# acoustics FREE

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## Summary

From the earliest stages of Greek thought, sound was thought to originate as the result of an impact between two objects. At first it was believed that the swiftness and force of the impact affected both volume and pitch; then it became clear that these were two different parameters. Pitch, in particular, was connected either to quantitative factors, such as the speed of the movement or the number of subsequent impacts, or to qualitative ones, like the *idiotes* ("peculiarity") theorized by Theophrastus. The least investigated parameter of sound is timbre, which was usually attributed to the physical characteristics of the source.

**Keywords:** acoustics, sound (theories of), pitch, ancient science, ancient theories of sense perception

**Subjects:** Science, Technology, and Medicine

**Updated in this version**

Text and bibliography have been updated.

There is no specific branch of ancient Greek science or physics named *akoustike*; nevertheless, the Greeks showed a keen interest in sound and its characteristics from the earliest stages of their literature. In the Homeric poems, sound is conceived of as something that possesses magnitude and direction. Such adverbial forms as *mega* and *megala* are often used to convey the idea of loudness (see, e.g., *Il.* 4.506 <http://www.perseus.tufts.edu/hopper/text?doc=Hom.+Il.+4.506&fromdoc=Perseus%3Atext%3A1999.01.0133>; 14.147 <http://www.perseus.tufts.edu/hopper/text?doc=Hom.+Il.+14.147&fromdoc=Perseus%3Atext%3A1999.01.0133> etc.); a piercing shout uttered by Agamemnon to his soldiers through the turmoil of battle (*Il.* 8.227 <http://www.perseus.tufts.edu/hopper/text?doc=Hom.+Il.+8.227&fromdoc=Perseus%3Atext%3A1999.01.0133>) is described with the same adverb (*diaprysion*) that appears elsewhere (*Il.* 17.748 <http://www.perseus.tufts.edu/hopper/text?doc=Hom.+Il.+17.748&fromdoc=Perseus%3Atext%3A1999.01.0133>) in an image of a ridge that lies in the middle of a plain, causing rivers to be diverted. The well-known formulae of the "winged words" (*epea pteroenta*) and the "fence of teeth" (*herkos odonton*) imply a notion of the movement of sound toward a direction.

With the advent of philosophy, an interest in acoustics was shared by philosophers concerned with sense perception (see e.g., Theophr. *Sens.*), medical writers (e.g. Hippocr. *De victu* 1.8 and 15, on hearing and voice), and music theorists. The first acoustic theories originated from the observation of everyday-life objects and the ancestral craftsmanship of pipe and lyre makers. Thus Archytas of Tarentum (fr. 1 Huffman) established a causal relationship between the force and the speed of the initial blow (*plaga*) between two objects and the loudness and pitch of the resulting sound, which travels all the way to the ear like a missile: the stronger and swifter the blow, the louder and the higher the sound. Since he did not separate pitch from volume, there is no room in his theory for sounds low-pitched and loud, or high-pitched and feeble (such a distinction will be introduced by Aristotle (see e.g., *Top.* 1.106$^{a}$; *De an.* 419$^{b}$–421$^{a}$; *Gen. an.* 786$^{b}$–788$^{b}$; see also Panaetius the Younger *ap.* Porph. in Ptol. *Harm.* 1.3, pp. 80.7–81.5 Raffa = pp. 65.21–66.15 Düring). However, the Pythagoreans (see pythagoras (1), pythagoreanism) studied the relationship between pitch and the lengths of pipes and strings, showing not only that shorter pipes and strings do usually produce higher sounds, but also that some easily observable ratios between lengths produce the most common concords (the ratio 2:1 produces the octave; 3:2, the fifth; 4:3, the fourth). Both these approaches are essentially quantitative insofar as they link pitch to something that can be increased or decreased (the force of a blow), or is measurable (the length of a pipe or string). From this stage on, and as late as Boethius (see boethius, anicius manlius severinus and boethius, musical writings), ancient acoustics remained mostly quantitative (exceptions will be mentioned in due course).

The idea of a missile travelling through a medium is compatible with pipes and voice, for there are holes—for instance, the finger holes of the *aulos*, or the mouth itself in the case of people speaking or singing—from which one can imagine that sound be "projected" outside, as it were. Strings, on the other hand, function in a totally different way. Firstly, there is no hole, which means, no specific point from which the initial blow can spread; instead, the whole string is adjacent to the air and, when vibrating, it communicates its own movement to the medium by means of its entire length. Secondly, simple observation shows that the string's movement consists of a continuous series of movements, which is probably why, as strings are increasingly used for acoustics enquiries, the idea of the missile set in motion by a single blow is abandoned in favour of a plurality of impulses (*plegai*) that propagate through a medium (thus Plato, Aristotle, and later authors, e.g. ps.-Eucl. *Sect. can.*). Like the missile theory, this approach to pitch is quantitative: the more frequent the impulses, the higher the sound, and *vice versa*.

This theory raises at least three questions. The first is how do the impulses affect the medium? The general idea is that the motion coming from the source spreads to the medium, either passing from a portion of air to the adjacent one (thus, e.g., ps.-Arist. *Pr.* 11.6), or causing a sort of compression in the medium itself (see Ptol. *Harm.* 1.3), or even spreading spherically all around (thus the Stoics according to Diog. Laert. 7.158 *<http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0257%3Abook%3D7%3Achapter%3D1>*). The second question is why, if there are many blows, do we perceive a single sound instead of a series of different sounds? The usual answer is that the repetition is so quick that our sense of hearing is not honed enough to perceive it (see, e.g., ps.-Arist. *Aud.* 803$^{b}$–804$^{a}$ and Heracl. *ap.* Porph. *in Ptol. Harm.* 1.3 pp. 36.9–38.10. Raffa = pp. 30.1–31.26 Düring; on the issues raised by the latter see Raffa 2016, p. 727–728 n. 121). The third question is, if higher sounds are caused by swifter motions, why do we perceive two sounds of different pitches simultaneously instead of hearing the higher, which is supposed to be swifter, before the lower? This last objection was raised by Theophrastus (fr. 716 Fortenbaugh). It seems that the philosopher did not distinguish between the speed at which

sound travels through the medium from its source to the era—its "external speed," as we may put it—and the frequency of its impulses in a given time, which can be swifter of slower, but do not affect the overall speed of sound. This difference is likely to have been clear to Theophrastus, but he might have intentionally downplayed it for the sake of his polemic against quantitative acoustics and harmonics.

Theophrastus was apparently an isolated voice in ancient acoustics. He denied any involvement of quantitative factors in pitch variation and attributed it to a "peculiar quality" (*idiotes*) that each single note possesses. Unfortunately, too little is left of his work *On Music* for us to understand fully how this *idiotes* is to be construed; it is clear, however, that the philosopher also used it to account for the phenomenon of concords (for explanations of the same phenomenon according to the quantitative theory see, e.g., Pl. *Ti.*79$^{c}$–80$^{b}$ <http://www.perseus.tufts.edu/hopper/text?doc=Plat.+Tim.+79c&fromdoc=Perseus%3Atext%3A1999.01.0179>, Arist. *Sens.* 447$^{a–b}$; ps.-Euc. *Sect. can.* pp. 148–149 Jan). What is less clear, on the other hand, is whether Theophrastus' argument referred to any kind of sound or specifically to musical sounds, *phthongoi*, given that his main concern seems to have been with the way in which the soul produces melody, *melos*.

Despite Theophrastus' criticism, later harmonic theorists drew freely on Platonic and Peripatetic views (see peripatetic school) to justify their treatment of intervals as numerical ratios, to explain many properties of instruments (e.g., Nicom. *Ench.* 4), especially the monochord and related "scientific" devices (carefully discussed by Ptolemy (4)), sometimes (as in Theon (2) and Aristides Quintilianus) to account for "musical" attributes of the soul and the universe. Practical applications were found: Vitruvius discussed theatre design in the light of Stoic acoustics, explaining how hollow vessels, suitably pitched and placed, can improve an auditorium's resonance (*De arch.*5.3–5 <http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.02.0072%3Abook%3D5%3Achapter%3D3%3Asection%3D8>). Investigations of sound's pitch and transmission, and certain properties of sounding bodies, never adjudicated conclusively between rival views. Discussions of other acoustic phenomena are usually unsystematic and based on the common-sense principle that a sound's qualities reflect those of its causes. This is the case, for instance, with ps.-Arist. *Probl.* 11 or Plut. *Non posse suav.* 1096$^{a}$ <http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A2008.01.0394%3Astephpage%3D1096a>, and the fullest and most influential treatise, the pseudo-Aristotelian *De audibilibus*. The different timbres of human and animal voices are associated with the different qualities and conditions of the parts of the vocal apparatus (mainly the lung and the windpipe): accordingly, to mention just a couple of cases, those who have uneven windpipes will experience difficulties both in speaking and singing; and those with short windpipes will have higher voices. Similar considerations are applied to musical instruments and in particular *auloi*, whose mechanism is often compared to that of human phonation.

## Primary Texts

Archytas of Tarentum, fr. 1 Huffman.

ps.-Aristotle, *Problems*, sections 11 and 19.

ps.-Euclid, *Sectio canonis* (in particular the introduction, pp. 148–149 Jan).

Claudius Ptolemy, *Harmonics* 1.3, pp. 6.14–9.15 Düring (English translation in Barker, 1989, pp. 279–282).

Porphyry, *Commentary on Ptolemy's 'Harmonics'* 1,3, pp. 36–95 Raffa = pp. 29.27–78.2 Düring (NB: this text contains many quotations form otherwise lost authors, including the pseudo-Aristotelian *De audibilibus* and Heraclides; English translation in Barker 2015, pp. 133–249).

Vitruvius, *De architectura* 5.3–5.

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### Related Articles

Archytas

Aristotle

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Plato

Vitruvius (Pol(l)io)

Ptolemy (4), Harmonics