Contradictory markedness preferences across domains and the domain generalization bias

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1. Introduction

Investigators have uncovered evidence for LEARNING BIASES — biases inherent in learners that favor certain natural language phonologies over others.

- Simplicity bias (Moreton & Pater 2011)
- Naturalness bias (Hayes & White 2013)
- Similarity bias (White 2014)
- Domain generalization bias (see below)

<u>Broad questions</u>: How strong are these biases? In particular, to what extent can a learning bias be **defied** in a language?

Two cases of learning bias defiance come to mind:

- Unnatural constraints can be learned weakly (Hayes et al. 2009, Hayes & White 2013).
- Saltations — alternations that go against similarity bias — arise in languages, though by historical accident (Hayes & White 2015).

A family of findings now suggest the working of what I call DOMAIN GENERALIZATION BIAS:

- ➢ Learner tendency to favor phonological constraints that hold across morphological domains (Cho 2009, Martin 2011, Myers & Padgett 2014, Brown & Yang 2016, Chong 2016).

But I show two phonological systems **defy bias, displaying opposite drives across domains**:

- In Malagasy, *backness dissimilation* applies to the passive imperative suffix, yet roots show a moderately strong preference for *backness harmony*.
- A similar system arises in Yucatec Maya, and Mayan more broadly.

2.1 Suffixal backness dissimilation in Malagasy

Data/counts below extracted from Malagasy Dictionary and Encyclopedia of Madagascar (de la Beaujardière 2004), an online corpus containing around 86,000 Malagasy words.

- Available here: www.malagasyword.org

Inventory composed of four vowels (Parker 1883, de la Beaujardière 2004):

i		u
e		
	a	

Figure 1: *Malagasy vowel inventory*

Backness cooccurrence avoidance arises in the suffixal domain.

Passive imperative suffix conditionally undergoes **backness dissimilation** (Parker 1883, Zymet 2015).

- *–u* surfaces as *–i* after stems containing *u*, but is blocked by intervening front vowels.
- Conforms to patterns driven by Obligatory Contour Principle (Leben 1973 *et seq*).

	-u is underlying		
(1a)	/bata+u/	[bata-u]	'lift'
(1b)	/fana+u/	[fana-u]	'heat'
	Items undergoing local and nonlocal backness dissimilation		
(2a)	/bab**u**+**u**/	[bab**u**-**i**]	'plunder'
(2b)	/t**u**v+**u**/	[t**u**v-**i**]	'fulfill'
(2c)	/t**u**da+**u**/	[t**u**da-**i**]	'prevent'
(2d)	/**u**^{n}dan+**u**/	[**u**^{n}dan-**i**]	'bolster'
	Front vowels block		
(3a)	/t**uri**+**u**/	[t**uri**-**u**]	'preach'
(3b)	/**ure**+**u**/	[**ure**-**u**]	'massage'

- The alternation is nearly categorical in local setting, semi-regular across central vowels, and is nearly categorically blocked by front vowels.

	–u	***–i***	**Dissim. rate**
No trigger	1877	7	0.0%
Local	4	989	99.6%
Nonlocal	196	201	50.9%
Intervening front vowel	399	2	0.4%

Table 1: *Counts for Malagasy backness dissimilation*

Backness dissimilation seems to be *productive* in Malagasy:

- Dissimilation rates are overall drastic.
- Alternation was observed across generations (Parker 1883, Richardson 1885, Abinal & Victorin 1888, Rakotosaona 1972, Hallanger 1974, Rajemisa 1985).

In addition, dissimilation applies when passive imperatives attach to loanwords (data from the World Loanword Database: http://wold.clld.org):

					Loaned from:
(4a)	*Underlying –u*	/ankahala+u/	[ankahala-u]	'spider'	Malay
		/hihis+u/	[hihis-u]	'gum'	Malay
(4b)	*Dissimilation*	/sutru+u/	[sutru-i]	'spoon'	Malay
		/lambulambu+u/	[lambulambu-i]	'boar'	Banjarese
(4c)	*Blocking*	/burusi+u/	[burusi-u]	'brush'	French
		/futsi+u/	[futsi-u]	'white'	Malay

No other suffix with *u* to test whether dissimilation applies to multiple suffixes, but we do have some evidence for frontness dissimilation (Richardson 1885):

- Deletion applies to plain passive suffix *-ina* after *e*, but not after *u*:

(5a)	*Underlying –ina*	/buban+ina/	[buban-ina]	'calumny'
		/velum+ina/	[velum-ina]	'alive'
(5b)	*Deletion after e*	/bede+**i**na/	[bede-na]	'tattle'
		/enge+**i**na/	[enge-na]	'praise'
(5c)	*No deletion after u*	/babu+ina/	[babu-ina]	'plunder'
		/beku+ina/	[beku-ina]	'foreign words'

2.2 Phonotactic backness harmony in Malagasy

Corpus gives lots of harmonic roots:

(6)	k**iri**	'small hole'	sar**utru**	'cape'
	l**ufu**	'persistence'	t**e**v**i**ka	'spasm'
	uzuna	'curse'	ts**i**ndr**i**	'compression'
	r**i**r**i**n**i**na	'winter'	v**e**l**i**	'blow'

Counts of tier-adjacent vowel pairs reveal no preference for disharmonic sequences in roots — rather, they display the opposite preference, for *harmonic sequences*, both locally and nonlocally.

- Majority of roots in the corpus are classified as noun (2,743 in total), adjective (728), or adverb (746); verb forms are derived from these roots through affixation.

	# harmonic **V**C_0**V** *seq.s*	*# disharmonic* **V**C_0**V** *seq.s*	*# harmonic* **V**C_0aC_0**V** *seq.s*	*# disharmonic* **V**C_0aC_0**V** *seq.s*
Within noun roots	786	602	35	44
Within adj. roots	185	183	27	11
Within adv. roots	312	188	109	49
Within interj., conj., prep. roots	96	41	24	14
TOTAL	**1379**	**1014**	**205**	**118**

Table 2: *Raw counts of (dis/)harmonic sequences in roots*

There are over 300 more local harmonic sequences than there are local disharmonic sequences, and about 90 more nonlocal harmonic sequences than there are nonlocal disharmonic sequences.

Backness dissimilation is thus a DERIVED ENVIRONMENT EFFECT (Kiparsky 1973, 1993 *et seq*): it lacks a counterpart generalization in the lexicon.

Could these counts have arisen by chance?

- As I will argue below, more harmonic sequences are observed than chance predicts.

We calculate **expected proportion** of harmonic sequences given the frequency of instances of each of the vowel (see Appendix for details), and compare it to observed proportion.

	Expected rate	Observed rate
Local sequences:	51.6%	57.3%
Nonlocal sequences:	57.7%	63.5%

Table 3: *Expected proportions of harmonic sequences in roots*

To determine whether we're observing more sequences than chance would predict, we run a **Monte Carlo simulation** (Kessler 2001; *cf*. Martin 2011). To do this for local vowel sequences:

- Gather pairs of tier-adjacent vowels; shuffle the V2s of each pair, concatenate each of them to a V1; calculate new harmony rate; repeat 10,000 times (see Appendix).

The graph below is a histogram of harmony rate frequency after 10,000 Monte Carlo trials.

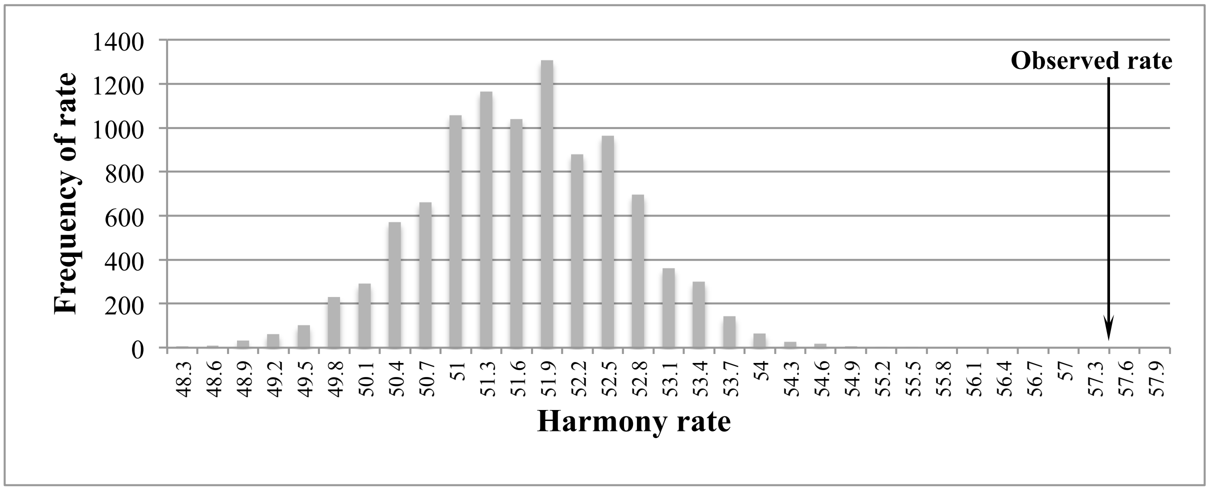

Figure 2: *distribution of harmony rates yielded by Monte Carlo trials, plus observed rate*

The **observed proportion of 57.3%** is greater than *any proportion* yielded by Monte Carlo trial.
- I.e., observed proportion is significantly greater than chance would predict ($p < 0.0001$).
- Similar story for nonlocal harmony ($p = 0.01$): the observed proportion is substantially higher than chance proportion (63.5% vs. 57.7%).

These results suggest overrepresentation is not coincidental, but rather reflects a **backness harmony preference** in the lexicon.

But perhaps learners don't actually pick up the harmony pattern? A generational study suggests otherwise:
- Roots in the online corpus are classified for which dictionary they appear in.
- The counts below show the asymmetry persists across multiple generations:

Dictionaries	*# harmonic* VC_0V *seq.s*	*# disharmonic* $\mathbf{V}C_0\mathbf{V}$ *seq.s*	*Local harm rate*	*# harmonic* VC_0aC_0V *seq.s*	*# disharmonic* $\mathbf{V}C_0aC_0\mathbf{V}$ *seq.s*	*Nonlocal harm rate*
Richardson (1885)	223	165	**57.5%**	38	12	**76.0%**
Abinal (1888)	215	137	**61.1%**	43	8	**84.3%**
Rakotosaona (1972)	322	209	**60.6%**	79	42	**65.3%**
Hallanger (1974)	229	179	**57.5%**	25	7	**78.1%**
Rajemisa (1985)	925	723	**56.1%**	217	44	**83.1%**

Table 3: *Backness harmony across generations*

- If unproductive generalizations fade out over the years (*cf*. Martin 2007), then these numbers suggest harmony is productive.

Local summary:

- Malagasy enforces backness dissimilation in the suffix domain, with the passive imperative alternating at drastic rates.
- But roots show a strong harmony preference.

2.3 Malagasy is not alone: opposite restrictions systems in Mayan

Yucatec Maya shows opposite restrictions governing suffix vowels.
- Two morphemes harmonize for backness and height under certain conditions,
- while two other morphemes undergo dissimilation instead.

Intransitive suffixes take backness and height from stem-final vowel (7a, b) unless stem ends in a coda consonant, in which case suffix vowel defaults to [a] (7c, d) (Blair 1964, Krämer 2001).[1]

Suffixal harmony

(7a) Intransitive imperfective		(7b) Intransitive perfective	
ʔ**a**h-**a**l	wake.up-IMPF	ʔ**a**h-**a**k	wake.up-SUBJ
ʔ**o**k-**o**l	enter-IMPF	ʔ**o**k-**o**k	enter-SUBJ
l**u**b'-**u**l	fall-IMPF	l**u**b'-**u**k	fall-SUBJ
w**e**n-**e**l	sleep-IMPF	w**e**n-**e**k	sleep-SUBJ
k**i**ːm-**i**l	die-IMPF	k**i**ːm-**i**k	die-SUBJ

Blocking by coda consonant

(7c) Intransitive imperfective		(7d) Intransitive perfective	
t'otʃ-b'-al	harden-PASS-IMPF	tuːkul-n-ak	think-N-SUBJ
		heːk'-n-ak	break-N-SUBJ
		ts'iːb'-n-ak	write-N-SUBJ

On the other hand, two derivational suffixes dissimilate from the stem-final vowel:
- *–kiːn*/*–kuːn*, used in the formation of deadjectival and denominal forms (glossed D below, following Krämer 2001),
- and *–en*/*–un*, a participle formed from positional verbs used in reduplication.

Dissimilation driving –kiːn vs. –kuːn

(8a)	**u**ts-k**i**ːn-t-ik	good-D-TR-IMPF
(8b)	h**a**w-k**u**ːn-t-ah	lie.down.face.up-D-TR-PERF
(8c)	saːs**i**l-k**u**ːn-s	light.up-D-CAUS-DET

[1] If matching amongst vowels were simply the result of reduplication, one would expect both length and tone (the latter withheld from transcriptions above) to copy, but they do not (Krämer 2001; *cf*. Stanton & Zukoff 2016).

- Suffix form chosen is the one that differs from the preceding vowel in the value of [back], providing evidence for the working of backness dissimilation in the grammar.

Dissimilation driving –en vs. –un

(9a)	h**a**ːy-**u**n-haːy	stretch-PART-RED = 'stretch here and there'
(9b)	k**e**ːb-**u**n-keːb	lean-PART-RED = 'lean here and there'
(9c)	ʃ**o**ːl-**e**n-ʃoːl	kneel-PART-RED = 'kneel here and there'
(9d)	k**u**ːl-**e**n-kuːl	seat-PART-RED = 'seat here and there'
(9e)	tʃ**i**ːl-**e**n-tʃiːl	lie-PART-RED = 'lie here and there'

Here the story is somewhat more complicated:

- *–en* is default allomorph for the participial morpheme,
- but if the preceding vowel matches for both [back] and [high], then *–un*, is selected (see Krämer 2001 for an analysis based on underspecification).

Hence in Yucatec Maya, two suffixes harmonize for backness and height, while another suffix dissimilates for backness, and yet another for both backness and height.[2]

See literature for similar systems in other Mayan languages (England 1983, Smith-Stark 1983, Edmonson 1988, Ayres 1991, Polian 2013; *cf.* Bennett 2016).

3. Domain generalization bias

DOMAIN GENERALIZATION BIAS: Learner tendency to favor phonological constraints that hold across morphological domains.

Though morphologically derived environment effects were purported to arise in some languages, Cho (2009) and Chong (2016) suggest some famous cases are either unstable or nonexistent.

Artificial language experiments suggest learners prefer grammars in which phonological constraints hold across domains:

- Myers & Padgett (2014) expose participants to phrase-final devoicing, who in turn generalize it to word-final devoicing.
- Chong (to appear) shows harmony alternations are more readily apprehended when roots show a harmony generalization.

Martin (2007, 2011), observes "leaking" — that is, a categorical phonotactic constraint weakly manifesting across compound boundaries:

- Navajo categorically enforces sibilant harmony in roots, while compounds with disagreeing sibilants are significantly underattested.
- Likewise, English bans geminates in roots, while compounds with geminates are significantly underattested.

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[2] Note that not all suffixes harmonize or dissimilate: the perfective and transitive imperfective *–ah* and *–ik* always surface with these forms, and do not depend on the final stem vowel.

- See Brown & Yang (2016) for a similar story in Japanese.

Opposite restrictions in Malagasy and Mayan are mismatch cases that are more drastic than derived environment effects. It's remarkable they even arise, given these findings.

4. MaxEnt grammar for Malagasy cooccurrence restrictions

Backness restriction in Malagasy is in large part gradient — I treat it within **Maximum Entropy Harmonic Grammar** (MaxEnt; Hayes & Wilson 2008).

In MaxEnt:

- Constraints are assigned a numerical "strength", or **weight**, instead of being ranked.
- Output forms are assigned **probabilities** ($\mathcal{P}$) instead of being partitioned into winners and losers.
- Probabilities are determined as a function of the weighted sum of the constraint violations, i.e. the **harmony** ($\mathcal{H}$).

I use the MaxEnt Grammar Tool (Wilson 2006), which takes in UR-SR pairs, their frequencies, constraints and tableaux and returns optimal weights for the constraints.

- Available here: http://linguistics.ucla.edu/people/hayes/MaxentGrammarTool/

First to cover backness dissimilation. I reproduce below the pertinent data:

(9a)	*-u is underlying*:	/bata+u/ → [bata-u]	'lift'
(9b)	*Local dissimilation*:	/bab**u**+**u**/ → [bab**u**-**i**]	'plunder'
(9c)	*Nonlocal dissimilation*:	/t**u**da+**u**/ → [t**u**da-**i**]	'prevent'
(9d)	*Front vowel blocking*:	/t**u**r**i**+**u**/ → [t**u**r**i**-**u**]	'preach'

We posit local and nonlocal variety of OCP, *applying only across the suffix boundary*:

(10a) OCP-L(back)/across+: $*\begin{bmatrix}\alpha\text{back}\\ \text{-low}\end{bmatrix} C_0{+}\begin{bmatrix}\alpha\text{back}\\ \text{-low}\end{bmatrix}$

OCP-NL(back)/across+: $*\begin{bmatrix}\alpha\text{back}\\ \text{-low}\end{bmatrix} C_0\text{a}C_0{+}\begin{bmatrix}\alpha\text{back}\\ \text{-low}\end{bmatrix}$

And we have low-weighted IDENT, violated by alternating forms.

As for the harmony preference in roots, we posit local and nonlocal variety of AGREE (Lombardi 1999, Bakovic 2000), *applying only within roots*:

(10b) AGREE-L(back)/within roots: $*\begin{bmatrix}\alpha\text{back}\\ \text{-low}\end{bmatrix} C_0\begin{bmatrix}\text{-}\alpha\text{back}\\ \text{-low}\end{bmatrix}$

AGREE-NL(back)/within roots: $*\begin{bmatrix}\alpha\text{back}\\ \text{-low}\end{bmatrix} C_0\text{a}C_0\begin{bmatrix}\text{-}\alpha\text{back}\\ \text{-low}\end{bmatrix}$

We feed into the MaxEnt learning tool the UR-SR mappings and frequencies below:

Within root			*Across suffix boundary*		
Input	Candidate	Freq.	Input	Candidate	Freq.
V_1V_2	uu, ii, ei, etc.	1379	u+u	u+u	4
	ui, eu, iu, etc.	1014		u+i	989
V_1aV_2	uau, iai, etc.	205	ua+u	ua+u	196
	uai, iau, etc.	118		ua+i	201
			ui+u	ui+u	399
				ui+i	2
			no.trigger+u	…+u	1877
				…+i	7

Table 4: *Learner input for the Malagasy system*

- Root inputs reminiscent of Martin (2007).

With these constraints, MaxEnt predicted the observed frequencies well, returning the following weights:

(11)
```
AGREE-L-rt      0.31
AGREE-NL-rt     0.55
OCP-L-+         10.45
OCP-NL-+        5.38
IDENT           5.34
```

Let's see the grammar in action. Below is tableau for local dissimilation:

(e.g., /babu+u/) /…**u**C_0+**u**/	$\mathcal{P}$	$\mathcal{H}$	OCP-L/across+ $w = 9.95$	IDENT $w = 4.84$
uC_0+**u**	0.01	-9.95	-1 ∗ 9.95	
uC_0+**i**	0.99	-4.84		-1 ∗ 4.84

Table 5a: *Tableau for local backness dissimilation*

- Grammar accurately predicts local dissimilation across 99% of the relevant forms.
- Nonlocal dissimilation tableau looks similar, accurately predicting a 51% rate.

But for root harmony over adjacent vowels, we have the following:

/V_1V_2/	$\mathcal{P}$	$\mathcal{H}$	AGREE-L/roots $w = 0.36$
uu, ii, ei, etc.	0.59	0	
ui, eu, iu, etc.	0.41	-0.36	-1 ∗ 0.36

Table 5b: *Tableau for front vowel blocking*

- Nonlocal harmony is captured similarly.

Blocking by front vowels is also modeled accurately: violation of higher weighted OCP-L/across+ and IDENT are traded for a violation of lower weighted OCP-NL/across+.

4.1 Overriding smoothing in Malagasy

On a deeper level, opposite restrictions systems complicate our understanding of domain generalization. Recall:

- Martin (2011) observes that strong phonotactic constraints can "leak" into the cross-boundary domain:
  - in Navajo sibilant harmony for instance, a categorical phonotactic generalization is mirrored by a statistical tendency across compound boundaries.
- Martin introduces a smoothing term into MaxEnt:
  - when learners weigh highly a phonotactic constraint, they also give weak positive weight to a domain-general constraint, thereby deriving tendencies in compounds.

For Malagasy we can invoke a suffixal OCP constraint together with a general OCP constraint, and the smoothing term would result in the learner weighing general OCP positively.

But the learner is free to counteract tendency simply by adjusting the weight of root-internal AGREE to the point of eclipsing general OCP, as the MaxEnt outputs below reveal:

Within root			*Across suffix boundary*		
Input	Cand.	Freq.	Input	Cand.	Freq.
V_1V_2	uu, ii, etc.	1300	u+u	u+u	0
	ui, eu, etc.	1000		u+i	1000
			no.trig+u	…+u	1000
				…+i	0

(12a)

```
AGREE-L-rt   9.83
OCP-L        9.57
OCP-L-+     19.39
IDENT       14.21
```

Table 6a: *Input with harmony preference*

Within root			*Across suffix boundary*		
Input	Cand.	Freq.	Input	Cand.	Freq.
V_1V_2	uu, ii, etc.	1000	u+u	u+u	0
	ui, eu, etc.	1000		u+i	1000
			no.trig+u	…+u	1000
				…+i	0

(12b)

```
AGREE-L-rt   9.66
OCP-L        9.66
OCP-L-+     19.32
IDENT       14.21
```

Table 6b: *Input with no preference*

Outputted grammars by MaxEnt match the desired frequencies nearly perfectly.

- The OCP drive is leaked into the root domain, and yet the overall result in (12a) is one in which opposing constraints result in *tendency reversal*,
- and in (12b) is one in which opposing constraints result in *tendency cancellation*, for better or for worse.

Thus the current representation of domain generalization bias in MaxEnt does *not* prevent derived environment effects most generally (*cf.* Martin 2011).

- Learner can simply weigh positively a counterconstraint to cancel out or reverse a generalization leaked into a domain.

Availability of natural counterconstraint to the learner might be what distinguishes Martin's cases from mine:

- learners may fail to entertain constraints favoring disharmonic sibilants or geminates, they being unnatural and typologically unmotivated;
- but harmony *and* dissimilation in back vowels are observed crosslinguistically (Clements and Sezer 1982, Itô 1984),
- and so it is reasonable to think the learner could entertain constraints for the latter in hypotheses about morphological domains.

It very well could be that derived environment effects arise and persist only in cases where there exists independent crosslinguistic evidence for the working of two opposing constraints.

And perhaps those in which there does not exist a natural opposing constraint are relatively prone to breaking down, as in Chong (2016), or being generalized, as in Martin (2011).

5. Discussion and conclusion

How might the Malagasy system have arisen?

- Perhaps opposite restrictions play a part in *marking the suffix boundary* — a drive that would directly conflict with domain generalization bias.
- Or perhaps it was historical accident, e.g. backness dissimilation originates as *u+u, but is eventually generalized into *u(C_0a)C_0+u.
    - o Note [uu] is absent from roots, unless <h> is silent (e.g., <adoho>).
    - o If true, then learners extrapolated in a way that defies domain generalization bias.

Are opposite restrictions systems really biased against? Two possibilities:

1) These systems are militated against by domain generalization bias. They are, after all, derived environment effects, and so this bias renders them rare.

2) These systems are *not* militated against by such learning bias.

- This would mean that domain generalization bias is only a bias against one kind of derived environment effect,
- namely, one in which structure X is underrepresented in Domain A but is neither under- nor overrepresented in Domain B.
- This is in line with how smoothing works in MaxEnt grammar (Martin 2011).

These data undermine strength of domain generalization bias: Malagasy learner must be able to acquire opposite cooccurrence restrictions across domains.

6. Appendix

A. The **expected proportion** of local harmonic sequences to disharmonic sequences is determined as follows. Gather all vowel pairs in which either vowel belongs to [i e u]. We calculate:

$$p(V_1 = [i]\ or\ [e]) * p(V_2 = [i]\ or\ [e]) +\ p(V_1 = [u]) * p(V_2 = [u])$$

- e.g., $p(V_1 = [\text{i e}]) = (\#\ \text{instances}\ V_1 = [\text{i e}])/(\#\ \text{instances}\ V_1 = [\text{i e}] + \#\ \text{instances}\ V_1 = [\text{u}])$.

The same can be done for nonlocal sequences by gathering all sequences of the form V_1aV_2, where V_1 and V_2 belong to [i e u]. The formula will be the same as above.

B. How does a **Monte Carlo simulation** work?

- Extract from roots all pairs of tier-adjacent vowels belonging to [i e u]:

ab**i**l**i**	→	$\mathbf{i_1 i_1}$
ab**u**n**i**	→	$\mathbf{u_2 i_2}$
af**u**v**u**ani	→	$\mathbf{u_3 u_3}$
alah**e**l**u**	→	$\mathbf{e_4 u_4}$
b**ue**r**i**ka	→	$\mathbf{u_5 e_5}$, $\mathbf{e_6 i_6}$
...		...

- Make a new set of V1-V2 pairs by fixing V1 and concatenating a random V2 from another pair:

$\mathbf{i_1 i_1}$	→	$\mathbf{i_1 e_5}$
$\mathbf{u_2 i_2}$	→	$\mathbf{u_2 u_4}$
$\mathbf{u_3 u_3}$	→	$\mathbf{u_3 i_2}$
$\mathbf{e_4 u_4}$	→	$\mathbf{e_4 i_1}$
$\mathbf{u_5 e_5}$	→	$\mathbf{u_5 i_6}$
$\mathbf{e_6 i_6}$	→	$\mathbf{e_6 e_5}$
...		...

- Calculate proportion of harmonic sequences in the new set. This proportion arose *by chance* given existing vowel frequencies, by randomly concatenating V1s with V2s.

- One Monte Carlo trial might produce 51% after random concatenation, another 53%, another 51.5%, another 49%, etc. Do this for 10,000 trials, and you have your bell curve.

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