ELSLEY ZEITLYN LECTURE ON CHINESE ARCHAEOLOGY AND CULTURE

# The Prehistory of Chinese Music Theory

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> The division of the octave into twelve semitones and the transposition of scales have also been discovered by this intelligent and skillful nation. But the melodies transcribed by travellers mostly belong to the scale of five notes.
>
> Helmholtz, *On the Sensations of Tone* (1863)[1]

THE EARLIEST TEXTS ABOUT MUSIC THEORY presently known from China are inscriptions on musical instruments found in the tomb of Marquis Yi of Zeng, the ruler of a small state in the middle Yangzi region, who died in 433 BC. Excavated in 1978, the tomb was an underground palace of sorts, a timber structure furnished with an astonishing array of lordly possessions (Fig. 1).[2] In two of its four chambers the instruments of two distinct musical ensembles were found. Beside the marquis's coffin in the east chamber was a small ensemble for informal entertainments, music for the royal bedchamber perhaps, consisting of two mouth organs, seven zithers, and a small drum. In the central chamber, shown under excavation in Figure 2, a much larger ensemble for banquets and rituals was found. Composed of winds, strings, drums, a set of chime stones, and a set of bells, it required more than twenty performers. The inscriptions about music theory appear on the chime stones and the bells. They concern

Read at the Academy on 26 October 2004.

[1] Quoted from Alexander Ellis's 1885 translation (p. 258) of the fourth German edition (1877).

[2] The excavation report, in Chinese, is *Zeng Hou Yi mu* (1989). Tan Weisi (1992), Shu Zhimei (1994), and *Zhongguo yinyue wenwu daxi, Hubei juan* (1996) contain good illustrations of the finds. So (2000) briefly introduces the tomb and discusses the musical instruments in detail; chap. 2 (=Bagley 2000) describes the bells and chime stones that are the focus of the present essay. The musical inscriptions are transcribed in the excavation report.

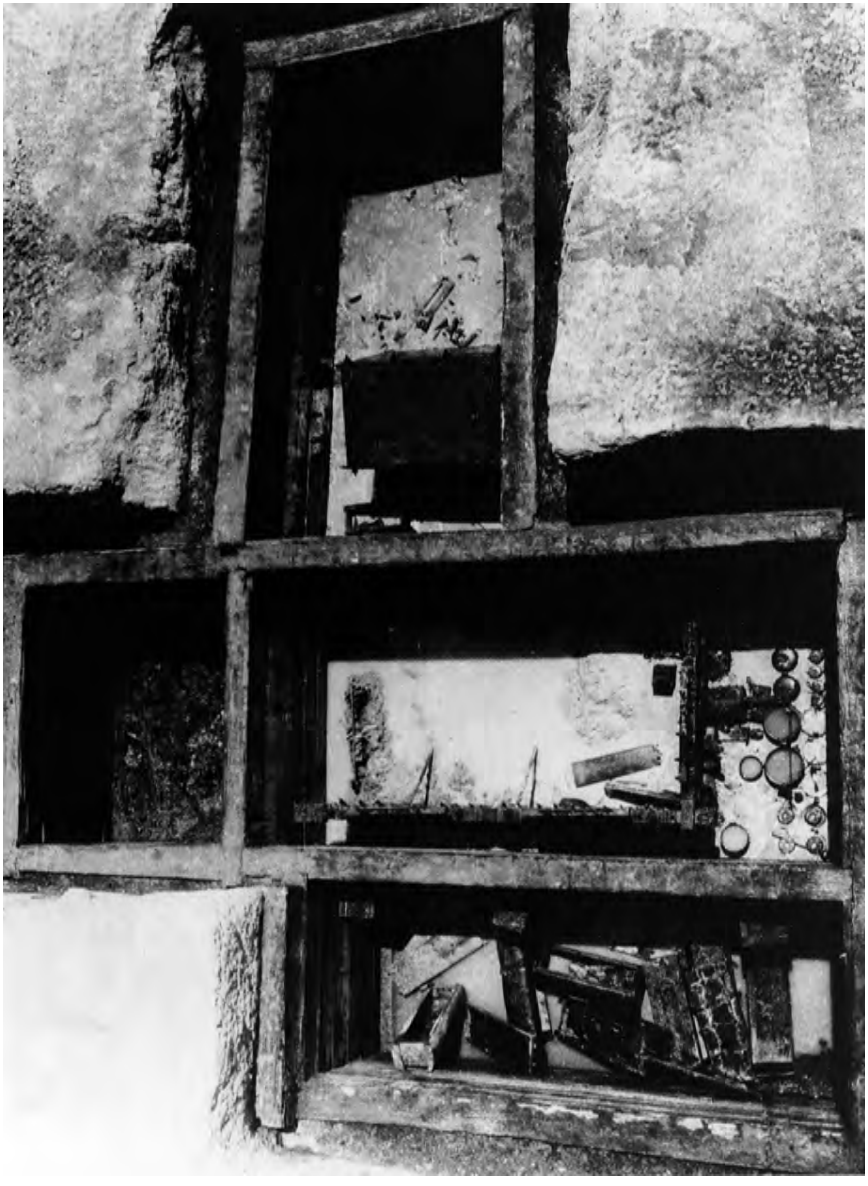

**Figure 1.** Tomb of Marquis Yi of Zeng (d. 433 BC), aerial view facing north, roof removed. Hubei Suizhou. Dimensions 15.72 m north–south by 19.7 m east–west After Shu Zhimei (1994: 113).

**Figure 2.** Tomb of Marquis Yi, central chamber under excavation, showing bells and chime stones *in situ*. After *Sui Xian Zeng Hou Yi mu* (1980: pl. 8).

pitches and scales, and the pitches they refer to can still be sounded by the bells. In this essay I shall first describe the inscriptions and then try to guess what sort of musical development lies behind them.

By way of giving a general idea of music at the Zeng court let me begin with a brief survey of the instruments in the central chamber. They are exceptionally fine but mostly well known as types from other archaeological finds.

The central chamber contained three drums, all different, a large one played by a standing performer (Fig. 3) and two small ones (Fig. 4).[3] The oldest drums yet found by archaeologists come from Neolithic sites of the third millennium BC.[4]

The wind instruments are of three types. The simplest are lacquered bamboo panpipes; the ensemble had two of these (Fig. 5). The oldest panpipes known at present date from the tenth century BC—bone examples have been found in a tenth-century tomb[5]—but an instrument that was normally made of perishable materials could of course go back much further than the examples we happen to have. Perishable materials survived extremely well in the Marquis of Zeng's tomb because it filled up with water shortly after it was closed and was tightly enough sealed so that conditions did not change afterwards.

Two transverse flutes made of lacquered bamboo have closed ends, five finger holes, a mouth hole, and a hole for air to escape from (Fig. 6). No earlier flute of this type has been found, but longitudinal flutes made of bone are known as early as the seventh millennium BC (Fig. 7). Unfortunately wind instruments do not give reliable pitch measurements,[6] so we have no firm information about musical scales until we start finding sets of bells tuned in a consistent pattern around 900 BC. Bells certainly were not the first instruments tuned to well-defined scales, but they are the first that survive in playable condition.

The ensemble had four mouth organs (*sheng*). They were not in good condition; Figure 8 shows a replica. The mouth organ is a reed instrument made from a gourd fitted with bamboo pipes (in the Zeng examples the reeds too were bamboo). In traditional music of recent times it has an accompanying role, playing the principal notes of the melody in parallel fifths and octaves. The oldest mouth organs known at present are only about a century older than the Marquis of Zeng's.[7]

[3] The third drum from the central chamber, a flattish one that may have been mounted in some kind of frame or stand, was found in fragments (Bagley 2000: 127).

[4] At a late third-millennium Neolithic site at Shanxi Xiangfen Taosi the remains of a drum were found in a grave that contained also a single chime stone (Li Chunyi 1996: 2).

[5] *Luyi Taiqinggong Changzikou mu* (2000: 192–4). The five sets of panpipes from this tomb have from five to thirteen pipes each but were not in a condition to give pitch measurements.

[6] Pitch measurements have been taken from the flutes of Figure 7 (Zhang *et al.* 1999), but they probably cannot be trusted to give meaningful information about scales. The extent to which pitches can vary with blowing technique is suggested by a careful recent study of a primitive bone flute of Palaeolithic date, Kunej and Turk (2000).

[7] Two were found in Dangyang Caojiagang M5, a Chu tomb of the sixth century BC, source also of the zither shown in Figure 29. See *Zhongguo yinyue wenwu daxi, Hubei juan* (1996: 152); *Wenwu* 1990.10.31. On the *sheng* see Thrasher (2001).

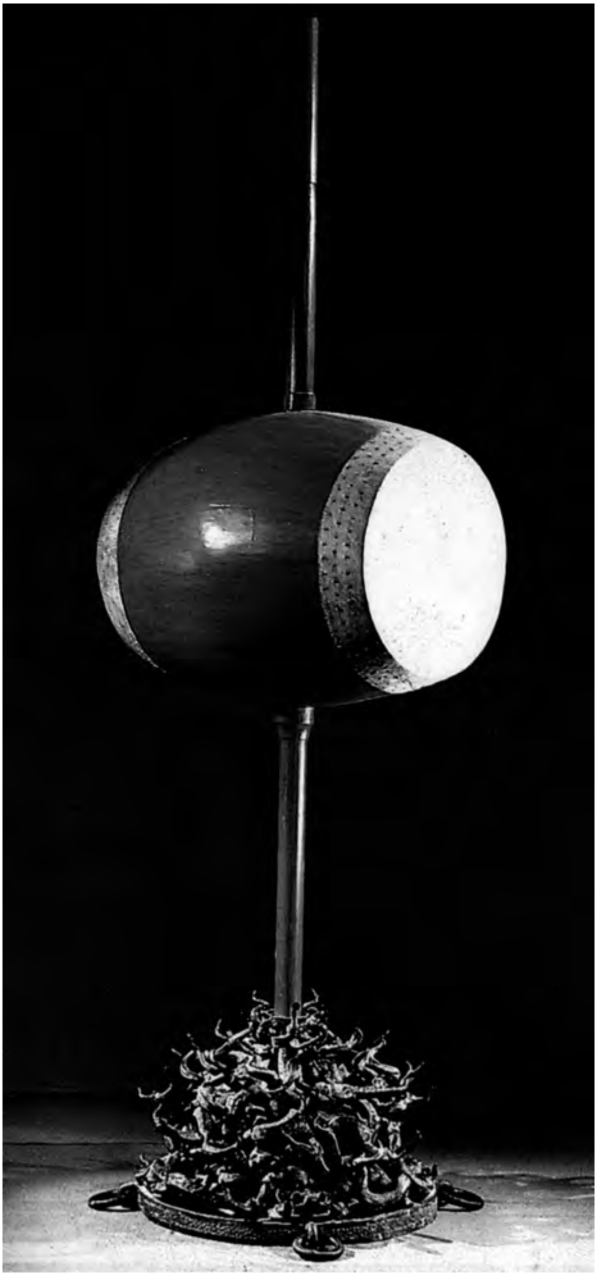

**Figure 3.** Drum (replica) with bronze base (original). Tomb of Marquis Yi. Overall height 3.65 m, diameter at drumheads 74 cm. After Shu Zhimei (1994: 135).

**Figure 4.** Drum with handle. Tomb of Marquis Yi. Diameter at drumheads 28 cm. After Shu Zhimei (1994: 134).

The only stringed instruments in the central chamber were seven large zithers of the type *se*.[8] The example shown in Figure 9 is lacquered wood, nearly two metres long, very refined in joinery, bridge-tuned, with holes for twenty-five strings. Strings did not survive on the instruments in the Marquis of Zeng's tomb, but they do survive on a zither from Mawangdui M1, a tomb dated *c.* 168 BC, and there they are silk, the standard material for instrument strings in all later periods.[9] Zithers as sophisticated as the marquis's must have had a long history behind them, but the oldest stringed instruments known at present are only about two centuries earlier than his. In Figure 10, which shows a replica of a seventh-century example, the movable bridges used for tuning can be seen. On present evidence we cannot even guess how far back stringed instruments might go, and that is unfortunate, because strings loom large in music theory. In the

[8] The east chamber contained another five zithers similar to those in the central chamber and two smaller ones of more unusual types (So 2000: chap. 3).

[9] On the Mawangdui zither and its tuning, which was probably pentatonic, see Mok (1978).

**Figure 5.** Panpipe, lacquered bamboo. Tomb of Marquis Yi. Largest dimensions 22.8 cm by 11.7 cm. After Tokyo National Museum (1998: 37).

West they have been central to theorising about musical scales since antiquity. A few centuries after the Marquis of Zeng's time they had the same role in Chinese music theory. But I will argue that in his time and earlier, what mattered to theorists was not strings but bells. Bells were musically important as early as the thirteenth century BC.

**Figure 6.** Transverse flutes, lacquered bamboo. Tomb of Marquis Yi. Lengths 29.3 cm, 30.2 cm. After Tokyo National Museum (1998: 42).

The most spectacular instrument in the tomb, visible in place in Figure 2, is a tuned set of sixty-five bells suspended in three tiers on an L-shaped rack (Figs 11–12).[10] The largest bell, the one nearest the photographer in Figure 12, is pitched two octaves below middle C and weighs 200 kg; the sixty-five bells together weigh about 2,500 kg. The set seems to have been played by a team of five performers, a number that argues for music of some complexity. Three distinct subsets on the middle tier, two on the long arm and a third on the short arm, carried the melody; they were played with mallets by three performers standing behind the rack (Fig. 13). Two performers standing in front of the rack used wooden poles to sound harmonising notes on the big bells of the lower tier.

The bells of the upper tier were probably not played. The two groups on the long arm of the upper tier seem instead to constitute a display of pitch standards. It is those upper-tier bells that will occupy us here, but first there are several things to be said about the set as a whole.

Notice first that this set was not a solo instrument, it was part of an ensemble. In ancient China bell sets were not carillons at the tops of towers, they were ensemble instruments that stood in a palace hall and performed in concert with other instruments, singers, and dancers.

[10] For detailed description see Bagley (2000).

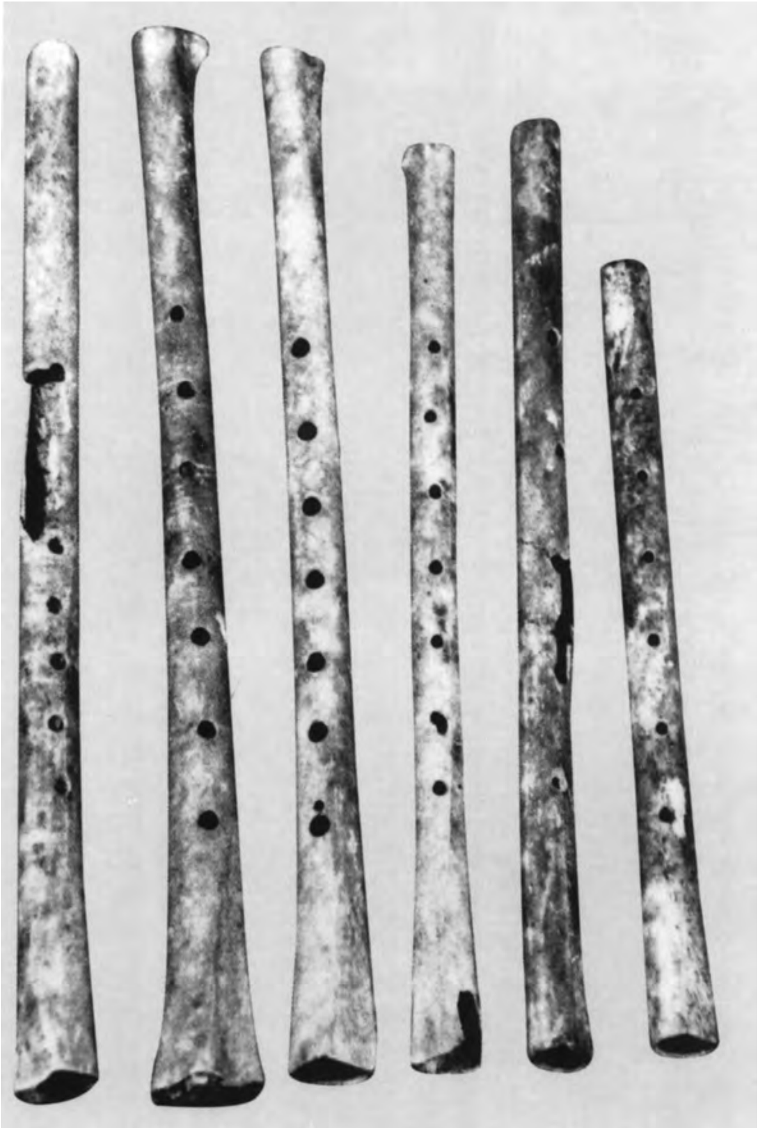

**Figure 7.** Bone flutes from Henan Wuyang Jiahu. Length of longest, 23.6 cm. Seventh millennium BC. After *Zhongguo yinyue wenwu daxi, Henan juan* (1996: 9).

Second, a word about its predecessors. Musicians began adding bells to their ensembles sometime around 1300 BC, at first just a single bell or maybe two. By 900 BC we find tuned sets that show a certain amount of standardisation—eight bells is a popular size—and a musical scale

**Figure 8.** Mouth organ (*sheng*), replica. Tomb of Marquis Yi. Length of gourd 22 cm. After Tokyo National Museum (1998: 41).

**Figure 9.** Twenty-five-string zither, lacquered wood. Tomb of Marquis Yi. Length 167 cm, width 42 cm. After So (2000: 69).

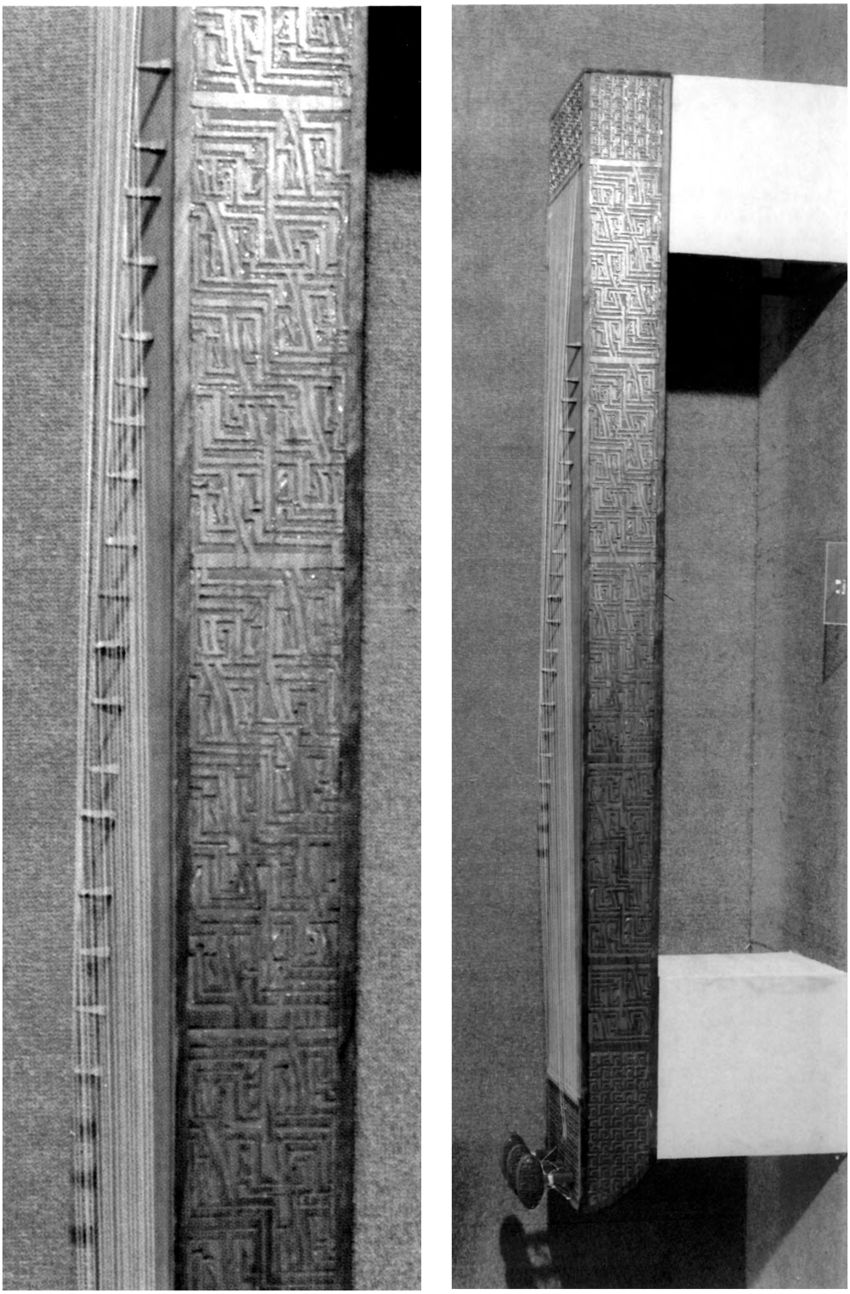

**Figure 10.** Eighteen-string zither from Hubei Dangyang Zhaoxiang M4 (replica), with detail showing bridges. Length about 2 m. Seventh century BC. After *Zhongguo yinyue wenwu daxi, Hubei juan* (1996: 132).

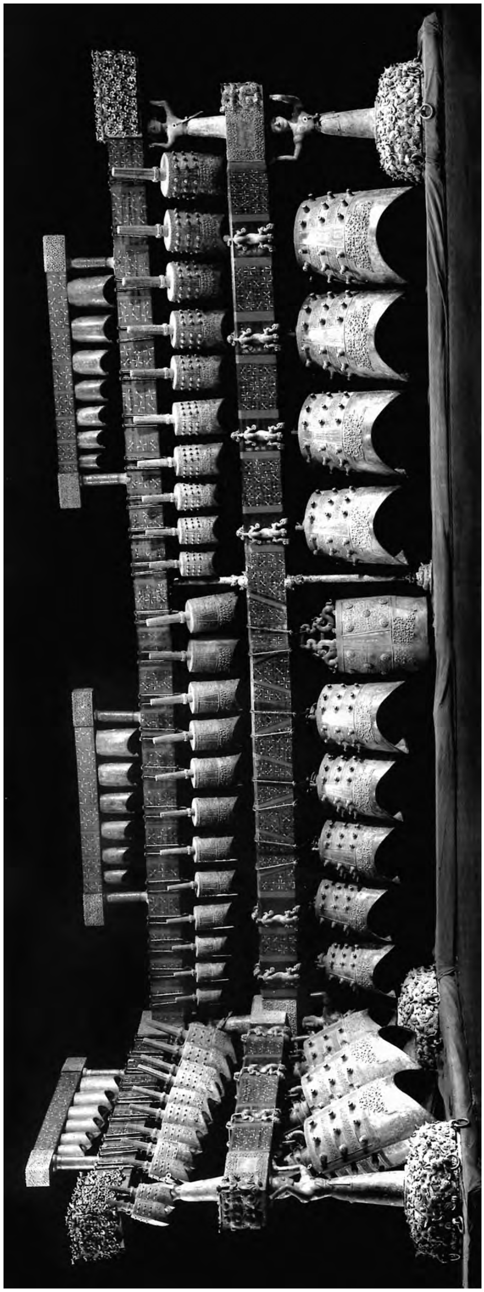

**Figure 11.** Set of sixty-five bronze bells on a lacquered wooden rack with bronze fittings. Tomb of Marquis Yi. Long arm 265 cm high, 748 cm long; short arm 273 cm high, 335 cm long. After Tan Weisi (1992: pl. 1).

**Figure 12.** Bells, rear view of short arm. After Tan Weisi (1992: pl. 2).

emerges unambiguously from pitch measurements. Known only from sets made for a short time in north China, it is a scale with four notes per octave, *do mi sol la*.[11] The Zeng assemblage supplies a five-note scale over

[11] This tetratonic scale is repeated over a compass of more than three octaves in a considerable number of northern sets made from the ninth to the seventh century, but it is otherwise unknown

**Figure 13.** Two performers standing behind the long arm of the rack and playing two of the three middle-tier subsets. (The third middle-tier set, on the short arm, is seen from the performer's side of the rack in Fig. 12.) Six wooden mallets for playing the middle-tier subsets were found in the tomb, along with two wooden poles for playing the lower-tier bells. After So (2000: 41).

a range of five octaves, along with shorter stretches of denser scales. It is the climax of a millennium of bell casting.[12]

Third, an acoustic peculiarity: ancient Chinese bells are not circular, they have an almond-shaped cross section (Fig. 14). This shape is impor-

(might it have been a peculiarity of Western Zhou ritual music?). A recording of music played on a well-tuned ninth-century set, the Shanghai Museum's *Jin Hou Su yongzhong*, is available from the museum on a CD with the English title 'Melody of Majesty, sounds from the chime bells of Su, Marquis of Jin'.

[12] The China Record Corporation (Beijing) has issued a CD and a CD-ROM devoted to the Marquis of Zeng's bells. (The music performed on the bells is not ancient; no musical scores

**Figure 14.** Mouth of middle-tier bell M3-8, showing almond-shaped cross section. The A-tone label is *gong*. After So (2000: 44).

tant for several reasons. It gives a bell fast attenuation (in other words, the sound dies away quickly, it does not linger and muddle the music); it gives a well-focused pitch, rather more musical than the sound of a circular bell; and it actually gives the bell two distinct pitches, depending on where it is struck. Striking on the central axis sounds one pitch, striking near the side sounds another. I will call the pitch obtained on the central axis the A-tone, the pitch at the side the B-tone. The B-tone is always higher than the A-tone. In the Zeng set it is higher by three semitones or four semitones, in other words the A–B interval is always a minor third or a major third.

Finally, these bells have gold-inlaid inscriptions that concern their pitches. On one side of each bell, each of the two strike points is labelled with the name of the pitch it sounds (Figs 15, 23 left). On the other side longer inscriptions relate the pitches to scales (Figs 16, 23 right). Since

survive from the marquis's time. The earliest extant piece of notated music in China is a zither tablature from the sixth century AD.)

**Figure 15.** Middle-tier bell M1-4, front view, showing strike-point labels. The A-tone label is on the central axis near the bottom edge; the B-tone label is near the right side, a little higher up. The inscription in the central panel, repeated on all 45 stemmed bells of the middle and lower tiers, reads 'Marquis Yi of Zeng made [this], cherish [it]'. Height 48.7 cm. After *Zhongguo yinyue wenwu daxi, Hubei juan* (1996: 217).

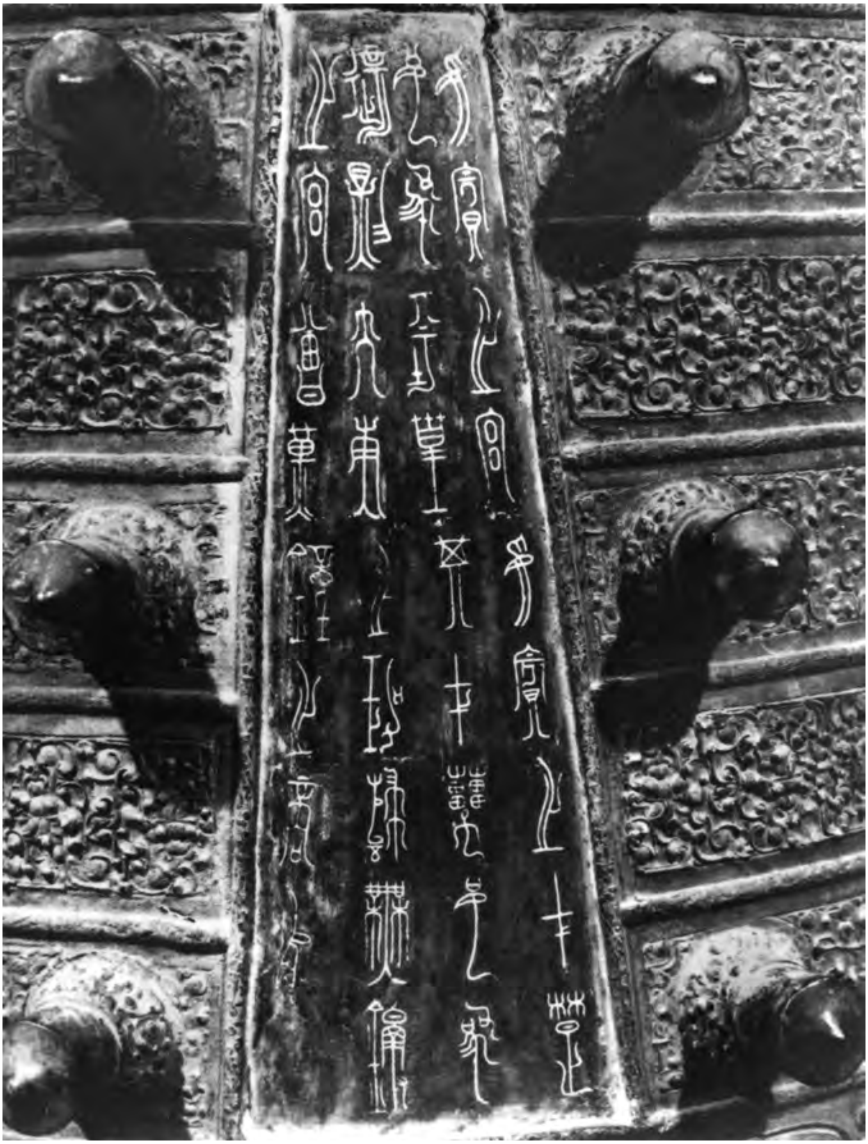

**Figure 16.** A-tone inscription from the back of lower-tier bell L1-2. (Elsewhere on this side of the bell is another inscription referring to the B-tone.) After Rao Zongyi and Zeng Xiantong (1985: pl. 13).

we can strike the bells and hear the pitches that we read about in the inscriptions, we have in effect a book about musical scales with a demonstration CD tucked inside the back cover.

The last instrument in the central chamber is a set of chime stones suspended in two rows on a bronze rack (Fig. 17). It was played by a seated performer equipped with two wooden mallets. Though chime stones go back to the late third millennium BC, Neolithic examples are always found singly; tuned sets do not seem to be any earlier than tuned sets of bells.[13] The Zeng chime stones were found in place on their rack: the set is visible, covered with mud, at the top of Figure 2. The stones are fragile—the limestone tends to crumble—and they do not give usable pitch measurements, but on their sides and edges they bear inscriptions about musical scales that were carved and then inlaid with red pigment (Fig. 18).

In what follows the two instruments that will concern us are the chime stones and one particular subset of the bells, the small ones on the long arm of the upper tier (the bells are displayed there in two groups but belong to one continuous sequence). On both instruments the pitches available constitute a chromatic scale; that is, the octave is divided into twelve semitone steps, the same twelve steps supplied by the black and white keys of a piano. In this respect the chime stones and the upper-tier bells are unique: they are the only chromatically tuned musical instruments known from ancient China. Let us examine first the instruments, then their inscriptions, and ask the question: How did the Zeng theorist think about musical scales?

First the chime-stone set. The chime stones are numbered in pitch order, from 1 to 41, and they span just under three and a half octaves in an unbroken chromatic sequence, twelve stones per octave. When the tomb was excavated the stones were hanging on the rack, as in Figure 17, but when the stones were not being played they were kept in three custom-made boxes, and the empty boxes were also found in the tomb, in the north chamber. The boxes have fitted, numbered slots showing which stone goes where, and when we put the stones in the boxes, we find that they are sorted in a very interesting way. Box number 1, shown in Figures 19 and 20, contains a *pentatonic* set starting on C. In other words, it contains three octaves of the notes CDEGA; these have the spacing of an anhemitonic pentatonic scale, *do re mi sol la*. Box number 2 contains

[13] On Neolithic chime stones see Li Chunyi (1996: 31). Li (p. 43) dates the earliest tuned sets to Yinxu 2, the second stage of the Anyang site, i.e. about 1200 BC; see also *Kaogu* 2000.11.58–64.

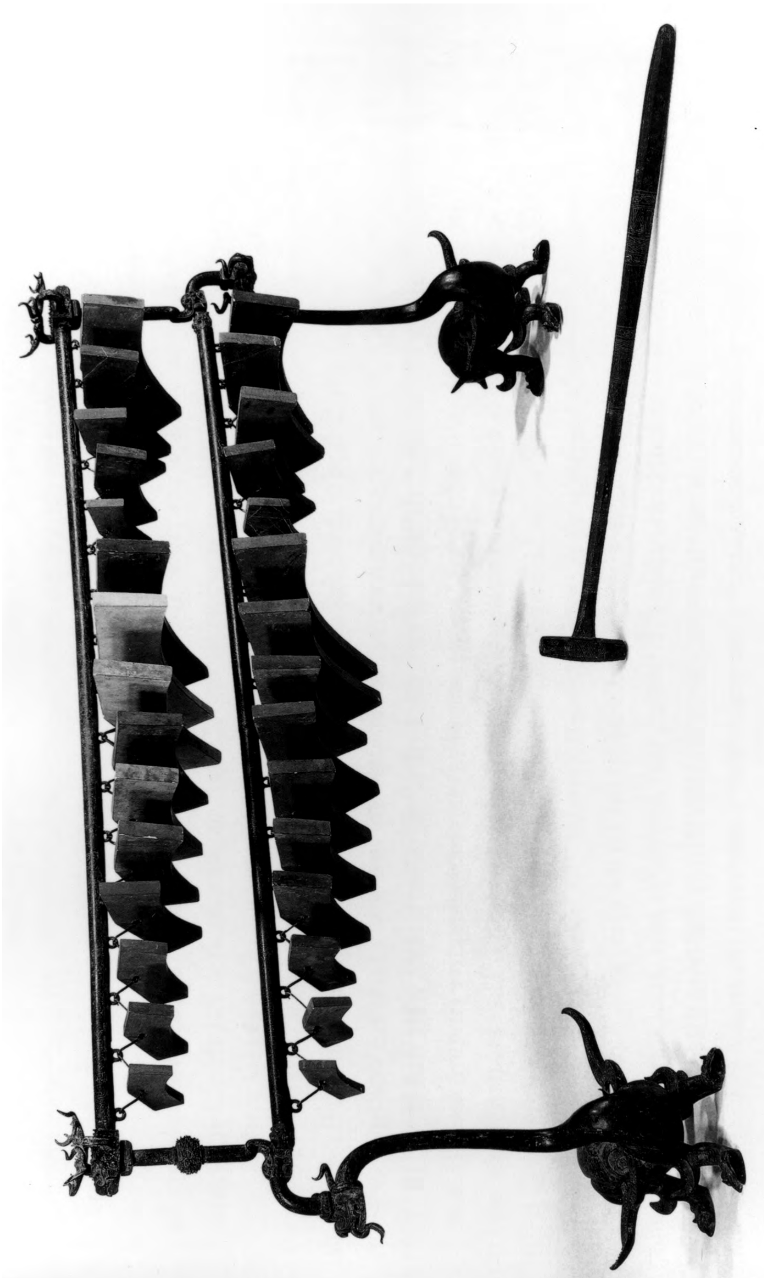

**Figure 17.** Set of thirty-two chime stones (replicas) on a bronze rack. Tomb of Marquis Yi. Length of rack 215 cm, height 109 cm. After So (2000: 53).

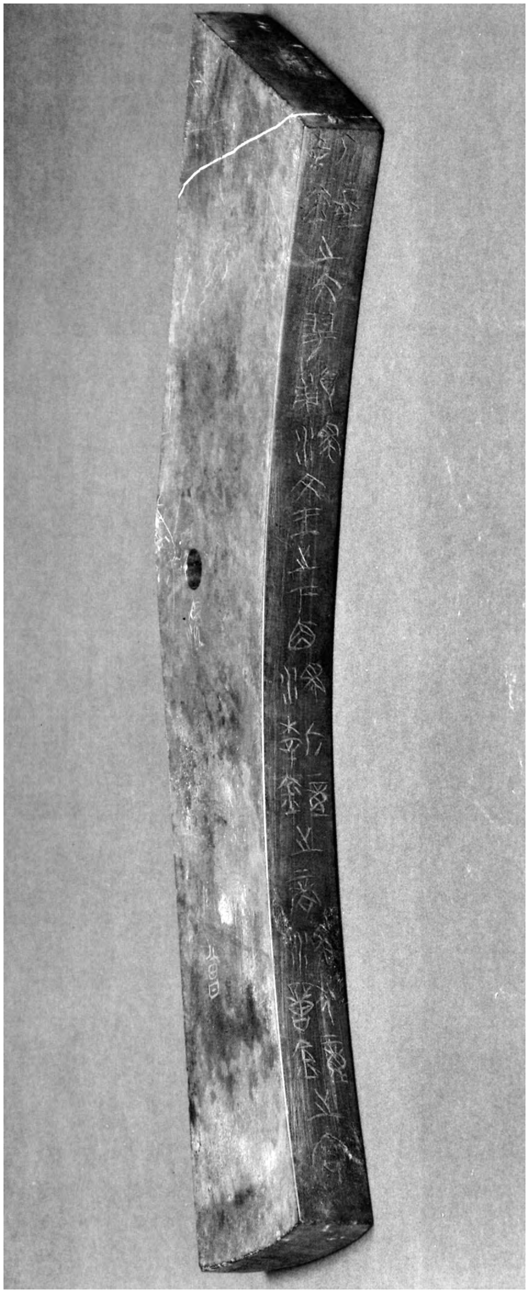

**Figure 18.** Chime stone number 12. The inscription on the side reads '*gongzeng* [*sol*-sharp] of *flat* Guxian', hence the pitch of the stone is G. Tomb of Marquis Yi. After *Zhongguo yinyue wenwu daxi, Hubei juan* (1996: 259).

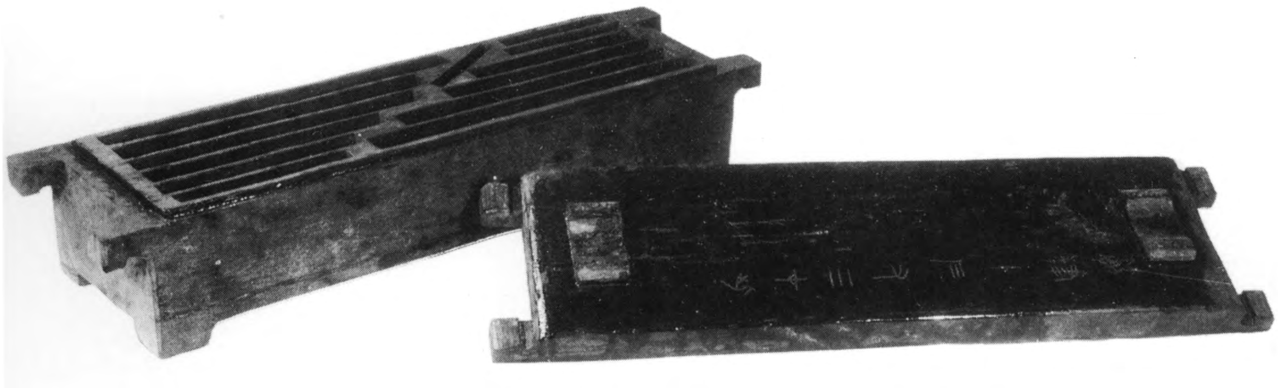

**Figure 19.** One of three lacquered wood boxes for chime stones, the box for the pentatonic set on C (Guxian). Tomb of Marquis Yi. Length 81.2 cm, height 32 cm, width 24 cm. After *Zhongguo yinyue wenwu daxi, Hubei juan* (1996: 261).

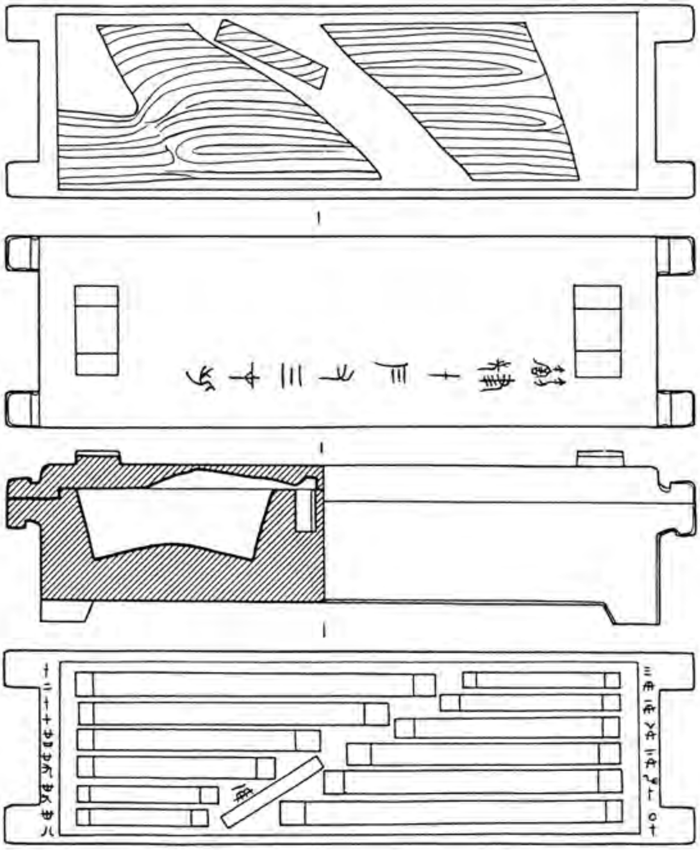

**Figure 20.** Drawings of the chime stone box for the pentatonic set on C (Guxian). After *Zhongguo yinyue wenwu daxi, Hubei juan* (1996: 261). The box lid is labelled 'Guxian stones, thirteen are within'. The numbering of the slots is visible at the bottom of the figure.

a pentatonic set that starts on F#, half an octave away, meaning that it does not share any notes with the first set. (See Figure 21. The pentatonic scale on F# is the black keys on a piano, the sharps. The scale on C, CDEGA, is all white keys.) And box number 3 contains three octaves of Bs and Fs, the only notes that belong neither to the C scale nor to the F# scale. The Bs and Fs fill out the chromatic scale—and the label on the lid of box number 3 says something like 'extras'. The boxes thus

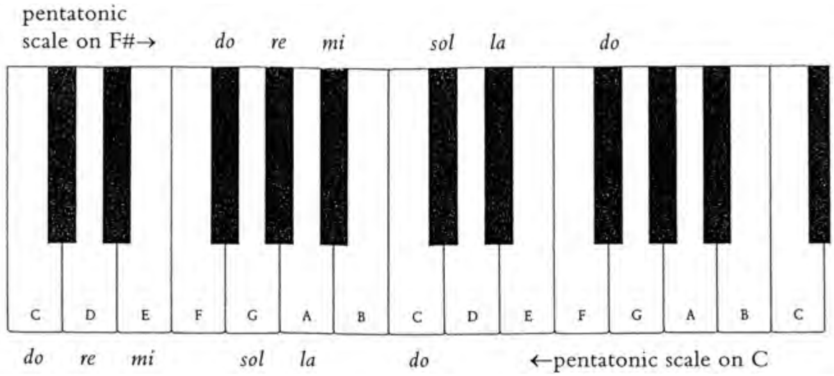


**Figure 21.** Piano keyboard labelled with pentatonic scales on F# and C. Like the Chinese terms *gong shang jue* . . . , the terms *do re mi* . . . are solmisation syllables, terms for describing the steps of a musical scale without specifying absolute pitches. For example, the syllables *do re mi fa sol la ti do* describe a major scale. If we set *do* equal to C, it is a C-major scale, if we set *do* equal to G, it is a G-major scale. C and G are absolute pitches, *do* is movable. The pentatonic scale of the Zeng inscriptions, the most common pentatonic scale worldwide, is *do re mi sol la do*. This is the anhemitonic pentatonic scale, so called because it has no semitone steps (the steps are two or three semitones).

sort the chime stones into two non-overlapping pentatonic scales plus leftovers.[14]

Notice two points here. First, though pentatonic music may have existed in China long before the fifth century, the Zeng instruments and inscriptions are at present the earliest unambiguous evidence for it. How much further back it might go is unknown.[15]

Second, although the boxes have slots for 41 stones, the two bars of the rack hold only 32. The set of chime stones was not displayed on the rack entire, in chromatic sequence. Instead, the player put three octaves of

[14] Along with the B and F stones the third box held the four largest stones from the C scale and the two largest and two smallest stones from the F# scale. This adjustment to the purely musical sorting allowed making all three boxes the same size.

[15] Ethnomusicologists have found pentatonic music in cultures all over the world (cf. Day-O'Connell 2001). Presumably it has arisen spontaneously many times in many places, as a purely aural phenomenon, presumably because the intervals that compose it are somehow favoured by the human auditory system. The alternative would be to suppose that it was invented in one place and spread from there to all the cultures where ethnographers find it (spreading in the form of tunes rather than as a scale, a theorist's abstraction, since most of the cultures in which ethnographers find it have no explicit music theory and no concept of a scale). But this does not seem very different from supposing that it can arise spontaneously, since the same special relationship to human auditory perception would have to be invoked to explain worldwide spread and long survival.

one pentatonic scale on the top bar and three octaves of another pentatonic scale on the lower bar (since a pentatonic scale has five stones per octave, sixteen stones supply just over three octaves). But he did not always put the C scale on one bar and the F# scale on the other. If those had been the only two scales he ever used, he would not have needed the third box of extras. The complete set of stones amounted to a chromatic reservoir from which he could select *any* pentatonic scale: no matter which of the twelve steps of the octave he chose as starting point, his chromatic reservoir furnished all the stones he needed.[16]

At first glance we might take this instrument to be designed for a player who was constantly transposing the pentatonic scale. On closer inspection, however, it does not seem well suited to that or indeed to any practical use. The suspension mechanism is complicated; hanging the stones was a clumsy chore. The player can hardly have been resetting the rack very often. Moreover, since the set has no duplicates, the only pairs of pentatonic scales that can be displayed complete are pairs that do not overlap, like C and F#. If the player wished instead to put C and F on the rack, he faced the problem that those two scales have four notes in common; once he had put the C scale on one bar, he had nothing left for the other bar but the three F stones.[17]

If the ability to play all possible pentatonic scales had really mattered, surely the player would have had a rack that displayed all 41 stones permanently, in chromatic order. The combination of chromatic coverage and pentatonic display does not look like the answer to a performance need; it looks more like a theoretical statement, perhaps an ostentatious declaration that *pentatonic scales are selections from the chromatic scale.* As we will see in a moment, the inscriptions on the stones, which certainly had no practical function, convey essentially this message. Before turning to them, however, let us examine the other chromatic instrument in the tomb, the bell subset on the long arm of the upper tier.

[16] The boxes were empty at the time of excavation, and the nine stones not on the rack were nowhere in the tomb. It is hard to know what to make of their absence. The display of stones found on the rack, which has a number of irregularities, is also difficult to interpret. It does however reveal that the scale on each bar was arranged not in pitch order but instead in the curious sequence (beginning at the player's left) *sol do sol do sol do re mi la re mi la re mi la*.

[17] The only pentatonic scales that do not overlap are scales separated by one semitone or six semitones (half an octave). Since both intervals are very dissonant, such scales are not likely candidates for use within a single piece of music (C and F, a fifth apart, would probably have been much more useful). Though I once took the design of this instrument to reflect performance needs (Bagley 2000: 55–6), for the reasons just given I now think otherwise.

The chromatic scale can be distributed over a series of two-tone bells in a very tidy way. Suppose the bronze caster makes a set in which the B-tone of each bell is three semitones above the A-tone, and the A-tones of successive bells are two semitones apart. Figure 22 shows such a set with the strike points numbered in order of ascending pitch. The A-tones are the odd numbers, the B-tones are the even numbers, and the sequence of tones 1 2 3 4 5 . . . is a chromatic scale. A performer who wishes to play the notes in pitch order will zigzag from the A-tone of one bell to the B-tone of the previous bell to the A-tone of the next bell.

The upper-tier bells are minor-third bells spaced two semitones apart; in other words, their chromatic scale has the layout shown in Figure 22.[18] Let us look at their inscriptions. On the front of each bell the A- and B-tone strike points are labelled with the names of the pitches sounded at those points (Fig. 23, left). The fronts of the six largest bells are shown in the top row of Figure 24. Since the strike-point labels name the notes the bells play, they name the notes of the chromatic scale; to put those names in pitch order we need only strike the bells and listen to the pitch that goes with each name. Pitch order is the zigzag pattern shown by the numbers in Figure 22. If we copy the labels off the strike points in that order, we obtain the list shown in Table 1.

The left column of Table 1 lists the pitches in ascending order, beginning at the bottom with the lowest, called *gong*, and ending at the top

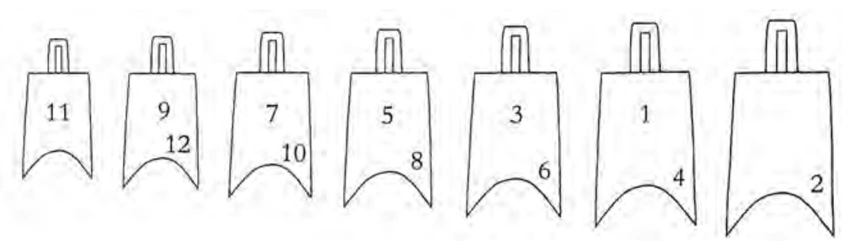


**Figure 22.** The chromatic scale constructed from minor-third bells. If the founder casts a set of bells in which the interval between successive bells is two semitones (that is, the A-tones are spaced at two-semitone intervals, and so are the B-tones) and the A–B interval is three semitones, the set will supply a chromatic scale.

[18] Throughout the present paper the only upper-tier bells referred to are the ones on the long arm of the rack (a single continuous set displayed in two groups). The ones on the short arm, irrelevant here, are an unrelated grouping of uncertain purpose. Erratically pitched (their inscriptions suggest that they belonged originally to two or three distinct sets), they may have been added only as visual balance for the bells on the long arm.

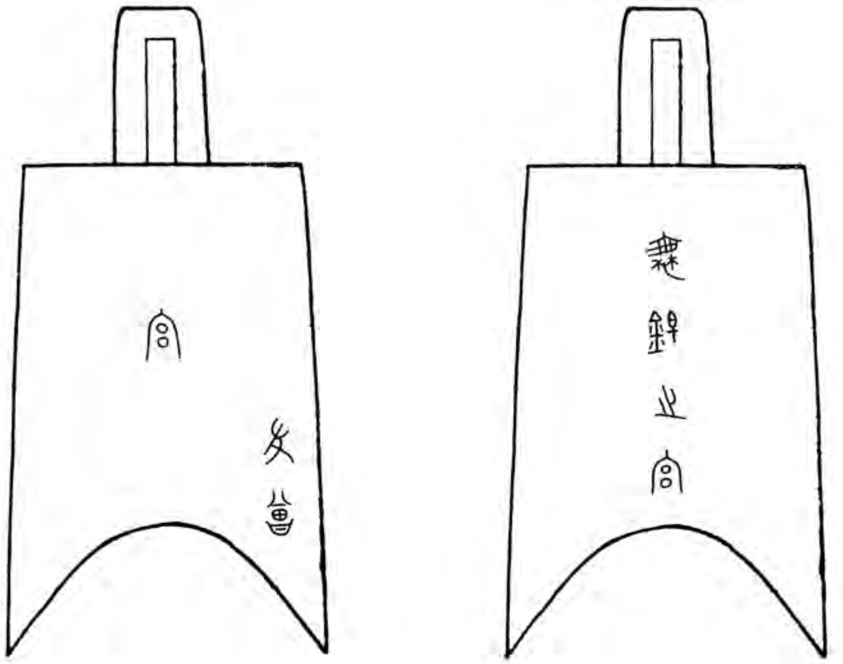

**Figure 23.** Front and back of the largest upper-tier bell (U3-7). *Left*: the front, with the strike-point labels *gong* and *zhizeng*. *Right*: the back, with the A-tone inscription '*do* of Wuyi'.

with the *gong* an octave higher. In the right column I have supplied some western equivalents to make it clear what the inscriptions are saying. The strike-point labels are using a solmisation system, a sort of *do re mi* nomenclature. Since our system *do re mi fa sol la ti do* is a set of names for the steps of the major scale—seven pitches of the octave—I have added some sharps to cover all twelve steps of the chromatic scale. Interestingly, the Chinese nomenclature has done something similar, but it is much more elegant than sharps and flats, and probably much less practical. In the Chinese nomenclature all the names are formed from four monosyllables and two suffixes.

The four monosyllables are shown in boldface in the leftmost column of Table 2. They are *gong*, *shang*, *zhi*, and *yu*, or in our terms *do*, *re*, *sol*, and *la*. The two suffixes are -*jue* and -*zeng*, and their function is to add major thirds: the suffix -*jue* adds one major third, the suffix -*zeng* adds two major thirds. In the right column of Table 2 we see that adding one major third to *gong* gives *gongjue*, adding two major thirds gives *gongzeng*. (Three major thirds would bring us to the next *gong*—three

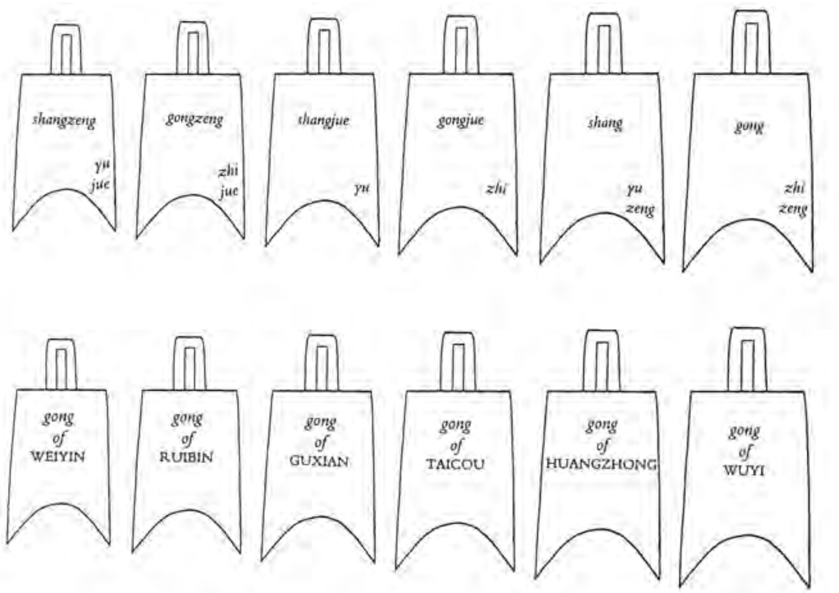


**Figure 24.** The six largest upper-tier bells, showing inscriptions on front and back. *Top row*: Fronts, with tone labels (solmisation terms) at the A- and B-tone strike points. *Bottom row*: Backs, with names of absolute pitches at the A-tone strike points. The strike-point labels on the fronts all assume Wuyi (=the A-tone of the largest bell) as reference pitch.

**Table 1.** Strike-point labels from the upper-tier bells, in order of measured pitch, with western names for equivalent pitches.

| | |
|---|---|
| [*gong*] | [*do* an octave above the first] |
| *zhijue* | *ti* |
| *shangzeng* | *la*-sharp |
| *yu* | *la* |
| *gongzeng* | *sol*-sharp |
| *zhi* | *sol* |
| *shangjue* | *fa*-sharp |
| *yuzeng* | *fa* |
| *gongjue* | *mi* |
| *zhizeng* | *re*-sharp |
| *shang* | *re* |
| *yujue* | *do*-sharp |
| *gong* | *do* |

major thirds are twelve semitones, an octave.) By adding major thirds to each of the four monosyllables, we obtain the complete chromatic scale. This neatly patterned nomenclature, known only from the Zeng inscriptions, describes the chromatic scale as a series of interlocked major thirds

**Table 2.** Strike-point labels (=solmisation terms for the chromatic scale), showing generation of the nomenclature from four monosyllables and two suffixes. To the monosyllables *gong*, *shang*, *zhi*, and *yu* (*do*, *re*, *sol*, and *la*) the suffix *-jue* adds one major third, the suffix *-zeng* adds two major thirds.

| | | |
|---|---|---|
| | *[gong]* | *[gong]* |
| | *zhijue* | |
| | *shangzeng* | |
| **yu** | *yu* | |
| | *gongzeng* | *gongzeng* |
| **zhi** | *zhi* | |
| | *shangjue* | |
| | *yuzeng* | |
| | *gongjue* | *gongjue* |
| | *zhizeng* | |
| **shang** | *shang* | |
| | *yujue* | |
| **gong** | *gong* | *gong* |

(here distributed over a series of interlocked *minor*-third bells). It is presumably not something performers needed, it is the invention of a theorist playing around with patterns of intervals.[19]

But what of the pentatonic scale? Everything about these bells is elegantly, ostentatiously chromatic, but when we looked at the chime stones, in their boxes and on their rack, it seemed clear that the scales that mattered to Zeng musicians were pentatonic. How does the pentatonic scale figure in these inscriptions?

It is embedded in the chromatic nomenclature, but not very obviously. Return for a moment to Table 1. In the right column of that table, I devised a nomenclature for the chromatic scale by taking the scale that really matters in our music and adding some suffixes. An archaeologist of the future could recover the scale that matters by dropping the suffixes. Might we do the same thing with the Zeng nomenclature? Not quite, but

[19] Zeng theorists also had a prefix *bian-* which flatted the note to which it was attached (for example, *bianzhi* is *sol*-flat). Probably more useful to performers than the *jue/zeng* nomenclature, this flatting prefix hints that a scale containing some semitone steps, perhaps one of the heptatonic scales we know from later Chinese music, was in use alongside the pentatonic (perhaps it originated as an ornamented version of the pentatonic; see Nettl 1956: 57). Unlike the *jue/zeng* nomenclature, the prefix *bian-* continued in use in later periods, in company with a sharping prefix that is not used in the Zeng inscriptions. (Lacking the sharping prefix, Zeng theorists could not name the note *mi*-sharp except by using the term *yuzeng* from the *jue/zeng* nomenclature.) However, *bian-* does not occur in the inscriptions considered here, those of the chime stones and the upper-tier bells, but only in certain subgroups of the middle- and lower-tier bells.

almost. If we drop the suffixes -*jue* and -*zeng*, we obtain not the pentatonic scale but only the four monosyllables in the left column of Table 2, the Zeng equivalents of our *do re sol la*; the third note of the scale, *mi*, is missing. What seems to have happened is this. The musicians did have five solmisation syllables for the pentatonic scale; they called the third note of the scale *jue*.[20] This was probably the original meaning of the word: it was the note a major third above *gong*. The theorist who invented the chromatic nomenclature simply turned it into a suffix that meant a major third above whatever it was attached to. The solmisation syllables for the pentatonic scale were (and still are) *gong shang jue zhi yu*. Some theorist converted *jue* to *gongjue* to create a pattern.

The inscriptions on the fronts of the bells have now given us solmisation terms for both the chromatic scale and the pentatonic scale. This is terminology for talking about scales and intervals; it is concerned with relative pitch. Zeng theorists also had names for absolute pitches. Those names are recorded on the backs of the bells, where only the A-tone strike points are inscribed (Fig. 23, right; Fig. 24, bottom row). If we think of the upper-tier bells as a set of tuning forks, the A-tones are the pitches of the tuning forks, and the names of those pitches are given on the backs of the bells.[21]

The back of the first bell says '*do* of Wuyi', the second says '*do* of Huangzhong', the third '*do* of Taicou', and so on. Wuyi, Huangzhong, and the rest are the names of the absolute pitches embodied in these A-tone tuning forks. In Table 3 the names are listed alongside the measured pitches obtained by striking the bells. These are the pitch standards of the state of Zeng.[22]

Notice that the standards do *not* constitute a musical scale. The A-tones of successive bells are two semitones apart, a whole tone apart, and Zeng composers were certainly not using a whole-tone scale. Zeng

[20] In the inscriptions of the middle- and lower-tier bells, the third note of the scale is often written not *gongjue* but *jue*.

[21] In calling these bells tuning forks I do not mean to suggest that they are better tuned than the middle- and lower-tier bells. (On the tuning of the various subsets see Lehr 1988.) In performance the only tuning that mattered was the tuning of the bells that were being played; the pitch standards on the upper tier were presumably put there for display, not for reference.

[22] For simplicity I discuss here only the six largest upper-tier bells. In fact the next three bells bear inscriptions of the same form naming three more pitch standards: Yingzi is an octave above Wuyi, Yingyin is an octave above Huangzhong, and Muyin is an octave above Taicou. The absolute pitches to which Zeng theorists gave names—always at two-semitone intervals—thus extend over an octave and a half. (The two-semitone spacing of the pitch standards is made explicit by the solmisation terms on the fronts of the bells, which effectively equate the standards with positions in the chromatic scale.)

**Table 3.** Pitch standards of the state of Zeng, from the A-tone inscriptions on the backs of the six largest upper-tier bells, with equivalent western absolute pitches measured at the A-tone strike points.

| | |
|---|---|
| WEIYIN | E |
| RUIBIN | D |
| GUXIAN | C |
| TAICOU | A# |
| HUANGZHONG | G# |
| WUYI | F# |

musicians seem to have thought of pitch standards as something distinct from notes of the scale: for them the octave contained twelve semitone steps but only six pitch standards.[23] Standards were not scale steps but choices of tonic. We will understand how the distinction could arise when we consider the origin of pitch standards, but first we should look at the chime-stone inscriptions, where we encounter a different set of standards.

The chime-stone inscriptions do not seem to have been written by a Zeng theorist. Instead of the Zeng pitch standards they use the standards of a neighbouring state, the state of Chu, and Chu theorists had twelve pitch standards spaced at semitone intervals (Table 4). Clearly some Chu music theorist took a whole-tone set of six like the Zeng set and used a flatting prefix to create another six.[24] Since the chime-stone inscriptions use the full set of twelve, we can imagine Chu theorists as operating with a set of twelve tuning forks spaced at semitone intervals, each labelled with one of the names in Table 4. Any tuning fork could be taken as the starting point for a pentatonic scale. The twelve standard pitches were the starting points for twelve pentatonic scales.

The inscriptions of the chime stones locate the stones in those scales. Each stone from the set of 41 participates in five pentatonic scales: it is *do*

[23] The fact that the pitch standards extend halfway into a higher octave (see the previous note) is another indication that they were thought of differently from scale steps: the standard an octave above Wuyi is not called Wuyi, it has a different and unrelated name.

[24] The prefix is *zhuo*- 'muddy'. (On a set of inscribed pitchpipes from a fourth-century Chu tomb at Jiangling Yutaishan, the standards that alternate with the muddy ones have the prefix *ding*- 'decided'; see Li Chunyi 1996: 377–81.) The fact that the flatting prefix for pitch standards differs from the flatting prefix *bian*- applied to solmisation syllables again points to a conceptual distinction between sets of standards and musical scales.

**Table 4.** Pitch standards of the state of Chu, with western equivalents obtained by measuring the pitches of middle-tier bells whose inscriptions mention Chu standards.

| | |
|---|---|
| *flat* GUXIAN | B |
| MUZHONG | A# |
| *flat* MUZHONG | A |
| SHOUZHONG | G# |
| *flat* SHOUZHONG | G |
| XINZHONG | F# |
| *flat* XINZHONG | F |
| WENWANG | E |
| *flat* WENWANG | D# |
| PINGHUANG | D |
| *flat* PINGHUANG | C# |
| GUXIAN | C |

in one scale, *re* in another, *mi* in a third, and so on. Stone number 24, for example, is pitched at G. It is therefore *do* in the pentatonic scale that starts on G, but it belongs to four other scales as well. If we wished to list all five of its roles, we could say that its pitch is '*do* in the G scale, *re* in the F scale, *mi* in the D# scale, *sol* in the C scale, and *la* in the A# scale'—and this is in fact what the inscription of stone 24 says, though of course it uses Chu names for the starting pitches.[25] Inscriptions of this form, beautifully carved and inlaid with red, appear on all the stones.[26] They were not for the player's benefit; like the gold-inlaid inscriptions on the bells, they were some sort of public statement.[27]

[25] Stone 24 is inscribed also with its sequence number and with two further phrases that specify where the pitch of the stone falls in the *chromatic* scales on B (*flat* Guxian) and F# (Xinzhong). For some reason, in addition to inscriptions locating it in five pentatonic scales, every stone in the set has inscriptions relating it to B and F#; moreover the inscription on B is given special prominence, appearing on the side of the stone rather than on the edge (the F# inscription appears on the under edge). These B and F# inscriptions are very puzzling.

[26] Because of damage to the stones, some of the inscriptions are incomplete or missing, but the pattern I have described seems clear. That is, it seems probable that every stone originally bore inscriptions relating it to five pentatonic scales and to the chromatic scales on *flat* Guxian and Xinzhong. The inscriptions on the upper edge of the stone relate it to unflatted standards; inscriptions mentioning flatted standards are on the under edge, along with the Xinzhong inscription. (Each stone belongs either to the scales of two flatted and three unflatted standards, or to the scales of three flatted and two unflatted standards.)

[27] When the stones were in the boxes, the inscriptions on their upper edges were visible (along with the sequence numbers written on the boxes next to the slots), and the player looking into the boxes could therefore have consulted them to identify the stones needed for an unflatted scale (see the previous note). But this can hardly have been the *raison d'être* of the inscriptions; assembling the stones for flatted and unflatted scales alike was perfectly straightforward using the sequence numbers (if stone 24 is a G, then so are stones 12 and 36). A finely carved catalogue of transpositions was addressed to a more important audience than the player.

Let me now summarise Zeng musical thinking as seen in these instruments and their inscriptions.

**1** First and most obviously, we see a clear emphasis on individual notes of definite pitch. These musicians think in terms of well-defined intervals and scales.

**2** Second, the scale that is musically most important to them is the pentatonic scale. They have a solmisation system for it that is still in use today, the syllables *gong shang jue zhi yu*.

**3** Third, they are much concerned with transposition. The inscriptions describe transpositions of the pentatonic scale.

**4** Fourth, the authors of these inscriptions attach great importance to absolute pitch. Not only do absolute pitches have names, they have different names in different states.[28]

**5** And finally, these theorists have a clear understanding of the chromatic scale. They have a solmisation system for it, and the bell and chimestone inscriptions effectively equate it with all possible transpositions of the pentatonic scale.

On this list the two things that are really unusual are the concern with absolute pitch and the chromatic scale. How might we account for them? By way of answer let me propose a hypothetical prehistory of music, a sort of scenario for the development of musical instruments and music theory. The crucial ingredient in my scenario, the ingredient missing elsewhere in the ancient world, is bells—tuned sets of bells used as musical instruments.

Bells in most times and places have been used for signalling, not for music. Compare the musical bells of Figure 12, from fifth-century China, with a typical fifth-century bell from outside China—typical in both size and function (Fig. 25). Cowbells, alarm bells, a bell that tolls the hours: these are signalling instruments. In Europe it is only in the last few centuries that bells have been turned to musical purposes. Towards the end of the Middle Ages tower bells began signalling the quarter hours with little melodic fragments, just as the bells in the tower at Westminster do today, and by the seventeenth century founders had learned to tune bells well enough to make carillons that could play full melodies. Yet bells remain

[28] The inscriptions of the middle- and lower-tier bells occasionally mention pitch-standard names that they identify as belonging to other states besides Zeng and Chu, but we do not have a complete list of standards for any state but these two. It is suggestive that Zeng has six standards per octave; Chu has a set of twelve obviously derived from a set of six; and the musical texts of later centuries list twelve independent names.

**Figure 25.** Bactrians bringing tribute to the Persian king. East Apadana stair, Palace of Darius and Xerxes, Persepolis, Iran. Early fifth century BC. Courtesy of the Oriental Institute, University of Chicago.

marginal to our musical culture for the simple reason that their lingering tones and dissonant partials make them not very musical. As a nineteenth-century Englishman put it, the true use of bells is for change-ringing; God gave man other instruments for music.[29]

In China too bells began as signalling instruments, but in China they were adopted into music very promptly, within a few centuries of their invention.[30] Since I want to ask how that might have happened, my hypothetical prehistory will start earlier, at a time long before bells existed.

Let me begin by imagining a distant prehistoric stage in which music is mostly sung, not played on instruments. Ethnomusicologists tell us that music does not have to use well-defined intervals—intervals like whole tones, thirds, fourths, and fifths—but that it very often does.[31] And since those intervals are central to the Chinese music of all the periods we know anything about, it seems reasonable to begin my scenario with a stage of sung melodies that contain well-defined intervals.

In the next stage instruments join the voices, instruments are drawn into an existing musical culture. At some point, a musician made a flute or (perhaps more likely, since the instrument is much simpler) a panpipe that could play the same melodies that were being sung. The musician who did that the first time was the first music theorist: to make an instrument that could play along with singers, he had to abstract a musical scale from an already existing melodic repertoire.[32] Melodies come first, scales are abstracted from them; scales lay out the intervals used in melodies.[33]

[29] Price (1983: 240, source not specified). Price's book gives a wonderfully informative history of bells in European culture.

[30] On the history of bells in China see Bagley (2000: 46–52). The earliest so far known, dating shortly before the middle of the second millennium BC, are tiny almond-shaped clapper bells—signalling bells—from the Erlitou site (Bagley 2000: 46 and fig. 2.14).

[31] See e.g. Nettl (1956: chap. 4, esp. pp. 53–4); Burns (1999: 217).

[32] In some primitive cultures vocal music is accompanied by instruments that are not in tune with it but in effect randomly pitched (Nettl 1956: 50, 58). If the first musical instruments were in the same way randomly pitched, then they antedate the stage that is of concern here. At some point in the history of music, an instrument-maker did make an instrument that could play the pitches being sung, and my concern is with that event.

[33] Abstracting a scale from a musical repertoire is something that ethnomusicologists do today. If in some remote corner of the earth the researcher can find aborigenes so isolated and deprived that they do not listen to western pop music, he tape-records their singing, returns home, listens to his tape over and over, and tries to extract a series of recurrent pitches from what he hears. If he finds that a certain collection of five pitches regularly constitutes the melodies, he will classify the music as pentatonic, though the aborigene composer of a new song may himself have no articulated concept of musical scale.

Unfortunately we do not know what scales were in use in China in the time before bells because instruments embodying them do not survive (or if they survive, like the Neolithic flutes of Figure 7, they do not give unambiguous pitch measurements). For the purposes of the present argument, however, the particular scale does not matter, so for convenience let me continue to speak of the pentatonic scale: let me suppose that the most important scale in the musical repertoire of the second millennium BC was pentatonic. Flutes and panpipes will have that scale built into them; zither players will tune to that scale; and the players may even give names to its five notes, thereby creating a solmisation system, a set of terms like *gong shang jue zhi yu*. Solmisation syllables could have originated very early, perhaps at the very moment when instrument-making theorists abstracted a scale from their music. They give musicians a vocabulary for talking about scales. If the zither player says the word *zhi*, he means the fourth string from the bottom.

Now at this stage the idea of absolute pitch is not very prominent in the musician's consciousness. Think about how instruments tune. Some instruments, like flutes, have a fixed tuning, but others, like zithers, must be tuned and retuned. How does the zither player tune? If he is playing solo, he can choose the pitch of one string at random and then tune the remaining strings by ear. If he is accompanying a singer, he will need to choose a starting pitch convenient to the singer. If he is accompanying a fixed-pitch instrument like a flute, he will need to take his tuning from the flute—but if the flute player ever accompanies singers, he will probably be equipped with several flutes differently pitched so that he can accommodate different singers. Transposing for the convenience of singers will be routine. At this stage absolute pitch is very much a matter of convenience, very flexible, very informal. That will change the moment a bell joins the ensemble.

Since most musical instruments are made of perishable materials, archaeology does not document the history of growing ensembles very well, but instrumental music must have been thriving by the time bells came onto the scene. Flutes, panpipes, drums, zithers, and singers are all plausible candidates for membership in the court ensemble of a great lord around 1300 BC. As we approach that time, it is reasonable to suppose that musicians have a repertoire of pentatonic tunes, ensembles of instruments that can play those tunes, and a solmisation vocabulary for talking about the pentatonic scale.[34]

[34] Let me reiterate that at this early stage the pentatonic is a convenient (and reasonable) assumption, not an established fact. It is entirely possible that the tetratonic bell sets made in

Then, somewhere in the Yangzi region, sometime around 1300 BC, a music master listening to a signalling bell said to himself 'that has a really nice tone' and decided to add it to his musical ensemble. Presumably this happened purely for acoustic reasons: the almond-shaped cross section—a feature that goes back to the earliest signalling bells—gave the bell a well-defined pitch, a pleasing tone, and fast attenuation. So the music master adopted a signalling device into a musical ensemble, and at that moment, that one bell became a musical instrument. To become a musical instrument, it did not have to be tuned; the other instruments tuned to the bell. If the flutes did not agree with the bell, new flutes were made; flutes are cheap. Musically speaking the bell could not do much, it could only reinforce the tonic with a sonorous bong now and then. But it was the prestige instrument, the glamorous, expensive one, so the ensemble took its pitch from the bell.

What happened next depended on the fact that music masters in the south had ample opportunity for close encounters with fine bells: for some signalling purpose we know nothing about, bells like the ones shown in Figure 26 were made in large numbers in the Yangzi region. That being so, the music masters and their patrons did not stop at one bell; intoxicated with that sound, they began hunting for more. They rummaged through existing bells—signalling bells—looking for a second one pitched at a nice interval away from the first: maybe a fifth away, maybe a major third. Any bell that happened to form a well-tuned interval with the first would be adopted into the ensemble immediately. A long time may have passed before any music master managed to assemble a complete pentatonic set, but he could punctuate his ensemble's music excitingly with just two or three.

The adoption of bells into musical ensembles had far-reaching consequences. First, of course, assembled sets were the ancestors of sets cast as sets. Casting tuned sets of bells is extremely difficult; bronze founders learned to do it by copying assembled sets. The Marquis of Zeng's bells would not exist if musicians had not begun assembling sets of bells a millennium earlier.

A second consequence was that bells became pitch standards. The moment a bell was added to the ensemble, it became the giver of pitch, it supplied the *do* that all the other instruments tuned to. When more bells

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the north in late Western Zhou times are the surviving trace of an earlier culture of tetratonic music.

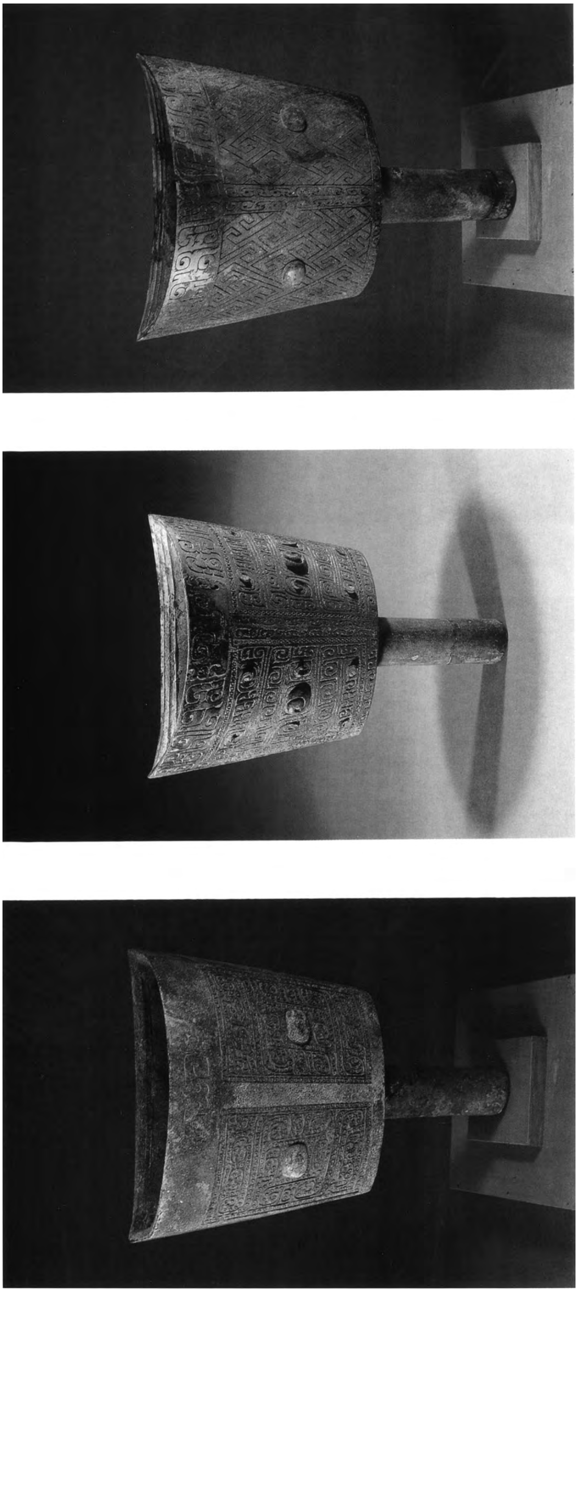

**Figure 26.** Three bells of the type *nao* from a tomb at Jiangxi Xin'gan Dayangzhou. Bells of this type were mounted stem downward, as shown here, and struck on the exterior. Heights (left to right) 41.5 cm, 43.5 cm, 45.3 cm. Thirteenth century BC. After *Xin'gan Shang dai da mu* (1997: colour pl. 21). Pitch measurements for these bells have not been published.

were added, the ensemble had more choices of *do*. Two or three bells gave the players two or three options for starting pitches.[35]

Not only did bells become pitch standards, they supplied names for pitch standards. Recall how easy it is for notable bells to acquire nicknames—think of Big Ben, or Great Paul in St Paul's Cathedral, or Great Tom at Oxford. If the bells in the ensemble have nicknames, then the musicians have names for their starting pitches. Three of the names listed in Table 4 end in the syllable *zhong*, which means 'bell'. In Table 3, Huangzhong means 'Yellow Bell', Wuyi probably means 'Tireless, Untiring'—not a bad name for a bell. Probably all the names on both lists originated as the nicknames of particular bells.[36]

Thus, when they became musical instruments, bells became pitch standards, bell names became names for absolute pitches, and one thing more: the instruments lent their extramusical associations to pitches. Bells were costly and imposing, they were objects of the highest prestige, and we know from inscriptions that some at least were made for use in important

[35] The subsequent history of bell music may have seen a sort of competition between punctuation and melodic use. At the stage when the ensemble included only one bell, the bell's function would have been to reinforce the tonic, i.e. punctuation. But when the ensemble included two or three bells spaced at musical intervals, the musician had two options. If he continued using only one bell in any given piece of music and thought of additional bells only as additional choices of tonic, then multiple bells were an incentive to transpose. But if he decided instead to use two or more bells in a single piece of music, then his music would need to stick to tonalities in which the pitches of those bells fell on scale, and transposition would be discouraged. (For example, a set of bells with pitches at *do mi sol la* supplies four starting pitches—four options for transposition—but only one scale in which the set can play complete tetratonic melodies. The fact that tetratonic sets typically repeat the four-note scale over three octaves argues that for the owners of those sets melodic use had priority; extended range was more important than transpositional flexibility.) As patrons became enamoured of bells as melodic instruments, therefore, a musical culture in the habit of transposing might have had to change its habits. But pressure in this direction might have come anyway from the growth of ensembles: as instruments of different characteristics were added to the ensemble, its ability to transpose probably tended to decline. Although the middle- and lower-tier bells of the Zeng assemblage do include three chromatic octaves, the pitches are distributed among the performers in such a way that probably only the pentatonic scales on C and F were very easily played; but the limitation may not have mattered, since most of the instruments that accompanied the bells were no more versatile. Performance needs in the marquis's time are perhaps seen more clearly, undistorted by his extramusical concerns, in the *Biao niuzhong* of *c.*404 BC, a set of fourteen small bells now divided between the Sumitomo Collection (Kyoto) and the Royal Ontario Museum (Toronto). The Biao bells supply three octaves of the seven-note scale *do re mi fa sol la ti do* (i.e. the western major scale, known also in later Chinese music). Besides heptatonic melodies in one tonality, this collection of pitches can play pentatonic melodies with three different choices of *do* (if the *do* of the set were C, it would contain pentatonic scales on C, F, and G).

[36] Falkenhausen (1992) argues persuasively that the Zeng names originated centuries earlier in the (non-musical) inscriptions of late Western Zhou bells.

rituals.[37] This made it easy for extramusical associations to attach themselves to bells and then to the absolute pitches the bells gave their names to. Later Chinese philosophising is much preoccupied with absolute pitch: the pitch of the Yellow Bell was an important natural constant, a property of nature, something like the speed of light. Music theory elsewhere in the world tends to concern itself with relative pitch; in other words, it is intervals and scales that acquire extramusical significance. The concern with absolute pitch is special to China. It arose in a culture of bell music.

Finally, the presence of three or four bells in the ensemble had, I believe, one further consequence. By providing fixed starting points for transposition, bells focused the musician's attention on the relationship between the transposed scale and the untransposed scale. In an ensemble whose players were in the habit of transposing the pentatonic scale to start on one bell or another of a tuned set, it would not have been a great leap to realise that dividing the octave into twelve semitones accommodates all possible transpositions. Depending on the spacing of the bells, three flutes tuned to three different bells might contain all twelve semitones. I can imagine a musician putting those twelve pitches on a zither and verifying for himself that each string in turn could be taken as the starting point for a pentatonic scale. I suspect that the chromatic scale was conceived by a clever music master thinking about transposition in an ensemble that had three or four bells.

This is a discovery that could have been made very promptly, it seems to me, once the music master had assembled a few bells at musical intervals. And as it happens, the earliest tuned set of bells currently known, an assembled set from the twelfth or eleventh century BC, provides clear evidence for the chromatic scale.[38] In 1993 ten bells were unearthed from

[37] Here I have in mind the inscriptions on ninth- and eighth-century (late Western Zhou) bell sets, which establish that their music accompanied rituals directed to the ancestors. We have no inscriptions bearing on the uses of earlier bells. In particular, we have no inscriptions on early bells from the Yangzi region, indeed no documents at all from the cultures that made and used them.

[38] Although at the moment these are the oldest bells known to be tuned to a musical scale, tuned sets probably go back a century or more earlier. The date is difficult to fix because tone measurements from early bells likely to have been used musically, e.g. those from Jiangxi shown in Figure 26, have not been published. (Since the bells from Jiangxi seem to be earlier than any yet found in Hunan, a promised volume of *Zhongguo yinyue wenwu daxi* devoted to Hunan province will only partly remedy the deficiency.) Until recently archaeologists did not bother to measure the pitches of unmatched bells found together because they assumed that bells not matched in decoration were not used for music; but of course it is the pitches, not the decoration, that make a set musical.

a pit in which they had been deposited at a place in the middle Yangzi region (Figs 27–8). As Figure 28 shows, the bells vary in decoration; they were not all cast at once, they were collected. But pitch measurements make it clear that the collecting was not random, these bells were brought together for musical reasons. Since they are two-tone bells, the ten bells supply twenty pitches; the twenty measurements are given in pitch order in Table 5.[39] They are given in cents (100 cents = one semitone), with middle C set to 0 cents. The lowest of the twenty pitches is the C# above middle C. Beginning with that C#, the list includes half an octave of the chromatic scale, six consecutive semitone steps (shown in boldface). Six consecutive semitones cannot be an accident; this is firm evidence for the chromatic scale in the twelfth or eleventh century. Two of the six tones, the D# and the F, are the A- and B-tones of a single bell (the one on the left in Fig. 28): the A-B interval of that bell is a perfectly tuned whole tone. In five more bells, one tone falls on scale and one does not.

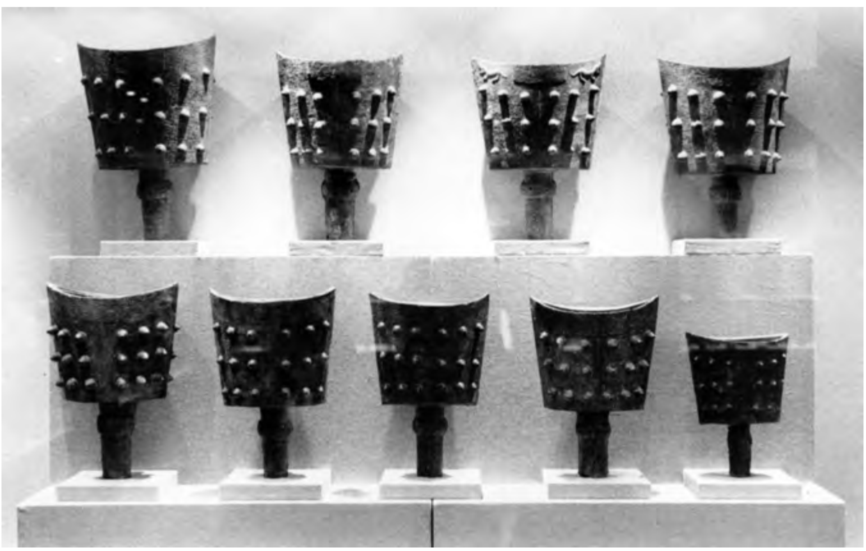

**Figure 27.** Nine bells (*nao*) from a deposit of ten at Hunan Ningxiang Laoliangcang (the tenth bell is the one on the left in Fig. 28). Heights from 36.5 to 53.5 cm. Twelfth or eleventh century BC. Author's photograph.

[39] The pitch measurements are reported in *Wenwu* 1997.12.26. Because it classifies the bells according to their decoration, the report has a cumbersome and confusing numbering for them. I have renumbered them in the order of their A-tone pitches.

**Figure 28.** Two bells (*nao*) from a deposit of ten at Hunan Ningxiang Laoliangcang. The bell on the left is number 3 in Table 5. The bell on the right is shown also in Fig. 27, top row, second from right. Heights 54 cm (left), 50 cm (right). Twelfth or eleventh century BC. After *Wenwu* 1997.12, colour pl. 2.1 (*left*), *Zhongguo wenwu jinghua 1997*, no. 48 (*right*).

Presumably each of the five was added to the set for the sake of the pitch that fitted, without regard to the other.

There remain four bells neither tone of which falls exactly on scale, though in most cases one tone or the other is not too far off. How might we explain these off-scale bells? What are they doing here? My student David Liu[40] suggests that we should be thinking about a music master who is assembling this set gradually, over a period of time. In his hunt for bells that supply desirable notes, he will every once in a while encounter a bell that improves on the tuning of a bell he already has. The A-tone of bell number 6 supplies a reasonably good F, 485 cents, but the B-tone of bell number 3, 500 cents, is much better; perhaps the ensemble was making do with number 6 until number 3 turned up. When the new bell arrived the old one was no longer needed, but bells like these are not lightly thrown away. Even if the musicians did not play all of them, the patron might want to keep them for the audience to look at: ten bells look twice as imposing as five, and the audience will not notice which ones are being

[40] In a seminar paper, Princeton University, May 2004.

**Table 5.** Measured A- and B-tones of ten bells unearthed in 1993 at Ningxiang in Hunan province. The bells, shown in Figs 27–8, date from the twelfth or eleventh century BC. Measurements are reported in cents (100 cents = one semitone), to an accuracy of ±5 cents, with middle C set at 0 cents. The right column identifies the bell and strike point that produce the given pitch; for example, 9B is the B-tone of bell number 9.

| Pitch (cents above C4) | | Bell and Strike Point |
|---|---|---|
| 830 | | 6B |
| 825 | | 10B |
| **800** | G# | 10A |
| 745 | | 7B |
| 730 | | 9B |
| 625 | | 8B |
| 610 | | 9A |
| **600** | F# | 8A |
| 555 | | 7A |
| 535 | | 5B |
| **500** | F | 3B |
| 485 | | 6A |
| **400** | E | 4B |
| 390 | | 5A |
| 310 | | 4A |
| **300** | D# | 3A |
| 235 | | 1B |
| **200** | D | 2B |
| 130 | | 2A |
| **100** | C# | 1A |

played and which ones are not.[41] On this interpretation, the ten bells represent a tuned set *in process of formation and improvement.*[42]

[41] Another explanation for the off-scale bells is possible. As Liu points out, the set contains a second series of pitches spaced at semitone intervals: 130, 235, 535, 625, 730, and 830 cents. Perhaps the music master was holding onto the bells that gave those pitches, as well as the ones pitched at 100, 200, 300, 400, 500, 600, and 800 cents, in order to improve his chances in his ongoing hunt for usable bells. If the next two bells he finds are pitched at 700 and 900 cents, they will fill out the latter scale. But suppose they are instead pitched at 330 and 430: then the first scale will be the better one. In other words, the music master is in the position of a poker player hoping that the next draw will fill out one or the other of two possible straights.

[42] The music master trying to assemble a set need not limit himself to hunting among existing bells; he might also cast and recast bells, at least while his patron's funds held out, in the hope of obtaining usable pitches. The fact that some of the bells in Figure 27 are matched in decoration would be explained if some were cast as additions to an already existing collection. No doubt it was by way of such experiments that founders learned to cast tuned sets. Whether founders at

Liu goes further and asks, what is the set good for? The pitches are clustered within less than an octave; the set supplies only four notes of the pentatonic scale, along with a good many other pitches that serve no obvious performance need. It is chromatic but incomplete. Why did the music master assemble it? Liu's answer is that if you are hunting for usable pitches among existing, randomly pitched bells, you take what you can get: if a minor third turns up, you take it, even if what you really wanted was a fifth.

And, he points out, this collecting of musical intervals suggests another possible path to the chromatic scale. Suppose the music master starts with one bell, finds a second bell pitched a major third above it, and then another bell pitched a minor third above it: the second and third bells are a semitone apart. A random adding and subtracting of musical intervals—random because the music master is hunting among randomly pitched bells—might well start a clever musician thinking about the chromatic scale. In the right setting, the chromatic scale is not a difficult idea.

In the history of European music, however, the chromatic scale is a late arrival. Fully chromatic keyboards did not appear until the late Middle Ages,[43] about seventeen centuries after the Marquis of Zeng's chime-stone set, and the scale with equal semitones, the one we use today, is something that musicians have embraced, or resigned themselves to, only in the last four centuries. European theorists took a different path to the chromatic scale, a mathematical detour. They thought of musical scales as arithmetical constructions, and this way of thinking made the twelve-note scale difficult to approach.

The observation that lies behind the arithmetic of musical scales, the discovery that small integers are mysteriously embedded in the workings of human auditory perception, can be illustrated using a Chinese zither from the time of Pythagoras, a century before the Marquis of Zeng (Fig. 29). This is a bridge-tuned instrument whose strings were almost certainly made of reeled silk, a fibre of highly uniform mass per unit length. For musicians using such instruments, simple numerical relationships between string lengths and musical intervals will have been easy to discover. Pluck

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this early stage were able to shift the pitches of a bell by filing the interior walls (difficult in the absence of tools harder than the bronze of the bells, and tricky in a two-tone bell) is unknown. Archaeologists, unused to thinking of early southern bells as musical instruments, have not looked for traces of filing.

[43] Meeùs (2001); Randel (2003) s.v. 'keyboard'.

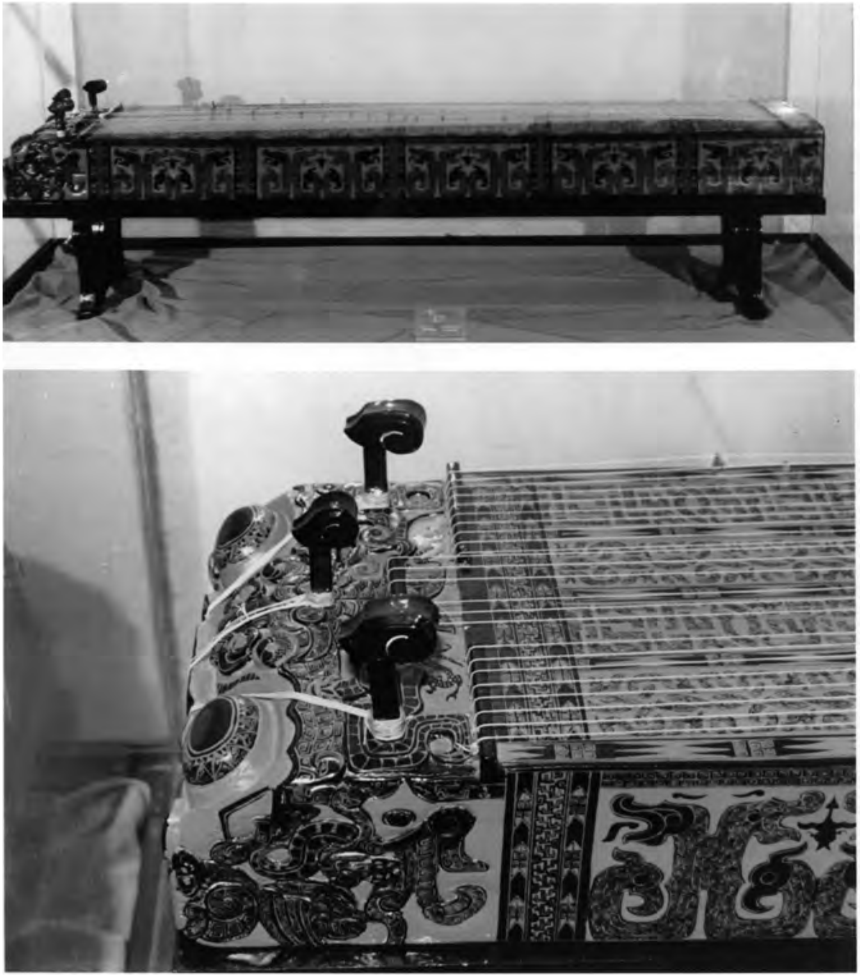

**Figure 29.** Twenty-six-string zither from Dangyang Caojiagang M5 (replica), with detail of left end. Length 210 cm, width 38 cm. Sixth century BC. After *Zhongguo yinyue wenwu daxi, Hubei juan* (1996: 128–9).

a string, then place a bridge at the midpoint and pluck to one side of the bridge; the second pitch will be an octave above the first. Put the bridge two-thirds of the way along the string; the pitch produced by two-thirds of the string will be a fifth above the pitch of the open string.[44] The player

[44] Strictly speaking, since introducing a bridge changes the tension in the string, the relationships just mentioned are not quite exact. However, if the player puts the bridge two-thirds of the way along the string and plucks on either side of it, the short part of the string will sound exactly an

who tunes by first bringing all the strings to the same pitch and then inserting bridges will position the bridges according to these ratios. Alert zither players will thus discover that pleasing musical intervals are given by strings whose lengths are in simple numerical ratios like 1:2 or 2:3 or 3:4. This is a discovery that we in the West associate with Pythagoras, sixth century BC, though it may have been known long before in Babylonia.[45]

Until these ratios were discovered, musical instruments were tuned by ear, the way a violinist tunes; musical scales were a strictly aural phenomenon. But once theorists understood that musical intervals can be represented by numerical ratios—ratios of string lengths—scales could be calculated arithmetically. Musicians of the Old Babylonian period may have made such calculations, Greek theorists certainly did, and so did Chinese theorists at least as early as the third century BC. Chinese texts dating from the third century explain how to calculate both the pentatonic scale and a chromatic set of pitch standards in terms of string-length ratios.[46]

What about the Marquis of Zeng's theorists in the fifth century? Did they know how to make such calculations? It is hard to imagine that they did not. Pythagorean ratios must have been at least as obvious on their stringed instruments as on any instrument available to Pythagoras. Yet nothing in the Zeng inscriptions betrays a knowledge of Pythagorean ratios; nothing in the tomb gives any hint that musical scales were mathematical objects. On the contrary, the inscriptions are catalogues of transpositions, and transposing is not an obvious preoccupation for musicians

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octave above the long part. Here only the uniformity of the string matters, not the tension, and uniform mass per unit length is achieved in reeled silk much more easily (indeed automatically) than in the gut strings of western instruments.

[45] Kilmer (2001); but cf. Crocker (1997), esp. p. 197. Beginning with Chavannes (1898), many western writers have taken it for granted that Pythagorean ratios (and hence, in their thinking, the chromatic scale) could not have been independently discovered in China but must have been transmitted from Greece or Babylonia to China; for a recent statement see McClain (1985). In Chavannes' day, when archaeology had not yet recovered early stringed instruments from China, the assumption was a little more reasonable than it is now.

[46] Cycle-of-fifths calculation of the pentatonic scale is first explained in a passage in *Guanzi* dating from the latter half of the third century (Rickett 1998: 259, 263); calculation of twelve pitch standards is explained at about the same time in *Lüshi chunqiu* (*c.*239 BC). (Note that Chinese musicologists, e.g. Chen Yingshi (1988–9), often assume a seventh-century date for the *Guanzi* passage, taking the text to date from the time of the statesman after whom it is named.) The names of the pitch standards calculated in *Lüshi chunqiu* (and mentioned a century earlier in *Guoyu* 'Zhouyu') are the names standard in later Chinese music theory, twelve independent ones rather than the six flatted and six unflatted names of the Chu set. The set of twelve independent names probably eliminated any need for solmisation terms for the chromatic scale. In later periods it was the basis for systems of notation (Kaufmann 1967).

who are calculating scales. If Zeng theorists did know the arithmetic of string lengths, their thinking was certainly not dominated by it. In the Marquis of Zeng's tomb it is not the stringed instruments that are inscribed with music theory.[47]

Let me propose a contrast between what I might call string cultures and bell cultures. In a musical culture where stringed instruments are dominant and music theory takes its start from Pythagorean ratios, theorists will become fascinated with the arithmetic of scales. Their extra-musical theorising will take the form of numerology; they will attach significance to intervals rather than to pitches because it is intervals, not pitches, that their simple numerical ratios so magically give. And the musicians of a string culture will take it for granted that the intervals that sound best are the ones that correspond to simple numerical ratios *exactly*—they will believe that the *most* beautiful fifth is the one produced by two strings with lengths *exactly* in the ratio 2:3—and they will try to build musical scales out of those so-called acoustically pure intervals. The scales so built will not have equal semitones; arithmetic does not allow it. The chromatic scale will not emerge automatically from transposing because transposed scales do not quite align. The effort to build scales from pure intervals diverts attention away from the idea that musical space can be mapped as an endless sequence of identical semitone steps.

[47] Most scholars who have written about the Zeng bells have taken it for granted that the Zeng inscriptions refer to, and the bell founder tuned to, arithmetically calculated scales. For example, McClain (1985) and several authors in Chen Cheng-yih (1994) go to great lengths trying to infer a method of calculation from the measured pitches or from the *jue/zeng* nomenclature (which they take to signify an emphasis on just thirds). But the bells are not well enough tuned to give the kind of information these authors wish for (see Lehr 1988), nor is there any reason to believe that a patterned nomenclature represents a method of calculation. No evidence supports the assumption from which these authors start. A few scholars go further and suppose that Zeng founders not only calculated their scales but also tempered the calculated tunings or supplied the bell players (but not the chime stone player!) with a choice of pitches for enharmonic notes. These writers seem unaware that in instruments with inharmonic partials, such subtleties of tuning, even if the bell founders had been able to achieve them, would serve little or no purpose. As Lindley (2001: 248) points out, 'Not all timbres . . . are equally conducive to temperament. In general, it is only when the component overtones of the timbre (together with the fundamental tone of the note) form a virtually pure harmonic series that consonant intervals will sound sufficiently different in quality from dissonant ones for the need for tempering the concords to arise. A pronounced degree of inharmonicity in the timbre, as in a set of chimes or a xylophone, eliminates the qualitative difference, except in the case of a unison or octave, between the sound of a pure concord and that of a slightly impure or tempered one.' See also Burns (1999). Though almond-shaped bells have more clearly focused pitches than circular bells, they do not have harmonic partials (Schneider and Stolz 1988). On the frequency spectra of the Zeng bells see Wang Yuzhu *et al.* (1988).

In Europe that sequence emerged only gradually in response to the demands of keyboard composers who wished to be able to transpose freely on fixed-pitch instruments. We call it the equal-*tempered* scale because it was arrived at historically by calculating scales in which the semitones were not equal and then tempering, adjusting. To us it is a regrettable compromise that sacrifices beautiful tuning in order to obtain freedom of transposition.[48]

But the instruments that mattered in ancient China were bells, not strings, and the theorists of a bell culture do not think in such terms. I am proposing instead that, in a culture focused on bells, and at a time when scales were a strictly aural phenomenon, the chromatic scale was discovered through transposition of the pentatonic scale. If in China the chromatic scale was not a difficult idea, surely the reason is that the theorists who discovered it were not doing string-length calculations that made transposition awkward. The chromatic scale as they conceived it would have been an equal-semitone scale because there was no reason for it to be anything else.[49]

However, soon after the Marquis of Zeng's time Chinese theorists became just as obsessed with arithmetic as their European counterparts, and the bell-centred musical culture I have been describing faded away: China joined the string cultures. Theorists applied Pythagorean arithmetic to the calculation of the chromatic scale and promptly ran into difficulties that kept them busy for the next two thousand years. As for their inheritance of ideas shaped by bells, they salvaged a little of it by grafting bells onto an origin myth for musical scales. According to the myth, pitches taken from the cries of the phoenix were copied in bamboo pitchpipes, the lengths of which formed simple numerical ratios, and the pitchpipes were then used to tune the fundamental pitch standard, the Yellow Bell. Using pitchpipes to tune bells does not make much sense, but it was a necessary rationalisation once Pythagorean arithmetic had come to be seen as the basis of music theory. And of course the phoenix was

[48] On European conceptions of the chromatic scale see Lindley (2001); also helpful is Randel (2003) s.vv. 'just intonation', 'mean-tone temperament', 'modulation', 'temperament'. The hold of Pythagorean numerology on the thinking of European theorists is illustrated by Lindley's remark that until Euclid's *Elements* appeared in Latin translation in 1482, 'the myth that a whole tone could not be divided into two equal parts was virtually unchallenged among scholars' (Lindley 2001: 260). Greek theorists, being better geometers, did at least consider the possibility of equal division of intervals (Bélis 2001).

[49] Accordingly it would be incorrect to call the scale 'equal-tempered', since it was not obtained by adjusting the intervals of some other scale. In a musical culture in which scales are not being calculated, temperament is an irrelevant notion.

needed to supply the absolute pitches that a bell culture demands but that Pythagorean ratios cannot provide.[50]

To summarise, it was bells that sent Chinese music theory in the direction it took. Bells made absolute pitch important, and bells took Chinese theorists straight to the chromatic scale. Many scholars seem to believe that the only path to the chromatic scale is the arithmetic of string lengths. I am proposing that there is another path, transposition; in fact I am suggesting that transposition leads *to* the chromatic scale, strings lead *away*.

One final remark. I have been using the Zeng instruments and inscriptions as evidence for *Chinese* music theory, I have been imagining a prehistory for *Chinese* music. Up to a point this is perfectly legitimate. Much that I have described from the state of Zeng was shared by other contemporary states, and much of it survived in later Chinese music and music theory. The instruments were not unique to Zeng, and the pentatonic scale, the chromatic scale, and the pentatonic solmisation terms *gong shang jue zhi yu* are features of Chinese music in all later periods. The Zeng names for absolute pitches also survived in later music theory (while the Chu names did not).

But some of what I have discussed is, on present evidence, confined to Zeng, or to Zeng and Chu. I have described two chromatic instruments; they are unique. So are their inscriptions and their nomenclature for the chromatic scale. We have thousands of bells from ancient China, but apart from the Marquis of Zeng's, not one has a musical inscription—not so much as a solmisation syllable at a strike point. Why do the Zeng inscriptions exist? Why did the marquis cover his bells with gold-inlaid inscriptions about transposing? This is like inlaying the keys of a piano with beautiful instructions for going from C-major to D-major. Clearly some extramusical statement is being made here, but we lack the key to decode it.[51] We do not know what was going on at the Zeng court. Marquis Yi was a patron of music and music theory like no other.

[50] On the calculation of scales in later Chinese music theory see Chen Yingshi (1988–9). As Chen explains, such calculations were driven not by the needs of musical performance but by astronomical and calendrical correlations, in somewhat the same way that musical numerology in Europe focused on extramusical associations (e.g. 'the music of the spheres'). Previously I supposed that the extramusical significance of the Zeng inscriptions might involve numerology of this kind (Bagley 2000: 61), but I would now see it as involving not Pythagorean ratios but absolute pitch.

[51] The middle- and lower-tier bell inscriptions, not discussed in the present paper, hint that the statement was in some way political. They are transposing inscriptions like those of the chime

*Note.* For helpful comments on drafts of this essay I am most grateful to Kofi Agawu, Peter Jeffery, David Liu, Katherine Rohrer, Kyle Steinke, Wang Haicheng, and Bell Yung.

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stones but with two complications: (1) many of them use a mixture of pitch standards, mentioning side by side the standards of Zeng, Chu, and other states; and (2) in the inscriptions on fourteen bells, the mention of a Zeng standard is followed by a parenthetical gloss equating it with standards belonging to other states (e.g. 'in the state of Jin, Guxian is called Liuyong'). What exactly the Marquis of Zeng meant by these announcements we do not know, but they would seem to involve the interstate political order and to connect it somehow with absolute pitch. As for the chime stone inscriptions, which make no mention of state names and on the surface are strictly musical in content, I have suggested above that their message might be 'pentatonic scales are selections from the chromatic scale'. But since I cannot guess why the marquis would wish to proclaim this message or what extramusical significance he might have attached to it, it is hard to be very confident that this is in fact what he meant to say.

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