Speech: purposeful activity
- speech patterns convey meanings
  - cf. English vowel system - vowel sounds vs. vowel letters
    (limb/hymn/live/sieve) - same vowel sound
  - vowel length: relative length before [g], [d], longer than
    before [k], [t]
  - shortening effect: voiceless consonants
  - lengthening effect: voiced consonants

**Phonology:** concerned with organization of speech in specific languages

languages select from potentially infinite speech sound inventory (Hockett: phoneme inventory of all known languages: between 13 and 75)

- Phonetics vs. phonology: differences and integration

**Phonetics**
- attempts generalization of speech organs and acoustics
- concerned with actual physical properties, can be precisely measured and described
- difference is not covered by competence/performance dichotomy
  - Integration: much work in phonetics is language specific
  - both: justified empirically
  - true reality: a “reality of integration” (Clark/Yallop 2002)

**Phonology**
- less interested in generalization across languages
- concerned with symbolic categories,
  e.g. describes allowed consonant sequences

Difficulties in methodology:
- phonetics: methods from natural sciences
- phonology: methods from humanities; concerned with
  the mental aspects of language

**Interpretation A:** phonetics deals with objective reality;
phonology deals with linguistic organization

**Interpretation B:** phonology tackles the true mental reality
behind speech; phonetics handles only the concrete outputs of this reality

In summary:
- character of phonetics: more general/universal
- character of phonology: more language specific

Phonetics and phonology: introduction to the fields

- indicates high extent of sound organization
- speech can be analyzed on various levels:
  a. anatomy/physiology focus
  b. unit of sound focus
  c. analyzing and processing of incoming sound wave

**Phonetics:** concerned with a-c; corresponds with:
1. anatomy and physiology of speech
2. articulatory phonetics (identification and classification of individual sounds)
3. acoustic phonetics (instrument analysis and measurement of sound waves)
4. auditory/perceptual phonetics

Phonetics and phonology: introduction to the fields

- body functions | recognition of pronunciation | sound wave | interpretation
- speech can be analyzed on various levels:
  a. anatomy/physiology focus
  b. unit of sound focus
  c. analyzing and processing of incoming sound wave

**Phonetics:** concerned with a-c; corresponds with:
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**Phonology:** concerned with organization of speech in specific languages

languages select from potentially infinite speech sound inventory (Hockett: phoneme inventory of all known languages: between 13 and 75)
Phonetics: an outline

- Study of the physical aspects of speech events
- phonetic description is relevant for preservation of pronunciation
devolution: 19th century, parallel research to a.) spelling reforms, b.) teaching, c.) deaf training,
d.) historical sound change: increase in phonetic research
today: phonetics is interdisciplinary: linguistics, psychology,
computer science, engineering

Areas of phonetic research:
1. production of speech
2. acoustics
3. perception

Areas: 1. Production of speech

Basis for:
a.) traditional transcription, cf. IPA and
b.) for phonological feature systems (cf. Ladefoged)
features: all sounds share some properties, cf. nasality
# interface between phonetics and phonology
A airstream mechanisms
B phonation/voicing
C articulation
D oro-nasal processes
E suprasegmental variation/prosody
= some segments/combinations of segments are made
more prominent via: loudness, length, pitch
(phonetically analyzed as: amplitude, duration, frequency)

Areas: 2. speech acoustics

Sound wave transmission from speaker to hearer is
described after prominent frequency components and
interval durations
+ speech: result of acoustic sources
- sources: phonation, larynx-produced noise, airstream
  constriction
vocal tract has filter functions
  function of these sources as ° formants
  ° formant resonances depend on airway size/shape
  ° airway size/shape: modified by articulators
Use of visual displays (frequency or intensity over time)
+ spectrograms

Anatomy and physiology of speech production

1. Airstream mechanisms and 2. Places of articulation
speech organs: body structures with varying tissue types
organs of speech: no system of primary biological functioning

1. Airstream mechanisms - subglottal and supraglottal
  - respiratory system: starts subglottally
  - respiration cycle: source of airflow + for sequential
    organization of speech
  - subglottal tract: contained in thorax (chest)
  - thoracic cage consists of ribs, shoulder blades, collar bones
  - diaphragm
  - reservoir for airflow: lungs; connected to windpipe
    (trachea) by bronchial tubes (join at trachea base)
Anatomy of speech production: **The lung-thorax system**
- System of contraction vs. expansion
  a. Inspiration: thoracic cavity enlarges by expansion of ribcage (structure rises)
  b. Lung volume increases → air pressure decreases
- Diaphragm and elastic recoil forces: control quiet breathing and create relaxation pressure
- Extreme expiration: even back muscles are used (shout)
- Tendency: consistent pressure below glottis (subglottal pressure $P_{sg}$)
C. Expiration: lung volume reduces → rising pressure relative to external atmosphere

Anatomy of speech production: **Larynx**
- Basic function: valve between esophagus and windpipe
- Speech function: source of sound and articulator
- Windpipe (trachea): series of cartilaginous sections
- Larynx: skeletal frame, series of cartilages
- Thyroid angle: gender difference
  - Male, $90^\circ$; female, $120^\circ$
- Tilting: important for vocal fold tension
- Conus elasticus and arytenoid cartilages form glottis
- Function controlled by muscles (abduction - opening, adduction - closing and tensioning of vocal folds)

Anatomy of speech production: **Phonation anatomy**
Phonation: vocal fold vibration
1. Glottis closed, vocal folds adducted
   → expiration airflow builds pressure until folds are forced apart
2. Folds start to open from bottom to top; air escapes through opening
3. Bernoulli effect: air escapes and accelerates / pressure reduces → vocal folds close again
   (pressure reduction presses folds together, supported by muscular elasticity)
4. Repetition of 1-3 → folds vibrate, escaping packets of air generate sound;
   → this produces a modulated airstream

Anatomy of speech production: **Phonation modulation**
1. Normal modulation during speech
   - Folds take longer for opening than for closing
2. Loud and bright speech
   - Speech modulation via rapid opening / closing
   - Less time spent with open folds
3. Soft speech, “breathy” voice
   - Folds do not close completely

Anatomy of speech production: **Phonation parameters**
- a.) Loudness: related to subglottal pressure
- b.) Pitch: correlate of frequency of vibration; determined by length and tension of the folds
- c.) Timbre: “mellowness” / “sharpness”; determined by mode of vocal fold vibration
- Increasing loudness: folds are closed for longer periods
- Bernoulli effect forces folds further apart / pulled together faster
- More “sharpness” generated by rapid velocity changes of airstream
Parameters are influenced by age effects: e.g. jitter (vibration in frequency), shimmer (vibration in loudness)

Anatomy of speech production: **Pharynx**
Pharynx: muscular tube between glottis and skull base
- Air passage for respiration, only passive contribution to speech production
  a.) Lowest section: laryngo-pharynx
  b.) Mid section: oro-pharynx, bound by soft palate
  c.) Upper section: naso-pharynx
Anatomy of speech production: **Velum and nasal cavity**

**Velum:** continuation of roof of mouth, flexible muscular tissue, ends in uvula (small tip of muscle)
- seals off entrance to naso-pharynx (velopharyngeal port)
- muscles serve to lower/raise velum and enhance closure
- some languages (French, Portuguese): oral/nasal vowels
- English/German: only oral vowels
- stops: intra-oral pressure build-up $\dagger$ only when velum is fully raised

**Uvula:** responsible for trill sounds in some languages

**Nasal cavity:** air intake system, mucous membranes line complex cavities without muscular structures

Anatomy of speech production: **Oral cavity**

**Oral cavity:** important for quality of speech sounds
- shape/volume can be modified
- limited by: tongue, palate/glossus muscle, roof of mouth, alveolar ridge
- place of most articulators:
  - lips, teeth, alveolar ridge, hard palate, soft palate

Anatomy of speech production: **Tongue and lips**

**Tongue:** changes volume/shape of oral cavity
- tongue complex muscular structure
- surface area: can be separated into tip, blade, front, center, back
- no anatomic reason for classification/subdivision, only phonetic reasons
- muscle systems shorten/expand, raise/lower, flatten/contract tongue

**Lips:** termination of oral cavity
- two muscular folds; functions: opening/closure, raising/lowering, rounding/protrusion
- different movements $\dagger$ precise lip control relevant in articulation: rapid opening/closure

Places of articulation: **Glottis articulation**

1. **Closed glottis:** vocal folds brought close together, no air passes
   - speech sounds emerge via closure and subsequent opening $\dagger$ glottal stop
   - used in many British accents
2. **Narrow glottis:** narrow gap for air vibration of folds propagates up the pharynx; all vowels and [m], [l], [v], [b]
   - are voiced speech sounds
3. **Open glottis**
   - gap for airstream, no vibration $\dagger$ voiceless speech sounds [s], [k]

Places of articulation: **Oro-nasal articulation process**

Airstream can pass: 1. nasal cavity; 2. oral cavity;
- direction determined by velum
- Velum can be manipulated by speaker

$\dagger$ two linguistically significant positions

1. **Raised velum:** raised and pressed against back of pharynx,
   - nasal cavity is blocked
   - air emerges through oral cavity,
   - creates oral speech sounds
   - cf. all English vowels, [v], [f], [l]
   - additionally, the oral cavity can be blocked as well $\dagger$ temporary full stoppage, cf. [p], [t], [happy]

2. **Lowered velum**
   - airstream has access to nasal cavity
   - if oral cavity is blocked, $\dagger$ entire airstream escapes through nasal cavity, creates nasal speech sounds [m], [n] [night, night]
   - some languages: oral passage is not independently blocked, airstream divided in two
   - creates nasalized oral speech sounds
   - cf. French vowels [vin]
Places of articulation: **Oral tract places - articulation**

- Classified according to: where articulation takes place
  1. labial: concerns lips; a.) labiodental (feel, veal)
     b.) bilabial (pea, bee, me)
  2. dental: refers to upper teeth (think, this)
  3. alveolar (toe, dough, no)
  4. postalveolar: from tooth ridge to start of hard palate (ray, sky)
  5. palatal: from hard palate to beginning velum (you, keep)
  6. velar: from velum to uvula (core, gore)
  7. uvular: tongue back touches uvula (Trompete)
  8. pharyngeal: from pharynx to tongue root (used in Arabic)
  9. glottal: glottal stop (pu’ for put, London accents)

Places of articulation: **Oral tract places - tongue position**

1. apical (tip/front of tongue, used in English and German alveolars)
2. laminal (anterior part of tongue blade, used in Australian aboriginal languages)
3. dorsal (from tongue blade to tongue root)
4. sublaminal (underside, used for retroflex, Hindi)

**Properties of consonants:**
- greater constriction/less prominence than vowels
- cannot stand as an entire syllable
- classified according to degree of constriction

**Properties of vowels:**
- central/nuclear in syllables
- stand as an entire syllable (cf. I, a, awe)
- prominent, constriction is irrelevant

**Manners of articulation:** **Cardinal vowels**

<table>
<thead>
<tr>
<th>Lips spread</th>
<th>Lips neutral</th>
<th>Lips rounded</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>4</td>
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<td>12</td>
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<tr>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
</tbody>
</table>

Cardinal vowels: 1. tongue as high and fronted as possible 2. as low and retracted as possible - established with lateral X-ray shots - all known vowels can be placed in this diagram - recent research: vowels can be produced with alternatives, not all vowels are covered

**Manners of articulation:** **Cardinal vowel approximation**

<table>
<thead>
<tr>
<th>English</th>
<th>German</th>
</tr>
</thead>
<tbody>
<tr>
<td>beat</td>
<td>Leben</td>
</tr>
<tr>
<td>bet</td>
<td>bet</td>
</tr>
<tr>
<td>spa</td>
<td>spa</td>
</tr>
<tr>
<td>hat</td>
<td>hat</td>
</tr>
<tr>
<td>hawk</td>
<td>hawk</td>
</tr>
<tr>
<td>gut</td>
<td>gut</td>
</tr>
</tbody>
</table>

**System of cardinal vowels (Jones):**

Cardinal vowels: 1. tongue as high and fronted as possible 2. tongue as low and retracted as possible

**Unobstructed vowel articulation**

A classification of speech sounds in terms of the type of obstruction made to the flow of air. A vowel makes very little obstruction, while a plosive (stop) makes a total obstruction. (Roach 1992)

**Properties of consonants:**
- most world languages have fewer vowels
- classical Arabic, Aboriginal languages: only 3 distinctive vowels
- vowel systems usually inhabit the outer regions of the cardinal vowels

**Properties of vowels:**
- central/nuclear in syllables
- stand as an entire syllable
- prominent, constriction is irrelevant
Manners of articulation: **Types of consonant articulation**

Parameters of description: degree of constriction; shape of constriction (stricture) and process (dynamic or stable)

1. **obstruents**
   a.) **stop**: formation and rapid release of complete closure
      - dynamic, velum raised
      - egressive pulmonic air escapes \( \rightarrow \) plosives (\( p, b, d, g \))
   b.) **fricative**: constriction is narrow enough to create a turbulent airstream, can be prolonged \( \rightarrow \) stable
      - parameters: stricture, place, phonation
      - airflow rate: higher in voiceless consonants (\( thought \))
      - lower in voiced consonants (\( there \))

2. **approximant (glide, semivowel)**:
   - constriction greater than vowel but not sufficient for turbulence \( \rightarrow \) semivowel (\( law, war, you, raw \))
   - usually voiced

3. **nasals**: stoppage in oral cavity
   - unlike stops, they are stable (\( many \))

4. **dynamic manners**
   a.) **flap** (\( Resultat \))
   b.) **tap** (\( matter \))
   c.) **trill** (\( perro \))

**Stricture**: shape of constriction
1. central: neutral concerning tongue (\( trip, chip \))
2. grooved: tongue creates narrow area along vocal tract (\( s, z, l \))
3. lateral: airstream is diverted from center to both sides (\( l \))

The units of speech: **Identification of speech units**

- language depends on discrete/finite options
- humans perceive relative contrasts; cf. pitch

**System**: a finite number of elements forms set of contrasting options

Units point to systemic nature, depend on levels of description (speech sounds/syllables/words)
- levels depend on focus, cf. description of stress
- relative parameter: syllable
- articulation: no discrete, comfortable entities
- working theory: any sound can be established as a stable state of articulatory mechanisms (= **target**)
- reality for stable sounds, only theory for dynamic sounds

The units of speech: **Parameters of speech units**

1. energy as parameter: \( \uparrow \) peaks of prominence: vowels
   - in syllables: vowels = nuclei
   - consonants: surround nucleus as onset/coda
   - vowels: high acoustic energy

2. sonority as parameter = energy in proportion to effort
   - sonorous sound: high output relative to effort
   \( \uparrow \) notions are: segmentation and structural organization

3. articulation: has primary features (place / manner)
   - has secondary features: has constrictions lower than primary and has alternative places

The units of speech: **Sonority and syllables**

Speech sounds: ranked according to relative sonority
- voiceless oral stops: minimal sonority, low vowels: high sonority; between these extremes: sonority spectrum
- oral stops - fricatives - nasals - laterals - semivowels - high vowels - low vowels
- peaks of sonority used to predict numbers of syllables

**Sonority**

<table>
<thead>
<tr>
<th>/a/</th>
<th>/e/</th>
<th>/i/</th>
<th>/o/</th>
<th>/u/</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>e</td>
<td>i</td>
<td>o</td>
<td>u</td>
</tr>
</tbody>
</table>

Variation of segments: **Consonants**

1. nasalization: permanent nasal articulation; pathological condition, dialectal or habit
2. labialization: rounded lips for any sound that has normally spread lips
3. palatalization: tendency of the tongue to move to a high front position
   - difference clear (\( l \)) / dark (\( l \)) (German/English)
4. affrication: stops are produced with more friction than necessary
5. vowel retroflexion: [\( r \)] - focusing in car, rear
Variation of segments: **Vowel length**

1. Length/duration depends on:
   a.) vowel quality;
   b.) surrounding components

a.) Low vowels are longer than high vowels, need more vocalic effort to produce
b.) Vowels are longer in front of voiced consonants than in front of voiceless consonants, cf. rib/rip; food/soot

- Length can be a differentiating feature, cf. seat/die; seek/sick
- Is a relative parameter, depending on comparable contexts

Variation of segments: **Onglide/offglide and diphthongs**

2. Onglide/offglide effects:
   - Simple vowels are stable, "articulators have steady target configuration"
   - Start/end of a vowel involve articulatory movement: vowel is preceded and followed by a transition of articulators; results in change in auditory quality: onglide/offglide, cf. fee in different varieties of English
   - Glide component can be distinctive, cf. diphthongs

- A sound in which there is a glide from one vowel quality to another (Roach)
  - RP: [i] [ei, ai, oi]; [u] [ou, au]; [o] [oe, eo, uo]
  - Are on a continuum with onglide/offglide

Variation of segments: **Vowels and consonants**

Syllabicity: syllabic nucleus: usually a vowel but can also be formed by nasal or lateral consonants
- Sudden [s,dn], model [mdl]
- German unstressed final -en as in haben [hab:m]

Segmentation: distribution of vowels and consonants according to phonotactic rules
- In sequences, phonemes are not allowed to appear in any possible order
- Phonotactics involve intuitive findings:
  - Bump, lump, hump, lump, clump: large, blunt objects
  - Muddle, fumble, straddle, fiddle, struggle, wriggle: clumsy, difficult action

Units of speech: **Units in phonology**

**Phoneme**: smallest unit of speech with distinctive function
- Each language has a relatively fixed set of phonemes
- Defined in contrast to phonemes of the same language
- Language acquisition includes phoneme acquisition

**Feature**: minimal contrastive element in phonology
- Originally phoneme considered the smallest constituent but: could be broken down into features
- Features form system of polar contrasts, labeled +, - or 0
- Features distinguish each phoneme from other phonemes
- Minimum number of features needed

Standard assumption: 12 features to be sufficient

Distinctive features: **Jakobson/Halle system**

**Jakobson**: one language has limited number of oppositions
- Can be captured as differential qualities
- Of two languages, the distinctive features must be language-specific

Jakobson/Halle: use perceptual terms for acoustic perception
- Spectrum between polar features:
  - Acute: high end of spectrum
  - Grave: low end of spectrum
  - High front vowels vs. back vowels
  - Palatal consonants vs. velar and labial consonants

Jakobson/Halle system: 12 polar contrasts (relative contrasts)

Distinctive features: **Prime features (Ladefoged)**

**Prime features**: measurable properties, e.g. [+/- nasal] = degree of raising of velum
- Any sound can be described according to this feature
- Most basic feature: [+/- voiced], binary
- Some features: multivalued (e.g. place), have more than 2 positions

- Other binary features:
  - Nasal, lateral, sonorant, back, syllabic
- Other multivalued features: height

<table>
<thead>
<tr>
<th>Feature</th>
<th>Options</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>voice</td>
<td>[+ voice] /- voice</td>
<td>/b, d, g/</td>
</tr>
<tr>
<td>place</td>
<td>[labial] [dent] [alveolar]</td>
<td>/p, b, t, d, l/</td>
</tr>
<tr>
<td>stop</td>
<td>[stop] [fricative] [approx]</td>
<td>/k, g, f, v/</td>
</tr>
</tbody>
</table>
Distinctive features: Chomsky - Halle feature system 1

Any feature defined as binary † multivalued features (place, stop, height) to be replaced

1. Place:
   a.) anterior vs. nonanterior
   obstruction in front of palato-alveolar region
   [+ anterior]: /p, t/ [- anterior]: /k, g/
   b.) coronal vs. noncoronal
   tongue blade raised from neutral position
   [+ coronal]: /t, d, n/ [- coronal]: /p, b, m/
   c.) distributed vs. nondistributed
   constriction with considerable distance along air flow
   feature differentiates fricatives
   [+ distributed]: /x/ [- distributed]: /f, θ/

Distinctive features: Chomsky - Halle feature system 2

d.) back vs. nonback
   tongue body retracted from neutral position
   [+ back]: /u, o, u/ [- back]: /i, e/
e.) high vs. nonhigh
   tongue body raised from neutral position
   [+ high]: /i/ [- high]: /e/
f.) low vs. nonlow
   tongue body lowered from neutral position
   [+ low]: /a/ [- low]: /e/

Distinctive features: Chomsky - Halle feature system 3

   anterior  coronal  high  back  low
   bilabial      +            -          -        -        -
   labiodental   +            -          -        -        -
   dental        +            +         -        -        -
   alveolar      +            +         -        -        -
   retroflex     -             +  +       -        -
   palatal       -             -          +       -        -
   velar         -             -          +       +       -
   glottal       -             -           -       +       +

Acoustic phonetics: Introduction

Def: The study of the physics of the speech signal. Mechanical vibrations of air to be analyzed by experimental techniques, e.g. spectrographs (Roach 1996)

Sound waves: variations of air pressure, are superimposed on outgoing air
Variations propagate through air as mechanical waves

pitch: depends on glottis vibration frequency, [p:] 100 Hz
   proportional to frequency, = peaks per second
Voiced speech sounds: have regular waveform
male: 80 - 200 Hz
female speakers: 400 Hz

Acoustic phonetics: Pitch and intensity

Voiceless sounds: airstream goes across irregular surfaces
higher rate of pressure changes; ~ around 2000 Hz
   waveform of the vowel
   (p:) at 100 Hz
(adapted from Ladefoged)

loudness/intensity: proportional to extent of pressure variation, measured in decibels (dB)
vowels: highest intensity; voiceless fricatives: low intensity
Acoustic phonetics: Quality of speech sounds
- depends on overtone structure; vowels distinguishable from overtones
- overtone noticeable when vowels are whispered
  highest overtones: [i] lowest overtones: [u]
  vowels have therefore 2 characteristic pitches
  1. pitch [i < a < o < u] decrease
  2. pitch increase for front vowels decrease for back vowels
  1/2 pitch = 1/2 formant
  - result of air vibration difference
  - in vocal tract: air vibrates at different frequencies simultaneously = resonant frequencies

Auditory phonetics: Theory of speech perception
Audition/function of hearing: auditory communication and localization of sound
Helmholtz 1885: auditory system as a frequency analyzer
Békésy 1960: incoming sound wave from tympanic membrane along basilar membrane to cochlea located in the inner ear
fig. adapted from Wilensky 2001:54

Auditory phonetics: Audition and speech recognition
Dependent on frequency, wave has different amplitudes at different locations
- high frequency: near base of cochlea
- low frequency: near apex of cochlea
- resonance mechanisms stimulate cochlea hair cells
Speech perception = mapping of serial acoustic signals onto sets of discrete linguistic representations
- representations: sequences of phonetic segments (C/V)
- no 1:1 mapping of acoustic properties and phonetic utterance
- parameters of complexity: coarticulation, context, lexicon

Auditory phonetics: Parameters of complexity
1. coarticulation: any acoustic signal contains parallel information for more than one phonetic segment
   keep /k i p/ /k/ different than in /k u l/ cool
   no precise form of acoustic properties that specify phonetic segments
2. context dependence
   - context influences acoustic consequences of variation
3. lexicon: an ambiguous sound is perceived as the correct segment cf. /p/ - /b/ perceived as /p/ in place, as /b/ in beef
   = processes of spoken word recognition
   - listener needs to decode the speech signal

Auditory phonetics: Debate in speech perception
A: modular, speech specific mechanisms compute input
B: general perceptual mechanisms apply
Acquisition issues in early L1 acquisition children map different variants spoken by different speakers to the correct phonetic utterance;
- later L1 acquisition: fine-tuning of speech perception
- children develop from "language-general" to "language-specific" perceivers of speech

Auditory phonetics: Spoken word recognition
Words are heard in sequence, seldom in isolation
- process involves segmentation and recombination
- limited set of phonemes leads to similar words
  steak /steik/ includes: stay /stei/ take /teik/ ache /eik/
  resembles:
  state /steit/ snake /snik/ stage /steig/
  is included in: mistake /mistek/
Auditory phonetics: Word recognition models

1. Marslen-Wilson/Welsch: cohort model
   - incoming word activates all other words beginning the same way (the whole “cohort” is activated)
   - gradual reduction of activation of rejected words
2. Luce/Pisoni/Goldinger: neighborhood activation model
   - lexical neighborhood is determining
   - most frequent words in a language are easier to recognize
3. McClelland/Elman: TRACE model
   - competition model of activated words via connectionist networks; network has feature detectors that analyze spectral components every 5 ms
   - competition offers solution to segmentation problem
   - general phenomenon: co-activation of competing words

Phonological organization of speech: Output issues

Human languages: systematizes output that is potentially possible
   - speakers use output within limitations of rule systems
   - phonological norms are acquired, not learned
   - perception of the “same” word even when uttered differently by different speakers
   - variation of size/shape of vocal tract differences
   - context-sensitive variation: articulation is influenced by neighboring sequences overlapping

Aspects of change in phonological organization

1. biomechanical and neuromuscular limitations (tongue tip speed, lip rounding rate change etc.)
   - inherent inertia, delay of motion, coarticulation
   - rapid talk: tendency of vowels to become centralized
2. relationship of thinking/speaking; effects: slips of the tongue, spoonerisms as in to shake a tower etc.
3. historical changes: assimilation (special /s/ ‘/z/)
   - change of consonant in front of velars

Prosody and intonation in phonetics and phonology

Prosody: grouping/relative prominence of elements making up the speech signal e.g. perceived rhythm of speech
   - hierarchy: from intonation phrase to syllable components
   - intermediate: syllable, metrical foot, prosodic word

Intonation: melody of voice; used to mark the pragmatic force of the information in the utterance
   - intonational events are aligned with most prominent elements of prosodic structure and at the edges
   - intonation provides information about prosodic structure

Prosodic markers of the speech signal

Segments in prosodically prominent positions: more forceful and fully articulated than in weak positions
   - edges of prosodic units: consonantal articulation strengthened at initial edges; final syllables: lengthened
   - a phoneme in one prosodic position can be like another phoneme, cf. /z/ ‘/s/ [clothes]

Prosody and intonation are language universals

Mandarin Chinese: lexical tone prosody: English permits prominence located anywhere in phrase
   - other languages: more prominent parts are moved to fixed prosodically prominent positions (German)

Prosody and syntax: Segmentation issues

Relevance of melody in recognition: aids in segmenting continuous input
   - listeners use rhythmic structure to determine where word boundaries are
   - segmentation: stress-based (English)
   - syllable-based (French)
   - mora-based (Japanese)

Stress used for disambiguation:
   - I read about the repayment with interest
   - therefore: importance of prosodic salience; semantically central words are highlighted via accent
   - but: no evidence that syntactic structure is derived from prosodic/intonational cues
   - placement of accent on new info/deaccenting of old info
Is prosodic info used to locate lexically unfilled positions?

Which book did the teacher read __________ to the class?

Bresnan et al: filler is "reactivated" when gap is auditorily processed; sentence processing theory: constituent hierarchy must be identified in order to process the right constituent at the gap

* Paradox: how can a "phonetically invisible" element (the gap) be identified?
- Hypothesis: prosodic markers provide information on determining gap locations (Nagel et al.)

Parsing strategies on gap-filling processes

1. Fodor: parser delays possible gaps until input is reached
   - problem: real-time processing constraints
2. Parser places possible gaps anywhere
   - problem: more than one possible gap
Which student did the teacher walk (___) to the cafeteria with __________?

- Walk opens argument position which turns out not to be the "true" gap
- Results are ambiguous sentences
3. Cues within sentence enable an "informed decision"
   - Lexical expectation hypothesis, supported predominantly by syntactic cues as e.g. strong transitivity; cf.
Which book did the teacher read __________ to the class?

- Problem: intransitive verbs

Experimental evidence for prosodic cues in gap-filling

Mary had orange juice this morning and I had grape _______ just last night
Mary had orange juice this morning and I had grape juice just last night
- Differences in gap region:
  1. Duration, word preceding gap is longer
  2. Pitch: greater extent between maximum and minimum
Result: dependent on reaction times a priming of the fillers occurred that can be correlated with prosodic cues
- Gaps are not "phonetically invisible"

Word boundary independence: (Supra) segmental contrast

- Allophonic rules ignore word boundaries
  - Implementation depends on tempo (= Prosody)
- Segmental phoneme function: primarily a contrastive function in single monomorphemic words
  - For segmental contrast, the size of the linguistic unit is irrelevant
    - Cf. cab/cap as in: I took a cab/cap
  - For subsegmental contrast:
    - Black bird vs. black bird; forms minimal pair
    - Concerning stress contour (# difference in meaning)
      - Involves units larger than single words
      - Phonological analysis is therefore not confined to words as segmental/morphological units

Stress beyond the single word

Linguistic unit with more than one stressed syllable: stresses of different relative prominence (primary and secondary stress); cf. polysyllabic
- Similar stress contour: in syntactic phrases e.g. blackbird
- Stress (acoustic definition): syllable is marked with greater duration/loudness than unstressed syllable
- Primary stress: also marked in pitch contour (intonation)

Phrasal stress and syntactic structure: Prominence rule

<table>
<thead>
<tr>
<th>Np</th>
<th>good friend</th>
<th>VP</th>
<th>knows everything</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP</td>
<td>heavy metal</td>
<td>AvP</td>
<td>drinks heavily</td>
</tr>
<tr>
<td>sentences</td>
<td>cigars smell</td>
<td>Janet smokes</td>
<td></td>
</tr>
<tr>
<td>Adj</td>
<td>good friend</td>
<td>AdvP</td>
<td>quite orderly</td>
</tr>
<tr>
<td>Adj</td>
<td>good friend</td>
<td>good</td>
<td>quite orderly</td>
</tr>
</tbody>
</table>

- Unmarked: all carry final stress, changed only for special emphasis
- Metrical trees reflect syntactic trees
  - Phrasal prominence rule: in a pair of sister nodes (N1, N2), where P is a phrasal category, N2 is strong
Compound stress and morphol. structure: **Prominence rule**

- complex prominence patterns

**compound prominence rule**: in a pair of sister nodes

\[ N_1, N_2 \], where L is a lexical category, \( N_2 \) is strong if it branches above the word level

- rule difference: in phrases, final parts are strong