Harvard-MIT Division of Health Sciences and Technology
HST.725: Music Perception and Cognition
Prof. Peter Cariani
Prof. Andy Oxenham
Prof. Mark Tramo

Music Perception & Cognition

Peter Cariani

Andy Oxenham

Mark Tramo

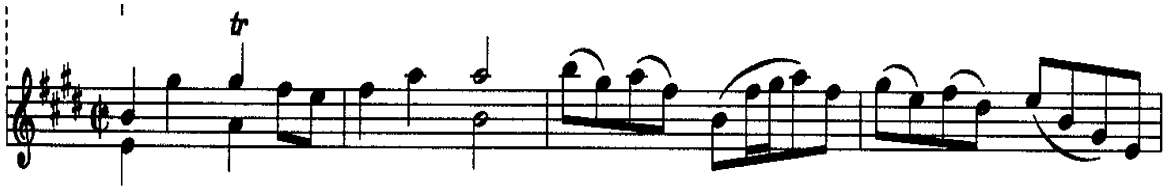
Eaton Peabody Laboratory of Auditory Physiology
Massachusetts Eye & Ear Infirmary

Department of Otology and Laryngology
Harvard Medical School

Speech, Hearing and Biotechnology Program
Harvard-MIT Division of Health Sciences & Technology

www.cariani.com

(Image removed due to copyright considerations.)



Outline

- Course mechanics
- Class survey
- Music, mind, and brain
  - FORM & QUALITY
  - PATTERNS OF EVENTS IN TIME
  - NEURAL MECHANISMS
  - MEMORY/GROUPING
  - EMOTION/MEANING
  - ORIGINS
- Overview of topics
- Music introduction

Texts

Deutsch, D. ed. 1999. The Psychology of Music. San Diego: Academic Press. REQUIRED

Handel, S. 1989. Listening: an Introduction to the perception of Auditory Events. MIT Press. REQUIRED.

Snyder, Bob. 2000. Music and Memory. MIT Press. REQUIRED.

McAdams & Bigand. 1993. Thinking in Sound: The Cognitive Psychology of Human Audition. Oxford. Recommended. (Available used for ~$6 via www.half.com)

Aello, R. ed. 1994. Musical Perceptions. Oxford University Press. Recommended.

Moore BCJ. 2003. An Introduction to the Psychology of Hearing, Fifth Ed.. San Diego: Academic Press. Recommended.

Course rationale(s)

- Music is an important aspect of the auditory sense that rivals speech and language in complexity
- Many of us come to auditory research through a native interest in music
- Music affords an alternative perspective on hearing and neuroscience, spanning acoustics, sensory physiology, auditory perception & auditory cognition
- We strive to be systematic and integrative in our treatment (lecture format)
- a primary goal is to facilitate intellectual synthesis; to organize disparate facts into coherent wholes
- We want students to choose & formulate their own problems, articulate their own perspectives, and delve deeply into an area of personal interest (term projects)

Organizing themes: Music, mind, and brain

- **FORM & QUALITY OF SOUNDS (tones)**
- **PATTERNS OF EVENTS IN TIME (events)**
- **NEURAL MECHANISMS**
- **MEMORY & ORGANIZATION**
- **EMOTION & MEANING**
- **ORIGINS: Why music?**

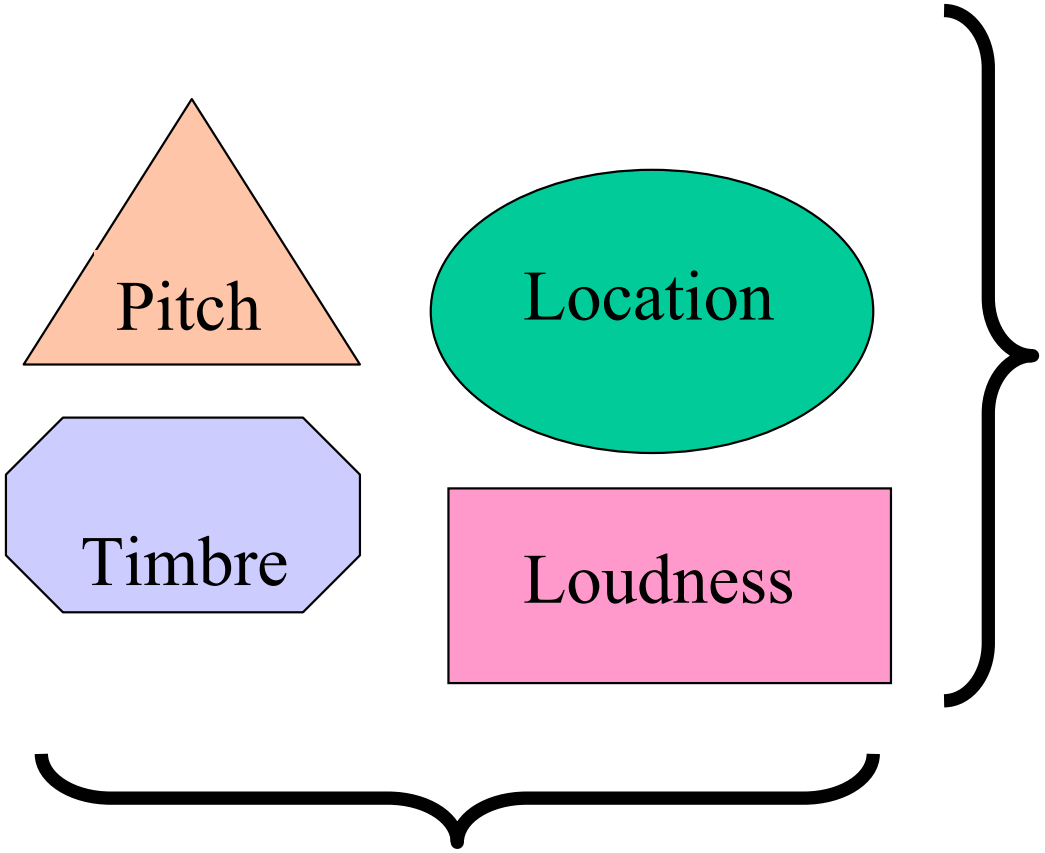
Auditory qualities in music perception & cognition

- **Pitch** — Melody, harmony, consonance
- **Timbre** — Instrument voices
- **Loudness** — Dynamics
- **Organization** — Fusions, objects. How many voices?

- **Rhythm** — Temporal organization of events
- **Longer pattern** — Repetition, sequence

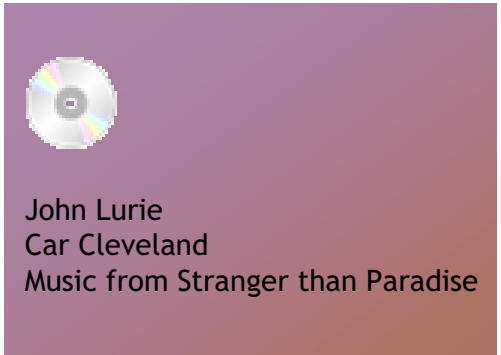
- **Mnemonics** — Familiarity
- **Hedonics** — Pleasant/unpleasant
- **Semantics** — Cognitive & emotional associations

Basic auditory qualities
Dimensions of auditory perception



TEMPORAL EVENT STRUCTURE
Meter, sequence

FUSION
Grouping into separate objects
Temporal co-occurrence
harmonic structure



Music: patterns of events in time
organized relations between events

Please see Mark Malinowski's Music Animation Machine Site (http://www.well.com/user/smalin/mam.html)

From cochlea to cortex

10,000k — **Primary auditory cortex (Auditory forebrain)**

Auditory thalamus

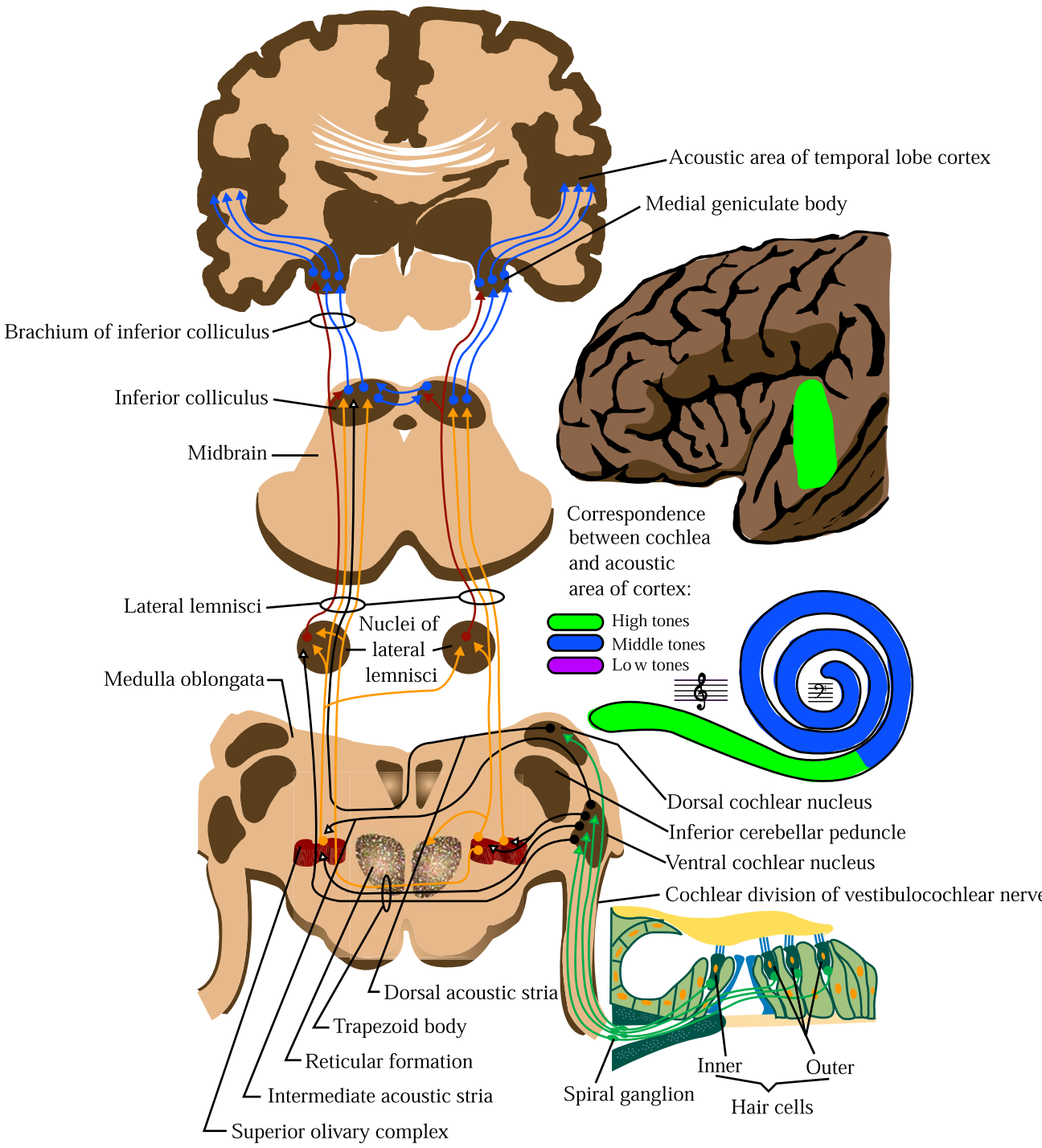
500k — **Inferior colliculus (Auditory midbrain)**

Lateral lemniscus

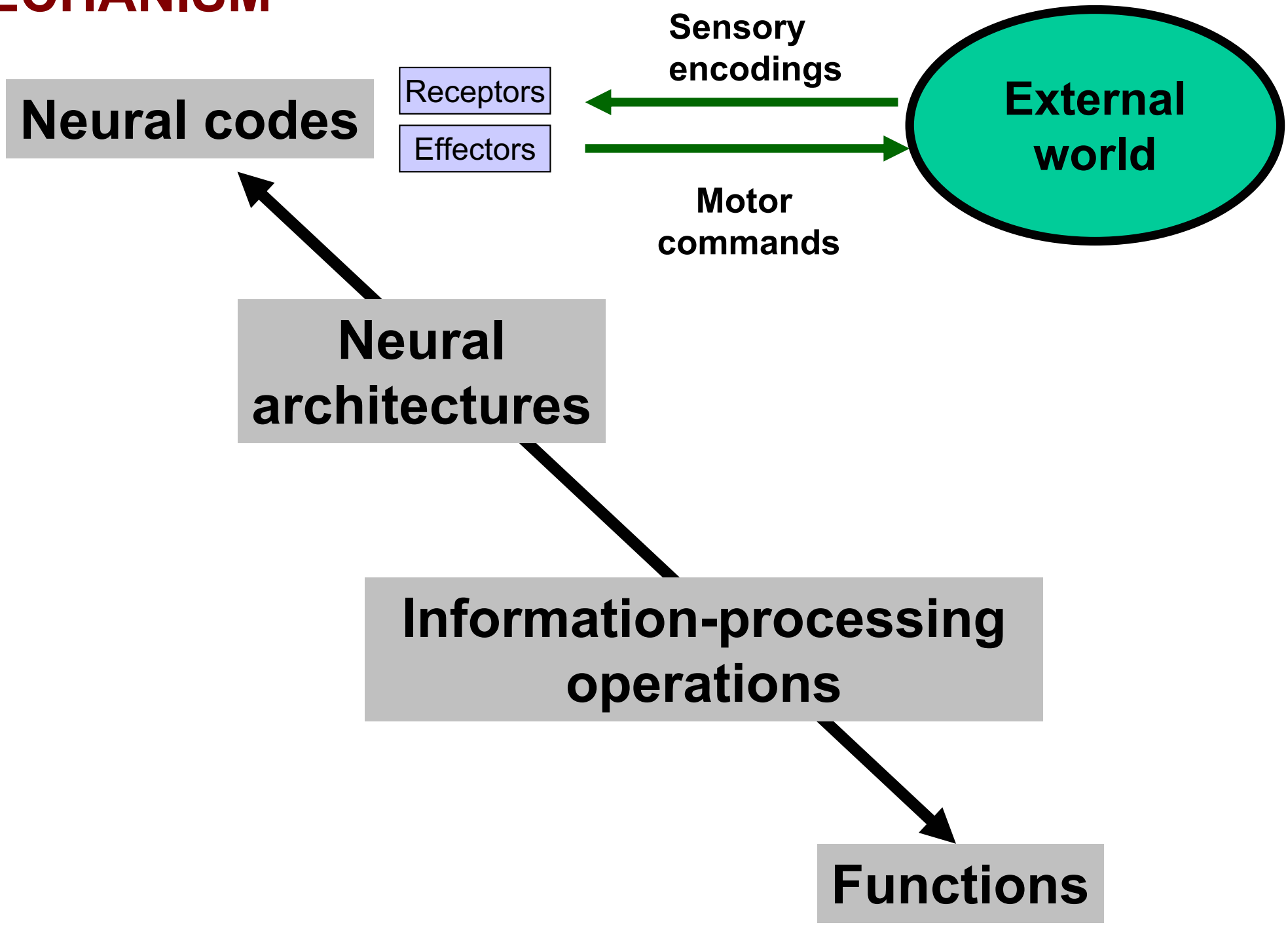
Auditory brainstem

30k — **Auditory nerve (VIII)**

3k — **Cochlea**



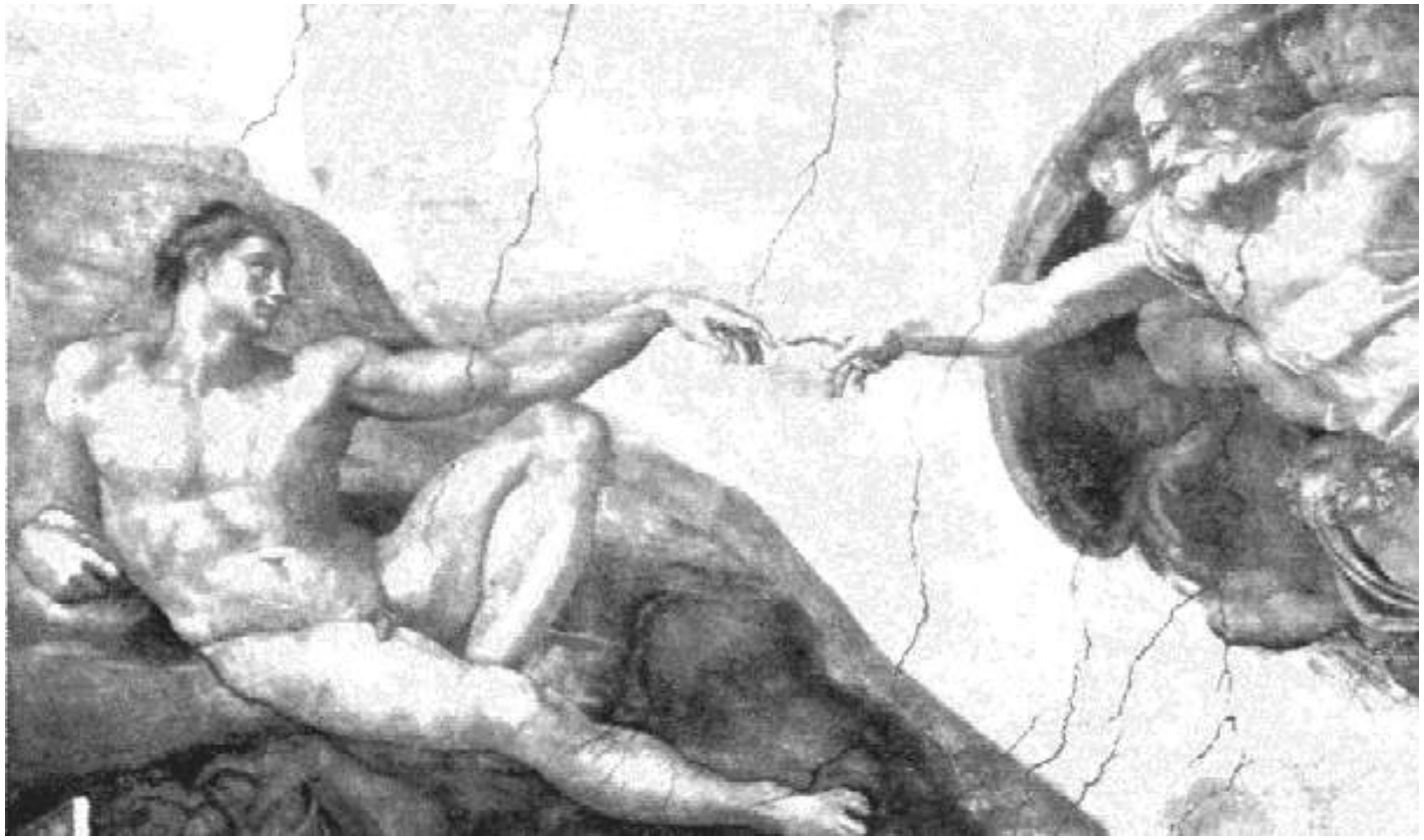
MECHANISM


Sensory encodings
Receptors
Neural codes
Effectors
External world
Motor commands
Neural architectures
Information-processing operations
Functions

MECHANISM

Neurophysiology
Neurocomputation

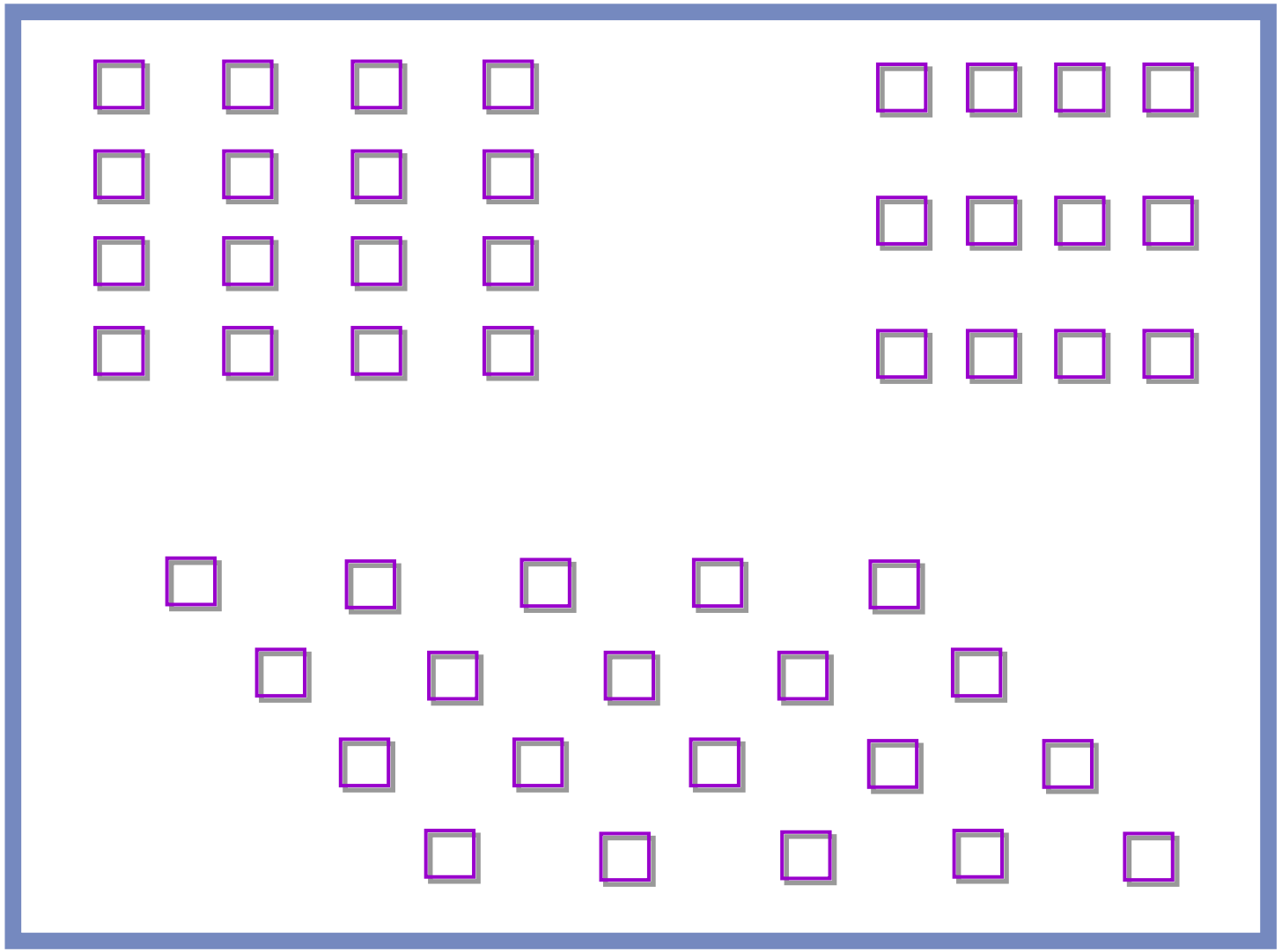
Music cognition
Music theory



Neurophysiology Neurocomputation	Music cognition Music theory
Neural responses	Schemas, grammars
Neural codes	Event structures
Neuroanatomy	Tonal hierarchies
Psychoacoustics	Memory
Reverse-engineering	Aesthetics, hedonics
Explaining pitch	Pitch as a primitive

Visual Grouping: Proximity Principle

Dember & Bagwell. “A history of perception”. In *Topics in the History of Psychology.* Edited by Gregory A. Kimble & Kurt Schlesinger. Hillsdale, N.J.: L. Erlbaum Associates. 1985. ISBN: 0898593115 (v. 1) 0898593123 (v. 2).



Acoustical grouping

(Snyder, Music & Memory)

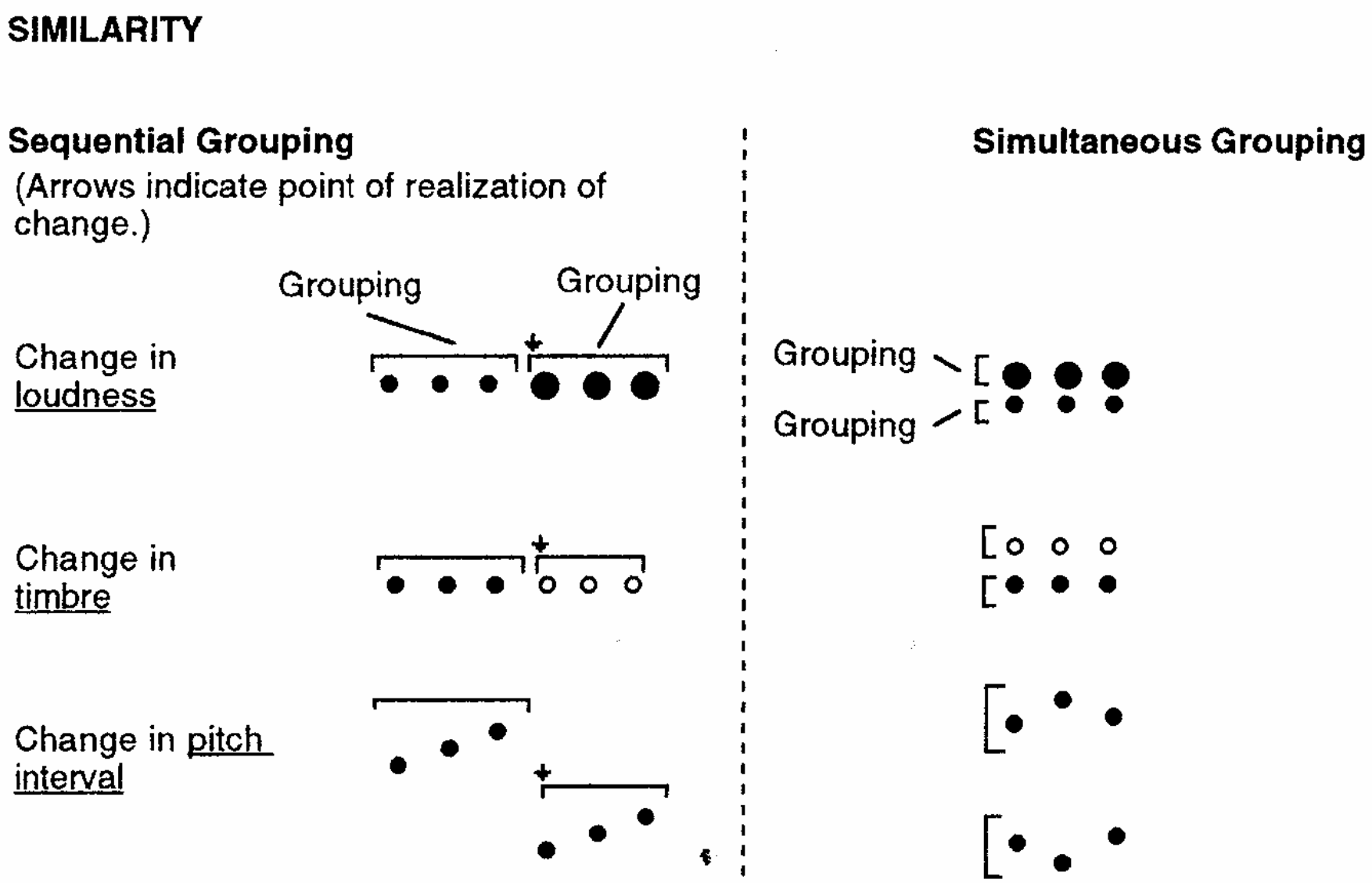


Figure 3.5
Acoustical grouping.

(Snyder, Bob. 2000. Music and Memory. MIT Press. ISBN: 0262194414. Used with permission.)

Melodic & rhythmic grouping

(Snyder, Music & Memory)

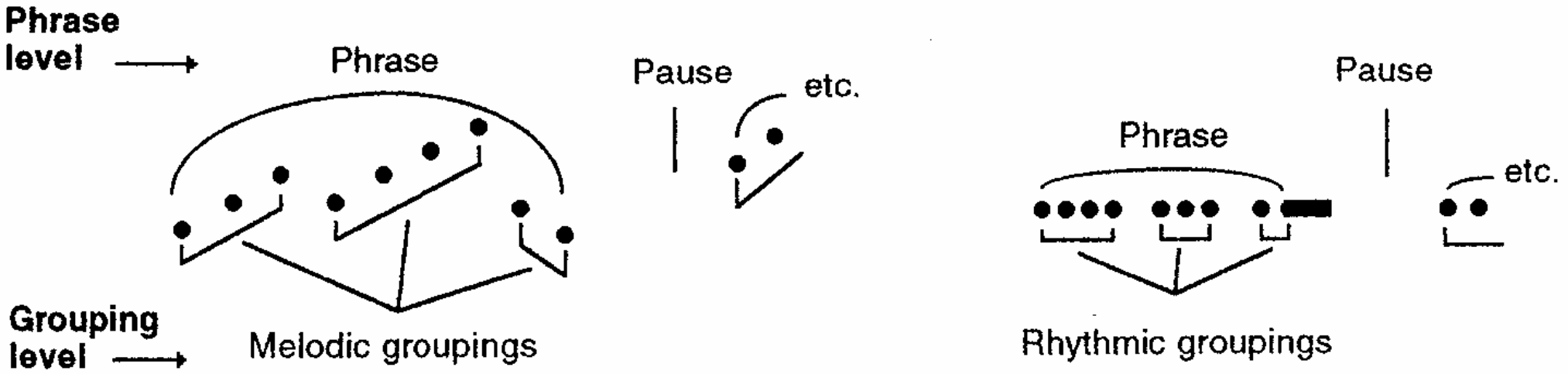
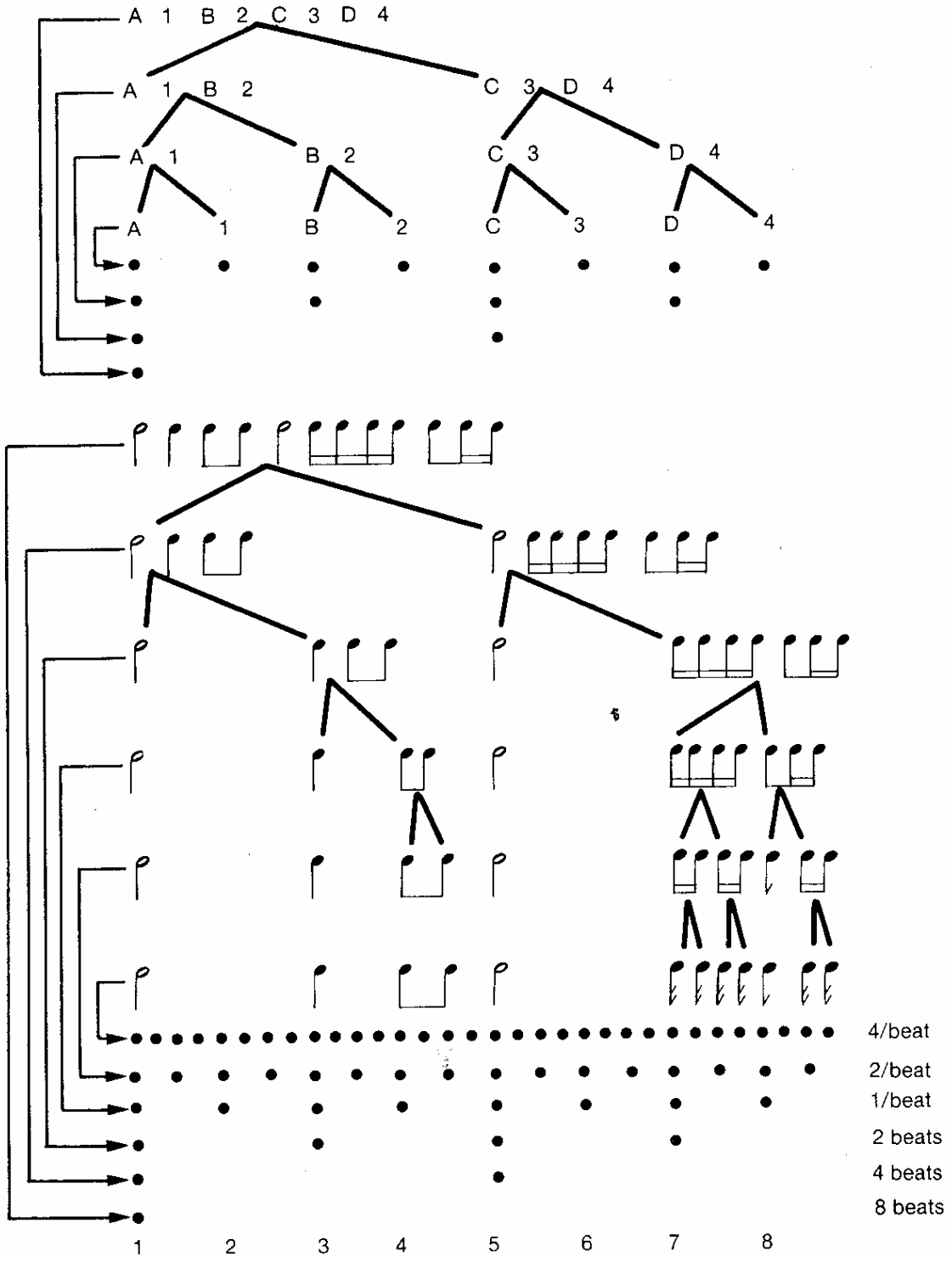


Figure 3.3
Melodic and rhythmic grouping.

Rhythmic Hierarchy



Series of figures from Handel, S. 1989. Listening: an Introduction to the Perception of Auditory Events. MIT Press. Used with permission.

Emotion & meaning in music

Psychological functions of music: why we do it

- Perceptual-cognitive interest (formalism)
- Mood control & emotional expression (expressionism)

The meaning of meaning: semiotics

Sources of meaning: reference and/or construction

- External env. associations: linkages w. memories
- Lyrics and their semantics
- Internal associations: body rhythms, patterns
- External musical associations, expectations (e.g. dirge)
- Intrinsic music expectations (harmonic & rhythmic org.)

What cues convey emotional meaning in music?

Harmony, rhythm, dynamics, expressive timing

Is the minor key (intrinsically) sad?

Tentative schedule: February 3-10

Tuesday Feb. 3 (Cariani)

Course mechanics

Survey of topics to be covered

Overview of the structure of music

Thursday, Feb. 8 (Cariani)

Overview of auditory perception and the time sense: pitch, timbre, consonance/roughness, loudness, rhythm, auditory grouping, event structure

Overview of the auditory system: Representation and processing of sounds in the auditory pathway

Tuesday, Feb. 10 (Cariani)

Musical acoustics

Musical pitch

February 12-24

Thursday, Feb 12 (Oxenham)

Psychoacoustically-based theories of hearing

Thursday, Feb. 19 (Cariani)

Representation of pitch in the auditory system

Neurocomputational models for pitch

Licklider, Terhardt, Grossberg & Cohen, Bharucha

Equivalence classes and octave relations; Neural evidence pros & cons

Tuesday, Feb. 24 (Cariani)

Timbre

February 26-March11

Thursday, Feb. 26 (Cariani)

Harmony I: Consonance, dissonance, and roughness

Theories: Helmholtz, Stumpf, Plomp, Terhardt

Sensory and hedonic aspects

Neural correlates (auditory nerve, midbrain, cortex)

Tuesday, March 2 (Cariani)

Scales and tuning systems

History, basic psychophysics, scales and tuning systems, role in music theory

Relations between auditory and cultural factors

Tuesday, March 9 (Tramo)

Music and the cerebral cortex. Overview of functional role of cortex in music perception & cognition.

Results of imaging and lesion studies. Hemispheric assymmetries.

Thursday, March 11 (Cariani)

Harmony II: chords and keys

March11-April 1

Tuesday, March 16 (Cariani)

Presentation and discussion of term projects

Thursday, March 18 (Cariani)

Melody

Tuesday, March 30 (Cariani)

Rhythm I: Rhythm perception and production

Rhythm II: Computational models

Thursday, April 1 (Cariani)

Time perception, event structure, and temporal expectations

Auditory scene analysis and organization of voices

Grouping of sounds – onset, harmonicity, rhythm

Grouping processes and musical structure

April 6-15

Tuesday, April 6 (Cariani)

Music, speech and language: parallels and contrasts (Bernstein, Jackendoff)

Thursday, April 8 (Cariani)

Emotion and meaning in music

Musical semantics, music and pleasure

Music and long-term memory

Tuesday, April 13 (K. Howland, music therapist)

"Clinical applications of the neuropsychology of music." Guest speaker Kathleen M. Howland Ph.D., MT-BC, CCC-SLP.

Thursday, April 15 (Oxenham)

Clinical issues. Music exposure and hearing loss. Music perception and hearing impairment. Music perception by cochlear implant users

April 22-May 13

Tuesday, April 27 (Cariani)

Developmental psychology of music

A question of origins: comparative and evolutionary psychology of music

Thursday, April 29 (Cariani)

Music performance. Organization and timing of movement.

Tuesday, May 4 (Cariani)

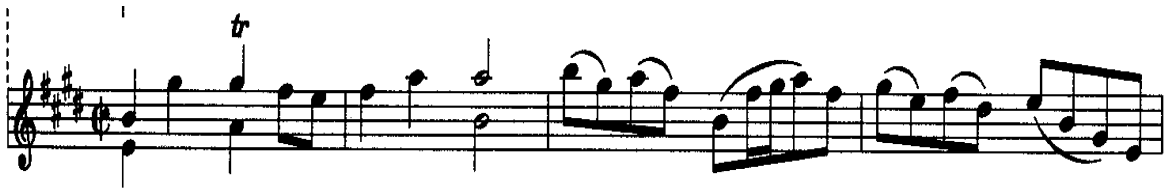
Special topics: absolute pitch, synesthesia, etc.

May 6-11

Student Term Project Presentations

Thursday, May 13 (Cariani)

Overview and recap of major themes; other special topics



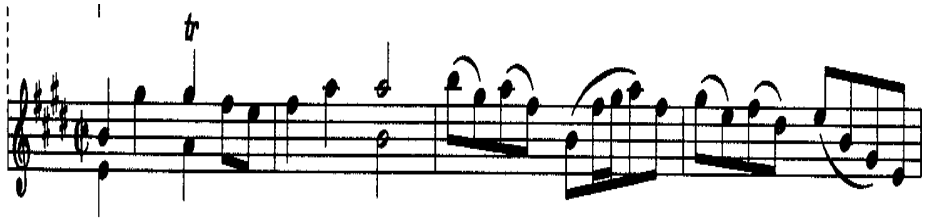
An Introduction to Music: Sound unfolding in time

(Image removed due to copyright considerations.)

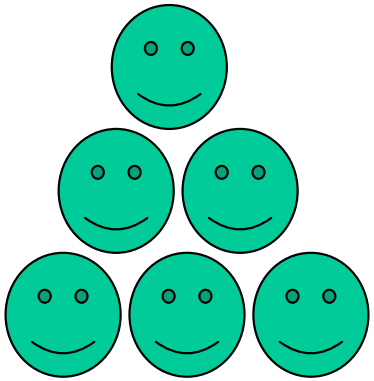
Sound unfolding in time: an introduction to music

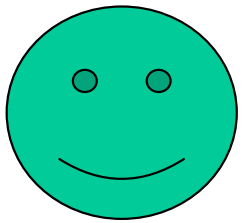
- Music: a bird's eye view; provisional definition
- Ubiquity of music: Nature and nurture
- Sound unfolding in time
  - Horizontal dimension (time, sequential sounds)
    - Melody (Temporal patterns/sequences of pitches)
    - Chord progressions, key modulations (Temporal patterns/sequences of pitch relations)
    - Rhythm (Temporal patterns/sequences of events)
  - Vertical dimension (sound quality, concurrent sounds)
    - Pitch (Dominant periodicities) & Timbre (spectrum, frequency microdynamics)
    - Harmony (Constellations of concurrent pitches)
  - Number of independent trajectories: voices, streams
- Relations to perceptual dimensions
- Psychological questions

Music as stimulus, idea, action, and private experience



relation





Psychology of music examines relations between music and mind.

Music is half of this relation.

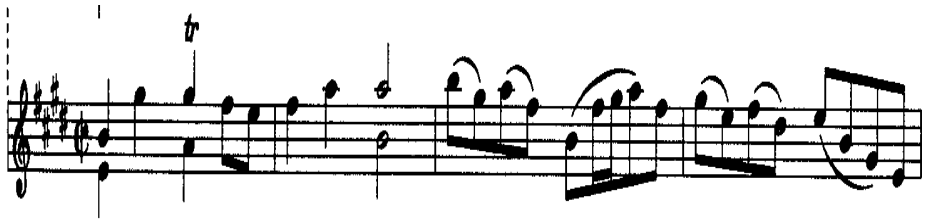
Mind has different facets:

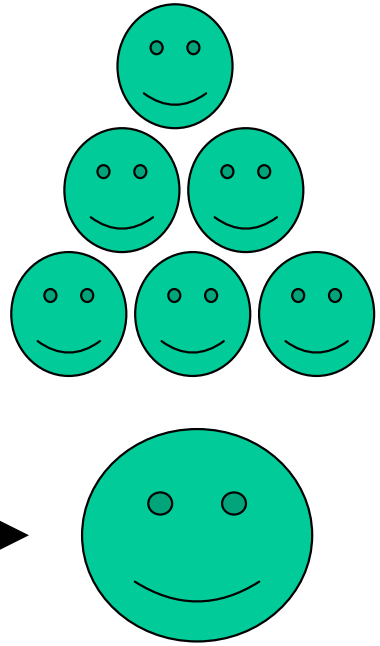
1st person experience
3rd person overt behavior
Underlying neural activity
Functional organization of
informational processes

Music: a provisional definition

Deliberate organization of patterns of sound for interest or pleasure.
Deliberate organization of auditory experience for interest or pleasure.

"Organization" can involve composition or
performance or selection of sounds
or even selective attention to sounds (Cage)
"Interest" and "pleasure" are similarly very broadly construed.

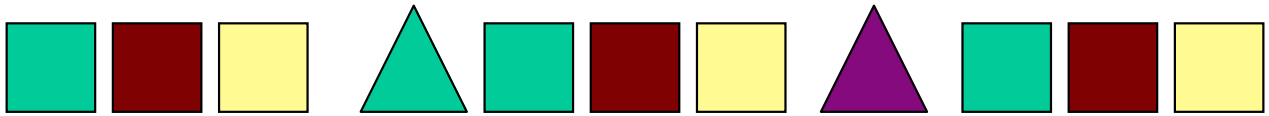




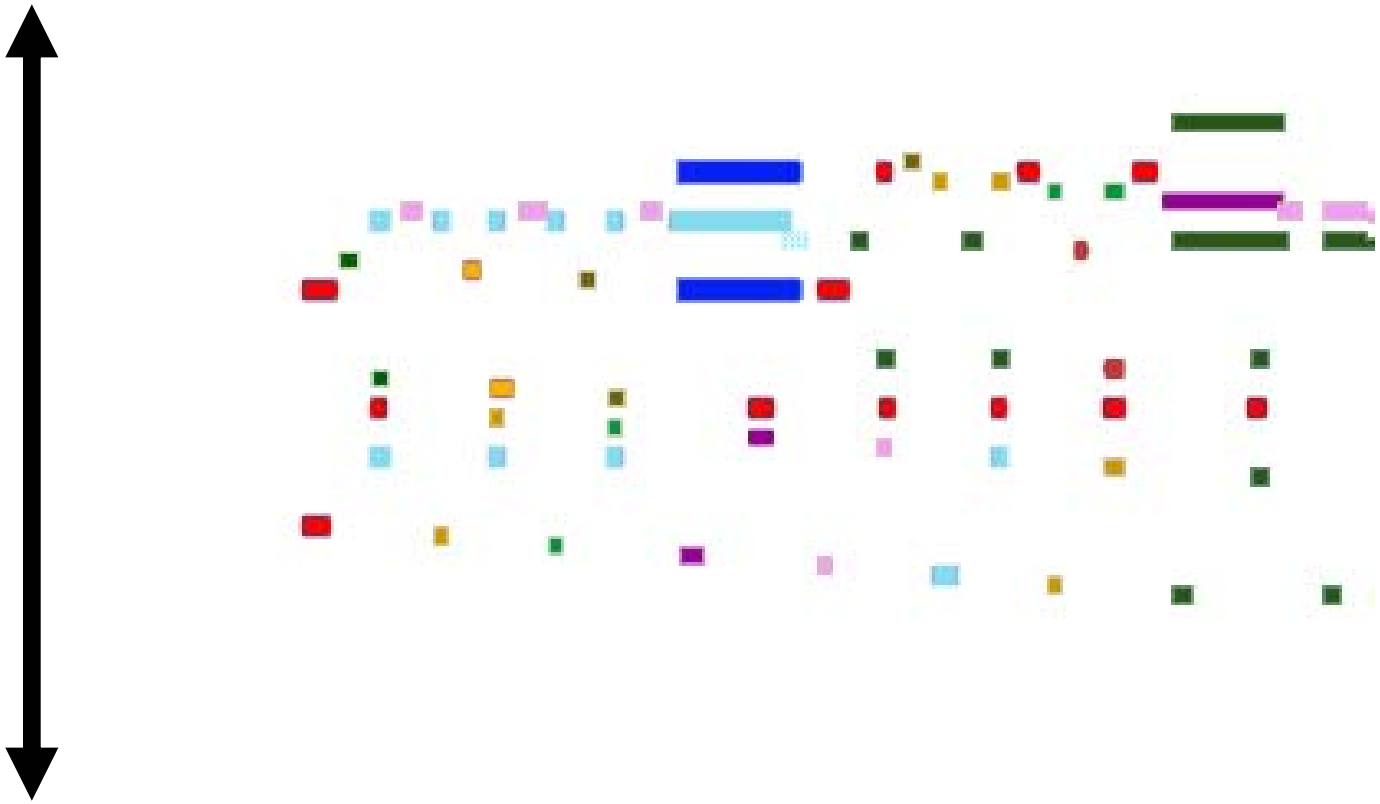
Ubiquity of music: Nature and nurture

- Music has been part of human culture for > 40,000 years
- Every known extant culture has some form of music
- Many cultures equate musical with social harmony (Greeks)
- Relative contributions of nature (biology) & nurture (culture) to the experience of music.
- A great deal of diversity exists across cultures in the forms music takes (ethnomusicology)
- There are universals related to how we hear that are given by biology (auditory science).
- But there are also the effects of culture-based training of how we hear (what aspects we attend to).
- There are also culturally-specific interpretations and meanings associated with what is heard.
- In these lectures we will focus mainly on the universals -- basic aspects of music that are shared across cultures.
- We want a general framework for talking about music that can encompass both the Western tonal music (classical, jazz, popular) as well as all the traditional musics of the world.

Horizontal and vertical dimensions



Tonal quality
(pitch, spectrum)



http://www.well.com/user/smalin/compare.htm

Time (beats, seconds)

Horizontal dimension (time)

Temporal patterns and sequences of sound-changes

Melody: temporal patterns of pitches

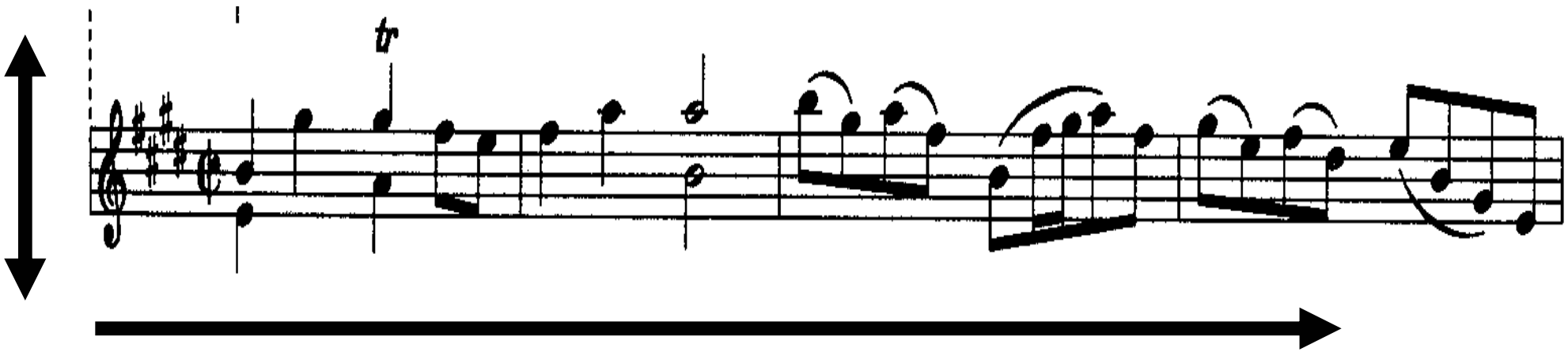
Cadences, key modulations:

temporal patterns of pitch constellations

Rhythm: temporal patterns of events

Bernstein on musical intervals and dimensions

Does music require discrete perceptual "atoms"?



Horizontal dimension (time)

Different musical cultures utilize different aspects of musical possibility. Ethnomusicologists, anthropologists, and historians have theories as to why cultures adopt particular musical styles.

Examples of music that are focused on melody.

(Traditional fiddle-playing in France -- video)

(Gasparyan, Armenian flute music)

Indian ragas

Examples of musics focused on chord progressions

Western symphonic "classical" music, Rock

Examples of music focused on rhythm

African drumming (many examples)

Mbira music, Senegal -- video

Vertical dimension (Harmony)

Patterns of concurrent sounds
Constellations of pitches (intervals, chords)
Sound texture (timbre)

Number of independent voices

Example of horizontal and vertical organization:
    Satie Music Animation Machine

Horizontal dimension involves temporal context & memory
    Build-up of representations and expenctancies
Vertical dimension involves tonal interactions
    Masking, fusions of sounds

Rethinking the role of time

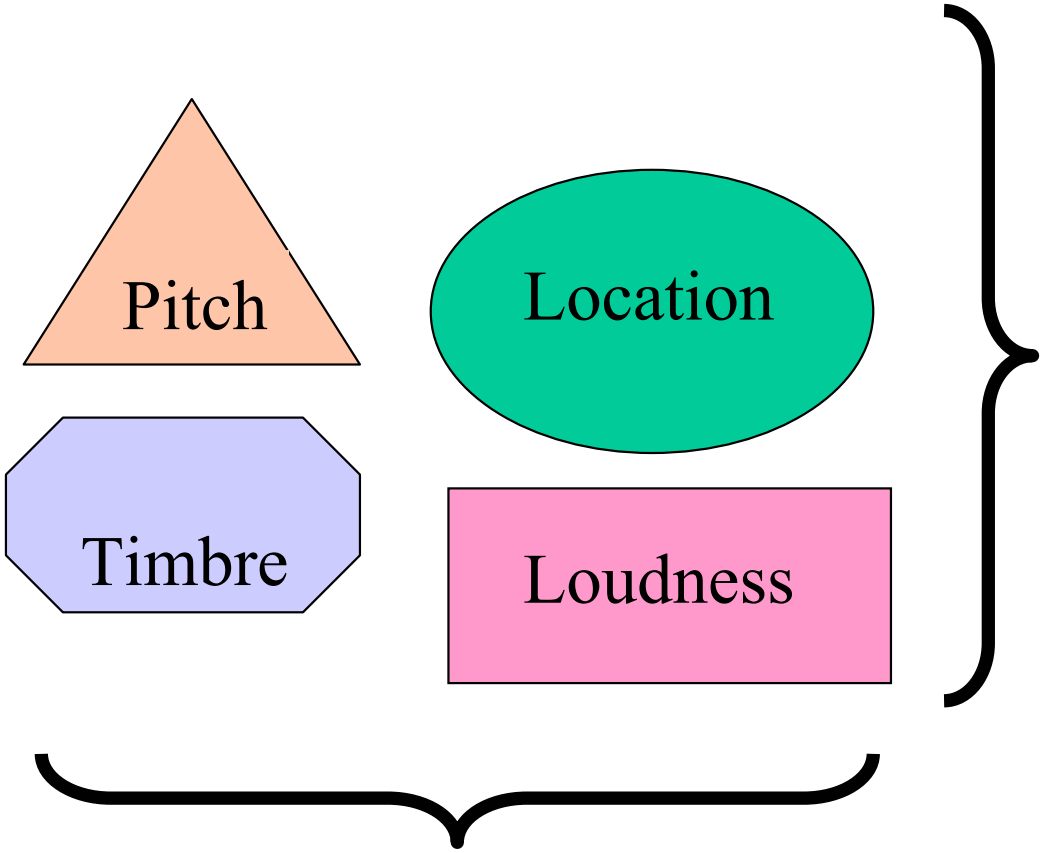
- **Time as coding auditory quality (pitch, timbre, rhythm)**

- **Time as metrical structure of events**
  Repetition and change in music
  Buildup of temporal pattern expectations

- **Time as ordinal sequence of events**

Perception
cognition
&
Motor
domains

Basic auditory qualities
Dimensions of auditory perception



TEMPORAL EVENT STRUCTURE
Meter, sequence

FUSION
Grouping into separate objects
Temporal co-occurrence
harmonic structure

John Lurie
Car Cleveland
Music from Stranger than Paradise

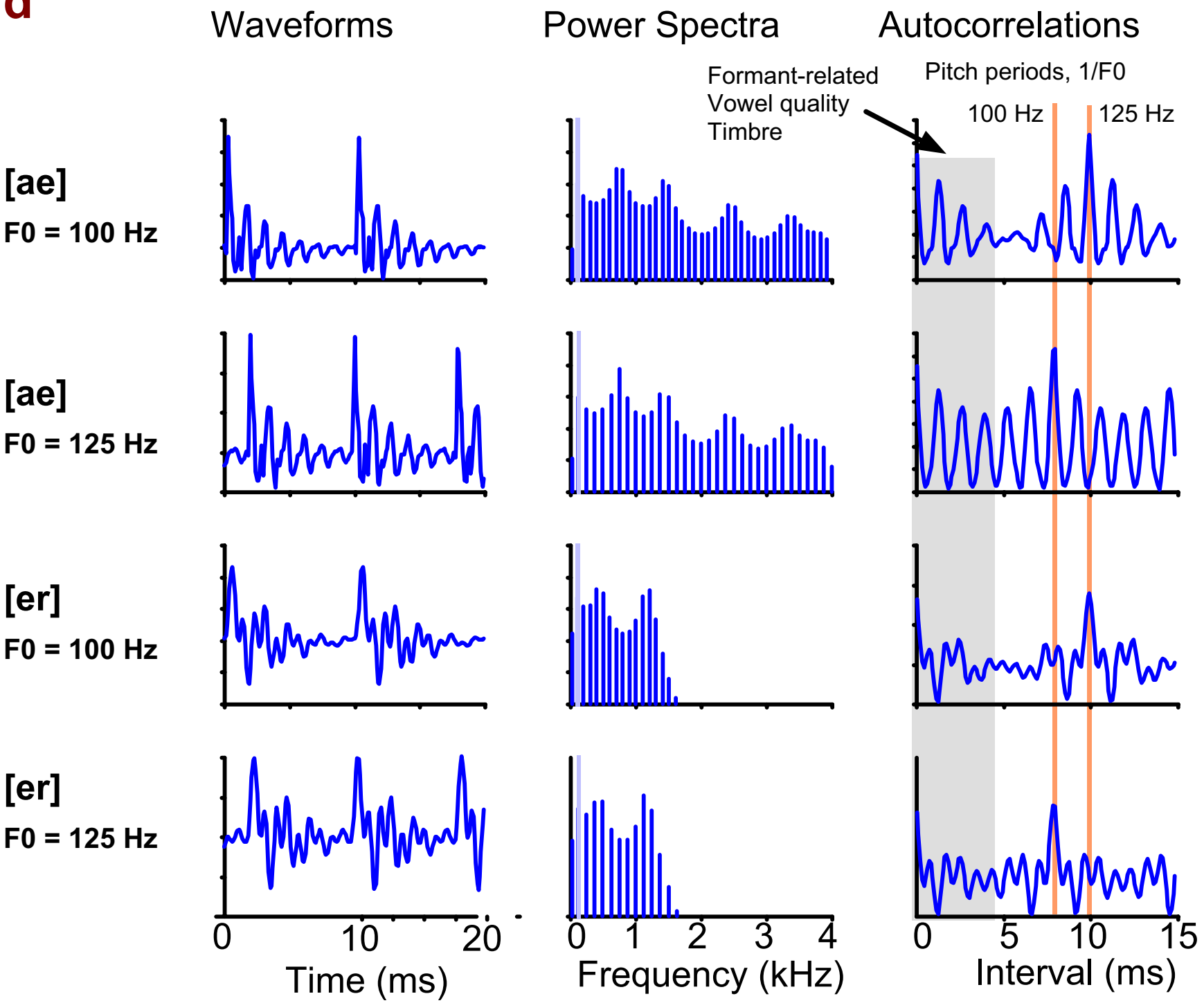
Auditory qualities in music perception & cognition

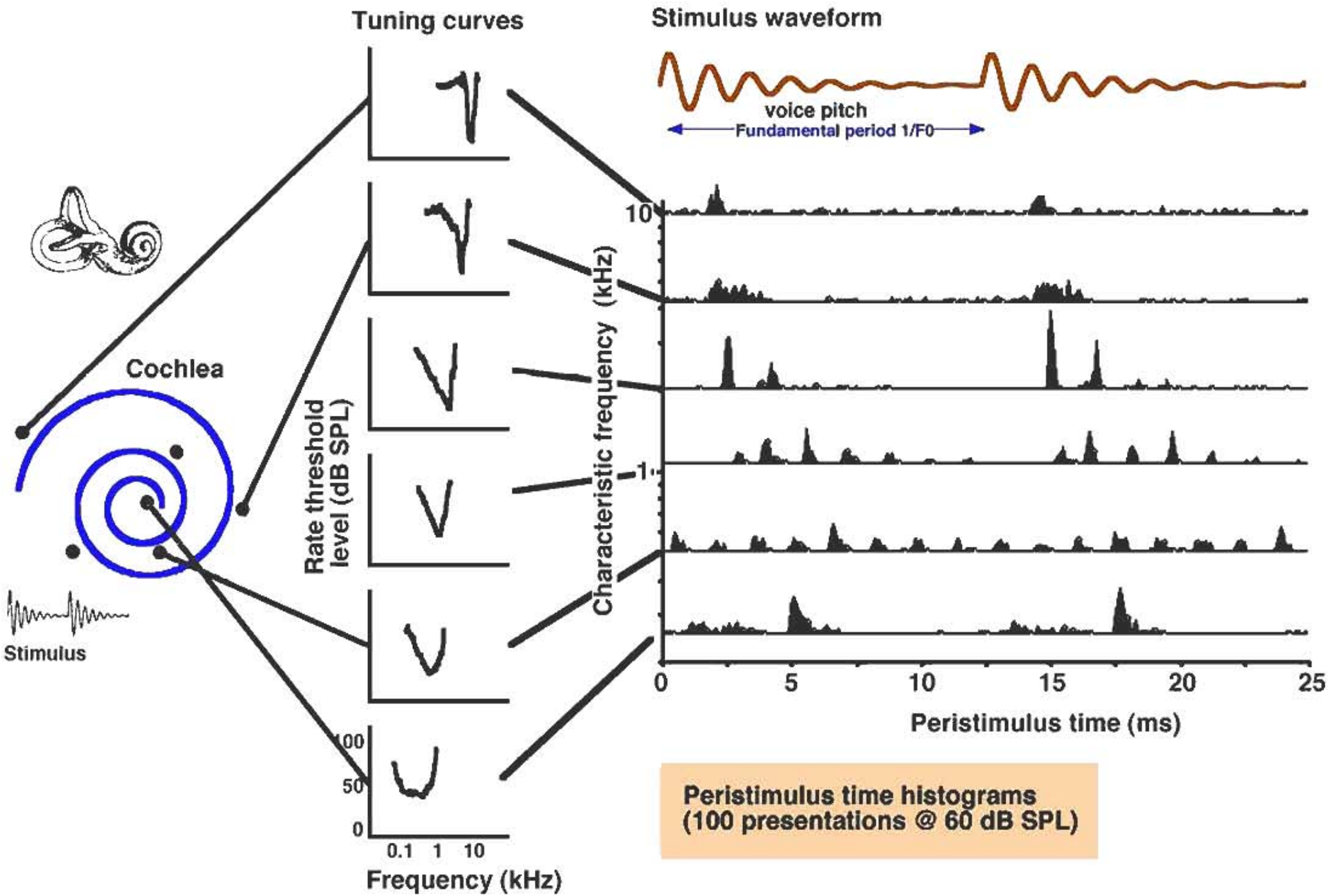
- **Pitch** — Melody, harmony, consonance
- **Timbre** — Instrument voices
- **Loudness** — Dynamics
- **Organization** — Fusions, objects. How many voices?

- **Rhythm** — Temporal organization of events
- **Longer pattern** — Repetition, sequence

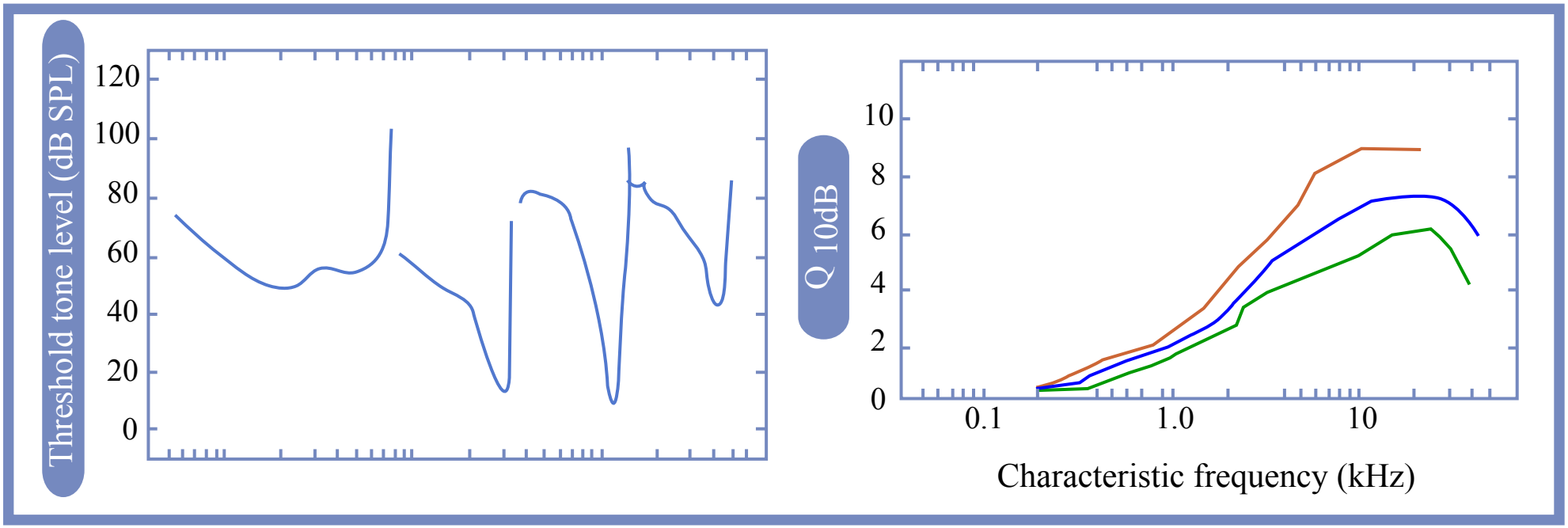
- **Mnemonics** — Familiarity
- **Hedonics** — Pleasant/unpleasant
- **Semantics** — Cognitive & emotional associations

Sound


Waveforms
Power Spectra
Autocorrelations
Formant-related
Vowel quality
Timbre
Pitch periods, 1/F0
100 Hz
125 Hz
[ae]
F0 = 100 Hz
[ae]
F0 = 125 Hz
[er]
F0 = 100 Hz
[er]
F0 = 125 Hz
0
10
20
Time (ms)
0
1
2
3
4
Frequency (kHz)
0
5
10
15
Interval (ms)

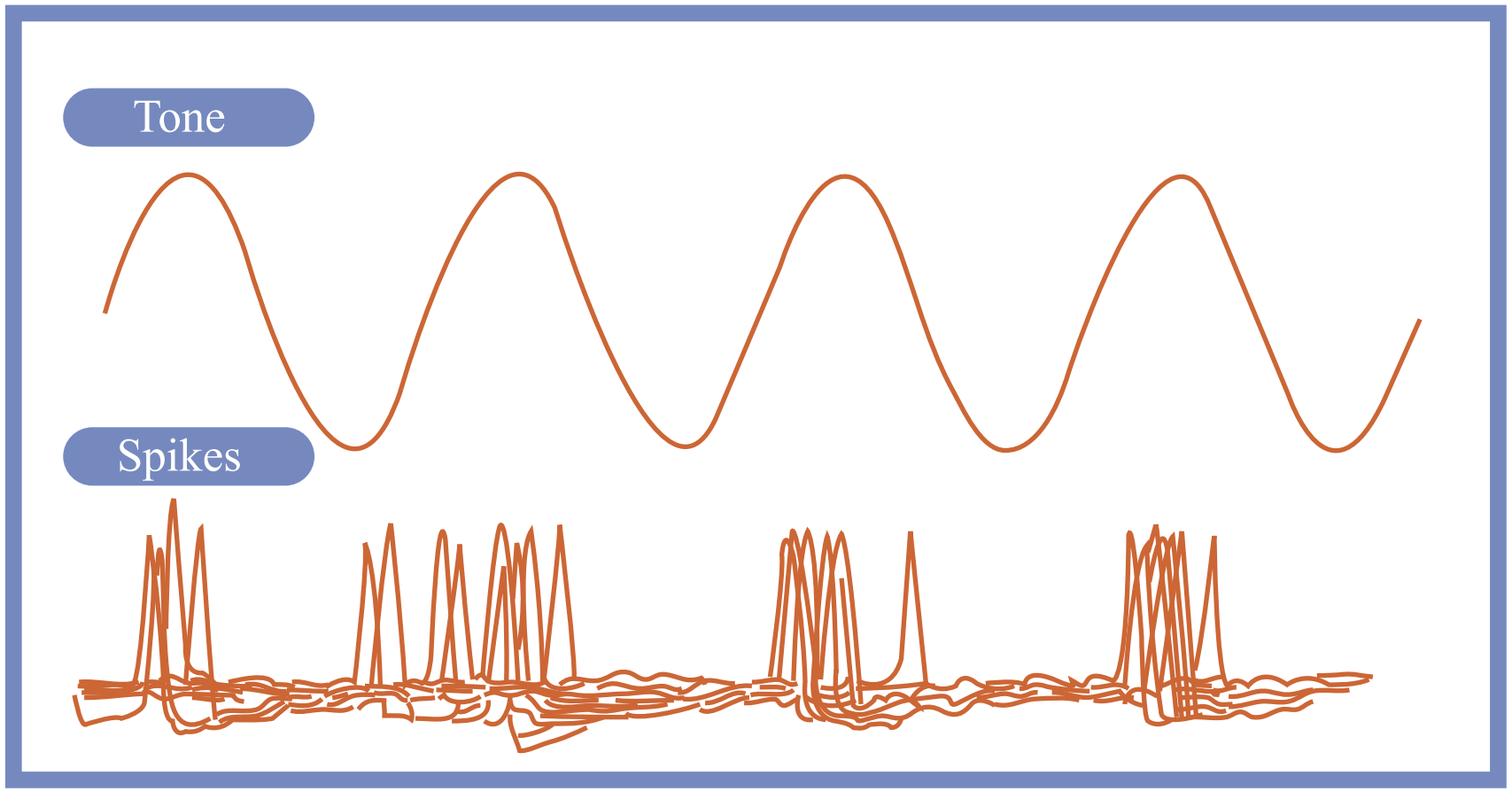

Tuning curves
Stimulus waveform
voice pitch
Fundamental period 1/F0
Cochlea
Stimulus
Rate threshold level (dB SPL)
100
50
0
0.1
1
10
Frequency (kHz)
Characteristic frequency (kHz)
10
1
0
5
10
15
20
25
Peristimulus time (ms)
Peristimulus time histograms
(100 presentations @ 60 dB SPL)

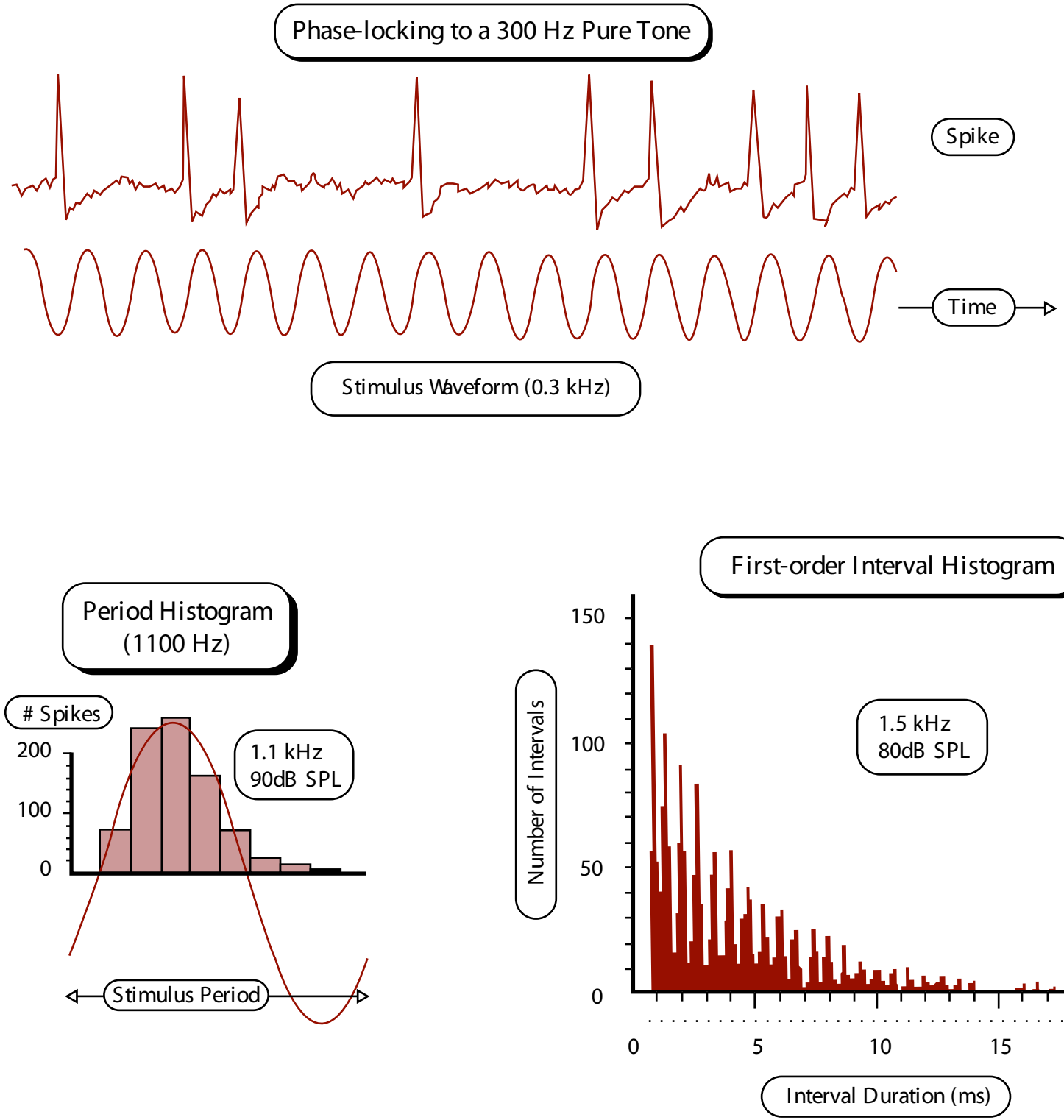
Frequency tuning of Auditory Nerve Fibers as a function of CF



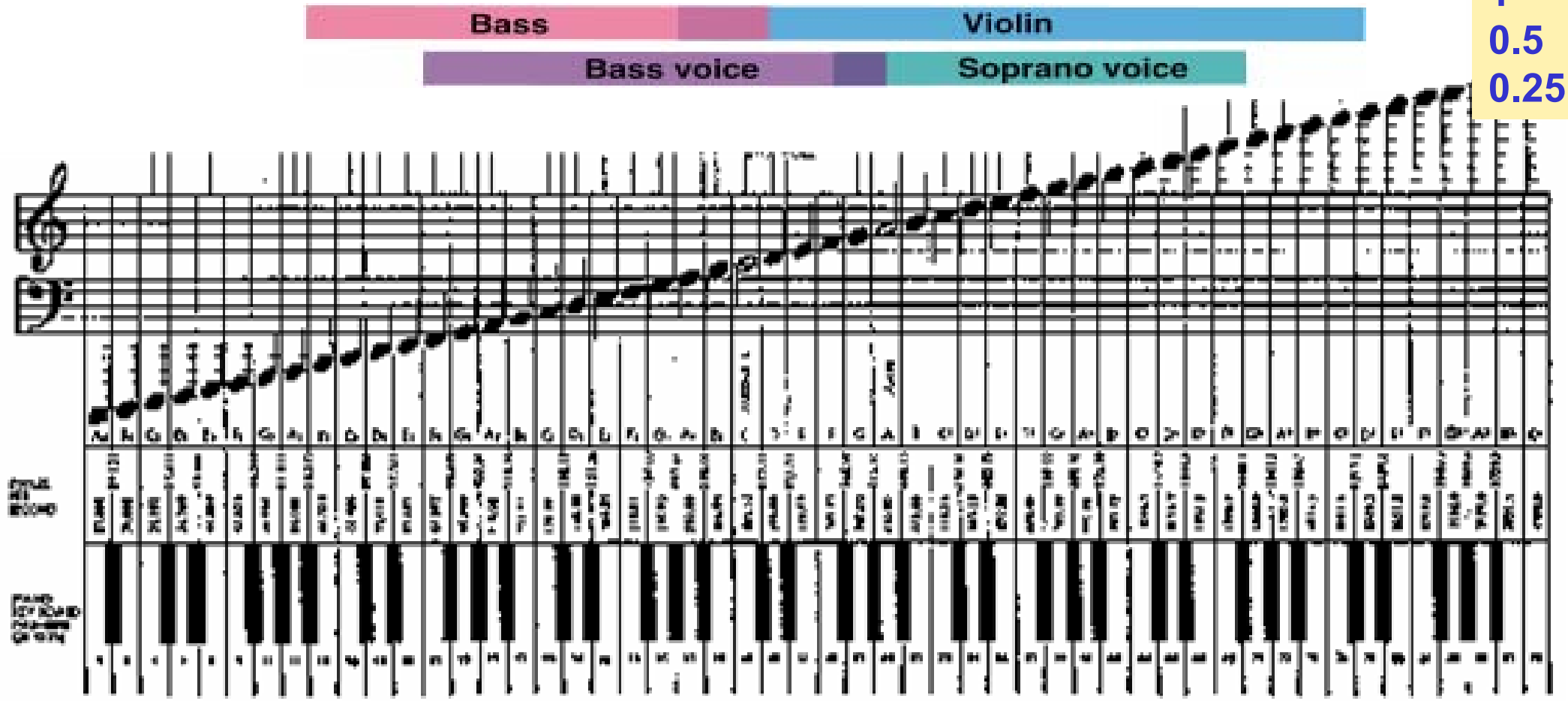
Figures adapted from a figure by Alan Palmer (From Palmer and Evans, unpublished data.)

Phase-locking in auditory nerve fibers




Phase-locking to a 300 Hz Pure Tone
Spike
Time
Stimulus Waveform (0.3 kHz)
Period Histogram
(1100 Hz)
Spikes
200
100
0
1.1 kHz
90dB SPL
Stimulus Period
First-order Interval Histogram
150
100
50
0
Number of Intervals
1.5 kHz
80dB SPL
0
5
10
15
20ms
Interval Duration (ms)

Frequency ranges of (tonal) musical instruments



Reading for Thursday

Deutsch: Weinberger Chapter

Handel: pp. 461-488