

The de audibilibus and peripatetic acoustics

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THE DE AUDIBILIBUS AND PERIPATETIC ACOUSTICS

I

In a previous article I attempted to determine the place of the pseudo-Aristotelian *De Coloribus* in the development of early Peripatetic theories of vision, and showed that it reproduces the views of Theophrastus and may have been written by Theophrastus himself¹. The short treatise known as the *De Audibilibus* (its Greek title is περὶ ἀκουστικῶν) has sometimes been taken for the work of the same man. It has not come down to us in its original form. What we have is a fairly long extract from a book of the same name incorporated in Porphyry's commentary on Ptolemy's *Harmonica*². Porphyry believed that the original was by Aristotle, and tells us that he had condensed it because of its length³. Modern scholars however are agreed that it is spurious⁴; the only dissentients have been TRENDELENBURG in 1833 and DÜRING in 1932, and DÜRING changed his mind two years later⁵. But there has been no such unanimity as to the author's possible identity. BRANDIS attributed it to Strato; he was followed by DIELS, CAPELLE, DÜRING (in 1934) and less confidently by the Oxford translators⁶. V. JAN ascribed it to Heracleides Ponticus⁷. Others have been more cautious. ZELLER, while admitting that there is some evidence to connect the book with Strato, did not consider it conclusive⁸. SUSEMIHL says that it must be by the same author as the *De Coloribus*, but without suggesting a name; he is followed by REGENBOGEN, who thinks that the author of both works must be either Theophrastus or Strato⁹. Most recently WEHRLI has

¹ The *De Coloribus* and its Author, *Hermes* 92, 1964, 59 ff.

² Pp. 67—77 in DÜRING's edition, in Göteborgs Högskolas Arsskrift 1932. A few notes by DÜRING are included in his »Ptolemaios und Porphyrios über die Musik«, *ibid.* 1934, pp. 169—73. Other editions are by BEKKER (pp. 800—804 in the Berlin Aristotle) and PRANTL (Teubner, 1883); there is a useful English translation by T. LOVEDAY and E. S. FORSTER in the Oxford Translation of Aristotle. Since DÜRING's edition is not easy to find I shall quote *Aud.* by page and line of the Berlin edition.

³ P. 67, 20 DÜRING τὰ τούτου (sc. Ἀριστοτέλους) συντέμνοντες διὰ τὸ μῆκος ἕνια παρατιθέμεθα. We have no means of telling how much Porphyry omitted. Two other pseudo-Aristotelian books have been summarised in the same way by later commentators, the early chapters of the *De Coloribus* by Sophonias In *De Anima* pp. 79—83, and *Meteorologica* Δ (to 384 b 19) in ps.-Alex. *Quaest. Nat.* 3, 14 (pp. 108—115 Bruns).

⁴ Cf. V. ROSE, *De Arist. libr. ordine et auctoritate*, (Berlin, 1854) p. 220 f.

⁵ TRENDELENBURG, ed. of *Arist. De An.* p. 107; DÜRING 1932 p. 67 n., 1934 p. 169 f.

⁶ C. A. BRANDIS, *Handb. d. Gesch. d. gr.-röm. Philos.* II 2, 1201; H. DIELS, *SBB* 1893 p. 114 n. 5; W. CAPELLE, *Straton (der Physiker)*, *RE* IV A (1931) 283 f., 312 ff.

⁷ *Musici Script. Graeci* (Leipzig, 1895) pp. 55, 137; see below, p. 450.

⁸ E. ZELLER, *Philos. d. Gr.* II 2³, 914 n. 9; so also G. RODIER, *La Physique de Straton de Lampsaque* (Paris, 1890), 48 f.

⁹ F. SUSEMIHL, *Gesch. d. Lit. i. d. Alexandrinerzeit* I, 155; O. REGENBOGEN, *Theophrast v. Eresos*, *RE Suppl.* VII (1937), 1544.

denied that either Strato or Heracleides could have written Aud., without suggesting any alternative¹.

The reason why this work has so often been attributed to Strato is simple: the opening paragraph of Aud. contains a theory of sound very like the one which Alexander ascribes to Strato.

Aud. 800a 1—13 Τὰς δὲ φωνὰς ἀπάσας συμβαίνει γίνεσθαι καὶ τοὺς ψόφους ἢ τῶν σωμάτων ἢ τοῦ ἀέρος πρὸς τὰ σώματα προσπίπτοντος οὐ τῷ τὸν ἀέρα σχηματίζεσθαι, καθάπερ οἴονται τινες, ἀλλὰ τῷ κινεῖσθαι παραπλησίως αὐτὸν συστελλόμενον καὶ ἐκτεινόμενον καὶ καταλαμβάνομενον, ἔτι δὲ συγκρούοντα διὰ τὰς τοῦ πνεύματος καὶ τῶν χορδῶν γινομένης πληγᾶς. ὅταν γὰρ τὸν ἐφεξῆς ἀέρα πλήξῃ τὸ πνεῦμα τὸ ἐμπύπτον αὐτῷ, ὃ ἄῃρ ἤδη φέρεται βίᾳ, τὸν ἐχόμενον αὐτοῦ προωθῶν ὁμοίως, ὥστε πάντῃ τὴν φωνὴν διατείνειν τὴν αὐτήν, ἐφ' ὅσον συμβαίνει γίνεσθαι καὶ τοῦ ἀέρος τὴν κίνησιν. διαχεῖται γὰρ ἐπὶ πλεονα ἢ βία τῆς κινήσεως αὐτοῦ γινομένης, ὥσπερ καὶ τὰ πνεύματα τὰ ἀπὸ τῶν ποταμῶν καὶ ἀπὸ τῆς χώρας ἀποπνέοντα. Cf. 801a 37 ὅταν ἡ (φωνή) διαλελυμένη προσπίπτῃ πρὸς τὴν ἀκοήν . . . ἀφεστηκέναι πόρρω δοκεῖ τῆς ἀκοῆς.

Strato fr. 114 = Alex. Aphr. In Arist. Sens. 126, 19 ff. εἴτε δὴ τῷ τὸ σχῆμα ὑπαλλάττεσθαι αὐτῶν (sc. τῶν ψόφων) ἐν τῇ φορᾷ εἴτε τῷ ἐκλύεσθαι τὸν τόνον τῆς πληγῆς, ὡς Στράτων λέγει (οὐ γὰρ φησιν ἐν τῷ σχηματίζεσθαι πως τὸν ἀέρα τοὺς διαφόρους ψόφους γίνεσθαι, ἀλλὰ τῇ τῆς πληγῆς ἀνισότητι), ἀλλ' οὖν, ὁποτέρως ἂν γίνηται τὸ μὴ οὕτως ἀκούεσθαι ὡς γίνεται ἡ φορὰ κτλ.

The resemblance is twofold. In both passages the view that the character of sounds is due to the way in which the air is shaped is rejected, while the importance of mechanical factors, i.e. the strength and regularity of the sound-producing blows, is emphasised. This is enough to establish a *prima facie* case for attributing both to the same author. But it does no more. Before we can definitely give the book to Strato or anybody else we must examine its doctrine as a whole and find its place in the development of Peripatetic theories of sound and music. Fortunately we have a considerable amount of material for comparison.

II

The *De Audibilibus* deals only with the physical nature of sound; nothing is said about the psychology of hearing. Most of it is devoted to explaining the peculiarities of particular sounds, but there is an introduction on the principles underlying all sound-production and other points of general application are discussed in digressions in the body of the work². A brief synopsis will make its structure clear.

¹ F. WEHRLI, *Die Schule der Aristoteles* 5 (Basel, 1950), p. 73 f.; 7 (1953), p. 102.

² Most of these digressions fit into their context quite well; only one, at 803 b 26—804 a 9, disrupts the paragraph in which it stands and could be moved with advantage, perhaps to come after 800 a 16. But this hardly warrants interfering with the text.

- I 800a 1 = 67, 24 DÜRING: some principles of sound-production.
- II How the condition of the organs of speech affects the voice.
- 800a 31 = 68, 16: on the structure of the lung.
 b 19 = 69, 4: on the structure of the windpipe.
- 801a 10 = 69, 26: on some other *πάθη* of the organs of speech, especially their moisture and dryness.
- III The qualities of vocal sounds.
- 801a 21 = 70, 1: how distant sounds are distinguished from those arising near at hand.
- 801b 2 = 70, 19: distinct and indistinct sounds.
 22 = 71, 3: clear voices.
- IV On the sounds of instruments.
- 802a 8 = 71, 25: how clear notes are produced on wind-instruments.
 a 17 = 71, 32: on horns.
 a 30 = 72, 10: digression on how sound travels and how its propagation can be checked.
 b 1 = 72, 21: on horns continued.
 b 18 = 72, 35: how differences in the mouthpieces of *αὐλοί* modify their sound.
- V Further remarks on vocal sounds, with illustrations from non-vocal sounds.
- 802b 29 = 73, 9: the causes of hard and soft voices, and hard and soft sounds on instruments.
- 803b 2 = 74, 20: rough voices and the noise made by files.
 b 17 = 74, 33: thin voices and the sound of the thin strings of a lyre.
 b 26 = 75, 6: *Digression* (a) how sounds are propagated.
 b 40 = 75, 19: (b) how we hear chords.
- 804a 9 = 75, 27: thick voices and the sound of bassoons.
 a 22 = 76, 3: piping voices and the sounds made by the smallest instrument in each family.
 a 32 = 76, 12: 'cracked' voices and the sound emitted when a cracked piece of earthenware is tapped.
 b 8 = 76, 24: aspirated and unaspirated vocal sounds.
 b 12 = 76, 27: why the voice sometimes breaks suddenly.
 b 26 = 77, 7: stammering.

The author's chief concern is with vocal sounds. The sounds made by musical instruments or in other ways, e.g. by artisans in the course of their work, are brought into the discussion, but for the most part they serve to illustrate principles first adduced to explain the sounds made by the voice in different circumstances¹. Even the section devoted exclusively to explaining the pecu-

¹ Cf. Porphyry p. 67, 18 ff. D.

liarities of some instruments (802a 8—b 29) appears as a long digression when the plan of the book is viewed as a whole.

The mechanical explanation of sound given in the first paragraph is applied consistently to all phenomena. All sounds are the result of solid bodies striking one another or being struck by currents of air or, in the case of vocal sounds, of the breath striking the outer air. This sets up a movement of expansion and contraction in the surrounding air which spreads outwards from its source, each layer of air pushing the next until the force of the original impulse is spent. The movement remains the same throughout, and so the sounds falling on the ear correspond to the blow which gave rise to them¹. Each sound is described as a vibration² consisting of many distinct beats separated by intervals of silence. »Strings make many separate blows on the air, but as the ear cannot perceive the intervals between them owing to the shortness of the intervening time, the sound seems to us to be one and continuous, as in the case of colours; for separate spots of colour often seem to become one, when they are in swift movement« (803b 34 ff.). In chords the blows comprising the higher note occur more often in a given time than those of the lower, but if the last blows of both (and presumably the first also) coincide we hear both as simultaneous continuous sounds³.

The volume and penetration of sounds depend on the strength of the original blow and the continuity and tension of the air. Up to a point the air moves as a continuous mass from the place of the first impact, then it begins to 'scatter'⁴; this is what makes it possible to judge the distance between the source of the sound and the hearer. If the scattering is prevented by artificial means, e.g. by speaking through a trumpet placed over someone's ear, the sound seems to originate much closer to the listener than it really does⁵. Sound generally travels in a straight line, although it can bend round obstacles such as knots in timber⁶. The writer knew that sound can be transmitted

¹ 800a 1—10, cf. 803b 27 ff. [Arist.] Probl. 11, 6. 899a 28 ὁ ἀήρ ὁ φερόμενος ποιεῖ τὸν ψόφον· καὶ ὥσπερ τὸ πρῶτον ψοφεῖ τὸ κινῆσαν τὸν ἀέρα, οὕτω δεῖ πάλιν ποιῆσαι τὸν ἀέρα αἰεῖ (δ') ἄλλον κινουῦντα εἶναι, ἄλλον δὲ κινούμενον. διὸ ὁ ψόφος συνεχῆς, ὅτι αἰεῖ ἐκδέχεται κινουῦντι κινῶν, ἕως ἂν ἀπομαρανθῇ, ὃ ἐπὶ τῶν σωμάτων ἐστὶ τὸ πεσεῖν, ὅταν μηκέτι δύνηται ὠθεῖν ὁ ἀήρ ἔνθα μὲν τὸ βέλος, ἔνθα δὲ τὸν ἀέρα. ἡ μὲν γὰρ φωνὴ γίνεται ἢ συνεχῆς ἀέρος ὠθουμένου ὑπ' ἀέρος, τὸ δὲ βέλος φέρεται σώματος ὑπ' ἀέρος κινουμένου. ἐνταῦθα μὲν οὖν αἰεῖ τὸ αὐτὸ φέρεται σῶμα, ἕως ἂν καταπέσῃ, ἐκεῖ δὲ αἰεῖ ἕτερος ἀήρ. Text after G. MARENGHI (Aristotele, Problemi di fonazione e di acustica, Naples, 1963). The comparison with missiles comes from Archytas Vors. 47 B 1 p. 434, 5 and Pl. Tim. 80a.

² τρόμος, 802a 42.

³ 803b 40 ff., cf. [Arist.] Probl. 19, 39. 921a 13 ff.

⁴ διακινεῖται, 801a 26, σχεδάνυσθαι, a 31; presumably this means that the particles of air begin to oscillate in different directions instead of moving in unison. Cf. 800a 11. 804a 39 ff.

⁵ 801a 22 ff., cf. Arist. GA 781b 11 ff.

⁶ 802a 30 ff., cf. [Arist.] Probl. 11, 49. 58. 25, 9; also, from an Atomist viewpoint, Lucr. 4, 599.

through a medium other than air, until stopped by a break in the medium; to illustrate this he refers to the practice of tapping masts to see if they are cracked, and to the fact that bronze statues give off a whistling noise when being filed unless a rope is tied around them to absorb the vibrations (802a 33 ff.).

The quality of each sound is governed by the force and speed of the blow which caused it. Other factors, such as the structure of the lung and wind-pipe in animals or the composition of the material of flutes and horns only affect the sounds which are produced indirectly, by speeding or retarding the flow of the breath and thus modifying its impact on the outer air. The same flute can produce hard or soft tones, depending on the force with which the breath travels through it (803a 9 ff.). Even the accidents of the breath itself, such as its moisture, are important chiefly for the effect they have on its movement¹. Clear sounds, for example, defined as sounds which carry far and make a strong impression on the ear, are caused by a powerful impact with adequate 'follow-through'. To produce such sounds a man must be capable of taking in a large amount of air and expelling it vigorously but in a controlled manner; therefore his lung must be large and soft and elastic, and his windpipe must be of the right length and width to allow his breath to flow evenly². If the lung is small and inelastic, it will be incapable of emitting a sufficient volume of air with the necessary power, or alternatively the breath may be forced out violently; in the latter case its impact on the outer air will be hard but will lack the all-important 'follow-through'; sounds produced under these conditions are hard but do not carry far, like arrows shot from a stiff bow³. For the same reason a hard sound will result if the wind-pipe is too long and too narrow for the breath to pass through evenly and it has to be forced out; moreover because the breath is excessively compressed in the wind-pipe it will be dispersed as soon as it emerges, so that the sound it makes will not carry far. But if the wind-pipe is too wide the breath is dissipated even before emerging and the voice becomes hollow (800b 19 ff.).

The same principles hold good of wind-instruments. Generally speaking instruments made of a smooth and hard material allow the breath to pass through quickly and give a strong, clear note; if their material is softer and less dense they retard the breath slightly and their tone is softer and sweeter (802a 8 ff.). If the tension of the air is lessened by the use of sloping reeds in the mouthpiece or by lipping, their tone becomes softer but loses something of its strength (801b 33, 803a 25 ff.). If the walls of the instrument are not smooth and obstruct the free passage of the breath, a dull, uneven sound results (802a 25 ff.). In the case of stringed instruments the strings which are most tightly stretched hit the air most violently and produce the hardest sounds (803a 27 ff.).

¹ 800a 17 ff., b 20 ff.; cf. [Arist.] Probl. 11, 22, etc. Contrast Arist. GA 788a 16 ff.

² 801b 25 ff. + 800a 15 f. + 800a 31 ff.

³ 800a 31 ff., 802b 29 ff.

Other kinds of sound are explained in much the same way. Rough sounds are due to an uneven impact (803b 2ff.). Children and others who can only emit a small amount of breath have thin voices and thin strings produce thin sounds (803b 17ff.), while 'thick'¹ sounds are produced if a large quantity of breath is emitted at once; and so on.

III

The views put forward in this book are a great advance on all earlier theories. It had long been realised that hearing is caused by the impact on the ear of air which has been set in motion by a blow of some kind, and high notes had been connected with swift, low notes with slow movements. But the real significance of this was unknown. It was simply assumed that the pitch of sounds depends on the speed with which they are propagated². The theories based on these assumptions suffered from several defects. Since there was no way of distinguishing the speed of a sound-movement from its violence or force, which determines the volume of the sound, earlier thinkers were forced to assume that the loudest sounds are also high-pitched; indeed, we find Archytas appealing to this supposed fact as evidence for his theory³. It was difficult to explain how two notes could be heard together as a chord, as Plato's attempt demonstrates⁴. Finally the mechanics of sound-propagation were left unclear. Plato, the earliest writer whose views on this question are extant, thought that particles of air travel from the sounding object to the ear⁵, and a similar doctrine has been attributed to Aristotle. This is certainly wrong⁶; but although Aristotle saw the difficulties of earlier views⁷, his solution is by no means clear.

¹ By 'thick' (παχέαι, 804a 9) sounds the author seems to mean sounds which we should call 'full' or 'rich' or even 'fruity'.

² Archytas Vors. 47 B 1, Pl. Tim. 67b, 80a (criticised by Arist. de an. 420a 31ff., cf. Thphr. fr. 89 W.); cf. J. I. BEARE, *Greek Theories of Elementary Cognition* (Oxford, 1906), 109ff.; B. L. VAN DER WAERDEN, *Die Harmonielehre der Pythagoreer*, *Hermes* 78, 1943, 174. 193; J. HANDSCHIN, *Der Toncharakter* (Zürich, 1948), 136. 143. See further below, p. 446.

³ Archytas p. 434, 3ff., cf. Thphr. fr. 89, 5ff., p. 63, 1ff. DÜRING.

⁴ Pl. Tim. 80a, cf. Thphr. fr. 89, 11 p. 64, 20 D.

⁵ Pl. Tim. 67d, 80a, cf. A. E. TAYLOR and F. M. CORNFORD (*Plato's Cosmology*, London, 1937) ad loc. It is certainly not justified to attribute a vibration theory to Plato (with TAYLOR). But CORNFORD's view (p. 321) that Plato regarded the cause of sounds as a series of discrete air-particles rather than a continuous stream is also doubtful; the idea that sounds consist of separate beats first occurs in Aud. 803b 34, where it seems to be introduced as a novelty. In [Arist.] Probl. 11, 45. 904a 20, which seems to reflect the traditional view, sound is described as a ῥύσις. Cf. BEARE 110 n. 1. — The Atomists also believed that sound is propagated by 'missiles' of air, but the presuppositions of their system were fundamentally different.

⁶ See below, p. 444.

⁷ Arist. De An. 420a 21ff. GA 786b29ff.; see below, p. 444.

All these problems were solved by the author of Aud. His discovery that every sound consists of many separate pulses enabled him to distinguish their frequency as the factor which determines pitch from the factors governing the other properties of sounds. By superseding the hypothesis that different notes are propagated at different speeds he was able to give a rational account of chords. To the old question »what is it that is actually transmitted« he gave an unequivocal answer: a vibration in the air. In these respects his teaching is extremely close to modern views, in spite of his ignorance of the mathematical properties of sound-waves¹. In other ways, however, his knowledge was limited. He did not realise that the volume of sounds is determined by the amplitude of their vibrations, and since he knew nothing of harmonics, he had no real explanation of the other qualities of sounds. In as far as there is any principle underlying his account of these qualities, it is that sounds somehow resemble their cause, e.g. thin sounds are produced by the impact of thin strings on the air, rough sounds by the uneven impact of rough objects such as files, and so on². Beyond this he often tries to gain an insight into phenomena by comparing them to others which are better known. For example, he says several times that air blown through narrow pipes produces hard sounds which do not carry far, because it flows through them violently but is scattered as soon as it emerges, like water after flowing through a narrow channel³. These illustrations, which are a prominent feature of the book, are meant as a substitute for a more precise explanation. Similar analogies were used by many Greek writers, both within the Lyceum and outside⁴. Yet they belong to a comparatively primitive stage in the development of scientific method, and they are often inaccurate or even misleading; e.g. the 'scattering' of sound-producing movements is compared to the gradual weakening of the force of winds (800a 12ff.), although the first case involves the displacement of masses of air while the second does not. There is no organic connection between these 'explanations' and the advanced theory of sound as a vibration, and it is rather incongruous to find them side by side. Such incongruities however are characteristic of Greek science.

¹ Compare, for example, the description of vibrations in air given by J. JEANS, *Science and Music* (Cambridge, 1937, etc.) 113f., with Aud. 800a 1–10.

² Aud. 803b 23. b 10; cf. 802b 12. 804a 9ff. This is a primitive idea, most fully worked out (on Atomist lines) by Lucr. 2, 398ff. (in particular 2, 410ff. ~ Aud. 803a 2ff.), 4, 542ff. Cf. Thphr. Ign. 36ff., where the qualities of various kinds of fire are said to be related to the qualities of its substrate.

³ Aud. 800b 27ff. 802b 35, cf. 801b 33. Similar analogies occur at 800b 1. b 6. 801a 32. b 4. 8. 23. 802a 12. b 33. 40. 803b 8. 38. In addition vocal and non-vocal sounds are often compared.

⁴ Cf. O. REGENBOGEN, *Kl. Schr.* 141ff.; H. DILLER, *Hermes* 67, 1932, 14ff.; G. E. R. LLOYD, *Polarity and Analogy* (Cambridge, 1966) 304ff.; P. STEINMETZ, *Abh. Ak. Mainz (Geistes- u. sozialwiss. Kl.)* 1964, 1, 11ff.

All the same it is necessary to ask whether Aud. is really a single work or a compilation from two or more sources. Its unity has never been challenged overtly, but CAPELLE has picked out some parts which he regards as certainly coming from Strato, implying thereby that the rest may belong to a different author¹. Such a view might seem to derive some support from a certain inconsistency in the language employed in the book. The vibration-theory was intended to replace the belief that the pitch of sounds depends on the speed with which they travel through air. In view of its novelty, we should expect its author to avoid any expression which might obscure the distinction between his doctrine and the older one. But there are several places where he says, without qualification, that high notes are due to swift movements². Does this mean that the vibration-theory was grafted on to an essay which in its original form reproduced the conventional view? On further consideration this appears unlikely. The passages in which this theory is mentioned are too closely interwoven with the rest of the text; the only one which could be easily removed is 803b 26—804a 8³, but the first half of this digression resembles the opening paragraph of Aud. so closely that both must be by the same hand. The terminological difficulty is resolved at Aud. 804a 2, where we are told that high notes cause more frequent impacts on the air because of the swiftness of their movement, and the same point is made in one of the Problems⁴. These passages

¹ RE IV A, 313. The sections CAPELLE accepts are 800a 1—13, 801a 21—27 and 803b 34—40, which refer to the vibration-theory, together with 800a 31—b 19, on elasticity; also the passages in which hearing and the other forms of sensation are compared, 801a 32—41, b 22—32, 802a 7—15, 803b 2—17. His choice of these is somewhat arbitrary, for the idea that there is a fundamental similarity between all the senses was accepted by all Peripatetics from Aristotle downwards.

² Aud. 801a 9. 803a 5.

³ See above, p. 436 n. 2.

⁴ Aud. 804a 2 *πλεονάκις μὲν γὰρ ἐν πάσαις ταῖς συμφωνίαις ὑπὸ τῶν ὀξυτέρων φθόγγων αἱ τοῦ ἀέρος γίνονται πληγαὶ διὰ τὸ τάχος τῆς κινήσεως*. cf. [Arist.] Probl. 11, 19. 901a 11 λέγοι δ' ἂν τις ὅτι καὶ θάττων ἐστὶν ἡ ποιοῦσα αὐτὴν (i.e. τὴν ὀξυτέραν φωνήν) κίνησις. εἴη δ' ἂν τοῦτο, εἰ πυκνὸν μὲν στενὸν δ' εἴη τὸ κινεῖν πνεῦμα τὸν ἀέρα. ὃ τε γὰρ ὀλίγος εὐκίνητότερός ἐστιν ἀήρ (κινεῖται γὰρ ὀλίγος ὑπὸ τοῦ στενοῦ), καὶ τὸ πυκνὸν πλείους πληγὰς ποιεῖ, αἱ τὸν ψόφον ποιοῦσιν. In this Problem the question is why low notes are heard better near their source and high ones further away; the answer is a confused attempt to combine three distinct theories: (a) 901a 7—13 repeats Theophrastus' explanation (fr. 89, 9 W. p. 64, 3 DÜRING) that high notes tend to travel in one direction only, while low ones spread evenly all around their source. (b) At 901a 13 the writer introduces the older explanation, criticised by Theophrastus, that high notes travel faster than low ones (FLASHAR in his commentary on this passage [Berlin, 1962, p. 541] wrongly says that Theophrastus accepted this explanation); the same view recurs in Probl. 11, 47. (c) 901a 11—16 The theory of Aud. is then used to explain theory (b): high notes move swiftly because the breath by which they are produced (the writer is thinking of vocal sounds) is thin and dense; being thin, it moves a small amount of air which can attain a high speed, and because of its density it causes many impacts.

show that expressions appropriate to the old conception of sound continued to be used in connection with the vibration-theory¹. The language of Aud. may lack precision, but its teaching is consistent. Thus there is no reason for doubting the unity of the book; it is completely homogeneous in all other respects, in subject-matter, method and language².

IV

Any attempt to find the place of this work in the history of ancient acoustics must start from its relationship to Aristotle's teaching. This is complex. Aristotle would certainly not have accepted the theory of sound it contains, and it is important to be clear about the reason. He would probably have admitted, as a matter of fact, that a series of brief sounds separated by very short intervals of silence could be perceived as one continuous sound, just as a mass of tiny coloured dots may appear as a single patch of colour³. But he could not have regarded this as the *κυρία αἰτία* of the genesis of sounds. The idea that sounds have an atomic structure would conflict with his belief that all movements, including the objective movements which produce sounds as well as the psychic movements to which they give rise in the hearer, are continuous and infinitely divisible, and that there can be no inherently imperceptible movement or interval of time⁴.

Nevertheless the connection of Aud. with Aristotle is close. The problem its author has set himself, to explain the qualities of voices and vocal sounds, was raised by Aristotle at the end of the GA⁵, and their accounts agree in many respects⁶. There are also cases where both refer to the same facts but explain them in different ways. E.g. at Aud. 803b 19 it is said that children have thin voices because they only move a small volume of air; Aristotle gives this as the reason for their having high voices (GA 787a 29). These details show that Aud. stands firmly in the Peripatetic tradition, but they are not the only link. Even the central doctrine of the book is derived from Aristotle's principles.

¹ Some later writers prefer to say that high and low notes are produced by 'denser' (*πυκνότεραι*) and 'rarer' (*ἄραιότεραι*) movements (Eucl. Sect. Canon. Prooem., Porphy. in Ptolem. Harm. p. 33, 10 D.).

² Cf. V. ROSE, *De Arist. Libr. Ordine et Auctoritate* p. 221.

³ Arist. Sens. 439b 19, GC 328a 13 ff.

⁴ Sens. 448a 19 ff., cf. Alex. ad loc. p. 146 ff.; also Index Arist. 391b 6 ff.

⁵ GA 5, 7, especially 786b 7 ff., 788a 16 ff.

⁶ Comparison with instruments, Aud. passim ~ GA 788a 21; Aud. 800b 18. 31. 802a 6 ~ GA 788a 29 ff.: soft lungs can 'husband' (*ταμιεύεσθαι*) the breath; 801a 27 ff. ~ GA 781b 6 ff., on the 'scattering' of different sounds and how it may be prevented; 804a 17. ~ GA 788a 1, HA 581a 16 ff., on *τραγίζοντες*. Other parallels are: Aud. 800b 2 ~ Arist. Resp. 480a 20, the lungs compared to bellows; 801b 6 ff. ~ HA 492b 33. 536b 8, PA 660a 26, (Probl. 902b 22), on *τραυλοί*; 804b 27 ~ [Arist.] Probl. 902a 25, etc., on *ισχνόφωνοι*. Cf. v. JAN, *Mus. Scr. Gr.* p. 50. HANDSCHIN p. 143 f.

It was fundamental to Aristotle's teaching about sensation that the form of the sense-object without its matter is transferred to the subject through a suitable medium; the object modifies the medium, which in turn modifies the sense-organ in the same way¹. In the case of sound an impact by a sonant object produces a movement in the medium, usually air, which is transmitted to the ear. What the exact nature of this movement is Aristotle was unable to say, but he seems to have regarded it as a qualitative alteration (*ἀλλοίωσις*) analogous to the modification produced by light and colour in transparent substances². One thing however is certain. Only the movement travels, while the medium remains stationary. The suggestion that Aristotle shared Plato's belief that actual particles of air were projected from the sonant object to the ear is certainly wrong³; he expressly says that sound is not a body but a movement in a bodily medium⁴. It is not even certain that he regarded pitch as a function of the speed with which sounds are transmitted⁵. What he says is that high and low notes are produced by, but not identical with, fast and slow movements respectively, and his discussion implies that he may have taken 'fast' and 'slow' in this context to denote the intensity of the stimulus experienced by the subject⁶. The only place where Aristotle seems to accept a connection between high and low voices and the speed with which masses of air are moved is in the chapter on animal voices in the GA; but here he is thinking primarily of the force with which the breath emitted from the mouth strikes the outer air⁷.

¹ Arist. de an. 424a 17ff.; cf. BEARE 216ff., H. SIEBECK, *Gesch. der Psychologie* I 2 (Gotha 1884) 21ff.

² De an. 417b 7ff. Later commentators postulated the existence in air and some other kinds of matter of something they called *τὸ διηχέες*, which was supposed to transmit sound in the same way as *τὸ διαφανέες* transmits light and colour. See Arius Didymus fr. 17, Prisc. Metaphr. p. 10, 19, 15, 33 BYWATER, and the commentaries on the De Anima of Simplicius and Philoponus (see the index of the Berlin edd. s. v.); cf. ZELLER, *Ph. d. Gr.* II 2³ (1879) 478.

³ This is the view of VAN DER WAERDEN 193.

⁴ Sens. 446b 25 ἔστι δ' οὔτε σώματα ταῦτα (sc. sounds and smells), ἀλλὰ πάθος καὶ κίνησις τις, . . . οὔτ' ἄνευ σώματος. Cf. Alex. Aphr. de anima 48, 7ff., in de sens. 126, 24, and the quotation from Alexander's commentary on Aristotle's de anima given by Simpl. in de an. 141, 22ff. and Philop. in de an. 361, 5ff.; this quotation is remarkably similar to Aud. 800a 5ff. and Probl. 11, 6. 899a28ff. (quoted above, p. 438 n. 1).

⁵ So BEARE 116, cf. ZELLER 835 n. 3.

⁶ De an. 420a 31 οὐ δὴ ταχύ τὸ ὀξύ, τὸ δὲ βαρὺ βραδύ, ἀλλὰ γίνεται τοῦ μὲν διὰ τὸ τάχος ἢ κίνησις τοιαύτη, τοῦ δὲ διὰ βραδυτήτα, καὶ ἔοικεν ἀνάλογον ἔχειν τῷ περὶ τὴν ἀφήν ὀξεῖ καὶ ἀμβλεῖ· τὸ μὲν γὰρ ὀξύ οἷον κεντεῖ, τὸ δ' ἀμβλὺ οἷον ὠθεῖ, διὰ τὸ κινεῖν τὸ μὲν ἐν ὀλίγῳ τὸ δὲ ἐν πολλῷ, ὥστε συμβαίνει τὸ μὲν ταχύ τὸ δὲ βραδύ εἶναι. Cf. Thphr. fr. 89 p. 63, 30ff. D., Prisc. Metaphr. I, 31 p. 14, 16 B.; HANDSCHIN 143.

⁷ GA 5, 7, especially 786b 26. 787a 30ff. Note that Aristotle here associates loudness with deep sounds, whereas Archytas and the theorists criticised by Theophrastus (fr. 89) associated loudness with high notes.

Aristotle, then, defined sound as a movement in a stationary medium, but he did not specify the nature of this movement beyond suggesting that it was an ἀλλοίωσις; this problem was left for his successors (we shall see how Theophrastus tackled it). The vibration described in Aud. meets many of Aristotle's requirements: only the movement is transmitted while the medium remains stationary, each part of the medium, and finally the ear of the subject, being affected successively in the same way. Even Aristotle's suggestion that high notes are the ones which »cause much movement in the sense-organ in a short time« finds an echo in the view that they are due to vibrations of higher frequencies. Thus the vibration-theory is a legitimate development of Aristotle's doctrine. Naturally it includes some un-Aristotelian features; the discrete structure of sound is one, and it is doubtful whether a vibration would count as an ἀλλοίωσις in Aristotle's sense—although it would not fit neatly into the category of »local motion« (φoρὰ) either. The first of these has an analogy in the theory of the discrete structure of matter which was held by both Theophrastus and Strato—Strato even believed that light-rays consist of separate particles¹—and a tendency to cut across Aristotle's conceptual distinctions is characteristic of the early Peripatetics².

One conclusion follows immediately. Not only was Aud. written by a Peripatetic, but the theory it contains is a Peripatetic product, not one borrowed from a different school.

V

This point is worth making because at least two other groups of thinkers held a similar theory in the third century BC. One of these was the Stoic school, whose explanation of sound has been preserved by several authorities. »When the air is struck by the breath it surges (κυματοῦται) in all directions ad infinitum, until (the movement) has filled the surrounding air, like the water in a swimming-pool when struck by a stone; but in this case the movement spreads in a circle, in the air it spreads in a sphere³.« The Stoics seem to have been the first to describe this motion as a wave—a characteristically vivid image and one still in use to-day. But there is no evidence that they tried to analyse the laws of sound-production in detail and probably their theory of sound, like so many of their scientific theories, was taken from the Lyceum.

¹ Str. 65 SA; cf. 64 SA, Thphr. Ign. 42, etc; GOTTSCHALK CQ 55, 1961, 73. 79.

² Cf. GOTTSCHALK, Hermes 92, 78; H. STROHM, Philologus 92, 1937, 249 ff.

³ Aet. 4, 19, 4 = SVF II 425, cf. Diog. Laert. 7, 158 = SVF II 872; also Hero (pseudo-Ptolemy) De Speculis I p. 316, 18 SCHMIDT (in a Pythagorean-Platonic context): *pulsa chorda fluctuantem intelligimus aerem*.

The other place where such a theory occurs in the third century BC is the introduction of Euclid's *Sectio Canonis*¹. Here we are told that sounds are caused by blows; high notes consist of »more and more closely spaced movements«, low notes of »fewer and less closely spaced movements«². Euclid takes this explanation for granted and it is clearly not his own invention, but his source is unknown. Many of the theorems of the *Sectio Canonis* are borrowed from Archytas³, but the introduction cannot be derived from this thinker⁴. Archytas, as we have seen, connected high notes with swift movements, but in the fragments which are attributed to him by name there is nothing to suggest that he took this to mean »high frequency«, and some of his arguments would be incompatible with such a view⁵. Probably he believed that pitch is governed by the speed with which sounds are propagated.

Whoever Euclid's source may have been, it is clear that the vibration-theory was current in the middle of the third century and must have been invented before that time, but after the death of Aristotle. It is also certain that Aud. was written during this period. Like the *De Coloribus* it is free from contamination with the doctrines of the Hellenistic schools⁶, and its terminology is if anything less advanced than Euclid's⁷. While strongly influenced by Aristotle's ideas its author is not in any way bound by Aristotelian dogma. His purpose was not to expound traditional views but to give a correct explanation of the phenomena, and his account is without precedent in his school. This independent development of their heritage was characteristic of the early Peripatetics.

¹ This book is generally accepted to-day as a genuine work of Euclid, with the proviso that the preface may be the work of a pupil based on a fuller treatment of the subject by Euclid himself (v. JAN, *Mus. Scr. Gr.* p. 115 ff.), and that the last two propositions were probably added by a later hand (VAN DER WAERDEN 187. 199, after TANNERY, *Mém. Scient.* 3, 213). TANNERY however has argued (l. c.) that it is entirely spurious and that the main body of the work dates from the middle of the fourth century. Cf. HULTSCH *RE VI*, 1051, SUSEMIHL, *Gesch. d. Lit. in der Alexandrinerzeit I* 717 n. 58.

² *Sect. Canon.* p. 23 M. (p. 148, 6 v. J). *ἐπειδὴ πάντες οἱ φθόγγοι γίνονται πληγῆς τινος γινομένης, πληγὴν δὲ ἀμήχανον γενέσθαι μὴ οὐχὶ κινήσεως πρότερον γενομένης, τῶν δὲ κινήσεων αἱ μὲν πυκνότεραί εἰσιν, αἱ δὲ ἀραιότεραι, καὶ αἱ μὲν πυκνότεραι ὀξυτέρους ποιοῦσι τοὺς φθόγγους, αἱ δὲ ἀραιότεραι βαρυτέρους, ἀναγκαῖον τοὺς μὲν ὀξυτέρους εἶναι, ἐπεὶ περ ἐκ πυκνοτέρων καὶ πλείονων σύγκεινται κινήσεων, τοὺς δὲ βαρυτέρους, ἐπεὶ περ ἐξ ἀραιωτέρων καὶ ἑλασσόνων.*

³ TANNERY, *Mém. Scient.* 3, 246 ff.; VAN DER WAERDEN 169.

⁴ As has been supposed by DIELS, *Vors. I*⁹ p. 430, 13; E. FRANK, *Platon u. die sog. Pythagoreer* (Halle, 1923) 174 f.; CORNFORD, *Plato's Cosmology* 322.

⁵ *Vors. 47 B 1* (Porph. in *Ptol. Harm.* p. 56 D), A 19a (*Theo Smyrn.* p. 61, 11); in the second passage the words *ἅτε πλήττουσαν συνεχῆς καὶ ὠκύτερον κεντοῦσαν τὸν ἄερα* look like a reminiscence of *Arist. de an.* 420b 2 (quoted above, p. 444 n. 6). See above, p. 440.

⁶ Cf. *Hermes* 92, 82.

⁷ See above, p. 442 f.

VI

The field of possible authors of *Aud.* has now been narrowed to three men, Theophrastus, Strato and Heracleides Ponticus. Each of these candidates has had one or more sponsors in the past. I shall begin by examining the claim of Theophrastus, since there is evidence enough to dismiss him without much difficulty. The evidence comes from two sources, Priscian's *Metaphrasis* in *Theophrastum*¹ and a long fragment from the second book of Theophrastus' *De Musica* preserved by Porphyry².

From Priscian's account of his psychology it appears that Theophrastus followed Aristotle in essentials but tried to elucidate his obscurities and to supplement his system where Aristotle had left it incomplete³. One of the problems he took up concerned the nature of the 'affection' which the medium undergoes when transmitting any kind of sensory movement from the object to the percipient. This affection, Theophrastus believed, was different for each kind of sensation⁴. In the case of sound it consisted of the air being 'shaped' in some way⁵. The same problem was raised in *Aud.*, but Theophrastus' answer is the one refuted in the opening sentence of that book.

Further light is thrown on Theophrastus' view by Porphyry's quotation. Here Theophrastus argues against the notion that the differences between musical sounds are due to a numerical principle. If individual notes owe their character to numerical ratios, the same will be true of melodies, which are series of notes. This leads to a dilemma. Either melodies are essentially determined by number; then the notion of melody is indistinguishable from the notion of number, and everything which partakes of number or quantity also partakes of melody⁶; or the numerical properties of sounds and melodies are only contingent and their essence is something different from number; in that case differences of pitch are either due to their numerical properties or to some other factor. If they are due to their numerical properties, the non-numerical

¹ Ed. I. BYWATER, in *Supplementum Aristotelicum* I 2, pp. 1–37.

² Thphr. fr. 89 W. = Porph. in Ptol. *Harm.* pp. 61–5 DÜRING; my references are to WIMMER's paragraphs and page and line of DÜRING's edition. German translation and notes in DÜRING's *Ptolem. u. Porph. über die Musik* (Göteborg, 1934) pp. 160–68; see also E. A. LIPPMAN, *Musical Thought in Ancient Greece* (Columbia UP, 1964) 157 ff.

³ Cf. E. BARBOTIN, *La théorie aristotélicienne de l'intellect d'après Théophraste* (Louvain-Paris, 1954), passim. Theophrastus used the same method in his *Metaphysica*, cf. the introduction and notes in the edition of ROSS and FOBES (Oxford, 1928).

⁴ Cf. *Arist. Sens.* 446b 25 ff.

⁵ *Prisc. Metaphr.* 1. 30 p. 14, 10 B. ἡ δὲ ὁσφρησις διὰ τοῦ ἀέρος ὥσπερ ἀναμιγνυμένου πῶς ἔοικε καὶ πάσχοντος, ἡ δὲ ἀκοὴ σχηματιζομένου. This view recurs in [*Arist.*] *Probl.* 11, 23.

⁶ § 2 p. 62, 7 ff. D.; Aristotle uses a similar argument against the view that numbers are the principles of other things, *Metaph.* 1093a 1.

factors contribute nothing to the essential nature of musical sounds, for all notes can be known by their pitch. But if differences of pitch are caused by some other property of notes this will be enough to explain their character without invoking numbers. Differences of pitch will be due to the inherent nature of sounds, in the same way as the differences between colours are due to their nature and not to numbers or ratios.

Various empirical arguments are adduced by Theophrastus in support of his thesis. The force required to produce a low note is no less than for a high note; indeed it is more of a strain to sound a low note on a flute because more air has to be blown into the instrument¹, and on stringed instruments the thickness of the low strings compensates for the extra tension of the high. If differences of pitch arose because high notes are more powerful than low ones or travel faster², it would be impossible to hear a chord. Granted that high notes can be heard at greater distances than low notes, the reason is not that they travel faster or involve greater quantities³, but because it is their nature to make a stronger impact on the sense-organ, just as white is easier to see than other colours⁴; they have a different shape⁵ in as much as they tend to travel in a straight line in the direction in which they are projected, while low notes spread evenly all round their source. This is confirmed by the observation that we can feel instruments vibrating when a low note is being played.

The cause of concordance, too, is to be found in the nature of musical sounds as such, and not in the intervals, as some thinkers would maintain. The nature of music, however, is this: it is a movement of the soul by which it gains release from the ills arising from the passions⁶.

The fragment I have just summarised comes from a book on music, much of which was apparently devoted to a consideration of the psychological origins of music and its effect on its hearers⁷, and no doubt this has influenced Theophrastus' treatment of the problem. But since some of the ideas found here

¹ § 6 p. 63, 6ff. D.; this seems to be directed against Archytas' argument (Vors. B 1 p. 434, 15) that the breath which leaves a flute through a hole near the mouthpiece produces a high note because it strikes the outer air hard, while the breath which has travelled to a lower hole merges more slowly and sounds a low note. But Theophrastus has confused the force with which air is blown into a flute with the force with which it emerges.

² As Plato thought, Tim. 80b.

³ § 8 p. 63, 20 D. τῷ πορρωτέρω διὰ τὴν τῆς κινήσεως ὀξύτητα διικνεῖσθαι ἢ (τῷ) διὰ τὸ πληθὺν γίνεσθαι, against Archytas Vors. B 1 p. 434, 2ff.

⁴ Cf. Arist. de an. 420a 30, quoted above, p. 444 n. 6.

⁵ σχῆμα, § 10 p. 64, 5, cf. Prisc. Metaphr. 1, 30 p. 14, 11 B.

⁶ § 14 p. 65, 13 D. μία δὲ φύσις τῆς μουσικῆς· κίνησις τῆς ψυχῆς ἢ κατ' ἀπόλυσιν γινομένη τῶν διὰ τὰ πάθη κακῶν, ἢ εἰ μὴ ἦν, οὐδ' ἂν ἡ τῆς μουσικῆς φύσις ἦν.

⁷ See fr. 88—91 W. and add Plut. Qu. Symp. 666 C; Philod. Mus. p. 36f. KEMKE; Censorinus de die nat. 12 init.; Marius Vict. s Ar. Gramm. 4, 2 p. 158ff. KEIL; cf. F. DIRLMEIER, Philol. Suppl. 30, 1 (1937) 98ff.

also occur in Priscian's *Metaphrasis*¹, it is legitimate to use this discussion as evidence for Theophrastus' general theory of sound. The most important feature of this theory, which is found in Priscian and in the *De Musica*, is that every sound, especially every musical sound, is a quality²; each note has an individual character which cannot be reduced to a number or numerical ratio. He tried to express his conception by saying that sounds are determined by the shape of the movement which gives rise to them³. This notion was suggested by Aristotle, who tried to explain the distortion of sounds by supposing that the shape of the air by which they are carried changes in the course of transmission⁴. But it seems to have been Theophrastus who gave it a central place in his teaching; Aristotle only refers to it once, almost casually. Now this is the theory criticised by Strato and at the beginning of *Aud.* This is enough to show that *Aud.* cannot be the work of Theophrastus.

There are even some indications that *Aud.* was written after the time of Theophrastus. Not only was he the chief exponent of the doctrine refuted in *Aud.*; he does not appear to have been acquainted with the vibration-theory, although it would probably have been included in his objections. At one point he does indeed deny that ἡ ὀξεῖα φωνὴ ἐκ πλειόνων συνέστηκεν ἢ πλείους ἀριθμούς κινεῖται⁵, and this has been taken to mean that his opponents made each sound consist of separate beats⁶. But the exact meaning of this phrase is obscure⁷; on the other hand most of Theophrastus' arguments are only valid

¹ Priscian's work is based on the fifth book of Theophrastus' *Physics* (*Metaphr.* 1, 49 p. 22, 34 B.), which was identical with the second book of his *περὶ ψυχῆς* (*Them. in de an.* 108, 11 = *Thphr. fr.* 53 b W.).

² Porph. in *Ptol. Harm.* p. 65, 19, cf. p. 58, 5 ff. 61, 8 D.

³ The connotation of the word 'shape' for Theophrastus was entirely qualitative. When modern writers on acoustics speak of the shape or form of a wave (e.g. E. K. SANDEMAN, *Radio Engineering* [London 1947] I 8, »The information contained by the sound-wave resides in its form, and not in the kind of medium in which the wave exists«), the word has the opposite implication; the 'form' of a wave is something that can be determined and described mathematically.

⁴ *Sens.* 446 b 7 οὐ γὰρ τὸ λεχθὲν φαίνονται ἀκηκοότες διὰ τὸ μετασχηματίζεσθαι φερόμενον τὸν ἄερα; cf. *Alex. ad loc.* p. 126, 3 ff.

⁵ § 5 p. 62, 31 D., cf. *Eucl. Sect. Can.* p. 149, 1 v. JAN (above, p. 446 n. 2).

⁶ By ZELLER II 2³, 835 n. 3, VAN DER WAERDEN 194 ff. and LIPPMAN 161, who attribute this doctrine to Heracleides Ponticus. See below, p. 450 f.

⁷ Cf. DÜRING (1934) p. 162 n. 2 »Größere Zahlen bewegen oder beanspruchen, d. h. durch größere Zahlen ausgedrückt sein« etc. But since the subject of κινεῖται is φωνή, πλείους ἀριθμούς must be an internal accusative and the phrase should be translated »The higher note is (not) moved in respect of higher numbers« every time it occurs (§ 3 p. 62, 15 D.; 5, 62, 31. 8, 63, 19. 10, 64, 5. 11, 64, 18). — V. D. WAERDEN claims to find another reference to vibrations at § 1 p. 61, 24 D. ἤς (i.e. τῆς φωνῆς) τὴν ἀκρίβειάν τινες ἐπεβάλλοντο εἰς τοὺς ἀριθμούς ἀναπέμπειν κτλ., with which he compares [*Arist.*] *Probl.* 19, 39. 921 a 13 ff. καθάπερ ἐν τοῖς μέτροις οἱ πόδες ἔχουσι πρὸς αὐτοὺς λόγον . . . οὕτω καὶ οἱ ἐν τῇ

against theories in which the pitch of sounds is associated with the speed of their propagation and the factors governing pitch are not distinguished from those which governs volume. Such views were held by the Pythagoreans and those who followed them¹, and it was the Pythagoreans also who believed that the essence of musical sounds (and of everything else) could be expressed by numbers². At least two of Theophrastus' arguments were aimed particularly at Archytas³. It could of course be argued that Theophrastus had both theories in mind. But nothing in his words suggests that he distinguished various schools of thought among his opponents and none of his arguments is directed specifically at the vibration-theory⁴. The conclusion cannot be avoided that Theophrastus did not know this theory and that it was only discovered after the *De Musica* had been written.

VII

I have mentioned already that VON JAN ascribed Aud. to Heracleides Ponticus, and some other writers think that Heracleides invented the vibration-theory and the author of Aud. borrowed it from him. The link with Heracleides is a passage quoted by Porphyry from the *μουσικὴ εἰσαγωγή* of a certain Heracleides—Porphyry does not say Heracleides Ponticus—containing a theory of sound similar in most important respects to the one put forward in Aud.⁵. Sounds, it is said here, are caused by a spatial movement arising from a blow at the source and penetrating to the ear. The blow itself does not occupy any time but falls in the instant separating the time during which the striker approaches object which is struck from the time in which it recedes. Each sound is a series of such impacts separated by insensible intervals of time, which is heard as one note, just as a point of colour on a spinning cone is seen as a continuous coloured line; the sense of hearing is weaker than sight and there is no reason why it should not be deceived in this way⁶.

συμφωνία φθόγγοι λόγον ἔχουσι κινήσεως πρὸς αὐτούς; he then translated ἀριθμούς in the Theophrastus passage by 'Rhythmen', taking this word as the equivalent of 'frequency'. This is certainly wrong. The word ἀριθμός appears to mean 'rhythm' only in technical writings on rhetoric, where the context makes the sense clear (e.g. Arist. Rhet. 1409b 5, 8, and the passages quoted in LSJ s. v. ἀριθμός VIII), and metres are only referred to in the Problem by way of comparison.

¹ They are ascribed to οἱ κατὰ τοὺς ἀριθμούς ἀρμονικοί by Arist. Top. 107a 15; cf. Pl. Tim. 80a, Porph. in Ptol. Harm. p. 66. 16 D., etc.

² Cf. VAN DER WAERDEN 175, HANDSCHIN 141.

³ See above, p. 448 nn. 1 and 3.

⁴ Contrast the care with which he distinguishes the theories he criticises at Metaph. 12f., etc. and cf. Arist. GC 324b 25ff., Metaph. 986a 22, etc.

⁵ Porph. in Ptol. Harm. p. 30ff. D.

⁶ Porph. p. 30, 29ff.; almost the same illustration is used at Aud. 803b 38ff.

Unfortunately neither the identity of this Heracleides nor the real authorship of the theory reported here is certain. At the very beginning of Porphyry's quotation Heracleides names Xenocrates as his authority for ascribing to Pythagoras the discovery that musical intervals are inseparable from numbers. This has led R. HEINZE to claim that the whole passage goes back to Xenocrates and that he first described sound as a vibration¹. DÜRING however has argued convincingly that only the sentence about Pythagoras comes from Xenocrates and everything else is the work of Heracleides, whoever he may be². Most recent scholars identify him with Heracleides Ponticus³. Others have denied the identification, and this is certainly right, although none of the suggested alternatives is very convincing⁴.

The arguments against attributing Porphyry's quotation to Heracleides Ponticus are in fact quite overwhelming. If he was the inventor of the vibration-theory, it is inconceivable that Theophrastus should not have known it, or should have ignored it in his own work. The doxographical reports about his views on sensation (fr. 122 SA) are hard to reconcile with this theory—although in view of their brevity and vagueness this argument is not conclusive⁵. A more important consideration is that the vibration-theory seems to presuppose Aristotle's ideas about sensation⁶. Heracleides Ponticus was older than Aristotle and an adherent of Plato long before the Lyceum was founded⁷. In spite of his later association with this school it seems that the starting-point of his natural philosophy was Plato's *Timaeus* rather than the teaching of Aristotle⁸.

¹ R. HEINZE, *Xenokrates* (Leipzig 1892 etc.) p. 5 ff. HEINZE finds an analogy between the notion of impacts which do not occupy any time and Xenocrates' doctrine of »indivisible lines« (cf. pp. 58 ff., 173 ff.); but since the indivisible lines do occupy space, the analogy breaks down.

² DÜRING (1934) p. 154 ff.

³ ZELLER II 1.4 1036 n. 1. II 2.3 915 n.; V. JAN, *Mus. Scr. Gr.* p. 53 ff., 137 ff.; DÜRING l. c.; VAN DER WAERDEN 193 ff. 199; LIPPMAN 142, 161; DIELS SBB 1893 p. 114 n. 4 (but see below, note 4).

⁴ HEINZE p. 5 ff.; DAEBRITZ RE VIII 481; WEHRLI, *Die Schule des Arist.* 7 p. 113. ZELLER I⁵, 402 n. suggests as the author Heracleides Ponticus the younger, a grammarian of the first century AD; contra DIELS, *Doxogr.* p. 151 n. 3. Elsewhere DIELS himself dates the author of this fragment to the second century AD (Vors. II⁹ p. 225).

⁵ Cf. the apparent discrepancy between Aetius' account of Strato's explanation of vision (fr. 113 SA) and Simplicius' description of his theory of light (65 SA), on which see my »Strato of Lampsacus: some texts« (Leeds, 1965) 154 ff. The poverty and obscurity of the doxographical reports about post-Aristotelian philosophers other than Stoics and Epicureans are the strongest possible proof of the debt we owe Theophrastus for his work on the Presocratics.

⁶ See above, p. 444 f.

⁷ See DAEBRITZ RE VIII 473, WEHRLI SA 7 p. 59.

⁸ See I. M. LONIE, *Phronesis* 9, 1964, 163 and *Mnemosyne* IV 18, 1965, 139 ff.

Other pointers are contained in the fragment itself. Heracleides Ponticus would have been most unlikely to quote the slightly younger Xenocrates as his authority for a well-known doctrine of Pythagoras. Porphyry says quite definitely that the title of the book from which he quotes was μουσικὴ εἰσαγωγή. We do not know of any work with this title by Heracleides Ponticus, and the word εἰσαγωγή only became usual as a book-title at a later period¹. Porphyry could have misquoted, but his title suits the character of the fragment too well for this to be likely. Heracleides' explanation of the nature of sound is preceded by an elaborate classification of possible kinds of movement, leading to the conclusion that the movement by which sound is produced is a local movement in a straight line from the sonant object to the ear; this is taken as an axiom on which the rest of the account is based². The presence of these long-winded preliminaries³ can be understood in an elementary textbook, but it is not easy to imagine a man like Heracleides Ponticus bothering with them. Another passage which points in the same direction is the laborious demonstration that the blows which constitute sounds are separated by intervals of silence (p. 31, 15—17).

Some other features suggest that this fragment belongs to a fairly late period and was the work of a mathematician rather than a philosopher. One is the quite unnecessary use of the word ὑποκείσθω on p. 30, 14. Another is the idea that the pulses which constitute sounds occupy no time (p. 30, 19ff. 31, 16). There is an obvious analogy between this view and a late version of the doctrine of 'visual rays', according to which the 'visual rays' have no breadth and touch their objects at geometrical points; according to Philoponus this theory was held by certain mathematicians⁴. The experiments on p. 30, 29 and 31, 8 are a further link between our Heracleides and these mathematicians, who appear to have made considerable use of experiments in their study of optical phenomena⁵. None of the points I have enumerated is decisive by itself, but collectively they leave little doubt that the Heracleides from whose work Porphyry quotes is not the elder Ponticus but a much later writer of the same name.

¹ The first writer known to have used it was Chrysippus, whose εἰσαγωγή εἰς τὴν περὶ ἀγαθῶν καὶ κακῶν πραγματείαν is quoted by Athenaeus and Origen (= SVF III 196, 17 ff.); the word εἰσαγωγή also occurs in three of his titles in Diogenes' catalogue (= SVF II 6, 28, 7, 16. 35), but not in the sense of 'introductory treatise'.

² P. 30, 14 D. ὑποκείσθω οὖν, φησιν, ὅτι ἔστι τις φορὰ ἡ περὶ τοὺς φθόγγους (εἰς) τόπον ἐκ τόπου, εἰς εὐθὺ ἐπὶ τὸ τῆς ἀκοῆς αἰσθητήριον φερομένη.

³ HEINZE, who regarded Xenocrates as the author of the whole piece, calls them »Charakteristisch für die gutgemeinte aber ungeschickte Gründlichkeit des X.« (p. 10). For parallels cf. Pl. Parm. 138b, Theaet. 181c, Leg. 893c; Arist. passim (see the Index Arist. 391b 26 ff.).

⁴ Philop. in de an. p. 326, 9.

⁵ Philop. in de an. 327, 12. 331, 36. 335, 13 ff.

VIII

Thus it appears that Aud. contains the earliest account of the vibration-theory, and we have no reason for regarding Heracleides Ponticus as the author of the theory or the book. This leaves Strato as the sole remaining claimant, if the search for an author is not to be abandoned. No cogent arguments have ever been advanced against his authorship. WEHRLI denies it because he thinks that Strato's acoustic theory was derived from Democritus¹, but this assertion is quite groundless. What evidence there is indicates that the theories of Strato and Democritus were diametrically opposed. According to Democritus sound is transmitted because the air is »broken into particles of the same shape as the fragments of the voice and rolled along with them« to the ear². His view is criticised by Epicurus in a passage bearing some resemblance to the first part of Alexander's quotation from Strato³, but Epicurus' own doctrine (which involves a stream of particles flowing from the object to the subject) is completely different from Strato's. It is altogether mistaken to suppose that Strato was influenced by the Atomists to any significant extent. His view that matter is composed of particles interspersed with void is already found in Theophrastus⁴, and in most other respects Strato remained firmly in the Peripatetic tradition.

At this point the positive indications in favour of Strato's authorship, inconclusive though they are in isolation, assume a new importance. Aud. was written by a Peripatetic at a time when Strato was one of the most prominent members of the school. It begins with a criticism of an earlier Peripatetic doctrine which is attributed to Strato by Alexander, and we know that Strato developed many of his theories in opposition to older Peripatetic, and especially Theophrastean, teaching⁵. There are a number of other passages in Aud. which bear some resemblance to known fragments of Strato's works. The description at 800a 4 ff. of how the air moves under the influence of the impact of the sonant object is very similar to Strato's account of the movement of winds⁶; this comparison is legitimate because of the analogy with winds posited at Aud.

¹ WEHRLI, *Die Schule des Aristoteles* 5 p. 74.

² Aet. 4, 19, 13 = Vors. 68 A 128 Δ. τὸν ἀέρα φησὶν εἰς ὁμοιοσχήμονα θρύπτεσθαι σώματα καὶ συγκαλινθεῖσθαι τοῖς ἐκ τῆς φωνῆς θραύσμασι.

³ Epic. Ep. I, 53 (cf. BAILEY ad loc.) οὐκ αὐτὸν οὖν δεῖ νομίζειν τὸν ἀέρα ὑπὸ τῆς προειμένης φωνῆς ἢ καὶ τῶν ὁμογενῶν σχηματίζεσθαι ~ Str. 114 SA.

⁴ See above, p. 445.

⁵ Str. fr. 65 against ps.-Arist. (= Thphr.) Col. 791a 27, 794a 6 ff. (also perhaps Arist. Meteor. 342b 5. 373b 2 ff.; cf. Hermes 92, 79. 82). Str. ap. Hero Spir. p. 16, 16 ff. SCHMIDT (p. 112, 11 ff. GOTTSCHALK, cf. fr. 64 SA) against Arist. Phys. 4, 6 ff. Also the discussion of time, etc., in fr. 70—77 SA.

⁶ Strato ap. Hero p. 12 S. = p. 110, 23 ff. GOTTSCHALK = fr. 88 SA; ap. (Arist.) Probl. 940a 6 ff. = p. 120, 13 ff. G.

800a 12. Aud. 801a 22ff. brings an explanation of how we locate the source of sounds. Strato was interested in this problem, and compared the ear's ability to distinguish the source from which sounds originate to the power of the mind of localising physical stimuli at the surface of the body (fr. 111 SA). The idea underlying the account of this phenomenon in Aud. is already in Arist. GA 781b 6ff., but in Aud. it is demonstrated by means of a simple experiment with an ear-trumpet. It is well-known that Strato regularly used such experiments¹. Another experiment is introduced by the words δῆλον δὲ τοῦτ' ἐστὶ καὶ ἐπ' αὐτῆς τῆς αἰσθήσεως (803a 21), which hardly differs from a sentence in a fragment of Strato². This experiment is the culmination of an argument which is very similar, in its form and general character, to one used by Strato to refute the opponents of his doctrine of void³. From all this it is reasonable to conclude that Aud. is the work of Strato.

IX

It only remains to consider the relationship of Aud. to the *De Coloribus*, with which it has sometimes been linked⁴. These books certainly have a great deal in common. In both the physical aspects of sensation are discussed to the exclusion of the psychological factors involved. In both the emphasis is on explaining particular phenomena, while the principles underlying these explanations are stated briefly and dogmatically. In both an interest is shown in the practices of artisans⁵. Their style is the same in many ways, in the frequency with which the argument is interrupted by digressions and in the use of such phrases as δῆλον δέ to introduce new points. But there are differences as well. Aud. is more tidily constructed than Col. and more systematically argued. Some of the ideas and language of Col. are closer to Aristotle than anything in Aud.; its laws of reflection and the biology of its last two chapters are taken directly from Aristotle, and at 791b 3 we find the Aristotelian definition of darkness as the privation (στέρησις) of light⁶. No such terminology is used in Aud. and the direct borrowings from Aristotle are limited to minor details. The vibration-theory itself, although inspired by Aristotle's teaching, is an independent development of his views which Aristotle would probably

¹ Fr. 63, 73 and Hero Spir. prooem. passim. Strato's experiments can be distinguished from those of the later mathematicians by the fact that he uses very simple apparatus, usually everyday objects, while the mathematicians have more sophisticated equipment specially designed for the purpose, such as the cones used by Heracleides ap. Porph. p. 30, 29ff.

² Fr. 64 init. = Hero Spir. p. 16, 16 S. (p. 112, 13 G.).

³ Ap. Hero Spir. p. 20 S. (p. 113, 22ff. G.).

⁴ See above, p. 435.

⁵ Aud. 802a 31ff. b 42ff.; Col. 794a 16ff. 795b 11ff.

⁶ Cf. Hermes 92, 75.

not have recognised. Finally the linguistic evidence adduced by REGENBOGEN¹ to prove the common authorship of Col. and Aud. suggests that, in spite of the general similarity between them, the language of Col. is even closer to that of Theophrastus' *De Musica* than of Aud. παρά for διά occurs six times in Col., four times in Mus. and twice in Aud.; ἰσχυρῶς instead of πάνυ six times in Col. and once each in Mus. and Aud.; and the redundant πάλιν (meaning »on the contrary«) seven times in Col., once in Mus. and not at all in Aud.² Since neither Mus. nor Aud. have come to us in their original form, these figures must be treated with reserve. But such as they are they, and the other evidence summarised in this paragraph, tend to confirm that Col. and Mus. belong to Theophrastus, and Aud. to Strato.

X

On the basis of these attributions we can tentatively reconstruct the development of acoustic theory in the Peripatos. It started from the Pythagorean teaching whose chief representatives for us are Archytas and Plato: sound is caused by a blow whose speed and force determines its pitch. Aristotle accepted this as a description of the phenomena but transformed its meaning by subordinating it to his doctrine of the qualitative nature of all sense-movements. For him high and low notes were not identical with fast and slow movement, but each was a qualitative alteration (of the percipient sense-organ and of the medium through which it was transmitted from the sonant object) brought about by a fast or slow impact³. He also tried to distinguish the factors which govern the volume of sounds from those which determine their pitch. In the GA (787a 2ff.) he says that pitch and loudness are two distinct properties of voices. The loudness of a voice depends on the amount of air which is set in motion, its pitch on the force with which the air is moved, i.e. on the strength of the vocal organs (the lungs, etc.) relatively to the amount of the air they expel at one time. Thus an animal capable of expelling a large amount of air vigorously will have a powerful, high voice; one which expels a large amount of air slowly, a loud, deep voice; animals which can only expel a small amount of air will have weaker voices, and again their pitch will depend on the force with which the air will move. There is no comprehensive treatment of sound in Aristotle's writings, but by combining his scattered remarks we obtain the following theory: sounds are qualitative movements whose nature is determined by the mechanical impact which gives rise to them. The character of the impact is

¹ RE Suppl. VII 1544.

² Mus. takes up four pages, and Aud. ten pages, of Porphyry's commentary on Ptolemy; Col. is about twice as long as Aud.

³ De an. 2, 8, especially 420a 31ff. Cf. Porph. in Ptol. Harm. p. 58, 12; SIEBECK 21ff. 30; HANDSCHIN 138. 143; LIPPMAN 140f.; and see above, p. 444ff.

itself determined by a combination of two factors, its speed or violence and the mass of the bodies involved¹.

Aristotle's distinction between perceived sound and the objective mechanical movement which gives rise to it made it possible to explain the psychological and educational influence of music, to which he attached great importance². His interest in these effects was something he inherited from his predecessors³, but the earlier mathematical and physical explanations of sound had offered no way of accounting for them⁴. This was an important advance. At the physical level Aristotle was less successful. He had shown that Archytas' theory was too simple, that more than one set of factors must contribute to the quality of sounds, but he knew too little of the mechanism of sound-production to find the correct solution. When faced with the problem why some notes are concordant he fell back upon the old answer, that they stand in a simple ratio to each other⁵.

Theophrastus continued where Aristotle left off. In his *Physics* he took over Aristotle's acoustic theory without any significant changes, except that he tried to give it greater precision by describing the movement of sound as a 'shaping' of the air⁶. It was in applying this theory to musical problems that he made his most original contribution; his point of view was determined by his observation that »of all the senses, hearing is the one most closely related to the passions«⁷. Here too many of his ideas were inspired by Aristotle. His

¹ Aristotle does not say how the mechanical movement is converted into a qualitative one. But in the *Mot. Anim.* (701 b 13 ff., 703 a 17 ff.) he describes the opposite process, the transformation of qualitative alterations of the *σύμφυτον πνεῦμα* arising from psychological stimuli into »pushing and pulling«.

² Arist. *Pol.* 1339 a 22 ff. 1340 a 6 ff.; cf. [Arist.] *Probl.* 19, 27. 29; also Arist. fr. 47 R³. (= *περὶ φιλοσοφίας* fr. 25 WALZER-ROSS) and 48 R.³ (= 24 W.-R.), presenting a Pythagorean-Platonic point of view.

³ Pl. *Rep.* 522 a ff., etc. Damon Vors. 37 B 6, etc. (a fuller collection of Damon's fragments will be found in F. LASSERRE's edition of [Plut.] *De Musica* [Olten & Lausanne, 1954] p. 74 ff.); for the Pythagoreans, cf. Vors. 58 D 1, from Aristoxenos (= fr. 26 SA).

⁴ Cf. W. A. HEIDEL, *Arch. Gesch. Philos.* 14, 1901, 388; HANDSCHIN 156; L. RICHTER, *Zur Wissenschaftslehre v. d. Musik b. Platon u. Arist.* (Berlin, 1961) 105.

⁵ *Sens.* 439 b 32, cf. BEARE 126; Aristotle also classed harmonics as a branch of mathematics (*An. Po.* 79 a 1, etc.). This does not alter the fact that his theory of sound was essentially qualitative; LIPPMAN's assertion that »Aristotle's conception . . . remains considerably closer to that of the Pythagoreans (than was that of Aristoxenos) . . . The harmonics of Aristotle rests on arithmetic and abstracts a specifically tonal mathematics from the physical world, disregarding sonority itself but denying an independent reality to harmonic law« (p. 145 f.), derives no support from his genuine writings.

⁶ See above, p. 447 ff. A strange form of this doctrine appears in *Probl.* 11, 19. 901 a 11, ἡ ὀξεῖα (φωνή) πόρρω ἀκούεται, ὅτι λεπτοτέρα ἐστὶ, τὸ δὲ λεπτὸν τὴν εἰς μῆκος αὐξήσιν ἔχει, cf. 11, 20. 901 a 20.

⁷ Fr. 91 W. τὴν ἀκουστικὴν αἴσθησιν Θ. παθητικωτάτην εἶναι φησι πασῶν, cf. [Arist.] *Probl.* 19, 27. 29.

definition of music at the end of fr. 89 (p. 65, 13 D.) is closely related to Aristotle's doctrine of catharsis¹, and his interest in orgiastic music was also inherited from Aristotle². But he went further than Aristotle in recognising the implications of regarding sound and music as primarily psychological phenomena. Aristotle was prepared to explain some properties of notes in terms of numerical ratios. Theophrastus denied that musical relationships could be reduced to numerical ones in this way. For him music was the direct expression of psychic movement. Each note was a unique entity whose essence could only be grasped directly by the ear. They were related to each other in the same way as the simple colours, i.e. as species of a genus³; if there were any differences between notes which could be expressed as numbers, they must be contingent and secondary to their specifically musical character.

Theophrastus was not the only member of the Peripatetic school to deny the possibility of explaining musical facts in terms of numbers. Early in the (so-called) second book of the *Harmonica* (p. 32. 10ff. MEIB.) Aristoxenos contrasts the method he proposes to adopt with those of his predecessors. They either did not say what principles underlie harmony or introduced principles which are foreign to the subject, by reducing musical notes to numerical relationships or to differences in the speed of movements. In contrast to them he intends to start from the phenomena and by reasoning from them to infer their underlying laws; for the movement of the voice in song is a natural one and the intervals it produces are governed by a natural law. The practical consequences of Aristoxenos' method can be illustrated by his definition of the tone. The Pythagoreans defined this as the interval between two notes related as 8:9; for Aristoxenos it was the difference between the fourth and the fifth⁴. These remarks of Aristoxenos only concern the method to be used in the study of harmonics. It was not his intention to investigate the physical or psychological origin of music; such question did not form part of the subject-matter of harmonics. For this was only one of the sciences into which the study of music was divided, and the musical phenomena whose relationship it investigates stand to it as first principles or ἀρχαί whose reality has to be established by sense, i.e. by the trained ear of the musician. If any attempt was to be made to go beyond these principles and to establish their logical dependence on other laws, this enquiry would belong to a different science⁵. But although Aristo-

¹ Arist. *Poet.* 1449b 27 (cf. BYWATER ad loc. p. 157), *Pol.* 1341b 38, etc.; cf. F. DIRLMEIER, *Hermes* 75, 1940, 89ff., REGENBOGEN RE Suppl. VII, 1533.

² Thphr. fr. 88 W. Arist. *Pol.* 1341b 34, etc.

³ Thphr. fr. 89, 4 p. 62, 25 D.; cf. Arist. *Sens.* 442a 20, 445b 20ff. (Index Arist. 857a 51ff.); Alex. in de *Sens.* 81, 10ff.; Porph. in Ptol. *Harm.* p. 58, 25. 61, 8 D.

⁴ *Harm.* 21, 20 MEIB. with MACRAN's note, p. 245; also 46, 1ff. MEIB. and testim. 55 DA RIOS (from Porphyry).

⁵ *Harm.* 1, 11ff. 43, 25ff. MEIB.; cf. 9, 2ff. 12, 4ff. 15, 6ff. und testim. 30–33, 65 DA RIOS; LIPPMAN 146.

xenos' purpose here was limited in this way, his attitude implies a theory of sound very close to that of Theophrastus, and later writers are fully justified in claiming that he also regarded differences of pitch as qualitative and not as quantitative¹. What Aristoxenos in fact did was to treat notes as points in 'musical space'. Concords and scales were determined by the intervals separating the notes, and they could be measured and numbered; but the unit of measurement was a purely musical one, the tone².

It was pointed out some years ago that the methodological principles laid down by Aristoxenos are derived from Aristotle's *Posterior Analytics* (I, 2), and that similar principles were followed by other members of the Lyceum working in different fields, notably the physician Diocles of Carystus³. Other fragments show that Aristoxenos shared the belief of Aristotle and Theophrastus in the psychological and ethical power of music, while expressly recognising its limits⁴. So it appears that his work on musical theory was considerably influenced by the outlook of his fellow Peripatetics. Is this also true of his most important innovation, the treatment of musical sounds as points in 'musical space'? We have seen already that he shared many of Theophrastus' objections to the Pythagorean view⁵, and on the positive side there are some analogies between Aristoxenos' theory and what we can infer of Aristotle's. Aristotle regarded colours and flavours as forming a continuous scale between two extremes, white and black and sweet and bitter respectively; the other colours and flavours were intermediate points on the scale, partaking of both extremes in different degrees⁶. No full discussion of sound is extant in Aristotle's writings, but his treatment of it would have been no different from his treatment of the other sensibles. This is implied by his doctrine that each of the senses is a 'mean' between the opposite extremes of the scale to which its proper objects belong, and by his frequent use of analogies between the various senses, especially sight and hearing. At one point he refers to the note μέση as a mean between νητή and ὑπάτη⁷. Again, Aristotle held that there were only a limited number of species of colours and flavours, but that the shades grouped

¹ E.g. testim. 47. 94 DA RIOS.

² Harm. p. 22f. MEIB. et passim; also testim. 56 (= fr. 93 SA). 94 DA RIOS. For criticism by later writers, see e.g. testim. 30. 53. 65 DA RIOS.

³ W. W. JAEGER, in *Hermeneia*, Festschrift O. Regenbogen (Heidelb. 1952) 97ff. = *Scripta Minora* 2, 441ff. JAEGER compares Aristox. Harm. 32, 10ff. and 43, 25ff. with Diocles fr. 112 WELLMANN; one might add [Arist.] Col. 792b 11ff.

⁴ Harm. testim. 23–4. 27 DA RIOS = fr. 2. 122–3 SA; qualified in Harm. 2 p. 31, 20ff. MEIB.; cf. LIPPMAN 115.

⁵ Harm. 32, 20ff. ~ Thphr. fr. 89 W.; above, p. 448. 457.

⁶ Arist. Sens. 439b 16ff. 442a12ff., cf. Ross ad loc.

⁷ Arist. Phys. 224b 30ff.; de an. 424a 10ff., Sens. 439b 25ff. 445b 22ff. etc. On the senses as μεσότητες, see de an. 424a 24, etc. Cf. BEARE 231ff.

under each species could in theory be multiplied indefinitely¹, and this belief also has a parallel in Aristoxenos. Greek musical theory recognised three types of scale, the enharmonic, chromatic and diatonic, which were distinguished by the position of the 'movable' notes, i.e. the middle two notes of the tetrachord (*παρυπάτη, λιχανός*, etc.). Aristoxenos accepted this framework, subdivided the chromatic genus into three species and the diatonic into two, and used the resulting six scales as the basis for his theory. But he admitted that several more sub-types were possible, some of which may actually have been in use at the time when he was writing; at one point he hints that theoretically the number of possible variants is infinite, because there is an infinite number of positions within the locus of each moving note at which that note can be placed².

Thus there is a close affinity between the theories of Aristotle and his followers. All these thinkers rejected the mathematical and physical approach to problems of sound in favour of one which paid more attention to the psychological and qualitative aspect of the phenomena, and their solutions have much in common. This did not exclude considerable differences of detail. Neither Theophrastus nor Aristoxenos simply took over Aristotle's teaching, nor is there any need to suppose that they borrowed from each other, although they knew each other's work and no doubt discussed problems of common interest together³. Each developed Aristotle's ideas in whatever way was most appropriate to the problems in which he was interested. What they shared was a fundamental conviction about the way in which these problems were to be tackled. At a more technical level they were prepared to take account of work done outside their own school, e.g. some of the scales discussed by Aristoxenos can be identified with those advocated by Archytas⁴.

It would not have been difficult for Theophrastus and Aristoxenos to justify their bias. The laws of harmony and the psychological power of music are no less real, and in many ways more interesting, than the physical facts of sound-production. Moreover the theories they rejected were too vague to explain the phenomena satisfactorily. Yet the data on which these theories were based—the connection between sounds and impacts and between musical intervals and numerical ratios—were the only relevant facts which had ever been scientifically demonstrated, and a physical theory of sound is a necessary

¹ Arist. *Sens.* 440b 23, 442a 12 ff. 445b 20 ff., cf. Ross ad loc.; Alex. in *Sens.* 81, 10 ff., BURNET on EN 1155b 14.

² *Harm.* p. 48, 9 ff. MEIB. Cf. W. P. WINNINGTON-INGRAM, *Aristox. and the intervals of Gk. Music*, CQ 26, 1932, 195 ff.

³ Theophrastus refers to Aristoxenos by name in fr. 88 W. (= Aristox. 6 SA), and his criticism of a doctrine that the intervals are the cause of the differences between notes (fr. 89, 11 p. 64, 24 ff. D.) may possibly be directed against him; cf. *Harm. testim.* 93 DA RIOS. On controversies within the Peripatos cf. *Hermes* 92, 74 f.

⁴ Cf. WINNINGTON-INGRAM l. c.

part of any system of natural philosophy. It is hardly surprising, therefore, that Strato should have returned to a question which his predecessors had treated rather lightly. His attitude was different for one thing. His interest was centred on the physical world—he was known in antiquity as ὁ φυσικός—and he seems to have been a more systematic thinker than Theophrastus, one who aimed at subsuming all phenomena under a comprehensive body of natural laws. Once his attention had been drawn to these problems he would have been quick to see the inadequacy of Theophrastus' attempt to explain the characteristics of sounds as the result of a 'shaping' of the air; the meaning of this expression was not at all clear, and its author did not say how a mechanical impact could cause the air to be affected in this way.

One would like to know how Strato arrived at his solution; unfortunately the available evidence only allows us to speculate on this point. Accurate observation of lyres would have shown him that a sounding string performs not one but a whole series of to-and-fro movements, and Aristotle's analysis of spatial movement would have taught him that each of these oscillations must be regarded as a complete movement (Phys. 261b 32). He also appears to have observed other sounding bodies; at Aud. 802a 42 the whistling noise made by a bronze statue while being filed is connected with its vibration (τρόμος)¹. The other component of Strato's theory, the idea that sound is a movement in a static medium, is clearly derived from Aristotle's doctrine of sensation². The correctness of this insight would have been confirmed by the unsatisfactory nature both of the earlier 'missile' theories, and of Theophrastus' alternative (fr. 89, 10 p. 64, 4ff. D.). In this way Strato's theory could have resulted from a combination of observations and perhaps experiments which were well within his power, and Aristotle's analysis of the nature of sensory movement. It is a measure of the fruitfulness of Aristotle's ideas that they could give rise to theories as different and as interesting as those of Theophrastus, Aristoxenos and Strato.

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¹ A similar observation is found at Thphr. fr. 89, 10 p. 64, 10ff. D.

² See above, p. 444.