Pitch

Patel: Chapter 1a

Introduction

- Music and language: Sound systems that every child learns in a culture.
- Pitch (primary in music), timbre (primary in language).
- Particulate systems.
  - a set of discrete elements of little inherent meaning (tones, phonemes) are combined to form structures with a great diversity of meanings.

Introduction: cont.

- Calls of some animals are holistic, sounds are not recombined to form new meanings.
  - Vervet monkeys: leopard call, snake call
- Whale and bird songs are structured sequences of discrete elements, but they don't show diversity of meanings.

Introduction: cont.

- DNA is a particulate system, but the components are fixed.
  - In language and music the components vary physically from token to token and in context.
- The mapping between sounds and categories varies in different native languages or musics.
- The components are psychological entities derived from a mental framework of learned sound categories.

Pitch contrasts in music

- Music: "sound organized in time, intended for, or perceived as, aesthetic experience."
- Pitch: "that property of a sound that enables it to be ordered on a scale going from low to high."
- Physical dimension is frequency, measured in hertz (cycles per second).

Pitch contrasts in music: cont.

- Pythagorus (570-495 BC):
  - On a monochord (instrument), pluck a string 1/2 as long (2:1 ratio) and the sound is an octave higher; the string vibrates at twice the frequency of the original.
  - pluck a string 2/3 as long (3:2 ratio) and the interval is a perfect fifth
  - Pluck a string 3/4 as long (4:3 ratio), and the interval is a perfect fourth.
  - Pluck a string that is 4/5 as long (5:4 ratio), and the interval is a major third.

Pitch contrasts in music: cont.

- Octave equivalence
  - Pitches separated by an octave are heard as the same pitch, and are given the same name, referred to as the pitches' *pitch class* or *chroma*, e.g. C.
  - Men and women sing the "same tune" an octave apart.
  - Infants and monkeys treat octave transpositions as more similar than other transpositions.
  - This aspect of music reflects the neurophysiology of the auditory system.

Pitch contrasts in music: cont

- Pitch helix
  - Perceived similarity of pitches is governed by proximity in terms of pitch height, and also by octave identity.
- Individual pitches can be combined to create new sonic entities (intervals, chords) that have distinctive perceptual qualities.
- The auditory system is skilled at separating sound sources based on their pitch, but not their amplitude, resulting in musical systems based on pitch, not loudness.

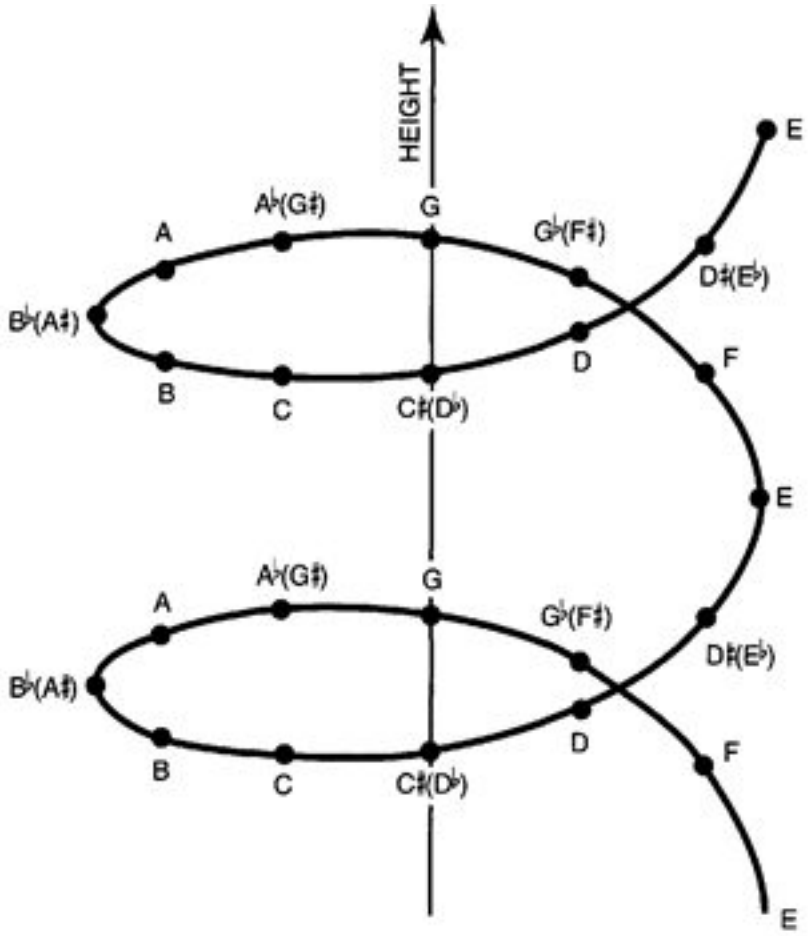
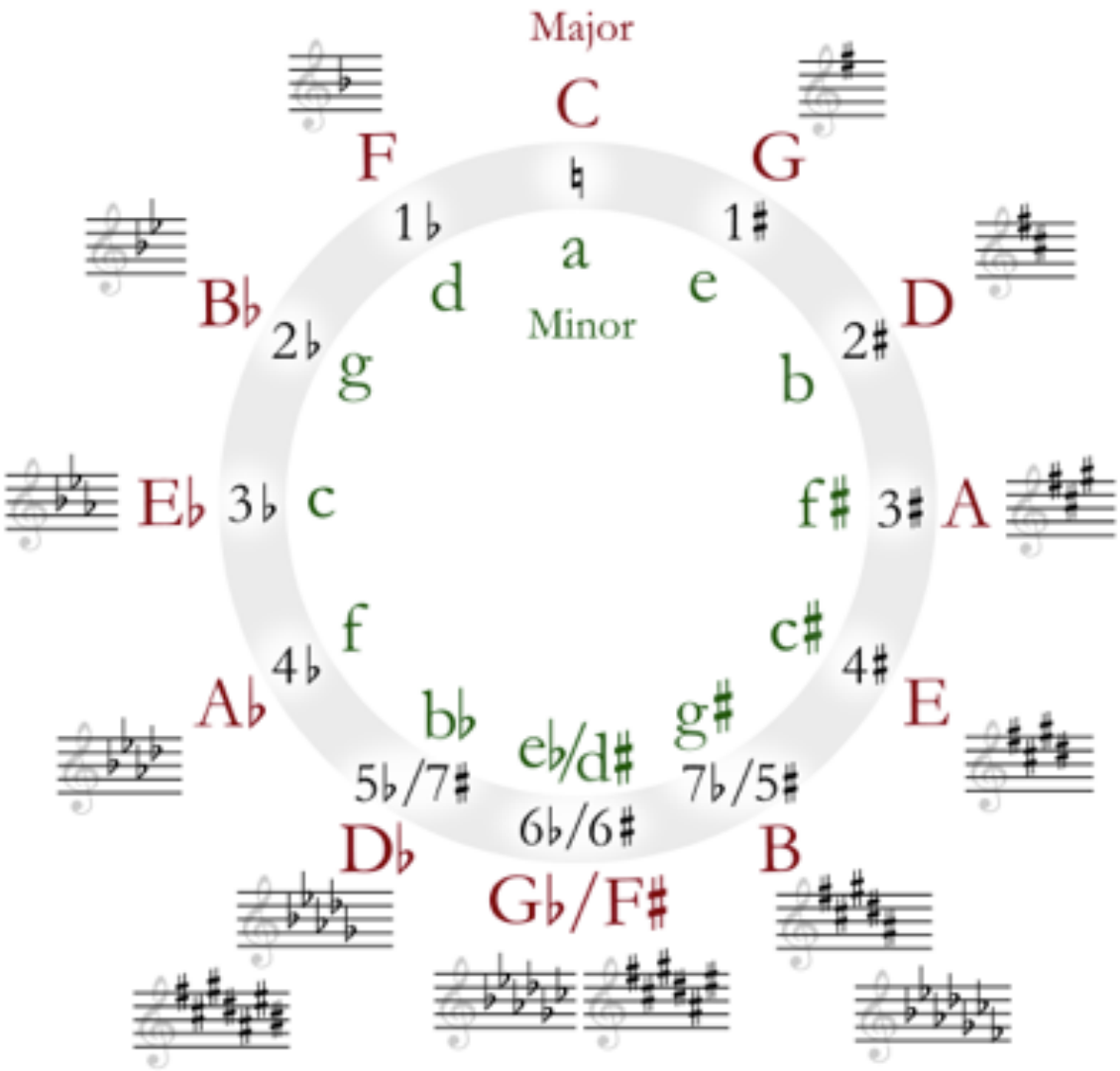


Figure 2.1 The pitch helix. Pitches are arranged along a line that spirals upward, indicating increasing pitch height, and that curves in a circular way so that pitches with the same chroma are aligned vertically, indicating octave equivalence. Adapted from Shepard, 1982.

Musical scales

- Musical scale: "a set of distinct pitches and intervals within the octave that serve as reference points in the creation of musical patterns."
- Western equal tempered music—12 equal sized intervals: semitones (divisible into 'cents')
- Diatonic major scale: [2 2 1 2 2 2 1]
  e.g. all white keys: C-D-E-F-G-A-B-C'
- To maintain the pattern when starting on a different note, sharps (one black key up) and flats (one black key down) are used.


Major
C
♮
a
Minor
G
1♯
e
D
2♯
b
A
3♯
f♯
E
4♯
c♯
B
5♯/7♭
g♯
F♯/G♭
6♯/6♯
e♭/d♯
D♭
5♭/7♯
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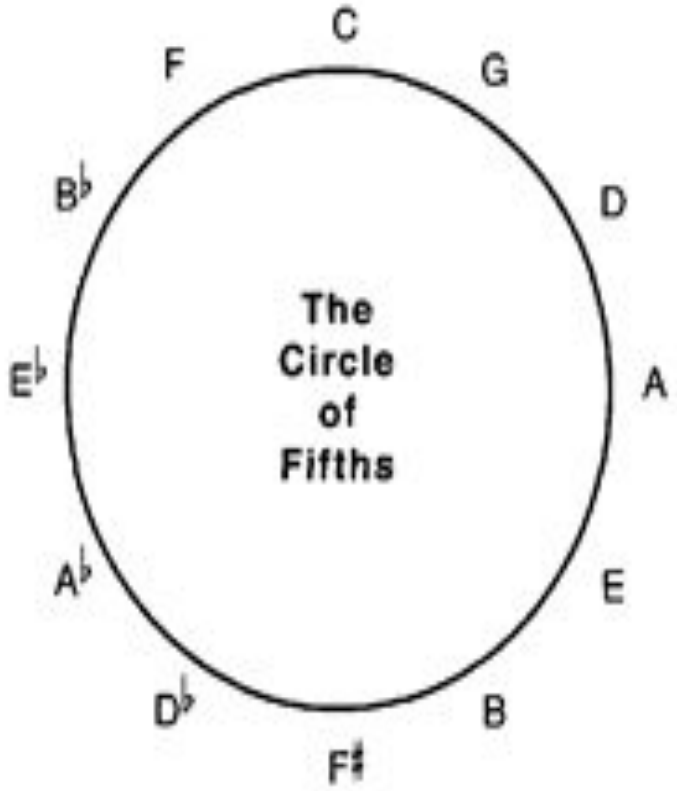


Figure 5.6 The circle of fifths for major keys. Each key is represented by a letter standing for its tonic. Keys that are adjacent on the circle share all but one pitch class.

Musical scales

- A sharp (#) is added each time the starting note goes up a fifth (to the fifth scale note): **F**ather-**C**harles-**G**oes-**D**own-**A**nd-**E**nds-**B**attle.
- See the "Circle of Fifths".
- A flat (♭) is added each time the starting note goes down a fifth (to the fifth scale note): **B**attle-**E**nds-**A**nd-**D**own-**G**oes-**C**harles-**F**ather.
- Scale degrees: 1(tonic), 2(supertonic), 3(mediant), 4(subdominant), 5(dominant), 6(submediant), 7(leading note).

Differences among scales systems culturally

- Amount of tonal material within each octave available for choosing pitches
  - Western system: 7 out of 12; Indian classical music: 7 out of 22 [Rag Multani].
- Number of pitches per octave
  - 2 in some Native American systems to 7, most common 5 (e.g. the Pentatonic scale: black keys: [2 3 2 2 3], Bobby McFerrin's demonstration)
- Interval patterns—spacing of pitches
  - Javanese pelog scale: 7 tones, different spacing. Gamelan music.
- How standardized the tunings are across instruments:
  - Javanese Gamelans tuned to the slendro scale vary as much as 75 cents.

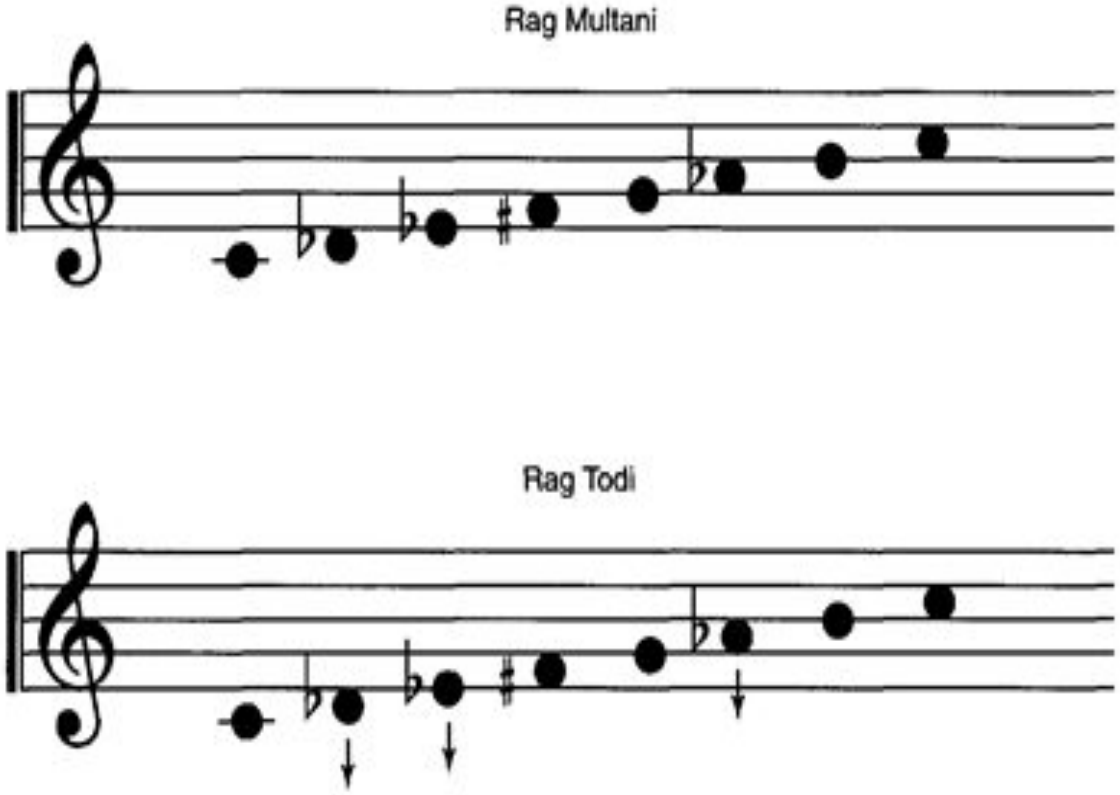


Figure 2.2a The ascending scales of two North Indian ragas. A raga is a musical form that includes a specific scale, particular melodic movements, and other features (Bor, 1999). In Rag Todi, three tones (d♭, e♭, and a♭) are slightly flatter (about 1/4 semitone) than their counterparts in Rag Multani (indicated by arrows). Courtesy of Dr. Arun Dravid and Michael Zarky.

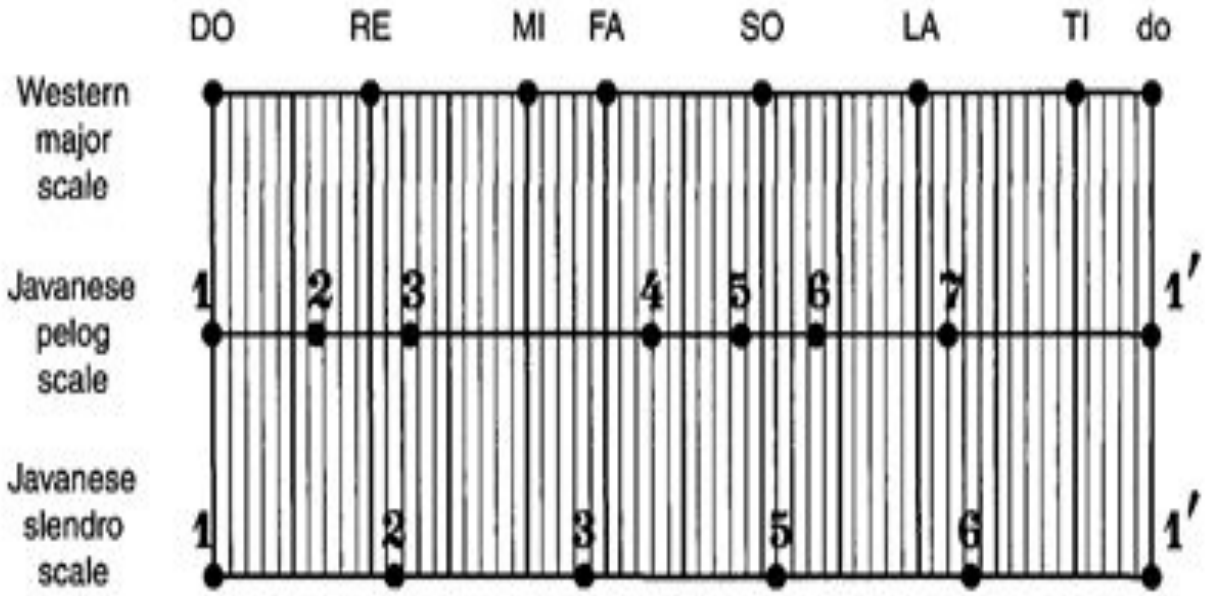


Figure 2.2b Frequency spacing between tones in the Western major scale and in two Javanese scales (pelog and slendro). The thin vertical lines mark 10-cent intervals. The tones of the Western scale are labeled with their solfège names. By convention, the five notes of the slendro scale are notated 1, 2, 3, 5, 6. Adapted from Sutton, 2001.

Commonalities among scale systems

- Number of pitches in a scale
  - Typically 5-7.
- Size distribution of intervals in the scale
  - Typically 1-3 semitones
    - Ergonomics—anything larger would be difficult to sing
    - Anything smaller would be hard to discriminate (80 cent threshold).
- Patterning of interval sizes within the scale
  - Typically asymmetric: differing in size.
  - A pattern of unequal intervals serves to make each tone unique in terms of its pattern of intervals with respect to other tones.
  - Helps listeners maintain a sense of where they are in relation to the first tone (the *tonic center).*

– Trehub et al. 1999 constructed unfamiliar asymmetric and symmetric scales based on 7 intervals per octave.
  - Western infants were better at detecting subtle pitch changes in repetitions of these scales when the scale was asymmetric, either familiar or unfamiliar.
  - But Western adults could only detect the pitch changes in the familiar asymmetric (diatonic) scale.

Pitch intervals as learned sound categories in music

- Pitch intervals and a perceptual illusion
  - Shepard & Jordan 1984: participants judged the 3rd and 7th interval in an equally spaced scale to be larger than the others
  - These are the intervals that are small (1 semitone) in a Western major scale.

Pitch intervals as learned sound categories in music cont.

- Pitch intervals and melody perception
  - Melodic contour: the pattern of ups and downs without regard to precise interval size, e.g. [+ + + - - - +]
  - Dowling 1978, inter alia: participants compared a novel melody to a precise transposition, a same contour lure, or a different contour.
  - When the delay between melodies is brief, listeners confuse the same contour lure with a precise transposition.
  - This confusion goes away after a distraction filled delay, as if the mental representation of pitch relations was being consolidated in terms of a sequence of interval categories.

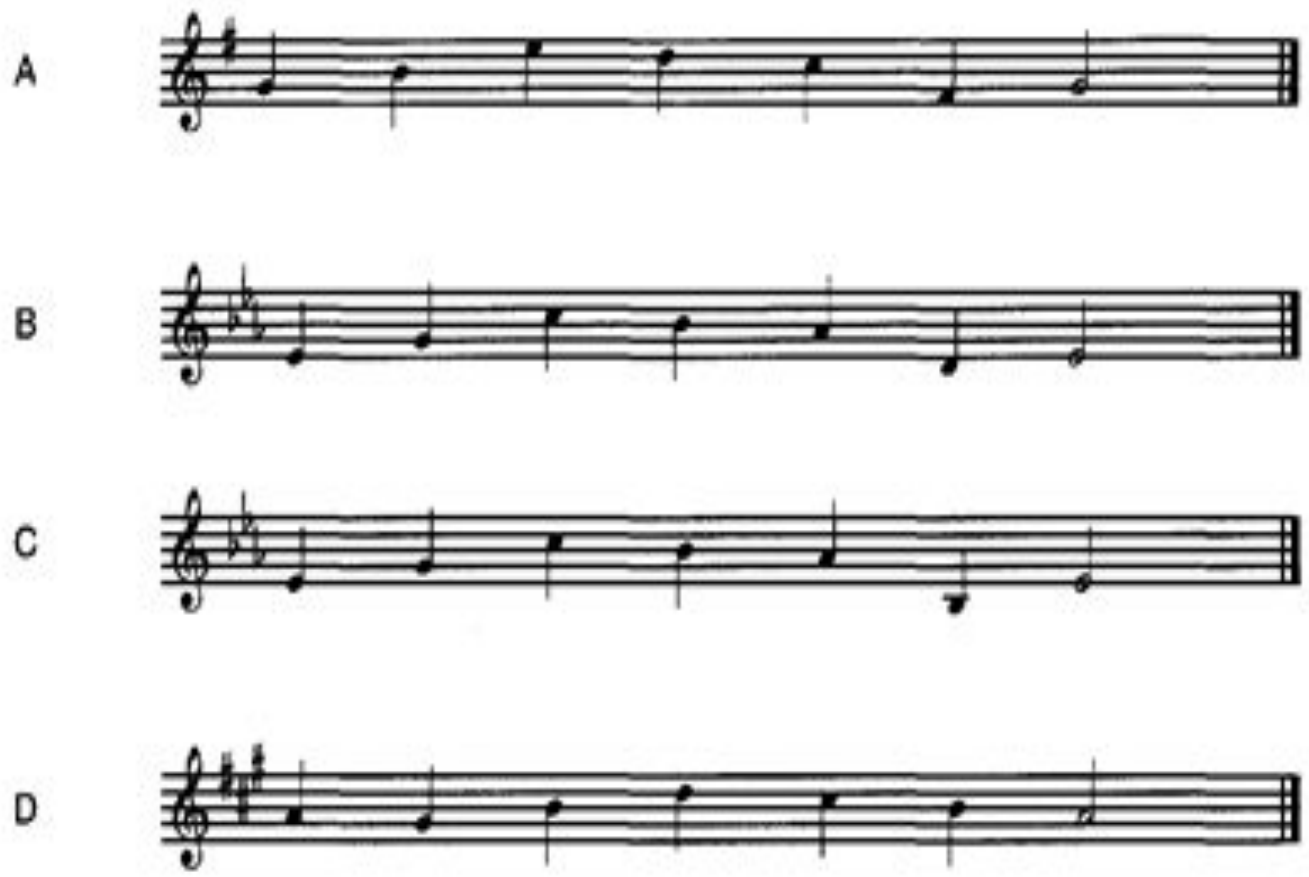


Figure 2.3 Tone sequences B, C, and D have different relations to tone sequence A. (B = exact transposition, C = same contour but different intervals, D = different contour.) After Dowling, Kwak, & Andrews, 1995. Cf. sound example 2.1a–d.

Pitch intervals as learned sound categories in music cont.

- Pitch intervals and categorical perception
  - (1) sounds that lie along a physical continuum are perceived as belonging to distinct categories rather than gradually changing from one category to another (identification task).
  - (2) Sounds of a given degree of physical difference are much easier to discriminate if they straddle a category boundary than if they fall within the same category (discrimination task).

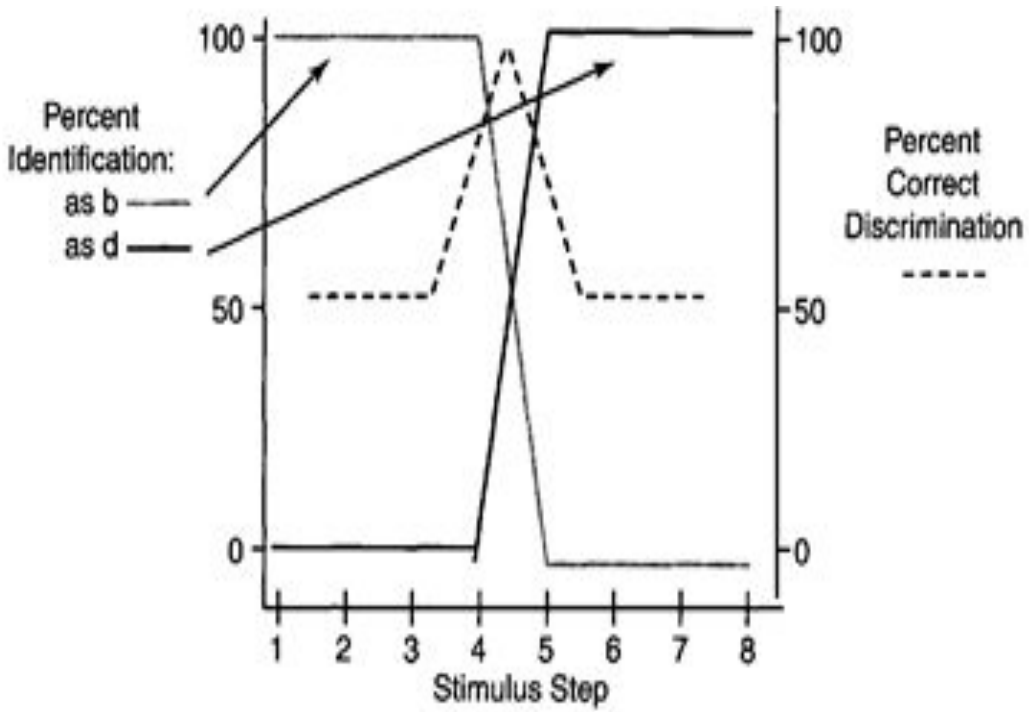


Figure 2.4 An idealized categorical perception function. A speech sound is changed from /b/ to /d/ via small acoustic steps of equal in size. Perception of the stimuli shifts dramatically from one category to the other at a particular point in the stimulus continuum, and discrimination between stimuli separated by one step along the continuum is best at this perceptual boundary. Courtesy of Louis Goldstein.

Pitch intervals as learned sound categories in music cont.

- Early evidence of CP between e.g. /p/-/b/ in infants was taken as evidence that special neural mechanisms had evolved for speech to transform continuous sound into discrete mental categories.
- But then CP was found in chinchillas (Kuhl & Miller 1975).
- Vowels and lexical tones do not show CP but are still interpreted as categories.
- Burns & Ward 1978 found CP of intervals for musicians.
- Nonmusicians do not show CP for intervals even in studies using familiar melodies for training (Smith et al. 1994).

Pitch intervals as learned sound categories in music cont.

- Pitch intervals and neuroscience
  - Mismatched Negativity (MMN) is an event-related potential (ERP) associated with automatic change detection in a repetitive auditory signal, and has neural generators in the auditory cortex.
  - The MMN is the difference between the ERP to the standard and the deviant tones, and consists of a negative-going wave that peaks between 80 and 200 ms. after the onset of the deviant tone (Haatinen & Winkler 1999).
  - The MMN is sensitive to learned sound categories.

Pitch intervals as learned sound categories in music cont.

- The MMN was significantly larger for a deviant in a sequence of five tones from the major scale than in a nonstandard sequence (Brattico et al. 2001).
- Nonmusicians showed a robust MMN to a final interval that was changed in size but not in contour for a repeating 5-note sequence that was transposed on every repetition (Trainor et al 2002).

Linguistic sound systems

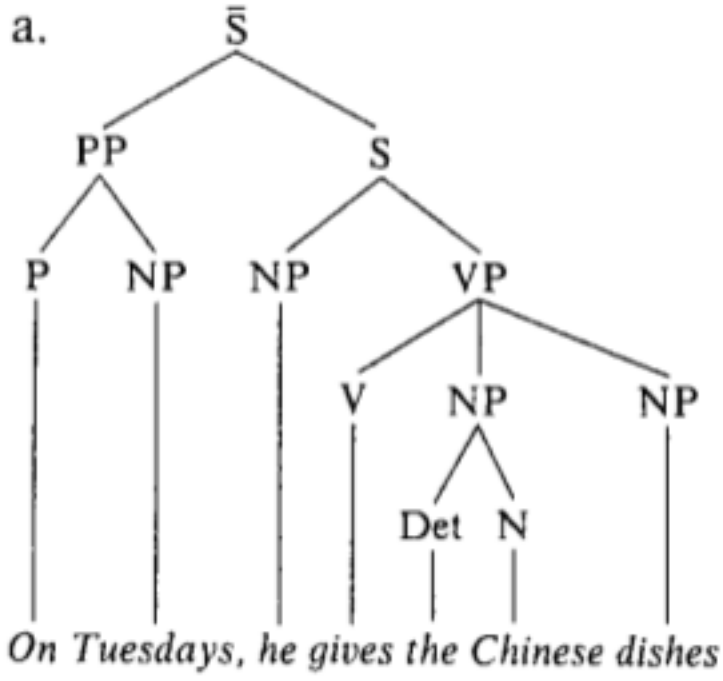
- Phonetics: "The science of speech sounds; includes the study of the acoustic structure of speech, and the mechanisms by which speech is produced and perceived."
  - Usually deals with the measurement of continuous acoustic or articulatory parameters.
- Phonology: "The study of the sound patterns of language; the study of how speech sounds are organized into higher level units such as syllables and words, how sounds vary as a function of context, and how knowledge of the sound patterns of language is represented in the mind of a speaker or listener."
  - Usually deals with the organization of categorically defined elements.

Linguistic sound systems cont.

- Phoneme: The minimal speech unit that can distinguish two different words in a language.
- Hierarchical organization: distinctive features, phonemes, mora, syllables, feet, prosodic words, clitic groups, phonological phrases, intonation phrases, utterances (the Prosodic Hierarchy).
- There are more than 7,000 languages, exhibiting a great deal of diversity, so a cross-linguistic perspective is crucial.
  - E.g. Mandarin is the most widely spoken tone language with one level tone and three contour tones, but it is typologically unusual to have only one level tone.

Prosodic Hierarchy (Hayes 1989)

(1) a.



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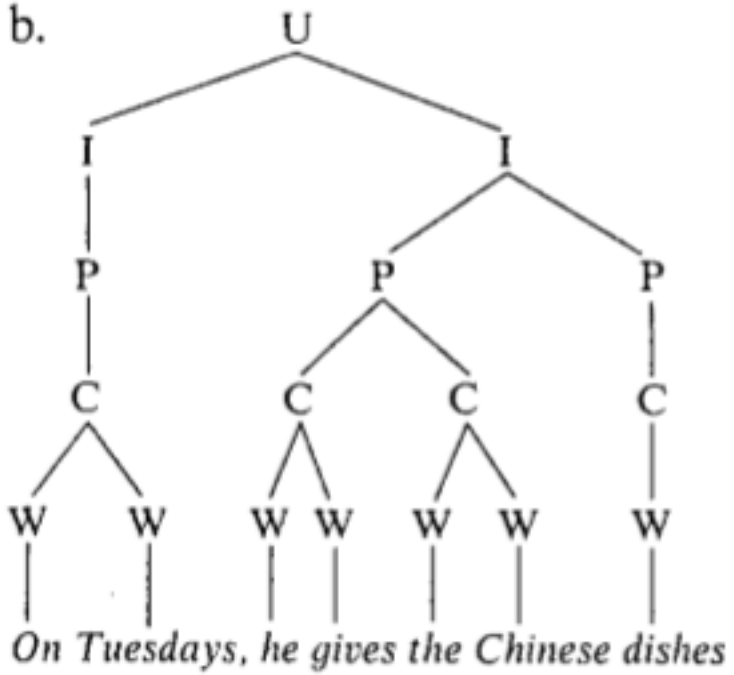


Pitch contrasts in language

- Vocal folds vibrate: fundamental frequency (F0).
- Gradient pitch contrast (emotion); categorical pitch contrast (tones in a tone language)
- Tone language: "a language in which pitch is as much a part of a word's identity as are the vowels and consonants, so that changing the pitch can completely change the meaning of the word."
- Over half the world's languages are tone languages (especially prevalent in Africa and Southeast Asia)

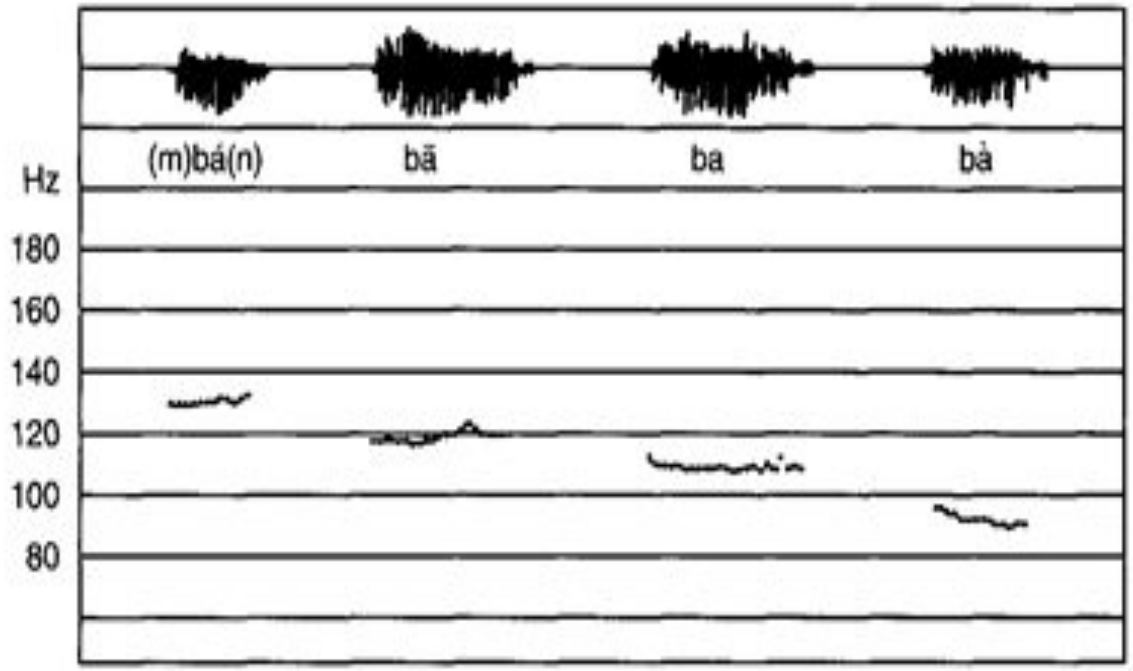


Figure 2.11 Examples of words with 4 different level tones from Mambila, a language from the Nigeria-Cameroon border. The four words illustrating these tones are as follows: T1 = mbán (breast), T2 = bā (bag), T3 = ba (palm of hand), T4 = bà (wing). The top panels shows the acoustic waveforms of the words, and the bottom panel shows voice pitch as recorded from one speaker. From Connell, 2000.

Pitch contrasts between level tones in language: general features

- The majority of the world's tone languages have only level tones, usually 2-3.
- Level tones are most comparable to music.
- Contour tones are quite common in four-tone systems.
- The maximum number of level tones is 5.
- Maddieson 1991: Are tones as far apart as they can be in the pitch space, or is there a more or less fixed interval (relative to the speaker's pitch range) which serves as a satisfactory contrast between levels?
  - The latter seems to be true: as the number of tones grows, so does the pitch range.

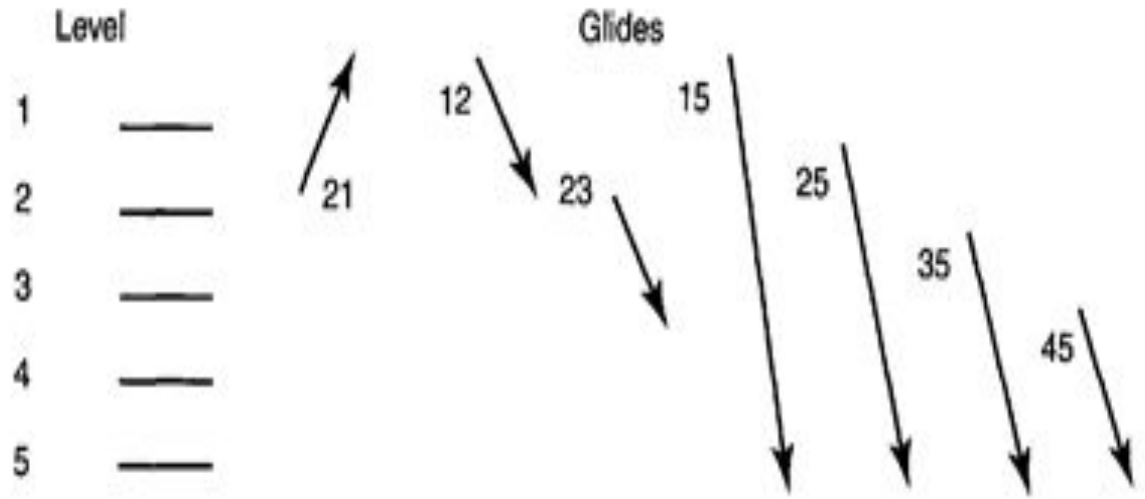


Figure 2.12 The linguistic tones of Ticuna, a tone language spoken by a small group of people from the Amazon regions of Peru, Columbia, and Brazil. This language has been analyzed as having 5 level tones and 7 glides. The numerals represent relative pitch levels in a speaker's voice. From Anderson, 1959, cited in Edmondson & Gregerson, 1992.

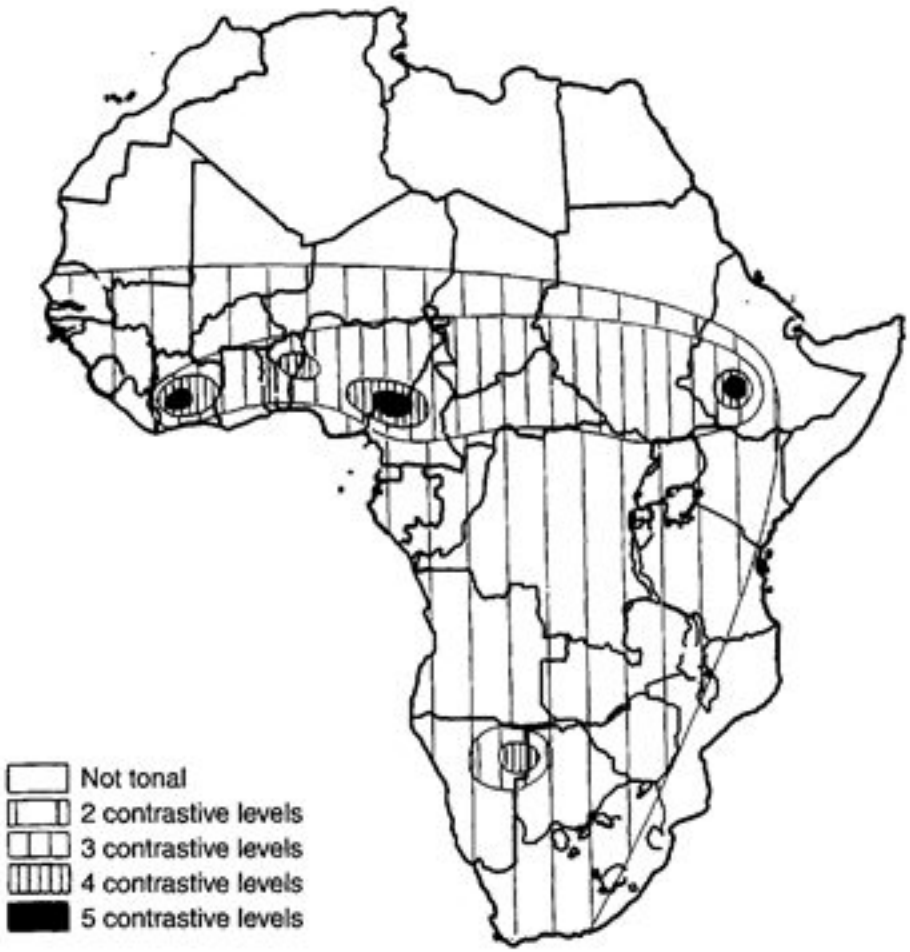


Figure 2.13 The geographic distribution of African tone languages according to their number of level tones. Note the pattern whereby 2-tone languages surround 3-tone languages, which in turn surround 4-tone languages, which in turn surround 5-tone languages. This may suggest a historical process of increasing or decreasing tonal differentiation. From Wedekind, 1985.

A closer look at pitch contrasts between level tones in a tone language

- There are two types of level tone languages: those with downtrend, which are unsuitable to compare to music, and those that do not downtrend ("discrete level-tone languages").
- Welmers 1973 describes Jukun (Nigeria) as having three stable level tones about the distance apart of a major triad (e.g. C-E-G).
- It is likely that variation in speech tones will be greater than in music tones since speech tones have to convey emotional as well as linguistic meanings.
- Ladd 1996 suggests that pitch range varies between speakers and also within speakers due to context and sentence position, but what stays relatively constant is pitch level as a *proportion* of current range.

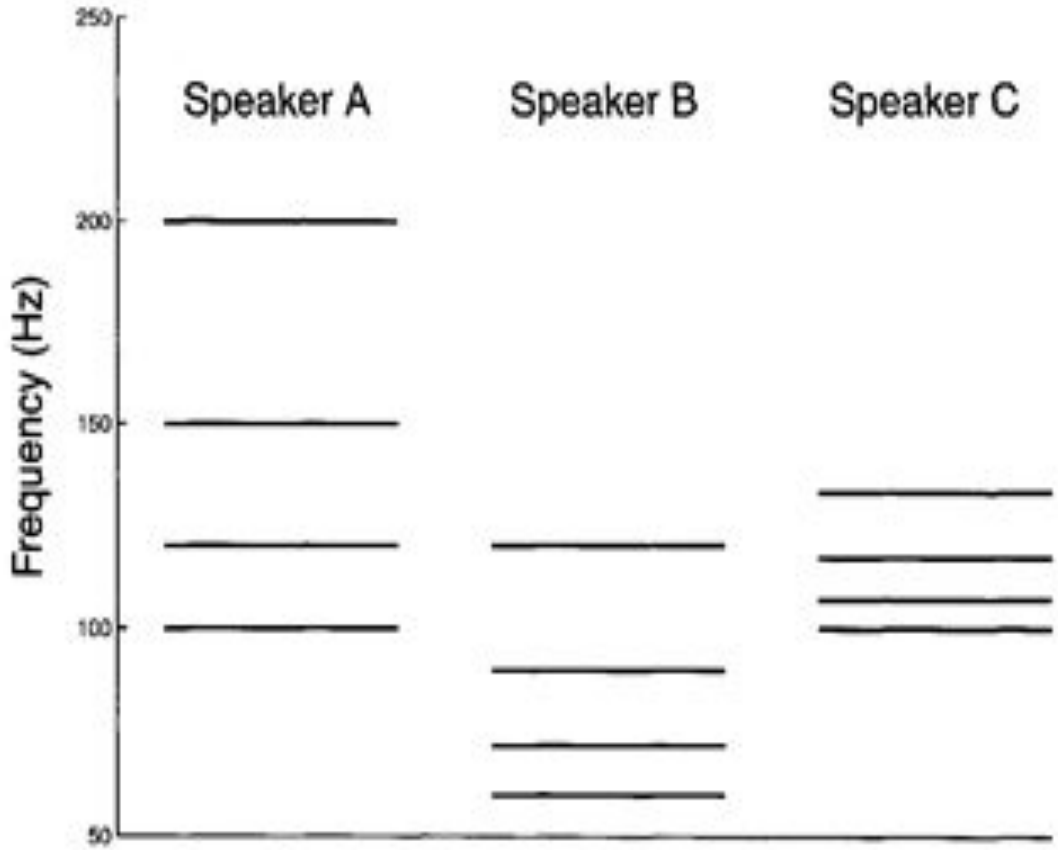


Figure 2.14 Examples of linguistic tone spacing illustrating the notion of range-based proportional scaling. See text for details.

Absolute pitch in speech?

- A listener must have some way of getting a relatively rapid and accurate estimate of where a given tone falls in the pitch range of a speaker. Honorof & Whale 2005: listeners can do this even when only hearing one syllable.
- Deutsch et al 2004: a linguistic tone's absolute frequency can be part of its identity as a sound category. Vietnamese and Mandarin speakers varied by ½ a semitone or less on two consecutive days. English speakers showed less consistency.
- Deutsch et al 2006 found that musicians who are native speakers of a tone language (Mandarin, 60%) are substantially more likely to have musical absolute pitch than are musicians who do not speak a tone language (English, 14%).

Mapping linguistic tone contrasts onto musical instruments

- Talking drum of West Africa, e.g. a 2-tone drum for 2-tone Lokole: the interval varies from drum to drum.
- Whistled speech, e.g. Mexican tone language Chinantec. Uses a combination of tone and stress distinctions to communicate messages with minimum ambiguity. Probably doesn't use a fixed tuning scheme.
- Krar speech, southwest Ethiopia—a 5-stringed instrument resembling a guitar is used to imitate the 5 discrete level tones of Benchnon, e.g. in a hide-and-seek game. Probably a great deal of mistuning is tolerable.

Intonation

- Autosegmental approach—an intonation contour can be described in terms of a sequence of high and low tones.
- H*L-L% is a typical nuclear (final) contour for a declarative statement; L*H-H% is a typical nuclear contour for a "genuine" yes-no question.

  – Do **you** still **work** for a **veterinarian**?
  H* !H* L*H-H%

  – Can we **talk** about the **job** things now?
  H* L*L-L%

  – Did **I** **tell** you that **I** have a new **job**?
  L+H* !H* !H* L*L-L%



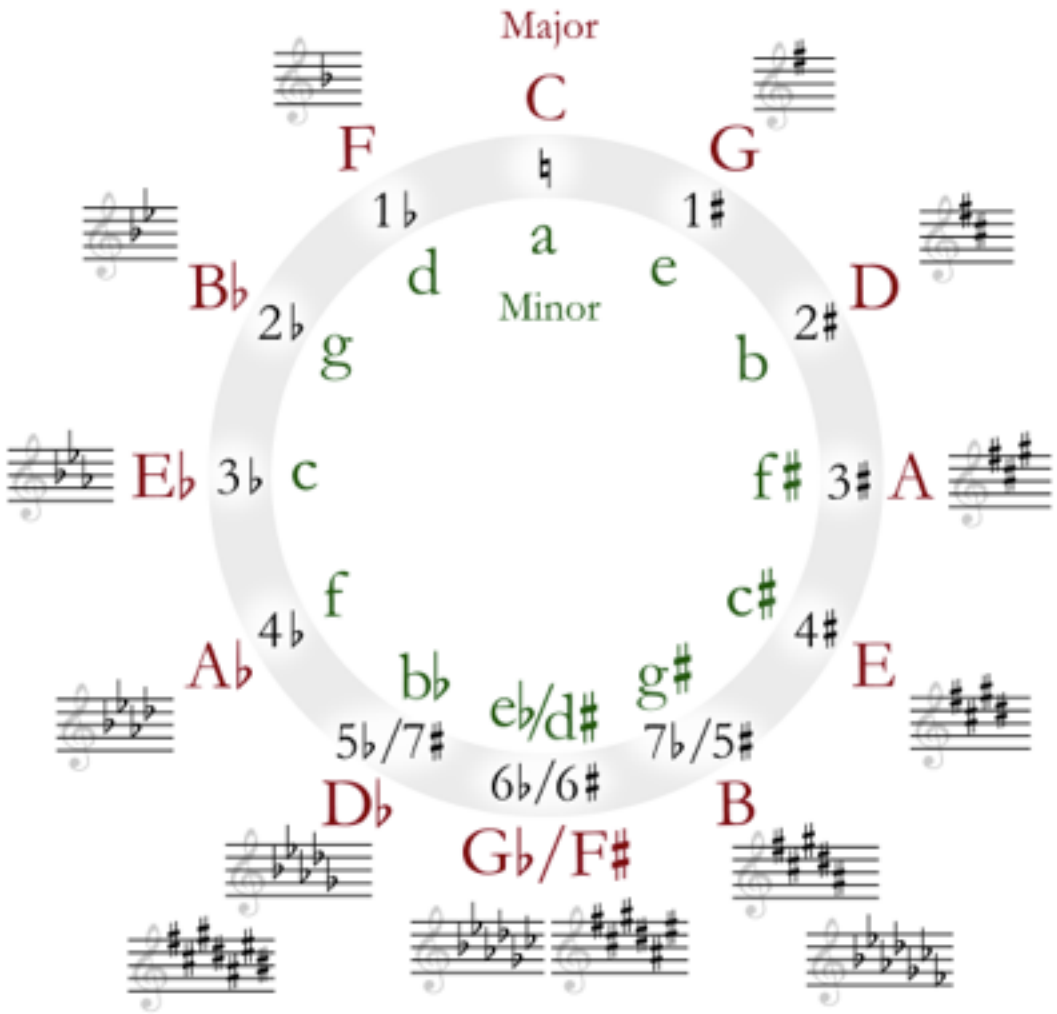
- We'll talk more about intonation in the chapter on melody.
- Babies seem to acquire intonation early: talking twins

Other scales

- Major scale: [2 2 1 2 2 2 1]

- Minor scales:
  - Natural minor [2 1 2 2 1 2 2]
  - Harmonic minor [2 1 2 2 1 2 1]
  - Melodic minor (different going up and down)

  - Relative minor/major: have the same key signature
  - See circle of fifths for key signatures of natural minors.


Major
C
F
G
1♭
1♯
a
d
e
Minor
B♭
D
2♭
2♯
g
b
E♭
3♭
c
f♯
3♯
A
f
c♯
4♭
4♯
A♭
E
b♭
g♯
e♭/d♯
5♭/7♯
7♭/5♯
6♭/6♯
D♭
B
G♭/F♯

Blues scale

- [3 2 1 1 3 2]
- Wharram, p. 72: "Blues music was originally an oral tradition. Blues singers use pitches that cannot be notated precisely. These "blue notes" or "bent pitches" are slightly flattened notes on the 3rd, 5th and 7th scale degree." In written music, the blues scale may be notated as follows:
- C - E ♭ - F - G ♭ - G - B ♭ - C
- Video illustrating the blues scale.