(h) SOUND (ACOUSTICS)

(1) Introduction

The term acoustics may be defined either broadly to cover the nature of sound in general, as a branch of physics; or more narrowly to denote our knowledge of sound as applied to the properties of halls and buildings. It is here taken in the broad sense, and this Section will therefore aim at describing not only the positive achievements of the Chinese in this field,[a] but also their attitudes to acoustic phenomena in ancient and medieval times. The whole subject is one of particular interest from the point of view of the history of science because it was one of the earliest fields, both in East and West, where quantitative measurement was applied to natural phenomena.

While no one has essayed hitherto an evaluation of the development of Chinese ideas on acoustics as a science,[b] scholars who have written on Chinese music have naturally had to deal with the subject to some extent. The earliest authoritative exposition by a Westerner was that of the Jesuit father Jean Joseph-Marie Amiot (+1718 to +1793; Chhien Tê-Ming[1]) who did (1) for this field something of what Antoine Gaubil[c] did for astronomy. Two indispensable monographs on Chinese music are those of Courant (2) and Levis (1), works which largely superseded the older contributions.[d] More recently the brilliant syntheses of Picken (1, 2) have become available.[e] Particularly important is the translation by Chavannes[f] of the *Yo Chi*[2] (Record of Ritual Music and Dance),[g] a precious document of the late Chou period;[h] as also his study of the standard pitch-pipes.[i] In our opinion, Chao Yuan-Jen (2) was too modest in his estimate of the musical contributions of the Chinese; for he hardly did justice to their great sensitivity to timbre,[j] their achievement as a people who formulated the only theory of melodic composition in a tonal language,[k] and the

[a] On the relations between music and mathematics we may cite the stimulating lecture of Archibald (2). The book of Jeans (2) would be very useful for the reader of the following pages to have at hand.

[b] The unpublished work of Kuttner (2) may do something to fill this gap, and an important book by Wu Nan-Hsün is eagerly awaited.

[c] Cf. Vol. 3, pp. 182ff.

[d] Such as those of Faber (1); Wagener (1); van Aalst (1); Dechevrens (1); Soulié de Morant (1), etc. Levis's book is considered rather idiosyncratic by some scholars.

[e] See also the dictionary articles of Robinson (3); Eckardt (1, 2) and Crossley-Holland (1). Some widespread misconceptions about Chinese music are considered by Robinson (5). Cf. Daniélou (1).

[f] (1), vol. 3, pp. 238–86.

[g] Contained in *Li Chi*, ch. 19 (tr. Legge (7), vol. 2, pp. 92ff.), which constitutes a parallel text to that of Ssuma Chhien in *Shih Chi*, ch. 24. It will be remembered (Vol. 2, p. 4) that there once existed a *Yo Ching*[3] (Music Classic), but this was lost very early. Three of the Han apocryphal treatises (cf. Vol. 2, pp. 380, 382) connected with this work have been preserved (*YHSF*, ch. 54), but they have not yet been investigated from the point of view of the history of acoustics. Besides these, a large number of musical and acoustic fragments, from the Han onwards, exist in the collections of Ma Kuo-Han (*YHSF*, chs. 30, 31) and Yen Kho-Chün, offering a field of promise for further research. The term *yo* (music) of course included ritual miming in the Chou, Chhin and Han.

[h] Another book of the same title, attributed to Liu Hsiang, exists in fragmentary form in *YHSF*, ch. 30, pp. 68aff.

[i] (1), vol. 3, pp. 630ff. (Appendix 2).

[j] Van Gulik (1).

[k] Levis (1).

[1] 錢德明 [2] 樂記 [3] 樂經

great wealth of their characteristic and distinctive melodic fund.[a] On Chinese musical instruments there is a substantial Western literature,[b] to which we shall refer from time to time as occasion arises, and useful books by Li Shun-I (*1*) and others.

An adequate treatment of Chinese musical literature throughout the ages would go far beyond our frame of reference, yet it is rather difficult to separate the primarily acoustic works from those primarily musical. The tradition of the late Chou *Yo Chi* gradually blossomed forth into encyclopaedic studies which included basic musical theory, tables of mode-keys, etc.,[c] systematic descriptions of instruments, orchestral arrangements, dances and costumes. None of these has come down to us from a time earlier than the Sung, but we still possess (if in incomplete form) the admirable *Yo Shu*[1] (Treatise on Acoustics and Music) written by Chhen Yang[2] late in the +11th century.[d] A similar work has been preserved in Korea. The *Akhak Kwebŏm*[3] (Standard Patterns in Musicology) was compiled in +1493 by Sŏng Hyŏn at the command of King Sŏngjong[4] (*r.* +1470 to +1494), to preserve the studies of court music which had been made by an outstanding musician, Pak Yŏn[5] (*fl.* +1419 to +1450).[e] This work, afterwards many times reprinted, is succinctly written, excellently arranged, and well illustrated; in all essentials it is of the Chinese tradition, with suitable Korean additions and modifications.[f] Apart from such encyclopaedias there is a great mass of information about acoustics and music in the chapters on these subjects in the successive dynastic histories, sources which have been utilised best by Courant (2) of Western scholars. In addition, much is to be found in ordinary encyclopaedias, such as the *Chhu Hsüeh Chi*[6] of Hsü Chien[7] (*c.* +700), in ethnological works, e.g. the *Fêng Su Thung I*[8] (The Meanings of Popular Traditions and Customs) by Ying Shao[9] in +175, and in miscellaneous books on scientific subjects like Shen Kua's[10] *Mêng Chhi Pi Than*[11] (Dream Pool Essays) of +1086, so constantly referred to throughout the present work.[g]

Besides all this there are numerous important studies by individual scholars. In due course we shall refer[h] to a special monograph on drums, written by Nan Cho[12] in +848, the *Chieh Ku Lu*,[13] while in a somewhat later generation Tuan An-Chieh[14] wrote

[a] Picken (1, 2, 3). An important Chinese secondary source which was not available to us until our work was nearly finished is the book of Wang Kuang-Hsi (*1*).

[b] For a general survey in relation to the musical instruments of other cultures, the books of Sachs (1, 2) and Schaeffner (1) are to be consulted. A brief survey will be found in Montandon (1), pp. 695 ff. Extensive studies specific to China are those of Fernald (1), Mahillon (1), Norlind (1), and above all Moule (10). An excellent album of illustrations of Chinese musical instruments has been produced recently by the Central School of Music's Research Institute at Shanghai; see Chhien Chün-Thao (*1*). The instruments probably used in the Shang period (*c.* −14th century) have been discussed by Gibson (1).

[c] See pp. 162, 169, 215, 218 below.

[d] Cf. *Lü Lü Hsin Lun*, ch. 2, pp. 16 ff. Chhen Yang's book is not to be confused with another of the same title, written by Hsintu Fang (cf. p. 189) about +570.

[e] Though the chief editor spoke slightingly of them in the preface.

[f] Cf. Hazard *et al.* p. 143.

[g] Cf. Vol. 1, p. 135, and many subsequent mentions as indexed.

[h] P. 161 below.

1 樂書	2 陳暘	3 樂學軌範	4 成宗	5 朴堧
6 初學記	7 徐堅	8 風俗通義	9 應劭	10 沈括
11 夢溪筆談	12 南卓	13 羯鼓錄	14 段安節	

his *Yo Fu Tsa Lu*[1] (Miscellaneous Notes on the Bureau of Music) in the Wu Tai period (+10th century). This deals with musical instruments and their origins, songs, dances, and famous performers. But just as pharmaceutical science in China through the centuries waits for Li Shih-Chen, so also in acoustics and musicology it was the last decades of the +16th century which produced the greatest master of the subject, overshadowing all his predecessors—Chu Tsai-Yü.[2] Much will be said of him later on;[a] here we wish only to refer to the elaborate monographs which he prepared with mathematical precision and illustrated with some of the best line-drawings in any Chinese technical work. The earliest of these treatises, the *Lü Li Yung Thung*[3] (The Pitch-pipes and their Calendrical Concordances) appeared in +1581,[b] and three years later saw the conclusion of the *Lü Hsüeh Hsin Shuo*[4] (New Account of the Science of the Pitch-pipes). The 'Essential Meaning of the Standard Pitch-pipes' (*Lü Lü Ching I*[5]) was ready by +1596,[c] and the 'New Account of the Science of Calculation (in Acoustics and Music)', *Suan Hsüeh Hsin Shuo*,[6] by +1603.[d] As we shall see later, Chu Tsai-Yü was not influenced by the coming of the Jesuits though his own influence on Europe may have been very great; he represents the final climax of indigenous acoustic and musical theory. During the +18th century Chinese works have to stand comparison with what was going on in post-Renaissance Europe, but even so, the productions of a Chiang Yung,[7] whose *Lü Lü Hsin Lun*[8] appeared about +1740, or a Tai Chen,[9] who in +1746 devoted himself to an admirable archaeological reconstruction of the forms of ancient bells,[e] are still deserving of careful study today.

In acoustics, as in so many branches of science, the Chinese approach was rather different from the European. Where ancient Greece was analytic, ancient China was correlative. We might look vainly before the Thang for such questioning as that recorded by Plutarch[f] who enquires

> why the narrower of two pipes[g] of the same length should speak (sharper and the wider) flatter? Why, if you raise the pipe, all its notes will be sharp; and flat again if you stoop it! And why, when clapt to another, it will sound the flatter; and sharper again, when taken from it?...And why, when one would have set up a copper Alexander for a Frontispiece to a Stage at Pella, the Architect advis'd to the contrary, because it would spoil the Actors Voices?[h]

[a] Pp. 139, 220ff. below.

[b] This was later included in his *Li Shu*[10] (Calendrical Opus), together with an 'Imperial Longevity Permanent Calendar' (*Shêng Shou Wan Nien Li*[11]), which has already been referred to in Vol. 3, p. 71).

[c] This was really only the first part of his *Lü Shu*[12] (Pitch-pipe Opus).

[d] This work, together with the *Lü Lü Ching I* and the *Lü Hsüeh Hsin Shuo*, was combined c. +1620 to form the *Yo Lü Chhüan Shu*[13] (Collected Works on Music and the Pitch-pipes).

[e] This was embodied in his *Khao Kung Chi Thu*[14] (Illustrations for the *Artificers' Record* (of the *Chou Li*), with a critical archaeological analysis), to which a special paper has been devoted by Kondō Mitsuo (*1*).

[f] Wang Chhung's contemporary in the +1st century.

[g] Baxter translated 'flute' here, yet the *aulos* was not a flute, but a pipe with a double reed. Among the Greeks true flutes were, if not absent, surprisingly rare.

[h] *Works*, 1096 A, 'Pleasure not attainable according to Epicurus', tr. Baxter (1), vol. 2, pt. 4, p. 118, mod.

1 樂府雜錄 2 朱載堉 3 律曆融通 4 律學新說 5 律呂精義 6 算學新說 7 江永 8 律呂新論 9 戴震 10 曆書 11 聖壽萬年曆 12 律書 13 樂律全書 14 考工記圖

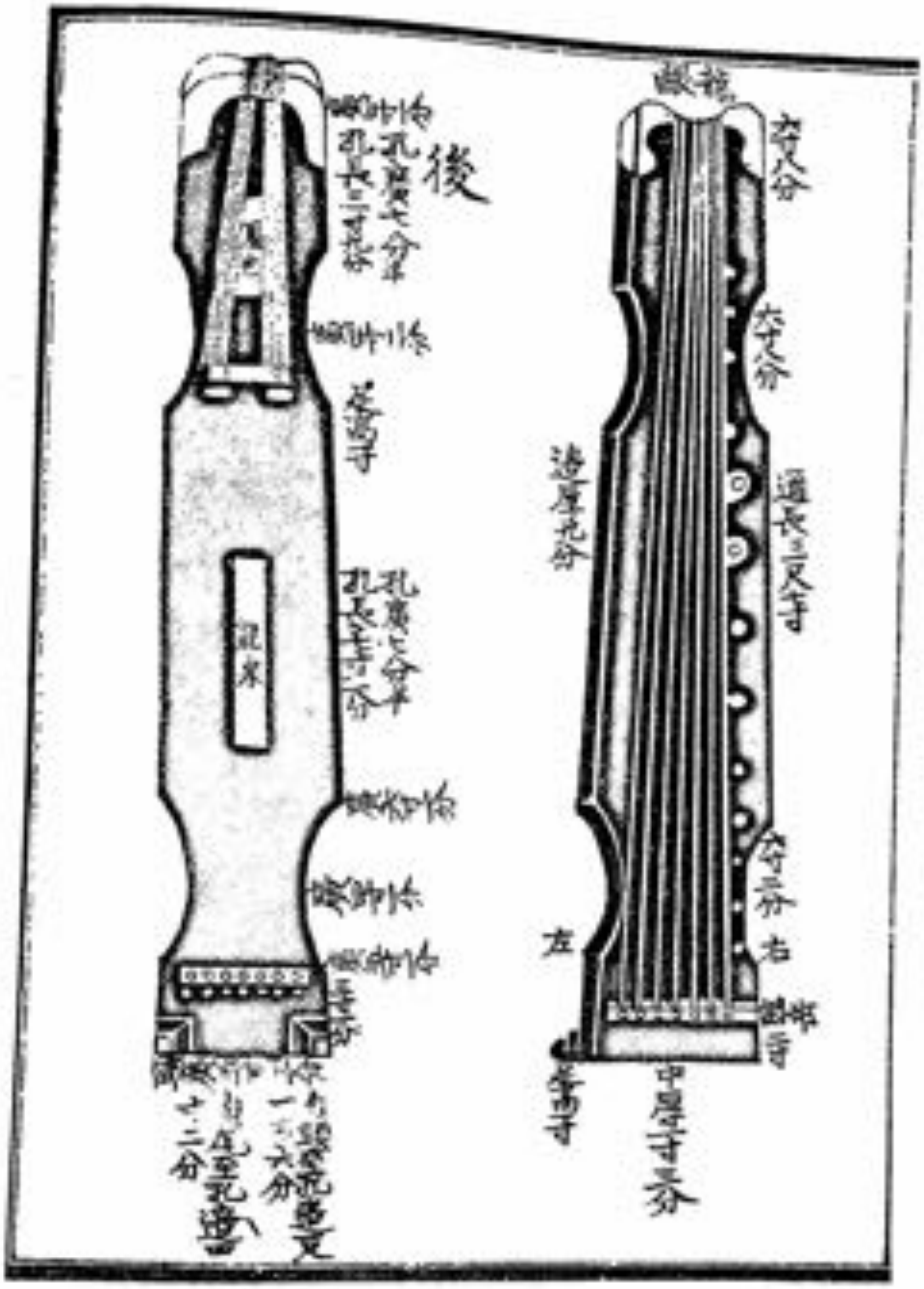

Fig. 297. The classical Chinese 'lute' (*ku chhin*), properly described as a seven-stringed half-tube zither. *Akhak Kwebŏm*, ch. 6, p. 21*b* (+1493).

Tung Chung-Shu, for example, in the −2nd century, when confronted by the much more striking phenomenon of sympathetic resonance, accepts it simply as being 'nothing miraculous', since it accords so well with the typically Chinese organic world-view.

> Try tuning musical instruments such as the *chhin*[1] or the *sê*.[2] The *kung* note or the *shang* note struck upon one lute[a] will be answered by the *kung* or the *shang* notes from other stringed instruments. They sound by themselves. This is nothing miraculous, but the Five Notes being in relation; they are what they are according to the Numbers (whereby the world is constructed).[b]

But in China we have to deal with two distinct currents, the literary tradition of the scholars, and the oral tradition of the craftsmen who were expert in acoustics and music. From what follows it will be seen that the latter must have done a great deal of experimentation, asking questions quite parallel to those asked by the Greeks—but the details were only rarely recorded.[c]

Tung Chung-Shu, indeed, was among the most scientific and philosophical minds of his age. In ancient and medieval times acoustic phenomena were often enough regarded as portents. Many strange sounds were recorded, but enquiry was concerned rather with what they could mean than with how they were caused. For example, it is noted that during the reign of the emperor Chhêng there occurred in −18 a case of a great rock emitting a noise like thunder.[d] The prognosticatory tradition was that such an event implied a disturbance of the element Metal,[e] due to unbridled love of war and conquest on the part of rulers. The people said simply that soldiers would come.

[a] Both the instruments named have commonly been considered lutes, but the term is literary and imprecise. The classical *chhin* is still in use today (Fig. 297)—an instrument of seven strings, correctly to be described as a half-tube zither (Sachs, 2), for it consists of a flat elongated board concave below and convex above, upon which are mounted the silk strings. A musician playing on a *chhin* may be seen on the back of a bronze mirror made in Tung Chung-Shu's own time (Bulling (8), pl. 31). The *sê* (Fig. 298) survives only in the form of a descendant called the *chêng*,[3] which has thirteen strings of brass wire but retains the integral board body. In true lutes the resonator box is distinct from the long or short neck upon which the strings are extended. Such instruments the Chinese had, but not during the seminal period of their acoustics on which much of our discussion will turn. All were variants of the celebrated *phi-pha*,[4] so often referred to in later poetry and literature. The history of this short lute has been carefully examined by Picken (6), who concludes that it was of non-Chinese provenance, introduced from some Central Asian people, probably Iranised Turco-Mongols, in the +2nd century. The most important of the earliest sources include Liu Hsi's[5] *Shih Ming*[6] (Explanation of Names) c. +200, and the *Phi-Pha Fu*[7] (Rhapsody on the Phi-Pha) by Fu Hsüan[8] (+217 to +278) in *CSHK* (Chin sect.), ch. 45, p. 6*a*. On musical interchange between East and West Asia see further Farmer (1, 2, 3).

[b] *Chhun Chhiu Fan Lu*, ch. 57, tr. auct., cf. Vol. 2, p. 281 above. Parallels in *Lü Shih Chhun Chhiu*, ch. 63, vol. 1, p. 122, tr. R. Wilhelm (3), p. 161; and *Chuang Tzu*, ch. 24, tr. Legge (5), vol. 2, p. 99; *Huai Nan Tzu*, ch. 11, p. 11*a*, cf. Wu Nan-Hsün (1), p. 167.

[c] One of the most stimulating comparisons of Greek with Chinese music and acoustics is that of Laloy (2). The work of Amiot and Chavannes in this context will be referred to below (p. 176) in connection with the 'Pythagorean controversy'.

[d] *Chhien Han Shu*, ch. 27A, p. 20*a*; *TSCC*, *Shu chêng tien*, ch. 158, p. 2*b*.

[e] Cf. Vol. 2, pp. 243ff. and Eberhard (6), p. 19.

[1] 琴 [2] 瑟 [3] 箏 [4] 琵琶 [5] 劉熙 [6] 釋名
[7] 琵琶賦 [8] 傅玄

Nevertheless, Chinese interest in sound, though it followed a different course from that of the Greeks, was by no means fruitless. Chinese invention enriched the world's civilisation in the sphere of acoustics and music no less than in other fields. The pages which follow will attempt to show first how the social life of the Chinese in pre-Han times brought them to focus attention on sound as a manifestation of Nature in equilibrium and disequilibrium. This entails a study of the concept of *chhi*,[1] subtle matter,

Fig. 298. The extinct 'great lute' (*sê*), a horizontal psaltery with twenty-five silk strings. *Hsiang Yin Shih Yo Phu*, ch. 1, p. 2*b*, in Chu Tsai-Yü's *Yo Lü Chhüan Shu* (+1620).

vital breath, or emanation. We shall then try to trace the advance towards acoustics as a science, with steadily improving systems of classifying sounds, and devices for measuring the pitch of musical notes. Finally, we shall describe some of the contributions which China has made to the world's understanding of sound, and of the nature of music.

(2) Correlation of Sound with Flavour and Colour

Few peoples ancient or modern have proved themselves more sensitive than the Chinese to the timbre of musical sounds. Van Gulik mentions[a] sixteen different 'touches' in playing on the silk strings of the classical 'lute' (*chhin*[2]) and lists yet

[a] (1), pp. 105, 125.

[1] 氣 [2] 琴

other manners of striking and pulling them. To take one example only, the vibrato termed *yin*:[1]

> A finger of the left hand moves quickly up and down over the spot indicated. 'A cold cicada bemoans the coming of autumn.' The plaintive, rocking drone of the cicadas should be imitated. Of this *yin* there exist more than ten varieties. There is the *chhang-yin*,[2] a drawn-out vibrato, which should recall 'the cry of a dove announcing rain'; the *hsi-yin*,[3] a thin vibrato, which should make one think of 'confidential whispering'; the *yu-yin*[4] or swinging vibrato, which should evoke the image of 'fallen blossoms floating down with the stream', etc. Remarkable is the *ting-yin*,[5] where the vacillating movement of the finger should be so subtle as to be hardly noticeable. Some handbooks say that one should not move the finger at all, but let the timbre be influenced by the pulsation of the blood in the fingertip, pressing the string down on the board a little more fully and heavily than usual.

Such a description suggests the infinite subtlety with which any given note could be played. Indeed, even today an expert *chhin* player will himself remain intently listening long after a note has become inaudible to other listeners. As Taoist thought put it:[a] 'The greatest music has the most tenuous notes (*ta yin hsi shêng*[6]).'

This was by no means an aestheticism without basis in physical fact. The ancient zither (*ku chhin*[7]) is the only musical instrument in any culture which has no frets and actually marks the nodes of vibration on the board. Recognition of individual harmonics, 'floating sounds' (*fan yin*[8]), using the same string, was already well advanced in the time of Hsi Khang[9] (+223 to +262). In Europe on the contrary this came very late, not before the +18th century. Indeed, the technique of playing the *chhin* mainly depends on exploiting the production of different timbres at the same pitch, and this was already developed to perfection by the later Sung (+12th century).

Nevertheless, the question remains, what did early Chinese thinkers believe sound to be? Their contemporaries in ancient Greece set themselves this question and tried to answer it. The Pythagoreans, for example, believed sound to be what Laloy describes[b] as 'la chose numérale par excellence'.[c] Theon of Smyrna,[d] about +150, attributes to Hippasus and Lasus (−5th century) the establishment of a relation between sound and speed, sound being something which is thrown so quickly that like a rapid discus it cannot be perceived in flight, but only on the instant of 'landing'. Archytas (*fl.* −370) went further and defined sound as speed itself.[e]

In ancient China, on the contrary, no parallel analysis and abstraction was made. Sound was regarded as but one form of an activity of which flavour and colour were others. The background for Chinese acoustic thinking was largely determined by a

[a] *Tao Tê Ching*, ch. 41.
[b] (1), p. 52.
[c] Cf. the remark of Leibniz, quoted by Archibald (2): 'Music is a hidden exercise in mathematics by minds unconscious of dealing with numbers.'
[d] *On the Uses of Mathematics for the understanding of Plato*, ch. 12 (ed. Bouilland, Paris, 1644). Cf. Freeman (1), pp. 86ff.
[e] Theon of Smyrna, ch. 13; Laloy (1), p. 64; Freeman (1), pp. 237ff.

[1] 吟 [2] 長吟 [3] 細吟 [4] 游吟 [5] 定吟 [6] 大音希聲
[7] 古琴 [8] 泛音 [9] 嵇康

concept which stemmed from the vapours of the cooking-pot, with its fragrant steam for which the word was *chhi*.[1] We have already had occasion to enlarge on the significance of this basic concept of Chinese pneumatism.[a] Karlgren gives for the word in Chou times the meanings 'vapour, air, breath, vital principle, temperament, to present food, to pray, beg or ask'.[b] It was clearly of wide connotation, and will be used in this Section (as in others) as a technical term for which there is no English equivalent. It moulded Chinese thinking from the earliest times, just as form and matter dominated European thought from the age of Aristotle onwards. For this reason one must have as good an understanding of its connotations as possible. Without this a European reader might consider the commentaries of many acute Han scholars writing on musical subjects as loaded with acoustic observations of a superstitious or nonsensical kind.

The common context, then, of the meanings of the word *chhi* given above is that of sacrifice to the ancestors. They are prayed in the *Shih Ching* to return and reinvigorate their descendants and their crops:

> Sonorous are the bells and drums. Brightly sound the stone-chimes and flutes.
> They bring down with them blessings—rich, rich the growth of grain!
> They bring down with them blessings—abundance, the abundance![c]

The ancestors are tempted to return to earth not only by the prayers of their descendants chanting liturgical phrases, but by the sounding of musical instruments and the delicious emanations which rise up from magnificent bronze cooking-vessels. When they arrive their eyes are also feasted with the sight of an assembly dressed in ceremonial clothing, furs and emblems all conforming to traditional themes of colour. From the earliest historical periods the Chinese were concerned with a synthesis of sound, colour and flavour, responding to the synthesis[d] of Nature manifested in thunder, rainbows and spicy herbs. One *chhi* rises up from the earth to heaven like steam from cooking-pots; another descends from heaven to earth, like ancestors spreading their reinvigorating influence. Their intermingling produces wind,[e] wherewith heaven makes music,[f] and brings into being not only rainbows which are heaven's colours, but the flowers of the changing year and with them the flavouring herbs in due season. All were signs and symbols of those great climatic processes on which the life of the ancient Chinese people depended, balancing ever between flood and drought.[g] Such was the environment which brought forth their organic philosophy.[h] A purely analytic treatment of sound would hardly have been consistent with it.

[a] E.g. Vol. 2, pp. 22, 41, 76, 150, 238, 275, 369; Vol. 3, pp. 217, 222, 411, 467, 480, 636. [b] K 517.
[c] *Shih Ching*, cf. Legge (8), pt. IV, i (1), no. 9; Mao, no. 274; tr. auct. adjuv. Karlgren (14), p. 243; Waley (1), p. 230. Perhaps −7th century.
[d] Almost an orchestration. Cf. p. 164 below.
[e] *Chhien Han Shu*, ch. 21 A, p. 4a: 'The *chhi* of heaven and earth unite and thereby produce wind.'
[f] *Chuang Tzu*, ch. 2: 'If Earth pipes, it is with all its apertures. If Man pipes, it is with the collected bamboos.' Cf. Vol. 2, p. 51.
[g] Cf. Vol. 1, pp. 87, 96, 114, 131, etc.; Vol. 3, p. 462ff., 472ff. Cf. Sect. 28 below.
[h] Cf. Vol. 2, pp. 51ff.; 281ff., 472ff.

[1] 氣

(3) The Concept of *Chhi* in relation to Acoustics

Chhi, then, had two main sources. It could go up from earth to the ancestors, and it could come down from heaven with the ancestors to earth. A third but very important source was in man himself, in his breath. With increasing sophistication *chhi* is thought of as something more rarefied than steam or breath. It becomes an emanation, a spirit, a *pneuma* (πνεῦμα). Naturally any attempt to trace the development of this idea must be rather hypothetical, but some form of hypothesis is necessary if Chinese acoustic thinking is to be understood.

In one of the early passages of the *Shu Ching*, which Karlgren[a] places not later than −600, there occurs the statement: 'Eighth: the several manifestations (*shu chêng*[1]). They are called rain, sunshine, heat, cold, wind, and their seasonableness.' With this may be compared a passage from the *Tso Chuan*[b] of perhaps some two centuries later: 'The six *chhi* are called Yin, Yang, wind, rain, darkness and brightness.' It is reasonable to suggest that the latter is a more sophisticated version of the idea contained in the former. The *Shu Ching* text would have a straightforward appeal to anyone engaged in farming, whereas the latter has the neat antithesis of the scholar. Its statement of the six *chhi* follows, by way of explanation, another: 'There are the six *chhi* of heaven. Their incorporation (*chiang*[2]) produces the five flavours; their blossoming (*fa*[3]) makes the five colours; they proclaim themselves (*chêng*[4]) in the five notes.'[b] The word *chhi*, then, is used sometimes in a general way for that form of emanation which goes up to and comes down from heaven, and sometimes for a particular form of its descent. Elsewhere in the *Tso Chuan*[c] it is stated that the *chhi* themselves make the five flavours. It is hard to know quite what is implied in 'descent', but the term 'six channels' (*liu thung*[5]) is sometimes used as a synonym for the six *chhi*.[d] Now this suggests a connection which is important for early Chinese acoustic theories, for if *chhi* is something which can be canalised or piped off,[e] the obvious instrument for the purpose would be a bamboo tube, such as is used in China for irrigation. Consequently, it is not surprising to find early references to the shaman-musician piping off his own *chhi* through bamboo tubes in an attempt to alter the

[a] (12), p. 33 (ch. 24, Hung Fan).

[b] Referring to −540; Duke Chao, 1st year (tr. auct. adjuv. Couvreur (1), vol. 3, p. 37).

[c] Duke Chao, 25th year (−516), tr. Couvreur (1), vol. 3, p. 380. 'The (six) *chhi* make the five flavours. (Their) manifestation makes the five colours. (Their sound) patterns (*chang*[6]) make the five notes.' The word *chang* means a pattern, signal, rule, to manifest, abundant. See K723, where the explanation of the graph is said to be uncertain. We suggest that the Shang bone character represents a flute or pipe with a drum. Compare this graph with K251 'a big flute', and K147*c* almost certainly a pellet-drum.

K723

K251*b*

K147*c*

[d] *Chuang Tzu*, ch. 33 (Thien Hsia); cf. Legge (5), vol. 2, p. 216.

[e] Ssuma Chêng in the +8th century, commenting on the *Shih Chi*, says indeed that a pitch-pipe is that by which one canalises *chhi* (*lü chê so i thung chhi*[7]).

1 庶徵 2 降 3 發 4 徵 5 六通 6 章
7 律者所以通氣

processes of Nature—of heaven's *chhi*—by sympathetic magic. Should we not see a rather late echo of this practice in the story of Tsou Yen[1] (−4th century) blowing on his pitch-pipes for the benefit of the crops?[a]

To call these magical tubes pitch-pipes, however, is probably an anticipation of subsequent developments, as will be made clear later. Probably 'humming tubes' would be more appropriate. They are referred to by various names, *lü*,[2] *thung*,[3,4] *kuan*,[5,6] and the other *lü*,[7] a term that is generally translated 'pitch-pipe', but the essential meaning of which is regular steps or regularity.

Here we should pause for a moment to realise the wider significance of the fact that Chinese acoustics (like other branches of physics) was from the first, if not analytical, highly pneumatic. Parallel lines of thought have already been described in meteorology[b] and in geology,[c] while later on we shall see how important the concept of *chhi* was in medicine.[d] Filliozat (1) has shown convincingly that Greek pneumatic medicine (e.g. in the Hippocratic *De Ventis*), of about the −5th century, derives from the same sources as that of the Indian *Suśruta Saṃhitā* and *Caraka Saṃhitā* (+ and −1st century).[e] Though the earliest extant expressions of these ideas in their simplest form occur in the Vedic literature, now regarded as contemporaneous with the late Shang period (−13th century), it seems overwhelmingly probable that their origin was Mesopotamian. From Babylonia they would have radiated to the south-east and north-east as well as to the west. Later in this Section[f] we shall find cause for thinking that China received from the Fertile Crescent certain information about sound much more precise than the stimulus to think about *chhi*[8] and *fêng*.[9] Moreover, as we saw above,[g] acoustic examples were frequently adduced by naturalist thinkers in ancient China to support their characteristic conception of a universal continuum and the reality of action at a distance by wave transmission therein. When we say, therefore, that the acoustics of the old Chinese philosophers was highly pneumatic, we must not forget that they thought of *chhi* as something between what we should call matter in a rarefied gaseous state on the one hand, and radiant energy on the other. Though all our assured knowledge gained by experiment makes us infinitely richer than they, is the concept of 'wavicles' in modern physical theory so much more penetrating? At any rate, the interconversion of matter and energy would hardly have been a surprise to them.

(i) *Conduits for* chhi; *the military diviner and his humming-tubes*

The fact that in Chou texts the number of the *chhi* should be six, and the number of the *lü* should also be six, is probably not a coincidence, and there is early authority for the belief that some tubes respond to a Yang *chhi* and others to a Yin, a different term

[a] We have already referred to this on p. 29 above. For the character of Tsou Yen see Vol. 2, pp. 232 ff. Cf. Dubs (5), p. 65.
[b] Vol. 3, pp. 467, 471, 479, 481, 491, etc.
[c] Vol. 3, pp. 637 ff.
[d] Section 44 below.
[e] Renou & Filliozat (1), vol. 2, pp. 147, 150.
[f] Pp. 177 ff. below.
[g] Pp. 29, 32.

1 鄒衍 2 呂 3 筒 4 筩 5 管 6 [illegible] 7 律 8 氣 9 風

being used to distinguish them. For example, in the *Chou Li* it is said:[a] 'The Grand Instructor (Ta Shih[1]) takes the Yin-tubes (*thung*[2]), and the Yang-tubes (*lü*[3]), listens to the army's note, and predicts good fortune or bad (*i thing chün shêng chao chi hsiung*[4]).'[b] In this passage the number is not specified, but in many instances they are referred to as the 'twelve pipes (*kuan*)', 'the six (Yang) *lü* and the six (Yin) *lü*', or sometimes quite simply as 'the six *lü*'.[c] Any enquiry into this subject is complicated by the fact that the literature spans many centuries during which musical evolution was rapid, and musical terms of necessity changed their meaning, as also by the fact that the number of tubes used was not necessarily the same at all periods. If a sketch of their evolution were to be attempted, one would postulate first an instrument of two tubes tied together, possibly one open and the other stopped, such as is suggested by the graph of the word *yung*[5] (K 1185*b*, *c*) (meaning—an instrument, to use); and its development in the word *yung*[6] (K 1185*h*, *i*) which means the loop of a bell, or (*tung*) a flute. This graph was further developed in the word *thung*[7] (K 1185*r*, *s*) meaning a channel or communication, previously referred to as a synonym for *chhi*; and in a later work (the −3rd-century *Han Fei Tzu*) by the addition of the bamboo radical to mean a tube (*thung*[8]).[d] All of these words belong to one common phonetic group.

K 1185*b*, *c* K 1185*i* K 1185*r*

For the next stage one would expect an increase in the number of tubes as the shaman himself develops nicer powers of discriminating between different sorts of *chhi*. In the *Tso Chuan* there is an instance where apparently four were used. The passage[e] describes how the officials of the State of Chin ask the Music-Master Khuang[9] about the outcome of a campaign if the troops of the southern State of Chhu besieging Chêng should march north. The Music-Master replies:

> There is no harm. I repeatedly hummed the northern 'wind'; I also hummed the southern 'wind'. The southern 'wind' was not vigorous. The sound signified great slaughter. (The State of) Chhu will inevitably fail to gain a victory.

Chêng Chung[10] (*fl.* +70), commenting on this passage, says that the northern 'wind' is Chia-chung[11] and Wu-yi,[12] the southern 'wind' Ku-hsien[13] and Nan-lü.[14] These are

[a] *Chou Li*, ch. 6, p. 14*a* (ch. 23); tr. Biot (1), vol. 2, p. 51.
[b] Cf. Vol. 2, p. 552, above.
[c] E.g. *Li Chi*, ch. 9 (Li Yün): 'The 12 tubes in turn act as fundamental (*Shih-erh kuan huan hsiang wei kung*[15])'; *Chhien Han Shu*, ch. 21A, p. 3*b*: 'The tubes are 12 in number; the Yang six compose the *lü* and the Yin six compose the (other) *lü* (*Lü yu shih-erh, Yang liu wei lü, Yin liu wei lü*[16])'; *Tso Chuan*, Duke Chao, 20th year (−521): 'The 5 notes, the 6 tubes..., etc. (*Wu shêng, liu lü*...[17]).'
[d] To this group of characters concerning tubes one could also add *sung*,[18] which means to croon or to sing to oneself.
[e] *Tso Chuan*, Duke Hsiang, 18th year (−554); Couvreur (1), vol. 2, p. 342.

1 大師 2 同 3 律 4 以聽軍聲詔吉凶 5 用 6 甬
7 通 8 筩 9 曠 10 鄭衆 11 夾鐘 12 無射
13 姑洗 14 南呂 15 十二管還相爲宮
16 律有十二陽六爲律陰六爲呂 17 五聲六律 18 誦

the names of four notes of the regular gamut of his day, which contained twelve notes in all.[a] In the first century of our era these twelve notes were divided into two groups of six, one group of which was regarded as Yang and the other as Yin. But by no 1st-century classification can the notes mentioned above be made to agree with this Yin and Yang division. According to the orthodox system described in the *Lü Shih Chhun Chhiu*, for example, Chia-chung is Yang and Wu-yi is Yin. In the *Chou Li* the opposite is the case. This fact, and also that four notes are named out of a possible twelve, suggests that Chêng Chung was drawing on some genuine tradition concerning the ancient art of divination by means of humming-tubes.

Before pursuing the idea of the evolution of simple pairs of humming-tubes into complex sets of detachable pan-pipes used for giving the pitch for a gamut of twelve notes, it will be worth while to examine more closely this remarkable passage from the *Tso Chuan* for its bearing on the concept of *chhi*. Since many of the terms are far from clear let us look at the passage in the original.[b] The two terms which cause most difficulty are *ho*[1] and *fêng*,[2] translated above as 'hum' and 'wind' respectively. In support of this we may quote the commentary of Fu Chhien[3] (+2nd century):[c]

> The southern pitch-pipe emanation (*Nan-lü chhi*[4]) did not come up (to its full strength). Therefore the note signified great slaughter.
>
> In speaking of the blowing of pitch-pipes, why do we say 'hum' and 'wind'? The note produced is the 'hum' (*Chhui lü erh yen ho yü fêng chê? Chhu shêng yüeh ho*[5]).
>
> Since the pitch-pipes are also the tubes (used for the practice of) 'observing the *chhi*' (see pp. 186 ff.), the emanation is called 'wind'. This is why we talk of the 'hum' and the 'wind'. (*I lü shih hou chhi chih kuan, chhi tsê fêng yeh. Ku yen ho fêng.*[6])

There can be little doubt that the Chinese of these early centuries believed they knew a way of divining the outcome of a battle by some peculiar process of blowing or humming through tubes.[d] There are other references to it besides those given above. For example, Ssuma Chhien quotes[e] a saying that

> on seeing the enemy from afar it is possible to know in advance what the outcome of a battle will be, for better or for worse. On hearing the sound it is possible to know whether there will be victory or defeat. Such is the method which has not varied under a hundred kings.

The use of hollow tubes, bones or branches as speaking trumpets for disguising or amplifying the voice of the shaman is widespread among primitive peoples.[f] That it

[a] Cf. below, p. 171.
[b] *Pu hai. Wu tsou ho pei fêng, yu ho nan fêng. Nan fêng pu ching. To ssu shêng. Chhu pi wu kung.*[7]
[c] *Chhun Chhiu Tso Chuan Chieh I*, in *YHSF*, ch. 34, p. 23*b*; tr. auct.
[d] See again Vol. 2, pp. 551 ff. The close connection between warfare and music is attested by the fact that the same character means both an army and a music-master (*shih*[8]).
[e] *Shih Chi*, ch. 25, p. 1*b*; tr. Chavannes (1), vol. 3, p. 294, eng. auct.; cf. Sachs (1), p. 25.
[f] Cf. Vol. 2, pp. 132 ff.

1 歌 2 風 3 服虔 4 南律氣
5 吹律而言歌與風者出聲曰歌 6 以律是候氣之管氣則風也故言歌風
7 不害吾驟歌北風又歌南風南風不競多死聲楚必無功 8 師

should occur in China is not remarkable. What is remarkable is that the Chinese should have attempted in this, as in so many other of their activities, to reduce the practice to a clearly regulated and classified system.

In a lost 'Book of War' (*Ping Shu*[1]) quoted by Chang Shou-Chieh[2] in his Thang commentary on this passage of the *Shih Chi*, five different states of morale are listed, all of which can be known by the skilful diviner. Every man has within his body his own *chhi*. The diviner uses his to set up a disturbance in the outside world when he blows through his humming-tube. One *chhi* will then 'by a kind of mysterious resonance'[a] react on another *chhi*, just as one musical instrument will touch off another which is in tune with it. In an army where many men are massed together there is a 'collective *chhi*' which floats above it, and which can be seen as a coloured cloud,[b] and heard as a note or sound. As the Thang scholar Ssuma Chên says in his commentary on the passage already cited:[c]

> Above every enemy in battle array there exists a vapour-colour (*chhi-sê*[3]). If the *chhi* is strong, the sound (note) is strong. If the note is strong, his host is unyielding. The pitch-pipe (or humming-tube) is (the instrument) by which one canalises (or communicates with) *chhi*, and thus may foreknow good or evil fortune.

There is a certain reasonable basis for this strange belief. If the divination were merely to discover the outcome of a battle it might not deserve much consideration. But, as can be seen from the passages quoted, it was primarily to discover the enemy's morale, and thus to deduce the chances of victory. This is a very different matter from the Roman practice of auguring victory by the observation of the flight of birds or the entrails of animals. In the days of close combat every commander was anxious to study his enemy for signs of morale. There is, for example, Thucydides' famous account of the defeat and death of Cleon, when his opponent Brasidas exclaimed: 'Those fellows will never stand before us, one can see that by the way their spears and heads are going.'[d] In the nervous tension which precedes a battle it would have been easy for the shaman to imagine the *chhi* which he believed to emanate from every individual in the opposing host to be gathering like a cloud above them; moreover, we ourselves are all in some measure able to judge the mood of persons we know well by the timbre of the human voice, a slight shrillness betraying anxiety, harshness, anger, and so on. If, then, as the ancient Chinese believed, sound is produced by *chhi*, and the *chhi* rising up from an army would have been considerable, how could the *chhi* from an army have failed to produce a sound? 'There is', as Ssuma Chhien concludes, 'nothing marvellous in this. It is quite natural.'[e]

It would be interesting to know what exactly was the method by which the different types of sound were distinguished. From the *Tso Chuan* passage it would seem to

[a] Cf. Vol. 2, p. 304.
[b] Cf. *Chin Shu*, ch. 12, pp. 9*b*ff., tr. Ho Ping-Yü (1).
[c] Tr. auct. Not in Po-na Pên ed.; *KHCP* ed., vol. 3 (p. 76).
[d] *History of the Peloponnesian War*, tr. Crawley, v, ch. 15.
[e] *Shih Chi*, ch. 25, p. 1*b*; cf. Chavannes (1), vol. 3, p. 294.

[1] 兵書 [2] 張守節 [3] 氣色

have been mainly a matter of whether the sound was vigorous or not. If it did not come up to full strength the notes indicated 'death'. 'Death' sounds implied that the army concerned had poor morale and would be defeated; vigorous sounds on the other hand implied success. If we knew exactly what these tubes were like it might be possible to have a clearer idea of what was meant by the term 'death' sounds.

In the *Li Chi* occur the words:[a]

> The five notes, the six fixed pitches and the twelve pipes take it in turn to act as fundamental (*wu shêng liu lü shih-erh kuan huan hsiang wei kung*[1]).

The word for pipe here is *kuan*.[2] So many different descriptions of it are given by various commentators that one is forced to the conclusion that it was frequently used merely as a generic term. But one scholar's opinion deserves particular attention, for though late—he was born in +1536—his understanding of ancient music was exceptional. This is Chu Tsai-Yü,[3] about whom more will be said in due course.[b] He gives it as his opinion[c] that *kuan* was the name for the *lü* when several were tied together, and that they were originally simple open notched pipes. Now notched pipes such as are pictured by Chu in his book, having a small semi-circle cut in the upper edge of one end of the tube, across which the player blows at right angles, are the earliest and most primitive of all such pipes.[d] If Chu is correct in his assumption that the early pitch-pipes were of this sort, one can begin to understand how a diviner could sometimes evoke 'death' notes, and sometimes notes which were 'vigorous'. For of all musical pipes those with a notch are the most difficult to play. As Chu says:[e]

> The thoughts must be serious, the mind peaceful, and the will resolute.... Open the lips and emit lightly a small (jet of) breath in blowing, causing the air to enter the tube continuously; then its correct note will be sounded.... For persons to blow the pitch-pipes, do not employ the old or the very young; their *chhi* is not the same as that of (persons who are) youthful and strong.

It is probable that in the tense moments before a battle, the shaman might from anxiety or excitement fail to emit the small jet of breath at exactly the right angle, or with the right degree of force, or with the constancy which was required, so that fluctuating, feeble or 'dead' notes would result. This then would have provided the basis for the divination, since the variation in the sounds, though arising from the state of morale of the shaman's own side, could well have been attributed, by means of the 'resonance' theory, to the *chhi* of the enemy. Pitch differences were not an essential part of the response.

[a] Ch. 9 (Li Yün), p. 61*b*; cf. Legge (7), vol. 1, p. 382.
[b] Cf. pp. 220ff. below.
[c] *Lü Lü Ching I*[4] (*Nei Phien*), ch. 8.
[d] Kunst (1), p. 57, after discussing this, mentions the Javanese *chalintu* as a modern example.
[e] *Lü Hsüeh Hsin Shuo*,[5] ch. 1, p. 19*a*; tr. auct.

[1] 五聲六律十二管還相爲宮 [2] 管 [3] 朱載堉 [4] 律呂精義
[5] 律學新說

Later a more detailed appraisal of the enemy's morale was attempted by a fivefold division of sound, the terms for which were *kung*,[1] *shang*,[2] *chio*,[3] *chih*[4] and *yü*.[5] These are the names of the five degrees of the pentatonic scale, if we give them the meaning which they have in works of the −4th century onwards. But clearly there was an earlier period when they did not have this meaning only, for if *kung* is translated as 'fundamental', the others being, for example, as in the standard first mode, major second, major third, perfect fifth, and major sixth; it is impossible to make sense of the statement in the *Kuo Yü*:[a]

> In the affair of Mu Yeh (the battle in which the old Shang kings were overthrown by King Wu of the Chou) the sounds all exalted the fundamental (*yin chieh shang kung*[6]).

For *kung* was not the name of a fixed note like our middle C, but any note could be *kung*, in the manner of our movable doh, as is clear from the above quotation from the *Li Chi*.

This is even clearer in the *Shih Chi* account, in which it is said:[b]

> When King Wu attacked Chou Hsin he blew the tubes and listened to the sounds. From the first month of spring (i.e. from the longest tube) to the last month of winter (i.e. the shortest tube) a *chhi* of bloody slaughter (was formed by their) joint action, and the ensuing sound gave prominence to (the distinctive quality of) the *kung* note.[c]

The fact that from Han times onward *kung*, *shang*, *chio*, *chih* and *yü* became the normal terms for the five notes of the scale, that is to say terms for distinguishing relations of pitch, helped to make these passages musically unintelligible; and the fact that Chavannes wrote off Chinese explanations of their own theories of *chhi* as 'pur pathos' denied subsequent writers the key to the problem. Yet it is sure that in divination these five terms are not concerned exclusively or even primarily with pitch, but rather with a certain quality of sound, or timbre. What that quality may have been is suggested by the words of Tung Chung-Shu in the work quoted at the beginning of this Section:[d]

> Violent winds in summer correspond with the note *chio*...crashing peals of thunder in autumn correspond with the note *shang*...autumn lightning flashes correspond with the note *chih*...cloudbursts of rain in spring and summer correspond with the note *yü*...rumbling thunder in autumn corresponds with the note *kung*.

The 'Book of War', previously mentioned, states[e] how these five qualities of sound may be interpreted.

[a] Cf. *Chou Yü*, ch. 3, p. 36*b*.
[b] Ch. 25, p. 1*b*; tr. Chavannes (1), vol. 3, p. 294, eng. auct.
[c] *Thui mêng-chhun i chih yü chi-tung, sha chhi hsiang ping erh yin shang kung.*[7]
[d] *Chhun Chhiu Fan Lu*, ch. 64; tr. auct. adjuv. Hughes (1), p. 308.
[e] It is in the commentary of *Shih Chi*, ch. 25, p. 1*b*; tr. auct.

[1] 宮 [2] 商 [3] 角 [4] 徵
[7] 推孟春以至于季冬殺氣相并而音尚宮 [5] 羽 [6] 音皆尚宮

The Great Instructor blows the tubes, uniting the sounds. If it is *shang* there will be victory in the fight; the soldiers of the army are strong. If it is *chio* the army is troubled; many vacillate, and lose their martial courage. If it is *kung* the army is in good accord; officers and men are of one mind. If it is *chih* there is restlessness and much irritation; the soldiers are tired. If it is *yü* the soldiers are soft, and little glory will be gained.

The diviner was apparently able to learn the morale of his own troops by blowing the pipes on the first day of the campaign, and of the enemy by blowing them before battle was joined. If then the emanation over Chou Hsin's army was held to emit the qualities of a *kung* note, showing that both armies were in good heart, that version of Chinese history which, in opposition to Mencius,[a] maintained that the Shang dynasty was overthrown only after bloody slaughter would seem more likely to be correct.

We are forced then to conclude that, as a development of the pseudo-science of divination, *kung*, *shang*, *chio*, *chih*, and *yü* were at one time names connoting qualities describing the volume or timbre of certain sounds. This enquiry conveniently introduces the subject of timbre in early Chinese thought and practice.

(4) Classifications of Sound by Timbre

The preceding paragraphs have attempted to show how early Chinese ideas of the nature of sound were based upon the concept of *chhi*. In fact it persisted until recent times, and was abandoned in scholarly circles only under the influence of physical theories of wavelength during the modern period. We shall now see how the Chinese advanced from an early stage in which they were concerned with a general quality of sound, boding good or ill, to an exact appreciation of how one sound may differ from another in timbre, volume and pitch. In doing so we shall see how the classification of sounds gradually became standardised, while sounds themselves were correlated with other phenomena. Today we regard timbre as that which distinguishes one note from another not by volume or pitch but by complex blends of overtones. The ancient Chinese music-masters would not have expressed themselves in this way, for the different elements which make up a sound were probably not thought of in isolation, but timbre was very important for them. Indeed the Chou classification of musical sound heralded that sensitivity to tone which was mentioned in the introduction to this Section. Since many European writers on Chinese music have been inclined to an opposing belief, it is interesting to find Juan Gonzales de Mendoza quoting the testimony of the Austin friars[b] that the Chinese 'do tune their voyces unto their instruments with great admiration'.[c] It may be that +16th-century Europeans, whose ears had not yet become accustomed to the rigid tuning of modern equal temperament, were more tolerant of other systems.

[a] *Mêng Tzu*, III, 2, v (5); tr. Legge (3), p. 149.
[b] See p. 215 below.
[c] Parke tr. p. 140.

(i) *Material sources of sound*

The phrase by which the Chinese designate the orthodox grouping of instruments is *pa yin*[1] or 'the eight (sources of) sound'. This is a convenient shorthand term for the eight different kinds of material which featured most prominently in the construction of the different types of instrument. One of the earliest texts in which they are catalogued is the *Chou Li*, where they are listed[a] as metal, stone, earth (or clay), skin, silk (threads), wood, gourd, and bamboo.[b] Instruments in which the sound-producing agents are so varied produce a variety of timbres. The Graeco-Roman classification into three genera, wind-instruments (*pneumatikon*, πνευματικόν), stringed instruments (*enchordon*, ἔγχορδον), and percussion instruments (*kroustikon*, κρουστικόν), was perhaps more scientific, and gave place only in modern times to the fivefold classification[c] of idiophones, membranophones, chordophones, aerophones, and electrophones.

The great variety of timbre in Chinese music in general, and in the instruments of the Confucian temple orchestras in particular, has often been emphasised.[d] Balinese *gamelan*[e] and Dayak long-house gong ensembles in Sarawak[f] preserve something of the spirit of the early Confucian orchestras,[g] while the court music of the Thang still lives in Japan.[h] This unaccustomed richness in variety of timbre was somewhat baffling to the first Europeans of modern times who experienced it, as may be seen, for instance, in the report of Matteo Ricci after attending a rehearsal at the Nanking *wên-miao*[2] (Confucian temple) in +1599.[i] Yet the most characteristic acoustic features of the music of the Chinese culture-area (extending as it does from Korea to Indonesia)[j] may be defined as twofold: the high proportion and multiplicity of chime-idiophones on the one hand, and the prominence of the bamboo plant (and the pitch-pipes derived from it) on the other.

It is clear that the eightfold Chinese classification of sounds was only arrived at gradually. In the *Yo Chi* (Record of Ritual Music and Dance), a book certainly com-

[a] Ch. 6, p. 12*a* (ch. 23), tr. Biot (1), vol. 2, p. 50.

[b] Probably the oldest extant classification of musical instruments in any civilisation, says Schaeffner (1), p. 124.

[c] Mahillon (1); Galpin (1), p. 25; Montandon (1), pp. 695ff.; Schaeffner (1), pp. 143ff., 179ff.

[d] E.g. by Picken (3).

[e] McPhee (1, 2); Picken (2), pp. 170ff.

[f] Private communication from K.R. (1957).

[g] Representations of orchestras from the Warring States period have come down to us, notably on bronze vessels such as the bowl from Huihsien (Fig. 299) preserved in the Archaeological Institute of Academia Sinica (cf. Yang Tsung-Jung (*1*), pl. 19), and the magnificent vase of the −4th or −3rd century known as the Yen-Yo Yü-Lieh Thu Hu[3] (Fig. 300) which may be seen in the Imperial Palace Museum at Peking (cf. Yang Tsung-Jung (1), pl. 20). Of Han representations one of the best is that in the I-nan tomb reliefs (Fig. 301); cf. Anon. (7), figs. 27*b*, *c*; Tsêng Chao-Yü *et al.* (*1*), pl. 48.

[h] Harich-Schneider (1); Picken (2), pp. 144ff.

[i] Trigault, tr. Gallagher, pp. 335ff.; d'Elia (2), vol. 2, pp. 70ff. Cf. Vol. 2, pp. 31ff.

[j] This is not only, or mainly, because of influences radiating from China in relatively late times, but rather because common cultural elements helped to shape Chinese music in the Chou period. Cf. Picken (2), pp. 180ff.; and Vol. 1, p. 89, above.

1 八音 2 文廟 3 燕樂漁獵圖壺

Fig. 299. An orchestra of the Warring States period (*c.* –4th century): the Huihsien bronze bowl (Anon. (*4*); Yang Tsung-Jung (*1*), etc.). Musicians beating upon suspended L-shaped chime-stones can be seen at the top; on the left, beyond the picture of a building, others are striking a row of suspended bells.

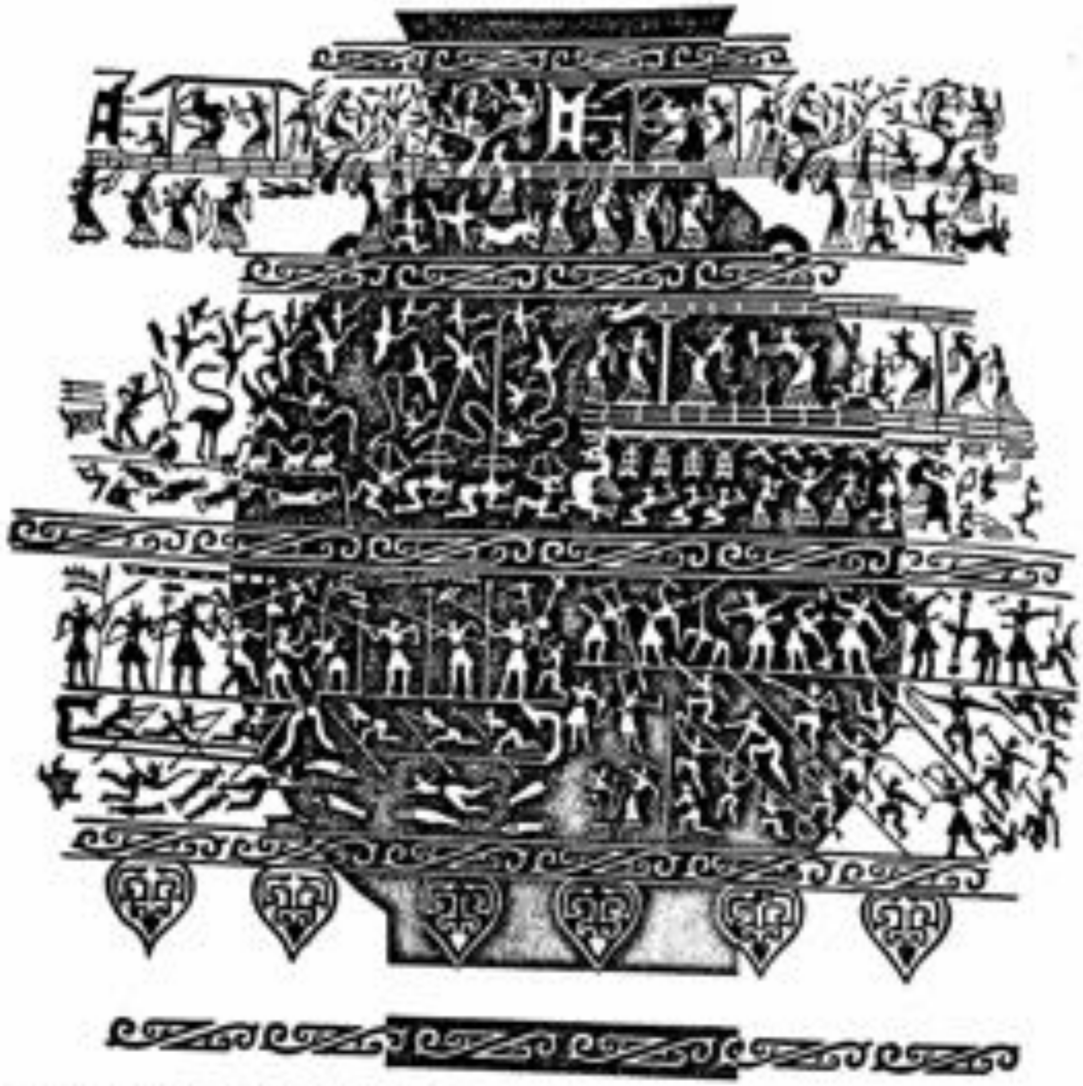

Fig. 300. An orchestra of the Warring States period (*c.* −4th century): the Yen-Yo Yü-Lieh Thu Hu bronze vase preserved in the Imperial Palace Museum, Peking. In the fourth row from the top, on the right, there are three ringers of bells, one musician in charge of the row of suspended chime-stones, one drummer with stand-drums and one person playing on a wind-instrument. The frame for the instruments is upheld by two large carved birds, and immediately to the right of it a kneeling figure appears to be playing the 'tiger-box' (see p. 150). The two turtles and the small bird seem to have strayed in from the scene of fishing and fowling on the extreme left of the same row, but the deer-like animal appears to be responding to the orchestra, like the dancing-girl with long sleeves caught in airy leap above the 'tiger-box' player. From Yang Tsung-Jung (*1*).

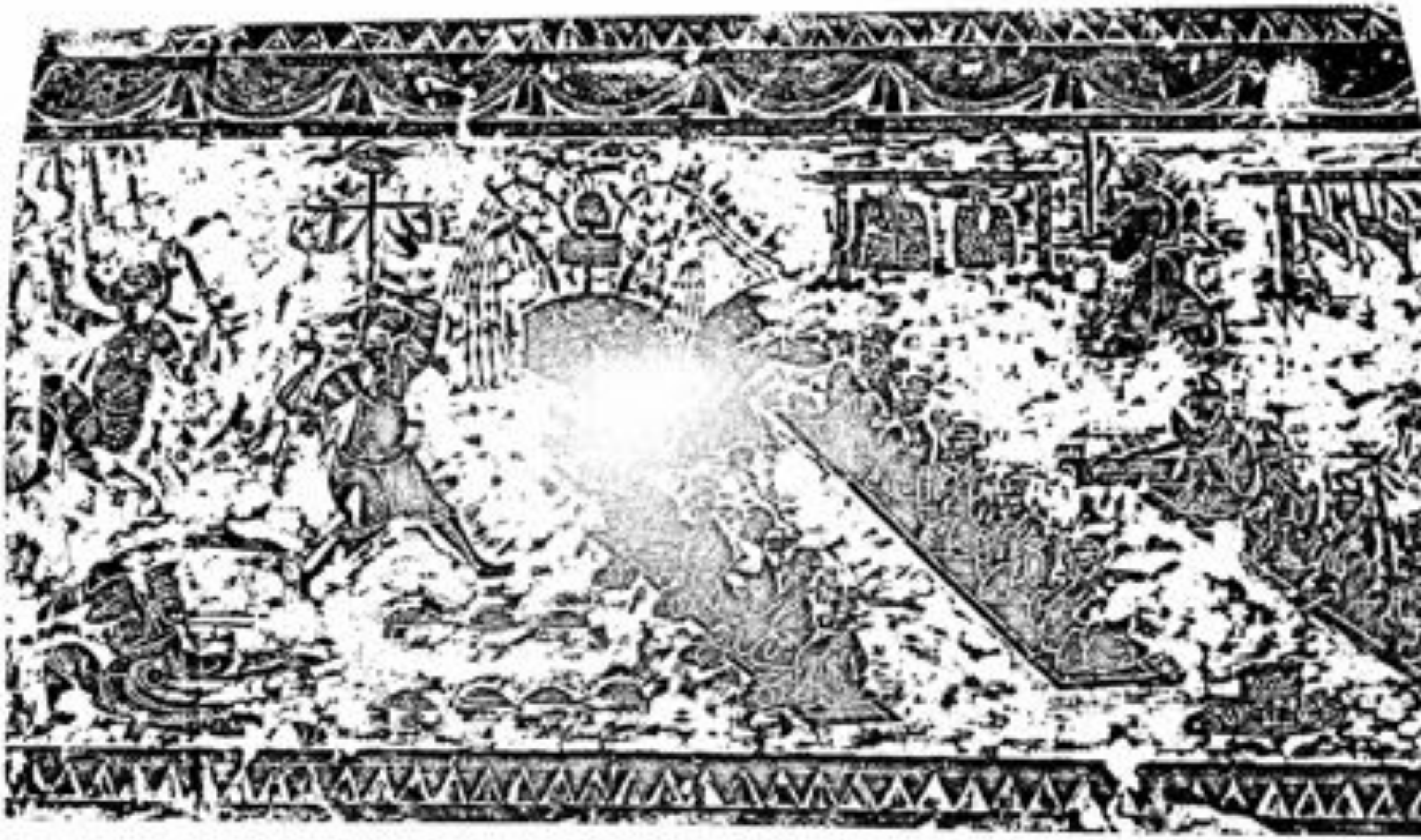

Fig. 301. *An orchestra of the Han period depicted in the reliefs of the I-nan tombs, Shantung, c.* +193 (from Tsêng Chao-Yü *et al.*, 1). In the background, stand-drums, bells and ringing-stones; in the front row, hand-drums; in the second row, pan-pipes; and in the third row, zither, ocarina and hand-organ with reeds. On the left, jugglers and acrobats.

piled from Chou sources, the following eight instruments of 'music' are listed:[a] bells, drums, pipes, flutes, ringing-stones,[b] feather (wands or dresses), shields, and axes. Only four 'sources of sound' occur here, namely metal, skin, bamboo, and stone (Fig. 302). In another passage in the same text it is said:[c]

> As the *Shih Ching* says: 'Guiding the people is very easy.' That is why the sages established the pellet-drum (*thao*[1,2]) and the stand-drum (*ku*[3]), the instrument which starts the miming (*chhiang*[4]) and the instrument which stops it (*chieh*[5]), the globular flute (*hsüan*[6]) and the flute (*chhih*[7]).[d] These six (instruments) gave the notes of numinous music charged with morality (*tê yin chih yin*[8]). After that (they established) bells (*chung*[9]), ringing-stones (*chhing*[10]), the blown pipe (*yü*[11])[e] and the (silk-stringed) zither (*sê*[12]) to go with them.

Elsewhere in the *Yo Chi* it is more specifically stated[f] that the instruments of music are the four sources of sound—metal, stone, silk and bamboo (*chin, shih, ssu, chu, yo chih chhi yeh*[13]).[g] From this and also other references it seems clear that there was a period from which many early texts derive, in which the 'eight sources of sound' were not yet classified and settled. This is reinforced by the fact that the *Tso Chuan* has only a single reference (−717) to the 'eight sources of sound'.[h] The passage states that 'dancing is that by which one regulates the eight sources of sound, and thereby conducts the eight winds (*wu so i chieh pa yin, erh hsing pa fêng*[14])'. References to the

[a] Para. 2, in *Shih Chi*, ch. 24, p. 11*b*; cf. Chavannes (1), vol. 3, p. 248.

[b] The sounds produced by striking flat L-shaped chime-stones of various sizes were among the most characteristic features of the orchestras of ancient China (Figs. 304, 305). We had occasion to mention them before in connection with centres of gravity (p. 34 above). For the conclusions of modern scholars on the geometry of their shaping, see Wu Nan-Hsün (*1*), pp. 127ff., Chhen Wên-Thao (*1*), pp. 67ff. Kuttner (1) believes that they originated from the flat annular stone symbols called *pi*[15] of which we had to say so much in Vol. 3, pp. 334ff., supposing that the *pi* itself was first struck to make music and that the 'dissection' of its annulus into fragments came about by removal of pieces in a tuning process.

[c] Para. 8, in *Shih Chi*, ch. 24, p. 32*a*, *b*; tr. Chavannes (1), vol. 3, p. 276, eng. et mod. auct. See Figs. 302 and 303.

[d] The *chhih* was a transverse pipe blown by a centrally placed hole, with finger holes on each side.

[e] The *yü* is generally considered a large 36-pipe form of the mouth reed-organ or *shêng*. But there was also the vertical pipe (*ti*[16]) with six holes and a back-stop. In the collection of my friend Mr R. Alley I have seen a bronze *ti* of the Warring States period, originally gilded, in which the holes are all situated at the lowest parts of as many regular annular constrictions, the diameter of the pipe swelling between them. The blown end or mouthpiece is shaped in dragon-head form, and the lower orifice is surrounded by ridges and indentations as if to secure a leather or wooden trumpet-like termination. Presumably this wavy form of tube had some acoustic significance.

[f] Para. 6, in *Shih Chi*, ch. 24, p. 25*b*; cf. Chavannes (1), vol. 3, p. 266.

[g] In these ancient times the metal category refers in general to bells. The different varieties of gongs (*lo*,[17] *tien tzu*[18]) did not originate in China, as has been shown by Kunst (3), but rather in Central Asia. Not until the Thang did they become common. Afterwards special types were evolved, including that which has become known in the West as the 'Chinese crash-cymbal' (*po*[19]), so named because of the brilliant crash it makes when struck with a drumstick.

[h] Duke Yin, 5th year; tr. Couvreur (1), vol. 1, p. 34, eng. auct.

1 鞉 2 鼗 3 鼓 4 椌 5 楬 6 壎 7 篪
8 德音之音 9 鐘 10 磬 11 竽 12 瑟
13 金石絲竹樂之器也 14 舞所以節八音而行八風
15 璧 16 笛 17 鑼 18 點子 19 鈸


后夔典樂圖
編鐘
編磬
鼓

Fig. 303. To the right the pellet-drum (*thao*); to the left the great stand-drum (*chien ku*). *Akhak Kwebŏm*, ch. 6, pp. 3*b*, 9*b* (+1493).

Fig. 302 (opp.). A late Chhing representation of the instruction of musicians by the legendary music-master Hou Khuei. Before him, on the table, are the zithers *chhin* and *sê*; to his right the reed-organ (*shêng*), the globular flute (*hsüan*) and the transversely blown straight flute (*chhih*); to his left the pan-pipes (*hsiao*) and the vertically blown bamboo flute open at both ends (*yo*). In the background the stand of bells and the great chime-stone; in the foreground the stand of chime-stones and the standing-drum. In front of Khuei's table, on the ground, are the percussion tub (*chu*) and the tiger-box (*yü*). Tea is being served. From *SCTS*, ch. 2, Shun Tien (Karlgren (12), p. 7).

Fig. 304. The stand of chime-stones (*chhing*). *Hsiang Yin Shih Yo Phu*, ch. 1, p. 13*a*, in Chu Tsai-Yü's *Yo Lü Chhüan Shu* (+1620).

eight winds, on the other hand, are frequent in the *Tso Chuan*. In the fact that the ancient Chinese correlated their sources of sound with winds evidently lies the clue to the early development of the four sources of sound into an ultimate eight.

(ii) *Winds and dances*

Mention was made earlier in this Section[a] of the great annual climatic cycle on which the life of the early Chinese people depended. The *Yo Chi* specifically relates it to music:[b]

> It is the Tao of heaven and earth that if cold and heat do not come at the right time there will be epidemics; if wind and rain do not come in due proportion there will be famine. (When the ruler) teaches (what is required by means of ritual mimes), that is the people's cold and heat. If his teaching does not come at the right time he may blast a whole generation. (When the ruler) acts that is the people's wind and rain. If his actions do not observe due proportion they will be without effect. That is why the former kings organised (the ritual mimes accompanied by) music, and so governed by force of example (i.e. by sympathetic magic). If these were good, the activity (of the people) mirrored his moral power.

There were many different dances in these ritual mimes, but all fell under two heads.

[a] P. 133 above.
[b] Para. 4, in *Shih Chi*, ch. 24, pp. 16*b*, 17*a*; tr. Chavannes (1), vol. 3, p. 256; eng. et mod. auct.

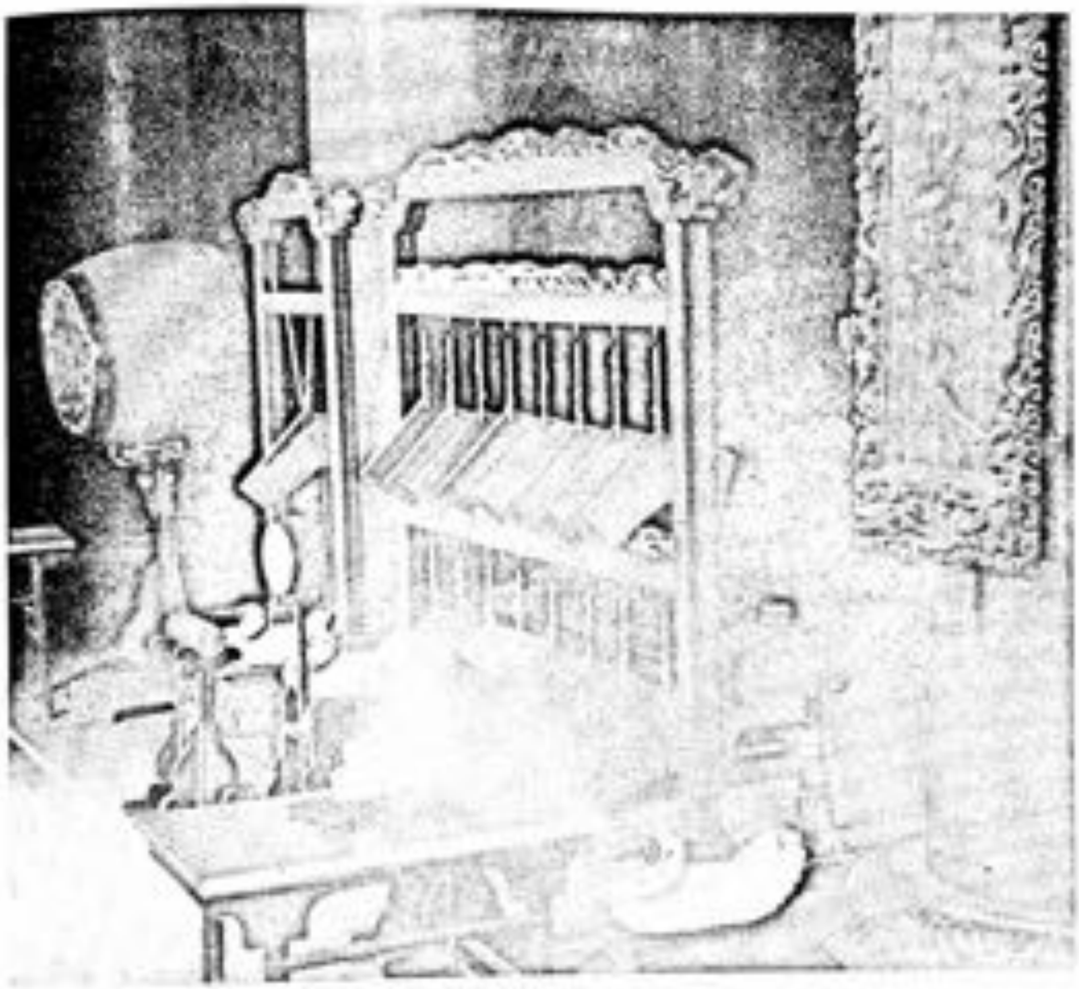

Fig. 305. Great chime-stone and stand of chime-stones in the main hall of the Temple of Confucius at Chhü-fou, Shantung (orig. photo., 1958). In the background a great stand-drum, behind the stones a reconstructed *sê*, in front of them a pellet-drum and a hand-drum. Lying flat on the table in the foreground, the pan-pipes.

pyrrhic (warlike) and peaceful. The pacific dances included beast dances and rain-making dances. Evidence of the latter is found in the *Yo Chi* where it is stated that 'the evolutions (of the dancers) symbolise wind and rain (*chou huan hsiang fêng yü*[1])'. There are many accounts in early texts of grand performances of music, with bells, stone-chimes, etc., followed by a great wind or a storm with thunder and rain.[a] But precise details of the dances themselves are scarce.

The winds, however, were certainly eight in number, one from each cardinal and one from each intermediate point. Chêng Hsüan says that in the 'cap dance' (*huang-wu*[2]) for the four cardinal points feathers were worn covering the top of the head, and the clothing of the dancers was adorned with kingfisher feathers. This dance was performed in time of drought.[b] It is not hard to see a connection between times of drought and kingfishers, birds which frequent rivers and watery places. He adds that these costumes had the brilliant colours of the plumage of the so-called 'phoenix' (*fêng*[3]). Feathers were used in all three of the pacific dances. Cranes were also imitated. The names of these ancient songs and dances are almost all that survive to tell the tale of rain-making music—'The South Wind' (according to Ssuma Chhien a song of birth and growth),[c] 'Receiving the Clouds', 'The White Clouds', and others.

In order to control the dances various instruments were used. Two have already been mentioned,[d] the *chhiang*, which was a hollow wooden beaten instrument used for starting the dances, and the *chieh*, for stopping them. Two others with the same function, and which perhaps they resembled, are the *chu*[4] and the *yü*.[5] The former derives from an agricultural pestle-and-mortar or wooden tub for crushing grain. The latter is a hollowed block of wood shaped so as to resemble a tiger with a serrated back (Fig. 306) and gives a rasping noise when brushed or struck smartly with a stick (*chen*[6]) split at the end into twelve leaves.[e] The way in which the dances were controlled is suggested by the following description in the *Yo Chi*:[f]

> In the ancient mimes the dancers advanced in ranks and retired in ranks (*chin lü thui lü*[7]),

[a] See, for example, the story of Duke Phing of Chin (−557 to −532) and the music-masters, *Shih Chi*, ch. 24, pp. 38*b*ff. (tr. Chavannes (1), vol. 3, pp. 288ff.); and also Legge (1) in his preface to the *Shu Ching*, p. 115, concerning the *Annals of the Bamboo Books*.

[b] See his commentary on the *Chou Li*, ch. 6, p. 7*b* (ch. 22), on the six types of dance; cf. Biot (1), vol. 2, p. 41.

[c] *Shih Chi*, ch. 24, p. 38*a*, cf. Chavannes (1), vol. 3, p. 287.

[d] P. 145 above.

[e] Later on, the Buddhists developed other hollow wooden instruments, such as the 'fish' (*yü pang*[8]) struck to assemble the monks; and the slotted box, flat below and convex above (*mu yü*,[9] *ao yü*[10]) used for accompanying the chanting of the *sūtras*, which found its way into Western bands in modern times. As late as World War II its sound was one of the most characteristic features of Chinese cities at night.

Another very curious, and hardly musical, instrument was the *hu tung*[11] which 'consists of a glass bulb, somewhat like a wine-decanter. As the bottom is extremely thin, when the mouth is applied to the open end and the breath drawn quickly in and out, it vibrates with a loud crackling sound' (Moule (10); cf. Bodde (12), p. 79). In view of the evidence given above concerning glass-blowing, this may have been a very late development.

[f] Para. 8, in *Shih Chi*, ch. 24, p. 30*b*; tr. Chavannes (1), vol. 3, p. 273, mg. et mod. auct. The technical terms in the second phrase are not certain, and have generally been taken to mean '(the music is) harmonious and correct with fulness', as in Chavannes' translation.

1 周還象風雨 2 皇舞 3 鳳 4 柷 5 敔 6 籈
7 進旅退旅 8 魚梆 9 木魚 10 鼇魚 11 鼓噹

keeping together with perfect precision, like a military unit. The strings, gourds, and reed-tongued organs all waited together for (the sound of) the tambourines and drums. The dance was started by a (note from a) pacific instrument (drum). Conclusions were marked by a (note from a) martial instrument (bell). (These) interruptions were controlled by means of the *hsiang*[1] drum. The pace was regulated by means of the *ya*[2] drum.

From this brief extract the impression emerges that what the ancient Chinese were seeking above all in their dance rituals was control. Whereas the Greeks seem from early times to have paid great attention to melody and the tuning of lyres, the Chinese were primarily concerned with rhythm and the control of movement by which the elements were to be influenced. Later the movements of men's minds, their passions, were to be controlled in the same way but symbolically and by suggestion.

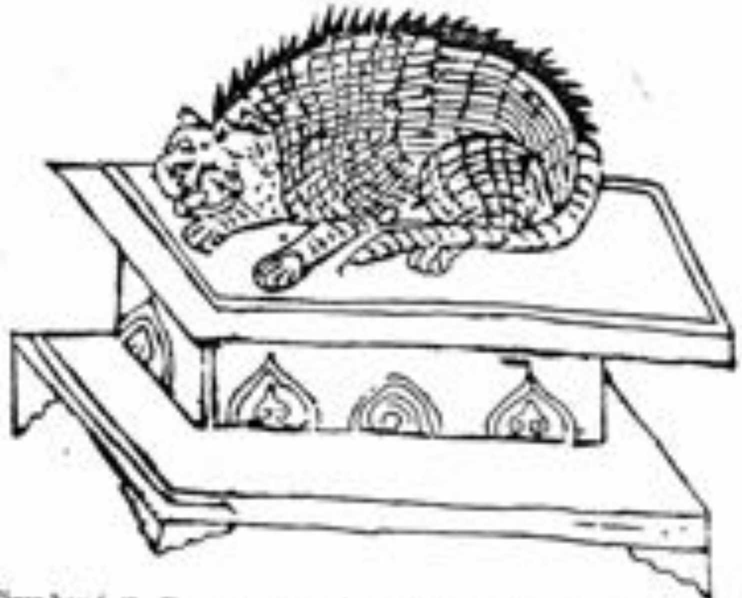

Fig. 306. Tiger-box (*yü*). From a Sung edition of Chhen Yang's *Yo Shu* (+11th century), cf. *Akhak Kwebŏm*, ch. 6, p. 11b.

The belief in the ability of the ritual mimes to control the weather[a] is specifically expressed in the *Yo Chi* where it says:[b] 'The eight winds follow (obey) the *lü* and are not turbulent (traitorous) (*pa fêng tshung lü erh pu chien*[3]).' The exact meaning of this statement depends on how the word *lü* is translated. The first and most probable alternative is that *lü* here has its earliest meaning of regulated dance steps.[c] The second interpretation would take *lü* to mean humming-tubes through which the shaman

[a] Widely distributed, of course, among primitive peoples. For instance, Frazer (1) says: 'The Motumotu in New Guinea think that storms are sent by an Oiabu sorcerer; for each wind he has a bamboo (tube) which he opens at pleasure' (vol. 1, p. 327). Frazer gives much other material on the magical control of the wind. Mem. *Macbeth*, Act 1, sc. iii, as Miss Su Lin reminds us.

[b] Para. 6, in *Shih Chi*, ch. 24, p. 24b; tr. Chavannes (1), vol. 3, p. 265, eng. et mod. auct.

[c] Cf. Vol. 2, pp. 551 ff. above, regarding the word *lü* (regulations, and standard pitch-pipes).

[1] 相 [2] 雅 [3] 八風從律而不姦

'whistles for a wind'. The third possibility is that *lü* has its normal later meaning of blown pipes by which the pitch was given to other instruments. The statement that 'the eight winds obey the pitch-pipes' would make sense if it could be shown not merely that certain pitch-pipes were associated with certain winds in a vague and undefined way, as was done in Han times,[a] but that a given wind was induced by its appropriate dance, that a given dance was initiated or regulated by its appropriate instrument, and that a given instrument, or the position occupied by a given source of sound, was associated with a certain pitch or note in a scale. In this way the regulated movements of the dance, the regulated positions of the instruments, and the regulated intervals of the scale, would all be connotations of the very broad concept of *lü*. Support for the idea that different instruments may have been associated with different notes is found in a statement in the *Chou Li*[b] that

> the Great Music-Master...weaves the gamut into patterns using the five notes (of the scale) ...and distributes the notes using the eight sources of sound (*Ta Shih...chieh wên chih i wu shêng...chieh po chih i pa yin*[1]).

An exact description of how some of the eight sources of sound were allotted to the five notes is given in the *Kuo Yü*.[c]

> The zithers *chhin* and *sê* exalt (or follow) the *kung* note. Bells exalt the *yü* note (*Chhin sê shang kung. Chung shang yü*[2]). Ringing-stones exalt the *chio* note. (Instruments of) gourd and bamboo exalt the note which is appropriate to them (*Shih shang chio. Phao chu li chih*[3]).

This difficult passage apparently means that instruments which do not produce a great volume of sound are principally used for music in which the mode uses the deeper notes of the gamut, these being loud (*ta*[4]) and the higher notes soft (*hsi*[5]). In this way loud instruments such as bells do not drown soft instruments such as zithers, and the music is level (*phing*[6]).[d]

The argument at this stage may be summarised as follows. The earliest known system by which the Chinese classified sounds was according to the materials from which their instruments were made. These originally numbered four—stone, metal, bamboo, and skin or leather. Their number was later increased to eight. This accorded with the fact that eight different winds were recognised. Each wind, it was thought, could be induced by a particular type of dance, and each dance was controlled by a particular musical instrument. It will now be shown that an attempt was made to form an eightfold classification of instruments or sources of sound correlated with the eight directions or sources of wind. From this division of the instruments of the orchestra it will later be suggested that there arose a further classification of sounds

[a] *Shih Chi*, ch. 25, pp. 4*a*ff.; cf. Chavannes (1), vol. 3, pp. 301ff.
[b] Ch. 6, p. 3*b* (ch. 22), tr. auct. adjuv. Biot (1), vol. 2, p. 38.
[c] *Chou Yü*, ch. 3, pp. 23*b*, 24*a*; tr. de Harlez (5), eng. auct.
[d] *Chou Yü*, ch. 3, p. 24*b*.

[1] 大師…皆文之以五聲…皆播之以八音 [2] 琴瑟尚宮鐘尚羽
[3] 石尚角匏竹利制 [4] 大 [5] 細 [6] 平

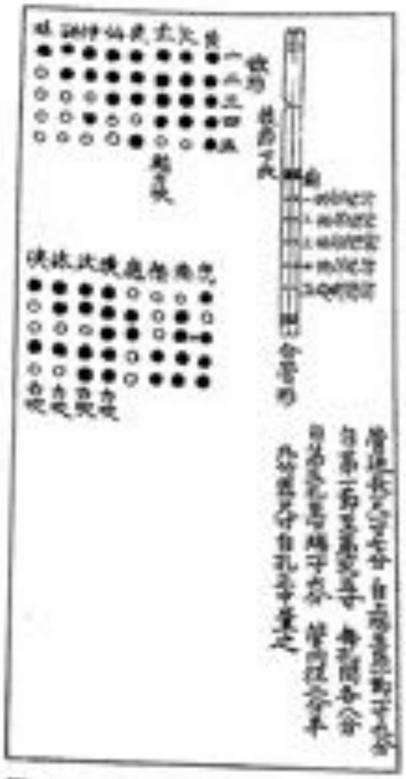

Fig. 307. The double pipe (*kuan*), from *Akhak Kwebŏm*, ch. 6, p. 12*b* (+1493).

Fig. 309. Musicians playing on reed mouth-organs (*shêng*). *Hsiang Yin Shih Yo Phu*, ch. 1, p. 13*b*, in Chu Tsai-Yü's *Yo Lü Chhüan Shu* (+1620). The nearest figure is marking the time with a sort of clapper (*chhung-tu*) consisting of twelve slips of bamboo strung together on a leather thong (like an ancient book); this is held in the right hand and struck with the left (cf. Moule (10), p. 12).

Fig. 308. The pan-pipes (hsiao), sixteen small bamboo pipes of different lengths fixed in a case (from Chhien Chün-Thao, 1).

according to pitch. For an instrument which had originally served only as the starting signal of the dance, or to keep the beat going, was capable eventually of convenient use for giving the pitch-note as well.

(iii) *Correlation of timbre with directions and seasons*

The association of the qualities of musical sounds with various moods is highly subjective, and varies from individual to individual. But in any one culture there may be stereotyped reactions to particular noises. Thus the *Yo Chi* describes five of the sources of sound as having such standard associations:[a]

> The sound of bells is clanging. Clangour produces a call as if to arms. Such a call gives rise to wild excitement. Wild excitement produces warlike emotion. When the *chün tzu* (man of breeding)[b] listens to the sound of bells he thinks of heroic military officers.

Chêng Hsüan observes that the effect of a bell is that of a warning to rouse the people, and explains that it causes a person's *chhi* to become abundant. The text proceeds:

> The sound of ringing-stones is a tinkling. Tinkling sets up a power of discrimination. Discrimination enables men to press on to their deaths. When the man of breeding listens to the sound of ringing-stones he thinks of loyal officials who have died on the frontiers.
>
> The sound of silken strings is a wailing. Wailing stimulates integrity. Integrity establishes resolution. When the man of breeding listens to the sound of the (silk-stringed) zithers *chhin*[1] and *sê*,[2] he thinks of resolute and righteous ministers.
>
> The sound of bamboo flutes is a gurgling like flood waters. Flood waters entail levies. Levies involve gathering the people (for their tasks). When the man of breeding listens to the sound of the bamboo pipes *yü*,[3] *shêng*,[4] *hsiao*,[5] and *kuan*,[6] he thinks of officials who have been the shepherds of the people.[c]
>
> The sound of the stand-drums and the tambourines is rowdy. Boldness (of spirit) sets up (physical) activity. Physical activity sets the people marching. When the man of breeding listens to the sound of drums and tambourines he thinks of great generals leading out armies.
>
> So when the man of breeding listens to the timbre (of different sorts of instruments) he does not listen merely to their clanging and tinkling, but he is also sensitive to their associations.

In the above translation it has been difficult to keep the effect of the Chinese definitions, the words of which are highly onomatopoeic as well as fully charged with meaning. For the Chinese of this archaic period the timbres of these five sources of sound—metal bells, chiming slabs of stone (Fig. 310), silken-stringed zithers, bamboo flutes, and drums of stretched leather—were respectively summed up by the words *k'ɛng*, *k'ieng*, **·ər*, **glâm*, *χwân* (i.e. *khêng*,[7] *chhing*,[8] *ai*,[9] *lan*,[10] *huan*[11]).[d]

[a] Para. 8, in *Shih Chi*, ch. 24, pp. 32bff.; tr. Chavannes (1), vol. 3, pp. 277ff., eng. et mod. auct.

[b] On this conception, see Vol. 2, p. 6.

[c] The *yü* was a single pipe and the *kuan* a double one, the *hsiao* was the pan-pipes and the *shêng* a mouth-organ with reeds; see Figs. 307, 308, 309.

[d] Respectively K 1252, 832, 550, 609, 158. The phonetic transcription of the ancient Chinese sounds used here and hereafter is that of Karlgren (1).

1 琴 2 瑟 3 竽 4 笙 5 簫 6 管 7 鏗
8 磬 9 哀 10 濫 11 讙

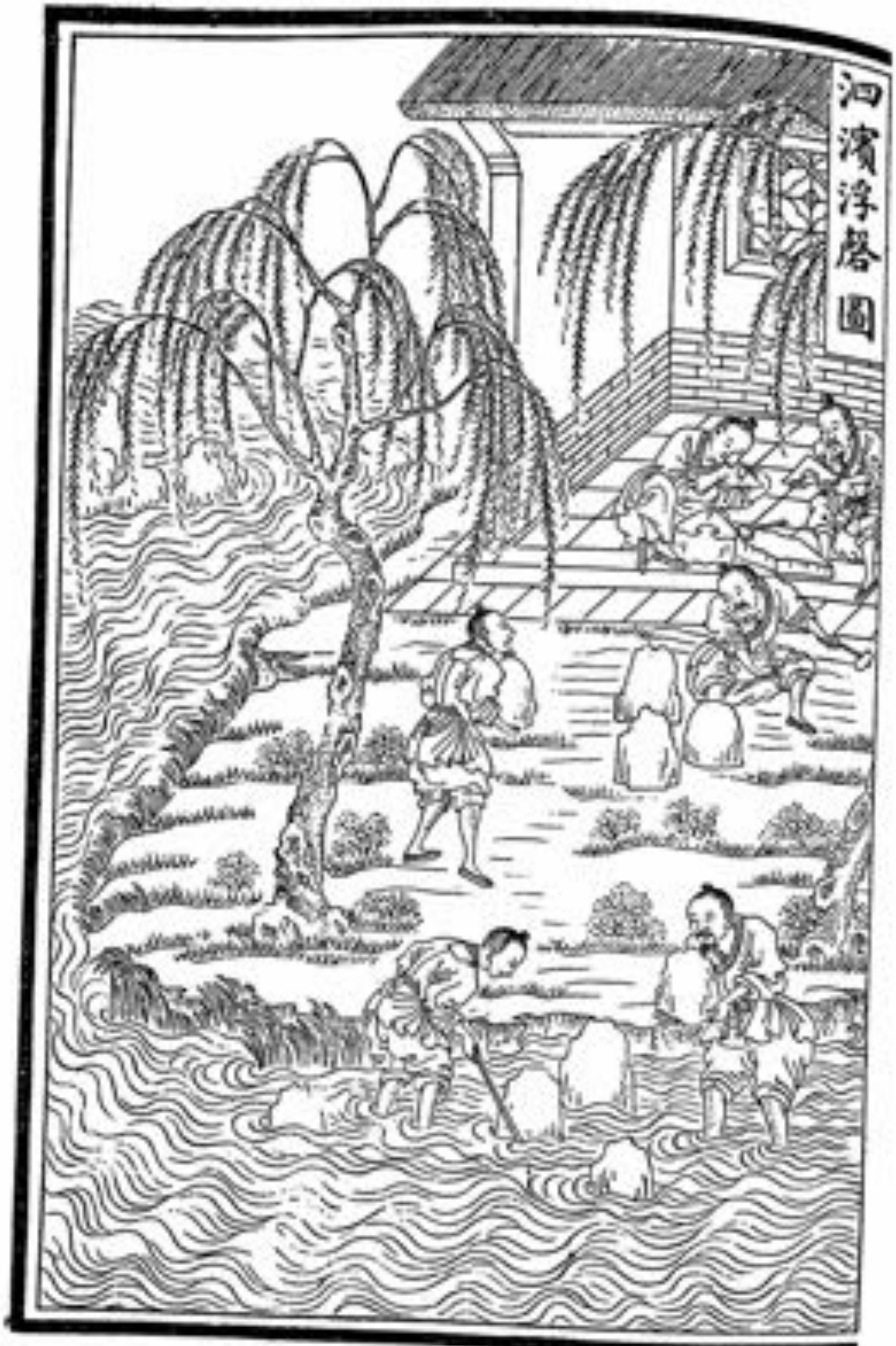

Fig. 310. A late Chhing representation of the making of chime-stones from the rocks of the Ssu River, described in the *Shu Ching*. From *SCTS*, ch. 6, Yü Kung (Karlgren (12), p. 14; cf. Vol. 3, p. 500).

The interesting point about this list of 'sources of sound' is that they number five, in accord with the symbolic correlations of Five Element theory, and not, as was usual later, eight. The latter are tabulated in most works of reference as shown in Table 44.

Table 44. *Traditional list of the eight sources of sound*

Source of sound	Compass-point	Season	Instrument
1. Stone	North-west	Autumn–Winter	Ringing-stone
2. Metal	West	Autumn	Bell
3. Silk	South	Summer	Lute or zither
4. Bamboo	East	Spring	Flute and pipe
5. Wood	South-east	Spring–Summer	Tiger-box (*yü*[1])
6. Skin	North	Winter	Drum
7. Gourd	North-east	Winter–Spring	Reed-organ (*shêng*[2])
8. Earth	South-west	Summer–Autumn	Globular flute

Comparing this orthodox list of eight with the five quoted from the *Yo Chi*, one is first struck by the fact that the reed-organ (*shêng*[2]) is here placed under the very unusual material 'gourd', whereas in the early text it is where one would expect to find an instrument which consists of a series of blown bamboo tubes (even if they happen to have a gourd serving as a wind-chest), namely under the material bamboo. Then again the order in which the points of the compass are listed is peculiar, for one would expect to find 'south-west' placed between south and west, and not attached at the end almost as an afterthought. The seasons also are strangely erratic. But the reason for this is probably quite simple. An earlier classification in fours was stretched[a] to harmonise with a later system of eights. The earlier was thus:

Compass-point	Season	Instrument
West	Autumn	Chimes (bells and ringing-stones)
South	Summer	Zithers
East	Spring	Pipes
North	Winter	Drums

Now in each of these cases there is a clear connection between the instrument and its corresponding quarter. First, autumn is the season when the Yang forces of nature

[a] The tiger-box and similar instruments of punctuation were scarcely of the same rank as the four great types of instrument.

[1] 敔　　[2] 笙

are in retreat, and bells or metal slabs were the instruments sounded when a commander ordered his troops to retire.[a] In winter there occurred one of the most solemn ceremonies of the year, when the sun was assisted over the crisis of the solstice by the help of sympathetic magic. The primeval instrument, the drum, was essential to this ceremony, and there could be none more fitting to announce the sun's renewed advance than the drum which also sounded the advance in human conflict and battle. In spring when men desire trees to bud and crops to grow, the most potent instrument would naturally be one made of bamboo, a plant of such vitality that it remains green even in winter. The various pipes of bamboo, then, through which men's *chhi* causes a similar *chhi* in Nature to respond, were the instruments of spring, and even in the orthodox eightfold classification the other vegetable substances, wood and gourd, were associated with this season. Finally, in summer when the silkworms are fattening on mulberry leaves, or spinning their cocoons, it was appropriate to play an instrument whose strings were of silk. Moreover, summer was the time when drought was to be feared, and the zithers which accompanied rain-making songs were believed to be excellent implements of magic. The association of the instruments with the points of the compass was no less straightforward. If autumn is the season of decline, the west is its direction, whereas spring and the east are contrary.[b] Similarly the north and winter must be associated with cold, and the south and summer with heat.

Since music was in ancient times a part of government, and intimately associated with agriculture, changes in the calendrical system necessitated changes in music. Hence an increase in the 'sources of sound' became inevitable. But the introduction of a fifth factor to be worked into the system during the rise of the Five Element theory gave rise to many complications.[c] It is to the credit of the Chinese as systematisers that they achieved a synthesis, where the Greeks, apart from occasionally including æther as a fifth element, left behind them no such pattern as we find in the *Yo Chi*.[d]

The ethical characteristics which the *chün-tzu* (man of breeding) associated with the five sources of sound deserve comparison with similar qualities attributed to the five notes. Our next study must therefore concern itself with pitch.

[a] Cf. Vol. 1, p. 552. Abundant evidence shows that in ritual music there was the closest association between bells and ringing-stones. Fig. 311 shows the stand of bells (cf. Hett's description (1) of Confucian ceremonies at Seoul (Korea) in our own time). The chime-stones were among the oldest of Chinese instruments, as is attested by the find (in 1950), in a great royal tomb at Anyang dating from about the −14th century, of a musical slab of grey limestone (Hsia Nai (1); Li Shun-I (*1*), p. 38). This is perfectly preserved and gives out a clear ringing note when struck. A conventional tiger, beautifully engraved, decorates its face (Fig. 312). On the Confucian temple ceremonies themselves see G. E. Moule (2); Shryock (1); Johnston (1); and Vol. 2, pp. 31 ff. Sets of seven and of nine chime-stones from the Warring States period are figured in Thang Lan (*1*), pl. 65. A set in use is depicted in the Wu Liang tomb-shrine reliefs of +147 (Jung Kêng (*1*), indiv. rubbing Hsin, 1); cf. Figs. 299, 300.

[b] See Vol. 2, p. 262.

[c] Cf. Vol. 2, pp. 242 ff. The note *kung* appropriate to zithers was given the central place of Earth, while bells and ringing-stones were separated, the note *yü* of the former going to Water and the note *chio* of the latter going to Wood. At the same time *chih* was assigned to Fire and *shang* to Metal. See Vol. 2, p. 262.

[d] Cf. Vol. 1, p. 246.

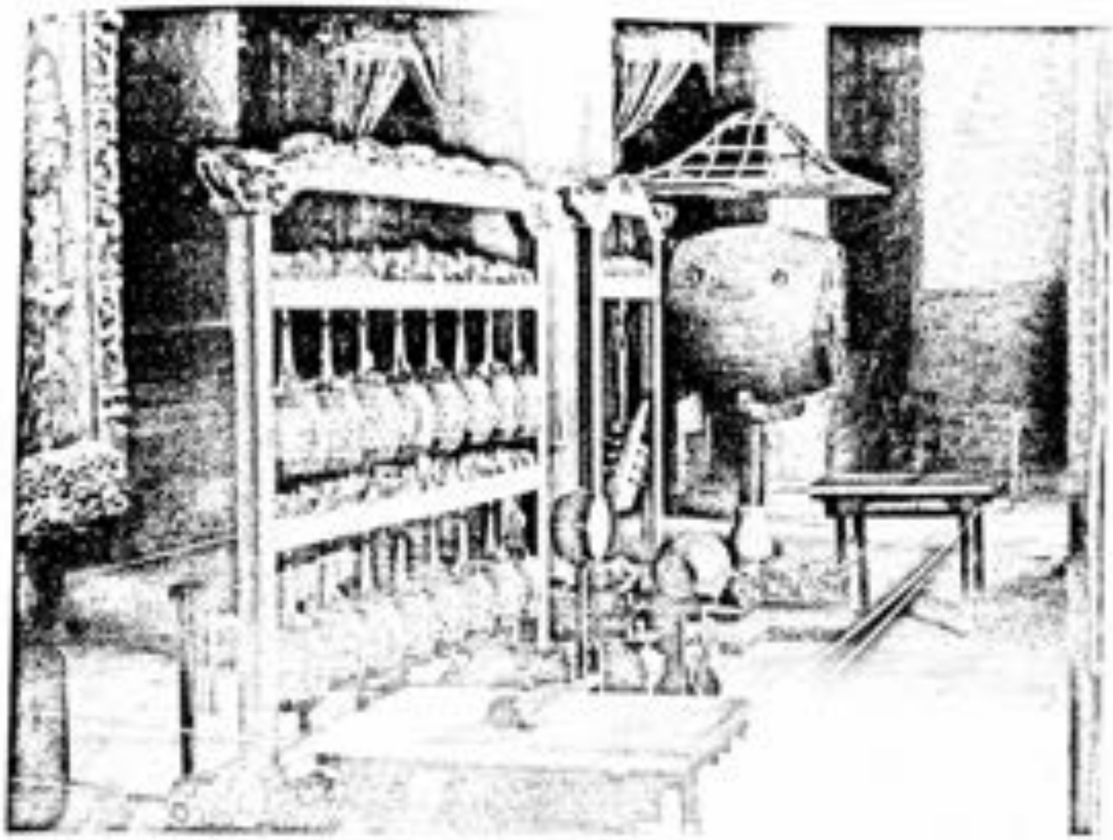

Fig. 311. Great hanging bell and [illegible] in the main hall of the Temple of Confucius at Chhü-fou, Shantung (orig. photo., 19[illegible] a great stand-drum, behind the bells a *hu chhin*, in front of them a pellet-drum [illegible] a small *shêng* on the nearer table.

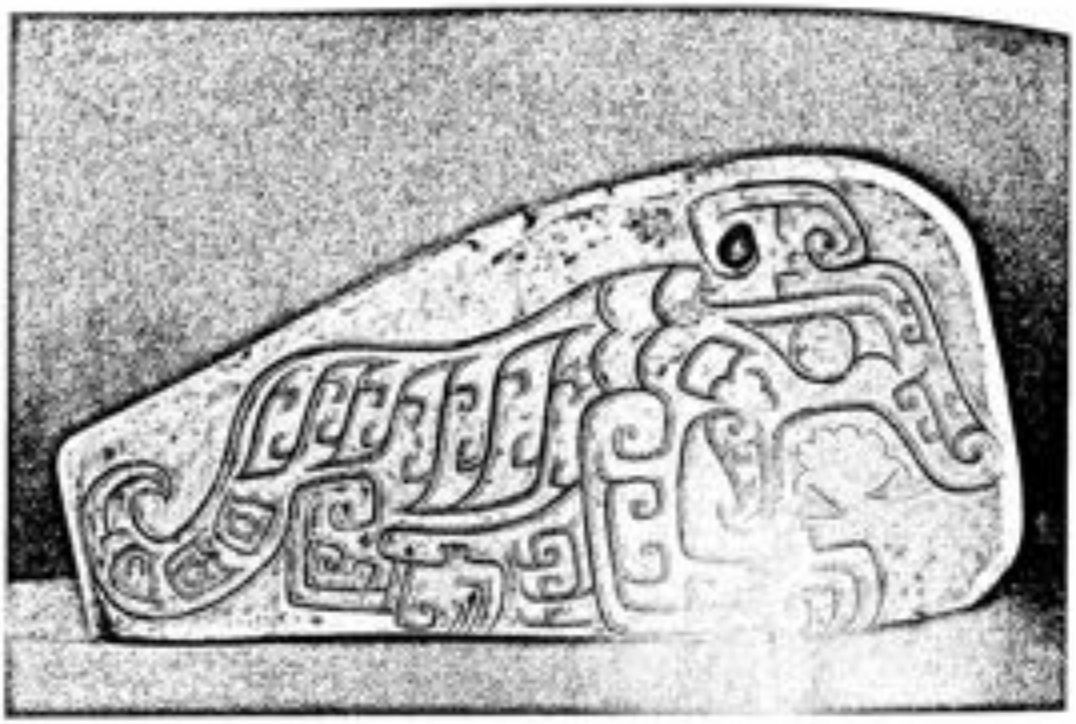

Fig. 312. One of the oldest and most magnificent specimens of a chime-stone, from a royal tomb of the Shang period at Anyang (*c.* −14th century). A stylised tiger is engraved on its face. Imperial Palace Museum, Peking (Anon. 26).

(5) Classifications of Sound by Pitch

By 'pitch' is meant that quality of sound which is determined by the frequency of vibration of an elastic body and of the air surrounding it, fast vibrations producing one type of auditory sensation and slow vibrations another. Language deals with these sensations by curious metaphors. Very rapid vibrations produce a less pleasant sensation than slow ones. The Romans described such notes as 'cutting' or 'sharpened' (*acutus*). Notes at the opposite end of the scale, however, were not 'blunt' but 'heavy' (*gravis*). English uses a consistent metaphor based on the scale or 'ladder' in which sounds at one end are said to be 'high' and at the other 'low'. Chinese uses a metaphor which is not surprising for a people whose economy was so bound up with hydraulic engineering, namely—clear (*chhing*[1]) and muddy (*cho*[2]).

In Greece names were invented which bore a clear relation to the strings of the lyre; for example, the lowest note, which was sounded by the top string as the lyre was held for playing, was called *hypatē* or 'uppermost'. Its octave was *neatē* or 'lowest', while between the two on the primitive lyre was a *mesē* or 'middle' (string). Later other names were invented, such as *lichanos* or 'first finger' (note), and *tritē* or 'number three'.

There is no such simplicity in the etymology of the original five notes of the Chinese scale. Their names, as stated on p. 140 above, are *kung*, *shang*, *chio*, *chih* and *yü*. Previous writers on Chinese music[a] have been content to say that these names seem to hold 'traces of an ancient symbolism'. But it is quite certain that these terms had symbolical associations. In the *Yo Chi*, for example, it is said[b] that

> *kung* acts as the prince, *shang* as the minister, *chio* as the people, *chih* as affairs, and *yü* as beings (animate and inanimate) (*kung wei chün, shang wei chhen, chio wei min, chih wei shih, yü wei wu*[3]).

To this Chêng Hsüan adds by way of commentary that

> in general, notes which are deep in pitch are noble, while those which are high in pitch are humble (mean) (*fan shêng, cho chê tsun, chhing chê pei*[4]).

These statements shed some light on the evolution of Chinese ideas about pitch.

The name for the note *shang*[5] (K 734) was pronounced **śjang* in archaic Chinese, and also had the meanings of 'discuss, debate, trade'. This character was anciently interchangeable with *hsiang*[6] (K 715), archaically pronounced **xjang*, which meant 'a window facing north, turn towards, formerly'.[c] With this may be compared *hsiang*[7] (K 714*c*, *d*) having the same archaic pronunciation as the preceding word, and a set of

[a] E.g. Laloy (2), p. 54.
[b] Para. 1, in *Shih Chi*, ch. 24, pp. 5*b*, 6*a*; tr. Chavannes (1), vol. 3, p. 240, eng. auct.
[c] Cf. Chavannes (1), vol. 3, pp. 278, 294.

1 清　2 濁　3 宮爲君商爲臣角爲民徵爲事羽爲物
4 凡聲濁者尊清者卑　5 商　6 向　7 嚮

similar meanings, 'facing towards, turn towards, a little while ago'.[a] The last and most interesting link is that this character in its earliest form (see below) is identical with the earliest form of the character *chhing*[1] (K 714*o*, *p*), archaically pronounced **k'jăng*, which meant a minister. In spite of the roundabout etymology the general connection is clear. In State discussion the minister turned towards his prince, like his echo *hsiang*[2] (**χjăng*, K 714*n*). In this context the word *hsiang*[3] (K 731), meaning 'to look at', 'mutually', may be noted, for (as we saw, p. 150) it was also the name of a drum which marked the intervals in music, thereby playing the role of 'a firm and just official' by seeing that the music is 'correct and just'. In addition it may be noted that *chhing-hsiang*[4] was a familiar compound term meaning minister.

K 714*d*

From the above analysis it will be clear that originally it was not so much that the note *shang* symbolised the minister as that 'minister' was the name of one of the notes. How it got that name may become clear from further examination of the other four note names. The first of these is *kung*,[5] which 'acts as prince'. *Kung* in Chou times meant a house. By a specialisation natural to an age in which princes lived in houses and the common people in huts and hovels, *kung* later came to mean a palace. Now it is stated in the *Chou Li*[b] that the Junior Aides (Hsiao Hsü[6])

> regulate the position of the musical instruments which are hung on frames. A prince has frames in the form of a house (*kung*[5]). Feudal lords have frames in the form of a chariot. Ministers and great officials have frames in the form of divided (walls). Ordinary gentlemen have single frames.

By this is meant that at musical court ceremonies stands or frames for sets of bells, ringing-stones or drums were set up, four frames enclosing a hollow square like the walls of a house. At the inferior courts named above, the southern wall, the northern and southern, and the northern, southern, and western walls respectively, were absent. The *kung* or house was, therefore, the name of a musical instrument placed in a certain position for the making of music at a princely court.

Two further note names seem to have derived from stands for suspended instruments, namely *chio* (horns) and *yü* (feathers). One of the odes in the *Shih Ching* has these lines:[c]

> There are blind musicians, there are blind musicians, present and ready in the Chou palace yard.
> (Their assistants) set up the serrated boards (to support the instruments), set up the drum posts, raising the tusks, planting the feathers (*shê yeh shê chü chhung ya shu yü*[7]).

[a] The graph shows two men sitting turned towards one another, with a food vessel between them, hence the better known later meaning of village and by extension country.

[b] *Chou Li*, ch. 6, p. 11*a* (ch. 22); tr. Biot (1), vol. 2, p. 47, eng. auct.

[c] *Shih Ching*, pt. IV, i (2), no. 5; Mao, no. 280; tr. auct. adjuv. Legge (8); Karlgren (14), p. 245; Waley (1), p. 228.

[1] 卿 [2] 嚮 [3] 相 [4] 卿相 [5] 宮 [6] 小胥
[7] 設業設虡崇牙樹羽

The exact meaning of some of the terms in this poem has been the subject of much comment, but the point is that certain posts from which drums and other instruments hung were ornamented with feathers; furthermore, either part of the wooden framework was cut so as to make sharp points (teeth) or angles (horns), or tusks or horns were fastened on to it.[a] Thus three of the five note names were terms used for describing stands supporting drums, bells or ringing-stones.

The hypothesis may now be suggested that the terms *kung*, *shang*, *chio*, *chih*, and *yü* originally referred to the positions occupied by certain instruments used in controlling the music and dancing. A number of references suggest that the earliest Chinese conception of a scale was not, as in the West, that of a ladder ascending from low to high or descending from high to low pitch, but of a court in which the notes are ranged on either side of the chief or *kung* note. As the commentator of the *Huai Nan Tzu* book succinctly puts it: 'The *kung* note is in the middle; therefore it acts as lord (*kung tsai chung yang, ku wei chu yeh*[1]).'[b] This refers to a statement in the text which says of the five notes that *kung* is their lord. It will also be recalled that in the quotation from the lost 'Book of War' (p. 141 above) the five notes or qualities of sound are listed in the order *shang*, *chio*, *kung*, *chih*, *yü*. This tradition of the notes being ranged not by pitch but by some sort of ceremonial array lends support to the view that at some time there were five stations round the dancing floor for posts and frames on which were hung the instruments for controlling the ritual mimes, the *kung* position for the house-frame, which was lord; the *shang* position for the *hsiang* drum regulating the proceedings like a just minister; the *chio* position for a stand dressed with horns; the *chih*[2] or summoning position, possibly associated with the *ying*[3] bell or drum[c] (both are known by name); and the *yü* position where the post or stand was adorned with feathers.

That these terms should later refer to the pitches of notes appears almost inevitable, for the instruments hung on the posts and frames were in fact the pitch-giving instruments, i.e. the ringing-stones, the bells, and, as is clear from early paragraphs of this Section, the drums. There is abundant evidence that from the earliest times it was these instruments which regulated the music. Two quotations will suffice. The first from the *Shu Ching*, where Khuei[4] (the great legendary musician), describing the arrangements for one of the ritual 'beast dances', says:[d] 'I strike the sounding-stone, I gently strike it, and the various animals lead one another on to dance.' The second is from the *Shih Ching* where a vivid description of ritual music contains the lines:[e]

[a] A comment of Chêng Hsüan's on drum-posts in the *Chou Li* relevant to this passage is here quoted in some editions of Mao's version of the *Shih Ching*; namely that 'they put (feathers) in the horns on the top of the uprights of the bell-frames'.

[b] *Huai Nan Tzu*, ch. 4, p. 8a. The comment is by Kao Yu[5] (*fl.* +210).

[c] *Ying* is an essential term in Chinese acoustics meaning resonance, especially that mysterious resonance referred to in connection with *chhi*, cf. Vol. 2, pp. 282, 304, 500, etc. The relation between the note *chih*, also read *chêng*, to summon (K891), and *ying* to respond (K890) is also etymologically close, *jəng and *tjəng.

[d] *Shu Ching*, ch. 2 (Shun Tien), tr. auct. adjuv. Karlgren (12), p. 7.

[e] *Shih Ching*, pt. IV, iii, no. 1, Mao, no. 301; tr. auct. adjuv. Legge (8); Karlgren (14), p. 262; Waley (1), p. 225.

[1] 宮在中央故爲主也 [2] 徵 [3] 應 [4] 夔 [5] 高誘

'Then we bring (the instruments) together in time and pitch, relying on the notes of our ringing-stones (*chi ho chhieh phing i wo chhing shêng*[1]).' Thus one might say that the musical interest of the Chinese in early Chou times was mainly focused on timbre and association. Exact pitch probably did not become a dominating factor among them till Babylonian influence made itself felt at the beginning of the −4th century.[a]

(6) The Development of Physical Acoustics

(i) *The pentatonic scale*

With the recognition of pitch intervals and the naming of notes, accurate measurement, observation and test become possible, and the science of acoustics has been born. One cannot say precisely when the Chinese first gave names to their notes, but the *Tso Chuan*, in passages for which the −4th century is a probable date, contains five references to the fact that the notes of the scale were five in number. Nowhere, on the other hand, does it refer to the notes by name. One might accept the previously quoted passage from the lost 'Book of War' as possibly the earliest instance of the notes being named in a surviving text,[b] but our argument has suggested that these names did not at that time necessarily refer to pitch. The same reservation holds true for a passage in Mencius (*fl.* −350), in which *chih* and *chio* are mentioned as follows:[c]

> (Duke Ching) called the Grand Music-Master and said: 'Make for me music to suit a prince and his minister pleased with each other.' And it was then that the Chih-shao[2] and Chio-shao[3] were made.

Legge says of this passage, 'The Chih-shao and Chio-shao were, I suppose, two tunes or pieces of music, starting with the notes *chih* and *chio* respectively'. If Legge's supposition can be accepted, this passage would provide a date to work from, but the evidence remains scanty at this period. Some fifty years later, however, there is no longer any doubt that *kung*, *shang*, *chio*, *chih* and *yü* were being used to distinguish different notes on stringed instruments.[d] This is attested by the definitions which open the chapter on music in the *Erh Ya* encyclopaedia.[e]

[a] A possible explanation for the origin of the names of the five notes has been sketched in some detail here, because anyone dependent on European works on Chinese music, or even on the orthodox Chinese accounts based on the dynastic histories from Han times onwards, will inevitably form the opinion that the ancient Chinese made a great point of absolute pitch, fixed by special pitch-pipes, if not indeed from the mythical age of the Yellow Emperor, then at least from high antiquity. This view is quite mistaken, as will be made clear in what follows.

[b] P. 141 above.

[c] *Mêng Tzu*, I (2), iv, 10; tr. Legge (3), p. 37.

[d] The *Chuang Tzu* book (ch. 2) cannot give evidence here, as has sometimes been thought. In connection with the legendary skill of the lutanists Chao Wên[4] and Shih Khuang[5] we read: 'Even the most skilful zither player, if he strikes the *shang* (note) he destroys the *chio* (note), if he vibrates the *kung* (note) he neglects the *chih* (note). It is better not to strike them at all; then the five notes are complete in themselves.' This extremely Taoist thought might be interpreted in our own idiom as a preference for 'piping to the spirit ditties of no tone', or for a totality in music which cannot be achieved when it is merely played. But we are in the +8th century, not the −4th, for the passage occurs not in the text, but in the Thang commentary of Chhêng Hsüan-Ying;[6] see *Chuang Tzu Pu Chêng*, ch. 1B, p. 18*a*.

[e] Ch. 7, p. 14*a*.

[1] 旣和且平依我磬聲 [2] 徵招 [3] 角招 [4] 昭文 [5] 師曠
[6] 成玄英

Still later (*c.* −150) there comes the work of Tung Chung-Shu to which reference has already more than once been made[a] on account of his statement that instruments are tuned to certain notes such as the *kung* and the *shang*, and that strings similarly tuned will sound in sympathetic resonance. It is remarkable that at this early period the Chinese were tuning even their drums and noting this phenomenon when they were struck.[b] In Europe, on the other hand, as late as the +16th century such writers on music as Virdung were content to describe drums as 'rumbling tubs'.[c] By −120 the *Huai Nan Tzu* book gives us an explicit statement not only that the five notes are named *kung*, *shang*, *chio*, *chih*, and *yü*, but that in combination with the twelve absolute pitches of the fixed gamut, sixty 'mode-keys' can be formed:[d]

(Given) a single note of fixed pitch, one can then interpeet it as the keynote of five (distinct modes).[e] (Given) twelve notes of fixed pitch, one can then elicit the keynotes of sixty (distinct mode-keys). (*I lü erh sêng wu yin, shih-erh lü erh wei liu-shih yin.*[1])

In spite of the scarcity of early evidence concerning notes in relative pitch, it is not suggested that there was no differentiation of pitches before the −4th century. There may well have been different terms for use with different instruments, a flute-player teaching a pupil tunes by naming the finger-holes on the flute, and a *chhin* player naming the different strings. If Ssuma Chhien (*fl.* −100) is to be believed there was even a system of notation for stringed instruments as early as the −6th century, for in the famous story of Duke Ling and the dancing cranes,[f] it is stated that he made his Music-Master Chüan[2] (*fl.* −500) write down the tune of the kingdom-destroying music composed by Music-Master Yen[3] in an earlier age. This was mysteriously borne to their ears when they were resting one night on the banks of the river where Yen had drowned himself after the Shang dynasty had fallen.

We may therefore conclude that by the −4th century a scale of five notes was without doubt used, and that the relations of the notes in this scale were designated by the terms *kung*, *shang*, *chio*, *chih*, and *yü*. We cannot say precisely what were the intervals between these five notes, however, without further information such as the relative lengths of five tuned strings of the same material at the same tension, or of five bamboo pipes of known dimensions identically blown. This precise information is not given in Chou texts. Some assistance may be looked for from archaeology however, for though excavated bells may no longer ring true on account of corrosion, and blown instruments such as globular flutes[g] may be misinterpreted because we cannot be

[a] Pp. 130, 140 above, and Vol. 2, p. 281.

[b] With regard to drums, we are fortunate in possessing (as already mentioned) a Thang work on their history and use, the *Chieh Ku Lu*[4] by Nan Cho[5] (+848).

[c] *Musica getutscht* (+1511); see Galpin (2), p. 26.

[d] Ch. 3, p. 13*a*; tr. auct. adjuv. Chatley (1), p. 27. Cf. Liu Fu (*1*).

[e] A mode is a pattern of intervals depending on the distribution of semitones and gaps between tones, in scales used for forming melodies. See further p. 169 below.

[f] *Shih Chi*, ch. 24, pp. 38*b*ff.; see Chavannes (1), vol. 3, pp. 287ff.

[g] These *hsüan*[6,7] were generally made of pottery. Ocarinas from the Shang period are preserved in museums at Chêngchow and Peking; cf. Li Shun-I (*1*), pp. 33, 47.

[1] 一律而生五音十二律而為六十音 [2] 涓 [3] 延 [4] 羯鼓錄
[5] 南卓 [6] 壎 [7] 塤

certain of the method of fingering used, the instrument for which ancient China was most remarkable, the sets of ringing-stones made of imperishable jade and other hard minerals, would provide a certain means of knowing ancient scales provided that on excavation a set was found to be intact and complete. There are many references in later Chinese history to the recovery of lost sets of ancient bells and stones, which were used for tuning those of later manufacture, so this knowledge may yet be forthcoming.

Remarkable discoveries of this kind have recently been made. The Archaeological Institute of Academia Sinica at Peking has a set of three *to* of different sizes, and another set of ten *ling*,[a] all in bronze of the Shang period from Anyang.[b] Ampler, though later, is the magnificent set of thirteen *chung* discovered in 1957 in a princely tomb of the Warring States period in the Huai River valley north of Hsinyang. This is preserved in the Honan Archaeological Institute at Chêngchow.[c]

Table 45. *Li Shun-I's frequency tests for ringing-stones and bells*

Frequencies	Ringing-stones		Bells	
	Theoretical vibrations/sec.	Tested vibrations/sec.	Theoretical vibrations/sec.	Tested vibrations/sec.
1	711·45	—	562·2	562·2 (given)
2	762·88	—	632·9	688·4
3	858·24	—	712·07	—
4	948·60	948·6 (given)	801·07	—
5	1017·17	1046·5	843·3	—
6	1144·32	—	949·38	915·7
7	1287·36	1278·7	1068·1	—

Experimental workers are now beginning to test the frequencies of such archaic ringing-stones and bells which evidently formed sets in series. Li Shun-I gives[d] results of this kind for three Shang ringing-stones from Anyang and three Shang bronze bells preserved in the Imperial Palace Museum (Table 45). In this table the observed frequencies are correlated with the theoretical values of the set obtained by the usual method of superior and inferior generation (cf. p. 173). For the stones, no. 5 is about a quarter tone out, which would be perceptible, but no. 7 only 9 vibrations/sec. flat, which at that pitch might be regarded as correct. This suggests that in Shang times stones were not more than approximately tuned to satisfy the ear. Of the bells, no. 2 would seem to be more than a quarter tone out, but

[a] For the definitions of these technical terms for different kinds of bells see p. 194 below.

[b] Chou sets of as many as nine are figured in Thang Lan (*1*), pls. 34, 54, 55, 56. Cf. Anon. (*17*), pls. 18, 19.

[c] Where I had the pleasure of examining it during the summer of 1958. The music of a copy of this chime of bells has been recorded and played over the radio.

[d] (*1*), pp. 24, 26. Cf. (*2*).

no. 6 only 44 vibrations/sec. flat, which might pass. In any case the tuning of a bronze bell will be affected if it is pitted by corrosion, so that sets of ringing-stones will be the best material for these studies, and definite conclusions will no doubt before long be possible.

(ii) *The heptatonic scale and later elaborations*

A pentatonic scale or a number of different pentatonic scales were thus in use in China by the −4th century. But there is also a tradition of heptatonic music, invented, as Chêng Hsüan and other commentators assert, by the Duke of Chou, the great minister at the founding of the Chou dynasty. It is strange that 'the seven notes' (*chhi yin*[1]) should only be referred to twice in the *Tso Chuan*,[a] and each time merely in a numerical catalogue, as, for example, 'the five tones (*shêng*[2]), the six pitches (*lü*[3]), the seven notes (*yin*[4]), the eight winds (*fêng*[5]), the nine songs (*ko*[6])'. In the above passage *shêng* has been translated as 'tones',[b] in order to distinguish it from the word *yin* here interpreted as 'notes'. These two words seem at one time to have meant quite different sorts of sound. The former in its earliest written form suggests the sound produced when one of the ringing-stones is struck, and the latter that produced by blowing through a flute or pipe. By the −2nd century, however, either *wu shêng* or *wu yin* is used for the 'five notes' of the scale. Moreover, the word *lü* (pitch) is also used as a synonym for note. We find frequent references to the seven pitches at this time, meaning the seven notes of a scale. This even occurs in the *Kuo Yü*, in a text possibly as early as the −4th century, where it is stated[c] that when Wu Wang attacked Chou Hsin in order to overthrow the house of Shang 'there were then seven pitches' (*yü shih hu yu chhi lü*[7]). Khung Ying-Ta (*c.* +600), commenting on the *Tso Chuan* passage quoted above, states that the seven notes were introduced at the start of the Chou dynasty. Chêng Hsüan, writing in the +2nd century, also comments on this line, and identifies the seven notes by reference to the fixed pitches of the gamut of his day, from which it is clear that he believed the seven-note scale to have a structure which in our modern notation, if one pitched the *kung* note on middle C, for example, would read C D E F♯ G A B, the 'five notes' being C D E G A, and the two attributed to the Duke of Chou being semitone notes known as *pien chih*[8] (F♯ in this instance) and *pien kung*[9] (B) respectively.[d]

This word *pien* means change,[e] or 'to become, on the way to', and the term itself suggests what a natural musical evolution would lead one to expect, namely, that these two notes were used as a help in passing from one note to another in a 'gapped scale', at any rate at first, though when the ear had become conditioned to this new refine-

[a] Duke Chao, 23rd and 25th years (−518 and −516); tr. Couvreur (1), vol. 3, pp. 355ff.
[b] Cf. Sect. 2 (Vol. 1, p. 36) and the Section on phonetics and linguistics in our concluding volume.
[c] *Kuo Yü* (Chou Yü), ch. 3, pp. 33*b*, 36*a*.
[d] Cf. *Lü Lü Hsin Lun*, ch. 1, pp. 18*b*ff.
[e] Cf. Vol. 2, p. 74.

[1] 七音 [2] 聲 [3] 律 [4] 音 [5] 風 [6] 歌
[7] 於是乎有七律 [8] 變徵 [9] 變宮

ment in sound, and would readily tolerate the presence of semitones, truly heptatonic music would be free to develop.

Whether or not truly heptatonic music was used in Chou times cannot be known, for no examples survive, yet something more than a hint is contained in many references to a 'New Music'. This was considered to be a great scandal, undermining the foundations of the ancient ritual. The *Shih Chi*, for example,[a] records how in the −4th century Prince Wên of Wei[1] observed that when he heard the ancient music his only fear was that he might fall asleep. When he listened to the tunes of the States of Chêng[2] and Wei,[3] on the other hand, this effect did not occur. One objection to the 'New Music' seems to have been that men and women mingled in the dance,[b] and another that the tempo was too quick;[c] but in certain passages it is specifically stated that the tones were wrong. Confucius, for example, in a famous passage in the *Lun Yü*, criticises not the mime-music (*yo*[4]), nor the songs (*ko*[5]), but the notes or tones (*shêng*[6]):[d] 'I hate the way that russet corrupts true red. I hate the way that the tones of Chêng confuse the orthodox music....'[e]

There was thus in ancient China a period of struggle between two different forms of music, an earlier one which used five regular tones, and a later one (stimulated perhaps by the infusion of new ideas from the western borders when the Shang were overthrown by the Chou), in which two auxiliary notes or semitones were used. To this day heptatonic music is stronger in the north of China than in the south. It is even maintained[f] that in the north the heptatonic scale predominates over the pentatonic.

While heptatonic influence was reinforced from the west more than once in later Chinese history, further elaborations were made in the division of the scale in China itself. In the Sui and Thang periods China was very receptive of influences from

[a] Ch. 24, p. 30*a*, *b*; cf. Chavannes (1), vol. 3, p. 272.

[b] This betrays a class prejudice, for the participation of the two sexes in dancing had been universal among the mass of the people since high antiquity (cf. Granet, 1, 2).

[c] Hawkes (1), p. 6, suggests that the essence of the innovation was the preponderance of pipes and flutes. Perhaps 'the mainly percussive music associated with the *Shih Ching* now gave way to a type of music dominated by various kinds of wood-wind'. This would have been mournful, erotic or languorous in slow movements, and rather excited or hysterical when fast—just the qualities which were criticised. Hawkes also associates the 'New Music' with the prosodic inventions of the Chhu Tzhu song style.

[d] *Lun Yü*, XVII, xviii; tr. auct. adjuv. Legge (2), p. 190.

[e] The parallelism between musical notes and ritual colours is evident, and just as some colours such as russet and purple are intermediate (*chien*[7]) between the five 'correct' spectral colours, so, it would appear, some notes are intermediate between the five 'correct' notes. Colours and sounds were described in Han times as 'tallies' (*fu*[8]). Lacking the prism and the optical ideas of the Renaissance the Chinese could hardly have arrived at Newton's analogy between the colours of the spectrum and the notes of the diatonic scale by measurement. What is remarkable is that in formulating a similar analogy intuitively, they chose correctly the three classical primary colours red, yellow, and blue. Where other peoples reached a total of five by including silver and gold or other 'false' colours, the Chinese included the two 'hueless colours' black and white to make their scale of five. Moreover yellow, which in fact occupies the middle of the spectrum, was regarded by the Chinese as the colour of the centre, the royal colour, which underlies all the others. That rainbows and the yellow earth of loess China may have assisted their thinking on these lines hardly detracts from the achievement. On the theory of synaesthetics in general, with a Chinese reference, see Ogden & Wood (1). Cf. p. 133 above.

[f] Hartner (7).

1 魏 2 鄭 3 衛 4 樂 5 歌 6 聲 7 間 8 符

Fig. 313

Fig. 314

Figs. 313, 314. An orchestra of heavenly musicians as imagined in the Thang period: frescoes from cave no. 220 at Chhien-fo-tung, near Tunhuang, painted *c.* +642. Besides the instruments which have appeared in previous illustrations and will easily be recognisable, we find the cymbals (*po*, cf. Moule (10), p. 24), the harp (*khung-hou*), the stand of metal plates (*fang-hsiang*), the true short lute (*phi-pha*) from Persia, and various hand-drums of Indian type. It is interesting that while the Chinese and Indian instruments are all played by spirits very lightly clothed in the manner of Buddhist apsaras, and some of dark complexions, the *phi-pha* and *fang-hsiang* players wear robes more Turkic or Persian in style. Anon. (*10*).

abroad, and not least in music.[a] We have already mentioned the playing of Japanese music at the court of Sui Wên Ti,[b] and the success of exponents of Indian music such as Tshao Miao-Ta[1].[c] This fascinating period has been the subject of a notable book by Hayashi Kenzō (*1*), translated into Chinese by Kuo Mo-Jo. The twelve ritual melodies of the Thang period which have survived have been carefully studied by Picken (4); all are in two heptatonic modes. Other scholars[d] have investigated the orchestras which played in the Thang[e] and Sung.

Levis describes[f] how the musical notations of Chiang Khuei[2] (+1155 to +1229), of the Sung dynasty, reveal that the scale was enlarged from its five- and seven-tone basis by cadential sharpening of one or two notes so as to comprise nine tones, in which the additional two were of an auxiliary nature. Chiang Khuei was certainly not alone in the use of these more complicated scales, and several other innovators departed from the traditional musical uses of their time. All the tunes of Chiang Khuei's *Yüeh Chiu Ko*[3] (Nine Songs for Yüeh)[g] of +1202 have now been fully transcribed and studied by Picken (5). As an example of the nine-tone scales actually used in Chiang Khuei's songs, we may quote the scale in C, where a microtone—*chê tzu*,[4] or turning-note, to give it Chiang Khuei's term—occurs between E and F. The scale then runs: C D E E³ F G A B♭. It would be a mistake, however, to believe, as Europeans frequently do, that Chinese music is characterised by 'quarter-tones'. The opposite is true; five-toned music is the rule, the use of semitones is met with, especially in the north, and microtones are quite exceptional.

(iii) *The twelve-note gamut and the set of standard bells*

The evolution of Chinese acoustic theory leads from the formation of scales in relative pitch to that of a gamut of notes of fixed or absolute pitch. The five-note scale *kung*, *shang*, *chio*, *chih*, *yü* may be compared to a movable doh scale in Western music, in

[a] On the general question of the musical relations between China and the West throughout the centuries, the valuable summary of Wang Kuang-Chi (1) may be consulted. Though foreign influences in China were many and great, Chinese music always retained its own very characteristic ethos, firmly fixed in appreciation and aesthetic.

[b] Vol. 1, p. 125, following Goodrich & Chhü Thung-Tsu (1). Twitchett & Christie (1) have translated the detailed and interesting account in *Hsin Thang Shu*, ch. 222c, pp. 9aff. of the Burmese orchestra presented to the court in +802.

[c] Vol. 1, p. 214.

[d] Yin Fa-Lu (*2*); Trefzger (1).

[e] We must not forget the remarkable representations of orchestras which are depicted on the frescoes at the Tunhuang cave-temples (cf. Figs. 313, 314). Reproductions and discussions will be found in Anon. (*10*), pls. 38, 39, 47, 48, 49 (for caves no. 172, 220 and 112); Phan Chich-Tzu (*1*), pp. 67, 104 (for caves no. 113 and 144); and Chhang Shu-Hung (*1*), fig. 12 (also no. 220). The composition is interesting. While instruments of the *shêng* (mouth-organ) and *chhin* (zither) types hold their own alongside the *phi-pha* lutes and a great variety of drums and cymbals, the bells and chime-stones of Confucian antiquity are conspicuous by their absence. A stand of metal plates (*fang-hsiang*[5]) deputises, however (Fig. 315). A prominent newcomer is the large yet portable harp (*khung-hou*[6]). At Mai-Chi Shan (e.g. in cave no. 51) the sistrum (*yün-lo*[7]), a hand-held framework of from three to ten tinkling cymbals (cf. Wang Kuang-Hsi (*1*), vol. 2, p. 52) is prominent, besides vertical flutes or pipes (*ti*[8]), in frescoes of the Northern Wei period.

[f] (1), p. 75.

[g] Contained in his *Pai Shih Tao-Jen Shih Chi Ko Chhü*[9] (Collected Poems and Songs of the White-Stone Taoist). Cf. Picken (1), p. 109; Yang Yin-Liu (*1*); Yang Yin-Liu & Yin Fa-Lu (*1*).

1 曹妙達　2 姜夔　3 越九歌　4 折字　5 方響　6 箜篌
7 雲鑼　8 笛　9 白石道人詩集歌曲

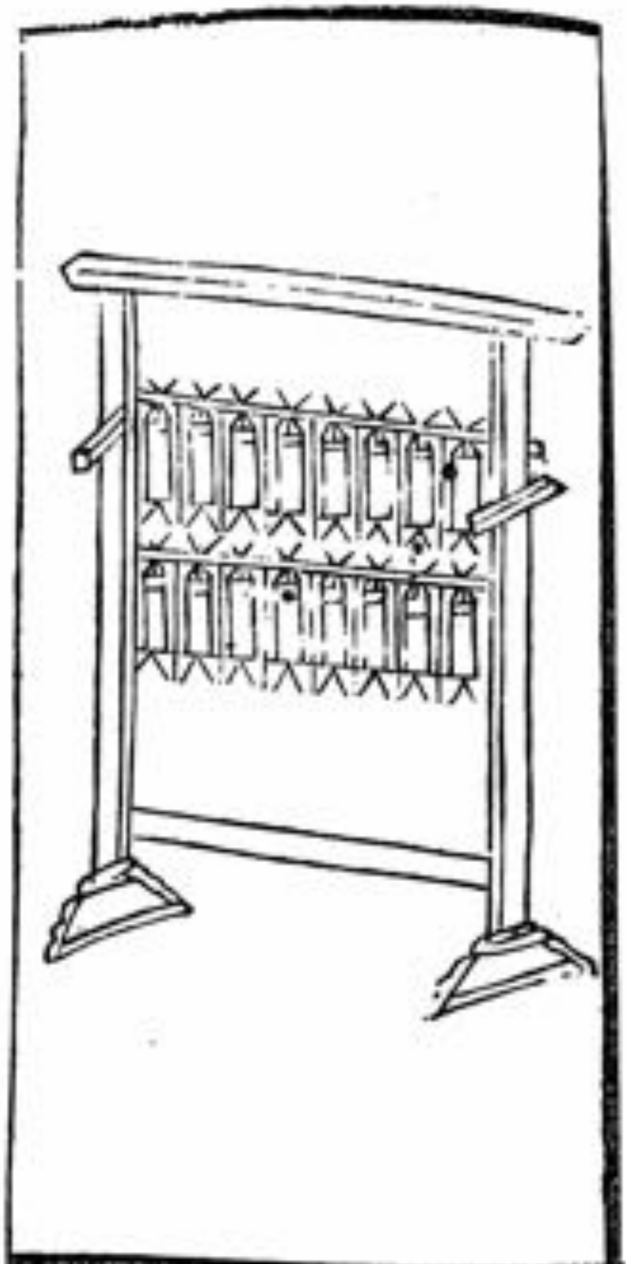

Fig. 315. The stand of metal plates (*fang-hsiang*), sixteen rectangular pieces of steel. From a Sung edition of Chhen Yang's *Yo Shu* (+11th century), cf. *Akhak Kwebŏm*, ch. 7, p. 14, *b*. Ma Tuan-Lin (*c*. +1300), classified the *fang-hsiang* as of foreign origin, like the *phi-pha*, quoting a Thang book, the *Ta Chou Chêng Yo* (see p. 193), as saying that it came in under the Hsi Liang (*Wên Hsien Thung Khao*, ch. 134 (p. 1195.1), cf. Moule (10), p. 145). The Western Liang State ruled in north-western Kansu during the first quarter of the +5th century.

which approximate equivalents would be doh, ray, me, soh, lah, in the standard or *kung* mode. But it would be misleading to press this analogy, for the movable doh system applies to a gamut in which the semitones are almost equal, and this is a fairly recent invention. In all major and minor scales the pattern of tones and semitones is identical, but the modes or patterns of our scales have been reduced, generally speaking, to two. Furthermore, a given note in one scale has exactly the same pitch or frequency in all other scales, no matter what the interval may be which it forms with other notes. For example, the note E may have a frequency of 644. It will have this frequency no matter whether it is regarded as a major third from middle C, or a minor third from C♯, or a major second from D, or any other interval. The pitches according to this system have been made identical for each key, the advantage being that a musician can now modulate freely from one key to another, without having to retune his instrument or adjust his playing to the altered pitch requirements of a different key.

This seems so obvious and desirable an arrangement today that we are likely to overlook its revolutionary nature and to forget the price which has been paid for the convenience, i.e. the sacrifice of some of the distinctive character between keys (cf. p. 215). In all early music these differed qualitatively, and still more so did the modes. Akin to this difference is that which we still appreciate in our major and minor.

The acoustic basis for the qualitative differences between keys in early music is as follows. There are certain musical intervals which are universally acceptable to the human ear; for example, the octave, the fifth and the fourth.[a] They are said to be 'just', when their frequencies form part of a series in arithmetic progression. If the frequencies of two sounds are in the relation of 1:2 they will form an octave; if of 2:3 a perfect fifth; if of 3:4 a fourth; if of 4:5 they will form a major third, and so on. Knowledge of this enabled the Greeks to calculate the pitch of strings of the same tension and thickness from their length, and had a decisive influence on the development of their acoustic theory. The 'just' intervals used in European music until the +17th century derived from Greek theory and were based on these proportions. In any scale, therefore, the frequencies of the octave, the fifth, the fourth and the major third were as just stated, while those of the minor third were as 5:6, of the major second as 8:9, of the major sixth as 3:5, and of the major seventh as 8:15. These are the proportions required for calculating diatonic scales[b] in just intonation. Given, for example, a fundamental note with a frequency of 200, its octave will be as 2:1, i.e.

[a] Everyone who has become personally familiar with Chinese music will have recognised the presence of a distinct 'melodic fund' quite different from that of occidental music, but just as pleasing aesthetically. As Picken (3) has pointed out, this is because in Chinese music the characteristic interval is always the fourth, and tunes are built up of chains of fourths, unlike European tunes, which are generally chains of thirds, though many Western folksongs were pentatonic. The watchword of Chinese music is 'order without mechanical symmetry', and while the West developed the harmony of simple melody, Asia developed complex melody. On the structure of Chinese instrumental music see von Hornbostel (2) and Picken (1), p. 125. In China music was never divorced from other activities, whether landscape painting, lyric poetry, alchemy or even mineralogy—thus the alchemical prince Ning Hsien Wang published in +1425 a famous collection of musical pieces using the entablature notation system (Picken (1), p. 118). Cf. on him, Vol. 3, pp. 513, 705 above. As for the connection between music and alchemy in the West, compare Read (2) and Tenney Davis (1) on Michael Maier (+1568 to +1622) and his *Atalanta Fugiens*.

[b] I.e. scales containing series of tones and semitones.

400; its perfect fifth will be as 3:2, i.e. 300. We may now compare the frequencies of two scales in just intonation, note for note, and see why it is that in this system the 'same' note, e.g. the note A, does not have the same frequency in the scale of D as it has in the scale of C. For this purpose the frequency of C will be taken to be 512. This represents an octave above middle C at 'philosophic pitch', by which reckoning an imaginary sound with a frequency of 1 is regarded as the lowest possible note, and middle C with a frequency of 256 as its eighth octave.

Table 46. *Frequencies of 'just' intervals in the scale of C major*

	INTERVALS IN JUST INTONATION CONSTRUCTED			
	from C as fundamental		from D as fundamental	
Notes	Frequency (vibrations/sec.)	Intervals (C to *x*)	Frequency (vibrations/sec.)	Intervals (D to *x*)
C	512			
D	576	Major second	576	
E	640	Major third	648	Major second
F	682·3	Fourth	691	Minor third
G	768	Fifth	768	Fourth
A	853·3	Major sixth	864	Fifth
B	960	Major seventh	960	Major sixth
C	1024	Octave	1080	Minor seventh

From Table 46 it is possible to see what intervals are formed by the different notes in the scale of C major with their fundamental note C, and their frequencies obtained by multiplying the frequency of the fundamental by the appropriate proportion; then by looking along to the same note in the right-hand column, to see the difference in frequency. The note E, for example, is a major third from C and a major second from D. Today we consider it to be the same note occurring in different keys, but in ancient times it was a different note, for the frequency of C multiplied by 5/4 is not the same as the frequency of D multiplied by 9/8. In just intonation, then, it was not possible to transpose a melody from one key to another, e.g. from C to D, without considerably altering its character, for the pitch relations within different keys are not identical.*

The musicians of ancient China were particularly sensitive not only to the obvious changes in character of music caused by the displacing of the semitones in heptatonic

* See Geiringer (1), p. 26. Cf. p. 216 below.

modes, and of the 'gaps' in pentatonic modes, but also to the subtler changes in character caused by transposition of a melody from one key to another within the same mode. Whether or not they were all used is uncertain, but there are references to sixty (pentatonic) and to eighty-four (heptatonic) mode-keys (*tiao*[1]). For example, in the *Huai Nan Tzu* book we have the passage already quoted[a] to the effect that if one has twelve notes of fixed pitch (*lü*), one can build on them the keynotes of sixty distinct mode-keys.

The heptatonic modes are familiar to the West under the names Dorian, Phrygian, Lydian, Mixolydian, Aeolian, Ionian and Locrian. Although there is no equivalent in classical Chinese for our modern debased and restricted conception of 'mode', the mode-keys were named in a simple and unambiguous way.[b] As Hartner says,[c] 'A method of indicating the shifting intervals of the five modes of the pentatonic scale...and of their eleven transpositions into all possible keys, was very conveniently obtained by combining the syllables of the ancient five-tone notation: *kung*, *shang*, *chio*, *chih*, *yü*, with the first syllables of the twelve *lü*, i.e. *huang*, *ta*, *thai*, *chia*, *ku*, *chung*, *jui*, *lin*, *i*, *nan*, *wu*, *ying*.' The names of the twelve *lü*[d] may be regarded as equivalents for our letters of the alphabet from A to G, including black notes. Thus where we are obliged rather awkwardly to say, for example, that a melody was in the key of C in the Lydian mode, the Chinese simply say 'the melody used *kung-huang*'.

So far we have followed the establishment of scales in relative pitch, which give a particular form to a melody regardless of the actual note on which it is pitched. But the existence of sixty or even eighty-four different scales, deriving from the five or seven different modes respectively, implies a fixed gamut of twelve semitones, such as is familiar to us on our keyboard instruments. Western manufacturers of these were faced with a dilemma. They wished to provide musicians with a keyboard capable of sounding all notes correctly for just intonation (which in theory means some eighty-four notes per octave) but they were physically unable to compress these into the natural span of a musician's hand. Chinese technicians were also dogged by the same dilemma, though it was not keyboard instruments that concerned them, but bells suspended on frames, a far more expensive and cumbersome proposition. Over 150 bells for a compass of three octaves would require the prowess of an athlete in the striker and the wealth of a prince in the purchaser. Of course, such elaboration was contemplated only in theory.

How the Chinese gamut of twelve notes came to be formed is intimately associated with the history of Chinese bells. In early orchestras they had a double use—for giving the pitch and for starting the music. As is said in the *Kuo Yü*:[e] 'Furthermore the bell does not (ring) false so we use it to lead off the notes (*chieh fu chung pu kuo, i tung shêng*[2]).'[f]

[a] P. 161 above.
[b] Cf. Chao Yuan-Jen (3).
[c] (7), p. 82.
[d] See p. 171 below.
[e] *Chou Yü*, ch. 3, p. 21*b*.
[f] A modern parallel for this practice is to be found in Indonesia. Sachs (1) has noted that 'when one asks for Javanese or Balinese tuning methods one is told that some old gong-founder owns a few highly respected metal bars inherited from a remote ancestor which he uses with more or less accuracy'.

[1] 調 [2] 且夫鐘不過以動聲

By the time of the Chou period at latest, the Chinese had advanced beyond the stage of striking lumps of ringing-stone or slabs of bronze which gave out the desired note by chance, and they were producing bells which they were able to tune with accuracy.[a] The earliest works frequently mention bells, their consecration with blood,[b] and their importance in musical performances. Often they have names, and the names are many and various. We can only guess at their meanings. Han commentators two thousand years ago also had to make such guesses. It is safe to say that the names were connected with the ceremonies in which they were used, the sympathetic magic of the name perhaps adding to the efficacy of the rite. Synonyms abounded; thus Lin-chung,[1] literally 'forest bell', is referred to in the *Chou Yü* passage just quoted as Ta-lin,[2] literally 'great forest'. Chêng Hsüan takes a bell named Han-chung[3] to be the same as Lin-chung, because in a list of pitch bells named in the *Chou Li*[c] its position in the sequence is that which would have been taken by Lin-chung some centuries later when the names of the instruments giving the fixed pitch scale had been standardised. The nomenclature of the gamut is complicated by such anachronistic interpretations of Han commentators, as well as by the general fluidity of names forming the system at the time when the gamut was being evolved. But the general process of evolution is fairly clear.

To accompany a singer in just intonation, or in any temperament other than Equal Temperament, on bells, would have required very large sets, but as we have seen the main purpose was to use bells for the initial note to set the pitch, or sound the keynote. Thus the most useful set of bells would in time be found to be one giving the gamut of twelve consecutive semitones which served as keynotes. It should not be imagined that this gamut ever functioned as a scale, and it is erroneous to refer to the 'Chinese chromatic scale',[d] as some Western writers have done. The series of twelve notes known as the twelve *lü* were simply a series of fundamental notes from which scales could be constructed.

It is not possible to say when the process of standardisation of bells and pitches was first completed, but the earliest reference in literature to the full set of twelve bells may be that in the *Kuo Yü*,[e] where they are mentioned in a discussion said to have taken place in the year −521.[f] Alternatively, if the *Yüeh Ling*[4] (Monthly Ordinances of the Chou Dynasty) really dates from as early as −600, the list in this text may take

[a] More will be said about actual tuning methods later (pp. 184ff.).
[b] Cf. *Mêng Tzu*, I (1), vii, 4; cf. Legge (3), p. 15.
[c] *Chou Li*, ch. 6, p. 12*a* (ch. 23); cf. Biot (1), vol. 2, p. 49.
[d] A chromatic scale is one composed of a continuous series of semitones.
[e] *Chou Yü*, ch. 3, pp. 21*b*, 26*a*ff.
[f] The High King of Chou whose name was Ching[5] wished to have a bell melted down and converted into another bell of lower pitch. His minister Shan Mu Kung[6] remonstrated with him, adducing many good reasons why this should not be done, one of the most compelling of which was that the smaller bell would not produce enough metal to make it. The sovereign, nevertheless, had his way and the bell was cast, but after his death it was found that in fact the bell was out of tune. The full list of bells with their names, qualities and definitions occurs in a conversation of this potentate with another of his acoustic advisers, Lingchou Chiu.[7] Cf. p. 204 below.

[1] 林鐘 [2] 大林 [3] 函鐘 [4] 月令 [5] 景 [6] 單穆公
[7] 伶州鳩

precedence.[a] Like bronze mirrors, bells were regarded in Chou times as instruments of high magical potency, their special merit being to attract or collect the emanations and essences generically known as *chhi*.[b] This *chhi*, it will be remembered, had six forms, Yin and Yang, wind and rain, darkness and brightness; the Yin and Yang being two antitheses into which all the others were in the last resort subsumed.

The types of bells naturally divided into two analogous groups, Yin and Yang. The *Kuo Yü* lists them as in Table 47.[c]

Table 47. *Classification of bells in the* Kuo Yü

Yang bells		Yin bells	
Huang-chung[1]	'yellow bell'	*Ta-lü*[7]	'great regulator'
Ta-tshou[2, d]	'great budding'	*Chia-chung*[8]	'compressed bell'
Ku-hsien[3]	'old and purified'	*Chung-lü*[9]	'mean regulator'
Jui-pin[4]	'luxuriant'	*Lin-chung*[10]	'forest bell'
I-tsê[5]	'equalising rule'	*Nan-lü*[11]	'southern regulator'
Wu-yi[6]	'tireless'	*Ying-chung*[12]	'resonating bell'

The names of these twelve bells thus stabilised became the names of the twelve notes which formed the classical Chinese gamut. The fact that the Yang scale is referred to in the *Kuo Yü* as pitches (*lü*), whereas the Yin notes are called *hsien*,[13] interstitials, i.e. notes which come between the regular pitches, strongly suggests that the standardised gamut of twelve semitones already existed at that date. No details are given in the text about the exact method by which the intervals were calculated, but the order in which the names appear represents an intermediate stage before their final form first recorded in the *Lü Shih Chhun Chhiu*[e] and a more primitive version of twelve pitches grouped in sixes which is preserved in the *Chou Li*.[f]

(iv) *The introduction of the arithmetical cycle*

In tracing the evolution of the gamut, three stages have been mentioned so far. First, there was the primitive stage preserved in the *Chou Li*, in which the notes had names,

[a] See Vol. 3, p. 195.

[b] In connection with the fancied relation between square earthly Yin bells and hollows, round heavenly Yang bells and mounds, etc., one may quote a Yüeh Ling commentary: 'Bells are hollows. The inside of the hollow receives *chhi* abundantly.' *Chhi* in subsequent acoustic theory is discussed below, pp. 202ff.

[c] *Chou Yü*, ch. 3, pp. 26bff.

[d] Also *Thai-tshou*.[14]

[e] Ch. 27 (vol. 1, p. 54); tr. Wilhelm (3), pp. 69ff.

[f] Ch. 6, pp. 11b, 12a (ch. 23); cf. Biot (1), vol. 2, p. 49. In concluding this subsection one can hardly avoid referring to the experiments in dodecaphonic music made in the present century by Schönberg, Webern, Alban Berg and others. It would be interesting to know whether the origins of this had anything to do with ancient twelve-note series such as that of China.

1 黃鍾 2 大簇 3 姑洗 4 蕤賓 5 夷則 6 無射
7 大呂 8 夾鍾 9 仲呂 10 林鍾 11 南呂 12 應鍾
13 閒 14 太簇

though some of them differed from those ultimately adopted.[a] Secondly, we have the twelve bells listed in the *Kuo Yü*, also divided into sixes, and here all the names agree with those of the ultimate orthodox gamut. We cannot say anything positive about the intervals of this gamut or the way they were arrived at, still less about the frequencies of any of the notes. But with the series of twelve notes described in the *Lü Shih Chhun Chhiu* about −240 a new stage is reached, for though the frequencies remain unknown, it at last becomes possible to see how the series of notes was obtained.

As this gamut of twelve notes bears certain resemblances to the so-called Pythagorean scale, the difference in construction between that scale and the Chinese is of great interest. The instruments on which the Greeks evolved their scales were the lyre and the cithara,[b] not, as in China, bells and ringing-stones. The framework of Greek scales was the octave made by tuning the two outside lyre strings, after which two inner strings were tuned to the intervals of the fifth and the fourth. In Homeric times all strings were tuned by ear. It was not until the −6th century that the quantitative discovery attributed to Pythagoras was made, concerning the half, two-third and three-quarter length strings needed if the octave, fifth and fourth were to be calculated. And the discovery that the interval of a major tone is that which lies between the fourth and fifth was not made until a century later by Philolaus.[c] There was then a parting of the ways in Greek music, one school, of which Aristoxenus of Tarentum was the leading exponent, maintaining that musical intervals should be judged by ear, the other, the Pythagorean, asserting that musical intervals were essentially mathematical. The mathematics of the Pythagorean scale, which are considerably more complicated than those of the Chinese gamut, and require a knowledge of means, were set forth by Plato,[d] though for metaphysical rather than musical reasons; and a full description of its most extended form was given by Euclid.[e]

The Chinese gamut of pitches, on the other hand, requires only the simplest mathematics and does not use the octave as a starting-point. Indeed, it does not even include a true octave at all. The only mathematical operation needed is the multiplication of certain figures by 2/3 and 4/3 alternately.[f] The frequency of a fundamental note multiplied by 3/2 produces a perfect fifth higher. Before the idea of frequency existed, however, the same relation was expressed simply in terms of length, the length of a resonating agent multiplied by 2/3 being equivalent to the frequency multiplied by 3/2. The length of a zither string, then, multiplied by 2/3 gives a note which when struck is a perfect fifth higher than its fundamental. This is the first step (or *lü*) in a process which evolves an unending spiral of notes. The length of the resonating agent which sounds the perfect fifth is then multiplied by 4/3, the resulting

[a] If indeed they were the same notes, though the possibility must be borne in mind that the passage describes two distinct scales in different registers.

[b] A lyre in which the sound-box cavity was continued into the arms, these also being hollow.

[c] See the (prob. +2nd-century) *Encheiridion Harmonices* of Nicomachus of Gerasa (Meibom's ed.), Bk. 1, pp. 13, 17, 27.

[d] *Timaeus*, 35B; Archer-Hind tr., p. 107.

[e] *Euclidis Introductio Harmonica* (Sectio Canonis), 'Canonem designare secundum systema, quod vocatur immutabile' (Meibom's ed.), p. 37.

[f] Cf. *Lü Lü Hsin Lun*, ch. 1, pp. 134ff.

note being a fourth below the perfect fifth, and therefore a major tone above the fundamental, since $1 \times 2/3 \times 4/3 = 8/9$, i.e. the same interval that Philolaus found by a different method to exist between the two tetrachords, e.g.

C — — — — F (tone) G — — — — C.

The Greeks used the interval of the tone as the basis of their scale structure, an octave being subdivided into a tone and two tetrachords, and a tetrachord being subdivided into two tones and a Pythagorean semitone or diesis. The Chinese did not become involved in the complications of the Greek semitones *apotomē* and *leimma*, but having advanced two steps from their fundamental note (the Huang-chung already referred to), went on to calculate a fourth note in the series by multiplying the length of the resonating agent of their third note by 2/3, which gave a length 16/27 that of the fundamental. This was their sixth. From the sixth a major third was produced by multiplying by 4/3, the product being 64/81. This note, it will be observed, is not justly tuned, for in just intonation the fraction would be 4/5, but it agrees with the Pythagorean major third. This process of multiplying by 2/3 or 4/3, whichever was required to keep the gamut within the compass of a single octave, was continued up to the twelfth note, these being the twelve *lü* (Fig. 316). The Chinese describe it as 'generation' (*shêng*[1]), the notes being like 'mothers' giving birth to 'sons'.[a] Notes produced by 4/3 multiplication were said to be of 'superior generation', while multiplication by 2/3 yielded 'inferior generation'. The *Lü Shih Chhun Chhiu* contains our earliest description (−239) of the system by which the notes of the Chinese gamut were generated.[b]

Our oldest source for any actual lengths calculated according to this 'up-and-down' principle is the *Shih Chi* (*c.* −90) of Ssuma Chhien. He is speaking of blown pipes, and gives the length of the Huang-chung pipe as 81 (tenths of an inch).[c] This is obviously a good figure to start from when one is calculating with 2/3 and 4/3 fractions. Correcting certain obvious errors,[d] the lengths of the pipes are given in Table 48. The actual lengths of these pitch-pipes are of no great value in themselves, for without further data, such as their diameters, we cannot calculate the frequencies obtained. But the manner in which these lengths are expressed is of great interest, for the use of a decimal system in conjunction with a system based on thirds has a strikingly Babylonian flavour.[e] To this point we shall return.

Before he lists the actual pitch-pipe lengths Ssuma Chhien gives the formula on which his calculations were based. It will be useful now to compare his proportions

[a] Cf. the Chinese terminology for arithmetical fractions, Vol. 3, p. 81.

[b] Ch. 27 (vol. 1, pp. 54ff.); tr. R. Wilhelm (3), pp. 69ff.

[c] Ch. 25, pp. 8bff. Chavannes (1), vol. 3, pp. 313ff. Cf. *Chhien Han Shu*, ch. 21A, pp. 3bff.

[d] See Robinson (1), pp. 44ff. and Chavannes (1), vol. 3, pp. 631ff. (Appendix II), where the errors are examined. They were first pointed out by the great Sung scholar Tshai Yuan-Ting[2] (+1135 to +1198) in his *Lü Lu Hsin Shu*[3] (New Treatise on Acoustics and Music), which is preserved in the *Hsing Li Ta Chhüan* (cf. Vol. 2, p. 459). On him see Forke (9), pp. 203ff. On the whole subject see further the paper of Yabuuchi (18), and Wu Nan-Hsün (1), pp. 73ff., 115ff., 264.

[e] Cf. Vol. 3, p. 82 for the use of the words *lü*[4] or *lü*[5] as 1/3. The *Shih Chi* in the present passage uses the more normal expression *san fên i*.[6]

[1] 生 [2] 蔡元定 [3] 律呂新書 [4] [illegible] [5] [illegible] [6] 三分一

for the notes of the gamut, twelve in all (to which a thirteenth, the octave, may be added by simply continuing the calculation an additional step), with the proportions of the eight notes of Timaeus' Pythagorean scale, so that their similarities and differences may be observed (Table 49).

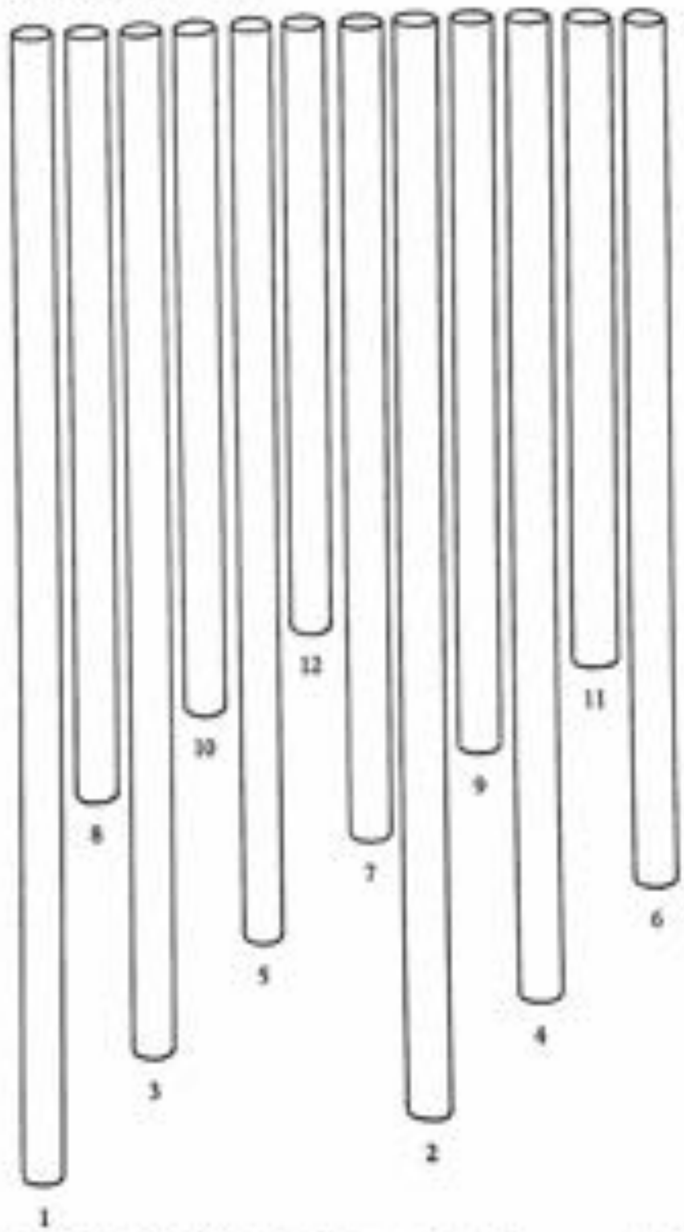

Fig. 316. The orthodox standard pitch-pipes drawn to scale. Reconstruction by K.R. to show the principle of superior and inferior generation. 1, *Huang-chung*; 2, *Ta-lü*; 3, *Ta-tshou*; 4, *Chia-chung*; 5, *Ku-hsien*; 6, *Chung-lü*; 7, *Jui-pin*; 8, *Lin-chung*; 9, *I-tsê*; 10, *Nan-lü*; 11, *Wu-yi*; 12, *Ying-chung*.

Like the twelve standard bells, the twelve pitch-pipes were also divided into two companies, Yang and Yin. Chêng Chung, commenting on the *Chou Li*[a] in the +1st

[a] Ch. 6, p. 16a, b (ch. 23).

Table 48. *Ssuma Chhien's calculations of the lengths of pitch-pipes*

Name	Inches	Tenths	Thirds of hundredths	Total (uncorrected)	Total (corrected)
Huang-chung	8	1	—	8·1	8·1
Ta-lü	7	5	1	7·53	7·585
Ta-tshou	7	2	—	7·2	7·28
Chia-chung	6	1	1	6·13	6·742
Ku-hsien	6	4	—	6·4	6·4
Chung-lü	5	9	2	5·96	5·993
Jui-pin	5	6	1	5·63	5·689
Lin-chung	5	4	—	5·4	5·4
I-tsê	5	4	2	5·46	5·057
Nan-lü	4	8	—	4·8	4·8
Wu-yi	4	4	2	4·46	4·495
Ying-chung	4	2	2	4·26	4·266

Table 49. *Comparison of the proportions of the Chinese and Greek (Pythagorean) scales*

	Chinese	Greek (Pythagorean)		Chinese	Greek (Pythagorean)
C	1	1	G	$\frac{2}{3}$	$\frac{2}{3}$
C♯	$\frac{2048}{2187}$	—	G♯	$\frac{4096}{6561}$	—
D	$\frac{8}{9}$	$\frac{8}{9}$	A	$\frac{16}{27}$	$\frac{16}{27}$
D♯	$\frac{16384}{19683}$	—	A♯	$\frac{32768}{59049}$	—
E	$\frac{64}{81}$	$\frac{64}{81}$	B	$\frac{128}{243}$	$\frac{128}{243}$
F	$\frac{131072}{177147}$	—	C	$\frac{262144}{531441}$	—
	—	$\frac{3}{4}$		—	$\frac{1}{2}$
F♯	$\frac{512}{729}$	—			

The notes in the left-hand columns are only arbitrarily selected by way of illustration.

century, says that the Yang pitch-pipes (*lü*[1]) were made of bamboo, but the Yin ones (*thung*[2]) of copper or bronze, the former material corresponding in the system of symbolic correlations to heaven, the latter to earth.[a]

It will be seen that the Pythagorean scale and the Chinese gamut (the spiral of fifths) are not identical, either in the general manner of their construction or in the particular proportions of certain notes, i.e. the octave and the fourth. Nevertheless, their resemblances were sufficiently striking to cause a misapprehension which has persisted for almost two hundred years.

(v) *Pythagoras or Ling Lun?*

The earliest account of the theoretical basis of Chinese music available in a European language is that written by the Jesuit Joseph Amiot in Peking in +1776, and published in Paris in +1780. Amiot accepted the traditional datings of Chinese history, and therefore believed that music in China originated in the year −2698. By this reckoning the Chinese would have had a gamut closely resembling the Pythagorean scale in many of its intervals more than eleven centuries before the birth of Pythagoras. He concluded that the Pythagorean claim for the invention of this scale was nothing less than an 'act of robbery'.[b] How precisely the plagiarism was carried out he did not explain, but assumed that Pythagoras, who was noted for his travels, must either have gone to China, or met someone from that country who transmitted the secrets of the scale. Noting that the Greek scale differed somewhat from the Chinese gamut, he concluded that the Greek version was a degenerate one.[c]

With the decline of China's prestige abroad during the 19th century, and the great revival of Hellenism, it was only to be expected that this judgment would be reversed. Chavannes, considering that there was no textual reference to the Chinese gamut earlier than the −3rd or −4th century, wrote:[d] 'Ce même système musical avait été exposé par les Grecs plus de deux siècles avant l'époque où les Chinois le connurent. N'est-ce pas aux Grecs que les Chinois l'ont emprunté?' And Chavannes attempted to explain how it was that the Chinese came to 'borrow' this acoustic system:[e] 'Sur la lourde vague de civilisation que l'expédition d'Alexandre avait fait déferler aux pieds des Pamirs surnagèrent les douze roseaux en qui chantait la gamme de Grèce.' Guesses of this sort take us no further forward than Amiot's mythology. Yet

[a] Biot (1), vol. 2, p. 56 has these materials interverted and should be corrected. The usual later name for the Yin pipes was *lü*.[3]

[b] Amiot (1), p. 8: 'l'Heptacorde des Grecs anciens, la lyre de Pythagore, son inversion des tétracordes diatoniques, et la formation de son grand système, sont autant de larcins faits aux Chinois du premier âge.' We find echoes of this point of view even today, e.g. in Hogben (1), p. 113, where he says: 'The Tyrian parentage of Pythagoras gives us a clue to the clear signs of Chinese influence in his teachings. He travelled in Asia.' And perhaps the work of Kuttner (3) will reopen the question.

[c] Cf. Robinson (1), pp. 48ff., who elucidates the part played by the Abbé Roussier in initiating the controversy.

[d] (1), vol. 3, p. 638.

[e] (1), vol. 3, p. 644.

[1] 律 [2] 筒 [3] 呂

they have been accepted for the last fifty years. For Amiot it may at least be said that in his day the scales were not regarded as identical, though since Chavannes loosely described them as 'ce même système' the mistake has spread.[a] Chavannes himself was aware that differences existed, but attributed them to lack of understanding by the Chinese, a people of whom, he adds in a conclusion unworthy of a great scholar, 'le caractère tapageur et monotone de leur musique est d'ailleurs bien connu'.[b]

Chavannes' hypothesis must be dismissed not merely because the Chinese were tuning sets of twelve bells in the same century as that which is said to have seen the lifetime of Pythagoras,[c] and in any case long before any possible influences of Alexander's expeditions could have brought the Greek formula into Chinese literature; but also because the Chinese gamut is in its structure essentially unlike the Pythagorean scale. Yet Amiot's notion that a transmission took place in the other direction at such an early date can no longer be taken seriously either. The simplest alternative hypothesis for which good reason can be found is that there radiated east and west from Babylonia the germ of an acoustic discovery which was developed in one way by the Greeks and in another by the Chinese; namely, that the pitch of notes emitted by strings when plucked is in part determined by their length. More particularly, the Babylonians, who had many highly developed stringed instruments, would have made the observation that one string half the length of another at the same tension will sound its octave, that a string two-thirds the length will sound its fifth, and that a string three-quarters the length will sound its fourth. Knowledge of these proportions is all that was needed to develop the Chinese 'spiral of fifths', and it is also the sum total of the acoustic discoveries which the ancient Greeks attributed to Pythagoras either as inventor or transmitter. The intricate developements of the Pythagorean scale in later centuries, which include the subdivision of the octave into tetrachords, the definition of the tone, and at some time not earlier than the −4th century, the subdivision of the tetrachords, are all specifically Greek discoveries; and for Timaeus' construction of a scale not by a series of perfect fifths, but by finding the arithmetic and harmonic means between the numbers of the Pythagorean *tetractys* (1 — 2 — 3 — 4 — 8 — 9 — 27), there is no Chinese equivalent.

It must be stressed that a Babylonian origin for these discoveries is hypothetical, for of Babylonian music we know very little. Yet such evidence as survives seems to indicate that this is the answer to the problem.

First of all, it is interesting and may be significant that both Greek and Chinese traditions gave credit for the origin of the acoustic systems to a foreign country. Greek authors writing before the capture of Babylon by Alexander the Great aver that Pythagoras visited Egypt,[d] while later authors say that in his travels he went to

[a] For example, Apel (1), p. 618, states categorically that the 'spiral of fifths' was 'invented by Pythagoras'. And even Chinese scholars such as Chao Yuan-Jen (2), p. 85, have been misled into thinking that 'the circle of fifths gives a Pythagorean scale'.

[b] (1), vol. 3, p. 642.

[c] Cf. the quotations from the *Kuo Yü*, above, pp. 151, 170.

[d] This is implied by Aristotle in *Metaph.* I, I, and is stated by Isocrates (*fl.* −380), in *Laud. Busir.* XI, 28.

Babylon.[a] Iamblichus goes so far as to say[b] that knowledge of the 'musical proportion'[c] was brought to Greece from Babylonia by Pythagoras. Certainly both Egyptians and Babylonians knew and used the 2/3 and 1/3 fractions.[d] Knowledge of the harmonic progression was enshrined by the Egyptians in the dimensions of a box described by the priest Ahmes in a papyrus in the Rhind Collection of the British Museum, dating from a time between −1700 and −1100.[e] But whatever the route by which the musical discoveries attributed to Pythagoras came to Greece, it is certain that they were based on facts long known to the world of the Fertile Crescent. As Burnet says,[f] 'The use of Babylonian as an international language will account for the fact that the Egyptians knew something of Babylonian astronomy.' Before Alexander's invasion such knowledge as the Greeks had of Babylonian science came to them by way of Lydia and Egypt. After the fall of Babylon it was realised that the fountain-head was in that city, and the legends were naturally adapted.

The story of Pythagoras' journey eastward to Babylon has a striking parallel in the legend of the westward journey of a certain Ling Lun, minister to Huang Ti, the mythical Yellow Emperor, who was supposed to have reigned for a hundred years in the −27th century. According to the legends various duties were assigned to the ministers of this ruler, and Ling Lun[g] was commissioned to establish the correct pitch for music.[h]

Anciently [says the *Lü Shih Chhun Chhiu*], Huang Ti ordered Ling Lun[1] to make pitch-pipes. So Ling Lun, passing through Ta-Hsia[2] towards the west,[i] travelled to the northern slopes of the Juan-yü[3] mountains,[j] and there in the valley of Hsieh-chhi[4] found bamboos with stems of which the hollow (part) and the thickness (of the walls) were uniform. Cutting one between the nodes to a length of 3·9 in.,[k] he blew it, and took its fundamental note (*kung*[5]) to be that of the Huang-chung tube. Blowing again, he said 'This is good enough',[l] and proceeded to make all the twelve pipes (*thung*[6]). Then at the foot of the Juan-yü

[a] This is first found in Strabo (*fl.* −25), XIV, 1, 16.

[b] *Fl.* +300 and later, *Introductio Nicomachi Arithmet.* pp. 141–2, 168 (Tennulius' ed.).

[c] In the musical proportion the second term is the arithmetical and the third the harmonic mean, e.g. 6:9::8:12, i.e.

$$a:\frac{a+b}{2}::\frac{2ab}{a+b}:b.$$

[d] See Heath (6), vol. 1, pp. 27ff.

[e] See Warren (1), p. 48.

[f] (1), p. 20.

[g] The name Ling Lun seems to be artificial, *ling* meaning music and *lun* a rule (Haloun, 6, 7). But this does not exclude the existence of a real person behind the legend.

[h] The fullest version of the story is given in the *Lü Shih Chhun Chhiu*, ch. 25 (tr. R. Wilhelm (3), pp. 63ff.), vol. 1, p. 49; but other references are quite frequent, as in *Chhien Han Shu*, ch. 21A, p. 4a; *Lü Lü Ching I*, ch. 8, p. 9b.

[i] It will be remembered that Ta-Hsia[2] was the ancient name for Bactria (many references in Vol. 1).

[j] The *Chhien Han Shu* text reads Khun-lun[7] here, i.e. the northern ranges of the Tibetan massif.

[k] This figure for the length of the fundamental pipe is very curious and has much exercised the commentators. The obvious emendation to 8·1 in. in accord with the *Shih Chi* has no authority and seems unlikely as a copyist's error. But the difference between the longest and shortest pitch-pipe is in fact 3·9 in. (8·1–4·2), and so is the length of the octave Huang-chung or thirteenth note, i.e. Chung-lü (5·9 × 2/3). The text perhaps became too compressed here.

[l] Here the text early became corrupt and commentators have never agreed on an assured version.

1 伶倫 2 大夏 3 阮隃 4 嶰谿 5 宮 6 筩
7 崑崙

mountains, he listened to the singing of the male and female phoenix[a] and divided the pitch-pipes accordingly (into two groups), the male notes making six and the female also six. In order to bring them together, the Huang-chung fundamental harmonised them. Indeed the Huang-chung fundamental (*kung*[1]) is capable of generating the entire (series). Therefore it is said that the Huang-chung fundamental is the source and root of the male and female pitch-pipes (*lü lü*[2]).[b]

Thus Ling Lun cut one of these non-tapering bamboo stems between the nodes to make his Huang-chung pipe, after which all the rest took their places in the series of twelve standard pitch-pipes. The *Lü Shih Chhun Chhiu* continues:

(Upon his return) Ling Lun, together with Jung Chiang,[3] was ordered by Huang Ti to cast twelve bells in order to harmonise the five notes (*i ho wu yin*[4]), so that splendid music might be made. It was on an *i-mao* day in the middle month of spring, with the sun standing in Khuei *hsiu*, that these were finished and presented. Order was given that this (set of bells) should be called Hsien chhih[5].[c]

This is of great interest as showing that all the other musical instruments were to be tuned in accordance with the pitch of the five notes emitted by the unaltering standard bells.

The truth enshrined in this strange story may be not only that in early times bells were used for giving the pitch to instruments in need of tuning,[d] but that the bells themselves were tuned[e] by strings, the lengths of which were determined by certain standard lengths of bamboo, just as the ratios of the octave and the fifth (which are in harmonic progression, e.g. 6:4:3) were preserved in the pyramid box or coffer described by the priest Ahmes. To keep certain bamboos of precise length as standard measures was a rational act for an early people, and foreshadowed our own practice of keeping standard measures in metal.[f]

No doubt the acoustic implications of the harmonic progression were not at first properly understood, for both in China and in Greece we find the formula for tuning strings applied in cases where it is quite inappropriate. Amiot, for example, says that he examined and measured some ringing-stones which he saw at the imperial court.[g] They had been made in the Sung period, and their four straight sides formed certain proportions of the *lü*, namely 27 in., 18 in., 9 in. and 6 in., which between them form octaves and fifths. Amiot observes that stone-chimes of more recent make no longer used these proportions. To shape a slab of stone so that its linear dimensions form octaves and fifths may have magical or possibly mnemonic uses, but represents a

[a] Cf. *Tso Chuan*, Duke Chuang, 22nd year (−671) where the male and female phoenix are said to sing together with gem-like sounds (*chhiang-chhiang*[6]); Couvreur (1), vol. 1, p. 179. Here the comparison is with chime-stones rather than pitch-pipes.

[b] Tr. auct. adjuv. Wilhelm (3).

[c] Tr. auct. adjuv. Wilhelm (3).

[d] Cf. p. 170 above.

[e] As will be shown later, p. 185 below.

[f] Cf. what was said above in Sect. 20g on the gnomon shadow template; Vol. 3, pp. 286ff.

[g] 'Essay on the Sonorous Stones of China' (an appendix to his *Mémoire*), p. 264.

[1] 宮 [2] 律呂 [3] 榮將 [4] 以和五音 [5] 咸池 [6] 鏘鏘

complete misapplication of acoustic laws, since the pitch of plates and of discs such as gongs is not determined in the same way as the pitch of elastic resonating agents such as strings and columns of air (cf. pp. 195, 213).

An even more curious application of the knowledge of the proportions required for producing musical intervals occurs in connection with details of foundry technique given in one of the later parts of the *Chou Li*, the Khao Kung Chi (Artificers' Record).[a] The passage, which will be studied in Section 36 on metallurgy, is one of the most venerable relics of the bronze-founder's art in any civilised literature, for it cannot be later than the −3rd century and may be a great deal earlier. It describes systematically the properties and uses of a whole series of alloys and defines the proportions of the metals composing them. Modern archaeological research has shown that such knowledge must have been possessed in considerable measure by the bronze-founders of the Shang period.[b] In any case it is curious to find that the proportions of a string required to sound the minor third, major third, fourth, fifth, major sixth and octave, namely 5/6, 4/5, 3/4, 2/3, 3/5 and 1/2, in just tuning, here appear in terms of copper content. How far the proportions of tin and copper in the making of the various vessels and implements is in accord with modern metallurgical knowledge on the one hand, and with what we can tell of ancient practice by analyses of alloys in existing specimens on the other, will be discussed in the appropriate place. The point here is the appearance of an acoustic series (if this set of simple fractions is not merely coincidental) in a metallurgical text.

That misapplications of harmonic laws were not exclusively Chinese, however, can be seen from an anecdote concerning Pythagoras. It was first recorded by Nicomachus of Gerasa[c] (*fl.* +100), and repeated by Iamblichus,[d] Boethius,[e] and others, to the following effect. Pythagoras, passing by a forge, heard the hammers ringing out to form the intervals of the octave, fifth, and fourth. After inspecting them he realised that this was due to the different weight of the heads of the hammers, which produced different notes according to their mass. He therefore made four similar weights the basis of his experiments, but no matter what he tested, strings by tension, vases by striking, flutes or monochords by measurement for length, he always found that the numbers 6, 8, 9, 12 formed the proportions of the consonances, 6:12 the octave, 8:12 the fifth, 9:12 the fourth. The statement that the consonances in the forge were produced by the proportionate weights of the heads of the hammers can no more be true than that the pitch of ringing-stones depended on the proportionate lengths of their sides. In Nicomachus' day this must have been fully recognised, for the acoustic properties of objects had long since been subjected to exhaustive tests. But that he and other experts should have repeated the story suggests that it was of respectable tradition, and inclines one to the belief that just as Thales used his partial knowledge of Babylonian astronomy to make some lucky predictions, so Pythagoras also may have

[a] On this see Vol. 1, p. 111. The passage referred to is in ch. 11, p. 20*b* (ch. 41), tr. Biot (1), vol. 2, pp. 490ff.
[b] Li Chi (3), p. 48.
[c] *Encheiridion Harmonices* (Meibom's ed.), Bk. 1, p. 10.
[d] *Vit. Pythag.* 1, 26.
[e] *D.* +524; *De Mus.* 1.

introduced a limited amount of Babylonian acoustic information which at first was not properly understood. But armed with the monochord for measuring intervals, the Greeks soon made progress far beyond a knowledge of those three consonances which we believe to have been their inheritance from Babylon.

The use of a sexagesimal cycle in calendar-making is very probably an example of Babylonian influence on China.[a] It is interesting to find that according to the legend, when Huang Ti sent Ling Lun to the west to fix the musical pitches, he entrusted Ta Nao[1] with the elaboration of the sixty-year cycle, and Jung Chhêng[2][b] with the redaction of a 'harmonious calendar',[c] as well as the division of the officials into five classes.[d] The association of the calendar with music is particularly significant, for we learn from a Western source that this also was Babylonian. Plutarch wrote:[e]

> The Chaldeans say that Spring stands to Autumn in the relation of a Fourth, to Winter in the relation of a Fifth, and to Summer in the relation of an Octave. But if Euripides makes a correct division of the year into four months of Summer, and of Winter a like number, of 'well-loved Autumn a pair, and of Spring a like number', the seasons change in the octave proportion.

The numbers which give these proportions are in fact spring 6, autumn 8, winter 9, and summer 12, the numbers used by Pythagoras for the musical consonances. From these proportions the seasons in Babylonia may be calculated as spring 2·1 months, autumn 2·7, winter 3·1, and summer 4·1. The fact that a brief spring and prolonged summer are more typical of Babylonia than of Greece enhances the value of this text.

It will now be convenient to summarise the present argument. The Chinese gamut is essentially different from the Pythagorean scale, though similarities led +18th-century writers to regard one merely as a degenerate form of the other. A more satisfactory hypothesis is that the Babylonians discovered the mathematical laws governing the necessary length of strings forming the octave, fifth, and fourth intervals. This knowledge spreading both west and east was used by the Greeks and the Chinese independently, the former for constructing their acoustic theory by subdivision first of the octave and later of the tetrachord, the latter for developing a spiral of notes by an alternating series of fifths and fourths from a given fundamental.

If this hypothesis is correct, it helps to explain why certain ideas are common to both Greeks and Chinese, and others not. The Chinese held, as did the Pythagoreans, that number is the basis of musical notes. Apart from the numerological cosmogonic passages in the *Tao Tê Ching*[f] and the *Huai Nan Tzu*,[g] the *Shih Chi* plainly declares[h]

[a] Cf. Vol. 3, pp. 82, 256, 397 above.

[b] Cf. Vol. 2, pp. 148, 150.

[c] References to these labours were collected by Chavannes (1), vol. 3, p. 323, but the most important study is that of Chhi Ssu-Ho (1); cf. Vol. 1, pp. 51 ff.

[d] These were designated by names of clouds coloured blue-green, red, white, black, and yellow, symbolising the four seasons and the 'mid-season'. Cf. Vol. 2, p. 238.

[e] *Moralia*, 'Creation of the Soul', 1028 F. See also the translation of John Phillips (+1694), p. 217, which, however, has many inaccuracies.

[f] Ch. 42 (Waley (4), p. 195).

[g] Ch. 3, p. 11b (Chatley (1), p. 23).

[h] Ch. 25, p. 11b; cf. Chavannes (1), vol. 3, p. 317.

[1] 大撓 [2] 容成

that 'when numbers assume form, they realise themselves in musical sounds (*shu hsing erh chhêng shêng*[1])'. Again, Sumerian harps occur with the bull, sheep or goat carved in their sounding boards,[a] while in China there was an association of the five notes with the five sorts of (domesticated) animals.[b] On the other hand, we do not find any theory of the harmony of the spheres in Chinese literature, and understandably so, for it was the child of Greek reasoning proceeding from the assumption that motion necessarily produces sound.[c] The Chinese, like the Babylonians, merely associated certain numbers with planets, and certain musical notes with numbers.

But the real reason why, starting from a common origin, Chinese acoustic theory took so different a road from that of the Greeks, must surely be that the Babylonian theory of proportions was applied to the music and the scales which actually existed in Greece and in China at the time, and naturally enough these were different, as also were the instruments on which the music was performed. The importance of the lyre and cithara in the history of Greek tuning is matched rather by the bells and stone-chimes of the Chinese than by any of their stringed instruments. In the need for tuning too, there was a world of difference, the former requiring constant adjustment and intimately associated with the pitch of the human voice, the latter immutable once out of the maker's hands.

There seems to have been a remarkable exchange of blown instruments between East and West in the centuries immediately preceding our era. The double-reed pipe or *aulos*[d] was used in Greece in classical, and the pan-pipes in post-classical times;[e] whereas in China the *kuan*[2] was known only in Han,[f] the pan-pipes (*hsiao*[3]) long before Han times. Pan-pipes are found today in a great arc stretching from north-west Brazil and Peru through Oceania across to Equatorial Africa,[g] a diffusion which indicates a very early origin. Von Hornbostel has suggested[h] that there was at one time a gamut of twenty-three *lü* or steps produced by over-blowing twelfths on a pipe

[a] Woolley (3), vol. 2, pls. 109, 111, 112.
[b] *Kuan Tzu*, ch. 58, p. 24; cf. Yin Fa-Lu (1). Indian parallels in the *Bṛhaddeśī* of Mataṅga-muni quoting Kohala (+1st century); Trivandrum Sanskrit series, no. 94, p. 13. Galpin (1), p. 59 gives a Sumerian one. Cf. Vol. 2, pp. 262, 263.
[c] Theon of Smyrna attributed the establishment of a relation between sound and speed to Lasos (*fl. c.* −500). The spheres were first suggested as a hypothesis by Eudoxus of Cnidus (−406 to −355), Plato's contemporary and associate (Berry (1), p. 28). We have already discussed them in relation to Chinese astronomical learning in Vol. 3, pp. 198, 220, etc.
[d] See Schlesinger (1).
[e] According to Galpin (1), p. 14, the pan-pipes were unknown in ancient Mesopotamia and did not appear in Egypt until the −4th century. In China the oldest mention of the *hsiao*[3] is no doubt in one of the *Shih Ching* odes which may be dated as of the −8th century (Mao, no. 280; Karlgren (14), p. 245 has 'flutes'; Legge (8) 'organ'; Waley (1), p. 218 correctly 'pan-pipes'). The mention in the *Shu Ching* (Historical Classic), ch. 5 (I Chi), tr. Karlgren (12), p. 12, with 'pan-flutes', will not be quite so old.
[f] The earliest reference seems to be that of Chêng Hsüan (+2nd century) who says: 'Two (pipes) are tied together and so blown; the present-day Office of the Grand Revealed Music uses it', *Chou Li Chêng I*, ch. 45, p. 13a. Cf. Robinson (1), pp. 116ff.
[g] For details of the distribution of pan-pipes see Schaeffner (1), pp. 279ff. on 'instruments polycalames'.
[h] In a highly controversial thesis. See the criticisms of Bukofzer (1) and the reply by Kunst (2).

[1] 數形而成聲 [2] 管 [3] 簫

and reducing by an octave. Since an over-blown fifth is slightly smaller (twenty-five cents) than a fifth measured mathematically on a string, twenty-three steps were necessary to form a more or less complete cycle comparable to the arithmetically calculated twelve *lü* of the Chinese. Though it is not very likely that such a cycle ever existed, it is conceivable that early pan-pipe tunings were made on the 'up-and-down' principle by which the Chinese generated their twelve *lü*.

The Babylonian discovery of the proportions of the consonances then became known in China. To a people striving for constant pitch in order that the music and its magical virtue might be retained for the reigning dynasty, the acquisition of this piece of mathematical knowledge must have been electrifying, for as Mencius says:[a]

> When the (sages) had used their power of hearing to the utmost they extended it by means of the six *lü* (mathematical proportions?) to determine the five notes; one cannot exhaust their use. (*Chi chieh erh li yen, chi chih i liu lü, chêng wu yin, pu kho shêng yung yeh.*[1])

And four and a half centuries later his words were echoed by one of the greatest Han experts on acoustics and music, Tshai Yung[2] (+133 to +192). In his commentary on the *Yüeh Ling* he wrote:[b]

> In determining the pitch of bells in antiquity they levelled off their notes by ear. After that when they could go no further they availed themselves of numbers and thereby made their measurements correct. If the figures for the measurements are correct the notes will also be correct.

This empirical and experimental use of number was a refreshing contrast to the numerological games and number-mysticism which fascinated so many scholars of the Chhin and Han.[c] No exact date can, of course, be given for the introduction of the Babylonian formula, but the above reference in Mencius coincides significantly with the development of the New Music to make the −4th century the later end of the bracket.

The conclusions here reached bear close similarity to those of Section 20*e* on astronomy. There it appeared[d] that in all probability the original body of Babylonian ideas and observations, spreading west and east, was developed in one way by the Greeks to form their ecliptic and heliacal system, while the Chinese developed it in quite a different way so as to evolve the polar and equatorial system with its lunar mansions and circumpolar key-constellations. Common origin of a few basic ideas followed by divergent development seems to have occurred in acoustics also.

[a] *Mêng Tzu*, IV, 1, (i), 5; tr. auct. adjuv. Legge (3), pp. 165, 166.
[b] *Yüeh Ling Chang Chü*[3] in *Li Chi Chi Chieh*, ch. 13, p. 64; tr. auct.; also quoted in *Hou Han Shu*, ch. 11, p. 18*a*, commentary.
[c] Cf. Vol. 2, pp. 287ff.
[d] Vol. 3, p. 256 e.g.

[1] 既竭耳力焉繼之以六律正五音不可勝用也 [2] 蔡邕 [3] 月令章句

(7) The Search for Accuracy in Tuning

The discovery that musical intervals are determined by mathematical ratios put the art of tuning on an entirely new basis. In Plato's *Republic* we can detect a certain contempt for the empirical experimentalist in sound:[a]

> 'As you will know, the students of harmony make the same sort of mistake as the astronomers; they waste their time in measuring audible concords and sounds one against another.' 'Yes', said Glaucon, 'they are absurd enough, with their talk of "sound-clusters" and all the rest of it. They lay their ears to the instrument as if they were trying to overhear the conversation from next door. One says he can still detect a note in between, giving the smallest possible interval, which ought to be taken as the unit of measurement, while another insists that there is now no difference between the two notes. Both prefer their ears to their intelligence.'

In the history of Chinese acoustics this air of condescending banter is fortunately absent. The musician or scholar with almost miraculous ability to detect small differences of tone was revered. Though un-Hellenic, this attitude bore good fruit in the world of practice.[b]

The Chinese, nevertheless, recognised the physical limitations of the ear, and used the measured steps of the *lü* as a check, as we have just heard Mencius say. Of course, tuning one bell against another by ear would simply lead to the sort of situation which moved Socrates to mirth, one 'expert' saying the two notes were exact, another declaring he could still detect a slight difference. Even if the word *lü* in Mencius meant 'pitch-pipe', that is to say a bamboo tube of such dimensions as to emit a desired note when blown, Socrates' objection would still apply, for only the ear could judge whether the note of a bell and that of a pipe were identical, and this would necessarily be a subjective judgment. The secret of the *lü* at this early stage, we believe, was the physical phenomenon about which so much has already been said in connection with the concept of *chhi*,[c] the 'humming-tubes' for canalising *chhi*,[d] and the interpretation of physical phenomena and human affairs[e]—resonance. If an instrument comparable to the monochord of Pythagoras was used, on which the measured steps, or *lü*, could be calculated mathematically, it would have been possible to tune a bell with absolute precision by means of this phenomenon. A string of measured length and tension being struck, if the proportions of the bell were correct a sympathetic note would be elicited by the string. If no note responded further rubbing and filing would be necessary till the bell's fundamental tone was perfectly tuned.

[a] 531 A. Cornford tr., p. 244.

[b] It is interesting that a form of the Chinese spiral or cycle of fifths has been used by piano-tuners in modern times, the interval of the fifth being, like that of the octave, one which can be fixed with tolerable accuracy by the ear alone. Cf. Closson (1), p. 117.

[c] Pp. 8, 32, 133ff. above, and, e.g. Vol. 2, p. 369.

[d] Pp. 135ff. above, and Vol. 2, p. 552.

[e] P. 129 above, and Vol. 2, e.g. pp. 282, 304, 500.

(i) *Resonance phenomena and the use of measured strings*

We have in fact evidence for the existence in Chou times of an instrument capable of serving this purpose. Commenting on the method of tuning bells mentioned in the *Kuo Yü*, Wei Chao[1] (+3rd century) states[a] that 'a board seven feet long (was used) having a string (or strings). They fixed them and so tuned.'[b] It is possible that by Wei Chao's time the principle on which this instrument functioned had been forgotten. His description is certainly far from clear, though he adds that the Office of the Grand Revealed Music of the Han possessed a *chün* or 'tuner'. Unfortunately, the text does not tell us whether one or more strings were used. But the great length of the instrument is interesting, for a long string would emit a good loud tone suitable for producing a sympathetic tone in a bell. Its great length would also make possible more accurate division of the string.

The *Kuo Yü* itself says:[c]

> We measure the pitches and (so) tune the bells (*tu lü chün chung*[2]). Every official can describe the principle (*pai kuan kuei i*[3]). We form the series using 3. We tune (the bells) using 6. We complete (the operation) at 12. (*Chi chih i san, phing chih i liu, chhêng yü shih-erh.*[4])

From this one may conclude that when the passage was written twelve bells made a complete set, divided into two groups of six, one Yang, the other Yin. That the series was formed 'using 3' refers to the denominator of the fractions used for calculating by 'superior generation' (4/3), and 'inferior generation' (2/3).

An interesting light on the art of tuning by resonance is given in the *Chin Hou Lüeh Chi*[5] of Hsün Chho[6] (*fl.* +312).[d] This says:

> The instrument for tuning the pitch of bells was neglected at the end of the Chou period. In the time of the Han emperors Chhêng (−32 to −7) and Ai (−6 to −1) many scholars devoted themselves to it, but it was again neglected by the end of the Later Han period.

The narrative goes on to describe how Tu Khuei[7] made efforts early in the +3rd century to tune the instruments according to ancient rules, not very successfully. But in the time of Hsün Hsü[8] (*d.* +289), some bells of about four centuries earlier were discovered in a provincial treasury, and it was possible to check them against pipes made with the help of jade measures of Chou time which had also been found.[e]

[a] *Chou Yü*, ch. 3, p. 26a; cf. p. 22a where the same statement is made using *chün*[9] and *hsien*.[10]
[b] *Chün chih chün chung, mu chhang chhi chhih yu hsien, chi chih i chün.*[11]
[c] *Chou Yü*, ch. 3, p. 26a, b; tr. auct.
[d] Quoted in the commentary of the +5th-century *Shih Shuo Hsin Yü*, ch. 20, p. 29b; tr. auct.
[e] An excellent account of the work of Hsün Hsü is given by Wu Nan-Hsün (1), pp. 145ff.

1 韋昭 2 度律均鐘 3 百官軌儀 4 紀之以三平之以六成於十二 5 晉後略記 6 荀綽 7 杜夔 8 荀勗 9 鈞 10 弦
11 鈞者均鐘木長七尺有弦繫之以均

Using the standard pitches they gave them their summons, and all (the bells) responded though they had not been struck (*i lü ming chih, chieh pu khou erh ying*[1]). The notes and the sympathetic tones (rhymes) agreed and became one (*shêng yin yün ho, yu jo chü chhêng*[2]).[a]

The *Thang Yü Lin* also gives an account[b] of how Tshao Shao-Khuei,[3] a great acoustic expert, once calmed the fears of a superstitious monk by his understanding of the principle of resonance. The monk had in his room a sonorous stone (*chhing-tzu*[4]) which seemed to produce sounds spontaneously. By filing off small portions of a bell in the monk's room which happened to be of the same frequency, and which was the cause of the trouble, Tshao altered the pitch of the bell so that the ringing-stone no longer responded to its note. Narratives of this kind are quite common in Chinese literature, and understandably so in view of the great philosophical importance of the idea of resonance to which attention has already been drawn.[c]

The search for accuracy in tuning may be traced back to the legend concerning Ling Lun's journey to the West for the rare bamboos. It has been suggested above that this legend could embody a good deal of literal truth if the bamboos which had been specially cut to the correct lengths were first used not for producing a sound by blowing, for which they would in fact be inaccurate,[d] but for measuring the correct distances on the strings of the tuner instrument (*chün*[5]), by which the bells were tuned. A feature of the Ling Lun legend is that on his return bells were tuned by means of the bamboos he brought back. But with such a perishable material doubt would naturally soon arise concerning the exact lengths required, since every time a fresh set was made errors would be liable to occur. With this background in mind one can understand the basis for a remarkable theory and technique which might otherwise be dismissed as pure nonsense.

(ii) *The cosmic tide in buried tubes*

How to verify whether tubes were of the exact length constituted a great problem. Bamboo tubes, as we saw earlier, had from ancient times been used for canalising *chhi*. One of the great manifestations of *chhi* was wind, and the winds of the eight directions were summoned each by its appropriate magical dance, led off by a note from an instrument made from one of the eight sources of sound. There was, therefore, a clear correlation between notes, winds, and directions. Probably no one was ever so simple as to hope that if bamboo tubes were pointed in the right direction the appropriate

[a] *Shih Shuo Hsin Yü*, ch. 20, p. 29*b*, comm., tr. auct. Another version of the story is given in *Sui Shu*, ch. 16, p. 11*a*, *b*.

[b] Ch. 5, p. 12*a*. Parallel stories in ch. 6, p. 6*a*.

[c] In the Section on fundamental ideas, Vol. 2, pp. 281ff., 304 above.

[d] The reason for the inaccuracy is that the effective length of a blown pipe is greater than the length of the pipe itself. The frequency of the note of a blown pipe with open ends equals the velocity of sound divided by twice the length of the pipe. But the effective length of the pipe, i.e. the length of its resonating air column, is its geometric length $+0.58D$, where D is the internal diameter. This is termed 'end-effect'. A vibrating string has no end-effect.

1 以律命之皆不扣而應 2 聲音韻合又若俱成 3 曹紹夔 4 磬子
5 均

wind would blow through them and sound the right note. But some ancient nature-philosophers set out to trap the *chhi* another way, that *chhi* which rose up from the earth combining with the *chhi* which descended from heaven to produce the different types of wind that blew at different seasons of the year.[a] In the words of the *Chhien Han Shu*:[b]

> The *chhi* of heaven and earth combine and produce wind. The windy *chhi* of heaven and earth correct the twelve pitch fixations (*chêng shih-erh lü ting*[1]).

Chhen Tsan[2] commenting[c] some time before the end of the +4th century on this passage says:

> The *chhi* associated with wind being correct, the *chhi* for each of the twelve months (causes) a sympathetic reaction (*ying*[3]) (in the pitch-pipes); the pitch-pipes (related serially to the months) never go astray in their serial order (*chhi lü pu shih chhi hsü*[4]).

Thus arose the strange practice termed *hou chhi*[5] (observing the *chhi*) or, more colloquially, *chhui hui*[6] (the blowing of the ashes). Perhaps the clearest statement of the principle of the technique was that of the Neo-Confucian philosopher Tshai Yuan-Ting (+1135 to +1198), notably expert in acoustics and music. In his *Lü Lü Hsin Shu* of about +1180 he wrote:[d]

> The (pitch-pipes) are blown in order to examine their tones, and set forth (in the ground) in order to observe (the coming of) the *chhi*. Both (these techniques) seek to (determine the correctness of the) Huang-chung tube by testing whether its tone is high or low, and whether its *chhi* (arrives) early or late. Such were the ideas of the ancients concerning the making (of the pitch-pipes)....
>
> If one desires to find the middle (i.e. the correct) tone and *chhi* without having anything available as a standard, the best thing to do is to cut several bamboos for determining the right Huang-chung length, making some shorter and some longer. Tubes are made for every tenth of an inch within their length range, with nine inches being taken as the (approximate) length standard for all, and circumference and diameter being measured (from this basis) according to the rules for making Huang-chung.
>
> If this having been done one blows them one by one, the middle (i.e. the correct) tone will be obtained, and if one sets them more or less deeply (in the ground), the middle (i.e. the correct) *chhi* may be verified. When its tone is harmonious and its *chhi* responds, the Huang-chung is really a Huang-chung indeed. And once it is really so, then (from it) may be obtained the (other) eleven pitch-pipes, as well as the measures of length, capacity and weight. Later generations, not knowing how to go about this, have sought (to construct accurate pitch-pipes) only by measuring with the foot-rule.

[a] A detailed study of the strange subject here to be unfolded has been made by Bodde (17). We are much indebted to Professor Derk Bodde for his kindness in sending us an advance typescript of this paper. Although our own account was already written we were thus enabled to round it out by several interesting additions.

[b] Ch. 21A, p. 4a, tr. auct.

[c] The family name of this commentator is not definitely known; see Yen Shih-Ku's preface to the *Chhien Han Shu*, p. 5b.

[d] Ch. 2, sect. 1. Contained in *Hsing Li Ta Chhüan*, ch. 24, pp. 2bff. Tr. Bodde (17), mod.

[1] 正十二律定 [2] 臣瓚 [3] 應 [4] 其律不失其序 [5] 候氣
[6] 吹灰

Commenting on this, Bodde says: 'Tshai's preference for mechanical trial-and-error rather than a mathematical formula is, one suspects, typical of a good deal of (medieval) Chinese scientific activity.' Experimentalists may feel that this is not unlike praise, though not so intended. In this particular context, it is true, we are dealing with proto-science, or even pseudo-science, rather than with science itself. But let us not forget that this distinction was far from being as obvious to the early Fellows of the Royal Society as it is to us, and that Kepler cast his own horoscope every year.

What now in concrete detail was the strange technique of 'watching for the *chhi*'? According to the classical account of it given by Tshai Yung, the method by which the length of the tubes was checked was as follows:[a]

> The standard practice is to make a single-roomed building with three layers (*san chhung*[1]) (i.e. concentric draught-proof walls). The doors can be closed and barred off (from the world outside), and the walls are carefully plastered so as to leave no cracks. In the inner chamber curtains of orange-coloured silk are spread out (forming a tent over the pitch-pipes), and certain stands are made out of wood. Each pitch-pipe has its own particular stand, set slanting so that the inner side is low and the outer side high,[b] all the pipes being arranged round the (circle of compass-)points in their proper (corresponding) positions.[c] The upper ends of the pitch-pipes are stuffed with the ashes of reeds, and a watch kept upon them according to the calendar. When the emanation (*chhi*) for a (given) month arrives, the ashes (of the appropriate pitch-pipe) fly out and the tube is cleared.

The *Hou Han Shu* adds a little more to this account:

> They rely on calendrical calculation and so await (the coming of the emanation); when it arrives the ashes are dispelled; that it is the emanation which does this (is shown by the fact that) its ashes are scattered. If blown by human breath or ordinary wind its ashes would remain together.[d]

That the results were not considered entirely satisfactory or convincing is suggested by later modifications described in the *Sui Shu*[e] in which the tubes were not simply held in stands, but buried in levelled earth so that only the ends were visible. It was then thought that the *chhi* emanation rising upwards like a tide from the Yellow Springs far under the earth would blow the ashes out of the longest tubes first, beginning with Huang-chung, each month a different tube being blown. The most interesting part of this strange experiment is the care which seems to have been taken

[a] Quoted from his commentary *Yüeh Ling Chang Chü*[2] in the *Li Chi Chi Chieh*, ch. 13, p. 6a; and *YHSF*, ch. 24, p. 31b, tr. auct. adjuv. Bodde (17). Parallel passage in *Hou Han Shu*, ch. 11, pp. 17b, 18a. Paraphrased in *Sui Shu*, ch. 16, pp. 10aff. tr. Bodde (17). Cf. *San Tshai Thu Hui* (+1607), Shih ling sect. ch. 1, pp. 14bff. and many other places.

[b] Thus the pipes all pointed towards the centre of the ring. An alternative interpretation of these words would mean that the pipes were partly buried.

[c] According to the system of symbolic correlations; cf. Vol. 2, pp. 261ff.

[d] The official history also informs us that within the palace twelve jade pitch-pipes were used and observations made only at the solstices, while at the Imperial Observatory there were sixty pitch-pipes of bamboo (cf. p. 169), with correspondingly more frequent observations.

[e] Ch. 16, p. 10a. This source reports (p. 11a) a noteworthy failure to make the method work, namely the experiments of Tu Khuei,[3] the famous musician (*d. c.* +223).

[1] 三重 [2] 月令章句 [3] 杜夔

to ensure that no ordinary wind could enter the sealed chamber.[a] A third formulation of the theory states[b] that all twelve tubes were blown twice a year, that is to say the *chhi* reached its waiting tube every fifteen days. The expression 'waiting for, or observing, the *chhi*' (*hou chhi*[1]) has an almost punning connection with the fact that the year contained seventy-two *hou*[2] of five days each, two making a *hsün*[3] and three a fortnight or *chhi*[4].[c] There was thus just room in the year for the sixty pitch-pipes of Ching Fang.[d]

The most extraordinary development came about the middle of the +6th century, when Hsintu Fang, the mathematician, astronomer and surveyor,[e] actually invented[f] certain rotary fans (*lun shan*[5]) which were fixed to the buried pipes so that they should rotate when the *chhi* blew out the ashes.[g] Further information as to the various forms of the technique may be obtained from Chin books still extant in fragmentary form,[h] e.g. the *Mei Tzu Hsin Lun*[6] (New Discourse of Master Mei)[i] which gives directions for preparing the ashes from the inner membranes of plants of the reed family. In a more sophisticated age scholars such as Chu Tsai-Yü (*b.* +1536)[j] and Chiang Yung

[a] This sealing is perhaps really the most significant technical feature of the whole story. The precautions against chance breaths of wind and other disturbances reached their greatest degree of elaboration by the middle of the +6th century. Besides the tent of orange silk, gauze covers were fitted for each pitch-pipe individually. According to the descriptions, the stands or holders for the pipes were rather like our retort-stands. And the walls were so arranged that the doors of the inner and outer walls were at the south, while the door of the middle wall was at the north. Thus there were imbricated corridors exactly as in modern photographic dark-room practice. These remarkable details of the pursuit of an essentially unreal phenomenon may be found in the commentary on the *Yüeh Ling* written by Hsiung An-Shêng[7] about +570, and in the *Yo Shu Chu Thu Fa*[8] (Commentary and Illustrations for the Book of Acoustics and Music), due to the eminent mathematician and astronomer Hsintu Fang,[9] his older contemporary. Hsiung's words (tr. Bodde, 17) are preserved in *Li Chi Chu Su*,[10] ch. 14, p. 74, and *Chin Shu*, ch. 16, p. 10*b*. Hsintu Fang's fuller account has only come down to us because it was preserved in the *Yo Shu Yao Lu*[11] (Record of the Essentials in the Books on Music and Acoustics) compiled about +670 by the celebrated Wu Huang Hou[12] (Wu Tsê Thien[13]), the empress of Kao Tsung, and later herself sole ruler. There it will be found in ch. 6, pp. 17*b*ff. It is quoted in full (more accessibly) by Hu Tao-Ching (*1*), vol. 1, pp. 325ff. Finally, a closely similar description was given by Chhen Yang in his *Yo Shu* of +1101 (ch. 102, pp. 4*b*ff.).

[b] *San Tshai Thu Hui*, Jen shih sect. ch. 9, p. 17*a*; see the diagram given by Robinson (1), p. 113.

[c] Cf. Vol. 3, p. 404.

[d] See p. 218 below. We have just seen that sixty pitch-pipes were used at the Han Observatory, hard though this is to believe.

[e] Often met with elsewhere, e.g. Vol. 3, pp. 358, 632. See above, p. 35.

[f] *Sui Shu*, ch. 16, pp. 9*b*ff. Cf. *TPYL*, ch. 871, p. 6*b*; tr. Pfizmaier (98), p. 43, and *Ku Chin Yo Lu*[14] (in *YHSF*, ch. 31, p. 8*a*, following *TPYL*, ch. 565, p. 8*a*). It is unfortunate that neither of his own fragmentary works (*Yo Shu* and *Yo Shu Chu Thu Fa*) make any mention of the rotary fans, nor can further light on them be obtained from any of his three biographies (*Pei Chhi Shu*, ch. 49, p. 3*b*, *Pei Shih*, ch. 89, p. 14*a*, *Wei Shu*, ch. 91, p. 13*b*).

[g] Perhaps they were small horizontally-rotating vane wheels like the zoetrope (see p. 123 above) or the helicopter top (Sect. 27*m* below). But the text clearly says that they were themselves buried in the ground, so it is difficult to visualise them. There were twenty-four of them so that there was one pipe for each of the fortnightly *chhi*.

[h] There is much in *TPYL*, ch. 16, pp. 2*a*ff., 5*a*, 7*b*, etc. This material, which needs special investigation, gives one the suspicion that the real originator of the method was Ching Fang (*fl.* −45, cf. pp. 213, 218 below), and that at first it had something to do with the practice of weighing 'ashes' to measure the humidity of the air (cf. Vol. 3, p. 471). Bodde (17) brings forward further evidence pointing to Ching Fang.

[i] *YHSF*, ch. 68, p. 30*a*.

[j] *Lü Lü Ching I*, ch. 1, pp. 117*a*, 127*b*.

1 候氣 2 候 3 旬 4 氣 5 輪扇 6 梅子新論
7 熊安生 8 樂書注圖法 9 信都芳 10 禮記注疏
11 樂書要錄 12 武皇后 13 武則天 14 古今樂錄

(*b.* +1681)[a] had no hesitation in dismissing the whole matter as unworthy of belief, 'erroneous and moreover unclassical'.

The development of a sceptical attitude towards the procedure of 'watching for the periodic arrival of the *chhi*', and finally, its frank rejection, raises points of considerable interest. When in +589 the emperor Sui Wên Ti commissioned Mao Shuang[1] and his colleagues to carry it out, and when later on they prepared their report on it, the *Lü Phu*,[2] there was no shadow of hesitation about the technique itself.[b] When the empress Wu wrote her book in the +7th century it was still firmly believed in. That Chhen Yang at the end of the +11th, and even the great Neo-Confucian philosopher Chu Hsi in the +12th[c] still accepted it, is not perhaps surprising. What is more curious, however, is that Shen Kua with all his scientific acumen also had no doubts, and gave instructions for making the process work.[d] By the Ming period, however, scepticism was rampant. Besides the scholars just mentioned, Hsing Yün-Lu[3] (*fl.* +1573 to +1620) made a devastating attack on the *hou chhi* practice about +1600 in his *Ku Chin Lü Li Khao*[4] (Investigation of the Calendars, New and Old).[e] After showing the scientific absurdity of the idea, he did not hesitate to accuse the astronomical-acoustic officials of purposeful deception, saying that they must have had some concealed mechanism analogous to the jack-work of clocks whereby the ashes were blown out of the tubes or the fans made to turn at the proper time. Bodde (17) has found two instances of attempts to use the technique not long before Hsing was writing, and these may well have been in his mind. One was connected with a court official named Chang Ê[5] (+1530 and +1539),[f] the other with Yuan Huang,[6] an acoustics expert, in +1581 or the following year.[g] There was scepticism at the time in both cases, but the second experiment was said to have been successful. Chiang Yung could not account for this, though he did not believe in it.[h] The interest of the whole story is that by the +16th century the procedure was being decisively rejected on scientific grounds. This is a rather striking demonstration of the fact that a rise of critical judgment on matters of natural science went on in the Ming paralleling (if not sometimes even preceding) that development of scientific scepticism which in Europe was the work of the scientific Renaissance. We shall find many other examples of this as we go on, notably among the pharmaceutical naturalists such as Li Shih-Chen (*d.* +1593). Such a parallel process cannot be without significance for the problem of why science in its distinctively modern form did not develop in China, and we shall return to it when in the end we come face to face with that grand enigma.

As for the pitch-pipes buried in the ground, and all their accompanying para-

[a] *Lü Lü Hsin Lun*, ch. 2, pp. 23*b*ff. Cf. Chang Chieh-Pin's *Lei Ching (Fu I)*, ch. 2, p. 14*b*ff.
[b] *Sui Shu*, ch. 16, pp. 10*a*ff. Opinions differed on the phenomenalistic interpretation of the results.
[c] *Chu Tzu Chhüan Shu*, ch. 41, pp. 20*b*, 26*a*.
[d] His remarks on the subject in *Mêng Chhi Pi Than*, ch. 7, para. 25 (cf. Hu Tao-Ching (*1*), vol. 1, pp. 325ff.) have been translated in full by Bodde (17).
[e] Ch. 33 (pp. 585ff., 528).
[f] See *Hsü Wên Hsien Thung Khao*, ch. 107, pp. 3747.1 and 3748.2.
[g] The episode is related in the preface of one of Yuan Huang's books, the *Li Fa Hsin Shu*, reproduced in Chiang Yung's *Lü Lü Hsin Lun*, ch. 2, p. 24*a*.
[h] *Lü Lü Hsin Lun*, ch. 2, p. 23*b*.

[1] 毛爽 [2] 律譜 [3] 邢雲路 [4] 古今律曆考 [5] 張鶚 [6] 袁黃

phernalia, was it not an archaic survival from the time when no one could distinguish cosmic magic from true science? And yet we are tempted to feel that there must have been some genuine natural phenomenon, even if only once observed, which sufficed to keep this strange technique living for a dozen centuries.[a] However that may be, no rational basis for the system can be suggested, but the following paragraphs will attempt to show what the need was which gave rise to it.

Let us summarise the semantic development of the word *lü* from its earliest beginnings. Probably it first meant the rule, regularity, or regulated step, in dancing. Secondly, when bells were tuned by resonance from the string of a 'tuner', the regularity of the *lü* would have been the measured steps or divisions of the string, i.e. the exact length of the string required for a given note, determined by the use of certain standard lengths of bamboo traditionally believed to enshrine the necessary proportions.[b] The discovery of these proportions would seem to have been Babylonian. Later on, a better understanding of the mathematics involved enabled the actual proportions of the *lü* to be preserved, and the scale to be reduced, so that the unwieldy 7-ft. tuner (*chün*) became obsolete.

Though knowledge of the mathematical formula guaranteed the relative proportions of the *lü*, and hence the relative pitch of the twelve notes in a cycle of fifths, it did not guarantee their absolute pitch, if the absolute lengths of the *lü* (measuring-rods) were still in doubt.[c] In an attempt to discover their absolute lengths as well as to check their proportions, a set of tubes was cut, it would seem, resembling the humming-tubes used by the *wu* shaman for canalising *chhi*. It was supposed that if the tubes were of the right length, each one with its opening so many inches above or below the ground according to the method used, the ashes would be blown out of the tube at the exact instant that the *chhi* reached that point. The *chhi* was thought of as ebbing and flowing like an annual tide, and therefore it was supposed that its exact distance from the earth's surface could be calendrically calculated.

In spite of its long persistence, this practice naturally never gave the results sought, and in the third stage we find *lü* used in a new sense. The generic word for a flute or pipe was *kuan*.[1] The standard lengths of bamboo having reassumed their canalisation function first as '*chhi*-detectors' planted in the earth, and then, by an easy transition, as blown pipes comparable to the '*chhi*-detectors' of the *wu* shamans, became in the third stage simply *lü-kuan*[2] or pitch-pipes.[d] Since the formula by which the pro-

[a] Early experimentation with vents of natural gas has been suggested, but it seems very improbable.

[b] It is to be noted that though the *Shih Ching* is one of our earliest reliable texts, and abounds in references to musical instruments and the need for their being properly tuned, the character *lü* is never used in it in the sense of 'pitch-pipe'. Evidence was marshalled by Chavannes (1), vol. 3, pp. 638ff. to show that before the −4th century *lü* were always bells, not pitch-pipes. Cf., however, Yabuuchi (18).

[c] Of course, the medieval Chinese did not think in terms of a continuous band of wave-frequencies, but they were aware that the pitch of the Huang-chung note had varied from dynasty to dynasty, just as we are aware that middle C today is considerably higher than it was in Elizabethan times.

[d] On the significance of the term *kuan* see *Lü Lü Ching I*, ch. 8, pp. 4aff.; *Lü Hsüeh Hsin Shuo*, ch. 1, p. 17a; *San Tshai Thu Hui*, Chhi yung sect. ch. 3, p. 15b, and many other authorities discussed in Robinson (1), pp. 126ff.

1 管　　2 律管

portionate lengths of string of the 'tuner' were calculated worked reasonably well for pipes, the *lü*, now meaning pitch-pipes, were, at least from Han times, the orthodox devices for giving the pitch to other instruments. Nevertheless, their adoption for this purpose, and the respect in which they were held on account of the undoubted antiquity of the *chhi*-detecting tubes, and of the whole concept of regularisation summed up in the word *lü*, focused men's attention on the acoustic properties of pipes, which will be considered below.[a] In the meantime it is worth noting that the only really general translation of the word *lü* in its acoustic sense is 'pitch-giver'.[b]

(iii) *Tuning by means of hydrostatic vessels*

There were, however, other methods of tuning instruments which first deserve consideration. We have already noticed[c] the interest which the Chinese (like the Alexandrians) took in hydrostatics, and among their oldest observations must have been the variation in acoustic properties caused by the filling of vessels to varying extents. One of our oldest accounts is that given by Kan Pao[1] (*fl.* +320) in his commentary[d] on a sentence in the *Chou Li*.[e] This sentence says: 'With the metallic instrument *chhun*, the note is given to the drums (*i chin chhun ho ku*[2]).' Chêng Hsüan's commentary on this is merely that this metal instrument is shaped like the end of a pestle, being wider at the top than the bottom, and that music causes it to emit a ringing sound. It associates with the drums and they sound together. But Kan Pao enlarges as follows:

> Water is filled in (to the *chhun*) to a height of one foot above the ground, and a container is filled with water and put underneath. The *mang*[3] (an apparatus on which strings were set) is placed between them. If the *mang* is shaken by hand, a tremendous noise like thunder is produced.[f]

The Chinese fully exploited the possibilities of water in relation to tuning, with its great advantage, precise control over microtonic adjustments by the addition or removal of small amounts of water.[g] 'In Thang times', we are told, 'bowls (were used) containing water; they added to it or diminished it, and thereby tuned the notes of the scale.'[h] The use of pottery vessels without water in them as musical instruments

[a] Pp. 199, 212ff.

[b] It will be seen that this is closely related to the normative significance of the word in its juridical sense; cf. Vol. 2, pp. 550ff.

[c] P. 34 above. See also our account of clepsydra physics, Vol. 3, pp. 313ff.

[d] Quoted in the *Kuang Chhuan Shu Po*,[4] a Sung book by Tung Yu,[5] ch. 2.

[e] Entry for 'Drumming Personnel' (Ku Jen), ch. 3, p. 36a (ch. 12); tr. Biot (1), vol. 1, p. 266; Kan Pao's commentary tr. auct.

[f] For one of the rare statements on the *chhun*, see Hsintu Fang's *Yo Shu*, in *YHSF*, ch. 31, p. 20a. As may be seen from Fig. 317, it normally faced upwards and had a tongue suspended from a crossbar. Archaeological evidence collected by Umehara Sueji (1) indicates that the *chhun* has affinities with the bronze drums of the Dôngsôn culture, and was probably introduced from Indo-China during the Han.

[g] As in the counterpoised cylinders rising and sinking in water, familiar as 'resonance tubes' in elementary textbooks of physics.

[h] Wu Jen-Ching & Hsin An-Chhao (1), p. 32. It will be remembered that the characters of the terms used for 'high' and 'low' sounds, *chhing*[6] and *cho*,[7] use the water radical.

[1] 干寶 [2] 以金錞和鼓 [3] 芒 [4] 廣川書跋 [5] 董逌
[6] 清 [7] 濁

is undoubtedly of great antiquity in China.[a] There is, for example, the famous reference to the behaviour of Chuang Chou at the death of his wife, making music by drumming on a bowl.[b] Pots were also used as primitive drums, first by themselves and later with a skin stretched over the top. Li Ssu of Chhu, a minister of Chhin State (−3rd century), referred disparagingly to the indigenous music of Chhin as 'beating on earthen jugs and knocking on jars'.[c] This was not, however, peculiar to Chhin, but merely represented a more primitive phase of music which had at one time been known to the Chinese of the central States, for in the *Shih Ching* the first ode of Chhen[d] speaks of the drummer on the mound beating his earthenware jars (*fou*[1]).

Fig. 317. The *chhun*, a bronze bell of elliptical section, wide at the mouth and narrowing towards the round base, suspended by a loop usually, as here, in the form of a tiger (*Ahhak Kuebôm*, ch. 6, p. 24*b*). Like the *ling*, it had a tongue, but hung from a crossbar as the *chhun* was open upwards. *Chhun* filled with various amounts of water were sometimes used for tuning purposes.

The *Ta Chou Chêng Yo*[2] mentions a set of eight tuned earthen vessels,[e] invented by Ssuma Thao[3] of the Thang period in +765 and presented to the throne. Other later sources speak of eight vessels (*shui chan*[4]) which were put on a table and struck.[f] If Ssuma Thao filled his vessels with different amounts of water, as seems very probable, he was a pioneer of this method.[g] For soon afterwards we have a clear account of sets of vessels tuned by the addition and removal of water; the details are given in the +10th-century *Yo Fu Tsa Lu*.[5] Tuan An-Chieh there says[h] that in the year +847 Kuo Tao-Yuan,[6] an official of the Bureau of Music,

> used (a set of) vessels (*ou*[7]) of Hsing[8] and Yüeh[9] twelve in number, in which the amount of water was increased or diminished (to tune them); when struck with sticks the vessels gave out sounds better than those of the metal plates (*fang-hsiang*[10]).

Later in the same century (*c.* +870) Wu Pin[11] was also known as a master of this method.

Wooden as well as earthen bowls were used for tuning purposes, and accounts survive of the wonderful skill with which these bowls were made, so that the rim

[a] A number of quotations are collected in *TPYL*, ch. 758, p. 14, *b*.
[b] *Chuang Tzu*, ch. 18; tr. Legge (5), vol. 2, p. 4; Waley (6), p. 21.
[c] *Shih Chi*, ch. 87, p. 5*a*; tr. Bodde (1), p. 19.
[d] Mao, no. 136; tr. Karlgren (14), p. 87; Legge (8), p. 153.
[e] In *TPYL*, ch. 584, p. 4*a*; the book is probably of Thang date.
[f] See *KCCY*, ch. 47, p. 12*a*.
[g] Cf. p. 38 above on the iron vessels with very smooth flanges studied by Li Kao and Li Yuan in the +8th century.
[h] P. 14*a*. This record, written after the end of the Thang period, is quoted in shortened form in *TPYL*, ch. 584, p. 4*a*.

[1] 缶 [2] 大周正樂 [3] 司馬滔 [4] 水盞 [5] 樂府雜錄
[6] 郭道源 [7] 甌 [8] 邢 [9] 越 [10] 方響 [11] 吳蠙

was perfectly even and level.[a] The *Thang Yü Lin*[1] describes a wooden bowl (*chhüan*[2]) which fitted so closely to a smooth lacquer plate that even when inverted full of water none flowed out. It was said that this bowl was used for tuning notes, and that strings so tuned could remain in tune for one month.[b] 'But', as the writer sadly remarks, 'wooden bowls today cannot compete with that old one.'

To summarise the evidence concerning this method, empty earthen pots were used as drums in very early times, and then perhaps in the Han period, and certainly in the Thang, were adapted as tuning devices by being filled with varying amounts of water. The use of water for testing the measurements of standard vessels of capacity, which has already been mentioned,[c] suggests a possible connection.

(iv) *The manufacture and tuning of bells*

The tradition of bell-making in China is so old, and the part which bells played there in music and the tuning of instruments is so important, that the art of the Chinese bell-founders deserves careful study.[d] Description of the processes involved requires the use of various technical terms, so it will be as well to begin with a description of bells in general, and to compare their evolution in Europe and China.

Galpin tells us[e] that some early European bells were formed in four-sided shape, with a ring or handle, by folding or riveting iron plates together and then brazing or bronzing them. As an example he cites St Patrick's Clog of about the +6th century, which is 6 in. high, 5 in. broad, and 4 in. deep. Though this construction was primitive, the Clog represents an advanced stage in campanological evolution, and has taken over features worked out in the course of centuries in China, such as the use of a clapper, the downward pointing mouth, and a suitable means of suspension.

Yetts suggests[f] that the evolution of the bell in China was on the following lines. The small hand-bell named *to*[3] (Fig. 318), with a barrel (in the earliest examples) of diameter greater than its height, was probably the ancestor of all Chinese bells. It was normally held with the mouth uppermost.[g] When the mouth of the *to* began to point downwards the hanging clapperless bells called *chung*[4] (Fig. 319) came into being.[h] Bells with clappers (the generic name for which is *ling*[5]) developed later.

An intermediate stage in the development of the clapper is surmised. The *to* described by Yetts (5) has no means by which a clapper could be suspended inside it. In the earliest times such bells were doubtless struck with a stick or hammer on the

[a] Cf. Sect. 26*c* (p. 38 above).

[b] *Thang Yü Lin*, ch. 5, p. 26*a*. These methods were associated with the names of Li Kuei-Nien,[6] one of three brothers all famous in music and dance in the Khai-Yuan reign-period (*c.* +720 to +735), and his disciple Jen Shih-Chün[7] (*d.* not long after +782).

[c] P. 40. Cf. pp. 199ff. below, esp. p. 201; and Vol. 3, pp. 471ff.

[d] Cf. Moule (10), pp. 35ff.

[e] (2), p. 42.

[f] (5), pp. 78ff.

[g] The normal position of a bell can, of course, be inferred from the ornamentation and the direction of the inscriptions. Cf. p. 200 below.

[h] See Koop (1), pl. 23, showing such a bell of the Chou period, and pl. 42. The former is reproduced in Fig. 319. The earliest dated bell of this type is connected by an inscription with the High King Mu of the Chou, and thus of the −10th century.

[1] 唐語林 [2] 棬 [3] 鐸 [4] 鐘 [5] 鈴 [6] 李龜年
[7] 任使君

Fig. 318. Clapperless upward-facing hand-bell (to). Chou period. Winkworth Collection (photo. Koop). Height 17 in.

Fig. 319. Clapperless downward-facing hand-bell (*chung*). Chou period, perhaps as early as the −4th century. It bears an inscription saying 'The Elder of Hsing in Ting (district) has made this bell, named Mysterious Harmony, with the note Jui-pin, for use'. Victoria and Albert Museum (photo. Korp). Height 22 in.

outside surface. But some *to* have four grooves running down near the two lateral edges at the top of the bell, and Yetts suggests that splints of bamboo may have been secured in these grooves, each so bowed back that its other end could be fixed in the groove opposite, thus forming a crossed splint over the mouth of the bell. From this a clapper could have hung down inside when it was held in the early upward-pointing position. The later clapper arrangement would then be a modification of this suitable for a downward-pointing mouth.[a]

Developments such as these, which had to take place in the evolution of the bell before it could be satisfactory merely as a noise-making instrument, had in fact been accomplished in China during a period of some thousand years, by the −5th century or earlier. But to make the bell an instrument of music it had to be properly tuned and this is regarded even today as a highly intricate matter. The bell, as Helmholtz said,[b] is a variety of curved metal plate. In both plate and bell the vibration frequency increases with the thickness and elasticity of the metal, changing in inverse ratio to the diameter and the specific gravity. For a given pitch and good tone quality a bell-maker must thus consider the nature and proportions of the metals used,[c] the profile, i.e. the inner and outer contours of the bell and the space between them,[d] the amount of metal needed to fill this, its temperature on pouring, and the rate at which it cools. But the required musical quality may still elude him, for the slight tolerances inevitable in mould-making and casting fall short of the necessary precision. The bell must then be brought to specification by removing small amounts of metal so as to thin it slightly in certain places.[e] This corrects the fundamental frequency, and brings several partial tones (often very noticeable, and liable to be dissonant) into consonant relationship with it.[f]

[a] As to the general question of the Asian origin of European bells and church-bells, which has been raised by Feldhaus (1, 16, 17, 20), Lynn White (1), p. 147, and others, it is at least certain that, since bronze bells were being made in the Shang period (−14th century), Chinese campanology is extremely ancient. Adequate comparisons of these bells with those of Babylonian and Hellenistic times have yet to be made, but it seems sure that during the −1st and +1st millennia the art of bell-founding in China was much more advanced than it was in Europe or the Middle East. Small round downward-pointing Assyrian harness-bells of the −7th century in cast bronze up to 4 in. high with hanging clappers of soft iron are in the British Museum, and a number of similar Roman examples of the +1st and +2nd centuries have been excavated, but none exceed 8 in. in height. As late as +1000 no bell more than 2 ft. high had been seen or heard of in Europe, though some were by then of fine workmanship, such as the Mozarabic Christian bell of Córdoba (+961). But the bell at Phing-ting in Shansi, an iron-casting of +1079, was already four or five times this size. Perhaps for once China taught Mesopotamia in high antiquity.

[b] Cf. Geiringer (1), p. 52.

[c] Most bells, both in China and the West, were always of copper–tin alloys (bronzes), but the Chinese early employed cast iron (cf. Needham, 31, 32).

[d] Western bell-founders have divided the side of the bell into four zones, the English terms being the 'lip', close to the rim; the 'sound-bow', the greatly thickened part just above, where the clapper strikes; the 'waist', most of the remaining flank; and the 'shoulder' at the top of it. We shall see that the Chinese bell-founders made similar distinctions, though we cannot take them to be exactly the same because of the different profiles of Chinese bells.

[e] There is evidence of this on both Chinese and Western bells.

[f] Modern European founders who practise this tuning control five frequencies in a bell. The English names of these, exemplified for a bell sounding C^1, are as follows: 'hum-note', C; 'fundamental', C^1; 'tierce', $E\flat^1$; 'quint', G^1; and 'nominal', C^2. Bells also have the peculiarity of producing another note which is solely aural, and cannot be picked up on any acoustical instrument. This is called the 'strike-note'. On untuned Western bells it lies close to, but just off, the fundamental; on tuned bells it agrees with the fundamental and reinforces it. The harmonics are excited by striking particular zones of the bell's periphery and tuned by adjusting others.

Chinese practice may now be considered as it is described in the *Chou Li*, though it must be borne in mind that this may represent the ideas of Han scholars on the art of bell-making, possibly a very different thing from the practical rule-of-thumb traditions of actual foundrymen. But even if the information is not strictly accurate, it is still of value in showing the awareness of the Chinese in early times of the many factors involved in the tuning of bells.

The entry on the bell-makers (Fu shih [1]) in the *Chou Li* [a] begins by naming the different parts of the bell. From the rim at the mouth to the loop or handle at the top the surface is divided into four zones. That nearest the rim is called the *yü*,[2] a word which is also used in the *Chou Li* meaning 'to chant'. Above this comes the zone called *ku*,[3] i.e. 'drum'; Chêng Chung [4] (*fl.* +50 to +83) says that this part is the strike-point (*chi-chhu* [5]). More accurately, however, the struck zone, termed *sui*,[6] is inside, and this is said to mean 'mirror' because the curve is concave like a burning-mirror.[b] Above this comes the part of the bell with straight cylindrical walls, as the name *chêng* [7] implies.[c] The fourth and highest zone is called *wu*,[8] which means 'dance'. No commentator offers any explanation of this term. In many bells the zones are separated by narrow bands embossed with studs of metal.

The author of this description then attempts to define the necessary proportions of the bell. He takes as his unit one-tenth of the distance formed by the two horns or points on its rim at the extremities of its oval circumference. To construct a bell after his pattern one would need to know the total height and both the long and short diameters of the zones at different specific points, the height allotted to each zone, the thickness of the metal and its weight, and details concerning the clapper if one was to be used.[d] The thickness is given as one unit, and a few of the diametrical proportions are given, but as a whole the information which has come down to us is quite inadequate. It may have been that the writer wished to give a formula covering all types and shapes of bells, and finding that impossible just set down such items as he believed to be of general validity. But even here one finds that his proportions produce a bulge in the third zone resembling an old-fashioned oil-lamp glass. He covers himself in conclusion, however, with the words:[e]

Thinness and thickness, that is what produces vibration (*chen* [9]) and throbbing (*tung* [10]) (respectively); purity or impurity (of the metal), that is what (causes the sound) to proceed outwards (*yu chhu* [11]) (i.e. from the vibrating walls of the bell themselves); the open or closed

[a] *Khao Kung Chi*, ch. 11, pp. 23ff. (ch. 41); tr. Biot (1), vol. 2, pp. 498ff. Wu Nan-Hsün (1), pp. 125ff. has a good discussion of it.

[b] Cf. pp. 87ff. above.

[c] This term came later to mean a small gong or cymbal.

[d] All such questions were studied in detail by the Chhing scholars such as Chhêng Yao-Thien (1) in his *Khao Kung (Chi) Chhuang Wu Hsiao Chi* (in *Huang Chhing Ching Chieh*, ch. 538) *c*. 1805; and his great master the archaeologist Tai Chen (+1723 to +1777) whose *Khao Kung Chi Thu* of 1746 (in *Huang Chhing Ching Chieh*, ch. 563) deals with bell-making on pp. 47ff. On the work of these men, especially on bells, see Kondō Mitsuo (1).

[e] Ch. 11, p. 24*b* (ch. 41), tr. auct. adjuv. Biot (1), vol. 2, p. 501.

[1] 鳧氏 [2] 于 [3] 鼓 [4] 鄭衆 [5] 擊處 [6] 隧
[7] 鉦 [8] 舞 [9] 震 [10] 動 [11] 由出

(form of the mouth), that is what (causes the sound) to proceed upwards (*yu hsing*[1]).[a] For all these things there are (special) explanations.[b]

These observations seem reasonable, and are followed by others to the effect that 'if (the walls of) a bell are too thick (it will sound like) a stone (*shih*[2])'. This may mean either a dull heavy sound as from an ordinary stone, or alternatively the timbre of the chime-stones used by the Chinese for music. The former seems more probable. 'If they are too thin (the sound will be) scattered (as by winnowing) (*po*[3]).' The word originally had the highly onomatopoeic sound **pwâr*. 'An open brim produces spreading (sounds); a closed brim produces choked (sounds) (*chhih tsê tsê; yen tsê yü*[4]).' The words *tsê* and *yü*[c] are metaphors, words originally meaning 'clearing trees' and 'densely wooded'. The idea of the sound being free or muffled is quite clear. Other details follow in which it is said that if a bell is large and short in the barrel its sound will be sickly and brief, but if it is small and long it will be healthy and rolling.

From the above one is forced to the conclusion that though the scholar who recorded some fragments of bell-lore in the *Chou Li* scarcely did justice to the foundrymen, it is evident that there existed in his day a wealth of technical terms and empirical knowledge. This is substantiated elsewhere in the *Chou Li* where twelve different types of sound are enumerated.[d] Chêng Hsüan says that they are bell sounds, but other commentators disagree, for the passage follows one describing the duties of the official responsible for the (pitch-)measuring tubes (Tien Thung[5]), and should apply to all instruments. However, it must be remembered that at this time bells gave the pitch to all the other instruments, so that an accurate enumeration of bell sounds here was quite appropriate. Moreover, a proof that they are bell sounds is that some of the terms are repetitions of the descriptions of bell sounds given above. The twelve are as follows:[e]

The sound (produced in) the upper part (of the bell) is rumbling (*han*[6]).
The sound (produced in) the straight part (of the bell, i.e. the *chêng*) is slow (*huan*[7]).
The sound (produced in) the lower part (of the bell) is spreading (*ssu*[8]).
The sound (produced by) the parts which curve outward is scattered (*san*[9]).
The sound (produced by) the parts which curve inward is hoarded (*lien*[10]).
The sound (produced by) a part which is somewhat too big is exaggerated (*ying*[11]).
The sound (produced by) a part which is somewhat too small is dark (incomplete) (*an*[12]).
The sound (produced by a bell of?) oval (shape) (lit. 'somewhat round', 'returning') is ample and full (*yen*[13]).
The sound (produced from) an open (mouth or brim) is *tsê*[14] (* *tsâk*).[f]

[a] This would certainly apply for bells held mouth pointing upwards.
[b] Oral traditions among the skilled master-craftsmen, themselves almost certainly illiterate.
[c] Cf. the medical use of this word to mean stasis in the pores or channels of the body; Sect. 7*j* (Vol. 1, p. 219), and Sect. 44.
[d] Ch. 6, p. 16*b* (ch. 23); tr. Biot (1), vol. 2, p. 56.
[e] Many of the terms used are obscure and the interpretation suggested is that which has seemed best after considering the opinions of all the available commentators.
[f] Three variants for this character occur, meaning 'bamboo cable' (*tso*[15]), 'clearing trees' (*tsê*[16]) or a kind of oak (*tso*[16] or *cha*[16]), and 'suddenly' (*cha*[17]). Chêng Chung says: 'The sound is forced and issues hurriedly'.

1 由興 2 石 3 播 4 侈則柞弇則鬱 5 典同 6 碮
7 緩 8 肆 9 散 10 斂 11 贏 12 韽 13 衍
14 筰 15 笮 16 柞 17 咋

The sound (produced from) a closed (mouth or brim) is choked (*yü*[1]).[a]
The sound (produced by) thin (walls) is a staccato shaking (*chen*[2]).[b]
The sound (produced by) thick (walls) is (like) stone (*shih*[3]).[c]

Of these twelve definitions the first three clearly apply to the barrel of the bell. The last four, concerning the thickness of the metal and the shape of the mouth, are treated in terms closely similar to those in the passage quoted above. There seems little doubt therefore that this text contains an analysis of the factors which interested the Chinese some two thousand years ago in the production of suitable harmonics from bells. Timbre can only be described by metaphor, as when we say that a sound is 'rich' or 'sharpened' or 'thin'. Phoneticians even speak of a 'dark L'. The Chinese can hardly therefore be criticised for such terms as 'dark' or 'choked'. On the contrary, the refinement of their investigation into the nature of bell-sounds in this early period is quite remarkable. The two factors given special prominence here are the diameters and contours of the bell, and the thickness of the metal. Four other factors yet remain according to modern practice—the elasticity and specific gravity of the metals used, the proportions of each, and the total mass. All of these were taken into consideration by the Chinese, though naturally they were not thought of quite in these terms. It will be better to use two heads, the nature of the metal used, and how much.

Following the description concerning the proportions of the different parts of the bell the *Chou Li* has a section describing the preparation of the metal by workers called Li shih[4] who made vessels (*fu*[5]) as standard measures of volume.[d] The commentators tell us that the *fu* measure was one-tenth that of the *chung*[6] (a word which the *Chou Li* constantly uses as a homonym for bell). The processes of these artisans applied also to the making of bells. In order that the copper might be quite pure it was melted three times before casting. The process was controlled by observation of the colour of the metal. The proportions of copper and tin used for bells (16–17% tin) are stated at the beginning of the chapter on metal-workers.[e] Weights of metal were checked against the weight of the standard vessels of capacity, and these standard vessels could themselves be checked by the pitch of the notes they gave out when they were struck, as it was contrived that they should emit particular notes of the scale.[f] The 'pitch-pipes' or, as we termed them above, standard measuring tubes, were used as standard rulers for measuring distances, and the twelve pitches, the notes, were used for checking the weight of vessels, or, when vessels were identical in weight,

[a] The commentary explains this as 'flurried but unable to escape'.
[b] Commentators say that this word must be taken here in the rather unusual sense of 'shaking' (*chen*[7]).
[c] Chêng Hsüan says that this means like the sound of musical stone-chimes.
[d] *Chou Li*, Khao Kung Chi, ch. 11, p. 25*b* (ch. 41); tr. Biot (1), vol. 2, p. 503. Cf. *Lü Lü Hsin Lun*, ch. 1, pp. 8*b* ff.
[e] Ch. 11, p. 20*b* (ch. 41); cf. Biot (1), vol. 2, p. 491. Cf. p. 180 above.
[f] Ch. 11, p. 26*a* (ch. 41); cf. Biot (1), vol. 2, p. 505.

1 鬱 2 震 3 石 4 栗氏 5 鬴 6 鍾 7 振

for checking the material of which they were made, since the composition of the alloy is one of the factors determining pitch.[a]

The information possessed by the Chinese in Chou times on bell-tuning, so far as we know it, may now be summarised. First, there was a wealth of empirical knowledge, not fully recorded, but orally handed down, the *Chou Li* author contenting himself with saying that on certain points special instructions are given.[b] Secondly, the Chinese appreciated the importance of accuracy in determining the diameter of the sound-bow and of other parts of the bell. Third, they seem not only to have listened very intently to the harmonics produced by bells, but to have classified the different sorts of timbre they produce, and to have attempted to attribute defects in timbre to faults in the form of the bell. Fourth, they paid great attention to the preparation, purification and weighing of the metal. We are not told, however, what was done to cure a flaw in tuning. We know indeed, from inspection of the whole field of bronzes, that few modern craftsmen could compare with the ancient Chinese for technical skill in bronze-founding, even the most intricate ornamentation being untouched on leaving the mould, and innocent of the file. So it may well be that cases in which bells required filing in order to tune them were so rare as not to deserve a mention. But elsewhere we are told that ringing-stones were tuned if necessary by filing down the sides or ends,[c] so it is reasonable to assume that filing would also have been resorted to for bells.

(8) Pitch-pipes, Millet-Grains and Metrology

While other early civilisations concerned themselves with linear measure, capacity, and weight in formulating their metrological systems, the Chinese were apparently unique in including pitch-measure (*lü* [1]), and that not merely on a par with, but as the basis of, the other three.[d] As the *Shih Chi* emphatically puts it:[e] 'The six *lü* are the root-stock of the myriad things (*liu lü wei wan shih kên pên yen* [2]).' The *Kuo Yü* describes this systematisation as follows:[f]

For this reason the ancient kings made as their standard the *chung* [3] vessel, (and decreed that) the 'size' of its pitch should not exceed that (produced by the string) of the *chün* [4] (seven-foot tuner), and that its weight should not exceed a stone (*tan* [5]) (120 catties). The measures of pitch, length, capacity and weight originate in this (standard vessel) (*lü tu liang hêng yü shih hu shêng* [6]).

[a] On this subject Chu Hsi's comment may be quoted: 'Quant à la régularité du poids, on considère par exemple que la matière des pierres sonores est ferme ou tendre, pure ou impure, et qu'il y a des sons légers ou graves, des sons hauts ou bas. En conséquence, on se sert encore des douze sons pour régulariser le poids' (tr. Biot (1), vol. 2, p. 58).

[b] One would not wish to exclude the possibility of the existence of written treatises on the technology of bell-making, either in the State of Chhi (whence the *Khao Kung Chi* probably derives) or in the Chhin and Han, but nothing whatever has survived and in any case oral tradition was certainly important.

[c] *Chou Li*, Khao Kung Chi, entry on the Chhing shih [7] (makers of stone-chimes), ch. 12, p. 5a, b (ch. 41); tr. Biot (1), vol. 2, p. 530.

[d] Something has already been said of Chinese metrology in Vol. 3, pp. 82ff.

[e] Ch. 25, p. 1a; cf. Chavannes (1), vol. 3, p. 293.

[f] *Chou Yü*, ch. 3, p. 22a; tr. de Harlez (5), eng. et mod. auct.

[1] 律 [2] 六律爲萬事根本焉 [3] 鐘 [4] 鈞 [5] 石
[6] 律度量衡於是乎生 [7] 磬氏

The standard measuring vessel *chung* is mentioned in the *Chou Li* and has been referred to already.[a] The word occurs in *Lieh Tzu* meaning a wine bowl, in the *Tso Chuan* meaning a grain measure, and is invariably used in the *Chou Li* and many other texts to mean a bell, for which today the term *chung*[1] would be a more normal appellation. The connection between grain-scoops and measures of capacity, bells and pitches is not hard to see. Primitive musicians all over the world used whatever was handy as their earliest instruments. In China the rice pestle-and-mortar existed in the classical orchestra till modern times as an instrument of percussion.[b] What more natural than that the primitive farmer when making music should use his grain-scoop or his bushel bowl and strike it for its rhythm, or if of metal, for its pitch? Standard measures and pitch were thus associated from primitive beginnings, and we have in the grain-scoop the first of all bells, which, as we noted above,[c] were in China originally clapperless. This origin also gives us a clue to the moral significance with which the *lü* were invested, for if the standard measures were not exact, cheating and corruption would follow, trade would be disrupted, disorders would break out, and all under heaven be thrown into confusion. The *Kuo Yü* writer develops his theme still further into the field of ethics and psychology, and in so doing takes up a position very like that of Plato in the *Republic* questing for justice in the State, where he lays it down that children should see and hear only that which is good.[d] The *Kuo Yü* says:[e]

> The ears and eyes are the pivots of the heart (because the heart is moved by what is seen and heard). That is why one should hear harmonious sounds only, and see nothing but what is correct and fitting. In this way hearing becomes clear and sight piercing, the meanings of words are comprehended, virtue shines forth, and men can be grave and firm, spreading this virtue among all the people.

The simple grain scoop having evolved into a bell, and the simple bell into a standardised measure or *chung*[2] of fixed dimensions, capacity and weight, as well as musical pitch, it was natural, when pipes became the standard pitch-givers, that they should inherit the measuring functions which had at one time belonged to bells.[f] Consequently we read of the number of grains of millet which the Huang-chung pipe ought properly to contain. It has sometimes been supposed that precise numbers of millet-grains governed the length and capacity of the Huang-chung tube and thus checked its pitch. Though this may have been so in and after the Han period, it is quite contrary to the earlier doctrine that the *lü* are the basis of all other measurements; for acting in their capacity as templates, they gave the lengths to the string-tuner, which in its turn gave the standard pitches. The standard measure, *chung*,[2] had to emit the Huang-chung note.

[a] Cf. above, p. 198.
[b] Cf. p. 149 and Fig. 302.
[c] P. 194.
[d] Cf. the detailed comparison of Phelps (1) on this.
[e] *Chou Yü*, ch. 3, p. 22*b*; tr. de Harlez (5), p. 85, eng. auct.
[f] Or perhaps the two kinds of instrument developed on parallel lines.

1 鐘 2 鍾

Nevertheless, the use of millet-grains in the reverse role of checking measuring instruments focused thought on the relation of length to diameter in pitch-pipes, and is highly relevant to a study of acoustic theory. The tables relating to millet-grains are given in the *Chhien Han Shu*, where measures of length, capacity and weight are treated in turn.[a] The smallest unit for each is given first, and thereafter four successive multiples. Thus if the *fên*[1] is the unit of length, ten *fên* make one inch; ten inches make one foot; ten feet make one *chang*;[2] ten *chang* make one *yin*.[3, b] Similarly with the other measures. The text says:

> The basis (of the linear measure) is the length of the Huang-chung (pitch-pipe) (*pên chhi Huang-chung chih chhang*[4]). Using grains of medium(-sized) black millet the length of Huang-chung is ninety *fên*, (one *fên* being equal to) the width of a grain of millet... (*i tzu-ku chü shu chung chê, i shu chih kuang tu chih chiu shih fên Huang-chung chih chhang*...[5]).
>
> Using grains of medium(-sized) black millet twelve hundred (grains) fill its tube....
>
> The contents of one (Huang-chung) tube, i.e. twelve hundred (grains of) millet, weigh twelve *chu*[6] (half an ounce, *liang*[7]).

Whether in fact the width (or thickness) of a millet-grain or its diameter or length was originally intended to serve as a unit, proved a fruitful source for subsequent disagreement; so also the exact number of grains required to make a foot length.[c] But these scrupulosities concern us only in so far as they formed a justification for varying the standard lengths of pitch-pipes in order to introduce a tempered form of scale.[d] Further refinements are mentioned in the *Chhien Han Shu*, such as levelling off the top of the tube for testing capacity by filling it with pure well-water so that an exact measure of the interstitial spaces and hence of the total volume could be gained.[e]

The chief point of interest in the use of cereal grains is that it indicates an increasing awareness of the need for accuracy. The old measures based on the human body, such as the foot, or the inch measured from the pulse in the wrist to the base of the thumb, were obviously not sufficiently accurate for measurements designed to achieve exact pitch. Precise linear measurements became necessary once an absolute pitch was sought for Huang-chung.[f] The old formula for calculating the *lü* was adequate

[a] Ch. 21A, pp. 9b, 10a, 11a; tr. auct. An account of this interesting metrological system was published in a Western language as long ago as 1879 by Wagener & Ninagawa (1), but Sarton & Ware (1) renewed interest in the subject recently. Though Ware knew of no source earlier than the *Chhien Han Shu*, there is a parallel passage in *Huai Nan Tzu*, ch. 3, pp. 12bff. (tr. Chatley (1), p. 26) which reveals an older, partly duodecimal, system of grain-packing metrology, also associated with the 12 *lü*.

[b] Cf. Vol. 3, pp. 85ff. where the significance of this adherence to the decimal system is emphasised.

[c] There are two diagrams from the *Chiu Ku Khao*[8] (A Study of the Nine Grains) by Chhêng Yao-Thien[9] (3) (Chhêng Chêng-Shih[10]), in *Huang Chhing Ching Chieh*, ch. 551, p. 9a, b. We are indebted to Dr Lu Gwei-Djen for this reference.

[d] The evolution of the tempered scale will form the concluding theme of this Section.

[e] P. 10a. The connection between this ancient practice and the marked interest of later Chinese mathematicians in packing problems (cf. Vol. 3, pp. 142ff. above) should not be overlooked.

[f] It is worth noting that the Han work *Chiu Chang Suan Shu* (Nine Chapters of Mathematical Art) contains (e.g. ch. 6, p. 20b) problems on the volumes of bamboo sections, involving arithmetical progression, and means of attaining desired ratios between items. See Vol. 3, pp. 25ff.

1 分 2 丈 3 引 4 本起於黃鐘之長
5 以子穀秬黍中者一黍之廣度之九十分黃鐘之長 6 銖 7 兩
8 九穀考 9 程瑤田 10 程徵士

provided that a particular absolute pitch of the fundamental was not desired, or could be obtained by applying measuring-rods of known length to the string of the tuner. But once these were lost or in doubt, or alternatively once an absolute pitch for the fundamental became a necessity, some new means of assessing length, volume and weight became imperative. Though millet-grains might vary individually, when large numbers of one given species were used a fairly consistent average would be struck.[a] This method of ensuring against the loss of standard measures traditionally enshrined in wood or metal was probably as practical as any that could have been devised. But of course as the centuries passed, perhaps because of the urge for magically 'making all things new' at changes of dynasties, perhaps because of the long-continuing search for the equal-tempered scale, and doubtless for other reasons also, the standard numbers of grains varied somewhat from time to time.[b]

(9) The Recognition of Sound as Vibration

The introduction of millet-grain counting as a measure of volumes initiated a phase in Chinese acoustic development which can properly be regarded as scientific.[c] It is interesting to compare the progress made in the Roman Empire in the same subject at a time contemporaneous with the Han dynasty in China. Vitruvius (*c.* −27) gives a great deal of acoustic information concerning the construction of theatres, the nature of the human voice, and the architectural arrangements needed to amplify it, such as the use of bronze vases set between the seats and tuned to different pitches, so that the different pitches of the human voice and its harmonics may be caught and amplified by resonance.[d] Of the nature of sound itself he says:[e] '(The voice) is moved in an infinite number of undulating circles similar to those generated in standing water if a stone is cast into it, when we see innumerable rings spread forth from the centre and travel as far out as they possibly can—extending indeed till they meet the confines of the limited space, or some obstruction which prevents the waves from reaching the outlets.' He speaks, too, of sound being somewhat of the nature of a blow on the taut membrane of a drum.

The Chinese also thought of sound in metaphorical terms deriving from observation of waves in liquid media at this period, though distinct statements of the analogy are rare before the +8th century. The following striking passage from the *Chhun Chhiu Fan Lu*[f] of Tung Chung-Shu (−2nd century) shows a conception of radiating wave-

[a] Large and small grains aberrant in size being rejected.

[b] In +589 Niu Hung[1] the jurist and three specialists (Hsin Yen-Chih,[2] Chêng I[3] and Ho Tho[4]) were commissioned to study the history of acoustic and other metrological standards; their results are given in *Sui Shu*, ch. 16, pp. 8bff. Cf. Courant (2), p. 84.

[c] Modern comparative anatomy and anthropology provide an equivalent in the shot poured into the crania of different types of animal or human races in order to compare the size of brain cavities.

[d] *De Architectura*, v, v, 1 ff.

[e] v, iii, 6 ff. Cf. also Diogenes Laertius, vii, 158, and Plutarch, *Plac. Philos.* iv, xix, 4. On the Stoics see again p. 12 above.

[f] Ch. 81; tr. auct. adjuv. Bodde, in Fêng Yu-Lan (1), vol. 2, p. 57.

1 牛弘　　2 辛彥之　　3 鄭譯　　4 何妥

fronts which he boldly applied to all media whatever their viscosity, including the aetheric *chhi* in which even psychological events participated.

> Man's (activity) brings about the growth of the ten thousand things below, and unites him with Heaven and Earth above. Thus it is that in accordance with his good government or disorderly, the *chhi* of movement or rest, of compliance or contrariness, act either to diminish or increase the transformations of the Yin and Yang, and to agitate everything within the Four Seas (*erh yao tang ssu hai chih nei*[1]). Even in the case of things difficult to understand, such as the spiritual (*shen*[2]), it cannot be said to be otherwise. Thus then, if (something) is thrown on to (hard) ground, it is (itself) broken or injured, and causes no movement in the latter; if thrown into soft mire, it causes movement within a limited distance (*hsiang tung erh chin*[3]); if thrown into water, it causes movement over a greater distance (*hsiang tung erh yü yuan*[4]). Thus we may see that the softer a thing is, the more readily does it undergo movement and agitation. The transforming *chhi* is much softer even than water, and (through it) the ruler of men ever acts upon all things without surcease. But the *chhi* of social confusion is constantly conflicting with the transforming (influences) of Heaven and Earth, with the result that there is now no (good) government.
>
> When the human world is well governed and the people are at peace, when the will (of the ruler) is equable and his character correct, then the transforming (influences) of Heaven and Earth operate in a perfect manner, and among the ten thousand things only the finest are produced. But when the human world is in disorder and the people become perverse, or when the will (of the ruler) is depraved and his character rebellious, then (their) *chhi* opposes the transforming (influences) of Heaven and Earth, harming the *chhi* (of Yin and Yang) and so generating calamities and disasters.[a]

This passage may be compared with another which we have already quoted from the astronomer Liu Chih,[b] written about +274. It will be remembered that he there compared the radiating light of the sun with the ripples sent out from the centre of a disturbance on a water surface. Vitruvius is just bracketed in time between Tung Chung-Shu and Liu Chih.

Two words which distinctly indicate a mental connection between waves in water and air are *chhing*[5] and *cho*.[6,c] Their ordinary meaning is 'clear' and 'muddy' respectively, but in acoustic contexts they are technically used. Chêng Hsüan says[d] that *chhing* (clear) means the notes of the gamut from Jui-pin to Ying-chung, i.e. the six upper notes, while *cho* (muddy) means the notes from Huang-chung to Chung-lü, i.e. the six lower notes. If a small stone is dropped into water it produces a sound of relatively high pitch, and sends out small ripples in close concentric circles; moreover, being small it does not much disturb the bed of the lake or stream so that the water

[a] Tung Chung-Shu certainly had in mind the theory of phenomenalism (see Vol. 2, pp. 378ff., Sect. 14*f* above), but he could easily have found telling examples in such matters as the neglect of water-works by bad rulers.

[b] P. 8 above. He was thinking of light and heat. The three Greek and Latin statements just mentioned (Vitruvius, −1st century; Plutarch, +1st; and Diogenes Laertius, Liu Chih's elder contemporary in the +3rd) explicitly refer to sound. Tung Chung-Shu, writing about −130, and therefore the most venerable of them, has all forms of radiating influence or energy in mind.

[c] Cf. p. 157 above.

[d] Commenting in the +2nd century on the *Yo Chi*, para. 6; in *Shih Chi*, ch. 24, pp. 24*b*, 25*a*.

[1] 而搖蕩四海之內 [2] 神 [3] 相動而近 [4] 相動而愈遠
[5] 清 [6] 濁

remains clear. If, on the other hand, a large stone is dropped into water, it produces a relatively loud deep sound, sending out large wide ripples over the surface, and it does disturb the river bed so that the water becomes muddy. Whether or not this theory of the origin of the terms be true, it certainly seems to fit contexts in which the words *chhing* and *cho* occur not entirely divorced from the other associations of sound such as timbre and volume.

The *Kuo Yü* refers[a] to pitch-range and the formation of sound by the human voice with considerable acumen for so early a period. The passage concerns the incident (−522) in which Ching,[1] the High King of Chou, desired to melt down a Wu-yi bell,[b] the second highest in the gamut, and thus falling in the *chhing* (clear) or upper pitch range, and to make from its metal a Ta-lin[b] bell generally known as Lin-chung,[b] the fifth highest of the gamut, also in the upper pitch range. But Wu-yi was a Yang (male) bell and therefore not loud but soft (*hsi*[2]), whereas Lin-chung was a Yin (female) bell and therefore loud (*ta*[3]). Even if the new bell were tuned correctly its volume would be false. Shan Mu Kung[4] remonstrated with the king, pointing out that debasing the pitches was as bad as debasing the currency. The people can only be trained to a precise appreciation of pitch intervals if the sounds which they hear are correctly tuned. That which enters through the ear and eye must be in accordance with correct measures or the heart will be corrupted:[c]

> For the measures (*tu*[5]) which are discernible to the eye do not exceed the intervals of the *pu*[6] (6 ft.), the *wu*[7] (3 ft.), the foot, and the inch. The colours which are discernible to it do not exceed the intervals of the *mo*[8] (5 ft., lit. 'dark'), the *chang*[9] (10 ft.), the *hsün*[10] (20 ft.), and the *chhang*[11] (40 ft.). The harmonies which are discernible to the ear lie within the intervals of the pitch-range (*chhing-cho*[12]); the pitch-range which is discernible to it does not exceed the range of the human voice.

The sentence referring to colours is not very clear, for one would expect the four measures given as measures of distance to be in fact measures of saturation of colour or some such distinction. But it is a correct observation that outside the middle range of pitch our ability to judge intervals increasingly diminishes. The other observation, that debasing musical sounds is like debasing the currency, a form of injustice which Plato would have regarded as undermining the State, also deserves attention.

The exposition of Shan Mu Kung continues as follows:[d]

> The ear takes in harmonious (*ho*[13]) sounds, and the mouth sends out excellent words... [The mouth takes in tastes, just as the ear takes in sounds (*khou nei wei erh erh nei shêng*[14]). Sounds and tastes generate *chhi* (*shêng wei sêng chhi*[15]).] When *chhi* is present in the mouth,

[a] *Chou Yü*, ch. 3, pp. 21*b*ff.
[b] For the characters see p. 170 and Table 47 on p. 171.
[c] P. 22*a*; tr. auct. adjuv. de Harlez (5), p. 64.
[d] *Kuo Yü*, Chou Yü, ch. 3, p. 23*a*; tr. auct. adjuv. de Harlez (5), p. 66. The sentences enclosed in square brackets are absent from some editions.

1 景　2 細　3 大　4 單穆公　5 度　6 步　7 武
8 墨　9 丈　10 尋　11 常　12 清濁　13 龢
14 口內味而耳內聲　15 聲味生氣

it makes speech, and when in the eye, intelligent perception. Speech enables us to refer to things in accepted terms. Intelligent perception enables us to take action at the right times. Using terms (correctly), we thereby perfect our government. Carrying out actions at the right times, we thereby bring abundance to (all) living things. When government is perfect and living things have abundance, joy reaches its solstice.[a]

From this passage it is possible again to see the correlative tendencies of the Chinese mind at work, for sound and taste are linked with government not by mere fantasy but by a correlative sequence.[b] The concept of *chhi* must be accepted as the point of departure for the argument, not because it was adequate to reality, but because, like the concepts of Aristotelian form and matter, or Newtonian space and time, there were periods in which it served a useful purpose as a tool for thinking.

The *Kuo Yü* does not attempt to explain more clearly than this how exactly a sound is formed by the action of *chhi*. But a hint of how this process was imagined to take place may be gained from a sublime passage in the *Yo Chi*, where the nature of music is described.[c]

The *chhi* of Earth ascends above; the *chhi* of Heaven descends from the height[d] (*ti chhi shang chi; thien chhi hsia chiang*[1]). The Yang and Yin come into contact; Heaven and Earth shake together (*Yang Yin hsiang mo; thien ti hsiang tang*[2]). Their drumming is in the shock and rumble of thunder; their excited beating of wings is in wind and rain; their shifting round is in the four seasons; their warming is in the sun and moon. Thus the hundred species procreate and flourish. Thus it is that music is a bringing together of Heaven and Earth (*ju tshu tsê yo chê thien ti chih ho yeh*[3]).

One does not have to look far into these words to see a reflection from early animistic times of the sort of belief which found expression in the story of Danae visited by Jupiter in a golden shower. Metaphors from the magical feather dances are strangely blended with words of awe, but also with tentative explanations, for example, 'The Yang and Yin rub together. Heaven and Earth shake together; their drumming is in the thunder....'

Thirteen or fourteen centuries later there is naturally a more sophisticated approach. In the Sung period we find this idea of rubbing taken up again and developed. Chang Tsai[4] writing (*c.* +1060) in his *Chêng Mêng*[5] on sound says:[e]

The formation of sound is due to the friction (lit. mutual grinding) (*hsiang ya*[6]) between (two) material things (*hsing*[7]), or (two) *chhi* (or between material things and *chhi*). The

[a] Note the elegant double-tracked sorites with its unified ending. On this and all other aspects of language in Chinese scientific and philosophical discourse, see Sect. 49.
[b] Cf. Vol. 2, pp. 261 ff. The idea of words being formed by some process connected with tasting might be dismissed as nonsense, had not Paget (2) published the results of his researches on the origin of speech, in which we find a connection between tasting gestures and the world-wide occurrence of such words as *sip*, *soup*, *gulp*, etc.; forms in which the lingual gesture is unmistakable.
[c] Para. 3, in *Shih Chi*, ch. 24, p. 14*a*, *b*; tr. auct. adjuv. Chavannes (1), vol. 3, p. 253.
[d] Cf. Sect. 21*d* (Vol. 3, pp. 467 ff.) on the meteorological water-cycle.
[e] *Sung Ssu Tzu Chhao Shih*,[8] Chang Tzu sect. ch. 7 (Tung Wu[9]), p. 12*b*; tr. auct. Cf. Bodde, in Fêng Yu-Lan (1), vol. 2, p. 487.

1 地氣上躋天氣下降 2 陰陽相摩天地相蕩 3 如此則樂者天地之和也
4 張載 5 正蒙 6 相軋 7 形 8 宋四子抄釋 9 動物

grinding between two *chhi* gives rise to noises such as echoes in a valley (*ku hsiang*[1]) or the sounds of thunder. The grinding between two material things gives sounds such as the striking of drumsticks on the drum. The grinding of a material thing on *chhi* gives sounds such as the swishing of feathered fans or flying arrows. The grinding of *chhi* on a material thing gives sounds such as the blowing of the reeds of a mouth-organ (*shêng*[2]). These are the inherent capacities in things for response (*wu kan chih liang nêng*[3]). People are so used to these phenomena that they never investigate them.

This extract[a] shows both the strength and the weakness of the traditional Chinese approach to such problems. One must admire the ability to classify and distinguish, but making distinctions is not the same as analysing a complex into its component factors.[b] Assuming the validity of the theory that sound is caused by 'friction' of things corporeal and incorporeal, its fourfold classification is admirable. Indeed, this type of thinking may still have a role to play in the classification of acoustic forms the complexity of which defies analysis as, for example, the grading of voices for the purpose of telephony, or the classification of musical timbres. But to say that the formation of sound is due to friction is obviously as much a defect of language as of thought. Perhaps it would not be too sweeping a generalisation to say that medieval science was as much handicapped by the failure of the Chinese language to make transitive and intransitive verb functions always explicit, as it was by the inability of some European languages to resolve verbs into specific physical operations.[c] To define friction as rubbing, and rubbing in terms of moving surfaces, or to define it as a force causing loss of motion would have seemed to Chang Tsai's correlative mind jejune, for friction would have seemed to him a perfect example of the way in which sound, colour and flavour combine. A knife placed against a rotating grindstone produces a harsh sound, a distinctive smell of charring, and yellow coloured sparks.[d]

Nevertheless, even before his day attempts had been made to reach a clearer understanding of the nature of sound. Than Chhiao[4] or some other Taoist writing in the *Hua Shu*[5] during the period of the Southern Thang (+938 to +975) makes the following statement:[e]

Chhi follows sound and sound follows *chhi*. When *chhi* is in motion sound comes forth, and when sound comes forth *chhi* is shaken. (*Chhi tshung shêng, shêng tshung chhi; chhi tung shêng fa, shêng fa chhi chen.*[6])

[a] Parallel passage in *Lü Lü Hsin Lun*, ch. 1, pp. 34ff. Chiang Yung goes on to advocate the experimental and quantitative study of all sources of sound.
[b] Cf. here particularly the argument in Vol. 3, pp. 156ff.
[c] Such questions must of course be left for Sect. 49.
[d] Other aspects of Chang Tsai's thinking in cosmology and astronomy have been discussed in Vol. 3, pp. 222ff.
[e] P. 12a, tr. auct. The place of this book in the history of optics (pp. 98, 116 above) will be recalled.

1 谷響 2 笙 3 物感之良能
6 氣從聲聲從氣氣動聲發聲發氣振 4 譚峭 5 化書

This is an important contribution. It is far more advanced than the Pythagorean conception of sound as a stuff composed of number which strikes the ear and becomes audible just as a swiftly travelling discus becomes visible at the moment of landing. It will be noticed that he is not speaking of air as such, for *chhi* is not merely air, though air under certain conditions may be described as *chhi*; when 'heat' dances above a flame, or smoking fumes arise from molten metal, and cooking-pots; the blast of furnace bellows,[a] forests shaken by the wind,[b] speech or music issuing from the human mouth.[c] It is the relation between sound and atmospheric agitation (*chhi*) which is important. The advent of sound transforms still air into *chhi* (air in a state of agitation), and air in a state of agitation produces sound. The use of the transitive verb *chen*[1] 'to shake' is particularly interesting, for it embodies so clearly the idea of vibration. This has occurred already in the description of the different sorts of sound produced by bells of different shapes: 'The sound (produced by bells with) thin (walls) is a staccato shaking.'[d] One can well understand that the Chinese should have realised that sound is produced by the 'shaking' of the air if in fact they gave such close attention to the timbre of bells. For large gongs and bells produce an inaudible pulsation of extremely low frequency but important in combination with the harmonics, which can be experienced when all normal sound has ceased as a faint pressure on the ear-drum. Indeed this is known in English as the 'shake'.[e]

Than Chhiao also anticipated Chang Tsai's theory of the grinding of *chhi* and material things, but by-passed the problem of how sound is formed by the use of a linguistic side-step, in this case 'riding' instead of 'grinding' or 'friction'. Still, his observations on the possible amplification of sound are interesting.[f]

> The void (*hsü*[2]) is transformed into (magical) power (*shen*[3]). (Magical) power is transformed into *chhi*. *Chhi* is transformed into material things (*hsing*[4]). Material things and *chhi* ride on one another (*hsing chhi hsiang chhêng*[5]), and thus sound is formed. It is not the ear which listens to sound but sound which of itself makes its way into the ear. It is not the valley which of itself gives out echoing sound, but sound of itself fills up the entire valley.

So far he seems only to be pointing out that sound is not the product of hearing but exists independently of sensation. But his word 'sound' covers both the physical and the psychological. However, he was probably concerned less with the auditory neural stimuli than with the physical disturbance of the air and its impact on the ear-drum. He then continues:

> An ear is a small hollow (*chhiao*[6]) and a valley is a large hollow. Mountains and marshes are a 'small valley' and Heaven and Earth are a 'large valley'. (Theoretically speaking, then)

[a] On the 'hard wind' of the cosmologists, see Vol. 3, pp. 222ff.
[b] 'On Wenlock Edge the wood's in trouble...'; so also *Chuang Tzu*, ch. 2 (cf. Vol. 2, pp. 50, 51).
[c] On 'jets musically inclined' see G. B. Brown (1).
[d] Cf. above, p. 198.
[e] I am grateful to the late Mr C. K. Ogden for the opportunity of experiencing this phenomenon on his large Burmese gong (K.R.). Cf. p. 195.
[f] P. 7b, tr. auct.

[1] 振 [2] 虛 [3] 神 [4] 形 [5] 形氣相乘 [6] 竅

if one hollow gives out sound ten thousand hollows will all give out sound; if sound can be heard in one valley it should be heard in all the ten thousand valleys.

Here the writer's contention seems to be that if sound is produced by a disturbance of the *chhi*, all *chhi* everywhere will be in a state of disturbance, and therefore capable of being heard wherever a hollow or resonant chamber exists to receive it. With this there can be no disagreement, and the modern use of amplifiers to detect very small 'disturbances in the *chhi*' attests its truth.

Than Chhiao's next words are equally interesting:

Sound leads (back again) to *chhi*; *chhi* leads (back again) to (magical) power (*shen*[1]); (magical) power leads (back again) to the void. (*Shêng tao chhi; chhi tao shen; shen tao hsü*.[2]) (But) the void has in it (the potentiality for) power. The power has in it (the potentiality for) *chhi*. *Chhi* has in it (the potentiality for) sound. (*Hsü han shen; shen han chhi; chhi han shêng*.[3]) One leads (back again) to the other, which has (a potentiality for) the former within itself. (If this reversion and production were to be prolonged) even the tiny noises of mosquitoes and flies would be able to reach everywhere.

Here the word *shen*[1] needs a little explanation. The translation '(magical) power' is rather inadequate. The character consists of a primitive graph apparently representing lightning,[a] modified by a symbol suggesting deity. Almost any single English word such as 'power', 'energy', etc. will carry misleading connotations. It is not difficult, however, to grasp the mechanism visualised by Than. Above the world is the empty void (*hsü*). Within this void there nevertheless exists a potentiality for energy,[b] for out of nothing it can produce power as in lightning. This lightning can produce *chhi* or atmospheric agitation, and atmospheric agitation can produce sound. So far the author has given within reasonable limits quite an accurate account of how the noise of thunder is generated. We would go a little further today, and explain that lightning produces a sudden heating of the air, which therefore expands violently and irregularly, causing pressure waves to travel through the air to the ears of the listener. But even as it stands his statement is rather remarkable for the +10th century.

The first part is intended to explain how it is that sounds die away. Than Chhiao evidently thought not that the waves of pressure in the air were getting feebler and feebler, but that the sound was changing back again into *chhi*. Gradually the agitation of the *chhi* would diminish, and it would revert to power itself, which would in its turn subside again into the void. It is tempting to regard this statement as an anticipation of modern views on the nature of energy, just as it is tempting to see in Democritus one who anticipated the findings of modern atomic physics and chemistry. Of course, such anticipations must not be overstressed. But Than would have had little difficulty in understanding the way in which today the tiny sound of a mosquito or a fly may be 'led back again' into electric power 'having in it the potentiality for' amplification of sound by means of 'agitation of the *chhi*' through a loudspeaker.[c]

[a] K385. See also Vol. 2, pp. 225, 226.

[b] This Aristotelian phrase seems to us to render not badly the sense of the word *han*, which means literally 'to hold in the mouth', hence 'to cherish', with the undertone of being able to spit it forth or radiate it again.

[c] Cf. van Bergeijk *et al.* (1).

[1] 神

[2] 聲導氣氣導神神導虛

[3] 虛含神神含氣氣含聲

As already suggested, Than Chhiao was probably not concerned so much with the psychological aspect of hearing. Disturbances and waves of pressure in the air do not become 'sound' until so interpreted by the brain, stimulated by nerves from the inner ear receiving the external impulses. That the medieval Chinese did not overlook the psychology of the auditory sensation is shown by the words of another Taoist, Thien Thung-Hsiu[1] (*c.* +742) in the *Kuan Yin Tzu*.[2] He describes the hearing process as follows:[a]

> It is like striking a drum with a drumstick. The shape of the drum is possessed in my person (in the form of the ear) (*ku chih hsing chê wo chih yu yeh*[3]). The sound of a drum is a matter of my responding to it (*ku chih shêng chê wo chih kan yeh*[4]).

To expand the analogy slightly, it seems that he believed that sounds strike the inner ear, in fact the ear-drum, just as drumsticks strike an actual drum; that is to say, they exert pressure. Nevertheless, it is the response (*kan*[5]) of a sentient being which enables one to describe this process as sound.

There is some reason for thinking that experiments with echoes were occasionally made. For example, the following story appears in the Ming book *Hsiang Yen Lu*[6] by Min Yuan-Ching[7] who attributes it to the +5th-century *Shui Ching Chu*.[b]

> The city of Chiangling[8] lies on a slope inclining to the south-east, along which the dyke called Chin Thi[9] is built, starting from the Ling Chhi[10] pool. This dyke was built by Chhen Tsun[11] upon the orders of Huan Wên[12] (+347 to +373). Chhen Tsun was very skilful as a military architect. Once he sent someone to beat a drum (on the slope), whereupon, listening to the sound at a certain distance, he deduced the height of the slope. The dyke was built relying on such data, and there was no mistake in the calculations.

It would seem that this story preserves, in garbled form, some study of the speed of travel of echo-sounds, or perhaps the time-interval between the visible action initiating the sound and its arrival at the observer's ear.

(i) *The detection of vibrations*

The *Mo Tzu* book, in its discussion of fortification technology, written perhaps by Chhin Ku-Li[13] in the early part of the −4th century, mentions the use of hollow vessels as resonators in order to determine the presence and direction of tunnelling and mining by the enemy besieging a city. Forke (3, 17) has termed them 'geophones'. The text says:[c]

> Should any unusual activity of the enemy be noticed, such as the building of walls or the piling up of earth, or perhaps streams becoming muddy which were not so before, then it is likely that he is sapping and mining. One must then at once make excavations within the

[a] Ch. 2, p. 5*b*, tr. auct.
[b] Cit. *KCKW*, ch. 2, p. 33*a*.
[c] Ch. 52, p. 9*a*; tr. Forke (17), eng. auct.

[1] 田同秀 [2] 關尹子 [3] 鼓之形者我之有也 [4] 鼓之聲者我之感也
[5] 感 [6] 湘烟錄 [7] 閔元京 [8] 江陵 [9] 金堤 [10] 靈溪
[11] 陳遵 [12] 桓溫 [13] 禽滑釐

wall and the moat in order to frustrate him. Within the city shafts are to be dug five paces distant from one another, to a depth of fifteen feet below the level of the base of the city wall, until one reaches three foot depth of water. Then large pottery jars are to be prepared each of a size sufficient to hold more than 40 *tou*;[a] their orifices are closed by a membrane of fresh skin, and they are sunk in the shafts. If men with good hearing are then set on watch to listen carefully, they will be able to hear clearly in which direction the enemy is digging. Then countermines are driven to meet them.

Since this would have been written about −370, our information on this Chinese practice[b] comes between dates for which there is evidence from Europe. From Herodotus[c] we learn that use was made of hollow shields as listening-posts at the siege of Barca by the Persians in the late −6th century; and Vitruvius[d] gives details of more refined procedures[e] employed by Trypho of Alexandria at the siege of Apollonia in Illyria in −214. It is hard to believe that this technique did not arise out of independent empirical observations made both in west and east. Its later developments included the use of bronze vases in theatres to improve the acoustics of the buildings, and of pottery vessels built into the walls of medieval structures.[f]

One of the most curious later applications of Chinese vibration detectors was the use of an instrument by the fishermen of northern Fukien for obtaining audible warning of the approach of shoals or 'runs' of fish.[g] At San-Tu-Ao bay, for example, great quantities of yellow fish are caught at those times of the year when they come up to brackish water to spawn. When the fishermen suspect that a run is about to occur, they take a section of bamboo about 2 in. in diameter and 5 ft. long, plunge it in the water to the depth of 3½–4 ft., and apply their ears to the upper orifice beside the boat. Western observers present have heard sounds like a confused distant rumble when the shoal was said by the fishermen to be about a mile away, an estimate which was confirmed by the catch in due course. It is to be presumed that prolonged experience would confer considerable skill in making the estimates. Although no references to this practice have been found in the Chinese literature, there is no reason for doubting its traditional character, and it may be assumed to be an indigenous technique, anticipating in its primitive way the modern use of echo-sounding in the detection of shoals of fish.[h]

[a] I.e. more than 200 litres.

[b] Certain small metal pots with holes in their concave lids, dating from the Chhin or Han, have been regarded as geophones, used perhaps to pick up the ground-transmitted vibrations caused by distant galloping horses. I am much indebted to Mr Rewi Alley for sending me photographs of these objects from Peking.

[c] IV, 200.

[d] X, 16, 10.

[e] Including suspended bronze vessels.

[f] They may subsequently have taken on another function, namely the lightening of the load in vaults (Straub (1), p. 19).

[g] The information on which this paragraph is based was kindly provided by Mr Horatio Hawkins, formerly a Commissioner of the Chinese Customs. Similar techniques are known and used in Malaya; cf. Robinson (4).

[h] Cf. Hodgson (1); Hodgson & Richardson (1); Burd & Lee (1).

(ii) *The free reed*

Much has been said above[a] of the efforts of the *wu* shamans to canalise *chhi* through pipes. The metallurgists were, however, also interested in this (perhaps indeed they were sometimes the same people), and hence in due time the process was bound to be mechanised. We must reserve the bellows and the piston-bellows for our discussions of mechanics and metallurgy (Sects. 27*b* and 30*d* below); here we would only point out that there is a close connection between valve clacks in pumps, and reeds in musical instruments. The beating reed is exactly like the valve in that it can completely close the aperture, but the free reed is able to vibrate within the aperture. The 'mouth-organ' (*shêng*[1]) goes back far into the Chou, since it is mentioned in the *Shih Ching*,[b] and the generally accepted view is that the principle of the free reed came to the West from China.[c] The *shêng* is therefore the ancestor of the harmonica or reed-organ group of instruments (harmonium, concertina, accordion, etc.) and there is concrete evidence that it was transmitted through Russia in the 19th century.[d]

One of the chief uses of piston-bellows in Europe was for musical organs.[e] Although afterwards so closely associated with the Christian liturgy, they were an invention of the Alexandrians, and Vitruvius gives a minute description of them towards the end of the −1st century.[f] At that time, and before, piston-bellows of bronze were used.[g] No such application of these was made anciently in China, but from the Chou onwards, as we have seen, the Chinese had had the little instrument known as *shêng*[1] or *yü*,[2] made of bamboo pipes with free reeds (*huang*[3]) and played by suction. Moule & Galpin (1) have described how in the +13th century a reed organ was brought from the West and created so much interest that it was reconstructed to play the Chinese scale.[h] It was called the Hsing Lung Shêng,[4] and ten or twelve were made for the imperial orchestra during the Yuan dynasty. According to the *Yuan Shih*, it had 90 pipes and was blown by one man (presumably using piston-bellows) while another man played it. The first was presented by Muslim kingdoms between +1260 and +1264, and the adaptation to the Chinese scale was made by Chêng Hsiu[5] of the Bureau of Music. There were slider-valves and an air-reservoir of leather. Since the instrument was a reed organ and not a flute-pipe organ, this Arabic invention pre-

[a] Pp. 135ff. above.
[b] Mao, no. 161, Karlgren (14), p. 104; Waley (1), p. 192. Cf. Eastlake (2).
[c] Helmholtz (1), pp. 95, 554; Moule (10), pp. 88ff.; Goodrich (12). The question is bound up with the origin and distribution of the simple 'Jew's harp', on which see Li Hui (1, 1); Picken (2), pp. 185ff.
[d] Scholes (1), pp. 787, 991; Schlesinger (2). By Fr G. J. Vogler (1749 to 1814), who saw and studied a *shêng* while at St Petersburg.
[e] Cf. E. W. Anderson (1).
[f] x, 8 (old editions, x, 13). Cf. Usher (1), pp. 80ff., and edn. pp. 136ff.; Neuburger (1), p. 230.
[g] There is a good illustration in the Perrault edition of Vitruvius, p. 325.
[h] The information is derived from *Yuan Shih*, ch. 71, pp. 4aff., *Cho Kêng Lu*, ch. 5, pp. 2aff., and the collected writings of Wang I[6] (d. +1373) (*Wang Chung Wên Kung Chi*[7]), ch. 15, pp. 23*b*ff.; all translated by Moule & Galpin (1).

[1] 笙 [2] 竽 [3] 簧 [4] 興隆笙 [5] 鄭秀 [6] 王褘
[7] 王忠文公集

ceded by two centuries the invention of the reed organ by Traxdorf in Nürnberg about +1460, while as reconstructed by the Chinese with free reeds ('apricot-leaves') it anticipated the European harmonium by no less than five and a half centuries. It seems to have had a swell mechanism, but in any case free reeds will allow sound variability by varying wind pressure without loss of pitch. One may say, therefore, that this application of air compression and conduction, though Hellenistic in origin, was improved by the Arabs and the Chinese during the late Middle Ages more quickly than in Europe where the lead was regained only after the Renaissance.

(10) The Evolution of Equal Temperament

This review of Chinese acoustic speculation in ancient and medieval times has shown how much was understood of the nature of sound produced by vibrating strings and columns of air. In the Chou period, as we have seen, tuning was done on a large stringed instrument, the *chün*. This fell into disuse towards the end of the dynasty, and the pitch which it had formerly given to the bells, and hence to all the other instruments of the orchestra, was henceforth given by pitch-pipes, the exact measurements of which consequently became a matter of great concern.

(i) *Octaves and spirals of fifths*

In predicting the sound which a pipe will produce when it is blown, it is not enough to know its length. The diameter is also important. Obviously a bamboo pipe a foot long and half an inch in diameter will not produce the same frequency note as one a foot long and two inches in diameter. Ignoring refinements, the pitch from two such pipes might be calculated as 537 and 501 vibrations per second approximately, a difference of more than a tempered semitone. The narrower the diameter the higher the pitch. If pitch-pipes had been in use in China from Chou times as guardians of standard pitch, one would expect to find not only details of the lengths of the different pipes in the *Chhien Han Shu*, but also details of their diameters. In fact there were different schools of thought on the matter.[a] One, of which Chêng Hsüan may be taken as representative, maintained that the diameters (or as he put it—the circumferences) of all the pitch-pipes should be the same.[b] 'The hollow of all pitch-pipes (should be) 9/10 of an inch in circumference (*fan lü khung wei chiu fên*[1]).' But Mêng Khang,[2] who lived slightly later than Chêng Hsüan (*c.* +220) declared that

> Huang-chung should be 9 in. long and 9/10 of an inch in circumference; Lin-chung should be 6 in. long and 6/10 of an inch in circumference; Ta-tshou should be 8 in. long and 8/10 of an inch in circumference.[c]

[a] See *Li Chi*, ch. 6 (Yüeh Ling), the first month, the pitch-pipe of which is Ta-tshou, for commentators' descriptions of pitch-pipe dimensions.
[b] *Li Chi Chi Chieh*, ch. 13, p. 64.
[c] *Chhien Han Shu*, ch. 21A, p. 7a, comm. This tradition recurs in *Sui Shu*, ch. 16, p. 8b.

[1] 凡律空圍九分 [2] 孟康

As far as it goes this suggests a tapering off in diameters from Huang-chung, and gives diameters rather narrower than those used by Chu Tsai-Yü when evolving his equal-tempered system in the +16th century.[a] Tshai Yung specifies[b] dimensions for Huang-chung only, but gives length, circumference and diameter, from which we are able to see that he was using only a crude approximation for π. 'The Huang-chung pipe is nine inches long, 3/10 of an inch in diameter, and 9/10 of an inch in circumference.'

If approximations like this were used in acoustic calculations, it would be profitless to look for such refinements as appreciation of surface-tension, air temperature and humidity in calculating the pitch of pipes, though the use of jade as a material does suggest an attempt to overcome some of the discrepancies due to temperature and humidity variation. But the most important factor for those who wish to calculate the pitch of blown pipes is that 'end-effect' of which an account has already been given.[c] There is no doubt that this factor was appreciated in Han times, though of course the mathematics involved in its calculation were not attempted. Ching Fang[1] (*fl.* −45) specifically states[d] that pipes cannot be used (accurately) for tuning (*chu shêng pu kho i tu thiao*[2]). For this reason he made an instrument called a *chun*,[3] 10 ft. long like a *sê*[4] with thirteen strings, and by its help worked out the proportions for the notes of the system of tuning which he advocated.

Another reason why Ching Fang was right to do his experimenting with strings rather than pipes is provided by Helmholtz's discussion of sympathetic resonance. 'The principal mark of distinction', he says,[e] 'between strings and other bodies which vibrate sympathetically, is that different vibrating forms of strings give simple tones corresponding to the harmonic upper partial tones of the prime tone, whereas the secondary simple tones of membranes, bells, rods, etc., are inharmonic with the prime tone, and the masses of air in resonators have generally only very high upper partial tones, also chiefly inharmonic with the prime tone, and not capable of being much reinforced by the resonator.' Thus the use of strings in tuning experiments enabled the experimenter to get a mathematically perfect octave, the octave string being half the length of the fundamental, or stopped at half its length. A pipe half the length of another pipe, on the other hand, does not necessarily give its octave. The octave must be calculated taking the factors of end-effect and diameter into account.

From the figures given above[f] in which certain intervals of the Pythagorean scale were compared with the Chinese spiral of fifths, the discrepancy between a Chinese 'octave' so produced and the true octave is apparent, the ratio of a true octave being 1:2, and of an 'octave' in the spiral of fifths 262,144:531,441. The ratio, therefore, between a true octave and a Chinese 'octave' is as 524,288:531,441. This is known as the comma maxima, or more frequently today on account of the mistaken association of the name of Pythagoras with the spiral of fifths, the Pythagorean comma.[g]

[a] See below, pp. 220–4.
[b] In his commentary *Yüeh Ling Chang Chu*, in the *Li Chi Chi Chieh*, ch. 13, p. 64, tr. auct.
[c] See p. 186 above.
[d] *Hou Han Shu*, ch. 11, p. 3*a*.
[e] (1), p. 45.
[f] See Table 49, p. 175.
[g] Cf. Grove (1), vol. 1, p. 688.

[1] 京房 [2] 竹聲不可以度調 [3] 準 [4] 瑟

In speaking of 'Chinese octaves' it would nevertheless be misleading to suggest that the true octave was unknown or not used. The true octave is in fact used wherever men and women, or men and boys, sing together, owing to the difference in the natural register of their voices. There is in addition textual evidence that scholars were aware that the octave is produced by halving the length of the resonating agent. Thus Tshai Yuan-Ting[1] (+1135 to +1198) commenting on the manner in which the pitch-pipes were associated with the months of the year, Huang-chung being the pitch for mid-winter and the others in succession through the year as described in the *Yüeh Ling*, says that the pitch for mid-summer is the octave, *shao-kung*,[2] of Huang-chung, and that the length of the Huang-chung pipe being 9 in., that of its octave is 4½ in. Other scholars refused to accept this, not because of any misgivings on the score of end-effect, but simply because the true octave is not part of the 'cycle of fifths' system which had been looked on as orthodox from the time of the publication of the *Lü Shih Chhun Chhiu* if not earlier. But Tshai Yuan-Ting was concerned with problems of temperament, and was in fact one of the pioneers of the equal-tempered system. For this a perfect octave is essential, as will be made clear in the following pages.

(ii) *Western music and Chinese mathematics*

European music has made such remarkable advances during the last five centuries that it is easy for Westerners to forget or ignore the very existence of other musical systems no less rich and no less highly developed in other directions. For example, while Europe learnt to cross its melodies and develop harmony in pitch, Africa concentrated on crossing its rhythms and developing harmony in rhythm.[a]

There are two recent musical developments most characteristic of Europe. First, the high level of technical ability and practice attained in the manufacture of instruments, for example, the drawing of wire with a tensile strength of up to 200 lb., or the use of an iron frame for the pianoforte, the casting of which is described by Scholes[b] as 'one of the most delicate operations in foundry practice'. Secondly, with the development of harmony, the disappearance of the old modes, accompanied by the tendency to modulate ever more freely from key to key, till at last in the twentieth century we have 'atonalism' and the 'twelve-note music' of Schönberg, which attempt to discard the seven-note diatonic system. The following pages will attempt to show, or to suggest (since proof at this distance in time seems no longer likely), that our modern facility in modulating from key to key is yet another instance of Europe's debt to the civilisation of China.

As has already been explained,[c] when just intonation is used in the tuning of instruments, the 'same' note in two different scales will not necessarily have the same frequency. For example, F will have a frequency of 682·3 if it is the perfect fourth

[a] Cf. A. M. Jones (1), p. 78.
[b] (1), p. 715.
[c] P. 168 above.

[1] 蔡元定 [2] 少宮

from C, but 691 if it is the minor third from D. This meant that many instruments were capable of playing only in the one key to which they had been tuned by their designer, and if used in alien keys would sound out of tune, for some of the notes would then have the wrong frequencies. In practice, this is something of an over-statement, for an instrument designed for a particular key could normally be used for a small number of related keys as well, the pitch differences in their respective notes being too small to give offence to the ear.

In China, however, this was in theory a particularly serious problem, for the fixed-key instruments *par excellence* were the very expensive chimes of bells and ringing-stones. In theory no less than sixty bells or stones would have had to be cast or trimmed if tunes in all the twelve keys were to be played without the ritual pentatonic melodies offending the ear.

A similar problem arose when it was desired to play with consorts of instruments if those instruments had not all been designed for the same key. Stringed instruments could readily be adapted to instruments of any key, since executants had only to adjust their playing to the keys required, as violinists do today; or alternatively the strings could be retuned to another key during an interval. But for instruments which could not be retuned a different system was required, a compromise system in which a given set of notes would do duty for as many different keys as possible. This could be done by 'tempering' the tuning, that is to say, sharpening some notes and flattening others, so as to make them more generally serviceable.

Rough and ready ways of tempering must have been used by practical musicians from very early times. Certainly there are many references to the need for the careful placing of frets (originally loops of string tied round the neck of the viol) in the +15th- and +16th-century works of such writers as de Pareja and Bottrigari.* It is likely that in China, where a rigidly accurate cycle-of-fifths system of tuning would have involved musicians in the same sort of difficulties as just intonation in Europe, bells and ringing-stones were skilfully filed or chipped in such a way that their princely owner would not be involved in the unnecessary expense of superfluous instruments. Similarly with flutes and pipes, a slight displacement of the finger-hole could imperceptibly sharpen or flatten a note to extend its range of usefulness. But these tentative steps towards some more generally useful system of tuning are not in themselves equal temperament of the sort which received its greatest publicity from Bach's *Wohl-temperirte Clavier*. When an instrument is tuned by equal temperament every semitone is equal to every other semitone. But the mathematics of this simple statement are relatively complicated.

The best short account of the evolution of equal temperament in Europe is probably that of Ellis (1), the translator of Helmholtz's *Sensations of Tone*, and inventor of the

* It is important to distinguish between the mathematically calculated system of equal temperament and the purely empirical methods of distributing the Pythagorean comma more or less equally over the twelve intervals, arrived at in Europe at this time, and in China five centuries earlier (cf. p. 219 below, on Wang Pho). For example, Jeans (2), p. 174, speaks as if Bartolomé Ramos de Pareja proposed equal temperament in his *De Musica Tractatus* of +1482. But historians of music (e.g. Eitner (1), vol. 8, under Ramis; Scholes (1) under Temperament 5, p. 924*b*; and Grove (1), vol. 4, p. 322) are agreed that it was a matter of adjusting the positions of frets according to purely practical and empirical rules.

'cents' system[a] of scale definition, whose contributions to musical knowledge have been used so effectively by others that their originator is now often forgotten.[b] He describes the four main systems of tuning: (*a*) Just Intonation, which derives from the astronomer Ptolemy (*fl.* +156), a system in which 'all fifths and all thirds are perfect'; then (*b*) Pythagorean Temperament, the relation of which to perfect fifths and fourths has previously been described.[c] Mean-tone Temperament (*c*), was a system perfected by Salinas in +1577, and based on perfect major thirds with other intervals so adapted that it was passably accurate for a total of about nine keys, but intolerable if one attempted to modulate into the others. This system was used for organs until quite recent times. Finally (*d*) Equal Temperament, in which 'every fifth without exception is one eleventh of a comma, or V (vibrations) 1 in 885 too flat, and every major third, without exception, is seven elevenths of a comma, or V 1 in 126 too sharp'.

As post-Renaissance music developed, great need existed in Europe for a system of tuning by which instruments of fixed key could transpose their music into as many keys as possible, preferably all, and by which even adaptable instruments, such as viols, could modulate from key to key without pausing to retune or readjust the frets. This was a revolution but it took place gradually. Equal-temperament tuning does not seem to have become general for the pianoforte in England until midway through the 19th century. Broadwood did not adopt it till as late as 1846.[d] Its very gradualness seems to have been one reason why its origin in Europe has been something of a mystery. Scholes rightly points out[e] that, although many people have a vague idea that Bach himself invented the system, there is no justification for this. It is more orthodox[f] to father the invention upon Andreas Werkmeister, who is said to have formulated the system of absolute equalisation between the semitones in +1691. But this can scarcely be justified, for Mersenne mentions[g] it in +1636 and gives the correct figures, adding elsewhere[h] that the system 'est le plus usité et le plus commode, et que tous les praticiens avouent que la division de l'octave en douze démitons leur est plus facile pour toucher les instruments'. Commenting on this passage Ellis says[i] that of the ease there is no doubt, but that of the customariness corroboration is required. In support of Mersenne, however, it is to be noted that Johann Caspar Kerll (+1627 to +1693), whose age of creative activity began not long after the publication of Mersenne's work, wrote a duet on a ground bass, passing through every key.[j]

The situation in Europe, then, was that from the +15th century onward, musicians were writing more and more in a style which made the use of an equal-tempered system inevitable, and that in the earlier writers of this period there are instructions

[a] A 'cent' is equal to 1/100 of the tempered European semitone.
[b] That there should be no entry for A. J. Ellis in Scholes (1), though much of its article on equal temperament is to be found verbatim in Ellis's paper here mentioned, appears to be a singular omission.
[c] Pp. 167ff., 172ff., 177, 181.
[d] Harding (1), p. 218.
[e] (1), p. 924.
[f] E.g. Closson (1), p. 56; Levis (1), p. 67.
[g] *Harmonie Universelle*, p. 132 (Bk. 2, prop. xi).
[h] *Harmonie Universelle*, Bk. 3, prop. xii, 'Des Genres de la Musique'.
[i] (1), p. 401.
[j] Scholes (1), p. 924.

on the tuning of lutes which suggest an approximation to equal temperament, but without specific reference or calculations. Ellis states categorically that 'in Europe neither Zarlino (+1562) nor Salinas (+1577) mentions equal temperament'.[a] But by +1636 we find Mersenne in possession of the actual figures, and stating that their use is a commonplace. At what moment did the actual mathematical formula appear, and who was the mathematician responsible? This question may be left for the present inside a bracket formed by the years +1577 and +1636, in order that attention may be given to the parallel development of acoustic and musical theory in China.

The need for a certain measure of compromise when different-keyed instruments are required to play in concert, and the nuisance of continual retuning or exchanging of instruments when music is played in many keys, both exerted a powerful influence on the development of Chinese musical practice. As an example of the former may be quoted the evidence of a European witness in the +16th century, Gaspar da Cruz, who left a description of life at Canton as he saw it in +1556.

> They played many instruments together sometimes, consorted in four voices which make a very good consonancy. It happened one night by moonshine, that I and certain Portugals were sitting on a bench at the riverside by the door of our lodging, when a few young men came along the river in a boat passing the time, playing on divers instruments; and we, being glad to hear the music, sent for them to come near where we were, and that we would invite them. They as gallant youths came near with the boat and began to tune their instruments, in such sort that we were glad to see them fit themselves that they might make no discord; and beginning to sound, they began not all together, but the one tarried for to enter with the other, making many divisions in the process of the music, some staying, others playing; and the most times they played all together in four parts. The parts were two small bandoraes (viols) for tenor, a great one for counter-tenor, a harpsichord that followed the rest, and sometimes a rebeck and sometimes a dulcimer for treble.[b]

The playing of many instruments together had been a characteristic of Chinese music from the earliest times, as can be seen from an ode in the *Shih Ching*, where bells and zithers, reed-organs and ringing-stones are described as sounding together.[c] The *Chou Li*, on the other hand, affords evidence of changes of key, for in describing the ritual of the three great sacrifices it lays down[d] that at the winter solstice there shall

[a] (1), p. 401.

[b] In *Tractado de las Cousas de China* (Evora, 1570), eng. *Purchas his Pilgrimes*, III, p. 81; mod. C. R. Boxer (1), p. 145. The instruments of this party would seem to have been three lutes of the *phi-pha*[1] type, one larger and deeper than the others, one *chêng*[2] following, with one *hu-chhin*[3] violin and a *chhin*[4] or *sê*[5] sometimes joining in. Such a party is described and illustrated in van Aalst (1), pp. 36, 64. The *hu-chhin* has not much entered into our argument so far. Although it is today an extremely popular instrument, closely associated with the classical opera, it came into China late (much later than the *phi-pha*), probably from Mongol culture. Commonly known as the Chinese violin, it has a small sound-box, a long neck with prominent pegs, and one or two double strings through which passes the hair-strip of the non-detachable bow. Further details will be found in Moule (10), pp. 121ff.

[c] Ku Chung;[6] Mao, no. 208, tr. Legge (8), p. 280; Karlgren (14), p. 160; Waley (1), p. 140.

[d] Entry for the Grand Music-Master (Ta Ssu Yo[7]), ch. 6, pp. 4b, 5a (ch. 22); tr. Biot (1), vol. 2 p. 34.

[1] 琵琶 [2] 箏 [3] 胡琴 [4] 琴 [5] 瑟 [6] 鼓鐘
[7] 大司樂

be six changes of melody using three modes, at the summer solstice eight changes of melody with four modes, and at the sacrifice to the ancestors nine changes of melody with three modes.[a] These three ceremonials thus employed all the five pentatonic modes distributed over eight of the possible sixty 'mode-keys'.[b]

It is therefore not surprising to find evidence of very early attempts to temper the scale, such as that recorded in the *Huai Nan Tzu* book, where the lengths of the pitch-pipes with their complicated standard fractions have been simplified into round numbers.[c] This was clearly done with some reference to the ear, and not merely as a mathematical convenience, for whereas the correct length of the pitch-pipe Chia-chung expressed in hundredths of an inch was 674·23, the *Huai Nan Tzu* gives it as 680, though 670 would have been an approximation mathematically truer.[d] This temperament does not, however, differ fundamentally from the cycle-of-fifths tuning.

This first approximation recorded in the *Huai Nan Tzu* dates from the −2nd century. From then on for some seventeen centuries there was an almost continuous succession of experimentalists, not all of whom can be mentioned here.[e] Developments oscillated between two extremes, one of which retained the purity of the tuning by reducing the number of mode-keys, while the other sacrificed the purity of tuning in attempts to embrace as many modes as possible. The former tendency reached its logical fulfilment during the Sui period (+581 to +618), when apparently only one mode-key was used, that of the *kung* mode in the Huang-chung key, for ceremonial music. Seven bells were used for giving a heptatonic scale in this mode-key, the other five bells of the gamut being held in abeyance and called 'dumb bells' (*ya chung*[1]).[f] Attempts to avoid this impoverishment took different channels, for which close parallels may be found in the history of European musical development. Only two forms of solution are possible: either to increase the available choice of notes so that every key may be rendered in perfect intonation, regardless of the difficulties of the performer and the complexities of the instruments; or to sacrifice purity of sound deliberately for the sake of a manageable compromise.

The most famous exponent of the former solution was Ching Fang[2] (*fl.* −45),[g] whose system continued the never-ending spiral of fifths calculated on a 10 ft. wooden tuner with thirteen strings starting at Huang-chung and working five times

[a] The Chinese text refers, as is normal, to 'mode-keys', by the method described above, p. 169. If the modes are isolated it will be found that the winter sacrifice uses modes III, IV and V, while the summer sacrifice uses modes I, II, III and IV. The ancestral sacrifice uses only modes I, III and IV.

[b] But the entire group of 'mode-keys' deriving in tonality from the *shang* note was excluded, since *shang* was considered to be 'hard' and therefore not suitable for the ritual music which purposed to lure to man's aid the spirits of heaven and earth by its sweetness.

[c] Ch. 3, p. 13*a* (Chatley (1), p. 27).

[d] P. 12*a* (Chatley (1), p. 25).

[e] Cf. Courant (2); Robinson (1).

[f] *Chhü Wei Chiu Wên*,[3] by Chu Pien[4] of the Sung period, ch. 5, p. 9*a*.

[g] We have met with him before (cf. Vol. 2, pp. 247, 309, 350; Vol. 3, pp. 227, 433, 470, 483) in connection with mutationism, astronomy, meteorology, and other things.

[1] 啞鐘 [2] 京房 [3] 曲洧舊聞 [4] 朱弁

round the cycle to the 60th note.[a] His work may be compared with that of Nicolas Mercator in Europe some seventeen centuries later, who arrived at a system of temperament having 53 degrees.[b] Ching Fang's microtonic experiments were taken up five centuries after his death by another naturalist, Chhien Lo-Chih[1] (*fl. c.* +450),[c] who continued the calculation of the spiral to the 360th degree.[d] Such a system would have been quite unworkable in practice.

Of the many other experimenters through the centuries much has been written, notably by Courant[e] who is an indispensable authority on this subject, and by Yang Yin-Liu (*1*) who has written a detailed account of the efforts of Chinese scholars to attain equal temperament. Chu Tsai-Yü himself, when writing of his own experiments,[f] focuses attention on four pioneers who had all made use of the stringed tuner described above[g] as the *chün*, or referred to it. Of these, the first—Lingchou Chiu[2]—only appears in the *Kuo Yü* as one of the interlocutors of the High King Ching of Chou (*c.* −520) in the discussion about the gamut of bells, the function of the 'tuner' and its relation to good government.[h] The second is Ching Fang (*d.* −37). The third is Chhen Chung-Ju[3] (*fl.* +516), who combined certain of Ching Fang's ideas with others of his own in a way which Chu Tsai-Yü says could not have been successful; and the fourth is the famous Taoist scientist and engineer Wang Pho[4] (*fl.* +959).[i]

Wang Pho worked out his system on a thirteen-stringed tuner,[j] but is also said to have tuned sets of bells to this temperament.[k] In common with the astronomer Ho Chhêng-Thien[5] (+370 to +447) he realised that it was hopeless to attempt to reach a workable solution by extending the spiral of fifths as Ching Fang had done, and that the perfect octave must be accepted as the framework within which subdivision is to take place. Ho Chhêng-Thien[l] simply measured the difference between a perfect octave and that interval, the sharpened octave, which is produced in its stead as the thirteenth note in the cycle of fifths, the difference being the so-called Pythagorean

[a] It is described at length in the *Hou Han Shu*, ch. 11, pp. 3*a*–16*a*; and briefly by Chu Tsai-Yü, *Lü Hsüeh Hsin Shuo*, ch. 1, p. 23*b*. Cf. Robinson (1), p. 101; Wu Nan-Hsün (*1*), pp. 132ff.

[b] Courant (2), p. 89. Christopher Simpson (*d.* +1669) in his *Division Violinist* advocated quarter-tones (Scholes (1), p. 575), as Tshai Yuan-Ting[6] had done before him in the +12th century when he inserted a *pien lü*[7] between each semitone (*Sung Shih*, ch. 131, pp. 11*a*ff., esp. pp. 12*b*, 13*a*). But the Moravian Aloys Hába (*b.* 1893) seems to have been the first European to have elaborated a scale of sixty notes to the octave like Ching Fang. According to Scholes, he could actually sing them all accurately.

[c] Well known to us as an astronomer and constructor of astronomical instruments, cf. Vol. 3, pp. 346, 384, etc.

[d] *Sui Shu*, ch. 16, pp. 4*b*ff. The names of the notes may be found in Shen Chung's[8] *Yo Lü I*[9] of about +570; in *YHSF*, ch. 31, pp. 31*a*ff.

[e] (2), pp. 88ff.

[f] *Lü Hsüeh Hsin Shuo*, ch. 1, p. 22*a*.

[g] P. 183.

[h] See above, pp. 170, 204.

[i] Biography in *Chiu Wu Tai Shih*, ch. 128, pp. 1*a*ff.

[j] See *Chiu Wu Tai Shih*, ch. 145, pp. 3*a*ff. His form of temperament was somewhat analogous to that of Ramos de Pareja five centuries later in that it was worked out for a stringed instrument with movable bridges.

[k] In the *Chi Ku Lu Pa Wei*,[10] ch. 1, by Ouyang Hsiu (+1007 to +1072); quoted by Wei Chü-Hsien (*1*), p. 68.

[l] +370 to +447. Cf. Vol. 3, pp. 287, 292, 384, 392, etc.; *Sui Shu*, ch. 16, pp. 4*b*ff.

1 錢樂之　2 伶州鳩　3 陳仲儒　4 王朴　5 何承天
6 蔡元定　7 變律　8 沈重　9 鍾律義　10 集古錄跋尾

comma. This difference he divided by twelve and distributed equally over all the thirteen notes except the fundamental. In this way he obtained a gamut which had the characteristics of a cycle-of-fifths scale and a true octave. It was not equal-tempered, however, for the original irregularities of the cycle-of-fifths tuning remained, and were in no way removed by the addition to each note of 1/12 of a comma.[a]

Wang Pho not only used the perfect octave as the basis of his calculations, but to a considerable extent broke away from the values of the cycle of fifths. His octave, fifth and major tone had the same values as for just intonation; but equal temperament would have required all his intervals to be sharpened except the octave. Ho Chhêng-Thien had taken a great step forward in establishing that the octave must be accepted as the framework for an equal-tempered system; Wang Pho departed further still from the orthodox tuning of the cycle of fifths. But by what calculation the twelve notes of the gamut could be so spaced that every semitone would be equal was still an unsolved mystery.

(iii) *The princely gift of Chu Tsai-Yü*

In +1536 was born one of China's most distinguished mathematical and musicological scholars. He was the son of Chu Hou-Huan[1] and a descendant of the fourth Ming emperor Chao. When[b] his father was unjustly reduced in rank by the emperor, he signified his filial grief by living in an earth-walled cottage for nineteen years. This time was spent in research into mathematical, musical and calendrical matters, the results of which were published at intervals and finally as a collected work.[c] His gift to mankind was the discovery of the mathematical means of tempering the scale in equal intervals, a system of such fundamental utility that people in all Western countries today take it for granted and are unaware of its existence.[d]

In the *Lü Hsüeh Hsin Shuo*[2] (A New Account of the Science of the Pitch-pipes), published in +1584, Chu Tsai-Yü[3] describes previous attempts at tempering the scale and shows their shortcomings before discussing his own 'new method', in which he 'used numbers for seeking harmony in the notes, and did not make the notes

[a] The work of Ho Chhêng-Thien was continued further by Hsiao Yen,[4] who ruled as Liang Wu Ti from +502 to +549. His book entitled *Chung Lü Wei*[5] (Apocryphal Treatise on Bells and Pipes) is still extant in fragmentary form. An excellent account of his interesting work is given by Wu Nan-Hsün (*1*), pp. 159 ff.

[b] His title in this capacity was Chêng Shih Tzu;[6] he is often so named in the dynastic history and similar official texts.

[c] His works, bound in four large volumes, are generally known by the name *Yo Lü Chhüan Shu*[7] (Collected Works on Music and the Pitch-pipes); but this title really refers to the earlier two of his four works on pitch-pipe theory, in addition to which there is one book on a perpetual calendar and another on the orchestration of ancient songs (cf. Robinson, 1). Details of Chu Tsai-Yü's life are to be found in the *Ming Shih*, ch. 119, pp. 14ff. esp. 3*b*, 4*a*.

[d] The story of his discovery and its probable transmission to the West has been fairly well known in China (cf. Liu Fu (*3*), Chang Chhi-Yün (*1*, preface), Wu Nan-Hsün (*1*), pp. 190ff. etc.) but has not before been recounted in a Western-language publication. For a much fuller survey, however, see Robinson (*1*).

[1] 朱厚烷 [2] 律學新說 [3] 朱載堉 [4] 蕭衍 [5] 鐘律緯
[6] 鄭世子 [7] 樂律全書

submit to (natural series of) numbers'.[a] That is to say, he found a true mathematician's solution. But fearing that mathematics alone might not guarantee the success of his system with posterity, he also made a deliberate study of ancient tuning instruments and then constructed one of his own (Fig. 320). In this the proportions of the scale were made manifest by studs placed at the appropriate tempered intervals to indicate the correct positions for the placing of the fingers after the manner of frets.

It was suggested at an earlier stage in this Section that the mathematical formula by which the lengths of the pitch-pipes were calculated was a foreign importation grafted on to the indigenous system. If the indigenous system had survived one would expect to find it as a still living tradition among the craftsmen and practising musicians, who were not concerned with the theories of scholars, naturalists and court ritualists. It was precisely a contradiction between these two different systems which focused Chu Tsai-Yü's attention on that aspect of the problem which gave him the solution.

After describing the musical theories of the great Sung philosopher Chu Hsi, who had advocated the orthodox pitch-pipe dimensions, Chu Tsai-Yü writes as follows:[b]

> I had made an attempt with the theory of the Sung (scholar) Chu Hsi, based on the ancient up-and-down principle, and using this tried to get the positions for the standard pitches on the zither (*i chhiu chhin chih lü wei* [1]). But I noticed that the (normal) notes of the zither were not in consonance with (those produced from) the positions of the standard pitches, and suspicions therefore arose in my mind.
>
> Night and day I searched for a solution and studied exhaustively this pattern-principle. Suddenly early one morning I reached a perfect understanding of it and realised for the first time that the four ancient sorts of standard pitches all gave mere approximations to the notes. This moreover was something which pitch-pipe exponents had not been conscious of for a period of two thousand years.
>
> Only the makers of the zither (*chhin* [2]) in their method of placing the markers at three-quarters or two-thirds (etc. of the length of the strings) had as common artisans transmitted by word of mouth (the way of making the instrument) from an unknown source. I think that probably the men of old handed down the system in this way, only it is not recorded in literary works.

From this statement one might infer that Chu Tsai-Yü had recovered the secret of equal temperament from the remotest antiquity, but in fact he does not say so.[c] His elation was due to the fact that as a conscientious antiquarian he had discovered in this living tradition a moral justification for defying the cycle of fifths which had been

[a] Note this very conscious repudiation of the numerological games and number-mysticism which had become so hallowed in China by centuries of transmission from the classics. Cf. pp. 134ff. above, and our comments in Vol. 2, pp. 287ff. Though so far from Europe, Chu Tsai-Yü was 'a man of the Renaissance', contrasting as much with Chhen Thuan (cf. Vol. 2, pp. 442ff.) or Shao Yung (pp. 455ff.) as a Joseph Glanville with an Agrippa of Nettesheim.

[b] *Lü Hsüeh Hsin Shuo*, ch. 1, p. 5a, tr. auct.

[c] He was careful to give his innovations an appearance of respectability (*Lü Hsüeh Hsin Shuo*, ch. 2, pp. 74ff.) by taking as his unit of measurement an inch of fictitious antiquity which he described as the Hsia inch, the inch of the most ancient Chinese dynasty. Of course, no scholar of his time would have been misled by this. What he says about the handing down of oral tradition among artisans is interesting (cf. Sect. 29 below in connection with shipbuilding).

[1] 以求琴之律位 [2] 琴

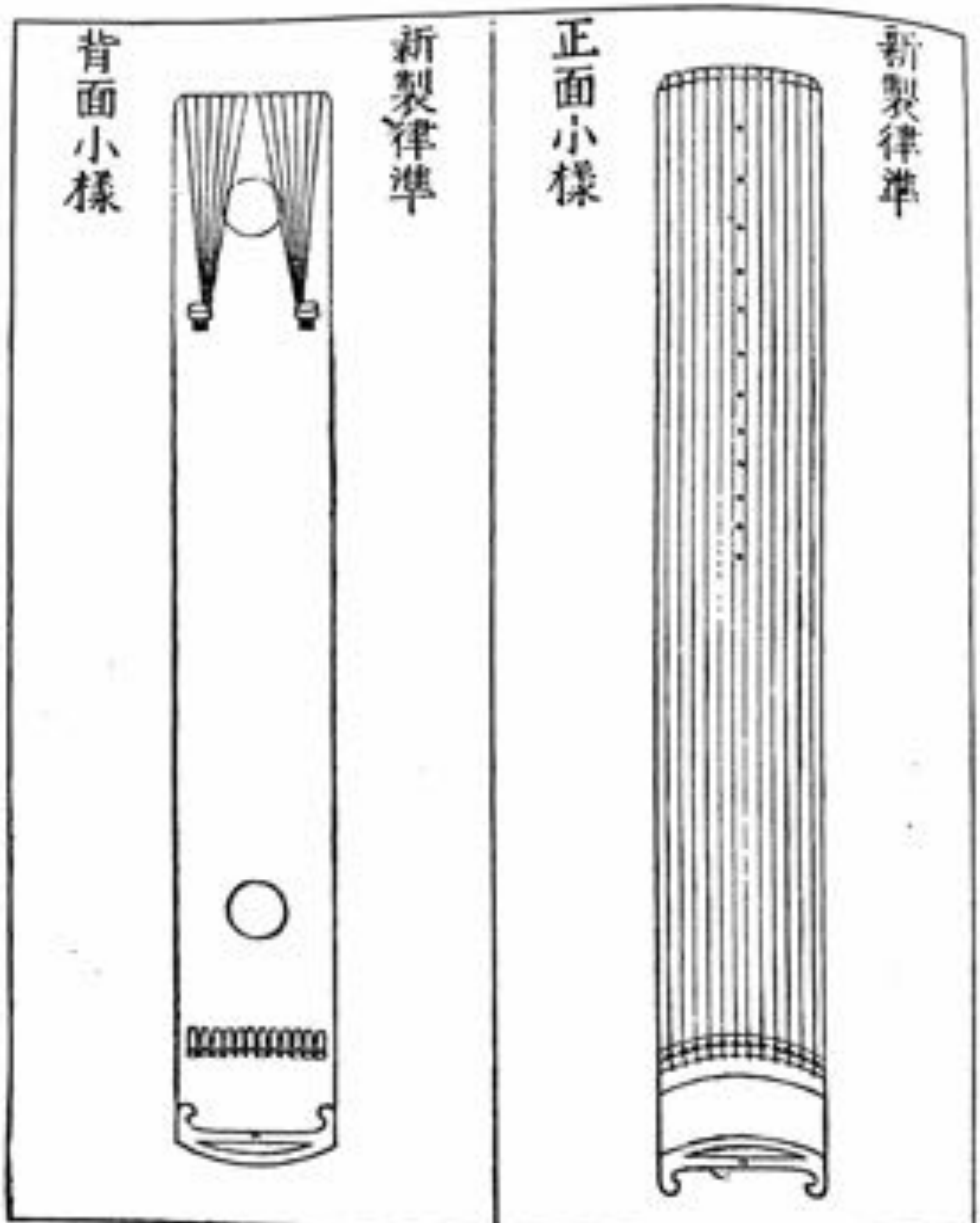

Fig. 320. Chu Tsai-Yü's tuning instrument (*chun*). From his *Lü Hsüeh Hsin Shuo*, ch. 1, p. 28a (+1584). The legends at the top read 'Sketch of the New *Chun*'; on the right the front, on the left the back of the instrument.

hallowed by two thousand years of history. Possibly the answer to his mathematical problem also occurred to him at the same instant, but this, which is for us the most interesting part of the story, he dismisses in a few words:[a]

> I have founded a new system. I establish one foot as the number from which the others are to be extracted, and using (square and cube root) proportions I extract them. Altogether one has to find the exact figures for the pitch-pipes in twelve operations.[b]

Applying this new principle he gives tables showing the lengths of the standard pitch-pipes and also of half-length and double-length pipes, giving in all a compass of three octaves. The principle which he had discovered was that to divide the octave into twelve equal semitones, the length of the fundamental string (or pipe if one ignores end-effect), and thereafter each successive length obtained, must be divided by the 12th root of 2. This is a very different matter from merely dividing the string into twelve equal parts, i.e. the whole string, 11/12, 10/12, 9/12, etc., for these proportions produce a very unequal temperament. If all intervals are to be equal, the ratio for each semitone must be altered by an equal amount. The ratio of the octave is 1:2. This can be expressed in the form $1:2^{12/12}$, since two to the power of twelve twelfths is two. To alter the ratio of each semitone by an equal amount, it was merely necessary to express each proportion thereafter as $1:2^{11/12}$, $1:2^{10/12}$, $1:2^{9/12}$, etc., and to know the exact length of each string, it was simply a matter of dividing the 1 ft. Huang-chung string by $\sqrt[12]{2}$, which is the same as $2^{1/12}$, and then dividing the length of each successive string so obtained by $\sqrt[12]{2}$. Thus a perfectly tempered scale was achieved.

This is the simplest method of calculating the lengths of the strings, and may have been the one used by Chu Tsai-Yü in the first place. Sung algebraists such as Chu Shih-Chieh[1] (+13th century) could certainly handle roots of high powers, but their books had at that time disappeared, and it is doubtful whether Chu Tsai-Yü could have been acquainted with their methods.[c] The method he shows in his published calculations achieves the same results by the use only of square and cube roots. Briefly it was as follows. Of the thirteen strings the lengths of which required calculation, two were already known, no. 1 being 1 ft., and no. 13 half a foot. He then found the square root of the product of these two lengths, which gave him the length of the middle string no. 7. The square root of the products of nos. 1 and 7 and nos. 13 and 7 then gave him the lengths of the two strings intermediate between these three, namely nos. 4 and 10 respectively. The lengths so far discovered may be expressed thus: 1 * * 4 * * 7 * * 10 * * 13.

In order to find the lengths of the remaining strings (nos. 11 and 12 may be taken as examples), he evidently had it clearly in his mind that the length of no. 10 was

[a] *Lü Hsüeh Hsin Shuo*, ch. 1, p. 5b, tr. auct.
[b] *Chhuang li hsin fa. Chih i chhih wei shih i mi li chhu chih. Fan shih-erh pien so chhiu lü lü chen shu.*
[c] Cf. Vol. 3, pp. 126ff. above.

[1] 朱世傑 [2] 創立新法置一尺為實以密率除之凡十二遍所求律呂真數

1 ft. × $2^{3/12}$; of no. 11, 1 ft. × $2^{2/12}$; and of no. 12, 1 ft. × $2^{1/12}$; and that as $2^{1/12}$ is the cube root of $2^{3/12}$, to find the length of string no. 12 he had merely to find the cube root of no. 10, and multiply one foot by it. Similarly 1 ft. multiplied by the square root of the length of no. 10 gave the length of no. 11, and like results may be got for the other unknown lengths by a similar process.

This rather complicated procedure was perhaps used as a check on the simpler method first mentioned, namely dividing the fundamental string by $\sqrt[12]{2}$, which is 1·05946, and repeating the process for each string or pipe as described above. The figure 1·05946 was of course obtained by Chu Tsai-Yü for the note immediately below his standard Huang-chung length. Double-length Huang-chung being 2 ft., the 12th note above it, Ying-chung, was 1·05946 ft. long. Chu says quite explicitly[a] that each string in turn must be 'divided by the figure for double-length Ying-chung... which is a way of getting the pitches in their serial order'.[b]

This statement leaves no doubt that Chu Tsai-Yü invented the formula for equal temperament just as it was known in Europe at a later date. It is particularly important to note how little had to be memorised by any traveller in touch with Chinese ideas for him to be able to transmit the idea to the mathematicians and musicians of Europe. Such a traveller would only have to say: 'I understand that the Chinese temper their viols with great accuracy. They simply divide the length of their first string by $\sqrt[12]{2}$ to get the length of the string for the second note, and then do the same again for the third note, and so on, till they reach the 13th which is a perfect octave.' Not a book but a sentence only was required for the diffusion of this great idea.

Although this temperament was worked out for strings Chu Tsai-Yü also applied it to pipes.[c] The pipes were the same lengths as the strings and if left uncorrected the equalness of their temperament would have been distorted by end-effect, but Chu Tsai-Yü compensated for this by also tempering their diameters, dividing each successive diameter by the 24th root of 2. Considering how little he can have known of the physics of end-effect his success is quite remarkable, remaining distortions being imperceptible to the human ear.

(iv) *Equal temperament in East and West*

Chu Tsai-Yü's formulation of equal temperament may justly be regarded as the crowning achievement of China's two millennia of acoustic experiment and research. One great question yet remains. Was it discovered independently or could it have been transmitted from China to Europe at the end of the +16th century? Certainly a time was coming when Europe could profit from such an invention, and there were many mathematicians in Europe capable of calculating just as Chu Tsai-Yü had done. Pacioli (+1494), for example, and Cattani (+1546), were able to handle roots of

[a] *Lü Hsüeh Hsin Shuo*, ch. 1, pp. 10aff. Cf. Robinson (1), p. 156.
[b] *Chieh i Ying-chung pei shu...wei fa chhu chih chi tê chhi tzhu lü yeh.*[a]
[c] Tables and illustrations showing lengths and internal and external diameters of his pitch-pipes are given in the same book, pp. 15bff. *Lü Lü Ching I*, ch. 8, pp. 4bff., 6aff.; *Lü Shu*, ch. 1, pp. 31ff.

[a] 皆以倍應鐘數…為法除之即得其次律也

high powers.[a] Nevertheless, it would be a remarkable coincidence if the same solution was found independently at opposite ends of the earth within a few years. And it is striking that so little can be ascertained about its European origin when everything is known about its invention in China.

The opening pages of the *Lü Hsüeh Hsin Shuo* contain the date +1584.[b] There is no doubt that by this time Chinese books were beginning to make their way into Europe in some quantity. From Paolo Giovio's reference in his *Historia Sui Temporis* (+1550) to the gift of a Chinese book by the King of Portugal to the Pope, down to Amiot's detailed *Mémoire* on Chinese music (+1776), there were innumerable literary contacts of Europe with China. But it is worth noting that both the friars and the Jesuit missionaries were almost invariably interested in Chinese music; not only because they lived in a musically educated age, but because one of the problems of their work was either how to adapt European music for the use of Chinese congregations, or how to teach European music to Christians brought up in a different musical tradition. In +1294, when John of Monte Corvino was singing masses in Cambaluc,[c] European music was not so different from East Asian music that it could not be appreciated there. But during the following centuries it underwent so marked and rapid a development on the road to harmony that by the time Amiot, some five hundred years later, came to play contemporary European music to gentlemen of the Chhing court, they found it so meaningless that they were scarcely affected by it.

Gaspar da Cruz in +1556 stood midway between these two points, and was able to give an accurate description of the sort of music he heard.[d] Twenty years later (+1575) the Austin friars Martín de Rada (Herrada) and Jerónimo Marín, who spent three months in China (Fukien), brought away many books some of which they afterwards caused to be translated in the Philippines. These included some 'Of musicke and songs, and who were the inventors thereof'.[e] But already ten years before (+1565)

[a] Cf. D. E. Smith (1), vol. 2, pp. 471 ff., and above, Vol. 3, p. 128.

[b] This, the 12th year of the Wan-Li reign-period, was the very year which saw the first establishment of Matteo Ricci at Chao-chhing.

[c] Cf. Vol. 1, pp. 169, 230.

[d] Cf. p. 217 above. On him see Boxer (1), pp. lviii ff.

[e] See Gonzales de Mendoza (1), Parke tr., pp. 103 ff., 134, 140 and 250; Boxer (1), pp. lxxxiv ff., 243 ff. the following other
As we have not mentioned this remarkably well-attested transmission elsewhere,
topics may also be noted:
'Of the mathematicall sciences, and of arithmeticke, and rules how to use the same.
'Of the nomber, and moovings of the Heavens; of the planets and stars, and of their operations and particular influences.
'Of the properties of stones and mettals, and of things natural that have vertue of themselves....
'For the making of ships of all sorts, and the order of navigation, with the altitudes of every port, and the qualitie of every one in particular.
'Of architecture and all manner of buildings, with the bredth and length that everie edifice ought to have for his proportion.
'Manie herbals, or bookes of herbes, for phisitions, shewing how they should be applied to heale infirmities.'

Boxer adds several interesting speculations about the fate of the books collected by Martín de Rada; some of them may still exist in European libraries. There are, for example, about half a dozen Chinese works in early +16th-century editions in the Library of the Escorial. Apprised of their existence by Professor Donald Lach, Dr Lu Gwei-Djen and I had the pleasure of examining them in September 1960. Since this house is Augustinian it seems quite likely that some of these books were brought back by de Rada—but today nothing of scientific interest remains except a small medical treatise and a calendar, and no book on music or acoustics.

the Jesuits had opened their house in Macao for training missionaries,[a] teaching them to read Chinese books, and from this college there soon came a flow of letters informing the Western world of the nature of Chinese civilisation. In +1582 the great Matteo Ricci (Li Ma-Tou[1]) began his Chinese studies in Macao,[b] and the Franciscan friars Jerónimo de Burgos and Martín Ignacio de Loyola landed at Canton.[c] Ignacio was one of the informants of Juan Gonzales de Mendoza whose book[d] was first published in Spanish in +1585. In +1588 Cavendish returned to England from his first voyage round the world. As was customary in those days he had his private musicians on board, and it is interesting to note that when the 'Great St Anna' was captured, one of the prisoners was a certain Nicholas Roderigo 'a Portugall, who hath not onely beene in Canton and other parts of China, but also in the islands of Iapon...'.[e] The following year the Jesuit Edouart de Sande (Mêng San-Tê[2]), writing of his travels in China, described how the officials discovered in his possession several books in the Chinese language, 'de quoy ils monstrérent estre bien aisés'.[f] The last two decades of the century were the golden age of Macao when relations with the Chinese were becoming stabilised, and interchange of ideas relatively easy. For a period beginning in +1580 the Viceroy of Kuangtung opened bi-annual 'fairs' at Canton which lasted for several weeks, during which there was an opportunity for the interchange of Chinese and Western goods as well as ideas.[g] In +1595 Ricci was in Nanking discussing amongst other things mathematics with Chinese scholars, and in +1601 he succeeded in making his home in Peking. From that time forward knowledge of Chinese civilisation spread in Europe with great rapidity.

Thus by the beginning of the 17th century Europeans were interested in Chinese music, and had some access to Chinese books. It cannot be proved that a copy of Chu Tsai-Yü's *Lü Hsüeh Hsin Shuo* or of his *Lü Shu* made its way to Europe and was there acted upon, but it is reasonable to say that there was ample opportunity between +1585 and +1635 for this to happen. The matter is worth pressing a little further. Between +1597 and the year of his death in +1610 Matteo Ricci became increasingly conscious of the part which his mission could play in the rectifying of the Chinese calendar. He would naturally have studied Chinese books on the subject, as did his successor in the task, Sabbathin de Ursis (Hsiung San-Pa[3]).[h] Among these would have been Chu Tsai-Yü's *Shêng Shou Wan Nien Li*, which even Wieger could do no less than describe as 'a complete treatise on the calculation of time with a perpetual calendar, a masterpiece which...magisterially sums up all the previous works on the

[a] Pfister (1), pp. 5, 10.
[b] Pfister (1), p. 23.
[c] See Boxer (1), p. lxxxix; and in full detail Pelliot (45).
[d] *Historia de las Cosas mas notables, Ritos e Costumbres del Gran Reyno de la China....*
[e] Hakluyt, *Voyages*, vol. 3, p. 817.
[f] Letter from Father Edouart de Sande in Macao, 28 September 1589, to R.P. General (of the Society of Jesus), in *Summaire des Lettres du Japon et de la Chine de l'an MDLXXXIX et MDXC*, p. 127. Cf. Pfister (1), p. 44.
[g] Cf. A. Kammerer (1).
[h] On the work of de Ursis see e.g. Bernard-Maître (1), p. 76; Pfister (1), p. 104. The early Jesuits must certainly have known of Chu Tsai-Yü's writings.

[1] 利瑪竇 [2] 孟三德 [3] 熊三拔

subject'.[a] Now pitch-pipe lore is so intermingled with calendrical science in Chu Tsai-Yü's writings, and the two were in fact so closely connected in Chinese thinking, that it would hardly have been possible to study the calendrical ideas without becoming acquainted with the pitch-pipe theories. Europeans as intelligent as Ricci and de Ursis discussing books with educated Chinese at the close of the +16th century could scarcely have avoided hearing of Chu's books so recently published.

An independent invention of equal temperament in Europe must therefore raise grave doubt. This doubt is increased when one finds that some sixteen years before Mersenne, the great Flemish mathematician and engineer Simon Stevin (+1548 to +1620)[b] left figures for the calculation of the scale in equal temperament among his unpublished papers.[c] Many of Stevin's papers had been circulated among his friends and were never returned. His son Hendrik gathered as many as possible intending to publish them, but only two volumes left the press.[d] The vital paper on equal temperament was not rescued from oblivion till it was found and published by Bierens de Haan (1) in 1884.[e] From this it can be seen that Stevin calculated 12 equal degrees within the octave represented by the figures 1 and ½. The method is interesting, for just as Chu Tsai-Yü first computed the length of his middle string Jui-pin, which was the square root of the product of the two octave lengths, i.e. $\sqrt[2]{2 \times 1}$ or $\sqrt[2]{1 \times \frac{1}{2}}$, so Stevin took $\sqrt[2]{\frac{1}{2}}$ as the ratio of the middle note of his octave, and expressed the other ratios in comparable fashion as follows:

$$1 : \begin{cases} 1 \\ \sqrt[12]{\frac{1}{2}} \\ \sqrt[6]{\frac{1}{2}} \\ \sqrt[4]{\frac{1}{2}} \\ \sqrt[3]{\frac{1}{2}} \\ \sqrt[12]{\frac{1}{32}} \\ \sqrt{\frac{1}{2}} \\ \sqrt[12]{\frac{1}{128}} \\ \sqrt[3]{\frac{1}{4}} \\ \sqrt[4]{\frac{1}{8}} \\ \sqrt[6]{\frac{1}{32}} \\ \sqrt[12]{\frac{1}{2048}} \\ \frac{1}{2} \end{cases}$$

Perhaps the most striking fact about all this is that if Stevin discovered these formulae uninfluenced by Chinese work on the subject, it was the second remarkable invention of his which had previously appeared in China, the first being his celebrated

[a] (3), p. 249. Chu Tsai-Yü presented his calendar to the throne in +1595, the year of Ricci's first journey to Nanking. In doing so Chu drew attention to the deficiencies of the current calendar (see *Jih Chih Lu*, ch. 30, p. 1a; cf. *Ming Shih*, ch. 31, p. 33a), envisaging doubtless, however, a reform along the traditional and characteristic Chinese lines, not a wholesale adoption of Greek conceptions such as the Jesuits were beginning to urge. But there is no doubt that the prospect of their aid was one of the factors which facilitated the journey of Ricci and his companions through Nanking to Peking in 1598 (see d'Elia (2), vol. 2, p. 8; Trigault (Gallagher tr.), p. 307).

[b] Cf. Vol. 3, p. 89, and in detail Sarton (2); Dijksterhuis (1).

[c] Fokker (1), p. 18; Dijksterhuis (1), pp. 276ff.

[d] Sarton (2), p. 243.

[e] See esp. pp. 54ff.

sailing carriage.[a] Although it could be a coincidence that he happened to design a machine, the idea of which is known (for example, from Ortelius' +1584 map of China) to have reached Europe from there, without ever having heard about it, yet as Duyvendak has said, this is generally not the way in which things happen. But it would be a still more remarkable coincidence if, after a large crowd of distinguished people had witnessed the trials of his 'sailing chariot' on the sands at Scheveningen (*c.* +1600), and had discussed this and other Chinese inventions, Stevin were then able to invent the formula for the equal-tempered scale a few years later[b] without being influenced at least through hearsay by the work of his distinguished contemporary in that distant land which had so roused the interest of Europeans that Mendoza's *History ... of China* had run into eleven editions in six languages in as many years.

It is a strange irony that though Chu Tsai-Yü's work was held in high esteem, his theory was put into practice but little in his own country; while Stevin's theory seems from Mersenne's account to have been widely adopted and utilised in Europe.[c] In any case it is fair to say that the European and modern music of the last three centuries may well have been powerfully influenced by a masterpiece of Chinese mathematics, though proof of transmission be not yet available. The name of the inventor is of less importance than the fact of the invention, and Chu Tsai-Yü himself would certainly have been the first to give another investigator his due, and the last to quarrel over claims of precedence. To China must certainly be accorded the honour of first mathematically formulating equal temperament. A less obvious but more precious gift may lie concealed in the example of this retiring scholar who declined the princely rank to which he was heir in order that he might carry on his researches, believing that for him who understands the meaning of the Rites and Music all things are possible. Such was the faith which animated Chinese students of sound for more than two millennia.

[a] This idea, and the probable Chinese sources of it, will be fully discussed in Sect. 27*e* below. Meanwhile, see Duyvendak (14).

[b] If his calculation of equal temperament may be placed in the same period as his *Hypomnemata mathematica*, it would be datable between about +1605 and +1608.

[c] It is true that at first his words were held in such slight regard that, to quote his son Hendrik, 'the erudite persons to whom the manuscripts had been entrusted detached several portions and left the rest scattered pell-mell in total confusion'.