Pharyngeal consonants and the aryepiglottic sphincter

JOHN H. ESLING
Department of Linguistics, University of Victoria,
P.O. Box 3045, Victoria, B.C. V8W 3P4, Canada
e-mail: esling@uvic.ca

1. Introduction

Recent laryngoscopic observations suggest that renewed discussion of pharyngeal articulations is warranted. The discussion involves the issues of place of articulation — the nature of the category "epiglottal" — and of manner of articulation — whether pharyngeal manners of articulation go beyond approximant and fricative to include trill and stop. In essence, the question is still the old one of how those sounds which are labelled auditorily as "pharyngeal" are produced. The observations reported here suggest that "epiglottal" articulations can be treated as a category of pharyngeal manners of articulation; and that manners of pharyngeal articulation are more closely parallel to uvular manners of articulation than previously assumed. The nature of pharyngeal approximants and pharyngeal fricatives is reexamined, evidence of trilling accompanying friction is presented, and the nature of the pharyngeal (epiglottal) stop is described. It is suggested that all four of these categories share a common place of articulation, and that they can best be described as differing in manner of articulation. The motivation for elaborating the phonetic detail of these distinctions is to facilitate a more precise description of phonemes that have been identified as pharyngeal in the languages of the world, and to provide a clearer explanation of phonetic and phonological processes that may be related to pharyngeal articulations.

The objectives of this paper are (1) to elaborate on the phonetic description of the epiglottal consonants, (2) to describe a new (previously unformulated) value for the epiglottal fricatives (trilling), (3) to propose that these sounds constitute a regular series of pharyngeal approximant, fricative, trills and stop, and (4) to propose that a secondary component influencing the production and perception of pharyngeal sounds is the height of the larynx (raised or lowered) accompanying pharyngeal stricture.

2. Background: Descriptions of pharyngeals

Hockett (1958) considered that pharyngeal articulations are produced by narrowing the pharynx from front to back. "As in the larynx, a complete closure can be made in the lower pharyngeal region, by drawing the root of the tongue back against the back wall of the passage. This produces a *pharyngeal catch*, which occurs as a speech sound in some dialects of Arabic" (p. 66). It is accepted in the present analysis that stop closure as identified auditorily by Hockett does indeed occur in the pharyngeal region, but not by the mechanism which he described.

Journal of the International Phonetic Association (1996) **26**(2): 65–88

In his 1968 review of articulatory possibilities, Catford advanced the term "epiglottopharyngeal" to characterize "extreme retraction of the tongue, so that the epiglottis approximates to the back wall of the pharynx" (p. 326), but doubted whether a stop articulation could be performed at this location "since it seems to be impossible to make a perfect hermetic closure between epiglottis and pharynx wall — stop-like sounds produced in this way appear to involve glottal closure as well as epiglottopharyngeal close approximation. However, epiglottopharyngeal *fricative*, *approximant* and possibly *trill* can be produced" (p. 326). Again, the present analysis agrees that an auditory classification of pharyngeal sounds includes "stop-like" sounds as well as fricative, approximant and trill categories. It should be pointed out that Catford's extensive table of articulatory categories (p. 327) holds open the possibility of epiglottopharyngeal stop and trill (signalled by question marks in his table) in articulatory parallel with fricative and approximant. What is needed is to decipher the nature of what is meant by "epiglottopharyngeal."

There is a second component associated with pharyngeal articulatory postures which has been identified auditorily, but which needs to be explained physiologically. Catford (1977a) has dealt extensively with these secondary auditory distinctions, positing articulatory explanations such as "ventricular" and "anterior" glottal. References to similar auditory qualities appear in various phonetic and phonological analyses of Semitic, Salish and Wakashan, and Caucasian consonants, and of Mon-Khmer languages to account for movements of the larynx that accompany the production of tone. The articulatory explanation that will be put forward in the present analysis involves the raising or lowering of the larynx, which can be observed laryngoscopically and which may accompany the primary mechanism of pharyngeal stricture that is described below. Early confirmation of larynx raising in pharyngeals is found in a study of Somali pharyngeals by Jones (1934), who commented that "it appeared that the ventricular bands and the surrounding tissue were in rapid vibration" (p. 8) and "that there was a lift in the glottis and a narrowing of the supraglottal pharynx" (p. 9). Jones's evidence and the findings of the present study support Nolan's (1983) observation of a relationship between larynx raising and pharyngealization.

Delattre (1968) identified the acoustic characteristics of pharyngealization, and in 1971 described a number of sounds in Arabic, German, Spanish, French, and American English which can be classified as involving pharyngeal constriction — in the upper pharynx for uvulars and in the lower pharynx for pharyngeals proper. This interpretation is interesting because it introduces the notions that constriction in the pharyngeal region can accompany a variety of backed sounds (even in languages that do not have pharyngeals per se), that this constriction can be observed to some extent cross-sectionally using x-ray technology, and that different areas of the pharynx may be involved in the production of pharyngeals. Although later analyses have held that constriction or narrowing at different places in the pharynx is responsible for the differences in pharyngeal sounds, it will be maintained in the present analysis that a single primary mechanism is responsible for the phenomenon of pharyngeal constriction (excluding uvulars as a separate place of articulation), and that a second, vertical component not shown in Delattre's x-ray tracings is responsible for secondary adjustments to pharyngeal quality.

Using fibreoptic laryngoscopy, Fujimura and Sawashima (1971) reported that final /t/ in American English can involve adduction of the ventricular folds, suggesting that the term "glottalization" involves a complex set of phenomena. The articulation observed by Fujimura and Sawashima apparently follows after glottal adduction or glottal stop, as in [t̰ʔ]. The tempting question is to ask how much more constricted this closure mechanism could be. If it starts with simple medial and interarytenoidal adduction of the vocal folds and progresses to ventricular fold closure, could it progress further to what has been called a "massive glottal stop" (J. Anthony, personal communication), i.e., to complete closure of the laryngeal (laryngeal-pharyngeal) valve as in a choking posture, and what articulatory movements are involved? The present analysis will examine the nature of this continuum of closure in detail, using auditory categories as a basis for the visual examination of sounds labelled as pharyngeal.

Catford's (1977a) comprehensive treatment divides both pharyngeals and laryngeals into two categories each. The principal bases for these distinctions are assumed to be auditory (based on sound qualities used in various languages), supported by articulatory observations. The less extreme of the pharyngeals, as in Danish /r/, is termed "linguo-pharyngeal" where "the root of the tongue, carrying with it the epiglottis, moves backwards to narrow the pharynx in a front-back dimension" (p. 163). Presumably, this is similar to but more retracted than the upper pharynx constriction that Delattre described for German or French /r/. The more extreme pharyngeal articulation, as in [ħ] and [ʕ], is termed "faucal or transverse pharyngeal" by Catford where "the part of the pharynx immediately behind the mouth is laterally compressed, so that the faucal pillars move towards each other. At the same time the larynx may be somewhat raised. ... It is largely a sphincteric semi-closure of the oro-pharynx, and it can be learned by tickling the back of the throat, provoking retching" (p. 163). These auditory and articulatory observations provide the rationale for at least a two-way distinction, but it remains unclear (1) what occurs beneath the visible faucal pillars during [ħ] and [ʕ], (2) whether the difference is one of degree, i.e., of manner of articulation, and (3) whether the simultaneous larynx raising is an inherent trait of lingual retraction or a second parameter under independent control.

Catford's (1977a) further characterization of laryngeals adds considerably to the understanding of pharyngeal activity. Simple "glottal" articulations, such as [ʔ], are as represented on the chart of the IPA. "Ventricular" articulations, on the other hand, occur when "the ventricular bands are brought together..., plus some generalized constriction of the upper larynx and pharynx." In contrast with [ʔ], "this ventricular or strong glottal stop may be represented by [ʕ̰ʔ]" (p. 163). Gaprindashvili (1966), as Catford observes, describes this same articulation as a "pharyngealized glottal stop" (1977a: 163). The strong glottal stop occurs in the Nakh languages and in some Dagestanian languages, and is sometimes termed a "pharyngeal stop" in the Georgian literature (Catford 1977b: 289). Since then, the IPA has incorporated a symbol for an "epiglottal plosive" into its inventory. To isolate what seems from the auditory descriptions to be the same sound, seven terms have been used thus far: "epiglottopharyngeal" stop, "massive glottal stop," "strong glottal stop," "ventricular stop," "pharyngeal stop," "pharyngealized glottal stop," and "epiglottal" stop. That the sound exists, and occurs in phonological contrast, is not controversial. An attempt will be made here to reconcile the articulatory descriptions.

An additional apparent complexity, pointed out by Catford, is the occurrence of the "breathy-voiced (or whispery-voiced) ventricular fricative trill [ɦʕ̯]" (1977a: 163). In contrast to Arabic [ħ] or [ʕ], which he regards as "upper pharyngeal or faucal," [ɦʕ̯] is described by Catford as being "produced much deeper in the throat, with occasionally 'bleat-like' ventricular trill plus ventricular turbulence." Thus, a second sound is distinguished on auditory and phonological grounds from the first, and termed a "glottal plus ventricular 'bleat'" (1977a: 163). The present analysis will endeavour to clarify these articulatory possibilities and identify the gestures that are responsible for the production of both [ʕ̯ʔ] and [ɦʕ̯], and to simplify the categories of phonetic reference used to describe them. This description will treat uvulars as a separate category, so that a transcription such as the following involves a primary uvular articulation and a secondary pharyngeal articulation: "Pharyngealized [χ] and [χʷ] occur in the Bzyb dialect of Abkhaz, in contrast with both plain uvulars and plain pharyngeals" (Catford 1977a: 193; see x-rays, Catford, 1983, p. 348). The secondary pharyngeal component of these uvular articulations is considered here to be identical to the mechanism for primary pharyngeal articulations.

In 1979, Laufer and Condax used laryngoscopy to observe the activity of the epiglottis in the production of Semitic pharyngeals. They present convincing evidence in favour of their argument that /ħ/ and /ʕ/ in Arabic and Hebrew involve constriction that is localized at (or around) the epiglottis. They also cite and confirm the findings of Al-Ani (1970, 1978) that under certain circumstances "Arabic /ʕ/ is produced... as a glide, as a voiced fricative and as a voiceless stop" (Laufer and Condax 1981: 55). Although Laufer and Condax imply that the epiglottis moves independently of the tongue root, the present investigation would suggest that the epiglottis itself (or the tongue root for that matter) is not as important to pharyngeal quality as what is happening beneath the epiglottis. Laufer and Condax make an insightful conjecture about /ʕ/ "where we cannot see a complete closure between the epiglottis and the pharyngeal wall, but where spectrograms show the sound to be either a voiceless stop or, sometimes, to consist of creaky (glottalized) voice. In these cases we assume (as with /ħ/) that the articulation is between the base of the epiglottis and the top of the arytenoids" (1979: 52). In their landmark article, Laufer and Baer (1988) demonstrate that the Semitic emphatics are pharyngealized and not velarized; and that the primary pharyngeal articulation of /ħ/ and /ʕ/ (involving the epiglottis and the root of the tongue in a constriction in the lower part of the pharynx) appears qualitatively the same as for secondary pharyngealization — the difference being one of degree of constriction. Their results suggest that lateral compression of the pharynx plays little role in pharyngealization, and is at least not independent of tongue/epiglottis retraction.

Ladefoged and Maddieson (1996: 37) discuss the many observations of what have been called either pharyngeal stops or epiglottal stops in languages of the world. They cite Catford (1983) who suggests that the "pharyngeal stop" of Chechen may be produced by the epiglottis as the active articulator folding back and down to meet the arytenoids, and Laufer and Condax (1981) who have identified stop closure occurring in the epiglottal region as one way to produce the Arabic and Hebrew pharyngeals. Butcher and Ahmad's

(1987) examination of an Iraqi dialect provides a thorough review of studies on pharyngeals and supports the view that the voiceless pharyngeal in Arabic is a fricative, and that the voiced pharyngeal can be regarded as an approximant, sometimes accompanied by a stop. They report further that variable ("20 to 160 ms") voicing striations appear in spectrograms often for /ʕ/ and sometimes for /ħ/ (1987: 166). These observations imply some form of what is usually called "laryngealization," but which may also be accounted for by trilling occurring at the pharyngeal place of articulation.

Interesting but still unresolved comments by Ladefoged and Maddieson are that "it may be that, instead of two distinct regions, pharyngeal and epiglottal, there is actually a range of possible gestures made in this one general area" (1996: 169); and that in certain vowels in Khoisan languages, vibration appears to be occurring around the epiglottis so that these sounds might be called "epiglottal fricative trills" (1996: 170). Their description of the general area, however, is still divided into distinct places of articulation, whereas Laufer and Baer's (1988) finding of differences in degree of constriction might be taken to imply distinct manners of articulation. The question of what structures are moving under conditions of extreme turbulence in the pharynx also needs further clarification. X-ray tracings often show approximate changes in position of the tongue and/or epiglottis, but the larynx and aryepiglottic folds (in the critical area behind the epiglottis intimated by Laufer and Condax in 1979) are not usually represented.

Recent x-ray photographs of "strident" vowels in Khoisan (Traill 1986: 126), also published in Ladefoged and Maddieson (1996: 311), very clearly illustrate a simultaneous narrowing of the pharynx behind the epiglottis, raising of the larynx, approximation of the arytenoid cartilages to the base of the epiglottis, and (reportedly) vibration of the arytenoids and of the epiglottis. Traill identifies this "laryngeal sphincter" as a phonatory mechanism, occurring in !Xóõ (Bushman) as a contrast between "plain voiced," "murmured" and "sphincteric" vowels, [a, a̤, a̰] (1986: 125). Fibreoptic laryngoscopic photographs support this description, showing very clearly a voicing mode and a breathy voicing mode at the glottis in contrast with the laryngeal sphincter in pharyngealized mode (1986: 124), which the photographs in the present analysis confirm. The detailed account presented by Traill (1985: 78-79), in which he comments on the balance between constricted aryepiglottic folds at the same time as an apparently abducted glottis and open supraglottal lumen, resembles most closely the configuration for the voiceless pharyngeal trill illustrated here.

The relevant questions for the present study are (1) whether there appear to be two distinct places of articulation in the pharynx, i.e., a pharyngeal stop and an epiglottal stop, (2) whether the epiglottis or some other structure is the active articulator, and (3) how the fricative, approximant and stop manners of articulation relate to this articulator.

As argued earlier by Catford (1968), the epiglottis does not generally compress fully against the back wall of the pharynx. The structures between the epiglottis and the glottis, however, play a major role in deglutition and have been described in the clinical phonetic literature. In their pioneering applications of laryngoscopic technology, Williams, Farquharson and Anthony observed a progression of constrictions consisting of "narrowing of the whole laryngeal vestibule from sphincteric action of the aryepiglottic folds, epiglottis and even the lateral pharyngeal walls" (1975: 310). The implication of this sequencing for articulatory phonetics is that lateral pharynx compression is the least likely available mechanism for producing pharyngeal quality; that epiglottal (front-back lingual) compression is more likely; and that the aryepiglottic sphincter is the most likely available mechanism for producing pharyngeal quality. Roach has already observed that "glottal closure" for certain glottalized consonants "is in fact made with closure not only of the true vocal folds but also of the false vocal folds and the aryepiglottic folds" (1979: 2). Gauffin notes that the protective closure of the larynx is performed by all the sphincter muscles of the larynx to constrict "larynx tube opening," characterizing a glottal stop as a "reduced protective closure" (1977: 308). This very clear reference to a primary anatomical mechanism implies that "full" protective closure would be associated with a strong glottal stop, i.e., a pharyngeal stop.

Painter describes this sphincter mechanism in detail as part of the swallowing process, where initially "approximating the cuneiform cartilages and aryepiglottic folds" means that "the epiglottis is drawn backwards over an already closed airway" (1986: 330). Thus, given Catford's explanation that the typical Arabic "pharyngealized sounds involve some degree of contraction of the pharynx either by a retraction of the root of the tongue, or by lateral compression of the faucal pillars and some raising of the larynx, or a combination of these" (1977a: 193), it is likely from a physiological point of view that the aryepiglottic sphincter plays a major role in the process. The articulatory phonetic issue then is to identify the dependence relationships between these different physiological gestures. Painter describes the components of the basic "effort and swallowing gestures" as a sequence of vocal fold adduction, ventricular fold adduction, cuneiform cartilage and aryepiglottic fold approximation, and epiglottis retraction (in conjunction with general tongue retraction). Catford's observation that the larynx raises during this general retraction gesture should also be taken into account. Painter then lays out several linguistic phonetic realizations of this sequence of gestures: laryngeal configurations for some consonants in European languages (viz. Delattre 1971), Semitic pharyngeals, pharyngeals in Caucasian languages, glottalization in North American languages (cf. Salish and Wakashan below), laryngealization in West African languages, implosives and ejectives, a feature of tone in Vietnamese and of segmental articulation in Danish, and one of the vowel harmony series in West African languages (1986: 330). This elaboration of auditory phonetic categories for pharyngealization can be related to the various adjustments of the mechanism bounding the "laryngeal vestibule" or supraglottal lumen.

A significant contribution to the understanding of the role of aryepiglottic postures in the production of distinctive voice qualities in singing is the finding of Yanagisawa, Estill, Kmucha and Leder (1989) that some widely recognized and even classical singing styles involve a tightened aryepiglottic sphincter. Their laryngoscopic photographs demonstrate that a range of auditory targets can be correlated with contrasting degrees of aryepiglottic fold closure, as well as with varying heights of the larynx for some of the target qualities. The auditory descriptions of the vocal styles which they investigated imply clear auditory parallels with pharyngealization in the labelling of voice quality and of segmental categories in speech. It is equally apparent that the sphincter mechanism represented in their photographs is the major physiological mechanism in the pharynx differentiating the singing qualities which they studied. They also argue that aryepiglottic constriction is not necessarily a detrimental posture for the health of the voice. It can be interpreted from these findings that spoken qualities probably utilize the same mechanism of pharyngeal stricture when speech sounds that involve a "narrowing" of the pharynx are produced. The photographic evidence invites a direct comparison of the singing styles with the laryngoscopic data obtained in the present study. Both are indicative of a posture where the laryngeal valve is so narrowly constricted that it is about to be shut off, as in the so-called strong glottal stop.

A further comment by Pierrehumbert in Honda, Hirai, Estill and Tohkura (1995: 37) suggesting that the pharyngeal consonants of Semitic and Salish involve a glottalized voice quality prompts an elaboration on the auditory quality resulting from aryepiglottic constriction. Honda et al. (1995: 36) identify a "tightening of the larynx tube, or the aryepiglottic space [for Opera, as] an effective gesture for producing a ringing voice quality used for producing loud and bright sounds." In conjunction with "a forward shift of the hyoid bone while maintaining a low larynx position for Opera quality," they identify "a bending and a stricture of the aryepiglottic space" (p. 36).

3. Method of observation

To investigate the articulatory correlates of pharyngeal quality, it would be desirable to observe speakers of languages where pharyngeal segments contrast phonologically, as has been customary in many of the studies cited here. On the other hand, a case can be made for establishing a framework of comparison based on articulatory possibilities such as those posited by Catford in 1968. Furthermore, phonological realizations of pharyngeal quality may not be immediately distinguishable from long-term pharyngeal voice quality settings or larynx height settings in any given speaker of a specific language. Therefore, the approach adopted initially in this study is to examine phonetically controlled articulations in order to document a baseline of pharyngeal articulatory possibilities.

Laryngoscopic images of the pharynx and larynx were obtained using a Kay Elemetrics Rhino-Laryngeal Stroboscope 9100 — a computer-controlled system including a dual halogen (fixed) and xenon (strobe) light source, a Panasonic KS152 camera, a Mitsubishi S-VHS video cassette recorder BV-2000 (running at 30 frames/sec) and printer. This system comes equipped with a rigid, oral endoscope; but the view obtained with the rigid scope does not extend beyond the apex of the epiglottis during activities involving pharyngeal constriction. In fact, it is difficult to see beyond the apex of the epiglottis even using a flexible fibreoptic laryngoscope during anything but a close front vowel. This was the case in the extensive laryngoscopic observations of Semitic pharyngeal articulations carried out by Laufer and Condax (1981) and Laufer and Baer (1988) with native-speaker subjects. In order to investigate the extent of view possible of the laryngeal and pharyngeal mechanisms behind the apex of the epiglottis during pharyngeal articulations, an Olympus ENF-P3 flexible fibreoptic laryngoscope was attached to the Kay system, for nasal insertion and using a 28mm lens for wide-angle view. The subject in all nasendoscopic observations was the author, producing maximally contrastive phonetically controlled speech data. The view from the naso-pharynx was adjusted to peer behind the apex of the epiglottis as far as possible, to view the glottis, pyriform recesses, arytenoids, and aryepiglottic folds. The pharyngeal/laryngeal view in the photographic images presented here is taken from above the larynx, at about the level of the uvula or lower, and slightly from the right of centre (the left of the picture). The image is not perfectly vertical but rotated about 20° (notch at the top), in order to eliminate Moiré effects — striated interference patterns produced by the interaction of fibrescopic and camera optics (Yanagisawa and Yanagisawa 1993: 262).

The original purpose of laryngoscopic filming was to contrast tongue and larynx position for the auditorily specified long-term voice quality settings raised larynx voice and lowered larynx voice. It soon became apparent that a raised larynx quality invokes the same tongue and epiglottal posture as a pharyngealized quality, and that a number of degrees along a pharyngealization continuum are possible which cannot be accounted for by observing the position of the tongue alone. It was therefore decided to examine pharyngeal options at the segmental level in more detail, in the context of larynx raising and lowering, before pursuing the long-term effects of these settings.

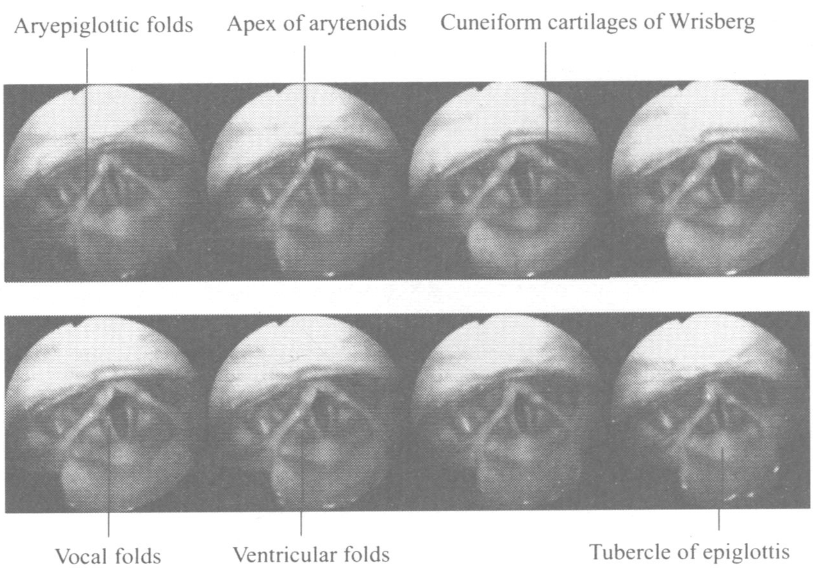

Figure 1. Rhino-laryngoscopic view of the lower pharynx: supraglottal lumen containing the glottis bounded by the epiglottis, aryepiglottic folds and arytenoids; with the posterior pharyngeal wall behind and the pyriform recesses beneath. An intervocalic [h] of about 266 msec duration is shown. This "laryngeal vestibule" is fully open (not constricted) with the glottis free to abduct. Eight-frame sequence: left to right, top to bottom.

In this initial collection of baseline data on pharyngeal postures, videotape films were collected of a matrix of phonetic productions: glottal stop and glottal fricative in contrast with pharyngeal stop, trill, fricative and approximant, in both raised and lowered larynx positions. Articulations were performed with a carrier phrase in the environment of the close front vowel [i _ i] to expose maximum pharyngeal area. This resembles a technique followed in earlier work, using similar equipment (Williams et al. 1975; Esling 1984). Frames of each articulation were then exported to a Macintosh computer for analysis in still-frame sequence and in animation. Frames of some key sequences are presented here in Figures 1-8. Visual interpretations are offered using standard landmark references.

4. Results of observations

In pharyngeal articulations with varying degrees of friction and closure, the epiglottis is seen to retract towards the posterior pharyngeal wall as described by Laufer and Baer (1988). This creates a narrowed or constricted space at the back of the oral tract, where the distance between the apex of the epiglottis and the posterior pharyngeal wall narrows to almost nothing during an open vowel. What is observed in these laryngoscopic images that has not been described in phonetic terms previously is the role of the aryepiglottic mechanism in the process of pharyngeal constriction. The phonetic articulations that we are describing involve essentially the same mechanism as in the physiological processes of gagging and swallowing (Logemann 1986: 49).

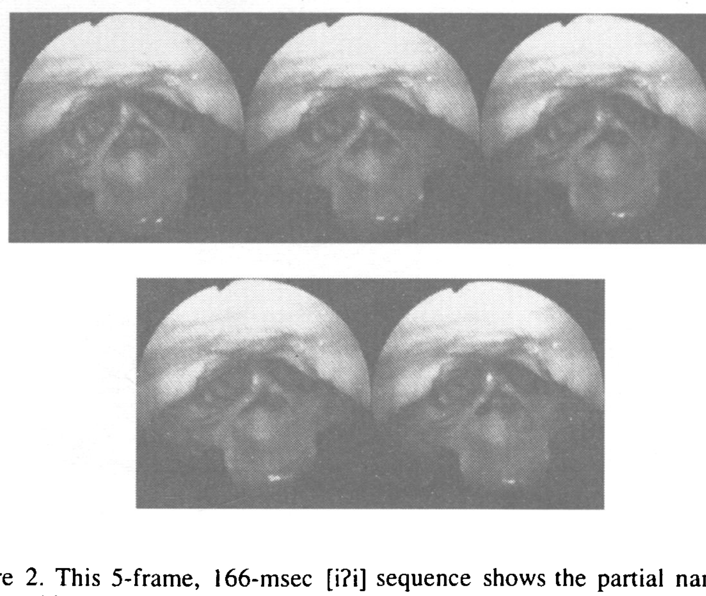

Figure 2. This 5-frame, 166-msec [iʔi] sequence shows the partial narrowing of the sphincter mechanism for a moderate glottal stop [ʔ]. The [i] articulation in the first frame represents the neutral posture for modal phonation. The larynx is neither raised nor lowered.

Pharyngeal stop closure is identified as a function of the laryngeal sphincter mechanism whereby the aryepiglottic folds approximate the tubercle of the epiglottis. While the perception of a simple glottal stop may result, at the very least, from a slowing of the vibratory pattern of the vocal folds, even more deliberate articulations of [ʔ] may involve little deformation of the structures of the laryngeal vestibule. The most extreme pharyngeal stop articulation, on the other hand, involves a close approximation of the cuneiform cartilages of Wrisberg in an anterior motion which has the anatomical effect of a pursing or pinching off of the laryngeal vestibule as described above. Glottal articulations are observed to retain a typically open laryngeal vestibule. Glottal fricatives, illustrated in Figure 1, are characterized by a brief abduction of the vocal folds within a still open laryngeal vestibule, while glottal stops, illustrated in Figure 2, show full adduction of the still visible vocal folds or an initiation of the sphincter mechanism that just obscures the vocal folds. This version of [ʔ] is more extreme than a perfunctory [ʔ].

Full pharyngeal occlusion of the airway is illustrated in Figure 3, where the close front vowel environment allows a continuous view of the aryepiglottic pursing of the vestibule. This articulatory posture is the same mechanism described by Painter (1986) and by Yanagisawa et al. (1989), taken to extreme closure, and matches the auditory phonetic quality found in Caucasian languages referred to by Catford as a "strong glottal stop" or "[ʕ̰ʔ]" (1977a: 163). In comparison with the [h] of Figure 1 and the [ʔ] of Figure 2, Figure 3 easily justifies Gaprindashvili's (1966) description of this sound as a "pharyngealized glottal stop." This sound, which has been termed "epiglottal," can be regarded as more properly aryepiglottic in origin and as pharyngeal in general place of articulation, but is still represented unambiguously by the stop symbol [ʡ] introduced by the IPA in 1989. Glottal closure is presumably simultaneous with pharyngeal closure, or precedes it slightly.

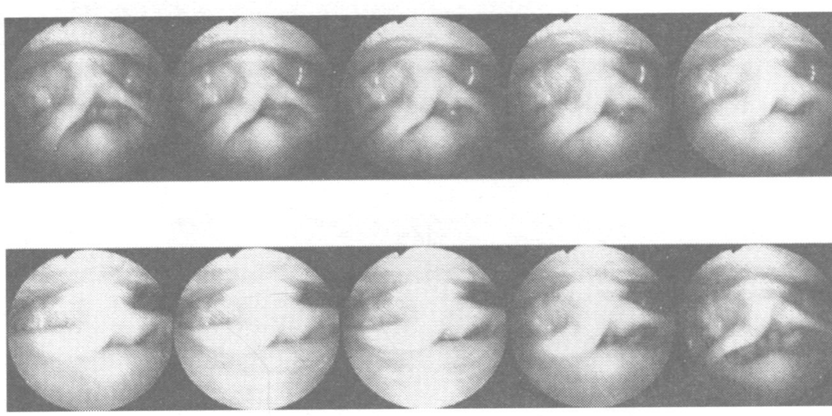

Figure 3. Full pharyngeal occlusion in an [iʡi] sequence, with the larynx raising as the tongue backs and the aryepiglottic folds squeeze against the base of the epiglottis. In this close-up shot of 1/3 sec of stop articulation, the supraglottal lumen is compressed, then released.

A pharyngeal approximant (necessarily voiced for audibility) resembles pharyngeal stop closure. As shown in Figure 4, the vibrating vocal folds are not visible during [ʕ], but the constricted posture of the aryepiglottic folds is clearly the principal mechanism that can be associated with the dominant auditory feature of pharyngealization. The challenge for research has been and will continue to be how to analyze the glottal vibratory pattern beneath the pharyngeal stricture, and how to determine the influence of increasing pharyngeal stricture on phonation.

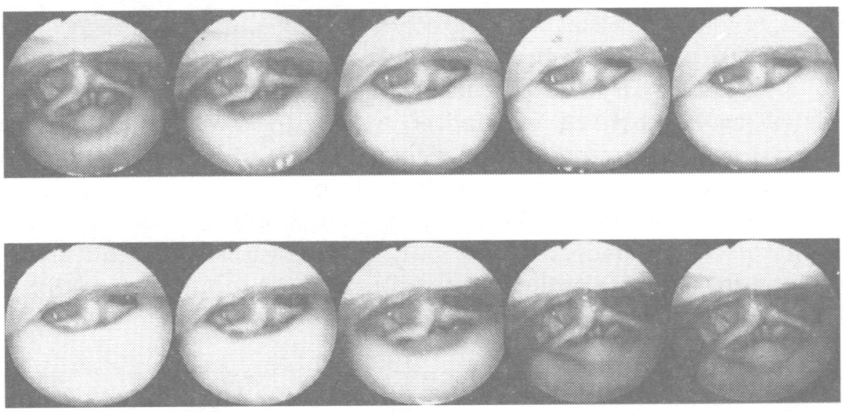

Figure 4. Voiced pharyngeal approximant in an [iʕi] sequence. These shots are further from the larynx than in Figure 3, but the larynx raising that accompanies antero-posterior compression is similar. The posture of the aryepiglottic folds resembles that for [ʡ], and voicing continues throughout, although this is difficult to distinguish visually.

The voiceless pharyngeal fricative retains aryepiglottic fold constriction, but with a narrow triangular space remaining open between the arytenoids as they press against the

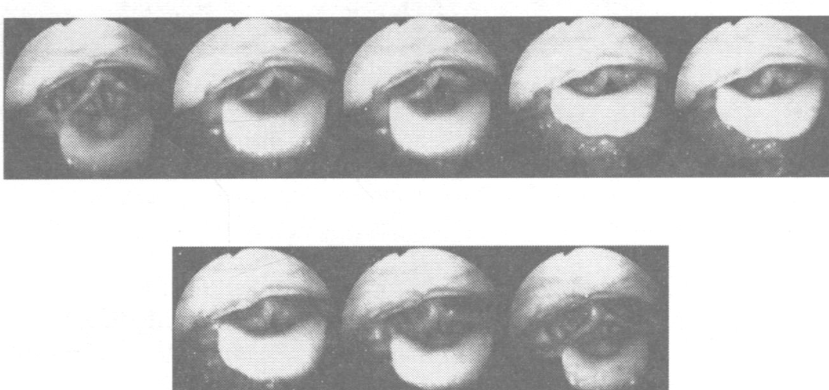

Figure 5. Voiceless pharyngeal fricative in a brief [iħi] sequence. In contrast to the glottal fricative in Figure 1, the supraglottal lumen is constricted into a funnel-shaped sphincter between the aryepiglottic folds as the tongue and epiglottis retract. The larynx raises for the consonantal articulation, and descends again for [i]. The first frame of the sequence is [h], anticipatory to [ħ].

epiglottal tubercle. This space presumably generates the friction accompanying voicelessness. Figure 5 illustrates the maintained interarytenoid gap, as well as the familiar aryepiglottic posture that we take to account for the pharyngeal component of [ħ].

Increasingly forced articulations of the approximant and the fricative yield additional activity between the constricted aryepiglottic folds and the base of the epiglottis — that of trilling. This would appear to be the vibration described by Traill (1985, 1986) as the sphincteric phonation observed in "strident" vowels. The voiced trill resembles the configuration of an approximant, with the addition of rapidly vibrating aryepiglottic folds, while the voiceless trill maintains the same interarytenoid opening as the voiceless fricative but with the addition of rapidly vibrating aryepiglottic folds. It is unclear whether the epiglottis mirrors this vibration, but the posterior pharyngeal walls do appear to be undulating in response to the airflow as the trilled airstream passes through the pharynx.

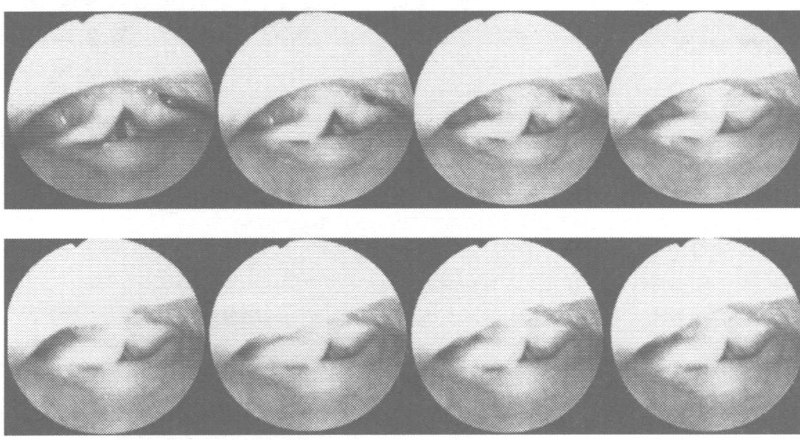

Figure 6. Voiceless pharyngeal trill [ʜ] from an intervocalic sequence. First frame: [ħ]. Remaining frames: medial interarytenoid gap with vigorous aryepiglottic fold trilling [ʜ]. The unmarked vertical laryngeal setting for trilling is raised larynx.

Figure 6 shows the more open configuration for the voiceless trill, resembling the medial openness of Figure 5, and Figure 7 shows the configuration for the intervocalic voiced trill. Auditory comparisons with the Caucasian sounds identified by Catford suggest that the voiceless trill is the same sound (and mechanism of articulation) as his "ventricular fricative trill [ɦ̰ʕ]" (1977a: 163). As in the case of uvulars, increasing airflow with compression is taken to instigate trilling. Since the trilling in the pharynx is aryepiglottic, the sounds which have been labelled epiglottal fricatives can logically be ascribed to these trills, taking trilling to represent an "enhanced" fricative auditorily. The trilled counterpart of [ħ] is thus symbolized as [ʜ], and the trilled counterpart of [ʕ] is symbolized as [ʢ]. The IPA symbols for the epiglottal fricatives have been taken to indicate that the articulation involves greater constriction than for their pharyngeal counterparts. In the interpretation presented here, this greater degree of stricture involves the aryepiglottic folds pressing against the base of the epiglottis to effect trilling of the aryepiglottic folds, presumably when the velocity of airflow is sufficient.

If an active articulator is considered to be moving against a passive articulator, in the case of pharyngeal articulations, the aryepiglottic folds could be considered the active articulator, and the epiglottis and tongue, once fully retracted, the passive articulator. From this perspective, instead of viewing the epiglottis as being pulled down to effect the laryngeal sphincter, the larynx and aryepiglottic folds are viewed as being pulled up (by the aryepiglottic muscles and thyroepiglottic muscles) towards the epiglottis. This is a matter for further debate.

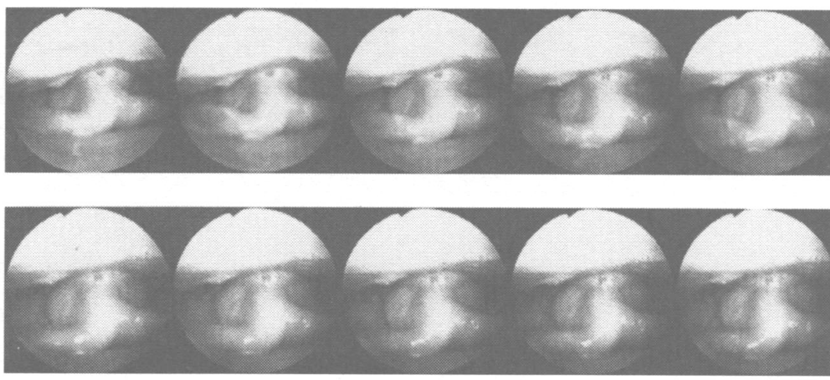

Figure 7. Voiced pharyngeal trill [ʢ] from an intervocalic sequence. These frames isolate sustained aryepiglottic approximation and trilling, primarily of the right fold. Aryepiglottic fold motion is blurred because film speed (30 frames/sec) is too slow to capture single periods of movement.

5. Anatomical/evolutionary discussion

There is good reason from an anatomical perspective to view the epiglottis as a passive articulator. In the human larynx, as well as in that of dogs and many other omnivores, "it is evident that protective closure is at the level of the upraised aryteno-epiglottic folds, and not at the glottis, which in this instance is bounded by the inferior division of the thyro-arytenoid fold" (Negus 1949: 60). This secondary valve has evolved to prevent passage of air through the larynx in species with independent use of the forelimbs (1949: 102). In the relatively flat angle of the vocal tract of a canine, the large epiglottis is in firm contact with the undersurface of a long and massive soft palate; the arytenoidal and aryepiglottic structures almost touch the back of the palate; the epiglottis is prevented from actively retracting by the pressure of the palate, but the aryepiglottic structures immediately behind the palate are free to approximate the epiglottis. One paralinguistic function of aryepiglottic trilling is growling, or imitating a dog growling; and this ability appears to be due to the anatomical evolution of aryepiglottic folds, held in place by the raised cuneiform cartilages of Wrisberg. Aryepiglottic folds are increasingly prominent in the evolution of bears, dogs, apes and humans; and in the canine family, the cuneiform cartilages hold the aryepiglottic folds parallel to the epiglottis and perpendicular to the glottis, giving the dog larynx a characteristically t-shaped appearance (Negus 1949: 84-86).

Negus explains that in carnivore species (e.g., the large cats), the function of the epiglottis is associated with olfaction and not with swallowing, to allow continuous nasal respiration while the mouth is open (1949: 29, 77). In these species, the folds of the glottal thyroarytenoid muscles themselves are capable of acting in a valvular manner, as the primary sphincter mechanism (p. 99). Surrounding the glottis in those species where breathing is not interrupted by swallowing, prominent lateral epiglottic folds are present to channel food and fluids around the glottis (pp. 78-80). These lateral folds are lost in

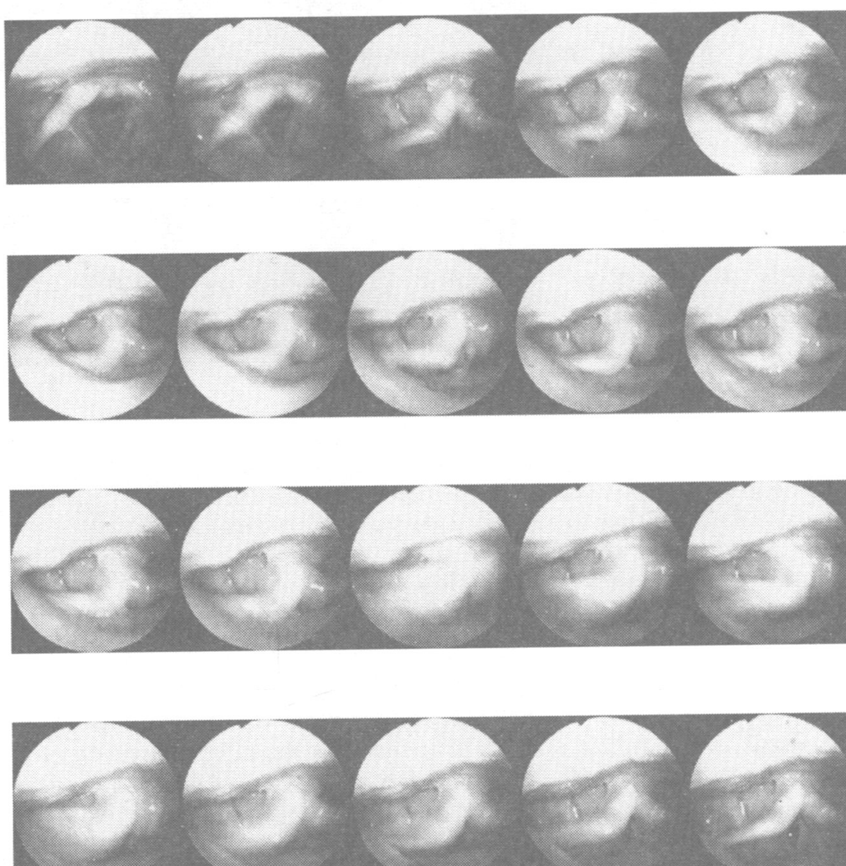

Figure 8. Throat clearing maneuvre. Beginning with an open glottis for breathing, the aryepiglottic sphincter compresses the laryngeal vestibule; the aryepiglottic folds trill against the base of the epiglottis as the larynx rises, the right fold (left in the picture) being dominant; glottal voicing is intermittent; then as the larynx descends, the sphincter relaxes to [ɦ] and then [h]. Most vigorous trilling is achieved in frames 13-16.

species that have evolved aryepiglottic folds with interpositioned cuneiform cartilages of Wrisberg.

It is also instructive to note that humans have "a fairly big but degenerate epiglottis; degenerate because of immobility and lack of function" (Negus 1949: 182), and to review the anatomical process of deglutition. "During swallowing, contraction of the sphincteric muscle fibres contained between the layers of the ary-epiglottic folds closes the aperture of the larynx and prevents inundation. The inner surface of the ary-epiglottic fold is smooth, as it passes down towards the thyro-arytenoid fold, which bounds the glottis or respiratory aperture" (p. 163). "In deglutition, the abductor muscles play a passive role, and by their relaxation allow the arytenoids to be drawn forwards towards the base of the tongue" (p. 169); "...it is not only the vocal cord but also the ary-epiglottic fold which is affected in cases of recurrent nerve paralysis, whether the disordered action concerns the dilator muscles alone or the sphincteric group as well; the vocal cord is moved by certain fibres of the sphincteric muscles, which are not, however, specialized for vocal purposes. Protective closure during deglutition is effected, in man, by the ary-epiglottic folds and not at the level of the glottis" (pp. 203-204). This anatomical account strengthens the interpretation that the epiglottis is not the active articulator, but that the aryepiglottic folds are.

To compare a physiological process with the auditory quality of pharyngealization, an episode of throat clearing is illustrated in Figure 8. The aryepiglottic sphincteric posture is adopted, as in holding the breath or preparing for a cough, and the aryepiglottic folds are observed to vibrate, producing a crescendo and decrescendo of trilling, in response to the forceful airstream.

6. Auditory/articulatory discussion

Laryngoscopic observations associate the tightening of the aryepiglottic space referred to by Honda et al. (1995), or of the laryngeal vestibule referred to by Painter (1986), with the sound qualities labelled by Laver (1980) as pharyngealized voice and raised larynx voice. It has been shown that these two qualities are not auditorily distinguishable from each other at a given pitch but that, given the same intended target, pharyngealized voice is the quality identified in a voice with low pitch and that raised larynx voice is the quality identified in a voice with higher pitch (Esling, Heap, Snell and Dickson 1994; Esling 1995). As auditory voice quality labels, they are complementary, and pitch-dependent.

Pharyngealization has been associated primarily with tongue retraction, as in the case of vowels. "Pharyngealized vowels involve a compression of the pharynx simultaneously with the primary vowel articulation. This is usually effected by a backward thrust of the root of the tongue, tending to narrow the pharynx in a front-to-back dimension" (Catford, 1977a: 182). This occurs in several Caucasian languages, and Catford reports that "pharyngealization adds a slightly 'squeezed' quality to the auditory impression of vowels in these languages and tends to impart a somewhat 'fronted' (advanced) quality to back vowels, both in terms of auditory impression and formant-shifts in spectrograms" (p. 182). Remembering that Catford also associates pharyngealization with raising of the larynx, the most likely explanation for this auditory impression, as Laver (1994: 330) speculates, is the acoustic effect of vocal-tract shortening caused by larynx raising. Since Catford does not use the term "raised larynx voice," it is a plausible candidate for the "squeezed, fronted" quality he identifies.

Nolan (1983: 182-187), investigating the relationship between larynx height and pharyngealization in long-term postures of the vocal tract, cites acoustic, radiographic and physiological evidence to associate pharyngealization with elevation of the larynx. Nolan's x-ray tracings (1983: 183) show clearly that the posture for raised larynx voice both alters the angle and constriction of the larynx tube and involves the tongue (and epiglottis) filling more of the lower pharyngeal space. Using laryngoscopic observation in the present study, it became quickly apparent with the rigid scope that the same mechanism was being used in retracting the tongue to the pharyngeal wall as in producing the auditory effect of a shortened vocal tract associated with raised larynx voice. With the fibreoptic scope, the source of constriction at the aryepiglottic sphincter mechanism is clear to see. It is also apparent that the larynx cannot raise for aryepiglottic closure, tucking itself up under the epiglottis as it does in pharyngeal stop mode during swallowing, for instance, without the tongue and the epiglottis also retracting. Thus, when the tongue retracts and the aryepiglottic folds constrict in a pharyngeal articulation, the natural, unmarked position of the larynx is raised. Nevertheless, the larynx as a whole can be raised or lowered during pharyngeal stricture. The interdependencies of these articulatory setting parameters could explain the conflicting acoustic effects observed by Nolan, where pharyngealization sometimes appeared to be affected by variable larynx heights.

A lowered setting of the larynx concurrent with pharyngealization would constitute a marked deviation from natural anatomical tendencies, and presumably be a more difficult muscular relationship to maintain. This vertical height dimension, however, can be added to the horizontal or front-back dimension of pharyngealization to achieve a varied set of auditory effects. In combination with four possible adjustments in manner of articulation at the aryepiglottic sphincter place of articulation, approximation, frication, trilling and plosion, a number of complex auditory effects can be accounted for. As these vertical movements are also related to pitch changes, however, further research to investigate and quantify the relationship of pharyngealization (tongue retraction and aryepiglottic-fold constriction) to vertical larynx-height adjustments will also need to control pitch independently.

Both horizontal (antero-posterior) and vertical adjustments are relevant in the description of pharyngeal features associated with tone. A number of languages in Southeast Asia use tones that may involve raised settings of the larynx, i.e., a degree of pharyngealization, as their distinctive feature. One of the six Vietnamese tones (Hanoi dialect) illustrates this quality (Esling in press). It is low in pitch with a pharyngealized (raised-larynx) component usually finishing in a stop, in contrast to another whisperier (lowered-larynx) low tone. The auditory similarity to pharyngeal approximant and stop consonants in other languages suggests that the aryepiglottic mechanism deserves further investigation in studies of Mon-Khmer tone. In Bruu, a Mon-Khmer language in the UCLA HyperCard database, *Sounds of the World's Languages*, tones described as having stiff vocal cords and tense vocal tract walls are a likely result of aryepiglottic constriction and larynx raising, judging by their auditory contrast to the non-stiff series. Mpi, a Tibeto-Burman language investigated by Jimmy G. Harris, and also in the UCLA database (Ladefoged and Maddieson 1996: 315-317), has a "laryngealized" series which is auditorily similar to the pharyngeal qualities described here and probably due to aryepiglottic constriction, i.e., actually pharyngealized. Ladefoged and Maddieson refer to the Mpi series as less creaky than the laryngealized vowels of some other languages, hinting that the explanation might not be solely glottal. As suggested below, the relationship of the pharyngeal articulator to pitch control and to phonation type may be to function as a secondary phonatory source.

The role of the pharyngeal articulator in languages with so-called tongue root distinctions also deserves further clarification. What is not clear in the x-ray data on West African retracted tongue root [–ATR] vowels to date is the action of the laryngeal sphincter when the tongue retracts and the larynx presumably raises. The hypothesis that suggests itself here is that the retracted tongue root vowels in Igbo and in Akan (Ladefoged and Maddieson 1996: 300-302) are produced by tongue backing and larynx raising due to pharyngeal constriction at the aryepiglottic sphincter. In this interpretation, based on an auditory classification using Laver's taxonomy, [+ATR] vowels have lowered larynx and are not pharyngealized, while [–ATR] vowels have raised larynx and are pharyngealized. The articulatory parallel to pharyngeal manners of articulation is worth pursuing for all of these tonal and vocalic register phenomena.

Where larynx height does not play a distinctive role, pharyngeal segments can be described as having the same manners of articulation that uvular segments have. It has been pointed out (viz. Delattre 1971) that pharyngeals may occur in European languages, for example, for Danish /r/. The /r/ of Parisian French dialect can also be realized as [ʕ], which is also used as a paralinguistic feature independently of the /r/ environment. An avenue for phonological research would involve the relationship between uvulars, including /r/, and the development of pharyngeals, as well as the relationship between long-term pharyngeal colouring and neighbouring segmental articulations. The idea of a uvular genesis of pharyngeals has already been broached in the historical linguistic literature (Jacobsen 1969). A related question to be deferred for further research is whether a pharyngeal stop can be imploded (viz. Catford 1977a: 74-75).

Manners of pharyngeal articulation are widely exploited in languages already described as having a pharyngeal place of articulation in their phonology. Northwest Coast languages of North America illustrate a series of sounds with a secondary articulation variably termed "glottal", "laryngeal" or "pharyngeal" (Carlson 1989). The qualities of /ħ/ and /ʕ/, as in Semitic, are taken to be a function of the aryepiglottic sphincter. The two voiced pharyngeals of Spokane, /ʕ/ and /ʕʷ/, also have glottalized counterparts /ʕ'/ and /ʕʷ'/, which are interpreted here as adding a stop component — i.e., being pharyngeal stops in the same way that Catford's [ʕ̰ʔ] represents a pharyngeal stop. The Caucasian language, Agul, described by Ladefoged and Maddieson (1996: 38, 167-170) and illustrated in the UCLA HyperCard database, offers a good example of this sound, represented as [ʡ]. Two voiceless pharyngeal continuants are also distinguished in Agul.

The one symbolized as pharyngeal [ħ] can be described using the terminology proposed here as a voiceless pharyngeal fricative with lowered larynx, i.e., expanded lower cavity resonance. The one sounding more constricted and symbolized as epiglottal [ʜ] can be described as a voiceless pharyngeal (aryepiglottic) fricative with raised larynx, essentially a voiceless pharyngeal trill. The voiced pharyngeal [ʕ] of Agul sounds slightly trilled in one example, but [ʢ] is not represented. Catford's impression that [ʜ] and [ʢ] are more "genuinely fricative" than [ħ] and [ʕ] (1990: 26) is supported by the present interpretation that they are fricatives with the addition of trilling. Ahousaht (sometimes called Nootka), a Wakashan language of the Northwest Coast, uses /ħ,ʕ/ phonologically (Jacobsen 1969), but has been observed to modify these sounds paralinguistically to more constricted versions which resemble the equivalent series in Caucasian languages. In the story of Sea Lion as narrated by George Louie in the Department of Linguistics at the University of Victoria, the pronunciation of [ħ] and [ʕ] in the speech of a person who is transformed into a sea lion tends to be realized as [ʜ] and [ʢ], where [ʜ] and [ʢ] are trills. Sea lion is also identified in narratives by the repeated use of a sustained [ʜʢ͜eː] or [ʜʢ͜aː] marker (Esling 1996a, 1996b).

In a suprasegmental role somewhat similar to that of tone, "strident" vowels in Khoisan (Traill 1986) are interpreted here to be produced similarly to the [–ATR] vowel series in West African languages (Ladefoged and Maddieson 1996: 300-302), and to be equivalent to pharyngealized vowels with respect to the place of the mechanism of production. This mechanism is the same phenomenon of a tightened aryepiglottic sphincter recognized by Yanagisawa et al. (1989) and Honda et al. (1995) in a number of singing styles, although details of manner of articulation or of larynx height may differ across these categories. The manner of articulation of the !Xóõ vowels, considering auditory quality and the laryngoscopic and x-ray evidence, is secondary voiceless pharyngeal trilling.

The perhaps confusing nature of the sounds produced at this place of articulation is their quasi-phonatory nature. As suggested by Traill (1986), it is possible in phonological terms to view the longer-than-usual sustained action of the laryngeal sphincter as a phonation type, in parallel to modal and breathy glottal phonation. In the same way, sustained pharyngeal approximation can function as a long-term voice quality or register (as in Ahousaht), underlying segmental articulations at other places of articulation for which it is the background. A degree of friction in the pharyngeal sphincter would contribute to the whisperiness or breathiness factor in the identification of long-term voice quality. As in the case of the strident Khoisan vowel series, sustained trilling of the aryepiglottic mechanism can be perceived as a quasi-phonatory component of background voice quality. Such is the case in the jazz singing style of Louis Armstrong, where voiced aryepiglottic trilling is the dominant feature of his phonatory voice quality; or in some of the speaking/singing voices in Cab Calloway's band referred to by Catford (1977a: 104). In these cases, pharyngeal (aryepiglottic) approximation, friction or trilling can function extralinguistically or even paralinguistically as a secondary phonatory process, integrating with features of glottal phonation in the perception of long-term voice quality.

Similarly to voiceless fricatives, a type of sustained whisper can also be attributed to the pharyngeal articulator. A distinctive quality of whisper appears to be analogous to "pharyngeal," "strident" or "[–ATR]" voiced phonation. This can be deduced from Catford's description of a number of related sounds. In what he describes as "anterior phonation," which is essentially the posture of the pharyngeal articulator described here, "the whole upper part of the larynx may be constricted to some extent: it appears as if the arytenoidal constriction essential for anterior phonation is part of a general sphincteric construction [sic] of the (upper) larynx" (1977a: 102-103). "Anterior voice" is related by Catford to "ventricular voice" in location, with the latter involving greater upper larynx constriction. The labels "tight, hard, sharp, tense" voice are cited in reference to accents which are impressionistically equivalent to "raised larynx voice" in Laver's (1980) terminology. In addition, Catford identifies "ventricular whisper" as produced in the same anterior location, in contrast to "posterior" interarytenoidal whisper. A possible term for this type of whisper could be "sphincteric" or "raised-larynx" whisper.

The pharyngeal articulator, as observed and described here, is also the likely source of the so-called "glottal whistle" which David Abercrombie taught to his students on the Phonetics Course at the University of Edinburgh — the "laryngeal whistle" described by Moolenaar-Bijl (1957). A sound originating in the throat, it could reportedly be produced by some as a true whistle, even during labial closure. This implies that the sound is postuvular; but it is unclear how the whistle could be solely glottal without setting the vocal folds into vibration. Catford characterized the "glottal whistle" as "voiceless falsetto, ... partly due to a kind of wake turbulence — in this case, periodic vortex-formation in the turbulent wake of air-flow past the thinned edges of the vocal folds" (1977a: 38). An optimal narrowing of the immediate supraglottal space, between the ventricular folds and continuing between the flattened aryepiglottic folds and the base of the epiglottis, would provide the channeling necessary to effect a whistle. This manner of constriction is essentially the same as for a pharyngeal fricative but with the correct angle and aim to produce a sine wave, just as the fricative [s] may be channeled by the front of the tongue into a whistle. In this interpretation, the "glottal whistle" is considered to be pharyngeal, i.e., aryepiglottic, in origin. This conforms well with Moolenaar-Bijl's description of an "inclination of the epiglottis, together with a narrowing of the pharynx" (1957: 166). It should also be pointed out that although Abercrombie and Catford have described the "glottal whistle" as glottal-laryngeal, Catford's category ventricular-laryngeal might also be considered in the whistle's origin. Ventricular-laryngeal is the same location cited by Catford to explain the sound which has been identified here as a voiceless pharyngeal (epiglottal) trill. It is therefore possible that pharyngeal fricatives and trills and the "glottal whistle" originate in a similar articulatory posture. In the present interpretation, the common place of articulation is the pharyngeal/aryepiglottic mechanism, with the addition of the required channeling or shaping to achieve the turbulence necessary to produce a whistle. The most reasonable hypothesis at this stage is that the fine adjustment for whistling involves the vertical, probably raised, positioning of the larynx. The next step will be to examine the phenomenon in more detail laryngoscopically, in conjunction with further studies of pharyngeal/aryepiglottic constriction under raised and lowered vertical larynx conditions.

7. Conclusions

The present analysis demonstrates: (1) that Catford's epiglottopharyngeal category involves the aryepiglottic folds behind the epiglottis, (2) that stop closure is possible at the aryepiglottic location, (3) that extreme retraction of the tongue towards the back wall of the pharynx accounts for only the orally visible component of pharyngeal articulation, (4) that not only stop closure is possible aryepiglottically but also trilling, and (5) that the pharyngeal fricative and approximant are also produced at the same location, i.e., that the "pharyngeal articulator" is essentially aryepiglottic. It is proposed that the IPA symbols for epiglottal articulations be applied to the basic manners of pharyngeal articulation as outlined in Table 1.

Table 1. Pharyngeal Consonantal Distinctions (Place/Manner/Voiceless-Voiced)

[ʔ]	Glottal plosive
[h]	Voiceless glottal fricative
[ʡ]	Pharyngeal (aryepiglottic) plosive ("strong" or "massive" glottal stop)
[ħ]	Voiceless pharyngeal (aryepiglottic) fricative
[ʜ]	Voiceless pharyngeal fricative with aryepiglottic trilling
[ʕ]	Voiced pharyngeal (aryepiglottic) fricative/approximant
[ʢ]	Voiced pharyngeal fricative/approximant with aryepiglottic trilling

As Laufer and Baer recall (1988: 184-185), Panconcelli-Calzia surmised correctly in 1924 that suprahyoid muscle participation, lowering (retraction) of the epiglottis, raising of the larynx, and constriction of the pharynx (but by the sphincter muscles not by the constrictor muscles) are all components of the production of pharyngeals. And Brücke (1860) was correct about the involvement of the epiglottis and the arytenoids; and Tur-Sinai (1937) was correct about the analogy to swallowing in the production of pharyngeals. The findings reported here suggest that whether the epiglottis moves independently of the tongue root is a moot point, since the aryepiglottic sphincter constriction moving up to meet a descending tongue and epiglottis is the principal active articulation. Pharyngeal quality is produced, it can be hypothesized, when the sphincter reaches a given degree of closure of the laryngeal lumen over the glottis.

There do not appear to be two distinct places of articulation in the pharynx. Rather, a "pharyngeal stop" and an "epiglottal stop" are one and the same thing. Although the tongue actively retracts into the pharynx, the epiglottis itself does not appear to be the active articulator; instead, the aryepiglottic folds move up and forward to meet the base of the epiglottis. These findings have a number of implications: there would seem to be more possibilities of articulation in the pharynx than previously expected, and a number of phonologically varied phenomena may use adjustments of the pharyngeal articulator in their production. There are, moreover, greater affinities than previously assumed between uvular and pharyngeal consonants of all manners of articulation. The vertical setting of the larynx tends to be raised as in "raised larynx voice" when pharyngeal constriction occurs, but the larynx as a whole can also be lowered while the aryepiglottic sphincter mechanism is narrowed or closed. In this scheme, two dimensions or planes of movement, antero-posterior, and raising-lowering of the larynx, are adequate to account for the auditory categories that have been used to label pharyngeal sounds.

Pharyngeal constriction has traditionally been divided into upper, mid and lower areas of the pharynx, based primarily on interpretations of sagittal x-ray data. Following Delattre's classification, uvulars are taken to represent constriction in the upper pharynx. In the light of the evidence presented in this paper, constriction in the mid region is more appropriately taken to refer to retraction of the tongue root and epiglottis and narrowing or closure of the aryepiglottic fold sphincter, together with larynx raising. What has been classified as constriction in the lower pharynx is better interpreted as tongue retraction and narrowing or closure of the aryepiglottic sphincter for pharyngealization, together with larynx lowering.

Acknowledgements

I am indebted to Lynn Marie Heap, my research assistant, for her participation in the filming of pharyngeal articulations, for her skilled and careful preparation of the photographs that appear here, and for her thoughtful suggestions at every stage of the data collection process. I would like to thank Dr. Alan J. Lupin and Dr. Michael Mawdsley for their indispensable assistance and procedural advice; Jocelyn Clayards for her assistance in the Phonetics Laboratory; and the staff of the University of Victoria Language Centre for providing the software and expertise to generate the images that appear here and the animations available on the web. The comments and reflections of many colleagues, particularly Thomas Hess, Craig Dickson, Barry Carlson, Ewa Czaykowska-Higgins, Jimmy G. Harris, Brenda Orser, and Roy Snell, are much appreciated, as is the technical assistance of the staff of Speech Technology Research Ltd. This research was carried out through a grant from the Social Sciences and Humanities Research Council of Canada (# 410-93-0539), without whose support (and that of the Canadian linguistics community) this work would not have been possible.

References

AL-ANI, S.H. (1970). *Arabic Phonology: An Acoustical and Physiological Investigation* (*Janua Linguarum* **61**). The Hague: Mouton.

AL-ANI, S.H. (1978). An acoustical and physiological investigation of the Arabic /ع/. In Al-Ani, S.H. (editor), *Readings in Arabic Linguistics*, 89-101. Bloomington, IN: Indiana University Linguistics Club.

BRÜCKE, E. (1860). Beiträge zur Lautlehre der Arabischen Sprachen. *Wiener Sitzungsberichte Philologisch Historische Classe* **XXXIV**, 307-356.

BUTCHER, A. and AHMAD, K. (1987). Some acoustic and aerodynamic characteristics of pharyngeal consonants in Iraqi Arabic. *Phonetica* **44**, 156-172.

CARLSON, B.F. (1989). Reduplication and stress in Spokane. *International Journal of American Linguistics* **55**, 204-213.

CATFORD, J.C. (1968). The articulatory possibilities of man. In Malmberg, B. (editor), *Manual of Phonetics*, 309-333. Amsterdam: North-Holland Publishing Company.

CATFORD, J.C. (1977a). *Fundamental Problems in Phonetics.* Edinburgh: Edinburgh University Press.

CATFORD, J.C. (1977b). Mountain of tongues: The languages of the Caucasus. *Annual Review of Anthropology* **6**, 283-314.

CATFORD, J.C. (1983). Pharyngeal and laryngeal sounds in Caucasian languages. In Bless, D.M. and Abbs, J. H. (editors), *Vocal Fold Physiology: Contemporary Research and Clinical Issues,* 344-350. San Diego: College Hill Press.

CATFORD, J.C. (1990). Glottal consonants ... another view. *Journal of the International Phonetic Association* **20**(2), 25-26.

DELATTRE, P. (1968). From acoustic cues to distinctive features. *Phonetica* **18**, 198-230.

DELATTRE, P. (1971). Pharyngeal features in the consonants of Arabic, German, Spanish, French, and American English. *Phonetica* **23**, 129-155.

ESLING, J.H. (1984). Laryngographic study of phonation type and laryngeal configuration. *Journal of the International Phonetic Association* **14**, 56-73.

ESLING, J.H. (1995). Pharyngeal phonetics: Larynx height, tongue root, and pitch dependence. *Chicago Linguistic Society* **31**, 143-152.

ESLING, J.H. (1996a). Pharyngeal voice quality settings. Paper presented at the British Association of Academic Phoneticians colloquium, York, March 1996.

ESLING, J.H. (1996b). Pharyngeal voice qualities: Auditory change with pitch and fibreoptic filming of aryepiglottic articulations. *Canadian Acoustics* **24**(3), 22.

ESLING, J.H. (in press). University of Victoria Phonetic Database (version 4.0). Victoria, BC: Speech Technology Research Ltd.

ESLING, J.H., HEAP, L.M., SNELL, R.C. and DICKSON, B.C. (1994). Analysis of pitch dependence of pharyngeal, faucal, and larynx-height voice quality settings. *ICSLP 94*, 1475-1478. Yokohama: Acoustical Society of Japan.

FUJIMURA, O. and SAWASHIMA, M. (1971). Consonant sequences and laryngeal control. *Annual Bulletin, Research Institute of Logopedics and Phoniatrics, University of Tokyo* **5**, 1-6.

GAPRINDASHVILI, SH.G. (1966). *Fonetika Darginskogo Jazyka.* Tbilisi: Metsniereba.

GAUFFIN, J. (1977). Mechanisms of larynx tube constriction. *Phonetica* **34**, 307-309.

HOCKETT, C.F. (1958). *A Course in Modern Linguistics.* New York: The Macmillan Company.

HONDA, K., HIRAI, H., ESTILL, J. and TOHKURA, Y. (1995). Contributions of vocal tract shape to voice quality: MRI data and articulatory modeling. In Fujimura, O. and Hirano, M. (editors), *Vocal Fold Physiology: Voice Quality Control,* 23-38. San Diego: Singular Publishing Group.

JACOBSEN, W.H. (1969). Origin of the Nootka pharyngeals. *International Journal of American Linguistics* **35**, 125-153.

JONES, S. (1934). Somali [ħ] and [ʕ]. *Le Maître Phonétique* **49**, 8-9.

LADEFOGED, P. and MADDIESON, I. (1996). *The Sounds of the World's Languages.* Oxford: Blackwell Publishers Ltd.

LAUFER, A. and CONDAX, I.D. (1979). The epiglottis as an articulator. *Journal of the International Phonetic Association* **9**, 50-56.

LAUFER, A. and CONDAX, I.D. (1981). The function of the epiglottis in speech. *Language and Speech* **24**, 39-62.

LAUFER, A. and BAER, T. (1988). The emphatic and pharyngeal sounds in Hebrew and in Arabic. *Language and Speech* **31**, 181-205.

LAVER, J. (1980). *The Phonetic Description of Voice Quality*. Cambridge: Cambridge University Press.

LAVER, J. (1994). *Principles of Phonetics*. Cambridge: Cambridge University Press.

LOGEMANN, J.A. (1986). *Manual for the Videofluorographic Study of Swallowing*. San Diego: College-Hill Press.

MOOLENAAR-BIJL, A.J. (1957). Laryngeal whistle. *Folia Phoniatrica* **9**, 164-168.

NEGUS, V.E. (1949). *The Comparative Anatomy and Physiology of the Larynx*. London: William Heinemann Medical Books Ltd. (Reprinted 1962).

NOLAN, F. (1983). *The Phonetic Bases of Speaker Recognition*. Cambridge: Cambridge University Press.

PAINTER, C. (1986). The laryngeal vestibule and voice quality. *Archives of Oto-Rhino-Laryngology* **243**, 329-337.

PANCONCELLI-CALZIA, G. (1924). *Die Experimentelle Phonetik in ihrer Anwendung auf die Sprachwissenschaft*. Berlin: W. de Gruyter & Co.

ROACH, P.J. (1979). Laryngeal-oral coarticulation in glottalized English plosives. *Journal of the International Phonetic Association* **9**, 2-6.

TRAILL, A. (1985). *Phonetic and Phonological Studies of !Xóõ Bushman (Quellen zur Khoisan-Forschung* **1**). Hamburg: Helmut Buske Verlag.

TRAILL, A. (1986). The laryngeal sphincter as a phonatory mechanism in !Xóõ Bushman. In Singer, R. and Lundy, J.K. (editors), *Variation, Culture and Evolution in African Populations: Papers in Honour of Dr. Hertha de Villiers*, 123-131. Johannesburg: Witwatersrand University Press.

TUR-SINAI (TURCHINER), H.N. (1937). *Ha-mivta ha-aliz* ('The Joyful Pronunciation'). Jerusalem: The Committee of the Hebrew Language (in Hebrew).

WILLIAMS, G.T., FARQUHARSON, I.M. and ANTHONY, J.K.F. (1975). Fibreoptic laryngoscopy in the assessment of laryngeal disorders. *Journal of Laryngology and Otology* **89**, 299-316.

YANAGISAWA, E., ESTILL, J., KMUCHA, S.T. and LEDER, S.B. (1989). The contribution of aryepiglottic constriction to "ringing" voice quality: A videolaryngoscopic study with acoustic analysis. *Journal of Voice* **3**, 342-350.

YANAGISAWA, E. and YANAGISAWA, K. (1993). Stroboscopic videolaryngoscopy: A comparison of fiberscopic and telescopic documentation. *Ann. Otol. Rhinol. Laryngol.* **102**, 255-265.

Appendix: Animations on the World-Wide Web

Animated images of some of the articulations shown here in still photographs can be viewed on the world-wide web at the University of Victoria Phonetics Laboratory research site:

http://web.uvic.ca/ling/research/pharynx.html

Synchronized audio is absent in the animations, but text descriptions and parallel audio files are provided for reference.

First movie: This articulation can be transcribed as an intervocalic stop sequence [iʔiʡi]. The initial stop is glottal and the second stop is pharyngeal, that is, the first involves the vocal folds and ventricular folds in the stricture while the second involves aryepiglottic fold constriction to achieve full closure of the supraglottal mechanism against the base of the epiglottis. This mechanism is observed to constitute the principal "pharyngeal articulator." This interpretation views the pharyngeal stop as auditorily equivalent to what has been called a "strong glottal stop," and to what has been called an "epiglottal stop." The pharyngeal stop is represented by the IPA symbol for an epiglottal stop [ʡ].

Second movie: This articulation is an intervocalic voiceless pharyngeal trill, [iʜi]. The IPA symbol for a voiceless epiglottal fricative is used to indicate that the articulation involves greater constriction than the voiceless pharyngeal fricative symbolized by [ħ]. The distinction as shown here is that the "more constricted" sounding fricative [ʜ] is effected by near closure of the supraglottal mechanism against the base of the epiglottis, resulting in the trilling of the aryepiglottic folds.

Third movie: This articulation is the voiced equivalent of [ʜ], a sustained voiced pharyngeal trill, represented by the voiced epiglottal fricative symbol [ʢ]. Requiring greater stricture than the homorganic pharyngeal approximant [ʕ], this articulation also involves the aryepiglottic folds pressing against the base of the epiglottis to effect a trill.

These images are partial illustrations of the progressive degrees of glottal-laryngeal-pharyngeal closure from [ʔ] through [ħ, ʕ] through [ʜ, ʢ] and finally to [ʡ] which characterize the antero-posterior, or lingual retraction, component of the pharyngeal articulator. Larynx height for the pharyngeal articulations is raised — the unmarked position for lingual retraction/ pharyngeal constriction. Pharyngeal constriction with larynx lowering is not shown here. The effect of these lingual/aryepiglottic maneuvres on pitch and on phonatory quality has yet to be made explicit.