* / Past ___

g. *á-katáv*

h. Phonology yields:
⇒ *katvá*. See (23) for the derivation.

This framework is similar to Optimality Theory with Optimal Interleaving (Wolf 2008) in that morphemes are inserted and evaluated sequentially. However, unlike OT-OI, there is no need for PRECEDENCE constraints to help regulate the phonology of different morphemes: the order is read directly off the tree, inviolably inside-out. The theories are similar in assuming spell-out from the root outwards (Wolf 2008:160) and in rejecting whole-phase spell-out (Wolf 2008:418). In contrast, though, my cycles proceed according to the syntactic structure which also feeds semantic interpretation.

The constraints in (22) and the tableau in (23) illustrate how syncope arises when a stressed vowel loses its stress to a stressed affix.

(22) a. **IDENT(STRESS)**: Input-output correspondents are identical in [stress].
Assign a violation mark for every stressed segment in the input which has an output correspondent that is not stressed.
Let S be a segment, I the input, O the output and $\mathfrak{R}$ a correspondence relation: $\forall$ S $\in$ I [$\exists$ S' $\in$ O & S $\mathfrak{R}$ S' $\rightarrow$ [Ś $\rightarrow$ Ś']]

b. **IDENT(STRESS)-AFFIX**: Input-output correspondents are identical in [stress] for affixes.
Assign a violation mark for every stressed affix in the input which has an output correspondent that is not stressed.

c. **MAX**: Do not delete segments.
Assign a violation mark for every segment in the input that does not have a correspondent in the output.

The ranking ID(V́)-AFF ≫ ID(V́), MAX syncopates de-stressed vowels.

(23) [T[3SG.F] *katáv*] 'she wrote':

	$á_{3SG.F}$ + katáv	*COMPLEX	ID(V́)-AFF	ID(V́)	MAX
	a. ákatav			*!	
☞	b. katvá				*
	c. ákatv	*!			*
	d. katavá			*!	
	e. katáva		*!	*	

I assume an undominated constraint banning multiple stressed syllables in a single word. The affix *á* is not able to attach as a prefix for general phonological reasons, (23a,c). Previous analysis assumed that syncope is the result of a specific constraint or constraints limiting the stem to one binary foot (Adam 2002; Bat-El 2003; Ussishkin 2005). The same result can be achieved with general constraints like *COMPLEX, as shown by Wallace (2013) for Arabic and as practiced here.

I should emphasize the crucial work done by IDENT(STRESS): the winning candidate, (23b), does not violate this constraint because under the formulation used here, a deleted vowel does not violate the I-O correspondence in the output. What this technical solution implements is the relationship between stress and syncope: syncope in verbal forms applies to underlyingly stressed vowels.

With this interlude for syncope out of the way we return to the main phenomenon: templatic effects in the morphophonology across morphosyntactic features.

3.1.2 Beyond citation forms

We are asking how best to account for the alternations that make up the verbal system of Hebrew. So far we have seen the basics of how the root interacts with functional heads to produce templatic effects. I will now demonstrate how this theory accounts for the behavior of different agreement features, mounting an argument against independent templates.

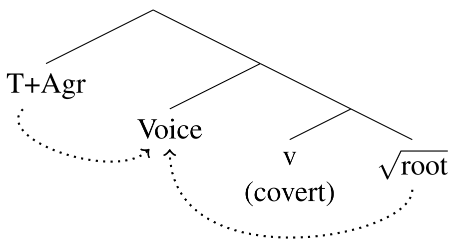
The stem vowels in (19) above are invariant: *a,á*. But in the three templates *XiY̯eZ*, *hitXaY̯eZ* and *heXYiZ*, the past tense vowels are determined by the subject's phi-features, depending on whether the subject is 1st/2nd person or 3rd person. The paradigms in (24) use $\sqrt{\text{bʃl}}$. In *XiY̯eZ* ('cooked') and *hitXaY̯eZ* ('got cooked'), 1st/2nd person have /a/ as the second vowel and 3rd person has /e/ (though this is only visible for 3SG.M). In *heXYiZ* ('ripened'), 3rd person has /i/. Boldfaced vowels show the difference in agreement: /a/ above the line (1st and 2nd person), /e/ or /i/ below it (3rd person). There are thus different vowels for different values of T.

(24) Past tense, vowels alternate:

	XiYeZ √bʃl		*hitXaYeZ* √bʃl		*heXYiZ* √bʃl	
	SG	PL	SG	PL	SG	PL
1	biʃál-ti	biʃál-nu	hitbaʃál-ti	hitbaʃál-nu	hevʃál-ti	hevʃál-nu
2M	biʃál-ta	biʃál-tem	hitbaʃál-ta	hitbaʃál-tem	hevʃál-ta	hevʃál-tem
2F	biʃál-t	biʃál-tem	hitbaʃál-t	hitbaʃál-tem	hevʃál-t	hevʃál-tem
3M	biʃ**é**l	biʃ<**é**>l-ú	hitbaʃ**é**l	hitbaʃ<**é**>l-ú	hevʃ**í**l	hevʃ**í**l-u
3F	biʃ<**é**>l-á	biʃ<**é**>l-ú	hitbaʃ<**é**>l-á	hitbaʃ<**é**>l-ú	hevʃ**í**l-a	hevʃ**í**l-u

Vowels are treated here as the spell-out of Voice. Since Voice is local to T+Agr, T+Agr can condition allomorphy of the vowels. This conditioning is symbolized by the higher dotted arrow in (25). The lower dotted arrow was already introduced in (13) to signal that the root can condition allomorphy (vowels) on Voice. As a result, different phi-feature values condition different stem vowels as in (24).

(25)



To derive a verb like *hevʃálti* 'I ripened' in *heXYiZ*, assume that the derivation might contain a special Voice head, $\text{Voice}_{\{D\}}$. This is Voice with a [+D] feature, requiring a DP in Spec,VoiceP. When this head is part of the syntactic structure, verbs are predicted to be either unergative (if there is no internal argument) or transitive. The head guarantees that there is an external argument; verbs in this template are productively causative. For example, *hevʃil* 'ripened' is traditionally an inchoative verb but can be used causatively as well:

(26) *ha-ʃemeʃ ha-xazaka ʃel xodeʃ september* ***hevʃila*** *et ha-anavim be-pitomiut*
the-sun the-strong of month September **ripened** ACC the-grapes in-suddenness
'The strong September sun suddenly caused the grapes to ripen.'[2]

See Doron (2003) and Kastner (2016a) for additional discussion of the morphosemantics of *heXYiZ*. The derivation proceeds along the lines of (27)–(28).

(27) *heXYiZ*: *hevʃál-ti* 1SG.PAST ∼ *hevʃíl-a* 2SG.F.PAST

a. $\text{Voice}_{\{D\}} \leftrightarrow$ *he-*, $\begin{cases} \textit{-í-} \\ \textit{-á-} \quad / \text{T[1st]} \_\_ \end{cases}$

b. T[Past, 1st] ↔ *-ti*

c. T[Past, 2nd] ↔ *-a* / ___ $\text{Voice}_{\{D\}}$

d. √bʃl ↔ *bʃl*

(28) a. *hevʃ**á**lti* 'I ripened': [T[Past,1SG] [$\text{Voice}_{\{D\}}$ [v √bʃl]]]
Cycle 1 (VoiceP): he-vʃál
Cycle 2 (TP): hevʃál-ti

b. *hevʃ**í**la* 'she ripened': [T[Past,3SG.F] [$\text{Voice}_{\{D\}}$ [v √bʃl]]]
Cycle 1 (VoiceP): he-vʃíl
Cycle 2 (TP): hevʃíl-a

[2] http://goo.gl/X9s7h0 (retrieved August 2016).

I have no principled reason, however, for why the 1st and 2nd person vs 3rd person split happens in the past tense but not in the future. The contrast might have to do with the future being built on a more "general" nonpast form, since the same stem of the future is used for infinitives, participles and imperatives.

The current theory has derived its first generalizations by making use of the underlying syntactic structure: Voice spells out theme vowels that may be conditioned by the root and by T+Agr under linear adjacency. Returning to lexical exceptionality, the next section explores how the root conditions Voice.

3.2 Vowels conditioned by T+Agr and the root

The lower of the two arrows in (25) reminds us of the prediction that stem vowels can be conditioned by the identity of the root, since Voice and the root are adjacent over silent v; this is exactly what we have already seen in Sect. 2.2. The Vocabulary Insertion rules in (29) are repeated from above.

(29) a. $\sqrt{\text{XYj}} \leftrightarrow$ *XYe* / T[Fut] ___ (14b)

b. Voice $\leftrightarrow$ (silent) / T[Fut] ___ $\sqrt{\text{XYj}}$ (14e)

As an example of a verb in the class $\sqrt{\text{XYj}}$ take *jikre* 'will happen'. On the first cycle (VoiceP), the rules in (29) insert *kré* as the form of [Voice [v $\sqrt{\text{k̭rj}}$]]. On the second cycle, the 3SG.M prefix *ji*—which is generated on T, above VoiceP—is added. No noteworthy constraints are at play here so I give the simple concatenation:

(30) /ji-k̭ré/ → [jikré] 'will happen'

The templatic effect which could be described as "CaCaC$_{\text{past-I}}$ → jiCCeC$_{\text{future-I}}$" is thus achieved without dedicated templates.

The combination of both arrows in (25) further predicts that the separate conditioning for T+Agr on the one hand and for the root on the other hand may interact. This is correct: for a /j/-final root like $\sqrt{\text{lvj}}$, the vowels in *helva* 'lent' are different than for a regular root like $\sqrt{\text{bʃl}}$. In (31), the regular root is on the left ('ripened') and the /j/-final root on the right. Underlined vowels are due to the root class and boldfaced ones are due to agreement. The derivation is sketched in (32).

(31) Past tense for two roots in *heXYiZ*:

	heXYiZ $\sqrt{\text{bʃl}}$		*heXYiZ* $\sqrt{\text{lvj}}$	
	SG	PL	SG	PL
1	hevʃ**á**l-ti	hevʃ**á**l-nu	helv**é**-ti	helv**é**-nu
2M	hevʃ**á**l-ta	hevʃ**á**l-tem	helv**é**-ta	helv**é**-tem
2F	hevʃ**á**l-t	hevʃ**á**l-tem	helv**é**-t	helv**é**-tem
3M	hevʃ**í**l	hevʃ**í**l-u	helv**á**	helv<**á**>-ú
3F	hevʃ**í**l-a	hevʃ**í**l-u	helv<**á**>e-tá	helv<**á**>-ú

(32) *heXYiZ*: *hevʃal-ti* 'I ripened' ~ *helve-ti* 'I lent'

a. $\text{Voice}_{\{D\}} \leftrightarrow$ *he-*, $\begin{cases} \textit{-á-} & / \text{ T[1st] \_\_\_} \\ \textit{-í-} & \end{cases}$

b. $\sqrt{\text{bʃl}} \leftrightarrow$ *bʃl*

c. $\sqrt{\text{lvj}} \leftrightarrow$ *lve* / $\text{Voice}_{\{D\}}$ ___

d. T[Past, 1st] $\leftrightarrow$ *-ti*

e. 3F.SG Past $\leftrightarrow$ $\begin{cases} -\textit{tá} & / \text{ V \_\_\_} \\ -\textit{a} & / \text{ \_\_\_ Voice}_{\{D\}} \\ -\textit{á} & \end{cases}$

Here is what I mean when I say that templates are *emergent* under this theory. Concatenation of the relevant exponents results in the verbal forms typical of the template we descriptively call *heXYiZ*, but there is no primitive *heXYiZ* to speak of. What we have is a syntactic head, in this case $\text{Voice}_{\{D\}}$, which is spelled out as a prefix and a stem vowel, (32a). Prosodic organization is the purview of the phonology: it ensures that verbal forms do not become arbitrarily long, for example, or do not have triconsonantal clusters. It is true that the language in general does not have any roots made up of a dozen consonants; but there is no CVCCVC skeleton that requires consonants and vowels to be filled in.

One loose end in (31) remains to be tied up. It can be seen that 3SG.F *helvetá* has the same vowel as the 1st/2nd forms, /e/, and not /a/ as in 3SG.M *helvá*. This surface similarity is due to the interaction of two separate processes: syncope of underlying *á* and epenthesis to repair an illegal cluster. As pointed out in Sect. 3.1.1, a stressed affix causes a stressed stem vowel to syncopate: *helv<á>-tá*. However, now an illegal cluster emerges, **hel**vt**á*. This state of affairs is repaired by an epenthetic *-e-*, yielding *helv<á>etá*. This process is regular, as can be verified by considering (33), where a regular root derives *jilbeʃú* ‘they will wear’ in *XaYaZ*.

(33) [T[3PL.M.Fut] [Voice [v √lbʃ]]] ‘they will wear’:[3]

ji-ú- + lbáʃ	*COMPLEX	ID(V́)-AFF	ID(V́)	MAX	DEP
a. jilbaʃú			*!		
☞ b. jilbeʃú				*	*
c. jilbʃú	*!			*	
d. jilbáʃu		*!			

Here is another example of this interaction, from the *niXYaZ* template in the past tense. When the suffix is stressed as in the 3rd person, deletion of underlying /a/ leads to an illicit cluster **xns*. This cluster is repaired using epenthetic /e/.

(34) Syncope followed by epenthesis in the regular past tense verb ‘entered’:

	niXYaZ √kns	
	SG	PL
1	ni-xnás-ti	ni-xnás-nu
2M	ni-xnás-ta	ni-xnás-tem
2F	ni-xnás-t	ni-xnás-tem
3M	ni-xnás	ni-xn<**á**>**e**s-ú
3F	ni-xn<**á**>**e**s-á	ni-xn<**á**>**e**s-ú

Looking at exceptional root classes, the same pattern as in (31) can be seen for a “doubled” root like √svv. Again the vowels in the root class (*sovev* ‘spun’) are different than in the regular forms (*biʃel* ‘cooked’), depending both on the root and on the combination of T+Agr. Underlined vowels are due to the root class and boldfaced ones are due to agreement.

(35) Past tense for two roots in *XiY̑eZ*:

	XiY̑eZ √bʃl		*XiY̑eZ* √svv	
	SG	PL	SG	PL
1	biʃ**á**l-ti	biʃ**á**l-nu	sov**á**v-ti	sov**á**v-nu
2M	biʃ**á**l-ta	biʃ**á**l-tem	sov**á**v-ta	sov**á**v-tem
2F	biʃ**á**l-t	biʃ**á**l-tem	sov**á**v-t	sov**á**v-tem
3M	biʃ**á**l	biʃ<**é**>l-u	sov**é**v	sov<**é**>ev-ú
3F	biʃ<**é**>l-á	biʃ<**é**>l-ú	sov<**é**>ev-á	sov<**é**>ev-ú

The lesson from structures such as (25) and the data above is that syntactic structure dictates what kind of allomorphy is allowed and what element it is conditioned by. Lexical considerations apply “first” (at Vocabulary Insertion), if the root has exceptional phonology such as that of a specific root class,

[3] Candidate (33c) assumes the prosodification [jilb.ʃu]. An alternative [jil.bʃu] can be ruled out by highly-ranked *CCC.

simply because the root is the deepest embedded element in the structure. Morphologically conditioned allomorphy then applies (additional rules of Vocabulary Insertion), followed by the general phonology of the language.

Root classes are thus similar to the conjugation classes of Romance languages (e.g. Oltra Massuet 1999; Bermúdez-Otero 2013) in that a representative vowel or vowels are chosen by the root, in a way that feeds into the rest of the morphophonological derivation but carries no syntactic or semantic import (see Faust 2012 for a similar analysis of the final /j/ in $\sqrt{\text{XYj}}$ as a class marker). This state of affairs is predicted by our framework: Voice is sensitive to T+Agr and can "see" the features on T while it also "sees" the root. Templates arise as an epiphenomenon.

3.3 Spirantization

I conclude the survey of allomorphic interactions with the postvocalic spirantization of /p/, /b/ and /k/. This lenition of stops to fricatives is modulated by both lexical and grammatical (morphosyntactic) factors. Here, too, we will see how some roots may be idiosyncratic but all are constrained by the structure. Two historic processes have led to the two patterns of exceptions which I single out. First, some stops which were historically "guttural" (uvular and pharyngeal) persist in not alternating with fricatives. Second, in two verbal templates spirantization of the middle consonant is blocked.

3.3.1 Exceptions by root

Some roots are exceptional in that they block postvocalic spirantization. These are cases where /k/ and /x/ were historically part of a phonemic distinction between voiceless pharyngeal /ħ/, voiceless uvular /q/ and voiceless velar /k/, plus an allomorphic distinction between /k/ and /x/ (the latter postvocalically unless geminated). In the historic system /ħ/ and /q/ did not participate in alternations but /k/ spirantized to [x]. These distinctions have been preserved in the orthography.

(36) Synchrony and diachrony in spirantization:

Orthography	Historically	Modern	Alternation
ח	/ħ/	/x/	✗
ק	/q/	/k̯/	✗
כ	/k/∼[x]	/k/∼[x]	✓

Following previous studies on spirantization, I assume that the alternation /k/∼[x] is regular and that non-alternating /k̯/ and /x/ are exceptions to the rule. There is evidence that speakers attempt to reduce spirantization irregularities such as these (Schwarzwald 1981; Adam 2002; Temkin Martínez 2008, 2010). Since my aim here is to point out the lexical exceptionality of individual roots, I will not pursue a more precise description of the empirical landscape. To provide a rough estimate of spirantization patterns: in a corpus of articles from the Hebrew Wikipedia (132,609 articles, over 130M tokens; Itai and Wintner 2008), /k/ appears 88.6 times per article, /k̯/ 70.9 times per article and /x/ 68.8 times per article. The three are roughly on a par.

The system must thus be characterized independently of orthographic aids and diachronic considerations. Consider the three roots in (37). The first is regular, $\sqrt{\text{ktb}}$: in the future tense, its underlying initial /k/ spirantizes postvocalically to [x], as in (37a). The second root, $\sqrt{\text{xnj}}$, has an underlying /x/ and does not undergo fortification to *[k] word-initially in the past tense, (37b) – it was historically $\sqrt{\text{ħnj}}$. The third, $\sqrt{\text{knj}}$, is exceptional: even after a vowel, initial /k̯/ does not spirantize, (37c) – it was historically /qnj/.

(37) Three roots in *XaYaZ*:

	Root		Past 3SG.M	Future 3SG.M
a.	‘write’	√ktb	**k**atav	ji-x̱tov
b.	‘park’	√xnj	x̱ana	ja-x̱ne
c.	‘buy’	√k̑nj	**k**ana	ji-**k**ne

The conclusion is again that individual roots might have special phonology associated with them, just as they have idiosyncratic interpretations in the semantics. But the syntactic structure plays a role as well, one which I will now delineate.

3.3.2 Exceptions by template

The middle root consonant of the templates *XiY̑eZ* and *hitXaY̑eZ* does not spirantize.

(38) No spirantization of *Y̑* in *XiY̑eZ* and *hitXaY̑eZ*:

			Template	Past 3SG.M	Future 3SG.M
√spr	a.	‘counted’	*XaYaZ*	sa**f**ar	jis**p**or
	b.	‘told’	*XiY̑eZ*	si**p**er	jesa**p**er
√lbʃ	c.	‘wore’	*XaYaZ*	la**v**aʃ	jil**b**aʃ
	d.	‘dressed up’	*hitXaY̑eZ*	hitla**b**eʃ	jitla**b**eʃ

The middle Y̑ was originally geminated in these templates, *XiYYeZ* and *hitXaYYeZ*. These templates are often still notated in similar fashion, in acknowledgment of gemination that is not preserved in contemporary usage (gemination in cognate templates has been preserved in many dialects of Arabic; Tucker 2010; Wallace 2013).

As emphasized throughout this paper, the seven templates have not only unique morphophonological properties but their own syntactic and semantic properties. The *XiY̑eZ* template has been called the “intensive” form of the verb (Doron 2003, 2013; Arad 2005). Unlike in studies that implicitly treat *XaYaZ* and *XiY̑eZ* as conjugation classes (Temkin Martínez 2008, 2010, 2013; Temkin Martínez and Müller 2016; Gouskova 2012), it is worth pointing out that a grammatical difference holds between the two. As discussed by Doron (2003) and Kastner (2016a), verbs in *XiY̑eZ* have a more strongly agentive reading than verbs with the same root in *XaYaZ*. In (39a) both an animate agent and an inanimate cause are possible with the “simple” *ʃavrú* ‘broke’ in *XaYaZ*, but in (39b) only the agent is available with the “intensive” *ʃibrú* ‘broke to bits’ in *XiY̑eZ*. The latter example does not spirantize /b/ to [v].

(39) Phonological and semantic differences, *XaYaZ* vs. *XiY̑eZ* (Doron 2003:20):

a. {✓ *ha-jeladim* / ✓ *ha-tiltulim ba-argaz*} ***ʃa<u>v</u>r**-u* *et* *ha-kosot*
the-children / the-shaking in.the-box **broke**-PL ACC the-glasses
‘{The children / Shaking around in the box} broke the glasses.’

b. {✓ *ha-jeladim* / ✗ *ha-tiltulim ba-argaz*} ***ʃi<u>b</u>r**-u* *et* *ha-kosot*
the-children / the-shaking in.the-box **broke**-PL ACC the-glasses
‘{The children / *Shaking around in the box} broke the glasses to bits.’

In order to derive the semantic difference I adapt the original proposal by Doron (2003) to state that an underspecified root √ACTION modifies Voice, forcing an agentive reading. It is √ACTION that blocks spirantization in the phonology and inserts the correct vowels for the templates currently under discussion, *XiY̑eZ* and *hitXaY̑eZ*. Specifically, I propose that the exponent of √ACTION carries a [–continuant] feature which docks onto the middle consonant for lexical roots that have a medial /p/, /b/ or /k/ (Zoll 1996; Wolf 2007).

(40) a. $\sqrt{\text{ACTION}} \leftrightarrow [\text{–cont}]_{\text{ACT}}$ / ___ { $\sqrt{\text{XYZ}}$ | Y ∈ p, b, k }

b. Voice ↔ *i,é* / T[Past] ___ $\sqrt{\text{ACTION}}$

See Faust (2016) for additional evidence that morphophonological processes target root classes differentiated by specific segments in Semitic languages, Wallace (2013) for a similar account of gemination in Akkadian, Emirati Arabic and Iraqi Arabic, and Moore-Cantwell (2013) for a wug study of irregular verbs in *XiY̯eZ*.

The floating [–cont] feature is docked using the following constraint, which Wallace (2013) adapted from the treatment of infixation by Yu (2003, 2005):

(41) **ALIGN-R($\sqrt{\text{ACTION}}$, [σ-)**: Dock the [–cont] feature of $\sqrt{\text{ACTION}}$ on the second syllable of the base.
Assign a violation mark for each [–cont]$_{\text{ACT}}$ feature not aligned with the right edge of the first syllable of the following morphological word.

The tableau in (18) derived *safar* ‘counted’ in *XaYaZ*. The *XiY̯eZ* instantiation of the same root, *siper* ‘told’, follows, where the ranking ID(FORTIS) ≫ *V-STOP protects non-spirantizing /p̯/.

(42) [Voice $\sqrt{\text{ACTION}}$ [v $\sqrt{\text{spr}}$]] ‘told’:

	i,é-[–cont]$_{\text{ACT}}$-$\sqrt{\text{spr}}$	ID(FORTIS)	ALIGN-R($\sqrt{\text{ACT}}$, [σ-)	*V-STOP	SWP	ID(CONT)
☞	a. sip̯ér			*		
	b. sifér	*!				*
	c. sip̯ré			*	*!	
	d. t̯ifér		*!	*		*

This discussion highlights once more the claim that syntactic structure predictably delimits allomorphic possibilities and phonological spell-out. Spirantization in Hebrew is not completely arbitrary (pace a strong reading of Temkin Martínez 2008, 2010); lack of it is based on morphosyntactic structure. The template *XiY̯eZ* is not a basic building block of the lexicon; it arises as an epiphenomenon when a certain functional morpheme, one whose semantic effects are readily observed, is embedded in syntactic structure.

3.4 Summary

This section showed how the spell-out of syntactic elements gives rise to templatic effects without treating the templates themselves as prosodic primitives. A stem-based approach, such as the one critiqued in Sect. 5, is not able to make the fine-grained distinctions between the exceptionality exhibited by root classes and the alternations induced by morphosyntactic heads. That kind of theory has no roots to begin with.

In keeping with the other theoretical claim about combining roots and structure, we have seen how functional material combines with lexical material in ways that are mutually constrained: the structure allows certain allomorphic patterns while individual roots can exercise their own idiosyncrasy. The next section tests this claim by examining cases in which the structure allows no allomorphic interactions.

4 Predictions for syncretism

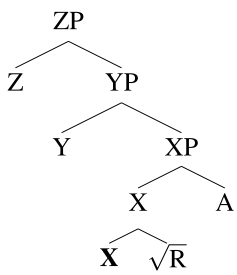
Any theory of morphology, in particular cyclic ones like the one employed here, must define locality domains for contextual allomorphy. In this section I describe the Strict Linear Adjacency Hypothesis of Embick (2010), testing out a prediction which has so far only been evaluated on languages with concatenative morphology. Contextual allomorphy is predicted to hold solely between adjacent overt elements as discussed next in Section 4.1. I confirm this prediction in Hebrew, arguing that it is borne out in two domains: syncretism in agreement affixes (Section 4.2) and syncretism in passives (Sections 4.3 and 4.4). Given that the patterns discussed in this section make crucial reference to the internal syntactic makeup of the verb, I do not believe they can be captured in a stem-based approach, a point I make explicit in Sect. 5.2.

4.1 The Strict Linear Adjacency Hypothesis

Studies of opacity effects in phonology have suggested that a "flat" derivation, proceeding wholesale with no internal cycles, cannot account for various phenomena in which the original existence of a certain conditioning environment is made opaque by subsequent operations. A number of frameworks have arisen in order to account for opacity within Optimality Theory, including OT-CC (McCarthy 2007), Harmonic Serialism (McCarthy 2008a,b) and Optimal Interleaving (Wolf 2008). All share a cyclic spell-out of morphological material.

I have assumed a version of the cycle in which each morpheme is spelled out in turn. Building on proposals developed by Bobaljik (2000) and Embick (2010, 2015), Sect. 3 took Vocabulary Insertion to proceed "inside-out", from the most deeply embedded element outwards. This process must be constrained by locality considerations; I adopt the Strict Linear Adjacency Hypothesis, according to which only adjacent overt elements can condition allomorphy on each other (Embick 2010; Marantz 2013a). As seen in Sect. 3, this theory can correctly analyze cases of allomorphy and other alternations in Hebrew. But the strict linear adjacency hypothesis also makes predictions regarding where *syncretism* is expected to hold: if an overt element Y appears between X and Z, [[X **Y**] Z], X will not be able to condition allomorphy of Z. And as shown by Embick (2010), the result of this configuration is usually syncretism of Z, such that Z has the same form regardless of X or any material below X. On the other hand, if Y is *silent*, X may still condition allomorphy on Z.

(43)



(44) Allomorphic alternations are possible between adjacent elements. If overt, each can require specific exponents from the other:

a. $\sqrt{\text{R}}$ and X

b. X and Y

c. Y and Z

(45) Allomorphy is possible across null exponents (according to the original proposal – if they are in the same syntactic phase):

a. $\sqrt{\text{R}}$ and Y if X is silent

b. X and Z if Y is silent

What this means is that if the root is in the position marked R, and X is the verbalizer v (assuming a silent verbalizer), then the root R will be visible to Y and not to Z, unless Y is covert. It is predicted that an overt head in Y would block the local configuration necessary for allomorphy of Z given a root in R, and that is what we will see for the Passive head in Sect. 4.3 as it merges in the position of Y.

Here is an example of what these allomorphic interactions look like. In Latin a linear intervention effect holds in the perfect: an overt Perf head can condition special person/number endings only if there is no overt intervening exponent of T (Embick 2010; Kastner and Zu 2015). In the present tense, T is covert and a special ending arises after the perfective morpheme *v*, namely -*ī* in (46b).

(46) Perfect and imperfect endings:

a. *am-**ō***
$\sqrt{\text{LOVE}}$-**1SG**
'I love'

b. *am-ā-*[*v*]*-**ī***
√LOVE-THEME-[Perf]-**1SG**
'I have loved'

Yet when T is spelled out by an overt exponent such as *ba/ra* in (47) or *b/r* in (48), the 1SG ending for a Class I root like √LOVE 'love' is consistent—*m* in the past and *o* in the future, without reference to the non-local Perf element.

(47) Past tense with -*m*:

a. *am-ā-ba-**m***
√LOVE-THEME-Past-**1SG**
'I loved'

b. *am-ā-*[*ve*]*-ra-**m***
√LOVE-THEME-[Perf]-Past-**1SG**
'I loved'

(48) Future tense with -*ō*:

a. *am-ā-b-**ō***
√LOVE-THEME-Fut-**1SG**
'I will love'

b. *am-ā-*[*ve*]*-r-**ō***
√LOVE-THEME-[Perf]-Fut-**1SG**
'I will have loved'

Perf can only condition the agreement ending when no overt exponent of T intervenes. This logic will guide our investigation of the Hebrew data. Similar patterns have been discussed by Gribanova (2015) for Russian, by Božič (2015) for Slovenian and by Embick (2010) for a variety of other languages, although arguments have been made that a strong version of the adjacency hypothesis must be weakened (Merchant 2015; Grestenberger 2015; Bermúdez-Otero 2016; Moskal and Smith 2016).

4.2 Agreement affixes do not depend on the root

As we have already seen, agreement affixes depend mostly on the tense of the verb and in some cases on the template. For example, 2PL agreement is marked by the suffix *-tem* in the past but by the circumfix *t-ú* in the future: *biʃáltem* 'you all have cooked' ∼ *tevaʃlú* 'you all will cook'. The table in (49) lists the agreement affixes, which never depend on the root.

(49) General affixal paradigms across templates:

	Past		Future	
	SG	PL	SG	PL
1	STEM-**ti**	STEM-**nu**	**j**-STEM	**n**-STEM
2M	STEM-**ta**	STEM-**tem**	**t**-STEM	**t**-STEM-**ú**
2F	STEM-**t**	STEM-**tem**	**t**-STEM-**í**	**t**-STEM-**ú**
3M	STEM	STEM-**ú**	**j**-STEM	**j**-STEM-**ú**
3F	STEM-**á**	STEM-**ú**	**t**-STEM	**j**-STEM-**ú**

The paradigm in (50) instantiates (49) by contrasting past and future forms for √bʃl in *XiYeZ*.

(50) Past and future for *biʃel* ‘cooked’:

	Past, *XiY̯eZ* $\sqrt{\text{bʃl}}$		Future, *XiY̯eZ* $\sqrt{\text{bʃl}}$	
	SG	PL	SG	PL
1	biʃál-**ti**	biʃál-**nu**	**j**-evaʃél	**n**-evaʃél
2M	biʃál-**ta**	biʃál-**tem**	**t**-evaʃél	**t**-evaʃ<é>l-**ú**
2F	biʃál-**t**	biʃál-**tem**	**t**-evaʃ<é>l-**í**	**t**-evaʃ<é>l-**ú**
3M	biʃél	biʃ<é>l-**ú**	**j**-evaʃél	**j**-evaʃ<é>l-**ú**
3F	biʃ<é>l-**á**	biʃ<é>l-**ú**	**t**-evaʃél	**j**-evaʃ<é>l-**ú**

As shown in (51), the same agreement affixes are used regardless of root class: $\sqrt{\text{lvj}}$, the root that exhibited exceptional alternations in (31), has the same affixes in (51) as $\sqrt{\text{bʃl}}$ does in (50). The verb is *helva* ‘lent’.

(51) Past and Future forms for a verb in $\sqrt{\text{XYj}}$:

	Past, *heXYiZ* $\sqrt{\text{lvj}}$		Future, *heXYiZ* $\sqrt{\text{lvj}}$	
	SG	PL	SG	PL
1	helvé-**ti**	helvé-**nu**	**j**-alvé	**n**-alvé
2M	helvé-**ta**	helvé-**tem**	**t**-alvé	**t**-alv<é>-**ú**
2F	helvé-**t**	helvé-**tem**	**t**-alv<e>-**í**	**t**-alv<é>-**ú**
3M	helvá	helv<á>-**ú**	**j**-alvé	**j**-alv<é>-**ú**
3F	helv<á>e-**tá**	helv<á>-**ú**	**t**-alvé	**j**-alv<é>-**ú**

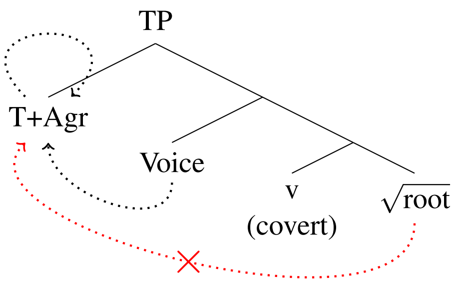
Agreement affixes depend on the template to a small degree. The 3rd person affixes are stressed in all templates save for *heXYiZ*, as was seen in (24), repeated here as (52).

(52) 3rd person suffixes are stressed in past tense *XiY̯eZ* ‘cooked’ and *hitXaY̯eZ* ‘got cooked’ but not *heXYiZ* ‘lent’:

	XiY̯eZ $\sqrt{\text{bʃl}}$		*hitXaY̯eZ* $\sqrt{\text{bʃl}}$		*heXYiZ* $\sqrt{\text{bʃl}}$	
	SG	PL	SG	PL	SG	PL
1	biʃál-ti	biʃál-nu	hitbaʃál-ti	hitbaʃál-nu	hevʃál-ti	hevʃál-nu
2M	biʃál-ta	biʃál-tem	hitbaʃál-ta	hitbaʃál-tem	hevʃál-ta	hevʃál-tem
2F	biʃál-t	biʃál-tem	hitbaʃál-t	hitbaʃál-tem	hevʃál-t	hevʃál-tem
3M	biʃél	biʃ<é>l-**ú**	hitbaʃél	hitbaʃ<é>l-**ú**	hevʃíl	hevʃíl-**u**
3F	biʃ<é>l-**á**	biʃ<é>l-**ú**	hitbaʃ<é>l-**á**	hitbaʃ<é>l-**ú**	hevʃíl-**a**	hevʃíl-**u**

Revisiting the diagram from (25) as (53), it is evident that Agr is local to T (the two are exponents of the same head), so T can condition allomorphy on it. In addition, Agr is local to Voice. Both Voice and T should be able to trigger allomorphy of Agr, which they do.

(53)



Relevant lexical items for *heXYiZ* are repeated from (32). The agreement affix in (54) cannot depend on any lower information such as the root.

(54) Paradigm invariance in *heXYiZ*: no reference to root class.

a. $2\text{SG.M} \leftrightarrow \begin{cases} \textit{-ta} & /\ \text{T[Past]}\ \_\_ \\ \textit{t-} & /\ \text{T[Fut]}\ \_\_ \end{cases}$

b. $3\text{PL} \leftrightarrow \begin{cases} \textit{-u} & \text{/ T[Past] \_\_\_ Voice}_{\{D\}} \\ \textit{-ú} & \text{/ T[Past] \_\_\_} \end{cases}$

T+Agr is not local enough to the root to be conditioned by it, since Voice contains overt material that intervenes, namely the vowels and a possible prefix. And so, different root classes cannot condition special agreement markers. The root is too deep in the structure, "obstructed" by overt Voice$_{\{D\}}$, for T+Agr to see it.

What this brief study of agreement affixes shows is that allomorphy is sensitive to linear adjacency of hierarchically arranged elements, as expected. Agreement affixes cannot be derived in the phonology proper: there is no reason for the past tense 1PL suffix *-nu* to alternate with the future 1PL prefix *n-*. This much must be treated by using separate Vocabulary Items. But allomorphy of this item cannot be conditioned by low material such as the root. If a theory derived verbs in a dedicated lexicon, a stem class could condition special endings; this is a false prediction of the stem-based account, since (49)–(51) all show that suffixes have nothing to do with individual roots or stems. No analysis that eschews internal structure can make the predictions developed here: that agreement affixes depend on the tense but not on the root (even though the "stem" does depend on the root) and especially that the paradigm is uniform across templates and across otherwise exceptional roots.

The current analysis makes another prediction. If additional overt material intervenes between T+Agr and Voice, agreement affixes should syncretize completely and show some default form. This is the case with passives.

4.3 Vowels syncretize in the passive

Sect. 3.1.2 demonstrated that 1st and 2nd person might have a different second vowel associated with them than does 3rd person, (55a). I note here that this split is neutralized in the passive: all phi-feature combinations have the same vowels, *u-á*, (55b).

(55) Passive syncretism for $\sqrt{\text{bʃl}}$ 'cook' agreement:

	Template	Past 3SG.M	Past 1SG
a.	*XiY̯eZ* (active)	biʃél	biʃál-ti
b.	*XuY̯aZ* (passive)	b**u**ʃ**á**l	b**u**ʃ**á**l-ti

Another generalization about syncretism in the passive is that tense does not matter for the vowels either: there might be a difference in vowels between past and future in the active, (56a), but not in the passive, (56b).

(56) Passive syncretism for $\sqrt{\text{bʃl}}$ 'cook' tense:

	Template	Past 3SG.M	Future 3SG.M
a.	*XiY̯eZ* (active)	biʃél	je-vaʃél
b.	*XuY̯aZ* (passive)	buʃ**á**l	je-v**u**ʃ**á**l

Together with a substantial body of work from both syntax-based and lexicalist camps, I assume that the Hebrew passive is generated by passivizing an existing active verb (Doron 2003; Reinhart and Siloni 2005; Ussishkin 2005; Laks 2011; Alexiadou and Doron 2012; Borer 2013; Kastner and Zu 2015). Passive forms are derived either from *XiY̯eZ* verbs (yielding *XuY̯aZ*) or *heXYiZ* verbs (yielding *huXYaZ*). This is done through the passive head Pass which merges above VoiceP but below T+Agr. The patterns of syncretism fall out naturally under our existing assumptions, as I will now demonstrate.

The full paradigms follow below, showing that the 1st/2nd person vs 3rd person split is neutralized in the passive, as is any distinction based on tense; the vowels on all stems are /u/-/a/ in the following two tables. In addition, for each pair of templates, the affixes are the same in each of the two tenses; for example, the standard 2SG.M past suffix *-ta* is used in both *XuY̯aZ* and *huXYaZ*.

(57) a. Past of passive *gudal* ‘was raised’ and *hugdal* ‘was enlarged’:

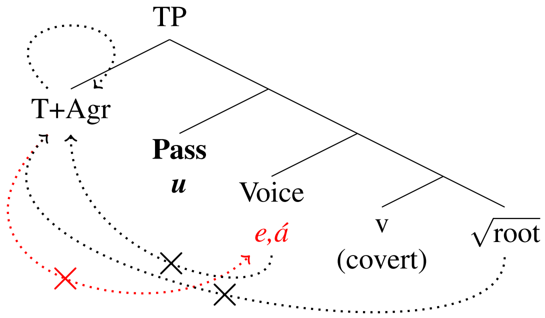
	XuY̯aZ $\sqrt{\text{gdl}}$		*huXYaZ* $\sqrt{\text{gdl}}$	
	SG	PL	SG	PL
1	gudál-ti	gudál-nu	hugdál-ti	hugdál-nu
2M	gudál-ta	gudál-tem	hugdál-ta	hugdál-tem
2F	gudál-t	gudál-tem	hugdál-t	hugdál-tem
3M	gudál	gud<á>l-ú	hugdál	hugd<á>el-ú
3F	gud<á>l-á	gud<á>l-ú	hugd<á>el-á	hugd<á>el-ú

b. Future of passive *jegudal* ‘will be raised’ and *jugdal* ‘will be enlarged’:

	XuY̯aZ $\sqrt{\text{gdl}}$		*huXYaZ* $\sqrt{\text{gdl}}$	
	SG	PL	SG	PL
1	j-e-gudál	n-e-gudál	j-ugdál	n-ugdál
2M	t-e-gudál	t-e-gud<á>l-ú	t-ugdál	t-ugd<á>el-ú
2F	t-e-gud<á>l-í	t-e-gud<á>l-ú	t-ugd<á>el-í	t-ugd<á>el-ú
3M	j-e-gudál	j-e-gud<á>l-ú	j-ugdál	j-ugd<á>el-ú
3F	t-e-gudál	j-e-gud<á>l-ú	t-ugdál	j-ugd<á>el-ú

This pattern is exactly what our theory of locality predicts: overt Pass blocks T+Agr from conditioning allomorphy on Voice as in (58), developing (53). Similarly, there is no special spell-out for the passive conditioned by certain roots since overt Voice intervenes. I give Pass as *-u-* in the tree but become more precise in (59c).

(58)



A derivation now follows for the different cycles deriving *huXYaZ* future tense *jugdelú* ‘they will be enlarged’: First the combination of $\text{Voice}_{\{D\}}$ and $\sqrt{\text{gdl}}$, then adding in Pass, and then the agreement affixes. Derivation of *jegudal* ‘he will be raised’ in the other passive template, *XuY̯aZ*, would proceed similarly.

(59) a. $\text{Voice}_{\{D\}} \leftrightarrow$ *e,á* / Pass ___

b. $\sqrt{\text{gdl}} \leftrightarrow$ *gdl*

c. Pass $\leftrightarrow$ $[\text{+high +round}]_{\text{Pass}}$

d. 3PL $\leftrightarrow$ *j,ú*

The passive *-u-* is analyzed as a floating autosegment, (59c), that must dock onto an existing vowel, using MAXFLT from Wolf (2007:3).

(60) **MAXFLT:** All autosegments that are floating in the input have output correspondents.
$\forall$F $\in$ I, where F is a feature:
[$\neg$ [$\exists$S $\in$ I such that S is a segment and F is attached to S]]
$\rightarrow$ [$\exists$F $\in$ O such that F $\Re$ F]

(61) VoiceP (a), PassP (b), TP (c):

'they will be enlarged'	W	∼ L	*COMPLEX	MAXFLT	SWP
Cycle 1: Only VoiceP a. (j-ú + [+high +round]$_{\text{Pass}}$) + **e,á-$\sqrt{\textbf{gdl}}$**	egdál	∼ egádl	W		
Cycle 2: Only PassP b. (j-ú) + **[+high +round]$_{\textbf{Pass}}$-egdál**	ugdál	∼ egdál		W	
Cycle 3: TP c. **j-ú-ugdál**	jug(de.lú)	∼ ju(ged.lú)			W

There is one more complication: the paradigm back in (31) showed that the 3rd person past tense suffixes of *heXYiZ* are not stressed: active 3SG.F *hegdíla*. Yet I assume that *huXYaZ* is derived from *heXYiZ* and in (57a), the *huXYaZ* 3rd person suffixes are stressed: passive 3SG.F *hugdelá*.

How does the stressed allomorph of the suffix get inserted in the first place? This is possible since Agr is local to Pass, so Pass conditions allomorphy of the affix, requiring stressed affixes. All passive affixes attract stress. Again, this allomorphy cannot be sensitive to any material below Pass, as is the case: neither the original template nor the root can condition allomorphy on the agreement affix.

(62) 3SG.F ↔ *á* / ___ Pass

There might be a way to give an even more general analysis: I am claiming that the suffixes in active *heXYiZ* and its passive counterpart *huXYaZ* are conditioned differently. But maybe both are stressed underlyingly, with the active form retaining stress on the stem and not allowing it to be attracted to the suffix. The outer affix would then be preferred as it attaches later and overwrites the inner one.

For example, take the 2PL future forms *tagdílu* (active) and *tugdelú* (passive). If the suffix *-ú* is always underlyingly stressed in this template, then stressed /í/ in the stem must "win out" somehow for stress purposes. Many analyses of Hebrew stress do note that high vowels are more resistant to change: Graf and Ussishkin (2002:251), Becker (2003:46) and Bat-El (2008:36,41) all point out that high vowels are less subject to reduction or deletion than other vowels. A useful formalism one could exploit is that of Harmonic Alignment, specifically as applied to vowels of differing sonority (Gouskova 2003:Ch. 4). High vowels like /i/ are less sonorous than /e/ and /a/, allowing us to place them on a sonority hierarchy from which individual markedness constraints can be derived; see Bat-El (2008) for such an analysis.

But let me summarize the structural claim I have been developing. Voice cannot "see" past Pass and onto T+Agr, so it picks one set of vowels for the entire paradigm. We now have a crosslinguistic prediction for passive suffixes as a special case of the strict linear adjacency hypothesis, building on Embick (2010): no contextual allomorphy should obtain on a verb stem across an overt passive affix.

4.4 Passive with different root classes

As a final verification of the predictions made by the current theory, we must examine the interaction of different root classes with Pass. The expectation is confirmed: paradigm invariance is compatible with lexical exceptionality—here identified as the conditioning of theme vowels by the root—since the two are triggered by different parts of the structure.

I take the root $\sqrt{\text{pnj}}$ to be representative of the class of /j/-final $\sqrt{\text{XYj}}$ roots in particular and of exceptional root classes in general. The paradigms in (63a) are for the pair *XiY̯eZ–XuY̯aZ* and those in (63b) are for the pair *heXYiZ–huXYaZ*. All forms are in the singular. Past tense is given on the left and future tense on the right, for each pair. Both parts of the prediction are borne out when compared to paradigms such as (57): vowels syncretize in the passive (on the right-hand side of each tense), although the form of the vowels is not regular *u-á* but rather a root-specific form.

(63) a. *XiY̯eZ* √pnj 'evacuate' in active and passive, for each tense:

	Past		Future	
	XiY̯eZ	*XuY̯aZ* (Pass)	*XiY̯eZ*	*XuY̯aZ* (Pass)
1	p**i**ní-ti	p**u**né-ti	j-e-f**a**né	j-e-f**u**né
2M	p**i**ní-ta	p**u**né-ta	t-e-f**a**né	t-e-f**u**né
2F	p**i**ní-t	p**u**né-t	t-e-f**a**n<é>-í	t-e-f**u**n<é>-í
3M	p**i**n<é>-á	p**u**n<é>-á	j-e-f**a**né	j-e-f**u**né
3F	p**i**n<é>-tá	p**u**n<é>-tá	t-e-f**a**né	t-e-f**u**n<é>-ú

b. *heXYiZ* √pnj 'refer' in active and passive, for each tense:

	Past		Future	
	heXYiZ	*huXYaZ* (Pass)	*heXYiZ*	*huXYaZ* (Pass)
1	hefné-ti	h**u**fné-ti	j-**a**fné	j-**u**fné
2M	hefné-ta	h**u**fné-ta	t-**a**fné	t-**u**fné
2F	hefné-t	h**u**fné-t	t-**a**fn<é>-í	t-**u**fn<é>-í
3M	hefn<é>-á	h**u**fn<é>-á	j-**a**fné	j-**u**fné
3F	hefn<é>e-tá	h**u**fn<é>e-tá	t-**a**fné	t-**u**fné

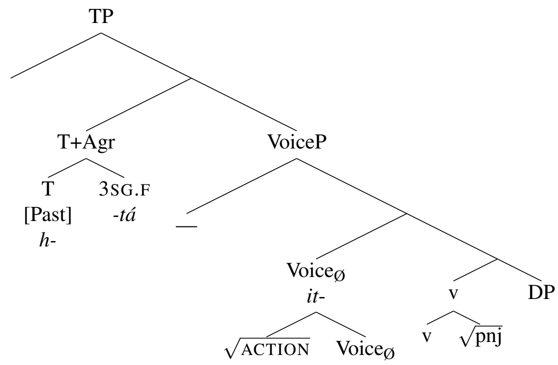
A falsification would consist of a new, unexpected form making reference to both the root and higher material such as Pass or T+Agr. The only potential falsification of the prediction lies with the past 3SG.F, which introduces *-ta*. As we have already seen, however, the conditioning environment of this allomorph of the suffix is predictable; it appears postvocalically as in (32e) in Sect. 3.2, and see also the characterization of *t-* as a feminine marker by Harbour (2008) and a different take in Faust (2016). The existence of *-tá* in the past tense passive 3SG.F forms above does not result from a banned allomorphic interaction of Voice and T+Agr over an intervening Pass head. Rather, the expected syncretic stems are generated and the correct phonologically conditioned allomorph of 3SG.F is inserted. The theory makes the right predictions.

4.5 Summary

The purpose of this section was to test the prediction that exceptional phonology is handled "low" (locally to the root) and then passed on to additional cycles, which themselves are not exceptional. This claim was borne out: linear adjacency is a key component in the calculation of allomorphy, after linearization of syntactic structure.

To make things more concrete, here are summarized derivations for past tense *hitXaY̯eZ hitpantá* 'she evacuated' in (64)–(66) and future tense *titpané* 'she will evacuate' in (67)–(69). These verbs instantiate the /j/-final root √pnj in *hitXaY̯eZ*, a template housing anticasuative, reflexive and reciprocal verbs (Kastner 2016b). A special nonactive Voice head, $\text{Voice}_{\emptyset}$, is modified by the agentive modifier √ACTION. The former contributes a prefix, the latter blocks spirantization of the middle root consonant, and both condition the vowels of the stem jointly.

(64)



(65) Vocabulary Items:

a. √pnj ↔ *pne*

b. √ACTION ↔ $[\text{–cont}]_{\text{ACT}}$ / ___ { √XYZ | Y ∈ p, b, k }

c. $\text{Voice}_{\emptyset}$ ↔ *it,a,é* / ___ √ACTION

d. T[Past] ↔ *h-* / ___ *it*

e. 3F.SG (Past) ↔ *-tá* / ___ V

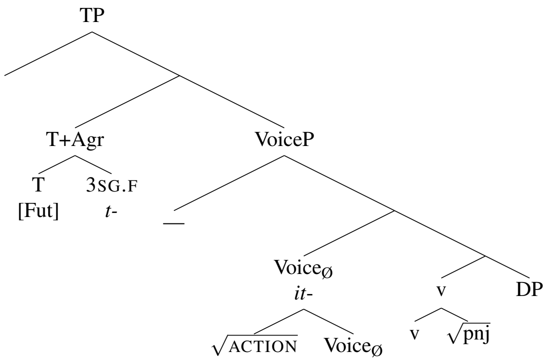
(66) a. Cycle 1 (VoiceP):
/it-a,e-pné/ → [it.pa.né]

b. Cycle 2 (TP):
/h-tá-it.pa.né/ → [hit.pan.tá]

The head Voice$_{\emptyset}$ on its own inserts a prefix, *ni-* in the past tense, and conditions the vowels typical of the template *niXYaZ* (Kastner 2016b). Full derivations are omitted in the interest of keeping the discussion focused.

Continuing on to the future tense equivalent of (64)–(66):

(67)



(68) Vocabulary Items:

a. $\sqrt{\text{pnj}}$ ↔ *pne*

b. $\sqrt{\text{ACTION}}$ ↔ [–cont]$_{\text{ACT}}$ / ___ { $\sqrt{\text{XYZ}}$ | Y ∈ p, b, k }

c. Voice$_{\emptyset}$ ↔ *it,a,é* / ___ $\sqrt{\text{ACTION}}$

d. 3SG.F ↔ *t-* / ___ T[Fut]

(69) a. Cycle 1 (VoiceP):
/it-a,e-pné/ → [it.pa.né]

b. Cycle 2 (TP):
/t-it.pa.né/ → [tit.pa.né]

The verbal templates are again epiphenomenal, arising due to combinations of vocalic affixes with a consonantal root. I believe that these results go beyond those of the alternative systems surveyed next in Sect. 5–6. Table 2 is repeated here as Table 3 with a summary of the different functional heads, all of which are motivated on both syntactic-semantic and morphophonological grounds.

Heads			Syntax	Semantics	Phonology	Sect.
	Voice				*XaYaZ*	3
	Voice	$\sqrt{\text{ACTION}}$		**Agentive**	*XiYeZ*	3.3.2
Pass	Voice	$\sqrt{\text{ACTION}}$	*Passive*	**Action**	*XuYaZ*	4.3
	Voice$_{\{D\}}$		EA		*he-XYiZ*	3.1.2
Pass	Voice$_{\{D\}}$		*Passive*		*hu-XYaZ*	4.3
	Voice$_{\emptyset}$		No EA		*ni-XYaZ*	4.5
	Voice$_{\emptyset}$	$\sqrt{\text{ACTION}}$	No EA	**Action**	*hit-XaYeZ*	4.5

Table 3: The requirements of functional heads in the Hebrew verb.

5 Alternatives: the stem-based approach

In this section I present a number of arguments against the stem-based theory of Semitic morphophonology (Bat-El 1989, 1994, 2003, 2008; Laks 2011, 2013a,b, 2014; Ussishkin 1999, 2000, 2003, 2005, 2006), mostly arguing against the proposal in Ussishkin (2005). Three arguments are leveled against this theory: the problem of the missing base (Section 5.1), the problem of overgeneration (Section 5.2), and the lack of a link to the syntax and semantics (Section 5.3).

On my analysis, the root is a morpheme and templates are epiphenomenal. Under the stem-based approach, all verbs are said to be derived from a base form in *XaYaZ* using a morphemic template, rather than by combining a root with functional heads. The root does not exist as a syntactic, morphological or phonological object. In direct juxtaposition to the proposal here, the stem-based approach treats the root as epiphenomenal and the verbal templates (*heXYiZ*, *hitXaY̯eZ*, etc.) as independent morphemes. Faithfulness to affixation, alongside modification of a stem in *XaYaZ*, are coupled with output-output faithfulness to derive the correct forms. The smallest morphological unit in the Hebrew verb, in a manner of speaking, is the verbal stem.

In the following example, Ussishkin (2005:194) derives *gidel* 'raised' in *XiY̯eZ* from *gadal* 'grew up' in *XaYaZ* by treating the templates as an affix and using three constraints:

(70) a. **MAX-AFFIX:** assigns a violation mark for each segment in an affix (the template) that does not have a correspondent in the output.

b. **MAX-IO:** assigns a violation mark for each segment in the input that does not have a correspondent in the output.

c. **MAX-OO:** assigns a violation mark for each segment in the base form that does not have a correspondent in the output.

(71) Instead of violation marks, individual vowels point out the violating segments.

gadal-i,e	MAX-AFFIX	MAX-IO	MAX-OO
a. gadal	i!e	ie	
b. gadel	i!	i	a
c. gidal	e!	e	a
☞ d. gidel			aa

In effect, the "affix" *i-e* spells out the template and is protected by highly-ranked MAX-AFFIX. The basic stem is *gadal*, source of all further derivations.

5.1 Issue 1: The problem of the missing base

At its core, the difference between the two theories traces back to the question of whether the grammar stores entire stems or smaller pieces that are then put together. The stem-based approach denies the existence of the root as a grammatical object, deriving instead surface forms from each other. However, a system in which one verb is derived from the other either assumes or predicts that there must always be a *XaYaZ* form to use as a base. As Ussishkin (2005:212) himself notes, this is incorrect:

(72) a. *nirdam* 'fell asleep' (≮ **radam* in *XaYaZ*)

b. *nifrad* 'separated' (≮ **parad* in *XaYaZ*)

c. *diber* 'spoke' (≮ **davar* in *XaYaZ*)

d. *kibel* 'received' (≮ **kabal* in *XaYaZ*)

Doron (2003) and Kramer (2006) list similar examples in Hebrew and Coptic.

Ussishkin (2005:213) speculates that the stem-based analysis could be modified to allow derivation from a different base, in which case the base would have to be identified on a paradigm-by-paradigm basis. Bat-El (2003) allows bidirectional derivations between templates, constraining the theory even less. I contend that having one root as the base of derivation for all forms is a more useful generalization.

5.2 Issue 2: Overgeneration

For the most part, stem-based analyses limited themselves to third person singular past tense forms (the citation form). Recall now that agreement affixes can be conditioned by the tense and the template, but not by root class. This behavior has a locality-based explanation in our theory but is not predicted on the stem-based approach. Since the stem-based approach does not permit hierarchical structure, the questions of allomorphy raised in this paper are difficult to address. Would the grammar be sensitive to the individual consonants in the stem? This must be the case, since the analysis in (71) distinguishes consonants from vowels. But if so, how come these consonants never condition allomorphy of the affix? The stem-based approach is not a theory that takes allomorphy into account, a clear problem when dealing with a language that squeezes four or five different morphemes into two or three syllables.

Turning to the passive, consider how Ussishkin (2005:196) derives passive forms for 3SG.M past. In (73), σ-ALIGN is a disyllabic constraint. The passive "affixes" are privileged by MAX-AFFIX, resulting in overwriting of the base vowels.

(73) a. *XuY̯aZ* from *XiY̯eZ*:

	gidel-u,a	MAX-AFFIX	σ-ALIGN	MAX-IO	MAX-OO
	a. gidel	u!e		ua	
	b. gudel	a!		a	
☞	c. gudal				ie

b. *huXYaZ* from *heXYiZ*:

	hegdil-u,a	MAX-AFFIX	σ-ALIGN	MAX-IO	MAX-OO
	a. hegudal		*!		i
	b. hegadil	u!		u	
☞	c. hugdal				ei

This analysis does not explain why vowels syncretize across person/gender combinations in the passive, as was discussed in Sect. 4.3–4.4. In order to capture the facts additional constraints would have to be introduced. These constraints would specify which vowel gets inserted for which combination of person and gender. While this undertaking is not impossible, the constraints on affixes would have to be ranked correctly with respect to affix faithfulness for both the base and the derived form.

In order to appreciate the problem we will go beyond citation forms. To create a future passive in this system, first derive the correct tense and then passivize. But it is not clear how the grammar would know which vowel in the stem to passivize without additional stipulations:

(74) a. hegdil → jagdil → ✓ jugdal
b. gidel → jegadel → ✗ jugadel / ✗ jugadal / ✓ jegudal

We could instead try to first derive the passive base and then allow tense and agreement to overwrite it. However, this kind of system allows for vowel allomorphy where syncretism exists:

(75) a. gidel → gudal → ✗ jegadel / ✗ jegadul / ✗ jegodol / . . . / ✓ jegudal
b. hegdil → hu-gdal → ✗ jehagdel / ✗ jehagdul / ✗ jehugdal / . . . / ✓ jugdal

These patterns—together with the semantic interpretation of passivization before tense—show that Pass attaches before T, unlike in an overwriting-of-stems approach. Whether passivization happens before inflection or inflection before passivization, vowel allomorphy must be constrained more than it was in Ussishkin (2005).

Even if a specific constraint were created to ensure that **jehugdal* becomes *jugdal*, the theory loses its internal consistency because active *i-a* in *XiY̯eZ* and *e-i* in *heXYiZ* double as markers of past tense (inflection) and template (derivation), so the theory must allow tense information to combine with the active stem first. Otherwise there would not be a base to begin with. Put differently, this theory could be salvaged by making an additional assumption about the role of structure in the derivation; yet this type of assumption is exactly what this product-oriented theory is reacting against.

In the theory developed in the current paper, different realization rules are sensitive to different structures and Pass is allowed to overwrite the first vowel it runs across. A similar solution could be devised for the stem-based theory, but this modification would admit a serial derivation based on hierarchical combination of the different morphemes. Even so, the morphosyntactic status of the affixes is not explicitly defined in the stem-based theory, leading us to the next problem.

5.3 Issue 3: Arbitrary affixation

On a general level, the problem of explanatory adequacy with the stem-based approach is that it stipulates certain vowel combinations without explaining where they come from. Are these vowels morphemes, and if so, what does the morpheme denote? What is its role in the syntax? The approach I am developing uses functional heads, which allow for a better description of the system as a whole.

Agreement affixes can be conditioned by the tense and the template but not by a special class of the root (Sect. 4). This behavior has a locality-based explanation in our theory but is not predicted by the stem-based approach. The root-based approach provides an answer to the question of what templates are: morphosyntactically, morphosemantically and morphophonologically. This answer requires a root.

5.4 Summary

The stem-based theory claimed to do away with the consonantal root as a theoretical device. This attempt to simplify the theory comes at a cost: an exaggerated role for templates which ignores their syntax and semantics. The theory also encounters empirical problems once we look past citation forms.

In essence, the stem-based approach accepts templates as morphemes but denies the root as a morpheme. The approach presented in this paper makes the opposite claim: roots are morphemes, but templates are an epiphenomenon of the spell-out of functional heads. Three weaknesses have been pointed out with the stem-based approach as a theory of morphophonology. The syntactic approach also allows us to describe the syntactic-semantic behavior of the templates more accurately (or rather, the behavior the functional heads), without compromising the phonological grammar.

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6 Alternatives: a root-based approach

The system illustrated in the current paper shows rampant allomorphy: the spell-out of Voice may be conditioned by a number of different triggers simultaneously (tense, agreement, passivization, the modifier $\sqrt{\textsc{action}}$, the features on Voice itself and the root). Within the same set of assumptions there is an alternative: each head is allowed to incrementally add single vowels and overwrite previous ones.

For example, Voice would add "default" /a/ and then $\sqrt{\textsc{action}}$ would add /e/, since that is always the second vowel in *XiY̯eZ*. Pass could then overwrite one or both of these. Without Pass, T would overwrite the first vowel to /i/ in the past or /e/ in the future.

(76) a. $\sqrt{\text{bʃl}}$ + Voice = *ba̲ʃl*

b. Add $\sqrt{\textsc{action}}$: *baʃe̲l*
Optionally add Pass: *bu̲ʃa̲l*

c. Add T[Past]: *bi̲ʃel*
Or T[Fut]: *je-vaʃel*

This process of single vowel insertion resembles the system in Faust (2012) where each vowel is considered individually. Faust (2012:481) ends up with rules like those in his (44), our (77)–(78), where "V" stands for "vowel" and the template is a morphological primitive.

(77) Vocabulary Items for *heXYiZ* with regular roots:

a. V ↔ XYaZ

b. V ↔ XYeZ / [present]

c. V ↔ XYoZ / [future], [infinitive]

d. $V_{Xi\underset{\frown}{Y}eZ}$ ↔ XYeZ / active, ___C(V)]$_{\#}$

e. V_{heXYiZ} ↔ XYiZ / active, ___C(V)]$_{\#}$

(78) Vocabulary Items for *heXYiZ* with $\sqrt{\text{XYj}}$ roots.

a. $\sqrt{\text{XYj}}$ ↔ XY / V

b. $V_{XaYaZ,Xi\underset{\frown}{Y}eZ}$ ↔ XYiZ / *heXYiZ* $\sqrt{\text{XYj}}$, [1/2 past]

c. V ↔ XYeZ / *heXYiZ* $\sqrt{\text{XYj}}$, [future]

d. V ↔ XYot / *heXYiZ* $\sqrt{\text{XYj}}$, [infinitive]

e. V [feminine] ↔ [-ta] / *heXYiZ* $\sqrt{\text{XYj}}$, [past]

Unfortunately, such a system is unrestricted in terms of locality: any element is capable of overwriting any vowel (similar problems arise for Faust 2016). In addition, overwriting vowels in one fell swoop would miss out on the notion that the inner domain (VoiceP) can see the morphology of the root whereas outer heads add affixes or overwrite local vowels (in the case of Pass). To a lesser degree, it is also doubtful to what extent one could tap into single vowels as indicators of structure. In other words, to what extent are these rules psychologically real. In contrast, the current theory makes the case for Vocabulary Insertion and the phonological derivation to feed directly off the locality inherent in the syntactic structure.

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7 Discussion and consequences

7.1 On underlying representations and surface forms

The syntactic root-based approach has so far been argued to be superior to a stem-based approach, as far as data coverage and predictive power are concerned. Yet there is also a potential argument for the stem-based approach which has not been pursued strongly, save for some discussion in Bat-El (2003): if surface forms all are that there is, this absolves the learner of the need to learn complicated underlying representations of roots and syntactic heads.

The argument goes as follows. If the stem-based approach uses product-oriented markedness constraints to regulate all derivations, there are much fewer underlying representations to learn. Stems and prosodic templates are learned as-is, without recourse to otherwise complicated rules or representations. There would be no need to posit an underlying $\sqrt{\text{knj}}$ for *kana* ‘bought’ – just learn the stem *kana* and inflect to future *jikne* ‘will buy’ by analogy to other forms, which themselves would be learned in a similar way. The noun *knija* ‘buying’ would presumably be learned separately.

While there is still much work to do on the acquisition of Semitic morphology, discarding the root is not the best way to go. Putting aside the considerable psycho- and neurolinguistic literature which does indicate a role for the consonantal root in processing, the question is whether it makes sense to treat the consonantal root as an independent object which must be learned. As a matter of fact, the case can be made for roots as part of both the acquisition process and the synchronic system.

In recent computational work, Kastner and Adriaans (2015) have proposed that if the learner divides the input into consonants and vowels, it should be able to make progress on basic acquisition tasks in Semitic. A number of computer simulations found that ignoring the vowels in the input leads the learner to perform better on the task of segmenting the input stream into separate phonological words in Arabic: presumably, if the input consisted only of root consonants (and the occasional affix or clitic), this situation would lend itself surprisingly well to insertion of word boundaries. Comparison with a non-Semitic language shows that focusing only on the consonants hinders performance in English, as is to be expected. In another set of simulations, the authors found that these segmented consonants can then be used to learn the famous OCP-Place restrictions in Arabic (Greenberg 1950:et seq.). If the consonantal root carries semantic meaning, and if it can be used to facilitate early phonological learning, then it should be part of the acquisition process.

The question, then, is not whether the consonantal root can be learned but how it can be learned. The product-oriented considerations arising from a stem-based approach ought to guide continued research in this area, but they do not form an argument for one representation over another.

7.2 The fate of the CV morpheme

This paper started off by recapping the seminal analysis of McCarthy (1979, 1981) who proposed that the Semitic verb is made up of three tiers: a CV skeleton (the template), individual consonants (the root) and a vocalic melody (additional grammatical information). The current proposal supports some of his assumptions and rejects others: roots remain, but CV skeletons are no longer needed as primitives in the theory. If the current proposal is on the right track, is there ever a need for CV skeletons as morphemes?

A theory of morphological CV skeletons predicts patterns that are perhaps unattested crosslinguistically and are certainly unattested in Hebrew. If CV skeletons are primitives, a language might have the alternations in (79) which are purely prosodic, metathesizing different segmental chunks:

(79) a. Intransitive template: CVC<u>VC</u> (*pit<u>ok</u>* 'wugged.intransitive')
Transitive template: CVC<u>CV</u> (*pit<u>ko</u>* 'wugged.transitive')

b. Causative template: CaC<u>V</u> (*pat<u>o</u>* 'wugged.causative')
Passive template: <u>V</u>CaC (*<u>o</u>pat* 'wugged.passive')

This is not the case in Hebrew: any change from one template to another is the result of added segmental (and syntactic) material, namely vocalic and consonantal affixes.

It is too soon to rule out CV skeletons entirely, although these skeletons might turn out to be purely phonological objects, not morphosyntactic ones. It may well be the case that in some languages prosodic templates constrain the morphophonology. In Chol, roots must fit in a CV skeleton (Coon To appear), as do roots in Quechua (MacEachern 1999; Gallagher 2013), stems in Rotuman (McCarthy 2000) and word forms in a number of other families (McCarthy 1989). Yet with the exception of the sizable literature on reduplication, it is not clear at this point whether any language employs CV skeletons as morphemes, though some proposals to this extent have been made in Yucatecan languages (Lois 2011) and in previous studies of Semitic.

An analysis of Iraqi Arabic that sits on the continuum between my approach and that of McCarthy (1981) is the one put forward by Tucker (2010), building on ideas in Kramer (2006). Tucker (2010) also concatenates roots and vowels under strict prosodic conditions without making reference to independent CV skeletons. I differ from him, however, in placing my phonological system within a larger syntax-based framework. This difference allows me to match up templates with meanings via functional heads. Tucker (2010) also limits himself to citation forms; as I have argued, the most consistent account of the system as a whole must make reference to agreement patterns and requires a cyclic view of the derivation.

Drawing on the analysis of Tucker (2010), unpublished work by Wallace (2013) provided a detailed analysis of non-concatenative morphology in Akkadian, Iraqi Arabic and Emirati Arabic, with a focus on patterns of syncope and gemination. Her theory did not make reference to CV skeletons, either. The ideas presented here develop Wallace's account and extend it to the entire verbal paradigm, mounting a cross-Semitic argument for transitioning from skeletons to functional heads.

7.3 Conclusion

Templatic effects in Hebrew verbal morphology were argued in this paper to be epiphenomenal, resulting from the combination of functional heads and lexical roots in an independently motivated syntactic structure. This claim stands in contrast to accounts which treat the templates as morphological primitives.

The theory makes use of the Semitic consonantal root as a store of idiosyncratic phonological and semantic information. A cyclic, locality-based theory of morphophonology was shown to make correct predictions about which elements can condition allomorphy on other elements and about the kind of information each element in the structure needs to provide: roots and functional heads. The theory was tested on Hebrew, allowing us to reconcile the idiosyncratic demands of consonantal roots with the grammatical constraints of verbal templates, in the morphophonology as well as the morphosyntax and morphosemantics.

This paper posed the following generalizations about Modern Hebrew and explained them within a theory of syntax-based morphology.

(80) a. Vowels in the verbal stem vary by root class.

b. The vowels vary by template, tense and phi-feature combination.

c. Agreement marking varies by template but not by root class.

d. Passive marking neutralizes vowel differences between templates.

Roots can belong to different classes, and their lexically specified phonology emerges only under the right locality conditions. This much is true of the theory employed here in general, before we have even considered Hebrew. But the same theoretical approach holds for non-concatenative morphology as well.

The system presented here covers a range of data which are unexpected on a stem-based approach. Verbal templates have been shown to emerge as a by-product of spelling out individual functional heads, rather than independent CV skeletons. Contemporary theorizing considers syntactic structure to feed interpretation at the interfaces; the current proposal explains how lexical material and functional material combine in the phonology and the semantics, leading to the emergence of morphophonological templates.

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