SOME QUESTIONS OF PHONETIC THEORY

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BY

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PREFACE

THESE four chapters form the first instalment of a book which is planned to appear in three parts because, for one reason, it is hoped that Part II. will appeal to a wider public than can reasonably be expected to read the complete volume. Part II., which will bear the sub-title of *An Essay towards the Abolition of Spelling*, is, however, the direct outcome of Part I., and it will present a Rectified Alphabet of such simplicity as those splendid men, Bishop Wilkins and his friends, the founders of the Royal Society, laboured in vain to discover. With regard to which it is not too much to say that if A. J. Ellis had not been "gassed" by the specious, pretentious twaddle of Helmholtz, the Simplifyd Spelerz of to-day would have no reason to exist, and school-rooms throughout the Empire would not resound to the doleful litany of "double-you eye jee, wig" and such-like incongruous formulæ. But to say more in this place would be to destroy the true serial effect, which is best maintained by the legend—(*To be continued in our next*).

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CHAPTER I

THE POSITION OF REST

1. THE older books on phonetics somewhat exaggerate the difficulties of examining the mouth by direct inspection. The method adopted by A. J. Ellis, of facing the sun with a narrow strip of looking-glass, is less convenient than turning away from the source of light and illuminating the mouth by reflection from a hand-mirror. As there is rarely sufficient quiet in the day-time for judging of small sounds, I have found it well to use a mirror and a small electric torch, with the room otherwise in darkness. An improvement on this plan is, for some purposes, to use a very small filament lamp connected with a cell by a wire which allows the lamp to be placed inside the mouth. Thanks to my Belgian guest of the winter before last, I possess such a lamp, only 5 mm. in diameter, enabling me to get a glimpse of the tongue and soft palate, even while sounding uː. (The symbols here used are those of the International Phonetic Association.)

2. The back of the mouth has been strangely neglected, and particularly the hind pillars of the fauces (arcus palato-pharyngeus). These twin folds of mucous membrane enveloping muscle are not indicated in the familiar diagrams showing the organs of speech—it is, indeed, not easy to show them in a sagittal view—and although briefly described at times, as by Viëtor (Elemente der Phonetik ^{5}, 1904, § 12), no mention is made of their *lateral* movements, by which, however, they are able to reduce the passage between pharynx and mouth, the faucial aperture, to very small proportions, or enlarge it to the full width of the pharynx.

3. The student is, or used to be, sorely puzzled from the very outset. He reads in Ellis or Sweet about the uvula which is pressed back against the wall of the pharynx in order to close the passage through the nose for all but the nasal sounds. If then he takes "uvula" in its usual meaning, as in anatomy, of the pendulous conical process suspended from the soft palate, he finds that by no effort can he move his uvula back to touch the wall of his pharynx. If he presses it back with his finger, this makes him retch, and he concludes—I judge from my own experience of some twenty years ago—that he too is fearfully and wonderfully made, but not as other men.

4. Or if he turn for enlightenment to foreign books, he finds it repeated on eminent authority that on looking at the back of his mouth while quietly breathing he will see the front and hind pillars of the fauces, with the uvula pendulous between them, and the wall of the pharynx behind (Jespersen, Fonetik,

§ 220, Lehrbuch, § 56; *cf.* Sievers, Grundzüge der Phonetik^5, 1901, § 49). Here again he is disappointed. For if he is breathing quietly—that is, through the nose—the said pillars, uvula, and wall are all invisible, hidden by the tongue, which meets the soft palate above the base of the uvula, forming a complete closure: the fauces are closed. It depends, then, on what is meant by quiet breathing. It is possible, of course, to breathe through the mouth, or to articulate whole sentences, so slowly and with so languid a current of breath (*i.e.* unintonated breath, "flatus," not voice or whisper) that no sound can be heard (*cf.* Sweet, Primer of Phonetics, § 101). One may, for example, articulate very slowly *Wait for me*, while a mirror moving over the mouth shows a stream of breath which, but for the stop **t**, is uninterrupted, and yet make no sound at all, except at the bursting of a saliva film which may form between tongue and palate as the **t** closure comes to an end. But with anything like a normal rate of respiration, if there is any passage of breath from pharynx into mouth, if, that is, the fauces are open, there is decidedly rough breathing, and not by any means the "quiet breathing" of the poet.

5. It may be objected that "ruhiges Atmen," "rolig ånding," mean not necessarily quiet breathing, but peaceful breathing. If that is so, the peace is purely "subjective." Certainly there are persons who habitually breathe in the way described by Sievers, with unruffled calm; but I take the opportunity of stating here, since no such person is likely to read these words, that they make an abominable noise. Not that the sound in itself is ugly. There

is nothing disagreeable in the panting of a dog, or of an athlete out of breath. Quiet breathing through the nose is not inaudible. If we wish to be perfectly silent, we hold our breath—that is, close the glottis. But the faint nasal fricative accompanying normal expiration—there is nothing nasal in its quality, by the way; it is genetically nasal, not acoustically—is a pleasing, not a displeasing, sound. It is the concomitant of sleep

> Full of sweet dreams, and health, and quiet breathing.

The lips may be parted, but as long as the tongue and the soft palate are not allowed to separate, all is well. When, on the other hand, one expects placid breathing, which should and must proceed, like that of the cow, entirely through the nose, buccal respiration suggests disagreeable things such as a cold in the head, or adenoids, or some other form of nasal obstruction. The avoidance of sounds and articulations which have unpleasant connotations of this kind is a factor of some importance in the development of certain languages, notably of English.

6. The error in Jespersen's and Sievers's description of the mouth during quiet breathing derives possibly from an ill-considered paragraph (21) of Sweet's *Handbook of Phonetics*, which is omitted in the *Primer*, and it may be regarded, in the context of the pages referred to, as a slight inadvertence. But when repeated by Sievers in his discussion of the position of rest of the organs of speech, it becomes a grave and fundamental error, producing or contributing to endless confusion.

7. In describing the position of rest or of indifference of the organs of speech (§ 55), Sievers states that

during quiet breathing the soft palate hangs down slack so that the breath can pass into the mouth as well as into the nose; and (§ 57) that this position of rest is the natural basis for the movements of articulation which lead to the formation of speech-sounds. More exact details cannot be given (§ 56) because there are too many individual variations. Thus for Sütterlin (Die deutsche Sprache der Gegenwart, 1907, p. 23) and many other grammarians, *Ruhelage* and *Artikulationsbasis* are just two out of a number of names for one and the same thing. Or, as Noreen puts it (Vårt Språk, I. p. 377), the basis of articulation is the position of the organs of speech when they are at rest, and may be altogether different in different individuals, or still more so in different nationalities. If that is so, then the phonetician's occupation, as far as it has to do with teaching how to speak foreign languages correctly, is gone. For only those individuals of any one nationality whose basis of articulation happens to coincide with that of typical members of a second nationality could hope to speak the foreign language really well. Their own native language they would speak badly, in proportion, since no object can remain at rest in two different positions at the same time. The question how to learn to speak a foreign language well is therefore solved. It cannot in general be done. Or are we to make the attempt nevertheless, and send schoolboys to bed with their mouths full of apparatus designed to correct their position of rest or indifference while they sleep, so that they may be ready with the proper basis of articulation for their French lesson in the morning?

8. There is no cause for alarm. Our pupils may enjoy their well-earned rest. For the blunt truth is that two entirely different things have been confused. I can offer no explanation for the fact that Sievers, after drawing freely on Sweet's *Handbook* (1877), did not clarify his ideas by reading § 184 of the *Primer* (1890), where it is plainly stated that the basis of articulation of a language is, not by any means the position of rest of the organs of speech, but the sum total of the general tendencies which control the movements and positions of these organs for a particular language.* Clearly, language, speech, is not rest, but action, and as it would be rash to conclude from the position of rest of a dog, which likes to curl up for a sleep, that if roused to action the animal will proceed to rotate about an imaginary axis, so it is equally unsafe to draw conclusions as to the organic basis of a language from the position of rest, for which the proof has yet to be furnished that it differs in any respect as between one race or language-community and another; or conversely, as is patent from the fact that those who have discussed the *Ruhelage* are ignorant of its most characteristic feature. A knowledge of *the* position of rest, unlike that of *a* basis of articu-

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* The first to recognise and attempt to define such differences of basis appears to have been John Wallis in his *Grammatica linguæ Anglicanæ*, Oxford, 1653 (*cf.* Jespersen, Fonetik, p. 22): Notandum tamen est, apud varias gentes nonnihil diversitatis inter pronunciandum reperiri, quæ non tam singularum literarum, quam totius potius loquelæ communis est affectio. Angli nempe totam pronunciationem quasi promovent, versus anteriorem oris partem, et faucibus apertioribus loquuntur; undi et soni fiunt distinctiores. Germani potius retrahunt versus posteriorem oris partem et gutturis imum; unde fortius et magis strenue pronunciant . . . .

lation, is no help in acquiring the pronunciation of a language, but it would have prevented the confusion which now, worse confounded, has found its way into school books, thanks to German thoroughness, and is likely to discourage effort in any logical-minded teacher or pupil. Here is an example from *A Primary German Course*, by Otto Siepmann, 1912, p. xiii: "People living in the same country and environment adopt for their organs of speech when they are quite at rest, as in sleep, a certain position which forms, as it were, the base of operation for their speech." And on p. xiv: "In English the tongue, when at rest, is left flat and allowed to lie low in the mouth with muscles relaxed. . . . In German the tongue, when at rest, does not lie so flat and low, and its muscles are less relaxed." Now what purpose can such chatter possibly serve, except to mystify? Was not the path of the beginner in German beset with real terrors in plenty, without conjuring up this turnip-headed bogy? In English, when the tongue is at rest, as in sleep,—there can be no English, no speech-sound represented by letters of the alphabet, except ŋ. And similarly when the tongue is at rest in German—a consummation, some would say, devoutly to be wished—there is no German, except the same ŋ, with the "glottal plosive" (ʔ) thrown in. But it may safely be said, on the other hand, that the Englishman, the Frenchman, and the German have this much at least in common with the native of Timbuctoo, that "when they are at rest, as in sleep," their soft palate and tongue are in contact, or, more exactly, so nearly in contact that the whole interstice is occupied by water-film (saliva), which must be broken before any air can pass from the pharynx into the mouth. If any one of these four men, while asleep, allows his soft palate and tongue to become separated by a narrow chink, he will probably snore, whether his mouth be open or closed; and if through the watches of the night he with open mouth persist in snoring, or in that loud, rough breathing with open fauces which Sievers and Jespersen call *ruhig*, *rolig*—it would be anything but *roligt* (**ruːlit**) in the Swedish sense of the word—he will probably have a nightmare, and wake with a parched mouth and the other disagreeable symptoms so poignantly described by the Lord Chancellor in *Iolanthe.* The discovery that English tongues, when quite at rest, are slackers, and that in Germany, not merely in Prussia, people sleep with their tongues at attention, so to speak, has its value. Evolved from its author's inner consciousness, at the suggestion, no doubt, of Sievers, § 56, it deserves, unless a claim to priority is raised, to be promulgated as Siepmann's Law. *Das Siepmann-'sche Gesetz der Zungenspannung in der Ruhelage* would have an air of importance, and would not find itself in altogether uncongenial company.

9. The tactile sense between the soft palate with the uvula and the tongue must be very weak. We have no sensation of contact, presumably because it is a comparatively rare thing for these parts to be separated. The assertion may therefore appear doubtful that if the lips are closed the mouth is normally—but not, *e.g.*, in humming—an air-tight chamber. It is not difficult, however, to devise proofs. If there were any opening from the mouth into the pharynx, the habit of smoking would not be widespread, and it is easy to gain the conviction that

the closure is perfect by holding smoke in the mouth while continuing respiration, as smokers, of course, habitually do. No smoke is inhaled except by a voluntary effort, or emitted through the nose; and if one listens carefully while performing the latter feat a faint click may be heard, more clearly perhaps if the ears are stopped. One may infer how this sound is caused by reversing the air-tight chamber—closing nostrils and glottis—opening the mouth so that it is "disposed," as Abbé Rousselot would say, for **ɑː**, and then watching the separation of tongue and soft palate.

10. "Blowing" smoke-rings is also instructive. The expression shows that the contact at the closed fauces is not felt, for the way to blow smoke-rings is not to blow. No air enters the mouth from the pharynx, but the smoke is sent out in vortex-rings by a succession of sudden upward and forward movements of the whole tongue. In these movements the larynx is implicated by reason of its attachments with the hyoid bone, and is jerked up as the tongue makes its dart forward. An unbroken sonant **ŋː** may be maintained, although not steadily, while one "blows" a series of smoke-rings. Each time the larynx rises there is an instant of imperfect vocality or "jerk of the voice without any breath"—that is, **ɦ** (*cf.* Sweet, Primer, § 120)—the effect of which upon the ear is to divide the sonant into a corresponding series of syllables of sonority, thus: **ŋː ɦŋː ɦŋː** *ad lib.* (**ŋː** being continuous, the **ɦ** would in Lloyd's notation, *Northern English*, § 71, have the index **ŋ**).

11. Some such simple, home-made experiment as the above is necessary in order to appreciate the

fact, unfamiliar to writers on phonetics, that "when the mouth is closed the soft palate and uvula rest against the tongue" (Piersol, *Human Anatomy*, 1907, p. 1569). This, then, is the main point of interest in the position of rest. A quiet man, like the Spectator "with his short face," spends all but a small fraction of his life with fauces closed. An infant, it is said, is in danger of suffocation if its nose is covered, not having learned to draw breath unnaturally, through the mouth. The title of Piersol's book will be noted. It is not American anatomy, which does not exist. And German anatomy only exists in the disordered fancy of half-demented *Germanisten.*

12. Now contrast the actual state of the closed mouth with the plate which has served as frontispiece to Viëtor's *Elemente der Phonetik* down to its fifth edition, 1904. Whether it continues to adorn this work in its sixth edition I do not know. It claims to represent a median section of the organs of speech in the position of rest. It would be more aptly styled a median section of the human head, showing the organs of speech incurably doctored, with the soft palate, etc., in a position of total collapse. There is something, I think, peculiarly Modern German in the assumption that a complex organism may be subjected to the utmost violence—on highly "scientific" lines, of course—and yet must needs reveal itself in a state of normal, peaceful functioning. It has been my privilege to inspect a similar preparation in the Anatomical Museum at University College. In order to give a clear structural view of the different organs, the tongue has been separated from the soft palate, so that there is an open passage

between the buccal and pharyngeal cavities, as in Viëtor's plate and in the imagination of Sievers, § 55. The uvula appears to have been left whole, and hangs considerably lower than in the living subject. It is not surprising that when a suspended arch, weighted in the middle, is cut in two and one half removed, the remaining portion should droop somewhat. In Viëtor's plate the distance between tongue and palate is everywhere greater than that between uvula and epiglottis, which almost touch ! This position, so far from being the position of rest, is one which neither Professor Viëtor nor any of his too numerous followers could possibly attain without first undergoing a surgical operation. It is found convenient in physiology to distinguish between the structural and the functional. That is a distinction which, I believe, in many branches of knowledge, and not merely in philology, does not commend itself to the German academic mind, in spite of Goethe (*cf.* Eckermann, Feb. 13, 1829). But as for Professor Viëtor's frontispiece, for just that purpose which it is supposed to serve, to illustrate the Position of Rest, his "median section" is a grotesque exhibition.

CHAPTER II

WILLIS ON VOWEL SOUNDS

13. Whenever the fauces are not required to be open, the position of rest is at once resumed, tongue and soft palate straightway resuming their insensible contact. The failure to recognise this fact is largely responsible for the fearful discord given forth by the many attempts to ascertain the "inherent pitch" of vowels, as tabulated by Ellis, Jespersen, Viëtor, Rousselot. The discrepancies cannot be accounted for, with Helmholtz or Lloyd (*cf.* Rayleigh, Theory of Sound, ii. 1896, p. 476), by differences of pronunciation due to the native language or dialect of the various investigators. For example, Koenig and Helmholtz both were natives of North-East Germany, the one hailing from Königsberg, the other from Potsdam. There is no reason to think that if they had met and compared notes either would have found the other's uː in any way differing in quality from his own, but the inherent pitch of North German uː as determined by Helmholtz is f, 175 v.d., while Koenig made it b♭, 224 or 225 v.d. (*cf.* Ellis, Sensations of Tone, 1885, p. 109; Koenig, Quelques expériences d'acoustique, 1882, pp. 43, 64). The phonetic symbol uː represents a vowel sound which

occurs in many languages, and as long as it is uː and is not gliding from or into something else, it is rightly regarded as identical by phoneticians of many nationalities. Scandinavian linguists, Storm, Jespersen, Danell, and others, call it the European uː, as opposed to the ʉː of Swedish *bo*, *rolig*, etc. But when we come to the acoustic definition of uː we are greeted with the following lovely chord, beginning from the *C* in the bass stave :—c d f g a b♭ c′ f′ f″ g″! Let the reader, if he feels tempted to take up this line of research, strike these notes on the piano with the help of an extra hand. The result should give him pause. The inherent pitch of uː is thus heard to range, or rage, over two octaves and a fifth, or from 131 to 784 double vibrations (v.d.) a second; and meanwhile we learn from Abbé Rousselot that the difference of one vibration in the inherent pitch, or proper tone, of ɑː brings with it an appreciable difference in the quality of the vowel. It is all very wonderful. Koenig's North German ɑː was a b″♭ of 896, or, in round numbers, 900 v.d.; that of Helmholtz a b″♭ of 932 v.d., about a quarter tone sharp by Koenig's standard of pitch. The ɑː of Hellwag was about 185 v.d., and that of Trautmann 1397. And so on with the other vowels. There are many other members of this German band, whose contributions to the general harmony, or *musique turque*, equally deserve to be included in the tabulations, as Hermann, Auerbach, etc. (*cf.* Auerbach in Winkelmann's Handbuch der Physik, ii. 1909, p. 688), but the performer who has made most noise in the world is Helmholtz, whose table of vowel-pitches decorates the pages of innumerable text-books of physiology, sound, etc., down to some of the most recent (*e.g.* Schäfer, Starling, Capstick).

14. The table is taken from the famous work, still regarded as the standard book on its subject, *Die Lehre von den Tonempfindungen*, which appeared in four editions, in 1862, 1865, 1870, and 1877, here referred to when necessary as H^1, H^2, H^3, H^4. The third edition was translated into English by A. J. Ellis, at the instigation of Max Müller, in 1875 (Ellis, 1875), and the fourth and last edition in 1885 (Ellis, 1885).* Sooner or later the student of phonetics who wishes to go into the theory of his subject is bound to find himself at grips with this standard work, *On the Sensations of Tone.* I consider it to be a very poor standard and a most wasteful and misleading work. I shall endeavour to show that wherever it bears upon phonetics Helmholtz's book has no right to be considered authoritative, and that his influence has been and is constantly bad. The reader must be warned: our path lies across a veritable quagmire of sham science or *Wissenschaft.* It will be heavy going, and we must pick our way. Here and there we shall flounder, but we shall reach firm ground at last.

15. The acoustical investigation of vowel sounds begins with Willis, of Cambridge (1800–1875), the impulse coming from Petrograd. Willis produced what he considered to be different vowels artificially by means of cylindrical pipes in association with a free reed, and advanced a fixed pitch theory which, "as far as general principles are concerned, left little

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* Unless otherwise stated, quotations are here made from this edition, but in each case the translation has been compared with the original.

to be effected by his successors" (Rayleigh, ii. p. 471). Willis also foresaw the immense linguistic value which the accurate determination of vowel-quality would have, if it could be arrived at by way of pitch: "Future experiments in more able hands than mine will, I trust, determine the matter with greater accuracy, and I should not even despair of their eventually furnishing philologists with a correct measure for the shade of difference in the pronunciation of the vowels by different nations" (Camb. Phil. Trans. iii. 1829, p. 243). But this idea is now generally ascribed to Helmholtz (as by Koenig, p. 42; Ellis in Ency. Brit.[9] 1887, xxii. p. 382), who adopted it without acknowledgment: "*I* should therefore recommend philologists who wish to define the vowels of different languages to fix them by the pitch of loudest resonance" (Ellis, 1885, p. 106). The readiness of Helmholtz to take a hint ought not to occasion any surprise. He did not suffer from excessive modesty. He felt, no doubt, that his were the more able hands which had been foretold, and did not hesitate to assume the mantle of Willis and other unconsidered trifles, such as the tuning-fork test of Wheatstone—which he bags, so to speak, in the same breath. Great men of letters, Shakespeare, Molière, borrow their material freely. Perhaps men of science —whose material is, in a sense, often enough their all —can be, should be, and usually are more punctilious, but the real test lies in the degree to which the worth of the loan is enhanced; so it is interesting to find that Helmholtz approved Willis's results in part, and corrected them where the artificial English vowels did not satisfy his delicate Prussian ear.

16. Willis held peculiar views. He thought that long vowels constantly changed in quality during their prolongation. His observations did not extend beyond English vowels—London was his native place—and if we consider his key-words, such as No and Pay, now conventionally transcribed as **nou**, **pei**, we see how closely he anticipated the findings of modern phonetic research, as, *e.g.*, in Scripture's *Speech Curves*, 1906. In this connection he used the word "glide" with the same meaning as Ellis, who by some curious lapse claimed to have introduced into phonetics a term which, through much bandying about in different senses, has almost lost its value. He was aware, too, that his apparatus merely gave a suggestion of the real vowels, and emphasised "the difference of quality between the artificial and the real vowels," a distinction which Helmholtz waives, at least as far as his own productions are concerned. The difference of quality between the vowels in Nought, pitch e″♭, and Paw, g″, is a puzzle. Sir John Herschel in 1845, like Lord Rayleigh in 1896 (ii. 471), was unable to detect any shade of difference (Encycl. Metrop. iv. p. 819), and invited his readers to pronounce the words Paw, Gnaw, Naughty, Nought for their own satisfaction. One is not surprised that Wheatstone could make nothing of Nought and put Aw in its place, opposite e″♭ (Sir Charles Wheatstone's *Scientific Papers*, 1879, p. 354). Ellis, who heard Willis's experiments repeated by Wheatstone, thought that by Nought was probably meant "the broad Italian open O, or English o in more." But that is hardly to the point. What one wants to know is not what Willis meant, but

what Helmholtz heard, that he should confirm the e″♭ and g″ of Willis. It is more likely that Willis was misled by the spelling, and imagined a difference of quality where there was none, and that Helmholtz followed suit; for by p. 106 the symbol which is set opposite Nought stands for a quality of ɔ tending towards ɑ, not in the contrary direction, and if Ellis's surmise is correct, pitch or no pitch, the key-words should be arranged in the order No Paw Nought Part, not, as in the table on p. 117, No Nought Paw Part. The key-word for æ was misprinted Paa in the original publication, and the failure of Helmholtz to recognise æ—without which any list of English vowels is singularly incomplete—from its pitch, f^3, proves that the imitation given by the 1·8 inch pipe was imperfect—in fact, not recognisable without the exercise of a little intelligent anticipation. The order of the words Pad, Pay, Pet, See suggests that Willis may have considered the vowel-glide or diphthong in *Pay* to begin with an open ɛ, lower in pitch than that of *Pet*. That would be a reasonable view—it was Wheatstone's—but for the magnitude of the interval, a diminished seventh, from d^4 to c^5. Sir J. Herschel thought Pay and Pet had perhaps changed places, and if Pay was indeed pei, no doubt they had. Helmholtz reduced the pitch of Willis's Pay vowel from d^4 to b^3♭, which is that of eː in his own table, thus identifying Pay with peː, the name of the letter P in the German alphabet. Nevertheless he keeps the vowel of Pet above that of Pay, and thus locates ɛ, c^4, halfway between eː, b^3♭, and iː, d^4, instead of on the other side of eː—a preposterous state of things. The condition in which Willis's table is left by

Helmholtz can hardly be deemed to establish unaided the right of the latter to requisition his predecessor's ideas.

17. Willis held that vowels are "not definite sounds like the different harmonics of a note, but, on the contrary, glide into each other by almost imperceptible gradations." A simple trial will convince anyone of the truth of this assertion, with respect at least to such a vowel, or rather vowel-glide, as the long O of Southern English, especially in its Cockney developments. The majestic sweep of Liza Doolittle right around the catenary from about **æ** to **u** might have taught her professor some phonetics if he had not been such an unimaginative Shavian noodle, and shown him that 130 is but a small number, as nought, in face of the infinity he was up against; in other words, that it's a long, long way to Tipperary.

18. The "catenary" is only a suggestion for the path of the peripheral vowels from **i**, **ɪ** through **ɑ** to **ʊ**, **u**; but a curve of some form it must be, to represent a continuous, not a gradual, change. On the difference see Whitehead, *Introduction to Mathematics*, in the Home University Library, ch. ix. The Viëtorian revival of the triangle was a silly business,* probably fathered (if one were to seek its paternity) by the wish to crab the Bell-Sweet quadrilateral, which does not pretend to be anything of the nature

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* *Cf.* Viëtor's schema (Elemente^3, p. 39). The angles **i u** of the triangle **i ɑ u** indicating tongue-positions are also points on an arc representing the palate. You can imagine the vowels **i** and **u** asking each other, like the Irishman, "Which is the way to the entrance out?"

of a graph, but sets out in tabular form a number of fixed positions, sufficient for practical purposes. It is not perfect. Muscular or tactile sensations are not always a safe guide, for if they were, the closing of the fauces in the position of rest would have been common knowledge long ago, and there would be some agreement as to the physiological meaning of Narrow and Wide. But it must not be dismissed, as I have heard it *ex cathedra*, off-hand, because the human head is not built on a square pattern—an observation which would not become less acute if triangular or prismatic were substituted for *quadratisch.* For obviously any attempt at a graph is a hazardous enterprise unless an adequate number of points can be accurately located. This is shown by the vowel-triangle, which is framed on the simple assumption that three points not on the same straight line must indicate that figure. But whereas extreme **iː** and **uː** may no doubt be regarded as fixed, since any further rise of the tongue or lessening of the lip-opening changes the vowels into buzzes or voiced fricatives, **j**, **w**, **g**, **gw**, there are a number of distinguishable, even distinctive, qualities of **ɑː** clustering around that symbol, as uncomfortably placed, one would think, on the apex of the triangle as were the disputed hosts of angels on the point of a needle. It was remarked by Helmholtz (p. 106) what small differences of pitch correspond to very sensible varieties of vowel-quality in the neighbourhood of **ɑː**, although this observation* is hardly borne out by his pitch of **ɑː** in Part—$d^3\flat$ in agreement with Willis, a

* The observation, I find, was not original, but was conveyed from Donders, *Utrecht Archiv*, 1858, i. p. 159.

minor third above the somewhat less "bright" North German **ɑː**, b″♭—when we compare Rousselot's astonishing results. In studying three or four modern languages one may find it necessary to get hold of several varieties of **ɑː**, distinct from Parisian **a** on the one side and from any **ɔ** on the other; and the whispering test, first employed to good purpose by Donders, of Utrecht, unreliable as it may have proved for determining absolute pitch, is most valuable when two adjacent vowels are to be compared. By this test the **ɑː** of *father*, in my own pronunciation, is always about a semitone higher than that of *farther*, when the two words are taken in succession. Which seems to show that even Sweet himself did not admit enough varieties of **ɑː** (*cf.* Primer of Phonetics, § 6). There is the difference of class and clarss, in half and 'arf. The comical metathesis, "'Now that the marks,' by which Mrs. Gamp is supposed to have meant mask, 'is off that creetur's face,'" presupposes in Dickens's London a clarss pronunciation of mask (which is **mɑːsk**, not **maːsk**) as marsk, which would also be **mɑːsk** if *father* and *farther* "have exactly the same sound in educated Southern English speech." In this one instance traditional spelling may claim to be more exact than the phonetician.

19. With such overcrowding at its apex, the triangle is neither sound in theory nor satisfactory in practice. The plea of a first approximation will not avail; a trial curve must be a curve. It is a matter for congratulation that the I. P. A. has given the triangle the go-by. But it would be a boon to have something in the way of an outline or diagram by which the relationship of the various symbols might

be more accurately measured than in the present scheme (Principles of the I. P. A., p. 10). This seems particularly desirable in the ɑː region, where a very slight change in the lie of the tongue is seen to correspond to a considerable difference of vowel-quality. Jespersen, who points out this fact (Fonetik, § 352), recognises four distinct varieties, although following Sweet with father = farther, alms = arms, and calls attention to the overlapping, which makes it difficult to discover what is permissible and what not. There is not always the same latitude in both directions. Recently I found when taking lessons in Flemish that my teacher (not a phonetician) was pained by the rusticity of an ɑː a trifle too much Back, but allowed an ɑː considerably more Front than his own to pass. If the Front and Back vowels were envisaged as lying along a small-linked chain suspended at extreme iː and uː, it might be possible for a few real phoneticians —not the people who rely on machinery to supply their evidently lacking experience and acuteness of ear—to count off the links to be allotted to each of the symbols considered sufficient for any one language or dialect by itself. By comparing pairs of key-words, as English *tart* with German *Tat*, English *mart* with Swedish *mat*, and so on, they might agree upon a determination at once more practical and more exact than anything to be expected from the acoustic methods now in vogue. But we do not want any more of the Helmholtz touch—to be told, for example, that the English ɑː of *part, tart,* d^{3}♭, is somewhat brighter than the German ɑː in *Tat*, b''♭. Helmholtz's blunderful revision of the English vowels in Willis's table would stamp him, but for his reputation otherwise acquired, as a person no less conceited than ill-informed.

20. Nor is there any profit in Auerbach's Dark U, a; Normal U, c′; Bright U, d′, etc. (p. 689), which illustrate the touching fidelity of the famulus, unable to unlearn what his master once taught him. Helmholtz applied the epithet dark or dull to U before he learnt, for his fourth edition, that German long vowels differ in quality from the short vowels represented by the same letters of the alphabet (*cf.* Ellis, 1885, p. 110; H^3, p. 173). Thus Bell's luminous distinction between Narrow (tense) and Wide (lax) is hidden from Auerbach. It is doubtful whether Helmholtz ever emancipated himself from nomic spelling sufficiently to distinguish **u** from **ʊ**, but after Koenig's criticism of his pitch of **uː** in 1870 as too low, Helmholtz in 1877 inserted in his table a second quality, spelt in the French way as OU, with a pitch which might rise even higher than Koenig's b♭, up to f′, an octave above **uː**, to represent "a U of higher resonance, more resembling O" (p. 110). But it is to be noted that Koenig, writing in French, naturally denoted his North German **uː** by the French spelling of the identical sound, OU: "Pour la prononciation des Allemands du Nord (à laquelle se rapportent aussi les expériences de M. Helmholtz) les voyelles sont donc caractérisées comme il suit: OU$(\mathrm{si}^\flat)_2$, O$(\mathrm{si}^\flat)_3$, A$(\mathrm{si}^\flat)_4$, E$(\mathrm{si}^\flat)_5$, I$(\mathrm{si}^\flat)_6$, soit en nombres ronds de vibrations simples, 450, 900, 1800, 3600, 7200" (Acoustique, 1882, p. 43, reprinted from Comptes rendus de l'Académie des Sciences, 25 avril, 1870). In the spelling alone is there any resemblance between French OU, which is **uː** or **u**, and German O, which is

either oː or some variety of ɔ. If a candidate with no better knowledge of the vowel sounds of English, French, and German than was possessed by Helmholtz when giving the final touches to what has been described as a classical, lucid, brilliant work of genius, were to present himself for an elementary examination in phonetics, he would fail to satisfy the examiners; and Auerbach with his "bright U," etc., would probably follow his master. Ellis added a feeble note (p. 111) to explain that brighter really meant duller, and to "prevent confusion"—an aim which could have been attained only by means of much more drastic handling, or by abstaining from translation. But in this latter case Max Müller would no doubt have found some one far less qualified to undertake the task. After 1871 the German boomsters were not to be denied. And if the phonetic part, the theory of vowel-quality, had been omitted, the "theory of audition," with which it is inextricably bound up, would have had to go too, and therewith the theory of concord and discord. All three theories stand or fall together. Their situation is precarious. I think we may anticipate a great fall at some time or other.

21. It is questionable whether an absolute whisper-pitch can be ascertained. According to Sweet, § 60, the pitch of whisper is invariable. But there must be physical reasons why the same person at different times finds different pitches for the same whispered vowel. One reason is that to intensify a whisper we may draw out the hind pillars of the fauces as described in § 2 above, and these membranes become responsible for a good deal of the sound. Their movement may

be readily watched with whispered ɑː, and their position when one makes as if to breathe upon a glass shows that the accompanying sound is due to them, and probably not—certainly not all—to the glottal lips, as Jespersen supposes (Fonetik, § 239). When Mr. Toots "breathed hard," through the mouth, he doubtless produced his effect by unconsciously narrowing his faucial aperture. But a diminution of the aperture should affect the pitch of the mouth-cavity, regarded as a resonator with two openings (*cf.* §§ 47, 53). Another reason is that the thorax is not a well-regulated bellows, except in singing, when with the ear in lieu of a manometer it may be, admirably so. The volume of air passing into and out of the lungs in a given time varies greatly under different conditions. If the pitch of an ocarina can vary with the force of the blast by as much as a major third, it is not likely that the pitch of such a resonator as the mouth-cavity can be constant under varying pressures. It is difficult to gauge such a change, since the mouth is liable to favour whichever view is in your mind, but even if the mouth is closed it is possible to force a whisper up a considerable stretch, imitating the rushing sound of a rising wind, and let it drop again. But all that does not matter for relative pitch. It is possible to decide very well which is the higher of two vowel sounds whispered successively under the same conditions, and to judge the interval, and that is all that is needed in order to mark off similar, but not identical, vowels on the suggested catenary to show the overlapping. The difference between tense (narrow) and lax (wide) quality might perhaps be represented by a chain which is weighted at the appropriate point.

22. Let us now make an example of Miss Doolittle's long-drawn Oh! It is not well rendered by Ah-ah-oh-au-au-au-uh (Pygmalion, von Bernhard Shaw, transl. S. Trebitsch, Berlin, 1913, p. 23), being one syllable, while au-au (ow-ow) >> is, of course, two. It may be denoted by **æ......u**, with the limited number of dots doing duty for an infinite number of points on a curve, or more immediately by **æ‿u**. When the exclamation is uttered, as by Mrs. Patrick Campbell, in no halting or uncertain manner, we have a fairly definite impression as to where it begins and ends, but between **æ** and **u** the vowel-glide proceeds by quite imperceptible "gradations" from half-open through open to close qualities, there being no passage through a minimum of sonority, no break in its continuity, to make it affect the ear as disyllabic (*cf.* Sweet, Primer, § 148; Jespersen, Fonetik, ch. xxiv.). If we go over the ground slowly, or stop here and there, we are able to recognise our whereabouts, but if the vowel-glide is whispered as one syllable there is a continuous fall of pitch through an interval of over an octave. That is to say, there are no gradations at all—no steps. Willis's idea was right, but his mode of expression was not so exact as that of the modern mathematician, who no longer tolerates vague half-metaphorical terms like "gradually" (I have already given the reference to Professor Whitehead's delightful little book). A pleasing illustration may be found in watching Mr. Pickwick on the ice, if we fix our gaze, not on his portly person in general, but

preferably on one of "his black gaiters tripping pleasantly through the snow"—a perceptible gradation in the direction of the slide—and then perceive it, about a yard and a quarter from its fellow, gliding slowly and gravely along, with a motion which while it lasts is continuous, not gradual. Sam Weller's performance is also worthy of regard.

23. There surely are few studies so burdened as is philology with a vague and shifty terminology—largely a heritage from German Romanticks—and if phonology is to escape from the reproach which lurks in its name (apparently, as Abbé Rousselot suggests, from *φόνος*, murder, or a corpse), there must be the constant endeavour to emulate in a modest way the precision of the newer mathematics. Thus it becomes necessary to explain why "vowel-glide" is here used in a different sense from that of Sweet, who applies it to little purpose as a generic term for the various beginnings and endings of voice, including the "glottal stop" (§ 118). These are, I think, better called "glottids" with Ellis, so as to leave "vowel-glide" for a continuous change of vowel-quality between "fixed positions," giving the impression of one syllable. The analogy is hinted at by Sweet in § 161. As in intonation there are voice-glides (comparable to a portamento in singing, or with Ellis to a violin-tone when a finger is run up the string) and voice-leaps (*cf.* legato) without any break (*cf.* staccato), so in the diphthong **æ‿u** we have a vowel-glide, with a corresponding glide in the pitch of the mouth-cavity, to be observed in whispering; whereas when two vowels come together, making, not a diphthong, but two syllables, as **uːi**, **ui**, or even **uɪ**,

there is a vowel-leap, with a corresponding leap, when **ui** is whispered, of perhaps a twelfth in the pitch of the mouth-cavity. The effect is analogous to that of a voice-leap in singing (*cf.* Sweet, § 161): there is no break, but the intermediate glide in the whisper is so rapid that we only hear the low pitch followed legato by the high pitch. If, however, **wi** is whispered instead of **ui**, we hear what corresponds to a slurred grace-note introducing the high note.

24. What whispering reveals thus seems to have some bearing on the disturbing question, What is a syllable? We must remember with Sweet that the distinction between voice-leaps and voice-glides is only a relative one, which cannot always be made with certainty. But sometimes at least a legato can be distinguished from a portamento. In fact, the vocalist who does not habitually make the distinction must be a very rare bird. And when, as between whispered **u** and **i**, the interval is a big one, this test may be very well applied to discover whether two written vowel symbols stand for one syllable (a diphthong) or two syllables. Professor Viëtor enumerates four diphthongs in Standard German (Lesebuch^4, 1911, p. 3) where Jespersen (§ 394) finds only three, the fourth having come to light in *Hui* and *Pfui* (pronounced **hui** and **pfui** according to Viëtor's dictionary). To my ear spoken **ui** is two syllables. The **u** will not glide into **i** unless we go round a loop, so to speak, down over **ʊ** and then across mixed half-rounded territory to about **ɪ** and so up. But that takes time. At any normal speech tempo we have to take a short cut, it seems, and whispered **ui**, or **uɪ** as in *doing*, is heard to be a leap, not a glide,

the pitch changing legato, not portamento. Moreover, you cannot sing *doing* to a single note. A crotchet may be written, but it becomes two quavers, just as with any other two short syllables occurring in a song as a metrical alternative for the long syllable at the same place in another verse. Nor can you sing *doing* to two notes written with a portamento sign without actually singing three notes, taking two (with the voice-glide) for the first syllable. It is clear that **ui** or **uɪ** is two syllables.

25. But now, snail-like, a dilemma begins to put forth its horns. According to Jespersen's explanation, which I have always thought satisfactory since first reading his Danish *Fonetik*, in a disyllable there must be a passage through a minimum of sonority. But if **i**, **y**, **u** are the least sonorous vowels, how can there be a minimum of sonority between **u** and **i**? Does it mean that there should be another category between classes 5 and 6 in Jespersen's table (§ 394), to contain mixed vowels less sonorous than **i**, **y**, **u**? Of course, **ui** or *doing* may be spoken with one "impulse of force," and according to Sievers may be regarded as one expiratory syllable; but that does not explain, as far as I can see, why we hear *two* syllables. The dualistic or cock-eyed view of the syllable leaves me cold. If I fall down a flight of stairs, bump-bump-bump, it is little consolation to me to be told that I have only fallen downstairs once. Listening to the whisper-pitch affords a better clue. If **ui** is taken at a slightly slower tempo, the disyllabic effect need not be destroyed, but we can hear enough to be sure that the pitch rises continuously and covers all the ground. The rise in pitch must, in fact, if the rapidity of the

rise is constant so that we can ignore Father Time, be represented graphically by a straight line, the shortest distance between two points. In any case, the interval must be measured along a straight line. But if with Willis and the acousticians generally we hold that vowel-quality is a function of the pitch of the mouth-cavity, the identical series of vowel positions must be gone through whether the transition from **u** to **i** be made slowly or quickly, whether by a glide or a leap, since the rise in pitch is continuous. The road is the same, only the velocity is different. And we know the road already, having gone over it more slowly, but with the same continuous rise in pitch. We recognised vowel-regions which are less close, and vowel-qualities which are therefore more sonorous, than **u** or **i**. But the whisper at its source in the larynx, or the thoracic pressure, can be kept constant during the production of whispered **ui**; and if we attempt to sing successively and steadily **ɑː** and **ui** to the same note, we succeed with **ɑː**, but with **ui** the one note becomes two of the same pitch, and the effect upon the ear can only be imitated with **ɑː** by means of a new impulse of force (to use Sweet's term) or jerk or physem (to adopt Ellis's alternatives for the same thing). The **ɑː** becomes then two notes and two syllables, **ɑɑ** (*cf.* Passy's *a à aller*, etc.), both from the expiratory point of view and from that of sonority; while sung **ui** is also two notes and also two syllables (although one from the eccentric expiratory point of view), but *not* two syllables of sonority, if "sonority" has its acoustic meaning of amplitude of the air vibrations. In this case Jespersen's principle of sonority—which, by the way, would make of a trilled **r** as many syllables as there are trills—must be subordinated to the principle of relativity, which is taken into account by Sweet, although he does not use the big word, but defines sonority as the force with which sounds strike the sense of hearing (§ 148).

26. It seems, then, that the sense of hearing need not be affected in exactly the same way as, say, the diaphragm of a gramophone. In his admirable *Study of Speech Curves* Scripture is led to the conclusion that "in speech there is a flow of sound which cannot truthfully be represented by any spelling; there are no well-defined limits between neighbouring sounds —not only because the limits are vague, but also because there are no independent sounds to be limited," and, moreover, that "glide" is "merely a makeshift to help us out of the difficulties introduced by the erroneous view that speech is made up of a series of independent elements" (Carnegie Institution, 1906, pp. 42, 43). Now the quotation from Willis at the beginning of § 17 above shows that "glide" was first applied to speech-sounds, namely, to certain English vowels, to express the same conviction as Scripture extends over all elements of speech, including, we must suppose, silences, represented in the tracings by straight lines (*cf.* p. 45, "the straight line for" t). Scripture's doctrine, which is Willis's stated in an extreme and exaggerated form, is contradicted by his own tracing of a Chinese vowel in Plate VII., in which, in spite of the 150-fold magnification, neither the eye nor a pair of dividers can find any difference in form in a series of groups of vibrations sufficiently long to allow the ear to determine the pitch of the voice with great precision

(*cf.* Rayleigh, ii. p. 453), and therefore, presumably, to form some idea of a definite vowel-quality which would permit the use of a symbol. So, at any rate, if the Chinese chose to replace their ideographs by phonetic spelling, there would be nothing in Scripture's discoveries to stand in their way. Again, with regard to the diphthong in *without*, Scripture is doubtful, since the form of the curve changes steadily from beginning to end, whether we can hear definite qualities of vowel at the beginning and end of the glide. Similarly, for intonation in speech, the tracings show that the wave-length changes at every wave (p. 100, *cf.* p. 129). But Mr. Daniel Jones found that by lifting the needle from a speech record and noting the pitch last heard, he was able to map out his *Intonation Curves.* As I am in the habit of using copies of the same records, I can certify that comparing the sound with the curves makes the ear more appreciative of intonation. And any phonetician who has tackled his subject at the right end (*cf.* Sweet's Primer, p. iv) will recognise the varieties of the diphthong in *out* denoted by **ʌʊt**, **ɑʊt**, **aʊt**, **æʊt**, **ɛʊt**, to say nothing of monophthongic forms, as **aːt**, **ɛːt**, etc., all of which are to be heard between London and Devonshire. For him it would only be necessary to hear Professor Kuno Meyer, for example, utter such a word as *out* or *mouth*, dwelling too long, German fashion, **ɑˑʊ**, on too open an **ɑ**—in fact, with too much mouth—to know that England was not his home, any more than English was his nature.

27. My own experience with the Flemish diphthong in *huis* persuades me that the beginning and end qualities can be determined, and provide sufficient

data for a good rendering of the whole flow of sound. Having once learnt, with the help of Roorda's *Klankleer*^{3}, 1911, § 138, to analyse the vowel-glide, which had previously eluded me, into **œʏ**—this agrees with Donders, *Physiologie der Spraakklanken*, 1870, § 19—I found that my pronunciation of *huis*, *Bruyn*, etc., passed muster with several Flemish-speaking Belgian friends. The steady rise in the whisper-pitch, of about a tone, shows that the **œʏ** in Flemish *Bruyn* (Brown) is as certainly a monosyllabic vowel-glide as the name of the bear from *Reynard the Fox* (Caxton having retained the Flemish spelling) now contains a vowel-leap, **uɪ**, which makes English *Bruin* disyllabic.

28. Listening to the whisper-pitch is helpful in many respects. It affords a means of control which is free from any preconceived ideas derived from spelling, whether traditional or more or less phonetic, for you are listening, not to the speech sounds—though you may direct your attention thither at any instant you choose—but to a kind of musical accompaniment which keeps strictly to a parallel path. Whispering proves that if *pay* is **pei**, *pale* is not **peil**, but rather **peəl** or **peˑl** (understanding a back **l** and leaving the glide to take care of itself), because in **pei** there is a marked rise in pitch, but in *pale* a steady fall from the moment the glide to back **l** begins. It proves, too, that in the face of speech curves which show no two consecutive vibrations alike, the ear is able to detect sounds as from fixed positions, both for vowels and consonants; and when these are written down with such indications as to force, time, etc., as a good system of phonetic

notation can give, there is no more difficulty in joining them up with glides and leaps than a violinist finds in playing an air from musical notation. But you must "know your notes," at least, and although I am under great obligation to Dr. Scripture's books, I cannot allow that their author was in 1906 quite competent to estimate the value of phonetic spelling, since in Plate X. he transcribes "*Come*, Rip, *what do you* say to *a* glass?" with **ə** for five of the vowels (the words in italics), and is then astonished to find that the vowel curves in **kʌm** do not resemble those in **hwət** or in **ə** (p. 50). If in speech no two successive sound waves are alike, but there is a gradual [*i.e.* continuous] change from instant to instant (Scripture, pp. 41, 100), we can only conclude that the ear somehow, if the change is not too rapid, contrives to strike a mean, and does not interpret the vibrations in the same absolute fashion as may be attempted with the stationary tracings. Apparently a slow rate of change over a brief space of time may be ignored, while a very rapid rate gives the impression of diminished amplitude. What is wanted is a Lioretgraphe, and to approach the problem from its simplest side, eliminating variables where possible. By singing **ɑː** and then **ui** with the same quality of voice, the same pitch, loudness, and decrease of force, reproducing the sounds, and then examining the tracing, a phonetician with a good musical ear who has access to Monsieur Lioret's splendid machine might discover whether there is anything in the tracings to account for the disyllabic effect, the two quavers instead of a crotchet, the minimum of sonority which is apparent to the ear.

29. It must not be thought that if two diphthongs start from the same "fixed position," and their whisper-pitch changes continuously in the same direction, their course must be the same, along the same path of vowel-quality. Let us take, on the one hand, **ɑʏ** and **ɛʏ** (as in Swedish *Europa*), whose destination is "rounded," and on the other **ɑɪ** and **ɛɪ**, which on arrival are not rounded. The whisper-pitch of **ɑʏ** rises by nearly a fourth; that of **ɑɪ** rises from the same point, but goes higher, perhaps a major sixth. That of **ɛʏ** may fall slightly, but as I am now speaking and gently whispering it—I hope some of the Swedish phoneticians will set me right—does not change. I hesitate to denote the pitch for fear of being a couple of octaves out, but I think it must be about $g^3\sharp$. In **ɛɪ** there is a rise over about a major third, say $g^3\sharp$ to c^4 by the physical standard, $c' = 256$ v.d.

30. A particular vowel is usually associated with a given oral configuration having a given pitch. It does not follow that a given pitch must be associated with one single quality of vowel. Since the pitch of a resonator is proportionate to the square root of its conductivity over its volume (*cf.* Capstick, Sound, 1913, § 165), and both quantities are variable in the resonator which is the human mouth, it follows that as $\frac{6}{3}$ comes to the same thing as $\frac{8}{4}$, we may expect to find more than one vowel with the same whisper-pitch. Their existence was known to Sweet, who argues rather *a priori* that vowels of the same pitch resemble each other in quality (Primer, § 63). This seems to be a mistake; for although there may be a tendency to confuse the **ə** in *sir*, *err* with **œ** (§ 62), it is hardly

possible to confuse other couples which agree in pitch, not mentioned by Sweet. For instance, if you note the pitch of a whispered **yː**, say $b^3\flat$, you can readily find an **εː** to match it; or with **øː**, say $a^3\flat$, a more open **εː** well on the way to **æ**, with the same pitch; but no one confuses any **εː** with **yː**. If Willis had included front rounded vowels with his select English company, he might, it seems, have found certain lengths of cylindrical tube capable of producing or suggesting two vowels which when spoken appear to the ear to be quite distinct. Wheatstone seems to have done this, to judge hastily from his version of Willis's table, but on examination we find that the d^4 pipe which gave **ε** (Willis's Pay) is in line with **œ**, as **i** with **y**, and this can only mean that the vowels in the second column are added by Wheatstone to show what **ε e i** become if rounded. It cannot mean that **i** has the same pitch as **y**, **e** as **ø**, etc., for that would be a patent absurdity. Willis admitted that there was much room for the exercise of fancy, but to allow the same pipe with the same reed to sound now one vowel, and now another quite distinct from the first, would be giving fancy too much scope. But, even if this had happened, it would be rash to conclude that Willis was altogether on a false scent, for subsequent theory supposes some, if not all, vowels to have more than one resonance-tone. In the mixture which we call whisper, however, it is evidently the front cavity which generally gives the dominating tone.

31. One thing certain is that you may whisper an **ε** of a determinate pitch and by a continuous modification of the two variables, lip-aperture and mouth-

capacity, conductivity and volume, keep the pitch constant until what was **ε** becomes **y**, after passing through a theoretically unlimited number of vowel-qualities. Similar lines of equal pitch may be followed from a somewhat more open **ε** to **ʏ**, and from an **ε** still more open to **ø**. So that Mr. Shaw's Professor Juggins, with his regal and his 130 vowels, undoubtedly has his work cut out for him. I doubt if he is equal to the task of filling the gap between infinity and 130. It would be a more fitting enterprise for Mr. Shaw himself, whose powers of cognition are also theoretically, *i.e.* in his own conceit, limitless. If to this purpose he were to devote that super-wit of his, begotten, as the old parody of *L'Allegro* has it,

> . . . on heaps of bricks and mortar
> And ashes soaked in cabbage-water,

he would at least be kept out of mischief.

32. The rambling course of this chapter leads up to the observation that although the Rev. Robert Willis, M.A., Fellow of Gonville and Caius College—who when twenty-one had exposed the fraud of the automaton chess-player—was only twenty-eight when he composed his memoir *On the Vowel Sounds, and on Reed Organ Pipes*, he knew a thing or two. He saw that if vowel-quality is a function of the pitch of a resonance chamber, it is a continuous function. Since one vowel may glide into another, vowels are not like the harmonics of a note, for harmonics cannot glide. They *must* leap. It was not until he was revising his book for its fourth edition in 1877 that the light which Willis had clearly seen began to dawn faintly upon the intelligence of Helmholtz.

CHAPTER III

THE WHEATSTONE TEST

33. Suppose we whisper æ‿u slowly, and continue to lower the pitch of the resonator by pushing forward the lips until the whisper becomes a whistle. It will now be found possible to whistle down a tone or two lower, but more and more faintly. In this way we reach the lower limit of the mouth compass, and as the fall may be made continuous there is no difficulty in determining the interval between the lowest pitch and that of æ. I make it something less than two octaves. We must avoid starting above æ, because with ε the vowels with double resonance-tones begin, according to Helmholtz, and we want to keep clear of complications. Now let us note that lowest semblance of a whistle, and pitching the voice on that note—whatever may be its place in the tablature—let us say æ‿u in a monotone, instead of letting the voice drop as it naturally would, with the larynx sinking slightly as the tongue is drawn back. The performance presents no difficulty whatever, but considerable interest; for if the resonator in question has a range of less than two octaves, it can only respond fully to two harmonics of the note which is in unison with its lowest pitch. For

the sake of plain argument, let us say that its range up to **æ** is just two octaves. Then the only harmonics (or harmonic upper partial tones, to substitute with Ellis several words for the one which was quite clear before Helmholtz appeared on the scene)— the only harmonics of the glottal note which can be reinforced by the mouth-cavity are the octave, the twelfth, and the double octave. It is therefore as plain as a pikestaff that vowels are "not like the different harmonics of a note," for if they were it would be impossible for anyone to sing more than two distinct vowels between **æ** and **u** on or above the lowest note he or she can whistle. But the most modest phonetician can distinguish and utter many more varieties than three on the line from **æ** to **u** at any pitch within his or her registers. Who but the mechanicals does not know **æ a ɑ** (two or three varieties) **ɔ o ʊ u**? How many distinct vowels Higgins places along this line, or Trautmann, I cannot say, but there really is no limit, except in the sensitiveness, real or imaginary, of the phonetician himself. Wheatstone was aware of this fact. When discussing Willis's table he admitted that between the usually pronounced vowels "practised ears might distinguish others, intermediate in each series; for each vowel may pass to the next in order, either above or below it, by [Willis's "almost" is omitted] imperceptible gradations." The vowels of any language or dialect may be regarded as an arbitrary selection from endless possibilities. This little matter was made plain for us by the great precursor of Newton, Dr. John Wallis, Savilian Professor of Geometry, who invented the symbol for infinity, ∞, and introduced the principle of continuity into mathematical science (see Dictionary of National Biography). In the *Tractatus grammatico-physicus, De Loquela*, prefixed to his *Grammatica linguæ Anglicanæ*, Oxford, 1653, he writes: Non nego tamen, in qualibet vocalium sede, ubi ego tres tantum gradus aperturæ proposui, fieri posse, ut plures fortasse, vel nunc dierum alicubi, vel saltem posteris aliquando seculis, observentur; adeoque posse sonos quosdam intermedios efferri . . .: *est enim aperturæ mensura, instar quantitatis continuæ, divisibilis in infinitum.* Ut enim, in ventis enumerandis, olim quatuor, deinde duodecim, tandem triginta duo numerantur: ita etiam, cum Arabes, et forsan Hebræi antiquiores, non nisi tres vocales (hoc est, in singulis sedibus unam) habuerint, nostro autem seculo in singulis sedibus saltem tres manifeste distinguendas observemus; quid impedit, quin posteri etiam hisce intermedios quotlibet interponant?

34. The *London and Westminster Review* for October, 1837, contained a wonderfully interesting article, signed "C. W.," on talking-machines, ancient and modern, and on Willis's work on vowel sounds, which the writer thought might be associated with the phenomena of "multiple resonance" recently investigated by Professor Wheatstone—who was no other than "C. W." himself. The view put forward in this paper is, to say the least, difficult to harmonise with the conclusions of Willis, who held that "each vowel was inseparable from a peculiar pitch" which may be, and generally will be, inharmonic to that of the reed in his artificial vowels, and to that of the glottal note in natural vowels. From various

experiments Willis inferred that cavities yielding (when sounded independently) an identical note "will impart the same vowel-quality to a given reed, or indeed to any reed, provided the note of the reed be flatter than that of the cavity" (Rayleigh, ii. p. 470). Wheatstone explains the meaning of the well-chosen term, multiple resonance*:—"A column of air will not only enter into vibration when it is capable of producing the *same* sound as the vibrating body which causes the resonance, but also when the number of the vibrations which it is capable of making is any simple multiple of that of the original sounding body, or, in other words, if the sound to which the tube is fitted is any harmonic of the original sound." When the two systems have the *same* pitch, on the other hand, we have the well-known "simple or unisonant resonance," exemplified by a tuning-fork "placed at the embouchure of a flute, the apertures of which are stopped, so that, if blown into, the flute would sound the same note; in the latter case the experiment is more remarkable, as the sound of the tuning-fork is scarcely itself audible. The same effect takes place when the cavity of the mouth is adjusted so as to be in unison with the tuning-fork" (1879 reprint, p. 358).

35. We must beware of interpreting Wheatstone by the light—which in my opinion is rather darkness visible—of Helmholtz, who, after repeating Willis's experiments in his own "masterly fashion," immediately improved upon them by using "properly

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* Already long in use, though in a less definite sense. *Cf.* D'Alembert, 1762, quoted in § 76 below.

tuned resonators" harmonic to the reed (p. 117). Helmholtz, we see, after reading Wheatstone's paper, jumped to the conclusion that what was required in order to obtain perfect artificial vowels was a maximum of multiple resonance, an idea which had been considered and rejected by Willis. It will be clear in time that this was not quite Wheatstone's opinion either. Here it will be better to let Wheatstone speak for himself. On p. 359 of the reprint he describes a very curious art or accomplishment, which has recently been re-discovered, quite independently, by Mr. Daniel Jones :—" About two years ago a young man named Richmond exhibited a novel kind of musical performance with the voice. On examining the circumstances under which the sounds were produced, it was ascertained that the continued sound or drone was produced by the larynx, and that he had acquired the art of adjusting the cavity of the mouth so as to fit it for resounding to any multiple. In this way he was able to command these subordinate sounds in any succession, and even to dwell upon them; and he could thus perform a great number of airs." It is to be observed that there is no mention of any change of vowel-quality. The different harmonics (or upper partial tones) of the glottal note were reinforced in turn by specially attuned resonators—the mouth-cavity in various adjustments. The result was not, as it should be by the Helmholtz theory and *ad hoc* experiments, a series of different vowels, but a series of musical notes without any suspicion of vowel-quality. Wheatstone's next paragraph, I must admit, seems contradictory. He states that wherever these subordinate sounds of multiple resonance can be distinguished, there also the vowel-qualities are heard; but here he was thinking no longer of Richmond, but of the jews'-harp, which may indeed be played while in and out breathed vowels are sounded. He then continues with reference to Willis:—"We do not mean to assert that each multiple resonance is a distinct vowel sound, but we infer that when a tube is added to a reed or a vibrating tongue, whatever may be its length, a quality is added to the original sound which depends on the feeble vibrations of the air in the added tube. These increase in number in proportion to the shortness of the tube; and when the number of vibrations thus excited is any multiple of the original vibrations of the reed, the energy of the resonance is so greatly augmented as to produce the effect of a super-added musical sound. Thus it is evident that the vowel-qualities and multiple resonances are different forms of the same phenomena." The conclusion is somewhat sudden, but in relation to the facts adduced, and as far as it goes, its propriety cannot be questioned. Different, yes; but how different?

36. It must here be said that all the acoustical investigations of vowel sounds suffer from a grave defect—an incomplete collection of material. All acousticians without exception, as far as I have been able to review their voluminous and scattered contributions, draw the same line as the aphonetic grammarian between vowels and consonants. Yet it is evident that all those consonants which Ellis calls vocals, and Sweet vowel-likes, such as **m**, **n**, **ŋ**, **b̩**, **d̩**, **g̩**;

more than one variety of **l** and **r**, etc., are from the acoustic point of view vowels, just as much as AEIOU, being continuous voice modified by supraglottal cavities or resonance chambers and their walls. Some of these chambers have no exit—they are airtight; but that does not matter—they are not sound-tight. The vowel-likes are, as a class, less sonorous than any vowel proper. Any one of them coming between vowels reduces the voice to that relative minimum of sonority which means a boundary between syllables. It is, therefore, convenient in grammar to call them, not vowels, but consonants. But until the acousticians have a theory to explain, *e.g.*, the difference between **mː** and **nː**, they cannot be considered to have got into close touch with their problem. Helmholtz, completely at sea, says that there is no real difference between **mː** and **nː**, because both are approximately "simple tones" (p. 117). And, perhaps, it was on this account that Koenig's manometric flames failed to detect any difference (Acoustique, p. 68). The normal ear, however, does not fail to distinguish a note which is hummed, with closed lips, from the same note intoned with the lips parted and the tongue in the *n* position; and this without any help from lip-reading or from the on- or off-glide.

37. The state of things is this. Willis and Wheatstone had approached the threshold. Then come Helmholtz and his followers, who proceed to batter and bawl at the door which he himself has banged, barred, and bolted. His answer to the question, How different ? is—Not at all. You think, no doubt, that **mː** is a different sound from **nː**, but it is not.

"It is only at the instant when the cavity of the mouth is opened or closed [the off- or on-glide] that a clear difference exists between these consonants" (p. 117). And the humming tone is very like uː (p. 116); "in humming, the peculiarities of the U tone are much enhanced" (p. 117). But the U tone is a "simple tone," reproduced by a single b♭ tuning-fork provided by the munificence of King Maximilian of Bavaria (Preface to H^1), the fork being driven by electricity :—"In this higher series of forks the prime tone b♭, when sounded alone, reproduced U" (p. 123). Professor M'Kendrick has heard the b♭ fork say uː— "We have performed many experiments with this apparatus, and find the results obtained by Helmholtz to be consistent with our experience" (Schäfer's Physiology, ii. 1900, p. 1218). No doubt, then, Professor M'Kendrick has much enhanced the peculiarities of the simple tone U of the b♭ fork, and made it hum as well. The tuning-forks used by Helmholtz gave "simple tones," and, by p. 289, tones whistled with the mouth are also simple tones. So there you have the exquisite Helmholtzian reason why nobody in his senses ever mistakes a hum for a whistle, and why Professor M'Kendrick, for all I know to the contrary, has heard a b♭ tuning-fork hum, whistle, and say uː all in the same breath. A mad world, my masters.

38. When Wheatstone wrote the words "a superadded musical sound" he gave an accurate description of the effect of Richmond's performance upon the ear. If the listener is not allowed to see the performer's lips, he will not hear any vowel or vowel-like other than a continuous ŋː. At a later stage (§ 60) I shall

describe an experiment by which anyone with a fair sense of pitch can convince himself—without any apparatus beyond that which Nature provides, the organs of hearing and of speech—that when a multiple resonance in the mouth-cavity approaches its maximum and is heard as a note, that note does not enter into the vowel-quality which may be heard together with it, but stands rather in chordal relationship with the fundamental tone of the glottal note. In other words, it modifies the quality of the voice, not the vowel. To a practised ear this resonance-tone may sometimes appear absurdly strong, sounding almost like a hooter, with a disturbing, unpleasant effect. It is then comparable to what is sometimes called the "blasting" in a gramophone, where a piece of music is performed in a key harmonic to the natural rate of vibration in some part of the machine, and either by simple or multiple resonance a certain tone is so much reinforced as to become disproportionately loud. If this fault lies in the reproducer and not in the record itself, it may be corrected by a slight change of tempo. The difference of a few revolutions of the disc in a minute brings about a marked rise or fall in pitch, and puts the unwelcome resonator out of tune. Similarly, the mouth resonator may be put out of tune by a slight change of adjustment and of vowel-quality; or, without altering the vowel, by singing some other note. The "super-added musical sound," audible as a tone or note, is not vowel-quality, which, if related to multiple resonance at all, is, as Wheatstone says, "a different form of the same phenomenon." The fixed pitches determined by Willis, to take only the first three, c″, e″♭, g″, which were approved by Helmholtz, do not lie in a harmonic series unless we take a fundamental absurdly low, below the range of even the adult male speaking voice, *sans compter les femmes et les petits enfans.* Harmonics 8, 10, and 12 of C (64) are c″, e″, g″. To bring in the e″♭ we must go down lower. With a C_1 (32)—below the limit of tones with definite pitch, according to Helmholtz, p. 177—the three might stand as harmonics 16, 19, and 24; but with resonators applied to the ear Helmholtz could not distinguish harmonics above 16 even in a powerful bass voice singing ɑː (p. 103). I wish, then, to suggest that the view which Wheatstone had adumbrated was that vowel-quality is produced in a resonator by some modification of the generating note due to changes of amplitude and phase in the "secondary pulsations" of Willis. Knowing what he did, having heard multiple resonance at its maximum under precisely those conditions which Helmholtz subsequently required by theory for the production of the most distinct vowels, and failing to detect any vowel-quality or change of vowel-quality whatever, he could not have anticipated the Helmholtz view without, on further thought, rejecting it. Helmholtz grasped as much as he could carry away from both Willis and Wheatstone, but if he grasped the general principles which had been deduced or divined, it surely was by the wrong end.

39. As we have seen, Helmholtz divided speech sounds into two classes, vowels and consonants, following the grammarians. To call certain vowels musical sounds, and to relegate others, with hisses, buzzes, silences, clicks, etc., to the category of noises

(p. 117), is to behave in an arbitrary way. In sound it is not possible to draw a hard-and-fast line between musical notes and noises. "The essential difference is that musical notes have a recognisable pitch, while noises have not; but few noises are entirely devoid of musical pitch, and few musical notes are devoid of unmusical noise" (Capstick, § 7). The spoken words "terrible nonsense" are all vowel in the acoustic sense but for three hisses (one a plosive), all three of which have a certain element of pitch. But Helmholtz had his plan. The perception of musical sounds he located in the fibres of Corti, regarded as a kind of miniature piano. In H^3 it was found necessary to shift the piano, its position having become, as we say, untenable. The perception of noises he placed elsewhere. The otoliths—which he calls *Hörsteine* (for *Ohrsteine*, "hear-stones" for ear-stones), someone having made a blunder, not without parallel in the wonderful German language, in turning the learned word into a "popular" one—he supposed to be specially interested in noises. In H^4 the popular *Hörsteine** no longer have anything to do with auditory sensations, and there is no longer a clear boundary between notes and noises (Ellis, 1885, p. 151). Nevertheless, on p. 117 the same consonants as in the earlier editions remain "noises, which have no constant pitch, and are not musical tones"; whereas the vowels, which were eight, and have now, unlike the little nigger boys, increased to nine, by the addition of the OU discussed in § 20

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* In a *New German-English Dictionary*, which is a mere glossary, by a "Lecturer of German," *Hörstein* is said to mean "otolite." Thus knowledge grows.

above, are musical sounds still, coming under the strict jurisdiction of Ohm's Law, and analysed by the ear into their simple harmonic components in accordance with Fourier's theorem.

40. These simple harmonic components, the fundamental tone and the upper partial tones, " are perceived synthetically, even when they are not always perceived analytically. But they can be made objects of analytical perception without any other help than a proper direction of attention" (p. 65). Yet Helmholtz does not despise other help. " Without the help of resonators, I should scarcely have succeeded in making the observations hereafter described with so much precision and certainty as I have been able to attain" (p. 44). " My own attempts to discover the upper partial tones in the human voice, and to determine their differences for different vowels, were most unsatisfactory, until I applied the resonators" (p. 52). But on p. 128 his success with artificial vowels leads Helmholtz to repeat that the ear " decomposes every wave form into simpler elements according to a definite law. It then receives a sensation from each of these simpler elements as from an harmonious tone. By trained attention the ear is able to become conscious of each of these simpler tones separately" (p. 128). An incalculable amount of trained attention has been given to the analysis of vowel and other sounds. No ear has ever become conscious of each of the simpler tones which are said to make up vowel sounds. The tracings from phonograph and gramophone records of speech, when the vowel curves are most laboriously subjected to the Fourier analysis into a series of sine-

curves, show that the fundamental tone—which gives the pitch of the voice, is reproduced by the machine as long as the record is any good at all, and can be heard when the vowels can no longer be distinguished—is usually lacking. One investigator was led to the remark that "the phonograph must be deaf to the glottal tone," although it certainly is not dumb (*cf.* Scripture, p. 109). Another explanation for the absence of the chief tone, the fundamental, proffered by Professor Hermann (a German), is that although it does not exist objectively in the tracings, it is heard subjectively, being developed in the ear after the manner of combination tones (*cf.* Rayleigh, ii. p. 477).

41. After misunderstanding Wheatstone, and making better vowels than Willis by using resonators which, when sounded independently, were of pitches harmonic to the reed, Helmholtz demonstrated the correctness of the view which had taken hold of him by means of apparatus designed for the purpose. Having ascertained the fixed pitches of certain vowels with "so much precision and certainty," he combined, in suitable strengths, the tones of a harmonic series of eight electrically driven tuning-forks, the fundamental of the series being either B♭ or b♭. "These experiments are difficult, and do not appear to have been repeated. Helmholtz was satisfied with the reproduction in some cases" (Rayleigh, ii. p. 477). But Professor M'Kendrick repeated them and was also satisfied. As has already been remarked in § 37, this uncanny Scot heard the b♭ tuning-fork say **uː**, and when that is done the rest is easy. "Much depends, in the appreciation of this experiment, on careful

attention, practice, and a good ear" (p. 1218). Professor M'Kendrick can have had but a poor sense of the ridiculous. However much careful attention is needed to analyse a vowel, little is necessary to recognise what Ellis calls generic vowels, as A O E, presented synthetically to the ear. No practice is required. The unpractised ear is only too ready, as language teachers know, to recognise as familiar vowels foreign qualities which only approximate to the sounds substituted for them. Generic vowels are recognised even in caricature. As Willis observed in 1828, even a parrot, or Mr. Punch, in speaking, will produce A's and O's and E's which are distinctly A's and O's and E's (p. 234). And if by a "good ear" is meant a good musical ear, the suggestion is utterly false. The best linguist I know is what musical people call tone-deaf. More documentary evidence might be brought forward showing that the imposing apparatus provided by royal munificence must be classed with the celebrated head of Memnon, of which Wheatstone recalls that "though in general it emitted only a musical sound, when the morning sun touched its lips, yet it is proved, by inscriptions engraven on the colossus, that the priests, proportioning the miracle to the credulity of the votaries, caused the statue sometimes to speak."

42. Ellis in his early dealings with Helmholtz was one of these credulous votaries. When a large bottle tuned to b♭ was made to speak it said **uː** and with a smaller one tuned to b′♭ blown by the same bellows, the combination of the two simple tones gave **oː** (p. 61). The synthetic vowel **oː** was a combination of two tuning-fork tones b♭ and b′♭ together with a weak f″ (p. 123). Curiously enough, Ellis heard the same effects with two tuning-forks c′ and c″ (p. 61). Is there, then, no special virtue in *B* flats? Is tuning-fork timbre in general uː timbre? If so, why fix U in the table at f, and OU at f′? More curious still, the fact was unknown to Helmholtz that "if a fork be employed after the manner of musicians with its stalk pressed against a resonating board, the octave is loud and often predominant" (Rayleigh, ii. p. 463). And Koenig found it unsafe in 1881, if a simple tone were desired, to use a tuning-fork mounted on a resonance-box, which seemed to favour the production of the octave (Acoustique, p. 152). Helmholtz assumed that his forks gave simple tones, and so he never heard the uː of his b♭ fork change to oː, although the note of this fork must frequently have had the same composition, b♭ and b′♭, as his oː from bottles. After immense experience in phonetics Ellis placed on record his conviction that there is much more to be learnt before spoken vowels can be satisfactorily imitated. This was after failing to hear in the synthetic vowels of Preece and Stroh, 1879, "any exact form of human vowel" with which he was acquainted, although he had made speech sounds an especial study for more than forty years, and although "there are really millions of different qualities of tone all recognised generically as the same vowel" (p. 543). And yet he still believed, as did Auerbach in 1909 in spite of Scripture, so deep was the impression made by Helmholtz, that harmonic partials in varying strength, causing different qualities of musical tone, are the foundation of vowels. And indeed no other view seems possible as long as the Helmholtz theory of audition blocks out the daylight. That pianoforte in the internal ear has got to be removed.—Well, we must have patience.

43. If by trained attention the ear is able to become conscious of each of the simple tones composing a vowel sound, the most direct method of performing the analysis would be to train the attention, do it, and have done with it. We should then be freed from the unending fiss-fass-fuss of this question. But this, it seems, is not the way of *Wissenschaft*. It was not the way of Helmholtz, who treated the problem, if we are to believe M'Kendrick (p. 1217), "in his usual masterly fashion." Since Auerbach thinks it worth while (p. 688) to claim the tapping test for himself, whatever credit attaches to the Wheatstone test should go to its originator, for it is plain, from the last sentence quoted in § 34 above, where Helmholtz got the idea from. To quote the latter through Ellis (1885, p. 106):—"If a b′♭ tuning-fork be struck and held before the mouth while O is gently uttered, or the O position merely assumed without really speaking, the tone of the fork will resound so fully and loudly that a large audience can hear it."

44. This statement requires to be examined. The resonator for vowels from **uː** to **aː** is here regarded as a single unbroken cavity extending from glottis to lips (p. 106), that of **ɑː** being shaped like a funnel, **oː** and **uː** like a bottle without a neck, and with a narrower mouth for **uː**. From **ɛ** to **i**

there are two resonance-tones (p. 107). (Helmholtz did not know **æ**, *cf.* § 16 above, and probably, like Sweet's German, would have pronounced "cab" as **kɛp.**) Among the numerous hollow vessels which reinforce a c″ fork, I find that a certain small brass pot is an excellent resonator, better even than a glass cylinder tuned to its maximum of resonance by pouring in water, as recommended by Tyndall. It is more convenient to experiment with. When a hole was drilled in the bottom of this pot, it was converted from an excellent c″ resonator into a second-rate one. With the pot fixed in a vice, and a finger alternately stopping and unstopping the hole while the fork was held steadily over the mouth of the pot, the sound was observed to swell out and diminish to such an extent that one might describe it in phonetic parlance as divided into syllables of sonority; and when the fork had become inaudible with the hole uncovered, it again resounded when the hole was stopped. This is much as was to be expected, for it is necessary to close the nipple of a Koenig's brass resonator in order to obtain a powerful sound from it, when a suitably tuned fork is presented to it (Rayleigh, ii. p. 217). By pushing the end of a rubber tube into the hole the resonance of my brass pot is to a great extent restored, but when I send a current of breath through the tube the tone diminishes, and becomes louder again when I cease to blow. This again is not surprising, for there is not equally good resonance when there is appreciable motion of the air inside the resonator (Capstick, p. 133). But what is surprising is that Helmholtz, if he knew these things, did not apply his knowledge. For if in place of the brass pot we consider the ɑː funnel cavity, or the oː bottle cavity, extending from the lips to the glottis, it is clear that the fork found suitable with the glottis closed would not sound so loud with the glottis open, if indeed in the latter case any tuning-fork whatever would be so much reinforced as to become audible throughout a lecture-room. When the hole in the brass pot, or the nipple of the Koenig's brass resonator, is open, no change of tuning-forks would bring back the same intensity of resonance; it is not so much that the fork is unsuitable as that the leaky pot is no longer a good resonator. When Helmholtz thus found the pitch of ɑː to be b″♭, it would seem therefore that his glottis must have been closed. But from the passage quoted above this was evidently not the case, for he claims maximal b′♭ resonance while oː was being uttered, as well as for the oː position merely assumed without really speaking, *i.e.* while he was "quietly" breathing in the Sievers manner, through the mouth (*cf.* § 7 above). Since with either voice or breath there is appreciable motion of the air from the glottis up, Helmholtz could not in this way have attained the maximum of resonance. If he had held his breath, it seems, he might have impressed an even larger audience.

45. Plainly there is something wrong, but to procure a b′♭ or b″♭ fork and fail to produce the effect described by Helmholtz would invite the rejoinder that one's oː or ɑː is not of the right quality. An ordinary Philharmonic c″ fork will help us out of the difficulty. It is very easy, if you breathe through the nose, to find the exact oː position of the lips

which will give full resonance to the vibrating c″ fork presented to the aperture, so that it may be heard throughout a lecture-room; but if while keeping the lips in the same position you sound the **oː** with either voice or whisper, or breathe out ever so gently through the mouth, there is no resonance worth mentioning. Or if, while continuing to breathe in just the ordinary way, through the nose, you alter the shape of the lips—changing the conductivity this time—the resonator is put out of tune. Teachers will find this application of the Wheatstone test of great practical value, not in trying for "inherent pitch," but in making clear the distinction between a vowel and a diphthong or vowel-glide, which is much obscured in pupils' minds by the orthography of English, or French, or German; and particularly in teaching English students of foreign languages not to substitute any kind of vowel-glide **ou** for an **o** or **oː**. It is true that in Southern English, in *note*, etc., the tense **o** often does not occur at all, the vowel-glide beginning "mixed" and ending "wide"; but if the pupil succeeds in getting loud resonance with a c″ fork, it must be with an **oː** lip-position, and if the lips close up towards **u**, the rapid diminuendo in the sound of the fork will show him how to keep a "fixed position," as for **oː** in German *Not*, **noːt**. Most teachers have a c″ tuning-fork. The exact pitch, whether High or Low Philharmonic, does not matter.

46. There is a very instructive toy musical instrument, made in New York and "protected by patents," called the Humanatone. The same instrument has recently been imitated or re-invented in Germany, is made in Berlin (*cf.* A. Musehold, Akustik und

Mechanik des menschlichen Stimmorgans, 1913, p. 40) in an inferior quality, and sold as the Wunderflöte. It collects the breath from the nostrils and conducts it as a sheet of air over a rectangular opening in a flat piece of metal which fits over the open lips. The air in the mouth being set in vibration gives ocarina tones over an extreme range of some 2½ octaves, rising from about g′. The instrument is not well adapted for an iː position of the lips. The average boy, when he has once realised that he must not try to blow, but must simply breathe through the nose, will learn to play a tune on the Humanatone with a rapidity which ceases to astonish when one reflects that most boys have already learnt to adjust the pitch of that homely resonator, the mouth, by flipping their cheek, tapping the teeth, or allowing the breeze to play across their open lips, or in fact, on a somewhat different scale, merely by whistling. Putting my lips in what I judge, after considerable practice, to be the best position for reinforcing a Low Philharmonic c″ fork, and applying the Humanatone, I invariably find, on sounding the fork subsequently, that the pitch of the mouth-cavity is about a semitone below the c″ fork. I am so confident of this result that I have more than once performed the experiment before an audience, and as I have no sense of absolute pitch, I believe there is no illusion, as there doubtless would be if I knew the pitch of the fork before testing that of the mouth. But the point to be pressed home is that the Humanatone cannot be made to utter its cuckoo-like tones except when the soft palate and the tongue in conjunction close the back of the mouth.

47. Having discovered a simple artifice by which the soft palate may be fixed up against the back of the pharynx and so kept clear of the tongue, I endeavoured to determine the difference of pitch for the same oː lip-position when the passage into the pharynx is (1) open and (2) closed. With the nose passage closed it is, of course, impossible to supply the air-current from the nostrils. I therefore had a Humanatone reconstructed so that the force to set the air in mouth and pharynx in vibration could be taken from a bellows. I expected (1), with a greater volume of air, to give a deeper note than (2), but found that (1) gave a very poor tone, with much windrush, the pitch being *about a fourth higher* than the ocarina tone which ensued when (2) the soft palate was allowed to drop down into the position of rest. The higher pitch of (1) shows that it was not that of the whole funnel or bottle from lips to glottis, but rather that of the mouth-cavity acting as a resonator with two mouths. It is calculated that if a resonator has two equal openings so far apart as not to interfere with each other, its pitch is nearly a fifth higher than if one of the openings is closed (*cf.* Capstick, § 166). With a well-regulated bellows and a suitable pressure the Humanatone pitches of the mouth open and closed at the fauces might perhaps be determined with some accuracy, but all I claim for my rough experiment and the interval of a fourth with rather exaggerated protrusion and rounding of the lips for oː is that it demonstrates something already beyond doubt, namely, that the tuning-fork which arouses strong resonance in a mouth-cavity closed at the fauces will not be noticeably reinforced

when the lip-position remains the same but the cavity has an opening into the pharynx. Further proof could be furnished in this way: it only takes one hand to fix the soft palate—I leave the reader for the present to guess how it is done—and if the c″ fork is presented with the right hand as before, no shaping of the lips will now produce resonance comparable to that which Wheatstone remarked upon. Helmholtz must have been a poor experimenter not to notice that the Wheatstone test and that of Donders, applied successively to the same lip-position, do not agree. The whisper pitch differs widely from that of the fork, and the approximate interval can be determined. As to the interval of about a fourth, it agrees with that between the lowest g′ of the Humanatone and the lowest clear whistled note, if this is c″. In whistling the resonator has two mouths, of course. But as Helmholtz claimed to whistle f, a twelfth below c″, the absolute pitch of the mouth-cavity is somewhat queered, and the question must be deferred. See § 56 below.

48. It was necessary to fix the soft palate, because otherwise one is constantly deceived. The soft palate meets the tongue whenever it has the chance, and without telling you anything about it. It is a regular trap. Wheatstone seems to have kept clear of it, but Helmholtz allowed himself to be caught, and after him Koenig, Rousselot, and others. When Helmholtz made the b′♭ fork resound loudly, it must have been when the **oː** position was "merely assumed"; and when he claimed to get the same resonance of b′♭ while gently uttering the same **oː**, he was the victim of an illusion. His results, b′♭, b″♭,

$b^3\flat$, for oː, aː, eː, seemed incontestable to Koenig, who, with the help of his own excellent tuning-forks, added b♭ for uː and $b^4\flat$ for iː, and guessed that these five vowels must always be found in the different languages because of the simple relation between their pitches, just as the same musical intervals exist in most parts of the world (Acoustique, p. 43). It has already been pointed out that Koenig's si$\flat_3$ is not exactly the b′♭ of Helmholtz, being nearer to the latter's a′, but the great measure of concord in the results of these two eminent investigators is impressive on paper (*cf.* Rousselot, Principes, p. 743) until we remember that whereas Helmholtz found the pitches of imaginary funnels and bottles extending from lips to glottis, Koenig's pitches are those of "la cavité *buccale*, disposée pour articuler une voyelle" (p. 42). Further, it did not occur to Koenig that his resultant series of octaves is singularly unfavourable to the theory of multiple resonance as the basis of vowel quality. As the ear is apt to err by an octave or even two in comparing different musical sounds, *e.g.*, a whistled with a hummed note, so these five *B* flats or *si bémols*, with their strong family likeness—they are all sib, one might say—would seem to show that the five most distinct vowels are, after all, much of a muchness, and we are farther than ever from a solution of the famous question propounded in 1779 by the Russian Academy, "What is the nature and character of the sounds of the vowels A E I O U, so different from one another?"

49. But for Abbé Rousselot, armed with his Koenig's *diapason à poids glissants* and Willis's idea (ascribed to Helmholtz) of determining dialectal

variants—particularly of ɑː, in which a very slight change, as Donders observed, may be significant (the observation is ascribed to Helmholtz)—by the pitch of a resonance-chamber, by means of the Wheatstone test (ascribed to Helmholtz), to traverse France from Paris to the Vosges and to the Pyrenees was but a step. The ɑː, which in Paris has an inherent pitch or proper tone of 906 v.d., rises to 907 v.d. in the Vosges, and up to 918 in the Pyrenees (*cf.* Rousselot and Laclotte, *Précis de la prononciation française*, 1913, p. 47). The difference of a single vibration, 906 and 907, corresponds to an appreciable difference in the quality of the vowel. This is, indeed, precise. No more of Koenig's round numbers, with 900 v.d. in place of the 896 of North German ɑː. We can now locate Helmholtz's North German ɑː, 932 v.d., by the same highly scientific method, somewhere in the Bay of Biscay. Give Higgins a Bellman's chart of the ocean, and he'll put his finger on the very spot.

50. Rousselot's description of the way he went to work shows plainly the deplorable influence of Helmholtz. You put the mouth in position for the vowel (on dispose la bouche pour la voyelle), present the tuning-fork, and without changing the organic movements . . . (Principes, p. 752). But p. 713: When the mouth is in position for ɑː, neither the uvula nor the pillars of the fauces are visible, being hidden by the tongue; but at the moment of the articulation of the vowel, the soft palate rises. . . .

This indicates a certain advance on Koenig, who thought the mouth giving resonance to the fork was "disposée pour articuler une voyelle" (p. 42).

But it is hard to see what is to be learnt from the pitch of a cavity which admittedly changes shape and volume when the vowel is articulated. And there is no accurate method of measuring intensity by ear, though Rousselot, by long practice, may have found it satisfactory to wait with the mouth so disposed until the fork becomes inaudible, and then to conclude, if the fork is inaudible when brought to the ear, that the right pitch is found. There are, meanwhile, certain organic movements. What are they? Evidently the subject is to be allowed to breathe while waiting upon the quiescent fork. But if he breathes "quietly" in the Sievers or adenoidal manner, through the mouth, the resonator does not work well. And if he breathes with his uvula, etc., hidden by the tongue, the tongue will form a perfect closure with the soft palate. This is proved by inspection, with the mouth illuminated as in § 1. The reader will be able to convince himself that it is so, no matter what the exact quality of *a* his mouth is "disposed" for. He will find on raising the soft palate and lowering the back of the tongue, gently, holding the breath, that the faucial aperture is covered by a transparent film, which could not form unless the interstice between tongue and soft palate had been completely occupied by saliva.

51. In the 1913 *Précis*, Rousselot is aware that the pitches determined so precisely are, like those of Koenig (p. 42), and of Helmholtz according to M'Kendrick (p. 1217), the pitches of the mouth-cavity. The ground has shifted in some extraordinary manner. So now let us go back. The original problem as it presented itself to Helmholtz's mind was by means

of the Wheatstone test to find the pitch of a resonance-cavity. The pitch thus found would indicate what harmonic of the glottal note, its intensity being exalted in a special degree by multiple resonance, gives a certain vowel its characteristic quality. There need not be coincidence, the vowel **ɑː** will be **ɑː** if the proper tone of the cavity is "near enough" (p. 110) to any harmonic to strengthen it. The ear, we are told, can by trained attention and Ohm's Law hear each harmonic of a note, and when assisted by the special Helmholtz resonators does so wonderfully well. *A fortiori* the harmonic which is so much strengthened cannot possibly escape detection. Nevertheless, to make assurance doubly sure, the tuning-forks are brought in, and the problem, which is a theorem, is treated in "masterly fashion." It is required for **ɑː** to find the pitch of a funnel-shaped column of air extending from the lips to the glottis; and also to prove that it is b″♭. As a plain matter of fact, Helmholtz went at this problem like a bull at a gate. To obtain maximal resonance, there must be no appreciable movement of air in the funnel: you must not utter voice, whisper, or breathe. The funnel must be closed at its narrow end: the glottis must be closed. Good. Now you set to work. You take a hammer and beat in the sides of your funnel so as to give it a false bottom somewhere about half-way down: you close the fauces. Then you bring along the tuning-forks to find the pitch of your original funnel. You seek it as the Snark was sought, with forks and hope; and what you find you give to an admiring world of *Wissenschaft*, in explanation of the quality of note emitted by your funnel before it became no funnel, under the impulses of a reed acting at its lower end, ignoring utterly the very peculiar nature of its walls, unlike those of any musical instrument. The same performance is gone through with the oː bottle, etc. The Helmholtz theory of vowel quality (down to H^3, 1870) is then summed up thus:—"Vowel qualities of tone consequently are essentially distinguished from the tones of most other musical instruments, by the fact that the loudness of their partial tones does not depend upon their numerical order, but upon the absolute pitch of those partials; thus, when I sing the vowel A (ɑː) to the note E♭, the reinforced tone b″♭ is the twelfth partial tone of the compound; and when I sing the same vowel A to the note b′♭, the reinforced tone is still b″♭, but is now the second partial of the compound tone sung" (1875, p. 172, through M'Kendrick, 1900, p. 1218). What happens when, *e.g.*, a soprano sings oː to any note in the treble stave, above b′♭ and not "near enough," is not explained. Perhaps the note is subjective and the vowel objective, or the other way about.

52. Rousselot's pitches would have a positive value if the opening into the pharynx could be considered constant for different qualities of really articulated ɑː, but it seems to be mainly the height of the back of the tongue upon which the quality depends. Or again, if the actual resonator were a funnel down to the glottis. In this case, the volume increasing and the conductivity remaining the same, the difference of one vibration (907–906) for the mouth-cavity becomes less than one for the whole funnel; so

that the inhabitants of the Vosges, men, women and children, some of them doubtless tone-deaf, who manage to hit off the ɑː of their dialect to such a nicety, would do so by adjusting the funnel so that its pitch is a fraction of a vibration per second above that of the Parisian. Now it is true that the human ear, under favourable conditions, can distinguish at this part of the scale a difference of ·3 to ·5 v.d. in two notes heard in succession (Rayleigh, ii. p. 433), but the average ear, or even a good musical ear, is not sensitive to such fine distinctions, for otherwise equal temperament would surely not be tolerated, nor the piano be considered a musical instrument. So it appears doubtful after all whether vowel-quality stands to the ear in any direct relation with the pitch of the cavity. It is a fact which needs emphasising, since there is much vague talk about training the ear, that a good ear in the phonetic sense (*cf.* Sweet, Primer, § 59) need not be a good ear in the musical sense: the appreciation of pitch may be very imperfect (*cf.* § 41 above).

53. The dispute as to the cavity whose pitch is sought with forks and heard in a whisper was settled by the Humanatone, which showed (§ 47) that for oː the resonator is not an unbroken cavity from the glottis up, Helmholtz's bottle or flask, but the mouth-cavity proper. And the close agreement of Helmholtz, Koenig and Rousselot on oː and ɑː—their extreme divergence is nearer a quarter than a semitone—proves that whatever may be the pitch of the resonator with two openings formed by the mouth when this is disposed, not for the Wheatstone

experiment, but for oː, spoken, whispered, or breathed, it cannot be b′♭ (which is the pitch of the same resonator closed at the back, its actual mouth), but must be higher, probably by a fourth or more. That is to say, the error in the fixed pitch of oː in Helmholtz's ubiquitous table is not one of a few vibrations, but of something like 150 v.d. As for ɑː, we have heard the pitch fall continuously in slowly whispered æ‿u, and this shows that the ɑː resonator is no more a funnel than that of oː is a bottle, but is again the mouth-cavity proper. Therefore b″♭ is not the right pitch for ɑː, but must be flat, though probably less than a fourth, since the relative increase of conductivity, the lip-aperture for ɑː being large, is probably less than in the case of oː. The Humanatone, properly blown, should give some information on this point. Also whispering after applying the Wheatstone test. A more convenient method, requiring no apparatus whatever, is explained in § 64 below, where the interval between the pitch of the mouth-cavity (1) open at the fauces for uː and (2) with the fauces closed, and the same lip-position, is shown to be a little more than a fourth.

54. So the real phonetic value of the Wheatstone test, in addition to its practical application advocated in § 45, is this:—it shows that b′♭ and b″♭ must go, and that the assertion that the ear, if assisted by resonators, can analyse vowel sounds into a Fourier series of harmonic components, is, at least in the case of Helmholtz and his assistant Auerbach, ludicrous. The characteristic tones for oː and ɑː, determined with "so much precision and certainty,"

cannot by any possibility be even approximately correct. But the table of fixed pitches is taken by specialists who know nothing of phonetics to be the most brilliant confirmation of the Helmholtz theory of audition. This table will be further examined in the next chapter.

CHAPTER IV

THE COMPASS OF THE MOUTH

55. It is not hard to outdo Miss Doolittle in the matter of a vowel-glide. One may begin at "narrow" **i**, and, passing into the "wide" path, follow it over **ɑ** to **ʋ** and **u**, and going slowly and without tarrying on the way, perform the whole journey in one syllable. Repeating pianissimo, in a whisper, we may observe the continuous fall of pitch. This road over **ɑ** is not the only way from **i** to **u** (*cf.* § 29). There are unfrequented tracks across "mixed" territory, also downhill all the way. Going back to the starting-point and noting the apparent pitch of **iː**, then coming down as far and no farther than the **aː** in *father*, I find I have covered an octave and about a semitone. Beginning again and going further, I do not reach the second octave until I have passed beyond my notion of hbnr **uː** into an **uː** with protruded lips that can be whistled, the note being a major third above a physical *C* (octave as yet unknown). Whistling down from this *E*, the *C* is weak, and about a tone lower the sound degenerates into a mixture like whisper. The **iː** I started from was articulated with the lips drawn back more than is necessary. Normal **iː** is probably not quite so high. Helmholtz found

F 2

the high resonance tone of iː for his table (d^4, a trifle nearer physical $d^4\sharp$) "with tolerable exactness" by whispering (p. 107); his tuning-forks, resonators, and vowel synthesis all failing him. If we then set down $d^4\sharp$ tentatively as the whisper-pitch of iː, we may take our departure. The whistle at e'' may signify land in sight to the supercargo, but the A.B. knows better. The cry of "Land ho!" came from the look-out some time ago. But when the whistle blows, we know where we are. We have had a very quiet voyage of something under two octaves. We kept the patent log going, and we know when we rounded the Cape. So we have a certain advantage over the Bellman and his crew. We get there. We are at e''. On this reckoning, therefore, the compass of the mouth-cavity shaped for vowels would be from something above e'' to $d^4\sharp$. Neither Helmholtz nor Koenig ever made the voyage, but they made faulty observations with extravagant instruments, and as the ports they made do not exist, they should be still at sea. Or else, as longshoremen, they have spun a thumping yarn. The range of the same cavity is, by Koenig's misapplication of the Wheatstone test, precisely four octaves, $b\flat$ to $b^4\flat$, while Helmholtz made it three octaves and a sixth, f to d^4, coming to grief away down at f, through whistling and letting his ears tickle, with precision and certainty.

56. The f whistled by Helmholtz is a remarkable phenomenon. In all cases, he tells us, where tones of very different quality have to be compared, it is easy to make a mistake in the octave (p. 108). He points out such mistakes of an octave made by Donders (p. 109), Tartini, and others (p. 62). But

if whistling with the lips gives simple tones (p. 289), as do tuning-forks (p. 23), these notes are theoretically of identical quality, and it should not be easy to err in comparing them. Yet either Helmholtz or Lord Rayleigh is not one but two octaves out, since Helmholtz arrived at f for the lowest pitch in his table by changing a whispered uː into a real whistle (p. 108). That would mean about c, in the bass stave, for his lowest whistled note, whereas, according to Rayleigh, ii. p. 224, the whistling sounds of the unaided mouth range from about c″ to c^5. Since a misprint is not an impossibility even in the best of books, and finding it difficult to realise that the lowest note I can whistle has the same pitch as nearly the highest squeak my glottis is capable of producing, I tried to settle the question experimentally. The ear is unreliable. Six people out of the seven whose lowest clear whistled note I found to be within a tone of my own, when asked to sing or hum the same note, gave the *C* as either c or c′. The seventh was a physicist, who was not to be caught. An attempt made with the cymograph in the phonetics laboratory at University College was interesting. After several Marey tambours had refused to respond, one was found which seemed willing to try, with a special mouth-piece and a high and loud whistled note. With a *C* two octaves above my lowest, that is, either c″ or c^4, tracings were obtained showing short stretches of regular vibrations which, when measured by those of the 100 v.d. fork running alongside, proved to be about five to one. The pitch recorded was, therefore, apparently in the neighbourhood of 500 v.d., c″, not c^4. On the other hand, Scripture's gramophone tracing No. 38 records a note given by a professional whistler—there is no mention that it was particularly high—with a frequency 2381, and pitch, therefore, a trifle above d^4 (Speech Curves, p. 34). As Scripture points out, the testimony of machines which only record and do not reproduce is not satisfactory ; and as the amateur c and the professional d^4 (not extreme) together make up well over four octaves for clear whistling with the lips, a better test had to be found. The vibrations of the Marey tambour are perhaps an instance of sub-multiple response. The rubber being about as inelastic in the physical sense as it is elastic in popular language, such a diaphragm cannot be trusted to record high frequencies. While casting about for a way out of this quandary, Mr. Daniel Jones showed me a simple test which is conclusive, and that in spite of the statement in text-books (as Capstick, § 156), that a mistuned octave gives beats caused by the first differential tone. A c′ fork beats with my lowest whistled *C* only when strongly vibrating, and even then the beats are hardly noticeable compared with those of the same whistle with a c″ fork. Whistling to an a^3 fork a note just an octave below my top limit, I can get beats slow or fast, which, at the interval of about a semitone, pass —as Lagrange and Thomas Young thought, and Helmholtz denied—into a beat-tone or differential tone. Further proof can be found in the resultant tones which may be heard when two persons whistle together, that the usual lower limit for a clear whistle is about c″. Auerbach, p. 691, gives his range as a′—c^4. How then did Helmholtz manage to whistle f, down in the bass stave, for uː? By mistake, evidently. The note he whistled was f″.

57. This f becomes "curiouser and curiouser." The Helmholtz ear and the Helmholtz resonators failed to analyse uː, and the Wheatstone test failed also. The synthesis, as we have seen, was simple. A B♭ fork gave "a much duller U than could be produced in speech"; a b♭ fork "when sounded alone, reproduced U" (p. 123). No f fork was invited to speak, but the investigator was guided by "another phenomenon" (p. 110): singing uː up the scale from c, Helmholtz feels "the agitation of the air in the mouth, and even on the drums of both ears, where it excites a tickling sensation, most powerfully when the voice reaches f. As soon as f is passed the quality changes, the strong agitation of the air in the mouth and the tickling in the ears cease." Thus f is fixed "with more certainty than by means of tuning-forks"!

58. Helmholtz did not distinguish clearly between a free vibration and a forced vibration. If the uː cavity attained its maximal resonance at f, it was because the inherent pitch of the cavity was either, as he concludes, f, or, as he omits to consider, some harmonic of f, perhaps f″. In unisonant resonance the maximum is reached when the period of the resonator is the same as that of the exciting tone; while for a maximum of multiple resonance the period of the resonator must coincide with that of a harmonic of the exciting sound. In other words, maximal resonance results only when the free vibra-

tion has a frequency which is the same as that of the forced vibration, whether this latter be that of the fundamental tone of the exciting sound or some multiple (*i.e.*, harmonic) of the same. The range of tone over which a system will respond more or less vigorously to the exciting sounds depends upon its rate of damping. The body of air in the mouth-cavity damping rapidly, it will resound to tones somewhat higher and somewhat lower than the ideal tone which corresponds exactly to its inherent pitch, the pitch of its free vibration, and of its maximal resonance. If, therefore, the tickling sensation which became most powerful at f was due to resonance, it ought not to have ceased suddenly as soon as f was passed, for if resonance can be perceived to wax, it can also be perceived to wane[*]: having risen to its maximum at f, it cannot softly and suddenly vanish away, like Thingumbob shouting. The probable explanation of "the sudden alteration in the quality of tone" which synchronised with the cessation of the tickling is that Helmholtz changed register. Since he was two octaves out over whistling, where the more usual deliberate error is one octave, it is likely enough that when he thought he began to sing on c, he really began at c′, and having strained up on chest register to f′, the usual limit, produced the next note

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[*] *Cf.* Zwaardemaaker, Nederl. Tijdschrift voor Geneeskunde, 1913, p. 640: Voor één bepaalde toonshoogte is de amplitude der trillingen van het resonantiegeluid maximaal; deze toon noemt man den resonantietoon. Van die toonshoogte uit neemt de intensiteit van het resonantiegeluid naar weerszijden af volgens regels, die door den graad van demping zijn gegeven.

with the other mechanism of the glottal lips, falsetto, which in an untrained voice, where the transition is abrupt, means diminished amplitude and a very different quality of voice, not vowel. Hence the sudden disappearance of the phenomenon which misguided him. And hence, partly, the insertion in H^4 of the mysterious ninth vowel at f′, with its French spelling OU (p. 110; *cf.* § 20 above).

59. Helmholtz obtained three vowel pitches by changing whisper into whistle. But for a clear whistle of high pitch, the tongue, that unruly member, appears to curl up at the sides, making a channel along which the air is forced with the aid of the buccinator muscles. It is unsafe to form the vowels **yː** or **øː** and then whistle, unless the whistle is intentionally kept at the same pitch as the whisper, since the resonator evidently changes. The only safe way is to whistle and give voice at the same time. This can be done with hollow voice and a quality of vowel which is not quite the "European" **uː**, since the lips are protruded in a way which is not natural to spoken **uː**. To whistle and utter voice at the same time is not a rare accomplishment. It can easily be acquired. The reader will doubtless have occasion to observe, during the perusal of these chapters, that a yawn, although it may be voiced, exhales a great deal of breath in little time, and that the quality of the voice is dull or hollow, while the pitch becomes very deep. By practising voiced yawns one learns to produce hollow voice at any pitch of the chest register. It seems that the cartilage glottis is open as in voiced h, **ɦ**, the imperfect vocality of which is noted by

Sweet, Primer, § 120. There is a leak in the pipe (une fuite dans le tuyau), as Dr. Marage puts it, which lets pass sufficient waste breath to whistle with. It should be possible in this way to determine the inherent pitch of the cavity, but for my part I find it difficult not to favour the whistle by a slight change in the lips. But trying to be fair while singing up the scale from c with hollow voice and a position which gives with a muffled uː at c a fairly clear whistled e″ (harmonic number 5), d is accompanied by f″♯ (harmonic 5), less clear; e by e″ (4), loud; f by f″ (4), perhaps still louder; g, no whistle, but with a slight change, g″ (4); a by e″ (3); b by a fairly clear f″♯ (3); c′ unaccompanied, unless with a slight change I whistle a clear g″ (3). From this difficult exercise it seems that the pitch of the unaltered cavity is about f″, and that the resonator in question responds perceptibly to forced vibrations ranging over at least a whole tone, from e″ to f″♯. And if this is so, it resembles in range the spherical resonator which Helmholtz heard reinforce three harmonics at the same time, namely, 15, 16, and 17 of a fundamental G_1, "g″ most, and f″♯, g″♯ somewhat less" (p. 178), a property of resonators with rapid damping which must make them unable to compete with a Fourier analysis on a very elaborate scale, as they are useless above harmonic 16. The quality of the vowel may be maintained unaltered whether a whistled tone be audible or not. If, then, vowel quality is conditioned by the reinforcement of a harmonic of the glottal note by the mouth-cavity, there is nothing for it but to fall back upon subjective and objective. Which is subjective, the quality of the vowel, or the multiple resonance heard at its apparent maximum in the whistled tone f″—a simple tone according to Helmholtz, p. 289—which accompanies hollow voice at f sustaining the vowel?

60. Some light is thrown on this question by a simpler exercise than whistling "seconds" to voice, which is, however, a good preparation for hearing harmonics without the resonators recommended so warmly and failing so amazingly in Helmholtz's book. Now that we know the approximate compass of the mouth-cavity, and can set aside the b♭'s and f's of Helmholtz and Koenig as entirely off the mark, we need not hesitate to denote the harmonics we hear. There is no longer any risk of mistaking the octave. After practising hollow voice with whistling, I became aware that with full quality voice and properly intonated breath, with no waste, it was possible to distinguish the resonance tone of the mouth-cavity perfectly well at certain pitches of the voice, if the vowel quality were changed so as to employ that contrast on which Willis laid so much weight for the appreciation of his artificial vowels. An example will make my meaning clear. The vowel in emphatic *do, you*, is often a diphthong or vowel-glide, **dʊu**. Singing this **ʊu** on c (128) I hear the tones g″ e″, harmonic number 5 succeeding 6 as the lip-opening diminishes, and the contrast brings out the two tones in unmistakeable fashion. Ascending by semitones, c♯ gives g″♯ and f″, etc. These things had better be presented in tabular form :—

Voice.	Vowel-glide.	Resonance-tones.	Harmonics.
c	ʊu in *do*	g″, e″	6 5
c♯	,,	weak brief g″♯, then loud f″	6 5
d	,,	either very faint a″ or weak f″♯, then loud f″♯	6, 5 5
d♯	,,	g″ fading away; then faint d″♯ at end	5 (4)
e	,,	weak g″♯, strong e″	5 4
f	,,	faint f″ becoming strong	4 4
f♯	,,	distinct f″♯ growing very loud	4 4
g	,,	g″	4 4
g♯	,,	g″♯ diminishing, then faint d″♯.	4 (3)
a	,,	brief a″ followed by e″	4 3
a♯	,,	faint f″ becoming strong	3 3
b	,,	f″♯ growing very loud	3 3
c′	,,	g″, a regular hoot	3 3

The tones f″♯, g″, and also g″♯ (§ 66 below) continue appreciably after the voice has ceased, without any resonator outside the mouth. In singing this scale the endeavour was made to counteract the tendency to sing louder with rising pitch, also to maintain each note equally loud, and not to exaggerate the glide for the sake of getting the harmonic to change; especially not to close up the lips more than is usual in speech. By under-rounding at the start, and putting the lips forward at the finish on d, it is perfectly easy to get three loud harmonics in succession, a″ f″♯ d″: 6, 5, 4. *The intervals*, minor third and major third, *relieve the ear of all uncertainty in assigning these tones to their proper octave*, and prove the total absurdity of the f or f′ of Helmholtz, the b♭ of Koenig, and the a of Auerbach.

61. In explanation of the loudness of g″ at c′, it must be remembered that harmonics low in order are normally stronger than higher ones. The indications

as to comparative loudness record merely my impression, of course. (At this point Professor Dr. Dormouse, whose education was finished at German universities before it began, will ejaculate "Subjective," and go to sleep again.) It is only when the ear is listening for the resonance-tones that they sometimes come out surprisingly loud. The g″ at c′ seems to be louder than the fundamental if I sing c-g-c′, and recalls the "blasting" of the gramophone (*cf.* § 38 above). But whether loud or soft; whether they change during the vowel-glide (the transition does not always occur at the same point of the glide); or whether there is no change except in intensity, as at f, f♯, etc.; and no matter, either, whether the reinforced harmonic is regarded as of fixed pitch or of relative pitch—the rival theories are both rather absurd—these resonance tones do not enter into the vowel to characterise it, but are heard, if heard at all, as belonging to the voice, not to the vowel. In singing up the chromatic scale above, I have had the advantage of a tone-deaf ear as an extra control. To this ear, very sensitive to vowel quality, the syllable I sang was just English *do* all the time; but the harmonics were entirely imperceptible to it, although it heard the "echo" when on one occasion the reinforced g″ of the voice at c′ made a glass shade over a gas-jet ring in an adjoining room. The glass, when tapped, gave a note which to my ear seemed to be g′, not g″, and singing to it I found it respond faintly to *do* at c, clearly at g, and at c′ continue to ring for perhaps a second. This glass resonator—not merely the air inside it—being a system which damps slowly, responds only when undertones of g″ are sung, and then to uː, oː, and ɑː—to ɑː with a note in which a higher octave predominates—but not to eː or iː, unless the voice is forced. And as it will not respond to the f″♯ in *do* at b, nor to the g″♯ at c′♯, it evidently has sharper definition than the g″ resonator used by Helmholtz (*cf.* § 59 above), except that, not being spherical, it has harmonics of its own.

62. Resuming the singing exercises, with a fixed position uː instead of a glide, and singing legato instead of separate notes, so as to get contrast, on the diatonic scale c to c′ I hear the tones e″, f″♯, e″, f″, g″, e″, f″♯, g″, being harmonics 5, 5, 4, 4, 4, 3, 3, 3; or with the lips a little closer and more forward, e″, d″, e″, f″—e″, —, —, being harmonics 5, 4, 4, 4, —, 3, —, —. The resonator is now out of tune for anything above f″. On the notes where multiple resonance is absent, the vowel, a muffled or slightly buzzed uː, was not heard to change quality in the least, but to my ear the musical quality of the voice changes: it becomes dull or "woolly." The alteration is very striking on passing from a to b. Sometimes d″ is audible at g (harmonic three), but at either d or g is fainter than the neighbouring e″ or f″. Which shows that the inherent pitch of this particular uː is probably a trifle below e″, while that of the former uː cavity is nearly a tone higher, between f″ and f″♯. It is essential in these exercises not to get flat, but to finish the octave in tune with the c′ fork. From singing scales in the manner here described—if the key is changed the melody made by the harmonics will not be the same, and the gaps will be in different places—I became convinced that the Helmholtz development of Willis's and Wheatstone's ideas is as

wrong in its general principle as his table of vowel-pitches is wrong in detail; but I did not quite see how to carry that conviction to other minds until the 4th of October last, 1915.

63. On that date—a red-letter day in the history of phonetics as I read it—Mr. Daniel Jones asked me to listen for harmonics while he sang a note with a series of changes in the mouth adjustment. To my astonishment and delight I immediately heard a delicate arpeggio ascending and descending the harmonic scale through some six or seven steps, the tones of the familiar sequence following one on the other like a peal of fairy bells. Each tone was perfectly damped before the next one sounded, and there was not the irregular intensity—one tone loud, the next soft—as in the plaintive melody e″, f″♯, e″, f″, g″, e″, f″♯, g″, of § 62. It is not difficult to acquire the art when you know the way. I trust I am not taking undue advantage of my colleague's generosity in allowing me to apply his discovery to my own purposes, when I say that besides an ear to hear, a certain tension of the lips is required, and for the harmonics to be at their clearest, a resonator with one opening. That is to say, the mouth is closed at the back, the voice being modified into the vowel-like ŋː. On subsequently reading Wheatstone's article once more, it became evident that the drone accompanied by various tones of multiple resonance which did not suggest anything beyond superadded musical sounds, must have been just ŋː,with the voice at a given deep pitch. By exchanging the fundamental, Richmond had, no doubt, learnt to complete the usual musical scale; otherwise, his repertoire of

airs (§ 35) must have been limited to bugle-calls, etc., which only employ harmonics. My own efforts have been restricted to *The Lost Chord*, an encouraging tune. The amateur of the *cornet à pistons*, it will be remembered, found he made astonishing progress as far as *weary and*, though there was trouble with *ill at ease.* We can do better than that. If we "hung" F, the harmonics 8, 9, 10, 11 answer well enough down to *noisy*, although *fingers wandered* sounds a bit sharp. But *keys* on 7 is hopeless. However, this is where one's instinctive knowledge of harmony comes to the rescue. We raise the voice a fifth to c, and produce a very powerful e″ for *keys* with harmonic 5. No, the real difficulty the artist has to contend with is to find an appreciative audience.

64. As we should expect, the effective compass of the mouth-cavity closed at the fauces extends below that of the cavity used to make vowels proper. The lower limit can be determined fairly readily. With the voice at G the first three harmonics ascend a major triad, and must therefore be g′ b′ d″: 4, 5, 6. With voice at E♭ the series 5, 6, 7, 8, 9 . . . . is heard, without 4. So with E. With F I have succeeded in hearing a faint f′, number 4. With F♯ there is no doubt about the series 4, 5, 6, 7, 8, 9, 10, 11, 12, though 5 strikes the ear better than the double octave, 4. The limit is thus, in my case, f′, a fourth below the lowest faint tone, b′♭, I have ever managed to whistle (*cf.* § 47). When I sing an uː followed by ŋː with the same lip-position, on F, the harmonic accompanying the vowel is the unmistakeable 7, a flat e″♭, but with ŋː it is number 5, a′, a drop of something between a fourth and a diminished fifth,

while a transitional 6, c″, is heard as the soft palate comes down to meet the tongue. This position of the lips, however, does not give a′ quite at its maximum.

65. It is plain that when ŋː is continuously sounded, no vowel is or can be uttered. Wheatstone heard no vowels, and apart from the suggestion from lip-reading —which, as I shall show in Chapter VI, in some investigators is so strong as entirely to dominate auditory sensations—there is no change of quality in the ŋː except that when the lips are brought very close together it takes on a certain tinge of mː. I have put this to the test with many different persons, and find that if I hide my face nothing is heard but ŋː. Even jumping from harmonic 5 to 10 of F, and back again from 10 to 5, is not observed to make any change—the harmonics being unheard—except in the sonority of the voice. But if the listener is allowed to see what I am doing—we all become more or less adept at lip-reading at a very early age—I am evidently "saying" different vowels. But here we have, even better than in uː with whistled harmonics (§ 59), precisely the conditions which according to Helmholtz are the cause of differing vowel quality: multiple resonance modifying the voice. It seems then that we are back at the exact point where Wheatstone left the question in 1837, and that Helmholtz and his followers have left out of consideration some factor which happens to be the all-important one. The harmonic overtone theory is impossible, if only for the reason that with ŋː at F one may hear at least nine successively reinforced harmonics, but at c′ apparently not more than three, namely c″, g″, c³: 2, 3, 4. If now you recognise nine vowels from u to

æ, and by choosing your fundamental deep enough, can cram nine harmonics into the compass of a twelfth, you may be tempted to assume that each harmonic will coincide in pitch with one of your nine vowels, and so by maximal resonance characterise each of the nine; but if to a higher fundamental there are only six harmonics to divide among your nine vowels, or only four, what then? Evidently the six positions, or the four positions, now giving maximal resonance will not be better vowels than the rest of the nine, or of the six; and since there is no exact measure of intensity, what you considered a moment ago to be a maximum may prove to have been something less, or for that matter something more than the maximum to which you are now listening. As nine into four won't go, so an unlimited number of vowels will not go into a limited number of harmonics. As Willis observed, vowels along the same line glide one into the other, but harmonics leap, each successive leap being the same if you consider the number of vibrations, but each less than the preceding one if you measure the intervals: octave, fifth, fourth, major third, minor third, then two to a fourth, large whole tone, small whole tone, etc., etc. Therefore vowels are not like harmonics of a note. The change of quality from i over ɑ to u is a continuous function of something; the fall in the whisper-pitch along the same track is also a continuous function of something. The two are not the same, since any ear can hear a difference in the quality of whispered vowels, and some ears can also hear at the same time a difference in the pitch of the whisper. Are the two related, and if so, how? That is the question. Which

Helmholtz burked. It certainly is a poser. So was Helmholtz.

66. The singing exercises of §§ 59, 62 seem to prove that the inherent pitch of a vowel, the pitch of the free vibration of the mouth-cavity, need not be constant, but may rise with the voice. This is shown most clearly with **uː** sung on F followed by the octave f. With f the audible harmonic is number 4, f″. With F it is number 7, e″♭–. Why not 8, f″, since with c′ the very loud resonance-tone is g″? The table here following completes the range of my chest-voice, excluding the deepest hollow voice notes, with the resonance-tones heard with what I consider an identical quality of hbnr **uː** throughout, and in some cases with **ʊu** in *do*.

Voice.	Vowel.	Resonance-tone.	Harmonic.	Glide.	Harmonics.
E♭	**uː**	e″♭	8	**ʊu**	11, 10, 9, *8*
E	,,	e″	8		
F	,,	e″♭–	7	,,	9, 8, 7
F♯	,,	e″–	7	,,	8, 7
G	,,	f″–	7		
G♯	,,	f″♯–	7		
A	,,	e″	6	,,	7, 6
A♯	,,	f″	6		
B	,,	f″♯	6		
c	,,	e″	5		

Cf. § 60, then

c′♯	**uː**	g″♯	3 (very loud, and persisting after voice)		
d′	,,	a″	3	**ʊu**	3
d′♯ (dull)	,,	faint d″♯	2	,,	*3*, (2)
e′	,,	less faint e″	2	**ʊː**	{("brilliant" voice)} *3*
f′	,,	strong f″	2		
f′♯	,,	,, f″♯	2		

While on notes from c′ up the inherent pitch appears to be between f″♯ and g″♯, and the loud resonance with b, c′, and c′♯ makes the voice sound raw and penetrating; on the deepest notes, where there is plenty of choice—in **dʊu** a series of three or four is heard—the harmonic which is reinforced is much lower, so that the maximum seems to occur about or below e″. Either, then, the quality of the vowel **uː** changes, which I cannot admit; or the resonator changes its inherent pitch without affecting the vowel. This is, indeed, highly probable, for both Donders and Storm, the two men who have made the most skilful investigation of whisper-pitch, found independently that **uː**—unlike **ɑː** and many other vowels—might vary over a considerable interval without any corresponding change of quality. As far as the lips are concerned in singing these scales, the position was maintained, and the sharpening or flattening of the resonator must be due to changes of its capacity. The explanation probably is that as the larynx rises or sinks, the tongue is moved bodily forward or drawn back with it. Whispering and whistling (§ 55) prove that the pitch of **uː** is above e″. In the octave c to c′, sung to **uː**, it is apparently between f″ and f″♯. If we make this our Landfall, we find that we are very close indeed to the Departure, homeward bound, marked upon the track-chart by Donders, the Hollander, who first showed seamanship in these stormy waters. That is to say, if we move the whole set of his observations one octave up, as evidently must be done. Anyone, I believe, who has a sense of pitch, will agree that the range of whisper from **iː** to **uː** without excessive rounding, is just about two octaves. It was a gross blunder on the part of Helmholtz (p. 109) to move Donders's uː *down* an octave, and his ɑː, etc., *up* an octave. The result is an enormous solution of continuity. Is it Ginnunga Gap, or the miracle of the Red Sea? His sensations of tone are sometimes too sensational.

67. Donders's notes are not correctly given either by Merkel or Helmholtz (Ellis, 1885, p. 109). They apply only to long vowels. He judged by intervals. His iː was a fifth above yː, which was an octave (read two octaves) above the *a d'orchestre*, a′ (p. 160). But a fifth above a′ is e″, not f″. His whisper-pitches in descending order are therefore as follows:—iː e^4, eː c^4♯, yː a^3, øː g^3, œː e^3, ɑː nearly a″♯, ɔ (long, but evidently not ɔː as in *paw*) nearly g″, uː f″ oː nearly d″♯. The range, two octaves and a semitone. Donders was most certain of his native yː, which he rightly held to be the same as French and German yː. By whispering yː he could give the *a d'orchestre* within one-eighth of a tone. He had discovered that in his whispered vowels he possessed the equivalent of a tuning-fork, and demonstrated in public that although he had no sense of absolute pitch, he could by whispering uː ɑː iː judge the pitch of any tuning-fork presented to him to one-eighth of a tone. There is no doubt in my mind that he could do this. He was invariably an octave out, but the error of an octave does not matter. We know now that by f′ he meant f″. An error of a semitone is vastly more important. For my part I have never learnt to subdivide a semitone, nor to carry in my mind the different kinds

of semitone (*cf.* Ellis, 1885, p. 457), but I have proved to myself scores of times that if I whisper quietly to myself in a quiet room "see, father, farther," I then can whistle a c^3 by which the c' (256) fork is a little sharp, but by what fraction of a semitone I cannot tell. On several occasions I have mystified friends by whistling "exactly" in tune with the fork. It is two octaves out, anyhow. If I have to whisper loud, I may be more than a semitone too high. That is perhaps due to the differing tension in the hind pillars of the fauces, and to the rising of the larynx, which takes place with a loud whisper just as when you "raise your voice." In the whispered words there is an approximation to a melody which can be picked out on the piano. The interval in *father* suggests a minor third, and in *farther* a major third. If I then whistle a semitone lower, making the corresponding fourth, I have c^3 very nearly. The whistle will not beat with the c' fork, but with a Koenig's fork as used by Rousselot (*cf.* Ellis, 1885, p. 446) I could tell, I believe, to within a few vibrations per second what is the pitch of the mouth-cavity in my pronunciation of *father*, and what in *farther*.

68. But, for all that, it is by no means plain sailing. When Donders wrote down his observations in 1857, the rise of orchestral pitch was approaching a climax. It "reached a' 448 at the Paris Opéra in 1858, and the musical world took fright." The *diapason normal*, a' 435, was made in 1858, about $\frac{1}{4}$ tone flatter than the then French opera pitch (Ellis, 1885, pp. 512, 513). In Vienna a' went on rising, 456 in 1859, 466 in 1861 (Auerbach, p. 201). Ellis assumes 440 for Donders, but if his *a d'orchestre*

was 448, the difference is more than $\frac{1}{8}$ tone, and might mean much more, since in setting down a note one generally goes by the nearest equal semitone. It will prove that good judges of whispered vowels are in much closer agreement than the horrible confusion of the tabulations leads one to infer. The suggestion in § 21 is not impracticable, but to carry it out the physicists' pitch, c′ 256 = 2^8, should be adopted, as a standard which will not change, whereas the musicians' a′, to take tuning-forks alone, has varied between 384 and 460 v.d., chamber-pitch since the seventeenth century rising and falling through a fifth, 374–567 v.d. (*cf.* Ellis, 1885, App. XX.).

69. With **oː** lower than **uː** it may look as though we are making a lot of leeway. Whisper **aː oː uː**, and it is plain that **uː** is deeper than **oː**. But here we have progressive lip-rounding. Though rounded lips are necessary for **oː**, a perfectly good **uː** may be pronounced with very little rounding, certainly without pushing forward the lips. This seems contrary to Rausch's *Sound-Charts.* But they were intended primarily for the instruction of deaf-mutes, and accordingly do not strictly apply to phonetic teaching. Anyone who has seen deaf-mutes converse will admit that their exaggerated lip-movements are neither necessary nor desirable for those who are blessed with the sense of hearing. *Ore enim magis quam labris loquendum est*, says Quintilian, and Sweet warns against "facial contortions" (Primer, § 53). As a matter of fact, "European" **uː** may be higher or lower than **oː**, or the two may have the same pitch. (Which shows that the pitch of the mouth-cavity is

not the determining factor in vowel quality.) Sweet suggests (Primer, § 61) that the *force* of the whisper will raise the pitch of **uː** from one to two tones, by throwing the sound forward to the lips; but that smacks too much of Sound Shifting, and has, I think, physically no meaning whatever. The variability of **uː** whisper-pitch was recognised by Donders (p. 159) and by Storm (Engl. Philologie, 1892, p. 99), who does not refer to Donders, but discovered independently the seeming paradox of **uː** above **oː**. Storm gives the valuable information that Sweet whispered **uː** at g (*i.e.*, g″); Vilhelm Thomsen, who as a Dane naturally spoke "European" **uː**, a trifle higher; while F. A. Wulff, the Swedish phonetician, placed **uː** at a″♯, a semitone higher than the Norwegian himself. (In Lyttkens and Wulff, Svenska Språkets Ljudlära, 1885, p. 349, Wulff's **uː** is on g″.) Swed.-Norw. **ʉː** might vary from g″ down to c″, the deepest pitch being most usual. I believe that if this vowel is kept characteristic, hbn **uː** "trångt labialiserad med något framskjutna läppar" (Gideon Danell, Svensk Ljudlära, 1911, p. 32), the higher the voice within a register the more audible the buzz. Including this deep-pitched vowel, Storm's whisper compass is two octaves, d″ to d^4; otherwise, from **oː** to **iː**, a twelfth, g″ to d^4, the whole table being here moved up two octaves, as it must be.

70. The vibration number of Storm's a′ is not given. That is a pity. The vowel **ø**, in *schön*, *peu*, *søt*, seemed to him the safest one to whisper, being nearly always in unison with (read two octaves above) the a′ fork. That is, Storm's **øː** has the same whisper pitch, a^3, if the forks agreed, as Donders's

yː. That is a proof that we must not expect, at least for rounded vowels, very close agreement between different persons. The assertion, often repeated from Helmholtz, that the cavity for the same vowel on the line ɑ to u, whether spoken by man, woman, or child, must have the same pitch, seems to be, like so much else in Helmholtz's book, entirely *a priori*, since the Wheatstone test proves nothing of the kind. Researches, badly conducted, by Von Zahn resulted in a variation of over an octave for one vowel ("ä," e′ to f″, nine whole tones according to Trautmann's peculiar scale, p. 50). Storm held that his own pitches were neither absolute nor constant. I think that if conditions are properly observed, the *relative* pitches of vowels on the same line could be determined with great accuracy, so that finally a track-chart might be provided which would prove useful to future adventurers upon these perilous seas forlorn, and Willis's idea of 1828 be realised.

71. The whispering test has been brought into discredit by Professor M. Trautmann, of Bonn, who claimed to define 140 oral and 140 nasal vowels. By whispering the proper vowel at a suitable tuning-fork he *excited* the fork so strongly that it filled a whole lecture-room (Sprachlaute, 1884–6, p. 49). The experiment has not been repeated. Roorda could not make it work with any combination of fork and vowel. What Trautmann really did must be plain enough from §§ 48–53 above. His book is largely compounded of Baconian idolism. His chief Idol of the Theatre, the fallacy of his system of harmonic tones, is of course the handiwork of Helmholtz, who, to make quite sure of his iː d^4, wrote

down three "fixed pitches" determined by the illusory Wheatstone test, and added d^4 to make a sequence of four notes, which, he says (p. 109), "can be readily *compared* with the same melodic progression on the pianoforte"—a very simple and convincing one-finger exercise, by which you may *compare* something with nothing, or the real with the imaginary, or the "objective" with the "subjective." Is there any reason to think that a limit can be set to the capacity of such a mind for hoodwinking itself? Trautmann fixed his iː first at f^4, then on changing forks (vibration number not given) at g^4, and finally again at f^4, *reducing* his range from two octaves to 14½ tones (p. 53). He was not aware, as Jespersen points out (Fonetik, p. 388), that there are six tones to an octave, nor of any difference between a major and a minor third (*cf.* Roorda, Klankleer, pp. 41, 42). His objective was an arrangement of vowels in harmonic sequences, or what he imagined to be such, and to this image he was prepared to offer sacrifice. In reality he set down a dissonant tetrad, a chord of the seventh, g'' b'' d^3 f^3, in the key of *C* instead of *G*, and repeated an octave higher; then built up his system of eight "harmonic tones," not knowing that his f^3, being considerably sharper than the seventh harmonic of g, makes all the difference between harmony and discord.

72. There is no ground for believing that vowel-pitches arrange themselves either in octaves, in harmonics, or at any set intervals. Even semitones, as the six in Sweet's *Primer*, § 61, are an illusion. For in the series *bat*, *bear*, *bet*, *bay*, *bit*, *beat*, if æ is placed with Storm on a^3 as the nearest semitone,

and we go up the chromatic scale to d^4, iː, where are we to place the "open" ɛ of *j'aime*, and the less open ɛ of Swedish *Sverge*, which is distinctly more open than the ɛ beginning the vowel-glide in *bear*? It is possible, certainly, to whisper up the Bell-Sweet chromatic scale, with *man*, a^3, *bear*, a^3♯, etc., but I have frequently noted both these vowels, taken separately or in other comparisons, as a^3, while if I whisper quietly "the man and the bear" the ɛ is an a^3 a shade *flatter* than æ, but much less than a semitone. If I do the same with "Leve Sverge" and write down the melody as c^4♯: a^3 g^3♯ d^4 a^3, I know that the representation is a clumsy one, but I begin to understand why F. A. Wulff locates Sw. *ärt* a tone below E. *man*, Dan. *gade*, with ë on the equal semitone between them.

73. Wulff's table of whisper-pitches, made independently in 1883, is of great interest. It gives 31 vowels on 22 notes of a piano "with normal tuning, but perhaps sometimes a little, not more than a semitone, too high" (Lyttkens and Wulff, pp. 348, 349). The whole table, like Storm's, must be raised two octaves, and when the deep-pitched Scandinavian vowels are omitted, covers, like Donders's, just a semitone over two octaves, but from oː f$''$ to iː f^4♯. The top notes are probably forced up, to allow a semitone each to vowels making an apparent chromatic scale, 13 of them, an unlucky number. I cannot myself force iː above f^4, when my larynx is as high as it will go, and begins to contribute various wheeze tones. My iː, quietly whispered, is between d^4 and d^4♯. It may be, as Roorda thinks (p. 42), that one could not find any

two persons with exactly the same whisper-pitches, but if we compare as follows :—

	Donders.	Wulff.	Storm.
yː	a^3	e^4 (grüssen)	b^3
øː	g^3	d^4	a^3

we may cheerfully despair of absolute pitch, for the relative pitch is here defined as precisely as ordinary musical notation permits, the interval being, in each case, a "tone" on the piano. The sooner the piano is locked up, and the key lost, the better. The idea of tones and semitones must be abandoned, and the true pitches of gently-whispered vowels in words and phrases determined by whistling at the pitch of the whisper with an adjustable fork vibrating at the ear, or with the help of such a set of forks as Ellis possessed (1885, p. 446). In this way it should be possible for a good musical ear, if, as does not follow, it is a good phonetic ear, to find the pitch of a vowel to within four beats a second. When vibration numbers are thus determined for pairs of vowels on the same genetic line, the intervals must be calculated by Ellis's method of logarithmic cents, which in the neatest fashion disposes of the difficulty of absolute pitch. For example, the difference between **yː** and **øː**, according to the notes given by Donders, Wulff, and Storm, is in each case exactly 200 cents (see App. XX, Section C, in Ellis, 1885)—while the g^3—c^3# of Helmholtz would make it 1,200 cents! The round numbers of equal temperament will not appear in excess, and it will be sufficient for practical purposes to make each link in a chain—keeping to the idea of catenaries—10 or perhaps 20 cents. Since Donders was sure of **yː** to less than one-eighth tone, 25 cents to a link would make the chain unnecessarily coarse, although fine enough, probably, except in some cases of overlapping (*cf.* § 19 above). What such a chart or map would look like, and how it would agree with the present I.P.A. plan of vowels arranged according to tongue and lip positions, there will be time enough to speculate. But a certain amount of coincidence there evidently will be, since the two main factors taken into account in the positional scheme are those which regulate the whisper-pitch. There would be *isotonic lines* from a certain **ε** to **ʏ**, **έ** to **y**, etc. Vowel-glides would be measured, and the difference in cents between whispered *mate* and *might*, or *bay*, *buy*, *boy*, would make London children prick up their ears. Miss Doolittle will be presented with a necklet having a certain number of links, not to be exceeded when she feels disposed to exclaim. We should perhaps understand why some vowels will not glide into others, while **ə** can hardly be prevented from losing itself in any following vowel. It was, no doubt, through studying whisper that Donders arrived at his definition of a diphthong, so excellent as far as it goes (Spraakklanken, 1870, § 19): "Tweeklanken ontstaan door *geleidelijken* overgang van den eenen klinker in den anderen. Behooren de beide klinkers tot dezelfde reeks, dan zijn de tusschenklinkers in den overgang hoorbar, en de aansluiting is zonder interruptie" (*cf.* § 24 above). Donders would not have considered **ui** a diphthong.

74. By some fluke or other, Trautmann certainly hit upon the right octave. But as he advanced nothing in support of his contention beyond the absurd statement that all sounds from cavities appear deeper in pitch than they really are, no one believed in his excitable tuning-forks, and Storm did not hesitate to shift all his vowel-pitches down again two octaves, to compare with his own. Trautmann was preceded by F. Grabow (Herrig's Archiv, LIV, 1875, p. 378), who whispered down from Helmholtz's iː d^4, and finished up at c″, a tone beyond two octaves. His table is evidently influenced by Helmholtz's "melodic progression on the pianoforte" (p. 109), and is of little use for comparison with Donders, Wulff, and Storm; so I have nothing against Trautmann's proposal to raise some of Grabow's pitches by "a third" (p. 48), so as to make them agree with his own. Some would have to be raised a minor third, others a major third, but the difference of a semitone, which he sometimes calls a whole tone, does not matter to Professor Trautmann.

75. As for Koenig, he was "köpenicked" into believing that the b′♭, b″♭, b^3♭ of Helmholtz, determined "with so much precision and certainty," represented a *law* (Acoustique, p. 43), the *B* flat law; and he made high forks in the hope of finding a b^4♭ resound. Herein he was successful, but with his uː b♭ he admits that the resonance was but "assez appréciable." The only useful comment I can offer is that, if I tune my mouth for a c″ fork, and then without changing present the c′ fork, there is appreciable reinforcement. And that not so much of the tone c′ as of the tone c″, the octave partial which is

contained in the "simple tone" c′, and now becomes distinctly audible. This would be a good way—if it were not "subjective"—to test tuning-forks for harmonics. Resonators are used in physical experiments to strengthen the prime tone of a fork, and it is sometimes assumed (*cf.* Capstick, § 156) that the fork is thereby purged of its octave partial. To the ear—which does not show proper respect for Ohm's Law—it no doubt is, but physically it surely is not. Why should it be? Resonators tuned to some of the lower harmonics would probably reveal their presence in the sound of tuning-forks which are reputed to give simple tones. If we thus raise the b♭ of Koenig an octave, and then haul him up the interval measured in § 64, between the rounded uː resonator closed and open at the fauces, we have salved poor Koenig from the wreck of the Helmholtz U-boat, and landing him safely between e″♭ and e″, there leave him.

76. The first to record the audibility of harmonics in the human voice was apparently Rameau. Helmholtz says (p. 51; H^3, p. 88) that Rameau, without any artificial aid, heard "the upper partials" of the voice, but does not say how many. It would be wrong to draw the conclusion, which seems implied in the context, that Rameau heard as many as sixteen. Helmholtz is here arguing for Ohm's Law and the power of the ear to make a complete analysis of a musical sound into its harmonic components. Presently he will shift his ground and prove you that it can't be done without using his spherical resonators. On referring to Rameau's *Nouveau système de musique théorique*, 1726, p. 17, I find that the only harmonics which Rameau and his friends distinguished were

numbers 3 and 5 (la douzième et la dix-septième majeure), and that they thought these tones were contained in the musical sounds given forth by sonorous bodies generally, strings and pipes as well as the voice. D'Alembert, *Eléments de musique*, 1762, p. 14, differs from Rameau in that he adds number 2, the octave, remarking in his preface, p. ix, that "cette *résonance multiple*, connue depuis longtems, est la base de toute la théorie de M. Rameau." It must not be overlooked that when we sing, the voice must be produced on some vowel or other, and the vowel which is to be understood in the case of these musicians is evidently an ɑː, the musical vowel *par excellence*, as Ellis somewhere observes. And, in fact, when one sings ɑː to a bass note in a quiet place (Rameau, p. 17) a number of harmonics may be distinguished successively, if the ear is thoroughly accustomed to the harmonic scale, one stronger than the rest, but not so much stronger, as generally with other vowels, as to drown the others. The method recommended by Helmholtz (p. 51) for familiarising the ear with these tones of multiple resonance is about as bad as it could be. The piano simply spoils the ear for this purpose, especially for those harmonics, as 7, 11, 13, etc., which do not occur in the ordinary musical scale. I do not believe that Helmholtz ever, in spite of all his talk, heard any vowel harmonics, either with the aid of his resonators or without. If he heard those tones reinforced which are given in his table, then the human mouth must vary so tremendously that there cannot be any question of "fixed pitches." It would require a mouth of Gargantuan capacity to reinforce the tone f.

If you sing e♭ to oː the reinforced harmonic is not, as he says, b′♭, number 3, but number 5, g″, which he claimed to hear with ɑː. Number 4, e″♭, comes out well with a much rounded uː. And if, singing the same note, e♭, you change oː—which is certainly what Helmholtz meant by O—into the open O of Ellis's translation (p. 51), slowly, there is a diminuendo in the mouth-tone, which then jumps up a minor third, to harmonic 6, b″♭, not b′♭. The next leap is the 6 : 7 interval, and you get the seventh harmonic of e♭, a flat d^3♭, at its strongest, but not so strong as the preceding 4, 5, and 6, with a quality of ɑː which tends towards ɔ. Number 8, e^3♭, can be faintly heard with something like a. The g″ which is given by ɑː, according to Helmholtz, p. 51, has the merit of disagreeing with his table, where ɑː is on b″♭, but even that will not make it right.

77. The best way to train the ear for hearing harmonics is undoubtedly that of Daniel Jones, which should find a place in the text-books of Sound. If I had understood Wheatstone's reference to Richmond at an earlier date, I should have been saved much labour. With a continuous ŋː the ear is not disturbed by differing vowel-quality, and the harmonics, although really less loud than with sung tense vowels, come out much more clearly. The fundamental being changeable at will, one can transpose indefinitely, and become quite familiar with the *intervals* from harmonic 4 up to 12 at least. If, then, you know the pitch of the fundamental, it should be impossible to go wrong in the octave of the harmonics which you observe. And thus with all tense vowels, at any rate, you are able to form an estimate of the inherent

pitch of the mouth-cavity, at which the maximum of multiple resonance occurs. The following table gives harmonics of the note c (128) observed with different vowels. It cannot be supposed that any series of harmonics will tally exactly with a predetermined series of vowels; and it is perhaps impossible to measure their relative intensity with any great accuracy by ear. Remembering the difference between a free and a forced vibration, we also see that a single table of this kind cannot be expected to give the inherent pitch of each vowel straight away. But it affords a valuable corroboration of what has been observed in whispering, both as to the compass of the mouth, and as to a number of vowels; and it can certainly be improved upon indefinitely by changing the fundamental. The great desideratum is a sound-proof room. Waiting for silence is an incredibly tedious game.

ʉ 4 rather guessed from contrast to 5 than clearly heard; with lips less forward, 5, (c″, e″).
u rounded, 5; less rounded, 6 (e″, g″).
ʊ 6 loud (g″).
o either 5 or 6, according to protrusion of lips (e″, g″).
ɔː in *awe*, 6 loud (g″).
ɔ 7 (b″♭–).
ɑ tending towards ɔ, 8 faint (c^3)
ɑː in *father*, 9 (d^3).
a 10 (e^3).
ʌ 10 (e^3).
œ 10 (e^3) louder than with a.

ə	10 or 11.
ø	11 (f^3+).
ɛ	12 (g^3)—*there*, ðɛə, 12 followed by 11.
ʏ	12 louder (g^3).
ɛ́	13 faint (a^3–).
y	13 loud (a^3–).
æ	in *man*, 12 or 13 (g^3, a^3–).
ɪ	14 or 15 ($b^3\flat$–, b^3).
eː	15 or 16 (b^3, c^4).
iː	17 or 18 (d^4); possibly 19.

With iː, 17 or 18, a lower harmonic may be heard, generally 12, sometimes alternating with 10 and 11. This perhaps accounts for the bleating quality of the voice when a tense iː is sung.

Some vowel-glides: *there*, 12 + 11; *they*, 13 + 16; *buy*, 10 + 15; *boy*, 6 + 14; œʏ, 11 + 12; ɛʏ, 12 or 12 + 11; ɑ·ʊ, 8 + 6; hʌʊs, 10 + 6.

78. Harmonics may also be heard with vowel-likes. In the inverted (cerebral) ṛ in its extreme form, as spoken in some parts of Somersetshire, there are two or three harmonics reinforced at the same time. In *bird*, bṛːd, sung on c, 12 and 11 are loud, and 10 less so. The dissonance of g^3 and f^3+ perhaps explains the harshness of this sound in speech and its unmusical quality in singing. In whispering it is most difficult to decide upon its pitch. The more I listen, the less certain I become which is the dominating tone. Sweet speaks of its snarling effect (Primer, § 46), but to Mr. Thomas Hardy it is "probably as rich an utterance as any to be found in human speech" (*Tess of the D'Urbervilles*, ch. ii).

79. When the note c is hummed, mː, with open

fauces, as is usual, and the lower teeth separated from the upper—if they touch, they jar, and tap out a note at the same pitch as the voice, but of very different quality—the harmonic which I hear is usually 5, e″. (*En passant*—if the reader admits the truth of the last parenthetical observation, and hears two distinct notes in absolute physical unison sounding concurrently, then the pianoforte in his cochlea, manufactured but not invented by Helmholtz, is damaged beyond repair. The gentle reader would save some reading and writing—and arithmetic—by thinking this out for himself.) By moving the tongue about while the note c is hummed, the harmonic series 5, 6, 7, 8, 9, 10 can be obtained, and if they are produced in rapid succession there is a Jews'-harp effect (*cf.* Wheatstone, p. 360), which becomes an angry twang with a deep fundamental, say F. At this pitch a clear hum is accompanied by harmonic 7, e″♭–, and a scarcely sensible movement of the tongue substitutes 8, f″. In fact, I cannot long prevent 7 from alternating with 8. While the tongue is moving up towards the hard palate, the harmonics change from 7, 8, up to 16, 17, and 18. I can get a very clear 18 of hummed F with the tongue in position for **iː**, but nothing above this g^3. By stretching forward the closed lips the pitch can be lowered through 6, c″, to 5, a′, and with the jaws as far apart as possible, a faint 4, f′.

mː together with **ṛː** is a curious combination. Besides 10 of F there are one or more higher harmonics. I have not succeeded in analysing this dissonance, which varies continually.

mː is not nasal. Grammarians call M a nasal sonant, etc., because the passage through the nose is open, but in its quality there is no nasality, or need be none. It is quite possible, however, to hum with a weak or a strong nasal twang (*cf.* Lennox Brown and Behnke, Voice, Song, and Speech, 1883, p. 213). One may learn to distinguish the sound of **mː** from **mː** together with **ŋː** by holding smoke in the mouth. In humming the smoke will pass out at the nostrils, but not so in **hʌmŋɪŋ**. Here the **mː** predominates, although the mouth is closed at the back. The teeth can be made to jar during **mŋː**, with smoke retained in the mouth, though their note is now very much fainter than with **mː**, when the smoke finds its exit. But if the voice vibrations pass through the soft palate so readily as to make **mŋː** hardly distinguishable in sound from **mː**, and if nasality is produced in the nose, how can there be any vowels which are not nasal? The question of nasality will be discussed in a later chapter.

80. In **b̩** at c the harmonic may be either 5 or 6 (usually), or 7, 8, 9, 10, 11. It is possible to "hub" a little tune to oneself, while another listener hears only **b̩** or "a kind of grunt" (Ellis) repeated. There is no doubt, however, that **b̩**, **d̩**, **g̩** differ in quality, and are distinguished without any guidance from lip-reading or from on and off-glides. This I have tested repeatedly. Also, without showing what I did, I held the end of a long piece of rubber tubing between the lips, and thus, having an outlet for the breath, although the soft palate was up, was able to sound **b̩ː** indefinitely. It was heard as **b̩ː**, not as **mː**. The harmonic with **d̩** is 7 of c, but **d̩** is not confused with **b̩** made with the same 7. Evidently there must be

something besides the pitch of the cavity to characterise the three distinct qualities of occluded or muted voice, b̩, d̩, g̩; and as they are three, not one, it is as reasonable to talk of *the* "Blählaut" (*cf.* Sweet, Primer, § 124) as it would be to talk of *the* media, *the* tenuis, etc. You can find "der sog. Blählaut" mentioned in a dozen books, but never a reason given for the singular number. The word, coined by Purkyně, the famous Czech physiologist (*cf.* Merkel, Schlund und Kehlkopf, 1862, p. 150) can only apply to b̩, since no "blähen," blowing out or in*fla*tion of the cheeks, is possible with d̩ or g̩. A better name would be "voiced mutes."[*] Some beginners are shocked at the idea of a "mute" which is not absolutely silent; but deaf-mutes make inarticulate sounds with the voice, and when violins are played with muted strings, they are not reduced to silence. The echoic root of the word, as in mum, mumble, murmur, etc., shows that it means, in the first instance, inarticulate rather than soundless. Sir Thomas Smith explains that animals are called dumb, "muta vocantur, non quod sonum non edunt, sed quia soni eorum nullis exprimuntur proprie literarum notis" (*De recta . . . scriptione*, Paris, 1568, p. 5). The voiced mutes d̩ and g̩ could be maintained *ad lib.* as well as b̩, if an outlet were provided to relieve the air-pressure in the supra-glottal cavity; and therefore they are, from the acoustic point of view, vowels. According to

[*] Wallis, 1653, called them semi-mutes: "exiguum enim sonum . . . efficiunt, qui per se quidem audiri potest nullo ulterius literæ sono accedente." For George Dalgarno (*Ars Signorum*, 1661, p. 7) they were "suffocatæ," formed "spiritu magno nisu retento et suppresso in gutture." Holder (*Elements of Speech*, 1669 p. 10) classified them as "murmur-mutes."

Capstick, § 190, "a vowel maintains its characteristics so long as it is maintained. It is not necessary to hear the beginning or end to decide what vowel it is. It is clear then that our recognition of any vowel must be by its quality. We distinguish between the vowel **ɑː** and the vowel **uː** in the same way as we distinguish between the sound of a violin and that of a flute." We also distinguish between the voiced mutes **b̩**, **d̩**, **g̩** in the same way: by ear. But hardly as Helmholtz thought we distinguish vowels, by virtue of a reinforced harmonic. For this may be the same in **b̩** as in **d̩**.

81. H. Grassmann, mathematician and Sanskritist, must, as Rousselot remarks, have had an unusually sensitive ear. He claims to have heard 25 harmonics while singing from **uː** to **yː** to **iː** on the note c. That takes **iː** up to g^4♯, nearly. In dealing with his paper in *Annalen der Physik, N.F.*, i. 1877, which I first consulted on March 28th, 1916, I have to go back over ground already traversed. Grassmann says (p. 606) that since the translation of Willis's memoir appeared in the same periodical in 1832, the theory of vowel and other speech sounds had been the object of his unceasing endeavour. That must be taken as a rhetorical flourish, seeing that his mathematical and physical papers alone make up three bulky volumes. This particular paper is but a poor result from forty-five years' work. The interesting point in it is the confirmation of what has been demonstrated above, that a fairly good ear can advantageously dispense with the help of the resonators employed by Helmholtz. According to Auerbach (p. 693) Grassmann has found no one to adopt his method, all preferring,

like Auerbach himself, to use resonators. This is doubtless due to Grassmann's insisting (p. 610) on beginning with the vowels from **uː** to **yː**, a most difficult path. To pass from **uː** to **yː**, the tongue has to change from high-back to high-front, while the lips remain rounded. We thus must follow a track across an indistinguished space of mixed rounded quality, and the strange vowels that can be thus formed Grassmann considers to be all *u* or gradations of *u*, seven of them, followed on the line from **yː** to **iː** by twelve of *ü* and an almost limitless number of *i* (p. 612). No wonder that he had no following, for if singing the note c you change from **uː** to **yː**, from 4 (buzzed **uː** or **ʉː**), 5 (hbnr **uː**) or 6 (less rounded **uː**) to **yː** which gives 13 of c, a flat a^3, the interval is so strange to the musical ear untrained to the harmonic scale that the beginner is not likely to begin at all.

82. As far back as 1854, Grassmann had called attention—which would not come—to these harmonics, extending from **uː** to **yː** to **iː** over three octaves, c'' to c^5—much too high (Ges. Werke, ii. 2, 1902, p. 188). It would mean harmonics 4 to 32 of c, 6 to 48 of F! In 1877 the same vowel-harmonics extend from c' to $g^4\sharp$ or so, *i.e.* the same compass, but at a different pitch, as in Helmholtz's book, which had meanwhile been studied. That is nonsense. The compass of the mouth from extreme **uː** or **ʉː** to **iː** is little more than two octaves, and from **uː** to **iː** in ordinary speech it need not much exceed a twelfth (*cf.* § 69 above). It can easily be shown that in Grassmann's case second thoughts, or even (n – 1)th thoughts, were not best. In fact, we have here another instance of the deplorable influence of Helm-

holtz. In 1854 Grassmann might, by a little concentration, have solved this part of the enigma. By 1877 he became just one of a sheepish crowd, following the lead of an erratic bell-wether. Grassmann says (p. 610) that skilful whistlers can whistle from a′ to a^4; yet three times, on pp. 611–2–3, he bids his readers put their mouths in position for whistling c′, a major sixth below a′. How on earth are they to do it? Yet, since Helmholtz whistled f, a fifth lower still, why not? Grassmann went astray with Helmholtz over the Wheatstone test: mouth in position for whistling c′, then instead of whistling, present a c′ fork and obtain strong resonance (p. 611). His acquaintance with the harmonic scale was not close. He marks 11 and 13 as inharmonic, with an x, but 7 of c he denotes by b^2♭. It is ridiculous to call harmonics inharmonic when you hear them one at a time together with the fundamental—the intervals 10 : 11, 11 : 12 are on the trumpet scale (*cf.* Ellis, 1885, p. 454). On the other hand the interval 24 : 25, 70 cents, he denotes by g^4 and g^4♯. Until Grassmann's 25 harmonics of c are confirmed by other observers, some of them must remain doubtful. I cannot myself get anything certain above 18 of c. Above a possible 19 iː becomes jː, which my ear fails to analyse in this way. The only way to make sure of the pitch is, as I have said, to judge the intervals of neighbouring harmonics. If Grassmann had listened to the next higher tone to his supposed c′, he would have found the interval to be a major third, not a fifth, and should thence have known that his lowest harmonic, with a "fine dark U," was c″ as in 1854, not c′. It is only by combining a sort of ɔː with extreme protrusion of the lips that I can for an instant strain down to 3 of c, g′—let alone 2, c′. In his mathematical treatment of vowel-harmonics Grassmann does not scruple (p. 616) to postulate an uː and an iː having as characteristic tones c′ and c^5 (*cf.* Koenig's four octaves) respectively. A pretty pastime.

83. If you sing up the chromatic scale from c to c′, rigidly adhering to a chosen lip-shaping for a back rounded vowel, you come to certain notes which are accompanied by very little multiple resonance, so that, in fact, no reinforced harmonic is audible. On beginning such a note there is at once the temptation to make a slight change which will bring out a harmonic (if you have learnt to hear harmonics) either higher in pitch or lower than the one which was audible with the preceding semitone, and make the production of the note less laboured. I am convinced that singers do this without knowing why, except that they thereby get such notes with less effort and with better "resonance"—whatever may be the meaning which they attach to this term. But if the temptation is resisted, the quality of the voice on such notes (containing no harmonic sufficiently near to the pitch of the mouth-cavity to be perceptibly reinforced) is, by contrast, soft; or, as I have described it in § 62 for want of a better word, "woolly." Grassmann has observed this phenomenon, after a fashion, and claims to hear two faint harmonics in place of one more loud, for example (p. 613) with an O on the note c, c′ and g′. Grassmann was mistaken. He never heard either c′ or g′ with any O, nor any two consecutive harmonics of c

making the interval of a fifth, for these could not be other than 2 and 3, c′ and g′, and both these tones are well below the compass of the mouth. Even c″ requires a buzzed **uː**, and the next harmonic is number 5, e″. Sing the vowel-glide **ɔou** on the note c, and you can hardly fail to hear two successive harmonics making the interval of a minor third. But the minor third is the 5 : 6 interval, and the two harmonics must, therefore, be harmonics 6 and 5 of the fundamental c, that is to say, g″, e″. If then you raise the voice an octave and sing the same vowel-glide on the note c′, you will hear the same g″ swell out and die away, to be followed, not by the slightest trace of e″, but, when the lip-opening has become somewhat smaller than is usual for **uː**, by a faint harmonic making the 3 : 2 interval of a fifth with the one preceding. When you have performed this exercise, not all the elaborate physical apparatus nor all the mathematical muddle-heads in the world will persuade you that the human mouth ever selects a harmonic much below c″ for its special response. And, meanwhile, you may observe that whether you sing c or c′, the vowel-glide proceeds on its way entirely unconcerned by the presence or absence of reinforced harmonics : the **ɔ** changes continuously into **o**, and **o** into **u**. Multiple resonance, as understood by Helmholtz, cannot therefore be the essential factor in vowel quality. According to Grassmann's interpretation, when no harmonic makes itself clearly heard, it is the vowel which becomes soft (p. 613). The conclusion at which I arrived some three years ago is that the vowel remains unchanged if the oral configuration remains the same, and that the change of quality is in the character of the voice. I see no reason to abandon this conclusion because H. Grassmann, after 45 years of unremitting toil, made a fool of himself at the bidding of Helmholtz. What are you to do with a man who, when a whistler whistles, hears **uː** in the low notes, **yː** in the higher, and **iː** in the highest (p. 611), except defer his case to another chapter?

84. As for what Auerbach (p. 692) modestly calls his "grundlegende" investigation with Koenig resonators in 1876, carried out in Berlin under the auspices of the great Helmholtz—*felix qui potuit*—the whole thing being beneath criticism, it must suffice to say that Auerbach found most of Helmholtz's pitches from f up, as opposed to those of Donders, exactly confirmed (Annalen der Physik, Erg. Bd., viii. 1878, p. 202). That, of course, is as it would be, for

> Will einer an unserm Speichel sich letzen,
> Den thun wir zu unsrer Rechten setzen.

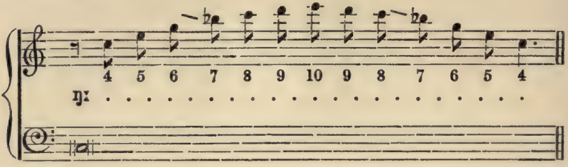
After 33 years, Professor Felix Auerbach's compromise table of characteristic resonance-tones, from "dark" **uː**, a, to normal **iː**, g^3, proves him as incompetent as ever. The whisper-pitch of **iː**, d^4, the only note worth retaining from Helmholtz, having vanished, there is nothing, in this range of three octaves less a tone, of any value whatever. There must be something radically wrong with the theory of resonators if it persuades a man that he hears the tones f or a intensified by the mouth. Ulysses put wax in his ears to escape the Sirens' song. Hermann von Helmholtz stopped one ear, and fitting resonators to the other ear with wax (p. 43), failed to hear in sung vowels certain overtones "above wonderfully there" (dort oben wunderbar) which can be clearly heard without any apparatus. Like that other Hermann, in the stucco Legend of the Rhine, "the shipper in the little ship," he seems to have come to grief on a "rocky clip," not very far from Bonn (*cf.* Mark Twain, A Tramp Abroad, ch. xvi.). I believe, in the words of the immortal Garnham,

> I believe the turbulent waves
> Swallow at last shipper and boat.

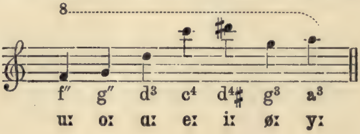
For having come so far, it will be well to ask what we mean by "vowel." By its derivation the word is connected with voice. But vowels can be formed without voice, some by snoring or hawking, all with whisper, or with breath. The in-breathed vowels < **aː eː iː oː uː**, though less sonorous, are every whit as distinctly characterised as their voiced counterparts. But here the glottis is wide open. The glottal lips are in no way implicated. Then what becomes of the theory which would explain vowel quality as a modification of the glottal note by multiple resonance? How can there be harmonics without a generating sound, the fundamental? In-breathed vowels are certainly vowels. They are also "voiceless fricatives," which are said to be the result of audible friction. What is that? Does "audible friction" mean anything? I hope the reader may be better prepared than I to answer this question.

We are indebted to Mr. Daniel Jones for the charm which brings some order into chaos, destroying that bugbear of the phonetician, the superlatively irrational comparative tables referred to in § 13.

Practise this little exercise, and listen to the elfin chime :—



And if text-books of physiology and sound must have their table of vowel-pitches, the following approximation has the demerit of not having been made in Germany, which is, perhaps, and perhaps not, outweighed by its not being a piece of outrageous bluff :—



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