ARTICLE V.

BRÜCKE'S PHYSIOLOGY OF SPEECH.

BY LEWIS R. PACKARD, PROFESSOR IN YALE COLLEGE.

DURING the last half-century the science of language has made most rapid and unexpected progress. It has, one may say, come into being within that time, and attained sufficient development to be marked off into departments, each of which covers more ground, and demands more labor for its mastery, than would before have been thought necessary for the whole field. One of these subdivisions is that which treats of the theory of the formation of the spoken sounds of language. To this but little attention has been given, until recently, in this country; and it is with a view to indicate the starting-point for it and make known more widely the method pursued by others in working out a theory, that we propose to give in the following pages some account of an excellent German work on the subject. The book, published in Vienna in 1856, is by Dr. Ernst Brücke, Professor of Physiology in the Hochschule of that city, and has the title, "Elements of the Physiology and Classification of the Sounds of Language." [1]

It was written, as the title page sets forth, for the use of students of language and teachers of the deaf and dumb; and one of its chief merits is, that it combines in such a high degree the theoretical and the practical; that, while it keeps in view the needs of a teacher of deaf mutes in describing by what position of the organs sounds are produced, it also pursues so exhaustive and scientific a method that its principles may be applied to the explanation of all possible sounds of known languages, with the single avowed exception of the so-called *clicks* of the languages of Southern Africa. To prove

[1] Grundzüge der Physiologie und Systematik der Sprachlaute für Linguisten und Taubstummenlehrer bearbeitet von Dr. Ernst Brücke, Professor, etc. Wien: 1856.

the presence of the practical element, I may quote one or two examples. Speaking of the difference between toneless and toned consonants (p. 8), he says, "Even the deaf mute understands it without difficulty, if he puts his finger on the larynx (the Adam's apple) of his teacher, and feels how it quivers, from the vibration within, when *v* is pronounced, but is not moved by uttering *f*." So again (p. 65): "The English *th* would serve as a Shibboleth for most Germans who have learned that language, but only because they have had unskilful teachers; not because they are naturally unable to utter the sound, for any one who has not lost his front teeth can with proper instruction learn to give it in a few minutes." No single quotation could serve as evidence that the author pursues a thoroughly scientific method throughout the book; it is only by studying the system that we can satisfy ourselves whether he has realized his own conception of the work before him, as expressed in the following words (p. 30): "In arranging the consonants, we must clearly understand that, as when treating of the vowels, our business is not to distribute into certain classes a heap of letters that we have learned from others, but to classify, on an exhaustive plan, all the possible methods of uttering a consonant. If to-morrow a new language should be discovered, whose sounds, like those of the Indo-European and Semitic languages, were produced only by the *expulsion* of breath, our system must have places ready for them all, so that we should not be obliged to form any new classes, or to give up our old ones."

The book consists, as its title indicates, of two parts; one treating of the physiology, the other of the classification of sounds. The second part is altogether historical and critical; for of course the author's own classification, with the reasons for it, has been already given in the first part. And it is of this first part, treating of the sounds of language from a physical point of view, that we propose to give an account. After a brief historical sketch of previous works on the subject, it proceeds to discuss in order the larynx and its sounds, the vowel sounds, including diphthongs, the simple consonants, the compounded consonants, and the softened (*mouillé*) consonants. We shall follow the same order.

The author's description of the chief organ of the human voice is admirably simple and clear, as we see especially by comparing it with one made so unintelligible by technical terms as that prefixed to Soule and Wheeler's "Manual of English Pronunciation and Spelling" (Boston, 1861), or with one so confused and ill-proportioned in its parts as that in Max Müller's third lecture (Lectures on the Science of Language, Second Series: New York, 1865). It consists, says he, of two highly elastic bands, which stretch across the larynx from front to back, and project like ledges from the sides towards the centre, being protected a little way above by the heart-shaped[1] cartilage called the epiglottis. They are made to vibrate by the air driven out of the lungs, and by this vibration produce the tone or sound heard in the vowels and toned consonants. In other words, they restrict periodically the passage of the air, being pressed up and asunder by it, and then coming together again, and thus produce the rhythmic pulsations of air which cause to our ears the sensation of sound. This vibration and consequent sound occurs, however, only when the edges of the vocal chords are, by the action of the muscles of the larynx, so brought together that the space between them is quite narrow. They can also, by the action of the same muscles, have their free edges so separated that the space between them is comparatively broad, and then the air comes noiselessly through the larynx, and becomes audible only by rustling against the sides of the cavity of the jaws. This rustling the Greeks indicate by the rough breathing, we by the consonant *h*. As, however, this so-called consonant is not produced under any of the conditions which attend the production of the consonants as a class, it is to be excluded from their number in systematic discussion and classification. In this

[1] Max Müller (p. 123 f.) calls it, less precisely, "leaf-shaped," and writing for an English audience, says it "falls over the larynx, like a saddle on the back of a horse."

place, therefore, the author discusses briefly the difference between the *spiritus asper* and *spiritus lenis* of the Greeks, the *Ha* or *Hha* and the *Ain* of the Arabic, and treats also, in passing, the guttural *R* of the dialect of Lower Saxony. The first two seem to differ, as the sonant *h* and silent *h* of the English, in the greater or less degree of power with which the breath is forced out of the lungs. It is not worth while in this sketch to linger upon these subordinate and somewhat obscure points.

There is yet another phenomenon of speaking to be mentioned by itself before we take up the main subject, and that is whispering. It is described (p. 8) as produced when the vocal chords are brought so near together as to check somewhat the passage of the air between them, yet not so near and in such tension as to vibrate enough to cause sound. What is then produced is not actual sound, but mere rustle of the air; yet the rustling is not now, as it is in the case of the *h*, against the inner sides of the mouth, but also against the sides of the larynx and the vocal chords. The degree of tension, however, of the chords is variable; for in whispering, as well as in speaking, there is a perceptible difference between *b* and *p*, *d* and *t*, etc.; that is, between the toned and toneless consonants. A little further on (p. 16), Brücke says that the difference between speaking aloud and whispering is, that in the first the vocal chords vibrate regularly in equal times, in the other, irregularly; and the same statement is made by Max Müller (p. 129). By bringing these two statements together, it would appear that regularity of vibration varies as the tension of the chords, — the more tense the chords, or the nearer together, the more regular the vibration, — and that at a certain point in their relaxation or separation the vibration becomes so irregular that voice passes into whisper.

We come now to the proper *sounds* of language, and first, the simple vowel sounds.

There are in every simple vowel sound or musical note three distinct parts, as Max Müller (p. 113) puts it, to be noticed and explained:

1. Strength or loudness.

2. Height or pitch.

3. Quality (in French, *timbre;* in German, *tonfarbe*), which, in vowels, means the perceptible difference by which we know *a* or *o* from *i*, *e*, or *u*.

The first of these, it is agreed, "depends upon the amplitude of the excursions of the vibrating particles of air" (Max Müller); that is, if a cord vibrates, upon the space it passes over (with a given length of the cord).

Brücke gives an interesting account of the various experiments by which the different causes of the other two qualities of sound have been ascertained. The experiment most worthy of mention here is that of an Englishman, Robert Willis, in 1828, who was the first to come near to the solution since established. He placed a piece of watch-spring in contact with a toothed wheel, so that it was made to vibrate by the teeth of the wheel as it revolved, and then found that the pitch varied with the rapidity of revolution, while the quality of the sound was changed by lengthening or shortening the vibrating part of the spring. This led him to distinguish between the primary and secondary vibrations of the spring, or impulses given by it to the air. Each time the spring left one of the teeth it gave the air an impulse, which was transmitted to the ear. These he called the *primary* impulses, and he noticed that the pitch of the sound produced depended on the rapidity with which they succeeded one another; that is, on the rapidity of the revolution of the wheel. But in trying to come to rest between two successive teeth, the spring would vibrate about its centre of equilibrium, and in so doing give rise to a new series of impulses of the air, which Willis called *secondary*. These followed each other more or less quickly, and so varied the quality of the sound, according as the free part of the spring was shorter or longer. It would be natural to infer that the primary impulses might follow one another so rapidly that there would not be time enough between any two for the secondary impulses of slower rates; in other words, that certain *qualities* of sound would become impossible as the *pitch* was raised above a certain height, and this is known to be the fact with the human voice. It is possible to sing *e* and *i*[1] on notes that are too high for *o* and *u*.

But how does this experiment apply to the human voice? We have in our throats, it is true, no toothed wheel or watch-spring; but we produce in a different way the same vibrations of air, and it seemed worth while to give this experiment in such detail because it is so simple and intelligible in itself, and because its results apply to what takes place in the production of vocal sound. We produce in our throats the primary and secondary pulsations of air; but here the primary are dependent directly on the vibrations of the vocal chords, and the secondary on the length of the column of air between them and the lips. This seemed to be proved by the fact that the same vowel sounds could be produced in an artificial tube with a metallic tongue[2] freely playing in it, and by observation of the effect of varying the length of the tube and the shape of its mouth. It is seen with such an instrument that the pitch of the tone depends on the vibrations of the metallic tongue, which give rise to the primary pulsations of air; while the quality of the tone is altered by lengthening or shortening the tube, or by varying the size of its mouth; that is, by varying the rapidity of the secondary pulsations. Thus Willis found that such a tube, with a wooden funnel for a mouth, could be made to produce in succession the vowels *i*, *e*, *a*, *o*, *u*, by gradually narrowing the opening by a board laid across it. The vowels of the human voice are more perfect than any thus artificially produced, partly because the single parts of the organ are better adapted to their work and the bones in proximity to them aid in the vibration (as may be easily seen in pronouncing *i* distinctly and loudly), and partly because both the ways of varying the quality of tone, — change in the

[1] The vowels are to be pronounced throughout as in Italian.

[2] It should be observed that this metallic tongue corresponds, not to the human tongue, but to the vocal chords, whose vibration it is intended to imitate.

length of the tube and in the size of its opening, — are employed in the human voice, as Brücke proceeds, after this prefatory account of experiments, to show. He takes up the vowels one by one, and analyzes the position of the organs in producing them.

U. In uttering this vowel the tube is lengthened as much as possible, by depressing the larynx and pushing forward the lips, so that the one is at its greatest distance from the other. At the same time the opening at the end is narrowed by bringing the lips together.

If the lips are not thus projected and brought together, it is indeed possible to utter an *u*, but then it will be noticed (by placing the finger on the Adam's apple) that the larynx is lowered more than in the other case, in the effort to supply the needed length to the tube; and besides, the *u* thus produced is by no means so full and perfect as the other. If the lips are opened wide, it is impossible to utter this vowel; for it is impossible to sink the larynx so low that the length of the tube shall compensate for the want of a narrow opening.

I. In producing *i* the tube is at its shortest, for the larynx is raised as high as possible, and at the same time the wide opening of the lips draws them back so that their distance from it is diminished. It is noticed, also, that the tongue rises close against the roof of the mouth, and leaves only a narrow channel in the middle for the air; but what effect this narrowing of the tube has upon the waves of air in it, Brücke confesses himself unable to say. He points out, however, that it may be the cause of that vibration of the bones of the skull mentioned above, which is noticed as occurring more strongly when *i* is fully uttered than with any other vowel.

When the lips are projected or the larynx depressed, as in pronouncing *u*, it is impossible to utter a clear, perfect *i*. If it is attempted, in the former case the German *ü* is produced, in the latter, an imperfect *i*.

A. This vowel stands between the two which have been described. In uttering it the vocal tube is, we might say, in its most natural position, and so shorter than for *u*, and longer than for *i*; since the lips are not projected, nor is the larynx depressed, while yet on the other hand, the lips are not retracted by wide opening of the mouth, nor is the larynx raised as in uttering *i*. It may be remarked, also, that the vocal tube is for this vowel open in its whole extent, and not closed in the middle as it is for *i*, nor at the end as for *u*.

These three are the cardinal vowels of the whole system. To this view of them we are thus led not less by the indications of physiology than by the historical development of the Indo-European and Semitic languages. The remaining vowels are but intermediate sounds, produced on the way from one to another of these; and hence we find, in treating them, that we have left the firm ground we have thus far trodden, and are stepping where the dividing lines are less distinct. Here is more room for variety of names and sounds. The two extremes and the one mean of the series have been discussed. The other vowels are the intermediate terms whose number, as well as the position and description of each, will vary as the powers and practice of different observers differ.

In passing from the position for *a* to that for *i* the intermediate sounds are produced by a gradual shortening of the vocal tube and narrowing of it in the middle. In going in the opposite direction, from *a* to *u*, they are produced by a gradual lengthening of it and narrowing of the mouth-opening. Now, to the question how many vowels are to be located between these extremes, the answer is given, so many as an ordinary ear, without special training, will notice as distinct sounds. A language is established by the speaking and hearing of the multitude, and has its sounds determined by the average ear and tongue, not by the trained organs of a critical student. On this principle Brücke marks off only three vowels between *i* and *a*, and three between *a* and *u*. The vowels are in their order from *i* at one extreme through *a* to *u* at the other, *i*, *e*, e^a, a^e, *a*, a^o, o^a, *o*, *u*.[1] We give the list and descriptions *verbatim*.

1. "The *i* of German and Italian, the *ee* of English, e.g. Germ. *wider*, Ital. *giro*, Eng. *wheel;* I denote it by *i*.

2. "The French *é*. It is the high *é* in the Hungarian word *szép* (pulcher), and in the New Slavonic *bêl* (albus). In German we have it long in *ewig*, *selig*, short in *werden*.

3. "The French *è*, or the German *e* in *Hehl*, *ehrlich*, *echt*, etc., which I denote by e^a.[2]

4. "The French *ê* or the German *ä*; in my notation a^e. English, *man*, *fat*,[3] Hungarian, *fekete* (niger).

5. "The pure or Italian *a* in *ballare*, *cantare*, etc.

6. "The deep *a* of German in *Wahl*, *Arm*, etc., which is also often heard in Hungarian, e.g. *bál* (miser), and which I will denote by a^o.

7. "The sound intermediate between *a* and *o*, which is heard in the English words *lord*, *scorn*, and in the French *encore*; in my notation o^a.

8. "The pure *o* as we utter it in *Oper*, *Woge*, etc., and in the Latin words *bonus*, *nomen*, etc. Its short sound is heard in the German *Ordnung*, and the Latin *orbis*, as at present pronounced. I denote it by *o*.

9. "The German *u* in *Muth*, *Duldung*, the French *ou;* in my notation *u*."

Besides this list, there is a number of other vowel sounds in frequent use, which Brücke describes as formed in the positions which the mouth assumes in passing from one

[1] Brücke's system of signs for vowel sounds is in form borrowed from algebraic notation, but in principle an imitation of the terms, such as north by west and west by north, of the mariner's compass.

[2] It will be difficult, we think, for an American tongue to make, or ear to detect, the difference between the *e* of *ewig* and that of *Hehl*. The sounds between *i* and *a* seem to be less sharply defined, and hence admit more variety of opinion, than those from *a* to *u;* perhaps the distance is less, while the number of stages is made the same.

[3] This seems a surprizing mistake. The peculiar short *a* in *man* or the different one in *fat*, is very unlike the French *ê*, or the German *ä*. The English *main*, *fate*, would have been more correct.

of these extremes to the other without going through the mean, a. His diagram makes it plain; i and u being the extremes, the list just given goes up one side of the triangle, through a, and down the other side to u. But we may go right across from i to u, or from e to o, or from e^a to o^a, and produce a new set of vowels.

$$\begin{matrix} & & & a & & & \\ & & a^e & & a^o & & \\ & e^a & & a^{oe} & & o^a & \\ e & & e^o & & o^e & & o \\ i & i^u & & & & u^i & u \end{matrix}$$

"The i^u is the y (Ypsilon) of the North German pronunciation, e.g. in *Myrte, Physik;* the u^i is the *ü* of the literary German in *Würde, über*, etc., the French *u*." "The o^e is the German *ö* in *Oel* and *hölzern*, while e^o is a sound somewhat rare in German, but perceptible generally in those words whose orthography wavers between *e* and *ö*, e.g. *zwölf* (low German *twelw*)." The a^{oe} he describes as the vowel sound heard in the French words *veuve* and *soeur*.

Thus far we have spoken only of perfectly formed vowels, in which, the various parts of the organs of speech were in full and perfect action to make the sound distinct and full-toned. But very often, perhaps in the majority of cases, this does not take place, and then we have imperfectly formed vowels. This fact has been noticed before in speaking of *u* and *i*. One may go through all the vowels in this way, giving them an indistinct utterance and varying the shape of the mouth and the length of the vocal tube but little, if at all, in changing from one to another. The vowels thus produced are hard to distinguish apart, and are often confused.[1]

There is one simple vowel sound still remaining to be mentioned here. It is that which Lepsius (quoted by Brücke,

[1] Brücke gives several examples of these indistinct vowels from the English language, where he says they abound, which seem to contain some errors. For the indistinct *o* he gives *not, hot, cough,* for the indistinct *i, pin.* Of these, *cough* has evidently not the same *o* sound with that of *not* and *hot,* but rather what he denotes by o^a, as in *scorn.* Then too, *not, hot,* and *pin* do not seem to belong here at all. They have not indistinct vowels, but the regular short sounds of their respective vowels. We have in English a series of short vowels quite distinct from one another, and distinct, in quality and quantity, both from the long vowels, as in *hat, bet, pin, not, but.* Both these and the corresponding long vowels may be, and often are, incompletely and indistinctly uttered; tending in that direction whenever unemphasized.

p. 24) calls the undefined vowel, Max Müller (p. 134) the neutral vowel. These names seem to be used to denote a short vowel sound which cannot well be assigned, by reason of its indistinctness, to any of the principal vowels, yet is itself one of the commonest sounds, at least in English. Max Müller gives as examples of it, *but*, *dust*, *spurt*, *assert*, *bird*, *ăgainst*, *finăl*, *principăl*, *ideă*, *captaĭn*, *villăge*; and says that all unaccented syllables in English have a tendency towards it. Brücke is more cautious, saying that in most of the examples of it commonly given, the vowel is really a short e^o, or an imperfectly formed o^e, o^a, or a^{oe}. Another remark of his applies to such cases as *finăl*, *principăl*, *captaĭn*, given above, and to *mutton*, *wooden*, etc., that often in pronouncing them there is in fact no vowel sounded between the two consonants of the final syllable. Where *d* or *t* precedes the vowel, the tongue often does not leave its position against the roof of the mouth before the *n* is heard, and no vowel can be uttered while the tongue is in that position; and there is a similar reason for not sounding *a* in the quick utterance of *principal* and *final*. Brücke agrees with Max Müller in saying that the occasions of indistinctness in a vowel sound are shortness and want of accent.

This leads him to a consideration of the question whether long and short vowels differ in quantity (or length) only, or in quality also. He starts with a quotation from Rudolph Von Raumer, who proves by German examples that there is a perceptible difference in quality between, for instance, long *i* as in *Bienen*, and short *i* as in *binden*. Brücke's discussion is too incomplete to be worth giving in full. His conclusions are:

1. That a vowel commonly long may be indefinitely shortened, or one commonly short lengthened, without letting either pass into the other; and that, therefore, it is wrong to regard the two classes, the long and the short vowels, as always differing each from each in *quantity*.

2. That of the German vowels, *o*, *u*, *ö*, and *i* are often in common conversation imperfectly enunciated when short;

but this sound of them is never prolonged; when lengthened they are the same in quality with the usual long *o*, *u*, *ö*, and *i*. On the other hand, *e*, *ä*, and *a* are always sounded alike, whether long or short.

3. That it is not worth while to try to distinguish by special letters the long from the short vowels. The letter should denote as exactly as may be the *quality* of the vowel, and the incidental matter of *quantity* be indicated by some added sign.

On the whole, then, his answer to the question would be, that there exists a difference in quality between the long and short vowels, but it is confined in German to the vowels *o*, *u*, *ö*, and *i*. We have expressed (in note on p. 266) the opinion that in English this difference extends to all the five common vowels.

Brücke's treatment of the diphthongs, which follows next, is to us one of the most unsatisfactory parts of the work. It consists entirely of a description of the way of producing a diphthong, and a criticism of the German characters for two of them. Max Müller is hardly more full, but then his plan allows little space for details, and he has used that little on less important topics. There are several points about the diphthongs which we should be glad to have treated more fully by the careful observations of Brücke and with the abundant illustrations of Max Müller. They deserve to be classified and arranged, if possible, in one scheme with the simple vowels. The preferences of different languages and the historical development of new combinations would be worth studying. The written signs, especially in German, demand explanation, as some of them represent sounds very different from those produced in passing from one to the other of their elements.

It remains only to speak of the nasal tone, which may be given to all vowels and diphthongs by opening the passage between the throat and the nose, and so letting the air vibrate through the hollow of the nose as well as that of the mouth. It is proved by a simple experiment that in pronouncing a vowel without this nasal tone, the air issues from the mouth only. If a flame is held so as to be reached by any air coming from the nose, but by none from the mouth, it does not flicker so long as the simple vowel is uttered, but does as soon as the nasal tone is given to the vowel. It is proved also, by holding the nose tightly and still uttering vowels with the nasal tone, that the tone is not produced only by the passage of air through the nose, but also by its vibration within the nasal cavity. Nasal vowels abound in French, but do not occur at all in German, and scarcely at all in English. It is noticed that in all known languages only four vowels *a*, *ä*, *ö*, and *o*, with perhaps *i* in Portuguese, ever have this nasal sound.

We have thus gone through Brücke's discussion of the vowel sounds; designing neither to adopt with implicit faith, nor to criticize, all he says, but simply to reproduce the main points of his system, with here and there a remark. We shall find the description of the consonants somewhat more systematic and interesting.

We come first upon a subject of various opinion, — the nature of the difference and the reasonableness of the distinction between vowels and consonants. The difference implied in the name *consonant*, that the vowels only are capable of being sounded alone, has been long since, Brücke says, proved not to exist, though it is still often enough taught as the real one. The use of it for the practical purpose of teaching may still be plausibly defended, even by those who would acknowledge that it was quite unscientific, because untrue. What then is the real difference between the two classes of sounds? A vowel is a sound in the production of which the channel from the vocal chords to the lips is open through its whole length; but in the production of a consonant "there is in the mouth-channel either a closing at some point, or at least a narrowing, which causes a perceptible noise, independent of any vocal tone." The locality of this closing is an essential element in the classification of consonants which Brücke proceeds to make. But it may be asked, is there any reason for this old-time distinction of sounds into these two classes—vowels and consonants? This question is answered in the negative by Professor W. D. Whitney,[1] who urges that all the sounds of language should constitute but one class, being arranged in it according to the degree of closure of the mouth-channel, beginning with the most open vowel and ending with the closest consonants. We can only say here that Brücke's view is an approximation to this, in so far as he makes the openness or closeness of the mouth-channel the only point of difference between the two classes.

There are now four different ways in which the passage of air through the channel of the mouth may be checked, more or less completely; and this causes a division of the sounds produced into four classes.

1. The passage of air through the nose is shut off, and also through the mouth, so that it is entirely checked. Thus the breath is dammed up, as it were, and when the check is removed, issues with a sudden explosion, whence the sounds thus produced are sometimes called explosives. By Brücke and others they are called check sounds (Verschlusslaute). These are the mutes.

2. The passage of air through the nose is shut off, and the channel of the mouth is so narrowed in one part or another as to allow the air to pass only with a sort of rustling or rubbing noise. Sounds thus produced are called by Brücke rubbing or friction sounds (Reibungsgeräusche), and are such as *f*, *s*, *z*, the German *ch*, and *j*. They are sometimes divided up under the names aspirates, sibilants, and semi-vowels.

With these he classes the *l* sounds, because they are produced similarly by a rustling or rubbing of the air against inner parts of the mouth, though in them it passes along the sides of the tongue instead of along the middle.

[1] In a paper "On the Definition and Relations of Vowels and Consonants," read before the American Oriental Society in May, 1865, and to be published in the Society's Journal.

3. The passage of air through the nose is shut off, while in the mouth some part is so placed as to be set in vibration by the issuing stream of air. Thus are produced the vibration sounds (Zitterlaute), of which *r* is the principal one.

4. The passage of air through the mouth is shut off, while that through the nose is open. Thus are produced what are called by Brücke resonants (Resonanten), and by others either nasals or semivowels. They have this in common with vowels, that they are produced by the sound of the voice proper, and not, as other consonants, by some noise independent of the vocal chords; but they differ from vowels in that the mouth-channel is closed in producing them, so that they cannot be used in connection with consonants as vowels are.

In one of these four ways every simple consonant (except of course the larynx sounds, *h* and the similar ones of other languages, which were spoken of at the outset) is produced; either by a check, a friction, a vibration, or a nasal resonance. But there is another principle of classification to be combined with this; viz. according to the part of the mouth in which the narrowing or entire closing takes place. It may be at the lips, the under lip meeting the teeth or upper lip; or at the front part of the tongue; or at the middle or back part of the tongue, when it rises to meet the upper parts of the mouth. Thus we have three places, in any one of which sounds may be produced in any one of the four ways above mentioned. These three classes, with four subdivisions in each, give twelve theoretical forms of consonant sound. But this must be multiplied by two, for in each form there may be a sonant or a surd letter produced; each form may be uttered with or without the accompaniment of sound from the vocal chords: except that the resonants, as their name implies, can be only resoundings of vocalized or sonant breath in the channel of the nose. This distinction into sonant and surd, which is more familiar under the names soft and hard, middle and smooth, must play a prominent part in any scientific analysis of consonant sound. Brücke discusses it at some length a little further on (pp. 55ff), and proves conclusively that the only difference between *b* and *p*, *d* and *t*, *z* and *s*, *v* and *f*, etc., is, that during the closing of the organs to produce the former letter of each couplet, the vocal chords are brought together so as to produce sound by their vibration as soon as the check is removed, or sometimes while it lasts; whereas in producing the second letter of each couplet they are not so brought together. The statement receives a curious confirmation from the fact that in modern Greek, since β and δ have the sounds of *v* and *th sonant*, the sounds of *b* and *d* are represented by μπ and ντ. Here μ and ν are added to give sound to π and τ; in other words, to represent the sonants corresponding to *p* and *t*.[1] It is, then, neither the greater force with which the air is expelled that distinguishes *p* from *b*, etc., as some have said, nor, as others, the tighter closing of the mouth-channel. The first is refuted by the example of the two English words *midshipman* and *clubman*, where the following *m* prevents any explosion of air at all in uttering *p* and *b*, yet without the explosion there is no difficulty in distinguishing one letter from the other. The second explanation is refuted by the showing of experiment, that, however tightly any part of the mouth-channel be closed, if the vocal chords are in motion only a sonant letter can be produced; and, however slightly it be narrowed, only a surd issues if the vocal chords are apart and motionless. These two alleged differences do indeed generally occur in pronouncing sonant and surd letters, but they are only incidental, naturally resulting from that which is the essential difference, viz. whether the stream of air in the throat is or is not obstructed by the vocal chords. If it is obstructed (that is, if the letter is a sonant), it is natural that the hinderance in the mouth-channel need not be so firm and tight, and that the explosion, when it comes, will be less violent than if the air rushes unchecked from the compressed lungs.

We proceed now to the description of the method of utter-

[1] For a somewhat parallel case, see note on p. 283 below.

ing the consonants, taking them up in three classes according to the place of articulation, that is, the place in the channel of the mouth where the obstruction or narrowing occurs; finding also in each class four subdivisions, according to the precise form of obstruction employed, and in each form, except the fourth, a surd and a sonant letter.

I. The first class includes those consonants whose place of articulation is at the extreme front of the mouth. The obstruction to the free passage of air is caused by bringing together the lips, or touching the upper teeth with the lower lip. Under this class we have as the first subdivision:

1. The check sounds. In producing *p*, the lips are closed and the passage of air through the nose also is cut off; then the breath, being pressed from the lungs into the mouth, issues by a sudden opening of the lips with explosive force. But the explosion does not occur when an *m* follows, as in *midshipman*, and in that case the *p* is produced by suddenly checking with the lips the stream of breath which pours forth in uttering *i*. Thus the letter *p* strictly denotes only the state of rest of the organs, when lips and nose-channel are both closed against the issuing air.

If now this air is vocalized by contracting the vocal chords so that they vibrate, and continue so through a part of the time of holding the lips shut, a *b* instead of a *p* is produced. It can be but for a moment that the breath is vocalized when the lips are shut thus, since it is done by forcing it over the vocal chords into the *cul-de-sac* of the mouth, which is soon full.

2. The friction sounds. It is clear that in pronouncing *f* the upper teeth are lightly pressed upon the lower lip, and the air rushes out between them. A sort of *f* can be produced without the teeth, by bringing the lips together so that the air in passing out between them makes a rustling noise, like that in the other case. This letter is the pronunciation given by some to the German *v*, though commonly no difference is made between it and *f*. This second *f* differs from *p* only in the less completeness of the closing of the lips. So also,

Brücke says, it is possible to produce with the under lip and upper teeth a sort of *p* sound,[1] from which the former or common *f* shall differ in the same way and degree. If now the common *p* is denoted in a systematic notation by p^1, and this second kind of *p* by p^2, then the *f* sounds would be correspondingly denoted by f^1 and f^2, the latter being the common *f*.

When the mouth is in the position for uttering *f*, it is only necessary to vocalize the breath in order to change the *f* into *v*, the German *w*, so that *v* is the sonant corresponding to the surd *f*, just as *b* corresponds to *p*. As there are two *f* sounds, f^1 and f^2, so are there also two *v* sounds, though in English we have only v^2, our common *v*. In German we find both v^2 (w^2 in a German system), as at the beginning of words, *wo*, *wann*, and v^1 (w^1) in the combination *qu*, as in *Quelle*, *quälen*.[2] Brücke makes the suggestion in passing, that in German *kw* should be written instead of *qu*, and that the letter *w* should be confined to the sound v^1, and *v* used for v^2. In fact, as he remarks, the German language has now two signs for the f^1 sound, *f* and *v*, and only one (besides *u* in *qu*), *w*, for v^1 and v^2.

3. The vibration sound produced by the lips in the position for p^1 does not occur in any language (unless in one obscure exception, p. 35) as an element of words, but only as an interjection of loathing; hence we pass it over. Brücke brings it into his system of notation, using the Greek ϕ for the toneless, and κ for the toned utterance.

4. When we put the lips in position for p^1, and let the breath vibrate the vocal chords and then pass out through the nose, we produce *m*, the resonant of this first class. There

[1] To utter an initial *p* in this way (the final *p* is easier) it seems necessary to place the upper teeth far down over the under lip, in order to make the check complete. Perhaps a very close and even set of upper teeth would make this unnecessary.

[2] We presume that Brücke here means, though his language seems to imply the opposite, to include in v^1 the sound of the German *w* after a consonant, as in *schwimmen*, *zwei*.

is, of course, no *surd* corresponding to this resonant letter, nor is there any m^2 in use.

II. In coming to the second class of sounds we leave the lips, and have to do with the tip or front part of the tongue when pressed against some inner part of the mouth.

1. The check sounds. There are four different ways of producing a *t* sound, which Brücke describes in the following order:

t^1 is produced by laying the sides of the tongue against the upper teeth, so that its tip touches the inner gum just above the upper front teeth. This closes the mouth-channel, and the passage through the nose being also closed, the air is checked as completely as in the case of *p*. This is the common, or, as Brücke calls it, the alveolar *t*.

t^2 is the cerebral or cacuminal *t* of Sanskrit. The tip of the tongue is turned up and back, so as to touch the roof of the mouth, and to give the under side of the tongue a convex curve towards the front.

t^3 is called by Brücke the dorsal *t*. In it the upper surface of the tongue has the convex curve towards the front, touching the forward part of the palate, while the tip is bent down and touches the lower front teeth. This kind of *t*, he says, is formed by many Germans in uttering *st* and *ts*.

t^4 is called the dental *t*, because in it the check of the breath is effected by the tongue with the teeth alone, without the help of the palate. It is produced by holding the teeth a little apart and stopping up the opening with the tongue. Our author remarks that it need hardly be distinguished from t^1, except for the peculiarity of the friction sound that corresponds to it.

To these four kinds of *t* sound correspond four sonants, d^1, d^2, d^3, d^4, the only difference being that in the latter the breath produces sound as it passes over the contracted vocal chords.

2. There are also four friction sounds corresponding to these four check sounds, and developed from them just as *f* and *v* were from *p* and *b*, by letting the check to the passage

of air be incomplete, leaving a small space through which it may rustle out.

From t^1 we have in this way s^1, which may be called the common *s*, though not so in German; from t^2 an s^2, which would correspond in use to the other cerebral letters, though, as Brücke states, the Sanskrit cerebral letter *ṣ* represents the sound *sh*, German *sch;* from t^3 an s^3, which Brücke says appears in the German words *heisz*, *liesz*, *dasz*, *das*, etc., and in the sharp, hissing *s* of the English.

From t^4 we have s^4, which is the ϑ of modern Greek, the Spanish *c* before *e* and *i*, and the surd *th* of English. The peculiarity of this s^4 was the reason for distinguishing t^4 above from the other forms of *t*. The position of the tongue may vary within certain limits; it is essential only that it should come close to the upper teeth so as to leave a narrow space behind them, through which the air passes to the teeth, producing the characteristic sound of the s^4 by striking upon them. It is easy to see from this position of the tongue how natural it is that the Greek ϑ appears as *f* in Russian.[1] The edge of the upper teeth lies midway between the lower lip and the tip of the tongue, and if the former instead of the latter is pressed upon it, *f* is produced.

The sonant series corresponding to these four surds Brücke denotes by z^1, z^2, z^3, z^4, and they are produced just as the surds are, with the addition of sound from the vibration of the vocal chords. Of these, z^3 is the common *z* of the English, and appears in German as initial *s* before a vowel, e.g. in *Sohn*, *singen*, while z^4 is the English sonant *th*, as in *other*, *with*, the δ of modern Greek, a sound which does not appear in German.

L sounds. Another series of friction sounds can be developed from the four forms of *t*, when, having the check for *t* perfectly formed in the front part of the mouth, one opens a passage for the air on each side of the tongue, between it

[1] So too in Latin *f* is sometimes the etymological representative of the Greek ϑ, as in ϑήρ, *fera*; ϑύρα, *foris*. Do not these facts support the view that the ancient sound of the ϑ was that of s^4?

and the upper back teeth. In this way an *l* is produced. The surds Brücke denotes by $\lambda^1, \lambda^2, \lambda^3, \lambda^4$, and the sonants by l^1, l^2, l^3, l^4, the figures having the same meaning as before. He remarks that the existence of these surds in German was pointed out by Joh. Müller, and that Purkinje asserts that they occur in Polish. Of the sonants, l^1 is the common *l* of German, and apparently also of English; l^2 is thought to be the peculiar *l* sound of the Vedic Sanskrit; and l^4 is produced by one who lisps (l^3 occurring in a combination to be described hereafter). Into his discussion of the different sounds of *l* in Polish we cannot follow our author.

3. Vibration sound. This is the common *r* sound, which Brücke denotes by *r* for the sonant and ψ for the surd. The tongue lies as it were in equilibrium, with its tip just behind the upper front teeth, neither touching them as in t^1, nor forming a narrow channel behind them as in s^1, but lying free, so that it is easily pressed down by the breath issuing from the lungs, and recovers itself only to be again depressed, and thus vibrates up and down.[1]

4. Resonants. If we place the organs of speech for d^1, d^2, d^3, d^4, successively, and then open a passage through the nose for the intoned breath, we produce n^1, n^2, n^3, n^4, which are thus related to *d* in its various forms as *m* is to *b*. The n^1 is the common *n* of the languages of Western Europe.

III. Sounds of this class have their place of articulation, that is, the place where the stream of air is stopped or narrowed to produce them, at the middle or back part of the tongue.

1. In order to teach deaf-mutes to utter a *k* sound, Brücke says the method is to make them utter a *t*, which is apparently an easy letter to learn by imitation, and then to press the front part of the tongue down with the finger or a spatula. In this way they are compelled to check the stream of air with the *back* part of the tongue against the palate, and in this position only a *k* can be uttered. If one pro-

[1] This vibration cannot be detected in the ordinary English *r*. As we commonly utter it, it seems to be not a vibrating, but a friction sound.

duces a dorsal *t*, t^3, and then moves the point of contact of tongue and palate backwards, he will find that, after passing a certain line, he cannot help uttering *k*. In general, the place of articulation of *k* begins where that of *t* ends. The essential difference between the two letters seems to consist in the size of the space in the throat behind the point of contact, it being larger for *t* than for *k*. There seems to be also an effort in the contraction of the soft palate, of which one is conscious just before the explosion of a *k*, to diminish that space still more than is done by drawing back the tongue.

There are two kinds of *k*, one uttered by contact of the tongue with the hard palate, the other with the soft palate. The line of division between these two palates is easily felt by running the forefinger back along the roof of the mouth. The tip will reach the soft palate just about as the third joint is entering the mouth. These two kinds of *k* are denoted by k^1, that on the hard, and k^2, that on the soft palate. There may be, of each of these, several subdivisions, according as the point of contact is farther forward or back in the peculiar region of each, but they are not thought to deserve special notation. Such a *k* sound as the Italian *ch* in *chiesa* is the farthest forward of all; back of it stands the German *ck* in *wickeln*, and at the inner limit of the region of k^1 the Caf of Arabic. At the front limit of k^2, and so at the line of division between the hard and soft palates, as may be proved by inserting the finger at the moment of uttering it, lies the *k* of the German words *Stock*, *Ruck*, etc.; and at the back limit of k^2, that is, at the inmost point of all the check sounds, lies the Kaf of Arabic.[1] In uttering this sound the passage of air through the nose is cut off by the meeting of the soft palate with the posterior half-arches of the palate, while the back part of the tongue rises to touch the soft palate, and so checks the air passing out through the mouth. It is impossible to utter any check sound, with a smaller space behind the place of the check than in this, because it is impossible

[1] We may illustrate these several kinds of *k* by the English words *speak*, *quick*, *back*, *dock*, *duck*: the last (Kaf) not occurring in English.

to close perfectly the channels of both nose and mouth at once if the check in the mouth is any further back, between the base of the tongue, for instance, and the uvula. But there is a friction sound, and perhaps a resonant, which closes the mouth-channel in its utterance at a point behind that of Kaf.

G corresponds to *k*, just as *b* to *p* and *d* to *t*, and has the same range and variety of articulation. It is not necessary to employ special notation for the different varieties of k^1 and k^2, g^1 and g^2, or even different signs in common language for these main divisions. For their use depends on a principle easily understood and remembered. Putting the vowels in the following order, *i*, *e*, *a*, *o*, *u*,[1] the kinds of *y* or *g* to be used with them would form a similar series from the one farthest forward to the one farthest back in the mouth. When one utters, or prepares to utter, *i* or *e*, the middle part of the tongue need move but a short distance to reach the hard palate and produce k^1 or g^1; in *a*, *o*, and *u*, it is the back part of the tongue and the soft palate, the parts whose contact produces k^2 or g^2, that are nearest together.

Brücke treats in this connection of a matter interesting to the student of German, the sound in that language of final sonants, namely *b*, *d*, and *g*, after resonants. The usage is quite variable, but the tendency appears to be to make all final sonants surd. This is the established rule for *d* after *n*, and for final *b*. The general reason seems to be the difficulty of uttering the final sonant. It is easy to see that after a resonant it requires a marked effort to force the breath over the vocal chords with motion enough to produce sound into the mouth, closed and already partly filled with air.[2] In English *b* and *d* are fully preserved after a resonant,[3]

[1] The order inversely as the length of the mouth-channel in pronouncing them.

[2] After a vowel there is no such effort needed: in that case is the difficulty that of timing the relaxing of the vocal chords exactly with the explosion of the consonant? For if they are relaxed too soon, we have a double letter, *dt* or *bp* or *gk*; if too late, it makes the word end in a vowel.

[3] This seems to be an error in fact in regard to *b*. It too, like *q*, is merged

but *g* disappears, the word ending with the sound of the resonant.

2. Friction sounds. As from *p* we formed *f*, and from *t* *s*, so in a similar way, by making the check imperfect and leaving a little channel for the air between the tongue and the palate, instead of *k* we utter a sound denoted in German by *ch*. Brücke denotes it in his system by χ, giving as examples of χ^1, *Licht*, *Recht*, of χ^2, *Wache*, *Woche*, *Wucht*, receding in position as in the case of *k*.

It was said above, in treating of *k*, that there was a friction sound farther back in the mouth than the farthest *k*. Brücke denotes it by χ^3, and says it is found only in certain compound consonants, used chiefly in Arabic. He describes it as produced by stretching the soft palate strongly back and upwards, and raising the back part of the tongue against the uvula and adjoining parts, so as to leave a slight space on each side and permit some air to pass. The sound thus produced is like *ch* (in German), but rougher and deeper.

The sonants corresponding to these surds are the different forms of the *Jot* or consonant *J* of German. Brücke denotes them by y^1, y^2, and y^3, corresponding respectively to χ^1, χ^2, and χ^3. In uttering y^2 there is often something of a harsh vibration of the tightly-stretched soft palate, which makes it, especially at the beginning of a word before a vowel, seem to be quite an *r* sound. "It is true," says our author, "that there may perhaps be some vibration even of the uvula or epiglottis in uttering this sound"; but he adds that he finds it possible to utter it in full perfection without any vibration at all.

3. Vibration sounds. When one puts the organs into position for χ^3, but then hollows the middle of the tongue, along which the uvula lies, into a channel, so that the uvula may vibrate freely in it, the stream of air in passing out will produce the toneless *r gutturale* or *uvulare*, in Brücke's sys-

entirely in the sound of the resonant, as in *bomb, climb, comb, crumb, dumb, jamb, lamb, limb, numb, thumb, womb.* After surds we write *d*, but pronounce *t*, in the preterite forms of verbs, e.g. *dropped, scoffed*, etc.

tem, ξ; and when vocal tone is added the sonant, *r uvulare* or *provençal r* of the French, which is ρ in Brücke's notation.

4. Resonants. By letting the air pass through the nose when the mouth-channel is closed, as for g^1 and g^2, we produce the two resonants of this class, which Brücke denotes by π^1 and π^2, and illustrates by the sound of *n* in *Klingel, Bengel*, for the first, and in *Wange, Schwung*, for the second.

Having thus gone through all the simple sounds, Brücke pauses before going on to the compounded sounds, and discusses in a general way certain points of the system thus developed. He discusses the connection between a check sound and its sign,—in other words, what part of the process of uttering a check sound does the letter represent,—and shows that it stands for the closed state of the organs, and not for the act of causing or ending that state. He discusses the difference between surds and sonants, of which the main points have been already given above. He discusses the meaning of the term *aspirate*, whether a sonant can ever be aspirated, and the relation of the friction sounds to their corresponding check sounds. He discusses briefly the proper classification of *l*,—whether it should go in with the friction sounds, or form with *r* and the resonants a group called *liquids*,—and refutes the theory that the resonants should be joined with the check sounds in a class called *explosives*. Finally he offers a brief general defence of his system, from which (p. 61) we translate the following:

"It will be perceived in my system that the several members have in their symmetrical arrangement a mutual dependence, which remains invariable throughout; that there are toned consonants corresponding to all the toneless ones, and differing from these only by the state of the vocal chords; that the check sound can always be formed from the appropriate friction sound simply by closing completely the mouth-channel at the point where it is only narrowed; that the resonant in no case differs from the sonant in any other respect than in the opened nose-channel; and that the *l* sound is formed from the corresponding *d* sound never otherwise than by opening side passages for the breath between the tongue and the upper teeth. There is not the least irregularity. From this fact and the fact that I have gone step by step over all the places of articulation which the tongue can reach,—from these two things, I say, it has been possible for me to give an exhaustive list of simple consonants. Had I not taken this course, but satisfied myself with arranging in their proper order the sounds I had myself heard, I should have found no place in my system for the cerebral sounds of the Sanskrit; for in 1848 when I worked out the system I had not the least knowledge of the sounds of that language."

Upon this we would remark only, that perhaps the system is a little too perfect,—not quite enough conformed to the facts of language. At least it seems as if p^2 and b^2, as well as ϕ and κ, were inserted only for symmetry or for the theory's sake, since it does not appear that they occur in use in any language; and it is hardly necessary to give four distinct forms of the surd *l* sound, λ^1, λ^2, λ^3, λ^4, when the very existence of such a surd in any form has to be proved.

It remains to give Brücke's account of the compounded consonants (*zusammengesetzte consonanten*) and of the softened (*mouillé*) sounds. By compounded consonants he does not mean *x* and *z*, each of which is really a group of two consonants, denoted by one sign for mere convenience, but such as the German *sch*, the French *j*, the English *sh*, in which, to give his definition, "the organs of speech take at the same time the positions for two different consonants." For example, if the tongue is in position for χ^2, and then the tip is turned up into the position for s^1, a sound combined of these two will be produced. And that it is not a mere succession of sounds appears from the fact that it can be prolonged indefinitely without either part's giving way to the other. Thus is produced the German *sch* [$s^1\ \chi^2$], and if it is made sonant, we have the French *j*, as in *jamais*, which would be denoted by [$z^1\ y^2$], the brackets in each case showing that it is a compounded sound, and not a succession of two simple sounds. In the English *ch* and *j* we have a simple sound followed by a compound sound denoted thus, t^1 [$s^1 \chi^2$] and d^1 [z^1 y^2].[1] It sometimes happens that a simple *k* in one language passes in another into one of the compound sounds. Thus the Latin *carmen* is in French *charme*, in English *charm*. This can be no argument for holding that *ch* is in either language a simple sound, unless it be a rule of comparative phonology that simple sounds must always appear as simple sounds only. But for such a rule there is no proof. It may be added that apparently only these two friction sounds, *s* and χ, are in fact thus combined into one. In the case of the resonants and check sounds it is possible to combine the positions for two of either class, but not to utter the combined sound. It is possible to place the organs rightly for *m* and *n*, or for *b* and *d*, at the same time; but no sound can be uttered without making one give place entirely to the other. In Arabic there are two consonants, Kha (surd) and Ghain (sonant), which consist of a friction sound and a vibration sound combined [χ^3 ξ] and [y^3 ρ].

To these are to be added two exceptional combinations of a vowel and a consonant; exceptional, because in most cases the conditions of consonant utterance preclude the possibility of simultaneous vowel utterance. They are [uv^1] and [iy^1]. When one fixes the mouth for *u* or *i*, and then narrows the space between the lips, or between the tongue and the palate, so as to produce the friction sound v^1 or y^1, the compound sound results, which Brücke understands to be the *w* of *water*, or the *y* of *year*.

Finally we have sounds for which there is no precise name in German or English, but which are known by the French name *mouillé*, *moistened*, which may in this application be translated *made liquid* or *softened*. They consist of certain consonants with the sound y^1 following very closely, so as almost to form one sound, and indeed several writers have treated them as such. This modification is applied to *n* and *l* in the four Romanic languages, and to several other letters

[1] The English *j* is transcribed into German by *dsch*, as *Dschonke* for *junk*.

besides these in languages of the Slavic family. That the sound thus produced is not a simple nor a compounded sound is proved clearly in this way: If one utters *campan*, the n^1 at its end can be prolonged indefinitely without variation; but if one utters *campagne*, and endeavors to prolong this *n mouillé*, he finds himself to have passed from n^1 (or n^3) into y^1, and to be prolonging the latter. In the moment of passing from n to y^1, the part of the tongue which was nearest the palate is lowered just enough to allow a slight stream of air to pass through, and it is this stream of air rubbing along out, that produces the friction sound y. These two sounds, n and y, cannot be uttered simultaneously, for n requires the mouth-channel to be closed and the nose-channel open, while y must have these conditions reversed. The change is so quickly made, that some do not admit that it takes place. Others have thought that the second part of the sound was not the consonant y or *jot*, but an i, or something intermediate between i and y. Brücke disproves the former theory by showing that he can utter i after any form of l, l^1i, l^2i, l^3i, l^4i, without producing an *l mouillé*, but as soon as he utters l^3y^1i, l^1y^1i, or l^4y^1i, he has the right sound of the Italian *gli*. As to the other theory, he does not know what is meant by "something intermediate between i and y," unless it be the compound sound described above as [iy^1], and for this he says the larynx must be raised higher than it ordinarily is for a letter *mouillé*. In general, it is the dorsal letters, l^3, n^3, t^3, d^3, s^3, z^3, that undergo this modification, because the tongue in uttering them is nearer to the position required for y^1 than in any other form of consonant sound.[1]

We have tabulated Brücke's signs for the simple consonants according to his classes and forms, in order to present the system at a single view after it has thus been explained at length. In only one place does the table vary from his

[1] Brücke seems to have had doubtful specimens of English imposed upon him as the best usage, for he describes the *t* of *tube* and the *s* of *suit* as letters *mouillé*, writing the words according to his notation $t^3y^1\bar{u}b$ and $s^3y^1\bar{u}t$.

use of signs. It has v^1, v^2, where he, writing in German, has w^1, w^2, because the English *v* corresponds to the German *w* in sound, and clearness seemed to require it rather than the German letter. The characters in italics and the Greek letters (except π^1, π^2, χ^2) denote sounds that do not occur, we believe, in English.

	Surds.	Sonants.
I. Lips:		
1. Check sounds,	p^1, p^2	b^1, b^2
2. Friction sounds,	f^1, f^2	v^1, v^2
3. Vibration sounds,	ϕ	κ
4. Resonants,		m
II. Front part of tongue:		
1. Check sounds,	t^1, t^2, t^3, t^4	d^1, d^2, d^3, d^4
2. Friction sounds,	s^1, s^2, s^3, s^4	z^1, z^2, z^3, z^4
L sounds,	λ^1, λ^2, λ^3, λ^4	l^1, l^2, l^3, l^4
3. Vibration sounds,	ψ	r
4. Resonants,		n^1, n^2, n^3, n^4
III. Back part of tongue:		
1. Check sounds,	k^1, k^2	g^1, g^2
2. Friction sounds,	χ^1, χ^2, χ^3	y^1, y^2, y^3
3. Vibration sounds,	ξ	ρ
4. Resonants,		π^1, π^2, (π^3?)

To complete the list of consonant sounds in English, we should add to these the following:

$[\mathrm{uv}^1] = w$	$[\mathrm{s}^1\chi^2] = sh$
$[\mathrm{iy}^1] = y$	$\mathrm{t}\ [\mathrm{s}^1\chi^2] = ch$
$\mathrm{k}\ [\mathrm{uv}^1] = qu$	$\mathrm{d}\ [\mathrm{z}^1\mathrm{y}^2] = j$
$\mathrm{h}\ [\mathrm{uv}^1] = wh$	