THE VOWEL E.

BY LOUIS BEVIER, JR.

THE vowels *a*, as in *father*, and *a*[°], as in *pat*, are quite uniform sounds in the mouths of most Americans. It is true that *a* is often sharpened in New England, and that *a*[°] is frequently nasalized more or less, but still it is easy, by pronouncing either in the presence of a speaker from whom one desires to get a record, to secure from him a pretty accurate reproduction.

Of the subject of the present study this is not the case. In the first place *e* itself varies considerably in different combinations of actual speech, from an open *e* (*ē*), not differing greatly from *a*[°] to a close *e*, approaching the French *é* (*ē*). In the second place speakers are accustomed to pronounce it short in most words, as in *net*, *pet*, etc., and it is difficult to get them to prolong it in singing at a registered pitch without a noticeable alteration of its timbre, the very matter of our study. Great care, however, has been taken in this respect, that all records analyzed should sound true, when produced, and when reproduced, and the quality is, I believe, sufficiently uniform to give trustworthy results.

The vowel here to be analyzed is the open *e* (*ē*) of *pet*. It has not seemed necessary to attempt an examination of a still more open *e*, as for example the German *ä*, because this nuance is not normal in our speech, and because the analysis of *a*[°] and *ē* are so similar that the intermediate may be constructed theoretically with sufficient exactness. On the other hand the vowel in *pate* is not here considered because it is not a simple sound, and must be reserved until the question of diphthongs is reached.

The following table gives a sufficient number of analyses to furnish a safe basis of generalization. For full explanation of the arrangement of facts in the table the reader is referred to the discussion of the vowel *a*[°], printed in the March number of this journal.

An examination of the table reveals that the upper partial, which

ANALYSES OF THE E-CURVE.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII
	152	304	456	608	760	912	1064	1216	1368	1520	1672	1824	1976	2128	2280	2432	2584
1	91.0	4.4	6.6	25.5	4.0	3.5	5.5	6.6	2.4	4.2	5.9	9.2	0.4	2.0	2.9	2.6	0.2
1	160	320	480	640	800	960	1120	1280	1440	1600	1760	1920	2080	2240	2400	2560	2720
6	101.8	7.9	5.7	9.8	2.6	3.9	5.3	3.9	5.7	6.7	8.2	1.6	1.8	2.3	1.0	1.2	0.8
6	165.8	34.3	2.3	31.1	1.0	0.5	2.6	0.8	4.2	6.9	6.0	2.4	1.0	1.2	1.0	0.3	0.7
1	181	362	543	724	905	1086	1267	1448	1629	1810	1991	2172	2353	2534	2715	2896	3177
	82.6	3.9	11.1	1.7	3.1	3.6	5.8	6.3	8.7	14.1	4.1	3.1	3.4	2.2	1.2	1.0	1.0
6	192	384	576	768	960	1152	1344	1536	1728	1920	2112	2304	2496	2688	2880	3072	3264
7	57.4	5.4	7.1	4.9	4.9	2.3	1.2	9.4	26.2	12.6	4.0	3.6	3.1	2.6	3.1	3.3	1.9
	47.0	7.0	7.5	4.3	3.6	7.9	2.1	7.0	11.5	23.2	4.9	3.6	1.5	1.3	1.1	1.0	0.4
2	202	404	606	808	1010	1212	1414	1616	1818	2020	2222	2424	2626	2828	3030	3232	3434
	64.2	2.8	12.1	4.1	4.7	5.9	6.2	12.5	10.	6.9	3.4	0.9	2.8	0.9	0.9	0.7	0.6
1	226	452	678	904	1130	1356	1582	1808	2036	2262	2488						
	236.0	6.9	21.9	3.5	6.3	7.6	17.3	12.5	1.5	2.6	4.2						
1	256	512	768	1024	1280	1536	1792	2048	2304	2560	2816	3072	3328	3584	3840	4096	4352
1	251.6	8.8	11.4	10.6	7.8	13.6	17.6	6.2	4.5	7.3	5.6						
6	136.9	8.8	5.0	14.6	4.2	28.8	18.0	5.9	2.3	1.2	1.4	1.5	1.0	0.6	0.5	0.1	0.7
7	97.0	11.2	3.5	6.3	6.5	17.3	32.3	2.6	3.0	4.3	1.7	1.3	0.5	1.2	0.7	0.6	0.6
1	272	544	816	1088	1360	1632	1904	2176	2448	2720	2992						
1	168.6	8.4	7.2	14.8	2.8	12.1	23.7	6.5	4.6	2.8	1.3						
1	94.4	10.4	14.2	10.6	7.0	28.4	10.8	3.8	1.5	1.0	0.0						

is most characteristic for e , and always present, lies higher in the musical scale than for a^e by an interval somewhat greater than a whole tone. The frequency of this characteristic and strongly reinforced upper partial is in the neighborhood of 1,800, whereas that of a^e lay as we saw (l. c.) at about 1,550 $\left(\frac{1,550}{1,800} < \frac{8}{9}\right)$. The actual frequency of this important upper partial varies within not very narrow limits, according to individual differences of utterance, and according to the pitch of the fundamental of which it must be an exact multiple. Thus in the table we find on I. 152, 1,824 (XII.) with an amplitude percentage of 9.2; on I. 160, 1,760 (XI.) with 8.2 and 6.0 respectively in the two examples; on I. 181, 1,810 (X.) with 14.1, and so on to the highest tones analyzed.

This region of resonance extends over a considerable range, so that on low fundamentals two consecutive upper partials may be strongly reinforced. For example, I. 192 of voice 6 shows both IX. and X. (1,728 and 1,920) strong, and so in many other examples. The limits may be approximately set at 1,600 and 1,950 with the maximum generally at about 1,800.

Besides this resonance there is always present at least one other, and often two others of lower pitch. These coincide very closely with those described in the study of a^e save that the lower centers at about 620 (cf. 650 for a^e). The upper has a frequency of about 1,050 as for a^e . A good example in the table which shows both of these resonances, in addition to the principal one above described, may be seen in I. 272 of voice 1. Here II. (544) is strong (15.8), IV. (1,088) is also strong (14.8), and VII. (1,904) predominately strong with an amplitude percentage of 23.7. The real strength of the last may be best appreciated if the same record is computed in energy percentages, which would give the following results: I. 0.2; II. 2.3; III. 1.1; IV. 8.0; V. 0.5; VI. 12.1; VII. 63.3; VIII. 6.2; IX. 3.9; X. 1.8; XI. 0.5.

More frequently the analysis shows but one of the two lower resonances at all important, either that in the neighborhood of 620 or a compromise between the two. The essential point for the character of the vowel is that there shall be, in addition to the uppermost resonance, a certain fullness of resonance at one or more

lower points. This can best be made plain by a detailed examination of several concrete cases. Take for example the two specimens at 160 by voices 1 and 6. Each shows the characteristic high resonance at XI. (1,760). This is a little below the point I have designated as the normal maximum, but is nearer to it than the next upper partial (1,920) would be. Still many examples may be found where 1,920 would be the dominant upper partial, representing presumably, other things being equal, a slightly closer ϵ . Following the records down the scale toward the fundamental, X., IX. and VIII. are weak, as they should be; VII. shows in each a greater amplitude percentage, but not quite as much greater as we should usually find at that pitch (1,120) which is quite near a region of resonance. Again VI. and V. are weak, which is according to the rule, and IV. is strong. In the second case it is very strong, much more so than is usual.

Compare next the five examples by different voices on the fundamental 320. Here II., which falls near the lowest resonance maximum, is strong in all, varying from the high amplitude percentage 37.8 to the moderate 13.8. On the other hand III. falls a little too low for strong reinforcement in most normal utterances. Still the first and second examples show considerable reinforcement, particularly the second where III. is very strong. At IV. all are relatively weak, as they should be. At V. the resonance begins to be important again in the case of the second and third examples, but not in the others. VI. falls near the resonance maximum and is consequently strong in all. Even VII. in the first and second examples is quite strong, although considerably above the usual ϵ resonance.

From a careful study of the table, and from numerous other analyses, the definition of ϵ may be formulated as follows: The vowel ϵ is a composite sound containing: (1) The chord-tone, or fundamental, varying within wide limits of loudness. In general it is strong below 200, but not so strong as that of a^ϵ . From 200 to 600 it is weak, but not so weak as that of a^ϵ . Above 600 it falls within a region of strong resonance and is very strongly reinforced.

(2) A characteristic ϵ resonance in the region of 1,800. This

resonance is always present, and is most important, but its pitch varies within moderate limits, as explained.

(3) A strong resonance at one or two lower points, centering at about 620 and 1,050 respectively. Both may be present, but at least one of them must be.

As was done for a^e , these facts may perhaps be best shown by plotting a resonance curve of amplitude percentages, obtained by averaging all the analyses made. This curve shows the women's

Fig. 1.

line, the men's line, and the average of both as for a^e . We observe that the resonance begins to rise very rapidly at about 550, reaches a very pronounced maximum at about 620, descends thence and rises to its second maximum at 1,050. From this point it descends abruptly, to rise gradually once more and reach its final maximum at about 1,800. Here a noteworthy difference appears between the women's line, and that of the men's voices, the latter showing the maximum on the average at about 1,700 and the former at about 1,850. This is true as an average result, but many records of men's voices show the resonance maximum as high as 1,900, and *vice versa*, many individual examples of women's voices as low as 1,700. There does, however, seem to be a tendency on higher fundamentals, both of men's and women's voices, to pitch this resonance a little higher.

As before, (I. c.), an individual record is plotted for the sake of illustration. It follows the average very closely. The fundamental is 152. I. (152), IV. (608), VII. (1,064), VIII. (1,216), XI. (1,672), and XII. (1,824) are important, and the rest weak. The maxima are in this case at IV., VIII. and XII. respectively.

For comparison a sheet of e -curves is added. The most casual

inspection will show that the characteristic resonance is of higher pitch than for *a*^e. A simple count of the minor crests is the most obvious test. Thus at 320 these minor crests number six, giving a frequency of 1,920; at 384 five, again 1,920; at 256 seven, giving a frequency of 1,792, etc.

It may be interesting to compare two similar records lying an octave apart in fundamental pitch. The comparison will be most striking in the case of 320 by voice 7, and 640 by voice 10, the former a contralto, the latter a soprano. The record on 320 is essentially a succession of triplets, two to each fundamental wave, while that on 640 is a succession of simple triplets. The elements 640 and 1,920 are common to both, and hence their great similarity; but in the 320-record V. (1,600) is also present, and makes the one triplet different from its fellow. The fundamental at 320 is too weak to count so far as the unassisted eye can discern. These curves have for convenience of publication been reduced to one-third of their size as recorded by the transcribing instrument.

E — Curves

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