Creative Computing II

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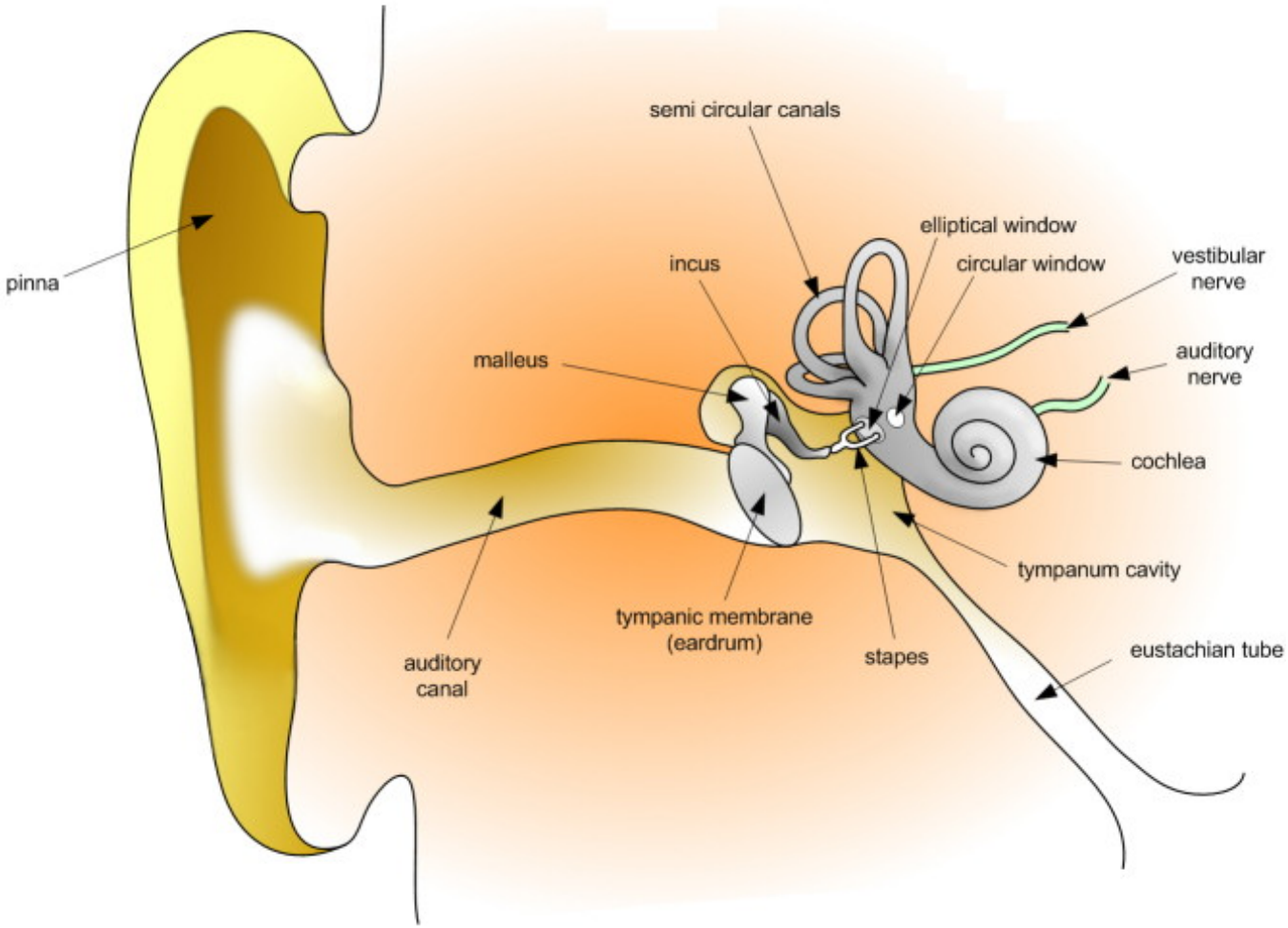
Autumn 2010, Wednesdays:
10:00–12:00: RHB307 & 14:00–16:00: WB316
Winter 2011, TBC

The Ear


semi circular canals
elliptical window
circular window
vestibular nerve
incus
auditory nerve
pinna
malleus
cochlea
tympanum cavity
tympanic membrane (eardrum)
stapes
eustachian tube
auditory canal

The Ear

Outer Ear

Outer Ear:

- *pinna*: flap of skin;
  - assists in sound source location.
- *auditory canal*:
  - resonant cavity;
  - amplifies frequencies close to 4kHz.
- *typmanic membrane* (ear drum):
  - converts pressure differences to mechanical vibration.

The Ear

Middle Ear

Middle Ear:

- *ossicles* (small bones):
  - *malleus* (hammer);
  - *incus* (anvil);
  - *stapes* (stirrup);
  - transmit mechanical vibrations to inner ear;
  - amplification by lever principle.
- elliptical window
  - small membrane (compare with ear drum);
  - amplification by area.

The Ear

Inner Ear

Inner Ear or *Cochlea*:

- filled with *perilymph fluid*
  - incompressible;
  - moves in response to elliptical window;
  - (circular window moves to compensate).
- *scala media* (inner channel)
  - walls made from membranes (Reissner's membrane and basilar membrane)
  - walls displaced by fluid motion
- basilar membrane
  - tapered in thickness;
  - different regions respond best to different frequencies;
  - regions attached to hair cells;
  - hair cells attached to *auditory nerve*.

Sound Perception

Pitch

- Pressure waves (oscillating between overpressure and underpressure) impact on Tympanic Membrane
- Oscillations transmitted (and amplified) through hammer to stirrup
- Moves fluid in Cochlea, moving against receptor cells; those cells fire, sending signal to brain.
- Sensitive to oscillations between 20Hz and 20kHz.
- High frequency sensitivity decreases with age.
- Peak sensitivity: between 1kHz and 3kHz.

Sound Perception

Pitch in speech

Vowel formants:

Vowel	Main formant region/Hz
u	200–400
o	400–600
a	800–1200
e	400–600 & 2200–2600
i	200–400 & 3000–3500

Sibilants:

- sh: peak energy around 4000Hz, top at 8000Hz;
- s: peak energy around 8000Hz, top at 10000Hz.

Sound Perception

Pitch in singing

Singing:

- sustained pitch on the vowels;
- terminal consonants are delayed and short.

How can a singer be heard over an entire orchestra?

- amplification (cheating!);
- *singer's formant*;
- in *trained* voices, clear formant around 3kHz.
- (refer back to perceived loudness)

[demonstration]

Sound Perception

Pitch and harmony

Harmony:

- perceptual quality when pitched sounds (notes) occur simultaneously or in close temporal proximity;
- structural theory for describing same.

What is a consonant chord?

- chord: multiple tones;
- **fundamental frequencies** related by small integer ratio.

Sound Perception

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What is a consonant chord?

- chord: multiple tones;
- **fundamental frequencies** related by small integer ratio.

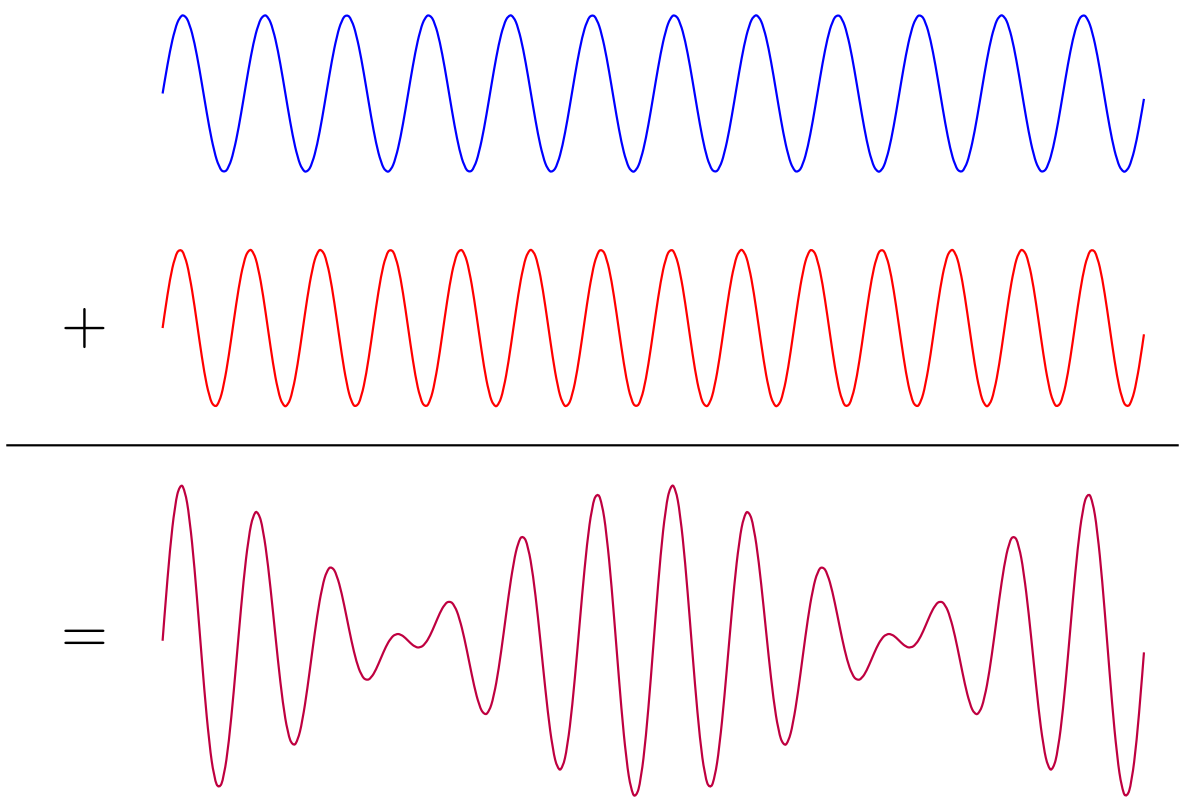
Why?

- no *beating*;
- no *dissonance*.

Sound Perception

Pitch and harmony

Beating:



$$\sin(A) + \sin(B) = 2\sin\left[\frac{A+B}{2}\right]\cos\left[\frac{A-B}{2}\right]$$

Sound Perception

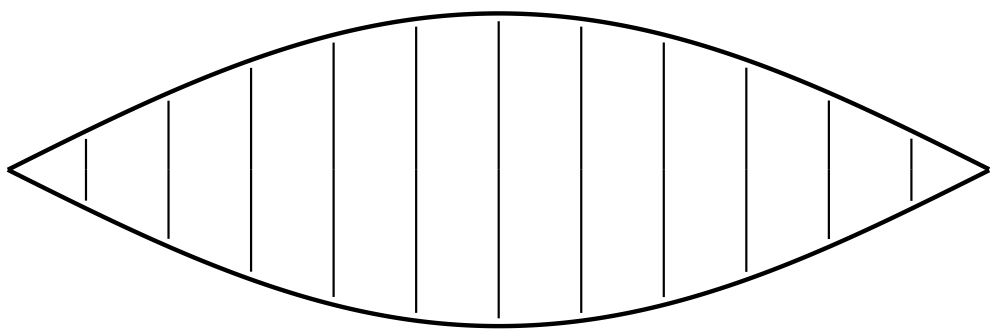
Pitch and harmony

One-dimensional instruments:

- stringed instruments (violin, viola, 'cello; guitar, piano) [string]
- wind instruments (flute, oboe, clarinet, basoon) [cavity]
- brass instruments (trumpet, trombone, tuba) [tubing]
- tuned percussion (xylophone, glockenspiel) [bars]

Vibrate at

- *fundamental* frequency;
- **harmonics**: integer multiples of the fundamental.



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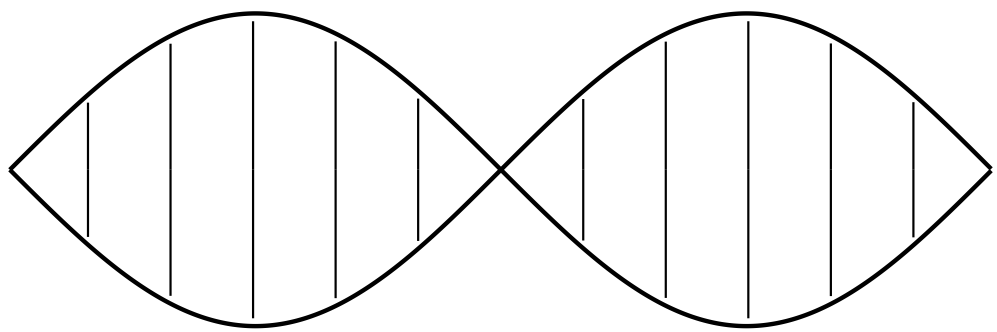

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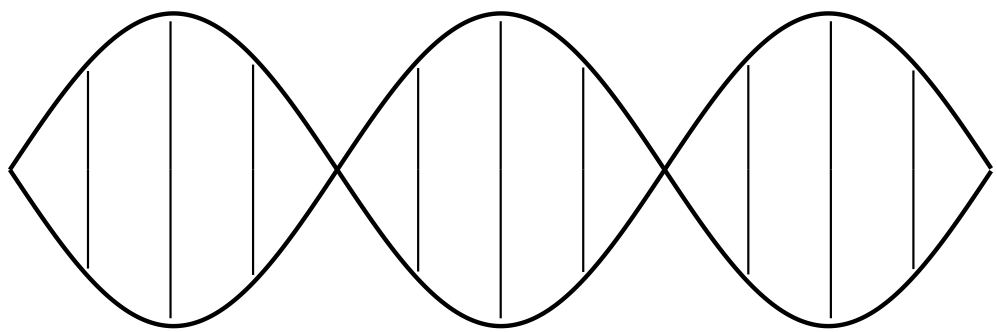

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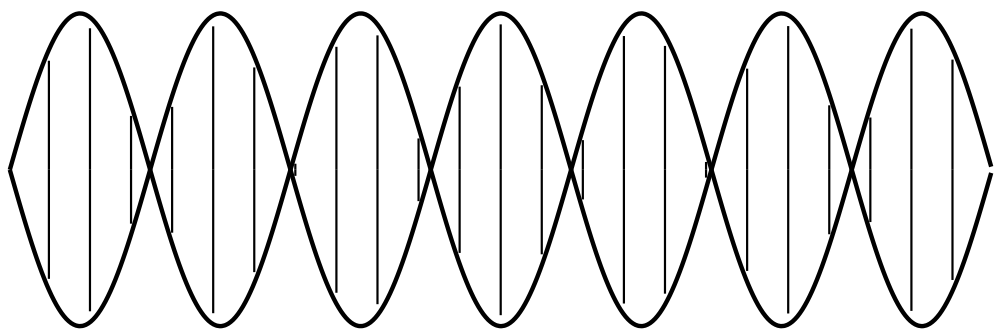
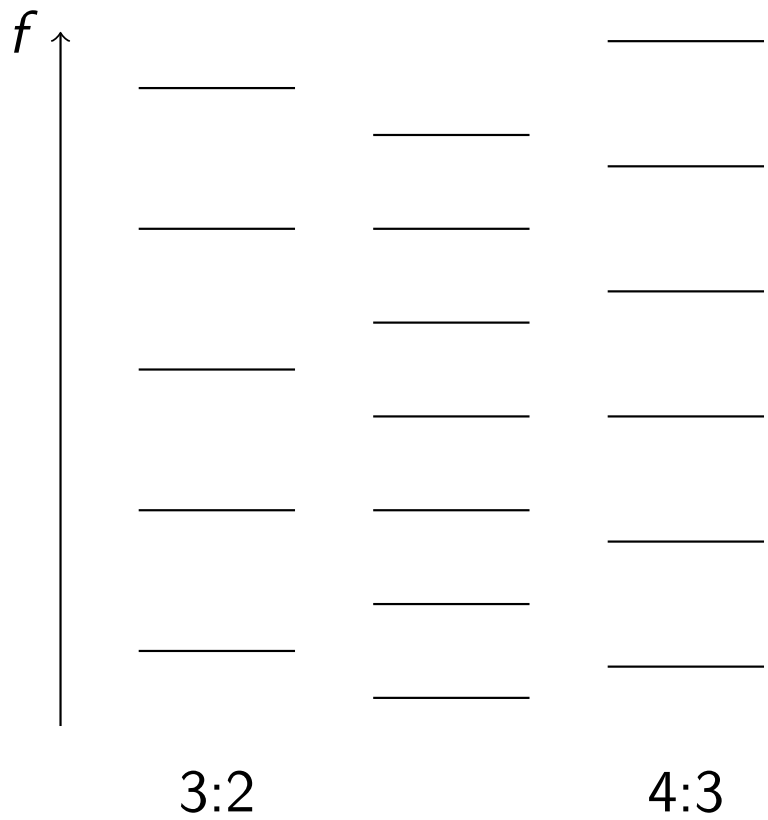


Sound Perception

Pitch and harmony

Dissonance:

- beating between *harmonics*:



critical bandwidth increases with frequency.

Sound Perception

Pitch and harmony

Western music: 12 equal-sized divisions to the octave.

- NB: not Universal.

Each note has a frequency a factor of $\sqrt[12]{2}$ above the previous one.

- Note names: C, C♯, D, E♭, E, F, F♯, G, G♯, A, B♭, B.
- Beware: labels different in different countries.
- Interval between notes: 'semitone'

Conventionally: A above 'middle C' is 440Hz

- Perfect fifth: should be $\frac{3}{2}$ above the root;
- $2^{\frac{7}{12}} = 1.4983...$
- close, but...

Sound Perception

Pitch and harmony

‘Perfect pitch’: like colour vision?

Different kinds:

- sing a named note without reference;
  - can be achieved by trained singers with muscle memory.
- name a heard note without reference.
  - difference in cognition;
  - not a different sensation;
  - correlation with
    - tonal languages?
    - musical exposure below age 4?
    - autism?

Sound Perception

Pitch and Melody

Melody:

- sequence of pitched events (notes) unfolding in musical time;

Perceived through large numbers of musical events:

- proximity (movement by small musical intervals);
- continuity (few breaks in a melody);
- common fate (repetition, with small alterations);

What makes a good melody?

Sound Perception

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What makes a good melody?

- if only I knew...

Sound Perception

Rhythm

Tempo:

- natural ‘pulse’ speed of music;
- often ambiguous (double / half speed).

Sound Perception

Rhythm

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- natural ‘pulse’ speed of music;
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Two experiments:

- ‘free’ tapping;

Sound Perception

Rhythm

Tempo:

- natural ‘pulse’ speed of music;
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Two experiments:

- ‘free’ tapping;
- beat detection in pulse train.

Sound Perception

Rhythm

Tempo:

- natural ‘pulse’ speed of music;
- often ambiguous (double / half speed).

Two experiments:

- ‘free’ tapping;
- beat detection in pulse train.

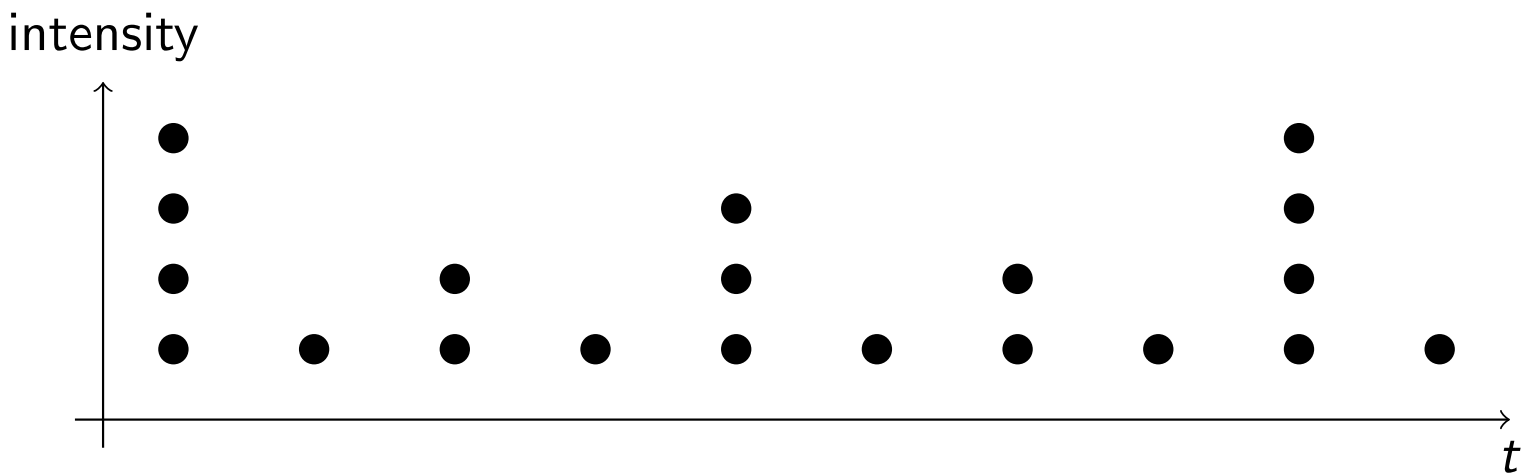
Preferred tempo: 0.2s – 0.8s

Sound Perception

Rhythm

Metrical Structure:

- hierarchy of temporal groups:
  - beats;
  - bars;
  - four-bar patterns;
  - larger groups (12-bar blues, 16-bar ‘question’/‘response’).



Sound Perception

Rhythm

Rhythm:

- choice of which elements in the hierarchy to emphasize;
- which to elide;

What makes a good rhythm?

Sound Perception

Rhythm

Rhythm:

- choice of which elements in the hierarchy to emphasize;
- which to elide;

What makes a good rhythm?

- if only I knew...