# Hermann von Helmholtz, *On the Sensations of Tone as a Physiological Basis for the Theory of Music* (1863)

## Abstract

Hermann von Helmholtz investigated questions related to "physical and physiological acoustics" and tried to connect his inquiries to "musical science and aesthetics." Helmholtz was particularly interested in aural perception, and he was responsible for introducing the distinction between "musical tones" and "noises." Musical tones were produced by "rapid periodic motions" and thus perceived as harmonic. Noises, on the other hand, resulted from "non-periodic motions" and were therefore perceived by the ear as disharmonic. Helmholtz's study was an important contribution to the understanding of acoustics; it is still referenced in the field of musicology today.

## Source

### Introduction

The present work attempts to connect the boundaries of two sciences, which, although drawn towards each other by many natural affinities, have hitherto remained practically distinct – I mean the boundaries of physical and physiological acoustics on the one side, and of musical science and aesthetics on the other.

[...]

In my somewhat unusual attempt to pass from natural philosophy into the theory of the arts, I hope that I have kept the areas of physiology and aesthetics sufficiently distinct. But I can scarcely conceal the fact that, although my reflections are confined to the lowest area of musical grammar, they will probably appear too mechanical and out of keeping with the dignity of art to those theoreticians who are accustomed to summoning enthusiastic states of mind, as they are evoked by the highest achievements of art, to the scientific study of its foundations. To them, I would simply remark, in conclusion, that the following investigation really only deals with the analysis of actual existing sensations – that the physical methods of observation being employed here are almost solely intended to facilitate and ensure the business of this analysis and to verify its completeness – and that this analysis of sensations would suffice to furnish all the results required for musical theory, even independent of my physiological hypothesis concerning the mechanism of hearing, which was already mentioned, but that I was unwilling to omit that hypothesis because it is so well suited to providing an extremely simple connection between all the diverse and complicated phenomena that present themselves in the course of this investigation.

### Chapter I.
### On the Sensation of Sound in General

Sensations result from the action of an external stimulus on the sensitive apparatus of our nerves. Sensations differ in kind, partly depending on the sensory organ that is excited, and partly depending on the nature of the stimulus employed. Each sensory organ produces particular sensations that cannot be excited by means of any other; the eye gives sensations of light, the ear sensations of sound, the skin sensations of touch. Even when the same sunbeams that excited the eye as sensations of light impinge on the skin and excite its nerves, they are felt only as heat, not as light. In the same way, the vibration of elastic bodies heard by the ear can also be felt by the skin, but in that case, they produce only a whirring fluttering sensation, not sound. The sensation of sound is the ear's peculiar reaction to external stimuli. It cannot be produced in any other organ of the body and is quite different from all the sensations of all the other senses.

[...]

The first and principle difference between various sounds experienced by our ear is that between *noises* and *musical tones*. The rushing, howling, and whistling of the wind, the splashing of water, the rolling and rumbling of carriages are examples of the first kind, and the tones of all musical instruments of the second. Noises and musical tones may certainly intermingle to the most varied degree, and pass insensibly into one another, but their extremes are widely separated.

The nature of the difference between musical tones and noises can be generally determined by attentive aural observation without artificial assistance. We perceive that, generally, a noise is accompanied by the rapid alteration of different kinds of sensations of sound. Think, for example, of the rattling of a carriage over granite paving stones, the splashing or seething of a waterfall or the waves of the sea, the rustling of leaves in the woods. In all these cases, we have rapid, irregular, but distinctly perceptible alterations of various kinds of sounds, which crop up fitfully. When the wind howls the alteration is slow; the sound rises slowly and gradually and then falls again. It is also more or less possible to separate different restlessly changing sounds from most other sounds. Later, we shall become acquainted with an instrument called a resonator, by means of which this distinction is made considerably easier for the ear. A musical tone, on the other hand, strikes the ear as a perfectly undisturbed, uniform sound that remains unaltered as long as it exists, and it presents no alteration of various kinds of constituents. To this then corresponds a simple, regular kind of sensation, whereas in a noise many various sensations of musical tone are irregularly mixed up and, as it were, tumble about in confusion. We can easily compound noises out of musical tones, as, for example, by simultaneously striking all the keys contained in one or two octaves of a pianoforte. This shows us that musical tones are the simpler and more regular elements of the sensation of hearing, and that consequently we first have to study the laws and peculiarities of this class of sensations.

Then comes the further question: What difference in the external excitation of auditory sensations causes the difference between noise and sound? The normal and usual means of excitation for the human ear is atmospheric vibration. In the case of noise, the irregularly changing sensation of the ear leads us to conclude that the vibration of the air must also change irregularly. Musical tones, on the other hand, are based on a regular, evenly continuing motion of the air, which in turn is excited by an equally regular motion of the original sonorous body, whose impulses were conducted to the ear by the air.

By now, those regular motions that produce musical tones have been precisely investigated by physicists. They are *oscillations*, *vibrations*, or swings, that is, up and down, or back and forth motions of sonorous bodies, and these oscillations must be regular, *periodic*. By a *periodic motion*, we mean one that returns to exactly the same state after exactly the same time period. The length of that equal interval between one state of the motion and its next exact repetition is called the *length of the oscillation*, vibration, or swing, or the *period* of the motion. The manner in which the moving body actually moves during that one interval is of no consequence. As an illustration of period motion, take the motion of a clock pendulum, of a stone attached to a string and whirled round in a circle with uniform velocity, of a hammer made to rise and fall uniformly through its connection to a water wheel. All these motions, however different in form, are periodic in the sense explained here. The length of their intervals, which, in these cases generally amounts to one or more seconds, is relatively long in comparison to the much shorter periods of vibration for musical tones, at least 30 per second for the lowest or deepest tones, or as many as several thousand in a second.

Our definition of periodic motion thus allows us to answer the proposed question as follows: *The sensation of a musical tone is due to rapid periodic motion of the sonorous body; the sensation of a noise to non-periodic motion.*

[...]

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