Musical Origins and the Stone Age Evolution of Flutes

When we, modern humans, emerged from Africa and colonized Europe 45,000 years ago, did we have flutes in fist and melodies in mind?

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Introduction

Music is an intensely emotional subject and the origins of music have fascinated people for millennia, going back to early historic records. An excellent review can be found in "Dolmetsch Online" (http://www.dolmetsch.com/musictheory35.htm). Intense debates in the late 19th and early 20th century revolved around the origins of speech and music and which came first. Biologist Charles Darwin, befitting his important recognition of evolution by sexual selection, considered that music evolved as a courtship display similar to bird song; he also felt that speech derived from music. Musicologist Spencer posited that music derived from the emotional content of human speech. The Darwin–Spencer debate (Kivy, 1959) continues unresolved. During the same period the eminent physicist Helmholtz-following Aristotle-studied harmonics of sound and felt that music distinguished itself from speech by its "fixed degree in the scale" (Scala = stairs, i.e. discrete steps) as opposed to the sliding pitches ("glissando") typical of human speech. As we will see, this may not be such a good distinction when analyzing very early musical instruments with our contemporary bias toward scales. More recent symposia include "The origins of music" (Wallin et al., 2000) and "The music of nature and the nature of music" (Gray et al., 2001). All sides of this ancient debate agree that music connects to human emotions. All agree also in the assumption that music started with vocalization--song. I will, however, avoid the tangle of perspectives and introspectives that characterizes this debate and focus on musical instruments, which are tools produced specifically for making music. I will also not now enter the debate of what constitutes music. According to composer John Cage, music is "organized sound." This organization can take the form of rhythm, melody or harmony as well as dynamics and timbre and any combination of these music variables. Finally, music is in the ear of the beholder.

Prehistoric Musical Instruments

With that, the quest moves to the historic and particularly the pre-historic origin of musical instruments emerging from archeology. The oldest instruments that can be discovered are necessarily those that are preserved over the centuries and millennia. Historical and biblical records describe and depict musical instruments going back over 5,000 years. (We will refer to early dates as 5kyBP, five thousand years before present). East Indian literature from 3.5kyBP describes a transverse flute. Both pictorial evidence and actual instruments are known from these early settled cultures. Most were made of wood and other perishable materials. But only bone and ivory flutes go back into pre-history, specifically to a period between the Middle and Upper Paleolithic around 40kyBP, when in Europe the invasion of modern human culture (previously referred to as Cro-Magnon) replaced Neanderthal culture after a brief period of overlap, known as the Chatelperronian. It is

thus of considerable interest to know more about these earliest preserved instruments that represent the only reliable evidence of music. Who invented them and why? What is involved in flute making? What kind of flutes did they make? What sound did they produce? And, most intriguingly, what music did they play?

To this end in the early 1980's, I began studying and reconstructing such preserved instruments and played them in the French caves along the river Vezere, where I was asked how I knew what to play. I gave two equally improbable answers: "The flute guides me" and "The rocks are full of dot patterns for notes." Together, these flip statements hide a sad truth: we do not know and *cannot* know. Even on a flute with finger holes that suggest a scale, the pitch is not reliably constrained. Finger combinations and blowing direction/strength can form intermediate pitches, and sliding fingers can create a complete "glissando" of all the instrument's possible pitches: the player makes music by organizing sound according to personal preference. However, it seems likely that any personal preference would be deeply engrained in the player's cultural context similar to local languages and dialects. Of course, preferences can have deep cultural roots, but they are not preserved. The oldest known music notation, carved in stone, dates from Greek and Roman culture over two millennia ago revealing familiar sounding melody; notation took its current form with the Roman philosopher Boethius (c. 480–524 AD).[1] Efforts to recreate Paleolithic music thus become a hybrid of recreating old instruments played by today's musicians. A similar effort has recreated the dinosaurs: bones and bone fragments can reasonably suggest body form and even motion, but not skin color and vocalization. For those aspects we rely on today's dinosaur relatives, the lizards, birds and crocodiles.

To appreciate the evolution of flutes it is instructive to sketch a series of developmental stages in flute construction that may have taken place to arrive at today's refined instruments. Each of these stages reflects a new invention and achieves a higher level of musical complexity. Instrument evolution emphasizes the importance of music in the cultures where they originated or where they were copied and became established. While the evolution of musical instruments is not driven by Natural Selection as are survival tools for hunting and fishing, the Rolling Stones and many other performers agree with Darwin that music emerged due to Sexual Selection: pleasing the opposite sex.

[1] *http://www.cengage.com/music/book_content/049557273X_wrightSimms_DEMO/assets/ITOW/7273X_0 1_ITOW_Boethius.pdf*

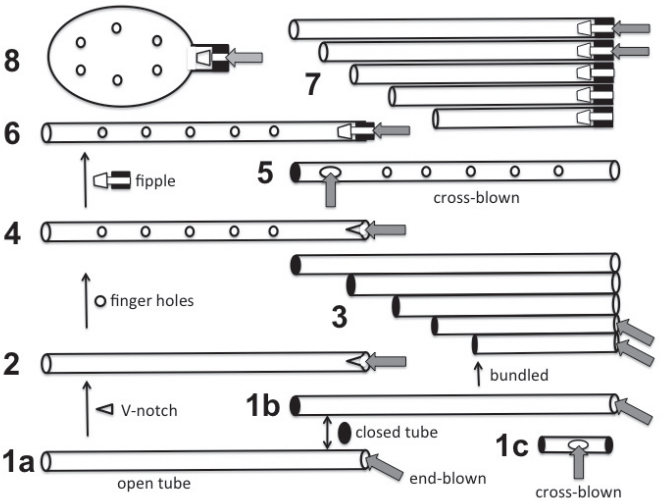

Figure 1. ***Evolution of Flute Technology***
Evolution of flutes; all but two are end-blown as in quenas, neys and recorders. 1a. open tube, 1b. closed tube, 1c. cross-blown whistle, 2. open tube (V-notch), 3. closed tube bundled: Pan pipes (depicted without V-notches), 4. open tube (V-notch) with finger holes: quena, ney, 5. cross-blown, closed tube with finger holes: transverse flute, 6. fipple with finger holes: recorder, 7. bundled open tube fipples: organ pipes. 8. closed vessel fipple with finger holes: ocarina.

1) *Found sound.* The simplest flute is not made but found: a hollow tube making sound by blowing across one of the two open ends (Figure 1-1a); its variant is closed at one end (Figure 1-1b). The player can blow the air stream straight or obliquely across the open top. Reeds, bamboo and bones, especially naturally hollow bird bones, provide ideal starting material. Such flutes do not require much modification to make sound. They produce one fundamental pitch with small fluctuations possible by varying air speed and blowing angle. Depending on tube dimensions, closed-end tubes can produce one or more harmonics. We might call this the "Coke bottle" stage. A simple variant is the cross-blown whistle, made of a small tube with both ends closed and a blowhole in the shaft (Figure 1-1c), often made from mammalian digits.

Note: Of course, one can also go to the trouble to *make* a tube, which can then be made into a flute. Incredibly, this is the case with some of the oldest instruments known. These are described below.

2) *V-notch.* The next stage is to carve a V or U-notch at one end of the tube and direct the airstream at the -sometimes beveled- notch (Figure1-2); notching facilitates sound production particularly in small, narrow-bore tubes.

3) *Panpipes.* To make it possible to play a series of different pitches, the stage 1 and 2 flutes above have been expanded in two directions. In one direction, bundling a series of closed-end tubes of different lengths forms the "Panpipe."

(Figure 1-3) The pitches of such pipes are constrained and would give a reasonable indication of the locally preferred musical scale. Alas, they are typically made of bamboo and other perishable materials.

4) *Finger holes.* In the other direction, different pitches were obtained by making finger holes in open-end tubes (with or without V-notches, Figure 1-4). Opening a finger hole has the same effect as shortening the tube to create a higher pitch. However, as mentioned above, different fingering combinations, finger placement, sliding over the finger holes, and airstream variation can all be used to create a "glissando" across the entire flute's range. The "scale" is thus not constrained and this makes the instruments unreliable indicators of any cultural scale. Of course, trained musicians almost automatically play "in tune" with a preferred scale. This flute stage forms the principle of the historically old as well as contemporary Quena (Balkans, S.America) and Ney (Egypt, Turkey).

5) *Transverse (cross-blown) flutes.* Another modification of the simple tube is to make a blow hole along the shaft and blow the airstream across the tube as in a whistle: the simplest transverse flute (Figure 1-5). Some complexity can be added by closing either or both ends (perhaps while playing), which changes the pitch in a few steps depending on tube length. Adding finger holes allows the playing of more or less discrete pitches. Still, fingering and blowing can produce a sliding pitch, and an uncertain scale. Transverse flutes, described from China (lacquered bamboo) and India ~2-3kyBP, have now reached their end point: today's gold and silver concert flutes are not different in principle. [Needless to say that the last 500 years have seen great technical improvements on the basic design.]

6) *Fipple flutes.* The transverse flute and the end-blown flutes of stages 1-4 in Figure 1 are easy to make but require good control of the air stream and are thus more difficult to play. Creating a more fixed airstream solves this problem. In fipple flutes, the blowing end is stoppered while cutting or leaving a narrow air channel that directs the player's air toward an –often beveled- edge of a hole just below the stopper (Figure 1-6). It is easy to see in today's recorders, penny whistles, etc. The flute is now as easy to play as breathing. Its sound power is typically enhanced as well. But who would have thought of a fipple? Here too, blowing and fingering can create variable pitches including glissandos.

7) *Organ pipes.* A different way to use fipple flutes is to "bundle" pipes of different lengths and diameters into a pipe organ (Figure 1-7). The oldest records (2kyBP) describe an air supply driven by water pressure; it was called a "hydraulis" presumably invented by Ctesibius of Alexandria[2] (~200 BC) and admired by the insane but musical Roman emperor Nero (37-68AD). Unlike fingered flutes, the pitch of a pipe organ is fixed and its scale tuned to the local culture.

8) *The Ocarina*, reputedly known for as much as 12,000 years and originating (independently?) in different cultures, uses a fipple mouthpiece, but the flute body is not a tube supporting standing waves but a closed, often ceramic, vessel (Figure 1-8). It functions as a "Helmholtz resonator" where pitch is determined by the number of open finger holes, not their position along a tube; it can play scales but does not produce reliable harmonics. Because it is played with fingers it can produce glissandos as well as scales.

Who Invented the Critical Steps in the Evolution of Flutes?

The sequence of major inventions from one-pitch whistles to pipe organs can be imagined as: V-notch, finger holes, bundling, and fipple (Fig. 1). Both finger holes and bundling allow the playing of several pitches and thus melodies, while V-notch and fipple designs facilitate both power and ease of sound production. We may reasonably assume that bundled flutes and flutes with finger holes are designed to play melodies, i.e. sequences of different pitches. This may signify an evolutionary step in music, or it may simply be an instrumental version of already established vocal music. Still, the earliest hard evidence for melodic music comes from bone and ivory flutes with finger holes. Since flute stoppers used in fipples are also likely to perish over time, it will be difficult-but not impossible- to recognize this design in the Paleolithic record.

None of this of course means that there was no music prior to bone flutes. Humans may have sung and danced for 200,000 years all across Africa long before invading Southern Europe and they may have made wooden flutes and a variety of drums and lyres made of wood and leather. Making complex instruments implies that music was important to the culture that devoted both time and imagination to develop the technology. It is not simple to "invent" a fipple and it makes no sense to carve an ivory flute from a solid

[2] http://www.mlahanas.de/Greeks/Ctesibius1.htm

mammoth tusk when ready-made hollow bird bones are everywhere. Yet, somehow it was done!

Before we review what is known about the recovered flutes that provide evidence about their playing potential, we need to establish what is a flute. How do we know that the object found buried under many layers of civilization and geological processes represents a flute? The designation "flute" is based primarily on finger holes, and most clearly on a series of at least 2 or 3 similar holes in a row. In addition, to function as flutes, both the tube length/diameter and the human-finger holes have constraints of size and spacing. By themselves, hollow tubes with or without V-notches are insufficiently constrained to know they were used as flutes. Tubes with one hole in the shaft can generate sound but also doubts: Was this hole made by humans and if so for what purpose? Fragments with human decorations and broken holes that are similar to decorations or parts of accepted flutes can still provide evidence for flute making (Conard et al., 2009). Of course, all reconstructions are physical models of the original according to the reconstructor's concept of what it "must have been." In addition, the dating of buried artifacts is an archaeological and physical art form in constant development leading to sometimes widely variable results (Higham et al., 2012). Therefore the dates presented here are closest available estimates with "oldest flute" dated 40-50kyBP (Table 1).

Table 1. Summary of the most complete flutes considered here.

Site	kyBP	found	mouthpiece	species	material
DivjeBabe	50	1995	V or fipple?	cavebear	femur
Geissen 1	35	1990	?	swan	radius
Geissen 3	43	1974-79	?	mammoth	tusk
HohleFels 1	35-40	2008	V-notch?	vulture	radius
Les Roches	30?	1878	?	mammal	ulna?
Isturitz	25?	1920-90	?	vulture	ulna
Jiahu	8-9	1980s	end	crane	ulna
Veyreau	4	1983	fipple	vulture	ulna
La Roque	1-30?	1920	fipple	mammal	ulna?

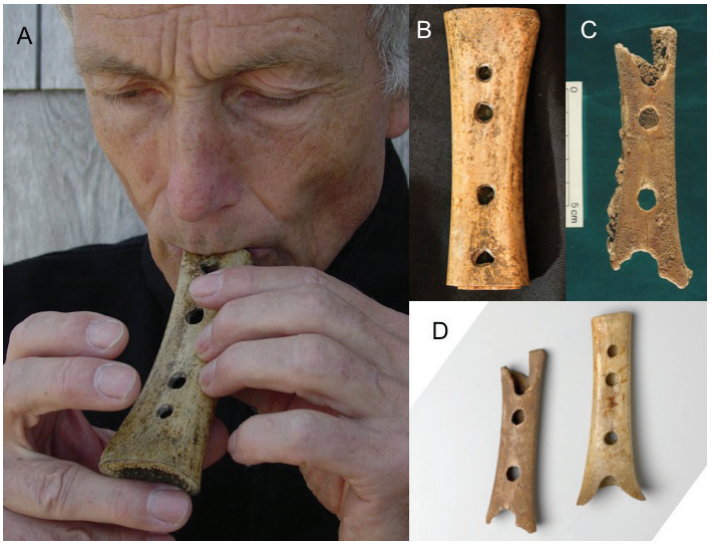

Figure 2. *The Divje Babe "flute". A. The author playing his replica/model of the Divje Babe flute made from a partially fossilized cave bear femur with a fipple mouthpiece, shown also in B. C. The original "bone with holes". D. Replica (left) and quena model (right), both made by Turk's team in Slovenia. [A, B courtesy Atema. C, D courtesy Ivan Turk. B. Photo: Jeremiah Seymour.]*

Paleolithic and More Recent Flutes

The Divje Babe"fluete", Slovenia (~50kyBP), Figure 2.
In 1995, Ivan Turk and his team discovered the oldest known "flute" in a Slovenian cavebear cave called Divje Babe ("Wild Woman"). What makes this discovery particularly exciting as well as controversial is that it came from a Neanderthal site. Turk and his team published a careful description of the "bone with holes" and its archeological and zoological context (Turk et al., 1997). It was dated with electron spin resonance to 50-60kyBP and to 46kyBP by the radiocarbon method. In life, the bone was the shaft of a femur of a young cave bear. The remaining bone is about 12 cm long by 3 cm wide with two complete round holes and at least one broken round hole all in a row in line with a U-shaped notch at one end. At the other end two wedge-shaped chips are missing; one includes part of the third hole and another hole could have been part of the other chip (Figure 2). It looks like a flute, but others consider it a bone with a series of holes chewed by a carnivore. Finding similar "flutes" in the same location would greatly enhance the human hypothesis. For the purpose of this essay it is important to discuss the main arguments of the controversy; simply stated: Did Neanderthals make flutes and what kind of flute was it?

If we interpret this bone-with-holes as a human artifact, it would represent a flute with three finger holes that can be played as a V-notch quena or stoppered as a fipple flute: both reconstruction models work. This would place the instrument at an advanced technological level. It would also credit Neanderthals with this technical capability and interest, since there is no evidence of modern humans at the Divje Babe site, while Neanderthal artifacts were found there (Turk et al., 1997). This contradicts substantial evidence and strongly held views that Neanderthals did not develop complex tools and ornaments, and only started making even simple ornaments after the arrival of modern humans in Europe during a period of physical and cultural overlap known

as the Chatelperronian (~40kyBP). In sum, while Divje Babe *flute* evidence is strong, its *Neanderthal* construction evidence is weak.

However, crediting an animal with this find may be more problematic than accepting human construction. Zoologists argue that scavengers looking for marrow crush bones with their molars or carnassials, which are located back in the jaw and are designed for this crushing job; in contrast, their dagger-shaped canines are designed for grasping prey. More importantly, the three holes are nicely lined up and fit human fingers (Figure 2A); also, there are no counter tooth marks on the opposite side of this bone suggesting a bite. To experimentally test the animal bite hypothesis, Turk et al. (2001) conducted an extensive series of biting tests using, in his words, *"mostly fresh bones of brown bear cubs and models of cave bear, wolf and hyena dentition (upper and lower jaw). We tested carnassials and canines of wolf and hyena and canines of cave bear. Sometimes, not always we succeeded in making one hole without cracking and splitting the bone. With multiple bites bones were split into two parts."* (Ivan Turk, pers. com., July 2014). A bone with one hole is thus difficult to recognize as a human artifact; two holes greatly increase the odds of human effort and three holes become highly unlikely to be made by a bone-crunching animal. The holes appear thus drilled not crushed. Still, Turk maintains the small possibility that his discovery was not man-made. When in 1997 I carefully examined this "bone-with-holes" I concluded that the likelihood of a human artifact is greater than the likelihood of animal damage. Of course, in science "never say never," but this holds for both hypotheses.

Based on my measurements and photographs, I tested the human hypothesis and reconstructed this "flute" (Figure 2) from a partially fossilized cave bear femur donated by Gernot Grabaeder in Vienna (Atema, 2004). In the reconstruction I assumed three finger holes and a mouthpiece at one end of the bone. I chose to make a fipple model, while Turk's team made quena models (Figure 2D). Both play well. The fipple reconstruction makes beautiful sounds (visit http://acousticstoday.org/?p=2370 to hear flute of Divje Babe). The Viennese cave bear bone was partially fossilized (presumably silicates replaced some of the carbon) resulting in a soft, hauntingly sweet and clear bell-like sound in the range of our current notation of D5-A5. In contrast, reconstruction from a fresh blackbear bone resulted in a still soft but dull, rough sound in a similar range. Being finger flutes, their pitch can slide along the entire range. The "bone with holes" can thus be used as a flute, but this does not prove it was.

Figure 3. *Swabian Alb flutes: A, B. Geissenkloesterle 3 re-assembled from recovered fragments; A. side view with carvings suggesting twine binding of the two ivory half-tubes, B. top view with two complete "finger" holes and two broken holes at each end. The spike suggests a fifth hole at the very end. C. Frances Gill playing an ivory model freely fashioned as a transverse flute (https://www.youtube.com/watch?v=PJjpHWo09tc). While the reassembled original (A, B) provides no evidence for cross blowing, this reconstruction shows the twine binding of the two ivory half pipes. D. Hohle Fels 1 reassembled from fragments showing four complete and one broken "finger" hole at one end and two "V-notches" at the other end. [A, B from Conard et al., 2009, C. courtesy Frances Gill, photo P. Geiger. D. Courtesy Nicholas Conard.]*

Flutes of Swabian Jura (35-43kyBP), Figure 3.

In contrast to the isolated discovery at Divje Babe, several flutes and other cultural artifacts (carved figurines and ornaments) have been excavated in the Upper Danube watershed of the Swabian Jura, in SW-Germany (Conard et al., 2009): the Ach river valley with the Geissenkloesterle and Hohle Fels caves and the nearby Lone valley with the Vogelherd cave. The finds include fragments of Aurignacian (the early modern human period) flutes (35-43kyBP) made of swan and vulture bones or carved from mammoth tusk ivory. Of these potential flutes, three could be reconstructed from pieces to provide sufficient evidence for the "flute" designation, while smaller fragments provide evidence of additional flutes. Extensive archaeological work at these sites provides cultural context and evidence that modern humans may have first entered Western Europe via the Danube river corridor (Conard et al., 2009; Higham et al., 2012). The discovery of both flutes and figurines provides strong evidence of Aurignacian culture and has led to imaginative but unverifiable speculations of Stone Age life. One hard fact is that people spent time and effort creating musical instruments of considerable complexity.

The well-researched and publicized **"Hohle Fels 1"** flute (Conard et al., 2009) was reassembled from 12 pieces; it is made from a griffon vulture (Gyps fulvus) wing bone (radius) and has five finger holes in a row (four plus a partial hole where the flute broke) and two apparent V-notches at one end (Figure 3D). The presence of two notches is so far unique and their function is unclear and perhaps not intentional. While seemingly far-fetched, it is possible that a now lost fipple was part of the original with one of the V-notches serving as the beveled edge of the sound hole. Unfortunately, I have not seen the Swabian flutes in person.

The **"Geissenkloesterle 1"** flute appears similar but is made of a swan radius. Friedrich Seeberger reconstructed this flute with a small single V-notch; copies are for sale at the local museum in Blaubeuren near Ulm and Steve Pollitt played one for me quena-style. He blew soft and sweet sounds using finger combinations to play improvisations tuned to our contemporary Western (diatonic) scale.

Ivory flutes such as **"Geissenkloesterle 3",** recently dated 43kyBP (Higham et al., 2012), present another level of complexity. Tusks are not natural flutes. Construction must therefore start with cutting and hollowing out an ivory rod split lengthwise. The bone halves then need to be bound (and glued?) together into a tube. To be playable this tube had to be completely airtight-sealed. This flute and some of the other ivory fragments show a series of -in one case 7- closely spaced grooves suggesting the location of thin ropes binding the two halves (Figure 3A, B). Either after, or more likely prior to, binding, the (4-5) finger holes need to be carved as well as the possible mouthpiece/blow hole. The half-pipe construction is astounding. Since ivory was used for figurine carving at the same sites, perhaps the material itself, coming from a formidable beast, had status/magic value. In addition, ivory is a different material from bird or mammal bone and this would affect sound quality (timbre), possibly making the sound "sweeter." Unfortunately, there is no evidence of a mouthpiece and playing mode cannot be established. The free reconstruction played by Frances Gill (Figure 3C) (https://www.youtube.com/watch?v=PJjpHWo09tc) shows a full-length ivory flute bound by twine, but there is no evidence that the original was a transverse flute.

The Isturitz flute(s) (~25kyBP)

In 1990 a 4-hole bird-bone flute (vulture ulna) was reconstructed from fragments that were originally recovered in the early 20th century from the cave of Isturitz in the Pyrenees area in SW France. This recovery history makes accurate dating impossible; a best guess is Upper Paleolithic "Gravettian" or ~25kyBP (Buisson, 1990). The reconstructed flute and other flute pieces from this site show interesting "decorations" in the form of wavy lines and series of parallel scratches. No mouthpiece can be determined, so that any playable reconstruction would remain imaginary.

Figure 4. *A. "Les Roche", B. "La Roque" reconstructed from a deer ulna, with four finger holes and a fipple in front and two thumbholes (not visible) in the back. The main addition is keeping the missing piece above the mouthpiece that is broken in the original C. There is evidence for a fifth hole at the bottom. Both originals have a museum label wrapped around. [A, C: Courtesy British Museum. B. courtesy Atema, photo Jeremiah Seymour.]*

The Vezere/Dordogne flutes: "Les Roches" and "La Roque" (1-30kyBP), Figure 4.

The British Museum has two mammalian bone flutes from the Dordogne area in France. The age of both pieces is uncertain. One flute (Figure 4A) has two holes and was excavated in 1878 in the valley known as Les Roches (or Castel Merle, near Sarlat). It looks similar to the Isturitz flutes and may be as old. The ends appear broken and worn and a playing method cannot be reliably reconstructed. The other flute, **La Roque**, (Figure 4C) has four (or five) holes on the front and two on the back. It was found at Pas du Miroir, now a popular tourist attraction known as Le Roc St Christophe.

In 1983, I studied the "**La Roque"** flute at the Museum and was then told it could be 32kyBP on the assumption that it had come from a remnant of Perigordian deposit that had survived intense human activity around the Medieval troglodyte settlement. However, the piece was found during 19th century road construction and in the absence of any record of its archaeological context this date -unfortunately- must be regarded as uncertain. The flute is made from a mammalian bone, 12.5 cm long and 2 cm diameter. From my sketches, photos and measurements I later reconstructed

a playable copy from a deer ulna adding only one small piece of bone where it had broken off (Figure 4B) (Atema, 2004). The remarkable aspect of this flute is that it was in all likelihood a fipple flute: the broken hole at the top shows two clear break surfaces just where one would expect them at the weak points resulting from fipple construction (Figure 4B, C). This leaves four intact finger holes in front, evidence of a fifth hole at the bottom where the flute may have broken, and two thumb holes in back. It fits human hands perfectly and can play a range from B4-G#5, including an overblown second octave. If played in straight steps, i.e. without bending and sliding, it most resembles a diatonic scale (visit http://acousticstoday.org/?p=2370 to hear flute of La Roque). If reconstructed with an additional fifth hole the flute would have been ~14.5 cm long and its lowest note would have been around our current A4 (concert A 440 Hz). However, we must consider that this flute is perhaps only 1kyBP old. Given its importance as a fipple flute, accurate dating would be worthwhile as a document of evolving music technology.

Figure 5. *The Jiahu flute collection (from one grave), some of which are directly playable as end-blown quenas. From Jiang et al., (1999).*

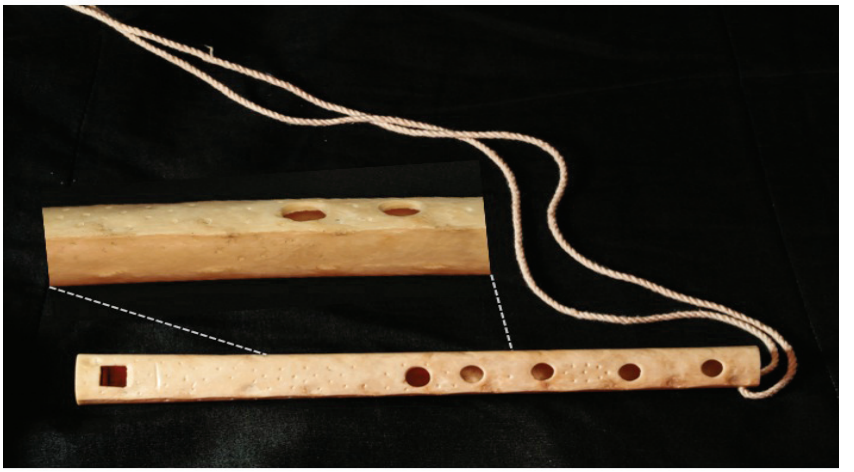

Figure 6. *The flute of Veyreau. Copy of the completely intact original, with square blowhole of the fipple and 5 finger holes. Note decorative dot patterns made as superficial pits (inset shows oblique side view). Carrying cord added to show probable function of small bottom hole. Cork stopper (added to create fipple) visible inside square blowhole. [courtesy Atema, photo Jeremiah Seymour.]*

The Jiahu flutes of China (8-9kyBP)

In the 1980's a large number of old flutes, 18-25 cm long, made from wing bones (ulnas) of red-crowned crane, were discovered in Jiahu (Hunan province, China) and -remarkably- some are playable (Jiang et al., 1999). They were cut and polished and had 5-8 finger holes in a row (Figure 5). The oldest two (9-8.6 kyBP, carbon-dated) were discovered in the grave of an adult man and have five holes; one can produce six, the other seven, pitches in an octave range starting at ~A440. The Chinese flutes are reported to play a pentatonic scale and from images appear to be end-blown without a stopper. There is no clear evidence of a V-notch for sound production. These flutes are remarkable in the number recovered at a single site and especially in the fact that some can still be played. Since they have finger holes and are approximately of the same length, their group-discovery is not evidence for Pan-pipes.

The flute of Veyreau (4kyBP), Figure 6.
The flute from Veyreau (Fages, Mourer-Chauvire, 1983) is 17.5 cm long with in front 5 round finger holes in line with a large square hole near one end. This fully intact flute is made of a wing bone (ulna) of a Griffon vulture; the front is beautifully decorated with dot patterns and one groove near the square hole (Figure 6). A tiny hole on the side at the very bottom suggests the flute was worn with a string around the player's neck. It was found in a burial cave in the South of France together with other artifacts and human bones from which the flute was carbon-dated at 4kyBP. The original is in the Cevennes Museum of Florac, France, where I studied it with Mr. Fages. It required only a (cork) stopper with a small air channel to start playing powerful sounds in a range of one and one half octave from A4 to D5 (visit http://acousticstoday.org/?p=2370 to hear flute of Veyreau). The large square hole at one end is the sound-generating hole of the fipple; there is no V-notch and when cross-blown it barely makes sound. It is a fipple flute. If we ignore "La Roque" due to dating uncertainty, it represents the earliest known "recorder." I made a copy from a contemporary vulture ulna including the subtle dot pattern decorations (Figure 6); it is essentially indistinguishable from the original. Of course, this flute is relatively recent by date but perhaps not by culture.

Interpretation of Flute Evolution

None of the flutes discussed here were primitive and all have *melodic* musical potential. But how our ancestors used this potential cannot be determined. There are many ways to make sound with a hollow pipe. Despite our fervent hopes to extract a musical scale from an instrument with holes that suggest discrete pitch steps, we cannot determine with certainty what scales local cultures favored. The one thing we can say with certainty about the finger holes is that they need to fit the human hand and fingers. All the recovered flutes show that they do, often perfectly. We can therefore suggest that finger hole size and spacing could have been more constrained by fingers than by pitch. The resulting pitches may have influenced cultural preference for certain intervals and harmonies. That preference in turn could later "fine-tune" the location and size of finger holes to facilitate playing "in tune." Interestingly, many people and particularly trained musicians, find it exceedingly difficult to NOT play in tune, "our" tune. This scale has become culturally engrained and affects us from birth or earlier; we do not know anything else. Replicas of the archeologically recovered flutes can easily accommodate the different scales and glissandos used in various cultures. Therefore we cannot credibly determine which scale if any was used in the Stone Age. Of the nine flutes in Table 1 only Jiahu can -apparently- be played as found, Veyreau only needed a stopper to complete the fipple, and La Roque required a small bone addition (and thus a modern copy) to complete the fipple. Hohle Fels 1 and Divje Babe suggest V-notch playing, as shown in modern reconstructions, but either could have been played also with a fipple. So far, the other flutes lack convincing signs of a playing mode. Despite the many uncertainties, the flute replicas and models can tell us something about three aspects of music: their range of pitches, their melodic potential and their dynamic range.

Only bone and ivory flutes go back into pre-history, specifically to a period between the Middle and Upper Paleolithic, when in Europe the invasion of modern human culture (previously referred to as Cro-Magnon) replaced Neanderthal culture after a brief period of overlap.

From the great spread of dates, materials and rare mouthpieces we cannot determine a chronology of flute making techniques as schematized in Figure 1. The only thing we can say with any certainty is that modern humans entered Europe with flute-in-hand. This was not a simple flute, but one that could play complex melodies over a span of 1-1.5 octaves. Such a flute would likely have evolved over long time periods from simpler instruments, which are difficult to recognize as flutes in the archaeological record. It is also clear is that we cannot extract their music with any certainty. Given the historic longevity of certain songs and the globally distributed use of the pentatonic scale, we can imagine that this scale reflects early human origin. But no facts back this up.

In addition to the flutes discussed here, people probably played flutes and other musical instruments made of perishable materials. Indeed, people make music with anything that produces sound. The carrot clarinet is an amusing and impressive example (https://www.youtube.com/watch?v=zrme04RIsE8#t=102), while personally, I play the lobster claw. This should tell us something about our interpretations of found objects that resemble flutes.

The Divje Babe flute presents a conflict that can be resolved only with further archeological discoveries. As it stands, the evidence for human construction outweighs the carnivore-gnawing hypothesis. The real question is if Neanderthal

people made it or that it somehow derived from modern humans…stolen or copied. It is not uncommon in archeology to start with a weak signal (a single "flute") that can either fade away or gain credibility with new discoveries. Therefore we must be careful to not dismiss prematurely the Divje Babe flute as a joke played on us by scavenging Paleolithic carnivores. There is no evidence that Neanderthals did or did not make this flute. When "we" arrived in Europe 45,000 years ago we may have inspired Neanderthals to make flutes or they may have started to make bone flutes instead of wooden flutes. Perhaps we saw Neanderthals play bone flutes and copied them. In the spirit of "Jurassic Park," we can imagine approaching a Neanderthal camp while playing a flute. To our surprise we hear another flute in the distance playing quite different tunes. Like mocking birds, we imitate their sounds and they modify their tune. When we enter the camp we are shocked to recognize the great differences in appearance and we do not understand each other's speech, but music paves the way toward acceptance and peaceful coexistence. When we wake up and the movie is over, we see that the Neanderthals are gone.

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Biosketch

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