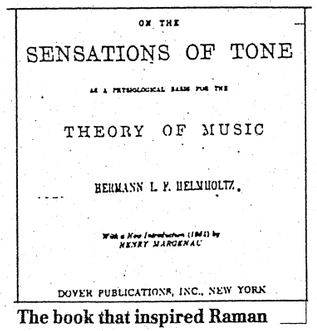


The book that inspired Raman

Raman and sound

Bowing to the great master

On the eve of the Raman Effect day, we take a look at his equally important work on musical instruments.

> Speaking of the modern world the supremest figure, in my judgement, is that of Mermann Von Helmholtz. In the range and depth of his knowledge, in the clearness of and profundity of his scientific vision he easily transcended all all other names I could mention, even including Isaac Newton. Rightly he has been described as the intellectual colossus of the nineteenth century. It was my great good fortune, while still a student at college, to have possessed a copy of of an English translation of his great work *The Sensations of Tone*. As is well known this was one of Helmoltz's masterpieces. It treats the subjects of music and musical instruments not only with profound knowledge and insight, but also with extreme clarity of language and expression. ... It can be said without exaggeration that it profoundly influenced my intellectual outlook. For the first time I understood, from its perusal, what scientific research really meant, and how it could be undertaken. I also gathered from it a variety of problems which were later to occupy my attention and keep me busy for many years."
>
> —*From a speech by Raman titled 'The Books That Influenced Me'.*

> 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 instruments are constructed and the variations of these designs that exist in different parts of the country, to discover the *raison d'etre* 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. ... the results obtained are very remarkable and significant."
>
> —*Raman in 'The Acoustical Knowledge of the Ancient Hindus', 1922.*

LISTENING to Yehudi Menuhin play the violin is for most people an unforgettable experience. One marvels at the smoothness and purity of tones which the maestro effortlessly produces. On the other hand, one wonders how the same violin in the hands of a less skilled player almost invariably produces a wheezy, impure sound—the so called 'wolf-note'. The answer to this was provided by Chandrasekhara Venkata Raman, who first explained how the wolf-note arises.

This work was in fact just one piece of his extensive researches on the violin and other musical instruments. While Raman's work on scattering of light is justifiably widely acclaimed (and in fact got him the Nobel Prize for discovering the Raman Effect), his work on musical instruments is also path breaking and deserves to be better known. His work on Indian instruments is of particular interest.

What prompted him to take up acoustics, a field which many thought had been thoroughly explored by nineteenth century scientists? One of the greatest influences in Raman's life was Hermann von Helmholtz who dominated mid-nineteenth century German science. "I think we owe it to Helmholtz that Raman took up the scientific study of Indian musical instruments," wrote S. Ramaseshan of Raman Research Institute, an expert on Raman's work.

Raman had devised several ingenious experimental apparatuses for his investigations on musical instruments and his laboratory in Calcutta was full of these Raman improvisations. For long these acoustical instruments, which included a piano, a mechanical violin player, sonometer, were lying uncared for, gathering dust and in a state of near ruin in a room in Calcutta's Science College. They were retrieved and restored to some shape only during the Raman Centenary year in 1988 when a Raman Museum was put together.

Stringed instruments are of several types; plucked, struck and bowed. Amongst these, the bowed instruments like the violin and cello are the most difficult to understand. A skilled player can do many things with a violin; change the speed of bowing, the pressure on the bow or even the distance from the bow to the bridge. It is on the violin that Raman carried out most of his work. He first showed that when a string is bowed, a kind of zig-zag wave, now called a Raman wave, runs up and down the string.

These waves change with the position of the bowing and thus change the tone. Besides carrying out a theoretical analysis, Raman took many photographs of vibrating strings, in itself a remarkable feat at a time when modern high speed photographic equipment was not available. He also explained the wolf-note as arising from a transfer of energy between the string and the belly of the violin.

A detailed account of these investigations was published as a monograph in 1918, which, according to Raman's biographer G. Venkatraman, is "truly a collector's item. The printing ...is of very good quality despite the presence of a liberal dose of mathematical symbols,..." Given that the details of the physics of the violin are so complicated, little wonder that we continue to hear the wolf-note today.

RAMAN the experimentalist par excellence, next turned to a detailed experimental study of the violin. The effects of varying the speed and pressure of bowing are hard to study with a human player because of lack of consistency. So Raman devised a mechanical violin player, which in his own words, "was improvised in the laboratory from such materials as were to hand," The experiments with the mechanical player confirmed the predictions made by him from general theoretical considerations.

His ingenuity in making the mechanical player was typical of him and characterised much of his later work. In fact after the violin, he studied the piano, in which the strings are struck by hammers. Here again he displayed his ingenuity by devising a mechanical set-up in which the effect of the position of the hammer could be varied.

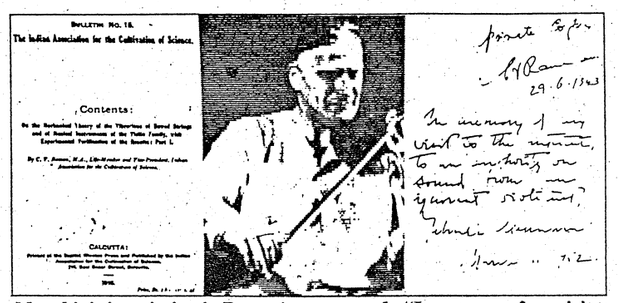
After studies on western string instruments, it was natural for Raman to turn towards Indian instruments. He studied two Indian string instruments in great detail—the tambura and the veena. What perplexed him was the fact that the tambura, in spite of being a simple instrument, produces a very rich tone, while a simple western instrument like the Spanish guitar produces a comparatively flat sound. This crucial difference was due to a difference in construction of the two, Raman pointed out.

While in the western instruments like the guitar, the strings pass over a sharp bridge, in the Indian instruments, the bridge is broad. In addition, in the tambura, a piece of thread is inserted between the string and the bridge. As Raman says, consequently there is "...a continual transformation ... of the fundamental vibration into the overtones". In lay language, Indian instruments possess a certain richness of tone which is usually referred to as the *jhankar*.

Interestingly, Raman made extensive studies on the tambura and the veena but published very little. Listening to a *gat* by Ravi Shankar with Allah Rakha on the tabla is undoubtedly an exhilarating experience. Indeed, can one imagine the former without the latter? Percussionists like Allah Rakah, Zakir Hussain and Umayalpuram Sivaraman are musicians in their own right. This is in sharp contrast to western classical music where the role of percussion is insignificant. Drums do play an important part in modern western music, but usually in orchestral ensembles. The reason lies in the essential difference between the construction of the tabla and the mridangam on the one hand and various western drums on the other.

WESTERN drums basically consist of a tight skin or membrane stretched on a circular frame. The vibrations of such a uniform circular membrane had already been extensively studied. These vibrations produce not only the fundamental but also a large number of overtones. These overtones "... stand in relation to each other in no sort of musical relation..." and result in a discordant or noisy sound. Raman sums it up well by saying "all instruments of percussion ... in which a circular drum head is employed have therefore to be regarded more as noise producers introduced for marking the rhythm rather than as musical instruments."

Indian drums like the tabla and the mridangam are very different. They employ loaded membranes which make the sound produced by them far richer. On one drumhead of the mridangam and on both the drums of the tabla, the load is a circle of dark paste *(syahi)* which is permanently attached to the playing surface. On the other surface of the mridangam, a temporary load of dough is used. The result is a profound change in the overtones which Raman found to be nearly like those of strings. It is this quality of the Indian drums which result in musical sounds. The drums are in fact tuned to the pitch of the singer or the instrumentalist. The actual playing is quite complicated and varying pressure is applied to different points on the drum to produce the different tones.

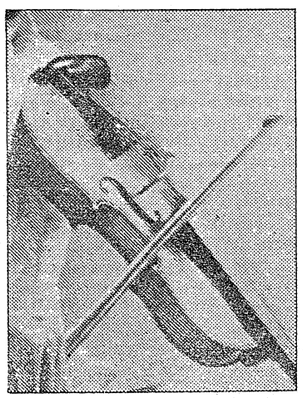


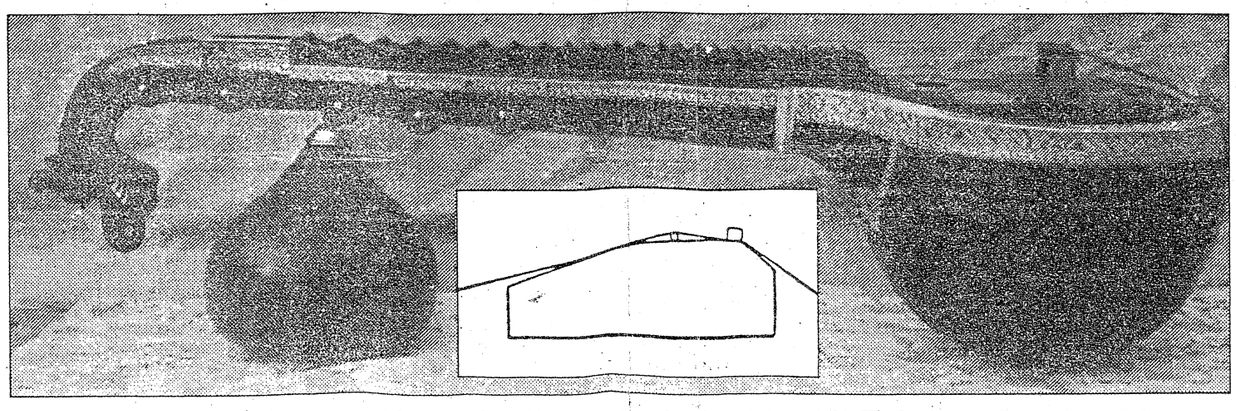
Menuhin's inscription in Raman's monograph: "In memory of my visit to the institute, to an authority on sound from an ignorant violinist."

Raman's investigations on musical instruments attracted a good deal of attention abroad. In the mid 1920's, the editors of the prestigous *Handbuch der Physik* series invited him to contribute an article on musical instruments and their tones. Although Raman's interest had by then shifted to the scattering of light, the invitation was too prestigious to be declined. What characteristics of the sound produced by various musical instruments give it desirable musical qualities? This is the question which he addressed in his article, which was published in 1927. He begins by explaining the meaning of the three attributes of a musical sound—pitch, loudness and timbre. However, to understand the musical sounds from the physics point of view, a quantitative analysis of notes is important.

Raman lays the foundations of this description and describes various methods of measurements which are found useful by the physicists. Then comes a detailed analysis of a variety of musical instruments with the pride of the place going to the violin which he describes here in a more concise manner than in his monograph. He also describes various wind instruments like the flute, the oboe etc, percussion instruments and even church bells and the jaltarang. This Handbuch article is undoubtedly a masterpiece and provides a fitting finale to Raman' investigations on musical instruments.

His work on musical instruments belongs to the early phase of his life and this has been overshadowed by his later work on light. In its own way, however, the investigations of musical instruments are path breaking, both for the precise observation of the phenomenon and the explanations of the observations. Raman belonged to the rare breed of scientists who are patient, persevering experimentalists and insightful as well as brilliant theoreticians.





The broad bridge of the veena (middle) and its curved surface (inset) give it a tone richer than that of instruments with a sharp bridge (left). The loaded membrane of the tabla (right) produces overtones.

■ A. Mukherjee/S. Mahajan