

THE SCALES OF SOME SURVIVING *AYAOI*

To know the scale of an aulos it is necessary to have a complete instrument. None of the surviving auloi are complete. It is the purpose of this article to attempt to reconstruct the missing parts of several auloi and thus to determine their scales.

All musical sounds consist of regular vibrations. The interval between two notes may be expressed as the rate of vibration of the higher note divided by the rate of vibration of the lower note. This ratio is very roughly the same as the length of the air column for the lower note (i.e. the distance from the reed to the first open hole) divided by the length of the air column for the higher note. This gross over-simplification has been used for all calculations in this article. The width of the air column, the size of the holes, and the reed itself affect the pitch considerably. The player also has a large control over the precise note played. And so the notes obtained by the ancients might have been very different from the notes obtained by ignoring these factors; although the player's control over pitch might have been used to lessen the effects of the other factors.

Intervals may also be represented in cents. There are 1,200 cents to the octave ($2/1$) or 100 cents to the tempered semitone (the smallest interval on the pianoforte). An interval in cents equals $3,896 \log$ its ratio. To add intervals in ratios, the ratios are multiplied; in cents, the cents are added. To subtract intervals in ratios, the ratios are divided; in cents, the cents are subtracted. For comparison with the notes calculated for the auloi the following equivalents may be useful. $1/1 = 0$ cents, $2/1 = 1,200$ cents, $3/2 = 702$ cents, $4/3 = 498$ cents, $5/4 = 386$ cents, $6/5 = 316$ cents, $7/6 = 267$ cents, $8/7 = 231$ cents, $9/8 = 204$ cents, $10/9 = 182$ cents, $11/10 = 165$ cents, $12/11 = 151$ cents.

If one assumes that two notes on an aulos are a certain interval apart (e.g. a perfect fourth ($4/3$) or an octave ($2/1$)) then one can calculate the missing part at the mouthpiece end which would produce this interval with the particular holes. The other intervals can then be calculated in cents. If these intervals in cents are good approximations to intervals known from ancient musical theory, the length of the missing section is probably correct.

The following points should explain the tables: the holes are numbered uniformly. 'x' means that all the holes are closed, '1' means the lowest hole, '2' the second lowest hole and so on. The increments are the distances from the exit to the centre of the lowest hole, from the centre of the lowest hole to the centre of the second lowest hole, etc. The cents are the intervals above the lowest note. The ratios are the intervals between consecutive notes in ascending order.

*The Elgin Aulos No. 1.*¹ Five finger-holes and a vent-hole. Length: 311 mm. Increments: 67 mm., 40 mm., $32\frac{1}{2}$ mm., 31 mm., 32 mm., 28 mm.

Assumption: Hole 1 to hole 4 is a perfect fourth. Air column for lowest note: 414 mm. Extrusion of mouthpiece: 170 mm. Cents: 0, 176, 334, 498. Ratios: $10/9$, $12/11$, $11/10$.

Assumption: Hole 3 to hole 6 is a perfect fourth. Air column for lowest note

¹ K. Schlesinger, *The Greek Aulos*, Methuen 1939, pp. 411 f.

364 mm. Extrusion of mouthpiece: 192½ mm. Cents: 0, 155, 329, 498. Ratios: 12/11, 10/9, 11/10.

*The Elgin Aulos No. 2.*¹ Five finger-holes and a vent-hole. Length: 343 mm. Increments: 44 mm., 53 mm., 34 mm., 32 mm., 31 mm., 37 mm.

Assumption: Hole 1 to hole 4 is a perfect fourth. Air column for lowest note: 476 mm. Extrusion of mouthpiece: 177 mm. Cents: 0, 205, 350, 498. Ratios: 9/8, 88/81, 12/11.

Assumption: Hole 3 to hole 6 is a perfect fourth. Air column for lowest note: 400 mm. Extrusion of mouthpiece: 188 mm. Cents: 0, 145, 298, 498. Ratios: 88/81, 12/11, 9/8.

*The Brauron Aulos.*² Five finger-holes and a vent-hole. Length: 229 mm. Increments: 43½, 42½, 34, 28, 28, 29 mm.

Assumption: Hole 1 to hole 4 is a perfect fourth. Air column for lowest note: 418 mm. Extrusion of mouthpiece: 232½ mm. Cents: 0, 186, 350, 498. Ratios: 10/9, 11/10, 12/11.

Assumption: Hole 3 to hole 6 is a perfect fourth. Air column for lowest note: 340 mm. Extrusion of mouthpiece: 231 mm. Cents: 0, 149, 312, 498. Ratios: 12/11, 11/10, 10/9.

So that two tetrachords may be played with the one hand the maker has placed the tetrachords in a special way. He has used the device that by moving the mouthpiece the two higher holes of the lower tetrachord may be used for the two lower holes of the higher tetrachord, the other holes being placed accordingly. This device is unnecessary on the Brauron Aulos since the interlocking intervals are the same. Moving the mouthpiece was suggested by K. Schlesinger,³ although the distances involved seem too slight for adding or subtracting bulbs, except possibly for exchanging bulbs of different sizes. Each of these auloi will play two tetrachords with the same intervals but in different order. This presumably has something to do with different modes (in the modern sense) of the same genus.

*Agora fragment D.*⁴ (Middle section of an aulos.) Increments between holes: 29½ mm., 26 mm., 32 mm.

Assumption: Hole 1 to hole 4 is a perfect fourth. Air column for lowest note: 350 mm. Cents: 0, 154, 299, 498. Ratios: 12/11, 88/81, 9/8.

From scale drawings⁵ the Agora fragment C and the Agora fragment E would play 12/11, 10/9, 11/10, (0, 153, 229, 498 cents) and 9/8, 16/15, 10/9, (0, 206, 316, 498 cents) respectively. If these latter three auloi were similar to the first three then these are the higher tetrachords.

The Elgin aulos No. 1, the Brauron aulos, and the Agora fragment C play scales which resemble Ptolemy's *ὀμαλόν*. The Agora fragment E resembles Ptolemy's diatonic *σύντρονον* and Didymus' diatonic.⁶

Pompeian Aulos No. 1. Ten finger-holes.⁷

Length: 497 mm. Increments: 46, 32, 43, 22, 19, 23, 54, 30, 22, 30 mm.

¹ Ibid., p. 419.

² J. G. Landels, 'The Brauron Aulos', *A.B.S.A.* lviii (1963), p. 117.

³ Op. cit., pp. 69 f.

⁴ J. G. Landels, 'Fragments of Auloi found

in the Athenian Agora', *Hesperia* (1963), p. 396 n. 11.

⁶ Ptol. *Harm.* 2. 14 ff.

⁷ A. A. Howard, 'The Αὐλός', *Harv. Stud.* iv (1893), p. 48.

⁵ Ibid., p. 393.

Assumption: x—hole 10 is an octave. Air column for lowest note 642 mm. Extrusion of mouthpiece: 145 mm. Cents: 0, 129, 231, 362, 437, 504, 589, 807, 940, 1,046, 1,200.

Tetrachords: using notes x, 1, 3, 5: 14/13, 8/7, 13/12; using notes x, 2, 4, 5: 8/7, 9/8, 28/27; using notes x, 2, 3, 5: 8/7, 14/13, 13/12.

Pentachord: using holes 5, 6, 7, 8, 10: 21/20, 8/7, 15/14, 7/6.

Pompeian Aulos No. 2. Ten finger-holes.¹ Length: 527 mm. Increments: 63, 33, 44, 24, 21, 26, 41, 31, 12, 31 mm.

Assumption: x—hole 10 is an octave. Air column for lowest note: 652 mm. Extrusion of mouthpiece: 125 mm. Cents: 0, 176, 276, 419, 502, 575, 677, 821, 981, 1,043, 1,200.

Tetrachords: using notes x, 1, 2, 4: 10/9, 21/20, 8/7; using notes x, 1, 3, 4: 10/9, 8/7, 21/20.

Pentachords: using notes 4, 5, 7, 8, 10: 22/21, 7/6 12/11, 9/8; using notes 4, 5, 7, 9, 10: 22/21, 7/6, 9/8, 12/11; using notes 4, 6, 7, 8, 10: 10/9, 11/10, 12/11, 9/8; using notes 4, 6, 7, 9, 10: 10/9, 11/10, 9/8, 12/11; using holes 4, 6, 8, 9, 10: 10/9, 6/5, 33/32, 12/11.

The suggestions for the pentachords are very tentative.

Pompeian Aulos No. 3. Twelve finger-holes.² Length: 492 mm. Increments 16, 29, 56, 22, 18, 21, 22, 22, 30, 25, 22, 30 mm.

Assumption: Hole 1 to hole 12 is an octave. Air column for lowest note: 594 mm. Extrusion of mouthpiece: 118 mm. Cents: 0, 87, 268, 340, 409, 489, 585, 676, 811, 931, 1,034, 1,200.

Tetrachords: using holes 1, 2, 4, 5: 22/21, 7/6, 12/11; using holes 1, 3, 5, 6: 7/6, 12/11, 22/21; using holes 1, 3, 4, 6: 7/6, 22/21, 12/11.

Pentachord: using holes 6, 7, 9, 10, 12: 21/20, 8/7, 15/14, 7/6.

Pompeian Aulos No. 4. Fifteen finger-holes.³ Length: 537 mm. Increments: 17, 47, 29, 32, 22, 21, 19, 21, 22, 21, 25, 21, 38, 27, 20 mm.

Assumption: Hole 1 to hole 13 is an octave. Cents: 0, 134, 211, 323, 396, 470, 539, 618, 707, 791, 906, 1,005, 1,200, 1,354, 1,478.

Tetrachord: using holes 9, 11, 12, 13: 9/8, 16/15, 10/9.

These four auloi have metal rings to close holes which were not needed. The octave seems to be divided into a tetrachord and a pentachord.

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¹ A. A. Howard, op. cit., p. 49.

² Ibid., pp. 49 f.

³ Ibid., p. 50.