جامعة نيويورك أبوظبي

NYU | ABU DHABI

PSYCH-UH 2218: Language Science

Class: Syllables and phonotactic constraints

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Psychology

Phonology - patterns in the sequences

If you look at a random set of words in any language, the arrangement of segments in the words appears to be relatively random:

open

beware

complain

computer

strength

church

autobiography

intercontinental

approximately

It is true that some of it is arbitrary. But quite a bit is predictable. There are patterns in the sequences of segments.

To be clear, the specific segments in any given word are arbitrary — there is no magical reason that "cat" involves the sounds it does. But many parts of the pattern of the sequence of sounds within a word are predictable.

Phonology is a field of study that investigates the patterns of sequences of sounds in a language (and across languages). The goal is to uncover the predictable parts, and create a theory of the cognitive system that underlies them.

A taste of some patterns

You might think that any sound can appear next to any other sound. But this isn't true. There are patterns in the sequences that we use. Here is a concrete example (that you may not have noticed before):

This is a **TEE**
In IPA it is [ti]

But this is a **CHREE**
In IPA it is [tʃɹi]

Is this a **TRAIN** [t]
or a **CHRAIN** [tʃ]?

Is this a **TRUCK** [t]
or a **CHRUCK** [tʃ]?

Is this a **TRANSFORMER** [t]
or
a **CHRANSFORMER** [tʃ]?

A taste of some patterns

Lots of consonants can appear before [r], but for some reason, [t] cannot. There is no word in US English that has the sequence [tr] at the beginning of a syllable. We can start to look at this systematically, and we will see a gap in the paradigm:

chr	sr
br	shr
fr	pr
gr	*tr
kr	vr

We use an asterisk to indicate that something never happens.

In fact, if you create novel words and ask English speakers to pronounce them, even if you spell them with a [t], they will pronounce it [tʃ]. **Try it!**

tronk	trimp
trallo	trulip

So this isn't an accident. It looks like English prohibits the sequence [tr], even for new words!

A taste of some patterns

There are lots of gaps like the [tr] gap. I want to show you one more because it is a little different, and therefore will give a good perspective on how to look for patterns in sequences of phonemes.

You know that the plural marker in English is “s”. (And sometimes “es”, but let’s set that aside for now and focus on “s”.)

Try pronouncing all of these plural nouns and pay attention to the plural marker “s”:

trips	knobs
cats	lids
snacks	tags

What do you notice about the way the “s” is pronounced in the two columns?

A taste of some patterns

The plural marker in the two columns is pronounced differently:

[s]	[z]
trips	knobs
cats	lids
snacks	tags

Do you notice a pattern?

The pattern is based on the consonant before the plural marker:

When the consonant before is voiceless, the plural marker is an [s].

When the consonant before is voiced, the plural marker is an [z].

Both [s] and [z] exist, but you will never find a plural [s] after a voiced consonant, and you will never find a plural [z] after a voiceless consonant. Go ahead and try to make up new words to test it!

Phonology attempts to explain these predictable patterns in the sequences of segments. But doing it requires a number of new concepts. Let's get started!

Today we start with **syllables**

(Our first piece of structure in language!)

What is a **syllable**?

You have an intuition about the existence of a unit of language called a **syllable**. The intuition we have is something like "a sequence of segments that form a rhythmic unit". Don't memorize this. It is not a precise definition.

word	IPA	syllable breaks	cv notation
open	opən	o.pən	v.cvc
beware	bəwɛr	bə.wɛr	cv.cvc
complain	kəmplen	kəm.plen	cvc.ccvc
computer	kəmpjutər	kəm.pju.tər	cvc.cv.cvc
strength	strɛŋkθ	strɛŋkθ	cccvccc
church	tʃərtʃ	tʃərtʃ	cvcc
autobiography	ɒtəbajɑgrəfi	ɒ.tə.baj.ɑ.grə.fi	v.cv.cv.v.ccv.cv
intercontinental	ɪntərkɑntənɛntəl	ɪn.tər.kɑn.tə.nɛn.təl	cv.cvc.cvc.cv.cvc.cv c
approximately	əprɑksəmətli	ə.prɑk.sə.mət.li	v.ccvc.cv.cvc.cv

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intercontinental	ɪntərkɑntənɛntəl	ɪn.tər.kɑn.tə.nɛn.təl	cv.cvc.cvc.cv.cvc.cv c
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It is worth checking your own intuitions for some of these words. How many syllables do you think they have? It is totally ok to do that thing from school where they had you clap to count the syllables. This works! I do it! It works because syllables are "beats" in the rhythm of the word.

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For many words, it is critical to look at the IPA when trying to uncover the syllables. That way we are sure to list all of the segments, and to group them accurately.

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One convention to show syllable breaks is to put a period in between. I'll do that here for clarity.

What is a **syllable**?

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We can also abstract away from the specific segments, and instead look at whether they are a consonant (C) or vowel (V). Doing this helps to reveal patterns in the syllable structures.

Can we create a phonetic definition of syllable?

The first thing we can do is look for a physical correlate of the syllable. It is something like a "beat". Is there a physical property that correlates with that?

One possibility is a property called "sonority", which is just a fancy way of saying the amount of sound energy.

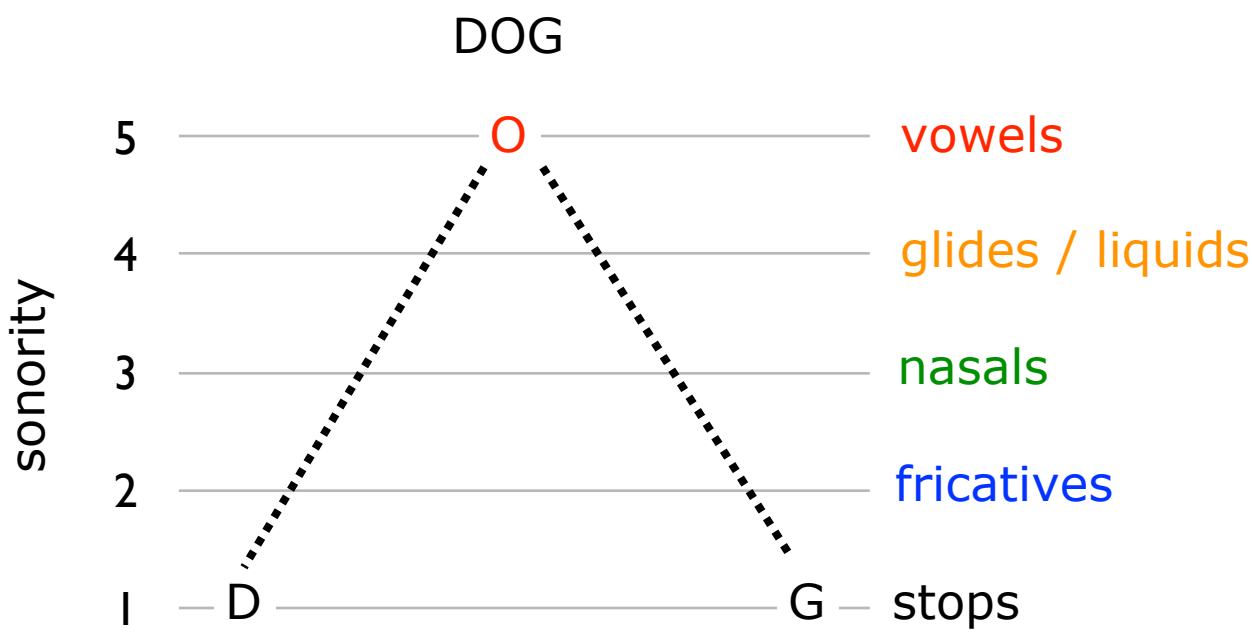
Sonority is a spectrum. Different types of segments have different levels of sonority. You can check your intuitions about how much sound energy is involved with each of these types of segments:

highest sonority:	vowels	a, e, o
	glides	w, j
	liquids	l, r
	nasals	n, m, ŋ
	fricatives	f, s
lowest sonority:	stops	p, t, k

Can we create a phonetic definition of syllable?

Armed with sonority, we can try to define syllable based on it.

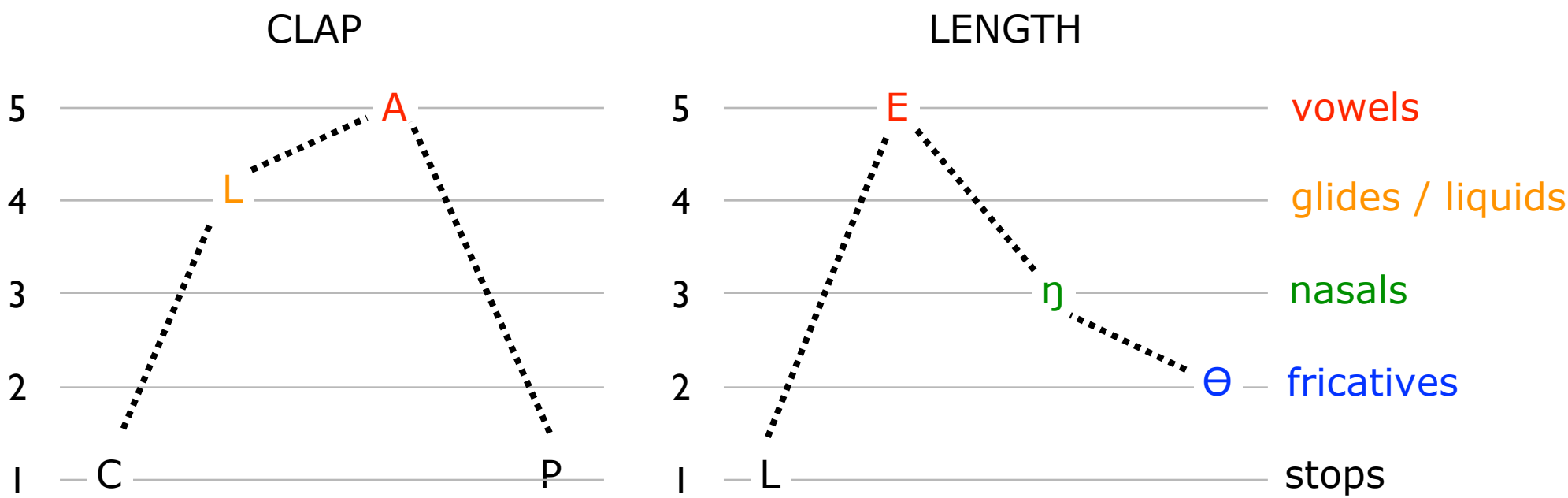
Perhaps something like “a single sonorous peak”. So, a word with two syllables will have two peaks, a word with three will have three peaks, etc.



This actually works fairly well. This is not surprising. There should be a rough phonetic correlate of the concepts we are exploring!

Can we create a phonetic definition of syllable?

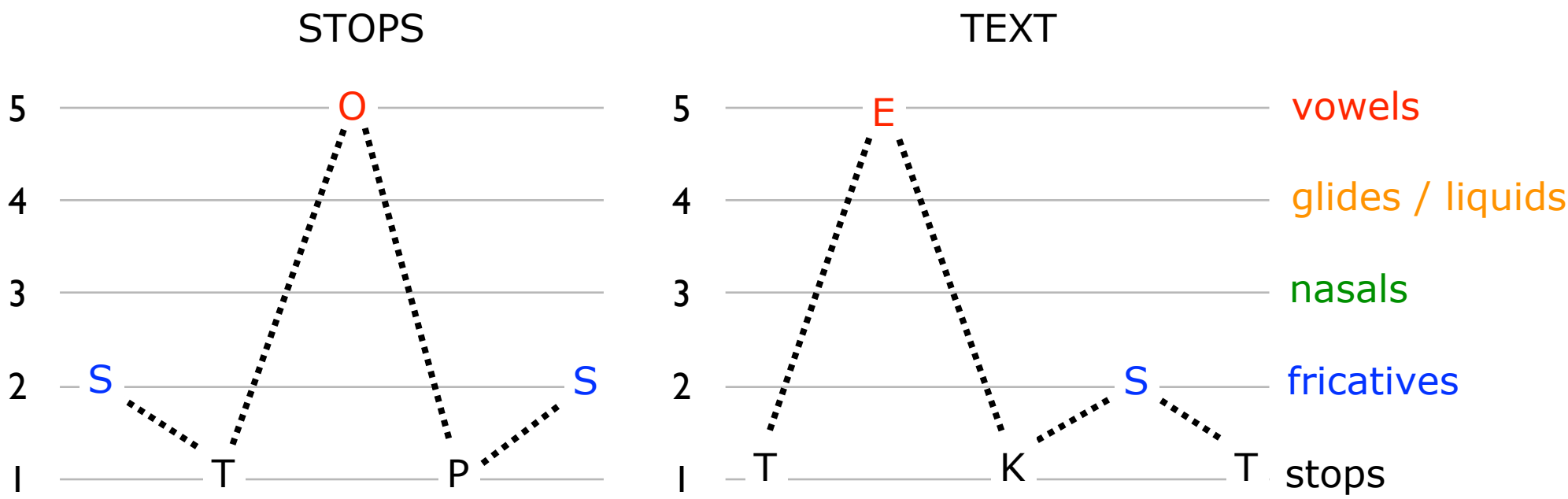
The issue is in the details. In order for this to work easily, we need only one peak per syllable.



Most syllables have only a single peak. This works so well that some linguists have proposed a principle called the **Sonority Sequence Principle**, which states that sonority always decreases as you move away from the vowel in a syllable.

But there are syllables that do not follow the Sonority Sequence Principle

There are syllables that do not follow the SSP. Here we can see smaller peaks at both the beginning and end of syllables:

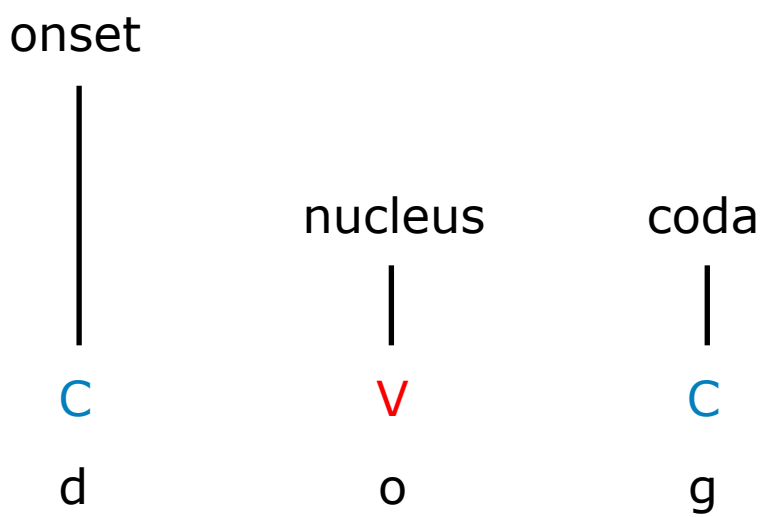


It is not impossible to maintain our phonetic definition of a syllable in the face of multiple peaks, but it significantly complicates things. The system will need a method for figuring out whether a second peak is in the same syllable. That means machinery to compare the relative height of the peaks, and decide if it is “high enough”.

This is challenging enough that most language scientists don’t try to define syllables phonetically.

Let’s try a phonological definition instead

A common strategy in language science (and science more generally) is that when a physical description fails to work perfectly, we postulate abstract cognitive definitions. For sound patterns, the abstract cognitive theory is called **phonology**.



First, we break the syllable down into three components:

Nucleus: the most sonorous part of the syllable. It forms the metaphorical “core”, hence the name. This is typically a vowel, but can be other sonorous segments.

Coda: Zero, one, or more consonants that follow the nucleus.

Onset: Zero, one, or more consonants that precede the nucleus.

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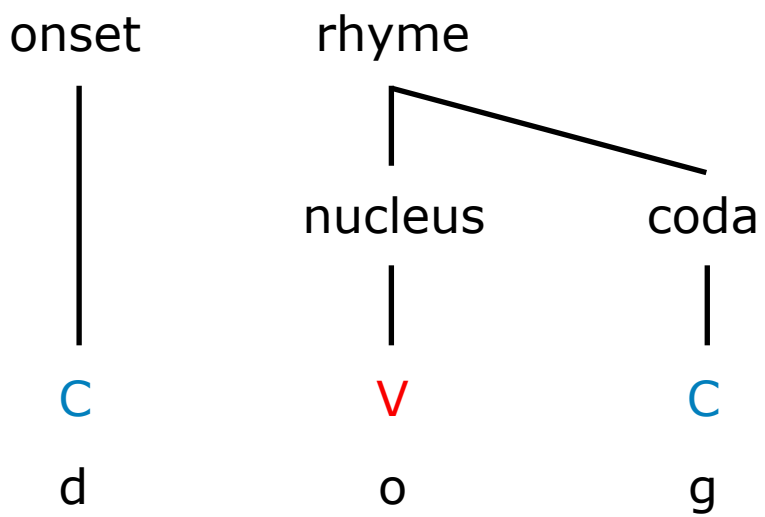

Next, note some interesting subgroups inside of the syllable:

rhyme: the combination of the nucleus and coda (sometimes called rime).

The big idea is that these two elements behave like a unit sometimes. You already know this because you have an intuition about words that “rhyme” — two words that share a nucleus and coda:

stunt - brunt

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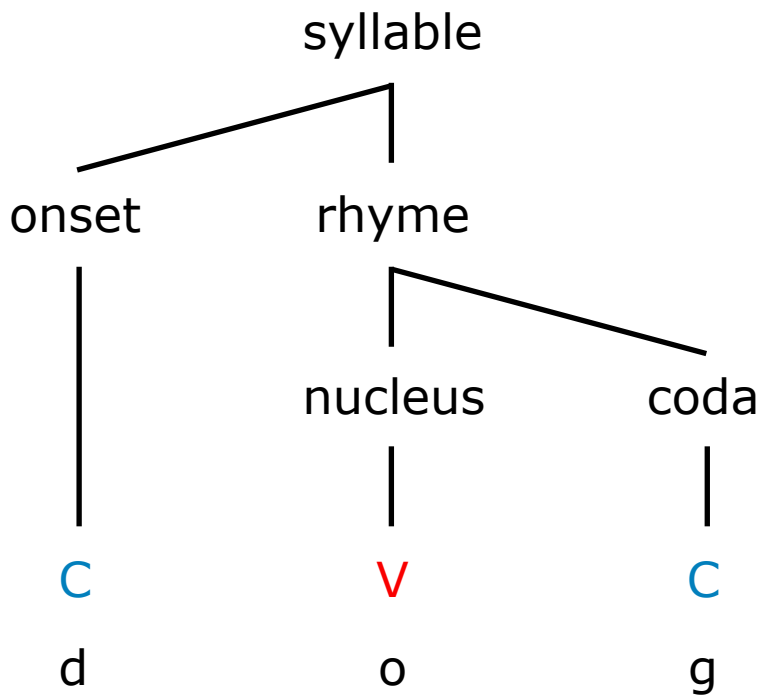

The onset must combine with the rhyme to form the complete syllabus.

The idea behind this is that the onset should behave like it is separate from the rhyme (nucleus and coda).

So what we will want to do is look for evidence that the onset behaves like it is separate from the rhyme… we will see this in the next slides!

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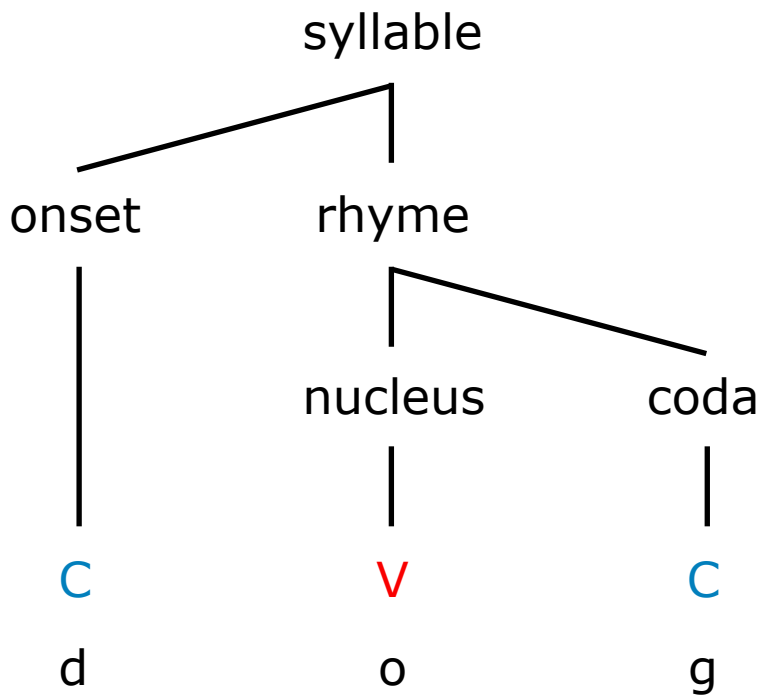

This diagram is called a **tree**. We will see lots of trees in this course!

The idea behind calling it a "tree" is that it looks like an upside-down tree. The root is on top ("syllable") and the leaves are on the bottom (C, V, C).

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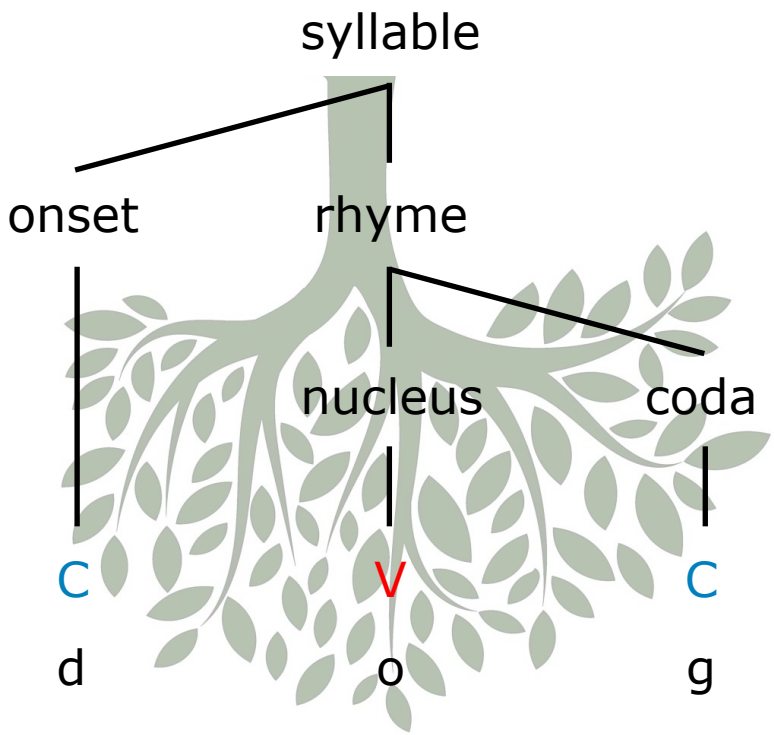

This diagram is called a **tree**. We will see lots of trees in this course!

Here I am just putting a cartoon of a tree, upside down, behind it so you can see the tree-ish-ness of the diagram.

Let's try a phonological definition instead

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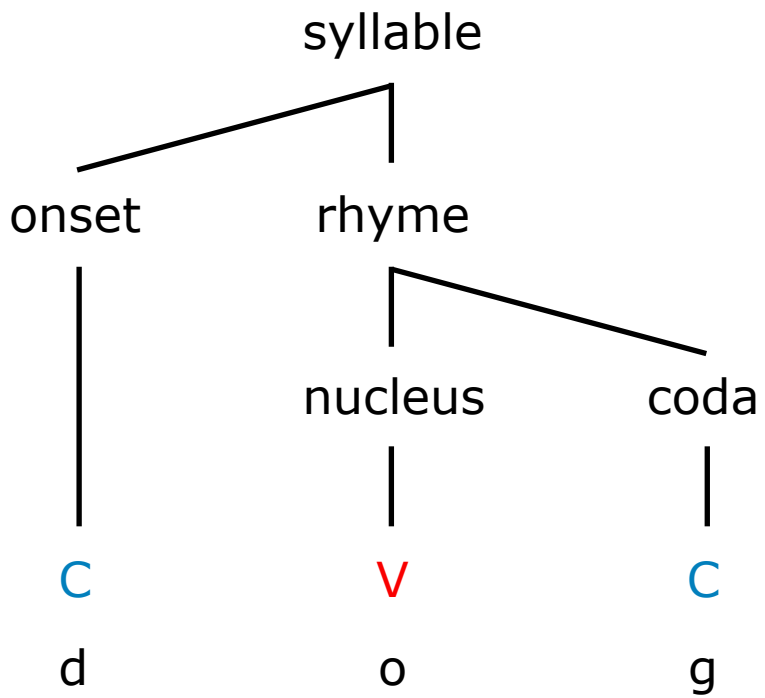

Tree diagrams capture **hierarchical structure**.

Hierarchical structure is a pervasive property of human language. It will show up over and over again in this course. So it is an important concept.

Hierarchical structure: smaller units are combined to form larger units.

Two items that combine are linked with two lines that converge into a node. We label that node in order to show that they formed a new unit with certain properties.

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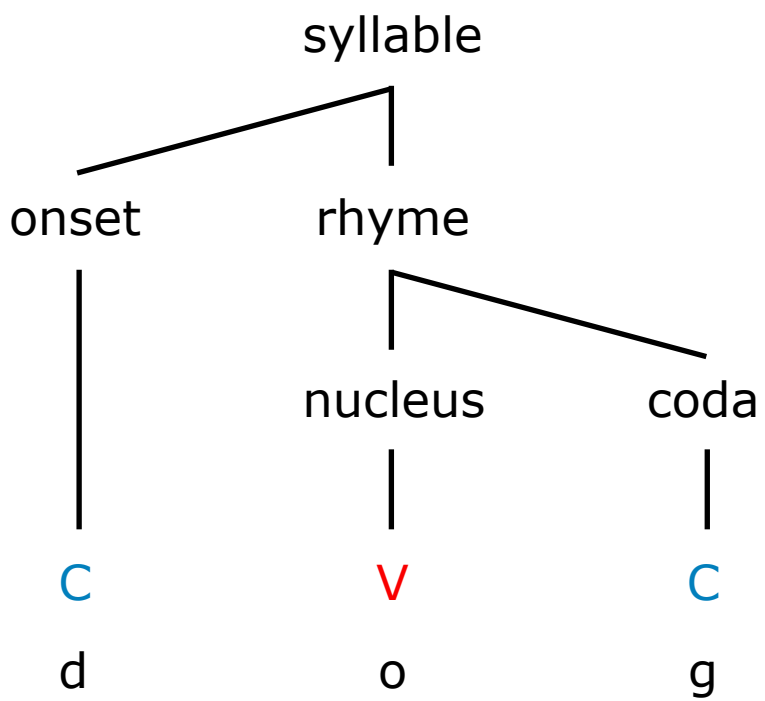

To recap, here is what this diagram is telling us:

First, syllables are not just strings of C-V-C (or CCVCC, etc). They have hierarchical structure. This is a big change, and a substantive hypothesis!

Second, the nucleus and coda form a unit together called the rhyme to the exclusion of the onset. This is a substantive hypothesis. We will want more evidence of this.

The units we call onset, coda, etc are units. This means that if they contain multiple items (like multiple Cs in the onset), those items won't be separable!

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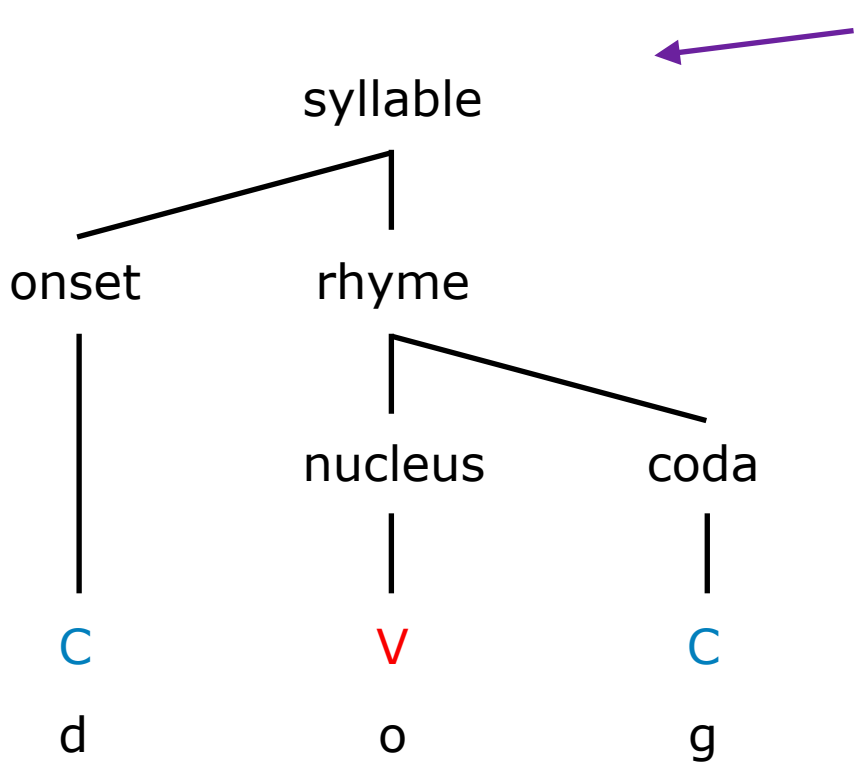
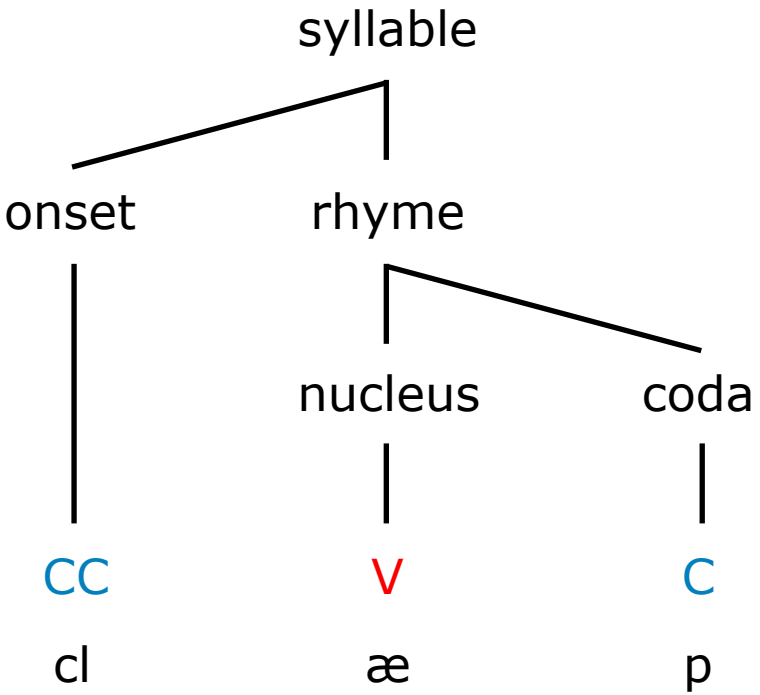
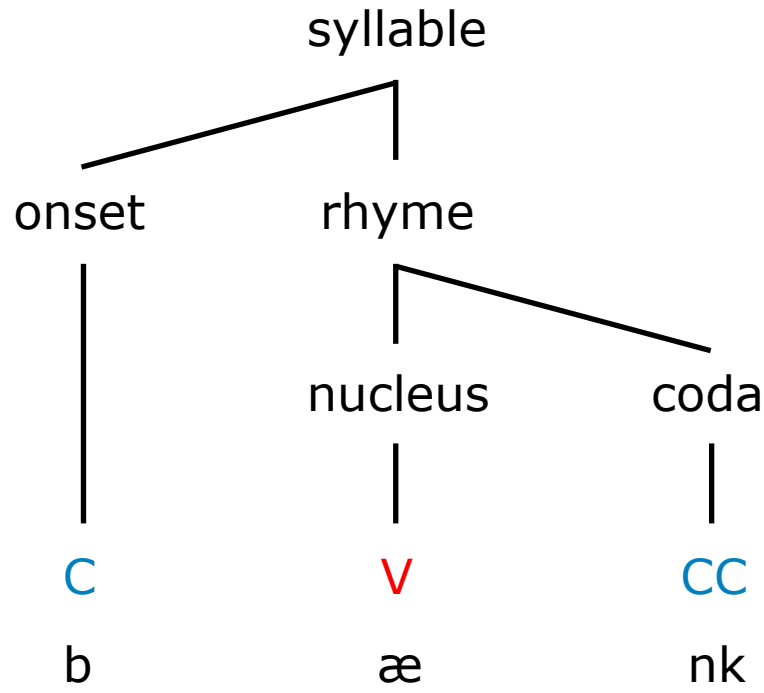
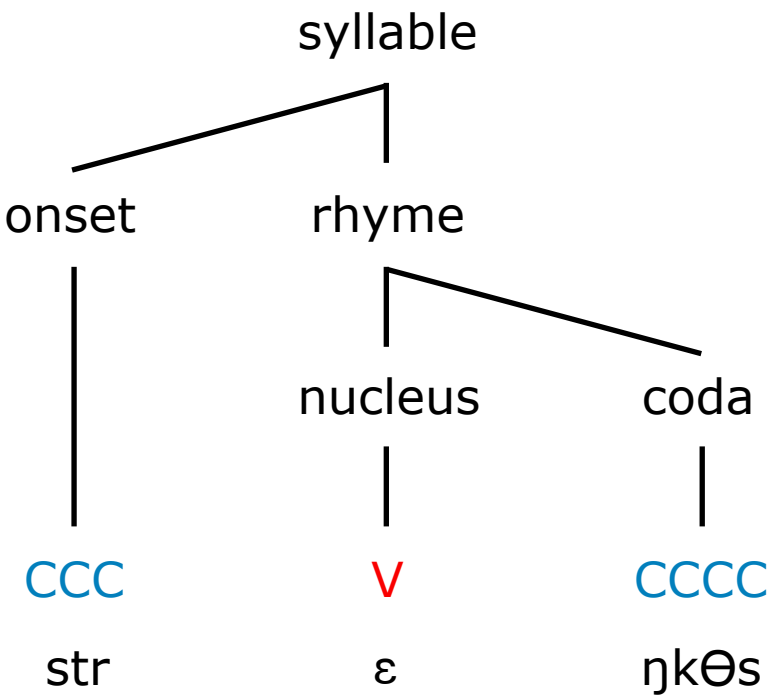


This is our phonological definition of a syllable!

It is an abstract unit with hierarchical structure. Its constituents (the things that make it up) are the nucleus, coda, and onset, combined in a specific way.







The idea is that any syllable (in any language) should have this structure - onset, nucleus, coda.

Evidence for syllable structure

Now that we know what a syllable is (a specific hierarchical arrangement of segments), we can ask whether we have evidence for syllable structure.

Here is evidence that syllables are constrained — you can't just combine segment sequences in any which way.

We can see this by noting that we can't syllabify English words in different ways (syllabify means to split into syllables):

word	correct breaks	incorrect breaks
complain	kəm.plen	kə.mplen
computer	kəm.pju.tər	kə.mpju.tər
autobiography	ɒ.tə.baj.ɑ.grə.fi	ɒ.tə.baj.ɑgr.ə.fi
intercontinental	ɪn.tər.kɑn.tə.nɛn.təl	ɪ.ntər.kɑ.ntə.nɛ.ntəl
approximately	ə.prɑk.sə.mət.li	ə.prɑ.ksə.mə.tli

Evidence for syllable structure

One big question we will often ask is whether something we see is due to **memorization** or due to **rules**.

This is a big question in cognitive science. There is a big difference between memorizing a list of facts, and having a set of rules that cause the facts.

One great way to test whether some facts are memorized or rule driven is to test items that people have never seen before. There is no way to have memorized something you have never seen before. So if the fact appears with the new item, it must be due to a rule!

So, all we have to do is makeup some new possible words in a given language, and ask whether they show the same syllabification pattern as real words!

nonsense word	correct breaks	incorrect breaks
semplain	sɛm.plen	sɛ.mplen
rimputer	rɪm.pju.tər	rɪ.mpju.tər
autotriography	ɒ.tə.traj.ɑ.grə.fi	ɒ.tə.traj.ɑgr.ə.fi
ontercantinontal	ɑn.tər.kæn.tə.nɑn.təl	ɑ.ntər.kæ.ntə.nɑ.ntəl
appraximately	ə.præk.sə.mət.li	ə.prɑ.ksə.mə.tli

Evidence for syllable structure

Perhaps the most interesting evidence for the syllable structure we have postulated is that various phonological processes refer to parts of that structure.

For example, there is a type of speech error called a spoonerism (named after a guy name William Spooner) that involves swapping segments from one word to another, often in a way that is funny.

A pack of lies → A lack of pies

Snail tracks → Trail snacks

It is a real thing that people do. You can notice yourself making this kind of error. And it has also been studied quite extensively in the speech error literature.

One important fact is that spoonerisms don't split up the consonants in an onset. They affect all of the consonants in the onset together:

Play in the grass → Gray in the plass

* Glay in the prass

This is evidence that onsets form indivisible units, which is one of the claims of our theory!

Evidence for syllable structure

Another set of examples are word games like "Pig Latin":

latin	→	atinlay
happy	→	appyhay
bagel	→	agelbay

In pig latin, for words with only one consonant in the onset, you move the first consonant to end of the word, and make it a syllable by adding a vowel.

For words with multiple consonants in the onset, you move the entire onset:

string	→	ingstray
floor	→	oorflay

This again show that onsets form a unit, and that the unit is separate from the rhyme.

Notice that without the vowel "ay" (which is the nucleus of a second syllable), the new coda created by moving the onset would probably not be a possible word in English:

string	→	ingstr
floor	→	oorfl

This shows there are constraints on codas that are different from the constraints on onsets!

Evidence for syllable structure

Another example of a phonological process that targets syllables is **stress**.

Stress: acoustic prominence of a syllable in a word, usually accomplished through increased amplitude (loudness), but also through changes in frequency (pitch) or even changes in vowel quality (e.g. Japan -> Japanese).

My favorite example to really feel the effect of stress are noun/verb pairs that vary only be stress:

Did you record the lecture?
Did you make a record of the lecture?

Will you permit me to park in this lot?
Does the parking permit work in this lot?

As we can see, stress is applied to syllables. There are rules for how to determine which syllable is stressed. We won't study them here because the full theory is very complicated, but it is another aspect of phonology that is actively studied!

mon.tan.a
ar.cade

at.lan.tic
ar.thrit.ic

Evidence for syllable structure

Finally, and perhaps most importantly, we will sometimes need to refer to syllables in the phonological rules that we will learn in the next class!

But I don’t want to jump the gun on that, so we will wait until next time to see those.

Constraints on syllables

Now that we know what a syllable is (a specific hierarchical arrangement of segments), we can ask what kinds of syllables are possible in a language.

English syllables	example word
V	a
CV	tie
VC	it
CCV	try
CVC	cat
CVCC	limp
CCVC	stop
CCVCC	stilt
CCCVCCC	strength
CCCVCCCC	strengths

To condense this list, the full inventory is usually written like this:

(C)(C)(C)V(C)(C)(C)(C)

The parentheses mean "optional."

So this reads as: An English syllable must contain one vowel and may optionally contain 1, 2, or 3 consonants before the vowel and 1, 2, 3, or 4 consonants after the vowel.

Variation in constraints on syllables

Syllable inventory	example language	examples
(C)V	Fijian	Au nanuma na matamu “I remember your face”
CV	Hawaiian	Pupele ke poki “The cat is crazy”
(C)(C)V(C)	Darai (Nepal)	
(C)(C)(C)V(C)(C)(C)(C)	English	strengths

Languages vary in types of syllables that they allow. This raises a much broader set of questions that we can ask:

What counts as a well-formed syllable onset?

What counts as a well-formed syllable nucleus?

What counts as a well-formed syllable coda?

We call the study of these questions **phonotactics**. Let’s look at this next!

Japanese and epenthetic vowels

Japanese word forms are very restricted.

Most of the words in Japanese are iterations of CV (consonant vowel).

You can see this restriction in the form that English words take when they are borrowed into Japanese:

English Word	Japanese Word
fight	fai.to
festival	fe.su.ti.ba.ru
zeitgeist	zei.to.gei.su.to

Epenthesis: the process of inserting an extra vowel
Epenthetic Vowel: a vowel that is inserted for phonotactic reasons

Evidence for syllable inventories

Here's an experiment from Dupoux et al. 1999 looking at the role of syllable inventory in perception.

Step 1: Record a Japanese speaker saying words with a middle vowel, such as E.BU.ZO

Step 2: Cut out the **u** to differing degrees (from each end of the U)

EB ZO
EBUZO
EBUZO
EBUZO

Step 3: Play the words for French speakers, and ask them if they hear a U. (French allows both EB.ZO and E.BU.ZO as possible syllabifications.)

Step 4: Play the words for Japanese speakers, and ask them if they hear a U. (Japanese only allows E.BU.ZO; EB.ZO is not possible because EB can't be a syllable.)

Evidence for syllable inventories

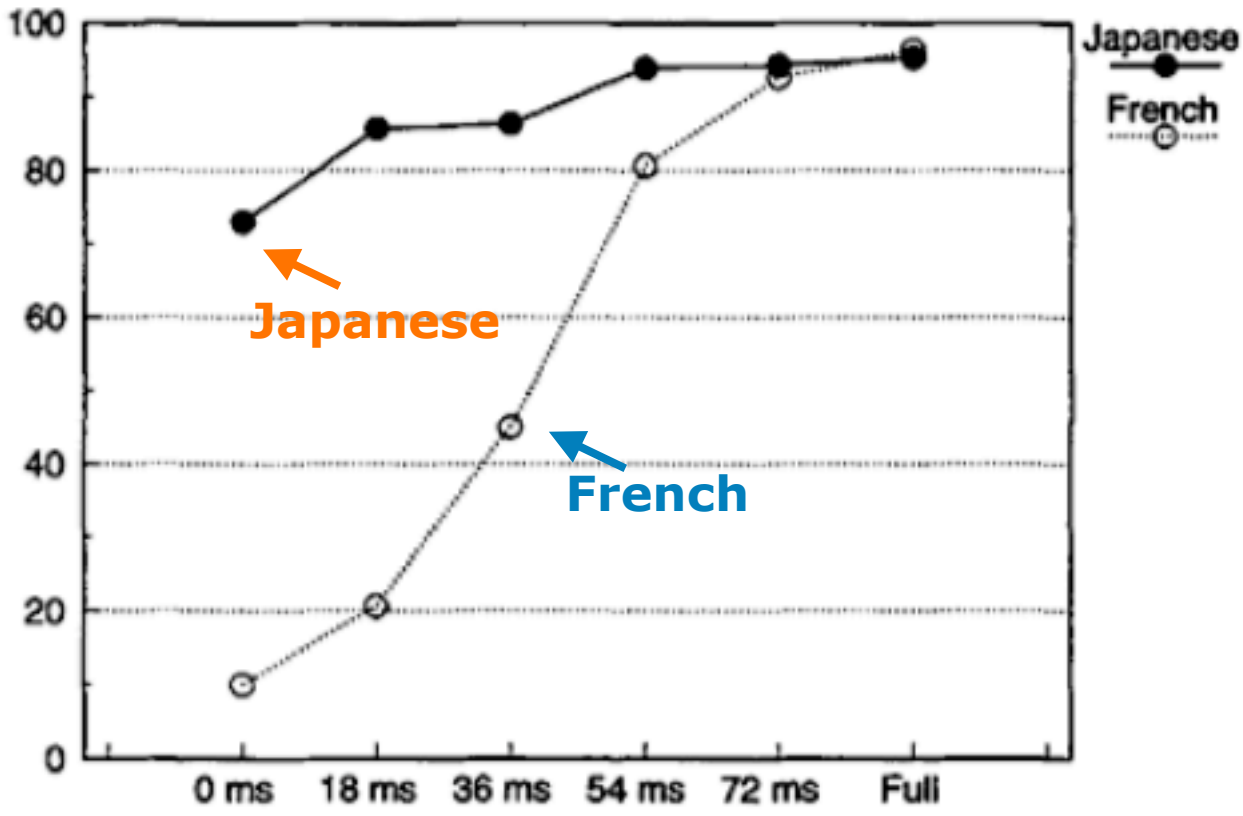


Figure 1. Percentage (*y* axis) of [u] vowel judgments in stimuli such as *ebuzo* in French and Japanese participants as a function of vowel duration (*x* axis) in Experiment 1.

For French speakers, their responses saying that they heard a U seems to track how much U is present in the signal.

But for Japanese speakers, a large majority report hearing a U even when there is absolutely no U present in the signal. Their minds add the U to fit the syllable inventory of their native language!

Phonotactics

(The study of possible and impossible sequences of segments)

Looking for "gaps in the paradigm"

Phonotactic constraints rule out certain sound sequences. Finding them is straightforward — we just need to look at every possible combination of segments, and ask whether they are a possible word.

This is very easy to do in your native language, because you can create the permutations and judge them as possible or impossible yourself.

For example, in English, we could decide to look at the combination of stop consonants (p, t, k, b, d, g) with liquids (r, l) in syllable onsets. The easiest step is to find actual words with the combinations:

	r	**l**
p	prank	plate
t	trick	*
k	crash	clap
b	brick	blank
d	drink	*
g	graph	gloss

For any gaps in the paradigm (asterisk means impossible), we can then try to make up new words, and ask native speakers if they think that this could be a new word in the language. This tells us whether the gap is accidental or systematic!

nonce
plinny
*tlinny
clinny
blinny
*dlinny
glinny

Phonotactic constraints are based on syllable structure

Phonotactic constraints appear to be dependent on the structure of the syllables. This is simultaneously more evidence for the importance of the structure of the syllable, and a classic example of how all of the components of the system of mental representations of language work together to give the complexity that we see!

	onset	coda
sp	spim	misp
st	stim	mist
sk	skim	misk
ps	*psim	mips
ts	*tsim	mits
ks	*ksim	miks
spl	splim	*mespl
slp	*slpim	*meslp
psl	*pslim	*mepsl
pls	*plsim	*mepls
lps	*lpsim	melps
lsp	*lspim	melsp

[s] followed by a voiceless stop is possible in both onset and coda

But a voiceless stop followed by [s] is only possible in the coda.

Here we see that the sequence of [s] a voiceless stop [p] and the lateral liquid [l] only works in one sequence in the onset, and only two (different) sequences in the coda!

Some examples of phonotactic constraints in English

Onset restrictions

No ŋ in onsets:

English can have n (another nasal) in both onsets and codas:	tin	nit
English can have m (another nasal) in both onsets and codas:	tim	mit
But English can only have ŋ in codas:	tiŋ	*ŋit

If the onset has two consonants (CC), English only has certain options:

stop + liquid:	trim	s + voiceless stop:	spot
stop + glide:	twin	s + nasal:	snot
fricative + liquid:	free	Everything else is impossible. That is why so many combinations can't be onsets (fb, pn, etc).	
fricative + glide:	f(y)ume		

Some examples of phonotactic constraints in English

Coda restrictions

No h in codas.

Words like "oh" don't really have an h segment at the end. They end with the vowel. Remember, the IPA symbol h is a glottal consonant.

If the coda contains both a nasal and a voiceless stop, then they must share place of articulation:

both bilabial	both alveolar	both velar
jump (dʒʌmp)	stunt (stʌnt)	stink (stɪŋk)

bilabial and velar	alveolar and bilabial	velar and alveolar
*jumk (dʒʌmk)	*stunp (stʌnp)	*stingt (stɪŋt) but you can add a k! as in stɪŋkt)

Some examples of phonotactic constraints in English

Nuclei restrictions

Nuclei are already fairly restricted by definition - they are vowels in all languages.

But in some languages it is also possible to have a restricted set of consonants as a nucleus. English is one of those languages. There are only three consonants that can do it.

syllabic ɹ̩	banner	bæ.nɹ̩
syllabic l̩	cuddle	kʌ.dl̩
syllabic n̩	kitten	kɪ.tn̩

They are called **syllabic consonants**. In IPA, we put a little vertical line under them to show that they are syllabic. We will see these in some of our rules next class!

The phonotactic constraints that we have seen are all specific to English. And only a fragment — there are many more constraints in English.

But we can repeat the same kinds of investigations for other languages. The answer may be different. For example, several languages allow ŋ in onsets (Vietnamese, Dholuo (in Kenya/Tanzania)). But the process is the same!

Phonotactic constraints explain lots of patterns in segment sequences!

Phonotactic constraints are a major part of phonology. As such, being able to analyze the phonotactics of a language can help explain a lot of phonological phenomena that you may notice in your daily life. Here is one example.

Borrowing is when one language imports a word from another language. When this happens, the word is often pronounced differently. It is pronounced according to the phonotactics of the language doing the borrowing!

gnostic
pneumonia
tsunami
Bach

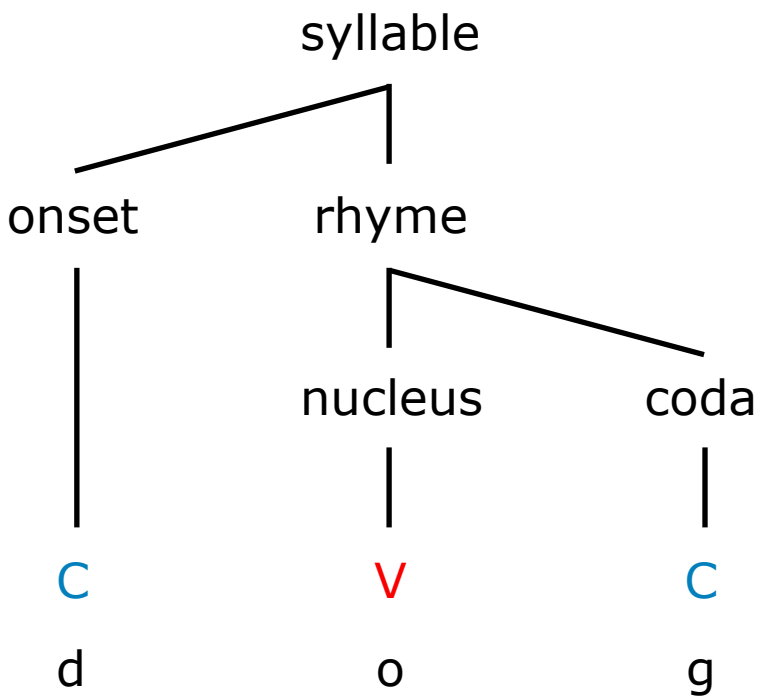
These are all words that English has borrowed from other languages (Greek, Japanese, German). But they each contain a sound or sound sequence that is not possible in English (phonotactics). So the pronunciations have changed.

This is not just about English. The same thing happens in all languages. As we have seen, Japanese has borrowed a number of words from English (because of the US military occupation after WWII). Here are a couple of additional examples:

beer (bir)	→	bi.ru	post	→	po.su.to
CVC		CV.CV	CVCC		CV.CV.CV

But there is more…

Syllable structure plus phonotactic constraints explain quite a bit of the patterns that we see in sequences of segments:



English can only have ŋ in codas:	tiŋ	*ŋit

But there are other patterns that are a bit more complex that we still need to explain, like this one. And that is for next time!

This is a **TEE**
In IPA it is [ti]

But this is a **CHREE**
In IPA it is [tʃɹi]