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A Learning Theory for Abstract Underlying Phonemes

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1. Introduction

Introduction

Compton & Dresher (2011) propose that in some Inuit dialects there is evidence for a covert contrast between /i/ and /ə/ which is neutralized on the surface to [i].

Mayer, Major, & Yakup (2022) reject this sort of analysis in general, suggesting that the covert contrast is not learnable [*emphasis* added]:

> an underlying featural contrast is used to condition phonological behavior, despite corresponding to no observable phonetic differences *in the conditioning segments themselves* [...] These analyses therefore make strong claims [...] that there is some learning mechanism that leads to such a representation. Mayer, Major, & Yakup (2022)

Introduction

Mayer et al. are not the only phonologists who require 'observable phonetic differences in the conditioning segments themselves' to diagnose an underlying featural contrast.

In Esimbi (Tivoid), all vowels in roots are high ([i, ɨ, u]) on the surface; however, some roots take prefixes with [i, u], others with [e, o], and others with [ɛ, ɔ].

Archangeli & Pulleyblank (2015) reject the abstract analysis of Hyman (1988) in which root vowels of various heights all neutralize on the surface to high vowels [*emphasis* added]:

Introduction

> Assuming that a phonological difference in the roots is the source of the difference in prefix height requires that height distinctions be encoded in roots even though there is no surface evidence—*in the roots*—for the required distinction. Archangeli & Pulleyblank (2015)

Archangeli & Pulleyblank doubt that abstract underlying height contrasts can be learned because of an 'opacity problem'.

Since the term 'opacity' was introduced by Kiparsky (1973), it has been assumed that opaque rules pose particular learnability problems.

Introduction

This assumption has led to attempts to constrain or completely do away with phonological opacity, or to prefer analyses that do not have it.

I will argue that the learnability problem has been misconceived: rule opacity does not pose a learning problem!

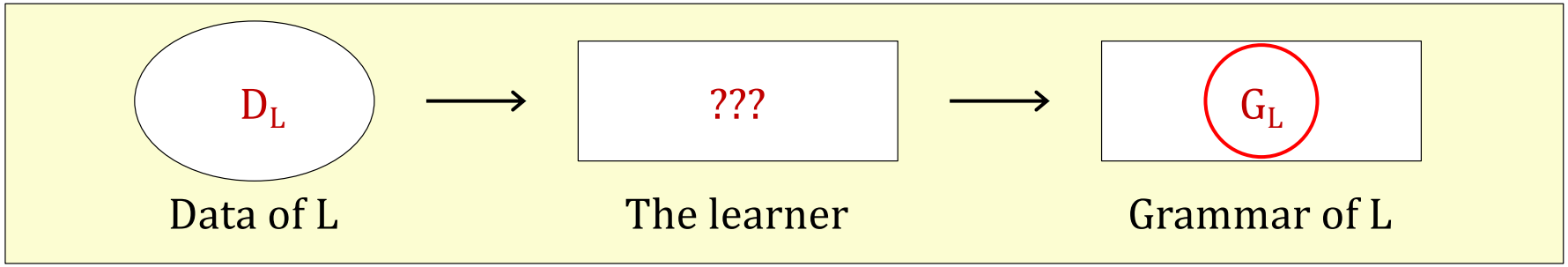
Rather, opacity is a solution within a particular theoretical framework for a learning problem that exists independently of that framework.

I will argue that there is indeed a learning mechanism that leads learners to posit abstract underlying representations and opaque rules.

2. The Learning Problem for Phonology

The learning problem for phonology

Before we get into opacity, I want to emphasize the obvious point that what is easy or hard to learn depends a lot on what learners bring to language acquisition.



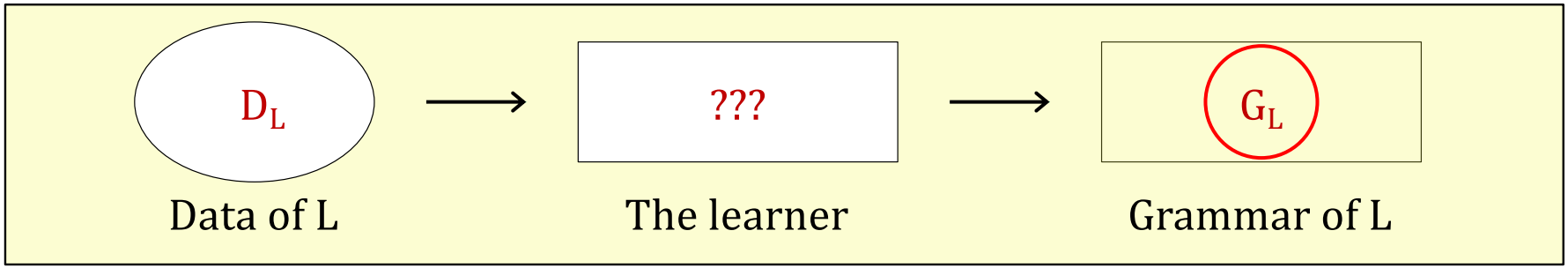
The diagram illustrates a learner born into a community that speaks a language, L, who is exposed to data D_L from L, and somehow arrives at a grammar of L, G_L.

A goal of generative grammar is to determine G_L for each L. A correct grammar of L achieves descriptive adequacy (the term used by Chomsky 1965).

The learning problem for phonology

What are these G_Ls like?

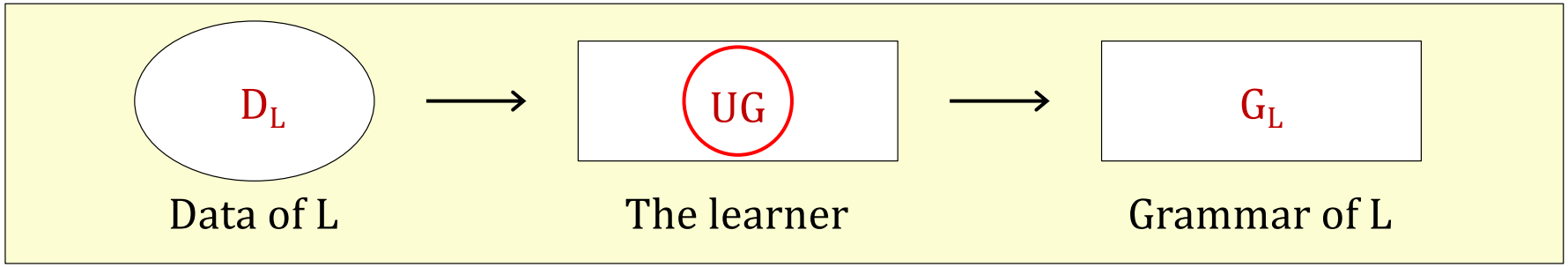
- Do they draw on a set of universal fully-specified features, or do they have language-particular contrastive features?



- Do they have features at all?
- Or do they have unary elements, or particles, or gestures?
- Ordered rules or parallel constraints?
- Unique representations or exemplar clouds?
- Are the grammars stochastic?
- How much phonetic detail is included in lexical representations?

The learning problem for phonology

These are all questions that phonologists argue about; but presumably these are not issues for learners.

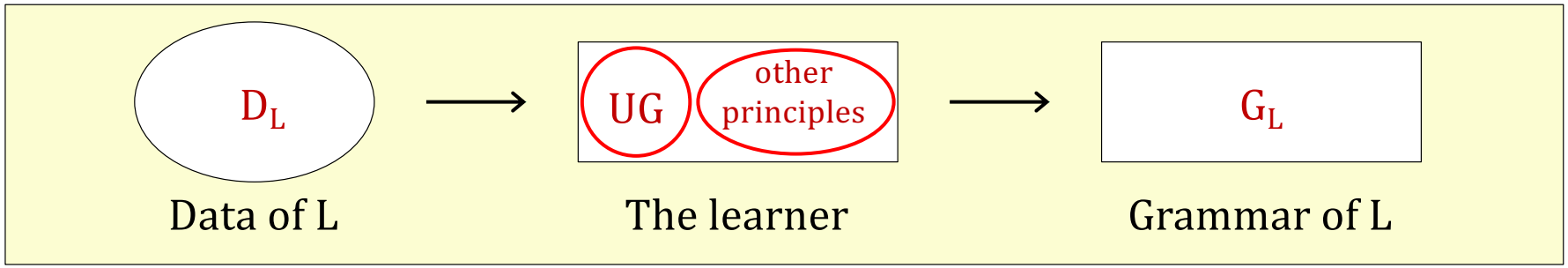


We assume that the basic form of each G_L is determined by the innate set of cognitive principles that learners are equipped with, which can convert D_L into G_L.

In generative grammar these principles have been called Universal Grammar (UG). In Chomsky's terms, a correct theory of UG achieves explanatory adequacy.

The learning problem for phonology

Some understand UG in a narrow sense to mean innate principles exclusive to the language faculty, which have to work together with other cognitive principles.



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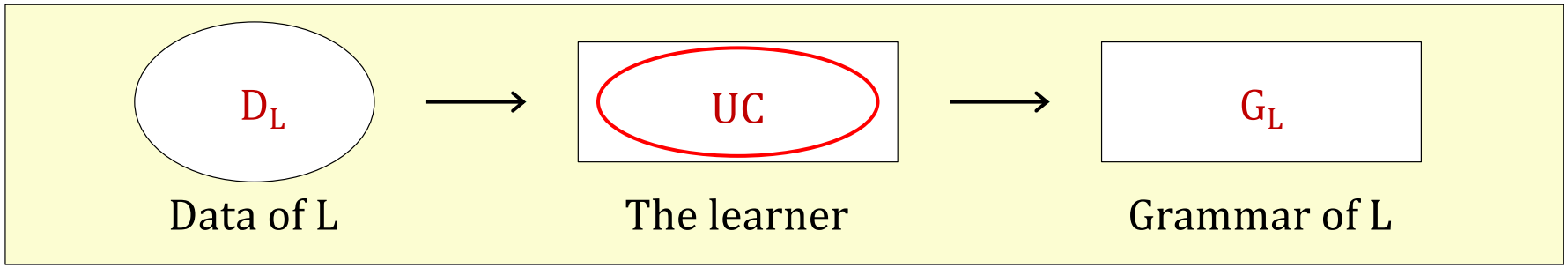
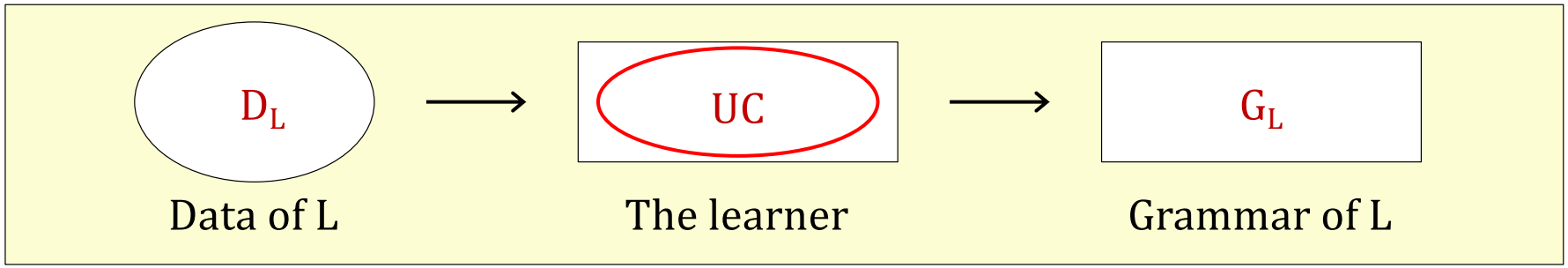


I am not concerned with this issue, so I will use UC to refer to the learner's innate cognitive endowment, whether exclusive to language or more general than that.

By definition, UC is the stuff that learners do not have to learn (for Bayesians, UC is the hypothesis space and the set of priors in the learning scenario).

The learning problem for phonology

Of course, as with UG, we linguists have to arrive at the correct theory of UC: Does it dictate features or elements, single representations or clouds, etc.?

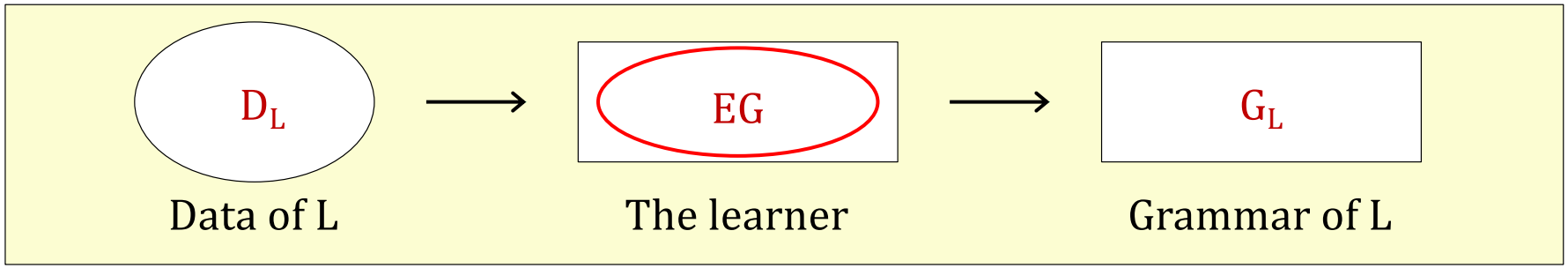


This is a classic poverty of the stimulus problem: the data D_L does not by itself tell the learner what the units of mental represention are.

Therefore, UC must be rich enough to bridge the gap between D_L and G_L.

The learning problem for phonology

Archangeli & Pulleyblank (2015) argue that infants do not learn grammar 'due to an innate capability specific for language, the Universal Grammar hypothesis'.



They propose that language learners make use of basic cognitive principles not special to language, what they call the Emergent Grammar hypothesis (EG).

The basic principles of EG are the following:

Principles of EG (Archangeli & Pulleyblank 2015)

a. Ability to create categories
b. Ability to attend to frequency
c. Ability to generalize and create a symbolic system

That's it! Recall that these principles have to determine what grammars are like :

The above principles are consistent with any conceivable grammar; they cannot guide the learner to any particular G_L, whatever it is.

This is not a serious proposal!

- Are features universal and fully-specified, or language-particular and contrastive?
- Do languages have features at all?
- Or do they have unary elements, or particles, or gestures?
- Ordered rules or parallel constraints?
- Unique representations or exemplar clouds?
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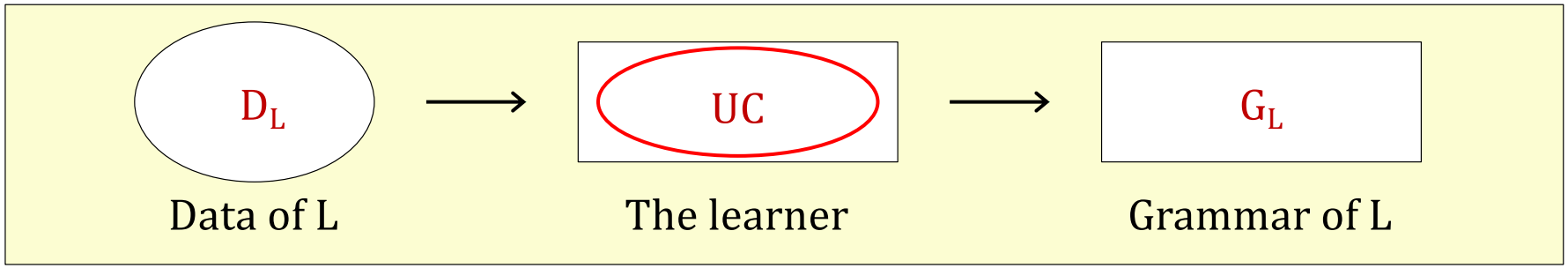
The learning problem for phonology

Whatever the exact nature of the phonological grammar, solving the poverty of the stimulus requires a contentful theory of UC.



Let's now turn to an actual case.

3. Abstract /ə/ in Inuit Dialects

‘Strong *i*’ and ‘weak *i*’ in Inuit dialects

Many Inuit dialects make a distinction between ‘strong i’, which causes palatalization (or assibilation) of some consonants, and ‘weak i’, which doesn’t.

For example, in Barrow North Slope Iñupiaq (Inuit; Kaplan 1981), the suffixes -lu (‘and a N’), -nik (‘N.OBL.PL’), and -tun (‘like a N’) follow a stem whose last vowel is u.

(1)	Stem	Gloss	‘and a N’	‘N-OBL.PL’	‘like a N’
a.	iɣlu	‘house’	iɣlu-lu	iɣlu-nik	iɣlu-tun

‘Strong *i*’ and ‘weak *i*’ in Inuit dialects

These suffixes all begin with an alveolar consonant which is palatalized after some i, as shown in (b). This i is called ‘strong i’ in the literature.

After other i (‘weak i’) in (c), there is no palatalization, and the suffixes appear as they do after u (and also after a, not shown here).

(1)	Stem	Gloss	‘and a N’	‘N-OBL.PL’	‘like a N’
a.	iɣlu	‘house’	iɣlu-lu	iɣlu-nik	iɣlu-tun
b.	iki	‘wound’	iki-ʎu	iki-ɲik	iki-sun
c.	ini	‘place’	ini-lu	ini-nik	ini-tun

‘Strong *i*’ and ‘weak *i*’ in Inuit dialects

Following Kaplan (1981), Compton & Dresher (2011) propose that weak i derives from an underlying vowel that is distinct from strong i.

Whereas strong i is underlyingly /i/, weak i derives from underlying /ə/.

(1)

	Stem	Gloss	‘and a N’	‘N-OBL.PL’	‘like a N’
a.	iɣlu	‘house’	iɣlu-lu	iɣlu-nik	iɣlu-tun
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c.	ini	‘place’	ini-lu	ini-nik	ini-tun

‘Strong *i*’ and ‘weak *i*’ in Inuit dialects

This abstract analysis reflects the historical derivation of strong and weak i from Proto-Eskimo as reconstructed by Fortescue, Jacobson, & Kaplan (1994).

Of course, child learners of modern Inuit dialects have no access to the Proto-Eskimo origins of these words.

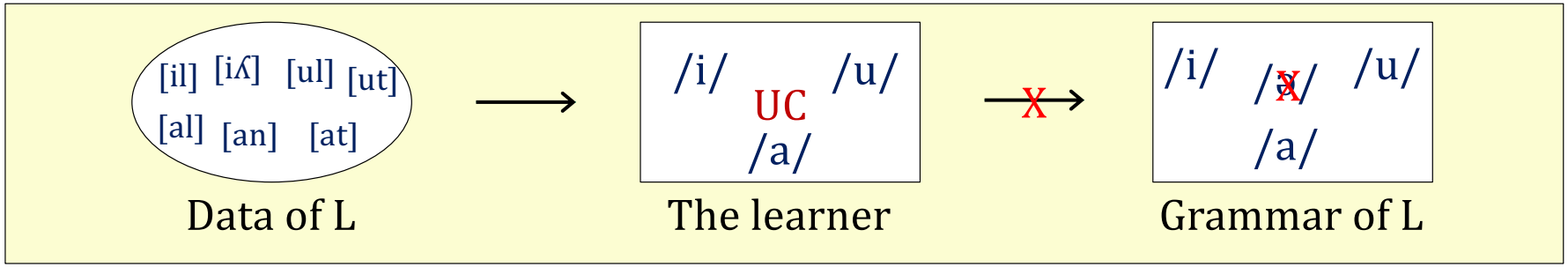
The abstract analysis is not motivated by Proto-Eskimo, but by the synchronic data that learners have access to.

(1)	Stem	Gloss	‘and a N’	‘N-OBL.PL’	‘like a N’	Proto-Eskimo
a.	iɣlu	‘house’	iɣlu-lu	iɣlu-nik	iɣlu-tun	*əŋlu
b.	iki	‘wound’	iki-ʎu	iki-ɲik	iki-sun	*əki
c.	ini	‘place’	ini-lu	ini-nik	ini-tun	*ənə

4. A Learning Theory for Abstract Phonemes

A learning theory for phonology: Some assumptions

How hard is it to learn an underlying phoneme that never exists as such at the phonetic surface? In our case, to acquire an underlying /ə/ in Inuit dialects?



It depends on the contents of UC. If UC limits the learner to underlying representations that exist at the surface, then there is no path to acquiring /ə/ in Inuit.

A learning theory for phonology: Some assumptions

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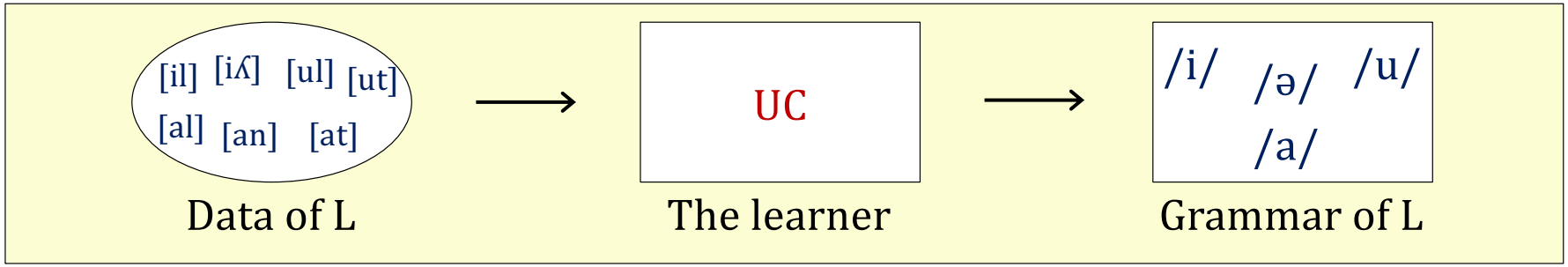
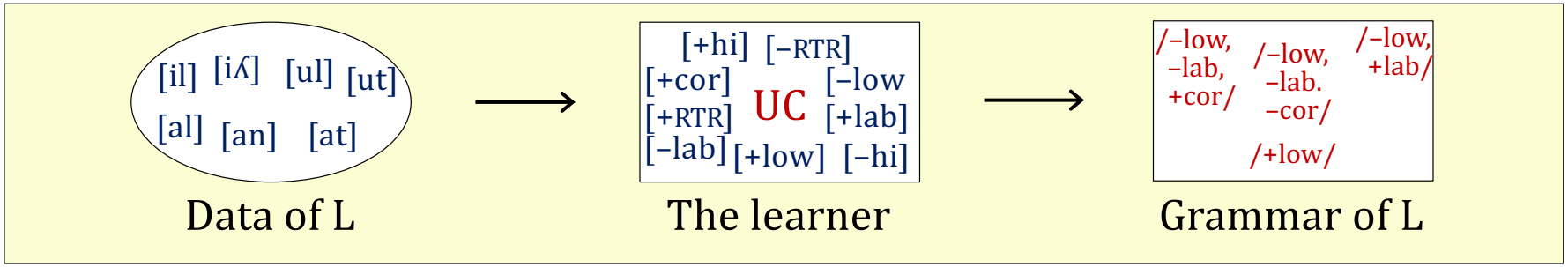


It depends on the contents of UC. If UC limits the learner to underlying representations that exist at the surface, then there is no path to acquiring /ə/ in Inuit.

But I know of no evidence for this limitation, which would perhaps have some rationale if UC treated phonemes as undecomposable primes.

A learning theory for phonology: Some assumptions

Most theories of phonology, however, assume that phonemes and segments are composed of smaller units, i.e., features or elements of some kind.



If so, then it is these primes that are the material of phonological computation, not unanalyzed segments.

I will argue that this kind of computation can easily lead to abstract phonemes.

A learning theory for phonology: Some basic assumptions

I make the following basic assumptions, which are standard in most theories of phonology:

- Learners analyze segments into features.
- Interactions between segments involve features.
- Learners have access to the morphological make-up and paradigmatic membership of lexical items.
- Learners attempt to arrive at a single underlying form for each lexical item.
- Where possible, rules and representations formulated in phonological terms are preferred to those that mention non-phonological terms (e.g., diacritics or morphosyntactic terms).

Some further assumptions about features

There are various views as to the nature of the features or elements that constitute segments. For concreteness, I will assume the following:

- Features are binary and language particular.
- Each feature has a marked and an unmarked value, determined on a language-specific basis (Rice 2003, 2007, building on Trubetzkoy 1939).
- On a language-particular basis, either both values of a feature may be active, or marked values may be more active than unmarked values, which can serve as defaults and may be more or less inert.

An assumption about rules

Dresher (1981) suggests that 'the most common phonetic rules involve the assimilation of one feature to a feature in its environment'.

I proposed that a rule of the general form in (2) is a highly-valued rule that learners would be drawn to construct:

(2) Template for a highly-valued rule

$$\begin{bmatrix} \beta G \\ \gamma H \\ . \\ . \\ \varphi P \end{bmatrix} \longrightarrow [\alpha F] \; / \; \begin{matrix} \_\_\_\_ X\,[\alpha F] \\ [\alpha F]\, X \_\_\_\_ \end{matrix}$$

If a segment S = [βG, γH, ... φP] takes on a feature [αF] in the presence of another segment T, i.e.

S → [αF]/____T *or* S → [αF]/T____

the learner will suppose that T also bears [αF].

An assumption about rules

A similar constraint has recently been proposed by Danesi (2022) under the name of the No Ex Nihilo Hypothesis (3).

(2) Template for a highly-valued rule

$$\begin{bmatrix} \beta G \\ \gamma H \\ . \\ . \\ \varphi P \end{bmatrix} \longrightarrow [\alpha F] \; / \; \begin{matrix} \_\_\_\_ X\,[\alpha F] \\ [\alpha F]\, X \_\_\_\_ \end{matrix}$$

(3) No Ex Nihilo Hypothesis (Danesi 2022: 192)

Phonological computation cannot manipulate primes that are absent from the representation of the target and the trigger.

A learning theory for weak *i*

Returning to the question of strong and weak i in Inuit dialects, it is clear in (1b) that stem-final i is what causes palatalization of the suffix-initial consonants.

It is not so obvious what the palatalizing feature is; for now, let's call it [+P].

By our assumptions, the learner posits that i and the palatalized consonants carry this feature, and that stem-final u does not.

(1)	Stem	Gloss	'and a N'	'N-OBL.PL'	'like a N'
a.	iɣlu	'house'	iɣlu-lu	iɣlu-nik	iɣlu-tun
b.	iki	'wound'	iki-ʎu	iki-ɲik	iki-sun

A learning theory for weak *i*

But (1c) presents conflicting signals: stem-final i is phonetically the same as i in (1b), hence [+P]; but the suffixes that follow it suggest that it is not [+P].

The learning theory tells the learner how to resolve this conflict.

In classical generative phonology, the resolution occurs via a derivation: stem-final i in (1c) has [+P] at the surface but lacks it underlyingly.

(1)	Stem	Gloss	'and a N'	'N-OBL.PL'	'like a N'
a.	iɣlu	'house'	iɣlu-lu	iɣlu-nik	iɣlu-tun
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c.	ini	'place'	ini-lu	ini-nik	ini-tun

5. Assigning Features to Abstract Phonemes

A learning theory for phonological features

So how does a learner assign features to weak i? The same way that features are assigned to every other phoneme.

Compton & Dresher's analysis is couched in terms of Contrastive Hierarchy Theory (CHT), whose main tenets are shown in (4):

(4) a. The Successive Division Algorithm (SDA; Dresher 1998, 2003, 2009): Contrastive features are assigned by successively dividing the inventory until every phoneme has been distinguished.

b. Variability of feature ordering: Features and feature ordering are language particular and thus can vary over space and time.

c. The Contrastivist Hypothesis (Hall 2007): The phonological component of a language L operates only on those features which are necessary to distinguish the phonemes of L from one another.

A learning theory for phonological features

Since the ordering of features is language particular, learners need a way to determine which features are contrastive and how they are ordered.

According to the Contrastivist Hypothesis, only contrastive features can be active; therefore, by hypothesis, a feature that is found to be active must be contrastive.

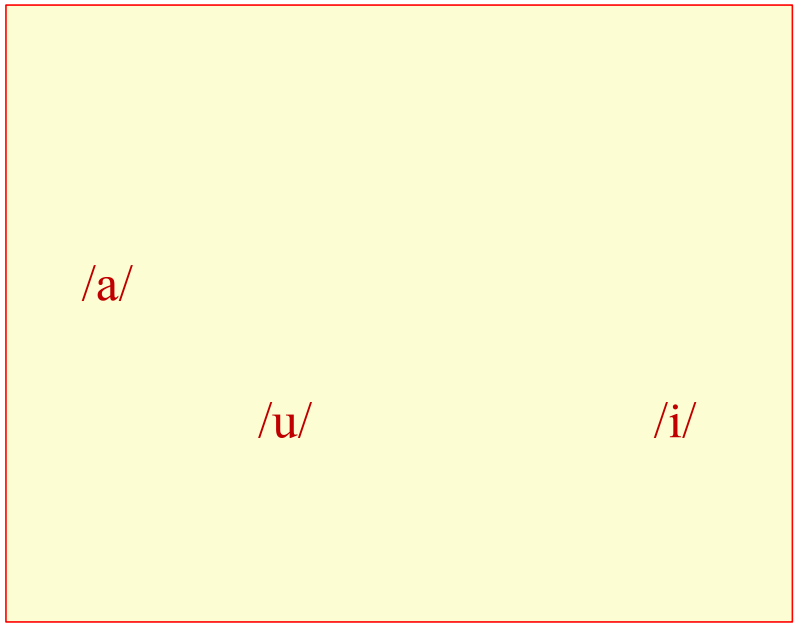
In CHT, then, an important source of evidence for learners is phonological activity, which can be defined as in (5):

(5) Phonological activity (adapted from Clements 2001: 77): A feature can be said to be active if it plays a role in the phonological computation; that is, if it is required for the expression of phonological regularities in a language, including both static phonotactic patterns and patterns of alternation.

Inuit-Yupik contrastive hierarchy (Compton and Dresher 2011)

There are Inuit dialects which have 3 underlying vowels, /i, a, u/.

(6) Three-vowel Dialects



These dialects have completely lost any contrast between P-E *i and *ə.

Interestingly, none of these dialects have palatalization after /i/.

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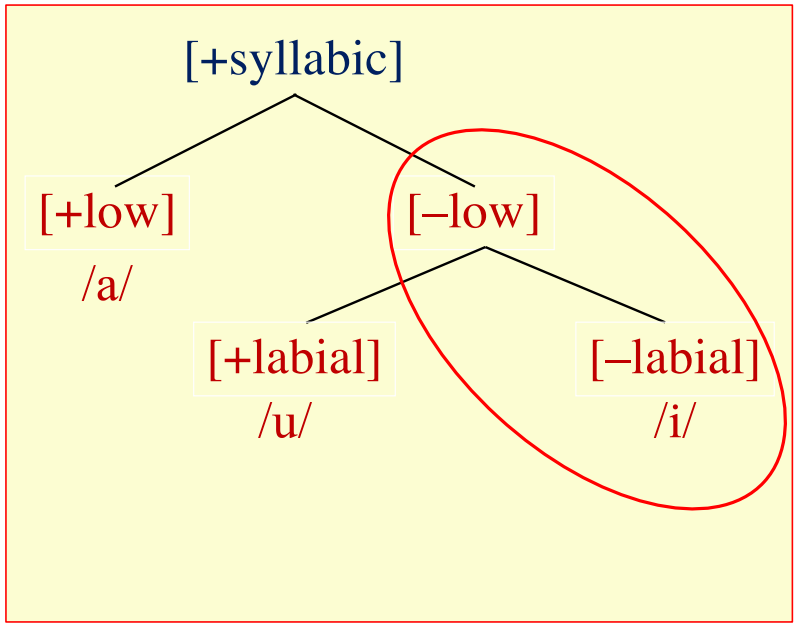


These dialects have completely lost any contrast between P-E *i and *ə.

Interestingly, none of these dialects have palatalization after /i/.

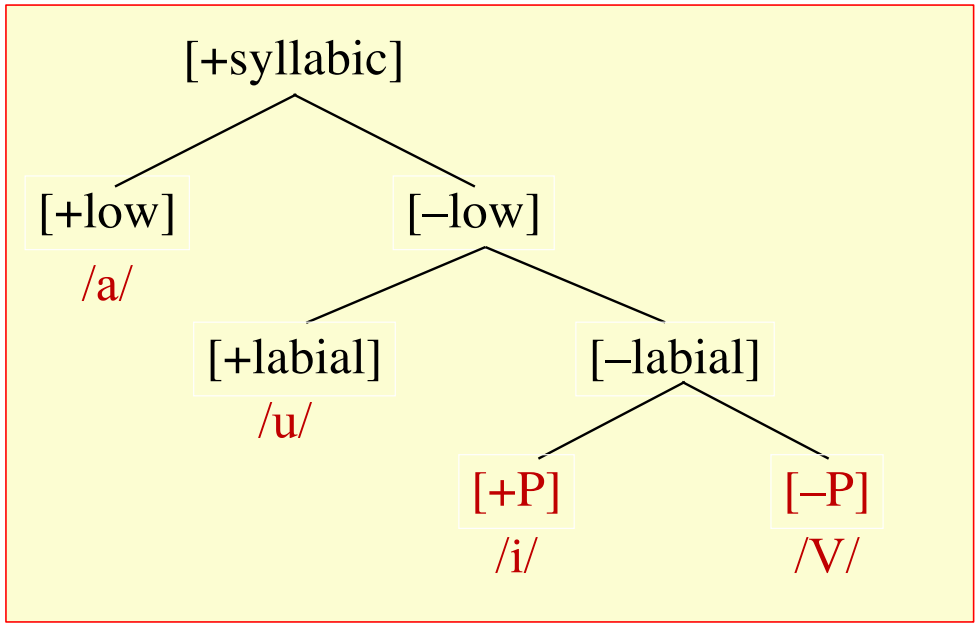
Compton & Dresher (2011) propose that this is because the Inuit-Yupik contrastive hierarchy has: [low] > [labial] at the top.

Thus, /i/ in these dialects has no contrastive palatalizing feature; it's the unmarked vowel.

Inuit-Yupik contrastive hierarchy (Compton and Dresher 2011)

Now consider dialects which have retained 4 underlying vowels.

(7) Four-vowel Dialects



These dialects have a contrast between strong i and weak i; i.e., between /i/ and a fourth vowel, which for now we can call /V/.

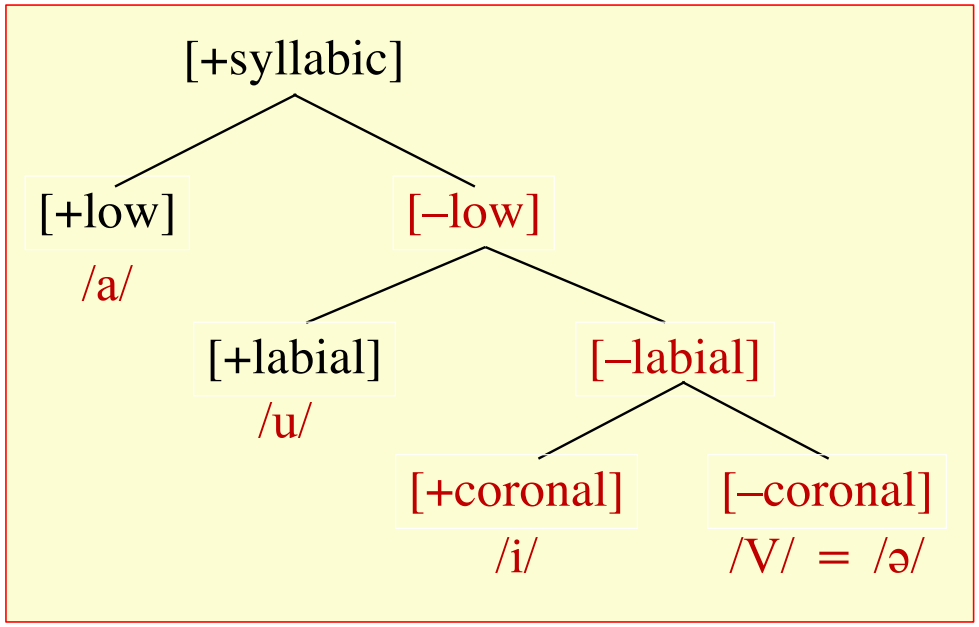
The contrast between /i/ and the fourth vowel /V/ requires a third feature, which must be the palatalizing feature [+P].

What is [P]?

Inuit-Yupik contrastive hierarchy (Compton and Dresher 2011)

Compton & Dresher (2011) proposed that [P] is [coronal].

(7) Four-vowel Dialects

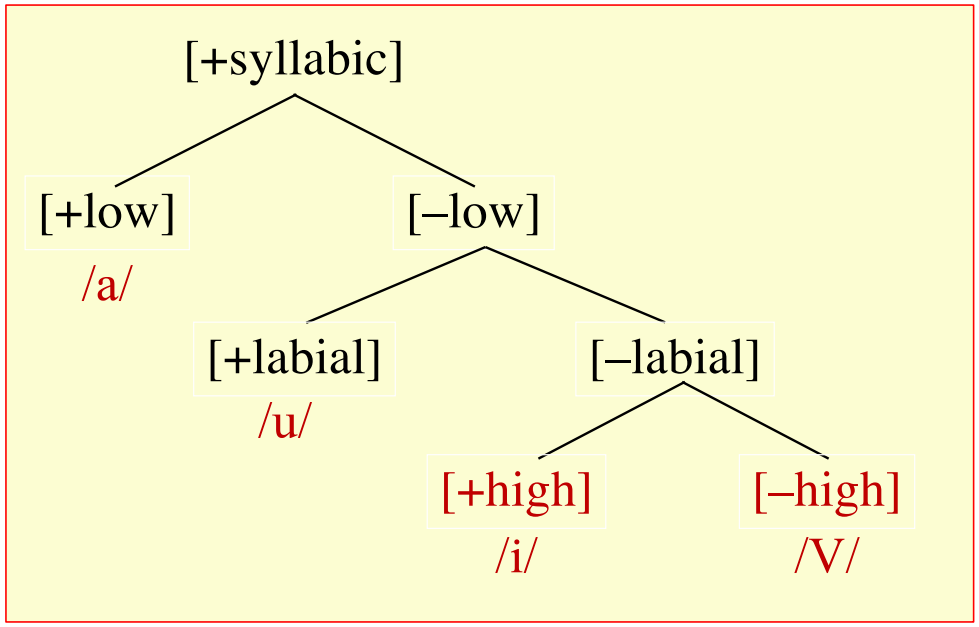


This followed studies that argued that V-place [coronal] causes palatalization of consonants (Clements 1976, 1991; Hume 1994), even those with C-place [coronal] (see Kochetov to appear for a review).

If strong /i/ is [+coronal], then weak /i/ must be: [–low, –labial, –coronal] , i.e., a central vowel we could call /ə/.

Inuit-Yupik contrastive hierarchy (Compton and Dresher 2011)

(7) Four-vowel Dialects



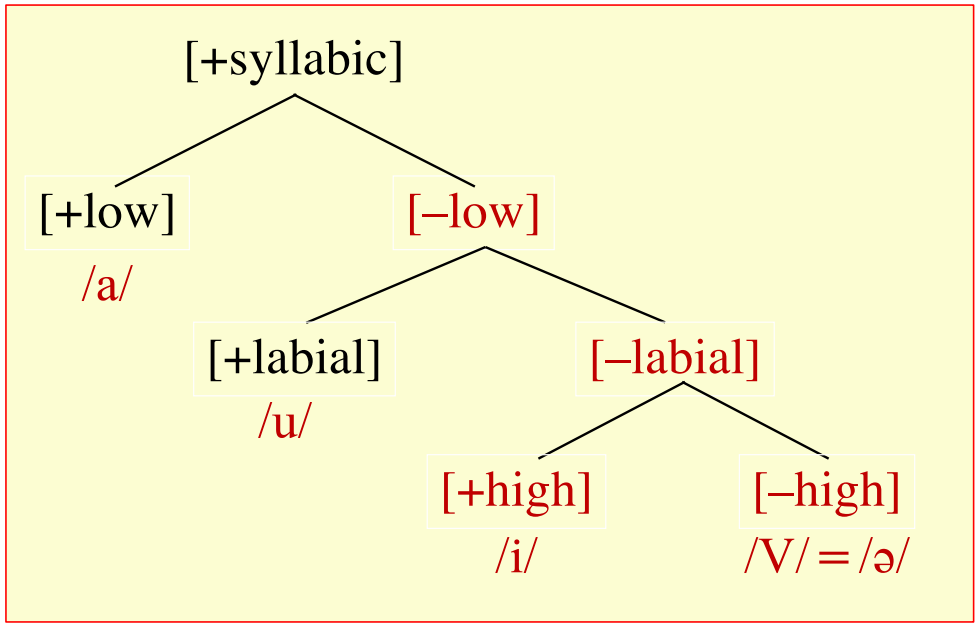
Kaplan (1981) followed Chomsky & Halle (1968) (SPE) in proposing that the palatalizing feature is [high].

This view is supported by Lahiri & Evers (1991) and Lahiri (2018), who argue that the palatalization of /l/ to [ʎ] and /n/ to [ɲ] amounts to the change of [–high] to [+high].

Inuit-Yupik contrastive hierarchy (Compton and Dresher 2011)

In our case, it doesn't matter that much what we call the palatalizing feature.

(7) Four-vowel Dialects



Whether feature theory has C-place and V-place tiers is determined by UC; it's not something the learner has to figure out.

Suppose we assume that the third feature is [high]. On this view:

Weak /i/ must be: [–low, –labial, –high], which again = /ə/.

What about /t/ to [s]?

As to /t/ to [s], Kaplan proposes that adding [+high] to /t/ gives [tʃ], which then becomes [s].

The palatalization of /t/ is [s] in many Inuit dialects, presumably by a similar mechanism as proposed by Kaplan for Iñupiaq.

(1)	Stem	Gloss	'and a N'	'N-OBL.PL'	'like a N'
a.	iɣlu	'house'	iɣlu-lu	iɣlu-nik	iɣlu-tun
b.	iki	'wound'	iki-ʎu	iki-ɲik	/iki-tʃun/ → iki-sun
c.	ini	'place'	ini-lu	ini-nik	ini-tun

6. Derivations and Rule Opacity

Derivations with strong and weak *i*: opacity

I have now presented the outline of a learning theory that can lead an Inuit learner to identify weak i with an underlying set of features that amount to /ə/.

To complete the story, let's consider sample derivations with strong and weak i.

In (8a), Palatalization applies to /l/ that follows underlying ('strong') /i/.

(8)	a. 'and a wound'
UR	/iki+lu/
Palatalization	ikiʎu
SR	[ikiʎu]

Derivations with strong and weak *i*: opacity

In (8b), Palatalization does not apply to /l/ that follows underlying /ə/ (weak i).

The neutralization of /ə/ to [i] must follow the application of Palatalization.

The relative ordering of Palatalization and /ə/ → [i] makes the former opaque.

(8)	a. 'and a wound'	b. 'and a place'
UR	/iki+lu/	/inə+lu/
Palatalization	ikiʎu	—
/ə/ → [i]	—	inilu
SR	[ikiʎu]	[inilu]

Rule opacity

Opacity is a term introduced by Kiparsky (1973) to describe a phonological rule whose structural description is contradicted at the surface.

Kiparsky's formulation is given in (9):

Our case is type (a): Palatalization is opaque because at the surface there exists unpalatalized [l] (= A) in environment i_____ (= C_____).

(9) A rule A → B/C____D is opaque to the extent that

a. there exists A in environment C____D (apparent underapplication);

b. there exists B (derived from A) in environment other than C____D (apparent overapplication).

Rule opacity and learnability

Does this opacity thereby make Palatalization hard to learn?

No! In our learning scenario, learners have *already* acquired the rule of Palatalization, as well as the underlying contrast between /i/ and /ə/.

Ordering Palatalization before /ə/ → [i]—i.e, creating opacity—is a solution to the problem of conflicting signals sent by weak i.

(8)	a. 'and a wound'	b. 'and a place'
UR	/ikiɨ+lu/	/inə+lu/
Palatalization	ikiʎu	—
/ə/ → [i]	—	inilu
SR	[ikiʎu]	[inilu]

7. Conclusion

Conclusion

To reiterate: in (8b) and words like it, [i] in [inilu] signals that it has the palatalizing feature ([+high] or [+coronal]), but the [l] signals that it doesn't (*[iniʎu])

The conflict is resolved by assigning both [+high] and [–high] to the weak i.

UC tells the learner how to accommodate these contradictory specifications.

(8)	a. 'and a wound'	b. 'and a place'
UR	/iki+lu/	/inə+lu/
Palatalization	ikiʎu	—
/ə/ → [i]	—	inilu
SR	[ikiʎu]	[inilu]

Conclusion

To reiterate: in (8b) and words like it, [i] in [inilu] signals that it has the palatalizing feature ([+high] or [+coronal]), but the [l] signals that it doesn't (*[iniʎu])

The conflict is resolved by assigning both [+high] and [–high] to the weak i.

UC tells the learner how to accommodate these contradictory specifications.

(8)	a. 'and a wound'	b. 'and a place'
UR	/ik[+hi]+lu/	/in[–hi]+lu/
Palatalization	ikiʎu	—
/ə/ → [i]	—	in[+hi]lu
SR	[ikiʎu]	[inilu]

In derivational generative phonology, the accommodation takes the form of a derivation with ordered rules.

Conclusion

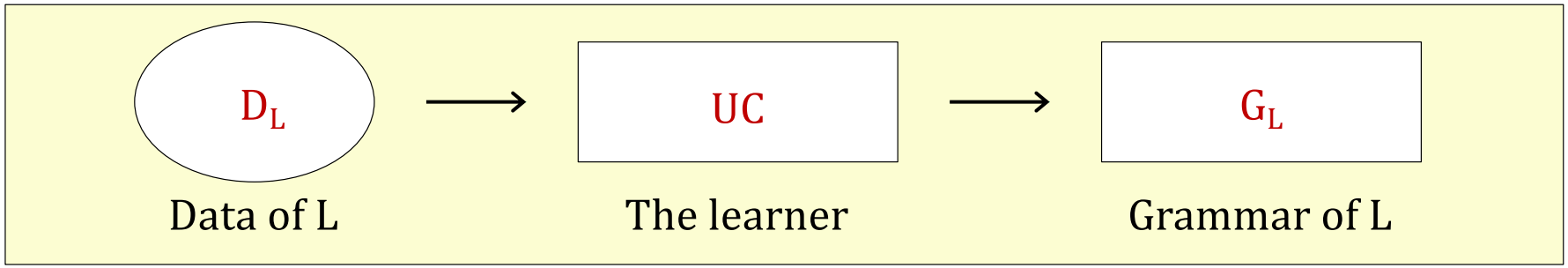
Opacity effects are crucially bound up with the poverty of the stimulus, and the phenomena that manifest them are valuable as probes into the structure of UC.

Efforts to do away with opacity on learnability grounds are therefore misguided, because opacity is not a learning problem, but a solution to a problem posed by conflicting signals in the data.

The conflicting signals will still be there, however we choose to analyze them.

Conclusion

In conclusion: There is no theory of learning without a specification of UC.



And we learn about UC by studying individual grammars G_L.

The other way around doesn't work!

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Phonology/Phonetics Workshop ([mot^{h}] 2024)
McGill University, April 19–21, 2024

THANK YOU! / MERCI!

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