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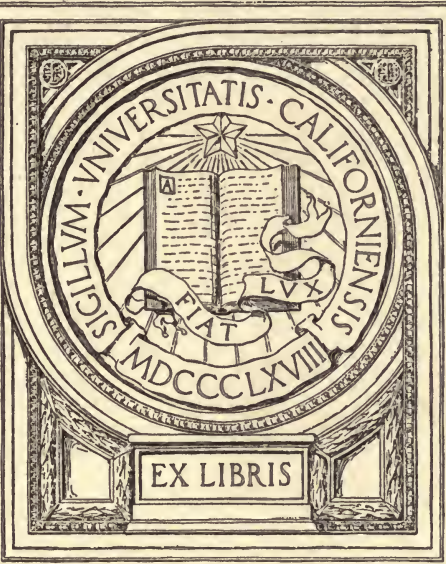


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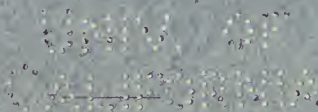
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VOWEL MEASUREMENTS

BY

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Vowel Measurements.

By CHARLES H. GRANDGENT,

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In a paper addressed to linguists and phoneticians it were superfluous to dwell upon the importance of phonetics. All scholars interested in philological research or in modern language instruction must be aware that the teaching of living tongues is greatly improved by a knowledge of phonetics, and that without this science the satisfactory pursuit of comparative philology is impossible. Whatever be the system we adopt in the French and German courses of our colleges and schools, we must admit that pronunciation is an essential element; and the intelligent teaching of pronunciation demands an acquaintance with the physical action by which the sounds of human speech are created and modified. The American teacher, if he have exceptional advantages and an unusually delicate ear, may perhaps be able by mere imitation to acquire a correct foreign accent himself, but neither he nor the foreigner can ever, without a knowledge of phonetics, tell his pupils how to reproduce it. As for the science which we commonly call philology, it consists mainly of the study of sound-changes; and the only solid foundation for such study is, obviously, a thorough mastery of the principles of sound-production.

Knowing these things, we cannot but regret that such an important branch of learning is, in spite of the wonderful achievements of a few investigators, neither widely pursued nor firmly established. In fact, much remains to be done before phonetics, as a whole, can be acceptably presented to the public. This being the case, is it not the duty of everyone concerned with philology to do his share toward the development of the parent science? It seems to me that it is, and that belief has impelled me to contribute my mite to the neglected cause.

Before entering on a course of original research, one naturally makes the practical inquiry: which part of the subject is

in greatest need of more light? In respect to phonetics this question is easily answered: what we most want is accurate information concerning the pronunciation of vowels. The acoustic relations of both vowels and consonants have been thoroughly studied; and, although the reports of various experts disagree, we know as much about this topic as is necessary for philological or pedagogical purposes. Phoneticians are, in the main, agreed as to the formation of the consonants; some matters, such as the tongue-positions for *s* and *sh*, are not quite clear; but in most cases tongue-painting has furnished us with conclusive evidence.¹ With regard to the vowels, however, there is, owing to our imperfect knowledge of the subject, a sad lack of harmony. Admirable work has been done by several men; without their studies such further investigation as I am about to propose would be inconceivable; and if they have failed to convince the learned world, or even fully to agree among themselves, it is perhaps because they and their followers have had to contend with three drawbacks. In the first place, being so few, instead of confining themselves to their own dialects, they felt obliged to attempt the analysis of a host of foreign sounds, many of which must inevitably have been ill pronounced. This broad method was doubtless necessary at first; but, thanks to the results obtained by it, we can now demand something more precise. Secondly, they adopted, in general, no system of real measurement, but trusted mainly to sensation and to ocular observation. Now there are very few vowels during the emission of which we can look well into the mouth through its normal aperture; and if we lower the jaw more than usual, we cannot utter the sounds in a natural way.² For most vowels, then, mere ocular examination is an unsafe guide: Still more uncertain is sensation; for feeling depends far less on the actual movements of the organs than on the preconceived idea in the

¹ See TECHMER, *Internationale Zeitschrift*, i, 1, Tab. iv.

² See an article by Prof. SHELDON and myself, called 'Phonetic Compensations,' in *MOD. LANG. NOTES*, iii, 6. This kind of compensation is, I think, illustrated in the chart that accompanies Dr. TECHMER's pamphlet 'Zur Veranschaulichung der Lautbildung' (Barth, Leipzig, 1885): if I remember his pronunciation rightly, the author forms *a*, as I do, with the tongue lying nearly flat in the bottom of the mouth; but in the drawing, which represents a man uttering *a* with his mouth stretched open to its widest extent, the middle of the tongue is violently raised, evidently to compensate for the enlargement of the mouth-cavity through unnatural jaw-lowering. Similar compensations are to be noted in *Phonetische Studien*, ii, 2, 'On the BELL Vowel-System'.

observer's mind.³ So far as I know, the only actual measurements of any importance made hitherto are those of MERKEL⁴; and even his are really systematic and trustworthy only for the movements of the jaw. The third hindrance to which I referred is the well-nigh irresistible tendency to construct theories on insufficient data. Many investigators have, I fear, designed their system first, and then pared off the toes and heels of their facts to make them fit the symmetrical slipper into which they were to be thrust. It should, nevertheless, be said that the systematizing tendency has brought forth good as well as evil; for without it we should scarcely have seen that scheme of vowel-classification which has made modern phonetics possible.

If, then, we wish to improve on the work done hitherto, we must observe these four rules: begin your examination with a mind free from all prejudice; restrict yourself, in your publication of positive results, to your own dialect or to one with which you are equally familiar⁵; make no unqualified statement that is not based on careful measurement; conduct your investigations in such a way as not to interfere with the natural utterance of your sounds.

For several years I have been pursuing a series of experiments with a view to ascertaining the best method of vowel-measurement, and I have finally hit upon one that seems to promise good results. I offer it to my fellow-workers such as it is, hoping that, bettered by their criticism, it may prove useful to other investigators.

The subjects of my research are the principal vowels of my native Boston dialect, as I pronounce them in careless speech.

They are:—

1. \bar{u} ⁶: as in 'boot', 'suit'. I measure the second half of the vowel, which is somewhat more rounded than the first. The

3. How far a really good observer may be led astray by "sensation" is sadly apparent in some parts of the article 'On the BELL Vowel-System,' by the late W. R. EVANS, *Phonetische Studien*, ii, 1.

4 See 'Physiologie der menschlichen Sprache,' 1866, pp. 68, 82, 85, 86, 89, 91, 93, 98, 103. See also, however, VIETOR, 'Phonetik,' 1887, p. 36; and BRÜCKE, 'Grundzüge der Physiologie und Systematik der Sprachlaute,' 1876, pp. 37, 38.

5 In *Phonetische Studien*, iii, p. 114, SWEET says: "The only observations that can be fully relied on are those made by trained observers on themselves."

6 The "long" and "short" marks are used in this article merely to distinguish different vowel-qualities: they have no reference to quantity. The correspondence of my symbols with those used by the American Dialect Society is as follows: my \bar{u} = Am. Dial. Soc. \bar{u} , \bar{u} =u, \bar{o} = \bar{o} , \bar{a} = \bar{a} , o= \bar{o} , u= \bar{u} , \bar{e} = \bar{e} , \bar{o} =o, a= \bar{a} , e= \bar{e} , i= \bar{i} , \bar{i} =i, \bar{e} = \bar{e} , \bar{e} =e, \bar{a} = \bar{a} .

latter part of my \bar{u} sounds nearly like German u in *gut* and French *ou* in *doute*, but it has less energetic lip rounding, and seems to be pronounced a little^{le} further forward in the mouth.

2. \bar{u} : the vowel in 'bull', 'hoof'. It regularly takes the place of \bar{a} before any sound written r or *er*, as in 'doer', 'endure', 'insurance', 'newer', 'poor.' A variety of \bar{u} regularly precedes \bar{a} when that vowel is final or followed by a voiced consonant, as in 'do', 'room', 'rude', 'rule', 'through' (pronounced *d \bar{u}* , *r \bar{u} um*, etc.).

3. \bar{o} : as in 'boat', 'note'. I measure the second half, the first half being less rounded.⁷ The latter part of my \bar{o} is very similar in sound to German o in *not* and French \acute{o} in *côte*.

4. \hat{a} : as in 'all', 'bought', 'daughter', 'for', 'law'; somewhat similar in sound to French o in *tort*, but with less lowering of the jaw and no real rounding.

5. o : the vowel called (when heard in such words as 'boat,' 'road', 'stone') "short New England o ". In my dialect, however, it exists only in the following cases: first, in the word 'whole' and its compounds; second, in the diphthong $o\bar{z}$ in 'boy', 'moist', etc.; third, instead of \bar{o} before any sound written r or *er* (as in 'door', 'roaring', 'slower,' 'store.');

fourth, in unaccented syllables of some words oftener seen than heard (as 'phonetic'=*fon \hat{e} tik*, 'November'=*nov \hat{e} mbe*; but 'polite'=*pelait*). A sound intermediate between \bar{o} and o regularly precedes \bar{o} when that vowel is final or followed by a voiced consonant, as in 'bowl,' 'home', 'road', 'so' (pronounced *bo \bar{o} l*, *ho \bar{o} m*, etc.). My o seems somewhat similar to French o in *bonne*, *botte*, *homme*, *poli*, but is apparently pronounced further back in the mouth.

6. u : as in 'but', 'come', 'enough', 'squirrel', and sometimes in 'got,' 'what.' It is also the vowel that takes the place of an r (except r between spoken vowels) or final *-er*, after \bar{u} , \hat{e} , and o (as in 'sure' or 'shoer', 'nor' or 'gnawer', 'sore' or 'sewer': pronounced *sh \bar{u}* , *n \bar{u}* , *sou*).

7. \bar{e} : as in 'bird', 'nerve', 'nurse', 'pearl', 'sir'.

8. \bar{o} : as in 'hot', 'John', 'tomorrow'. My \bar{o} is unrounded, and hence unlike that of SWEET and of some Americans, from which it seems to differ also in other respects. When pro-

⁷ See SWEET, 'Primer of Phonetics', 1890, p. 75.

nounced with the mouth very wide open, it sounds strikingly like French *â* in *pâte*.⁸

9. a: as in 'ask', 'far', 'father', 'hard', 'pass', 'quarrel,' and sometimes in 'got', 'what.' A forward variety of it forms the first element of *aï* (as in 'I', 'die', 'eye', 'height', 'light'); a slightly retracted variety forms the first element of *aü* (as in 'cow', 'out', 'plough').

10. e: the unaccented vowel in 'again' 'better', 'ogre', 'sofa'. It takes the place of an *r* (except *r* between spoken vowels) or final *-er*, after *ɨ* and *ʒ* (as in 'dear', 'payer', 'there': pronounced *dʒe*, *pʒe*, etc.).

11. i: as in 'eat', 'feet', 'receipt', 'suite'. I measure the second half of the vowel: the first half tends slightly towards *ɨ*.

12. ɨ: as in 'beard' 'Erie', 'fit', 'merely', 'near', 'steer', 'win'. An *ɨ* that tends somewhat towards *i* regularly precedes final *i* and *i* before a voiced consonant, as in 'fee', 'feed' (pronounced *fʒi*, *fʒid*.) When *ɨ* is unaccented, as in the last syllable of *siti* ('city') or *nékid* ('naked'), it is slightly flattened and retracted, approaching *é* in sound. Compare SWEET'S 'Primer of Phonetics', pages 15, 74, and 77.

13. é: as in 'fate', 'great', 'straight'. I measure the second half: the first half tends slightly toward *ʒ*.

14. ʒ: as in 'bet', 'fare', 'mayor', 'men', 'stair', 'tear', 'their', 'where'. A variety of this *ʒ* regularly precedes final *é* and *é* before a voiced consonant, as in 'afraid', 'bathe', 'blaze', 'name', 'rail', 'rain', 'say', 'they', 'weigh', (pronounced *efrʒéd*, etc.). Compare SWEET'S 'Primer of Phonetics', page 74.

15. ʌ: as in 'cat', 'man'.

These fifteen vowels, then, are to be analyzed. What are the organs whose positions we must determine? The raw material of all spoken vowels is, as every one knows, the sound borne in the vibrating breath that rises from the larynx. This sound passes, on its way to the outer air, through a large resonance-chamber and a comparatively small orifice. Sometimes there are two spaces and two openings. What we must ascertain for every vowel is the size, shape, and place both of the cavity or cavities and of the narrow passage or passages. These factors are determined by the form and position of the lips, jaw, tongue

⁸ See *Phonetische Studien*, i, 2, p. 171; and SWEET, 'Primer of Phonetics,' 1890, pp. 76 and 85.

epiglottis, and soft palate. If the larynx perceptibly rises and falls as we go from one vowel to another, its movement must change the dimensions of the pharynx, and should therefore be noted also.⁹ In my case, however, this motion of the larynx is altogether too slight to be measured. The protrusion and retraction of the hyoid bone are connected with the movements of the tongue, and need not be separately studied.¹⁰ There remain, then, the five organs just enumerated, whose changes of shape and location we must carefully examine.

The easiest measurements are, obviously, those of the lips and jaw: with these we shall begin. In performing the following experiments it is of the greatest importance to pronounce the vowels naturally. It is perhaps best to look away for a few moments from the mirror before which all these investigations must be pursued, and speak over and over again a common word containing the desired vowel; then, by glancing suddenly back at the glass, the real lip-position can be caught. To draw the outlines of the lips correctly, four measurements, which can be taken with a slip of paper, will probably be found necessary—those marked in Figure 1¹¹ AD, BC, *ad*, and *bc*. The rest can be drawn free-hand. I give figures showing the lip-positions for all my vowels. It will be seen that the general outlines are always the same: this is, I think, a characteristic feature of English vowels. My *ū*, *ō*, *ū*, *o*, and *ö* are rounded.

The jaw-lowering can be noted by a simple device. On a strip of pasteboard, an inch long by a quarter of an inch wide, is marked a scale of millimeters, with the zero at the bottom. This scale is glued, in a vertical position, to the most prominent part of the chin. A slender stick, about a foot long, is then suspended from the upper part of the face in such a manner that it will hang alongside the pasteboard. The stick is held steady at the lower end by the hand of the experimenter, who now fastens a little pointer to it at such a spot that when the jaws are firmly closed it will be just opposite the zero. This being done, the vowels are pronounced, and the pointer indicates in millimeters the amount of jaw-lowering. The measurements for my vowels are given in the drawings at the end of this article.

⁹ MERKEL ('*Physiologie der menschlichen Sprache*', p. 103) notes a very decided rise and fall of the larynx. TECHMER (*Internationale Zeitschrift*, i, 1, Tab. iii) indicates something similar.

¹⁰ See MOD. LANG. NOTES, iii, 6, p. 364.

¹¹ See end of this article.

It is worthy of note that the difference in mouth-opening between my closest and my widest vowels does not exceed four millimeters. In French and German the difference is, of course, far greater.¹²

We next come to the difficult subject of palate and tongue. Here the greatest drawback is the unwillingness of the organs to perform their natural functions when in contact with any foreign substance. Only by long and patient practice can the rebellious tongue and palate be entirely subjected to their owner's will. It can, however, be done. In the course of varied experiments I have gained sufficient mastery over these sensitive organs to make, at will, either of them assume the correct position for any vowel in my dialect, and retain that position in spite of the presence of a finger or an instrument. Before beginning any systematic measurements it is well thoroughly to explore with the finger all parts of the mouth and as much as possible of the pharynx, with a view both to training and hardening the organs, and to gaining a general knowledge of the movements of tongue and palate. Much can be learned in this way; in fact, for some measurements I have discovered no better method.¹³ Before long it will be found expedient to pronounce the sounds mentally rather than aloud; for when the organs are in the proper position for a vowel, the presence of a finger in the mouth of course diminishes the size of the resonance-chamber and so alters the sound; and the observer, catching this false note, involuntarily shifts his tongue. A helpful instrument in all these researches is a tiny electric light that can be held in the mouth.¹⁴ With the aid of this burner the outline of the tongue from side to side can be observed from the mouth-aperture, and can be drawn with sufficient accuracy free-hand. Drawings of these outlines for my vowels accompany the representations of lip positions and longitudinal tongue-profiles at the end of this paper. Those for *i*, *y*, *é*, *è*, and *ä* were made with the head thrown

¹² MERKEL ('*Physiologie der menschlichen Sprache*', p. 103) makes the difference between *i* and *ä*. PASSY (*Phonetische Studien*, i, 1, p. 24) gives diagrams which seem to indicate a little more jaw-lowering. WESTERN ('*Englische Lautlehre*', 1885, pp. 5 and 83) implies that the distinction between *i* and *ä* is almost entirely a matter of jaw-position. 7"

¹³ In his introduction to the *Revue des patois gallo-romans*, i, 1, the Abbé ROUSSELOT says, in the course of an 'Analyse des sons', in speaking of the vowels (p. 13): "Je ne tiendrai compte ici que des mouvements de la langue et de ceux des lèvres. L'explorateur que j'emploie est tout simplement le doigt."

¹⁴ I have made use of a small glass bulb enclosing a one-candle-power incandescent burner connected by two thin wires with a three-cell battery.

back, and represent the passage between the front part of the tongue and the roots of the teeth; the others represent the highest part of the tongue that can be seen, and the section of the palate that is over it.

For our main investigations the starting point must be the upper teeth and the hard palate. The first thing to be done is to make an outline drawing of the whole palate from front to back. A cast of the immovable hard palate can be obtained from a dentist, or constructed by the observer himself from a pulp made of tissue paper. After having carefully measured in the mouth the distance (Figure 2, *bc*) from the lower edge of the upper front teeth to the middle of the arch that forms the inner limit of the hard palate, we can take the front part of our outline from the cast. The drawing should include a cross section of one of the upper front teeth. The back portion of our line, consisting of the profile of the soft palate, will vary with the different vowels. For every vowel it is best to make several measurements. If we look into the widely-opened mouth, we see that the way into the pharynx leads through a double arch, broken at the top; from the centre of this arch hangs the uvula. After setting the soft palate in the correct position for the vowel,¹⁵ we take a long, narrow strip of wood, and measure the distance from the edge of the upper front teeth, first to the inner (*bf*), next to the outer (*be*) pharyngeal arch, and then to a point half-way between the outer pharyngeal and the palatal arches (*bd*, Figure 2).¹⁶ These points being fixed, we can draw the outline of the soft palate. To complete the drawing (cf. Figure 2), a section of the lower front teeth should be added in the proper position. The lips may, if desired, be outlined also.

Such a drawing as this having been prepared for every one of the fifteen vowels, we can now proceed to the tongue-measurements. For these I have constructed a set of instruments consisting of card-board ovals varying in length from five to

¹⁵ The soft palate can readily be trained to take the proper positions. It is well to begin by watching its movements in natural speech, and then to try holding the tongue down with the finger and uttering the vowels mentally. Before long the tongue will stay down of its own accord, and the soft palate will move independently of it.

¹⁶ For the sake of greater accuracy (as these data are of the highest importance), we may make some supplementary measurements. Open the mouth wide; determine the exact position of *a* (Figure 2) with reference to *b*; then measure *af*. The positions of *a* and *b*, and the distances *ab*, *af*, and *bf* being known, we can find the exact location of *f*. Similarly we can, if necessary, calculate the positions of *e* and *d*.

twenty-five millimeters, each of which is firmly fastened to a piece of pliable silver wire about six inches long, which projects at right angles from the centre of the ellipse. The observer sits at his desk with the proper drawing before him, and with pencil, mirror, and instruments at hand. He selects the largest instrument that can, so far as he is able to judge, be used for the vowel in question; bends the wire so that it will hold the upright oval as nearly as possible at right angles to the tongue; places the card-board at the very back of the wide-open mouth; then raises the jaw, and, while pronouncing the vowel naturally, pulls the oval forward until it touches simultaneously the palate and the tongue.¹⁷ Thereupon he stops, marks with his thumb-nail the point of the wire that is in contact with the lower edge of the upper front teeth, and then takes the instrument from his mouth and applies it immediately to his drawing, being very careful not to bend the wire. When the instrument occupies on the drawing a place exactly similar to that which it held in the mouth, the top of the ellipse being opposite the palate line, he marks with a dot on the paper the position of the lower end of the oval, thus indicating the point where it rested on the tongue. After that, he takes the next smaller instrument, performs the same experiment, and makes another dot; and so on, until all the available instruments have been used. Then he changes the process, beginning at the big cavity just behind the roots of the teeth, and moving the instruments both backward and forward. For some vowels, of course, he will find that only one of these two sets of measurements will be possible. Finally, by connecting all the dots he has made on the paper, he obtains the longitudinal profile of the tongue for the desired vowel. The shape of the root of the tongue; the size of the pocket between it and the epiglottis, and also the distances between the raised edge of the epiglottis and the back of the tongue on the one hand, and the inner wall of the pharynx on the other, can best be ascertained with the finger.¹⁸ When these distances are considerable, I have found it a good plan to swing the end of the

17 Great care should be taken, especially in measuring *i*, *y*, *é*, and *è*, lest the card-board sink into the back of the tongue and thus indicate a false position. If this digging into the tongue cannot be avoided, some allowance must be made for it. Much care is required, also, to keep the oval perpendicular to the tongue.

18 To admit the finger the mouth must, of course, be opened wider than usual; but this jaw-lowering, which amounts to three-quarters of an inch at the teeth, is far less perceptible at the back of the mouth.

finger gently from one object to the other, to continue this movement until it becomes, so to speak, habitual, and then, on taking the finger out, to reproduce the swing before a ruler or on the drawing. In this way a tolerably reliable measurement can be made.

The drawings obtained by these methods form the last and the most important portion of this contribution. I would call attention to the fact that the large figures represent a section of the *middle* of the mouth: that is, the highest part of the palate, the lowest part of the central groove in the tongue, the greatest approximation of the front teeth, and the widest lip-opening. The uvula has been omitted. It must be remembered, too, that if the jaw be abnormally lowered, the tongue will be correspondingly raised: hence observers looking into their mouths will not be able to see all the tongue-positions as they are depicted here. Students of Phonetics will observe that in my dialect there is nothing corresponding to SWEET'S definitions of "narrow" and "wide".¹⁹ I have no doubt that such a distinction exists in the speech of some persons; I can, if I try, make something like it myself for *i* and *ɪ*, *é* and *ɛ*;²⁰ but it does not seem to be my natural way of creating a difference between "close" and "open" sounds.

My *a*, *ɔ*, and *ɛ* are also widely different from SWEET'S descriptions;²¹ my *u* is probably²² pronounced further forward; I have not, to the best of my knowledge, his "narrow" *æ* (a vowel between *ɛ* and *ä*), although I often hear it from Americans. My drawings show, further, that most pictures of the tongue-positions for *i*, *ɪ*, *é*, *ɛ*, and *ä* represent the tongue as extending too far back: it really descends sharply just behind the highest point, leaving in the back of the mouth a very big chamber, which seems to be the distinguishing feature of "front" vowels.²² This chamber is, in the case of *i*, *ɪ*, and *é*, connected with the outer air by a long, narrow passage; but for *ɛ* and *ä* the space before the tongue is so widened as to lose its tunnel-

¹⁹ My drawings appear to show a regular gradation from *ä* to *i* and from *ä* to *ü*: nearly all German phoneticians have maintained that this was the case with their vowels.

²⁰ See JESPERSEN, 'Articulations of Speech Sounds', 1889, p. 17. SWEET himself says, 'Primer of Phonetics', 1890, p. 18: "The distinction between narrow and wide is not so clear in the back vowels."

²¹ SWEET: 'Handbook of Phonetics', 1877, p. 16; 'History of English Sounds', 1888, p. 3; 'Primer of Phonetics', 1890, pp. 21, 72, 73. In the last work, p. 72, SWEET says of his "mid-back-narrow" *u*: "This vowel is slightly advanced."

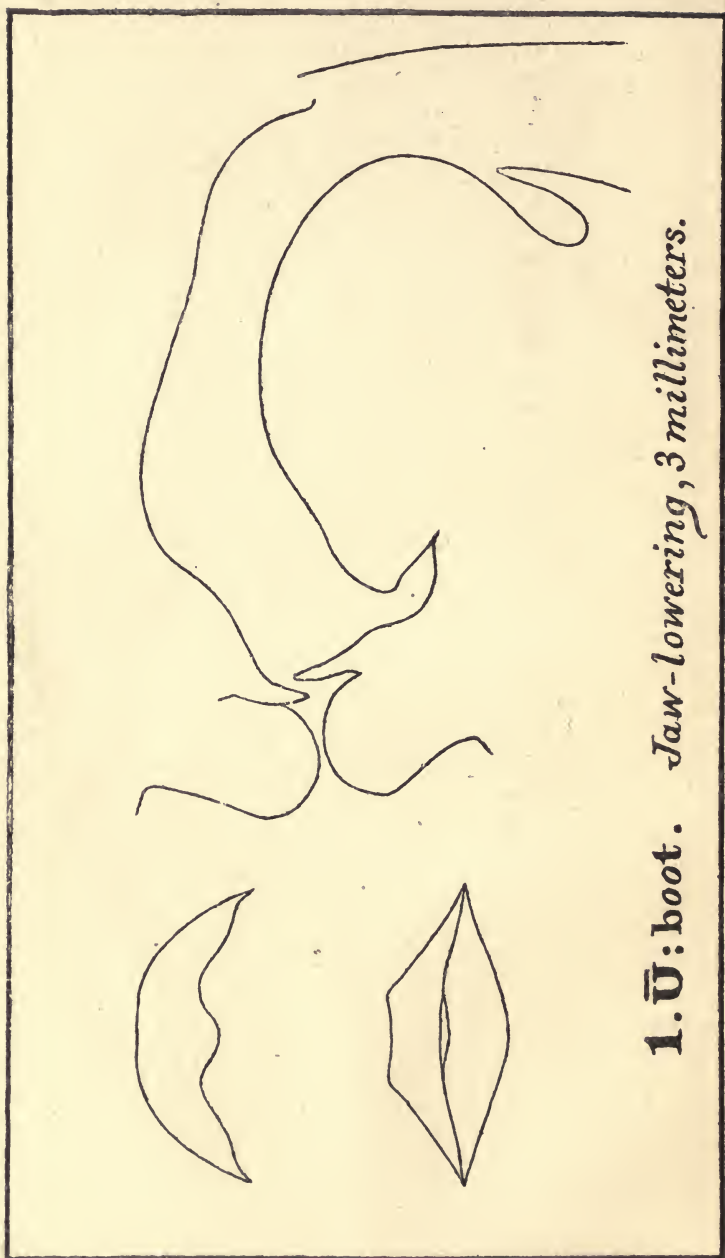
²² See *Proceedings of the American Philological Society* for 1884, pp. xxxviii-xl.

like character. \bar{u} , \bar{y} , \bar{o} , and \bar{a} have their principal mouth-cavity in front of the highest part of the tongue: we may, then, aptly call them "back" vowels. My "front" and "back" vowels form two nearly parallel and vertical series. In the case of δ , a , e , o , u , and \bar{e} the mouth-chamber is above the whole tongue; but while δ , a , and e leave the tongue almost perfectly flat, o , u , and \bar{e} require a hump in some part of it. The elevation for \bar{e} seems to be thinner from front to back, and the tongue less retracted, than for u and for o , which latter vowel is distinguished from u only by its rounding and by a slightly higher jaw-position. \bar{O} has a bigger cavity than a ; a differs from e in the slope of the epiglottis and back of the tongue, and has also a larger chamber. The biggest mouth-cavities are apparently those of \bar{a} ²³ and \bar{i} . I have already stated that my δ is unrounded: I think I may safely say the same of my \bar{a} . My \bar{u} and \bar{o} have, on the other hand, very marked rounding; \bar{y} , o , and \bar{e} are less rounded.

Before concluding, I wish to express the hope that other and more competent observers, and especially scholars of different nationalities, may find time to make, by these or other methods, accurate studies of their own vowels. There are many difficulties to be overcome²⁴—some of them I have pointed out—but the work is intensely interesting, and, on the whole, easier perhaps than this scanty account makes it appear. It is, in my opinion, only through comparing the results of many experiments by many men that we can construct a complete and reliable vowel-system.

²³ With persons who round the \bar{a} , the mouth-cavity for that vowel is probably somewhat smaller than with me. BELL, however, says ('Speech Reading and Articulation Teaching', 1890, p. 13): "Enlarge the cavity of the mouth to the utmost Emitted . . . voice will then have the quality of what is called the 'Low Back' vowel". I do not see how VIETOR can say ('Phonetik', 1887, p. 15): "Bei u ist der Resonanzraum im Munde am grössten." It seems to me that no back vowel can have a smaller cavity than \bar{u} . The low pitch of this vowel is evidently caused by rounding. Cf. SWEET, 'Primer of Phonetics', 1890, p. 26.

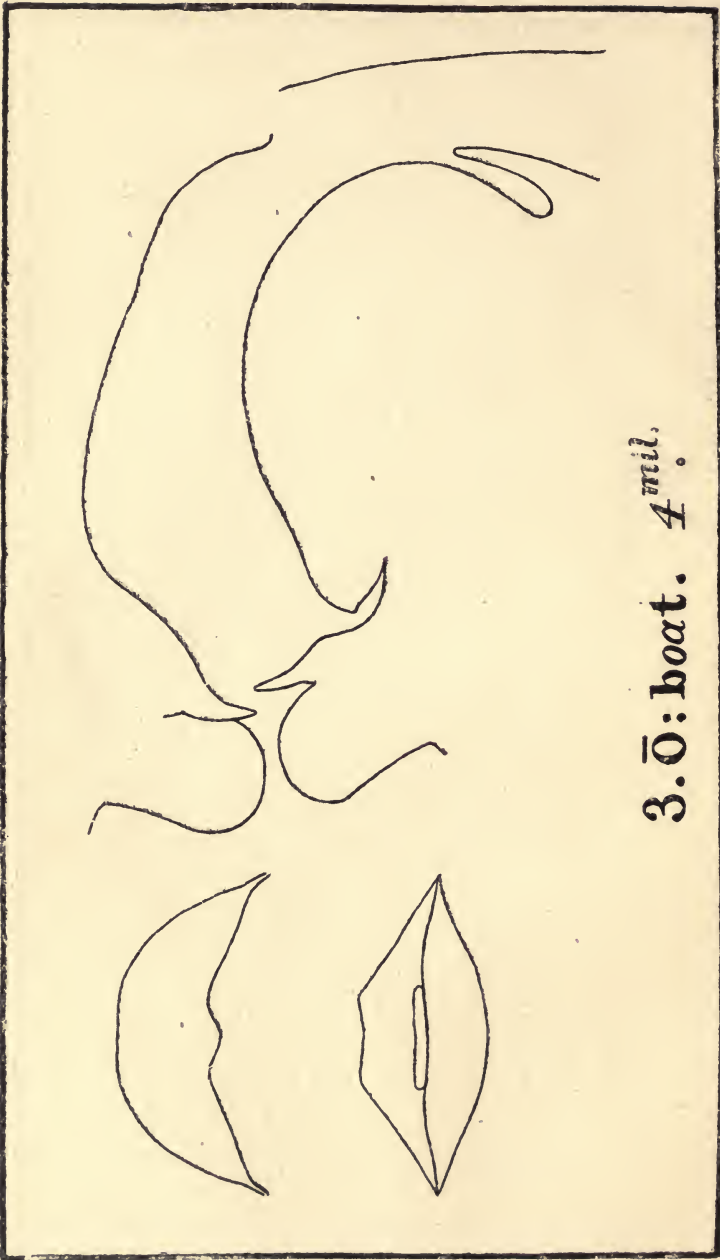
²⁴ I ought, perhaps, to say that I made hundreds and hundreds of preparatory measurements before I thought myself sufficiently skilled to begin on the final experiments, the results of which are set forth in this article. The ticklishness of the soft palate, which, at first, is apt to produce choking and retching, can easily be overcome by a little practice; but the sensitiveness of the pharynx, which, if exploration in that region be long continued, is liable to develop into sore throat and coughing, I have never been able to cure. The difference in the effect of contact on the parts touched sometimes affords a clue to the whereabouts of the end of the exploring finger, when that member is not sensitive enough to distinguish, by its own sensation, the soft palate from the inner wall of the pharynx.



1. \bar{U} : boot. Jaw-lowering, 3 millimeters.



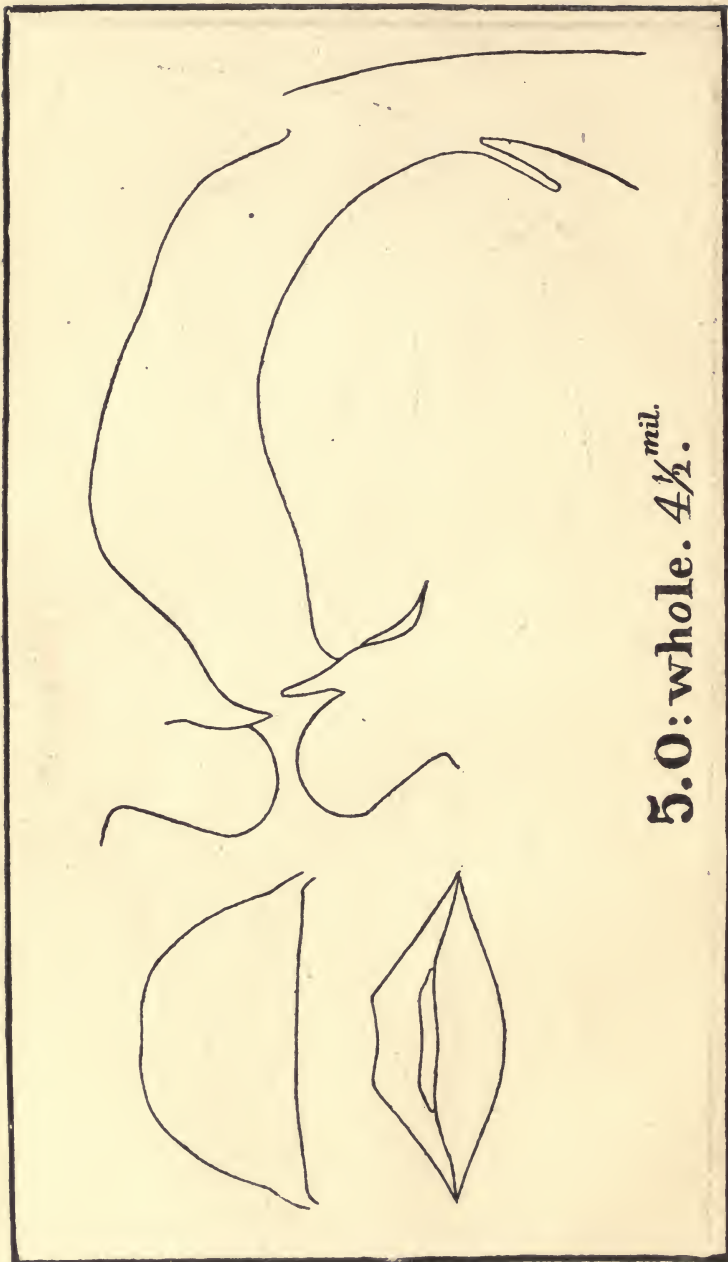
2. ū:book. 3½^{mil.}.



3.0: boat. 4^{mil.}



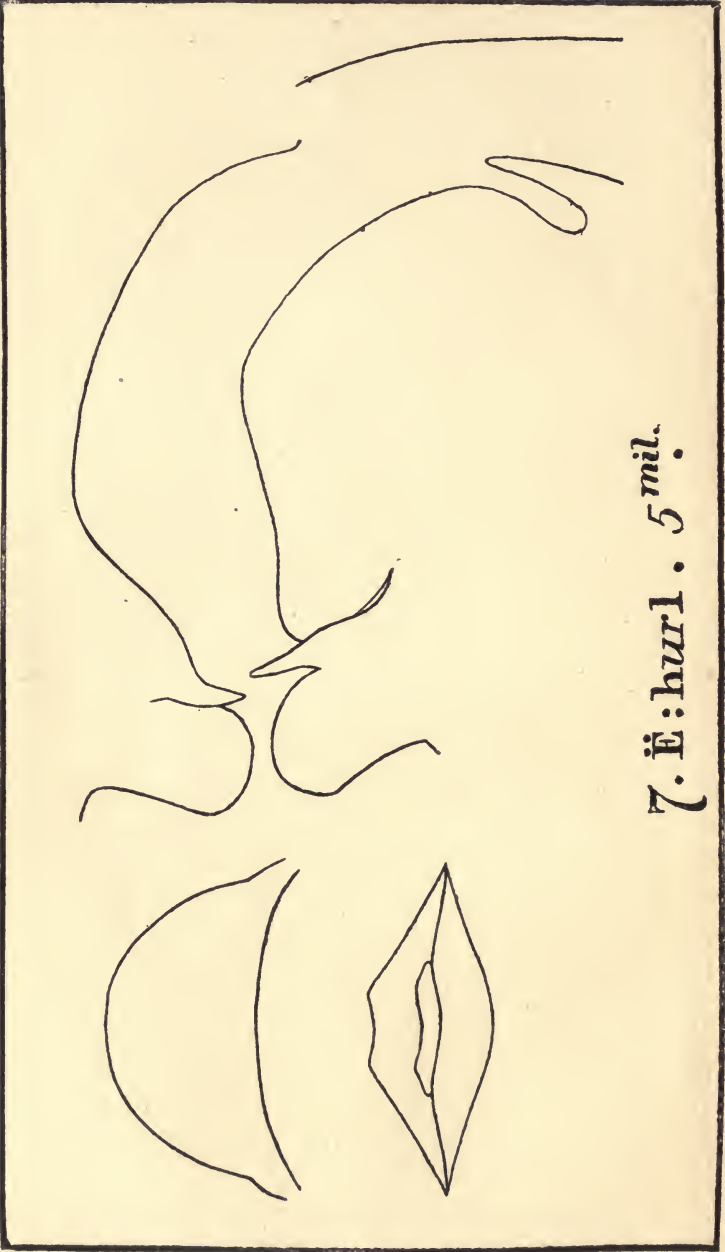
A. \hat{A} :bought. $6\frac{1}{2}$.^{mil.}



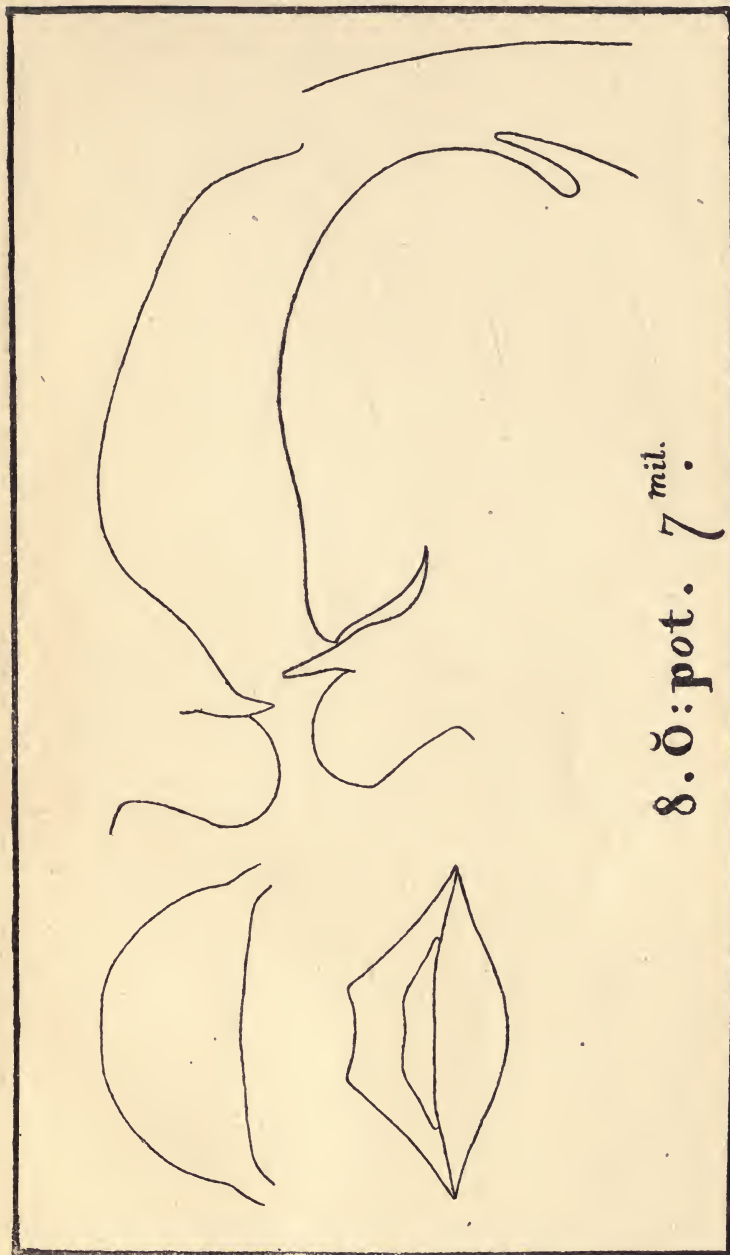
5.0: whole. $4\frac{1}{2}$ ^{mil.}



6. U: huɪ. 6^{mil.} .



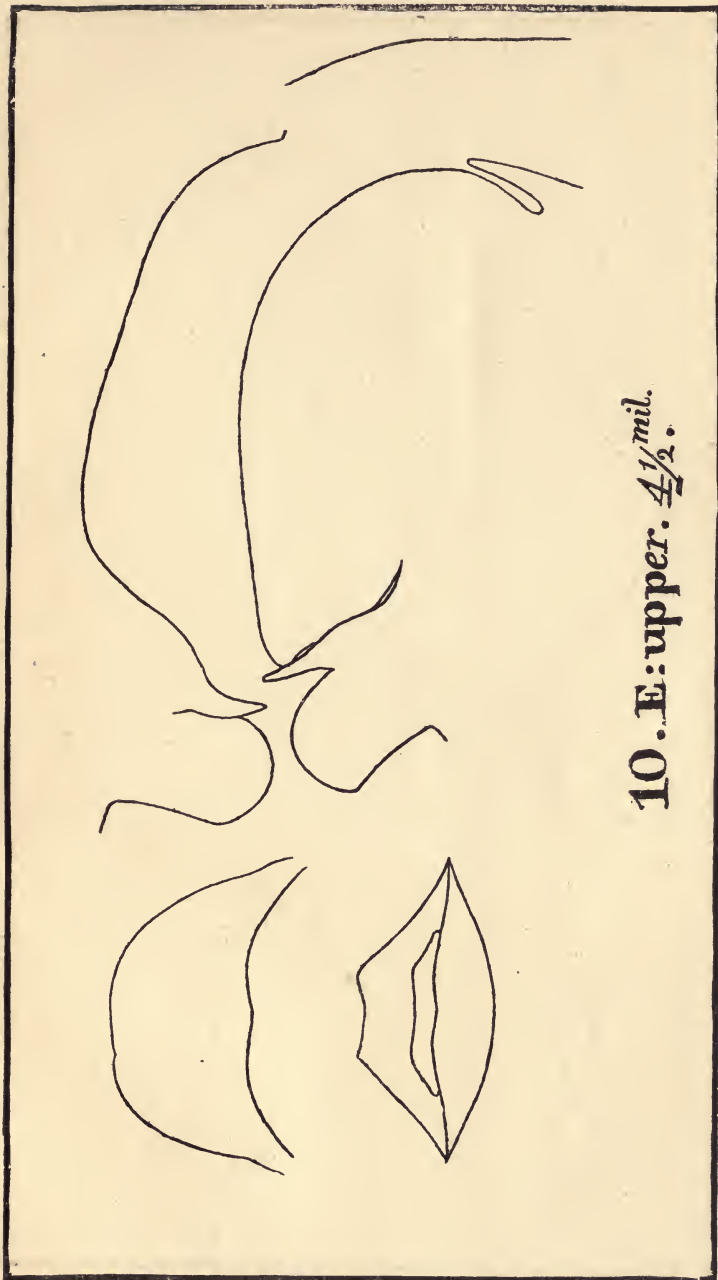
7. *Ë:hurl*. 5 mil.



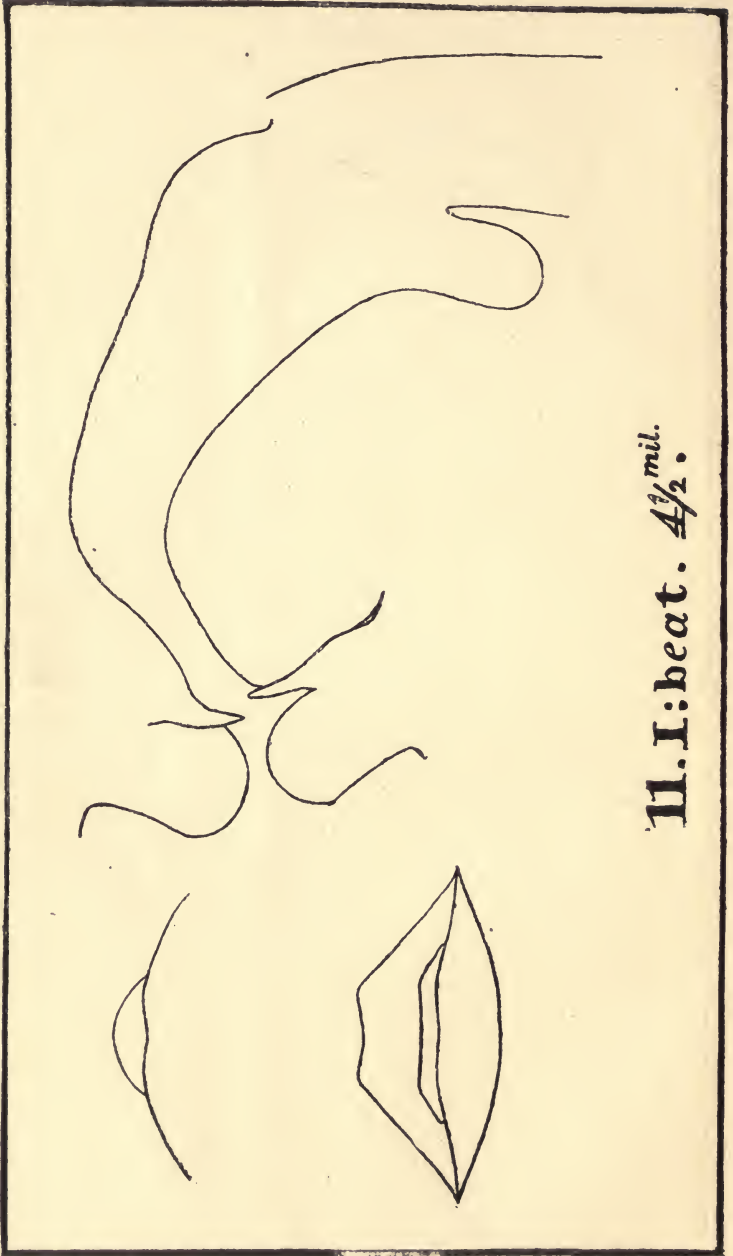
8. Ö: pot. 7^{mil.}



9. A: part. 7^{mil.}



10. E: upper. $4\frac{1}{2}$ mil.



11. I: beat. $4\frac{1}{2}$ mil.



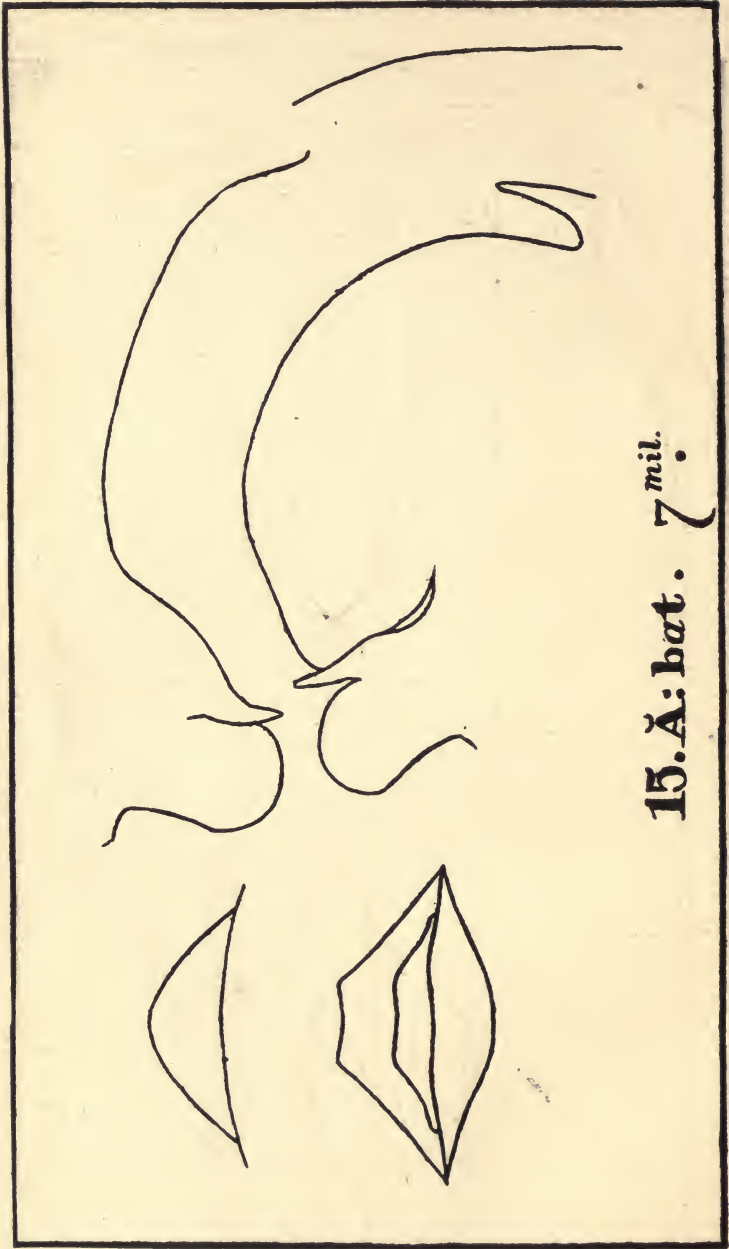
12. ĭ:bit. 5 mil.



13. É:bait. 5½ mil.



14. **ä**:bet. 6^{mil.}



15. *Ä: bat.* 7^{mil.}

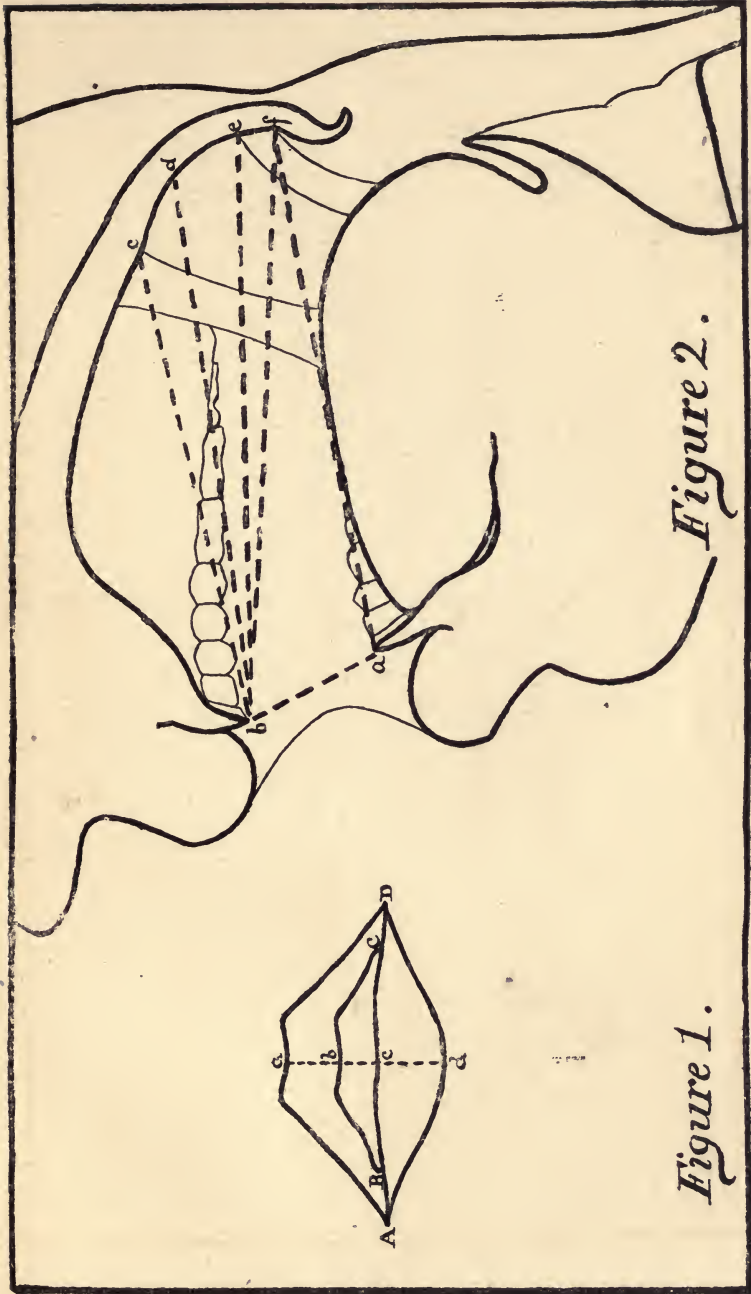


Figure 2.

Figure 1.

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