



## The origin of language: paleontological evidence

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**ABSTRACT:** The origin and evolution of speech can be approached from the analysis of the paleontological record. Historically, this has mainly dealt with the reconstruction of the upper respiratory tract of human fossils [1-2]. However, after decades of controversy no clear results have arisen from these studies. We propose a new approach to this issue based on the possibility to reconstruct the sound power transmission, through the external and middle ear, in fossil specimens. Of all the human special senses, audition is the most readily accessible in skeletal remains since it is based on physical properties that can be approached through their skeletal structures [3-4]. Studying auditory capacities in fossil species is a major challenge, but has become feasible since the advent of CT-based analyses. The results obtained in the more than 500 kyr old fossils from the site of the Sima de los Huesos (SH) in the Sierra de Atapuerca (Spain) show that these hominins had the same auditory capacities as modern humans [5]. Specifically, they show a widened bandwidth of heightened sensitivity in the midrange frequencies compared with chimpanzees. The Mathematical Theory of Information developed by Claude Shannon [6-7] offers an appropriate theoretical framework within which to interpret these results. The widened bandwidth suggests a greater channel capacity characterized the Atapuerca (SH) hominins, a feature that is directly correlated with the amount of acoustic information that can be received by the human ear.

Although the study of audition is an indirect approach to the question of speech capacity in fossil specimens, prior attempts to reconstruct the linguistic capacities in fossil hominins have led to conflicting results and have often not been based on sound anatomical relationships between skeletal structures and language production [2] [8-10]. The recent discovery that Neandertals share with modern humans two derived substitutions in the FOXP2 gene offers tantalizing new evidence for the possible presence of spoken language in Neandertals [11]. At the same time, the beginnings of human speech have recently been suggested to date to the origin of the genus Homo [12]. The evidence for modern-human-like auditory capacities in the Atapuerca SH hominins is consistent with these recent suggestions, based on other lines of evidence, that the Neandertal evolutionary lineage (*Homo heidelbergensis*, *Homo neanderthalensis*) already showed a set of anatomical adaptations related to the presence of a highly-efficient oral communication system.

## 语言的起源：古生物学的证据

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**摘要:** 语音的起源和进化可以通过研究古生物学的资料得到线索。历史上, 这项工作主要是通过对人类化石的上呼吸道的重建得以实现[1-2]。然而, 经过多年的争论, 此方面的研究并没有得到一个明确的结果。本文提出了新的研究方法, 这个方法的基础是有可能根据化石推测声音通过外耳和中耳传播的途径。在人类的各种感官中, 听力是可以通过察骨骼结构而了解的一种物理属性, 因而最容易研究[3-4]。根据人类化石研究听力难度很大, 直到CT技术发展之后才变得可行。对阿塔坡卡的洛斯胡色裂谷遗址50万年前的人类化石的研究结果表明, 这个古人种拥有与现代人相同的听觉能力 [5]。和黑猩猩相比, 他们的中段频率中的频带宽度更宽, 代表更高的灵敏度。克劳德香农发展的信息数学理论[6-7]为这些结果提供了适当的理论基础。阿塔坡卡古人类较宽的频带宽度显示了更大的通路容量, 这一特性直接与人耳能接收到的声音信息的数量相关。

尽管听力的研究是对化石人类语音能力的间接研究方法，却优于结果相矛盾的发音能力重建的尝试，而且后者往往没有考虑到骨骼结构和语言产生在声音解剖学基础上的关联[2,8-10]。最近发现尼安德特人和现代人在*FOXP2*基因上都有两个突变，这一发现为尼安德特人有口头语言的可能性提供了新的证据[11]，同时提示人类语音的产生可以追溯到真人属的起源时期 [12]。基于一些其他的证据，尼安德特进化世系（海德堡人--尼安德特人）已经显示出一系列的解剖学上的适应，这些适应与一个高效的口头交流系统相关。而阿塔坡卡的古人类达到现代人类的听觉能力与这些研究结果相一致。（陆艳 译）

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