Making Medieval & Renaissance Woodwind Instruments

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Modern instruments

The goals of instrument makers received a major overhaul with the rise of romanticism in the 18th century. Romanticism valued the spontaneous expression of strong emotion by individual genius. This, coupled with increasing technical refinement, produced modern instruments that:

- have a very wide pitch range, at the very least two and a half octaves
- are fully chromatic without resorting to cross-fingering
- are in good tune over their full range
- have a very wide dynamic range
- allow expressive variation in timbre
- are adequately loud

A modern musician will often specialize in a single instrument, with the pinnacle of expressive power in an instrument only achievable by extremely fine motor control after extended practice.

Medieval and renaissance instruments

Medieval and renaissance instrument makers did not have the technical skill to create an instrument with all of the above features in the one instrument. Various features had to be sacrificed to allow others to be achieved. Nor would they necessarily recognize some of the above to be desirable. The social status of musicians was also different, and the line between composer and musician was very blurred.

One rough division we might make is into haut and bas instruments. A haut instrument would be suitable for playing outdoors, it would be loud, bright in tone, be relatively high pitched, and perhaps be in tune over a moderately wide pitch range. A lively or martial instrument. A bas instrument would be an indoors instrument, quiet, soft in tone, low pitched, and perhaps with a limited pitch range but capable of greater chromaticism. A more refined instrument.

Consort music became popular during the renaissance. This is harmony played by a group of the same type of instrument in different sizes, blending into a unified sound. Since a range of sizes were used, individual instruments did not need a wide range of pitch. It would not be uncommon for the musicians of a consort to switch instruments en masse several times during a performance. Instruments for consort music would fall into the bas category.

Physics

A wind instrument is a resonant tube excited by pressure pulses from some excitation mechanism. Reflected pulses from the tube in turn prod the excitation mechanism into producing further pulses of pressure. The physics of resonant tubes produces a limited set of possibilities which we can use to classify instruments. Resonant tubes respond *linearly* to excitation and are easy to model. For example, we can compute the correct places to put finger holes relatively easily. The excitation mechanism is *non-linear* and defines much of the unique character of each instrument.

Pressure waves travel up and down a cylindrical or conical tube at the speed of sound. A closed tube end reflects a pressure wave back the way it came. An open tube end also reflects a pressure wave, but positive pressure becomes negative and vice versa.

Reeds and lips behave similarly to a closed end. When hit with a pressure wave, the reed or lips are pushed open, allowing a burst of air through like a slightly amplified reflection.

The mouthpiece of a flute or recorder-like instrument behaves like an open end. In these, air flows across a hole. When a negative pressure wave reaches the hole, the flow is sucked into the instrument, creating a wave of positive pressure. When a positive pressure wave reaches the hole existing flow into the tube is diverted outside instead, creating a negative pressure wave.

Tube resonant frequencies

- **A cylindrical tube of length L open at both ends can resonate at wavelengths 2 L, 2/2 L, 2/3 L, 2/4 L, etc.**

- **A tube open at one end can resonate at wavelengths 4 L, 4/3 L, 4/5 L, 4/7 L, etc.**

Thus a cylinder with one end closed has a deeper pitch for the same length. Rather annoyingly, its second register is a twelfth rather than an octave above its first register. Since it has odd numbered harmonics only, the timbre is also different.

However, surprisingly:

- **A conical tube closed at the apex of the cone will resonate at wavelength 2 L, 2/2 L, 2/3 L, 2/4 L, etc,** just like a cylinder open at both ends of the same length.

So, for example, a saxophone (conical bore) plays an octave higher than a clarinet (cylindrical bore) of the same length.

Finger holes

An open finger hole effectively shortens the length of the tube. How much the tube is shortened is dependant on the position of the hole, the relative area of the hole to the bore cross-section, and which register the instrument is playing in (this last is more of a problem with small holes).

Small holes are necessary for cross-fingering to work -- closing holes below a large open hole has little effect. Small holes also reduce the loudness of higher harmonics, producing a less bright sound (this might or might not be desirable).

Modern instruments have complicated key mechanisms that allow a hole for every pitch in the chromatic scale, making cross-fingering unnecessary, and therefore allowing large holes.

Bore deviations

A bore that widens or narrows at certain points has an effect on the resonant frequencies, and the effect can be different in different registers. Careful placement of bore deviations can correct the register-dependant effect of small finger holes.

For example, from the baroque onwards, recorders have had a cylindrical bore near the mouthpiece that transitions to a conical bore that shrinks toward the end. The Western concert flute takes the opposite approach, the bore is largely cylindrical but shrinks toward the mouthpiece. The Chinese dizi flute has a covered hole between the mouthpiece and the finger holes, effectively widening the bore slightly at this point.

An instrument that is in tune over several registers has a different timbre to one that is not, and it may be desirable to make an instrument that is in tune in the upper registers even if these registers are not reachable.

Common medieval and renaissance instruments

There are many wonderfully strange medieval and renaissance instruments. I am here only going to describe some of the more common ones.

Notably absent are single-reeded instruments such as the clarinet and saxophone. The earliest such instrument, the chalumeau, was developed in the late baroque.

A figure from Baines (1962) showing the prevalence of various instruments over time:

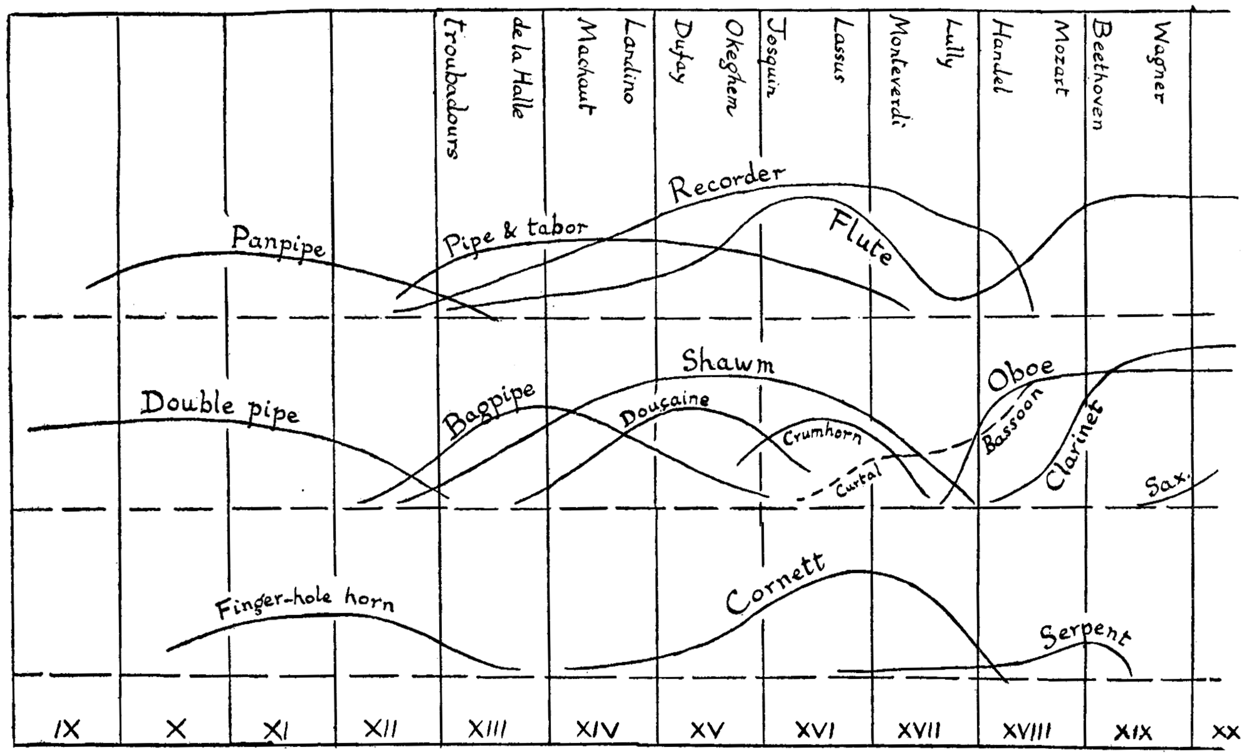

FIG. 49. *Chronological scheme of European woodwind instruments and precursors. Each hump indicates* approximately the period of the instrument's employment in courtly and professional music.

Shawm - double reed - conical bore

Also known as the "hautbois", literally "high wood", a name that eventually evolved to "hoboy", and finally "oboe".

The shawm reed resembles a modern bassoon reed, although with different proportions. The shawm's double reed is not simply a reed squashed flat. Instead there is a complicated procedure in which a strip of reed is carefully prepared then folded over on itself, and the fold cut to form the air entryway. This dates back to at least the 16th century.

Figure from Baines (1962) showing steps in bassoon reed making:

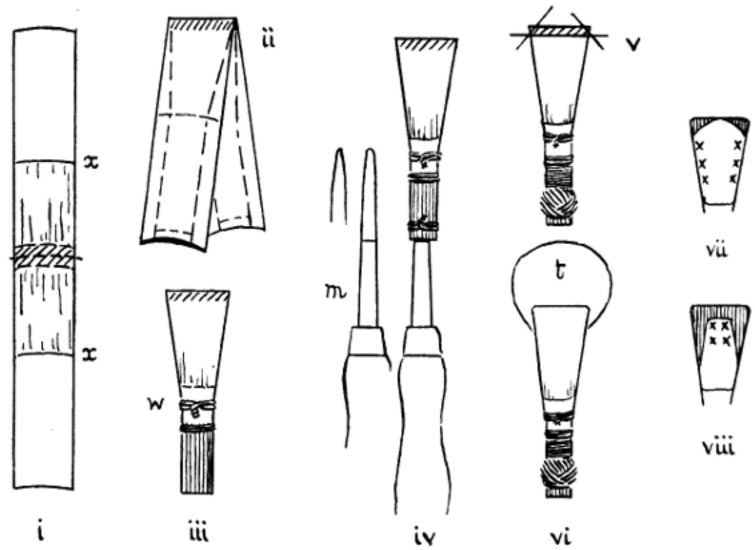

FIG. 12. *Stages in bassoon reed-making.*

A feature found in the shawm but not the oboe is the "pirouette", a cylinder of wood around the reed against which the lips are pushed, allowing the reed to be blown on with greater force. This sacrifices the fine control that an oboe player can apply by adjusting the pressure of their lips on the reed, and may even have made the upper register unreachable -- the conical bore would still be desirable as a way to produce a loud, high pitched, bright tone.

Douçaine - double reed - cylindrical bore

There is some debate over the exact nature of this instrument. One of the finds from the wreck of the *Mary Rose*, from the fleet of Henry VIII, was an instrument that is proposed to be a douçaine, an instrument mentioned by several medieval and renaissance authors (Myers, 1983). It is similar to a shawm, being a double-reed instrument, but has cylindrical rather than conical bore, producing a softer sound, and an octave lower than a shawm of the same length.

Crumhorn - double reed - cylindrical bore

Similar to the douçaine, but J shaped rather than straight, and the reed is enclosed in a cap and does not come in contact with the lips. The cap arrangement makes this an easy instrument to play, but it is not possible to overblow into higher registers and it therefore has a limited range. A typical consort instrument.

Bagpipes - single and double reeds - cylindrical bores

The "chanter" pipe excited by a double reed is used to play a melody, while one or more single reeded "drone" pipes drone. All are fed air from a bladder.

Cornett - lips - conical bore

Similar to a shawm, a conical instrument with finger holes, but using the lips to produce sound as with a trumpet. Made with an octagonal cross section and wrapped in leather, for no apparent reason.

Pan pipes - flute-like - cylindrical bore

This is an easy one to make. A series of tubes, such as a series of reeds, each closed on the bottom. Blowing across the top of a particular tube yields a particular note. It helps if the top of the hole is shaped like:

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     <==blow==
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There is a variant that consists of a block of wood with with a series of holes drilled in it. Several such panpipes have been found in Roman sites in France, Germany, and England, and one at a Viking site in York (Clare, 1993).

The pipes can be fine-tuned by dribbling wax into the holes.

Transverse flute / fife - flute-like - cylindrical bore

It's a tube with some holes in it. One end is stopped up. You blow across a hole near the stopped up end. (The mouth-hole acts as one of the ends of the resonant tube, so acoustically it is still open at both ends.) For all their simplicity, transverse flutes are expressive and have a decent range.

The measurements for extant tenor renaissance flutes indicate a rather small embouchure hole and finger holes (Puglisi, 1979). While the bore is cylindrical, the exterior has a slight taper. Military flutes may be somewhat different but there are too few examples to judge (Puglisi, 1988). Also, a tenor flute might not have been a solo instrument as it is today, as the range would have been more restricted.

"Flute" is the older term. "Fife" derives from "pfiefe" (German for pipe). "Flute" can also be used to refer to recorder-like instruments.

Cheap plastic or metal fifes are available, a good second instrument after a recorder for the SCA. Flutes are also very easy to make.

Renaissance flutes had a cylindrical bore. The Baroque saw a change to a cylindrical headpiece and conical body narrowing toward the end. This produces a softer, sweeter sound and increases the range. A single key was added, allowing E-flat to be played and hence full chromaticism by cross-fingering. The modern Boehm flute has a cylindrical body and conical head, something of a return to the original form and timbre, but retaining the increased range. Boehm also went a bit nuts adding extra keys.

Recorder / Flageol - recorder-like - cylindrical bore

A popular consort instrument. The name "recorder" dates back to the 14th century. "Flageol" is an Old French term. A diminutive form, "flageolet", seems to have come to strand for this whole family, but I'm not sure when this became common.

Two flageols were sometimes played simulataneously (the ancient Greeks had a similar trick using two double-reed pipes -- the "aulos", plural "auloi").

Renaissance recorders had a cylindrical bore. Since the baroque era, recorders have had a cylindrical head and a conical body (narrowing toward the end). This produces a sweeter, softer sound and increases the range of the instrument.

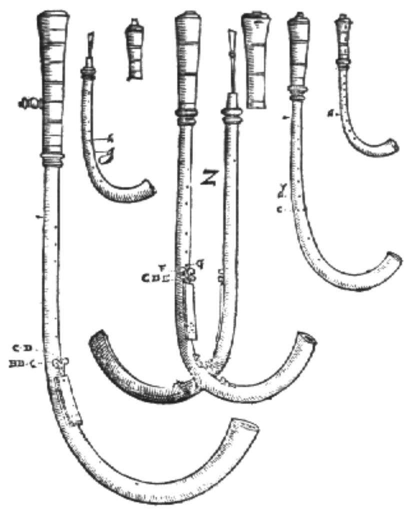
Tabor pipe / Three-hole pipe - recorder-like - cylindrical bore

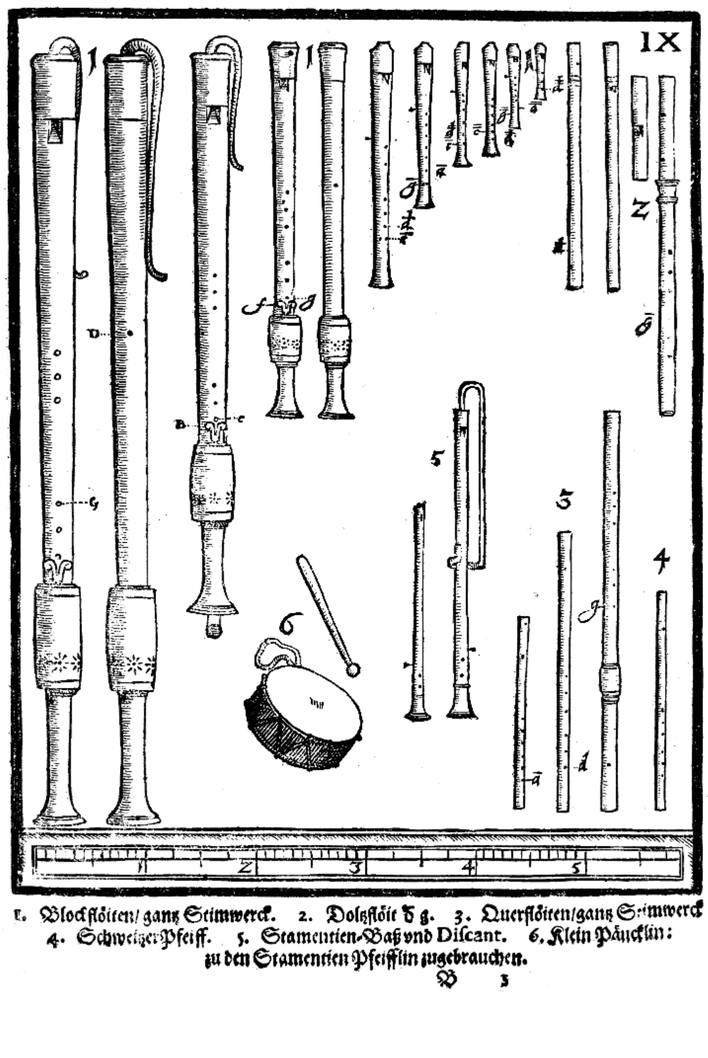
This is a recorder-like instrument that can be played with the left hand alone, leaving the right hand free to beat a tabor-drum. It has only three finger holes, yet is able to produce a complete scale. The fundamental register is not used. Instead it is overblown in 2nd, 3rd, and 4th registers. The 3rd register is an interval of a fifth above the 2nd, while the 4th is an octave above the 2nd.

Much of the music in Orchesography is suspiciously easy to play on this instrument.

Pipe and tabor player from Arbeau (1589):

Crumhorns, and recorders, flutes, and three hole pipes from Praetorius (1620):





Notes on making your own instrument

Hopkin (1996) gives a good non-mathematical introduction to instrument making in general, and Robinson (1973) has good practical advice on wind instruments in particular.

Wooden tubes

Making a wooden tube seems to be the hardest part of making an authentic instrument.

An auger drill will make a very nice cylindrical bore. A lathe is then very useful for making the outside match where the bore ended up going.

Auger drill:

Another option is to hollow out two halves of the instrument using a router, then strap or glue them together. This is how the cornett was made in period.

Semi-circular “core box” router bit:

Gluing wood: PVA weakens when damp, and the instrument will become damp from being played! There are PVA glues with additives that make them somewhat water resistant. Titebond III brand glue has excellent water resistance (my dad did some testing).

Gluing wood to metal: Wood will tend to expand and contract due to dampness, so brittle glue will tend to crack. Even if they don’t fail completely, they may break a seal. Ideally, don’t rely on a sealing metal to wood. Failing this, urethane glue has a bit of elasticity and may work ok.

Alternatively, you could use plastic or aluminium pipe, or bamboo.

Effect of the wall material on the sound

By all accounts that I trust, the material that an instrument is made from has very little effect on its sound. However the texture of the surface of the bore is very important!

If using wood, it is essential to oil the bore. The actual oil doesn’t seem to matter, so far as I can tell. Almond oil is sometimes recommended, but cooking oil should also be fine. I’ve also used wax to good effect.

Drinking straw reeds

A drinking straw with the tip carefully flattened (eg using your teeth) will make a loud buzzing sound when held between the lips and blown.

By careful thinning of the tip, a softer more pleasing sound can be produced. I currently use a diamond coated tile saw for this (these are surprisingly cheap), but sandpaper or a grinding stone that fits to an electric drill also work.

The reed may tend to produce a tone that sags away from the resonant frequency of a tube it is attached to. A sufficiently fine tip seems to fix this problem, and careful embouchure control also helps.

Finger holes that are too small can produce notes that sound weakly and are especially prone to sagging in frequency.

Finding a straw large enough to match the size of your resonant tube is important. I have had some success with "sipahh" straws (the kind that contain sugary granules that flavour milk as you suck through them).

This is all something of a black art, but it is possible to very cheaply produce a reed that produces a good first approximation of the buzzy double-reed medieval sound, and which allows a degree of expressive control.

Flutes

Creating the mouthpiece of a flute is as simple as drilling a hole in the side of a tube and stopping up the end.

For an alto flute, I like a bore diameter of around 19mm. Scale this linearly to other sizes. I like an embouchure hole that is a little over half the diameter of the bore. I leave a gap of one hole diameter between the edge of the hole and the stopper. This yields a flute that is quite easy to play. Extant renaissance flutes have somewhat narrower bores, and smaller embouchure holes.

See also http://www.cwo.com/~ph_kosel/designs.html

Three hole pipes

If you are willing to put up with a modern material such as plastic or aluminium, the tube of a three-holed tabor pipe is straightforward to make. To this, the head of a soprano or sopranino recorder may be attached. It is important to match the diameter of the tube's bore to that of the head.

Finger hole placement

The mathematics of hole placement is a little involved. See Fletcher and Rossing (1998) and Nederveen (1969) for details. I have written some software to automate hole placement:

http://www.logarithmic.net/pfh/design

This will position holes based on a list of fingerings, so you can design instruments with cross-fingerings. It can also design simple bore deviations based on drilling and covering some extra holes (rather like the dizi flute), allowing instruments in tune over a larger range and with improved timbre. Included are example designs for a reed-pipe, a flute with various fingerings, and a three-hole pipe. Support for conical bores is present but untested.

See also:
http://homepages.bw.edu/~phoekje/acoustics/mahome.html
http://www.cwo.com/~ph_kosel/flutomat.html

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