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

Systems of pitch relations: Scales, tunings and notations

HST 725 Lecture 10 Music Perception & Cognition

(Image removed due to copyright considerations.)

www.cariani.com

Scales

- Systems of discrete pitches
- Determine tonal systems
- Wide variety of scales in the world
- Octaves, fifths, & fourths very common
- Numbers of notes:
  - pentatonic (5 notes/octave)
  - diatonic (8 notes/octave)
  - chromatic (12 notes/octave)
  - "microtonal" (from Western perspective, > 12 notes/octave)
- Possible reasons for numbers of notes (7±2)

Scales II

- First note: tonic, key, frame of reference
- Ordering of musical intervals
- Modes (Greek or ecclesiastical modes)
- **Major scale** pattern:
- T-T-S-T-T-T-S
- **Minor scale** pattern:
- T-S-T-T-S-T-T
- Circle of fifths: which scales share the same notes,
  - and are therefore related in pitch space
- Ascending vs. descending intervals
- Scale notes vs. expressive deviations from them

Pythagorean ratios

Please see Figures 2-5, and 2-6 of Pierce, John R. *The Science of Musical Sound.* Revised edition. New york: W. H. Freeman, 1992.

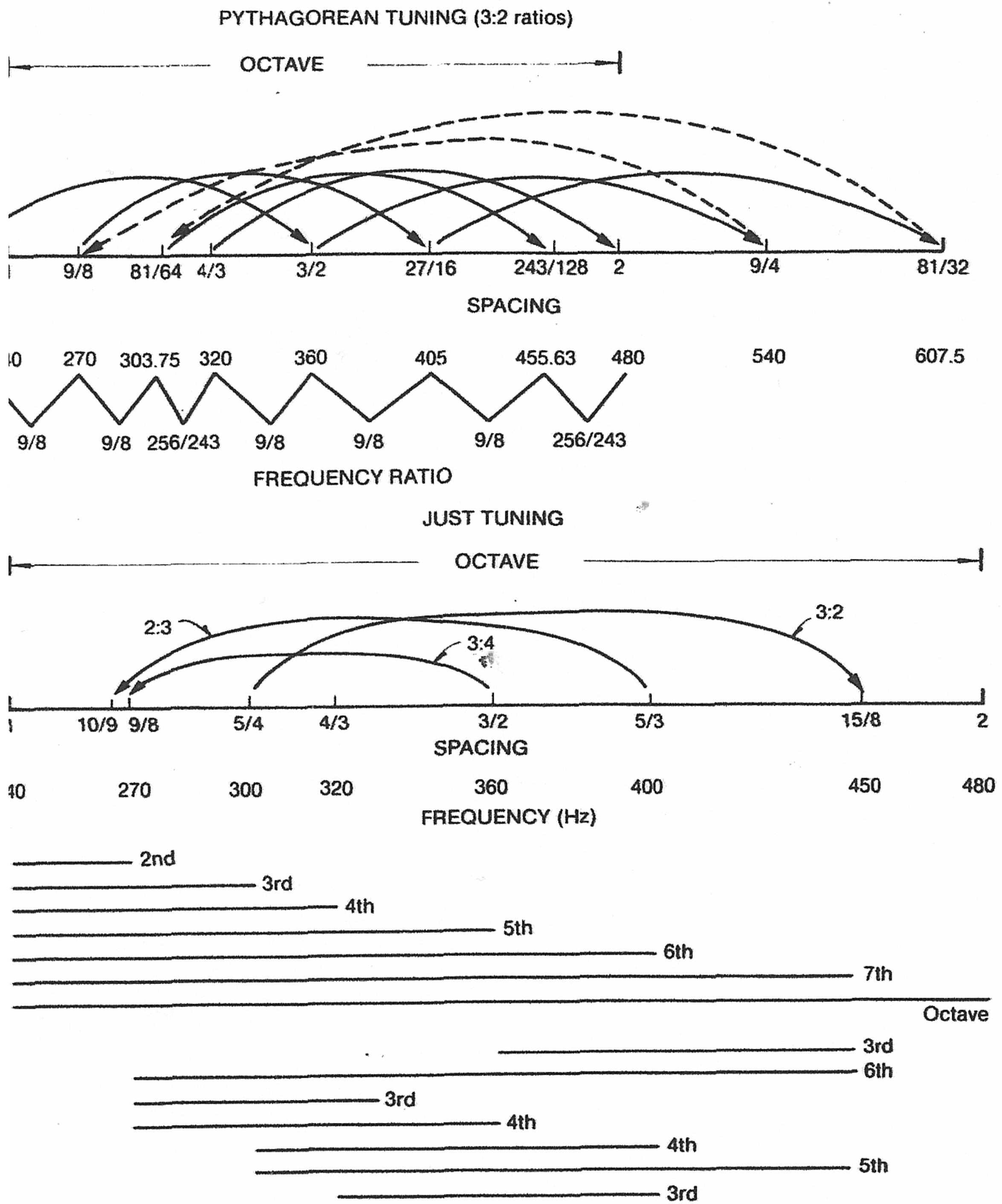
Predicted consonance of harmonic complexes (n=1-6)

Please see Figure 11 of Plomp, R., and W. J. M. Levelt. "Tonal consonance and critical Bandwidth." *J. Acoust. Soc. Am.* 38(1965): 548-560.

Mathematics, numerology music, and mysticism

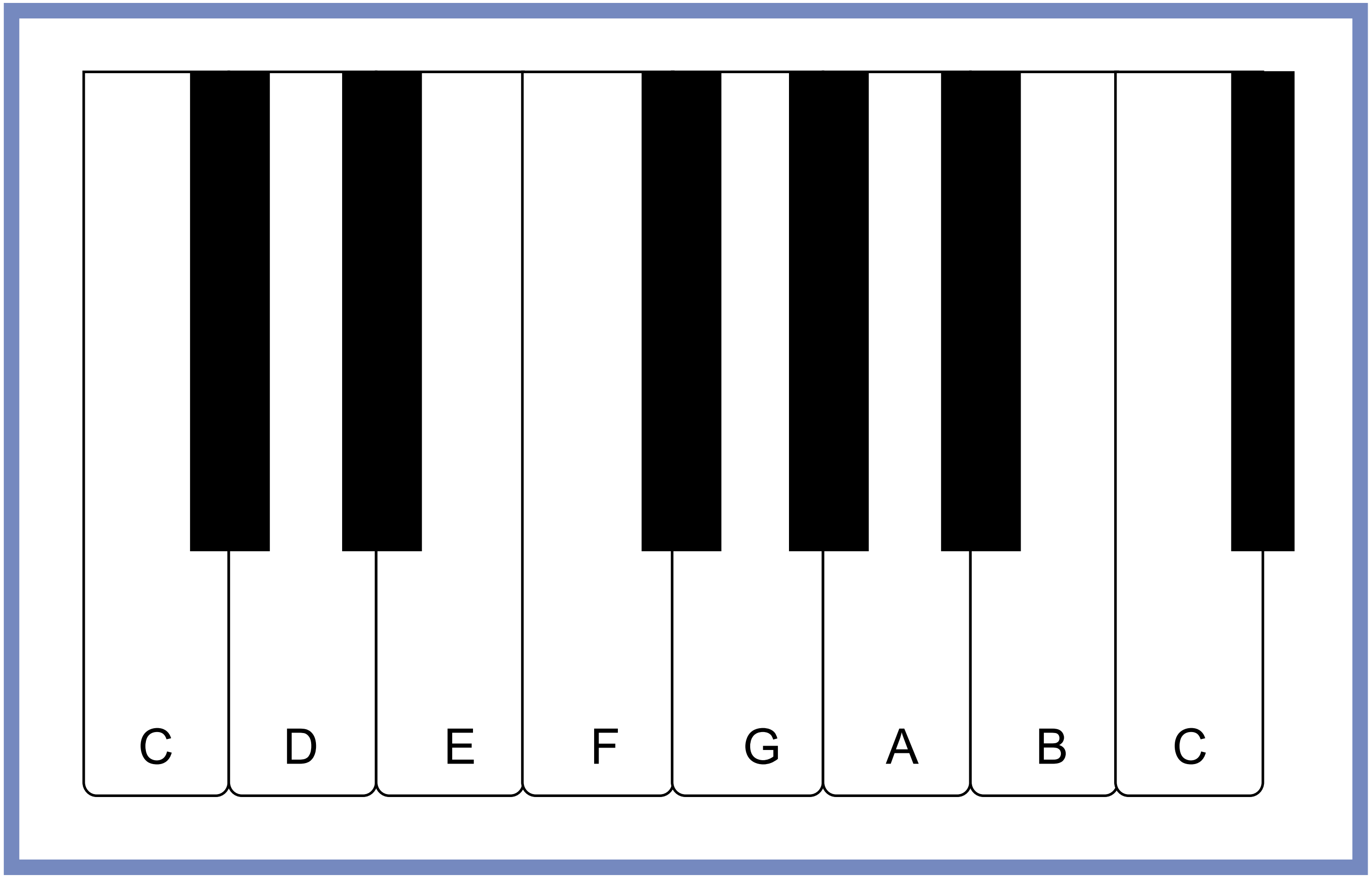
- Drawn by Robert Fludd, the **Monochord** invented by Pythagoras, showing correspondences between pitch, proportion and astral bodies. http://www.elodielauten.net/concept.html

Pythagorean & Just tuning systems



igure 10.2
ythagorean and just tuning: Musical scale construction based on simple numerical ratios
ythagorean scale notes are generated by using the consonant 3:2 ratio. Each new note is
enerated by multiplying the previous frequency by 3/2. In the top panel, the solid arrows
how the generated notes, and the dashed arrows show the octave equivalents necessary to
eep the scale notes within a single octave. As shown below the notes, the frequency ratio
etween adjacent notes is not the same across all possible pairs. Just tuning notes are
enerated using small whole number ratios in the bottom panel. Difficulties arise when
itting in extra notes. There are two possibilities shown for the second note. Other note
some sharps and flats) also cannot be defined unambiguously. The intervals beginning with
he first note of the scale and intervals beginning with different notes of the scale are shown

C-Major diatonic scale

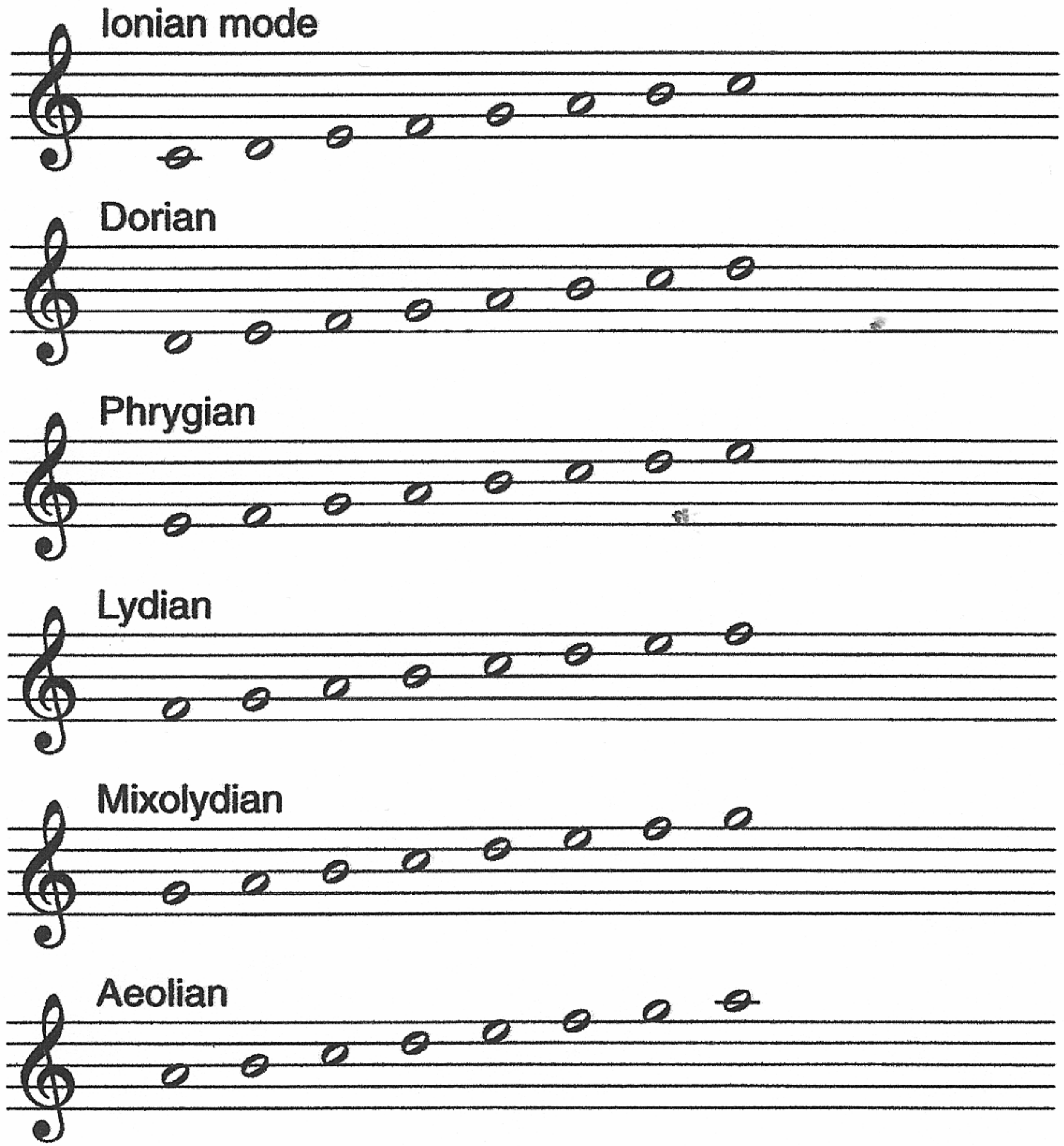


Diatonic scale

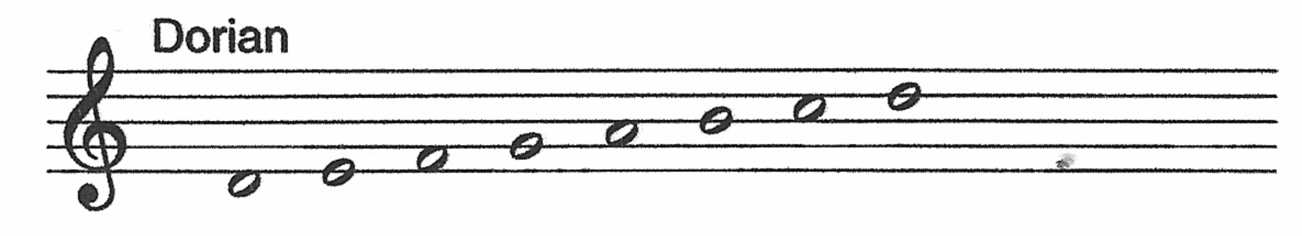
In Music theory, the diatonic major scale is a fundamental building block of the Western musical tradition. The diatonic scale is composed of two tetrachords separated by intervals of a whole tone. The pattern of intervals in semitones is as follows 2-2-1-2-2-2-1. The major scale begins on the first note and proceeds by steps to the first octave. In solfege, the syllables for each scale degree are "Do-Re-Mi-Fa-Sol-La-Ti-Do". The natural minor scale can be thought of in two ways, the first is as the relative minor of the major scale, beginning on the sixth degree of the scale and proceeding step by step through the same tetrachords to the first octave of the sixth degree. In solfege "La-Ti-Do-Re-Mi-Fa-Sol." Alternately, the natural minor can be seen as a composite of two different tetrachords of the pattern 2-1-2-2-1-2-2. In solfege "Do-Re-Mi-Fa-Sol-La-Ti-Do." All of non-folk Western harmony from the somepoint in the late Renaissance up to the late nineteenth century is based upon these two objects and the unique relationships created by this system of organizing 7 notes. It should be kept in mind that most pieces of music change key, and thus scale, but are still related to the beginning diatonic scale. The white keys on a piano correspond to the diatonic scale of C major (C-D-E-F-G-A-B-C), with the notes a whole tone apart, except for E-F and B-C, which is an interval of a semitone (half a tone). Diatonic comes from the greek "diatonikos" or "to stretch out". It is sometimes used to refer to all the modes, but is generally used only in reference to the major and minor scales.

http://www.knowledgegeek.com/item/Diatonic_Scale_272.aspx

Modes



Modes



http://www.8notes.com/articles/modes/

Lydian mode example

http://www.pathguy.com/modes.htm#phrypara

Phrygian

http://www.pathguy.com/modes.htm#phrypara

An "exotic" mode

"The Answer is Dark" is an example of one of those more exotic modes. It's in a mode of a scale that uses 3 half-step intervals, causing one interval to be an augmented second. In the chart below, the bottom line designates the type of interval between each member of the scale where: h = half step a = augmented whole step w = whole step

G# A B# C# D# E# F# G#

h a h w w h w

Listen to a MIDI file of the scale mode:

It would be in G# Mixolydian except that the A# has been lowered to A. This is sometimes called a "mixed mode" because it has characteristics of two diatonic modes.

http://www.elvenminstrel.com/tolkien/modes.htm

Circle of Fifths

Please see Figure 10.5 (b) Zuckerkandl, Victor. *The Sense of Music*. Princeton, N.J.: Princeton University Press, 1959.

Kay Gardner on scales and modes (audiocassette)

Ms. Gardner is coming from a New Age perspective on music and spirituality. Although we don't necessarily believe all she asserts, her discussion & musical demonstration of modes and scales is clear and pertinent to our concerns.

These illustrate how scales, tonal centers, and direction of melodic movement affect how we perceive music. The modes have different characters even though they all use the same 8 notes.

Please see Gardner, K. (Kay). *Sounding the Inner Landscape: Music as Medicine*. Rockport, Mass.: Element, 1997.

Modes

According to the nomenclature of medieval music theorists, who were dealing largely with unchorded plainsong, our natural major is the church "Ionian Mode" (C-D-E-F-G-A-B-C), and our natural minor is the church "Aeolian mode" (C-D-D#-F-G-G#-A#-C). I became curious about modes when I learned that "Wreck of the Edmund Fitzgerald" and "Scarborough Fair" use the old balladic scale which matches the church "Dorian Mode" (C-D-D#-F-G-A-A#-C). I used the eerie church "Mixolydian mode" (C-D-E-F-G-A-A#-C) for my intranet version of "The Pathology Blues", on our quizbank. You can also hear the church "Mixolydian mode" in "The Beat Goes On", "Luck Be a Lady Tonight", "Norwegian Wood", "Day Tripper", "Sundown" (Gordon Lightfoot), "Cats in the Cradle", "City of New Orleans" (verse but not chorus), and the theme to "Star Wars". Caedmon recordings used it for the tune for the mystical first song in Yeats's play "The Only Jealousy of Emer". The other church modes are novelties at best. Some of the old Gregorian chant "Sing my tongue..." seems to be Phrygian mode. There is some of the church "Phrygian mode" in "Fiddler on the Roof", and if the song is fully transposed into the church Phygian mode, it still sounds okay. My own attempt to write a song using the church Phrygian mode was dismal. I wrote a little song in an unabashed church "Lydian mode". The mode itself suggested the subject. Unless you only use the subdominant as a leading tone for the dominant, any melody you write in this "mode" will be unnerving -- the subdominant is equidistant from the lower and upper tonics. A correspondent pointed out that the "Lydian" mode makes up some of the "Jetsons" and "Simpsons" theme. Bartok wrote a short piece in the Lydian mode .In the Locrian mode, the dead-center position of the dominant makes this even more unmusical. A music professional told me once that no ethnomusicologist has ever documented a folk tune in what medieval theorists called the "Locrian mode". I browsed a little in Plato, Aristotle, pseudo-Plutarch's "De Musica", and of course the Oxford History of Music, and came away wondering if the medieval music theorists (Boethius, Gregory the Great, their successors) really meant the same thing as did the Greeks who named the modes. Today most people (following a scholar named Westphal) tell us that the Greek modes were indeed used as "scales" with the tonic notes being the low-pitched one, just as the church mode theorists say. This seems to be based on statements in Plato and Aristotle that the modes had distinct emotive qualities, as our major and minor scales do. Another school of thought (that of Munro) claims that for the ancients, the modes were actually keys, i.e., you could play any melody in any mode. If this is true, then the ancient Greeks had either perfect pitch or a standard pitchpipe. I think people have probably liked similar tunes in different eras. I tried to figure out how the ancient Greeks would have played some of our favorites. Ancient Greek lyres typically had seven strings. (Some Hebrew lyres must have had ten strings -- see Psalm 33.) The system of modes is also called "harmoniae", which meant "fitting" or "tuning". Greek writers on music talk about the normal tuning comprising two tetrachords, i.e., a series of four notes with the lowest and highest separated by a major fourth and sharing the center string. Pythagoras and Terpander are both credited with the idea of having the highest string be an octave of the lowest string.

Scala (Program for calculating scales)

http://www.xs4all.nl/~huygensf/scala/http://www.xs4all.nl/~huygensf/scala/

Scala is a powerful software tool for experimentation with musical tunings, such as just intonation scales, equal and historical temperaments, microtonal and macrotonal scales, and non-Western scales. It supports scale creation, editing, comparison, analysis, storage, tuning of electronic instruments, and MIDI file generation and tuning conversion. All this is integrated into a single application with a wide variety of mathematical routines and scale creation methods. Scala is ideal for the exploration of tunings and becoming familiar with the concepts involved. In addition, a very large library of scales is freely available for Scala and can be used for analysis or music creation. Great care has been taken to make Scala's functions and operations very general. The range of parameter values that commands accept is made as wide as possible. Often various forms of input are allowed. No arbitrary restrictions are made. Scales are stored in a flexible format . Intervals can be entered and saved as either ratios or in cents and be intermixed within a single scale. Constructing scales from scratch is one of Scala's strengths. The kinds of scales that can be made with Scala include: equal temperaments, Pythagorean (meantone) scales, Euler-Fokker genera ,Fokker periodicity blocks , harmonic scales, Partch diamonds and Wilson combination product sets. In addition, a set of command files is included to build other kinds of scales such as triadic scales, circular mirrorings, circulating temperaments, etc., and to serve as examples.

Three tuning systems

Pythagorean, Just, and Equal Temperament Tuning Systems

Interval name	Solfeggio	Letter notation	Pythagorean tuning (PT) Numerical origin	PT Frequency ratio	PT Cents	Just intonation (JI) Numerical origin	JI Frequency ratio	JI Cents	Equal temperament (ET) Frequency ratio	ET Cents
Unison	DO	C	1:1	1.000	0.0	1:1	1.000	0.0	1.000	0
Minor second		D♭	$2^8:3^5$	1.053	90.2	16:15	1.067		1.059	100
		C♯	$3^7:2^{11}$	1.068	113.7	16:15	1.067	111.7	1.059	100
Major second	RE	D	$3^2:2^3$	1.125	203.9	10:9	1.111	182.4	1.122	200
						9:8	1.125	203.9		
Minor third		E♭	$2^5:3^3$	1.186	294.1	6:5	1.200	315.6	1.189	300
		D♯	$3^9:2^{14}$	1.201	317.6	6:5	1.200	315.6	1.189	300
Major third	MI	E	$3^4:2^6$	1.265	407.8	5:4	1.250	386.3	1.260	400
Fourth	FA	F	$2^2:3$	1.333	498.1	4:3	1.333	498.1	1.335	500
Tritone		G♭	$2^{10}:3^6$	1.407	588.3	45:32	1.406	590.2	1.414	600
		F♯	$3^6:2^9$	1.424	611.7	64:45	1.422	609.8	1.414	600
Fifth	SO	G	3:2	1.500	702.0	3:2	1.500	702.0	1.498	700
Minor sixth		A♭	$2^7:3^4$	1.580	792.2	8:5	1.600	813.7	1.587	800
		G♯	$3^8:2^{12}$	1.602	815.6	8:5	1.600	813.7	1.587	800
Major sixth	LA	A	$3^3:2^4$	1.688	905.0	5:3	1.667	884.4	1.682	900
Minor seventh						7:4	1.750	968.8		
		B♭	$2^4:3^2$	1.788	996.1	16:9	1.777	996.1	1.782	1000
		A♯	$3^{10}:2^{15}$	1.802	1019.1	9:5	1.800	1017.6	1.782	1000
Major seventh	TI	B	$3^5:2^7$	1.900	1109.8	15:8	1.875	1088.3	1.888	1100
Octave	DO	C	2:1	2.000	1200.0	2:1	2.000	1200.0	2.000	1200

SOURCE: Burns and Ward 1982 and Martin 1962 by permission of publisher.

Just Intonation Network

http://www.justintonation.net/

What is JUST INTONATION? JUST INTONATION

is any system of tuning in which all of the intervals can be represented by ratios of whole numbers, with a strongly-implied preference for the smallest numbers compatible with a given musical purpose. Unfortunately this definition, while accurate, doesn't convey much to those who aren't already familiar with the art and science of tuning. The aesthetic experience of just intervals and chords, however, is unmistakable. The simple-ratio intervals upon which Just Intonation is based are the fundamental constituents of melody and harmony. They are what the human auditory system recognizes as consonance, if it ever has the opportunity to hear them in a musical context. The significance of whole-number ratios has been recognized by musicians around the world for at least 5000 years. Just Intonation is not a particular scale, nor is it tied to any particular musical style. It is, rather, a set of principles which can be used to create a virtually infinite variety of intervals, scales, and chords which are applicable to any style of tonal music (or even, if you wish, to atonal styles). Just Intonation is not, however, simply a tool for improving the consonance of existing musics; ultimately, it is a method for understanding and navigating through the boundless reaches of the pitch continuum—a method that transcends the musical practices of any particular culture. Just Intonation has depth and breadth. Its fundamental principles are relatively simple but its ramifications are vast. At present, Just Intonation remains largely unexplored. A few pioneering composers and theorists have sketched in some of its most striking features, but the map still contains many blank spaces where the adventuresome composer many venture in hopes of discovering new musical treasures. In light of its numerous virtues, why isn't Just Intonation currently in general use? Like so many of our peculiar customs, it is largely an accident of history. During the 16th, 17th, and 18th centuries, when Western harmonic music and keyboard instruments were co-evolving, instrument technologies were inadequate to the task of developing affordable, playable instruments that could accommodate the intricacies of Just Intonation. As a result, various compromises or *temperaments* were attempted. Twelve-tone equal temperament was ultimately adopted because it provided the greatest facility for transposition and modulation with the smallest number of tones, and because it made all of the intervals of a given type equally out of tune, thus avoiding the contrast between in-tune and out-of-tune intervals that characterized some earlier temperaments.

Just Intonation Network II

http://www.justintonation.net/

Equal temperament was not adopted because it sounded better (it didn't then, and it still doesn't, despite 150 years of cultural conditioning) or because composers and theorists were unaware of Just Intonation. The adoption of twelve-tone equal temperament was strictly a matter of expediency. Equal temperament allowed eighteenth- and nineteenth-century composers to explore increasingly complex harmonies and abstruse modulations, but this benefit was short-lived. By the beginning of this century, all of the meaningful harmonic combinations in the equally-tempered scale had been thoroughly explored and exploited, and many composers believed that consonance, tonality, and even pitch had been exhausted as organizing principles. What was really exhausted was merely the limited resources of the tempered scale. By substituting 12 equally-spaced tones for a universe of subtle intervallic relationships, the composers and theorists of the 18th and 19th centuries effectively painted western music into a corner from which it has not yet succeeded in extricating itself. Fortunately a few visionary composers, most notably Harry Partch and Lou Harrison, rediscovered the source of truly viable new musical resources. These farsighted musicians recognized that in the acoustically pure intervals of Just Intonation, and in the diverse traditions of World music were to be found sufficient material to fruitfully occupy generations of composers. Unfortunately, until recently composing and performing sophisticated music in Just Intonation presented such difficulties that only the most dedicated enthusiasts were likely to invest the required time and effort. However, due to the recent appearance of affordable electronic instruments with programmable tuning capabilities, it is now possible for almost any musician to explore Just Intonation without first making a major commitment. The technical barriers having been largely removed, the only thing lacking for a widespread growth in the use of Just Intonation is an increased awareness of intonational principles and their musical applications on the part of our more adventuresome musicians. It is to encourage this development that the Just Intonation Network was founded.

Just intonation -- conclusions

- Although differences between just and equally-tempered tunings might not be discriminable when notes are presented sequentially (as for measuring JNDs),
- these differences can become apparent when notes are sounded together.

- The differences are somewhat subtle, but are most obvious when the notes are sustained harmonic complexes, e.g. organ-like.

Microtonal music

- http://www-math.cudenver.edu/~jstarret/microtone.html
- **Most of the music we hear in based on a system called 12 tone equal temperament (or 12TET for short), where the octave is divided into 12 equal parts. Microtonal music is generally defined as any music that is not 12TET. Some folks base their music on the harmonic series, some divide the octave into 19 or 31 equal parts, some divide the octave into 43 unequal parts, some don't divide the octave at all.... There are an infinite number of ways to choose your tonal resources.**

see also http://www.corporeal.com/cm_main.html

Bill Sethares:

1. Relations between tuning systems & dissonance:

For inharmonic instruments, there are situations where just tunings sound more dissonant.

2. Experiments with alternate scales and tunings -- 10 TET music. **"Ten Fingers: If God had intended us to play in ten tones per octave, he would have given us ten fingers."**

Please see Sethares, William A. *Tuning, Timbre, Spectrum, Scale*. New York: Springer, 2004.

Consonance perception: different conceptions

- Psychophysics of consonance
  - Meanings of "consonance" and "dissonance"
  - Euphonious, "pleasant" vs. jarring, unpleasant
  - Smooth, well-defined, unified vs. rough, buzzy, unsettled
  - see Sethares (1999), Ch. 4 for more depth
  - Tenney (1988) book, History of 'Consonance' and 'Dissonance'
    - melodic: relatedness of pitches sounded successively
    - polyphonic: interval between two simultaneous tones
      - pleasant vs unpleasant combinations; fusion of tones
    - contrapuntal: from music theory voice leading techniques(4th diss)
    - functional: relationship of individual tones to root or tonic
    - sensory: roughness and presence of beats

Consonance perception: theories

- Theories consonance
- Cultural conditioning
- Small Is beautiful, simple
  - small integer ratios (1:1, 2:1, 3:2, 4:3, 5:4)
  - simpler, smoother waveforms
  - less complex interspike interval patterns
- Fusion of tones
  - consonance related to number of competing pitches, unity of perception (Stumpf)
- Roughness: interactions of nearby tones in filters (Helmholtz, cochlear & neural filtering)

Upcoming topics

- **Wednesday, Oct. 22** Harmony: Chords and keys
- **Monday, Oct. 27** Melody
- **Wednesday, Oct. 29** Rhythm
- **Monday, Nov. 3** **Tramo:** Music and the cortex.
- **Wednesday, Nov. 5** Auditory scene analysis
- **Monday, Nov. 10** Time perception
- **Wednesday, Nov. 12** Emotion and meaning in music
- Psychological theories of musical preference
- **Monday, Nov. 17** **Bharucha:** Music and the brain
- **Wednesday, Nov. 19** Music, speech, and language
- **Monday, Nov. 24** Development and plasticity

Reading/assignment for next meeting

- **Wednesday, Oct. 22**
- **Harmony: Chords and keys**
  - Perception of chords, pitch multiplicity (Parncutt, Terhardt), higher order structure of pitch space (Shepard, Krumhansl), fundamental bass, keys, major-minor and resolved/unresolved chords, tonality induction, tonal schemas/key relations, computational models, neural correlates of tonal relations and expectations (fMRI, ERP)
- **Reading:**
- Handel, Chapter 10, "Grammars of music and language"
- Aello, Chapters 8 & 9, Butler & Brown, "Mental representation of tonality in music" Bharucha, "Tonality & Expectation"

Tonal consonance: interactions of tones

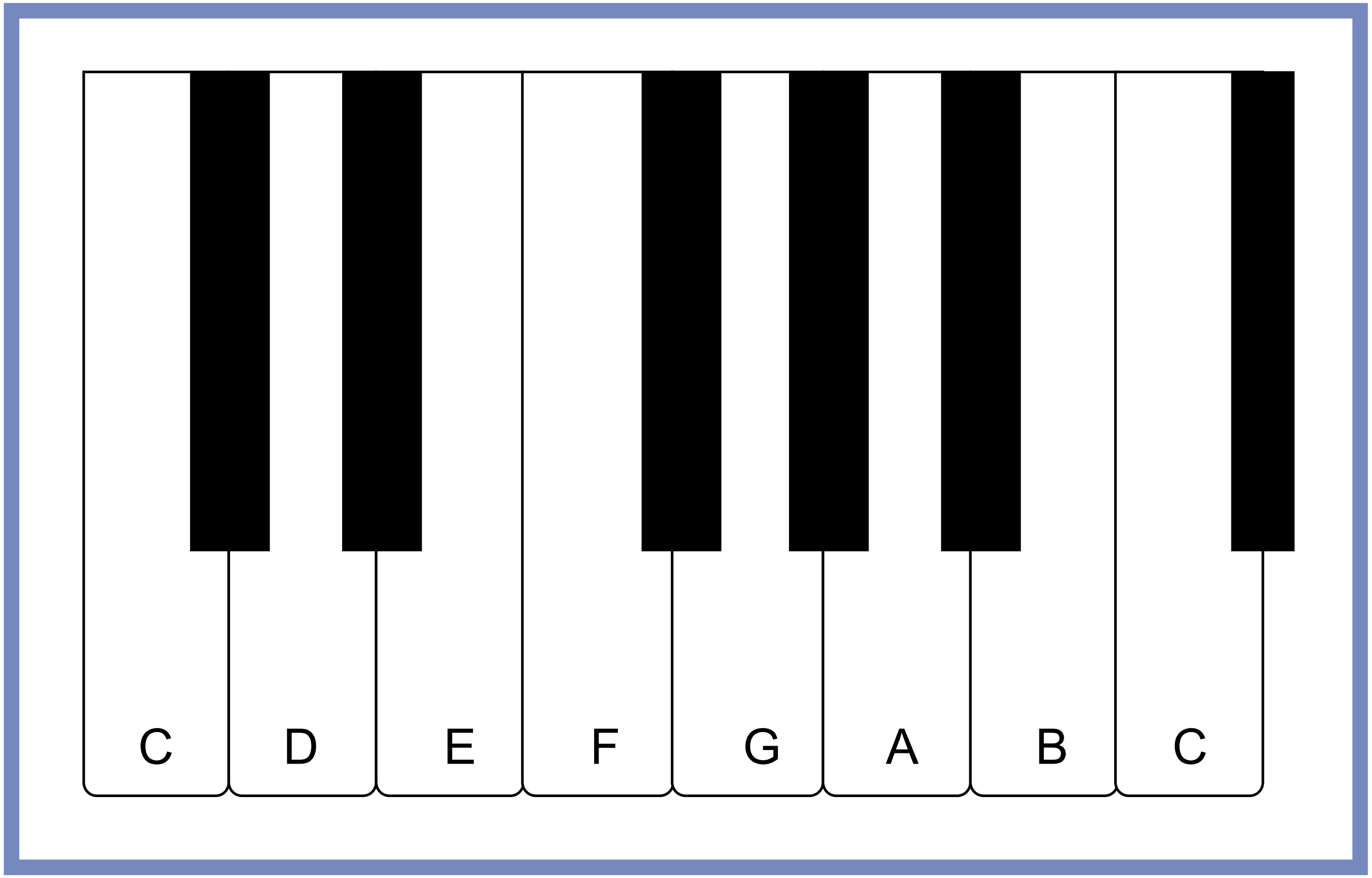
- **Pythagorean experiments**
- **Beating, roughness, fusion**
- **Psychophysics of consonance**
  - **Meanings of "consonance" and "dissonance"**
  - **Euphonious, "pleasant" vs. jarring, unpleasant**
  - **Smooth, well-defined, unified vs. rough, buzzy, unsettled**
- **Neural correlates of roughness (cochlear filtering)**
  - **Periodicities below the range of the pitch mechanism**
  - **Population-wide fluctuations in discharge rates**
- **Neural correlates of tonal fusion (pitch)**
- **Consonance in music**
  - **Tuning systems and scales**
  - **Instability-Stability (tension-resolution)**

Pythagoras

Pythagorean ratios

Please see Figure 2-5 and 2-6 of Pierce, John R. *The Science of Musical Sound*. Revised ed. New York: W. H. Freeman, 1992.

C-Major diatonic scale



Consonant intervals

In most tonal contexts, these intervals are perceived as more consonant. However there can be contexts where some of these intervals can be dissonant.

CONSONANT INTERVALS

Name of Interval	Octave	Fifth	Fourth	Major third	Minor third	Major sixth	Minor sixth
Notes (in Key of C Major)	C-C	C-G	C-F	C-E	E-G	C-A	E-C
Ideal Frequency Ratio	2	3/2	4/3	5/4	6/5	5/3	8/5
Number of Semitones	12	7	5	4	3	9	8

Sethares' exposition of sensory consonance

Please see Sethares, William A. *Tuning, Timbre, Spectrum, Scale*. New York: Springer, 2004.

From beating to roughness to tonal separation

Please see Sethares, William A. *Tuning, Timbre, Spectrum, Scale*. London, New York: Springer, 1998.

Consonance perception: different conceptions

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    - functional: relationship of individual tones to root or tonic
    - sensory: roughness and presence of beats

Consonance perception: theories

- Theories of consonance
- Terhardt, Helmholtz: sensory (peripheral beating) & cognitive (expectations, context)
- Cultural conditioning
- Small Is beautiful, simple
  - small integer ratios (1:1, 2:1, 3:2, 4:3, 5:4)
  - simpler, smoother waveforms
  - less complex interspike interval patterns
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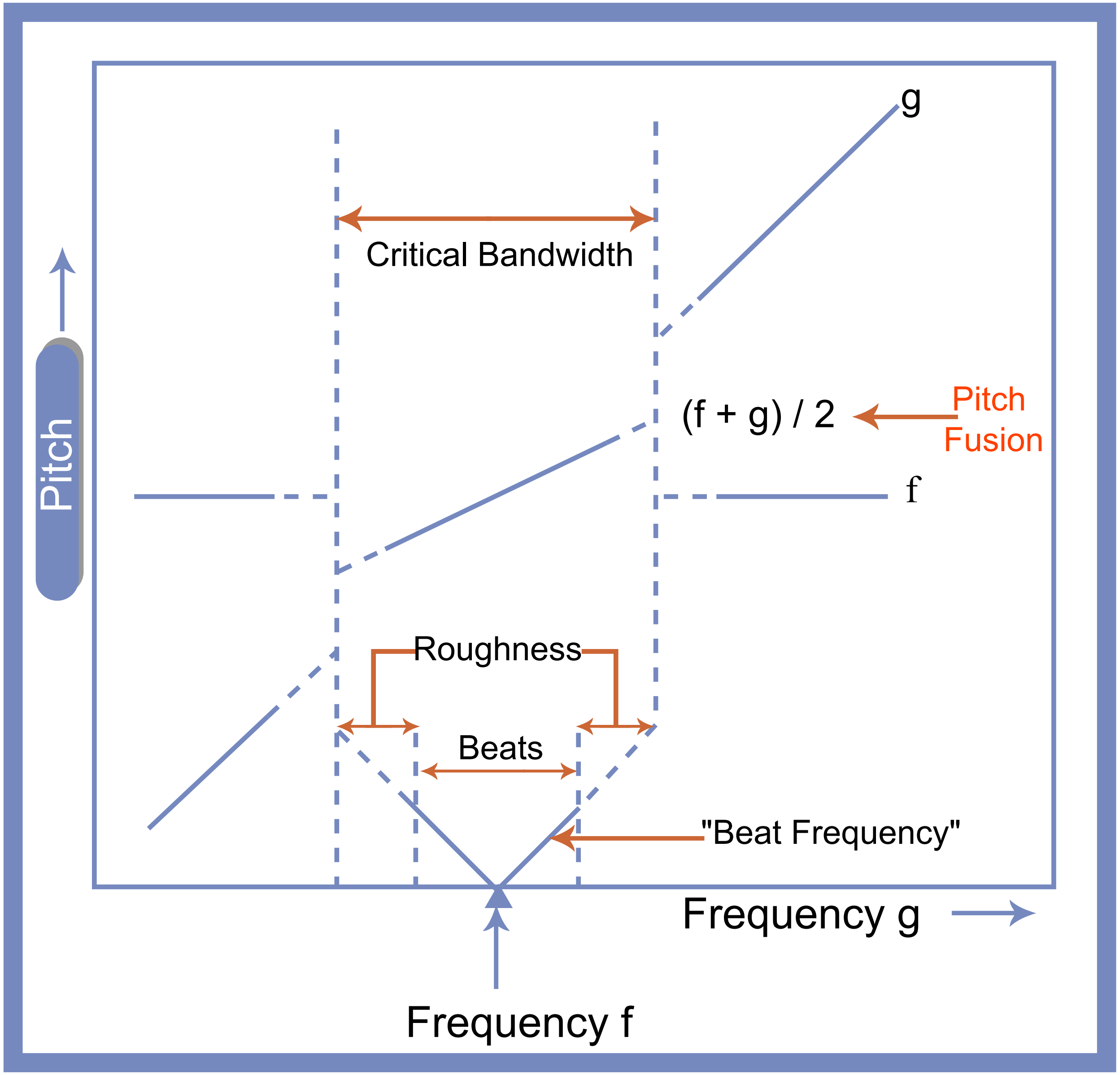
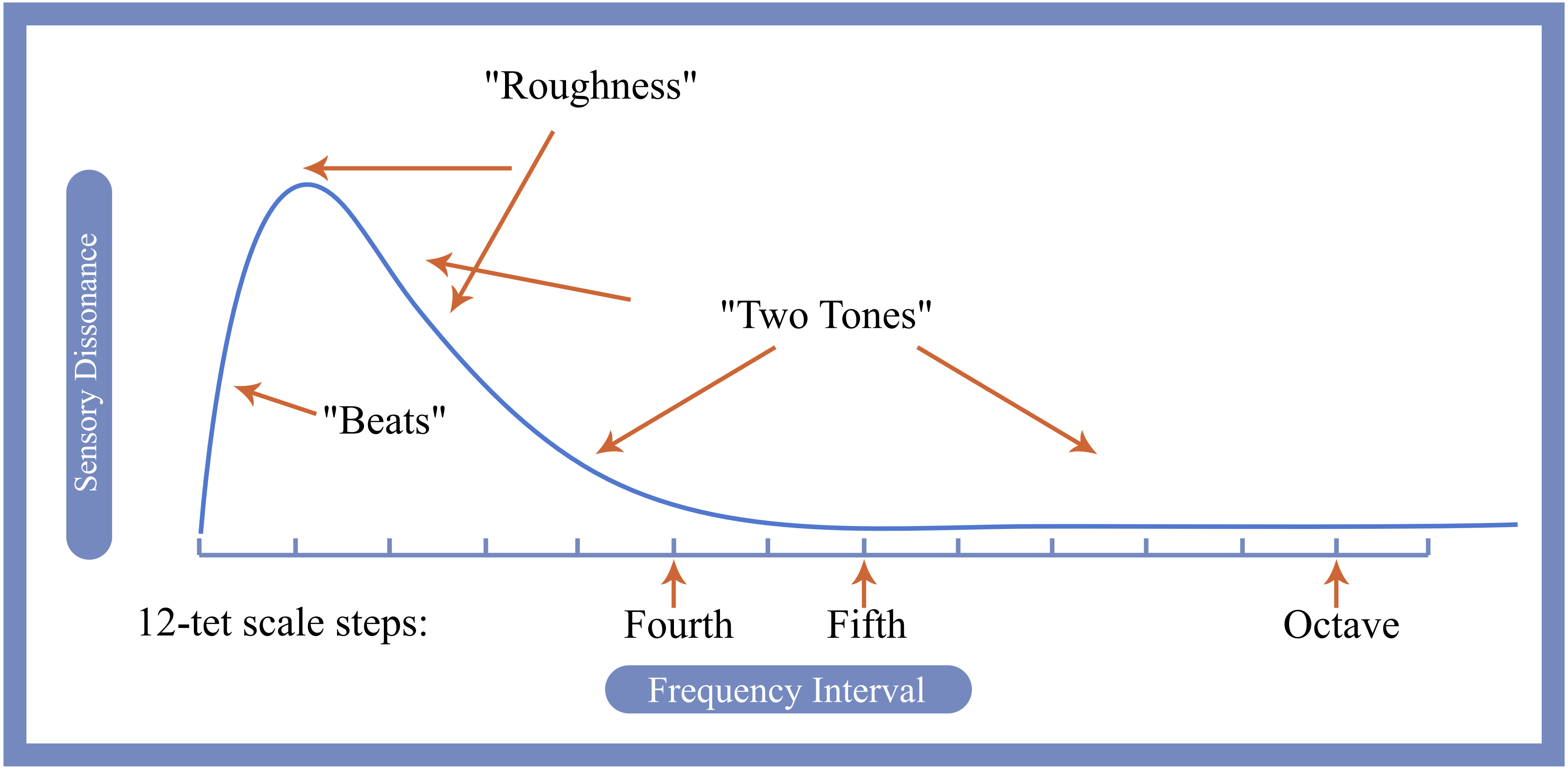
Tonal interactions



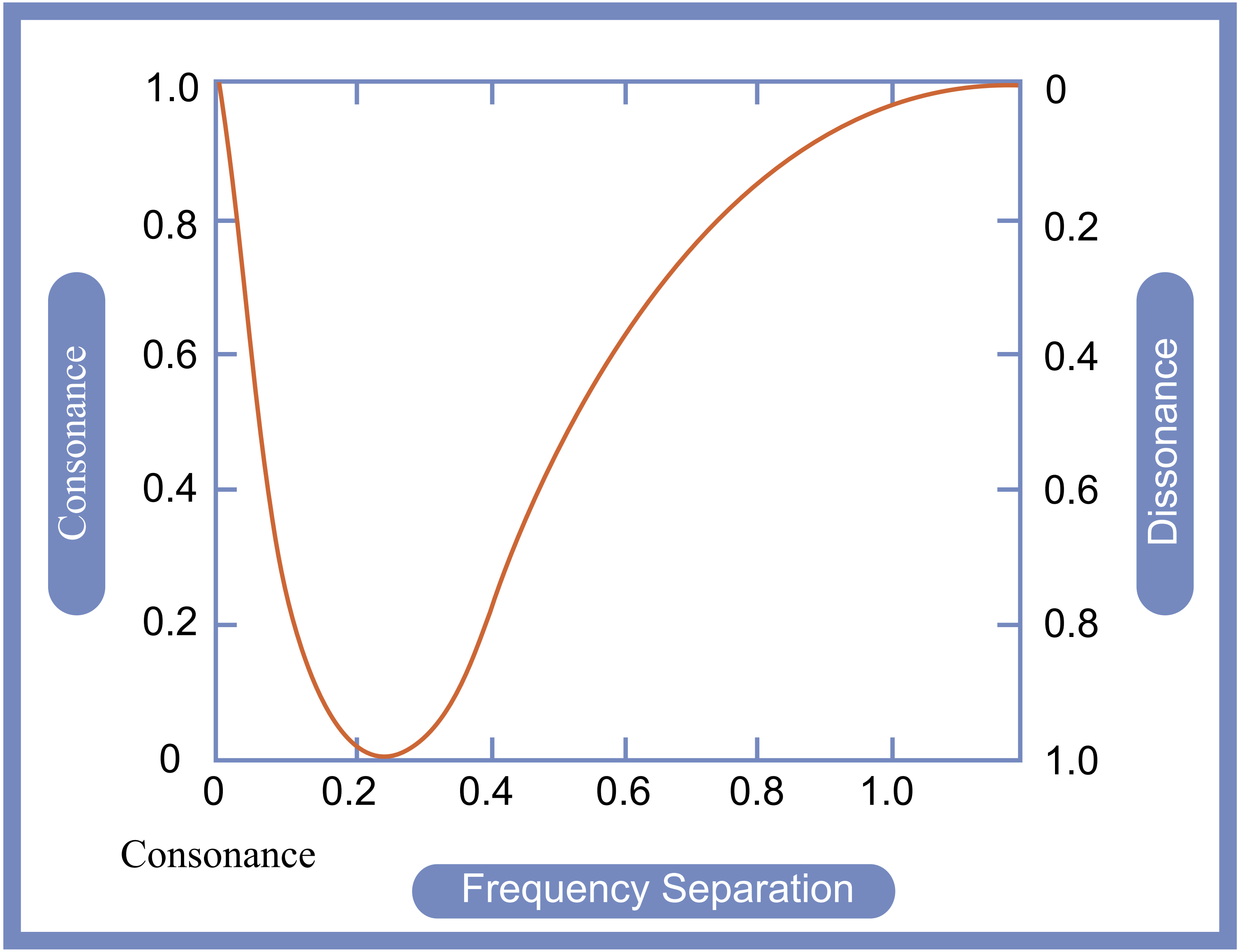
Spectral fusion

Please see Sethares, William A. *Tuning, Timbre, Spectrum, Scale*. London, New York: Springer, 1998.

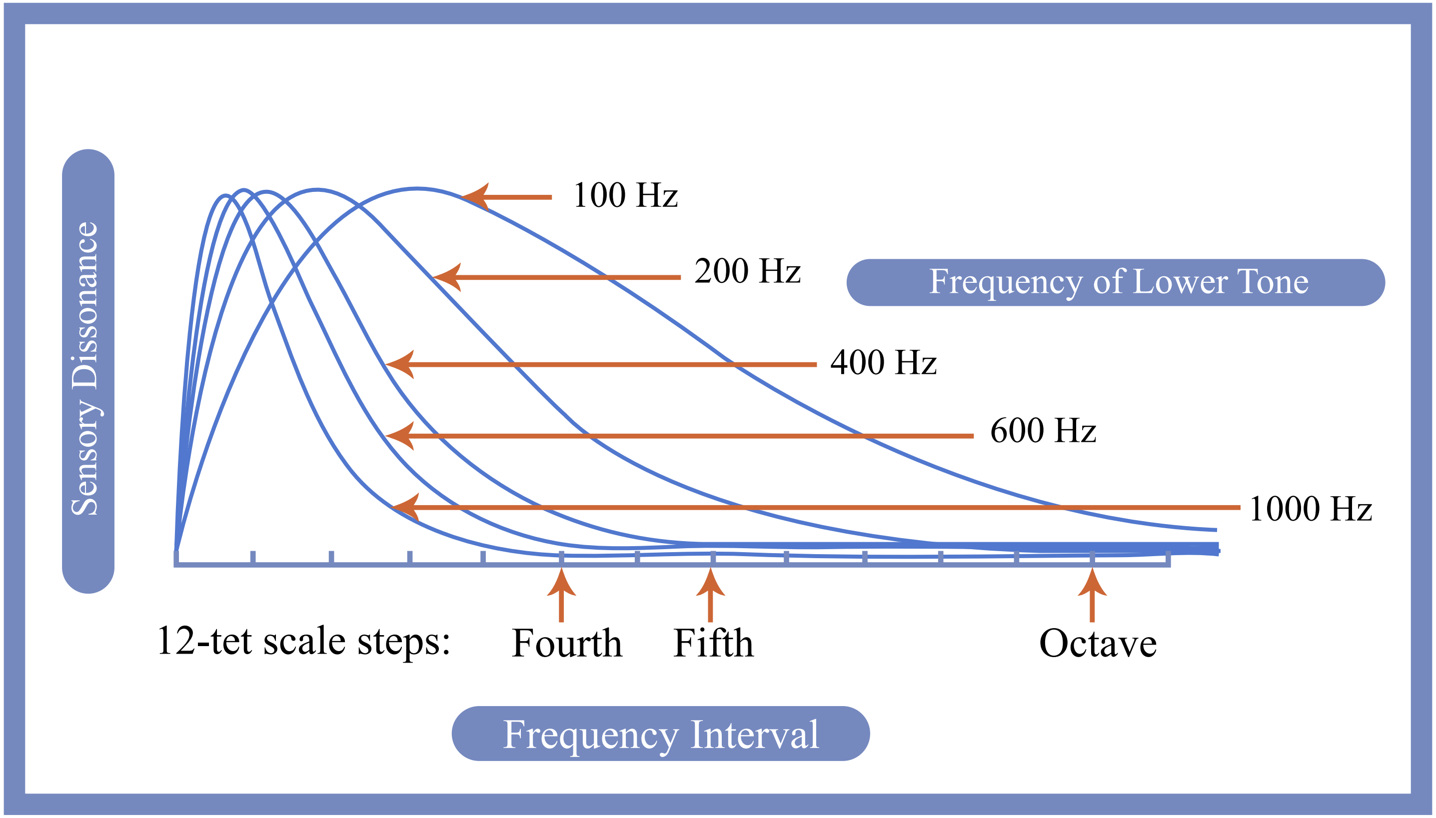
Sensory dissonance (roughness)



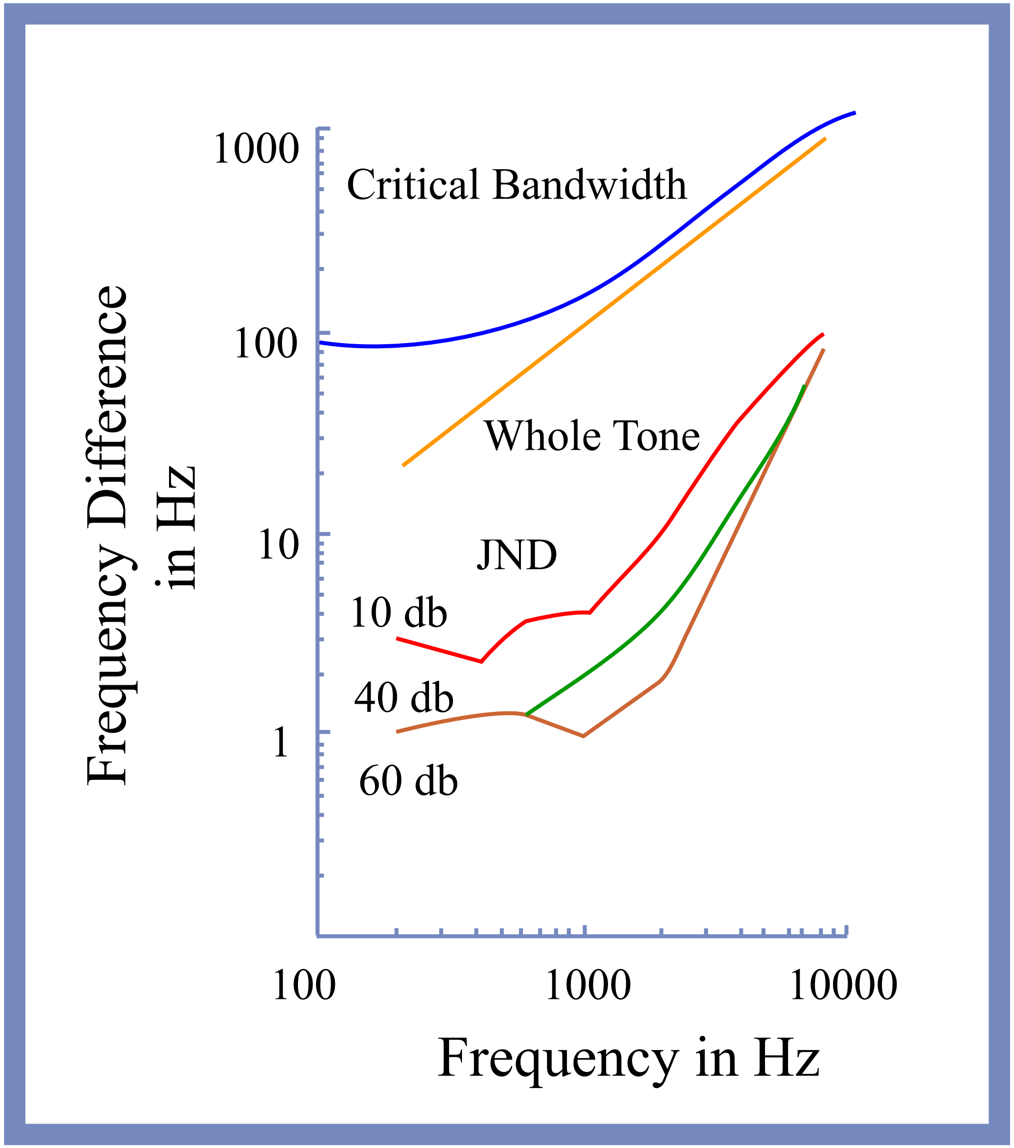
Plomp & Levelt (1965) Dissonance of pure tone dyads



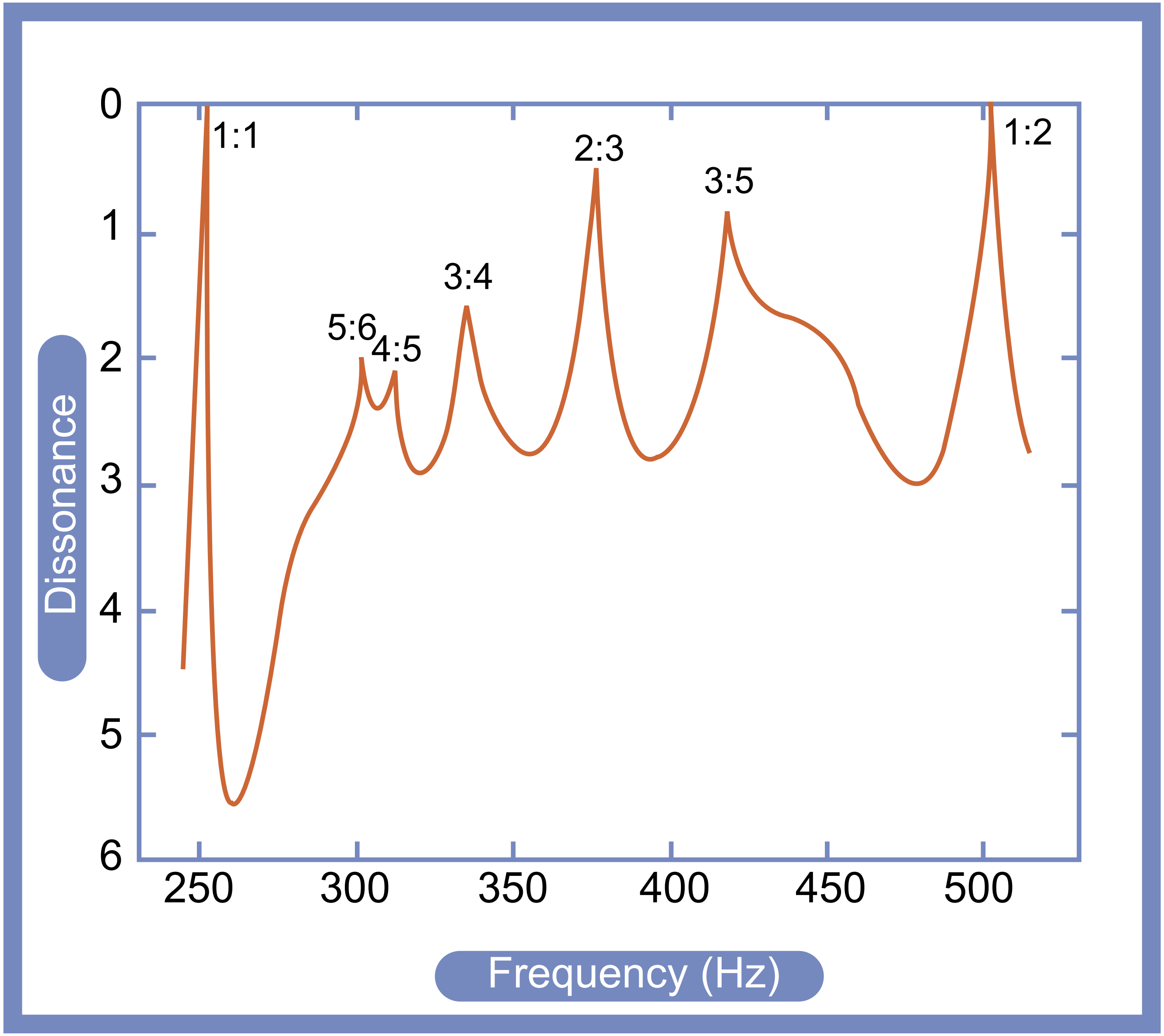
Roughness of musical intervals as a function of frequency

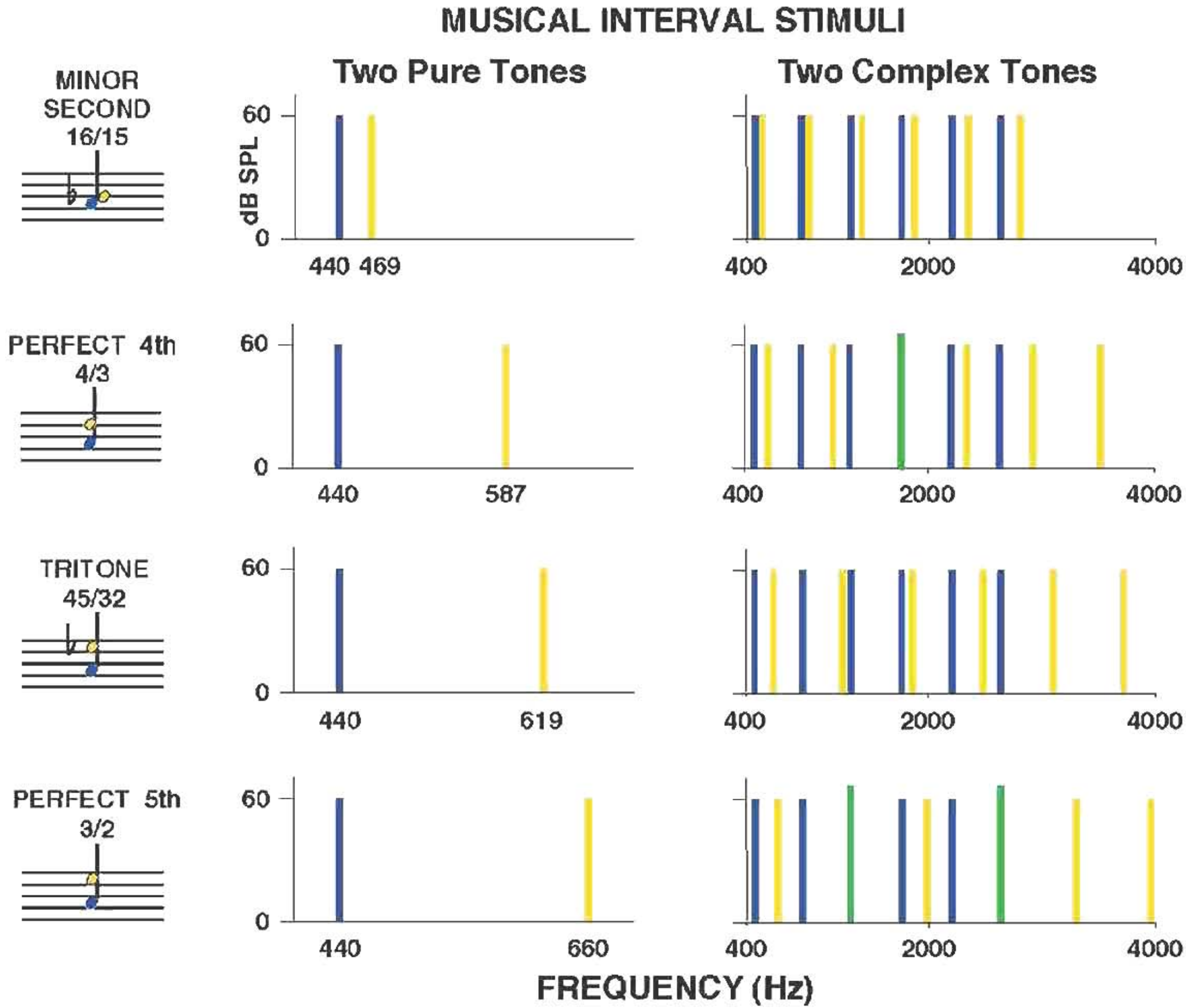


Frequency discrimination is much finer than tonal fusion



Predicted consonance of harmonic complexes (n=1-6)





MUSICAL INTERVAL STIMULI
Two Pure Tones
Two Complex Tones
MINOR SECOND
16/15
PERFECT 4th
4/3
TRITONE
45/32
PERFECT 5th
3/2
dB SPL
60
0
440
469
587
619
660
400
2000
4000
FREQUENCY (Hz)

Beating of harmonics and corresponding flucttutations in neural discharge rates

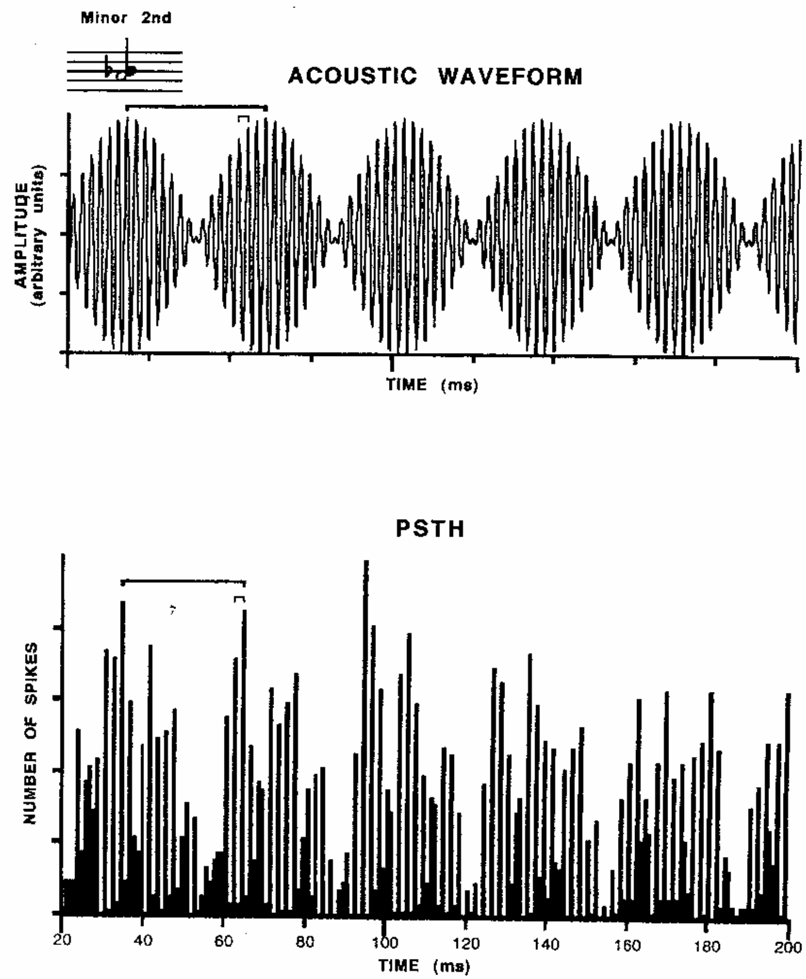


FIGURE 5. (*Top*) Acoustic waveform of a minor second composed of two pure tones with the root at A_4. *Thick bars* show the period of envelope fluctuations that render the minor second rough ($P = 1/\Delta F = 34.1$ ms). *Thin bars* show the period of fluctuations under the envelope that corresponds to the mean frequency of the tones and the pitch of the interval ($P = 2.20$ ms). (*Bottom*) Poststimulus time histogram (PSTH) showing the number of spikes fired by a single auditory nerve fiber during the steady state portion of its response to the minor second. Note that the global and local fluctuations in firing rate mirror those seen in the acoustic waveform of the minor second. This fiber was sensitive to frequencies at both the root and the interval at 60 dB SPL. Bin width = 1 ms. Number of stimulus repetitions = 100.

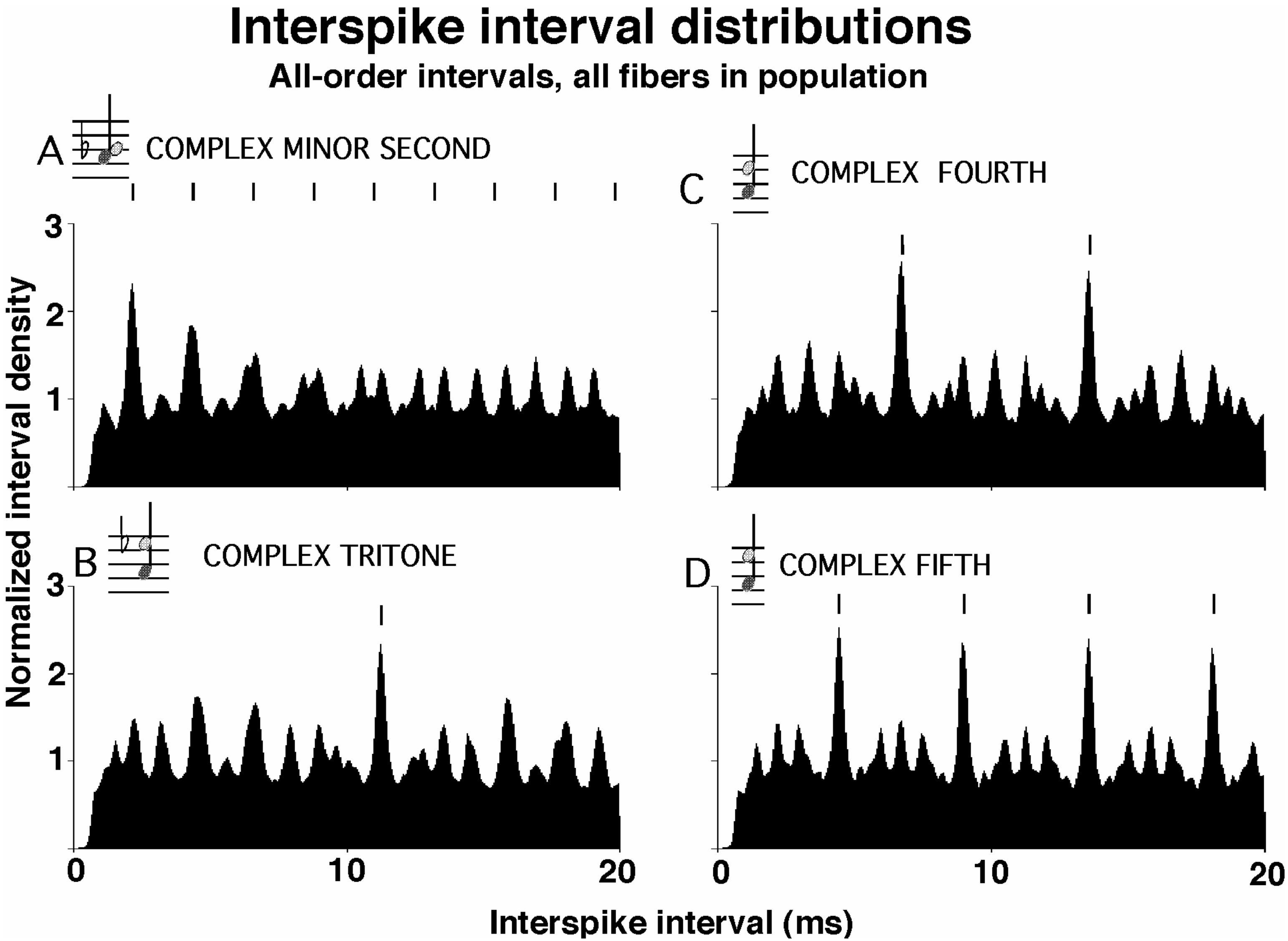
Neural coding of roughness

Discharge rate fluctuations in neuronal ensembles in the 20-120 Hz range encode beatings of nearby harmonics

These fluctuations exist in ensembles of auditory nerve fibers (CF band) and across the whole AN population.

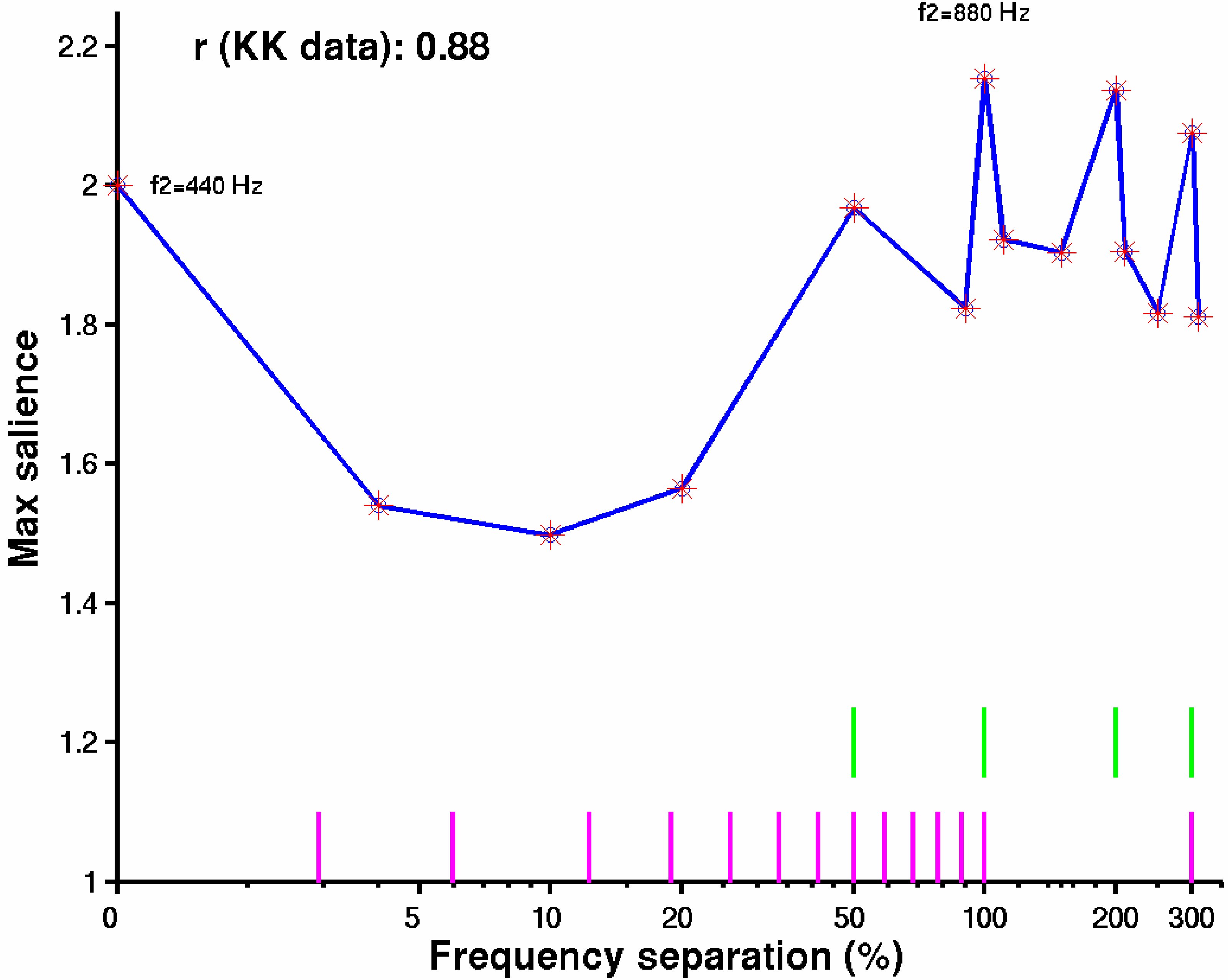
They are seen at the level of the midbrain (IC) -- work by McKinney, Delgutte, & Tramo

Not clear whether it is the rate fluctutations or existence of low periodicities below the pitch range that cause the roughness quality per se

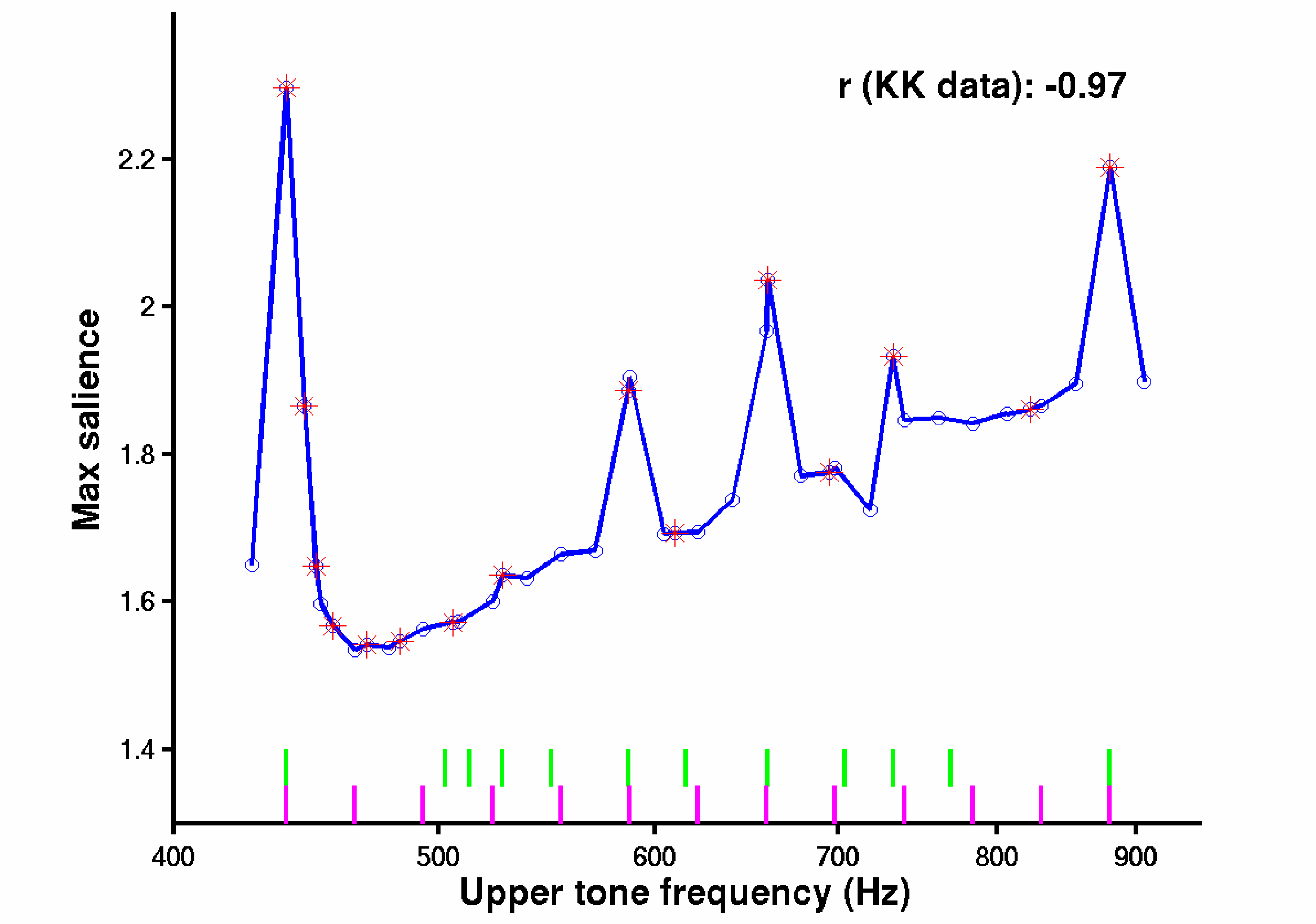


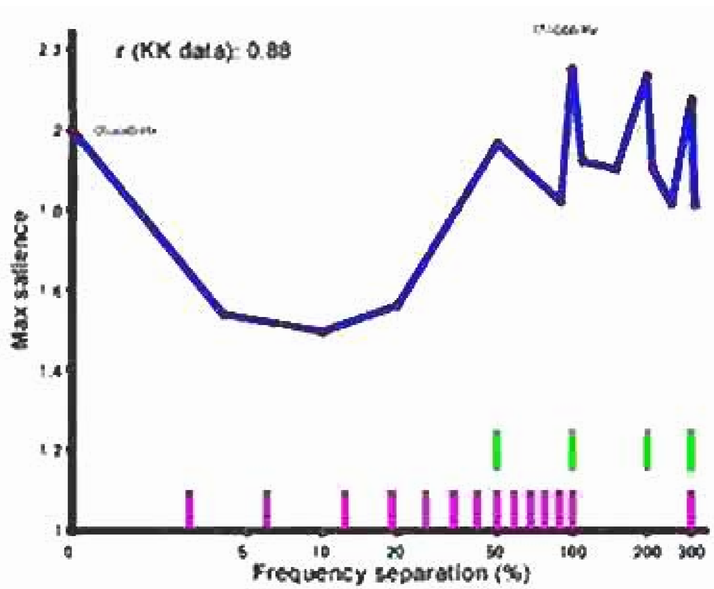
Tramo, M. J., P. A. Cariani, B. Delgutte, and L. D. Braida. "Neurobiological Foundations for the Theory of Harmony in Western Tonal Music." *Ann N Y Acad Sci* 930 (2001): 92-116.

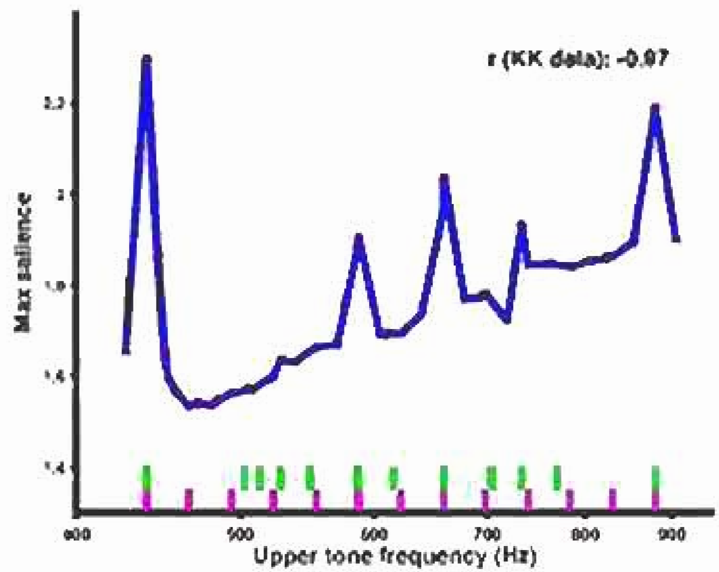
Pure tone dyads



Complex tone dyads




r (KK data): 0.88
Max salience
Frequency separation (%)


r (KK data): -0.97
Max salience
Upper tone frequency (Hz)

Neural coding of pitch fusion

Covaries with roughness models; many parallels

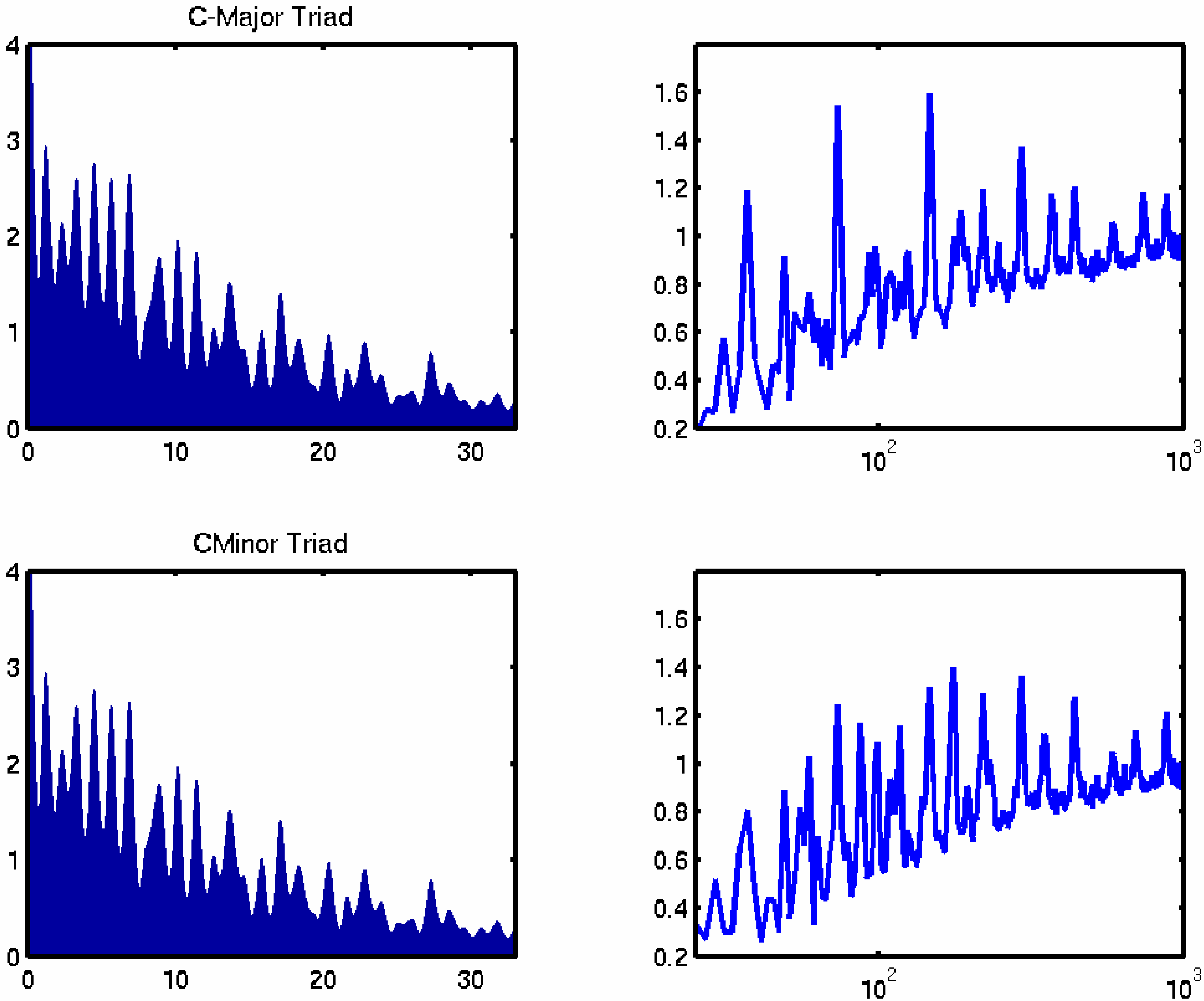
Explains consonance data

Responsible interval information probably exists at least up to the level of the midbrain (IC) -- work by Greenberg (FFR)

Interval models parallel spectral pattern approaches (e.g. Parncutt)

Pitch competition and stability leads to a theory of tonal stability and higher levels of tension-relaxation.

Pitch-stability of major and minor triads



Reading/assignment for next meetings

- **No class this Thursday**
- **Tuesday, March 9** (Tramo) Music and the cerebral cortex. Overview of functional role of cortex in music perception & cognition. Imaging and lesion studies. Hemispheric asymmetries.

Reading: Tramo: Music of the Hemispheres and Tramo et al on consonance

- **Thursday, March 11** (Cariani)
- Presentation and discussion of term projects
- Scales and tuning systems

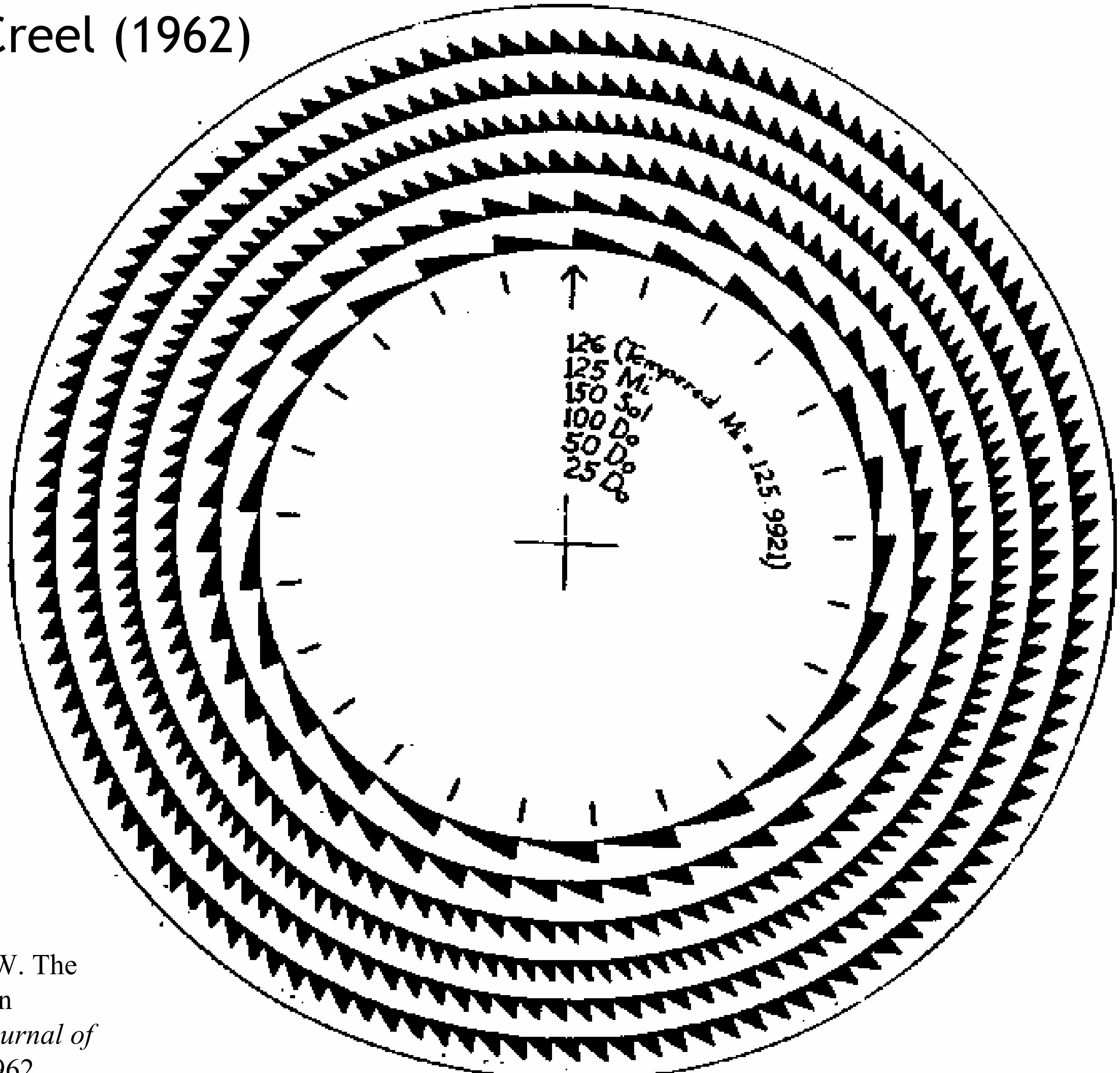
History, basic psychophysics, scales and tuning systems, role in music theory. Relations between auditory and cultural factors

Reading: Deutsch, Burns chapter on intervals & scales

Boomsliter & Creel (1962)

Long temporal pattern hypothesis for pitch, harmony, rhythm

Used Licklider's model



Boomsliter P and Creel W. The long pattern hypothesis in harmony and hearing. *Journal of Music Theory* 5: 2-31, 1962.