

In making a garden-hose recorder, bamboo flute, or any other woodwind-type instrument, you must eventually face up to this decision. Here are some possibilities:

1. Follow someone else's detailed instructions that tell you exactly where to drill each hole. Or make a close copy of an existing instrument, merely placing the holes the same way. Results are likely to be fairly good this way (although you may still want to follow suggestions below for fine adjustments), but it won't teach you much about why the holes were where they were. (25)
2. Drill holes more or less at random, taking a chance on whether you will like the result. You might come up with an interesting scale that you would enjoy listening to--there's no law saying we can only use diatonic major scales. And you might learn quite a bit--for example, that evenly spaced holes don't give evenly spaced notes--if you try to understand why the results come out as they do. But of course this procedure is most appropriate to playing with cheap and easily workable materials, so that it's no big deal to throw one away and turn out another with a different pattern of holes. The garden hose is good for this.
3. Drill according to the predictions of a simple theory; for instance: Each half-step on the equal-tempered scale represents a 6% increase in frequency, hence for a complete octave you need the sequence of frequencies  
 $1, 1.059, 1.122, 1.189, 1.260, 1.335, 1.414, 1.498, 1.587, 1.682, 1.782, 1.888, 2$   
 or a subset like the underlined ones that makes a major scale. But wavelengths are inversely proportional to frequencies, and pipe lengths are half-wavelengths, so divide each of these numbers into one to obtain the sequence  
 $1, .944, .891, .841, .794, .749, .707, .667, .630, .595, .561, .530, .500$   
 which tells fractions of the total length of the pipe for each hole. That is, measure the length of the pipe from the edge that breaks up the airstream to the bottom end, and multiply it by each of these numbers to tell how far down from the top to put the holes. Or if you want to get into "just" scales, you can generate a slightly different set, such as  
 $1, .889, .800, .750, .667, .593, .533, .500$ .  
 Unfortunately, the result will not be what was intended. True, it is informative to discover this, but you do not want to be taken by surprise after hard work on a really nice piece of wood.
4. Realize that the big issue here is that boring a hole does not give as high a pitch as would completely cutting off the tube at that same point, because the hole does not let the air flow as freely as an end would; some small pressure difference can still be maintained across the hole; the presence of the bottom part of the pipe still has some effect. A complete theory to deal with this gets quite complicated, but we can quote a useful approximate result from it. Turn the page for the big secret.

Let  $b$  be the distance from the actual hole down to an imaginary hole that would correspond to the simple theory of part 3 above. Let  $A$  be the cross-sectional area of the air column; that is,  $A = 0.785 d^2$ , where  $d$  is the inner diameter of the tube. And let  $D$  be the diameter of the hole. Then  $b$  times  $d^2$  is approximately equal to  $A$ . This suggests either of two procedures:

Calculate the position of the imaginary hole with the simple theory.

Decide how big your hole is going to be, and calculate  $b = A/d^2$ .

Then drill your actual hole that much higher up the tube.

Decide where you want the hole to be (perhaps for convenience in being able to put your finger on it). Measure the distance from there down to the calculated position of the ideal imaginary hole. Calculate  $D^2 = A/b$  and make your hole that big.

5. Regardless of how you make your initial decision, you would like to leave as much room as possible for correction, or fine tuning. So you may want to use these tricks:

A. If you want to have your instrument in-tune with others, leave it a little too long while you get the mouth-hole working. Then trim off the lower end a bit at a time until you get the pitch (with no holes yet) up to what you want for the lowest note in your scale.

B. Work from the bottom up, and finish each hole completely before going up to the next one. Any time you backtrack and modify lower holes, you will be changing more than one note at a time.

C. Make each hole smaller at first than its eventual size. Then if you have gotten the hole a little too high on the tube, you will be able to get by with just leaving the hole small. Or if the hole is too low (and so the pitch too low) you can go ahead and enlarge it. Although any enlargement of the hole must raise the pitch, you still have considerable control, because enlarging the hole on the upper side will raise the pitch rapidly while enlarging it on the lower side will raise the pitch only slightly. So when you first drill the small hole, the pitch should be too low, and as you enlarge the hole the pitch should approach whatever is desired. If you approach this pitch too rapidly (the pitch is nearly right but you still want a larger hole), then cut mainly on the lower side; if you approach too slowly (the hole is nearly as big as you want it but the pitch still needs to come up a lot), then do your cutting on the upper side of the hole.

6. If the instrument does not overblow easily for the second octave, you can try putting a small thumbhole roughly a third of the way down the tube. (That is a compromise--it would ideally be halfway down for the lowest note but only about a quarter (halfway to the first open hole) for the highest.) Or leaking a little air from one or another of the higher holes already there will probably serve the same purpose.