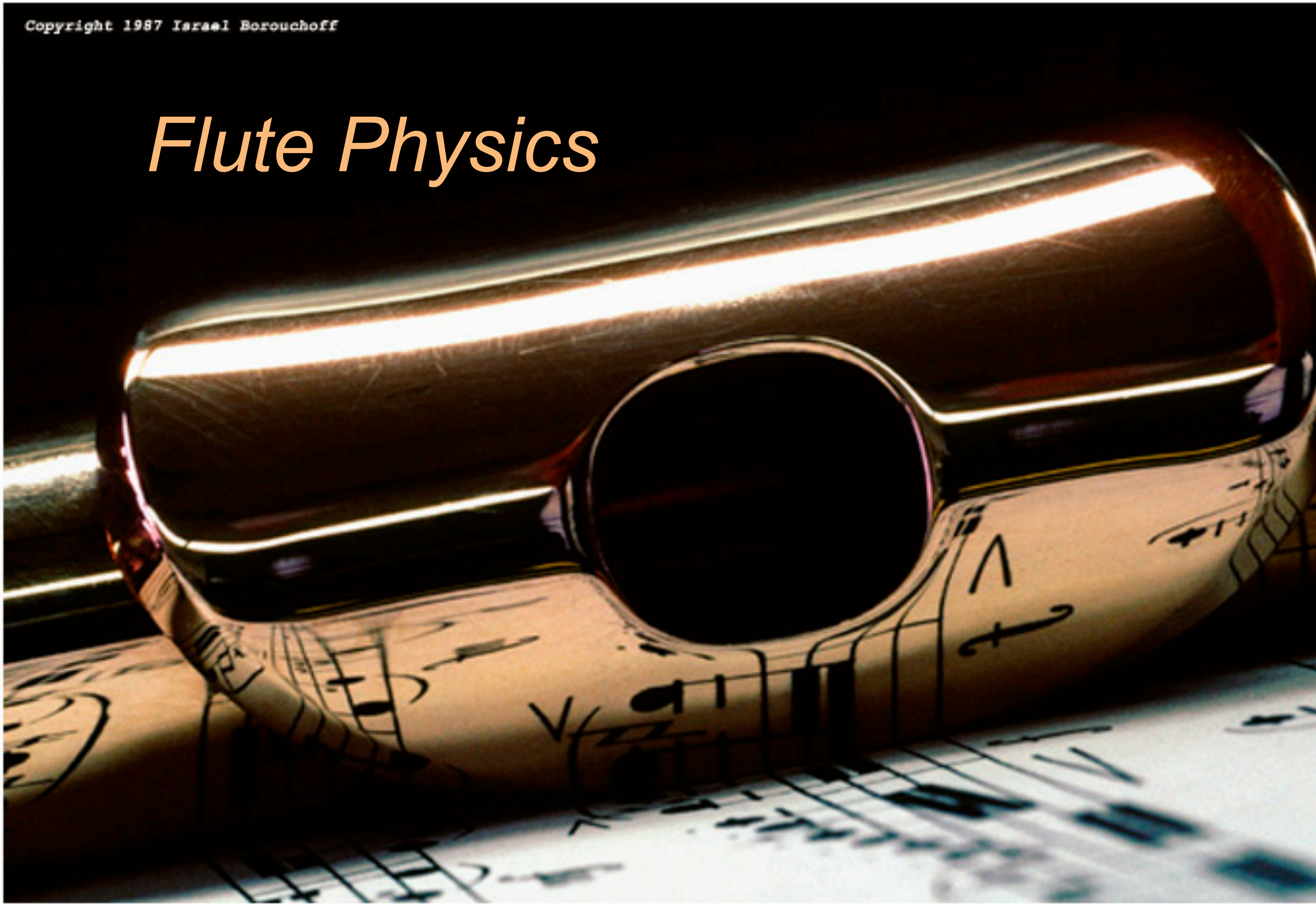
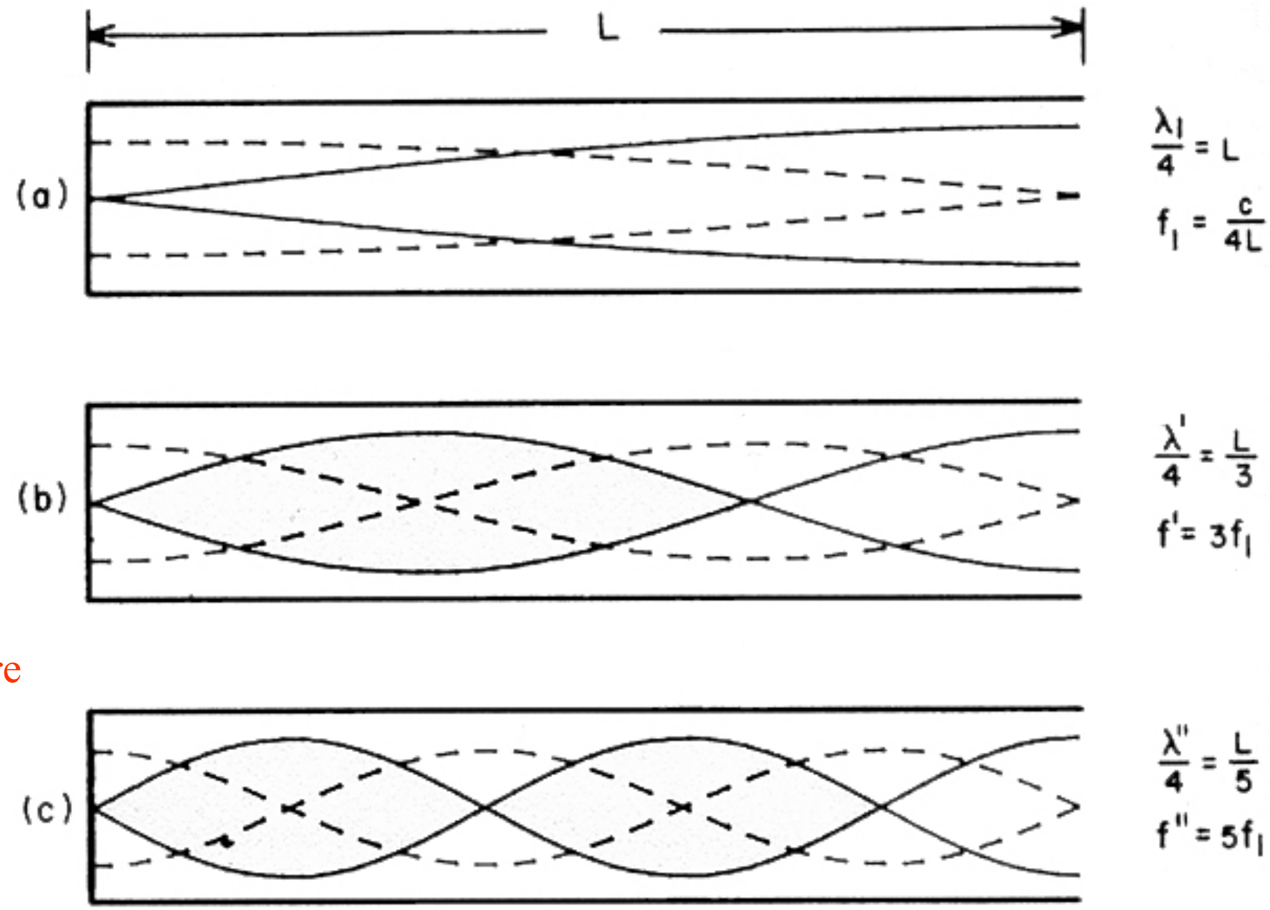


Gold Flute Mouthpiece

Normal modes of a column



No pressure variation,

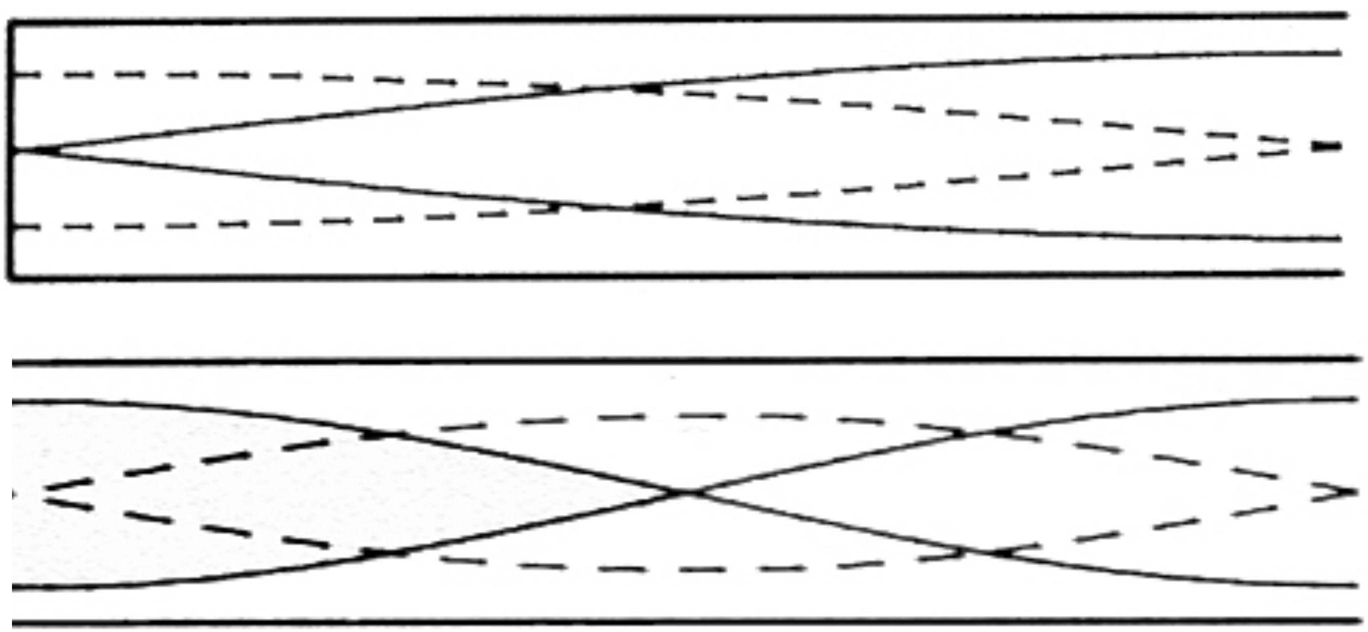
large motions

No motions,

large pressure variations

FIG. 9. First three vibration modes of an air column closed at one end and open at the other. Solid lines give displacement amplitudes; dashed lines, pressure amplitudes.

Is the flute
-an open column
-a closed column or
-one end open and other end closed?



How can we find out?

Experiments on the open pipe

- Blocking the end
- Half blocking the end
- How are high notes made easier to play?
- Harmonics of Flute $$f = c / \lambda$$
  Frequency f is speed of sound c divided by wavelength λ
- Fingering and pitch change. Effectively shortening the pipe.
- Comparing the flute and the recorder lengths

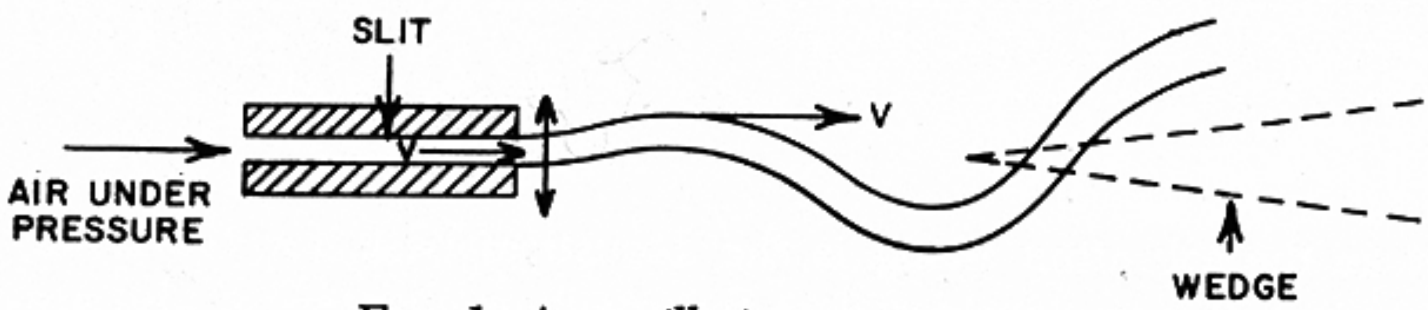
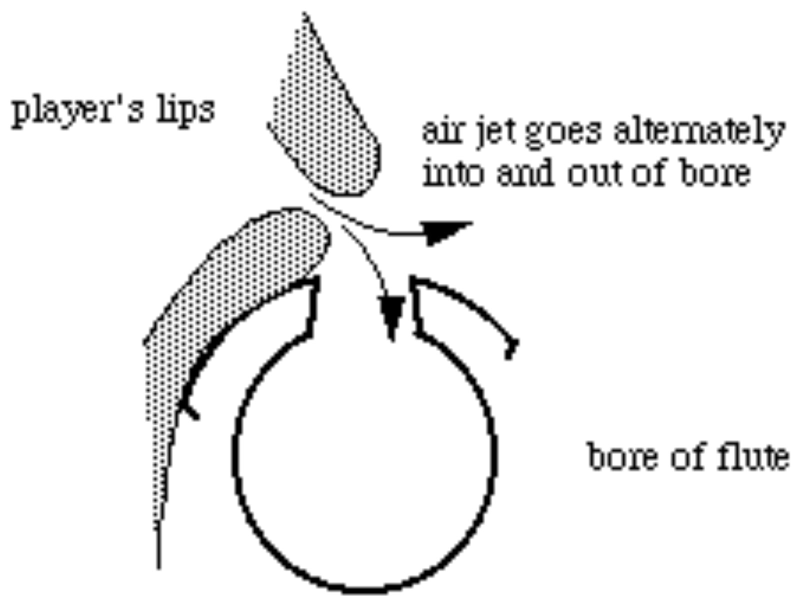
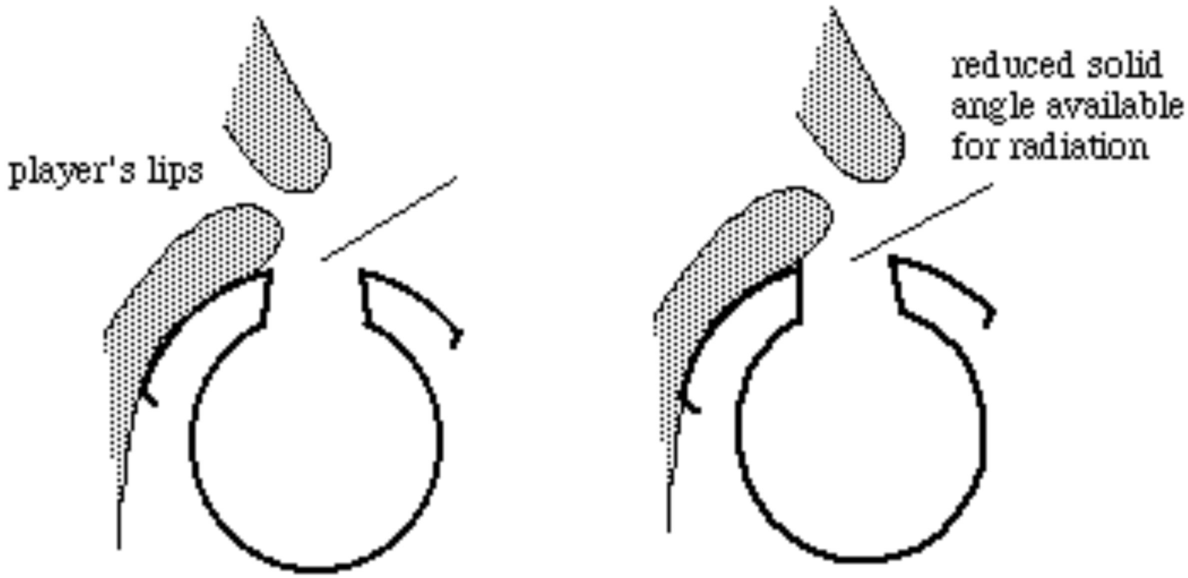


FIG. 1. An oscillating air stream.

Oscillating Air Stream



Pitch



What changes the pitch?
-Speed?
-Distance from mouth to edge?
-Covering of hole?

Blowing

- **Breathy sound**:
  How do you get rid of it?
- **High notes vs low notes:**
  What does the flutist do to change octave?

(whirly tube?)

- **Vibrato:**
  How does it change the sound?
  (dynamics, timbre, pitch)
  How does the flutist do it?

Thumb hole

Favors the higher overtones allowing the flutist to play an octave higher without over-blowing. However the thumb hole is not in the correct place for every note in the octave. → fingering changes from octave to octave

Dynamics

- As the vibration becomes larger, more harmonics appear. Loudness in most instruments is accompanied by a change in strength of overtones.
- The flute does not have a big dynamic range. Why?
- How do flutists compensate?

Perceptual fusion and voicing

- Voices stand out if their overtones move together. If overtones don't move in pitch then the sound does not sound like a voice. Tones with no variation in pitch sound dull.

- Demo from Perry Cook's book. A bell has many overtones. 3 groups of overtones are given different vibratos. As the vibrato grows three voices are heard separately.

Adjusting pitch

- The distance between the mouth and edge is fixed for a recorder. When you blow harder the note is sharper.
- Flutists can compensate by turning the flute.
- Some recorder players compensate with different fingerings for louder notes!
- If you add vibrato exact pitch is less precise (add vibrato to allow louder notes to still be effectively in pitch)– vocalists do this too

Material of Flute

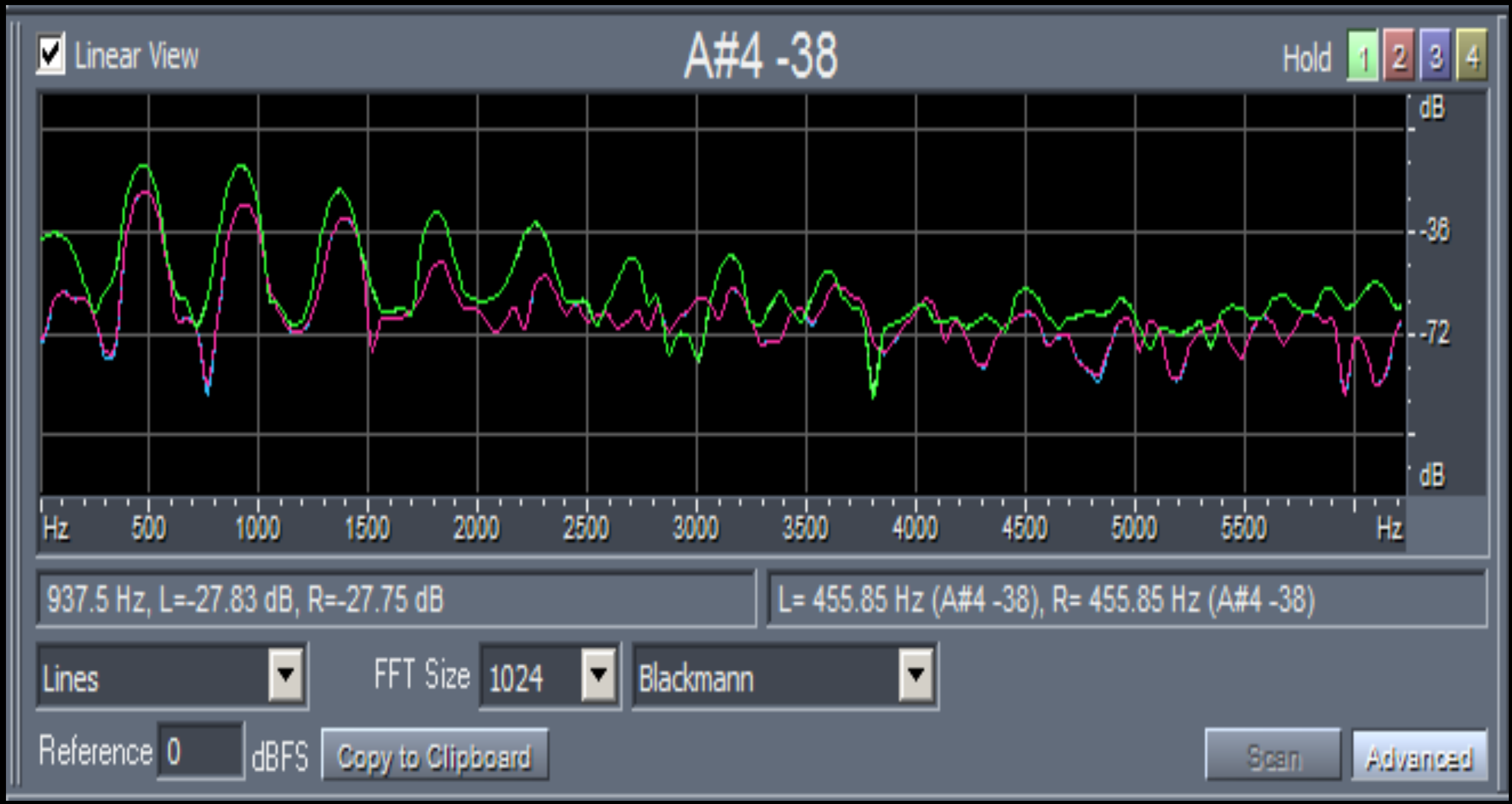
- Does it matter? Wood vs metal. Silver vs. steel.
- How about with recorders?
- What part of the instrument mostly affects the tone?

Timbre, temperature and humidity.

Experiments with Heads

Record wooden flutes vs metal flutes

Wood vs metal flutes



wood flute — **metal flute** —

The modern flute (Boehm)

- Larger holes and covering system
- Key rings and coupling of keys
- Cylindrical body and tapered head

  How do these characteristics improve or change the sounds of the flute?

F# experiment, low high notes flute+recorder

Moving crown while playing low notes and then high notes

Recorders and tapered barrel

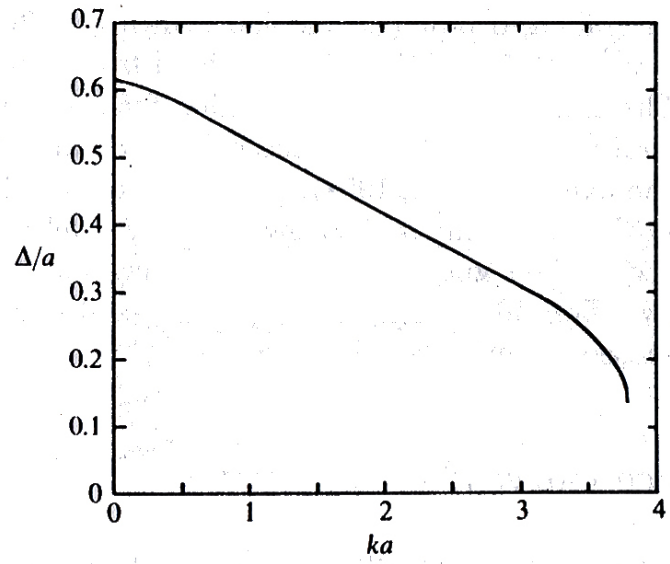
Taper improves higher octave tuning at the expense of some tonality and loudness

Experiment: octaves with penny whistles and recorder

End correction

Effective length of pipe is $L+\Delta$

from Fletcher and Rossing



URE 8.9. The calculated end correction Δ for a cylindrical pipe of radius *a*, ed as Δ/a, as a function of the frequency parameter *ka*, (after Levine and inger, 1948).

$\Delta \sim 0.61a$ where *a* is the diameter of the pipe
For a flanged pipe *$\Delta \sim 0.85a$*
As the end correction depends on wavelength, a flute is not in pitch across octaves. This leads to the design of tapered ends.

End correction

- Width of the barrel does make a difference.

Experiment: diameter barrel

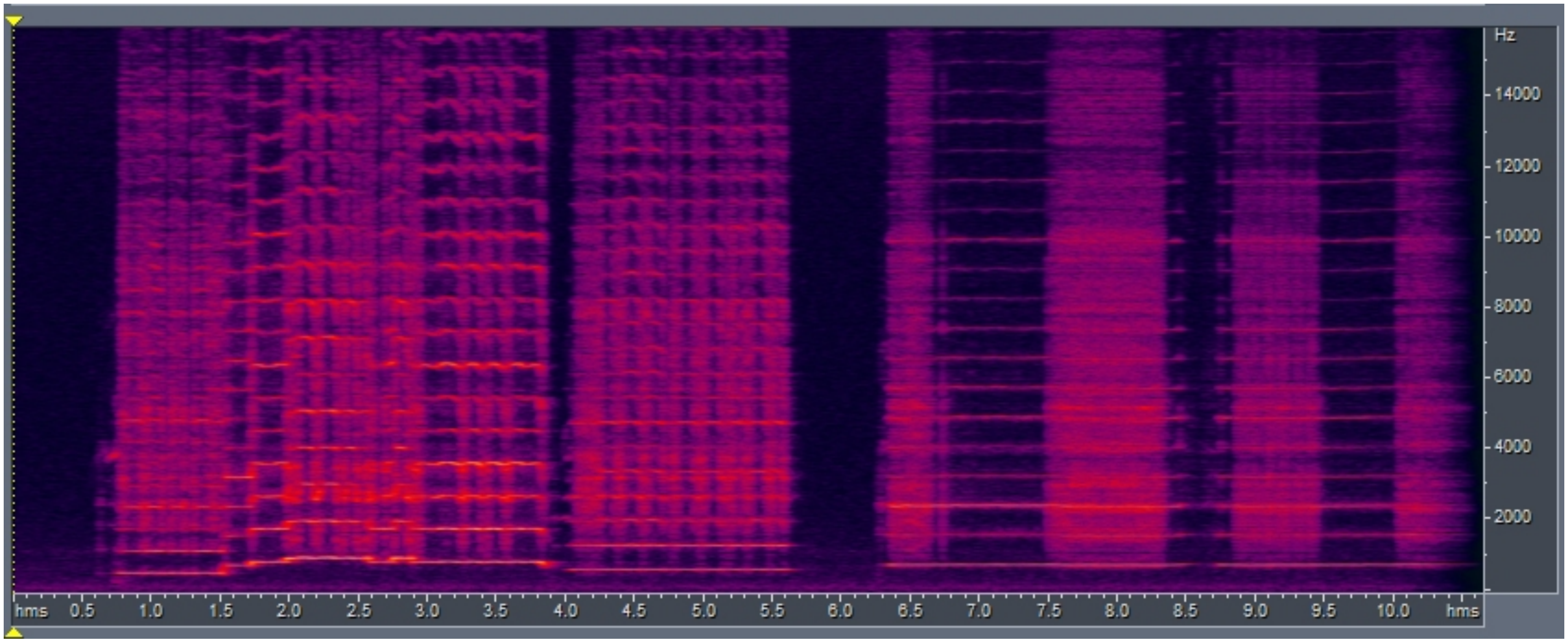
- End of flute does change the pitch (see Chinese flute).
- Placement of rice paper

near mouth so all notes

have extra vibration

Dizi

Chinese flute



- Rice paper has its own vibrating frequencies and also adds noise

Design of Mouthpiece

depth of mouthpiece determines
pitch range for a single note


TUNE-G
TUNE-E
TUNE-B

What sets diameter of bore?

- Short fat bores are poorer in high overtones.
- If the bore is too thin, the low overtones are difficult to excite (e.g. thin whirly tube).
- This would suggest that one uses the same ratio of bore diameter to length for all instruments. However for low notes the sound is dull unless the high overtones are strong. In organs the lower pipes tend to be narrower. (2/3 diameter increase for a pipe twice as long).

Narrow vs Wide Flutes

- Narrow flutes are better for high registers
- Wider flutes louder and have richer timbre

- e.g. Indian flutes vs penny whistle, piccolo, Japanese flute

Wide holes vs narrow holes

- recorder vs bamboo flutes

Hole size and Flared ends

- Louder sound if holes are larger
- The sound that escapes through a hole depends on the wavelength. If the wavelength is much larger than the hole then not much sound radiates.
- Low instruments tend to have bells at the end
- Instruments with finger holes (meaning not brass) tend to lack bells.
- Bells on instruments with holes (clarinets, oboes) tend to primarily affect notes played with nearly all holes closed.
- Exceptions: bassoon (bass but no bell), sax (large holes *and* large bell), trumpet (has bell but is soprano)

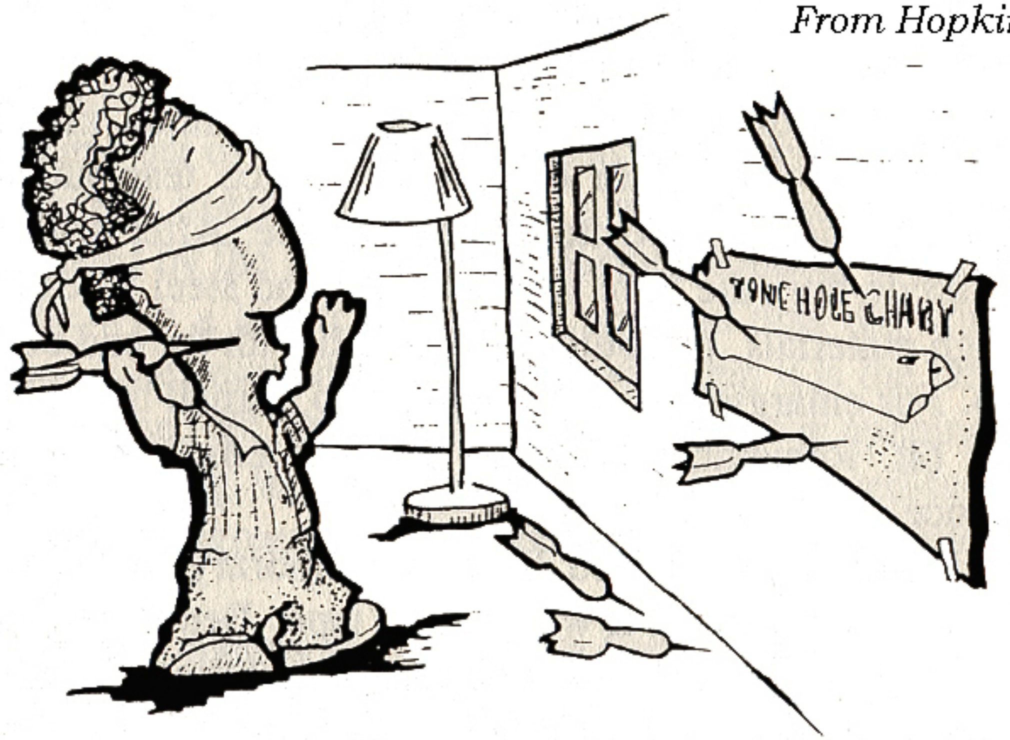
Flared ends and buildup of sound

- The shape of the end sets boundary condition as a function of frequency.
- If radiation is too efficient then sound won’t build up inside instrument. Trade off between build up and radiation.

Calculating pitch

In practice it is difficult to calculate the pitches played by a flute as a function of positions and size of holes

From Hopkin



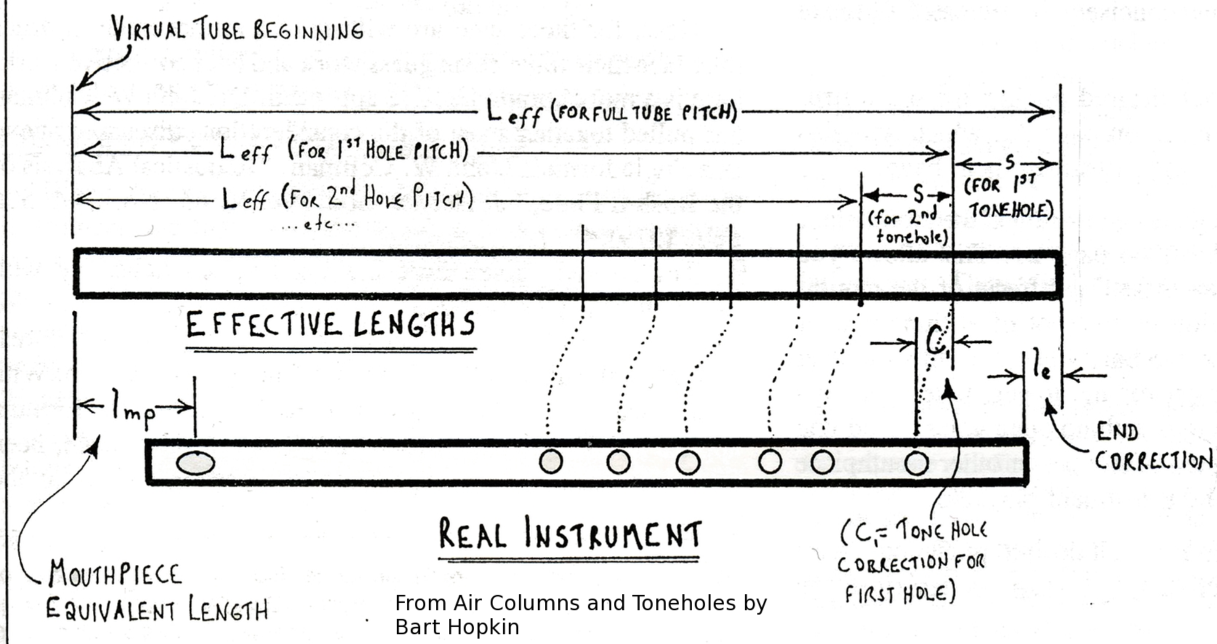
The Scientific Approach to Tonehole Placement.

Trends in pitch

To raise the pitch:

- Larger holes
- Decrease distance between holes and blow hole
- Additional holes outside the last open hole
- Decrease distance of cork from blow hole
- Thicker barrel requires larger holes for same pitch
- The smaller first open tone hole is, the more effect subsequent ones have in raising pitch
- Subsequent holes have less effect on higher registers

Calculating effective lengths with corrections



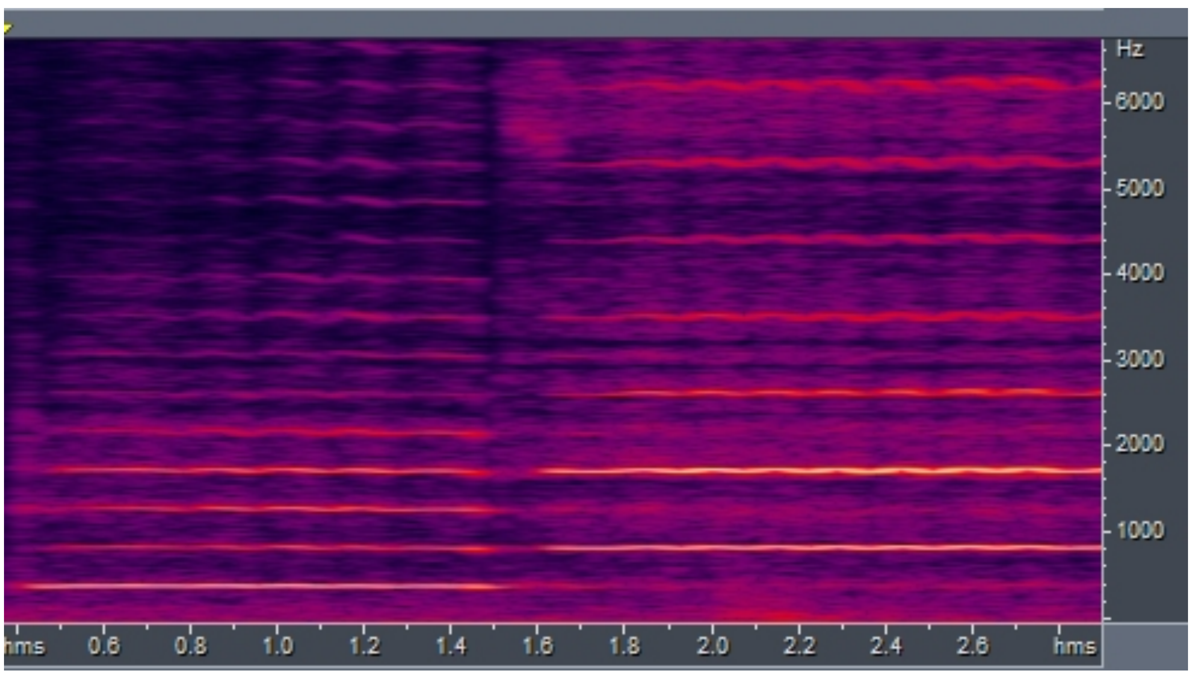
From Air Columns and Toneholes by Bart Hopkin

FIGURE 14

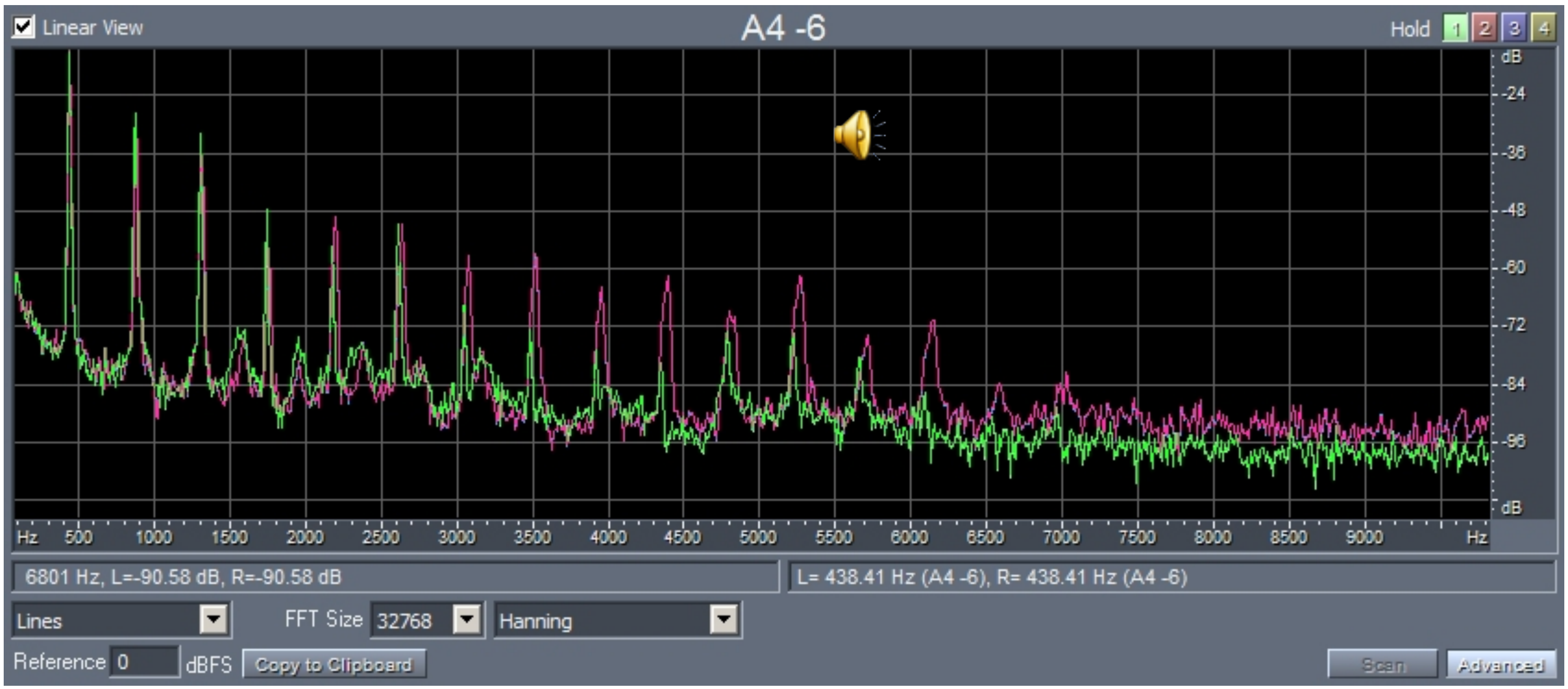
A REAL FLUTE AS IT RELATES TO AN IMAGINARY TUBE SHOWING THE EFFECTIVE TUBE LENGTHS. The seven vertical lines on the upper tube indicate effective lengths (L_{eff}) corresponding to the six toneholes and the full tube length on the real instrument shown below. Also shown are the end correction, the mouthpiece equivalent length (l_{mp}), the distance *s* between effective lengths, and the tonehole correction C (distance between the effective length and the actual tonehole location) for the first hole.

Octaves

- Low octave overtones are present even in the higher note



Differences between plastic and wood recorders



Wooden flutes

Differences:

- Diameter
- Holes, size, placement
- Types of mouthpieces
- Material/type of wood

Additional compromises

- Requiring fingers to cover holes
- No additional mouthpiece
- Material
- Restriction to one register

Pan Pipes

Solomon Islands – Pan pipes – from musical instruments of the world

Breathy sound

Closed end so an octave lower than a transverse flute

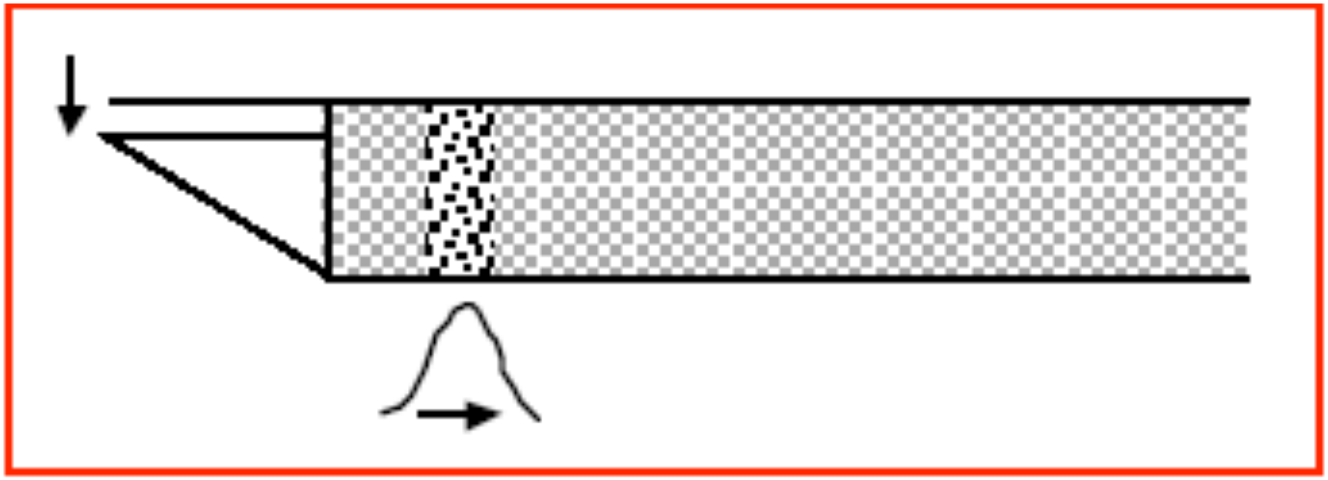
End blown flutes- Algoza (Rajasthan)

- end blown, beveled end
- one drone one melody flute
- continuous blowing (circular breathing like the digeridu)

Reed Instruments

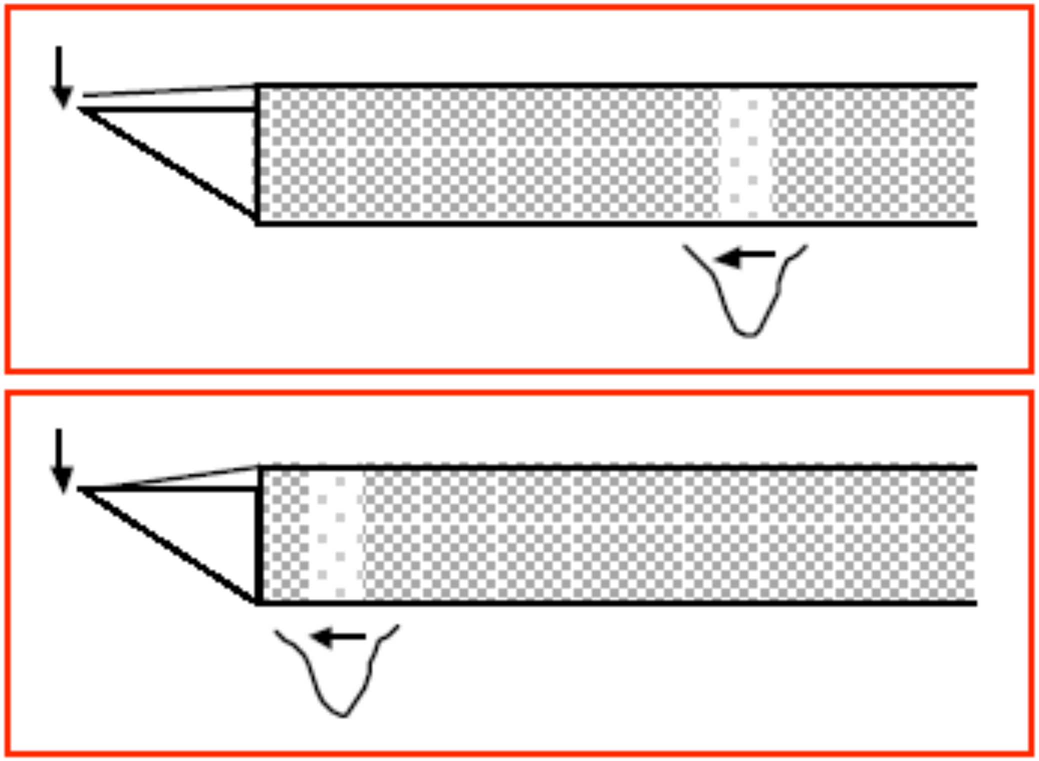
Figure 6.2: A clarinet mouthpiece and reed. By holding her mouth in just the right position and with just the right tension, the clarinet player causes the reed to vibrate up and down against the mouthpiece. Each time the reed rises, creating an opening above the mouthpiece, a burst of air from the player enters the clarinet. The length of the clarinet largely controls the frequency of the reed's vibration.

www.tufts.edu/as/wright_center/physics_2003_wkshp/book/

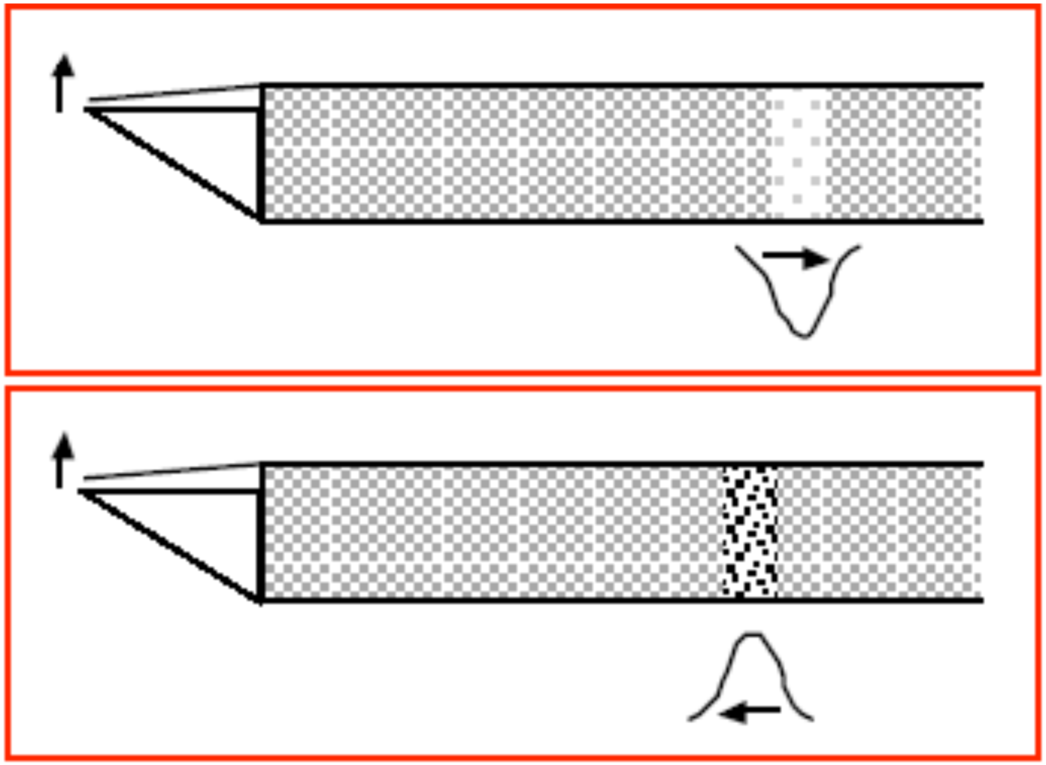


1. The puff of air the player initially blows through the instrument begins to pull the reed toward the body of the instrument and creates a region of high pressure that moves toward the end of the instrument.

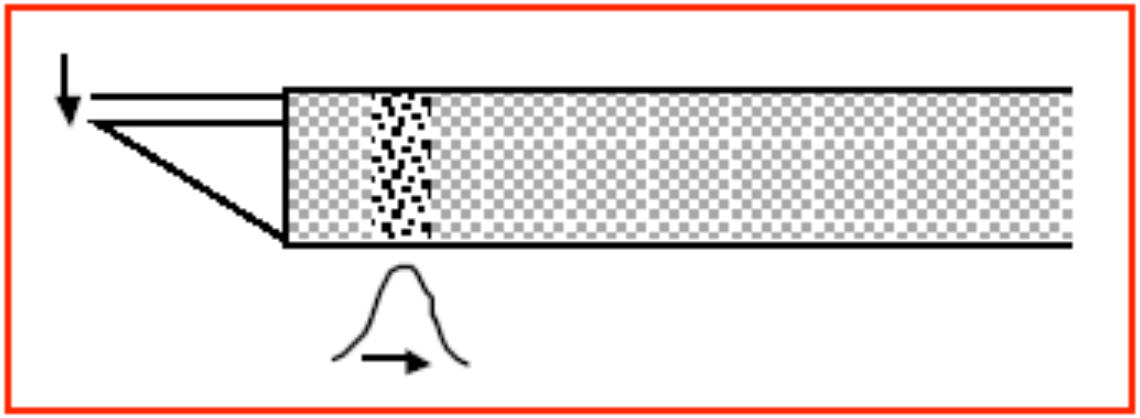
www.tufts.edu/as/wright_center/physics_2003_wkshp/book/



2. When the high-pressure region reaches the lower, normal air pressure at the end of the instrument it is largely reflected. This causes the reflected pulse to be a negative or low-pressure pulse and has the effect of pulling the reed toward the body of the instrument, closing the gap sharply.

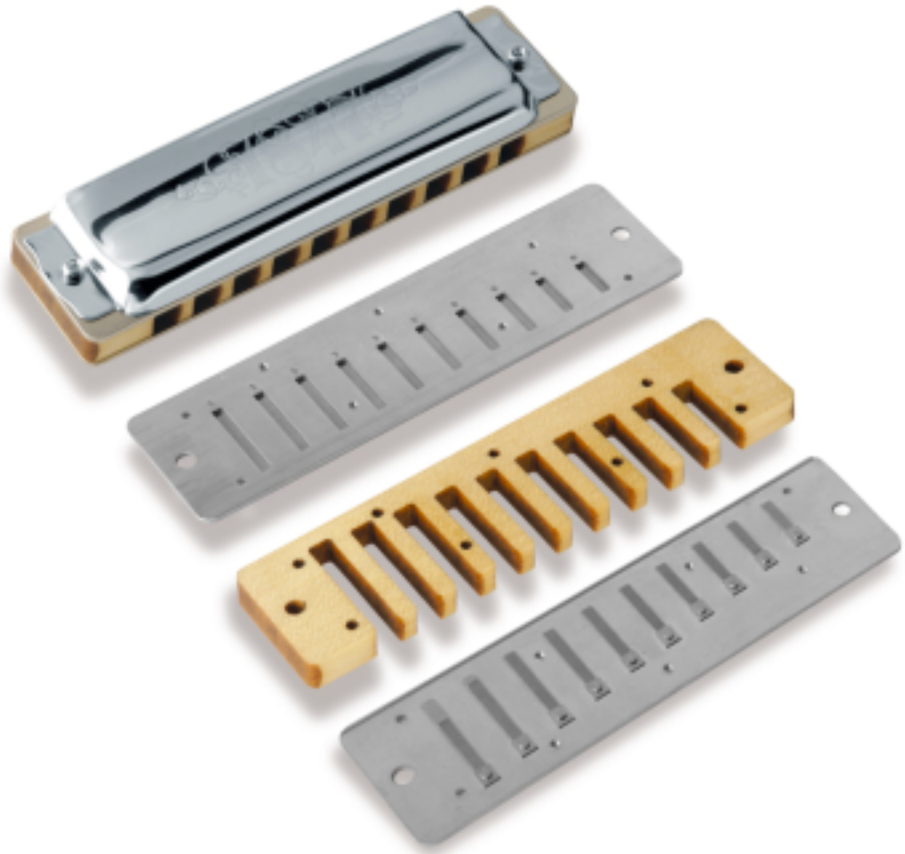


3. The low-pressure pulse is reflected from this closed end of the instrument and moves back to the other end. When it reaches the higher, normal air pressure, it largely reflects again, this time as a high-pressure pulse.



4. When the high-pressure pulse reaches the reed, it forces it open and allows the air from the player to enter and reverse the direction of the high-pressure pulse. This pattern of feedback makes it easy for the player to keep the reed frequency at the same frequency as that of the pressure wave inside the instrument.

Harmonica

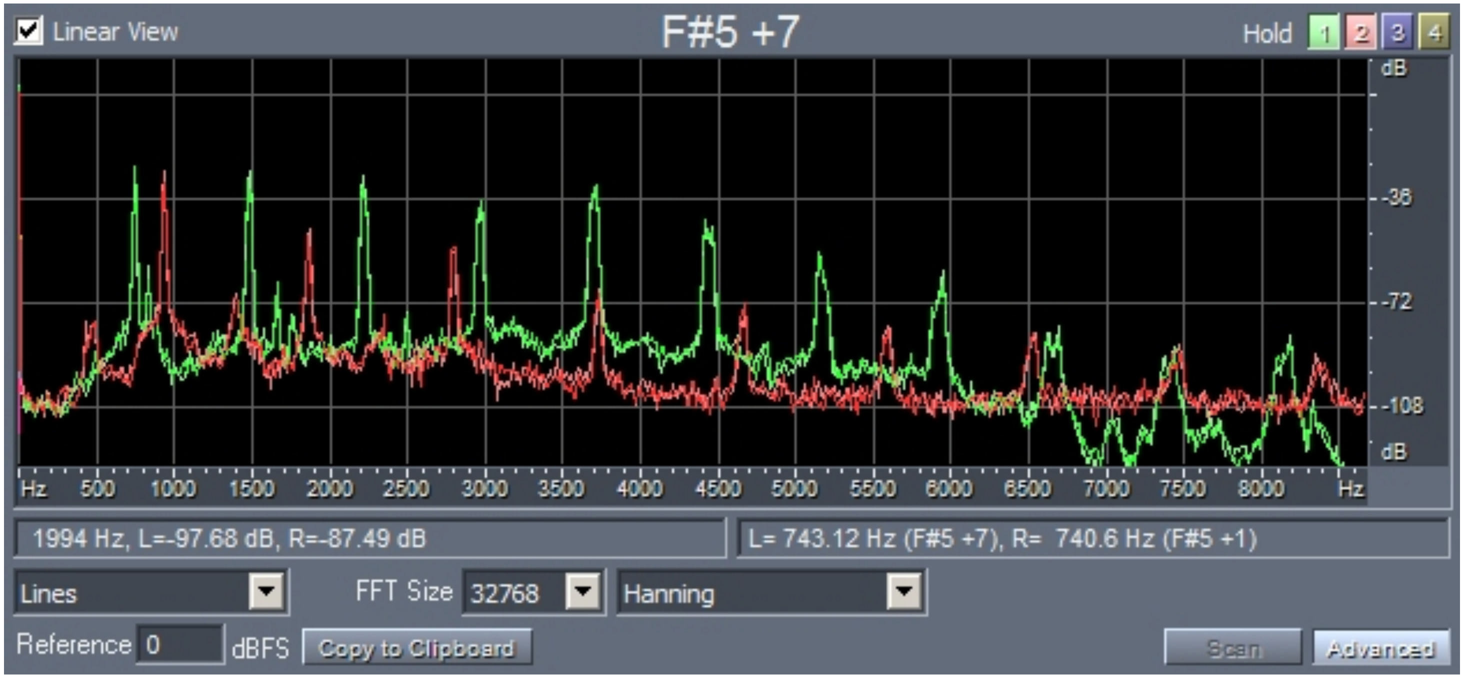


- Length of reeds set pitch
- Two sets of reeds, one for blow, other for draw

Sardinian triple clarinet -- Launeddas

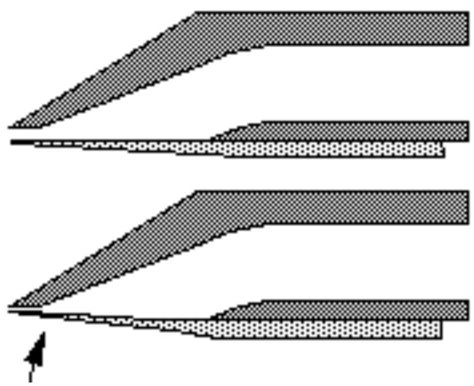
Spectrum of oboe vs flute

- red is flute, green is oboe



Excitation for reed instruments

- For excitation of tube of air
- trap door analogy for clarinet reed



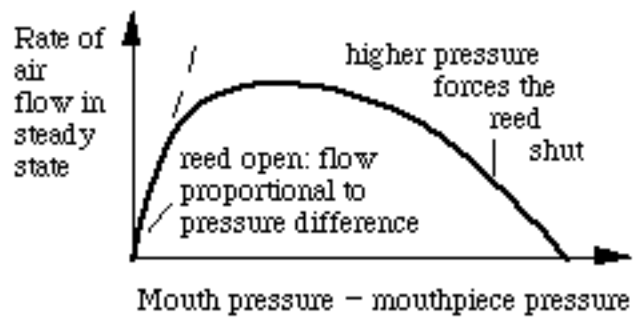


image from http://www.phys.unsw.edu.au/jw/clarinetacoustics.html#reed

- converting DC pressure into AC flow

Timbre depends on how hard you blow

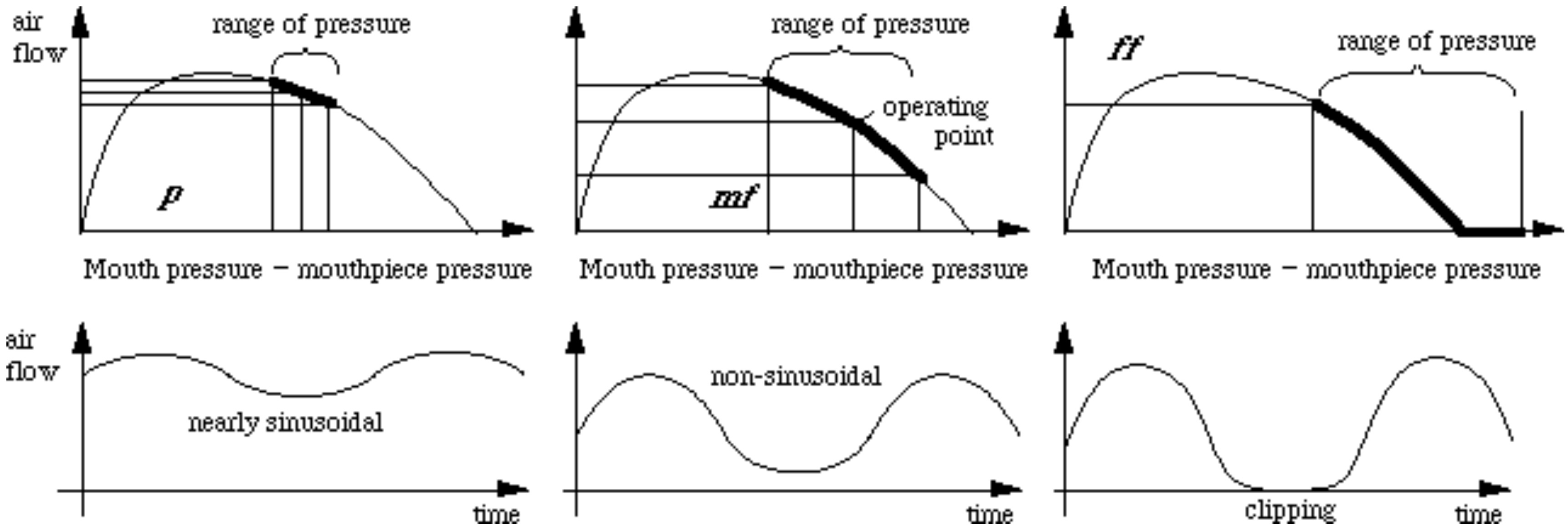


image from http://www.phys.unsw.edu.au/jw/clarinetacoustics.html#reed

- Blow pressure affects the shape of the airflow curve and so the timbre. Blowing harder increases the strength of higher harmonics.

Excitation of digi

Other noises

sound recorded near mouth

sound recorded in room

Figure 6.4: While the trumpet player's lips are not a true "reed," when they buzz against the mouthpiece, they provide the same frequency of airbursts as a mechanical reed.

Note: the shape of the mouthpiece is important as it affects the high frequency response of the instrument!

Wooden trumpets Central African Republic

- Ongo ensemble of the Banda people consists of wooden and antelope horn trumpets

Closed/open pipe

- Which instruments behave like closed ends?

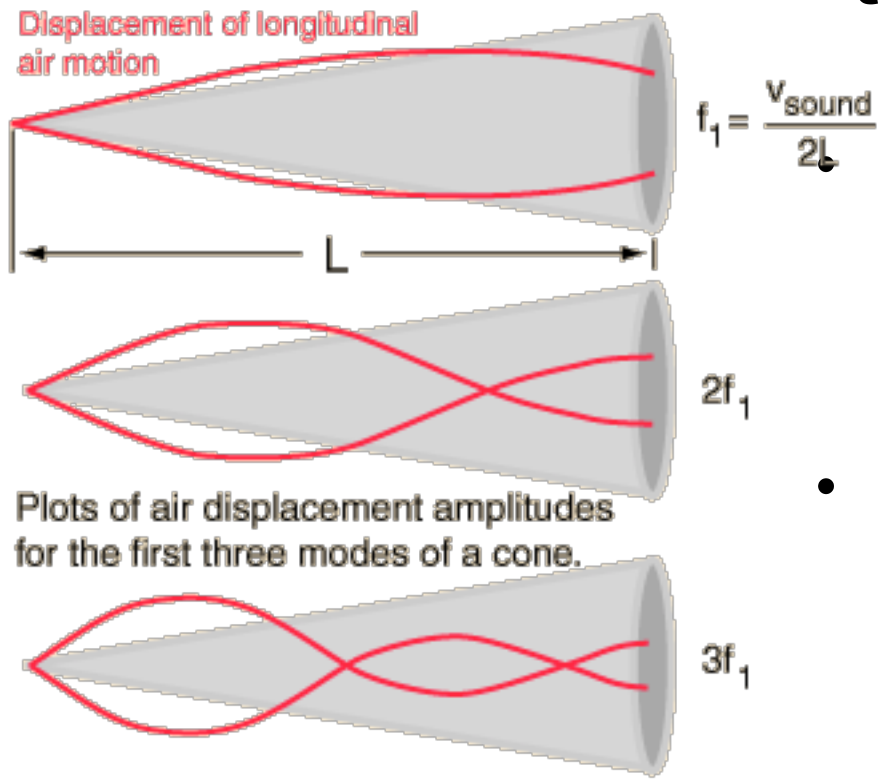
Clarinet, oboe, brass, some pan pipes?

- Which ones have open/open ends?

Organ, flute, recorders, organ pipes

We might expect odd integer overtones from the brass, however the bell at their end shifts the overtone spectra to nearly all integers

Wavelength shift due to conical bore

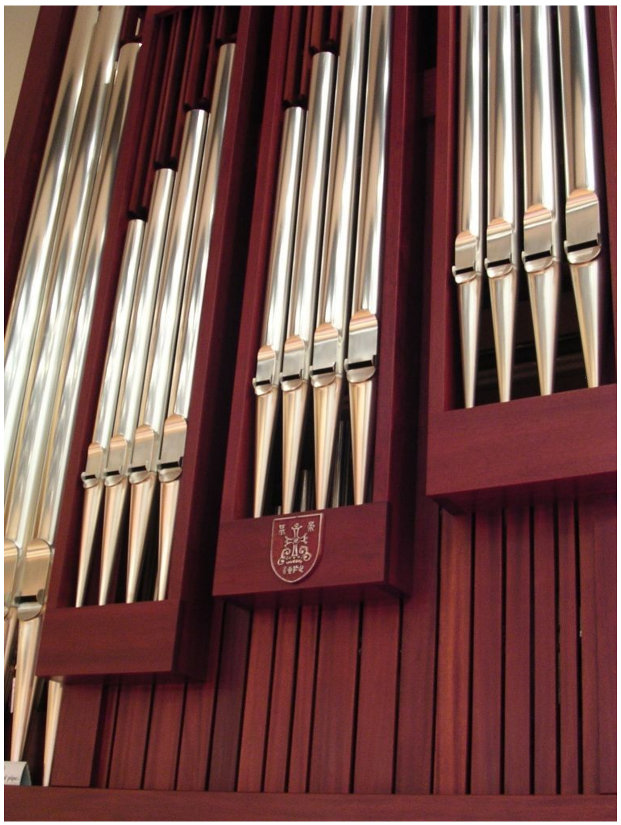


- Easiest way to think of this is in terms of volume and air piling up at anti-nodes.
- Mouthpiece cuts off the end of the cone but is an approximate match to volume of that cone.

Ocarinas

- More like Helmholtz resonators.
- Pitch is changed by adding holes

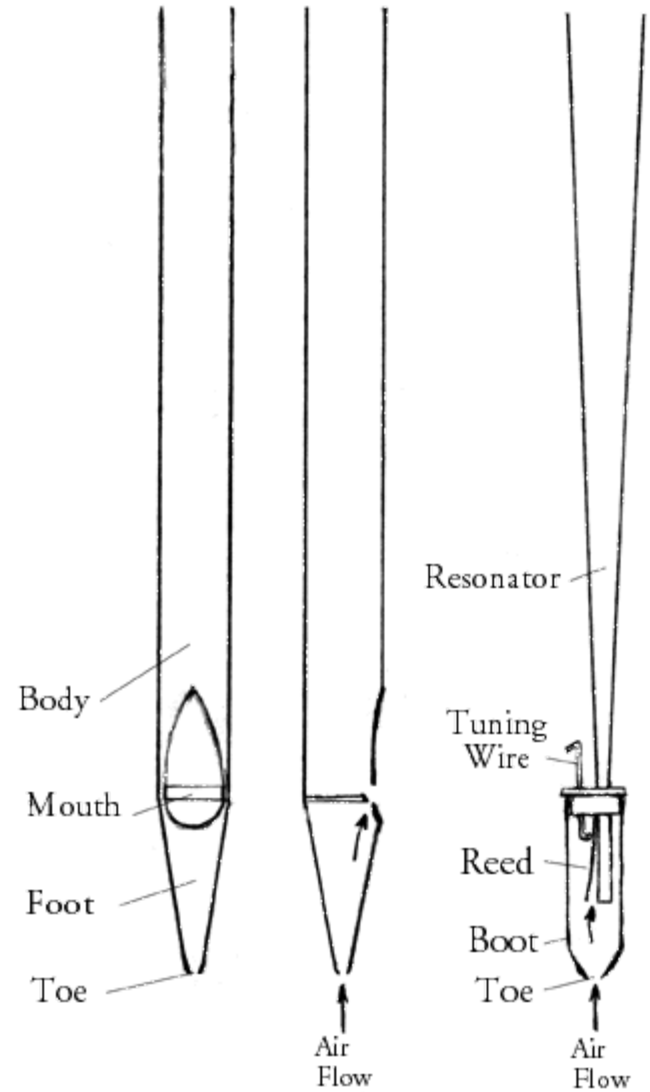
Organ pipes



Technological innovations led to improved air pumps in the late middle ages showcased in churches

Types of organ pipes

- open/closed flue type – acoustics similar to flute but airflow is very important
- Reed type– tuned by adjusting length of reed – like the quack caller hunters use but with a more interesting resonator.

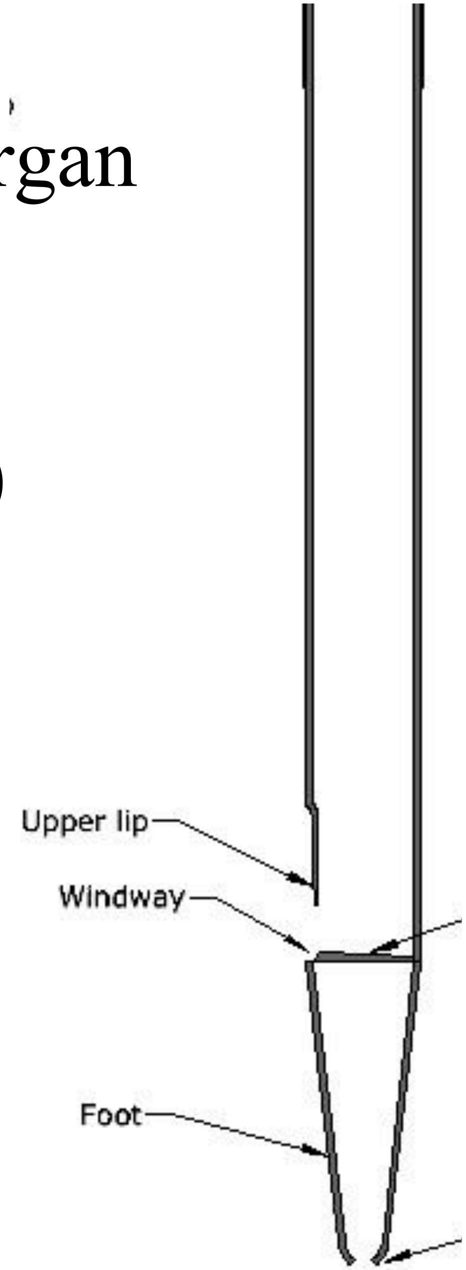


Voicing of Craighead-Saunders Organ
Christ Church (Episcopal)
Eastman Rochester Organ Initiative
by **Munetaka Yokata** (2008)

Adjusting the depth and shape of the lip

The organ is a reproduction of a 1776 organ from Vilnius Lithuania


this image from Oberlin to illustrate voicing



Organ Pipe Voicing
Delay of fundamental harmonic