rada "council". Some American Indian, African and Caucasian languages contain strident counterparts of the /l/ phoneme - lateral affricates and/or constrictives (9). Despite the high damping of their formants all these phonemes retain manifest acoustic traces of their relation to liquids. They are liquids with superposed stridency (cf. below 2.441).

2.33 Supplementary Source: Voiced vs. Voiceless

2.331 Stimulus. The voiced or "buzz" phonemes as /d b z v/ vs. the voiceless or "hiss" phonemes are characterized by the superposition of a harmonic sound source upon the noise source of the latter (10). For the voiced consonants this means a joint presence of two sound sources. The spectrum of voiced consonants includes formants which are due to the harmonic source. The most striking manifestation of "voicing" is the appearance of a strong low component which is represented by the voice bar along the base line of the spectrogram (11).

2.332 Production. Voiced phonemes are emitted with concomitant periodic vibrations of the vocal bands and voiceless phonemes without such vibrations.

2.333 Occurrence. The use of the distinctive consonantal opposition voiced vs. voiceless is widespread in the world; e.g., in Europe it is found in all Slavic languages as well as in Hungarian: cf. Russian /don/ "Don" - /ton/ "tone". The extension of this feature to liquids is extremely rare; e.g. in Gaelic voiced /r l/ and the corresponding voiceless /r̬ l̬/ may occur in the same positions. (On the nasal consonants see 2.443).

Vowels are normally voiced. It is still questionable whether there are languages in which parallel to the consonantal opposition voiced vs. voiceless, there actually is a similar distinctive opposition of voiced and murmured vowels, as reported about a few American Indian languages, e.g., Comanche. Either the vocal murmur is not a distinctive feature and functions merely as a border mark, or it may be a concomitant of the tense-lax opposition (Fig. 12).

In languages lacking an autonomous opposition of voiced and voiceless consonants, the latter is either used as a mere concomitant of the opposition of lax and tense consonants, as in English (cf. 2.434), or oral consonants are normally voiceless, as in Finnish dialects. Here the difference between "hiss" and "buzz" acts as a concomitant factor of the consonant-vowel opposition. In some of these languages an automatic voicing of consonants takes place in certain phonemic contexts.

2.4 RESONANCE FEATURES

This class includes:

1) three types of features generated in the basic resonator: a) the compactness feature, b) three tonality features, c) the tenseness feature,
2) the nasalization feature due to a supplementary resonator.

2.41 Compact vs. Diffuse

2.411 Stimulus. Compact phonemes are characterized by the relative predominance of one centrally located formant region (or formant). They are opposed to diffuse phonemes in which one or more non-central formants or formant regions predominate.

Compact vs. diffuse vowels: English (RP) pet /pˈet/ - pit /pˈit/; pat /pˈat/ - putt /pˈət/; pot /pˈot/ - put /pˈut/. Compact vs. diffuse consonants: kill - pill or till; shill - fill or sill; ding /dˈiŋ/ - dim or din. The Czech symmetric pattern of compact and diffuse oral consonants presents good examples of the one-to-one correspondence: ti /ci/ "they" - ty /ti/ "them"; šál /ʃa:l/ " shawl" - sál /sa:l/ "hall; kluk /kluk/"boy" - pluk /pluk/ "regiment"; roh /rox/ "horn" - rov /rof/ "grave".

In the case of the vowels this feature manifests itself primarily by the position of the first formant (11): when the latter is higher (i.e. closer to the third and higher formants), the phoneme is more compact. The closer the first formant is to the upper formants, the higher will be the intensity level of the region above the first formant, especially the level between peaks. (See Fig. 4.).

In the consonants, compactness is displayed by a predominant formant region, centrally located, as opposed to phonemes in which a non-central region predominates; (cf. Fant's analysis of Swedish stops (3)). The compact nasals have a dominant formant region between the characteristic nasal formants (200 cps and 2500 cps). Delattre's observations on the positions of the first formant in stops and nasal consonants (12) corroborate the parallelism between the compactness feature in vowels and consonants.

It has been suggested that the proper measure for the feature of compactness would be somewhat akin to the measures of dispersion accepted in statistics. The usual measure for this is the second moment about the mean. Preliminary calculations suggest this as a possible measure of compactness. Certain questions regarding the proper weighting of the frequency vs. intensity spectrum remain open: especially whether a weighting like the equal loudness contour should be applied to the spectra before the moments are computed.

2.412 Production. The essential articulatory difference between the compact and diffuse phonemes lies in the relation between the volume of the resonating cavities in front of the narrowest stricture and those behind this stricture. The ratio of the former to the latter is higher for the compact than for the corresponding diffuse phonemes. Hence the consonants articulated against the hard or soft palate (velars and palatals) are more compact than the consonants articulated in the front part of the mouth. In the case of vowels the compactness increases with an increase in the cross-sectional area of any constricted passage. Thus open vowels are the most compact, while close vowels are the most diffuse.

A higher ratio of the volume of the front to that of the back cavity can be also achieved by shortening the pharynx. This is the case in the production of compact consonants. In the corresponding diffuse consonants the pharyngeal cavity is lengthened by raising the velum and lowering the hyoid bone. X-ray photographs of the articulation of Finnish vowels and their measurements made by Sovijärvi are particularly revealing in this respect (13). The volume of the pharyngeal cavity for a diffuse phoneme is always bigger than for the corresponding (ceteris paribus) compact phoneme. (See Fig. 5).

2.413 Perception. Because of the higher over-all level usually associated with a longer duration, the compact phonemes display a higher "phonetic power" than the diffuse phonemes, ceteris paribus. Fletcher's calculations give the following "average values" ((14): table VIII, last column) for consonants of American English (and similar results for vowels):

Compact		Diffuse			
/k/	3.0	/t/	2.7	/p/	1.0
/g/	3.3	/d/	1.7	/b/	1.1
/ʃ/	11.0	/s/	0.9	/f/	1.0
/ŋ/	12.0	/n/	4.1	/m/	2.9

On the perceptual level a distinct association links the consonantal and vocalic opposition of compactness and diffuseness. As a recent experiment in Haskins laboratories (15) discloses, the same artificial "schematic stop was judged by a large majority of the subjects to be [p] when paired with [i] and [u], but to be [k] when paired with [a]". The contact with [a], the most compact, and with [i] and [u], the most diffuse of the vowels, prompts the association of this stop with [k], the most compact, and with [p], the most diffuse of the stops, respectively. Similarly the scale of magnitude, i.e. the small-vs.-large symbolism, latently connected for the average listeners with the opposition of compact and diffuse, works alike for vowels and for consonants (16).

The opposition compact vs. diffuse in the vowel pattern is the sole feature capable of presenting a middle term in addition to the two polar terms. On the perceptual level, experiments that obtained such middle terms through the mixture of a compact with the corresponding diffuse vowel (17) seem to confirm the peculiar structure of this vocalic feature, which sets it apart from all other inherent features.

2.414 Occurrence. The distinction of compact and diffuse vowels is apparrently universal. A few geographically scattered languages such as Tahitian and Kasimov-Tatar lack compact consonants (both velars and palatals). Often compact consonants occur only among stops, as in Danish.

But while consonants obey a strict dichotomy and may be either compact or diffuse, a parallel state in the vocalic pattern is frequent but not universal. E.g. in Roumanian (and similar relations exist in many other languages) the open /a/ and the close /ɨ/, as in rad "I shave" - rîd "I laugh", are opposed to one another as compact vs. diffuse. The corresponding mid vowel /ə/ is diffuse with respect to /a/ (cf. răi "bad" - rai "paradise") but at the same time compact in relation to /ɨ/ (cf. văr "cousin" - vîr "I introduce"). Thus compactness and diffuseness may be envisaged as two opposites, one symbolized by "plus" and the other by "minus": then /ə/ would be denoted by ±. This opposition of two contraries could, however, be resolved into two binary oppositions of contradictories: compact vs. non-compact and diffuse vs. non-diffuse. In this case, /ə/ would be doubly negative -- both non-compact and non-diffuse.

2.42 Tonality Features

This sub-class of the resonance features comprises three distinct dichotomous features capable of interacting variously with one another: a) the gravity feature, b) the flattening feature, and c) the sharpening feature.

2.421 Grave vs. Acute

2.4211 Stimulus. Acoustically this feature means the predominance of one side of the significant part of the spectrum over the other. When the lower side of the spectrum predominates, the phoneme is labeled grave; when the upper side predominates, we term the phoneme acute. Two measures suggest themselves as proper for this feature: a) the center of area, and b) the third moment about the center of area. As stated above (cf. 2.411), it is necessary before applying these criteria to normalize the spectra in some way. At present the proper normalizing function is still undetermined.

The great advantage of the third moment lies in the fact that here the predominance of the lower end of the spectrum would give negative values, while the predominance of the upper end would give positive values. Thus we could determine the gravity or acuteness of a sound without reference to any other standards. However, the fact that we must cube one of our variables (the frequency difference) seems to make the third moment an extremely sensitive measure which can only be used with extreme caution.

When using the center of area we avoid these difficulties, but at the same time we lose the advantages outlined above. The absolute values of the center of area cannot indicate whether a phoneme is grave or acute, for the center of area of an acute phoneme might well be lower than that of a grave; cf. the centers of area of the acute /e/ and the grave /f/ in the English word deaf. Thus it is impossible to decide whether a given phoneme is grave or acute without knowing at least some of the other features which the phoneme in question possesses.

Grave vs. acute vowels: Turkish /kɨs/ "malevolent" - /kis/ "tumor", /kus/ "vomit!" - /kys/ "reduce!"; /an/ "moment - /en/ "width", /on/ "ten" - /øn/ "front"

The position of the second formant in relation to that of the other formants in the spectrum is the most characteristic index of this feature: when it is closer to the first formant the phoneme is grave; when it is closer to the third and higher formants it is acute.

Grave vs. acute consonants: fill - sill, pill - till, bill - dill, mill - nil. In identifying the gravity feature of a consonant it is often profitable to observe the second formant in the adjacent vowel, if any: it is lowered in the case of grave consonants, and raised if the consonant is acute. This is the method advocated by Visible Speech (1). In some cases the position of the third and even higher formants may also be affected.

2.4212 Production. The gravity of a consonant or vowel is generated by a larger and less comparted mouth cavity, while acuteness originates in a smaller and more divided cavity. Hence gravity characterizes labial consonants as against dentals, as well as velars vs. palatals (see Fig. 5,) and, similarly, back vowels articulated with a retraction of the tongue vs. front vowels with advanced tongue (19).

Usually, however, a notable auxiliary factor in the formation of grave phonemes (back vowels and labial consonants as well as velars if opposed to palatals) is a contraction of the back orifice of the mouth resonator, through a narrowing of the pharynx, whereas the corresponding acute phonemes (dental and palatal consonants and front vowels) are produced with a widened pharynx. For instance, the widths of the cross-section of the pharyngeal cavity for the two classes of Czech consonants deviate from its width in silence (13.3 mm) as follows (measurements in mm):

Grave	Acute
/u/ - 3.8	/i/ + 15.2
/o/ - 5.5	/e/ + 4.0
/f/ - 4.7	/s/ + 6.3
/x/ - 3.8	/ʃ/ + 1.7
/p/ - 2.5	/t/ + 0.5
/k/ - 2.6	/c/ + 12.7
/m/ - 2.5	/n/ + 8.9 (See Fig. 5)

2.422 Flat vs. Plain

2.4221 Stimulus. Flattening manifests itself by a downward shift of a set of formants or even of all the formants in the spectrum.

Flat vs. plain vowels: Turkish /kus/ - /kɨs/, /kys/ - /kis/; /on/ - /an/; /ɸn/ - /en/ (See Fig. 4). We employ a conventional musical term for labeling this feature, and in phonemic transcription we may correspondingly use a subscript or superscript musical flat "♭" to denote the flat consonants. Examples from Rutulian, a North Caucasian language: /iaḳ/ "light" - /iak/ "flesh" /χ♭ar/ "more" - /χar/ "hail". (See Fig. 6).

2.4222 Production. Flattening is chiefly generated by a reduction of the lip orifice (rounding) with a concomitant increase in the length of the lip constriction. Hence the opposition flat vs. plain has been genetically termed "orifice variation", and the opposition grave vs. acute "cavity variation" (18).

Instead of the front orifice of the mouth cavity, the pharyngeal tract, in its turn, may be contracted with a similar effect of flattening (20). This independent pharyngeal contraction, called pharyngealization, affects the acute consonants and attenuates their acuteness (See Fig. 7). The fact that peoples who have no pharyngealized consonants in their mother tongue, as, for instance, the Bantus and the Uzbeks, substitute labialized articulations for the corresponding pharyngealized consonants of Arabic words, illustrates the perceptual similarity of pharyngealization and lip-rounding. These two processes do not occur within one language. Hence they are to be treated as two variants of a single opposition-flat vs. plain. The two phonetic signs [t̫] and [t̪] used for rounded and pharyngealized consonants respectively could be replaced by a single symbol in the phonemic transcription. The subscript or superscript musical flat which we have employed for the Caucasian rounded consonants can also be used for the Arabic pharyngealized consonants: /ḍ♭irs/ "molar" - /dirs/ "camel's tail", /s♭alb/ "crucifixion" -/salb/"despoiling."

On the autonomous use of the "back orifice variation" for the grave consonants and for the vowels see 2.4236.

2.423 Sharp vs. Plain

2.4231 Stimulus. This feature manifests itself in a slight rise of the second formant and, to some degree, also of the higher formants.

Examples: Russian /m̗'at̗/ "to rumple" -/m̗'at/ "rumpled" -/m'at̗/ "mother" - /m'at/ "checkmate", /kr'o̗f/ "blood" - /kr'of/ "shelter" (see Fig. 9).

2.4232 Production. To effect this feature, the oral cavity is reduced by raising a part of the tongue against the palate. This adjustment, called pala-

talization, is made simultaneously with the main articulation of a given consonant and is linked with a greater dilatation of the pharyngeal pass in comparison with the corresponding plain consonant. The pharyngeal dilatation of the plain acute consonants is further augmented for the sharpened ones. The pharyngeal contraction of the plain grave consonants is supplanted by a dilation for the sharpened ones (see Fig. 9). Hence the behavior of the pharynx is particularly important in the sharpening of the grave consonants and may, under certain circumstances, become its main factor (see 2.4236).

2.4233 Perception of Tonality Features. The intelligibility of acute phonemes is seriously impaired by the elimination of their high frequencies, while the grave phonemes are hardly recognizable when losing the low frequencies (21 and 14). A schematic stop is perceived as [t] when endowed with distinctly higher frequencies and as [p] when endowed with distinctly low frequencies (cf. 2.413).

Two phonemes contrasted as grave and acute (e.g., /u/ vs. /y/ or /ɨ/ vs. /i/ or /f/ vs. /s/) are easily identified as dark and light respectively by responsive subjects synesthetically oriented, while the contrast of flat and plain, /u/ vs. /ɨ/ or /y/ vs. /i/, produces rather a sensation of depth, breadth, weight and bluntness vs. thinness, height, lightness and shrillness. A closer study of these two dimensions of auditory sensation in their relation to the distinct acoustic stimuli and to the reactions of the same listeners upon the compactness feature could contribute to the elucidation and delimitation of the different sound attributes.

The increased "corpulence" and "hardness" ascribed by the Arabic grammatical tradition to the pharyngealized consonants in terms of auditory experience is similarly applied by Caucasian observers to the rounded consonants.

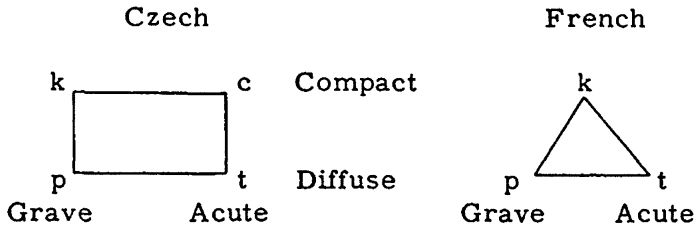
The sharpened acute consonants as /s̱/, /ṯ/ are sensed by responsive subjects as slightly brighter than /s/, /t/ and the sharpened grave /f̱/, /p̱/ as somewhat less dark than /f/, /p/.

Subjects endowed with colored hearing refer to vowels as chromatic and to consonants as achromatic, grayish. The contrast between acute and grave phonemes is correlated with the white-black, yellow-blue and green-red responses, whereas compact phonemes are prevalently matched with the colors at the greatest distance from the white-black axis (22). Experiments in vowel mixing show that grave and acute vowels when sounded simultaneously are not perceived as a single vowel (17). This test may be compared to a similar experience with colors - the non-existence of bluish yellow or reddish green (23).

2.4234 Occurrence of Tonality Features. Each language presents at least one tonality feature. We term it primary. Moreover, a language may contain one or two secondary tonality features.

2.4235 The Primary Tonality Feature. Consonants almost universally possess a tonality feature. As a rule, the diffuse consonants exhibit the opposition

grave vs. acute, which often is found also in the compact consonants. In other words, the consonant patterns usually include both labial and dental phonemes and frequently also mutually opposed velars and palatals. Such is, for instance, the case in several Central European languages - Czech, Slovak, Serbocroatian and Hungarian. Their consonant phonemes form a square pattern, while in languages such as English and French, which do not split their compact consonants into grave and, ceteris paribus, acute phonemes, this pattern is triangular:



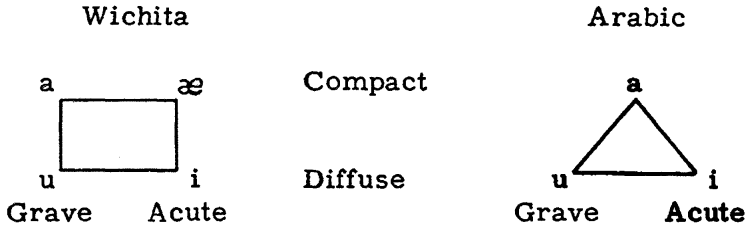
In the few American and African languages that have no labials, their absence, for the most part, can be traced to the traditional use of labrets. Moreover, most of these rare consonant patterns, devoid of the opposition grave vs. acute, have another tonality feature: flat vs. plain; e.g. Tlingit (Alaska), Iroquoian, and Wichita (Oklahoma); cf. such Tlingit word-pairs as [ja:k̲] "canoe"-[ja:k] "shell".

In vowel patterns with only one tonality feature, the following three cases are found: a) the opposition grave vs. acute alone; b) rarely, the opposition flat vs. plain alone; c) quite frequently, a fusion of the two oppositions. Examples for the first kind are Wichita (24) and Slovak, with such pairs as Slovak mat' /mac/ "mother" - mät' /mæc/ "mint", or Japanese, where the grave phoneme opposed to /i/ is produced without lip-rounding. In Russian, which exemplifies the second type, close phonemes /u/ and /i/ are opposed to each other only as flat (rounded) to plain (unrounded), because in certain positions both of these phonemes are represented by front variants and in certain others by back variants: [ʃ̂yd̠'it̠] "to play pranks" -[ʃ̂id̠'it̠] "to smoke", [rv'u] "I tear" - [rv'ɨ] "moats". In these cases only one of the two processes is phonemically relevant, while the other is a redundant feature appearing only in certain definite phonemic contexts. The third type, an indissoluble fusion of both processes, takes place in Spanish and Italian: e.g. Spanish /puso/ "he put" - /piso/ "tread", /poso/ "sediment" - /peso/ "weight". Here in the opposition grave vs. acute a wide undivided mouth cavity is always accompanied by rounding, while a smaller and more comparted cavity is never accompanied by rounding. Thus in these patterns only the optimal grave and the optimal acute are opposed to each other.

If there is only one tonality feature in the vowels of a given language, then it may be lumped with the primary (or only) tonality feature of the consonants, regardless of which of the three above patterns actually occurs. For example, Russian uses one opposition (flat vs. plain) as the only tonality feature in the

vowels, and another (grave vs. acute) as the primary tonality feature in the consonants. The difference between these features is, however, redundant since it accompanies the opposition of vowels vs. consonants, and consequently the only relevant factor here is the common denominator of the two tonality features.

The sole or primary tonality feature is often confined to diffuse vowels. Hence vowels, like consonants, form either a square or a triangular pattern:



2.4236 The Secondary Tonality Features. In a number of languages the consonants use the opposition flat vs. plain as a secondary feature, in addition to the primary feature, i.e. the opposition grave vs. acute. Flattening produced by lip-rounding is wide-spread in the Caucasus and also occurs in some native languages of Asia, Africa and America. It mainly affects velars, but is sometimes extended to other consonants as well. Another variety of flattened phonemes, the pharyngealized (so-called emphatic) consonants appear in some Semitic and adjacent languages. This process affects the diffuse acute (dental) consonants and attenuates their acuteness, while in the compact consonants it fuses with the primary opposition grave vs. acute and intensifies the distinction between palatals and velars by imposing upon the latter a very strong pharyngeal contraction.

The distinction of retroflex and dental consonants, characteristic in particular of various languages in India, is another manifestation of the same opposition (see Fig. 8): both the contraction of the pharynx and the elongation of the resonating cavity take place in producing emphatic as well as retroflex consonants, but for the former the first process, and for the latter the second one seems to be of greater pertinence.

Liquids and glides, also, undergo either rounding or pharyngealization and may partake in the opposition flat vs. plain. Thus Circassian distinguishes a rounded and unrounded glottal catch: /ʔ̣a/ "say!" - /ʔa/ "hand". Arabic has an aspiration with and without contraction of the pharynx: /ḥadam/ "it was hot" - /hadam/ "he pulled down", /jaḥdim/ "it is hot" - /jahdim/ "he pulls down".

The opposition of sharpened and plain consonants plays an important part, e.g., in Gaelic, Roumanian, Polish, Russian and several languages adjacent to the latter. It primarily affects the diffuse acute consonants (dentals), but is sometimes extended also to other classes (labials and velars).

In a few languages rounded (flat) and palatalized (sharp) consonants may co-exist, e.g. the Abkhazian language in the Caucasus opposes a plain phoneme as /g/ to the corresponding flat /g̫/, on the one hand, and to the sharpened /g̱/, on the other. In single languages such as Dungan Chinese and Kashmiri, the two co-existing oppositions realize all four possible combinations: 1) rounded unpalatalized, 2) unrounded unpalatalized, 3) rounded palatalized, 4) unrounded palatalized. (Cf. the vowel series /u/ - /ɨ/ - /y/ - /i/). E.g. Kashmiri distinguishes in this manner four different grammatical forms of the verb "to do": /kar̫/ - /kar/ - /kaṟ/ - /kar̫̱/. In the rounded palatalized phonemes the second formant moves closer to the third while at the same time all formants are moved down in frequency.

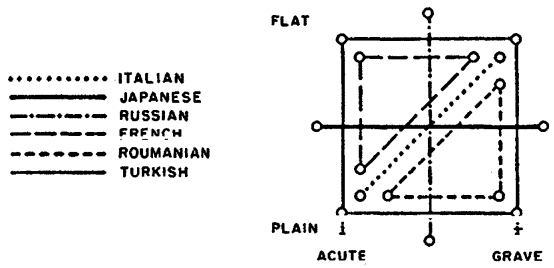
Finally the combination of flats and sharps within one language can acquire another form. Beside languages such as Arabic, which confine the autonomous role of the pharynx to its contraction for the flattening of the acute consonants, there are a few languages in the NE Caucasus which employ the widening of the pharynx to sharpen the grave consonants. This is the essence of the so-called "emphatic softening" (25). Both these processes - the flattening of the acuteness and the sharpening of the gravity - may be reduced to a common denominator: the attenuation of the primary feature through a pharyngeal modification. Consequently we may transcribe the dentals with narrowed pharynx in one and the same way. Examples from Lakkian (NE Caucasus): /d̈a:/ "middle" - /da:/ "come", and /m̈a/ "bolt" - /ma/ "have it.".

In a great number of languages each of the two oppositions - grave vs. acute and flat vs. plain - acts separately in the vowel pattern. If in such a language two vowel phonemes are opposed to each other by contrary positions of their second formant, then at least one of these two phonemes is at the same time opposed to a third phoneme by a shift in the first three formants and in some of the higher formants. Thus French (and similarly Scandinavian languages, standard German, and Hungarian) distinguishes two classes of acute vowels and one - an optimal class - of grave vowels: plain acute - flat acute - flat grave: nid /ni/ "nest" - nu /ny/ "naked" - nous /nu/ "we".

Other languages, e.g. Roumanian and Ukranian, have two classes of grave vowels - flat as /u/, plain as /ɨ/ - and only a single, optimal class of acute vowels - plain as /i/. A comparable distribution appears in the variety of English described by D. Jones (RP). Diffuse vowels: acute in pit /pˈit/ - plain grave in putt /pˈət/ - flat grave in put /pˈut/; compact vowels: acute in pet /pˈet/ - plain grave in pat /pˈat/ - flat grave in pot /pˈot/. It is true that in pat the contextual variant representing the phoneme /a/ is the front [æ], but the tongue in producing this English vowel is more retracted than in producing acute vowels, and moreover a pharyngeal contraction "appears to be an inherent characteristic of the sound", as noted by D. Jones and other observers. This connects it with the back variant of the same phoneme and with the other grave vowels.

Finally in Turkish both the grave and the acute vowels are split into two opposite sub-classes - flat and plain: /kus/ - /kɨs/ - /kys/ - /kis/; /on/ - /an/ -

/ɸn/ - /en/. Cf. the diagram:



When a language possesses only three classes of vowels: an optimal grave, an optimal acute and an attenuated class, i.e. either flat acute or plain grave, then, as far as the structure of the vowel pattern does not prevent it, it is possible to interpret all three classes in terms of one opposition. With this assumption, /u/ is "+", /i/ is "-" and /y/ or /ɨ/ is "+" vs. /i/, but "-" vs. /u/ and hence may be symbolized by "±". The opposition flat vs. plain as a secondary tonality feature of vowels supplements the optimal grave vs. acute opposition by an attenuated grave and/or acute; for instance /u/ and /i/ by /ɨ/ and/or /y/. In a few Caucasian, Nilotic and Hindu languages, a similar attenuation is performed by a dilation of the pharynx (sharpening) for the grave vowels and its contraction (flattening) for the acute vowels. This pharyngeal behavior generates two series of centralized vowels opposed to the back and front vowels respectively, e.g., in Dinka (Anglo-Egyptian Sudan) /ü/ - /u/, /ö/ - /o/; /ï/ - /i/, /ë/ - /e/: /dit/ "bird" - /dit/ "big".

2.43 Tense vs. Lax

2.431 Stimulus. In contradistinction to the lax phonemes the corresponding tense phonemes display a longer sound interval and a larger energy (defined as the area under the envelope of the sound intensity curve; cf. 2.31).

In a tense vowel the sum of the deviation of its formants from the neutral position is greater than that of the corresponding lax vowel (cf. 2.13). A similar deviation may be presumed for the spectrum of the tense consonants (called strong or fortes) in comparison with their lax counterparts (called weak or lenes).

In consonants, tenseness is manifested primarily by the length of their sounding period, and in stops, in addition, by the greater strength of the explosion.

The opposition of tense and lax vowels has often been confused with the distinction between more diffuse and more compact vowels and with the corresponding articulatory difference between higher and lower tongue position. But the more diffuse vowels are, ceteris paribus, shorter than the more compact, whereas the tense vowels have a longer duration than the corresponding lax.

Examples. Tense vs. lax consonants: English pill - bill, till - dill, kill - gill /gil/, chill - gill /ʧil/, fill - vill, sip - zip. Tense vs. lax vowels: French

saute /sot/ "jump" - sotte /sot/ "fool" (fem.), pâte /pạt/ "paste" - patte /pat/ "paw", las /lạ/ "tired" - là /la/ "there", jeûne /ʒø̣n/ "fast" - jeune /ʒ ø̣n/ "young", tête /tẹt/ "head" - tette /tet/ "suckle", thé /tẹ/ "tea" - taie /te/ "pillow case" (the difference in duration which is crucial for the distinction between /ẹ/ and /e/ before consonants is notably reduced at the end of the word).

French Tense and Lax Vowels

	F_1	F_2	F_3	$\Sigma\Delta f$
Neutral Position (Mlle. D.)	570	1710	2850	
saute /sọt/	480	1000	2850	
Δf	90	710	0	800
sotte /sot/	520	1400	3000	
Δf	50	310	150	510
pâte /pạt/	600	1200	2800	
Δf	30	510	50	590
patte /pat/	650	1600	2650	
Δf	80	110	200	390
tête /tẹt/	600	2100	3200	
Δf	30	390	350	770
tette /tet/	600	1900	2500	
Δf	30	190	350	570
thé /tẹ/	450	2300	3200	
Δf	120	590	350	1070
taie /te/	600	2100	2650	
Δf	30	390	200	620

The sum of the deviations of the formants of a tense vowel is always greater than that of the corresponding lax vowel. Tense vowels are usually considerably longer than the corresponding lax vowels (32).

2.432 Production. Tense phonemes are articulated with greater distinctness and pressure than the corresponding lax phonemes. The muscular strain affects the tongue, the walls of the vocal tract and the glottis. The higher tension is associated with a greater deformation of the entire vocal tract from its neutral position. This is in agreement with the fact that tense phonemes have a longer duration than their lax counterparts. The acoustic effects due to the greater and less rigidity of the walls remain open to question.

2.433 Perception. Rousselot's (26) and Fletcher's (14) tests have shown that ceteris paribus, tense phonemes possess a higher audibility than the corresponding lax phonemes. For English consonants, Fletcher (Table IX) gives the following data on the number of decibels by which single sounds must be attenuated in order to render them inaudible.

Tense:	k 83.8	t 84.1	p 80.6	s 82.4	f 83.6
Lax:	g 82.9	d 78.9	b 78.8	z 81.6	v 81.4

The importance of the difference in the duration for the distinction of tense and lax consonants is illustrated by the experiments of L. G. Jones: when the beginnings of [p], [t], [k] (originally produced by cutting the corresponding constrictives, cf. 2.3113) had been erased on tape recordings, they were apprehended by native English listeners as [b], [d], [g]. Slavic listeners, however, still heard [p], [t], [k], since not the tenseness but the voicing feature is relevant for them (see 2.434).

2.434 Occurrence. In many languages, e.g. Cantonese, the consonant phonemes display neither of the two oppositions, voiced vs. voiceless and lax vs. tense.

In a number of languages only one of these two oppositions is relevant. If the opposition of tense and lax consonants is the only distinctive one, then either none of them are voiced, as, for instance, in Danish, or voicing and voicelessness become concomitant factors of laxness and tenseness respectively, as in English or French. In such languages the tenseness feature is more constant than the redundant voicing feature. This hierarchy is illustrated, for instance, by the French pattern, where [ʒ], the voiced lax (lenis) consonant of such forms as tu la jettes, becomes a voiceless lax [ʒ] before the voiceless [t] in vous la jetez but is still distinguished from [ʃ], the voiceless tense (fortis), in vous l'achetez. In some of these languages the tense stops are aspirated either generally, or, as in English, the aspiration is confined to certain positions.

The inverse relation is observable, e.g. in Slavic languages, where the voicing feature is the relevant one, while the tenseness feature is only concomitant and optional to a certain degree.

Finally, there is a relatively limited number of languages where both of these oppositions are present in the phonemic pattern. In this case the autonomous opposition voiced vs. voiceless is ordinarily confined to the stops; the aspira-

tion is used to implement the opposition of tense and lax stops, and, for the most part, only the unvoiced stops are split into aspirated and non-aspirated; e.g. Suto (South Africa): /dula/ "sit" - /tula/ "crack" - /thula/ "to butt" (27). Seldom, especially in a few Indic languages, the voiced class, too, presents pairs of tense and lax stops (aspirated and unaspirated respectively). Conversely, in some languages of the Caucasus, which distinguish voiced, checked, lax and tense stops (e.g. in Lezgian and Ossete), the redundant feature of aspiration marks the lax stops in contradistinction to the tense.

The prevocalic or postvocalic aspiration /h/ is opposed to the even, unaspirated onset or decay of a vowel. The former is a tense glide (spiritus asper), and the latter, a lax glide (spiritus lenis), which properly speaking is a zero phoneme. This opposition (/h/ - /#/) occurs in English in initial prevocalic position:

hill:ill≃pill:bill; hue /hi'uu/: you / i'uu/≃tune / ti'uun/; dune / di'uun/. The lax counterpart of /h/ presents an optional variant: in cases of emphasis a glottal catch may be substituted for the even onset: an aim can appear in the form [ənʔ'eim] in order to be clearly distinguished from a name [ən'eim]. Ordinarily languages which possess an opposition of tense and lax consonants have an /h/ phoneme too.

An example of the opposition tense vs. lax in liquids is presented by the strongly rolled and flapped /r/ in Spanish: tense in perro "dog" - lax in pero "but".

The opposition of tense and lax vowels occurs in various regions of the world: sometimes it encompasses the entire vocalic pattern, but most often it affects only some of the vowel phonemes, as in Italian with its two pairs of tense and lax vowels, e.g. /tọrta/ "tart" -/torta/ "crooked" (fem.), /pesca/ "fishing" - /pesca/ "peach".

2.44 Supplementary Resonator: Nasal vs. Oral

2.441 Stimulus. The nasalization feature may pertain both to consonants and to vowels: English din - did, dim - dib, ding /diŋ/ - dig; French banc [bą̃] "bench" - bas[bạ] "low".

The spectrum of the nasal phonemes shows a higher formant density than that of the corresponding oral phonemes (see Fig. 11). According to M. Joos (28) between the first and the second vowel formants there appears in the nasal vowels an additional formant with concomitant weakening in the intensity of the former two. In vowels like /a/ with a high first formant the additional nasal formant appears below, rather than above, the lowest formant of the corresponding oral vowel.

The nasal consonants add to the corresponding oral stops (/m/ to /b/, /n/ to /d/, /ŋ/ to /g/, and /ɲ/ to /ʄ/) a nasal murmur throughout their closure period. In addition to several variable formants, this murmur possesses two constant and clear formants, one at about 200 cps. and the other at about 2500 cps.

The formants in the murmur part are relatively stable: in the spectrogram they appear as straight horizontal lines, and the transitions to and from the adjacent phoneme are usually quite abrupt.

The additional poles and zeros, due to nasalization, are a local distortion in the spectrum without any influence on the other resonance features. These fundamental features are determined solely by the original set of non-nasal poles which affect the entire spectrum.*

2.442 Production. The oral (or more exactly, the non-nasalized) phonemes are formed by the air stream which escapes from the larynx through the mouth cavity only. The nasal (or more exactly, nasalized) phonemes are, on the contrary, produced with a lowering of the soft palate, so that the air stream is bifurcated and the mouth resonator is supplemented by the nasal cavity.

2.443 Occurrence. The opposition oral vs. nasal is nearly universal in consonant patterns, with isolated exceptions such as Wichita (24). But a great number of languages have no distinction of nasal vs. oral vowels. The number of nasal phonemes in the vowel and consonant pattern is never higher, and usually lower, than the number of oral phonemes. Nasality can be combined with other resonance features, and with rare exceptions at least two nasal consonants are distinguished - the diffuse acute /n/ and the diffuse grave /m/. Frequently there is, in addition, one compact nasal; rarely, two: one acute /ɲ/ and the other grave /ŋ/. In respect to the voicing feature the nasal consonants behave like liquids; normally they are voiced and seldom partake of the opposition voiced vs. voiceless: cf. Kuanyama (SW Africa): /na/ "with" - /n̥a/ "quite" (27). Other consonantal source features are also very rare in nasals.

2.5 CONCLUSION

The inherent distinctive features which we detect in the languages of the world and which underlie their entire lexical and morphological stock amount to twelve binary oppositions: 1) vocalic/non-vocalic, 2) consonantal/non-consonantal, 3) interrupted/continuant, 4) checked/unchecked, 5) strident/mellow, 6) voiced/unvoiced, 7) compact/diffuse, 8) grave/acute, 9) flat/plain, 10) sharp/plain, 11) tense/lax, 12) nasal/oral.

No language contains all of these features. Their joint occurrence or incompatibility both within the same language and within the same phoneme is to a

* John Lotz has made the following suggestion: "There are vowels which are not nasal and there are vowels which are nasal and consequently show a consonantal disruption of the vocalic pattern. But the nasal quality is clearly superposed, since it can only function in addition to another quality. In general terms, if a feature is implied - and in the hierarchy secondary - we subtract it from the total wave and thus obtain the basic phenomenon."