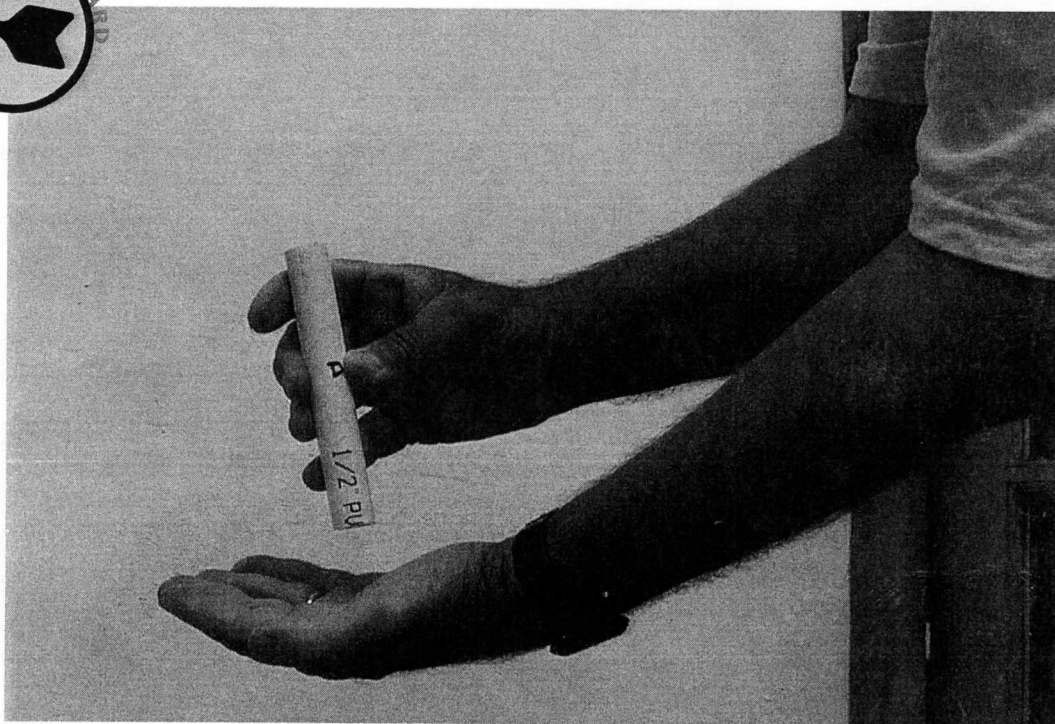


Palm Pipes

**Make music that's
entirely out of hand.**

If you bang the open end of a piece of PVC pipe against the palm of your hand, you'll make a musical sound. The frequency, or pitch, of the sound depends on the length of the pipe. Based on this simple but significant fact, you can make instruments for your own pipe band. You'll find it surprisingly easy to play some simple songs.



Materials

- PVC shears or hacksaw (Inexpensive PVC shears are amazingly handy for cutting PVC pipe and can be bought at hardware or home improvement stores; if available, an electric band saw, chop saw, or table saw makes the job of cutting many pieces of PVC go even faster.)
- $\frac{1}{2}$ -in PVC pipe, about $6\frac{1}{2}$ ft (2 m) long
- centimeter ruler
- sandpaper (if necessary)
- permanent marker pen
- some friends

ASSEMBLY

1 Cut a piece of PVC to each of the 15 lengths listed in the box shown here.

2 If the cutting process leaves sharp edges or fragments on the ends of any of the pipes, remove them with sandpaper.

| Note | Length (cm) | Frequency (Hz) |
|----------------|-------------|----------------|
| F ₁ | 23.6 | 349 |
| G ₁ | 21.0 | 392 |
| A ₁ | 18.7 | 440 |
| B ₁ | 17.5 | 446 |
| C ₁ | 15.8 | 523 |
| D ₁ | 14.0 | 587 |
| E ₁ | 12.5 | 659 |
| F ₂ | 11.8 | 698 |
| G ₂ | 10.5 | 784 |
| A ₂ | 9.4 | 880 |
| B ₂ | 9.2 | 892 |
| C ₂ | 7.9 | 1046 |
| D ₂ | 7.0 | 1174 |
| E ₂ | 6.2 | 1318 |
| F ₃ | 5.9 | 1397 |

3 Label each pipe with the musical note corresponding to its length. The subscripts in the list refer to the octave of the note. (The first note in the list is the F above middle C.)

To Do and Notice

Play the songs below by gathering a group of people, distributing one pipe to each person, and having each player sound his or her pipe at the right time. Before you begin, each person should practice making a good tone by holding the pipe vertically with one hand and banging the bot-

tom end into the palm of the other hand. It's important not to cover the top end of the pipe.

Playing a song is easiest if there's one player per note, but if you have too few people, you can have one or more players take responsibility for two pipes. If you do this, however, make sure a person doesn't have to sound two different notes in a row. If you have many more people than

there are notes in a song, you can have some players play pipes that are an octave lower than the ones called for. For example, when the F₂ pipe for "Twinkle, Twinkle, Little Star" is being played, another player can play the F₁ pipe at the same time.

You may find it helpful to have one person act as a conductor. A little practice will help a lot. Have fun!

Mary Had a Little Lamb

(Pipes C₁, D₁, E₁, and G₂: four players)

E D C D E E E D D D E G G
E D C D E E E D D E D C

Twinkle, Twinkle, Little Star

(Pipes F₂ through D₂: six players)

F F C C D D C B₁ B₁ A A G G F
C C B₁ B₁ A A G C C B₁ B₁ A A G
F F C C D D C B₁ B₁ A A G G F

Jingle Bells

(Pipes C₁ through G₂: five players)

E E E E E E E G C D E
F F F F F E E E E D D E D G
E E E E E E E G C D E
F F F F F E E E E G G F D C

My Country 'Tis of Thee (America)

(Pipes E₁ through D₂: seven players)

F F G E F G A A B₁ A G F G F E F
C C C C B₁ A B₁ B₁ B₁ B₁ A G
A B₁ A G F A B₁ C D B₁ A G F

What's Going On?

When you hit the open end of the pipe against your hand, air molecules in the bottom of the tube are squeezed together. This starts a process that takes four trips up and down the tube (see figure 1).

The molecules that have been squeezed together, in turn, squeeze the molecules next to them, and so on. In a sort of domino effect, the pulse of compression (high-pressure air) travels up the tube. When the pulse of compression reaches the top of the tube (see figure 1b), it expands outward into the air around the tube. In the process, some air molecules overshoot the end of the tube, producing a region of expansion (low-pressure air) in the top of the tube.

Air molecules just below the area of expansion rush upward to fill it, creating a pulse of expansion that travels back down the tube. When this pulse reaches the bottom, it reflects off your palm and travels back up the tube as another pulse of expansion (see figure 1c).

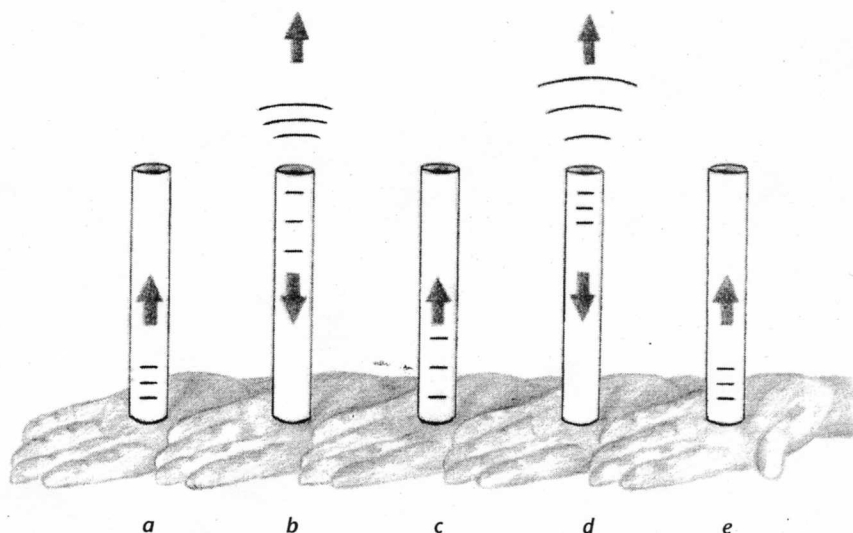


Figure 1 Slap the pipe with your hand: (a) a compression pulse travels up; (b) the compression reflects from the open end as an expansion; (c) the expansion reflects from your hand; (d) the expansion reflects from the open end as a compression; and (e) the process repeats.

When it reaches the top, some air from outside the tube rushes into the low-pressure area, creating an area of compression, which travels as another pulse back down the tube (see figure 1d).

When this pulse of compression reaches the palm of your hand (see figure 1e), it reflects, and at this point the whole process repeats itself.

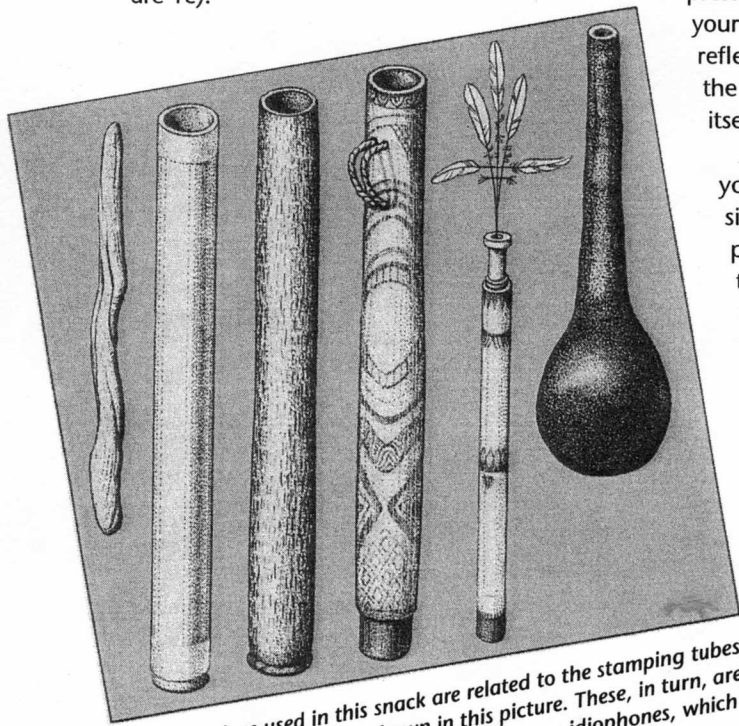
A pulse that starts at your palm as a compression makes four complete transits of the tube (up as a compression, down as an expansion, up as an expansion, and down as a compression) before one whole cycle is completed. This four-part cycle corresponds to one wavelength of a sound, or one single vibration. A series of these repeated cycles is the source of the

sound you hear when you "play" one of the pipes.

The length of the tube affects the note that the tube produces. Because the speed of sound waves is the same in all the tubes, the length of the tube has a direct effect on the time it takes for a compression-expansion pulse to make its four transits of the tube. The longer it takes for a pulse to complete its cycle and start over again, the fewer the cycles, or vibrations, per second. The fewer the vibrations per second, the lower the frequency of the sound, and the lower the musical note. Thus, long tubes produce lower notes, and short tubes produce higher notes.

So What?

Instruments with a long tube, such as a bass saxophone, produce lower frequency notes than instruments with shorter tubes. Although modern symphony instruments may seem quite complex, the basic relationship between long and short tubes is the same as exists for the simple palm pipes in this snack.



The palm pipes used in this snack are related to the stamping tubes, stamping stick, and gourd shown in this picture. These, in turn, are part of a larger family of instruments known as idiophones, which includes rattles, bells, gongs, and xylophones, among others.

Twinkle, Twinkle, Little Star

(Pipes F₂ through E₂: three players on Melody [M], and three players on Harmony [H])

| | | | | | | | | | | | | | | |
|----|---|---|----------------|----------------|----------------|----------------|---|----------------|----------------|----------------|----------------|---|---|---|
| M: | F | F | C | C | D | D | C | B _b | B _b | A | A | G | G | F |
| H: | C | C | A | A | B _b | B _b | A | G | G | F | F | E | E | C |
| M: | C | C | B _b | B _b | A | A | G | C | C | B _b | B _b | A | A | G |
| H: | A | A | G | G | F | F | C | A | A | G | G | F | F | C |
| M: | F | F | C | C | D | D | C | B _b | B _b | A | A | G | G | F |
| H: | C | C | A | A | B _b | B _b | A | G | G | F | F | E | E | C |

Going Further

Two Voices

Have one group of players play the melody notes (M) of "Twinkle, Twinkle, Little Star," while another group plays the harmony notes (H) shown below each melody note.

If It Hertz

You can calculate the approximate frequency of sound that any length of pipe will produce. Here's how:

The velocity of a sound wave (v) is equal to its frequency (f) times its wavelength (λ). Rearranging this equation gives $f=v/\lambda$. The value for v is about 350 m/s, the speed of sound in air around room temperature. The

value for λ can be obtained by multiplying the tube length (in meters) by 4 (which is the number of transits a compression-expansion pulse makes inside the tube for one sound wave). Therefore, if you divide 350 m/s by a tube's λ value, you obtain the approximate frequency (in cycles per second, or *hertz*) of the note the tube will produce. (Exact values involve additional considerations, such as the diameter of the tube.)

The Difference a Diameter Makes

Reflection of a sound wave doesn't occur exactly at the open end of a tube but instead happens at a point slightly beyond the end. The larger the diameter of the pipe, the farther

from the end the reflection occurs. To more accurately estimate the value for the frequency, add 0.3 of the inside diameter to the length of the tube. Try this snack with pipes of different diameters.

Credits & References

This activity was developed by Gene Easter and Bill Reitz. Art Fortgang first brought it to our attention.

Hopkin, Bart. *Musical Instrument Design*. Tucson, Ariz.: See Sharp Press, 1996. An invaluable reference for designing and experimenting with homemade musical instruments.

SOME SONGS FOR PALM PIPES

| Note | Length (cm) | Frequency (Hz) |
|------|-------------|----------------|
| C | 15.8 | 523 |
| D | 14.0 | 587 |
| E | 12.5 | 659 |
| F | 11.8 | 698 |
| G | 10.5 | 784 |
| A | 9.4 | 880 |

Mary Had a Little Lamb (C,D,E,G)

E D C D E E E D D D E G G

E D C D E E E E D D E D C

Twinkle, Twinkle, Little Star (C,D,E,F,G,A)

C C G G A A G F F E E D D C

G G F F E E D

G G F F E E D

C C G G A A G F F E E D D C

Oh Susanna (C,D,E,F,G,A)

C D E G G A G E C D E E D C D

C D E G G A G E C D E E D D C

F F A A A G G E C D

C D E G G A G E C D E E D D C

Songs for Palm Pipes.....2/13

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Eensie Weensie Spider (C,D,E,F,G)

G C C C C E E E D C D E C

E E F G G F D F G E

C C D E E D C D E C

G G C C C D E E E D C D E C

Farmer in the Dell (C,D,E,G,A)

G C C C C C

D E E E E E

G G A G E C

D E E D D C

London Bridge (C,D,E,F,G,A)

G A G F E F G

D E F E F G

G A G F E F G

D G E C

Reference

Square Wheels, by Don Rathjen, Paul Doherty and the Exploratorium Teacher Institute, The Exploratorium, San Francisco, 2002. See **Palm Pipes**, pp. 59-62.