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ANTHROPOLOGY

First record of the sound produced by the oldest Upper Paleolithic seashell horn

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Anthropologists and ethnomusicologists assert that there is no society without song, and more specifically, there is no ritual or celebration without accompanying sound. The production of sounds in social contexts is very ancient. Here, we report on the study of a seashell from the decorated cave of Marsoulas and demonstrate that the Magdalenian occupants of this site transformed this shell into a wind instrument. It is one of the very rare examples, if not the only one for the Paleolithic period, of a musical instrument fashioned from a large shell, and the first conch shell of this use thus far discovered. We already know that prehistoric people transformed many shells into portable ornaments and that they thus attributed substantial corporal symbolism to them. This seashell horn, with its unique sonority, both deep and strong with an enduring reverberation, sheds light on a musical dimension until now unknown in the context of Upper Paleolithic societies.

INTRODUCTION

Discoveries of flutes dating to the Aurignacian and Gravettian show that Upper Paleolithic societies were already making music at that time (*1*–*3*). Other research has focused on the sonorous dimensions of decorated caves (*4*, *5*). A previously unidentified musical instrument has been recovered from the collection of the Natural History Museum of Toulouse. The seashell horn was discovered in the cave of Marsoulas (Haute-Garonne, France), located in the Pyrenean foothills. Marsoulas was the first decorated cave to be discovered in this region in 1897 and has been studied from the end of the 19th century until the present day (*6*–*9*). In addition to the abundant and complex art on its walls, it contains archaeological levels attributed to the early Pyrenean Magdalenian, recently dated to (1σ) 18,261 to 18,011 years cal before present (BP) (14,850 ± 120 years BP; wood charcoal, GifA 17257) and 18,064 to 17,731 years cal BP (14,590 ± 70 years BP; bear bone, Lyon 43054). Calibrations were computed with IntCal20, R 4.0.3 and the package rcarbon (*10*–*12*). These radiocarbon dates are reported here.

The seashell has been forgotten for more than 80 years (Fig. 1) (*13*, *14*). Although qualified as an "exceptional discovery," when it was discovered at the entrance of the cave in 1931 by H. Bégouën and J. T. Russell, the object was described by them as having no trace of human intervention and was interpreted as a "loving cup" (*6*, *13*–*15*). Nevertheless, new observations have revealed numerous clues of human modifications of it, which make it a possible musical instrument.

RESULTS AND DISCUSSION

The shell is a large specimen of *C. lampas* (Linnaeus, 1758), a mollusk originating from the North-East Atlantic and the North Sea. Today, it can be found in Ireland and France (Brittany, Pas-de-Calais) at its northern limit (*16*, *17*). Although rare, it is still present in the Bay of Biscay and the Basque and Asturian coasts of Spain. This animal inhabits rocky bottoms, sometimes interspersed with sandy spaces up to 80 m deep. *Charonia* also exist in the Mediterranean Sea, but these specimens are smaller and thinner (*18*, *19*). Its size (31 cm long and 18 cm wide) and its robustness, especially the thickness of the shell, reaching 0.8 cm in some areas, argue in favor of an adaptation to temperate/cold water conditions (*20*).

Archaeologically, the link between the inhabitants of Marsoulas and the Atlantic coast is supported by some artifacts found in the entrance and interior of the cave; in the osseous industry, there is a spear point fragment made from a cetacean bone, and, among the shells, the Atlantic origin of two *Capulus ungaricus* specimens, perforated by abrasion and found in the same layer as the *Charonia lampas*, is certain. Furthermore, the presence of a rock crystal tool in this same layer provides a link with the stratigraphy inside the cave, as all the other rock crystal tools originate from the layer with Lussac-Angles spear points published by Cau-Durban (Layer II) (*7*). These particular spear points are characteristic of limited distribution and are chrono-culturally constrained to a few sites outside the core area of Lussac-Angles and to a specific time period, namely, the Early or early Middle Magdalenian, which is consistent with the new dates reported here for Marsoulas as noted above.

Our detailed analysis of the *Charonia* revealed numerous clues of human intervention. To characterize and describe them on its surface, we digitized the shell via photogrammetry and carried out (with Dstretch ImageJ) an observation of the surface images to highlight the least visible pigments. Furthermore, computed tomography (CT) scans provided a very detailed visualization of the internal portions of the shell, such as the columella and the spire whorls. These observations suggest that considerable transformations were made to the conch shell to enable it to be blown:

- Impact points are visible from the anterior canal ascending along the labrum, attesting that the labrum and the outer lip were entirely retouched to regularize the edge (Fig. 2A).
- The apex, which is the point of departure for the formation of the shell and thus its most solid part, was intensively transformed (Fig. 2, C and D). A series of strikes truncated its conical extremity, which has undergone considerable transformation

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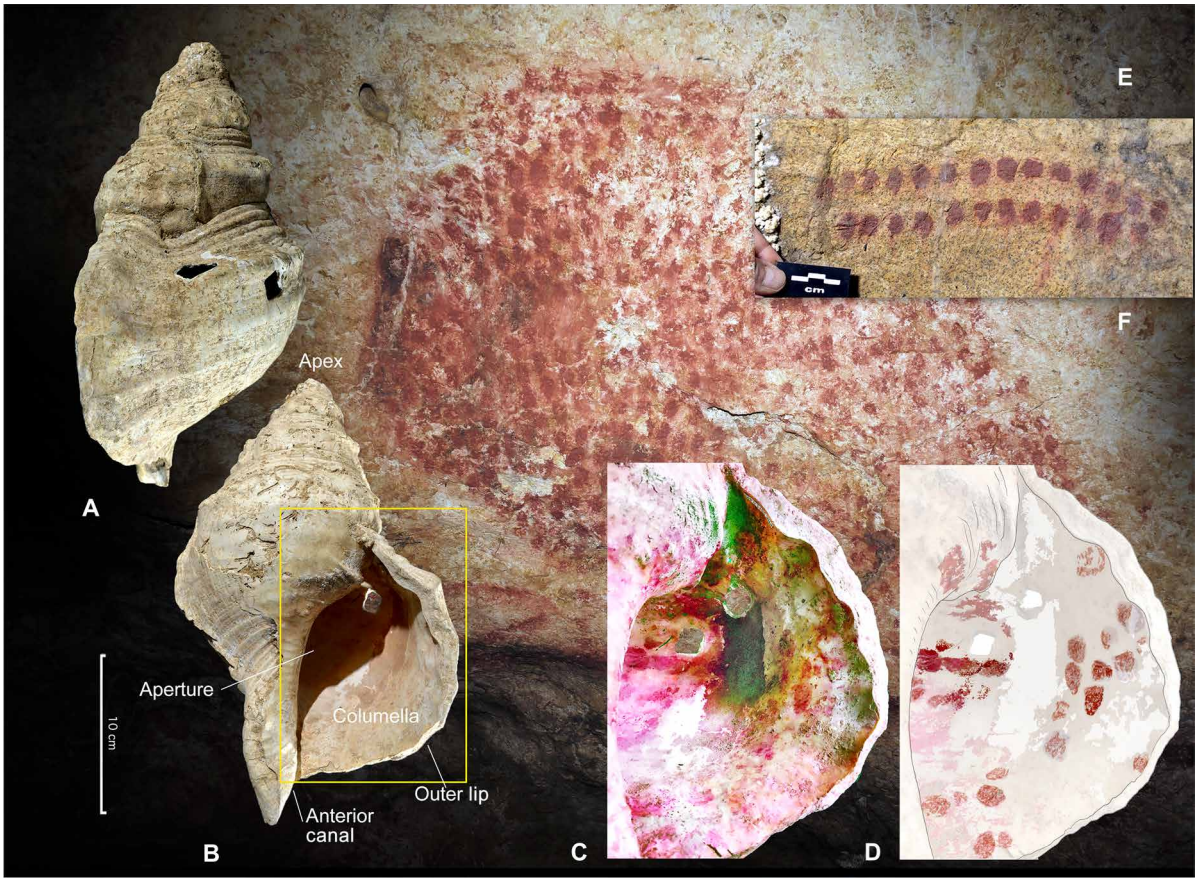

Fig. 1. Marine shell of *Charonia lampas* from Marsoulas cave (France). (**A**) Side view. (**B**) Front view and naming of the anatomical areas. (**C**) Vestiges of red pigment preserved on the columella (image enhanced with Dstretch-rgb0). (**D**) Tracing of red dots and lines visible on the enhanced photo. Very similar red dots, produced with the fingertips, are present on the walls of the cave. (5) Set of red dots forming a bison silhouette (length, 1.10 m). (6) Geometric sign formed by a double line of dots. [Photos (A to C, **E**, and **F**): C. Fritz; drawing (D): G. Tosello.]

eliminating approximately six spires. This operation created a rounded opening with irregular edges, 3.5 cm in diameter. The extreme robusticity of the apex of *Charonia* shells and the organization of the impacts excludes any possibility of accidental fracture due to crashing waves while the shell was in the sea, for example.

- A thin layer of a brownish colored material is preserved on the outside and inside of the apex (Fig. 2D). It seems to be an organic compound used to attach a tube in the apex hole to form a system of labial prehension.

- Internal perforations were realized, probably to maintain this mouthpiece in the axis of the circulation of air. At the apex of the shell, we discovered an internal perforation, 1 cm in diameter, piercing the roof of the seventh spire to a depth of 3.5 cm (Fig. 3, A to D). The outside of the nearly circular hole displays striations characteristic of tool skidding (Fig. 3B). The tool movements would have been highly constrained by the small diameter of the opening, which is the only point of access to the inside of a *Charonia* shell (Fig. 3C).

Such modifications are known in later periods to facilitate the operation of this type of wind instrument with the mouth. The collections of the Musée du Quai Branly-Jacques Chirac (Paris, France) provide a large comparative collection of conch shells from around the world exhibiting a variety of different techniques used to create a mouthpiece, including abrasion, lateral perforation of a hole a few centimeters from the apex, or destruction of the apex on the axis of the shell, as on the conch shell from Marsoulas. In terms of apex modification, the conch shell most similar to the Marsoulas one is a nondated specimen from Syria (Fig. 3, G and H). As can be seen on other conch shells from historic times, a composite mouthpiece could have been made with a tube penetrating the shell through the apex and fixed with an organic material (such as resin or wax), which would explain the brownish residues on the apex edge and inside the shell (Figs. 2 and 3). For the Marsoulas conch shell, we can imagine the use of an empty bird bone tube maybe to fix a horn mouthpiece like the one in Fig. 3A.

External anthropic modifications (removal of the labrum) (Fig. 4) do not alter the air flow and vibrations inside the shell and therefore the sound output. On the other hand, the fracture of the apex is necessary to blow into the conch shell. In addition, the apex arrangement is necessary to be able to place the lips correctly on the mouthpiece and avoid air leakage during play.

Traces of colors and engravings attest to a decoration of the seashell horn. A few red pigment remains are still visible to the naked eye; these are dispersed on the external part of the shell and the columella. An enhanced image obtained by the decorrelation stretching technique shows that juxtaposed red dots, of a size and shape compatible with fingerprints, covered the internal surface of the shell up to the lip (Fig. 1). The dots are associated with lines of the

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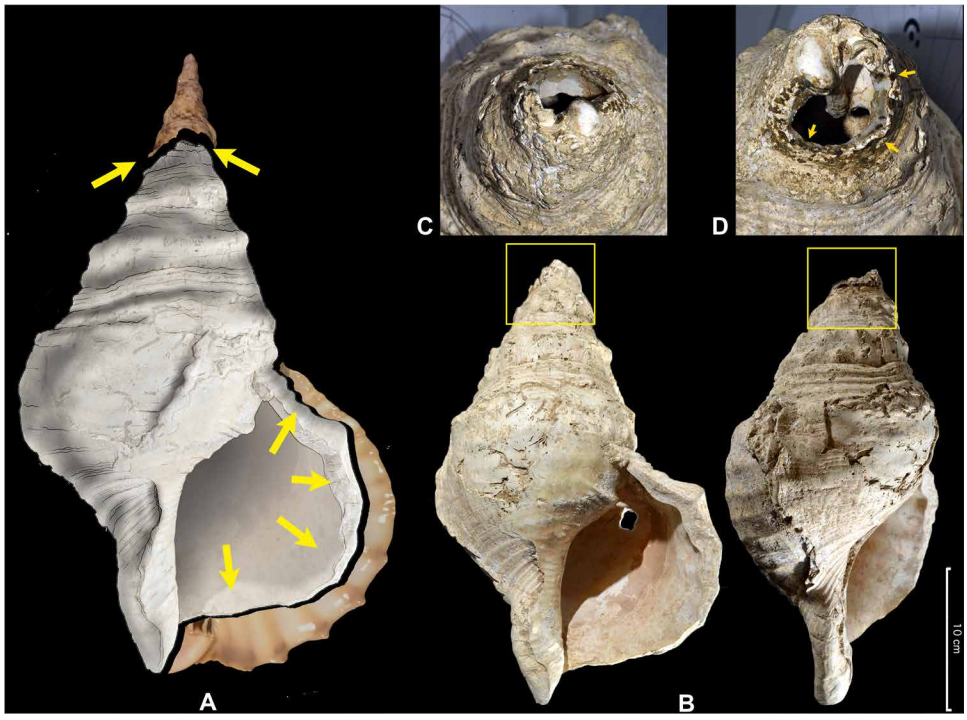

Fig. 2. The Charonia shell bears the traces of important modifications of human origin. (**A**) Elimination of the labrum (outer lip) by series of strokes. (**B**) Opening of the apex by destruction of the first six spires. (**C**) In top view, the chipped edge of the mouth indicates a summary work. (**D**) A deposit of brownish organic matter covers the fractured edge of the apex. [Photos (A to D): C. Fritz.]

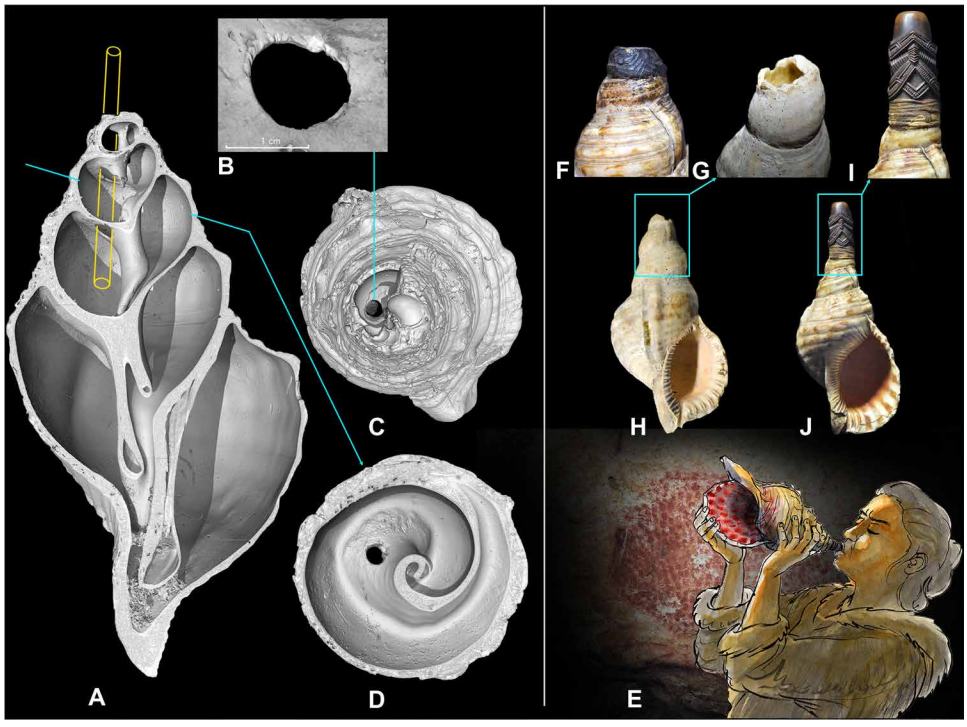

Fig. 3. The Charonia, wind instrument. (**A**) Sagittal section of the three-dimensional (3D) model of the shell that makes it possible to visualize the hole drilled at the level of the sixth spire (after opening the apex; see Fig. 2), probably to introduce a tube to facilitate the fitting of a mouthpiece. (**B**) Detail of the circular perforation drilled from the apex. The streaks on the edge are due to a skidding tool. (**C**) Top view of the 3D model showing the perforation. (**D**) Three-dimensional (3D) cross section at the level of the seventh spire. (**E**) The conch of Marsoulas in its Magdalenian context (hypothetical restitution). (**F**) Conch from Southeast Asia, the mouth of which is covered with a black coating, intended to protect the lips of the blower. (**G** and **H**) Conch from Syria and detail of its chipped mouth, close to that of Marsoulas. (**I** and **J**) Conch from New Zealand and its mouthpiece made of a decorated bone tube. [3D model captures (A to D): C. Fritz; drawing (E): G. Tosello; photos (F to J): Musée du Quai Branly-Jacques Chirac/E. Kasarhérou.]

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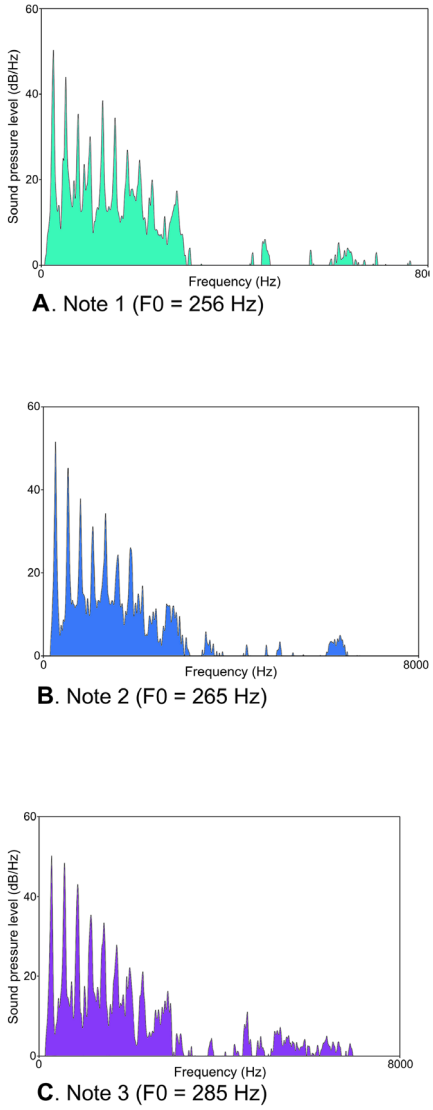

Fig. 4. Spectral analysis of the sounds produced by the conch of Marsoulas. (**A**) Note 1 (F0 = 256 Hz). (**B**) Note 2 (F0 = 265 Hz). (**C**) Note 3 (F0 = 285 Hz). [Diagram: J. Tardieu and P. Gaillard.]

same color. These marks are similar to motifs present on the walls of the cave (bison covered with a layer of dots, a large sign associating dots and red lines, etc.). X-ray fluorescence spectrometry was carried out to characterize this color. The pigment is an ocher, which contains iron, silicon, and potassium (aluminum is not detected). As the remains of the colors are very weak, it was not possible to compare their composition to the ones found in the paintings in the cave. Concomitant with these colored elements, very fine engravings are visible under the thin layer of red pigment on the internal lip of the shell, at its opening. While some of the marks look more like accidental scratches or striations, other more organized ones, with deeper and more regular lines, appear to be intentional, even if we were unable to identify any figurative representation. These schematic decorations can be related to those present on rock art paintings in Marsoulas and more widely in Cantabrian caves, where stylistic peculiarities are observed, such as dotted bisons, quadrangular signs, striated necks of engraved hinds, etc. (*13*). These elements still attest to possible links between Marsoulas and Cantabrian caves. The radiocarbon dates recently obtained, situating the prehistoric occupations to around 18,000 years cal BP, are coherent with all these elements.

Around the world, conch shells have served as musical instruments, calling or signaling devices, and sacred or magic objects depending on the cultures. Their distribution extends across Oceania, New Zealand, Europe, India, Tibet, Japan, Indochina, New Guinea, and beyond. The oldest known conch shells in the Mediterranean are from Ancient Greece (*21*, *22*). To our knowledge, the Marsoulas shell is unique in the prehistoric context, not only in France but also at the scale of Paleolithic Europe and perhaps the world. In this continuum, the Marsoulas conch shell provides new information on the production of sound and music in the Upper Paleolithic.

This extraordinary archaeological artifact is multifaceted: It is a musical instrument, a decorated prestige object, and a symbol of the ocean and long-distance contacts on the Atlantic coast and Cantabria (Spain). Meanwhile, the role of the coastal environment in Paleolithic societies is still poorly known. We do know that some Magdalenian groups obtained osseous materials from the coast to make tools (*23*) and portable art objects [e.g., sperm whale tooth at Le Mas d'Azil (Ariège France) and Las Caldas (Asturias, Spain)]. The musical dimension of the conch shell from Marsoulas provides outstanding information on the symbolic activities linked to cave art.

The music was probably very important in the symbolic world of human beings during the Upper Paleolithic period. However, only few musical instruments have been preserved and discovered: Flutes, whistles, and bullroarer are attested in deposits of this period (*24*); older objects possibly associated with the practice of music are more questionable (*25*–*27*). There were probably also drums, but these instruments made of wood and skin have not been preserved (*24*).

We now have strong evidence that the Marsoulas shell comes from the archaeological level attributed to the beginning of the Magdalenian period. Its decoration with red pigments and graphic elements that exist on the walls of the cave supports this attribution. This is the first time that a symbolic link is attested between an ornate cave and a musical instrument. As with art, music is a production of social interactions. The strong link that must exist between image and sound certainly had a social function, which was to take its importance in social practices and rituals (*28*, *29*). More than the meaning of the image, paleolithic sound production is still a difficult interpretative field that can only be based on archaeological artifacts.

Methods

The program Dstretch (plugin to ImageJ) was used for highlighting red paintings in digital pictures. Painted and nonpainted areas were analyzed by x-ray fluorescence spectrometry with a device developed by the Laboratoire d'Archéologie Moléculaire et Structurale and based on a bullet x-ray source from Moxtek (USA) and a 25-mm^2 silicon drift detector from Amptek (USA). CT was carried out with a micro-CT scanner General Electric v|tome|xs at CNES, Toulouse. Visualization and analysis of CT data were realized with VGStudio MAX (Volume Graphics).

MATERIALS AND METHODS

To respond to the hypothesis that this shell could be a musical instrument, we organized an experimental session at the PETRA platform (Maison des Sciences de l'Homme de Toulouse, France) to record the sound it can produce today. The seashell was entrusted

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to a musicologist and horn player, specializing in wind instruments. The mouthpiece was protected to blow into the retouched extremity of the apex. To play the shell, the musician vibrated his lips in the manner necessary to play the trumpet or trombone (*30*). This vibration propagates into the tube, causing the air to vibrate according to the acoustic impedance of the tube. The musician thus chooses the vibration frequency among the possible resonances of the air column via the muscular tension of the lips and the control of the air mass moving in the tube. The cavity of a conch shell has a section whose width increases as a function of the length according to the law of the "Archimedean spiral" (*30*, *31*). From an acoustic perspective, this type of section can be considered as conical (*21*, *22*), as with the French horn, for example. The spectrum of sounds produced should, therefore, have a fundamental frequency (F0) accompanied by harmonics whose frequencies are whole multiples of F0: 2 × F0, 3 × F0, 4 × F0, etc. In addition, the envelope of the spectrum will decrease in function of the frequency.

Several high-quality notes were produced, corresponding to the natural resonances of the conch shell. The intensity produced is approximately 100 dBA at 1 m of the conch. The sound is very directive, with the maximum energy situated in the axis of its aperture. We conducted spectral analyses with the free computer software package Praat (version 6.0.29). In Fig. 4, graphs 1 to 3 show the average spectra of three notes produced by the musician. The spectrum displays the fundamental frequency F0 of each note (256, 265, and 285 Hz, respectively, representing each time an interval of approximately ½ tone in a tempered musical system), as well as several harmonics whose frequencies are whole multiples of the F0. In addition to the F0 and harmonics, the analyses showed the presence of parasite energy corresponding to the noise described in the qualitative analysis of the sound. Note 3 (graph 3) contains the most noise. The spectrum also displays a decrease in energy according to the frequency. The lowest note is close to C and the two others are respectively close to a C-sharp and a D, equaling a halftone each time. During the experiments, the musician remarked that the apex in its current chipped form is not functional because it could injure the lips of the instrumentalist. He thinks that an intermediary tube was probably necessary to remedy this problem, and he proposed the hypothesis that a mouthpiece was present when it was used during the Magdalenian period.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/7/7/eabe9510/DC1

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