THE TUNING OF THE BABYLONIAN HARP

By DAVID WULSTAN

IN *Revue de Musicologie* XLIX (1963), 3–17 (henceforth cited as *RM* XLIX), and again in *Studies in Honor of Benno Landsberger* (= *Assyriological Studies* No. 16, Chicago (1965), 268–272, henceforth cited as *AS* 16),[1] Mme. Duchesne-Guillemin has put forward a theory for the tuning of the Babylonian harp, based on a tablet from Ur, U.3011, and another tablet of unstated provenance in the University Museum, Philadelphia, CBS 10996. The CBS tablet contains a list of intervals with their names, repeated twice over, while the Ur tablet gives the names of the nine strings, presumably of the harp, followed by part of a similar list of intervals (extremely fragmentary). Starting from the observation that the third string has the name " thin string ", Mme. Duchesne-Guillemin infers that the semitone occurred between the third and fourth strings, so that the harp would have been tuned to a scale equivalent to our C major, running from C to the D in the octave above (using, as throughout this article, names of notes and scales in a relative not absolute sense). Observing further that the list of intervals contains three rising fifths followed by four descending fourths, she suggests that the list is a tuning cycle, in which the inclusion of thirds and sixths is explained by the principle that " c'est la *superposition* des gestes sur les mêmes cordes, pour les regler et les corriger, qui *constitue l'accord* " (her italics; see *RM* XLIX, 15), though this view is modified in *RM* LII. The inclusion of the tritone—an impossible tuning interval—she can only explain by the necessity for completeness (*ibid*). She remarks incidentally that the fourth string, named " Ea made it ", is to be identified with the Greek μέση.[2]

With regard to the thin string, Mme. Duchesne-Guillemin contends that its presence indicates that the distance between this and the next higher note was a semitone, on the grounds that decreased calibre would make this string relatively sharp, i.e. nearer in pitch to its upper neighbour. However, the note below would also be relatively flat, which does not fit in with her theory. Moreover, if relaxed relative to the tension of the adjacent strings, the thinness of the string would then have no bearing on the tuning. Thus the presence of the thin string is no reason to suppose that the Babylonian harp was tuned to the scale of C.

Nor can the CBS list of intervals as it stands, be a tuning cycle, because it violates the basic principle of such a cycle—that each step should start from

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[1] See also *Revue de Musicologie* LII (1966), 147–162.   [2] *RM* XLIX, 13–15, and *AS* 16, 269.

a note that has already been generated. It could only be interpreted as such
a cycle if alternate intervals are taken; but even then the appearance of the
tritone, which must necessarily intervene if three fifths and four fourths are
taken in a heptatonic scale, should surely serve as a warning that something
is wrong. The list seems to be a catalogue containing all possible intervals
except the tones, semitones, and sevenths. A tuning cycle can only be extracted
from it by a process of selection.

Here is an abridged version of the text of the two tablets as transcribed
and corrected by Mrs. Draffkorn Kilmer:

CBS 10996 column i

Line 11.	SA *qud-mu-ú*	*ù* SA 5-*šú*	1,	5 SA *niš* GAB.RI
12.	SA 3 *uḫ-ri*	*ù* SA 5-*šú*	7,	5 SA X (y) Z
13.	SA *ša*-GE$_6$	*ù* SA 4 *uḫ-ri*	2,	6 SA *i-šar-tum* ('normal')
14.	SA *qud-mu-ú*	*ù* SA 4 *uḫ-ri*	1,	6 SA *šal-šá-tum* ('third')
15.	SA 3-*šú* SIG	*ù* SA 3-*šú uḫ-ri*	3,	*7 SA *em-bu-bu* ('pipe')
16.	SA *šá*-GE	*ù* SA 3-*šú uḫ-ri*	2,	*7 SA 4-*tu* ('fourth')
17.	SA ^{d}*É-a*-DÙ	*ù* SA *qud-mu-ú*	4,	11 SA NIM MURUB$_4$[3]
18.	SA *qud-mu-ú*	*ù* SA 3-*šú* SIG	1,	3 SA GIŠ.NIM.MA
19.	SA 5-*šú*	*ù* SA *šá*-GE$_6$	5,	2 SA MURUB$_4$-*tu* (= *qablitu*, ('middle')
20.	SA *šá*-GE$_6$	*ù* ^{d}*É-a*-DÙ	2,	4 SA ⌜*ti-tur*⌝ MURUB$_4$-*tu* ('bridge', 'middle')
21.	SA 4 *uḫ-ri*	*ù* SA 3-*šú* SIG	6,	3 S[A *kit-mu*] ('cover')
22.	SA 3-*šú* SIG	*ù* SA 5-⌜*šú*⌝	3,¹	[5 SA *ti-tur i-šar-tum*] ('bridge, normal')
23.	SA 3-*šú uḫ-ri*	*ù* [SA ^{d}*É-a*-DÚ	7,	4 SA *pi-tum*]
24.	SA ^{d}*É-a*-DÚ	[*ù* SA 4 *uḫ-ri*	4,	6 SA *muš-du*]

(Remainder of col. i destroyed.)

Nabnitu XXXII column i (Ur 3011)

sa.di	*qud-mu-u*[*m*]	fore (string)
sa.uš	*sá-mu-šu-um*	next (string)
sa.3 sa.sig	*ša-ál-šu qa-a*[*t-nu*]	third, thin (string)
sa.4.tur	*A-ba-nu-*[*ú*]	{ Sum: fourth, small / Akk.: Ea-creator

³ *nit/d* MURUB in *KAR* 158 viii (see p. 223). For
convenience, the interval names have been normalized
in this article so that all the Akkadian terms end in
-*um*. It will be noticed that the nominal values of
the intervals divide them into two groups, 'primary'
(fourths and fifths) and 'secondary' (thirds and
sixths), and also that the intervals appear to be
'invertible', a phenomenon assumed throughout.

5.	sa.di.*5 (text 4)	*ḫa-am-šu*	fifth (string)
	sa.4.a.ga.gul	*ri-bi úḫ-ri-i[m]*	fourth of the behind (string)
	sa.3.a.ga.gul	*šal-ši úḫ-ri-im*	third of the behind (string)
	⌐sa.2.a.ga¬.gul	*ši-ni úḫ-ri-im*	second of the behind (string)
	[sa.1].[a].ga.gul.la	*úḫ-ru-um*	the behind-one (string)
10.	9 .sa.a	9 *pi-it-nu*	nine strings
	[ ] x (y)	*pi-is-mu*	. . .
	[ ]	*i-šar-ti*	normal
	[ ]	[*ti*]-⌐*tú*¬-*ur i-šar-tum*	bridge, normal
	[ ]	[*ki-i*]*t-mu*	cover
15.	[ ]	[x y (z) *k*]*i-it-mu*	. . . cover
	[ ]	[x y]-*um*	. . .
	[ ]	[x y-*u*]*m*	. . .

(Remainder of col. i broken.)[4]

The nine strings named in U.3011 may be notated in Roman numerals I–IX, with VI, VII, VIII, IX for the ' behind ' strings.   That the order is ascending is fairly clear from the epithets ' fore ' and ' behind ', which correspond to the way that harps and similar instruments are held in iconography of Near-Eastern origin.   V is the middle string about which the nine-fold numeration revolves.   It may be a coincidence that this is one of the strings in the interval *qablītum*, but the interval name itself is so reminiscent of the Greek word μέση that it would naturally be a strong candidate for the main tuning interval or note, *cf.* Ps-Aristotle XIX, 20:

Διὰ τί ἐὰν τις μέν τὴν μέσην κινήσῃ ἡμῶν, ἁρμόσας [δὲ] τὰς ἄλλας χορδὰς, κέχρηται τῷ ὀργάνῳ, οὐ μόνον ὅταν κατὰ τὸν τῆς μέσης γένηται φθόγγον, λυπεῖ, και φαίνεται ἀνάρμοστον ἀλλὰ καὶ κατὰ τὴν ἄλλην μελῳδίαν·

" How is it that if one alters the tuning of the *mesē* after the other strings have been tuned, and plays, everything sounds wrong not just when one comes to the *mesē*, but throughout the whole melody? "[5]

The CBS tablet refers to seven rather than nine strings.   Since U.3011 refers, nevertheless, to some of the same interval names, the obvious assumption can be made that the scale was heptatonic and was repeated in the higher octave on harps with more than seven strings as necessary.   This is indeed proved by a new tablet to be dealt with later (see page 220).   It can also be assumed that the consonances of the fourth and fifth, together with the octave, were recognised in the Near East[6] and also the consonant third and sixth from their

trumpet-type and other instruments having notes of the 'harmonic series'.[7] In any case these are the scientifically, and more important, aurally consonant intervals; as opposed to seconds and tritones, they can be tuned accurately by ear.

Tuning

If the CBS sequence interpreted by the names of the strings given by U.3011 can be made to give forth a tuning cycle, the component intervals of the cycle would have to be a selection out of the total number. The striking resemblance of the term *qablītum* and μέση immediately marks off this interval as being a strong probability for the opening interval of any tuning cycle. The word *išartum*, reminiscent of our term 'perfect' also seems to be a candidate for inclusion in such a cycle. That its component notes follow on from the components of the *qablītum* interval, and that these two intervals together form the equivalent to the Greek 'standing notes' reinforces this likelihood. Pressing the analogy further with the Greek system one can provide pitch-names for the three notes: *qablītum* (V–II): A (*mesē*)—E; *išartum* (II–IV): E–B. These, being perfect intervals in our sense, would be tuned easily by ear. The intervals *šalšatum* and 4-*tum* are also obvious choices for the third and fourth elements in a tuning cycle, for the fact that they are both nominally thirds/sixths disposes of any possibility that the names might be quantitative in character, or that they might refer to string-length ratios. There is, furthermore, no known series in which they were the third and fourth intervals. However, because they are thirds or sixths, not fourths or fifths, these two intervals would be susceptible to more than one consonant tuning—'major' and 'minor'. This is no difficulty provided that the scale required from the tuning sequence is known. The tuner, knowing the scale, would be able to select the correct interval by ear. We may perhaps again make the assumption that there was a close correspondence between the Greek and Babylonian systems, at least as a working hypothesis. The choice is then a simple matter. Thirds and sixths tuned by ear to their harmonic consonances are of necessity non-Pythagorean, and so the resultant scale would tend towards some form of 'Just intonation' rather than the Pythagorean scale.

The comparative values of the 'Just' and Pythagorean scales, together with those of the modern equal-tempered scale are given in the following table, expressed in cents. Unlike frequency ratios, cents can be added and subtracted in order to evaluate the relative distances between notes; they are obtained from the frequency ratio thus:

$$\frac{1200}{\log 2} \times \log \frac{f_1}{f_2}$$

The octave (ratio 1/2) has therefore 1200 cents, and on the equal tempered piano (line 1 of the table), where all the semitones are equal, the tone will

[7] *Cf.* Lavignac-Laurencie, *Encyclopédie de la Musique* (1913), pt. I, 41.

have the value 200, the semitone 100.   However, the piano is not 'naturally' tuned, but incorporates a mean error throughout the octave in order to be able to play chromatic music. The other two scales given are 2) 'Just Intonation', and 3) 'Pythagorean Intonation'.   Just Intonation, which is really only a temperament, does seem, however, to have a basis in nature, in that most of its intervals are found in the 'harmonic series'. Pythagorean intonation is the result of tuning in cyclic fourths or fifths.

		C	D	semitone E F	G	A	semitone B C'
1	Equal temperament	o	200	400 500	700	900	1100 1200
2	Just intonation	o	204	386 498	702	884	1088 1200
3	Pythagorean intonation	o	204	408 498	702	906	1110 1200

It can be seen that the 'just' values for the fourth and fifth are 498 and 702, while the thirds could be either 316 (E — G) or 386 (C — E), the sixths 814 (E — C') or 884 (C — A = G — E').   These are the main intervals in the 'harmonic series', and are audibly more consonant than, e.g. the interval D — F, 294. With these values the notes generated by the *qablītum*, *išartum*, *šalšatum* and *4-tum* intervals can be calculated, on the assumption that the Babylonian scale was similar to that of the Greater Perfect (Changeless) System of Ptolemy. Two intervals need to be added to this tuning sequence, however, in order to supply the two missing notes of the scales. The obvious choices would be *titur qablītum* and *titur išartum*; for the names of these two intervals seem to imply that they fill in gaps left by the *qablītum* and *išartum* intervals themselves, which indeed they do. Nevertheless, as will be seen later (p. 224) the *titur* nomenclature may have arisen in a different way, so the grounds for the inclusion of these two intervals are not as strong as might at first seem to be the case. However, the values of the final notes of the series will be the same whatever intervals are used for the tuning, with one possible exception: if the interval GIŠ.NIM.MA were used to establish the pitch of string III from I (as tuned from the *šalšatum*) 510 cents would be the result. This must remain a possibility, but this value is less consonant with the other notes generated by the other intervals; as a working hypothesis therefore, the two 'titur' intervals mentioned above will be taken as the final components of the tuning sequence.   The complete tuning process can then be set down as follows; taking a value of 884 for V (mesē — A):

1	*qablītum*	V — II	A — E	884 − 498 = 386
2	*išartum*	II — VI	E — B	386 + 702 = 1088
3	*šalšatum*	VI — I	B — D	1088 − 884 = 204
4	*4-tum*	II — VII	E — C	386 + 814 = 1200
5	*titur qablītum*	II — IV	E — G	386 + 316 = 702
6	*titur išartum*	V — III	A — F	884 − 386 = 498

The scale resulting from this sequence is:

D	E	F	G	A	B	C
204	386	498	702	884	1088	1200

i.e. a Just Intonation scale on D, or in the phraseology of Ptolemy, a Phrygian octave-species in diatonic syntonon tuning. Though this scale seems quite likely, it needs support from other tablets before it is taken seriously. As will now be shown, a recently discovered tablet suggests, on the contrary, Pythagorean tuning, or rather, a series of tunings; but a parallel phenomenon exists in Greek theory, where Pythagorean tuning, though accepted as the norm, is yet described as dissonant.[8]

The fragment 7/80

The text of this recently discovered tablet is transcribed by Professor Gurney on pages 229–233 of this journal. It is in two parts, the second of which is a sequence of successive changes of tuning that could loosely be called ' modulations ', while the first part is the reverse of this, a de-modulating sequence. It is clear that in this tablet two uses of the interval names are in evidence: some, as in the CBS tablet, express a relationship between two strings, others, as in the tablet *KAR*.158 (see p. 223) refer to a mode or tuning. Thus the first ' paragraph ' of the second ' chapter ' can be interpreted as follows:

> If the harp is in *išartum* tuning,
> You have played the *qablītum* interval
> You adjust strings II and IX
> And the harp is now in *kitmum* tuning.

The mention of two strings in this case is added evidence for the assumption that the Babylonian scale was heptatonic, since these two strings would then be an octave apart. The significance of the use of the *qablītum* interval to change the tuning is seen more clearly in the first ' chapter '. Here, in the demodulating equivalent of the above paragraph, it is the *išartum* interval that is adjusted, and is described as ' not clear ', i.e. dissonant. Since there is only one interval in the scale that is a fourth or fifth, and at the same time dissonant, viz., the tritone, the interpretation of the formula is a comparatively simple matter. Because the whole tablet follows the cyclic order known from *KAR*.158, the whole cycle can be reconstructed; and because the adjustment of the tritone into a consonance (within the context of a heptatonic scale), can be effected solely in one direction if only one string is undergoing tuning, the following sequence results:[9]

[8] *Cf.* Aristoxenus, *Harmonics* 23 and also the passage quoted above p. 217) which does not make sense in the context of Pythagorean tuning.

[9] Because the tuning relies on the consonance of the fourth or fifth, and because the sequence involves retuning all the primary intervals, the resulting tuning will be Pythagorean whatever might have been the intonation at the outset.
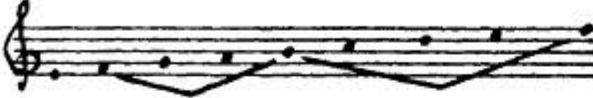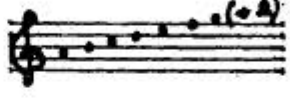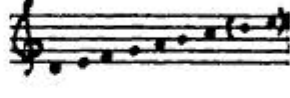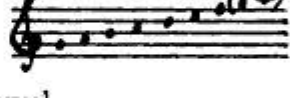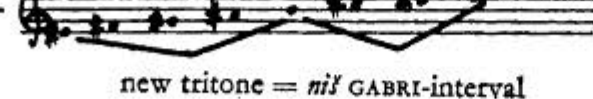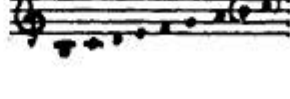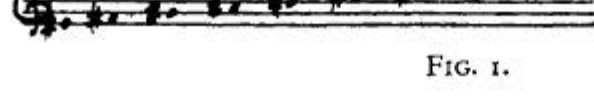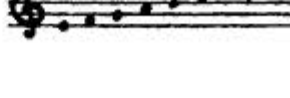
FIG. 1.

We see that the interval names known from CBS 10996 have no fixed qualitative values such as the modern reader might expect, since their character changes with each successive tuning. Furthermore the naming of the scales by one of these intervals does not seem at first sight to be particularly logical. Now it may be observed that the pentachord F–C always appears in the position in the scale denoted by the name of the scale (e.g. in *išartum* tuning it is II–VI, *qablītum* tuning it is V–II/LX, etc.). Is this fortuitous, or was this pentachord regarded in some way as characteristic or normative? Though this is possible, there is another explanation. It cannot have escaped the reader familiar with Greek theory that the order of the Babylonian species is the same as that of the Greek species in Ptolemy's System, when arranged in the order dictated by their names: Dorian, hypo-Dorian, Phrygian, and so forth. Also, it can be seen that the difference between the left- and right-hand versions of the scales presented above is the difference between the Greek thetic and dynamic nomenclature. If we go further in our analogy of Greek practice and look for the characteristic Dorian segment (E–B) in each of the Babylonian species it is found that this segment is described by the same interval name as its eponymous tuning only on the basis of the thetic D scale postulated on p. 220. In other words, if this scale is accepted as a basic matrix and the 7 species projected on to it, each scale is named by the position of its characteristic segment as orientated on the (thetic) D scale. Thus:

FIG. 2.

The fact that, in the naming of intervals in the CBS tablet, only seven strings are mentioned even though nine strings are the norm in U.3011 and the fragment 7/80, seems to indicate that the nine-stringed harp was a later modification

of a seven-stringed precursor, as with the Greek lyre. If this were so, such a seven-stringed harp (dating, of course, prior to the period represented by 7/80, the Old Babylonian Period) would have been augmented at either end by one string; this much can be gathered from the fact that the nine-stringed harp terminology of U.3011 centres round the fifth string. Such a postulated addition would explain why there are two *qablītum* intervals, *nit/d* MURUB and *qablītum* itself, succeeding each other in scalar order, the latter being the original, the former a later addition in order that the *išartum* scale could be projected upon the extended gamut using the same interval names for both scales except for the added interval, named *nit/d* MURUB. Thus the *išartum* scale could have been projected on to this 9-note (*embubum*) scale, followed later by the tunings of 7/80. As in the Greek system, only at the *išartum* (Dorian) scale does thetic and dynamic notation correspond, though this correspondence would occur, according to the Babylonian method of naming intervals, at the *embubum* scale.

Modes

The tunings, or octave-species given above, are also named in a catalogue of songs found in the tablet *KAR* 158 viii.

From the shape of the imperfect tablet and the fact that the intervals form a closed cycle, it can be seen that only seven mode-species were there named, and that they occur in the same order as the species names of the fragment 7/80. They are as follows:

line 45   23 *iratu ša e-šir-te Akkadî* KI   *cf.* CBS.10996 l.13
           " 23 love songs, of the ' normal ' (type), Akkadian "

     46   17 *iratu ša ki-it-me*
           " 17 love songs, of the ' cover ' (type) "

     47   24 *iratu ša eb-bu-be*
           " 24 love songs, of the ' flute ' [*recte* pipe] (type) "

     48   4 *iratu ša pi-i-te*
           " 4 love songs, of the . . . (type) "

     49   [   ] *iratu ša ni-it/d* MURUB₄
           " . . . love songs, of the . . . (type) "

     50   [   ] *iratu ša ni-*iš* GAB.RI
           " . . . love songs, of the . . . (type) "

     51   [   ] *iratu ša* MURUB₄-*te* (= *qablite*)
           " . . . love songs, of the ' middle ' (type) "

(Transcription from *AS* 16, 267–8.)

This terminology must give rise to speculation as to whether the tunings were modes. However, it was not until the Middle Ages that any attempt was

made to equate scales with modes.   The latter were originally a series of classes
of chants within each of which were defined formularic and, perhaps more
important, ethos characteristics.   While it is quite possible that the Babylonians
associated each mode with a different octave-species, the precise nature of the
modal formulae cannot be determined at present, and it is quite likely that
the names in *KAR*.158 simply indicated the tunings which were best adapted
for the exigencies of each class of songs.[10]   It should be noted also that the
number of ' modes ' is seven, not eight as is normal in other cultures, arguing
that the scales may be more theoretical (seven being the maximum possible
number of species whereas the number of possible modes is not fixed from a
purely musical standpoint) than practical.   Another point worth mentioning
is that the sevenfold classification applies only to a group of the songs men-
tioned in *KAR*.158, not to all, as though some were outside the modal order.
From these facts it can be seen that, whatever may be brought to light about
the Babylonian octave-species, modality is a far more complex problem about
which there is no information at present.

' Primary' and ' Secondary' Intervals[11]

In the CBS sequence the foregoing are the names of the seven ' primary '
intervals.   Now in the latter part of U.3011 the following intervals are named,
or reconstructable:

> *išartum*
> *titur išartum*
> *kitmu*
> [*titur*] *kitmu*
> [*embubu*]

The word *titur* is an obvious reconstruction, and *embubu* follows from the
fact that the alternate intervals in U.3011 are in the order of *KAR*.158.   *Titur
kitmum* does not figure in CBS, but, assuming that it is a synonym for another
(secondary) interval, it is most likely to be *mušdum*, since the extension of the
series based on this hypothesis produces *qablītum* followed by *titur qablītum*,
which is what one would expect from the extant beginning.   It is further
possible that all the secondary intervals were alternatively described as *titur*
intervals.   Using the line numbers of CBS the series given in *KAR*.158 and
that projected from the above interpretation of U 3011 are:

[10] *Cf.* the Biblical terms עַל־עֲלָמוֹת and עַל־הַשְּׁמִינִית mentioned in I Chron. 15 as tunings, and also the presumably early psalm super- scription מִכְתָּם (= *kitmum*?) denoting, perhaps, that such psalms had been composed within a modal order.

[11] See footnote 3.

KAR No. 158, viii (primary intervals)	13	21	15	23	17	11	19						
U 3011 (primary, alternating with intermediate, secondary intervals)	13	22	21	24	15	12	23	14	17	16	11	18	19	20

Thus, whereas the arrangement of intervals in CBS is a stepwise progression of primary intervals alternating with a similar progression of secondary intervals, U.3011 follows the cyclic order (the ' modal ' order of KAR.158) for the primary intervals, but with the secondary intervals arranged in stepwise progression, as in CBS.

The Harmony of the Spheres

As early as Plato[12] the planets are described as emitting definite musical notes. This doctrine has always been thought to have been borrowed from the Near East. It is of interest, therefore, to see that the Babylonian tunings are organised according to this theory. The notes said to be sounded by the planets were, according to Greek theory:

Saturn   Jupiter   Mars   Sun   Venus   Mercury   Moon

FIG. 3.

This is the scale *išartum*. But the order of the octave species was Dorian, hypo-Dorian, Phrygian etc., giving the starting notes E, A, D etc. This progression is by (conjunct) tetrads: it is the same progression followed by the starting-notes of the seven Babylonian tunings, *išartum, kitmum, embubum* etc., and comprehends the ' primary ' intervals. A similar progression is followed by the Arabic *aṣābi'*. In relation to the ' scalar ' order of the planets, as explained by Dio Cassius[13] this tetrad order is the order of the days of the week Saturnday, Sunday, Moonday etc. A tetrad ordering of *this* sequence will produce a further series Saturn, Mars, Venus etc., which corresponds musically to the secondary intervals of the CBS tablet, thus:

Saturn   Mars   Venus   Moon   Jupiter   Sun   Mercury

FIG. 4.

[12] *Timeus* 36, *cf.* also Plutarch, *In Timeo* 56 and   [13] *History*, xxxvii, 17–18.
Nichomachus, *Harmonics* 3 and *Excerpts* 5–6.

Neugebauer's contention[14] that the Babylonians can have had nothing to do with the naming of the days of the week is based on Dio's other explanation of their origin by reference to 'rulers', each planet ruling a different hour of the day: since there were 24 hours in the day, the first hour of each successive day was ruled by the various planets in the 'days of the week' sequence. Since the Babylonians had no 24-hour calendar, Neugebauer prefers to see the order of the planets given in the Greek horoscopes as the progenitor of the hebdomadal sequence, though pointing out at the same time that the order of the planets mentioned in Babylonian horoscopes of the Seleucid period could not have resulted in such a sequence. However, the Greek horoscope order Sun, Moon, Mars, Mercury, Jupiter, Venus, Saturn is clearly not directly related to the hebdomadal sequence, and the ordering of the Babylonian and Greek octave-species in tetrads lends more credence to Dio's tetrad explanation than his alternative involving 'rulers'. Thus the possibility remains that the Babylonians can be given some credit for the naming of the days of the week as well as for the doctrine of the Harmony of the Spheres.

The " Thin String "

The contention that the " thin string " indicates that the pitch of this string was a semitone below its upper neighbour has been dealt with on p. 215. If the epithet " thin string " were, nevertheless, to be taken as an indication of tuning, the same argument would apply to the " small string ", whose decreased length would also make it nearer in pitch to its upper neighbour. Thus a scale such as indicated on p. 220 would be indicated. However, a recognisable decrease in calibre would produce a note at least a fifth away; therefore to preserve the stepwise progression, the tension would have to be altered. The value of the terms " thin " and " small " as indicative of a pitch relationship is, as a result, worthless. This can be seen from the application of the law

$$\text{frequency} \propto \frac{\sqrt{\text{tension}}}{\text{length} \times \text{diameter}}$$

It seems likely that the " thin " and " small " strings were, like the coloured strings on modern harps, a method of identification. This is necessary particularly on large instruments, for otherwise there is no pattern (such as that made by the black and white keys of the piano) from which the player can get his bearings. If the " thin " string were made longer relative to its frequency, the next higher string would appear small and produce a distinctive pattern. Taking the values of the scale given on p. 220 this would have the following appearance:

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[14] *The Exact Sciences in Antiquity*, 1957, 168 ff.

String	O	I	II	III	IV	V	VI	VII
Frequency ratio	1	9/8	5/4	4/3	3/2	5/3	15/8	2/1
Length ratio	1	8/9	4/5	4/5	2/3	3/5	8/15	1/2

In this diagram the diameters and tension are taken as constant, except in the case of III where, for example, a diameter of two-thirds the normal would be balanced by a tension of about half the normal.

Applied to a large harp, this pattern would probably be practical only in the higher portion of the harp. Because of the incursion that a relatively longer " thin string " would make in the sloping side of the harp, it would be disastrous to the architecture of the bottom of the harp, should a nick intrude (in the soundboard in the case of an upper-chested harp) and in any case a thin string would provide a sufficiently recognisable point of reference. However, the " thin string " without any increase in length would hardly serve for recognition purposes at the top end of the harp, for the feasible differences in diameter would be so small; therefore the additional identification provided by the apparently " small string " would be invaluable.

On small harps this system would be a needless complication; there is no iconographic evidence, indeed, to show that it was ever used on harps of ordinary range, though this is not, of course, conclusive. However the large four-octave harps shown in the " Elamite Orchestra " on the relief of Ashur-

banipal (BM.124802), while of course not showing the " thin string " do have
the nick in the upper octave mentioned above. Furthermore, the longer string
occurs at about the 18th note from the bass, which would be the correct
position for the " thin string " according to U.3011 if the seven-note series is
transposed up two octaves.[15] It is also interesting to note that the interval
GIŠ.NIM.MA is the interval between the bottom note of each octave and the
" thin string "; this might imply, if not pure coincidence, that the " thin string "
was an Elamite invention (NIM.MA, read *Elam-ma*, being the normal written
form of the country Elam).

Conclusion

We now know that the Babylonians had seven octave species similar to,
but far antedating, those known from Greek sources. How far these represent
theoretical, rather than practical, tunings we cannot at present tell. Nor can
it be said, on the basis of the material available so far, what connection, if any,
the tunings had with " modality " if such a concept existed.[16] The indications
are, however, that Greek musical thought owed some debt to the Babylonians.

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[15] *New Oxford History of Music*, I, plate VIII (c).   [16] *Cf.* D. Wulstan, *The Origin of the Modes* (*Studies in
Eastern Chant* III).