The articular possibilities of man

J. C. CATFORD

English Language Institute, University of Michigan, Ann Arbor, Michigan

1. Introduction

1.1. Human speech, or the 'phonic substance' in which linguistic forms are manifested, is a complex process which has to be broken down for purposes of analysis and discussion into at least six distinct aspects or phases. These phases of phonic substance are the following:

(a) the neuro-muscular phase: the firing of 'motor-units' and the contraction successively and/or simultaneously of muscles,

(b) the organic phase: the gross postures and movements of organs in the vocal tract,

(c) the aerodynamic phase: mass movements and sub-sonic pressure changes of the air in the vocal tract,

(d) the acoustic phase: micro movements, at audio frequencies, of the air molecules: sound-waves,

(e) the neuro-receptive phase: stimulation of the auditory nerve etc.,

(f) the perceptual phase: (a) auditory, (b) kinaesthetic.

1.3. In discussing the articulatory possibilities of man we shall be chiefly concerned, as in traditional phonetics, with (b), the organic phase, though from time to time the aerodynamic phase must be referred to, since some limitations on sound-producing possibilities are aerodynamic rather than anatomical or physiological.

1.4. A survey of 'what is pronounceable' in general human terms is subject to some degree of uncertainty and approximation owing to the fact that human vocal tracts differ somewhat in anatomical details. Differences in the musculature of the face and larynx, in the shape and
size of the tongue, in the height of the palate, and the like, are to be observed both between individuals and between races or mating-groups of various kinds. For some differences of these types see Brosnahan (1961, ch. 4).

Just what phonetic limitations are imposed, for example, by the absence of the thyreoepiglotticus inferior muscle in about 80 per cent of Japanese as opposed to its presence in 86 per cent of Germans is unknown. But that anatomical and physiological differences do exist is certain; and some of these have obvious articulatory implications. For example, it is well established that more men than women can roll up the edges of the tongue; this implies the absence of certain articulatory possibilities in many women and some men. Again the length and freedom of movement of the tongue varies from one individual to another. Some people can curl up their tongue retroflexively so that the tongue-point touches the uvula: others can barely reach the center of the hard palate. Consequently apico-uvular articulation is a possibility for some people but not for others.

1.5. In what follows we will refer from time to time to some of the more bizarre possibilities, but on the whole, we will be concerned with what may be assumed to be reasonably general. In the last analysis, our judgment in these matters is based on the personal knowledge and experience of a phonetician who has for long observed the articulatory possibilities and limitations of himself and of other phoneticians, of many students of phonetics, and of speakers of a great number of familiar and 'exotic' languages.

1.6. One final remark: following the title of this chapter, I have, in this introduction, referred to 'articulatory possibilities', using the terms 'articulatory' and, by implication, 'articulation' in a general, or semi-popular, way, to refer to the whole range of vocal sound-producing activities of man. In the next, and following, sections, the term articulation will be used in a more limited, strictly technical, sense, contrasting with the terms initiation and phonation.

2. Components of sound production

2.1. The human vocal tract may be described as an apparatus for the conversion of muscular energy into acoustic energy. This process is carried out by means of two functionally distinct types of sound-productive activities of the vocal organs: these are, on the one hand, bellows-like or piston-like movements which set the air in the vocal tract in motion, and on the other hand, valve-like postures or movements which regulate the flow of air and, in so doing, generate sound-waves, or, in some cases simply modulate sound-waves generated by other activities.

2.2. For these two basic activities we use the terms initiation and regulation; and it is convenient to distinguish, somewhat arbitrarily, two varieties of the latter, namely phonation and articulation.

2.3. Initiation is a bellows-like or piston-like movement of an organ or organ-group (an initiator) which causes a pressure-change in an adjacent part of the vocal tract and consequently initiates a flow of air. Initiation-types have been described in Catford (1939 and 1947) and at greater length in Pike (1943). Pike introduces the term 'initiator', but uses 'airstream mechanism' for what we here call 'initiation'.

2.4. Phonation covers all regulatory activities occurring in the larynx (with one exception): it thus includes such features as 'breath' or 'voicelessness' 'voice' 'voice-qualities' etc. It excludes those laryngeal activities (glottal closure and vertical displacement of the larynx) which have an initiatory function in the production of 'glottalic' sounds (see section 3.2 below).

The somewhat arbitrary exception-which we make is that glottal stop [p] is regarded for the present purpose as a form of articulation, not phonation. This makes for simpler treatment of certain aspects of articulation. The so-called 'glottal fricative' [h] however is regarded as a type of phonation. In purely articulatory terms [h] is equivalent to 'voiceless vocoid' (cf. Pike, 1943).

2.5. Articulation, then, covers glottal stop and all those regulatory activities which occur in the pharynx, mouth, and nose. Thus, the labial closure of [p], the narrow dorso-velar channel of [X] which generates turbulent ('Fricative') air-flow, the open, specifically shaped, oral cavity of [c] which generates no sound of itself but merely modulates the phonatory sound of 'voice' generated at the larynx — all these, and others, are types of articulation.
2.6. Initiation, phonation and articulation are the three basic components of sound-production in the human vocal tract. In what follows we shall systematically survey the parameters over which each of these components can vary, and then consider the possible combinations of initiation, phonation, and articulation. We are concerned here chiefly with the total, human, sound-productive potential — what Baudouin de Courtenay called 'anthropophonics' — a useful term which is worth reviving (De Courtenay, 1881). We will, however, give some attention to the extent to which this anthropophonetic potential is utilised in the languages of the world, both in terms of the actual manifestation in phonic substance of the phonological units of particular languages, and in terms of the distinctive features which distinguish one phonological unit from another in particular languages.

3. Initiation

3.1. The sound-productive parameters to be first considered under this head are location and direction. The latter is most conveniently regarded as a dichotomy — egressive versus ingressive. Egressive and ingressive initiation, however, imply on the one hand an initiatory volume-decrease and on the other an initiatory volume-increase. The absolute rate at which this initiatory volume-change occurs is, in itself, a fact to be considered, and we discuss initiation-rate, and initiator-power, as additional initiatory parameters in 3.6 below.

3.2. Initiatory location

There are three major locations of initiatory activity: the lungs, the larynx and the mouth. Following Beach (1936) and Catford (1939) we will call the first two pulmonic and glottalic. The third is velaric which covers a variety of possibilities in the mouth, of which only velaric is utilised in any language.

To these three we may add oesophageic. Oesophageic initiation is used by some laryngectomised persons, usually, or often, alternating with glottalic: laryngectomised speech may use oesophageal egressive initiation for vocoidal and other open articulation types (e.g. fricatives), but glottalic egressive initiation for stops.

3.3. The initiatory movement may be one which reduces the volume of the vocal tract adjacent to the initiator (on its outward or mouthward side), generating positive pressure and an actual or potential flow of air out of the vocal tract — egressive initiation. On the other hand, the initiatory movement may increase the volume of the tract adjacent to it, generating negative pressure and an actual or potential flow of air into the vocal tract — ingressive initiation.

3.4. The major initiation types are thus the following:

3.4.1. Pulmonic egressive. The lung-volume decreases, positive pressure is generated in the vocal tract in and above the lungs and air flows up the trachea and outward through the larynx, pharynx, nose and/or mouth. Pulmonic egressive initiation is utilised in all languages, and in most is the only initiation type used.

3.4.2. Pulmonic ingressive. The lung-volume increases, negative pressure is generated in and above the lungs and air flows into the mouth and/or nose and down through the pharynx, larynx and trachea. Pulmonic ingressive initiation is not regularly utilised in any language: that is, no phonemes are obligatorily produced with this initiation-type and pulmonic ingressive is never a distinctive feature contrasting with pulmonic egressive. It is often used, however, in occasional ingressive exclamations or short utterances e.g. in English no may be said entirely ingressively, and yes may be uttered with pulmonic ingressive ye but pulmonic egressive [s]. In rapid 'sotto voce' counting the numerals may be continuously uttered on an air-stream which alternates between pulmonic...
egressive and pulmonic ingressive with the regular alternations of respiration. It is reported that a pulmonic ingressive air-stream is used in the Swiss-German custom of 'Fensterle' (Diethe, 1950) in which a village boy talks to a village girl beneath her window, using pulmonic ingressive initiation to disguise his voice.

3.4.3. Glottalic egressive. The basic type of glottalic egressive initiation involves complete glottal closure and some type of stricture above the glottis. The larynx moves upwards, generating positive pressure in the pharynx and/or mouth and a potential outflow of air. Glottalic egressive initiation is regularly utilised in all Caucasian languages (Cherkess, Kabardian, Chechen, Avar, Georgian, etc.) and in at least two Indo-European languages of the Caucasus area (Ossetic and Eastern Armenian), in many Amerindian languages, in some African languages, and sporadically throughout the world. Glottalic egressive sounds are often called 'ejecitives' by British phoneticians, and, somewhat misleadingly, 'glottalised' by Americans. 'Misleadingly', since the term 'glottalised', on the analogy of 'palatalised' etc. suggests a secondary articulatory modification, rather than a basic initiation mechanism (cf. Catford, 1947).

3.4.4. Glottalic ingressive. In this initiation type the glottis is closed and the larynx moves downwards, generating negative pressure in the pharynx and/or mouth and a potential inward flow of air. In its basic, unphonated form this initiation-type is rare, but is reported for Tojolabal, of Mexico, and for Cakchiquel, a language of Guatemala; in the latter, at least, glottalic egressive and ingressive initiation types are in phonological opposition.

3.4.5. Velaric egressive. In velaric egressive initiation there is a firm closure between the dorsal surface of the tongue and the velum. In addition, there is a stricture further forward in the mouth. A forward and/or upward movement of the central part of the tongue generates positive pressure behind the articulatory stricture, and thus initiates a (potential) outflow of air.

Velaric egressive initiation is not known to be phonologically utilised in any language. It is, however, an initiation type sometimes used in ejecting a small foreign body from the tip of the tongue — in this case the articulation is often of apico-labial stop type (see 5.4 below). It should be noted that this form of spitting may also use glottalic egressive initiation. Velaric egressive initiation is also often used in blowing smoke-rings, and by Scottish chanter players, who can play continuously for long periods by inhaling quickly through the nose while maintaining a velaric egressive initiation. With bilabial affricate articulation, it is part of a shoulder-shrugging gesture of dismissal sometimes used by Frenchmen.

3.4.6. Velaric ingressive. In velaric ingressive initiation there is a firm closure between the dorsal surface of the tongue and the velum, and also a stricture further forward in the mouth. A downward and/or backward movement of the tongue generates negative pressure behind the articulatory stricture, and thus initiates a (potential) inflow of air. This is the initiation type of what are most commonly called 'clicks'. It is regularly utilised only in a few languages of South Africa, particularly Bushman, Sandawe, Hottentot, Zulu and Xosa. It occurs sporadically in some of the Shona languages (Doke, 1931), and is reported by Ladefoged (1964) in a number of languages of West Africa. In both these latter cases there is some doubt as to whether the velaric ingressive effect is more properly regarded as an initiatory activity or as an incidental effect of multiple articulation. It must be noted that articulatory movements change the volume of the oral cavity, and these oral volume changes often accelerate or decelerate the flow of air through the mouth. In the cases of multiple stop articulation in the mouth cited by Ladefoged, a slight movement of one of the articulators may generate quite a high intra-oral positive or negative pressure.

Outside of the South African languages mentioned above velaric ingressive initiation is not attested as phonologically utilised in any language. It occurs, however, as the initiation of an audible gesture of negation or regret in many languages. This is the sound represented by [t] in IPA notation ('alveolar click') and in English conventionally as 'tut tut'.

3.4.7. Oesophageic. In this initiation type air, having been gulped into the oesophagus, is allowed to escape as a controlled belch. Oesophageic initiation is only egressive, and is normally used only by laryngeotomised persons (cf. 3.2 above).

3.5. We can now summarise the basic initiatory possibilities of man. In the following table 0 means that that type is impossible, + means that that type is anthropophonically possible, though not known to occur as a regular, normal, initiation type in any language while ++ means that that type is regularly used in at least one language.
In all languages, even those using two or more initiation types, initiation is basically pulmonic egressive. There are good anthropophonics reasons for this. First, the volume of air which can be stored in the lungs and trachea is of the order of ten times greater than that which can be stored in the pharynx and mouth, enabling speech to proceed for several seconds without interruption. Secondly, the larynx is anatomically more adapted to controlled, sound-producing, egressive flow than to ingressive flow. In those languages which use them, glottalic and velaric initiation are merely superimposed, as it were, momentarily as the initiation of particular ‘consonantal’ segments.

<table>
<thead>
<tr>
<th>Location</th>
<th>Egressive</th>
<th>Ingressive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonic</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Glottalic</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Oralic (sp. velaric)</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Oesophageal</td>
<td>+</td>
<td>0</td>
</tr>
</tbody>
</table>

For these and other reasons, Van Ginneken’s theory (occasionally supported by other scholars) that ‘primeval’ human speech consisted entirely of ‘clicks’ is extremely implausible (Van Ginneken, 1938). In some cases, it is perfectly clear that glottalic or velaric initiation has evolved from pulmonic as a result of transitory phonatory or articulatory phenomena; for example, the Sindhi implosives (voiced glottalic ingresses) which derive from larynx-lowering associated with prolonged voiced stops: again, the transient clicks (velaric ingresses) in the Shona dialects, which are associated with multiple articulation. It is much more reasonable to assume that human speech was once entirely pulmonic egressive, and that other initiation types arose from normalisation and phonologisation of what were formally accessory or incidental or overlapping movements of phonation or articulation.

3.6. Initiation rate and initiator power

The dichotomy egressive/ingressive refers, of course, to two opposite ends of a continuous scale of rate of initiatory movement respectively on the positive and negative sides of a neutral, or zero, point (absence of initiatory movement).

3.6.1. Initiation rate. Since the effective result of movement by any initiator is a change of volume somewhere in the vocal tract, we measure rate of initiatory movement (initiation rate) in terms of volume-change per unit time (cm\(^3\)/sec). It should be noted that initiation rate is related to, but certainly not identical with, the rate of airflow (volume-flow) out of or into the vocal tract. During the closure (the closed phase) of stop consonants, for instance, there is no flow out of or into the tract, but the initiator is normally moving at least part of the time, and articulatory volume-changes in the mouth often accelerate or decelerate flow through the mouth; so that oral volume-flow is rarely an accurate indication of initiation rate.

The range of initiation rate in man is considerable, going from momentary zero’s or near-zero’s with some stop articulations, through a mean of around 150 cm\(^3\)/sec during normal fairly quiet speech to peaks of 1000 to 1500 cm\(^3\)/sec during /h/ sounds, with much higher rates, up to 8000 cm\(^3\)/sec or more during forced exhalation.

3.6.2. Initiator power. During speech, variations in the cross-sectional area of regulatory channels impose a varying impedance on the passage of air, and lead to variations of pressure in the vocal tract between the initiator and these strictures. These pressure variations impose a varying load on the initiator which has to perform more work per unit time to move against a high pressure-load than against a low pressure-load. Since ‘work performed per unit time’ represents the mechanical concept of ‘power’, we call this initiator power and define it as initiation rate times pressure-load — irrespective of which particular initiator is operating at a given time. There is accumulating evidence that initiator power is the physiologico-physical correlate of what is most commonly perceived as ‘stress’. On this cf. e.g. Ladefoged and McKinney (1963) and as yet unpublished experiments carried out at the University of Edinburgh by R. J. Beresford and the author, in which simultaneous recordings were obtained of oesophageal pressure (an index of subglottal pressure) and of rate of thoracic volume decrease (an index of pulmonic egressive initiation rate). These indicate that, though either pressure or initiation rate may on occasion be lower in a perceptually ‘stressed’ syllable than in an ‘unstressed’ one — nevertheless, the product of the two is normally higher in ‘stressed’ syllables than in ‘unstressed’ ones.
Considerable variations in initiator power are anthropophonically possible, and are, of course, exploited phonologically in many languages. In all languages there seems to be a tendency to deliver the pulmonic egressive air stream in a series of ‘pulses’: but the way in which initiator power output is distributed throughout each such ‘pulse’, and the way the pulses themselves are distributed in relation to superimposed phonatory and articulatory activities, are very variable, leading to differences such as that between ‘stress-timed’ and ‘syllable-timed’ rhythm and so forth (cf. Pike, 1943 and 1957).

4. Phonation

The parameters surveyed under this head are stricture-type, location, vocal fold tension, vertical larynx displacement. Some of these are dealt with incompletely in all books on phonetics. For more detail than can be given here, see Catford (1964).

4.1. Stricture-type

Laryngeal strictures range over a continuum, from complete closure to fully open, in which state the cross-sectional area of the human glottis is about 52 per cent of that of the trachea (Negis, 1949), so that the glottis in man is, as Negus says, ‘a markedly obstructed point’ which always impedes air-flow to some extent.

Presumably all human beings can vary the area of the laryngeal stricture over this range, which we segment, for purposes of discussion, into five or six sub-ranges, or types of phonatory stricture: (closed glottis), creak, voice, whisper, breath and nil phonatory strictures.

4.1.1. (Closed glottis) has, for the present purpose, been excluded from phonation (cf. 2.4 above).

4.1.2. Creak involves a periodic, low frequency (around 40 to 60 cps) opening of a chink near the thyroid end of the glottis. The auditory effect resembles a stick being dragged along a railing.

4.1.3. Voice. Periodic opening and closing of the glottis at frequencies from about 70 cps upwards. The vocal folds vibrate most effectively when air flows upwards, there being a pressure difference of at least 2 cm water across the glottis. Inverse voice, involving a higher pressure above the glottis and a downward flow, is also possible, but produces an irregular, ‘croaking’ effect.

4.1.4. Whisper. The vocal folds or ventricular bands are somewhat abducted — at normal rates of flow and pressures up to about 25 per cent of maximal glottal area. The air-flow is turbulent, and a relatively high velocity jet is projected upwards into the pharynx or downwards into the trachea.

4.1.5. Breath. Vocal folds widely separated, with relatively low velocity turbulent flow: the sound of ‘audible breathing’.

4.1.6. Nil phonation. Glottis wide open, as for breath but with low volume-flow (below about 250 to 400 cm³/sec). Air-flow is non-turbulent, generating no sound (silent breathing).

Both breath and nil phonation are the phonation types of ‘voiceless’ sounds.

4.1.7. Various combinations of these phonatory stricture types are possible, including at least the following: (a) breathy voice: breath plus voice — glottis relatively wide open, low velocity turbulence, as for breath, with the vocal folds ‘flapping in the breeze’;
(b) whispery voice: whisper plus voice, glottis narrowed, generating high velocity turbulence as for whisper, with simultaneous vocal fold vibration;
(c) whispery creak: whisper (presumably through a whisper channel at the posterior, arytenoidal, end of the glottis) plus creak;
(d) voiced creak, or ‘creaky voice’ — also called ‘laryngealised voice’, in which creak and voice co-occur. For a description see Ladefoged (1964, p. 16) and Ohala and Vanderslice (1965);
(e) whispery voiced creak: whisper, voice plus creak with relaxed vocal folds — a form of ‘whisky-voice’.

4.1.8. Breath, voice, whisper, whispery voice and creaky voice at least all appear to be utilised phonologically in one or another language, whispery voice being perhaps the commonest form of what is sometimes called ‘breathy phonation’ in North Indian languages, and creaky voice occurring in certain West African languages (Ladefoged, 1964) and a number of Amerindian languages. All other phonatory stricture types with the possible exception of pure creak are used ‘paraphonologically’ — i.e. as generalised indications of social or emotional ‘sets’ in at least some languages (e.g. whisper in ‘conspiratorial’ contexts, breathy voice in sighing whispery voice in ‘tender’ or ‘affectionate’ contexts etc.).
4.2. Phonatory locations

The locus of phonatory strictures may be any one (or more) of the following types.

4.2.1. Glottal or ‘normal’: that is, involving the true vocal folds as a whole, without any specific, active, restriction to any one part.

4.2.2. Ligamental. Actively restricted to the anterior, ligamental, part of the glottis. Ligamental whisper, voice and creak are possible. Ligamental voice has ‘sharp’, ‘clear’ slightly ‘harsh’ quality. In English, often parafunctionally associated with anger or severity. In some languages, phonologically contrasting with normal voice (e.g. Logbara and possibly other Nilotic languages), or with whispery voice (e.g. some varieties of Hindi).

4.2.3. Arytenoidal. Ligamental glottis tightly closed, but with the arytenoid cartilages separated. One type of whisper, and possibly a kind of creak can be produced arytenoidally.

4.2.4. Ventricular. The ventricular bands can be approximated to produce whisper and voice-like or creak-like phonatory strictures.

4.3. The following table sums up the full range of phonation types so far reviewed. As before, 0 means (probably) impossible, + means possible, and ++ means regularly, phonologically, utilised in at least one language. In addition, ? means uncertain.

<table>
<thead>
<tr>
<th>Stricture type</th>
<th>Glottal</th>
<th>Ligamental</th>
<th>Arytenoidal</th>
<th>Ventricular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voiceless</td>
<td>++</td>
<td>0</td>
<td>0</td>
<td>?</td>
</tr>
<tr>
<td>Whisper</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Voice</td>
<td>++</td>
<td>++</td>
<td>0</td>
<td>?</td>
</tr>
<tr>
<td>Creak</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>+</td>
</tr>
<tr>
<td>Breathy voice</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Whispery voice</td>
<td>++</td>
<td>+</td>
<td>0</td>
<td>?</td>
</tr>
<tr>
<td>Whispy creak</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Voice creak</td>
<td>++</td>
<td>?</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Whispy voiced creak</td>
<td>++</td>
<td>?</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

4.4. Vocal fold tension

Not only the tension, but also the length and thickness of the vocal folds can be varied considerably (cf. Hollien et al., 1960).

4.5. Vertical larynx displacement

The larynx can slide up and down in the throat. This can, of course, be part of the initiatory movement in glottalic initiation, and in addition, a downward larynx movement may occur as an accessory to the voicing of stop articulations.

Vertical larynx displacement can, however, be an independent activity, which is best regarded as a phonatory activity. In general, the acoustic effect of larynx raising or lowering is to raise or lower the frequency of the first formant of vowels. Javanese is a language in which larynx-lowering is phonologically utilised (possibly plus some other phonatory modifications) to distinguish vowels preceded by what are usually transcribed as [b d g] etc., from what are transcribed [p t k] etc.: both series of stops are voiceless.

5. Articulation

We come now to articulation in the strict technical sense: those airflow-regulating activities which, with the exception of [], occur above the larynx. For articulation, as for phonation, the two major parameters are stricture-type and location: other parameters are duration and tension.
5.1. Stricture types

Articulatory strictures, like phonatory strictures, form a continuum from fully closed to fully open. It is necessary, however, for purposes of discussion to segment this continuum into at least five different ranges of degree of openness: stop, trill and flap, fricative, approximant, and resonant.

5.1.1. Stop. Stricture type involving complete, firm, closure, maintained for at least a centisecond or two, during which time there is normally a build-up of pressure behind the stop — usually of the order of 8 to 10 cm water in pulmonic egressive stops, up to 40 or 50 cm water in unphonated glottalic egressive stops, and down to about — 10 cm water in voiced glottalic egressive stops (implosives). Much higher pressures, of course, are anthropophonically possible. Stops may or may not have an audible approach (coming together of articulators) or release (audible, 'plosive', separation of articulators). The one invariant, present in all stops, is a relatively maintained and maintainable closure.

5.1.2. Trill and flap. These both involve relatively loose contact between articulators. In trill there is a maintained tension in an articulator (or pair of articulators) such that the pressure of the initiatory air stream sets the articulator(s) in periodic vibration, one, or both, flapping against the other, usually at frequencies of the order of 25 to 35 cps. In flap there is a single, momentary, loose contact between articulators. It is the essential momentariness, and the looseness of contact, which distinguishes a flap from a stop.

5.1.3. Fricative stricture-type involves the formation of an articulatory channel of such small cross-sectional area (of the order of 4 to 30 mm²) that at normal operating volume-flows (say 150 to 200 cm³/sec) the airflow through the channel is always turbulent. In the case of s- and j-type fricatives, in addition to this 'channel turbulence' a high-velocity jet is projected against an obstruction (the teeth, particularly the upper teeth) creating an additional eddying turbulence around the edges of the teeth. It is the turbulent flow of fricatives which generates their characteristic 'jet noise' or 'hiss'.

5.1.4. Approximant. This useful term is borrowed from Ladefoged (1964) though defined here somewhat differently. Approximants have a range of cross-sectional channel areas somewhat larger than that of fricatives, roughly definable in terms of the presence or absence of turbulent flow whether or not the sound is voiced, in approximants flow is turbulent when the sound is voiceless, but non-turbulent (laminar) when the volume-flow is reduced by voicing. A typical example is the approximant [j] of British English (RP). This frequently has laminar flow (and hence no 'hiss') when voiced (as in ray or Bray), but turbulent flow (and hence 'hiss') when voiceless (as in pray). Other examples are typical 'frictionless' l-sounds, 'nasals' ([m], [n], etc.), the 'higher' or 'closer' vowels ([I], [e], [u], [o], etc.) all of which are characterised by laminar flow (no 'hiss') when voiced, but turbulent flow through the oral (or, for [m], [n], etc., nasal) articulatory channel, and 'fricative-like' hiss, when voiceless.

5.1.5. Resonant articulatory stricture is characterised by the fact that the channel area is so great that, at normal volume-flows, there is no turbulence at the locus of articulation whether the sound is voiced or voiceless. Mid to open vowels come into this category, as do certain wide-channel l-sounds, with extreme lateral contraction of the tongue. When a sound with such a stricture type is combined with voiceless phonation, the result is either silence (if the phonation is of nil type — see 4.16), or else is a sound entirely generated by turbulent air-flow through the glottis (breath type phonation) and merely modulated by the oral articulatory stricture.

5.1.6. To these ranges of articulatory stricture type, we might add whistle as a particular type of approximant or fricative (probably the latter, since most if not all, whistles can retain their character when voiced). The nature of whistle is not clearly understood (cf. Pike, 1943) but it clearly involves a delicate balance between channel area (and perhaps shape) and volume-flow.

Presumably whistle is a universal human articulatory stricture type, though, unlike the stricture-types listed above, whistle is not normally or regularly utilised in any language. As a secondary substitute for certain features of normal speech, however, whistle is known to be used in certain situations by speakers of at least three languages, Mazateco and Zapotec of Mexico, and the Spanish dialect of La Gomera, in the Canary Islands. In the whistled variant of the first two languages, both tone languages, whistle essentially simulates word-tone and rhythm, much as do African 'talking drums'. In La Gomera, since the language is not a tone language, whistle indicates various articulatory features. For details, see Cowan
5.1.7. Under articulatory stricture types we must finally consider a different parameter, which we may call (adapting a useful term from Peterson and Shoup, 1965), oral air-path.

The articulatory channel may be central or lateral. In the case of stops, which have no open channel during their most characteristic phase, the closure, the approach or release may be either central or lateral.

5.2. Articulatory locations

The locus of articulation may be the glottis (for [ʔ]) or any point above. Again, we are dealing with a parameter which admits of a few ‘natural’ divisions, but which, for the most part, can only be segmented somewhat arbitrarily into a number of areas and zones.

It is, in fact, convenient to recognise three major areas of articulation: nasal, oral and pharyngo-laryngeal.

The nasal area is actively involved only when the soft palate is lowered so that air flows through the nasal cavity. Traditionally, sounds involving nasal air-flow plus complete oral closure ([m], [n] etc.) are called nasal(s). Whenever the oral stricture is of an open type the traditional term is nasalised, e.g. the nasalised vowels [ə], [æ] etc. We shall adopt this rather uneasy usage, treating nasalisation as a secondary modification of oral articulation (see 5.5 below), but treating the anthropophonic possibilities of purely nasal articulation more fully.

5.2.1. Nasal area. Articulation in this area involves air-flow through the nasal cavity. The central channels of the nasal cavity are covered by mucous membrane, which may swell pathologically, blocking the nasal air-path, but are not subject to independent muscular movement. Consequently, only two nasal articulatory zones need be discussed: nareal and velo-pharyngeal.

(a) Nareal. Articulation at the nares, or nostrils. What are most commonly called ‘nasal consonants’ are, in fact, nareal approximants, since they involve non-turbulent flow through the nostrils when voiced, but turbulent flow when voiceless. A further narrowing of the nostrils creates a fricative-type channel, such that, at normal operating volume-flows, flow through the nostrils is turbulent, even when the sound is voiced. Such (voiced) nareal fricatives, though anthropophonically possible, do not appear to be utilised in any language.

(b) Velo-pharyngeal. Articulation between the upper surface of the velum and the back wall of the naso-pharynx. This is the articulatory location which Pike (1943), calls ‘velic’.

Velo-pharyngeal stops articulation, of course, accompanies every purely oral sound, and is only named as such when the stop is purely released into the nose, as in the sequences [fn] and [dn] of English cotton and sudden.

Velo-pharyngeal fricative articulation occurs in various forms of ‘cata- rhal snort’ but is not known to be phonologically utilised in any language.

5.2.2. Oral area. Articulatory locations in this area are best described in terms of the juxtaposition of articulators attached to the upper jaw (upper articulators) with articulators attached to the lower jaw (lower articulators).

(a) Upper articulators. These consist of the upper lip, the upper teeth, and the entire roof of the mouth from the backs of the upper teeth to the uvula. This is a continuum, with the possibility of articulation occurring at any point, or over any short longitudinal section.

We segment the continuum into a series of zones, named as follows: labial, the entire upper lip, subdivided when necessary into an outer and an inner half: dental, the upper teeth: alveolar, the ridge behind the teeth back to the point where the curvature ceases to be convex and merges with the concave curvature of the vault of the hard palate, subdivided into a front half (alveolar proper) and a rear half (postalveolar): palatal, the hard palate from the rear end of the alveolar zone back to the division between hard and soft palate, subdivided into a forward half (prepalatal) and a rear half (palatal proper): velar, the front half of the soft palate: uvular, the rear half of the soft palate, including the uvula.

(b) Lower articulators. These consist of the lower lip, the lower teeth, and the entire tongue from its forward attachment behind the lower teeth up over its tip, or apex, and back to the tip of the epiglottis. Lower articulators are named in formal description of articulation by means of prefixed forms ending in o or i (e.g. labio-, denti-).

Labio-, the entire lower lip, subdivisible into outer and inner: denti-, the lower teeth: sublamino-, the ‘underblade’ below and behind the tip: apico-, the apex, or tip; lamino-, the ‘blade’ or upper surface of the tongue to about 1 cm behind the apex: dorso-, the entire remaining surface of the tongue, subdivided, when necessary into a front and a back half.

(c) The conjoint articulatory possibilities of the upper and lower oral articulators have certain anatomical limitations. The lower lip can con-
tact the upper lip, upper teeth and alveolar ridge, but no further back than that: hence labiolabial, labiodental, and labioalveolar are possible. The apex of the tongue in some people can perhaps reach back to the uvula, making apico-uvular articulation a possibility, but for most people the rearward limit is probably apicopalatal. The blade can make contact from the upper lip back to the prepalatal zone — laminolarial to laminoprepalatal. The under-blade can contact the inner surface of the upper lip, the inner surfaces of the upper teeth, and the alveolar, postalveolar and prepalatal zones — sublaminolarial (inner) to sublaminoprepalatal. The dorsal surface of the tongue can articulate with the entire upper articulatory continuum, but most normally with the range from prepalatal to uvular.

5.3. Pharyngo-laryngeal

5.3.1. Pharyngeal. The oro-pharynx and laryngeal pharynx can be constricted in various ways, principally by (a) extreme retraction of the tongue, so that the epiglottis approximates to the back wall of the pharynx (epiglottopharyngeal), and by (b) a lateral folding of the back wall of the pharynx (pharyngeal).

At the epiglottopharyngeal location it is doubtful if a stop articulation can be formed, since it seems to be impossible to make a perfectly 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.

At the pharyngeal location, fricative and approximant stricures are possible. Pharyngeal approximant appears to be the normal articulation of the Arabic ha [h] and ‘ain [i], often wrongly described as ‘fricatives’. Normally, the voiced member of the pair, [i], has non-turbulent, ‘non-fricative’ air-flow.

5.3.2. Laryngeal or glottal: represented by glottal stop.

5.4. We now summarise the various combinations of stricture type and location in the oral and pharyngo-laryngeal areas. It may be assumed that nasal articulation (i.e. oral stop plus nareal approximant) is possible with an oral closure at any point where oral stops can occur.

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1 Central resonants are listed only for dorsal articulations: these, together with dorsal approximants, are what are most commonly called vowels. On the other hand lateral resonants are listed almost throughout: this is because laterals have precisely localised articulations, and in most cases intense lateral tongue contraction will produce a resonant-type stricture.

2 It should be noted that labial articulation, particularly the open types, are subject to considerable variation with regard to the general shape of the lips (rounded etc.).

3 A bilabial lateral is said to occur regularly in some Irish Gaelic dialects.

4 Somewhat rare, but occurring in some African languages, cf. Ladefoged (1964).

5 Typical (u) of several Indian languages.

6 Dento-dental (bidental) fricative occurs in at least one dialect of Cherkess (Circassian), where it corresponds to the velar fricative, [x], of other dialects (author's observation and cf. Passy, 1907).

7 E.g. Danish intervocalic d, usually transcribed [d].

8 Common form of [s], [z].

9 This (as also the dental approximant) is one form of (British) English 'friative r'.

10 Apico-velar lateral resonant occurs at least in Javanese, as a form of final [l].
It is worth noting that of the 162 combinations listed here as anthropophonically possible, only 67 or 41 per cent, are known to be regularly utilised in any language.

5.5. Multiple and modified articulation

Simultaneous articulation may occur at more than one locus. When the two (or more) strictures are of the same degree (both stop, both fricative, etc.) we have a (co-ordinate) multiple articulation. When one of the two strictures is more open than the other, we generally regard the opener stricture as a secondary modification of the closer, primary, articulation.

General types of oral multiple articulation can be specified in terms of the lower articulators, as involving any two, or more, of (lower) labial, (lower) dental, apical or dorsal articulations: to these we may add glottal. More specifically, we have such multiple articulations as the bilabial/dorsal stops, [KP], [Gb] of many African languages, the various oral/glottal (specifically, bilabial/glottal, apicoalveolar/glottal etc.) stops, [P], [T], [K] of many dialects of English, and other languages. It should be noted that these oral/glottal stops (which may be called glottalised oral stops, if we arbitrarily assign a lower stricture ranking to glottal than to oral articulation) have pulmonic egressive initiation, the glottal closure having purely articulatory function, unlike glottalic egressive [P], [T], [K], in which glottal closure is part of the initiatory mechanism (cf. Catford, 1947).

In modified articulation we have a distinctly 'primary' articulation accompanied by a relatively more open 'secondary' articulation. Traditionally, however, nasal articulation is always regarded as secondary to an open oral articulation, even when the oral articulation is of resonant type (as in 'open' vowels) and the nasal articulation is of approximant type (cf. 5.2.1.1 above).

Secondary articulations are named by derivatives ending in -ised of the terms referring to articulatory locations, e.g. bilabialised, (apico-)alveolarised, palatalised, pharyngalised etc., or to the oral air-path (lateralised).

Secondary articulation is possible at virtually all the articulatory locations listed in 5.4. As typical examples we may cite the [J]-type sounds of English, Russian and (Southern) Swedish.

English [J] is, typically, palatalised (apico- or lamino-) postalveolar fricative.

Russian [J] is, typically, velarised apico-postalveolar fricative.

Southern Swedish [J] is, typically, apico-postalveolarised velar fricative.

Lateralised implies lateral contraction of the tongue — Japanese r is, at least often, a lateralised apicoalveolar flap.

Nasalised approximants and resonants (particularly nasalised dorsal approximants and resonants, i.e. 'nasalised vowels') are common. Nasalised fricatives are rarer, but a well-known example is the Japanese 'syllabic nasal' as in hon 'book', which is often a nasalised dorsovelar fricative ʔ. In fact in this case so much air is diverted through the nose that air-flow through the oral channel is non-turbulent, but the dorsovelar stricture is probably of fricative type.

5.6. Articulatory sequences

Virtually any articulation can succeed any other. We must, however, briefly mention here that certain homorganic articulatory sequences have traditionally acquired special names. These include:

(a) Geminate; sequence of identical articulations (with or without the same phonation type).

(b) Affricate: stop plus homorganic fricative when these occur within the same initiator-power pulse and are regarded as a single phonological unit.

(c) Lateral affricate, lateral palatalisation: stop plus homorganic lateral.

(d) Nasal palatalisation: stop plus homorganic nasal.

(e) (Pre-)nasalised stop: nasal plus homorganic stop within the same initiator-power pulse, or regarded as a single phonological unit.

It is clear that these types of sequences are selected for special designations on arbitrary or phonological grounds. From a purely anthropophonically and articulatory point of view they are not essentially different from many other homorganic sequences.

Aspirated and preaspirated sounds are not, of course, purely articulatory sequences and are referred to below, under combinations of phonation and articulation.
5.7. Articulatory duration and tension

5.7.1. Considerable variation in the temporal duration of most articulatory stricture types is possible, and is exploited phonologically in many languages. At least two articulatory stricture types admit of no duration whatsoever. These are flaps and the class of approximants known as semivowels. These two classes of stricture types are essentially momentary, a flap being essentially an approach to a loose closure immediately followed by a release, and a semivowel being an approach and/or release to or from an approximant stricture type which, if maintained, would be classified as a 'vowel'.

For all the other, 'maintainable', stricture types duration is limited only by physiological restrictions. The 'open' stricture types — fricative, approximant and resonant — can be maintained until the articulators become intolerably fatigued. Stop articulation can be maintained only as long as one can hold one's breath, and trill articulation requires an egressive air stream in the case of bilabial and apical trill and therefore must be interrupted during inhalation: uvular trill can be maintained with both egressive and ingressive air streams and can therefore be indefinitely maintained. It is true that certain combinations of phonation and stop have an aerodynamically limited duration: but that is another matter. Here we are concerned only with articulation as such.

5.7.2. Articulatory tension is a somewhat obscure subject which has not been illuminated by loose use of such terms as 'tense' and 'lax' usually with reference to vowels, and 'fortis' and 'lenis' with reference to consonants. The first two terms are difficult to dissociate from differences in tongue position, and the latter terms have sometimes been used almost as synonyms for 'voiceless' and 'voiced'. Recently, however, some evidence has been adduced for the existence of variations in articulatory muscular tension as an independent anthropophonic and phonological parameter (Kim, 1965).

6. Initiation in relation to phonation and articulation

6.1. Initiation and phonation

The initiation types reviewed in 3.5 can be combined with phonation types as follows:

(a) Pulmonic egressive can combine with all phonation types.
(b) Pulmonic ingressive, with all except voice, the 'inverse voice' occurring with this initiation being of an atypical 'croaking' kind, not easily differentiated from inverse creak.
(c) Glottalic egressive: basic glottalic egressive initiation involves closed glottis, and is thus phonationless, or unphonated. It is, however, possible to produce glottalic egressive stops with croaking inverse voice, since the rising glottis generates positive pressure in the pharynx and there can thus be a downward airflow through the larynx. Such voiced glottalic egressive sounds are not known to occur in any language.
(d) Glottalic ingressive: in this type of initiation the air pressure in the pharynx and mouth is lowered below the subglottal pressure level, permitting upward air-flow through the glottis. Voice, whisper, creak, and creaky voice can thus be combined with glottalic ingressive initiation. Voiced glottalic ingressive sounds, 'voiced imjectives', are fairly common: 'creaky voiced imjectives' apparently occur in some West African languages (Ladefoged, 1964).

Velaric initiation does not involve any airflow through the larynx. All velaric sounds are thus unphonated, though, of course, they may be accompanied by pulmonic or glottalic sounds of various phonation types.

6.2. Initiation and articulation

In general, trill and flap articulation cannot combine with ingressive initiation, except that uvular trill is possible with pulmonic ingressive initiation. Otherwise, stop and fricative articulatory stricture types are combinable with all types of initiation, the opener types only with pulmonic initiation.

7. Phonation in relation to articulation

Voiceless, whisper and voice phonation can combine with any articulation, except [F], which is, of course, phonationless. Creak can combine with any articulatory stricture type except fricative. In creak the volume-flow is so low, being of the order of 12 to 20 cm³/sec, that it will not generate turbulent flow even through very narrow fricative type articulatory channels.
Voiced stops are certainly possible, but the duration of voicing with such articulations is severely limited by the fact that the flow of air through the glottis very quickly raises the supraglottal pressure to a point where the essential transglottal pressure difference of 2 to 3 cm water is abolished and voicing ceases. It is anthropophonically possible to delay pressure-equalisation up to about 1 second by lowering the larynx and expanding the pharynx to the maximum, and though a delay of this extent does not normally occur in any language a slight lowering of the larynx often accompanies voiced stop articulation.

Another variable to be considered here is the distinction between unaspirated sounds (chiefly stops) on the one hand and aspirated or preaspirated sounds on the other. This is essentially a matter of the time relations between the closed phase of the articulation and the time of onset (aspiration) or cessation (preaspiration) of voicing. On this, see the study by Lisker and Abramson (1964). It is probable that the difference between unaspirated and aspirated is not purely a matter of timing, since oral pressure recordings frequently show a level, or even slightly falling, oral pressure during unaspirated stops, but oral pressure rising right up to the moment of release in aspirated stops — for a clear example, see plate 5 in Ladefoged (1964). This implies a difference in the control of the initiatory air-flow.

8. Conclusion

The preceding has been, of necessity, a superficial survey of 'the articulatory possibilities of man', possibilities which are, in fact, infinite, since they depend on variations along a number of parameters, some of which in fact represent merely limited choices, but many of which are genuinely continua. Only a small selection out of this infinite variety is known to be regularly, phonologically, utilised in the languages of the world. Phonetics, however, must be prepared to deal analytically and descriptively with any initiatory, phonatory or articulatory event which can possibly occur in the human vocal tract, since at any moment the investigation of some as yet unstudied language, of 'speech defects' or of the speech of children may reveal the communicative, linguistic, use of some so far unrecorded type of sound.

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