Old bone flutes

BY JELLE ATEMA

As a young child Jelle Atema stalked animals in the forest and cut little flutes from hollow reeds. Jelle studied biology at the University of Utrecht, the Netherlands, and flute with Jean-Pierre Rampal during summers in Nice, France. He moved to the USA where he now lives by the sea in Woods Hole, Massachusetts. He is Professor of Biology at the Boston University Marine Program, where he and his students study chemical signals asking fish, lobsters, snails and robots how they make sense out of underwater odour patterns. Jelle Atema continues to perform on the flute and has also commissioned chamber music works.

WHEN AND WHERE DID HUMANS ORIGINATE? JELLE ATEMA BELIEVES IT WAS WHEN WE STARTED PLAYING MUSIC. BUT WHAT IS MUSIC? DID HUMANS OF 50,000 YEARS AGO MAKE MUSIC… OR JUST SOUND? HIS INTEREST IN THE RECONSTRUCTION OF THE WORLD'S OLDEST FLUTES COMES FROM THIS HUMAN QUEST FOR ORIGINS, IN WHICH BONE FLUTES CAN HELP US FIND SOME OF THE ANSWERS TO INTRIGUING QUESTIONS ABOUT OUR ANCESTORS.

Bone preserves well and bone flutes allow us a unique acoustical window into the life, the sounds and perhaps the music of our paleolithic ancestors. The simplest flutes one can make are open pipes blown across the top like pan pipes or coke bottles. More sophisticated construction technique is required to make a fipple flute with an air channel such as that found in a recorder or organ pipe.

In this article, I will argue (with three examples spanning 50 millennia) that some of the best-preserved bone flutes may have been 'fipple' flutes. If so, both Cro Magnon and Neanderthal people possessed remarkable technical knowledge and manual skill 50,000 years ago and probably much longer. Furthermore, the finger holes of a flute temptingly suggest specific pitches from which we might try to reconstruct an ancestral scale. Based on careful reconstructions of bone flutes, I will argue that pitch variation around any finger position is so great that attempts to reconstruct prehistoric musical scales must be taken as mere suggestions. Finally, the most intriguing question of the function and meaning of flute sounds for our ancestors must remain in the realm of poetry. We can only guess at their emotional experience when they heard the sound of their exquisitely crafted flutes.

Introduction

Our Ice Age ancestors, both Cro Magnon and Neanderthal, may have used many different sound-producing tools, but only bone preserves well. This leaves us with flutes to argue whether such tools were musical instruments. The argument has no scientific answer as it depends on our definition of 'music' versus 'sound'… and music is 'in the ear of the beholder'! It is as difficult to prove that humans of 50,000 years ago appreciated music as it is to prove that animals make music. That should not prevent us from documenting as carefully as possible what the instruments of our ancestors can do in our contemporary hands. We can determine the limits of their sound and their musical potential. I will now argue with a series of three well-preserved bone flutes ranging in age from 4,000-53,000 years old that these instruments may have been fipple flutes with greatly variable sound possibilities. The complexity of the flute construction and the potential for making a wide range of sounds suggest that our ancestors found flute sounds important.

To appreciate the excitement as well as the interpretation limits of the discovery of bone flutes from paleolithic times one needs to have some simple knowledge of flutes (something which I suspect is not lacking in readers of this magazine!). It is important to know how different types of flute are made both if one wants to evaluate the technical skill of construction and if one wants to interpret the flute remains. Then it is important to know how flutes are played to evaluate to what extent distinct tones can be produced and modulated. As the reconstructed flutes will demonstrate, we can play all sorts of music with them and some sound truly beautiful, but we can not determine how our ancestors played those same instruments.

Simple flute science

Flutes produce sound by 'cutting' an air stream over an edge; this causes turbulence and air vibrations. In open or closed pipes the frequency of the vibration depends on the length and diameter of the pipe. By blowing faster, the frequency first doubles to produce the higher octave. Increasing air speed as well as other blowing techniques will produce different higher intervals even in simple pipes without additional finger holes. More subtle variation in blowing will also modulate the frequency up or down sometimes as much as a full tone in a contemporary scale.

There are two fundamentally different ways of cutting the air stream to produce sound.

1) Blowing across the end of a pipe (panpipes, quenas, nais, coke bottles) or across a hole in the shaft of a pipe (transverse flutes).

2) Blowing into an air channel that directs the air stream onto the bevelled edge of a sound hole (penny whistles, recorders, organ pipes).

The first type is based on simple construction, but more difficult to play, since the player must control the air stream so that it hits the air-cutting edge just right. The second type, referred to as a fipple flute,

is easy to play because the channel directs the air stream. However, it is more difficult to make. It requires insight and considerable construction technique to
a) put a stopper in the pipe,
b) cut an air channel into the stopper and/or the inner wall of the pipe such that the air is directed onto
c) the bevelled edge of a hole in the wall of the pipe.
I will now go on to discuss the reconstruction of three ancient flutes.

The Flute of Veyreau

This 4,000 year old, beautifully decorated flute is made of a wing bone (ulna) of a Griffon (or a Black) vulture. It was found in a burial cave in the South of France together with other artefacts and human bones from which the flute was dated by carbon isotope analysis (Fages, Mourer-Chauvire, 1983). The original is in the Cevennes Museum of Florac, France, where on 13 May 1988 I studied it with Mr Fages.

This flute is in perfect condition! I only needed to add a channelled cork stopper to make it come to life. The original flute sounds very much like the reconstruction I made later (discussed below). There is little doubt that this is a fipple flute, since all that was required to make a strong sound across the entire range of notes was a properly shaped stopper. The original stopper must have been made of less durable material, perhaps a cork from the local cork oak, *Quercus suber*. Even if made of wood, wax or clay, the stopper would most likely be lost over the ages.

In October 1988, thanks to Mr Dominique Albouy of the Cevennes National Park, I obtained an identical vulture (*Gyps fulvus*) ulna from which I reconstructed the Flute of Veyreau. I included its decorative dots and lines, which are lightly carved into the bone surface, and the little hole at the bottom, which suggests a cord for carrying the flute around the neck. The copy is identical to the original. An interesting note is that Griffin vultures have been extinct in France since the 1930s. They were recently reintroduced with great success in the Florac area, allowing me access to this perfectly matched bone for the reconstruction.

> “We can only guess at the **emotions** of our **ancestors** when they heard the sound of their **exquisitely** crafted flutes”

The flute of Veyreau plays like a soprano recorder. But, unlike the recorder we know, its scale is neither pentatonic nor diatonic; one could call it ‘hexatonic’. It has a range of one-and-a-half octaves. When played ‘straight’, the lowest note is A# (using A440 as the standard) and the note sequence is A#-B-C#-D#-F-G# and in the next octave A#-B-C#-D#. When not playing straight, the pitch of each tone can be modulated by a full chromatic step. This would allow the entire chromatic scale to be played and then some. The sound is clear and strong but slightly ‘raspy’; this is probably due to the thin walls of a typical bird bone.

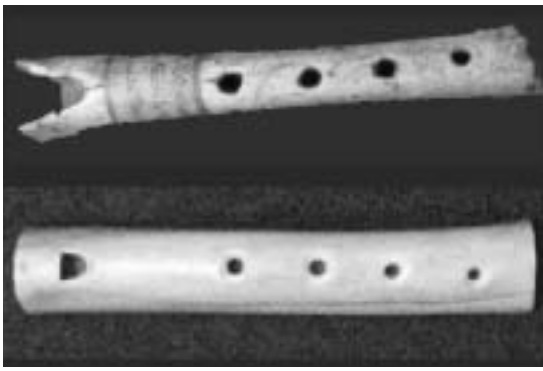
The flute of Roque St Christophe/ Pas du Miroir

This important instrument is also known as the flute of Abri Blanchard and has been described several times. It has not been dated accurately, but Harrold (1988) and others, including Randall White of the American Museum of Natural History, believe it to be Aurignacian I and thus 25,000-35,000 years old. The original is remarkably complete and in good shape compared to many other flutes of the same vintage. It appears unplayable as a result of critical breakage and material accumulated inside.

The ‘Roc’ flute, together with other Abri Blanchard material, was sold to the British Museum in London in the 1920s. The label on the original identifies it as follows: ‘Commune de Pelzac sur Dordogne, Pas du Miroir La Roque, donnée par Mr Mercier, maire’. The Pas du Miroir is along the Vezere river in Central South France in the area of Lascaux, near the Roque St Christophe, not far from the Abri Blanchard. An early reconstruction sent to me in 1984 by Mark Newcomer of the British Museum, through the good offices of John Pfeiffer, author of *The Creative Explosion* (1982), suggested that it was a ‘quena’ flute. By playing it off the upper lip instead of the customary lower lip I could coax sound and melodies out of this model. (I recorded the sound of the Newcomer replica in 1985 in the painted cave of Font de Gaume near Les Eyzies, Dordogne, France, for the exhibit ‘Dark Caves, Bright Visions’, curated by Randall White of the American Museum of Natural History.)

However, upon careful examination of the original in London (10 September 1986) I discovered break surfaces that suggested that this flute was a fipple flute like the flute of Veyreau. To make a fipple flute from a long bone, one must bevel the tone hole and direct the air stream towards this bevelled edge. To direct the air effectively, one should carve out a small channel along the inside of the pipe above the tone hole. This becomes a weak spot. The original was broken in exactly that place, leaving a U-notch above the finger holes. The bevel at the bottom of the U and a fine protrusion along one of the sides of the U are good indicators that a piece was broken off, corresponding directly with the weak spot. The flute has four finger holes in front and two at the back for the thumbs.

The original bone has not been identified accurately, but it resembles the ulna of a deer. On 1 October 1986 I reconstructed two identical copies (one is shown above) of this flute, using the ulnas of a contemporary North American deer, *Odocoileus virginianus*, that had died on Naushon Island, MA. (One copy of the ‘Roc’ flute replica I gave to my inspiring teacher, the French flute virtuoso, Jean-Pierre Rampal. The other one I used to record a sound track for the American Museum of Natural History, which has been heard in the permanent exhibit Hall of Human Biology since 1992.)



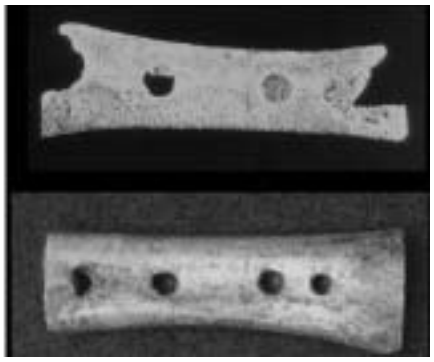
The original and reconstructed Cro Magnon flute. The original is chipped (top left in figure); the author kept the reconstruction intact, creating a strong, beautiful and enchantingly clear tone.

I reconstructed the flute of Roque St Christophe as a fipple flute, leaving the (presumed broken) bridge over the tone hole and carving an internal air channel to correspond directly to the break surfaces on the original. I also bevelled the lower edge of the tone hole and stoppered the top of the flute with cork. The original is chipped at the bottom; I kept the bottom intact.

This flute reconstruction plays with great ease. It has a strong, beautiful and enchantingly clear tone, a far cry from the early sounds generated from the ‘quena’ model of this flute. Its range is one and-a-half octaves in the high piccolo range from D# to G#. Based again on A440 as the standard and ‘straight’ playing, its scale is diatonic in B: D#-E-F#-G#-A#-B-C# and the second octave: D#-E- F#-G#. However, the pitch and finger possibilities of this flute are so flexible that one can easily play a chromatic scale and even a glissando like a slide whistle. The range can be extended below D# to include D-C# by partially closing the open end of the pipe with a finger.

The Neanderthal flute of Divje Babe

In 1995, Ivan Turk and his team discovered the oldest known flute in a bear cave called Divje Babe (‘wild woman’). His scholarship and that of his colleagues resulted in accurate dating and description of the flute and its context (Turk et al, 1997). What makes this discovery particularly exciting is that it came from a Neanderthal site. The flute is made from the femur of a young cave bear. Under the tone-producing area, it clearly has two and possibly a third finger hole and perhaps a thumb hole in the back. Both the third finger hole and the ‘thumb hole’ could be part of large chips that broke off. The tone-producing



Original and reconstructed Neanderthal flutes. The author is shown playing the latter on the first page of this article.

area (on the left in the figure above) is both worn and somewhat broken but has microscopic signs of bevelling consistent with its function of producing sound.

The Slovenian team, specifically Drago Kunej and Mira Omerzel-Terlep, reconstructed this flute as an end-blown 'quena'. The sound is produced by placing the flute against the lower lip and chin, covering most of the top of the pipe and aiming the air stream directly at the bevelled edge of the lower part of the U-notch. They report that this produced a 'clear sound' and that the use of the three finger holes allowed three to six different notes corresponding to Bb-B-C-C#-D-D#, depending on blowing direction and strength.

On 10 September 1997, I visited Ivan Turk in Ljubljana and inspected the original, from which I made sketches and measurements for future replicate building. This information is available in the book describing all details of the discovery (Turk et al, 1997). I also played the 'quena' replica made by Drago Kunej from a cave bear femur and the metal replicas for sale at the Museum. They make good sounds.

However, the wear and breakage of the sound-generating area did not allow me to determine if this flute was indeed a 'quena', as my Slovenian colleagues had decided. I wanted to see if it could just as well have been a 'recorder', similar to the other bone flutes I had reconstructed. The Turk group had not at that stage found an appropriate cave bear bone for me to try this model. A recent visit to the Museum of St Gallen, Switzerland had turned up some appropriate bones but not the permission to 'mutilate' one into a musical instrument.

While the search for the right bone went on, I used a human femur of the proper outside dimensions to try my recorder hypothesis. I copied very carefully the wide sound-producing area near the distal (knee) end and kept the 'missing piece', as in the flute of Roque St Christophe. The tone hole was bevelled at its lower end as in the original and it was equally wide. Like my Slovenian colleagues, I decided to consider the third front hole a real finger hole but to leave out the possible thumb hole in the rear.

The resulting flute plays easily and produces a reasonably clear tone, although it is less brilliant than the 'Roc' reconstruction. It has a small range of B'-C"-D"-F" and notes in between when using different finger combinations and/or blowing techniques. The first three notes of this group form a fragment of a diatatonic C-major scale; the last three notes form a fragment of a pentatonic scale in C. The sound possibilities are less than in the 'Roc' flute.

Meanwhile, Professor Gernot Rabeder of the Paleontology Department of the University of Vienna generously donated a proper cave bear femur for this reconstruction of Neanderthal sound. (Dr Ulrike Griebel of the Lorenz Institute in Vienna hand-delivered the cave bear bone just in time for me to make the replica I played at the American Association for the Advancement of Science meeting, 19 February 2000 in Washington DC.) Thus, the reconstruction (pictured above) was made from a young cave bear femur dated 50-100,000 years old and partially fossilized. I followed the same principles as in the reconstruction of the other flutes. The bone's distal (knee) end is the sound-producing end. The bone matches the original perfectly here. The proximal (hip) end flares out more in this bone than in the original. This should not affect the sound quality, but it may change the pitch of the flute to some degree.

I made three finger holes, matching the size of the original and assuming that the smaller bottom hole was indeed a finger hole, not a break. I considered the potential 'thumb' hole on the other side a fracture and did not include it in the model. The final scale would sound more complete to our ears if this extra hole existed.

The critical difference with the Slovenian reconstruction is the fipple. I cut a sound hole with bevelled lower edge and stoppered the flute with a cork. I cut a small channel in the cork aimimg the air at the bevel. The resulting sound is clear and sweet but not powerful. I was hesitant to cut a larger sound hole for fear of fracturing such a precious bone. In fresh bone this would not have been a problem. The resulting scale D-Eb-F-A does not match any normal scale.

> "Flute manufacture was **complex** while other tools were **simple** which may indicate the importance of music"

However, with changes in blowing and with finger combinations a few other tones can be produced. Additional lower tones (C-C#) can be made by partially covering the bottom hole of the pipe.

Reconstructions

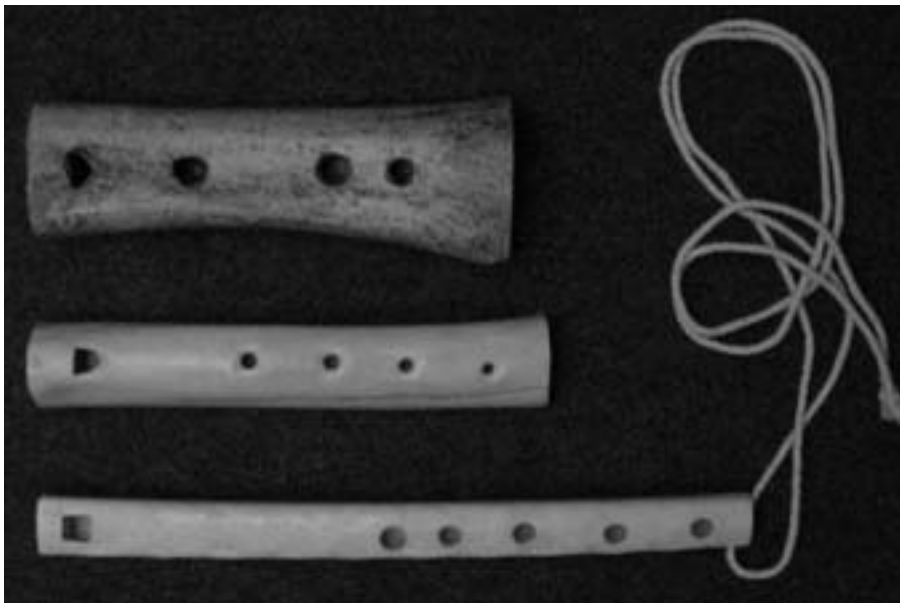
All reconstructions are models – embodiments of someone's ideas. This is particularly clear in the reconstruction of fragmented prehistoric material. In the case of these three flutes, I wanted to

Top: work on the Cro Magnon flute. Below: Bronze Age flute and vulture bone.

demonstrate the possibility that there is a long line of fipple flute technology dating back over 50,000 years. Given the slow pace of technological innovation in prehistoric times and the rarity of discoveries of well-preserved prehistoric flutes, fipple flutes may have been made for 100,000 years or more. Very similar bone fipple flutes have been in use through the Middle Ages up to recent centuries all over Western Europe, where they are not uncommonly found near villages and in old wells.

Pitch variation

Flutes are about the only instruments that suggest the possibility of determining the pitch of different fingerings and hence allow the reconstruction of ancient scales. However, a player can 'bend' the tone so much that the pitch obtained by any single finger position can vary by a semitone or more. This allows the player a great amount of pitch freedom. Even the most sophisticated contemporary flutes must be fine-tuned at all times during playing. A flautist trained in Western music will automatically adjust the pitch to correspond to what sounds 'right' to our Western ear. Playing reconstructed bone flutes, I find myself correcting the pitch to what sounds familiar. But with effort I can play 'wrong' or 'straight', trying to avoid any bending, to get the pitch of each fingering. At the other extreme, I can 'slide' through all pitches in a glissando. In other words, one can make these little flutes do many different things. In the absence of a prehistoric teacher, we modern students are left in an only



The three reconstructed flutes described in this article: top, Neanderthal flute of fossilized cave bear bone; middle, Cro Magnon flute of contemporary deer bone; bottom, bronze age (southern France) flute of contemporary vulture bone.

marginally constrained pitch environment. It is for this reason that I caution against facile conclusions about prehistoric pitches and scales, much as we would love to know.

Music?

The pitch problem is at least partially constrained: we know the range of the flute sounds and get a hint of a scale even if we can not determine which scale was actually used. But the next problem is even more difficult to approach scientifically. We would love to learn something about the function of the sounds produced by these flutes. But here we are entirely in the realm of our imaginations. The flutes could have been used as bird-call hunting tools, communication signal whistles for group hunting or tribal war; they could have been used for religious ceremonies, entertainment at dances, to accompany courtship rituals or send off the spirits of the dead to the world beyond. In some of these contexts we could speculate that the sounds became… music.

Biomusic

It would be interesting to know which scales our prehistoric ancestors found acceptable and pleasing, or – more fundamentally – whether they cared about scales at all. Was there a prehistoric Bach to codify a particular interval series? The flute reconstructions show both pentatonic and diatonic scales or scale fragments when played 'straight', ie. with a constant airstream. The answer eludes us. But perhaps we can make comparisons with animal sounds. Some birds and whales, for example, seem to 'agree' among their respective species that certain interval series are 'right'. Even local 'dialects' emerge which can be stable or change over the years. This comparison was the subject of the AAAS symposium on 'BioMusic' (Gray et al, 2001).

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This manuscript was based on a presentation given at the annual meeting of the American Association for the Advancement of Science, 19-21 February 2000 in Washington, DC, in the Symposium 'BioMusic: The Music of Nature and the Nature of Music'.

FLUTES, BONES AND THE LANGUAGE OF LOBSTERS: MORE ABOUT JELLE ATEMA

During high school days, on family holidays, I explored the French forests alone, tracking and observing animals and duetting with the birds on little flutes I made from hollow reeds. Later, at the University of Utrecht (The Netherlands), I became fascinated in the sensory worlds of other animals, in particular the mysterious world of underwater sensing. My work became centered on chemical, hydrodynamic and acoustic signals that inform animals about their world.

At the same time, I became more and more involved in flute performance. A solo appearance with the harpist of the Concertgebouw Orchestra led me to Jean-Pierre Rampal, with whom I studied for three years. I have since played in various venues, including the Rockefeller University and Merkin Hall in New York and at the Shanghai Conservatory (while teaching a course in aquatic chemoreception). Some of my finest performances have been with Sam Sanders and Ransom Wilson at the Cape and Islands Festival and with Rampal and the Colorado Quartet. I have commissioned and premiered two flute and strings compositions by Ezra Laderman.

During my doctoral work in Ann Arbor, Michigan, I became intrigued by the evolution of sensory systems. In order to understand the physiological filter properties of receptor organs, I needed to know more about the physics of stimuli in different environments, such as air and water, and about the behavioural functions of the sense organs. The Oceanographic Institution in Woods Hole then invited me to study 'chemical communication in the sea'. I chose lobsters as expert animals to teach me about chemical communication.

Perhaps not surprisingly for a musician, I found a number of acoustic analogies in the receptor cells used for sensing odour plumes. The whip-like antennules support frequency discrimination over three 'octaves' of water motion: a low-frequency cochlea. Currently, we are testing odour orientation algorithms with sharks, larval fish, lobsters and lobster-inspired robots. We are also analyzing the signals that regulate social behaviour and lobsters' ability to recognize individuals.

Many parts of my disparate interests come together in the search for the origins of human music. The oldest preserved musical instruments are bone flutes dating back as far as 53,000 years. This oldest flute remnant may be Neanderthal.

I let the reconstructed flutes mentioned in this article guide me in musical improvisation just as I did as a boy in the forest. They show the complexity of flute manufacture at a time when hunting and other tools were simple. This seems to indicate that music was important. The sound possibilities of these flutes are so broad that they do not allow us to determine with certainty what scales our ancestors liked to play. But we can hear the range of possibilities.

When I played one of these instruments by candlelight in front of the rock paintings of the beautiful cave of Fond de Gaume in the French Dordogne area, the small audience was transported back in tears to our ancestors.

All of us want to know where we came from and where life and human life originated, perhaps with the hope of predicting our future.