Linguistic
Inquiry

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On the Speech
of Neanderthal Man*

Introduction

Language is undoubtedly the most important factor that differentiates man from other animals. Language is, in itself, a system of abstract logic; it allows man to extend his rational ability. Indeed, it has often been virtually equated with man's abstract logical ability (Chomsky 1966). It is therefore of great interest to know when a linguistic ability similar to that of modern Man evolved. One of the most important factors in determining the form of man's linguistic ability is his use of "articulate" speech. We will discuss the speech ability of an example of Neanderthal man, the La Chapelle-aux-Saints fossil, in the light of its similarity to certain skeletal features in newborn humans. We herein use the term "Neanderthal" as referring to the so-called classic Neanderthal man of the Würm or last glacial period.[1]

Our discussion essentially involves two factors. We have previously determined by means of acoustic analysis that Newborn humans, like nonhuman primates, lack the anatomical mechanism that is necessary to produce articulate speech (Lieberman 1968; Lieberman *et al.* 1968, 1969). That is, they cannot produce the range of sounds that characterizes human speech. We can now demonstrate that the skeletal features of Neanderthal man show that his supralaryngeal vocal apparatus was similar to that of a Newborn human. We will also discuss the status of Neanderthal man in human evolution.

[1] The La Chapelle-aux-Saints fossil as decribed by Boule (1911–1913) is perhaps the archetypal example of "classic" Neanderthal man. As Howells (1968) notes, there is a class of classic Neanderthal fossils that can be quantitatively differentiated from other fossil hominids. We recognize that some of these other fossil hominids exhibit characteristics that are intermediate between classic Neanderthal man and modern Man. These fossils may have possessed intermediate degrees of phonetic ability, but we will limit our discussion to the La Chapelle-aux-Saints fossil in this paper.

The Anatomical Basis of Speech

Human speech is essentially the product of a source, the larynx for vowels, and a supralaryngeal vocal tract transfer function. The supralaryngeal vocal tract which extends from the larynx to the lips, in effect, filters the source (Chiba and Kajiyama 1958; Fant 1960). The activity of the larynx determines the fundamental frequency of the vowel, whereas its formant frequencies are the resonant modes of the supralaryngeal vocal tract transfer function. The formant frequencies are determined by the area function of the supralaryngeal vocal tract. The vowels /a/ and /i/, for example, have different formant frequencies though they may have the same fundamental frequency. Sounds like the consonants /b/ and /d/ also may be characterized in terms of their formant frequencies. Consonants, however, typically involve transitions or rapid changes in their formant frequencies which reflect rapid changes in the area function of the supralaryngeal tract. The source for many consonants like /p/ or /s/ may be air turbulence generated at constrictions in the vocal tract.

A useful mechanical analog to the aspect of speech production that is relevant to this paper is a pipe organ. The musical quality of each note is determined by the length and shape of each pipe. (The pipes have different lengths and may be open at one end or closed at both ends.) The pipes are all excited by the same source. The resonant modes of each pipe determine the pipe's "filter" function. In human speech the phonetic qualities that differentiate vowels like /i/ and /a/ from each other are determined by the resonant modes of the supralaryngeal vocal tract.

The acoustic theory of speech production which we have briefly outlined thus relates an acoustic signal to a supralaryngeal area function and a source. It therefore is possible to calculate the range of sounds that an animal can produce if the range of supralaryngeal vocal tract area function variation is known. The phonetic repertoire can be further expanded if different sources are used with similar supralaryngeal vocal tract area functions. We can, however, isolate the constraints that the range of supralaryngeal vocal tract variation will impose on the phonetic repertoire, from the effects of different source functions. In short, we can see what limits would be imposed on the Neanderthal phonetic repertoire by his supralaryngeal vocal tract even though we can not reconstruct his larynx.

Skeletal Structure and Supralaryngeal Vocal Tract

The human Newborn specimens used in this study were six skulls, and six heads and necks completely divided in the midsagittal plane, and all of the cadavers dissected by the coauthor (E.S.C.) for his book on newborn anatomy (Crelin 1969). The specimens of adult Man were fifty skulls, six heads and necks completely divided in the midsagittal plane, and the knowledge derived from dissections of adult cadavers made by the coauthor and his students during twenty continuous years of teaching human anatomy. The Neanderthal specimens were casts of two skulls with mandibles and

an additional mandible of the fossil man from La Chapelle-aux-Saints described by Boule (1911–1913). The casts were purchased from the Museum of the University of Pennsylvania. Detailed measurements were made on the casts and from photographs of this fossil. The original fossil was also examined at the Musée de L'Homme in Paris by one of the authors (PL). Skulls of a chimpanzee and an adult female gorilla were also studied.

When the skulls of Newborn and adult Man are placed beside the cast of the Neanderthal skull there appears to be little similarity among them, especially from an anterior view (Figure 1). Much of this is due to the disparity in size, because when

Figure 1.   Skulls of Newborn (A), and adult Man (C), and cast of Neanderthal skull (B)

they are all made to appear nearly equal in size and are viewed laterally, the Newborn skull more closely resembles the Neanderthal skull than that of the adult Man (Figure 2). The Newborn and Neanderthal skulls are relatively more elongated from front to back and relatively more flattened from top to bottom than that of adult Man. The squamous part of the temporal bone is similar in the Newborn and Neanderthal (Figure 2). The fact that the mastoid process is absent in the Newborn and relatively small in the Neanderthal adds to their similarity when compared with the skull of adult Man shown in Figure 2. However, the size of the mastoid process varies greatly in adult Man. It is not unusual to find mastoid processes in normal adult Man as small as those of Neanderthal, especially in females. The mastoid process is absent

in the chimpanzee and relatively small in the gorilla. Other features that make the
Newborn and Neanderthal skulls appear similar from a lateral view are the shape of
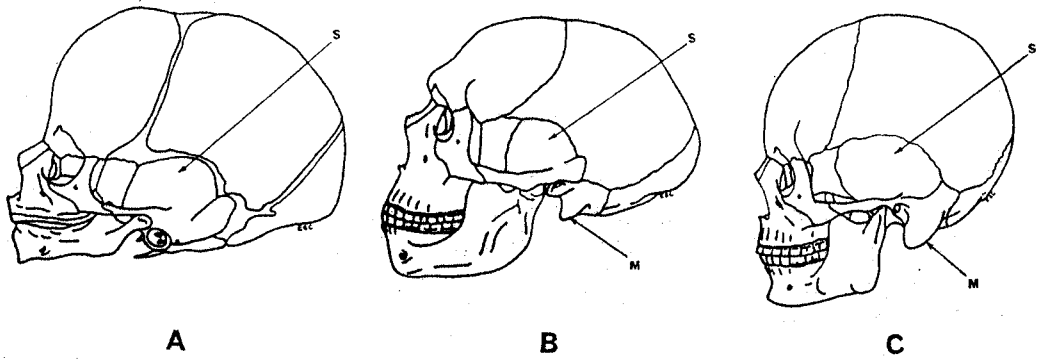the mandible and the morphology of the base of the skull.

A   **B**   **C**

*Figure 2.   Lateral views of skulls of Newborn (A), Neanderthal (B), and adult Man (C). M—
Mastoid process, S—Squamous Portion of Temporal Bone*

The Newborn and Neanderthal lack a chin, thus they share a pongid character-
istic (Figure 2). The body of the Newborn and Neanderthal mandible is longer than
the ramus, whereas they are nearly equal in adult Man (Figure 3). The posterior
border of the Newborn and Neanderthal mandibular ramus is more inclined away

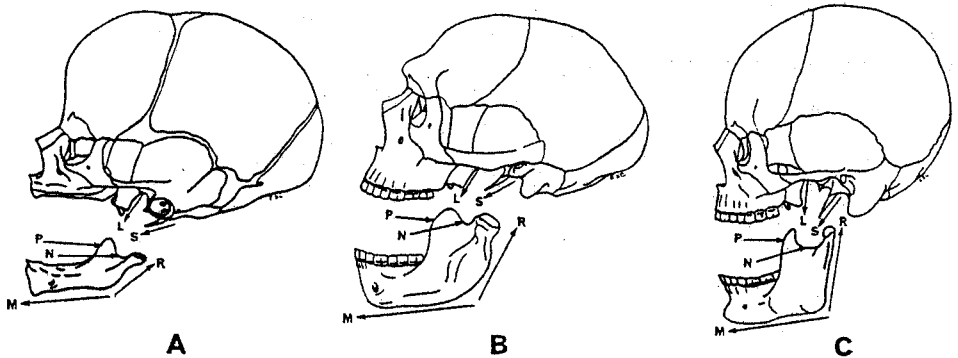**A**   **B**   **C**

*Figure 3.   Lateral views of skulls of Newborn (A), Neanderthal (B), and adult Man (C). L—Angle
of Pterygoid Lamina, S—Angle of Styloid Process, P—Coronoid Process, N—Notch, R—Ramus,
M—Body*

from the vertical plane than that of adult Man. In Newborn and Neanderthal there
is a similar inclination of the mandibular foramen leading to the mandibular canal
through which the inferior alveolar artery and nerve pass (Figure 4). The mandibular
coronoid process is broad and the mandibular notch is relatively shallow in Newborn
and Neanderthal (Figure 3).

The pterygoid process of the sphenoid bone is relatively short and the posterior border of its lateral lamina is more inclined away from the vertical plane in Newborn and Neanderthal when compared with adult Man (Figure 3). The styloid process is also more inclined away from the vertical plane in Newborn and Neanderthal than
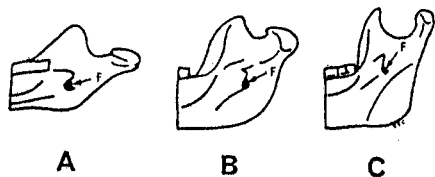

Figure 4. Deep surface of ramus of mandible of Newborn (A), Neanderthal (B), and adult Man (C). F—Mandibular Foramen

in adult Man (Figure 3). There are sufficient fossil remains of the Neanderthal left styloid process to determine accurately its original approximate size and inclination.

The dental arch of the Newborn and Neanderthal maxillas is U-shaped, a pongid feature, whereas it is more V-shaped in adult Man (Figure 5).

In the Newborn skull the anteroposterior length of the palate is less than the distance between the posterior border of the palate and the anterior border of the
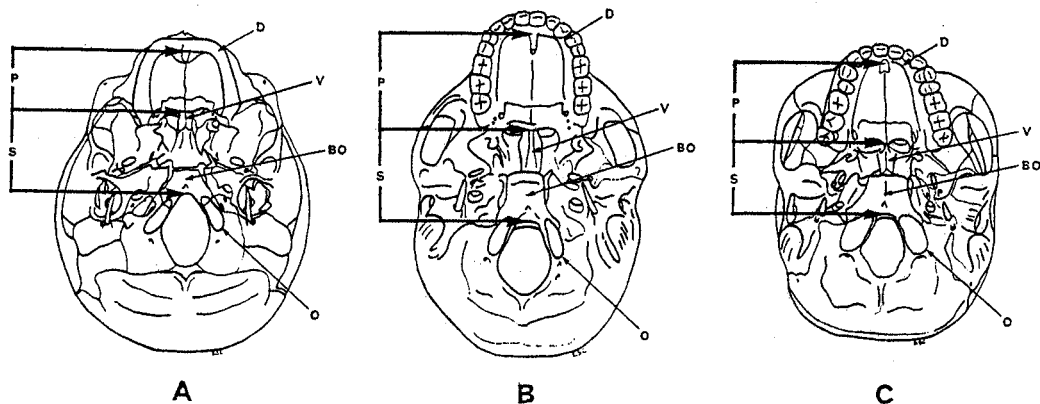

Figure 5. Inferior views of base of skull of Newborn (A), Neanderthal (B), and adult Man (C). D—Dental Arch, P—Palate, S—Distance Between Palate and Foramen Magnum, V—Vomer Bone, BO—Basilar Part of Occipital, O—Occipital Condyle

foramen magnum, i.e. 2.1 cm average (range 2.0–2.2 cm) and 2.6 cm average (range 2.5–2.7 cm) respectively (Figure 5). In Neanderthal the length of the palate is equal to the distance between the palate and the foramen magnum, i.e. 6.2 cm. In the skull of adult Man the length of the palate is greater than the distance between the palate

and the foramen magnum, i.e. 5.1 cm average (range 4.6–5.7 cm) and 4.1 cm (range 3.6–4.9 cm) respectively. Only two of the 50 skulls of modern adult Man studied were exceptions. In one the distance between the palate and the foramen magnum was 0.4 cm greater than the length of the palate and in the other the distances were the same (4.6 cm). Note the great absolute length of the distance between the palate and foramen magnum in Neanderthal man compared to adult Man. The relatively greater distance between the palate and the foramen magnum in the Newborn and Neanderthal when compared with adult Man is related to the similar relative size and shape of the roof of the nasopharynx in the Newborn and Neanderthal. The basilar part of the occipital bone, between the foramen magnum and the sphenoid bone, is only slightly inclined away from the horizontal toward the vertical plane (Figure 5). Therefore, the roof of the nasopharynx is a relatively shallow and elongated
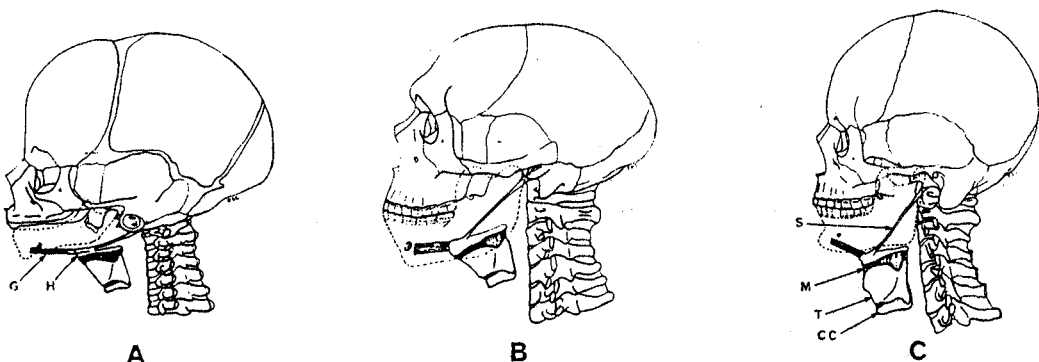

Figure 6.   Skull, vertebral column and larynx of Newborn (A), and adult Man (C), and reconstruction of Neanderthal (B). G—Geniohyoid Muscle, H—Hyoid Bone, S—Stylohyoid Ligament, M—Thyrohyoid Membrane, T—Thyroid Cartilage, CC—Cricoid Cartilage. Note that the inclination of the styloid process away from the vertical plane in Newborn and Neanderthal results in a corresponding inclination in the stylohyoid ligament. The intersection of the stylohyoid ligament and geniohyoid muscle with the hyoid bone of the larynx occurs at a higher position in Newborn and Neanderthal. The high position of the larynx in the Neanderthal reconstruction follows, in part, from this intersection.

arch, whereas in adult Man it forms a relatively deep, short arch (Figures 8 and 9). In adult Man, without exception, the basilar part of the occipital bone is inclined more toward the vertical plane than toward the horizontal plane. Related to the shape of the roof of the nasopharynx in Newborn and Neanderthal, the vomer bone is relatively shorter in its vertical height and its posterior border is inclined away from the vertical plane to a greater degree than in adult Man (Figures 5 and 9).

In Figure 5 the foramen magnum is shown to be elongated in the anteroposterior plane in the Newborn, Neanderthal, and adult Man. Its shape is variable in both Newborn and adult Man where it frequently is more circular. The occipital condyles of Neanderthal are similar to those of the Newborn and the gorilla by being relatively

small and elongated. Since the second, third, and fourth cervical vertebrae of the man from La Chapelle-aux-Saints are lacking, they were reconstructed to conform with those of adult Man (Figure 6). The Neanderthal skull is placed on top of an erect cervical vertebral column instead of on one sloping forward as depicted by Boule (1911–1913) and Keith (1925). This is in agreement with Straus and Cave (1957). In addition, the spinous processes of the lower cervical vertebrae shown for adult Man in Figure 6 are curved slightly upward. They are from a normal vertebral column and were purposely chosen to show that those of Neanderthal were not necessarily pongid in form. In fact, the cervical vertebral column of Neanderthal also resembles that of Newborn (Figure 6).

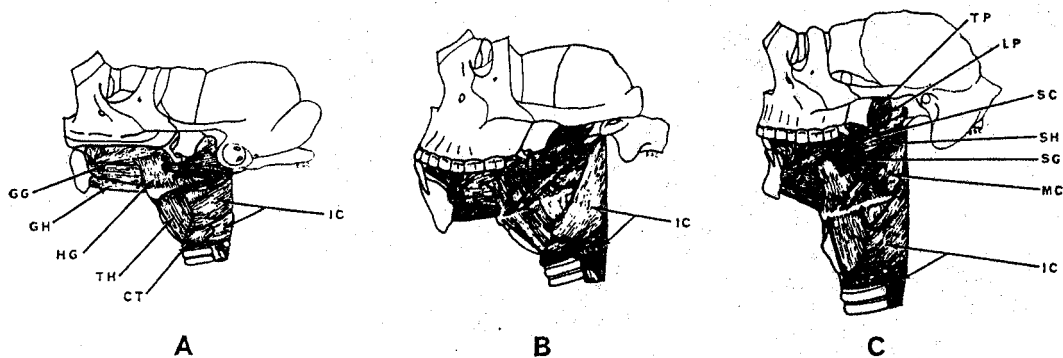In order to reconstruct the supralaryngeal vocal tract of Neanderthal it was

Figure 7. Tongue and pharyngeal musculature of Newborn (A) and adult Man (C), and reconstruction of Neanderthal (B). GG—Genioglossus, GH—Geniohyoid, HG—Hyoglossus, TH—Thyrohyoid, CT—Cricothyroid, TP—Tensor Veli Palatini, LP—Levator Veli Palatini, SC—Superior Pharyngeal Constrictor, MC—Middle Pharyngeal Constrictor, IC—Inferior Pharyngeal Constrictor, SH—Stylohyoid SG—Styloglossus

essential to locate the larynx properly. Because of the many similarities of the base of the skull and the mandible between Newborn and Neanderthal, coupled with the known detailed anatomy of Newborn, of adult Man and of apes, it was possible to do this with a high degree of confidence (Figure 6). Although the larynx was judged to be as high in position as that in Newborn and apes, it was purposely dropped to a slightly lower level to give Neanderthal every possible advantage in his ability to speak.

Once the position of the larynx in Neanderthal was determined, it was a rather straightforward process to reconstruct his tongue and pharyngeal musculature (Figure 7). The next step was to reconstruct the vocal tract of Neanderthal by building his laryngeal, pharyngeal, and oral cavities with modelling clay in direct contact with the skull cast. After this was done a silicone-rubber cast was made from the clay mold

of the air passages, including the nasal cavity. At the same time similar casts were made of the air passages, including the nasal cavity of the Newborn and adult Man. This was done by filling each side of the split air passages separately in the sagittally-sectioned Newborn and adult Man heads and necks to ensure perfect filling of the cavities. The casts from each side of a head and neck were then fused together to make a complete cast of the air passages.

Even though the cast of the Newborn air passages is much smaller than those of Neanderthal and adult Man it is apparent (Figure 8) that the casts of the Newborn
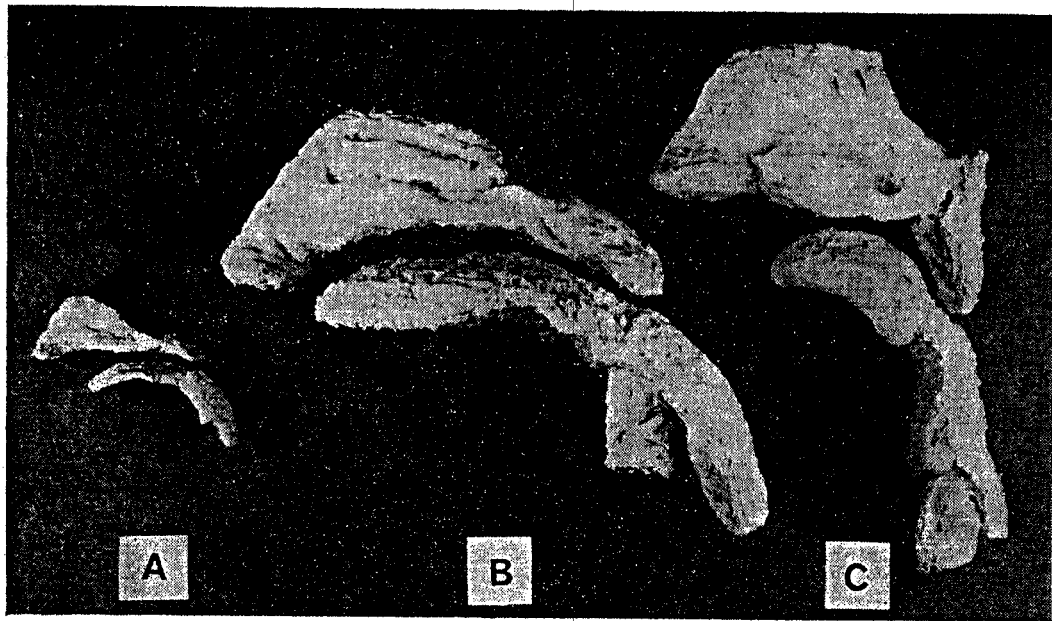

Figure 8.   Casts of air passages of Newborn (A), Neanderthal reconstruction (B), and adult Man (C). The nasal, oral, and pharyngeal air passages are shown.

and Neanderthal are quite similar and have pongid characteristics (Negus 1949). When outlines of the air passages from all three are made nearly equal size, one can more readily recognize what the basic differences and similarities are (Figure 9). Although the nasal and oral cavities of Neanderthal are actually larger than those of adult Man, they are quite similar in shape to those of the Newborn in being very elongated. The high position of the opening of the larynx into the pharynx in Newborn and apes is directly related to the high position of the hyoid bone; therefore, the opening of the larynx into the pharynx is in a high position in Neanderthal (Figure 9). The development of the Newborn pharynx into the adult type is primarily a shift in the location of the opening of the larynx into it from a high to a low position. This is probably the result of differential growth where the posterior third of the tongue, be-

tween the foramen cecum and the epiglottis, shifts from a horizontal resting position within the oral cavity to a vertical resting position, to form the anterior wall of the oral part of the pharynx (Figure 9). In this shift the epiglottis becomes widely separated from the soft palate. Also the large posterior portion of the pharynx below the opening of the larynx in the Newborn is lost as it in large part becomes part of the acquired supralaryngeal portion.

Supralaryngeal Vocal Tract Limits on the Neanderthal Phonetic Inventory

We cannot say much about either the laryngeal source or the dynamic control of Neanderthal man's vocal apparatus. We can, however, determine some of the limits on the range of sounds that Neanderthal man could have produced by modelling the reconstruction of his supralaryngeal vocal tract.

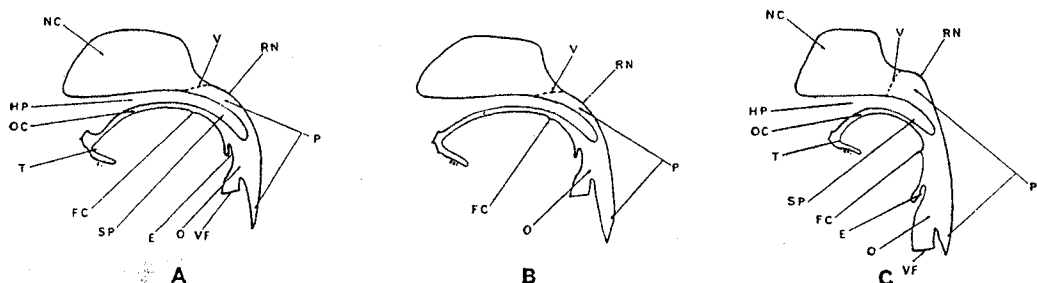We measured the cross-sectional area of the Neanderthal and Newborn vocal

Figure 9. Supralaryngeal air passages of Newborn (A), Neanderthal reconstruction (B), and adult Man (C). NC—Nasal Cavity, V—Vomer Bone, RN—Roof of Nasopharynx, P—Pharynx, HP—Hard Palate, SP—Soft Palate, OC—Oral Cavity, T—Tip of Tongue, FC—Foramen Cecum of Tongue, E—Epiglottis, O—Opening of Larynx into Pharynx, VF—Level of Vocal Folds

tracts shown in Figure 8 at 0.5 cm intervals. These measurements gave us "neutral" area functions which we perturbed towards area functions that would be reasonable if a Newborn or a Neanderthal vocal tract attempted to produce the full range of human vowels. This can be conveniently done by attempting to produce vowels that are as near as possible to /u/, /a/, and /i/ (the vowels in the words *boot, father,* and *feet*). These three vowels delimit the human vowel space (Fant 1960). We also investigated vocal tract area functions for various consonants. In all of these area functions we made use of our knowledge of the skull and muscle geometry of Man and the Neanderthal skull as well as cineradiographic data on vocalization in adult Man (Perkell 1969), and Newborn (Truby *et al.* 1965). When we were in doubt as, for example, with respect to the range of variation in the area of the larynx, we used data derived from adult Man that would enhance the phonetic ability of the Neanderthal vocal tract (Fant 1960).
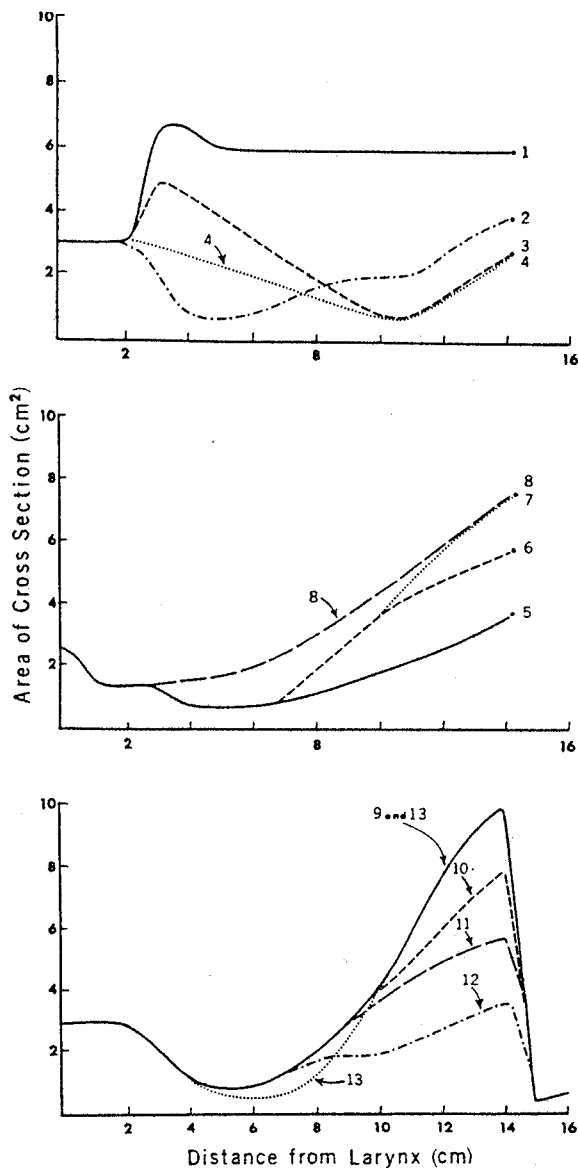
Figure 10.   Area Functions of the supralaryngeal vocal tract of Neanderthal reconstruction modelled on computer. The area function from 0 to 2 cm is derived from Fant (1960) and represents the distance from the vocal folds to the opening of the larynx into the pharynx. Curve 1 is the unperturbed tract. Curves 2, 3, and 4 represent functions directed towards a "best match" to the human vowel /i/. Curves 5–8 are functions directed towards a "best match" to /a/, while curves 9–13 are directed towards /u/.

Typical supralaryngeal area functions for the nonnasal portion of the Neanderthal vocal tract are plotted in Figure 10. We were able to determine what sounds would result from these area functions by using them to control a computer-implemented analog of the supralaryngeal vocal tract.

The computer program represented the supralaryngeal vocal tract by means of a series of contiguous cylindrical sections, each of fixed area. Each section can be described by a characteristic impedence and a complex propagation constant, both of which are well-known quantities for uniform cylindrical tubes. Junctions between sections satisfy the constraints of continuity of pressure and conservation of volume velocity (Henke 1966). In this fashion the computer program calculated the three lowest formant frequencies of the vocal tract filter system which specify the acoustic properties of a vowel (Chiba and Kajiyama 1958; Fant 1960).

In Figure 11 the first and second formant frequencies of the vowels of American English are plotted for a sample of 76 adult men, women, and children (Peterson and Barney 1952). The labelled closed loops enclose the data points that accounted for 90 per cent of the samples in each vowel category. The points plotted in Figure 12 represent the formant frequencies that corresponded to our simulated Neanderthal vocal tract. We have duplicated the vowel "loops" of Figure 11 in Figure 12. Note that the Neanderthal vocal tract cannot produce the range of sounds plotted for the human speakers in Figure 11. We have compared the formant frequencies of the simulated Neanderthal vocal tract with this comparatively large sample of human speakers, since it shows that the speech deficiencies of the Neanderthal vocal tract are different in kind from the differences that characterize different human speakers, even when the sample includes adult men, adult women, and children. The acoustic vowel space of American English would not appear to be anomalously large compared to other languages although exhaustive acoustic data is lacking for many languages (Chiba and Kajiyama 1958; Fant 1960). It is not necessary to attempt to simulate the sounds of all languages with the computer implemented Neanderthal vocal tract since the main point that we are trying to establish is whether Neanderthal man could produce the full range of human speech. Figures 11 and 12 show that the Neanderthal vocal tract cannot produce the full range of American English vowels. Note the absence of data points in the vowel loops for /u/, /i/, /a/, and /ɔ/ in Figure 12. Since all human speakers can inherently produce all the vowels of American English, we have established that the Neanderthal phonetic repertoire is inherently limited. In some instances we generated area functions that would be appropriately human-like, even though we felt that we were forcing the articulatory limits of the reconstructed Neanderthal vocal tract, e.g. functions 3, 9, and 13 in Figure 10. However, even with these articulatory gymnastics the Neanderthal vocal tract could not produce the vowel range of American English. The computer simulation was also used to generate consonantal vocal tract functions. It indicated that the Neanderthal vocal tract was limited to labial and dental consonants like /b/ and /d/.

Figure 11. *Formant frequencies of American English vowels for a sample of 76 adult men, adult women and children. The closed loops enclose 90 per cent of the data points in each vowel category, after Peterson and Barney (1952).*

The Neanderthal vocal tract also might lack the ability to produce nasal versus nonnasal distinctions. In human speech the nasal cavity acts as a parallel resonator when the velum of the soft palate is lowered, e.g. in the initial consonant of the word *mat*. The parallel resonator introduces energy minima into the acoustic spectrum and widens the bandwidths of formants (Fant 1960). In the Neanderthal vocal tract the posterior pharyngeal cavity which leads to the oesophagus will act as a parallel resonator whether or not the nasal cavity is coupled to the rest of the vocal tract. The energy minima associated with the parallel pharyngeal resonator, however, occur at rather
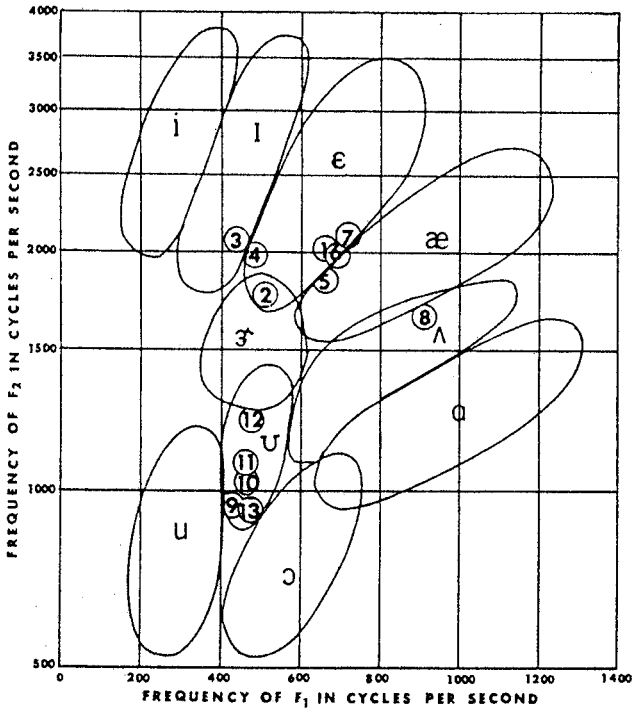

Figure 12. Formant frequencies calculated by computer program for Neanderthal reconstruction. The numbers refer to area functions in Figure 10. The vowel loops of Figure 11 are repeated.

high frequencies, and it is not clear whether they will have a perceptual effect. Our computer simulation did not allow us to introduce parallel resonators so we could not investigate this phenomenon quantitatively. It is possible that all Neanderthal vocalizations had a "nasal" or "seminasal" quality.

We modelled the Newborn vocal tract in the same manner as the Neanderthal vocal tract. The computer output of the Newborn vocal tract was in accord with instrumental analyses of Newborn cry and perceptual transcriptions of Newborn vocalizations (Lieberman *et al.* 1968). The modelling of the Newborn vocal tract

thus served as a control on the way in which we estimated the range of supralaryngeal area functions and the synthesis procedure. If we had not been able to synthesize the full range of Newborn vocalizations, we would have known that we were underestimating the range of supralaryngeal vocal tract variation. Since we followed the same procedures for the Neanderthal and Newborn vocal tracts and indeed "forced" the Neanderthal vocal tract to its limits, it is reasonable to conclude that we have not underestimated the phonetic range of the reconstructed Neanderthal vocal tract.

Our computer simulation thus shows that the supralaryngeal vocal tract of Neanderthal man was inherently incapable of producing the range of sounds that is necessary for the full range of human speech. Neanderthal man could not produce
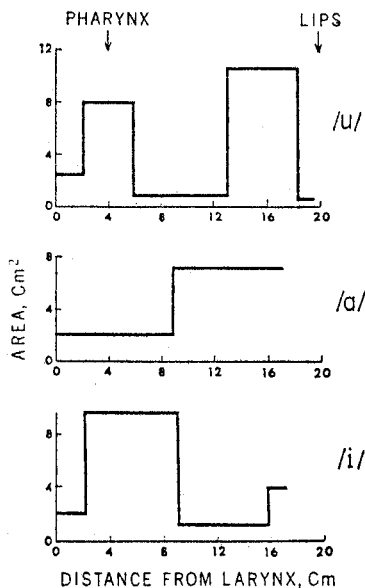

Figure 13.   Schematized area functions for the human vowels /a/, /u/, and /i/. Note that the area function changes abruptly and the area of the pharyngeal region is independent of the area of the front part of the supralaryngeal vocal tract, after Lieberman, Klatt, and Wilson (1969).

vowels like /a/, /i/, /u/, or /ɔ/ (the vowel in the word *brought*) nor could he produce consonants like /g/ or /k/. All of these sounds involve the use of a variable pharyngeal region like Man's where the dorsal part of the tongue can effect abrupt and extreme changes in the cross-sectional area of the pharyngeal region, independent of the oral region.[2] The area functions in Figure 13 are typical of the human vowels /a/, /u/, and /i/.

[2] Several studies (Negus 1949, DeBrul 1958, Coon 1966) have suggested that the evolution of the human pharyngeal region played a part in making "articulate" speech possible. Negus (1949) indeed presents a series of sketches based on reconstructions by Arthur Keith where he shows a high laryngeal position for Neanderthal man.

The Neanderthal vocal tract, however, has more "speech" ability than the nonhuman primates. The large cross-sectional area function variations that can be made in the Neanderthal oral region make this possible since the Neanderthal mandible has no trace of a simian shelf (Boule 1911–1913) and the tongue is comparatively thick. It can produce vowels like /I/, /e/, /U/, and /æ/ (the vowels in the words *bit, bet, but*, and *bat*) in addition to the reduced schwa vowel (the first vowel in *about*). Dental and labial consonants like /d/, /b/, /s/, /z/, /v/, and /f/ are also possible although nasal versus nonnasal contrasts may not have been possible. If Neanderthal man were able to execute the rapid, controlled articulatory maneuvers that are necessary to produce these consonants and had the neural mechanisms that are necessary to perceive rapid formant transitions (special neural mechanisms appear to be involved in Man (Whitfield 1969; Lieberman *et al.* 1967)), he would have been able to communicate by means of sound. Of course, we do not know whether Neanderthal man had these neural skills; however, even if he were able to make optimum use of his speech-producing apparatus, the constraints of his supralaryngeal vocal tract would make it impossible for him to produce "articulate" human speech, i.e. the full range of phonetic contrasts employed by modern man.

On the Evolutionary Status of Neanderthal Man: Speech Apparatus, Brain, and Language

Of all the living primates only man has an extensive supralaryngeal pharyngeal region that allows all of the intrinsic and extrinsic pharyngeal musculature to function at a maximum for speech production by changing the shape of the supralaryngeal vocal tract (Negus 1949). It appears that the ontological development of the vocal apparatus in Man is a recapitulation of his evolutionary phylogeny.[3] If so, Neanderthal

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[3] Apart from the absence of brow ridges and certain other specializations, the total form of the Newborn and Neanderthal skulls makes them members of the same class with respect to adult modern Man. The various anatomical features that we have discussed indicate this similarity but the total similarity of the complex form is most evident to the human pattern recognizer. Human observers are still the best "pattern recognition systems" that exist. Modern statistical and computer techniques, while they are often helpful, have yet to achieve the success of human observers whether music, speech, or "simple" visual forms like cloud patterns form the input. Both the Neanderthal and the Newborn skulls have a "flattened out" base where there is space for the larynx to assume a high position with respect to the palate. The anatomical similarities between Newborn and Neanderthal skulls are also evident in the La Farrassie I and Monte Circeo skulls as well as the La Quina child's skull (estimated age 8 years).

The La Quina skull, which lacks the massive brow ridges of the adult Neanderthal skulls, retains the anatomical features that result in a flattened out base. These similarities, of course, recall Haeckel's "Law of Recapitulation" (Haeckel 1907). Neanderthal man and modern Man probably had a common ancestor who had a flattened out skull base and a high laryngeal position, but who lacked massive brow ridges. The skulls of Newborn modern man and the La Quina Neanderthal child both point to this common ancestor insofar as they lack massive brow ridges though they retain the aforementioned similarities. Classic Neanderthal man and the ancestors of modern man diverged. The massive brow ridges of adult Neanderthal man reflect this divergence. They are a specialization of Neanderthal man. We do not find any trace of brow ridges in Newborn modern man since classic Neanderthal man is not a direct ancestor of modern man. He perhaps is a "cousin". The evidence which many scholars have interpreted as a general and complete refutation of Haeckel's theory should be reconsidered. The process of mutation and natural selection, of necessity, results in many variations. It is not surprising to find the presence of what appear to be many fossil species that are not in the direct line

was an early offshoot from the mainstream of hominids that evolved into modern Man, just as Boule (1911–1913) recognized. It is unlikely that Neanderthal man can represent a specialized form of modern Man (Coon 1966) or an extremely specialized species that evolved from *Homo sapiens* (Leakey and Goodall 1969).

Natural selection would act for the retention of mutations that developed a pharyngeal region like Man's because these developments increase the number of "stable" acoustic signals that can be used for communication. The sounds used in human language tend to be acoustically "stable". They are the result of supralaryngeal vocal tract configurations where deviations from the "ideal" shape result in signals that do not differ greatly from the acoustic signals that the ideal shape produces (Stevens, in press). Errors in articulation thus have minimal effect on the acoustic character of the signal. The vowels /a/, /i/, and /u/ are the most stable vowels. The Neanderthal supralaryngeal vocal tract cannot produce these vowels which involve a variable pharyngeal region and the associated musculature (Figures 7, 9, and 13). The descent of the larynx to its lower position in adult Man thus would follow from the advantages this confers in communication. The adult human laryngeal position is not advantageous for either swallowing or respiration. The shift of the larynx from its position in Newborn and Neanderthal is advantageous for acquiring articulate speech but has the disadvantage of greatly increasing the chances of choking to death when a swallowed object gets lodged in the pharynx. In this respect non-human primates also have anatomical advantages (Negus 1949). The only function for which the adult vocal human tract is better suited is speech.

In our synthesis procedure we made maximum use of the reconstructed Neanderthal vocal tract. This perhaps yielded a wider range of sounds than Neanderthal man actually produced. It is possible, however, that Neanderthal man, who had a large brain, also made maximum use of his essentially nonhuman vocal tract to establish vocal communication. This would provide the basis for mutations that lowered the larynx and expanded the range of vocal communication in modern Man's ancestral forms.

Whether or not he did possess this mental ability may never be known. A fairly good intracranial cast was made from the La Chapelle-aux-Saints fossil (Boule and Vallois 1957). Although Neanderthal has a cranial capacity equal to that of modern Man, this cannot be regarded as a reliable indicator of his mental ability. Cranial capacity varies greatly in modern Man and cannot be correlated with individual mental ability. There are indications that Neanderthal may not have had a sufficiently developed brain for articulate speech since his brain, although large, had relatively

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of human evolution. There is no reason to assume that all of the evolutionary hominid "experiments" are direct ancestors of modern Man, or that all fossil species of elephants are direct ancestors of modern elephants, etc. Many discussions of Haeckel's theory implicitly make this erroneous assumption when they review ontogenetic and phylogenetic data. Ontogenetic evidence can provide valuable insights into the evolution of living species.

small frontal lobes (Figure 14). From the developmental and phylogenetic viewpoints, it is the differences in the frontal lobes that distinguish most especially the human from the subhuman brain (Crosby *et al.* 1962). Although the frontal lobes of the Newborn are well developed, the brain has some grossly primitive features (Crelin 1969).

The incline of the basilar part of the occipital bone of the Newborn skull results in a corresponding incline of the adjacent brain stem away from the vertical plane to form a marked angle where it passes vertically out of the foramen magnum to become the spinal medulla (cord). In adult Man the vertically-oriented brain stem follows from the inclination of the adjacent basilar part of the occipital bone (Figure 9). Since the base of the Neanderthal skull is so similar to that of the Newborn, the brain stem was similarly inclined (Figure 14). Boule and Vallois (1957) noted that
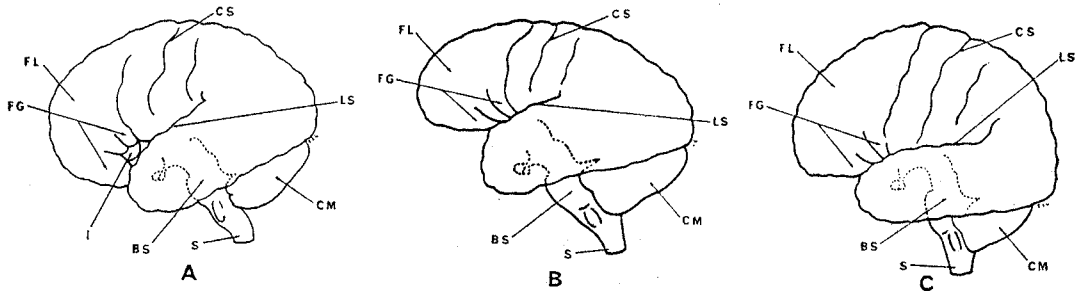

Figure 14. Lateral view of brain of Newborn (A) and adult Man (C) and Neanderthal (B). The Neanderthal view is based on the intracranial cast of Boule and Vallois (17). FL—Frontal Lobe, FG—Inferior Frontal Gyrus, CS—Central Sulcus, LS—Lateral Sulcus, BS—Brain Stem, CM— Cerebellum, S—Spinal Medulla (cord), I—Insula.

on the Neanderthal intracranial cast the lateral sulcus of the brain gaped anteriorly. They interpreted this as an exposure of the insula. If this is true, it is another similarity Neanderthal brain has to the Newborn brain. During brain development in Man the insula gradually becomes completely covered by the enlarging inferior frontal gyrus. At birth the insula is still exposed (Crelin 1969) (Figure 14). Since the insula also becomes completely covered by the inferior frontal gyrus in apes, it is illogical that it would not do so in Neanderthal (Connolly 1950). Therefore, the interpretation of the exposure of the insula in the Neanderthal brain is disputed.

Note that we are not claiming that neural developments played no role in the evolution of speech and language. We are simply stating that the anatomical mechanism for speech production is a necessary factor. Neural development is also necessary; the two factors together produce the conditions sufficient for the development of language. There is some evidence that indeed shows that the speech output mechanism and neural perceptual mechanisms may interact in a positive way. In recent years a

"motor" theory of speech perception has been developed (Lieberman *et al.* 1967). This theory shows that speech is "decoded" by Man in terms of the articulatory maneuvers that are involved in its production. Signals that are quite different acoustically are identified as being the same by means of neural processing that is structured in terms of the anatomical constraints of Man's speech production apparatus. Signals that are acoustically similar may, in different contexts, be identified as being dissimilar by the same process. Animals like bullfrogs also "decode" their meaningful sounds by means of detectors that are structured in terms of the anatomical constraints of their sound-producing systems (Capranica 1965). These neural processes are species-specific and they obviously can only evolve as, or after, the species develops the ability to produce specific sounds. The brain and the anatomical structures associated with signalling thus evolve together. Enhanced signalling, i.e. phonetic ability, correlates with general linguistic ability in the living primates where modern man and the nonhuman primates are the extremes (Lieberman 1968, Lieberman *et al.* 1969).

The articulatory maneuvers that underlie human speech constrain the entire neural embodiment of the grammar of language. The range of sounds and phonetic contrasts of speech form "natural" dimensions that structure the phonologic, syntactic, and lexical properties of all human languages (Jakobson *et al.* 1963, Postal 1968, Lieberman 1970). The hypothetical language that Neanderthal man could have employed would have been more "primitive" in a meaningful sense than any human language. Fewer phonetic contrasts would have been available for the linguistic code.

Fully developed "articulate" human speech and language appear to have been comparatively recent developments in Man's evolution. They may be the primary factors in the accelerated pace of cultural change. Our conclusions regarding Neanderthal man's linguistic ability, which are based on anatomical and acoustic factors, are consistent with the inferences that have been drawn from the rapid development of culture in the last 30,000 years in contrast to the slow rate of change before that period (Dart 1959).

Conclusion

Neanderthal man did not have the anatomical prerequisites for producing the full range of human speech.[4] He probably lacked some of the neural detectors that are

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[4] Debetz (1961) in connection with attempts to explain directly the causes for the appearance of certain characteristics belonging to Homo sapiens notes that, ". . . the peculiarities of the skull, whose importance in the evolution of man is not in any case less important then the peculiarities in the structure of the hand and of the entire body, remain inexplicable". We have shown that some of the differences between the skull structure of "classic" Neanderthal man and Homo sapiens are relevant to the production of the full range of human speech. Earlier unsuccessful attempts at deducing the presence of speech from skeletal structures, which are discussed by Vallois (1961), were hampered both by the absence of a quantitative acoustic theory of speech production, and suitable anatomical comparisons with living primates that lack the physical basis for articulate human speech.

involved in the perception of human speech. He was not as well equipped for language as modern man. His phonetic ability was, however, more advanced than those of present day nonhuman primates and his brain may have been sufficiently well developed for him to have established a language based on the speech signals at his command. The general level of Neanderthal culture is such that this limited phonetic ability was probably utilized and that some form of language existed. Neanderthal man thus represents an intermediate stage in the evolution of language. This indicates that the evolution of language was gradual, that it was not an abrupt phenomenon. The reason that human linguistic ability appears to be so distinct and unique is that the intermediate stages in its evolution are represented by extinct species.

Neanderthal culture developed at a slow rate. We may speculate on the disappearance of Neanderthal man and we can note that his successors, for example, Cro Magnon man, who inhabited some of the old Neanderthal sites in the Dordogne (Boule and Vallois 1957), had the skeletal structure that is typical of Man's speech mechanism. Neanderthal man's disappearance may have been a consequence of his linguistic—hence intellectual—deficiencies with respect to his sapiens competitors. In short, we can conclude that Man is human because he can say so.

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