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A study of dimensions and proportions**

By Lars Frydén

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The shape of the violin body

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The violin has a quite complicated geometric shape, which has remained largely unchanged since the violins of the 16th and 17th centuries. However, it is still not clear how the craftsmen of those times went about marking out the outline and other details of the violin body. Today's practice is simply to use patterns copied from some old, classical instrument. All the same, the strict and ingenious regularity that characterized the old Italian instruments has been upset. The neck and fingerboard are now made longer, and the shape of the bridge is different from that of the classical models. What is more, most old instruments have been rebuilt to conform to these principles, thus obscuring the geometrical procedure that may originally have been used in constructing the shape of the violin. Below, however, I put forward a reconstruction of what may have been the original procedure.

Object of study

As a starting point I chose a violin with a label bearing the name of Andreas Guarnerius. According to a certificate from Hamma & Son, Stuttgart, however, it was probably made by Francesco Ruggieri. Still, whether we are to believe the label or the certificate, there is no doubt that the instrument comes from 17th-century Cremona.

The original neck and fingerboard have been replaced with the newer, longer style, as on most other instruments from this time. I have therefore ignored these dimensions in the following discussion.

The instrument was photographed by Carl-Hugo Ågren from directly in front at a distance of about 5 meters, using an air photography camera. Errors due to perspective will therefore be practically negligible. A positive 1:1 scale copy was made. The present study is based on measurements of this photograph, which were compared with direct measurements on the instrument itself. The measurements are shown on Table I. Since we must assume that an instrument of this age will be worn on exposed spots, corrections ranging from 0 mm to 4 mm have been introduced, depending on the amount of wear that could be observed. Measurements across the grain of the wood have also been corrected for shrinkage. The corrections used were 1.5 per cent for the belly, which is made of spruce, and 0.2 per cent for the back, which is of harder maple-wood. Both the measured and the corrected values are shown on Table I.

Table I. Measured dimensions.

Transverse dimensions:	Formula	BACK					BELLY			
		Measured value	Wear	Shrinkage	Corrected value	Measured value	Wear	Shrinkage	Corrected value	
		mm	mm	%	mm	mm	mm	%	mm	
Upper bouts	$2P + \Lambda$	167.2	0.8	0.2	168.4	164.5	1.6	1.5	168.6	
Narrowest point below upper bouts	$\Lambda + H - U - 2M$	148.8	0	0.2	149.1	146	0.7	1.5	148.9	
Waist	$U + 2(M - S)$	108.3	0	0.2	108.5	106	1.1	1.5	108.7	
Narrowest point above lower bouts	$\Lambda + 2F - U - 2M$	179.2	0	0.2	179.6	176.2	0	1.5	178.8	
Lower bouts	$U + 2M$	204.1	3.1	0.2	207.6	201	4	1.5	208.1	
F-hole	R	-	-	-	-	125	0	1.5	126.9	
F-hole	4M	-	-	-	-	103	0	1.5	104.5	
F-hole	2M	-	-	-	-	51.5	0	1.5	52.3	
<i>Longitudinal dimensions:</i>										
C		348	-	-	-	348	-	-	-	
H		221	-	-	-	221	-	-	-	
R		127	-	-	-	127	-	-	-	
U		-	-	-	-	153	-	-	-	
F		-	-	-	-	125.3	-	-	-	

Observations

A closer examination shows that the same dimensions recur at many different points. The combined length of the lower and middle bouts, to the level of the upper corners, is equal to the distance from the neck mounting to the narrowest point of the body below the middle bouts (see Fig. 1). This length H is similar to that of the somewhat shorter neck preserved in completely intact violins from the same period. I shall henceforth assume hypothetically that the length of the original neck of the instrument was equal to H. This gives us the value L for the total length of the instrument. If we measure off the length of the body C on the total length L, starting from the scroll, we come down as far as the upper corners (see Fig. 2). Further, the relationship $2C - L = R$ holds, where R is the length of the upper bouts down to the corners. We also find this same length R in the lower bouts.

The ratio 1:2 obtains between many pairs of dimensions. If we halve the length of the neck H, we obtain the distance from the neck mounting to the narrowest point above the C-bouts (Figs. 3a and b). Halving the distance U from the neck mounting to the upper edge of the f-holes gives us the distance from the bottom edge of the body to the broadest point of the lower bouts. The same length U is also the distance from the narrowest point below the C-bouts to the broadest part of the upper bouts (Fig. 4).

The difference $2H - C$ gives us the value K, which is equal to the distance from the

Fig. 1. The length of the neck, H, is equal to the combined length of the lower and middle bouts. H is also equal to the distance from the neck mounting to the narrowing between the middle and lower bouts.

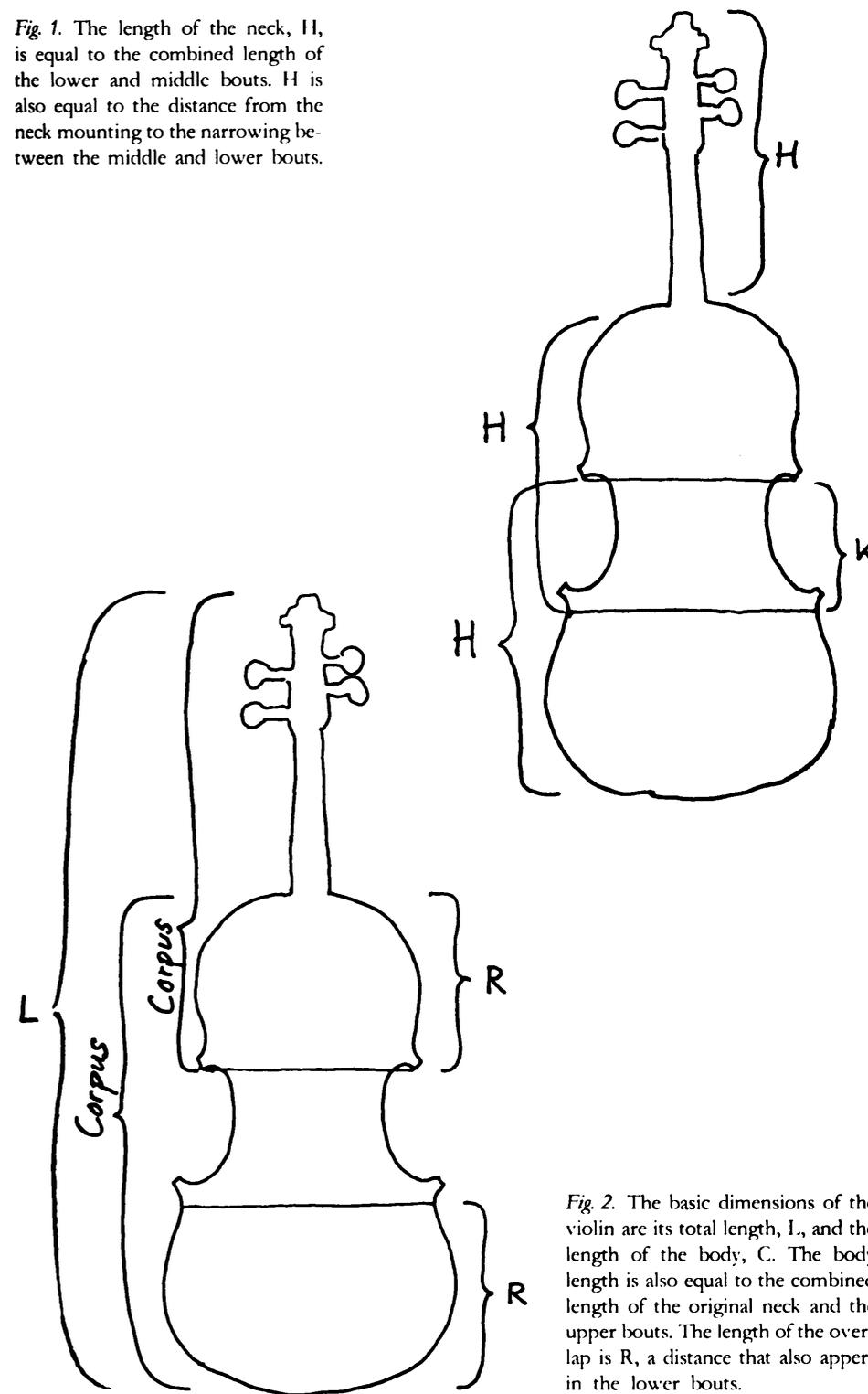


Fig. 2. The basic dimensions of the violin are its total length, L, and the length of the body, C. The body length is also equal to the combined length of the original neck and the upper bouts. The length of the overlap is R, a distance that also appears in the lower bouts.

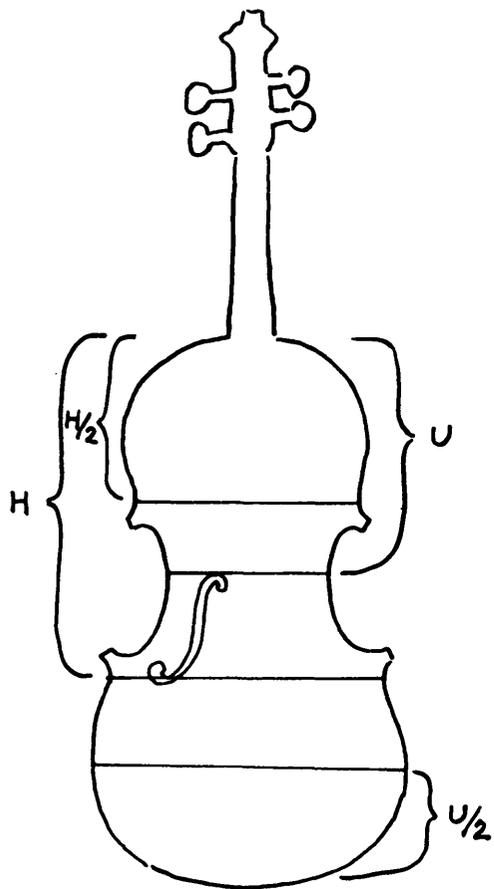


Fig. 3a.

Fig. 3. By dividing the length of the neck, H, into two equal parts we obtain H/2, which is equal to the distance from the neck mounting to the narrowing between the upper and middle bouts. Halving the distance U (the upper part of the body down to the f-holes) gives us U/2, which is equal to the distance from the bottom edge to the broadest point of the lower bouts. Similarly, the distances 2M and 4M both occur.

upper corners to the narrowest point below the C-bouts (Fig. 1). Thus a whole series of dimensions recur, unchanged or halved, in various places.

A large number of other dimensions seem to be related by another, more complex ratio (see Fig. 5 and Table II). This ratio F is approximately equal to 1.63:1.

- L/C = F
- U/K = F 153/(348-2x127) = 1.628
- 2E/U = F 2x125.3/153 = 1.638
- H/A = F
- MP/M = F

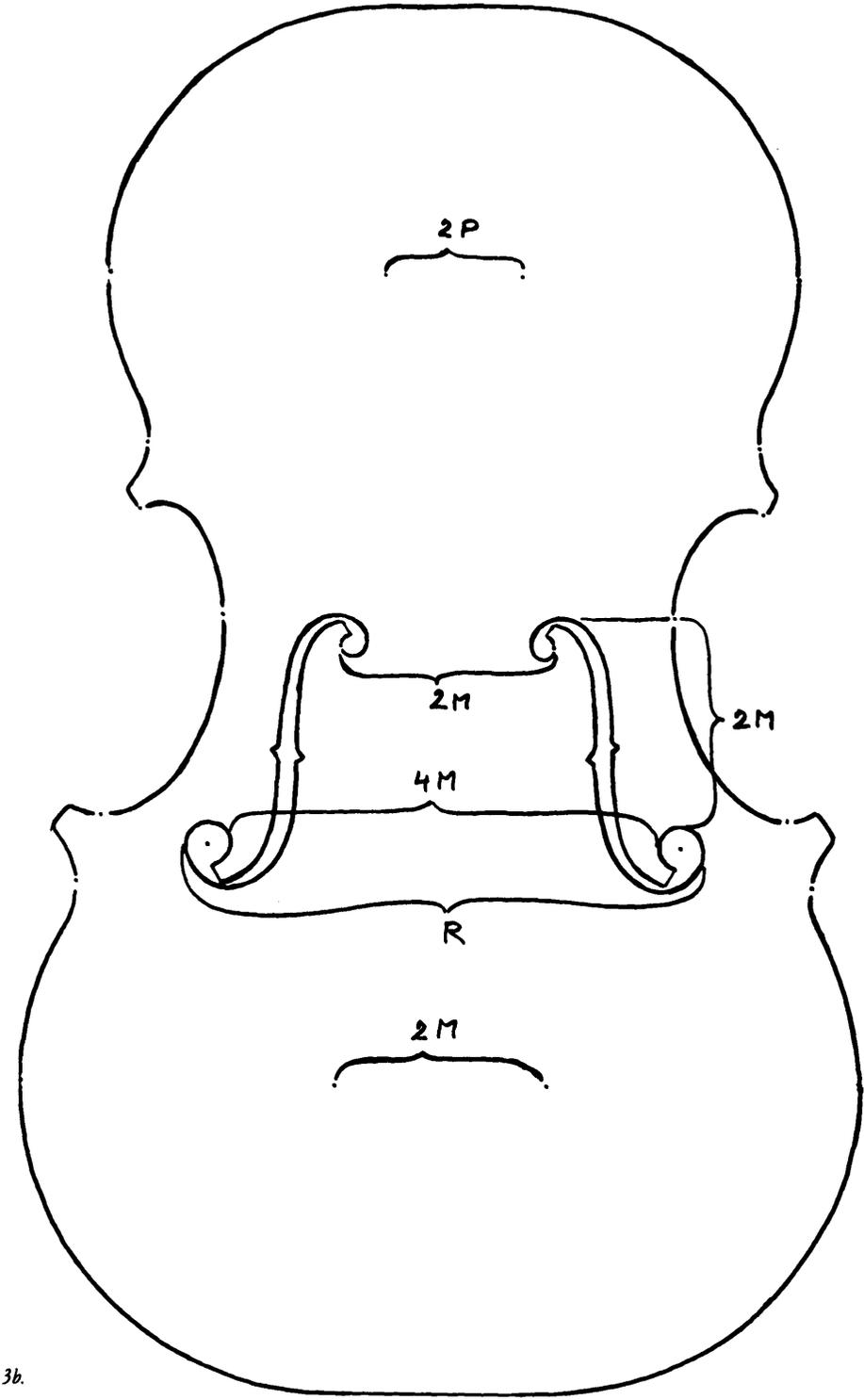


Fig. 3b.

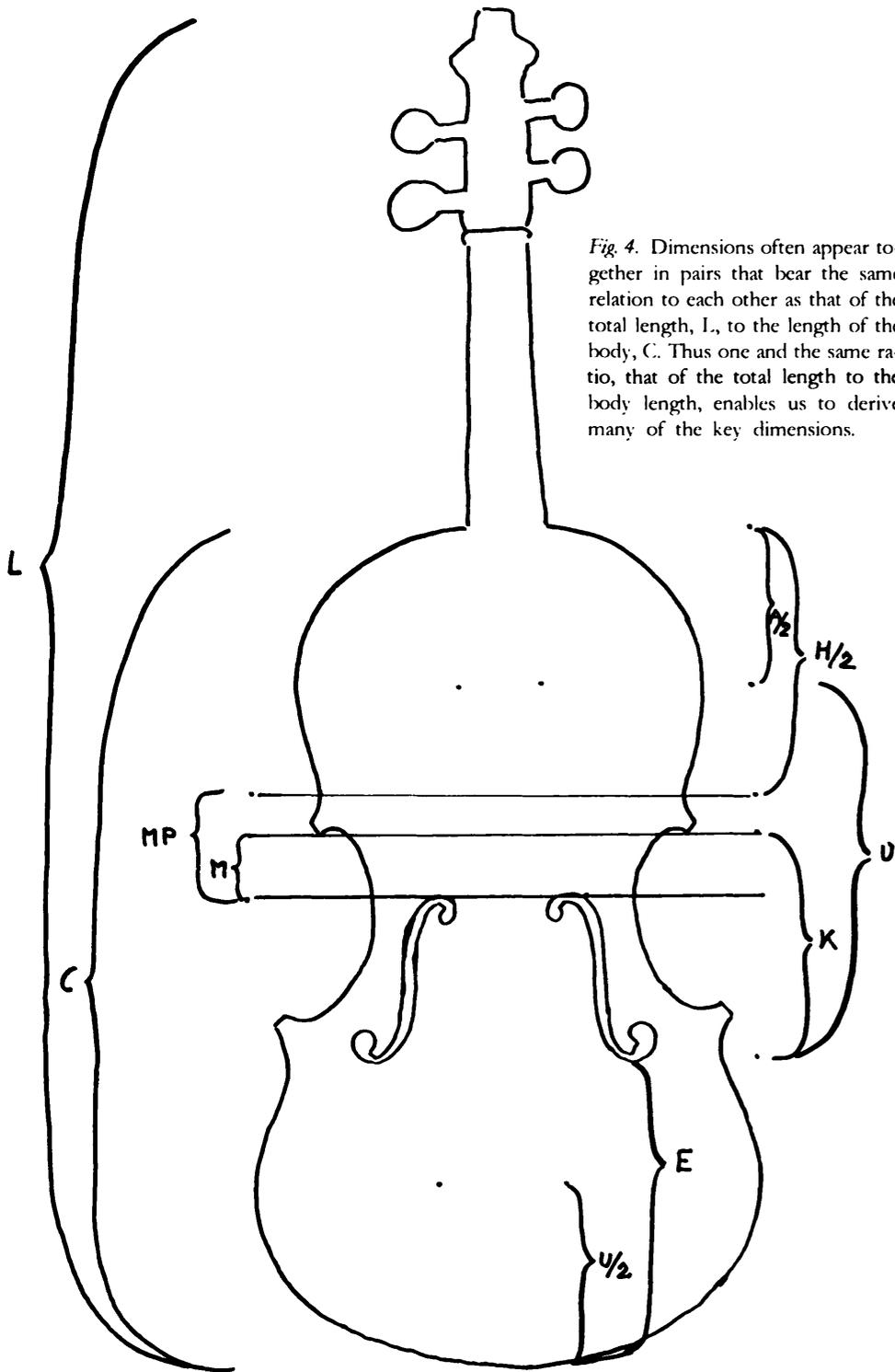


Fig. 4. Dimensions often appear together in pairs that bear the same relation to each other as that of the total length, L , to the length of the body, C . Thus one and the same ratio, that of the total length to the body length, enables us to derive many of the key dimensions.

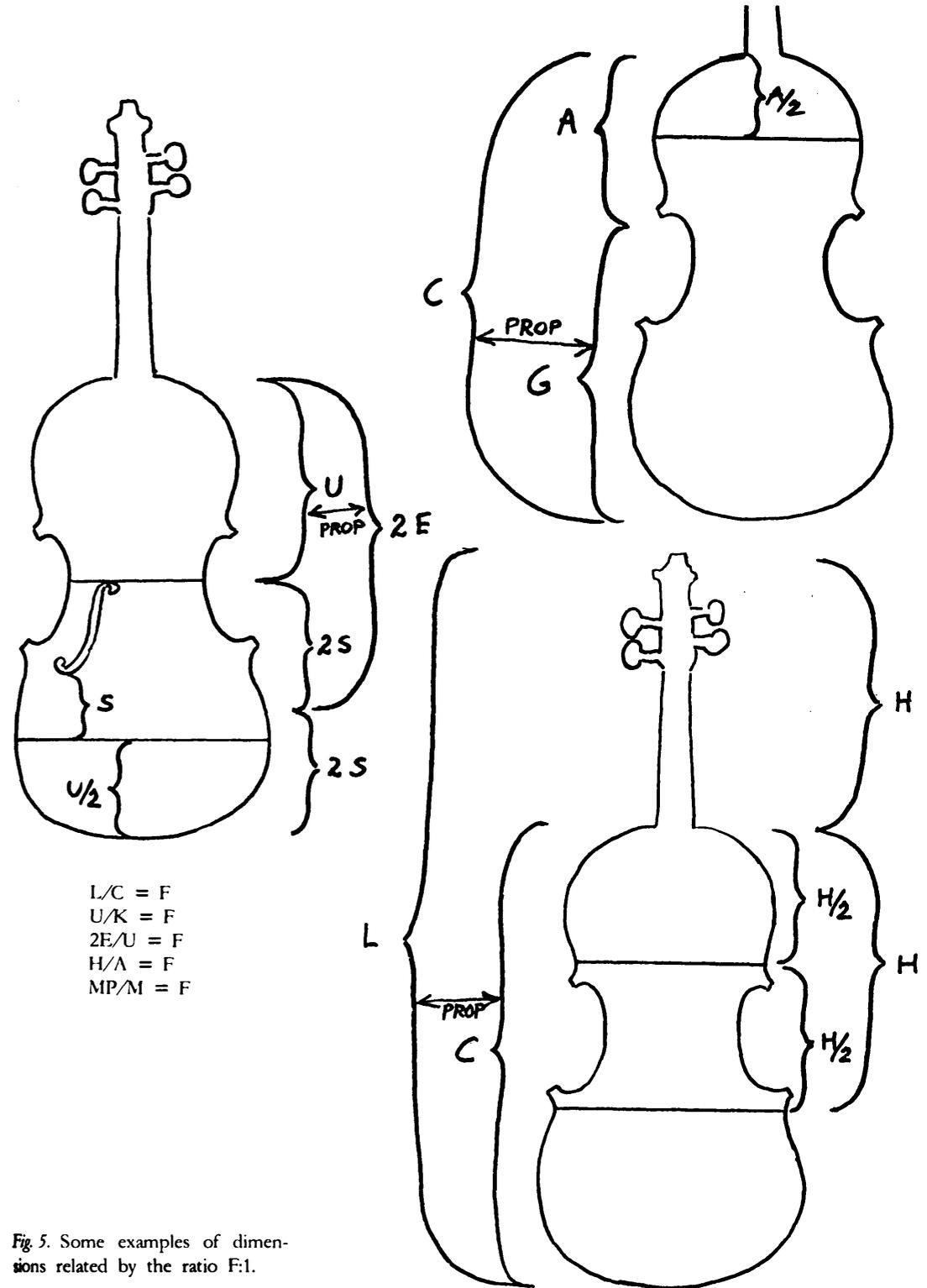


Fig. 5. Some examples of dimensions related by the ratio $F:1$.

Designing

We may now ask how a violin maker went about obtaining the dimensions he needed to mark out his violin belly. He could of course use a compass and straight edge to set off equal lengths at various points, and also to double the length of a line. But the same instruments can also be used to construct a line bearing a given ratio to any other given line. This can be done by means of a triangle in the manner illustrated in Fig. 6. The height of the isosceles triangle is equal to the length L of the violin, and its base is equal to the length C of the body. Other lengths can be obtained by using the triangle in the manner illustrated.

So far I have shown that all the dimensions needed to draw up the outline of the body by geometrical means can be obtained from one basic length, a ratio, and a design procedure. A possible design procedure is shown on Table II.

From equations (5), (6a), (9c) and (9d) we can derive the following equation for the ratio F :

$$F^3 - 2F^2 + 0.75F - 0.25 = 0$$

which gives

$$F = 1.634764$$

This ratio cannot be expressed as a simple ratio of reasonably small integers, but it might have been originally derived from this equation and would also have been easy to preserve, e. g. in concrete form as a reducing compass (see Fig. 7). A reducing compass has the property that the distances between the longer and the shorter pairs of legs are always in the same ratio to each other. The violin maker might also have kept a set

Table II. Design procedure.

GIVEN: Body length C and ratio F .

L	$= C \times F$	(1)
H	$= L - C; H = C(F - 1)$	(2a, b)
R	$= C - H$	(3)
P	$= R - H/2$	(4)
G	$= C/F$	(5)
A	$= C - G; A = H/F$	(6a, b)
MP	$= (H - A) \times 1/2$	(7)
M	$= MP - P; M = MP/F$	(8a, b)
U	$= H/2 + MP; U = 2MP + A/2$	(9a, b)
U	$= A(F - 1/2); U = C/(2F - 1)$	(9c, d)
K	$= U/F; K = C - 2R$	(10a, b)
K	$= M + A/2; K = H - R$	(10c, d)
B	$= 2M + U$	(11)
E	$= U \times F/2$	(12)
S	$= E - U/2; S = C/2 - E; S = (C - U)/4$	(13)
P	$= (R - M - A/2)/2$	(14)

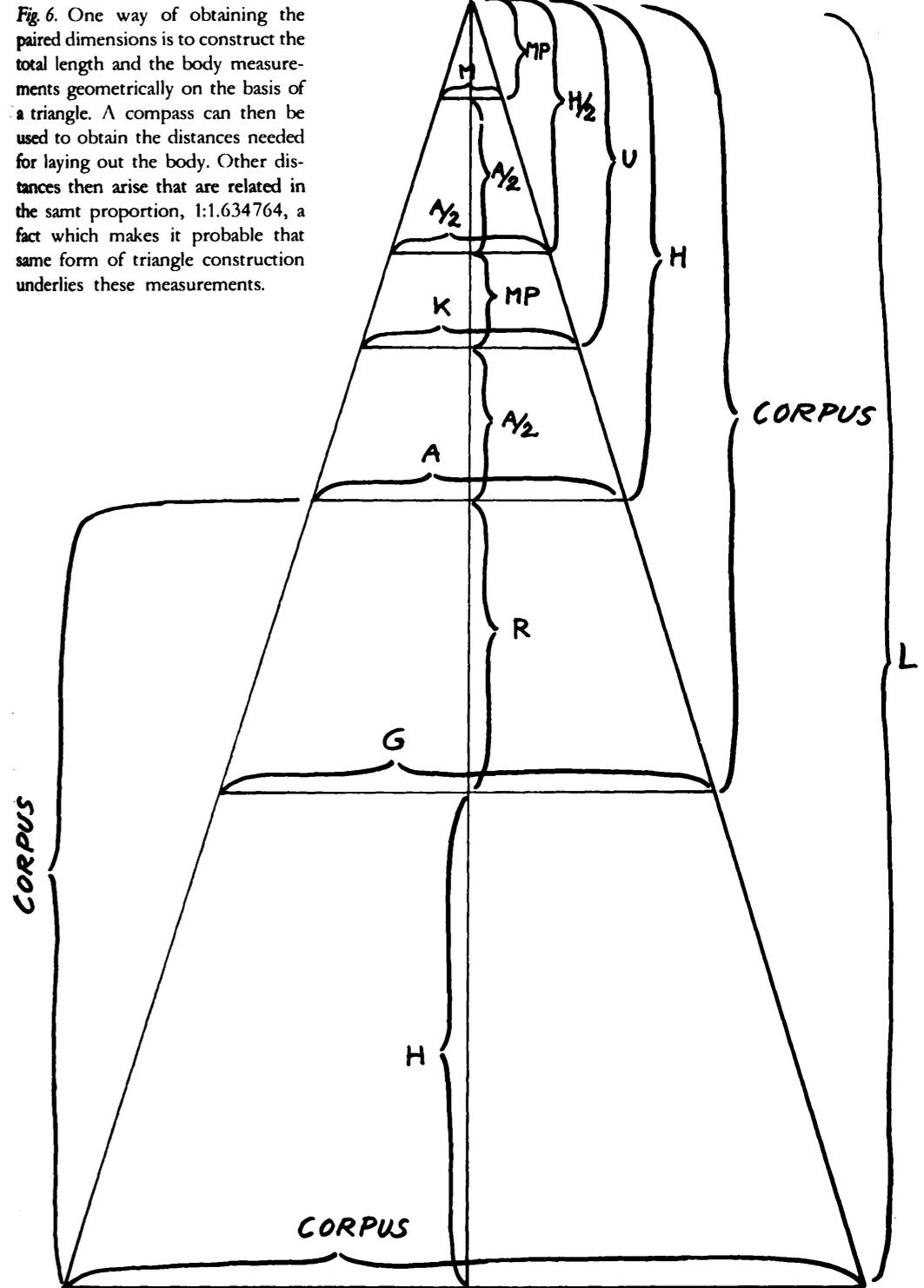


Fig. 6. One way of obtaining the paired dimensions is to construct the total length and the body measurements geometrically on the basis of a triangle. A compass can then be used to obtain the distances needed for laying out the body. Other distances then arise that are related in the same proportion, 1:1.634764, a fact which makes it probable that same form of triangle construction underlies these measurements.

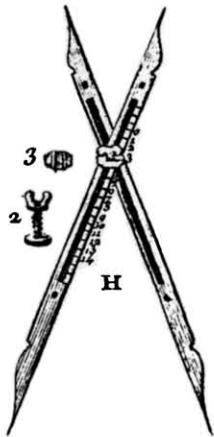


Fig. 7. Some form of reducing compass may also have been used. The two pairs of legs are set to the desired ratio, in this case 1:1.634764. When one pair of legs is then set to a given distance, the other pair will automatically supply a distance bearing the required ratio to the first.



Fig. 8. Before drawing up the body, the violin maker may have enlisted the aid of a mathematician to set his compasses to the distances he needed. He will then have gone down into his workshop with a ready-made series of measurements, but measurements linked by internal relationships. The compasses he used could be locked.

of compasses in his workshop, each of them preset to one of the lengths he needed for marking out the belly (see Fig. 8).

The actual work of marking out the shape of the back and the belly on a rectangular sheet of wood may have followed the procedure illustrated in Fig. 9. It is of interest to note that all the key design points can be reached from one of the longer edges of the rectangle. Fig. 10 shows a possible location of the f-holes. Note that the edges of the f-holes can be obtained from diagonals joining important design points. The continuous lines in Figs. 9 and 10 are obtained by the above procedure, while the dotted lines have been derived from certain key points only. It is interesting that violins tend to differ most from one another in just those details of the belly that are composed of a number of curves.

Above I have presented a method that could have been used when marking out the belly and the back of the violin. The procedure is based on a basic dimension, the body length C , and on the proportions 2:1, 1:1, and 1.634764:1. It is obvious that the measurements on which this study is based are of very limited accuracy. Wear and shrinkage could only be estimated. It is therefore important to check how well the dimensions computed

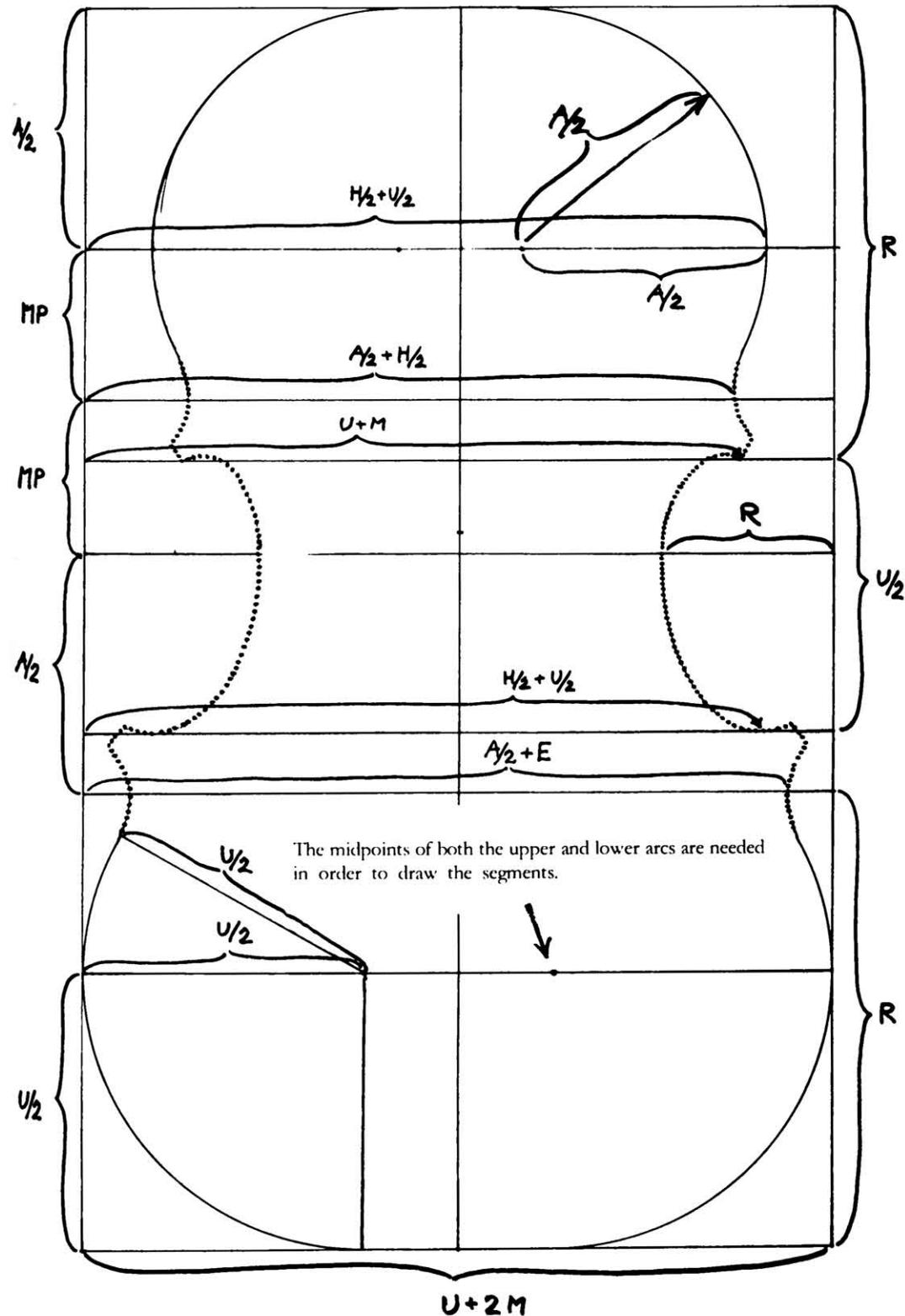


Fig. 9. The craftsman set off the points by measuring inwards from the edge. In this way he could avoid placing the compass point in the body unnecessarily.

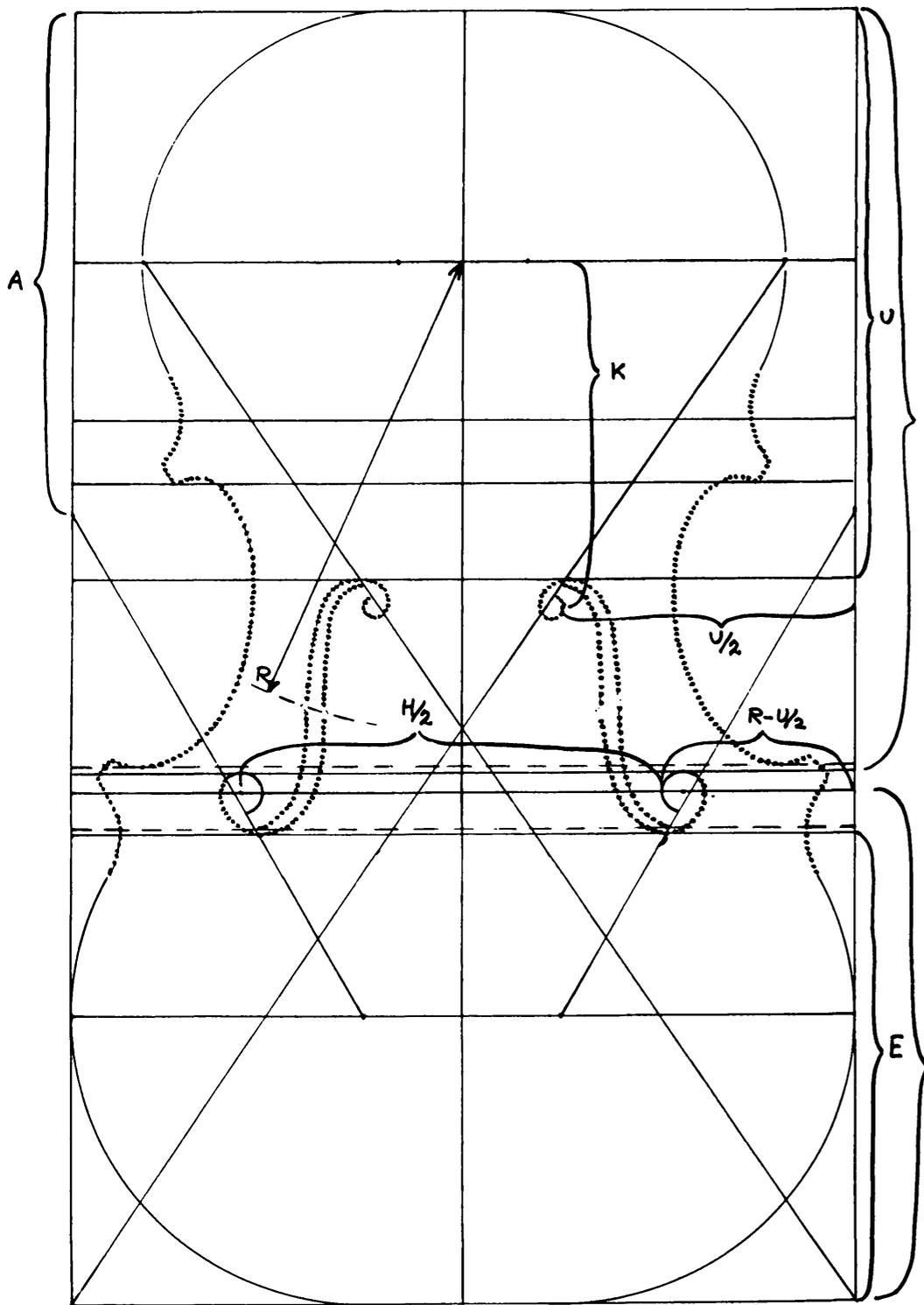


Fig. 10. The continuous lines are geometrically determined. Personal taste could be exercised in the shaping of the curves in the dotted portions.

Table III. Computed dimensions and corrected measurements

Dimension	Formula	Computed value mm	BACK		BELLY	
			Measured value mm	Difference mm	Measured value mm	Difference mm
H	$L - C; C(F - 1)$	220.9	221	- 0.1	221	- 0.1
R	$C - H$	127.1	127	+ 0.1	127	+ 0.1
U	$MP + H/2$	153.3	-	-	153	+ 0.3
E	$UF/2$	125.3	-	-	125.3	± 0
$U + 2M - 2S$		108.4	108.3	+ 0.1	108.7	+ 0.3
Upper bouts Narrowest point below upper bouts	$2P + A$	168.4	168.4	± 0	168.6	- 0.2
Narrowest point above lower bouts	$A + H - U - 2M$	150.2	149.1	+ 1.1	148.9	+ 1.3
Lower bouts	$A + 2E - U - 2M$	180.0	179.6	+ 0.4	178.8	+ 1.2
F-hole	$U + 2M$	205.8	207.6	- 1.8	208.1	- 2.3
F-hole	R	127.1	-	-	126.9	+ 0.2
F-hole	$4M$	104.8	-	-	104.5	- 0.3
F-hole	$2M$	52.4	-	-	52.3	+ 0.1
L	$C \times F$	568.9				
MP	$(H - A)/2$	42.9				
P	$R - H/2$	16.7				
A	H/F	135.1				
M	$MP - P$	26.2				
G	C/F	212.9				
K	U/F	93.8				
S	$E - U/2$	48.7				

by the above procedure agree with the actual measurements of the violin shown on Table I. The measured and calculated values are compared on Table III. The result shows quite a close agreement, as a rule within a few tenths of a millimeter. This seems to argue in favour of the possibility that the above method of derivation may actually have been used. It also appears likely that the hypothetically assumed length of the neck was indeed the original one; the neck will then have been part of the system of interrelated dimensions that seem to characterize the violin as a whole.

Here we have studied the dimensions and proportions of just one classical violin. The result shows an interrelation among most of the dimensions: they can all be derived from one dimension, the length of the body, by means of two ratios, 2:1 and 1.634764:1. There is much to suggest that other violins possess similar characteristics. The complicated design procedure can also be seen as fitting in well with the fondness of that period for numbers and ratios. Presumably, the violin maker will have begun by preparing a series of dimensions. This series (an ingenious construction in itself) would then be a firm foundation to build on. He could then introduce his independent, personal variations in the shapes if he wished, without sacrificing the impression of unity that lies hidden

in the series of dimensions. It is likely that the final result, the shape of the violin belly, gains an aesthetically appealing completeness if the distances between its details recur on a reduced or magnified scale at a number of different points. We may wonder whether the same effect is achieved when a strict geometric design procedure is replaced by the simpler method of tracing patterns copied from some famed exemplar.

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