Formal and Computational Approaches to Phonology

Monday: Introduction; Generative Phonology

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Outline of the week

Today: review of basic phonetics and phonology, from structuralism to generativism. Computational aspects of generative theories.

Tuesday: Optimality Theory. Introduction to the framework, and problems of the theory. Expressivity, implementations.

Wednesday: Lower level modelling: the emergence of phonology. (de Boer)

Thursday: Maximum entropy phonotactics. (Hayes and Wilson)

Friday: Auditory dispersion and change. (Boersma and Hamann)

Phonology and Phonetics

Phonetics is the study of the sounds of speech: how they're made, what they sound like (to instruments), what they're perceived as (by us).

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Phonetics deals in continua, and arranges them into convenient labelled regions for notational purposes; phonology takes the labelled regions and makes them abstract symbols in a finite system.

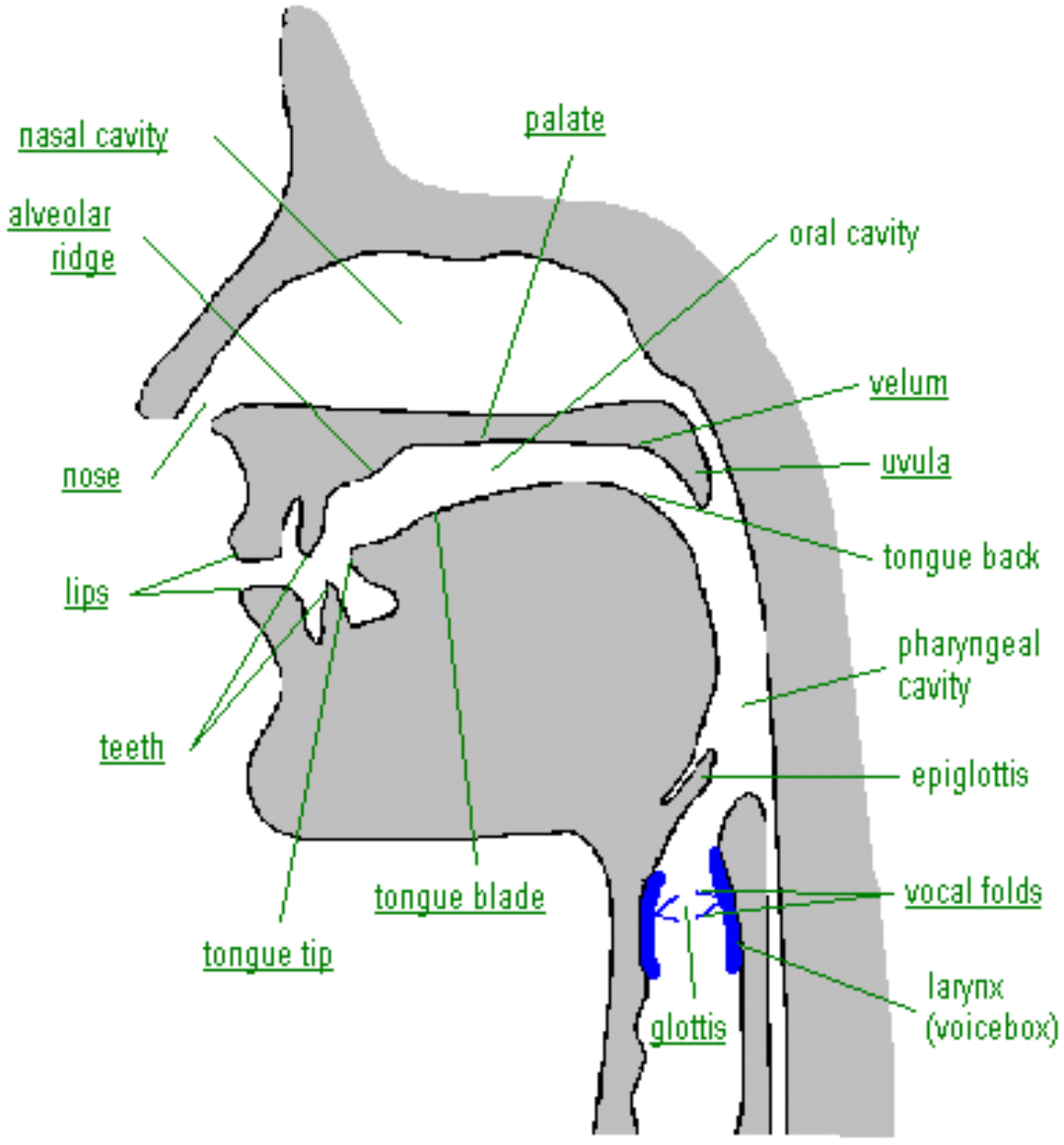
(Where's the boundary? Is phonology really discrete?)

The landscape we have to deal with

A quick survey of the kinds of sounds and contrasts humans use . . .

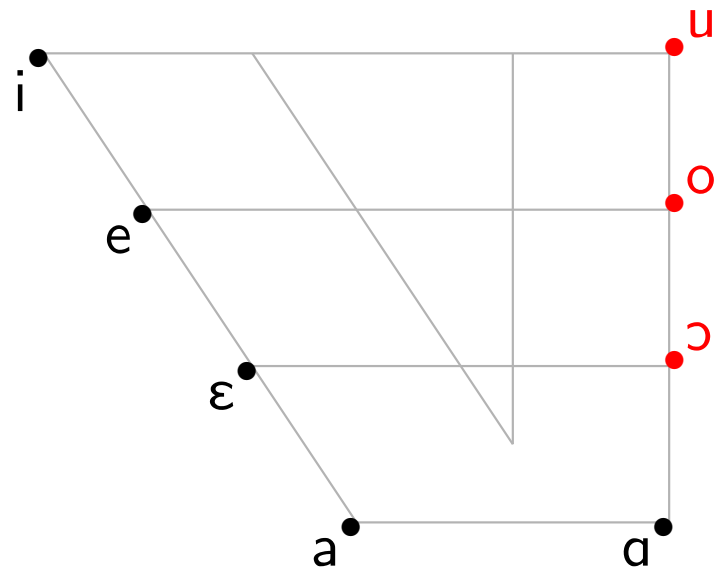
(Canonical reference: Peter Ladefoged and Ian Maddieson, *The Sounds of the World's Languages*), with 80GB of recordings at `http://archive.phonetics.ucla.edu/`

Speech Organs



(Diagram: Summer Institute of Linguistics)

Vowels



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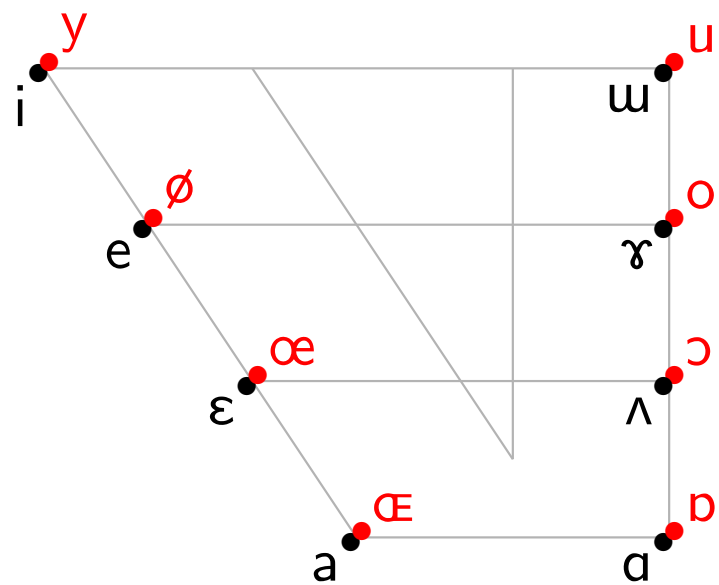

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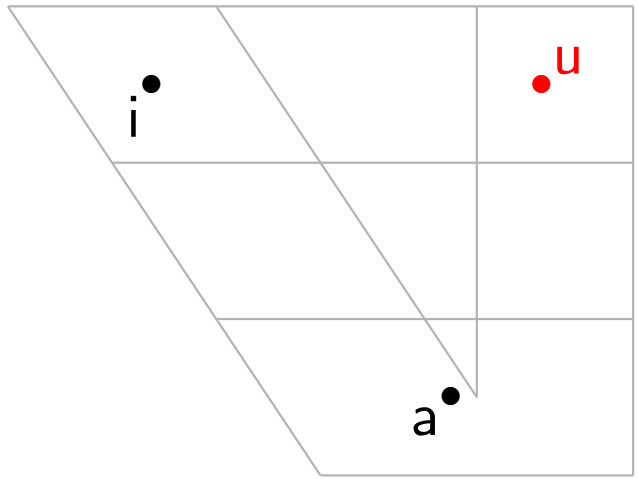
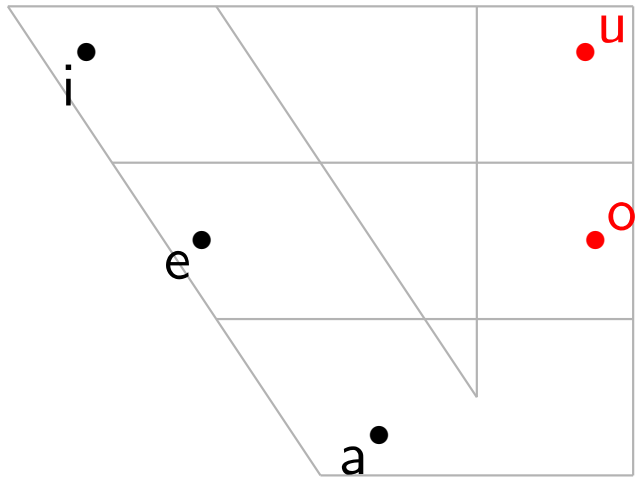
3 vowel system



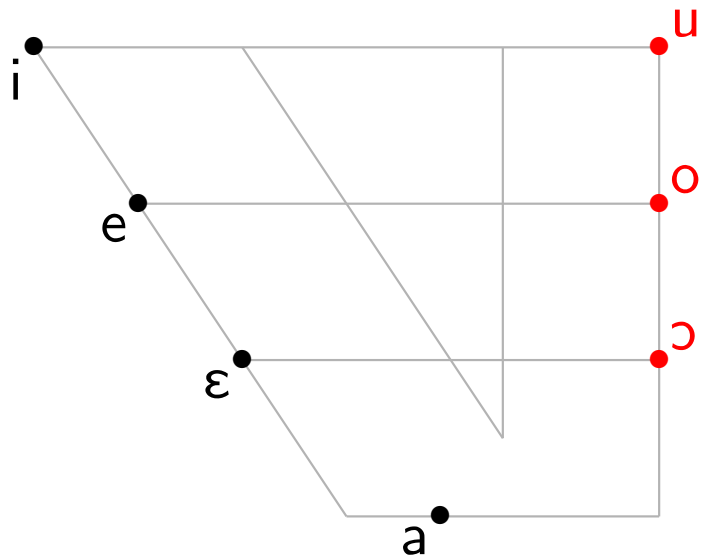
Many australian languages.

5 vowel system



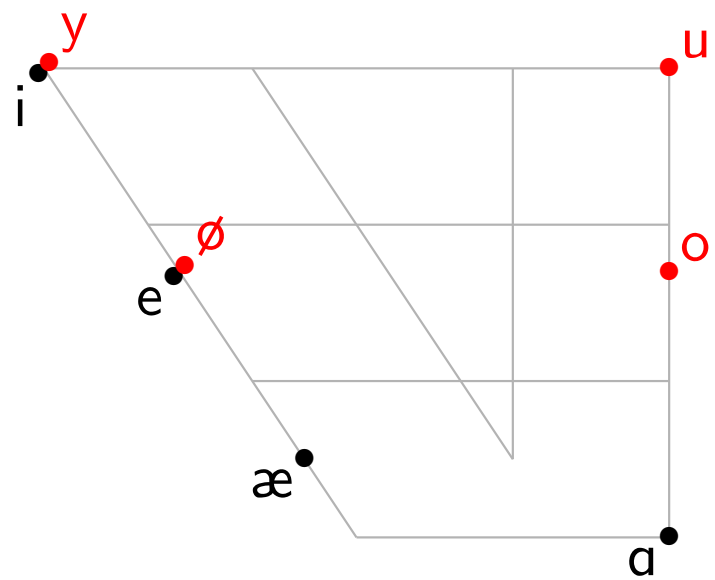
Latin (with long vowels), Spanish, Modern Greek, many others.

7 vowel system



Standard Italian

8 vowel system



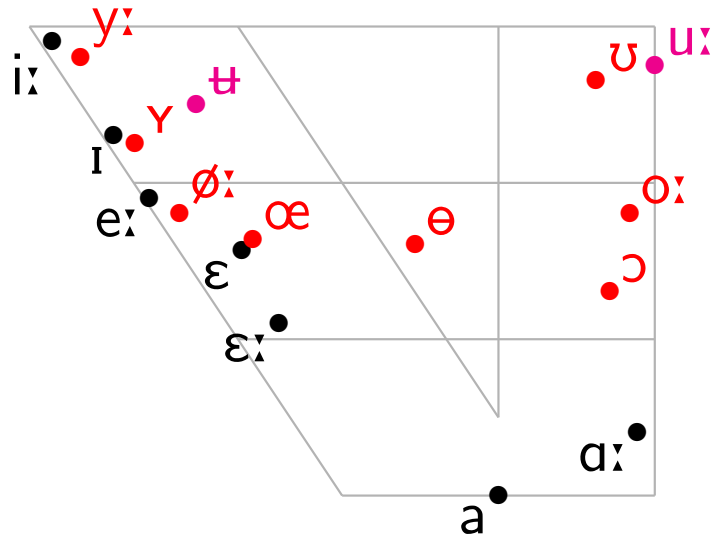
Finnish (written *i*,*y*,*e*,*ö*,*ä*,*a*,*o*,*u*).

Finnish has *vowel harmony*: /y/–/u/, /ø/–/o/, /æ/–/ɑ/ form front–back pairs, and a word contains only front vowels or only back vowels, together with /i/ and /e/.

All the 46 diphthongs allowed by vowel harmony exist.

Swedish vowels

sil	*hel*	*bot*
sill	*häl*	*bott*
syl	*häll*	*mål*
syll	*nöt*	*moll*
ful	*nött*	*mat*
full	*matt*	



Swedish has a large number of vowels crammed into the high front area. [play all]

The use of a three-way lip-rounding distinction is (almost?) unique.

Data: O. Engstrand, *JIPA* 20(1) 42–44

Bells and whistles: creak, murmur etc.

There are many ways of adding a distinctive quality to a vowel:

Nasalization is widely used (French, Portuguese, Hindi, many others).

Creaky voice (laryngealization, glottalization) is part of tones in some (South-East) Asian languages; used in many American languages; and in Danish.

Breathy voice (murmur) used in many African and American languages, and Gujerati.

Pharygealization used in African and American languages.

Advanced Tongue Root (ATR) is a feature of many central African languages.

Consonants

are formed by obstructing, wholly or partly, the air stream. Traditionally classified by:

place: where is the obstruction/constriction? E.g tongue-tip or back of tongue ([t] vs [k]).

manner: how is the obstruction made? E.g. complete block, constriction, almost no constriction, trill, etc.

other aspects: voicing, secondary articulations.

Some different places

Bilabial [p] occurs in almost all languages.

Apico- Made by the tip of the tongue against:

-dental [t̪]: teeth. Usually actually made with blade of tongue. French etc. /t/.

-alveolar [t]: alveolar ridge. English etc. /t/.

retroflex [ʈ]: curled up, even to hard palate. Hindi etc.

lamino- Made by the blade (front) of the tongue:

-dental [t̪]: against the teeth

-palatal [c]: against the hard palate. E.g. Hungarian.

dorso- Made by the body or back of the tongue:

-velar [k]: against soft palate. almost all languages.

-uvular [q]: against uvula or back of soft palate. Arabic, Caucasian, African, etc.

The glottal stop [ʔ] – widely used, phonemically and phonetically.

Voicing and friends

Many (not all) languages distinguish /p/ from /b/, /t/ from /d/, /k/ from /g/, etc. Often phonetically described by *voice onset time*: when you start vocal cord vibration relative to the release of the stop closure.

Many languages distinguish voiced, voiceless and aspirated: typical VOT values initially: -30 ms (voiced: French /b/), 0 to 20 ms (voiceless: French /p/, English /b/), 100 ms (aspirated: English /p/).

Some languages use *breathy voice* to produce 'voiced aspirates'. E.g. Hindi [p] [p^h] [b] [$b^ɦ$]

(Are voicing and aspiration independent?)

Some use *creaky voice* to form another variant.

Some use *ejectives* [p'].

Some use voiced *implosives* [ɓ], and even voiceless implosives.

Some have aspiration *before* the stop closure.

Other consonants

Voiced/voiceless *fricatives*: when the obstruction is not quite closed, but narrow enough to produce turbulent airflow: [ɸ/β] [f/v] [ɕ/ʝ] [x/ɣ] [χ/ʁ] [ħ/ʕ] [ʜ/ʢ] [h/ɦ]

Coronal fricatives are particularly complex, and also phonologically active: [θ/ð] [s/z] [ʃ/ʒ] [ʂ/ʐ] [ʂ/ʐ] [ɕ/ʑ]. Some languages have four of these – but three is bad enough. Since we're in Poland:

Chrząszcz, by Jan Brzechwa

W Szczebrzeszynie chrząszcz brzmi w trzcinie
[fʂtʂɛbʐɛʂɨɲɛ xʂɔw̃ʂtʂ bʐmi ftʂtɕiɲɛ]
In the town of Szczebrzeszyn a beetle buzzes in the reeds
I Szczebrzeszyn z tego słynie.
[iʂtʂɛbʐɛʂɨn stɛgɔ swɨɲɛ]
And Szczebrzeszyn is famous for it.
Wół go pyta: „Panie chrząszczu,
[vuw gɔ pɨta paɲɛ xʂɔw̃ʂtʂu]
An ox asks him: "Mister beetle,
Po cóż pan tak brzęczy w gąszczu?"
[pɔ tsuʂ pan tak bʐɛntʂɨ vgɔw̃ʂtʂu]
What are you buzzing for in the bushes?"

and so on

Translation from Wikipedia; transcription adapted from Wikipedia

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Approximants don't have audible friction: [w,j] etc.

Nasals [m,n,ɲ,ŋ,ɴ]: every language has some.

Rhotics [r,ɾ,ʀ,ʁ] etc. (Just how are an Italian [r] and a Dutch [ʁ] similar?)

Laterals [l] etc.

Clicks [ʘ,ǃ,ǀ,ǁ,ǂ] are remarkably rare.

Phonology

The job of phonology is to sort out how a language makes a system out of the wealth of possibilities we've just glanced quickly over.

Formal and computational approaches have a strong tendency to deal with easy languages . . . or English . . .

The core problems are when two 'sounds' are the same as far as the language is concerned, and how the resulting set of equivalence(?) classes is organized, and how and why it changes over times.

From 600 BC to AD 1950

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Despite problems such as

- partial neutralization – archiphonemes etc.
- the need for phonetic similarity criterion (English ŋ/h)
- marginal phonemes (English ʒ, x)

the structuralist phoneme is embedded in the psyche of every linguist.

(Is it in the psyche of every language user?)

N.B. the defn presupposes 'unit of sound' . . . segment?

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- incompatibility and redundancy: what's a dental velar? Do (middle) English /i/ and /u/ differ because of [round] or because of [front]? (Or the acoustic correlates thereof.)

Features widely used both descriptively and in theories (with a dip in the 1990s).

Radical formalism: *SPE*

Chomsky and Halle's *Sound Pattern of English* threw away structuralist phonemes. Instead:

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Example rewrite rule (20.III):

$$\mathrm{V} \rightarrow [-\text{tense}] \quad / \quad \text{——}[+\text{cons}] \begin{bmatrix} +\text{cons} \\ -\text{voc} \end{bmatrix}$$

"vowels become lax when before a consonant cluster the second of which is not a glide"

In *SPE*, /j/ and /w/ are both consonantal and vocalic; /l/ and /r/ are neither consonantal nor vocalic.

This accounts for *descri**b**e* ∼ *descri**p**tion*, because later another rule will turn tense /i/ into /ai/.

Grammar[']s gone mental

SPE tried to explain not just phonology, but morphophonology. Your mental lexical entry (*underlying reprentation – UR*) for a word is essentially how it was pronounced in early Middle English – and the rules recapitulate the historical changes since then.

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For many years, the formalism of *SPE* dominated phonological writing. But few took the same broad approach of sweeping all morphophonology into the mental grammar. For most people, URs are very close to surface forms.

Currently, features are widely used as *representations*, but *SPE* rewriting is out of fashion as *computation*.

A question to ponder

As phonologists, are we:

1. just(!) trying to come up with a formal (mathematical, computational) model that correctly *describes* what happens; or
2. trying to understand the way in which *our brains process* language.

Phonologists quite often write as if (2), but when put to the question, say (1).

Autosegmentalism

In the late 80s and 90s, autosegmental (Goldsmith) grammars arose. Different levels of phonology work in independent *tiers*, which come together by *associations*. Even in one 'level', e.g. phonemic, different features run concurrently on tiers.

Autosegmental theories include Government Phonology, Dependency Phonology and many other variants. They were the big thing until the sociological phenomenon that is Optimality Theory – see tomorrow.

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But everybody agrees that phonological phenomena are *regular*, both intuitively and in the CS sense; and probably less powerful than general regular transducers. (Would you believe a phonological rule that said '/a/ $\rightarrow$ [e] if followed by at least ten syllables not containing an /u/'?)

SPE in more detail – features

To analyse *SPE*, we need to be more precise about what it is.

We have a set of *features*. In intention, these are *universal*, enough to describe all languages. In practice, they are enough for the language in question; universalism is controversial, and even universalists are not sure what the universal set is.

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The *SPE* features relevant to segmental sized *units* in English are:

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There are various dependencies between these features, some of which are necessary (e.g. $[+\text{low}] \Rightarrow [-\text{high}]$), some of which are asserted to be universal, and some of which are language-specific.

Units – the alphabet of the system

The segments on which the rules operate are *partial* maps from the set of features to the values $\{+, -\}$; or alternatively, three-valued $\{+, -, \perp\}$ vectors over the feature set. The rules are so arranged that the output segments are fully specified, that is, are feature vectors over $\{+, -\}$; but this is not a necessary consequence of the formalism.

So from a formal language viewpoint, we take the *alphabet* to be the set of (three-valued) feature vectors over the given feature set.

The rules

As we saw, the rule notation is equivalent to the very general form:

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Moreover, the rules are *schematic*: the symbols are not units, but classes such as V or [+cons,−voc]. This is understood by instantiating the scheme in all possible ways. Such schematic rules reduce exponentially the space required to represent the rule system; but they do not change the complexity of the class of transducers definable by such rule systems.

So, we still have full context-sensitive power . . . or do we?

Rule ordering and cyclicity

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Johnson (and later and more accessibly Kaplan and Kay) showed that these restrictions are sufficient to make *SPE* grammars **equivalent to** regular transducers.

So, *SPE* phonology is finite automata; and the complexity of generating the surface from the UR is linear in the size of the surface form.