Agenda

• Articulatory processes: Sounds are pronounced differently in different environments
• Using diacritics to represent other features of phones (narrow transcription)
• phones vs. phonemes
• Phonological analyses
<table>
<thead>
<tr>
<th>English</th>
<th>Spanish</th>
</tr>
</thead>
<tbody>
<tr>
<td>pin</td>
<td>poco</td>
</tr>
<tr>
<td>pool</td>
<td>peso</td>
</tr>
<tr>
<td>pace</td>
<td>papa</td>
</tr>
<tr>
<td>pill</td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>Spanish</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>tool</td>
<td>todo</td>
</tr>
<tr>
<td>tea</td>
<td>te</td>
</tr>
</tbody>
</table>
Aspiration

Aspiration: Period of voicelessness after release of the stop (before the following vowel)
Aspiration
Aspiration

pin spin tip
Aspiration

tall

stall

bit

note

notation

attack
Aspiration
Aspiration

[p], [t], [k]
(6) The consonants of English classified by voicing, place of articulation, and manner of articulation.

<table>
<thead>
<tr>
<th>Manner of Articulation</th>
<th>Bilabial</th>
<th>Labiodental</th>
<th>Interdental</th>
<th>Alveolar</th>
<th>Palatal</th>
<th>Velar</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop</td>
<td>p</td>
<td>b</td>
<td></td>
<td>t</td>
<td>d</td>
<td>k</td>
<td>g</td>
</tr>
<tr>
<td>Fricative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affricate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasal</td>
<td>m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Lateral Liquid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>tj</td>
</tr>
<tr>
<td>Retroflex Liquid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glide</td>
<td>w</td>
<td>w.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

State of the Glottis: Voiceless | Voiced
time
tree
pot
stop
water
button
Did you transcribe them like this?

<table>
<thead>
<tr>
<th>word</th>
<th>pronunciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>[taɪm]</td>
</tr>
<tr>
<td>tree</td>
<td>[tri]</td>
</tr>
<tr>
<td>pot</td>
<td>[pat]</td>
</tr>
<tr>
<td>stop</td>
<td>[stæp]</td>
</tr>
<tr>
<td>water</td>
<td>[ˈwɔtər]</td>
</tr>
<tr>
<td>button</td>
<td>[ˈbʌtən]</td>
</tr>
</tbody>
</table>
The “t” is pronounced differently in each word

<table>
<thead>
<tr>
<th>Word</th>
<th>Pronunciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>[θɑlm]</td>
</tr>
<tr>
<td>tree</td>
<td>[tsɹi]</td>
</tr>
<tr>
<td>pot</td>
<td>[pʰaʃt̠]</td>
</tr>
<tr>
<td>stop</td>
<td>[stap]</td>
</tr>
<tr>
<td>water</td>
<td>[wɑrəɾ]</td>
</tr>
<tr>
<td>button</td>
<td>[bəʔən]</td>
</tr>
</tbody>
</table>
The “t” is pronounced differently in each word

<table>
<thead>
<tr>
<th>Word</th>
<th>Pronunciation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>$[^\text{th}a\text{lm}]$</td>
<td>aspirated</td>
</tr>
<tr>
<td>tree</td>
<td>$[^\text{ts}f\text{ri}]$</td>
<td>palatalized</td>
</tr>
<tr>
<td>pot</td>
<td>$[^\text{p}^\text{h}\text{at}^-]$</td>
<td>unreleased</td>
</tr>
<tr>
<td>stop</td>
<td>$[^\text{st}\text{ap}]$</td>
<td>unaspirated</td>
</tr>
<tr>
<td>water</td>
<td>$[^\text{wa}\text{r}\text{e}r]$</td>
<td>flap (voiced)</td>
</tr>
<tr>
<td>button</td>
<td>$[^\text{b}^\text{e}\text{r}\text{en}]$</td>
<td>glottal stop</td>
</tr>
</tbody>
</table>
Why are they all spelled with a “t”? 
How do we store the pronunciations of “water” and “button”?

[warɛər]  or  [wɔtər]
[bə?ən]  or  [betən]
Hypothesis A: [warər] must be stored as a special pronunciation of “water”

Hypothesis B: the pronunciation of “t” as [ɾ] is derived by a rule
Is the pronunciation predictable?

<table>
<thead>
<tr>
<th>th¹</th>
<th>r</th>
<th>?</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>water</td>
<td>button</td>
</tr>
<tr>
<td>top</td>
<td>little</td>
<td>kitten</td>
</tr>
<tr>
<td>table</td>
<td>butter</td>
<td>carton</td>
</tr>
<tr>
<td></td>
<td>notable</td>
<td></td>
</tr>
</tbody>
</table>
Patterns

\[^{th}\] occurs at the beginning of stressed syllables.

\[^{r}\] occurs between two vowels

\[^{?}\] occurs in the middle of words before a syllabic nasal.
Articulatory Processes

• Sounds are pronounced differently in different environments

These are RULES in mental grammar
Different pronunciations of /t/ in English

/t/ → [tʰ] → [t] → [ɾ] → [ʔ]
Rules

the sound /t/ changes to [?] before a syllabic nasal

/t/ → [?] / _ ən
Rules

the sound /t/ changes to [ɾ]
between two vowels

/t/ → [ɾ] / V _ V
Rules

the sound /t/ changes to [ɾ]
between two vowels

NOTE:
these are NOT rules about spelling
In what sense are these all the same “sound”??
The way words are stored in the Mental Lexicon

time /taɪm/
tree /tri/
pot /pat/
stop /stæp/
water /ˈwɔːtər/
button /ˈbʌtən/
Lexicon

/watər/

Rules

/t/ -> [ɾ] / V_ V

Output

[warər]
Lexicon
/waṭər/

Rules
/t/ -> [ɾ] / V_ V

Output
[waɾəɾ]

Phoneme

Allophone
Phoneme

- the abstract representation of a sound.
- the way the sound is stored in word in the mental lexicon
Allophone

- how the sound is actually produced in a given environment
- an instance of a phoneme
Articulatory Processes

- Sounds are pronounced differently in different *environments*

These are RULES in mental grammar
environment =
the phonological context of a sound
– position in the word
– neighboring sounds
Articulatory Processes are RULES

Not just automatic reflexes of the vocal tract

How do we know?
Articulatory Processes are RULES

Not just automatic reflexes of the vocal tract

How do we know?

Evidence: Different processes in different languages

e.g., “cotton” is not pronounced with [?] in some dialects
Summarizing so far…

There are RULES in mental grammar that determine the pronunciations of sounds
Building a Grammar

What is stored: Lexicon

What we hear: Output

/taɪm/  →  [θaɪm]
/tri/   →  [tʃri]
/pat/   →  [pʰatɾ]
/stap/  →  [stap]
/watər/ →  [waɾəɾ]
/bʌtən/ →  [bɛʔən]
Different pronunciations of /t/ in English

/t/

[tʰ]
[t]
[ɾ]
[ʔ]

Phoneme

Allophones
Inventory of Phonemes

• Are [p] and [b] different phonemes in English?

• Two steps in finding out the phonemic status of sounds
Inventory of Phonemes

First step: look for *minimal pairs*
- if difference between sounds causes a difference in meaning => *contrastive*
  => different phonemes
Inventory of Phonemes

- Are [p] and [b] different phonemes in English?

  pin vs. bin \([p\text{ɪn}]\) vs. \([b\text{ɪn}]\)
  tap vs. tab \([tæp]\) vs. \([tæb]\)

→ contrastive distribution

Conclusion:
\(/p/\) and \(/b/\) are separate phonemes
In contrast…

\[\text{[war\text{r}\text{e}r]}\]
\[\text{[wat\text{r}\text{e}r]}\]

... no difference in meaning

\[\text{[t^h]}\text{ and [t] are allophones of } /t/\]
Why?

- Lexicon – collection of Sound+Meaning pairs
- Sound information in lexical items is encoded in terms of phonemes
- That’s why only phonemes affect meanings
Quick summary: Minimal pairs

• [mæp] vs. [næp]
• If a sound is used *contrastively* to create different meanings, then that sound is a phoneme of that language.

• [pʰæt] vs. [pæt]
• [pʰ] and [p] are in *complementary distribution* (cf. free variation *leap*)
Inventory of Phonemes

Second step:
If no minimal pairs, look for a pattern (distribution of the two sounds)

– What environments does sound X occur in?
– What environments does sound Y occur in?
Exercise: making generalizations about the environments

can /k(æ)n/

I can ask  [ɑɪ  kæn  æsk]
I can see   [ɑɪ  kən  si]
I can bake  [ɑɪ  kæm  bɛɪk]
I can play  [ɑɪ  kæm  plɛɪ]
I can go    [ɑɪ  kəŋ  gou]
I can gather [ɑɪ  kəŋ  ɡæðər]
Generalizations

[m] occurs before a bilabial consonant
[ŋ] occurs before a velar consonant
[n] occurs everywhere else (elsewhere)

→ Complementary distribution
Generalizations => Rules

/n/ becomes [m] before a bilabial consonant

/n/ becomes [ŋ] before a velar consonant

elsewhere /n/ is pronounced [n]
But don’t [m] and [n] belong to separate phonemes in English?

• How can you show that [m] and [n] are separate phonemes?
[m] and [n]

\[
/\text{n}/
\]

\[
[\text{n}] [\text{m}] [\text{ŋ}]
\]

\[
/\text{m}/
\]

\[
[\text{ŋ}]
\]
Quick summary: Allophones

\[ /p/ \]
\[ \text{[p]} \quad \text{[p^h]} \]

a) **Superman and Clark Kent**

How do we know that they are actually the same person? → They can NEVER occur in the same environment at the same time.

b) **Ice, water, steam:**

Are all H\(_2\)O but have a different manifestation depending on the environment they occur in:

- \(< 0 \text{ C} \) → occurs as ice
- \(> 0 \text{ C and } < 100 \text{ C} \) → occurs as water
- \(> 100 \text{ C} \) → occurs as steam
Now apply the same process to determine the grammars of other languages
Example

If we find a Minimal Pair, then the phones that differentiate them are **phonemes** in the language under investigation.

<table>
<thead>
<tr>
<th>English</th>
<th>Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) iglumut (to a house)</td>
<td>a) iglumut (to a house)</td>
</tr>
<tr>
<td>b) ukiaq (late fall)</td>
<td>b) ukiaq (late fall)</td>
</tr>
<tr>
<td>c) aiviq (walrus)</td>
<td>c) aiviq (walrus)</td>
</tr>
<tr>
<td>d) aniguvit (if you leave)</td>
<td>d) aniguvit (if you leave)</td>
</tr>
<tr>
<td>e) aglu (seal’s breathing hole)</td>
<td>e) aglu (seal’s breathing hole)</td>
</tr>
<tr>
<td>f) iglumit (from a house)</td>
<td>f) iglumit (from a house)</td>
</tr>
<tr>
<td>g) anigavit (because you leave)</td>
<td>g) anigavit (because you leave)</td>
</tr>
<tr>
<td>h) pinna (that one up there)</td>
<td>h) pinna (that one up there)</td>
</tr>
<tr>
<td>i) ani (female’s brother)</td>
<td>i) ani (female’s brother)</td>
</tr>
<tr>
<td>j) iglu (snow house)</td>
<td>j) iglu (snow house)</td>
</tr>
<tr>
<td>k) panna (that place up there)</td>
<td>k) panna (that place up there)</td>
</tr>
<tr>
<td>l) aivuq (she goes home)</td>
<td>l) aivuq (she goes home)</td>
</tr>
<tr>
<td>m) ini (place, spot)</td>
<td>m) ini (place, spot)</td>
</tr>
<tr>
<td>n) ukiuq (winter)</td>
<td>n) ukiuq (winter)</td>
</tr>
</tbody>
</table>
Inuktitut

Minimal Pairs:

iglumut - iglumit
ukiaq - ukiuq
aiviq - aivuq
aniguvit - anigavit
aglu - iglu
pinna - panna
ani - ini

So what can we conclude about phonemes in Inuktitut?
Inuktitut

Minimal Pairs:

<table>
<thead>
<tr>
<th>iglumut</th>
<th>-</th>
<th>iglumít</th>
</tr>
</thead>
<tbody>
<tr>
<td>ukiaq</td>
<td>-</td>
<td>ukiúq</td>
</tr>
<tr>
<td>aiviq</td>
<td>-</td>
<td>aивúq</td>
</tr>
<tr>
<td>aniguvit</td>
<td>-</td>
<td>anigavít</td>
</tr>
<tr>
<td>aglu</td>
<td>-</td>
<td>iglu</td>
</tr>
<tr>
<td>pinna</td>
<td>-</td>
<td>panna</td>
</tr>
<tr>
<td>ani</td>
<td>-</td>
<td>ini</td>
</tr>
</tbody>
</table>

So what can we conclude about phonemes in Inuktitut?

- [u] – [i]
- [a] – [u] → form contrastive pairs
- [a] – [i]

⇒ __________________________
Inuktitut

Minimal Pairs:

<table>
<thead>
<tr>
<th>Word</th>
<th>Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>iglumut</td>
<td>iglumit</td>
</tr>
<tr>
<td>ukiaq</td>
<td>ukiuq</td>
</tr>
<tr>
<td>aiviq</td>
<td>aivuq</td>
</tr>
<tr>
<td>aniguvit</td>
<td>anigavit</td>
</tr>
<tr>
<td>aglu</td>
<td>iglu</td>
</tr>
<tr>
<td>pinna</td>
<td>panna</td>
</tr>
<tr>
<td>ani</td>
<td>ini</td>
</tr>
</tbody>
</table>

So what can we conclude about phonemes in Inuktitut?

[u] – [i] form contrastive pairs

⇒ these are phonemes in Inuktitut
Exercise on stating generalization
Natural class
Exercise: making generalizations about the environments

can /k(æ)n/

I can ask [æsk]
I can see [sɪ]
I can bake [beɪk]
I can play [pleɪ]
I can go [gou]
I can gather [gæðər]
Generalizations => Rules

/n/ becomes [m] before a bilabial consonant

/n/ becomes [ŋ] before a velar consonant

elsewhere /n/ is pronounced [n]
Generalizations => Rules

/n/ becomes [m] before a bilabial consonant

/n/ \rightarrow [m] / ____ (bi)labial consonant

/n/ becomes [ŋ] before a velar consonant

/n/ \rightarrow [ŋ] / ____ velar consonant

elsewhere /n/ is pronounced [n]

/n/ \rightarrow [n] / elsewhere
More data…

- hat trick [hæt trɪk]
- hit batsman [hɪp bætsmən]
- night class [nɑɪk klæs]
- bad dream [bæd drem]
- head band [hɛb bænd]
- bad guy [bæg gʌɪ]
Generalizations on /n/ =>

Rules

/n/ → [m] / ___ (bi)labial consonant
/n/ → [ŋ] / ___ velar consonant
/n/ → [n] / elsewhere

These rules apply to /t/ and /d/! Can you write the rules?
rules

- \(/n/ \rightarrow [m] / \_\_\_ (bi)labial consonant
  \(/n/ \rightarrow [\text{\textquoteleft\textprime}n] / \_\_\_ velar consonant
  \(/n/ \rightarrow [n] / elsewhere

- \(/t/ \rightarrow [p] / \_\_\_ (bi)labial consonant
  \(/t/ \rightarrow [k] / \_\_\_ velar consonant
  \(/t/ \rightarrow [t] / elsewhere

- \(/d/ \rightarrow [b] / \_\_\_ (bi)labial consonant
  \(/d/ \rightarrow [g] / \_\_\_ velar consonant
  \(/d/ \rightarrow [d] / elsewhere
Back to features...

- /n/ = voiced, alveolar nasal (stop)
- /t/ = voiceless, alveolar stop
- /d/ = voiced, alveolar stop
• /n/ = voiced, **alveolar nasal (stop)**
• /t/ = voiceless, **alveolar stop**
• /d/ = voiced, **alveolar stop**

• Are there any other alveolar stops in English?
(6) The consonants of English classified by voicing, place of articulation, and manner of articulation.
• /n/, /t/ and /d/ form a Natural Class of alveolar stop.
Exercise

• Which phones belong to the following natural classes?

  – High vowels
  – back vowels
  – voiceless fricatives
  – voiced bilabial
  – Labial consonants
New classes

• **obstruents** – produced with an obstruction of the airflow
  – stop, fricative, affricates

• **sonorants** – produced with a relatively open passage
  – nasals, liquids, glides, and vowels

labial obstruents [p, f, b, v]
labial sonorants [m, w]
So, what kind of rules are there?
Assimilation

- \( /n/ \rightarrow [m] / \_\_\_ \) (bi)labial consonant
- \( /n/ \rightarrow [\eta] / \_\_\_ \) velar consonant
- \( /n/ \rightarrow [n] / \) elsewhere

- **What feature assimilates?**
Dissimilation

Greek

/epta/ → [efta]

/ktizma/ → [xtizma]

What dissimilates here?
Insertion

- Schwa insertion in English

Plural forms of...

fox, ditch, bush, orange, maze
Insertion

- Vowel insertion in loan words in Japanese
  e.g. McDonald’s

(cf. phonotactic constraints)
Deletion

• /h/ - deletion

He handed her his hat.
Exercises
For tomorrow

- LF Phonology 3.5
- Read Werker (I’ll email you the paper)