

The acoustical knowledge of the ancient Hindus

C V RAMAN, M.A.

(Sir Taraknath Palit Professor of Physics, University of Calcutta)

1. Introduction

Music, both vocal and instrumental, undoubtedly played an important part in the cultural life of ancient India. Sanskrit literature, both secular and religious, makes numerous references to instruments of various kinds, and it is, I believe, generally held by archaeologists that some of the earliest mentions of such instruments to be found anywhere are those contained in the ancient Sanskrit works. Certain it is that at a very early period in the history of the country, the Hindus were acquainted with the use of stringed instruments excited by plucking or bowing, with the transverse form of flute, with wind and reed instruments of different types and with percussion instruments. It is by no means improbable that India played an important part in the progressive evolution and improvement of these instruments and might have served as a source from which their knowledge spread both eastwards and westwards. It would form a fascinating chapter of history to try and trace the gradual development of musical instruments and musical knowledge, from the rhythmic chanting of the Rigveda in the ancient home of the Aryan race to the Indian music of the present day. But the materials available for the writing of this history seem to be all too meagre. Much of the long period over which the gradual evolution must have spread lies in the dim and remote past of which but the vaguest glimpses can be obtained from such records as exist. Something more definite regarding the acoustical developments in Ancient India might perhaps be gleaned from a study of the musical instruments, the models of which have been handed down as heirlooms for untold generations. Several of the Indian stringed instruments, for example, disclose in their design, even on a superficial examination, a quite remarkable appreciation of the principles of sound-production and of resonance. A fuller study seemed likely to lead to results of considerable interest. It was this hope that induced me some two years ago to commence a systematic examination by modern scientific methods of the ancient Indian musical instruments. The objects I set before myself were to investigate the traditional designs according to which these Indian instruments are constructed and the variations of these designs that exist in the different parts of the country, to discover the *raison d'être* of the

methods of construction employed and to find the special tone-characters which were held in esteem by the designers. It seemed that such an examination might also prove useful from the practical stand-point by disclosing the best designs and indicating the directions in which any improvements might be possible. Various circumstances have delayed the complete carrying out of the projected work, and it is probable that little progress might have been made with it up to date, but for the fact that my attention was recently drawn somewhat forcibly to the musical qualities of the ancient Indian instruments of percussion. Through the kindness of an enthusiastic fellow-worker, Mr Sivakali Kumar, some good specimens of the Indian percussion instruments were put at my disposal and I have been enabled to carry out a scientific examination of their acoustical properties. The results obtained are very remarkable and significant and are being described in detail in a monograph "On Musical Drums" which will be published by the *Indian Assoc. Cultiv. Sci.* I propose in this short essay to indicate the main results of this investigation and to show how far they throw light on the state of acoustical knowledge in ancient and medieval India.

2. Acoustics of percussion instruments

By way of preface, I shall first refer to a few facts regarding the vibrations of stretched membranes which are familiar to students of physics and which it is useful here to recall. As is well known, the vibrations of a circular stretched membrane or drum-head excited by impact are generally of an extremely complex character. Besides the gravest or fundamental tone of the membrane, we have a large retinue of overtones which stand to each other in no sort of musical relation. These overtones are always excited in greater or less degree and produce a discordant effect. All the instruments of percussion known to European physicists in which a circular drum-head is employed have therefore to be regarded more as noise producers introduced for marking the rhythm than as musical instruments. This is true even of the kettle-drum which is tuned to a definite pitch and occasionally used in European orchestral music. As has been shown by the late Lord Rayleigh in a paper published some time ago, the air enclosed in the shell of the kettle-drum does not produce any advantageous alterations of the pitch relations of the overtones. All the instruments of percussion known to European science are thus essentially non-musical and can only be tolerated in open air music or in large orchestras where a little noise more or less makes no difference. Indian musical instruments of percussion however stand in an entirely different category. Times without number we have heard the best singers or performers on the flute or violin accompanied by the well known indigenous musical drums, and the effect with a good instrument is always excellent. It was this, in fact, that conveyed to me the hint that the Indian

instruments of percussion possess interesting acoustic properties, and stimulated the research.

3. The Indian musical drums

The number of different types of percussion instruments known and used in India is almost legion. They represent a very wide variety of stages of development and variations of form to suit different purposes. It does not fall within the scope of this short essay even to attempt a discussion of the different forms. Those who are curious to see these types of drums can no doubt find specimens in the various provincial museums of India. A specially good collection is to be found in the anthropological section of the Indian Museum at Calcutta, and some of them are described with illustrations in the catalogue of the exhibits available in the Museum. The instrument to the remarkable acoustical properties of which I wish especially to direct attention is the musical or concert drum which is most highly esteemed by Indians and which figures largely in the Sanskrit literature, namely the *Mridaṅga*. The essential feature of this instrument at the present day is, first, a massive hollow wooden body in the form of two truncated cones put end to end, one of which is longer than the other. Over the two ends of this body are stretched the two drumskins, which are each provided with a tightening ring of leather and are kept in a state of tension by a leather rope which passes through apertures in the rings at 16 equidistant points around the circumference. Eight cylindrical tuning blocks of wood inserted at regular intervals under the tension-rope provide the means for a rough adjustment of tension. The fine adjustment of tension of the smaller drumhead to equality in the 8 octants of the circumference is carried out by pulling up or pushing down the tightening ring by stroking it with a small mallet. The large drumhead gives the base note, and its pitch and tone-equality are adjusted by spreading a temporary load of wetted *ātā* or wheat flour over it. The most remarkable feature of the drum is the manner in which the second or smaller drumhead is constructed. This membrane as first put on in the construction of the drumhead is double, the layers being of specially chosen leather of uniform thickness and connected to the tightening ring so as to be in a state of tension. The upper layer is then cut away in the middle exposing a circular area of the lower membrane, and leaving an annular ring of the outer membrane round the margin, of which the width is regulated according to the requirements of the tone-quality. The centre of the exposed circle of the inner membrane thus formed is loaded concentrically in several successive layers of gradually decreasing radii and of graduated thickness with a dark coloured composition which is put on at first in the form of a paste and is then rubbed in till it becomes dry and permanently adherent to the membrane. The composition of this material is finely powdered iron filings, charcoal and starch, and when put on the membrane it is flexible in a noteworthy degree. The putting on of the load is

carried out in stages, the sound of the drumhead being continuously tested during the progress of construction. Its final adjustment and regulation of thickness is an art which is handed down from generation to generation as traditional knowledge, and acquired by long training and experience.

4. The acoustic characters of the *Mṛidaṅga*

A physicist trained in acoustical research noticing the drumhead of the *Mṛidaṅga* naturally wishes to know exactly what acoustical purpose is intended to be served by the peculiar method of construction described above. This is a question which can only be answered by a physical examination of the vibrations of the drumhead and of the tones to which it gives rise. Such an examination has been carried out by me and has led to extremely remarkable results. It was stated above that a percussion instrument generally gives rise to inharmonic overtones. The examination of the *Mṛidaṅga* shows that it forms an exception to this rule, and gives rise to harmonic or musical overtones in the same manner as a stringed instrument. I find in fact that the physical behaviour of the drumhead is in many respects unlike that of an ordinarily circular stretched membrane, and approaches that of a stretched string. In the same manner as a stretched string, the loaded membrane of the *Mṛidaṅga* can divide up and vibrate in 1, 2, 3, 4, or 5 parts which are separated by rectilinear nodal lines perpendicular to any chosen diameter of the membrane and give the respective overtones standing in the harmonic relation of pitch. The duration of these harmonic overtones is in descending order of magnitude, being quite considerable for the first, second and third harmonics which accordingly give a fine musical effect. Tones of higher pitch than the fifth harmonic are either not excited at all in the usual manner of playing, or if excited are of too short a duration and too small in intensity to be perceptible as musical tones. In my monograph, I am giving a full discussion of the acoustical properties of the instrument together with illustrations of its mode of vibration which explain the manner in which the loading increases the duration of the tones and gives rise to the harmonic properties of the overtones. It appears in fact that the loading results in modifying the pitch of the numerous overtones which an ordinary circular drumhead is capable of giving rise to and of bringing them together in groups standing to each other in harmonic relations. The success of the arrangement depends entirely on the extent and distribution of the loading adopted and upon the arrangement provided by which the tensions of the membrane in 8 different octants may be exactly equalized. It is in fact made abundantly evident by the investigation that the acoustic properties of the instrument are not the results of mere chance but bear the evidence of the most painstaking care and skill shown in the design and construction of the instrument.

5. The technique of playing the Mṛidaṅga

If the instrument is in itself a noteworthy piece of acoustic workmanship, still more remarkable is the manner in which its acoustic characters are utilized in actual musical practice. The drumhead is played with the hand and fingers and possesses a highly developed and finished technique. A very fair amount of practice is required even for acquiring a rudimentary knowledge of the instrument, but the finest technique can be mastered only by years of training and experience. The physical basis of the technique lies in the manner of striking the drumhead and upon the tone-quality, intensity and duration of the sounds elicited thereby. The strokes involve the exact regulation of the region of contact, the softness or hardness of the blow, its duration and force, and provide for touching the membrane with some of the fingers either during or after the blow so as to damp out certain harmonics and bring out certain others. Some of the recognised strokes provide for bringing out either the first or the second or the third harmonic practically by itself, or in combination with one or more of the five available tones. The strokes on the drumhead may be either by themselves or may be simultaneous with strokes on the base side of the drum which is tuned to one octave below the pitch of the first drumhead. Over and above this is the fact that the drumming is practically continuous and proceeds on a complex and varied metre and rhythm of its own depending on the accompaniment. All this may serve to give some idea of the extraordinary degree of development which the construction and use of percussion instruments has attained in India.

6. Conclusion

The study of the Indian musical drum and of the manner in which out of the most unpromising materials has been built up a genuine musical instrument which satisfies the most stringent acoustical tests and which even now stands on a pedestal high above the types of percussion instruments known to European Music, leaves very little doubt in one's mind as to the highly-developed artistic tastes and acoustic knowledge of the ancient Hindus. The high esteem in which the instrument itself has always been held in India and the existence of many treatises in the original Sanskrit dealing elaborately with its construction and technique is not without significance. Indeed, from the references that appear in certain of these treatises, it is clear that the general nature of the acoustic results obtained with this instrument had long been known, and that the pitch and duration of the different tones obtained by striking the drumhead at different points had been fully studied. The Hindus were well aware that sounding bodies generally give rise to many different tones simultaneously, and the evidence available points irresistibly to the conclusion that the development of the Indian

musical drum was the result of deliberate and probably prolonged efforts to improve the tone quality of percussion-instruments by bringing the overtones into musical relation with each other. The success of the results obtained remains a striking testimony to the acoustic knowledge and skill that must have inspired those efforts.